

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE
ENGINEERING AND TECHNOLOGY

**NEW MODEL AND COMPERATIVE STUDY OF
CORRELATION FACTORS WITH
MONTHLY AVERAGE OF DAILY GLOBAL SOLAR RADIATION**

M.Sc. THESIS

İnal Begüm TURNA

Department of Physics Engineering

Physics Engineering Programme

DECEMBER 2015

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Thesis Advisor: Assist. Prof. Zuhall ER

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

**GÜNLÜK TOPLAM GÜNEŞ İŞİNİMİNİN AYLIK ORTALAMASINA İLİŞKİN
KORELASYON FAKTÖRÜ KIYASLAMA VE YENİ MODEL ÇALIŞMASI**

YÜKSEK LİSANS TEZİ

**İnal Begüm TURNA
(509121129)**

Fizik Mühendisliği Anabilim Dalı

Fizik Mühendisliği Programı

Tez Danışmanı: Yard. Doç. Zuhale ER

ARALIK 2015

İnal Begüm TURNA, a **M.Sc.** student of **ITU Graduate School of Science Engineering and Technology** student ID **509121129**, successfully defended the **thesis/dissertation** entitled “**NEW MODEL AND COMPERATIVE STUDY OF CORRELATION FACTORS WITH MONTHLY AVERAGE OF DAILY GLOBAL SOLAR RADIATION**”, which he/she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Assist. Prof. Zuhall ER**
İstanbul Technical University

Jury Members : **Assist. Prof. Zuhall ER**
İstanbul Technical University

Assoc. Prof. Şaziye UĞUR
İstanbul Technical University

Assist. Prof. Nilgün DEMİR
Uludağ University

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To my family,

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(Physics Engineer)

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ABBREVIATIONS

PV	:Photovoltaic
CSP	:Concentrated Solar Power
UN	:United Nations
EU	:European Union
TEIAS	:Turkish Electricity Transmission Company
GENSED	:Solar Energy Industries Association and Industry
EPDK	:Republic of Turkey Energy Market Regulatory Authority
DMI	:Turkish State Meteorological Service
GEPA	:Solar Energy Potential Atlas
MPE	:Mean Percentage Error
MAPE	:Mean Absolute Percentage Error
MBE	:Mean Bias Error
RMSE	:Root Mean Square Error
t-Stat	:t-Statistical Method

SYMBOL LIST

θ	: The angle of incidence of Sun rays ($^{\circ}$)
θ_z	: The solar zenith angle ($^{\circ}$)
δ	: The solar declination angle ($^{\circ}$)
w	: The hour angle ($^{\circ}$)
w_s	: The mean sunrise/sunset hour angle ($^{\circ}$)
w_{sr}	: The sunrise hour angle on tilted surface ($^{\circ}$)
w_{ss}	: The sunset hour angle on tilted surface ($^{\circ}$)
w_1, w_2	: The hour angles for investigated hour ($^{\circ}$)
γ	: The surface azimuth angle ($^{\circ}$)
β	: The tilt angle ($^{\circ}$)
ϕ	: The latitude of the location ($^{\circ}$)
Z	: The solar altitude of the location (km)
I_{sc}	: The solar constant ($\sim 1367 \pm \% 3 \text{ W/m}^2$)
H_c	: The monthly average clear sky daily global (total) radiation on horizontal surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H	: The monthly average daily global radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H_0	: The monthly average daily extraterrestrial radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H_b	: The monthly average daily direct (beam) radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H_d	: The monthly average daily diffuse radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H_T	: The monthly average daily global radiation on the inclined surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H'	: Daily global radiation
H_{bT}	: The monthly average daily direct (beam) radiation on the inclined surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H_{dT}	: The monthly average daily diffuse radiation on the inclined surface ($\text{MJ.m}^{-2} \cdot \text{day}^{-1}$)
H/H_0	: The relative global radiation
I_o	: The monthly average hourly extraterrestrial radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
I	: The monthly average hourly radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
I_b	: The monthly average hourly direct (beam) radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
I_d	: The monthly average hourly diffuse radiation on the horizontal surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
I_T	: The monthly average hourly radiation on the inclined surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
I_{bT}	: The monthly average hourly direct (beam) radiation on the inclined surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
I_{dT}	: The monthly average hourly diffuse radiation on the inclined surface ($\text{MJ.m}^{-2} \cdot \text{h}^{-1}$)
S	: The monthly average daily hours of bright sunshine (h)
S_0	: The monthly average maximum possible daily sunshine duration (h)
S/S_0	: The relative sunshine duration

a, b	: Coefficients of correlations
n	: Number of day of year starting from the first of January
K	: Daily clearness Index
A	: Coefficient varies from models
r	: The ratio of hourly global radiation and the daily global radiation
a', b'	: Coefficients of r
k	: Hourly clearness index
I'	: Hourly global radiation,
r_d	: The ratio of hourly diffuse radiation and daily diffuse radiation
R_b	: Ratio of hourly direct radiation
R	: The ratio of hourly global radiation
$\bar{R}_b$	: The ratio of the average daily direct radiation
$\bar{R}$	: The ratio of average daily global radiation
MPE	: Mean Percentage error
MAPE	: Mean absolute percentage error
MBE	: Mean bias error (MJm ⁻² d ⁻²)
RMSE	: Root mean square error (MJm ⁻² d ⁻²)
t-Stat	: t-statistical analysis

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NEW MODELS AND COMPERATIVE STUDY OF CORRELATION FACTORS WITH MONTHLY AVERAGE OF DAILY GLOBAL SOLAR RADIATION

SUMMARY

Energy demand led to solar energy and installing photovoltaic facilities become the mainstream power supplier today. Solar energy has become a trending topic not only for scientific researches but also for the governments and companies as well. Therefore, there have been conferences, meetings with regard to improvements of solar technology and science behind, meanwhile analysing the yearly situation of solar technology in terms of economic, legal and governmental aspects. However, there are some obstacles for investors that can not be ignored. The most important ones are installment costs and legal regulations. This situation force investors to do the right project before installation. Thereto, building solar plants with suitable setup to the correct geographic areas by utilizing information of solar radiation data is the start point of solar energy facility investment projects. In these premises several solar radiation models have been improved in order to estimate the solar radiation at a given location or larger areas. One of the main objective of this thesis is to review the solar radiation models available in the literature and evaluate for the defined regions and related stations in Turkey in order to develop new models. Therefore, this Master of Science Thesis aims to compares the models for several stations in four regions where the total solar radiation range varies by region. Further, thesis also aims to imply the statistical analysis methods in order to detect the most appropriate model.

In the first part of this thesis, the improvements in the solar energy field are explained for Turkey and World. Besides, the current status of solar energy installed capacities are explained with numbers due to the yearly reports that published around the world by governments and solar energy related societies. Furthermore, literature reviewed in this thesis with regard to the models proposed to determine global solar radiation datas for specific or general regions. The studies published for the models, are detailed in the literature part of the first chapter.

The investigation for solar plant installations has to be done scientifically for to define the most appropriate facility. Therefore, the physics of solar energy has major role. In this context, in the second chapter this thesis states, theorical knowledge of solar angular and radiation calculations. The descriptions of solar angles are detailed meanwhile the pathway of solar radiation through the atmosphere is explained. Besides the descriptions of physics of solar energy, the related fundamental equations of solar radiation are also defined. The daily extraterrestrial radiation fundamental equations are detailed meanwhile the daily solar radiation on horizontal surface is stated in this chapter that are within the topic of this thesis. Although the hourly fundamental calculations of solar radiation on horizontal and inclined surface are not the topic of this thesis, the global, direct and diffuse solar radiation are also detailed for the knowledge of the physics of solar radiation fundamentals.

Further, in the third chapter, experimental study is explained by the description of the region and the global solar radiation calculation by models selected from the literature. The models that are evaluated in the literature are chosen which the studies enlightens as some station(s) within Turkey region. The third chapter summarize briefly the models and the studies that the models are purposed. Furthermore, the chapter defines the field that the thesis evolved. This thesis, includes Turkey region with four different solar radiation ranges which are named under regions. There are 5 stations for each region that are evaluated under the selected models.

In the fourth chapter, calculations are detailed and 4 regions each 5 stations illustrated. Each station evaluated for selected models which are grouped by 6 sets of models. On the other hand, models are evaluated for each station of each region, but only Istanbul and one selected station for each region are illustrated by the model results figures. Further, statistical analysis results are shown for regions. By the end of fourth chapter, new models purposed by this Master of Science Thesis is given for selected stations and Istanbul, Turkey according to the measured and calculated data of the monthly average daily global radiation and the monthly average maximum possible daily sunshine duration.

In the conclusion, the importance of solar energy is stated and the improvements around the world are evaluated by means of report datas. Furthermore, forecasts are given for the improvents of solar energy field. In the following, the models are compared by the statistical analysis results of each selected station. At the end, the purposed models by this thesis are evaluated by the statistical analysis methods.

AYLIK ORTALAMA GÜNLÜK TOPLAM GÜNEŞ IŞINIMI KORELASYON FAKTÖRÜ KİYASMALA VE YENİ MODEL ÇALIŞMASI

ÖZET

Enerji, tüm çeşitleriyle dünyaya yön veren, insanlık tarihinin en başından itibaren varolmuş ve olmaya devam edecek önemli bir unsurdur. Dünyanın değişimi, her ne kadar nüfus ve teknolojiyle orantılı olsa da enerji; teknolojiyi ve dünyayı döndüren çarklardan en önemlisidir. Nüfus artışı, sanayileşme ve teknolojideki gelişmeler ile akabinde gelen küreselleşme sonucunda enerjiye olan ihtiyaç gün geçtikçe artmaktadır. Dünyada enerji başlangıçta fosil yakıtlara dayansa da, zamanla bu tür yenilenmeyen yakıtların bir başka deyişle başlıca kömür, petrol ve doğalgaz rezervlerinin tükenmesiyle ve fosil yakıtların ekosisteme verdikleri zararın artması sonucunda küresel ısınma probleminin ortaya çıkmasıyla farklı enerji kaynaklarına yönelinmiştir. Her ne kadar, fosil enerji kaynakları Dünya enerji talebinde önemini gelecekte de sürdürecektir olsa da, bu tür kaynaklara alternatif olan enerji kaynakları çok eski olmamakla birlikte geçmişten günümüze kadar varlığını devam ettirmiş ve teknolojik gelişmeler, bilimsel çalışmalar ve ekonomik yatırımlar sayesinde gün geçtikçe gelişen, ekosisteme duyarlı ve önü açık enerji sahaları var olacaktır. Bahsi geçen, enerji kaynakları başlıca; rüzgar, güneş, jeotermal, hidrolik enerji ve biyoenerji gibi enerji kaynakları olan bu sürdürülebilir enerji kaynakları gelişmekte olup, ilerleyen teknoloji ile gelecekte fosil yakıtlardan ziyade başvurulacak yegane yakıt türü olacaktır.

Sürdürülebilir enerji kaynakları içerisinde önemli yere sahip olan güneş enerjisi, teknolojinin de gelişmesine paralel olarak dünya genelinde rağbet görmektedir. Dünya'nın her yerinde konu ile ilgili çeşitli konferanslar, iyileştirme toplantıları yapılmakta ve her yıl devlet kanalları, kuruluşlar, dernekler ve üniversiteler yıllık raporlar sunmaktadır. Bu bağlamda, tezin amaçlarından biri dünya ve Türkiye genelinde güneş enerjisi teknolojisinin yerini tayin etmektir. Öte yandan, geniş kapsamlı bir uygulama alanına sahip bu enerji sahasında, bölgesel ve kısmi projeler yürütülmektedir. Yapılan projelerin ilk kurulum maliyetlerinin yüksek olması gibi sebeplerden ötürü, proje çalışması başlamadan önce çeşitli incelemeler ve analizler yapılmaktadır. Bahsi geçen bu ön değerlendirmenin kapsamı; bölge yapısından, maliyet analizine kadar uzanan geniş bir yelpazeye sahiptir. Öte yandan incelenmesi gereken birincil unsur uygulama bölgesine ait güneş ışınım süreleri ve ışınım özellikleridir. Işınım ölçüm cihazlarının alım ve kalibrasyon maliyetleri yüksek olduğundan gelişmekte olan ülkeler başta olmak üzere dünya genelinde ışınım değerleri tayinine ait modeller ortaya sunulmuş ve sunulmaya devam etmektedir. Modeller, genellikle seçili kısıtlı bölgeleri kapsasa da geniş alanlara yönelik hesaplamalar çıkartılma yönünde de çalışmalar vardır. Bu tezin esas amaçlarından biri, literatürde var olan ve Türkiye özelinde geliştirilmiş yatay düzelmeye gelen ışınım modellerini ortaya koymak ve Türkiye genelinde belirlenen bölgelerdeki seçilen istasyonlar özelinde literatürden seçilen bu modelleri değerlendirmektir. Modeller için

yapılan istatistik analiz sonucunda tez dahilinde en uygun modelleri belirlemek amaçlanmıştır. Öte yandan, Enerji ve Tabii Kaynaklar Bakanlığından alınan veriler dahilinde yeni modeller literatüre kazandırılmak bu tezin en önemli amaçlarından biridir.

Tezin ilk bölümünde, güneş enerjisinin Türkiye ve Dünya genelinde gelişimine ve mevcut durumuna yer verilmiştir. Dünya ve Türkiye için yayınlanan kurulu güç ve yapılan/yapılacak olan yatırımlara yönelik devletler, kurum ve kuruluşlar hazırlanan tarafından yıllık raporlar ve mevzuatlar incelenmiştir. Öte yandan, enerji yatırımlarının hukuki ve hükümet açısı incelenmiş, mevcut devlet destekli projeler rakamlarla ifade edilmiştir. Yapılan bu analiz devamında, literatürde yayınlanan güneş enerjisi ile ilgili çalışmalar değerlendirilip tezin literatür kısmında detaylandırılmıştır. Bahsi geçen bu çalışmalar, güneş ışıınım değerlerinin tayinine ait literatüre kazandırılan modellerin incelenmesini ve belirli bölgeler için analizlerini kapsamaktadır. Öte yandan, literatüre yeni güneş ışıınım modelleri sunan çalışmalar da tezin literatür incelemesi kısmına dahil edilmiştir. Literatür kısmında bahsedilen bu analiz, tez konusu kapsamında olup, bu bağlamda literatürde var olan model çalışmaları ve/veya literatüre sunulan modellerin tarama çalışmaları gözönüne alınmıştır. Tez kapsamında olmayan, farklı meteorolojik parametrelere, bölge coğrafyası ve iklimine bağlı modellerden bahsedilmemiştir. Bunun yanısıra, tezin literatür kısmında incelenen tez konusu kapsamındaki modeller yine tez konusu dahilindeki bölge olan Türkiye için türetilen ve literatürde varolan modellerdir.

İlk kısmın akabinde, tezin ikinci bölümünde güneş enerjisi fiziğine değinilmiştir. Güneş enerjisi uygulamaları için yapılacak olan hesaplamalarda, seçilecek bölge için yıllık güneş ışıınım değerleri önemli bir yere sahip olmakla birlikte bunun için en önemli ve temel unsur güneşin konumu ve güneşten gelen ışıınım açılarıdır. Bu bağlamda, güneş ışıınım açılarının fizik bilimi açısından ne ifade ettiği bu bölümde tanımlanmış ve temel bağlantılar verilerek detaylandırılmıştır. Tez kapsamında varolan bu açıların detaylandırılmasının yanısıra bu açıların tez konusu dahilinde olan ışıınım hesaplamaları için mevcut önemi ve kullanımı ilerleyen bölümlerde görülmektedir.

Öte yandan, tezin ikinci kısmına konu olmuş olan ışıınım; ışıınının tanımı ve güneş ışıınınının atmosferi geçip yeryüzüne gelene kadarki yolculuğundan bahsedilmiştir. Güneş enerjisi uygulamalarında önemli yere sahip olan anlık ve günlük güneş ışıınım hesapları hem atmosfer dışı hem de yeryüzü için irdelenmiştir. Bunun yanısıra, yeryüzüne gelen ışıınım, eğik ve yatay düzlem için anlık ve günlük detaylandırılmasının yanı sıra toplam, direk ve yaygın ışıınım hesaplamaları olarak da anlatılmıştır. Her ne kadar tez kapsamında, yatay düzlem için günlük toplam güneş ışıınım inceleme ve hesaplamalarına yer verilmiş olsa bahsi geçen diğer hesaplamaların teorik bilgisi bu bölüm kapsamındadır.

Tezin üçüncü bölümü, deneysel çalışmanın detaylandırılmasını içermektedir. Öncelikle, teze konu olan Türkiye'nin güneş ışıınım yapısının anlatılmasının yanı sıra metrekareye düşen ışıınım değerleri rakamsal olarak yansıtılmıştır. Akabinde, ışıınım değerlerine bağlı olarak ayrılan bölgeler tanımlanmıştır. Tez kapsamında, Türkiye 4 bölgede incelenmiş ve her bölge için yine ışıınım değerlerine göre 5' er istasyon belirlenmiştir. Bahsi geçen bölgeler ve istasyonlar tezin bu bölümünde detaylandırılmıştır. Öte yandan, literatür kısmında bahsedilen ve tez konusu dahilinde Türkiye'nin belirli bölge ve/veya istasyonları için daha önce literatüre sunulan ve tez dahilinde irdelenmek adına seçilen modeller yine bu kısımda detaylandırılmıştır. Modellerin konu olduğu çalışmalardan kısaca bahsedilmiştir. Modellerin formülleri ve formüllerin bağlı olduğu parametreler bu kısımda sunulmuş ve modeller ile ilgili

açıklama yapılmış, var ise aynı modele ait alt formüllerin temsil ettiği hesaplama detaylandırılmıştır.

Tezin hesaplama bölümü olan dördüncü bölümünde, Türkiye genelinde 4 bölge için seçilen 5'er istasyon görsel olarak sunulmuş ve her bir bölgenin tabii tutulduğu hesaplamalar açıklanmıştır. Detaylandırmak gerekirse, literatürden seçilen modeller 6 set halinde gruplanmış ve her bölgedeki istasyonlar için ayrı ayrı hesaplamaları yapılmıştır. Bu hesaplamalar sonucunda, her bir bölge için temsili bir istasyon seçilmiştir. Tezin bu kısmında seçili istasyonların yanı sıra tez çalışmasının geçtiği istasyon olan İstanbul' un da hesaplamaları dahil edilmiştir. Seçili istasyonlar ve İstanbul istasyonu için model hesaplamaları grafiksel olarak sunulmuş ve grafiğin ortaya çıkması konusunda uygulanan modeller her bir hesaplama sonucu için tablolar dahilinde detaylandırılmıştır.

Dördüncü bölümde, yukarıda anlatılan her bölge için seçili istasyonların literatür modellerinin irdelenmesinin yanı sıra, modellerin her bir bölge ve her bölgedeki her bir istasyon için uygunluk durumlarının irdelenmesi adına literatürde en sık kullanılan istatistiksel analiz metodları altında incelenmiş ve tezin bu kısmına dahil edilmiştir. Her bir bölge için yapılan bu irdelemeler tablolar halinde sunulmuştur.

Tezin yine dördüncü bölümünde, İstanbul ve seçili istasyonlar için yatay düzleme gelen günlük güneş ışınlamına dair hesaplanan ve ölçülen değerler irdelenmiştir. Bu çalışma akabinde İstanbul ve her bölgenin seçili istasyonuna ait yeni modeller korelasyon faktörü ile ortaya konulmuştur.

Tezin son kısmında, yapılan çalışma doğrultusunda ortaya çıkan sonuçlara değinilmiş, varılan nokta tartışmış ve yapılan çalışmaya dair sonuç çıkarılmıştır. Güneş enerjisinin önemine değinilmiş ve teknolojisinin gelişimi yatırımlar açısından rakamlarla kıyaslanmıştır. Öte yandan, ileriye dönük iyileştirme adına öneride bulunulmuştur.

Akabinde, yapılan tez çalışması dahilinde her bir bölgede seçilen istasyonlar için makul olan model tayini yapılması adına istatistik açıdan değerlendirilmiş ve modeller kıyaslanmıştır. Öte yandan, tez konusu dahilinde olan Türkiye bölgesi için her bir bölgedeki seçilen istasyonlar ve tezin geçtiği istasyon olması açısından İstanbul istasyonu için ileri sürülen yeni korelasyonlar istatistiksel olarak irdeleniş ve yorumlanmıştır.

1. INTRODUCTION

Each morning, the sun rises in the east, makes its slow journey across the sky, and then sets in the west. Then it continues a journey around the other side of the Earth, and rises again next morning. Think about your arrival at university in the morning during the fall and spring months versus the winter months. If your university such as ITU is located in the northern hemisphere, it is likely that you start school in the dark each morning for several months during winter. Due to tilt of the earth, locations closer to the equator experience fairly consistent sunrise and sunset times throughout the year. But the further north you travel, the more widely these sunrise and sunset times vary. Accurate quantitative data of the variation of solar radiation reaching the earth surface, together with relevant meteorological parameters are essential requirements for a wide range of scientific studies.

The exact time of sunrise and sunset will be useful not only for people who like to gaze at the starlight sky, but also photographers who can catch the most picturesque frame at the junction of day and night. The fundamental unit of solar time is day. Two types of solar time one apparent true solar time (sundial time) and mean solar time (clock time). Sunrise is the time when the upper part of the Sun is visible, and sunset is when the last part of the Sun is about to disappear below the horizon (in clear weather conditions).

The azimuth displayed is the horizontal direction of the Sun at sunrise and sunset. Since the times used for the sunrise and sunset calculations are also used for azimuth calculation.

When architects make decisions about how university buildings are designed, they may consider how much sunlight the buildings will receive at various times throughout the day. Between sunset and sunrise, the Earth's surface gathers no solar energy but continues to radiate away its stored heat. Typical one of the example is thermal design of environmental control of the buildings. The design and estimation of performance of solar systems also requires detailed knowledge of solar radiation data.

The technology is progressing steadily and the dependence of electric energy becomes more crucial thence the investigation of electric energy supply is more challengeable than ever which evokes the demand to new energy sources besides coal, oil and nuclear power.

The aforesaid issue has been underlined in the World Energy Council with the UN Framework Convention on Climate Change which allures all parties in various industries to incept investment on renewable energy sources [1]. Therefore the solar power is one of the most considerable sustainable energy source and has paramount historical background started with converting sun light to electricity in 19th century and then after observations on photovoltaic (herein after called as PV) effect by Alexandre Edmond Becquerel on electric energy production has been advanced and there is still greater concern on the development of new technologies which would enable more efficient approaches [2].

Worldwide growth of photovoltaics has been fitting an exponential curve for more than two decades. During this period of time, photovoltaics (PV), also known as solar PV, has evolved from a pure niche market of small scale applications towards becoming a mainstream electricity source. Figure 1.1. shows worldwide growth of PVs, installed PV in watts per capita and also exponential growth on semi-log chart.

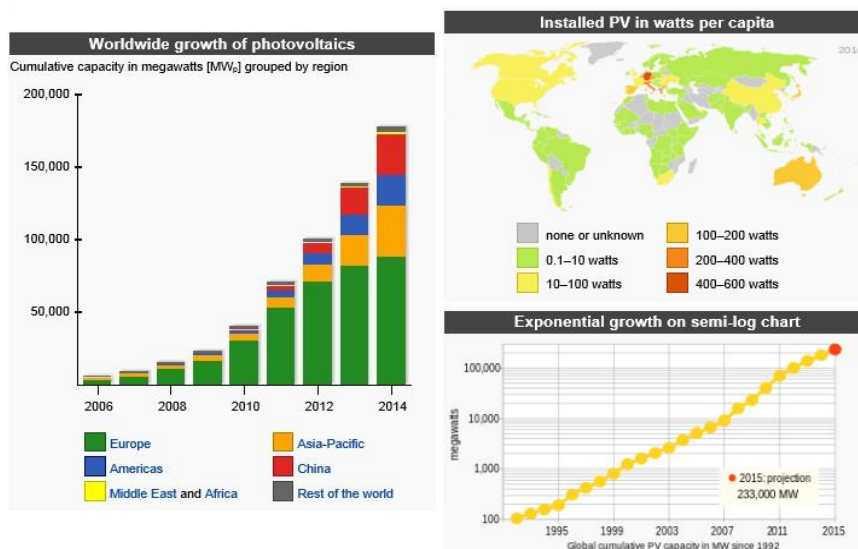


Figure 1.1 : Worldwide final developments of photovoltaics [3].

Subsequently the PV is the most promising solar technology in this century which converts solar radiation to electric energy while the demand on electricity is growing together with the increase in population and the need of industry due to supply of

services to the society. Furthermore; economic, governmental and environmental priorities have another concern on the development of the PV systems.

Two major key drives are becoming more predominant in governmental aspect such as the policies and subsidies. Policies are mainly cannot be restricted within the framework of regional issues as the energy concern is worldwide and communities' including nongovernmental organizations involvement and concern on environment inherently is casting those policies. Ergo, governments and in global sense state policies are expecting to bolster not only the investors, universities and communities that could improve PV technologies and but also the new research fields on entire sustainable energy technologies.

Inherently, installation of PV plant varies by the region and mainly depends on its economic cost in terms of feasibility which the premier investment decision is based on. Particularly the PV installation cost would become acceptable especially the operating expenditure for its reliability and maintainability together with its revenues are reckoned with.

With this chapter, the Master of Science Thesis also highlights the World & Turkey sustainable energy potential and investment statistics based on various states in conjunction with the planned energy demand. Thereto the pros and cons of the investment has also briefly pointed out within the perspective of sustainable energy while highlighting the solar power, in terms of several common obstacles or infirmities were pointed out.

1.1. World Sustainable Energy Potential

Sustainable energy has gained more popularity both by investors or government officials since the three decades. In 1990, the most common sustainable energy sources were coined as hydro power and biomass [1]. Then after when the researches have demonstrated suitable ground for their efficient application, solar energy, wind energy and geothermal energy have become indispensable alternatives in the gamut of sustainable energy sources.

The statistics of Renewable Energy Policy Network for the 21st Century, obviously underlines the rise in renewable electricity production since the year 2000 [4]. Thereby it was observed that energy production capacity gathering by biomass energy and

geothermal energy remained reasonably steady while there was an acceleration in production of wind energy infrastructure until 2008 and then electricity production capacity by wind energy went upwards rapidly. Hydropower which remains as renewable energy since 1993 it has the increase gradually reaching a peak at 2003 and then continued fluctuated, however it can be interpreted as the general trend was upwards. On the other hand, solar power which considered as PV and concentrated solar power continued to increase not leveling off by the end of 2009 and rose sharply without doubling the 2009 peak. The measured figures on electric energy production was reached 748 GW in the year 2000 and has inclined up to 1560 GW in 2013 by increasing 108% of installed capacity. Figure 1.2. shows the renewable energy indicators in 2013.

		START 2004 ¹	END 2012	END 2013
INVESTMENT				
New investment (annual) in renewable power and fuels ²	billion USD	39.5	249.5	214.4 (249.4)
POWER				
Renewable power capacity (total, not including hydro)	GW	85	480	560
Renewable power capacity (total, including hydro)	GW	800	1,440	1,560
Hydropower capacity (total) ³	GW	715	960	1,000
Bio-power capacity	GW	<36	83	88
Bio-power generation	TWh	227	350	405
Geothermal power capacity	GW	8.9	11.5	12
Solar PV capacity (total)	GW	2.6	100	139
Concentrating solar thermal power (total)	GW	0.4	2.5	3.4
Wind power capacity (total)	GW	48	283	318
HEAT				
Solar hot water capacity (total) ⁴	GW _{th}	98	282	326
TRANSPORT				
Ethanol production (annual)	billion litres	28.5	82.6	87.2
Biodiesel production (annual)	billion litres	2.4	23.6	26.3
POLICIES				
Countries with policy targets	#	48	138	144
Feed-in Number of states/ provinces/ countries	#	34	97	98
RPS/ quota policies Number of states/ provinces/ countries	#	11	79	79
Tendering Number of states/ provinces/ countries	#	8	45	55
Heat obligations/ mandates Number of countries	#	n/a	19	19
Biofuel obligations/ mandates ⁵ Number of countries	#	10	52	63

Figure 1.2 : Renewable energy indicators 2013 [4].

Evaluation of sustainable energy according to countries indicates that there are several countries are always remaining at the top of the list. In Europe region in accordance with The European Wind Energy Association promulgated data total installed capacity during 2013 was 11,159 MW. Germany was the prime country in Europe with 29 percent of total capacity as followed by United Kingdom with 1,883 MW which

referred to 1,883 MW [5]. Figure 1.3 is illustrated EU Members State Market Shares for New Capacity Installed During 2013 in MW.

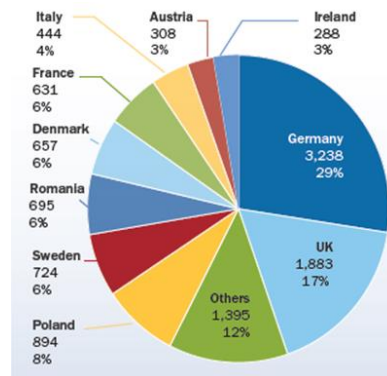


Figure 1.3 : EU Members state market shares for new capacity installed during 2013 in mw. total 11,159 MW [5].

Thereby, as a worldwide base scaling, Germany was in the third place in the list whereas China was the leader of the world in wind energy which United States was coming after. However, United States take the lead at the geothermal energy installed capacity at 2015 with 5,09 GW which is followed by Asia Pacific countries with 4,81 GW such as Philippines is the second and followed by Indonesia and Mexico. Likewise, China and United States are one of the most giant producer countries in biomass and hydropower energy [6]. Figure 1.4. represents Installed capacity in 2015 worldwide (12,6 GWe).

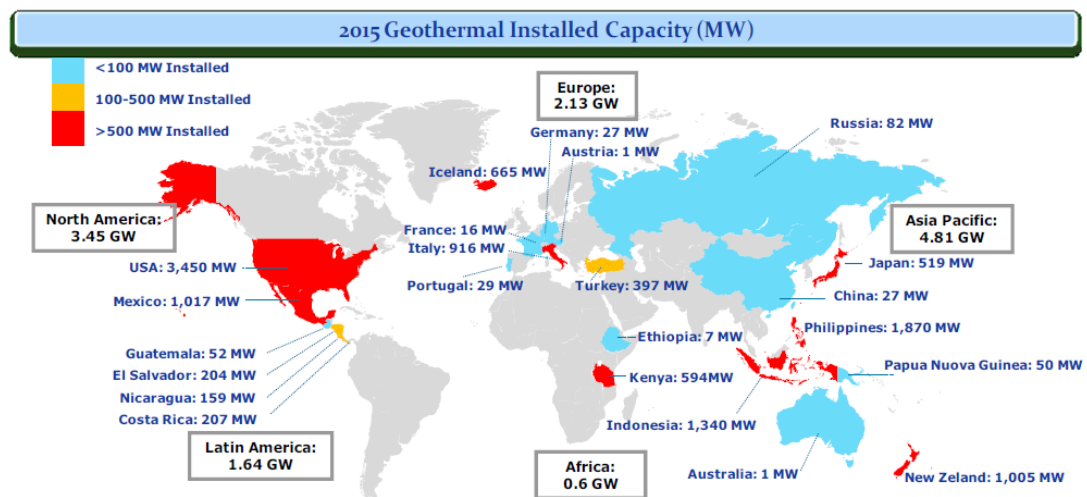


Figure 1.4 : Installed capacity in 2015 worldwide (12,6 GWe) [6].

All in all, European Photovoltaic Industry Association has underlined in their Global Market Outlook report that global PV cumulative installed capacity at the very first

part of the 2000 inclined not leveling off by reaching 138,833 MW at the end of 2013 [7]. Subsequently it is obvious that sustainable energy installed capacity increases while the time elapses and is expected to increase in the short-run while the environmental concern and pressure on pair pollution prevention efforts are persistently interrogates the future of the planet. Figure 1.5. shows the evolution of global PV cumulative installed capacity 2000-2013 [7].

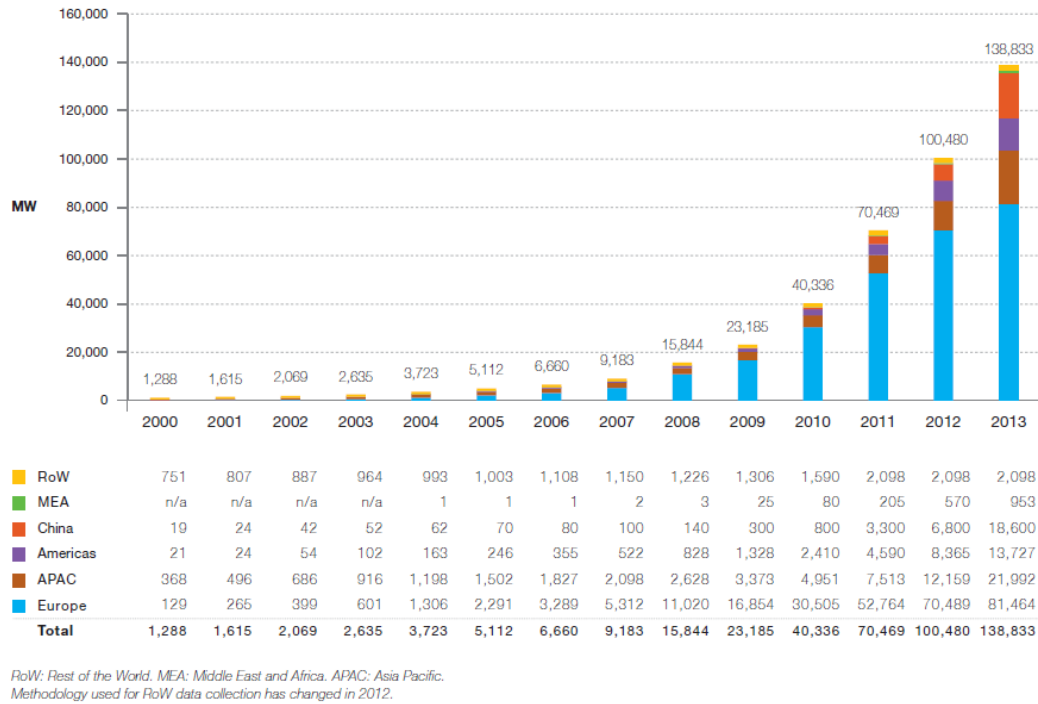


Figure 1.5 : Evolution of global PV cumulative installed capacity 2000-2013 [7].

Solar power has a capacity and potential which significantly decline the energy demand by efficient technology and permanent energy source if properly managed and supported by prudent authorities. The aforesaid efficient technologies gather energy that sun emits and the small amount of the radiation intercepted by the earth, reaches to the surface which allows to generate extensive energy. Inherently radiation could be converted to heat or electricity.

In this study, the production of electric energy from solar radiation was mainly considered based on two systems which are the PVs and concentrated solar power (CSP). The main difference between those two developed technologies is the existence of turbine. PV systems use solar cells to transform solar radiation to electricity directly while CSP systems make the same transformation by the turbine after solar thermal energy used to produce steam. The PV systems has major percentage of world

cumulative solar power capacity when its usage is compared with the application of CSP systems.

As the World Energy Council stated in the 2013 Survey to clarify the distinction global annual renewable electricity capacity growth rate between 2000 and 2013 was 23.3 % for CSPs while it was 46.8% for PVs. In the meantime it was worth to mention CSPs have put into field of application in 2007 with only 5 percent over cumulative electricity capacity. Then after it was increased slightly and in 2010 it had the dramatic incline reaching a peak about 83%. The world's latest economic crisis had unfortunately, caused to decline the electricity production sharply and fluctuated until the end of 2013.[1]

PV systems, on the other hand, had illustrated growing percentage until 2007 like CSP system which decreased about twenty seven percent in only one year. The slight dip followed by swift recovery reaching a peak at the end of year after. Then entered a period of fluctuation, however; the general trend was upwards. It could be articulated that PV installed capacity in Europe region was witnessed a rise sharp in between 2007 and 2008 [1], which was followed by rapid increase until 2013. Therefore it would be fair to underline that the solar PV development was not only related with the manufacturing in Europe region. It was also recognized that there is still a wide application of PVs in Asia Pacific region predominantly by China and finally the US had significant improvement capacity on PV technology together with the existing installed capacity. Consequently it would be more realistic to utter that solar energy is permanent as long as the sun exists, by the utilization of both PVs and CSPs technologies.

1.2. Turkey Sustainable Energy Potential

The energy balances in Turkey varies according to political, scientific and environmental issues as similar to the world. In order to evaluate the sustainable energy potential of Turkey, the electrical energy status should be clarified. Thereto, the Ministry of Energy and Natural Resources published Turkey's electric energy statistics which shows numerical facts about not only about electrical energy consumption and generation but also import and export values. In general, import figures unfortunately rise steadily with inconsiderable fluctuations meanwhile data pairs related to our

electrical export values fluctuates however the general trend is upwards as stated in the table below. [8]

Year	Generation	Import	Export	Consumption	Generation Rate	Consumption Rate
2004	150.698	464	1.144	150.018	7,2%	6,3%
2005	161.956	636	1.798	160.794	7,5%	7,2%
2006	176.300	573	2.236	174.637	8,9%	8,6%
2007	191.558	864	2.422	190.000	8,7%	8,8%
2008	198.418	789	1.122	198.085	3,6%	4,3%
2009	194.813	812	1.546	194.079	-1,8%	-2,0%
2010	211.208	1.144	1.918	210.434	8,4%	8,4%
2011	229.395	4.556	3.645	230.306	8,6%	9,4%
2012	239.497	5.826	2.954	242.370	4,4%	5,2%
2013	240.154	7.429	1.227	246.357	0,3%	1,6%
2014	250.435	7.805	2.696	255.545	4,3%	3,7%
2015 End of June	124.929	3.632	1.550	127.012		

Figure 1.6 : Power generation and consumption ratio [8].

Over and above the facts about power generation shows that although there has been an 1,8 percentage of decline at 2009, generally the values inclined until the end of 2014. Likewise, at 2009 the consumption ratio decreased however the general trend is upwards for ten years. The increase in consumption is mainly due to the rise in our population while increase in generation is related to rise in consumption as the energy need is rise as time goes by.

The power generation is related mainly to installed capacities of power plants. The power plants in Turkey tripled from 2002 to 2013 by reaching the number 907 from 300 number of facilities. Afterwards, rose steadily until the end of the September 2014 with 1.059 number of power plants where 87 of those are wind, 73 solar facility without license and 14 geothermal energy plants. [9] Furthermore, TEIAS (Türkiye Elektrik İletim A.Ş.) represents a detailed report including installed capacities for last three years of Turkey at the beginning of October this year which covers the data pairs until the end of September 2015. The report shows the installed capacity inclined slightly from 64.007,5 MW capacity at 2013 to 72.155,6 MW capacity by the end of

September 2015. [10] The detailed evolution of power plants is shown in the Figure 1.7 with regarding to the mentioned report.

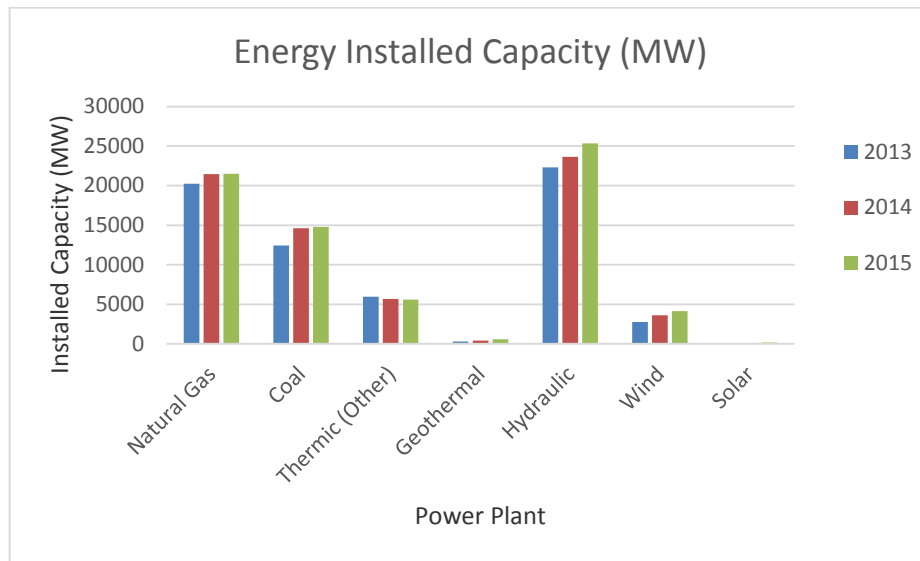


Figure 1.7 : Power plants installed capacities.

The hydraulic, natural gas and coal energy capacities has major role for overall capacity. Although natural gas and coal capacity increased for the first year of the last three years, between 2014 and 2015 almost remained steady. On the hand the figure represents that the renewable energy sources even though could not reached the highest peak in the graph, they increase promisingly by the end of September 2015. Besides, one of the most important sustainable energy resource, solar energy, has no any installed capacity until 2013 and afterwards has inconsiderable capacities compared to others as represented at the figure below.

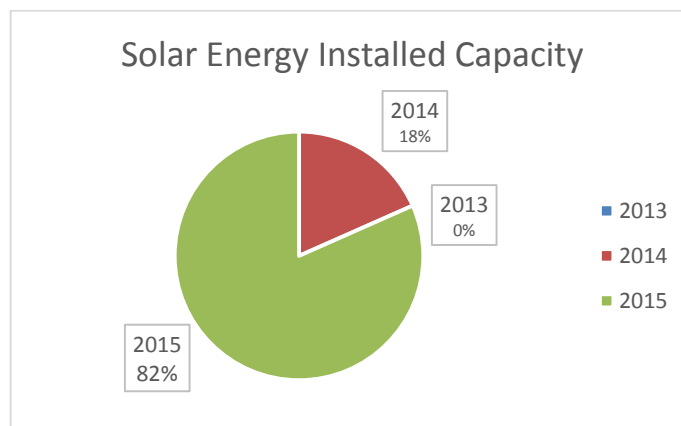


Figure 1.8 : Solar energy installed capacity.

Solar energy has major role in Turkey's renewable energy roadmap since the country is located geographically in a region called the "solar band". Solar Energy is the most important alternative clean energy resource which is still untapped in Turkey. The Turkish solar market holds a tremendous potential for the international photovoltaic industry. While constantly increasing energy prices and growing energy demand make energy from conventional sources more and more expensive, the country has superior solar radiation. In just last two years, solar energy is booming as indicated Figure 1.8.. The solar power plant capacity is almost zero in terms of others; however, report indicates that it starts with the value of 40,2 MW at 2014 capacity continued to rise not levelling off by reaching 178,6 MW capacity at 2015. [10] Government aimed to increase the installed capacity of solar power plant. According to this purpose, the Ministry of Energy and Natural Resources determine the regions and cities for the solar energy investments and published the map below.



Figure 1.9 : The region for the solar energy investment field [11].

The figure represents the chosen regions and cities which the Ministry also detailed that there are 27 regions and 38 stations are allowed for investments. However, the capacity is limited for the solar power plants until the end of the 2013 with 600 MW total in Turkey general which due to the law number 6094. After the beginning of the 2014, the installed capacity limit is determined by the council of ministers. [12] The legal limits for installed capacities until the end of the 2013 are given in the Figure 1.10.

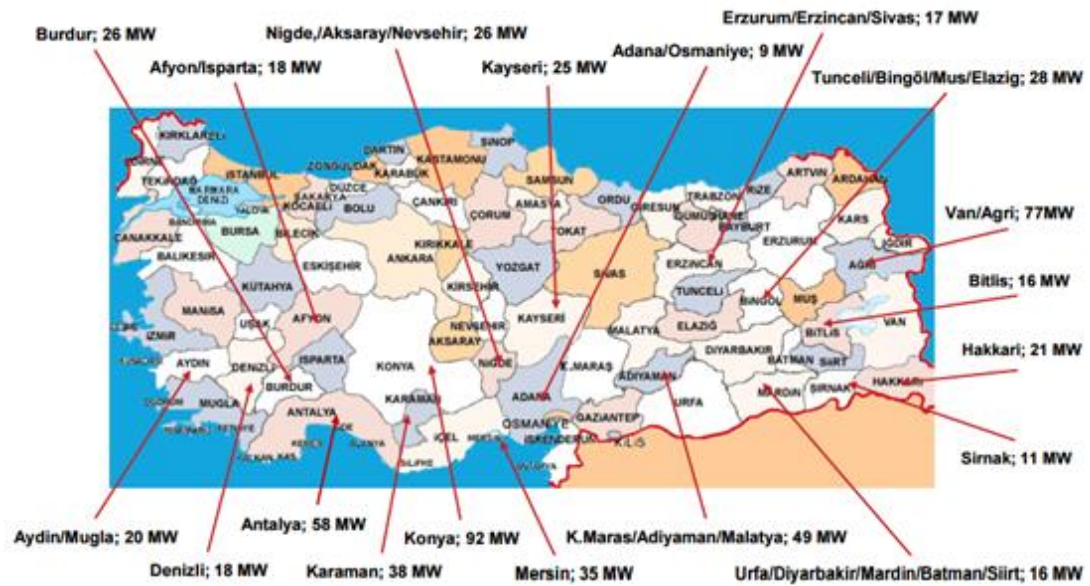


Figure 1.10 : Many projects above 1MWp are currently in the licensing pipeline for the 600 MW[13].

As it is stated that the highest limit is 92 MW for Konya which is followed by Van-Agri with the installed capacity value of 77 MW. On the other hand, the least value is for Erzincan which is located in the eastern Anatolia region of Turkey and according to the map that government published it is the north border of signed region.

1.3. Literature Survey

The solar radiation received by earth surface is one of the most applicable parameter that is usable in hydrology, climatology, energy and meteorological modeling. Many different experimental equations had been suggested by researchers to estimate the parameter in different regions.

Scientists need to review the literature for this Master of Science Thesis because of the historical overview of the theory and the research literature, with a special emphasis on the literature specific to the thesis topic. It serves as well to support the argument/proposition behind this Master of Science Thesis, using evidence drawn from authorities or experts in our research field. The review is shaped by a focus on key areas of the thesis, including research which provides a background to the topic. Reviewed literature include a range of sources such as Journal articles, Monographs, Computerized databases, Conferences proceedings, Dissertations, Empirical studies, Government reports and reports from other bodies, Statistical handbooks and Books. A number of these had received on the web. Review of the literature should set up a

theoretical framework for our research to have a understanding of the key concepts/ideas/studies/ models related to our topic. Review of the literature supplies additional properties into the thesis. These additional properties can write here such as discussion of literature ideas in a context appropriate for our own investigation, clarification of important definitions/terminology, comparison with the work of others and development of the research space.

Literature survey especially for topic of the future expectation of the PV s role in compensating energy demand and topic of the solar calculations/simulations, reviewing documents from the corresponding governmental and also global institutions is necessary. The data bases provided on internet by the World Energy Concil, World Bank and Ministry of Energy&Natural Resources, are relevant for understanding Turkish economy and its progress and also energy marketing requirement of Turkey. Also, Turkish institutes like GENSED (Solar Energy Industries Association and Industry), TEIAS (Turkey Electricity Transmission Company) and EPDK (Republic of Turkey Energy Market Regulatory Authority) publish official statements and offer informing documents and studies. In order to reach a solid basis for analysis, the intention is to have more than one source on one topic, preferably one in Turkish and one in English. Also, since the development of solar industry is reasonably recent, the data and information is expected to be restricted within a time frame of a few years back.

Ahmad and Tiwari [14] published their study whose major aim is to review the global solar radiation models available in the literature. The models divided into four groups according to their correlation types as linear models, polynomial models , angular models and other types of models that are all derived from Angstrom type equations which is the first developed model for to calculate global solar radiation data. By using the sunshine duration and monthly average daily global radiation in a given location the reviewed models evaluated to compute the monthly average daily global solar radiation on a horizontal surface for New Delhi.

Besharat and et. al.[15] in 2013 presented a review and a case study for Yzad city, Iran about the evaluation of global solar radiation models in the literature. The models reviewed chronologically and divided into four categories such as; sunshine based models related to the sunshine duration parameters, cloud based models based on the cloudiness, temperature based models with the maximum and minimum air

temperature values, and other meteorological parameters based models use the various meteorological variables. The geographical and meteorological data of Yazd, Iran is used for the evaluation of the reviewed models. Moreover, the models analysed statistically and for each category the most accurate model is proposed. Besides, the most appropriate model over all for Yazd is decided which is in the sunshine based models category and recommended for the similar climatic conditions.

Wanxiang et. al. [16] evaluated global solar radiation models from literature for Shanghai, China by using the 42 years meteorological data. The result of the evaluation of 89 monthly and 19 daily global solar radiation models discussed depending on the models correlation types and parameters for the model inputs. Analysis shows that linear and polynomial models are more applicable rather than complex model according to the correlation type of the models. The study, consider direct parameters as latitude, altitude, and sunshine duration and indirect parameters as the monthly mean maximum temperature and relative humidity. In terms of parameter input, the indirect parameters can not improve the accuracy of the models. As a result, the polynomial models are most accurate for both daily and monthly estimations. Also, those results are proposed for the similar geography and climate as Shanghai.

Tiris and et. al.[17] has done an analysis study of solar radiation for Gebze, Kocaeli. The measured hourly and daily solar radiation data is evaluated for the period between January 1984 and December 1992. As a result of the evaluation of measured data, the maximum and the minimum values of global solar radiation are examined and recorded. Besides, due to statistical analysis of the 9 years measured data, new correlations are suggested for the global radiation calculations.

Aksoy[18] evaluated a well known quadratic model for six location from Turkey as Ankara, Antalya, Samsun, Konya, Urfa and Izmir using the data from August 1993 to July 1995 obtained from the Turkish State Meteorological Service. The results and the data obtained from the instrument called pyrheliometer that measures direct solar radiations does not match. Therefore, the study suggested a general quadratic formula for Turkey. As the comparison result of the new correlation and the measured values shows that the annual error of the new correlation is more reliable than the data obtained from the Turkish State Meteorological Service.

Togrul and Onat [19] analysed the monthly global solar radiation in terms of geographical and meteorological parameters. The solar radiation data gathered from solar radiation measurement instrument; pyranometer, for a period of time between April 1994 and March 1995 for Elazig, Turkey is compared with the data from the suggested multiple linear regressions. The results shows that suggested one of the correlation has less error for estimating global solar radiation in Elazsig.

Togrul and et. al. [20] aimed to develop a model to estimate global solar radiation for Elazig, Turkey. Accordingly, the measured global solar radiation data between the years 1983 and 1994 are taken from the Meteorological Station of Elazig. Multiple correlations with different regression constants are suggested which are monthly based solar radiation model depends on the ratio of sunshine duration. The correlation types of the models are as logarithmic, second, third, fourth and fifth order polynomial equations contains two periods; winter and summer. Consequently, it is seen that the models with second, third and fourth order are more dependable than others.

Ertekin and Yaldiz [21] reviewed twenty six models in the literature which are models for the calculation of the solar radiation on the horizontal surface. Those models are evaluated for the data set belongs to Antalya, Turkey. In order to, define the most appropriate and applicable model for Antalya several statistical models are applied which gives information about long term and short term performance of the models. According to the statistical analysis results, the most accurate model is defined with the equation type of third degree correlation to calculate the solar radiation on the horizontal surface. As a result of this study, Ertekin and Yaldiz purposed a model with adapting the the most accurate model's correlation for investigating station; Antalya.

Ulgen and Hepbasli [22] published a reviewed and a case study for Izmir. The models selected from the literature used to calculate the solar radiation on horizontal surface. This study groups the models based on their equation types as; linear models, polynomial models, angular models and the rest named as other models. Further, the statistical analysis which compared measured and calculated values for investigated models are done in order to compare the relevance of present models. As a result, Ulgen and Hepbasli suggested two different empirical correlations for Izmir, Turkey using the data between October 1993 and 2002. Besides, the purposed models compared with the results of calculated models from the literature which is concluded as the new models are acceptably appropriate and applicable for investigated city.

Tahran and Sari [23] published a study for Central Black Sea Region of Turkey where the cities for the region are Amasya, Corum, Ordu, Samsun and Tokat. The main purpose of this study is to suggest two model for solar radiation calculations that one model is to calculate diffuse solar radiation and the other is for global solar radiation. In this approach, the six diffuse solar radiation models in the literature are reviewed and the new model is suggested in accordance the forecast of those six models as the diffuse radiation measurement data is not available for investigated region. On the other hand, the new two models with cubic and quadratic correlation types are proposed for global solar radiation based on the data from Turkish State Meteorological Service within the year range between 1997 and 2001 for five investigated stations of Turkey.

Aras, Ballı and Hepbaşlı [24] considered the Central Anatolia Region for Turkey in order to investigate the global solar radiation calculations. The study evaluated twelve provinces of Turkey which are Afyon, Ankara, Cankiri, Corum, Eskisehir, Kayseri, Kirsehir, Konya, Nevsehir, Nigde, Sivas and Yozgat. The study suggested three different correlation types which are linear, quadratic and cubic for each province of Central Anatolia Region based on the data obtained from Turkish State Meteorological Service in the period from January 1990 to December 1996. As a result of this study, not only for defined provinces but also for Central Anatolia Region in general three types of models are brought into literature.

Bakirci [25] selected five models with different correlation types in the literature which were developed in order to estimate the global solar radiation on horizontal surface. On the other hand, in the study the measured data is obtained from Turkish Meteorological Service within the period of 1991-2005, for the purpose of finding the most accurate model for several provinces which are chosen from different region of Turkey. Besides five models in the literature, there are two models suggested for this study with the correlation types of linear exponential and exponential equations. The correlation constants for new models are developed for each provinces and Turkey in general with regard to the Turkish Meteorological Service measured data. Furthermore, the statistical analysis methods are applied to investigate the models in the literature and the derived new model. Consequently, the accurate models are represented for Turkey and the results show that the new models are resonable.

2. SOLAR CALCULATIONS

Good quality, reliable radiation data is extremely important for all activities in the solar energy sector. Photovoltaic (PV) and concentrating solar power (CSP) thermal systems may have slightly differing requirements, but they need accurate solar radiation information for the same reasons. Radiation data depends on the solar basics which respect to the meteorological and astronomical evaluations.

Different weather conditions that are called Seasons being experienced throughout the world with respect to the annual movement of the earth around the sun with together the influence of the inclination of Earth's axis. The northern hemisphere due to the southern hemisphere have turned more heated by the sun until September. In this case reversed between the 3 September and 21st March and duration of time of day and night are equal in both hemispheres. This equal duration situation is called the Equinox. Earth is located in the position closest to the sun as the sun orbits around January 2-3. This location is called Perihelion.

The solar radiation on the Earth's surface is defined with respect to the Earth's rotation around own axis and Sun's orbit which leads astronomical angles between radiations from the Sun and the Earth's surface. As to benefit effectively of radiations, there are two of fundamental terms of solar energy are necessary for accurate prediction of the Sun's position described by astronomical angles; the solar altitude and the solar azimuth. Above these two angles the declination angle and hour angle need to be defined. [26]

The polar axis is the earth axis of rotation and the ecliptic plane is the plane of orbit of the earth around the sun which ecliptic axis is normal to. The polar axis is inclined with the angle of 23,45 degree from the ecliptic axis which leads to declination angle. The solar declination angle is an angle between the equator axis and the Earth's orbit which vary according to seasons and months with respect ot the Earth-Sun position as presented in the Figure 2.1.

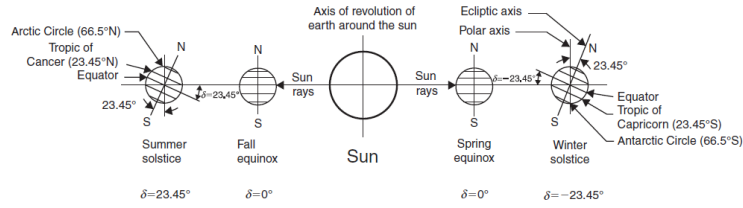


Figure 2.1 : Solar declination [27].

The declination angle is the most important angle in terms of the astronomical angles between solar radiation and Earth. The declination value vary between -23,45 degree which is the winter solstice at the time 21th of December and 23,45 degree which is the summer solstice at the time 21th of June and symbolized by δ .

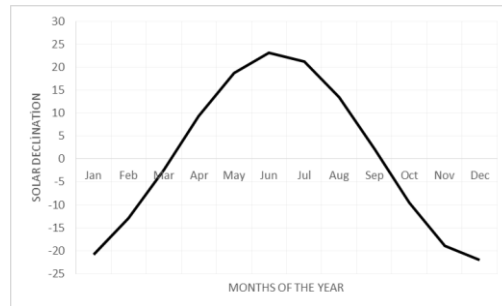


Figure 2.2 : Monthly variation of solar declination.

Further, the variation of the solar declination according to the average day of the month throughout the year is represented in the Figure 2.2. As it is seen the zero values are at March and September which are respectively fall and spring equinox. Besides, the local extremum value which is negative represents winter solstice and conversly the local extremum value which is positive represents summer solstice.

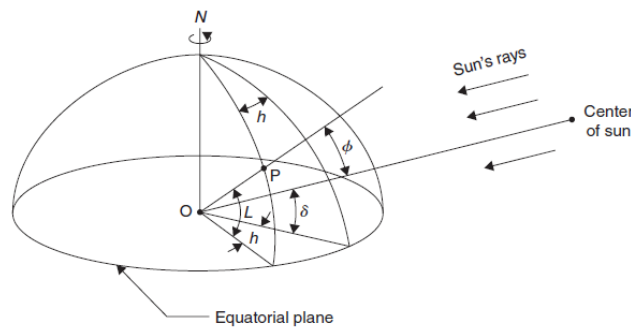


Figure 2.3 : Visual presentation of declination and hour angle [27].

The hour angle is between the longitude where the sun rays perpendicular and the longitude of the considering point as stated in the Figure 2.3. Local noon is described

as the sun reaches its highest point in the sky. Therefore, the hour angle is equal to zero at local noon. The hour angle has negative values while reduces to zero until reaching to local noon which then after hour angle increases by having positive values. The earth rotates 15 degrees per hour, so as the hours passes from local noon corresponds to an angular motion of the sun in the sky of 15 degree as Figure 2.4. represents.

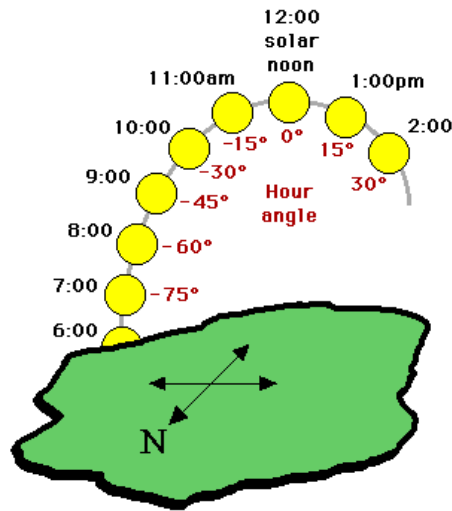


Figure 2.4 : The solar time distribution [28].

So that, since the hour angle changes fifteen degrees per hour, calculation allows to evaluate the angle hourly. Likewise, the sunrise and the sunset hour angles has importance to determine the solar radiation.

As the solar altitude angle is the angle between the Sun's rays in other words the direction of the geometric center of the Sun and the horizontal plane of the considering point which may be defines as the complement of the solar zenith angle. To clarify, the solar zenith angle is the angle between the normal of the horizontal surface and the direction of the Sun whose values are 90 degrees at the sunrise and sunset while it is 0 degrees at the solar noon. Conversely, the solar altitude angle is 90 degrees at the solar noon and is 0 degrees at sunrise and sunset. Further, there has been an angle similar to the solar zenith angle which is the incidence angle with an important difference. The incidence angle is also the angle between the normal on a surface and the Sun's rays where if the surface is horizontal, the incidence angle is equal to the solar zenith angle and varies according to the tilted surface with respect to its angle with the horizontal surface.

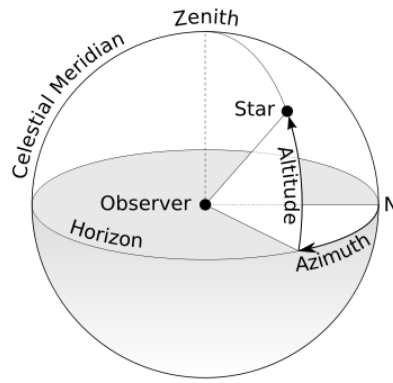


Figure 2.5 : The solar altitude, solar zenith angle and solar azimuth angle representation [29].

