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N. Yu. Denisova, K. G. Gribanov, M. Werner, N. S. Malygina, "Modeling of isotope composition of precipitation in the foothills of the Altai with two atmospheric circulation models ECHAM," Proc. SPIE 11208, 25th International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics, 112087R (18 December 2019); doi: 10.1117/12.2540767

SPIE.

Event: XXV International Symposium, Atmospheric and Ocean Optics, Atmospheric Physics, 2019, Novosibirsk, Russian Federation

Modeling of isotope composition of precipitation in the foothills of the Altai with two atmospheric circulation models ECHAM

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ABSTRACT

In order to validate the isotopic models of the general circulation of the atmosphere ECHAM5-wiso and ECHAM6-wiso, modeling in nudging mode was made. These model data were compared with experimental data on the isotope composition (δHDO and $\delta H_2{}^{18}O$) of precipitation for stations in the foothills of Altai mountains (52.596° N, 85.25° E) created and maintained by the Institute for Water and Environmental Problems SB RAS.

Keywords: atmospheric general circulation model, water isotopes, reanalysis

ECHAM is an atmospheric general circulation model, developed at the Max Planck Institute for Meteorology [1,2]. It forms the atmospheric component of the climate model MPI-ESM. MPI-ESM couples the atmosphere, ocean and land surface through the exchange of energy, momentum, water and carbon dioxide.

Significant differences between ECHAM5 and ECHAM6 concern the land processes, the radiation schemes, the computation of the surface albedo, the triggering condition for convection, and the inclusion of the land model JSBACH in ECHAM6.

Models ECHAM5 and ECHAM6 have a nudging mode to known values of air temperature, wind speed and surface pressure. Data from a retrospective analysis ERA-Interim [3] was used as these values for the ECHAM5 model and data from a retrospective analysis ERA5 [4] was used as these values for the ECHAM6 model in this paper. These climate databases were created using the spectral model of the European Center for Medium-Range Weather Forecasts (ECMWF). ERA5 has several advantages compared to the previous ERA-Interim reanalysis: higher spatial and temporal resolution, which allows for a better understanding of convective ascending flows, gravitational waves, tropical cyclones and other mesoscale processes in the atmosphere.

Models ECHAM5 and ECHAM6 were supplemented with a wiso module that takes into account the isotopic composition of water in precipitation and water vapor. This module was developed at the Alfred Wegener Institute of Polar and Marine Research [5,6], Bremerhaven, Germany.

Usually, concentration ratios of different isotopologues are expressed in terms of delta values:

$$\delta H_2{}^{18}O = \left(\frac{{}^{H_2{}^{18}O}/_{H_2O}}{\left({}^{H_2{}^{18}O}/_{H_2O}\right)_{SMOW}} - 1 \right) \cdot 1000‰, \quad (1)$$

$$\delta HDO = \left(\frac{{}^{HDO}/_{H_2O}}{\left({}^{HDO}/_{H_2O}\right)_{SMOW}} - 1 \right) \cdot 1000‰, \quad (2)$$

where symbols of chemical elements indicate their concentration, and symbol SMOW relates is standard mean ocean water.

The Institute for Water and Environmental Problems SB RAS has observation station in the foothills of Altai mountains (52.596° N, 85.25° E). The experimental base of the monitoring station contains laser spectrometers PICARRO L2130-i, designed to measure the concentration of water vapor in air and the values of $\delta H_2{}^{18}O$ and δHDO. The measurements of the isotopic composition of precipitation have been carried out since June 2014.

To verify the general atmospheric circulation models with embedded fractionation of water isotopes ECHAM5-wiso and ECHAM6-wiso, the average daily data on the isotope composition of water vapor in precipitation at monitoring stations in the foothills of Altai mountains (52.596° N, 85.25° E) with the results of the simulation were compared.

