# *Regional consistency analysis of the water cycle from recently derived satellite products*


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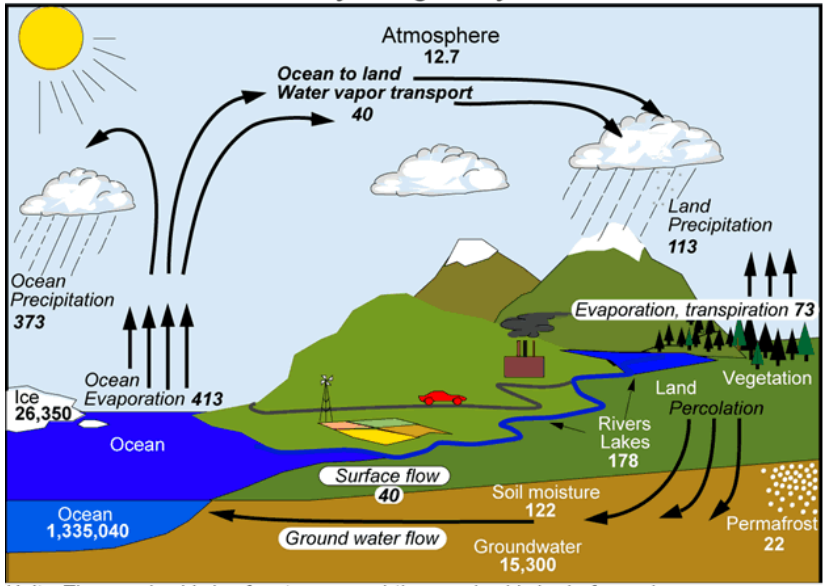
**Hydrological Cycle**




Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Trenberth et al 2006

8th GEWEX Science Conference:
Extremes and Water on the Edge

## Motivation

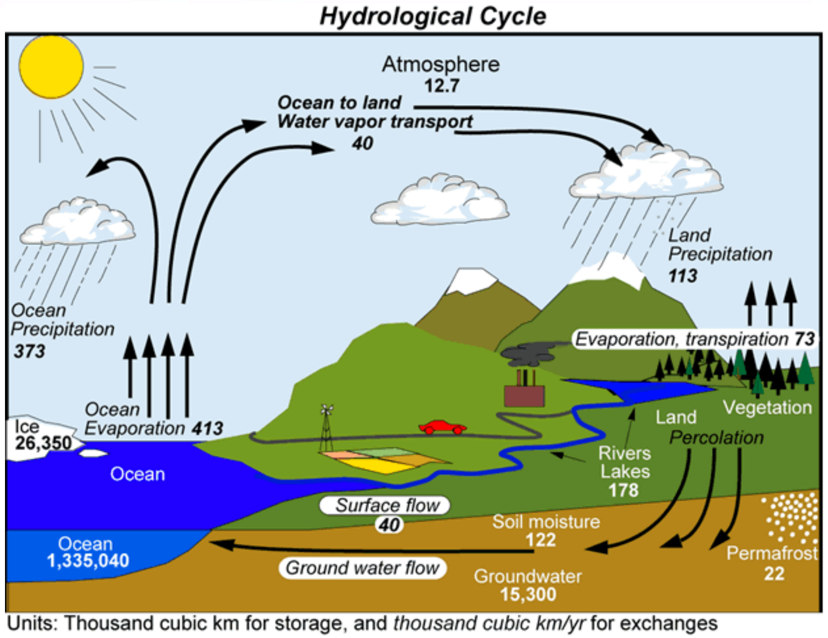
- *The land water cycle is a key element of the climate system representing all water exchange processes at the surface.*
- *It is a useful physical framework for studies of land-atmosphere interactions, land use effects, land management, and extremes.*

*Satellite products related to the water cycle are increasing in quality, spatial resolution and temporal coverage… but they are obtained with independent approaches:*

- *To what extent can long-term sets of higher resolution satellite data represent the water cycle from continental to regional scales?*
- *And if they do, is it for the right physical reasons?*

*I will examine the physical consistency of independently computed water cycle terms, in particular I will show some climatological features, like the mean annual cycle and the diurnal cycle.*

# The water cycle




Trenberth et al 2006

$$P - E = R + \partial W / \partial t + Res$$

$$W = SM + GW + SWE + Wcan + Ws$$

(Storage)

P Precipitation
E Evapotranspiration
R Surface and subsurface runoff
Res Residual terms

(Irrigation…water pumping…)

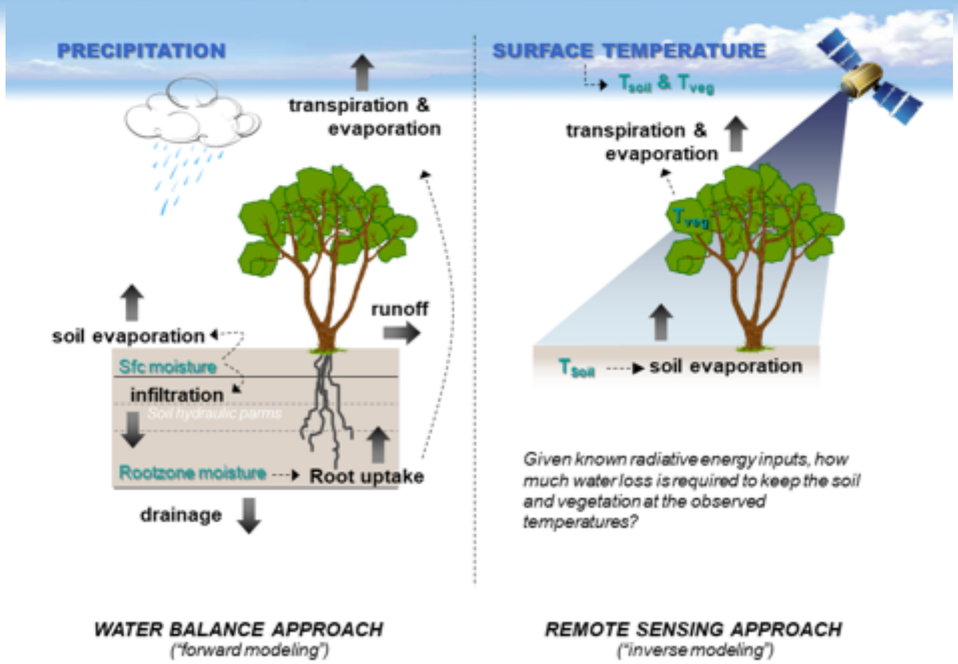
SM Soil Moisture
GW Groundwater
SWE Snow Water Equivalent
Wcan Canopy Water
Ws Surface Water

