Land Surface Climatology in the NCEP Climate Forecast System Reanalysis (CFSR)

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NOAA/NCEP/EMC

NCEP CFSR

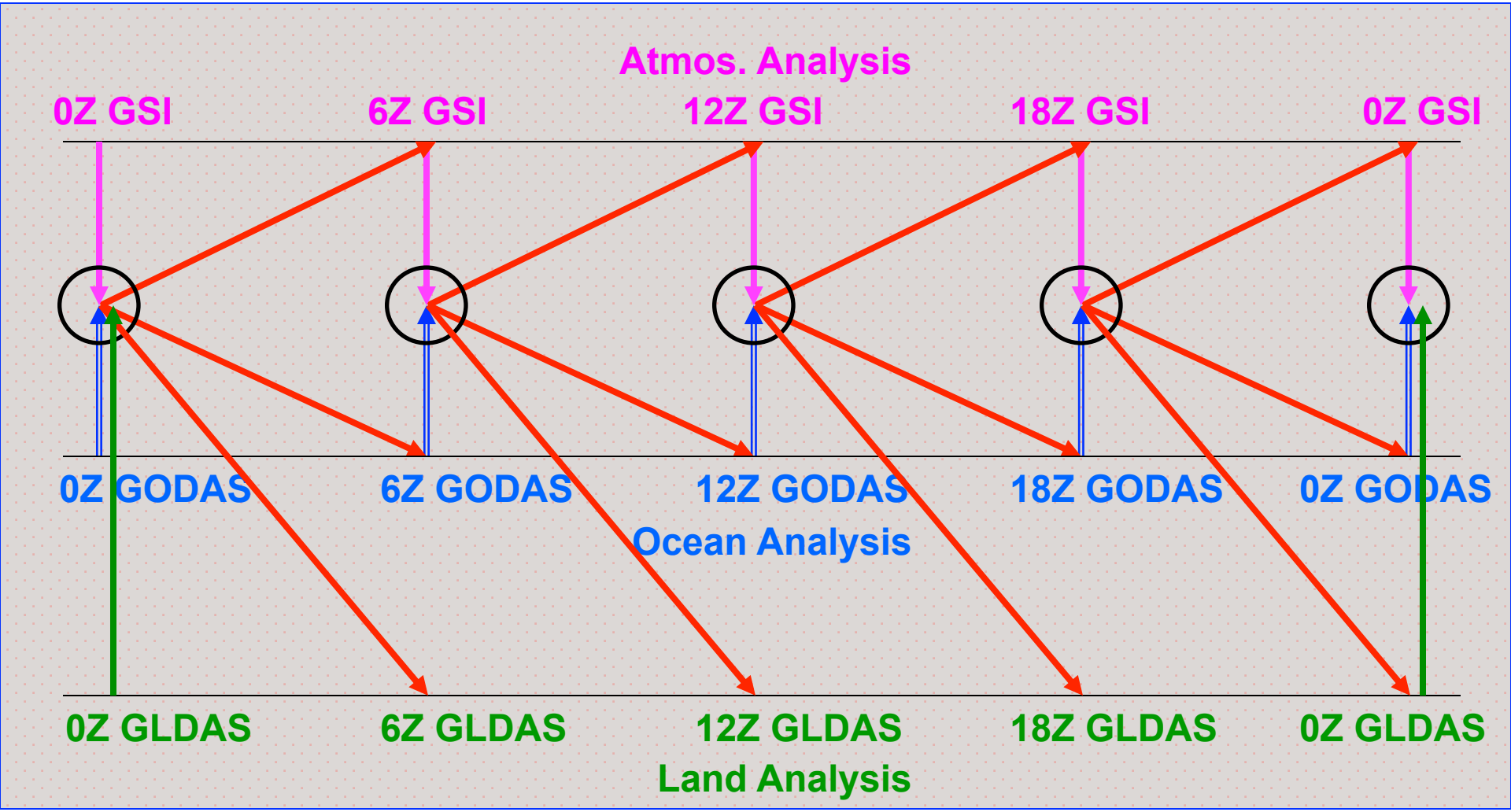
Global Reanalysis of the atmosphere, ocean, seaice and land over the 32-year period (1979-2010)

1. Analysis Systems : Operational GDAS
Atmospheric (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

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



GFS and CFS: Land Model Upgrade

Noah LSM (new) versus OSU LSM (old):

- **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

Noah LSM replaced OSU LSM in NCEP operations
Global Forecast System (GFS) in late May 2005
Climate Forecast System v2 (CFSv2) in March 2011

Land Information System

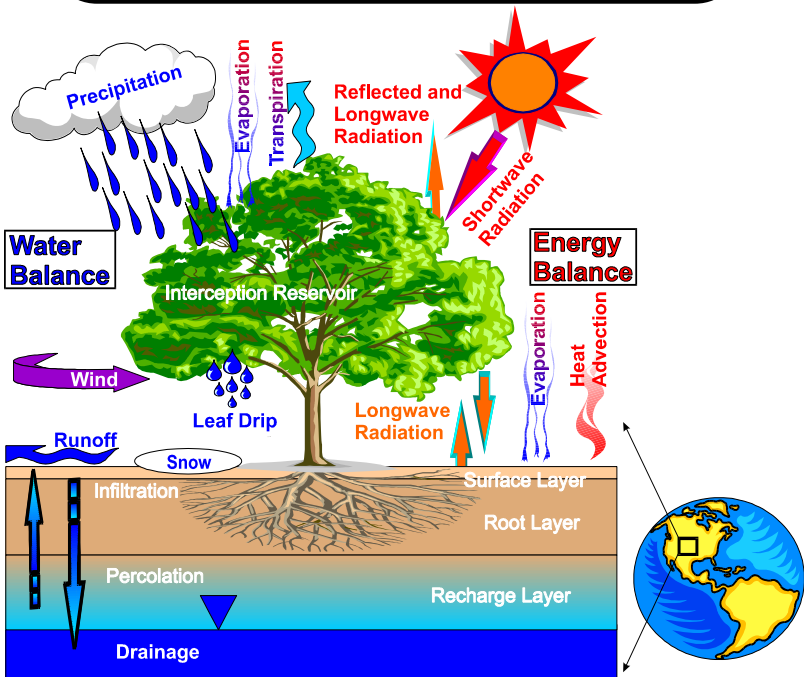
Land Surface Characteristics
Topography
Land Cover
Soil

