The Effect of Merging Subtropical Jet Stream and Polar Fronts Jet Stream on Heavy Rainfall in Southwest Asia

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Research Article

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Abstract

The purpose of this paper is to show the effect of high troposphere winds and currents on low troposphere events at sea level. For this study, precipitation data from atmospheric stations in South Asia and west of the Zagros Mountains were used. After preparing these data, 500 and 300 hectopascal level maps were used to interpret the weather conditions. Vertical transect flow maps were used to identify the position of the jet stream. The results showed that the merger of the polar front jet stream and the subtropical jet stream provide the conditions for accelerating atmospheric currents and reaching more humidity and stronger ascent conditions to South Asia. Jet streams merger have three major effects on low pressure. If the Jet stream vorticity is the same as the curvature vorticity, the low-pressure centers on the low level will be strengthened, otherwise they will weaken due to the opposite effects. The low pressure under the Jet stream divergence area helps to strengthen it. The difference in wind speed in the jet stream with low pressures, stranger low pressures in the low level.

Introduction

This study presents a detection scheme for upper-tropospheric jet streams. Here is the acronym for polar front Jet stream (PFJ) and subtropical Jet stream (STJ). Atmospheric jet streams are swiftly flowing air currents thousands of kilometers long, a few hundred kilometers wide, and only a few kilometers thick. Wind speeds in the central core of a jet stream often exceed 100 knots and occasionally exceed 200 knots. Jet streams are usually found at the tropopause at elevations between 10 and 15 km (6 and 9 mi), although they may occur at both higher and lower altitudes. The jet stream situated near 30° latitudes at about 13 km above the subtropical high is the subtropical jet stream. The jet stream situated at about 10 km near the polar front is known as the polar front jet stream or, simply, the polar jet stream. Since both are found at the tropopause, they are referred to as tropopause jets. When the polar jet stream flows in broad loops that sweep north and south, it may even merge with the subtropical jet. Occasionally, the polar jet splits into two jet streams. The jet stream to the north. is often called the northern branch of the polar jet, whereas the one to the south is called the southern branch The looping (meridional) pattern of the polar jet stream has an important function. In the Northern Hemisphere, where the air flows southward, swiftly moving air directs cold air equatorward; where the air flows northward, warm air is carried toward the poles. Jet streams, therefore, play a major role in the global transfer of heat. Moreover, since jet streams tend to meander around the world, we can easily understand how pollutants or volcanic ash injected into the atmosphere in one part of the globe could eventually settle to the ground many thousands of kilometers downwind. The jet streams involved may be identified as the Arctic front jet stream, the interpolar and polar front jet stream, and the subtropical jet stream (Sidney M et al. 1962).

Reiter, E.R and Whitney, L .F said in 1969 that " The subtropical jet stream overrides the polar front jet stream one, and the air within it ascend. Cyclonic shears are very strong in this southwesterly flow east of the trough. Actually, while one jet axis may be apparent in the horizontal, there may be two, one superimposed on the other, in a vertical cross-section". Linwood and Whitney (1976) said that the storms occurred after the surface warm sector moved beneath the left exit region of the wind maximum associated with subtropical jet stream. Divergence is dominant over the jet stream exit regions and convergence over the entrance regions, which is found to be consistent with the vertical motion field in the ECMWF analyses (Hisashi N 1992).

Gallego et al (2005) said "the meridional distance between pairs of contour lines of the circumpolar stream function at 200 hectopascal (hPa), and identify jets using the minimum average distance between all considered pairs of contour lines". They said scheme requires jets to be circumpolar and thus cannot account for their discontinuous nature. Barnes and Hartmann (2010), Athanasiadis et al. (2010), and Woollings et al. (2010) said" infer mean jet axes using local maxima in the meridional profiles of the zonal wind. The latter approach works well for smooth mean fields".

According to the theory Haines and Mulanotte-Rizzoli, split-jet causes an explosive intensification of atmospheric phenomena (Haines. 1993). The looping nature of the polar jet stream has an important role in the development of mid-latitude cyclonic storms (Ahrens .C 2011). In the winter, almost all visible wind maxima are encompassed by only one jet body that covers considerable parts of the Northern Hemisphere. The choice of a particular wind speed threshold is somewhat arbitrary because it does not correspond to a fundamental change in the flow characteristics. Jet axes are an important aspect of the wind structure within jet bodies, because they can be related to at least two dynamical concepts describing the interplay between jets, wave breaking, and blocking. First, the location of the jet axis separates areas of main anti-cyclonic and cyclonic wave breaking, because the type of shear shapes the development of baroclinic disturbances (e.g., Davies et al. 1991) and determines the dominant type of wave breaking (Thorncroft et al. 1993; Rivière 2009; Barnes and Hartmann 2012). Second, the jet axis marks the line of maximum wind speed and is hence associated with a steep gradient in relative and potential vorticity (PV). This gradient constitutes a waveguide that determines the propagation and interaction of Rossby waves (Spensberger, C., T. Spengler and C. Li,2013). We apply these concepts to understand the effect of the pronounced ridge–trough couplet over the eastern of sea Mediterranean and the western of Iran that dominated in the winter rain.

Berry et al. (2007) introduced a scheme that does not suffer from any of these restrictions. Based on Hewson (1998), they detect finite-length jets of any orientation from instantaneous data to study African easterly jets. They use the fact that the wind shear changes sign across the jet axis, which is also reflected in a sharp gradient in the orientation of deformation across the jet axis (Spensberger and Spengler 2014). While the Berry et al. (2007) scheme performs well for African easterly jets, its value has not yet been demonstrated for upper-tropospheric jet streams. The main aim of this study is to adapt the Berry et al. (2007) scheme for upper-tropospheric jet detection and to demonstrate its value as a diagnostic for large-scale dynamics by pinpointing features in the synoptic evolution of the boreal winter 2013/14 that previously went unnoticed Spensberger , C., T. Spengler and C. Li,

Kadlec's describes as follows: "The northern polar jet stream is oriented in a trough-ridge pattern while the southern or Subtropical jet stream is curved anticyclonically. The average distance across the cirrus pattern varies from approximately 400 n.mi. in the area of formation east and south of the upper trough to between 1,000 and 1,500 n.mi. in the ridge. This extensive area of cloud cover occurs when the two jet streams converge to within 300 n.mi. in the trough area. If the separation between the two jet streams is 400 n.mi. or more, two separate areas of cirrus may form with clear skies occurring between the two jet streams near and downwind of the ridge line ....". The object of this paper is to expand on this concept by providing additional documentation.

