Water Vapor Tracers in MERRA Replay mode using the NASA/GSFC GEOS-5 GCM

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1. Motivation

Coupling processes between the land and atmosphere have been generally studied with dynamic models in ensemble simulations. Coupling with the Earth surface is also an important component of extreme weather and climate events. In this project, we will investigate the land-atmosphere coupling in the GEOS-5 ADAS by implementing water vapor tracers (WVTs, Bosilovich and Schubert, 2002) as a method of disaggregation of the local and remote water sources during extreme events.

2. General Approach of Tracers

The source and sink equations for the WVTs are located in a new "H2O_GridComp" gridded component module within the GEOS-5 GCM's "AeroChem" gridded component. The sources (surface evapotranspiration; rain evaporation) and sinks (condensation) of the WVTs are calculated using equations detailed in Section 4. A source mask (currently over 50 major surface regions, river basins, ocean/lakes, etc.) is defined (Fig. 1), and separate 3-D fields of WVTs are accumulated (via the sources/sinks) and output for each of the regions. The dynamics of the GCM advects the WVTs around the globe in the same method as the total moisture in the atmosphere.

The advantages of WVT diagnostics:

- Quantitative estimates separating local and remote water sources
- Linked to model dynamics and physics
- Additional diagnostics in regional transport and budget studies

3. Tracers in MERRA Replay mode

The WVTs were run in a "Regular" replay mode in the GEOS-5 ADAS. This mode replays to an existing analysis by simulating the IAU (i.e., ANA-BKG) process. The existing analysis and initial states used here are from the MERRA reanalysis (Rienecker et al., 2011). The figures below show the masks and sample figures of the fraction of a mask's WVT that originated from surface evaporation within that mask relative to the sum of all WVTs from all masks.

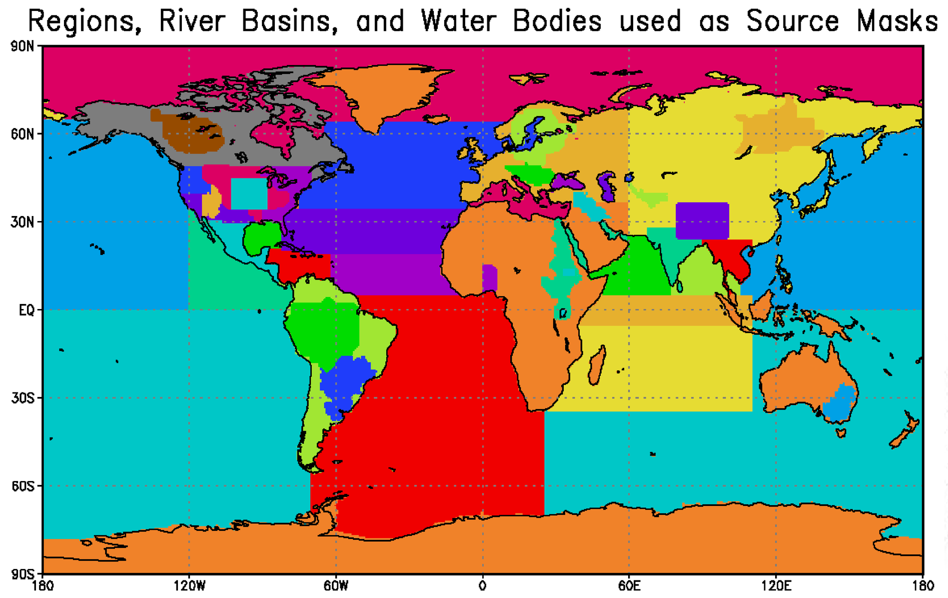


Figure 1: Map of source masks (regions/basins) for surface evaporation for the WVTs.

