The arctic airmass and arctic front in Finland

This presentation is based on my Master's thesis in meteorology (2002): Arctic front. University of Helsinki,Finland, Faculty of Science, Department of Physical Sciences, Division of Atmospheric Sciences.

Introduction

Mid- and high latitude weather is characterized by contrasts that take place on a time scale of the order of a few days. Most of these changes in temperature, wind, weather and cloud cover are the effects of extra-tropical cyclones. These occur during all seasons, but are most frequent in the autumn and winter. The polar front is typically located at mid-latitudes and separates polar air masses from the mid-latitude air masses. Along the polar front the mid-latitude cyclone will develop in response to oscillations within the polar jet stream at upper levels.

Within the polar air a secondary frontal zone, limited to the lower troposphere, can form in winter and this is known as the arctic front. It separates extremely cold air across areas near the pole from less cold airmasses further south and frequently is fixed orographically to the immediate coastal fringes and the pack ice boundary. In addition, its position is greatly influenced by the extent of snow cover on continental land. As the baroclinic zone of the arctic front remains restricted to the lower troposphere, it does not appear useful to define 'arctic air' in addition to polar air. Also, it would be very difficult in individual cases to distinguish between air which actually comes from arctic regions and equally cold or colder air which originates far to the south within anticyclonic conditions over snow-covered continental land.

Classification of jet streams

According to the model of Palmen and Newton (1969), four air masses (tropical air masses (TA), mid-latitude air masses (MLA), polar air masses (PA) and arctic air masses (AA)) and three fronts or jet streams (subtropical, polar and arctic) are defined.

One of the most important result of my master's thesis is represented in Table 1 and in Figure 1. The Palmen and Newton model was too simple when analyzing the European winter 2000-2001. North of subtropical jet stream there were two or three, sometimes even four, westerly jet streams observed at the same time across Europe.

According to Table 1, the Palmen and Newton model was valid in only half of the cases observed in Europe between 1st December 2000 and 31st March 2001. In almost every other case, three or sometimes four westerly jet streams were observed during this period.

One front or jet stream	1/110	1%
Two fronts or jet streams	55/110	50%
Three fronts or jet streams	51/110	46%
Four fronts or jet streams	3/110	3%

Table 1. Observed fronts or jet streams across Europe, north of the subtropical jet stream between 1st December 2000 and 31st March 2001.

It is likely that sometimes there may be a subtropical front, a southern branch of the polar front, the polar front itself, a northern branch of the polar front and arctic front across the whole of Europe at the same time. It is not always easy to distinguish specific jets if there are several branches within a meridional cross-section across Europe (Fig 1). The most important features used to classify the fronts are: their location in a north-south direction with respect to other fronts, the specific location and height of the jet stream, and temperature of the air masses.

