Stratosphere and the North Hemisphere's Winter Weather

M.A. Vukcevic

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(M. A. Vukcevic 01/12/2010)

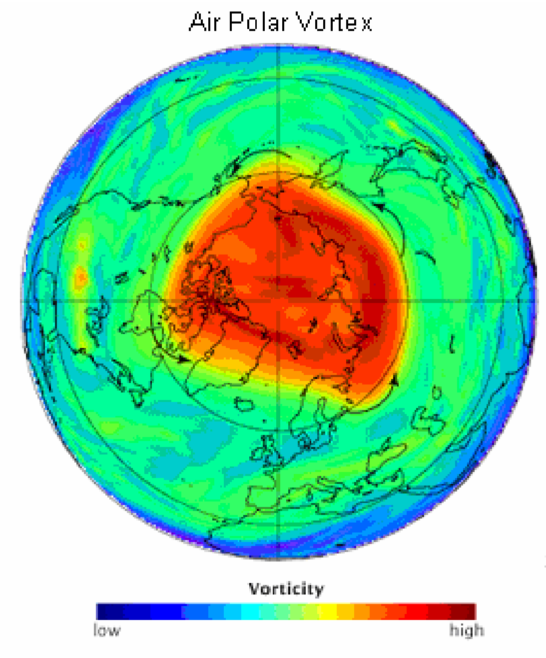
Abstract: Sudden Stratospheric Warming of up to 50^0C is a regular feature of the Arctic's winter, but much less frequent in the Antarctica rarely exceeding 10-15^0C. Recent paper 'Tropospheric forcing' by Peters *et al* 2010 analysing Jan 2003's event, is considered for formulating a possible alternative but not exclusive cause. The author of this study postulates that the North Hemisphere's winter weather is affected by volcanic eruptions at high latitudes via the SSW occurrences. This appear to be result of volcanic hot gas plumes, as they rise through the troposphere, push upwards a dome of the warm tropospheric air into the stratosphere. Result of this air movement causes deformation and in more pronounced cases splitting of the polar vortex. Graphic analysis of the SSWs, with possible link to concurrent volcanic eruptions, is presented for the most recent winters. Coincidence of number of the SSW cases with the volcanic eruptions appears to confirm the hypothesis.

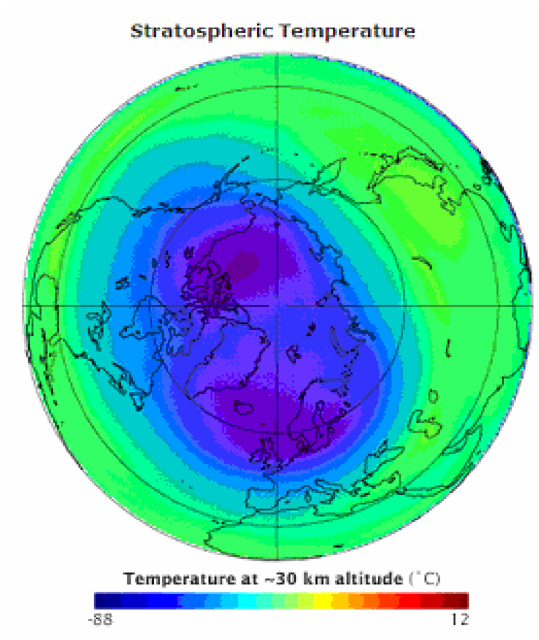
I

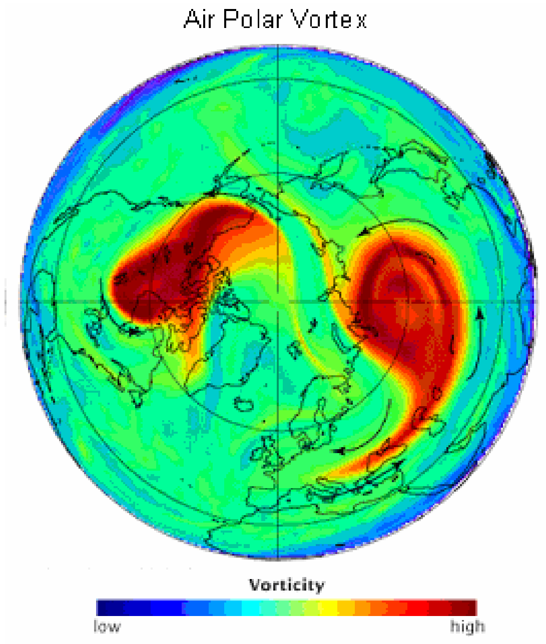
SUDDEN STRATOSPHERIC WARMING

In the winter, little to no sunlight reaches Earth's northern extremes. Deprived of energy, the stratosphere over the Arctic grows cold. Farther south, where the Sun is shining, the air is warmer and air pressure is higher in the stratosphere. The cold air mass creates a low-pressure system in the stratosphere that sits over the Arctic throughout the winter.

Air flows away from the high-pressure system towards the low-pressure system. Because the Earth is turning, the air is deflected to the right as it moves north, creating a strong counter-clockwise (west to east) current of wind, which scientists call the polar night jet.

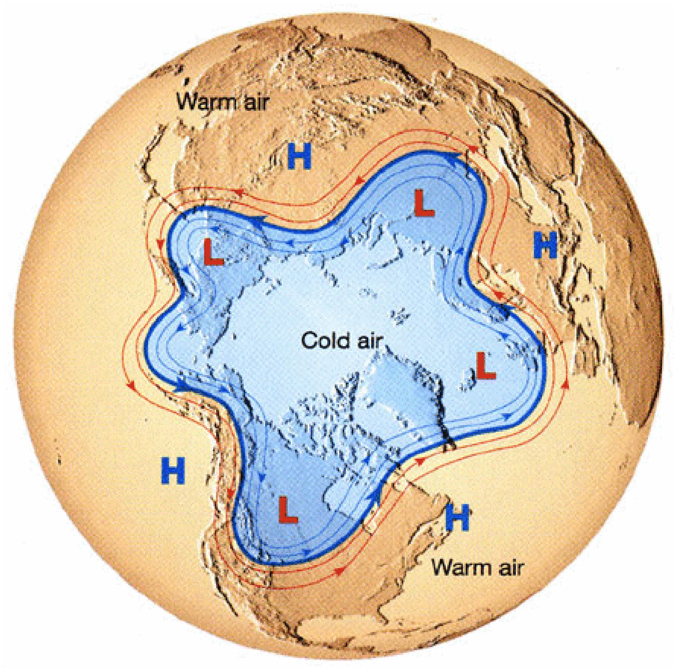




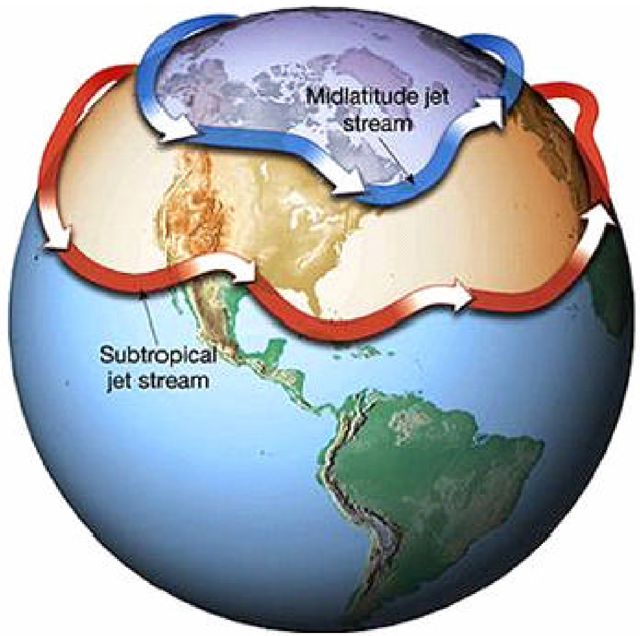


The big change in the Arctic came when the polar vortex is ripped apart. This can occur if warm air from the lower atmosphere travels upward into the stratosphere. The disturbance moves the centre of the Arctic air mass, elongating it and eventually splitting it apart.

This severely distorts normal polar jet stream, having important effect on the weather in North America, Europe and the north part of Asia.



Rossby (or planetary) waves are giant meanders in high-altitude winds that are a major influence on weather. Their emergence is due to shear in rotating fluids, so that the Coriolis force changes along the sheared coordinate. In planetary atmospheres, they are due to the variation in the Coriolis effect with latitude. The waves were first identified in the Earth's atmosphere in 1939 by Carl-Gustaf Arvid Rossby who went on to explain their motion.

