Coupling between the neutral atmosphere and the ionosphere during the major stratospheric warming in January 2009.

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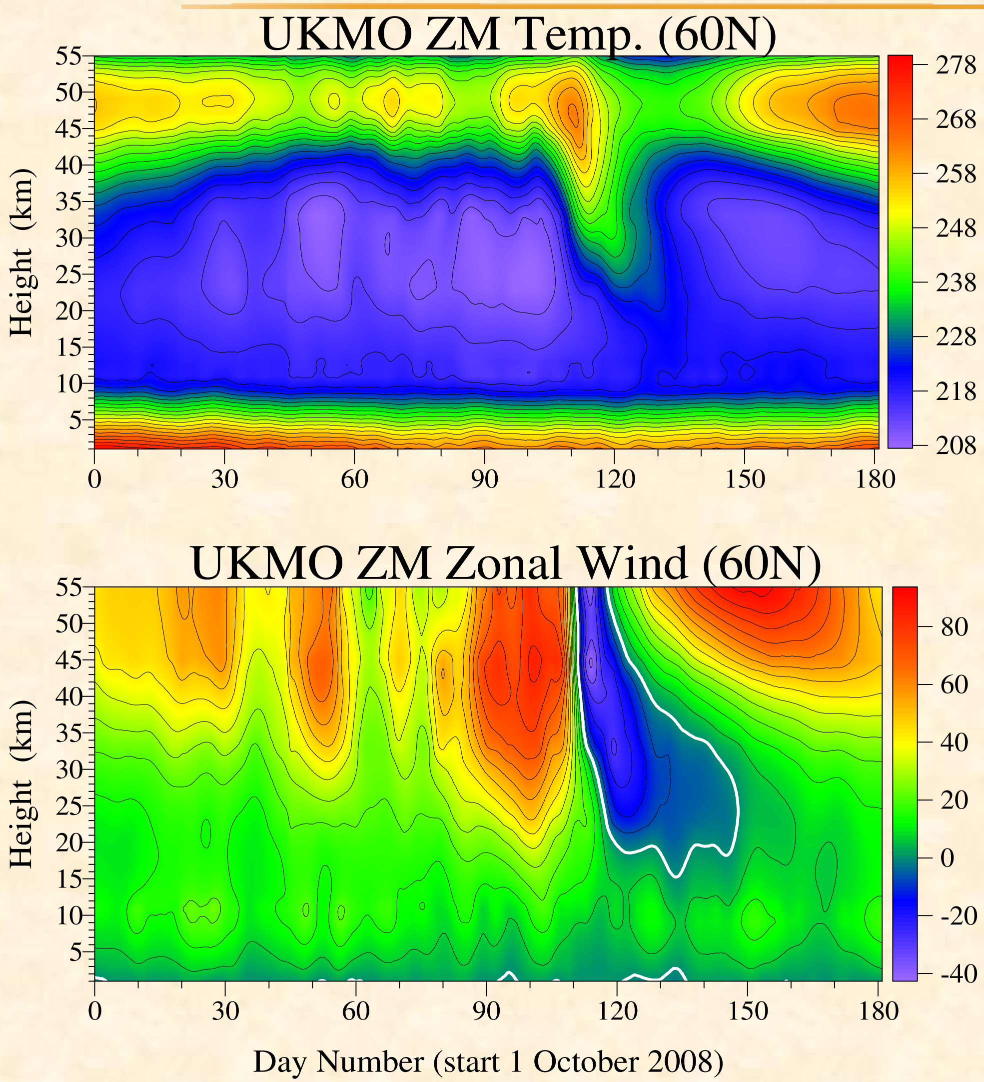
Introduction

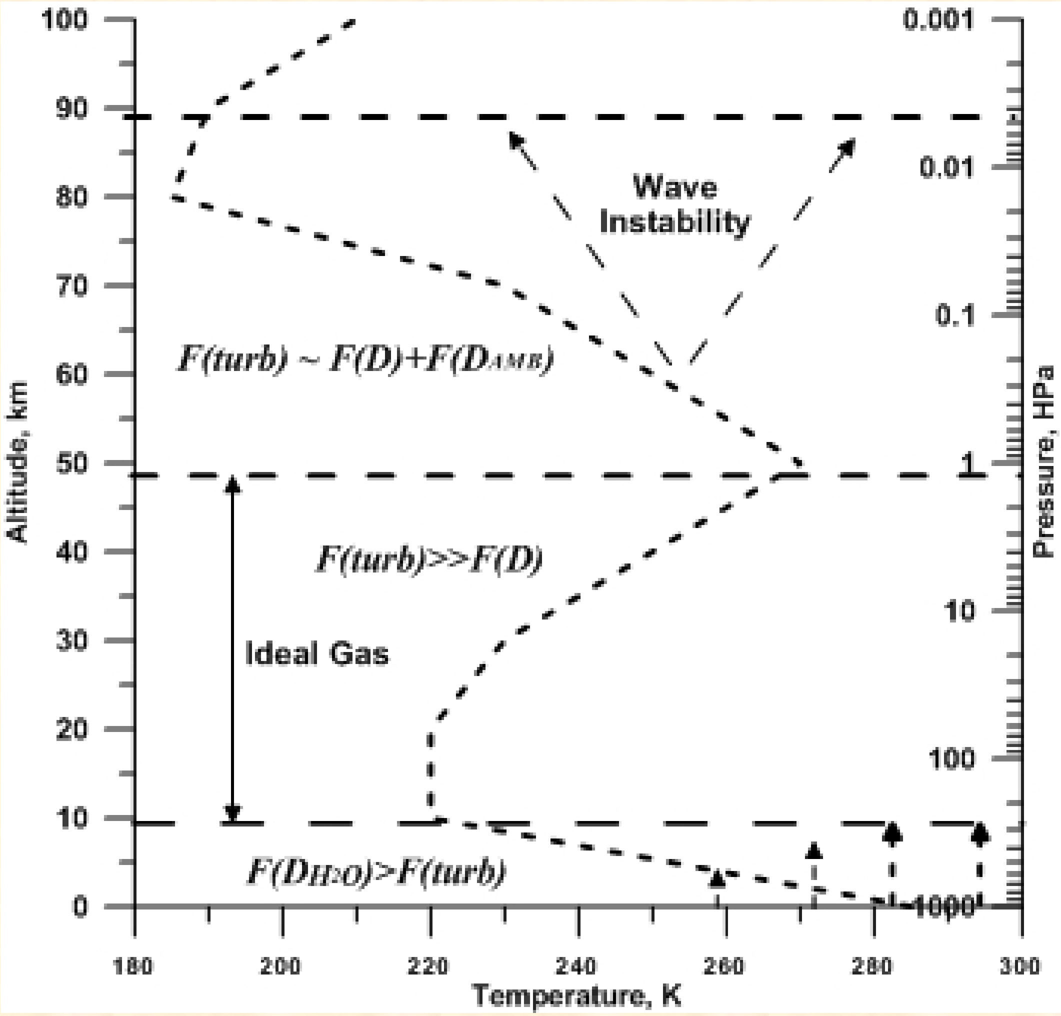
- The coupling of dynamical processes in the middle atmosphere and in the ionosphere over Siberia during Sudden Stratospheric Warming (SSW) in January 2009 is investigated.
- For middle atmosphere dynamics analysis we use the database of UK Met Office and MLS Aura data.
- COSMIC data were used for studying of the ionosphere dynamics as well as data from Siberian ionosondes in Novosibirsk, Irkutsk, Norilsk and Yakutsk.
- As the physical mechanism of SSW we consider the changing of the atmosphere structure in winter polar troposphere-stratosphere regions over continents, and penetration of wave activity from troposphere to stratosphere, which changes the structure of stratospheric circulation.
- Winter polar vortex splits on group of cyclones and anticyclones. Maximal heating effect of SSW-2009 was observed on vortexes borders with northward fluxes.
- Data of ionosondes network show SSW effects in the ionosphere which depend on observatories sites positions relatively to the circulation zones.
- As mechanism of neutral atmosphere impact to the ionosphere we consider the uplifting/lowering molecular gas to/from lower thermosphere above the active regions of stratosphere/mesosphere circulation.

TROPOSPHERE-STRATOSPHERE COUPLING (1)



According to the World Meteorological Organization's criteria for a major SSW, both the zonal mean temperature gradient and zonal mean zonal winds at 10 hPa (~30 km height), reverse sign poleward of 60^{o} during the event.

