Impacts of microphysics, convection and waves on wintertime distributions of TTL water

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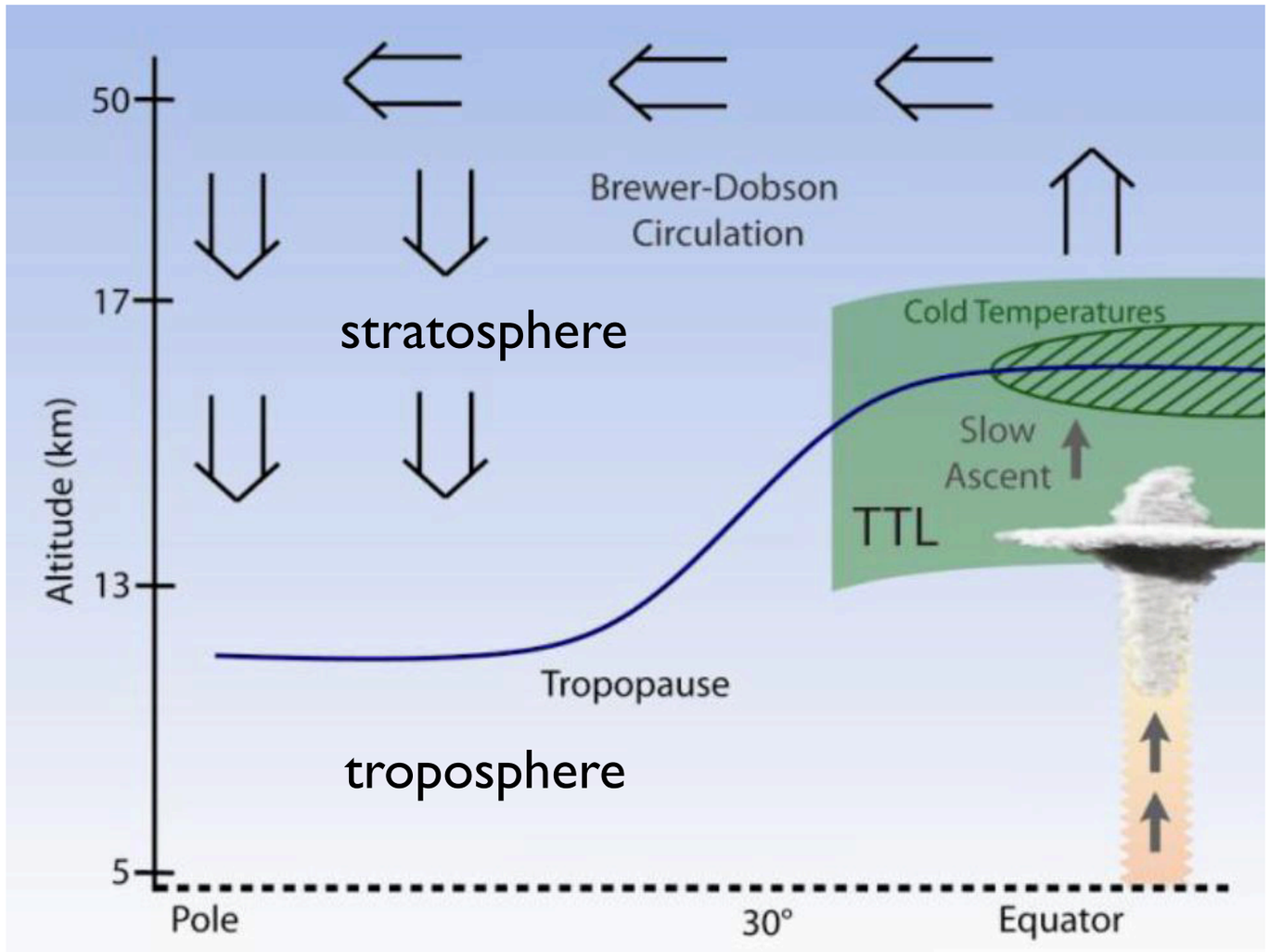
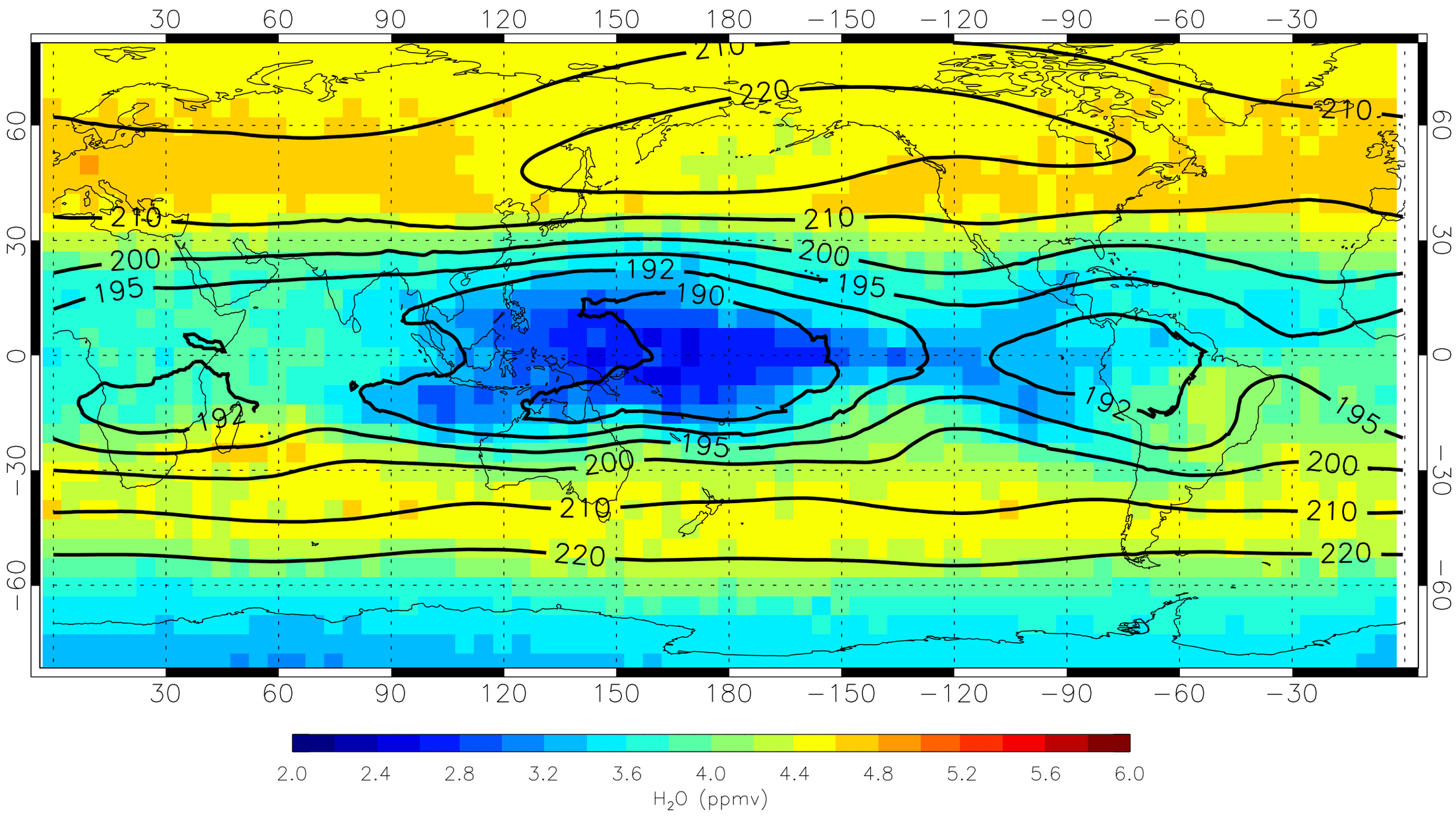


