The role of the stratosphere for decadal climate prediction

– STRATO –

Ulrike Langematz, Anne Kubin, Janna Abalichin
Institut für Meteorologie, Freie Universität Berlin (FUB)

Martin Dameris, Duy Sinh Cai
Deutsches Zentrum für Luft- und Raumfahrt (DLR),
Institut für Physik der Atmosphäre, Oberpfaffenhofen

Katja Matthes
Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR)

Goals and Tasks

- **Importance of the stratosphere** for mid-term predictions of climate change:
  - Quantification of the influence of stratospheric **solar forcing** on decadal climate variability.
  - Quantification of the role of **stratospheric dynamical variability** for decadal climate prediction.
  - Response of the **atmosphere-ocean system** to stratospheric decadal forcing.
- **Quantitative statements for improvements** of the MiKlip numerical prediction model for mid-term climate change due to the consideration of stratospheric processes.

Progress in STRATO (Feb. 2014)

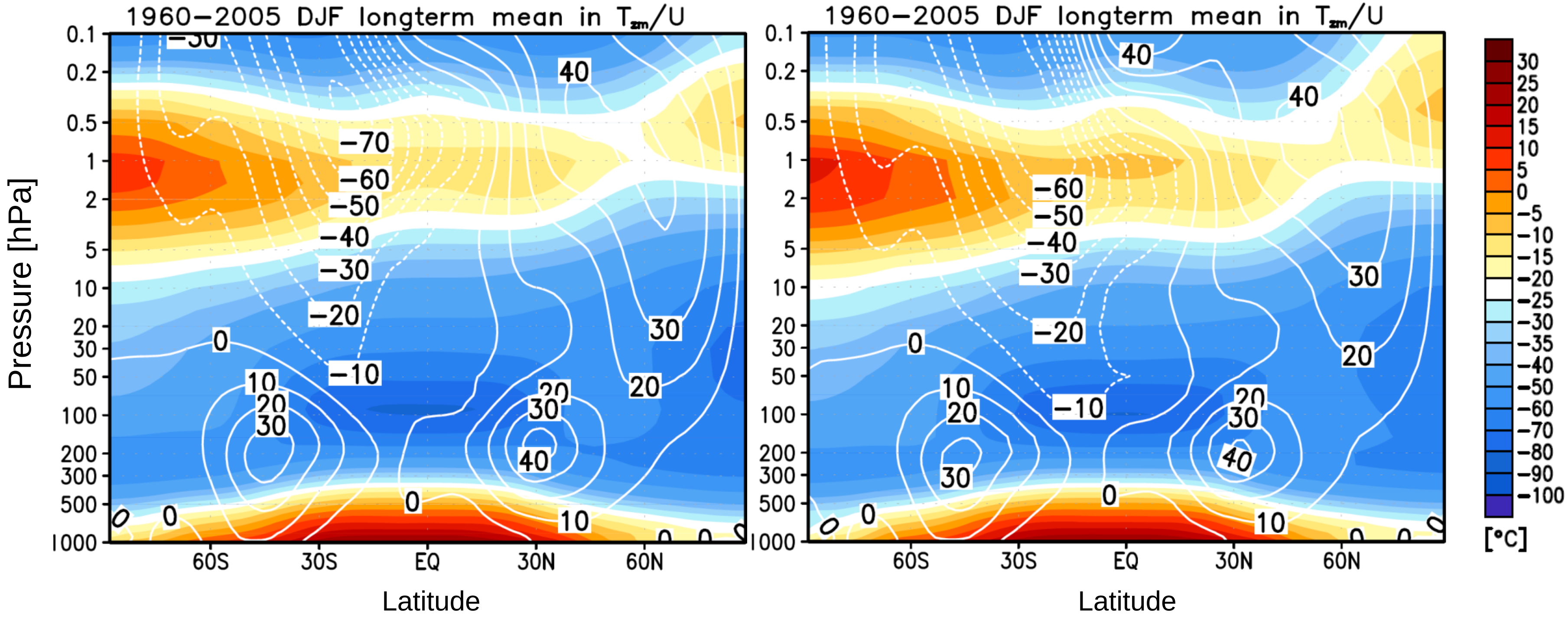
WP / Milestone	Progress	Comment
EMAC reference simulations	– RCP 4.5 and 6.0 scenarios 1960-2100 completed	
EMAC-O simulations 1960-2070	– Three 160ys time slices AOGCM runs (1860; 2x1960) completed	– Transfer of AOCCM to new HPCF computer system – Tests ongoing
EMAC-O simulations 1960-2070 with modulated solar cycle amplitudes	– Preparation of solar input data completed – 50 ys simulated	– Will be started after successful transfer of AOCCM to new computer
Analysis of solar decadal signal	– Ongoing	– Will be completed by A. Kubin (after return from maternity leave in Feb. 2014)
Analysis of stratospheric dynamical variability	– Ongoing	
Analysis of role of atmo-sphere-ocean interaction	– Ongoing	

Comparison with MiKlip baseline prediction system

years 1960 – 2005

EMAC
fixed SST, inter. chem.

