CESM1-WACCM (CMIP5)

Climate Model Report Card

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Model Name: Community Earth System Model version 1.0 with Whole Atmosphere Community Climate Model

Developers: National Science Foundation, US Department of Energy, and National Center for Atmospheric Research (NSF-DOE-NCAR)

Data Portal: https://cera-www.dkrz.de, www.earthsystemgrid.org

Spatial Resolution: 1.88° x 2.5°

Temporal Resolution: monthly

LAKE COMPONENT

Name: Lake model within NCAR's Community Land Model, version 4 (CLM4.0)

Reference: [1]Oleson, K. W., Dai, Y., Bonan, G., Bosilovich, M., Dickinson, R., Dirmeyer, P., ... & Zeng, X. (2010). Technical description of version 4.0 of the Community Land Model (CLM). *Tech. Note NCAR/TN-478+STR.*

Description: The lake model is from Zeng et al. (2002), which is based on various one-dimensional models that vertically solve the thermal diffusion equation for 10 layers of water and ice. Each grid cell is assigned a percentage of lake, wetland, glacier, urban, and soil, where lake percentages are from Cogley's (1991) 1.0° x 1.0° perennial freshwater lake data. Snow cover above lakes is greatly simplified and soil beneath lakes is not considered.[1] CLM4.0's lake model was greatly improved for deep lakes with CLM-LISSS (Lake, Ice, Snow, and Sediment Simulator), but this was not used in CMIP5.[2]

Vertical Layers | Depths: 10 layers for a maximum depth of 50m

Vertical Mixing (y/n): Yes

Horizontal Mixing (y/n): No

Lake Ice: The 10 layers can be water or ice, and frozen lake albedos are based on sea ice values from NCAR LSM (Bonan, 1996).[1]

ATMOSPHERE COMPONENT

Name: Whole Atmosphere Community Climate Model (WACCM), version 4 (CAM4 with high-top atmosphere)

Reference: [3]Neale, R. B., Richter, J. H., Conley, A. J., Park, S., Lauritzen, P. H., Gettelman, A., ... & Lin, S.-J. (2010). Description of the NCAR Community Atmosphere Model (CAM 4.0). *Tech. Note NCAR/TN-485+STR.*

Physical Parameterizations: Deep convection scheme (Zhang & McFarlane, 1995) modified for convective momentum transports (Richter & Rasch, 2008), shallow/mid-tropospheric moist convection scheme (Hack, 1994), evaporation of convective precipitation and cloud microphysics (Sunqvist, 1988), non-convective cloud processes (Rasch & Kristjansson, 1998; Zhang et al., 2003), shortwave radiation (Berger, 1978), longwave radiation (Ramanathan & Downey, 1986), atmospheric boundary layer process (Holtslag & Boville, 1993),[3] non-orographic gravity waves and turbulent mountain stress (Richter et al., 2010)[4]

Chemistry: Interactive chemistry is fully integrated into CAM's dynamics and physics. WACCM is tailored toward the middle and upper atmosphere, extending to the lower thermosphere (~140km), and includes heterogeneous and ion chemistry and that can simulate the ozone hole and the ionosphere, respectively.[4,5] The chemical mechanism of WACCM4 includes 59 species, 217 gas-phase chemical reactions, and 17 heterogeneous reactions on aerosols.[4]

Historical Run(s): 1850-2005

Future Scenario(s): RCP2.6, RCP4.5, RCP8.5

Future Time Period(s): 2006-2099

LAND COMPONENT

Name: Community Land Model (CLM), version 4.0

Reference: [1]Oleson, K. W., Dai, Y., Bonan, G., Bosilovich, M., Dickinson, R., Dirmeyer, P., ... & Zeng, X. (2010). Technical description of version 4.0 of the Community Land Model (CLM). *Tech. Note NCAR/TN-478+STR.*

 # Land Cover Types: 5 land cover types (soil, wetland, lake, urban, glacier) and 16 vegetation plant function types (PFTs), where each grid cell can contain multiple surface types and up to 4 PFTs.[1] Full PFT list in Oleson et al. (2010).

 # Soil Layers: 15 ground layers (+up to 5 for snow), where the upper 10 (0m to 3.8m) are hydrologically active soil layers and the lower 5 are bedrock layers (3.8m to 42m) for a total depth of 42m.[1,3]

Soil Moisture: Vertical moisture between the 10 hydrologically active soil layers is governed infiltration, surface and sub-surface runoff, gradient division, gravity, canopy transpiration, and groundwater interactions.[1]

Runoff: Surface runoff consists of Dunne runoff (overland-flow from saturation excess) and Hortonian runoff (infiltration excess). A TOPMODEL-based runoff model called SIMTOP, described by Niu et al. (2005), is used for runoff parameterization.[3]

Sub-Grid Lakes (y/n): Yes. Grid cells can be assigned a percentage of lake, wetland, glacier, and soil, with lake percentages from Cogley's (1991) 1.0° x 1.0° perennial freshwater lake data.[1]

Carbon Fluxes: CLM4 contains a prognostic carbon-nitrogen (CN) biogeochemical model (Thornton et al., 2007) that simulates carbon cycling and nitrogen limitation in vegetation, litter, and soil-organic matter, although it is turned off for this model (see CESM1-BGC, where it is turned on).[5,6]

Land Use Change: CLM4 includes transient land cover and land-use change (LCLUC) with 0.5° resolute data from Hurtt et al. (2006) that describes changes in land cover from 1850-2005 between crop, pasture, primary vegetation, and secondary vegetation classes.[1,3]

Groundwater: There is an unconfined aquifer below the 10 soil layers.[3]

Additional References

[2]Deng, B., Liu, S., Xiao, W., Wang, W., Jin, J., & Lee, X. (2013). Evaluation of the CLM4 lake model at a large and shallow freshwater lake. *Journal of Hydrometeorology, 14*(2), 636-649.

[3]Lawrence, D. M., Oleson, K. W., Flanner, M. G., Thornton, P. E., Swenson, S. C., Lawrence, P. J., ... & Slater, A. G. (2011). Parameterization improvements and functional and structural advances in version 4 of the Community Land Model. *Journal of Advances in Modeling Earth Systems, 3*(1).

[4]Marsh, D. R., Mills, M. J., Kinnison, D. E., Lamarque, J. F., Calvo, N., & Polvani, L. M. (2013). Climate change from 1850 to 2005 simulated in CESM1 (WACCM). *Journal of climate, 26*(19), 7372-7391.

[5]Hurrell, J. W., Holland, M. M., Gent, P. R., Ghan, S., Kay, J. E., Kushner, P. J., ... & Marshall, S. (2013). The community earth system model: a framework for collaborative research. *Bulletin of the American Meteorological Society, 94*(9), 1339-1360.

[6]Gent, P. R., Danabasoglu, G., Donner, L. J., Holland, M. M., Hunke, E. C., Jayne, S. R., ... & Zhang, M. (2011). The community climate system model version 4. *Journal of climate, 24*(19), 4973-4991.