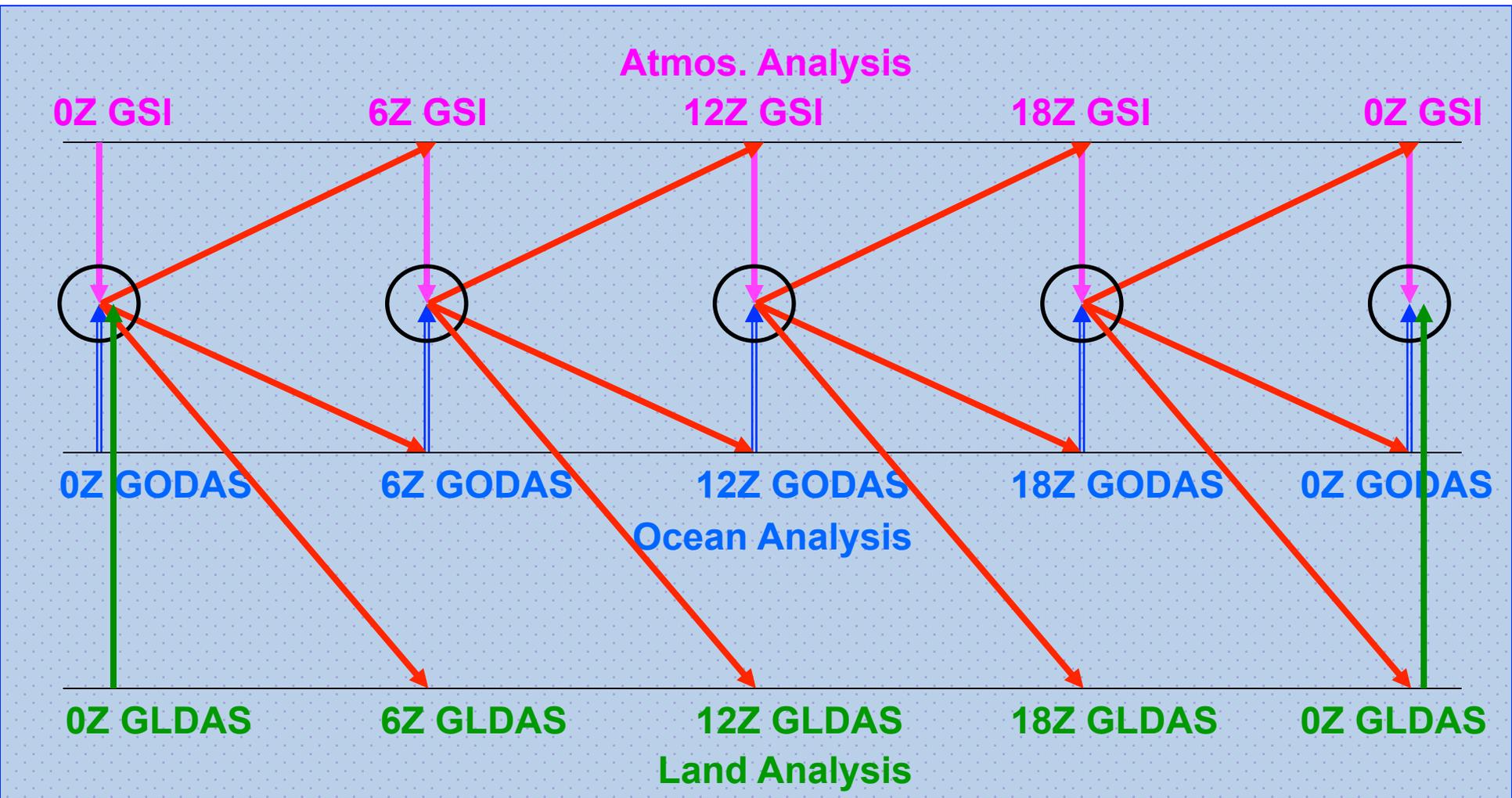# Implementation of Land Information System in the NCEP Operational Climate Forecast System CFSv2

Jesse Meng, Michael Ek,

Rongqian Yang, Helin Wei

Outline

- NCEP CFSRR
- Land component CFSv1 vs CFSv2
  - Land surface model upgrade from OSU to Noah
  - LIS infrastructure for CFSv2 GLDAS
  - Observed precipitation
  - Observed snow cover and snow depth
- Result
  - Soil moisture
  - Land surface water and energy budgets
  - Prediction skill

CFSRR

A new Global Reanalysis of the atmosphere, ocean, seaice and land over the 32-year period (1979-2010)

1. Analysis Systems :   Operational GDAS
                    Atmospheric (GADAS/GSI)
    Ocean-ice (GODAS)   Land
                    (GLDAS/LIS)

2. Atmospheric Model :   Operational GFS

                    New Noah Land Model

3. Ocean Model :   New MOM4 Ocean Model

                    New Sea Ice Model

3

Suru Saha, NOAA/NCEP/EMC

CFS/CDAS Execution (24-hr span) : Note daily GLDAS

Time

Suru Saha, NOAA/NCEP/EMC

Community Noah land-surface model

ATMOSPHERIC FORCING (near surface)
- PRECIPITATION
- TEMPERATURE
- HUMIDITY
- SURFACE PRESSURE
- WIND

RADIATION FORCING (at surface)
- DOWNWARD SOLAR
- DOWNWARD LONGWAVE

PRECIPITATION
TRANSPIRATION (E_T)
CANOPY WATER EVAPORATION (E_C)
CONDENSATION
INTERCEPTION
DIRECT SOIL EVAPORATION (E_d)
DEPOSITION SUBLIMATION to/from snowpack
SENSIBLE HEAT FLUX to/from surface
atmospheric
LONGWAVE RADIATION
terrestrial
SOLAR RADIATION

SURFACE RUNOFF
INFILTRATION
SNOWMELT
SOIL HEAT FLUX

INTERNAL SOIL MOISTURE FLUX
INTERNAL SOIL HEAT FLUX

ROOT ZONE
SUBROOT ZONE

2 or more soil layers (recommend ≥4)

MOISTURE BUDGET
SUBSURFACE RUNOFF

HEAT BUDGET

STATE VARIABLES

SKIN TEMPERATURE	SOIL TEMPERATURE	SNOW DEPTH
CANOPY WATER	SOIL WATER	SNOW WATER
	SOIL ICE	

SURFACE PARAMETERS

VEGETATION TYPE	ROUGHNESS
GREEN VEGETATION FRACTION	ALBEDO
SOIL TEXTURE	SLOPE FACTOR

ftp://ftp.emc.ncep.noaa.gov/mmb/gcp/ldas/noahlsm

5

CFS Land Model Upgrade
Noah LSM (v2) versus OSU LSM (v1):

- **Noah LSM (vegetation, snow, ice)**
  - 4 soil layers (10, 30, 60, 100 cm)
  - Frozen soil physics included
  - Add glacial ice treatment
  - Two snowpack states (SWE, density)
  - Surface fluxes weighted by snow cover fraction
  - Improved seasonal cycle of vegetation
  - Spatially varying root depth
  - Runoff and infiltration account for sub-grid variability in precipitation & soil moisture
  - Improved thermal conduction in soil/snow
  - Higher canopy resistance
  - Improved evaporation treatment over bare soil and snowpack

- **OSU LSM**
  - 2 soil layers (10, 190 cm)
  - No frozen soil physics
  - Only one snowpack state (SWE)
  - Surface fluxes not weighted by snow fraction
  - Vegetation fraction never less than 50 percent
  - Spatially constant root depth
  - Runoff & infiltration do not account for subgrid variability of precipitation & soil moisture
  - Poor soil and snow thermal conductivity, especially for thin snowpack