Simulations using both models were performed in nudging mode to the known values of temperature, surface pressure, divergence and vorticity of the wind speed with the following parameters (tab.1):

25th International Symposium On Atmospheric and Ocean Optics: Atmospheric Physics, edited by Gennadii G. Matvienko, Oleg A. Romanovskii, Proc. of SPIE Vol. 11208, 112087R
 · doi: 10.1117/12.2540767

Table 1. Modelling parameters

Model	ECHAM5-wiso	ECHAM6-wiso
Horizontal resolution	T106 (1.125°x1.125°)	T63 (1.88°x1.88°)
Vertical resolution	31 levels	47 levels
Time step	6 minutes	6 minutes
Data source for nudging mode	ERA-Interim	ERA5

Figures 1 and 2 show the relative concentrations of isotopologues ($\delta H_2{}^{18}O$ and δHDO) in precipitation for the observation station. The figures show the measurement data (indicated with blue dots) and the results of the model experiments performed at the Climate and Environment Physics Laboratory UrFU (orange dots for ECHAM5-wiso and grey dots for ECHAM6-wiso). The experimental data contain 187 measurements of the isotopic composition of precipitation in the period from June 2014 to December 2016. Figure 3 shows d-excess in precipitation for the observation station, which was calculated using

$$d - excess = \delta HDO - 8 * \delta H_2^{18}O \quad (3)$$

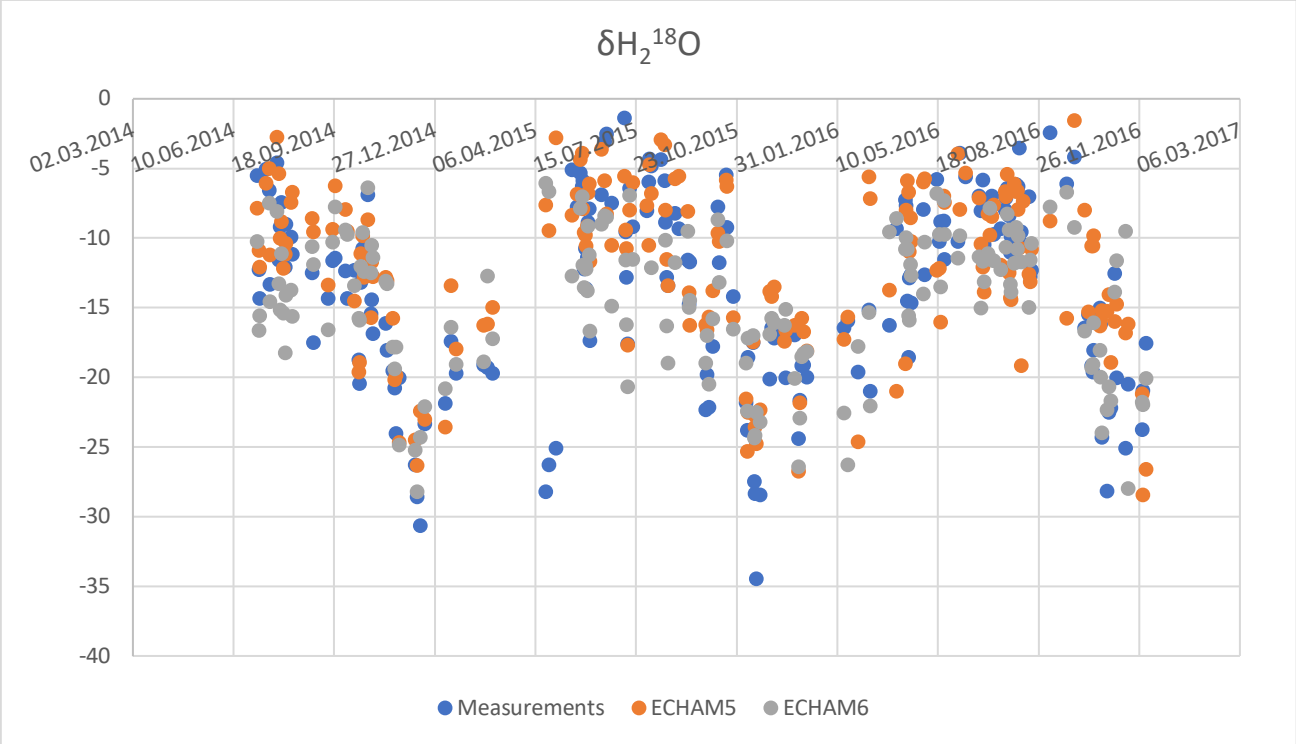

Fig. 1 – Comparison of model and measured data on $\delta H_2{}^{18}O$ in precipitation collected at a monitoring station in the foothills of the Altai

