Effects of Convection on Clouds and Water in the Tropical Tropopause Layer

Leonhard Pfister and Eric Jensen, NASA Ames Research Center

- Why are we interested in Clouds and Water in the Tropical Tropopause Layer?
- What's been done before?
- What is our model formulation – how do we treat convection?
- What are the water vapor and cloud distributions, and why?
- What can Aura do for this problem?
- Conclusions

Motivation

- TTL regulates water input to the stratosphere
- Water in the TTL affects cloud distribution and global radiation budget
- How are water vapor and cloud distributions in the TTL maintained?

Background and Previous Work

- Large areas of subvisible cirrus clouds near tropical tropopause (e.g. Wang et al)
- Dehydration due to horizontal motion through cold regions (Holton, Gettelman, Haynes, and others)
- Detailed microphysical modeling – (Jensen and Pfister)
  - 40 day back trajectory for 1995-1996 winter from a grid of points in the TTL
  - Evaluate vertical temperature profiles along these back trajectories ("temperature curtains")
  - Initial water vapor imposed and .2-.5 mm/s updraft (clear sky radiation)
  - Use full 1-D microphysical model and time-varying T to calculate clouds and water along each trajectory.
  - Water vapor results show good agreement with HALOE obs (Randel, Rosenlof)

BUT – convection MUST BE important

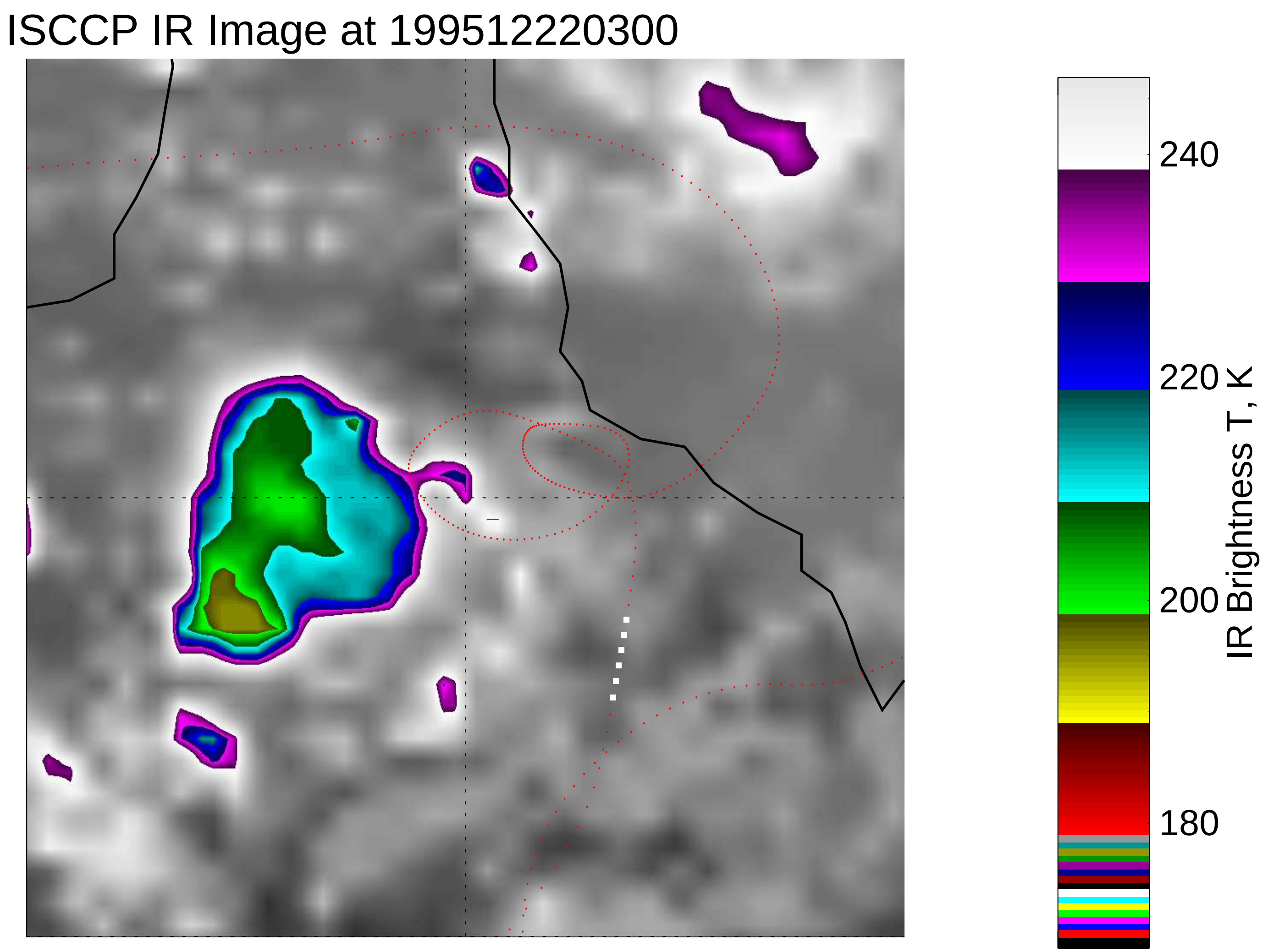
- Isotopic water ratios cannot be explained solely by slow ascent/horizontal flushing (Kwang et al.; Webster and Heymsfield)
- Convective turnover times are such that convection and slow ascent comparable at tropopause (Dessler, Gettelman et al)
- Evidence that overall cold temperature maintained by convection (Salby, Dessler and Kim, Randel)
- Connection of SVC to convection (Massie, Spang, Pfister)

