Recent advances in the vertical coupling in the Atmosphere–Ionosphere System - Review of IAGA WG II C/ICMA/SCOSTEP activity

Petra Koucká Knížová
Institute of Atmospheric Physics
Czech Academy of Sciences
Boční II/ 1401, Prague
Czech Republic

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IAGA Division II
WG C – Meteorological Effects on the Ionosphere

Areas of interest: physics behind the forcing mechanisms which originate in the lower atmosphere and play an important role in the coupling of the upper atmosphere and ionosphere.

(i) coupling of spatial domains through dynamics
(ii) coupling through transport of atmospheric constituents and feedback of dynamics on the chemistry
(iii) electrodynamic coupling of the atmosphere and ionosphere and the role of the electrical processes in the coupling
(iv) improve understanding the space climatology
(v) satellite measurements, ground based measurements, theoretical studies, models
(vi) Solar impact and modulation of coupling processes

Overlapping with ICMA (The International Commission on the Middle Atmosphere) and SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) – project CAWSES II/ Task 4 (Climate And Weather of the Sun-Earth System) and VarSITI (Variability of the Sun and Its Terrestrial Impact)

Dora Pancheva – WG II C leader, Division II chair 2011-2015

First meeting in Prague 2000 - Workshop on Lower Atmosphere Effects on the Ionosphere and Upper Atmosphere

Vertical Coupling in the Atmosphere–Ionosphere System:

- 2000 Prague
- 2004 Bath
- 2006 Varna
- 2011 Prague
- 2014 Antalya
- **2016, 25-29 July, Taipei**

Prague 2011

http://www.ss.ncu.edu.tw/~vcais6/

Special Issues – Journal of Atmospheric and Solar-Terrestrial Physics

- **Vertical Coupling in the Atmosphere/Ionosphere System, 2nd IAGA/ICMA Workshop on Vertical Coupling in the Atmosphere/Ionosphere System,** Bath, UK, 12 - 15 July, 2004
  Volume 68, Issues 3–5, Pages 245-598 (February 2006) - Edited by Dora Pancheva, Bela G. Fejer, Rolando R. Garcia, Jan Lastovicka and Robert A. Vincent

- **Vertical Coupling in the Atmosphere/Ionosphere System, 3rd IAGA/ICMA Workshop,** Varna, Bulgaria, 18–22 September 2006
  Volume 69, Issues 17–18, Pages 2081-2522 (December 2007) - Edited by Dora Pancheva, Christos Haldoupis, Daniel Marsh and Mike Taylor

- **Recent Progress in the Vertical Coupling in the Atmosphere-Ionosphere System,** Prague, 14-18 February, 2011
  Volume Volumes 90–91, Pages 1-222 (December 2012) - Edited by Dora Pancheva, Petra Koucka Knizova, Kazuo Shiokawa and Weixing Wan

- **Recent advances in the vertical coupling in the Atmosphere–Ionosphere System**
  Volume 136, Part B, Pages 125-250 (December 2015) - Edited by Petra Koucka Knizova, Katya Georgieva, William Ward and Erdal Yigit
  Volume 141, Pages 1-56 (April 2016) - Edited by Petra Koucka Knizova, Katya Georgieva, William Ward and Erdal Yigit

- Atmospheric waves, Sudden Stratospheric Warming, Generation of waves by meteorological events and characterization of their source spectrum.
- Propagation of atmospheric waves (acoustic-gravity waves, tides, Kelvin waves, tidal and planetary waves) from the source region to the ionosphere–thermosphere.
- Linking ionospheric variability (electric fields, plasma parameters, etc.) and meteorological events on various time scales.
- Sun-Earth connection, space weather, atmospheric response to energy impact.
- Galactic Cosmic Rays influence on the processes in the atmosphere
- Theoretical modelling – wave generation, evolution, interactions

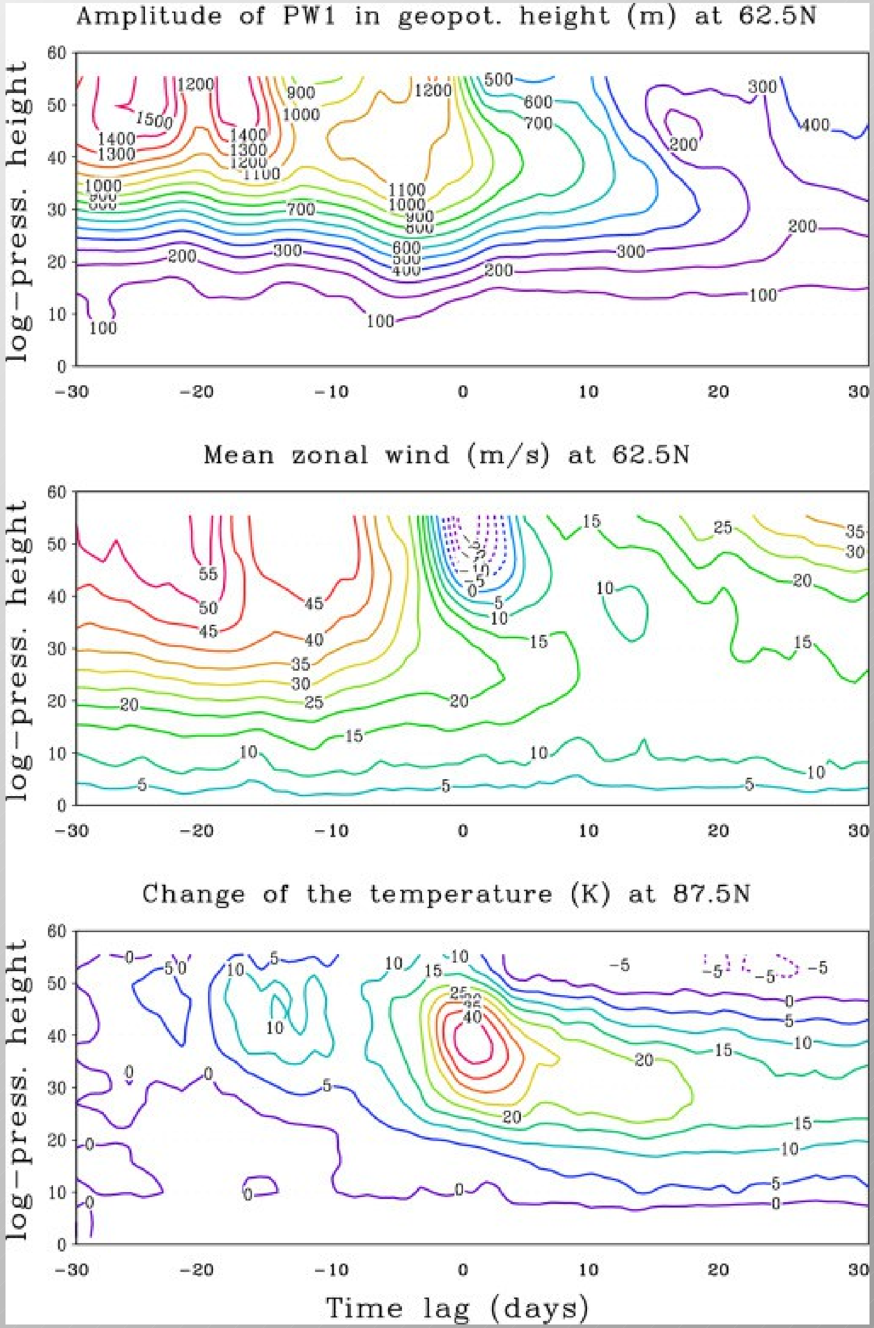
- The SSW events are more intensive and/or the frequency of these events is higher under the easterly QBO phase.