While blocking events therefore come in several different flavours, one type dominates in Europe at least. and by most metrics that scientists have developed, Europe emerges as the region of most frequent events. amongst the mid-latitudes at least, Europe is 'blocking central'.

A typical European block develops as follows. at first, out over the Atlantic, the jet will likely be strong and fostering vigorous storm activity. these storms grow as Rossby waves, undulations of the jet north and south. so the jet snakes its way towards Europe, and as it gets closer the waves get larger, swinging further to the north and then back even further to the south. what occurs next truly counts as high drama on the jet stream : blocking is what happens when the Rossby waves break(Woollings ,Tr. 2019).

Discussion

Two groups of maximum wind velocity were determined at high levels of the troposphere and named subtropical Jetstream and front polar Jetstream. Both are western winds. The maximum wind along wind the subtropical Jetstream is at 200 hPa. While the front polar Jetstream is at level 300 hPa. Difant (1959) and karein (1979) believed that the interaction in the jet strean could play an important role in cyclogenesis in central and eastern Mediterranean Sea. Thorncroft and Flocas (1997) studied the interaction of two Jetstream in north Africa showing that the front polar Jetstream moved downward and interacted with surface instabilities associated with tropical Jetstream and caused a rotation. The subtropical Jetstream position is seen in Figure 1 over a 30-year period in North Africa and South Asia.

In this article, we are looking at the impact of merger of the two jet streams on heavy rainfall in Southwest Asia. For this purpose, heavy rain was considered on December 29, 2019. The extent of this precipitation was the western slopes of the Zagros Mountains in Iran. This precipitation caused a large flood in the Karun and Karkheh rivers. The floods destroyed towns, villages and facilities. In this flood, the Jetstream subtropical collide with the Jetstream of the polar front. Jetstream have three major effects on low pressure. If the Jetstream vorticity is the same as the curvature vorticity, the low-pressure centers on the low level will be strengthened, otherwise they will weaken due to the opposite effects. The low pressure under the Jetstream divergence area helps to strengthen it. The difference in wind speed in the jet stream with low pressures, stranger low pressures in the low level.

On December 20,2019, a huge floods hit the region of southwest Asia. The floods were caused by heavy rainfall caused by the merging of the subtropical Jetstream with the polar Jetstream. In the table no 1 provided illustration information about the rainfall in the three periods with floods in southwest Asia.

The importance of jet stream flow is that the speed surge moves eastward within Polar front jet stream. What is evident to note is that the speed surge moves eastward within Polar front jet stream, therefore, polar front jet stream and its speed surge play a role in guiding and moving the cyclones as well as the polar front jet stream. Therefore, just as the polar front jet stream plays a role in the formation of the cyclones, so does the polar front jet stream and its velocity cores play a role in guiding and moving the cyclones. In other words, the position and intensity of the mid-width cyclones depend on the shape and position of the waves that occur in the polar front jet stream, also, their displacement path is a function of the jet stream passage path. Cyclones are formed in the eastern part of the Polar front jet stream and descend to the east below the jet stream (Masoudian , 1390). Also, the seasonal shifting of the subtropical jet stream causes the intermittent domination of tropical and subtropical regimes over the Iranian climate. In the cold period of the year when this jet stream is located in the south of Iran, subtropical climatic factors such as westerly winds and cyclones enter Iran, but in the warm period of the year when the Jet stream is located in the northern parts of the country, tropical climatic factors are dominated Iran. (Alijani, 1374).

Prizrakos et al. (2005) analyzed the reciprocal relationship between the polar front jet stream and the subtropical jet stream by examining the cycles of March 15, 1998 in Cyprus and the relationship between the jet stream and the subtropical jet stream in the eastern Mediterranean cyclogenesis. The results show that the low-pressure mass that moved northeast from Cyprus and the Atlas Mountains on March 15, 1998, is associated with an increase in hydrodynamic instability due to the proximity of Polar front jet stream and subtropical jet stream. The polar front jet stream should be pulled south from its position and merge with the subtropical jet stream which is pulled north from its position; It is associated with an increase in hydrodynamic instability, which intensifies cyclogenesis process.

Harnick et al. (2014) by investigation the abnormal integration of African and North Atlantic jet stream in the Northern Hemisphere in winter 2010 and examination the North Atlantic jet stream, which was unusually regional in winter 2010. For this reason, the African and Atlantic jet stream, which were usually separate, joined together to form a regional jet stream. In addition, latitude-altitude and temporal variations of the North Atlantic jet stream during the period (winter 2010) had the characteristics of the North Pacific jet stream. In this study, which deal with the possibility of changing the ruling regime, defined a monthly index for the area of occurrence of storms, which indicates the occurrence of a stable and mixed storm in the past.

Climatic interpretation of precipitation on January 11, 2002

Figure (2) shows the jet stream’s map from January 8 to 11, 2002 at 300 hectopascal (hPa). The average rainfall in South Asia reached 46 mm per day on January 11, 2002. At 300 hPa, two jet streams can be detected, the jet stream that has affected Iran in southwest Asia and following the wave of westerly winds at high altitudes has spread as a long wave from North Africa from Libya to Central Asia. This is the subtropical jet stream. The central core of the jet stream with a speed of 70 meters per second from the east of the Persian Gulf and northeast of Saudi Arabia and Kuwait to East Africa. Gradually, in the following days, the core of jet stream moved to the east and reached the central part of Iran. In the north of the Black Sea, the core of polar front jet stream with a curvature to the south, transferred moisture and cold air into the subtropical jet stream from the Mediterranean Sea and the Black Sea. The wind speed in the polar front jet stream has reached 60 meters per second. At the 300 hPa level, with the transfer of cold air from high latitudes into the subtropical jet stream, the conditions of the lower levels became more unstable. This instability was transmitted to the southern parts of Asia by moving east of jet stream. The speed of rainy westerly winds has a significant relationship with the speed of subtropical jet stream.