Tropical
Tropopause
Layer

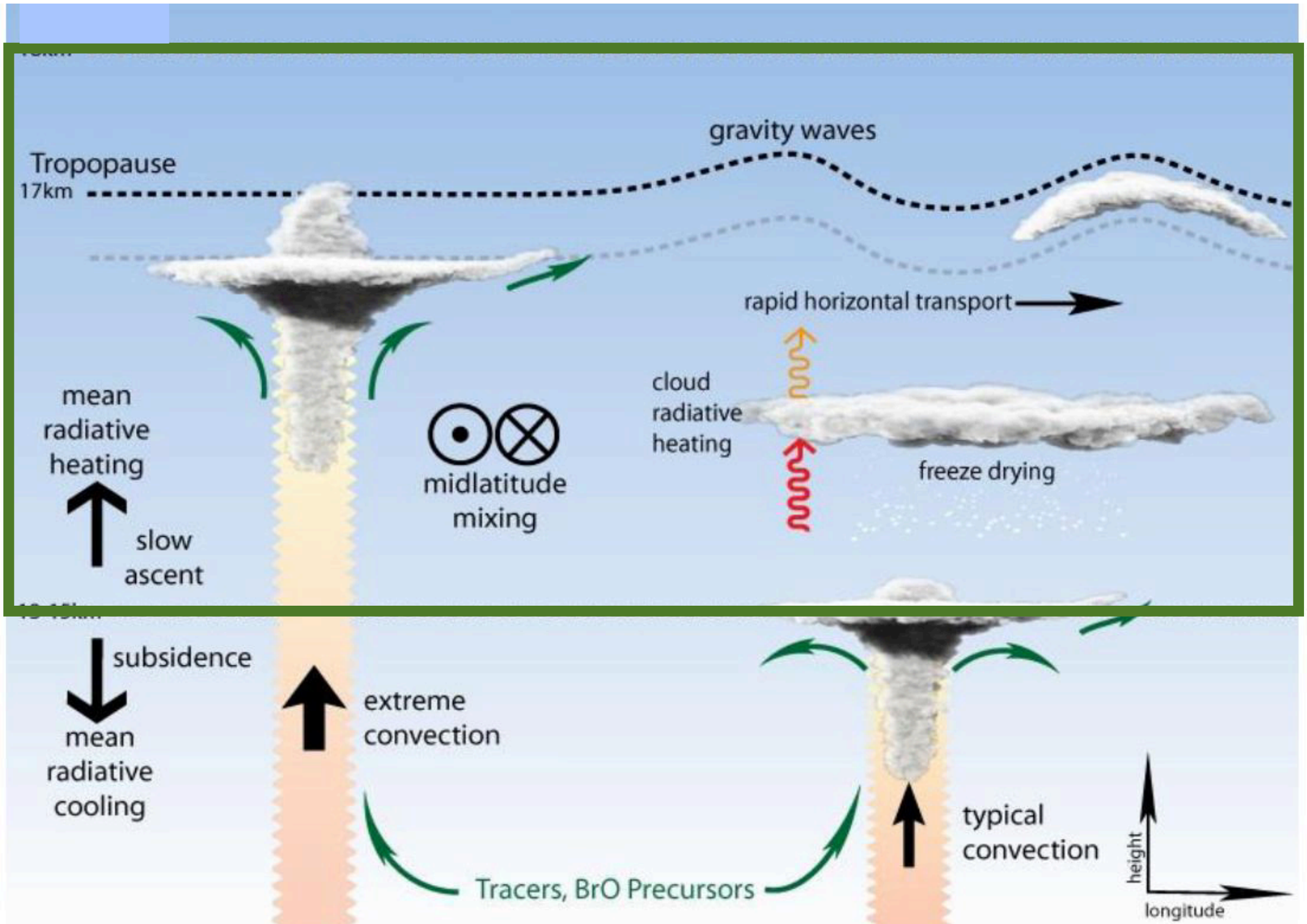
H_2O (color, MLS), T (contours, ERA-Interim) at 100 hPa
Dec-Jan-Feb 2006-07



➤ Cold temperatures in the TTL play a leading role in regulating stratospheric-entry H_2O

Many processes influence TTL water, directly and indirectly (via T modulation)

18 km
70 hPa
420 K



14 km
150 hPa
355 K

T
T
L

Research Questions

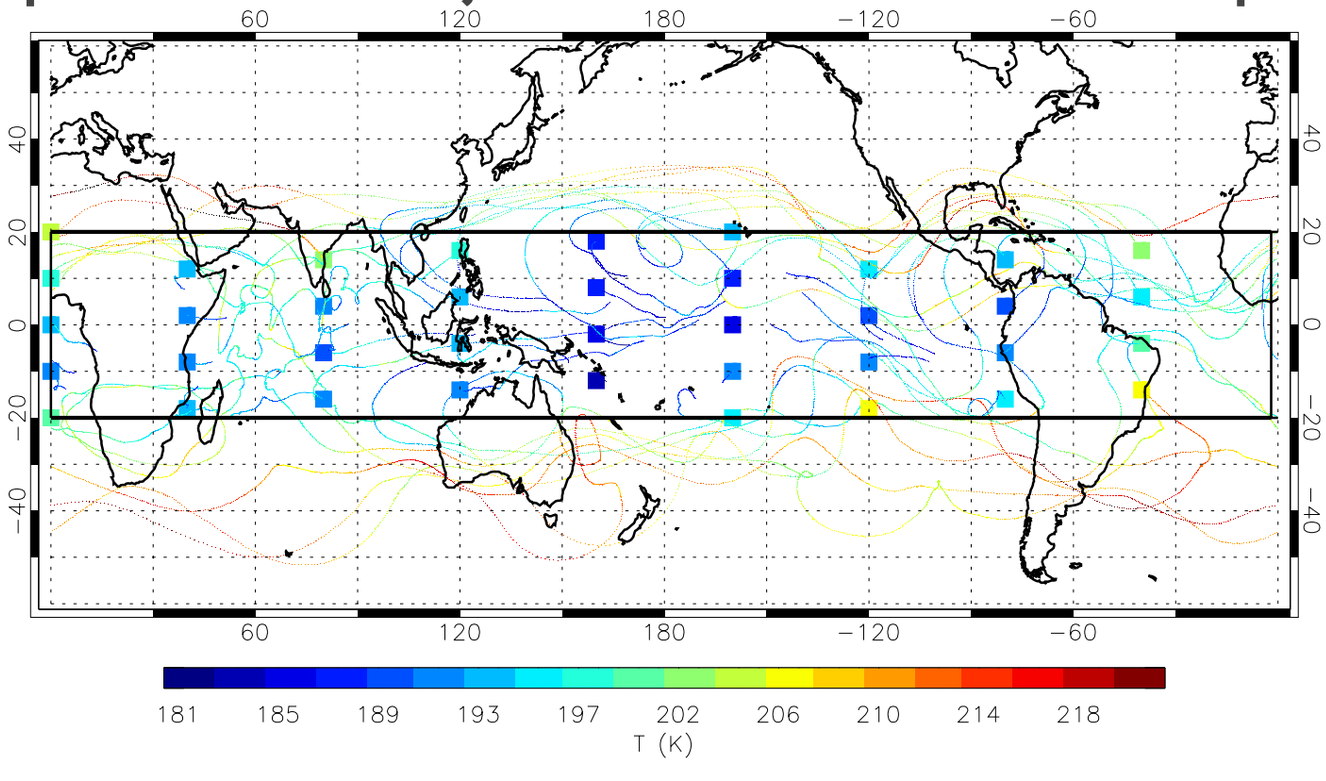
1. How does **convection** affect TTL water?
2. How important is detailed **cloud microphysics** in determining TTL water?
3. What is the impact of **wave**-driven T variability on TTL dehydration?

Method

(modified version of *Jensen and Pfister 2004*, *Bergman et al. 2012*, *Ueyama et al. 2014*)

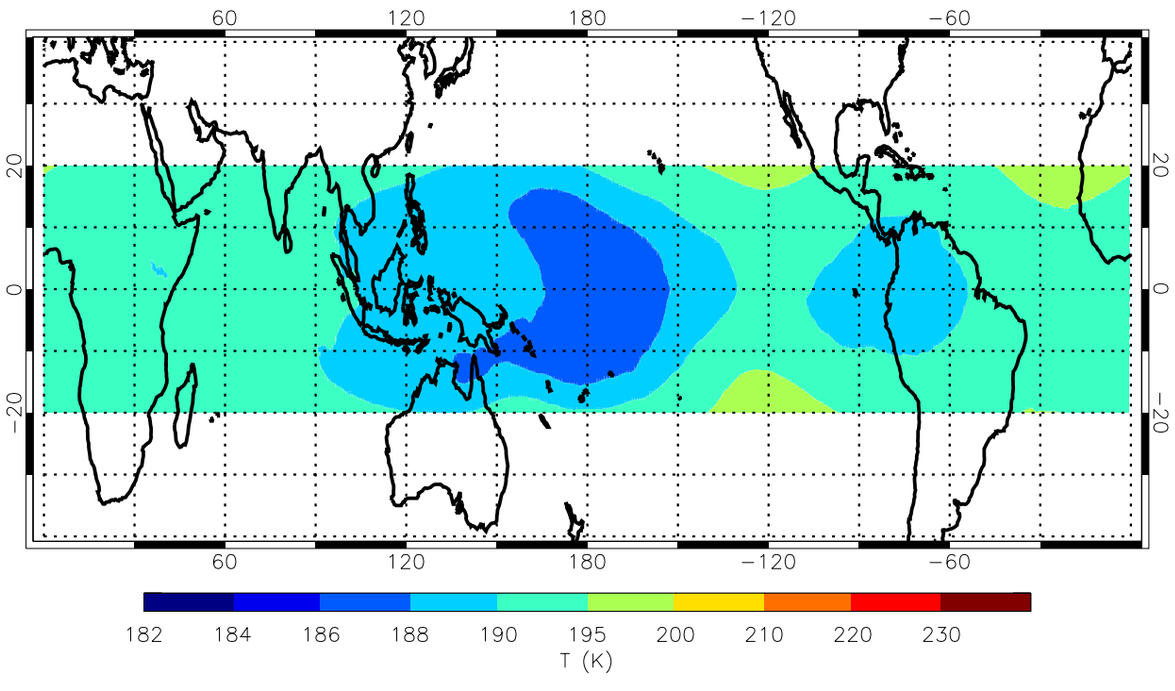
1. Calculate 60-day backward diabatic trajectories from every 2° lat x 2° lon grid points in the tropics (20°S - 20°N) at 371 K (~100 hPa) level ending at 1 Feb 2007 using ERA-Interim temperatures and winds