Other than the above the azimuth angle as represented in the Figure 2.5. is also used for defining the position of the Sun. The azimuth angle is between the south - north direction of the horizontal surface and the projection of the Sun's rays and is measured due north . At solar noon, in the northern hemisphere the direction of the Sun is south and conversly in the southern hemisphere the direction of the Sun is north. The angle varies clockwise direction due north so east is 90 degrees, south is 180 degrees and the west is 270 degrees. So that at the equinoxes the azimuth angle is 90 degrees at sunrise and 270 degrees at sunsets as the Sun's rays are perpendicular to equatorial plane.

To conclude the solar angles are defined and visualized in this section so as to use in the solar radiation measurement. In order to to evaluate the solar radiation characteristics, the Sun' s ray should be assessed not only with the solar angles but also with the fundamentals of the solar radiation which is explained in the following section.

2.1. Solar Radiation

In physics, radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium. One type of the radiation includes electro-magnetic radiation (also known as "continuum radiation"). The others are called particle radiation such as α , β , and neutron radiation (discrete energy per particle) and acoustic radiation such as ultrasound, sound, and seismic waves [30].

Electromagnetic radiation is a form of energy propagated in the form of the electric and magnetic waves oscillate perpendicular to each other and to the direction of propagation through space. The electromagnetic spectrum is the frequency based range of electromagnetic radiation with the scale from below the radio radiation with low

frequencies and high wavelengths and to the gamma radiation with high frequencies and low wavelengths as shown in the Figure 2.6.

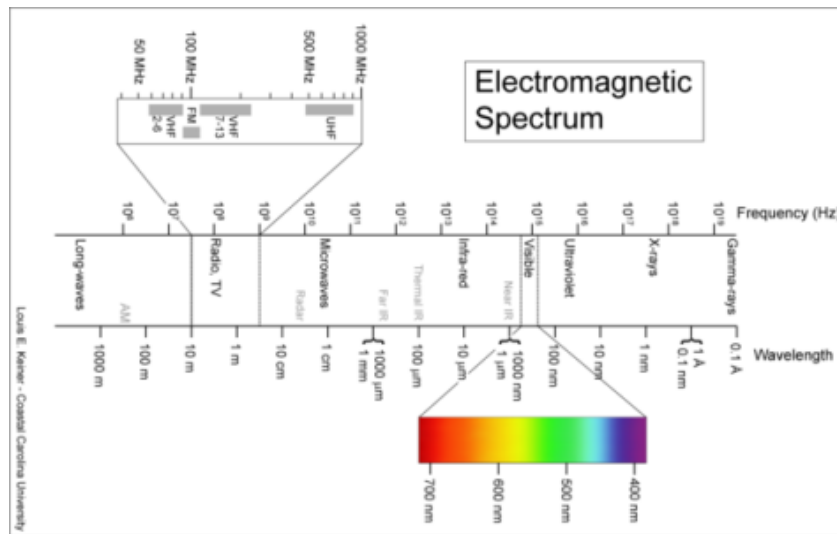


Figure 2.6 : Electromagnetic spectrum [31].

The atmosphere is composed of the gases as 78,1 percent of nitrogen and 20,9 percent oxygen where there is also water vapor and aerosols which can not be defines certainly as they vary. [32] According to the wave length of the electromagnetic radiation comes from the Sun; which is called as solar radiation then after, and the radius of the atmospheric particle, the radiation scattered, reflected back out in to the space and absorbed by the atmosphere meanwhile the rest of the radiation pass through the atmosphere by changing its direction named as the atmospheric refraction. In other words, reduction of the solar radiation by absorption of atmospheric gases and aerosols and scattering of aerosols is atmospheric attenuation.[33]

The absorption is depends on the atmosphere layer and the wavelength of the radiation. To be more specific, X rays and gamma rays have short wavelengths and are absorbed at high altitude in the ionosphere meanwhile the ultraviolet rays whose wavelength is longer than X rays and gamma rays, are absorbed at the 15-40 km above the Earth' s surface by the ozone layer. Besides, water vapor and carbon dioxide absorbs the infrared rays in the lower atmosphere. [34]

The scattering is another factor affects atmospheric attenuation. The degree of the scattering occurs is related to the interection between the particle size and the wavelength of the radiation and also density of the particles. [35] Air molecules are relatively small by size by comparison to radiation. Therefore, the scattering from air

molecules leads us to the Rayleigh theory which is inversely proportional to the fourth power of the wavelength.[36]

As to clarify, both the effects of Rayleigh scattering by air molecules and absorption by oxygen, ozone, water and carbon dioxide radiation which are defined above are shown in Figure 2.7.

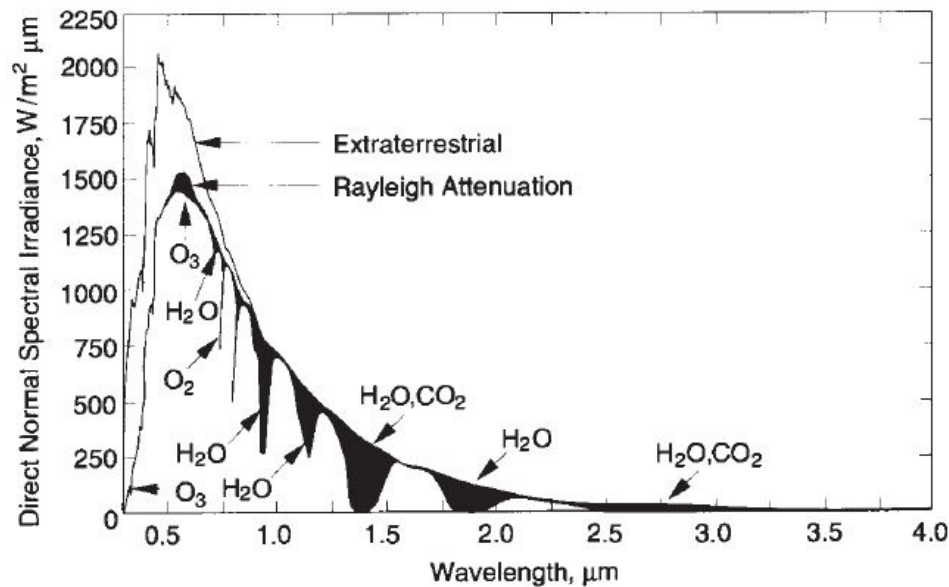


Figure 2.7 : Scattering and absorption by the atmosphere [37].

The figure above shows the atmospheric attenuation in terms of irradiation and wavelength. The Rayleigh scattering is represented by the difference between the extraterrestrial curve and the curve at the top of the shaded areas. Besides, the absorption bands are represented by the shaded areas.

So, the solar radiation on the Earth surface has less intensity than the solar extraterrestrial radiation and the solar radiation on Earth's surface consists of 7 percent of ultraviolet, 46 percent of visible and the rest is infrared region with 47 percent. [38]

Solar (solar) power derived from the system varies depending on the supply energy from the Sun, trigonometrically terms between the Sun and surface of system and meteorological data. Therefore, knowledge of the solar radiation data is an important parameter in the design of systems operating on solar energy for specified region. These parameters can be defined with preparing of suitable correlation for some region where has not the knowledge of the solar radiation data. The solar radiation propagating from the sun without having been scattered by the atmosphere is called

direct (beam) radiation meanwhile diffuse radiation is the solar radiation received from the sun after its direction has been changed by scattering by the atmosphere. Besides, the reflected radiation which occurs from reflection on other surfaces or objects has also significant role for the solar determinations.

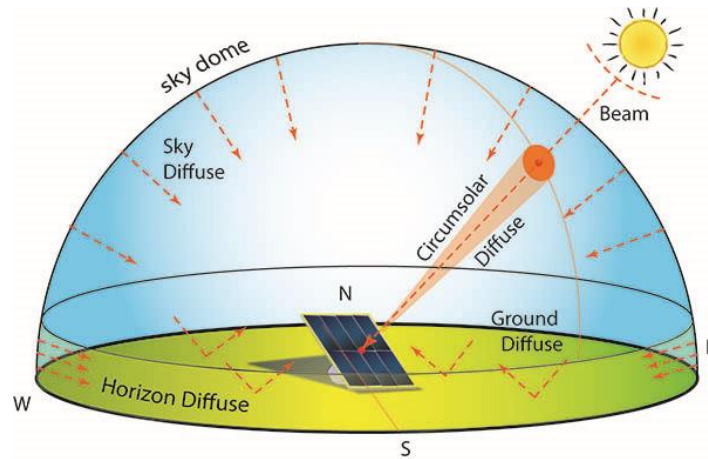


Figure 2.8 : Illustration of solar direct (beam) and diffuse radiation and reflection for tilted surface [39].

The solar radiation evaluation varies depending on the angle between the corresponding surface and the horizontal plane whether the surface is horizontal or tilted. The direct radiation, diffuse radiation and in specific cases the reflection is determinative for the total solar radiation. On the horizontal surface the direct radiation and the diffuse radiation are the significant factors meanwhile reflection take into consideration for evaluating the total solar radiation on the tilted surface as presented in the Figure 2.8.

To sum up, the direct and diffuse radiation determines the total solar radiation with respect to the atmospheric conditions and slope of the corresponding surface which decides whether reflection from environment is significant or negligible.

2.2. Calculation and Fundamental Equations

Improving solar plants by taking into account both the variation of the incidence radiation' s direction during the day time and the variation of the declination angle among the year, provides facilities to benefit from the solar energy.

The solar constant (I_{sc}) which has almost the value of $1367 \pm 3 \text{ W/m}^2$ where n is the number of days of the year starting from first January.

$$\delta = 23.45^\circ \sin \left[\frac{360(284 + n)}{365} \right] \quad (2.1)$$

$$w = 15(\text{solar time} - 12) \quad (2.2)$$

$$w_s = \cos^{-1}(-\tan \phi \tan \delta) \quad (2.3)$$

where,

ϕ ; the latitude of the related location,

δ ; the solar declination angle,

w_s ; the mean sunrise/sunset hour angle

Solar radiation calculations is done by due to the solar hour angle (w) whose 15 degrees equals to one hour as time. Also, hour angle has positive values before noon and negative values after noon as shown in the Figure 2.4. The trigonometric correlation between the latitude (ϕ) of the location and zenith (θ_z), declination(δ), and hour angles(w) is as below [26]:

$$\cos \theta_z = \cos \delta \cos \phi \cos w + \sin \delta \sin \phi \quad (2.4)$$

There has been correlations related to those calculations in the literatur; however, as the thesis is experimental the knowledge of this section is not detailed.

On the other hand the solar radiation information is fundamental input for solar energy studies and solar plant industry. Solar radiation can be identified with radiation measurement devices. In spite of the importance of solar radiation measurements, in many developing contries the measuring equipments are not affordable because of their expenditures. Accordingly, numerous methods have been developed to determine the daily or monthly solar radiation data depending on various parameters such as different weather conditions, sunshine hours, latitude of the site. Besharat mentioned in his study the factors that solar radiotion is basicly based on which are solar constant, sun earth distance, solar declination and hour angle as astronomical factors; latitude and elevation as geographical factors; azimuth and tilt angle as geometrical factors; atmospheric constituents and scattering as physical factors and extraterrestrial solar radiation, humidity, cloudliness, sunshine duration, temperature and reflection etc. as meteorological factors.[15] By all of the methods developed in

the history whether according to these factors or not there has been Angstrom method at the very beginning which other methods are improved from. Angstrom proposed a correlation for determining monthly average daily radiation to clear day radiation in a given latitude which also related to average fraction of possible sunshine hours.[25]

The empirical equations for estimating solar radiation: availability on horizontal surface for cloudy skies is;

$$\frac{H}{H_c} = a + b \left(\frac{S}{S_0} \right) \quad (2.5)$$

where,

H; the monthly average daily global (total) radiation on horizontal surface

H_c; the monthly average clear sky daily global (total) radiation on horizontal surface

a,b; coefficients of correlations

As H_c is difficult to estimate, Prescott [14] have modified the Angstrom's method by depending on extraterrestrial radiation instead of clear sky daily radiation as below. [16]

$$\frac{H}{H_0} = a + b \left(\frac{S}{S_0} \right) \quad (2.6)$$

where, H₀ is the monthly average daily extraterrestrial radiation, S is the monthly average daily hours of bright sunshine and S₀ is the monthly average maximum possible daily sunshine duration.

The monthly average daily extraterrestrial radiation on a horizontal surface, H₀ (MJ.m⁻².day⁻¹) and the monthly average hourly extraterrestrial radiation on a horizontal surface, I₀ (MJ.m⁻².h⁻¹) are obtained from the equations below respectively which basically depends on solar constant and angles. [26]

$$H_0 = \frac{24}{\pi} I_{sc} \left[1 + 0.033 \cos \left(\frac{360n}{365} \right) \right] \left[\cos(\phi) \cos(\delta) \sin(w_s) + \frac{\pi}{180} w_s \sin(\phi) \sin(\delta) \right] \quad (2.7)$$

$$I_0 = \frac{24}{\pi} I_{sc} \left[1 + 0.033 \cos \left(\frac{360n}{365} \right) \right] \left[\cos(\phi) \cos(\delta) (\sin(w_2) - \sin(w_1)) + \frac{\pi}{180} (w_2 - w_1) \sin(\phi) \sin(\delta) \right] \quad (2.8)$$

where, w₁ and w₂ are the hour angles for investigated hour in order to calculate the monthly average hourly extraterrestrial solar radiation on horizontal surface.

Besides, the monthly average maximum possible daily sunshine duration as S_0 basically depends on mean sunset/sunrise hour angle and can be computed as;

$$S_0 = \frac{2}{15} w_s \quad (2.9)$$

In other way, by using latitude of the given location and the solar declination angle S_0 can be defined as;

$$S_0 = \frac{2}{15} \cos^{-1}(-\tan \phi \tan \delta) \quad (2.10)$$

To conclude, the monthly average daily extraterrestrial radiation on a horizontal surface and the monthly average maximum possible daily sunshine duration can both be computed by the correlations as indicated in this section. In order to determine the monthly average daily global radiation on given location the solar radiation models have been developing since the Angstrom equation 1924.

Besides the calculation of the solar radiation on the extraterrestrial surface, the solar radiation on the Earth's surface is explained in the following. The calculations are consists of global (total), direct (beam) and diffuse solar radiation on the horizontal and inclined surface. Monthly average solar radiation which are total, diffuse and direct radiations on the horizontal surface of the Earth calculations are given with below correlations. [36] Therefore, the total monthly average daily solar radiation on the horizontal surface H ($\text{MJm}^{-2} \text{day}^{-1}$) is given by the mathematical formula Eq. (2.11).

$$\frac{H}{H_0} = a + b \left(\frac{S}{S_0} \right) \quad (2.11)$$

On the other hand, the monthly average daily diffuse radiation on the horizontal surface H_d ($\text{MJm}^{-2} \text{day}^{-1}$) is related to daily clearness index which the ratio of daily global radiation and the daily extraterrestrial radiation.

$$K = \frac{H'}{H_0} \quad (2.12)$$

$$\frac{H_d}{H} \approx AK \quad (2.13)$$

where; H' is daily global radiation, K is daily clearness index and A is coefficient varies from models.

The monthly average daily direct (beam) radiation on the horizontal surface H_b ($\text{MJm}^{-2} \text{day}^{-1}$) is derived from the total and diffuse radiation.

$$H = H_b + H_d \quad (2.14)$$

Besides above calculations monthly average hourly solar radiation on the horizontal surface of the Earth calculations are given as in the following equations with regard to the total, diffuse and direct radiations equations. The total monthly average hourly radiation on the horizontal surface I ($\text{MJm}^{-2}\text{h}^{-1}$) is derived from the r which is the ratio of hourly global radiation and the daily global radiation.

$$r = \frac{\pi}{24} (a + b \cos w) \frac{\cos w - \cos w_s}{\sin w_s - (2\pi w_s / 360) \cos w_s} \quad (2.15)$$

$$a' = 0,409 + 0,5016 \sin(w_s - 60) \quad (2.16)$$

$$b' = 0,6609 - 0,4767 \sin(w_s - 60) \quad (2.17)$$

$$r = \frac{I}{H} \quad (2.18)$$

where,

a' and b' ; the coefficients of the ratio of hourly global radiation and the daily global radiation.

Furthermore, the monthly average hourly diffuse radiation I_d ($\text{MJm}^{-2}\text{h}^{-1}$) can be calculated in two different ways as the one way is related to the ratio of hourly global radiation and the monthly average hourly extraterrestrial radiation on the horizontal surface.

$$k = \frac{I'}{I_0} \quad (2.19)$$

$$k = \frac{I_d}{I} \quad (2.20)$$

where,

I' ; the hourly global radiation,

k ; hourly clearness index.

On the other hand, another way to calculate I_d is;

$$r_d = \frac{I_d}{H_d} = \frac{I_0}{H_0} \quad (2.21)$$

$$r_d = \frac{\pi}{24} \left(\frac{\cos w - \cos w_s}{\sin w_s - (2\pi w_s/360) \cos w_s} \right) \quad (2.22)$$

where,

r_d ; the ratio of hourly diffuse radiation and daily diffuse radiation

Also, the monthly average hourly global radiation is the summation of direct and diffuse radiation.

$$I = I_b + I_d \quad (2.23)$$

Monthly average solar radiation on the inclined surface of the Earth calculations are given as below. The total, diffuse and direct radiations are represented as;

The total monthly average hourly solar radiation on the inclined surface I_T ($\text{MJm}^{-2} \text{h}^{-1}$) is as shown below;

$$I_T = I_{bT} + I_{dT} \quad (2.24)$$

where,

I_{bT} ; The monthly average hourly direct radiation on the inclined surface ($\text{MJm}^{-2} \text{h}^{-1}$)

I_{dT} ; The monthly average hourly diffuse radiation on the inclined surface ($\text{MJm}^{-2} \text{h}^{-1}$)

The monthly average hourly direct radiation on the inclined surface is calculated relating to the geometric factor.

$$R_b = \frac{I_{bT}}{I_b} = \frac{\cos \theta}{\cos \theta_z} \quad (2.25)$$

$$\begin{aligned} \cos \theta = & \sin \delta \sin \phi \cos \beta - \sin \delta \cos \phi \sin \beta \cos \gamma + \cos \delta \cos \phi \cos \beta \cos w \\ & + \cos \delta \sin \phi \sin \beta \cos \gamma \cos w + \cos \delta \sin \beta \sin \gamma \sin w \end{aligned} \quad (2.26)$$

$$\cos \theta_z = \cos \delta \cos \phi \cos w + \sin \delta \sin \phi \quad (2.27)$$

$$I_{bT} = R_b I_b \quad (2.28)$$

where; R_b is the ratio of hourly direct radiation.

On the other hand the monthly average hourly diffuse radiation on the inclined surface is calculated as;

$$I_{dT} = I_d \frac{1 + \cos \beta}{2} \quad (2.29)$$

where,

β ; the tilt angle ($^{\circ}$)

As I_{dT} and I_{bT} are explained in the upper sections, I_T can be calculated as below as well;

$$I_T = I_{bT} + I_{dT} \quad (2.30)$$

$$I_{bT} = R_b I_b \quad (2.31)$$

$$I_{dT} = I_d \frac{1 + \cos \beta}{2} \quad (2.32)$$

So;

$$I_T = R_b I_b + I_d \frac{1 + \cos \beta}{2} \quad (2.33)$$

$$R = \frac{I_T}{I} \quad (2.34)$$

where,

R ; the ratio of hourly global radiation.

Furthermore, the daily solar radiation on inclined surface is derived as the following. The monthly average daily solar radiation on the inclined surface H_{bT} (MJ/m²day) is calculated relating to the monthly average daily solar radiation on the horizontal surface H_b (MJ/m²day). [40]

$$H_b = H \left(1 - \frac{H_d}{H} \right) \bar{R}_b \quad (2.35)$$

$$\bar{R}_b = \frac{H_{bT}}{H_b} \quad (2.36)$$

$$\begin{aligned}
& (\cos \beta \sin \delta \sin \phi)(w_{ss} - w_{sr})(\pi/180) - \\
& (\sin \delta \cos \phi \sin \beta \cos \gamma)(w_{ss} - w_{sr})(\pi/180) + \\
& (\cos \beta \sin \delta \sin \phi)(w_{ss} - w_{sr})(\pi/180) + \\
& (\cos \beta \cos \delta \cos \phi)(\sin w_{ss} - \sin w_{sr})(\pi/180) + \\
& \cos \delta \cos \gamma \sin \phi \sin \beta (\sin w_{ss} - \sin w_{sr}) - \\
& \cos \delta \sin \beta \sin \gamma (\cos w_{ss} - \cos w_{sr})
\end{aligned} \tag{2.37}$$

$$\bar{R}_b = \frac{2(\cos \phi \cos \delta \sin w_s + (\pi/180)w_s \sin \phi \sin \delta)}{2(\cos \phi \cos \delta \sin w_s + (\pi/180)w_s \sin \phi \sin \delta)}$$

where, w_{sr} and w_{ss} are sunrise and sunset hour angle on tilted surface and $\bar{R}_b$ is the ratio of the average daily direct radiation.

The total monthly average daily solar radiation on the inclined surface H_T ($\text{MJm}^{-2}\text{day}^{-1}$)
 $\bar{R}$; The ratio of average daily global radiation

$$\bar{R} = \frac{H_T}{H} \tag{2.38}$$

$$\bar{R} = \frac{H_T}{H} = \left(1 - \frac{H_d}{H}\right) \bar{R}_b + \frac{H_d}{H} \left(\frac{1 + \cos \beta}{2}\right) \tag{2.39}$$

So;

$$H_T = H \left(1 - \frac{H_d}{H}\right) \bar{R}_b + H_d \left(\frac{1 + \cos \beta}{2}\right) \tag{2.40}$$

Moreover, the monthly average daily diffuse radiation on the inclined surface H_{dT} ($\text{MJ/m}^2\text{day}$) is calculated by according to the meaning of the total radiation.

$$H_T = H_{bT} + H_{dT} \tag{2.41}$$

To summarize, the solar radiation both on the horizontal surface and inclined surface calculations are described.

3. EXPERIMENTAL STUDY

Building solar plants with suitable setup to the correct geographic areas by utilizing information of solar radiation data is the start point of solar energy facility investment projects. In these premises several solar radiation models have been improved in order to estimate the solar radiation at a given location all around the world. Complete and accurate solar radiation data at a specific region are quite important for the solar energy related researches, a number of formulas and models have been developed to estimate solar radiation for the locations where measured values are not available. So several empirical correlations have been developed from the past. In this thesis the global (total) solar radiation models available and studied for Turkey in the literature is reviewed. Also the solar radiation models examined at the identified solar radiation regions.

3.1. Description of Selection of The Regions

The potential amount of solar radiation that can reach the surface is determined by its location and time of the year. Due to differences in the position of the sun, the potential radiation differs at various latitudes and in different seasons. The actual solar radiation reaching the surface depends on the atmosphere and the presence of clouds which reflect and absorb major parts of the radiation. [41]

The world solar region is defines as the 35° of north and south of the equator that has the most beneficial in terms of solar energy. The region has solar radiation between 2000 and 3500 hours a year and solar potential of 3,5 and 7 kWh per metersquare a day. [42] Due to the geographic advantage, Turkey is in the world solar region. As Turkish State Meteorological Service (DMI) published the information from 102 station; between the years 1985 and 2014 Turkey' s average daily solar radiation hour is 6,8 hours and the information from 141 statiton which have been closed since 2006, between the years 1985 and 2006 Turkey's average daily solar radiation is 353,7 cal

per centimeter square. [44] Besides, Turkey's solar radiation and yearly solar radiation hours is given in the table below.

Region	Total average solar radiation kWh/m ² -year	Average sunshine duration h/year
Southeastern Anatolia	1.460	2.993
Mediterranean	1.390	2.956
East Anatolia	1.365	2.664
Central Anatolia	1.314	2.628
Aegean	1.304	2.738
Marmara	1.168	2.409
Black Sea	1.120	1.971

Figure 3.1 : Solar energy potential of Turkey [44].

Due to the table, the south eastern anatolia region has the highest solar radiation value and followed by mediterian region with 1390 kWh per metersquare. Besides, the solar radiation atlas represented with Figure 3.1. aslo provides the yearly kilowatt hour value per meter square information.

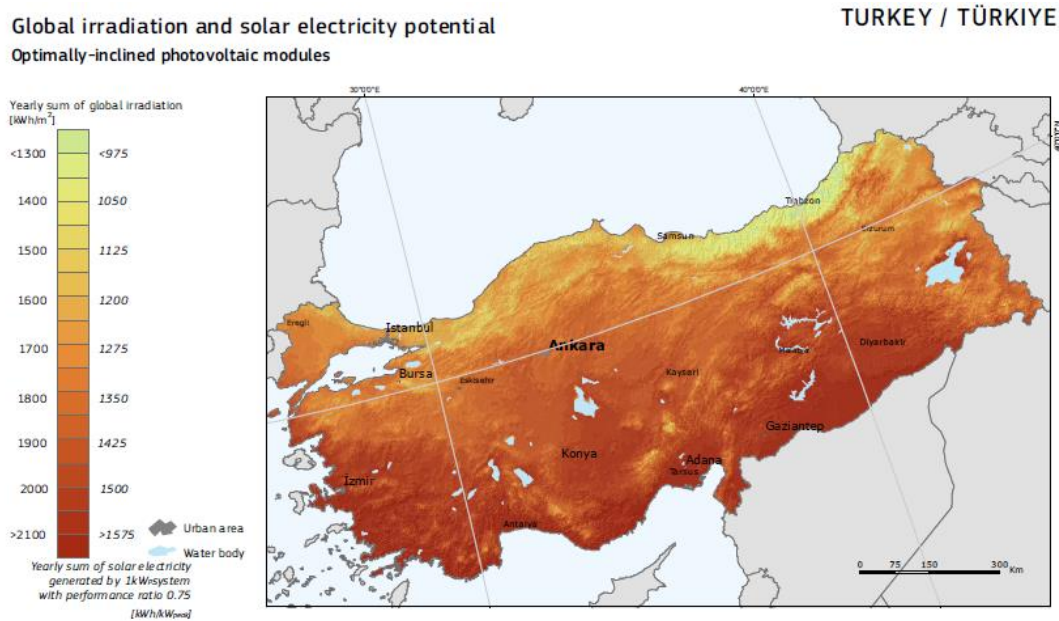


Figure 3.2 : The total solar irradiation map for Turkey [45].

The Ministry of Energy and Natural Resources provides the solar radiation atlas monthly average daily solar radiation by using the twelve month daily values. According to the solar radiation information gathered from Figure 3.2, it is seen that Turkey can be evaluated in regions which in this thesis a region of the solar distrubition

is divided into four regions that includes 5 stations due to their total solar irradiation map of Turkey.

3.1.1. First region

The global solar radiation yearly value is in a range between 1400 KWh/m² and 1500 KWh/m² which are the lowest values for Turkey Solar map. The chosen five stations are Edirne, Kastamonu, Istanbul, Samsun and Zonguldak as shown in Table 3.1.

Table 3.1 : Description of stations of the first region.

Solar Radiation Distribution: 1400-1500 KWhm⁻²year⁻¹			
Stations	Provinces	Altitude (meter)	Latitude (degree)
Station 1	Edirne	41	41,67
Station 2	Kastamonu	775	41,40
Station 3	Istanbul/Maslak	91	41,10
Station 4	Samsun	4	41,29
Station 5	Zonguldak	10	41,46

As the altitude and latitude values are important for the calculation of the solar angle which is the starting point of solar radiation calculations, the altitude and latitude values are given in the table above.

3.1.2. Second region

The global solar radiation yearly value is in a range between 1500 KWh/m² and 1600 KWh/m². The chosen five stations are Ankara, Ardahan, Bilecik, Izmir and Tokat as shown in Table 3.2..

Table 3.2 : Description of stations of the second region.

Solar Radiation Distribution: 1500-1600 KWhm⁻²year⁻¹			
Stations	Provinces	Altitude (meter)	Latitude (degree)
Station 1	Ankara	850	39,90
Station 2	Ardahan	1810	41,11
Station 3	Bilecik	620	40,09
Station 4	Izmir	30	38,42
Station 5	Tokat	623	40,40

The altitude and latitude values are represented for each provinces. Furthermore, provinces are named after as station, from then onwards each province is pronounced by their station number.

3.1.3. Third region

The global solar radiation yearly value is in a range between 1600 KWh/m² and 1700 KWh/m². The chosen five stations are Erzincan, Hatay, Kayseri, Sanliurfa and Usak as shown in Table 3.3..

Table 3.3 : Description of stations of the third region.

Solar Radiation Distribution: 1600 - 1700 KWhm⁻² year⁻¹			
Stations	Provinces	Altitude (meter)	Latitude (degree)
Station 1	Erzincan	1185	39,55
Station 2	Hatay	85	36,41
Station 3	Kayseri	1054	38,72
Station 4	Sanliurfa	518	37,35
Station 5	Usak	906	38,67

3.1.4. Fourth region

The global solar radiation yearly value is in a range between 1700 KWh/m² and 2000 KWh/m² which are the highest values. The chosen five stations are Antalya, Hakkari, Karaman, Mugla and Van as shown in Table 3.4..

Table 3.4 : Description of stations of the fourth region.

Solar Radiation Distribution: 1700 - 2000 KWhm⁻² year⁻¹			
Stations	Provinces	Altitude (meter)	Latitude (degree)
Station 1	Antalya	30	36,90
Station 2	Hakkari	1720	37,38
Station 3	Karaman	1033	37,18
Station 4	Mugla	625	36,93
Station 5	Van	1727	38,55

3.2. Description of Models

The methods for calculating solar energy from meteorological data require various climatologically and physical parameters for solar energy systems. Some of the data are measured directly in weather stations. Other parameters are related to commonly measured data and can be derived with the help of a direct or empirical relationship[41].

For many locations in the world solar irradiation can be looked up. For a more accurate indication of how much energy is falling on a surface at an angle, a series of calculations must be done. Calculations are especially useful for real system design

and may also be useful simulation modeling studies. There have been many published articles describing solar calculations for solar applications.

When doing design work, scientists and engineers gloss over initial basic calculations. Many people did analyses of what was wrong with the design, but this one is perhaps the best (please note that it does contain some potentially offensive language). Technological development gives many opportunities to analyze of the system. One of the opportunity is simulation methods. The simulation models are made by the scientists for design of the real systems. Skipping basic background estimation and calculation may save you a small amount of time and headache early in the design process, but it can cost you greatly in the long run. Using good estimation techniques and basic calculations can ensure that the work ends up being useful, rather than something doomed to sit on paper or in a computer forever.

In order to understand how to collect energy from the sun, one must first be able to predict the location of the sun relative to the collection device. In this chapter we develop the necessary equations by use of evaluating the literature review. Table 3.5 is prepared for listed of constructor name and model number under preliminary approach.

Table 3.5 : Numbers of the model and constructor(s) name.

Model Number and Constructor(s) Names			
Model 1	Kilic and Ozturk	Model 10 (e)	Togrul et. al. (e)
Model 2	Ogelman et. al.	Model 11	Ertekin and Yaldiz
Model 3	Akinoglu and Ecevit	Model 12	Ulgen and Ozbalta
Model 4	Tasdemiroglu and Sever	Model 13 (a)	Ulgen and Hepbasli (a)
Model 5	Yildiz and Oz	Model 13 (b)	Ulgen and Hepbasli (b)
Model 6	Tiris et. al.	Model 14 (a)	Ulgen and Hepbasli (a)
Model 7	Aksoy	Model 14 (b)	Ulgen and Hepbasli (b)
Model 8 (a)	Togrul and Onat (a)	Model 15 (a)	Aras, Balli, Hepbasli (a)
Model 8 (b)	Togrul and Onat (b)	Model 15 (b)	Aras, Balli, Hepbasli (b)
Model 9	Togrul and Onat	Model 15 (c)	Aras, Balli, Hepbasli (c)
Model 10 (a)	Togrul et. al. (a)	Model 16 (a)	Tahran, Sari (a)
Model 10 (b)	Togrul et. al. (b)	Model 16 (b)	Tahran, Sari (b)
Model 10 (c)	Togrul et. al. (c)	Model 17	Bakirci
Model 10 (d)	Togrul et. al. (d)	Model 18	Bakirci

As, it is illustrated in the Table 3.5. there is subindex for some models which are Model 8, 10, 13,14, 15 and 16. Those notifications shows that the constructors are same meanwhile the correlation types are vary by subindex. Further, the more detailed description of the models are represented in the section 3.3. below.

3.3. Monthly Average Daily Solar Radiation Models On The Horizontal Surface

The solar radiation vary according to the location examined as the value of variables are unique to the site. Hence, there has been various models developed. In the present study, several solar radiation on horizontal surface is examined for Istanbul Maslak region. In this study, models in the literature for Turkey region are evaluated.

Model 1: Kilic and Ozturk [22] improved a and b regression coefficients of Angstrom equation in 1983. The input values are declination angle, latitude of the site and the elevation.

$$a = 0,103 + 0,000017Z + 0,198 \cos(\phi - \delta) \quad (3.1)$$

$$b = 0,533 - 0,165 \cos(\phi - \delta) \quad (3.2)$$

Model 2: Ogelman and et. al. [16] proposed a correlation between ratio of sunshine duration and ratio of solar radiation. Also, between the years of 1979 and 1981 in Adana as 880 days and between the years 1977 and 1987 in Ankara as 962 days of data were used to develop this second order polynomial equation model.

$$\frac{H}{H_0} = 0,195 + 0,676 \left(\frac{S}{S_0} \right) - 0,142 \left(\frac{S}{S_0} \right)^2 \quad (3.3)$$

Model 3: In 1990 Akinoglu and Ecevit [25] developed a second order polynomial equation from Ogelman' s model which found from the study of Ogelman H. And Ecevit A., Tasdemiroglu E. with the name of "A new method for estimating solar radiation from bright sunshine data."

$$\frac{H}{H_0} = 0,145 + 0,845 \left(\frac{S}{S_0} \right) - 0,280 \left(\frac{S}{S_0} \right)^2 \quad (3.4)$$

Model 4: In 1991 Tasdemiroglu and Sever [14] also improved the Ogelman' s model with different regression coefficients for for six locations in Turkey as; Ankara, Antalya, Diyarbakir, Gebze, Izmir and Samsun using the data between years 1966–1982.

$$\frac{H}{H_0} = 0,225 + 0,014 \left(\frac{S}{S_0} \right) + 0,001 \left(\frac{S}{S_0} \right)^2 \quad (3.5)$$

Model 5: Three year after Tasdemiroglu and Sever, Yildiz and Oz [15] published another similar correlation by using the data from five different location in Turkey.

$$\frac{H}{H_0} = 0,2038 + 0,9236 \left(\frac{S}{S_0} \right) - 0,3911 \left(\frac{S}{S_0} \right)^2 \quad (3.6)$$

Model 6: Tiris and et. al. [17] determined regression correlations for Gebze, Kocaeli as below.

$$\frac{H}{H_0} = 0,18 + 0,62 \left(\frac{S}{S_0} \right) \quad (3.7)$$

Model 7: Aksoy [18] published a second order polynomial equation for six location from Turkey as Ankara, Antalya, Samsun, Konya, Urfa and Izmir using the data from August 1993 to July 1995 obtained from the Turkish State Meterological Service.

$$\frac{H}{H_0} = 0,148 + 0,668 \left(\frac{S}{S_0} \right) - 0,079 \left(\frac{S}{S_0} \right)^2 \quad (3.8)$$

Model 8: Togrul and Onat [19] proposed a model based on declination angle, sunshine duration ratio and monthly average daily extraterrestrial radiation for Elazig Turkey.

$$8a) \quad H = -1,3876 + 0,518H_0 + 2,3064 \left(\frac{S}{S_0} \right) \quad (3.9)$$

$$8b) \quad H = 2,765 + 4,9597 \sin(\delta) + 2,2984 \left(\frac{S}{S_0} \right) \quad (3.10)$$

Model 9: Togrul and Onat [16] after one year sugested an equation with declination angle proposed an equation with using the data dates between April 1994–March 1995 for Elazig, Turkey.

$$\frac{H}{H_0} = 0,21521 + 0,62487 \left(\frac{S}{S_0} \right) - 0,2205 \left(\frac{S}{S_0} \right)^2 \quad (3.11)$$

Model 10: Togrul and et. al. [20] suggested monthly based solar radiation model depends on the ratio of sunshine duration for Elazig, Turkey using the data between 1983 and 1994. Togrul proposed five different correlation sets with equation types as logarithmic, second, third, fourth and fifth order polynomial equations.

a) Logarithmic type of equations:

From October to March;

$$\frac{H}{H_0} = -0,0059 \ln\left(\frac{S}{S_0}\right) + 0,2255 + \left(-0,0076 \ln\left(\frac{S}{S_0}\right) + 0,4556\right)\left(\frac{S}{S_0}\right) \quad (3.12)$$

From April to September;

$$\frac{H}{H_0} = -0,1752 \ln\left(\frac{S}{S_0}\right) + 0,1474 + \left(0,1486 \ln\left(\frac{S}{S_0}\right) + 0,5125\right)\left(\frac{S}{S_0}\right) \quad (3.13)$$

b) Second order polynomial equation:

From October to March;

$$\frac{H}{H_0} = 0,2371 + 0,4358\left(\frac{S}{S_0}\right) + 0,0188\left(\frac{S}{S_0}\right)^2 \quad (3.14)$$

From April to September;

$$\frac{H}{H_0} = 0,4037 + 0,0203\left(\frac{S}{S_0}\right) + 0,2352\left(\frac{S}{S_0}\right)^2 \quad (3.15)$$

c) Third order polynomial equation:

From October to March;

$$\frac{H}{H_0} = 0,276 + 0,359\left(\frac{S}{S_0}\right) - 0,366\left(\frac{S}{S_0}\right)^2 + 0,607\left(\frac{S}{S_0}\right)^3 \quad (3.16)$$

From April to September;

$$\frac{H}{H_0} = -0,068 + 2,0955\left(\frac{S}{S_0}\right) - 2,761\left(\frac{S}{S_0}\right)^2 + 1,422\left(\frac{S}{S_0}\right)^3 \quad (3.17)$$

d) Fourth order polynomial equation:

From October to March;

$$\frac{H}{H_0} = 0,216 + 0,914 \left(\frac{S}{S_0} \right) - 1,423 \left(\frac{S}{S_0} \right)^2 + 0,382 \left(\frac{S}{S_0} \right)^3 + 1,065 \left(\frac{S}{S_0} \right)^4 \quad (3.18)$$

From April to September;

$$\frac{H}{H_0} = -0,399 + 5,333 \left(\frac{S}{S_0} \right) - 12,849 \left(\frac{S}{S_0} \right)^2 + 14,088 \left(\frac{S}{S_0} \right)^3 - 5,569 \left(\frac{S}{S_0} \right)^4 \quad (3.19)$$

e) Fifth order polynomial equation:

From October to March;

$$\frac{H}{H_0} = 0,163 + 1,965 \left(\frac{S}{S_0} \right) - 8,837 \left(\frac{S}{S_0} \right)^2 + 22,257 \left(\frac{S}{S_0} \right)^3 - 26,557 \left(\frac{S}{S_0} \right)^4 + 12,308 \left(\frac{S}{S_0} \right)^5 \quad (3.20)$$

From April to September;

$$\frac{H}{H_0} = 5,606 - 39,687 \left(\frac{S}{S_0} \right) + 120,7408 \left(\frac{S}{S_0} \right)^2 - 181,821 \left(\frac{S}{S_0} \right)^3 + 136,762 \left(\frac{S}{S_0} \right)^4 - 40,974 \left(\frac{S}{S_0} \right)^5 \quad (3.21)$$

Model 11: Ertekin and Yaldiz [21] proposed third order polynomial equation for Antalya, Turkey. The developed model was done by evaluation of 6 years global solar radiation and 27 years day length.

$$\frac{H}{H_0} = -2,4375 + 11,946 \left(\frac{S}{S_0} \right) - 16,745 \left(\frac{S}{S_0} \right)^2 + 7,9575 \left(\frac{S}{S_0} \right)^3 \quad (3.22)$$

Model 12: Ulgen and Ozbalta [15] improved the Angstrom equation for Izmir Bornova, Turkey by suggesting new regression coefficients.

$$\frac{H}{H_0} = 0,2424 + 0,5014 \left(\frac{S}{S_0} \right) \quad (3.23)$$

Model 13: Ulgen and Hepbasli [22] suggested two different empirical correlations using the data between October 1993 and 2002 for Izmir.

$$13a) \quad \frac{H}{H_0} = 0,3092 \cos(\phi) + 0,4931 \frac{S}{S_0} \quad (3.24)$$

$$13b) \quad \frac{H}{H_0} = 0,2408 + 0,3625 \left(\frac{S}{S_0}\right) + 0,4597 \left(\frac{S}{S_0}\right)^2 - 0,3708 \left(\frac{S}{S_0}\right)^3 \quad (3.25)$$

Model 14: Ulgen and Hepbasli [14] also proposed a linear and a third order polynomial equation for capital cities of Turkey; Ankara, Istanbul and Izmir.

$$14a) \quad \frac{H}{H_0} = 0,2671 + 0,4754 \left(\frac{S}{S_0}\right) \quad (3.26)$$

$$14b) \quad \frac{H}{H_0} = 0,2854 + 0,2591 \left(\frac{S}{S_0}\right) + 0,6171 \left(\frac{S}{S_0}\right)^2 - 0,4834 \left(\frac{S}{S_0}\right)^3 \quad (3.27)$$

Model 15: Aras, Balli and Hepbasli [24] improved a method for selected part of Turkey. The study consists of twelve stations as Central Anatolia Region for the years 1990 and 1996. There are first, second and third order polynomial correlations with sunshine duration dependency.

$$15a) \quad \frac{H}{H_0} = 0,3078 + 0,4166 \left(\frac{S}{S_0}\right) \quad (3.28)$$

$$15b) \quad \frac{H}{H_0} = 0,3398 + 0,2868 \left(\frac{S}{S_0}\right) + 0,1187 \left(\frac{S}{S_0}\right)^2 \quad (3.29)$$

$$15c) \quad \frac{H}{H_0} = 0,4832 - 0,6161 \left(\frac{S}{S_0}\right) + 1,8932 \left(\frac{S}{S_0}\right)^2 - 1,0975 \left(\frac{S}{S_0}\right)^3 \quad (3.30)$$

Model 16: Tahran and Sari [23] evaluated the years between 1997 and 2001 for five stations of Turkey Amasya, Corum, Ordu, Samsun and Tokat as Central Black Sea Region.

$$16a) \quad \frac{H}{H_0} = 0,1874 + 0,8592 \left(\frac{S}{S_0}\right) - 0,4764 \left(\frac{S}{S_0}\right)^2 \quad (3.31)$$

$$16b) \quad \frac{H}{H_0} = 0,1520 + 1,1334 \left(\frac{S}{S_0}\right) - 1,1126 \left(\frac{S}{S_0}\right)^2 + 0,4516 \left(\frac{S}{S_0}\right)^3 \quad (3.32)$$

Model 17: Bakirci [15] published a model with third order polynomial correlation for Erzurum, Turkey.

$$\frac{H}{H_0} = 0,6307 - 0,7251 \left(\frac{S}{S_0} \right) + 1,2089 \left(\frac{S}{S_0} \right)^2 - 0,4633 \left(\frac{S}{S_0} \right)^3 \quad (3.33)$$

Model 18: Bakirci [25] improved Angstrom equation by determining different a and b regression constants.

$$\frac{H}{H_0} = 0,2786 + 0,4160 \left(\frac{S}{S_0} \right) \quad (3.34)$$

4. CALCULATIONS

The description of the region selection and the models are detailed in the previous section. In this context, the present section of this thesis shows results of the evaluated models for regions and the statistical analysis outcome meanwhile new models are stated by the end part of the calculations chapter of this thesis.

4.1. Model Calculations

The results of the solar radiation models on the horizontal surface for the clean air conditions are stated in this section of the thesis. The five stations are chosen for each four regions. In order to evaluate in general form the reviewed models for each station, models grouped as six sets as shown in the Table 4.1. below.

Table 4.1 : Description of the calculations due to the models for stations in the region.

Region					
Station 1		Station 2		Station 3	
Station 4		Station 5			
Calculation of Set 1	Calculation of Set 2	Calculation of Set 3	Calculation of Set 4	Calculation of Set 5	Calculation of Set 6
Model 1	Model 6	Model 10 (a)	Model 11	Model 14 (a)	Model 16 (a)
Model 2	Model 7	Model 10 (b)	Model 12	Model 14 (b)	Model 16 (b)
Model 3	Model 8 (a)	Model 10 (c)	Model 13 (a)	Model 15 (a)	Model 17
Model 4	Model 8 (b)	Model 10 (d)	Model 13 (b)	Model 15 (b)	Model 18
Model 5	Model 9	Model 10 (e)		Model 15 (c)	

The corresponding model constructors for model numbers shown in the table, is given in the third section of this thesis. Furthermore, the corresponding model equations are detailed and explained in the previous section. The models are evaluated respectively due to the groups stated in the table. Furthermore, the regions and five stations of each corresponding regions are shown in the Figure 4.1.

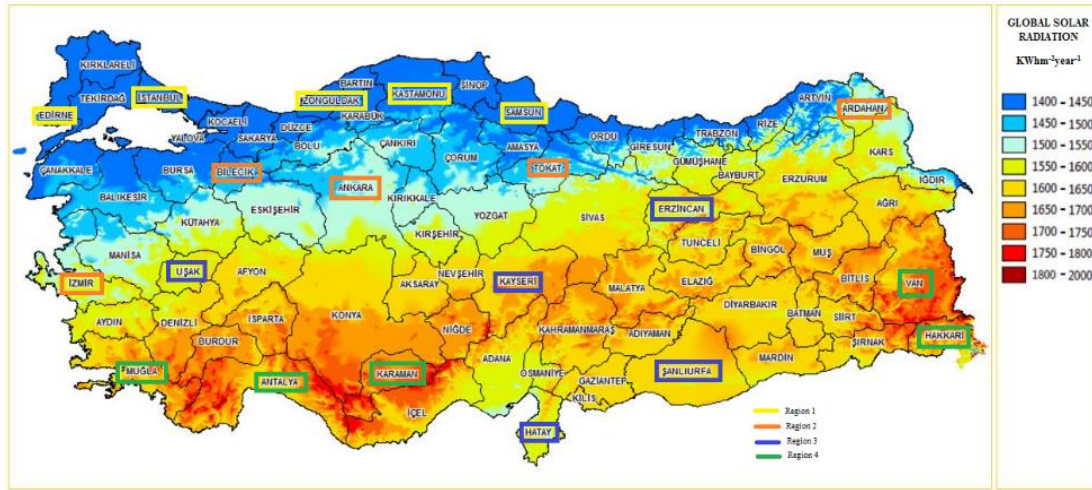


Figure 4.1 : Illustration of regions and related stations [48].

The calculation evaluation figures consists of the monthly average daily global radiation versus month of the year values for models of corresponding sets and the measured monthly average global radiation for each month of the year which is taken from Turkey Meteorology Station. In the following, each set is investigated for chosen station of each regions. The evaluation of the rest of the stations are given in the Appendix-A.

4.1.1. The global radiation model evaluation for the first region

The first region consists of the stations; Edirne, Istanbul, Zonguldak, Kastamonu, and Samsun. The reviewed models are evaluated for those stations and selected station results which are the results of station 2 for this region, are shown in the following figures. Besides other stations as Istanbul is the main station for this Master of Science Thesis, the model figures are also stated in this section.

The models evaluated for each month of the year for Istanbul with the altitude of 91 meter, and the latitude of 41,10 degrees. The model calculation evaluations are represented below by beginning with the first set results with Figure 4.2 which represents the graph of the Monthly Average of Daily Global Radiation versus Month of the Year for the 3rd Station of First Region with respect to the 5 models which are called Model1 by Kilic and Ozturk, Model2 by Ogelman et. al., Model 3 by Akinoglu and Ecevit, Model 4 by Tasdemiroglu and Sever, Model 5 by Yildiz and Oz. Besides models, the measured monthly average global radiation for each month of the year which is taken from Turkey Meteorology Station is also included. Further, the related correlations for the mentioned models are stated as well.

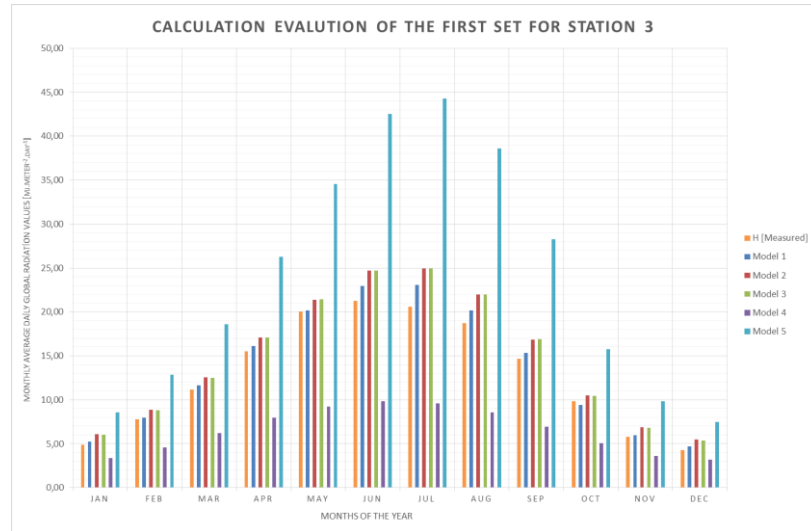


Figure 4.2 : First set of the models for station 3.

Releated equations for first set of the models for Station 3 with Figure 4.2 is illustrated on the Table 4.2. to clarify the dependence of parameters due to the models. As, it is seen all models are depends on relative sunshine duration except Model 1 which has coefficients of correlation related to latitude angle, declination angle and solar altitude.

Table 4.2 : First set of the model correlations for station 3 of region 1.

Model No	Releated Equations for First Set of The Models for Station 3		
Model 1	$a = 0,103 + 0,000017Z + 0,198 \cos(\phi - \delta)$ $b = 0,533 - 0,165 \cos(\phi - \delta)$	Model 2	$\frac{H}{H_0} = 0,195 + 0,676 \left(\frac{S}{S_0} \right) - 0,142 \left(\frac{S}{S_0} \right)^2$
Model 3	$\frac{H}{H_0} = 0,145 + 0,845 \left(\frac{S}{S_0} \right) - 0,280 \left(\frac{S}{S_0} \right)^2$	Model 4	$\frac{H}{H_0} = 0,225 + 0,014 \left(\frac{S}{S_0} \right) + 0,001 \left(\frac{S}{S_0} \right)^2$
Model 5	$\frac{H}{H_0} = 0,2038 + 0,9236 \left(\frac{S}{S_0} \right) - 0,3911 \left(\frac{S}{S_0} \right)^2$		

The Figure 4.2 shows that model 5 has the greatest values and model 4 has the least values for each months of the year. Although the other models have near values to measured monthly average daily global radiation, the model 1 represents the most appropriate results in the first set. Using eq. 3.1 and 3.2 which is the correlation constants for the Model 1, the monthly average daily global radiation values were calculated and monthly average daily global radiation values determined between 5,26 MJm⁻²d⁻¹ and 23,06 MJm⁻²d⁻¹ for Istanbul. Further, the second set for the region 1 station 3 is given Figure 4.3.

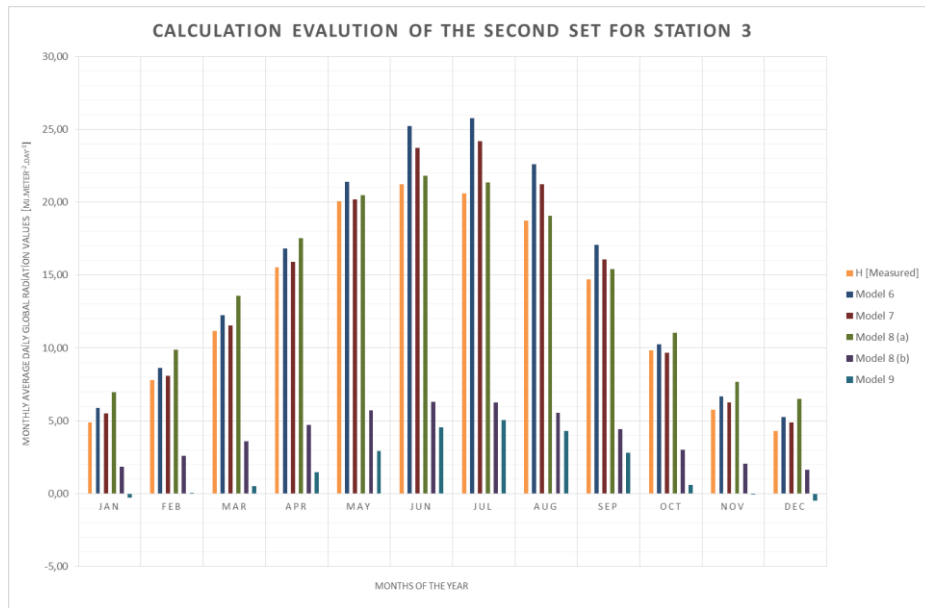


Figure 4.3 : Second set of the models for station 3.

Releated equations for second set of the models for Station 3 with Figure 4.3. is illustrated on the Table 4.3.

Table 4.3 : Second set of the model correlations for station 3 of region 1.

Model No	Releated Equations for Second Set of The Models for Station 3		
Model 6	$\frac{H}{H_0} = 0,18 + 0,62 \left(\frac{S}{S_0} \right)$	Model 8 (a)	$H = -1,3876 + 0,518H_0 + 2,3064 \left(\frac{S}{S_0} \right)$
Model 7	$\frac{H}{H_0} = 0,148 + 0,668 \left(\frac{S}{S_0} \right) - 0,079 \left(\frac{S}{S_0} \right)^2$	Model 8 (b)	$H = 2,765 + 4,9597 \sin(\delta) + 2,2984 \left(\frac{S}{S_0} \right)$
Model 9	$\frac{H}{H_0} = -0,21521 + 0,62487 \left(\frac{S}{S_0} \right) - 0,2205 \left(\frac{S}{S_0} \right)^2$		

In the second set of the calculations negative values are seen for Model 9 by Togrul and Onat where the Figure 4.3. represented. The correlation proposed in the Model 9 is for Elazig where the solar radiation distribution is belong to the fourth region. Therefore, the negative values and showing the lowest values besides others are not unexpected for Model 9 as the solar radiation distributions are in different ranges for Elazig and evaluated station. On the other hand, the highest values are varies as until april and after october Model 8 (a) and the rest of the year Model 6 represent the highest values in the second set results for region 1 station 3.

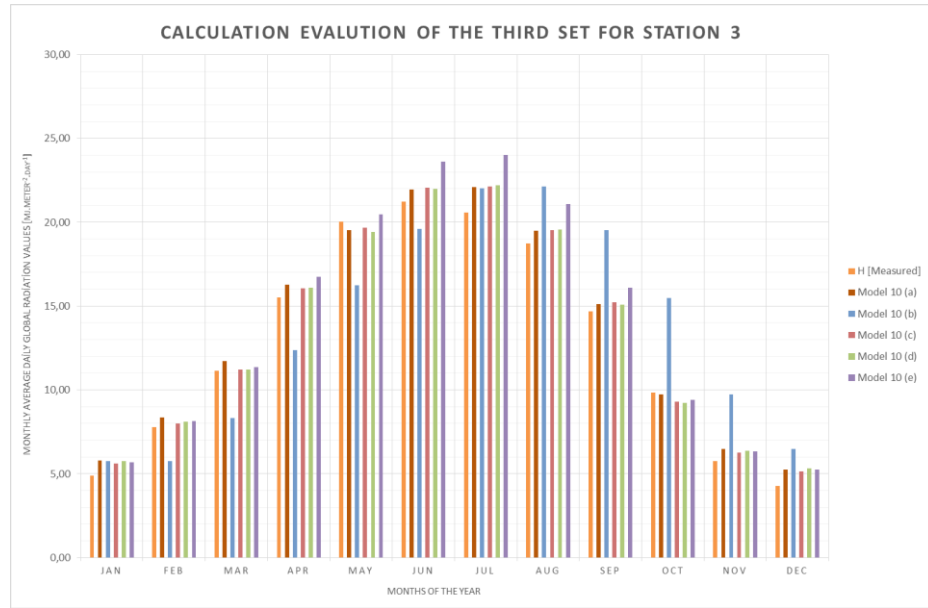


Figure 4.4 : Third set of the models for station 3.

Releated equations for third set of the models for Station 3 with Figure 4.4 is illustrated on the Table 4.4. to clarify the dependence of parameters due to the models.

Table 4.4 : Third set of the model correlations for station 3 of region 1.

Model No	Releated Equations for Third Set of The Models for Station 3	
Model 10 (a)	From October to March; $\frac{H}{H_0} = -0,0059 \ln\left(\frac{s}{s_0}\right) + 0,2255 + \left(-0,0076 \ln\left(\frac{s}{s_0}\right) + 0,4556\right)\left(\frac{s}{s_0}\right)$	From April to September; $\frac{H}{H_0} = -0,1752 \ln\left(\frac{s}{s_0}\right) + 0,1474 + \left(0,1486 \ln\left(\frac{s}{s_0}\right) + 0,5125\right)\left(\frac{s}{s_0}\right)$
Model 10 (b)	From October to March; $\frac{H}{H_0} = 0,2371 + 0,4358\left(\frac{s}{s_0}\right) + 0,0188\left(\frac{s}{s_0}\right)^2$	From April to September; $\frac{H}{H_0} = 0,4037 + 0,0203\left(\frac{s}{s_0}\right) + 0,2352\left(\frac{s}{s_0}\right)^2$
Model 10 (c)	From October to March; $\frac{H}{H_0} = 0,276 + 0,359\left(\frac{s}{s_0}\right) - 0,366\left(\frac{s}{s_0}\right)^2 + 0,607\left(\frac{s}{s_0}\right)^3$	From April to September; $\frac{H}{H_0} = -0,068 + 2,0955\left(\frac{s}{s_0}\right) - 2,761\left(\frac{s}{s_0}\right)^2 + 1,422\left(\frac{s}{s_0}\right)^3$
Model 10 (d)	From October to March; $\frac{H}{H_0} = 0,216 + 0,914\left(\frac{s}{s_0}\right) - 1,423\left(\frac{s}{s_0}\right)^2 + 0,382\left(\frac{s}{s_0}\right)^3 + 1,065\left(\frac{s}{s_0}\right)^4$	From April to September; $\frac{H}{H_0} = -0,399 + 5,333\left(\frac{s}{s_0}\right) - 12,849\left(\frac{s}{s_0}\right)^2 + 14,088\left(\frac{s}{s_0}\right)^3 - 5,569\left(\frac{s}{s_0}\right)^4$
Model 10 (e)	From October to March; $\frac{H}{H_0} = 0,163 + 1,965\left(\frac{s}{s_0}\right) - 8,837\left(\frac{s}{s_0}\right)^2 + 22,257\left(\frac{s}{s_0}\right)^3 - 26,557\left(\frac{s}{s_0}\right)^4 + 12,308\left(\frac{s}{s_0}\right)^5$	From April to September; $\frac{H}{H_0} = 5,606 - 39,687\left(\frac{s}{s_0}\right) + 120,7408\left(\frac{s}{s_0}\right)^2 - 181,821\left(\frac{s}{s_0}\right)^3 + 136,762\left(\frac{s}{s_0}\right)^4 - 40,974\left(\frac{s}{s_0}\right)^5$

The model 10 by Togrul and et. all. has a different correlation types which named and represented as shown in the Figure 4.4. Model 10 (b) inclined gradually until July except January by showing the lowest results. However, till the end of the year although monthly average daily global radiation values are declined Model 10 (b) represents the highest values compared with the others. Besides, the most appropriate model is Model 10 (a) as it gives the nearest values to the measured monthly average daily global radiation. The peak of solar radiation occurs in the cases of Istanbul between August and December, the solar radiation fluctuates from 22,14 MJm⁻²d⁻¹ to 5,15 MJm⁻²d⁻¹ for all models.

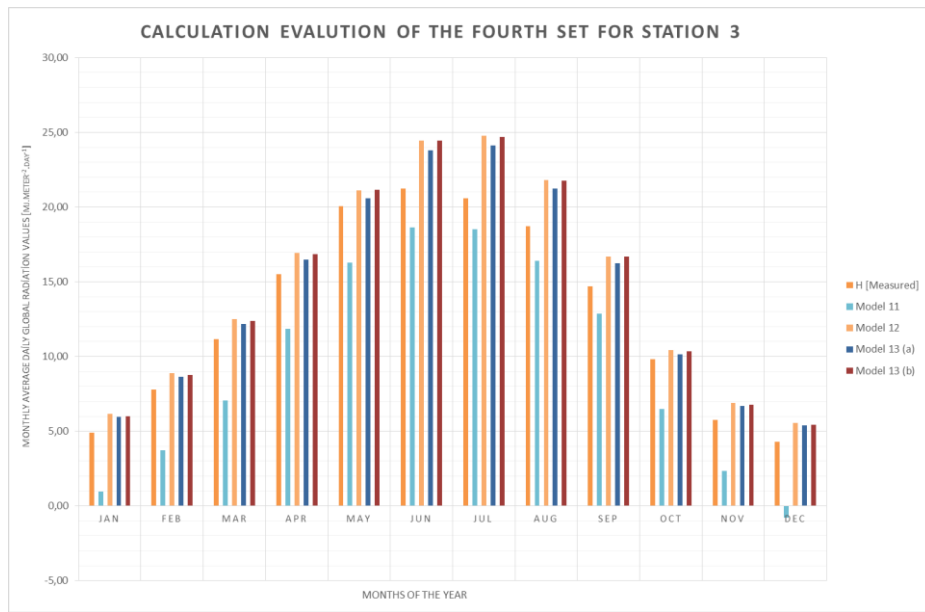


Figure 4.5 : Fourth set of the models for station 3.