TROPOSPHERE-STRATOSPHERE COUPLING (2)



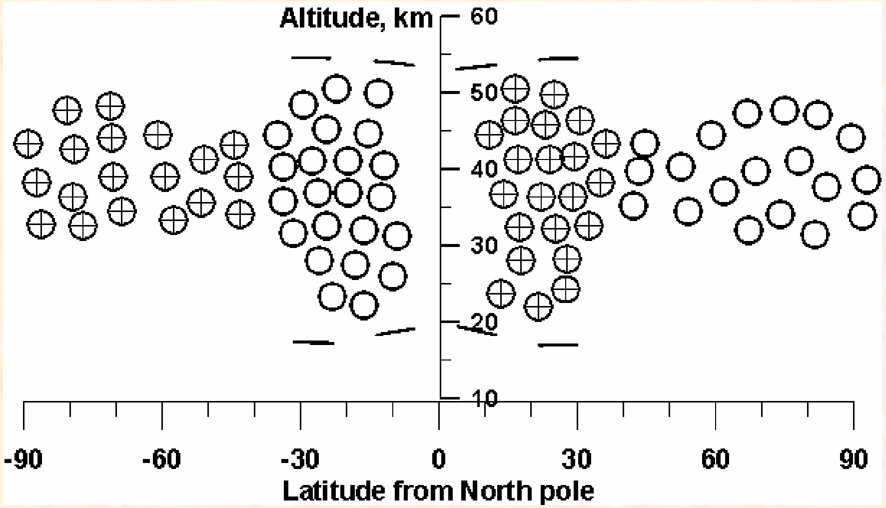
In warm seasons the troposphere dynamics is governed by water diffusion/condensing processes. Tropopause is the natural barrier for tropospheric wave acivity.

During winter solstice in auroral zone and in the high-midlatitudes over continents, water diffusion is small. Troposphere gets the same properties as the stratosphere. Tidal and stationary planetary waves can path upward from the troposphere.

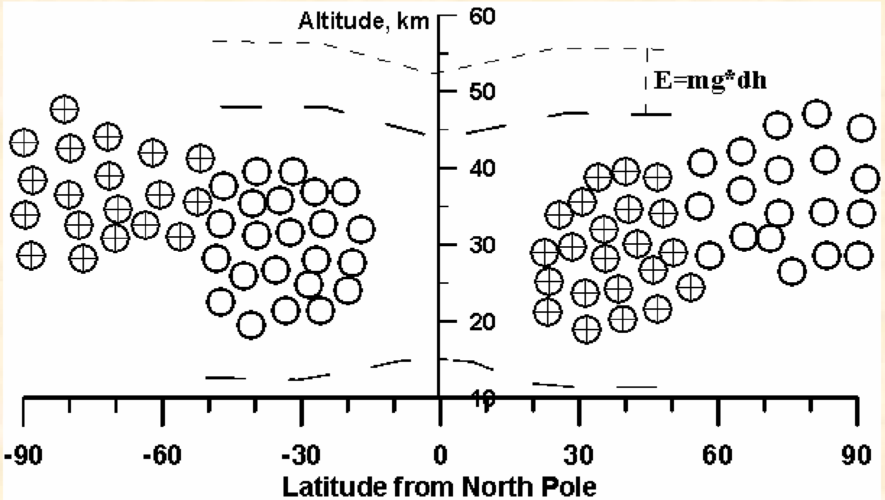
Dzh.Pedlosky, Geophysical Hydrodynamics. 1984,
A. Jill Atmosphere-Ocean dynamics, Academ Press 1982.

TROPOSPHERE-STRATOSPHERE COUPLING (3)

October



December

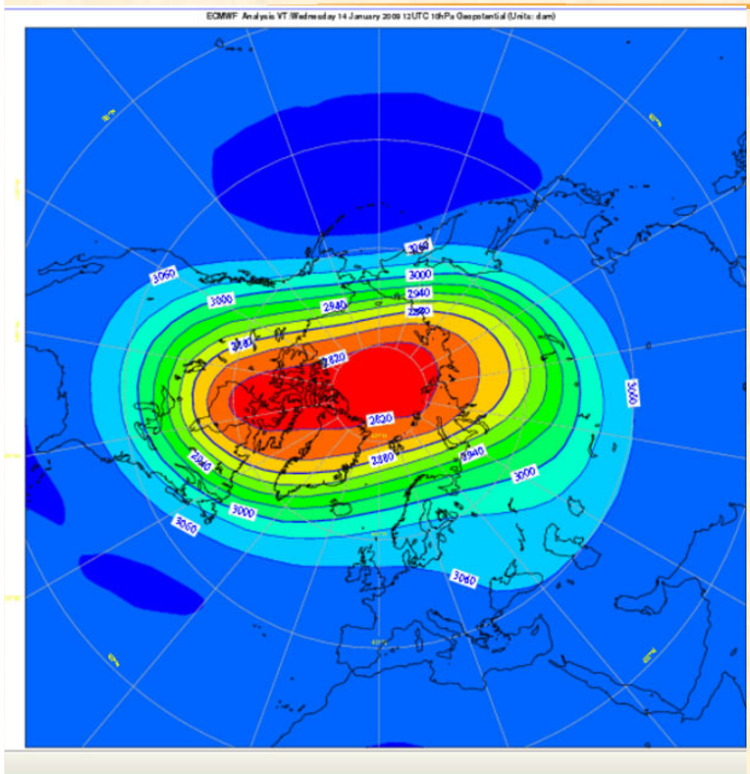


During the polar night at quiet geomagnetic conditions there is no energy input into the stratosphere. Gas becomes cooler and lowers.

Gravity potential of the gas transfers to the kinetic energy of polar vortex, which is the main driver of SSW.

When vortex reaches the 40-th latitudes, it becomes unstable and may be destroyed by waves from troposphere and mesosphere.

TROPOSPHERE-STRATOSPHERE COUPLING (4)

