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Empirical Models for the Correlations Between Total Ozone Column and Latitude in different regions in IRAQ

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Abstract: This Research aimed at find a correlation between Total Ozone Column (TOC) and Latitude in different regions in Iraq using several Mathematical Models.

Models were used for that [Linear Models, Quadratic Models, Exponential Models, Logarithmic Models, Power Models]. Several statistical tests [R^2, R, MAE, RMSE] were used to control the validation and goodness of these Models. Quadratic Model gave the highest R^2 among the other models in all stations. R^2 obtained between (TOC) & Latitude in Winter & Spring months were very high and ranged between (0.953 – 0. 976). Summer months show a good correlation in June & July and week correlation in August. In Autumn months a good correlation was obtained in October & November and week correlation was obtained in September. The highest R^2 means that there is a highly significance correlations between Total Ozone Column and Latitude. This mean that these Models gave a very good results to estimate (TOC) from Latitude.

Keywords: NASA, Regression Models, IRAQ, Latitude, TOC, R^2, MAE, RMSE

النماذج الرياضية لعلاقات الارتباط بين طول عمود الأوزون وخط العرض في مناطق مختلفة من العراق

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المستخلص: هدف البحث إلى إيجاد علاقات ارتباط بين طول عمود الأوزون الكلي (TOC) وخط العرض في مناطق مختلفة من العراق باستخدام عدة نماذج رياضية؛ والنماذج الرياضية المستخدمة لهذه الدراسة هي [النماذج الخطية، النماذج من الدرجة الثانية، النماذج شبة اللوغاريتمية، النماذج اللوغاريتمية، النماذج الاسية].

نماذج إحصائية متعددة [R^2, R, MAE, RMSE] تم استخدامها لتحديد جودة ومدى صلاحية هذه النماذج اظهرت النتائج أن النموذج من الدرجة الثانية اعطى أعلى معامل تحديد [R^2] مقارنة ببقية النماذج في المحطات كافة. أوضحت النتائج أن قيم [R^2] التي تم الحصول عليها بين (TOC) وخطوط العرض خلال أشهر الشتاء والربيع كانت عالية وتراوحت بين (0.953 – 0. 976). خلال أشهر الصيف كانت علاقات الارتباطً جيدة خلال شهري حزيران وتموز أما خلال شهر اب فأظهرت علاقات الارتباط ضعيفة. خلال أشهر الخريف كانت علاقات الارتباطً جيدة خلال شهري تشرين الأول وتشرين الثاني، أما خلال شهر ايلول كانت علاقات الارتباط ضعيفة. القيم العالية لمعامل التحديد R^2تعني وجود ارتباط قوي بين (TOC) وخطوط العرض وهذا يعني جوده هذه النماذج في تخمين ال (TOC)من خطوط العرض.

الكلمات المفتاحية: ناسا، نماذج الانحدار، العراق، خطوط العرض، طول عمود الأوزون الكلي، معامل التحديد، الخطأ لمعدل الجذر التربيعي، نسبة الخطأ للقيمة المطلقة لمعدل الانحراف.

Introduction.

Ozone in atmosphere represents a natural shield against the harmful solar UV radiation which reaches the Earth's surface and exerts unfavorable influence on the human health, on the other biological life, and ecosystems [1]. Although ozone amount represents as maximum 0.0012% of the total atmospheric composition it plays a very important role in weather and climate on regional to global spatial scales, acting as a major greenhouse gas [2, 3]. In addition, ozone absorbs the most energetic part of the solar ultraviolet (UV) radiation spectrum, protecting life on earth from this sun's harmful radiation [4, 5]. It is well-known that UV radiation can induce detrimental effects on human health particularly on the skin, sight and immune system [6, 7]. The total ozone column at any location on the globe is defined as the sum of all the ozone in the atmosphere directly above that location. Most ozone resides in the stratospheric ozone layer and a small percentage (about 10%) is distributed throughout the troposphere [8].

The interaction of processes such as ozone production, loss, transport that governs ozone variability observed on different time scales helps to determine both the amount of ozone in the stratosphere as well as its distribution with latitude, longitude and altitude [9, 10]. Total ozone varies strongly with latitude over the globe, with the largest values occurring at middle and high latitudes during most of the year.

Ozone depletion is greater at higher latitudes (towards the north and south poles) and negligible at lower latitudes (between 30° N and 30° S). Thus, cities at lower latitudes generally receive more sunlight because they are nearer the equator implying an increase in UV radiation [11].