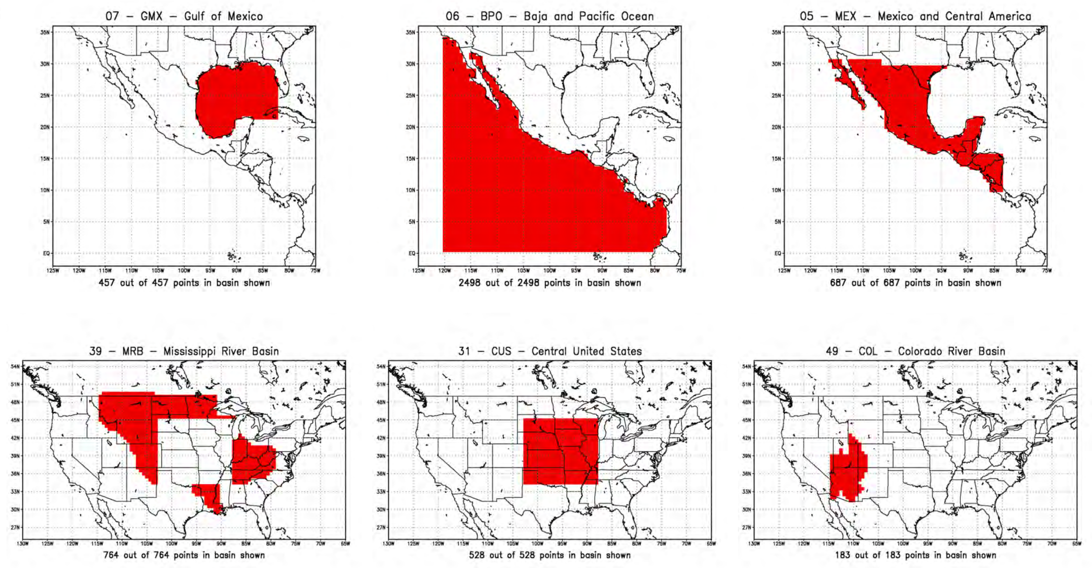
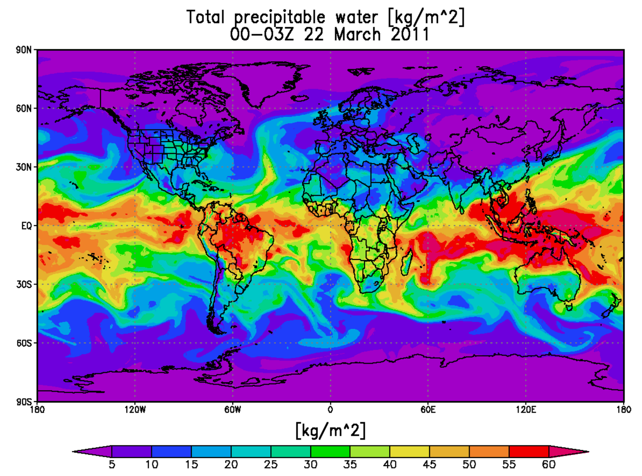
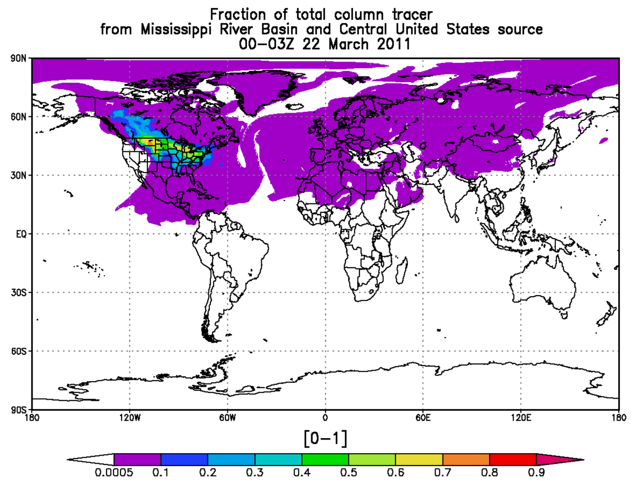


Figure 2: Close-up for some individual source masks (regions/basins) within and surrounding CONUS.





