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Estimate Surface Low Pressure System Using Polar Jet Stream Core during winter

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Abstract

Present paper investigated the relationship between polar jet stream core speed at 300 hPa level and the surface low pressure system. Winter seasons were studied during years from 2014 to 2016. February months were chosen from winter seasons which the polar jet stream passes with high frequencies over the area of study. The polar jet structure was almost continuous jet-type that the increasing in the jet core speed would decrease the pressure value in the low pressure system. the Pearson's (R) statistical test used to show the strength of that relationship which accessible values were between (83% strong and over strong) that presented the core speed values as a good element to derive equation connecting between the low pressure system value in (hPa) at surface and core speed value in (kt) at 300 hPa level . The simple linear regression technique is used to drive the equation that connects between the low pressure system and the jet core speed value which was [Low pressure center value (hPa) =1042.57−(0.307 × core speed (kt)]. The general fit equation was tested against some jet stream cases at 300 hPa that were the highest value of the jet core speed, the lowest and middle selected value which presented the percentage errors were between (0.03-0.09). the chart analyzing presented the lowest low pressure system center corresponded the highest the jet core speed values as shown in 11 Feb., 2015 at 00 UTC which the core speed was 150 (kt) corresponding the surface low pressure system which was 993 (hPa).

Keywords: Polar Jet, winter, core speed, surface.

الخلاصة

درس هذا العمل العلاقه بين قلب التيار النفاذ القطبي ضمن مستوى ارتفاع (٣٠٠ هكتوباسكال) والمنخفض الجوي السطحي خلال فصل الشتاء للفتره من ٢٠١٤ الى ٢٠١٦. اختيرت اشهر شباط من فصل الشتاء والتي يكون خلالها اعلى عدد للايام التي يمر خلالها التيار النفاذ القطبي فوق المنطقه للمختاره للبحث. بيت الدراسه بان شكل التيارالنفاذ القطبي كان على العموم شكل واحد وهو الشكل المستمر في تركيبه غير متقطع ولكن عدد الايام التي يمر فيها غيرثابت من شهر الى اخر وكان قلب التيار النفاذ القطبي سهل التميز و يمتلك علاقه عكسيه بينه وبين قيمه مركز المنخفض الجوي السطحي. استخدم الاختبار الاحصائي لبيتراسون ((Pearson's (R)) لبين قوه الترابط للعلاقه بين قيمه مركز المنخفض الجوي السطحي وسرعه قلب التيار النفاذ القطبي وكانت له قيم مابين(٠,٦ -١). حيث ان هذه الاسباب شجعت من اتخاذ سرع ريح قلب التيار القطبي كمتغير اساسي لاشتقاق معادله لتنبؤ بقيمه مركز المنخفض الجوي السطحي بالعتماد على قيمه سرع قلب التيار النفاذ القطبي. استخدمت تقنيه الانحدار البسيط لشتقاق هذه المعادله و التي هي:
(قيمه مركز المنخفض الجوي السطحي (وحده هكتوباسكال) = ١٠٤٢,٥٧- (٠,٣٠٧ × قيمه سرعه رياح قلب التيار(وحده عقده). أختبرت هذه المعادله المشتقة للقيم مرصوده مختاره والتي هي اعلى قيمه سرعة ريح لقلب التيار و اقل قيمه سرعة ريح و قيمه وسطيه مختاره و كانت نسبه الخطا هي مابين تقريبا (٠,٠٣ – ٠,٠٩). وكذلك بين تحليل الخرائط السطحيه وخرائط الرياح العليا للمستوى ٣٠٠ (هكتوباسكال) بانه أقل قيمه لمركز المنخفض الجوي قابلها أعلى قيمه سرعة رياح لقلب التيار النفاذ و كان ذلك في تاريخ ١١ شباط ٢٠١٥ حيث كانت قيمه مركز المنخفض الجوي السطحي ٩٩٣ (هكتوباسكال) قابتها قيمه سرعة ريح لقلب التيار مقدارها ١٥٠ عقده .

Introduction

The polar jet stream is meandering of fast air current nearly at 300 hPa level due to barotropic disturbance which it considers important for the north/south transport of energy and moisture [1]. The polar jet stream is often associated with the polar front which it is the global boundary separating the cold polar air from warm subtropical air that gave it the name of polar front jet stream [2].

