Plan and Preliminary Progress on Developments of the CLM Hydrologic Component

L. Ruby Leung, Maoyi Huang, Mark Wigmosta, Bill Gustafson, Yinghai He, Andre Coleman, Teklu Tesfa

Pacific Northwest National Laboratory

CESM Land Model Working Group

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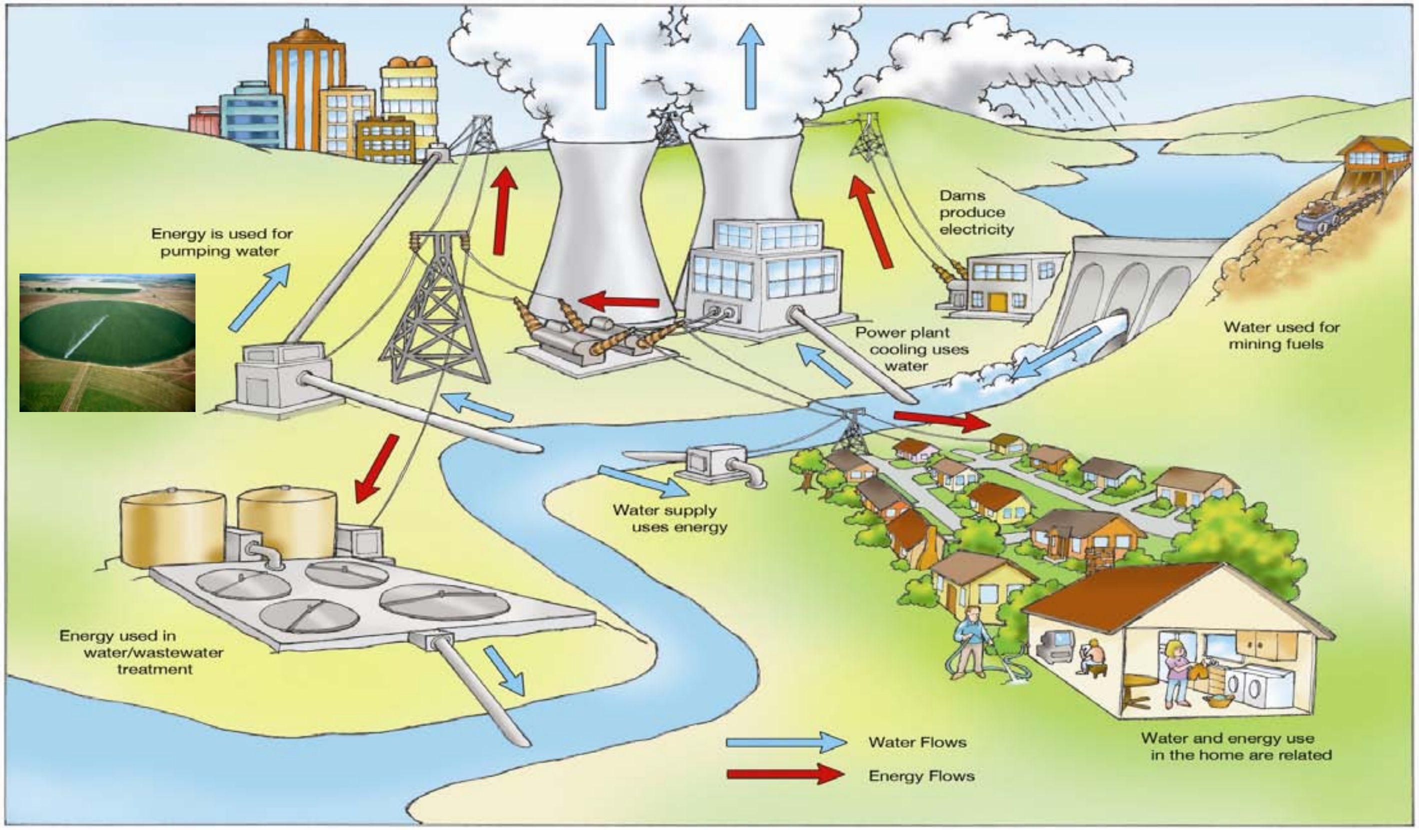
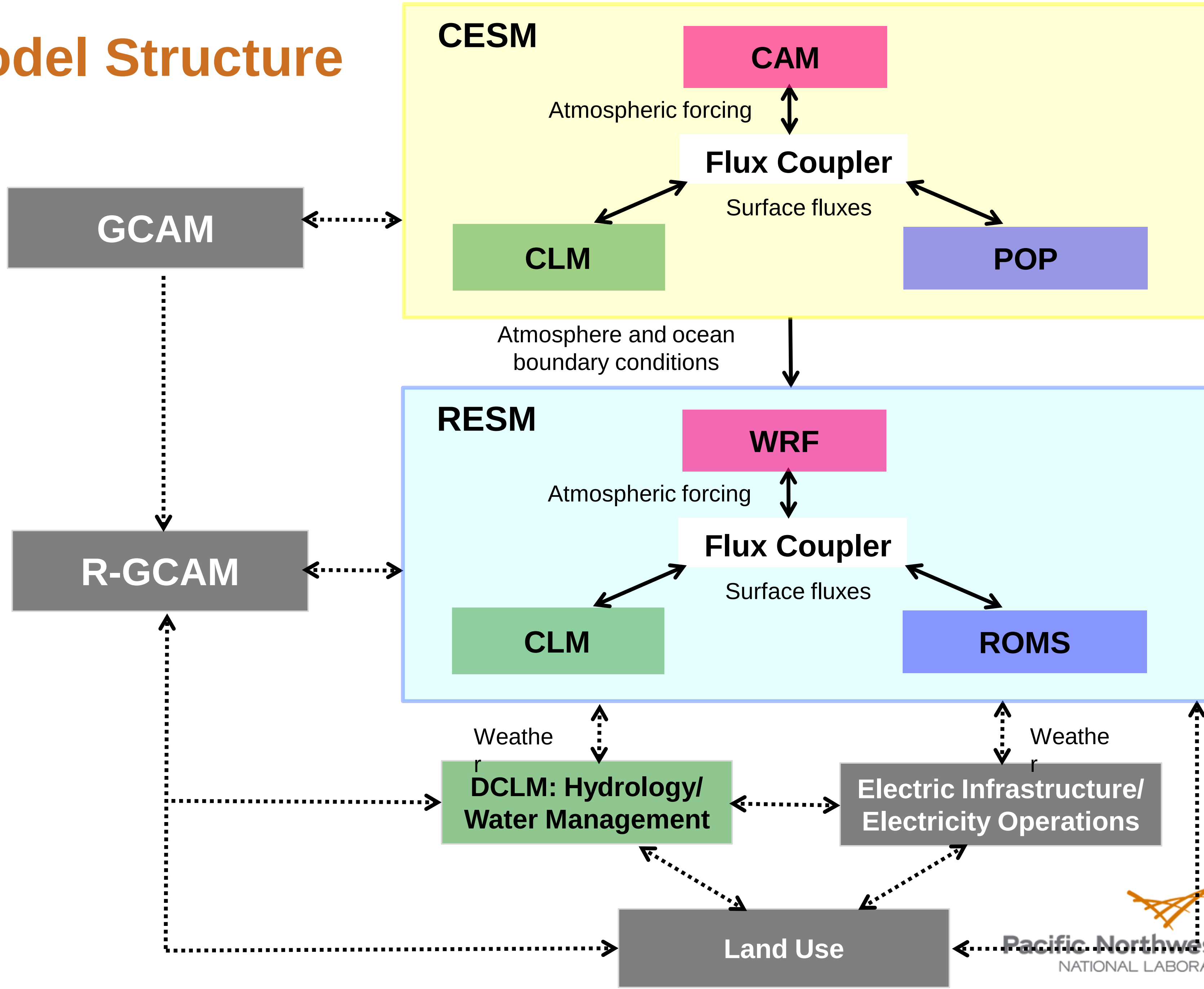
Representing Human-Earth System Interactions