SO

Convective Formulation

- Use existing temperature curtain trajectories
- Move them through 3-hourly IR brightness Temps from ISCCP
- Adjust brightness temps by 7K
- Calculate cloud top altitude based on brightness temps in neighborhood of curtains
- Change water vapor and clouds based on that cloud top altitude

Treatment of Convection in Model



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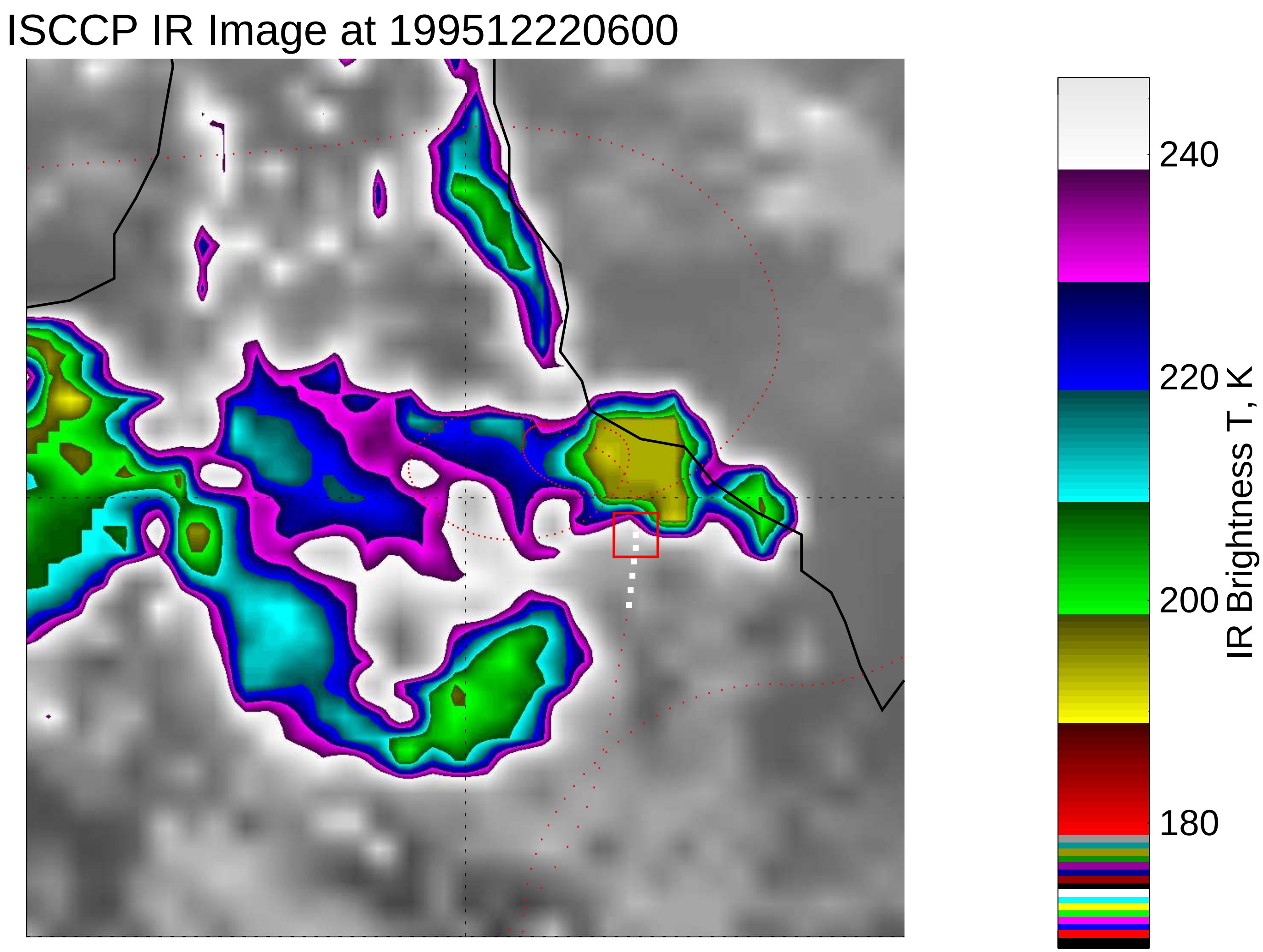

