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Meteorological Analysis of Severe Dust Storm over Middle East: Case Study

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Abstract

Dust storms are frequent across the Middle East but usually focus on Iraq and the Arabian Gulf region where clouds of sand are whipped up from arid areas. On 6 to 9 September 2015, a massive dust storm whipped across at least seven countries in the Middle East and enveloped the east Mediterranean. The storm was unusual for this time of year. The aim of this work is to investigate the meteorological conditions that led to the formation and spreading of the storm. Satellite images, aerosols index, surface and upper air weather maps were analyzed for the period of the storm. Satellite images indicated that the huge dust storm was a result of two merged storms, one came from the Syrian Desert and the second initiated over the Sanai Peninsula. Results showed that the region was dominated by a low-pressure system. Two thermal convection lows, which developed just above the Syrian Desert and the Sanai Peninsula, are believed to be main cause of lifting up dust from ground surface. The strong trough dominated the region indicated that there were a warm and dry weather conditions at the surface. The results also indicated that the horizontal wind patterns, at surface and 850 hPa pressure levels spread dust all over the region. The 850 hPa pressure vertical wind was notably negative (ascending air) over the two source areas of dust, while the vertical wind was positive (descending air) above the east Mediterranean and the coastal countries. This situation of descending air made dust to travel near the earth surface.

Keywords: Dust Storm, TOMS AI, Synoptic.

الخلاصة

العواصف الغبارية متكررة الحدوث فوق الشرق الأوسط ولكن حدوثها يتركز فوق العراق ومنطقة الخليج العربي حيث تهب كتل كبيرة من الرمال من هذه المناطق القاحلة. خلال الفترة من 6-9 أيلول (سبتمبر) 2015 هبت عاصفة غبارية كبيرة غطت سبعة بلدان على الأقل في الشرق الأوسط وغلفت شرق البحر الأبيض المتوسط وهذه العاصفة تعتبر غير اعتيادية خلال هذا الوقت من السنة. يهدف هذه البحث الى دراسة الظروف الأنوائية المسببة لهذه العاصفة ولعملية انتشارها. تم تحليل الصور الفضائية ومعامل الهباء الجوي وخرائط الطقس السطحية وخرائط طبقات الجو العليا لفترة العاصفة الغبارية. دلت الصور الفضائية بان العاصفة كانت نتيجة اندماج عاصفتين غباريتين واحدة نشأت من الصحراء السورية والثانية من شبه جزيرة سيناء. بينت النتائج بان المنطقة كانت تحت تأثير منظومة منخفض جوي. وان منخفضين الحمل الحراري التي تشكلت فوق الصحراء السورية وشبه جزيرة سيناء هما المسببان الرئيسيان لرفع الغبار من السطح. ان الاخدود الجوي الشديد والذي كان مسيطرا فوق المنطقة أشار الى وجود حالات طقس دافئة وجافة عند السطح. ودلت النتائج أيضا بأن أنماط الرياح السطحية وعند المستوي الضغطي 850 هيكتوباسكال ساعدت على انتشار الغبار فوق المنطقة. ان السرعة الراسية عند المستوي 850 هيكتوباسكال كانت سالبة بدرجة ملحوظة (هواء صاعد) فوق منطقتي مصدر العاصفتين بينما السرعة الرأسية كانت موجبة فوق شرق البحر الأبيض المتوسط والبلدان الساحلية وان هذا الوضع للهواء النازل جعل الغبار يتحرك قرب سطح الأرض.

Introduction

Dust storm is a natural event that occurs widely in arid and semi-arid regions around the world, especially in subtropical latitudes, it is characterized by strong winds, and dust filled air extending over a large area [1]. The most common events of the dust storms take place in the region extending from the west coast of North Africa through the Middle East into Central Asia [2]. In Iraq, severe dust storms are summertime phenomena associated with the Shamal. Shamal is a northwesterly wind blowing over Iraq and the Arabian Gulf countries (including Saudi Arabia and Kuwait),

