Role of Land Processes in the Boreal Summer Intraseasonal Variability

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June 2010

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Outline:

1. Does land matter in weather and climate?
2. Current land models and measurement technology
3. Role of land processes in boreal summer intraseasonal variability
4. Land versus ocean interactions with atmosphere
5. Suggestions for future land-related research

Ocean skin temperature prognostic scheme (Zeng and Beljaars 2005) implemented in ECMWF and WRF

Bulk algorithm for computing ocean surface fluxes (Zeng et al. 1998) implemented in NCEP

1. Does land surface matter in climate?

1950's: No
1960's-1970's: Not really
1980's-1990's: Yes (ISLSCP, GEWEX, BAHC)
2000's: Even more important (Water, Carbon)

Does land surface matter in weather forecasting?
(taking the evolution of ECMWF land model)

1989: Bucket model (no vegetation)
1994: 2 soil layers, vegetation stomatal resistance
1999: 4 soil layers, 1 vegetation layer with LAI = 3, no separate snow layer
2000's: 4 soil layers, 1 snow layer, variable LAI, 8 tiles

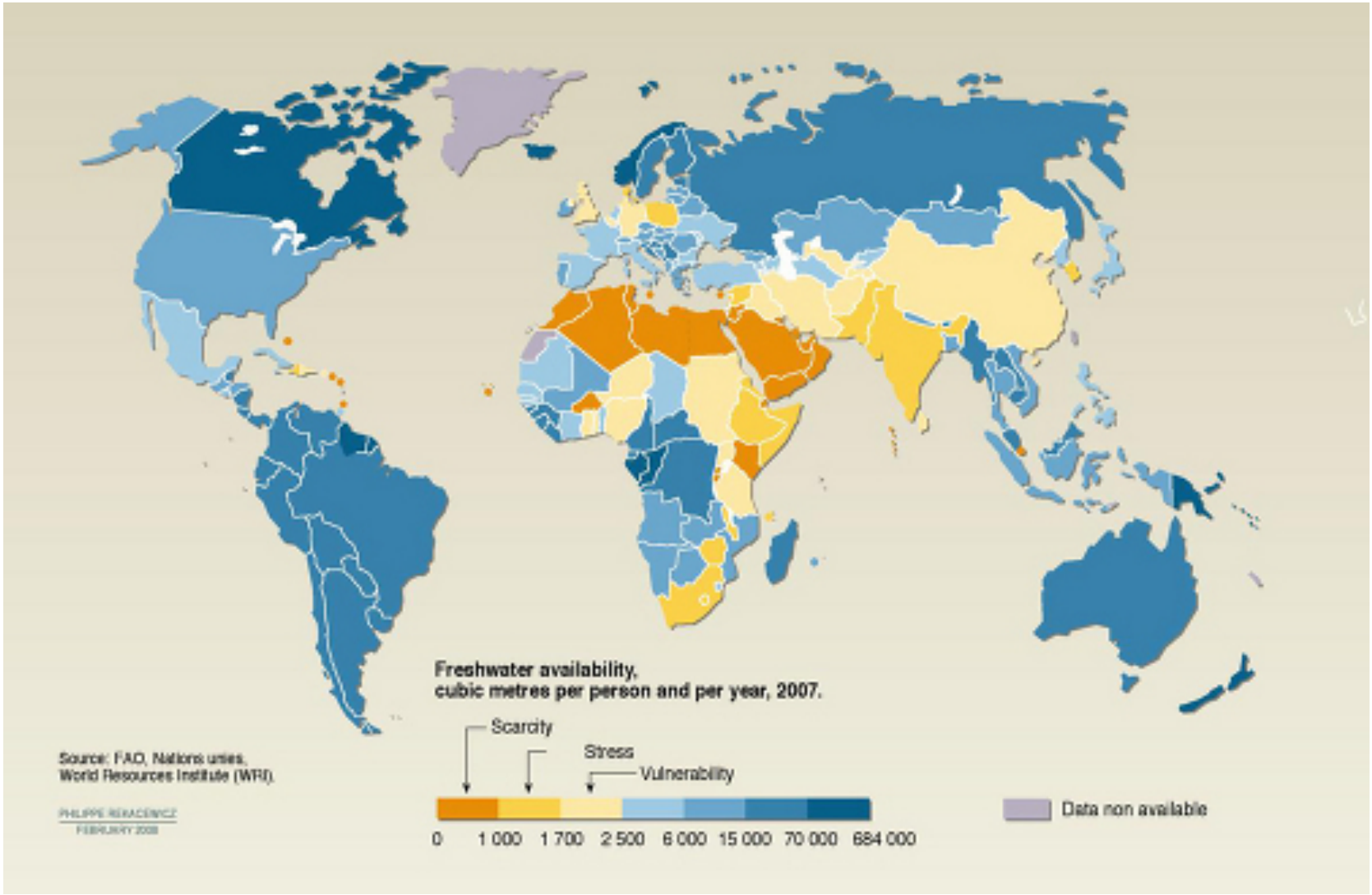
Overall Assessment of Influence

Land-Surface Influence	Plausible Physical Basis	Climate Record Evidence	Model Evidence	Further Evidence (Model, Obs., or Expt.)	Credibility (* see below)	Quantification (Good, Medium, Poor) Long-term / Short-term
<u>Influence of existing land-surfaces</u>						
Effect of topography	Yes	Yes	Yes	Yes	Ext. Likely	Medium/Low
Contribution to atmos. water	Yes	Yes	Yes	Yes	Ext. Likely	Medium
<u>Influence of transient changes</u>	But can these be totally separated?					
Effect of soil moisture	Yes	Yes	Yes	Yes	Very Likely	Poor
Regional	Yes	Yes	Yes	Yes	Likely	Poor
Meso-scale						
Effect of vegetation vigour	Yes	Yes	Yes	Yes	Very Likely	Poor
Effect of frozen precipitation	Yes	Yes	Yes	Yes	Very Likely	Poor
<u>Influence of change in land cover</u>						
Effect on 2 m climate	Yes	Yes	Yes	Yes	Ext. Likely	Good
Effect of regional-scale changes	Yes	Yes	Yes	Yes	Very Likely	Medium
Effect of imposed heterogeneity	Yes	Yes	Yes	Yes	Very Likely	Medium

Extremely likely > 95%; Very likely > 90%; Likely > 66%;
More likely than not > 50%; Unlikely < 33%; Very Unlikely < 10%;
Extremely unlikely < 5%

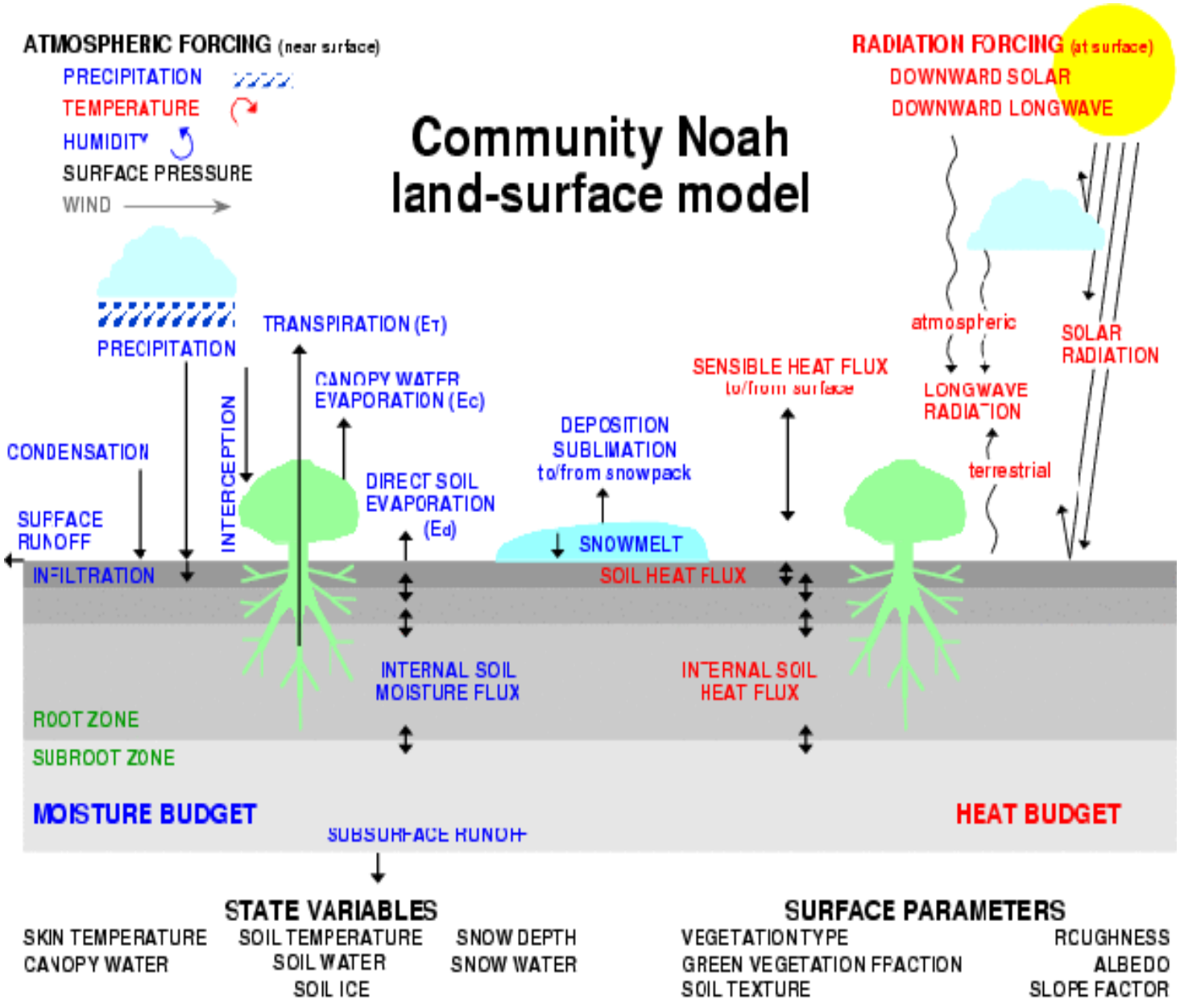
Shuttleworth (2010)

