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Verification of the isotopic atmospheric general circulation model for a monitoring station in Labytnangi

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ABSTRACT

To validate the atmospheric general circulation models ECHAM5-wiso and ECHAM6-wiso, supplemented with isotopic modules, a simulation was performed in the nudging mode to known values of temperature, pressure, speed and wind direction obtained from a retrospective analysis. The simulation results were compared with the data on the isotopic composition (δHDO and $\delta H_2{}^{18}O$) of water vapor and precipitation at the monitoring station in Labytnangi (66.660° N, 66.409° E).

Atmospheric general circulation model, water isotopes, isotopic composition of precipitation

The ECHAM general atmospheric circulation model created at the Max Planck Institute of Meteorology in Hamburg [1,2] is the atmospheric component of the MPI-ESM climate model, which includes models of the atmosphere, ocean, land and connects them through energy, momentum exchange, water and carbon dioxide.

At the Alfred Wegener Institute of Polar and Marine Research models ECHAM5 and ECHAM6 were supplemented with wiso modules that take into account the fractionation of water isotopes in all phase transitions [3, 4]. Usually, concentration ratios of different isotopes 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.

To validate the isotopic models of the general atmospheric circulation ECHAM5-wiso and ECHAM6-wiso the simulation results were compared with the daily average data on the isotopic composition of precipitation and water vapor in the atmospheric air at the surface obtained at the monitoring station in Labytnangi (66.660° N, 66.409° E). The location of the station is shown on the figure 1.

The station for monitoring the isotopic composition of water vapor was organized by the Climate and Environmental Physics Laboratory UrFU in Labytnangi. The monitoring station is equipped with a Picarro L2130-i laser spectrometer designed to measure the isotopic composition of water vapor in air or in pure nitrogen. The spectrometer is periodically calibrated using standard samples of liquid water, which are dosed into the evaporator, where they are mixed with the dried atmospheric air and get into the analyzer. The station is also equipped with a Vaisala WXT520 automatic weather station. Their work is controlled via the Internet. Air sampling is carried out from the top of 8 meters high post. The analysis is carried out continuously with the measurement of the content of water isotops about once every 1-5 seconds. Monitoring point is located on the banks of the Ob river, which causes disturbance of the data due to the water vapor directly from the water surface of the rivers in the warm season.

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Fig. 1 – Comparison of model and measured data on $\delta H_2{}^{18}O$ in water vapor in the air collected at a monitoring station in Labytnangi in 2013–2015

Modeling using both models was performed in the nudging mode to known values of temperature, pressure, wind divergence and vorticity with the parameters presented in Table 1. The fields of known values in this paper were taken from the ERA-Interim retrospective climate analysis [5] for the ECHAM5 model and ERA5 [6] for the ECHAM6 model.

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 2–5 show the relative concentrations of isotopes ($\delta H_2{}^{18}O$ and δHDO) in water vapor in the air and in precipitation for the observation station. The figures show the measurement data (indicated with blue color) and the results of the model experiments performed at the Climate and Environment Physics Laboratory UrFU (orange color for ECHAM5-wiso and grey color for ECHAM6-wiso). The correlation coefficients between the measured delta values and model data for two models were also calculated (Tables 2–3).

