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CENTRAL REGION TECHNICAL ATTACHMENT 89-20

ARCTIC OUTBREAKS

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1. Introduction

Several years ago a checklist (Van Ess, 1985) was developed to assess the severity of Arctic outbreaks. The original checklist is still basically valid, but it needed to be: (1) updated for NMC Nested Grid Model (NGM) use, (2) more responsive to forecaster decisions, and (3) incorporate atmospheric lapse rates and isentropic analyses.

The new Arctic outbreak numerical system is designed as a fairly quick method to determine if a statement, advisory, or warning is needed in an Arctic outbreak. The system is based on the Nested Grid Model, and integrates weather factors (elements) that are important in wind forecasting. Each element is given points based on how it's strength will contribute to the overall wind production. The points are then added and a decision made as to no advisory, advisory, or watch/warning.

The updated checklist has been tested and found to consistently define the weak, moderate, and strong outbreaks. Forecast decisions are somewhat easier to make when the systems are weak or strong. Weather systems that "rate" in the moderate category are more difficult since the issue/no issue decision is not as straightforward. In this situation knowledge of mesoscale factors such as amount of loose snow available and local terrain enhancements are important.

2. Weather Elements Used in Checklist Analyses

The following is a brief description of the forecast elements used in the numerical rating:

A. Magnitude and Position of the 500 mb Vorticity

Most Arctic pushes toward the Northern Plains are associated with a short upper level wave. The focus of the Arctic push and resultant wind depends a lot on the strength and location of the vorticity maximum. Often, the stronger the vorticity the greater the subsidence in the west and southwest quadrants. The stronger the subsidence the greater the potential for transport of strong winds into the boundary layer.

When a vorticity maximum moves into a favorable position the resultant surface wind on the west side depends on the significance of several variables. The following paragraphs describe the individual variables and how they relate to the total Arctic outbreak scheme.

B. Three Hourly Pressure Changes

One parameter that is easy to monitor and highly important is the three hourly pressure change. In general, the stronger the upper level warm advection the faster the pressure falls, and the stronger the cold advection the faster the pressure rises. Large pressure rises indicate a strong surge of cold air and gusty surface winds. In a situation of large pressure falls and rises, the pressure gradient is usually increasing rapidly, which enhances higher surface winds. The forecaster should track these centers because their path usually point to the location where the wind will be the strongest in the near future.

C. Subsidence

There is good subsidence on the west and southwest quadrant of a strong vorticity maximum. How to measure this in a quick and easy way is difficult. The NIVA concept (Negative Isothermal Vorticity Advection - Sangster, 1980) offers the best measure. Lowering thickness values indicates cold advection and subsiding air. Furthermore, tightly packed vorticity lines on the back side of an upper level trough, are usually associated with the greatest degree of subsidence. Thus, the forecaster should look for regions where the angle between the 500 mb vorticity lines and 1000-500 mb thickness lines is 60 to 90^{o}.

D. Cold Air Advection

The rate of change of cold air advection is often an indication of the intensity of the system and the strength of the winds. One excellent way to look at this is by forecasting the cold advection in the layers from 850 mb to 500 mb. The most dramatic change will occur at the 850 mb level. Another way to monitor cold air advection through the entire lower layer (surface-500 mb) is by using thickness values. Surface isobars that cross tightly packed thickness lines at a large angle indicate greater cold advection.

E. Lapse Rate

It should be remembered that cold air advection alone will not sustain a strong wind for a long period of time unless high momentum upper level winds continue to be transported into the boundary layer. The steeper the lapse rate the more rapid the adiabatic descent of the high momentum winds. Thus, a forecaster should look at current soundings upstream to see if the system has adiabatic (or near) lapse rates. If it is between rawinsonde runs, construct a sounding out of forecast temperature advection.

An additional note, the production/maintenance of adiabatic lapse rates, in Arctic outbreaks, is "one step ahead" of the opposite destruction/erosion due to warming generated by subsidence. Sufficient warming in the 850 to 500 mb layer may result in a more stable layer rate which will limit the mixing and transport of higher momentum air into the lower atmosphere.

F. Vorticity Comma

SWIS is an excellent tool to not only check the NGM's accuracy, but to find the vorticity commas. A strong vorticity center will show up as a circulation center on SWIS. As stated before, maximum winds will occur to the west and southwest of the circulation center.

If the short wave and vorticity are strong, and the NGM model has a good trend on the situation, it will forecast an area of lower relative humidity heading into the forecast area (air drying as it descends adiabatically to the surface). If SWIS hints or actually shows this is taking place, extrapolation of the dry axis over the forecast area would give another clue that strong subsidence will occur.

Isentropic charts show adiabatic motion in all levels of the atmosphere. The charts can be used to estimate the magnitude of downward motion in the dry slot, mentioned above. The greater the wind speed and the more perpendicular the flow to the pressure gradient, the stronger the subsidence, and hence the greater the potential for downward transfer of higher momentum air. In general, look for wind speeds greater than 45 kts on the isentropic charts (in the dry slot) with air parcels descending adiabatically just upstream of the forecast area. It also helps if the pressure difference between isentropic surfaces decreases from northwest/north to southeast/south in the area upstream of the forecast area. This vertically confluent isentropic flow would imply a downward accelerating air parcel.

