Project 519: **NATHAN**

GEOMAR

Quantification of Natural Climate Variability in the Atmosphere-Hydrosphere System with Data Constrained Simulations

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Introduction

A quantification of natural variability of the atmosphere-hydrosphere system is essential to reliably estimate the anthropogenic contribution to the recent global warming and to improve the accuracy of climate predictions. This project aims to separate and quantify the natural contribution to climate variability on seasonal to multi-decadal timescales by utilizing various types of geodetic monitoring data and complementary unconstrained and constrained numerical models of the atmosphere-hydrosphere system.

Tools

DART: The Data Assimilation Research Testbed

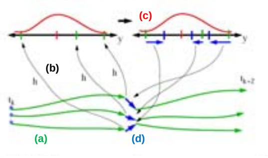


Figure by Jeff Anderson, NCAR.

DART is a community facility for data assimilation with the Ensemble Kalman Filter, developed and maintained by the Data Assimilation Research Section (DAReS) at the National Center for Atmospheric Research (NCAR) (Anderson et al., 2009).

DART takes an ensemble of model initial states and advances them forward in time **(a)**, then interpolates the ensemble to the observation grid **(b)**. After comparison to observations **(c)** optimal increments are computed for each ensemble member, and mapped back into changes in the model variables **(d)**.

NCAR's Community Earth System Model (CESM)

A coupled model system. (Gent et al, 2011)

NCAR's Whole Atmosphere Community Climate Model (WACCM)

A fully interactive chemistry-climate model from the Earth's surface through the thermosphere (145 km). (Garcia et al., 2007; Richter et al., 2010)

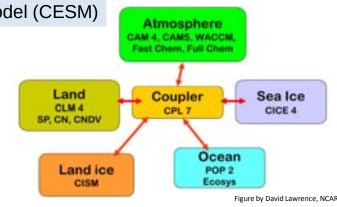
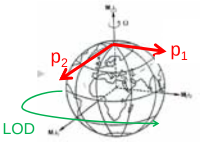


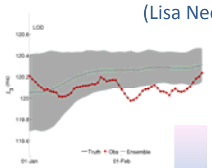
Figure by David Lawrence, NCAR.

Assimilation of Earth Rotation Data

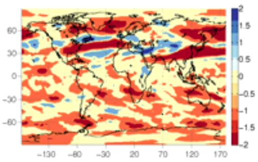
(Lisa Neef, PostDoc)



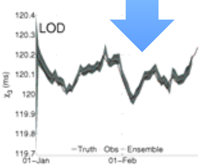
We observe 3 components of Earth rotation: two angles of polar motion (p_1 and p_2) and length-of-day (LOD) anomalies. These global parameters are related to the wind and pressure fields by the exchange of angular momentum between the atmosphere and the solid earth.



The LOD anomaly excited by atmospheric variations is computed from the axial atmosphere angular momentum. In an ensemble of 64 simulations, the LOD anomaly captures the annual cycle, but not shorter-timescale variations.



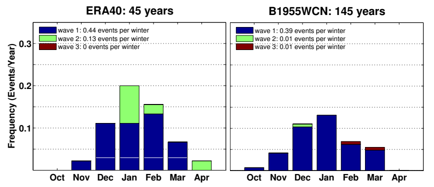
This figure shows the error reduction in the zonal wind field (m/s), relative to a case where no LOD observations are assimilated, averaged over 2 months. Improvements are seen primarily around the tropospheric subtropical jets.

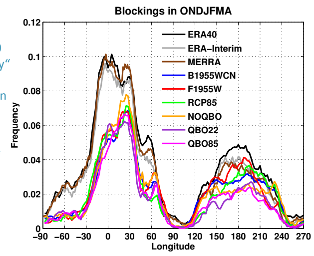


Assimilation of LOD anomalies forces all 64 ensemble members to take on the observed LOD anomaly (within the observation error), by changing the model's wind and surface pressure fields.

Dynamical Coupling between the Stratosphere and the Troposphere

(Felicitas Hansen, PhD student)





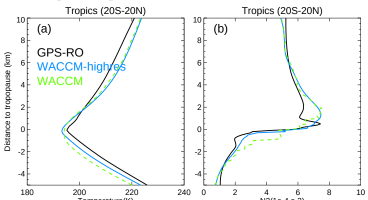
Top: Distribution of major SSWs for ERA40 (left) and „natural only" simulation (right), distinguishing between wave-1 to wave-3 preconditioning.

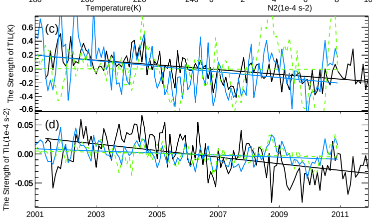
Bottom: Frequency of blocked days in ONDJFMA in model simulations and reanalysis data.

