Community Land Model: Update on Progress, Plans, and Results from CCSM4 Simulations

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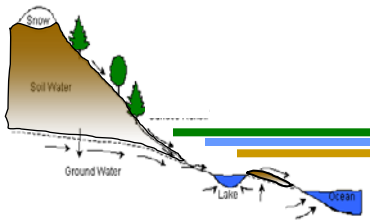
with input from lots of LMWGers

NCAR is sponsored by the National Science Foundation



Advances for CLM4

- Terrestrial carbon and nitrogen cycle (CN); merge with DGVM (CNDV)
- Transient land cover/land use change including wood harvest
- Urban model
- Revised hydrology scheme
- Revised snow model (SNICAR, snow cover fraction)
- Improved permafrost representation
- New surface datasets
- MEGAN VOC emissions model

Parameterization Improvements and Functional and Structural Advances in Version 4 of the Community Land Model

David M. Lawrence[1], Keith W. Oleson[1], Mark G. Flanner[2], Peter E. Thornton[3], Sean C. Swenson[1], Peter J. Lawrence[1], Xubin Zeng[4], Zong-Liang Yang[5], Samuel Levis[1], Koichi Sakaguchi[4], Gordon B. Bonan[1], and Andrew G. Slater[6]

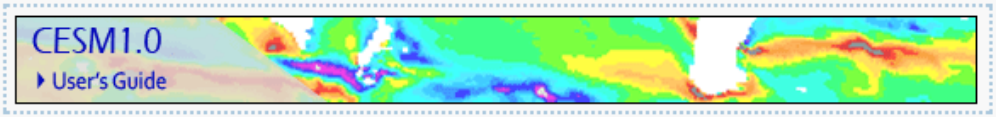
ABOUT CESM 1.0

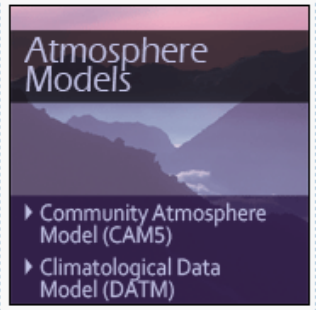
The Community Earth System Model (CESM) is a coupled climate model for simulating the earth's climate system. Composed of four separate models simultaneously simulating the earth's atmosphere, ocean, land surface and sea-ice, and one central coupler component, the CESM allows researchers to conduct fundamental research into the earth's past, present and future climate states. Please see the brief overview of the notable model improvements.

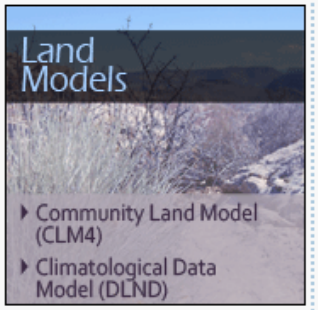
MODEL OUTPUT DATA AND DIAGNOSTICS

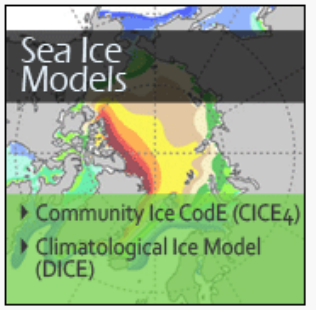
- Model Output Diagnostic Plots
- Model Output Data (ESG)
- Post Processing Utilities

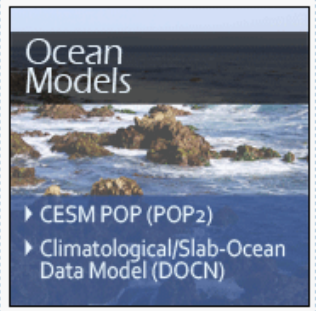
MODEL DOCUMENTATION











CESM PROJECT

The Community Earth System Model (CESM) is a fully-coupled, global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states.

CESM is sponsored by the National Science Foundation (NSF) and the U.S. Department of Energy (DOE). Administration of the CESM is maintained by the Climate and Global Dynamics Division (CGD) at the National Center for Atmospheric Research (NCAR).

MODEL SOURCE CODE

Copyright and Terms of Use

All CESM source code is subject to the following Copyright Notice and Disclaimer.

Acquiring the Code

CESM source code is distributed through a public Subversion code repository. This code can be checked out using Subversion client software, such as the command tool svn, or simply viewed with a web browser.

A short registration is required to access the repository. After registering, you will receive an email containing a user name and password that is necessary to gain access to the repository.

Acquistion of the code is more fully described in the CESM1.0 User's Guide.

Version Summaries and Known Problems

The following table lists the available versions of code along with their test record and any known problems in the code.

CESM1.0: CLM DOCUMENTATION

Introduction

The Community Land Model version 4.0 (CLM4.0) is the land model used in the CESM1.0. CLM4.0 is the latest in a series of land models developed through the CESM project. More information on the CLM project and access to previous CLM model versions and documentation can be found via the CLM Web Page.

Documentation

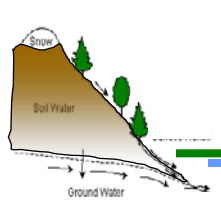
- CLM4.0 User's Guide [html] [pdf] (Last update: Jun/17/2010)
- What's new in the CESM1.0 release of CLM4? [pdf]
- What's new in CLM4.0 relative to CLM3.5? [pdf]
- CLM4.0 Technical Note [pdf] (Last update: Jun/17/2010)
- CLM4.0 Urban Model Technical Note [pdf] (Last update: Jun/17/2010)
- CLM4.0 Carbon-Nitrogen (CN) Model Technical Note (in preparation)
- CLM4.0 Code Reference Guide [html]

Model output and offline forcing data and diagnostic plots

- CLM4.0 offline control simulations: Diagnostic plots
- CLM4.0 offline control simulations: Model output data
- CLM4.0 offline control simulations: Model forcing data

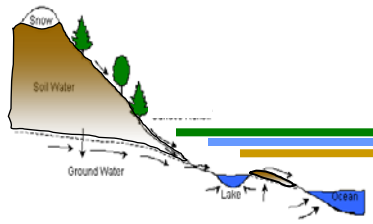
CLM Post-Processing Utilities

- CLM Diagnostic Package: Code (via svn repository, registration required)
- CLM Diagnostic Package: User's Guide



CLM4 in CESM1

- Aerosol and nitrogen deposition
  - Regridding on the fly; aerosol deposition file in datm or cam namelist
  - Larger than roundoff, but climate neutral
- Multiple elevation classes in support of Community Ice Sheet Model
- Bug fix to snow hydrology
  - Snow liquid water plus ice content could on occasion exceed the snow layer thickness
- New namelist options
- Improved User's Guide



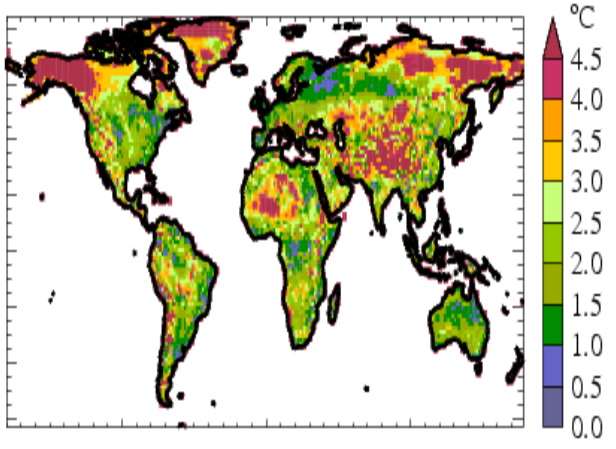
CCSM4 simulations

- 1850 control and 20th century
  - CLM is fully active with CN on and transient land cover change, aerosol and nitrogen deposition
- CCSM4 Land focused J. Climate Special Issue paper
  - “Mean, variability, and 20th century transient terrestrial climate in CCSM4”

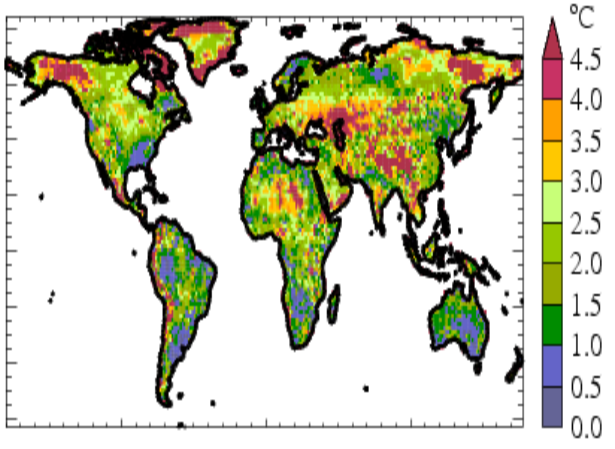
T_{air}: RMSE and Annual Mean Bias (CCSM4 vs CCSM3)

Reduced RMSE at high lats and in tropics
Mixed results for bias, E. Europe warm bias related to no aerosol indirect?