Precipitation Forcing

Non-precip Meteorological Forcing

Land Variables
Soil Moisture
Soil Temperature
Snow

Noah LSM



CFSR land analysis

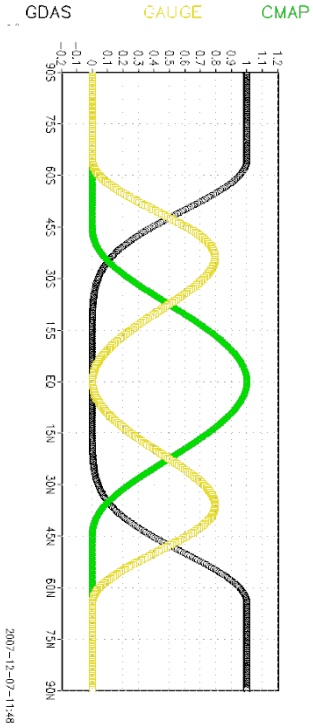
Soil Moisture
Soil Temperature
Snow

CFSR surface file

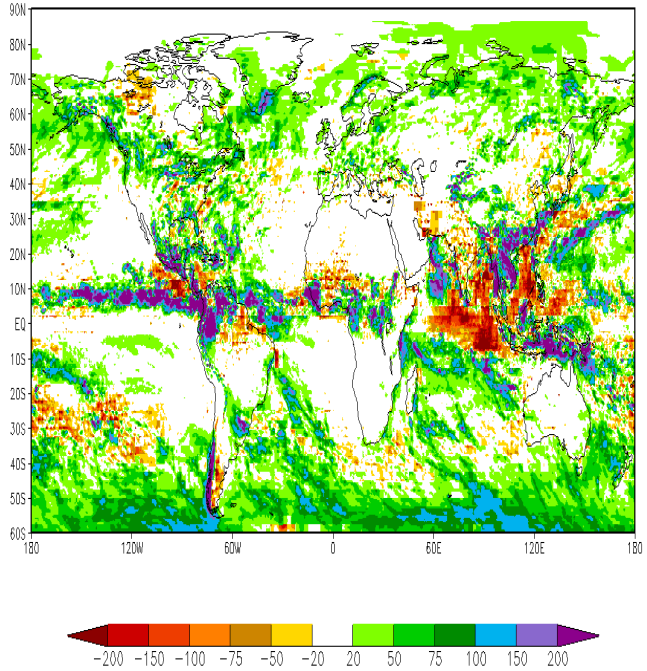
`gdas1.t00z.sfcanl`

Christa Peters-Lidard et al., NASA/GSFC/HSB

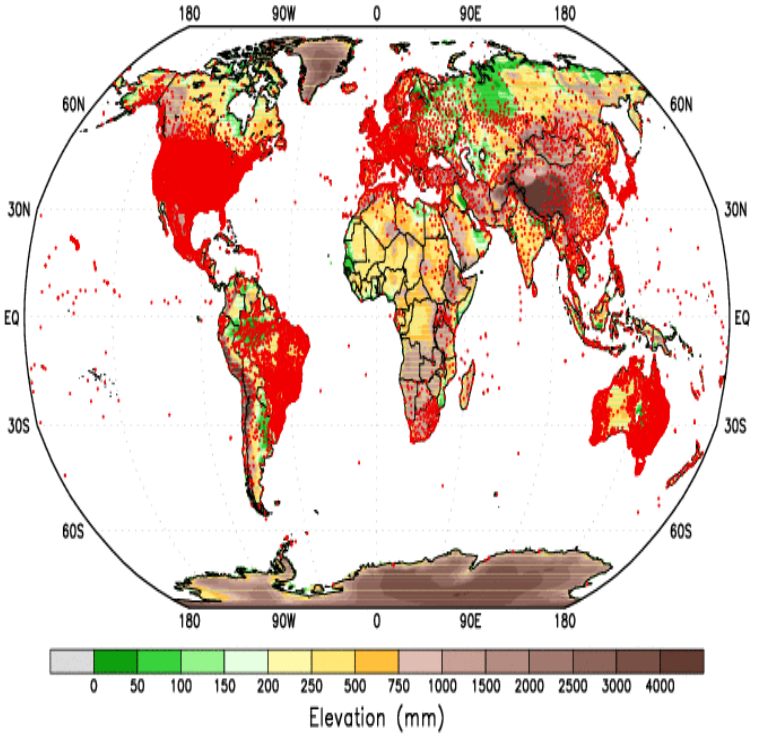
GLDAS/LIS Precip Forcing



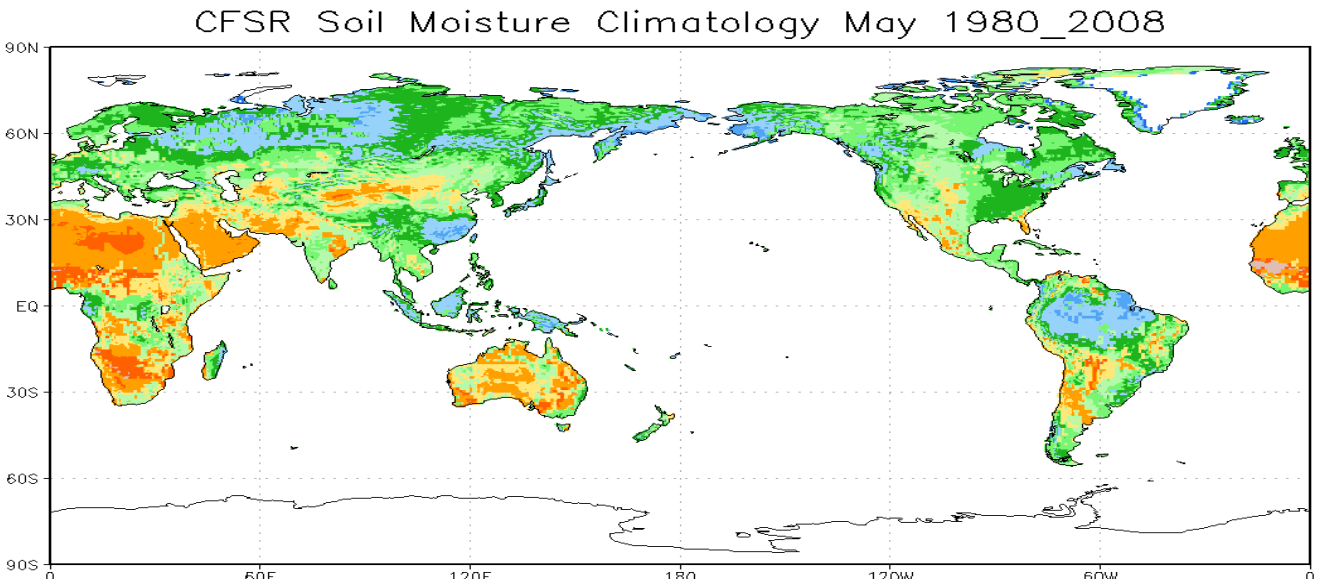
Precip Diff CFS-CMAP

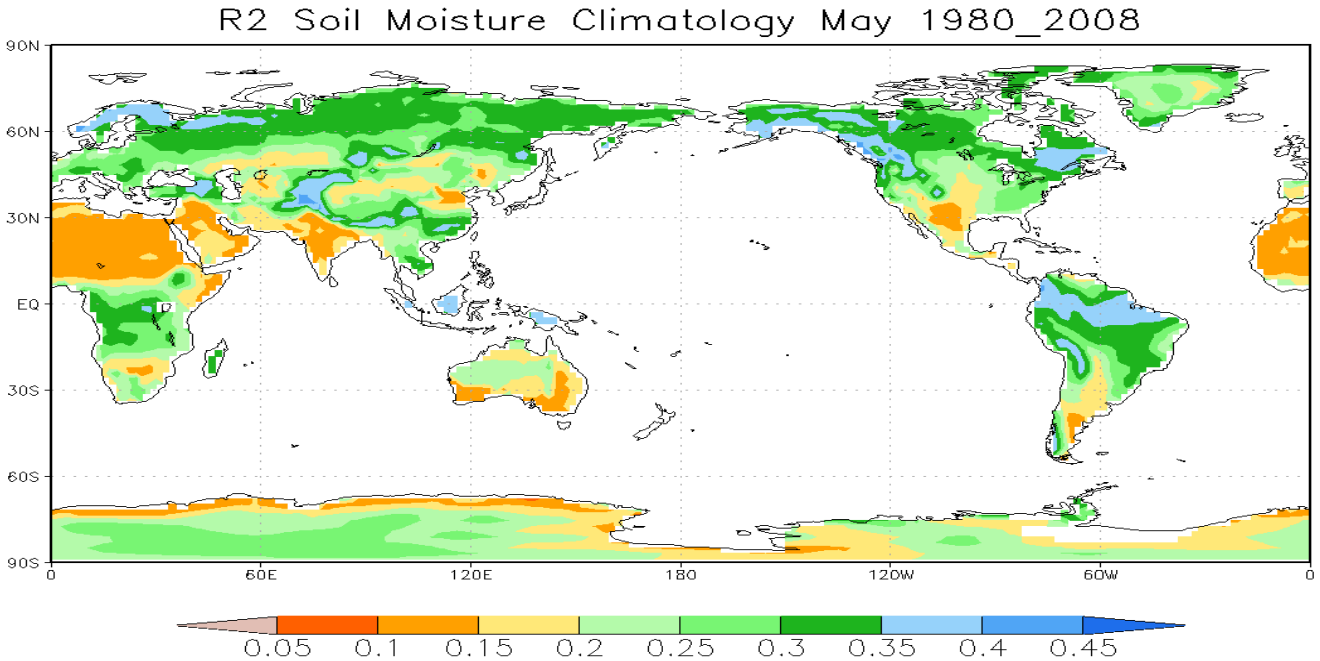