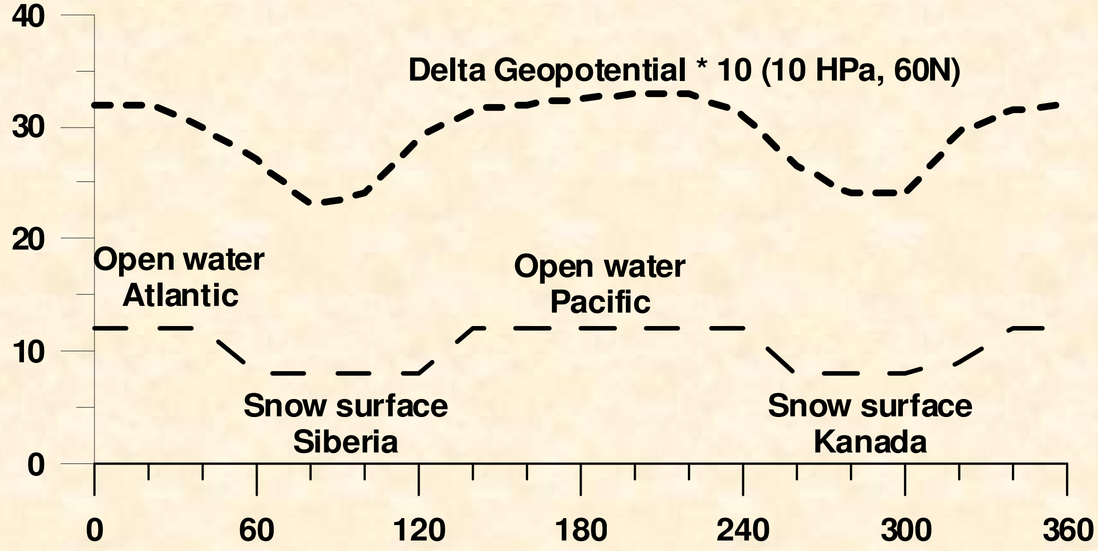


Geopotential surface in the stratosphere

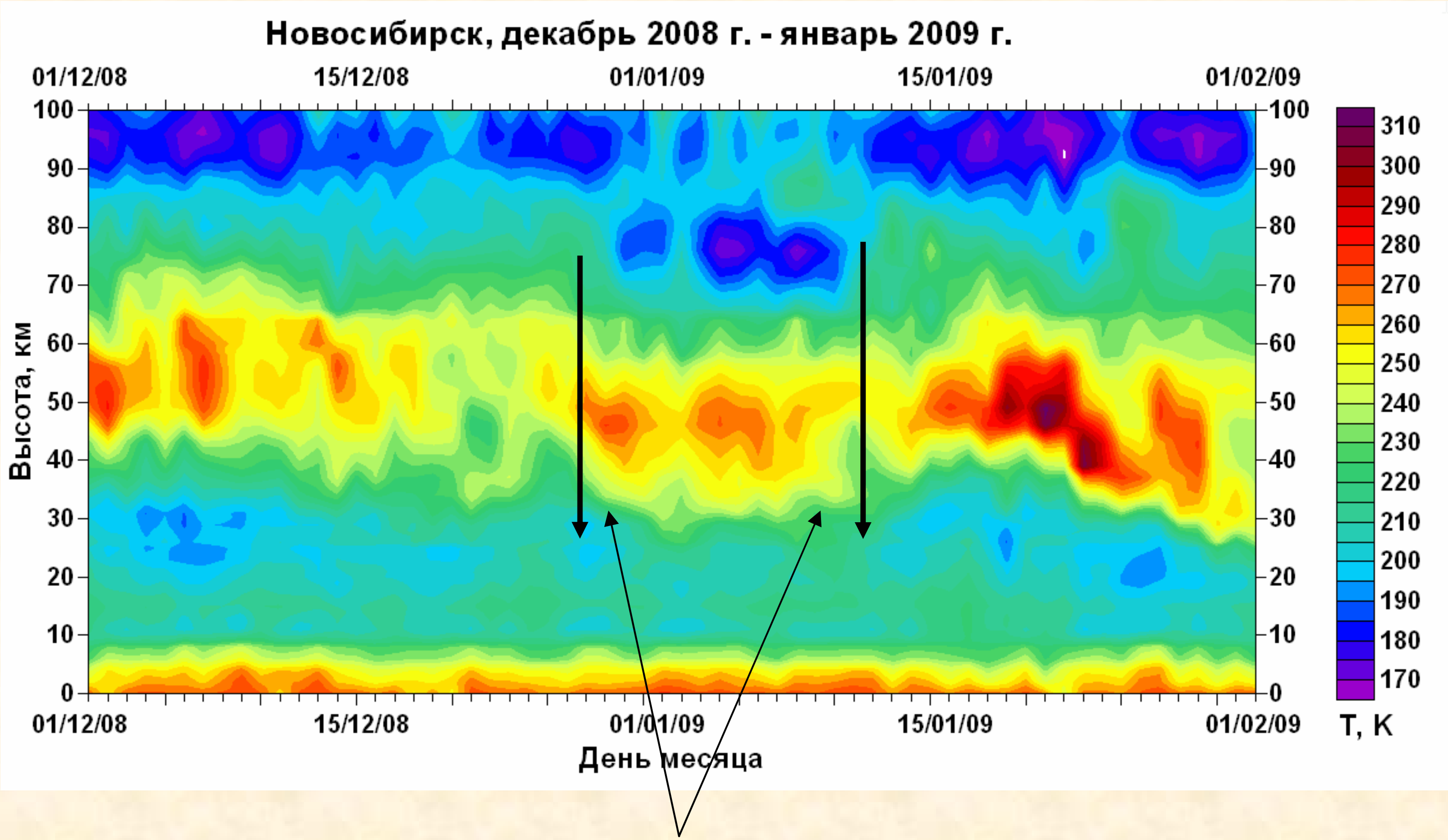
Winter polar vortex is pulled out toward the cold and dry continents.

In solstice the troposphere over Siberia has the same properties as stratosphere.

All atmosphere structures in height interval 30-60 km decrease their latitudes on ~10 km.



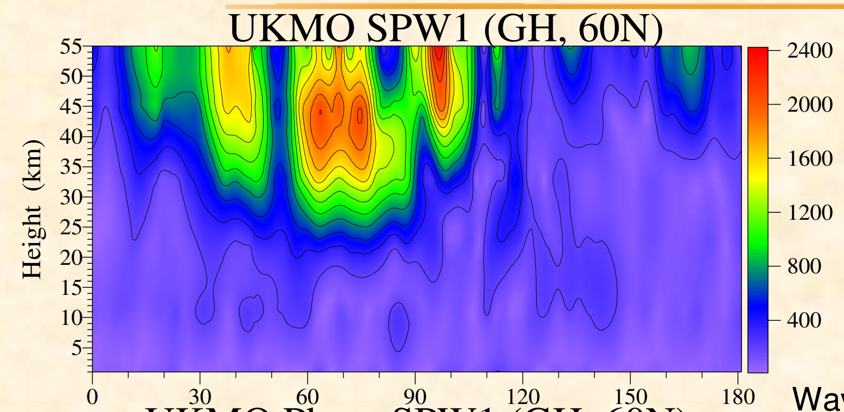
TROPOSPHERE-STRATOSPHERE COUPLING (6)

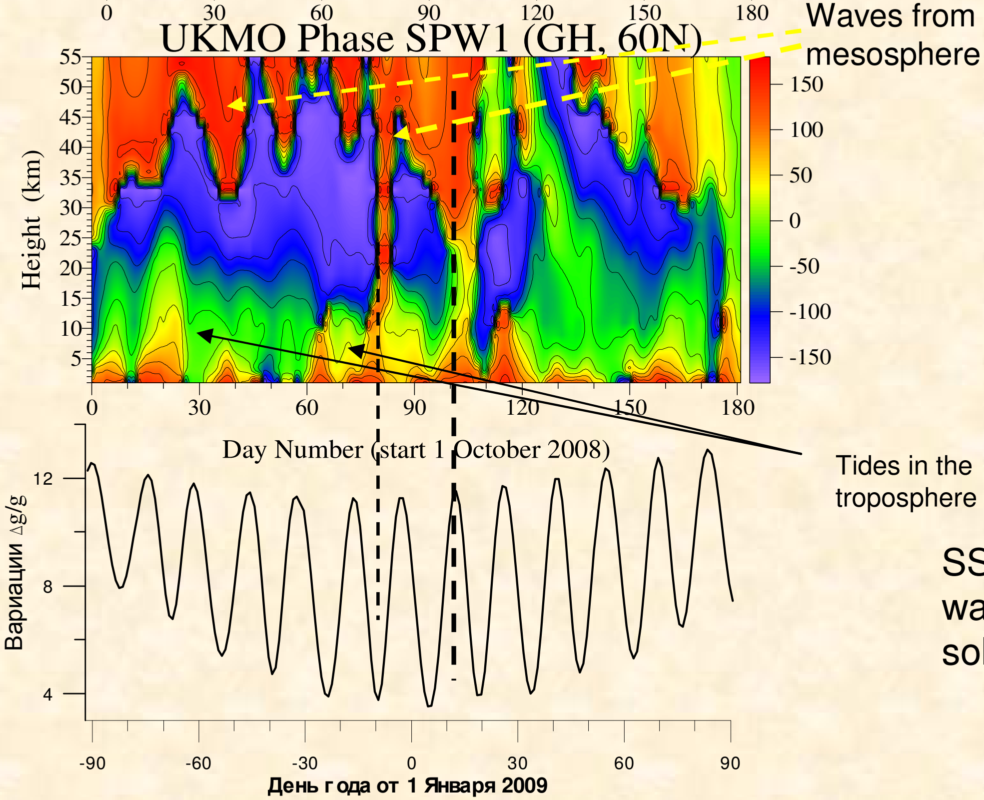


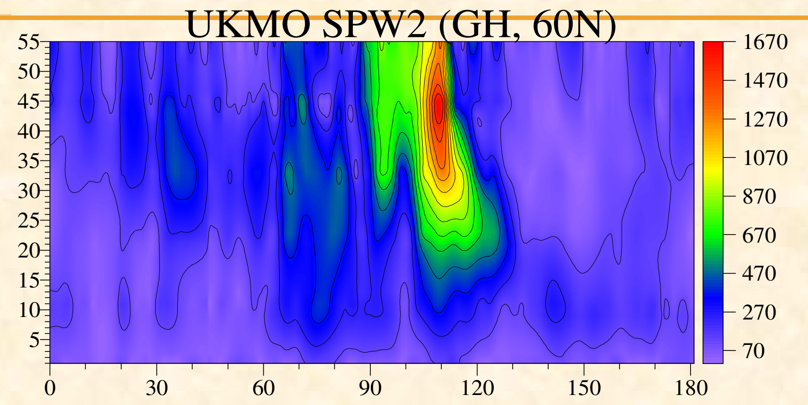
Over dry continent the mesosphere and the stratosphere is shifted downward. The troposphere is replaced by stratospheric gas. This is the reason for -40^0-50^{0}C temperatures in Nordic Siberia.