often strong during the day, but decreasing at night. This weather phenomenon occurs anywhere from once to several times a year, mostly in summer and sometimes in winter. Much of the dust entrained by the Shamal is deposited in the Arabian Gulf region and the Arabian Sea. In some areas (e.g. Negev Desert, Jordan, western and northern Iraq and the northern part of Saudi Arabia), the peak dust season occurs in spring and winter. In these seasons, dust storms are generated by depressions moving eastward from the Mediterranean [3]. Dust storm is a major problem in Middle East that has a wide concern by research community; Abdi Vishkaee *et al.* [4] studied and analyzed the emission and transport of dust over Iraq and northwest Iran which is associated with strong winter Shamal events. Fattahi *et al.* [5] studied the synoptic patterns of the dust storms in southwest Iran for period 1961-2013. Al-Jumaily and Ibrahim [6] analyzed the synoptic patterns leading to formation the dust storms over Iraq. Hamidi *et al.* [7] analyzed of dust storms in Middle East during the period of 2003-2011. The analysis showed that the main dust sink for frontal dust storms in Tigris and Euphrates alluvial plain is extended from center of Iraq to west, center and north of Iran and south coast of Caspian Sea. Sissakian *et al.* [8] discussed the types and the main causes in development of sand and dust storms in Iraq and their regional and local extensions. They found that the regional event generally extends to the surrounding regions of Iraq, and the most effective reason from the local causes is the haphazard driving and military operations especially in the Iraqi Southern Desert. Sehatkashani *et al.* [9] evaluated the behavior of dust events by applying 3 hourly intervals dust records of 35 national synoptic meteorological stations in western and southwestern Iran for period 2000-2009. Dehghanpour *et al.* [10] analyzed the synoptic conditions of dust systems in Yazd Province to understand the formation and origin of dust and to help in reducing damages in this area. Mashat and Awad [11] examined the statistical and synoptic features of the various classes of autumn dust over the Northern Saudi Arabia by using the aerosols index from TOMS satellites. Ghandali *et al.* [12] analyzed the synoptic conditions of dust storm in Ahwaz city by using NOAA data and arranging of sea level pressure patterns and level of 500 hPa to study the formation of the sources of dusts. On 6 to 9 September 2015 a thick cloud of dust covered the Middle East countries and Eastern part of the Mediterranean. The cloud was formed as results of two dust severe storms that merged together. These storms were unusual for this time of the year and came soon after another dust storm, which was a typical shamal dust storm. The storm took a cyclonic shape over Iraq on Sept. 1 and moved southeast towards the Gulf on the next two days. The aim of this work is to analyze the meteorological situations of the 6-9 Sept. dust storms.

Materials and Methodology

Figure 1 shows the geographic map of western part of the Middle East that was affected by the 6-9 September 2015 dust storms. Satellite images of the dust storms captured by the Meteosat Second Generation satellite were provided by the EUropean Organization for the Exploitation of METeorological SATellites (EUMETSAT). Dust is detected by an RGB composite based upon infrared channel data. It is designed to monitor the evolution of dust storms during both day and night. The Dust RGB is composed of a combination of the SEVIRI IR8.7, IR10.8 and IR12.0 channels [13]. Analysis of dust concentration is based on an Aerosol index derived from the Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite [14]. Positive values indicate the presence of absorbing aerosols such as desert dust [15] [16] .Meteorological variables related to the emission and transportation of dust storms include surface variables (mean sea level pressure and horizontal wind) and 850 hPa pressure level (geopotential height, horizontal wind, vertical pressure wind). Data of these variables were obtained from the European Center for Medium-Range Weather Forecasts (ECMWF) reanalysis data with $1^{o}\times1^{o}$ resolution [17]. Data were processed by freely available software of MeteoInfo [18].

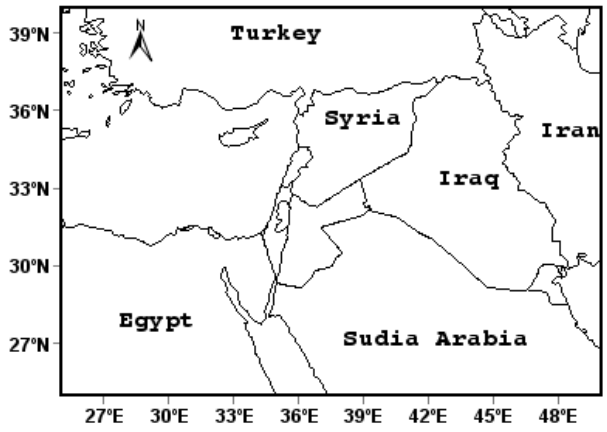

Figure 1: Map of the area of interest.