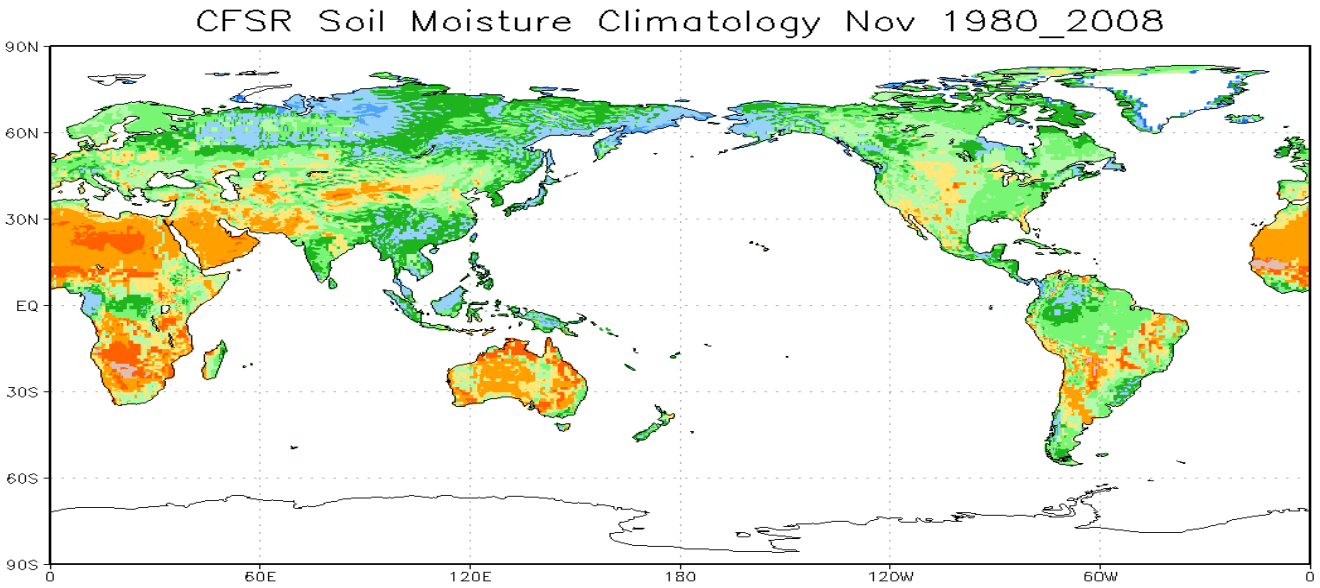
Precip Gauge locations

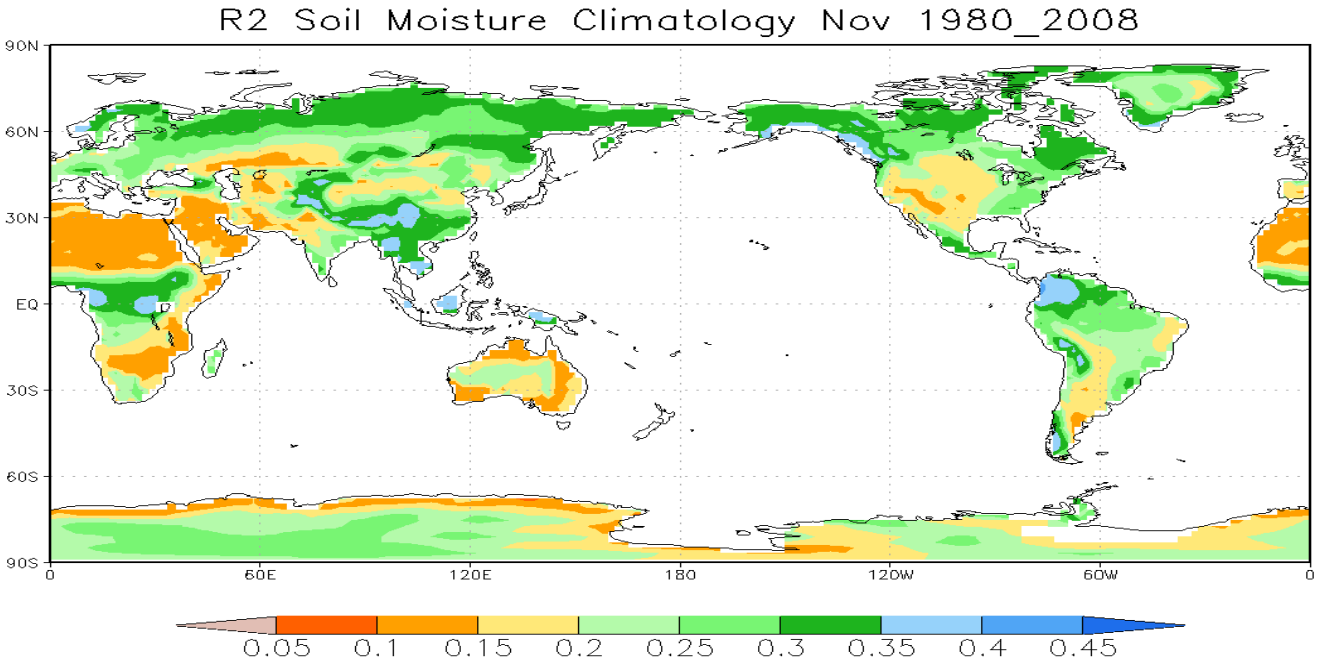


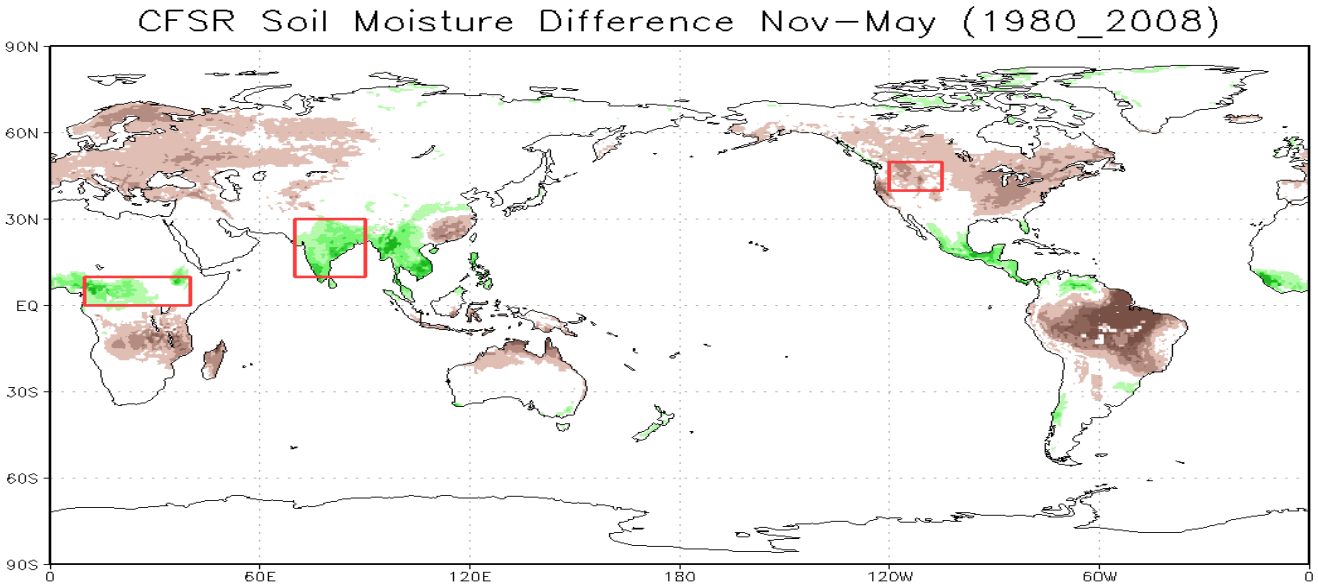
A blended precip forcing is used in GLDAS with the heavier weights of
CFS/GDAS – high lats
Gauge – mid lats
CMAP – tropics.

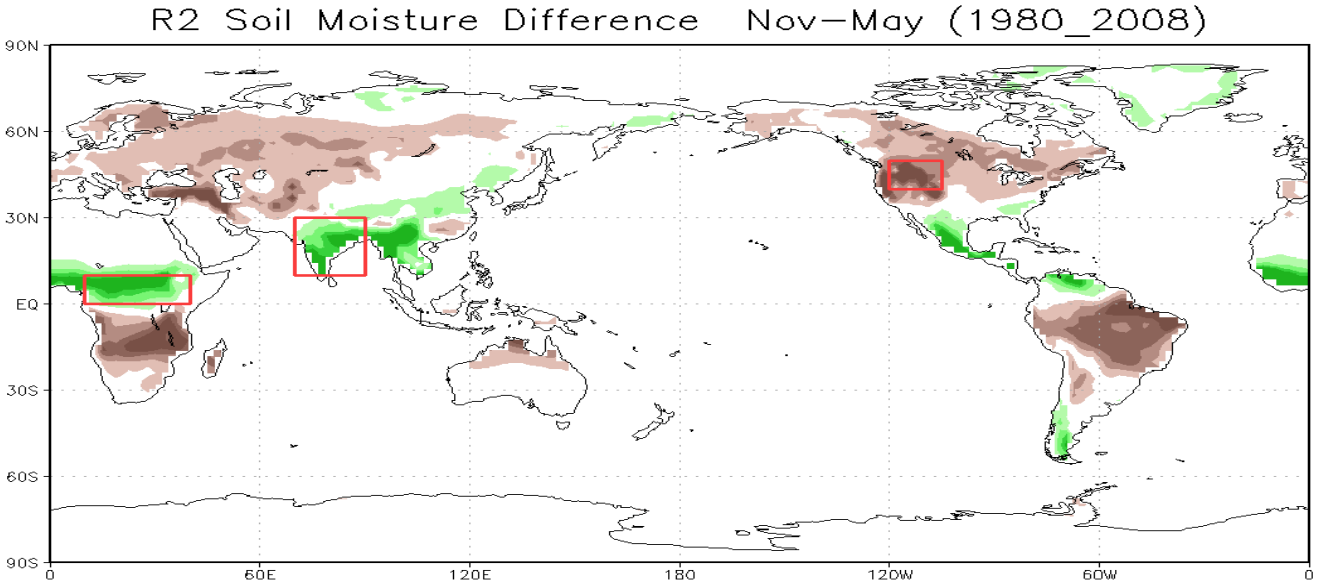

CFSR Soil Moisture Climatology May 1980_2008
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0

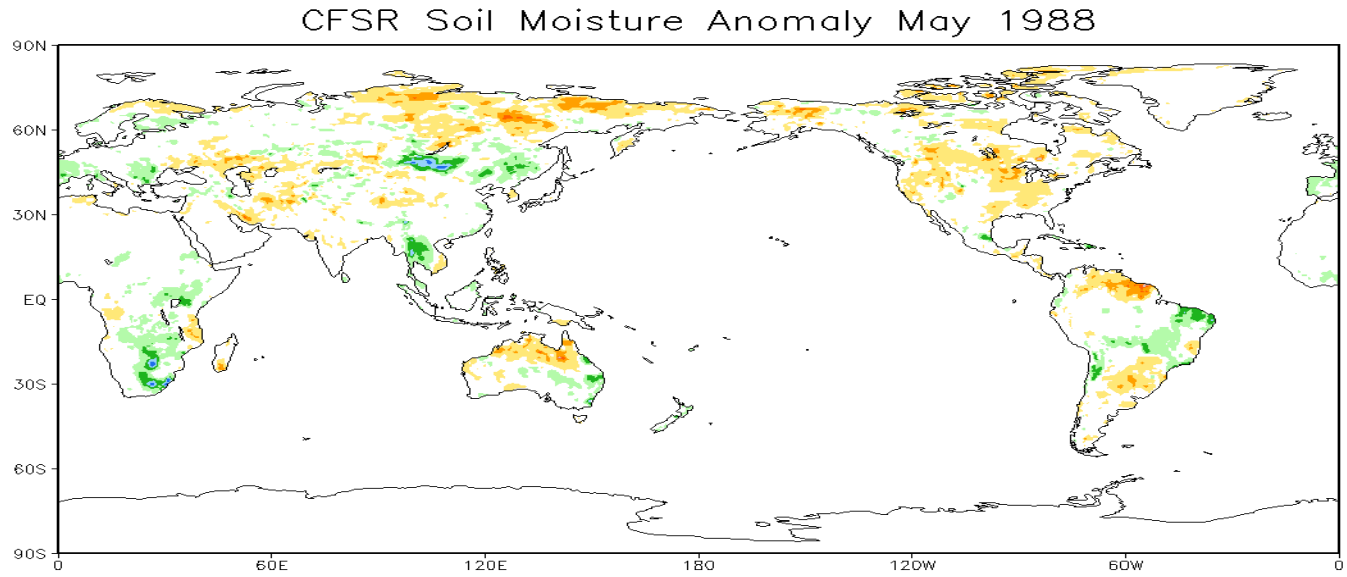

R2 Soil Moisture Climatology May 1980_2008
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45