- Predicting future climate changes and evaluating impacts of alternative mitigation and adaptation strategies require significant improvement in the accuracy of Earth system models and more complete representations of human systems
- Water-energy-land use interactions require high spatial resolutions



Model Structure



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CLM development tasks

- CLM will provide a consistent framework for modeling biophysics, soil hydrology, and terrestrial BGC processes across scales - CESM, RESM, spatially explicit models
  - Couple WRF-CLM-ROMS as the RESM
  - Add VIC hydrology to CLM
  - Include groundwater table dynamics
  - Include hydraulic redistribution

- Develop distributed extensions of CLM for more spatially explicit modeling of hydrology (DCLM)
  - Develop fully distributed and semi-distributed capability in CLM
  - Develop CLM input data for high resolution modeling

- Water management and irrigation will be added to CLM
  - Represent irrigation for crops in CLM and DCLM
  - Represent water management in CLM and DCLM

Merging of CLM4 and VIC

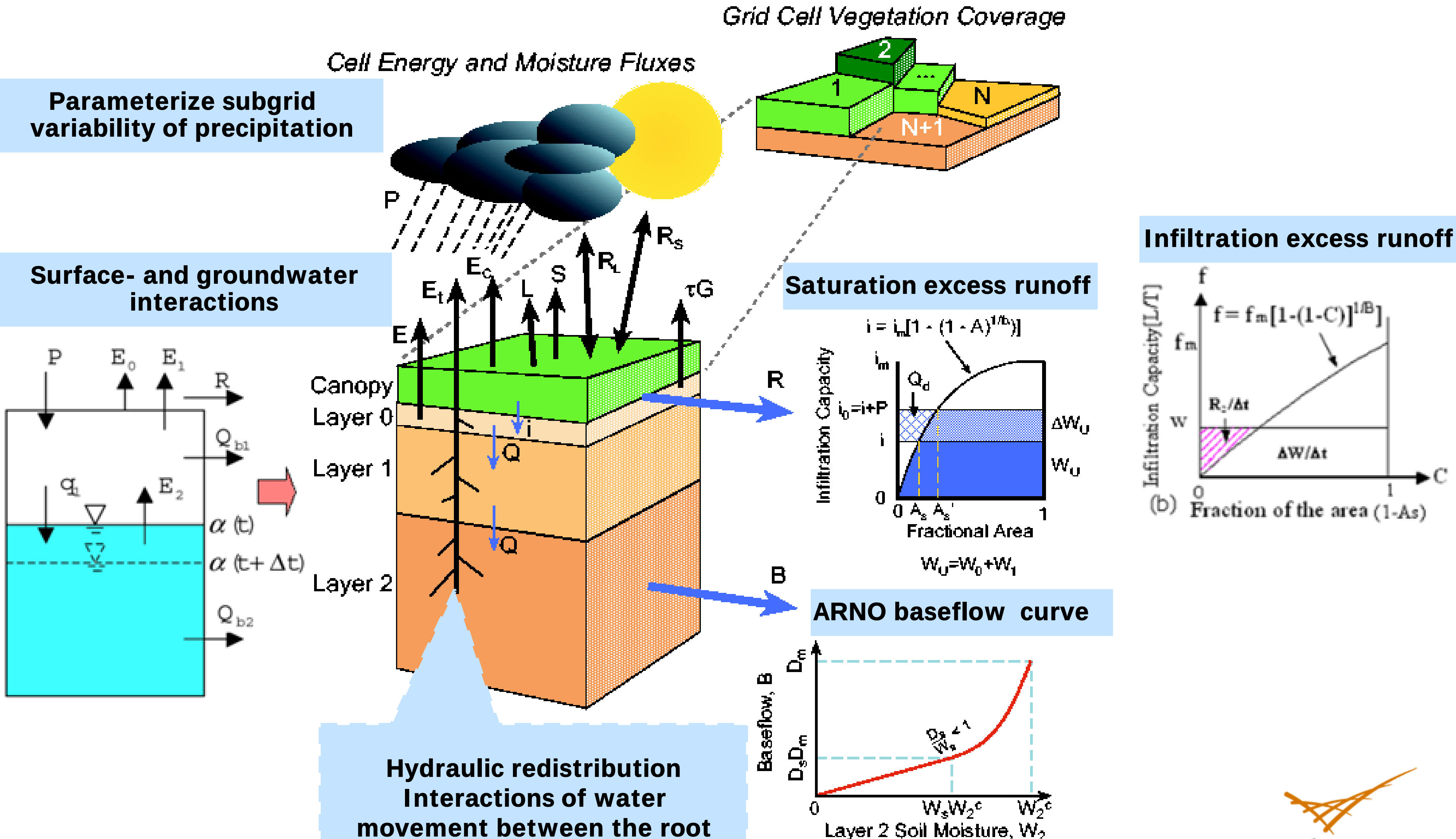
Parameterize subgrid variability of precipitation