Land Information System

Christa Peters-Lidard et al., NASA/GSFC/HSB
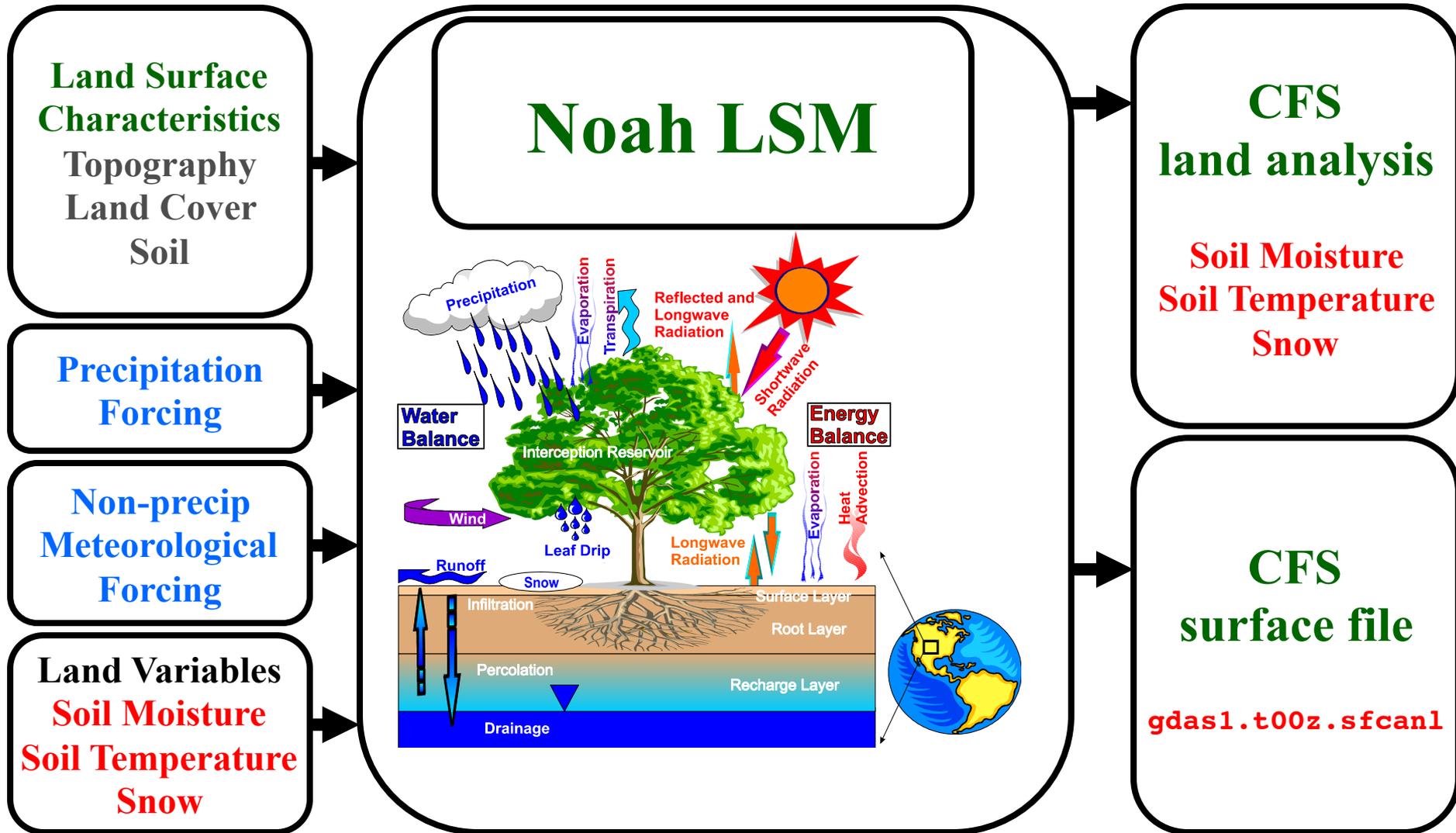
Verification for operational precip forecast June 2010 [mm]

GFS

GFS - CMAP
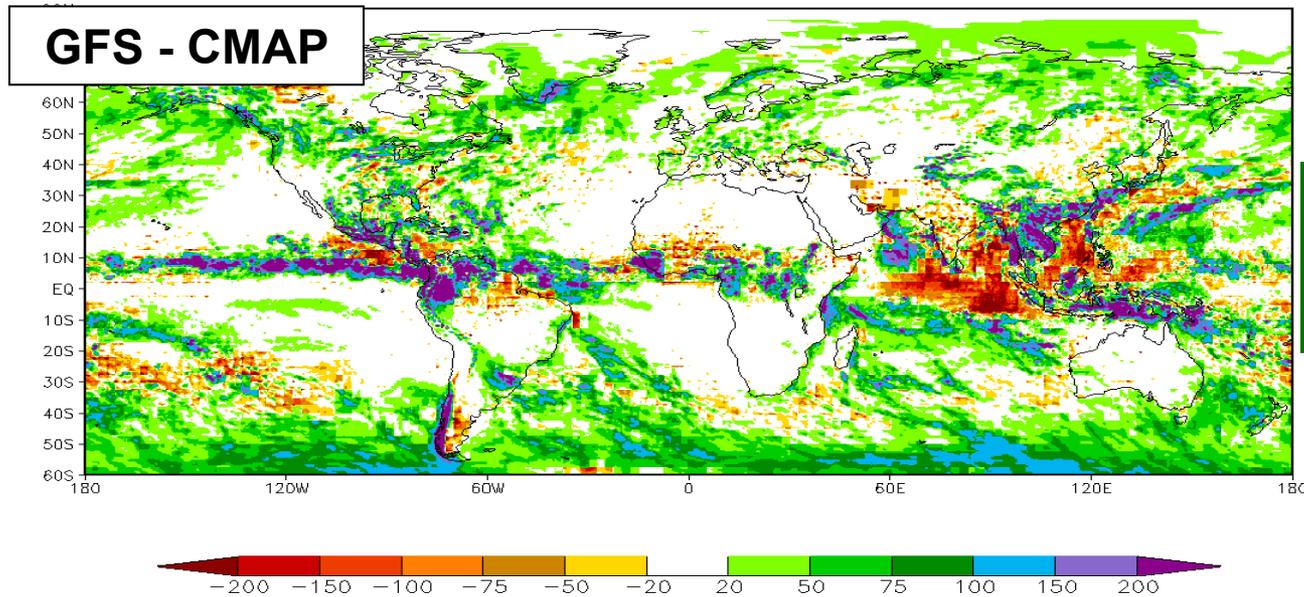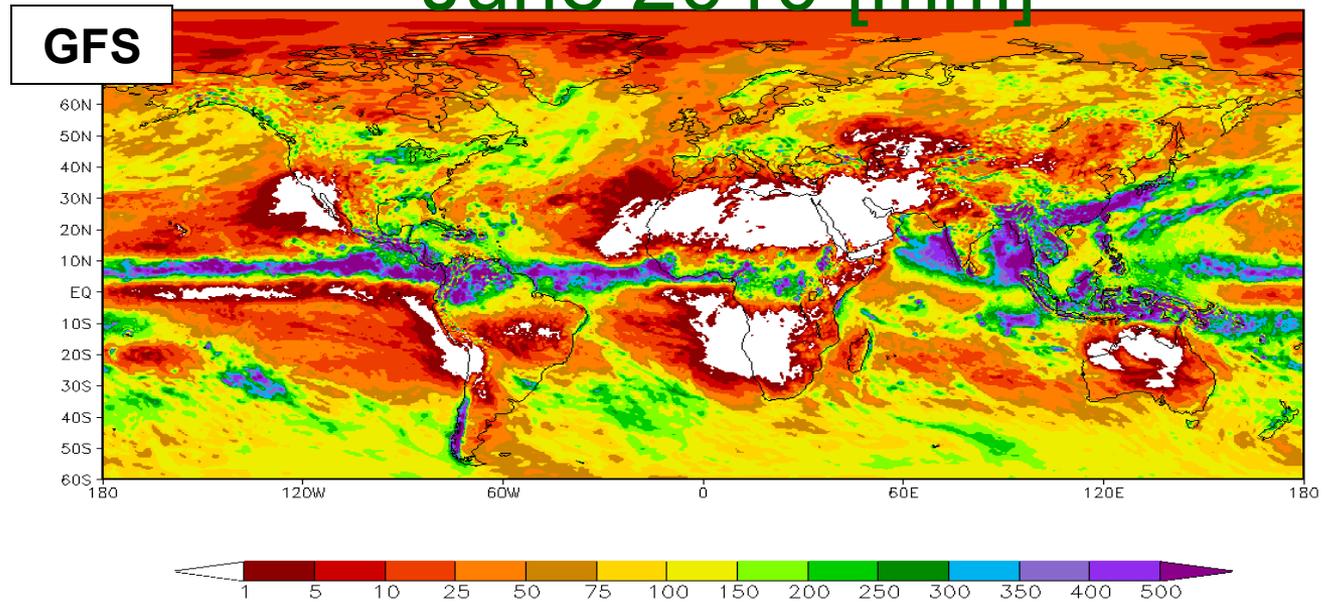
GFS yields high precip bias in tropics.

