Observational and diagnostic studies for AMMA

[land-surface-atmosphere feedbacks]

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Silver Springs, May 5, 2006

Background references

- Betts, A. K and P. Viterbo, 2005: Land-surface, boundary layer and cloud-field coupling over the south-we stern Amazon in ERA-40. *J. Geophys. Res., 110*, D14108, *doi:10.1029/2004JD005702*.
- Betts, A.K., J.H. Ball, A.G. Barr, T.A. Black, J.H. McCaughey and P. Viterbo, 2006: Assessing land-surface-atmosphere coupling in the ERA-40 reanalysis with boreal forest data. *Agric. For. Meteorol.(accepted)*

  (*Preprint: ftp://members.aol.com/akbetts/BettsetalFCRN26.pdf*)
- Betts, A. K., 2006: Radiative scaling of the nocturnal boundary layer and the diurnal temperature range, *J. Geophys. Res*., 111, *D07105*, *doi:10.1029/2005JD006560*

What does AMMA need?

Models that are properly coupled across all scales!

- Point and spatial evaluation of models
- Evaluation of model land-surface-atmosphere coupling against data
- **Conceptual understanding of land-surface-atmosphere coupling!**

Clouds are a crucial link in land-surface feedback

- Cloud fields are a tightly coupled component; impacting surface energy budget and evaporation
- *Partly linked locally to ‘soilwater’ which impacts evaporation, and LCL*
- *Partly linked to larger-scale dynamics*

Consider the chain of processes involving water

Precip $\longrightarrow$ SMI $\longrightarrow$ λE $\longrightarrow$ clouds $\longrightarrow$ Precip

Precip → SMI	SMI → λE	λE → clouds	clouds → Precip
vegetation	*vegetation*	*BL param*	*dynamics*
soils		*RH*	*microphysics*
runoff			*Cu param*

LW,SW radiation

R_{net} , H

SMI : soil moisture index [0<SMI<1 as PWP<SM<FC]

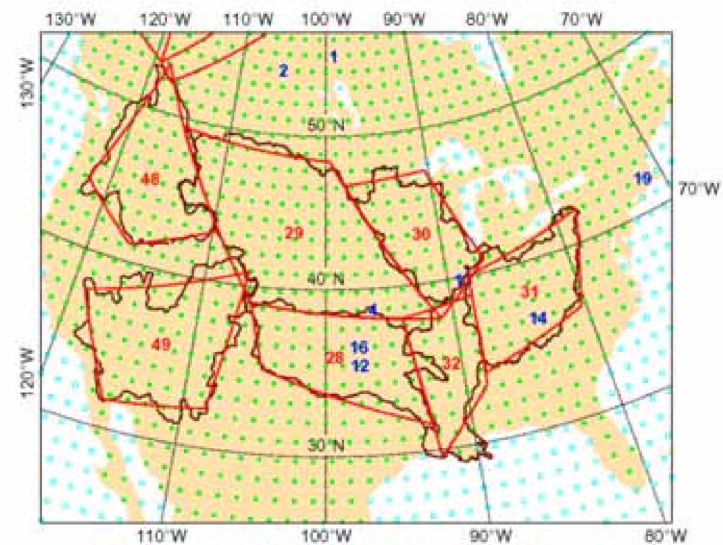
α_{cloud}: *‘cloud albedo’ viewed from surface*

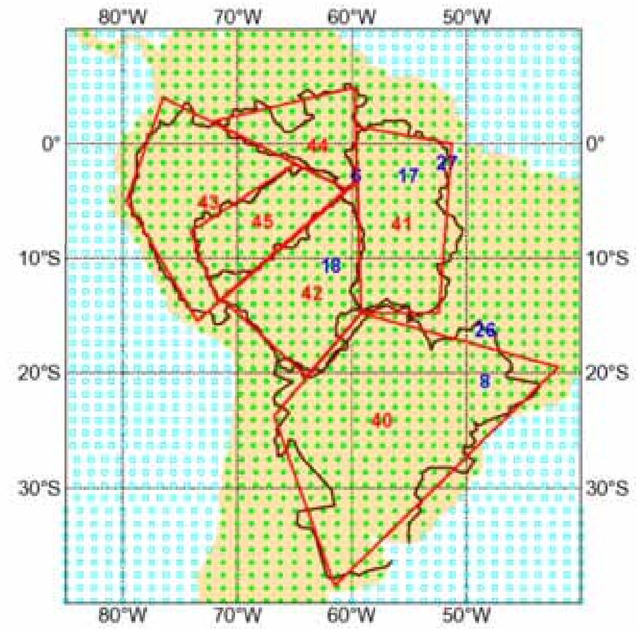
ERA40 river basin budgets

- Basin averages: hourly archive
- **Daily averages**

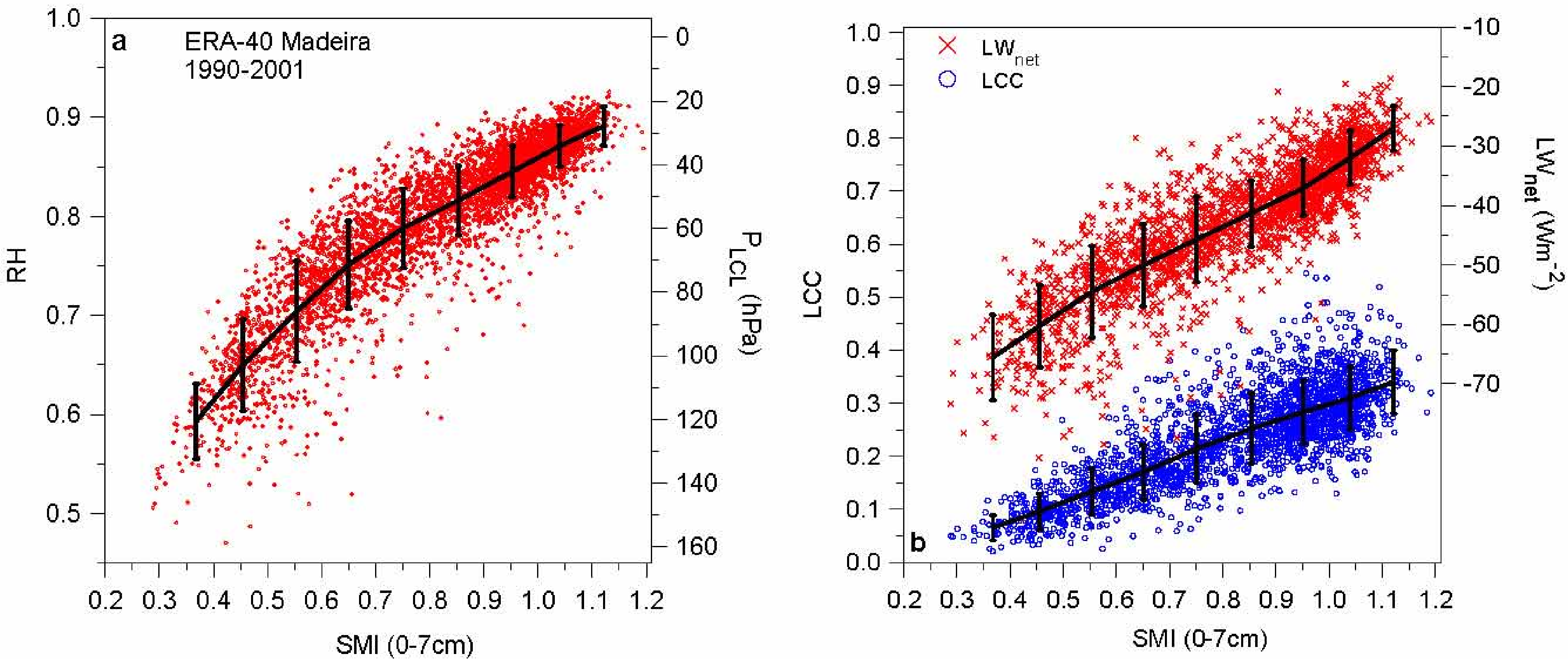
- **Madeira : Amazon: 1990-2001**

- Mississippi: 1980-2002



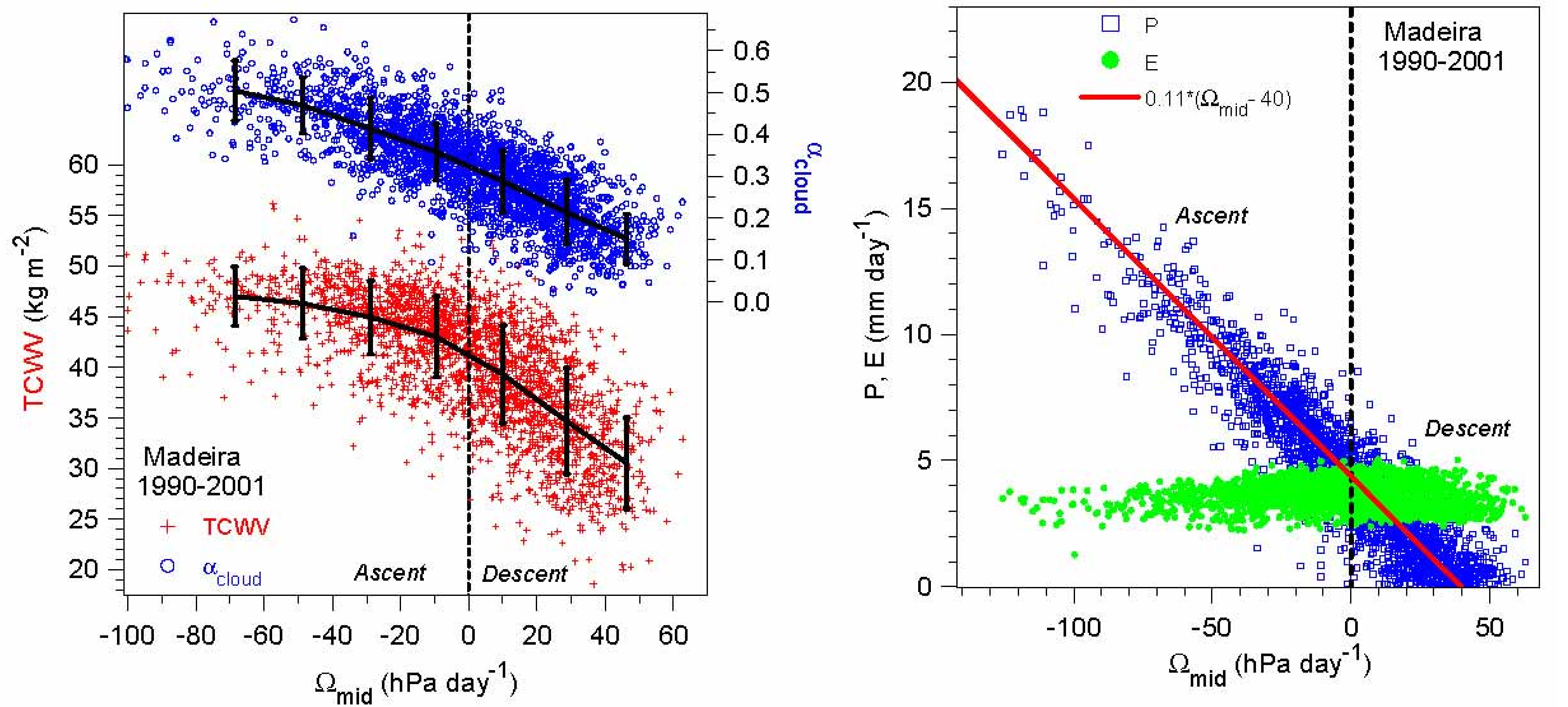


ERA40: Surface 'control'



- Madeira river, SW Amazon
- Soil water ⟶ LCL, LCC and LW_{net}

ERA-40 dynamic link (mid-level omega)



- $\Omega_{mid} \rightarrow$ Cloud albedo, TCWV and Precipitation

How well are physical processes represented?