The calculation evaluation of the fourth set for station 3 is given above with the Figure 4.5. Related equations for fourth set of the models for Station 3 with Fig 4.5. is illustrated on the Table 4.5.

Table 4.5 : Fourth set of the model correlations for station 3 of region 1.

Model No	Releated Equations for Fourth Set of The Models for Station 3		
Model 11	$\frac{H}{H_0} = -2,4375 + 11,946 \left(\frac{S}{S_0}\right) - 16,745 \left(\frac{S}{S_0}\right)^2 + 7,9575 \left(\frac{S}{S_0}\right)^3$	Model 13 (a)	$\frac{H}{H_0} = 0,3092 \cos(\phi) + 0,4931 \frac{S}{S_0}$
Model 12	$\frac{H}{H_0} = 0,2424 + 0,5014 \left(\frac{S}{S_0}\right)$	Model 13 (b)	$\frac{H}{H_0} = 0,2408 + 0,3625 \left(\frac{S}{S_0}\right) + 0,4597 \left(\frac{S}{S_0}\right)^2 - 0,3708 \left(\frac{S}{S_0}\right)^3$

Similar to the second set calculation evaluation, there is negative values for this set above. Ertekin and Yildiz proposed a solar radiation model for Antalya which is named as Model 11 in this Master of Science Thesis. Antalya has a hot-summer Mediterranean climate with hot and dry summers and mild and rainy winters. Station parameter that depends on the climate is important property of calculations for model. Antalya has solar radiation distribution is a range between 1700 and 2000 KWhm⁻² year⁻¹, however; the recent mentioned region is in a range of solar radiation distribution between the values 1400 and 1500 KWhm⁻² year⁻¹ which explains the reason of the negative results. On the other hand, the near calculated results to the measured result is generally are Model 13 (a) and (b) by Ulgen and Hepbasli.

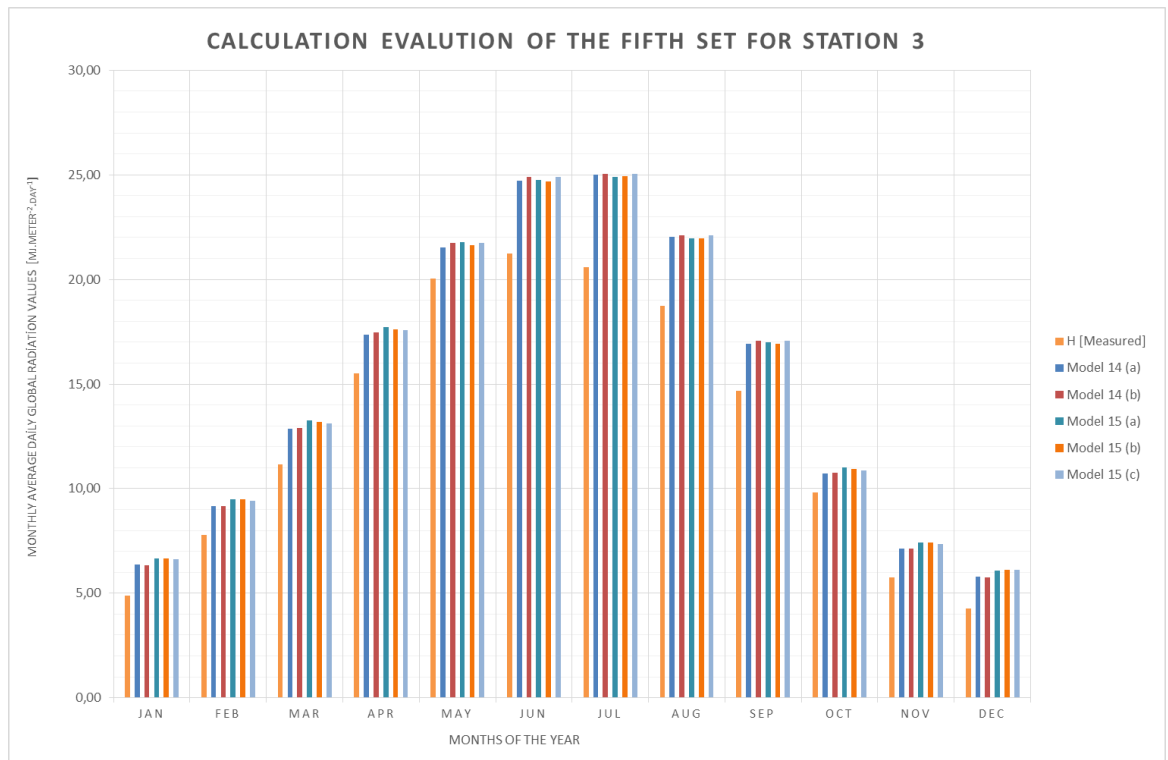


Figure 4.6 : Fifth set of the models for station 3.

Releated equations for fifth set of the models for Station 3 with Figure 4.6. is illustrated on the Table 4.6. to clarify the dependence of parameters due to the models. The Figure 4.6. represents the calculation evaluation of Model 14 (a) and (b) by Ulgen and Hepbasli and Model 15 (a), (b) and (c) by Aras, Balli and Hepbasli. As the figure shows the result of the models are similar. Although, the highest and lowest values varies, in winter season Model 14 (a) and (b) are more appropriate than others.

Table 4.6 : Fifth set of the model correlations for station 3 of region 1.

Model No	Releated Equations for Fifth Set of The Models for Station 3		
Model 14 (a)	$\frac{H}{H_0} = 0,2671 + 0,4754 \left(\frac{S}{S_0}\right)$	Model 14 (b)	$\frac{H}{H_0} = 0,2854 + 0,2591 \left(\frac{S}{S_0}\right) + 0,6171 \left(\frac{S}{S_0}\right)^2 - 0,4834 \left(\frac{S}{S_0}\right)^3$
Model 15 (a)	$\frac{H}{H_0} = 0,3078 + 0,4166 \left(\frac{S}{S_0}\right)$	Model 15 (b)	$\frac{H}{H_0} = 0,3398 + 0,2868 \left(\frac{S}{S_0}\right) + 0,1187 \left(\frac{S}{S_0}\right)^2$
Model 15 (c)	$\frac{H}{H_0} = 0,4832 - 0,6161 \left(\frac{S}{S_0}\right) + 1,8932 \left(\frac{S}{S_0}\right)^2 - 1,0975 \left(\frac{S}{S_0}\right)^3$		

Furthermore, the last set for station 3 shown in the Figure 4.7. The figure below represents Model 16 (a) and (b) by Tahran and Sari that has similar values among the entire year where, Model 17 and 18 belong to the studies by Bakirci which have different results except September by having not the same value but the nearest value to eachother compared to the rest of the year. On the other hand, the nearest calculated models to measured data are Model 16 (a) and (b) stated in the figure.

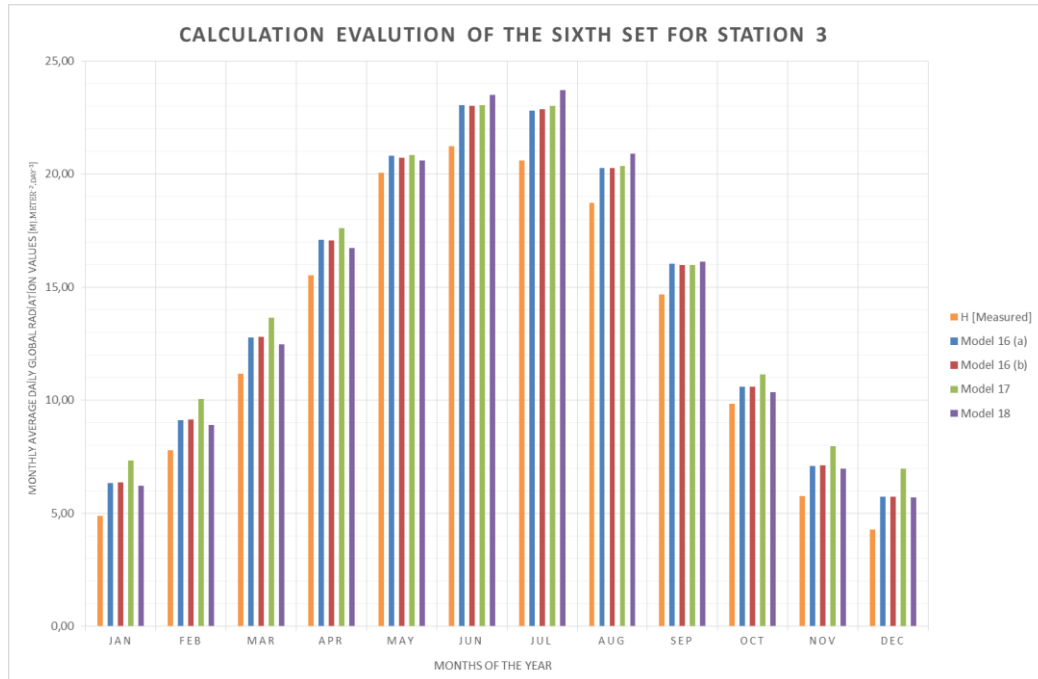


Figure 4.7 : Sixth set of the models for station 3.

Releated equations for sixth set of the models for Station 3 with Figure 4.7. is illustrated on the Table 4.7. to clarify the dependence of parameters due to the models.

Table 4.7 : Sixth set of the model correlations for station 3 of region 1.

Model No	Releated Equations for Sixth Set of The Models for Station 3
Model 16 (a)	$\frac{H}{H_0} = 0,1874 + 0,8592 \left(\frac{S}{S_0}\right) - 0,4764 \left(\frac{S}{S_0}\right)^2$
Model 16 (b)	$\frac{H}{H_0} = 0,1520 + 1,1334 \left(\frac{S}{S_0}\right) - 1,1126 \left(\frac{S}{S_0}\right)^2 + 0,4516 \left(\frac{S}{S_0}\right)^3$
Model 17	$\frac{H}{H_0} = 0,6307 - 0,7251 \left(\frac{S}{S_0}\right) + 1,2089 \left(\frac{S}{S_0}\right)^2 - 0,4633 \left(\frac{S}{S_0}\right)^3$
Model 18	$\frac{H}{H_0} = 0,2786 + 0,4160 \left(\frac{S}{S_0}\right)$

Then onwards the calculation evalution for station 3 of region 1 is demonstrated, the selected station Kastamonu for region 1 is represented in the following. The models evaluated for each month of the year for station 2; Kastamonu with the altitude of 775 meter ,and the latitude of 41,40 degrees.

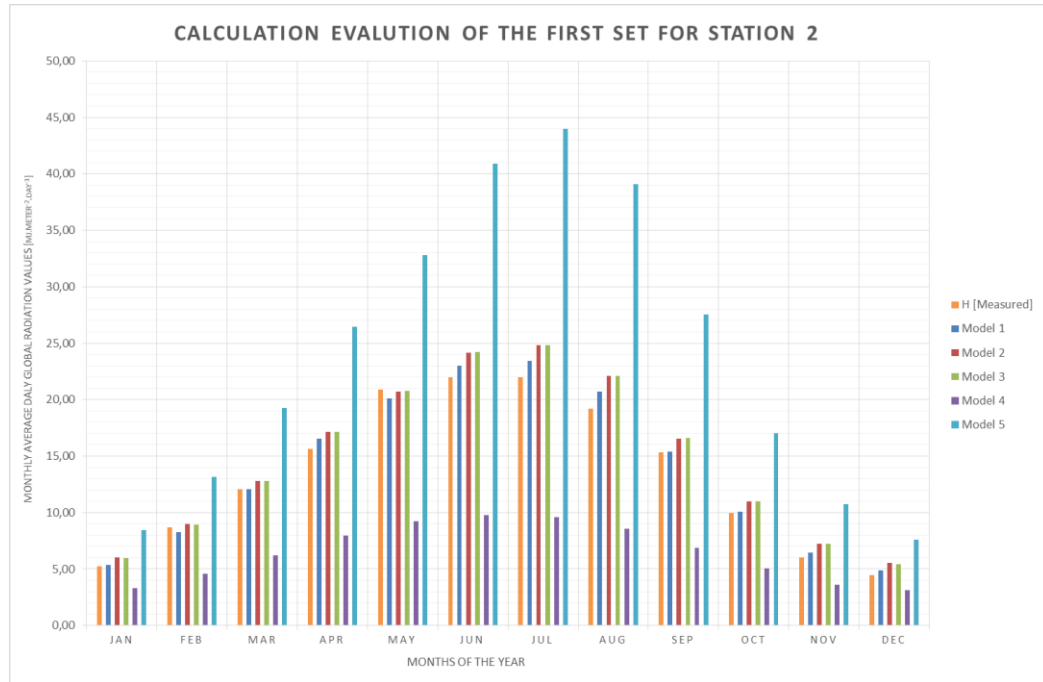


Figure 4.8 : First set of the models for station 2.

The first set calculation evalution is given in the Figure 4.8. Releated equations for first set of the models for Station 2 with Fig 4.8 is illustrated on the Table 4.8. to clarify the dependence of parameters due to the models.

Table 4.8 : First set of the model correlations for station 2 of region 1.

Model No	Releated Equations for First Set of The Models for Station 2		
Model 1	$a = 0,103 + 0,000017Z + 0,198 \cos(\phi - \delta)$ $b = 0,533 - 0,165 \cos(\phi - \delta)$	Model 2	$\frac{H}{H_0} = 0,195 + 0,676 \left(\frac{S}{S_0}\right) - 0,142 \left(\frac{S}{S_0}\right)^2$
Model 3	$\frac{H}{H_0} = 0,145 + 0,845 \left(\frac{S}{S_0}\right) - 0,280 \left(\frac{S}{S_0}\right)^2$	Model 4	$\frac{H}{H_0} = 0,225 + 0,014 \left(\frac{S}{S_0}\right) + 0,001 \left(\frac{S}{S_0}\right)^2$
Model 5	$\frac{H}{H_0} = 0,2038 + 0,9236 \left(\frac{S}{S_0}\right) - 0,3911 \left(\frac{S}{S_0}\right)^2$		

Figure 4.8. represents the graph of the Monthly Average Daily Global Radiation versus Month of the Year for the models of the first set for the 2nd Station of First Region. Besides models, the meaused monthly average global radiation for each month of the year which is taken from Turkey Meteorology Station is also included. The figure indicates the higest and the lowest values belong to model 5 with the value of 43,95 MJm⁻²d⁻¹ and model 4 with the values of 3,12 MJm⁻²d⁻¹.The model 1 represents the most appropriate results in the first set compared to other four model for Kastamonu. Further, the second set results are given below Figure 4.9.

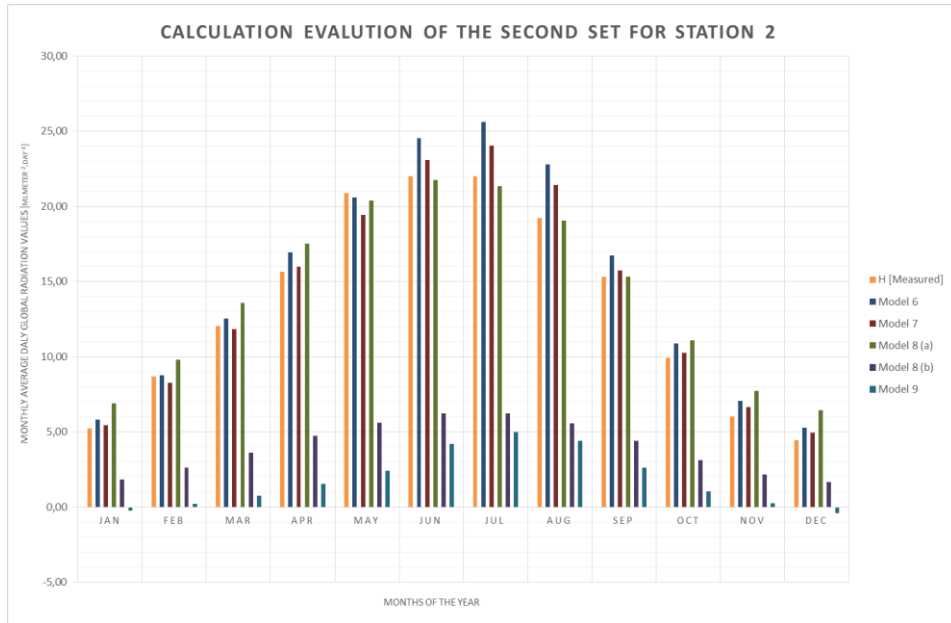


Figure 4.9 : Second set of the models for station 2.

Releated equations for second set of the models for Station 2 with Fig 4.9. is illustrated on the Table 4.9. to clarify the dependence of parameters due to the models.

Table 4.9 : Second set of the model correlations for station 2 of region 1.

Model No	Releated Equations for Second Set of The Models for Station 2		
Model 6	$\frac{H}{H_0} = 0,18 + 0,62 \left(\frac{S}{S_0} \right)$	Model 8 (a)	$H = -1,3876 + 0,518H_0 + 2,3064 \left(\frac{S}{S_0} \right)$
Model 7	$\frac{H}{H_0} = 0,148 + 0,668 \left(\frac{S}{S_0} \right) - 0,079 \left(\frac{S}{S_0} \right)^2$	Model 8 (b)	$H = 2,765 + 4,9597 \sin(\delta) + 2,2984 \left(\frac{S}{S_0} \right)$
Model 9	$\frac{H}{H_0} = -0,21521 + 0,62487 \left(\frac{S}{S_0} \right) - 0,2205 \left(\frac{S}{S_0} \right)^2$		

As, the Model 9 by Togrul and Onat proposed for Elazig which has solar radiation distribution range belongs to fourth region, there is negative values of monthly average daily global radiation results in January and December for the model 9. On the other hand, the first five months of the year model 6 and model 7 has quite equal values with measured datas, while the rest of the year until the last three months model 8 (a) shows the best results. Meanwhile, model 8 (b) and model 9 have lower values compared with the measured data.

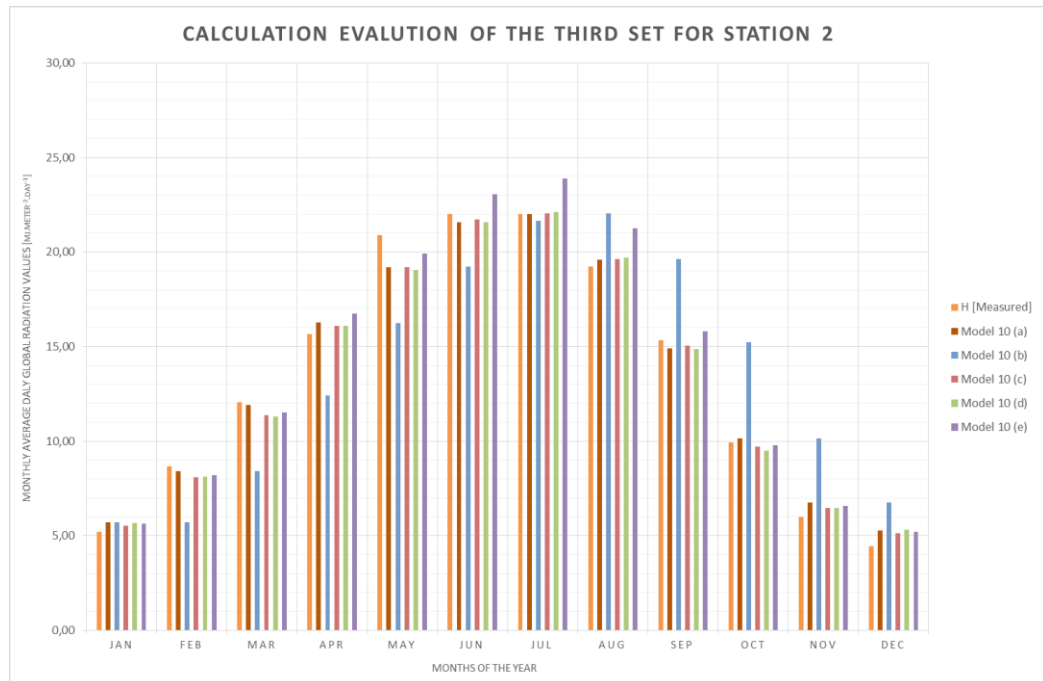


Figure 4.10 : Third set of the models for station 2.

Releated equations for third set of the models for Station 2 with Fig 4.10. is illustrated on the Table 4.10.

Table 4.10 : Third set of the model correlations for station 2 of region 1.

Model No	Releated Equations for Third Set of The Models for Station 2	
Model 10 (a)	From October to March; $\frac{H}{H_0} = -0,0059 \ln \left(\frac{S}{S_0} \right) + 0,2255 + \left(-0,0076 \ln \left(\frac{S}{S_0} \right) + 0,4556 \right) \left(\frac{S}{S_0} \right)$	From April to September; $\frac{H}{H_0} = -0,1752 \ln \left(\frac{S}{S_0} \right) + 0,1474 + \left(0,1486 \ln \left(\frac{S}{S_0} \right) + 0,5125 \right) \left(\frac{S}{S_0} \right)$
Model 10 (b)	From October to March; $\frac{H}{H_0} = 0,2371 + 0,4358 \left(\frac{S}{S_0} \right) + 0,0188 \left(\frac{S}{S_0} \right)^2$	From April to September; $\frac{H}{H_0} = 0,4037 + 0,0203 \left(\frac{S}{S_0} \right) + 0,2352 \left(\frac{S}{S_0} \right)^2$
Model 10 (c)	From October to March; $\frac{H}{H_0} = 0,276 + 0,359 \left(\frac{S}{S_0} \right) - 0,366 \left(\frac{S}{S_0} \right)^2 + 0,607 \left(\frac{S}{S_0} \right)^3$	From April to September; $\frac{H}{H_0} = -0,068 + 2,0955 \left(\frac{S}{S_0} \right) - 2,761 \left(\frac{S}{S_0} \right)^2 + 1,422 \left(\frac{S}{S_0} \right)^3$
Model 10 (d)	From October to March; $\frac{H}{H_0} = 0,216 + 0,914 \left(\frac{S}{S_0} \right) - 1,423 \left(\frac{S}{S_0} \right)^2 + 0,382 \left(\frac{S}{S_0} \right)^3 + 1,065 \left(\frac{S}{S_0} \right)^4$	From April to September; $\frac{H}{H_0} = -0,399 + 5,333 \left(\frac{S}{S_0} \right) - 12,849 \left(\frac{S}{S_0} \right)^2 + 14,088 \left(\frac{S}{S_0} \right)^3 - 5,569 \left(\frac{S}{S_0} \right)^4$
Model 10 (e)	From October to March; $\frac{H}{H_0} = 0,163 + 1,965 \left(\frac{S}{S_0} \right) - 8,837 \left(\frac{S}{S_0} \right)^2 + 22,257 \left(\frac{S}{S_0} \right)^3 - 26,557 \left(\frac{S}{S_0} \right)^4 + 12,308 \left(\frac{S}{S_0} \right)^5$	From April to September; $\frac{H}{H_0} = 5,606 - 39,687 \left(\frac{S}{S_0} \right) + 120,7408 \left(\frac{S}{S_0} \right)^2 - 181,821 \left(\frac{S}{S_0} \right)^3 + 136,762 \left(\frac{S}{S_0} \right)^4 - 40,974 \left(\frac{S}{S_0} \right)^5$

The figure 4.10. represents the model 10 with sub-models by Togrul et. al. which are different correlation types of models. The graph, put forth a general fluctuation as the highest values and lowest values are differ from models for each month.

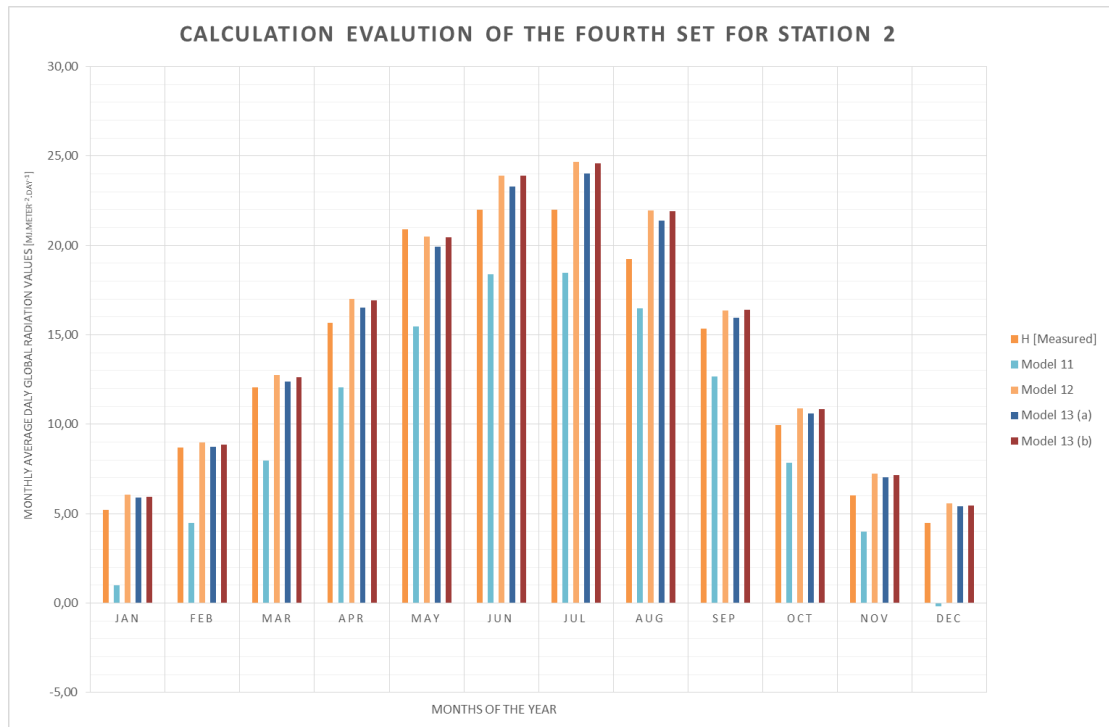


Figure 4.11 : Fourth set of the models for station 2.

Releated equations for fourth set of the models for Station 2 with Fig 4.11. is illustrated on the Table 4.11. to clarify the dependence of parameters due to the models.

Table 4.11 : Fourth set of the model correlations for station 2 of region 1.

Model No	Releated Equations for Fourth Set of The Models for Station 2
Model 11	$\frac{H}{H_0} = -2,4375 + 11,946 \left(\frac{S}{S_0} \right) - 16,745 \left(\frac{S}{S_0} \right)^2 + 7,9575 \left(\frac{S}{S_0} \right)^3$
Model 12	$\frac{H}{H_0} = 0,2424 + 0,5014 \left(\frac{S}{S_0} \right)$
Model 13 (a)	$\frac{H}{H_0} = 0,3092 \cos(\phi) + 0,4931 \frac{S}{S_0}$
Model 13 (b)	$\frac{H}{H_0} = 0,2408 + 0,3625 \left(\frac{S}{S_0} \right) + 0,4597 \left(\frac{S}{S_0} \right)^2 - 0,3708 \left(\frac{S}{S_0} \right)^3$

The figure of the fourth set results for region 1 station 2; Kastamonu is given above. There is negative value in december gathered from model 11 as the model proposed for different global radiation range. Besides the model 11 has lowest values, the model 12 by Ulgen and Ozbalta has highest values except in May the measured data has soared dramatically.

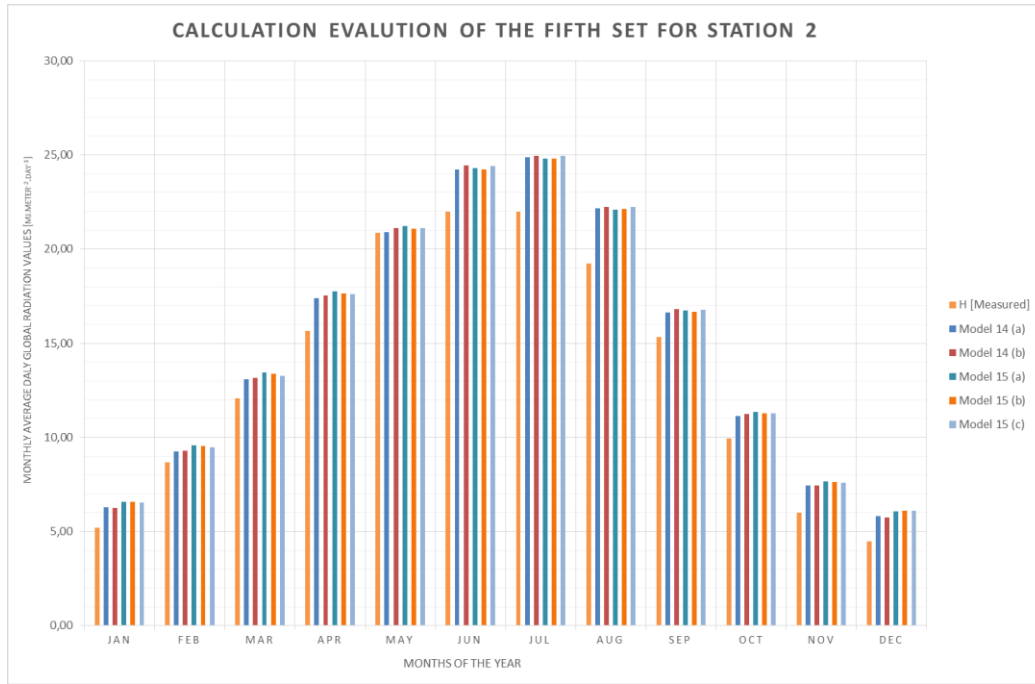


Figure 4.12 : Fifth set of the models for station 2.

Related equations for fifth set of the models for Station 2 with Fig 4.12. is illustrated on the Table 4.12. to clarify the dependence of parameters due to the models.

Table 4.12 : Fifth set of the model correlations for station 2 of region 1.

Model No	Related Equations for Fifth Set of The Models for Station 2
Model 14 (a)	$\frac{H}{H_0} = 0,2671 + 0,4754 \left(\frac{S}{S_0} \right)$
Model 14 (b)	$\frac{H}{H_0} = 0,2854 + 0,2591 \left(\frac{S}{S_0} \right) + 0,6171 \left(\frac{S}{S_0} \right)^2 - 0,4834 \left(\frac{S}{S_0} \right)^3$
Model 15 (a)	$\frac{H}{H_0} = 0,3078 + 0,4166 \left(\frac{S}{S_0} \right)$
Model 15 (b)	$\frac{H}{H_0} = 0,3398 + 0,2868 \left(\frac{S}{S_0} \right) + 0,1187 \left(\frac{S}{S_0} \right)^2$
Model 15 (c)	$\frac{H}{H_0} = 0,4832 - 0,6161 \left(\frac{S}{S_0} \right) + 1,8932 \left(\frac{S}{S_0} \right)^2 - 1,0975 \left(\frac{S}{S_0} \right)^3$

The figure 4.12. shows the fifth set results. Obviously, models have higher results compared to measured data. Besides, both models 15 (a), (b) and models 16 (a), (b), (c), in themselves has almost equal results as model 15 (a) and (b) are suggested by

Ulgen and Hepbasli and models 16 (a), (b) and (c) presented by Aras, Balli and Hepbasli.

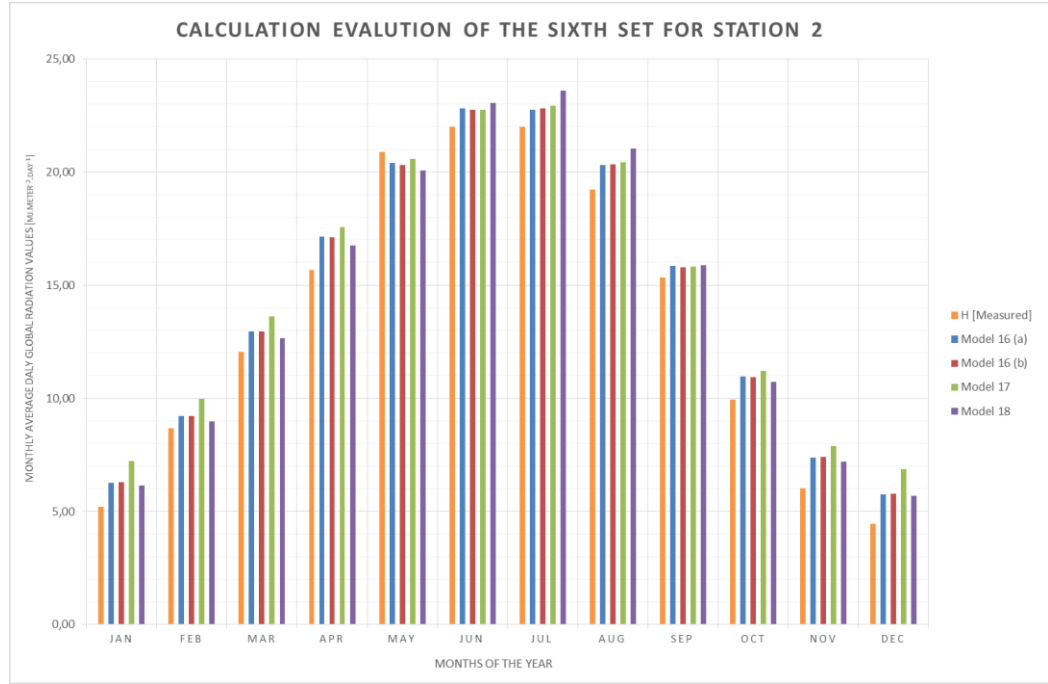


Figure 4.13 : Sixth set of the models for station 2.

Releated equations for sixth set of the models for Station 2 with Fig 4.13. is illustrated on the Table 4.13. to clarify the dependence of parameters due to the models.

Table 4.13 : Sixth set of the model correlations for station 2 of region 1.

Model No	Releated Equations for Sixth Set of The Models for Station 2
Model 16 (a)	$\frac{H}{H_0} = 0,1874 + 0,8592 \left(\frac{S}{S_0} \right) - 0,4764 \left(\frac{S}{S_0} \right)^2$
Model 16 (b)	$\frac{H}{H_0} = 0,1520 + 1,1334 \left(\frac{S}{S_0} \right) - 1,1126 \left(\frac{S}{S_0} \right)^2 + 0,4516 \left(\frac{S}{S_0} \right)^3$
Model 17	$\frac{H}{H_0} = 0,6307 - 0,7251 \left(\frac{S}{S_0} \right) + 1,2089 \left(\frac{S}{S_0} \right)^2 - 0,4633 \left(\frac{S}{S_0} \right)^3$
Model 18	$\frac{H}{H_0} = 0,2786 + 0,4160 \left(\frac{S}{S_0} \right)$

The last set for station 2 represents the results for four models; Model 17 (a) and Model 17 (b) by Tahran and Sari, Model 18 and 19 by Bakirci. As, figure above stated the

four model has almost equal results in September. Further, model 16 (a) and model 16 (b) have similar results in general in the entire year. The measured monthly average daily global radiation data has always lower values compared to models except May as, inclined sharply.

Overall, the monthly average daily global radiation values goes upwards in the first half of the year by reaching a peak at June or July and towards the second half of the year decline gradually. The investigation results for region 1 station 2 and station 3 with six sets each are given above. The other selected stations for the rest of the regions are evaluated in the following sections.

4.1.2. The global radiation model evaluation for the second region

The stations for the second region are Izmir, Bilecik, Ankara, Tokat and Ardahan. The models in the literature selected for this thesis are evaluated for those stations and selected station which is station 2 detailed as below. The altitude and latitude values for the station 2 are 1810 meter, and 41,11 degrees respectively. The display of the six set for station 2 begins with the first set shown in the Figure 4.14.

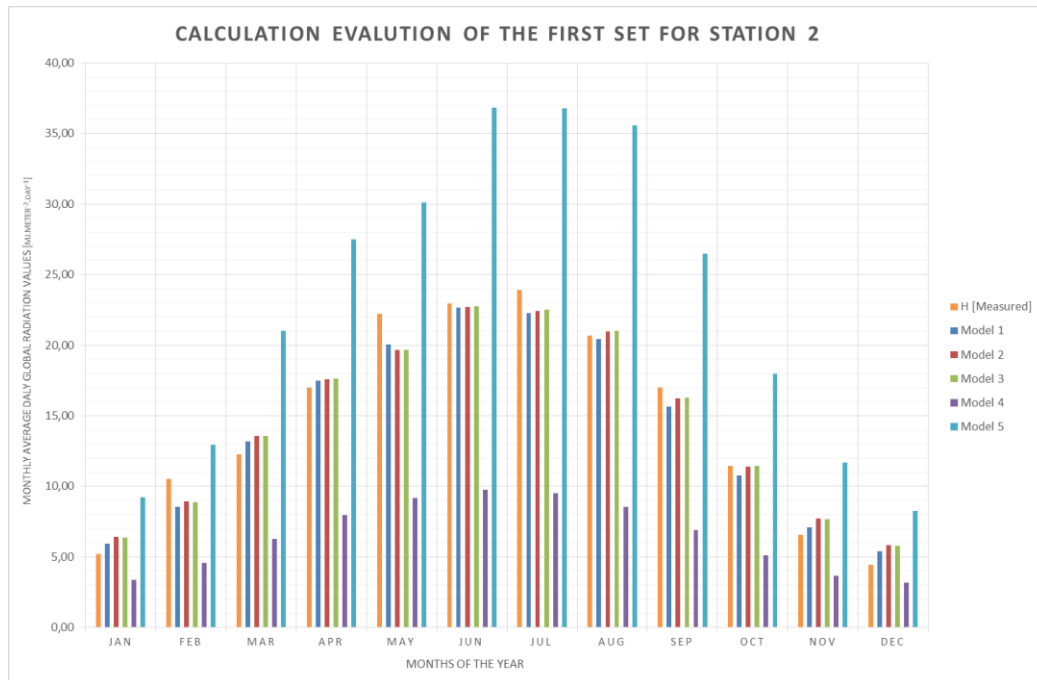


Figure 4.14 : First set of the models for station 2.

Releated equations for first set of the models for Station 2 with Fig 4.14. is illustrated on the Table 4.14. to clarify the dependence of parameters due to the models.

Table 4.14 : First set of the model correlations for station 2 of region 2.

Model No	Releated Equations for First Set of The Models for Station 2		
Model 1	$a = 0,103 + 0,000017Z + 0,198 \cos(\phi - \delta)$ $b = 0,533 - 0,165 \cos(\phi - \delta)$	Model 2	$\frac{H}{H_0} = 0,195 + 0,676 \left(\frac{S}{S_0} \right) - 0,142 \left(\frac{S}{S_0} \right)^2$
Model 3	$\frac{H}{H_0} = 0,145 + 0,845 \left(\frac{S}{S_0} \right) - 0,280 \left(\frac{S}{S_0} \right)^2$	Model 4	$\frac{H}{H_0} = 0,225 + 0,014 \left(\frac{S}{S_0} \right) + 0,001 \left(\frac{S}{S_0} \right)^2$
Model 5	$\frac{H}{H_0} = 0,2038 + 0,9236 \left(\frac{S}{S_0} \right) - 0,3911 \left(\frac{S}{S_0} \right)^2$		

As Figure 4.14. represents, the Model 1 has the highest values by having the most different results compared to the monthly average daily global radiation data likewise the Model 4 shows the lowest values. On the other hand, the rest of the models for the first set and the measured data have similar results except a few peaks such as in February, May and July. Further, the next set is given below figure for Ardahan.

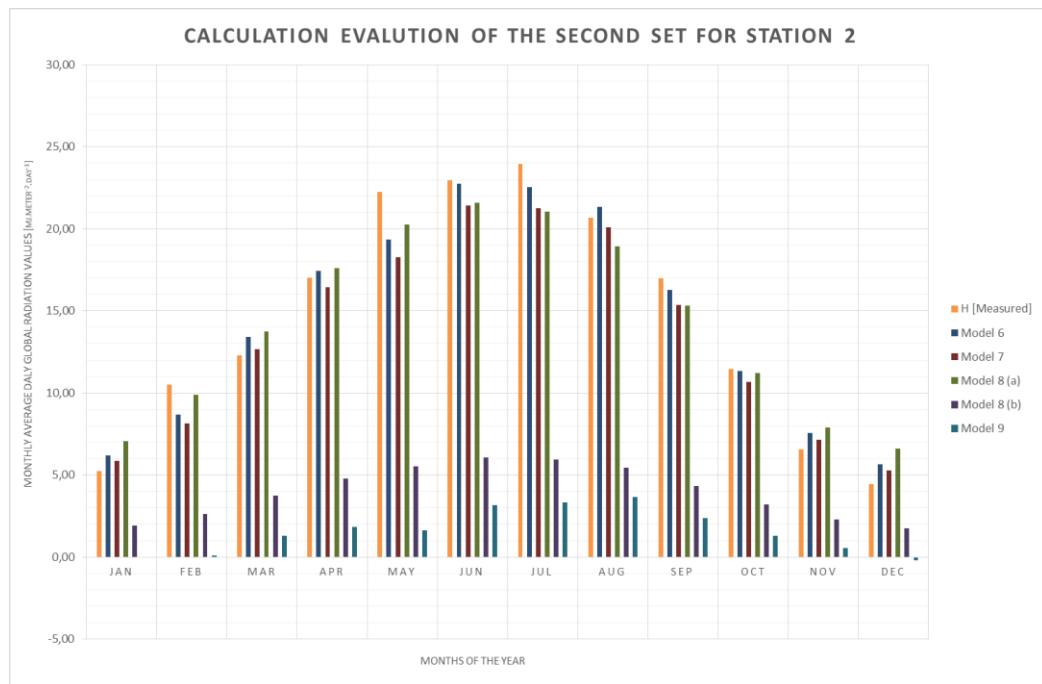


Figure 4.15 : Second set of the models for station 2.

Releated equations for second set of the models for Station 2 with Fig 4.15 is illustrated on the Table 4.15. to clarify the dependence of parameters due to the models. The negative data value in the December as shown in the Figure 4.15 which belongs to

Model 9 which is proposed for Elazig is because of the difference of the solar radiation distribution of Ardahan and Elazig.

Table 4.15 : Second set of the model correlations for station 2 of region 2.

Model No	Releated Equations for Second Set of The Models for Station 2
Model 6	$\frac{H}{H_0} = 0,18 + 0,62 \left(\frac{S}{S_0} \right)$
Model 7	$\frac{H}{H_0} = 0,148 + 0,668 \left(\frac{S}{S_0} \right) - 0,079 \left(\frac{S}{S_0} \right)^2$
Model 8 (a)	$H = -1,3876 + 0,518H_0 + 2,3064 \left(\frac{S}{S_0} \right)$
Model 8 (b)	$H = 2,765 + 4,9597 \sin(\delta) + 2,2984 \left(\frac{S}{S_0} \right)$
Model 9	$\frac{H}{H_0} = -0,21521 + 0,62487 \left(\frac{S}{S_0} \right) - 0,2205 \left(\frac{S}{S_0} \right)^2$

Although, Model 8 (a) and (b) both proposed by Togrul and Onat, there is an extensive difference because of the correlation types. Besides, the third set datas for station 2 is given in the Figure 4.16.

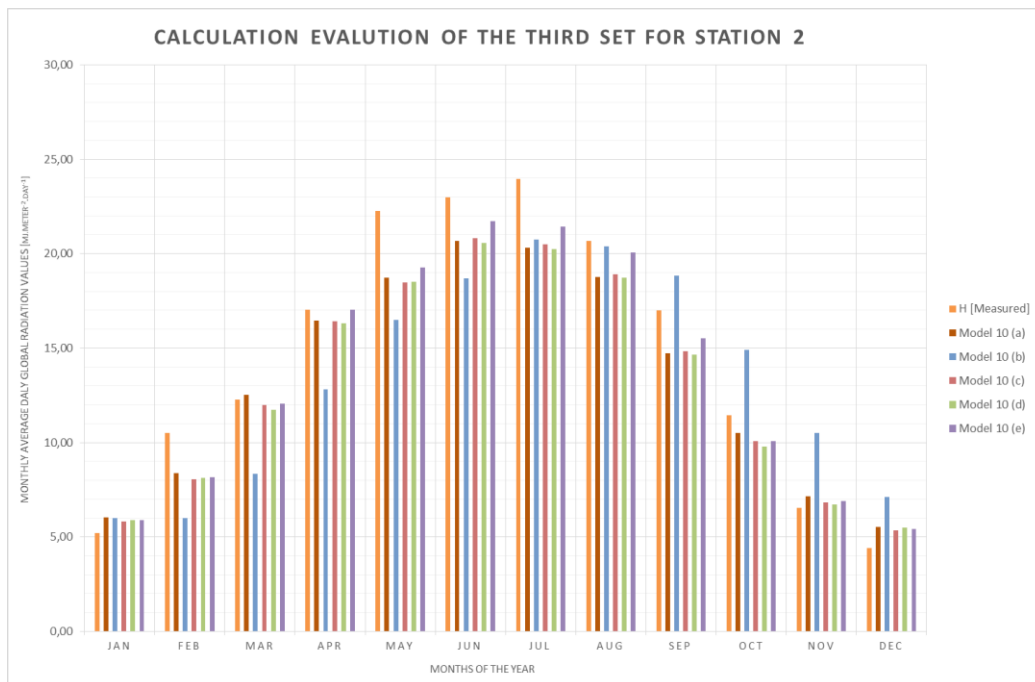


Figure 4.16 : Third set of the models for station 2.

Releated equations for third set of the models for Station 2 with Fig 4.16. is illustrated on the Table 4.16. to clarify the dependence of parameters due to the models.

Table 4.16 : Third set of the model correlations for station 2 of region 2.

Model No	Releated Equations for Third Set of The Models for Station 2	
Model 10 (a)	From October to March; $\frac{H}{H_0} = -0,0059 \ln\left(\frac{S}{S_0}\right) + 0,2255 + \left(-0,0076 \ln\left(\frac{S}{S_0}\right) + 0,4556\right)\left(\frac{S}{S_0}\right)$	From April to September; $\frac{H}{H_0} = -0,1752 \ln\left(\frac{S}{S_0}\right) + 0,1474 + \left(0,1486 \ln\left(\frac{S}{S_0}\right) + 0,5125\right)\left(\frac{S}{S_0}\right)$
Model 10 (b)	From October to March; $\frac{H}{H_0} = 0,2371 + 0,4358\left(\frac{S}{S_0}\right) + 0,0188\left(\frac{S}{S_0}\right)^2$	From April to September; $\frac{H}{H_0} = 0,4037 + 0,0203\left(\frac{S}{S_0}\right) + 0,2352\left(\frac{S}{S_0}\right)^2$
Model 10 (c)	From October to March; $\frac{H}{H_0} = 0,276 + 0,359\left(\frac{S}{S_0}\right) - 0,366\left(\frac{S}{S_0}\right)^2 + 0,607\left(\frac{S}{S_0}\right)^3$	From April to September; $\frac{H}{H_0} = -0,068 + 2,0955\left(\frac{S}{S_0}\right) - 2,761\left(\frac{S}{S_0}\right)^2 + 1,422\left(\frac{S}{S_0}\right)^3$
Model 10 (d)	From October to March; $\frac{H}{H_0} = 0,216 + 0,914\left(\frac{S}{S_0}\right) - 1,423\left(\frac{S}{S_0}\right)^2 + 0,382\left(\frac{S}{S_0}\right)^3 + 1,065\left(\frac{S}{S_0}\right)^4$	From April to September; $\frac{H}{H_0} = -0,399 + 5,333\left(\frac{S}{S_0}\right) - 12,849\left(\frac{S}{S_0}\right)^2 + 14,088\left(\frac{S}{S_0}\right)^3 - 5,569\left(\frac{S}{S_0}\right)^4$
Model 10 (e)	From October to March; $\frac{H}{H_0} = 0,163 + 1,965\left(\frac{S}{S_0}\right) - 8,837\left(\frac{S}{S_0}\right)^2 + 22,257\left(\frac{S}{S_0}\right)^3 - 26,557\left(\frac{S}{S_0}\right)^4 + 12,308\left(\frac{S}{S_0}\right)^5$	From April to September; $\frac{H}{H_0} = 5,606 - 39,687\left(\frac{S}{S_0}\right) + 120,7408\left(\frac{S}{S_0}\right)^2 - 181,821\left(\frac{S}{S_0}\right)^3 + 136,762\left(\frac{S}{S_0}\right)^4 - 40,974\left(\frac{S}{S_0}\right)^5$

The model 10 (b) inclined slightly during the first half of the year by having the lowest values compared to others as Figure 4.16. shows. On the other hand, although general trend is downward, Model 10 (b) has the highest values rest of the year. Besides, the gap between the measured monthly average daily global radiation and the rest of the models is almost negligible except few months of the year.

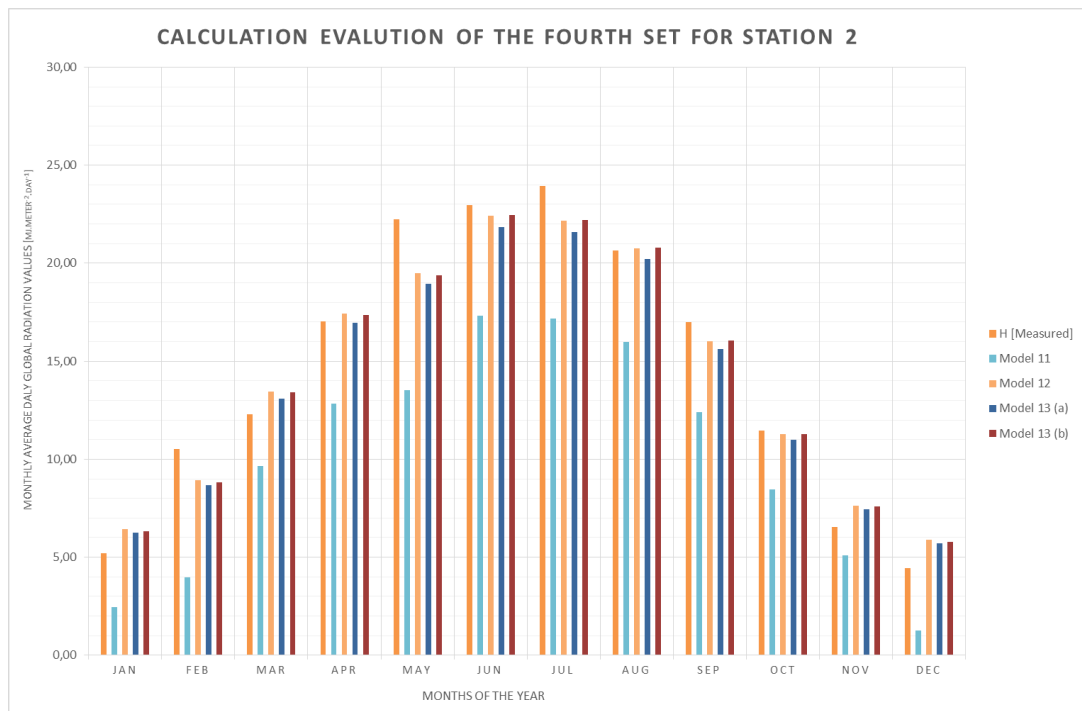


Figure 4.17 : Fourth set of the models for station 2.

Releated equations for fourth set of the models for Station 2 with Fig 4.17. is illustrated on the Table 4.17. to clarify the dependence of parameters due to the models.

Table 4.17 : Fourth set of the model correlations for station 2 of region 2.

Model No	Releated Equations for Fourth Set of The Models for Station 2
Model 11	$\frac{H}{H_0} = -2,4375 + 11,946 \left(\frac{S}{S_0}\right) - 16,745 \left(\frac{S}{S_0}\right)^2 + 7,9575 \left(\frac{S}{S_0}\right)^3$
Model 12	$\frac{H}{H_0} = 0,2424 + 0,5014 \left(\frac{S}{S_0}\right)$
Model 13 (a)	$\frac{H}{H_0} = 0,3092 \cos(\phi) + 0,4931 \frac{S}{S_0}$
Model 13 (b)	$\frac{H}{H_0} = 0,2408 + 0,3625 \left(\frac{S}{S_0}\right) + 0,4597 \left(\frac{S}{S_0}\right)^2 - 0,3708 \left(\frac{S}{S_0}\right)^3$

The Model 13 (a) and (b) by Ulgen and Hepbasli show similar values among the year while difference between Model 11 and other data sets is significant in the Figure 4.17. On the other hand, the relation between Model 12 and Model 13 (a), (b) is almost remains same. Meanwhile, the monthly average daily global solar radiation values for Ardahan varies between the values 1,27 MJm⁻²d⁻¹ and 22,44 MJm⁻²d⁻¹.

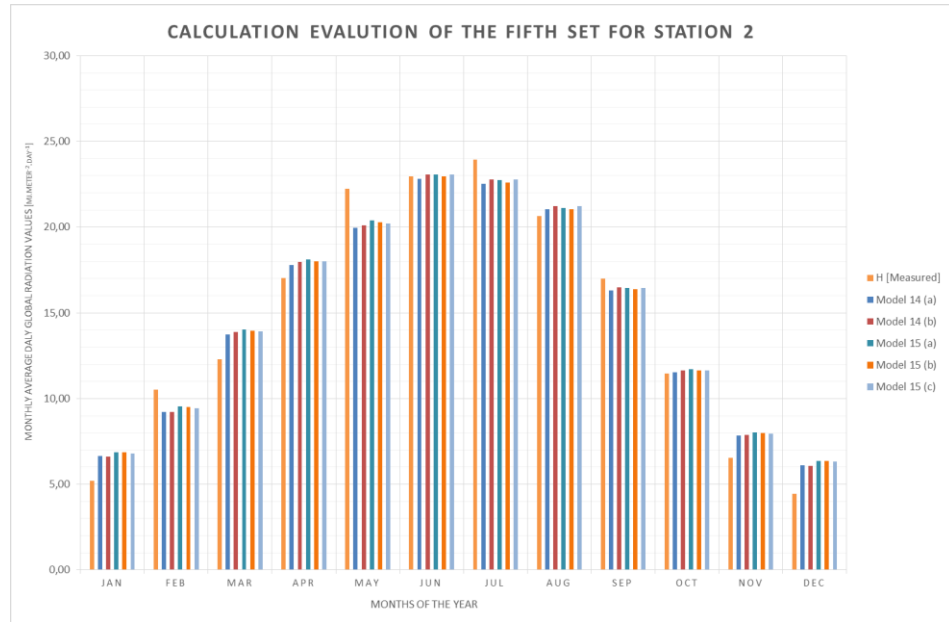


Figure 4.18 : Fifth set of the models for station 2.

Releated equations for fifth set of the models for Station 2 with Fig 4.18. is illustrated on the Table 4.18. to clarify the dependence of parameters due to the models.

Table 4.18 : Fifth set of the model correlations for station 2 of region 2.

Model No	Releated Equations for Fifth Set of The Models for Station 2
Model 14 (a)	$\frac{H}{H_0} = 0,2671 + 0,4754 \left(\frac{S}{S_0} \right)$
Model 14 (b)	$\frac{H}{H_0} = 0,2854 + 0,2591 \left(\frac{S}{S_0} \right) + 0,6171 \left(\frac{S}{S_0} \right)^2 - 0,4834 \left(\frac{S}{S_0} \right)^3$
Model 15 (a)	$\frac{H}{H_0} = 0,3078 + 0,4166 \left(\frac{S}{S_0} \right)$
Model 15 (b)	$\frac{H}{H_0} = 0,3398 + 0,2868 \left(\frac{S}{S_0} \right) + 0,1187 \left(\frac{S}{S_0} \right)^2$
Model 15 (c)	$\frac{H}{H_0} = 0,4832 - 0,6161 \left(\frac{S}{S_0} \right) + 1,8932 \left(\frac{S}{S_0} \right)^2 - 1,0975 \left(\frac{S}{S_0} \right)^3$

The figure 4.18. represents the fifth set results for station 2 of region 2 with the models as Model 14 (a) and (b) by Ulgen and Hepbasli and Model 15 (a), (b) and (c) by Aras, Balli and Hepbasli. Among the year, during each month models have almost same values while the difference to the measured monthly average daily global radiation data varies in some months.

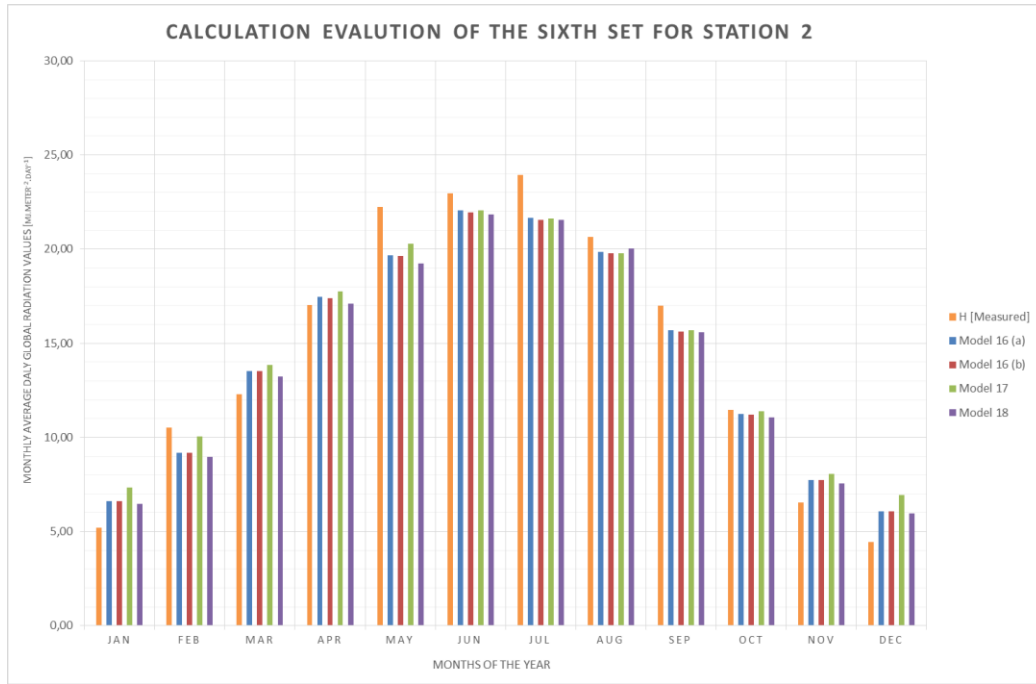


Figure 4.19 : Sixth set of the models for station 2.

Releated equations for sixth set of the models for Station 2 with Fig 4.19. is illustrated on the Table 4.19. to clarify the dependence of parameters due to the models.

Table 4.19 : Sixth set of the model correlations for station 2 of region 2.

Model No	Releated Equations for Sixth Set of The Models for Station 2		
Model 16 (a)	$\frac{H}{H_0} = 0,1874 + 0,8592 \left(\frac{S}{S_0}\right) - 0,4764 \left(\frac{S}{S_0}\right)^2$	Model 17	$\frac{H}{H_0} = 0,6307 - 0,7251 \left(\frac{S}{S_0}\right) + 1,2089 \left(\frac{S}{S_0}\right)^2 - 0,4633 \left(\frac{S}{S_0}\right)^3$
Model 16 (b)	$\frac{H}{H_0} = 0,1520 + 1,1334 \left(\frac{S}{S_0}\right) - 1,1126 \left(\frac{S}{S_0}\right)^2 + 0,4516 \left(\frac{S}{S_0}\right)^3$	Model 18	$\frac{H}{H_0} = 0,2786 + 0,4160 \left(\frac{S}{S_0}\right)$

The last set of calculation evaluations for station 2, Ardahan, is represented in the Figure 4.19. The monthly averagedaily global radiation of models and measured data is compared on monthly basis. The Model 16 (a) and Model 16 (b) shows similar results during the year meanwhile Model 17 shows different behavior at the beginning and end of the year. The calculation evaluation figures for the Station 2 of the 2nd region are represented and explained. The selected stations for third and the last region is described likely in the following sections.

4.1.3. The global radiation model evaluation for the third region

The third region consists of Usak, Kayseri, Hatay, Sanliurfa and Erzincan. The models in the literature are evaluated for those stations and represented as below for the selected station, station 1 for region 3. The altitude and the latitude of the Station 1; Erzincan, is 1185 meter and 39,55 degrees respectively. The first set of results are given in the Figure 4.20 as below.

