Exp. Theo. NANOTECHNOLOGY 10 (2026) 661-679 https://doi.org/10.56053/10.2.661

Nanodata technology enhances the monitoring of snowstorm over Baghdad city

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Received 21/1/2026, *Received in revised form* 27/3/2026, *Accepted* 22/3/2026, *Published* 15/4/2026

A snowstorm is a type of winter storm. It is accompanied by strong winds, reaching speeds of about 56 km/h and a little more, as rain forms in the form of snow inside the clouds in the winter; Because the temperatures at the top of the storm are cold enough to form flakes of snow, as snow grains are a group of ice crystals that form when water vapor condenses inside water droplets and freezes. The strength of the storm is determined by the winds accompanying it and not the amount of snow resulting from it, and it can be. The storm may last for about three hours or more. The choice of the year 2020 over Baghdad city, located between the two latitudes (33.375° - 44.375°) North and longitudes (33.375° - 44.375°) East. Otherwise, the hourly mean of low, medium, and high cloud cover (LCC, MCC, HCC), as well as temperature (T), relative humidity (RH), and height. As well as Snow Albedo, Snow Density, Snow Cover, Snow Depth, Snow Fall, and Snow Melt. And results that the snow albedo is observed high from 12 days to 4:00 pm, snow cover is high from 10 days to 01:00 am, snow density is observed to be high from 12 days to 04:00 am, and snow depth is observed to be high from 10 days to 02:00 am and snowfall is observed high during 11 days to 06:00 am and snow melt is observed high during 10 days to 00:00 am.

Keywords: Synoptic analysis; Atmospheric; Snowstorm; Nanodata.

1. INTRODUCTION

1.1 Nano data technology

Nano data technology plays an increasingly important role in synoptic and extreme weather analysis through the use of nano sensors, nanomaterials, and nano-enabled data processing systems. In the synoptic analysis of the snowstorm that affected Baghdad City on Feb. 11, 2020, nanotechnology can enhance the monitoring and interpretation of atmospheric conditions associated with rare cold-weather events in arid regions [1].

Nano-based sensors enable high-resolution measurements of key meteorological parameters such as temperature, humidity, aerosol concentration, cloud microphysics, and radiative fluxes. These sensors, when integrated with satellite observations and numerical weather prediction outputs, improve the detection of rapid atmospheric changes preceding snowstorm formation. Nanomaterials such as metal-oxide nanoparticles and graphene-based sensors offer fast response times and high sensitivity, allowing accurate observation of boundary-layer cooling, moisture transport, and cloud nucleation processes [2]. In this case study, nano data technology supports synoptic-scale analysis by providing detailed local-scale observations that complement reanalysis and satellite data. The integration of nano sensor observations with GIS, remote sensing, and atmospheric models contributes to a better understanding of snowfall mechanisms over Baghdad, including cold air advection, vertical instability, and aerosol–cloud interactions. Consequently, nanotechnology-based monitoring systems represent a valuable tool for improving early warning systems and impact assessment of unusual weather events in Iraq [3]. When snow and cold are combined with extremely high winds that last for several hours or perhaps overnight, the result is a severe storm known as a blizzard [4]. The intensity of the winds is what distinguishes severe blizzards from ordinary ones. At least 35 mph (56 km/h) of wind can produce a severe blizzard, which is characterized by strong gusts and snow drifts that lower visibility to 0.25 m (400 m) [5]. A typical blizzard or even a typical snowfall can quickly become a severe blizzard since blizzards typically bring with them extremely low temperatures, strong winds, ice, freezing rain, and slush. For a number of reasons, Blizzards can be quite dangerous. There are blizzard winds that are stronger than hurricanes and some that are just as fierce. Strong gusts and never-ending precipitation can make blizzards continue up to five days [6]. Some of them can result in a scene that is entirely white, which occurs when there is little to no visibility due to heavy snowfall [7].

1.2 A cold day in hell snow in Baghdad

There is no mistaking the stench in the air in Baghdad early Friday morning. A faint, metallic smell pervaded the city as the gloomy day broke. And at 8:00 a.m., anyone who has witnessed fall transition into winter north of the Mason-Dixon Line would have informed you that it meant snow [8]. As snowflakes appeared in the distance and drifted sideways through the city, the light rain that is pouring in Baghdad on Friday local time is turning to ash. The silence that followed as the puddles ceased to crackle with drips appeared to obscure the morning call to prayer that rose from mosques [9]. People on the streets, huddled in bulky coats, looked up in awe. Nobody in Baghdad could recall the last time they had seen snowfall. According to several Iraqis, this had never occurred. Others asserted that snow arrived in Baghdad over 40 years ago, when the city had many smaller green spaces rather than a single large green area. As the snowfall persisted for a large portion of the morning, everyone appeared shocked, and Baghdad slowly woke up, as it always does on Fridays, the first day of the weekend. This winter, the capital has been particularly frigid, with nighttime lows staying just above freezing for days at a time. The city has not experienced such cold weather in at least a decade, according to longtime inhabitants, and many people struggled to keep their houses warm during the ongoing power outages [10]. Geographical characteristics facilitate the interaction of cold air from the north with warm, humid air from the south, resulting in the formation of a snowfall near a center of low pressure. As a result, warm air from the south and cold air from the north are forced toward the low-pressure area, where they collide and start to circle the low-pressure core. The cold air is forced beneath the warm air in a counterclockwise direction; due to the fact that warm air is lighter; Its higher temperature causes the warm air to become colder and more humid as it rises. This cold air then freezes into snow, ice grains, or frozen rain, which falls through the cold air mass and is swiftly carried to the ground by the blizzard's powerful winds [11]. A snowfall can only form if three conditions are met: cold air, rising warm air, and humidity. For snow to fall, cold air below the freezing point is required, and snow storms can occasionally form when strong winds carry the snow that has fallen. Low temperatures in the clouds and on the ground are also necessary for snow storm formation. Heat will melt if the Earth's air is not cold enough because temperature is forced [12].

Rain or freezing rain could result from this. Water vapor is what makes the air moist, and breezes that blow across a big lake or the ocean are good sources of moisture. Snowstorms are also impacted by lakes and oceans because when the wind blows over them, water starts to evaporate from the surface. However, a large amount of water vapor cannot be carried by cold air. Since a snowfall can only form if warm air rises above cold air, rising warm air is crucial for cloud formation. This occurs in two situations: In addition to bringing warm air from the poles to the equator, winds also carry cold air from the poles to the equator and mix the two. Snowfall happens when a front forms. These are the primary causes of snowstorms and the conditions necessary for them to occur. Figure 1 illustrates that while the temperature stays at or below 0 degrees Celsius from the cloud base to the ground, precipitation keeps falling as snow [13].