- Nonlinear wave–wave and wave–mean flow interactions can play an important role before and during SSW. These processes can lead to the excitation of SPW in the upper stratosphere.

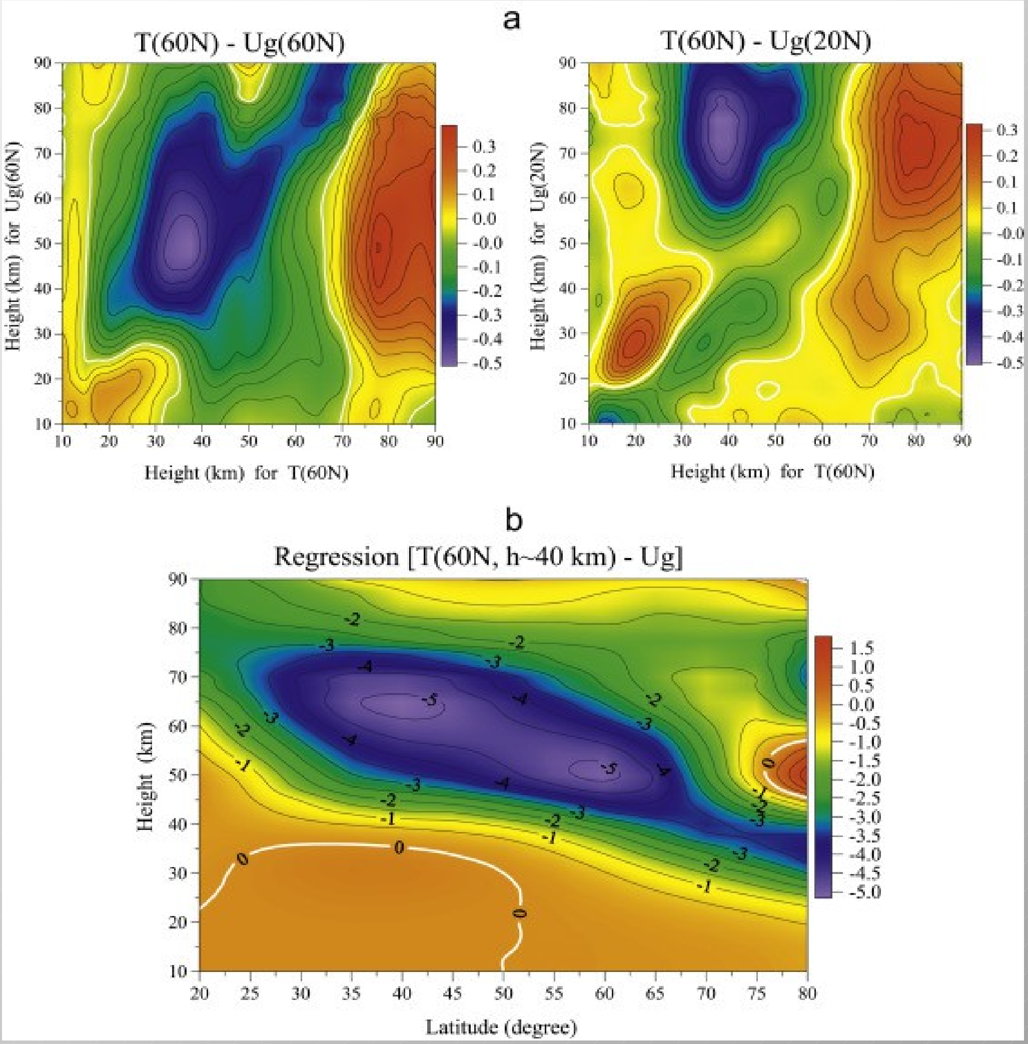
- Important to consider the dynamical processes in the stratosphere long before – at least 2–3 weeks before the onset of SSWs, or even longer.

- The SSW definition recommended by the WMO (Butler et al., 2015) can be reconsidered, at least in respect to the altitude (for instance, these events have to be looked at about 40 km and judged by temperature changes, and/or even higher for the zonal jet reversals).

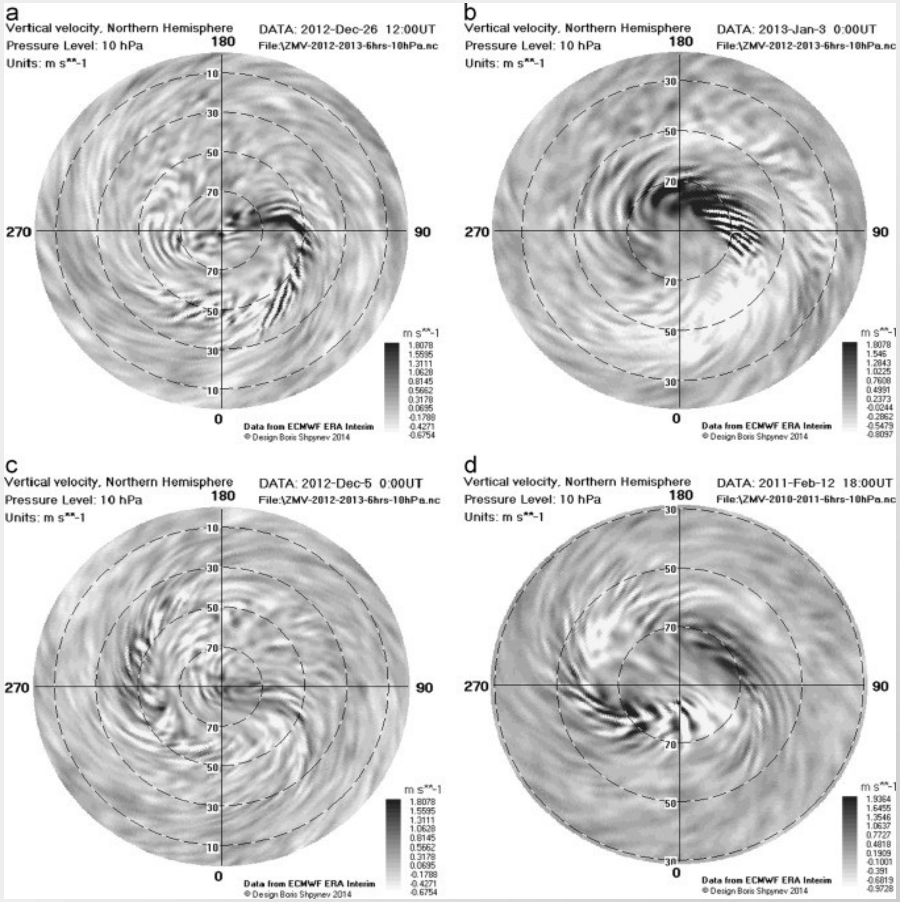
Pogoreltsev et al.



- Influence of the high-latitude stratospheric temperature on the low-latitude TEC
- Extra-long planetary waves (20-25 days) as a dynamic coupling agent in the middle atmospere and ionosphere
- Temperature at altitude of ~40 km and latitude of ~60°N describes the most typical winter conditions.
- The contribution of the stratospheric temperature on the TEC is almost half of that of F10.7.