# *Precipitation*

| | |
|---|---|
| TMPA | *TRMM Multi-Satellite Precipitation Algorithm*<br>Res: 0.25 x 0.25<br>Length: 20+ years<br>Source: NASA |
| Persiann | *Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks*<br>Res: 0.25 x 0.25<br>Length: 30+ years<br>Source: UCI Center for Hydrometeorology & Remote Sensing |
| CMORPH | *CPC Morphing Technique*<br>Res: 0.07 x 0.07<br>Length: ~ 15-20 years<br>Source: NOAA |

# Evapotranspiration

*Water balance approach*




*Energy balance approach (Remote sensing)*

$$RN - G = H + \lambda E$$

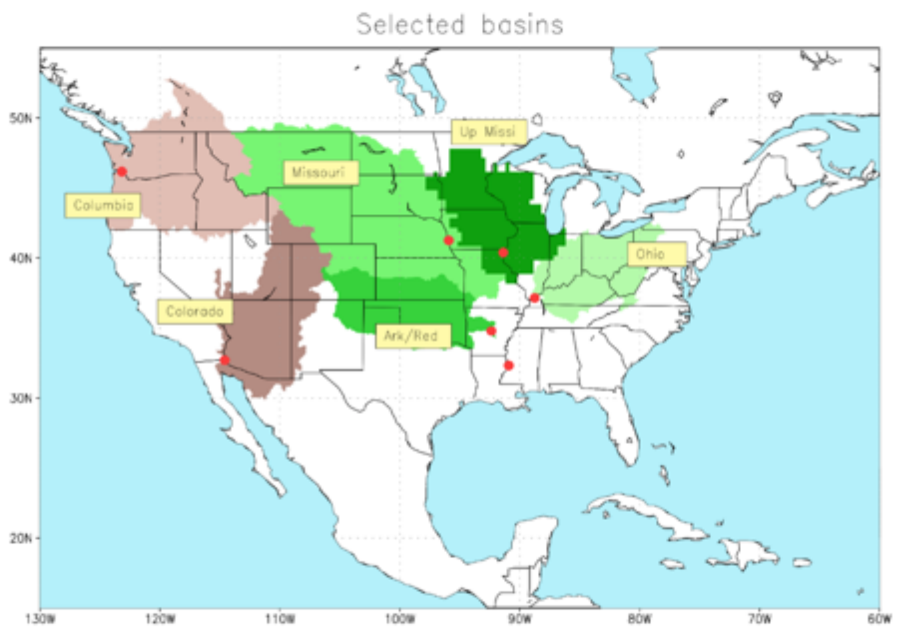
*[Anderson et al 2007]*

NOAA's GOES Evapotranspiration and Drought Product System (GET-D)

Res: 0.05 x 0.05

*This product uses satellite observations of land surface temperatures taken by NOAA's GOES and vegetation information from NOAA's and NASA's VIIRS instrument.*

*The Diagnostic Model ALEXI is based on TIR remote sensing that <u>requires no information regarding antecedent precipitation or soil moisture storage capacity</u>*




| | |
|---|---|
| Streamflow | *USGS in-situ observations* |
| Runoff | No satellite observations. We use Noah-LIS products when needed<br>Res: 0.125 x 0.125 |
| Soil Moisture | *Soil Moisture Active Passive (SMAP) mission Level-4* ***Surface and Root-Zone Soil Moisture*** *(L4_SM) data product is generated by assimilating SMAP L-band brightness temperature observations into the NASA Catchment land surface model*<br>Res: 9 km |
| GRACE | Freshwater storage by the Gravity Recovery and Climate Experiment (Grace)<br>Res: 250-300 km |

