Project: **169**
Project title: **Gekoppeltes Ozean-Atmosphären-Stratosphärenmodell**
Principal investigator: **Ingo Kirchner**
Report period: **2017-01-01 to 2017-12-31**

Schwerpunkte des Projekts

Ein Schwerpunkt des Projekts waren Entwicklungsarbeiten am gekoppelten Erdsystemmodell in Kooperation zwischen dem Institut für Ozeanographie der Russischen Akademie der Wissenschaften "P.P.Shirshov" in Moskau und dem Institut für Meteorologie der Freien Universität Berlin. Ziel der Sensitivitätsexperimente war die Untersuchung eines neuen Datenassimilationsschemas im Ozeanmodell. Ein weiterer Teil der Ressourcen wurde für Untersuchungen der Urbanisierung des Berliner Stadtgebietes verwendet. Hier kam das WRF Modell mit zusätzlicher Chemie und Aerosolen zum Einsatz. Beide Themen werden auch 2018 weitergeführt.

Experiments with Kalman filter assimilation (K. Belyaev, N. Tuchkova)

The main idea of modeling with MPI-ESM on DKRZ computers connecting with data assimilation (DA) methods in climate forecasting. The work are include set of numerical experiments with different strategy of assimilation the observed data. Several experiments with and without assimilation of sea level , temperature and salt are conducted and the results of those experiments are analyzed. In particular, it is shown that the ice concentration in Arctic zone of Russia fits better to observations then in control experiments i.e. without assimilation.
Original DA method based on the given variational minimum and variance minimum principle is derived. Initialization has been done from climate Atlas NCEP and spin up computations have been performed to establish the constant energy regime of currents in the ocean from 1850 until 2010 yr. The date 01.01.2010 yr has been selected as initial date for further DA experiments. DA method is based in the minimization of the following functional

$$L(K,\varphi) = KQK' + [(I - KH)\Lambda]\varphi, \qquad (1)$$

where: K is unknown and needed to be determined matrix of dimension $r \times n$, Q is the covariance matrix of model error (difference between model and observations taken in observational points) of dimension $\mathrm{n} \times \mathrm{n}$, which is supposed to be known, H is known matrix of dimension $n \times r$,which projects from phase-space of the model with dimension *r* into phase-space of observations with dimension *n*, *I* is identity matrix of dimension $r \times r$, Λ is the model operator with dimension $r \times 1$, φ is an auxiliary vector of Lagrange multipliers with dimension $1 \times r$. Apostrophe above means the transpose of vector or matrix. The minimum of functional (1) makes a transparent physical sense, namely, it provides a minimum of variance of diffusion given by matrix KQK' under condition that known or defined from observations drift vector $(I - KH)\Lambda$ and leads to eqs (2), where C is given or set up in grid points observational vector for observational variables. For non-observed variables vector C is constrained as an average in time for previously computed values

$$KQ - \frac{1}{2}\varphi'(H\Lambda)' = 0, \quad (I - KH)\Lambda = C. \qquad (2)$$

System (1) has an unique solution if and only if matrix Q is invertible, which means that all observations are linearly independent. Other worlds, it is impossible to substitute one of observation by linear combinations of others. The solution is obtained as

$$K = \frac{(C - \Lambda)(H\Lambda)'Q^{-1}}{(H\Lambda)'Q^{-1}H\Lambda}. \qquad (3)$$

Several numerical experiments have been carried out with DA where model result has been corrected by formulae (1) and (3), and observed data of sea level were taken from AVISO (http://www.aviso.altimetry.fr). Vector C for sea level has been set up as interpolation onto model grid points of observed sea level minus

model sea level on previous time-step. For other model variables the values were taken as time average of corresponding variables minus their model value on previous time step.
The experiments have been executed as follows: starting from modeled 2010 г, the model has been integrated without assimilation (free run) until 2012, then during 3 years (2012-2014) the model has been integrated with the correction each 3 month with respect to formulae (1)-(3),then again it has been integrated free until 2016. Observations were taken on the end of each 3-month period and previously have been smoothed with 11-point filter along track. In parallel the control experiment, i.e. integration without correction has been performed on entire period 2010-2016 yr.

Part of numerical experiments for sea level observation were in 2016 for MPI-ESM with low resolution and the experiments for temperature and salinity observation were in 2017 for MPI-ESM with high resolution.

Experiments with WRF for urban region of Berlin (Huidong Li)

I installed WRF/CHEM in DKRZ, and run the model for the simulation of urban climate and atmospheric aerosols. I did mainly three works:

1. I studied the impact of land cover data on the simulation of urban heat island using WRF coupled with Noah LSM.
2. I developed a new method for the quantification of urban heat island and urban dry island using the modeling results of WRF/UCM. I am preparing a manuscript for this work.
3. I evaluated WRF/CHEM in simulating aerosols and its radiative effect on urban heat island for Berlin. That is the key section of my PhD thesis.

References

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