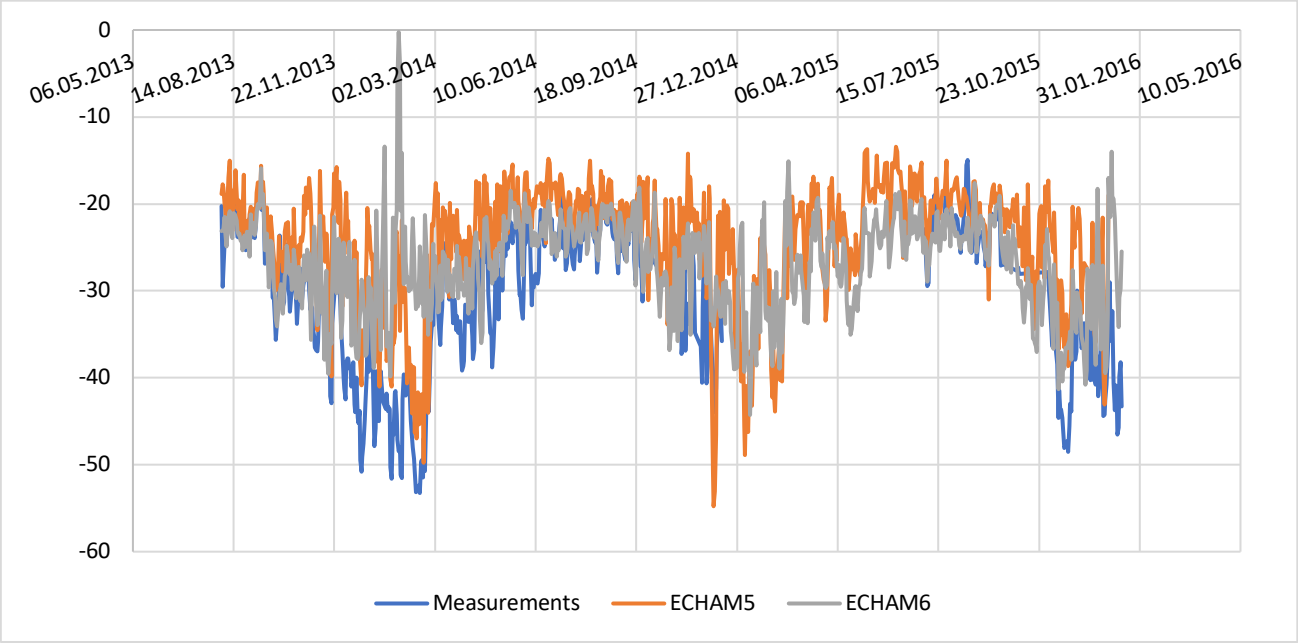

Fig. 2 – Comparison of model and measured data on $\delta H_2{}^{18}O$ in water vapor in the air collected at a monitoring station in Labytnangi in 2013–2015

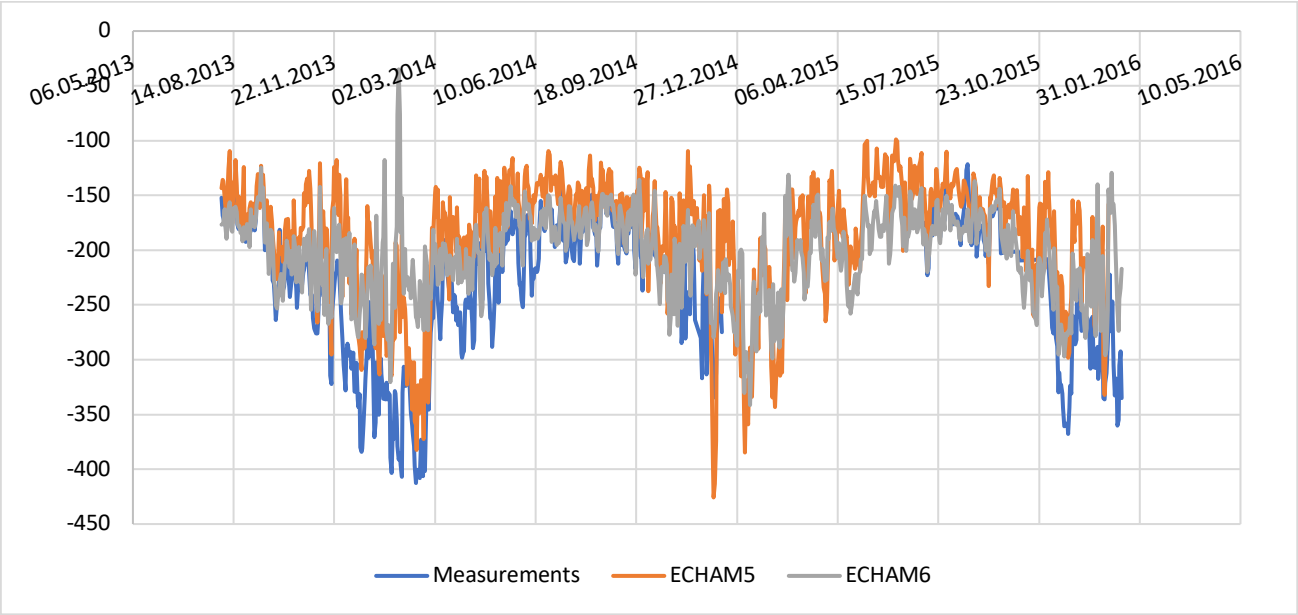

Fig. 3 – Comparison of model and measured data on δHDO in water vapor in the air collected at a monitoring station in Labytnangi in 2013–2015