Land processes are obviously crucial to societal needs



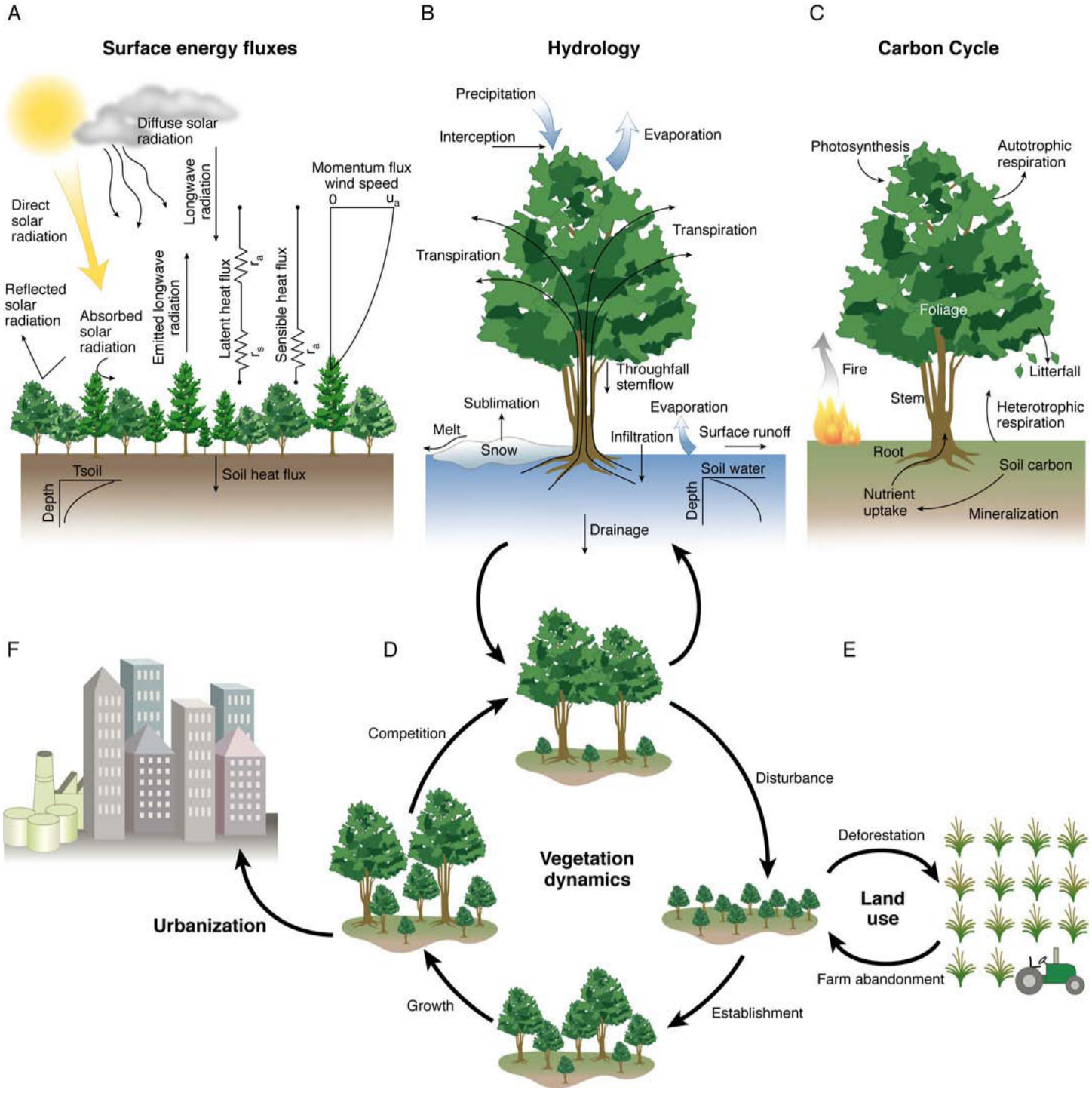
From UNEP

2. Current land models and measurement technology



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

Noah used in NCEP, WRF



CLM4 used in CCSM

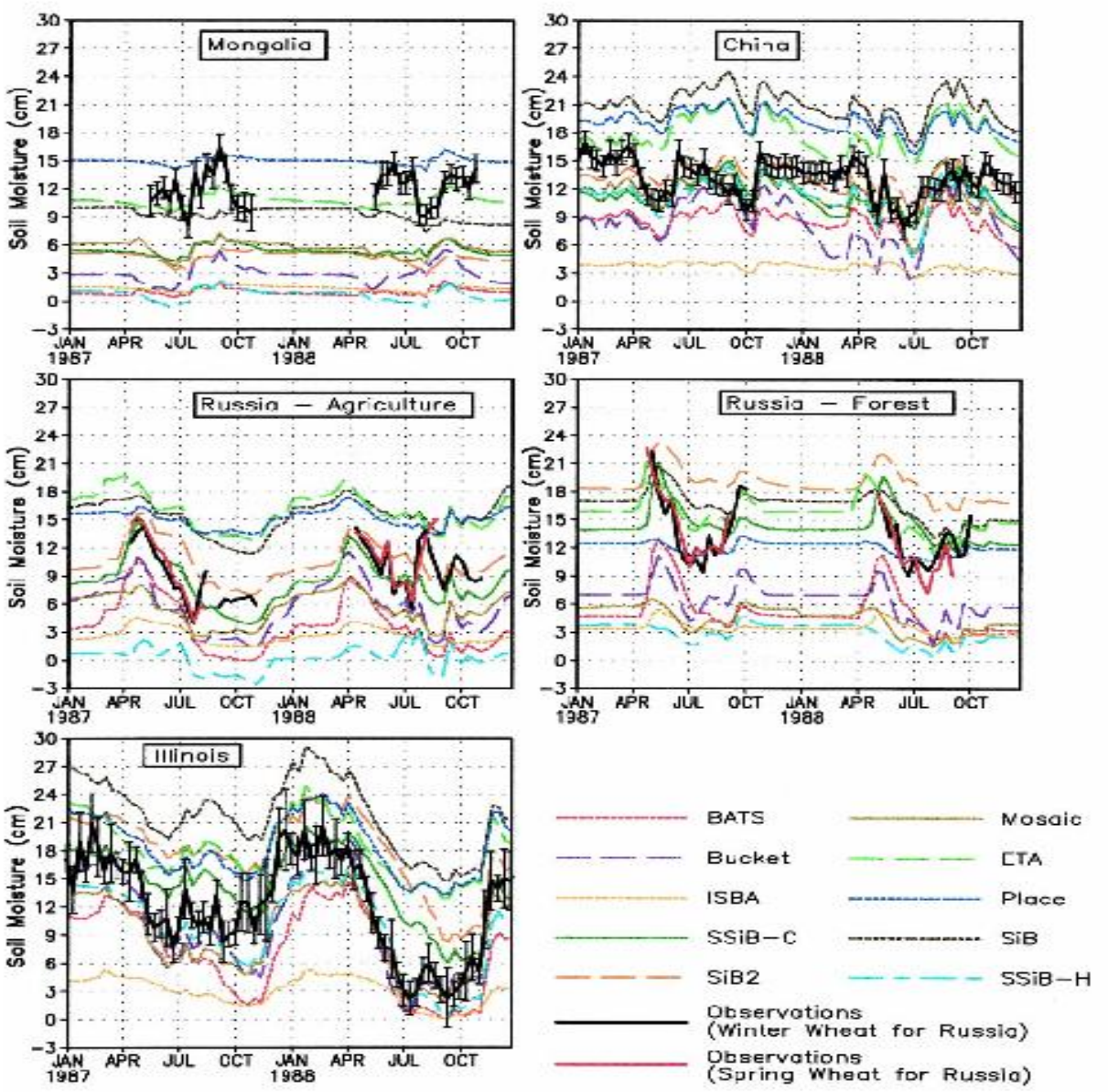
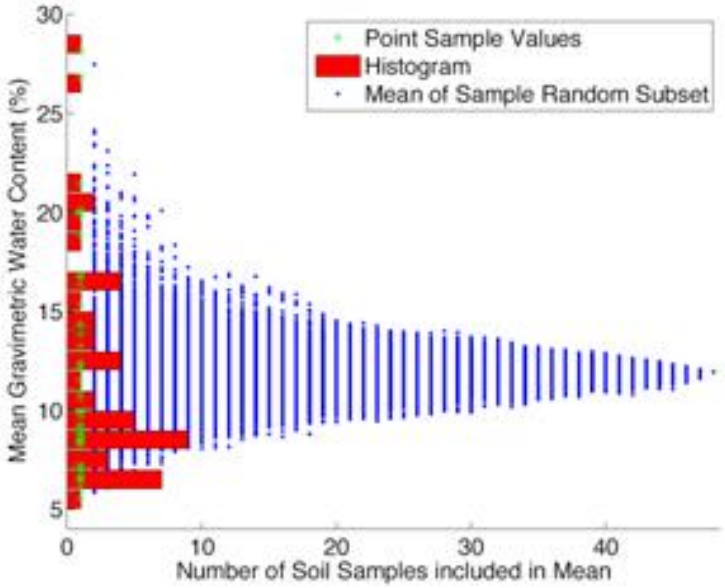