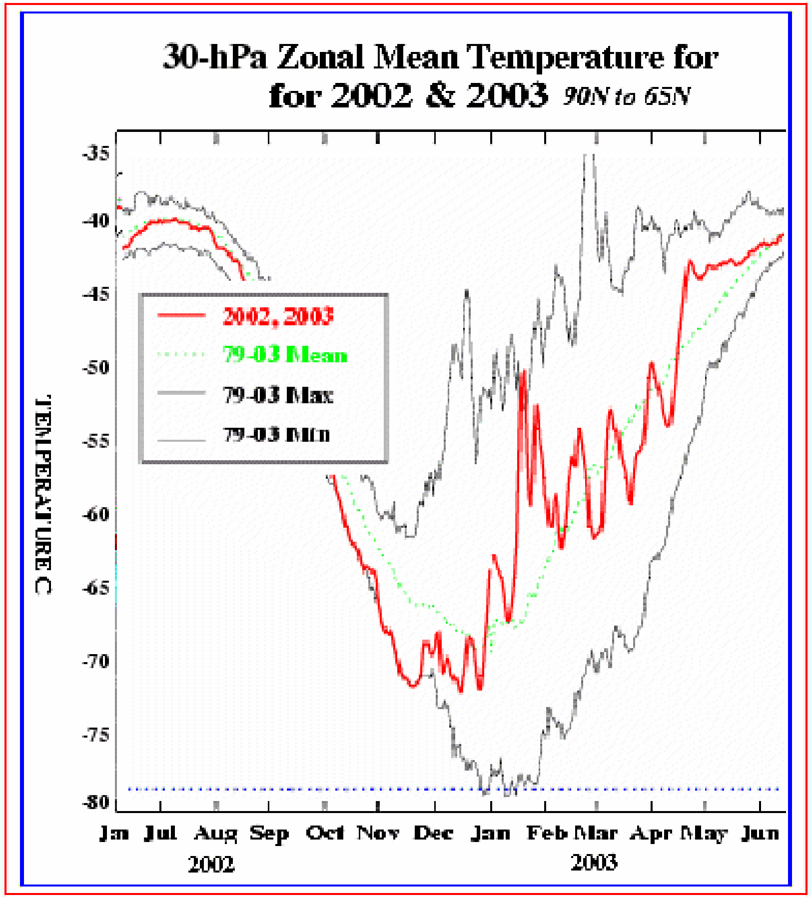


Rossby waves in the atmosphere are easy to observe as (usually 4-6) large-scale meanders of the jet stream. When these loops become very pronounced, they detach the masses of cold, or warm, air that become cyclones and anticyclones and are responsible for day-to-day weather patterns at mid-latitudes.

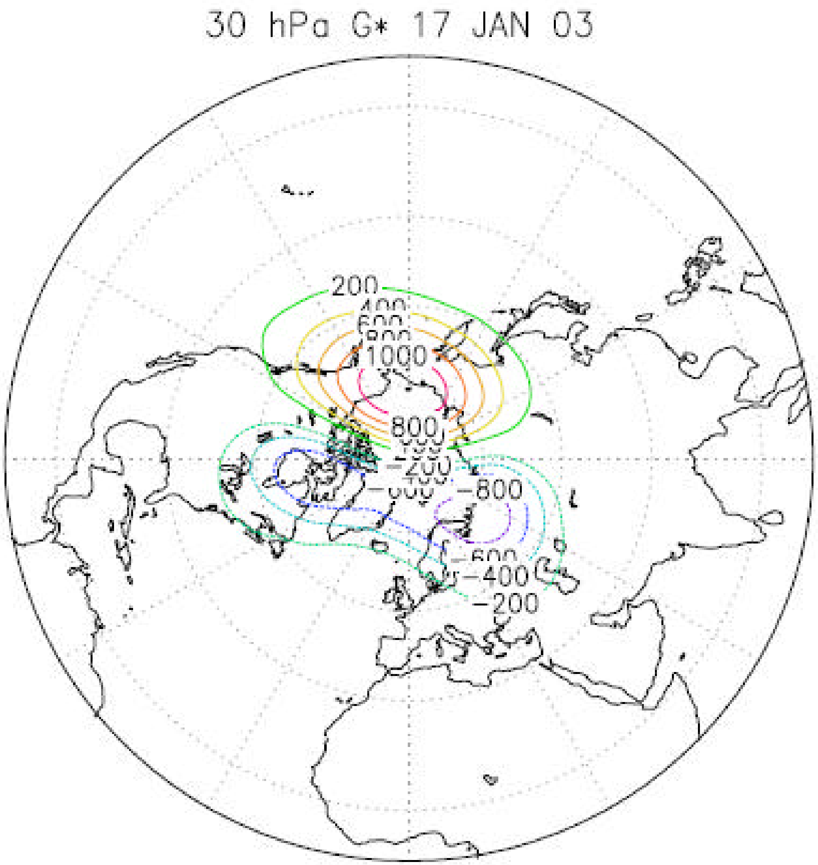
Recent paper ‘Tropospheric forcing of the boreal polar vortex splitting in January 2003’ (Peters *et al*) is a good guide to the atmospheric phenomenon of a sudden stratospheric warming (SSW).
http://www.ann-geophys.net/28/2133/2010/angeo-28-2133-2010.pdf

The paper describes dynamical linkage between troposphere and stratosphere. In particular SSW events are a prominent feature of interannual variability of the extratropical stratosphere over the Arctic region with the strongest SSW event ever observed in January 2009.
A sudden stratospheric warming event could lead to a fast and significant increase of the polar stratospheric temperature (up to 40 K) and to a reversal of mean zonal circulation. Moreover, the polar stratospheric vortex could be shifted off the pole, or in some cases a splitting event may occur.
Occasionally due to enhanced meridional circulation is not confined to middle and high latitudes but also could cause cooling of equatorial troposphere.
Paper’s authors suggest that variations in the polar vortex and in temperature-dependent polar ozone depletion, which may be induced by tropospheric forcing mechanisms, may have a substantial feedback on the tropospheric and stratospheric wave propagation, but it will not considered here.
The article concentrates on the tropospheric forcing processes of the major SSW and polar vortex splitting in January 2003, giving a good example of understanding this process.

NOAA analyses are derived each day at 8 stratospheric levels, 70. 50, 30, 10, 5. 2. 1. and 0.4 hPa (approximately 18-55 km).
Here is shown graph for the lower stratosphere, 30 hPa (approx. 30 km) over latitude region 90-60N, including the relevant period i.e. January 2003 analysed by(Peters *et al* .
The record low temperatures of the boreal polar stratosphere were observed during the early wintertime period of 2002–2003. Seasonal evolution of zonal mean temperature for the polar region are shown in the diagram. From the graph it can be seen that number of minor SSW took place before major burst in mid January 2003.
It should be noted that the events of sudden stratospheric warming are usually confined to the winter months (November to March), but on this unusual occasion they are extended well into April, when the insolation of the Arctic is on the rise, so such events are not so frequent.



Peters *et al* show polar map for 17 January 2003 event. Incursion into the stratosphere occurred above the Bering strait with contours of geopotential height perturbations.
Geopotential height approximates the actual height of a pressure surface above mean sea-level. When a collection of geopotential height reports are contoured on a given pressure surface, it is possible to identify upper air troughs and ridges, which are very important influences on surface weather conditions.