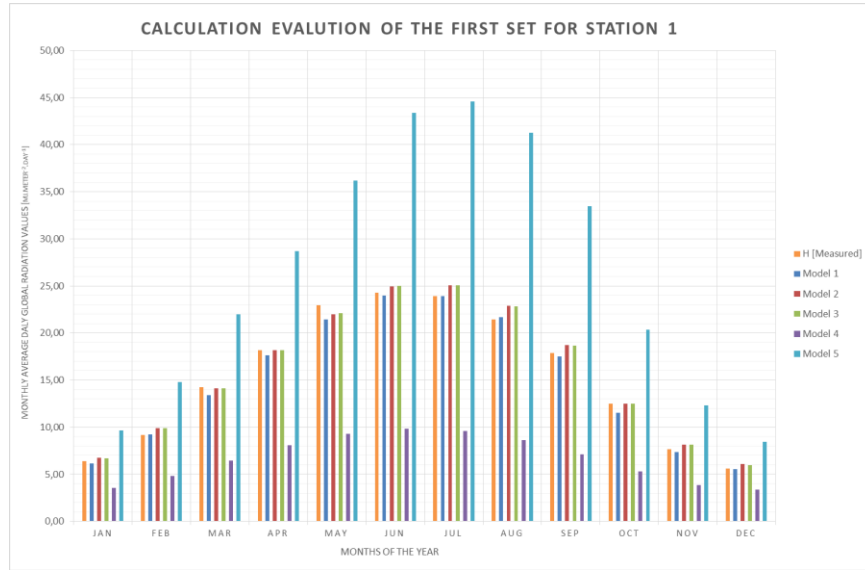


Figure 4.20 : First set of the models for station 1.

Releated equations for first set of the models for Station 1 with Fig 4.20. is illustrated on the Table 4.20. to clarify the dependence of parameters due to the models.

Table 4.20 : First set of the model correlations for station 1 of region 3.

Model No	Releated Equations for First Set of The Models for Station 1		
Model 1	$a = 0,103 + 0,000017Z + 0,198 \cos(\phi - \delta)$ $b = 0,533 - 0,165 \cos(\phi - \delta)$	Model 2	$\frac{H}{H_0} = 0,195 + 0,676 \left(\frac{S}{S_0} \right) - 0,142 \left(\frac{S}{S_0} \right)^2$
Model 3	$\frac{H}{H_0} = 0,145 + 0,845 \left(\frac{S}{S_0} \right) - 0,280 \left(\frac{S}{S_0} \right)^2$	Model 4	$\frac{H}{H_0} = 0,225 + 0,014 \left(\frac{S}{S_0} \right) + 0,001 \left(\frac{S}{S_0} \right)^2$
Model 5	$\frac{H}{H_0} = 0,2038 + 0,9236 \left(\frac{S}{S_0} \right) - 0,3911 \left(\frac{S}{S_0} \right)^2$		

The figure shows the calculation evalution of the first set for Erzincan which indicates that model 5 proposed by Yildiz and Oz has extremely different values which has range

between $8,43 \text{ MJm}^{-2}\text{d}^{-1}$ within the winter season and $44,59 \text{ MJm}^{-2}\text{d}^{-1}$ which belongs to the July, compared to other models and also the measured monthly average daily global radiation data. Besides, Model 1 by Kilic and Ozturk has similar but not equal values with the measured data almost each month of the year.

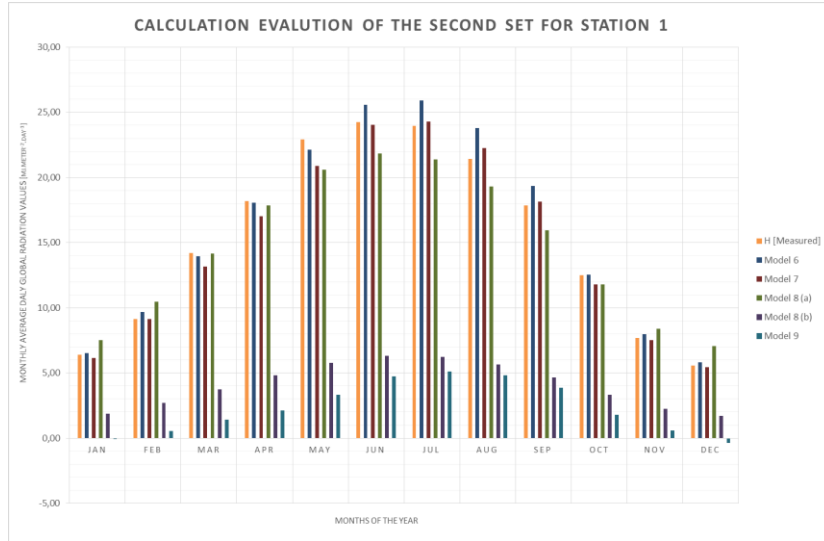


Figure 4.21 : Second set of the models for station 1.

Releated equations for second set of the models for Station 1 with Fig 4.21. is illustrated on the Table 4.21.

Table 4.21 : Second set of the model correlations for station 1 of region 3.

Model No	Releated Equations for Second Set of The Models for Station 1		
Model 6	$\frac{H}{H_0} = 0,18 + 0,62 \left(\frac{S}{S_0} \right)$	Model 8 (a)	$H = -1,3876 + 0,518H_0 + 2,3064 \left(\frac{S}{S_0} \right)$
Model 7	$\frac{H}{H_0} = 0,148 + 0,668 \left(\frac{S}{S_0} \right) - 0,079 \left(\frac{S}{S_0} \right)^2$	Model 8 (b)	$H = 2,765 + 4,9597 \sin(\delta) + 2,2984 \left(\frac{S}{S_0} \right)$
Model 9	$\frac{H}{H_0} = -0,21521 + 0,62487 \left(\frac{S}{S_0} \right) - 0,2205 \left(\frac{S}{S_0} \right)^2$		

Similar to the stations demonstrated above for 1st and 2nd regions for the stations Kastamonu and Ardahan, Model 9 represents negative values with the same reasons for this station; Erzincan. On the other hand, figrue for Model 8 (b) has huge difference compared to the measured monthly average daily global radiation contrary to Model 8 (a). Besides, the Model 6 has nearest datas to the measured values until June by having a peak at July at the first half of the year. However, the relation between Model 6 and

the measured monthly average daily global radiation data shows that nearest almost equal values.

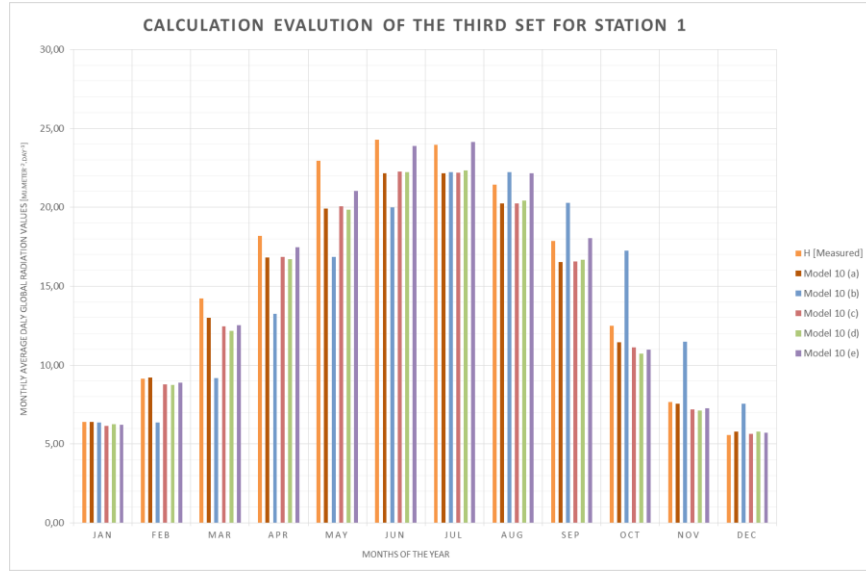


Figure 4.22 : Third set of the models for station 1.

Releated equations for third set of the models for Station 1 with Figure 4.22. is illustrated on the Table 4.22.

Table 4.22 : Third set of the model correlations for station 1 of region 3.

Model No	Releated Equations for Third Set of The Models for Station 2	
Period	From October to March;	From April to September;
Model 10 (a)	$\frac{H}{H_0} = -0,0059 \ln\left(\frac{S}{S_0}\right) + 0,2255 + \left(-0,0076 \ln\left(\frac{S}{S_0}\right) + 0,4556\right)\left(\frac{S}{S_0}\right)$	$\frac{H}{H_0} = -0,1752 \ln\left(\frac{S}{S_0}\right) + 0,1474 + \left(0,1486 \ln\left(\frac{S}{S_0}\right) + 0,5125\right)\left(\frac{S}{S_0}\right)$
Model 10 (b)	$\frac{H}{H_0} = 0,2371 + 0,4358\left(\frac{S}{S_0}\right) + 0,0188\left(\frac{S}{S_0}\right)^2$	$\frac{H}{H_0} = 0,4037 + 0,0203\left(\frac{S}{S_0}\right) + 0,2352\left(\frac{S}{S_0}\right)^2$
Model 10 (c)	$\frac{H}{H_0} = 0,276 + 0,359\left(\frac{S}{S_0}\right) - 0,366\left(\frac{S}{S_0}\right)^2 + 0,607\left(\frac{S}{S_0}\right)^3$	$\frac{H}{H_0} = -0,068 + 2,0955\left(\frac{S}{S_0}\right) - 2,761\left(\frac{S}{S_0}\right)^2 + 1,422\left(\frac{S}{S_0}\right)^3$
Model 10 (d)	$\frac{H}{H_0} = 0,216 + 0,914\left(\frac{S}{S_0}\right) - 1,423\left(\frac{S}{S_0}\right)^2 + 0,382\left(\frac{S}{S_0}\right)^3 + 1,065\left(\frac{S}{S_0}\right)^4$	$\frac{H}{H_0} = -0,399 + 5,333\left(\frac{S}{S_0}\right) - 12,849\left(\frac{S}{S_0}\right)^2 + 14,088\left(\frac{S}{S_0}\right)^3 - 5,569\left(\frac{S}{S_0}\right)^4$
Model 10 (e)	$\frac{H}{H_0} = 0,163 + 1,965\left(\frac{S}{S_0}\right) - 8,837\left(\frac{S}{S_0}\right)^2 + 22,257\left(\frac{S}{S_0}\right)^3 - 26,557\left(\frac{S}{S_0}\right)^4 + 12,308\left(\frac{S}{S_0}\right)^5$	$\frac{H}{H_0} = 5,606 - 39,687\left(\frac{S}{S_0}\right) + 120,7408\left(\frac{S}{S_0}\right)^2 - 181,821\left(\frac{S}{S_0}\right)^3 + 136,762\left(\frac{S}{S_0}\right)^4 - 40,974\left(\frac{S}{S_0}\right)^5$

The model 10 with different correlations by Togrul and et. al. demonstrated in the Figure 4.22. where model 10 (a), (c) and (d) has quite equal results. Besides model 10 (b) and (e) shows variant behavior especially between June and October.

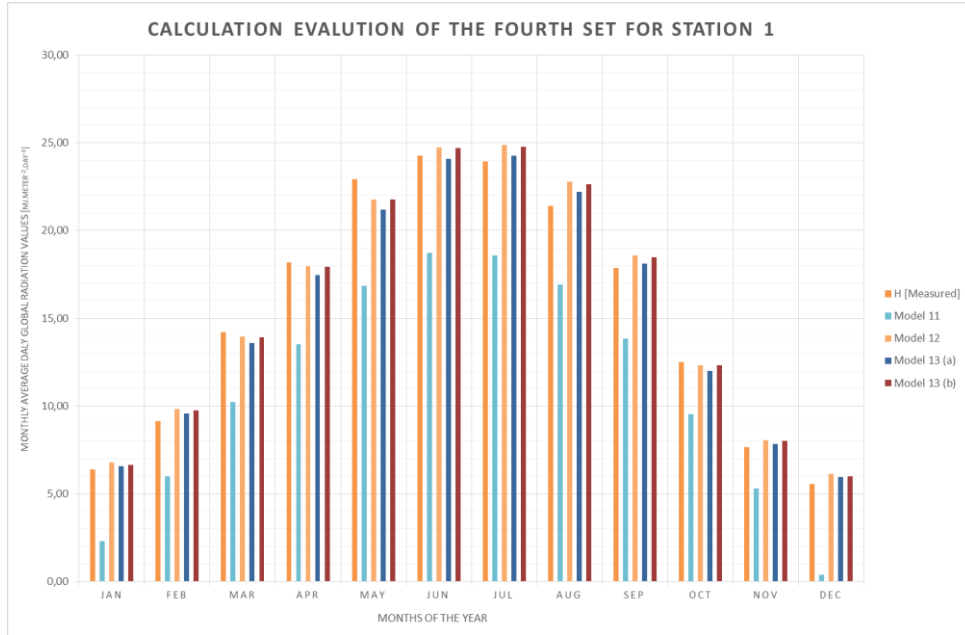


Figure 4.23 : Fourth set of the models for station 1.

Releated equations for fourth set of the models for Station 1 with Fig 4.23. is illustrated on the Table 4.23.

Table 4.23 : Fourth set of the model correlations for station 1 of region 3.

Model No	Releated Equations for Fourth Set of The Models for Station 1		
Model 11	$\frac{H}{H_0} = -2,4375 + 11,946 \left(\frac{S}{S_0}\right) - 16,745 \left(\frac{S}{S_0}\right)^2 + 7,9575 \left(\frac{S}{S_0}\right)^3$	Model 13 (a)	$\frac{H}{H_0} = 0,3092 \cos(\phi) + 0,4931 \frac{S}{S_0}$
Model 12	$\frac{H}{H_0} = 0,2424 + 0,5014 \left(\frac{S}{S_0}\right)$	Model 13 (b)	$\frac{H}{H_0} = 0,2408 + 0,3625 \left(\frac{S}{S_0}\right) + 0,4597 \left(\frac{S}{S_0}\right)^2 - 0,3708 \left(\frac{S}{S_0}\right)^3$

The figure above shows the calculation evalution of the fourth set for Erzincan, station 1 of the 3rd region. The model 11 proposed by Ertekin and Yildiz has the lowest values which is expected as the solar radiation distribution range is different from station 1. On the other hand, model 12 and 13 (b) represents almost same results during the year.

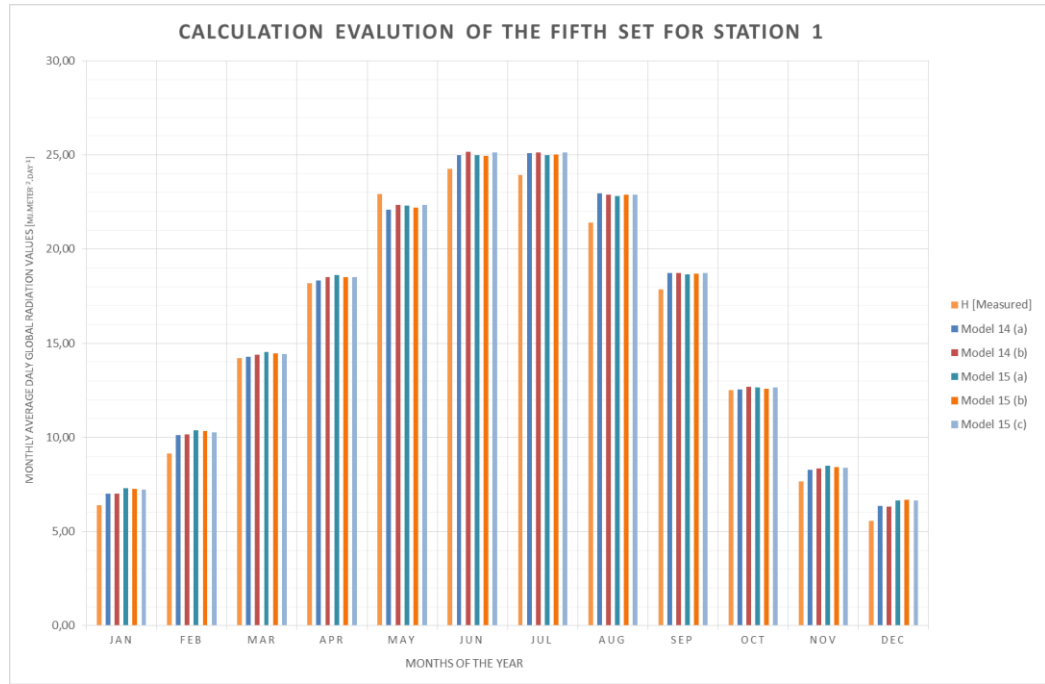


Figure 4.24 : Fifth set of the models for station 1.

Releated equations for fifth set of the models for Station 1 with Fig 4.24. is illustrated on the Table 4.24. to clarify the dependence of parameters due to the models.

Table 4.24 : Fifth set of the model correlations for station 1 of region 2.

Model No	Releated Equations for Fifth Set of The Models for Station 1		
Model 14 (a)	$\frac{H}{H_0} = 0,2671 + 0,4754 \left(\frac{S}{S_0} \right)$	Model 14 (b)	$\frac{H}{H_0} = 0,2854 + 0,2591 \left(\frac{S}{S_0} \right) + 0,6171 \left(\frac{S}{S_0} \right)^2 - 0,4834 \left(\frac{S}{S_0} \right)^3$
Model 15 (a)	$\frac{H}{H_0} = 0,3078 + 0,4166 \left(\frac{S}{S_0} \right)$	Model 15 (b)	$\frac{H}{H_0} = 0,3398 + 0,2868 \left(\frac{S}{S_0} \right) + 0,1187 \left(\frac{S}{S_0} \right)^2$
Model 15 (c)	$\frac{H}{H_0} = 0,4832 - 0,6161 \left(\frac{S}{S_0} \right) + 1,8932 \left(\frac{S}{S_0} \right)^2 - 1,0975 \left(\frac{S}{S_0} \right)^3$		

The fifth set of calculations for station 1 represents appropriate results with the measured monthly average daily global radiation data as shown in the Figure 4.24. The measured data has lower or almost equal values compared to the models in the fifth set among the year except there is a peak in May with the monthly average daily global solar radiation value of 22,93 MJm⁻²d⁻¹.

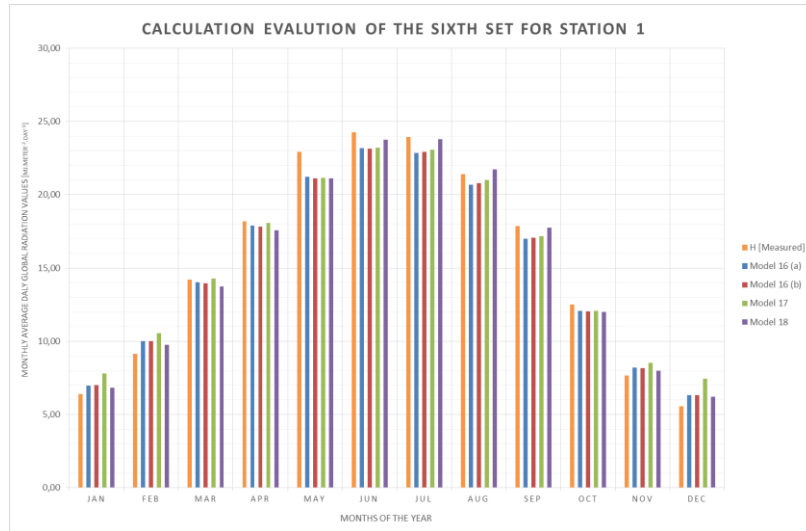


Figure 4.25 : Sixth set of the models for station 1.

Releated equations for sixth set of the models for Station 1 with Fig 4.25. is illustrated on the Table 4.25. to clarify the dependence of parameters due to the models.

Table 4.25 : Sixth set of the model correlations for station 1 of region 3.

Model No	Releated Equations for Sixth Set of The Models for Station 1
Model 16 (a)	$\frac{H}{H_0} = 0,1874 + 0,8592 \left(\frac{S}{S_0} \right) - 0,4764 \left(\frac{S}{S_0} \right)^2$
Model 16 (b)	$\frac{H}{H_0} = 0,1520 + 1,1334 \left(\frac{S}{S_0} \right) - 1,1126 \left(\frac{S}{S_0} \right)^2 + 0,4516 \left(\frac{S}{S_0} \right)^3$
Model 17	$\frac{H}{H_0} = 0,6307 - 0,7251 \left(\frac{S}{S_0} \right) + 1,2089 \left(\frac{S}{S_0} \right)^2 - 0,4633 \left(\frac{S}{S_0} \right)^3$
Model 18	$\frac{H}{H_0} = 0,2786 + 0,4160 \left(\frac{S}{S_0} \right)$

The last set of results for station 1 of region 3 represented in the Figure 4.25. as the most appropriate model differs according to the months. The Models have near results to the measured monthly average daily global radiation daha except May and June as shown above.

The calculation evalution figures for Erzincan, the Station 1 of the 3rd region are represented and explained as in six figures above. The selected stations for fourth region is illustrated in the following sections.

4.1.4. The global radiation model evaluation for the fourth region

The five stations for the fourth region are Mugla, Antalya, Karaman, Van and Hakkari. The reviewed models are evaluated for those stations and selected station which is station 1. Also, the figures for selected region given in the following. The altitude and latitude values of station 1 are 30 meter and the of 36,90 degrees respectively.

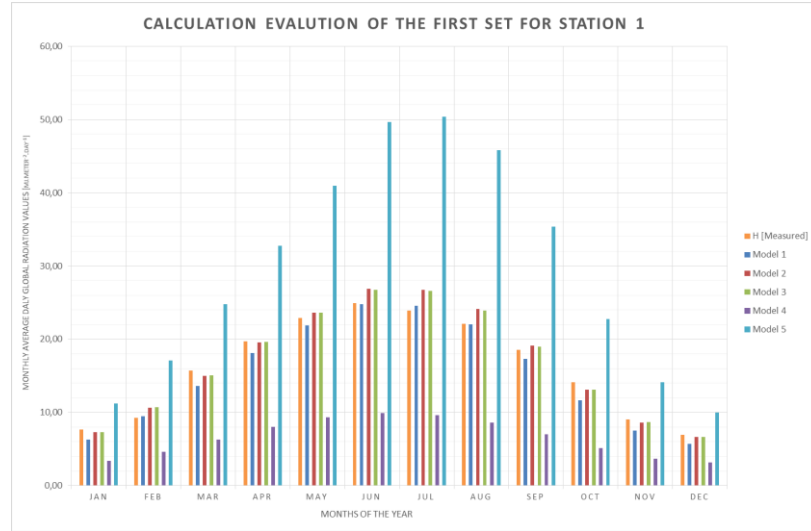


Figure 4.26 : First set of the models for station 1.

Releated equations for first set of the models for Station 1 with Fig 4.26. is illustrated on the Table 4.26. to clarify the dependence of parameters due to the models.

Table 4.26 : First set of the model correlations for station 1 of region 4.

Model No	Releated Equations for First Set of The Models for Station 1		
Model 1	$a = 0,103 + 0,000017Z + 0,198 \cos(\phi - \delta)$ $b = 0,533 - 0,165 \cos(\phi - \delta)$	Model 2	$\frac{H}{H_0} = 0,195 + 0,676 \left(\frac{S}{S_0} \right) - 0,142 \left(\frac{S}{S_0} \right)^2$
Model 3	$\frac{H}{H_0} = 0,145 + 0,845 \left(\frac{S}{S_0} \right) - 0,280 \left(\frac{S}{S_0} \right)^2$	Model 4	$\frac{H}{H_0} = 0,225 + 0,014 \left(\frac{S}{S_0} \right) + 0,001 \left(\frac{S}{S_0} \right)^2$
Model 5	$\frac{H}{H_0} = 0,2038 + 0,9236 \left(\frac{S}{S_0} \right) - 0,3911 \left(\frac{S}{S_0} \right)^2$		

Although during the year generally, the most appropriate model for the first set for Antalya is Model 2 by Ogelman et. all. and Model 3 by Akinoglu and Ecevit, in August the measured monthly average daily global radiation value and Model 1 by Kilic and Ozturk are almost equal where the measured monthly average daily global solar

aradiation data is $22,10 \text{ MJm}^{-2}\text{d}^{-1}$ and the result for Model 1 is $22,05 \text{ MJm}^{-2}\text{d}^{-1}$. Besides, the highest and lowest values respectively belong to model 5 and model 4 as represented in the figure above.

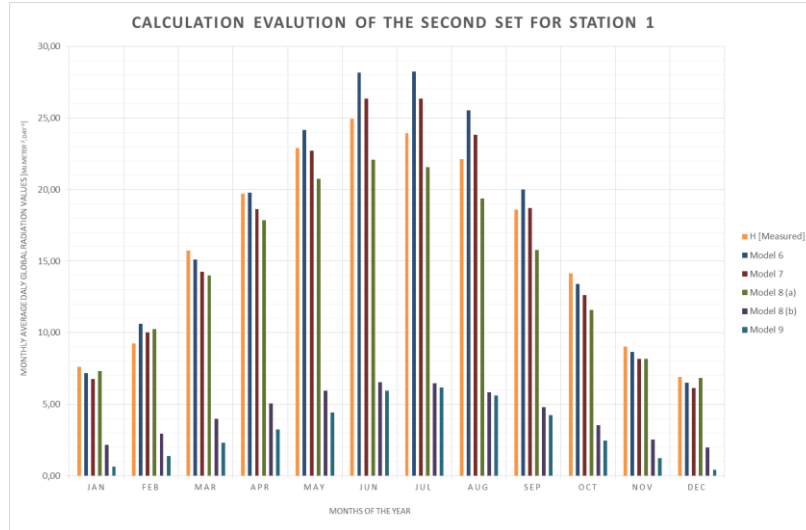


Figure 4.27 : Second set of the models for station 1.

Releated equations for second set of the models for Station 1 with Fig 4.27. is illustrated on the Table 4.27. to clarify the dependence of parameters due to the models.

Table 4.27 : Second set of the model correlations for station 1 of region 4.

Model No	Releated Equations for Second Set of The Models for Station 1		
Model 6	$\frac{H}{H_0} = 0,18 + 0,62 \left(\frac{S}{S_0} \right)$	Model 8 (a)	$H = -1,3876 + 0,518H_0 + 2,3064 \left(\frac{S}{S_0} \right)$
Model 7	$\frac{H}{H_0} = 0,148 + 0,668 \left(\frac{S}{S_0} \right) - 0,079 \left(\frac{S}{S_0} \right)^2$	Model 8 (b)	$H = 2,765 + 4,9597 \sin(\delta) + 2,2984 \left(\frac{S}{S_0} \right)$
Model 9	$\frac{H}{H_0} = -0,21521 + 0,62487 \left(\frac{S}{S_0} \right) - 0,2205 \left(\frac{S}{S_0} \right)^2$		

The Figure 4.27. shows the second set results for 1st station of 4th region. The lowest results compared to measured monthly average daily global radiation are belong to model 8 (b) and model 9. Although model 8 (a) and (b) proposed as a result of the same study, the results for the Station 1 shows there is a huge gap because of the difference correlation types. On the other hand, model 6, 7 and 8 (a) have more similar

results with themselves and the measured monthly average daily global radiation although values fluctuates during the year.

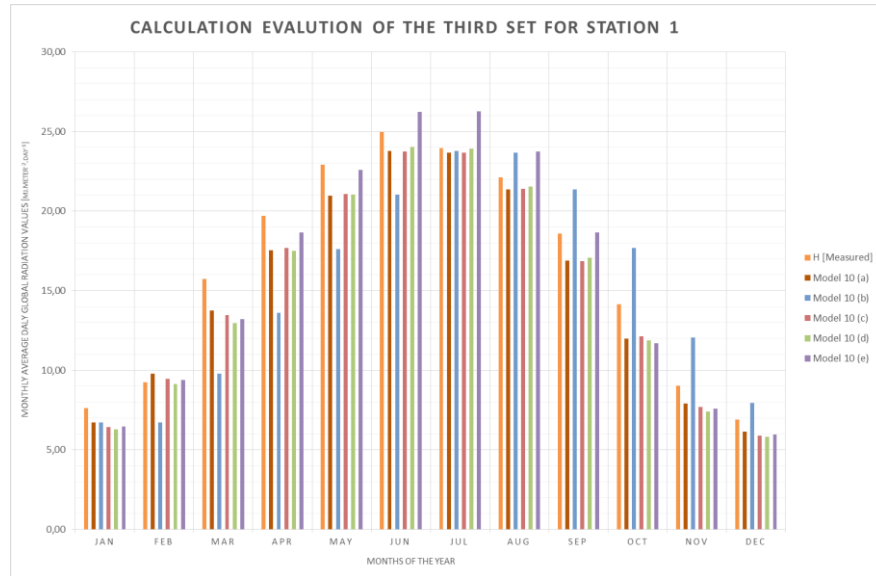


Figure 4.28 : Third set of the models for station 1.

Releated equations for third set of the models for Station 1 with Fig 4.28 is illustrated on the Table 4.28. to clarify the dependence of parameters due to the models.

Table 4.28 : Third set of the model correlations for station 1 of region 4.

Model No	Releated Equations for Third Set of The Models for Station 1	
Period	From October to March;	From April to September;
Model 10 (a)	$\frac{H}{H_0} = -0,0059 \ln\left(\frac{S}{S_0}\right) + 0,2255 + \left(-0,0076 \ln\left(\frac{S}{S_0}\right) + 0,4556\right)\left(\frac{S}{S_0}\right)$	$\frac{H}{H_0} = -0,1752 \ln\left(\frac{S}{S_0}\right) + 0,1474 + \left(0,1486 \ln\left(\frac{S}{S_0}\right) + 0,5125\right)\left(\frac{S}{S_0}\right)$
Model 10 (b)	$\frac{H}{H_0} = 0,2371 + 0,4358\left(\frac{S}{S_0}\right) + 0,0188\left(\frac{S}{S_0}\right)^2$	$\frac{H}{H_0} = 0,4037 + 0,0203\left(\frac{S}{S_0}\right) + 0,2352\left(\frac{S}{S_0}\right)^2$
Model 10 (c)	$\frac{H}{H_0} = 0,276 + 0,359\left(\frac{S}{S_0}\right) - 0,366\left(\frac{S}{S_0}\right)^2 + 0,607\left(\frac{S}{S_0}\right)^3$	$\frac{H}{H_0} = -0,068 + 2,0955\left(\frac{S}{S_0}\right) - 2,761\left(\frac{S}{S_0}\right)^2 + 1,422\left(\frac{S}{S_0}\right)^3$
Model 10 (d)	$\frac{H}{H_0} = 0,216 + 0,914\left(\frac{S}{S_0}\right) - 1,423\left(\frac{S}{S_0}\right)^2 + 0,382\left(\frac{S}{S_0}\right)^3 + 1,065\left(\frac{S}{S_0}\right)^4$	$\frac{H}{H_0} = -0,399 + 5,333\left(\frac{S}{S_0}\right) - 12,849\left(\frac{S}{S_0}\right)^2 + 14,088\left(\frac{S}{S_0}\right)^3 - 5,569\left(\frac{S}{S_0}\right)^4$
Model 10 (e)	$\frac{H}{H_0} = 0,163 + 1,965\left(\frac{S}{S_0}\right) - 8,837\left(\frac{S}{S_0}\right)^2 + 22,257\left(\frac{S}{S_0}\right)^3 - 26,557\left(\frac{S}{S_0}\right)^4 + 12,308\left(\frac{S}{S_0}\right)^5$	$\frac{H}{H_0} = 5,606 - 39,687\left(\frac{S}{S_0}\right) + 120,7408\left(\frac{S}{S_0}\right)^2 - 181,821\left(\frac{S}{S_0}\right)^3 + 136,762\left(\frac{S}{S_0}\right)^4 - 40,974\left(\frac{S}{S_0}\right)^5$

The calculation evaluation of the third set for Antalya is represented in Figure 4.28. The model 10 with five submodels are represented in the figure above. The model 10 (b) started with the lowest values and inclined slightly by having the highest values for the second half of the year. Besides, the model 10 (e) represents peaks between the months of the year June and August.

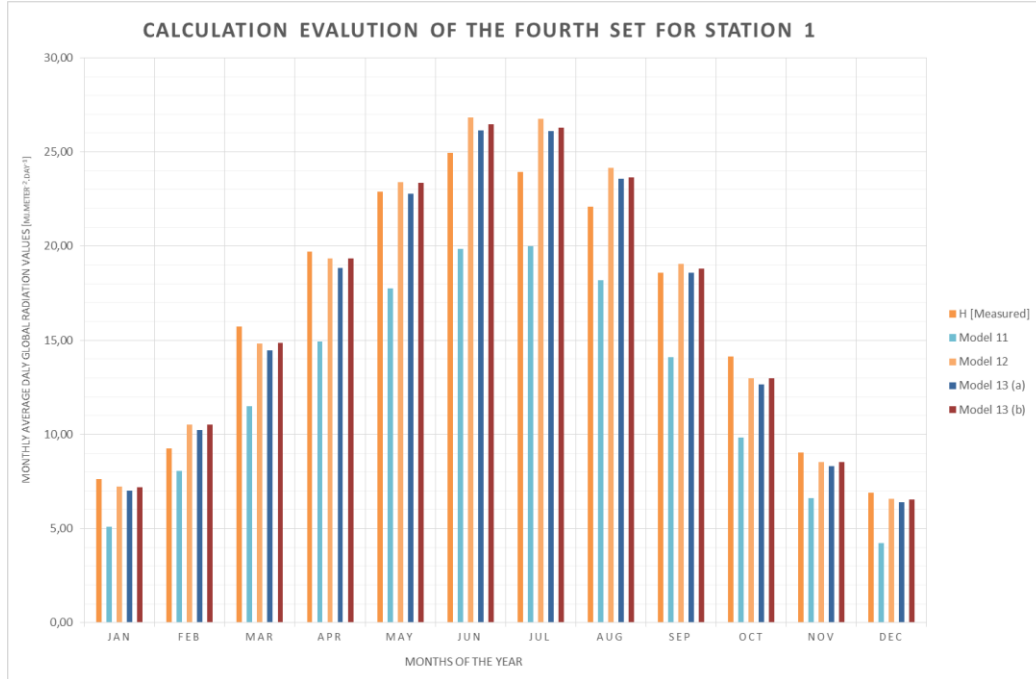


Figure 4.29 : Fourth set of the models for station 1.

Related equations for fourth set of the models for Station 1 with Fig 4.29. is illustrated on the Table 4.29. to clarify the dependence of parameters due to the models.

Table 4.29 : Fourth set of the model correlations for station 1 of region 4.

Model No	Related Equations for Fourth Set of The Models for Station 1		
Model 11	$\frac{H}{H_0} = -2,4375 + 11,946 \left(\frac{S}{S_0} \right) - 16,745 \left(\frac{S}{S_0} \right)^2 + 7,9575 \left(\frac{S}{S_0} \right)^3$	Model 13 (a)	$\frac{H}{H_0} = 0,3092 \cos(\phi) + 0,4931 \frac{S}{S_0}$
Model 12	$\frac{H}{H_0} = 0,2424 + 0,5014 \left(\frac{S}{S_0} \right)$	Model 13 (b)	$\frac{H}{H_0} = 0,2408 + 0,3625 \left(\frac{S}{S_0} \right) + 0,4597 \left(\frac{S}{S_0} \right)^2 - 0,3708 \left(\frac{S}{S_0} \right)^3$

Calculation evaluation of the fourth set for 1st station of the 4th region is shown in the Figure 4.29. where the model 12 and 13 (a), (b) have stable variation within

themselves. Meanwhile, model 11 has lower values compared to measured monthly average daily global radiation datas during the year. Besides, Figure 4.30. shows the results of the fifth set with five models.

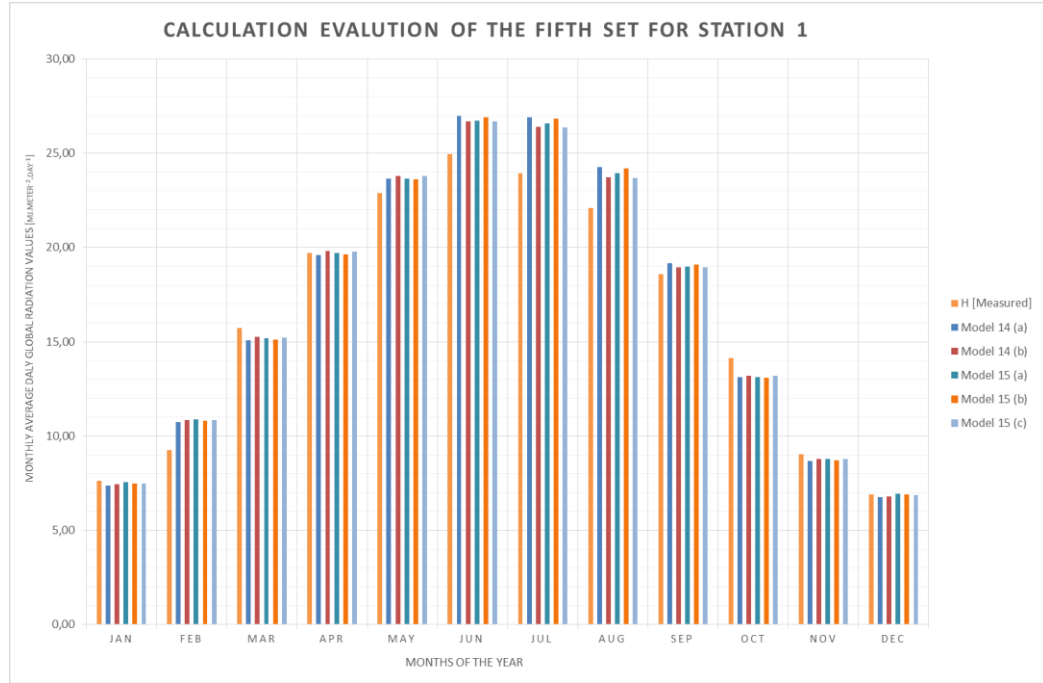


Figure 4.30 : Fifth set of the models for station 1.

Releated equations for fifth set of the models for Station 1 with Fig 4.30. is illustrated on the Table 4.30. to clarify the dependence of parameters due to the models.

Table 4.30 : Fifth set of the model correlations for station 1 of region 4.

Model No	Releated Equations for Fifth Set of The Models for Station 1		
Model 14 (a)	$\frac{H}{H_0} = 0,2671 + 0,4754 \left(\frac{S}{S_0} \right)$	Model 14 (b)	$\frac{H}{H_0} = 0,2854 + 0,2591 \left(\frac{S}{S_0} \right) + 0,6171 \left(\frac{S}{S_0} \right)^2 - 0,4834 \left(\frac{S}{S_0} \right)^3$
Model 15 (a)	$\frac{H}{H_0} = 0,3078 + 0,4166 \left(\frac{S}{S_0} \right)$	Model 15 (b)	$\frac{H}{H_0} = 0,3398 + 0,2868 \left(\frac{S}{S_0} \right) + 0,1187 \left(\frac{S}{S_0} \right)^2$
Model 15 (c)	$\frac{H}{H_0} = 0,4832 - 0,6161 \left(\frac{S}{S_0} \right) + 1,8932 \left(\frac{S}{S_0} \right)^2 - 1,0975 \left(\frac{S}{S_0} \right)^3$		

The model 14 (a) , (b) and model 15 (a), (b), (c) represented in the figure above with almost similar behavior. At the several months of the year such as January, March and

October, November, the measured monthly average daily global radiation has higher value compared to the evaluated models.

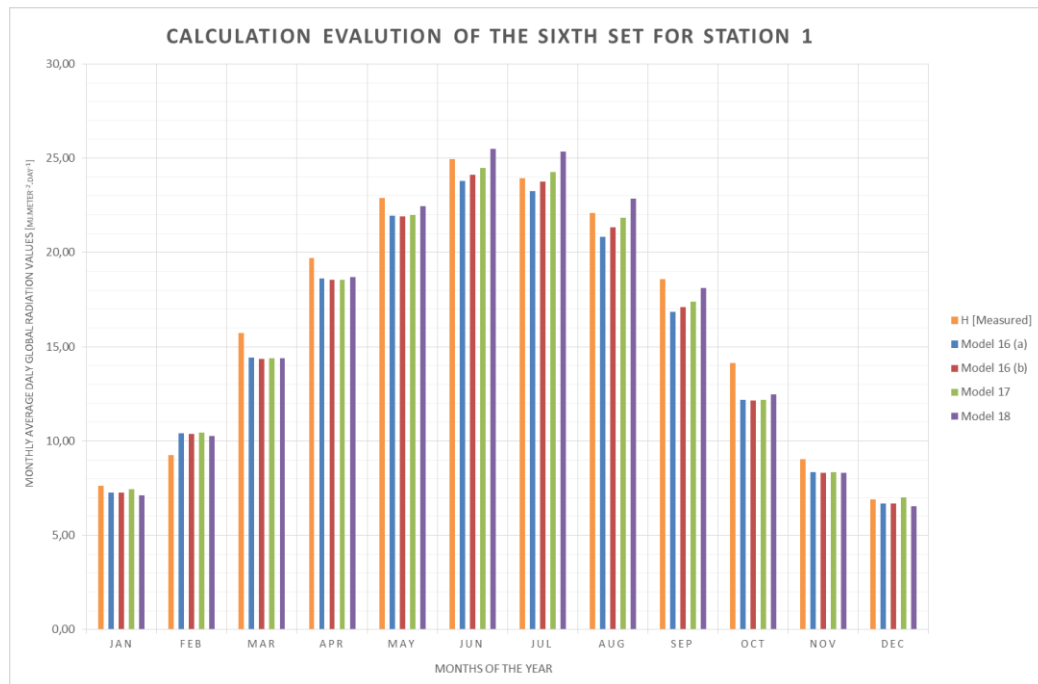


Figure 4.31 : Sixth set of the models for station 1.

Releated equations for sixth set of the models for Station 1 with Fig 4.31. is illustrated on the Table 4.31. to clarify the dependence of parameters due to the models.

Table 4.31 : Sixth set of the model correlations for station 1 of region 4.

Model No	Releated Equations for Sixth Set of The Models for Station 1		
Model 16 (a)	$\frac{H}{H_0} = 0,1874 + 0,8592 \left(\frac{S}{S_0} \right) - 0,4764 \left(\frac{S}{S_0} \right)^2$	Model 17	$\frac{H}{H_0} = 0,6307 - 0,7251 \left(\frac{S}{S_0} \right) + 1,2089 \left(\frac{S}{S_0} \right)^2 - 0,4633 \left(\frac{S}{S_0} \right)^3$
Model 16 (b)	$\frac{H}{H_0} = 0,1520 + 1,1334 \left(\frac{S}{S_0} \right) - 1,1126 \left(\frac{S}{S_0} \right)^2 + 0,4516 \left(\frac{S}{S_0} \right)^3$	Model 18	$\frac{H}{H_0} = 0,2786 + 0,4160 \left(\frac{S}{S_0} \right)$

The last set of the calculation evalution for Antalya is represented as in the Figure 4.31. by four models which are Model 17 and 18 by Bakirci and Model 16 (a) and (b) by Tahrn and Sari. Until May the results of those four models are quite equal by having lower values compared to measured monthly average daily global radiation except

February. Afterwards until the beginning of the September the model 18 has higher values than the measured data and other three models.

As a consequent, the reviewed models are evaluated for selected stations of each region explained above. For further evaluation of the models for four region the statistical analysis is essential which is given in the following section.

4.2. Model Statistical Analysis

In the literature several statistical models have been applicable in order to evaluate the accuracy and the performance of the solar radiation models.[46] From the calculated results, it is seen that contribution of global solar radiation behaves gaussian distribution. The performances for the models for 20 stations have been done in terms of widely used statistical indicators, Mean Bias Error (MBE) and Root Mean Square Error (RMSE). By the whole of these analysis methods, the most extensively used are defined as in the sub-sections. According to define those statistical analysis methods, first of all the main error analysis method, the relative percentage error, should be defined. The relative percentage error (e) is defines the deviation between the measured and calculated data which is represents as;

$$e = \left(\frac{ci - mi}{mi} \right) 100 \quad (4.1)$$

The variable c_i is the calculated value that is obtained from the evaluated models. Besides mi is the measured data received from the Turkish State Meteorological Service. The ideal result for the relative percentage error evaluation is equal to zero. [16] As, the first step of the analysis, the relative percentage error, is defined above, the other statistical analysis methods is decribed in the following sub-sections

4.2.1. The mean percentage error

The mean percentage error (MPE) presents the average of the alteration of the monthly average daily solar radiation calculated from models and measured values [14]. The MPE equation is as;

$$MPE = \frac{1}{n} \sum_{i=1}^n e \quad (4.2)$$

where n is the amount of the number of data pairs.

4.2.1.1. First region MPE results

The MPE figures for region 1 with 5 stations are represented with tables below. The results are within acceptable error, with the MPE ranging from -91,27 to 98,90 as tables below represent.

Table 4.32 : MPE results for the first region.

MPE Values For First Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	9,14	3,08	4,99	0,90	3,36
2	22,03	11,29	16,06	11,82	14,76
3	21,75	10,86	15,43	11,48	14,24
4	-46,52	-48,27	-45,41	-47,56	-46,35
5	98,90	73,95	80,60	72,89	78,95
6	22,54	10,31	14,90	10,44	13,67
7	15,22	3,79	8,04	4,00	6,92
8a	16,76	12,13	18,05	13,74	16,13
8b	-66,56	-69,00	-67,83	-68,67	-67,98
9	-84,93	-90,61	-91,27	-91,15	-90,82
10a	11,12	2,63	7,11	3,43	5,87
10b	17,77	8,65	12,93	9,05	11,71
10c	8,94	0,70	5,24	1,45	3,99
10d	8,61	0,88	5,88	1,37	4,35
10e	13,71	4,31	9,24	4,60	7,78
11	-19,73	-36,25	-39,21	-33,92	-37,06
12	21,29	10,76	15,68	11,18	14,29
13a	18,04	7,73	12,50	8,12	11,15
13b	20,43	9,85	14,55	10,36	13,28
14a	23,54	13,31	18,44	13,83	16,97
14b	23,89	13,76	18,76	14,45	17,38
15a	25,16	15,71	21,12	16,40	19,53
15b	24,91	15,40	20,90	15,96	19,25
15c	24,76	15,30	20,80	15,85	19,18
16a	17,71	9,88	14,73	11,16	13,39
16b	17,90	9,90	14,82	11,08	13,43
17	22,07	16,06	22,58	16,88	20,40
18	18,39	9,14	14,19	9,74	12,71

Table 4.32. represents the MPE results for 5 stations of the 1st region. The model 1 by Kilic and Ozturk is more appropriate for station 3, 4 and 5 compared to other models. Further, for the MPE results of station 1 and 2 shows that model 10 (d) and 10 (c) respectively, gives the lowest values compared to zero. Overall, table above indicates that the station 2 has MPE values closest to zero compared to other stations. The MPE investigations are done in the following section for other regions.

4.2.1.2. Second region MPE results

The 2nd region with 5 stations' statistical analysis, the mean percentage error results which are ranging from -91,36 to 101,94 is given in the Table 4.33. as below.

Table 4.33 : MPE results for the second region.

MPE Values For Second Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	1,05	0,24	1,10	6,42	-0,22
2	9,04	4,11	9,38	18,61	8,22
3	8,79	3,90	8,92	18,43	7,94
4	-51,65	-51,40	-49,47	-51,18	-50,72
5	76,10	60,96	72,02	101,94	71,24
6	9,17	2,81	8,62	20,80	7,65
7	2,68	-3,14	2,16	13,45	1,31
8a	5,61	5,57	9,78	7,91	7,29
8b	-71,02	-70,85	-70,38	-69,93	-70,62
9	-87,35	-91,36	-90,37	-80,78	-89,29
10a	-0,43	-3,60	0,67	7,40	-0,62
10b	4,74	1,59	6,27	11,71	5,14
10c	-2,23	-5,57	-1,22	5,77	-2,41
10d	-2,52	-6,00	-0,89	4,64	-2,63
10e	1,65	-3,02	2,66	10,23	1,01
11	-30,05	-35,25	-38,07	-13,09	-33,59
12	8,37	3,40	8,89	17,86	7,57
13a	5,46	0,56	5,91	14,78	4,64
13b	7,65	2,75	7,97	16,97	6,86
14a	10,48	5,84	11,34	19,51	9,88
14b	10,91	6,52	11,73	19,47	10,44
15a	12,11	8,18	13,60	20,08	11,90
15b	11,84	7,69	13,35	20,04	11,55
15c	11,83	7,58	13,29	19,60	11,60
16a	5,76	3,58	7,58	11,40	6,22
16b	5,83	3,45	7,63	11,92	6,17
17	9,91	8,12	13,79	13,91	10,97
18	5,98	2,01	7,19	13,92	5,65

According to the table above; Model 1 having MPE results as 0,24 for Station 2 and - 0,22 for Station 5 by taking the nearest values to zero for mentioned stations. Meanwhile, 1st and 3rd stations shows the values respectively -0,43 and 0,67 by having the least difference with zero. Considering the total of the MPE results, 2nd station have much more lower values of statistical analysis for models.

4.2.1.3. Third region MPE results

The mean percentage error data sets for 3rd region represents the values reanging between -88,25 and 103,08. The table below consists of five stations for third region with the MPE values of reviewed models in the literature.

Table 4.34 : MPE results for the third region.

MPE Values For Third Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	-2,74	7,21	-0,60	3,55	2,23
2	3,58	18,89	6,71	13,33	10,34
3	3,33	18,90	6,40	13,04	10,24
4	-53,88	-51,68	-54,70	-53,64	-52,97
5	66,90	103,08	78,54	94,46	82,79
6	3,64	21,20	8,08	15,74	11,37
7	-2,53	13,89	1,50	8,61	4,72
8a	0,69	7,20	-0,42	2,53	3,45
8b	-72,61	-70,81	-72,64	-71,88	-71,59
9	-88,25	-79,69	-84,78	-81,31	-84,36
10a	-5,34	7,41	-3,02	2,62	0,19
10b	-0,42	11,02	1,92	6,63	4,77
10c	-7,04	6,12	-4,53	1,17	-1,71
10d	-7,27	4,85	-5,02	0,10	-2,48
10e	-3,40	9,97	-0,31	5,62	2,40
11	-34,55	-11,54	-27,14	-16,84	-21,88
12	2,97	17,95	6,16	12,74	9,54
13a	0,20	14,89	3,35	9,80	6,64
13b	2,28	17,47	5,21	11,64	8,92
14a	5,00	19,51	7,87	14,25	11,35
14b	5,42	19,93	7,79	13,88	11,74
15a	6,60	19,91	8,81	14,69	12,41
15b	6,36	19,74	8,78	14,78	12,17
15c	6,37	19,96	8,32	13,98	12,09
16a	0,60	11,59	1,23	5,80	5,51
16b	0,65	11,75	1,70	6,56	5,66
17	4,75	12,88	4,86	8,70	8,03
18	0,76	13,81	3,08	8,84	6,47

Table 4.34. indicates that Model 10 (a), (d) and (e) are gining the least valuesfor last four station while model 13 (a) is the most appropriate model for 1st station. However, in general first station have values which are near zero compared with the other stations.

4.2.1.4. Fourth region MPE results

The mean percentage error results for the last region is given in the Table 4.35. with the values between the lowest in general is -82,54 and the highest with the value 127,10 considering whole data set for each stations.

Table 4.35 : MPE results for the fourth region.

MPE Values For Fourth Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	-8,11	16,41	0,04	2,93	4,60
2	1,99	23,72	7,62	12,27	10,68
3	1,87	23,14	7,41	12,14	10,63
4	-58,66	-53,99	-55,94	-54,51	-55,48
5	75,27	127,10	84,24	92,99	90,78
6	4,20	29,33	9,82	14,71	13,18
7	-2,17	20,92	3,09	7,70	6,29
8a	-8,43	3,59	-2,55	0,86	-1,12
8b	-72,95	-69,63	-73,36	-72,31	-71,90
9	-82,54	-73,26	-82,26	-80,74	-80,49
10a	-7,89	11,71	-2,63	1,48	-0,03
10b	-4,31	15,60	1,23	4,96	4,37
10c	-9,03	13,98	-3,91	0,19	-1,17
10d	-9,98	14,12	-4,75	-0,97	-2,49
10e	-5,07	17,20	0,26	4,29	2,49
11	-24,51	-6,63	-21,88	-16,51	-17,07
12	1,32	23,42	7,00	11,53	9,88
13a	-1,31	20,33	4,22	8,63	7,04
13b	0,63	21,74	6,12	10,76	9,28
14a	2,63	24,27	8,45	12,96	11,25
14b	2,63	22,82	8,31	12,96	11,41
15a	2,92	23,24	8,89	13,28	11,46
15b	2,91	23,97	8,91	13,26	11,41
15c	2,68	22,67	8,47	12,98	11,38
16a	-4,77	9,97	0,67	4,81	3,22
16b	-4,35	11,57	1,22	5,28	3,55
17	-2,99	13,21	3,20	6,72	4,61
18	-2,29	17,47	3,33	7,54	5,85

Table above points out that station 3 and station 5 having the least values within the table by having results from model 1 with the value of 0,04 and model 10(a) with the value of -0,03 respectively. Overall, 1st station of 4th region have more appropriate of results compared to others.

4.2.2. The mean absolute percentage error

Mean absolute percentage error (MAPE) is the absolute average value of relative error. [47]

$$MAPE = \frac{1}{n} \sum_{i=1}^n |e| \quad (4.3)$$

As known e is the relative percentage error where the ideal value is zero.

4.2.2.1. First region MAPE results

The MAPE figures for region 1 of 5 stations are represented with table below. The results are within acceptable error, with the MAPE ranging from 0,7 to 98,90.

Table 4.36 : MAPE results for the first region part 1.

MAPE Values For First Region					
Model No:	Station 1	Station 2	Station 3	Station 4	Station 5
1	9,14	3,08	4,99	0,90	3,36
2	22,03	11,29	16,06	11,82	14,76
3	21,75	10,86	15,43	11,48	14,24
4	46,52	48,27	45,41	47,56	46,35
5	98,90	73,95	80,60	72,89	78,95
6	22,54	10,31	14,90	10,44	13,67
7	15,22	3,79	8,04	4,00	6,92
8a	16,76	12,13	18,05	13,74	16,13
8b	66,56	69,00	67,83	68,67	67,98
9	84,93	90,61	91,27	91,15	90,82
10a	11,12	2,63	7,11	3,43	5,87
10b	17,77	8,65	12,93	9,05	11,71
10c	8,94	0,70	5,24	1,45	3,99
10d	8,61	0,88	5,88	1,37	4,35
10e	13,71	4,31	9,24	4,60	7,78
11	19,73	36,25	39,21	33,92	37,06
12	21,29	10,76	15,68	11,18	14,29
13a	18,04	7,73	12,50	8,12	11,15
13b	20,43	9,85	14,55	10,36	13,28
14a	23,54	13,31	18,44	13,83	16,97
14b	23,89	13,76	18,76	14,45	17,38
15a	25,16	15,71	21,12	16,40	19,53
15b	24,91	15,40	20,90	15,96	19,25
15c	24,76	15,30	20,80	15,85	19,18
16a	17,71	9,88	14,73	11,16	13,39
16b	17,90	9,90	14,82	11,08	13,43
17	22,07	16,06	22,58	16,88	20,40
18	18,39	9,14	14,19	9,74	12,71

As Table 4.36. represents the 5 stations of region 1 evaluation with statistical analysis methods. This section gives information about the mean absolute percentage error data

sets of first region which are the absolute values of MPE analysis results. Overall, tables above indicates that the station 2 has MAPE values close to zero compared to other stations while station 1 has higher values.

4.2.2.2. Second region MAPE results

The Table 4.37. shows the 2nd region MAPE values with the range between 0,22 to 101,94. The results represents the most appropriate model for each station and the station that has least error.

Table 4.37 : MAPE results for the second region.

MAPE Values For Second Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	1,05	0,24	1,10	6,42	0,22
2	9,04	4,11	9,38	18,61	8,22
3	8,79	3,90	8,92	18,43	7,94
4	51,65	51,40	49,47	51,18	50,72
5	76,10	60,96	72,02	101,94	71,24
6	9,17	2,81	8,62	20,80	7,65
7	2,68	3,14	2,16	13,45	1,31
8a	5,61	5,57	9,78	7,91	7,29
8b	71,02	70,85	70,38	69,93	70,62
9	87,35	91,36	90,37	80,78	89,29
10a	0,43	3,60	0,67	7,40	0,62
10b	4,74	1,59	6,27	11,71	5,14
10c	2,23	5,57	1,22	5,77	2,41
10d	2,52	6,00	0,89	4,64	2,63
10e	1,65	3,02	2,66	10,23	1,01
11	30,05	35,25	38,07	13,09	33,59
12	8,37	3,40	8,89	17,86	7,57
13a	5,46	0,56	5,91	14,78	4,64
13b	7,65	2,75	7,97	16,97	6,86
14a	10,48	5,84	11,34	19,51	9,88
14b	10,91	6,52	11,73	19,47	10,44
15a	12,11	8,18	13,60	20,08	11,90
15b	11,84	7,69	13,35	20,04	11,55
15c	11,83	7,58	13,29	19,60	11,60
16a	5,76	3,58	7,58	11,40	6,22
16b	5,83	3,45	7,63	11,92	6,17
17	9,91	8,12	13,79	13,91	10,97
18	5,98	2,01	7,19	13,92	5,65

As it is seen above each model evaluated for each station under the mean absolute percentage analysis method. The most applicable model for each station are defined as; Model 1 for 2nd and 5th stations, Model 10 (a) for 1st and 3rd stations and the last one is Model 10 (d) for the 4th station. The entire table shows us that models in general shows least error for station 2 of this region.

4.2.2.3. Third region MAPE results

The mean absolute percentage error analysis is also done for the 3rd region. The results shows the the values of the defined errors changes between 0,10 and 103,08 as can be seen in the table below.

Table 4.38 : MAPE results for the third region.

MAPE Values For Third Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	2,74	7,21	0,60	3,55	2,23
2	3,58	18,89	6,71	13,33	10,34
3	3,33	18,90	6,40	13,04	10,24
4	53,88	51,68	54,70	53,64	52,97
5	66,90	103,08	78,54	94,46	82,79
6	3,64	21,20	8,08	15,74	11,37
7	2,53	13,89	1,50	8,61	4,72
8a	0,69	7,20	0,42	2,53	3,45
8b	72,61	70,81	72,64	71,88	71,59
9	88,25	79,69	84,78	81,31	84,36
10a	5,34	7,41	3,02	2,62	0,19
10b	0,42	11,02	1,92	6,63	4,77
10c	7,04	6,12	4,53	1,17	1,71
10d	7,27	4,85	5,02	0,10	2,48
10e	3,40	9,97	0,31	5,62	2,40
11	34,55	11,54	27,14	16,84	21,88
12	2,97	17,95	6,16	12,74	9,54
13a	0,20	14,89	3,35	9,80	6,64
13b	2,28	17,47	5,21	11,64	8,92
14a	5,00	19,51	7,87	14,25	11,35
14b	5,42	19,93	7,79	13,88	11,74
15a	6,60	19,91	8,81	14,69	12,41
15b	6,36	19,74	8,78	14,78	12,17
15c	6,37	19,96	8,32	13,98	12,09
16a	0,60	11,59	1,23	5,80	5,51
16b	0,65	11,75	1,70	6,56	5,66
17	4,75	12,88	4,86	8,70	8,03
18	0,76	13,81	3,08	8,84	6,47

Table 4.38. not only points out the edge values for MAPE but also defines the most applicable model for stations. For instance, Model 10 in general is much more applicable for this region as the least values are seen for 2nd, 3rd, 4th and 5th stations from the results of the models 10 (d), (e) and (a) respectively. On the other hand, Model 13 (a) represents the closest result to ideal error value for 1st station. Besides, the table above shows that the most acceptable values for the 1st station of 3rd region.

4.2.2.4. Fourth region MAPE results

The last region's mean absolute percentage error results are given as the table below.

The value range of MAPE data set is from 0,03 to 127,10 among five stations.

Table 4.39 : MAPE results for the fourth region.