a sample of the trajectories and their temperatures

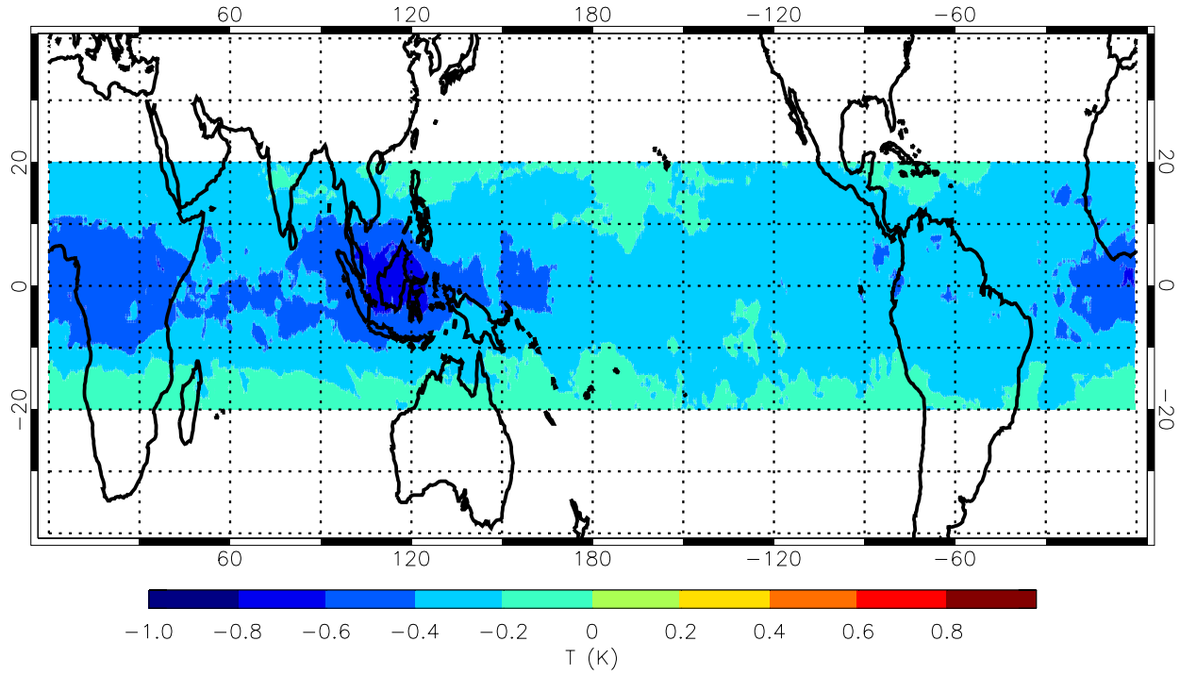


ERA-Interim data (DJF 2006-07) with *Kim and Alexander 2013* wave scheme

cold point temperature (CPT) with waves



CPT difference (waves – no waves)

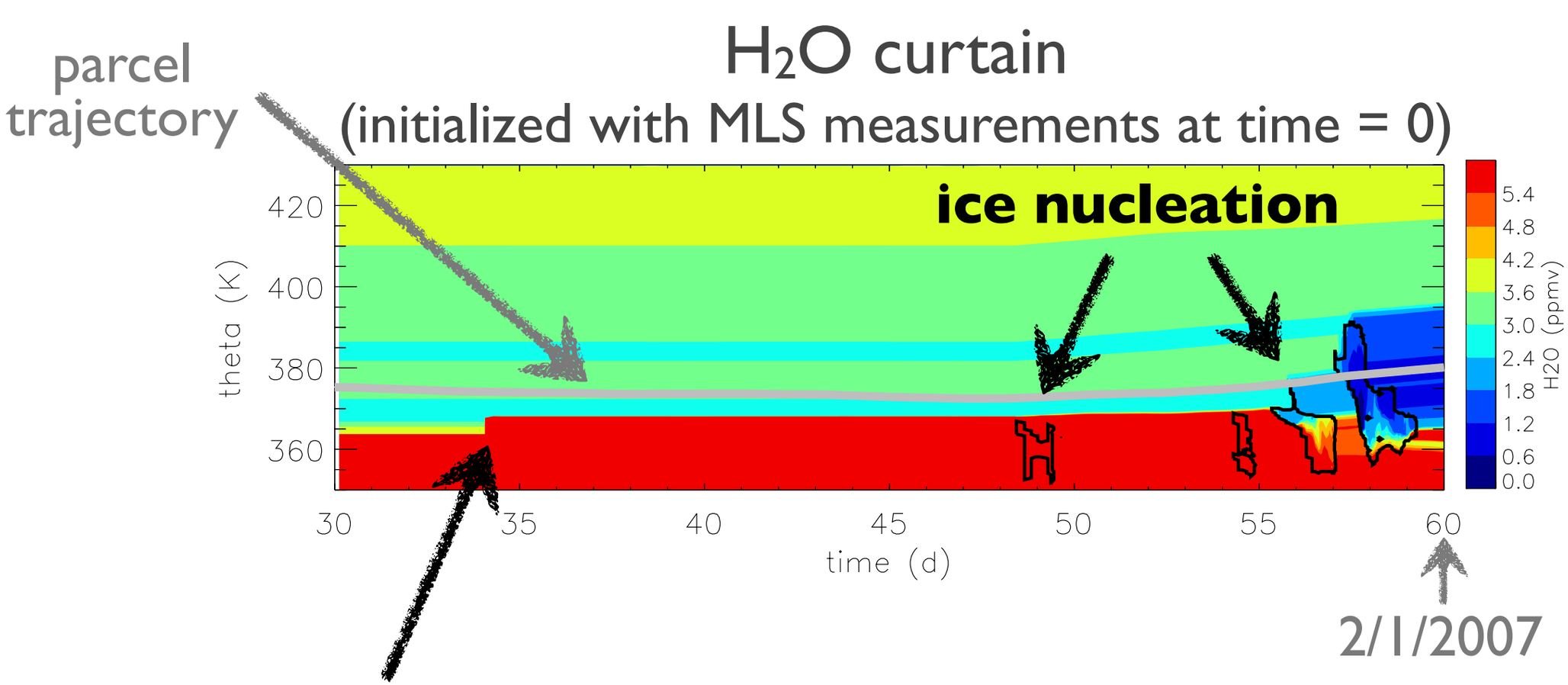


➤ Waves decrease CPT everywhere in the tropics (min –0.8 K over Indonesia)

Method

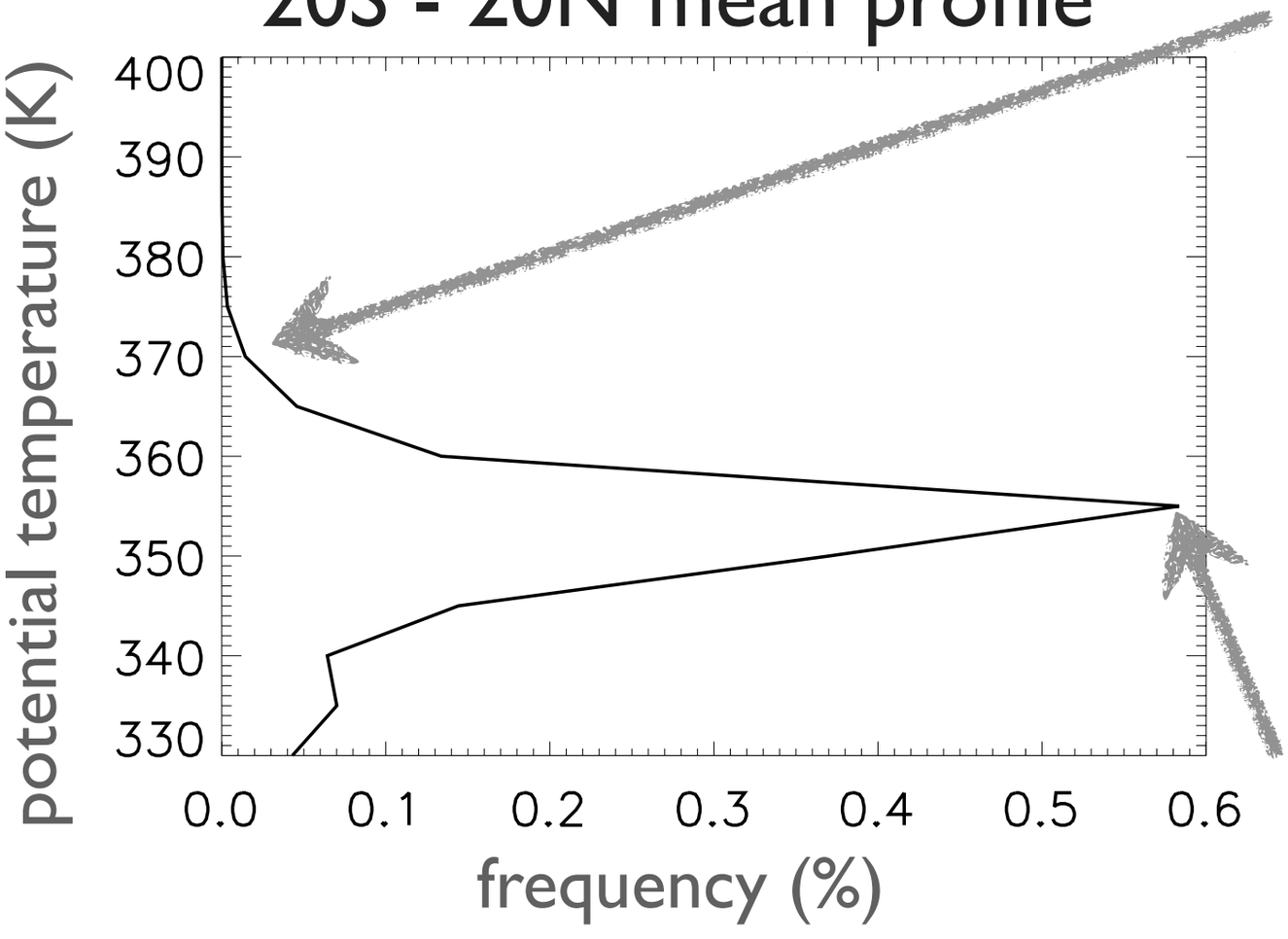
(modified version of *Jensen and Pfister 2004*, *Bergman et al. 2012*, *Ueyama et al. 2014*)

2. Use 1D (height) time-dependent microphysical model to simulate clouds along each parcel trajectory and calculate their time-integrated effects on H_2O mixing ratio