# *The water cycle at regional scales*

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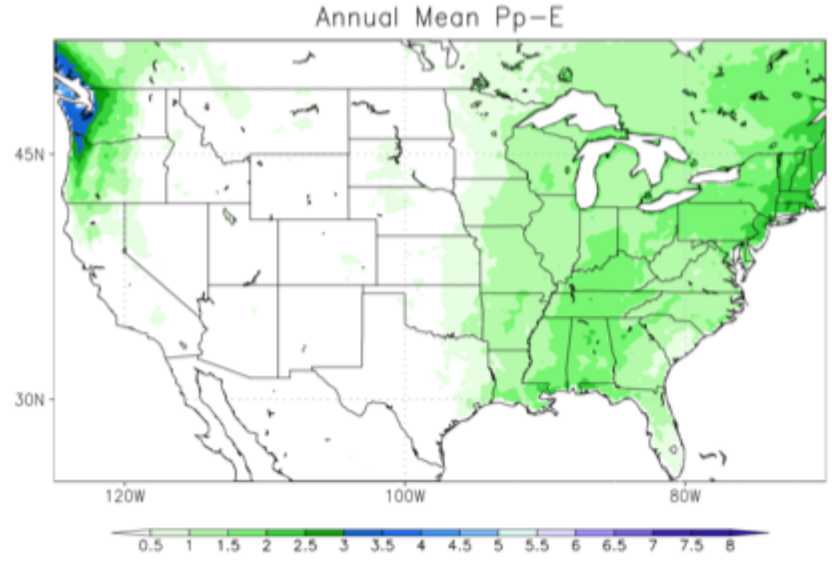
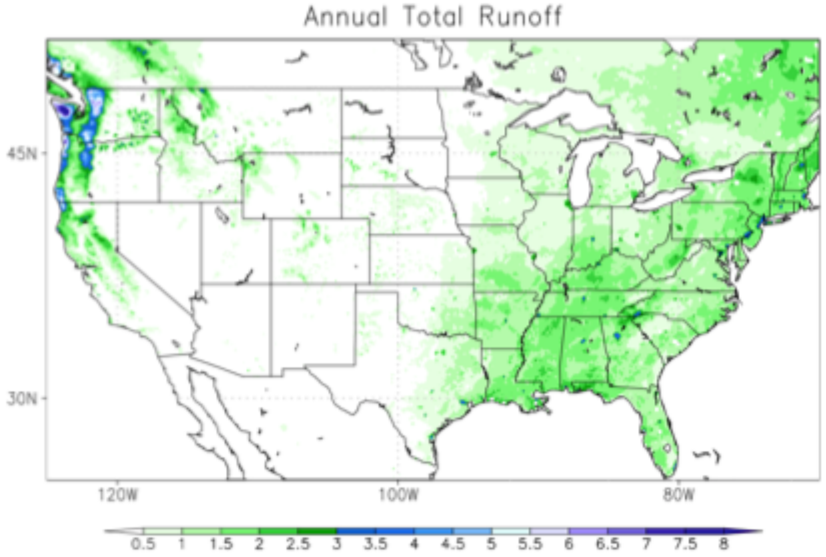
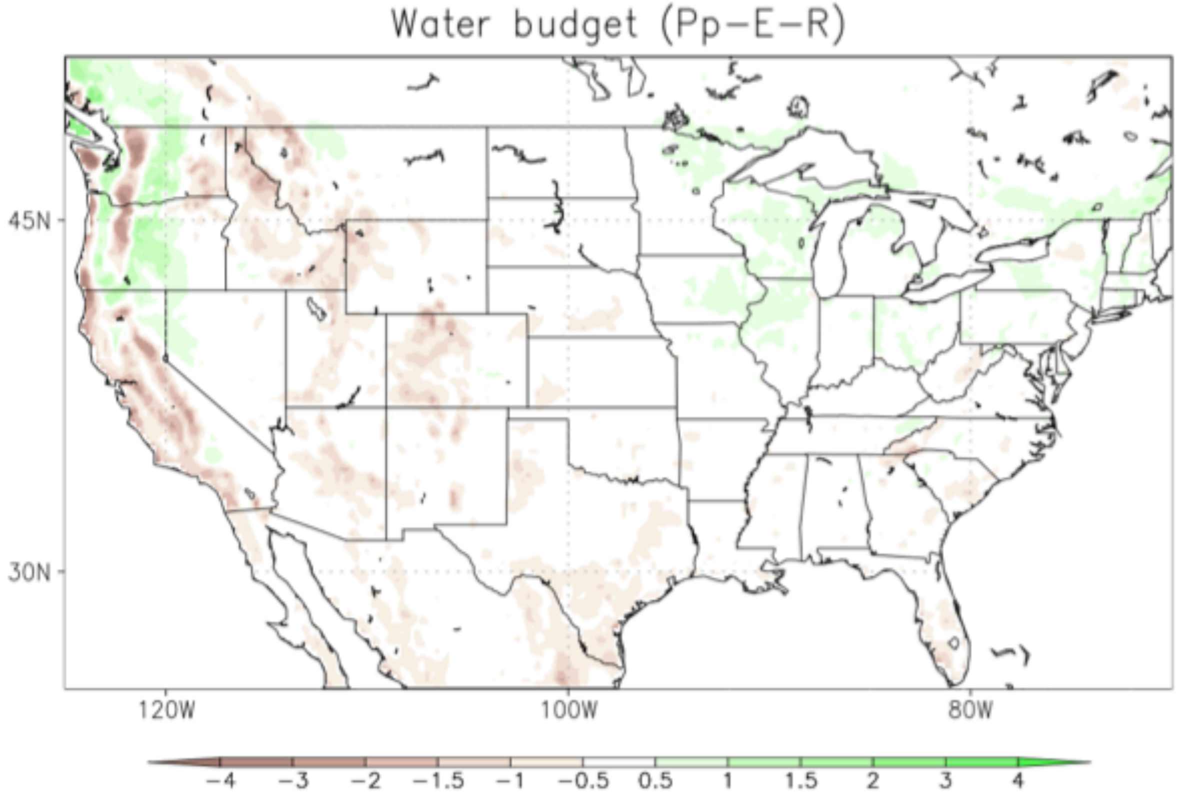
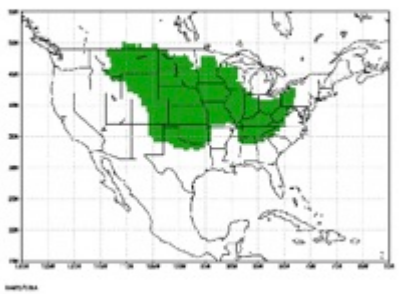



mm/day

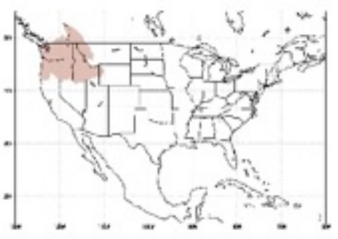


# Mississippi River Basin

| Mississippi | |
| --- | --- |
| $P_{pe}$ / $P_{tmpa}$ | 2.21 / 2.24 |
| E | 1.5 |
| Streamflow (obs) | 0.60 |
| Runoff (Noah) | 0.66 |