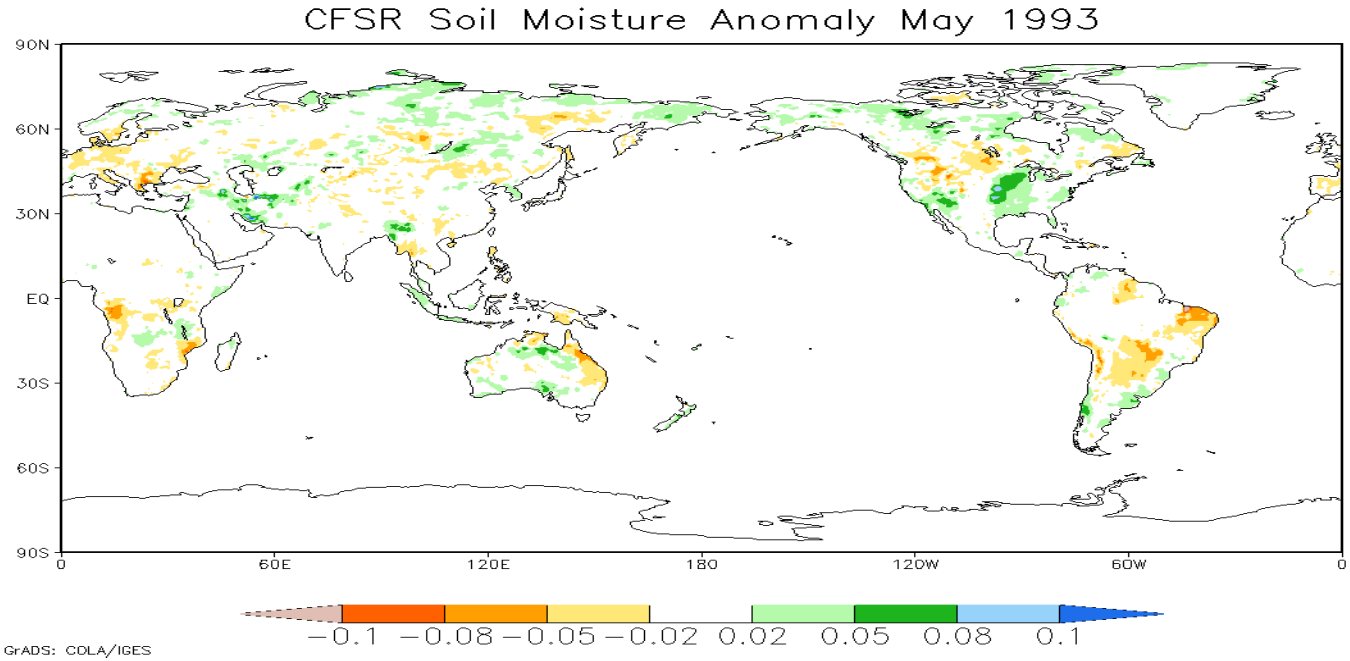

CFSR Soil Moisture Climatology Nov 1980_2008
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0


R2 Soil Moisture Climatology Nov 1980_2008
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


CFSR Soil Moisture Difference Nov–May (1980_2008)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0

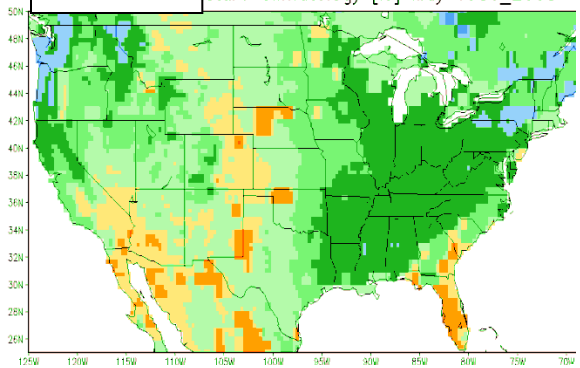

R2 Soil Moisture Difference Nov–May (1980_2008)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−0.1 −0.08 −0.05 −0.02 0.02 0.05 0.08 0.1


CFSR Soil Moisture Anomaly May 1988
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0

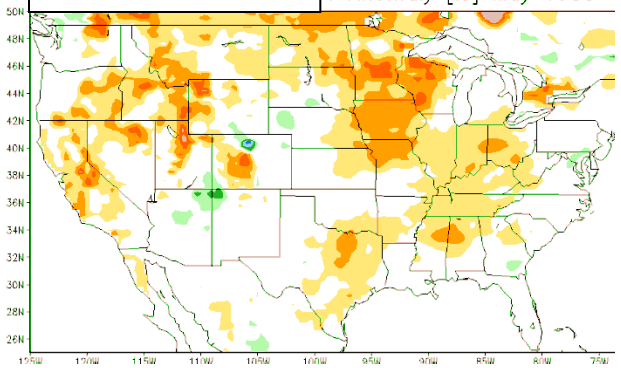

CFSR Soil Moisture Anomaly May 1993
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−0.1 −0.08 −0.05 −0.02 0.02 0.05 0.08 0.1
GrADS: COLA/IGES