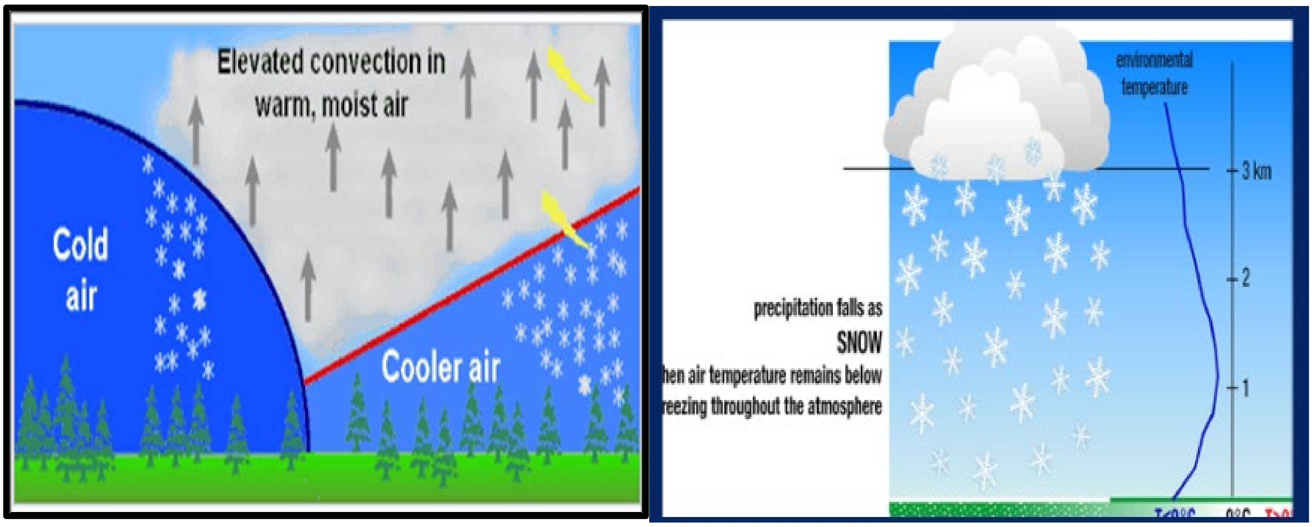

Figure 1 Snowstorm condition [13].

There are four types of snowstorms [14]:

1. Winds in the presence of snow (Wind + Snow = Blizzard): Even though snow accumulates on the earth's surface, consistent snowfall is not a snowstorm; rather, a snowstorm is defined as one that lasts three days and is accompanied by winds exceeding 56 km/h. There will be enough snowfall to cut visibility to 400 meters or less, at least for a few hours.
2. Large-Scale Frontal Blizzards: These occur when the weather system has low pressure in the winter, when the winds circle the extratropical cyclone in a counterclockwise spiral, and when fronts form, where air masses collide with one another around the turbulence. This process raises one air mass above another, which results in precipitation. Cold air then prefers to descend to the west from these low levels, which typically results in snowfall.

3. Ground Blizzards: These types of blizzards can happen when there is no snow falling, but they are more common because there are fewer barriers to the wind flow, and the accompanying winds are powerful enough to push the snow falling either horizontally or upward.
4. Mountain Blizzards: Because snow storms originate in mountains and high altitudes, winds are typically greater than at lower elevations, and the rough terrain influences and intensifies the storm's path. As a result, high mountains get a lot of rain that turns into snow. Mountain snowstorms are prevalent due to the combination of strong winds and heavy snowfall, which is caused by the lower temperatures at higher elevations.

There are three stages of snowstorms [15,16]:

Development stage: Masses of moisture are raised into the atmosphere during the first stage of a blizzard, where heat is produced by the ground heating, where two winds collide and force air upward, or when winds blow over terrain that is getting higher.
Because high altitudes have lower temperatures, moisture carried upward cools into liquid droplets of water, which manifest as cumulonimbus clouds. Latent heat is released when water vapor condenses into a liquid, warming the surrounding air and reducing its density. Convection causes the air to tend to rise in an updraft.
Maturity stage: Warm air keeps rising throughout a thunderstorm's mature phase until it reaches a region of warmer air and is unable to rise anymore. The tropopause is frequently this "lid." Rather, the air is compelled to disperse, which gives the storm its characteristic anvil shape. Cumulonimbus is the name of the resulting cloud. Droplets of water congregate to form heavier, bigger droplets, which then solidify into ice particles. It melts and turns into rain as it falls. The drops remain in the air long enough to grow so big that they fall as hail instead of melting entirely if the updraft is strong enough.
Dissipation stage: The storm controls the downward direction during the dissipation phase. From the storm, clouds will push downward, hit the ground, and disperse. The storm evaporates when the updraft vanishes and the storm's flow is interrupted by cold air transported to the ground by the downdraft. Figure 2, illustrates how storms wane in the absence of vertical wind shear.

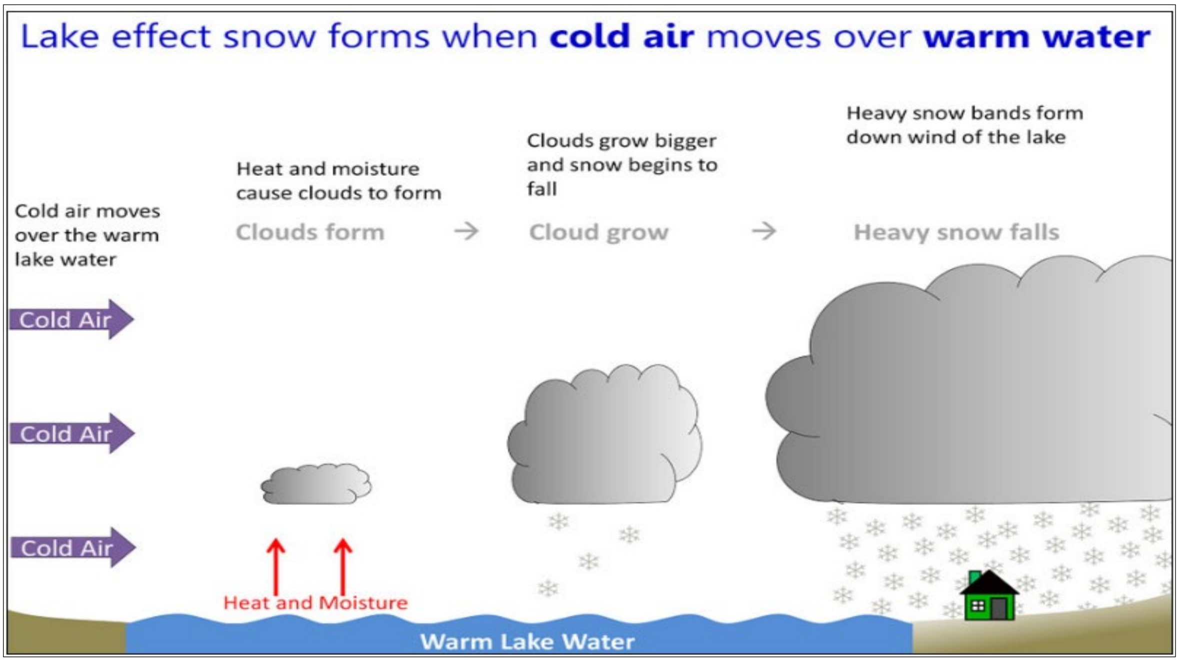

Figure 2 The stages of growth and development of snowstorms [15].