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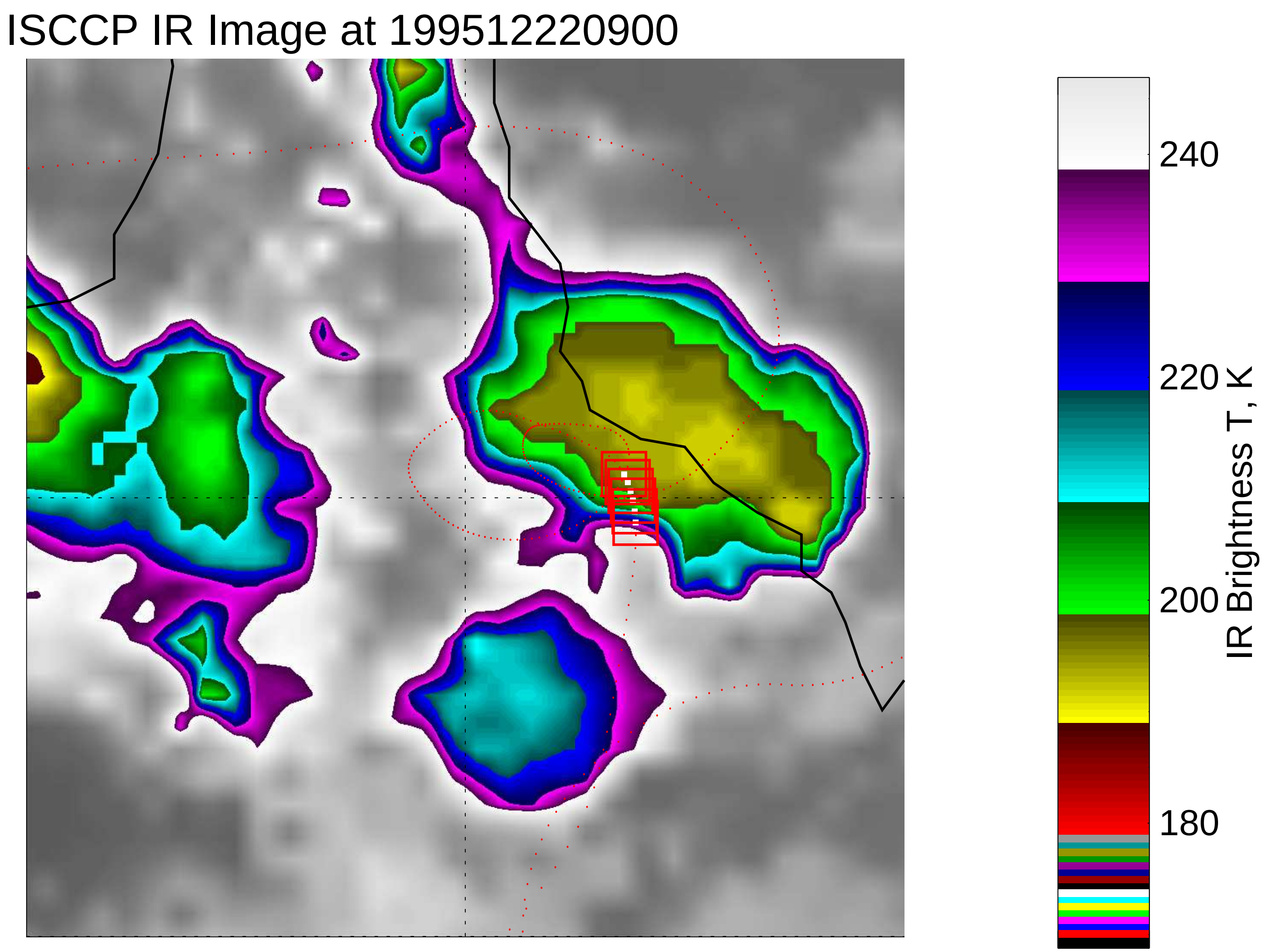

