UTLS water vapour from trajectories

Yu Liu, Stephan Fueglistaler, Peter H. Haynes
Y.Liu@damtp.cam.ac.uk

DAMTP, University of Cambridge

ACTIVE meeting, 21 May 2009
Motivation

- Estimates of stratospheric water vapour using Lagrangian calculations based on synoptic-scale winds and temperature fields (ERA-40) can explain mean and seasonal cycle of water vapour entry mixing ratio to within $\sim 0.2$ ppmv [Fueglistaler et al. 2005].

- Predicted interannual and longer term changes in entry mixing ratio give high correlations with observations [Fueglistaler and Haynes, 2005].

Questions:

- How sensitively do the results depend on the type of trajectory and input meteorological data?

- Can this method be used to estimate water vapour in the extratropical UTLS region?
Method

- Use ECWMF ERA-40 and ERA-Interim reanalysis data, provide at T159L60 resolution every 6 hours.
- **kinematic** (vertical velocity calculated from mass continuity equation) and **diabatic** (vertical motion driven by diabatic heating rates) trajectories.
- Initialise globally on $2^\circ \times 2^\circ \times 10K$ grid between 310K and 450K isentropic levels every 10 days in 2001 and 2005 and integrate backwards for 5 months.
- Calculate the water vapour mixing ratio at the end of trajectory from the minimum saturation mixing ratio over ice encountered along each trajectory. Include methane oxidation for stratospheric trajectories.

Troposphere-to-Stratosphere (TST) trajectories: $\theta < 335K$ and $|PV| < 2$ PVU in the previous 5 months.
Water vapour on 400K: Entry mixing ratio and Lagrangian Cold point for 2001

- Previous studies [e.g. Fueglistaler et al. 2005, Fueglistaler and Haynes 2005] all used ERA-40 kinematic trajectories.
- 4 Experiments: ERA-40 kinematic, ERA-40 diabatic, ERA-Interim kinematic, ERA-Interim diabatic
- Trajectories initialised on 400K between (30°N, 30S), $[\text{H}_2\text{O}]_e = [\text{H}_2\text{O}].$
- New experiments give $\sim0.5$ ppmv lower water vapour mixing ratios compared to ERA-40 kinematic trajectories, corresponding to $\sim1K$ lower LCP temperatures.
- Slower vertical transport than ERA-40 kinematic trajectories: residence time in the TTL is longer by $\sim10$ days.

LCP = Lagrangian Cold Point (Location of minimum saturation mixing ratio along trajectory)
Zonal mean water vapour mixing ratio for October 2001

- Reconstruct zonal mean water vapour mixing ratio for October 2001 from trajectories.
- Kinematic trajectories show more vertical dispersion.

- Polar regions determined by local temperature with ERA-40 colder at 340K than ERA-Interim.
- Comparing with MLS October 2005 values show excessively high mixing ratios for ERA-40 kinematic trajectories in NH high latitudes.
Location of minimum saturation mixing ratio along TST trajectories

- Trajectories initialised on 360K potential temperature surface between (50°N, 90°N) and (50°S, 90°S).
- PDF of where TST trajectories attain minimum saturation mixing ratios is plotted as function of latitude and height.
- Large number of ERA-40 kinematic trajectories experience minimum smr below 340K in extratropics (high values) which explains the anomalously high water vapour mixing ratio on 360K (previous page).
- Pathway implied by minimum smr location (shown by black arrow) is not thermodynamically feasible.
Reconstruct zonal mean water vapour mixing ratio from ERA-Interim kinematic trajectories.

Can reproduce features in water vapour distribution: propagation of entry mixing ratio to high latitudes along isentropes at around 390K; dehydration in the polar vortex in October.
Conclusions

- Estimated water vapour mixing ratios in the UTLS are sensitive to the input meteorological data and trajectory method.
- The ‘best’ trajectories predict water vapour mixing ratios lower than observations. This could be due to missing processes in the dehydration model or to convective injection.
- ERA-40 kinematic trajectories give excessive troposphere-to-stratosphere transport and therefore should be used with caution in trajectory studies of the UTLS region.
- Model driven by ERA-Interim can reproduce major seasonal variations of water vapour within the time period of trajectory integration.