Ioffe Physical Technical Institute

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TEMPORAL VARIABILITY OF SOLAR ACTIVITY INFLUENCES ON THE LOWER ATMOSPHERE AND ITS POSSIBLE REASONS

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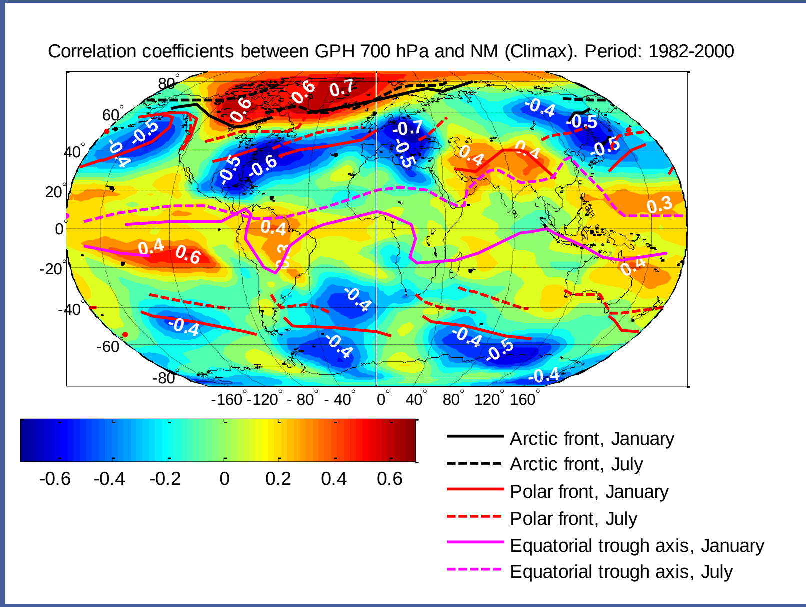
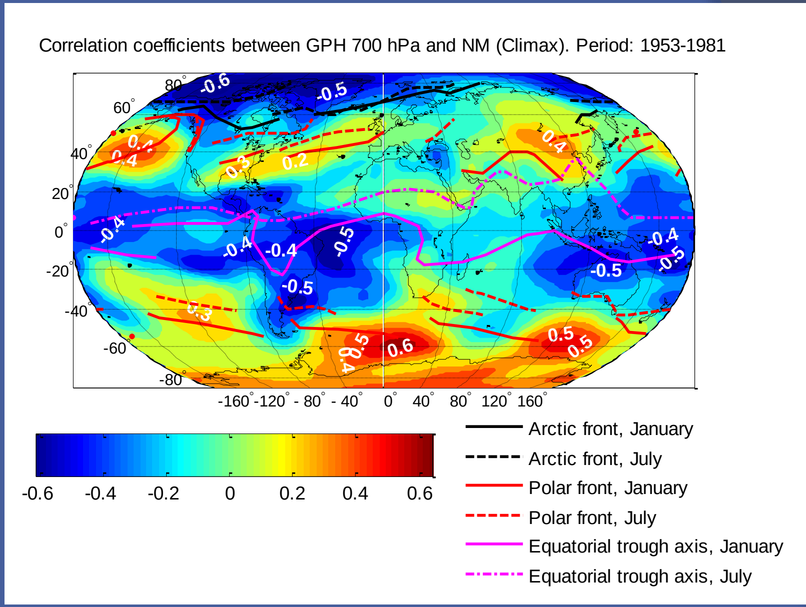
Solar-climatic links are characterized by **temporal variability** which remains **an unresolved problem**. This variability

- gives rise to doubt a reality of solar activity influence on atmospheric processes
- makes difficult forecasting future climate changes

The aim of this study to consider **manifestations** and **possible reasons** for temporal variability in solar-atmospheric links

GCR effects on troposphere pressure in different time periods





Depending on a time period, GCR increases in the 11-yr solar cycle result in **opposite effects** in pressure variations:

1982-2000

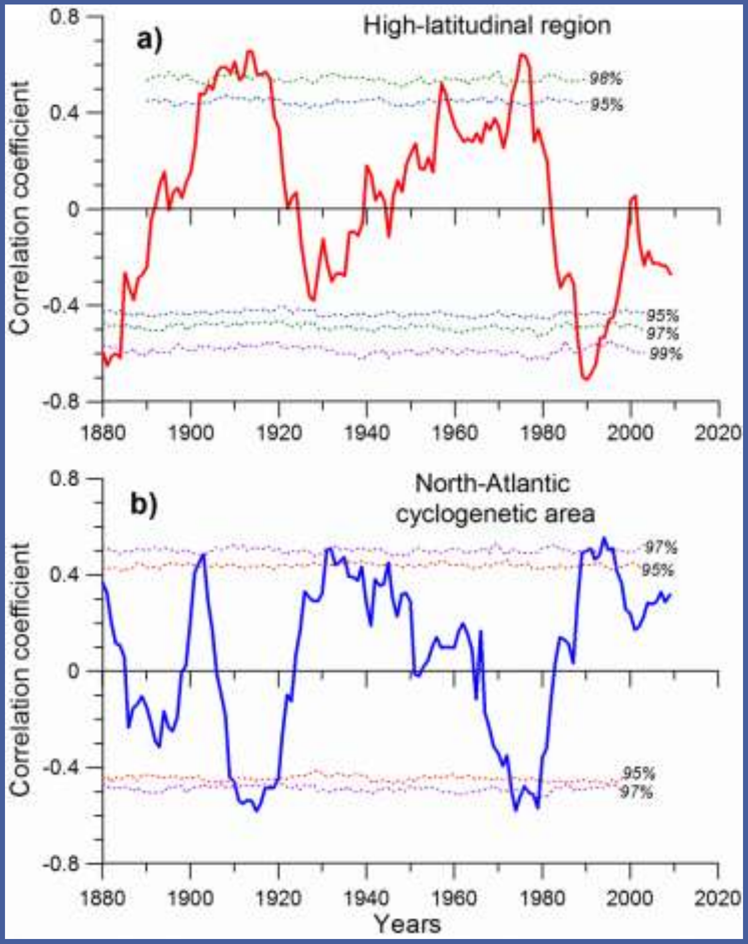
- **Intensification of extratropical cyclogenesis** (pressure decrease) at Polar fronts
- **Intensification of Arctic anticyclones** (pressure increase)
- **Weakening of the equatorial trough** (pressure increase)

1953-1981

- **Weakening of extratropical cyclogenesis** (pressure increase) at Polar fronts
- **Weakening of Arctic anticyclones** (pressure decrease)
- **Intensification of the equatorial trough** (pressure decrease)

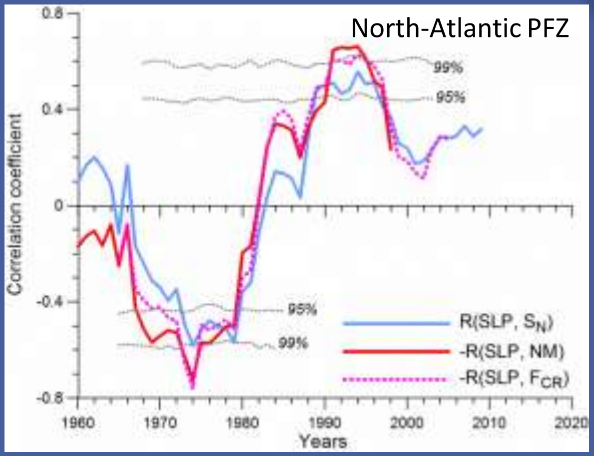
Veretenenko and Ogurtsov, Adv.Space Res, 2012

Temporal variability of correlation links between sea-level pressure (SLP) and sunspot numbers (SN)