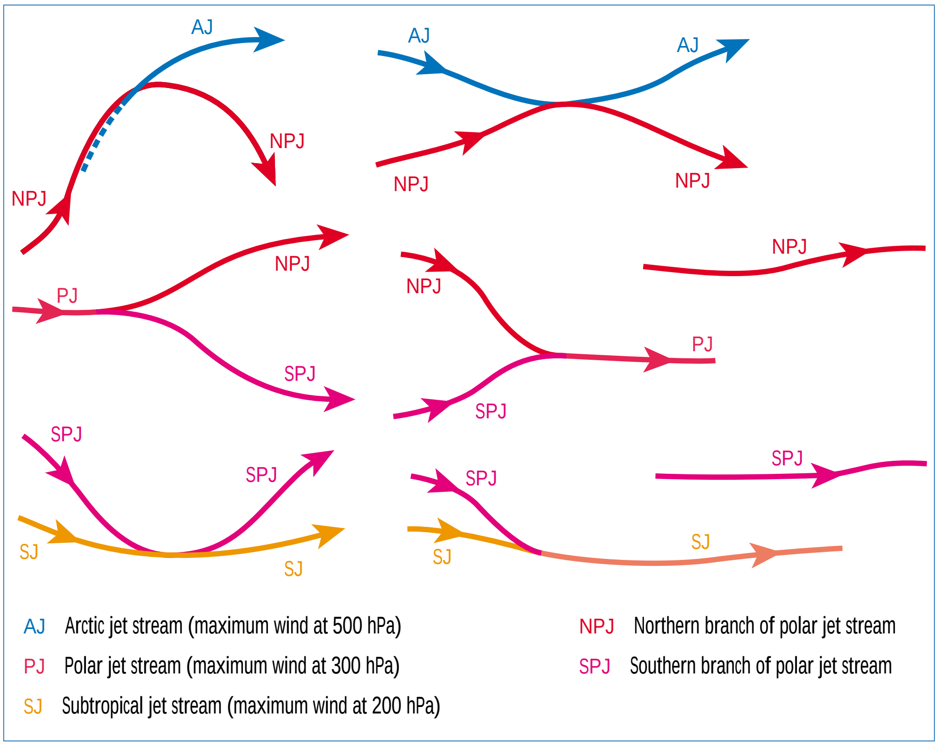

Figure 1: A schematic proposal for the classification of jet stream branches.

The polar jet stream can be split, for example, when a blocking high lies across northern Europe. In this case the jet stream deflected to the south is called the 'southern branch' of the polar jet (SPJ). On the other hand, the jet deflected to the north is called the 'northern branch' of the polar jet (NPJ). Each can co-exist because of the upstream bifurcation in the flow pattern at middle and upper levels of the troposphere, with downstream confluence then likely to the east of a block. The SPJ and NPJ are new conceptual models.

In almost every other case during the winter 2000-2001, three westerly jet streams were observed to the north of the subtropical jet stream. In these cases two branches of the polar jet were observed across the same meridian, in either a SPJ+PJ+NPJ or SPJ+SJ+AJ configuation (where PJ is the polar jet and AJ is the arctic jet). Very occasionally, in less than 3 % of cases, there were four westerly jet streams observed.

Apparently two jet streams can also converge when one is located under the other. There appears to be only one jet stream, though there is in fact a SPJ+SJ or NPJ+AJ. A few cases involving localised jet streams linked to triple point disturbances and also easterly jet streams have been omitted in this study.

The Arctic front

The arctic front separates the cold polar airmass from even colder air of arctic origin. It is located to the north of polar front in winter. Arctic fronts occur frequently over the Arctic Sea, sometimes over Scandinavia, and sometimes reach as far south as the North Sea. Arctic fronts are not found in Finland during the summer.

The arctic front is typically a shallow tropospheric feature, with the strongest baroclinicity observed most often in the lowest layers up to 2-3 km above the surface. In the middle and upper troposphere baroclinicity is weak or absent. Normally the front lies below an extensive cold upper low or trough.

Strong gradients in the 850hPa potential temperature, 500hPa wind field and the 1000-500hPa thickness are the most useful parameters when identifying the arctic front. In contrast, fields at higher levels (such as 500hPa temperature field or 300hPa wind) do not help to locate the arctic front.

Arctic airmasses

An ‘arctic airmass’ across northern Europe is defined as one with temperatures lower than -18ºC at 850hPa, and with 1000-500hPa thickness less than 5080m in the winter. Arctic airmasses are not found in Finland in the summertime. In the northern hemisphere summer, arctic airmasses are found only near the North Pole.

Arctic airmass modification is very efficient over warm, open sea, especially in the boundary layer. Latent heat flux is often much weaker than sensible heat flux above a relatively warm sea in a cold air outbreak. An arctic airmass can remain unchanged above cold snow-covered ground, as modification mechanisms are weak.