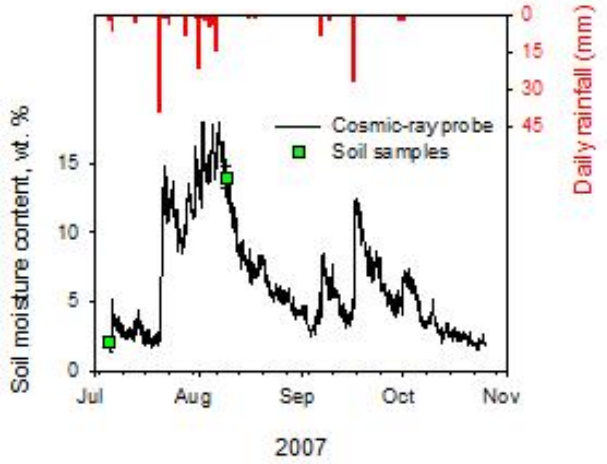
FIG. 13. Two year time series of plant available soil moisture in the 10 meter from 10 models for the areas in Fig. 12. Observations are also displayed, along with the one standard deviation confidence interval.

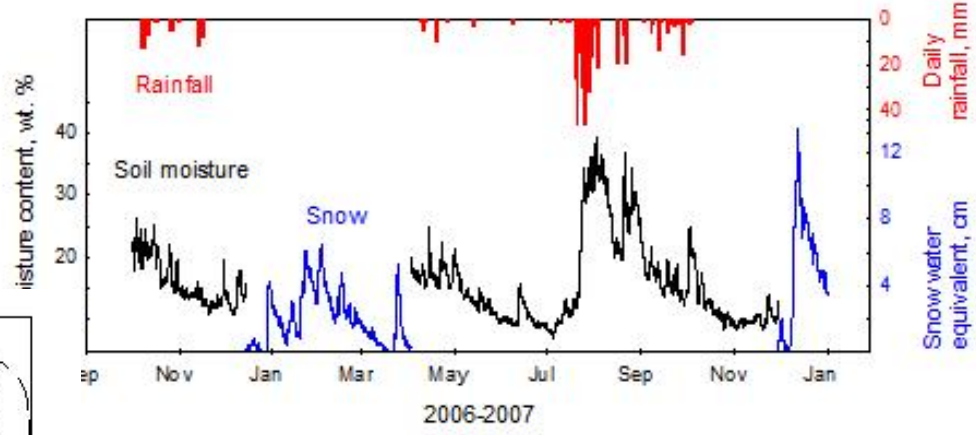
Difficulties in land modeling

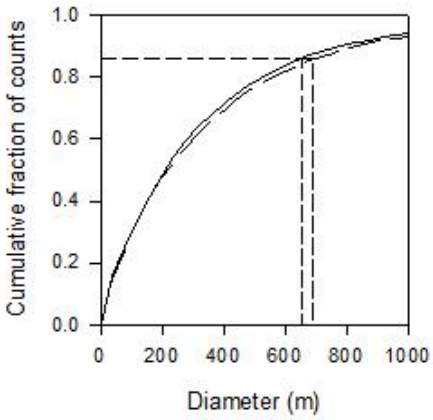
PILPS, GSWP (Dirmeyer et al. 1999)

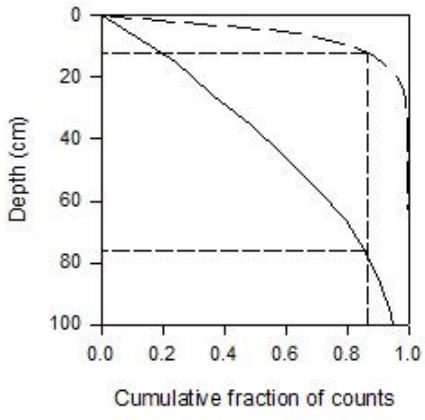
COsmic-ray Soil Moisture Observing System (COSMOS)







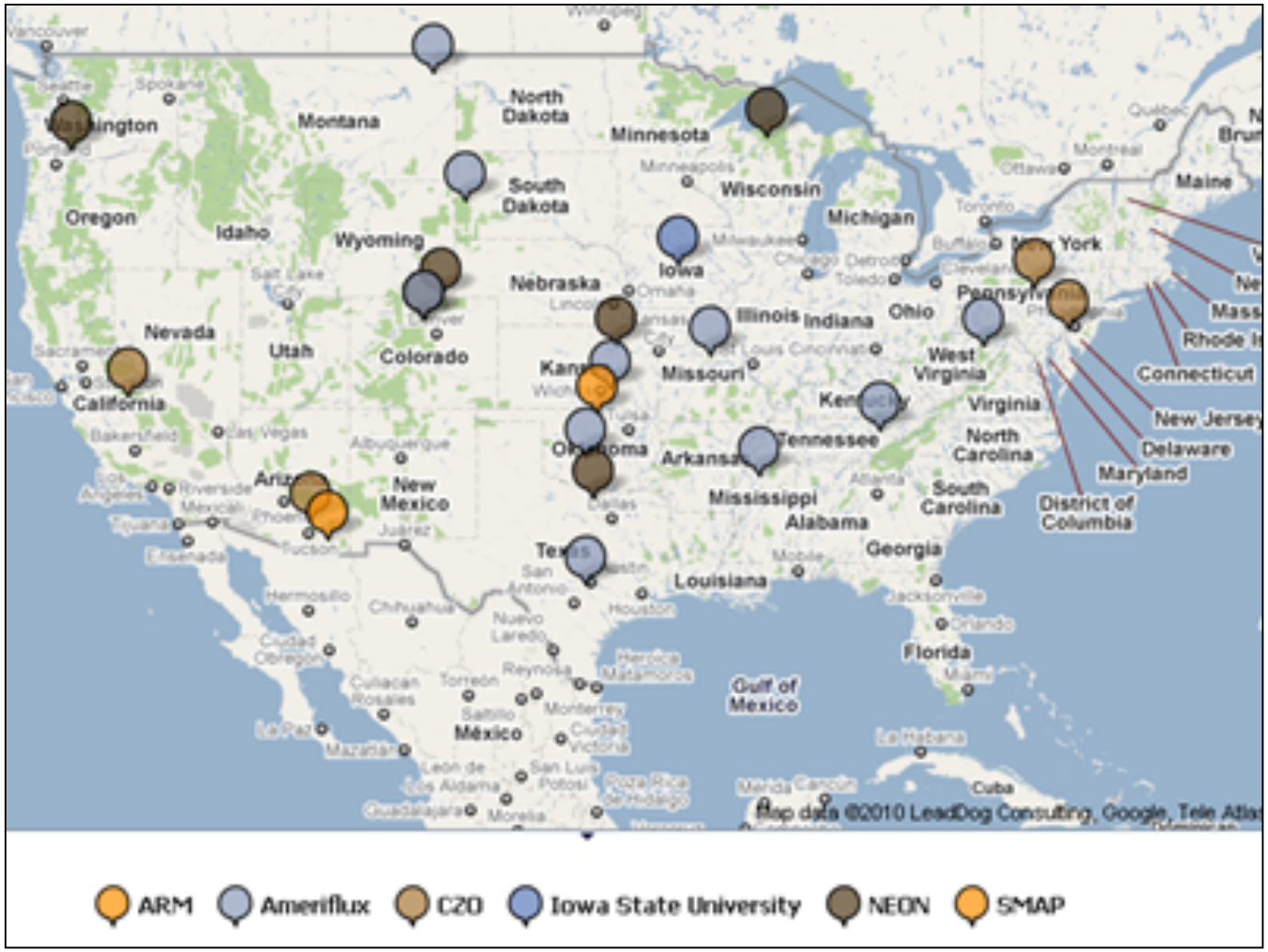




To install 50 COSMOS probes over the U.S. ($5.5M/4yr from NSF)