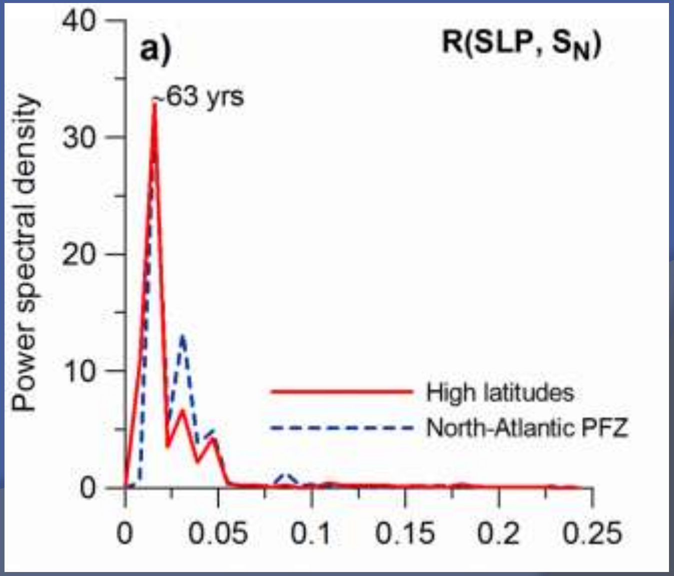


Temporal variations of correlation coefficients R(SLP,SN) reveal a distinct **~60-year periodicity.**

This periodicity is most pronounced at high latitudes and in the North Atlantic cyclogenetic area (Polar frontal zone) near the coasts of North America.



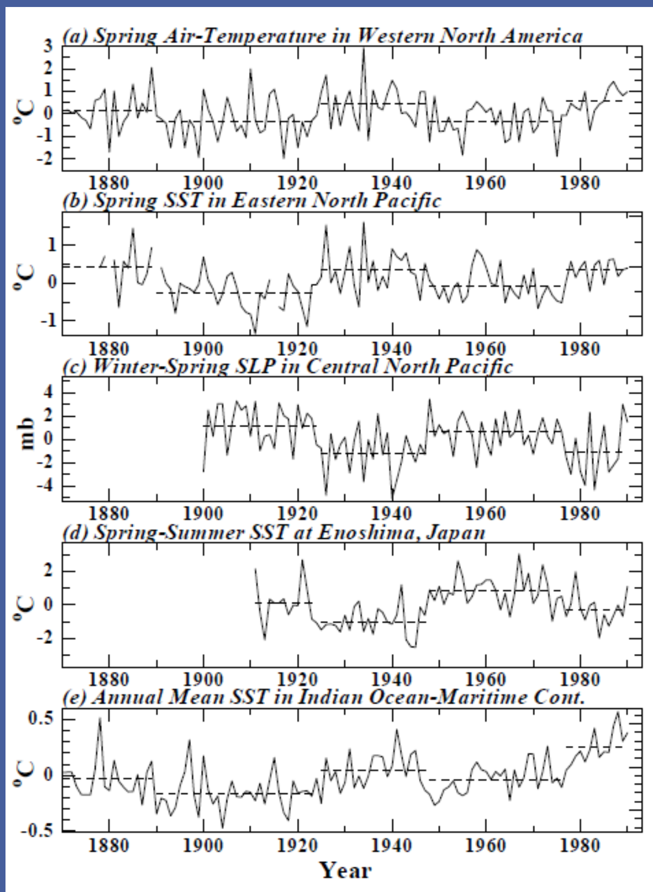
Correlation coefficients between SLP and SA/GCR characteristics in the North-Atlantic cyclogenetic area for sliding 15-yr intervals



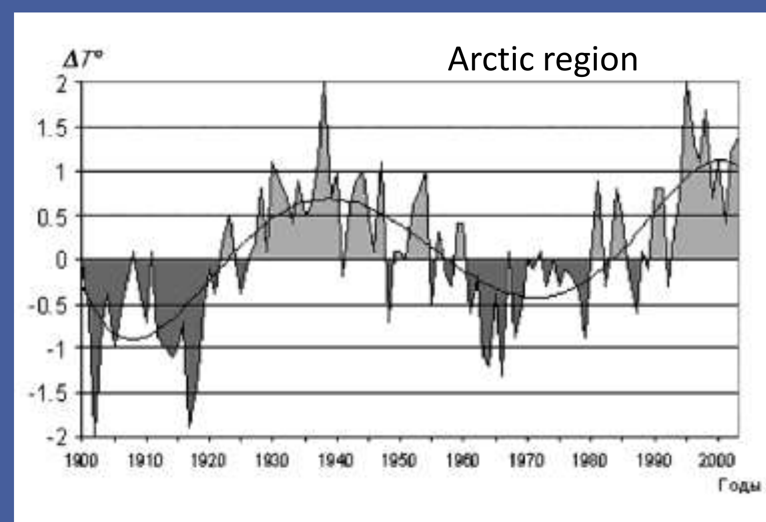
~60-year cycle in different climatic characteristics

~60-year cycle is a well–known variation observed in a large number of atmosphere and ocean characteristics:

- Global temperature anomalies
- SST variations in the North Atlantic (the Atlantic Multidecadal Oscillation)
- Alternation of cold and warm epochs in the Arctic
- Oscillations of temperature and pressure in the North Pacific region
- Oscillations of global mean sea level



Minobe, Geophys.Res. Lett. 1997



(Gudkovich et al., Problems of Arctic and Antarctic, 2009)

Vangengeim-Girs classification of the main types of large-scale circulation in the Nortern hemisphere

Main types of large-scale circulation (classification by G. Vangengeim and A. Girs)

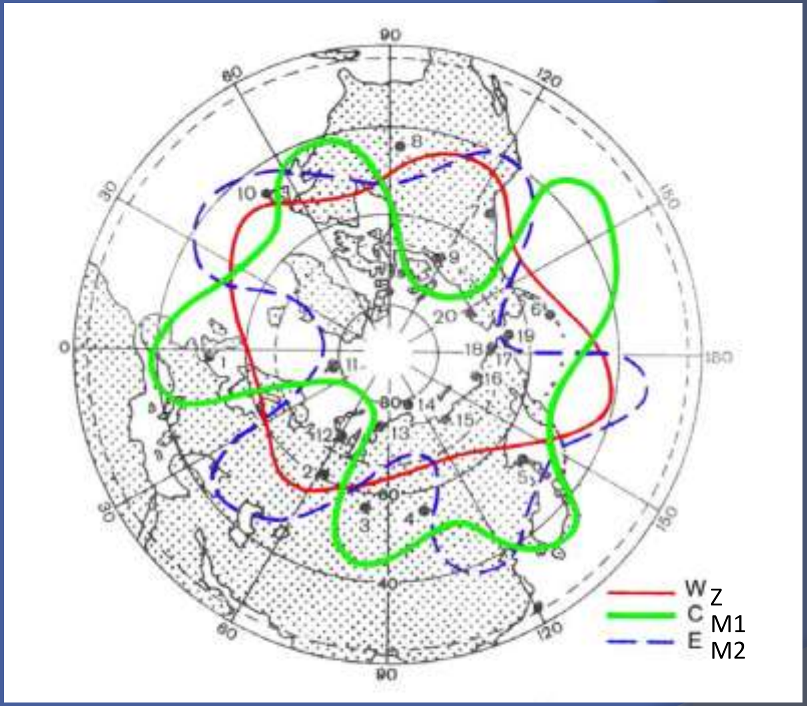
	Atlantic-Eurasian sector	Pacific-American sector
Zonal	W	Z
Meridional	C	M1
Easterly	E	M2

- **Zonal circulation forms W, Z :**

small-amplitude waves in pressure field move rapidly from west to east.