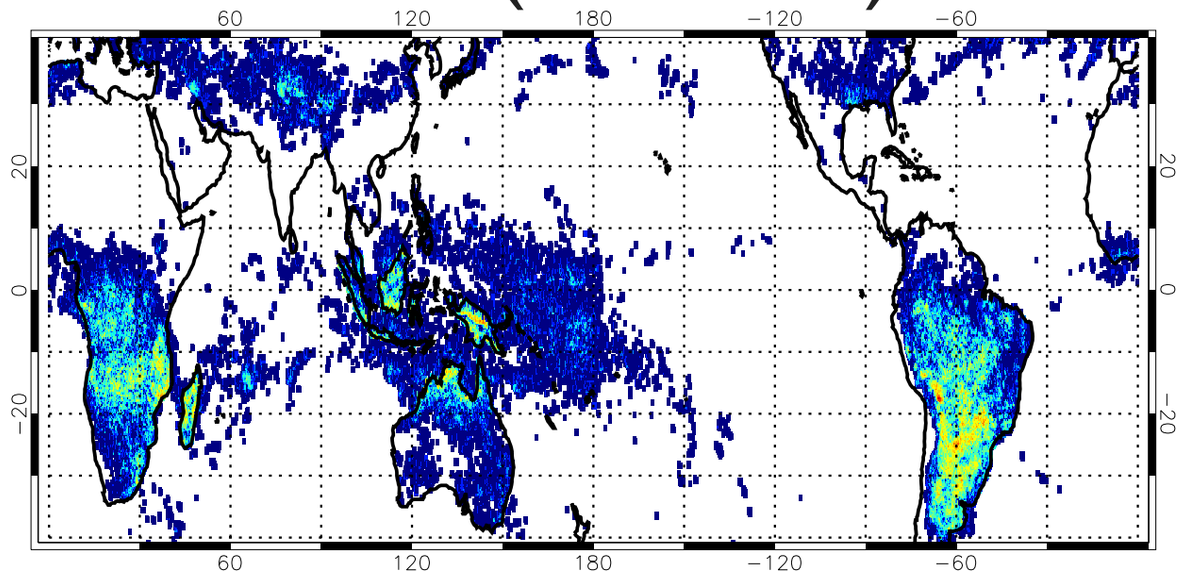


Convective cloud top distribution

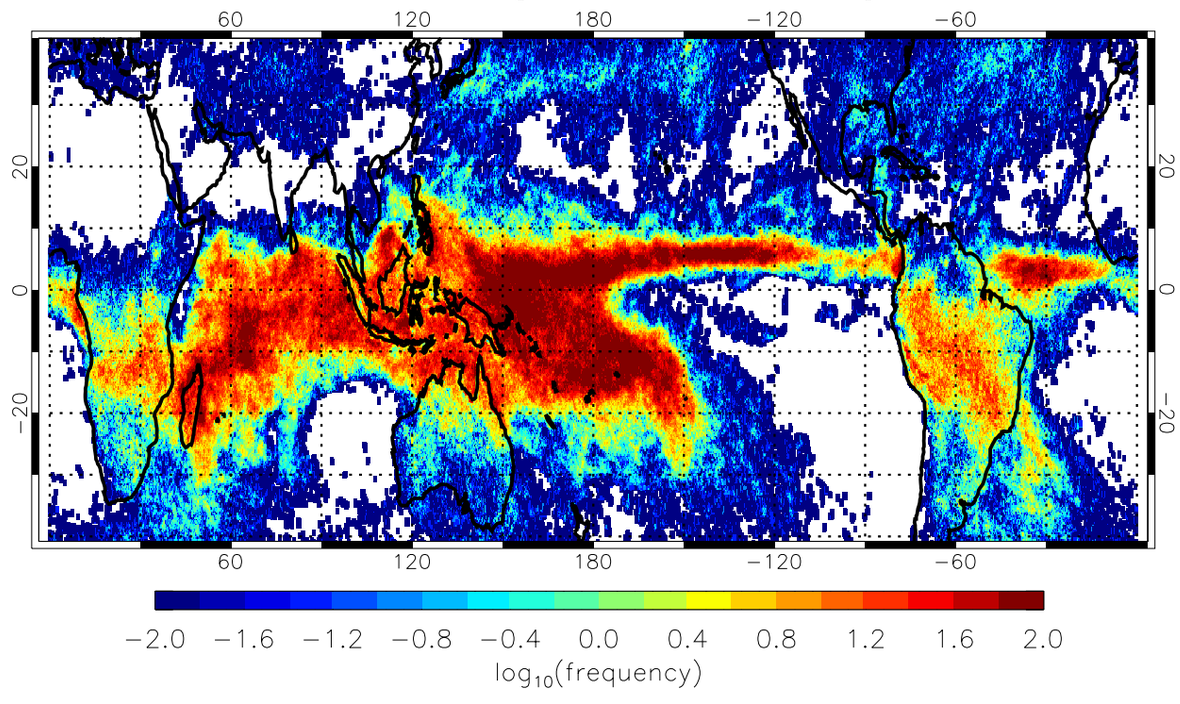
Dec-Jan-Feb 2006-07
20S - 20N mean profile



370 K (100 hPa)



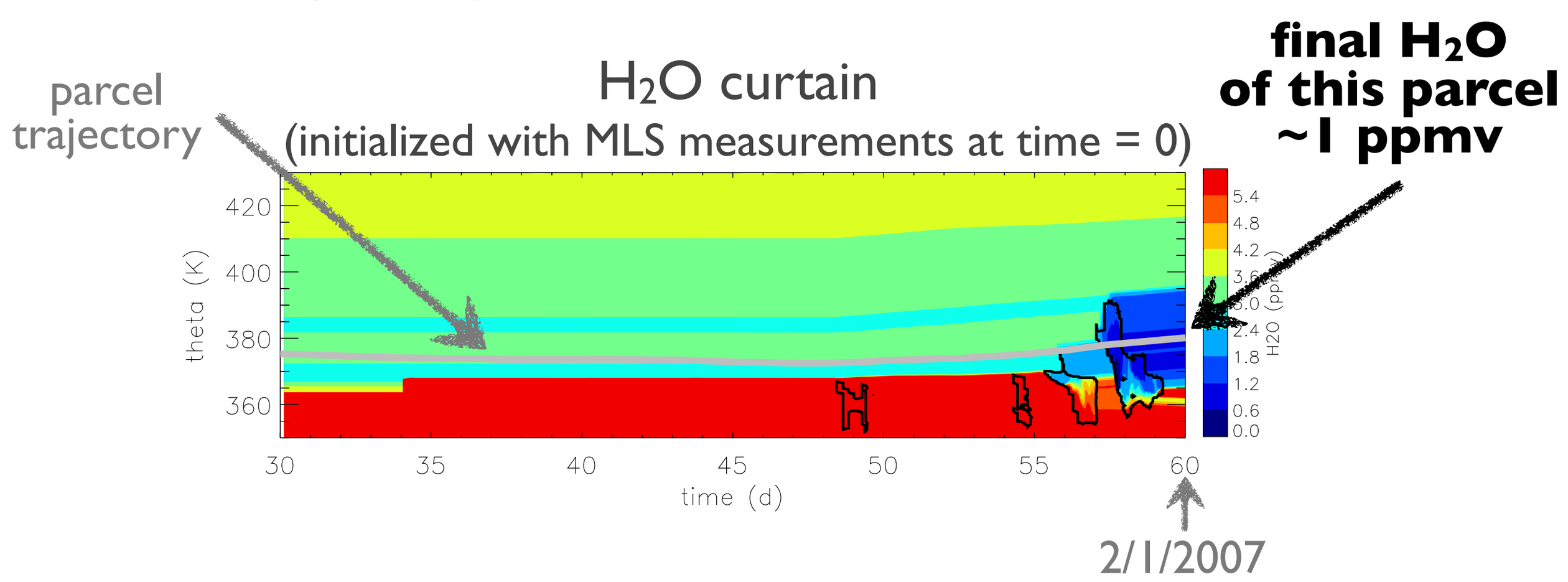
355 K (150 hPa)



Method

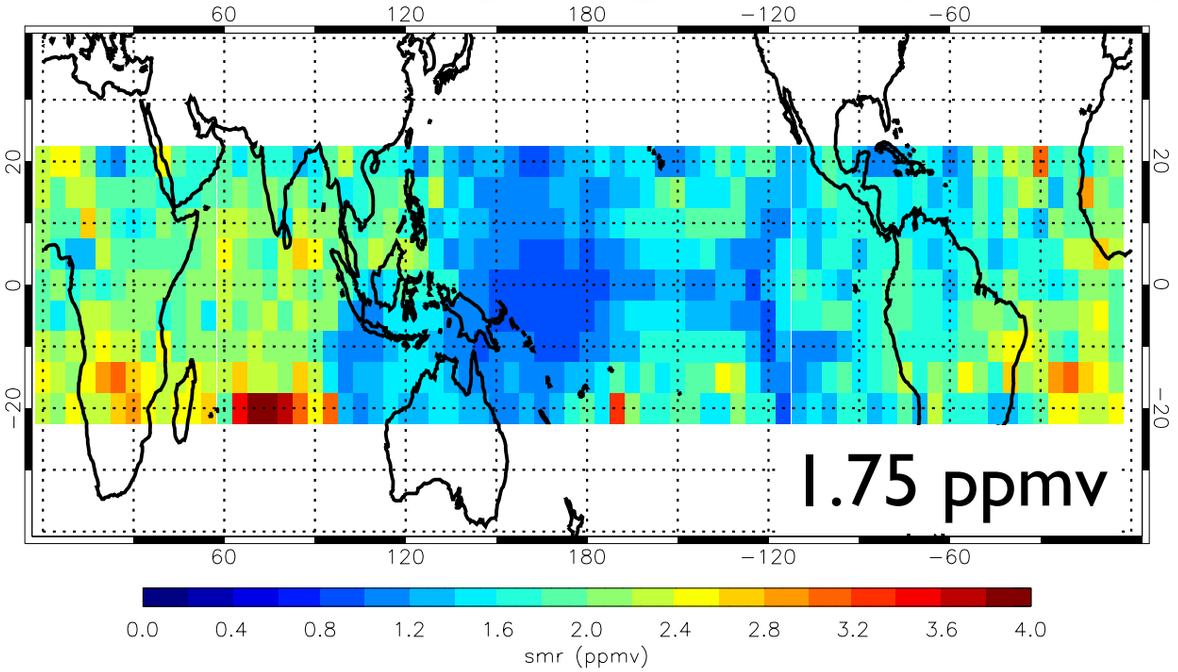
(modified version of *Jensen and Pfister 2004*, *Bergman et al. 2012*, *Ueyama et al. 2014*)