8

Comparison of Method in Assimilation of precipitation and snow

CFSv1

Precip

Model precip, nudges soil moisture (1st layer) during the next **5 days** using the difference between **CMAP** and model precip –
directly use of the observed precip.

Snow

Weekly snow cover, model snowdepth is used if consistent otherwise adjusted to snow cover without affecting soil moisture –
directly use of snow cover.

Comparison of Method in Assimilation of precipitation and snow

CFSv2

Precip

"Open loop" approach, uses observed precip to drive off-line Noah LSM and the resulting land states are used to update model's land states *daily* – *implicit use of observed precip.*

Snow

Observed snowcover and snowdepth are used to adjust (if more than twice or less than half of analysis) model's snowdepth everyday otherwise untouched – *implicit use of observed snow.*

Precip forcing for CFS GLDAS

<u>CPC Unified Daily Gauge Data</u>

- Dense gauge networks from special CPC collections over US, Mexico, and S. America;
- GTS gauge network elsewhere
- Daily reports available from ~17,000 stations

Elevation (mm)

Mingyue Chen and Pingping Xie, NOAA/NCEP/CPC
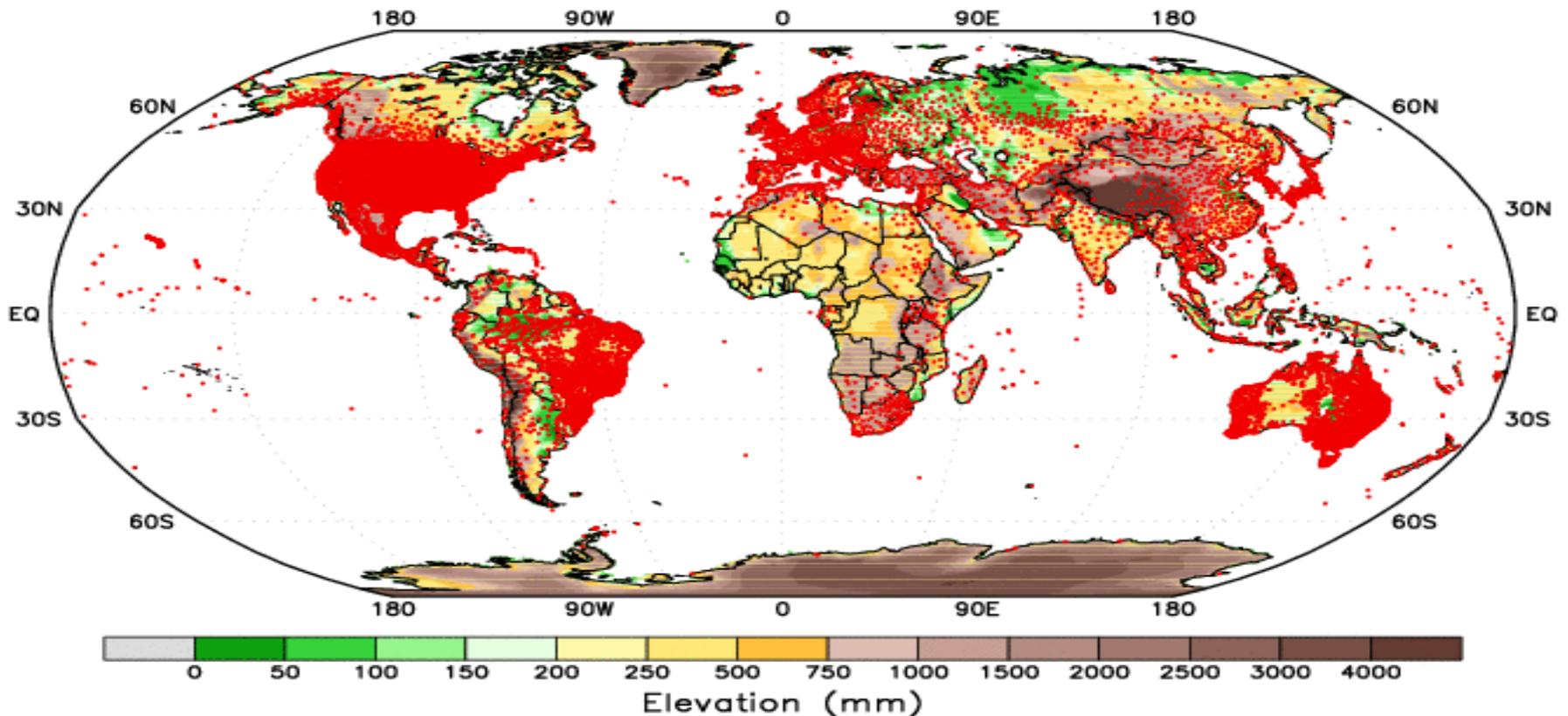
Blended precip forcing for CFS GLDAS