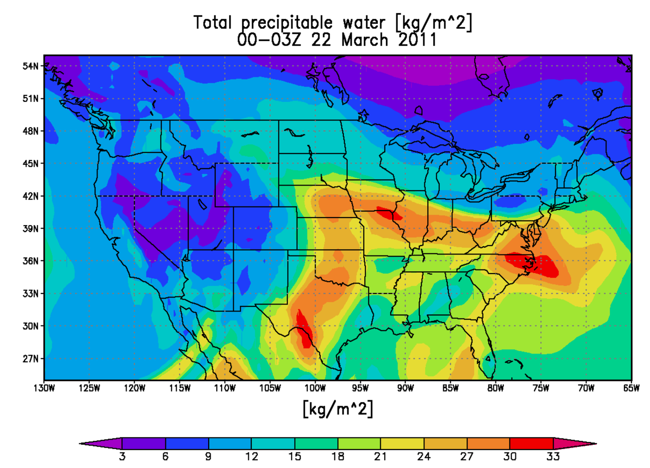


Figure 3 (left): TPW (Total precipitable water) [kg/m^2] from the MERRA replay averaged from 00-03Z on 22 Mar 2011. **Figure 4** (middle): Fraction of total column WVT from the combined source region of the Mississippi River Basin and the Central United States region. **Figure 5** (right): Close-up of TPW over the CONUS domain and surrounding regions (same field as Figure 3 with diff intervals).

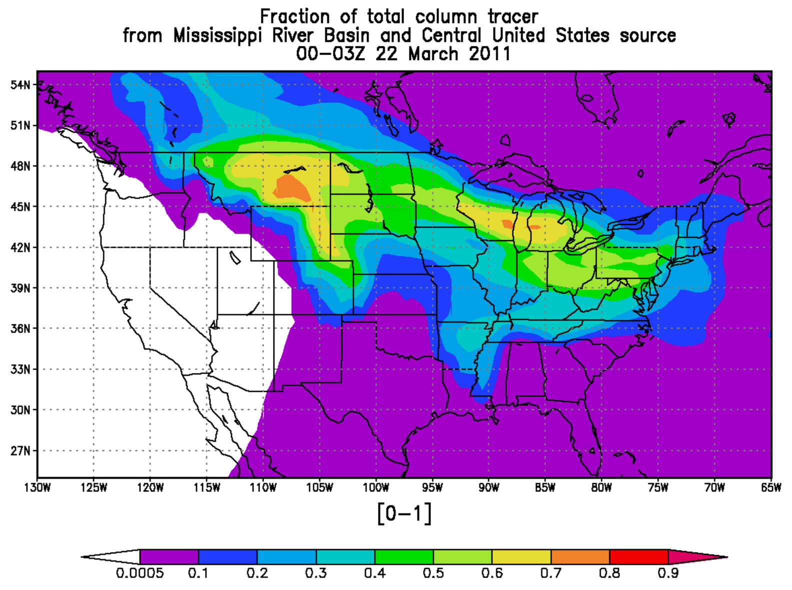


Figure 6: Fraction of total column WVT from combined MRB/CUS basins (same field as Figure 4).