3. Compare the simulated H_2O mixing ratios on the final day of the trajectories (MLS averaging kernel applied) with corresponding MLS measurements at 100 hPa



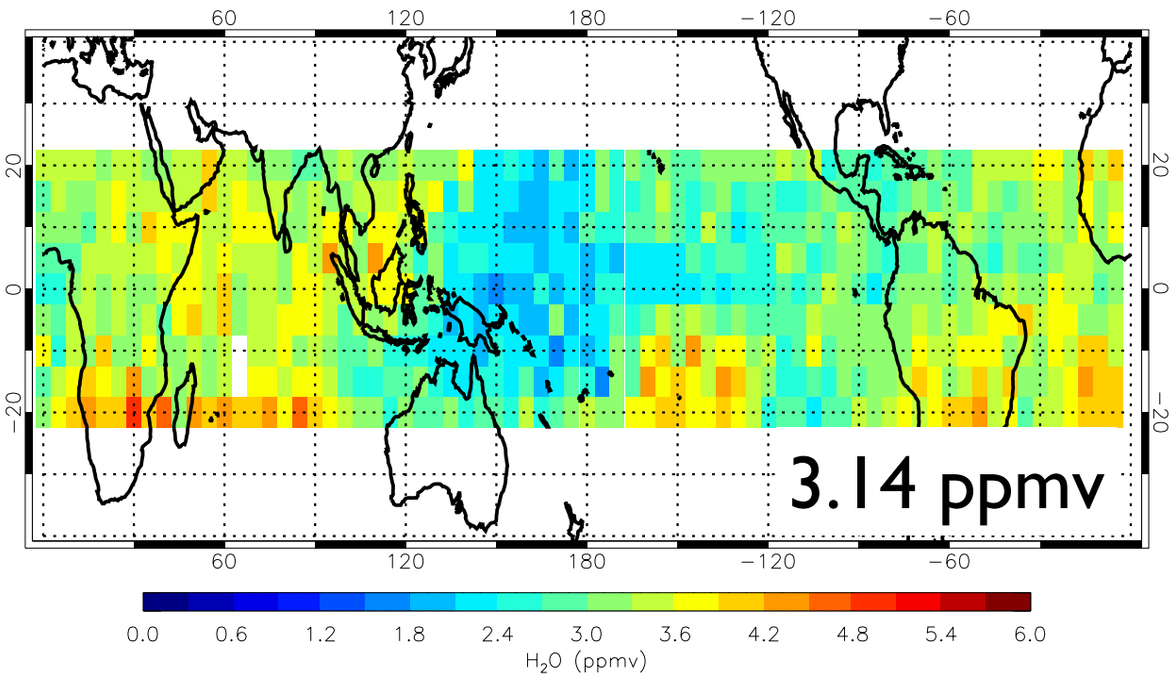
100 hPa H_2O
(1 Feb 2007)

min saturation mixing ratio
(based on Lagrangian Dry Point)



(0 - 4 ppmv)

MLS

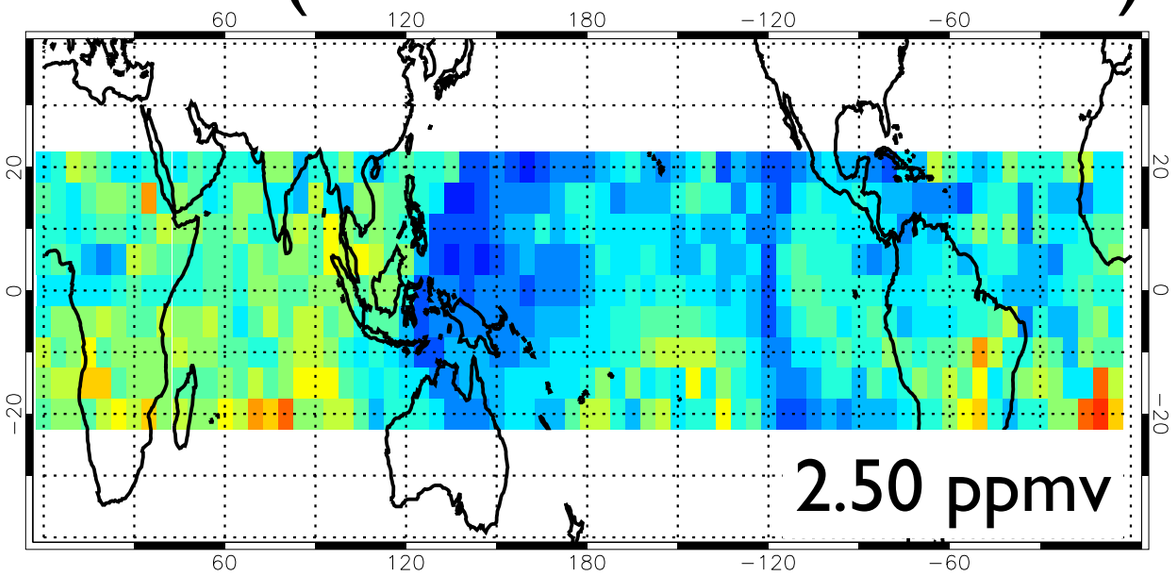


(0 - 6 ppmv)

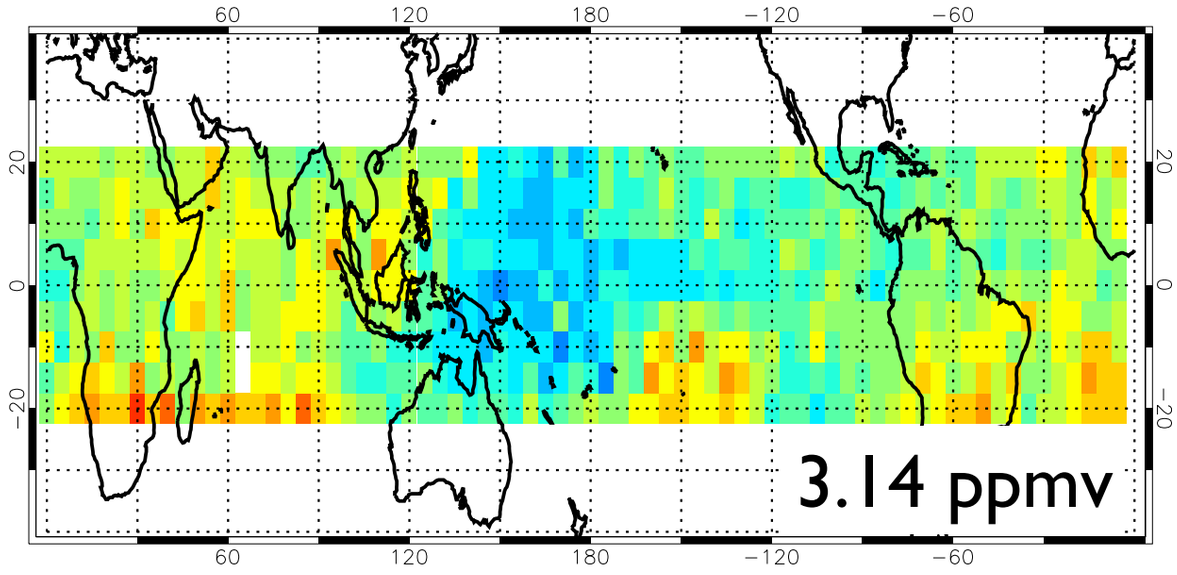
➤ LDP of the trajectories (no cloud simulation) underestimates TTL humidity by ~45%

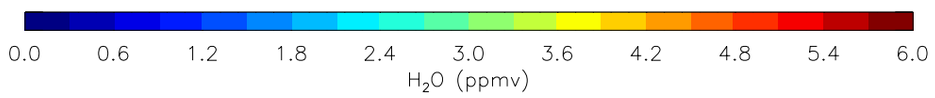
100 hPa H_2O

model (micro + conv + waves)