The mechanism develops perception to create the droplet, which forms the clouds, it needs what is known as condensation nuclei, CNN. Cloud condensation nuclei CCN are defined as particles that can nucleic cloud droplets. it is a solid or liquid aerosol particle that is water soluble, such as salt particles. The condensation nuclei help the droplets to overcome the surface tension of the curved surface. With a large number of condensate nuclei, the water vapor content is divided between these nuclei to produce a large number of very small droplets that form clouds [17]. The diffusion of water vapor causes these droplets to grow slowly, and the droplets are distributed according to their size in a monodisperse distribution. This distribution reduces droplet collisions and does not promote droplet growth, so got clouds but no rain. In warm clouds where the temperature is above 0 °C, rain can form in the tropics, especially over the oceans, where fewer CCNs are allowing the formation of a smaller number of larger droplets. There is a difference between the growth of water droplets and the growth of ice crystals [18]. In clouds cooler than 0 °C, ice crystals grow faster than water droplets, as ice crystals need less water vapor saturation than water droplets. Most of the water is transferred to ice crystals, which are then heavy enough to fall off like precipitation. Some clouds, consisting of ice crystals and super-cooled cloud droplets, which are called mixed-phase clouds MPC, play a major role in precipitation in most mid-latitude depressions, through the seeder and feeder process as shown in Figure 3 [19].

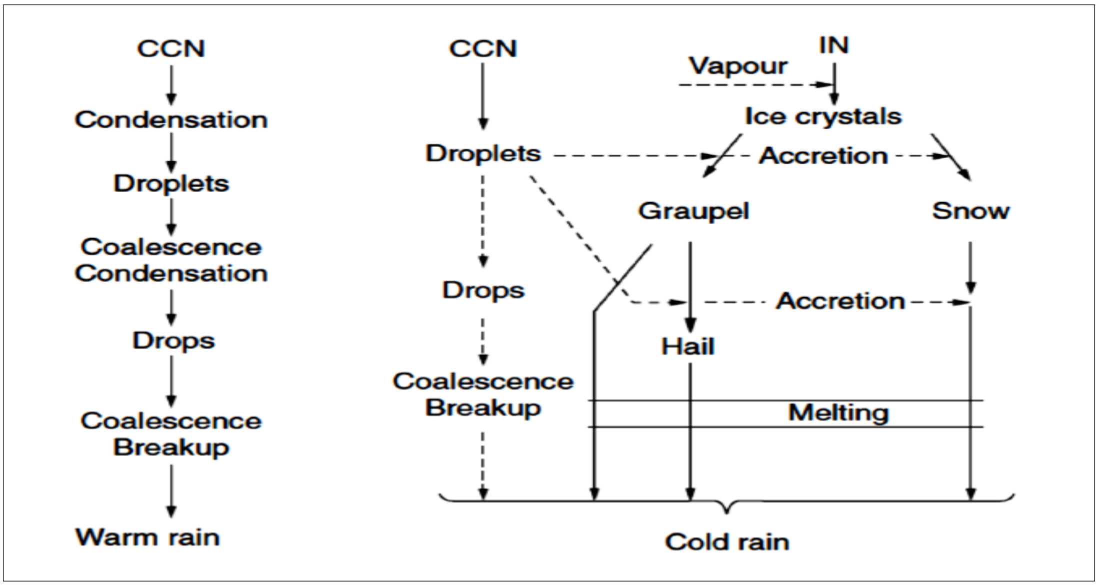

Figure 3 A diagram showing precipitation [19].

2. DATA AND METHODOLOGY

2.1 Study stations and location

The city of Baghdad, which is located in the center of Iraq on both sides of the Tigris River and has coordinates of 33.20" N, 44o 23" E, and 34 meters above sea level, serves as both the country's capital and its primary administrative hub [20]. Baghdad is home to roughly 7.8 million people [21]. Baghdad experiences hot, long, dry summers, chilly winters, and brief springs due to its semi-arid, subtropical, and continental climate [22]. The winter months of October through May see a lot of rainfall, with an average of 140 mm per year [23]. Summer temperatures ranged from a high of 51°C to a low of -4°C [24]. The hourly averages of temperature, height, and relative humidity as well as the cloud cover of LCC, MCC, and HCC for the three days (10-12 Feb. 2020) over Baghdad are obtained from the European Center for Medium-range Weather Forecasts [25]. The following formulas are used to determine the dew point. The saturation vapor pressure is found from the Clausius-Clapeyron equation [26,27]:

$$e_s = e_o \exp\left[\frac{L}{R_V} \left(\frac{1}{T_\circ} - \frac{1}{T} \right) \right] \quad (1)$$

where e_s is saturation vapor pressure at each height (mb), T is temperature taken from the European site (°K), e_o is pressure (6.11mb); T_0 = Temperature (273.15 °K), L is latent heat (2.5×10^6 J kg^{-1}) and $R_V$is specific gas constant for wet air (461.5 J kg^{-1} k^{-1}). Calculating the vapor pressure through the following equation [28, 29]:

$$RH = \frac{e}{es} \times 100\% \quad (2)$$

Relative humidity (RH) is defined as the ratio of the vapor pressure (e mb) to the saturation vapor pressure (es mb). By using the actual vapor pressure rather than the saturation vapor pressure and solving for T, the Clausius-Clapeyron equation can be used to determine the dew point temperature [30-33]:

$$Td = \left[\frac{1}{T_\circ} - \frac{Rv}{L} \ln\left(\frac{e}{e_\circ}\right) \right]^{-1} \quad (3)$$

3. RESULTS AND DISCUSSION

3.1 Dew point temperature change and temperature with height

Figure 4 shows the change in temperature and dew point with altitude for three days (10-12 Feb. 2020) at the times 00:00 am and 12:00 pm over the city of Baghdad. Pressure levels are adopted from 100-1000 millibars. As it became clear on the 10 Feb. 2020 at the time of 00, there are cumulus clouds and altocumulus as the temperature curve and dew point approached, which represents the base of the cloud, and then the curve moves away, and the point of their departure represents the top of the cloud at a pressure level of 550 millibars, but as for time noon, it is not accompanied by clouds. On the next day, 11 Feb. 2020, there are clear cumulonimbus clouds at both times (low and medium clouds). This day is accompanied by a snowstorm in most areas of Baghdad, and the clouds continued for the next day (medium and high clouds). This depended on weather factors and the polar depression that reached Baghdad with the help of these factors, the most important of which are temperature and relative humidity.