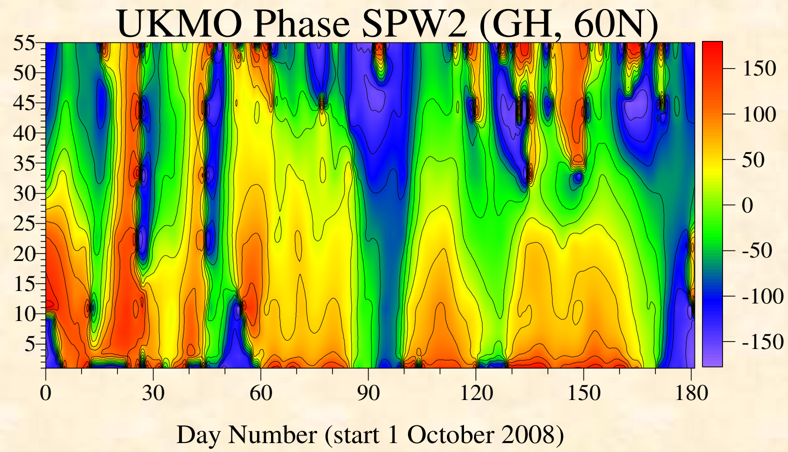
But stratosphere is involved into tidal processes…

Planetary waves as indicator of tidal effects



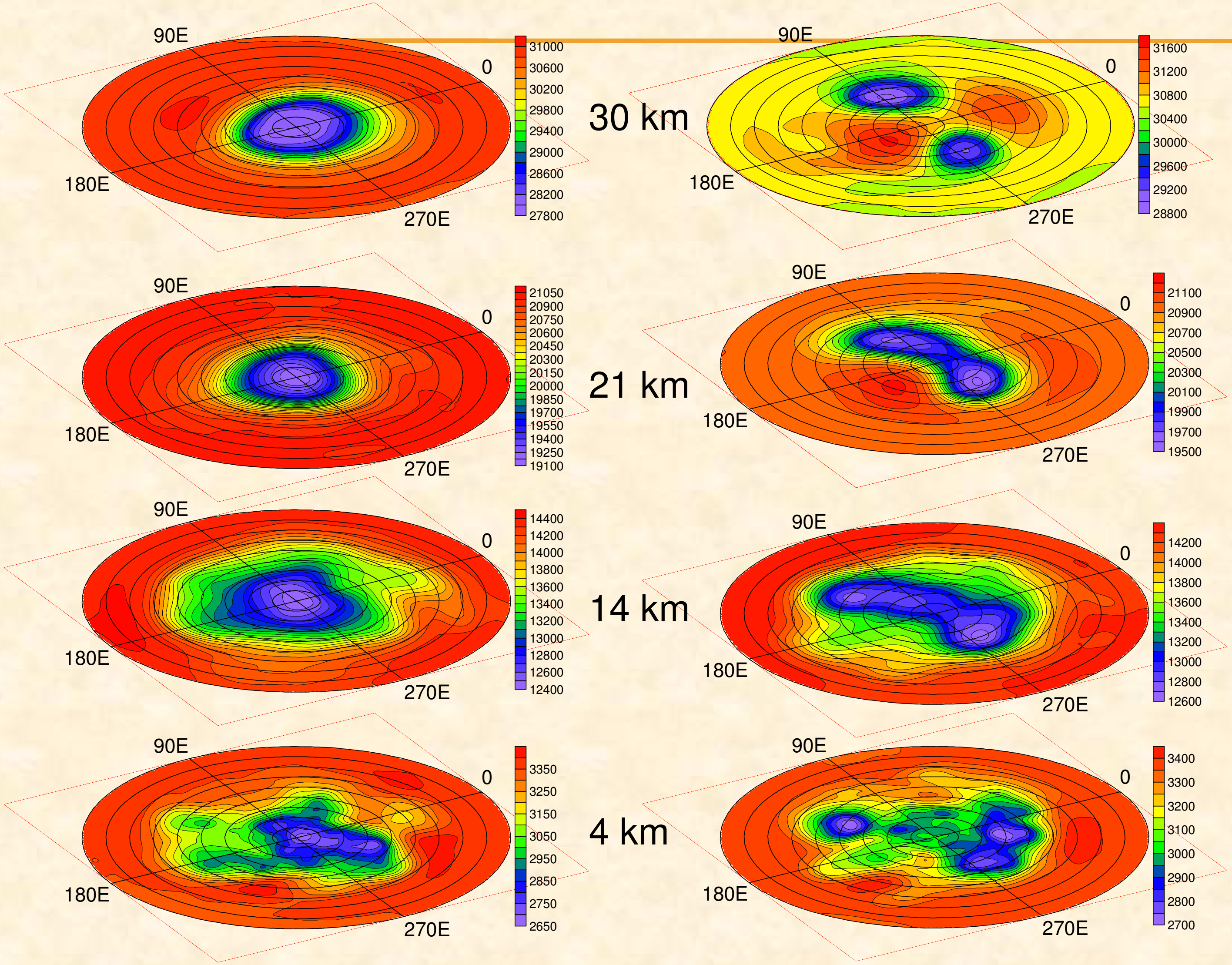






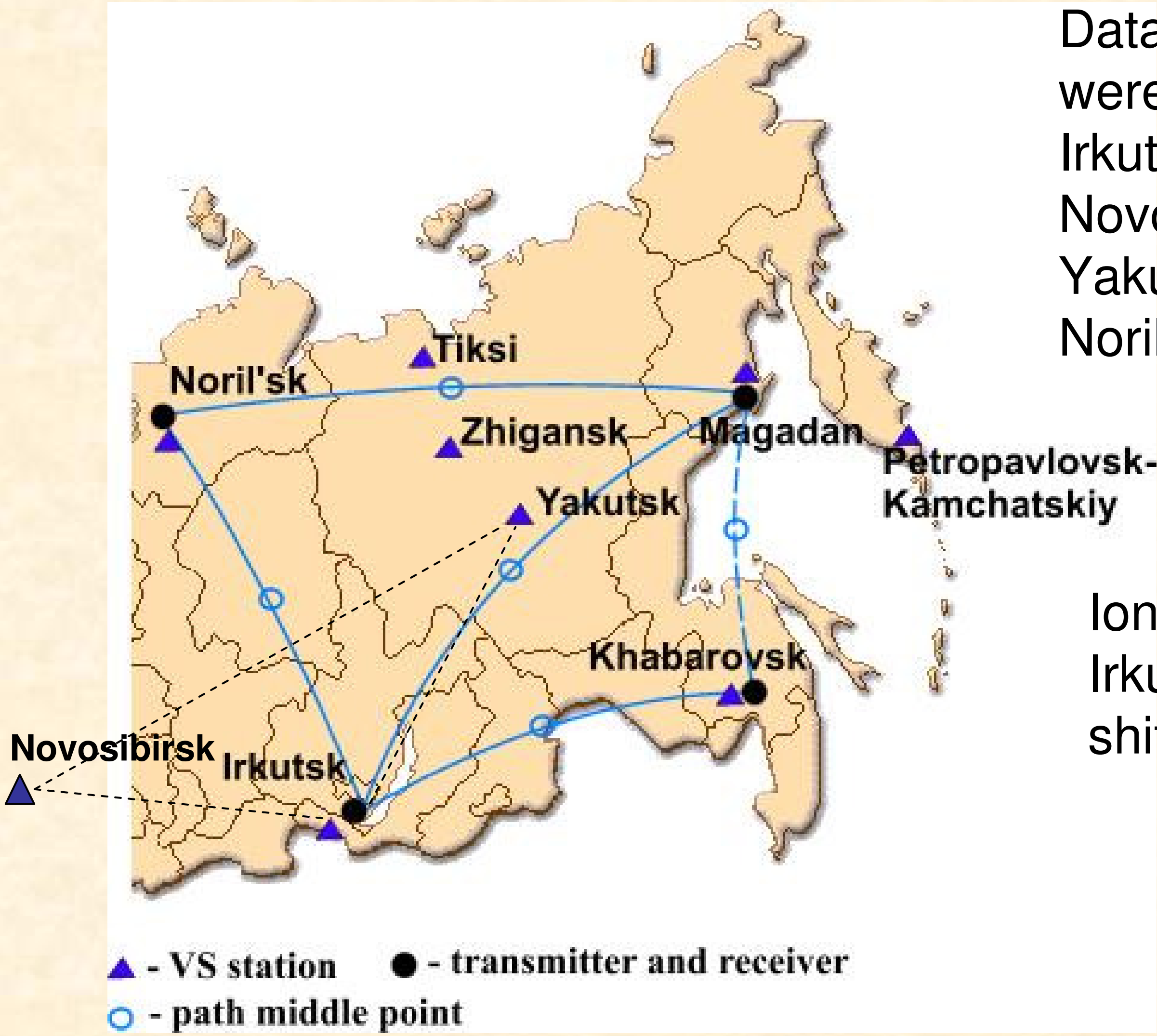
SSW starts when the phase of stratospheric wave coincide with the phase of phase-different solar-lunar tide in lower atmosphere.