- **Meridional circulation forms C, M1 and easterly circulation forms E, M2 :**

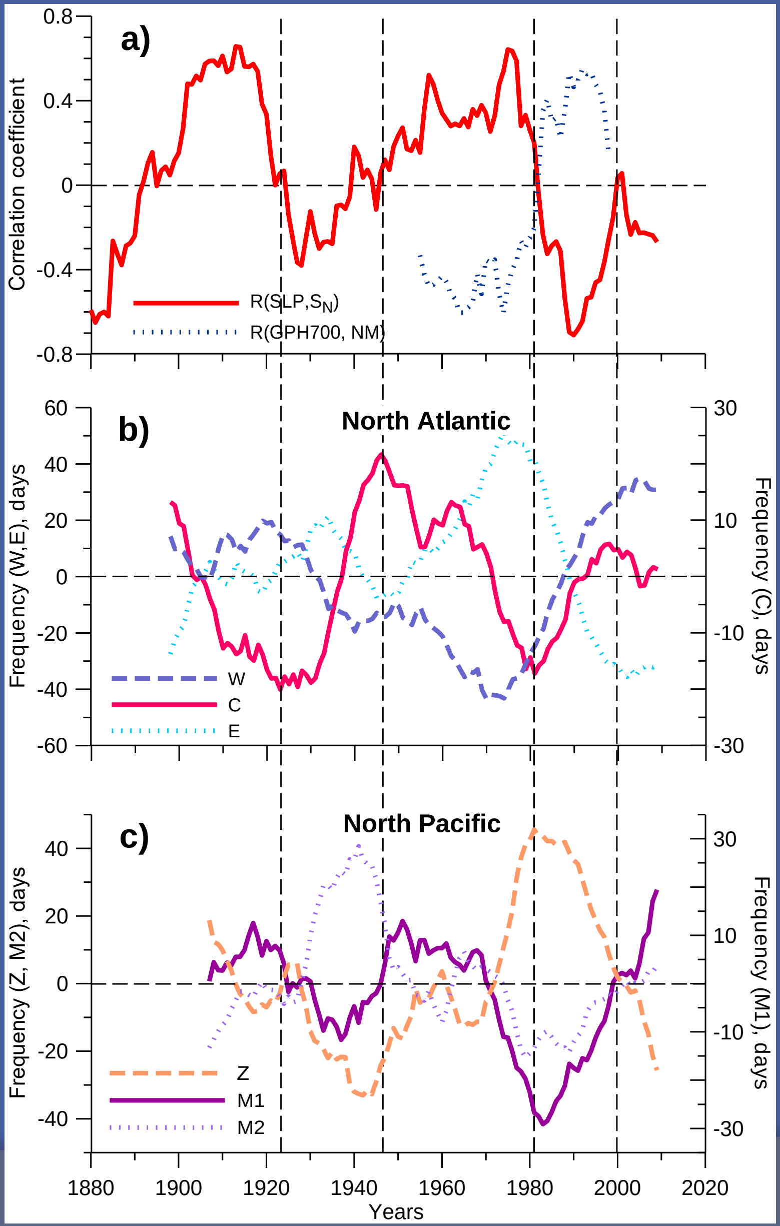
slowly moving or stationary large-amplitude waves in pressure field



Disposition of troughs and crests in the middle atmosphere for the circulation types: **zonal (W_Z), meridional (C_{M1}), easterly (E_{M2}) .**

(Girs, 1974)

Temporal variability of SA/GCR effects on troposphere pressure and the evolution of the large-scale circulation forms



The reversals of SLP-SN correlations take place near **turning points** in the evolution of the main types of large-scale circulation.

The correlation sign seems to be closely related to the character of **meridional circulation forms C (M1) :**

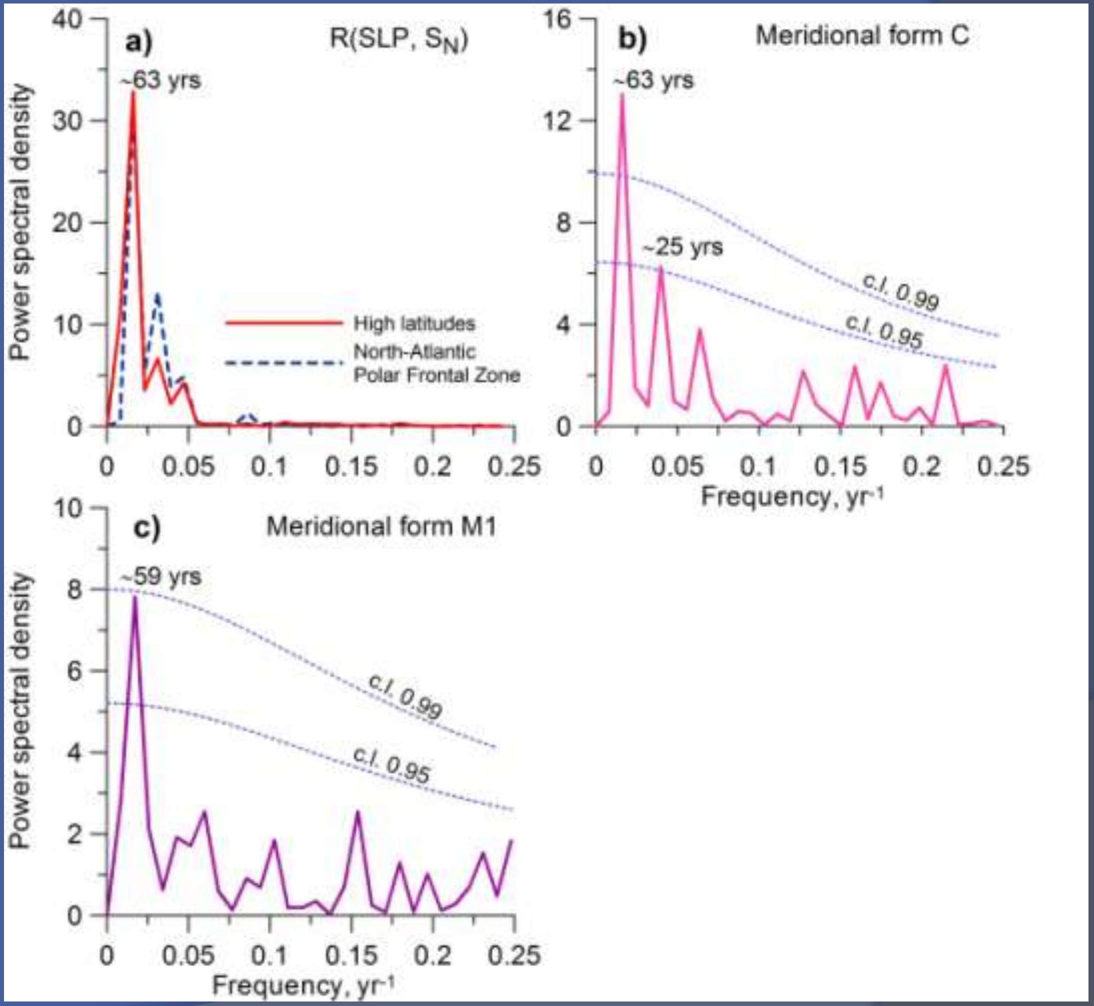
- **Intensification of C (M1) – negative SLP-S_N correlation** (positive correlation with GCR fluxes)
- **Weakening of C (M1) – positive SLP-S_N correlation** (negative correlation with GCR fluxes)

a) Correlation coefficients SLP-SN and SLP-GCR at high latitudes (60-80N) for sliding 15-year intervals;
b) Frequencies of occurrence of the main circulation forms in the North Atlantic (15-year running averages);
c) The same in the North Pacific.