The distribution of ozone is the result of the large-scale circulation of air in the Stratosphere ultraviolet radiation is highest, toward the poles. Ozone accumulates at middle and high latitudes, increasing the vertical extent of the ozone layer and, at the same time, total ozone. Values of total ozone are that slowly transports ozone from the tropics, where ozone production from solar generally smallest in the tropics for all seasons [12, 13**].**

Satellite measurements have been providing a better continuous geographical distribution. These measurements require validation against ground-based measurements for the verification of their accuracy and to develop correction algorithms where necessary. Ozone monitoring through ground-based instruments and comparison with data from satellites for mid-latitude regions is essential because, in these densely populated [12, 14]

The objective of this paper is to find correlations between TOC & Latitude in different regions in IRAQ.

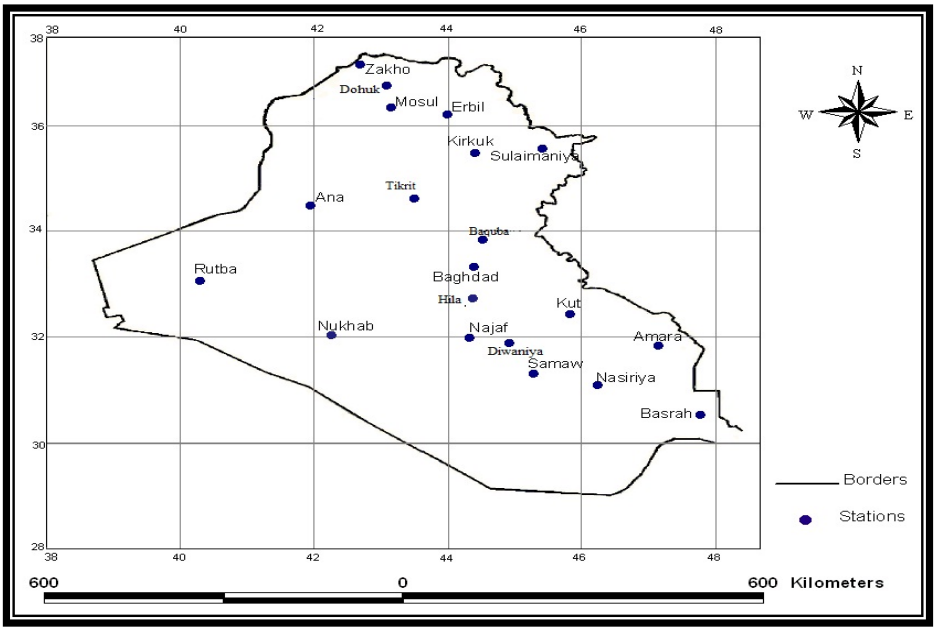
Data Source and Methodology

The total Ozone Column (TOC) data were taken from instrument developing by NASA/ Goddard Space Flight Center (TOMS) continue by the Ozone Monitoring Instrument (OMI) record for the TOC. The TOC was found for (20) meteorological stations well distributed throughout Iraq [Zakho, Dohuk, Mosul, Erbil, Tikrit, Baquba, Ramadi, Baghdad, Rutba, Kut, Hilla, Diwaniya, Najaf, Nukhuyb, Samara, Nasiriya, Basra] for the period (1998-2017)

Fig (1) Show the locations of these stations on the map of Iraq. Table (1) show the Latitude, Longitude, and Elevation of these stations. Table (2, 3) show the mean monthly and seasonally values of Total Ozone Column in all stations for the period (1998-2017). Five mathematical models [Linear, Quadratic, Linear-logarithmic, Logarithmic and Power] were used to test the correlations between TOC and Latitude in the different stations. Mean Absolute Error [MAE], Root Mean Square Error [RMSE], Coefficient of Determination[R^2] and Correlation Coefficient [R] were used for the purpose of evaluating results.

Table(1) geographical coordinate of different stations

Station	Latitude	Longitude	Altitude (m)
Zakho	37.13º	42.69º	440
Dohuk	36.86º	43º	565
Mosul	36.34º	43.13º	223
Erbil	36.19º	44.01º	420
Sulaimaniya	35.55º	45.43º	882
Kirkuk	35.46º	44.39º	350
Tikrit	34.6º	43.68º	110
Baquba	33.74º	44.62º	600
Ramadi	33.42º	43.3º	50
Baghdad	33.32º	44.42º	34
Rutba	33.03º	40.28º	645
Kut	32.5º	45.82º	305
Hila	32.48º	44.43º	120
Nukhuyb	32.04º	42.25º	305
Diwaniya	31.98º	44.92º	75
Najaf	31.97º	44.44º	60
Amara	31.83º	47.14º	150
Samawa	31.31º	45.28º	30
Nasiriya	31.05º	46.26º	9
Basra	30.5º	47.81º	5



Fig(1): Location of different stations in Iraq

Results & Discussion

Table (2) the show the mean monthly values of Total Ozone column (TOC) in all stations. We can deduce from the table:

1- The maximum monthly mean values of (TOC) was obtained in Zakho station, while the minimum monthly mean was obtained in Basra station.
2- The values of (TOC) in the other stations was ranged between the two stations.
3- This is due to latitude effect in Ozone.
4- Spring months gave the maximum values of (TOC) while Autumn months gave the minimum values of (TOC)
5- The Ozone concentration is found to be maximum around March and April months and it decrease during Autumn and reaches to a minimum values in October.
6- The different between the maximum value of (TOC) in March and the minimum values in October was as follow: (63) DU in Zakho, (58) in Dohuk and Mosul, (56) in Kirkuk and Sulaimaniya, (49) in Tikrat, (44) Baquba and Ramadi, (43) in Baghdad, (41) in Ratba, (39) in Kut and Hilla, (34) in Nakhyeb and Diwaniya, (33)in Najaf and Ammara, (34) in samawa, (32)in Nasiriya, (26)in Basra.
7- This mean that the difference between Maximum value and the minimum value decrease from the North of Iraq ta ward the South of Iraq, where Latitude decrease from the higher value in Zakho (37.13°) in the North of Iraq to (30.5°) in Basra in south of Iraq.

Table (2): Mean Monthly values of TOC for different stations

Month / Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Des.
Zakho	327	338	345	341	327	309	295	292	287	282	289	302
Dohuk	319	329	336	334	321	299	294	285	281	278	286	296
Mosul	318	327	334	332	321	299	294	285	281	276	286	298
Erbil	316	326	330	329	317	296	293	282	279	274	285	295
Sulaimaniya	311	322	328	325	315	293	292	282	277	272	282	290
Kirkuk	313	322	329	324	311	294	291	286	280	275	286	295
Tikrit	308	315	324	323	313	293	290	287	282	275	284	290
Baquba	302	309	318	317	306	293	289	286	281	274	282	287
Ramadi	301	310	317	318	308	294	290	287	282	273	284	286
Baghdad	303	309	317	318	307	294	290	287	281	274	283	286
Rutba	294	302	313	316	308	292	286	283	277	272	277	280
Kut	296	303	311	311	303	292	289	286	280	272	279	281
Hilla	296	302	311	312	303	292	288	285	280	272	279	281
Nukhuyb	290	294	305	307	300	290	288	285	278	271	276	277
Diwaniya	290	295	306	308	301	290	287	283	277	271	275	277
Najaf	290	295	304	306	300	290	288	285	279	271	276	277
Amara	288	294	303	304	297	290	288	286	279	270	275	277
Samawa	288	295	304	305	298	290	288	285	280	270	278	277
Nasiriya	289	294	303	305	298	290	288	286	279	271	277	278
Basra	282	287	296	299	294	289	288	285	279	270	274	273

Table (3) Show the mean Seasonally and Annually values of (TOC) for the different stations

From the table we can see that (TOC) has a notable seasonal behavior which should be considered. The spring season show higher values of (TOC) than the other seasons. Autumn season show the lower values of (TOC).

We can see also clearly that the seasonal mean of (TOC) decrease from the north of Iraq toward the south of Iraq, where the latitude decrease in the same behavior.

The mean annual values of (TOC) in all stations was shown also in table (3).

The maximum annual mean of (TOC) was obtained in Zakho station (311) DU and the minimum value was obtained in Basra station (284) DU. The other values of the annual mean of (TOC) decrease from the north of Iraq toward the south of Iraq. This is due to also the latitude effect on Ozone.

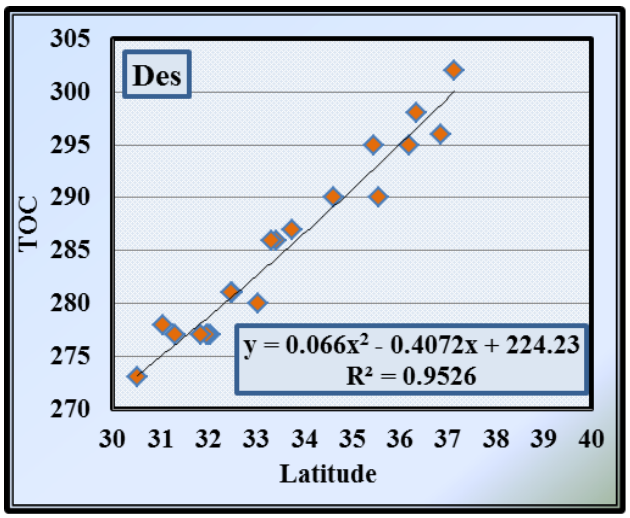
Table (3) The Mean Seasonally and Annually values of TOC for different stations