MLS



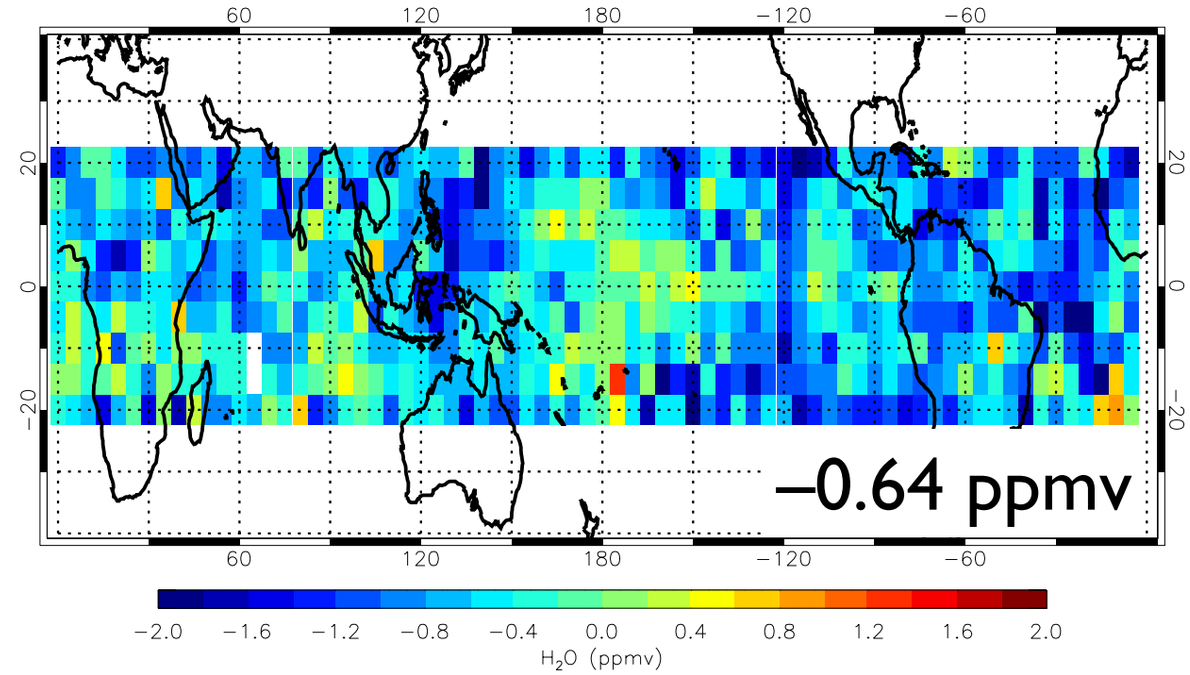


- reasonable agreement with MLS
- model too dry nearly everywhere

(exception over western Pacific)

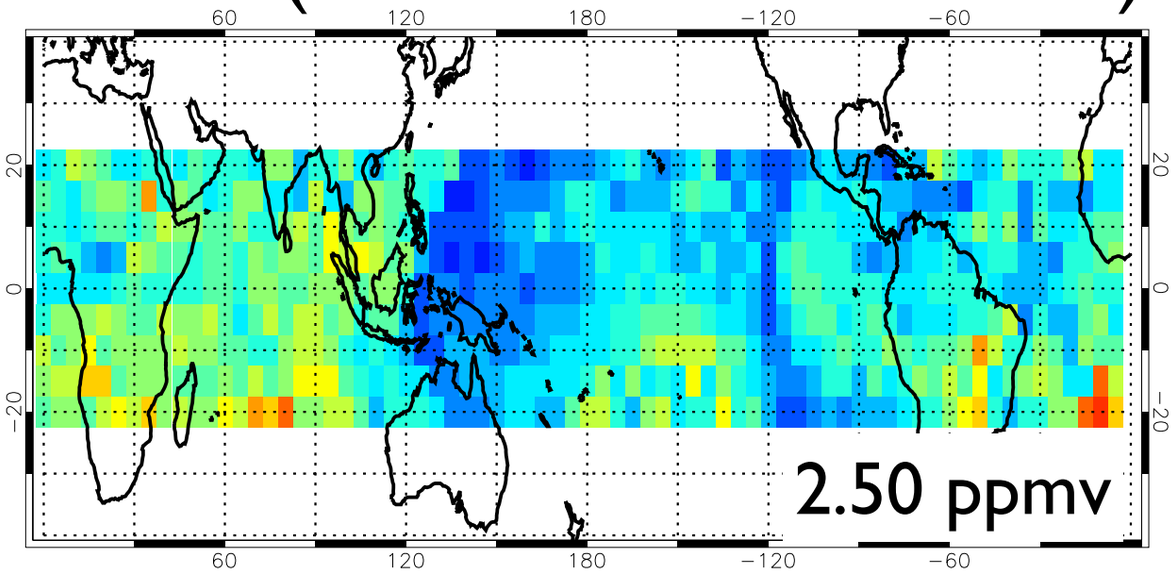
- *T too cold?* ✗
- *too little convective influence?* ✗
- *missing convective injection of ice?*
- *too many ice nuclei?* ✗
- *not enough mixing?*

model – MLS

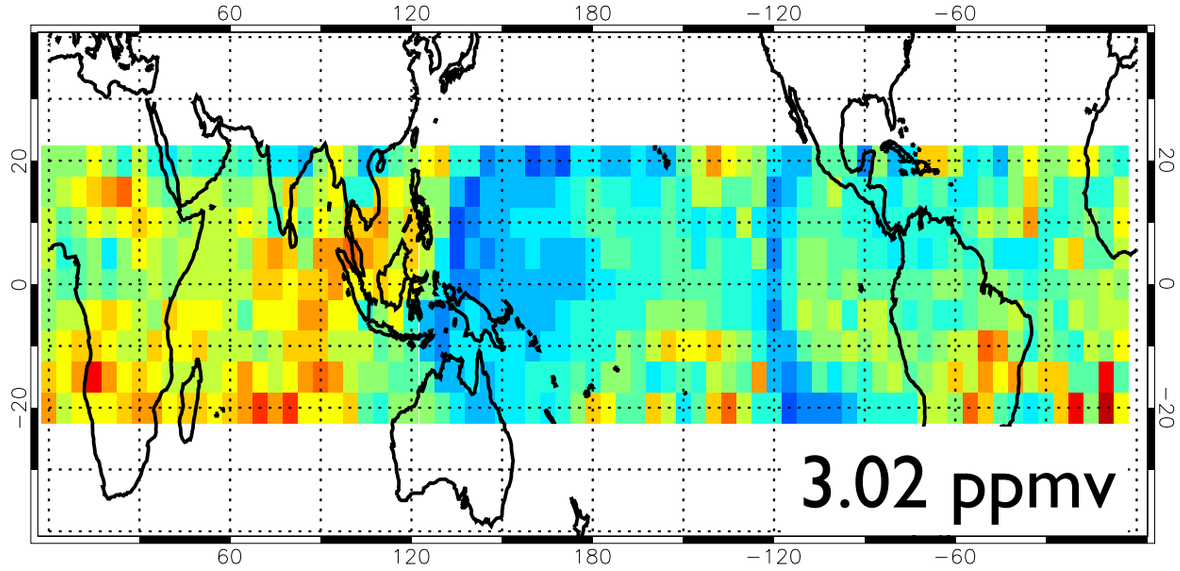


100 hPa H_2O

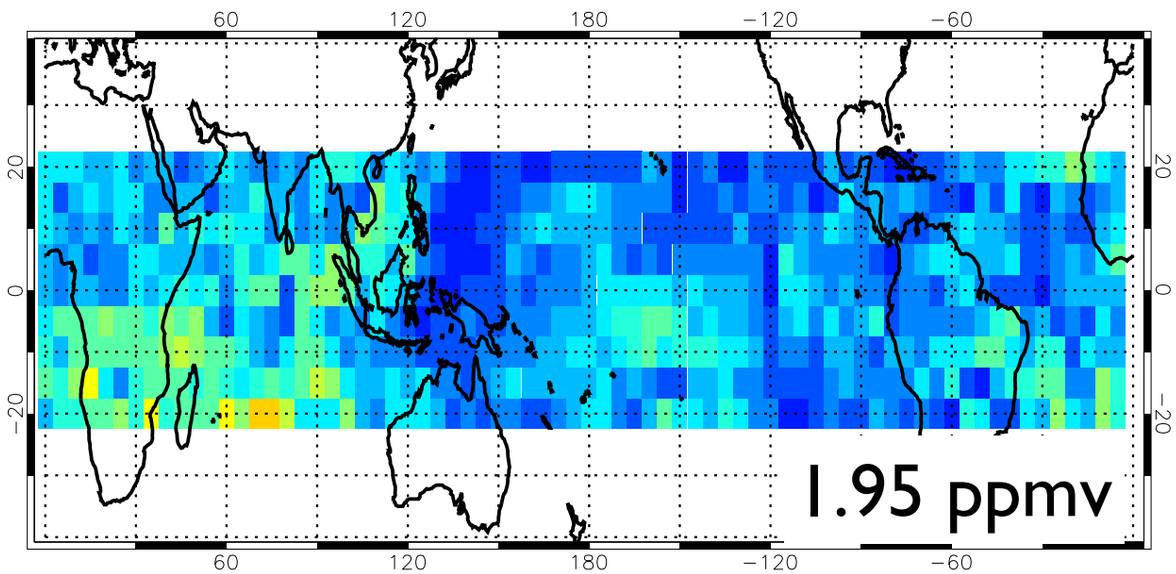
model (micro + conv + waves)