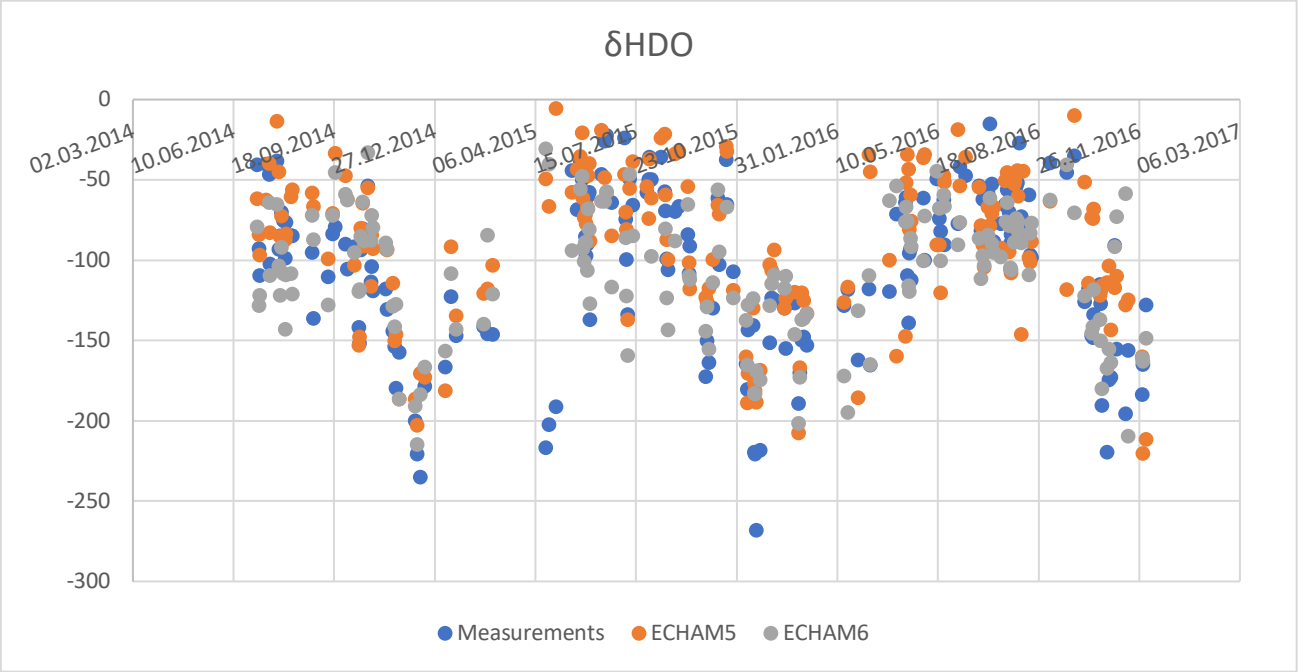

Fig. 2 – Comparison of model and measured data on δHDO in precipitation collected at a monitoring station in the foothills of the Altai