Precip difference (GFS-CMAP)
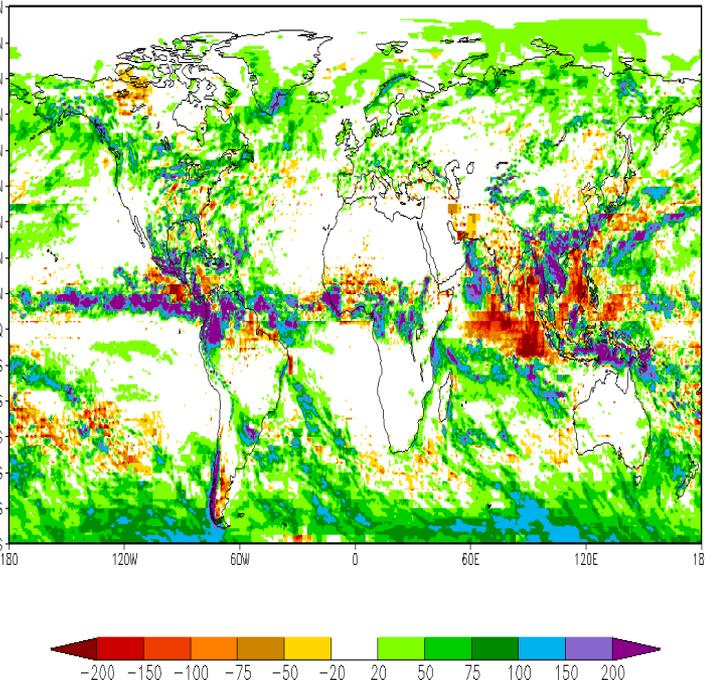
Global Gauge Distribution
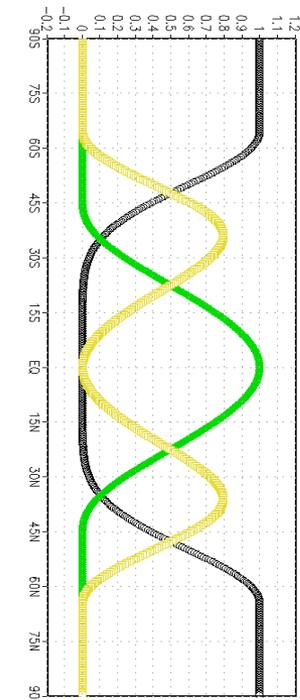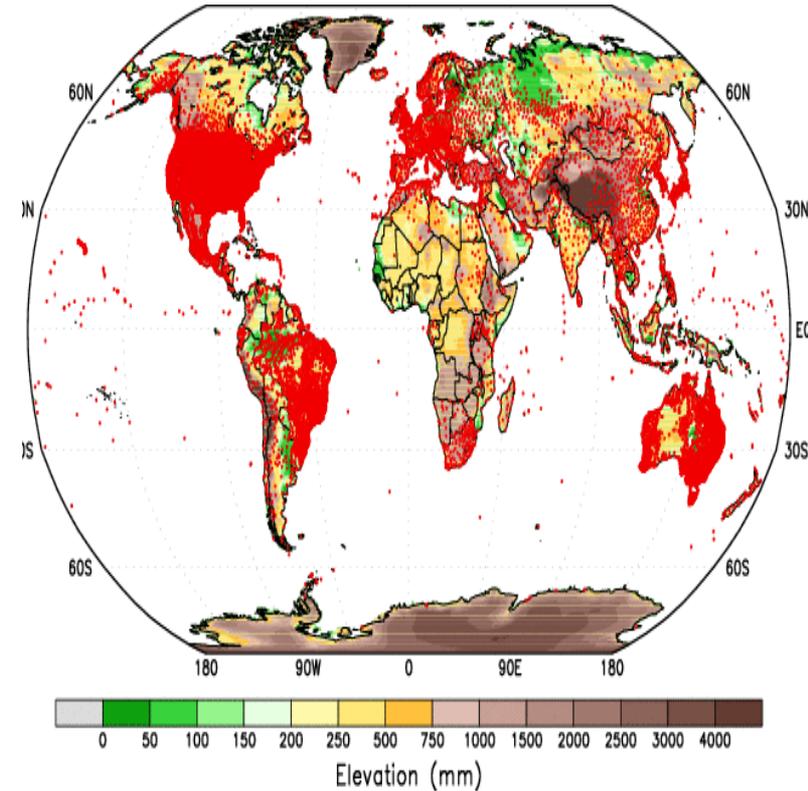
A blended precip forcing is used in CFS with the heavier weights of
CFS/GDAS – high lats
Gauge – mid lats
CMAP – tropics.

Snow analysis for CFS GLDAS

Snow cycled in CFSv2/**GLDAS** if model within 0.5x to 2.0x of the observed value (IMS snow cover, and AFWA snow depth products), else adjusted to 0.5 or 2.0 of observed value.
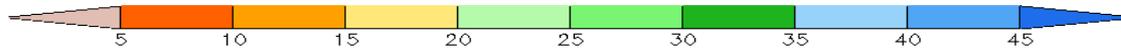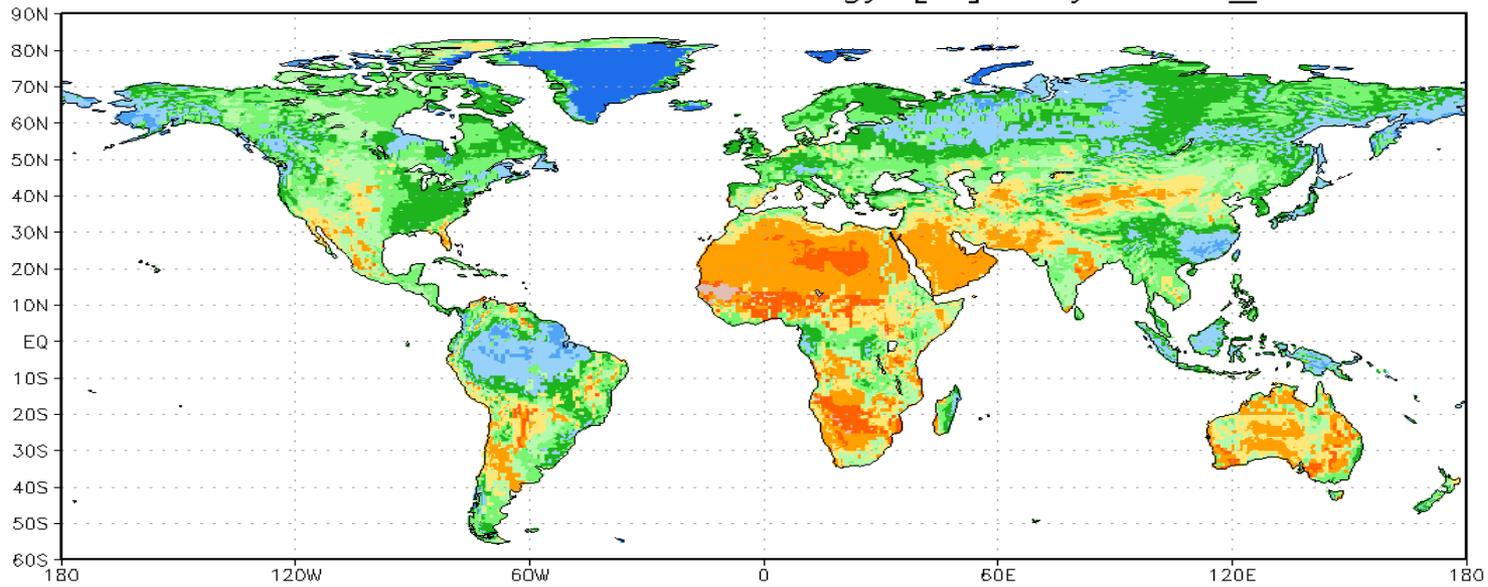
IMS Snow cover