| | |
| --- | --- |
| Res (obs) | -0.11 / -0.14 |
| Res (Noah) | -0.05 / -0.08 |

All units are mm/day

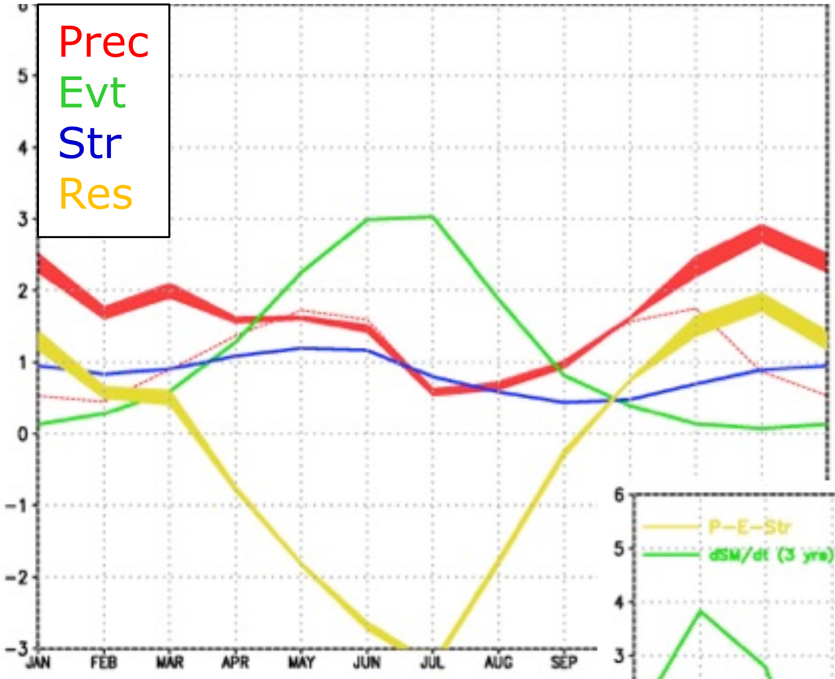


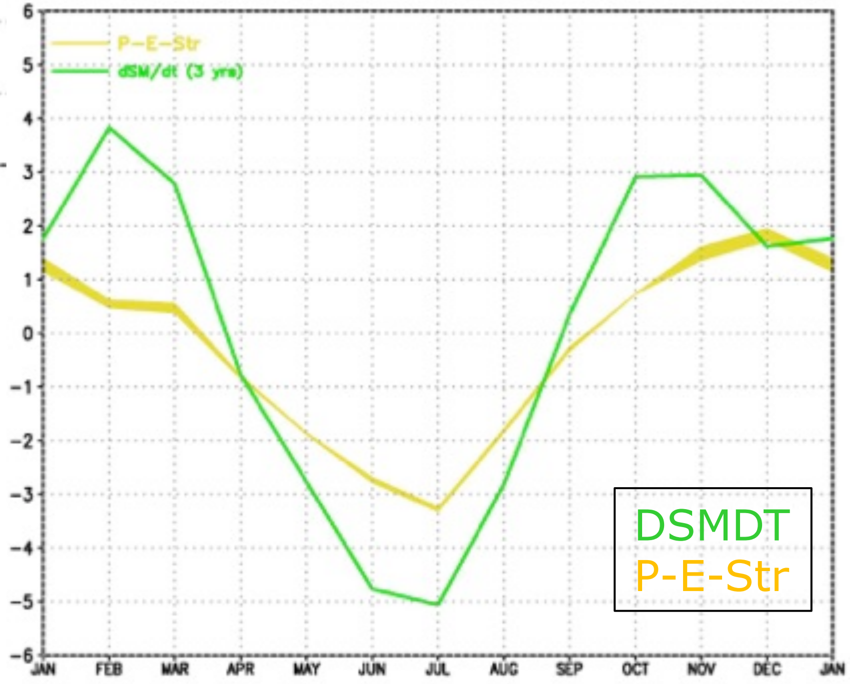
# Columbia River Basin

| Columbia | |
|---|---|
| $P_{pe}$ / $P_{tmpa}$ | 1.70 / 1.56 |
| E | 1.15 |
| Streamflow (obs) | 0.83 |
| Runoff (Noah) | 0.90 |

| | |
|---|---|
| Res (o) | -0.28 / -0.42 |
| Res (n) | -0.35 / -0.49 |

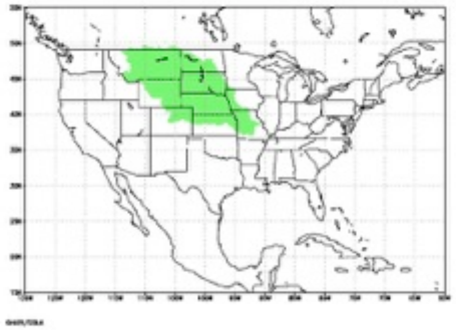
All units are mm/day

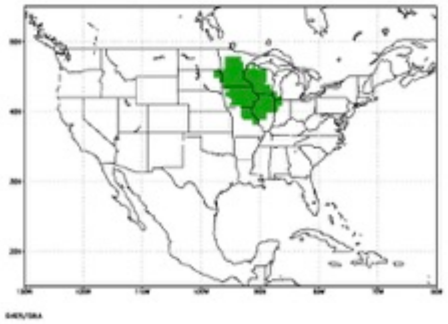


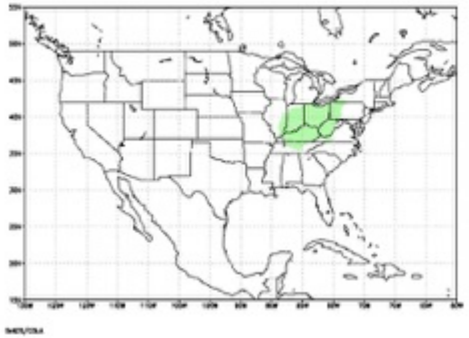



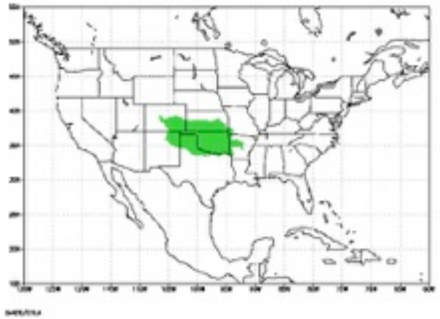
Sub basins

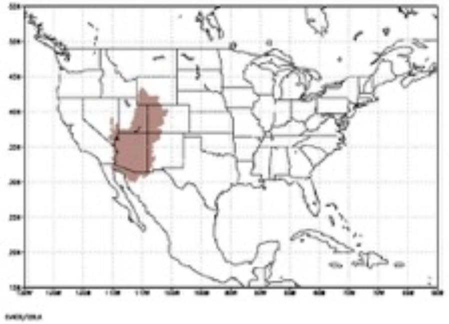
| Basin | Precip | EVT | Str | Res (mm/d) | Res/P |
|---|---|---|---|---|---|
| **Up Miss** | 2.73 | 1.65 | 0.24 | **0.83** | **0.30** |
| **Missouri** | 1.45 | 1.17 | 0.09 | **0.20** | **0.14** |
| **Ohio** | 3.50 | 1.96 | 1.34 | **0.25** | **0.07** |
| **Ark/Red** | 1.97 | 1.56 | 0.26 | **0.18** | **0.09** |
| **Colorado** | 0.85 | 0.96 | 0.003 | **-0.11** | **-0.13** |





