Department of Physics and Astronomy

Radio and Space Plasma Physics Group

Dynamical coupling between the solar-terrestrial environment and the lower atmosphere

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INTRODUCTION

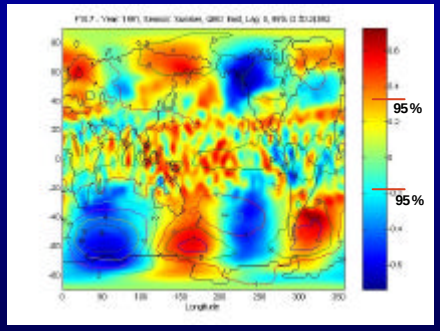
- The energy in the near-Earth plasma is small compared to the Total Solar Irradiance and is often neglected in climate studies.
- However, the tenuous thermosphere is highly sensitive to Solar-Terrestrial inputs.
- Recent advances in geophysical fluid dynamics and numerical modelling suggest that dynamical linkages with the lower atmosphere are possible.
- 'Space weather' plays an integral role in this process.

AN HISTORICAL ASIDE

- In *Phil. Trans.* (1801) Herschel noted high wheat prices when sunspots were few.
- As wheat production increases with temperature, higher solar activity was correlated to higher temperatures.
- This conclusion was opposite to earlier findings.
- Later observations in his notebook suggested he came to the view that colder weather was related to more sunspots!

Sir William Herschel (1738-1822)

A footnote on solar-climate correlations

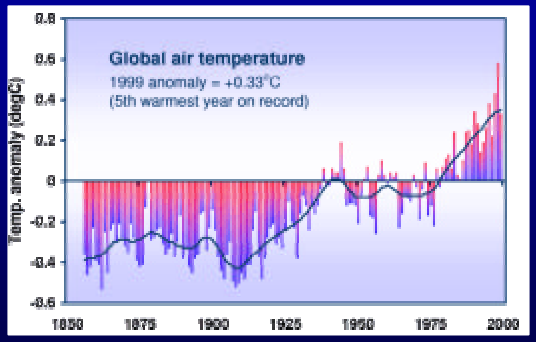


Plot courtesy of Chris Calvey

Data supplied by Wesley Ebisuzaki from NCEP

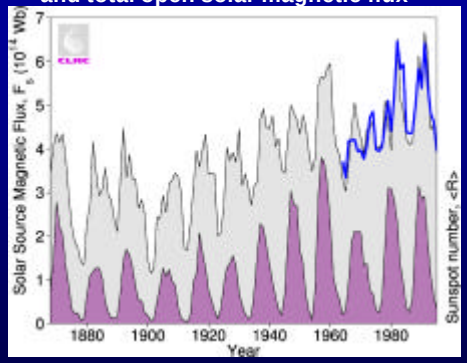
- In Southern Hemisphere, solar correlation is spatially coincident with meteorological anomalies.

Land surface anomalies 1860 - present



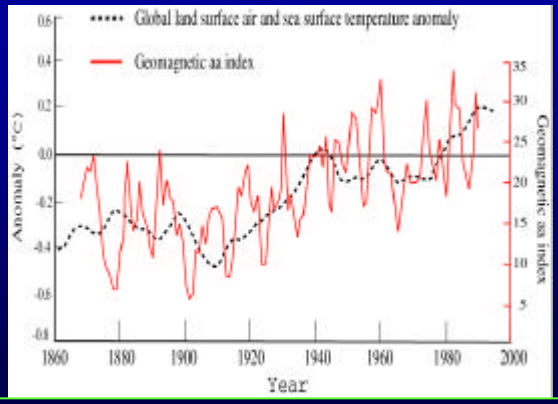
(IPCC 2001)

Secular trend in sunspot number, geomagnetic activity and total open solar magnetic flux