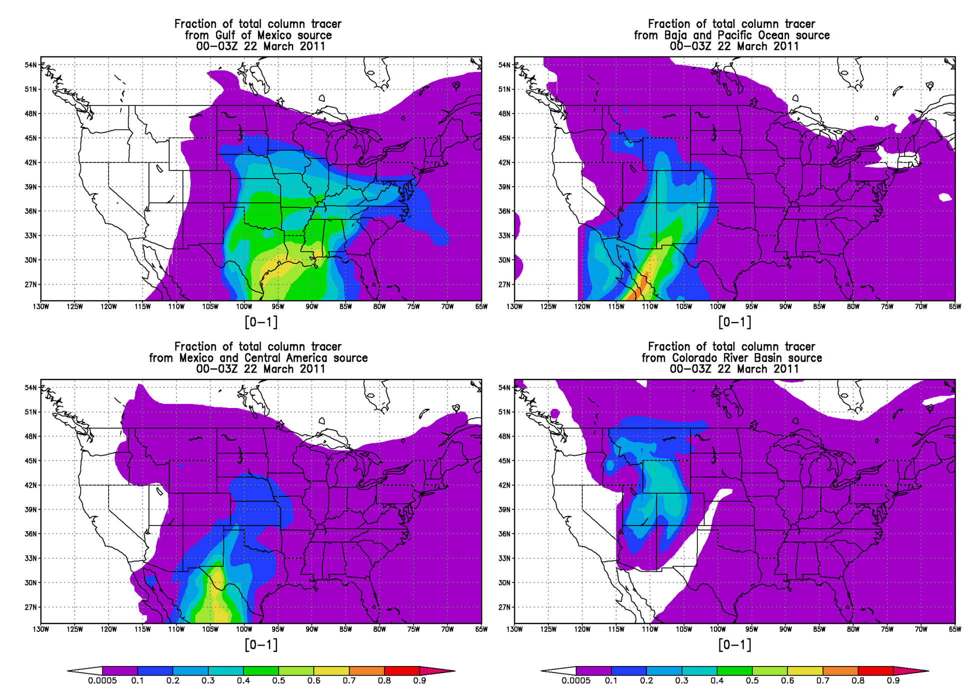


Figure 7 (left): Fractions for other WVT source regions (GMX, BPO, MEX, COL).

4. Source and sink equations for WVTs

Pseudo-code for the WVTs is below, looping over the number of masks, and starting near the top of the column and integrating down to the surface:

do i = 1,number_of_masks

$QT_{i,km} = QT_{i,km} + (EVAP * g * dt / DELP_{km}) * MASK_i$ ← **Source: Surface Evaporation**

$TPT_i = PTL_i = 0.0$

do $k = 2,km$

$QVO_k = Q_{V_k} - (DQDT_k * \delta t)$

$FRT_{i,k} = QT_{i,k} / QVO_k$

where $DQDT_k$ negative

$TPT_i = TPT_i - (DQDT_k * FRT_{i,k})$

$QT_{i,k} = QT_{i,k} + (FRT_{i,k} * DQDT_k * \delta t)$ ← **Sink: Condensation in the column**

where $DQDT_k$ positive

$FRP_{i,k} = TPT_i / PTL_i$

$TPT_i = TPT_i - (DQDT_k * FRP_{i,k})$

$QT_{i,k} = QT_{i,k} + (FRP_{i,k} * DQDT_k * \delta t)$ ← **Source: Rain Evaporation in the column**

$PTL_i = PTL_i - DQDT_k$

enddo ! k = number of km vertical layers

enddo ! i = number_of_masks

where:

$QT_{i,k}$ = 3-D tracers
QVO_k = Qv before moist physics
$FRT_{i,k}$ = tracer fraction of total water
TPT_i = total precip of a tracer
Qv_k = 3-D specific humidity
$DQDT_k$ = moist physics tendency of Qv
$FRP_{i,k}$ = fraction of precip of a tracer
PTL_i = vertical integration of total precip

The dynamics of the GCM advects the QT tracers passively, and conserves the mass of the tracers. The evaporation of rain and condensation only occur within the atmospheric column. *PTL* at the bottom of the column equals the precip.

5. Next Steps

- Evaluate WVT performance in hydrological extremes
- Use tracers to assess impact of water vapor assimilation (an additional source or sink term)
- Develop coupling strength diagnostics based on WVT diagnostics

6. References

Bosilovich, M.G. and S.D. Schubert, 2002: Water vapor tracers as diagnostics of the regional hydrologic cycle. *J. Hydrometeor.*, **3**, 149-165.

Rienecker, M. R. and co-authors, 2011: MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. *J. Climate*, Vol. **24**, Iss. 14, 3624-3648.

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