G. Jet Position and Strength

As indication of how much wind could reach the lower layers of the atmosphere can be seen by monitoring the wind speed of the 850 mb through the jet level. A strong jet moving close to the forecast area will create higher winds lower in the atmosphere if associated with a short wave. Once strong winds have reached the 850 mb level it's only a matter of mixing them to the surface. In a strong cold advection/mixing environment a near adiabatic flow can be set up, with a resultant steady transport of wind to the surface.

H. Directional Wind Shear

Air is more readily transported down if it has little directional shear in the vertical. Look for wind from approximately the same direction from the surface to 300 mb. If the wind has little directional but strong magnitude shear with height, expect a rapid downward transport of high velocity air.

I. Geostrophic (Sangster) Wind

The geostrophic wind (9AM) is a very useful tool to show a trend in the lower level winds. During an Arctic outbreak look for increasing wind over and upstream from the forecast area.

J. Snow Cover

Greater amounts of loose snow result in a higher potential for blowing snow. Even a "cap" of refrozen melted snow, over a deep snow cover, can be broken by strong Arctic winds. Consequently, the "loose" snow underneath the cap will then be available for blowing.

3. Numerical Rating of Systems

The points given each element is based on its relative importance in wind production. A weak factor will be awarded a 0 or 1, moderate a 2 or 3, and strong a 4 or 5. Adding all the points at the end of the appraisal will put the potential in a weak, moderate, strong, or "must" warn/watch category:

A WEAK SYSTEM (20 to 35 points) will likely produce some drifting snow but little else, even with ample loose snow.

A MODERATE SYSTEM (35 to 50 points) will produce some blowing and drifting snow. An advisory may be needed if there is fresh loose snow.

A STRONG SYSTEM (50 to 65 points) will produce considerable blowing and drifting snow and an advisory is a must. If there is ample old loose snow on the ground, or considerable new falling snow, then the term "near blizzard" should be used in conjunction with an advisory.

WARN/WATCH (65+ points) needs a warning, or if projecting into the future, a watch.

A. 500 mb (Vorticity Center)	1	3	5
1. Magnitude	16-18	19-22	>22
2. Position	>300 mi east	150-300 mi east	60-100 mi east
B. Subsidence	0	2	4
1. Spacing of NVA lines	loose	moderate	tight
2. Spacing of thickness lines	loose	moderate	tight
3. Angle between vorticity lines and thickness lines	<30	30-60	>60
C. Hourly Pressure Changes	1	3	5
1. Three hourly pressure rise	2-4 mb	4-6 mb	6-10 mb
2. Total pressure difference in rise/fall couplet	3-5 mb	6-8 mb	9-14 mb
3. Forecast path of center of pressure rise bubble	>200 mi east or west	100-200 mi east or west	<100 mi east or west

D.	Cold Air Advection	0	2	3
	1. Surface geostrophic CAA angle isobars cross thickness lines	0-30	30-60	60+
	2. CAA 850-500 mb	1	3	5
	a. 850 mb (temperature difference between start and end of CAA)	<10	10-18	18+
	b. 700 mb (etc.)	<6	6-10	10+
	c. 500 mb (etc.)	<5	5-9	10+
E.	Lapse Rates	1	3	5
	To what level does adiabatic lapse rate extend to?	sfc-850 mb	sfc-700 mb	sfc-500 mb
F.	Jets	1	3	5
	1. How strong is 850 mb wind	<30 kts	30-45 kts	>45 kts
	2. How strong are 300/250 mb winds	<70 kts	70-100 kts	>100 kts
	3. Strength of forecast winds 3 to 6 thousand feet (FD)	<30 kts	30-45 kts	>45 kts
G.	Directional Wind Shear	1	2	4
	To what level do we have little directional wind shear?	sfc-850 mb	sfc-500 mb	sfc-300 mb
H.	Geostrophic Wind (Sangster Winds)	1	3	5
	What is the wind speed over or upstream of forecasted area?	<30 kts	35-45 kts	50-70 kts
I.	Vorticity Comma/Dry Slot on SWIS	0	2	4
	1. Is vorticity comma and dry slot evident on SWIS?	no	yes (somewhat defined)	very apparent
	2. What is forecast relative humidity in dry slot?	>70%	50-70%	<50%
	3. Extrapolation of dry slot axis position relative to forecast area	<150 mi east or west	60-150 mi east or west	<60 mi east or west
J.	Loose Snow Cover	0	1	4
	How much snow is available in the state and upstream?	hard packed or 0-1"	2-4" loose 2-4" loose	>3" >3"

The last question to ask is "How long will the wind blow?" This is a tough question. In most cases, the wind will blow longer than expected. Once an adiabatic flow is established, and higher momentum air is being mixed and transported downward, it takes a major change to stop it. The major change may come in the form of a surface ridge line, or the end of cold advection in the lower level. Two major factors are apparent: (1) The wind should subside after the center of the surface pressure rise area moves through the forecast target area, and (2) the wind should subside after the 850 mb colds air advection ends.

4. References

Sangster, W. E., 1980: A New Concept in Diagnosing Large-Scale Vertical Motion. Central Region Technical Attachment 80-20, available from NWS Central Region, Scientific Services Division, Kansas City, MO.

Van Ess, R. L., 1985: Forecasting Ground Blizzards. Central Region Technical Attachment 85-22, available from NWS Central Region, Scientific Services Division, Kansas City, MO.