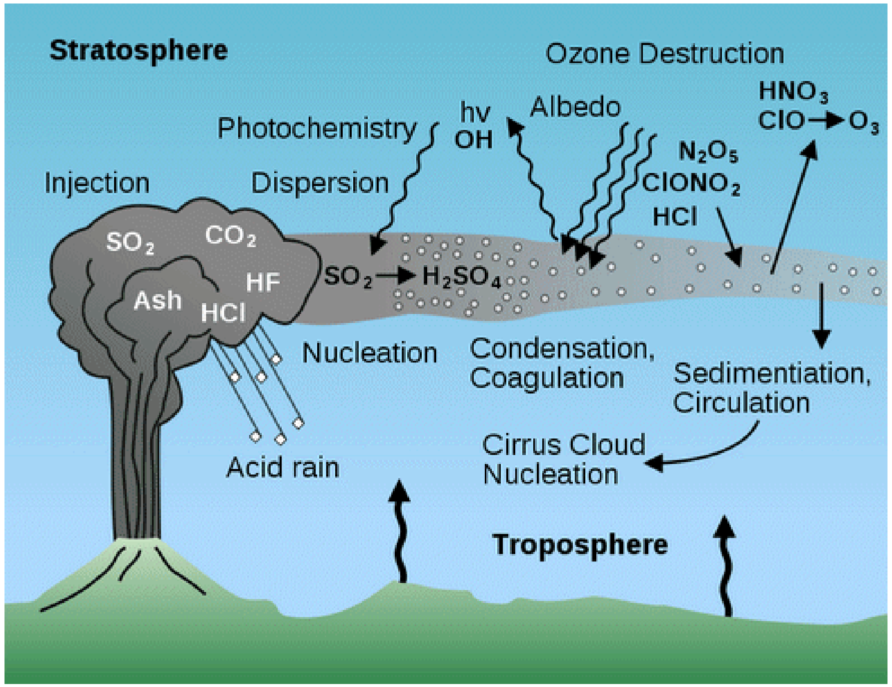
Peters *et al* illustration of the SSW in January 2003

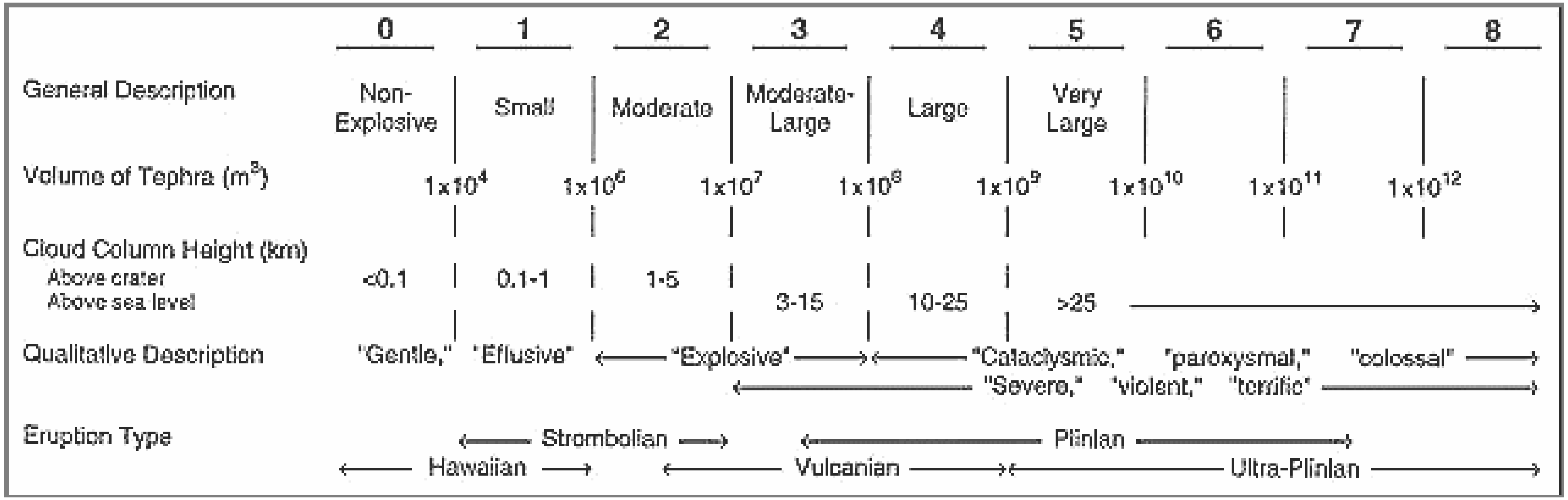
Geopotential height is valuable for locating troughs and ridges which are the upper level counterparts of surface cyclones and anticyclones.

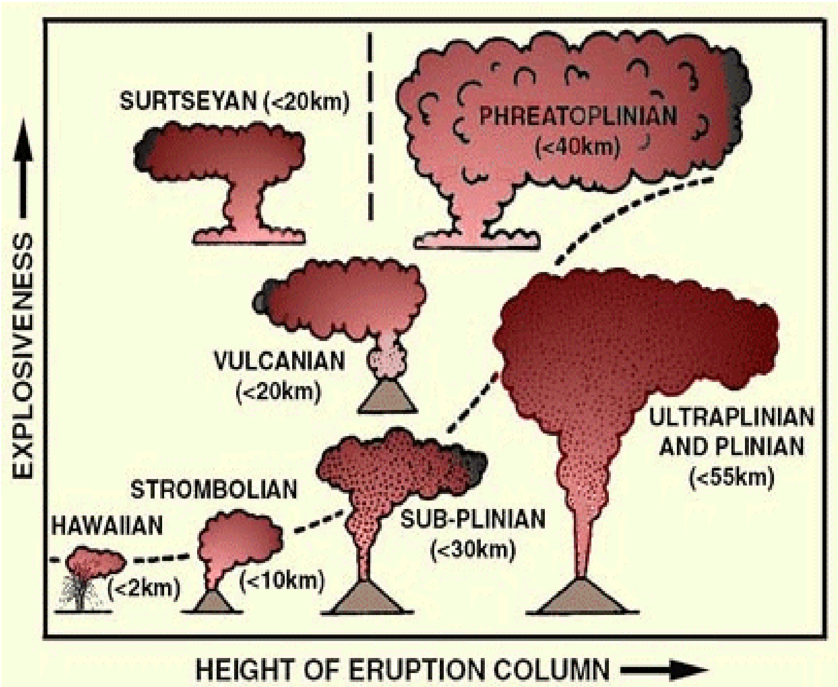
The periodic increase in geopotential heights it is assumed, is related to the flux in ozone from above. Ozone absorbs radiation from the Earth, and when created above 10hPa it drifts downward followed by its chemical destruction.

It is known that planetary wave activity strongly influences stratospheric temperature and air circulation over the Arctic and Antarctica during the winter-spring season.
Authors consider possibility of Rossby wave trains in the middle and upper troposphere contributed to the major sudden stratospheric warming in Jan-Feb 2003 which accompanied polar vortex splitting.

It should be noted that the Arctic has two nearby active volcanic areas: Iceland in the North Atlantic and Kamchatka peninsula with Aleutian archipelago.
The fact is that the January SSW was recorded above Bering strait while in the nearby Kamchatka's peninsula there was an ongoing intense volcanic activity. Peters *et al* do not mention this, possible relevant factor, in their study.
At first sight this fact may appear irrelevant, since effect of volcanic eruptions on both troposphere and stratosphere is well known and documented as illustrated in this graphic.







Volcanic explosions are given numbers to measure the intensity of their eruptions. The scale is called the "Volcanic Eruption Intensity" scale or VEI. The VEI goes from "0" to "8" according to intensity. There is also descriptive classification as shown in this illustration; strombolian type of eruption is frequently referred to.

There are two major volcanoes currently active in the Kamchatka peninsula: Sheveluch and Klyuchevskoy.

Klyuchevskoy is Kamchatka's highest and most active volcano. The volcano's crater is at 3600 m elevation. It has about 80 lateral explosive vents. Larger eruptions: 1980 ,85, 90,2005, 2007,2009 and 2010. On 23 rd October 2010, the ash plumes reached a height of 10 km extending 300 km north - east of the volcano.