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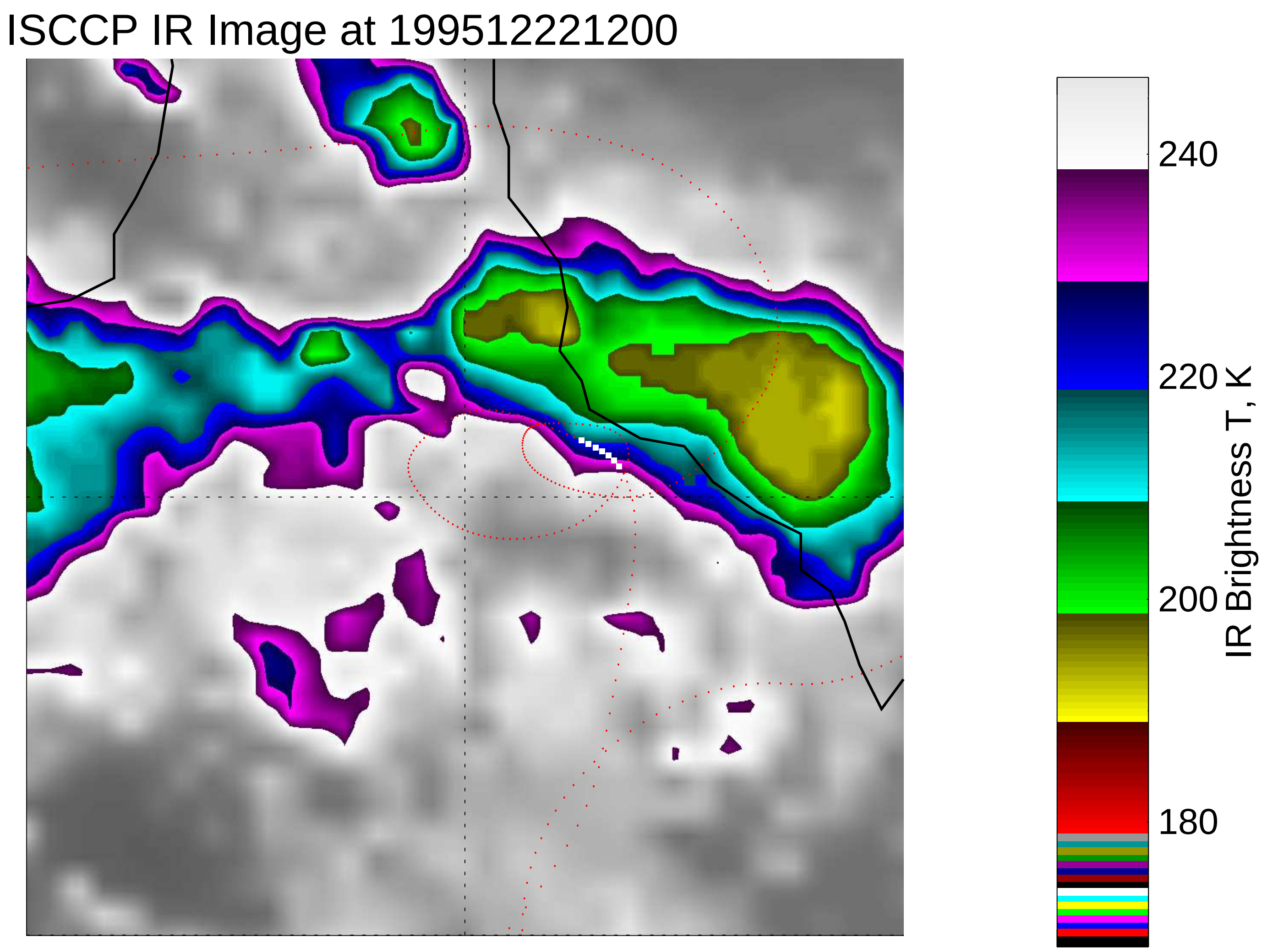