- Basin-scale assessment of ERA40 biases
  [Betts et al. 2003a, 2003b, 2005]
- Flux tower data can assess both biases and the coupling of physical processes *on the point scale*

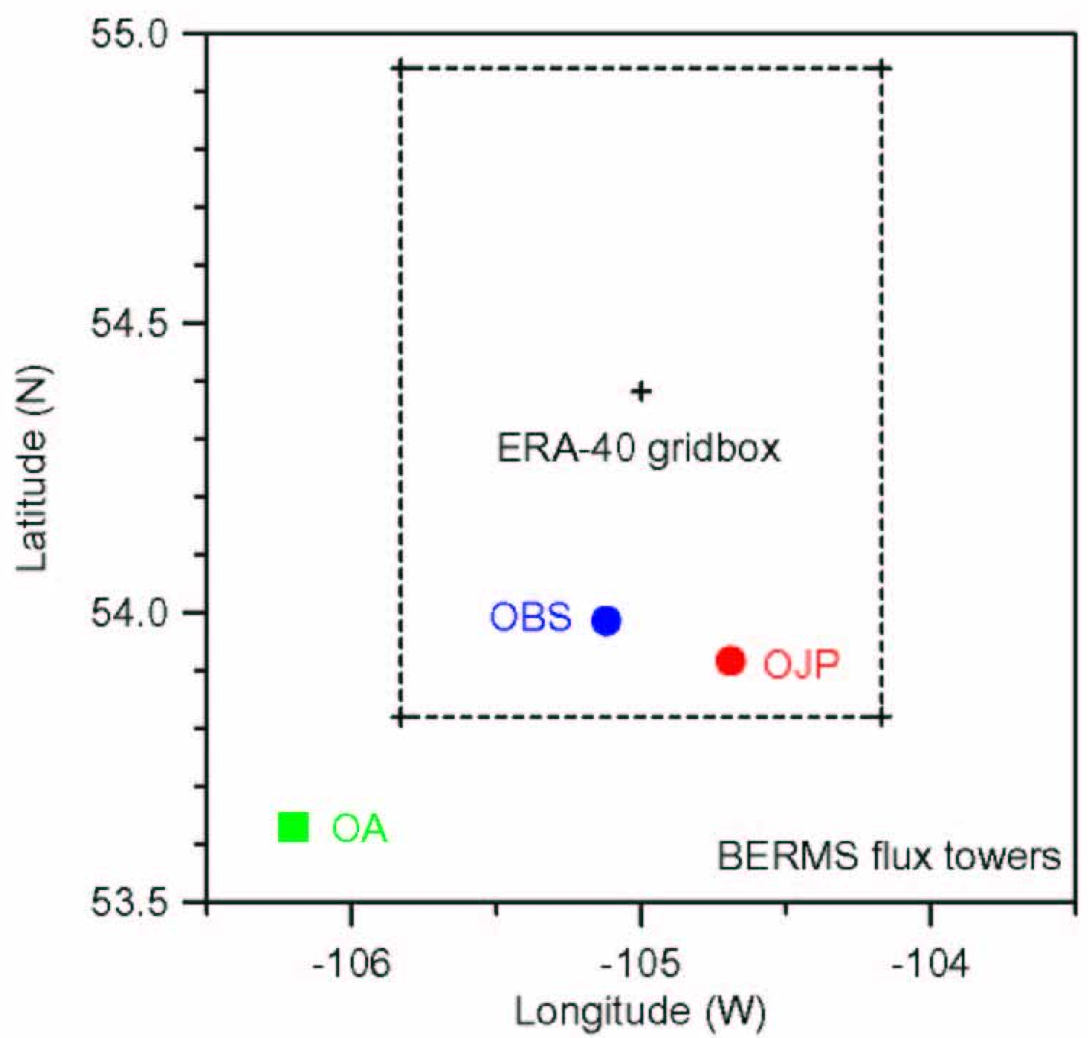
Compare ERA-40 with BERMS flux towers in Saskatchewan

Focus:

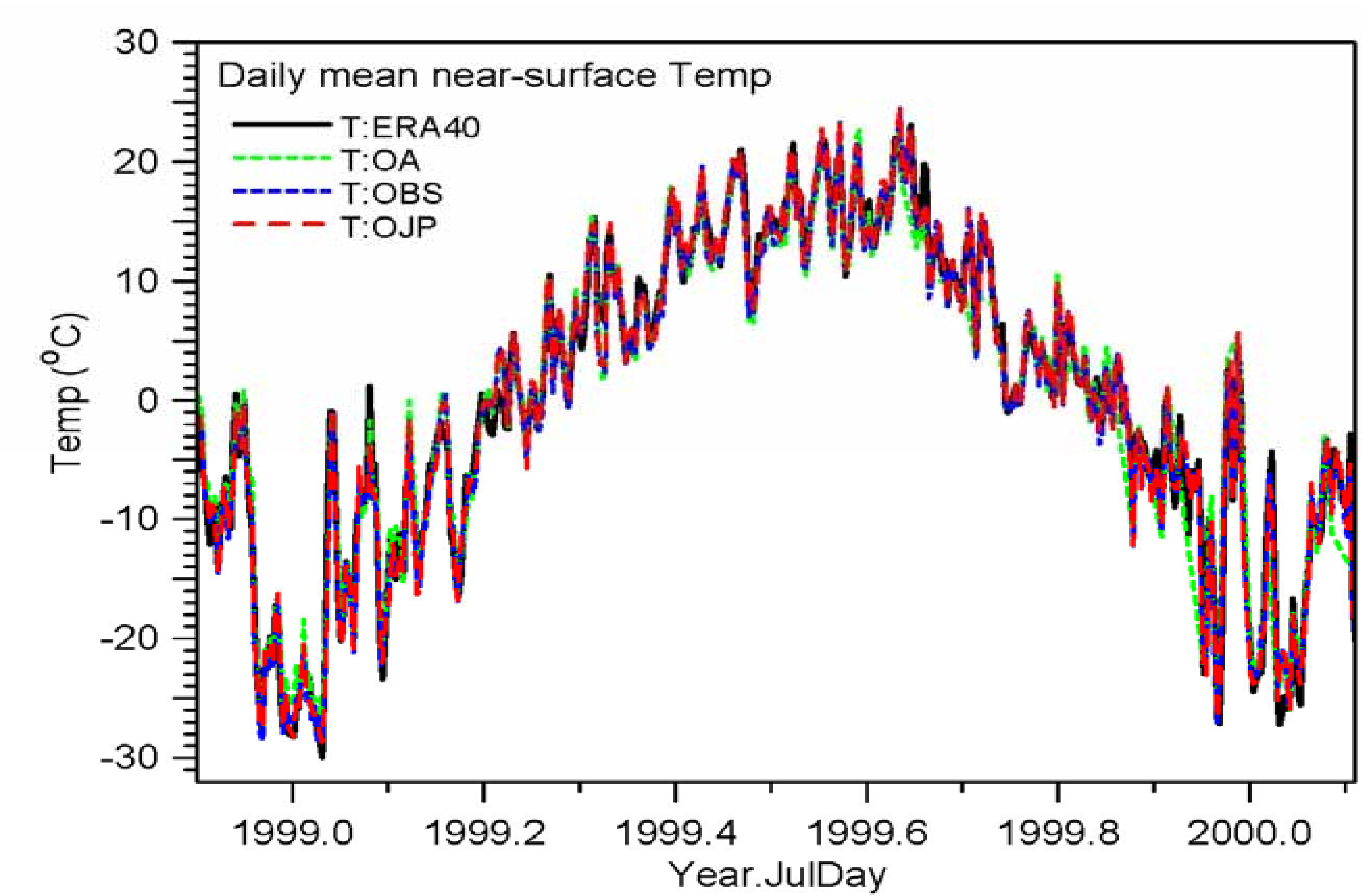
- Coupling of clouds to surface fluxes
- Define a 'cloud albedo' that reduces the shortwave (SW) flux reaching surface
  - *Basic 'climate parameter', coupled to surface evaporation [locally/distant]*

Compare ERA-40 with BERMS

- ECMWF reanalysis
- ERA-40 hourly time-series from single grid-box
- BERMS 30-min time-series from
  Old Aspen (OA)
  Old Black Spruce (OBS)
  Old Jack Pine (OJP)
- Daily Average



Global model improvements [ERA-40]

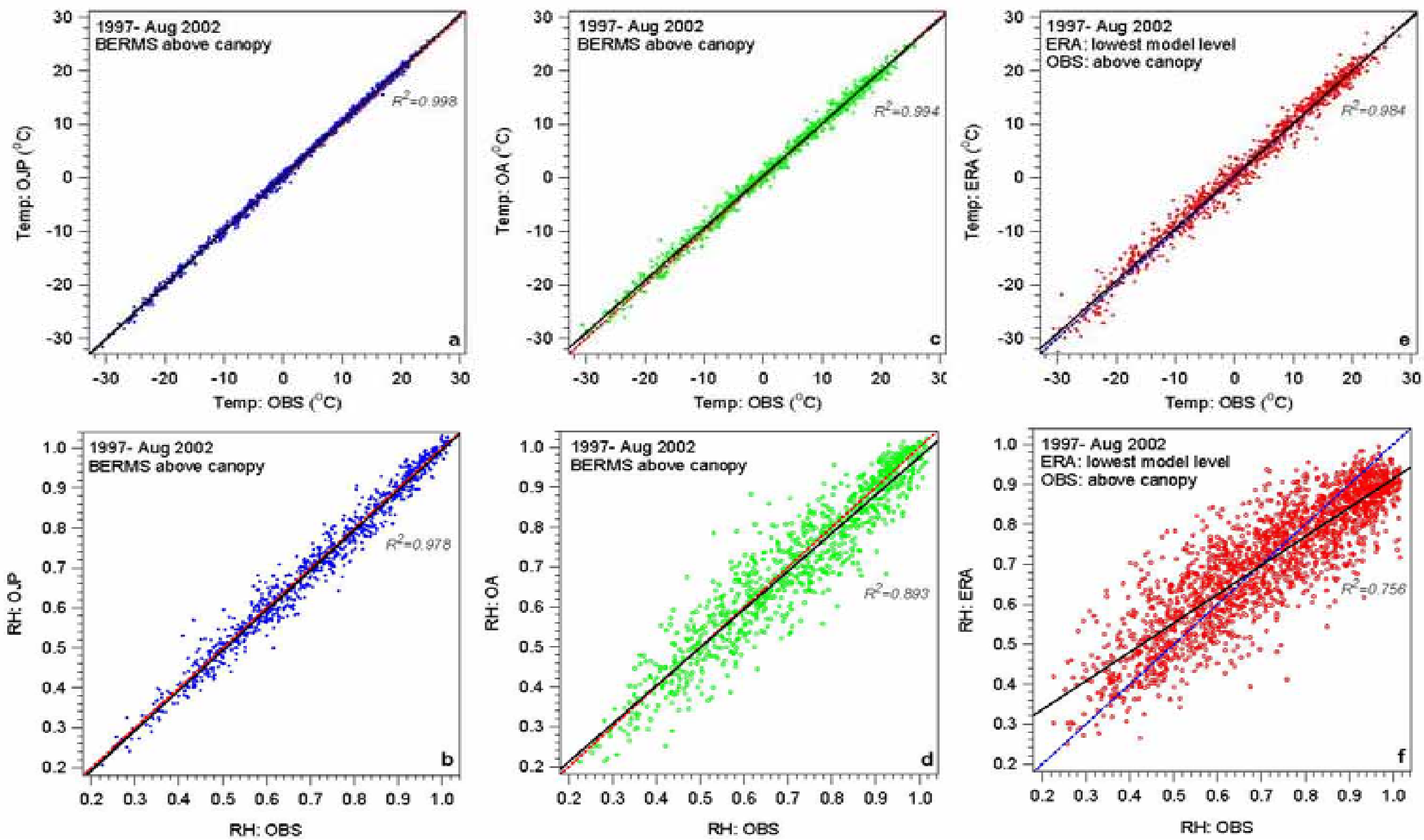


- Reanalysis T bias is now small in all seasons [ERA-40 land-surface model developed from BOREAS]
- BERMS inter-site variability of daily mean T is small