Spectral characteristics of intensity of meridional circulation and SA/GCR effects on troposphere pressure

The temporal variations of **SLP-S_N correlations** and annual **frequencies of occurrence of the meridional circulation forms** are characterized by **a ~ 60-year periodicity.**

This confirms **a possible link** between **the character of SA/GCR effects** and **the regime of the atmosphere circulation**.

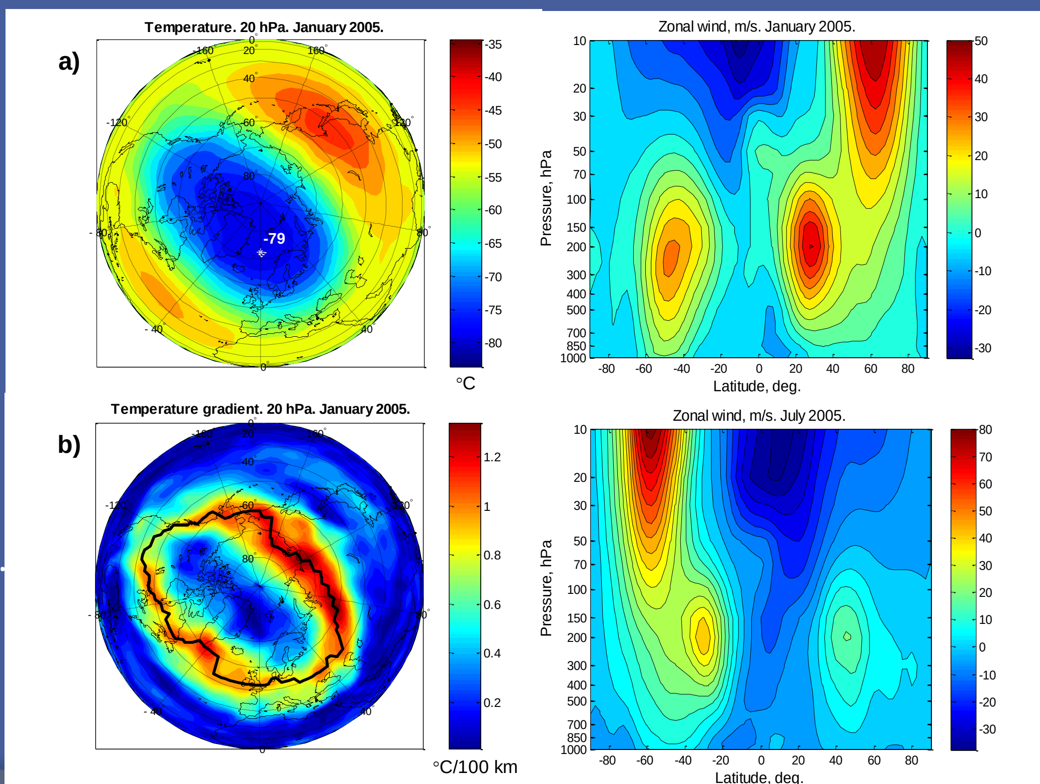


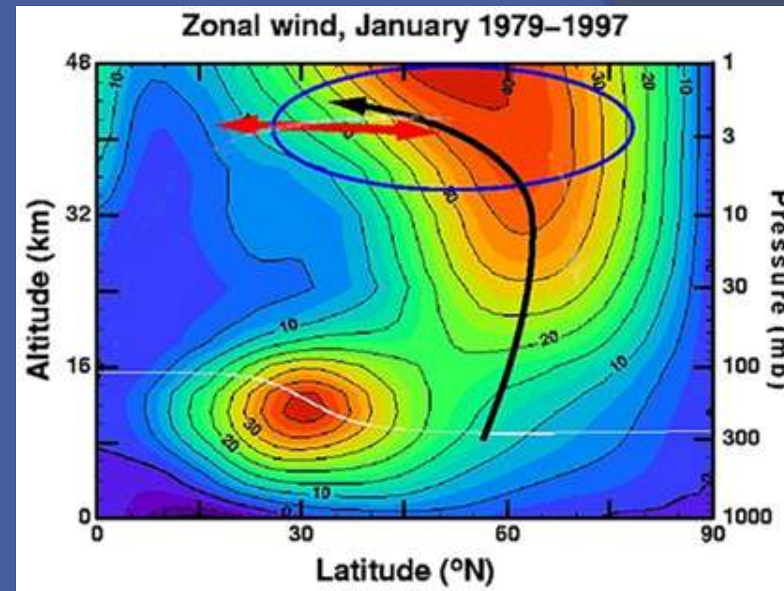
Stratospheric Polar Vortex and its part in the troposphere-stratosphere coupling

The Polar Vortex is a cyclonic circulation formed at polar latitudes above the level 500 hPa.

The Polar Vortex is seen in the stratosphere as

- an area of low temperatures, with temperature gradients at its edges being increased
- an enhancement of zonal wind velocity.

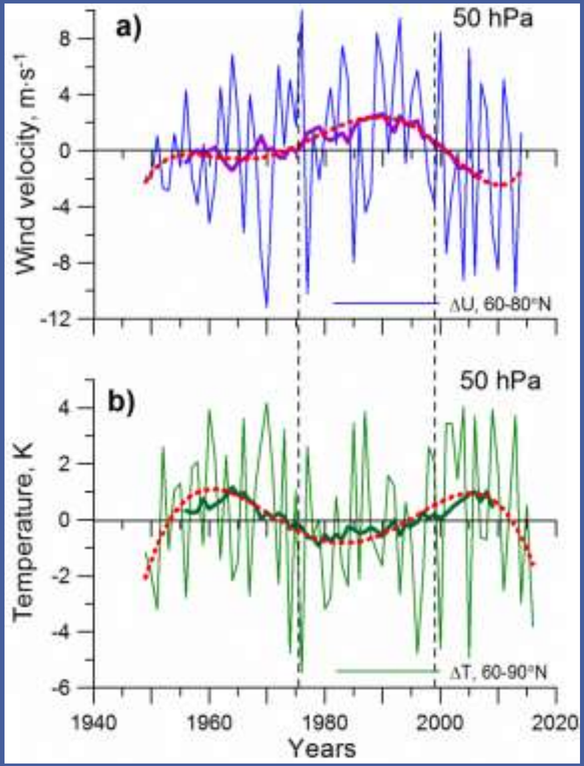




Newman and Mooris, Stratospheric Ozone.
http://www.ccpo.odu.edu/SEES/ozone/oz_class.htm

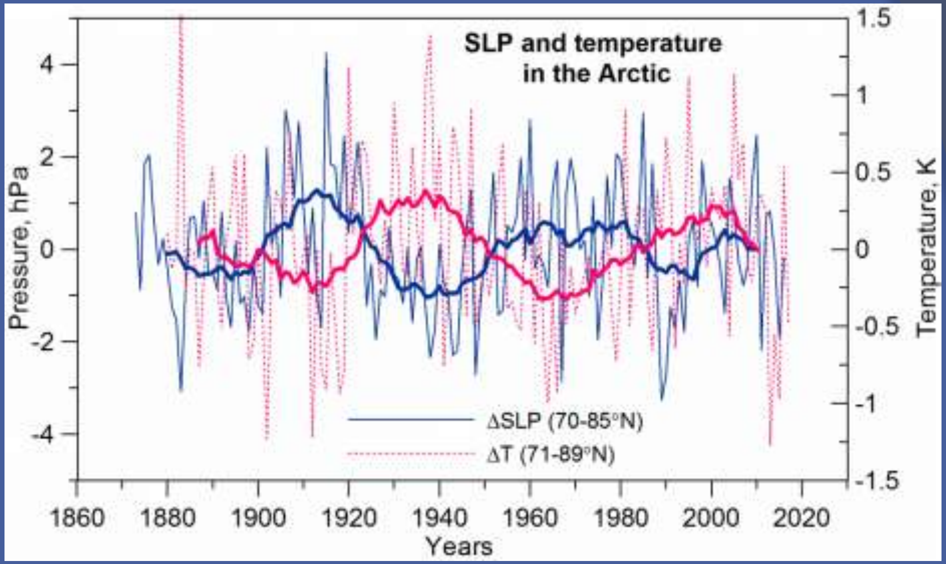
A key feature of the Polar Vortex is its capability to influence the stratosphere-troposphere coupling via planetary waves.