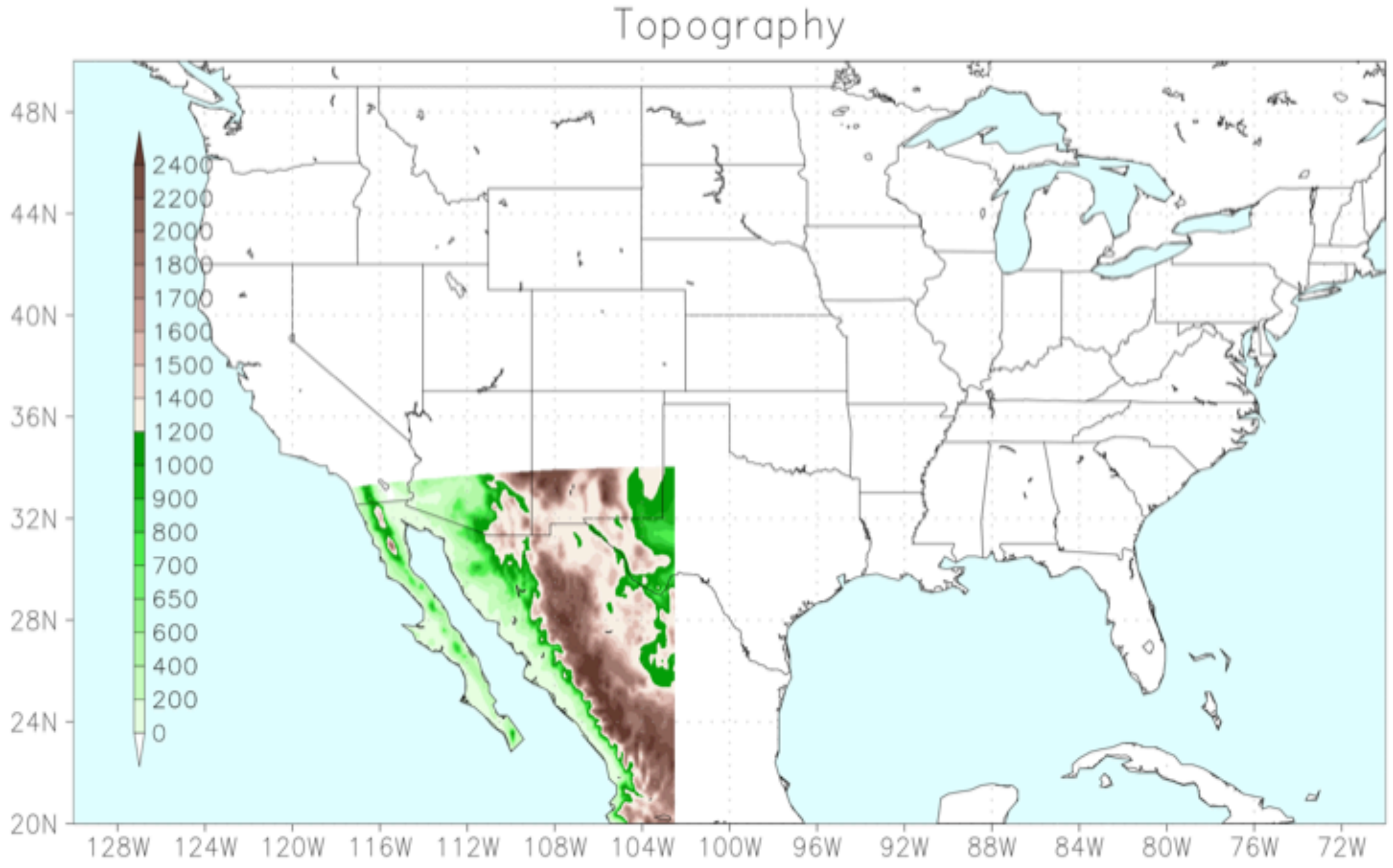




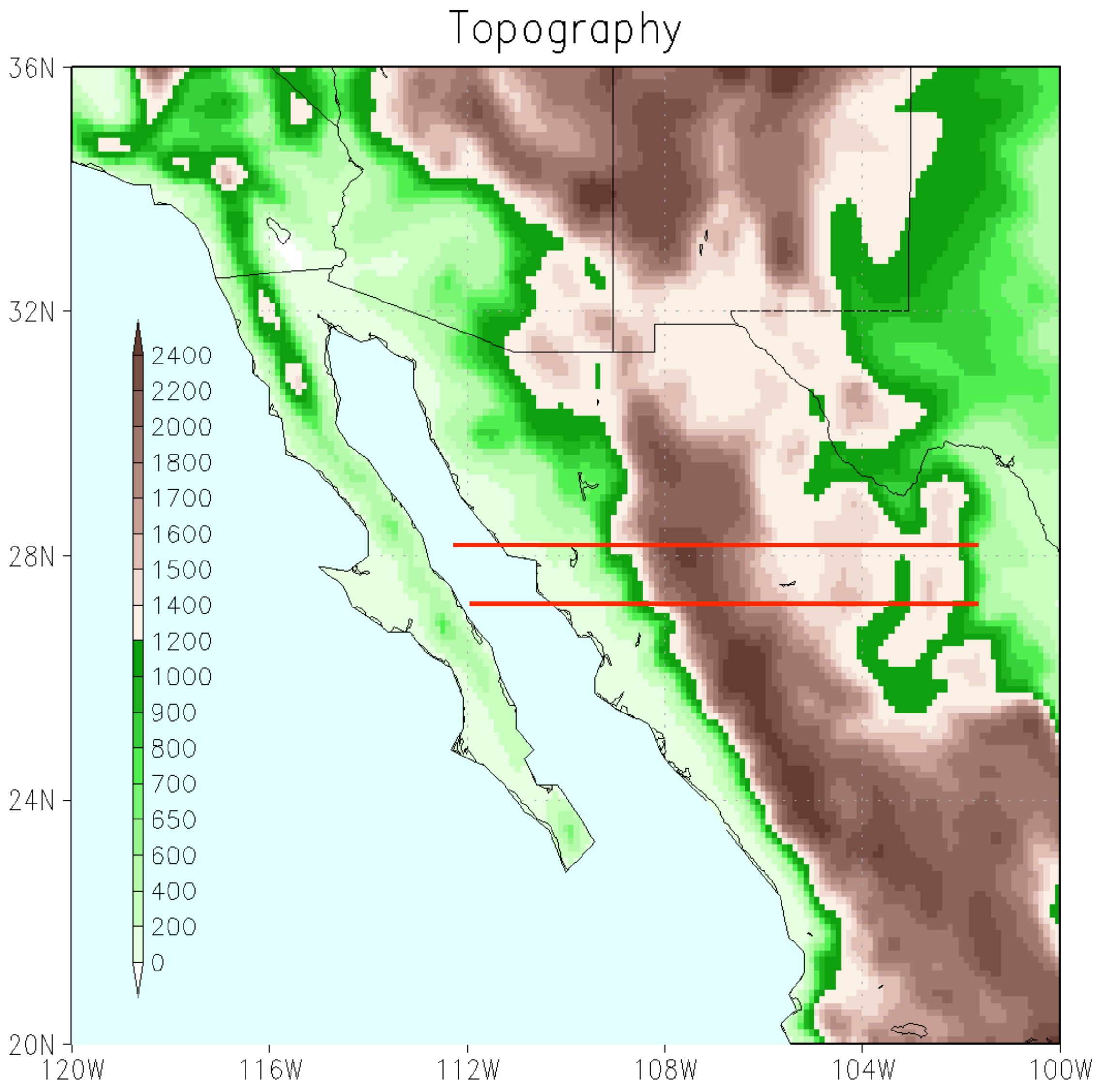


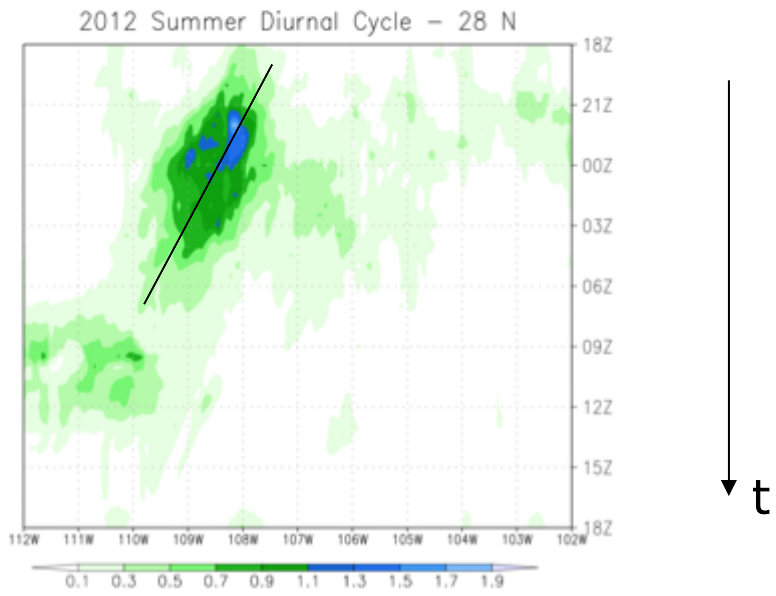
# *Local scales*

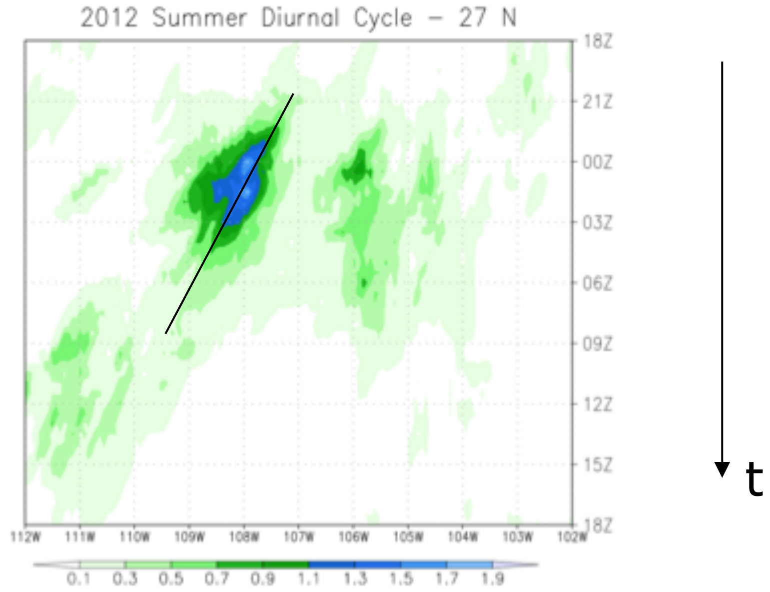
*(the North American Monsoon)*



# Local features – The North American Monsoon diurnal cycle



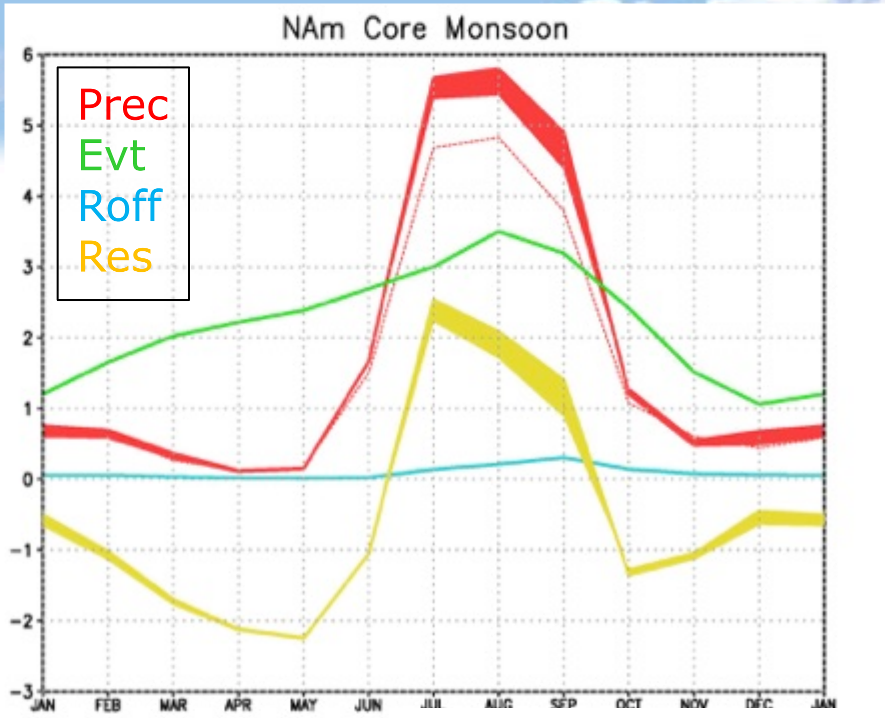



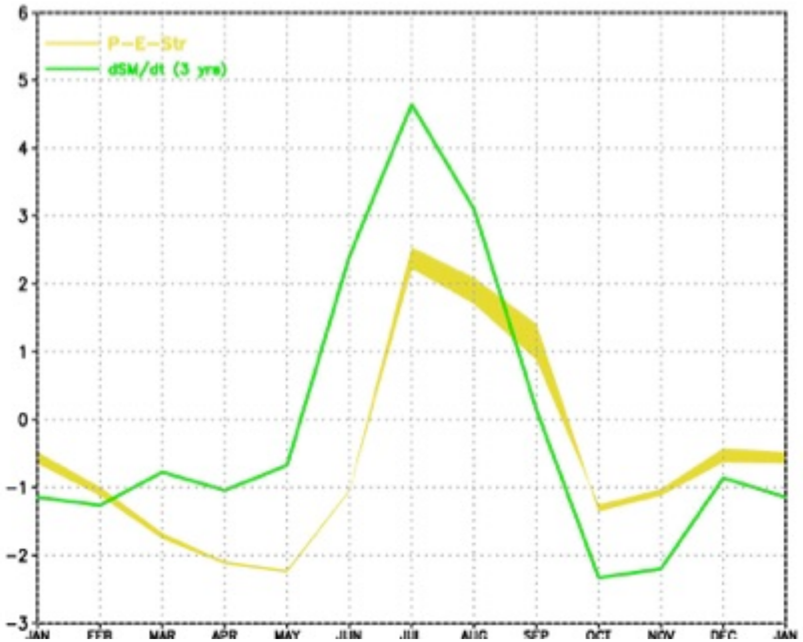



# North American Core Monsoon

| Core Monsoon | |
|---|---|
| $P_{pe}$ / $P_{tmpa}$ | 1.83 / 1.80 |
| E | 2.20 |
| Runoff (Noah) | 0.10 |
| Streamflow (obs) | - |

| | |
|---|---|
| Res (n) | -0.47 / -0.50 |