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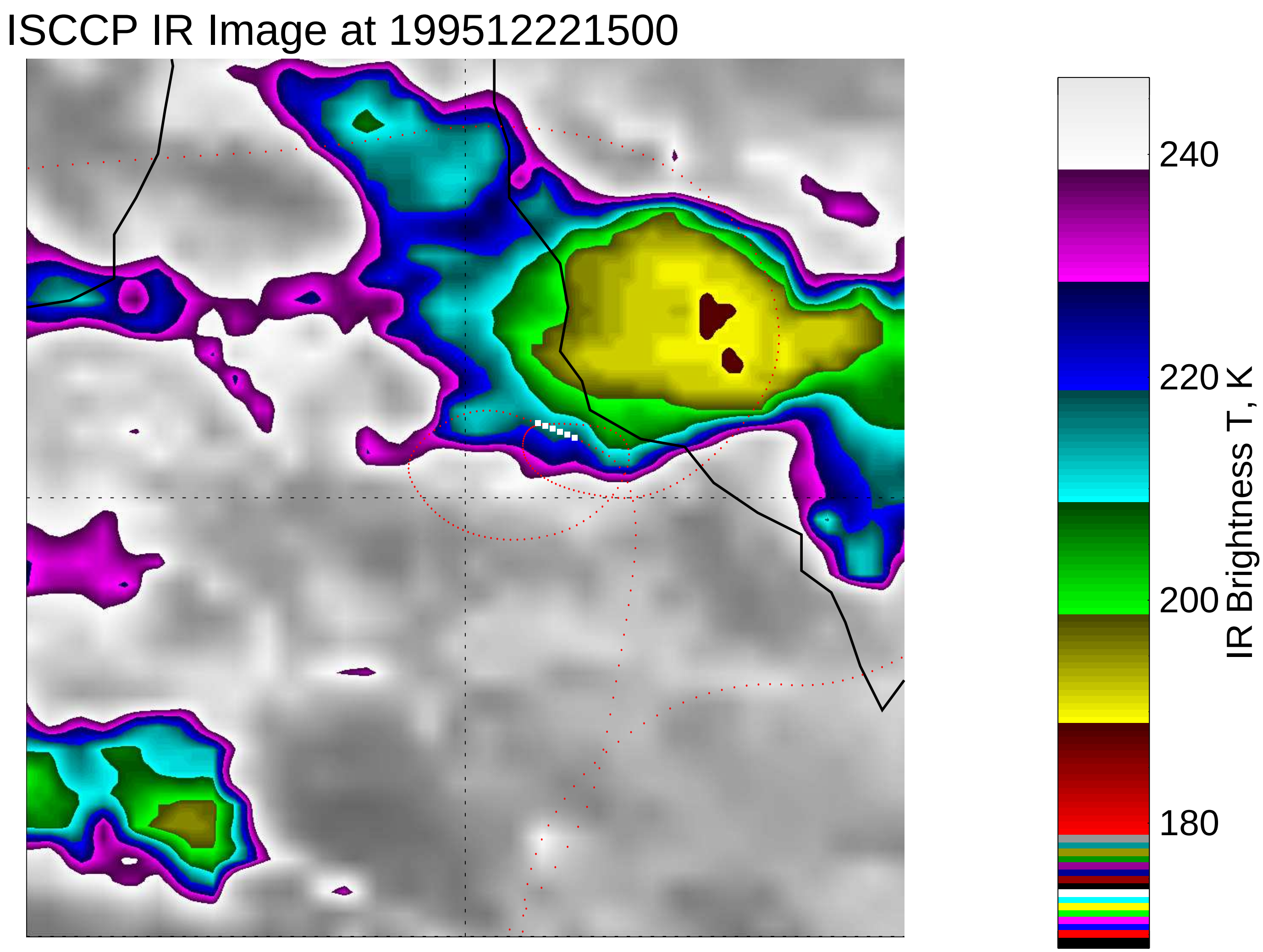