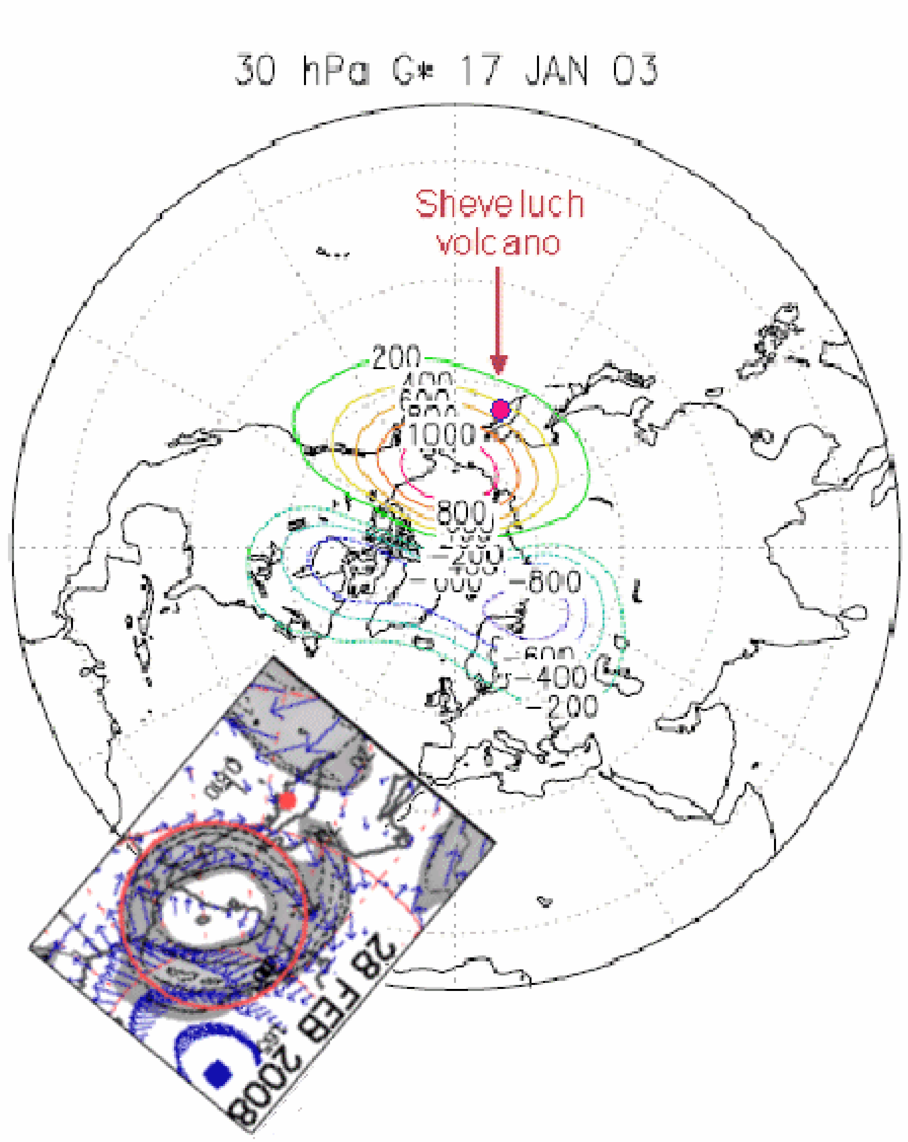
Sheveluch is one of the most active volcanoes on the Kamchatka's peninsula. It has been erupting frequently since 1985. It is noted for its explosive eruptions, with plumes often reaching altitude of 7-8 km.

There were number of eruption during October 2010, on the 27th explosive eruption was accompanied by the ash column reaching a height of 12.5 km.

Sheveluch :27th explosive eruption was accompanied by the ash column reaching a height of 12.5 km.

http://www.temis.nl/protocols/o3field/data/2010/10/o3col2010102712_np.gif

These strong eruptions from both Sheveluch and Klyuchevskoy volcanoes may have been precursor to the Arctic's jet stream perturbations causing an early onset of very cold winter weather in the North Europe.



Even if hot eruption gases do not reach stratosphere a dome of the existing troposphere will be formed above and on most of occasions would be pushed further up into stratosphere.

This is of particular interest if volcanic eruption is within area covered by the planetary wave.

Any intrusion will result in certain amount of the 'sudden stratospheric heating'. If the intrusion is substantial than SSW would be considerable and the polar vortex would be ripped apart , with well known consequences for the Northern Hemisphere's middle latitudes weather. Could such intrusion, triggered by a volcanic eruption taken place in January 2003.

Here is how Peters *et al* describe Jan 2003 SSW:

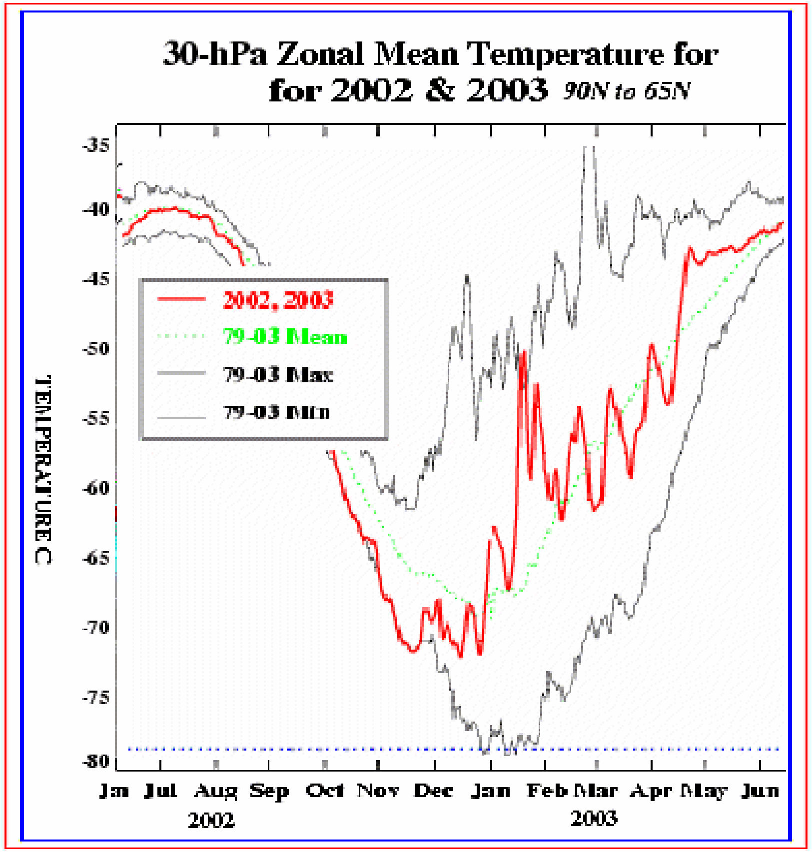
"Six sudden stratospheric warming events, including the major warming event with a splitting of the polar vortex in mid-January 2003, have been identified. "

Was there a coincidental volcanic eruption at the time. Not in Iceland or Aleutian, but there was in the Kamchatka peninsula from Sheveluch volcano, it is described by US Geological Survey as: http://pubs.usgs.gov/of/2005/1310/of2005-1310.pdf page 32

"The number of these explosions observed and detected seismically varied from as many as 25 per week in early January 2003 to several per week in June. By the end of June, the number of explosions had diminished and seismicity remained at or just above background levels through the end of the year."

Geographic proximity of the Sheveluch volcano to the area of the geopotential height increase leads to a possible conclusion that the events of the sudden stratospheric warming and the volcanic eruptions are linked.

The inset shows jet stream vortex formed on 28 Feb 2008 at the time of one of the Sheveluch's eruption. Degree of probability of a coincidence needs to be considered (jetstream images are not available for 2003). Similar event was observed further east during the eruption of Klyuchevskoy volcano on 24 Jan 2010.



Here is another look at the the seasonal evolution of zonal mean temperature for the polar region. The Sheveluch volcano eruptions were already going during December 2002 but intensified by mid January 2003.

USGS: "The number of these explosions observed and detected seismically varied from as many as 25 per week in early January 2003 to several per week in June."

This is entirely consistent with above evolution graph from NOAA, and indeed may contradict Peters *et al*, since by the end of May occurrence of a SSW event should be highly unusual.

It could be concluded that the 'sudden' stratospheric warming of January 2003 was not sudden at all, but gradual and lasted well into the spring of 2003, by which time this would have been a very rare event.

Analysis of the 2003 SSW by Peters *et al* appears to be partially correct while the conclusion does not.

Alternative interpretation offered here is:

Eruptions of the Kamchatka's Sheveluch volcano were already happening in December of 2002. Plume of hot volcanic gases, if not reaching the stratosphere directly, may have created dome of warm tropospheric air above, which protruded in stratosphere and started initial SSW. Volcanic explosions during January became stronger and more frequent, events culminating in the strong SSW as described by Peters *et al*, to eventually dwindle away by June 2003, by which time SSW would naturally be most unlikely anyway.