Results and Discussion

Figure 2 shows the Meteosat images of the dust storms for days, 6 to 9 September 2015 at 12 UTC. Pink color indicates dust and brown color indicates cloud. It is clear that the first storm was initiated on 6 Sept. from a region near the Turkey, Syria, and Iraq borders. This region is considered a major dust source in the region due to the decline in farming and damage caused to the land due to ongoing conflicts in northern Iraq and Syria. Later on the same day the storm took a semi-circle shape as it moved southwest covering most of Syria. On 7 September the dust was spread into two directions; west-ward covering north Lebanon, east cost of the Mediterranean, and Cyprus; and south-ward covering the Jordan-Iraqi border area. The bluish-colored area inside the storm region indicates the local dust that was picked up and merged with the primary dust storm. On 8 Sept. the storm moved to the west and dust covered all countries on the east cost of the Mediterranean and large parts of the east Mediterranean. On the same day, a second dust storm was triggered in the Jordan-Saudi Arabia border region and started to merge with the first storm. On 9 Sept. the two storms completely merged and spread northeast toward Iraq and southwest covering the north part of Egypt. Figure 3 illustrates the daily AI for the storms period. The maps clearly indicate that the first storm started with AI value of more than 3.3 at the center of the storm. On the 7 and 8 Sept. the storm became thicker with AI values ranging from 4 to 4.5. On 9 Sept. the AI, values were more than 5 which indicate a high concentration of dust. Figure 4 gives the chart of mean sea level pressure (shaded patterns) and horizontal wind speed (barbs) for the four days' period of the storms. It is clear that the area was dominated by a low-pressure system. The center of the system was located over the middle of Iraq on 7 Sept. and moved southwest towards Saudi Arabia on the next day. On 8 and 9 Sept., the system was loosening its strength but remained on same area. It is notable that on 6 Sept. a thermal convection formed over Syria, which is believed that this is the main cause of lifting dust from the ground into air aloft. On 7 Sept., the wind was circulating counter-clockwise around the center of low-pressure system and spreading dust over entire area located west of the center of the system. On 8 Sept., two thermal convection area are notable, one was located over the Gulf of Aqaba and the other one was located over the north part of Saudi Arabia. On 9 Sept., the two thermals were lifting spreading dust westward. On the same day, this new storm was merged with first storm forming a huge storm that covered the entire region. Figure 5 shows the 850 hPa geopotential height (Shaded) and horizontal wind (barbs) maps for 6 to 9 Sept. 2015. It is clear that during the four days of the storms, the region was dominated by a distinct trough, i.e. geopotential height bend strongly to the north, strong troughs are accompanied by warm and dry weather conditions at the surface.

The horizontal wind patterns show that on 6 Sept. two thermal lows formed, one over the Iraq-Syria borders and the second over the Gulf of Aqaba and they slightly moved southward on the next day. On 9 Sept., wind was northeasterly over areas just west of the thermal lows. It is believed that such wind pattern has helped spreading dust all over the area. Figure 6 shows the 850 hPa pressure vertical velocity for 6 to 9 Sept. 2015.

It is clear that a relatively strong upward motion (negative vertical velocity) existed over

western part of Iraq and eastern part of Syria, where the first storm was initiated. This strong upward motion has helped lifting dust upward

