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Informational digital diagrams applied to predict spring wind, snow, and sandstorms

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Abstract: Using informational digital diagrams, we analyzed the snow event that occurred on Feb 26, 2006 and the sandstorm on Apr 11, 2006 in Xi'an. Results indicate that, under similar weather circumstances, different events evidently exhibit unique vertical structure features. Informational digital diagrams provide a method for transitional weather prediction, a problem for present extrapolative analysis system.
Keywords: Transition, Informational Digital Diagrams, sandstorm

Introduction

Shaanxi province lies in the middle latitude area of northwest China where there are cold dry winters, hot rainy summers, warm dry springs, and cool wet autumns. The east-west trending Qinling Range located in the middle of Shaanxi is regarded as the division between the dry and wet climates of China. The climate is dry north of Qinling and wet to the south. Xi'an, on the north side, suffers dry rainless springs with extreme temperature differences and whose primary disastrous weather are drought, cold waves, strong winds, sandstorms, and minor rainfall with low temperatures. Disastrous weather occurs during transitional weather evolutions, in which strong winds or sandstorms are examples of distinct disastrous weather events in the northern regions of China and even have impacts overseas. Traditional weather predicting methods are mostly based on analyzing the denseness of isobars. Many of the predictions are made by inertial extrapolation after the event occurs. The majority of event sources can't be predicted, bringing serious losses.

Sandstorms are carried by strong winds. There will be no sandstorm weather when there is no wind. In traditional meteorological theory, wind comes from horizontal air pressure gradients which results in the dense isobar prediction method (Zhu el al., 1992). Ouyang (1998) and Ouyang et al. (2002) pointed out that horizontal gradients aren't the final wind theory and proposed the evolutionary Blown-ups theory and informational digital diagrams (IDD). IDD uses both regular and irregular information, the latter being discarded by the present inertial extrapolation system. The emphasis of the Blown-ups theory and IDD is:

1. Air pressure systems lag weather phenomenon because, first, atmospheric movement derives from changes and uneven distribution of heat, which causes density changes and redistribution so the relative air pressure changes and redistribution always lag the heat changes; second, the relation between geopotential height and air pressure, or the wind-pressure relation, in present theory is calculated by a linear system 'static approximation formula' which supposes that density is constant so that the air pressure system is lagged information. In IDD, the reverse sequence replaces air pressure information.

2. The ultra-low temperature (UT) information appears above the troposphere. The discovery of UT touches not only meteorology but also the core issue

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of the transitional change of matter, called the 'twist knot'. The twist knot is a special event, not confined to disastrous weather. Mathematically, the twist knot is a curvature change, the third-order derivative of a nonlinear equation. The N-S equation doesn't include the third-order derivative term. However, predicting disastrous weather depends on solving the problem of the twist knot. Based on this problem, Ouyang proposed the IDD to deal with irregular information.

The northern part of Shaanxi province is located to the east of the Mu Us desert. Because of its special geographic location and environment, it is one of the provinces receiving more sandstorm weather. Meteorologically, based on the different visibility induced by the quantity of sand and dust, dusty weather is graded as four levels: haze, blowing dust, dust storm, and strong dust storm, which is also called "black dust" in China. Dust or sandstorms are disastrous and especially strong convective weather. Their range can reach synoptic scale. With their movement, they can influence distant areas. Their unstable structure penetrates all atmospheric layers, so their time scale is longer than other strong convective weather, they destroy visibility, and, more importantly, symbolize biological destruction.

Blown-ups theory and information digitalization

The Blown-ups theory is an evolutionary transition theory advanced for problems of change. It belongs to the set of interactive non-inertia systems and considers that rotation is the basic and general movement of matter. The core issue is that the directional differences of coupled rotation can cause damage and destruction of matter. Undoubtedly, matter rotating in different directions will lead to irregular secondary vortices. The quantitative analysis systems of modern science can't cope with irregular events. So Ouyang and Peng (2005) point out that irregular events or transitional information don't follow logical quantitative evolutions.