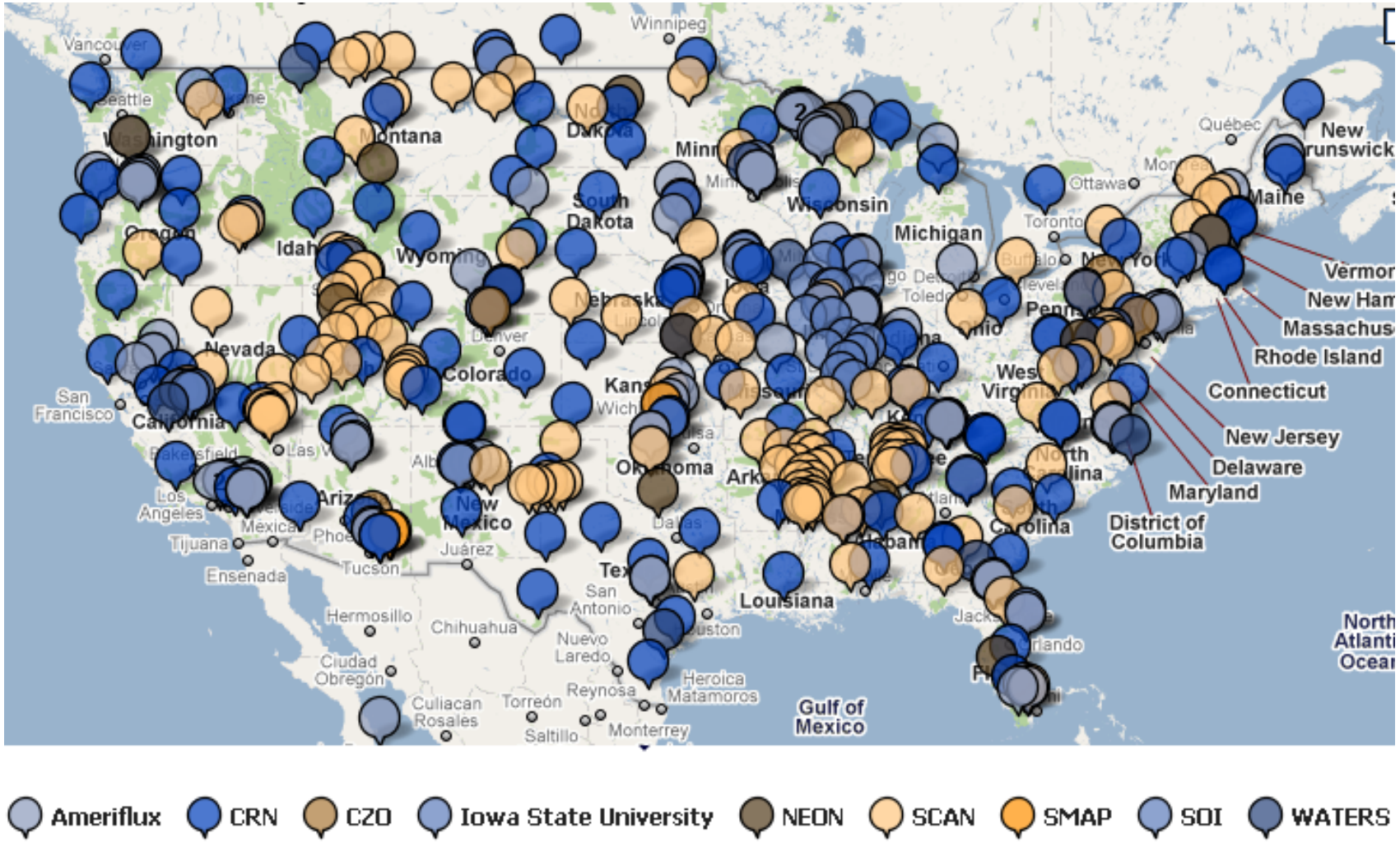
COSMOS Project Plans in the Next 4 Years

24 Probable/Possible Sites for COSMOS Deployments During 2010



Looking to the Future

Large Scale COSMOS Deployments at up to 500 Sites



3. Role of land processes in boreal summer intraseasonal variability

a. MJO (eastern propagation)

Maritime Continent as a MJO prediction barrier

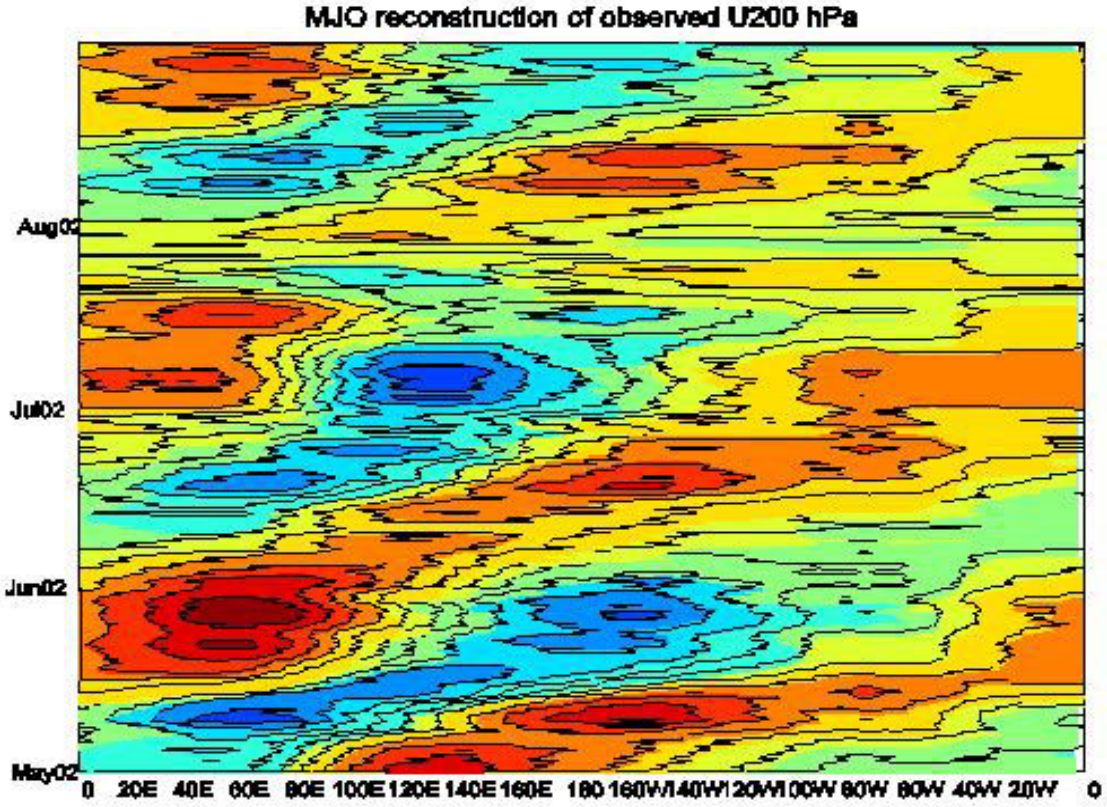
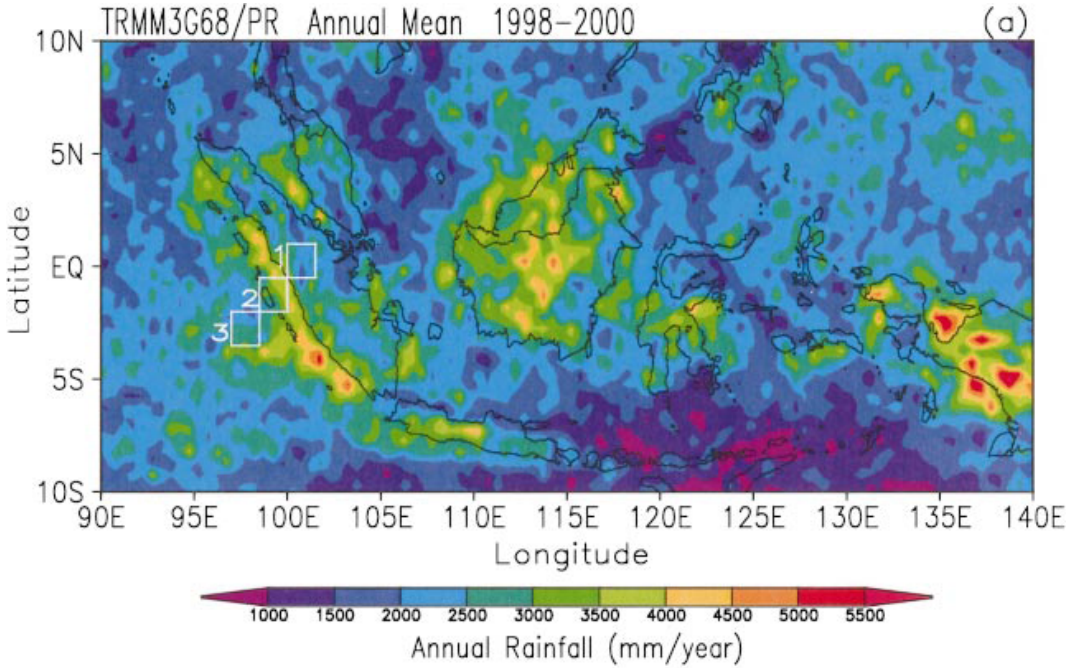
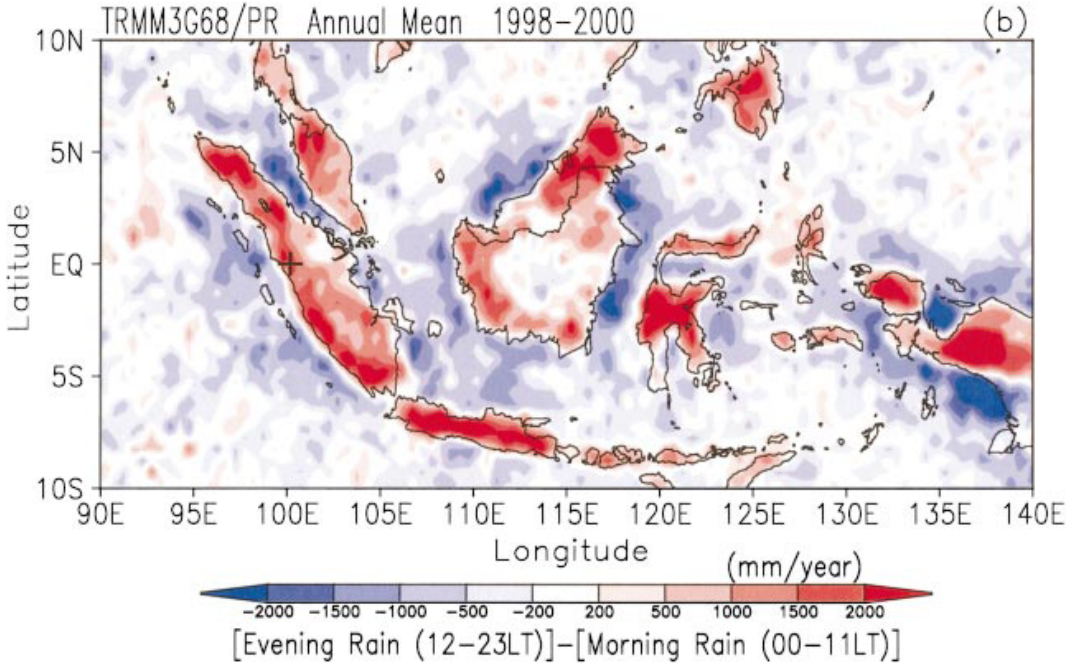


Figure 6: Longitude – time graph of the projection of the observed zonal velocity at 200 hPa averaged between 20S – 20N on the two EOFs shown in Figure 1.