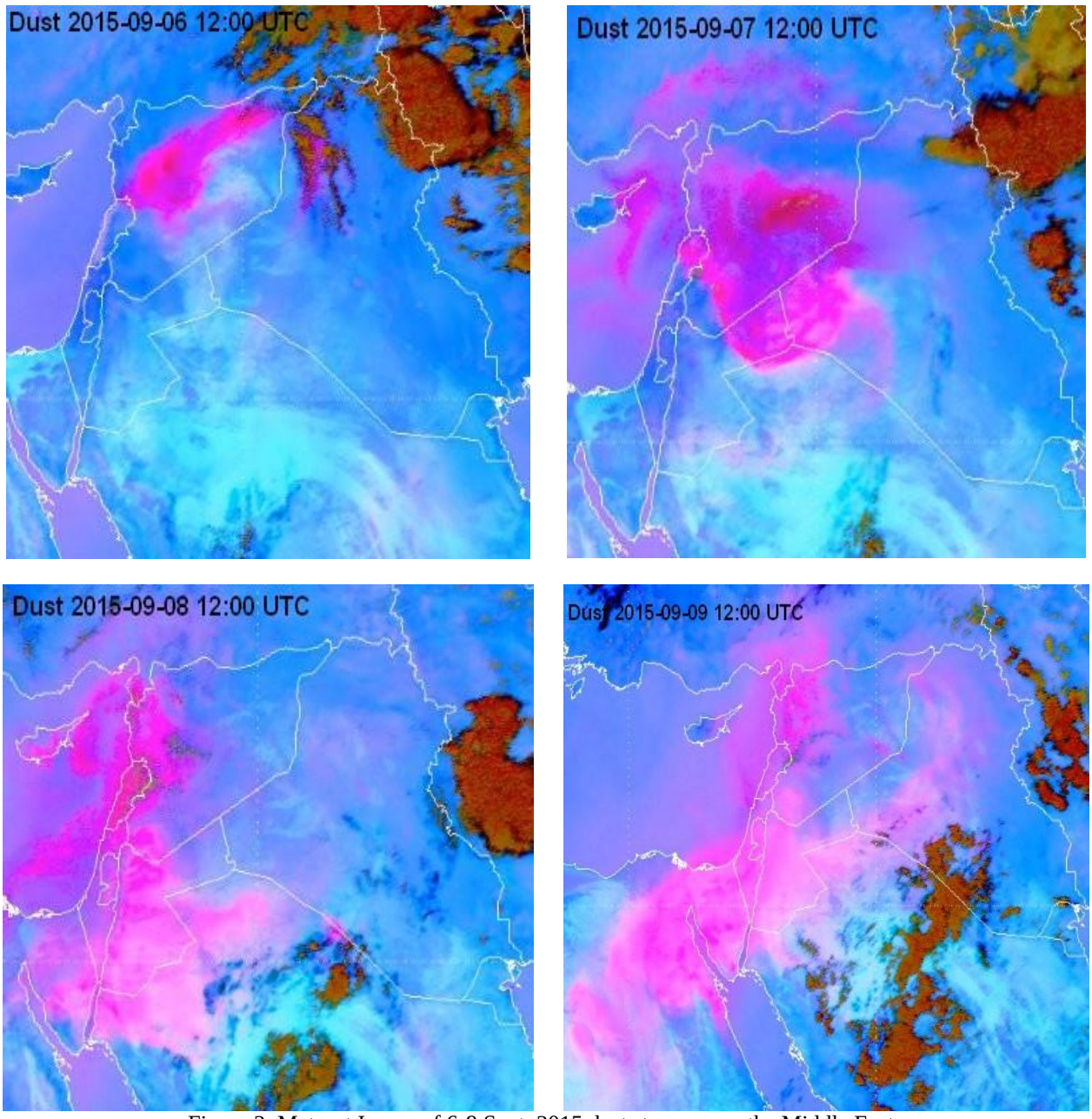

Figure 2. Metosat Image of 6-9 Sept. 2015 dust storms over the Middle East.

The vertical velocity was weakening on this area for the following three days. On 8 Sept. another strong vertical velocity area (but slightly less strong than the first) was located over Sinai Peninsula and was getting stronger on 9 Sept. It is believed that the second dust storm was associated with this pattern of the vertical velocity. Also it's notable that on 7 and 8 Sept., the vertical wind was positive (downward motion) over the eastern coast of Mediterranean thus keeping dust near the ground over these areas.