The polar front jet (PFJ) locates at the intersection of polar and mid-latitude tropospheric leafs. It is produced by a temperature difference and is closely related to the polar front. It has a more variable position. In summer, its position will shift towards the poles and in winter towards the equator [3]. The polar jet stream is stronger in winter and has a continuous structure. It greatly influences the climate of regions close to about 60o latitude and hence it controls the path, speed and intensity of cyclones there [4]. The polar front jet structure is variable. It may be strong with small amplitude or weak with wide amplitude. The weaker jet tends to be wavy, sporadic, and meander northward and southward alongside its path especially in the northern hemisphere see Figure (1) [5].

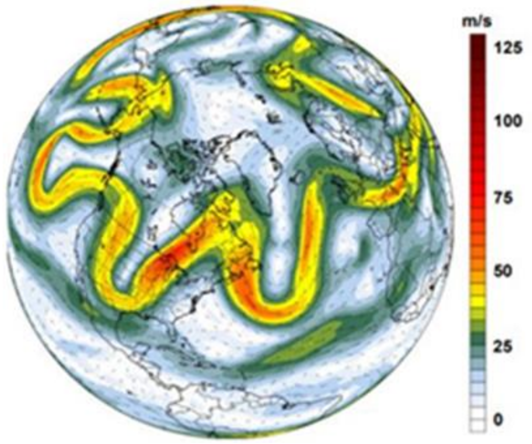

Figure 1: A waver polar jet stream 14 May 2014.

The polar jet stream impacts in the Euro-Atlantic region and Mediterranean region. It influences on the rainfall distribution. In general, rain in the Mediterranean region is restricted to the jet stream [6]. The position and strength the polar jet stream was studied by using the global climate models which present the sort of jet which has intensification and pole-ward shift. They indicated that these features are caused mainly by the anthropogenic climate change. The observations confirmed the results presented by the models [7]. Above and below the jet core the upper frontogenesis process happens. It provides substantial deformation of the tropopause that will contribute by building the structure and evolution of lower stratospheric frontal zones [8]. The jet streaks is the center of the jet core which it divides to four quadrants that the wind is divergent in the right entrance and left-exit regions which leads to upward vertical motion and convergent in the left-entrance and right-exit regions which leads to downward vertical motion [9].

The core of the polar jet stream can detect by determining the latitude and height of the maximum zonal wind speed of the jet stream [10]. The statistical tests are a technique that use for exploring the linear relationship between two variables. The Pearson correlation coefficient and Simple linear regression consider two of the common statistical tests. The Pearson correlation coefficient (R) (see equation (1)) shows the linear relationship between two variables and the direction of that relationship which is increase or decrease and also the strength of that relation weak or strong. It describes by a number between -1 and 1 [11]. (See Table (1)) according to [12].

Table 1: The relationship between (R) and the formula strength [12].

Correlation value	Interpretation of strength of correlation
$0.9 < R < 1.0$ ($-0.9 > R > -1.0$)	Very strong positive (negative) correlation
$0.7 < R < 0.9$ ($-0.7 > R > -0.9$)	strong positive (negative) correlation
$0.5 < R < 0.7$ ($-0.5 > R > -0.7$)	moderate positive (negative) correlation
$0.3 < R < 0.5$ ($-0.3 > R > -0.5$)	weak positive (negative) correlation
$0.0 = R < 0.3$ ($0.0 = R > -0.3$)	No relationship

$$R = \frac{\sum_{i=1}^{X}(X_i - \bar{X})\,(Y_i - \bar{Y})}{(n-1)S_X\, S_Y} \qquad (1)$$

$\bar{X}$: The arithmetic mean of the data X_1, X_2,... X_n
$\bar{Y}$: The arithmetic mean of the data Y_1, Y_2,... Y_n
S_X: The standard deviation of the data X_1, X_2, ... X_n
S_Y: The standard deviation of the data Y_1, Y_2, .. Y_n

The Simple linear regression is the study of the relationship between two variables to get a linear equation between these two variables. It assumes the data distributes normally as gradient, then it calculates the slope of the gradient see the equations (2) and (3) [13].

$$Y = a + b\,X \qquad (2)$$

$$b = \frac{\sum_{i=1}^{X}(X_i - \bar{X})\,(Y_i - \bar{Y})}{\sum_{i=1}^{X}(X_i - \bar{X})^2} \qquad (3)$$

b: Slope of straight line

(Y = a + bx)

a: gradient Constant and show the fraction value cut from of Y – axis of the straight

(Y = a + bx)

The aim of this work is to study the structure of polar jet stream during winter then finding a relationship between the polar jet core speed and the intensification of the surface low pressure system.