As a different concept compared to the traditional approaches, Blown-ups theory considers the irregular information is a causal objective event which can't be broken down by quantitative analysis. Thus, the information digitalization method using irregular information is introduced and applied. In 1963, Ouyang discovered the UT phenomenon and its features near the troposphere. This phenomenon can induce convection and can cause convection weather systems to move. This inspired Ouyang to use the ultra-low temperature information. Ouyang et al. (1994) analyzed various methods and chose to use the IDD method. This method reveals irregular information of the UT temperature such as height and cloud properties while using a 'rolling flow' to analyze predicting information like cloud generation, development, and dissipation.

Blown-ups theory makes the most use of irregular meteorological observation information. The V-3θ diagram is designed based on Blown-ups theory (Ouyang et al., 2002).

The 3θ are θ, θ_{sed} and θ^* and compose the three curves of P–T phase space in the vertical direction, that is, the vertical section image of each observation station. V is the wind vector of the sounding data set on curve θ^* consisting of wind direction and wind speed. Potential temperature θ is selected because the uneven distribution and changes of heat are the cause of movement and changes in the atmospheric factors and phenomenon. The shape and structure of the θ curve approximately denote the slope rate of P –T phase space:

$$\theta = T \bullet (P_0 / P)^{R/C_P}, \qquad (1)$$

where θ is potential temperature, T is air temperature (K), P_0 is horizontal air pressure (hPa), P is air pressure at a random level, R is the gas constant of dry air, and C_P is specific heat capacity at constant pressure. Obviously, θ increases as P decreases. Therefore, observations such as θ abruptly decreases, stays unchanged, the θ increase slows down with decrease in P, or apparently has a turning point compared to the average value, all indicate the existence of UT phenomenon in the upper levels of the troposphere. This is the twist knot area of atmospheric curvature change and is the irregular information leading to disastrous weather predictability.

If we change the θ_{se} of traditional meteorology to θ_{sed}, then

$$\theta_{sed} = T_d \bullet \left(\frac{1000}{p}\right)^{R_d / C_{pd}}, \qquad (2)$$

where P is air pressure, T_d is dew point temperature, R_d is the gas constant of dry air, and C_{pd} is the specific heat capacity at constant pressure of dry air. In the equation (2), the dew point temperature replaces the original temperature of the condensation level (Ouyang et al., 2002) in order to compare the water vapor state of the atmospheric structure. θ^* is the calculated value of pseudo-equivalent potential temperature assuming the atmosphere is in a saturated state. Analyzing the included angle between θ_{sed} and θ^*, we can get the water vapor content and water saturation in each level of atmosphere as well as the structural features of the water vapor distribution. On this basis, the degree or quantity of disastrous weather can be determined and predicted. Other explanations of V-3θ images are available in Ouyang (1998).

Comparative case analysis

In February and April, 2006, two weather events with wind, sandstorm, and precipitation occurred in Xi'an induced by cold air moving southward. The abrupt disastrous weather threatened various city establishments and raised an urgent need for disaster prevention. Especially since the wind lasted a long time and was followed by rain. With traditional prediction methods it is often difficult to predict such special weather. We used IDD to predict and analyze these two weather events and compared the predictions with the existing operational prediction system. It is necessary to make clear that, in the prediction process, the weather analysis of a single station should include data from stations over an area of 10 – 15 degrees of latitude and longitude.

Wind and snow weather on 26 to 27 Feb, 2006

At 05:00 am on 26 Feb, 2006, a grade 4 partial north wind started to blow in Xi'an. The transient wind speed reached 12 m/s. The temperature evidently dropped but it was wet with good visibility and no sand storm emerged. The wind continued for about 12 hours. At 02:00 am on the 27 th Xi'an embraced a snow storm in early spring. The strong wind blew down many billboards and trees. The unexpected snow and low temperatures was an inconvenience to local people and put pressure on road snow cleaning crews.