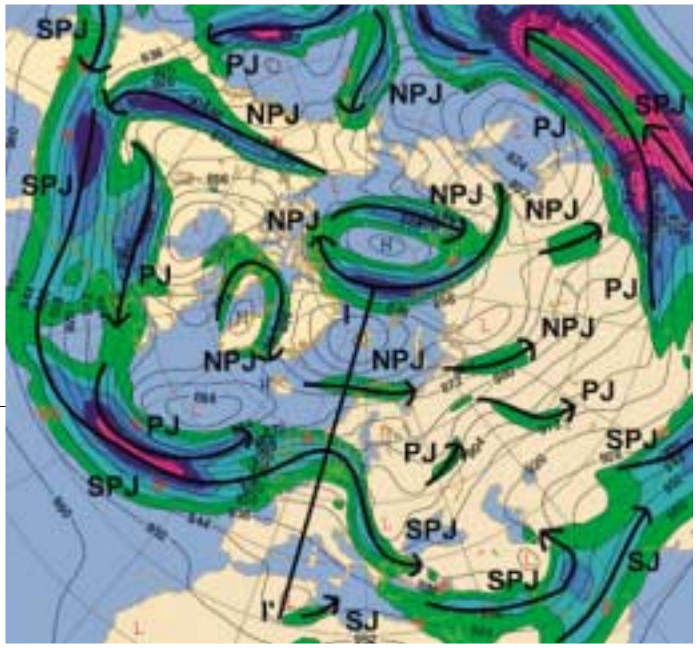

Figure 2: Distribution of isotachs and jet streams at 300hPa on 11th December 2000, 12UTC (AJ: arctic jet stream, NPJ:northern branch of polar jet stream, PJ: polar jet stream, SPJ: southern branch of polar jet stream, SJ: subtropical jet stream).

A short case study

An example of the appearance of airmasses, jet streams and fronts is presented in the case study of 11th December 2000.

The arctic jet stream is situated lower down in the troposphere and is also weaker than the polar jet stream (Figs 2,3 and 4). The arctic front does not extend as high as the other frontal zones (Fig 4). It is important to be able to

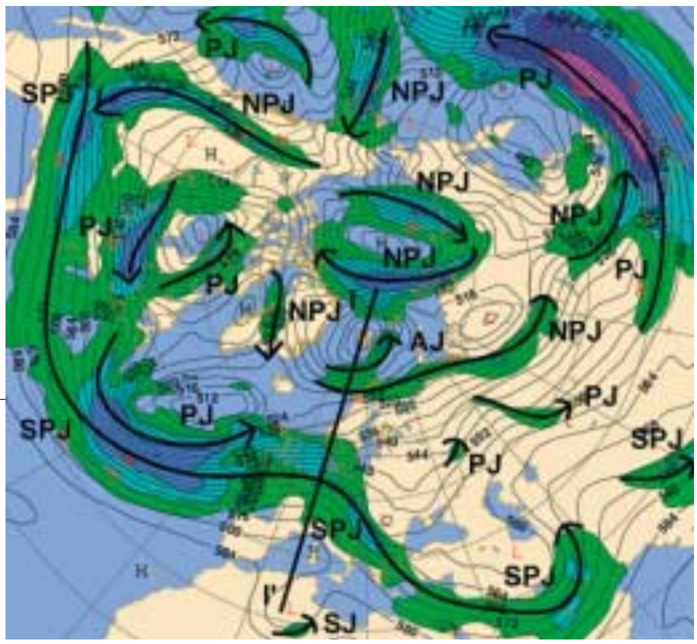

Figure 3: Distribution of isotachs and jet streams at 500hPa on 11th December 2000, 12UTC (AJ: arctic jet stream, NPJ:northern branch of polar jet stream, PJ: polar jet stream, SPJ: southern branch of polar jet stream, SJ: subtropical jet stream).

detect arctic fronts and to be able to distinguish them from other frontal zones and troughs (Fig 5). Along all four frontal zones, baroclinic disturbances will develop. They can be analysed using the Norwegian frontal model. Thorough frontal analysis is important, especially in the nowcasting period (up to 12 hours).