Surface- and groundwater interactions

Saturation excess runoff

Infiltration excess runoff

ARNO baseflow curve



Hydraulic redistribution Interactions of water movement between the root system and soil porous media

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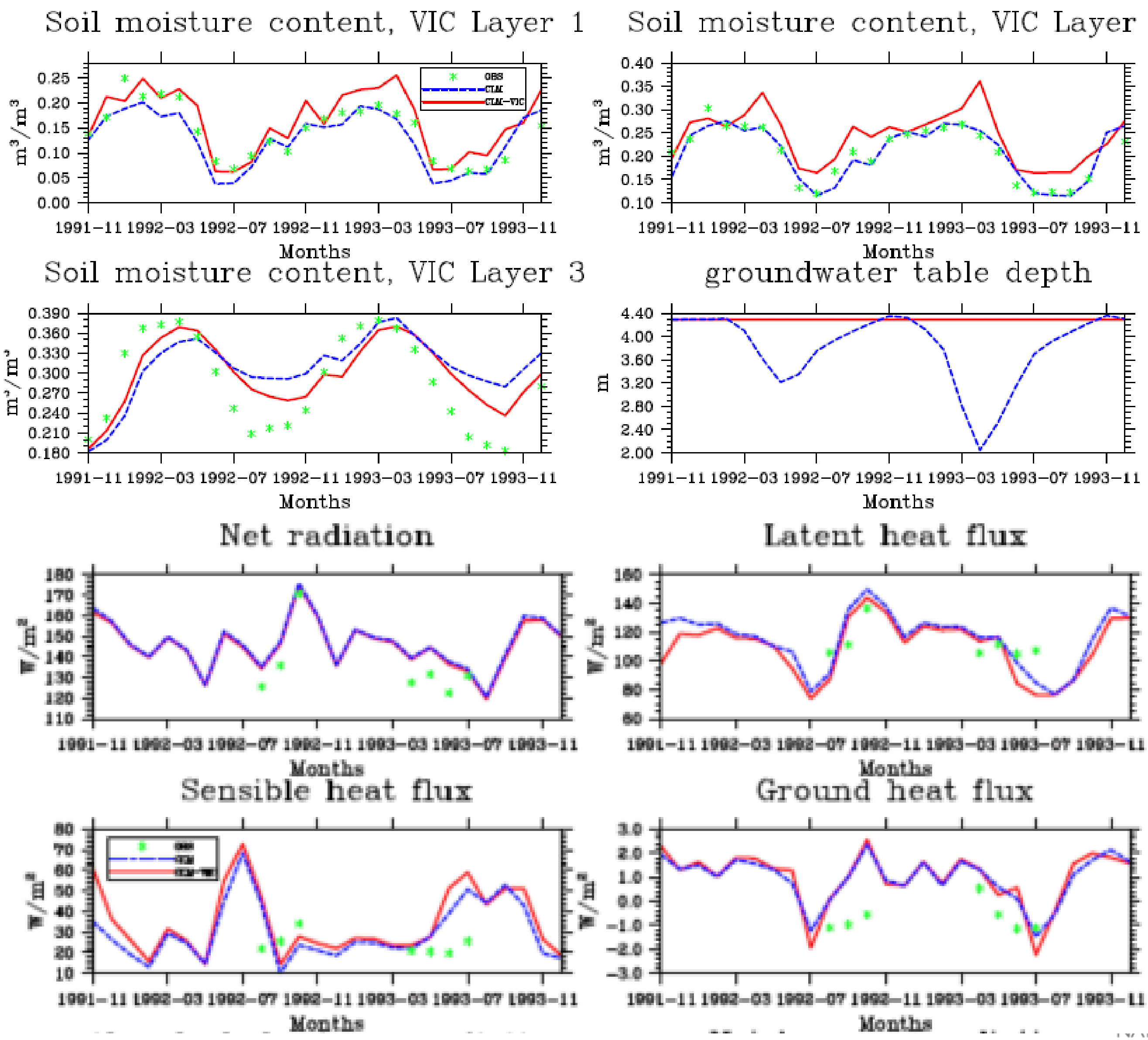
Compare CLM and CLM-VIC at flux tower sites

