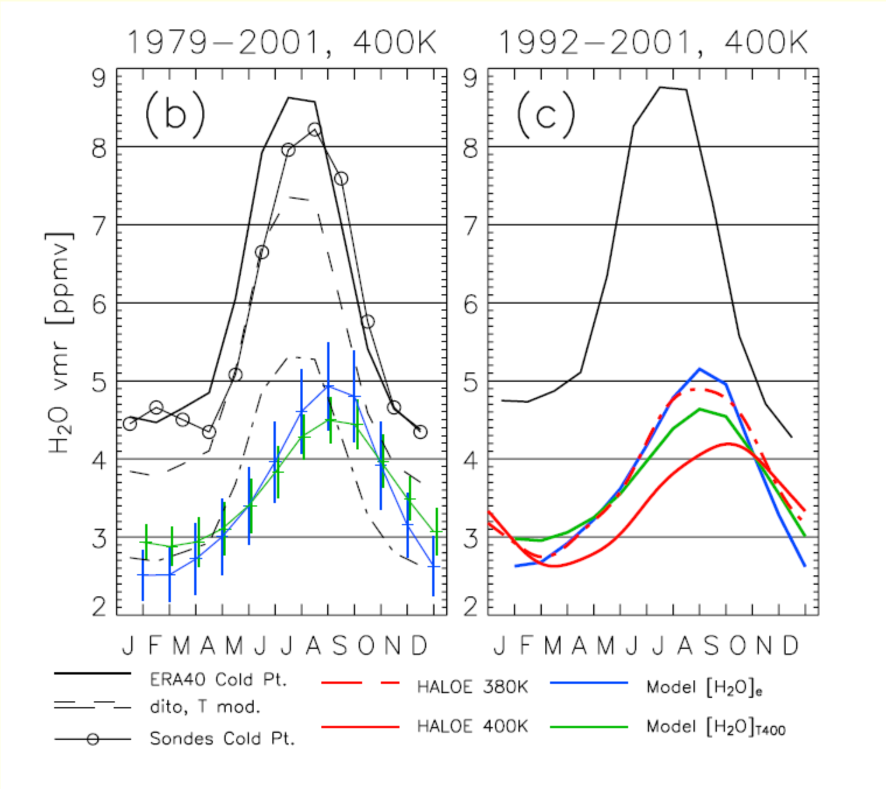
UTLS water vapour from trajectories

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

DAMTP, University of Cambridge

ACTIVE meeting, 21 May 2009

Motivation



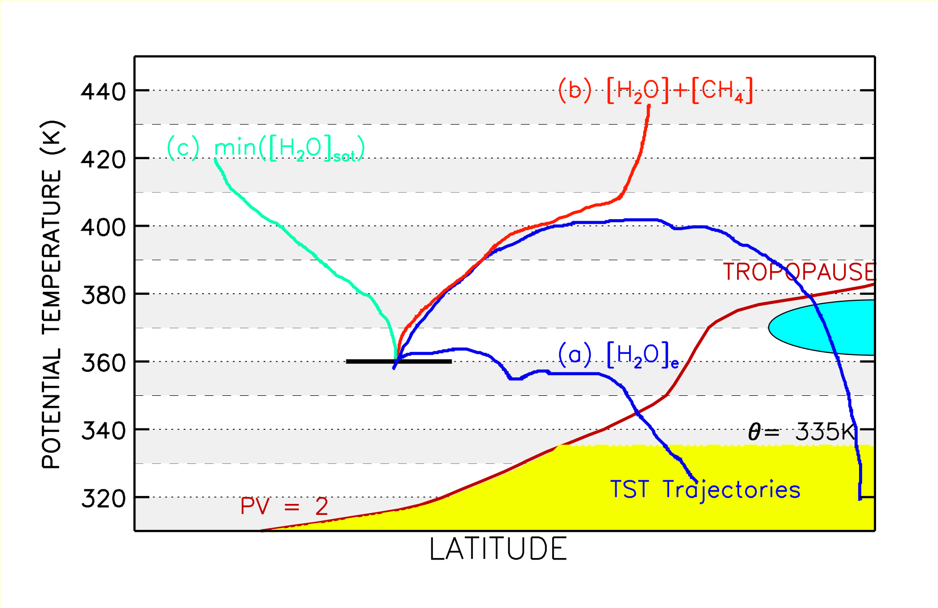
[Figure 3(b) and (c), Fueglistaler et al. 2005]

- 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 ~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?