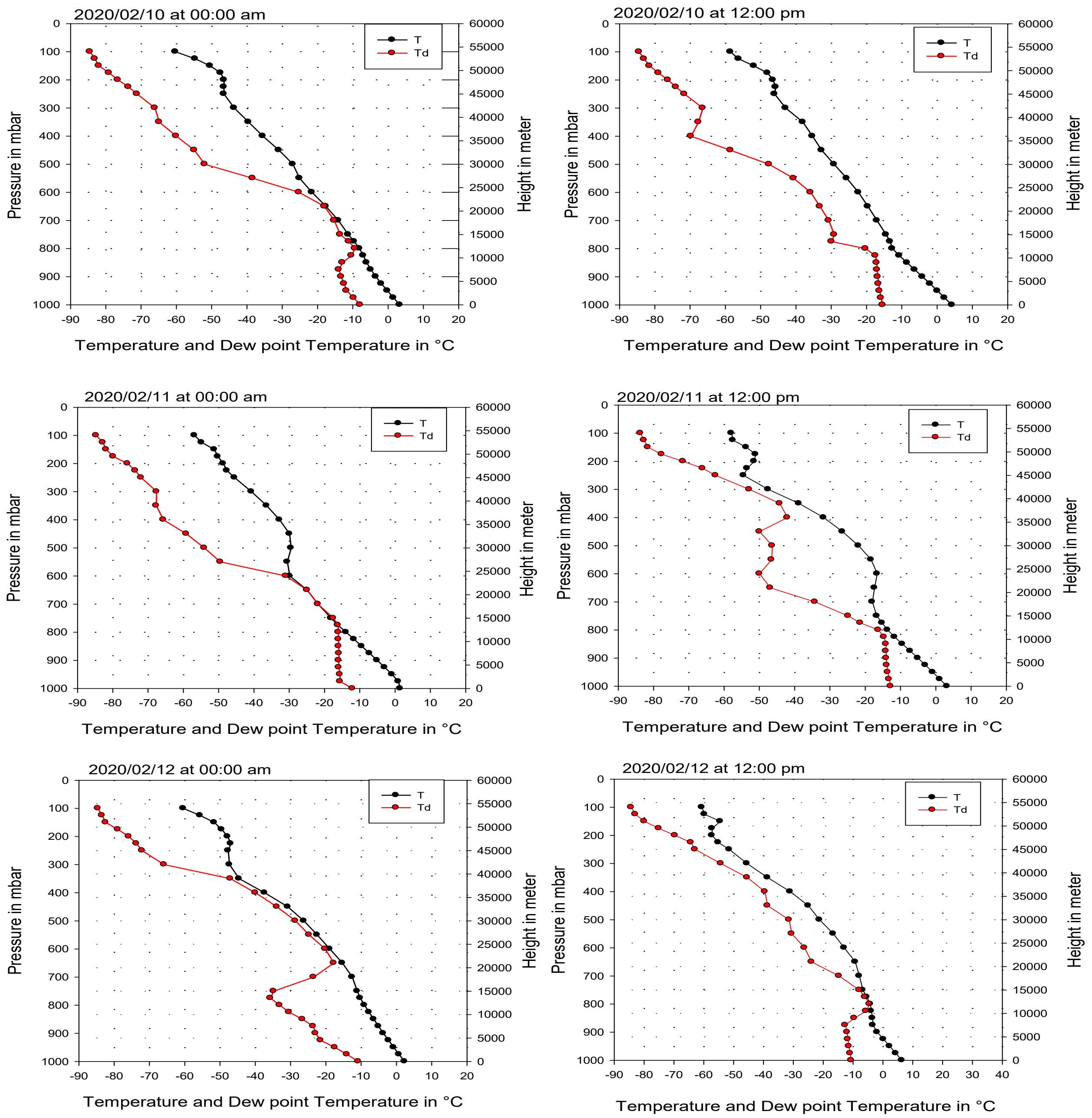

Figure 4 Determine snowstorm from the temperature and dew point curves for the days (10-12 Feb. 2020) in Baghdad city.

3.2 Analysis behavior of the type of cloud cover over Baghdad

Figure 5, the behavior of the hourly low, medium, and high cloud cover data over the Baghdad station is analyzed, where we concluded that on day 10 there are moderate clouds, on day 11 it is characterized by low and medium clouds, and on day 12 it is characterized by medium and high clouds. Low clouds consist of liquid water droplets and have different forms depending on the vertical development of temperature, which include stratus (St), stratocumulus (Sc), and cumulus (Cu). While cumulonimbus (Cb) has a base at the low level of clouds, its vertical extension may reach the troposphere and be classified as vertically developed clouds. Medium clouds consist of water droplets, ice crystals, or a combination of both and are located in the middle levels of the troposphere between the heights of 2-8 km. These clouds depend on the height and time of the year as well as on the vertical structure of the temperature in the troposphere and be at a temperature without freezing. It also refers to the approaching warm front and includes altostratus (As), altocumulus (Ac), and nimbostratus (Nb). Also, upper clouds consist of ice crystals, are at freezing temperatures and heights (5-20) km, and have different types where be feathers, white, and soft, which include cirrus (Ci), cirrostratus (Cs), and cirrocumulus (Cc).