Positive vorticity and subtropical jet stream curvature at 300 hPa are significantly associated with positive vorticity of pressure systems at sea level. Positive rotation and curvature are observed in Southwest Asia in figures 2(c and d). Divergence in the area of wind output from the core of jet stream intensifies the conditions of convergence at ground level and ascends of air dynamics. The direction of jet stream and the passage through the humid areas causes the moisture flux to the study area.

In Figure2 (a-d) the polar front jet stream, with a sharp curvature has, a north-south direction also cold air transmits high latitudes to the south. The polar front jet stream merges with the subtropical jet stream after reaching it. The merger of polar front jet stream in subtropical jet stream intensifies the wind speed and consequently boosts the transfer of moisture (clouds) from moisture sources at this level.

Climatic interpretation of precipitation on February 4, 2007

Figure 4 shows the position of jet stream from 1 to 4 February 2007 at 300 hPa. On February 4, 2007, the average rainfall in South Asia had reached 81.4 mm per day. At 300 hPa, two jet streams can be detected. The jet stream affecting Iran in southwest Asia and following the wave of westerly winds at high altitudes had spread as a long wave from North Africa from Sudan to Central Asia. The central core of this jet stream was located in the center of Saudi Arabia at a speed of 70 meters per second.

Progressively, in the following days, the core of jet stream moved to the east and reaches the central part of Iran. In the north of the Black Sea, the core of jet stream, the polar front jet stream with a north-south direction, transferred moisture and cold air into the subtropical jet stream from the Mediterranean Sea and the Black Sea. The wind speed in the core of the polar front jet stream had reached 40 meters per second. At the 300 hPa level, Transmission of cold air at high latitudes into subtropical jet stream, the conditions of the lower levels become more unstable, Thus, this instability is transmitted to the southern parts of Asia by moving east of jet stream. The speed of rainy westerly winds had a significant relationship with the speed of subtropical jet stream. Positive vorticity and subtropical jet stream curvature at 300 hPa were significantly associated with positive vorticity of pressure systems at sea level.

Figures 4 c and d show positive vorticity and curvature in North Africa. (What is evident to note is that) The wind outlet region from the core of jet stream was located in South Asia and on Iran. Divergence in the area of wind outlet from the core of jet stream, led to intensification conditions of convergence at the ground level and the ascent of air dynamics. The direction of the jet stream and the passage through the humid areas caused the moisture flux to the study area.

Figure 5 shows the vertical section of the atmosphere from sea level to an altitude of 100 hPa on February 2, 2007. Two cores of west wind speed can be seen. The wind speed in the core of the western jet stream reached 55 meters and the polar front jet stream reached 40 meters per second. The merger of these two rivers was created on this day. The confluence of these two winds increased the wind speed in the upper parts of the troposphere.

Climate Interpretation of precipitation March 25, 2019

While the rain had covered Iran for 4 days and the soil capacity in terms of water absorption had reached a maximum, the rain starts on March 25, 2019. At this stage, the rainfall in terms of volume and intensity caused a huge flood in the western provinces of Iran. The daily rainfall in the stations of southwestern Iran had reached more than 100 mm. The role of the Mediterranean region was significant in examining the weather conditions of these rainy days. Cold air had fallen from high latitudes into this low-pressure center. From the southern latitudes, warm air was advection to the north.

The infiltration of hot air from the south and cold air from the west, had caused the formation of a hot air front in the hot air froth in northern Iran and a cold front in the cold air froth in western Iran. The advection of hot air from the south to the southern region of Iran to the Zagros heights had caused an increase in temperature and snowmelt in the Zagros heights and an increase in the volume of runoff, especially in the western Zagros river basin.

One of the most important factors that was effective in the rains of February 25, 2019 was the merger of subtropical jet stream and polar front jet stream in the South Asian region. On March 23, 2019, the polar front jet stream core was located in the north of the Black Sea and directed atmospheric currents to the north-south. The center of the subtropical jet stream core was located in subtropical North Africa on Libya, and its tongues extended to South Asia. Trough-like curvature in southwestern Iran had induced positive vorticity in lower layers of the troposphere thus, it has exacerbated instability. The northern currents of the Arctic front had transferred the cold air of the northern latitudes into the subtropical jet stream and provided conditions for further rise (Figure 6).

Positive vorticity and subtropical jet stream curvature at 300 hPa were significantly associated with positive vorticity of pressure systems at sea level. Positive vorticity and its curvature were seen in South Asia in Figure a-6. The wind outlet region from the core of jet stream were located in South Asia and on Iran, in addition, its direction was from south to north. Divergence in the region of wind outlet from the core of jet stream, intensified the conditions of convergence at the sea level and the ascent of air dynamics. The direction of the jet stream and the passage through the humid areas caused the moisture flux to the study area. Figure d-6 shows a positive vorticity intensification in Southwest Asia.

Figure 7 shows the vertical transect of the atmosphere from sea level to an altitude of 100 hPa on March 25, 2019. Two jet streams surge had taken place on this day The merger of these two jet streams had taken place. The merger and confluence of these two jet stream, cause increases wind speed in the upper troposphere. With increases wind speed, more moisture reaches South Asia.

Conclusions

Troposphere in the northern hemisphere is controlled by two strong jet stream. Subtropical jet stream that is about 30 degrees' north latitudes and a polar front that moves above the polar front. Both of these jet streams go from west to east and strengthen western currents in this hemisphere. The polar front jet stream should be pulled south from its position and merge with the subtropical jet stream which is pulled north from its position; It is associated with an increase in hydrodynamic instability, which intensifies cyclogenesis process. Sometimes this phenomenon also occurs in the South Asian region and the polar front jet stream merges with the subtropical jet stream. In this case, South Asia is faced with an increase in positive vorticity, an increase in the divergence of the troposphere mid-level and the intensification of the speed of western winds. That leads to more moisture to the east. These conditions have been exacerbated by heavy rainfall and floods in South Asia and southwest Iran. The most suitable position of subtropical Jetstream is to intensify the instability of the underlying layer between Egypt and the west of the Persian Gulf, where the central core of Jetstream is located in southern Jordan. The most suitable position of polar front Jetstream is in north of black sea. Subtropical Jetstream causes warm, humid air advection of Red Sea and Persian Gulf and polar front Jetstream causes cold, humid air advection of Black Sea and Mediterranean Sea. Joining the two Jetstream in South Asia will lead to the formation of an air front, ascent and instability. Following these conditions, torrential rain is expected in South Asia. In the three selected days of January 11, 2002 and February 4, 2007 and March 25, 2019, heavy rainfall in South Asia, which was determined by the research conducted in this paper, was that strengthening the jet stream at high levels of troposphere was an important factor in strengthening the conditions of ascent and moisture transfer to this region.