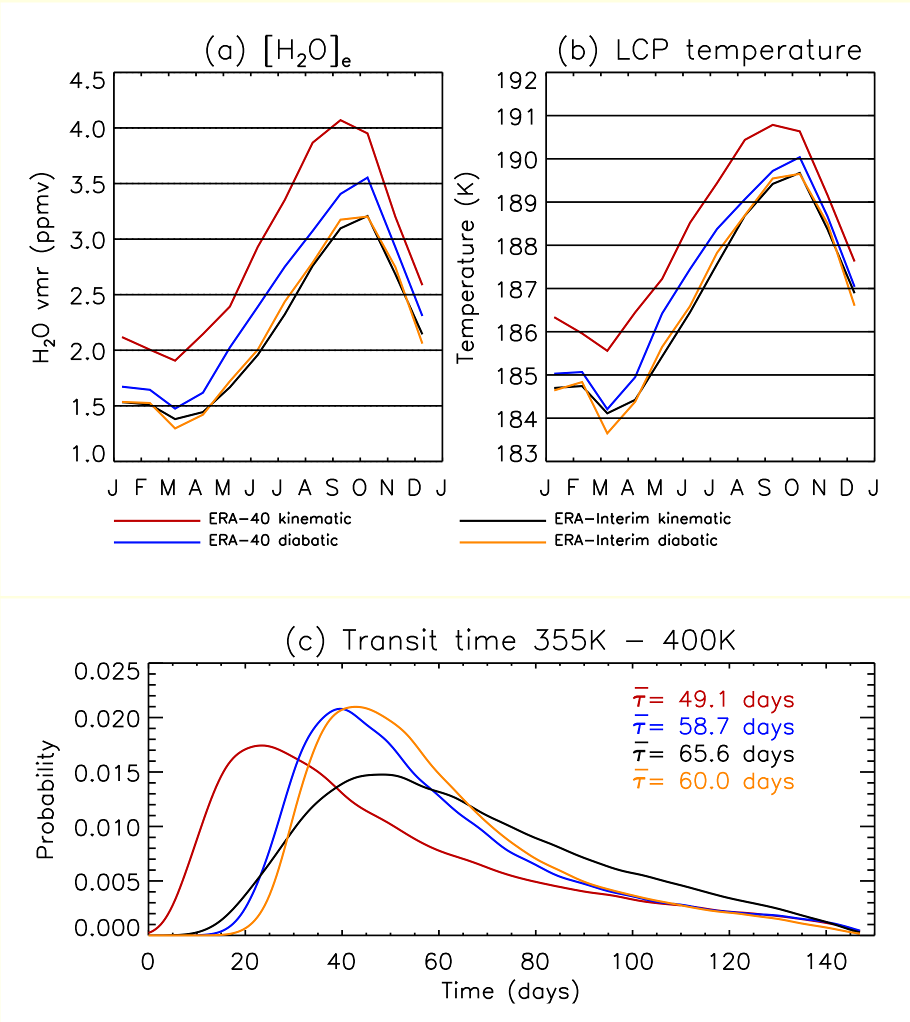
Method



Troposphere-to-Stratosphere (TST) trajectories: $\theta < 335$K and $|PV| < 2$ PVU in the previous 5 months.

- 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 $2^\circ \times 2^\circ \times 10$K 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.