CONUS soil moisture
May climatology and anomaly

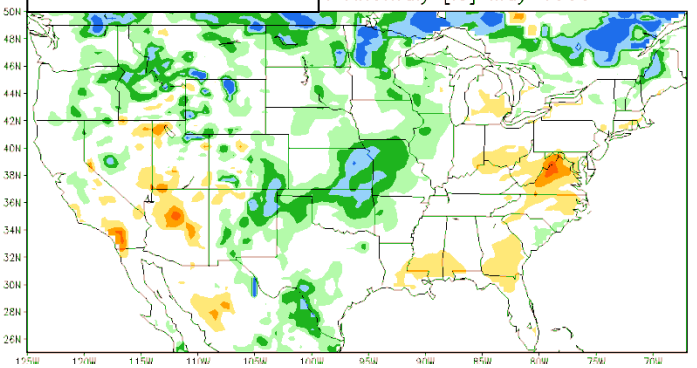
CFSR



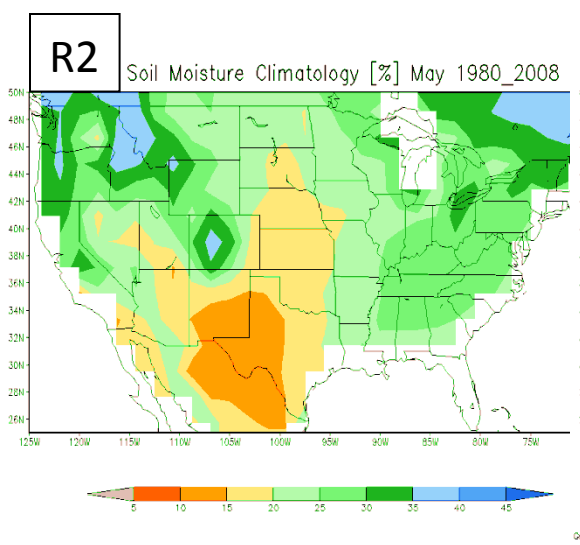
CFSR 1988



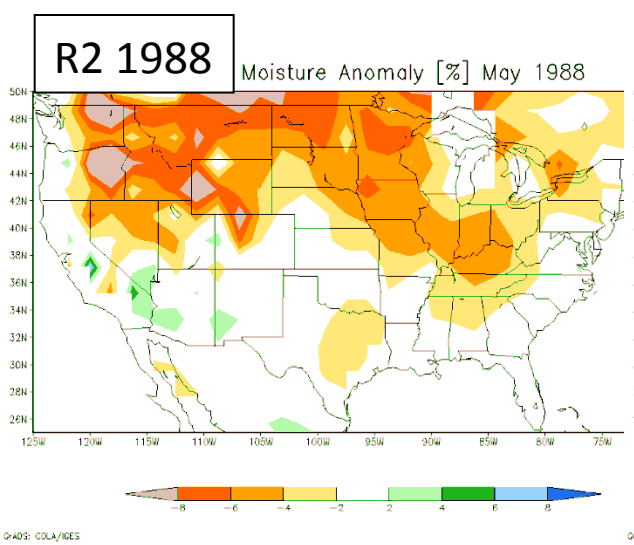
CFSR 1999



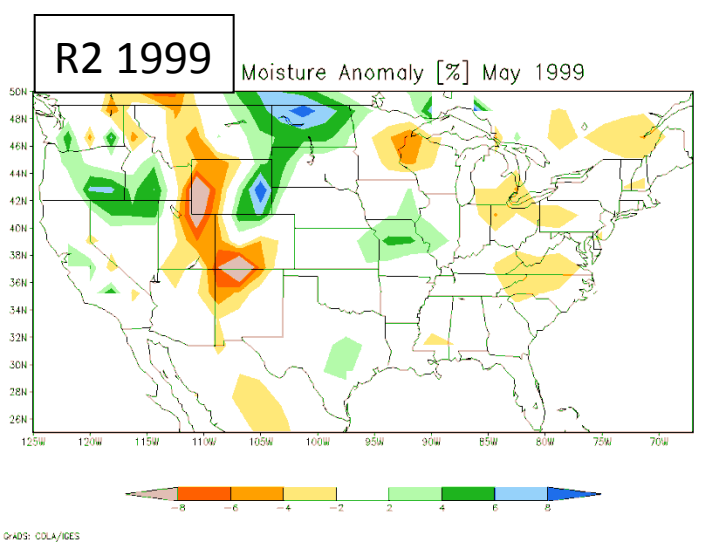
R2



R2 1988

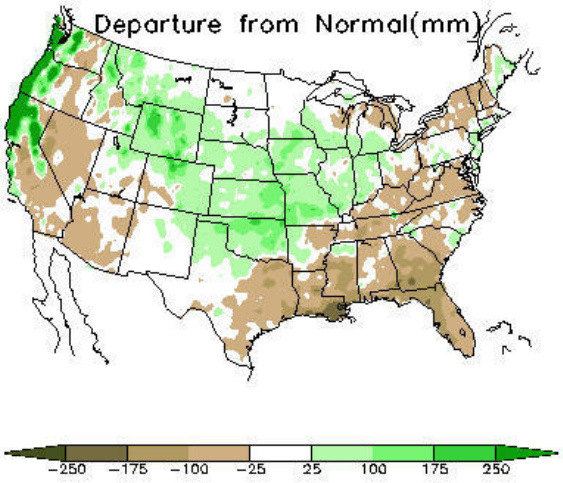


R2 1999



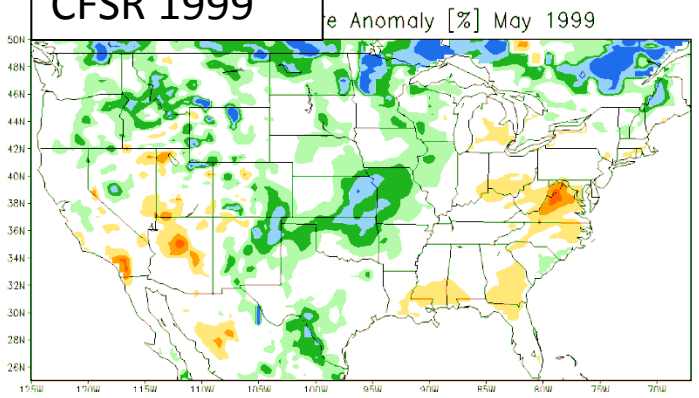
CONUS soil moisture
May climatology and anomaly

CPC 90-day obs precip anomaly ended 30Apr1999

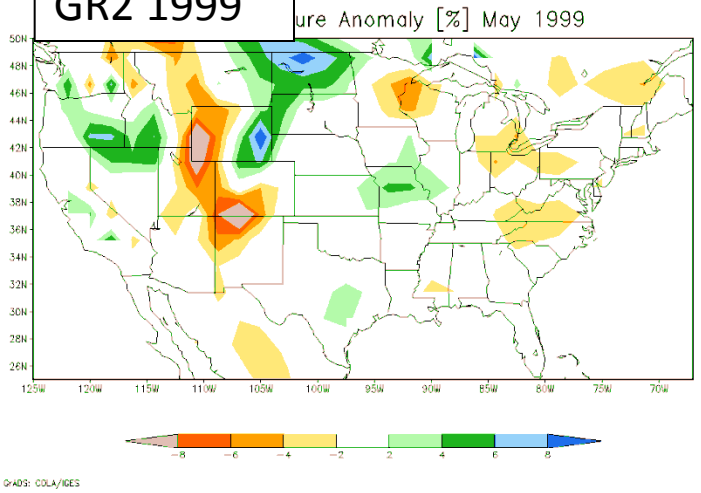


CFSR soil moisture anomaly corresponds well with observed precip anomaly.