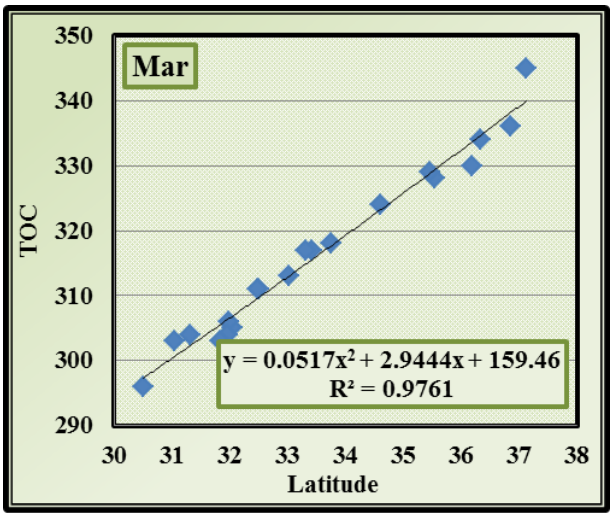
Season / Station	Winter	Spring	Summer	Autumn	Annual
Zakho	322	337	298	286	311
Dohuk	314	330	291	281	304
Mosul	315	329	291	282	304
Erbil	312	325	288	279	301
Sulaimaniya	308	322	287	277	299
Kirkuk	310	321	290	280	300
Tikrit	304	320	290	280	298
Baquba	299	314	290	279	295
Ramadi	299	315	290	280	295
Baghdad	299	314	290	279	295
Rutba	292	312	278	275	291
Kut	294	308	289	277	291
Hilla	293	309	289	277	291
Nukhuyb	278	304	288	275	288
Diwaniya	278	305	286	274	288
Najaf	287	303	288	275	288
Amara	287	301	288	275	287
Samawa	286	302	288	276	288
Nasiriya	287	302	288	276	288
Basra	281	297	287	274	284

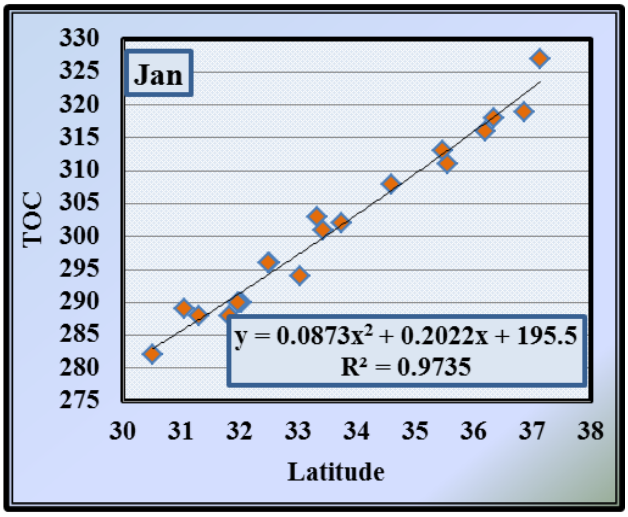
Five Mathematical Models were used to test the correlation between (TOC) and latitude during the months of the year.

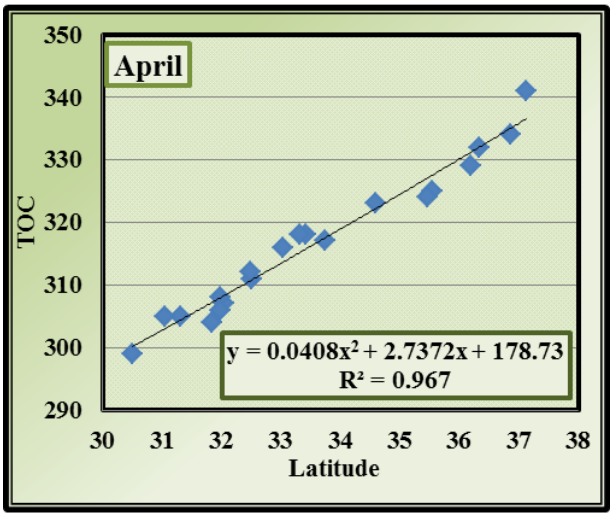
From these Models we chose the Model which give the highest (R^2).

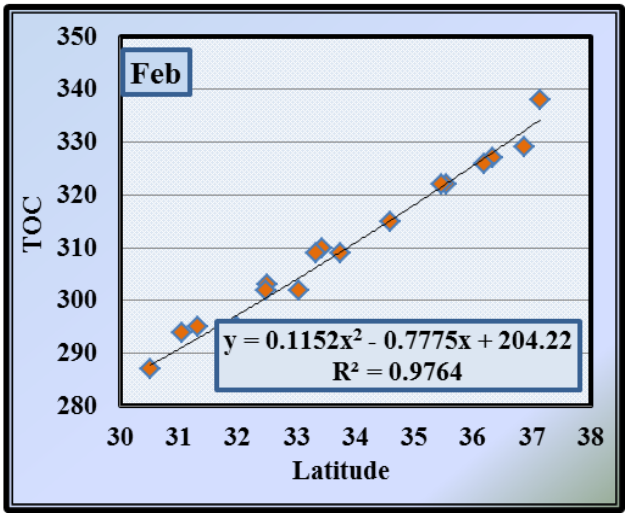
Fig [2, 3, 4, 5] show the correlations between (TOC) and latitude during the months of the seasons [winter, spring, summer and Autumn].