On the 500 hPa synoptic chart of 08:00 am on 25 Feb, 2006, there was a weak trough at Lake Balkash and west of Lake Baikal was another trough. The high latitude atmospheric circulation area of the Euro-Asian continent consisted of two troughs on either side of a ridge. The middle-latitude area of China featured high pressure to the west and low pressure to the east. A northwest wind blew from Xingjiang to Shaanxi. Such a circulation was unfavorable for precipitation in Shaanxi. At lower levels, the wind was a partial west wind with no apparent partial south component which contained no available water vapor. There was only one station above 700 hPa with an emerging northwest wind which formed a weak shear with the west wind at Xi'an station. On the surface chart, the cold air center appeared to the west of Lake Baikal and Shaanxi was at the bottom of the high pressure center. Analyzing with the present prediction method, the circulation of the upper and lower levels didn't support each other and the cold air centered on surface was far too north. These observations were all against the wind and precipitation at Xi'an and directly led to the failed prediction of this weather system. Thus, we use V–3θ images to analyze this weather process below.

From the energy of the V-3θ diagram at 08:00 am on 25 Feb, we can see that the θ line has an obvious turning point at two levels and θ forms a quasi-right-angle with the T axis above 700 hPa which denotes a strong UT with unstable layer structure. For water vapor, there was a warm layer below 700 hPa. θ_{sed} was between θ and θ^*, which meant that water vapor was abundant at lower levels but comparably less at upper levels at Xi'an. This structure of dry at upper levels and wet at lower levels was favorable to developing instability. For wind, the speed of the northwest wind above 500 hPa reached 20 – 40 m/s, the southeast wind at 700 hPa was 8 m/s, and the partial north wind at 850 hPa was weaker which didn't cause a dropping temperature or dry air. Compared to the north wind at lower levels of Yan'an station (Figure 1), the Xi'an station (Figure 2) showed more partial west wind component and the temperature does not drop but increases. Meanwhile, having θ^* forming an obtuse angle with the T-axis indicated unstable structure. The real north wind would decrease the temperature and dry the air (separating θ_{sed} and θ^*). The wind at lower levels of Ping Liang station was a real north wind (Figure 4).

However, in the vertical direction through all levels, the wind structure on Figure 2 at 08:00 am on 25 Feb could be regarded as a general "climb-hob rolling flow". Relatively, the wind structure of Figure 3 was partly an inverse rolling flow because it was dry at lower levels and a south wind existed at 700 hPa which constructed a

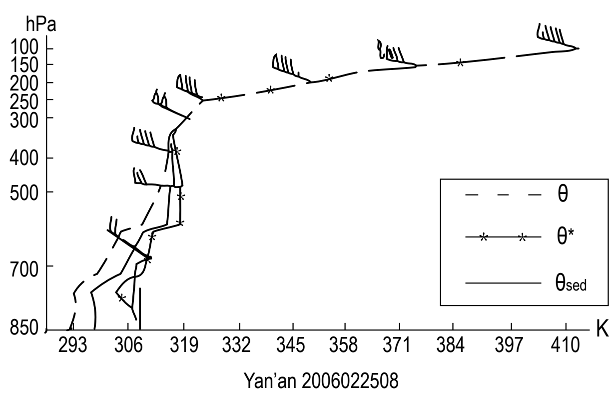

Fig. 1 V-3 diagram of Yan'an station at 08:00 on 25 Feb, 2006.

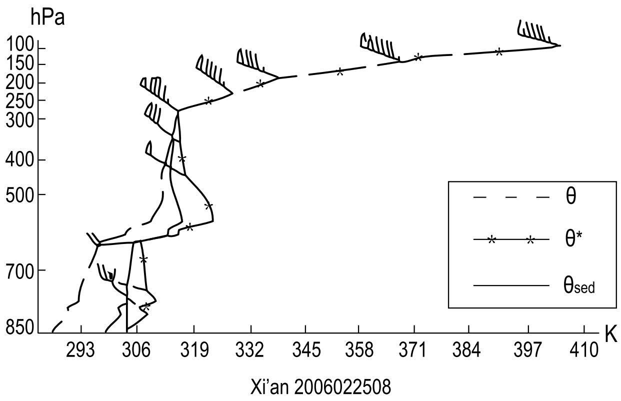

Fig. 2 V-3 diagram of Xi'an station at 08:00 on 25 Feb, 2006.