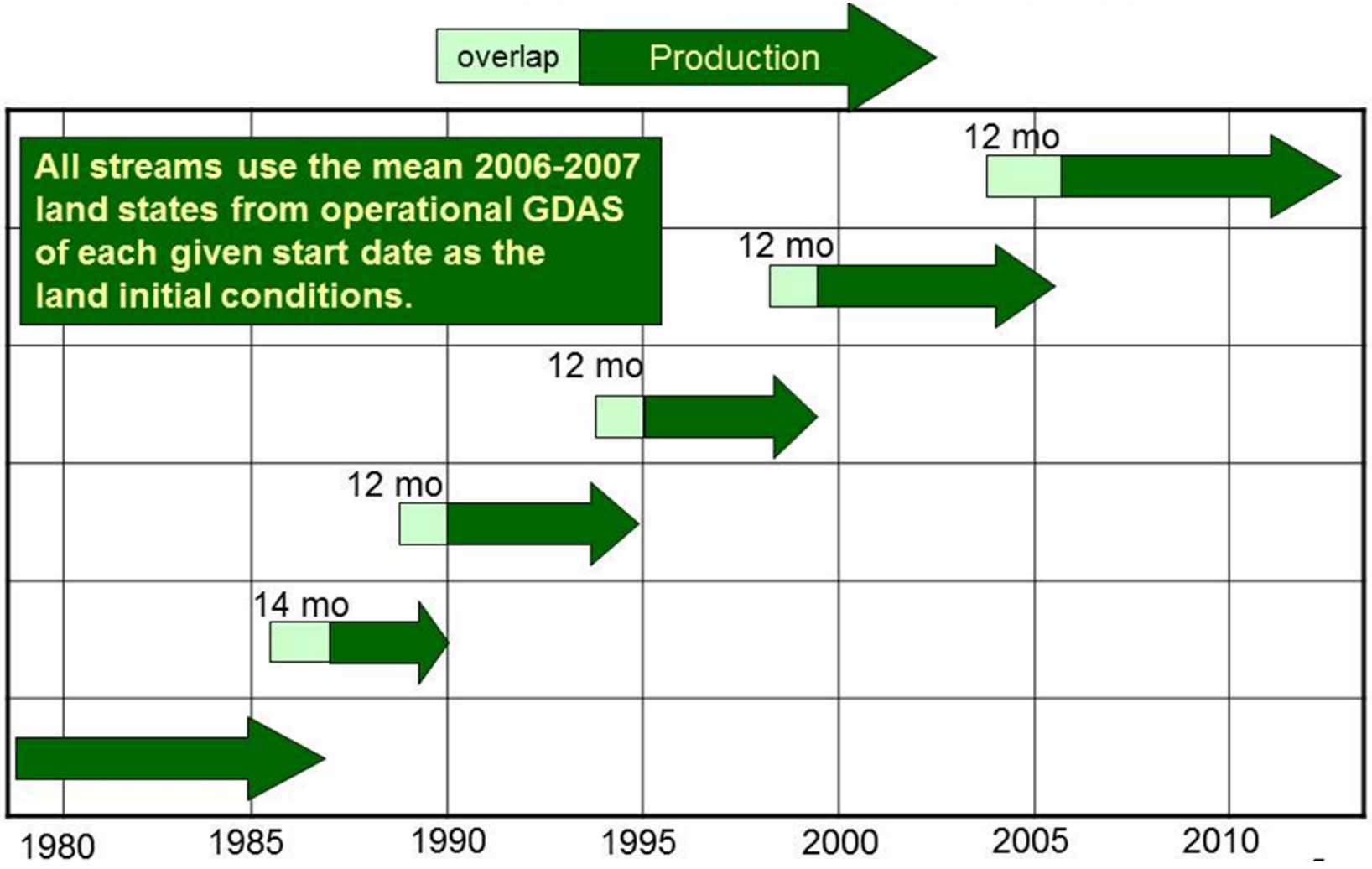
CFSR 1999

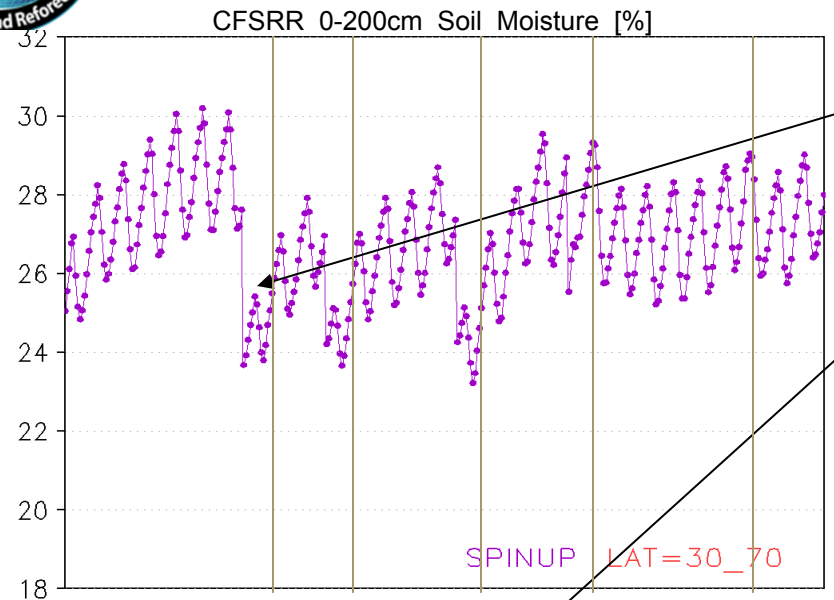


GR2 1999

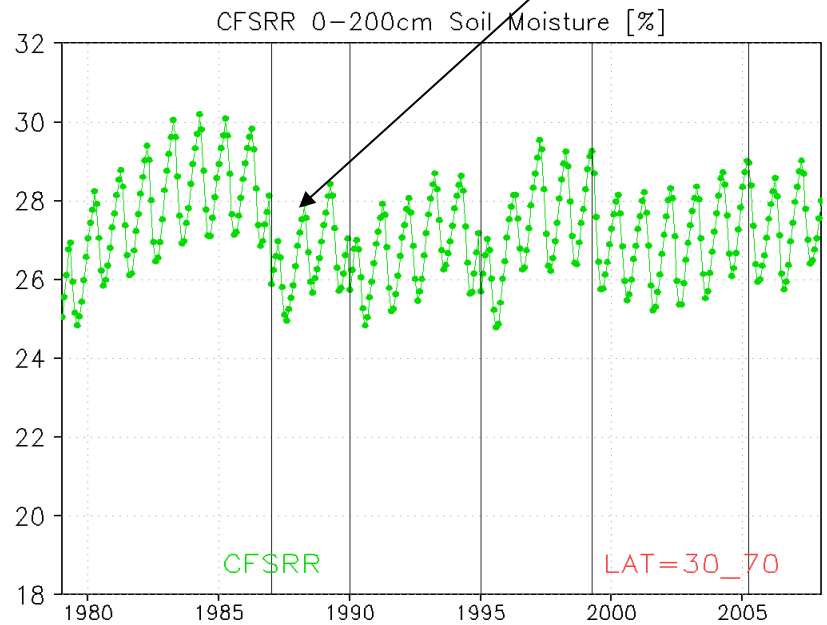


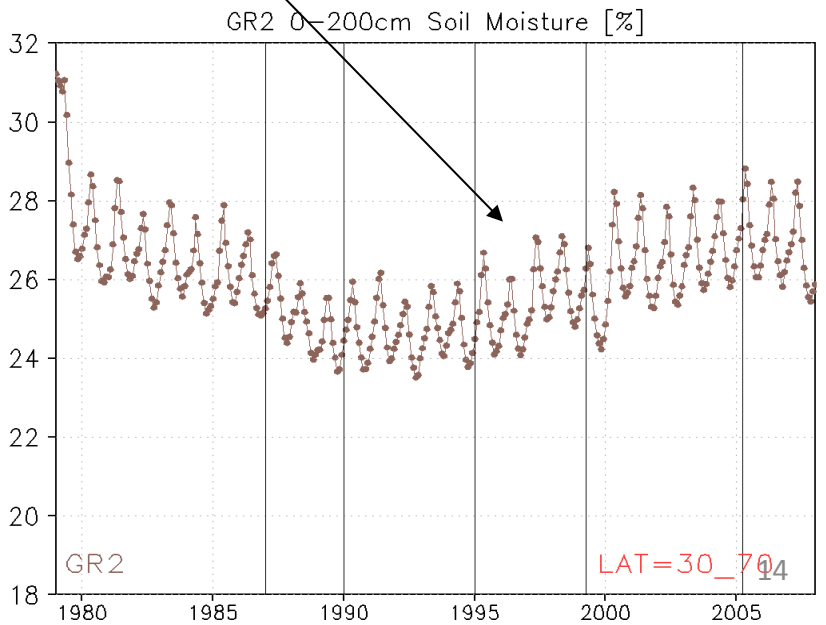
CFSR Production Streams



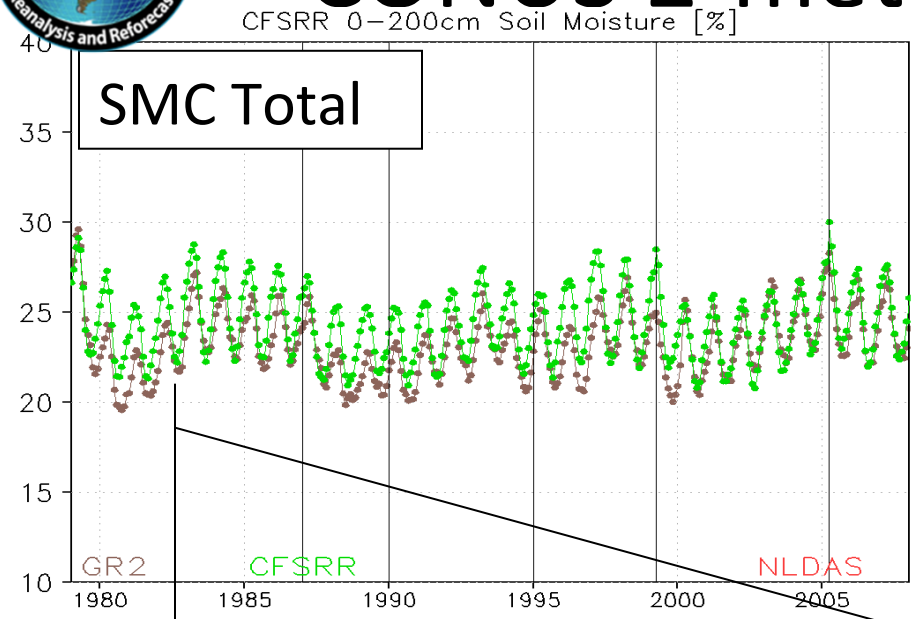


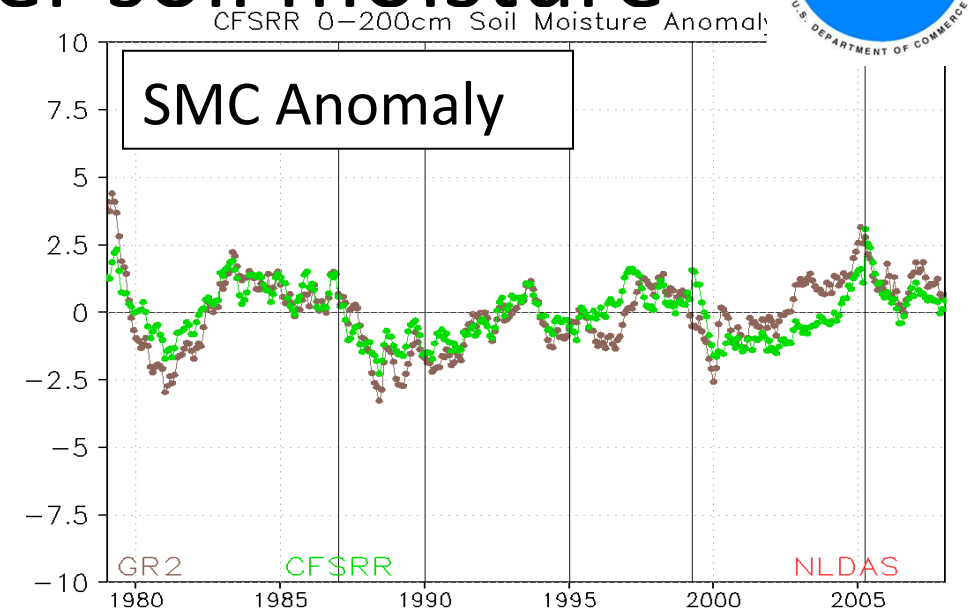
- Overlapping between streams is essential.
- With at least 12-month overlapping, the discontinuity between streams is reduced.
- R2, while executing one single continuous stream, also showed an upward trend over the past two decades.