Declarations

Conflict of Interest: The authors declare no conflict of interest.

Funding statement: The author received no financial support for the research, authorship, and/or publication of this article.

Author & Contribution: This article is the result of the author's personal research over the past two years.

Availability of data and material: The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Code availability: Software application or custom code is not used in this research.

Ethical Approval: Since this study did not involve human subjects, it did not require ethical approval statement.

Consent to participate: This study did not involve human participants.

Consent for publication: Author give his consent to the publication of the manuscript in Theoretical and Applied Climatology.

Statement:

I wanted to understand conditions that lead to heavy rainfall in the South Asia. One of the reasons for heavy rainfall is jet streams. Jet streams are high-velocity winds in the upper levels of the troposphere. With connected of jet streams increases the speed of westerly winds to the east. In this case, the moisture transfers to the study area increases. In this case, the moisture transfer to the study area increases and heavy rainfall occurs. Jet streams have three different effects:

1. They create dynamic cyclones.
2. They intensify the ascent of the air.
3. Increases moisture transfer.

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Table

Table 1: Precipitation in three periods with floods in Southwest Asia

Date of occurrence of precipitation	Regional average rainfall (mm)	Precipitation area
11 jan 2002	46	Southwest of Iran
4 feb 2007	100	Southwest of Iran
25 mar 2019	42	South of Asia

Figures

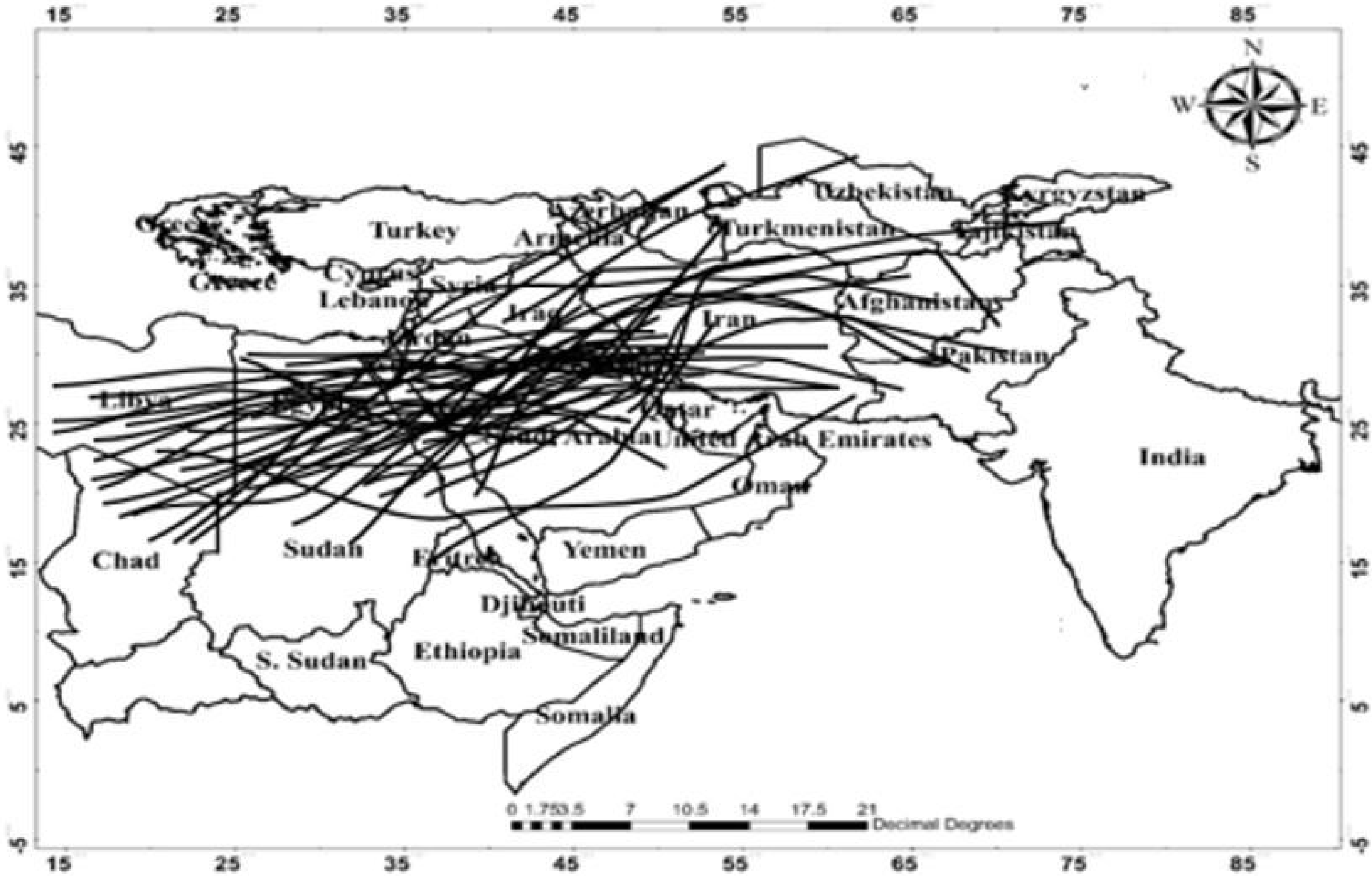

Figure 1

The position of the subtropical Jetstream over 2003-2004 in wet years in North Africa and South Asia (Mohammadi,Z. 2018)