CFSRR Soil Moisture Climatology [%] May 1980_2008

GR2 Soil Moisture Climatology [%] May 1980_2008

14
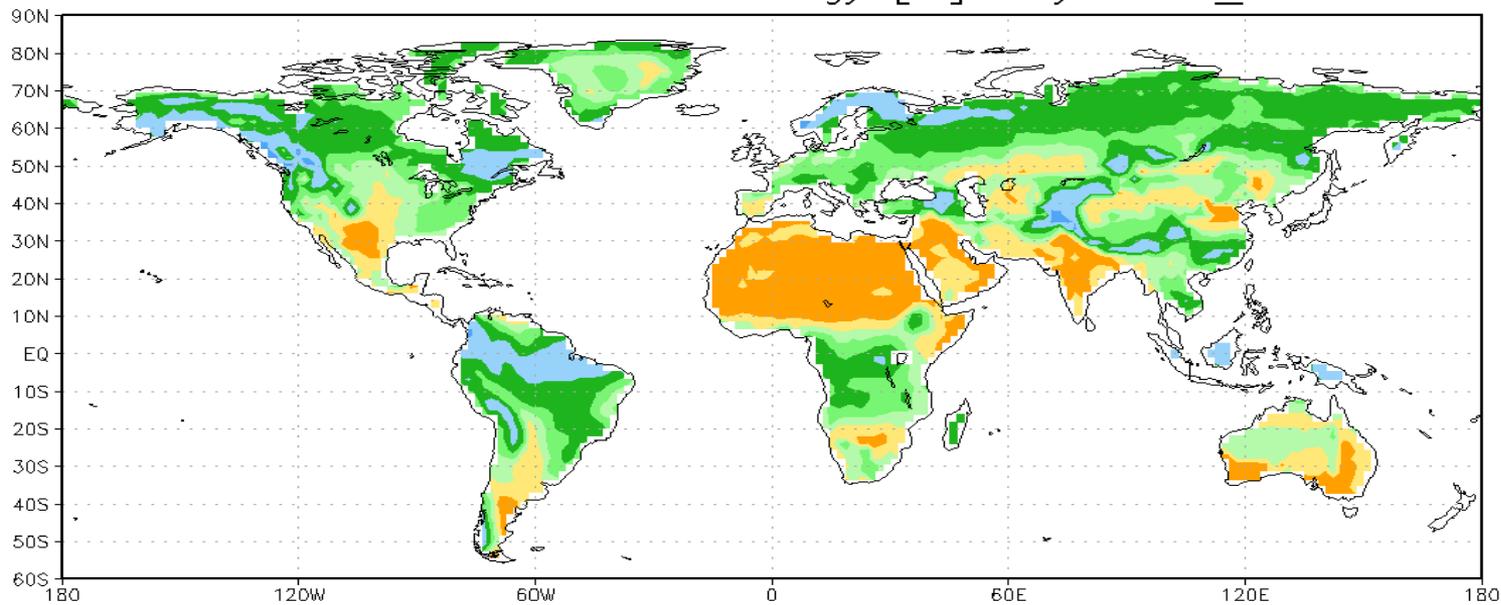
CFSRR Soil Moisture Climatology [%] Nov 1980_2008

GR2 Soil Moisture Climatology [%] Nov 1980_2008

15
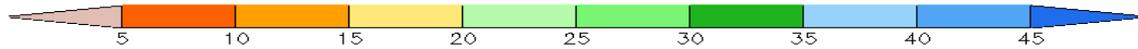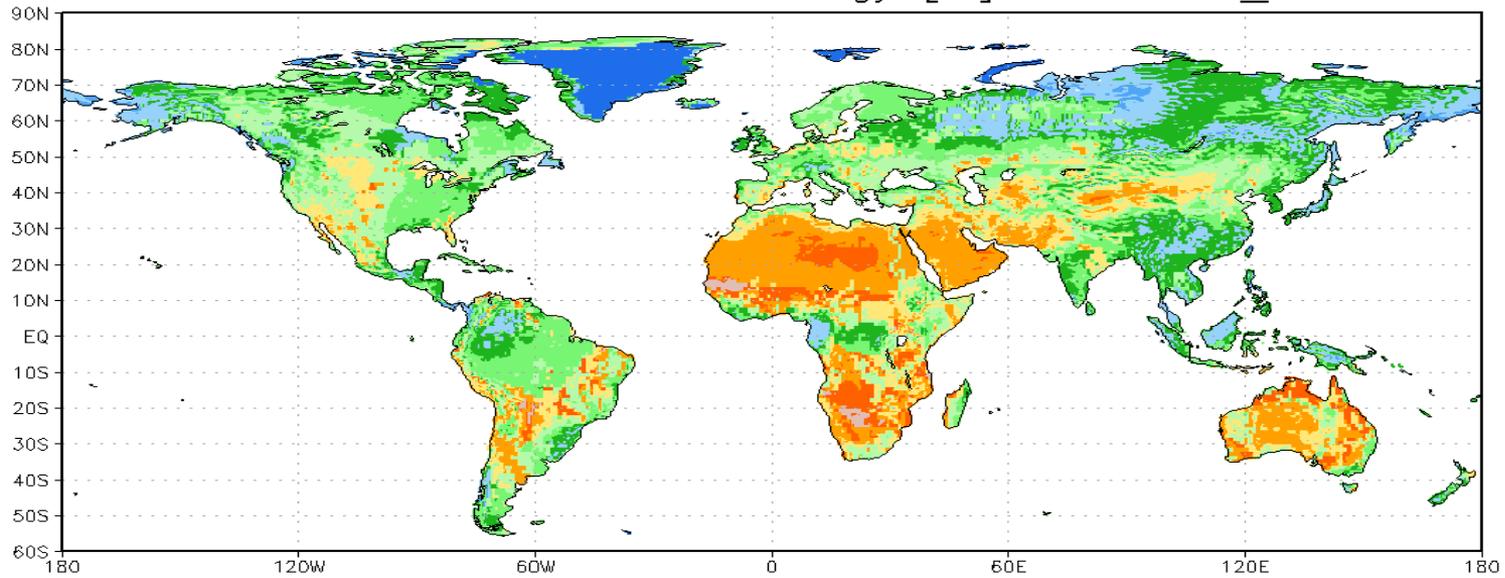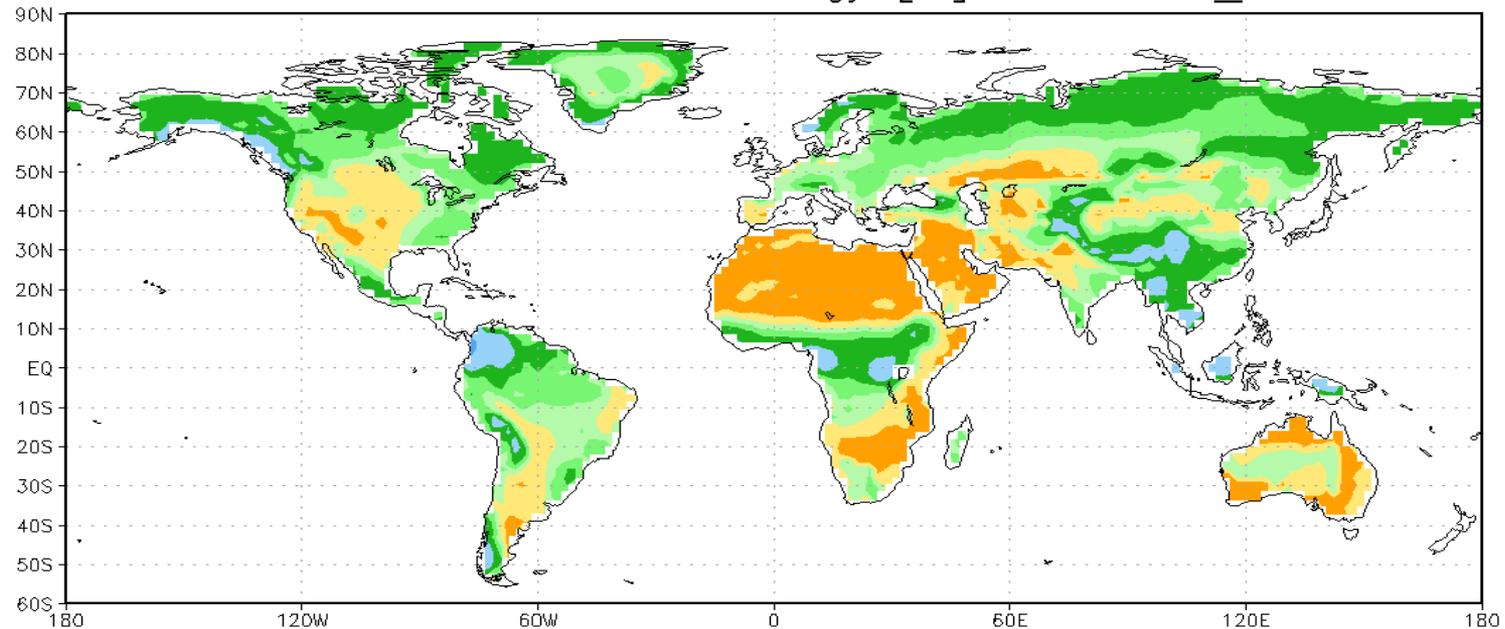
Water Balance Equation