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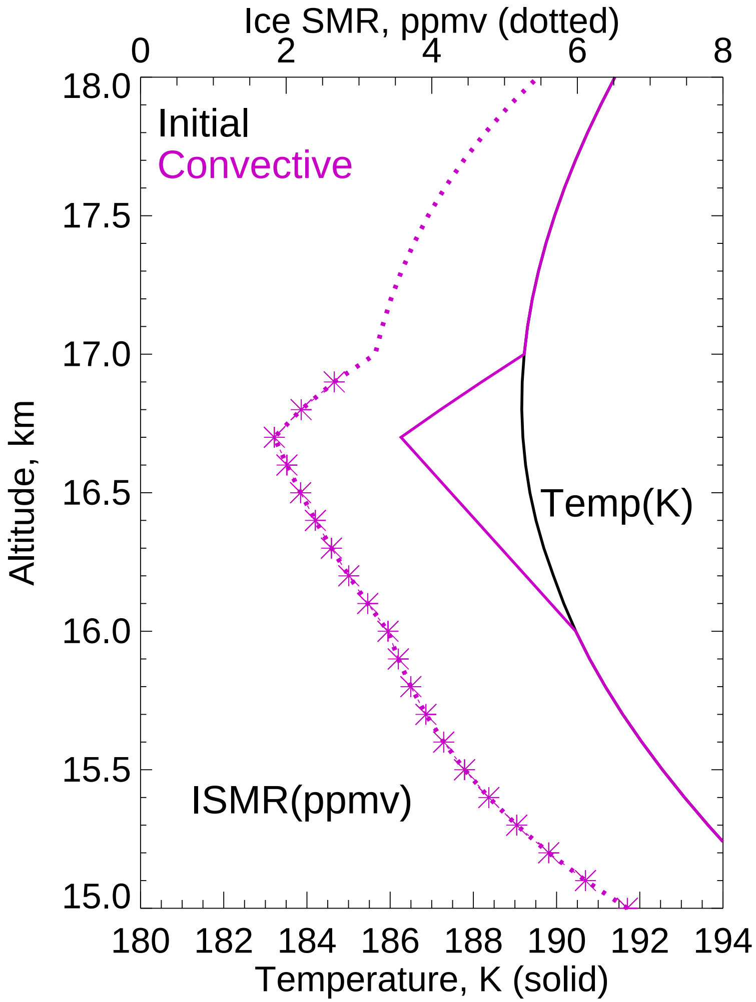
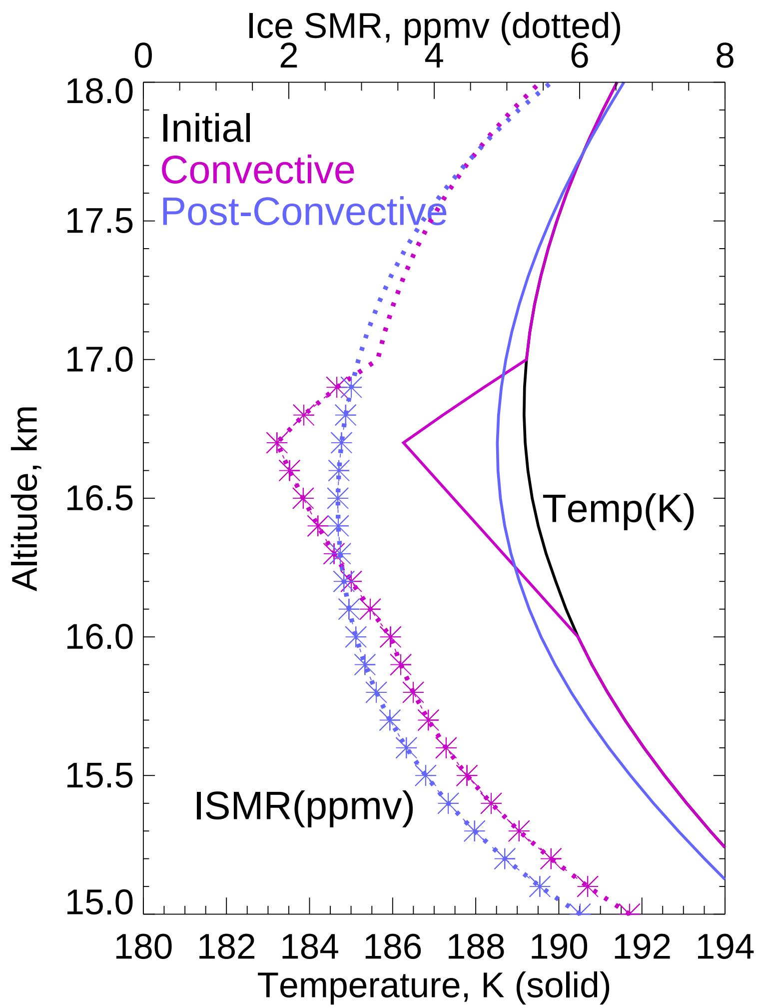