"During periods when the actively convective phase of the MJO is over the Indian Ocean and enters the Maritime Continent, i.e., at the beginning of July and August (Fig. 6) there is no improvement in skill (against the persistence forecast)." (Vintzileos and Pan 2009)



Mean



Diurnal amplitude

Mori et al. (2004)

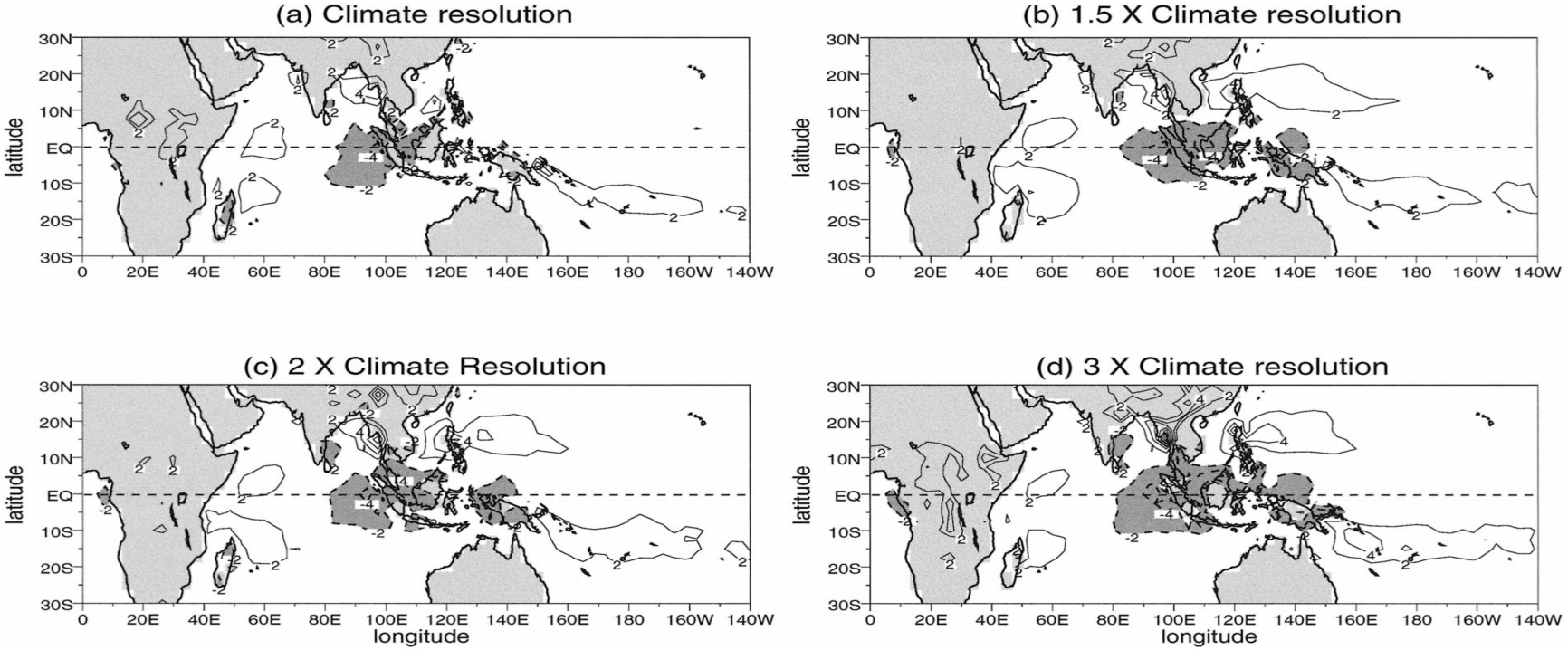
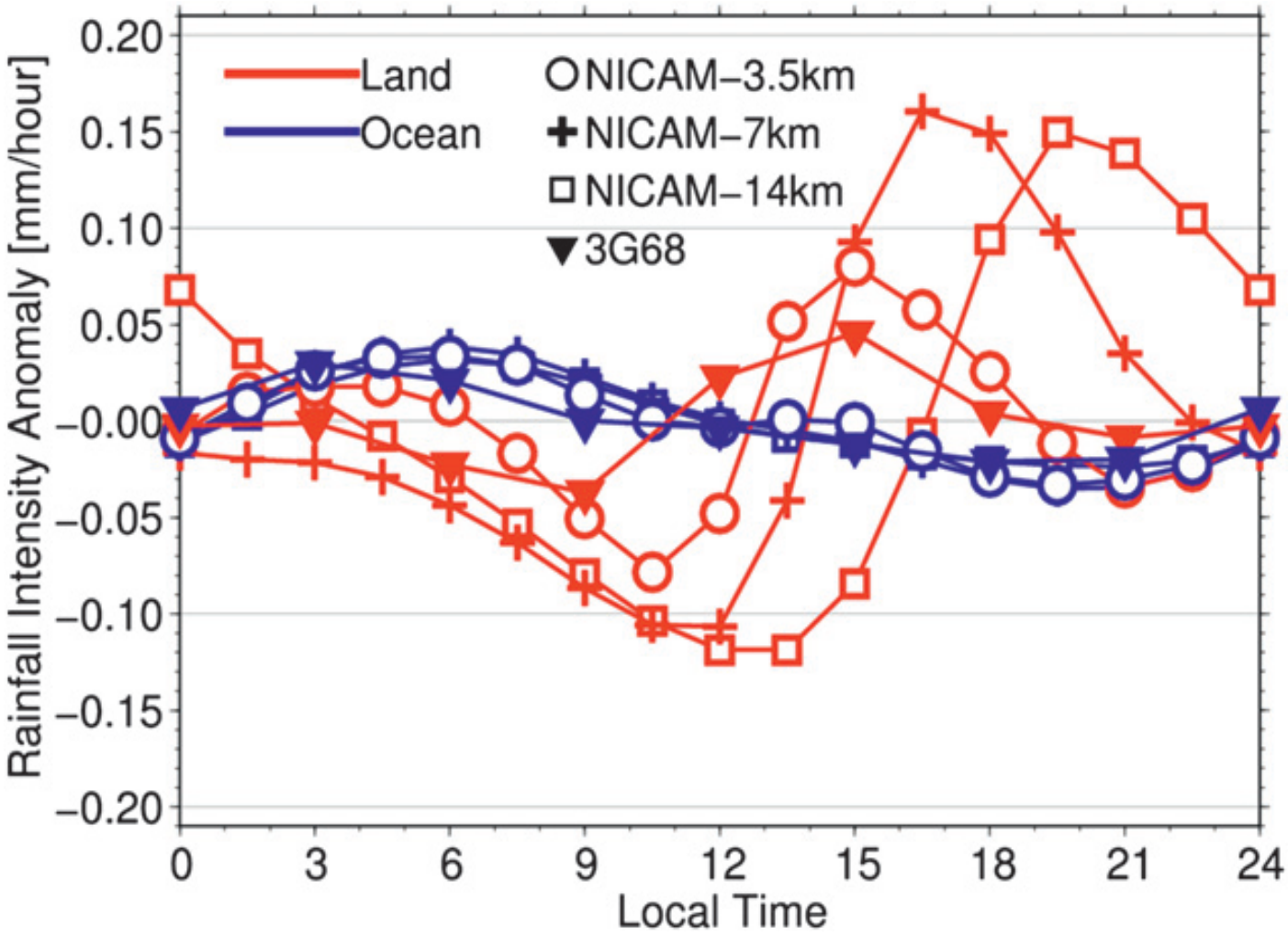


Fig. 2. Annual mean precipitation error (mm/day) from four UM AMIP II experiments with different horizontal resolution: (a) climate resolution (2.58 * 3.758). (Neale and Slingo 2003)

The pattern of the errors in the tropical precipitation persists and, if anything, is enhanced with increasing resolution.