| Res (o) | - |




All units are mm/day

# Summary

- Over the Mississippi River Basin, the climatological water cycle is well represented with a small residual term (in which we include the storage terms) that amounts to about 10% of the precipitation.

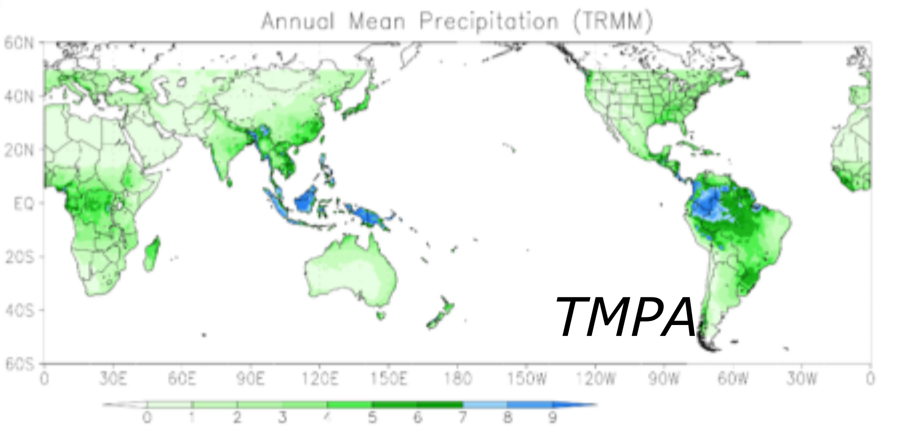
- Analysis of the annual cycle reveals the importance of storage terms if it is expected to achieve a balance throughout the year

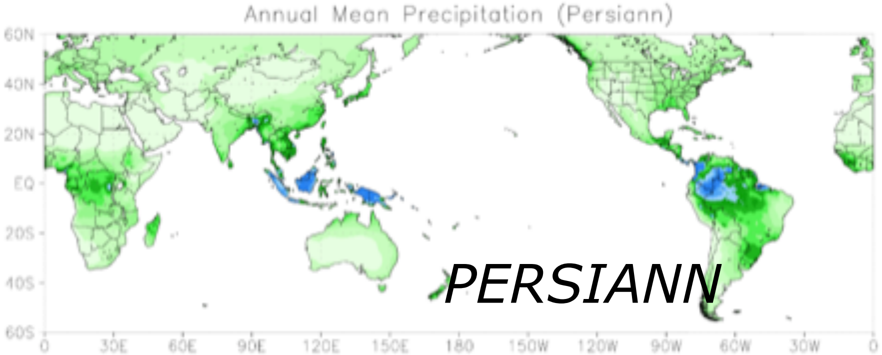
- Complex topography and cold processes still represent the challenge. While the overall shape of the annual cycle