Comparison of **BERMS and ERA-40**

T

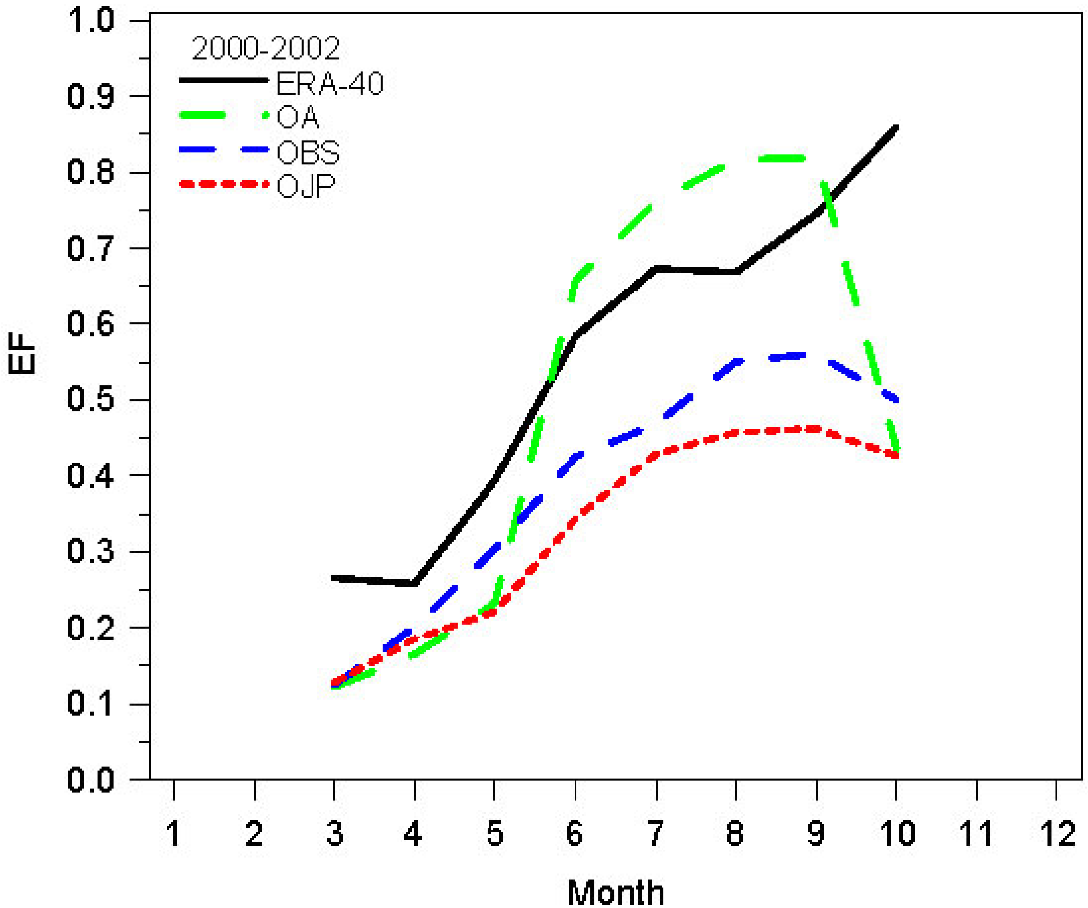
RH



OBS to:	**OJP**	**OA**	**ERA-40**
Spacing:	**29km**	**81km**	**[grid-point]**

Seasonal Evaporative Fraction

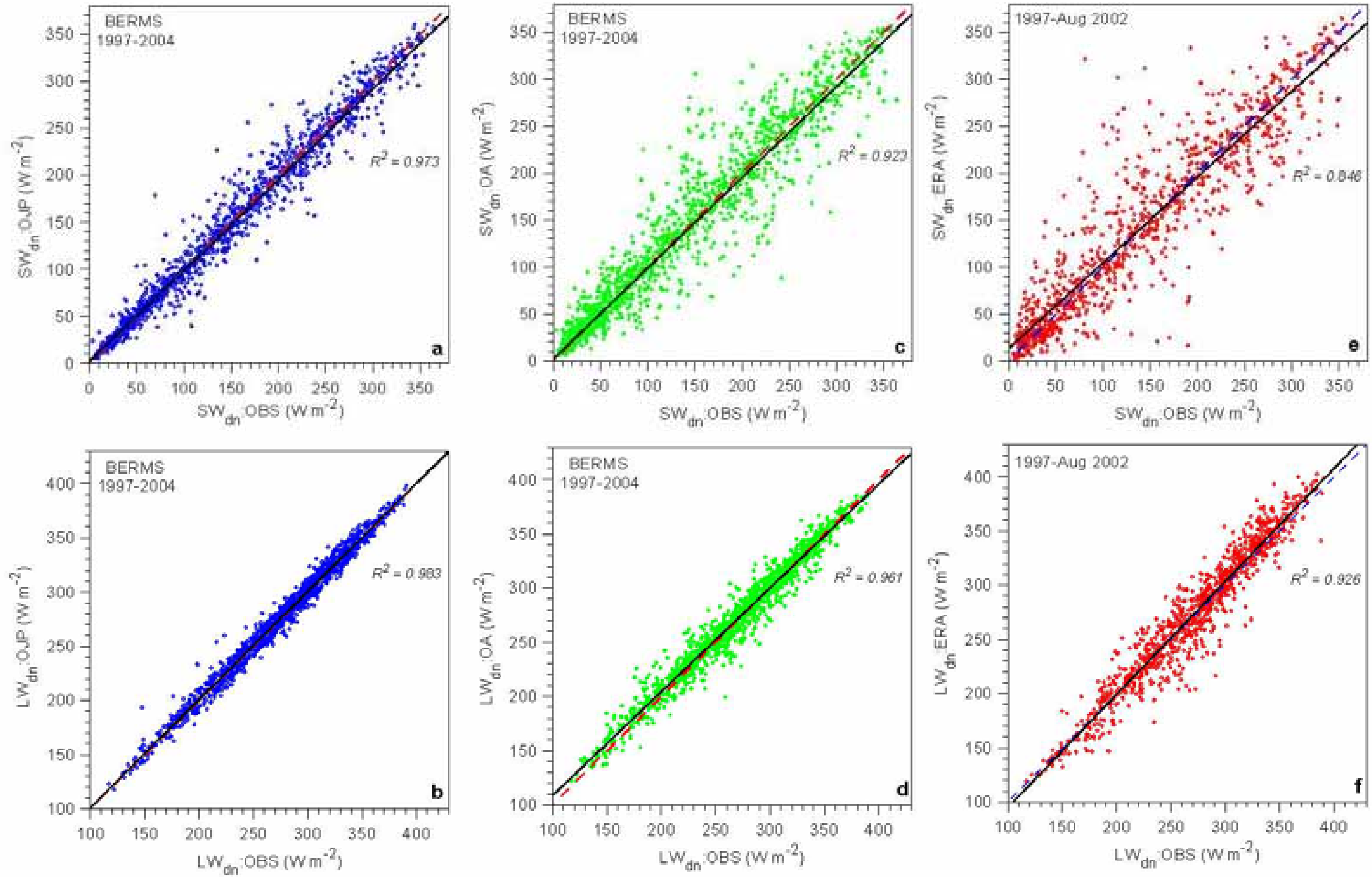
- Data as expected
  OA>OBS>OJP
- ERA-40 too high in spring and fall
  [Lacks vegetation seasonal cycle]
- ERA a little high in summer?