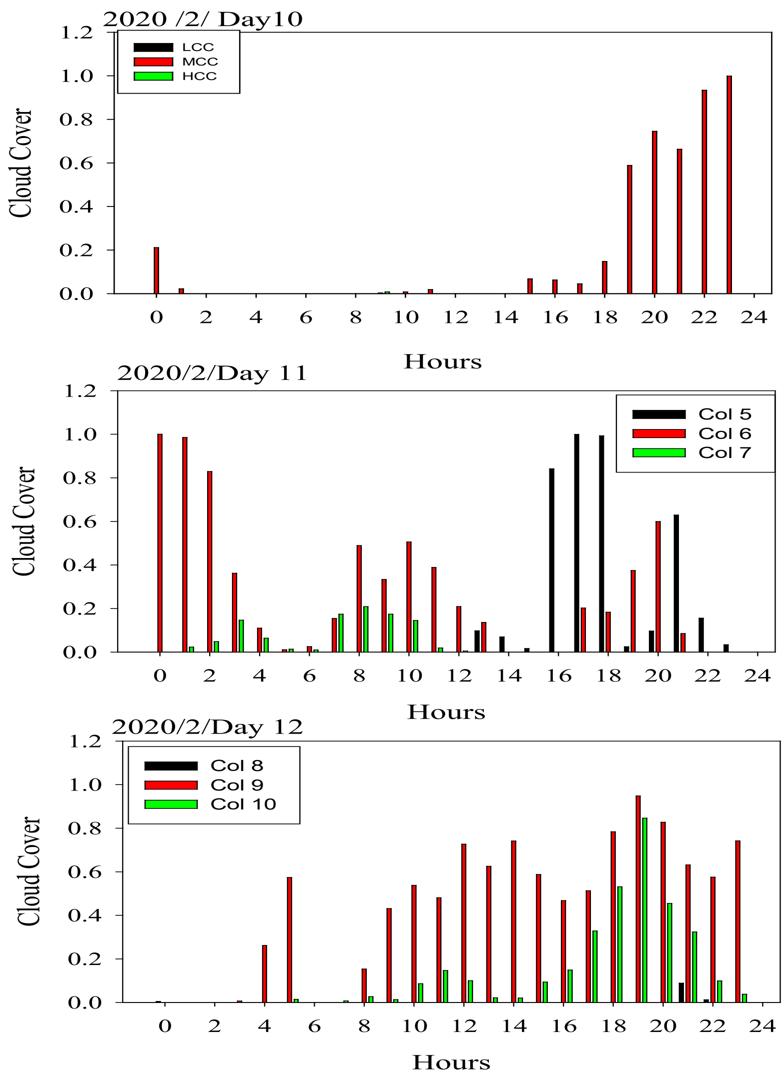

Figure 5 Type of Cloud Cover for the days (10-12 Feb. 2020) in Baghdad city.

3.3 Daily mean behavior of snow albedo, snow density, snow cover, snow depth, snow fall, and snow melt in Baghdad station

The daily means of Snow Albedo, Snow Density, Snow Cover, Snow Depth, Snow Fall, and Snow Melt for Baghdad city for 3 days of the year 2020, snow albedo is observed high in 12 Feb. at 4:00 pm, and snow cover is high in 10 Feb. at 1:00 am, and snow density is observed high in 12 Feb. at 04:00 am and snow depth is observed high in 10 Feb. at 02:00 am and snowfall is observed high in 11 Feb. at 06:00 am and snow melt is observed high in 10 Feb. at 00:00 am this is due to pressure systems, atmospheric cyclones, astronomical effects through the seasons, and region nature near Turkey boundaries and Mountainous regions also help form snow clouds as shown in the Figure 6.

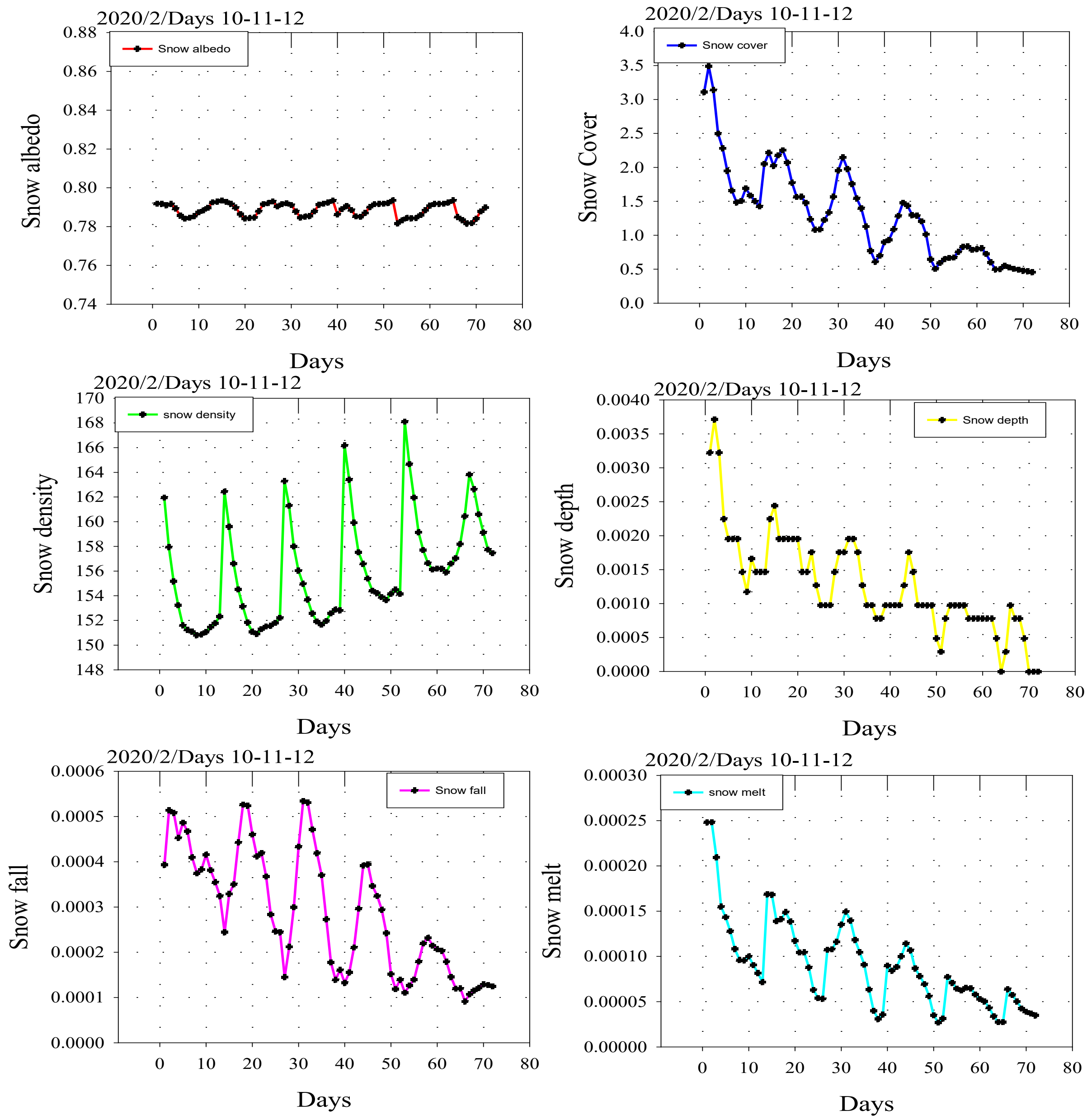

Figure 6 The daily means of snow factors for the days 10-12 Feb. 2020 in Baghdad city.

3.4 Accumulated precipitation for the days 10 – 12 Feb. 2020

Iraq and the neighboring regions have a rainfall case, with a duration of about three days from 11 to 12 February 2020. The accumulated precipitation reaches more than 50 mm in some regions, including North regines, heavy rain caused torrents to flow in the north and northeast of Iraq, as shown in Figure 7.