MAPE Values For Fourth Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	8,11	16,41	0,04	2,93	4,60
2	1,99	23,72	7,62	12,27	10,68
3	1,87	23,14	7,41	12,14	10,63
4	58,66	53,99	55,94	54,51	55,48
5	75,27	127,10	84,24	92,99	90,78
6	4,20	29,33	9,82	14,71	13,18
7	2,17	20,92	3,09	7,70	6,29
8a	8,43	3,59	2,55	0,86	1,12
8b	72,95	69,63	73,36	72,31	71,90
9	82,54	73,26	82,26	80,74	80,49
10a	7,89	11,71	2,63	1,48	0,03
10b	4,31	15,60	1,23	4,96	4,37
10c	9,03	13,98	3,91	0,19	1,17
10d	9,98	14,12	4,75	0,97	2,49
10e	5,07	17,20	0,26	4,29	2,49
11	24,51	6,63	21,88	16,51	17,07
12	1,32	23,42	7,00	11,53	9,88
13a	1,31	20,33	4,22	8,63	7,04
13b	0,63	21,74	6,12	10,76	9,28
14a	2,63	24,27	8,45	12,96	11,25
14b	2,63	22,82	8,31	12,96	11,41
15a	2,92	23,24	8,89	13,28	11,46
15b	2,91	23,97	8,91	13,26	11,41
15c	2,68	22,67	8,47	12,98	11,38
16a	4,77	9,97	0,67	4,81	3,22
16b	4,35	11,57	1,22	5,28	3,55
17	2,99	13,21	3,20	6,72	4,61
18	2,29	17,47	3,33	7,54	5,85

The least value in the Table 4.39 belongs to the Model 10 (a) MAPE results for 5th station which is followed by the value 0,04 result of Model 1 for 3rd station. On the other hand, Model 8 (a), Model 10 (c) and Model 13 (b) gives the most appropriate results for 2nd, 4th and 1st stations of the 4th region. In general, the most acceptable results are belong to the 1st station.

4.2.3. The mean bias error

Furthermore, the mean bias error (MBE) gives information about the accuracy and performance of the used models for the long term period. [15]

$$MBE = \frac{1}{n} \sum_{i=1}^n (ci - mi) \quad (4.4)$$

Also the ideal value MBE is zero. The MBE values vary between under estimation and over estimation. The MBE achieved in this thesis, expect for Eq. 4.4., are in the acceptable range.

4.2.3.1. First region MBE results

The MBE figures for region 1 with 5 stations are represented with table below which indicates the long term performance of the models. The results are within acceptable error, with the MBE ranging from -11,64 to 13,61.

Table 4.40 : MBE results for the first region.

MBE Values For First Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	1,23	0,40	0,68	0,10	0,50
2	2,69	1,31	1,91	1,30	1,77
3	2,67	1,30	1,88	1,30	1,75
4	-6,52	-6,97	-6,36	-6,68	-6,47
5	13,61	10,45	11,08	9,83	10,87
6	2,96	1,34	1,94	1,24	1,79
7	1,99	0,47	1,06	0,41	0,92
8a	1,32	0,78	1,40	1,05	1,26
8b	-8,88	-9,47	-8,91	-9,22	-8,98
9	-10,51	-11,64	-11,09	-11,57	-11,17
10a	1,13	0,03	0,61	0,12	0,48
10b	1,28	0,14	0,74	0,25	0,60
10c	0,98	-0,11	0,48	-0,02	0,35
10d	0,95	-0,14	0,49	-0,09	0,33
10e	1,83	0,51	1,14	0,50	0,98
11	-1,83	-3,57	-3,35	-3,42	-3,26
12	2,59	1,20	1,81	1,18	1,66
13a	2,18	0,81	1,42	0,79	1,27
13b	2,50	1,13	1,73	1,13	1,59
14a	2,81	1,48	2,09	1,47	1,94
14b	2,84	1,56	2,16	1,59	2,02
15a	2,90	1,68	2,30	1,72	2,15
15b	2,88	1,63	2,26	1,65	2,10
15c	11,74	1,85	7,92	2,68	6,23
16a	4,70	-3,58	1,85	-2,01	0,43
16b	4,88	-3,55	1,95	-2,09	0,47
17	2,11	1,29	1,95	1,42	1,78
18	2,08	0,86	1,47	0,89	1,33

Table 4.40. represents that model 4, 8 (b) and 9 shows less than expected values similarly model 12 has results that also below the expectations as represented in the table following.

Besides, not only for Table 4.10 model 13 for station 1 shows results that above expectations with the highest value in the table but also the table below represents the highest values for MBE is model 16 (c) for station 1 again.

As a result, 5 stations of region 1 is investigated with statistical analysis methods. This section gives information about the mean bias error data sets of first region. Overall, table above indicates that the station 2 has MBE values closest to zero compared to other stations while station 1 has higher values.

4.2.3.2. Second region MBE results

The 2nd region with 5 stations' statistical analysis, the mean bias error results which are ranging from -12,94 to 15,53 is given in the Table 4.41. as below.

Table 4.41 : MBE results for the second region.

MBE Values For Second Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	0,23	-0,39	0,19	0,87	0,03
2	1,23	-0,07	1,17	2,47	1,03
3	1,22	-0,06	1,15	2,43	1,03
4	-7,90	-8,02	-7,33	-7,97	-7,54
5	11,79	8,34	10,67	15,53	10,58
6	1,41	-0,15	1,23	2,98	1,09
7	0,46	-0,98	0,33	1,87	0,20
8a	0,10	-0,26	0,57	0,34	0,35
8b	-10,43	-10,56	-9,93	-10,46	-10,09
9	-12,18	-12,94	-12,03	-11,56	-12,14
10a	-0,28	-1,20	-0,17	0,72	-0,33
10b	-0,15	-1,11	-0,02	0,86	-0,18
10c	-0,42	-1,35	-0,32	0,61	-0,46
10d	-0,47	-1,46	-0,31	0,52	-0,53
10e	0,32	-0,90	0,38	1,54	0,16
11	-3,45	-4,51	-4,04	-1,93	-3,70
12	1,11	-0,20	1,07	2,38	0,91
13a	0,70	-0,58	0,67	1,94	0,51
13b	1,04	-0,24	0,99	2,22	0,86
14a	1,36	0,10	1,35	2,57	1,18
14b	1,42	0,23	1,43	2,50	1,28
15a	1,48	0,35	1,55	2,56	1,37
15b	1,45	0,27	1,51	2,59	1,32
15c	-2,70	-6,95	-0,64	4,84	-2,52
16a	-8,77	-10,94	-6,35	-3,36	-7,90
16b	-8,70	-11,07	-6,30	-2,85	-7,95
17	0,79	0,04	1,14	1,43	0,87
18	0,64	-0,47	0,71	1,70	0,53

The table above gives the long term performance information about the models. Although, station 2 shows results that are below expected, it gives the least values compared to others. Further, Model 17 shows result that is over estimations with the value of 0,04 and conversely Model 3 with the -0,06 error data is below expectations are the most appropriate models that are closest to expectations for 2nd station.

4.2.3.3. Third region MBE results

The mean bias error analysis is also done for the 3rd region. The results shows that the values change between -14,74 and 15,60 as can be seen in the table below.

Table 4.42 : MBE results for the third region.

MBE Values For Third Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	-0,40	0,88	0,04	0,58	0,28
2	0,43	2,46	1,06	1,96	1,35
3	0,42	2,45	1,02	1,90	1,34
4	-8,68	-8,20	-8,91	-8,75	-8,44
5	10,92	15,60	13,30	15,59	13,07
6	0,60	2,93	1,47	2,54	1,67
7	-0,35	1,82	0,41	1,39	0,65
8a	-0,65	0,32	-0,70	-0,32	-0,24
8b	-11,25	-10,84	-11,45	-11,32	-11,00
9	-13,02	-11,87	-12,79	-12,31	-12,43
10a	-1,07	0,64	-0,60	0,18	-0,30
10b	-0,93	0,76	-0,44	0,30	-0,14
10c	-1,21	0,55	-0,72	0,08	-0,45
10d	-1,27	0,46	-0,77	-0,03	-0,52
10e	-0,48	1,41	0,18	1,05	0,40
11	-4,32	-2,04	-3,59	-2,48	-3,12
12	0,31	2,34	0,98	1,90	1,24
13a	-0,10	1,89	0,55	1,45	0,81
13b	0,24	2,25	0,82	1,68	1,14
14a	0,56	2,53	1,19	2,08	1,46
14b	0,63	2,55	1,13	1,93	1,49
15a	0,69	2,52	1,22	2,04	1,52
15b	0,66	2,53	1,25	2,10	1,51
15c	-8,97	4,80	-7,35	-1,66	-3,11
16a	-14,74	-3,57	-14,44	-9,84	-9,69
16b	-14,69	-3,41	-13,97	-9,08	-9,54
17	0,02	1,34	0,29	0,88	0,60
18	-0,15	1,65	0,37	1,18	0,67

Table 4.42. represents that the most applicable models for long term performance. For instance, Model 17 with the value 0,02 is also the most expected result in general which

belong to the 1st station, Model 8 (a) gives above expected result 0,32 for 2nd station, Model 1 shows result as 0,04 for 3rd station, Model 10 (d) gives less than expected but closest to the estimated with the value of -0,03 for 4th station and at last station the most reliable model is Model 10 (b) with the value of -0,14 according to the MBE results. To clarify, the most appropriate models are explained as above although; there are over or below estimations results.

4.2.3.4. Fourth region MBE results

The Table 4.13. shows the 4th region MBE values with the range between -21,01 to 19,54. The most appropriate model for each station and the station that shows reasonable long term performance error can be gathered from the data sets below.

Table 4.43 : MBE results for the fourth region.

MBE Values For Fourth Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	-0,99	2,11	0,06	0,40	0,48
2	0,54	3,09	1,18	1,73	1,29
3	0,50	2,97	1,13	1,69	1,26
4	-9,67	-8,96	-9,47	-9,03	-9,34
5	13,34	19,54	14,58	15,25	14,65
6	1,05	4,08	1,72	2,28	1,84
7	-0,03	2,75	0,58	1,14	0,72
8a	-1,61	-0,30	-1,03	-0,54	-1,00
8b	-11,92	-11,29	-12,06	-11,62	-11,78
9	-13,06	-11,63	-13,08	-12,59	-12,77
10a	-1,19	1,14	-0,61	-0,08	-0,51
10b	-1,07	1,25	-0,50	0,06	-0,38
10c	-1,28	1,42	-0,71	-0,18	-0,60
10d	-1,36	1,48	-0,79	-0,27	-0,69
10e	-0,37	2,37	0,24	0,76	0,31
11	-3,72	-1,49	-3,38	-2,73	-3,08
12	0,45	3,09	1,10	1,64	1,19
13a	0,02	2,62	0,65	1,19	0,75
13b	0,31	2,75	0,93	1,48	1,06
14a	0,62	3,19	1,28	1,82	1,37
14b	0,57	2,86	1,20	1,75	1,33
15a	0,60	2,99	1,26	1,79	1,33
15b	0,63	3,15	1,30	1,83	1,36
15c	-13,56	6,78	-7,90	-2,98	-4,76
16a	-21,01	-5,92	-15,70	-11,14	-12,92
16b	-20,59	-4,32	-15,15	-10,67	-12,58
17	-0,55	1,40	0,11	0,59	0,10
18	-0,23	2,12	0,39	0,92	0,48

Table 4.43. gives the result that the 1st station shows much more expected results in general. Besides, Model 13 (a) shows the least error followed by Model 7 which are belong to the MBE result for 1st station.

4.2.4. The root mean square error

The root mean square error (RMSE) is an anlysis method that defines as below [46]

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (ci - mi)^2} \quad (4.5)$$

Unlike the mean bias error, the root mean square error provides information for short term period and gives alwalys positive values or zero. [16]

4.2.4.1. First region RMSE results

The short term performance of the region 1 is represented in the tables below. The results are within acceptable error, with the RMSE ranging from 0,32 to 17,45.

Table 4.44 : RMSE results for the first region.

RMSE Values For First Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	1,52	0,79	1,03	0,32	0,84
2	2,97	1,58	2,20	1,38	2,03
3	2,95	1,58	2,19	1,39	2,03
4	7,52	8,01	7,38	7,65	7,46
5	15,82	12,27	13,15	11,13	12,78
6	3,44	1,81	2,44	1,42	2,24
7	2,36	1,07	1,54	0,64	1,36
8a	1,54	1,24	1,59	1,33	1,45
8b	9,95	10,58	9,97	10,27	10,03
9	11,31	12,56	11,91	12,49	12,02
10a	1,23	0,67	0,78	0,54	0,67
10b	3,56	3,40	3,29	3,10	3,31
10c	1,14	0,64	0,72	0,44	0,62
10d	1,19	0,73	0,79	0,55	0,69
10e	2,28	1,03	1,55	0,73	1,38
11	1,95	3,71	3,47	3,54	3,40
12	2,87	1,48	2,09	1,25	1,91
13a	2,43	1,14	1,69	0,88	1,52
13b	2,76	1,42	2,03	1,22	1,86
14a	3,07	1,69	2,33	1,53	2,15
14b	3,07	1,77	2,40	1,66	2,24
15a	3,09	1,83	2,46	1,75	2,29
15b	3,09	1,79	2,43	1,69	2,25
15c	17,45	14,40	16,50	13,86	14,82
16a	16,00	14,97	14,57	14,01	13,58
16b	15,94	15,19	14,87	14,33	13,86
17	2,17	1,47	2,03	1,54	1,85
18	2,23	1,08	1,63	0,95	1,46

Tables represents 5 stations of region 1 is investigated with statistical analysis methods. This section gives information about the root mean square error data sets of first region. Overall, tables above indicates that the station 2 has RMSE values close to zero compared to other stations while station 1 has higher values.

4.2.4.2. Second region RMSE results

The Table 4.45. shows the 2nd region RMSE values with the range between 0,44 to 24,03. The results below gives the short term performance about the models.

Table 4.45 : RMSE results for the second region.

RMSE Values For Second Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	0,59	1,17	0,65	1,21	0,44
2	1,44	1,26	1,49	2,72	1,22
3	1,42	1,25	1,49	2,64	1,23
4	8,87	9,17	8,32	8,94	8,50
5	13,64	9,23	12,58	17,58	12,16
6	1,84	1,28	1,78	3,43	1,46
7	0,94	1,75	1,06	2,25	0,75
8a	1,14	1,65	1,12	1,37	1,04
8b	11,46	11,80	10,96	11,46	11,12
9	13,01	14,13	12,87	12,35	13,01
10a	0,64	1,99	0,60	1,05	0,69
10b	3,39	3,58	3,44	3,48	3,40
10c	0,65	2,01	0,67	0,91	0,70
10d	0,80	2,11	0,72	0,92	0,81
10e	0,95	1,54	0,96	2,10	0,72
11	3,55	4,94	4,30	2,22	3,84
12	1,34	1,32	1,37	2,67	1,10
13a	0,96	1,52	1,04	2,23	0,77
13b	1,25	1,32	1,34	2,44	1,06
14a	1,53	1,25	1,58	2,82	1,32
14b	1,57	1,23	1,66	2,66	1,42
15a	1,59	1,27	1,68	2,74	1,45
15b	1,58	1,27	1,65	2,82	1,40
15c	11,29	22,41	13,17	15,73	11,88
16a	15,37	23,75	15,09	18,16	14,65
16b	15,38	24,03	15,26	17,41	14,85
17	1,06	1,55	1,31	1,63	1,10
18	0,81	1,50	0,92	1,91	0,70

As it is seen above each model evaluated for each station under the root mean square error analysis method. The most applicable model for short term performance for each station are defined as; Model 1 for 1st, 2nd and 5th stations, Model 10 (a) for 3rd station

and Model 10 (c) for the 4th station. The entire table shows us that models in general shows least error for station 2 of this region.

4.2.4.3. Third region RMSE results

The Table 4.46. shows the 3rd region RMSE values with the range between 0,59 to 19,71. The results below gives the short term performance about the models.

Table 4.46 : RMSE results for the third region.

RMSE Values For Third Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	0,62	1,03	0,68	0,95	0,60
2	0,74	2,53	1,41	2,21	1,52
3	0,72	2,52	1,33	2,10	1,49
4	9,74	9,11	9,90	9,71	9,45
5	12,61	16,87	15,52	17,80	14,84
6	1,10	3,08	2,10	3,05	2,03
7	0,83	1,92	1,17	1,83	1,04
8a	1,63	1,45	1,62	1,52	1,43
8b	12,35	11,76	12,46	12,27	12,04
9	13,94	12,67	13,59	13,05	13,28
10a	1,42	1,00	0,95	0,68	0,80
10b	3,69	3,19	3,72	3,49	3,43
10c	1,46	0,87	0,99	0,59	0,77
10d	1,55	0,74	1,09	0,66	0,86
10e	0,93	1,65	1,23	1,75	1,02
11	4,46	2,52	3,76	2,66	3,33
12	0,71	2,42	1,38	2,20	1,43
13a	0,67	1,97	1,05	1,76	1,05
13b	0,64	2,32	1,15	1,89	1,31
14a	0,82	2,60	1,50	2,33	1,61
14b	0,82	2,61	1,33	2,07	1,59
15a	0,87	2,59	1,43	2,22	1,62
15b	0,88	2,59	1,51	2,34	1,64
15c	14,72	15,71	12,04	11,83	12,97
16a	19,69	17,77	18,89	18,11	17,97
16b	19,71	17,25	18,24	16,98	17,69
17	1,08	1,54	0,85	1,15	1,01
18	0,68	1,73	0,77	1,39	0,88

Table 4.46. defines the most applicable model relating to the short term performances for stations. For instance, Model 1 is much more applicable with the least values belong to 1st, 3rd and 5th stations. On the other hand, Model 10 (c) and (d) represents the closest result to ideal error value for 4th and 2nd stations respectively. Besides, the table above shows that the most acceptable values for the 1st station of 3rd region.

4.2.4.4. Fourth region RMSE results

The Table 4.47. shows the 4th region RMSE values with the range between 0,60 to 23,12. The results below gives the short term performance about the models.

Table 4.47 : RMSE results for the fourth region.

RMSE Values For Fourth Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	1,34	2,19	0,60	1,00	0,70
2	1,31	3,15	1,40	2,04	1,39
3	1,23	3,02	1,32	1,97	1,36
4	10,48	9,95	10,42	9,93	10,43
5	15,59	20,80	16,50	17,06	16,05
6	1,99	4,19	2,16	2,75	1,97
7	1,26	2,81	1,07	1,64	0,92
8a	2,01	1,74	1,90	1,63	2,12
8b	12,86	12,36	13,02	12,53	12,93
9	13,82	12,58	13,85	13,35	13,75
10a	1,43	1,46	0,99	0,96	1,24
10b	3,60	3,54	3,62	3,34	3,66
10c	1,47	1,78	0,99	0,86	1,19
10d	1,58	1,86	1,04	0,91	1,12
10e	1,52	2,47	1,14	1,57	0,81
11	3,91	2,06	3,61	3,08	3,64
12	1,31	3,15	1,37	1,99	1,30
13a	1,12	2,68	0,99	1,59	0,95
13b	1,12	2,81	1,13	1,78	1,18
14a	1,37	3,25	1,50	2,13	1,46
14b	1,17	2,92	1,33	1,98	1,43
15a	1,23	3,05	1,41	2,04	1,44
15b	1,33	3,21	1,50	2,11	1,46
15c	15,53	20,33	13,01	14,38	15,59
16a	23,12	21,03	20,62	19,89	21,68
16b	22,55	19,44	19,78	19,10	20,95
17	0,98	1,61	0,84	1,13	1,08
18	0,95	2,20	0,72	1,30	0,86

The least value in the Table 4.47. belongs to the Model 1 RMSE result for 3rd station which is followed by the value 0,70 result of again Model 1 for 5th station. On the other hand, Model 10 (a), Model 10 (c) and Model 18 gives the most appropriate results for 2nd, 4th and 1st stations of the 4th region. In general, the most acceptable results are belong to the 1st station.

4.2.5. The t statistic method

The t statistic method (t-stat) includes MBE and RMSE values. The performance of the model and the t-stat value are inversely proportional. To clarify as the t-stat value smaller, the performance and the accuracy of the solar radiation model is better. [15]

$$t - stat = \sqrt{\frac{(n-1)MBE^2}{RMSE^2 - MBE^2}} \quad (4.6)$$

The analysis methods that mentioned above and used for to evaluate the accuracy of the models used in this study should have smaller values for better performances[16].

4.2.5.1. First region t-Stat results

In Table 4.48 the T-STAT calculations is collected with respect to the models for five stations in the year 2015. This table gives sense a clear trend, starting from the winter months where the diffuse horizontal irradiation almost linearly increases to peak in July and then linearly decreases to the minimum value in December. Table shows the errors involved over the five stations with available calculations in 2015. The T-STAT ranges from 0,11 to 16,01.

Table 4.48 : t- Stat results for the first region.

T - STAT Values For First Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	4,63	1,99	2,94	1,09	2,46
2	7,08	4,90	5,73	9,07	5,87
3	7,12	4,77	5,49	8,35	5,64
4	5,79	5,85	5,64	5,95	5,78
5	5,60	5,40	5,19	6,24	5,37
6	5,62	3,64	4,33	5,99	4,41
7	5,20	1,62	3,14	2,71	3,04
8a	5,57	2,68	6,10	4,32	5,73
8b	6,54	6,65	6,61	6,75	6,65
9	8,31	8,18	8,48	8,13	8,36
10a	7,78	0,14	4,15	0,73	3,46
10b	1,28	0,14	0,77	0,27	0,61
10c	5,66	0,60	2,91	0,15	2,29
10d	4,47	0,64	2,63	0,53	1,85
10e	4,47	1,89	3,61	3,10	3,35
11	9,29	11,96	12,01	12,19	11,35
12	6,93	4,65	5,76	9,31	5,88
13a	6,67	3,37	5,08	6,86	5,09
13b	7,05	4,35	5,40	8,14	5,51
14a	7,60	5,92	6,76	11,73	6,96
14b	8,14	6,26	6,83	11,04	7,04
15a	8,97	7,88	8,63	16,01	8,93
15b	8,50	7,39	8,35	15,74	8,63
15c	3,02	0,43	1,81	0,65	1,54
16a	1,02	0,82	0,42	0,48	0,11
16b	1,07	0,80	0,44	0,49	0,11
17	14,74	5,94	11,63	7,64	11,28
18	8,46	4,37	6,98	8,99	7,05

Table represents 5 stations of region 1 is investigated with statistical analysis methods. This section gives information about the t-stat data sets of first region. Overall, tables above indicates that the station 2 has t-stat values close to zero compared to other stations while station 4 has higher values. Further, with the value of 0,14 of Model 10 (a) and (b) has better performance for station 2.

4.2.5.2. Second region t-Stat results

The t-stat analysis is also done for the 2nd region. The results shows the the values of the defined errors changes between 0,01 and 13,98 as can be seen in the table below.

Table 4.49 : t- Stat results for the second region.

T - STAT Values For Second Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	1,38	1,17	1,04	3,40	0,20
2	5,42	0,18	4,27	7,23	5,27
3	5,47	0,16	4,04	7,65	5,10
4	6,46	5,99	6,17	6,51	6,37
5	5,70	7,00	5,31	6,26	5,85
6	4,01	0,39	3,17	5,81	3,76
7	1,86	2,23	1,10	4,97	0,90
8a	0,30	0,53	1,97	0,86	1,17
8b	7,30	6,65	7,10	7,41	7,17
9	8,82	7,59	8,72	8,81	8,58
10a	1,62	2,52	0,95	3,12	1,79
10b	0,14	1,09	0,01	0,85	0,17
10c	2,81	3,03	1,77	2,99	2,88
10d	2,46	3,17	1,62	2,28	2,80
10e	1,20	2,38	1,41	3,58	0,75
11	13,98	7,45	8,99	5,81	11,85
12	4,97	0,50	4,14	6,63	4,90
13a	3,53	1,38	2,82	5,95	2,96
13b	4,96	0,62	3,70	7,35	4,50
14a	6,29	0,27	5,49	7,37	6,69
14b	7,20	0,62	5,63	8,98	7,10
15a	8,46	0,95	7,82	8,54	9,66
15b	7,62	0,73	7,41	7,78	8,88
15c	0,82	1,08	0,16	1,07	0,72
16a	2,30	1,72	1,54	0,62	2,12
16b	2,28	1,72	1,50	0,55	2,10
17	3,73	0,08	5,84	6,15	4,25
18	4,30	1,11	3,98	6,59	3,87

Table 4.49. shows that the Model 10 (b) has better performance than other models for 1st, 3rd and 5th station meanwhile the model 17 and 16 (b) shows least values for 2nd

and 4th stations respectively. Besides, over all station 2 has much more lower results than other station in general.

4.2.5.3. Third region t-Stat results

The Table 4.50. shows the 3rd region t-stat values with the range between 0,07 to 14,94. The results represents the model that has the better for each station.

Table 4.50 : t- Stat results for the third region.

T - STAT Values For Third Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	2,74	5,55	0,20	2,52	1,78
2	2,32	13,39	3,82	6,35	6,39
3	2,38	13,73	3,96	6,89	6,75
4	6,50	6,84	6,84	6,91	6,60
5	5,74	8,05	5,51	6,02	6,17
6	2,16	10,47	3,24	5,01	4,86
7	1,56	9,84	1,23	3,89	2,65
8a	1,44	0,76	1,58	0,72	0,56
8b	7,32	7,90	7,71	7,92	7,46
9	8,70	8,92	9,23	9,45	8,81
10a	3,83	2,77	2,68	0,89	1,32
10b	0,86	0,82	0,40	0,29	0,14
10c	5,00	2,67	3,52	0,42	2,44
10d	4,65	2,65	3,33	0,14	2,50
10e	2,02	5,38	0,50	2,47	1,39
11	13,28	4,59	10,65	8,38	8,86
12	1,60	12,70	3,32	5,66	5,62
13a	0,52	11,37	2,03	4,83	3,98
13b	1,33	13,15	3,38	6,54	5,93
14a	3,11	13,78	4,28	6,48	6,97
14b	4,03	14,81	5,39	8,65	8,58
15a	4,34	14,94	5,51	7,74	8,81
15b	3,79	14,43	4,88	6,86	7,83
15c	2,55	1,06	2,55	0,47	0,82
16a	3,75	0,68	3,93	2,15	2,12
16b	3,71	0,67	3,95	2,10	2,12
17	0,07	5,76	1,20	3,92	2,45
18	0,75	10,23	1,83	5,27	3,88

As table above shows that the Model 10 (b) and (d) has better performance than other models for 5th and 4th stations meanwhile the model 17 and 16 (b) shows least values for 1st and 2nd stations respectively and also Model 1 has better performance for 3rd station. Besides, over all station 1 has much more lower results than other station in general.

4.2.5.4. Fourth region t-Stat results

The last region's t-stat results are given as the table below. The value range of t-stat data set is from 0,06 to 17,35 among five stations.

Table 4.51 : t- Stat results for the fourth region.

T - STAT Values For Fourth Region					
MODEL NO:	Station 1	Station 2	Station 3	Station 4	Station 5
1	3,60	12,12	0,35	1,43	3,12
2	1,49	17,35	5,15	5,34	8,51
3	1,49	17,20	5,48	5,57	8,39
4	7,91	6,85	7,24	7,24	6,68
5	5,48	9,07	6,26	6,63	7,41
6	2,06	14,21	4,39	4,92	8,59
7	0,08	15,09	2,17	3,21	4,17
8a	4,44	0,58	2,14	1,17	1,77
8b	8,17	7,45	8,17	8,19	7,34
9	9,52	8,08	9,53	9,39	8,29
10a	4,98	4,15	2,62	0,28	1,50
10b	1,03	1,25	0,46	0,06	0,35
10c	5,94	4,40	3,49	0,70	1,91
10d	5,51	4,36	3,86	1,01	2,58
10e	0,83	11,19	0,72	1,83	1,36
11	10,41	3,46	8,82	6,38	5,28
12	1,20	16,51	4,44	4,82	7,47
13a	0,06	15,20	2,90	3,73	4,27
13b	0,95	16,04	4,76	5,02	6,78
14a	1,70	17,15	5,46	5,50	8,83
14b	1,84	15,81	7,02	6,35	8,46
15a	1,83	17,20	6,53	6,05	8,15
15b	1,77	17,00	5,86	5,68	8,49
15c	5,94	1,17	2,54	0,70	1,06
16a	7,21	0,97	3,90	2,24	2,46
16b	7,44	0,76	3,95	2,23	2,49
17	2,22	5,71	0,43	2,00	0,32
18	0,83	11,91	2,15	3,30	2,22

As table 4.51. shows respectively the most appropriate models for 1st, 2nd, 3rd, 4th and 5th stations as Model 13 (a), 8 (a), 1, 10 (b) and 17 for the last region. Besides, over all station 1 has much more lower results than other station in general.

4.3. New Model Evaluation Corelation Factor

Several correlations have been found in the literature review to estimate global solar radiation. Some of them have selected and applied to predict monthly average daily global solar radiation at horizontal surface for Istanbul and selected stations where are called Edirne, Ardahan, Erzincan and Antalya. The correlations used in this thesis are shown in Figure 4.32, 4.34, 4.35, 4.36 and 4.37. Quadratic and qubic correlations have been used early also for different correlation by power correlation has been purposed by us.

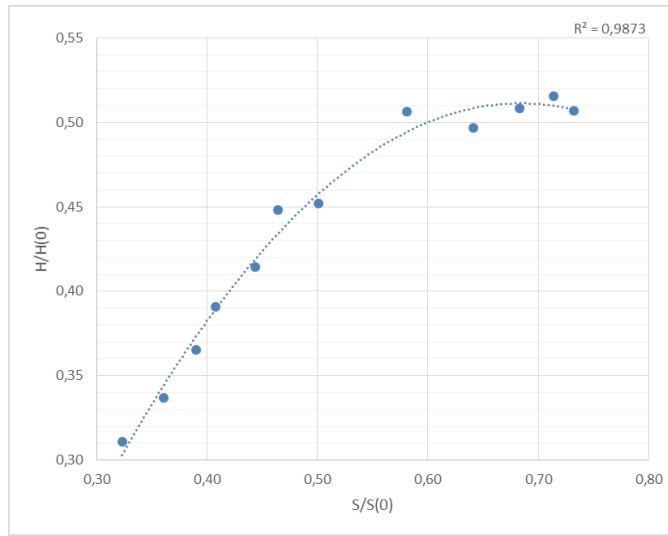


Figure 4.32 : New model for station 3 of region 1.

The results illustrate that, there are statistically significant relationships between relative global radiation and relative sunshine duration. This is further clear by high values of coefficient of determination R^2 (0,9873) across the variables. Suggested mathematical new model for Istanbul of region 1 is given by the Eq. 4.7.

$$\frac{H}{H_0} = -1,5992 \left(\frac{S}{S_0} \right)^2 + 2,1874 \left(\frac{S}{S_0} \right) - 0,2367 \quad (4.7)$$

where,

H/H_0 ; is the relative global radiation

S/S_0 ; is the relative sunshine duration

So it is clear seen that coefficient of determination R^2 is the correlation factor of the quadratic equation.

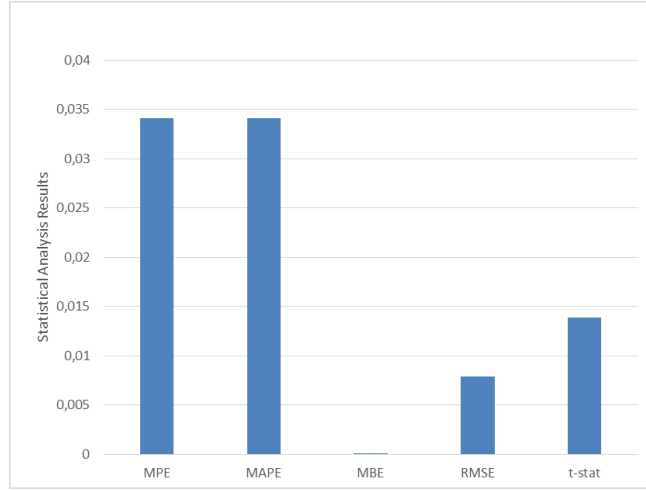


Figure 4.33 : Statistical analysis for region1 station 3.

Figure indicates statistical analysis result obtain for the new model used. It is clear that the correlation of determination R^2 , MBE($\text{MJm}^{-2}\text{d}^{-2}$), RMSE($\text{MJm}^{-2}\text{d}^{-2}$) and t-Stat vary from one variable to another variable. MBE value is obtained in this study as 10^{-5} .

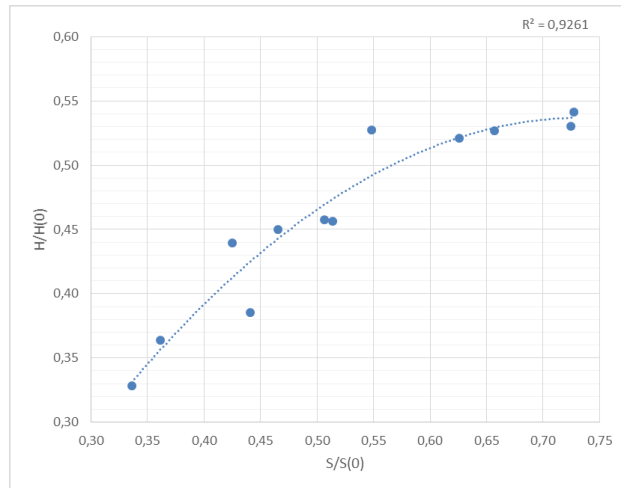


Figure 4.34 : New model for station 2 of region 1.

Fig 4.34. represents the value of coefficient of determination of 0,9261. Suggested mathematical new model for Edirne of region 1 is given by the Eq.4.8.

$$\frac{H}{H_0} = -1,2927 \left(\frac{S}{S_0} \right)^2 + 1,9008 \left(\frac{S}{S_0} \right) - 0,1618 \quad (4.8)$$

where, H/H_0 ; is the relative global radiation and S/S_0 ; is the relative sunshine duration.

So it is clear seen that coefficient of determination R^2 is the correlation factor of the quadratic equation.

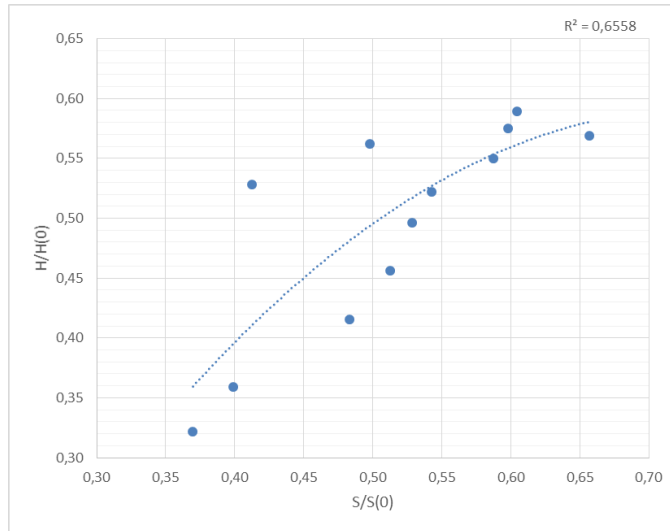


Figure 4.35 : New model for station 2 of region 2.

Fig 4.35. represents the value of coefficient of determination of 0,6558. Suggested mathematical new model for Ardahan of region 2 is given by the Eq. 4.9.

$$\frac{H}{H_0} = -1,7445 \left(\frac{S}{S_0} \right)^2 + 2,5606 \left(\frac{S}{S_0} \right) - 0,3488 \quad (4.9)$$

where,

H/H_0 ; is the relative global radiation

S/S_0 ; is the relative sunshine duration

So it is clear seen that coefficient of determination R^2 is the correlation factor of the quadratic equation.

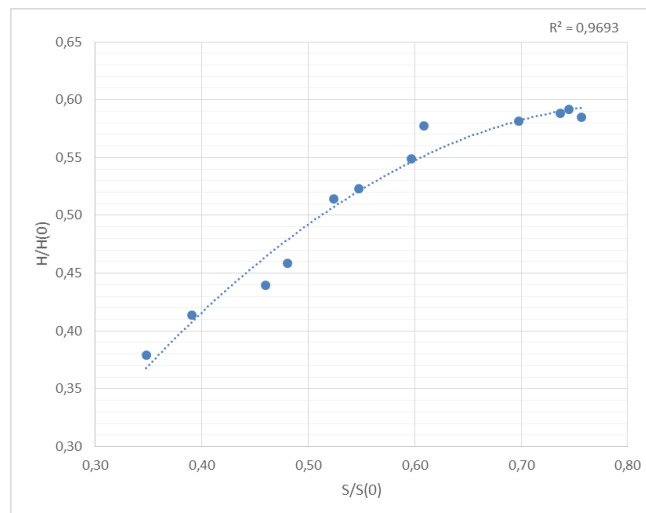


Figure 4.36 : New model for station 1 of region 3.

Fig 4.36. represents the value of coefficient of determination of 0,9693. Suggested mathematical new model for Erzincan of region 3 is given by the Eq. 4.10.

$$\frac{H}{H_0} = -1,03 \left(\frac{S}{S_0} \right)^2 + 1,6875 \left(\frac{S}{S_0} \right) - 0,0942 \quad (4.10)$$

where,

H/H_0 ; is the relative global radiation

S/S_0 ; is the relative sunshine duration

So it is clear seen that coefficient of determination R^2 is the correlation factor of the quadratic equation.

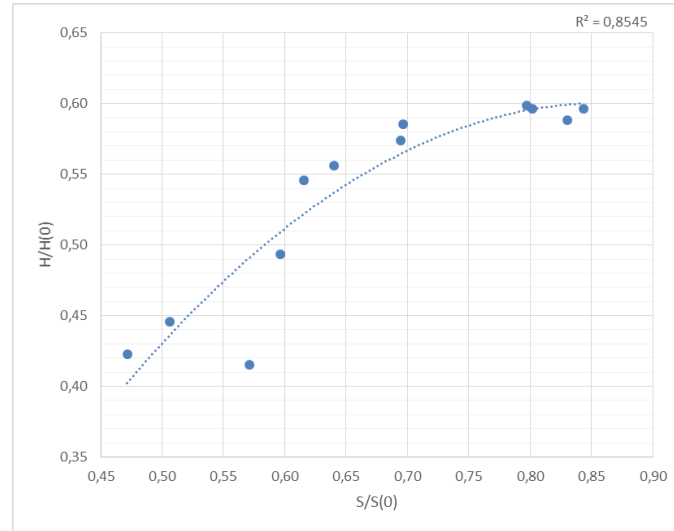


Figure 4.37 : New model for station 1 of region 4.

Figure 4.37. represents the value of coefficient of determination of 0,8545. Suggested mathematical new model for Antalya of region 4 is given by the Eq. 4.11.

$$\frac{H}{H_0} = -1,3126 \left(\frac{S}{S_0} \right)^2 + 2,2575 \left(\frac{S}{S_0} \right) - 0,3703 \quad (4.11)$$

where,

H/H_0 ; is the relative global radiation and S/S_0 ; is the relative sunshine duration.

So it is clear seen that coefficient of determination R^2 is the correlation factor of the quadratic equation.

Therefore, there is a significant variation of R^2 - values, show between the Figure 4.35 and Figure 4.32, 4.34, 4.36, 4.37 for considered new model, but Figure 4.35 has lower R^2 values compared to Figures 4.32, 4.34, 4.36, 4.37.

Ardahan is in a location where it is in the intermediate position by means of solar radiation range compared to other stations. Therefore, although the sunshine duration data sets for Ardahan recorded from the GEPA as well as the others, the convergence of the GEPA datas also effects results of the correlations.

5. CONCLUSION AND RECOMMENDATIONS

The sustainable energy is the precise and unique solution to compensate the existing energy demand that was mentioned in the previous sections which needs investment to expand its field of application in this planet. The PV market has grown despite the constraints confronted by sectors such as the impact of economic crisis and obstacles on implementation of policies.

On the contrary, the solar investments were increased gradually having a peak in 2011 with 157,8 billion US dollars, and the investment declined having 113,7 billion US dollars by the end of 2013 according to the data that was published by Frankfurt School of Finance and Management [49]. The fluctuation was not witnessed solely in PV sector but also the overall global trend in renewable investment had a peak and then go downwards by not slowing down. When the total new investments are evaluated on regional basis, it illustrates that the changes in figures are similar as expected. In the meantime it was reported by Bloomberg in January 2014 that investment in clean energy in China had not affected excessively that raised slightly although there were fluctuations in these periods such as to total sustainable energy investments declined in 2013 with 12% compared with the year 2012 and 23% decline compared with the year 2011 on a worldwide basis [50].

The technological costs may be referred to the economical aspect of the sustainable energy where the pinpoint of the decline in sustainable energy investments as mainly in the developed nations could be related to uncertainties in incentive policies especially in Europe and United States. Therefore the other reason that causes the decrease of the investments in Europe might be China, because China prefers to invest sustainable energy projects more than their need.

It was believed that as long as scientific researches and developments continue, the technology will be improved by the time. Energy resources and efficient technologies will be the indispensable solution to the energy demand under the circumstances of appropriate strategies. Sustainable energy potential depends on environmental

conditions. Further, the governmental, technological and scientific contribution have the major role of energy supply and its application in every branch of the industry. Therefore, the less constraints on the aforesaid mainstreams will eventually could cause to enlarge the utilization of those alternative resources.

The climate is most favourable for solar energy utilization, but the distribution of solar radiation is not well known. The importance of this study, lies on the fundamental of knowledge of the monthly average global solar radiation and the monthly average maximum possible daily sunshine duration are analysed for 20 cities in Turkey. The four different solar radiation ranges of Turkey are named under regions meanwhile 20 cities named as stations which are selected within the mentioned solar radiation ranges. There have been chosen 5 station for each 4 region. Furthermore, the models related to the monthly average global solar radiation and the monthly average maximum possible daily sunshine duration, are evaluated and detailed, from then onwards each model form the literature that are illustrated in this Master of Science Thesis are examined under the groups of 6 set of models for each 5 stations of 4 regions within Turkey. On the other hand, only Istanbul and one selected station for each region are illustrated by the model results figures. Besides, the appropriate model for the sets of each selected stations are mentioned according to the results, however; to be more exact some other analysis are also done for the model results.

Furthermore, we have been get quadratic regression analysis from using equations 4.7, 4.8, 4.9, 4.10 and 4.11 for several stations which the equations are due to on the fundamental of knowledge of the monthly average global solar radiation and the monthly average maximum possible daily sunshine duration. Information about solar radiation can also be achieved using correlations between solar radiation and other meteorological and geographical parameters.

The statistical analysis methods; MPE, MAPE, MBE, RMSE and t-Stat which are use in this thesis in order to evaluate the results of the reviewed models. To remind, one station is selected for each region. Besides evaluation of each model for each station in the region, the statistical analysis is also done for the selected stations as represented in the following Table 5.1. to 5.5. Furthermore, new model correlations that this thesis proposed as in the section 4.3., are also evaluated by the statistical analysis and represented in the Table 5.6. Graphical evaluation that the data is used via the Tables 5.1., 5.2., 5.3, 5.4 and 5.5 shown in Appendix-B.

The mean percentage error values are represented as in the Table 5.1. for selected stations of regions. The table represents the most applicable model for stations.

Table 5.1 : MPE results for selected stations.

MODEL NO:	MPE			
	Region 1 Station 2	Region 2 Station 2	Region 3 Station 1	Region 4 Station 1
1	3,08	0,24	-2,74	-8,11
2	11,29	4,11	3,58	1,99
3	10,86	3,90	3,33	1,87
4	-48,27	-51,40	-53,88	-58,66
5	73,95	60,96	66,90	75,27
6	10,31	2,81	3,64	4,20
7	3,79	-3,14	-2,53	-2,17
8a	12,13	5,57	0,69	-8,43
8b	-69,00	-70,85	-72,61	-72,95
9	-90,61	-91,36	-88,25	-82,54
10a	2,63	-3,60	-5,34	-7,89
10b	8,65	1,59	-0,42	-4,31
10c	0,70	-5,57	-7,04	-9,03
10d	0,88	-6,00	-7,27	-9,98
10e	4,31	-3,02	-3,40	-5,07
11	-36,25	-35,25	-34,55	-24,51
12	10,76	3,40	2,97	1,32
13a	7,73	0,56	0,20	-1,31
13b	9,85	2,75	2,28	0,63
14a	13,31	5,84	5,00	2,63
14b	13,76	6,52	5,42	2,63
15a	15,71	8,18	6,60	2,92
15b	15,40	7,69	6,36	2,91
15c	15,30	7,58	6,37	2,68
16a	9,88	3,58	0,60	-4,77
16b	9,90	3,45	0,65	-4,35
17	16,06	8,12	4,75	-2,99
18	9,14	2,01	0,76	-2,29

According to the MPE results, Model 10 (c) by Togrul and et. al. is the most applicable model for the selected station of region 1 with the MPE value of 0,70 that is the lowest value compared the other results. Model 13 (a) and Model 13 (b) by the same constructors Ulgen and Hepbasli, are more applicable than other reviewed models for respectively selected stations of 3rd and 4th region where Model 1 shows the lowest values for 2nd station. Furthermore, not only MPE analysis is done but also MAPE statistical analysis evaluated as in the Table 5.2.

Table 5.2 : MAPE results for selected stations.

MAPE				
MODEL NO:	Region 1 Station 2	Region 2 Station 2	Region 3 Station 1	Region 4 Station 1
1	3,08	0,24	2,74	8,11
2	11,29	4,11	3,58	1,99
3	10,86	3,90	3,33	1,87
4	48,27	51,40	53,88	58,66
5	73,95	60,96	66,90	75,27
6	10,31	2,81	3,64	4,20
7	3,79	3,14	2,53	2,17
8a	12,13	5,57	0,69	8,43
8b	69,00	70,85	72,61	72,95
9	90,61	91,36	88,25	82,54
10a	2,63	3,60	5,34	7,89
10b	8,65	1,59	0,42	4,31
10c	0,70	5,57	7,04	9,03
10d	0,88	6,00	7,27	9,98
10e	4,31	3,02	3,40	5,07
11	36,25	35,25	34,55	24,51
12	10,76	3,40	2,97	1,32
13a	7,73	0,56	0,20	1,31
13b	9,85	2,75	2,28	0,63
14a	13,31	5,84	5,00	2,63
14b	13,76	6,52	5,42	2,63
15a	15,71	8,18	6,60	2,92
15b	15,40	7,69	6,36	2,91
15c	15,30	7,58	6,37	2,68
16a	9,88	3,58	0,60	4,77
16b	9,90	3,45	0,65	4,35
17	16,06	8,12	4,75	2,99
18	9,14	2,01	0,76	2,29

As the mean absolute percentage error analysis is the absolute results of the mean percentage error as mention previously in the Table 5.1. Although, data sets have changed the most appropriate models for the selected stations of the four region remain same such as Model 10 (c) by Togrul and et. al., Model 1 by Kilic and Ozturk, Model 13 (a) and Model 13 (b) by Ulgen and Hepbasli gave the appropriate results for selected stations for 1st, 2nd, 3rd and 4th region respectively. On the other hand, MBE results points out different models for stations.

Table 5.3 : MBE results for selected stations.

MODEL NO:	MBE			
	Region 1 Station 2	Region 2 Station 2	Region 3 Station 1	Region 4 Station 1
1	0,40	-0,39	-0,40	-0,99
2	1,31	-0,07	0,43	0,54
3	1,30	-0,06	0,42	0,50
4	-6,97	-8,02	-8,68	-9,67
5	10,45	8,34	10,92	13,34
6	1,34	-0,15	0,60	1,05
7	0,47	-0,98	-0,35	-0,03
8a	0,78	-0,26	-0,65	-1,61
8b	-9,47	-10,56	-11,25	-11,92
9	-11,64	-12,94	-13,02	-13,06
10a	0,03	-1,20	-1,07	-1,19
10b	0,14	-1,11	-0,93	-1,07
10c	-0,11	-1,35	-1,21	-1,28
10d	-0,14	-1,46	-1,27	-1,36
10e	0,51	-0,90	-0,48	-0,37
11	-3,57	-4,51	-4,32	-3,72
12	1,20	-0,20	0,31	0,45
13a	0,81	-0,58	-0,10	0,02
13b	1,13	-0,24	0,24	0,31
14a	1,48	0,10	0,56	0,62
14b	1,56	0,23	0,63	0,57
15a	1,68	0,35	0,69	0,60
15b	1,63	0,27	0,66	0,63
15c	1,85	-6,95	-8,97	-13,56
16a	-3,58	-10,94	-14,74	-21,01
16b	-3,55	-11,07	-14,69	-20,59
17	1,29	0,04	0,02	-0,55
18	0,86	-0,47	-0,15	-0,23

The mean bias error gives information about the long term performance of the models. As Table 5.3. represents, the MBE results of the most appropriate models for selected stations of each region has lowest values compared to other models. Model 10 (a) with the value of 0,03 error is above estimations however has the most appropriate result for 2nd station of 1st region. On the other hand, Model 17 by Tahrán and Sari, shows lower results for 2nd and 3rd regions' selected stations. At last, the Model 13 (a) is most applicable model for the selected station of 4th region. Further, for the short term performances of the models are evaluated under the root mean square error by giving the results as the Table 5.4. for the regions.

Table 5.4 : RMSE results for selected stations.

MODEL NO:	RMSE			
	Region 1 Station 2	Region 2 Station 2	Region 3 Station 1	Region 4 Station 1
1	0,79	1,17	0,62	1,34
2	1,58	1,26	0,74	1,31
3	1,58	1,25	0,72	1,23
4	8,01	9,17	9,74	10,48
5	12,27	9,23	12,61	15,59
6	1,81	1,28	1,10	1,99
7	1,07	1,75	0,83	1,26
8a	1,24	1,65	1,63	2,01
8b	10,58	11,80	12,35	12,86
9	12,56	14,13	13,94	13,82
10a	0,67	1,99	1,42	1,43
10b	3,40	3,58	3,69	3,60
10c	0,64	2,01	1,46	1,47
10d	0,73	2,11	1,55	1,58
10e	1,03	1,54	0,93	1,52
11	3,71	4,94	4,46	3,91
12	1,48	1,32	0,71	1,31
13a	1,14	1,52	0,67	1,12
13b	1,42	1,32	0,64	1,12
14a	1,69	1,25	0,82	1,37
14b	1,77	1,23	0,82	1,17
15a	1,83	1,27	0,87	1,23
15b	1,79	1,27	0,88	1,33
15c	14,40	22,41	14,72	15,53
16a	14,97	23,75	19,69	23,12
16b	15,19	24,03	19,71	22,55
17	1,47	1,55	1,08	0,98
18	1,08	1,50	0,68	0,95

According to the RMSE results of the reviewed models stations of the 2nd and 3rd regions has the same applicable model which is the Model 1 by Kilic and Ozturk. On the other hand, Model 10 (c) , shows the closest value to zero for 2nd station of 1st region meanwhile Model 18 by Bakirci gives the most appropriate result for the short term performance of selected station of 4th region. In order to, define the better model performance the t-Stat analysis is also done as represented below.

Table 5.5 : t-Stat results for selected stations.

T-STAT				
MODEL NO:	Region 1 Station 2	Region 2 Station 2	Region 3 Station 1	Region 4 Station 1
1	1,99	1,17	2,74	3,60
2	4,90	0,18	2,32	1,49
3	4,77	0,16	2,38	1,49
4	5,85	5,99	6,50	7,91
5	5,40	7,00	5,74	5,48
6	3,64	0,39	2,16	2,06
7	1,62	2,23	1,56	0,08
8a	2,68	0,53	1,44	4,44
8b	6,65	6,65	7,32	8,17
9	8,18	7,59	8,70	9,52
10a	0,14	2,52	3,83	4,98
10b	0,14	1,09	0,86	1,03
10c	0,60	3,03	5,00	5,94
10d	0,64	3,17	4,65	5,51
10e	1,89	2,38	2,02	0,83
11	11,96	7,45	13,28	10,41
12	4,65	0,50	1,60	1,20
13a	3,37	1,38	0,52	0,06
13b	4,35	0,62	1,33	0,95
14a	5,92	0,27	3,11	1,70
14b	6,26	0,62	4,03	1,84
15a	7,88	0,95	4,34	1,83
15b	7,39	0,73	3,79	1,77
15c	0,43	1,08	2,55	5,94
16a	0,82	1,72	3,75	7,21
16b	0,80	1,72	3,71	7,44
17	5,94	0,08	0,07	2,22
18	4,37	1,11	0,75	0,83

The Table 5.5. represents that there are two models; Model 10 (a) and Model 10 (b) are better for 2nd station of 1st region which gives the same t-Stat value as a result of different type of correlations proposed by the same constructor Togrul and et. all. Besides, Model 17 gives the most appropriate results for selected stations of 2nd and 3rd regions, meanwhile Model 13 (a) shows better performance compared to the other models for 1st station of 4th region.

Table 5.6 : Statistical analysis results for new correlations of selected stations.

	Region 1 Station 2	Region 2 Station 2	Region 3 Station 1	Region 4 Station 1
MPE	0,169419	1,194582	0,038838	0,278311
MAPE	0,169419	1,194582	0,038838	0,278311
MBE	-0,000023	0,000024	-0,000064	-0,000057
RMSE	0,018722	0,049757	0,012724	0,025987
t-stat	0,003991	0,001631	0,016737	0,007308

Performance of various correlations for new models which are proposed in this thesis were evaluated in terms of MPE, MAPE, MBE, RMSE, t-Stat. This statistical parameters are computed by equations showns in Table 5.6

The models use radiation and geographical parameters of the location under study. It only requires the monthly average daily global radiation and the monthly average maximum possible daily sunshine duration. The aggrement between the calculated and estimated values is remarkable and it is recomended for use in any location in Turkey or stations with similar climate.

New model provided resonably high degree of precession in the forecast of monthly daily average global solar radiation on the horizontal surfaces. The estimated values of global solar radiation reveals that solar radiation can be very efficiently used to compensate for energy inadequency. Computed values of monthly daily average global solar radiation using correlations have been compared with calculated values as shown in Figures 4.32, 4.34, 4,35, 4.36, 4.37.

The coefficient of determination R^2 is between the 98 % and 65% for average correlation, so all the correlations fit the data adequetly. Thus, these can be used for the prediction of radiation values at Turkey. The correlation factors clearly show that the quadratic correlation has maximum value of R^2 (98%) and minimum value of errors likes MBE and RMSE, so quadratic correlation give best estimation of the global solar radiation at Istanbul.

Nowadays, to sustain the economical improvements, qualifications of both factor of efficiency and production factors should be developed continuously. In this context, with this Master of Science Thesis, the issue is considered by aspects as investigation of solar energy sector and establishment of Turkey profile. The solar radiation calculations of primary importance are envisaged that will provide quality of the improvement of the factor of efficiencies.

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APPENDICES

APPENDIX A: Calculation Evaluation Results of Models for Stations of Regions

APPENDIX B: Statistical Analysis Results of Regions

APPENDIX A

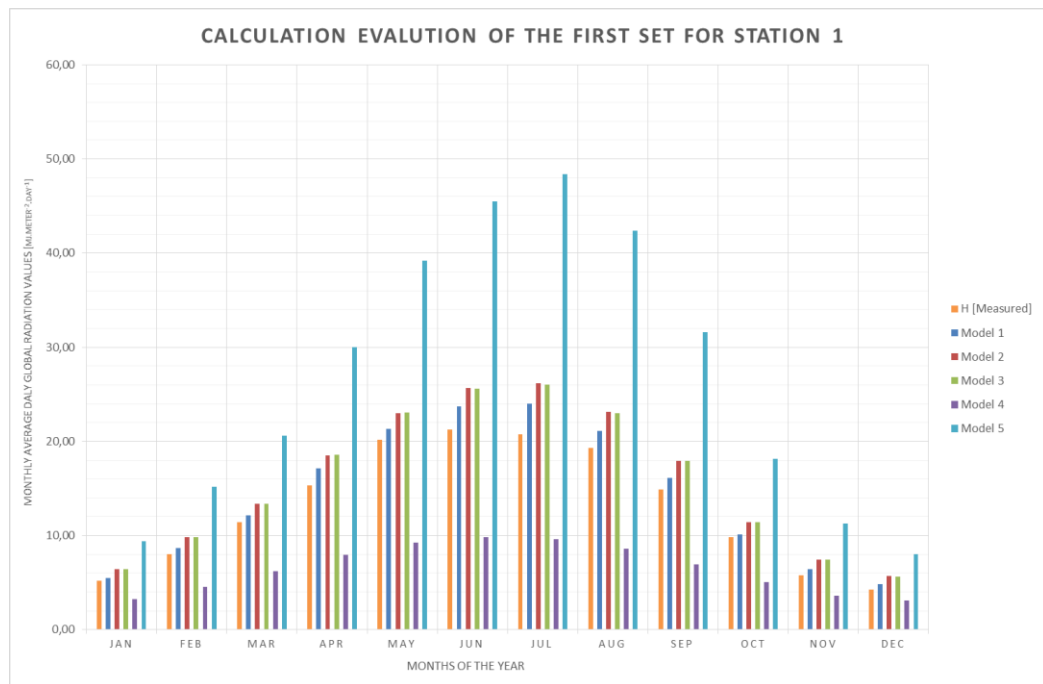


Figure A.1 : First set of the models for region 1 station 1, Edirne.

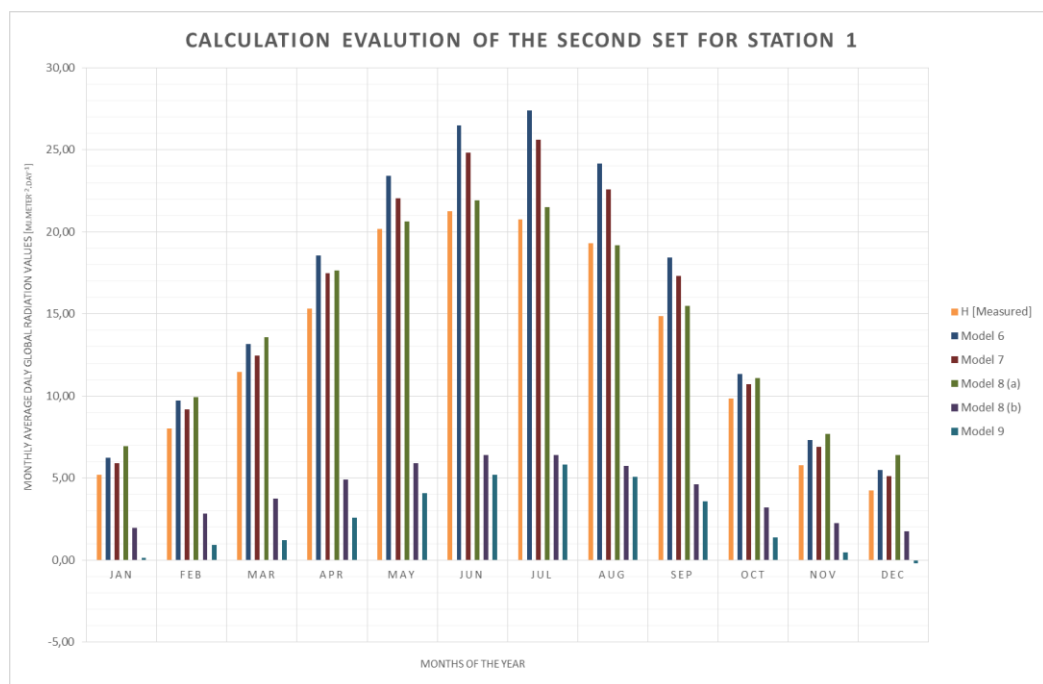


Figure A.2 : Second set of the models for region 1 station 1, Edirne.

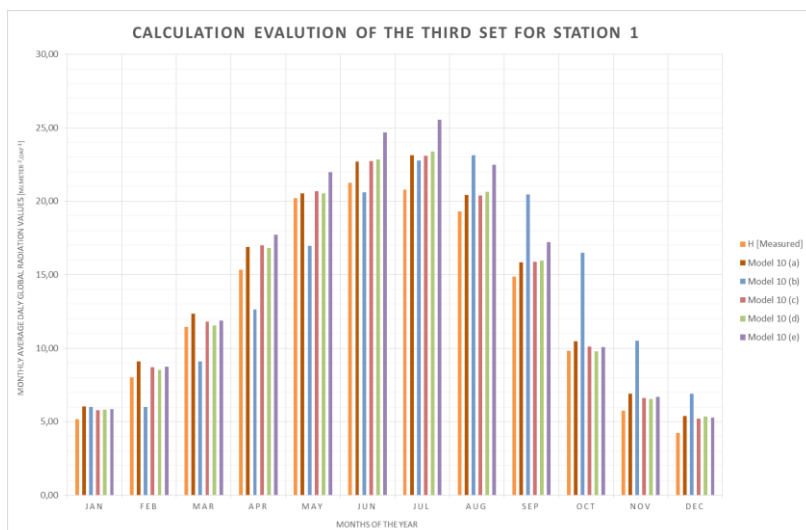


Figure A.3 : Third set of the models for region 1 station 1, Edirne.