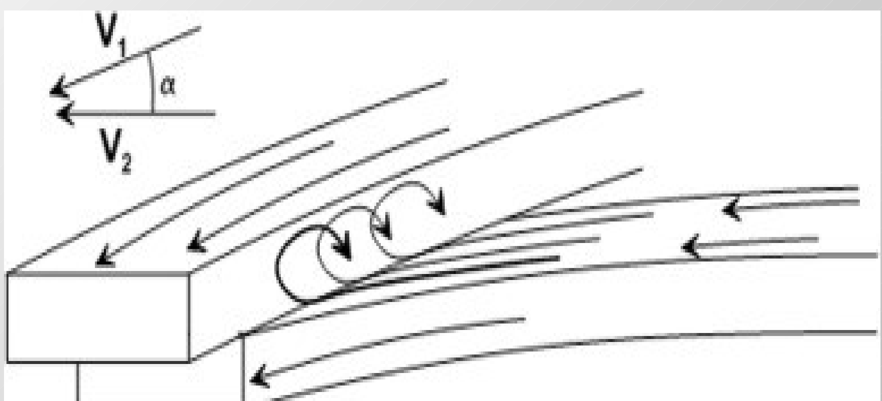


Mukhtarov and Pancheva



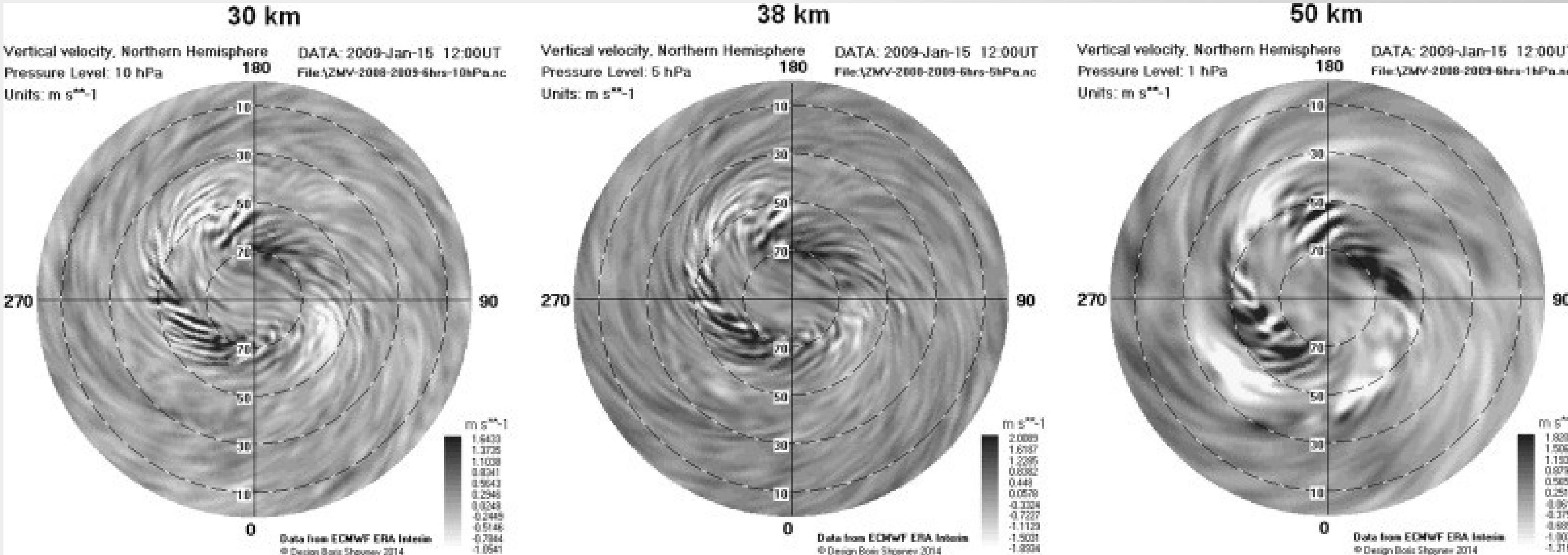
Presence of regions with significant shear of horizontal velocity which favors for inducing of shear-layer instability that appears as gravity wave on boundary surface.

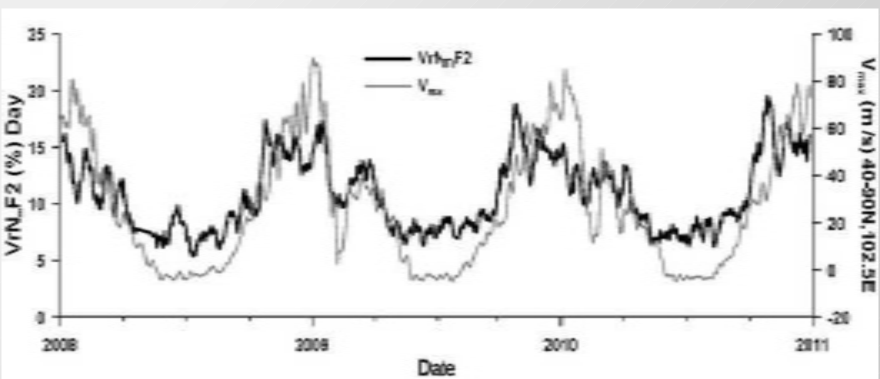
During powerful SSW the main jet-stream can amplify these gravity waves to very high amplitudes that causes wave overturning and releasing of wave energy into the heat due to the cascade breakdown and turbulence.



Winter Brewer-Dobson circulation is the result of well pronounced downward spiral jet-stream circulation (time scale about 20-30 days) and has no relation to PW-GW interaction.

Shpynev et al.