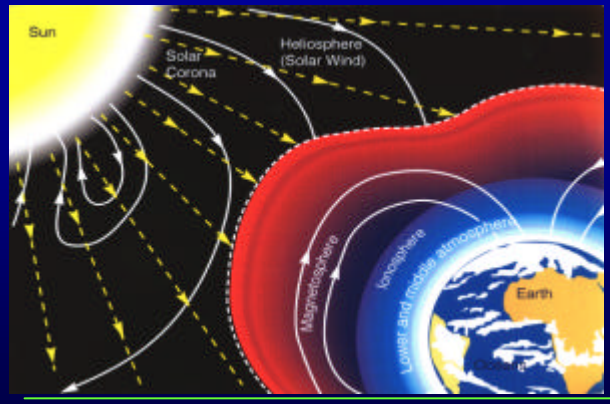


Lockwood, Stamper and Wild (1999)

Space weather influences on climate (or *vice versa*)?

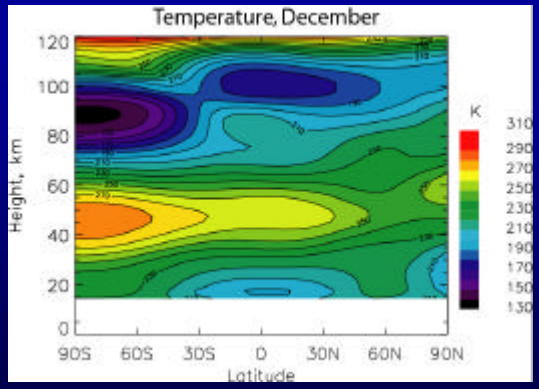


Solar-terrestrial 'road map'

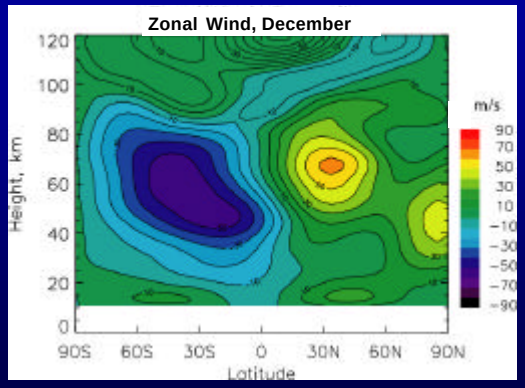


The residual circulation

Proposed by Brewer (1949) and Dobson (1956) to account for the transport of all long lived chemicals



European Space Weather Week 29th November, 2004
ESTEC, The Netherlands
University of Leicester



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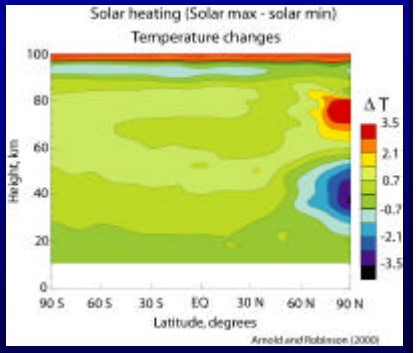
Dynamical Coupling with the thermosphere

- Largest forcing above 70 km
- Winter vortex is unstable
- Planetary waves propagate freely
- Feedback between radiation, dynamics and chemistry



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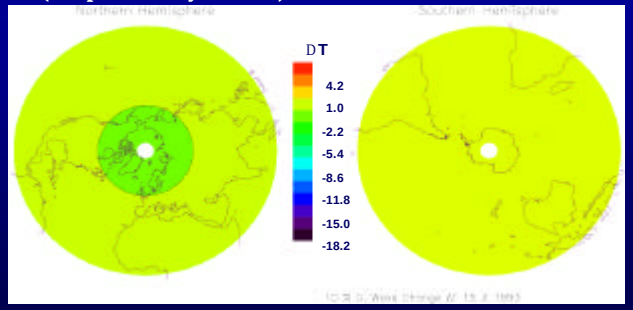
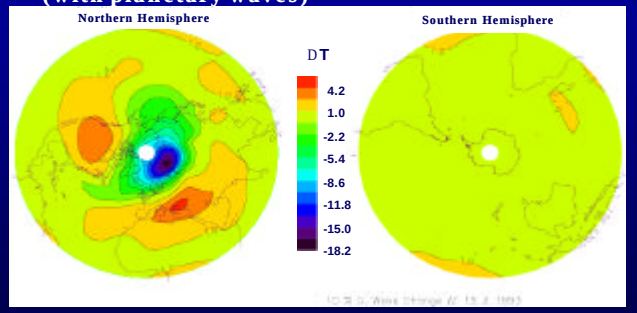
Gravity wave driving of the residual circulation (no planetary waves)