Diurnal cycle of the precipitation intensity anomaly averaged over 15^{O}S–15^{O}N. (Sato et al. 2009)

b. Intraseasonal monsoon variability (northward propagation)

Webster (1983) based on 2-D model: existence of northward propagation depends on interactive land hydrology

Ferranti et al. (1999) based on ECMWF model: spatial characteristics and northward propagation are primarily caused by internal atmospheric dynamics, but the temporal characteristics depends on interactive land

Interactive land

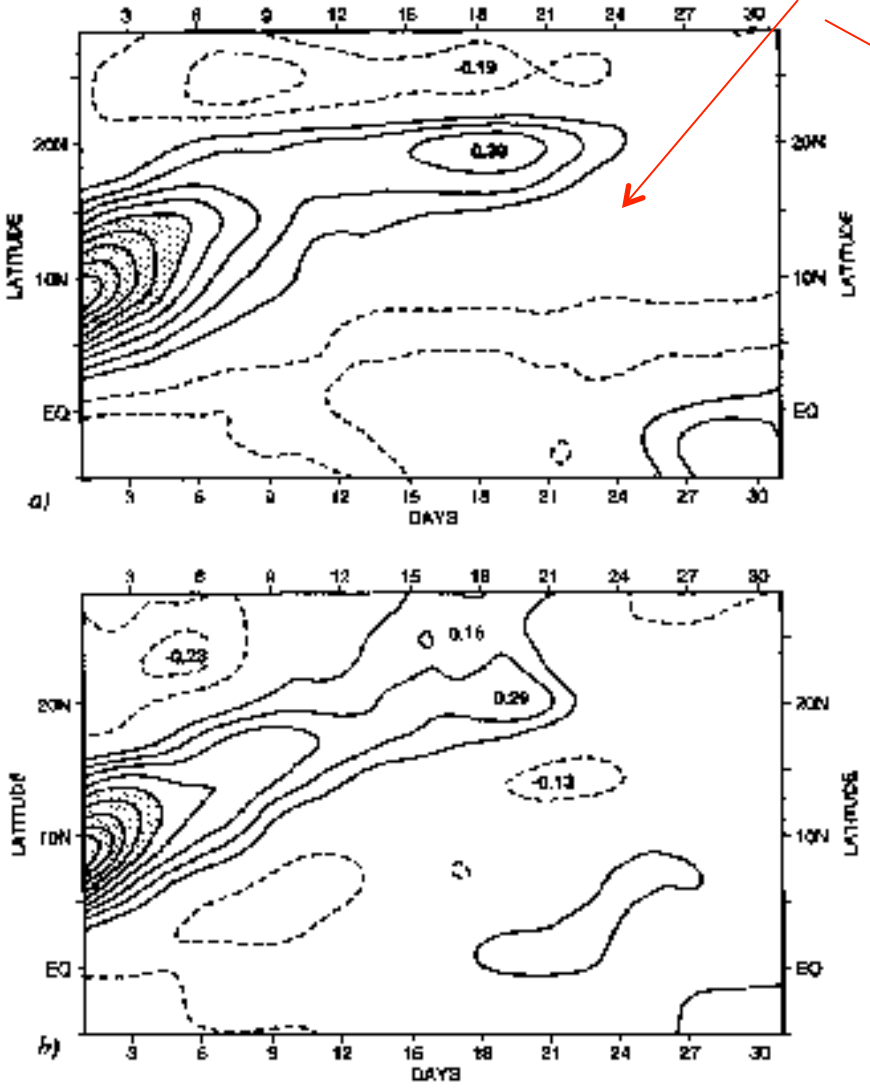


Figure 14. Time lagged correlation for precipitation data averaged between 80°E and 100°E and 9°N to with all the other points: (a) ISW; (b) PSW. Contour interval 0.1. Stippling shows values greater than 0.4

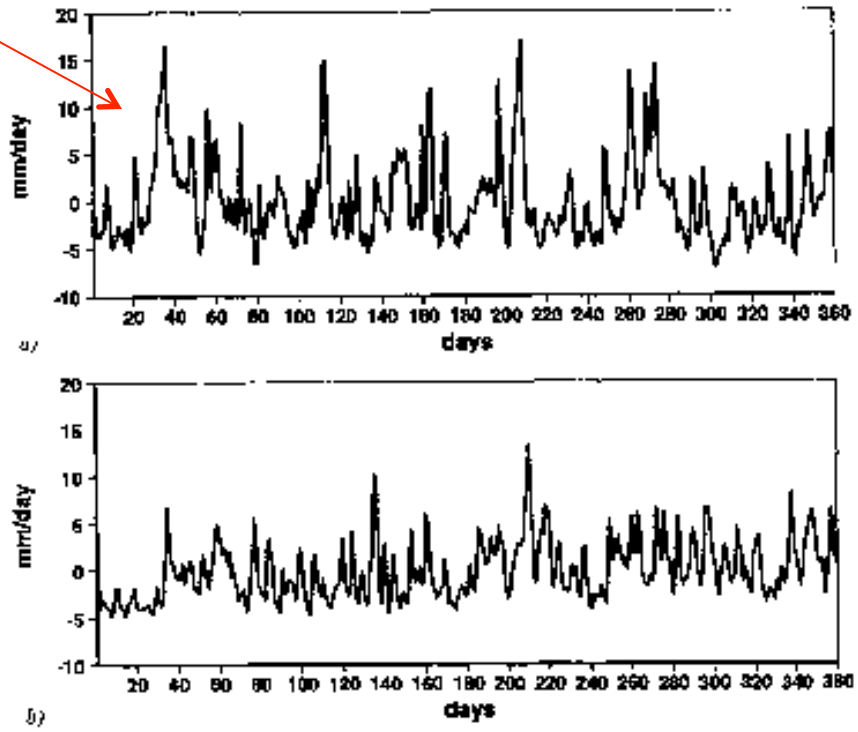


Figure 15. Daily series of precipitation anomalies over India (mm d⁻¹): (a) for the interactive soil-wetness (ISW) simulation; (b) for the prescribed soil wetness (PSW) simulation.

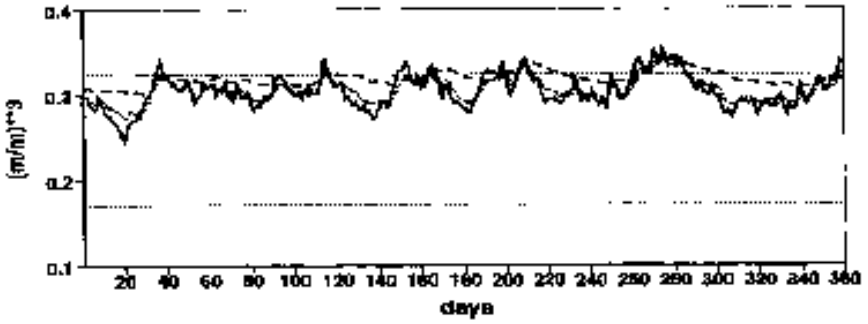
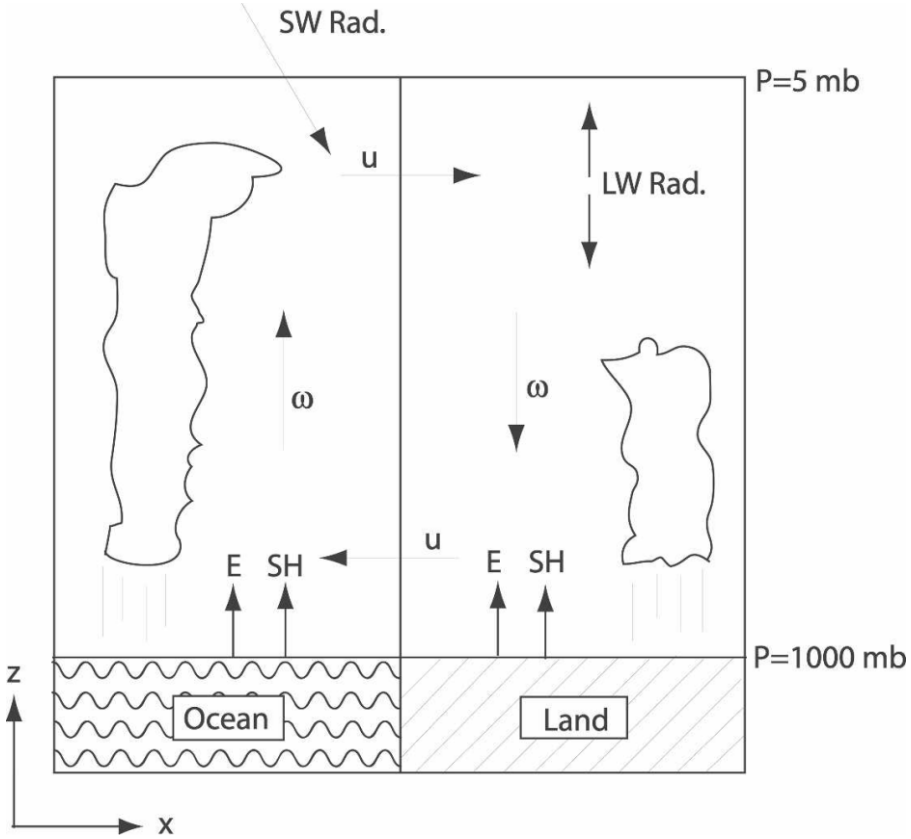