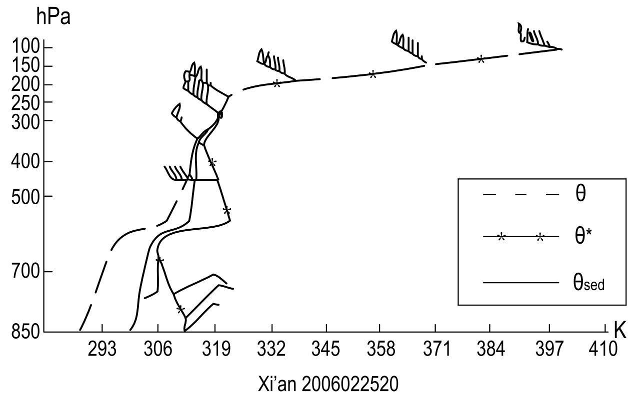

Fig. 3 V-3 diagram of Xi'an station at 8:00pm on 25 Feb, 2006.

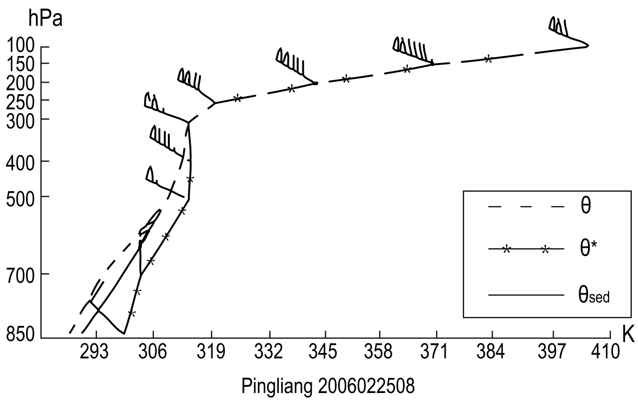

Fig. 4 V-3 diagram of Ping Liang station at 8:00pm on 25 Feb, 2006.

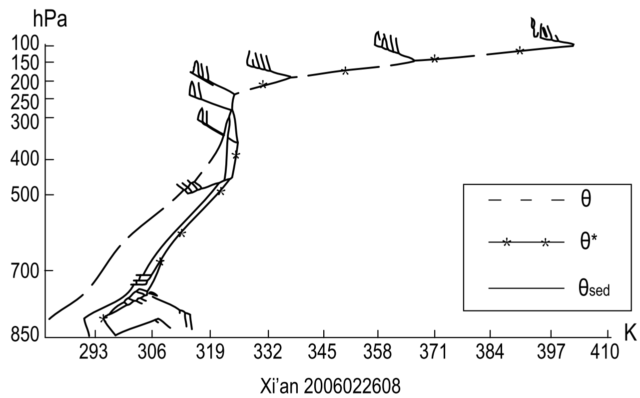

Fig. 5 V-3 diagram of Xi'an station at 08:00pm on 26 Feb, 2006.

"climb-hob rolling flow" above 700 hPa and an inverse rolling flow below. Although the weather had changed, the layering didn't disappear completely but was much weaker than at 08:00 am which certainly inhibited dust spreading. Since the temperature at 700 hPa was below 0°, the precipitation should be in the form of snow. Comprehensively, this weather event would be predicted as windy and snow. The real snowfall was 12 mm in 12 hours.

It is necessary to note that the UT phenomenon in the troposphere is important irregular information which works for wind, torrential rains, strong convections, and sand storms but also snow. Hence, the application of UT in disastrous weather forecasts decreases the prediction failure rate for weather forecasters.

Wind, dust, and rain weather on 11 Apr, 2006

On the evening of 10 Apr, wind, sand storm, and cold wave weather started in some places in Shaanxi province, during which Xi'an experienced a maximum temperature decrease of 21° in the downtown area. The dusty weather was the strongest sand storm occurring in Xi'an since 1999. The over grade 6 northwest wind occurred in most parts of northern and middle Shaanxi and the maximum transient wind speed reached 22 m/s. The maximum wind speed in Xi'an reached grade 4 and visibility was less than 1 km.