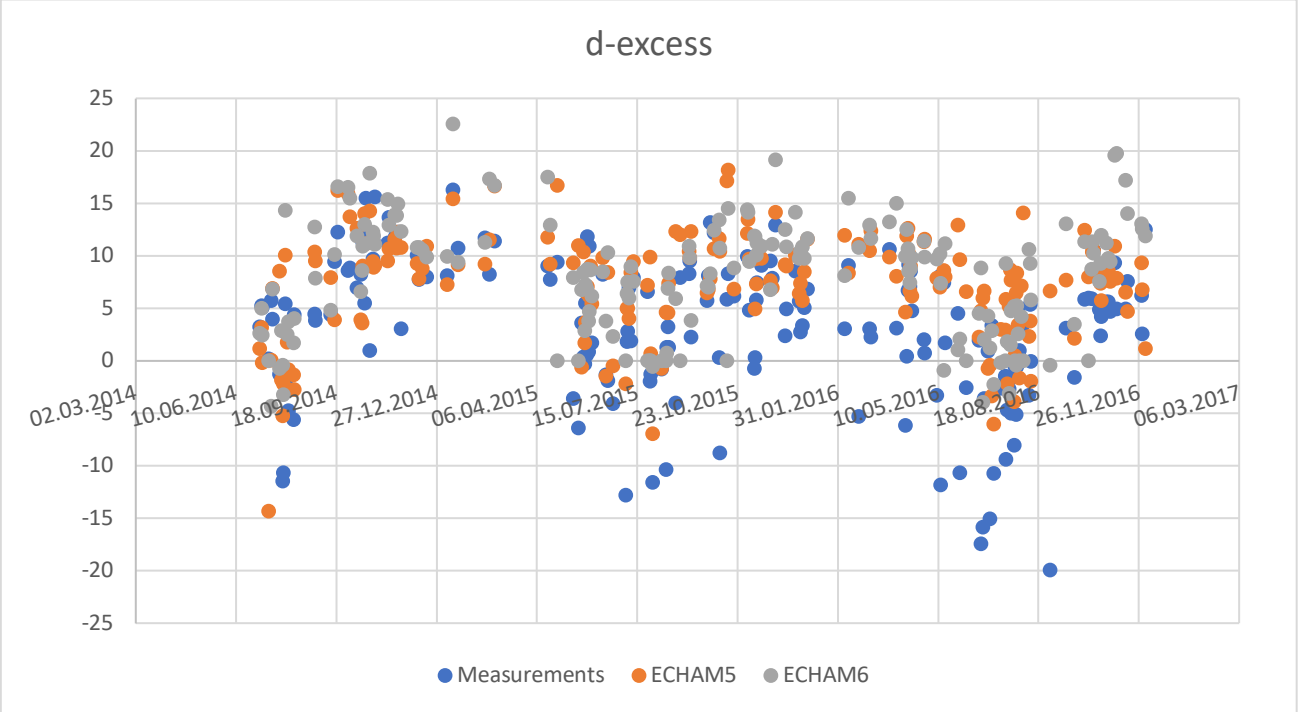

Fig. 3 – Comparison of model and measured data on d-excess in precipitation collected at a monitoring station in the foothills of the Altai

Table 2. Correlation coefficients between measured values and modeling

	ECHAM5-wiso	ECHAM6-wiso
$\delta H_2{}^{18}O$	0,70	0,74
δHDO	0,68	0,71
d-excess	0,47	0,56

The correlation coefficients between measurements of the delta values of water isotopologues in the atmosphere at all stations and modeling for two models (tab. 2) were calculated. It can be seen that the correlation coefficients are several percent higher for the ECHAM6-wiso model in relaxation mode to the ERA5 reanalysis data.

The study was supported by Russian Science Foundation grant No.18-11-00024.

REFERENCES

1. Roeckner E. et al. The atmospheric general circulation ECHAM 5. PART I: Model description. Max Planck Institute for Meteorology, Hamburg, 2003. 127 p.
2. Stevens, B., et al. Atmospheric component of the MPI-M Earth System Model: ECHAM6 // J. Adv. Model. Earth Syst. 2013. N 5. P. 146–172.
3. European Centre for Medium-Range Weather Forecasts. 2017, updated monthly. ERA5 Reanalysis. Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory. URL: https://doi.org/10.5065/D6X34W69.
4. ERA-Interim: New ECMWF reanalysis products from 1989 onwards. URL: http://old.ecmwf.int/publications/newsletters/pdf/110_rev.pdf.
5. Cauquoin, A., Werner, M. and Lohmann, G. Modeling of water stable isotopes in the ECHAM6 atmospheric general circulation model: current status and perspectives // EGU General Assembly 2017, Vienna (Austria), 24 April 2017 – 28 April 2017.
6. Werner M., Langebroek P. M., Carlsen T., Herold M., Lohmann G. Stable water isotopes in the ECHAM5 general circulation model: Towards high-resolution isotope modeling on a global scale // J. Geophys. Research 2011. V. 116. D15109.