MPI-ESM LR historical
coupled ocean, prescribed ozone



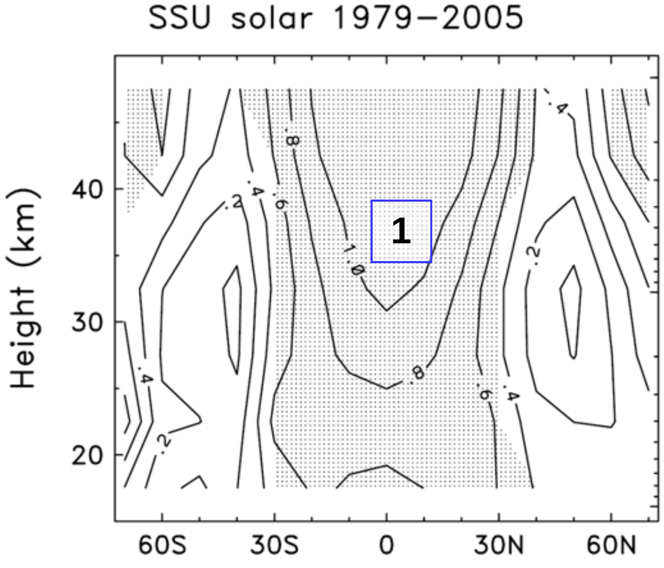
- Good agreement between models and ERA-Interim (not shown)
  - ➔ colder and stronger NH polar vortex in EMAC;
  - ➔ warmer summer stratopause in MPI-ESM;
  - ➔ differences due to radiation schemes, interactive chemistry, or atmosphere-ocean coupling, model resolution?

WP1: Solar signal in EMAC and MPI-ESM I

- Kodera and Kuroda (2002): Solar signal in stratosphere → downward propagation

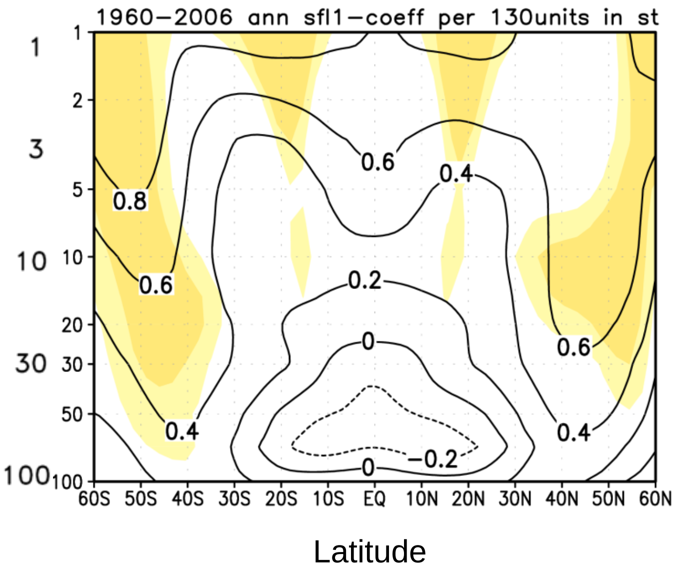
Solar temperature signal (K/130 F10.7 units)

SSU (observations)

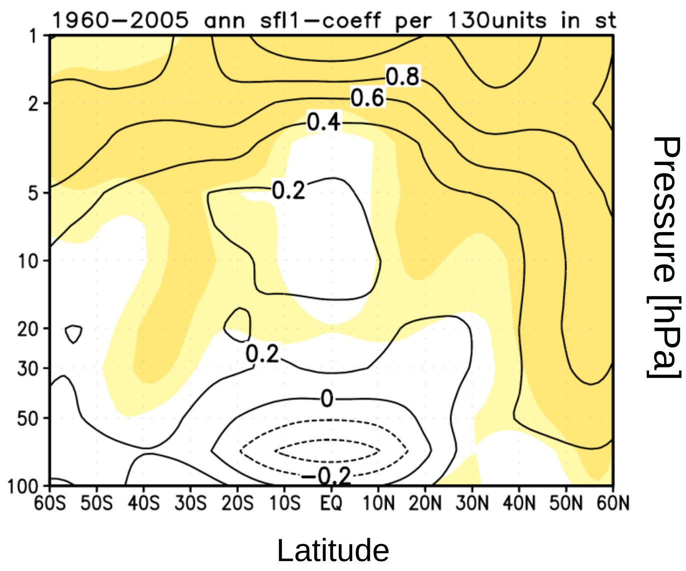


Randel et. al., 2009

EMAC



MPI-ESM LR historical

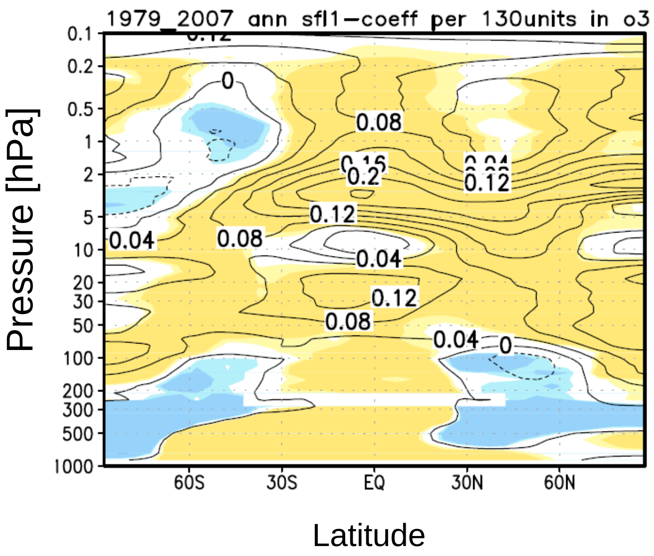


- Significant solar signal in global upper and mid-latitude lower stratosphere in EMAC.
- Assessment from observations difficult.
- **Solar signal in MiKlip baseline prediction system improved compared to ECHAM5.**