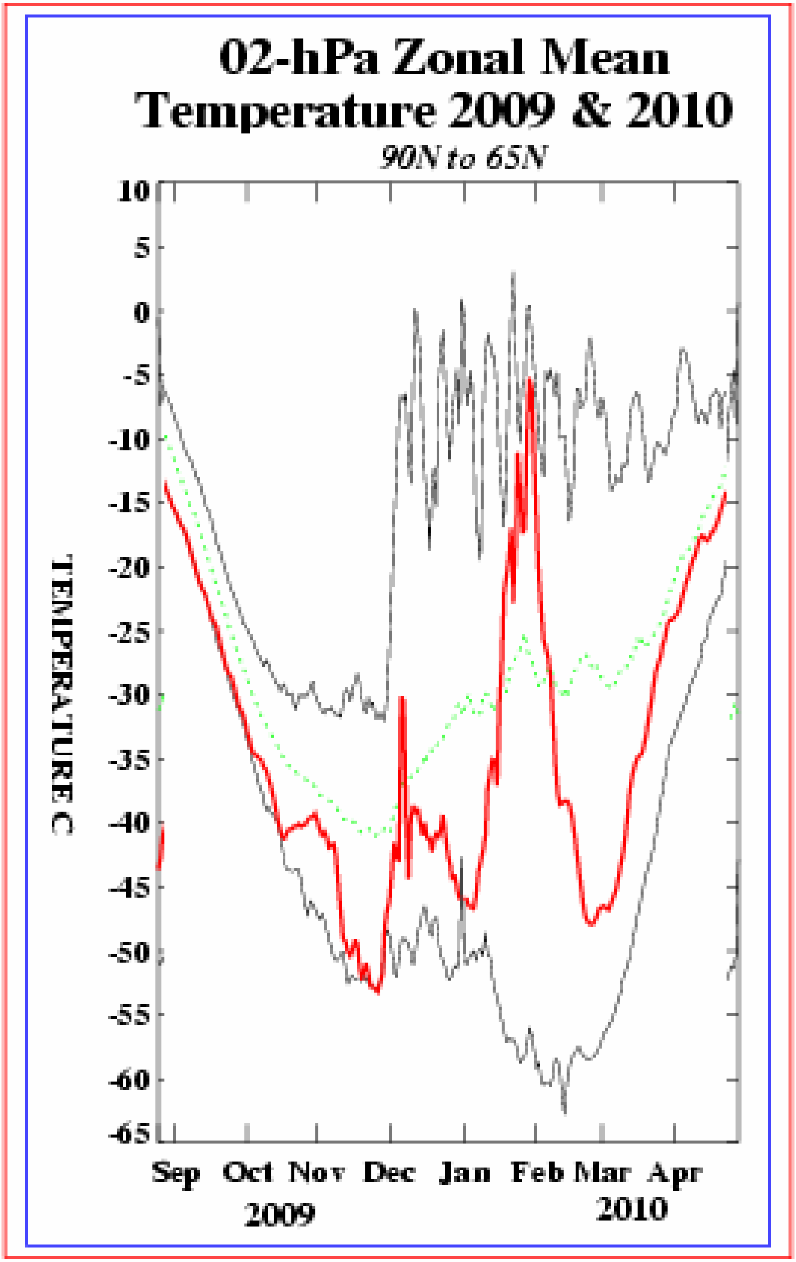
This has important implications for understanding of the SSW of winter 2009/10, when the polar vortex was ripped apart, while Klyuchevskoy volcano was in full swing from December 2009 through March 2010.

NASA has compiled short movie of the Arctic vortex break-up and the stratospheric warming occurring in January/February of 2010.

http://earthobservatory.nasa.gov/images/imagerecords/36000/36972/npole_gmao_200901-02.mov

It is important to note that Klyuchevskoy has started eruptions again this November (2010) and if volcanic explosions increase in the intensity, the Arctic's polar vortex might be interrupted again, resulting in another severe winter in the middle latitudes of the Northern Hemisphere.

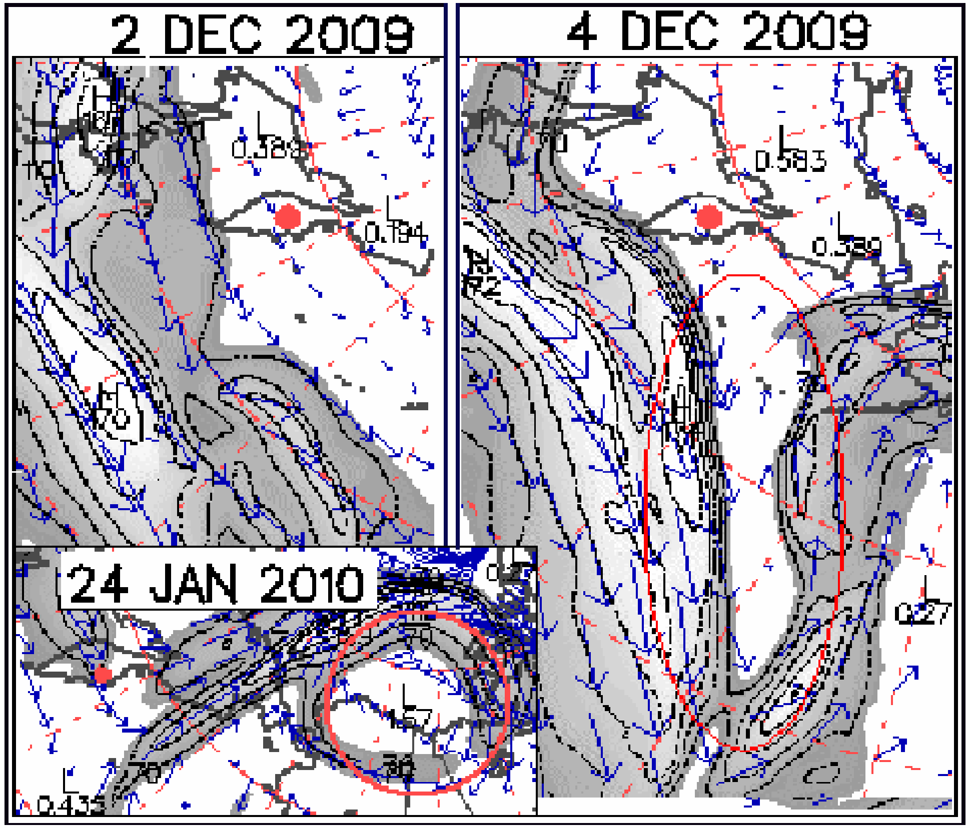
Next pages are devoted to analysis of the SSW occurrences from 2005 to 2010. Higher sensitivity 2-hPa (40km altitude) and 10-hPa (30 km altitude) charts are used for purpose of demonstration.



2009 / 2010 WINTER

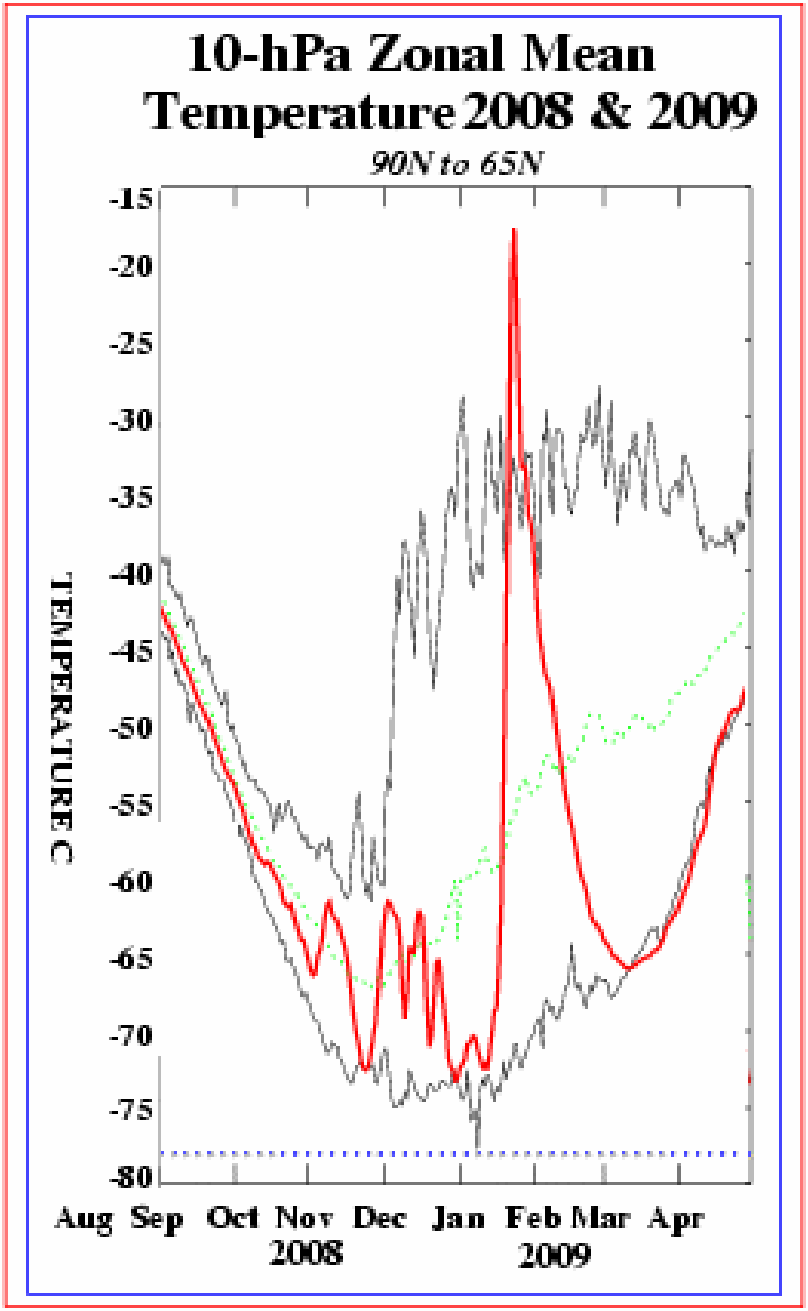
December, 2009

KVERT: Klyuchevskoy volcano December 4: explosive summit activity of strombolian style, and continuing, projecting fragments of lava to more than 300 m height.