Comparison of **BERMS and ERA-40**

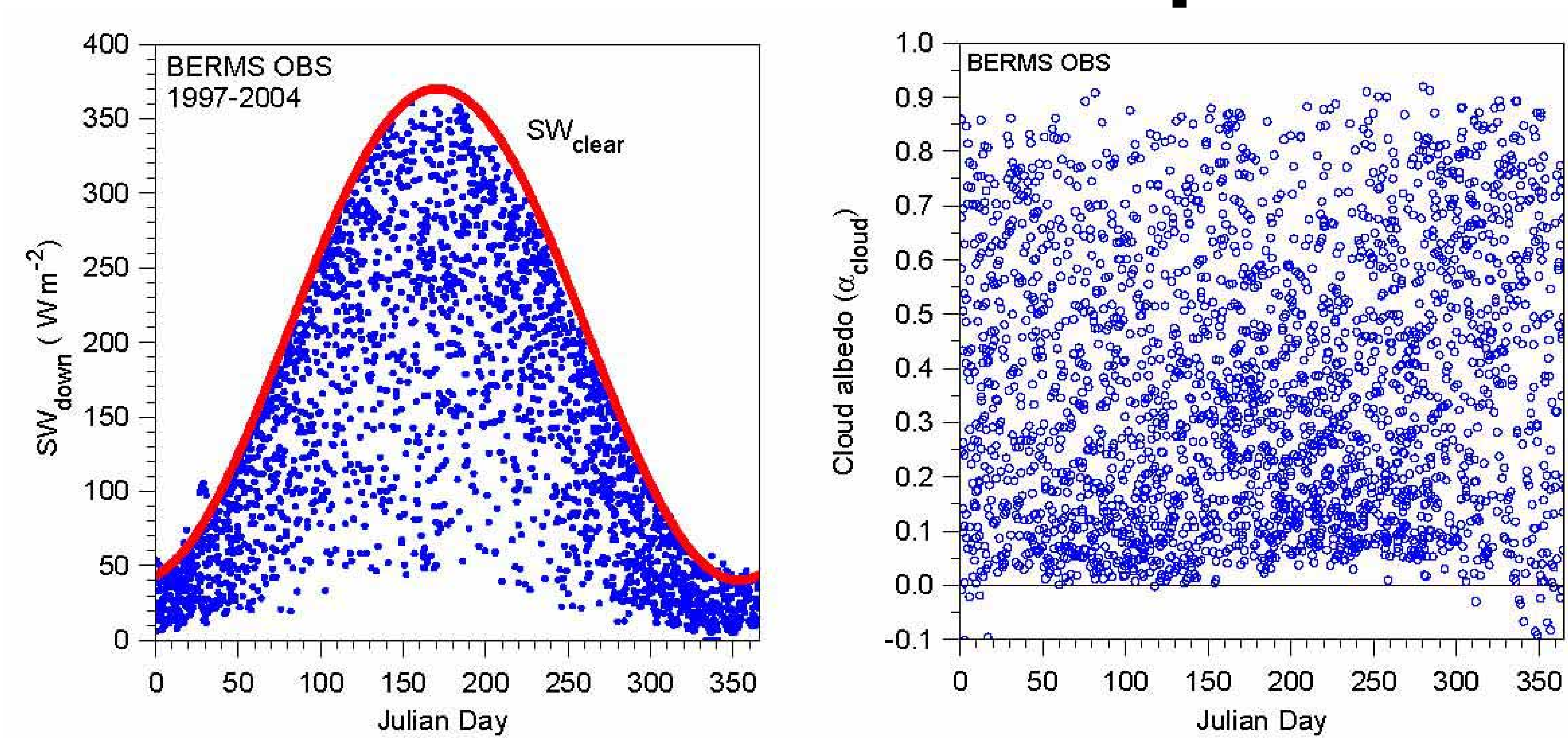
SW_{dn}

LW_{dn}



OBS to:	**OJP**	**OA**	**ERA-40**
Spacing:	**29km**	**81km**	**[grid-point]**

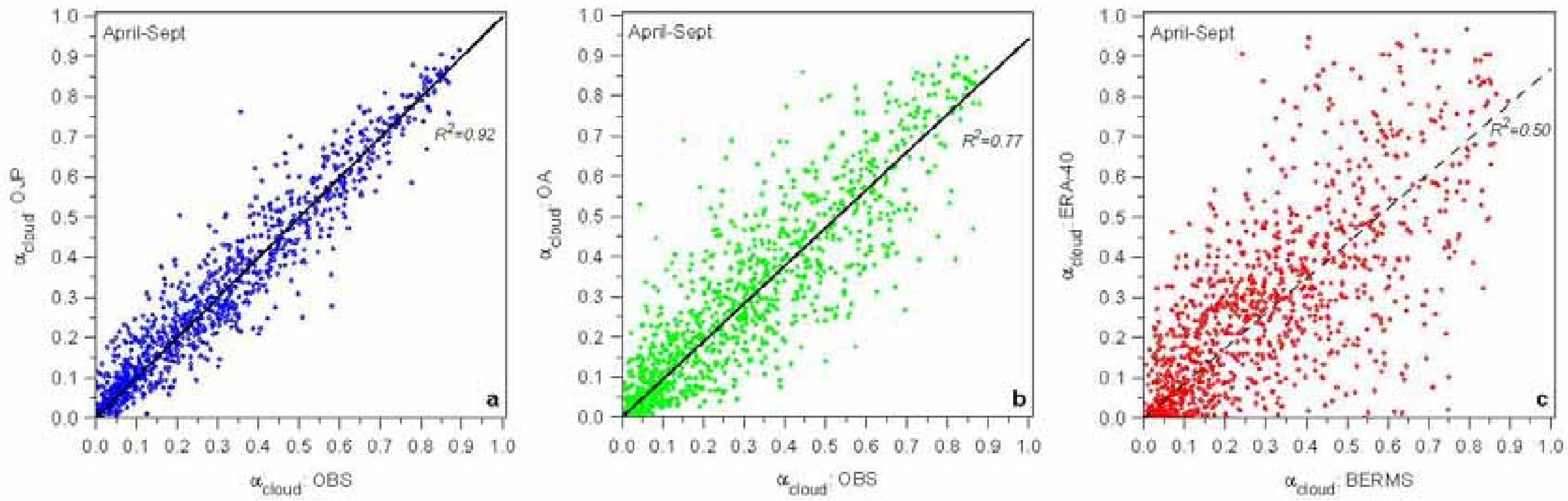
BERMS: Old Black Spruce



- Cloud 'albedo': α_{cloud} = 1- SW_{down}/SW_{clear}
- SW_{net}= (1- α_{cloud})(1- $\alpha_{surface}$)SW_{clear}

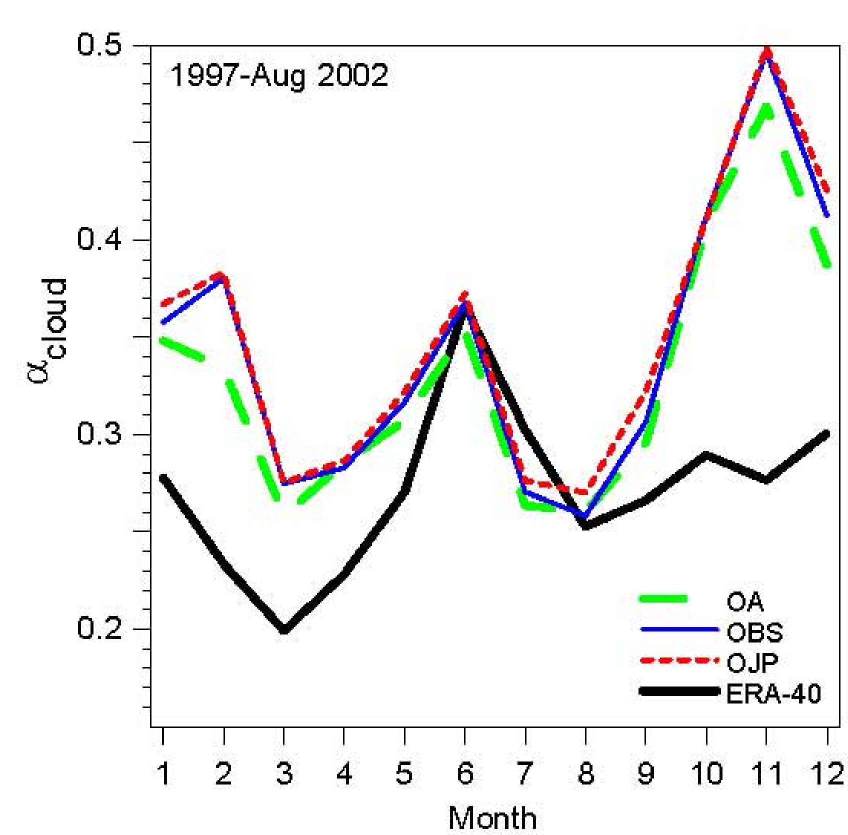
Cloud albedo comparison (daily)

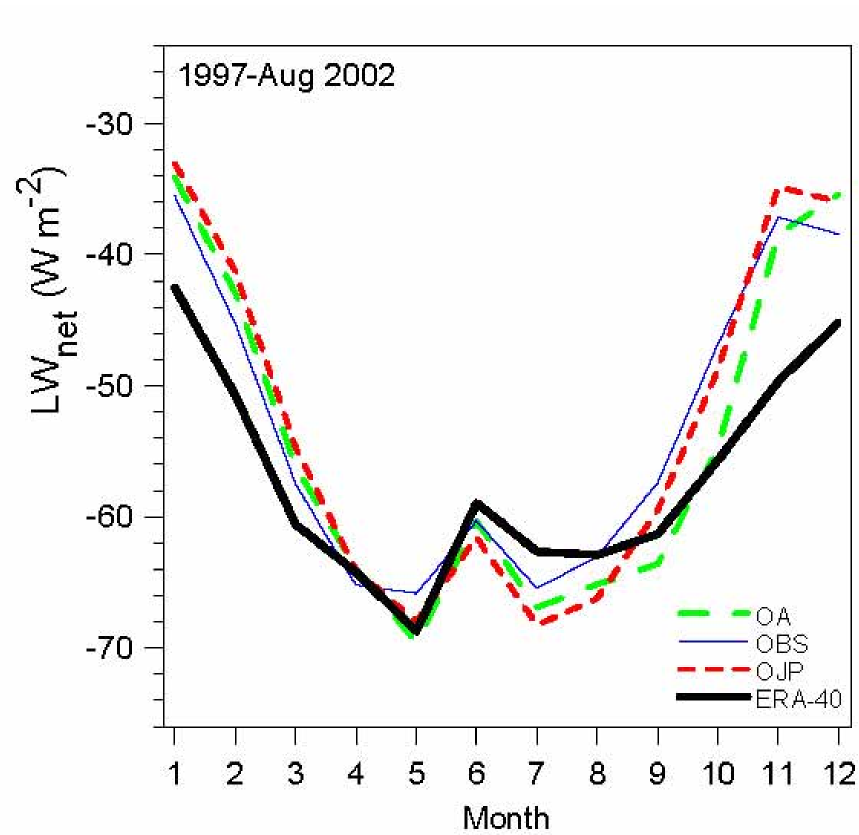
α_{cloud}



OBS to:	**OJP**	**OA**	**ERA-40**
Correlation:	**Good**	**Fair**	**Poor**
Spacing:	**29km**	**81km**	**[grid-point]**

Cloud albedo and LW comparison

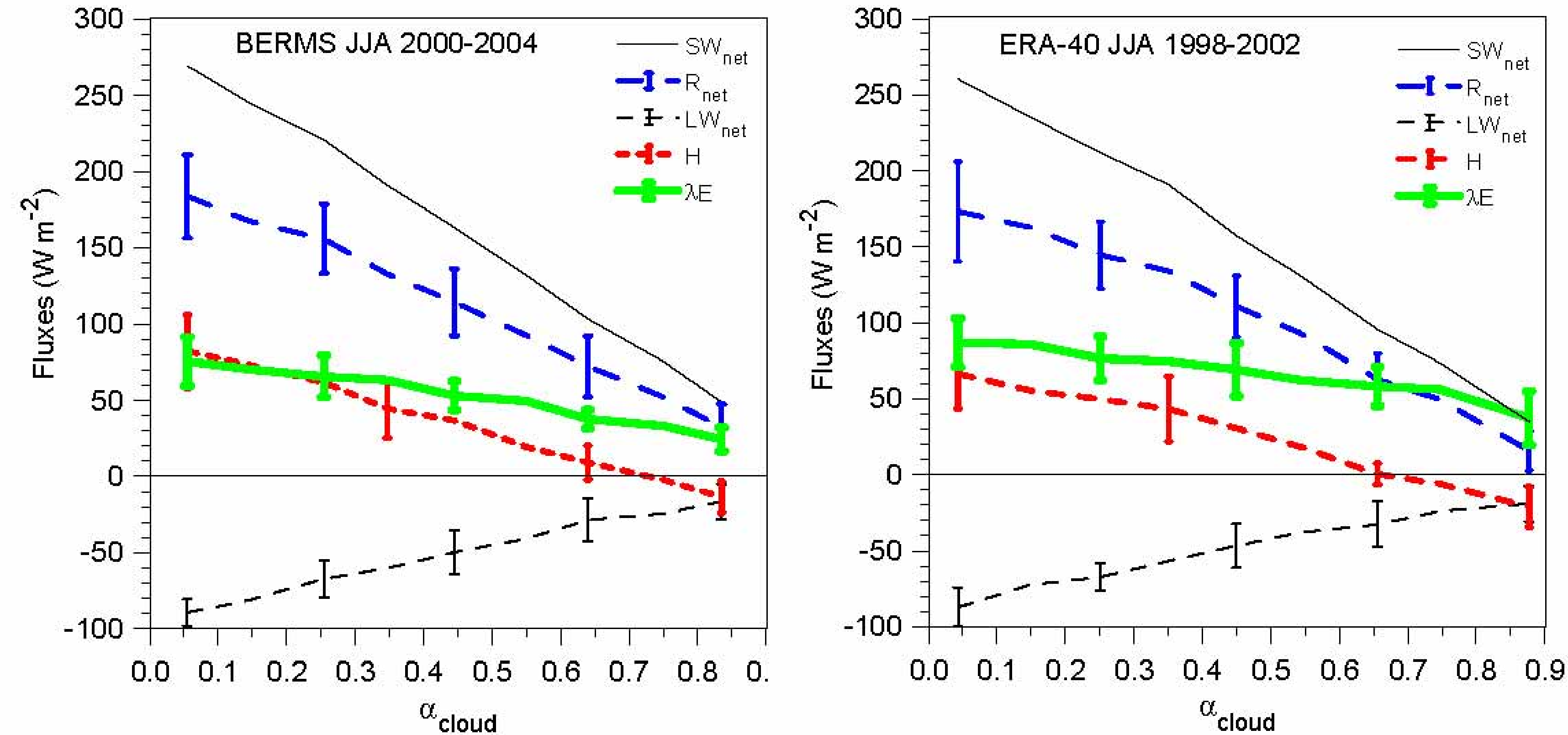




ERA-40: low α_{cloud} [except summer]