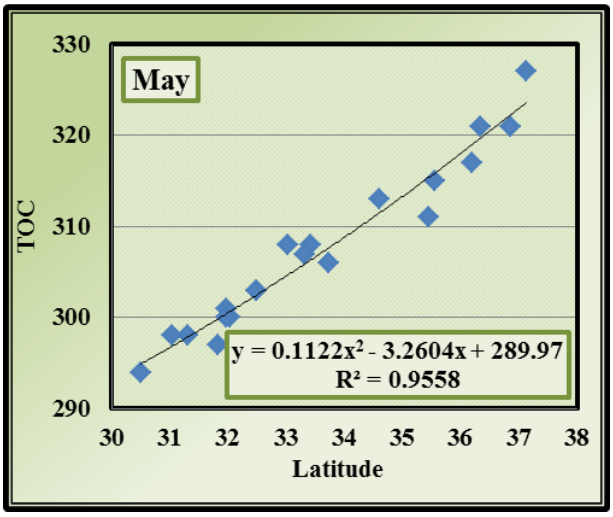


Fig (2) the correlations between (TOC) and latitude during the months of the seasons in winter

Fig (3) the correlations between (TOC) and latitude during the months of the seasons in spring.

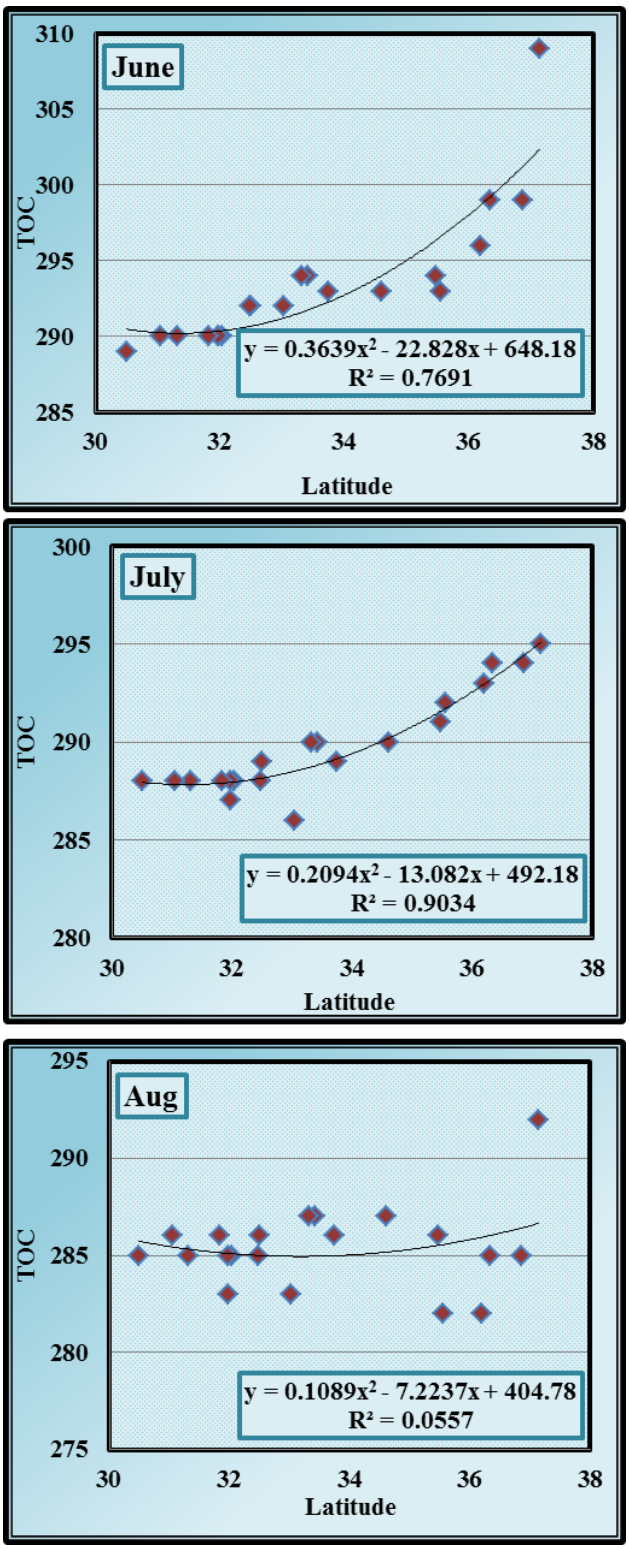


Fig (4) the correlations between (TOC) and latitude during the months of the seasons in summer