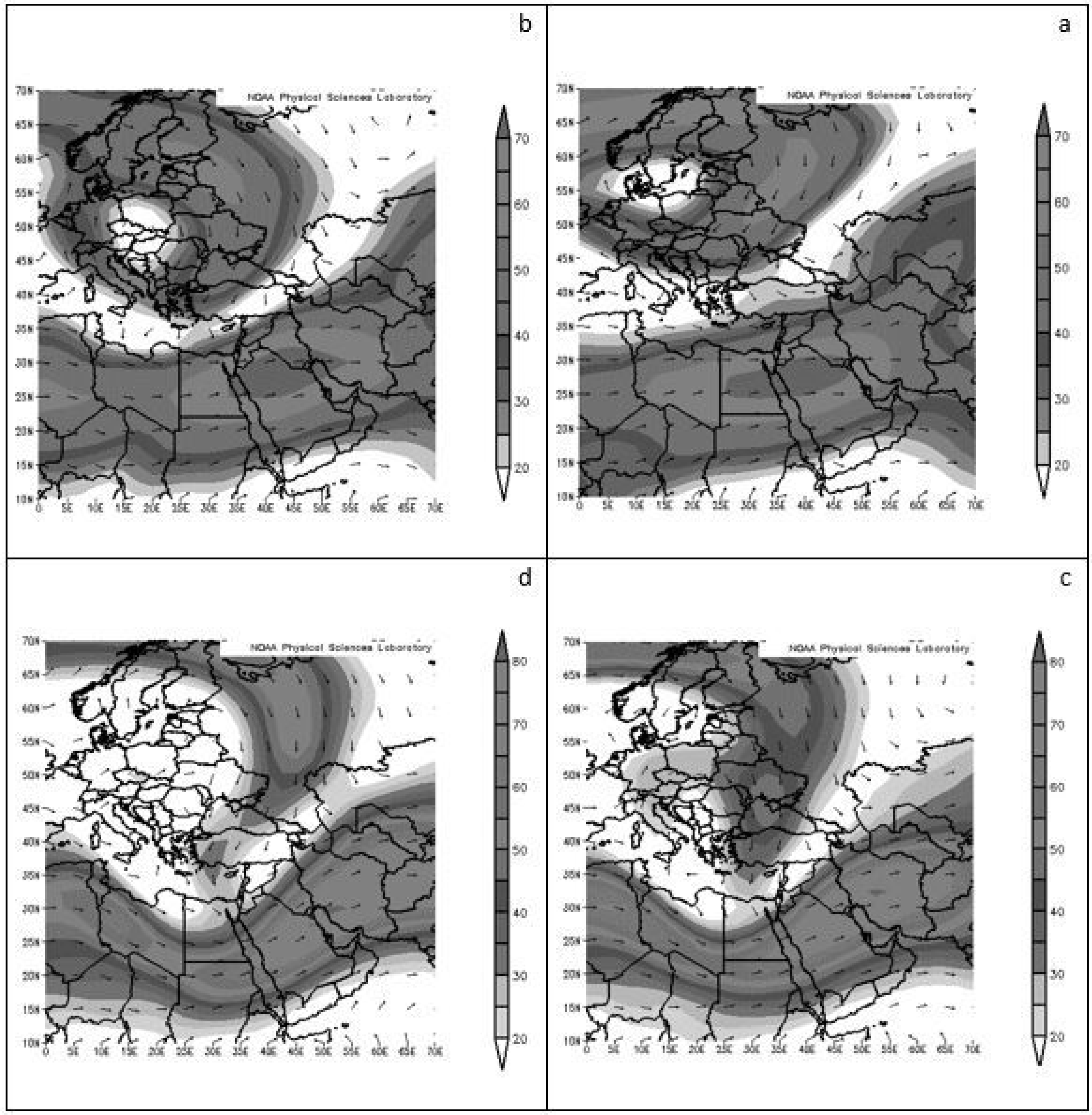

Figure 2

a:The position of the subtropical jet stream and the polar front jet stream on January 8, 2002 at the level of 200 hPa, the central core of the subtropical jet stream had been stretched at a speed of 70 meters per second in west-east direction and the polar front jet stream with direction The north-south was deeply curved and merged with the subtropical jet stream. b: The same situation On January 9, 2002, at the same level, the jet stream core moved eastward and settled on the Arabian Peninsula. c :The same situation On January 10, 2002, at the same level, the jet stream core moved further east and settled to the west of Iran. d : The Same situation On January 11, 2002, the day of maximum rainfall at the same level, the jet stream core had moved east then was located in central Iran.