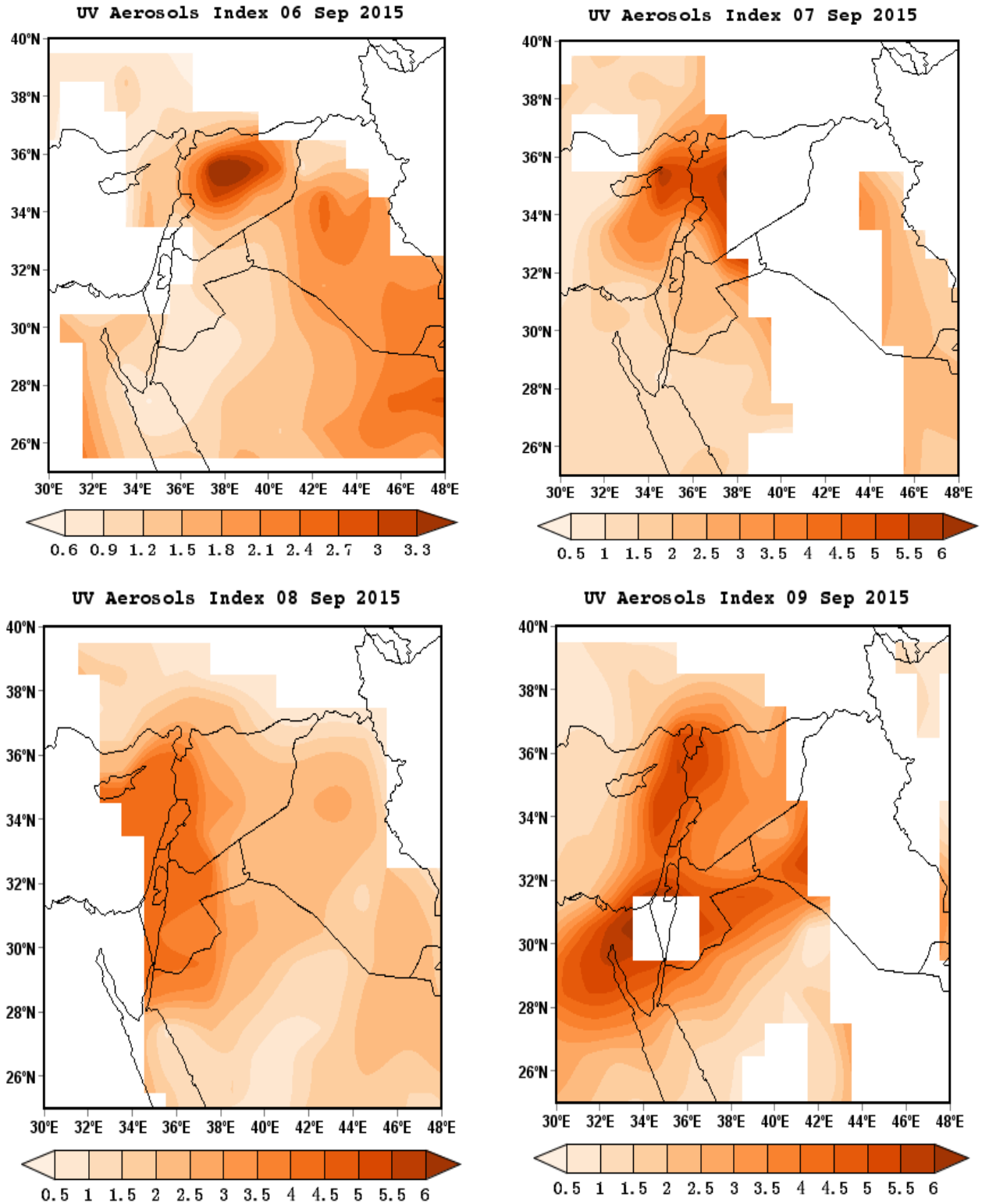

Figure 3: UV Aerosols Index for 6-9 Sept. 2015 over Middle East.