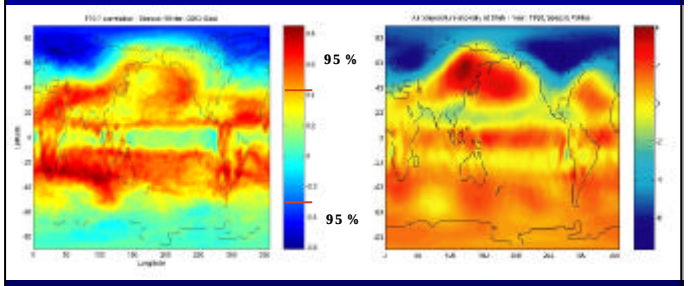
Arnold and Robinson (2003)

Gravity wave driving of the residual circulation (with planetary waves)



Arnold and Robinson (2003)

Labitzke and van Loon revisited

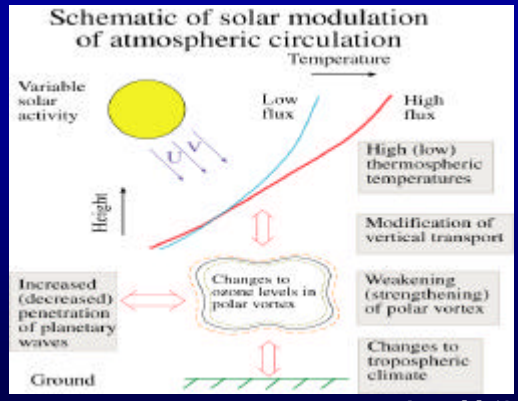


Correlation of monthly winter F10.7 with temperature at 25 km for 40 year set. NCEP database. QBO East years

Temperature anomaly 1980

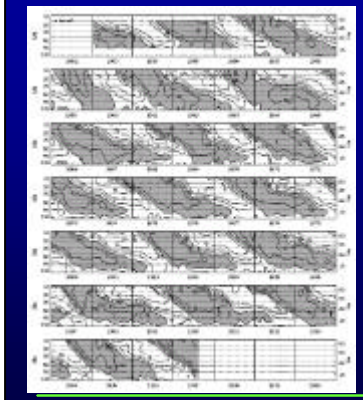
Plots courtesy of Chris Calvey

Schematic of solar modulation of atmospheric circulation



Arnold (2003)

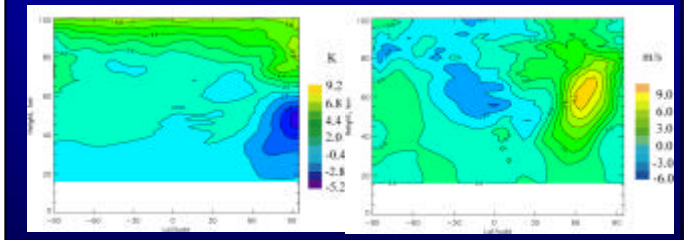
SOLAR FORCING OF THE QBO



- Small-scale waves such as gravity waves drive QBO (e.g. Mayr et al 1997).
- Period and amplitude observed to vary with solar cycle (Salby and Callaghan 2000).
- Phenomenon modelled successfully (Mayr et al. 2003).