is similar to those previously estimated, the residuals reach about 0.4 mm/d or 22% of the precipitation for the Columbia River Basin.

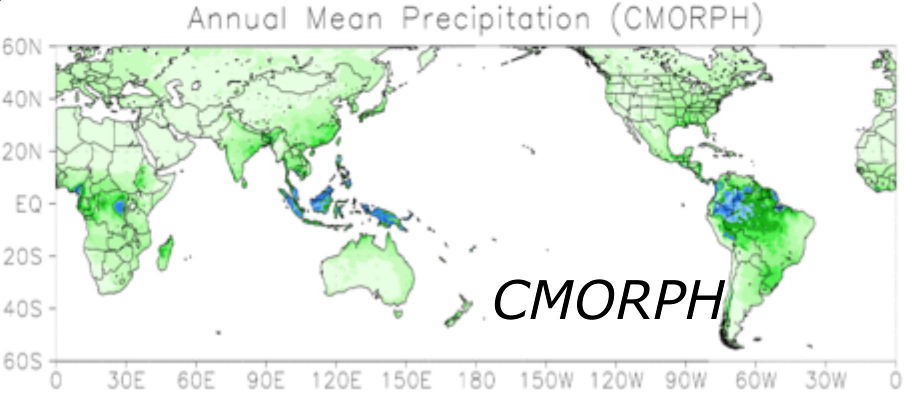
- Over the North American monsoon, important features relating topography and precipitation are well represented. The diurnal cycle of precipitation is realistic and responds to physical processes related even to small topographic features.

- It remains to be seen what are the amounts and roles of the storage terms, particularly snow, in determining a balanced seasonal evolution of the water cycle.