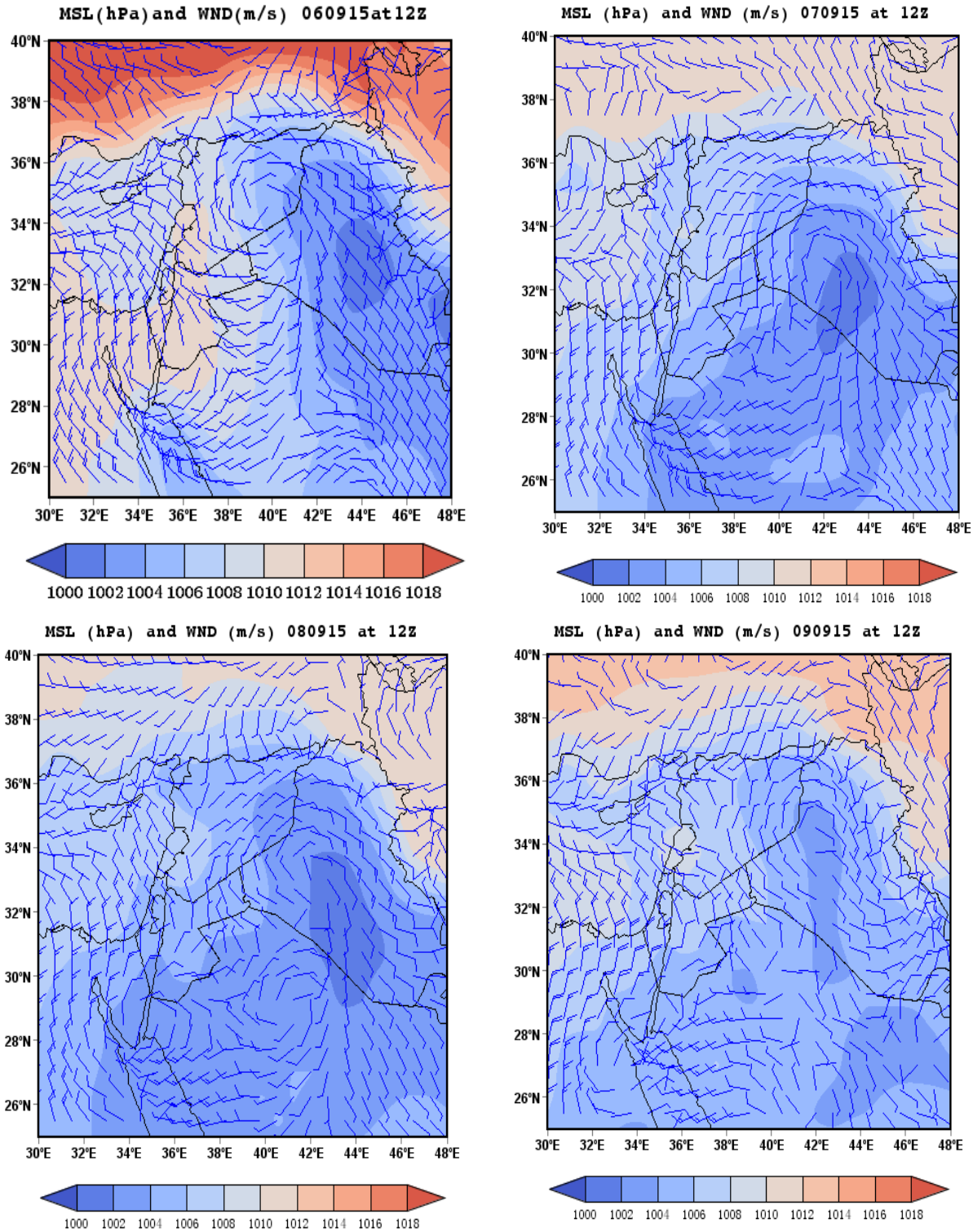

Figure 4: Mean Sea Level Pressure (MSL) and Surface Wind (WND) maps for 6-9 Sept. 2015.