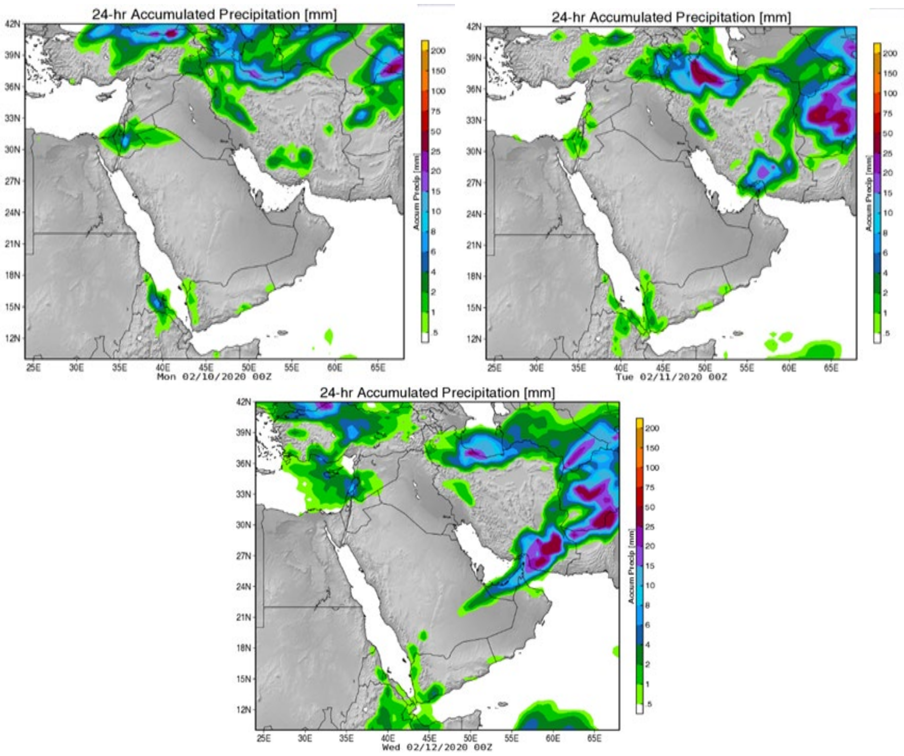

Figure 7 Accumulated precipitation at 24 hr. for the days 10-12 Feb. 2020 over Middle East.

3.5 Snowstorms for the days 10 – 12 Feb. 2020

Snowstorms are usually caused by rising moisture in the atmosphere in the region of a subtropical cyclone, that is, an area of low pressure. A cyclone pushes a relatively warm, moist mass of air upward above a cold mass of air. If the air near the surface is not cold enough over a deep layer, ice falls as rain instead. The total amount of snowfall resulting from a blizzard depends on three things: How quickly warm air rises above cold air. The amount of water vapor available in the form that will fall. The speed at which a storm moves, the slower its speed, the more ice it drops in one area, as shown in Figure 8.

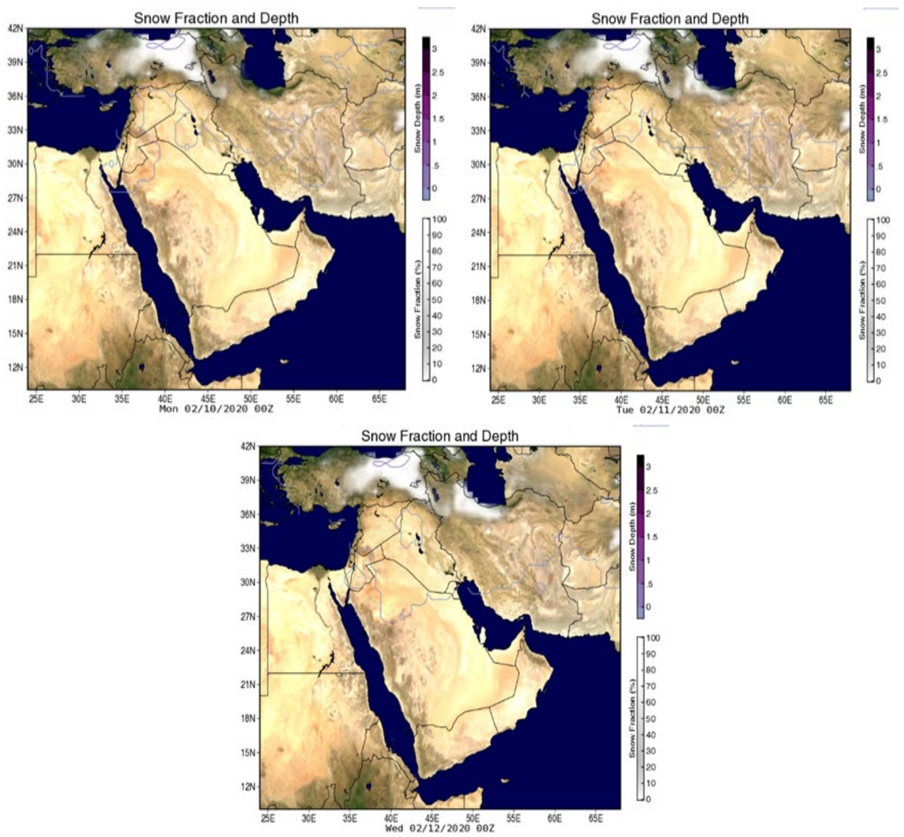

Figure 8 Snow cover at 24 hr. in days 10-12 Feb. 2020, for the Middle East.

3.6 Potential vorticity for the days 10 – 12 Feb. 2020

Iraq and the neighboring regions have a potential vorticity case, with a duration of about three days 10-12 Feb. 2020. The potential vorticity reaches more than 4.2 PV in some regions, including Baghdad city, as shown in Figure 9.

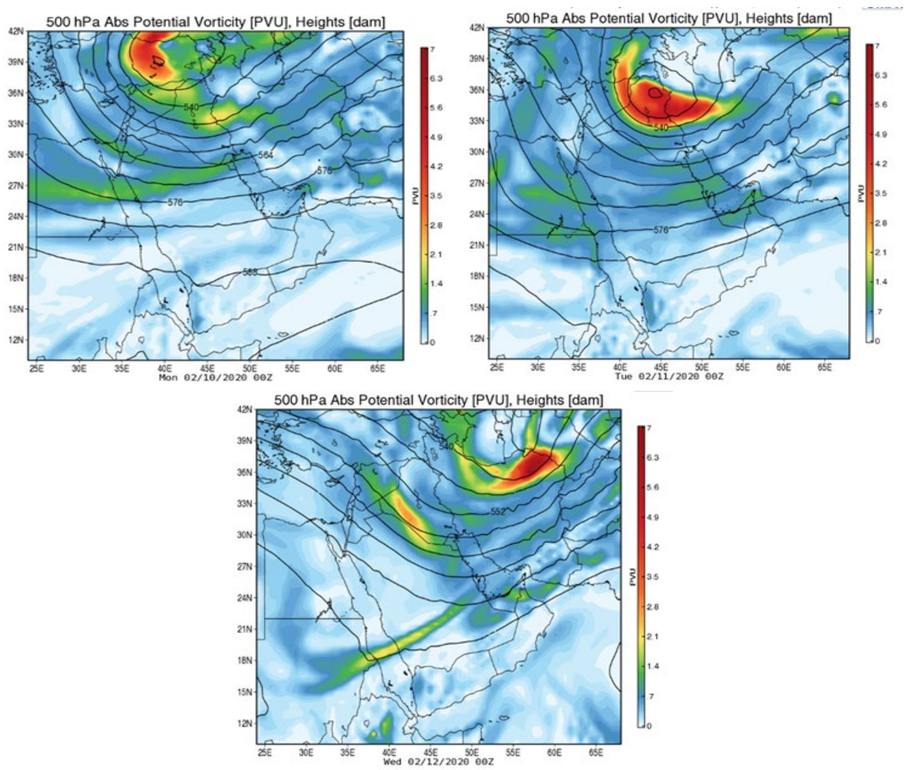

Figure 9 Potential vorticity at 24 hr. for the days 10-12 Feb. 2020, over Middle East.