Data from Naujokat (2000)

30-day climate average perturbation in January using Steve 3-D (self-consistent gravity waves)

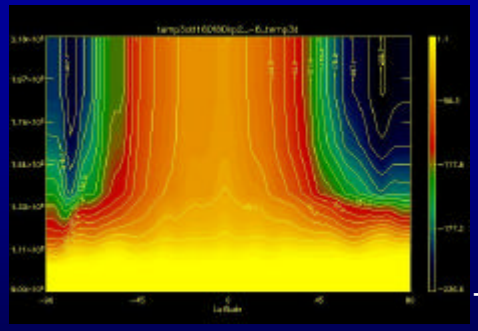


Change in temperature

Change in zonal wind

(England et al. 2004)

Differential heating between Kp 2 and Kp 6-



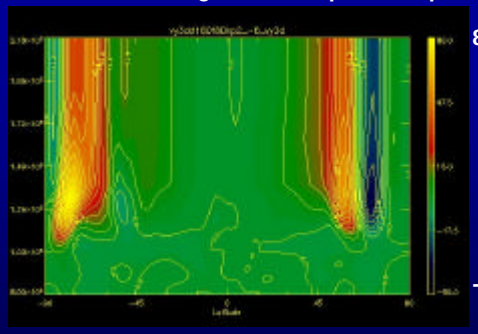
O K

-240 K

Temperature

(Courtesy Harris and Lyons)

Differential heating between Kp 2 and Kp 6-

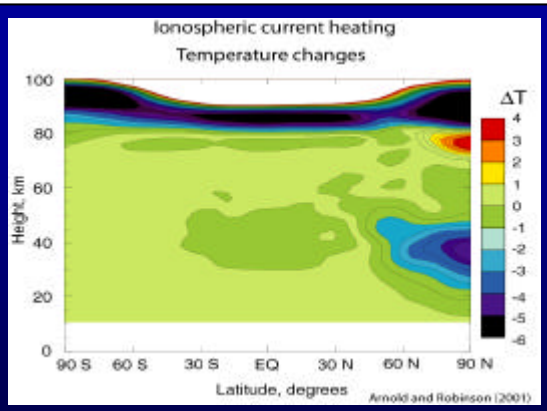


80 m/s

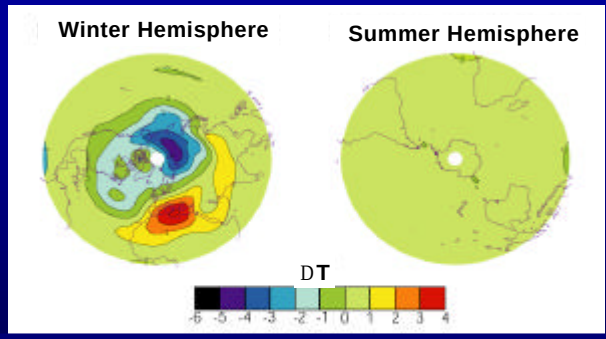
-50 m/s

Zonal winds

(Courtesy Harris and Lyons)



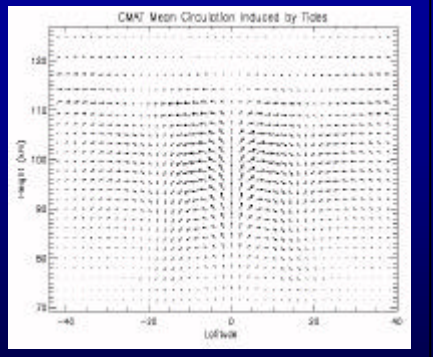
Note: daily varying Ap doubled forcing *cf.* mean Ap



Geomagnetically induced temperature perturbations at ~ 40 km

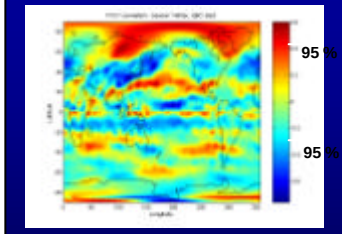
DON'T FORGET THE TIDES!