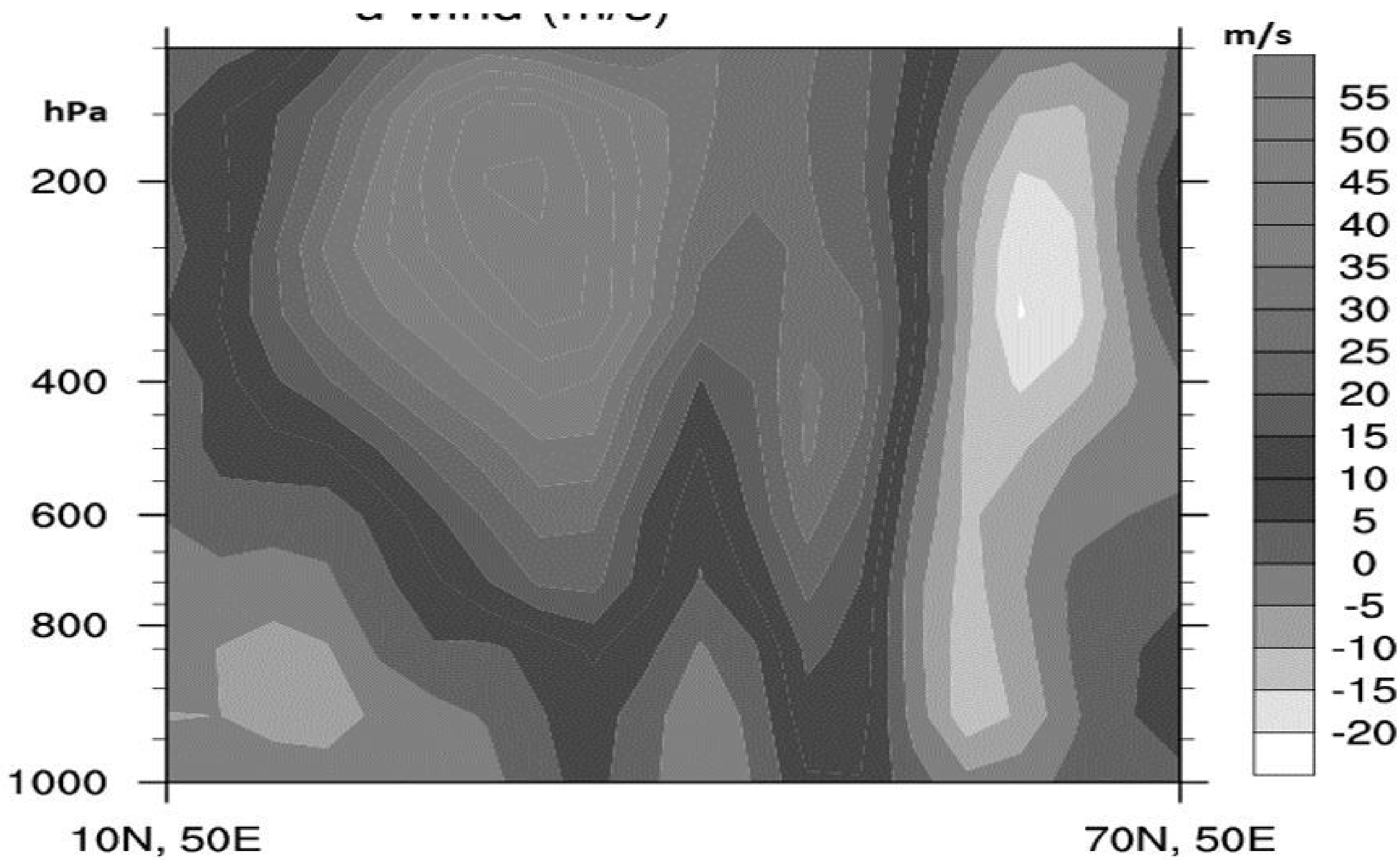

Figure 3

Vertical cross section of atmosphere and west wind speed, merged of subtropical polar front jet stream and polar front tornado, January 8, 2002

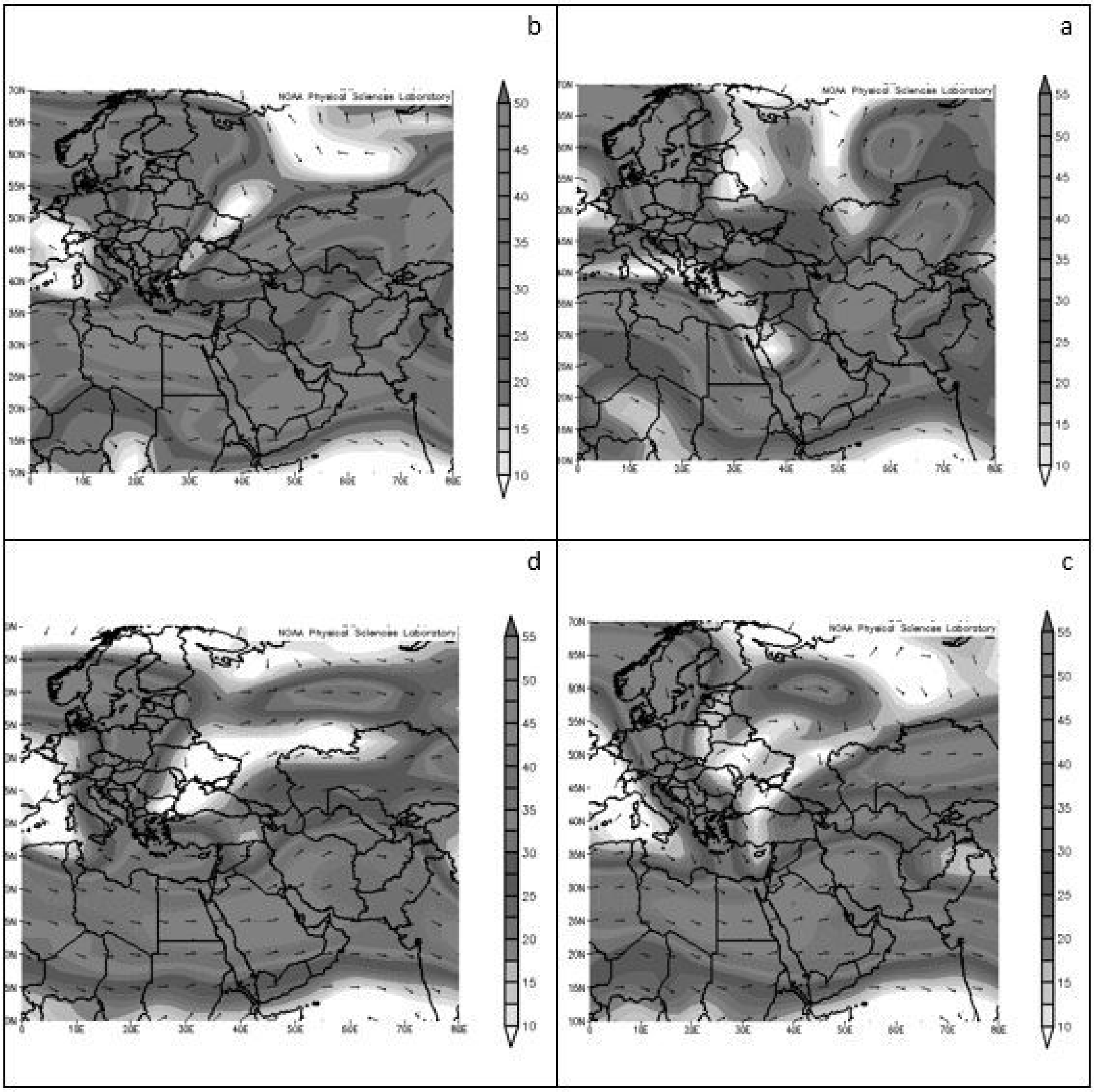

Figure 4

a- Position of the subtropical jet stream and the polar front jet stream on February 1, 2007 at the level of 300 hPa, the central core of the subtropical jet stream was stretched at a speed of 70 meters per second with a west-east direction and the polar front jet stream in a north-south direction. It had merged with the subtropical jet stream, also, polar front jet stream with north-south direction were merged with the subtropical jet stream. b- The same situation On February 2, 2007, at the same level, the core of jet stream went east and settled on Egypt. c - The same situation On February 3, 2007 at the same level, the core of jet stream had gone further east and reached the Black Sea. d - The same situation on February 4, 2007, on the day of maximum rainfall, the trough of jet stream had gone to the east and reached the center of Iran.