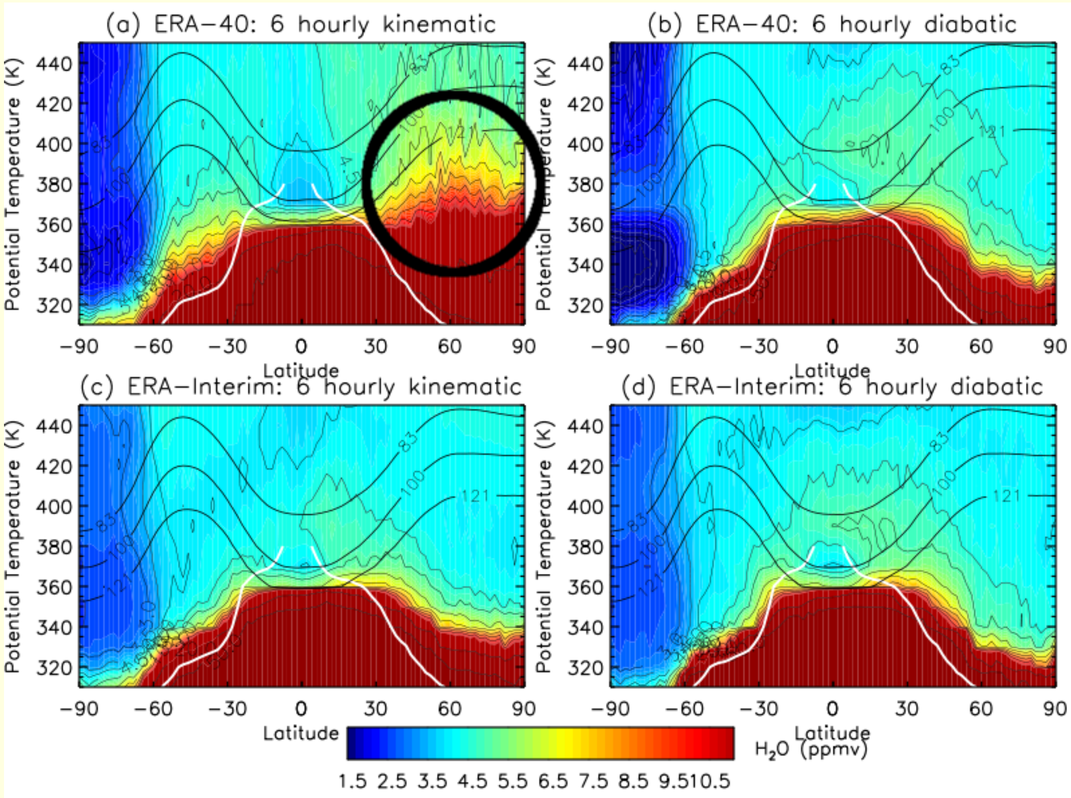
Water vapour on 400K: Entry mixing ratio and Lagrangian Cold point for 2001

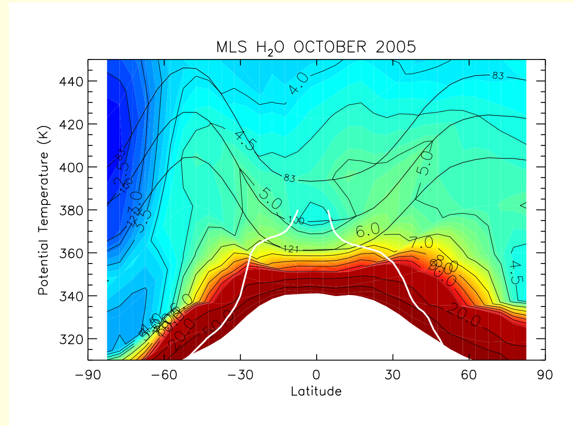


LCP = Lagrangian Cold Point (Location of minimum saturation mixing ratio along trajectory)

- 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), $[\mathrm{H_2O}]_\mathrm{e} = \overline{[\mathrm{H_2O}]_\mathrm{TST}}$.
- New experiments give ~0.5 ppmv lower water vapour mixing ratios compared to ERA-40 kinematic trajectories, corresponding to ~1K lower LCP temperatures.
- Slower vertical transport than ERA-40 kinematic trajectories: residence time in the TTL is longer by ~10 days.