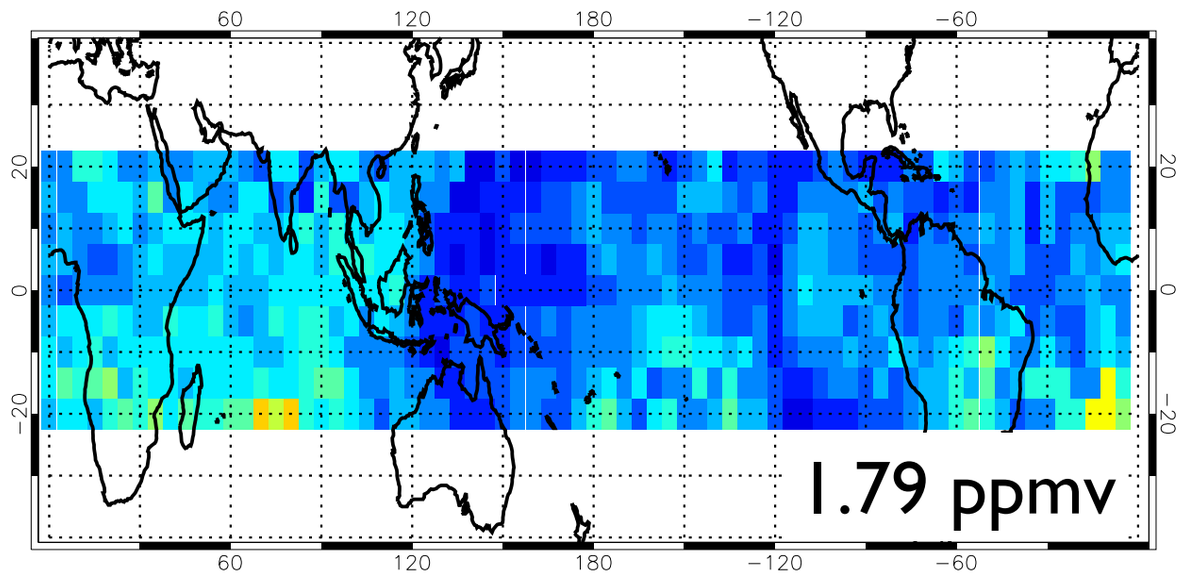
micro + conv + **no waves**

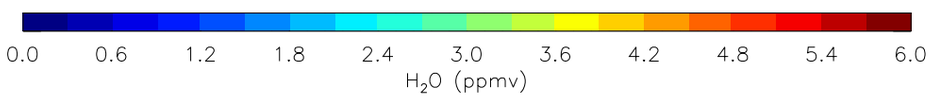


micro + **no conv** + waves



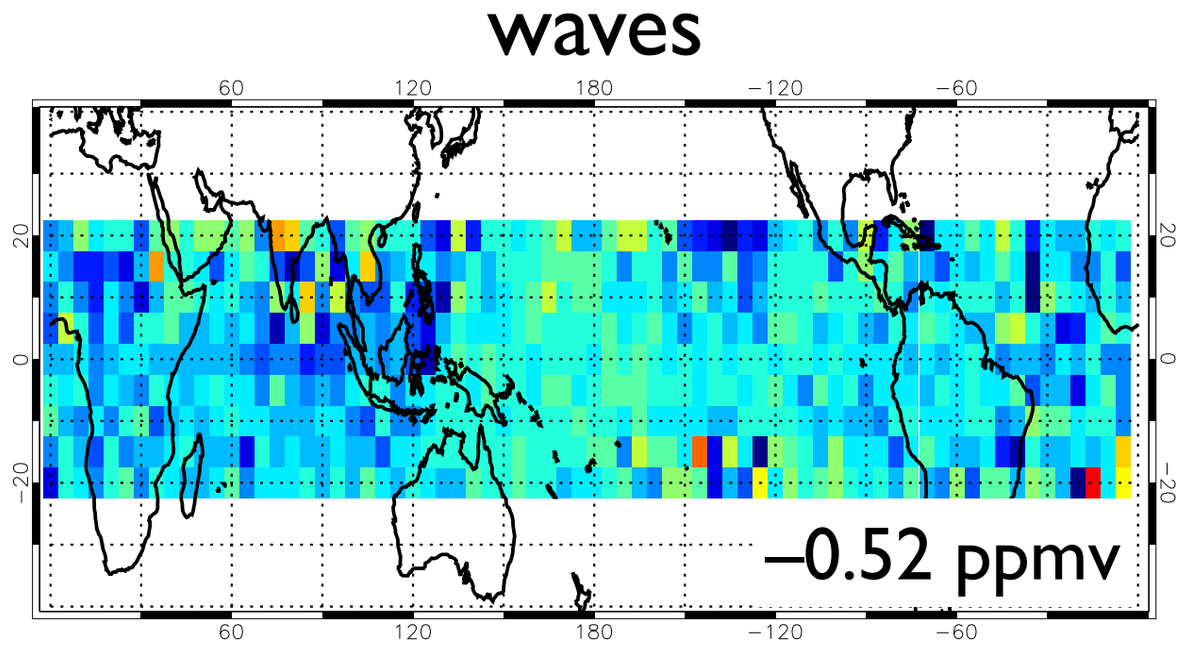
no micro + conv + waves

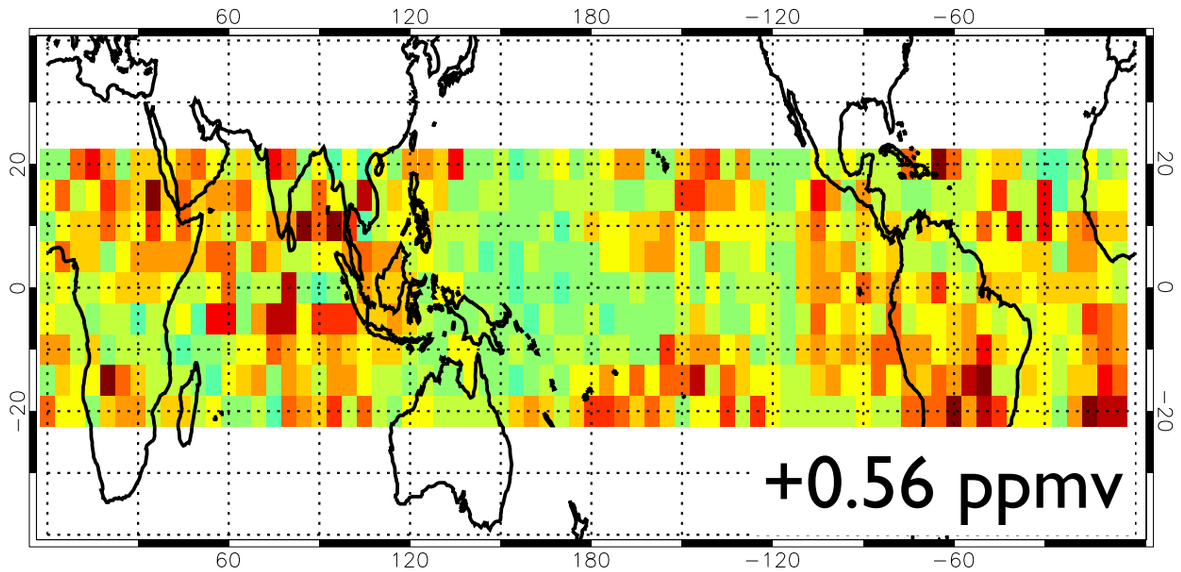


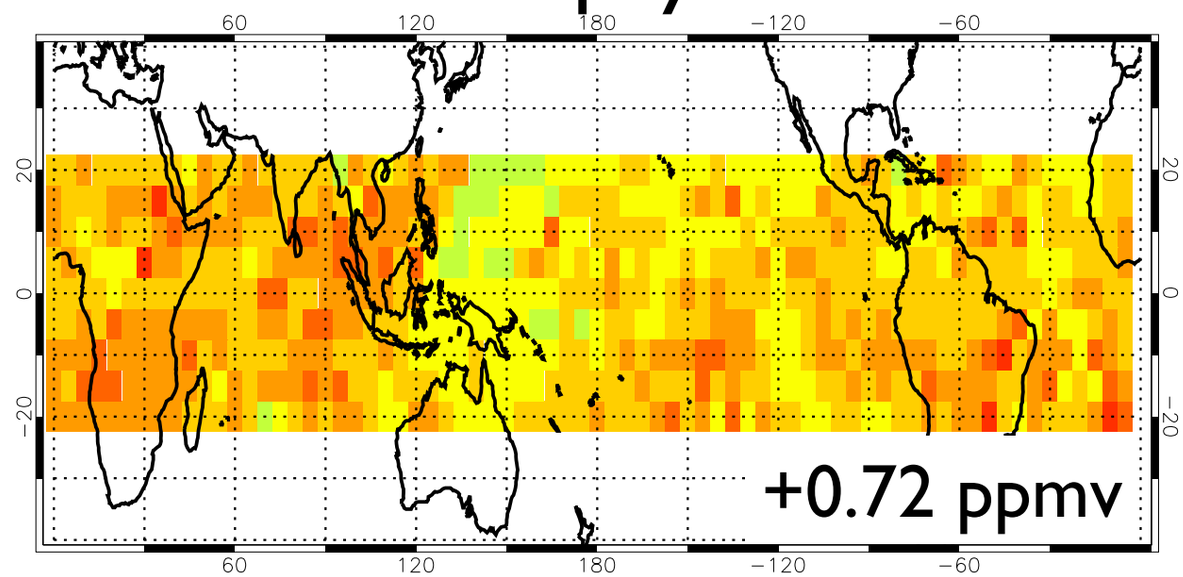


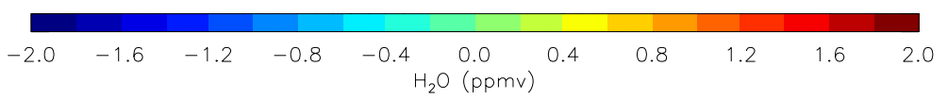
Impact on 100 hPa H_2O

- dehydration pattern by waves resembles CPT difference pattern
- convection moistens everywhere, except over cold T region in western Pacific
- moistening effect of microphysics is spatially uniform