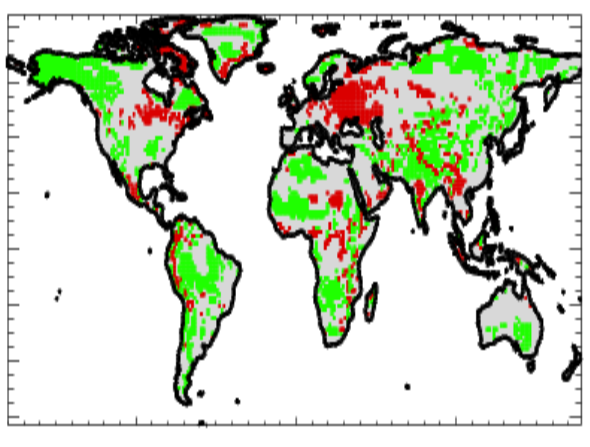
T_{air} RMSE: CCSM3
3.01°C



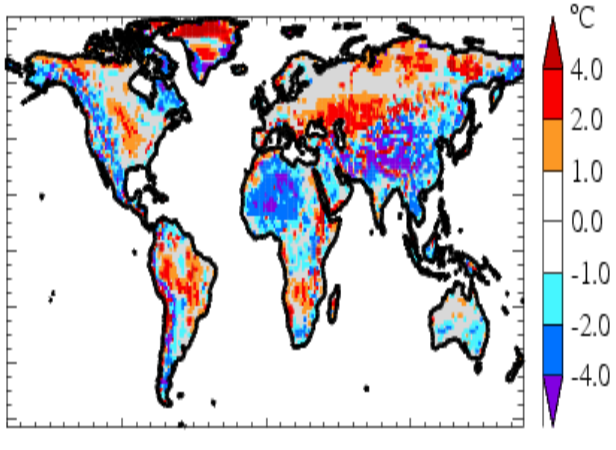
T_{air} RMSE: CCSM4
2.71°C



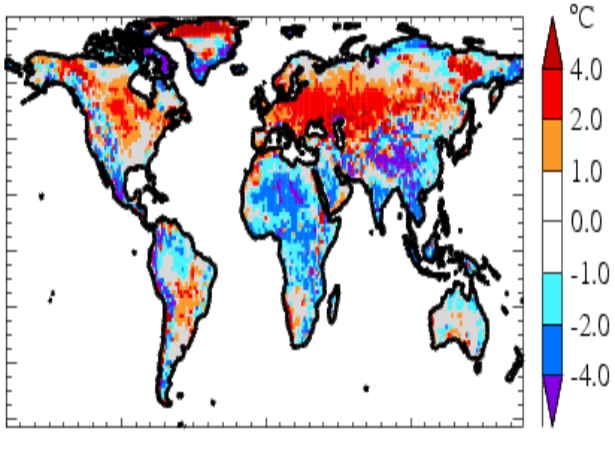
T_{air} RMSE: CCSM4 vs CCSM3
27.1%(+) 12.9%(−)



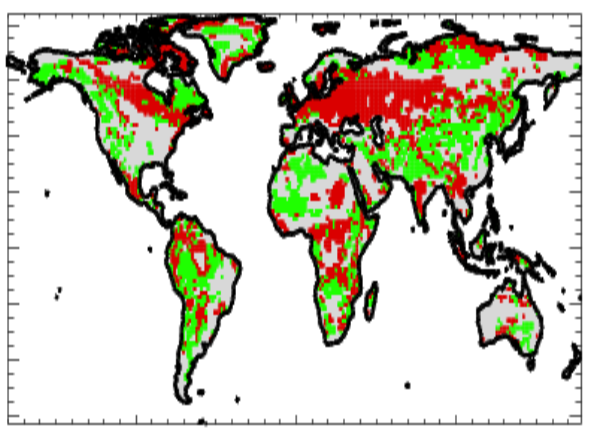
T_{air} ANN Mean Bias: CCSM3
-0.28°C



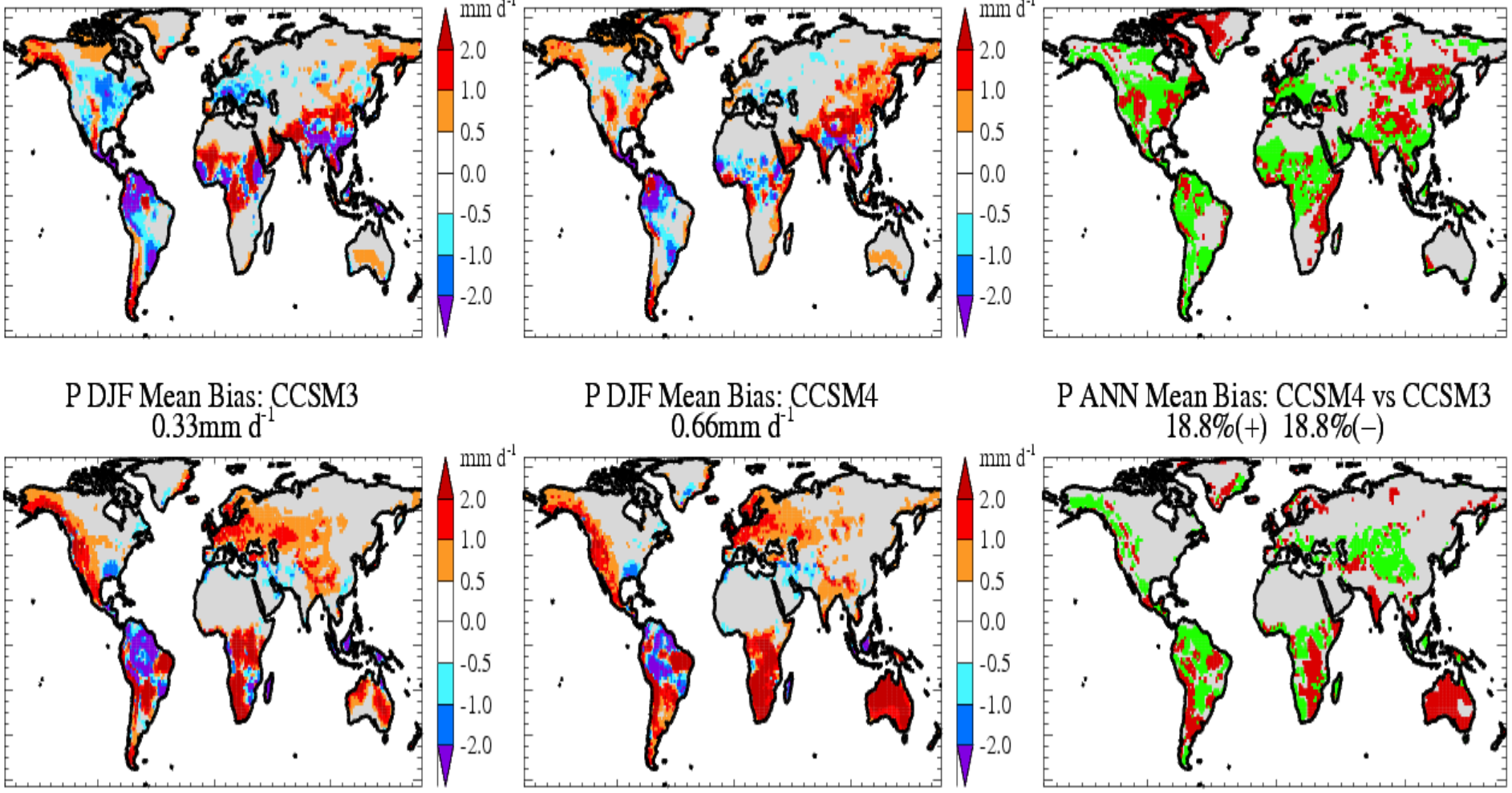
T_{air} ANN Mean Bias: CCSM4
-0.17°C

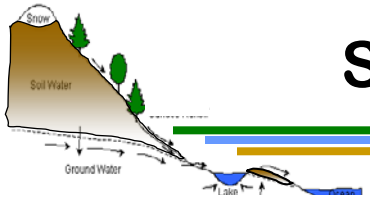


T_{air} ANN Mean Bias: CCSM4 vs CCSM3
27.7%(+) 28.3%(−)



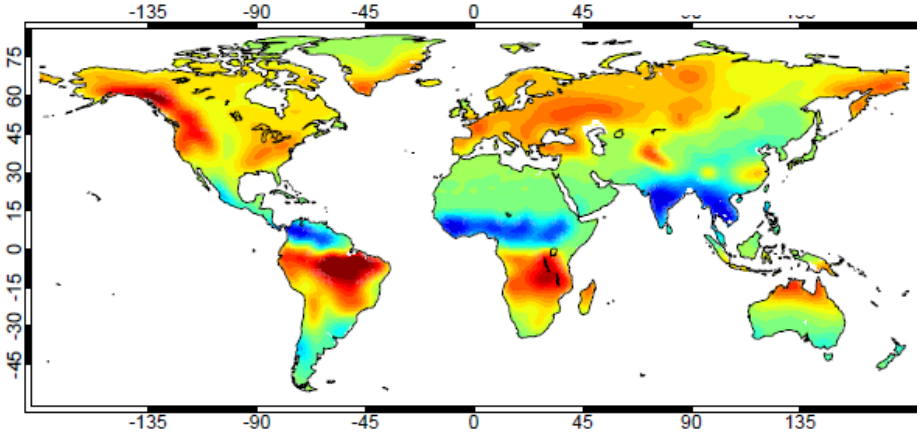
Precip: JJA and DJF Mean Bias (CCSM4 vs CCSM3)



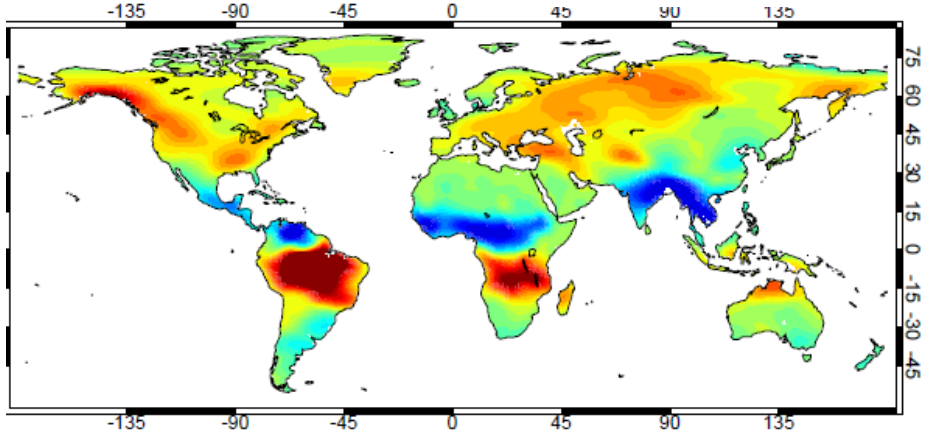


Soil (and snow) water storage (MAM – SON)

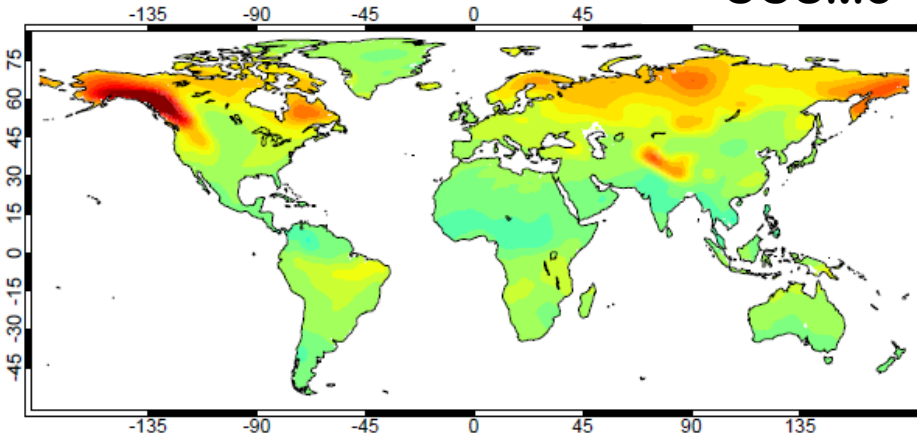
CCSM4



GRACE (obs)