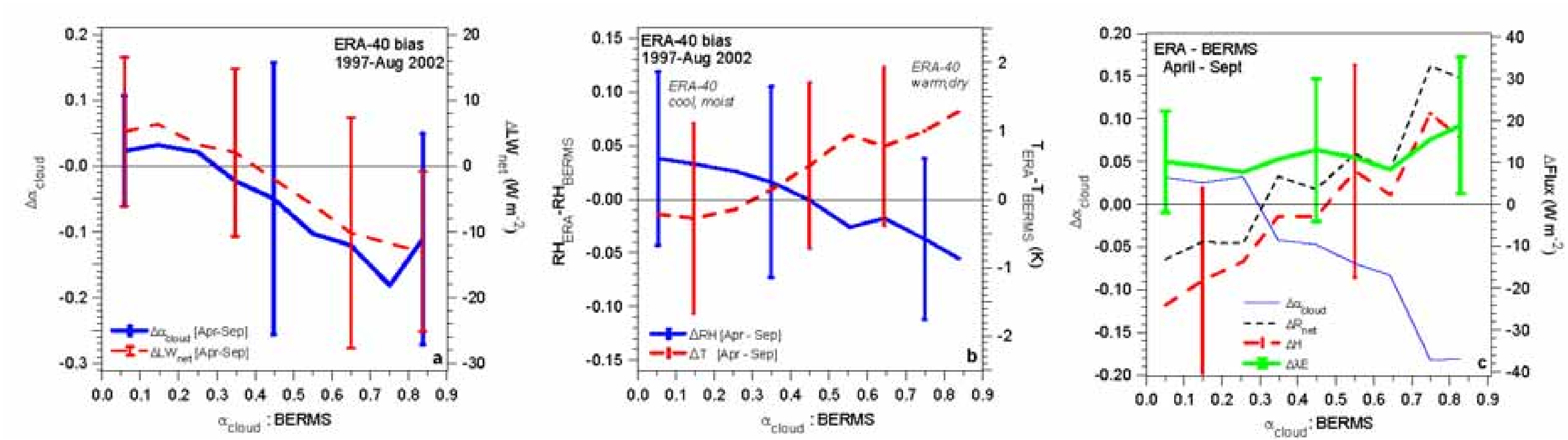
LW_{net} bias [winter]

How do fluxes depend on cloud cover?



- Quasi-linear variation
- Evaporation varies less than other fluxes

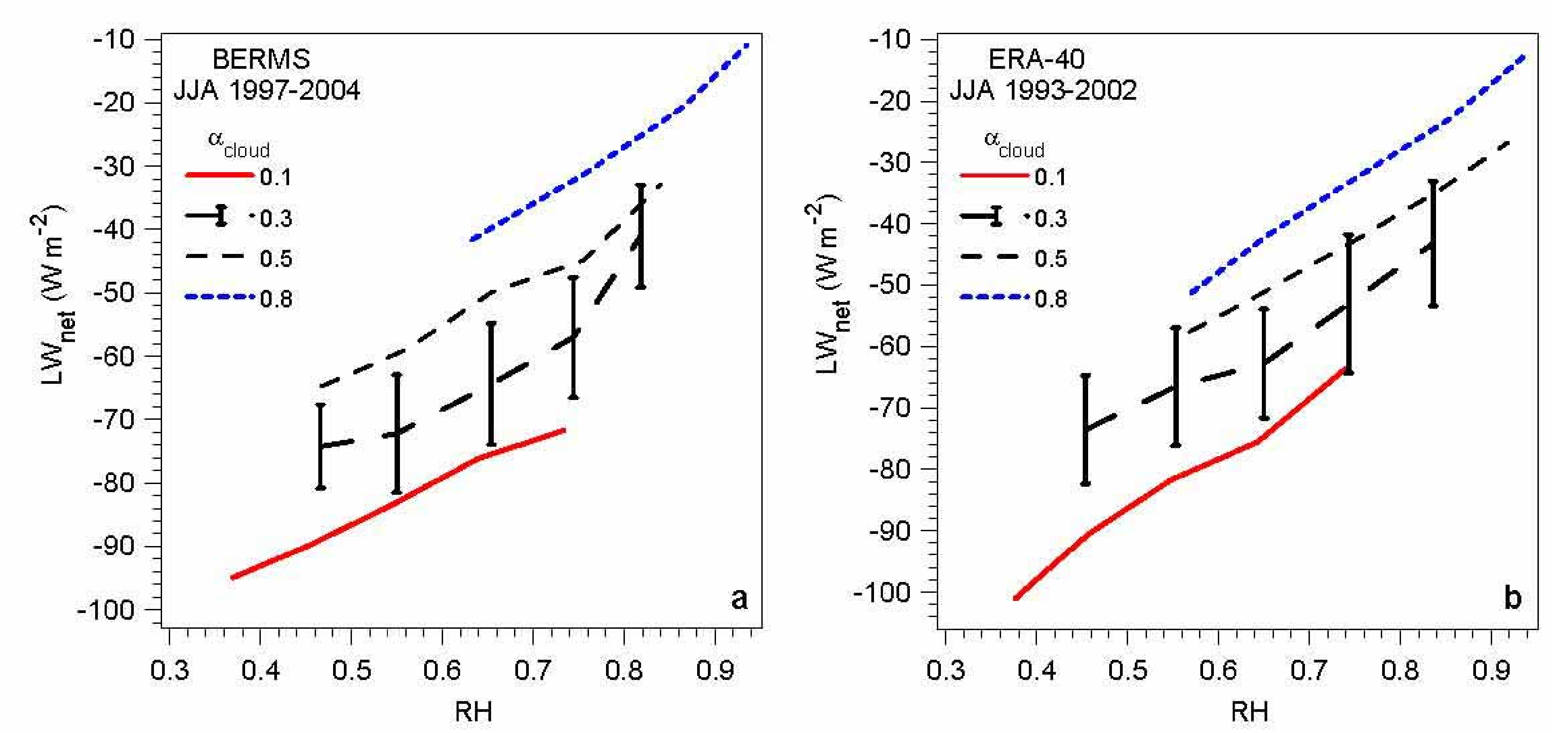
How do model biases depend on cloud cover?



Across range of observed cloud cover shift from

- cloudy-cool-moist bias to warm-dry-less-cloud bias
- H and R_{net} [but not λE] coupled to cloud bias

LW_{net} on RH and α_{cloud}



- Outgoing LW_{net} falls as RH and cloud cover increase
- Higher RH means lower LCL & depth of ML
- *LW coupling same for BERMS and ERA-40*
- *LW_{net} is linked to diurnal temperature range [Betts, 2006]*

Coupling of regional water vapor convergence, clouds and land-surface processes

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A03 Role of Circulation in Regional Hydroclimate Variability
AGU, May 23, 2006

Historical perspective

- For about 15 years, ‘cloud feedbacks’ have been labeled a ‘challenge’; a ‘major source of uncertainty in climate modeling’
- Why?   Seems odd because they are so easily observed!
- *A quantitative framework, which links clouds to both surface and large-scale processes has been missing.*

Organize data by

‘cloud albedo’

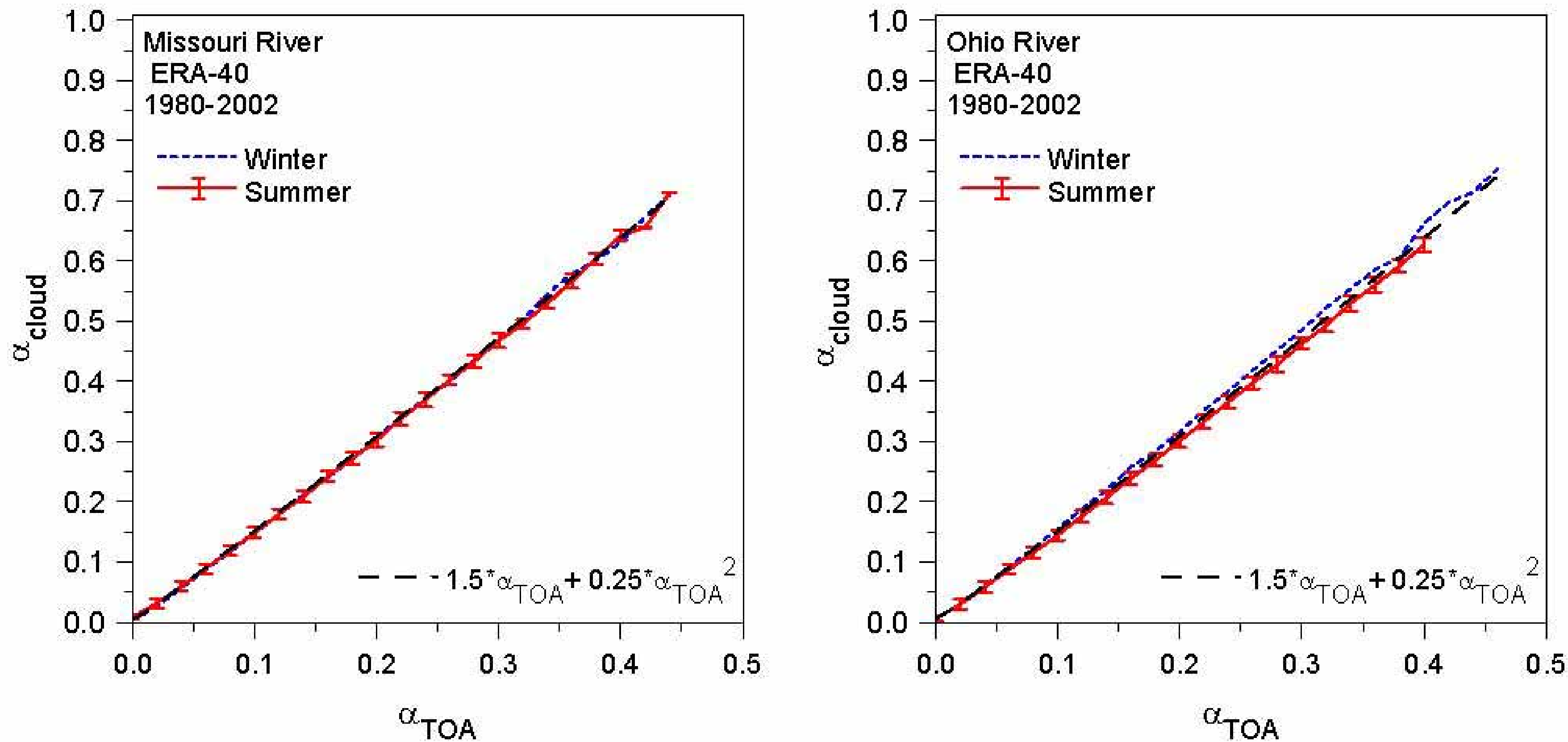
and the links become transparent and verifiable

Definitions

- *VIMC*: Vertically integrated moisture convergence
- α_{cloud} *:* 'cloud albedo' viewed from surface – *measure of surface SW cloud forcing*
- *SMI :* soil moisture index