Zonal mean water vapour mixing ratio for October 2001

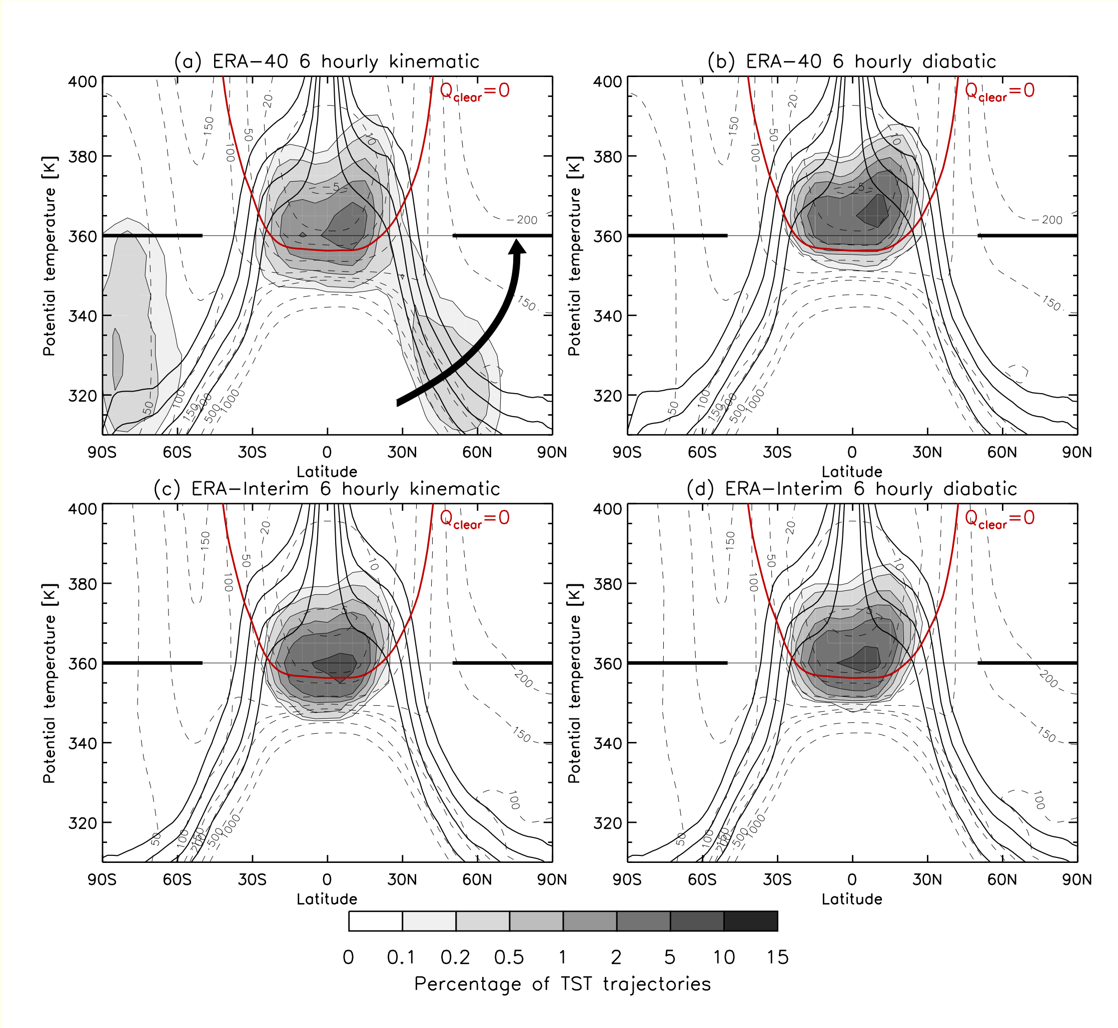




- Reconstruct zonal mean water vapour mixing ratio for October 2001 from trajectories.
- Kinematic trajectories show more vertical dispersion.

- 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.