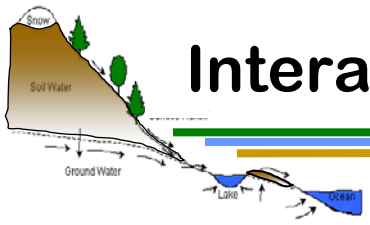
CCSM3



300 200 100 0 -100 -200 -300 (mm)

GRACE satellite measures small changes in gravity which on seasonal timescales are due to variations in water storage

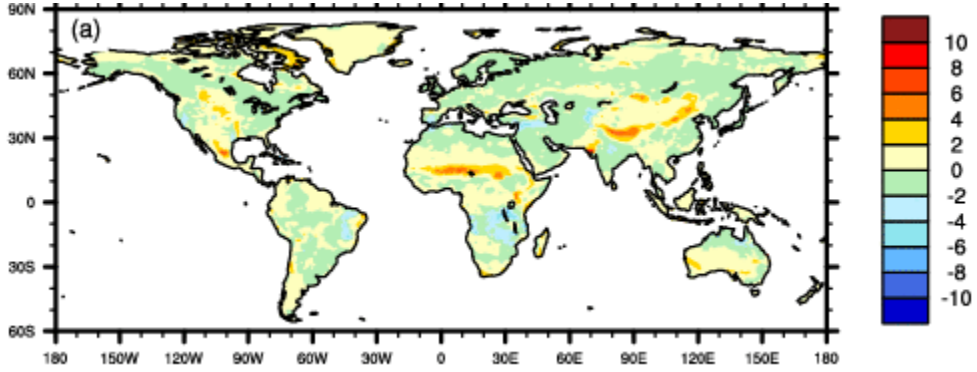
CCSM3 and CCSM4 data from 1870 and 1850 control



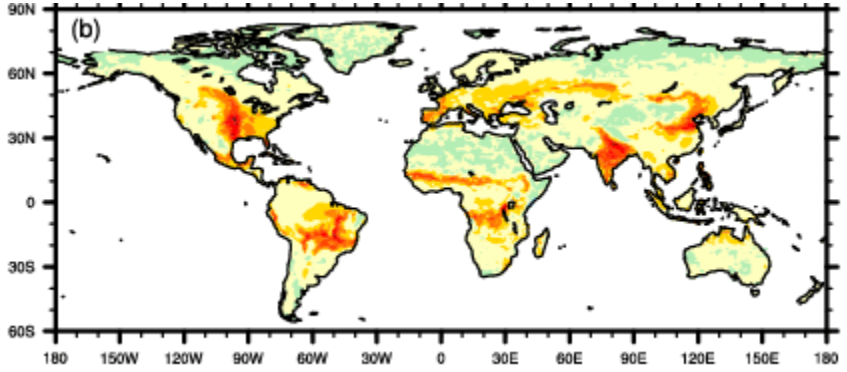
Interannual variability (JJA): Latent Heat Flux (offline)

