DMI-HIRHAM5 (NA-CORDEX)

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Climate Model Report Card

Model Name: The HIRHAM Regional Climate Model, version 5

Institution(s): Danish Climate Centre at the Danish Meteorological Institute (DMI) and the Potsdam Research Unit of the Alfred Wegener Institute Foundation for Polar and Marine Research (AWI)

Data Portal: www.earthsystemgrid.org

LAKE COMPONENT

Name: Simple lake model from ECHAM5 general circulation model

Reference: [1]Roeckner, E., Bäuml, G., Bonaventura, L., Brokopf, R., Esch, M., Giorgetta, M., ... & Tompkins, A. (2003). The atmospheric general circulation model ECHAM5, part 1, Model description, *Rep. 349*, Max-Planck-Inst. for Meteorol., Hamburg, Germany.

Description: A simple mixed-layer lake model is used to calculate water temperature, ice thickness, and ice temperature for "big" lakes (defined as grid cells with land-fraction less than 50%). Ice/water fraction is set to 0 when a grid cell's land-fraction is over 50%.[1]

However, Mailhot et al. (2019) cites that HIRHAM5 imports lake surface characteristics (including temperature and ice cover) from the nearest GCM lake tile[2], and https://na-cordex.org/rcm-characteristics.html cites that HIRHAM5 "interpolates lapse-rate corrected SST for lakes" for grid cells with land-fraction less than 50%.

Vertical Layers | Depths: Constant-depth mixed layer (10m)[1]

Vertical Mixing (y/n): Yes

Horizontal Mixing (y/n): No

Lake Ice: Ice formation calculations only occur when the cooling is large enough to form ice with a thickness greater than 0.1m. Ice thickness is derived from a thermodynamic ice model and allows for a snow layer above the ice. It does not allow for partial ice coverage over lakes, meaning the entire lake is either ice-covered or ice-free. The freezing temperature of freshwater is used for the formation of lake-ice.[1]

ATMOSPHERE COMPONENT

Name: HIRLAM7 dynamics and ECHAM5 physics

References: [1]Roeckner, E., Bäuml, G., Bonaventura, L., Brokopf, R., Esch, M., Giorgetta, M., ... & Tompkins, A. (2003). The atmospheric general circulation model ECHAM5, part 1, Model description, *Rep. 349*, Max-Planck-Inst. for Meteorol., Hamburg, Germany.

Undén, P., Rontu, L., Jarvinen, H., Lynch, P., Calvo, J., Cats, G., ... & Tijm, A. (2002). HIRLAM-5 Scientific Documentation. *Scientific Report*. SMHI, S-601 76 Norrkoping, Sweden.

Physical Parameterization(s): Mass flux convection scheme (Tiedtke, 1989) for cumulus convection with modifications for penetrative convection from (Nordeng, 1994), shortwave radiation scheme (Fouquart & Bonnel, 1980), longwave radiation scheme (Morcrette, 1984; Mlawer, 1997), gravity wave spread theory (Hines, 1997), cloud microphysical scheme (Lohmann & Roeckner, 1996), cloud cover scheme (Tompkins, 2002), prognostic equations for water vapor, cloud water, cloud ice content (ECHAM5)[1]

Chemistry: Water vapor, cloud water, and ice are prognostic variables while cloud cover is a diagnostic variable. Carbon dioxide, methane, N_2O, and 2 CFCs all have constant mixing ratios, although methane and N_2O have the option to decrease vertically. Ozone follows the climatology of (Fortuin & Kelder, 1998). Aerosol distributions follow (Tanre, 1984).[1]

Spatial Resolution: 0.44° grid, available data interpolated to common half-degree lat-lon grid

Simulation Timestep: 10 min

Output Data Temporal Resolution: daily, monthly, seasonally, annually

GCM Driver(s): EC-EARTH

Reanalysis Driver: ERA-Interim

Historical Run(s): 1989-2011 (ERA-Interim), 1951-2005 (EC-EARTH)

Future Scenario(s): RCP4.5, RCP8.5

Future Time Period(s): 2006-2100

LAND COMPONENT

Name: From ECHAM5 general circulation model - an implicit scheme described by Schulz et al. (2001) is used to couple the land surface and the atmosphere

Reference: [1]Roeckner, E., Bäuml, G., Bonaventura, L., Brokopf, R., Esch, M., Giorgetta, M., ... & Tompkins, A. (2003). The atmospheric general circulation model ECHAM5, part 1, Model description, *Rep. 349*, Max-Planck-Inst. for Meteorol., Hamburg, Germany.

Schulz, J.-P., Dumenil, L., & Polcher, J. (2001). On the land surface-atmosphere coupling and its impact in a single-column atmospheric model. *J. Appl. Meteorol., 40*, 642–663.

 # Land Cover Types: 6 main surface types (snow/ice (snow on lake ice, snow on land, lake ice), bare soil, vegetation, wet skin, open water, sea ice)[1] with 74 vegetation/land use classes from the 96 Olson ecosystem types list.[1,3,4] Full class list in Hagemann (2002).

 # Soil Layers: 5 layers (+1 for snow) with thicknesses of 0.065m, 0.254m, 0.913m, 2.902m, 5.7m (9.8m total)[1]

Soil Moisture: Changes in soil water (from rainfall, evaporation, snow melt, surface runoff, and drainage) are calculated for a single bucket with maximum storage capacity varying geographically by a probability density function. Then, a "storage capacity distribution curve" is defined which shows the fraction of the wet grid-cell that has reached the storage capacity).[1]

Runoff: The runoff and drainage scheme is described in the work of Dümenil & Todini (1992) and uses a heterogeneous distribution of field capacities within each grid-cell. Surface runoff is defined as the excess water once the maximum saturation of a whole grid-cell has been reached. There is no infiltration for frozen soils[1].

Sub-Grid lakes: No

Carbon Fluxes: Undocumented

Land Use Change: Undocumented

Groundwater: Undocumented

Additional References

[2]Mailhot, E., Music, B., Nadeau, D. F., Frigon, A., & Turcotte, R. (2019). Assessment of the Laurentian Great Lakes' hydrological conditions in a changing climate. *Climatic Change, 157*(2), 243-259.

[3]Rechid, D., Raddatz, T. J., & Jacob, D. (2009). Parameterization of snow-free land surface albedo as a function of vegetation phenology based on MODIS data and applied in climate modelling. *Theoretical and applied Climatology, 95*(3-4), 245-255.

[4]Hagemann, S. (2002). An improved land surface parameter dataset for global and regional climate models. *Rep. 349*, Max-Planck-Inst. for Meteorol., Hamburg, Germany.