Methodology

The global forecast system (GFS) weather charts used to study the behavior of PFJ and the associated low pressure systems in Middle East (20-45)° N, (30-60)° E focusing on the middle of Iraq. The included charts are surface weather charts which they depicted total precipitation and cloud cover and the 300 hPa level upper charts which they depicted geopotential height in (m), temperature gradient (Celsius/ latitudes), and core speed values in (knot) at two times (00 and 12) UTC on winter seasons by choosing Februaries months which were highest days numbers when the polar jet streams passed over study area during three years 2014-2016, (see Table (1) and Figure (2) according to [14].

Table 2: weather stations used in this study.

Iraq Regions	Station name (city)	location
middle	Haditha	34.13° N, 42.35° E
	Balad	34° N, 44.15° E
	Baghdad	33.3° N, 44.4° E

The surface routine weather conditions of the three stations were also studied: which they are the METAR (Meteorological Aerodrome Report) and the TAF (Terminal Aerodrome Forecast 24 hours).

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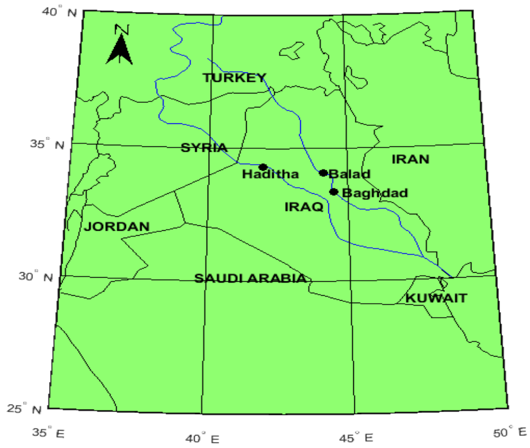

Figure 2: The locations of the surface weather stations [14].

The Relationship between Low Pressure and Core Speed

Tables (3), (4) and (5) showed the speed of the jet stream core that associated low pressure system events during 2014, 2015 and 2016 at 00 and 12 UTC, respectively. Choosing the events depends on the existing of the polar jet stream with (60 knots and above) at 300 hPa upper level. The tables also listed the lowest surface pressure and the corresponding weather conditions in the vicinity of the three stations. The analyzing presented that the structure polar jet stream is continuous jet-type during Februaries 2014, 2015 and 2016 at (00+12) UTC (as shown in Table (3), (4) and (5)).

Table 3: Polar jet stream events and the corresponding weather at 00, 12 UTC February 2014.

a.00 UTC

Day	PFJ			Low pressure system	
	core speed (kt)	Discontinuity	Pressure (hPa)	Weather condition at 00 UTC	The remarkable Weather condition during the day
3	110	No	1014	Nil	Shower rain (09 UTC) Baghdad
16	110	No	1009	Nil	Thunder storm (16 UTC) Baghdad
23	100	No	1016	Nil	Blowing dust (09 UTC) Baghdad
27	95	No	1019	Nil	Blowing dust (10 UTC) Baghdad
17	120	Yes	1006	Nil	Blowing dust (11 UTC) Baghdad

b.12 UTC

Day	PFJ			Low pressure system	
	core speed (kt)	Discontinuity	Pressure (hPa)	Weather condition at 00 UTC	The remarkable Weather condition during the day
3	110	No	1012	Nil	Shower rain (09UTC) Baghdad
16	125	No	1006	Nil	Thunder storm (16UTC) Baghdad
17	110	No	1010	yes	Blowing dust (12UTC) Baghdad
27	100	No	1016	Nil	Blowing dust (11UTC) Baghdad

Table 4: Polar jet stream events and the corresponding weather at 00, 12 UTC February 2015.