$\sigma_2 - \sigma_1$

CLM4SP – CLM3.5

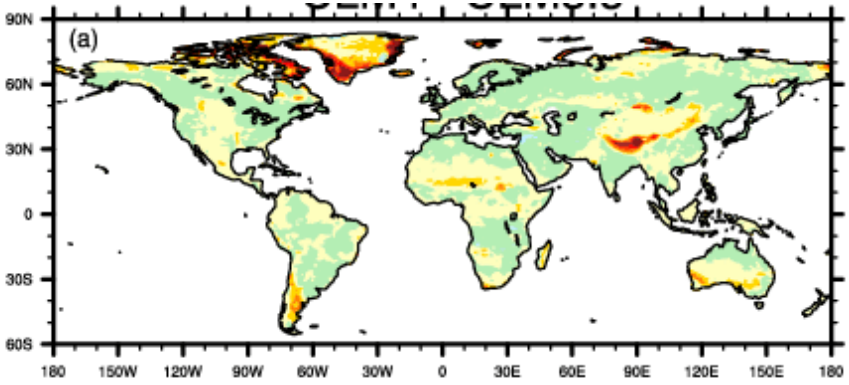


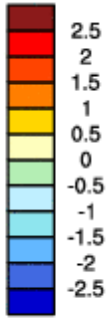
CLM4CN – CLM4SP



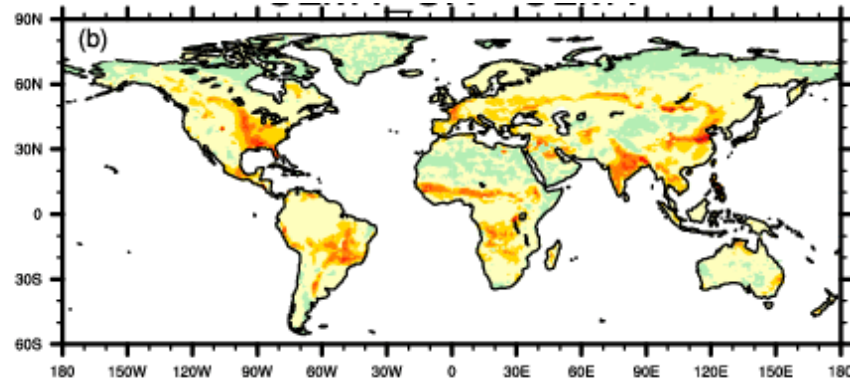
$(\sigma_2 - \sigma_1)/\sigma_1$

CLM4SP – CLM3.5

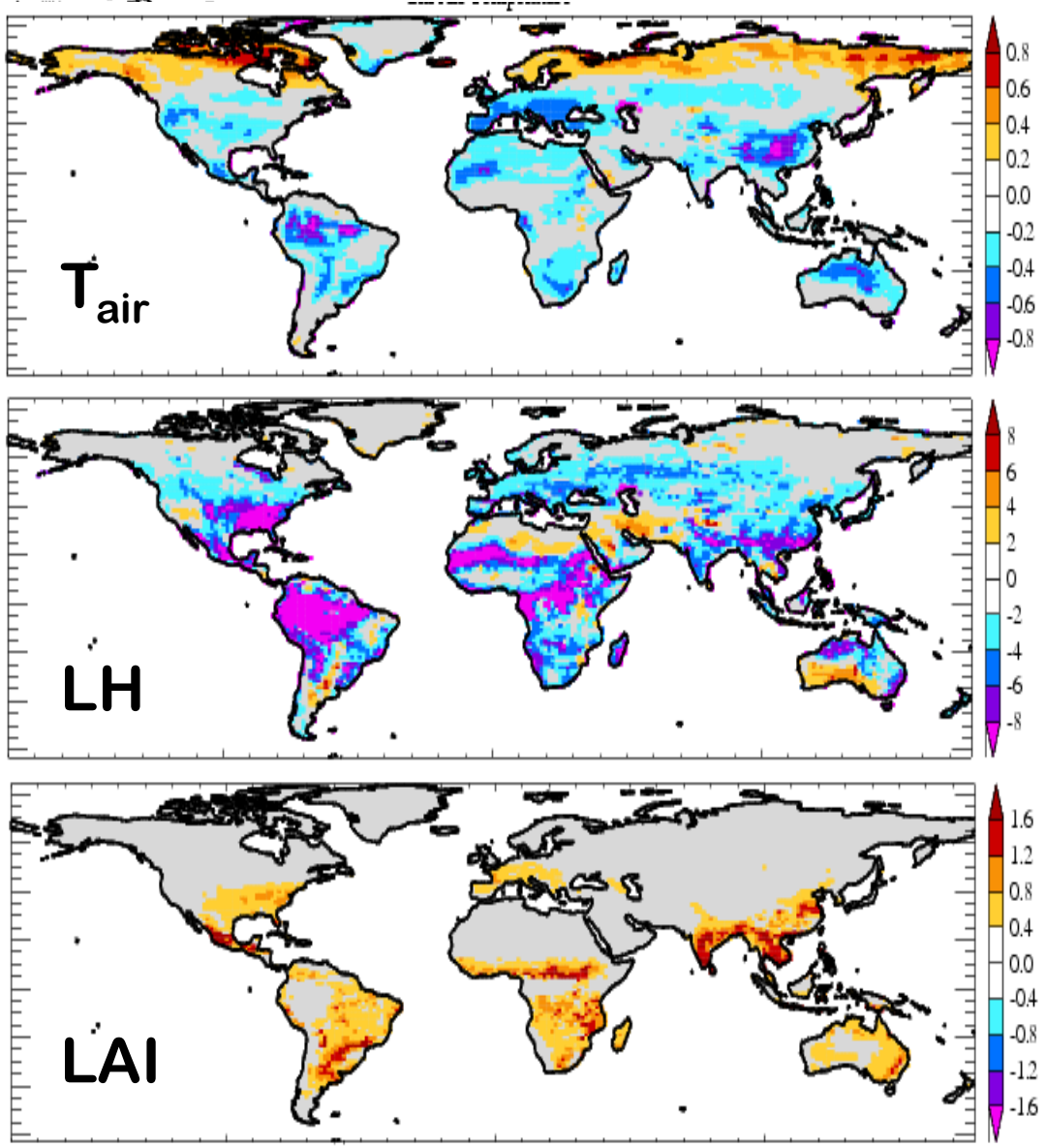




CLM4CN – CLM4SP

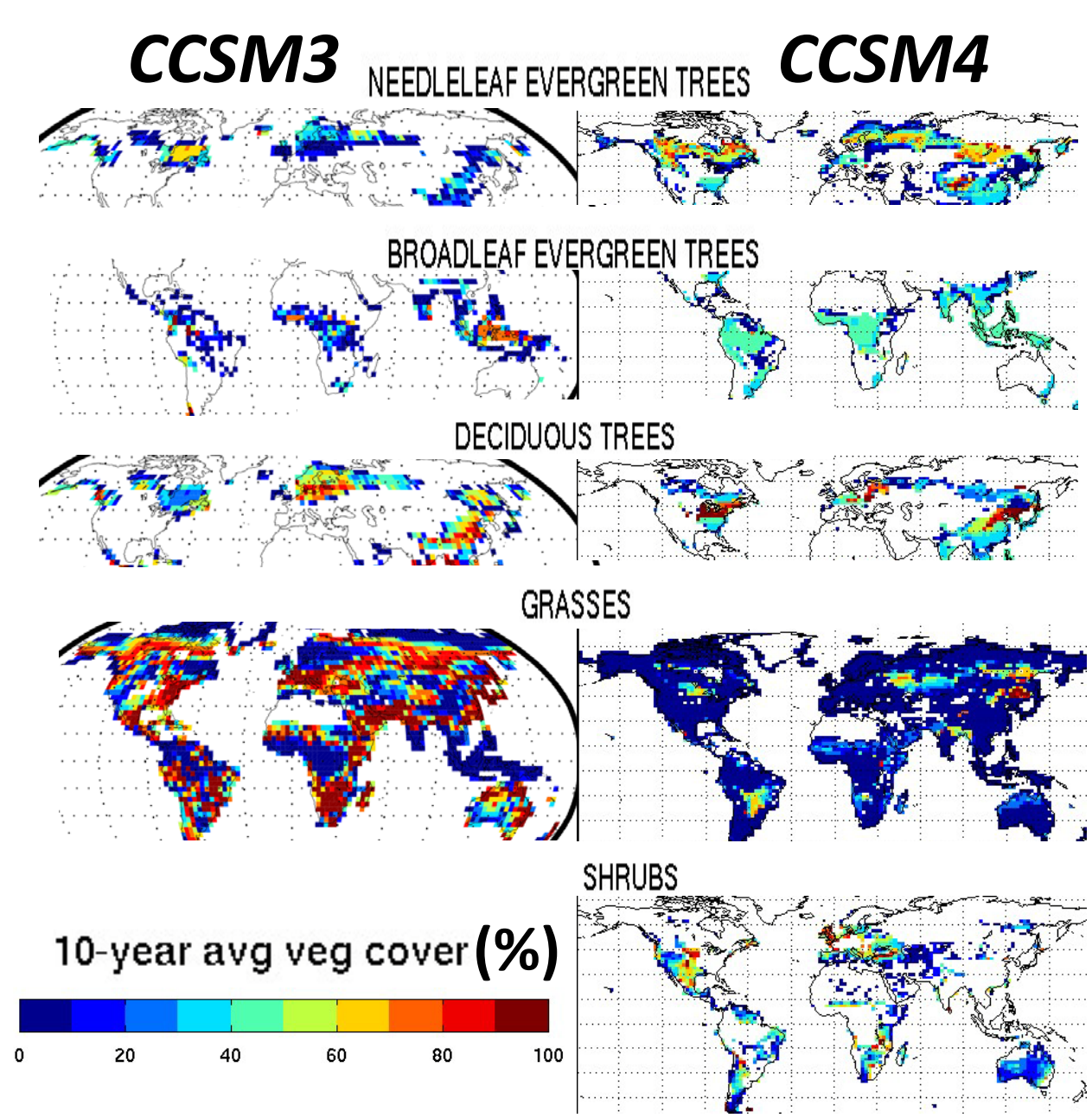


CCSM4 – CCSM3 (St. Dev.)



Despite increase in LAI variability (by definition) lower variability in LH and T_{air} due to wetter model

Planning supplementary 1850 control and 20th century simulation with prescribed MODIS LAI



Bonan & Levis (2006)

Castillo & Levis (in prep)

Dynamic vegetation improvements

Better simulated:

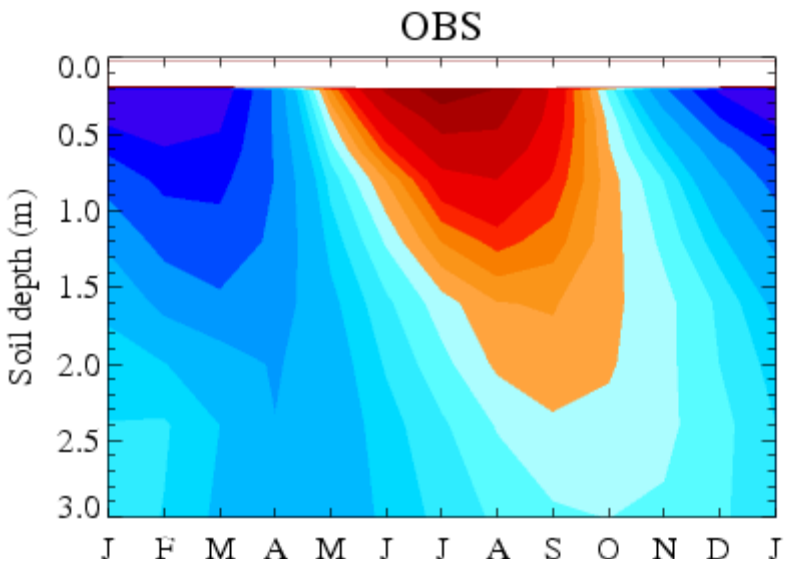
boreal forests
tropical forests
eastern US forests
shrubs: NEW!

Due to:

- improved CLM hydrology
- improved CAM simulation
- merging of DGVM with Thornton's CN … => CNDV
- shrubs (Zeng *et al.* 2008)

Drawback: long spinup associated with CN

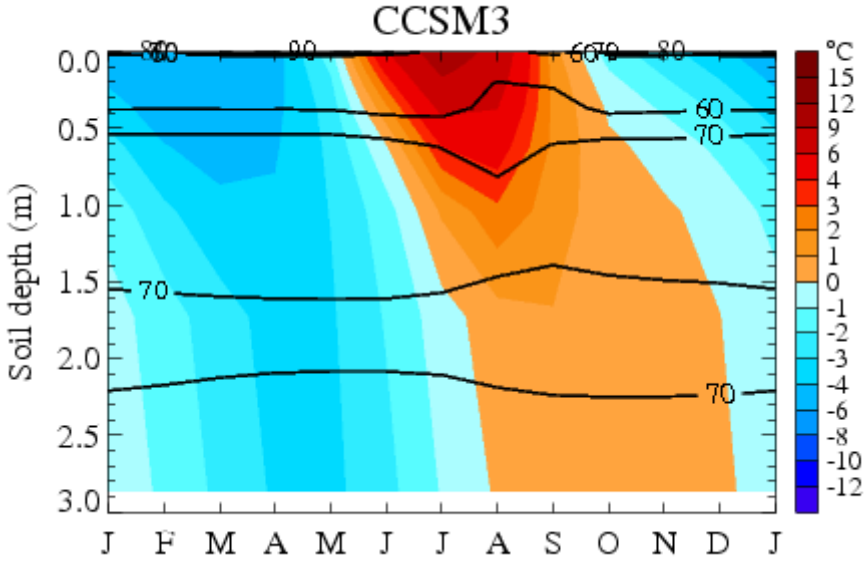
Soil temperature (permafrost)
Siberian soil temperatures

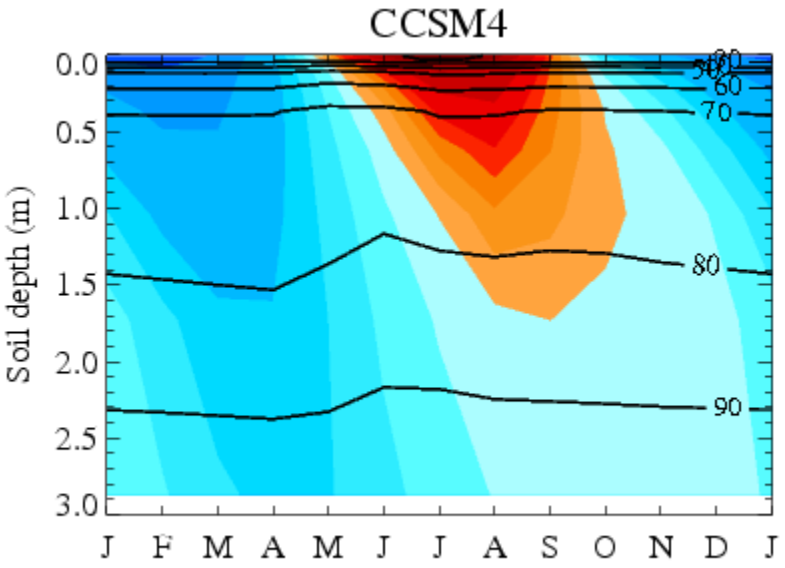


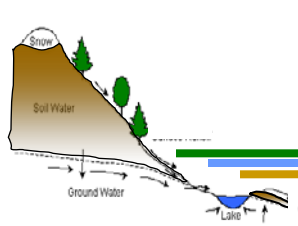
Improved soil temperature due to organic soil but …

(a) too dry near surface (too much drainage through icy layers)