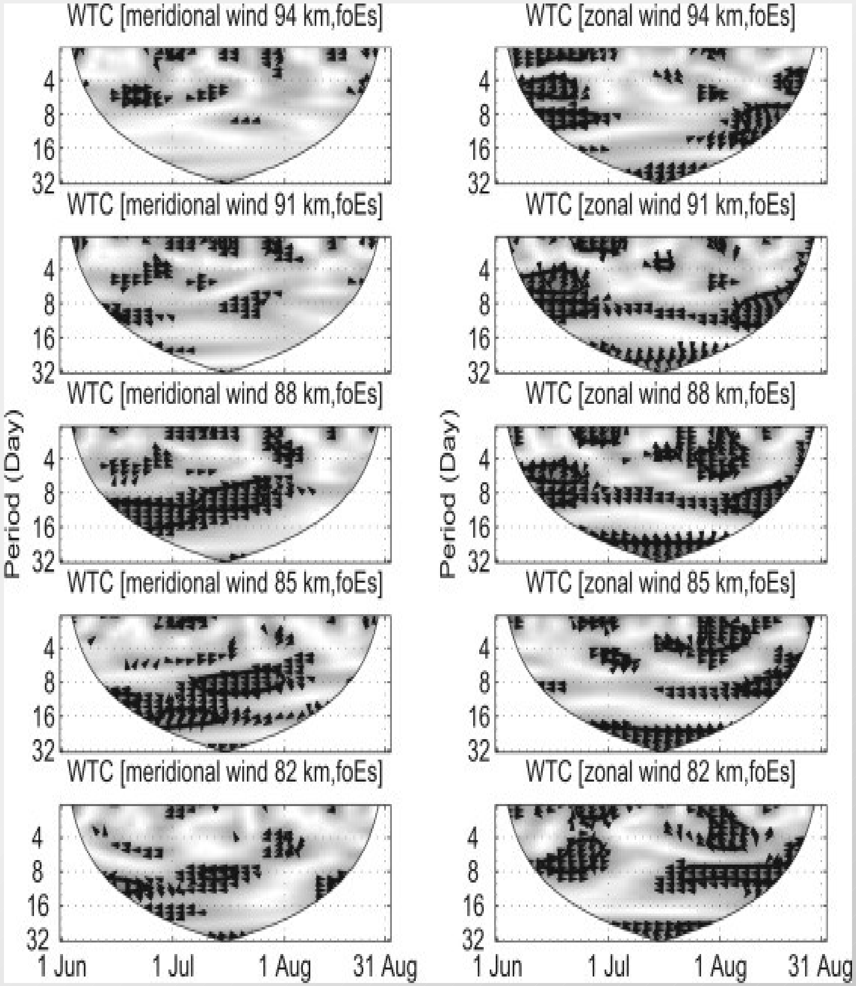


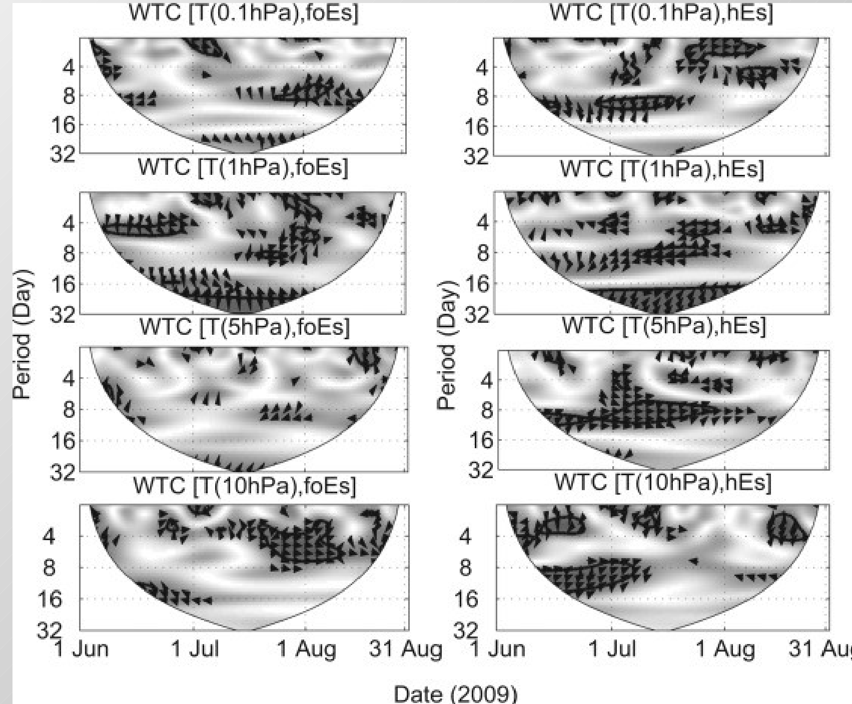
Waves are associated with stratospheric jet currents mostly localized at 50-80°N.
At the boundary between air flows atmospheric waves with various scales are formed.

Wave-like disturbances propagate from the stratosphere up into the lower mesosphere, with the increase in the amplitude.

Increase in the *F2* layer wave-like disturbances corresponds to periods of stratospheric wave activity

Chernigovskaya et al.

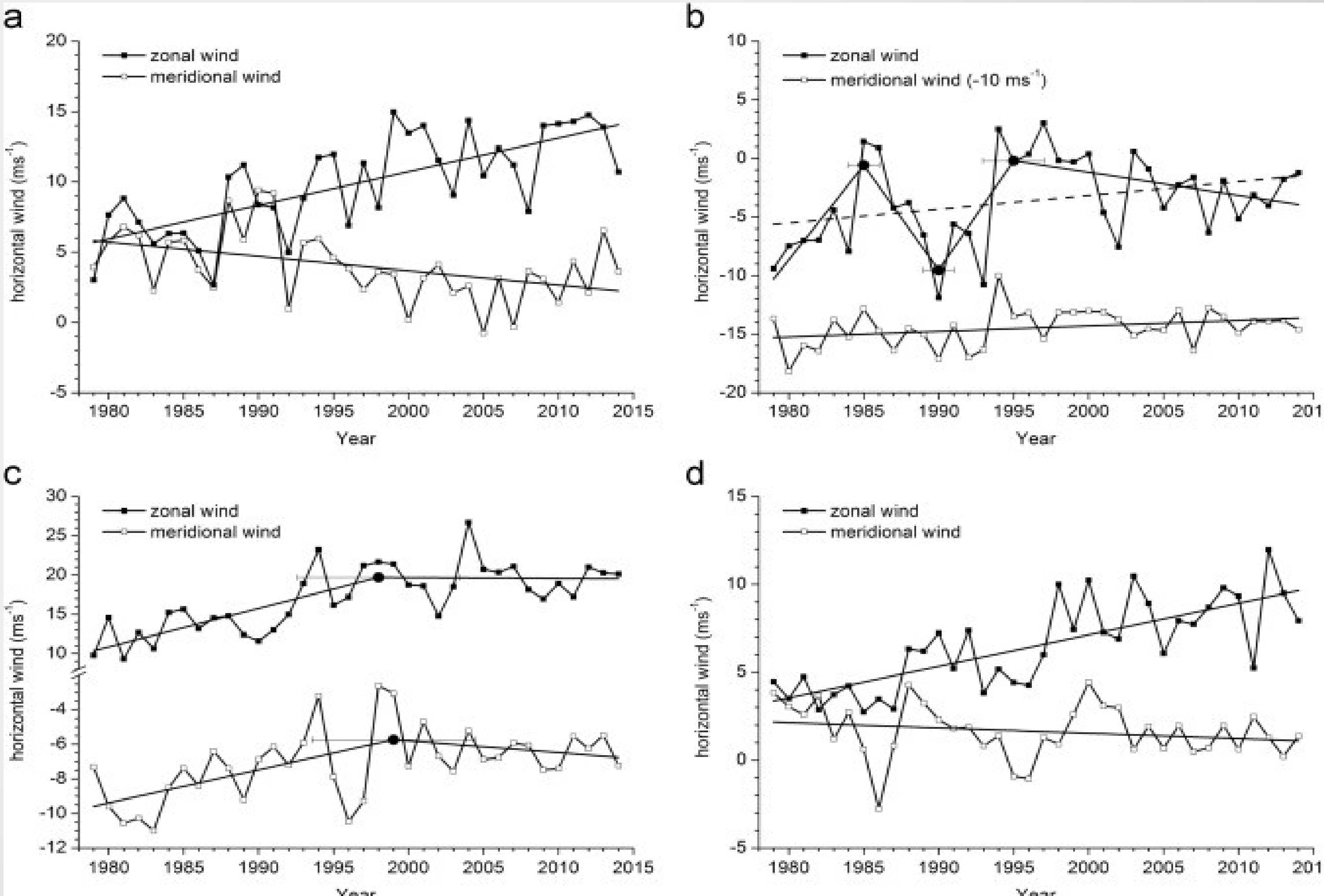




Dominant periods detected in temperature and wind data coherent with the Es data are 2, 5, 9–10, and 15 day periods which correspond to the planetary eigen-modes.

Certain coherent structures are persistent through the atmosphere.

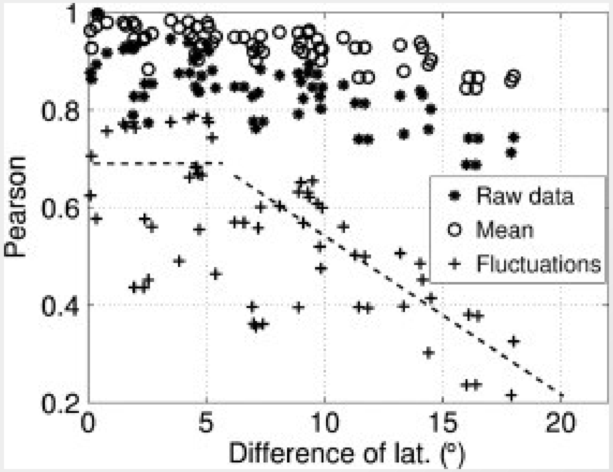
Mosna et al.