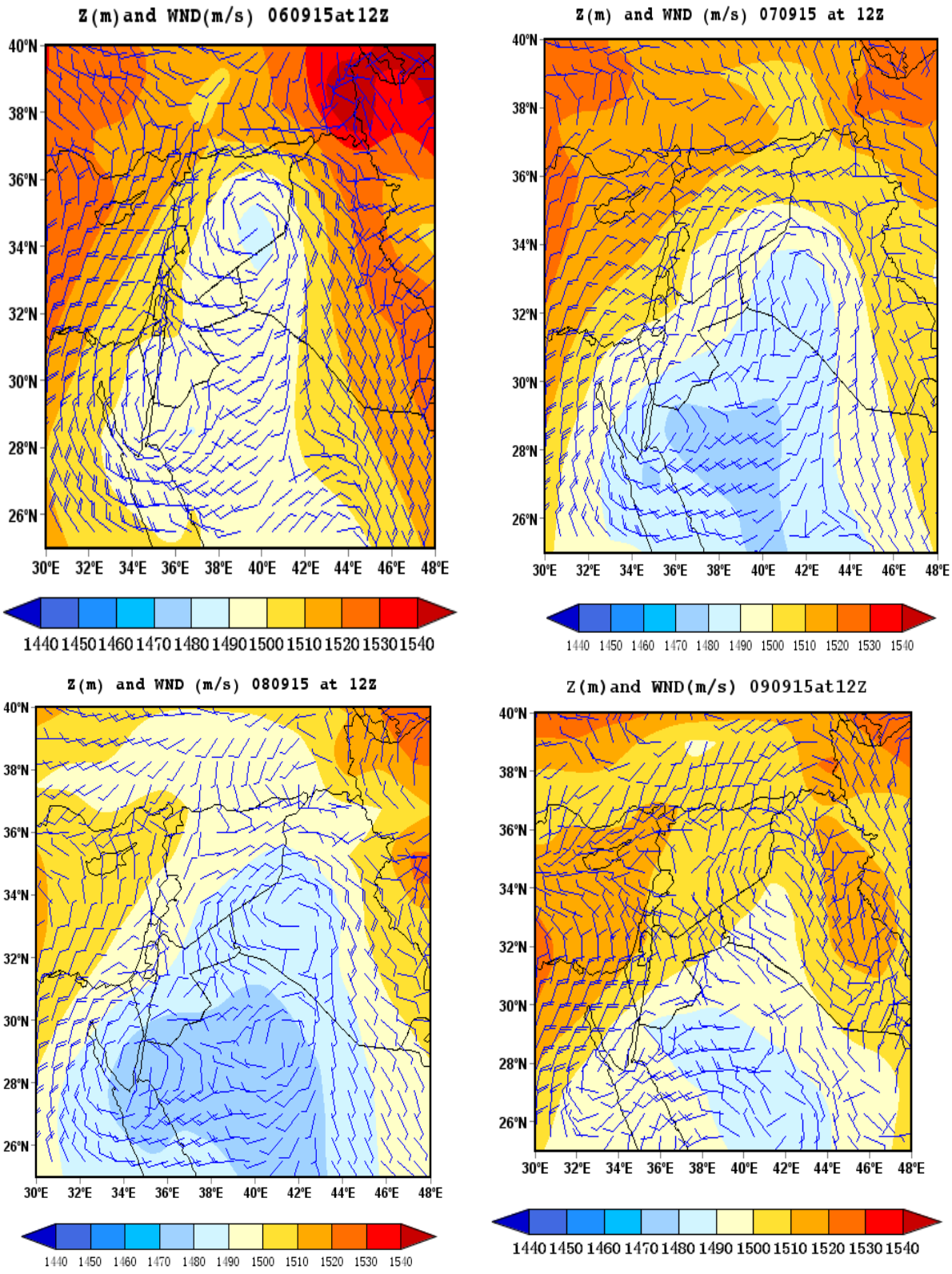

Figure 5: 850 hPa geopotential height and horizontal wind maps for 6-9 Sept. 2015.