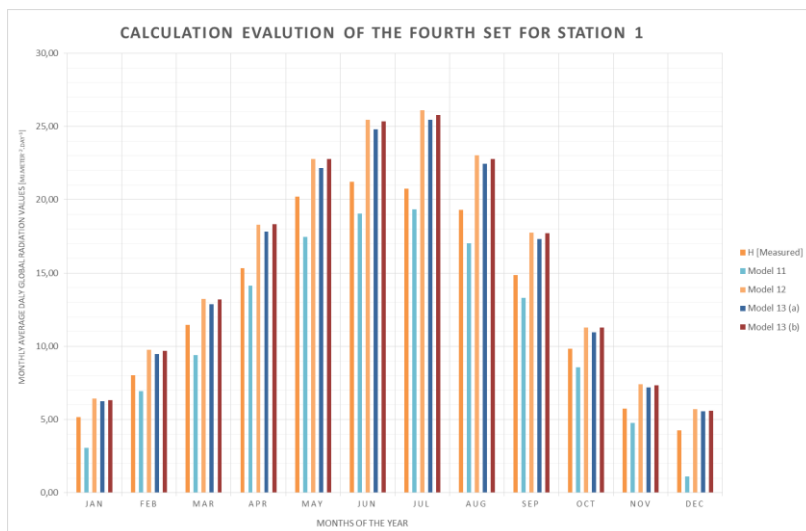


Figure A.4 : Fourth set of the models for region 1 station 1, Edirne.

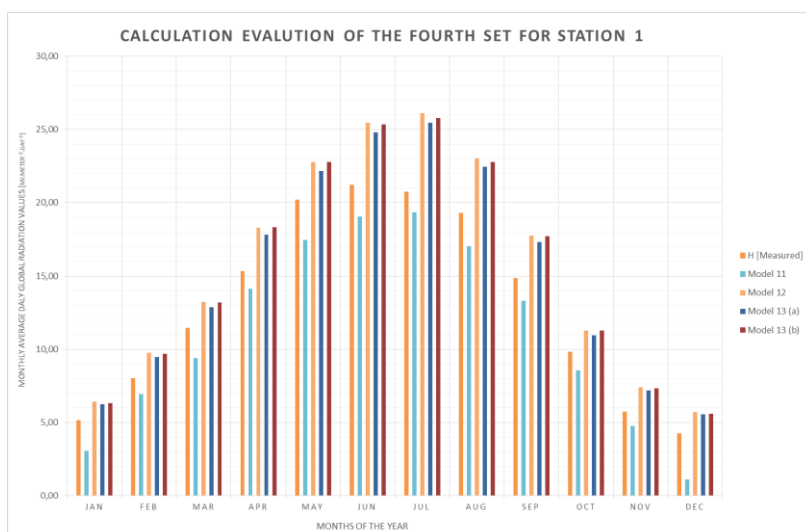


Figure A.5 : Fifth set of the models for region 1 station 1, Edirne.

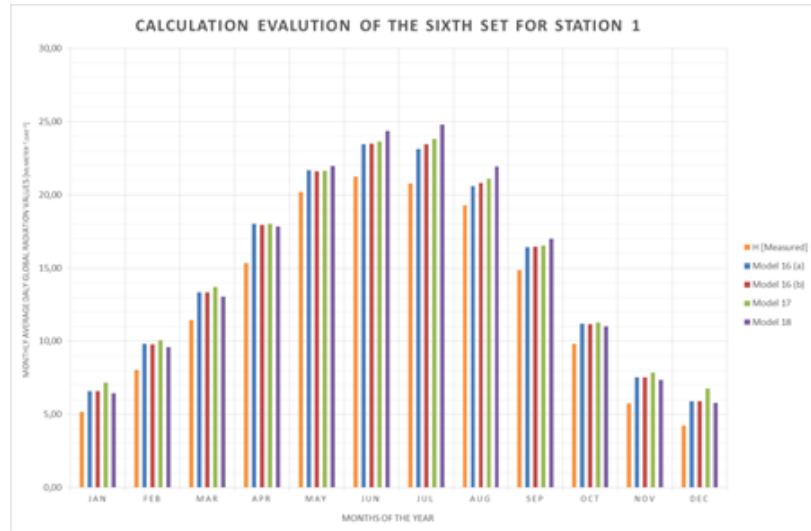


Figure A.6 : Sixth set of the models for region 1 station 1, Edirne.

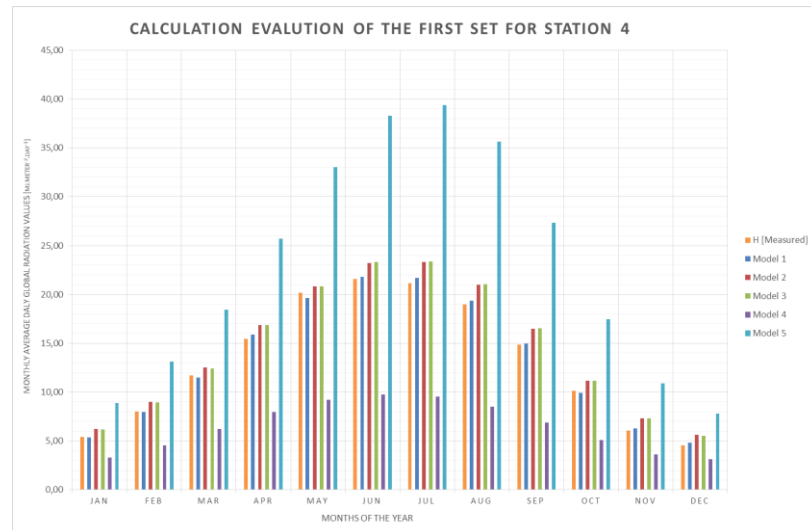


Figure A.7 : First set of the models for region 1 station 4, Samsun.

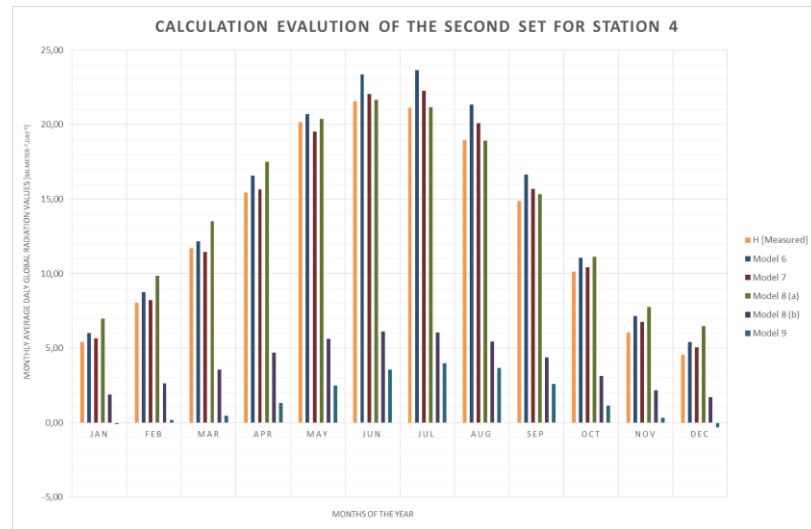


Figure A.8 : Second set of the models for region 1 station 4, Samsun.

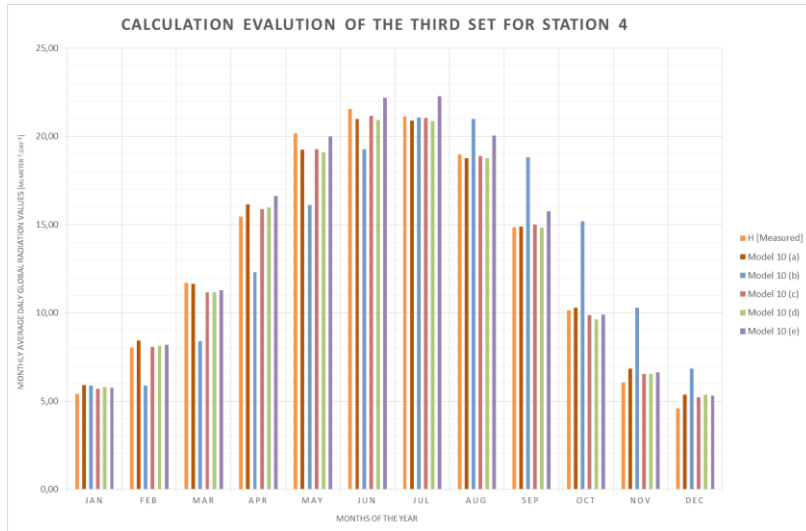


Figure A.9 : Third set of the models for region 1 station 4, Samsun.

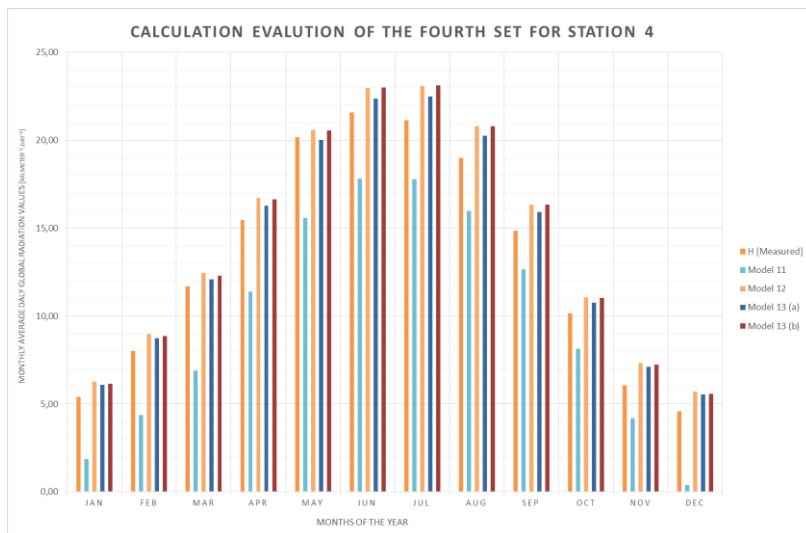


Figure A.10 : Fourth set of the models for region 1 station 4, Samsun.

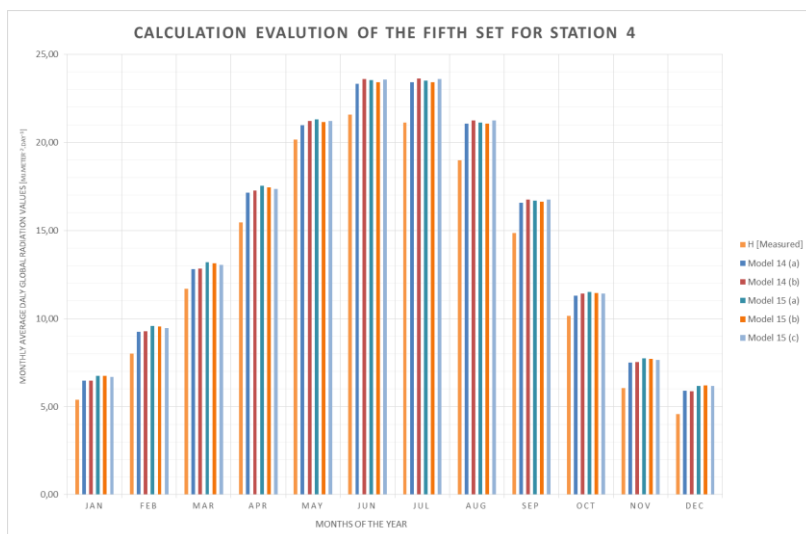


Figure A.11 : Fifth set of the models for region 1 station 4, Samsun.

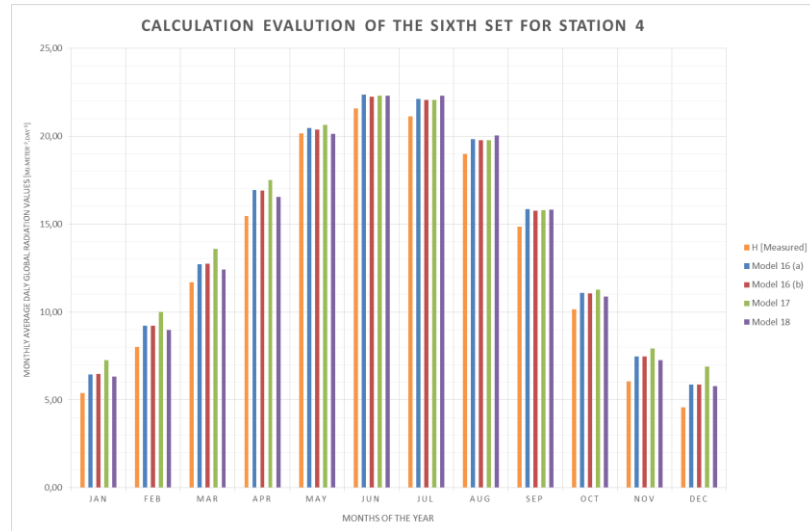


Figure A.12 : Sixth set of the models for region 1 station 4, Samsun.

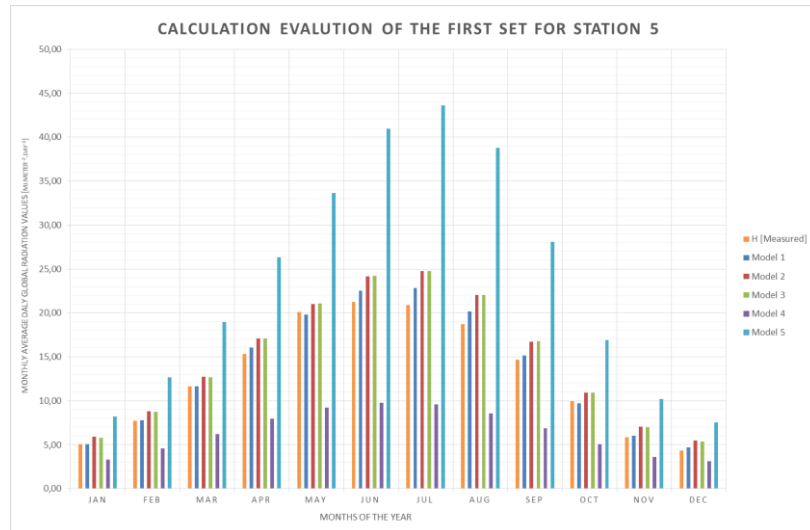


Figure A.13 : First set of the models for region 1 station 5, Zonguldak.

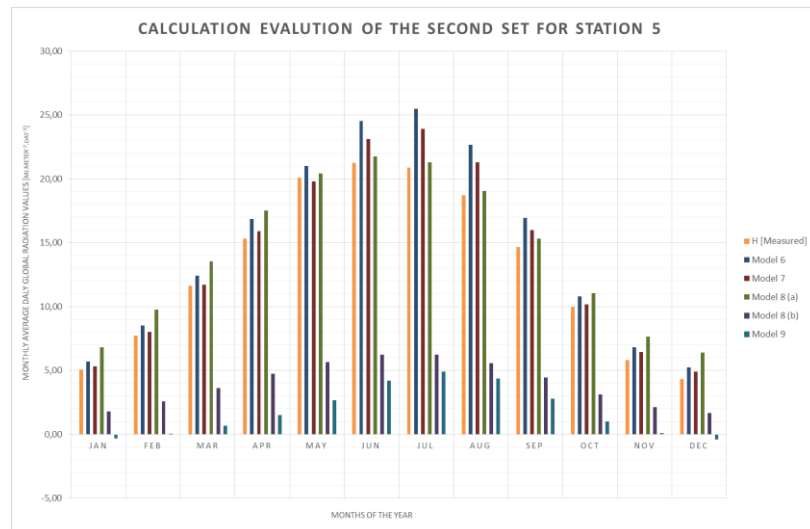


Figure A.14 : Second set of the models for region 1 station 5, Zonguldak.

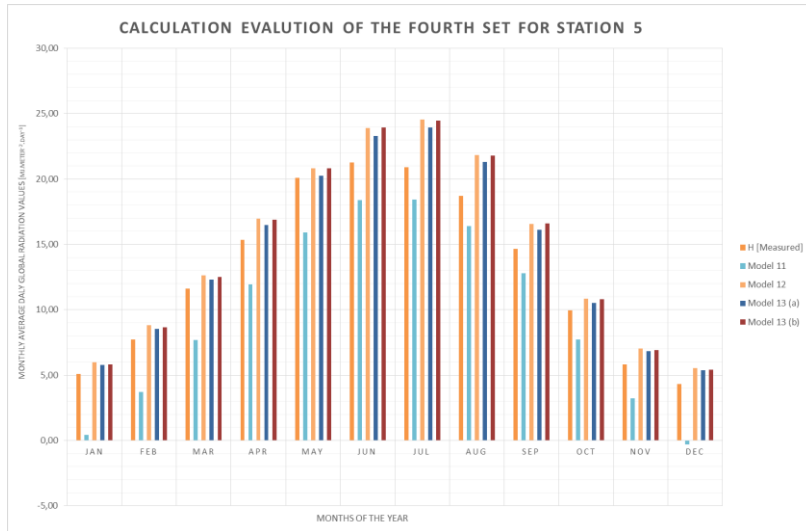


Figure A.15 : Third set of the models for region 1 station 5, Zonguldak.

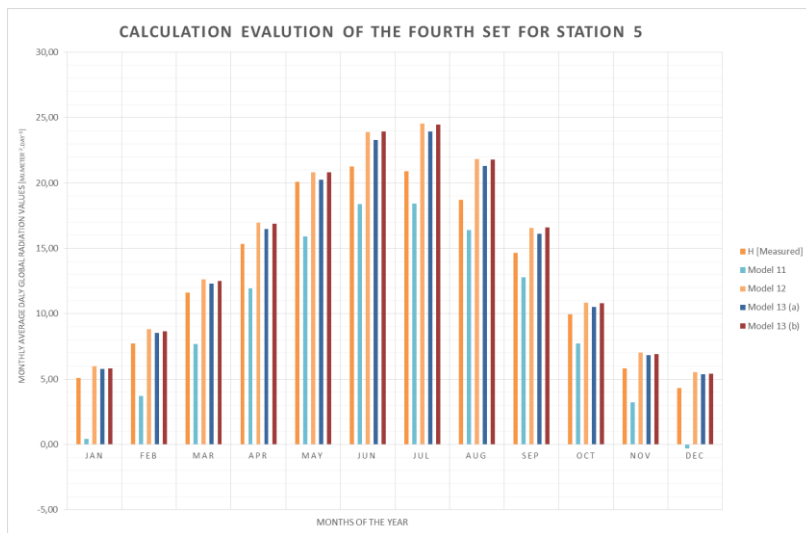


Figure A.16 : Fourth set of the models for region 1 station 5, Zonguldak.

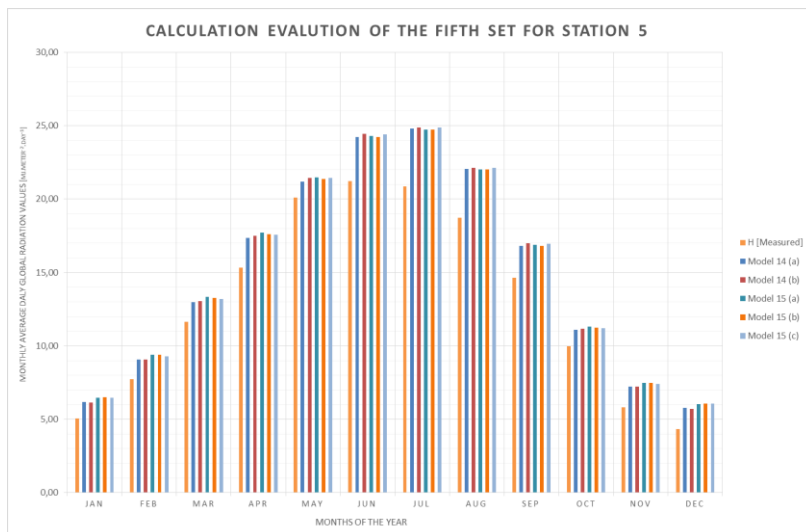


Figure A.17 : Fifth set of the models for region 1 station 5, Zonguldak.

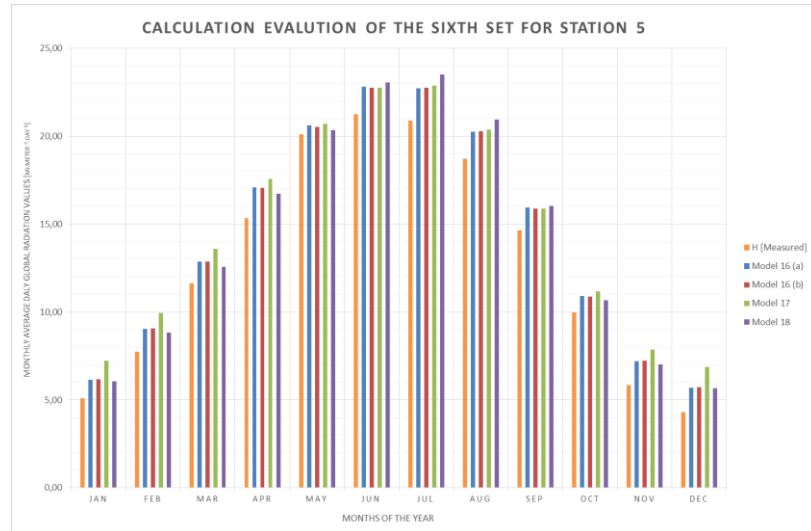


Figure A.18 : Sixth set of the models for region 1 station 5, Zonguldak.

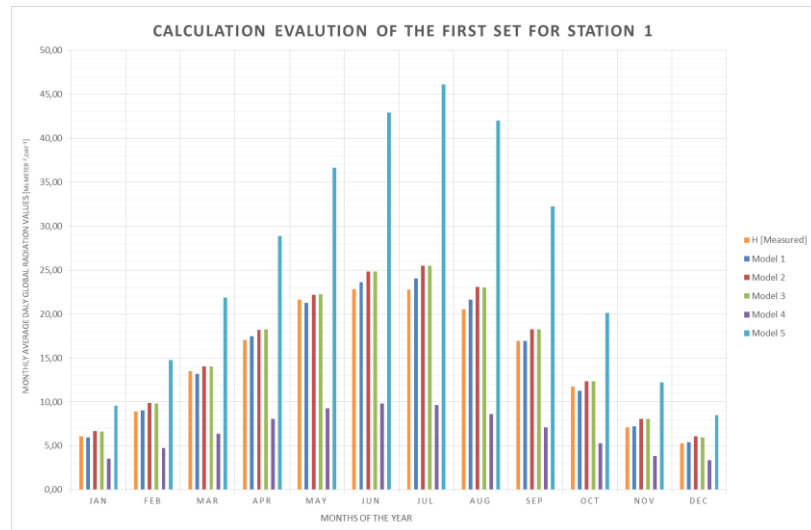


Figure A.19 : First set of the models for region 2 station 1, Ankara.

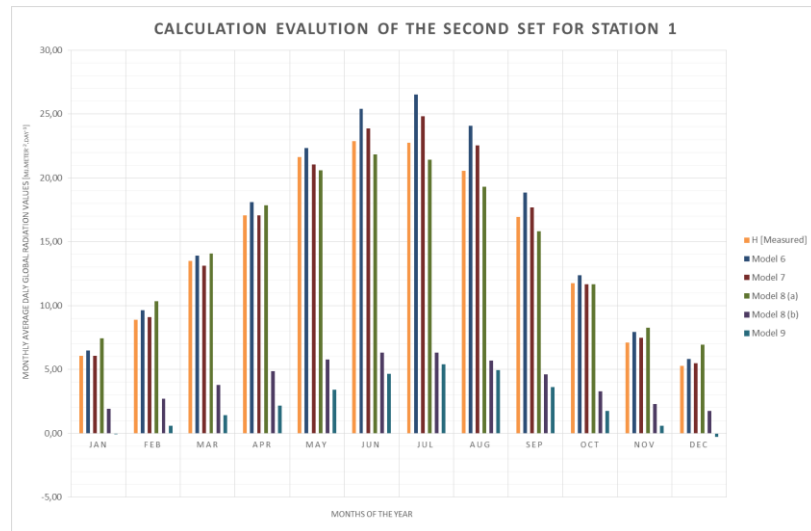


Figure A.20 : Second set of the models for region 2 station 1, Ankara.

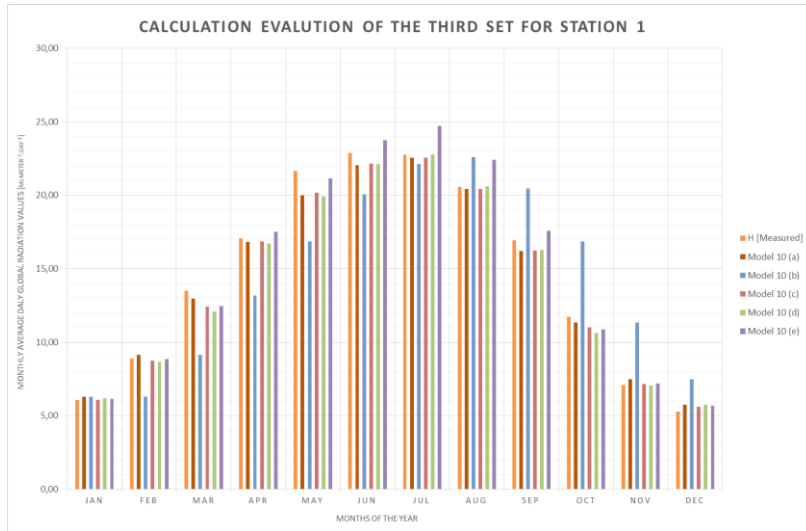


Figure A.21 : Third set of the models for region 2 station 1, Ankara.

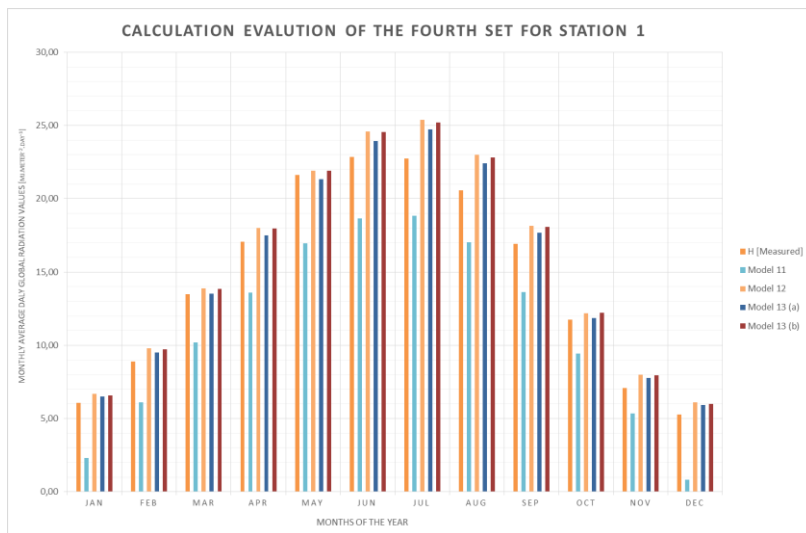


Figure A.22 : Fourth set of the models for region 2 station 1, Ankara.

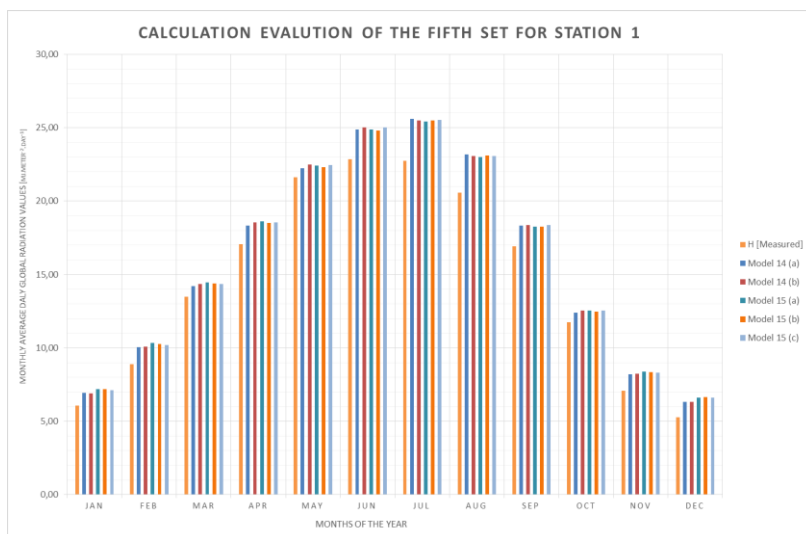


Figure A.23 : Fifth set of the models for region 2 station 1, Ankara.

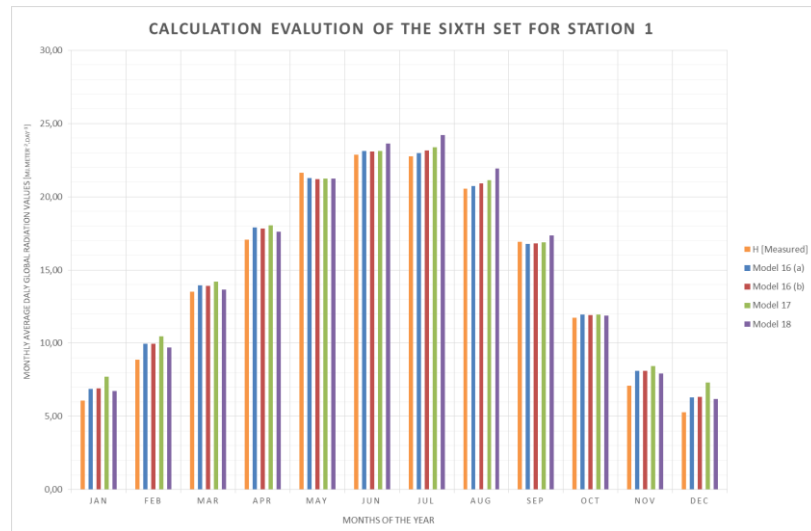


Figure A.24 : Sixth set of the models for region 2 station 1, Ankara.

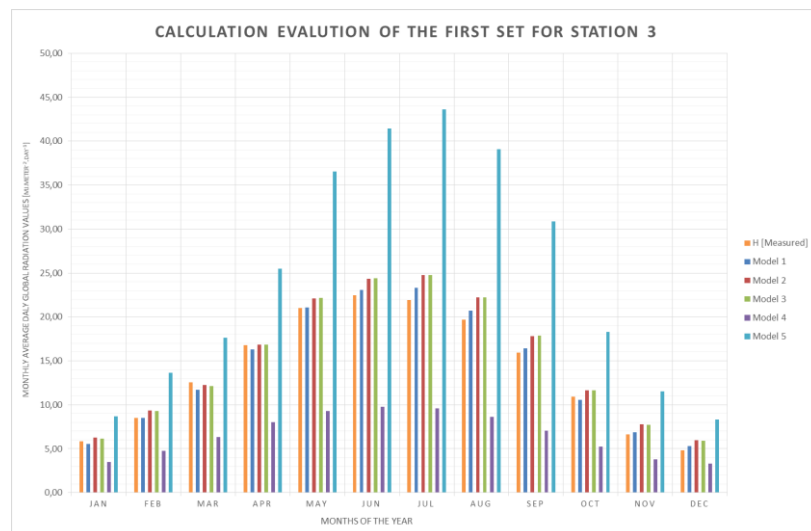


Figure A.25 : First set of the models for region 2 station 3, Bilecik.

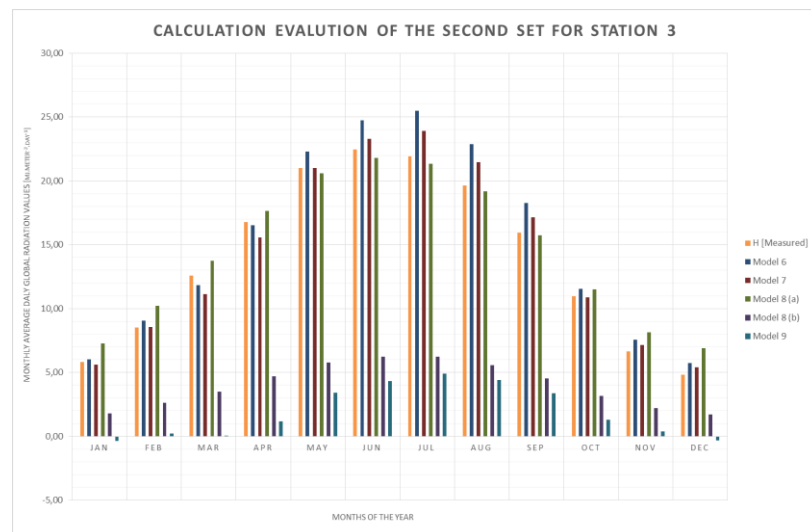


Figure A.26 : Second set of the models for region 2 station 3, Bilecik.

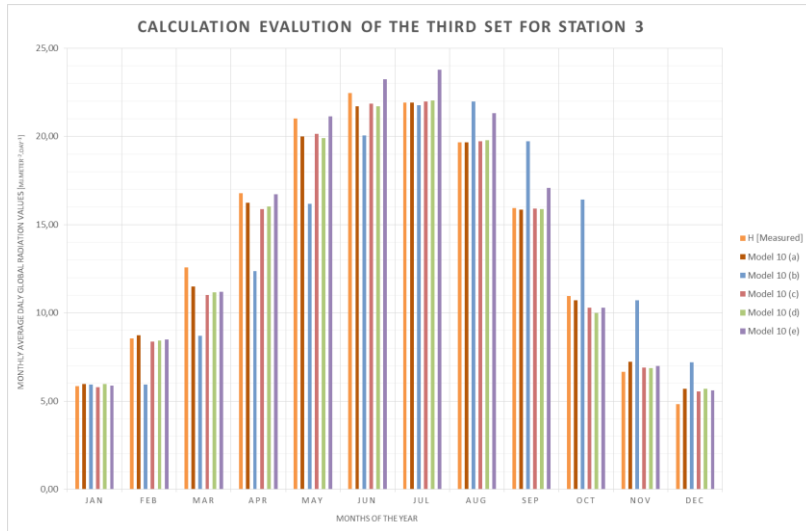


Figure A.27 : Third set of the models for region 2 station 3, Bilecik.

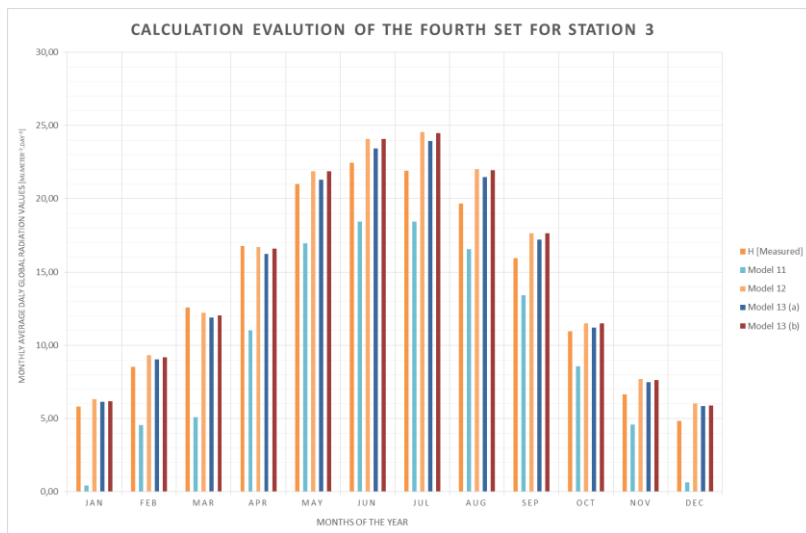


Figure A.28 : Fourth set of the models for region 2 station 3, Bilecik.

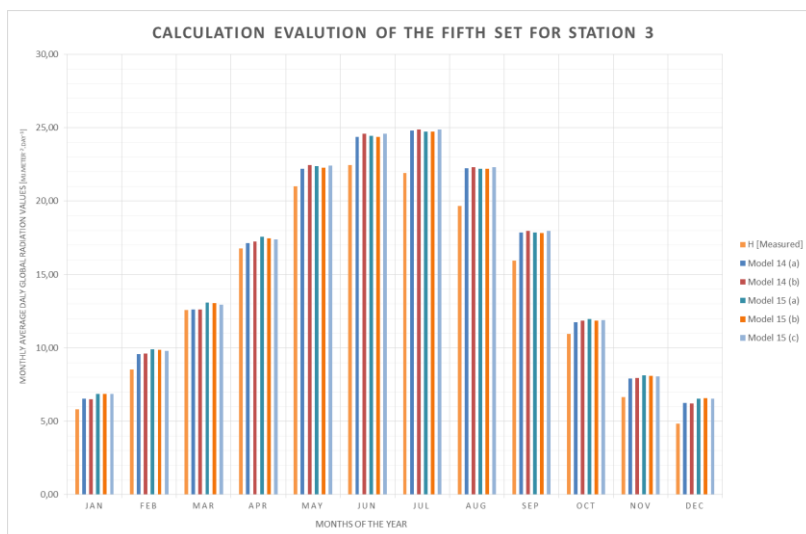


Figure A.29 : Fifth set of the models for region 2 station 3, Bilecik.

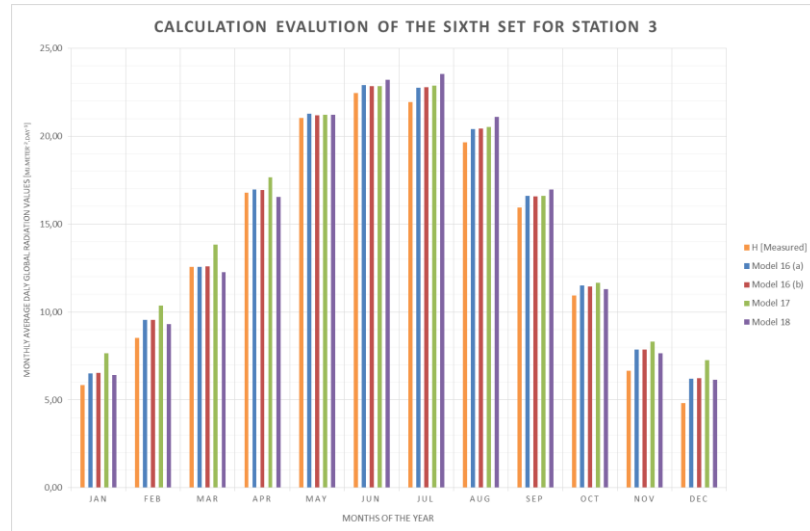


Figure A.30 : Sixth set of the models for region 2 station 3, Bilecik.

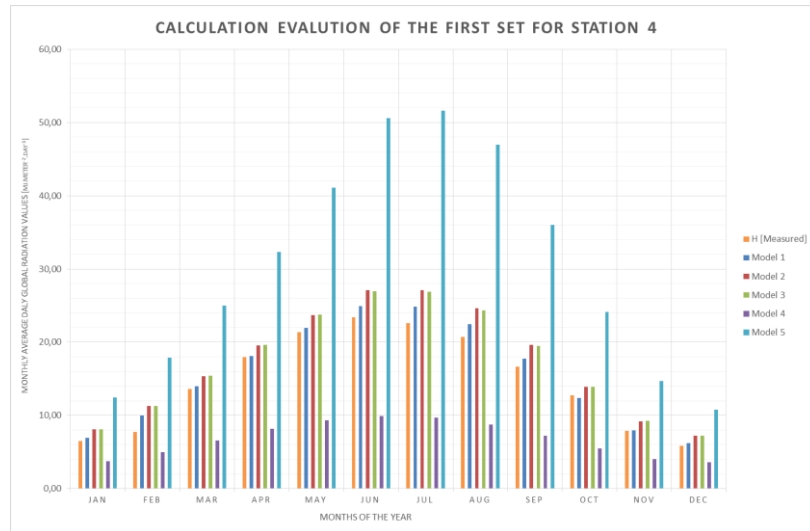


Figure A.31 : First set of the models for region 2 station 4, Izmir.

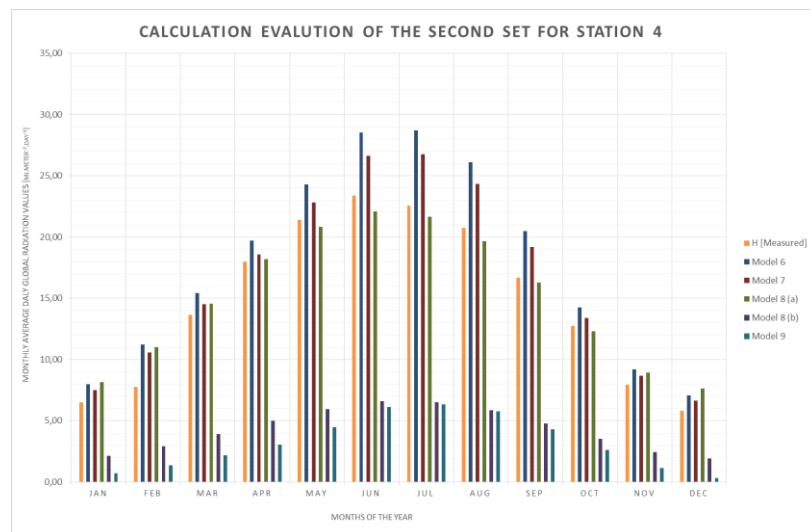


Figure A.32 : Second set of the models for region 2 station 4, Izmir.

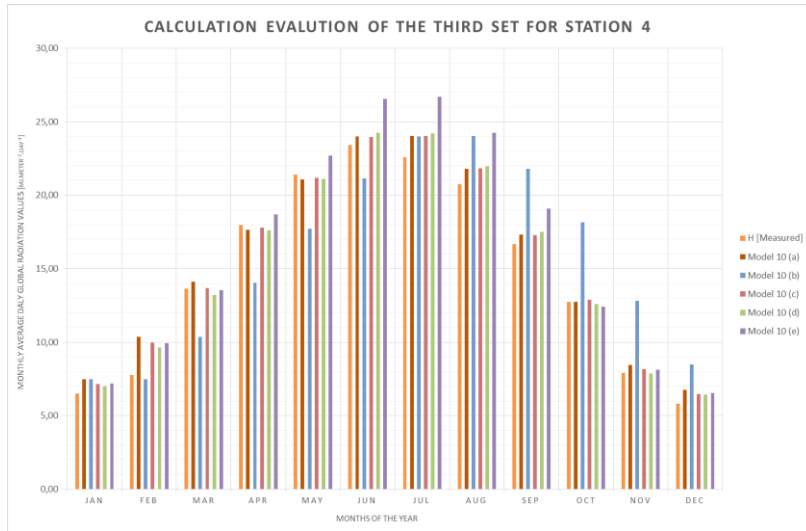


Figure A.33 : Third set of the models for region 2 station 4, Izmir.

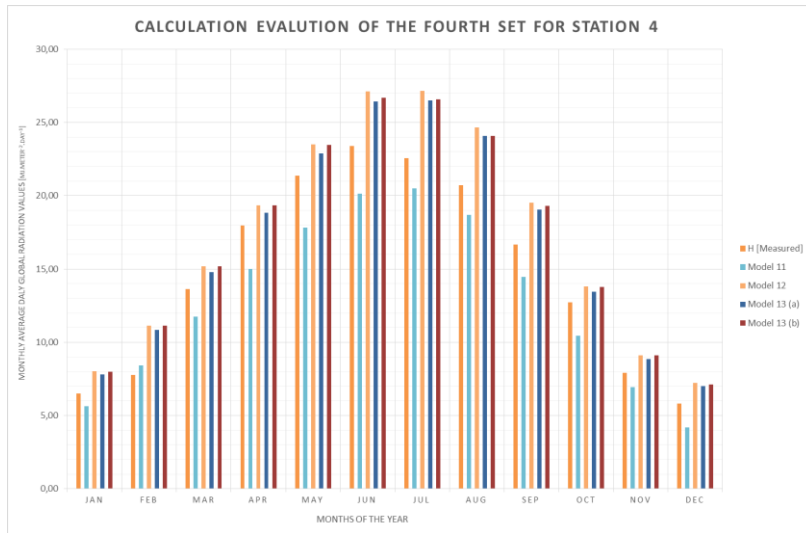


Figure A.34 : Fourth set of the models for region 2 station 4, Izmir.

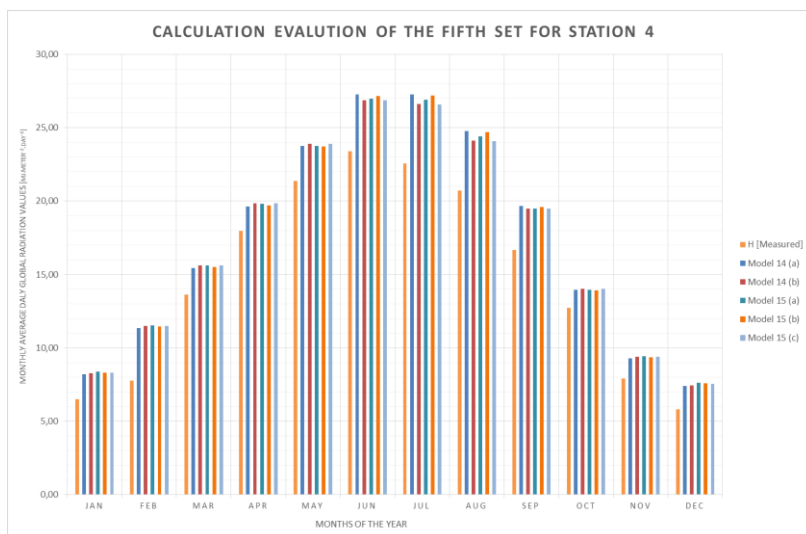


Figure A.35 : Fifth set of the models for region 2 station 4, Izmir.

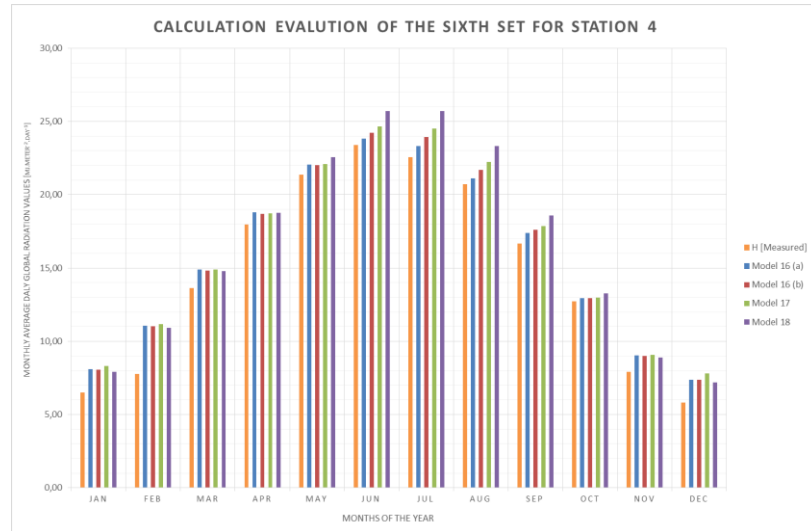


Figure A.36 : sixth set of the models for region 2 station 4, Izmir.

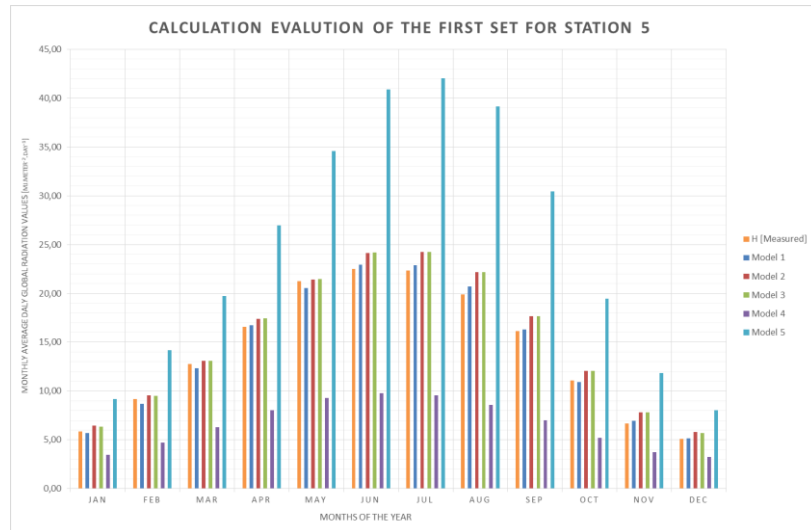


Figure A.37 : First set of the models for region 2 station 5, Tokat.

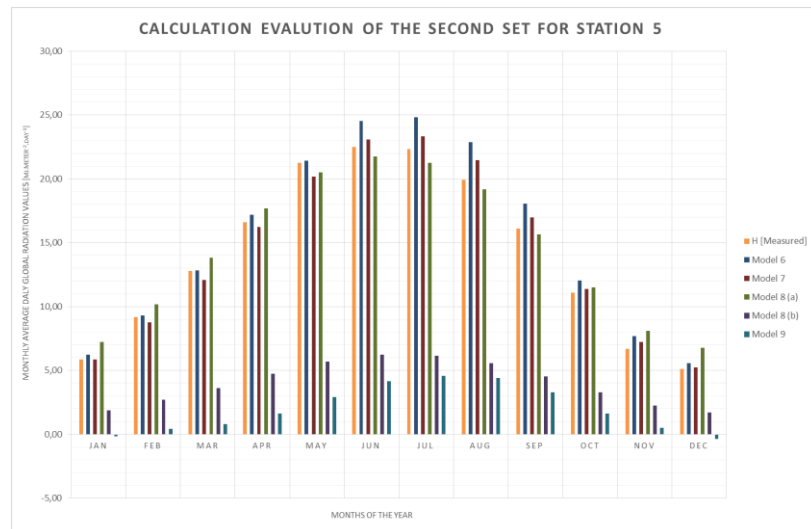


Figure A.38 : Second set of the models for region 2 station 5, Tokat.

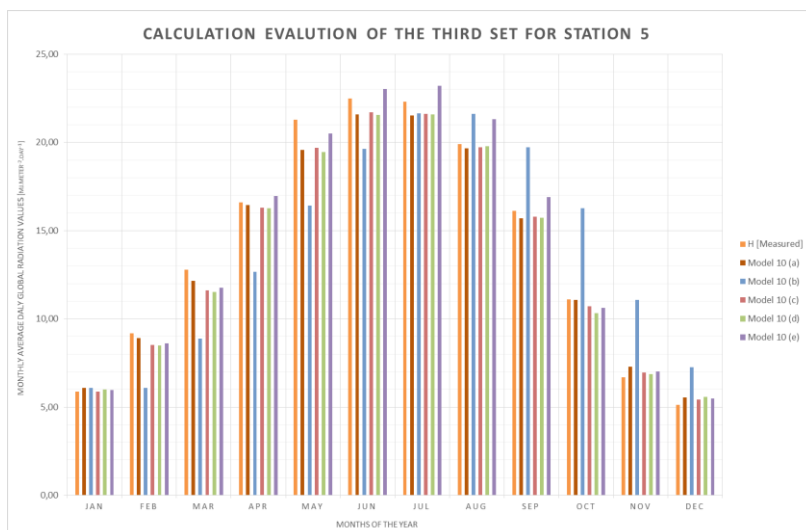


Figure A.39 : Third set of the models for region 2 station 5, Tokat.

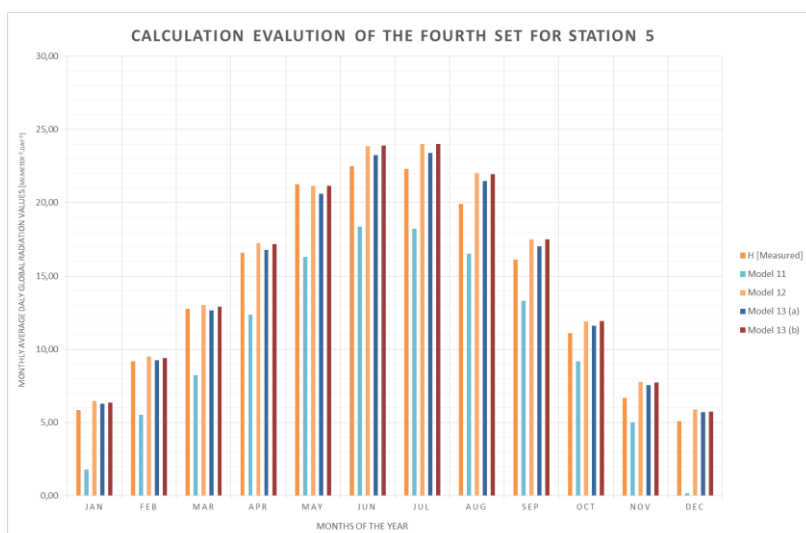


Figure A.40 : Fourth set of the models for region 2 station 5, Tokat.

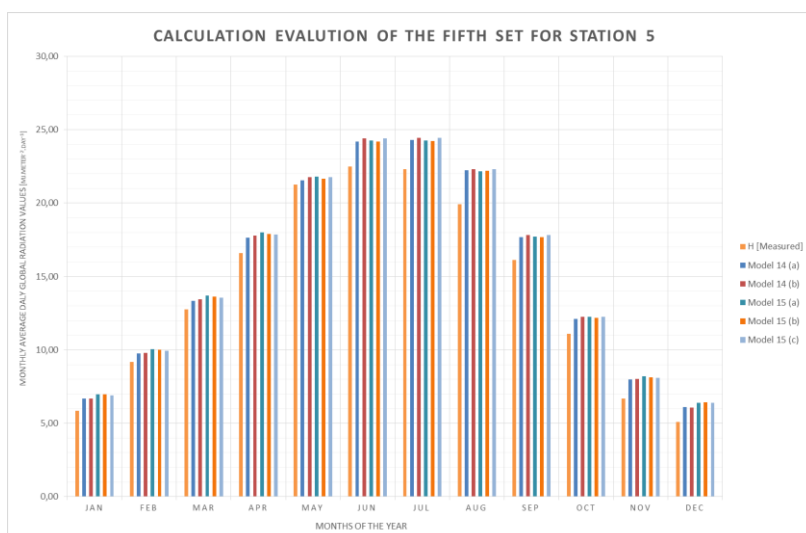


Figure A.41 : Fifth set of the models for region 2 station 5, Tokat.

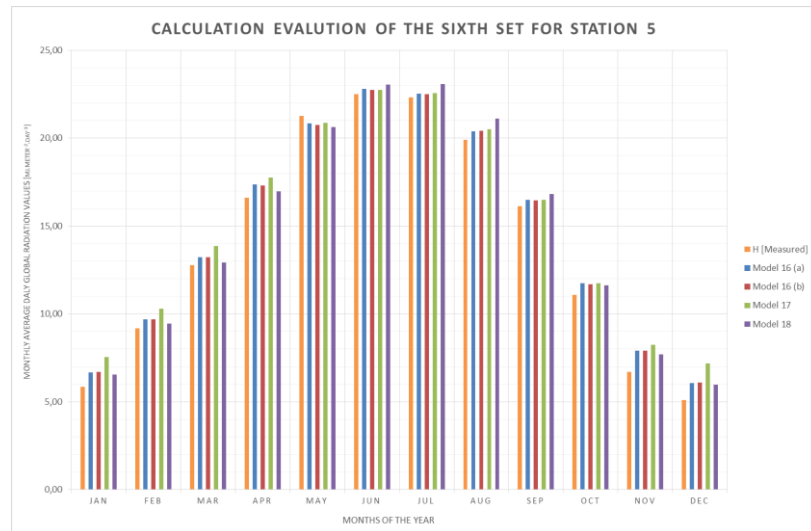


Figure A.42 : Sixth set of the models for region 2 station 5, Tokat.

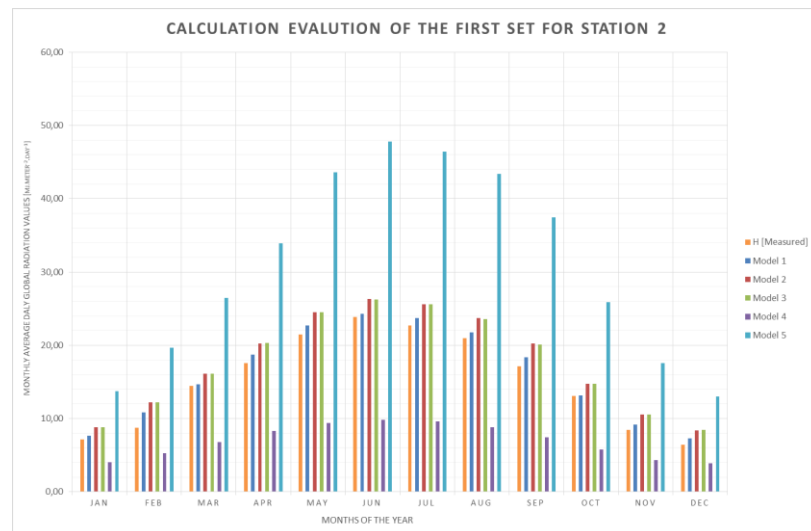


Figure A.43 : First set of the models for region 3 station 2, Hatay.

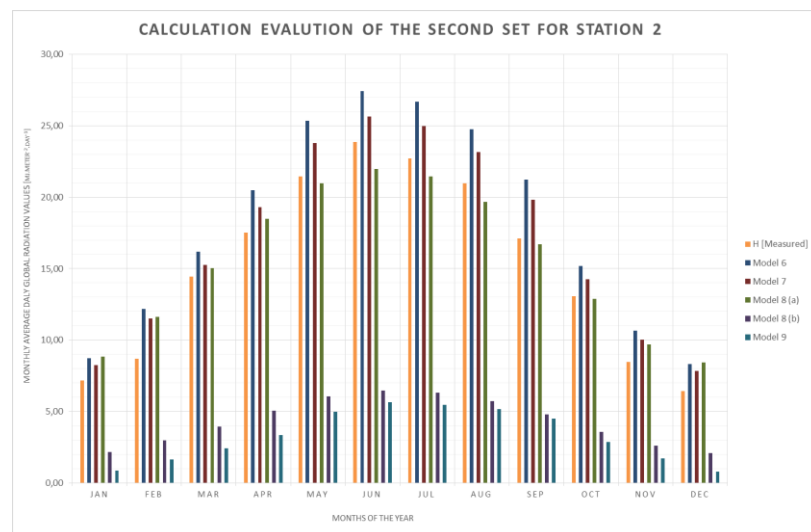


Figure A.44 : Second set of the models for region 3 station 2, Hatay.

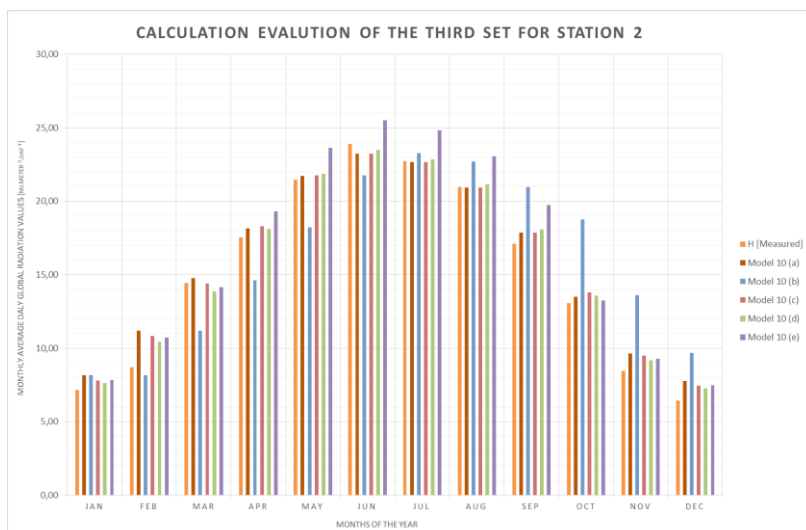


Figure A.45 : Third set of the models for region 3 station 2, Hatay.

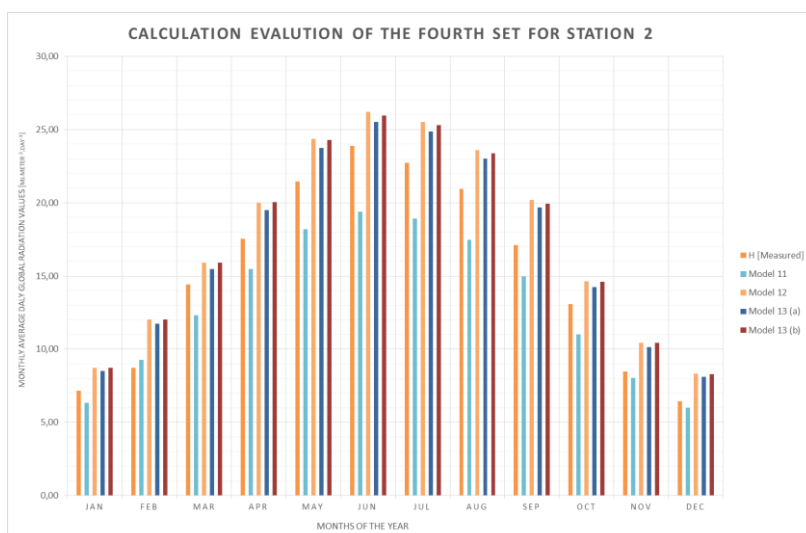


Figure A.46 : Fourth set of the models for region 3 station 2, Hatay.