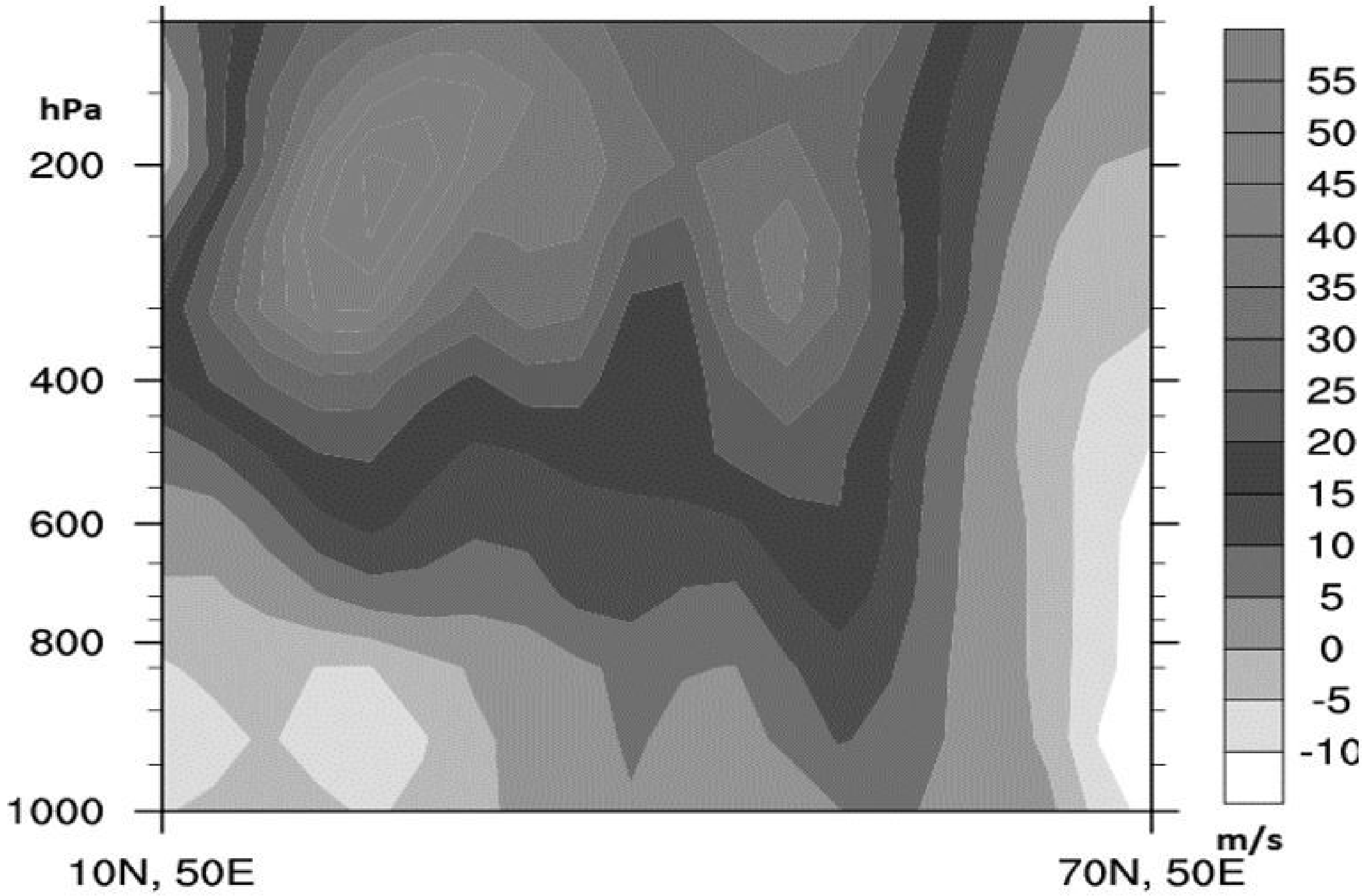

Figure 5

Vertical transect of atmosphere and west wind speed, merger of tropical jet stream and polar front jet stream in February 2, 2007.

