

Physics of snow cover in climate model INMCM

A. Yu. Chernenkov^{1,2}, S. V. Kostykin²⁻⁴, and E. M. Volodin²

¹MIPT, Phystech School of Applied Mathematics and Informatics

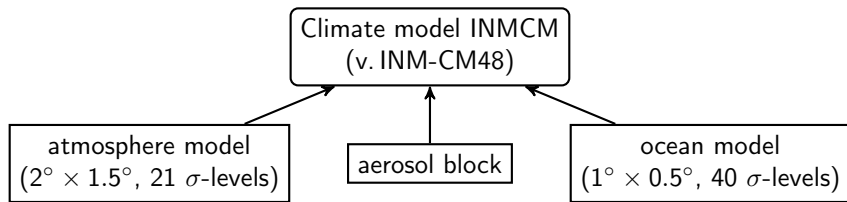
²Marchuk Institute of Numerical Mathematics, Russian Academy of Sciences

³Izrael Institute of Global Climate and Ecology

⁴Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences

(Contact: chernenkov.ayu@phystech.edu)

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Version INM-CM48¹ participate in the international project for comparing climate models CMIP6 (Coupled Models Intercomparison Project)

¹Volodin et al., 2018

Modelling of snow cover properties

Snow melting and refreezing processes:

$$\frac{\partial S}{\partial t} = P - M + S_{wat} + S_{rfrz} - \frac{\mathcal{E}}{\mathcal{L} \cdot \rho_w}$$

Assumptions:

- Excess energy \rightarrow snow melting, deficit energy \rightarrow melt water refreezing
- Snow-melt water oozes through snow layer to soil
- Snow-layer moisture S_{wat} is limited by its porosity

Snow cover aging:

- Snow density^a:

$$\rho_{snow} = \rho_{sn}^{old} \cdot \delta_{old} + \rho_{sn}^{new} \cdot \delta_{new} + \rho_w \cdot \delta_{wat} + \rho_{ice} \cdot \delta_{rfrz}$$

$$\rho_{sn}(t + \Delta t) = f(\rho_{sn}(t), H_{sn}(t), T_{sn}(t))$$

- Snowflake effective radius^b:

$$r_e(t + \Delta t) = [r_e(t) + \delta r_{e,dry} + \delta r_{e,wet}] \cdot f_{old} + r_{e,0} \cdot f_{new} + r_{e,rfrz} \cdot f_{rfrz}$$

^aGusev et al., 2002

^bBrun, 1989; Flanner and Zender, 2006;

Modelling of snow cover properties

Snow pollution by atmosphere aerosols (e.g. black carbon)^a:

$$\frac{dM_{bc}}{dt} = -C_{MSE} Q_{melt} \frac{M_{bc}}{M_{sn}} S + I_{bc} \sigma S, \quad C_{bc} = \frac{M_{bc}}{M_{sn}}$$

^aChernenkov, Kostykin, 2021

Snow-covered surface albedo^{a,b}:

$$alb = f(\alpha, \mu) = \alpha + (A + B \cdot \alpha^C) \cdot \left(\frac{1 - \mu}{1 + \mu} \right)^D, \quad \alpha(r_e, C_{bc}) = \sum_{i,j=0}^{N=5} \sigma_{i,j} r_e^i C_{bc}^j$$

(μ – cosine of solar zenith angle)

^aFlanner et al., 2007

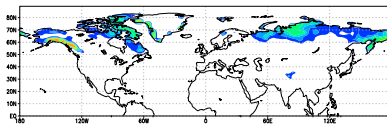
^bSaito, 2019

All calculations were carried out with original and modified versions of INM-CM48:

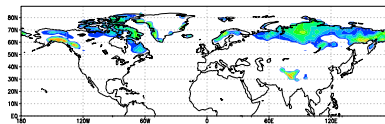
- Snow melting and aging
 - ◇ Long experiment from 1967 to 2010
 - ◇ Series of experiments from 1997 to 2016 starting from set of perturbed initial conditions
(change in sea level temperature at the equator by 0.1 degrees)
- Same modifications + snow contamination and albedo changing
 - ◇ Experiment from 1997 to 2007

Calculations were performed using the HPC system of the Marchuk Institute of Numerical Mathematics of the Russian Academy of Sciences

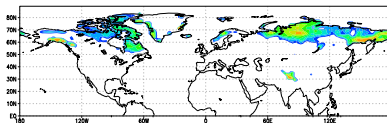
Snow water-equivalent thickness, [mm] (averaged 1998–2007, month – May)



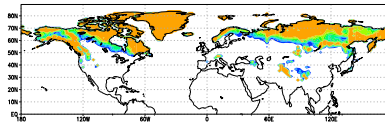
INMCM48-old v.