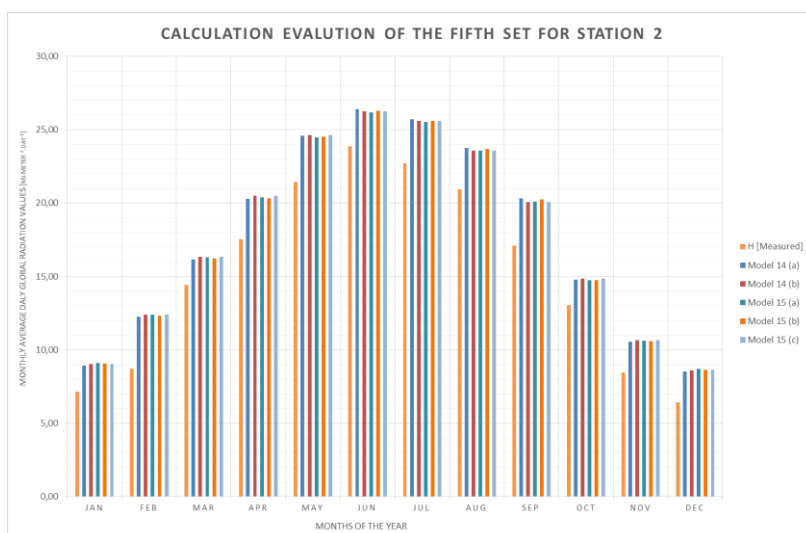


Figure A.47 : Fifth set of the models for region 3 station 2, Hatay.

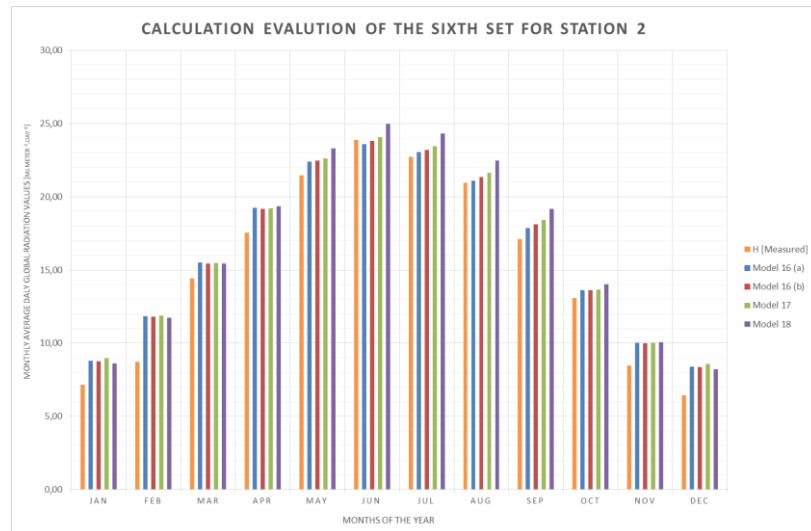


Figure A.48 : Sixth set of the models for region 3 station 2, Hatay.

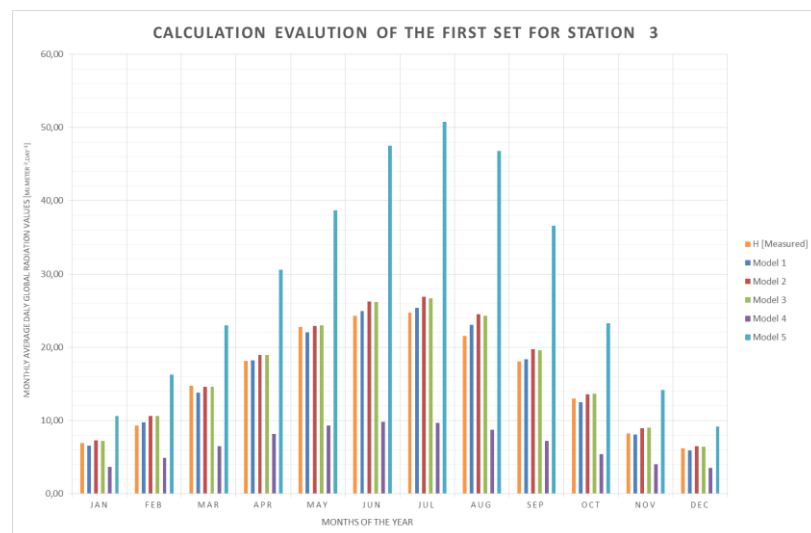


Figure A.49 : First set of the models for region 3 station 3, Kayseri.

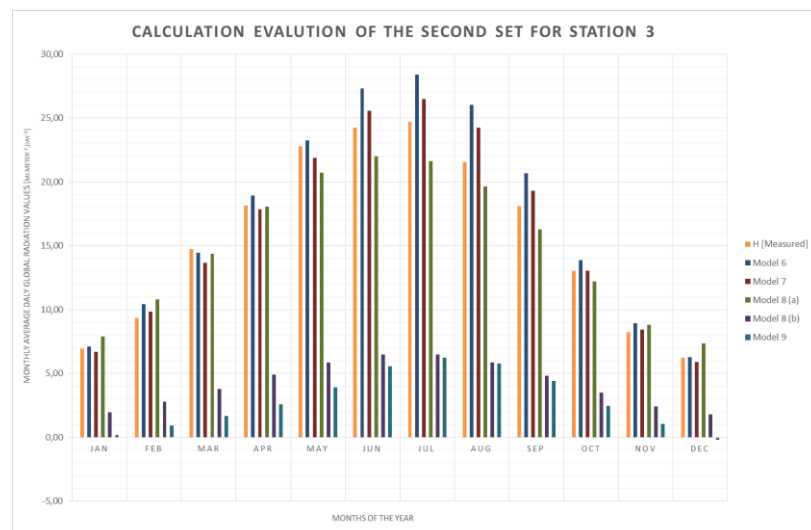


Figure A.50 : Second set of the models for region 3 station 3, Kayseri.

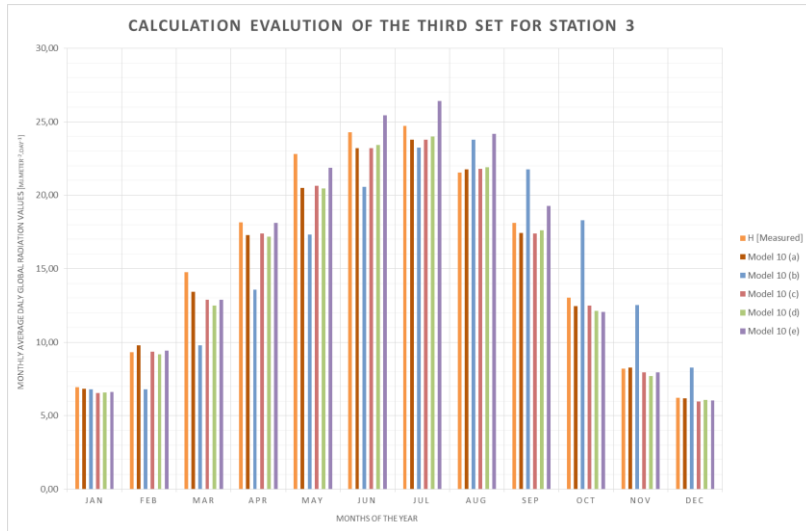


Figure A.51 : Third set of the models for region 3 station 3, Kayseri.

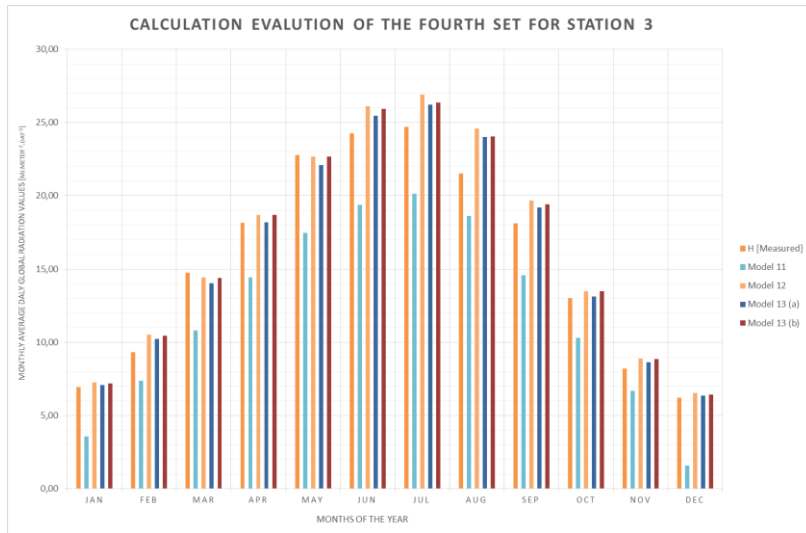


Figure A.52 : Fourth set of the models for region 3 station 3, Kayseri.

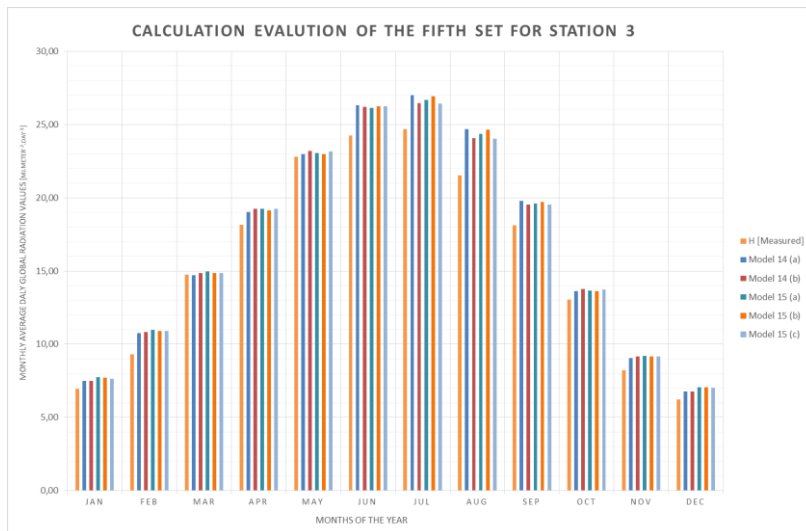


Figure A.53 : Fifth set of the models for region 3 station 3, Kayseri.

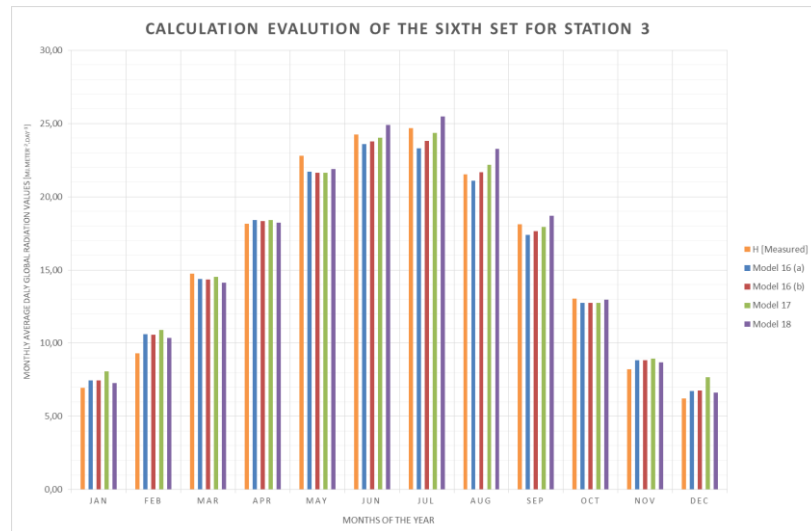


Figure A.54 : Sixth set of the models for region 3 station 3, Kayseri.

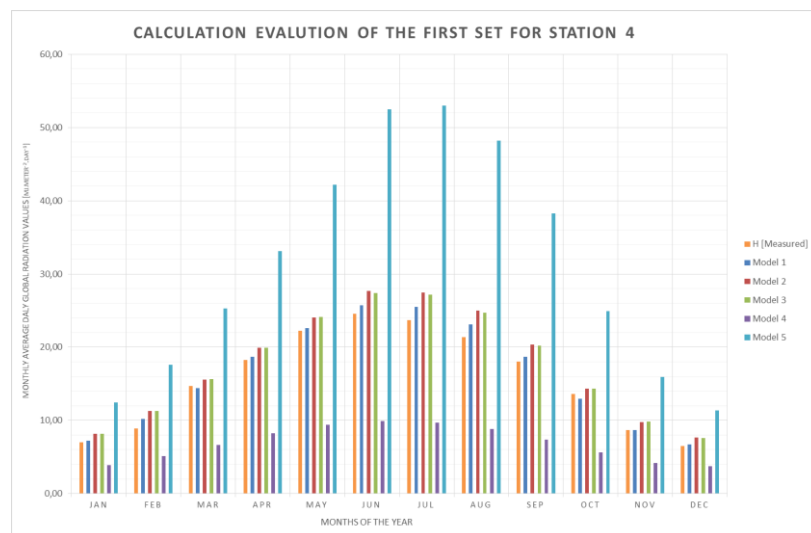


Figure A.55 : First set of the models for region 3 station 4, Sanliurfa.

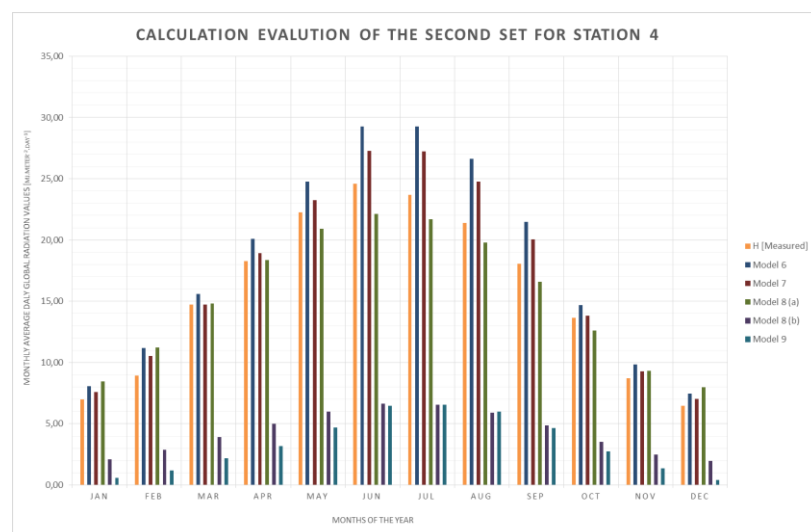


Figure A.56 : Second set of the models for region 3 station 4, Sanliurfa.

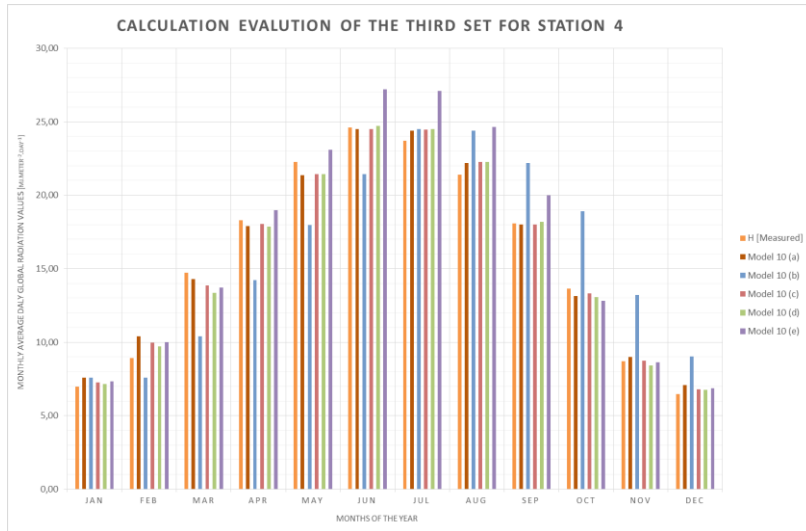


Figure A.57 : Third set of the models for region 3 station 4, Sanliurfa.

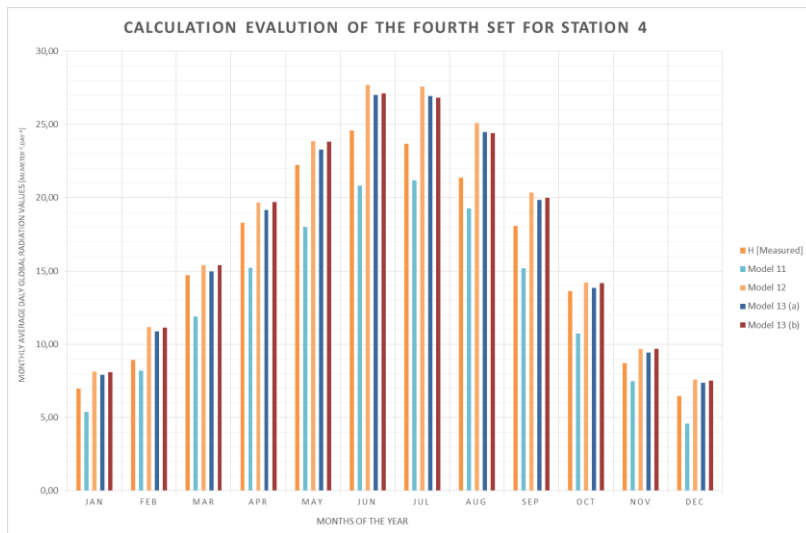


Figure A.58 : Fourth set of the models for region 3 station 4, Sanliurfa.

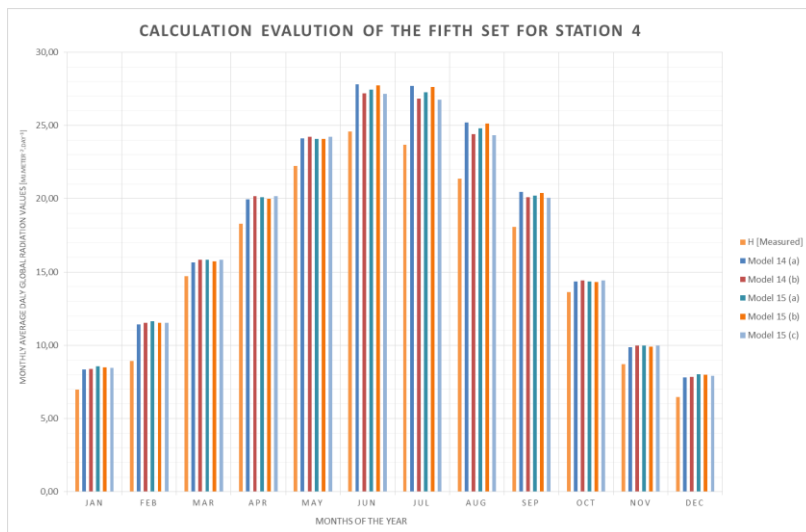


Figure A.59 : Fifth set of the models for region 3 station 4, Sanliurfa.

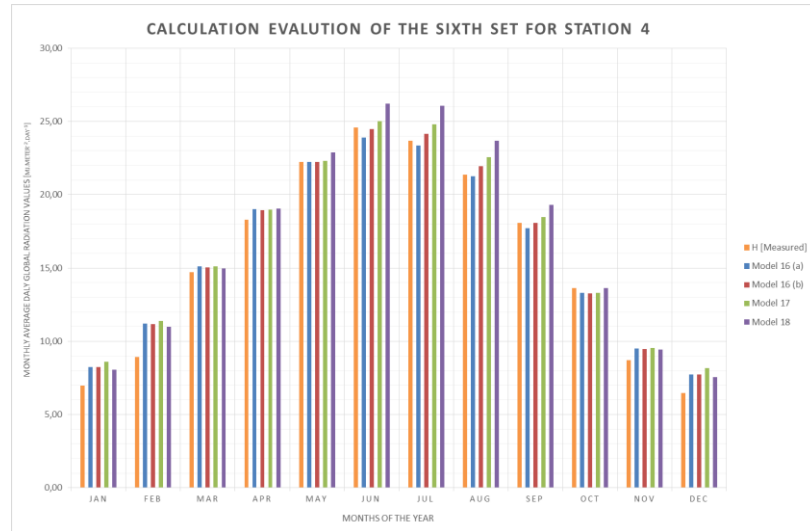


Figure A.60 : Sixth set of the models for region 3 station 4, Sanliurfa.

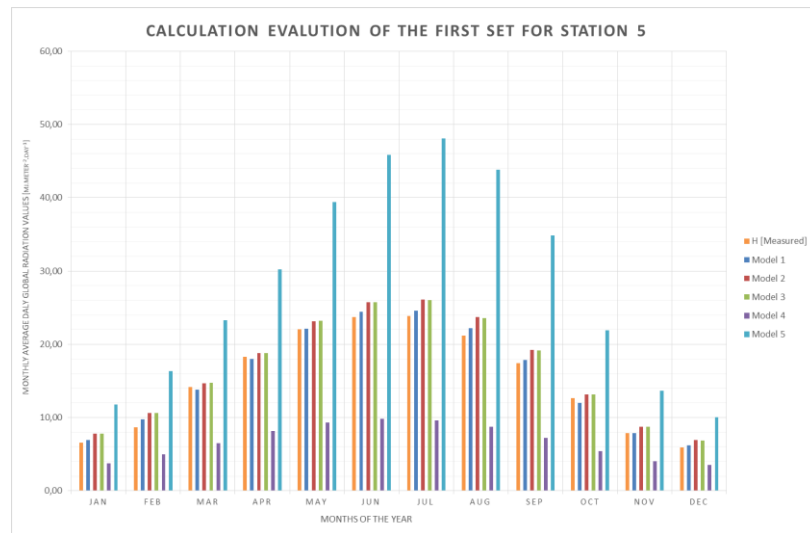


Figure A.61 : First set of the models for region 3 station 5, Usak.

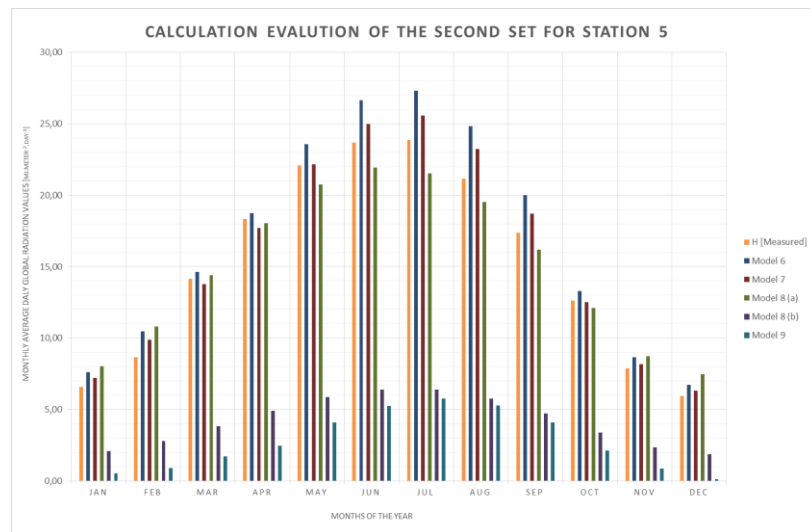


Figure A.62 : Second set of the models for region 3 station 5, Usak.

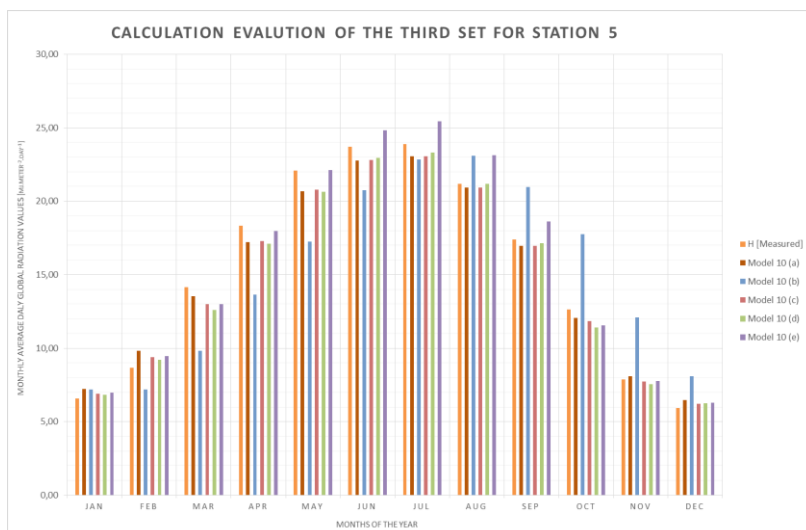


Figure A.63 : Third set of the models for region 3 station 5, Usak.

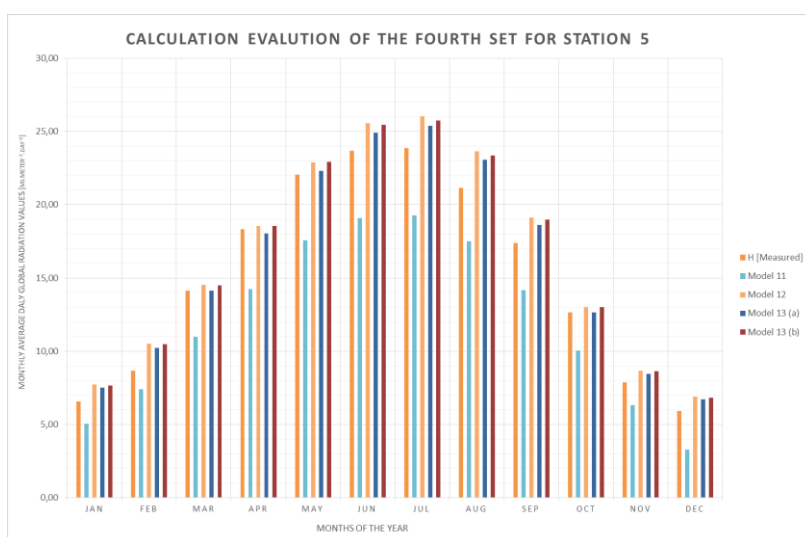


Figure A.64 : Fourth set of the models for region 3 station 5, Usak.

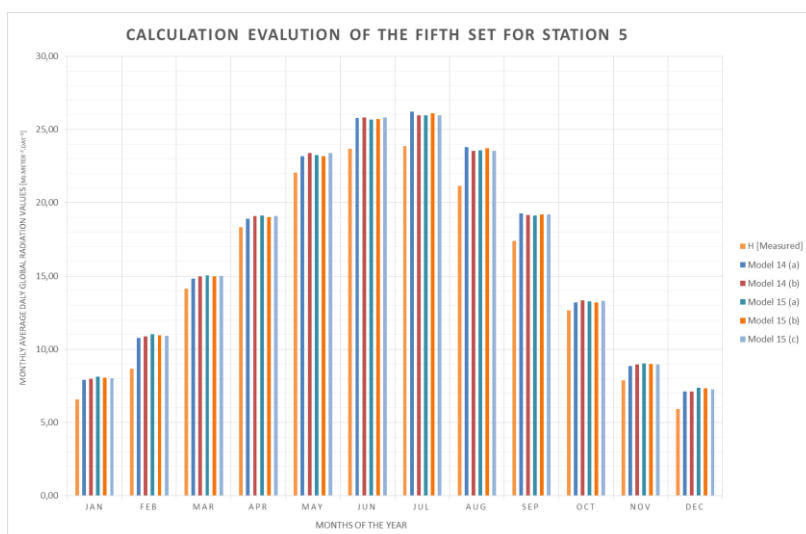


Figure A.65 : Fifth set of the models for region 3 station 5, Usak.

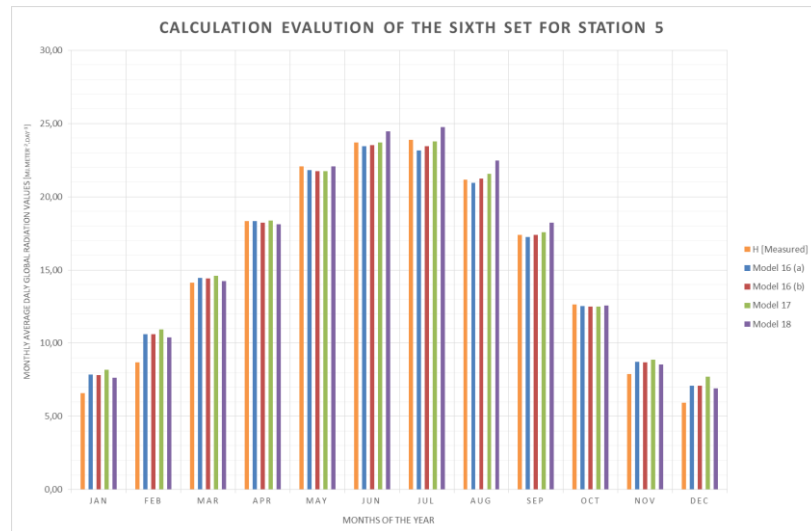


Figure A.66 : Sixth set of the models for region 3 station 5, Usak.

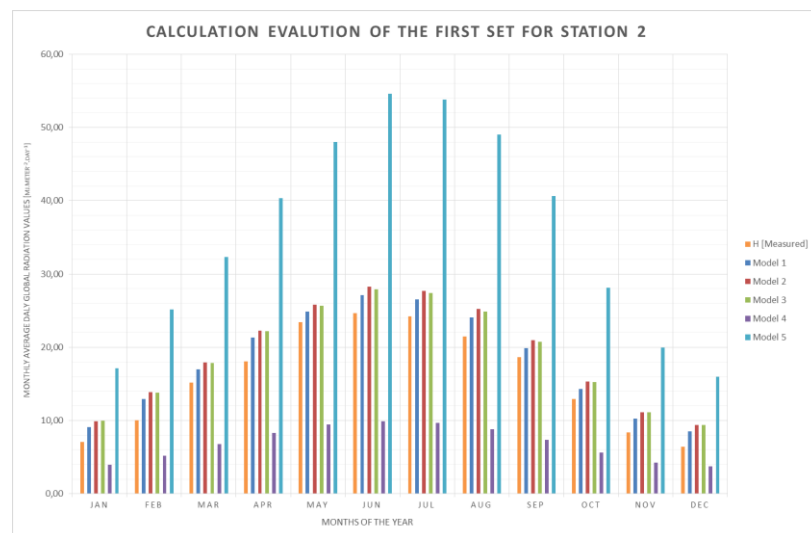


Figure A.67 : First set of the models for region 4 station 2, Hakkari.

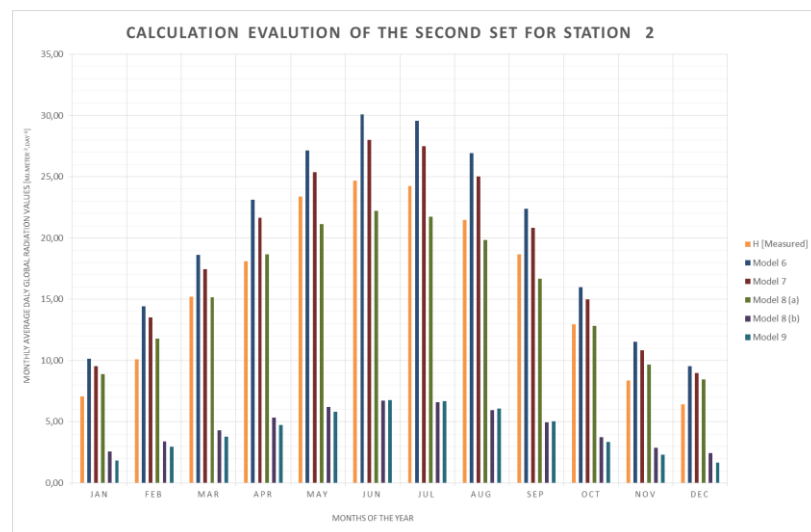


Figure A.68 : Second set of the models for region 4 station 2, Hakkari.

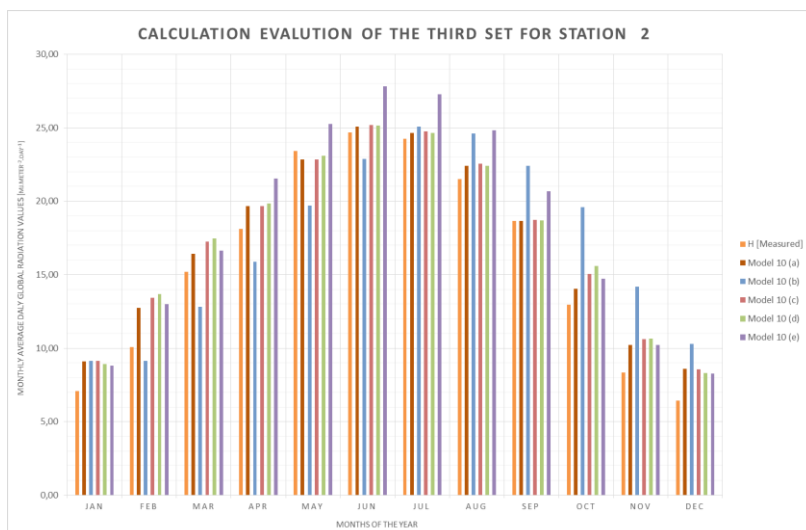


Figure A.69 : Third set of the models for region 4 station 2, Hakkari.

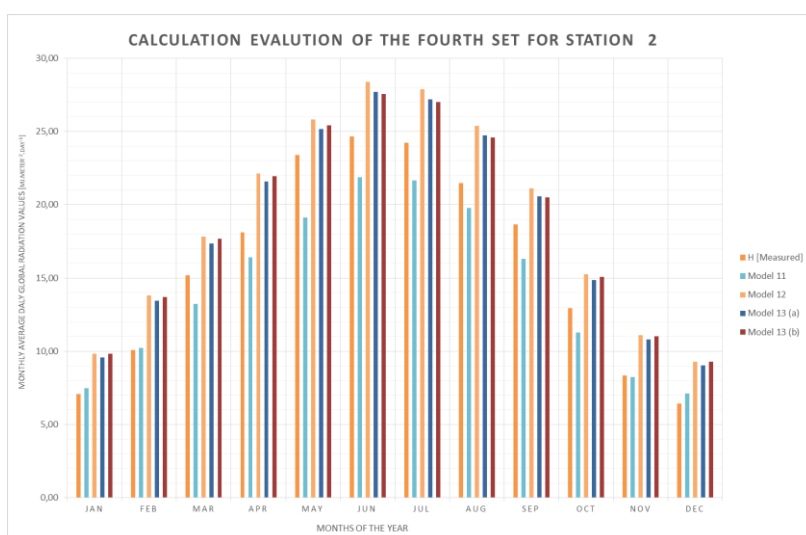


Figure A.70 : Fourth set of the models for region 4 station 2, Hakkari.

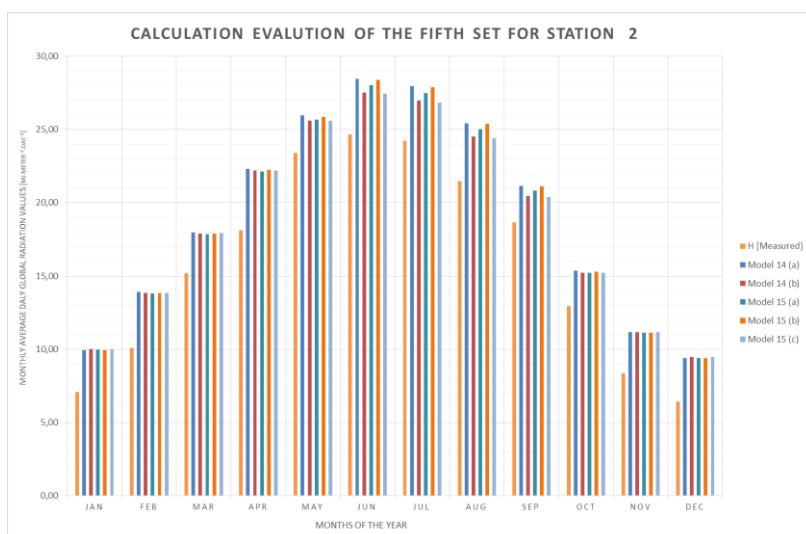


Figure A.71 : Fifth set of the models for region 4 station 2, Hakkari.

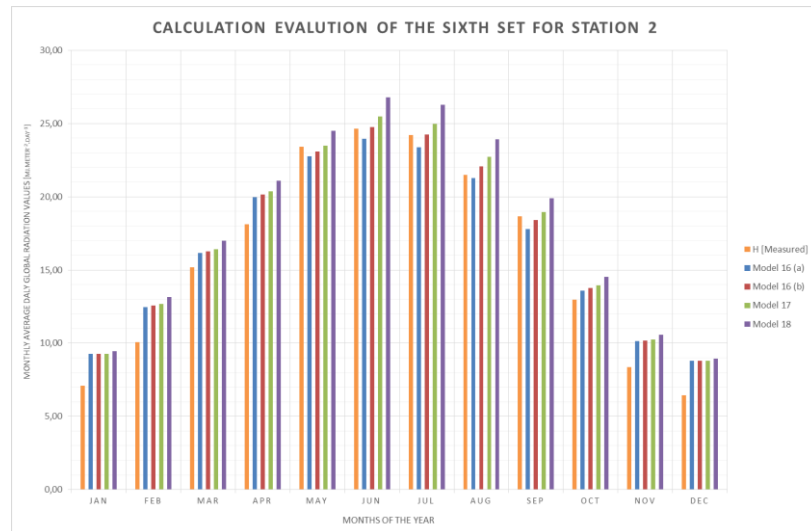


Figure A.72 : Sixth set of the models for region 4 station 2, Hakkari.

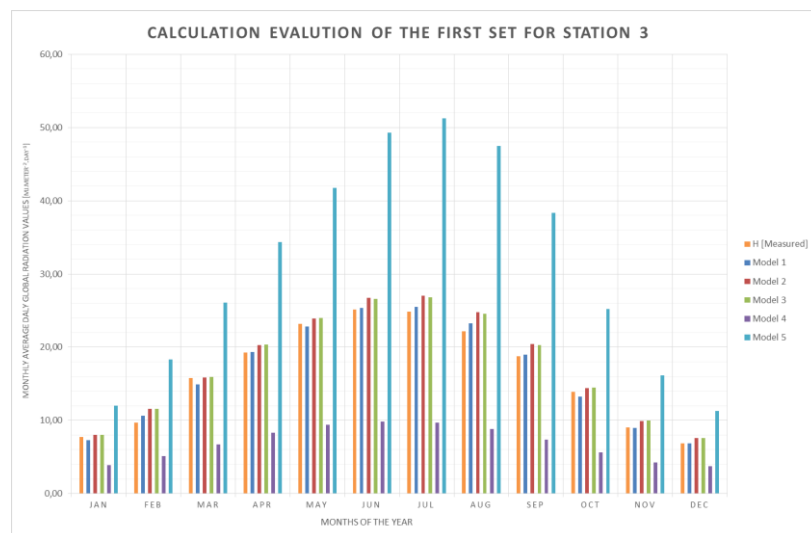


Figure A.73 : First set of the models for region 4 station 3, Karaman.

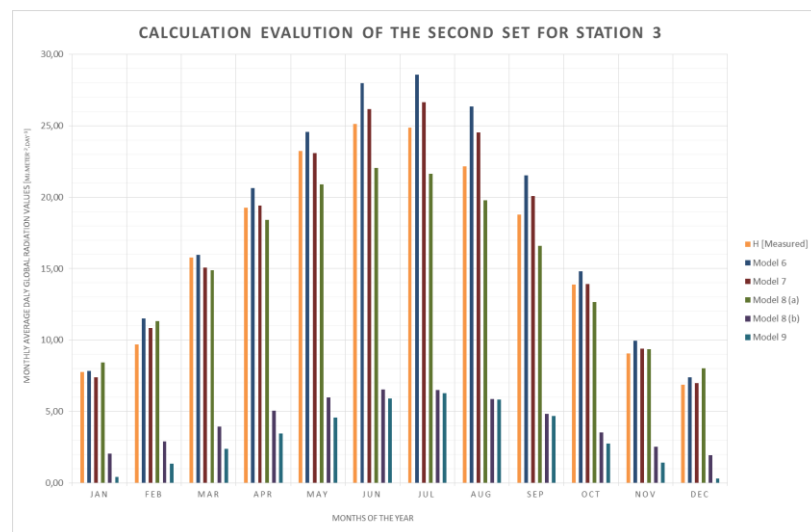


Figure A.74 : Second set of the models for region 4 station 3, Karaman.

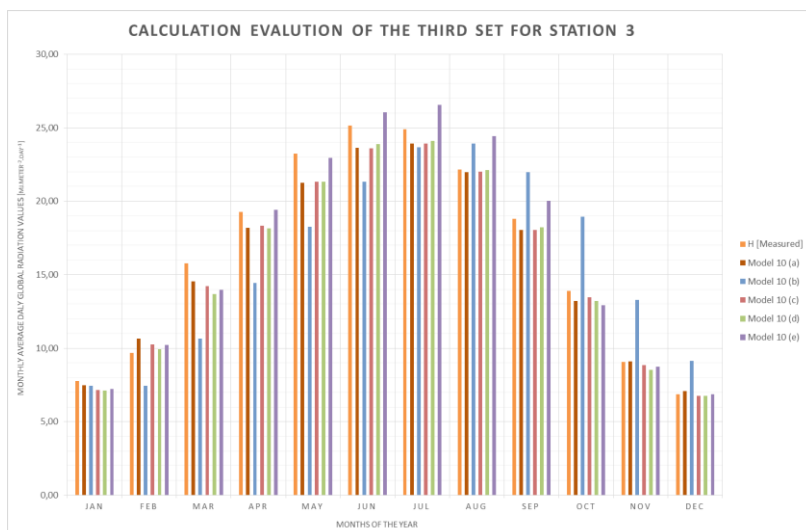


Figure A.75 : Third set of the models for region 4 station 3, Karaman.

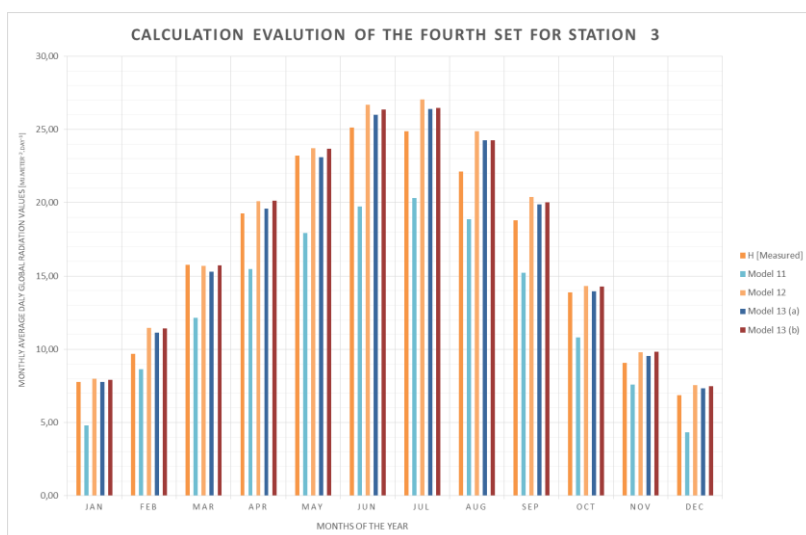


Figure A.76 : Fourth set of the models for region 4 station 3, Karaman.

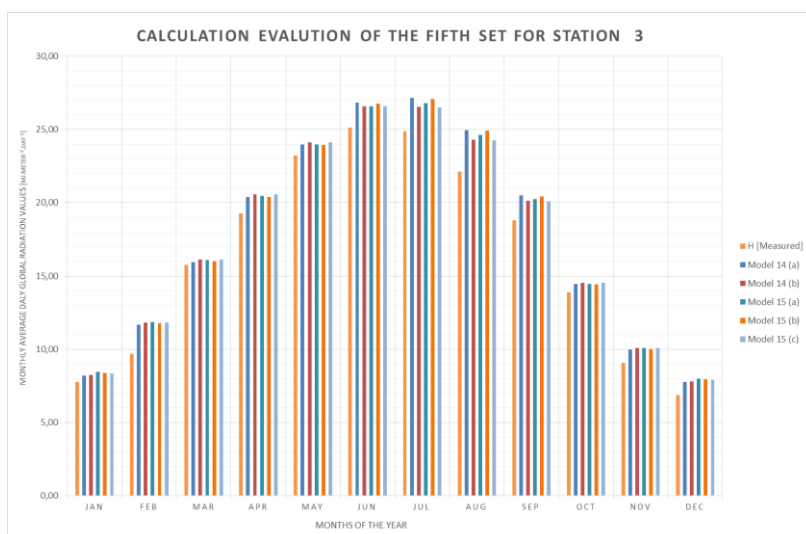


Figure A.77 : Fifth set of the models for region 4 station 3, Karaman.

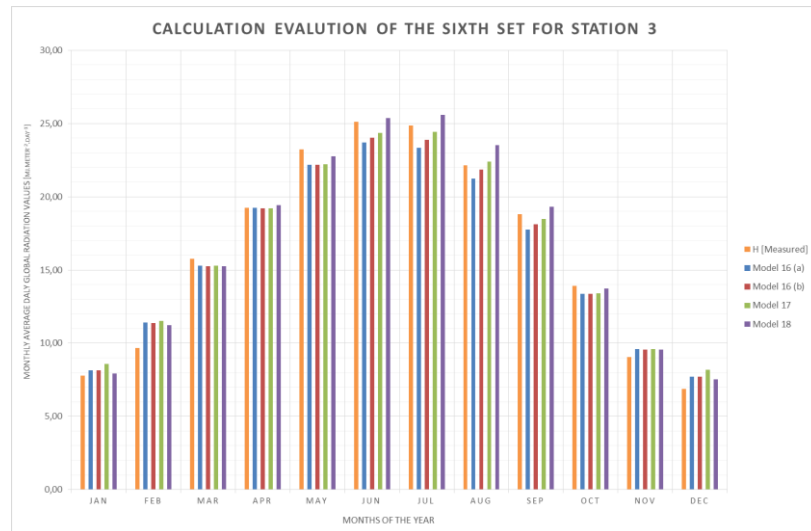


Figure A.78 : Sixth set of the models for region 4 station 3, Karaman.

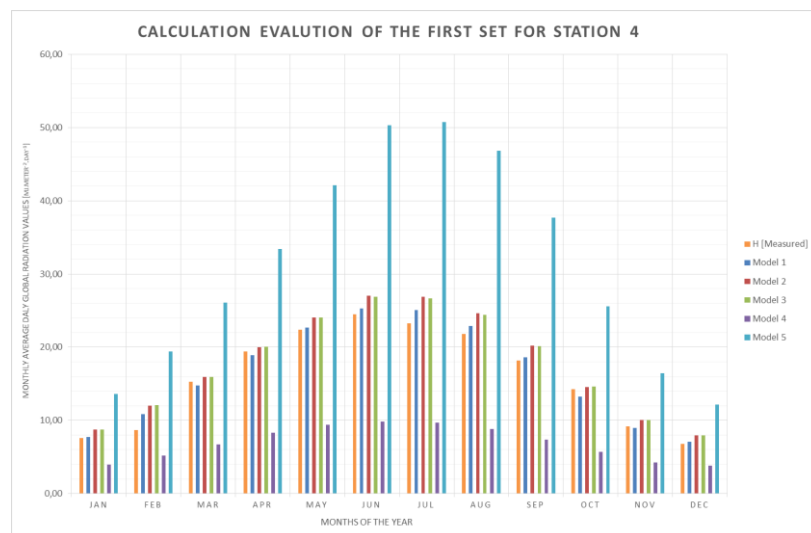


Figure A.79 : First set of the models for region 4 station 4, Mugla.

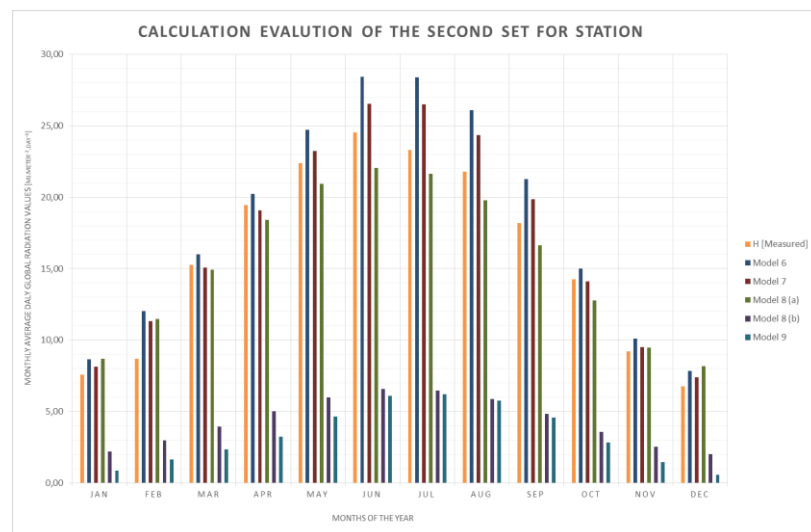


Figure A.80 : Second set of the models for region 4 station 4, Mugla.

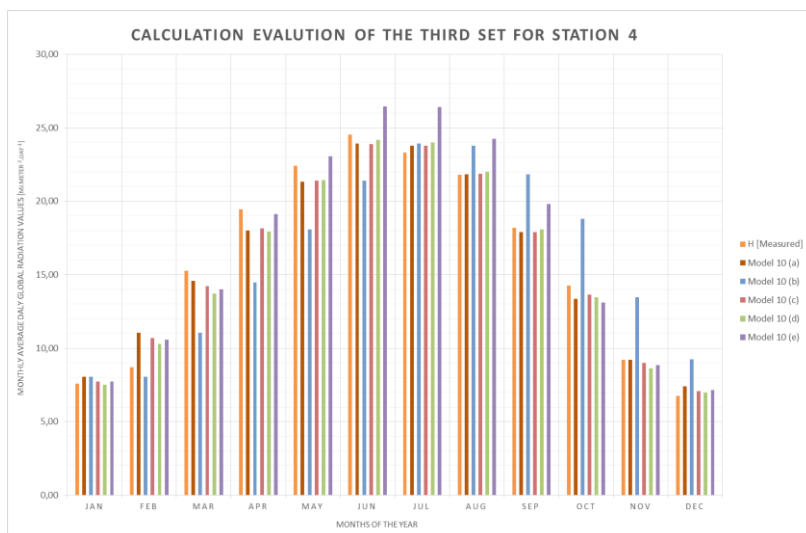


Figure A.81 : Third set of the models for region 4 station 4, Mugla.

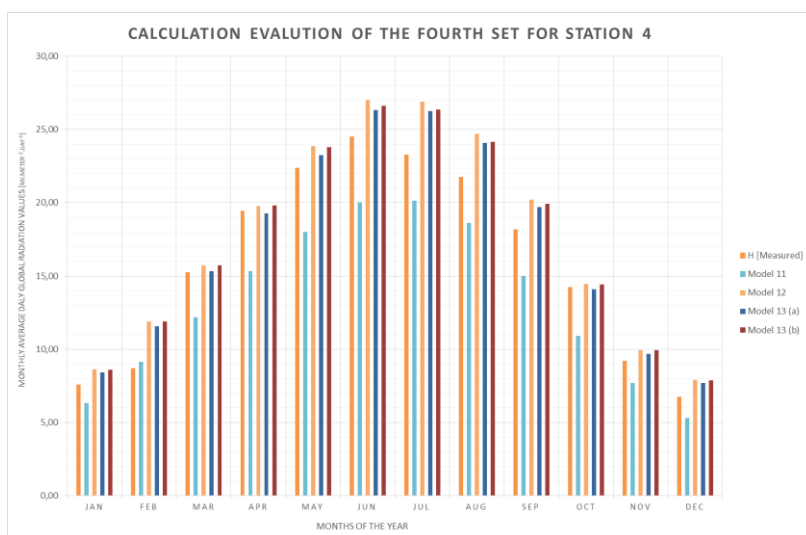


Figure A.82 : Fourth set of the models for region 4 station 4, Mugla.

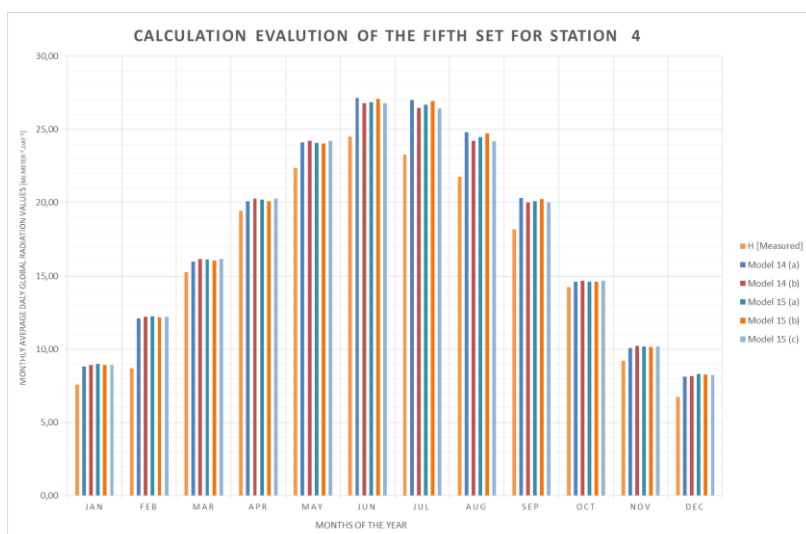


Figure A.83 : Fifth set of the models for region 4 station 4, Mugla.

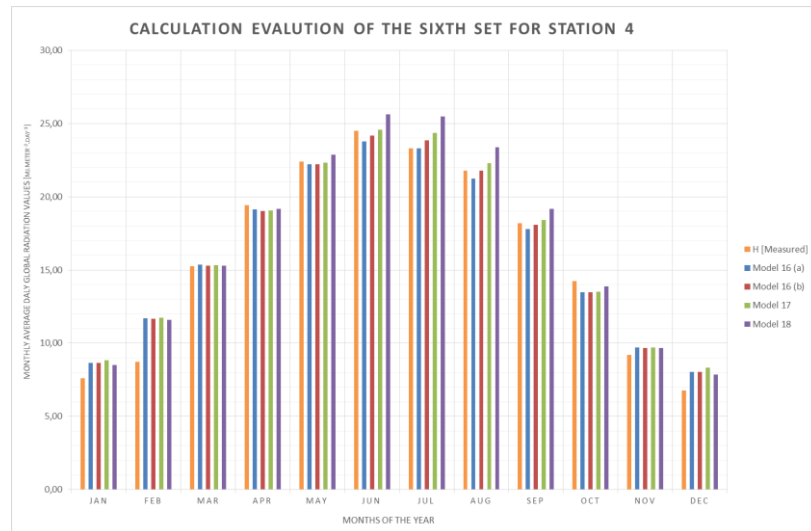


Figure A.84 : Sixth set of the models for region 4 station 4, Mugla.

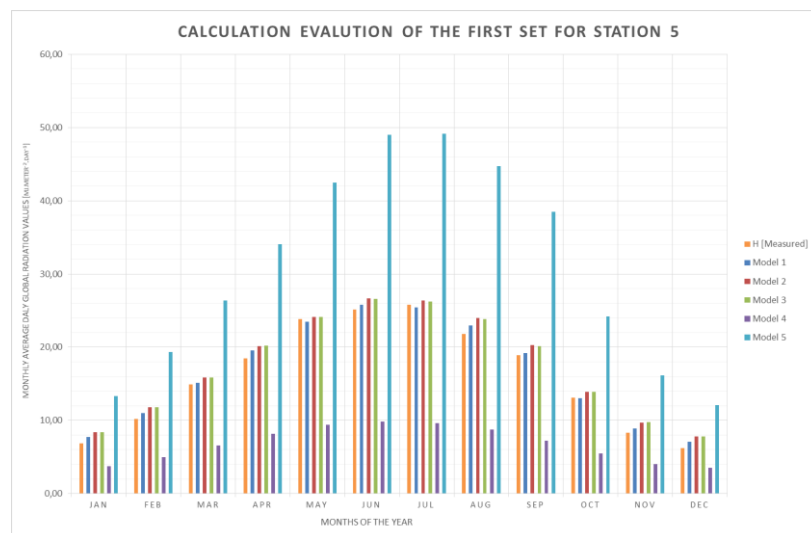


Figure A.85 : First set of the models for region 4 station 5, Van.

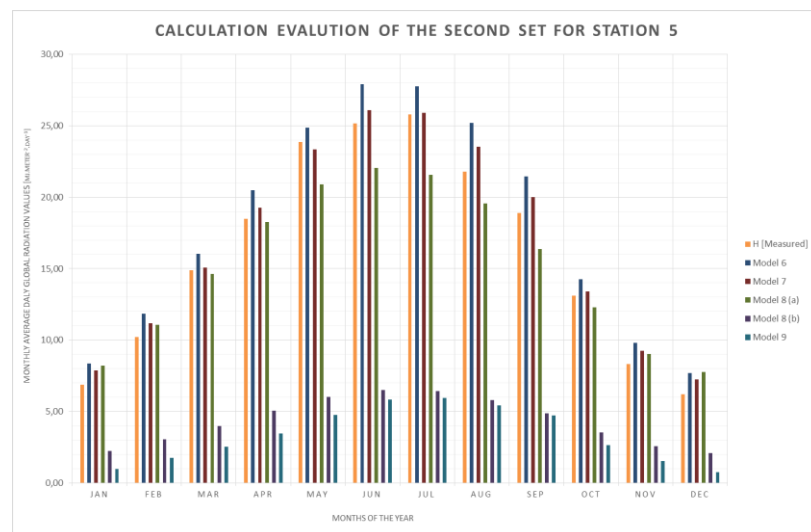


Figure A.86 : Second set of the models for region 4 station 5, Van.

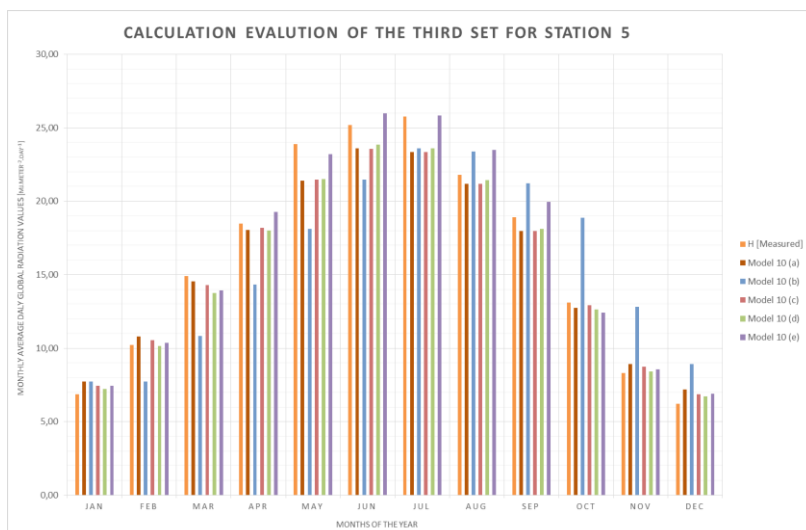


Figure A.87 : Third set of the models for region 4 station 5, Van.

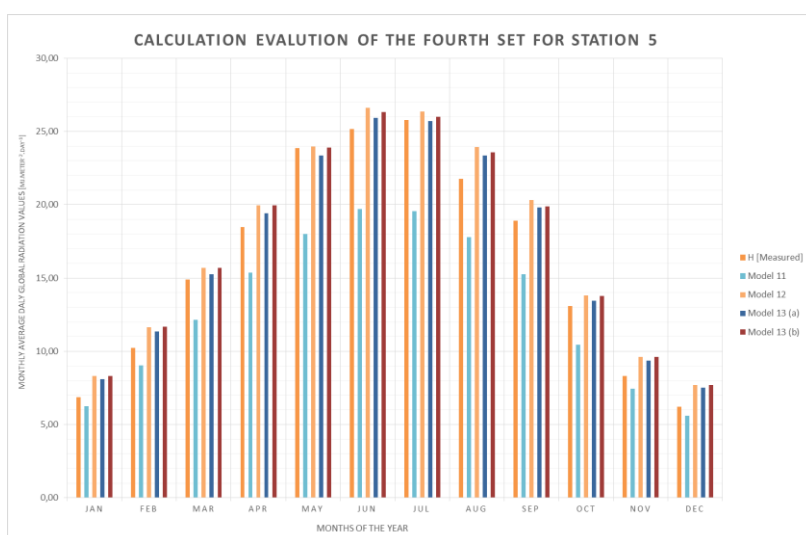


Figure A.88 : Fourth set of the models for region 4 station 5, Van.