~60-year periodicity in the Polar Vortex strength



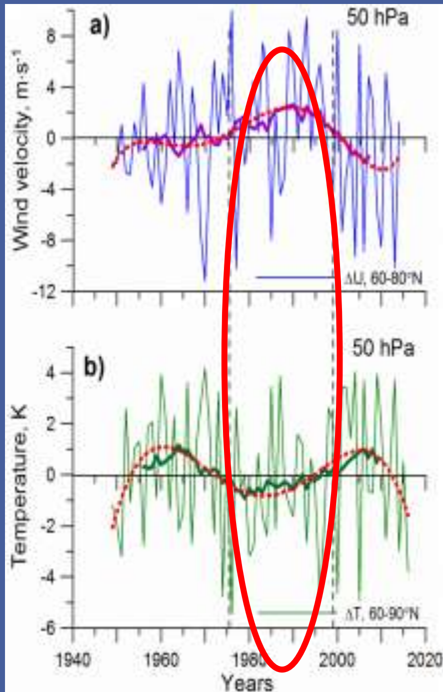
Estimates of the Polar Vortex strength on the base :

- NCEP/NCAR reanalysis data since 1948;
- The Arctic Oscillation since the end of the XIX century

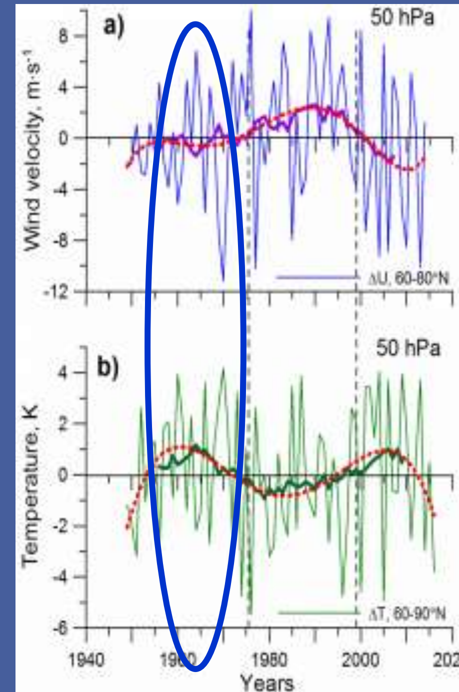


The data suggest a ~60-year periodicity in the vortex strength

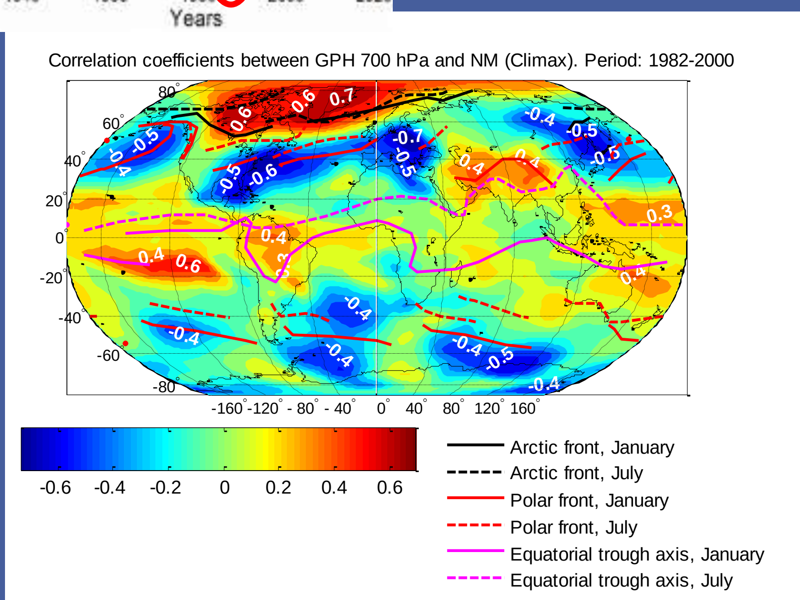
		Arctic (near surface)		Stratosphere (50 hPa)	
		SLP anomalies	Epoch	Wind velocity	Temperature
Strong vortex	~1920-1950	negative	warm	-	-
	~1980-2000	negative	warm	enhanced	lowered
Weak vortex	~1900-1920	positive	cold	-	-
	~1950-1980	positive	cold	lowered	increased