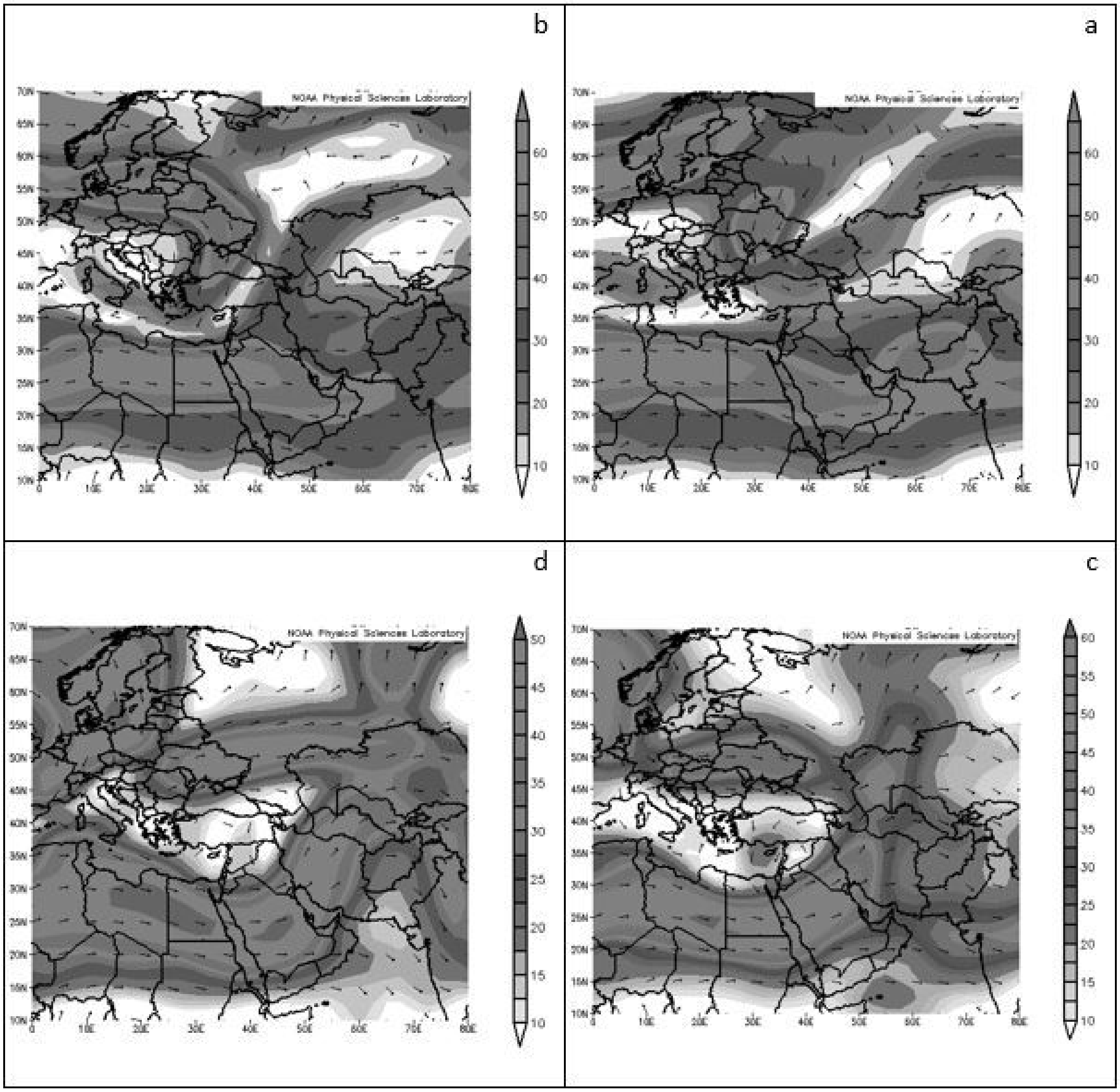

Figure 6

a- shows a Position of subtropical jet stream and polar front jet stream on March 23, 2019 at the level of 300 hPa, the central core of the subtropical jet stream with a speed of 70 meters per second was drawn in a west-east direction and the polar front jet stream was drawn in a north direction. The south was merging with the subtropical jet stream. b: The same situation On March 24, 2019 at the same level, the core of jet stream went east and reached Egypt. c: The same situation on March 25, 2019, at the same level as the day of maximum rainfall, the core of jet stream went further east and reached Saudi Arabia. d: The same situation on March 26, 2019, the tongue of jet stream on Iran has been pulled to the north.

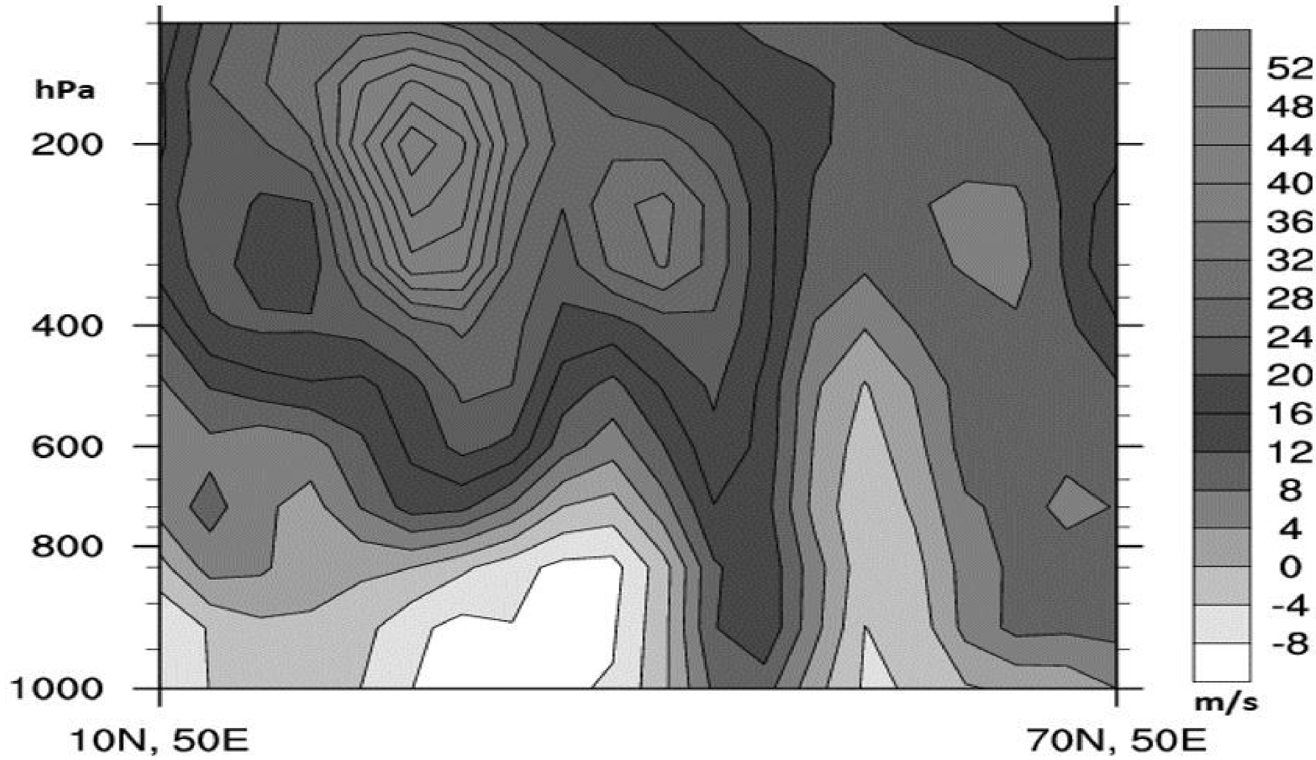

Figure 7

Vertical transect of atmosphere and west wind speed, merger of subtropical jet stream and polar front jet stream, March 25, 2019