$$0 = -\Delta W/\Delta t + P + \text{Residual} - E - R$$

$\Delta W/\Delta t$: Storage change in Soil Moisture and Snow Water Equivalent.

P: Precipitation.

Residual: Soil moisture and snow updates

E: Evaporation.

R: Runoff.

(CFSv1 does not close water balance; CFSv2 does.)

Surface Water Budget

Snow Water Equivalent Updates (mm)
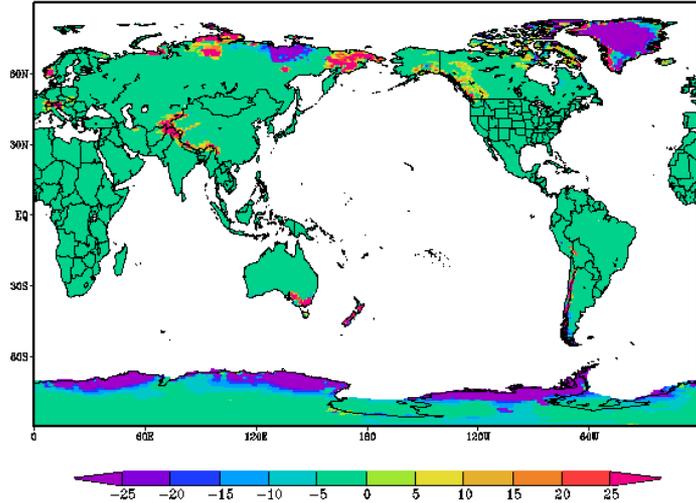
Total Soil Moisture Updates (mm)
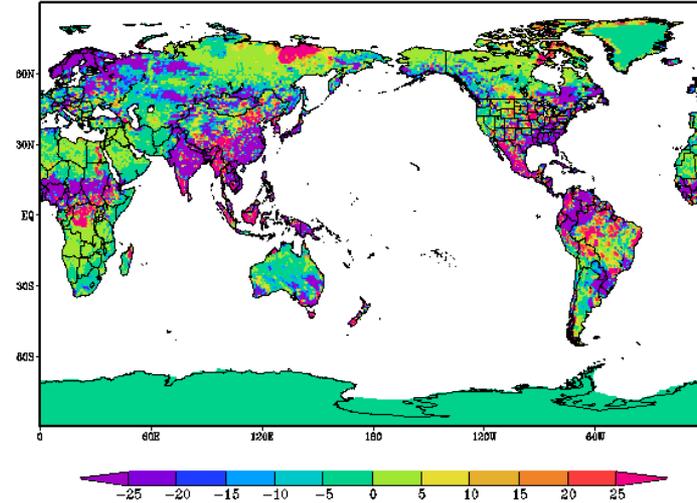
Total Precipitation (mm)
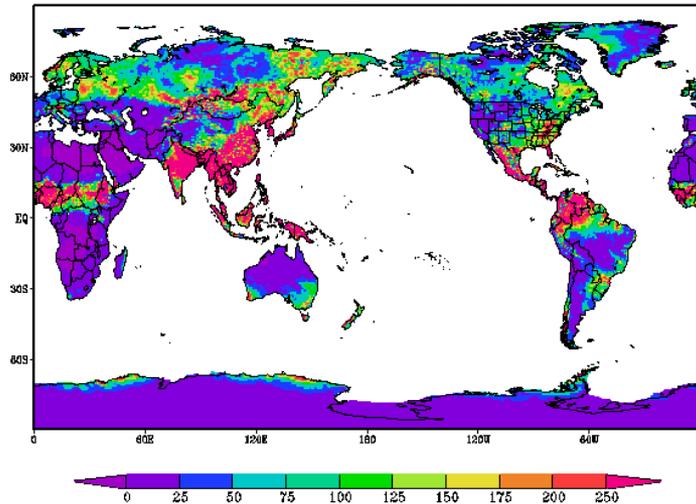
Water Residual (% over Total Water Source)
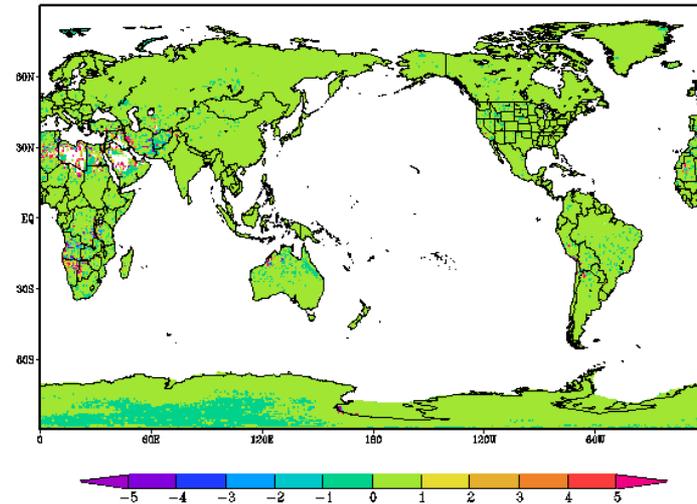
Energy Balance Equation

$$0 = SW + LW - SH - LH - G - SNOHF$$

SW: Net Solar Radiation

LW: Net Longware Radiation

SH: Sensible Heat Flux

LH: Latent Heat Flux

G: Ground Heat Flux

SNOHF: Snow Melt Heat Flux

(CFSv1 does not close energy balance; CFSv2 does.)