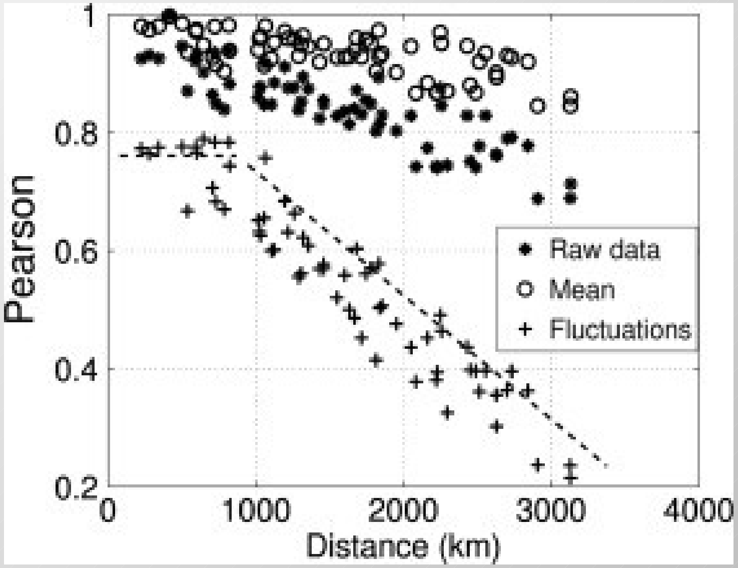


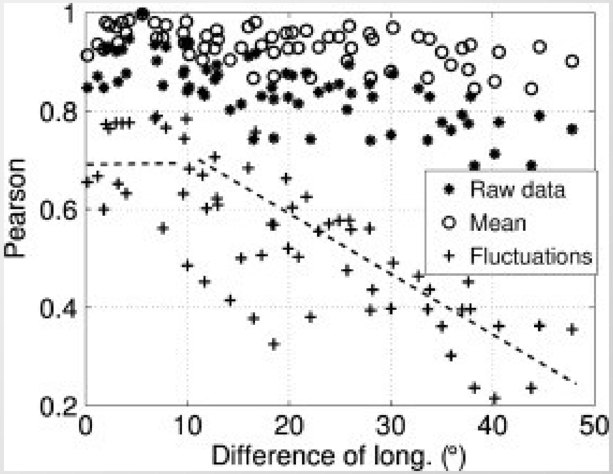
Midlatitude zonal winds in the MLT show positive trends towards more westerly winds throughout the year, while the meridional wind trends are negative in autumn/winter and positive in spring/summer.

The trends of both zonal and meridional summer prevailing winds are changing after 1995.

Jacobi et al.







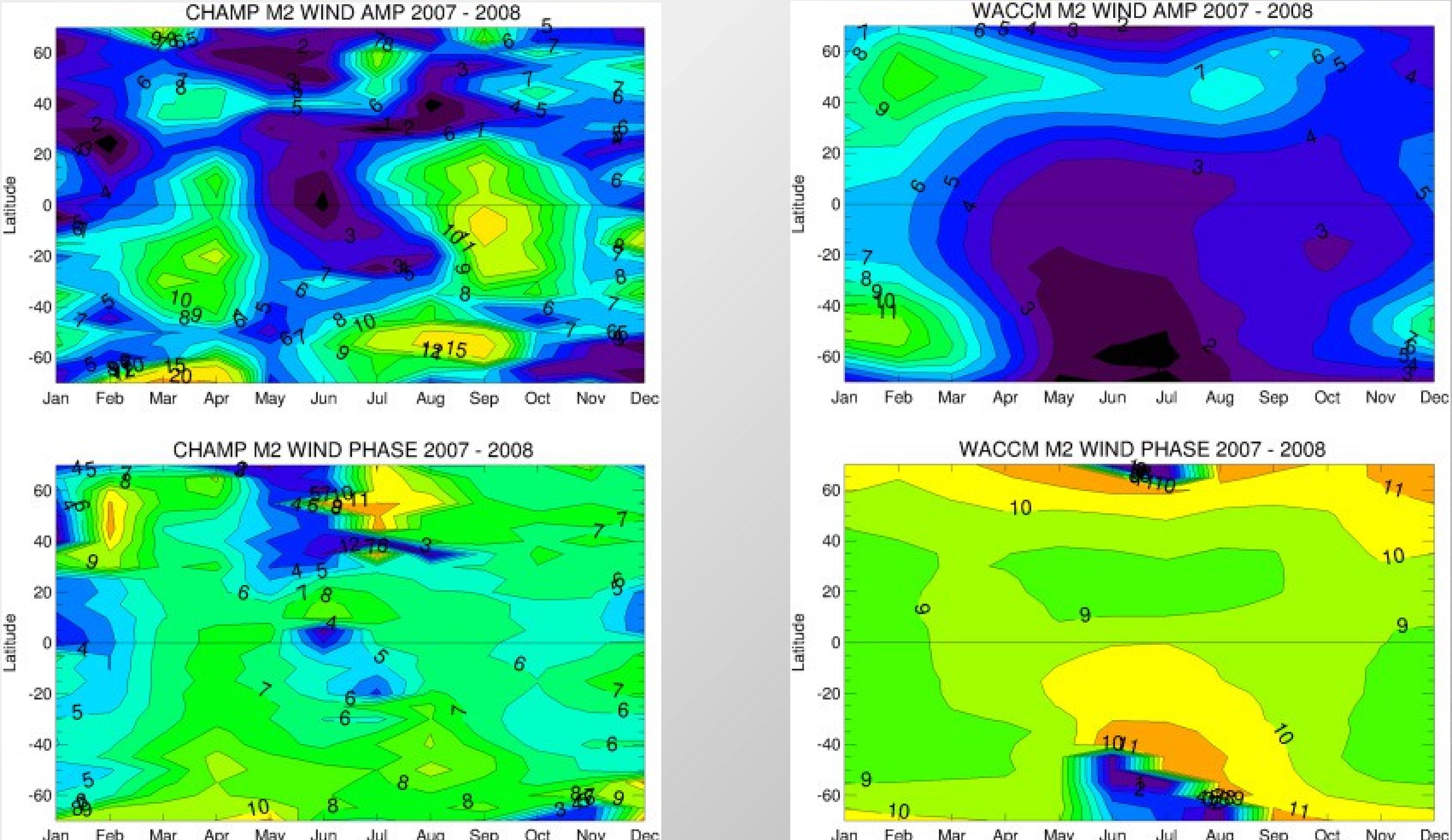
Correlation coefficients of foF2 are high not only for raw data and subtracted mean courses but for fluctuations around mean as well.

At the surface distance exceeding 1000 km and/ or about 10 degrees of latitudinal difference between stations, the correlation coefficient of fluctuations decrease rapidly.

As a possible source of the common influence on scale 1000 km/10 degree we propose tropospheric systems

Large tropospheric mesoscale systems have typically up to 2000 km in diameter.

Koucká Knížová et al.