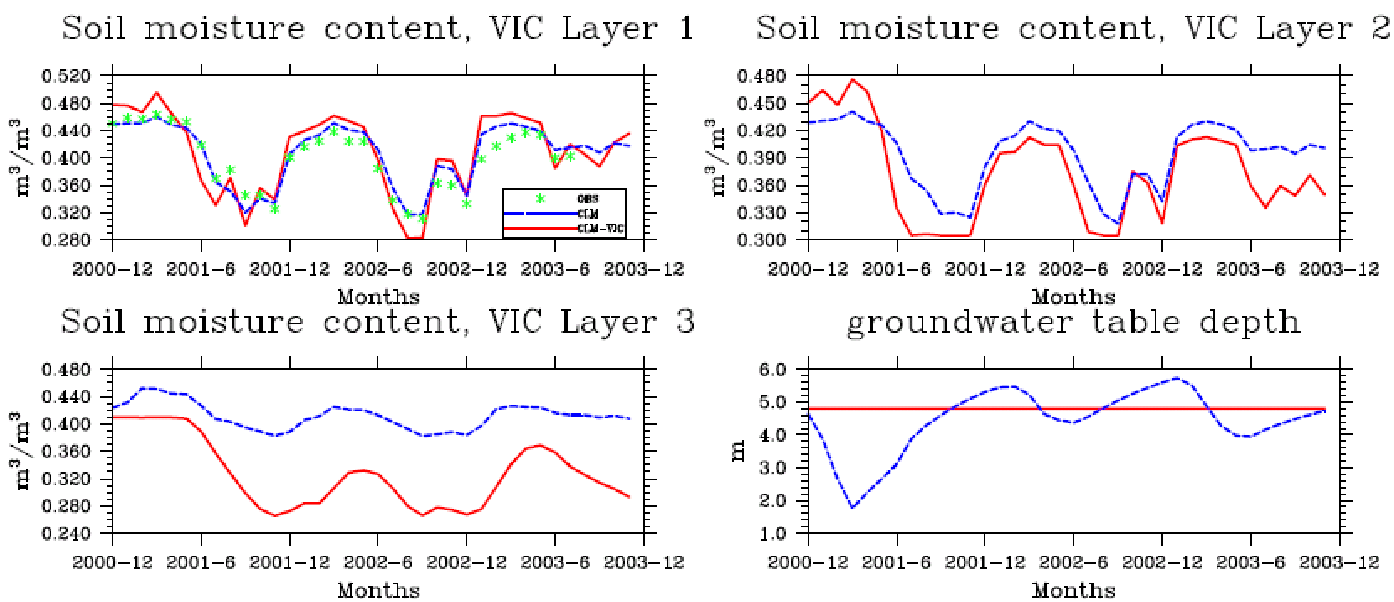
- Currently focus on the impact of model structure, rather than parameter values, on simulations – VIC parameters fixed across sites

Site	Lon	Lat	vegetation	Source of site phenology
ABRACOS	-61.90	-10.10	Tropical rainforest	CLM4 input data
LBA-KM67	-54.96	-2.86	Tropical rainforest (primary)	LBA-MIP
LBA-KM83	-54.97	-3.02	Tropical rainforest (logged)	LBA-MIP
Morgan Monroe	-86.41	39.32	Deciduous Forest	MODIS
Tonzi	-120.97	38.43	Savanna (43% tree, 57% grass)	MODIS (tree), ground measurements (grass)
ARM-SGP	-97.48	35.54	Cropland (wheat and corn rotation)	MODIS
Goodwin Creek	-89.97	34.25	Grassland	MODIS

ABRACOS


Soil moisture content, VIC Layer 1
Soil moisture content, VIC Layer 2
Soil moisture content, VIC Layer 3
groundwater table depth
Net radiation
Latent heat flux
Sensible heat flux
Ground heat flux
OBS
CLM
CLM-VIC
m³/m³
m
W/m²
Months
1991-11 1992-03 1992-07 1992-11 1993-03 1993-07 1993-11