Surface Energy Budget

Latent Heat Flux (W/m2)
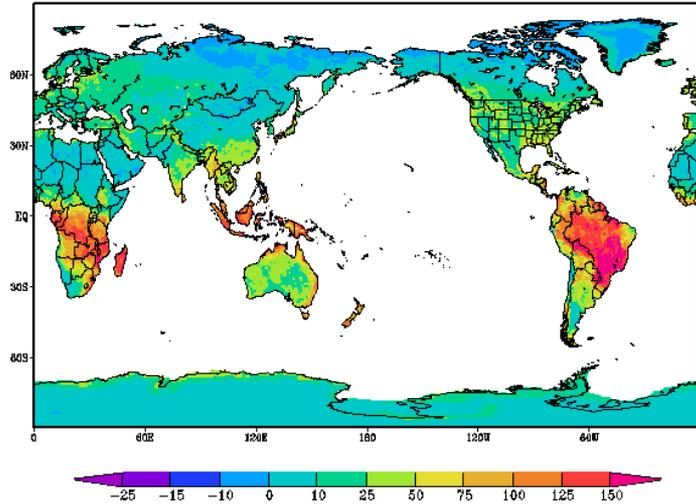
Sensible Heat Flux (W/m2)
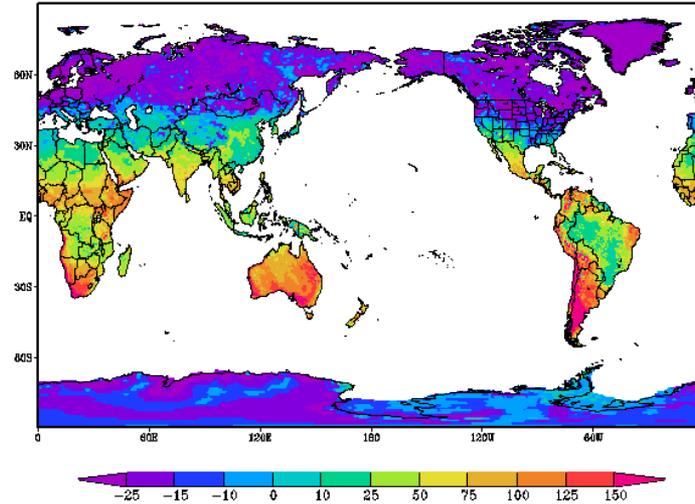
Snow Phase Change Energy (W/m2)
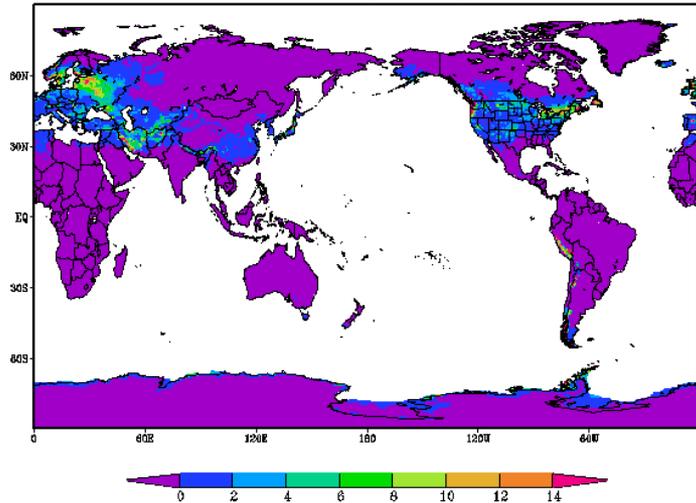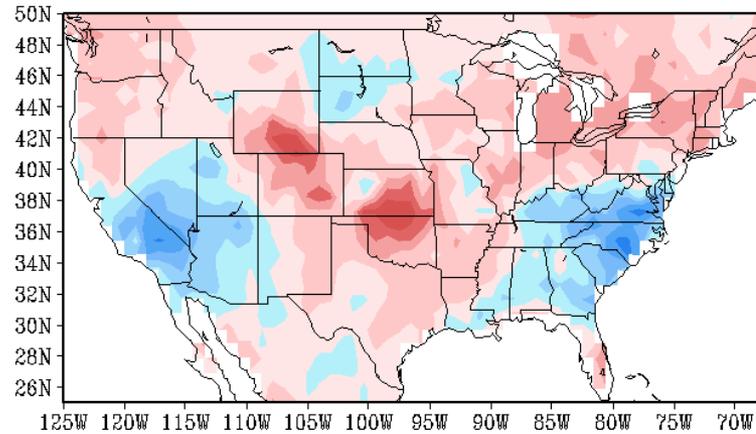
Energy Residual (W/m2)
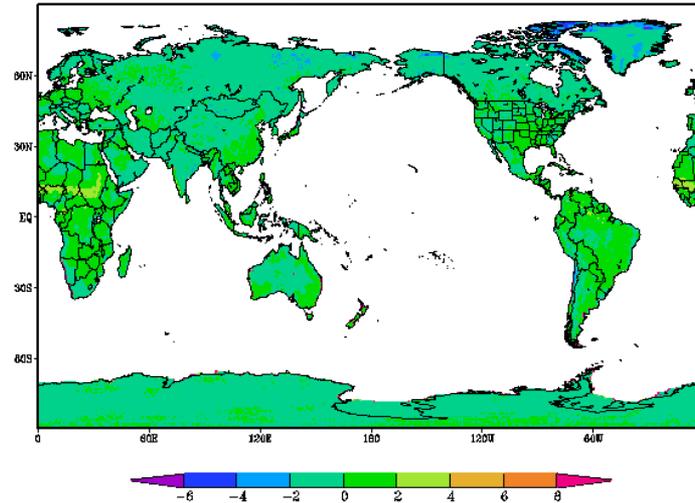
Prediction Skill
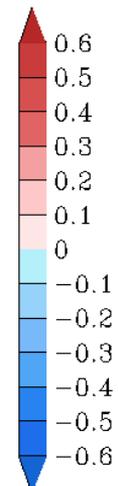

(a)

(b)