a.00 UTC

day	PFJ		Low pressure system		
	core speed (kt)	Discontinuity	Pressure (hPa)	Weather condition at 00 UTC	The remarkable Weather condition during the day
7	90	No	1010	Nil	Shower rain (11 UTC) Haditha
9	110	No	999	Nil	Thunder storm (17UTC) Balad
11	150	No	993	Nil	Dust storm (22UTC) Balad
12	140	No	1008	yes	Thunder storm (00 UTC) Haditha
16	100	No	1014	Nil	Thunder storm (08 UTC) Baghdad
19	120	No	1010	Nil	Thunder storm (09 UTC) Haditha

b.12 UTC

day	PFJ		Low pressure system		
	core speed (kt)	Discontinuity	Pressure (hPa)	Weather condition at 00 UTC	The remarkable Weather condition during th day
7	85	No	1012	Nil	Shower rain (17 UTC) Baghdad
9	140	No	1008	Nil	Thunder storm (17UTC) Balad
11	150	No	1000	Nil	Dust storm (22 UTC) Balad
12	115	No	1007	Nil	Thunder storm (00 UTC) Haditha
16	110	No	1010	Nil	Thunder storm (08 UTC) Baghdad
19	135	No	1008	Nil	Thunder storm (19 UTC) Haditha
20	140	No	1001	Yes	Thunder storm (12 UTC) Balad

Table 5: Polar jet stream events and the corresponding weather at 00, 12 UTC February 2016.

a.00 UTC

day	PFJ		Low pressure system		
	core speed (kt)	Discontinuity	Pressure (hPa)	Weather condition at 00 UTC	The remarkable Weather condition during the day
6	100	No	1006	Nil	Thunder storm (09 UTC) Baghdad
7	100	No	1006	Nil	Shower rain (07 UTC) Baghdad
8	85	No	1016	yes	Shower rain (00 UTC) Balad
11	80	No	1019	Yes	Thunder storm (00 UTC) Baghdad
22	130	No	1002	Nil	Thunder storm (07 UTC) Balad
23	90	No	1010	Nil	Thunder storm (08 UTC) Haditha

b.12 UTC

day	PFJ		Low pressure system		
	core speed (kt)	Discontinuity	Pressure (hPa)	Weather condition at 00 UTC	The remarkable Weather condition during the day
6	90	No	1010	Yes	Thunder storm (12UTC) Baghdad
11	90	No	1018	Nil	Dust (14UTC) Haditha
22	120	No	1004	yes	Thunder storm (18UTC) Baghdad
23	85	No	1012	Nil	Thunder storm (13UTC) Baghdad

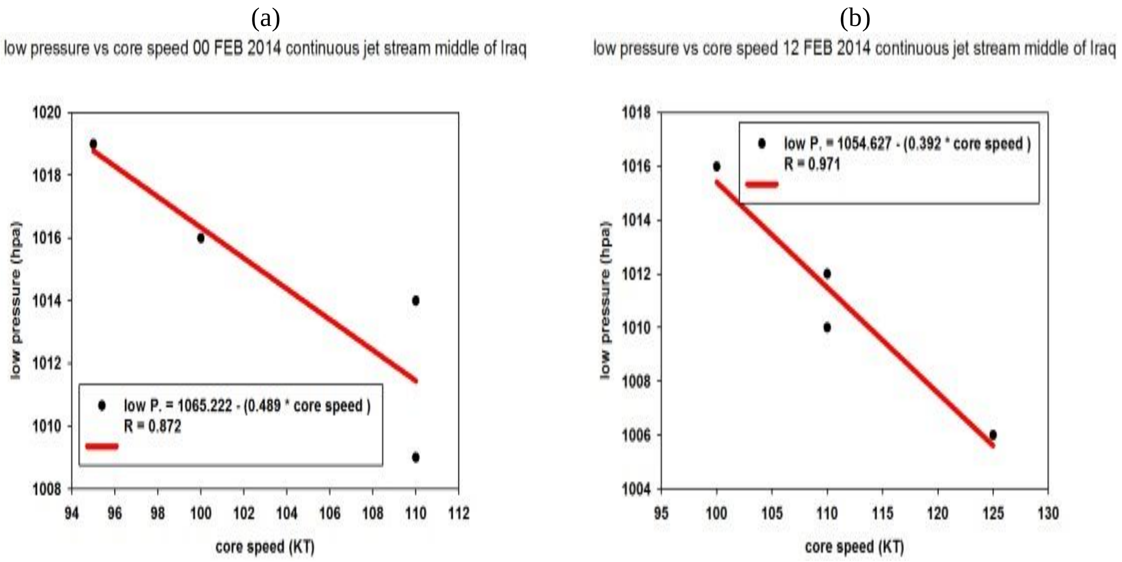

Figure 3: low pressure versus core speed middle of Iraq (continuous) jet-type (a) in February 2014 at 00 UTC and (b) in February 2014 at 12 UTC.