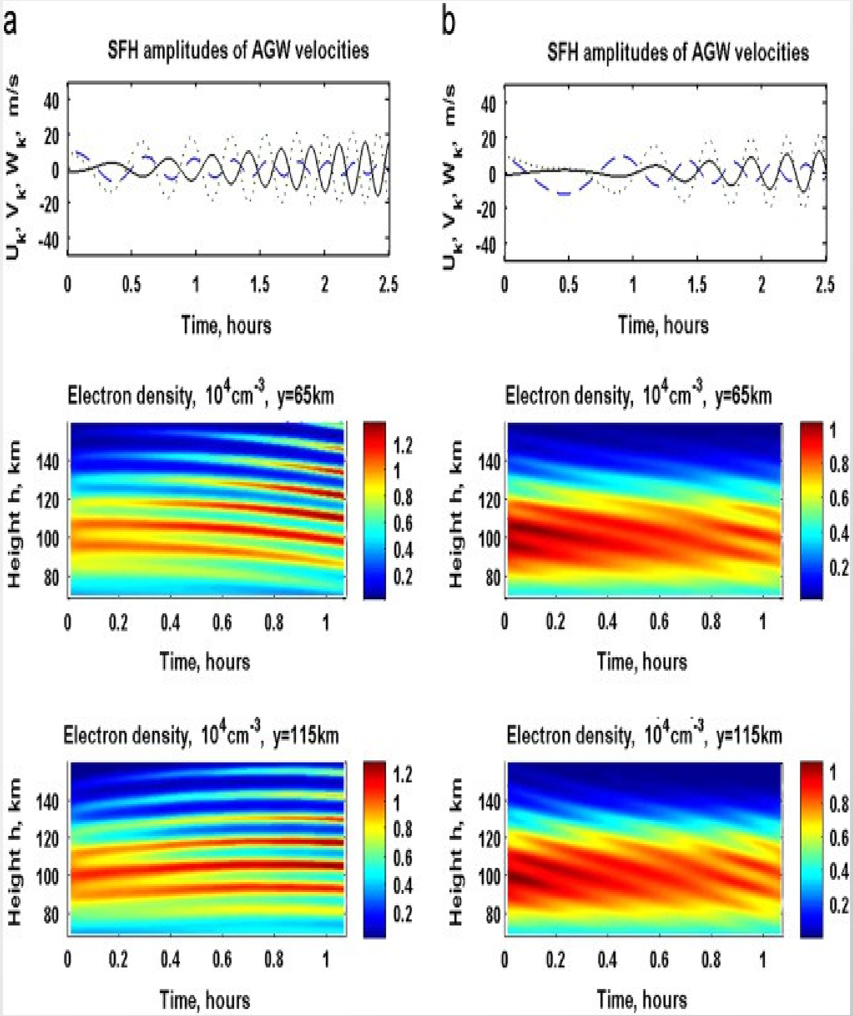


Low latitude $M2$ amplitude maxima between 10 and 15 m s^{-1} that occur twice yearly close to equinox.

$M2$ in WACCM-X exhibits only one global-scale maximum per year. Amplitudes are comparable with observations

$M2$ is a climatological feature of the thermospheric wind system, with the potential to modulate transport of plasma along magnetic field lines.

Lieberman et al.



Didebulidze et al.

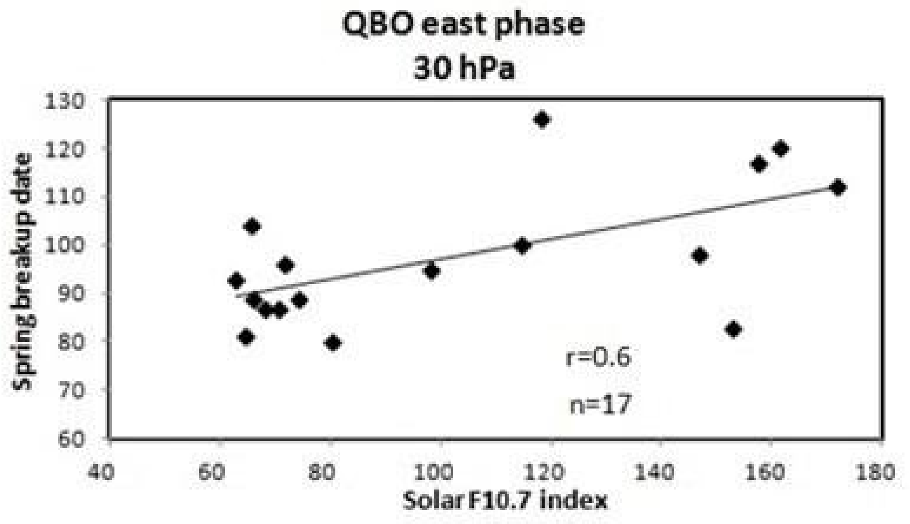
The AGWs influence the horizontal and vertical motion of ions, and lead to their convergence into thin horizontal layers.

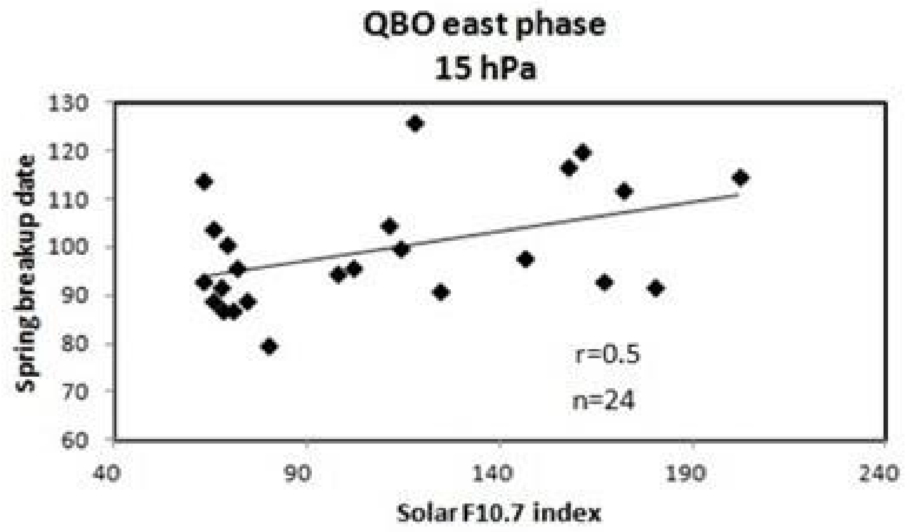
Ion/electron density of Es layer depends on the value of the horizontal shear of a magnetic north-directed background wind.

It is shown that the plasma density of Es layers also depends on the horizontal and vertical amplitudes of AGWs' velocity perturbations, which increase in the horizontal shear flow and cause a formation of multilayered sporadic-E.

The Es layers mainly move downwards, but at certain spatial location, where temporal changes in wave phase caused by background shear flow and AGW are small, these layers are almost horizontal.

- The vertical spatial location of the horizontal Es layers is determined by the vertical wavelength of atmospheric gravity waves.