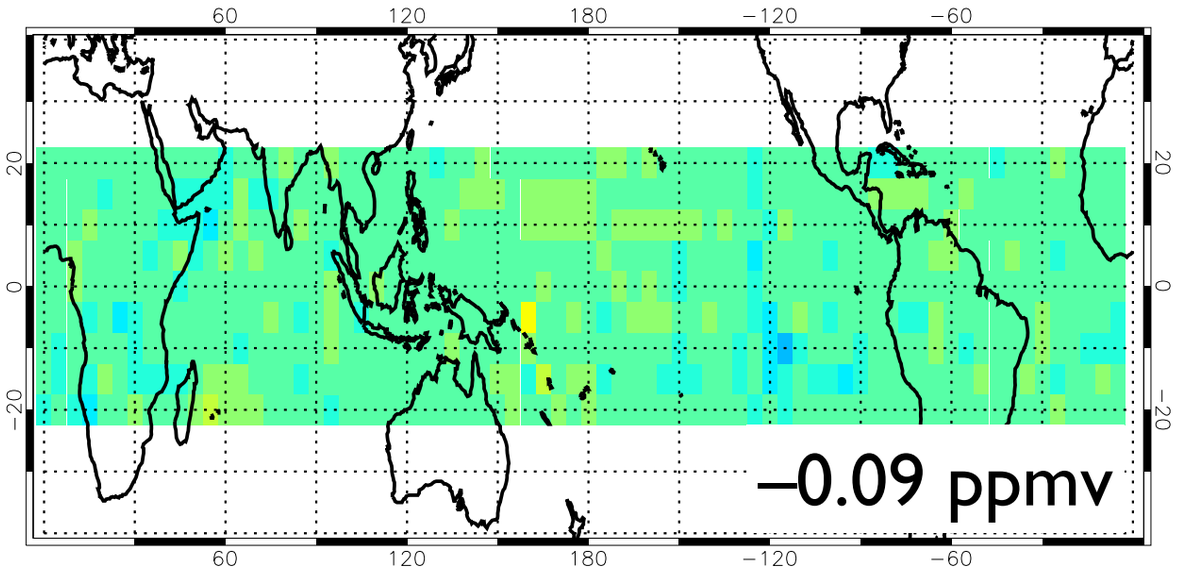




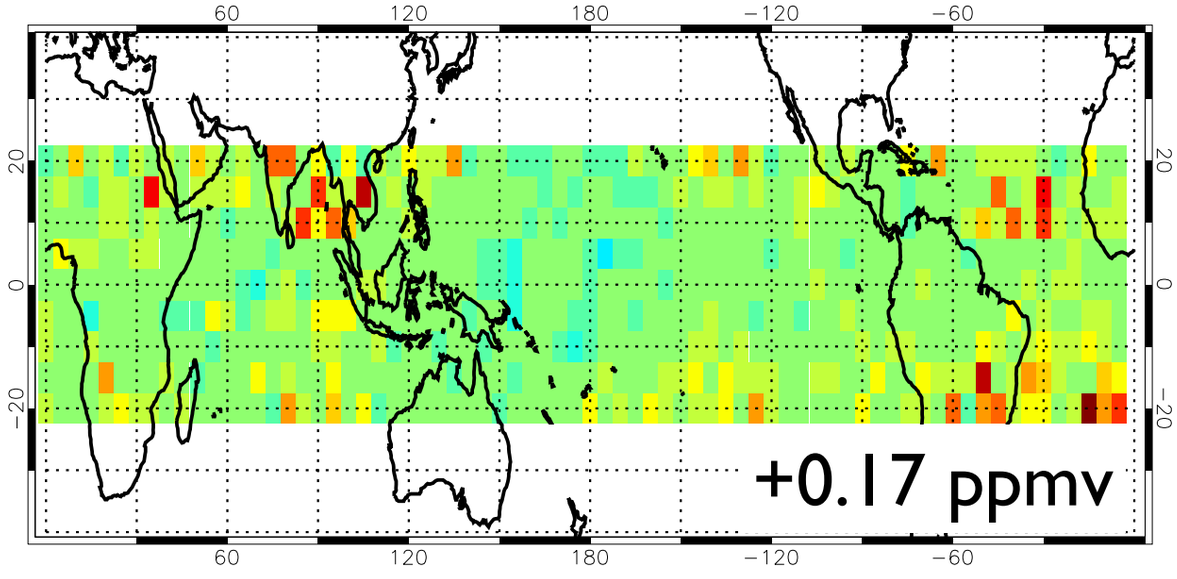


more sensitivity tests

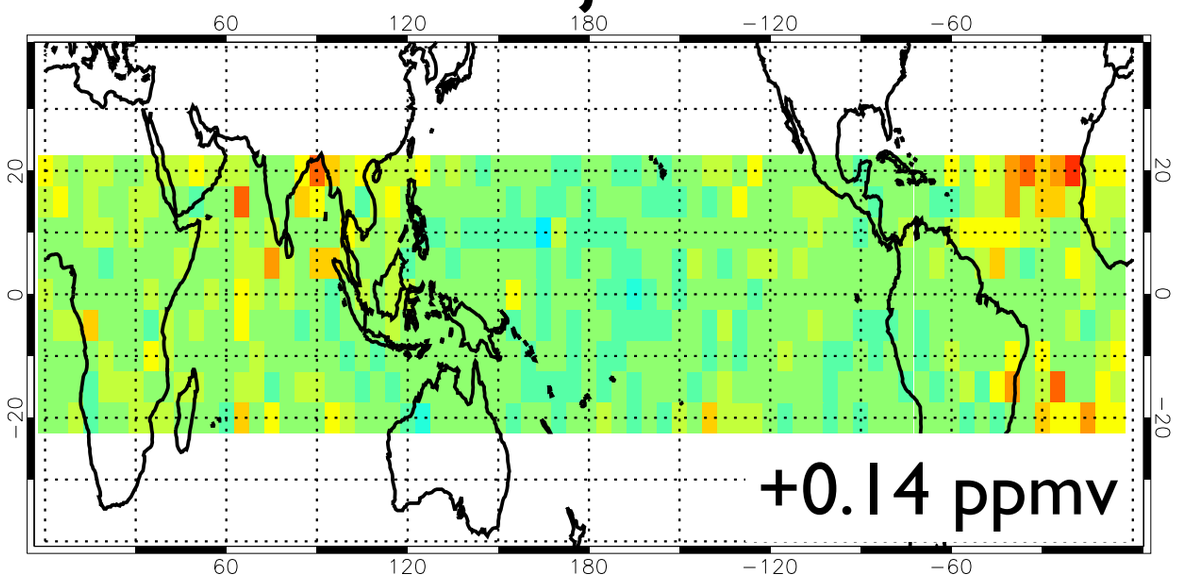
low N_{aer} (het. nucleation)



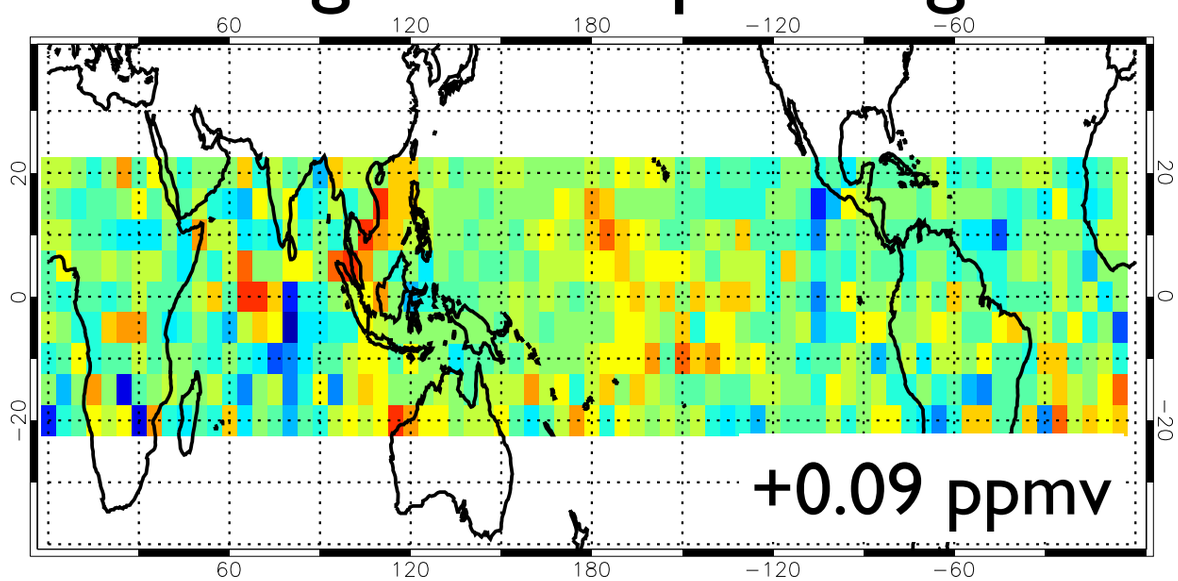
convection (θ > 370K)

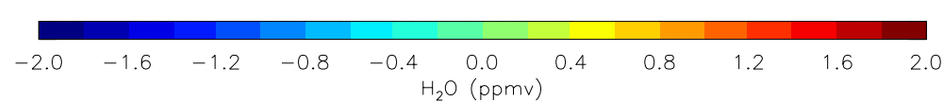


30-d trajectories



large-scale upwelling





Summary

- Spatial pattern of wintertime TTL (100 hPa) H_2O, as observed by MLS, is largely explained by the saturation (temperature) history of parcels, but Lagrangian Dry Point underestimates the tropical mean humidity by a factor of two

- Simulation with microphysics, convection and waves improves agreement with MLS, but is still 20% too dry
  - role of mixing? convective anvil ice?

- Impacts on 100 hPa H_2O:
  - waves –0.52 ppmv
  - convection +0.56 ppmv
  - microphysics +0.72 ppmv