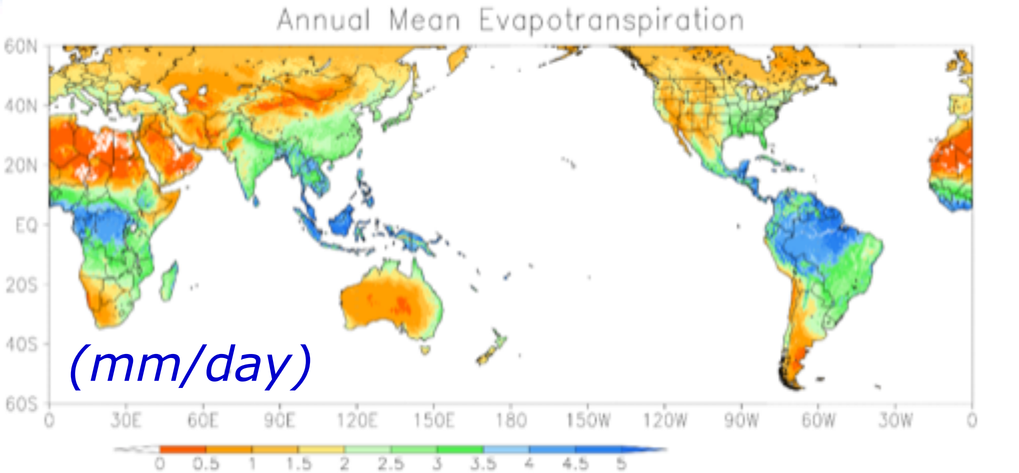
# Precipitation



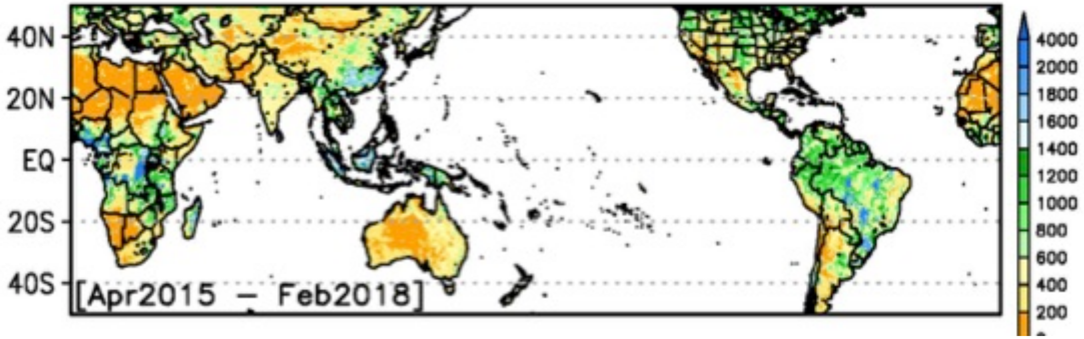




# Evapotranspiration

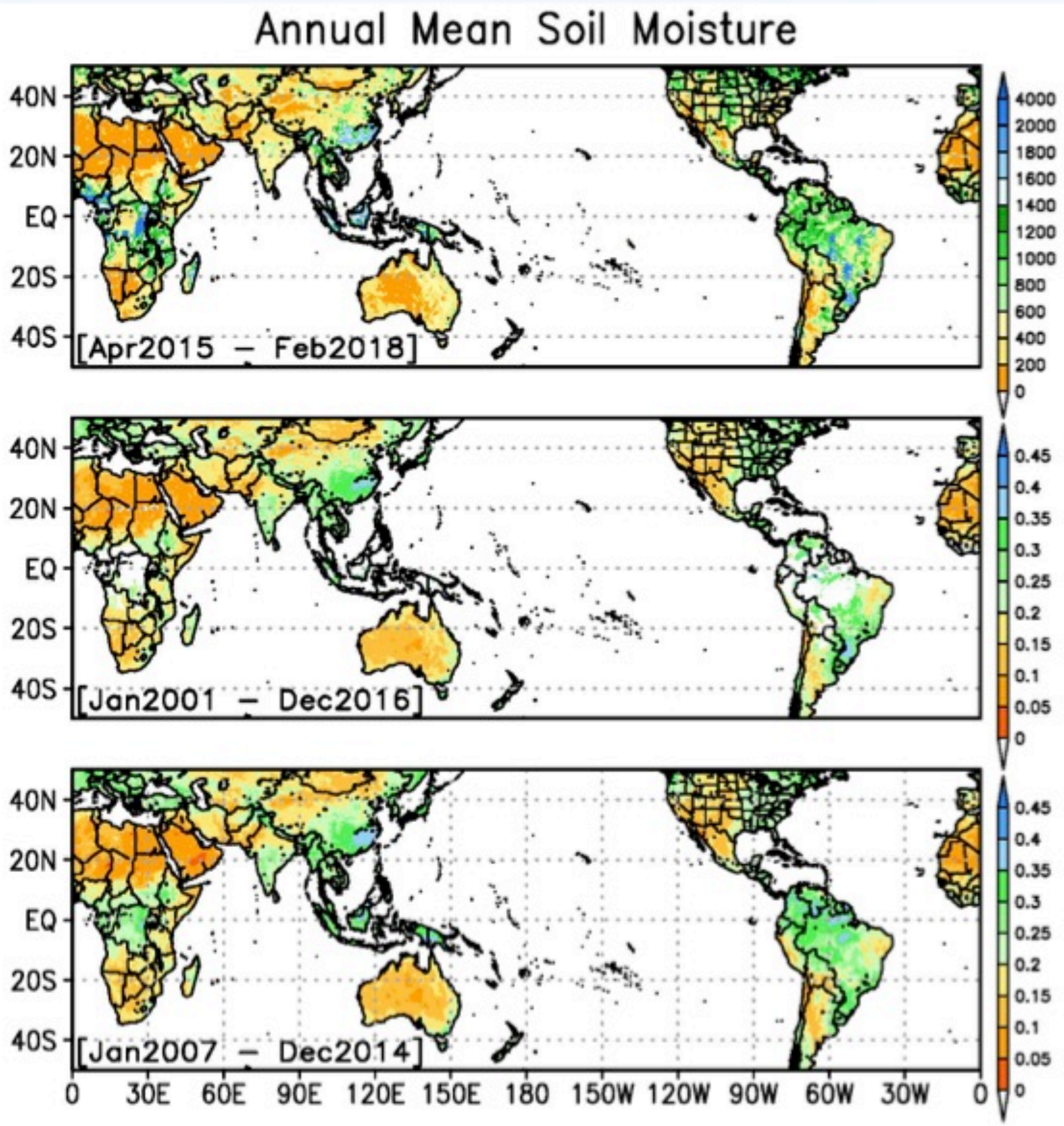



# Soil moisture




(mm/day)

# Soil Moisture




*SMAP (root zone)*

*ESA CCI (top layer)*

*SMOPS (top layer)*