INMCM48-mid v.



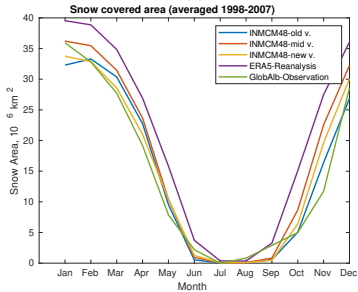
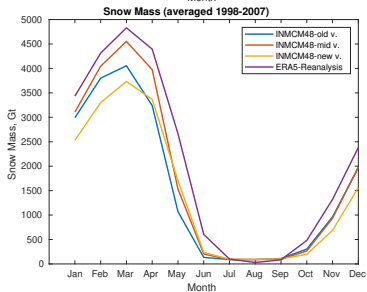
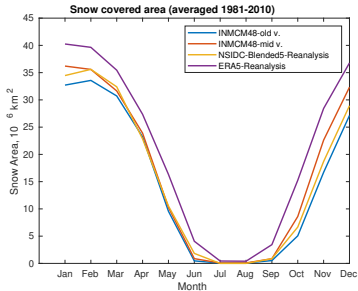
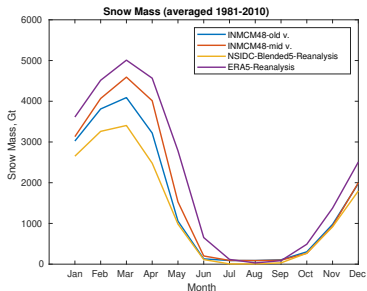
INMCM48-new v.



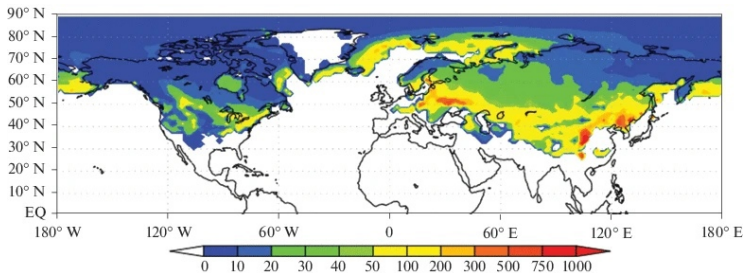
ERA5-reanalysis



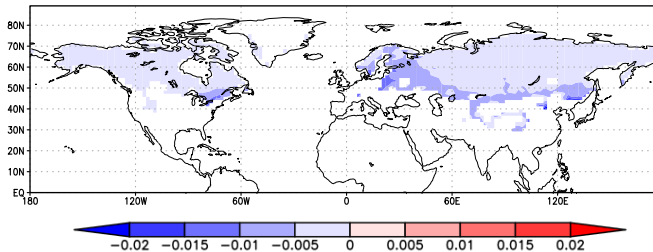
Annual variation of snow mass and covered area in the Northern Hemisphere



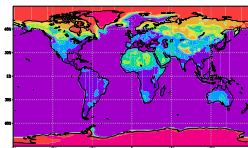
BC-concentration in snow (January 1998), [ng/g]



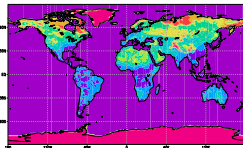
Snow albedo reduction due to black carbon (January 1998)



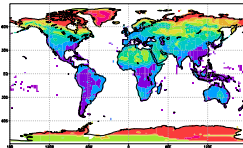
Surface Albedo (averaged from 1998 to 2007, month – March)



INMCM48-new v.



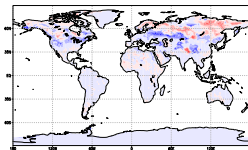
ERA5-reanalysis



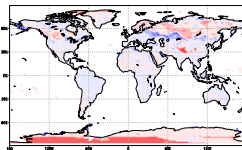
The Globalbedo project*



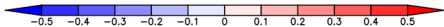
Difference of albedo (averaged from 1998 to 2007, month – March)



INMCM48-new v.
VS
ERA5-reanalysis



INMCM48-new v.
VS
The Globalbedo project



*<http://www.globalbedo.org/>

- Modified Land-Snow model in INMCM
- Modeled snow cover corresponds to observational data and reanalyses
- Implemented technology for calculating atmosphere aerosols concentration in snow
- Implemented physically based parametrization of snow albedo
- Modeled surface albedo corresponds to observation data and reanalyses
- Updated timing of snow-cover melting in middle and high latitudes

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Thank you for attention!

Questions?

chernenkov.ayu@phystech.edu