- „Natural only" simulation (145-year coupled simulation with CESM) shows lower than observed Stratospheric Sudden Warming (SSW) frequency
- In the model run, almost all SSWs are wave-1 SSWs
- Model run shows lower than observed blocking frequency, especially in the Atlantic
- Remarkable differences between the different forcing experiments → how is this related to the dynamical trop ↔ strat coupling?

Thermal Structure and Variability of the Upper Troposphere / Lower Stratosphere (UTLS)

(Wuke Wang, PhD student)





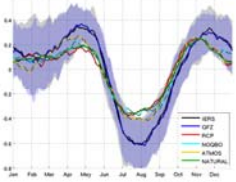
(a) Temperature and **(b)** buoyancy frequency (N2) profiles using the tropopause as a reference level, averaged for GPS-RO profiles and instantaneous output data from WACCM simulations for 2001-2010. De-seasonalized monthly mean anomalies of the strength of the TIL (STIL) in the tropics, **(c)** temperature, **(d)** N2.

- Sharp tropopause for temperature profile (a)
- Enhanced buoyancy frequency (N2) (b) for a tropopause-based average from GPS Radio Occulatation (GPS-RO) profiles and instantaneous output from WACCM
- The tropical Strength of Tropopause Inversion Layer (STIL) decreased about 0.4 K (for temperature) / 0.05 10-4 s-2 (for N2) in the past decade in GPS-RO data
- WACCM high resolution run (finer vertical resolution, about 300m in UTLS) captures the observations better than the standard WACCM (about 1km in UTLS).

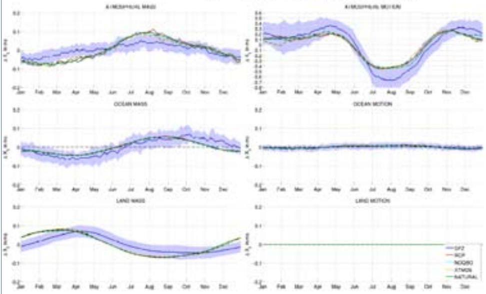
Natural and Anthropogenic Variations in the Earth Rotation

(Christof Petrick, PhD student)

All figures: Annual cycle of the change of length of day in milliseconds from observations (IERS), reanalysis data (GFZ) and four CESM experiments (RCP, NOQBO, ATMOS, NATURAL). Shaded regions show one standard deviation of the observations and the reanalysis data.



- Major features are represented in the model, slight deviations only in ATMOS, which is entirely due to the absence of the ocean component
- Neither QBO, nor anthropogenic factors appear to have major impact



- Mass component in the CESM atmosphere catches the correct phase, but exaggerates the mass excitation and falls short on the motion term compared to the excitation based on ERA Interim data.
- The ocean component compares well with the OMCT based values, while the land features a clearly different phase, which is most likely due to diff. precipitation patterns.

Outlook

- Expansion of DART-CAM to DART-CESM
- Assimilation of GRACE Gravity data to investigate whether GRACE data can constrain atmospheric models, as well as enable the application of these observations as a constraint on other components of the CESM
- Assimilation of GPS-RO Refractivities which can be used to correct model temperature profiles (Anderson et al. 2009) , and are a valuable source of information about the UTLS region
- Analysis of the influence of external forcings on stratosphere-troposphere coupling

Publications

Martin-Puertas, C., **K. Matthes**, A. Brauer, R. Muscheler, **F. Hansen**, **C. Petrick**, A. Aldahan, G.Possnert, and B. van Geel, 2012: Regional Atmospheric Circulation shifts induced by a Grand Solar Minimum, Nature Geoscience 5, 397-401 doi:10.1038/ngeo1460.

Neef, L. J. and **K. Matthes** (2012): Comparison of Earth rotation excitation in data-constrained and unconstrained atmosphere models. Journal of Geophysical Research, 117(D2), D02107.

Petrick, C., **K. Matthes**, H. Dobslaw, and M. Thomas, 2012: Response of a General Ocean Circulation Model to Different Natural Forcings from a Stratosphere-resolving Chemistry-Climate Model, J. Geophys. Res., doi:10.1029/2011JD017390.

Hansen, F. and **K. Matthes**: Sensitivity of Stratospheric Dynamics and Chemistry to QBO Nudging Width in the Chemistry-Climate Model WACCM; to be submitted to JGR.

Neef, L. et al.: Stratospheric Sudden Warmings Affect Earth Rotation Variations; to be submitted to GRL.

Wang, W., **K. Matthes** and T. Schmidt: The recent variability of the tropopause inversion layer estimated from GPS-RO data and WACCM simulations; to be submitted to GRL.

DKRZ User Workshop
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Acknowledgements

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