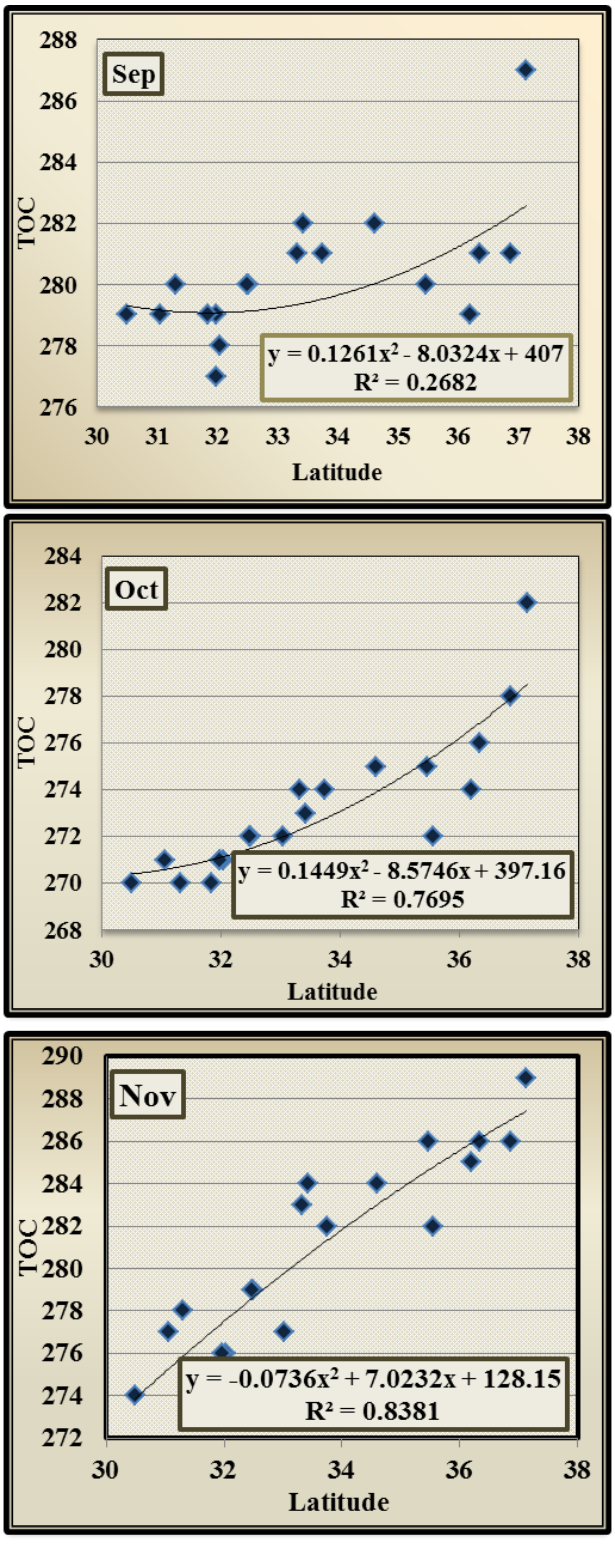


Fig (5) the correlations between (TOC) and latitude during the months of the seasons in Autumn

Table (4) show the Models with Regression and statistical indicator during the months of the year.

Months	Correlations	R^2	R	MAE	RMSE
Jan	$y = 0.0873x^2 + 0.2022x + 195.5$	0.974	0.987	0.95	0.87
Feb	$y = 0.1152x^2 - 0.7775x + 204.22$	0.976	0.988	1.02	0.92
Mar	$y = 0.0517x^2 + 2.9444x + 159.46$	0.976	0.988	0.87	0.81
April	$y = 0.0408x^2 + 2.7372x + 178.73$	0.967	0.983	0.88	0.82
May	$y = 0.1122x^2 - 3.2604x + 289.97$	0.956	0.978	0.81	0.78
June	$y = 0.3639x^2 - 22.828x + 648.18$	0.769	0.877	0.86	0.93
July	$y = 0.2094x^2 - 13.082x + 492.18$	0.903	0.950	0.28	0.35
Aug	$y = 0.1089x^2 - 7.2237x + 404.78$	0.0557	0.236	0.923	0.891
Sep	$y = 0.1261x^2 - 8.0324x + 407$	0.2682	0.518	0.865	0.881
Oct	$y = 0.1449x^2 - 8.5746x + 397.16$	0.770	0.877	0.58	0.66
Nov	$y = -0.0736x^2 + 7.0232x + 128.15$	0.838	0.915	0.91	0.83
Des	$y = 0.066x^2 - 0.4072x + 224.23$	0.953	0.976	0.94	0.82

We test all the Models and we find that Quadratic Model gave the best fit among the Models where it give the highest (R^2). From table (4) we can deduce:

A highly acceptable correlation was obtained between (TOC) and latitude during **winter and spring months** where [R^2] during winter months ranged between [0.953-0.974] and during spring months ranged between [0.956-0.976].