Polar vortex splits by four.



January 8, 2009 January 23, 2009

Stratosphere / Ionosphere Coupling



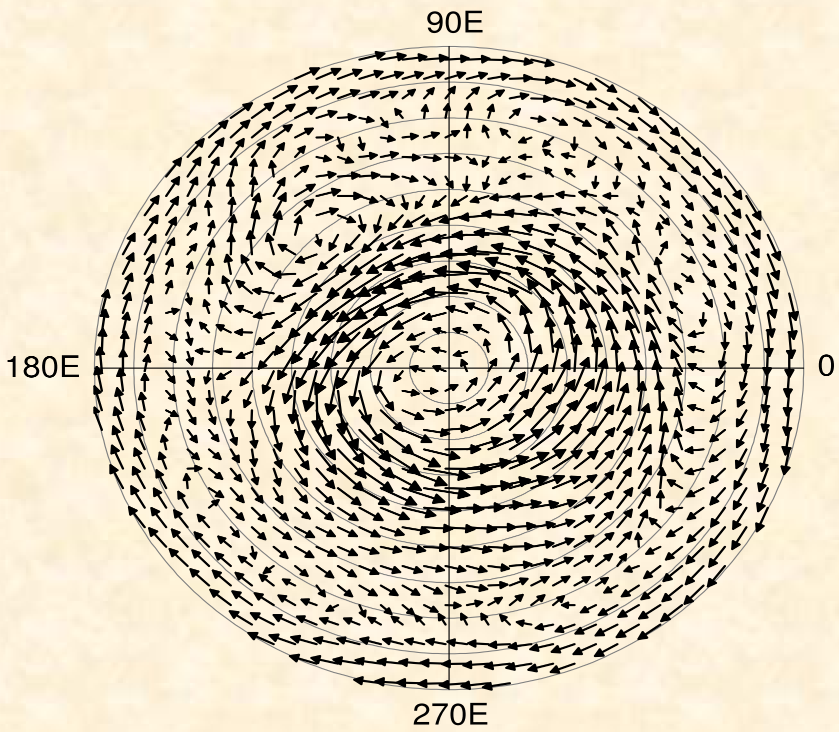
Data of Siberian ionosondes were used:
Irkutsk (52^{o}N, 104^{o}E),
Novosibirsk (54.6^{o}N, 83.2^{o}E)
Yakutsk (62^{o}N, 129.7^{o}E)
Norilsk (69^{o}N, 88^{o}E)

Ionosondes in Novosibirsk, Irkutsk and Yakutsk are shifted on longitude by ~20^o

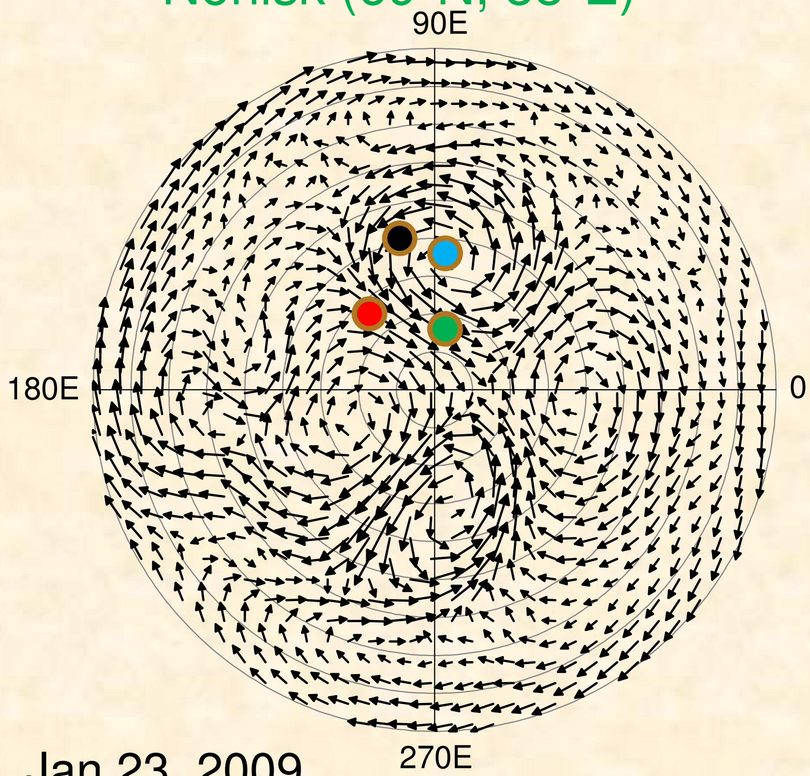
Ionospheric Effects

Ionosondes are situated in different zones of circulation

Irkutsk (52°N, 104°E),
Novosibirsk (54.6°N, 83.2°E)
Yakutsk (62°N, 129.7°E)
Norilsk (69°N, 88°E)