The present operational method of sand storm forecasting is to judge the intensity of the cold air center and trace its direction and speed. The prediction results are not good. Furthermore, the method doesn't give a clear explanation of its mechanism. Especially, it is unable to predict the location and intensity of wind and sand storm weather. Based on the wind and dust weather, on a surface synoptic chart of 08:00 on 10 Apr, the Mongolia cyclone center lay at longitude 112.37° E and latitude 45.73° N and its center value was 894.0 hPa. The cold front trended southwest to northeast and moved along the northwest path into the Hetao area. Xi'an station was before the southeast tail of the cold front. Based on the

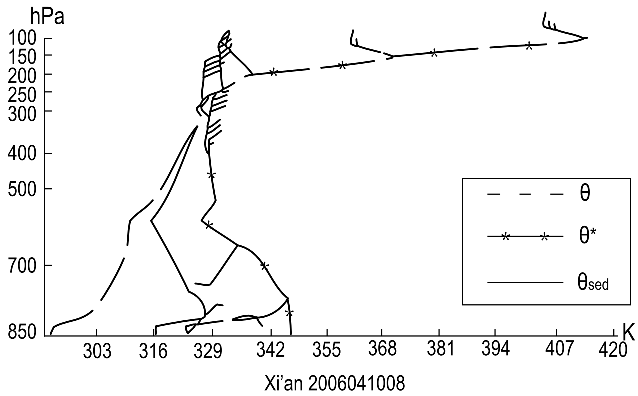

Fig. 6 V-3 diagram of Xi'an station at 08:00 on 10 Apr, 2006.

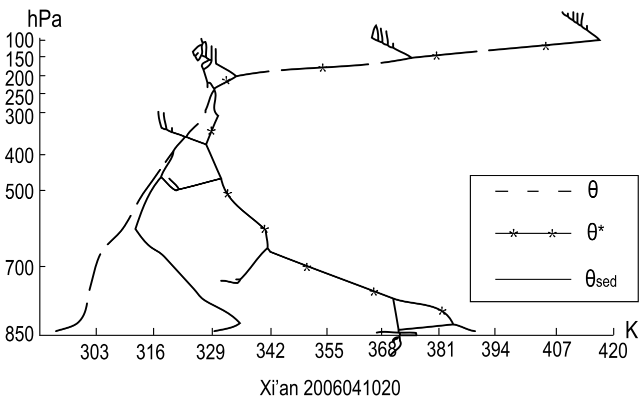

Fig.7 V-3 diagram of Xi'an station at 20:00 on 10 Apr, 2006.

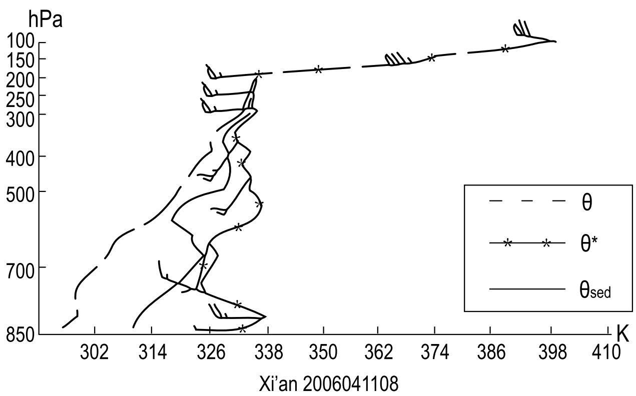

Fig.8 V-3 diagram of Xi'an station at 08:00 on 11 Apr, 2006.

information, it was difficult to say whether wind and dust weather would emerge or precipitation would occur after the cold front. As far as the cold air movement prediction itself is concerned, there are difficulties in extrapolating the direction and speed of the cold front. There were large differences of wind and sand storm intensity among stations near the cold front. Meanwhile, it posed uncertainties as to whether there would be sand storm weather in all stations inside the control of cold front, precipitation after the front, and what the water vapor situation would be like in at each station. The conventional data analysis couldn't give a satisfactory answer. Here we give an analysis based on the V-3θ diagram in Figures 6 to 8.

On Figure 6 of 08:00 on 10 Apr, we can recognize a deep left-turning super UT in the upper levels. The wind directions were all almost due north above the 500 hPa level and south at 850 hPa which formed a climb-hob rolling flow. Both θ^* and θ_{sed} formed obtuse angles with the T-axis, showing strong instability.