LBA-KM83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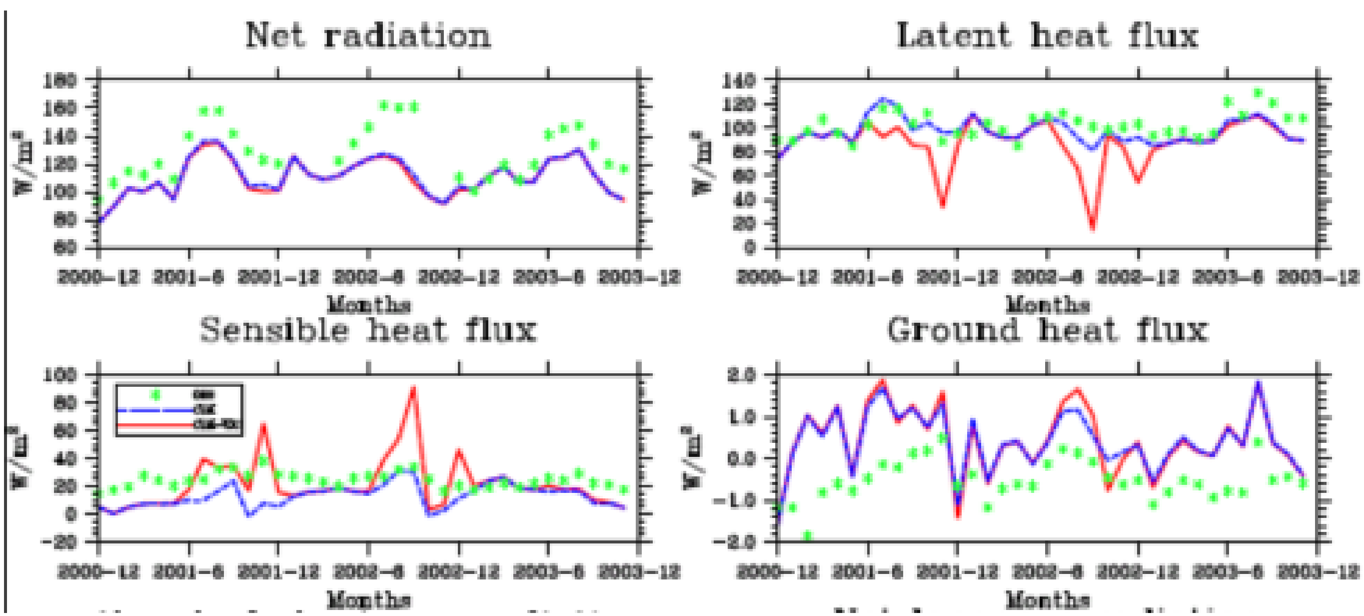
Net radiation
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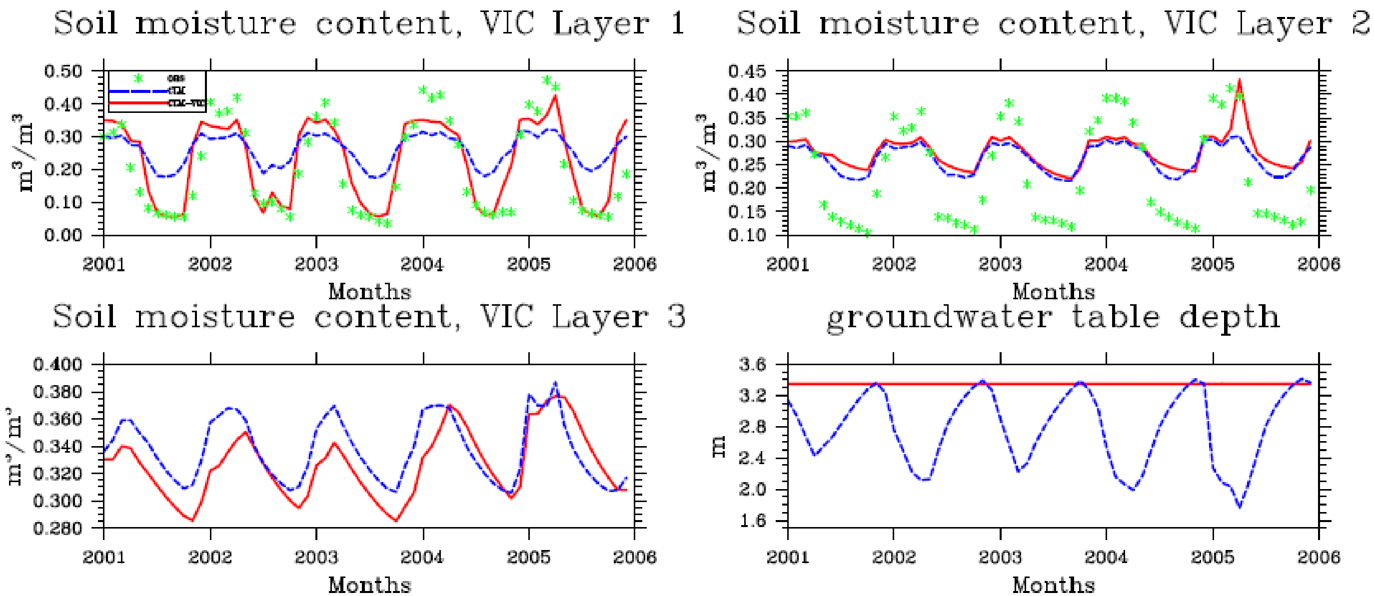
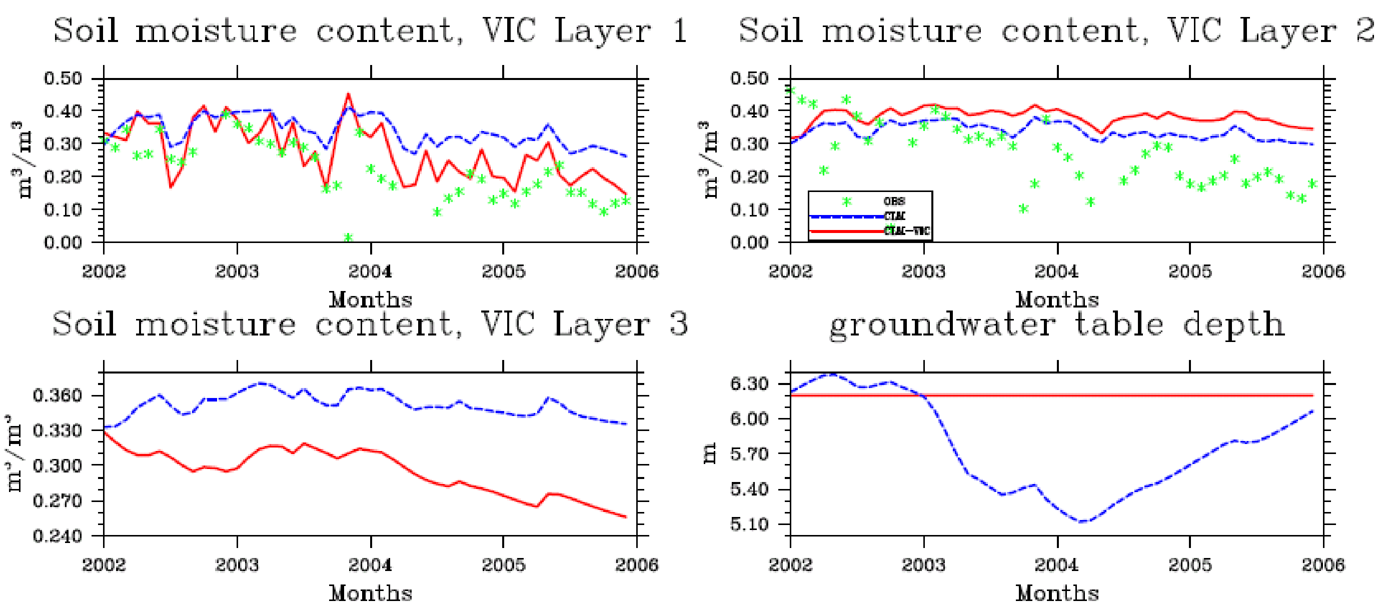
Tonzi