January 2010: KVERT&VAAC January 8- 22 : Eruptive activity of Klyuchevskoy is maintained with an elevated level and diversifies. Intense strombolian activity (projected bombs at 500m height) Phreatic explosions are sometimes observed, forming plumes of which the height can reach 8000 m! Vortex in process of formation. The activity can be clearly seen on the Zonal temperature chart as a series of incremental SSW steps.

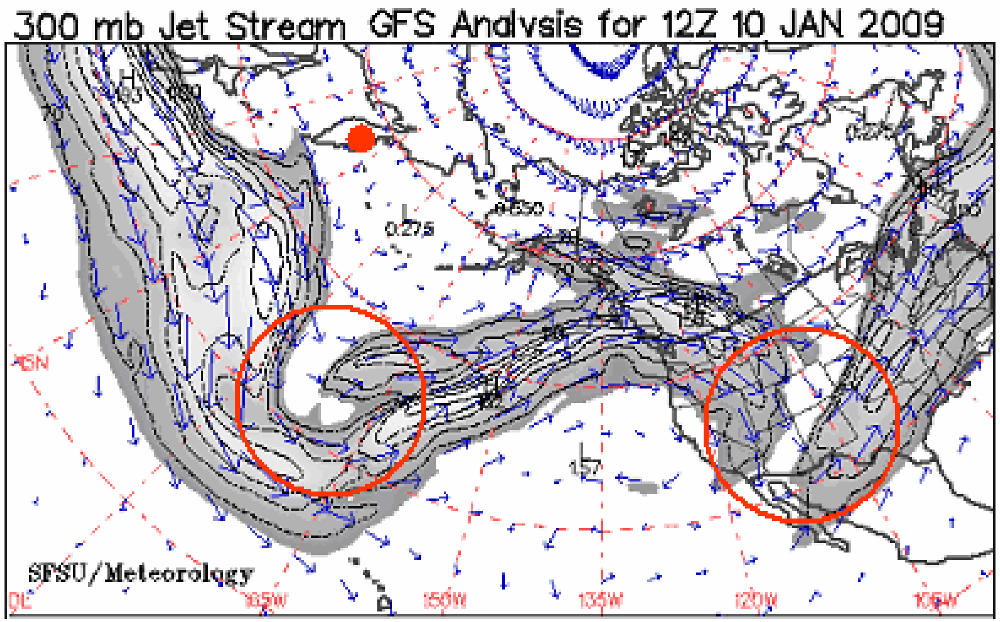
2008 / 2009 WINTER



January 2009 KVERT reported that seismic activity at Shceveluch was above background levels during 2-9 January. Based on interpretations of seismic data, ash plumes rose to an altitude of 8.8 km (28,900 ft) a.s.l. on 7 January and to an altitude of 5.7 km (18,700 ft) a.s.l. on the other days during the reporting period.

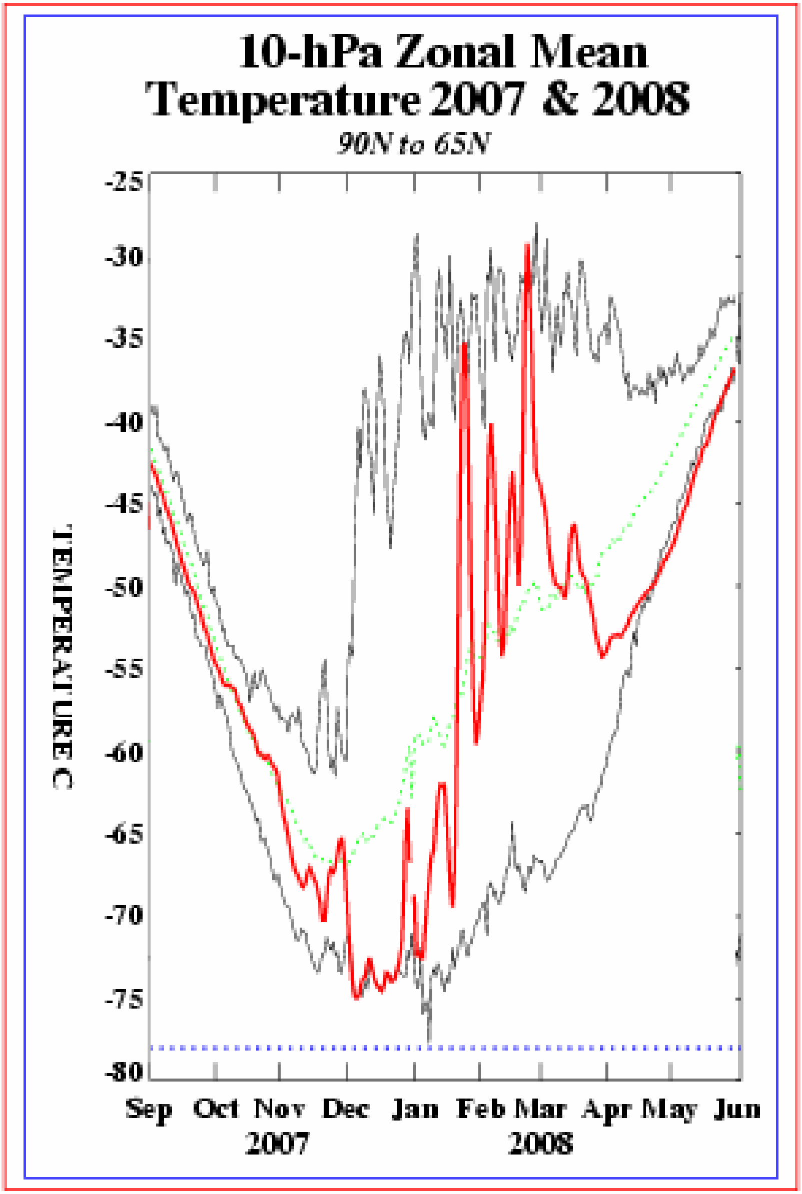
The sudden surge in the stratospheric temperature in the first 10 days of January is consistent with above volcanic activity.

Jet stream shows curios distortion of the jet stream which may have been result of the short volcanoes eruption some hours earlier. There is also a break up of jet of similar shape, possibly from previous days eruption.



February 2009 KVERT: 13-20 Feb ash plumes likely rose to an altitude of 4.6 km (15,100 ft)

The SSW shows a slowdown in the drop of the temperature around mid February consistent with activity at Shceveluch at the time.



2007 / 2008 WINTER

December 28 2007:

VAAC: Shceveluch volcano new intense eruptive phase

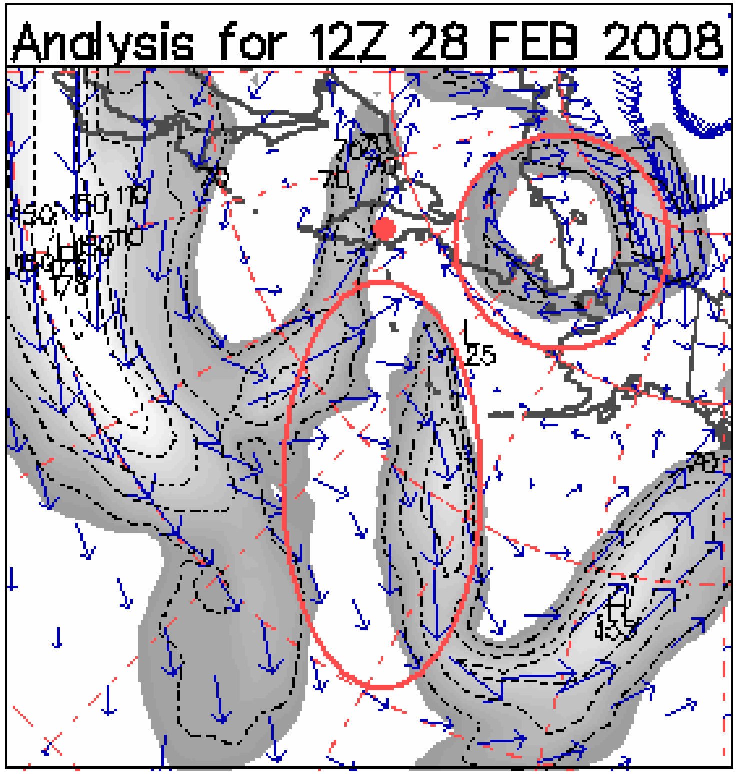
January 18-25 2008:

KVERT: Activity at Shceveluch. ash plumes rose to an altitude of 4.3 km during 17-18, 20, and 23 January.