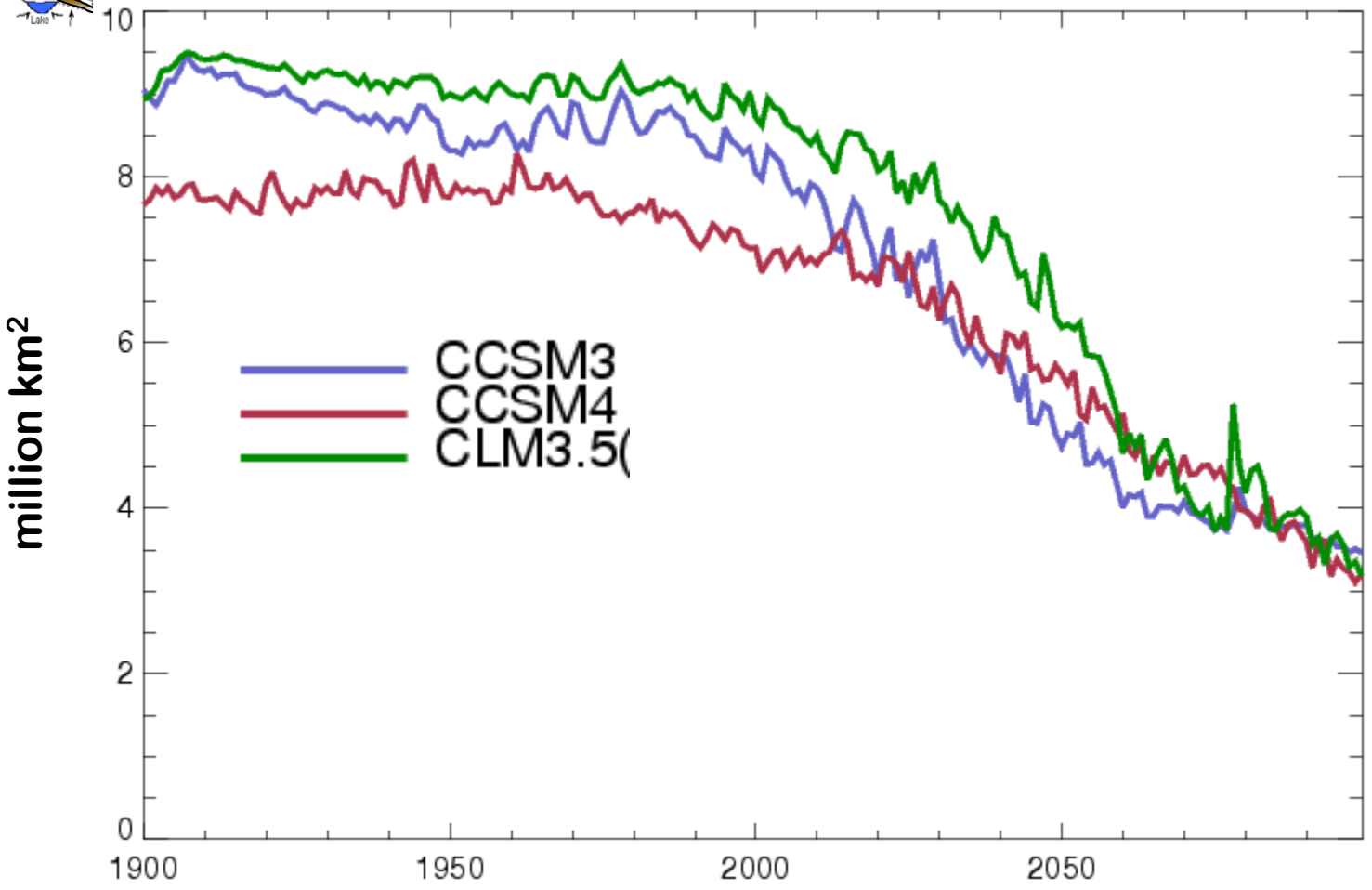
(b) too warm in winter due to excessive snowpack depth (too much snowfall or lack of blowing snow algorithm)