ARM-SGP



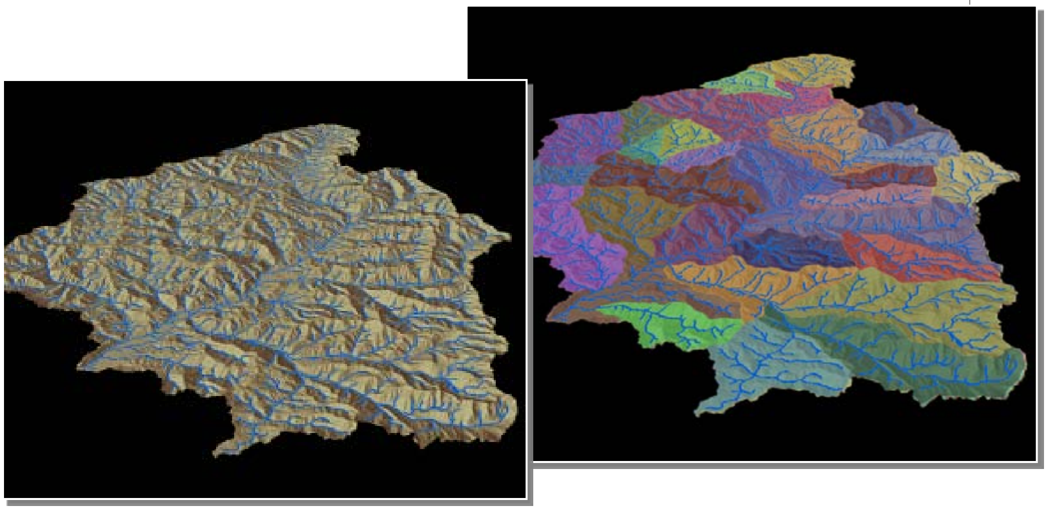
Preliminary Conclusions

- VIC surface runoff parameterization (i.e., the VIC curve) produces more dynamic saturated fraction at the land surface and therefore more dynamic surface flow and variations in soil moisture content close to the surface – important for simulating ET at sites with short or no vegetations (e.g. Tonzi, ARM-SGP)

- Representing a shallow unconfined aquifer seems to be important in humid climate regions with deep-root ecosystems - serve as a constraint to improve the partitioning of both water and energy budgets (e.g., LBA-KM83)

- Next step is to incorporate the shallow aquifer parameterization in VIC (Liang et al. 2003) and hydraulic redistribution parameterization by Liang et al. (2010)

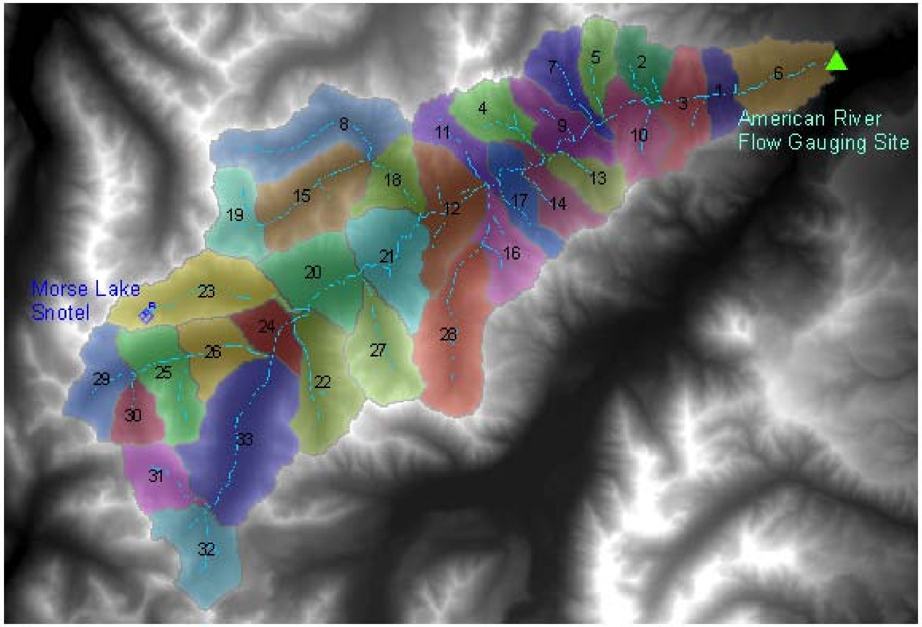
DCLM – Multi-Scale Modeling



- **As CLM is applied to higher grid resolution, lateral redistribution of soil moisture becomes important**
- **Fully-distributed fine scale hydrologic simulation capability**
  - Basic unit: Raster grid
  - Cell-to-cell routing
  - Simulation of subbasins at the 10- to 1000-meter scale
- **Semi-distributed regional scale hydrologic simulation capability**
  - Basic unit: subbasins that follow the natural topography and are hydrologically independent
  - Cell-to-channel routing
  - For example, ~ 9000 subbasins representing Columbia Basin