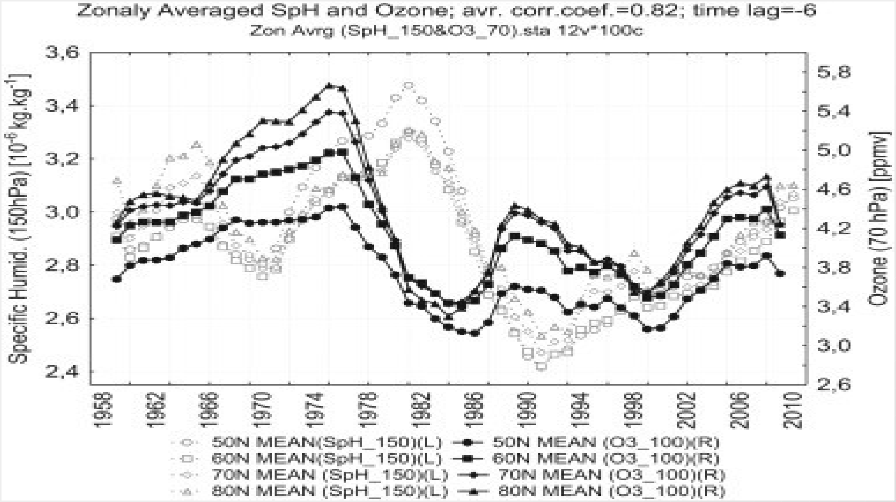


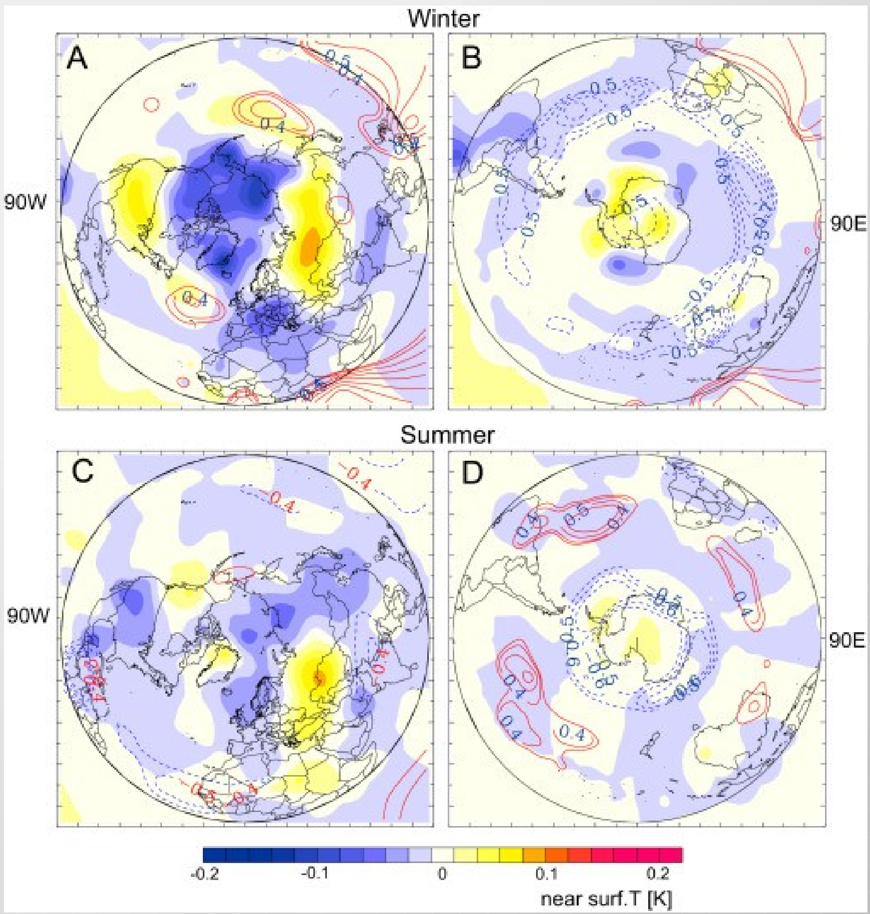
Grouped according to the phases of the Quasi-Biennial Oscillation (QBO):
dependence of spring transition dates on solar activity.

Dividing data on early and later spring transition:
the stronger influence of solar signal is revealed at late spring transition.

Under high solar activity conditions, the relation between spring transition dates and solar activity is stronger than at low one.

Rakushina et al.

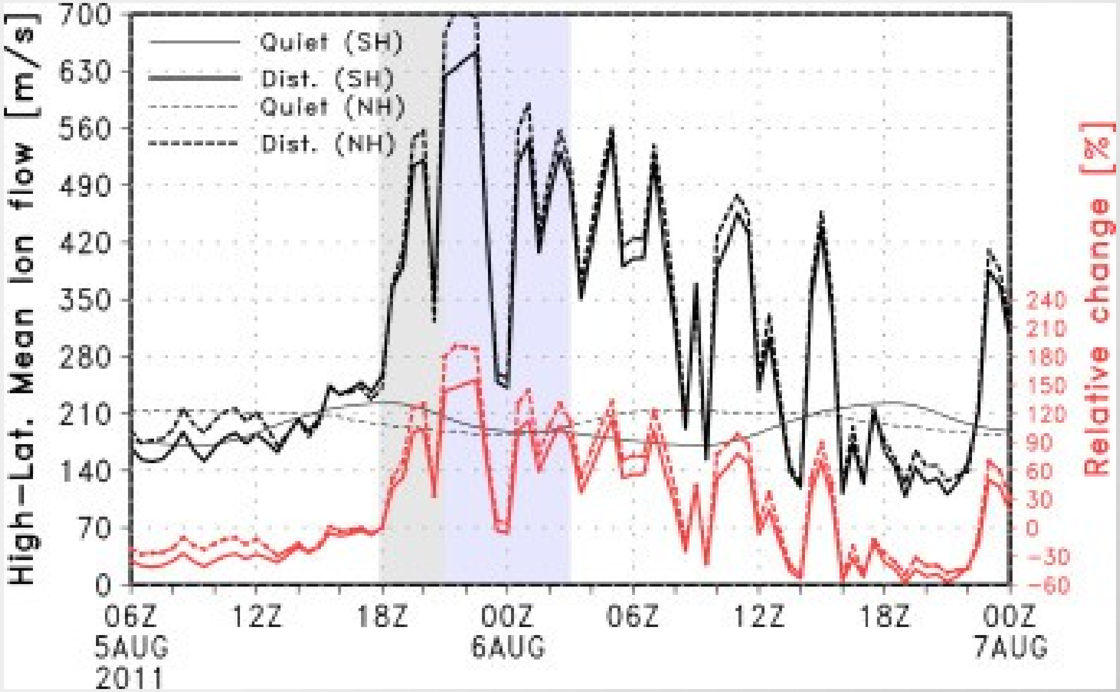




Energetic particles influence on the lower stratospheric ozone, followed by warming/cooling, and drying/moisturing of the upper troposphere – lower stratosphere region, is capable of explaining the surface T variability during the studied period 1957-2012.

Existence of centers of action, where lower stratospheric ozone constantly influence the water vapour density near tropopause.
Winter NH – North Atlantic, North Pacific
Summer SH – Indian and Pacific extra-tropics, South Atlantic magnetic anomaly.
NH is more sensitive to GCR
SH to solar protons

Kilifarska



High- latitude mean ion flows are enhanced by up to 150–180%.

Largest ion flows are found in the main phase of the storm.

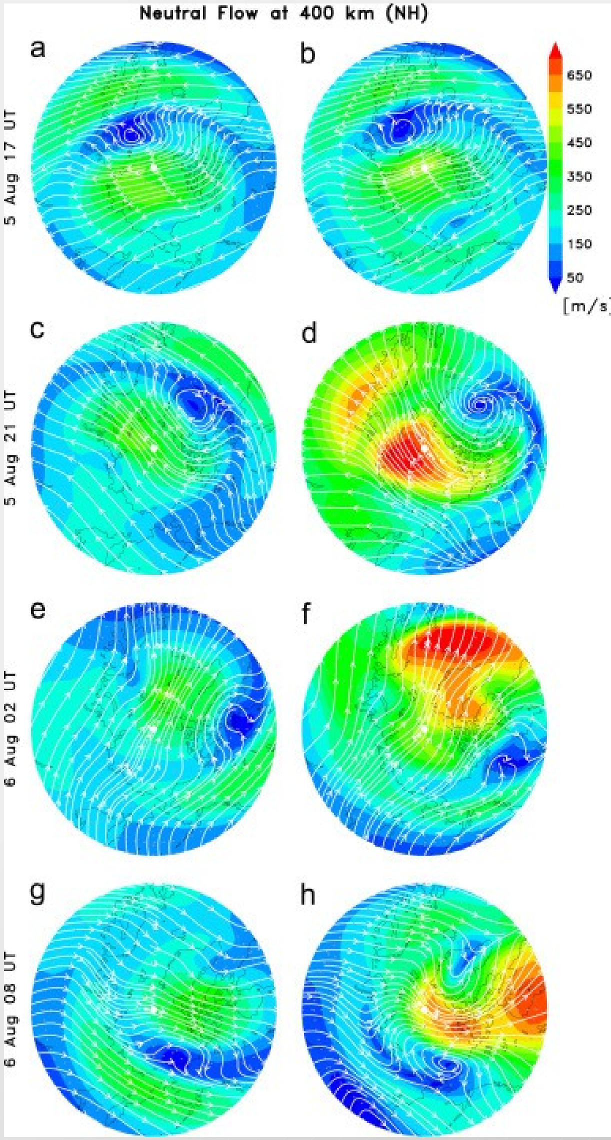
Global mean neutral temperature increases by up to 15%, while the maximum thermal response is higher in the winter Southern Hemisphere at high-latitudes than the summer Northern Hemisphere: 40% vs. 20% increase in high-latitude mean temperature, respectively.