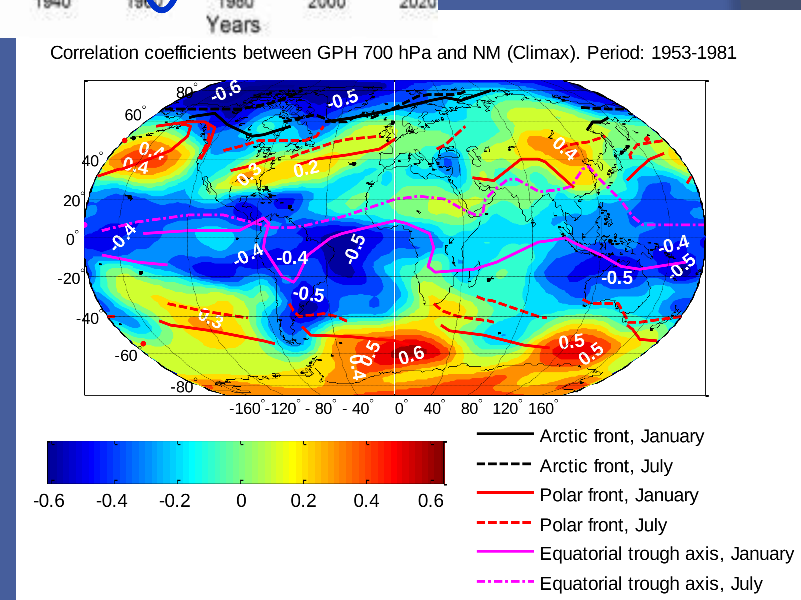


Strong vortex conditions



Weak vortex conditions

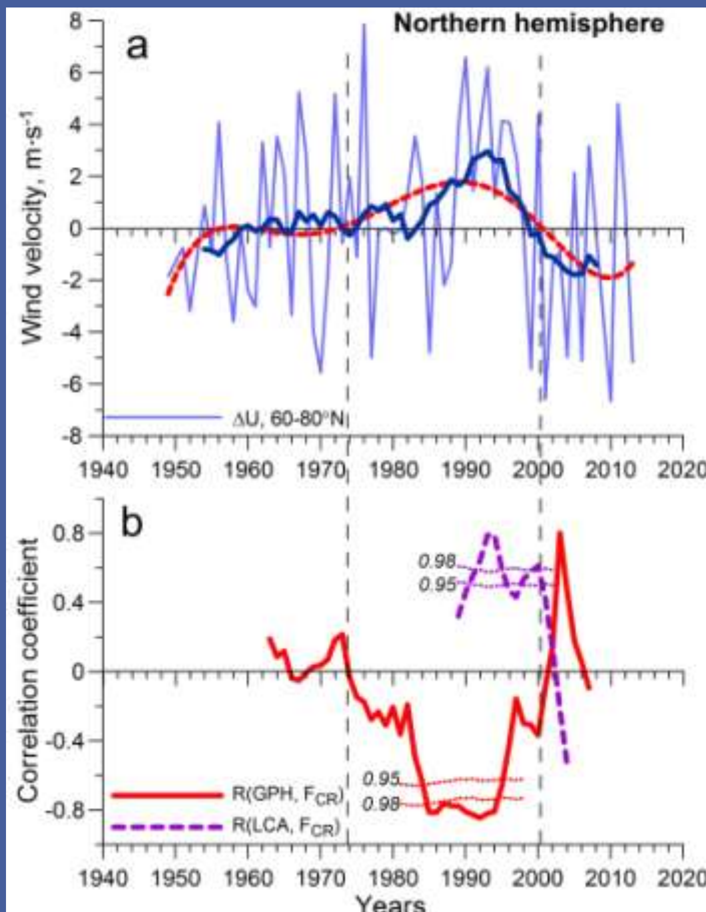




Intensification of extratropical cyclones with GCR increase

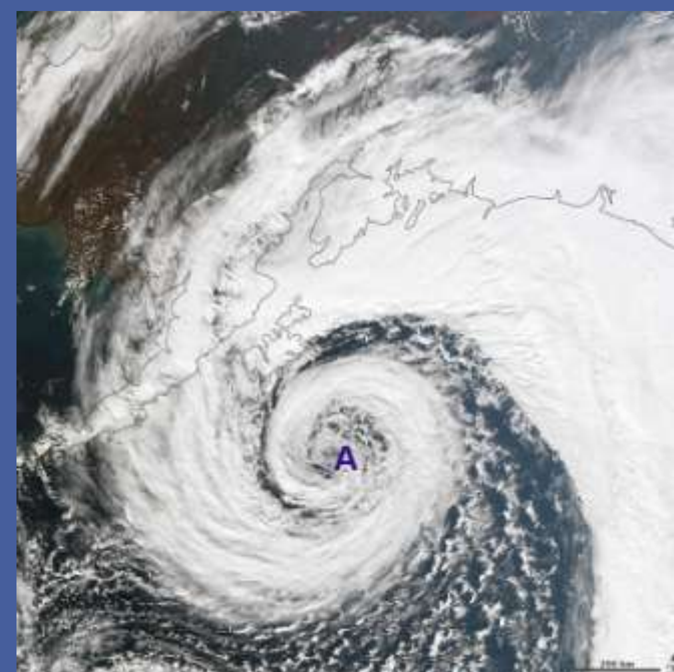
No cyclone intensification with GCR increase

Reversal of pressure/GCR and low clouds/GCR correlations near 2000



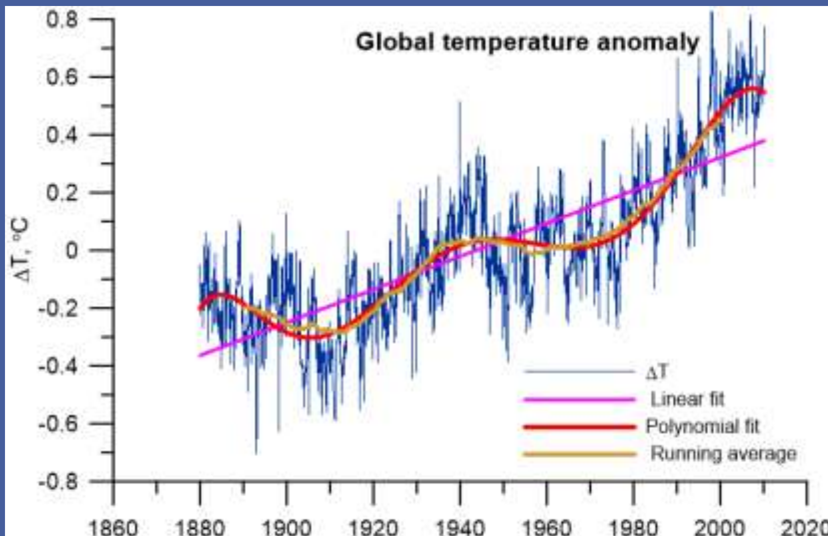
Veretenenko and Ogurtsov, JASTP, 2016; Bull. RAS, 2017

A sharp weakening of the vortex near 2000 resulted in the change of correlation pressure/GCRs and then to the reversal of the correlation low clouds/GCRs

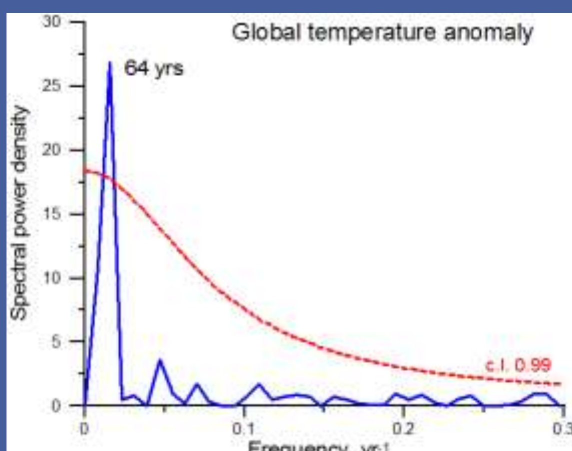


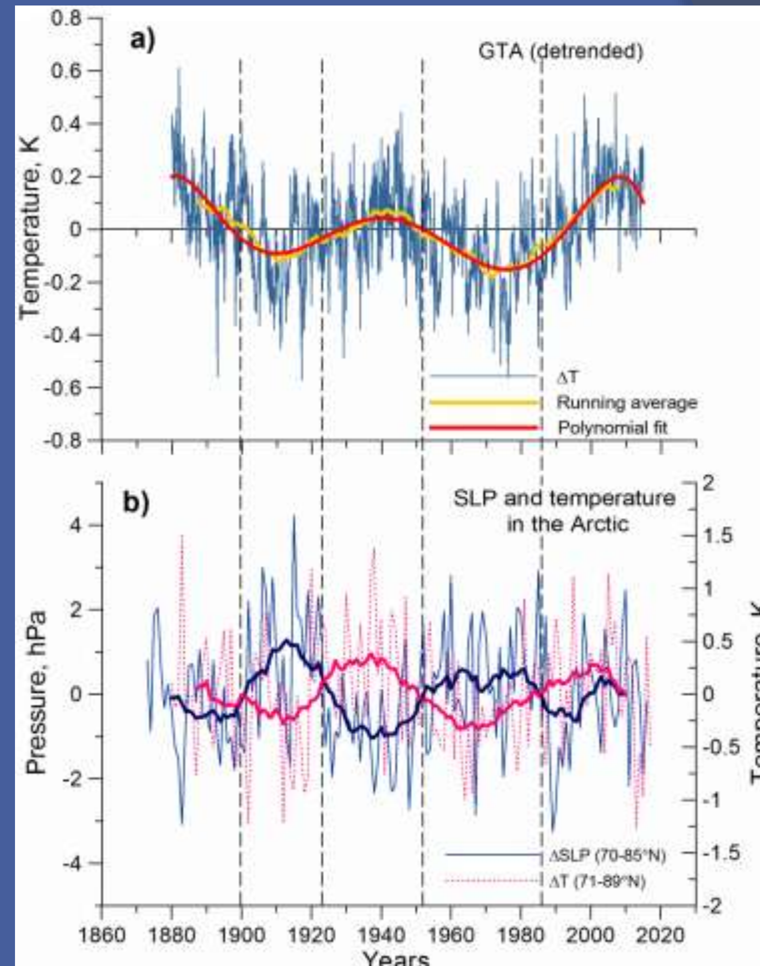
Cloud system of an extratropical cyclone
https://earthobservatory.nasa.gov