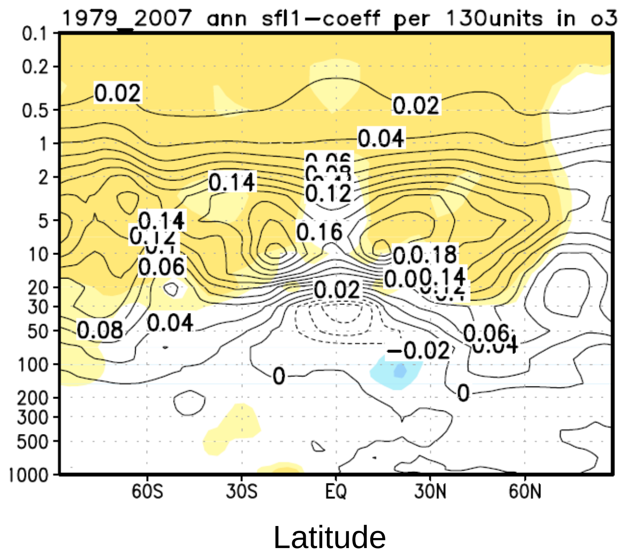
WP1: Solar signal in EMAC and MPI-ESM II

Solar ozone signal (ppm/130 F10.7 units)

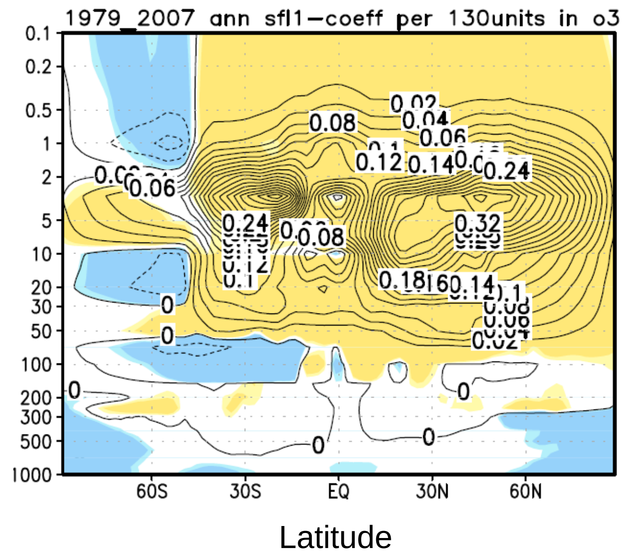
NIWA ozone database



EMAC



MPI-ESM LR historical

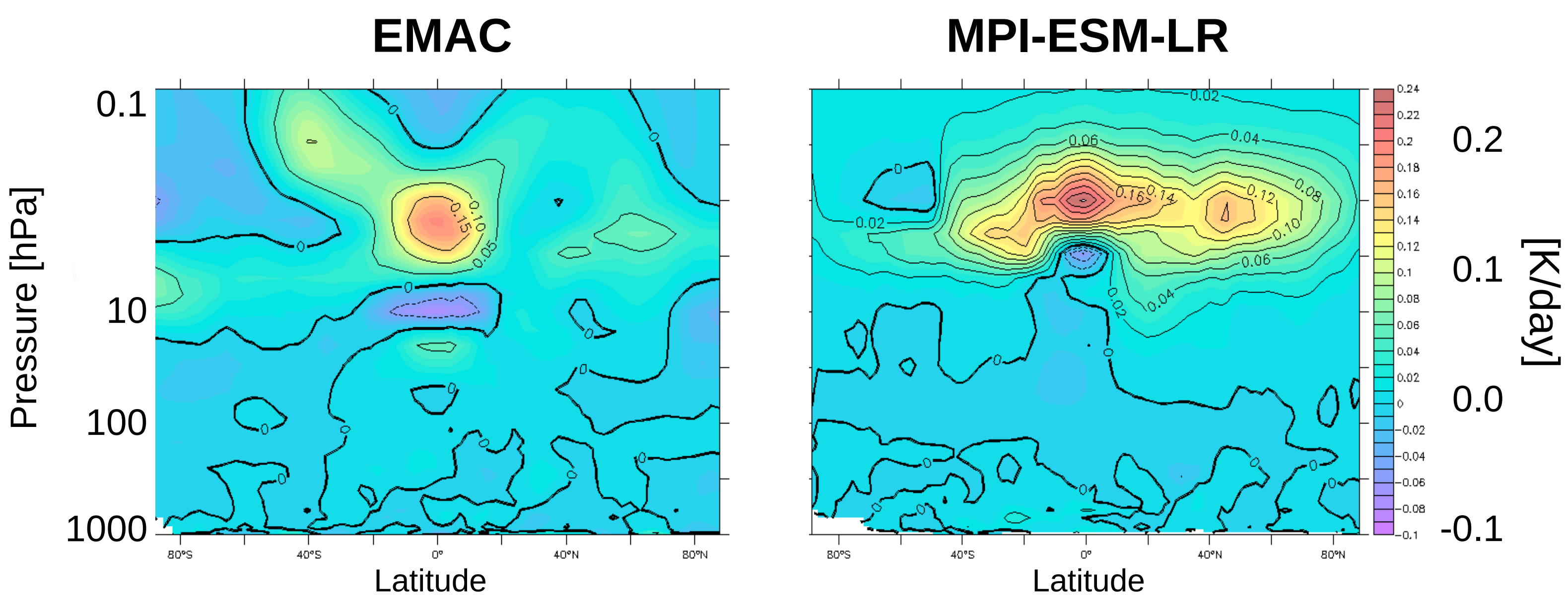


- Significant solar ozone signal in middle and upper stratosphere in observations and EMAC.
- **Prescribed solar ozone signal in MiKlip baseline prediction system is overestimated.**

WP1: Solar signal in EMAC and MPI-ESM III

Solar signal in annual mean short-wave heating rates [K/day]

Difference between solar maximum (1968-1969) and solar minimum (1964-1966)



- Overestimated ozone signal in MiKlip baseline prediction system leads to enhanced short wave heating and temperature response.