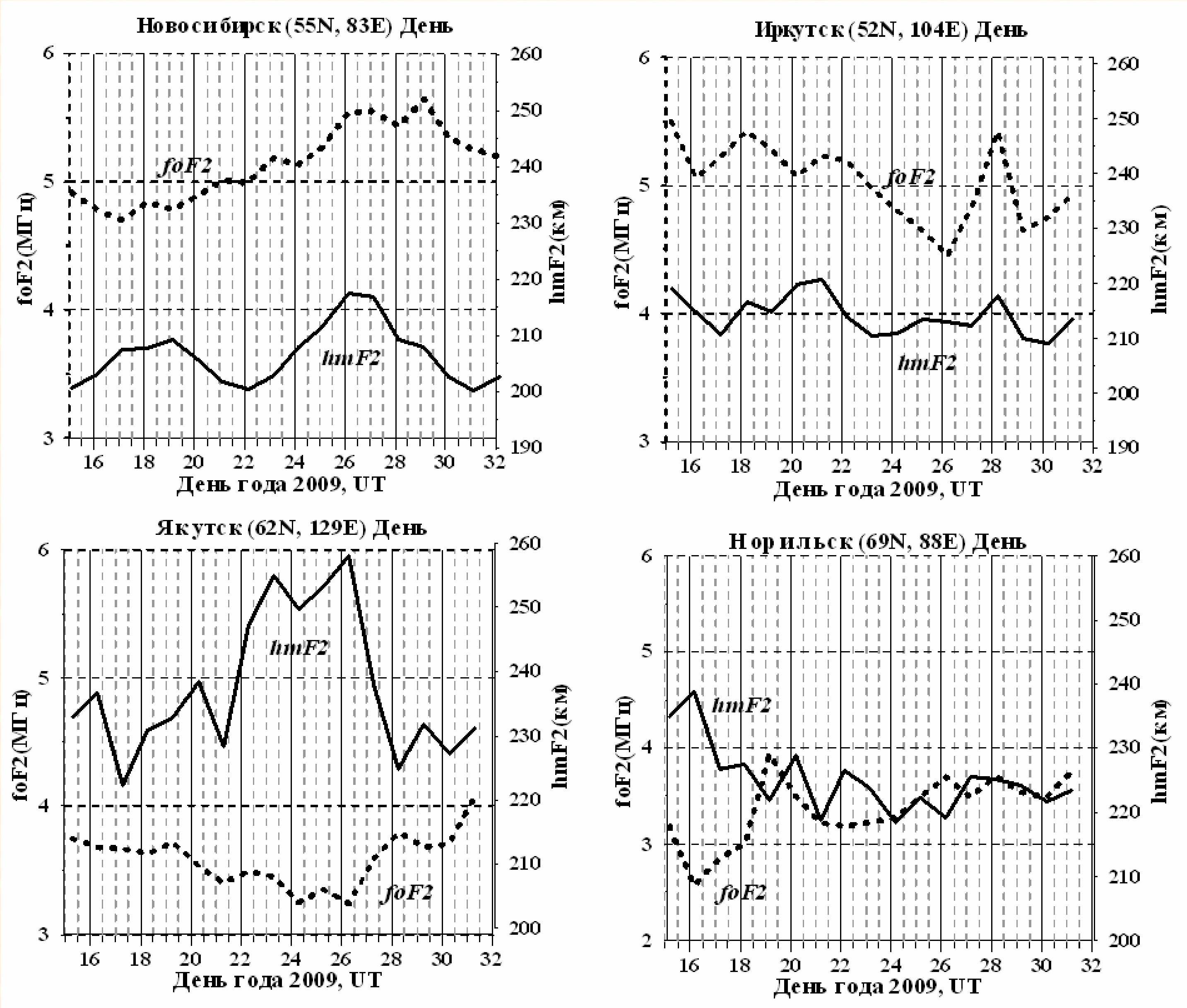


Jan 8, 2009

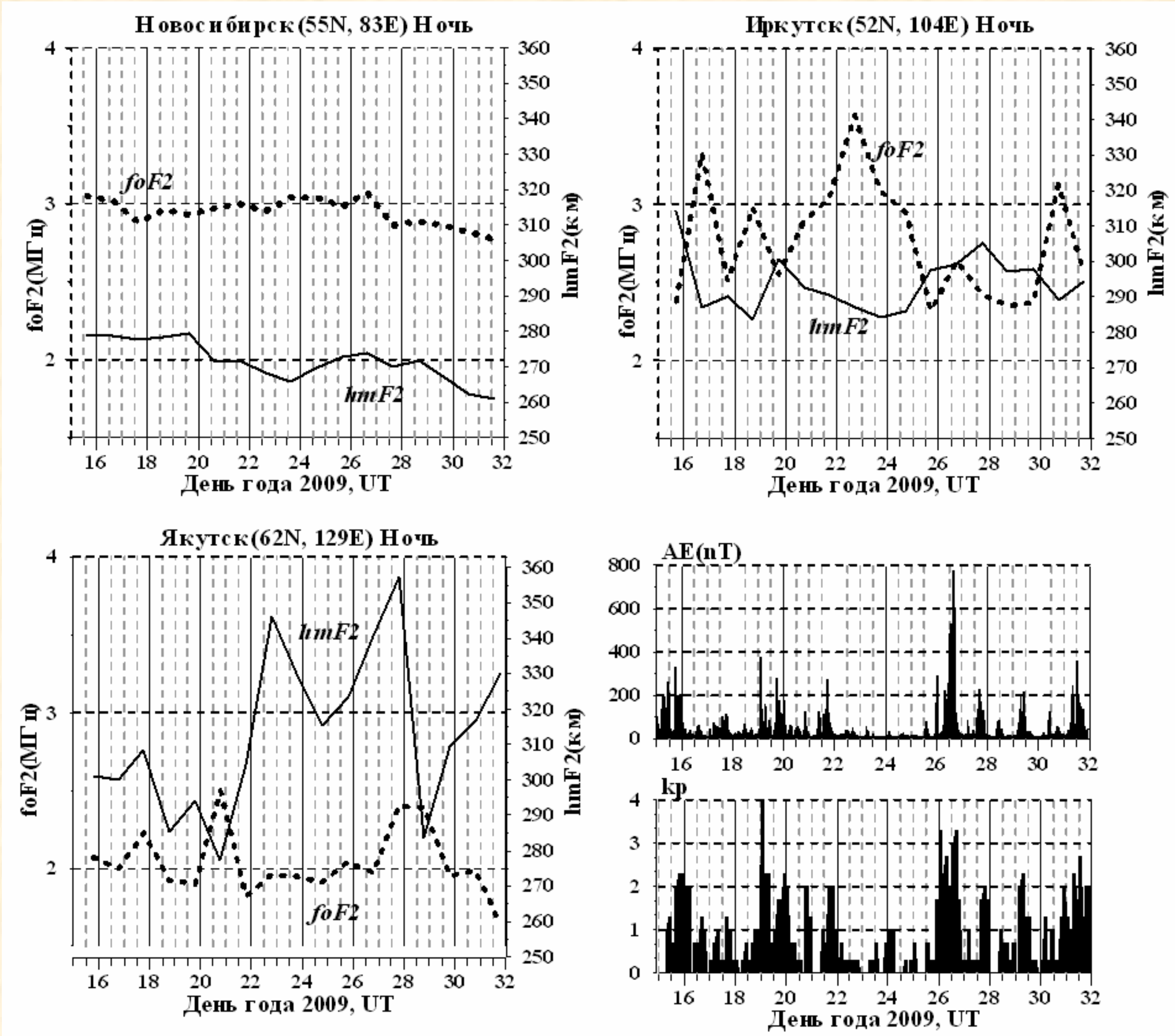


Jan 23, 2009

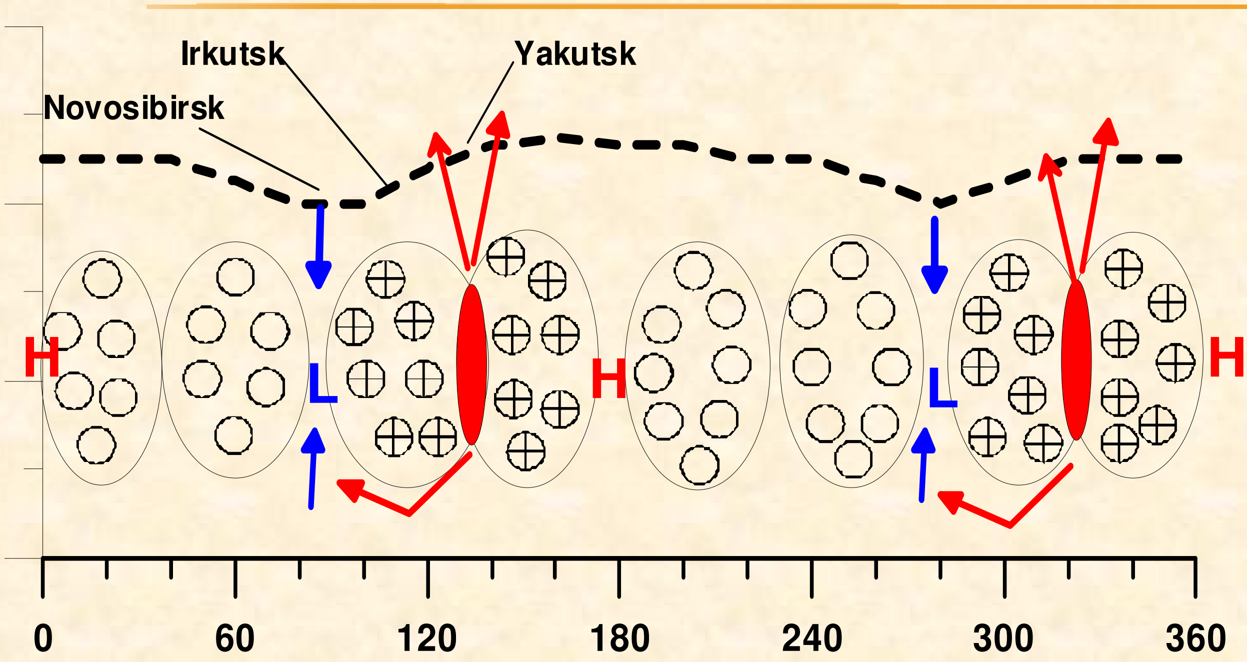
Ionospheric Effects (day)



Ionospheric Effects (night)