Table 2. Correlation coefficients between measured values and modeling

	ECHAM5	ECHAM6
$\delta H_2{}^{18}O$	0,70	0,76
δHDO	0,76	0,81

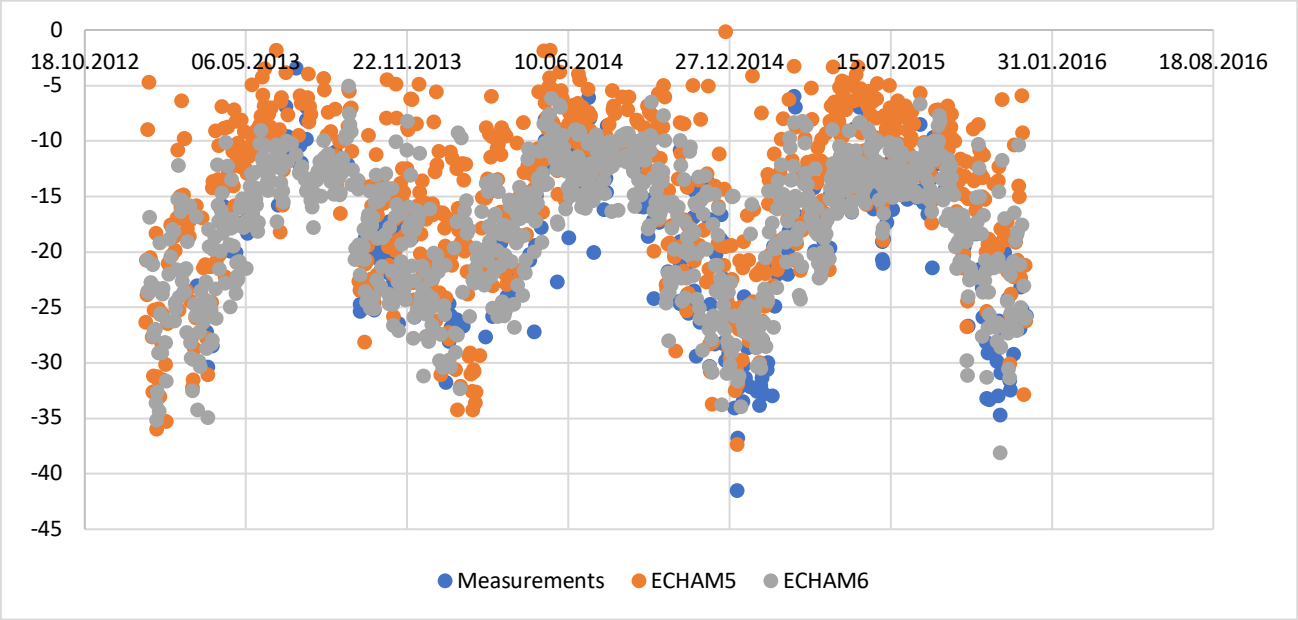

Fig. 4 – Comparison of model and measured data on $\delta H_2{}^{18}O$ in precipitation collected at the monitoring station in Labytnangi in 2013–2017

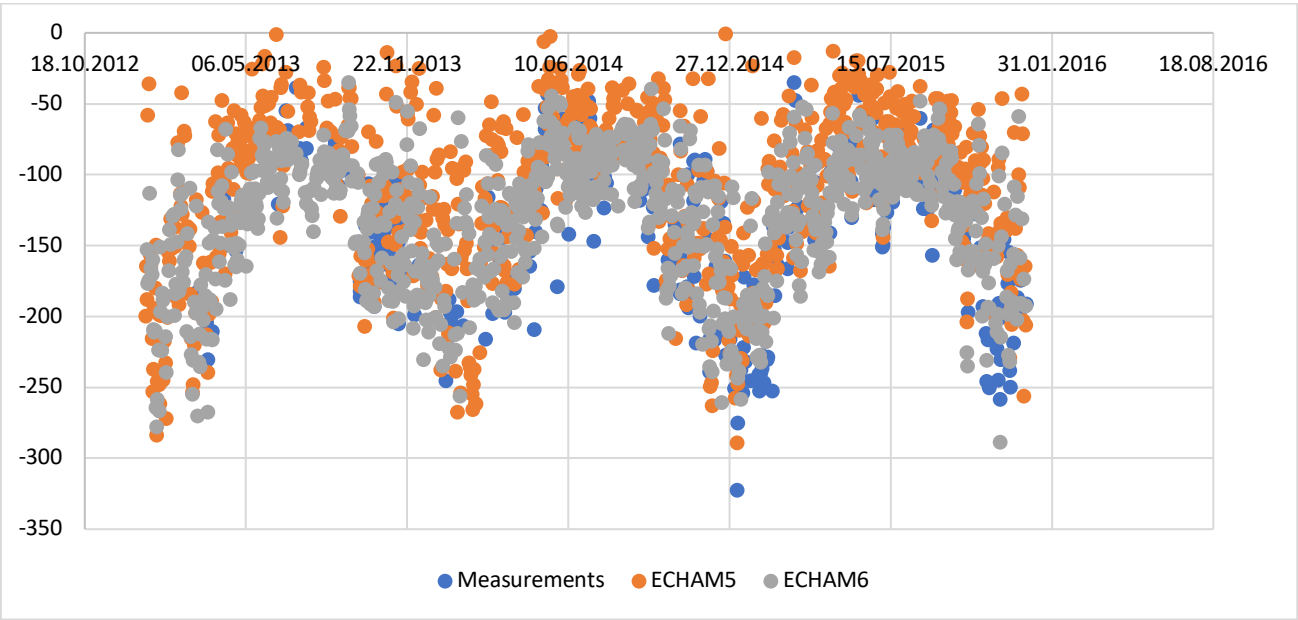

Fig. 5 – Comparison of model and measured data on δHDO in precipitation collected at a monitoring station in Labytnangi in 2013–2017

Table 3. Correlation coefficients between measured values and modeling

	ECHAM5	ECHAM6
$\delta H_2{}^{18}O$	0,76	0,83
δHDO	0,77	0,81

The results obtained indicate that both models generally reflect seasonal variations in the isotopic composition of water vapor in the air at the monitoring station in Labytnangi. The correlation coefficients between measurements of the delta values of water isotopes in the atmosphere water vapor and in precipitations at the monitoring station in Labytnangi and modeling for two models (tab. 2, 3) were calculated. It can be seen that the correlation coefficients are several percent higher for the ECHAM6-wiso model in nudging mode to the ERA5 reanalysis data.

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