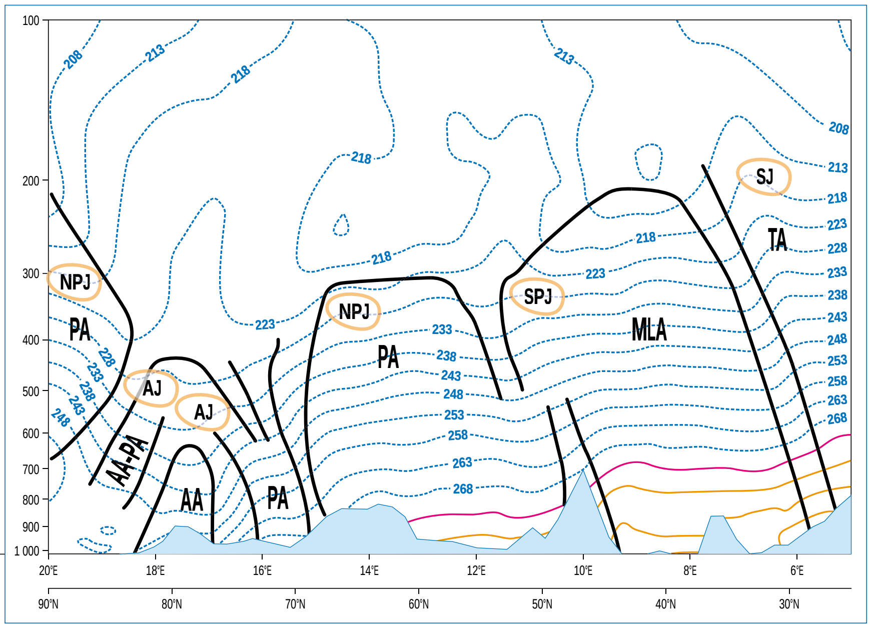

Figure 4: Vertical cross section along the line I-I' in Fig 2. and 3. Distribution of jet streams, potential temperature (K) within the frontal zones and airmasses based on the model of Palmen and Newton on 11th December 2000, 00 UTC.

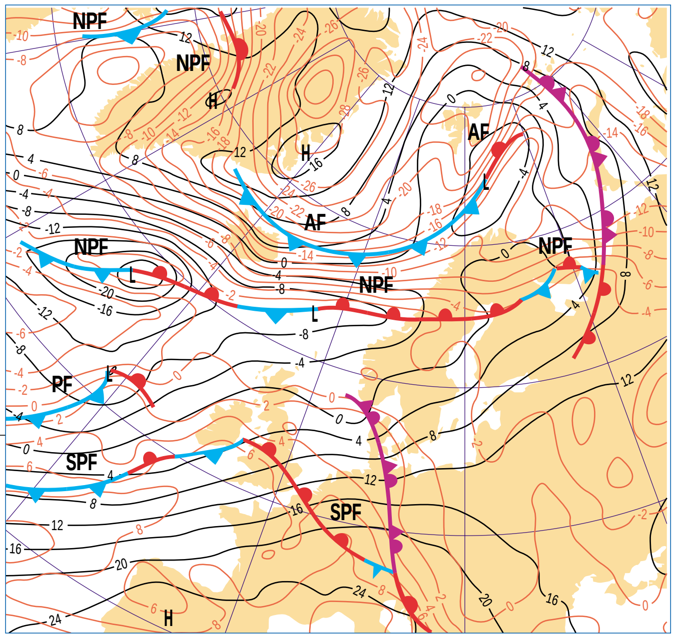

Figure 5: Pressure distribution (solid lines, in hPa) and fronts in the surface field on 11th December 2000, 12 UTC. (AF: arctic front, NPF:northern branch of polar front, PF: polar front, SPF: southern branch of polar front).

References:

Palmen, E. H. and C.W. Newton, 1969: Atmospheric circulation systems: Their structure and physical interpretation. Academic Press, New York.

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