Assessing the land-surface, boundary layer and cloud-field coupling in ERA-40

Alan K. Betts
Atmospheric Research, Pittsford, VT
akbetts@aol.com

Co-investigators
ERA-40 data: Pedro Viterbo
BERMS Data: Alan Barr, Andy Black, Harry McCaughey

AMS Session J5, Atlanta, Jan 31, 2006
Background references


• Preprints: ftp://members.aol.com/akbetts
Land-surface coupling

Models differ widely [Koster et al., Science, 2004]

Precip $\rightarrow$ SMI $\rightarrow$ $\lambda E$ $\rightarrow$ clouds $\rightarrow$ Precip

vegetation $\rightarrow$ vegetation $\rightarrow$ BL param $\rightarrow$ dynamics

soils $\rightarrow$ RH $\rightarrow$ microphysics

runoff $\rightarrow$ Cu param

$\text{LW,SW radiation}$

$R_{\text{net}}, H$

$\text{SMI : soil moisture index [0<SMI<1 as PWP<SM<FC]}$

$\alpha_{\text{cloud}}$: ‘cloud albedo’ viewed from surface
ERA40: soil moisture $\rightarrow$ LCL and EF

- River basin daily means
- Binned by soil moisture and $R_{\text{net}}$
ERA40: Surface ‘control’

- Madeira river, SW Amazon
- Soil water $\rightarrow$ LCL, LCC and $LW_{\text{net}}$
ERA-40 dynamic link (mid-level omega)

- $\Omega_{\text{mid}} \rightarrow$ Cloud albedo, TCWV and Precipitation
Compare ERA-40 with 3 BERMS sites

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

OBS to:  OJP  OA  ERA-40
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
Cloud ‘albedo’: $\alpha_{\text{cloud}} = 1 - \frac{SW_{\text{down}}}{SW_{\text{clear}}}$
Cloud albedo comparison (daily)

\[ \alpha_{\text{cloud}} \]

**OBS to:**
- OJP
- OA
- ERA-40

**Correlation:**
- Good
- Fair
- Poor

**Spacing:**
- 29km
- 81km
- [grid-point]
Cloud albedo and LW comparison

ERA-40: low $\alpha_{\text{cloud}}$ [except summer]

$LW_{\text{net}}$ bias [winter]
How do fluxes depend on cloud cover?

- Quasi-linear variation
- Evaporation varies less than other fluxes
\( \text{LW}_{\text{net}} \) on RH and \( \alpha_{\text{cloud}} \)

- Outgoing \( \text{LW}_{\text{net}} \) falls as RH and cloud cover increase
- Higher RH means lower LCL & depth of ML
- \( \text{LW} \) coupling same for BERMS and ERA-40
Conclusions -1

• Flux tower data have played a key role in improving representation of physical processes in forecast models

• Mean biases have been greatly reduced, but errors in cloud fields are visible

• Models can help us understand the coupling of physical processes
Conclusions - 2

• Are observables coupled correctly in a model? Accuracy of model ‘daily climate’

• Key non-local observables:
  – BL quantities: RH, LCL
  – Clouds: reduce SW reaching surface, $\alpha_{\text{cloud}}$
Conclusions - 3

• Cloud albedo is as important as surface albedo [with higher variability]

• Clouds, BL and surface are a coupled system

• H depends more on $\alpha_{\text{cloud}}$ than does $\lambda E$
Background references


• Preprints: [ftp://members.aol.com/akbetts](ftp://members.aol.com/akbetts)
Daily mean fluxes give model ‘equilibrium climate’ state

• Map model climate state and links between processes using daily means

• Think of seasonal cycle as transition between daily mean states
  + synoptic noise
Climate and weather forecast models

How well are physical processes represented?

- SMI → Evaporation → clouds → $SW_{net}$, $LW_{net}$

- FLUXNET data can assess both biases and poor representation of some physical processes and their coupling
Compare ERA-40 with 3 BERMS sites

- **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]
$P_{LCL} \rightarrow \alpha_{\text{cloud}} \text{ and } LW_{\text{net}}$