➡ Is the improved solar signal in MiKlip baseline prediction system due to an improved SW radiation code or the result of an unrealistic ozone signal? (ongoing work)

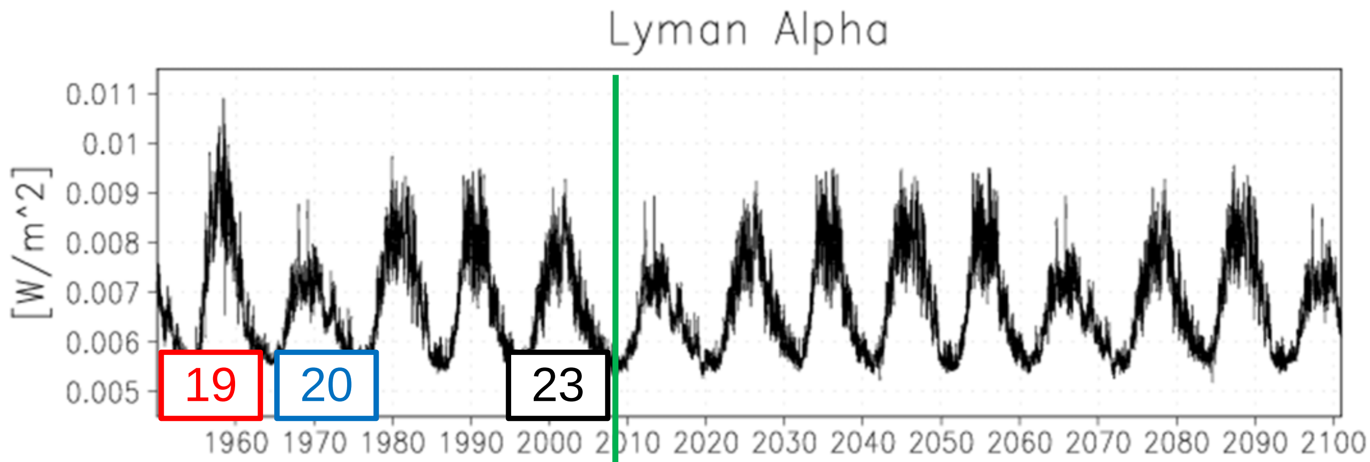
WP1: Range of solar signal in EMAC

Construction of solar cycles with strengthened and weakened amplitude

Ratio of solar cycles around their maxima gives factors for

Strengthening: SC19/SC23
Weakening: SC20/SC23

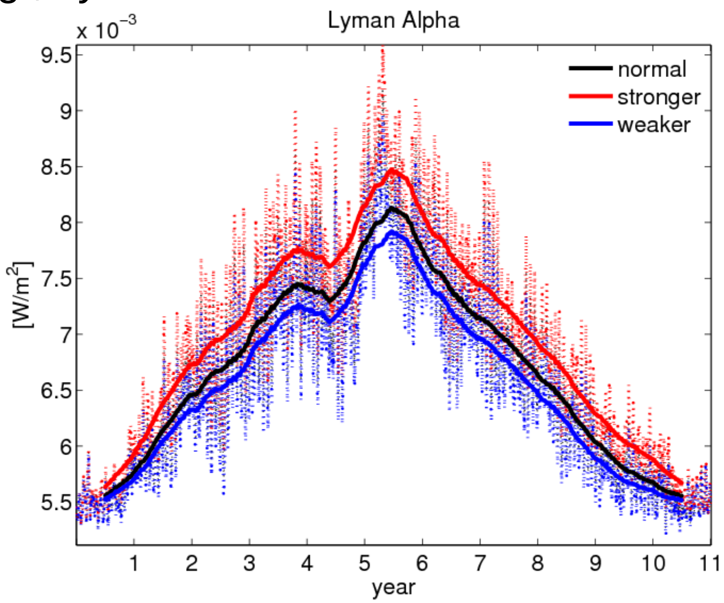
of the solar cycle amplitude.



Observations

Irregular repetition of solar cycles 20-23
(guideline of CCMI)

e.g., cycle 23

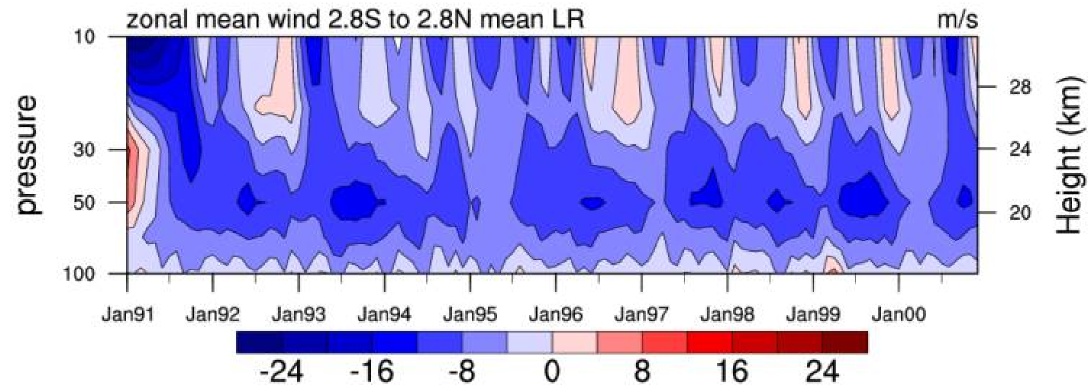


- SC multiplied by strengthening or weakening factor around its maximum ⇨ Solar maxima enhanced.
- Linear interpolation of multiplication factor towards minimum of solar cycle ⇨ Solar minima unchanged.

