Linking AIRS Water Vapor to Remote-Sensing Precipitation and Surface Evaporation: A Way to Understand Global Hydrological Cycle

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Precipitation:
TRMM, GPCP, ...
MERRA, ECMWF, ...

Surface evaporation:
GSSTF2b, OAFlux, ...
MERRA, ECMWF, ...

Atmospheric water:
AIRS, IASI q retrievals,
MERRA, ECMWF
Question to Ask

• Are these independent estimates of components of hydrological cycle physically consistent with each others?
Local Balance for Hydrological Cycle (Yanai et al., 1973)

\[ S = -\left( \frac{\partial[q]}{\partial t} + [u] \cdot \frac{\partial[q]}{\partial x} + [v] \cdot \frac{\partial[q]}{\partial y} + [\omega] \cdot \frac{\partial[q]}{\partial p} \right) \]

\[ = C - E + \frac{\partial[\omega'q']}{\partial p} \]

- \( q \): AIRS specific humidity (g/kg)
- \( x, y, p \): longitude, latitude, pressure coordinates
- \([\ ]\): averaged over a \(10^\circ \times 5^\circ\) grid
- \( u, v, \omega \): winds from GEOS5 MERRA
- \( E, C, -\frac{\partial[\omega'q']}{\partial p} \): Evaporation, Condensation, eddy term
- \( S \): In literature, it’s related to Q2

\[ \int S \cdot dp/g = \int (C - E + \frac{\partial[\omega'q']}{\partial p}) \cdot dp/g \]
\[ \approx \text{Precipitation} - \text{Surface Evaporation} \]
Local Balance for Hydrological Cycle

\[ \int S \cdot dp/g \approx \text{Precipitation} - \text{Surface Evaporation} \]

S: AIRS q profiles and MERRA or other reanalysis winds

Precipitation: TRMM 3B42 (Huffman, 2007)

Surface Evaporation: GSSTF2b (Shie et al., 2009; Chou et al., 2003)
What to Test?

• Seasonal Climatologies of hydrological cycle (J. Climate under review)
  
• All-time scale variability of P–E
  
• Processes:
  Indian Monsoon (Wong et al., 2011, J. Climate)
  Atmospheric Rivers (on-going research)

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Seasonal Climatologies of $sdp/g$
(AIRS $q$ + MERRA winds)

Winter 2004-2008

DJF AIRS/MERRA (mm/day)
Seasonal Climatologies of $\jS_{dp/g}$
(AIRS $q +$ MERRA winds)

Winter 2004-2008
DJF AIRS/MERRA (mm/day)

Summer 2004-2008
JJA AIRS/MERRA (mm/day)
Comparison of $\int \frac{Sdp}{g}$ with $P-E$

Winter 2004-2008
DJF AIRS/MERRA (mm/day)

Summer 2004-2008
JJA AIRS/MERRA (mm/day)

$\int \frac{Sdp}{g}$
AIRS q
MERRA winds

$P-E$

P: TRMM 3B412
E: GSSTF2b
Comparison of $\int Sdp/g$ with $P–E$ for the MERRA

Winter 2004-2008

Summer 2004-2008

$\int Sdp/g$

MERRA q budget

$P–E$

MERRA P and E modules
All Time-Scale Variability

Regions for Wavelet Analyses
Indian Continent and Bay of Bengal Precipitation

![Graph showing precipitation over time for the Indian/Bengal region.]
Indian Continent and Bay of Bengal Precipitation
\[ \int \] AIRS q and MERRA winds

\[ \int \] MERRA q budget

MERRA P–E

TRMM 3B42 P
All Time-Scale Variability

Regions for Wavelet Analyses
All Time-Scale Variability

Regions for Wavelet Analyses
Conclusions:

• AIRS q combined with the MERRA or ECMWF winds reproduces reasonable climatologies of P–E, compared to TRMM 3B42, GPCP, and GSSTF2b

• agreeable pattern of wavelet spectra over the ITCZ, maritime continents, and Indian continent, but underestimates the intraseasonal time-scale variability

• wavelet spectra of AIRS and MERRA dynamically calculated q sink do not agree with the retrieved P over the Tropical Africa
FFT Filter of Indian Precipitation 30-100 days
Hovmöller Diagram of Time Lag Composite of Anomalies

\[-\int S \cdot dp/g \text{ from AIRS } q \text{ and MERRA winds}\]

TRMM 3b42 Precipitation – OAFlux Surface Evaporation

Column q SNK–SRC Anomaly (mm/day)

Prcp.–Evap. Anomaly (mm/day) 70–90E
Local Balance for Hydrological Cycle

\[ \int S \cdot dp/g \approx \text{Precipitation} - \text{Surface Evaporation} \]

S: AIRS q profiles and MERRA or other reanalysis winds

Precipitation: TRMM 3B42 (Huffman, 2007)

Surface Evaporation: GSSTF2b (Shie et al., 2009; Chou et al., 2003)

Local Balance for Atmospheric Energy Cycle

\[ \partial[T]/\partial t + [u] \cdot \partial[T]/\partial x + [v] \cdot \partial[T]/\partial y + [\omega] \cdot \partial[T]/\partial p - \kappa \omega T/p = Q_1 \] (diabatic heating)

L. H. S.: AIRS T retrievals, and MERRA winds

R. H. S.: TRAIN Q1 (L’Ecuyer and Stephens, 2007; Grecu and Olson, 2006)
What to Test?

• **Seasonal Climatologies of hydrological cycle** (J. Climate under review)

• **All-time scale variability of P–E** (J. Climate under review)

• **Processes:**
  
  Indian Monsoon (Wong et al., 2011, J. Climate)
  Atmospheric Rivers (on-going research)
FFT Filter of Indian Precipitation 30-100 days
Hovmöller Diagram of Time Lag Composite of Anomalies
\[ -\int S \cdot dp/g \text{ from AIRS } q \text{ and MERRA winds} \]
\( \int S \cdot dp/g \) from AIRS \( q \) and MERRA winds

TRMM 3B42 Precipitation – OAFlux Surface Evaporation
On-Going or Future Work:

• Validation the AIRS/MERRA heating sources with TRAIN Q1 on climatologies and all time-scale variability (Bill Olson and Tristan L’Ecuyer)

• Water vapor sinks and heat sources associated with the Atmospheric Rivers (Ju-Mee Ryoo)

• Understanding the effect of clouds on biases of the q sinks and heat sources (Eric Fetzer)
Sneak Peek on Atmospheric River

(a) q Sink 600–850 hPa 20051228
(b) q Sink 600–850 hPa 20051229
(c) q Sink 600–850 hPa 20051230
(d) TRMM P 20051228
(e) TRMM P 20051229
(f) TRMM P 20051230
Comparison of $\int Qdp/g$ (On-going Research)

Winter 2004-2008

Summer 2004-2008

$\int Qdp/g / L$

AIRS T

MERRA winds

$\int Q1 dp/g / L$

Q1: TRAIN Q1
Comparison of $\zeta Sdp/g$ between AIRS/MERRA and purely MERRA