Semi-Distributed Simulation: American River Basin

American River Basin Subcatchments

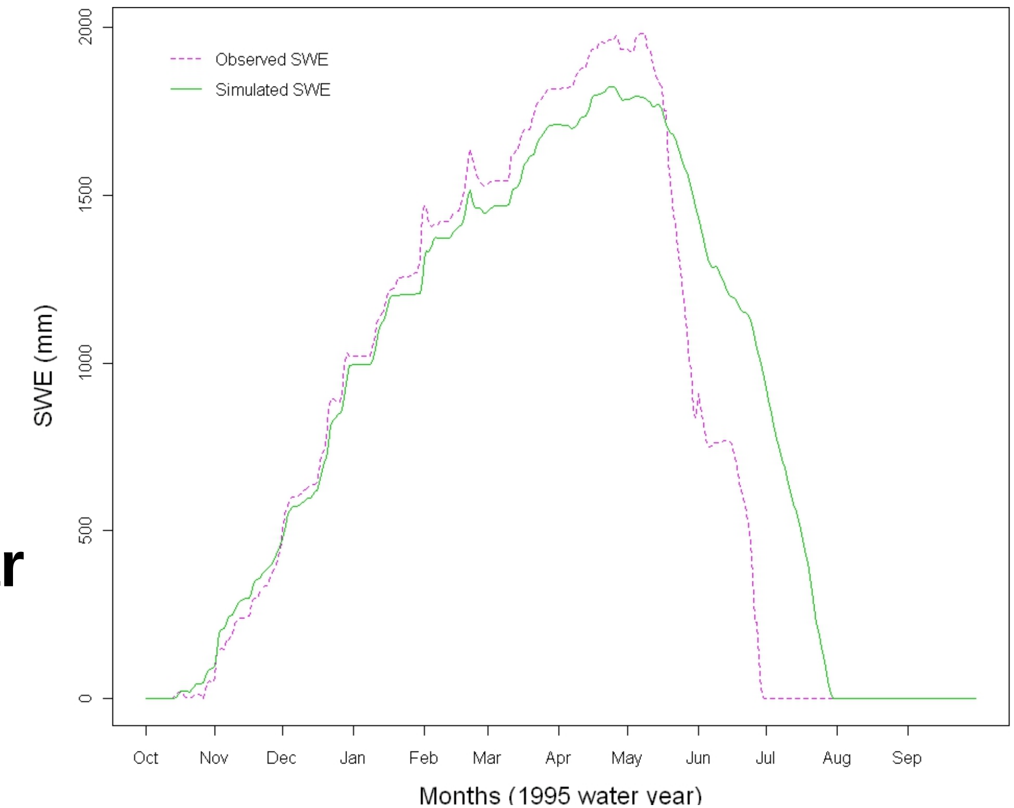


Subbasin-to-channel routing

Semi-Distributed Simulation: American River Basin

- **American River Basin**
  - Snow dominated
  - 204 km^2
- **Subbasins and channel network delineated from 30m DEM**
  - 33 subbasins
  - Average area of 6.2 km^2
- **Simulation for water year 1995**
  - DCLM run at 3-hr time step
  - Meteorological data disaggregated from the NRCS Morse Lake SNOTEL site