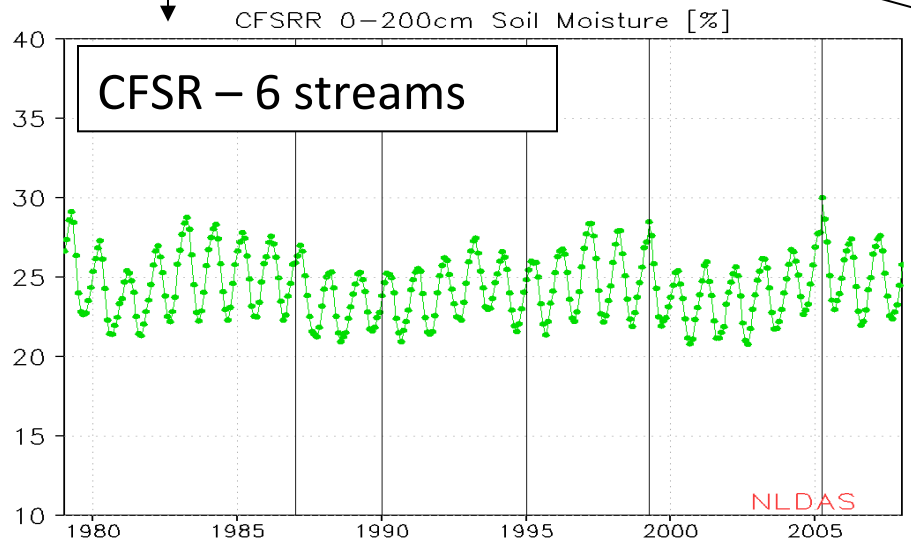


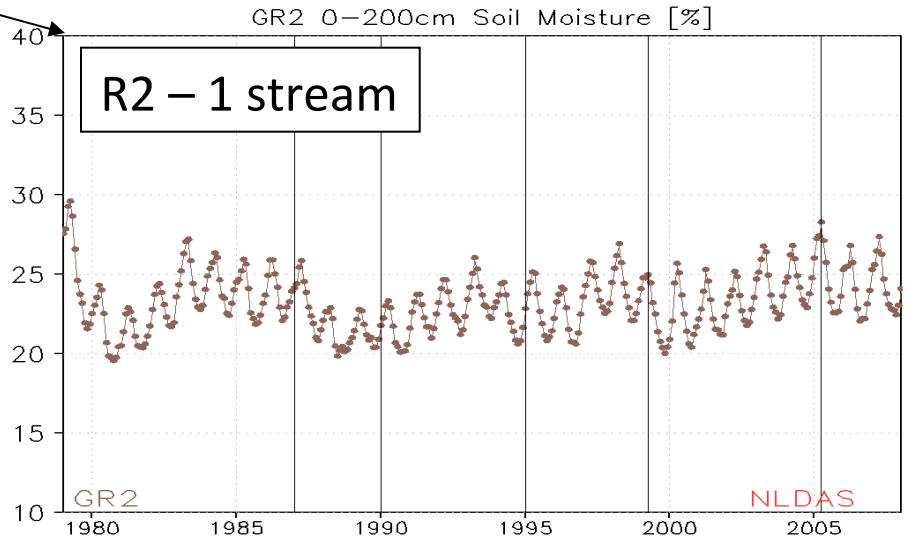


CONUS 2-meter soil moisture



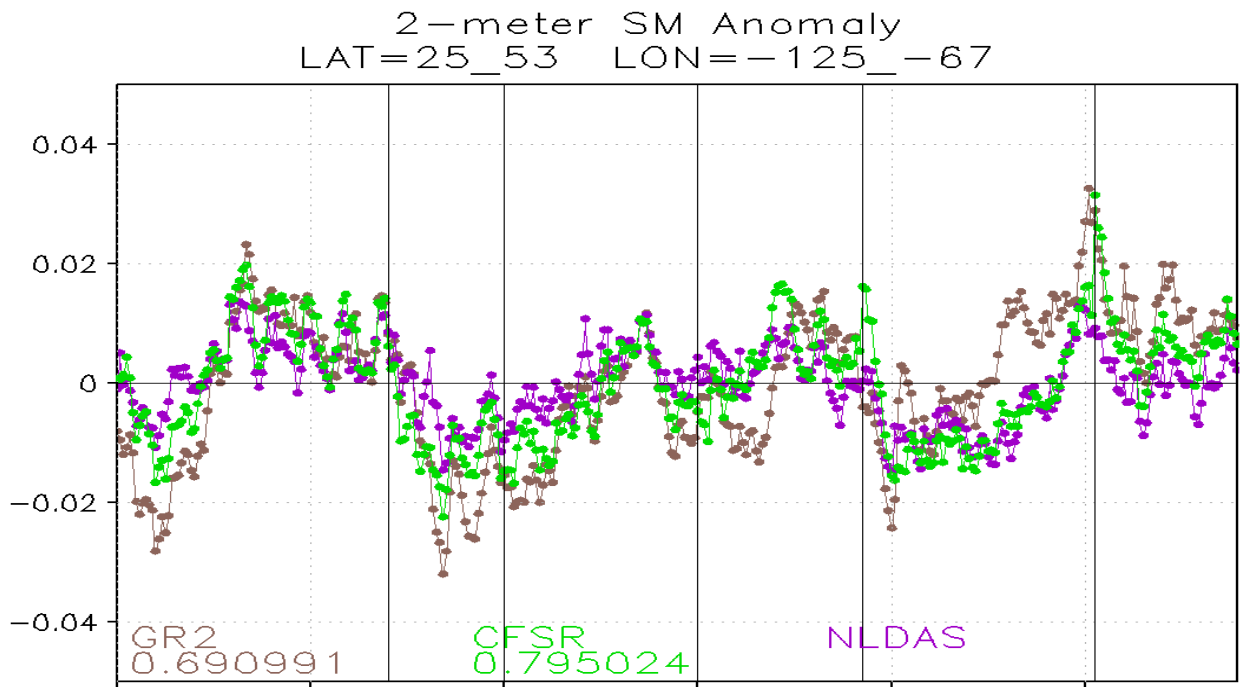




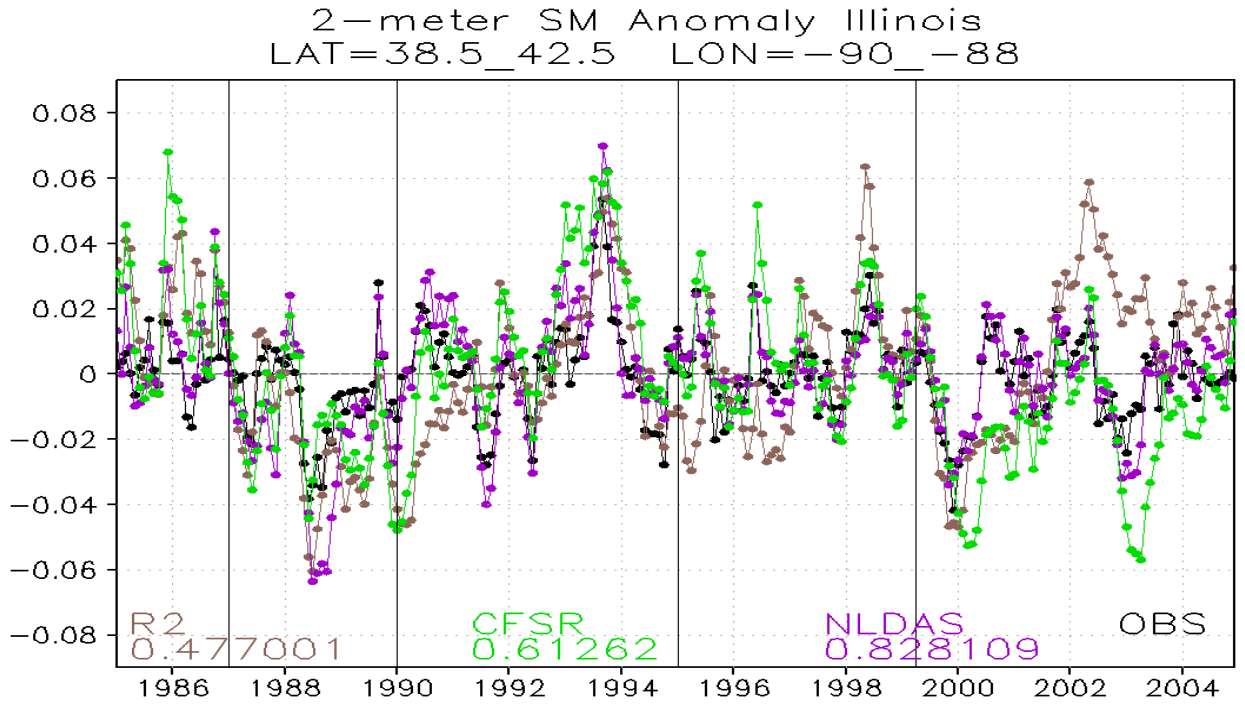


Trend? Natural or model driven?

CONUS



Illinois



Water Balance Equation

$$P - E - R - \Delta W/\Delta t + \text{updates} = \text{residual}$$

P: Precipitation

E: Evaporation

R: Runoff

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

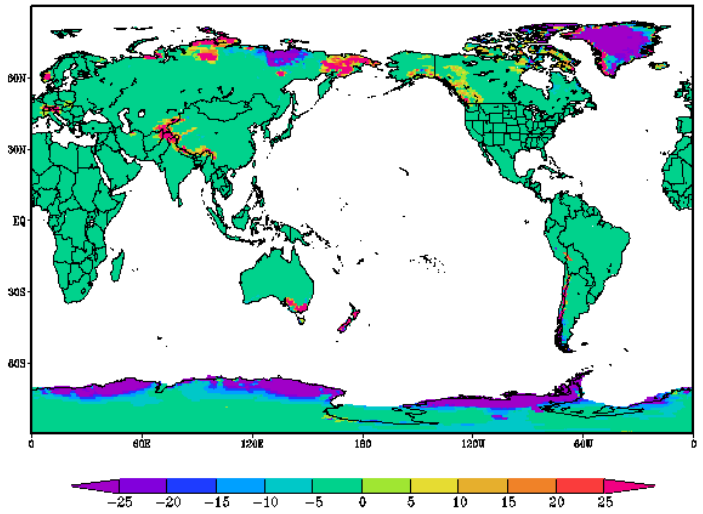
updates: Soil moisture and Snow updates in land analysis

R1/R2 data do not close water balance;

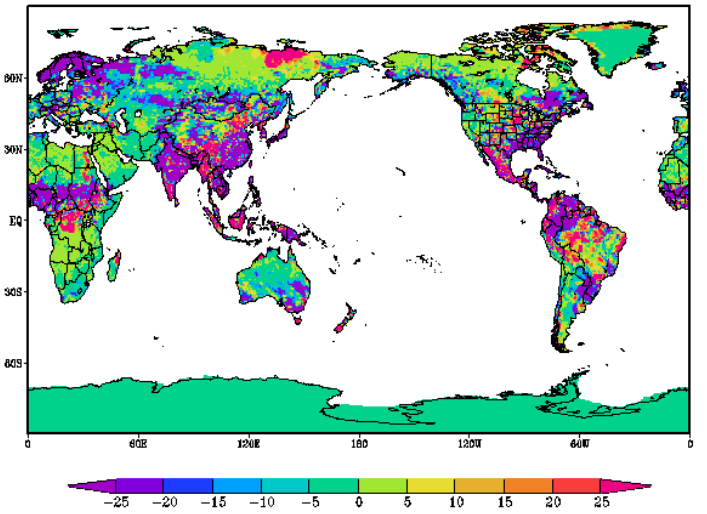
CFSR does.