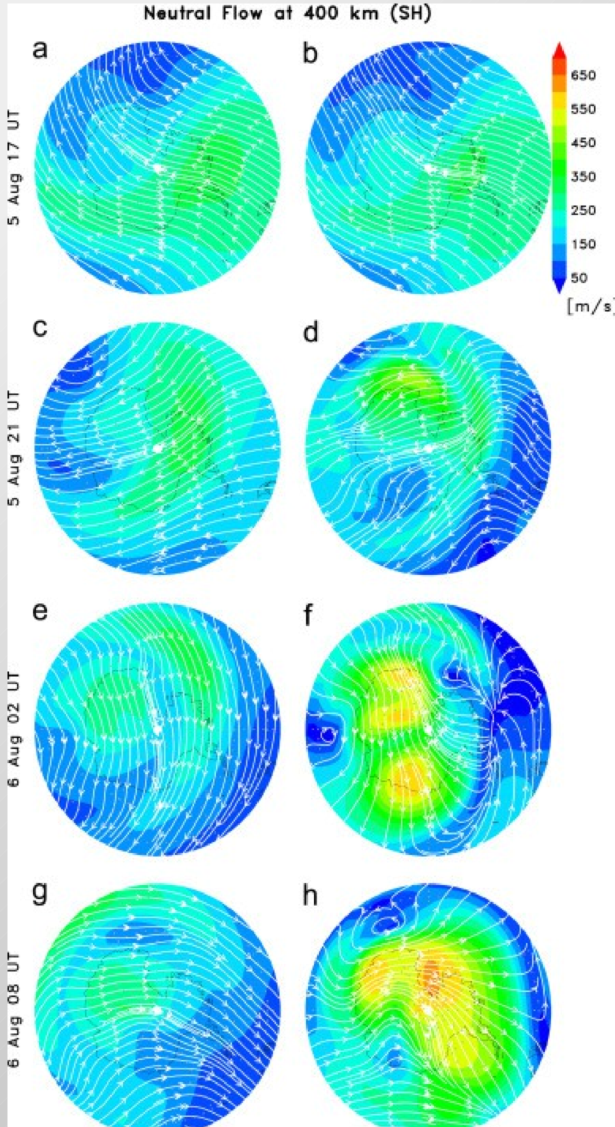
The global mean Joule heating increases by more than a factor of three.

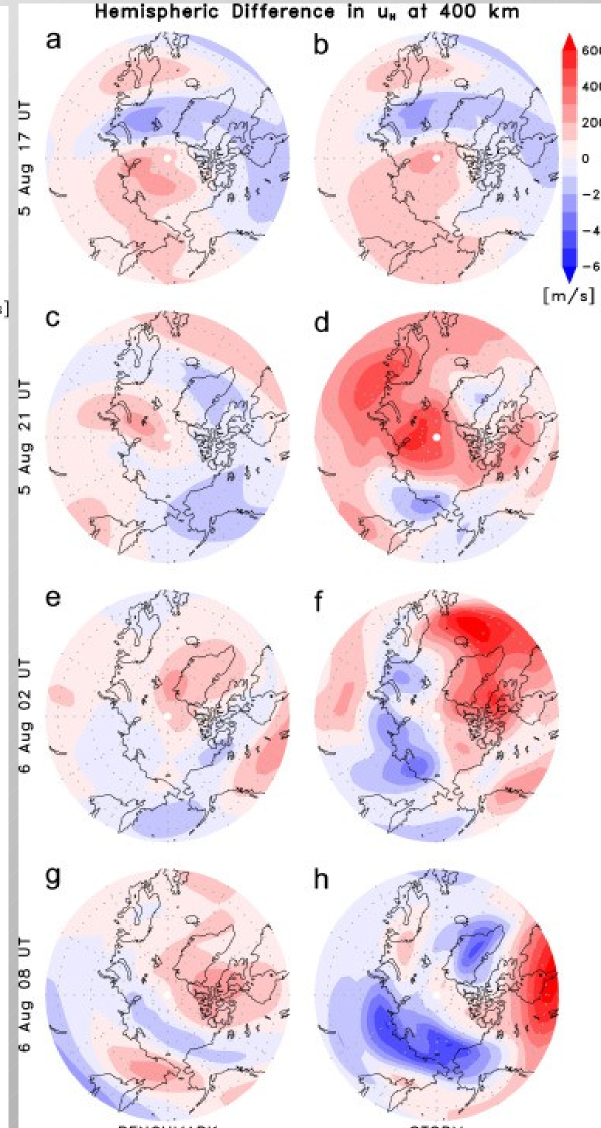
Distinct hemispheric differences in the magnitude and morphology of the horizontal ion flows and thermospheric flows during the different phases of the storm.

The largest hemispheric difference in the thermospheric circulation is found during the main and recovery phases of the storm, demonstrating appreciable geographical variations.

Yigit et al.


Neutral Flow at 400 km (NH)
a
b
c
d
e
f
g
h
5 Aug 17 UT
5 Aug 21 UT
6 Aug 02 UT
6 Aug 08 UT
650
550
450
350
250
150
50
[m/s]


Neutral Flow at 400 km (SH)
a
b
c
d
e
f
g
h
5 Aug 17 UT
5 Aug 21 UT
6 Aug 02 UT
6 Aug 08 UT
650
550
450
350
250
150
50
[m/s]


Hemispheric Difference in u_N at 400 km
a
b
c
d
e
f
g
h
5 Aug 17 UT
5 Aug 21 UT
6 Aug 02 UT
6 Aug 08 UT
600
400
200
0
−200
−400
−600
[m/s]
BENCHMARK
STORM

Yigit et al.

Large tropospheric sources of dimensions ~100km or more at equatorial geomagnetic latitudes create large electric fields in the lower ionosphere at night: millivolts per meter, due to the horizontal orientation of the magnetic field, the effect of Hall conductivity, and the self-consistent conductivity decrease. The horizontal dimension of these fields in eastward direction is 300 to 400 km, in agreement with the configurations of the related electric currents.

These currents are reoriented in the lower ionosphere from predominantly vertical to actually horizontal due to the magnetic field orientation and to the effect of Hall conductivity.

The horizontal scale of Quasi-static electric fields and currents is hundreds of kilometers – much larger than in the case of high and middle latitudes.

The electric fields at altitudes above 90 km generated by thunderstorms are sensitive to the solar activity, since the con- ductivity there increases during solar maximum, with respect to its minimum.

During solar minimum, of the vertical dimension of sprites increases by up to 1.5 km than those during solar maximum.

Reduction of cloud conductivity by a factor of 5–10 leads to larger vertical dimension of sprites due to descending of the sprite lower boundary by up to 5km related to the case of unmodified cloud conductivity.

Tonev and Velinov

http://www.ss.ncu.edu.tw/~vcais6/

Workshop is organized by the International Association of Geomagnetism and Aeronomy (IAGA), the
International Commission on the Middle Atmosphere (ICMA) of the International Association of Meteorology and Atmospheric Science (IAMAS), and the Scientific Committee on Solar Terrestrial Physics (SCOSTEP).
The 6th Workshop is locally organized and hosted in Taiwan by
National Central University, National Cheng Kung University, and Academia Sinica.