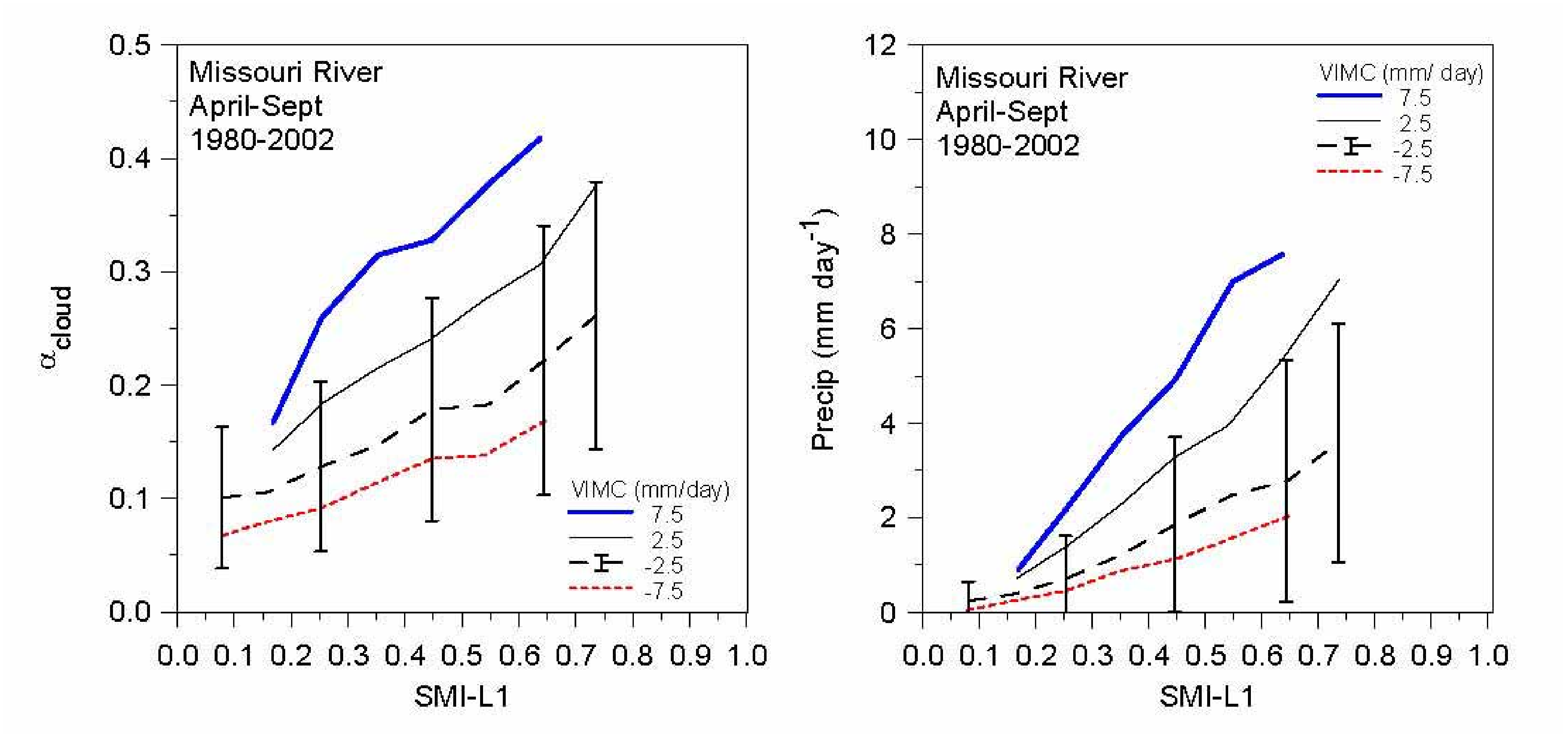
  [0<SMI<1 as PWP<SM<FC]

Surface and TOA cloud albedo are tightly related

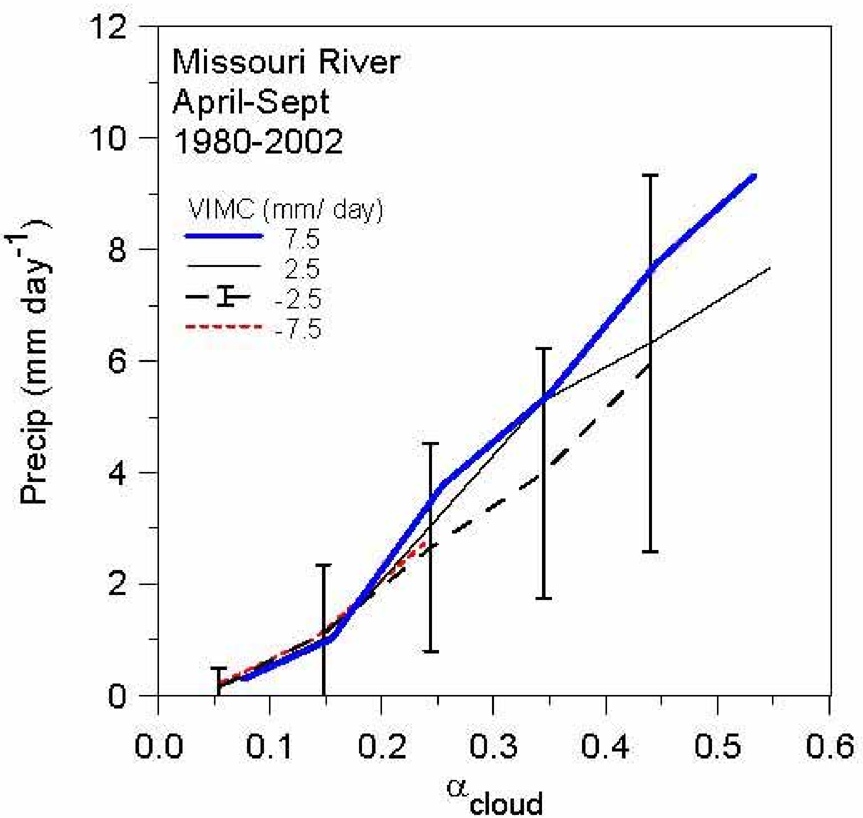


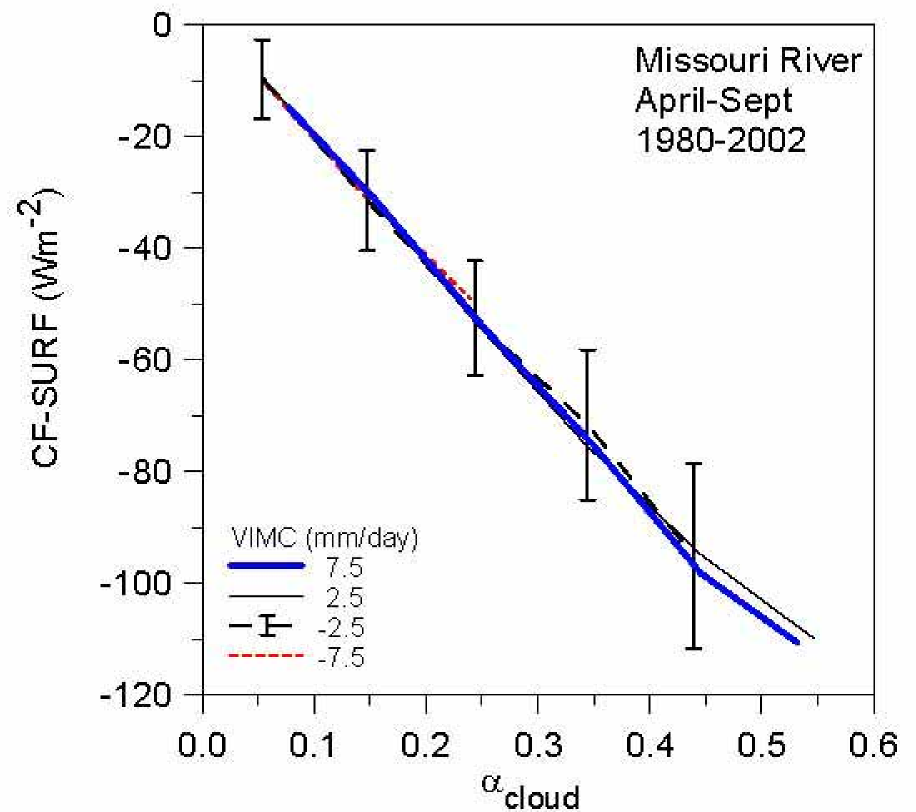
- α_{cloud} = SWCF:SURF/SW_{net}(clear)
- α_{TOA} = SWCF:TOA/SW_{dn}(clear)