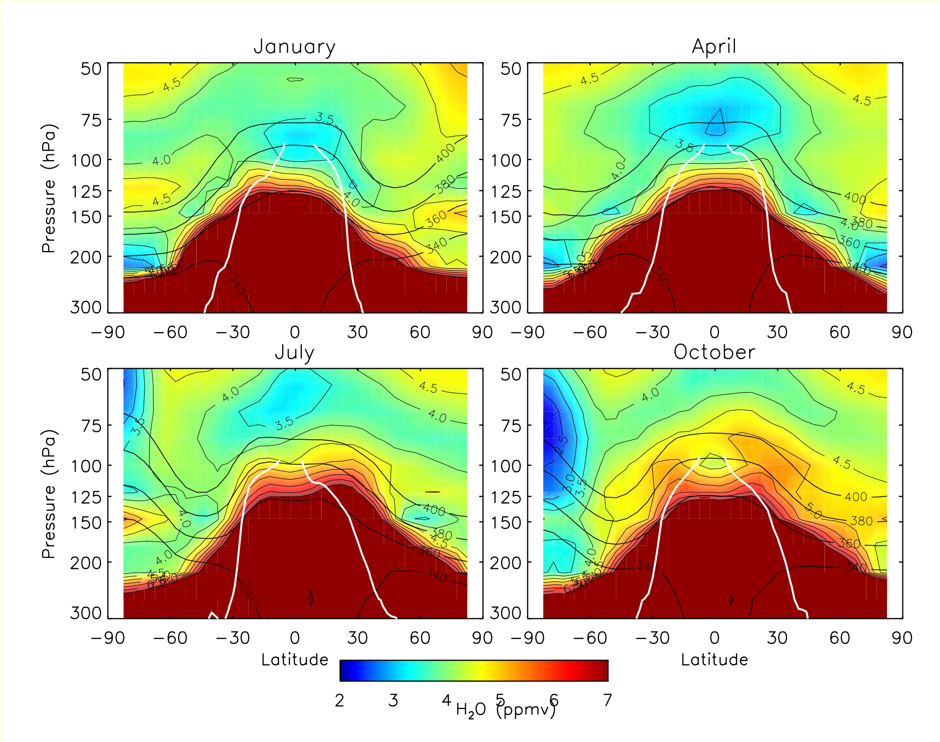
Location of minimum saturation mixing ratio along TST trajectories



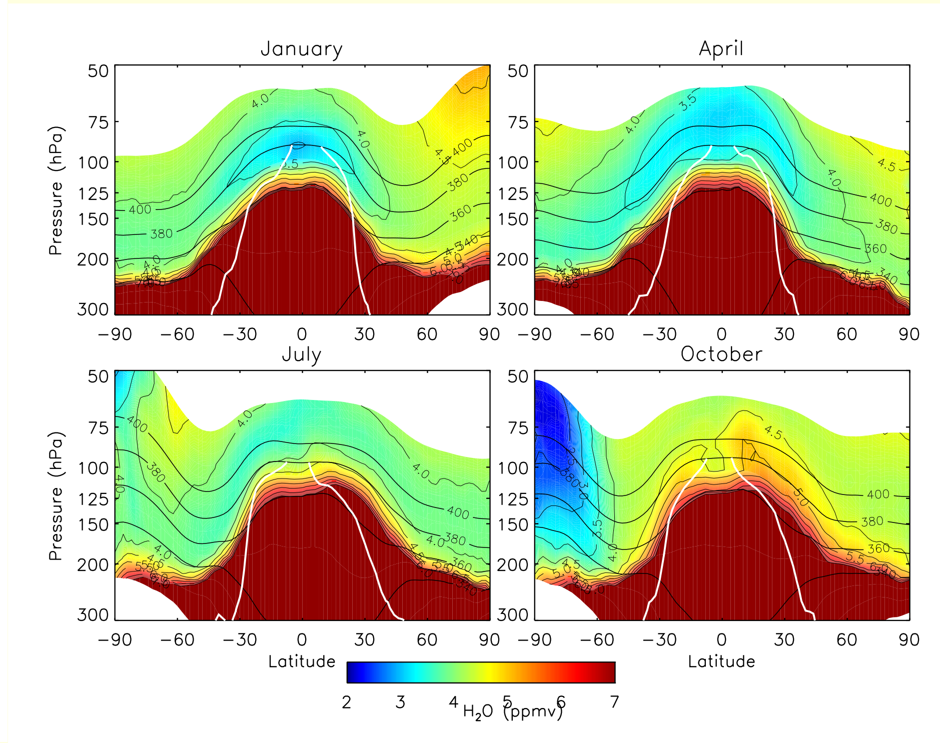
- Trajectories initialised on 360K potential temperature surface between (50°N, 90°N) and (50°S, 90°S).
- PDF of where TST trajectories attain minimum saturation mixing ratios is plotted as function of latitude and height.
- Large number of ERA-40 kinematic trajectories experience minimum smr below 340K 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.

Zonal mean monthly mean H_2O mixing ratio 2005

AURA MLS



ERA-Interim kinematic trajectories



- 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.