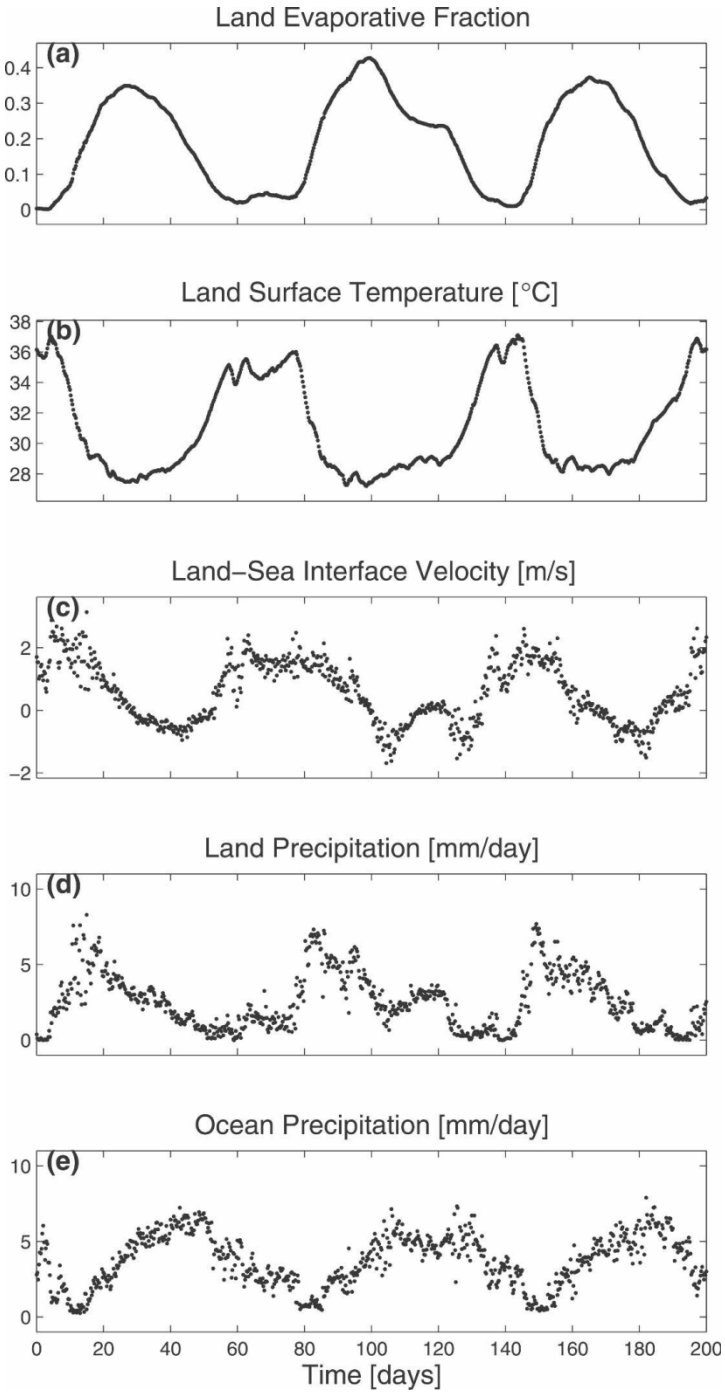
Figure 16. Daily series of soil wetness ($m^3 m^{-3}$) averaged over India, for the surface layer (solid line), for the root zone (dotted line), for the deepest layer (dashed line).

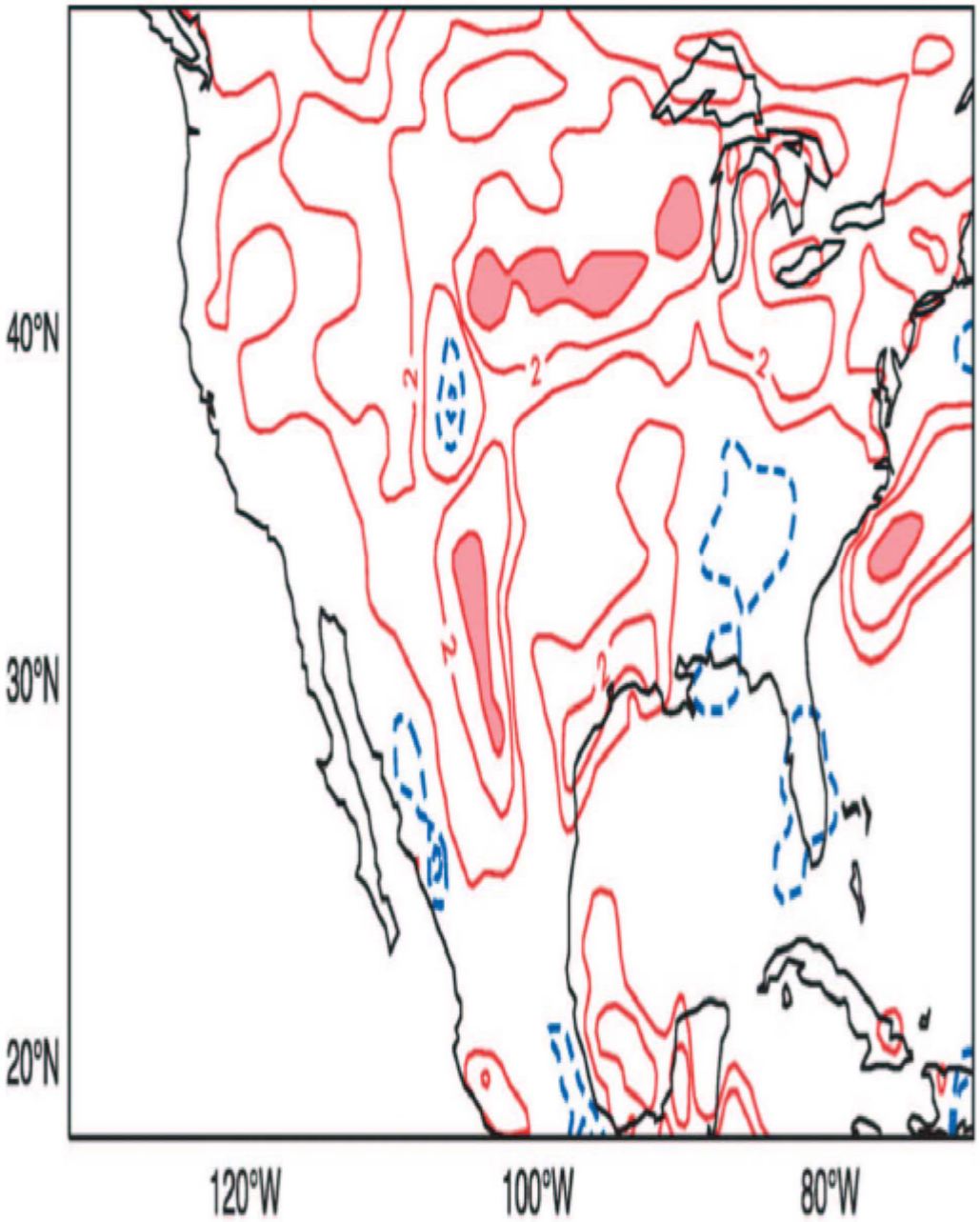
Ferranti et al. (1999)

c. Tropical and subtropical land-sea-atmosphere coupling:

Self-sustaining oscillation without weather, diurnal cycle, or annual cycle (Abbot and Emanuel 2007)







d. Land effect on weather prediction and climate simulation

Difference in monthly forecast precip inJuly 1993 starting with wet and dry soils *(Beljaars et al. 1996)*

4. Land versus ocean interactions with atmosphere

Rnet = SWnet + LWnet = SH + LH + Fs,n

L: a) SW absorbed in a thin soil layer (~1 mm);
b) Fs,n = 0 for T > days;
→ Ts is a response variable with large diurnal cycle;
d) both Ts and SM are important state variables;
e) SH and LH partitioning is controlled by SM

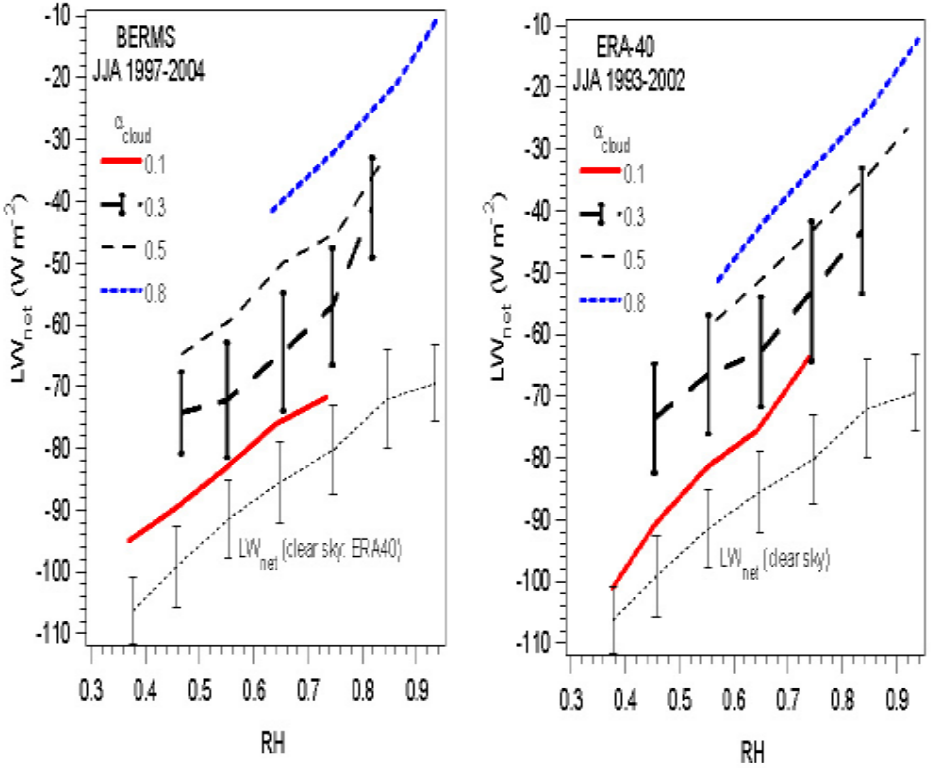
O: a) SW absorbed in a thick ocean layer (~50 m);
b) Fs,n ≠ 0 for T> days;
→ SST is a forcing variable;
d) SST is the primary state variable;
e) LH >> SH