Surface Water Budget

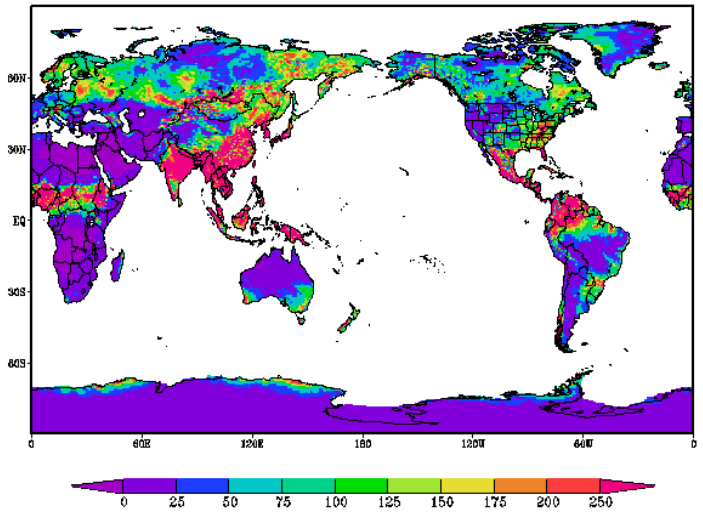
Snow Water Equivalent Updates (mm)



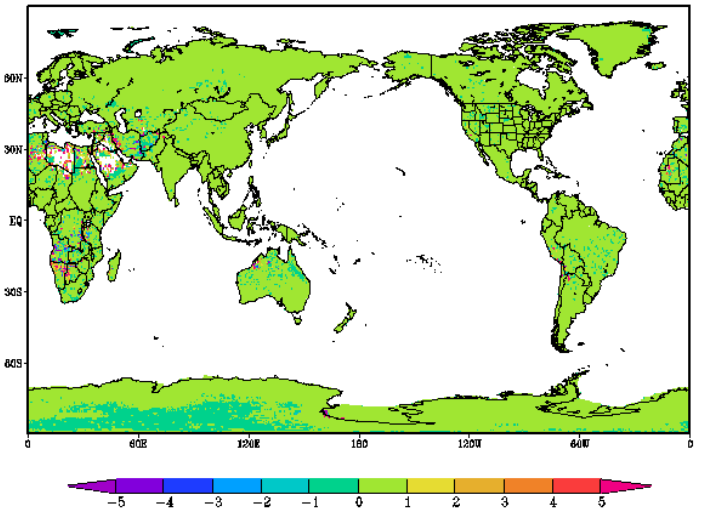
Total Soil Moisture Updates (mm)



Total Precipitation (mm)



Water Residual (% over Total Water Source)



Energy Balance Equation

SW + LW – SH - LH – G – SNOHF = residual

SW: Net Solar Radiation

LW: Net Longware Radiation

SH: Sensible Heat Flux

LH: Latent Heat Flux

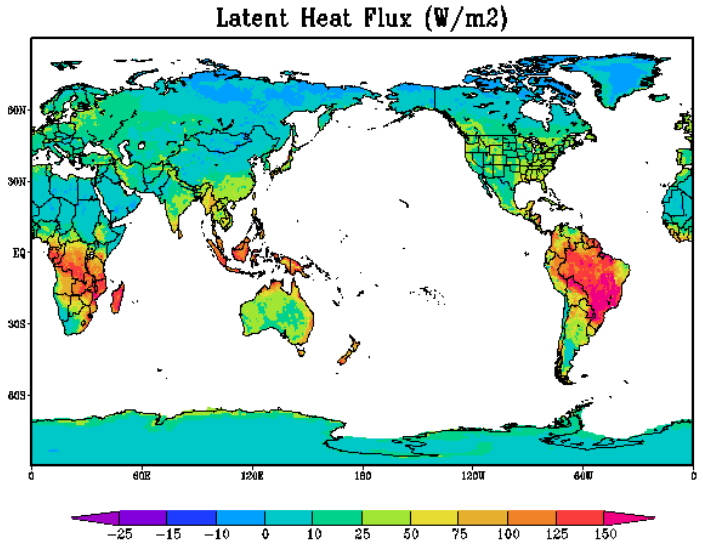
G: Ground Heat Flux

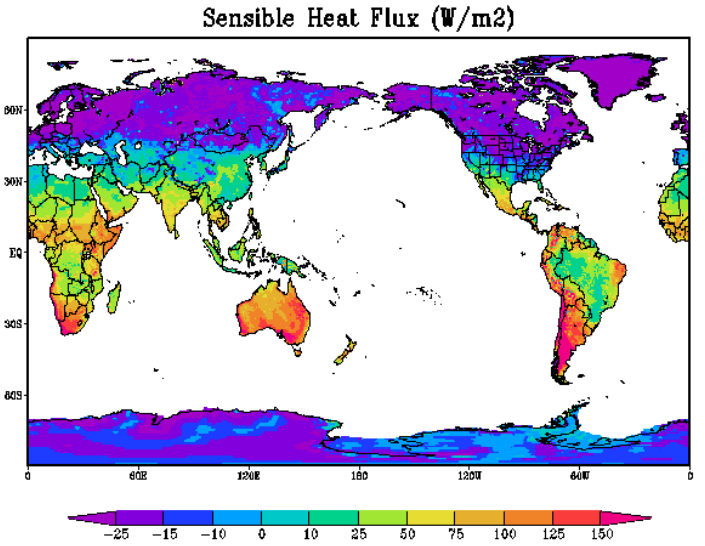
SNOHF: Snow Melt/Freeze Heat Flux

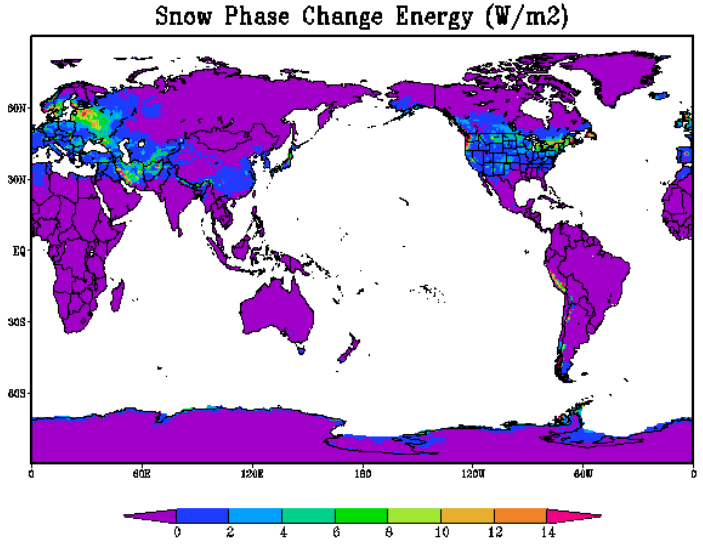
R1/R2 data do not close energy balance;

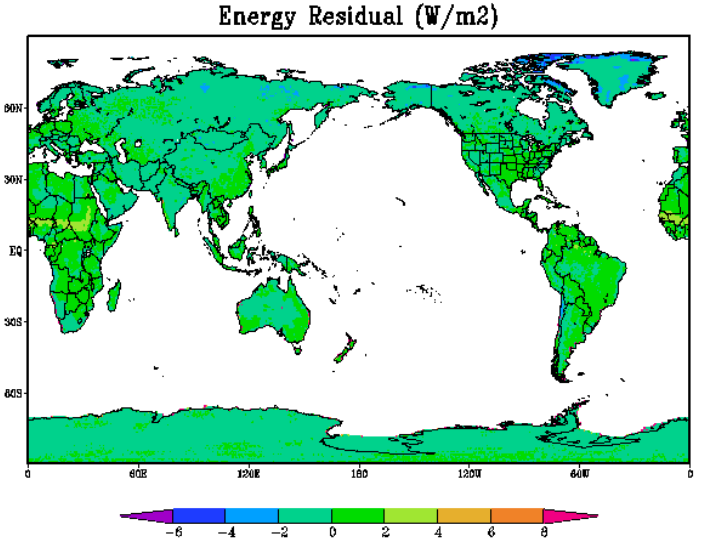
CFSR does.

Surface Energy Budget









Global Drought Monitor
One-stream GLDAS

- **Motivation:** CFSR was executed in 6 streams.
- **Solution:** Proposing a One-stream GLDAS (1979-realtime).
- **Configuration:** Same as CFSR (LIS T382).
- **Forcing:** CFSR surface forcing and blended precip forcing.
- **Initial condition:** Spin up land states for 1 January, 1979.
- **Spin up:** 1978 went from weak warm ENSO to neutral,
  with a similar condition, 2003 was selected for spin up.
  Start with CFSR land states of 1 January, 2003,
  execute 5-year recursive spin up with 2003 forcing, then
  another 5-year recursive spin up with 1979 forcing.

Conclusions

- CFSR and R2 carry similar seasonal soil moisture climatology, with differences due to model physics upgrades and forcing, mostly precipitation.
- On regional scale of CONUS, anomaly correlation of (CFSR,NLDAS) soil moisture time series is higher than (R2,NLDAS).
- On local scale of Illinois, anomaly correlation of (CFSR,obs) soil moisture time series is higher than (R2,obs) but lower than (NLDAS,obs).
- Land surface water and energy budget closure.
- A retrospective one-stream GLDAS is in process to resolve the issues of spin up and stream discontinuity to support the proposed Global Drought Monitor.