~60-year oscillations in global temperature anomalies and the Arctic Oscillation



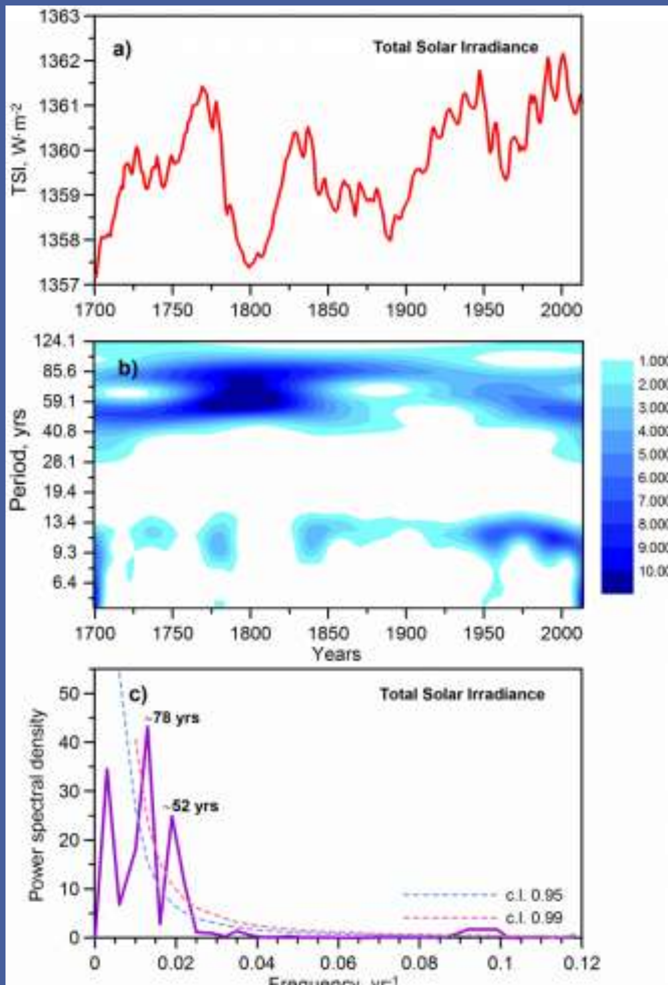
Data of Climatic Research Unit,
www.cru.uea.ac.uk/cru/info/warming



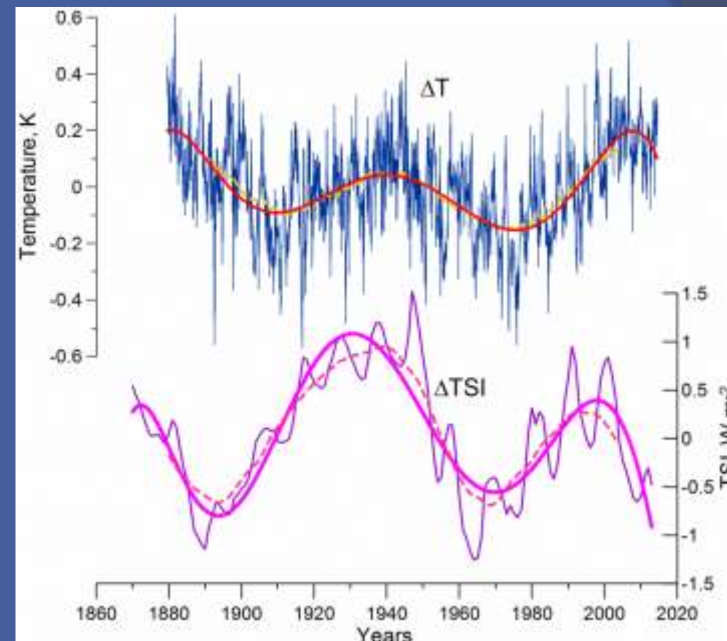


~60-year variations in SLP and temperature in the Arctic (the Arctic Oscillation) coincide well with similar variations of global temperature.

Global temperature anomalies and variations of Total Solar Irradiance (TSI)



Long-term variations of TSI according to Hoyt-Schatten reconstruction (1993) updated in (Scafetta and Wilson,2014)



One of possible reasons for ~60-year variations in global temperature anomalies may be TSI variations

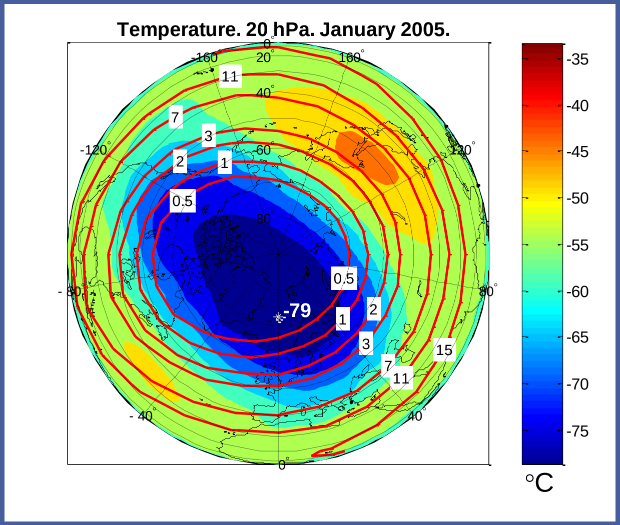
$\Delta TSI = \pm 1$ W·m^{-2}

$\Delta T = \lambda \Delta F = \lambda(1 - A)\Delta TSI/4 \sim 0.1$°C

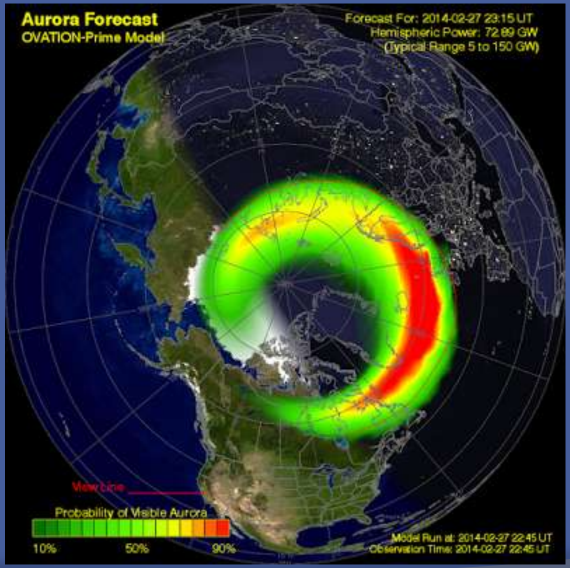
A=0.3 – the Earth's albedo

λ =0.5 K·(W·m^{-2})$^{-1}$ – the climate sensitivity parameter

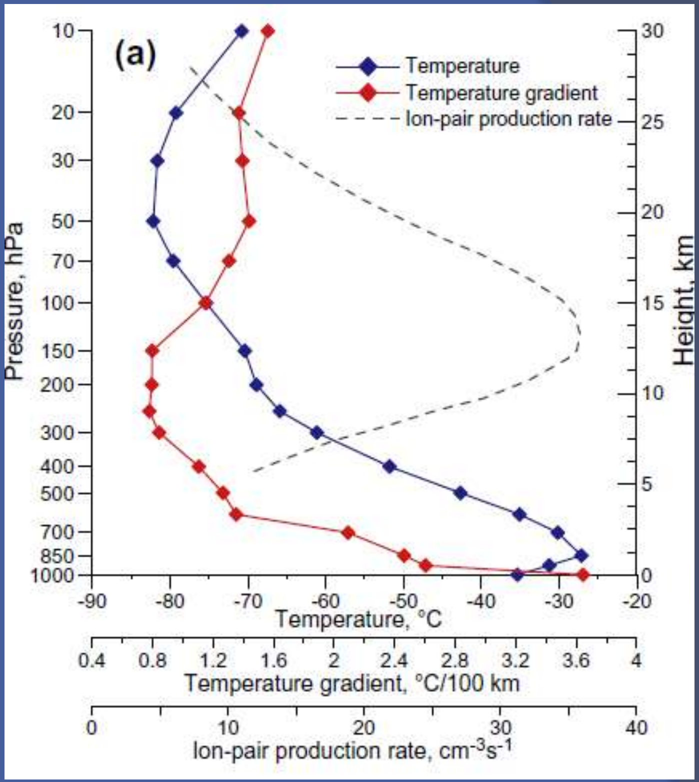
Polar Vortex: favorable location for solar influences