3.7 Relative humidity for the days 10 – 12 Feb. 2020

Iraq and neighboring regions witnessed high of relative humidity in 12 February due to the significant decrease in temperature and the passage of an air depression that worked to form relative humidity in all stations of Iraq, as shown the Figure 10.

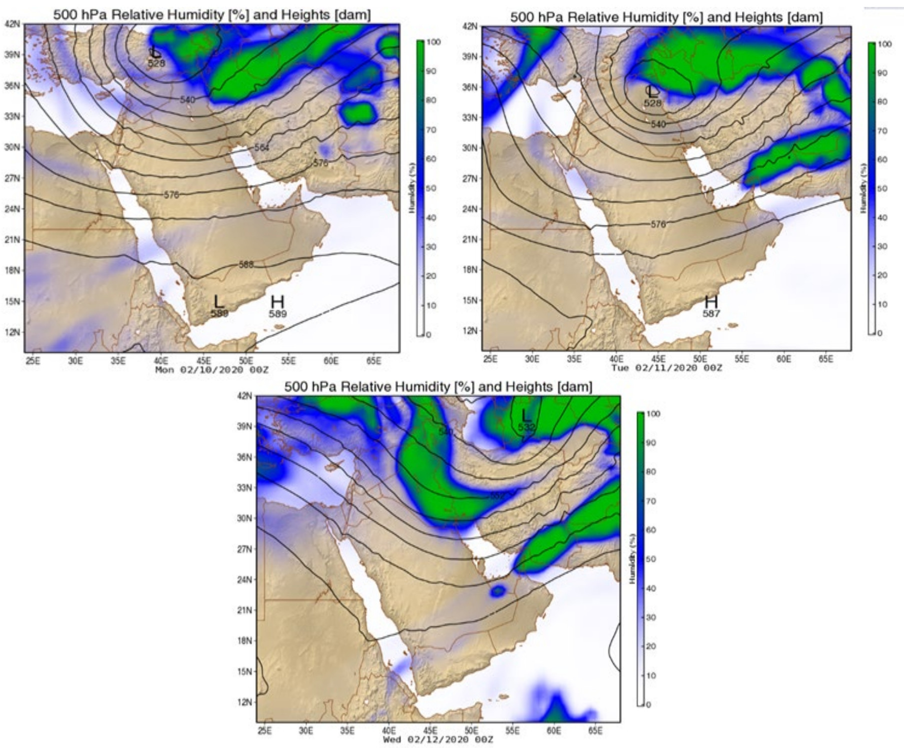

Figure 10 Relative humidity at 24 hr. for the days 10-12 Feb. 2020 over Middle East.

3.8 Temperature for the days 10 – 12 Feb. 2020

Iraq and neighboring regions witness low temperatures in February due to the significant decrease in solar radiation and the passage of an air depression that works to form pressure systems in all stations of Iraq, as shown in Figure 11.

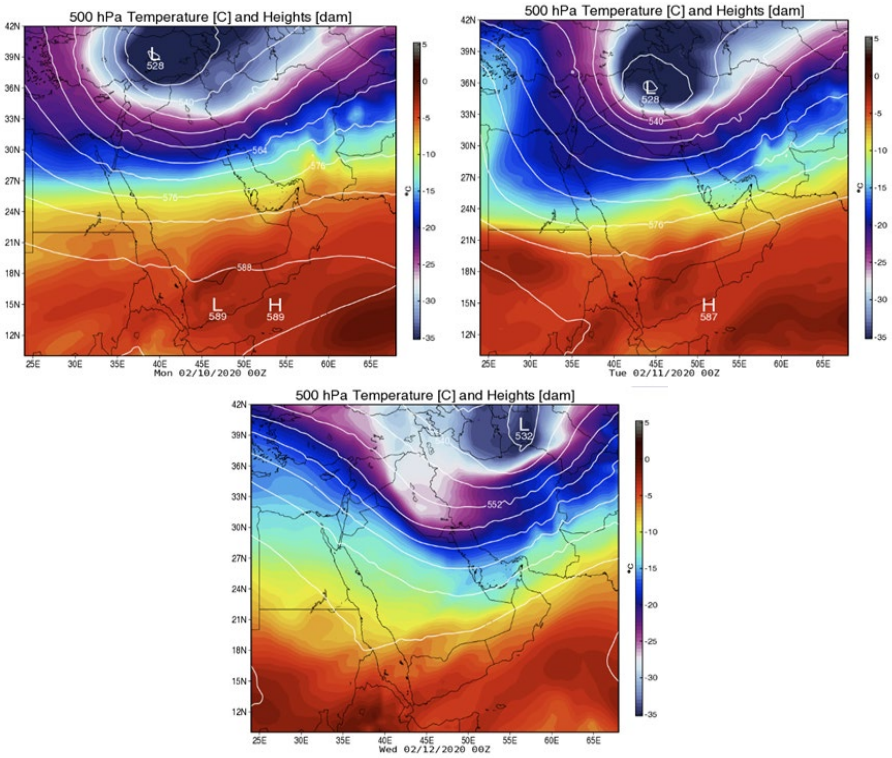

Figure 11 Temperature at 24 hr. for the days 10-12 Feb. 2020 over Middle East.

3.9 Relative vorticity for the days 10 – 12 Feb. 2020

On the surface, a low-pressure area (LPA) formed, centered in East Africa on the western coast of the Red Sea. LPA extension toward western north and formed a road to moisture transport from the source to the convergence zoon at the far end of the LPA extension (north of Iraq) the integrated water vapor transport (IVT) every 12 hours for the days 10-12 Feb. 2020, Figure 12 shows that the source of moist which feed the case is from east Africa (Red Sea Basin).