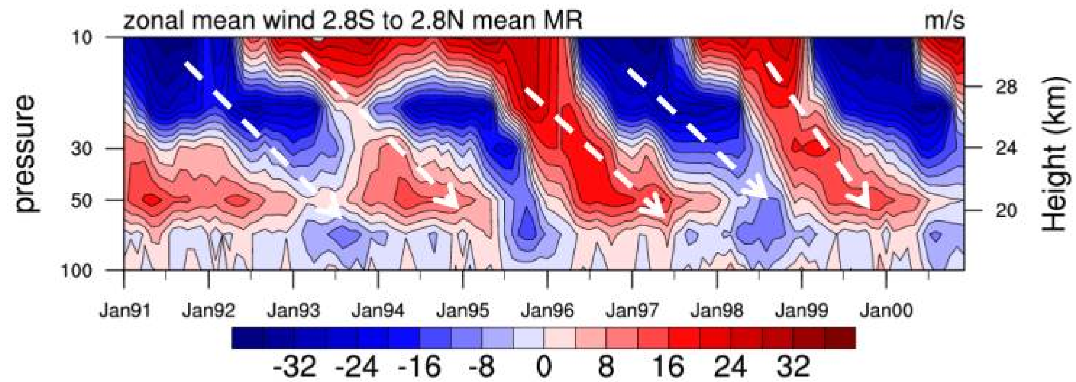
Simulations with modified solar cycles will be started as soon as transfer of EMAC-O to new computer is completed.

WP 2: Stratospheric dynamics: Internal variability and decadal climate prediction

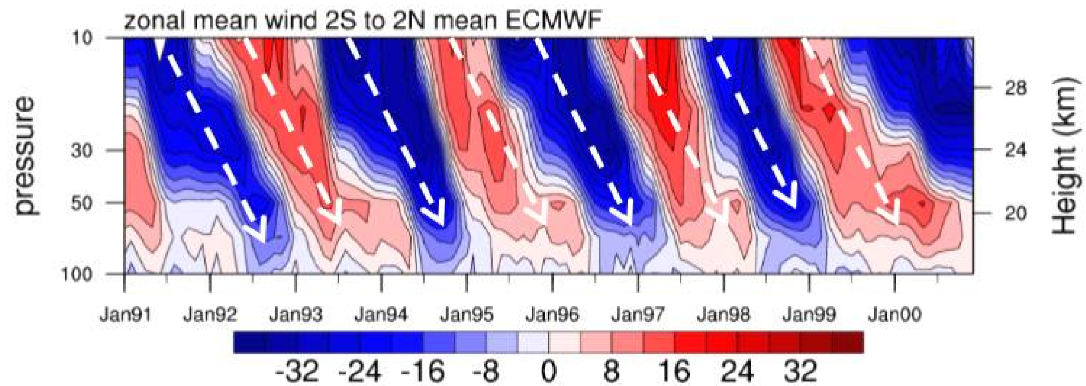
b1-LR



b1-MR



ERAI



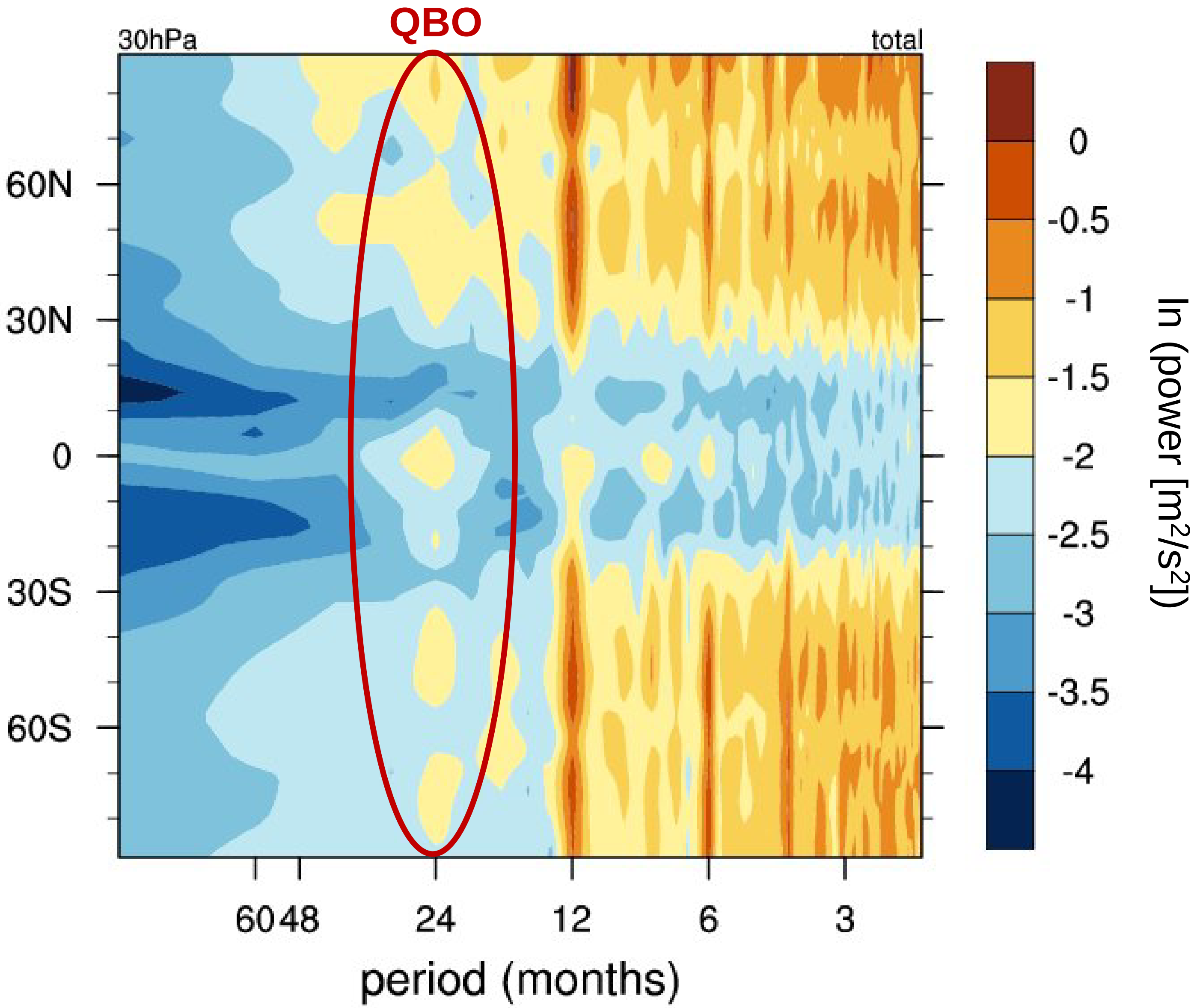
The QBO is the leading mode in the (tropical) stratosphere!