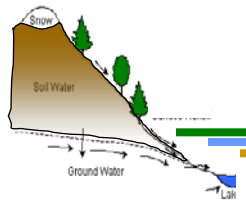




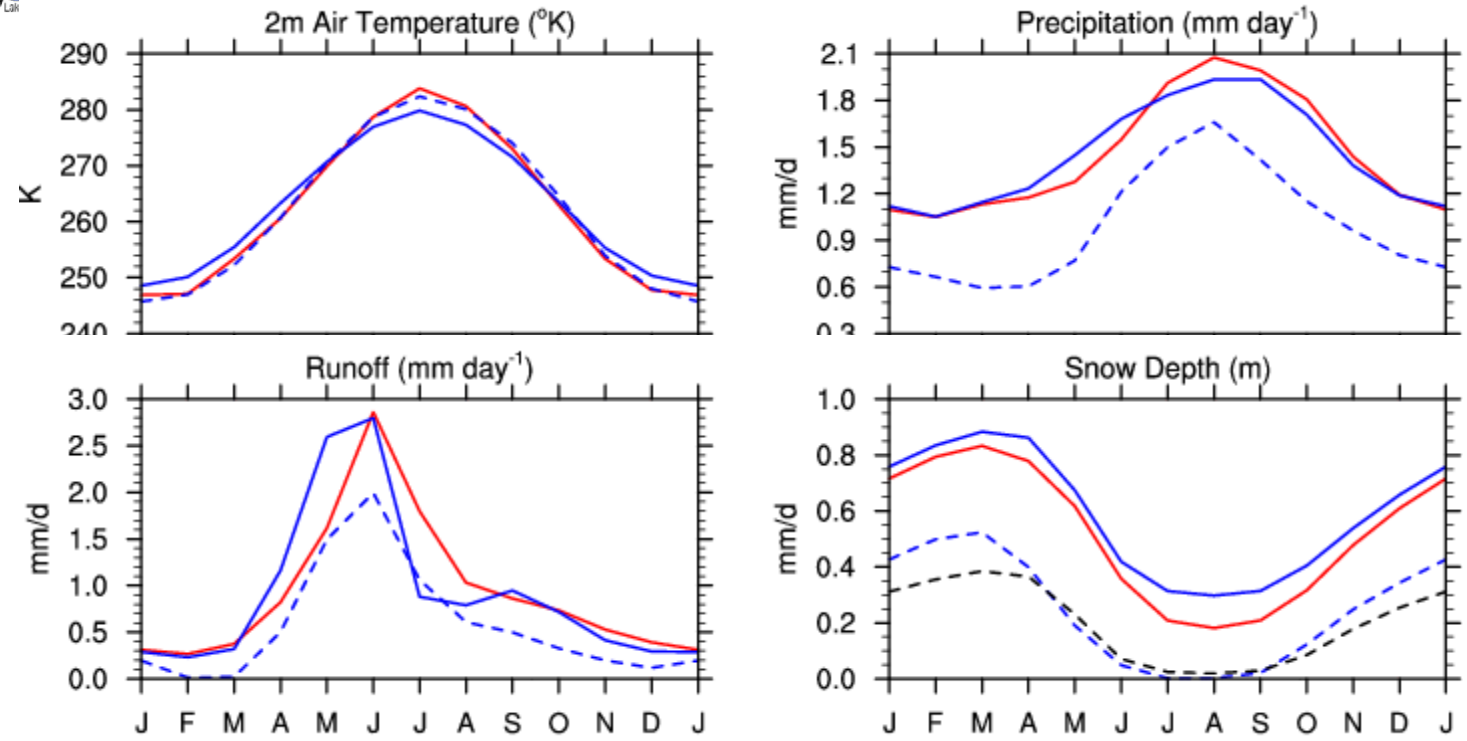


Near-surface permafrost extent





Arctic land climate biases



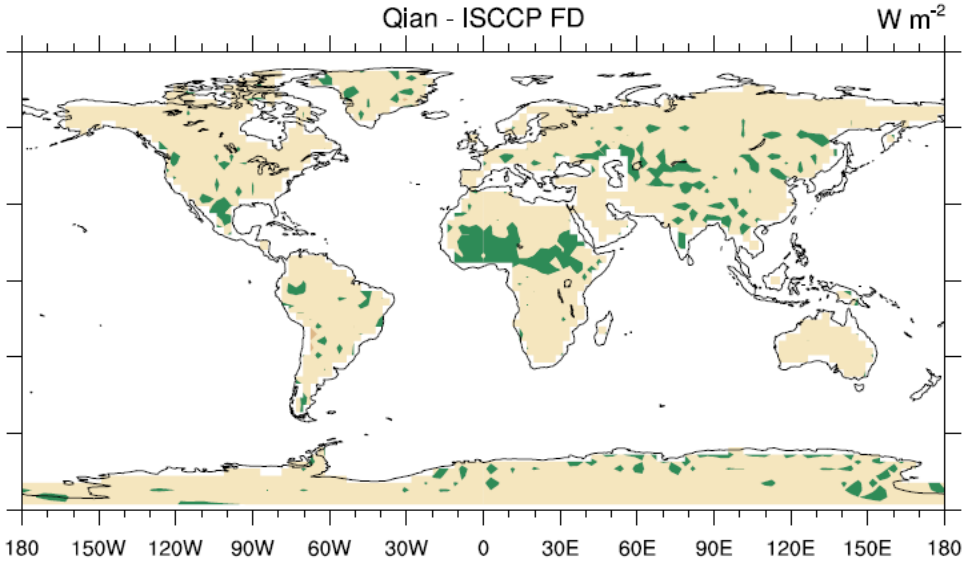
CMC Snow

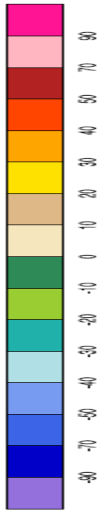
Willmott-Matsuura, GRDC, USAF

CCSM3

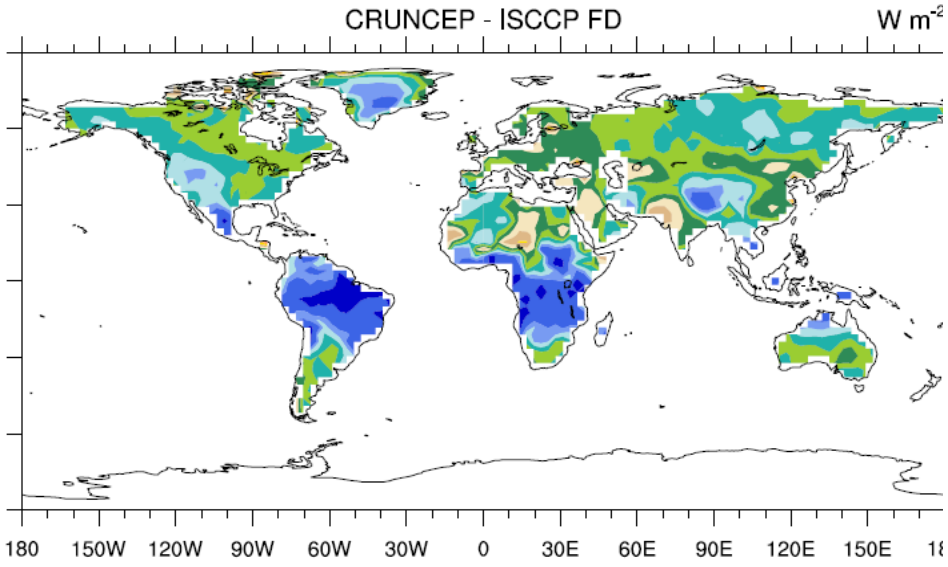
CCSM4

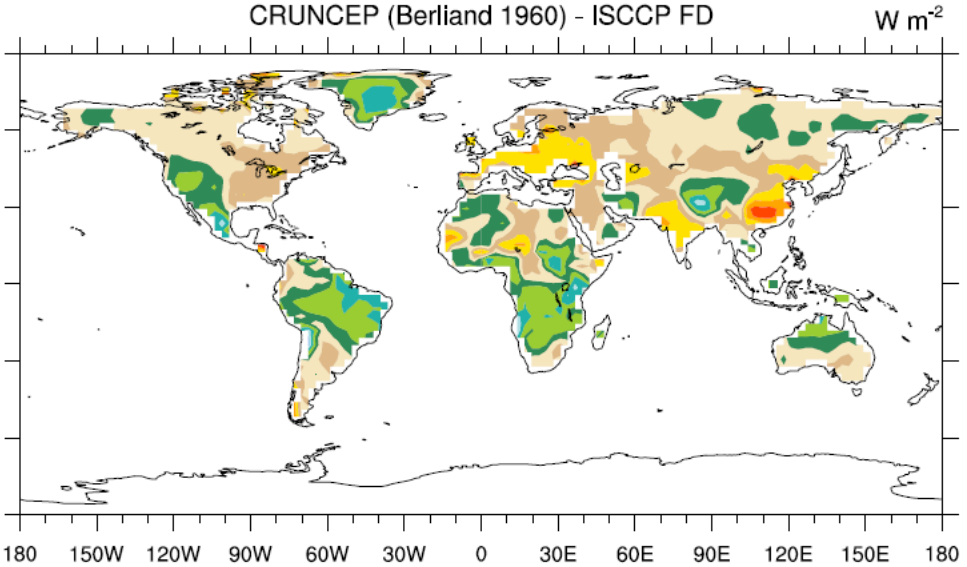
Alternative meteorological forcing datasets



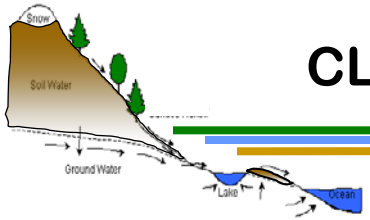


CRUNCEP meteorological forcing dataset used in Global Carbon Project assessments (1900-2009, updatable)



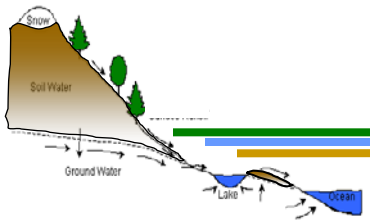


P. Viovy



CLM near-term development activities, CLM4.x (~ 1 year)

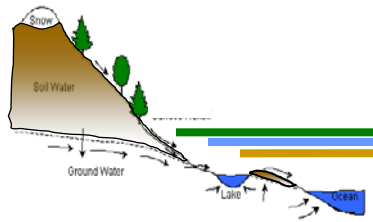
- Crops and irrigation (by end of summer) – still CLM4.0
  - Unified PFT physiology file in netCDF
  - Connections not perfect
- Revised cold region hydrology
  - Impedance factor, root depth for Arctic veg, perched water table
- Gross Primary Productivity
  - Canopy radiation, update photosynthesis model (co-limitation)
- Improved fire algorithm including human triggers and suppression
  - Kloster et al., *Biogeosciences*, 2010
- Revised lake model
- Dynamic landunits
  - Transitions glacier to vegetated, lake area change



CLM medium-term development activities

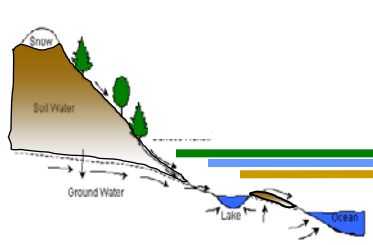
- Methane emissions model
- Prognostic wetland distribution, surface water store
- 3-D canopy radiation
- High resolution and improved River Transport Model

- Ecosystem demography, temporal response to disturbance
- Soil carbon
- Sub-grid soil moisture and snow heterogeneity
- Isotopes (?)
- N_2O emissions
- Riverine transport of nutrients and sediments

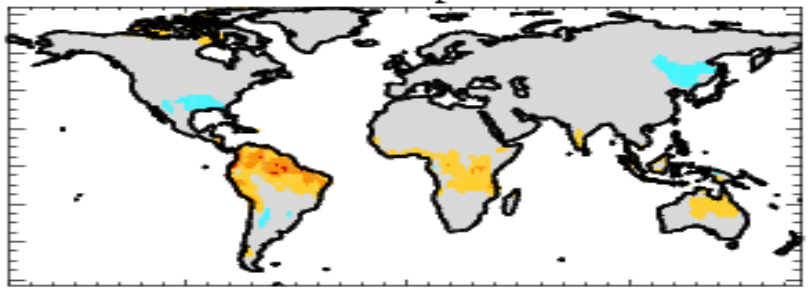


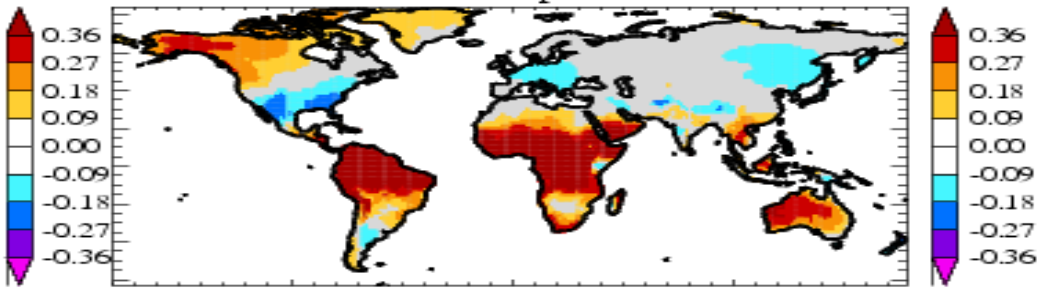
Journal of Climate Special Issue papers

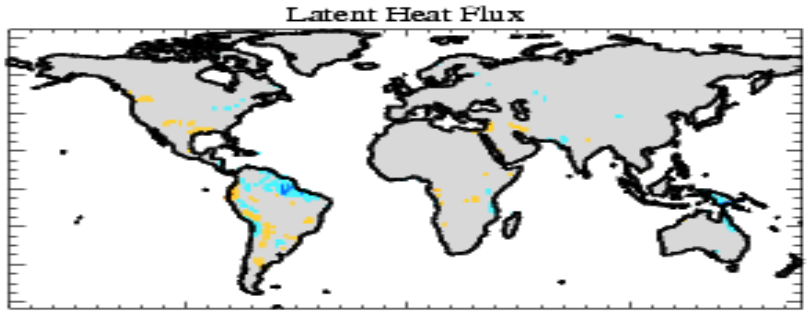
- ***Mean terrestrial climate simulations and transient response over 20th and 21st centuries in CCSM4***
  - ***Lawrence D, Oleson, Swenson, Bonan, Levis, Thornton, Lawrence P, Yang, Flanner, Zeng, …***
- ***The biophysical impacts of landcover and land use change over 20th and 21st centuries***
  - ***Lawrence P, Feddema, Bonan, Oleson, Lawrence D, …***
- ***Land-atmosphere interactions across several generations of CAM/CLM***
  - ***Lawrence D, Neale, Oleson, …***
- ***Urban climate in the 21st century***
  - ***Oleson, Bonan, Feddema, …***
- ***Dynamic Vegetation in CESM1***
  - ***Levis, Bonan, …***

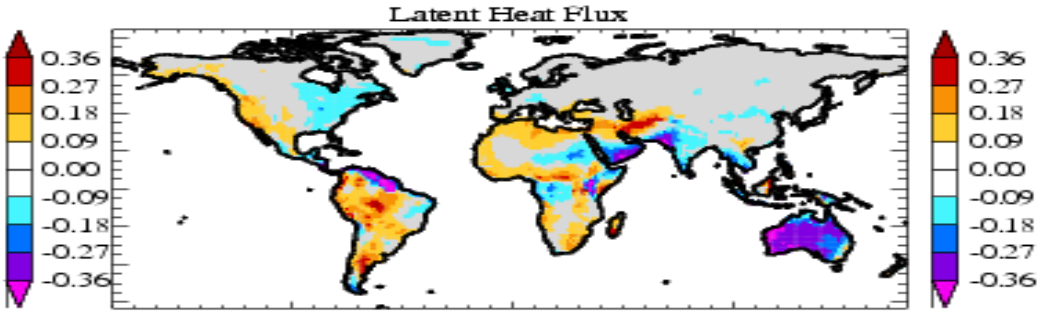


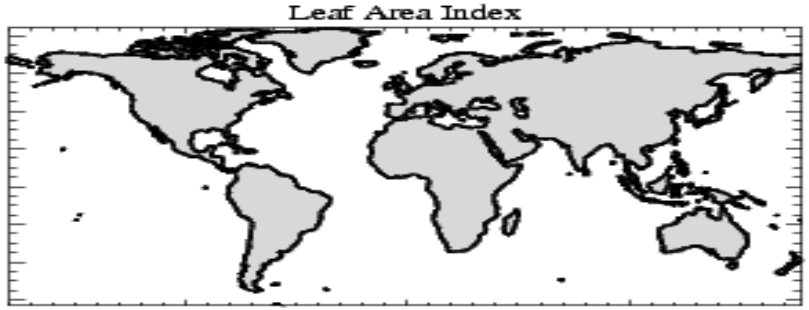
Nino 3.4 correlation with various fields