We can also see that the [MAE] was ranged between [0.94-1.02]% for winter months and between [0.81-0.88]% for spring months indicating an excellent fitting between (TOC) and latitude during winter and spring months.

The [RMSE] for the regression correlations was ranged between [0.82- 0.92] % for winter months and between [0.78- 0.82] % for spring months which show a good performance.

During Summer months [R^2] for these months was [0.769, 0.903, 0.055] indicating also a good correlation in June and July and a week correlation August.

During Autumn months [R^2] for these months was [0.268, 0.770, 0.838] indicating also a good correlation in October and November and a week correlation September.

Fig (6) correlation between [TOC & Latitude] during the seasons of the year.

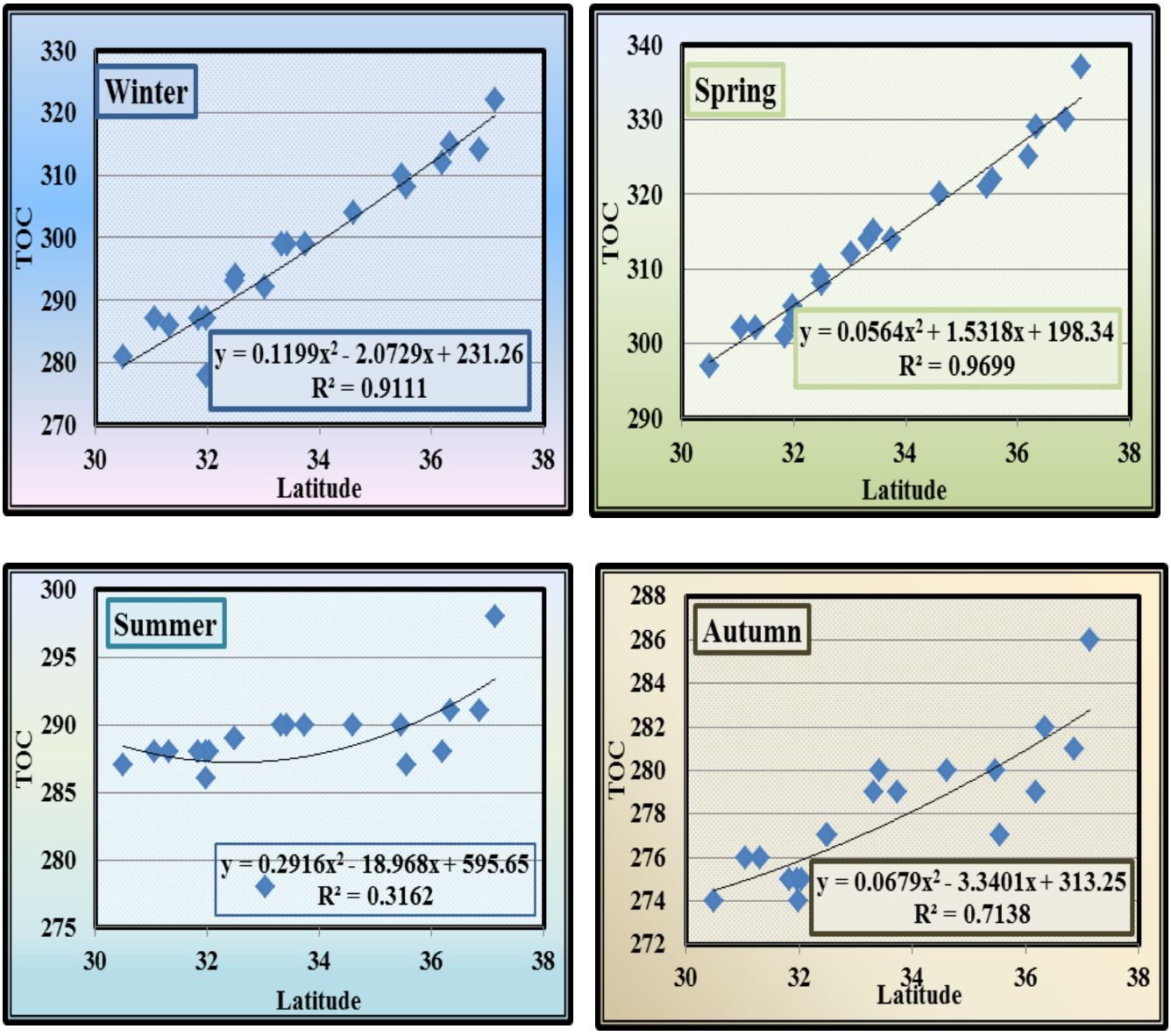
From the figure we can see:

A highly acceptable correlation was obtained in winter and spring season where [R^2] in these season are [0.9111, 0.9699] respectively.