20

Yang et al., 2011 J. Climate
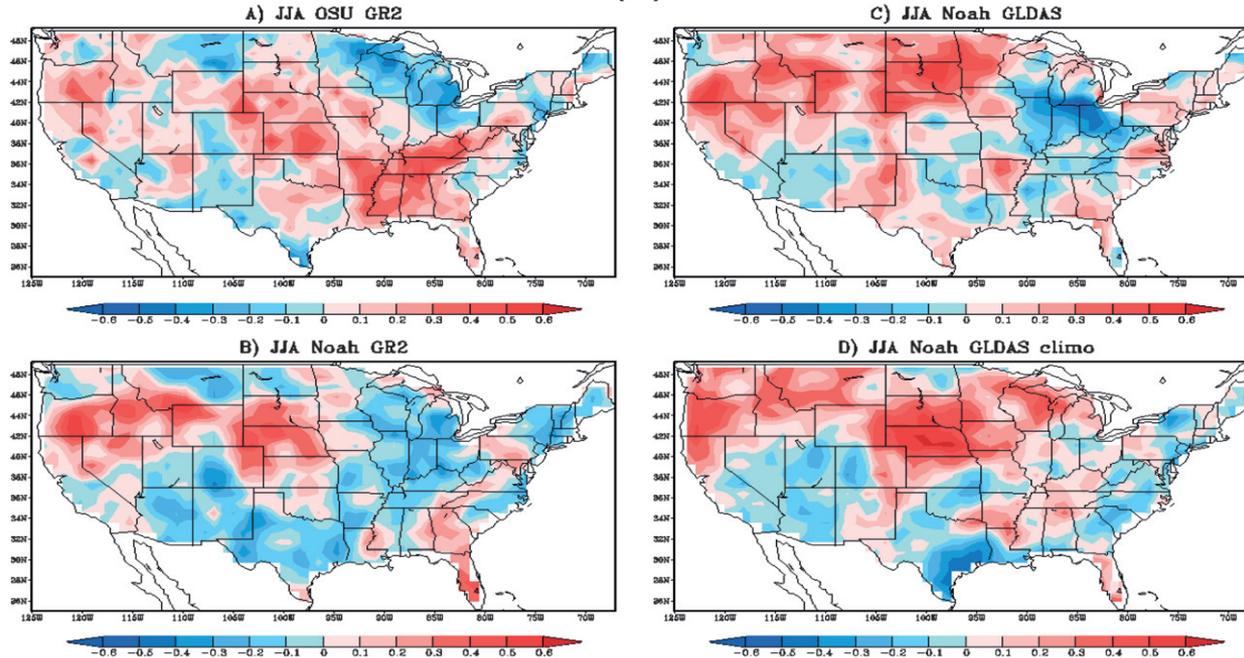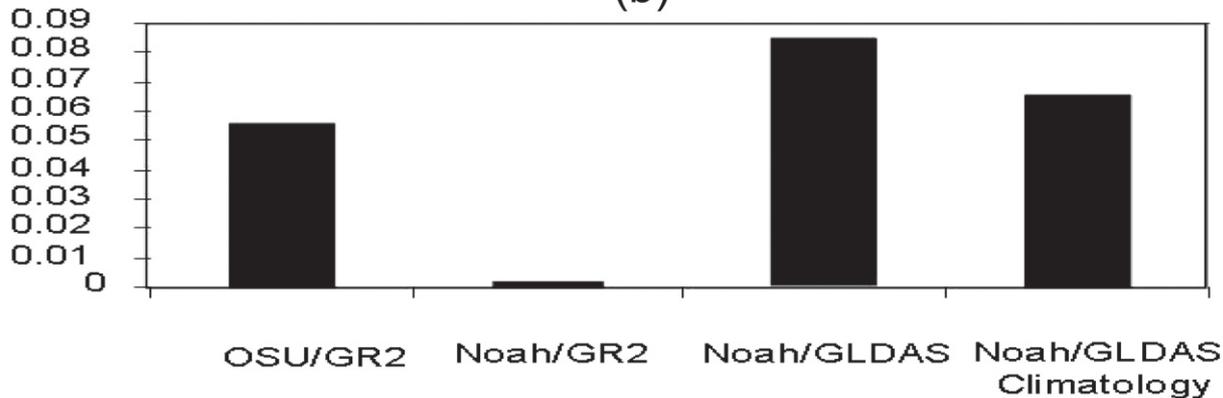
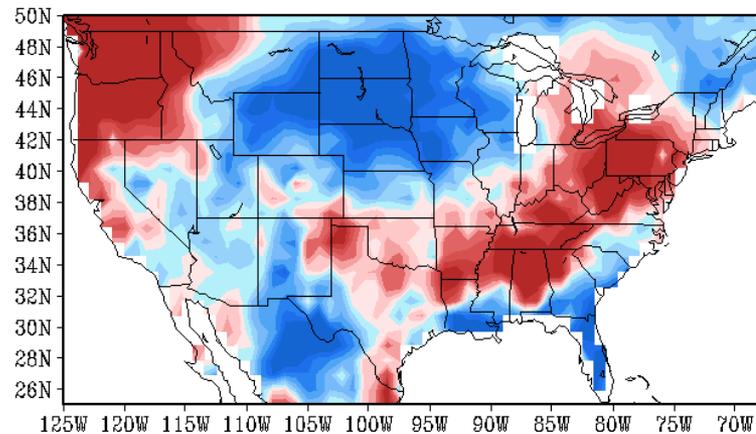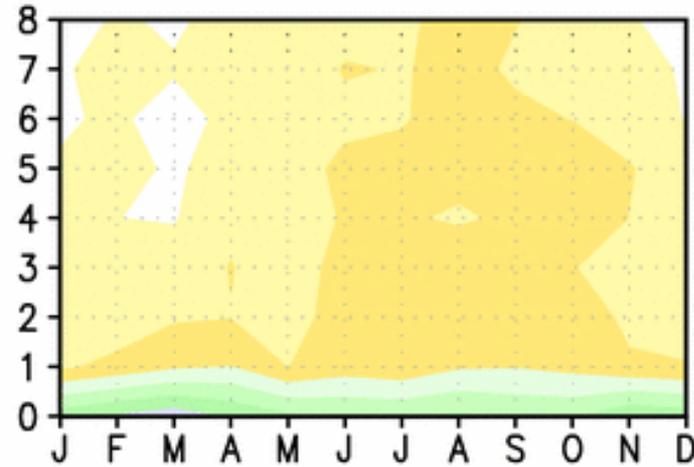# Prediction Skill

T2m Z0 – Control May
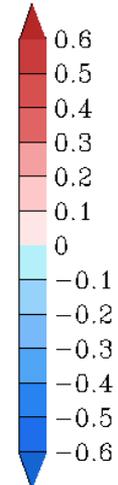
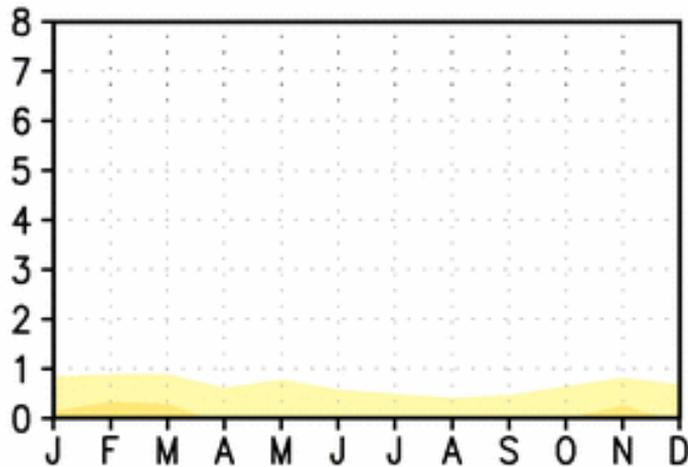T2m Z0 – Control June

Prediction Skill

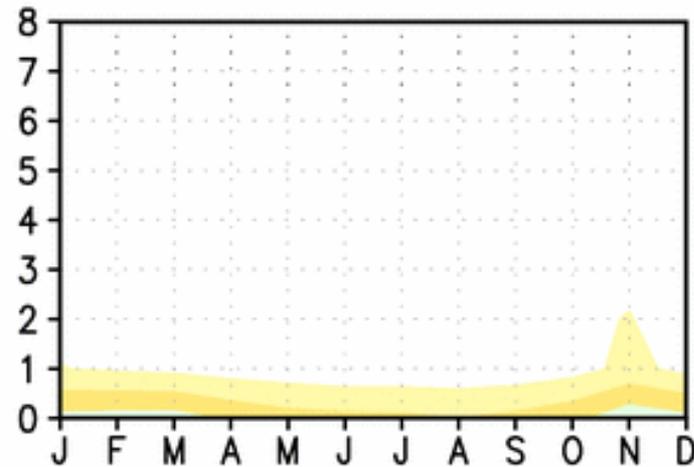Huug ven den Dool, NOAA/NCEP/CPC
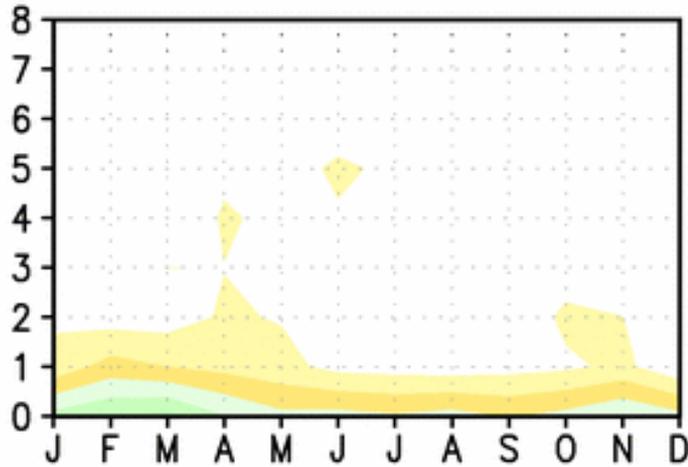
Summary

- CFSv2: A new generation of NCEP operational climate prediction and data assimilation system
- Noah land surface model upgrades
- LIS infrastructure for CFS GLDAS
- Blended forcing to utilize observed precip to reduce the impact of forecast model bias
- Optimal soil moisture fields consistent with prediction model physics
- Energy and water budgets closure
- Improved prediction skill