(a) (b)

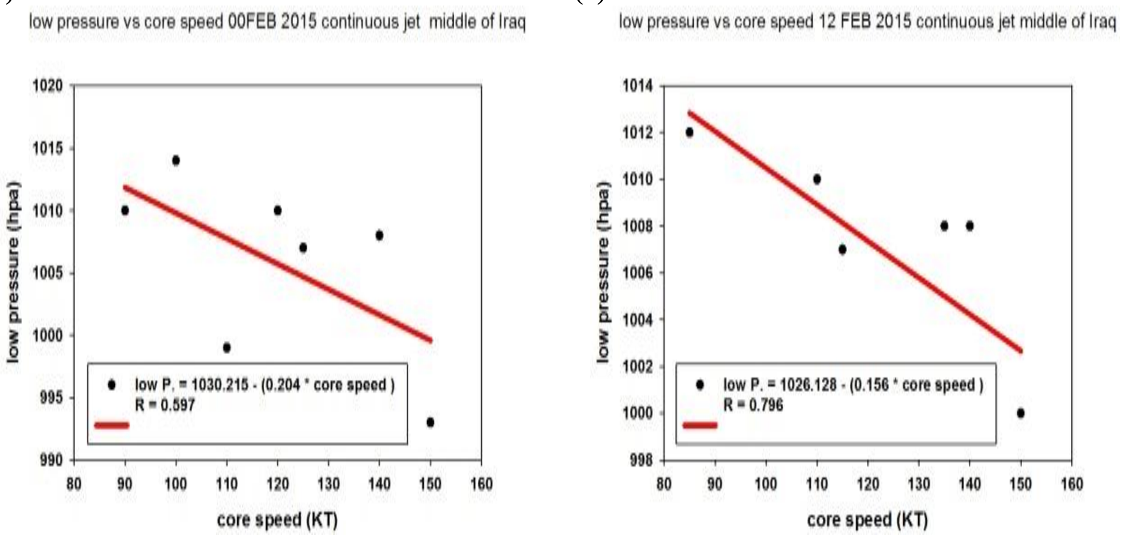

Figure 4: low pressure versus core speed middle of Iraq (continuous) jet-type (a) in February 2015 at 00 UTC and (b) in February 2015 at 12 UTC.

(a) (b)

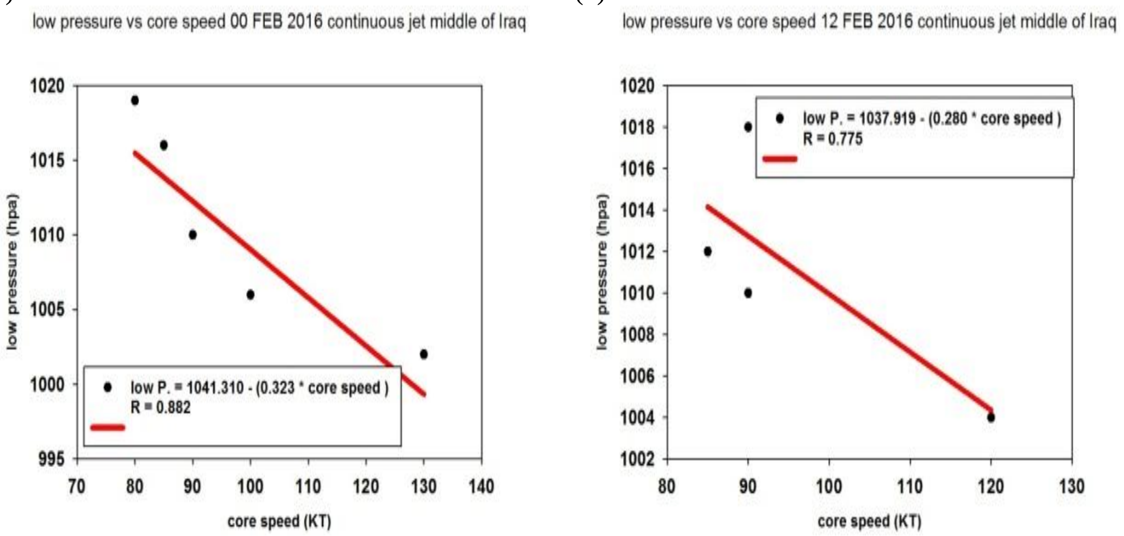

Figure 5: Low pressure versus core speed middle of Iraq (continuous) jet-type in February 2016 (a) at 00 UTC and (b) at 12 UTC.