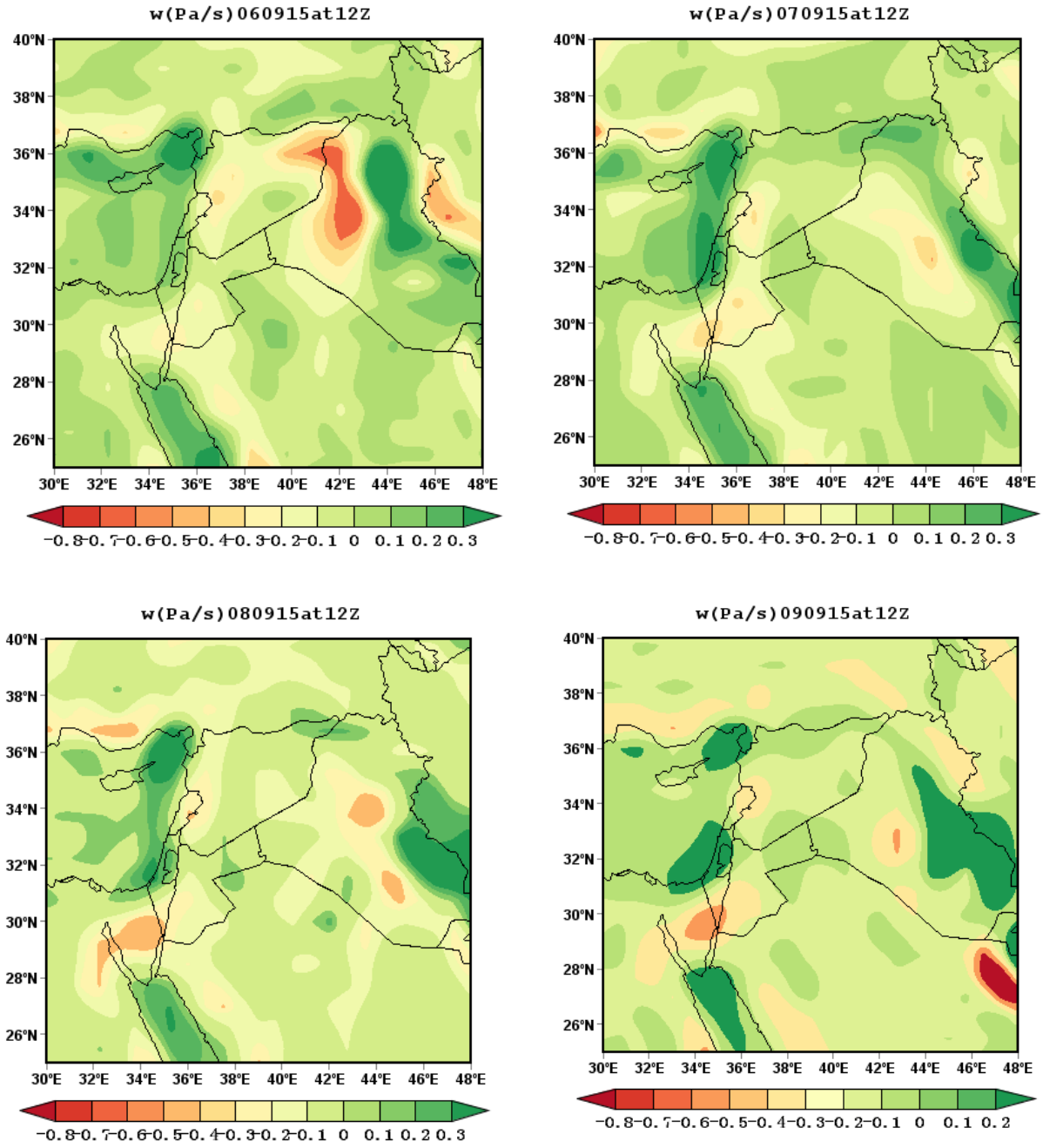

Figure 6: 850 hPa pressure vertical velocity maps for 6-9 Sept. 2015.

Conclusion

The present study analyzed the severe dust storm that has occurred in the Middle East on 6 to 9 September 2015 and showed that the storm came because of two merged storms. The strong dust storm was blown from the Syrian Desert and the second storm formed over the Sanai Peninsula. The region was dominated by a low surface pressure and a strong ridge at 850 hPa pressure level. The ridge is an indicator of dry and warm conditions at the surface. In addition, thermal convection lows formed during the daylight times over the dust source areas helps lifting dust from surface into the air. The storm under investigation was unprecedented for this time of the year. It is believed that the decline in farming and damage caused to the land due to ongoing conflicts in northern Iraq and Syria contributed to the heavy dust storm that hit the Middle East.

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