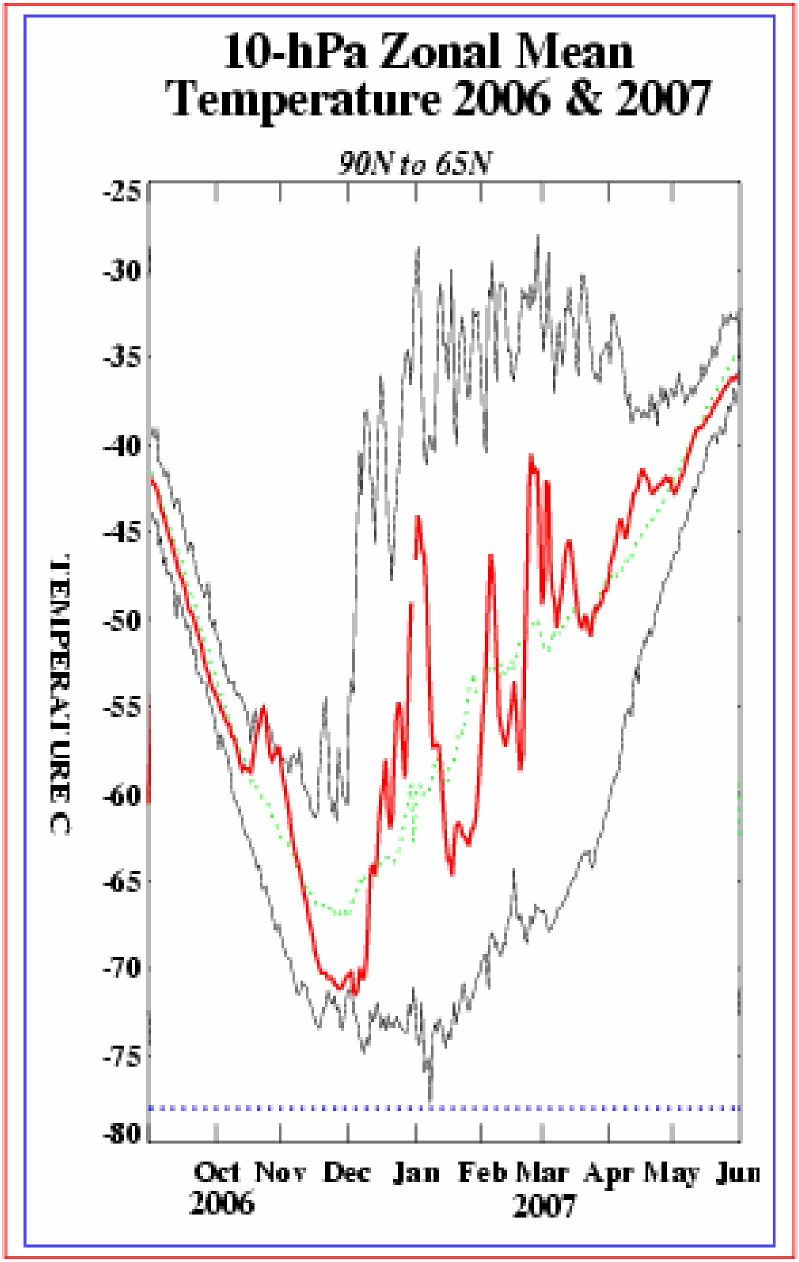
February 28 2008:

KVERT: Shceveluch. Plumes of ashes of more than 3000m height were produced between the 24 and February 26.

The above dates are consistent with some of the peaks in the SSW and the break-up of the jet stream.



The Bering Strait vortex is reminiscent of the Jan 2003 SSW high analysed by Peters *et al.*



2006 / 2007 WINTER

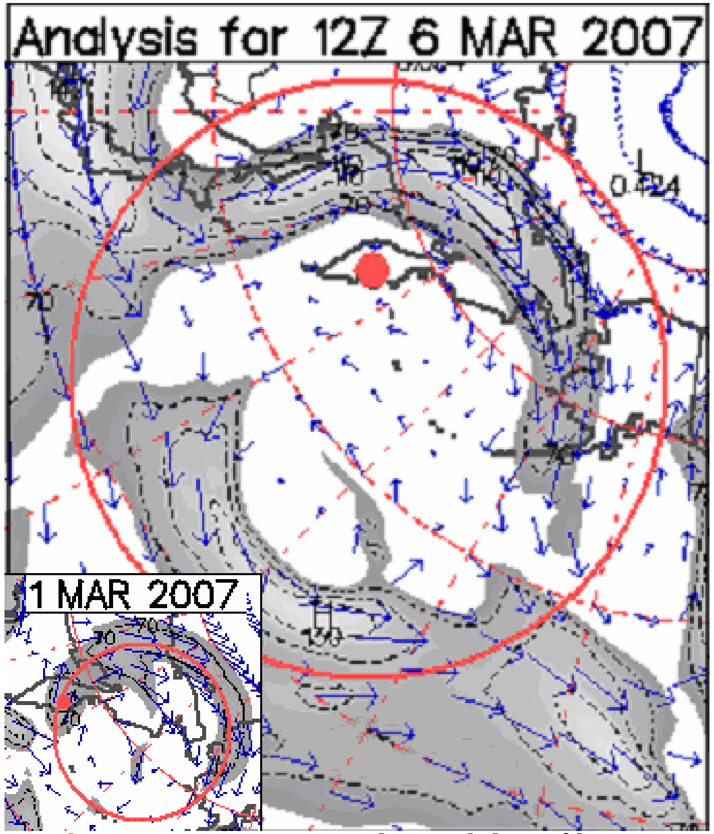
December 5 : KVERT Shceveluch. An explosion projecting of ashes at an altitude of 7 kilometers; December 29 eruption is in progress with 5 explosions per day on average.

January 28 KEMS **Karymsky** eruptive activity, quasi permanent

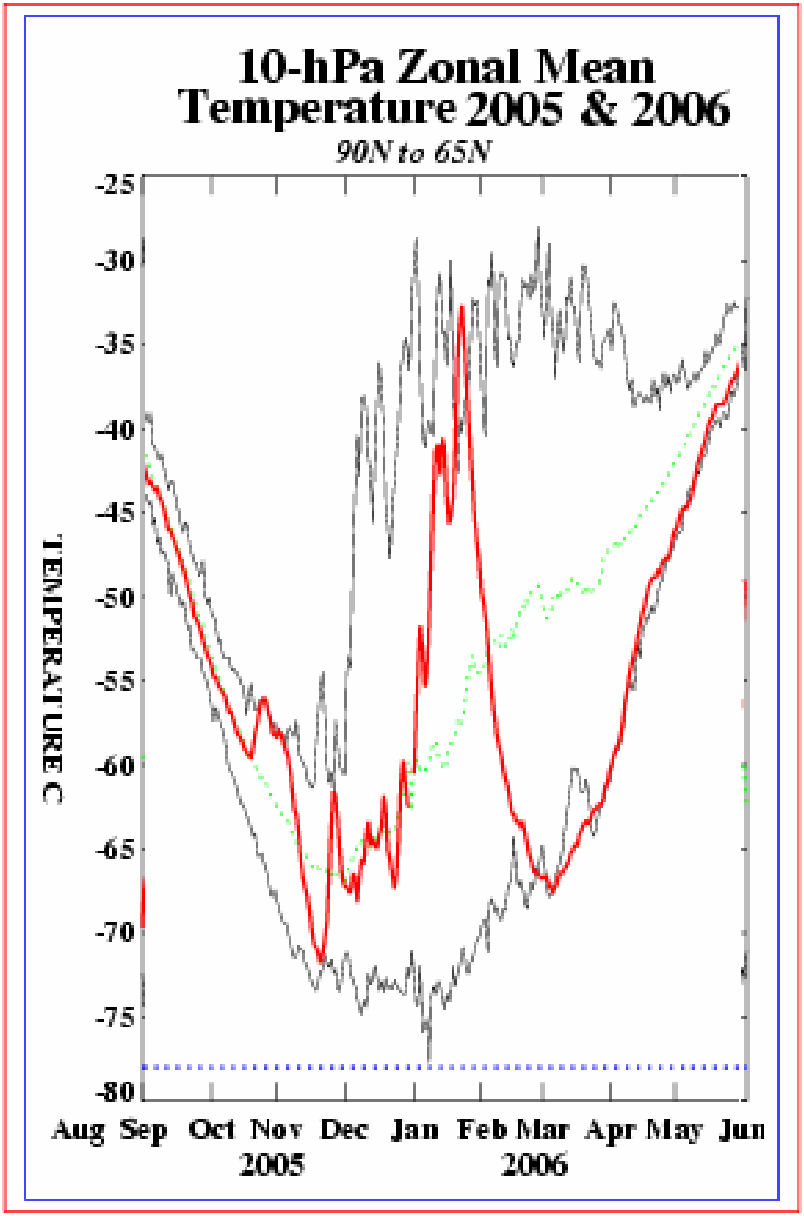
February 26 KVERT Shceveluch eruption with ashes occurred