WP 2: Stratospheric dynamics: Internal variability and decadal climate prediction

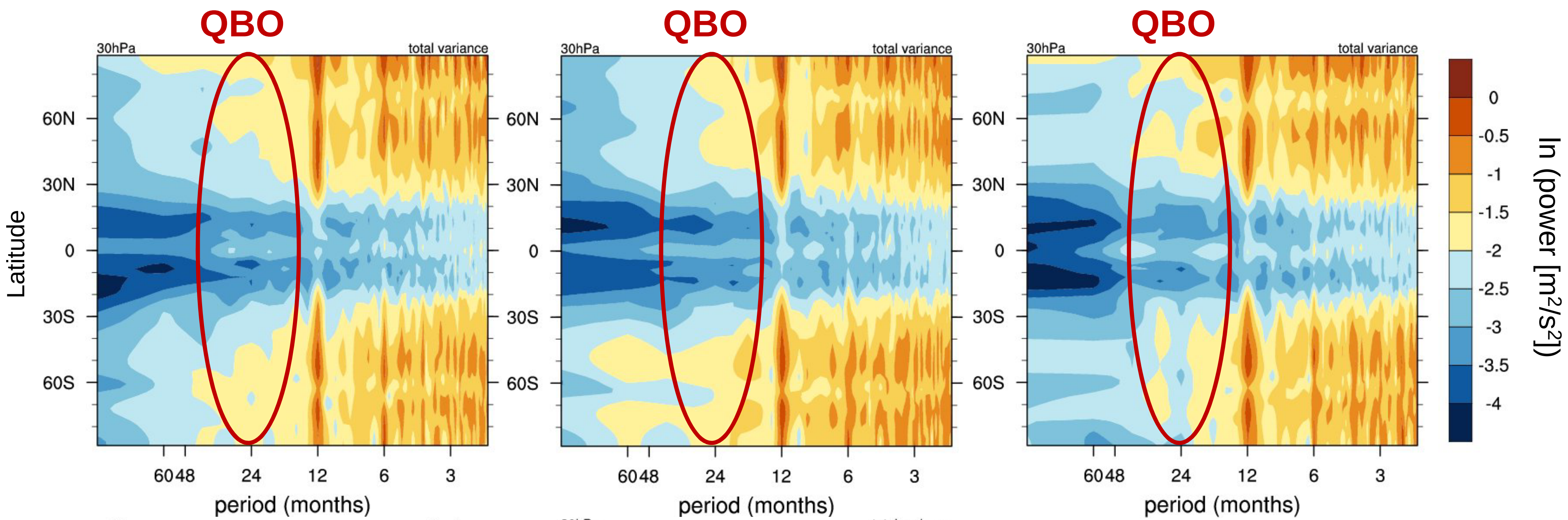
ERAI

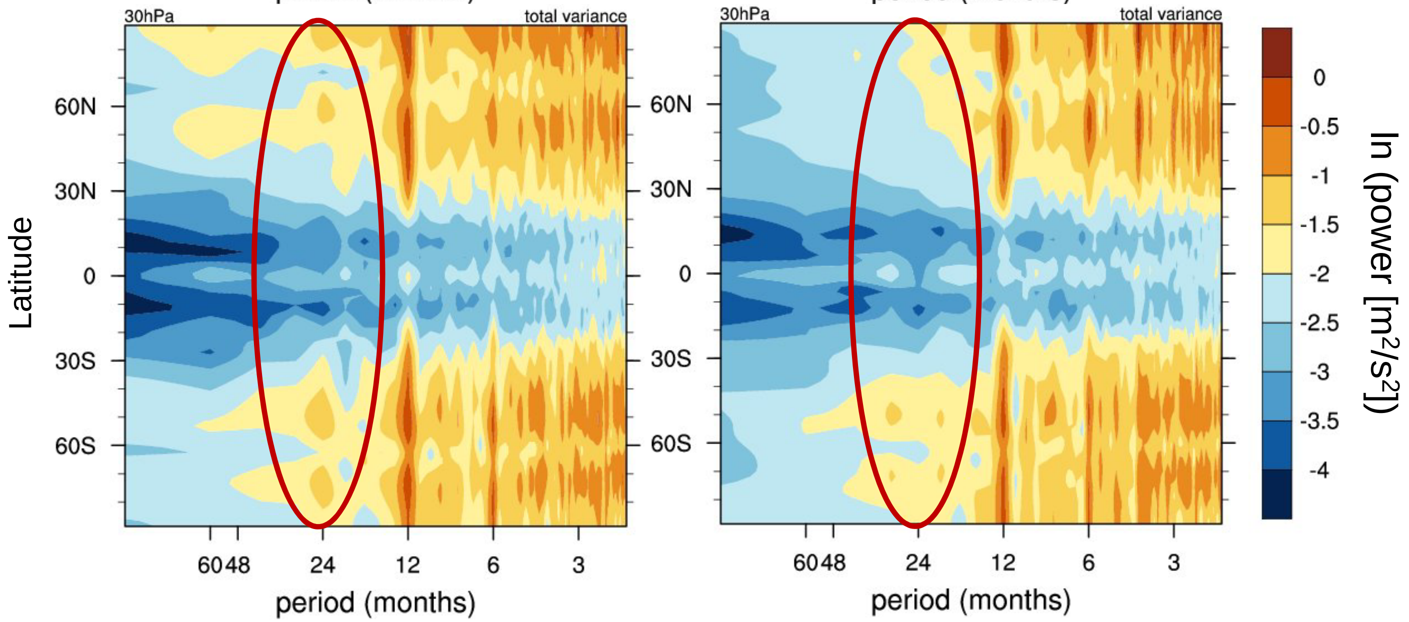
power of zonal mean zonal wind sum over all wave lengths