The middle and lower atmospheric layers were dry and more obvious on Figure 7 at 20:00 on the 10th. According to Ouyang et al. (2002), if θ_{sed} is lying partially left between θ and θ^*, then a holistic dry structure, such as a dust event, should be predicted. Taking sand origin and atmospheric instability into account, a sand storm event was predictable. This sand storm weather event caused visibility in northern and middle parts of Shaanxi to be less than 1km and in Wuqi and Dingbian counties even less than 500 m. From analysis of Figure 8 at 08:00 on 11 Apr at Xi'an, we see that, although the UT still existed, the temperature raised a little and, what was important, the wind field turned into an inverse rolling flow, resulting in only a 4 m/s south wind. Between 850 hPa and 700 hPa a concentrated water vapor layer appeared, favorable for precipitation, and stratification was stable above 850 hPa, displaying a vivid calabash shape which is a typical shower structure. As a result, a 1.8 mm. shower ended the sand storm.

Discussion

Undoubtedly, these two cases both showed the phenomenon of strong wind before snow or dust, although the main process of the second case was the sand storm in Xi'an. The V-3θ diagram clearly showed different structural evolution processes of wind-to-snow and wind-to-sand storms. During which, the IDD of the atmosphere in the vertical direction discovered the apparent features and difference of transient structure change. This undoubtedly displayed a direct concept for identifying weather changes, atmospheric structure evolution, and an energy transition mechanism. It not only exhibited the usefulness of irregular information but also gave a specific method for predicting disastrous weather.

The pivotal distinctive phenomenon between these two cases lies in whether dust occurred. From the IDD view point, the atmospheric structure difference was obvious, too.

(1) At lower levels of the UT structure, θ formed an approximate 80° angle with the T-axis in both cases, denoting the instability. At 300 hPa, θ formed a quasi-right angle with the T-axis in the first case, while forming an obtuse angle in the second case, and maintaining a left bow shape in case two through all levels, which was much stronger in intensity and depth than the first case.

(2) On 26 and 27 Feb, the rolling wind flow was formed by northwest and southeast winds. Meanwhile, the east wind component near the surface was rather big and favorable for precipitation. This characteristic matches the precipitation principle for Shaanxi. On 11 Apr, the rolling flow was partly a climb-hob rolling flow formed by partial north and southwest winds. Based on analysis of the upper reach stations, the first cold air came from the northwest direction. The second cold air turned its direction from north to west and was stronger than the first.

(3) On the 26 and 27 Feb, the water vapor situation indicator θ_{sed} stood partially right between θ^* and θ. Meanwhile, the θ_{sed} forming a big included angle with θ, showed that there was a certain amount of water vapor in the atmosphere. Furthermore, θ_{sed} and θ_{sed} were almost superimposed at the 700 hPa level, indicating an existing moist layer which supplied a quick moisture-increasing mode unfavorable to spreading sand. On 11 Apr, θ_{sed} stood partially left between θ^* and θ. θ_{sed} and θ nearly superimposed at upper levels, showing a poor water vapor content. A bigger included angle existed between θ_{sed} and θ^* throughout all levels, which indicated that the atmosphere was accordingly dry and favorable to spreading sand.

First, as far as weather forecasting is concerned, wind is not only a weather phenomenon but also provides advanced information of rain, snow, and sand storms. The reason why there are differences among weather conformations is because of differences in water vapor and temperature which are reflected in atmospheric structure. Thus, IDD can both distinguish structures and determine the magnitude of disastrous weather. More important is extracting wind information from other meteorological observations as the primary decisive factor and which advances a ‘reverse order frame’ adjustment to reality.

Second, disastrous weather itself is a special small probability event, so it is reasonable to apply small probability information. Therefore, the modern scientific system is unable to deal with irregular information, which inhibits relative application method research. We introduce the IDD method due to its ability to apply irregular information. As seen in the IDD analysis in this paper, the truer the irregular information, the better the prediction will be. In conclusion, to study prediction as a problem or method should start from an irregularity or particularity basis.

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