March 29 NASA: the Shceveluch erupted sending an ash cloud skyward roughly 9,750 meters (32,000 feet).

SSW chart dates are consistent with some of the volcanic activity.



March 6: No eruption reported. Possibility of hot gases rising through to stratosphere breaking and diverting the jet stream, eruption was reported 8 days earlier on Feb 26, jet stream may have been to strong for full vortex to form.



2005 / 2006 WINTER

December 2, 2005:

Bezymianny volcano explosion

January 2006:

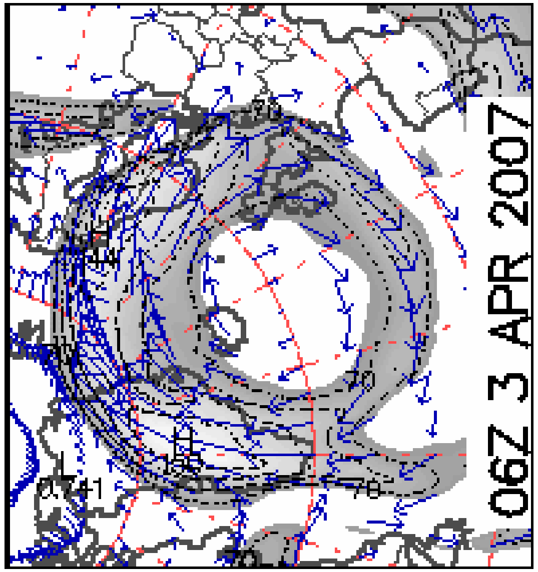
Shceveluch. Its activity is maintained through January with explosive activity, giving rise to plumes approximately 3000m height.

The SSW graph is consistent with above dates of volcanic activity.

Note: Jet steam maps are not available for this period from the sfsu.edu archives website.

Most of the time for whole of period considered (2006 – 2010) jet stream is solid over Euro-Asian land mass, from approximately 90E to 145E longitudes, Break up usually occurs east of the Kamchatka peninsula.

Vortex formation is a rare event; away from Kamchatka-Bering strait area only a single one was found above Iceland on 2/3 April 2007, but no reference to volcanic activity was found.

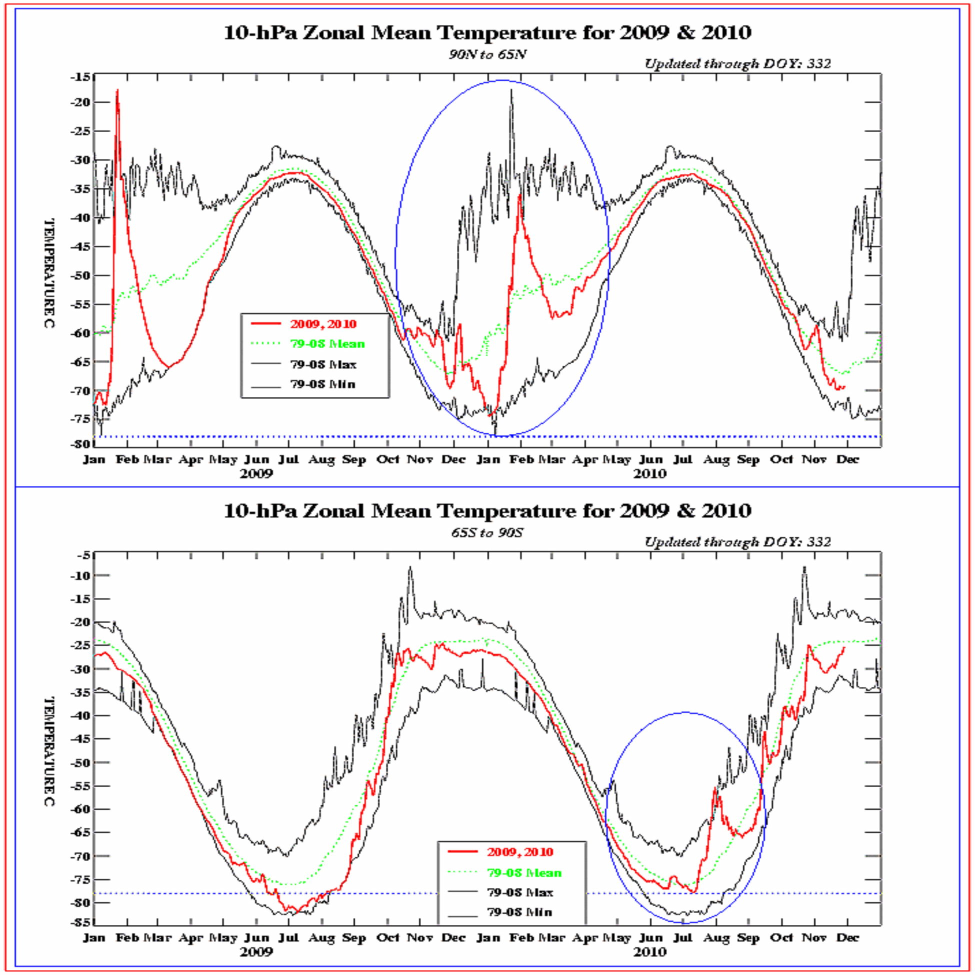


Sudden Stratospheric Warming apparently appears during most of the N hemisphere's winters. The SSW should not necessarily be a precondition for a cold winter.

III

SUDDEN STRATOSPHERIC WARMING IN THE ANTARCTICA

Sudden Stratospheric Warming events are extremely rare in the Antarctica. There are some plausible explanations for this, but most likely is that there is only one active volcano in the area, Mt. Erebus.. The volcano has occasional strombolian eruptions, but no Antarctica winter SSW event was recorded during last 30 years, while they are regular in the Arctic, which also can be concluded by observing min/max values of the zonal temperature, and comparing those to the Arctic' min/max charts.



CONCLUSION

It has been demonstrated that there is a strong possibility that the Sudden Stratospheric Warming (SSW) is on certain occasions caused by the Kamchatka's peninsula volcanoes.

Of importance is further understanding of the jet stream's fragmentation and its consequences for the Northern Hemisphere's weather. Establishment of the more certain correlation between the observed Kamchatka's volcanic activity and the area's jet stream patterns could be of crucial importance for the climate science.

At the time of writing (01/12/2010) there is an ongoing volcanic activity of Kamchatka's volcanoes, while the most of the Western Europe is in the grip of unusually early and cold winter weather.

REFERENCES:

Peters *et a*l: Tropospheric forcing in January 2003

http://www.ann-geophys.net/28/2133/2010/angeo-28-2133-2010.pdf

USSG:

http://pubs.usgs.gov/of/2005/1310/of2005-1310.pdf

NASA:

http://earthobservatory.nasa.gov/images/imagerecords/36000/36972/npole_gmao_200901-02.mov

NOAA:

http://www.cpc.ncep.noaa.gov/products/stratosphere/temperature/

Volcans du Monde:

http://www.activolcans.info/

SFSU:

http://squall.sfsu.edu/crws/archive/jet_nh_arch.html