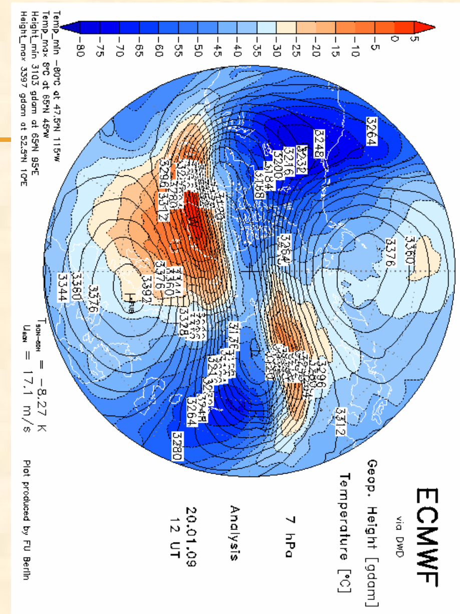
Circulation cross section at 60^0N

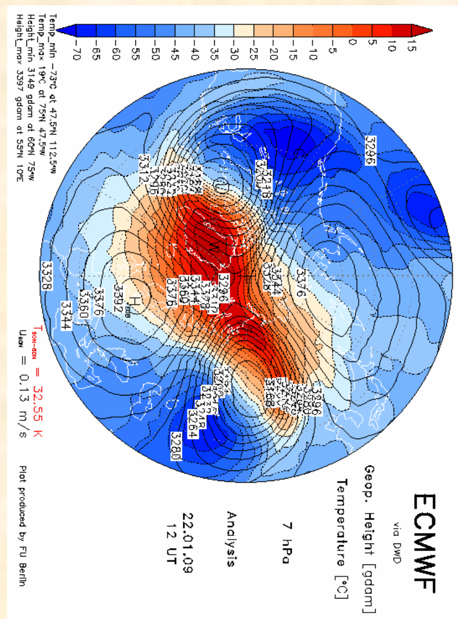


Regions of adiabatic compressing appear on the borders where fluxes are directed poleward. (East cyclone and West anticyclone).

Vertical drift from this region increases the concentration of molecular gas in lower thermosphere and decreases electron density in Yakutsk.

Above and below the cyclone rarefying zones appear. The upper zone extracts molecular gas from lower thermosphere, and increases electron density in Novosibirsk.

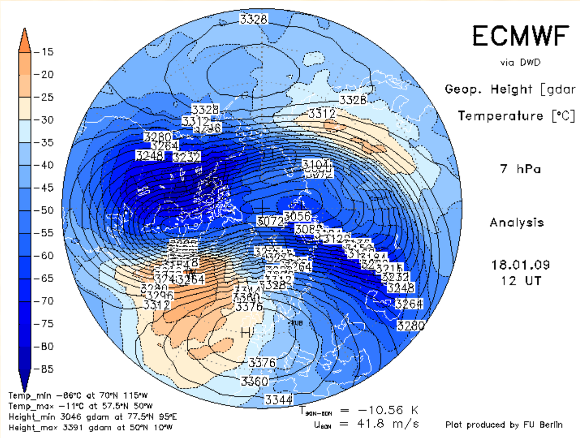


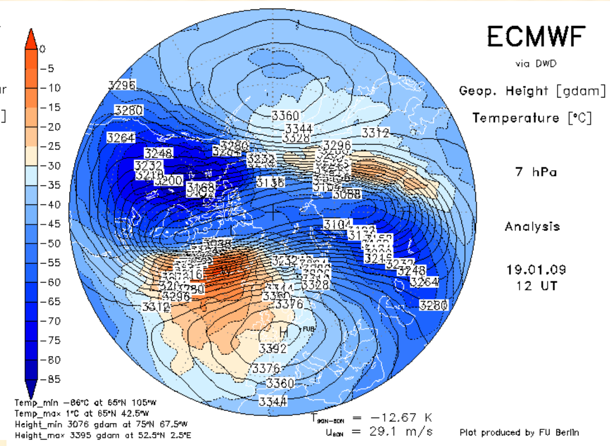


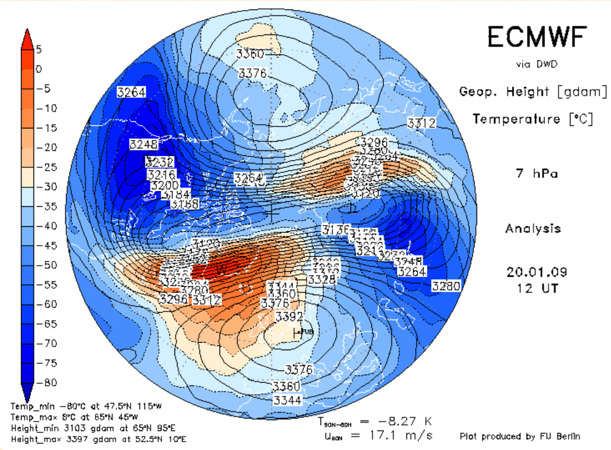
Conclusions

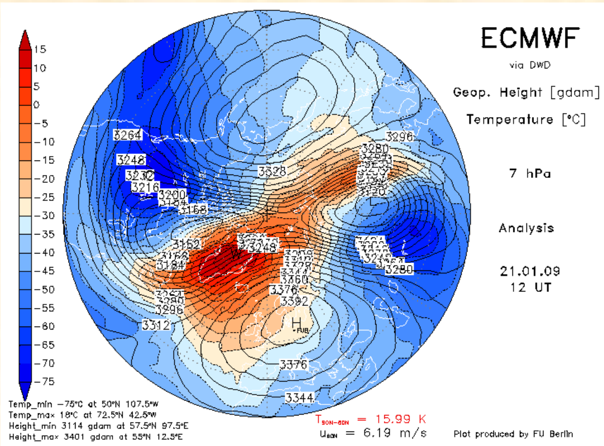
- Sudden Stratospheric Warming is the very pronounced aeronomic process, which involves all atmospheric regions from troposphere to thermosphere.
- Polar night initiates the slow, but very effective process of adiabatic cooling of stratosphere region and this process transfers the gravity potential of summer/autumn stratosphere to rotational momentum of winter circumpolar vortex.
- Difference between the cool and dry winter continental surface and ocean surface is so mach, that the troposphere disappears over continents, and all low atmosphere processes, including the tides, can affect directly on the stratosphere dynamics.
- Stratospheric cyclones are very rare atmospheric events, but their physical mechanism corresponds to well known nature of atmospheric cyclones/anticyclones with regions of adiabatic compression and expansion.
- These processes transport molecular gas to the thermosphere, and change the ionosphere dynamics, which is clearly observed by ionosondes in regions of active stratospheric circculation.

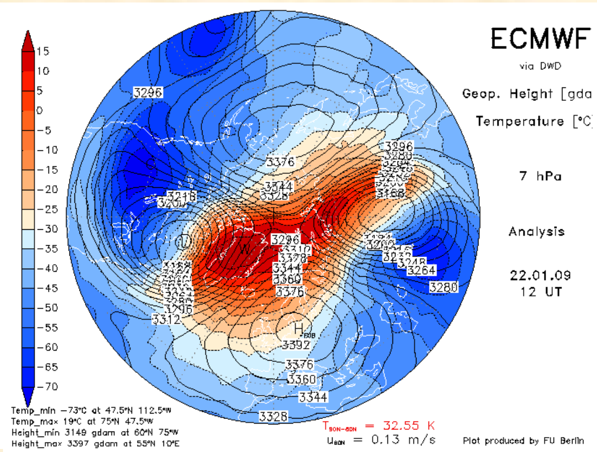
Thank You for Attention!