α_{cloud}, Precipitation increase with SMI and VIMC



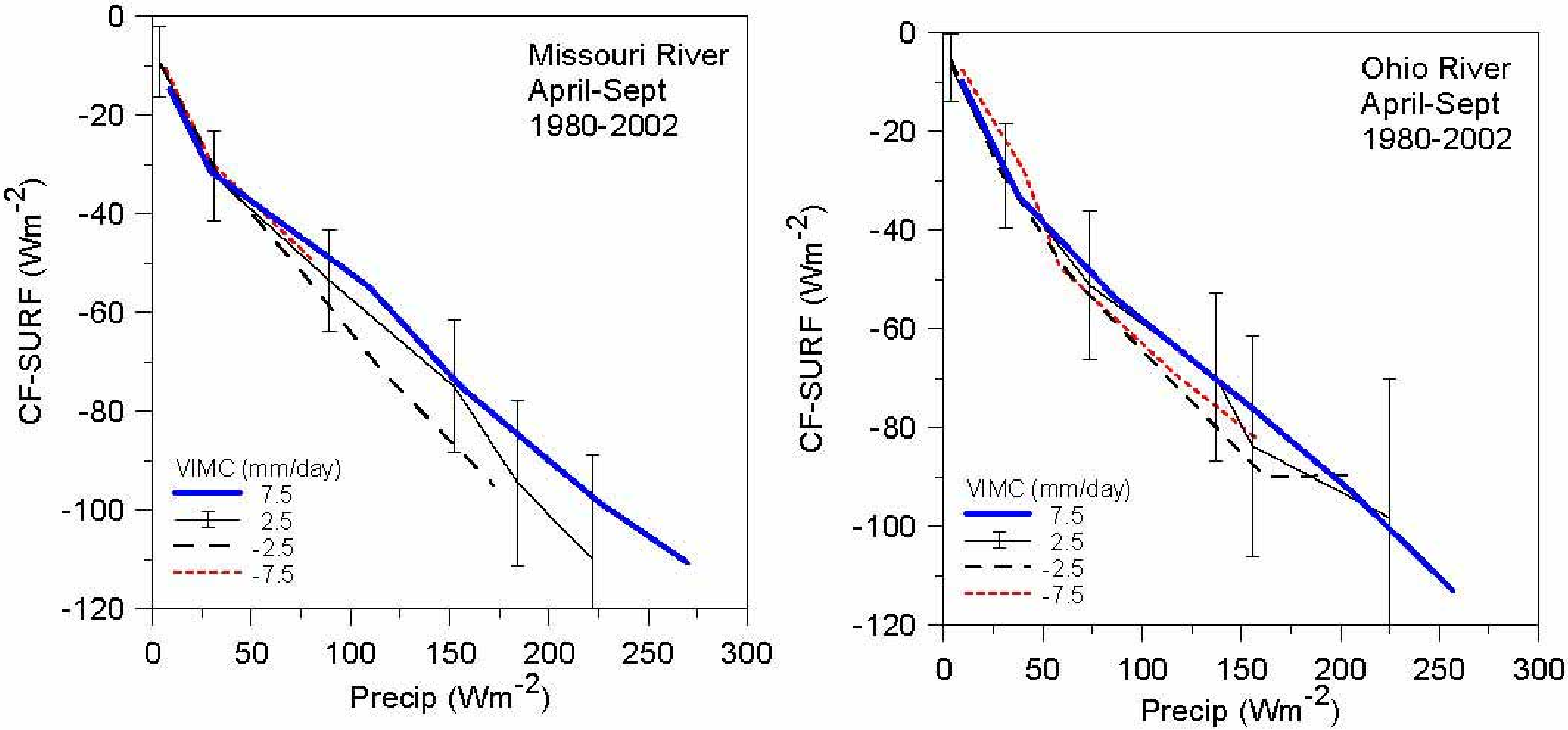
α_{cloud} is the critical link





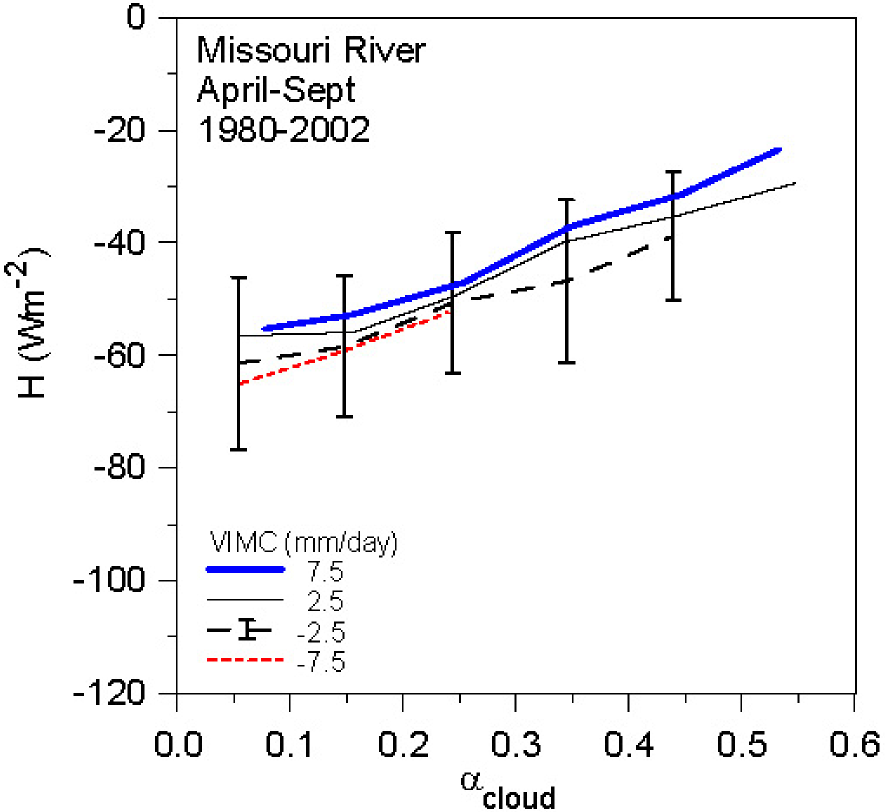
- α_{cloud} has quasi-linear relations
  to precipitation and surface cloud radiative forcing
- Not dependent on moisture convergence, VIMC

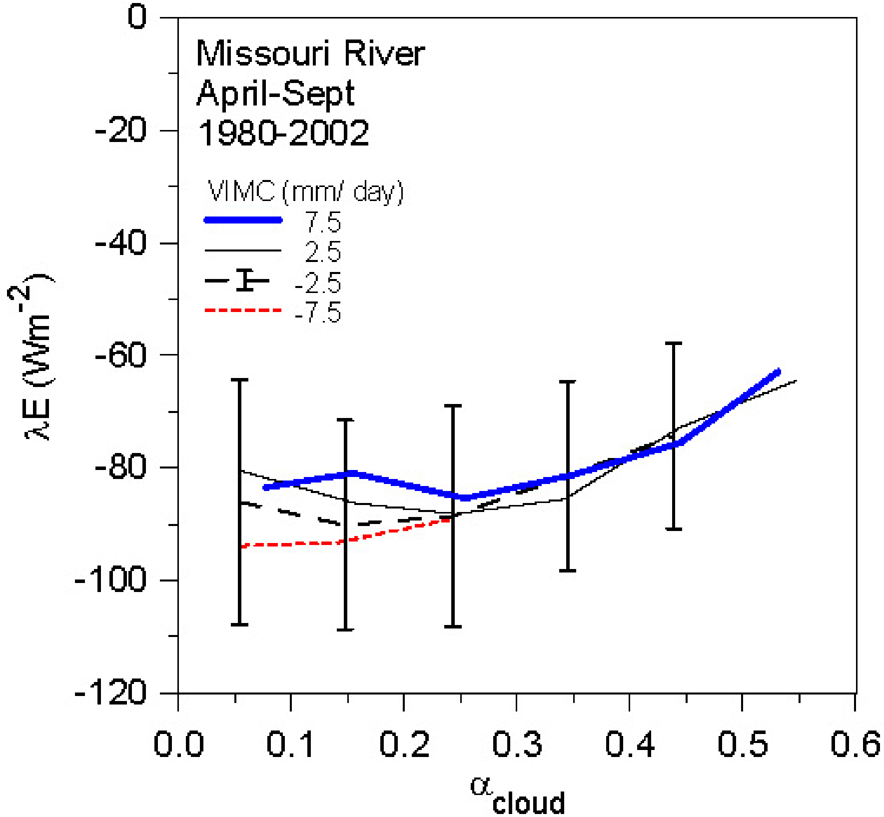
Relation of surface cloud forcing to precipitation forcing [Wm^{-2}]



- Same relationship, not dependent on VIMC
- CF-SURF is ≈ 40% of precipitation *in ERA-40*

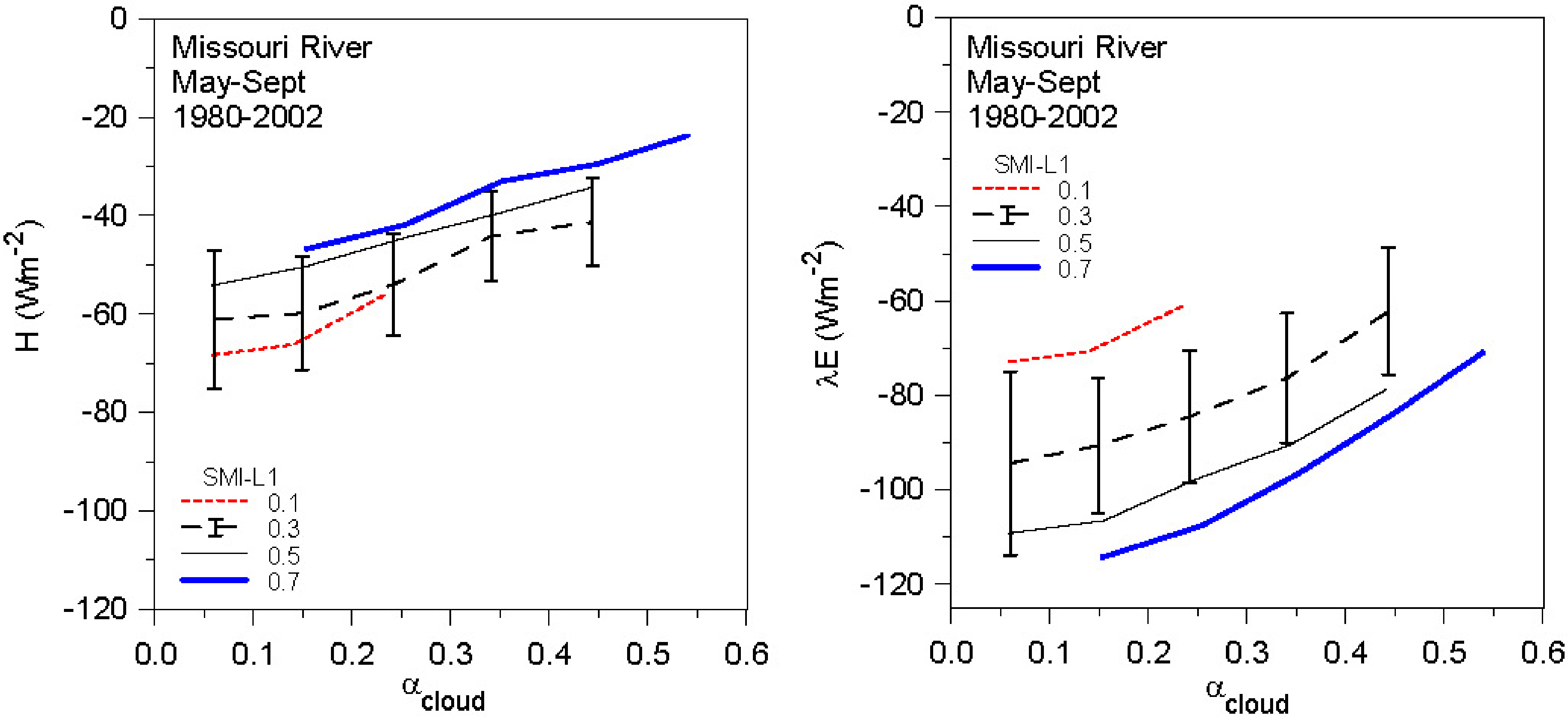
Surface fluxes vary with α_{cloud} but not VIMC