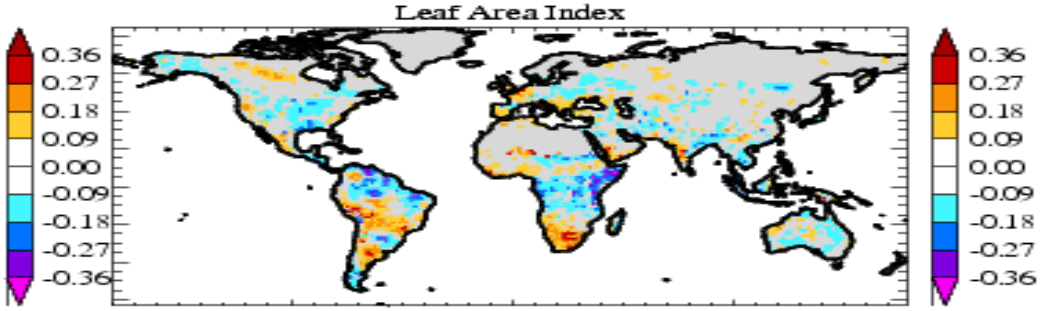


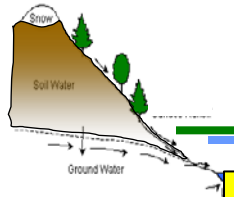








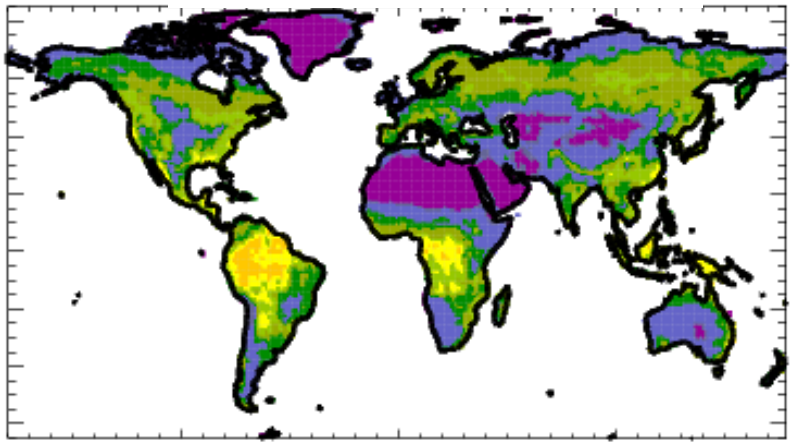


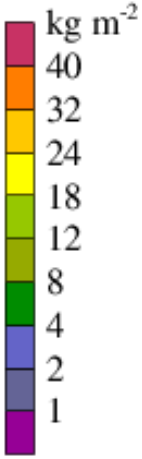


Land carbon stock biases
(Carbon fluxes simulated better than stocks)

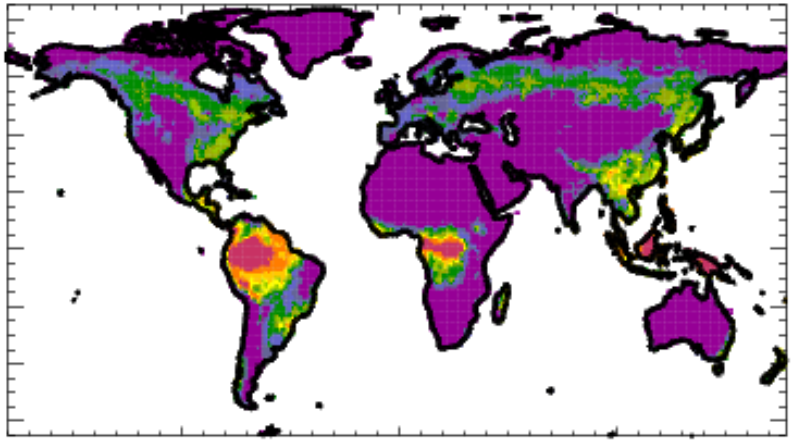
Vegetation Carbon

Olson (obs, high est.)



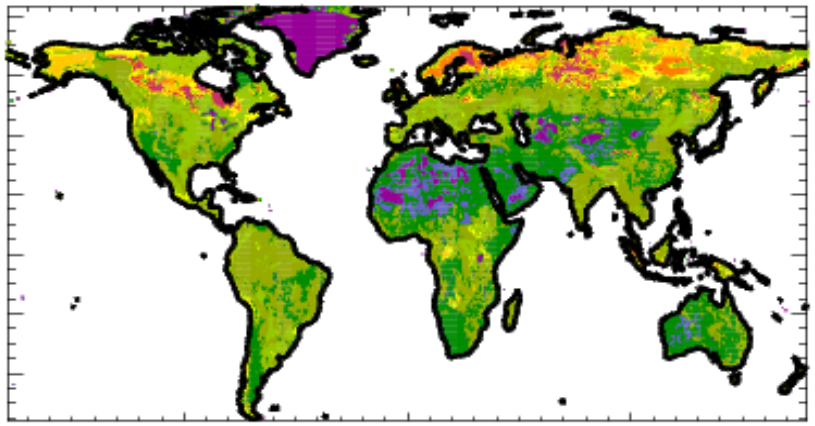


CLM4CN

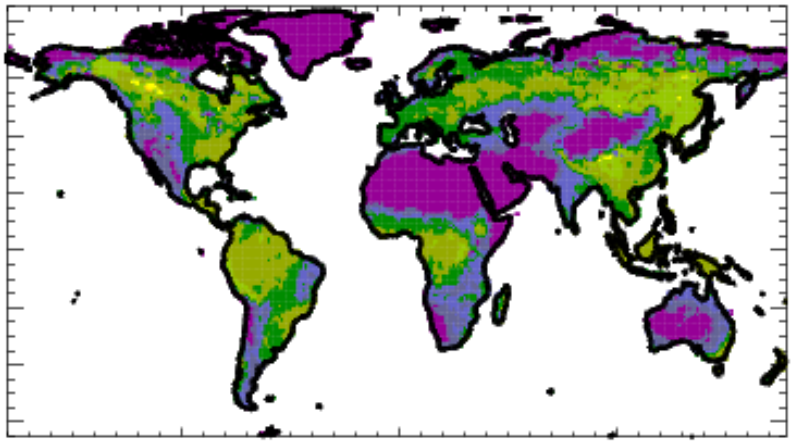


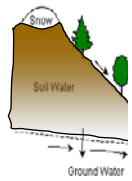
Soil Carbon

IGBP Soil carbon content (0-1m)