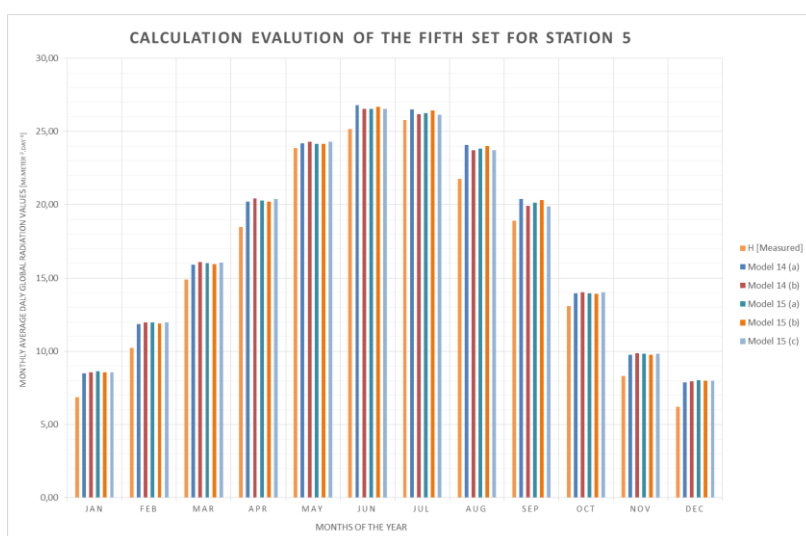


Figure A.89 : Fifth set of the models for region 4 station 5, Van.

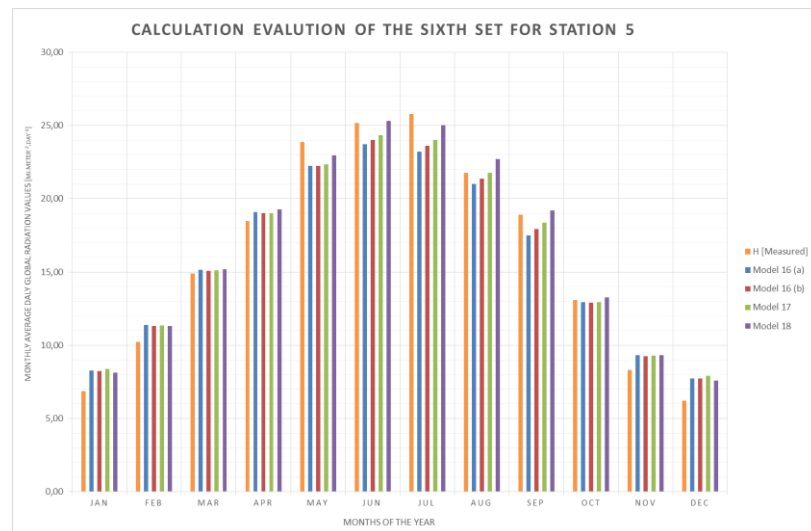


Figure A.90 : Sixth set of the models for region 4 station 5, Van.

APPENDIX B

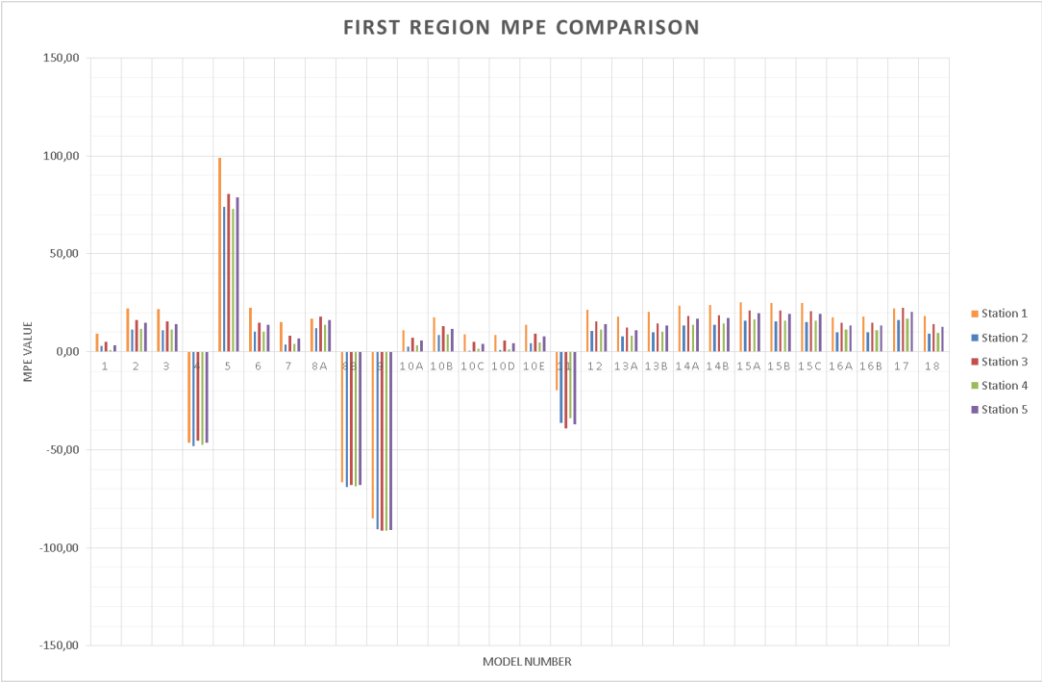


Figure B.1 : First region MPE comparison.

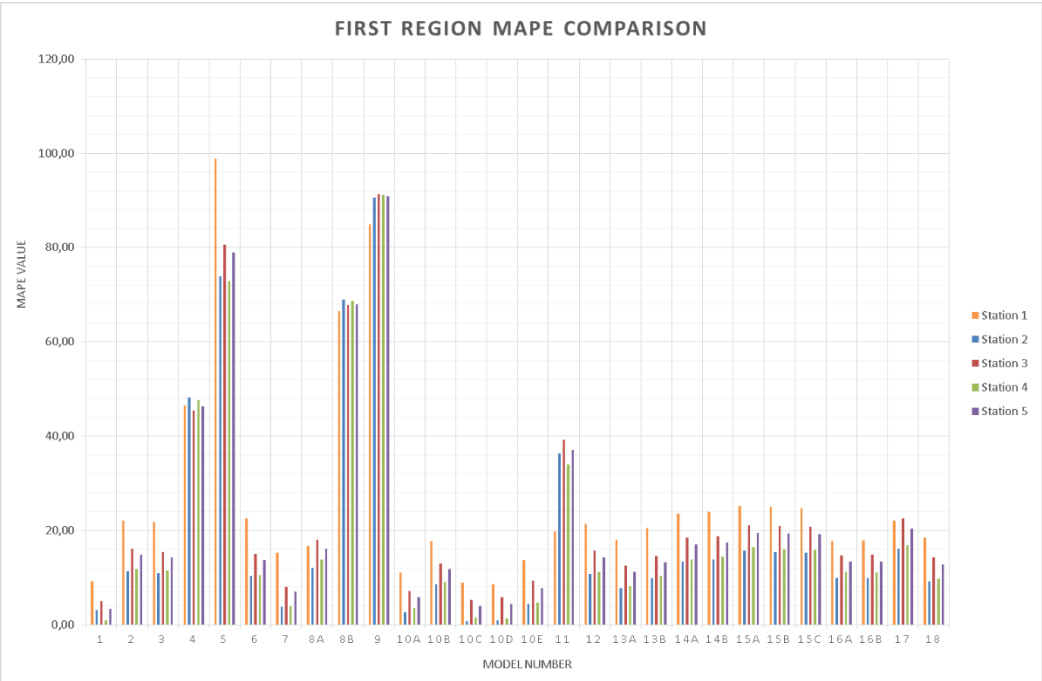


Figure B.2 : First region MAPE comparison.

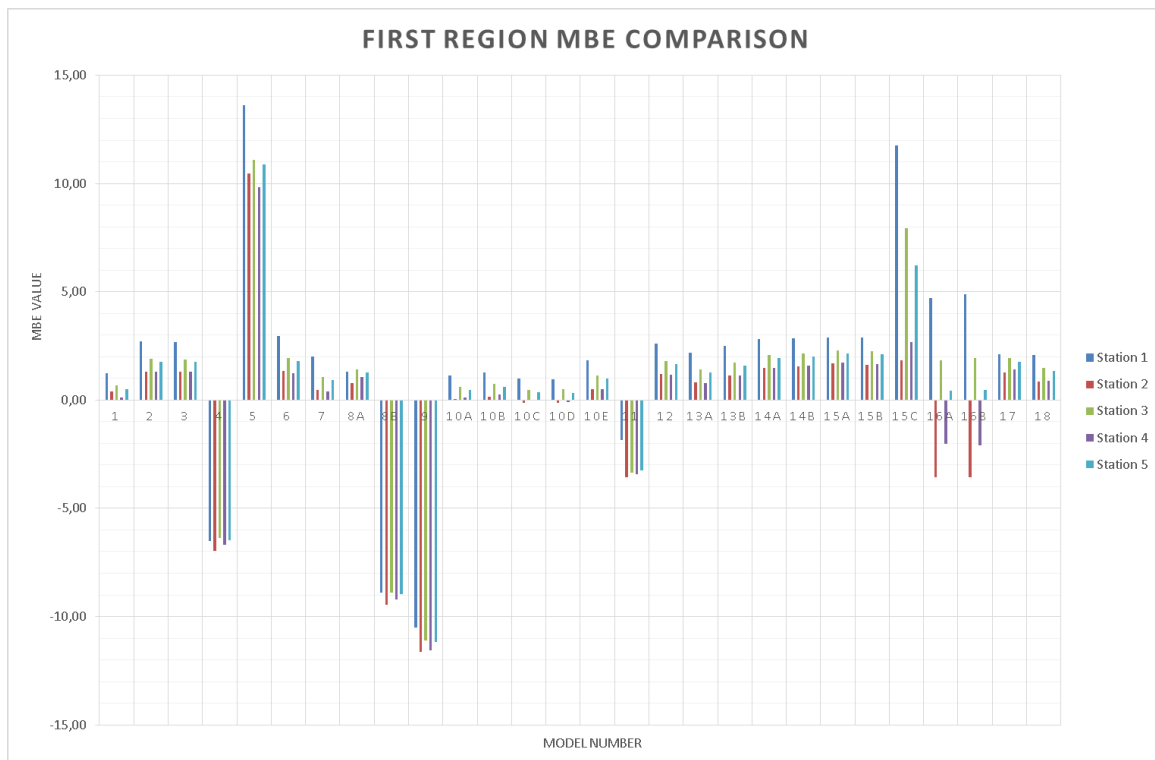


Figure B.3 : First region MBE comparison.

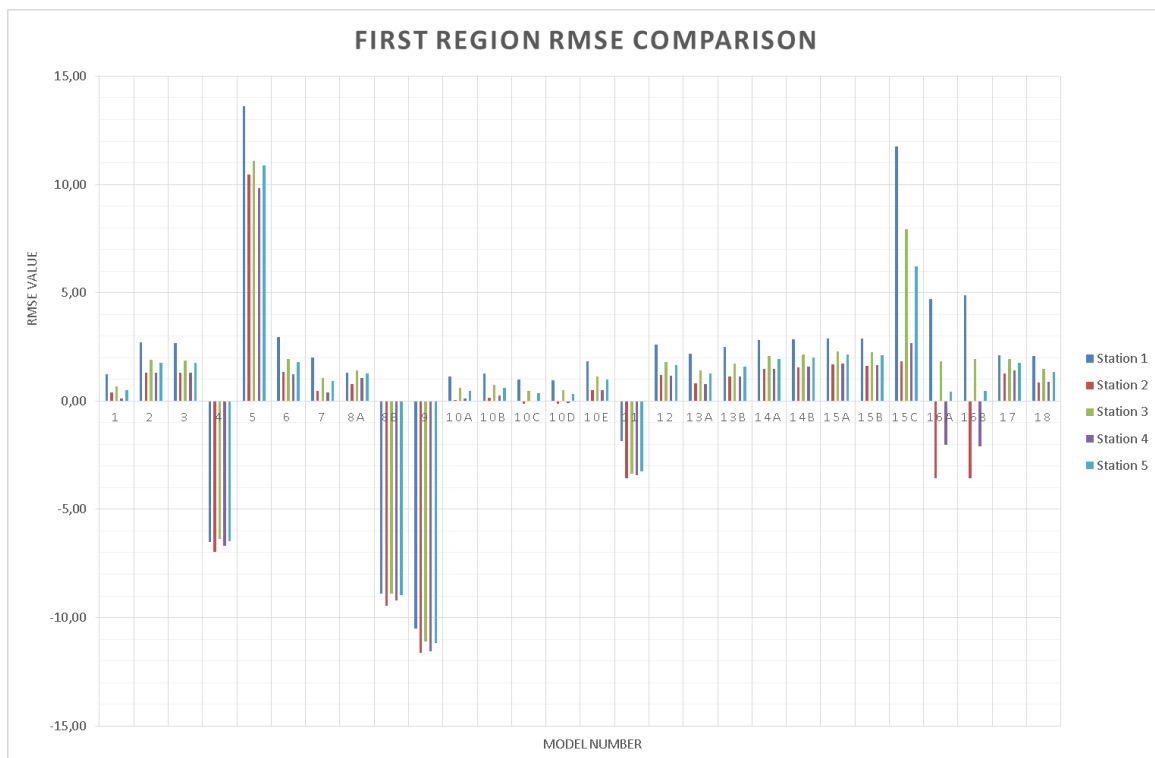


Figure B.4 : First region RMSE comparison.

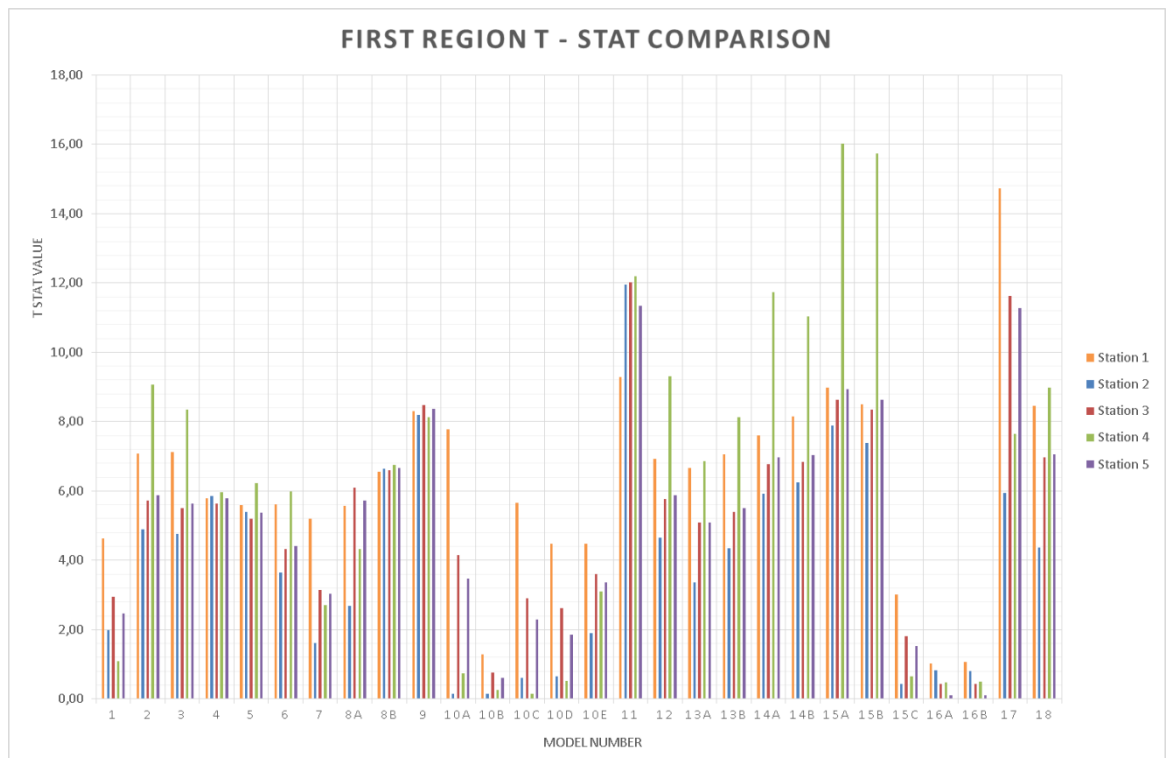


Figure B.5 : First region t-stat comparison.

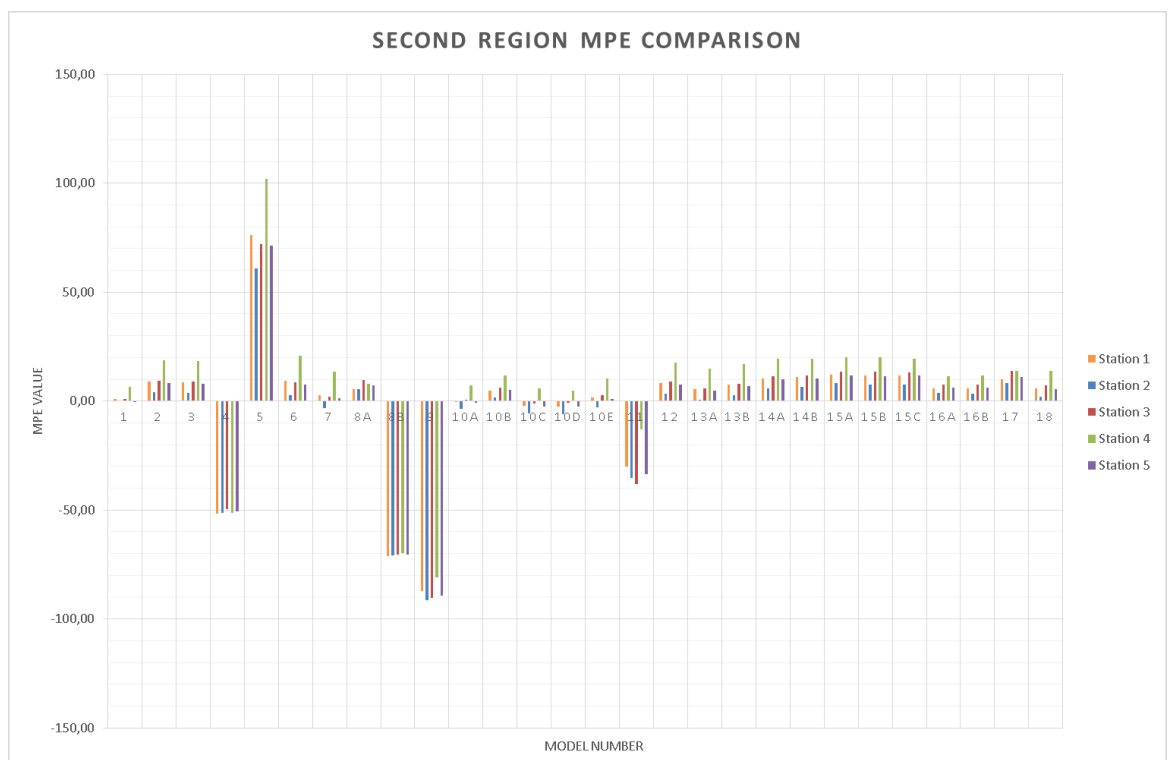


Figure B.6 : Second region MPE comparison.

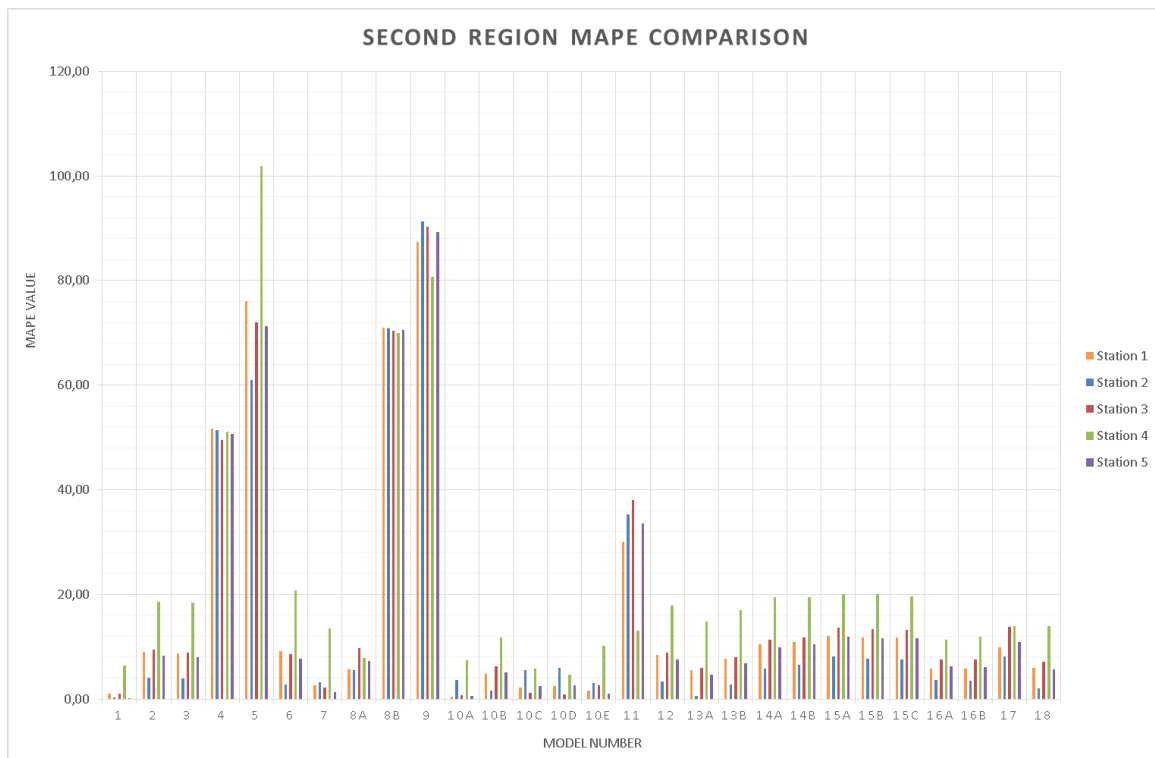


Figure B.7 : Second region MAPE comparison.

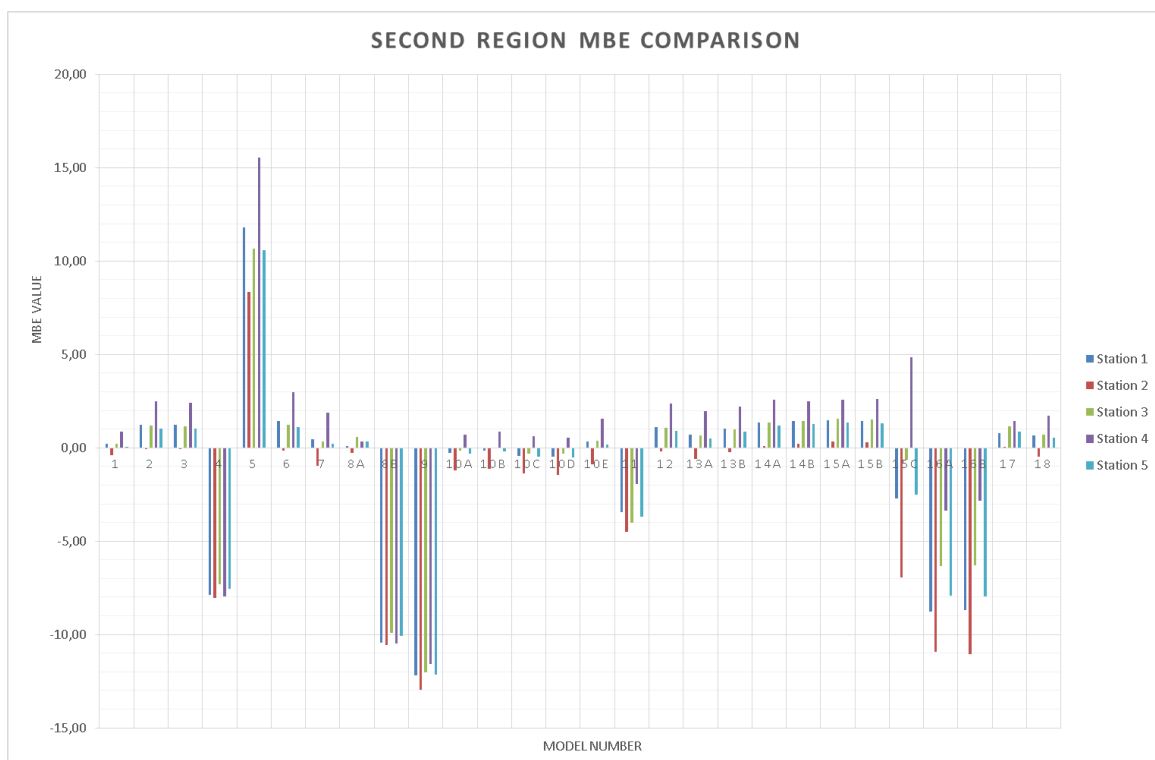


Figure B.8 : Second region MBE comparison.

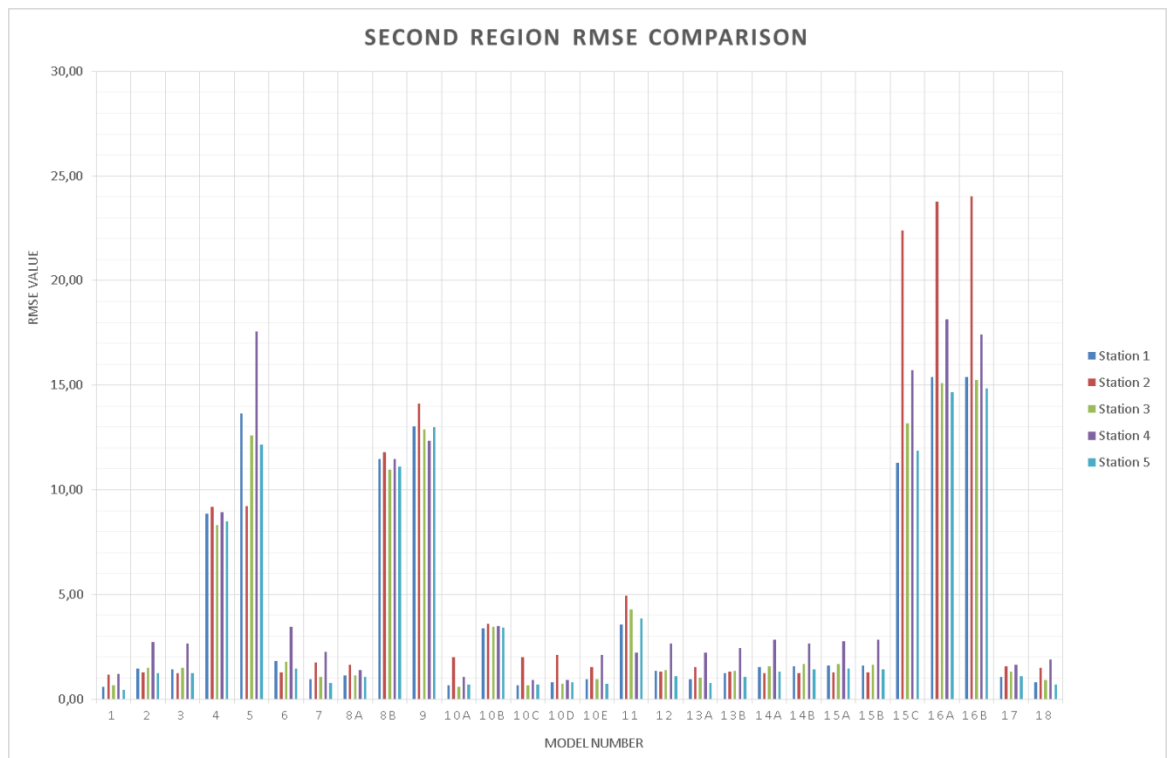


Figure B.9 : Second region RMSE comparison.

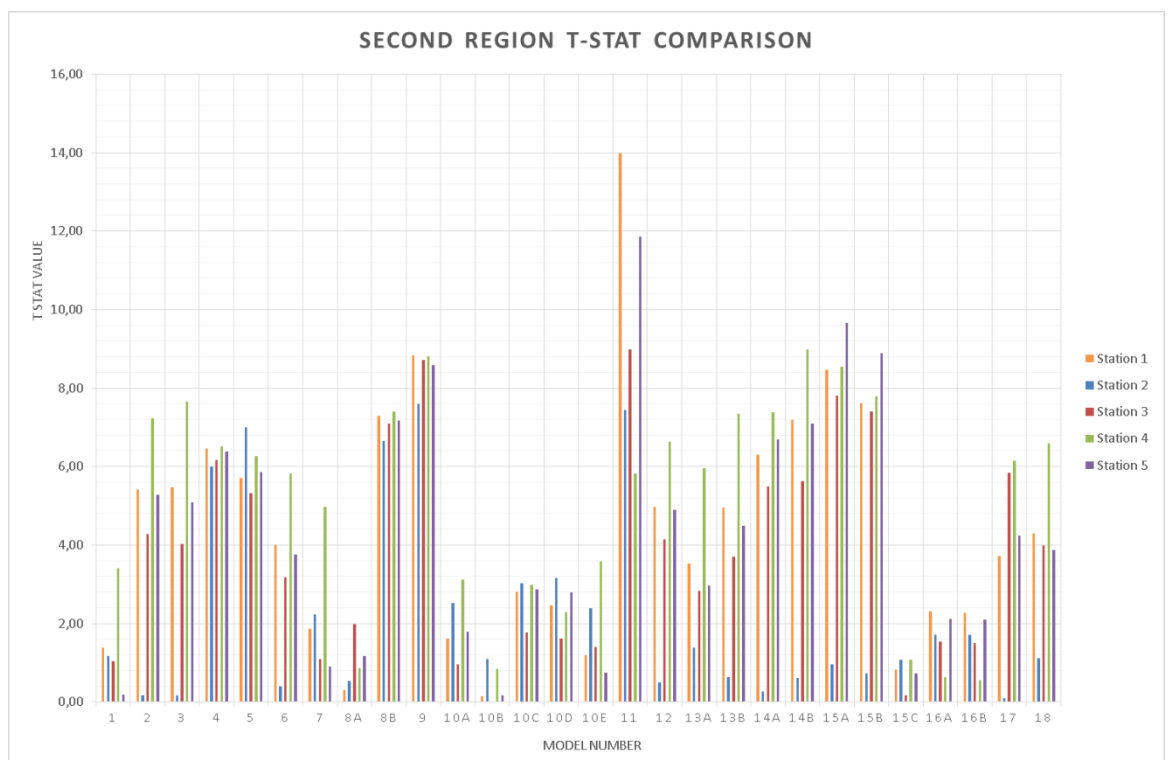


Figure B.10 : Second region t-stat comparison.

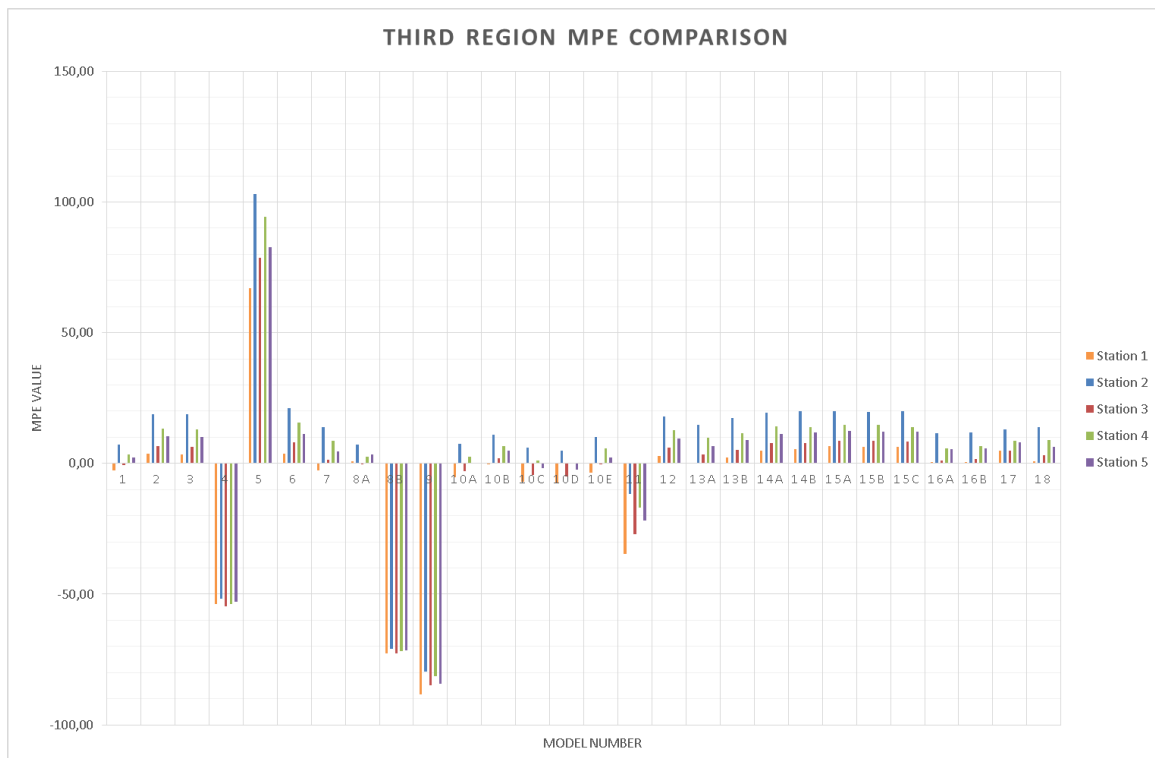


Figure B.11 : Third region MPE comparison.

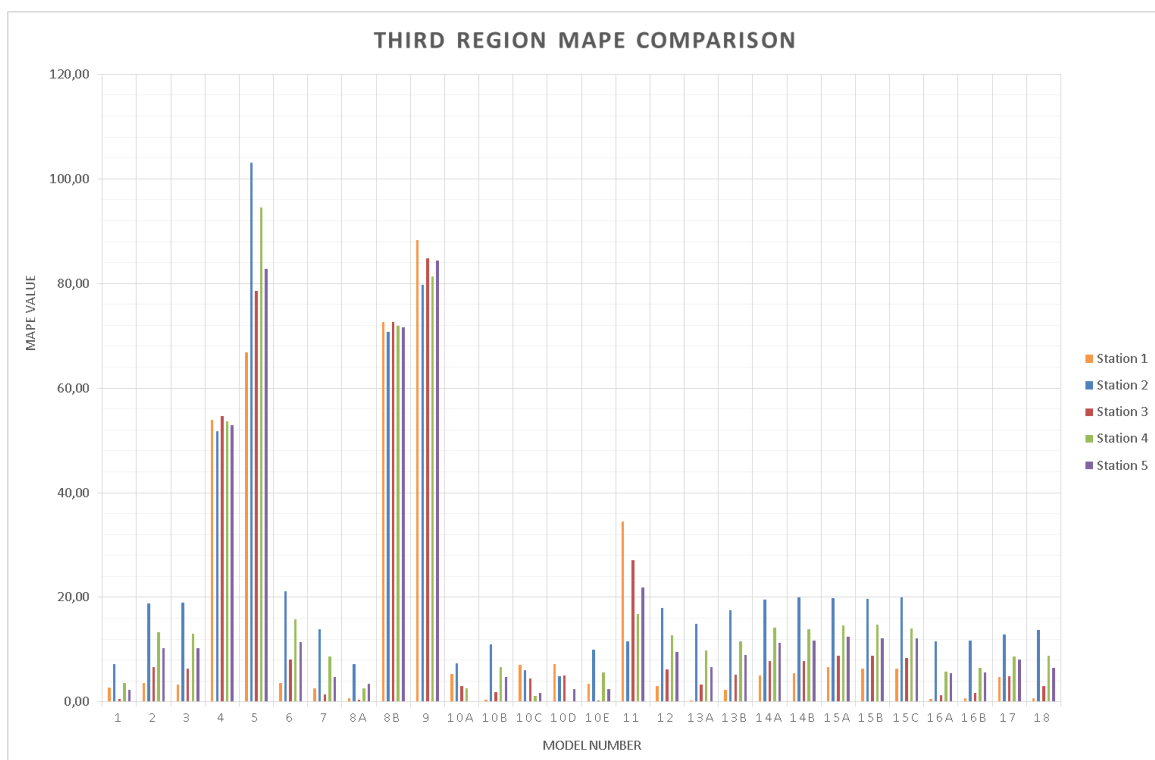


Figure B.12 : Third region MAPE comparison.

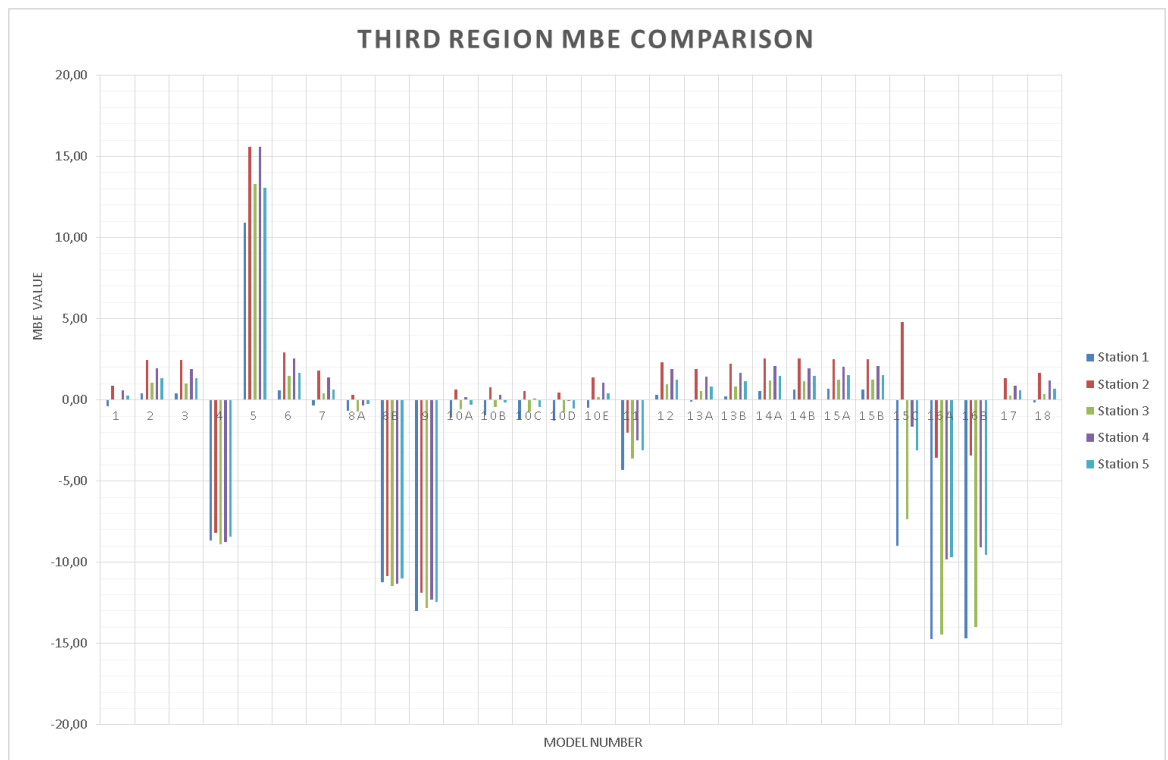


Figure B.13 : Third region MBE comparison.

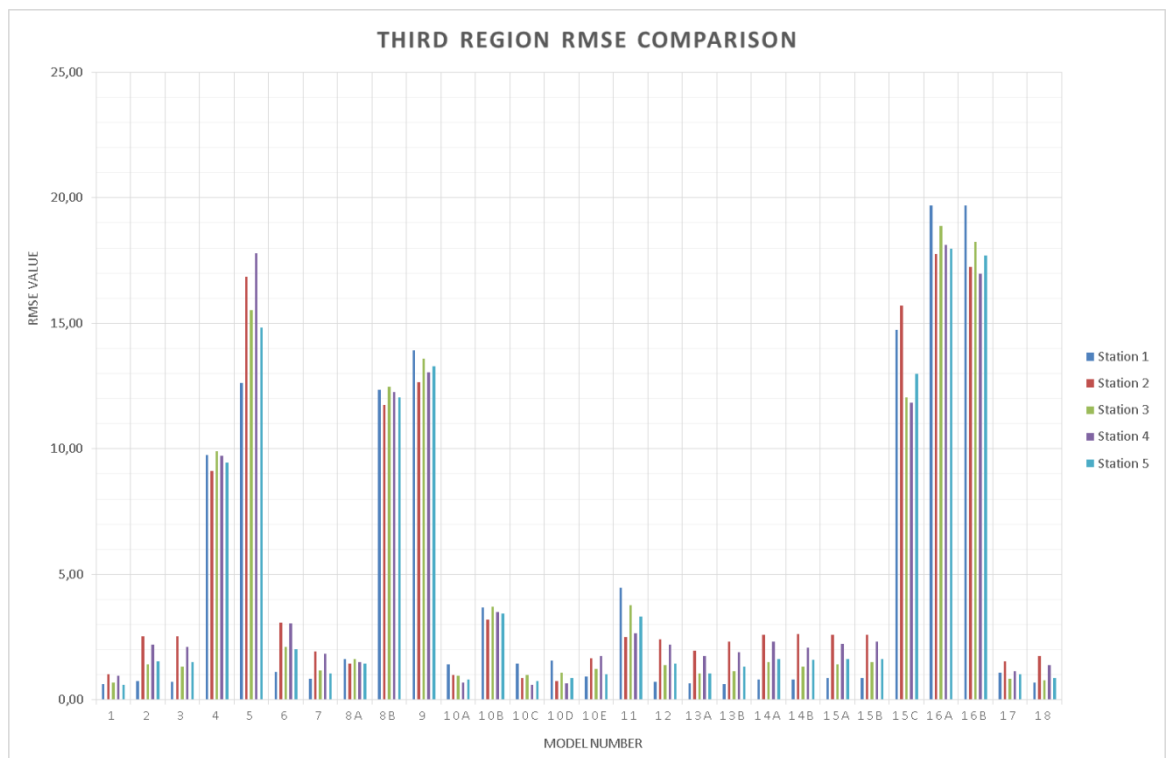


Figure B.14 : Third region RMSE comparison.

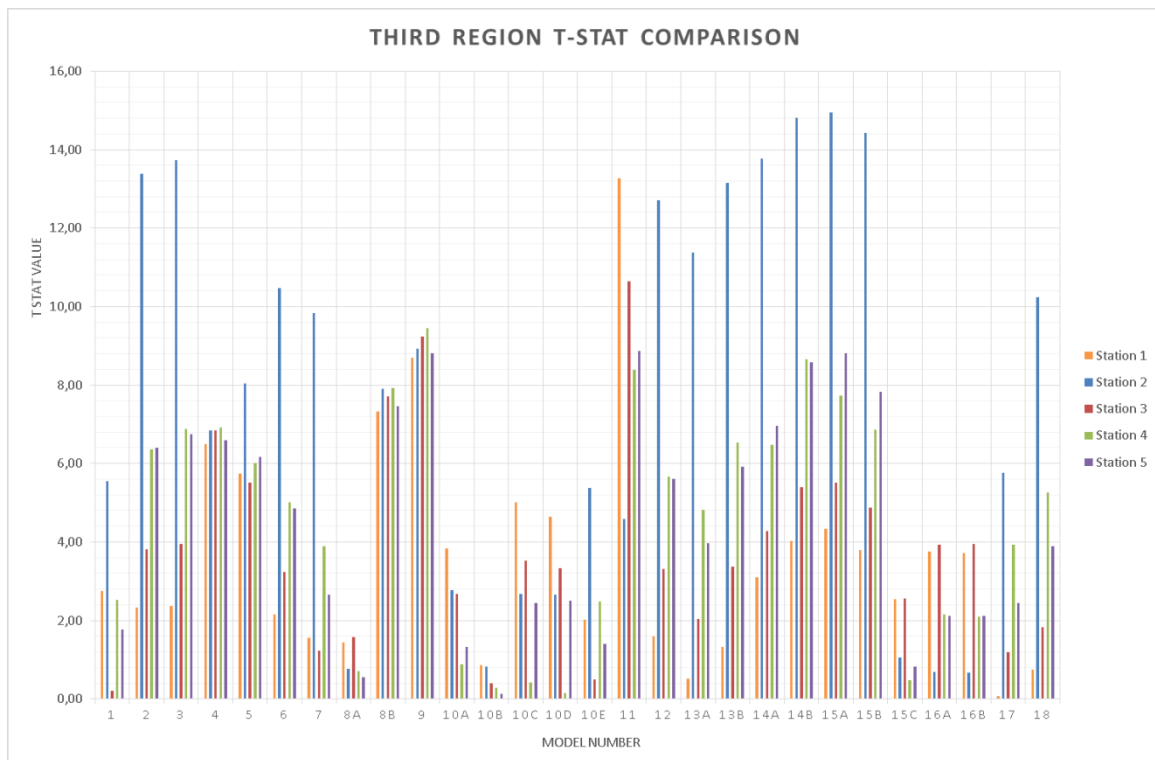


Figure B.15 : Third region t-stat comparison.

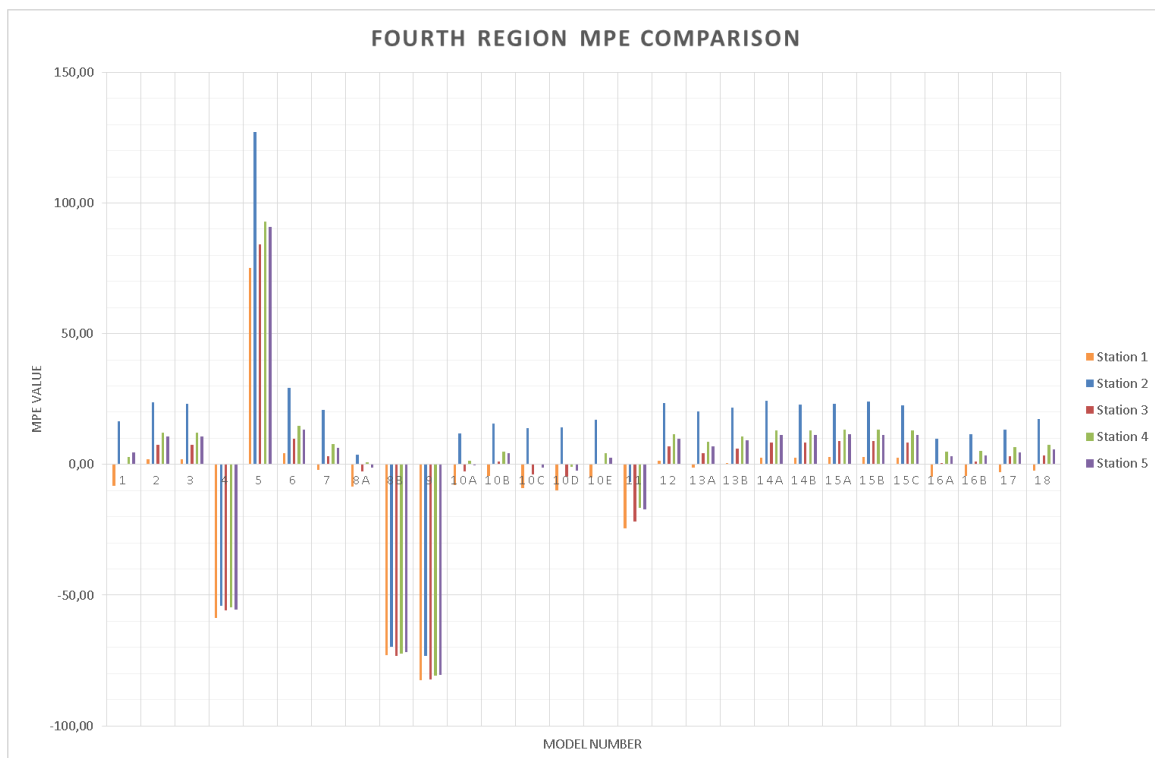


Figure B.16 : Fourth region MPE comparison.

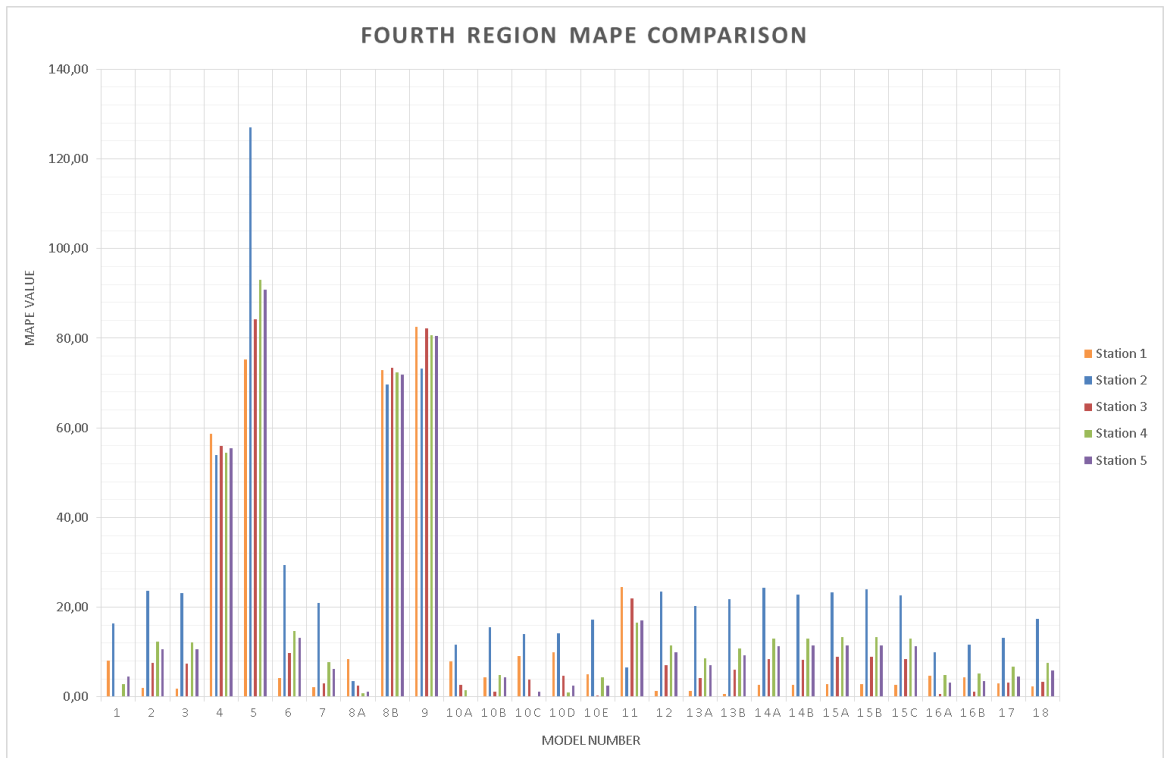


Figure B.17 : Fourth region MAPE comparison.

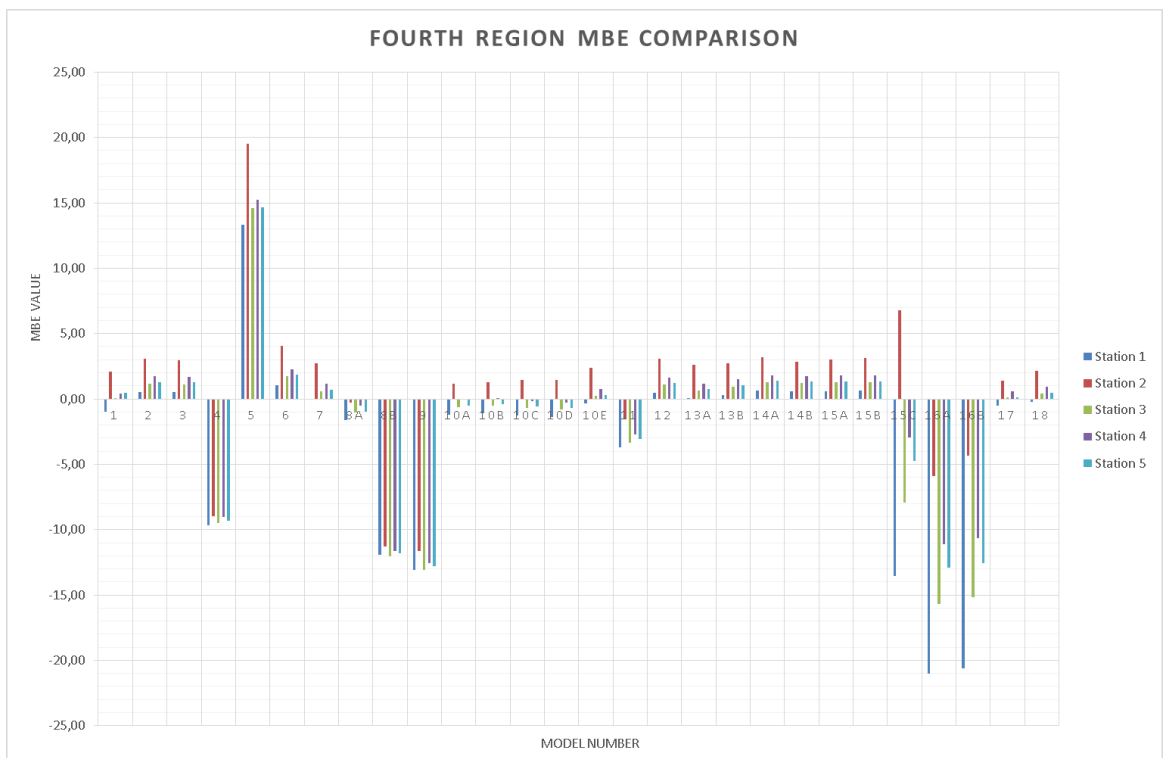


Figure B.18 : Fourth region MBE comparison.

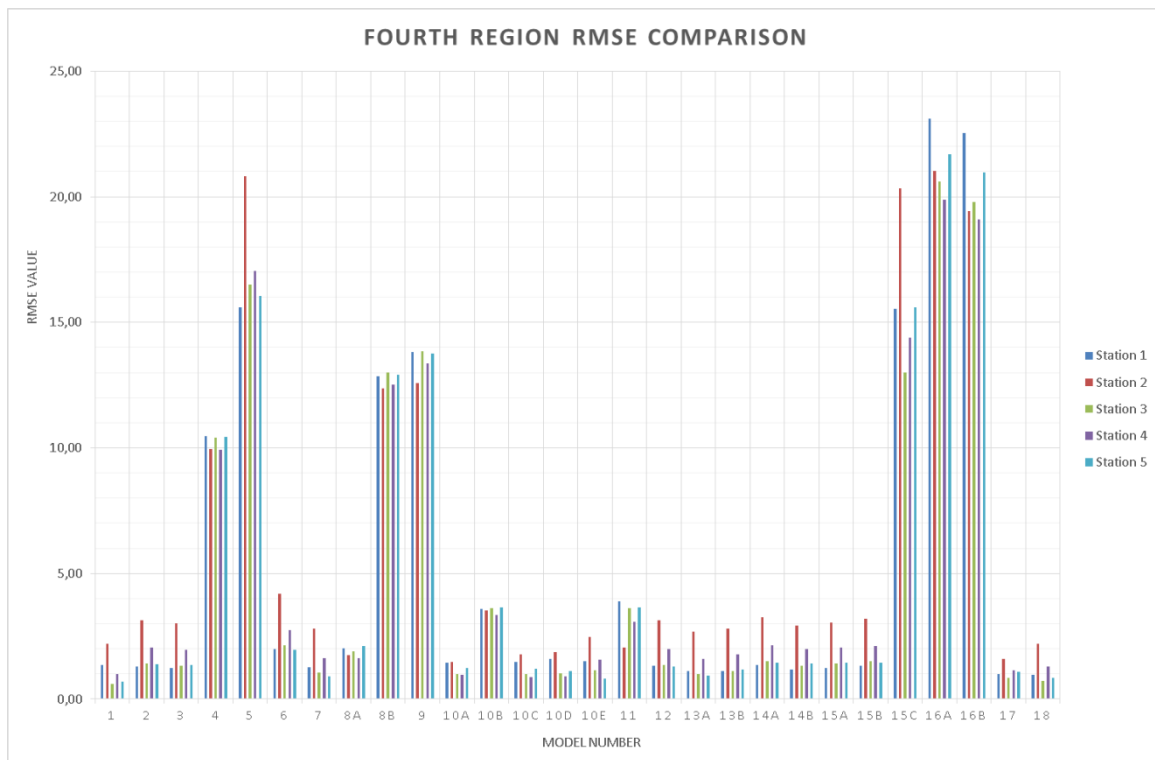


Figure B.19 : Fourth region RMSE comparison.

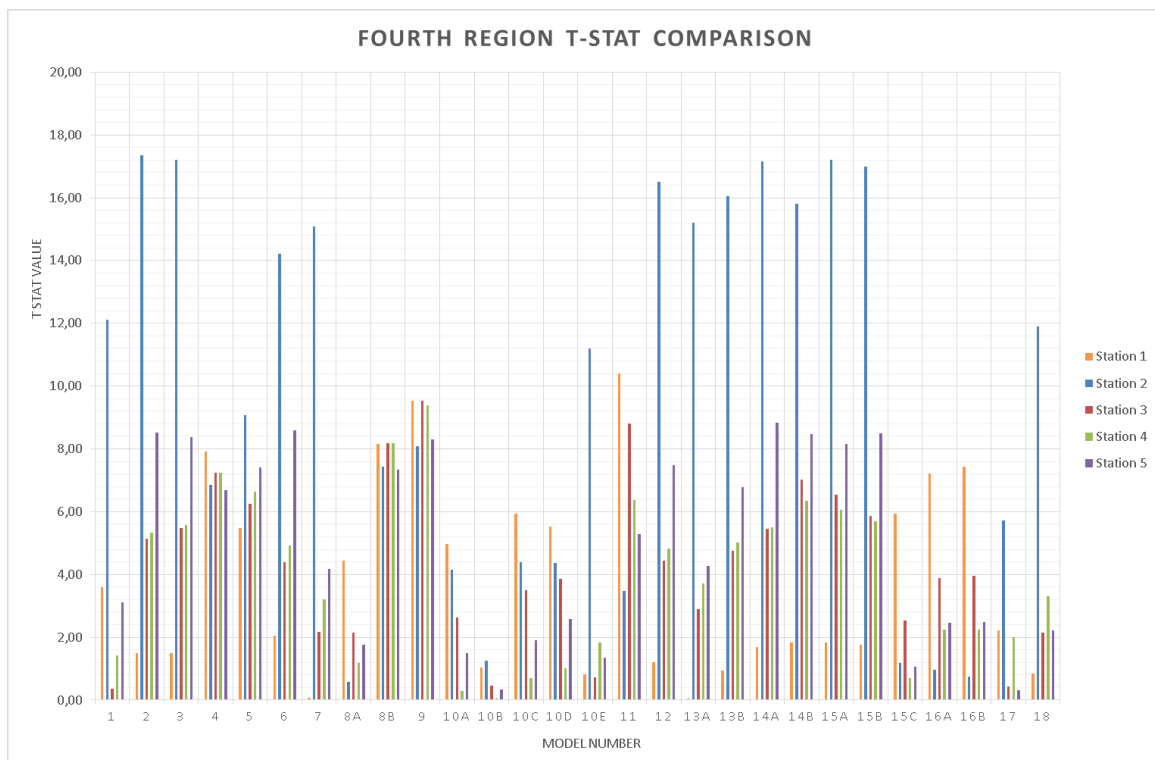


Figure B.20 : Fourth region t-stat comparison.

CURRICULUM VITAE



Name Surname: İNAL BEGÜM TURNA

Place and Date of Birth: ISTANBUL – 10.08.1989

E-Mail: turnai@itu.edu.tr

EDUCATION: ITU-Physics Engineering

B.Sc.: Physics Engineering

EDUCATION AND QUALIFICATIONS:

- 2013-2015 İstanbul Technical University, İstanbul, Physics Engineering, (in progress) (Master's Degree)
- 2006 -2013 İstanbul Technical University, İstanbul, Physics Engineering
2.75/4.00 (Bachelor's Degree)
Thesis: Organic Light Emitting Diots (2013)
- 2003-2006 Erenköy Kız Highschool, 5.00/5.00, İstanbul
- 1998 -2003 Eyüboğlu College, İstanbul

WORK EXPERINCE:

- Arçelik Intellectual Property Right Department, Project Engineer, until 2014
- İstanbul Technical University, Faculty of Science and Literature, Physics Laboratory Asistant, 2012
- TUBITAK UME, Laboratory Asistant (Internship) , 2011
- İstanbul Technical University, Faculty of Mechanical Engineering, (Internship), 2009

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- ER, Z., TURNA, İ.B., Future Expectation of PVs Roel in Compensating Energy Demand. *International Advances in Applied Physics and Material Science Congress & Exhibition*, April 16-19, 2015 Oludeniz, Turkey.