- Tides modulate the MLTI region.
- A new model that includes them is being created at UCL (CMAT2).
- The semi-diurnal tide has a strong solar component due to ozone heating.

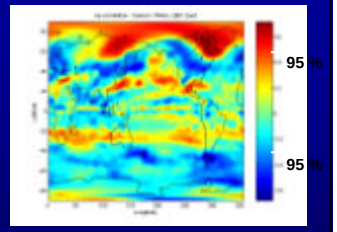


Harris et al. (2002)

Solar modification of the stratosphere



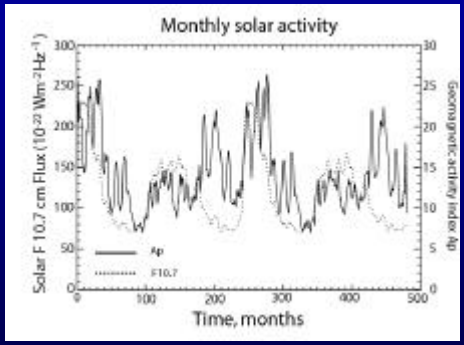
East phase (F10.7)



East phase (Ap)

Correlation between solar activity and potential vorticitiy at ~25 km sorted by phase of QBO using the 40 year NCEP data base. Analysis courtesy of Chris Calvey.

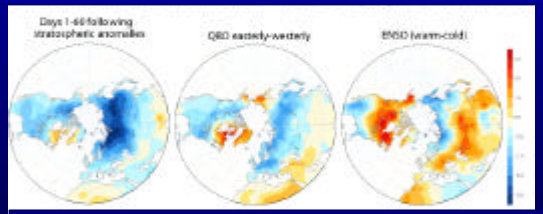
JUST CHECKING



Solar F10.7 and Ap are not as closely related as you might think!

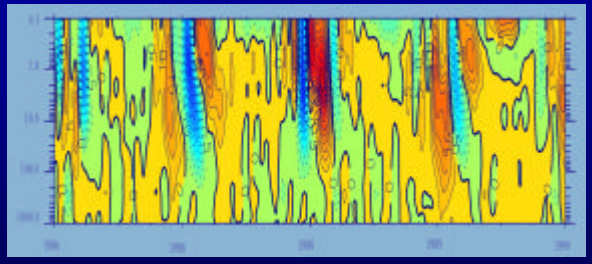
Stratosphere – troposphere coupling I

What is the impact on climate?



Temperature anomalies at the surface due to stratospheric processes (Thompson *et al*. 2002)

Stratosphere-troposphere II



ERA40 data of zonally averaged zonal wind anomalies at 60° N. The vertical axis is pressure in hPa. the horizontal axis is time (Image provided by Bo Christiansen, DMI).

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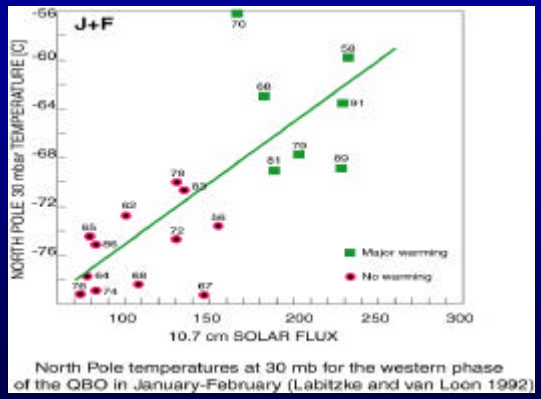
SUMMARY

- **The upper atmosphere plays a much greater role in the global circulation than previously believed.**
- **Waves are a key ingredient of this process.**
- **'Space weather' enhances the coupling by at least a factor of two.**
- **Climate models may well need to extend their upper boundaries into space to account for long-period oscillations such as the QBO.**



North Pole temperatures at 30 mb for the western phase of the QBO in January-February (Labitzke and van Loon 1992)