Red lines: Vertical geomagnetic cutoff rigidities (in GV) (*Shea and Smart, 1983*)

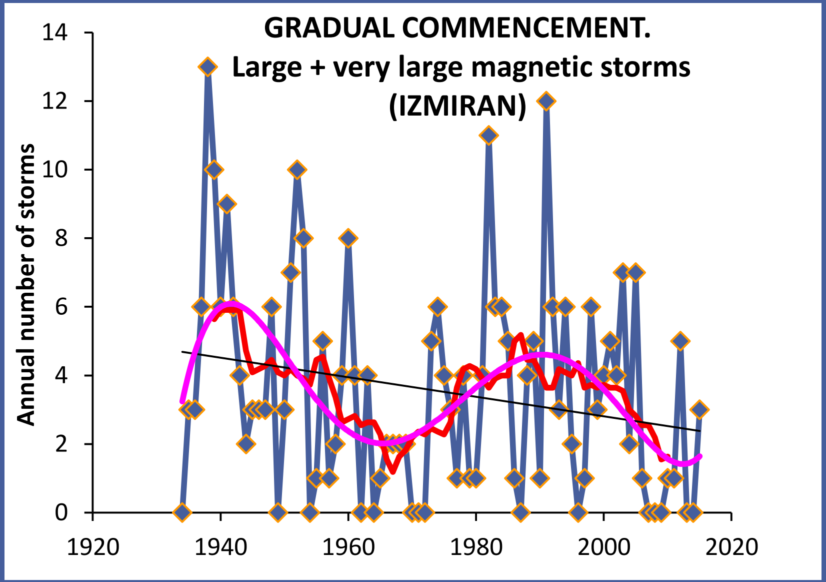


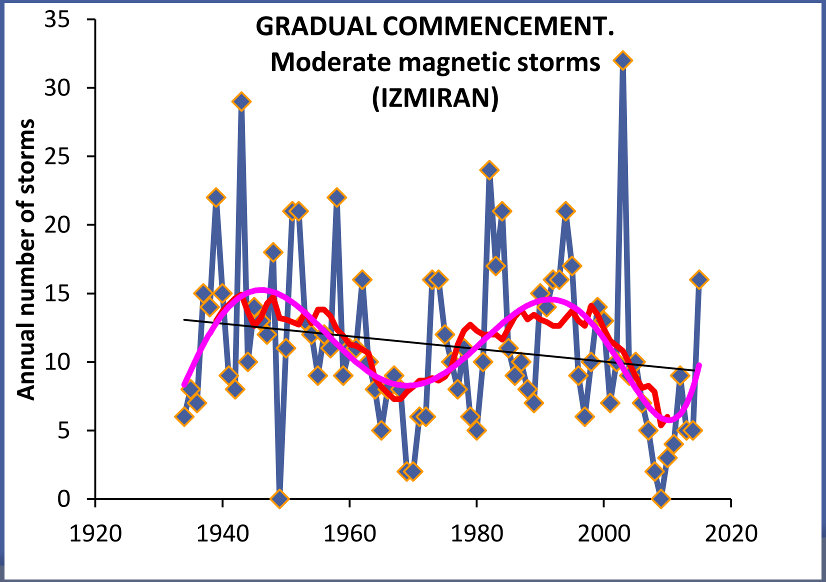
Aurora forecast for magnetic storm 27.02.2014
(http://www.swpc.noaa.gov/ovation/)



Height dependences of the Arctic air mass characteristics (January 2005) (*Veretenenko and Ogurtsov, Adv. Space Res. 2014*).
Dashed line: the ion-pair production rate in free air at polar latitudes (*R* = 0-0.6 GV)   (*Bazilevskaya et al., 2008*).

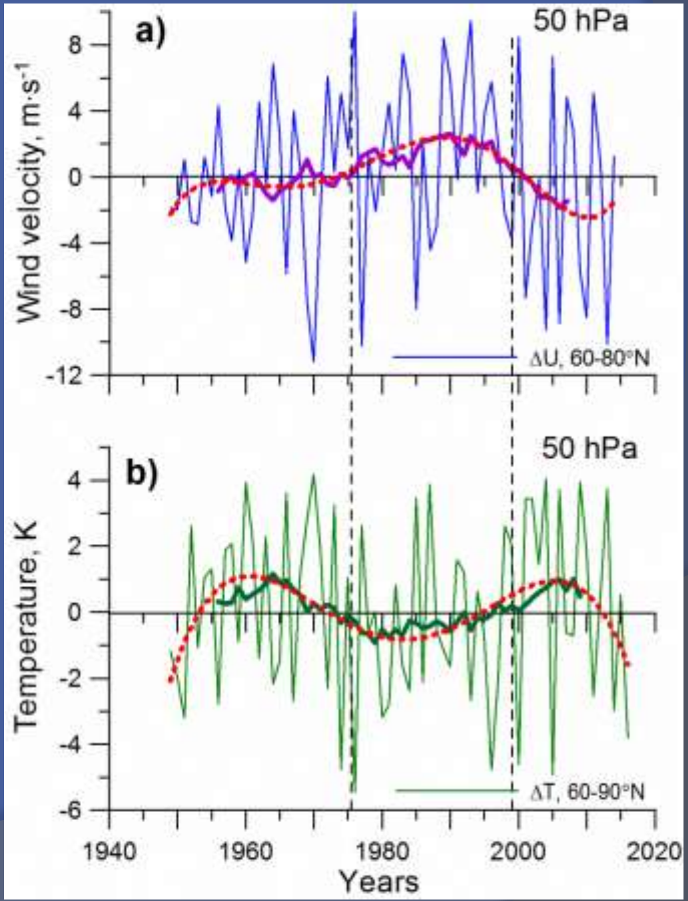
~60-year variation in magnetic storm occurrences





The polar vortex was **strong** when **occurrence of magnetic storms with gradual commencements (SG)** was **enhanced** (~1980-2000)

When **occurrence of SG storms** was **decreased**, the polar vortex was **weak** (~1950-1980)



Conclusions

1. Temporal variability of solar activity and galactic cosmic ray (GCR) effects on the lower atmosphere circulation is characterized by a roughly 60-year periodicity which seems to be due to changes of the epochs of the large-scale circulation.

2. Sign reversals of correlation links between atmospheric characteristics and solar activity/GCR variations coincide well with turning points in the evolution of the main forms of the large-scale atmospheric circulation, as well as with the transitions between the different states of the stratospheric polar vortex.

3. The stratospheric polar vortex seems to play an important part in the mechanism of solar-atmospheric links which is due to its capability to influence the troposphere-stratosphere coupling. The correlation reversals may be caused by changes of conditions for planetary wave propagation under a strong/weak vortex regime.

4. Global temperature variations associated with long-term changes of total solar irradiance, as well as geomagnetic activity may be considered as possible reasons for changes of the polar vortex state and the corresponding changes of large-scale circulation epochs at the multidecadal time scale