Stratosphere (30 hPa)



WP 2: Stratospheric dynamics: Internal variability and decadal climate prediction





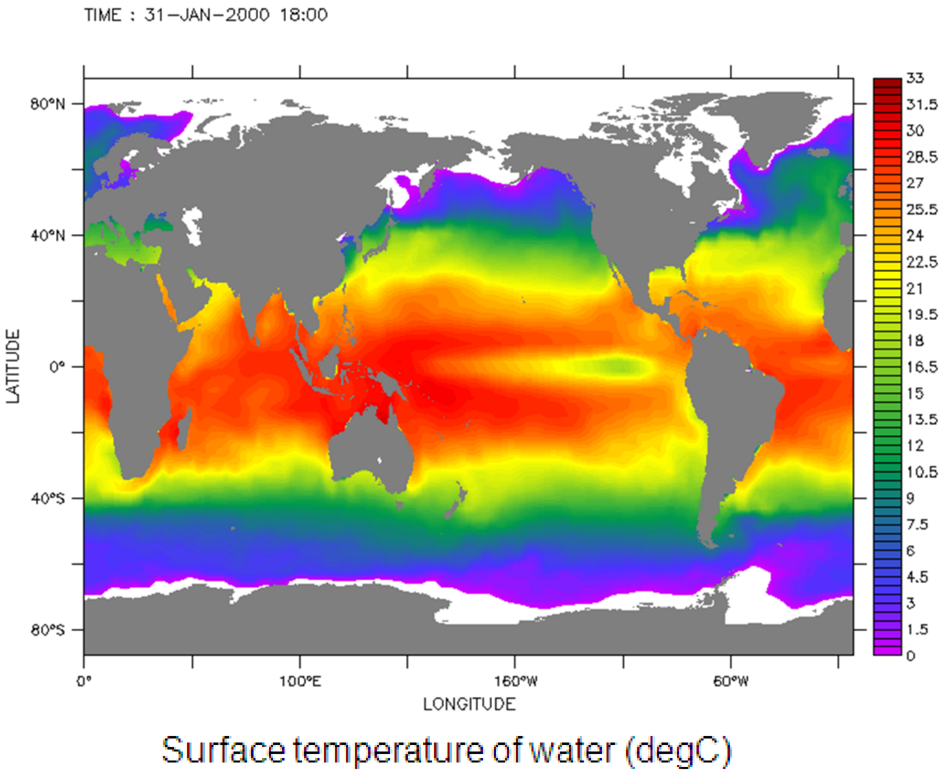
Examples (120)

Ensemble spread > 12 months

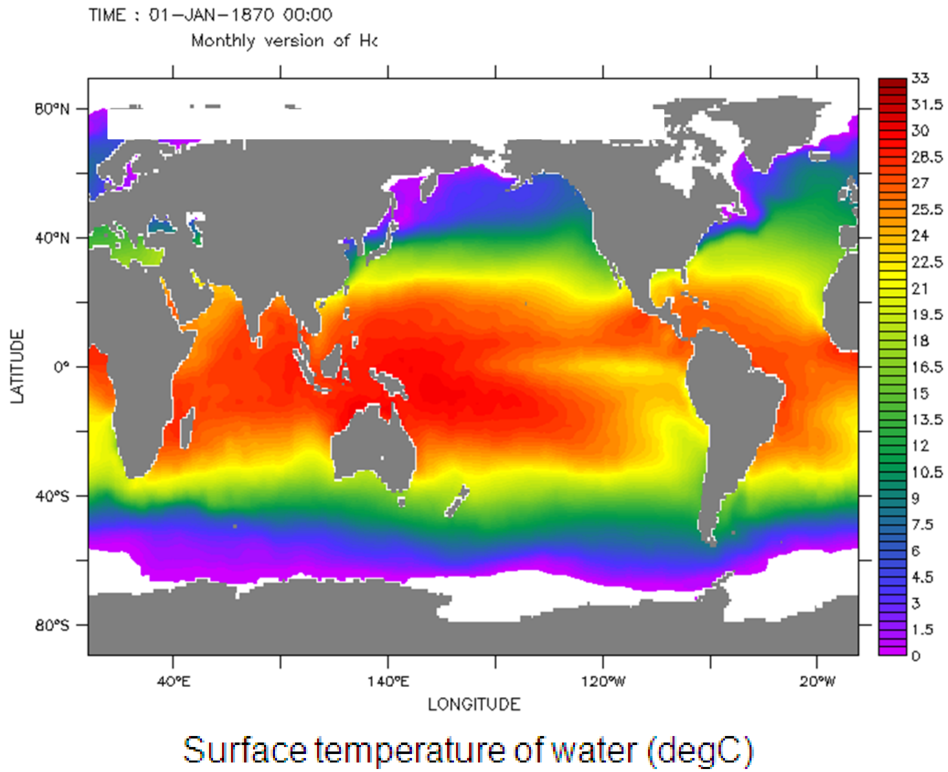
Freie Universität Berlin · DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft · IFM-GEOMAR