Table 6: The relationship equation between low pressure and core speed February months (Continuous) jet-type.

NO.	Equation (continuous) jet-type	slope	R	Relationship	Time+month+year Place
1	low P. = 1065.22 −(0.489 * core speed)	−(0.489)	R = 0.872	Indirect Strong	00 FEB 2014 Middle of Iraq
2	low P. = 1054.63 −(0.392 * core speed)	−(0.392)	R = 0.971	Indirect Very Strong	12 FEB 2014 Middle of Iraq
3	low P. = 1030.22 −(0.204 * core speed)	−(0.204)	R = 0.597	Indirect moderate	00 FEB 2015 Middle of Iraq
4	low P. = 1026.13 −(0.156 * core speed)	−(0.156)	R = 0.796	Indirect Strong	12 FEB 2015 Middle of Iraq
5	low P. = 1041.31 −(0.323 * core speed)	−(0.323)	R = 0.882	Indirect Strong	00 FEB 2016 Middle of Iraq
6	low P. = 1037.92 −(0.280 * core speed)	−(0.280)	R = 0.775	Indirect Strong	12 FEB 2016 Middle of Iraq

Table 7: the percentage error of the calculated low pressure of an exemplary three cases.

Case	Date	Discontinuity	Equation	Jet core speed (kt)	Calculated Low pressure center value	Actual low pressure center value	Percentage error (%)
7	11 Feb 2015, 00 UTC	No	4.3	150 (Max.)	996.52	993	0.35
8	11 Feb 2016 (00) UTC	No	4.3	80 (Min.)	1018.1	1019	0.089
9	12 Feb 2015 (12) UTC	No	4.3	115 (Mid.)	1007.27	1007	0.027

Discussion

From the analyzing data at the middle of Iraq during winter months chose Februaries which were the highest data compared by the others winter months which the polar jet stream passes over study area that showed the polar jet structure was generally continuous jet-type during the period from 2014 to 2016. The data used to plot a linear relationship between low pressure system center at surface in (hPa) and the jet core wind speed at 300 hPa levels in (kt) by using SigmaPlot programmed. The low pressure system centers values depicted on the y-axis while the jet core speed values depicted on x-axis that presented indirect relationship between them (see Figures (3), (4) and (5)). The Pearson's statistical test (R) has been selected to show the strength of that relationship which had taken values approximately between (0.6 to 1) that had shown the relationship accepted (see Table (1)) and the simple linear regression test is used to derive an equation that connects between the low pressure system centers values at surface in (hPa) and jet core wind speed values at 300 hPa in (kt) (see Table (6)).

General equations were derived from the equations listed in Tables (6)

By using an averaging technique:

$$\text{Low pressure center value (hPa)} = 1042.57 - (0.307 \times \text{core speed (kt)}) \quad (4)$$

Equation (4) will apply for the continuous structure jet-type during February.

The equation (4) was tested against some jet stream cases at 300 hPa. Table (7) lists examples of three cases represent maximum, middle, and minimum jet core values. For these three cases, the percentage errors were calculated to evaluate the skill of the equation (4) in simulation the pressure values in the center of low pressure systems.

Conclusions

The polar jet-type structure affects significantly on the low pressure value at surface but during Februaries were almost continuous jet-type structure. The determination of the jet-type will be easier because it is only one type and easy to recognizes on charts, in addition The structure of polar jet-type repeated regularly through its shape but different in days number from month to month during Februaries on years from 2014 to 2016. The relationship between the low pressure system center at surface and the polar jet core wind speed was indirect with suitable strength that the lowest low pressure system center corresponds the highest core wind speed value as shown in 11 Feb. 2015 at 00 UTC which the core wind speed was 150 (kt) corresponding the surface low pressure system which was 993 (hPa) , in addition the core wind speed of jet was easy to recognizing that made from the polar jet core wind speed as a good element for simulation any model to estimate low pressure system value from the jet core wind speed value, without needing to limit the structure of the jet stream because it is only one type continuous jet-type structure . the plotting between the low pressure system and core speed offered indirect relationships for the Februaries at two times 00, 12 UTC that presented the jet core wind speed can be as good element using to derive an equation to estimate the low pressure system center at the surface.

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