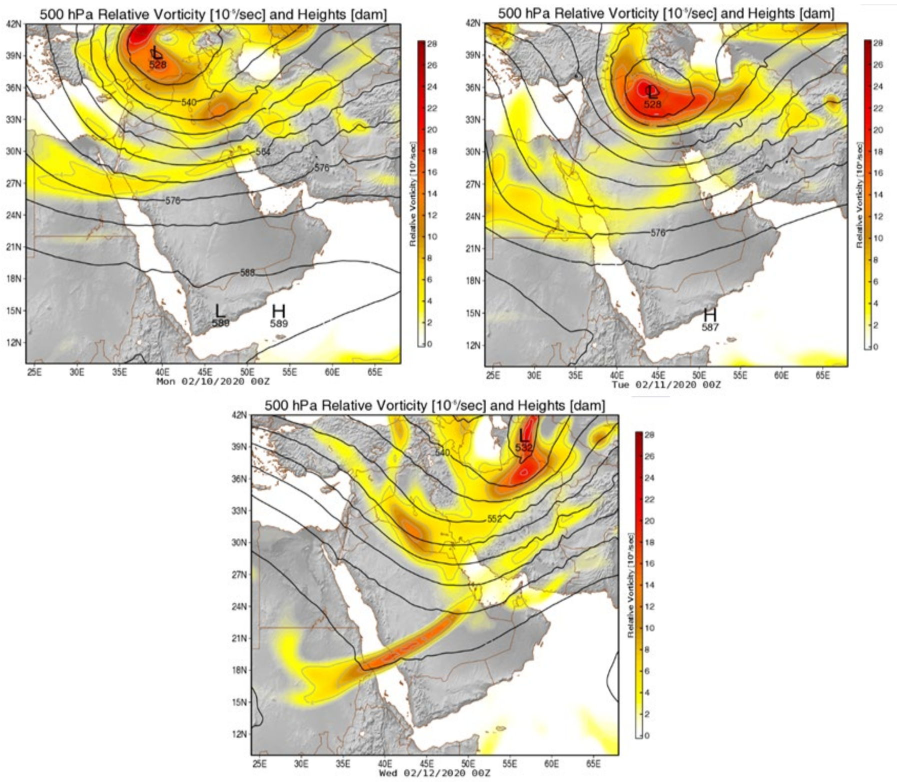

Figure 12 Relative vorticity at 24 hr. for the days 10-12 Feb. 2020 over Middle East.

3.10 Polar jet stream for the days 10 – 12 Feb. 2020

Wind speed and direction map at level 300 mb shows that the polar jet stream starts meandering toward the western south over the Middle East (western north of Iraq) as a part of Rossby wave propagation. Figure 13 shows the evolution of the polar jet stream meander PJSM over the Middle East and Iraq every 12 hours, the meander started, and a baroclinic instability can be expected to be associated with this case's evolution. Meander grows gradually with time and reaches the maximum horizontal extension in 10-12 February 2020, 00Z with maximum horizontal wind shear. The cut-off upper low, then the meander begins to retreat, even back to its original state. Through the above polar jet stream developments, a mid-latitude depression MLD formation is expected.

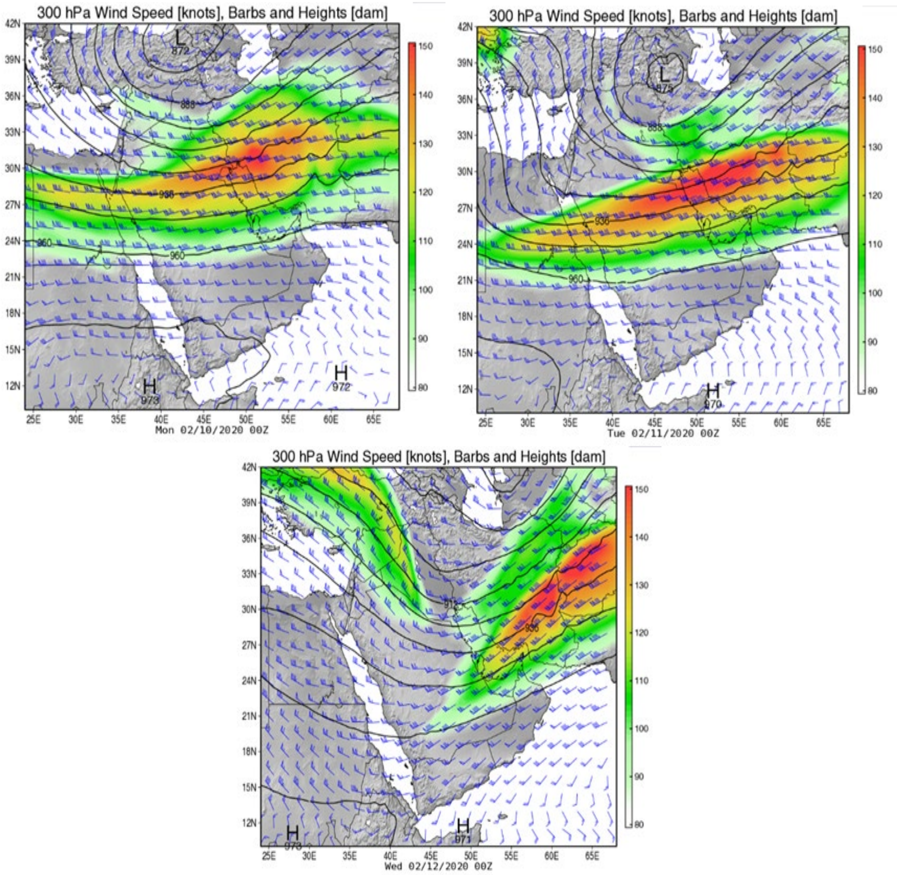

Figure 13 Polar jet stream evolution for the days 10-12 Feb. 2020 over Middle East.

4. CONCLUSIONS

The snow albedo was observed high from 12 days to 04:00 pm, snow cover was high from 10 days to 01:00 am, snow density was observed high from 12 days to 04:00 am and snow depth was observed high from 10 days to 02:00 am and snowfall was observed high during 11 days to 06:00 am and snow melt was observed high during 10 days to 00:00 am. In 10 Feb. 2020 at the time of 00:00 am, there were cumulus clouds and altocumulus as the temperature curve and dew point approached, which represents the base of the cloud, and then the curve moves away, and the point of their departure represents the top of the cloud at a pressure level of 550 millibars, but as for time noon, it was not accompanied by clouds. On the next day, 11 Feb. 2020, there were clear cumulonimbus clouds at both times (low and medium clouds). This day was accompanied by a snowstorm in most areas of Baghdad, and the clouds continued for the next day (medium and high clouds). The Wind speed and direction map at level 300 mb shows that the polar jet stream starts meandering toward the western south over the Middle East (western north of Iraq) as a part of Rossby wave propagation. On the surface, a low-pressure area (LPA) formed, centered in East Africa on the western coast of the Red Sea. LPA extension toward the western north and formed a road to moisture transport from the source to the convergence zone at the far end of the LPA extension (north of Iraq), the integrated water vapor transport (IVT) every 12 hours from 10 to 12 Feb. 2020.

ACKNOWLEDGMENTS

An acknowledgment to the European Centre for Medium-Range Weather Forecasts (ECMWF) and an acknowledgment to Mustansiriyah University.

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