A week correlation was obtained in summer season, where [R^2] equal to [0.3162], and a good correlation was obtained in Autumn Sean where [R^2] equal to [0.7138].

Table (5) show a comparison between (TOC) measured and (TOC) estimated from the models.

We can see a good agreement between the estimated values of [TOC] from the models and the measured values



Fig(6) correlation between [TOC & Latitude] during the seasons of the year

Table (5): A comparison between (TOC) measured and (TOC) estimated from the models.

Month / Station	Des.		Jan.		Feb.		Mar.		April		May	
	mea	est	mea	est	mea	est	mea	est	mea	est	mea	est
Zakho	302	300	327	323	338	334	345	340	341	337	327	324
Dohuk	296	299	319	322	329	332	336	338	334	335	321	322
Mosul	298	297	318	318	327	328	334	335	332	332	321	320
Erbil	295	296	316	317	326	327	330	334	329	331	317	319
Sulaimaniya	290	293	311	313	322	322	328	329	325	328	315	316
Kirkuk	295	293	313	312	322	322	329	329	324	327	311	315
Tikrit	290	289	308	307	315	315	324	323	323	322	313	311
Baquba	287	286	302	302	309	309	318	318	317	318	306	308
Ramadi	286	284	301	300	310	307	317	316	318	316	308	306
Baghdad	286	284	303	299	309	306	317	315	318	315	307	306
Rutba	280	283	294	297	302	304	313	313	316	314	308	305
Kut	281	281	296	294	303	301	311	310	311	311	303	303
Hilla	281	281	296	294	302	300	311	310	312	311	303	302
Nukhuyb	277	279	290	292	294	298	305	307	307	308	300	301
Diwaniya	277	279	290	291	295	297	306	306	308	308	301	300
Najaf	277	279	290	291	295	297	304	306	306	308	300	300
Amara	277	278	288	290	294	296	303	306	304	307	297	300
Samawa	277	276	288	287	295	293	304	302	305	304	298	298
Nasiriya	278	275	289	286	294	291	303	301	305	303	298	297
Basra	273	273	282	283	287	288	296	297	299	300	294	295
Month / Station	June		July		Aug.		Sep.		Oct.		Nov.	
	mea	est	mea	est	mea	est	mea	est	mea	est	mea	est
Zakho	309	302	295	295	292	287	287	283	282	279	289	287
Dohuk	299	301	294	294	285	286	281	282	278	278	286	287
Mosul	299	299	294	293	285	286	281	282	276	277	286	286
Erbil	296	299	293	293	282	286	279	281	274	277	285	286
Sulaimaniya	293	297	292	292	282	286	277	281	272	275	282	285
Kirkuk	294	296	291	292	286	286	280	281	275	275	286	285
Tikrit	293	294	290	290	287	285	282	280	275	274	284	283
Baquba	293	292	289	289	286	285	281	280	274	273	282	281
Ramadi	294	292	290	289	287	285	282	279	273	272	284	281
Baghdad	294	292	290	289	287	285	281	279	274	272	283	280
Rutba	292	291	286	289	283	285	277	279	272	272	277	280
Kut	292	291	289	288	286	285	280	279	272	272	279	279
Hilla	292	291	288	288	285	285	280	279	272	272	279	279
Nukhuyb	290	290	288	288	285	285	278	279	271	271	276	278
Diwaniya	290	290	287	288	283	285	277	279	271	271	275	277

Month / Station	Des.		Jan.		Feb.		Mar.		April		May	
	mea	est	mea	est	mea	est	mea	est	mea	est	mea	est
Najaf	290	290	288	288	285	285	279	279	271	271	276	277
Amara	290	290	288	288	286	285	279	279	270	271	275	277
Samawa	290	290	288	288	285	285	280	279	270	271	278	276
Nasiriya	290	290	288	288	286	285	279	279	271	271	277	275
Basra	289	290	288	288	285	286	279	279	270	270	274	274

Conclusion

1- A maximum values of [TOC] was obtained in March and minimum values was obtained in October in all stations.

2- [TOC] values decrease from the North of Iraq toward the south of Iraq according to the latitude values.

3- Spring season show the maximum vales of [TOC] ranged between (337- 297)DU while Autumn season show the minimum values ranged between (286-274)DU.

4- The mean annual values of [TOC] decrease from the north of Iraq (311)DU in Zakho station to word the south of Iraq (284)DU in Basra station.

5- Quadratic Model gave a highly acceptable correlations between(TOC and latitude) during winter & spring months where [R2] ranged between [0.953-0.976].

6- Good correlation was obtained in June, July, October and November where (R2) ranged between [0.769-0.903].

7- Week correlation was obtained in August & September.

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