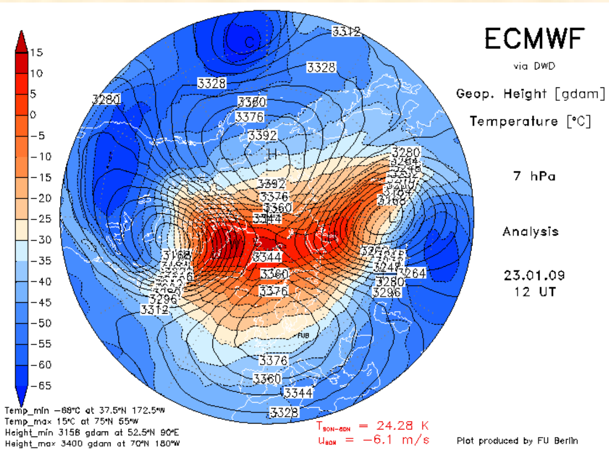

ECMWF
via DWD
Geop. Height [gdar
Temperature [°C]
7 hPa
Analysis
18.01.09
12 UT
Temp_min -86°C at 70°N 115°W
Temp_max -11°C at 57.5°N 50°W
Height_min 3046 gdam at 77.5°N 95°E
Height_max 3391 gdam at 50°N 10°W
T = -10.56 K
U = 41.8 m/s
Plot produced by FU Berlin

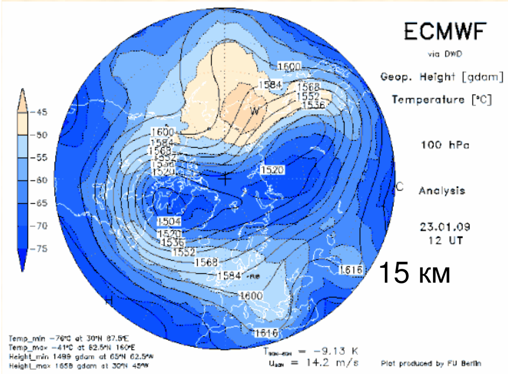

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
7 hPa
Analysis
19.01.09
12 UT
Temp_min -86°C at 65°N 105°W
Temp_max 1°C at 65°N 42.5°W
Height_min 3076 gdam at 75°N 67.5°W
Height_max 3395 gdam at 52.5°N 2.5°E
T = -12.67 K
U = 29.1 m/s
Plot produced by FU Berlin

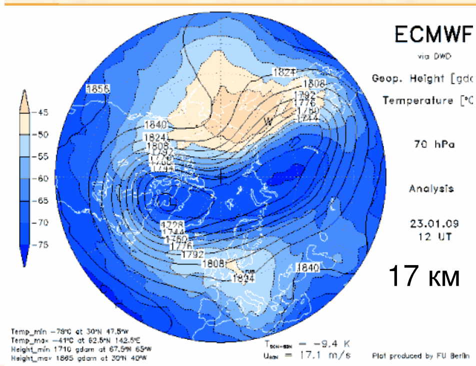

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
7 hPa
Analysis
20.01.09
12 UT
Temp_min -80°C at 47.5°N 115°W
Temp_max 8°C at 65°N 45°W
Height_min 3103 gdam at 65°N 95°E
Height_max 3397 gdam at 52.5°N 10°E
T = -8.27 K
U = 17.1 m/s
Plot produced by FU Berlin

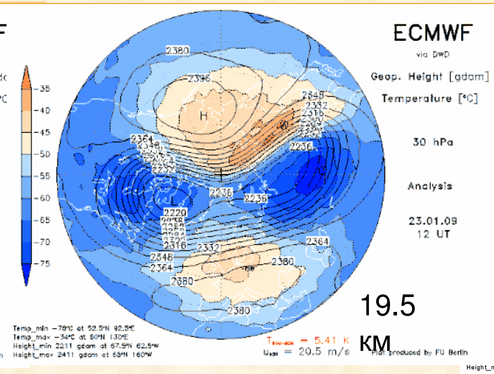

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
7 hPa
Analysis
21.01.09
12 UT
Temp_min -75°C at 50°N 107.5°W
Temp_max 18°C at 72.5°N 42.5°W
Height_min 3114 gdam at 57.5°N 97.5°E
Height_max 3401 gdam at 55°N 12.5°E
T = 15.99 K
U = 6.19 m/s
Plot produced by FU Berlin

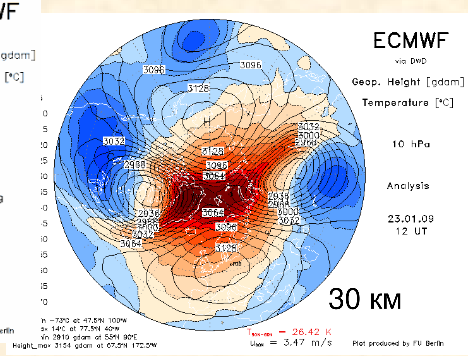

ECMWF
via DWD
Geop. Height [gda
Temperature [°C
7 hPa
Analysis
22.01.09
12 UT
Temp_min -73°C at 47.5°N 112.5°W
Temp_max 19°C at 75°N 47.5°W
Height_min 3149 gdam at 60°N 75°W
Height_max 3397 gdam at 55°N 10°E
T = 32.55 K
U = 0.13 m/s
Plot produced by FU Berlin

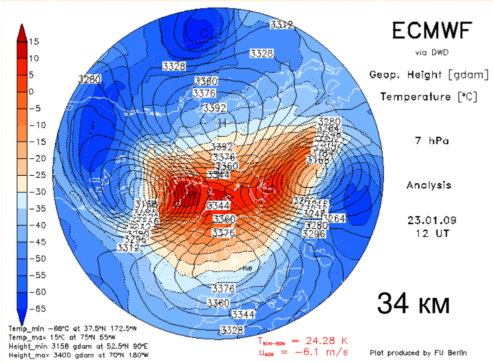

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
7 hPa
Analysis
23.01.09
12 UT
Temp_min -68°C at 37.5°N 172.5°W
Temp_max 15°C at 75°N 55°W
Height_min 3158 gdam at 52.5°N 90°E
Height_max 3400 gdam at 70°N 180°W
T = 24.28 K
U = -6.1 m/s
Plot produced by FU Berlin

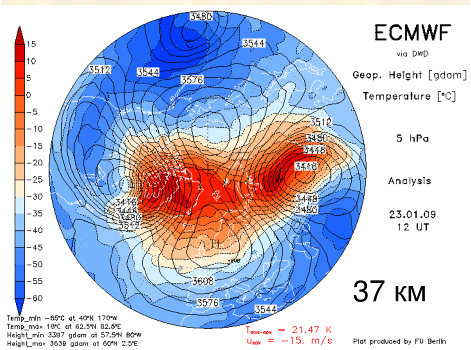

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
100 hPa
Analysis
23.01.09
12 UT
15 км
Plot produced by FU Berlin

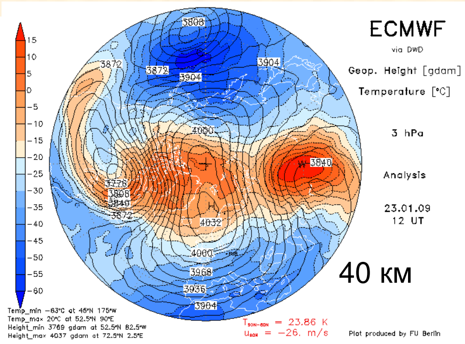

ECMWF
via DWD
70 hPa
Analysis
23.01.09
12 UT
17 км
Plot produced by FU Berlin

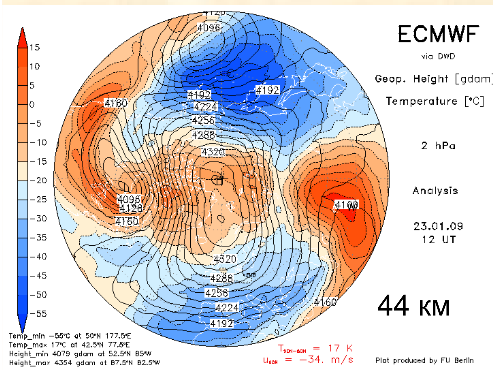

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
30 hPa
Analysis
23.01.09
12 UT
19.5
км

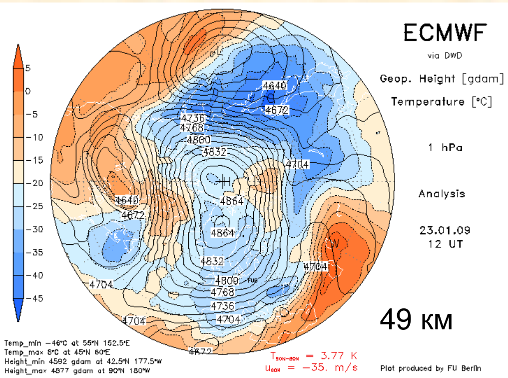

ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
10 hPa
Analysis
23.01.09
12 UT
30 км
Plot produced by FU Berlin


ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
7 hPa
Analysis
23.01.09
12 UT
34 км
Plot produced by FU Berlin


ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
5 hPa
Analysis
23.01.09
12 UT
37 км
Plot produced by FU Berlin


ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
3 hPa
Analysis
23.01.09
12 UT
40 км
Plot produced by FU Berlin


ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
2 hPa
Analysis
23.01.09
12 UT
44 км
Plot produced by FU Berlin


ECMWF
via DWD
Geop. Height [gdam]
Temperature [°C]
1 hPa
Analysis
23.01.09
12 UT
49 км
Plot produced by FU Berlin