Observed and simulated SWE at Morse Lake SNOTEL



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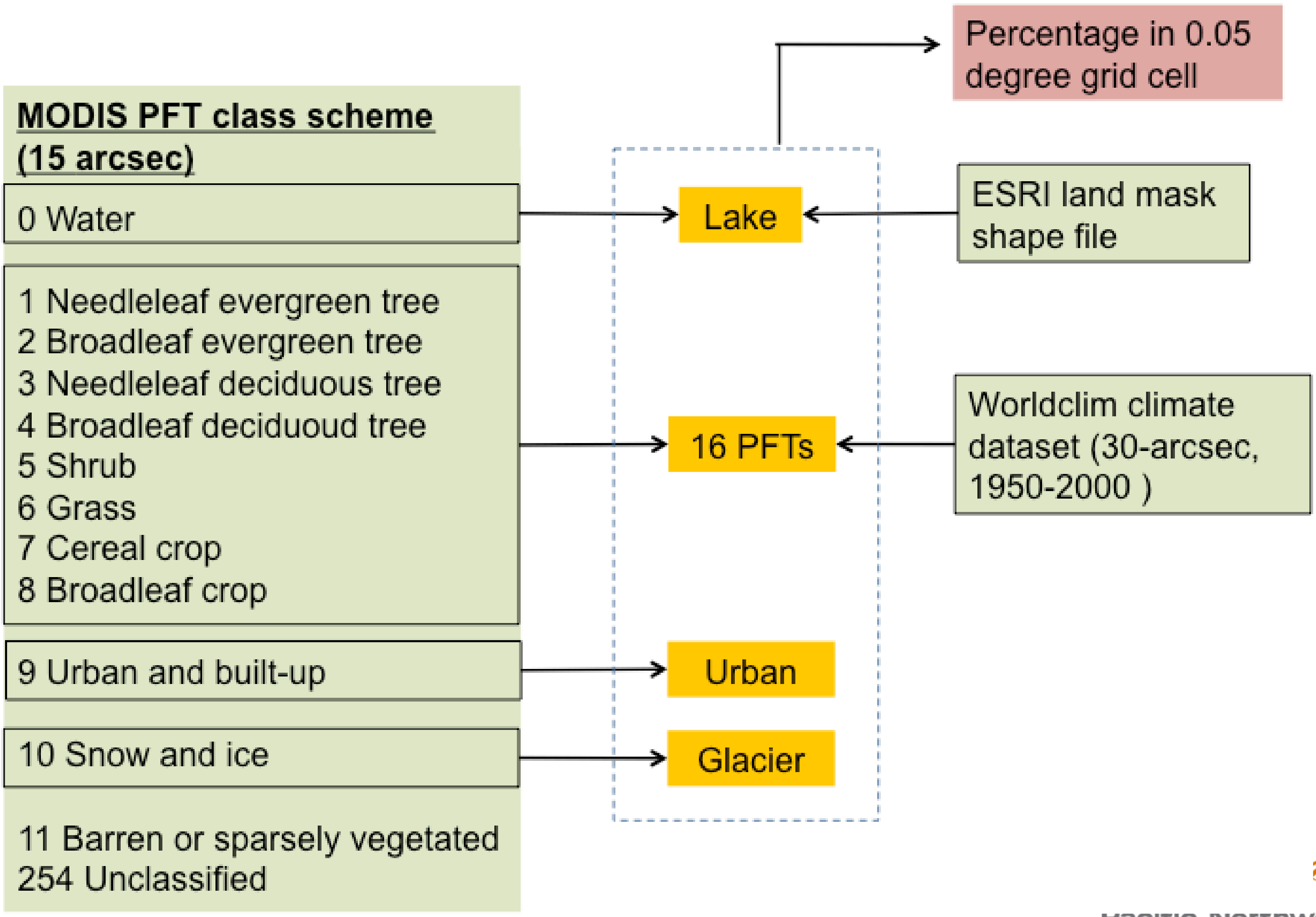
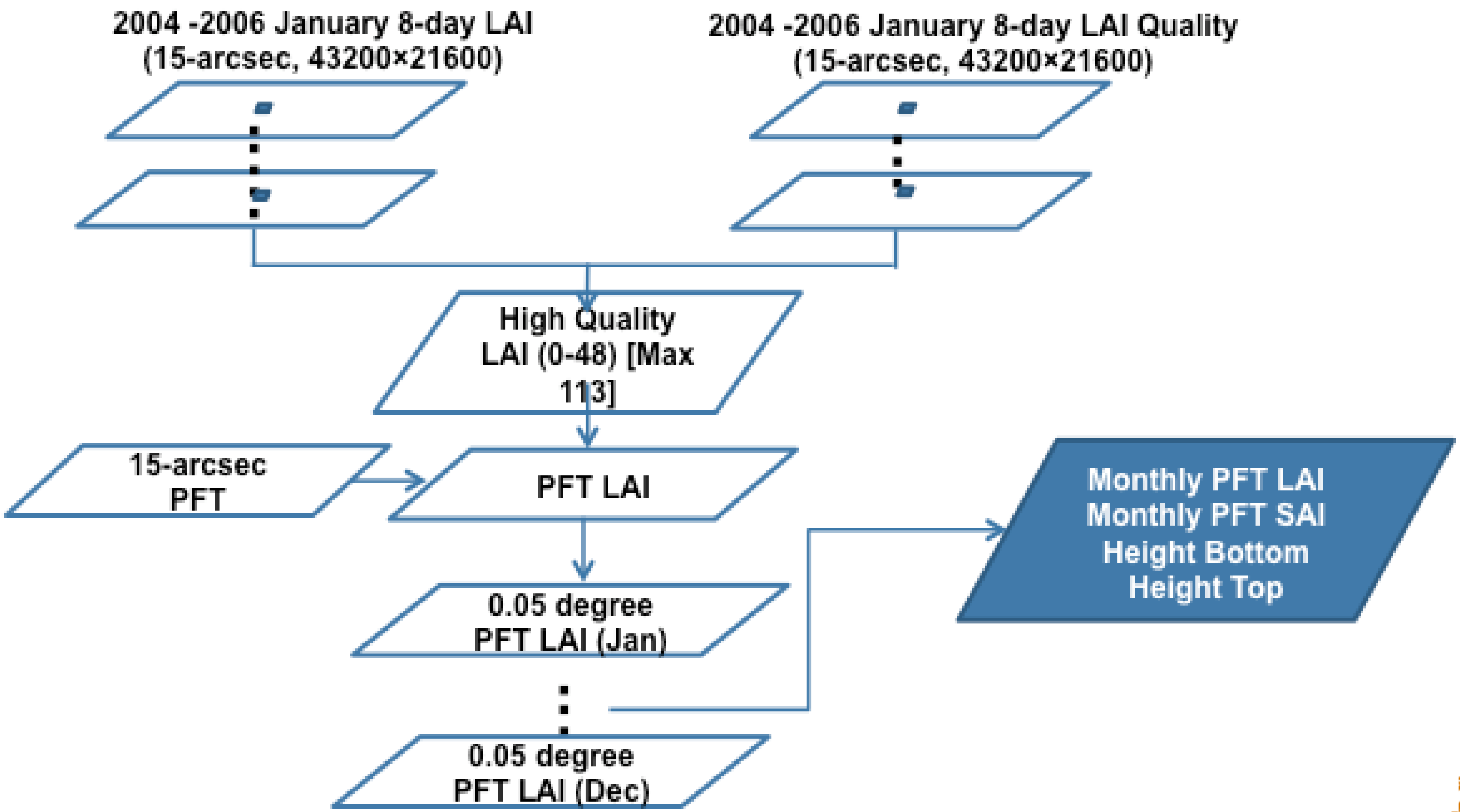
High Resolution Land Data Development for CLM



High Resolution Land Data Development for CLM

- **Mean Monthly Plant Functional Type Leaf Area Index**
- Source: MOD15A2 8-day 1km v005 LAI/FPAR product during 2004-2006



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High Resolution Land Data Development for CLM

- **Land cover updates for North America at 0.05º resolution**
  - Source: MOD12Q1 v005: 15-arcsec (~500m)
  - Updated wetland mapping: IGBP class scheme
  - Updated lake mapping: PFT class scheme
  - Updated urban area mapping: PFT class scheme
  - Updated PFT mapping: PFT class scheme
  - Updated LAI mapping
  - Updated Glacial mapping
- **Work in progress**
  - Create soil datasets: Harmonized World Soil Database
    - 30-arcsecond resolution
    - Only have two vertical layers: 0~30cm, 30~100cm ?
  - Irrigated area: Global Irrigated Area Map (10km) http://www.iwmigiam.org/info/gmia/default.asp

Representing Water Use and Management

- The reference crop ET is first calculated based on the Penman–Monteith method.
- Crop coefficients and heights specified by FAO are thereafter used to calculate leaf area index values throughout the growing season for the irrigated portion of the grid cell.
- Water for irrigation can come from the following sources: (1). Streamflow available in the channel within the grid cell; (2). Reservoirs in or outside of the river basin; (3). The local groundwater body.
- Inclusion of a reservoir module in the routing model
  - Reservoir (Flood control and Drought management)
  - Power (Hydro)
  - Environment (Fish habitat)
  - Irrigation needs
  - Groundwater recharge/withdrawal