WP 3: Response of the atmosphere-ocean system to stratospheric decadal forcing

Validation of EMAC-O 1860 time slice simulation with HadISSTs for 1871-1899



EMAC/MPIOM 1860 conditions



HadISST: time series 1871-1899

Freie Universität Berlin

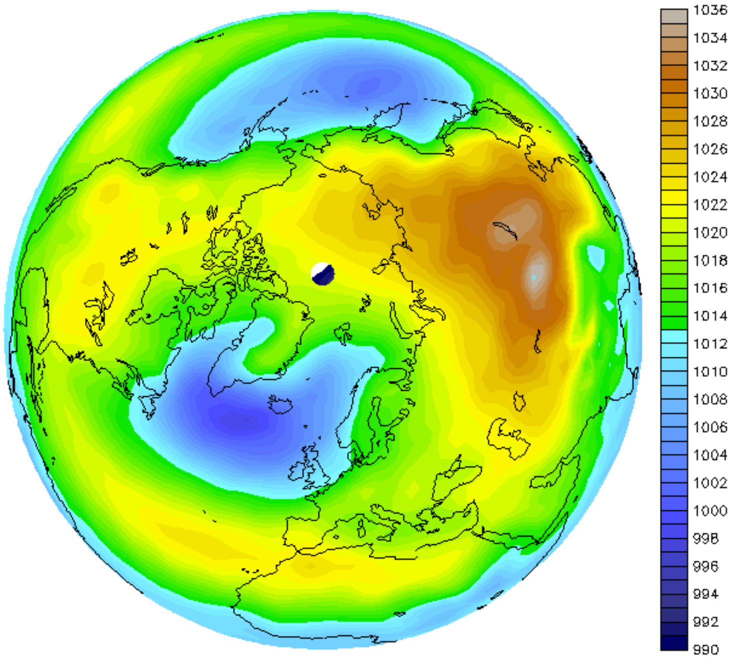
Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

IFM-GEOMAR

WP 3: Response of the atmosphere-ocean system to stratospheric decadal forcing

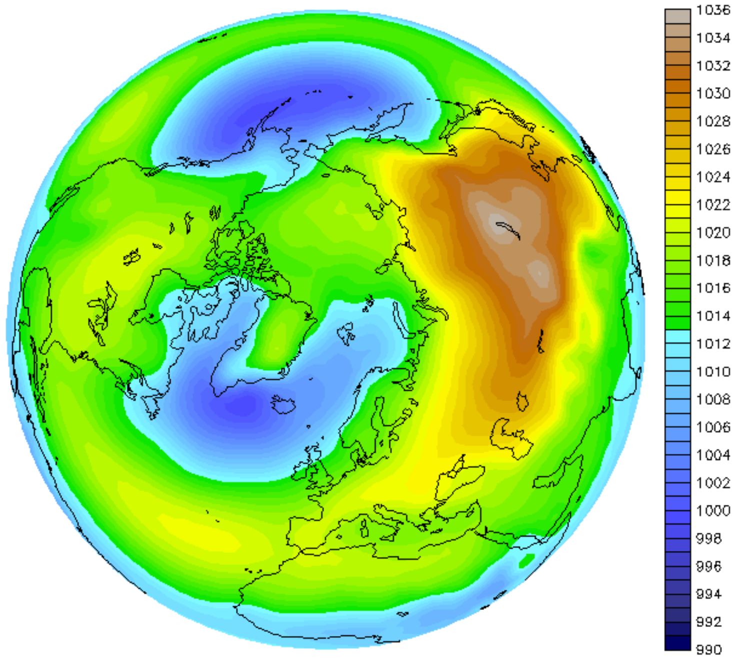
Comparison of EMAC-O-1860Ctl with NOAA-20th_C-Reanalysis

Mean sea level pressure



[hPa]

EMAC-O-1860Ctl:
1860 long term mean DJF



[hPa]

NOAA-20th_C:
1871-1899 long term mean DJF

Summary

- Decadal solar signal improved in MiKlip baseline prediction system. Possible reasons (radiation code, ozone) still need to be verified.
- Improved representation of stratospheric variability in tropics and polar regions important for variability patterns in lower troposphere.
- Consistent representation of lower boundary conditions (interactive ocean model) important for interpretation of total solar impact on tropospheric dynamics.

Collaborations within MiKlip-B

FastO3	**Fast stratospheric ozone chemistry for global climate models** Dr. Markus Rex, AWI Potsdam, Ulrike Langematz, FUB Application and evaluation of SWIFT in EMAC and EMAC-O (i.e. a model of the ECHAM family and in a model with a full chemistry scheme) , SWIFT will be coupled in the FAST-O3 project as sub-model to EMAC and EMAC-O. STRATO simulations will be used as reference for the evaluation of EMAC-SWIFT. Model output from these simulations will be provided to FAST-O3.