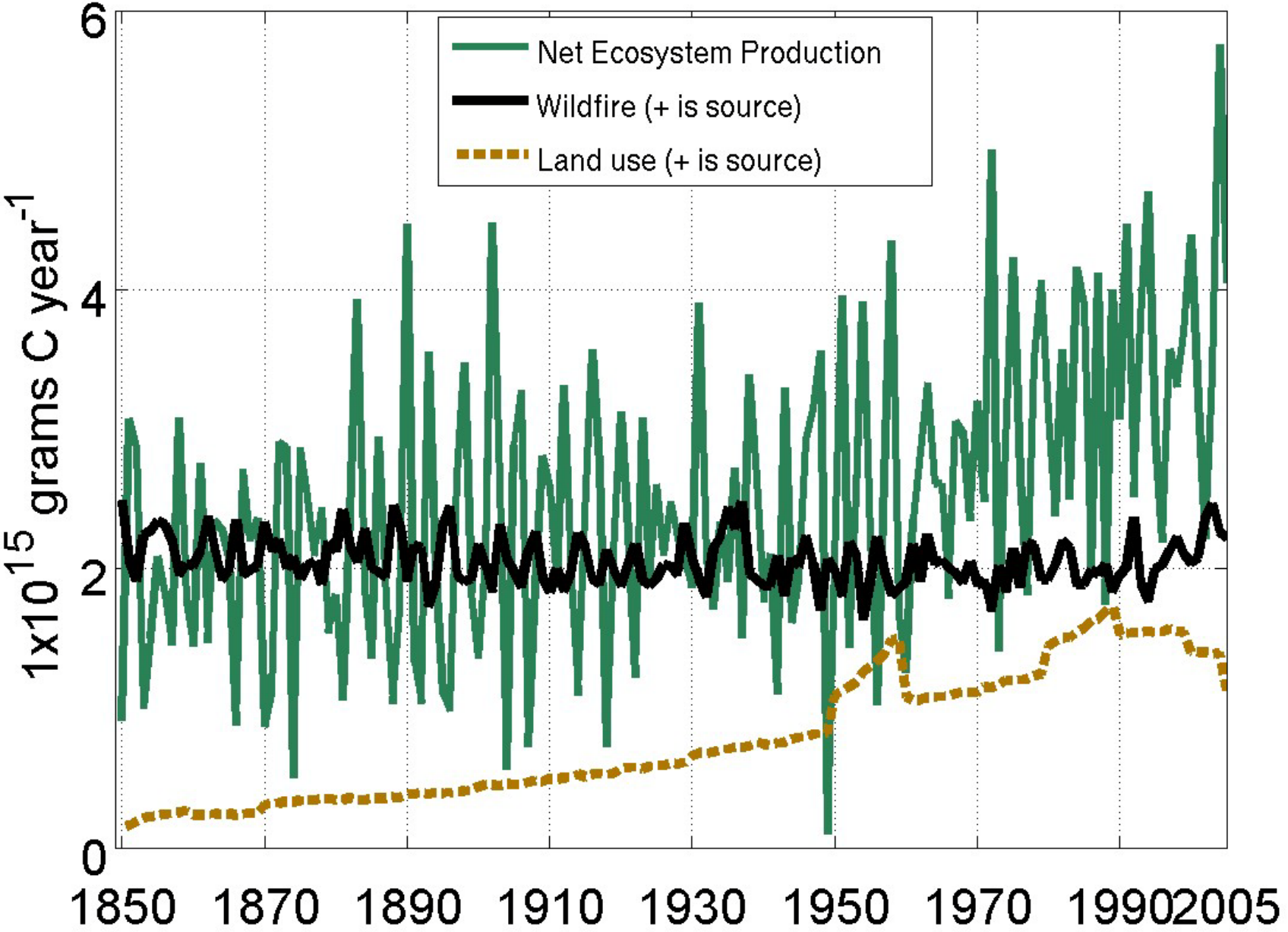


CLM4CN



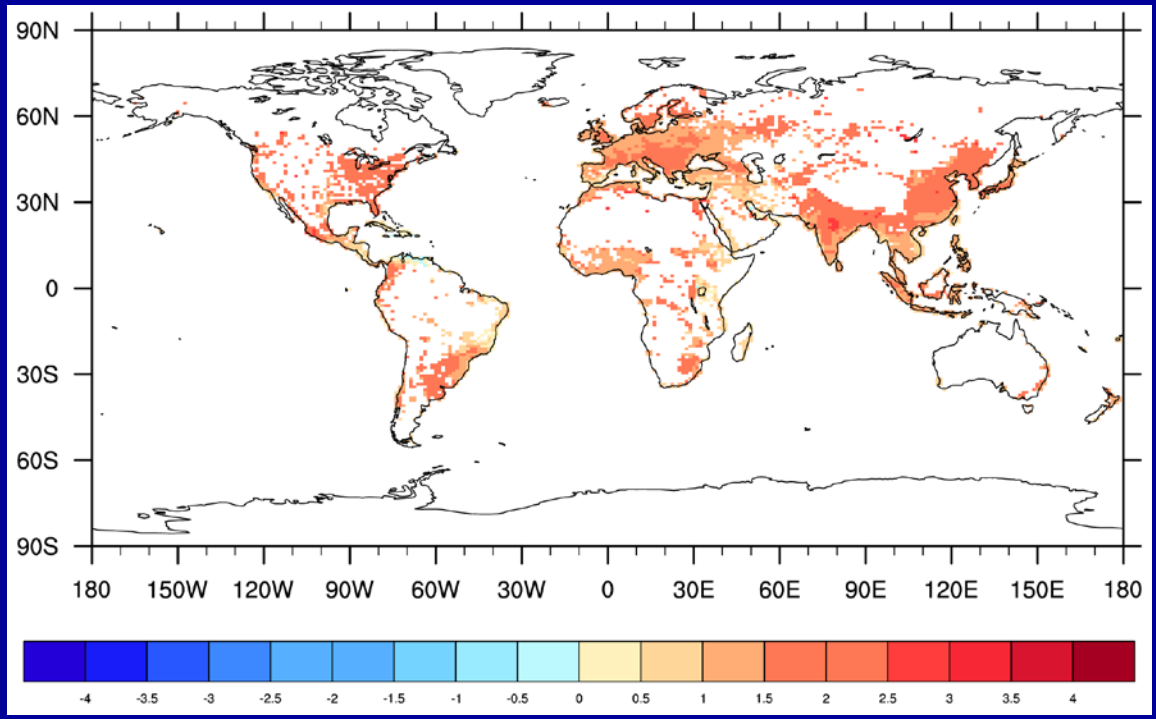


LAND TOTAL CARBON FLUXES



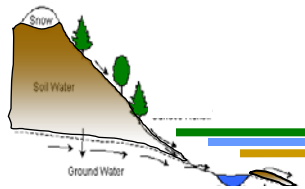
Urban Modeling in CCSM4

Present day Urban Heat Island (UHI) simulated by Community Land Model Urban (CLMU) (°C)



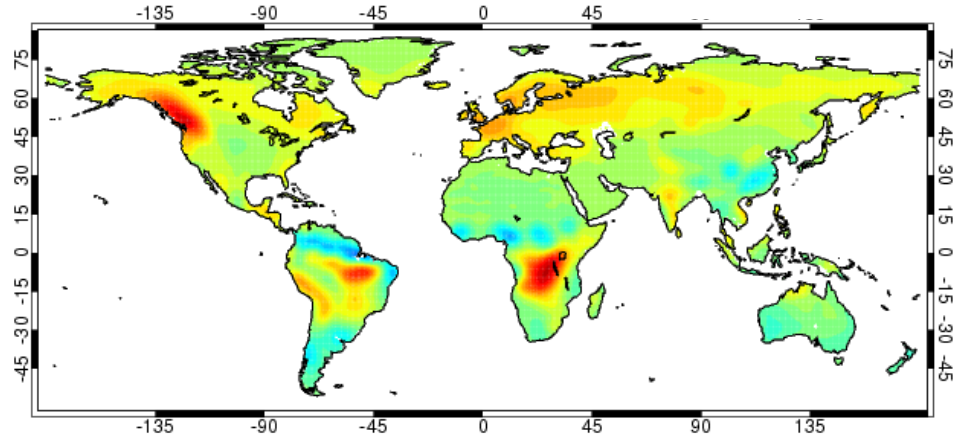
- The Community Land Model (CLM4) includes a new capability to represent urban processes, by incorporating a single-layer urban canopy model.
- Global simulation of the urban environment, in particular the temperature of cities.
- The UHI is a term that describes the fact that urban areas are generally warmer than surrounding rural areas.
- Modeled UHI ranges from near-zero up to 4°C with spatial and seasonal variability controlled by urban to rural contrasts in energy balance.

Oleson, K.W., G.B. Bonan, J. Feddema, M. Vertenstein, C.S.B. Grimmond, 2008a, *J. Appl. Meteor. Climatol.*
Oleson, K.W., G.B. Bonan, J. Feddema, M. Vertenstein, 2008b, *J. Appl. Meteor. Climatol.*

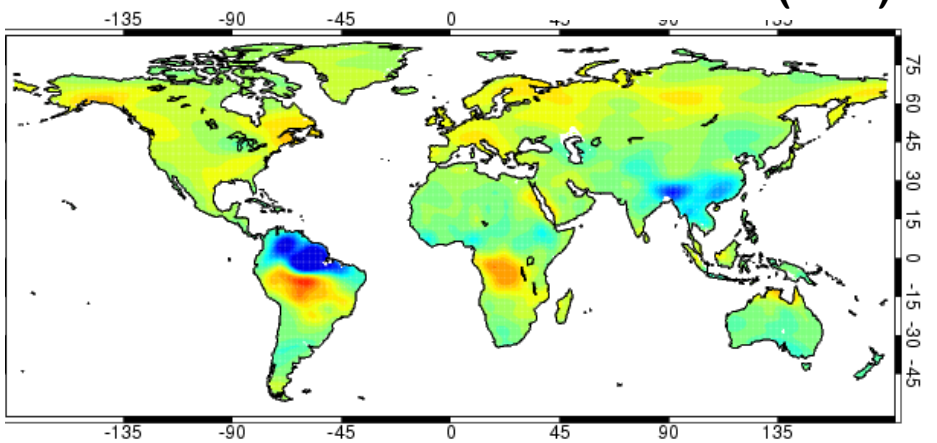


Soil (and snow) water storage (DJF – JJA)

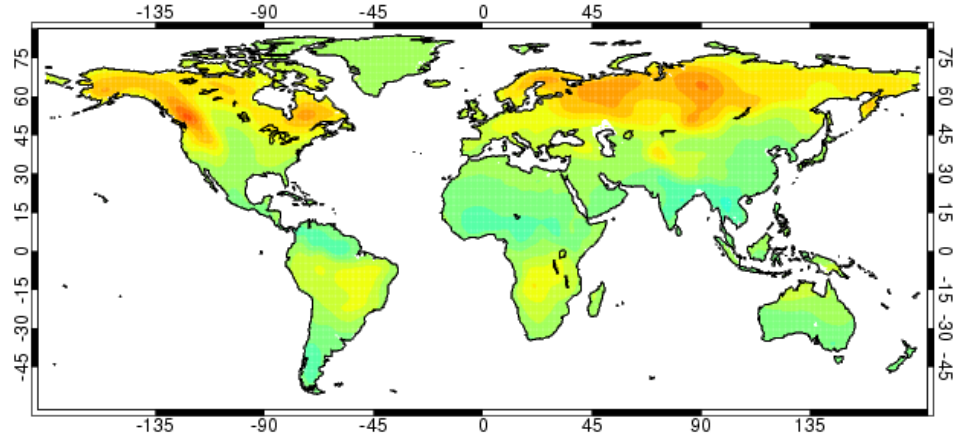
CCSM4



GRACE (obs)



CCSM3



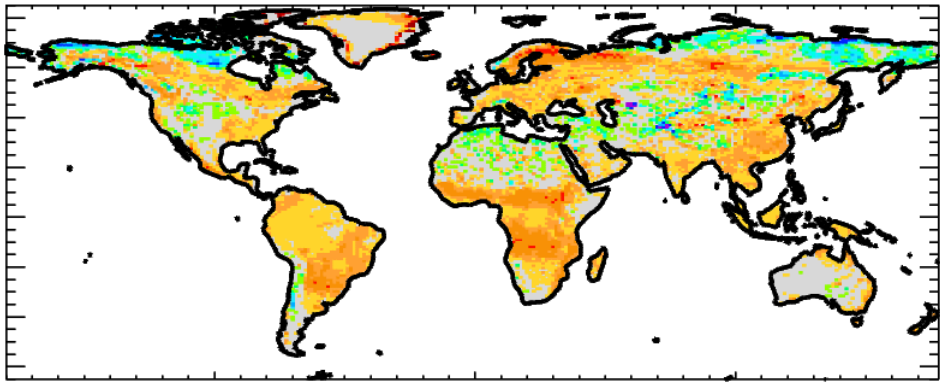
300 200 100 0 -100 -200 -300 (mm)

GRACE satellite measures small changes in gravity which on seasonal timescales are due to variations in water storage

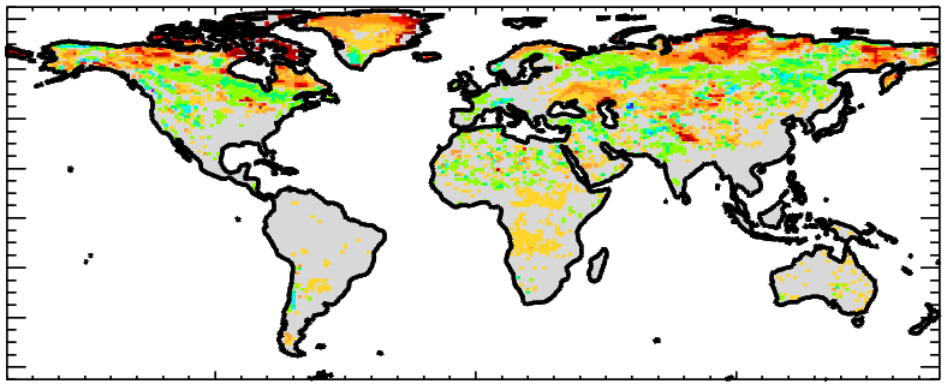
CCSM3 and CCSM4 data from 1870 and 1850 control

Surface albedo (CLM offline compared to MODIS)

CLM3.5 – Obs



CLM4SP – Obs



	Bias (%)		RMSE (%)	
Model	**Snow-free**	**Snow depth> 0.2m**	**Snow-free**	**Snow depth > 0.2m**
CLM3.5	**2.7**	**-5.0**	**4.1**	**11.9**
CLM4SP	**0.4**	**2.9**	**2.0**	**13.2**

Note: MODIS albedo biased high for snow at high zenith angle
(Wang and Zender, 2010)