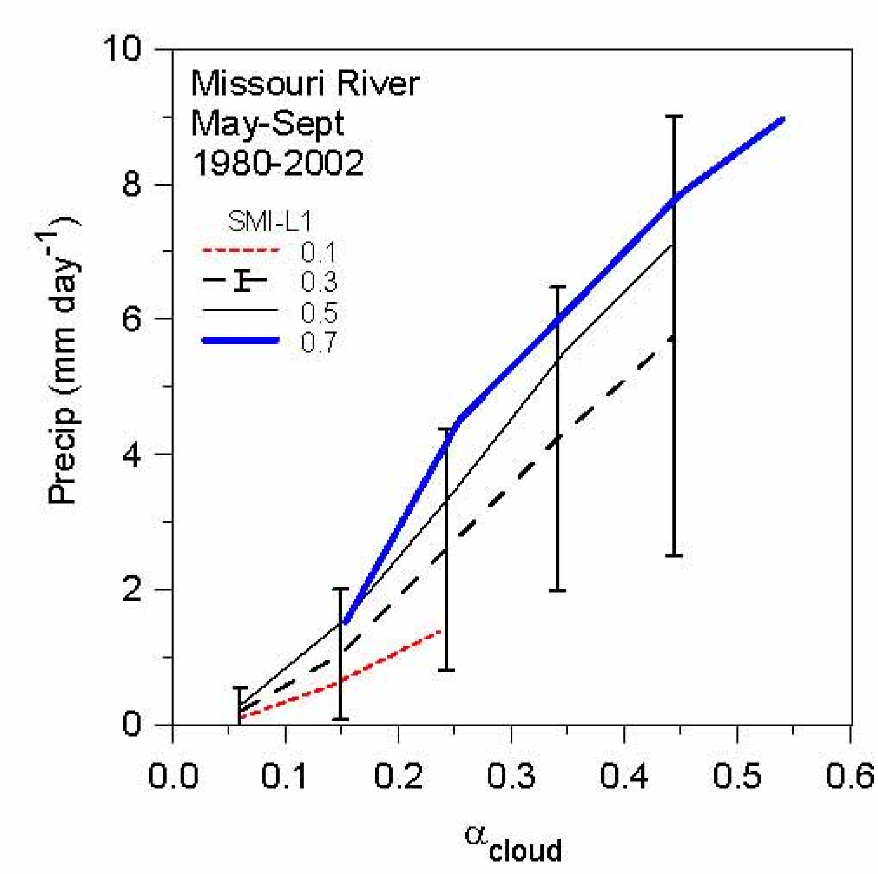
- H varies more with α_{cloud} than λE

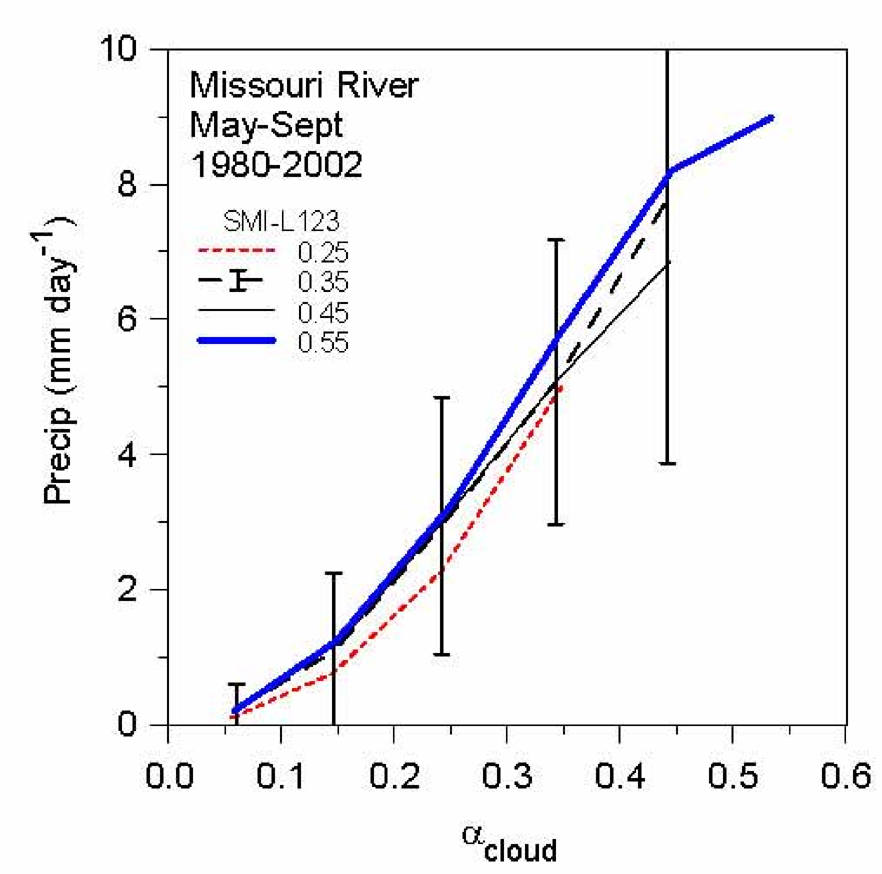
Surface fluxes vary with SMI



- L123 root-zone soil moisture similar

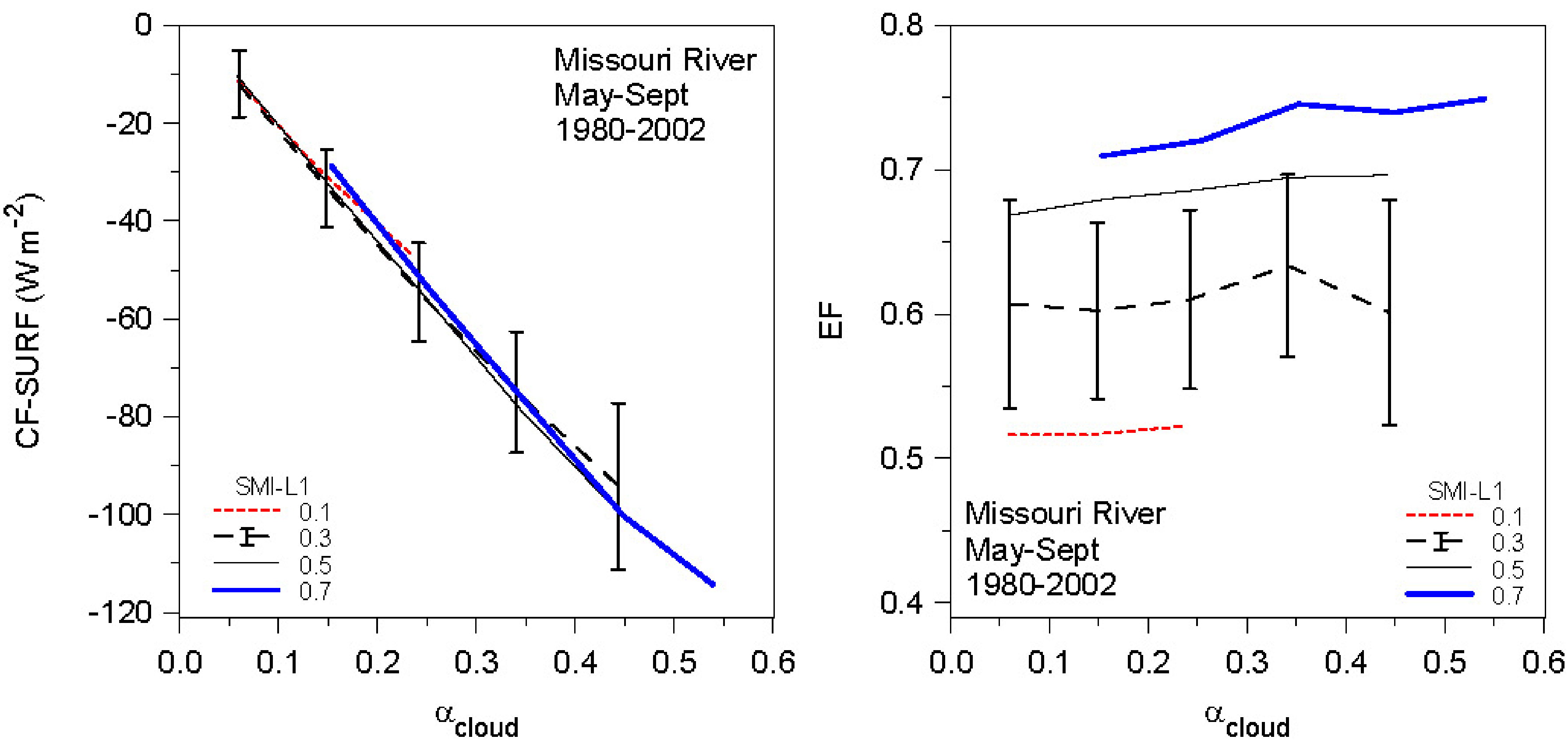
Precipitation varies with α_{cloud} and SMI-L1





- Coupling to SMI-L1 stronger than SMI-L123

ERA-40 SEB is partitioned into



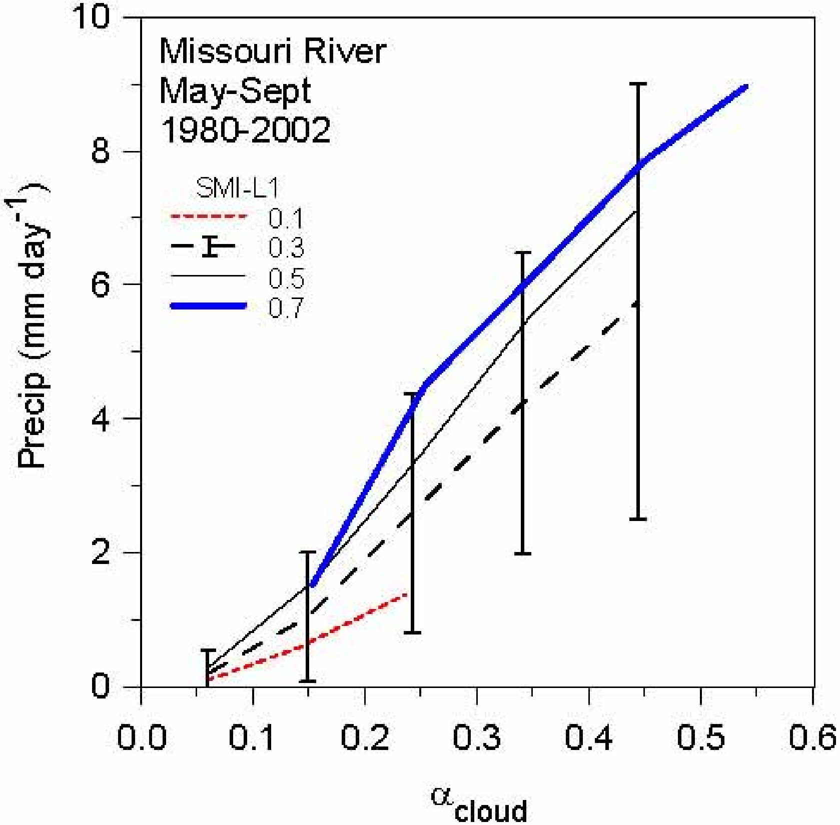
- Energy, a function of cloud albedo
- EF, a function of SMI

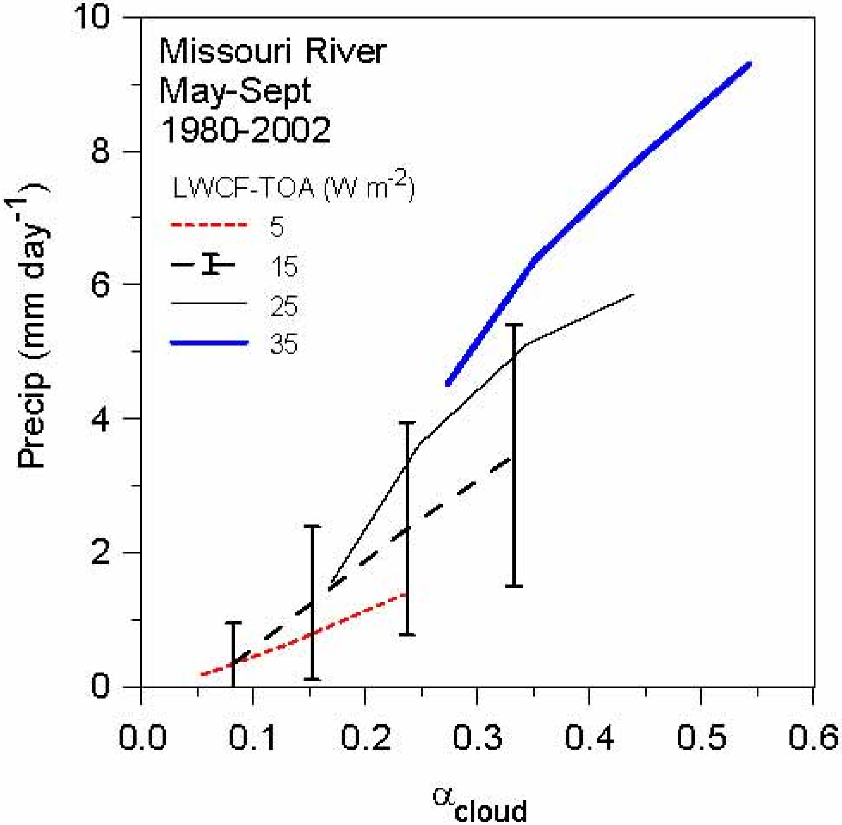
Satellite perspective on SEB

SEB energy balance a ‘soluble problem’ ?

1) Surface cloud forcing/α_{cloud} [visible]
2) EF from surface layer SMI [microwave]
3) Vegetation, slower component [NDVI]

Satellite perspective on Precip





Dependence of precipitation on α_{cloud} and

SMI-L1 LWCF-TOA

Conclusions

- **Organize data by ‘cloud albedo’**
- Cloud albedo is as important as surface albedo [with higher variability]
- Clouds, BL and surface are a coupled system; so biases coupled
- Coupling of LW_{net} to RH and α_{cloud} important to diurnal temperature range

Critical Issues

- Are observables coupled correctly in a model? Accuracy of model ‘daily climate’ important to forcing of monsoon

- Key non-local observables:
  - BL quantities: RH, LCL, θ_E linked to soilwater
  - Clouds: reduce SW reaching surface, α_{cloud} and outgoing LW_{net}
  - Aerosol: shift heating from surface to lower atmosphere

For AMMA

- Will we have sufficient/representative flux-tower data to assess models?
- Bamba (17.0N, 1.4W)
- Agoufou (15.33N, 1.48W)
- Wankama (13.63N, 2.63E)
- Banizoumbou (13.52N, 2.62E) [+ Niamey airport- ARM]
- Djougou (9.82N, 1.72E)

  [2 or 3 flux stations at each location each over a different land surface type]
- Can we link ‘cloud albedo’ derived from satellite data to surface fields and model analyses?
- Stratify by aerosol surface radiative feedback