SWnet = SWd- SWu =(1- α_s)(1- α_c) SWd(clear)

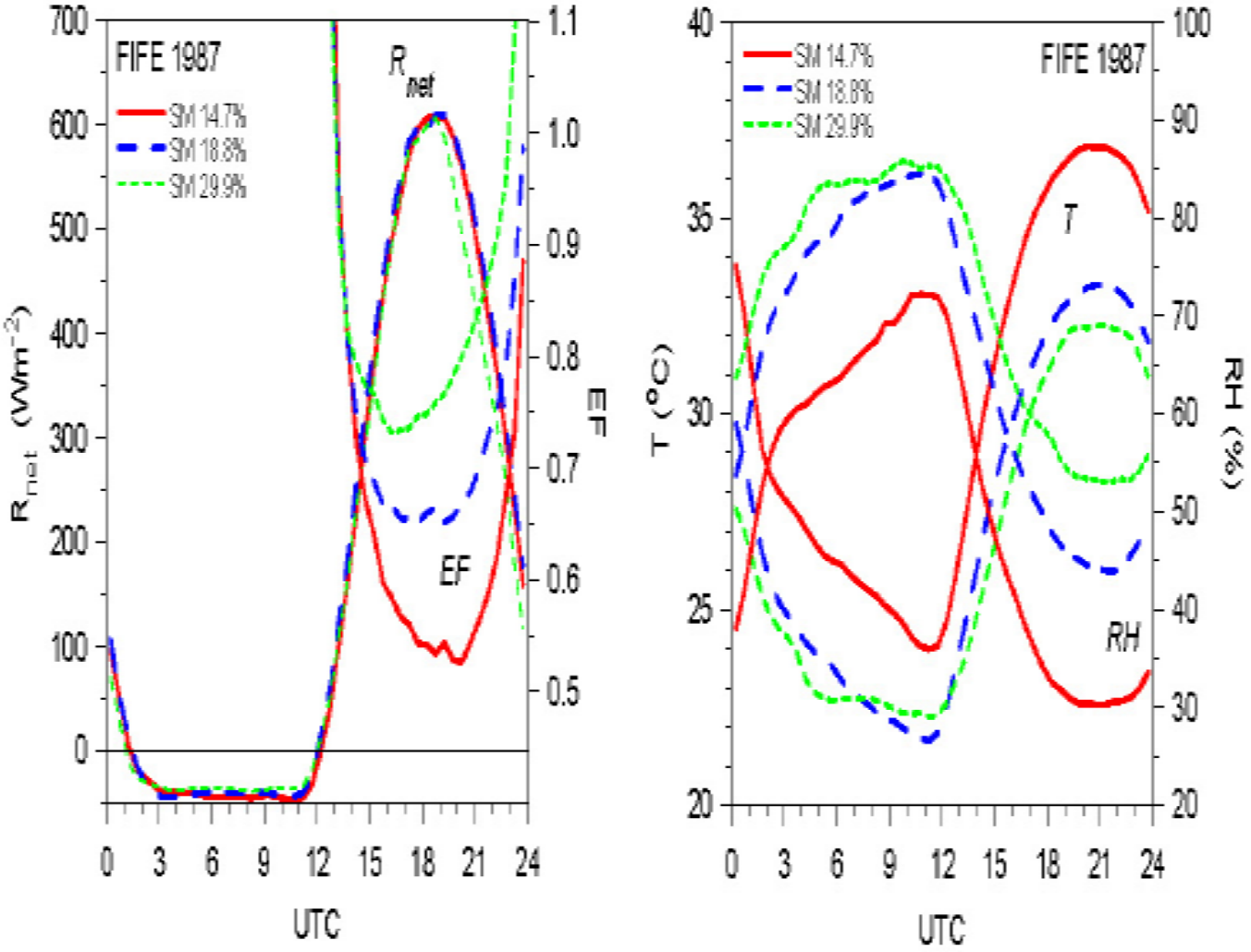
• surface albedo: α_s = SWu /SWd

• effective cloud albedo
SWCF = SWd - SWd(clear)
α_c = - SWCF/SWd(clear)
(Betts 2009)

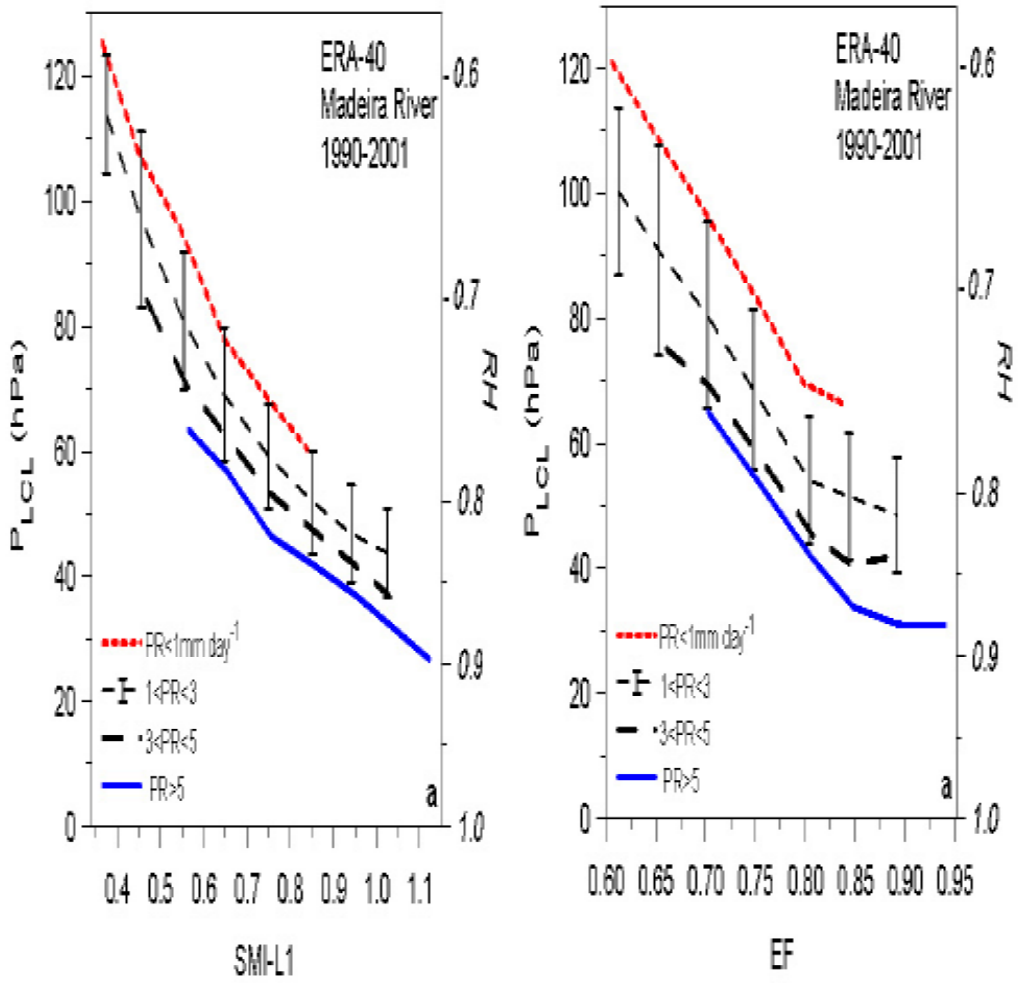
Therefore, SWnet is strongly affected by clouds
(cloud + ⟶ Swnet --)



LWnet is strongly affected by clouds and water vapor
(cloud + or water vapor + ⟶ LWnet – in magnitude)



Evaporative fraction: EF = LH/(LH+SH), Betts (2009)



Betts (2009)

L-A coupling:

SM + → LH +
→ P_{LCL} --
→ Precip +

SM + → SH --
→ T --
→ buoy --
→ Pre --

Land-atmosphere coupling

Albedo + → precip -- (Charney hypothesis)

Veg cover -- → Zo --
→ low level convergence change
→ precip change

Veg cover -- → dust +
→ CCN +
→ clouds and precip change

Veg cover -- → Albedo + → precip --

5. Suggestions for future land-related research

a. For MJO

- Idealized tests on the Maritime Continent impact -- replacing the Maritime Continent by oceans
- Resolve the Maritime Continent by using global or regional models with grid spacing of 5-10 km.

b. For monsoon-related intraseasonal variability

- AGCM with multiple land models
- Run GCM with fixed soil moisture from one simulation and with interactive land processes (GLACE design)

Terra-planet experiment (versus aqua-planet)

c. Land-related analyses

- Averaged diurnal cycle of surface variables over different phases of intraseasonal variability

- Quantify the land-atmosphere coupling strength of different models at intraseasonal scale by computing the Γ index:

$\Sigma P'P' = \Sigma P'E' + \Sigma P'C'$; $C = F_{in} - F_{out} - dW/dt + \alpha$

$\Gamma = \Sigma P'E' / \Sigma P'P'$ E', P' are deviations from climatology

[Motivation: Zeng et al. (2010) analyzing global and regional reanalyses, offline model output, regional and global modeling output as well as 2*CO2 modeling output]