Model Profiles

Treatment of Convection in Model



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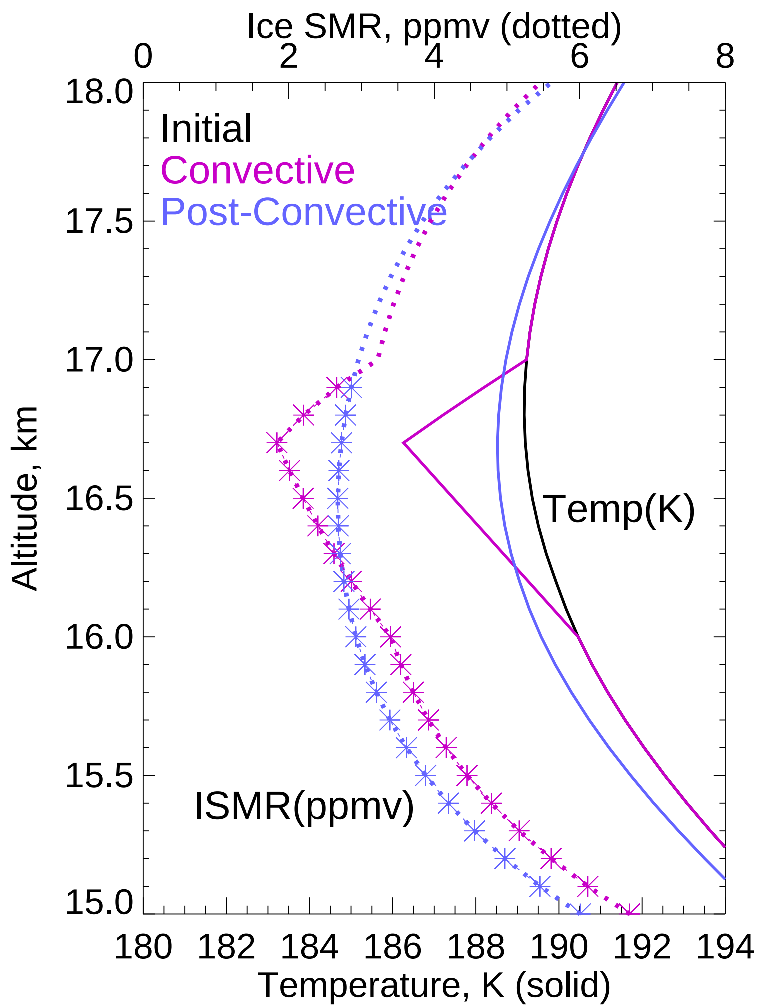

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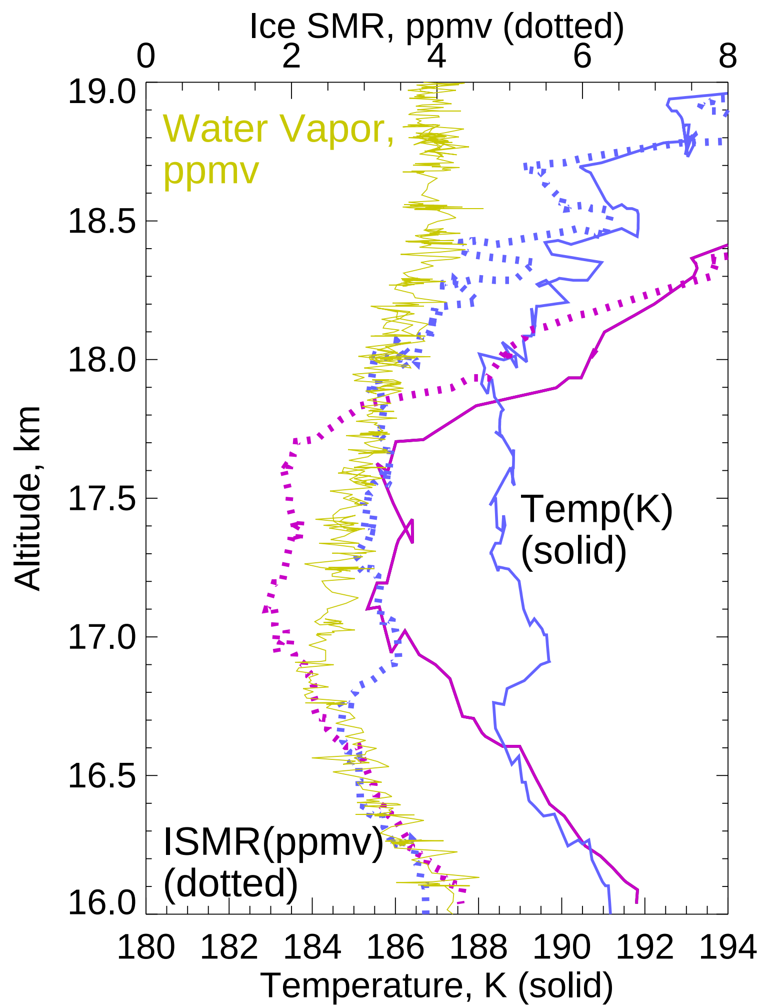

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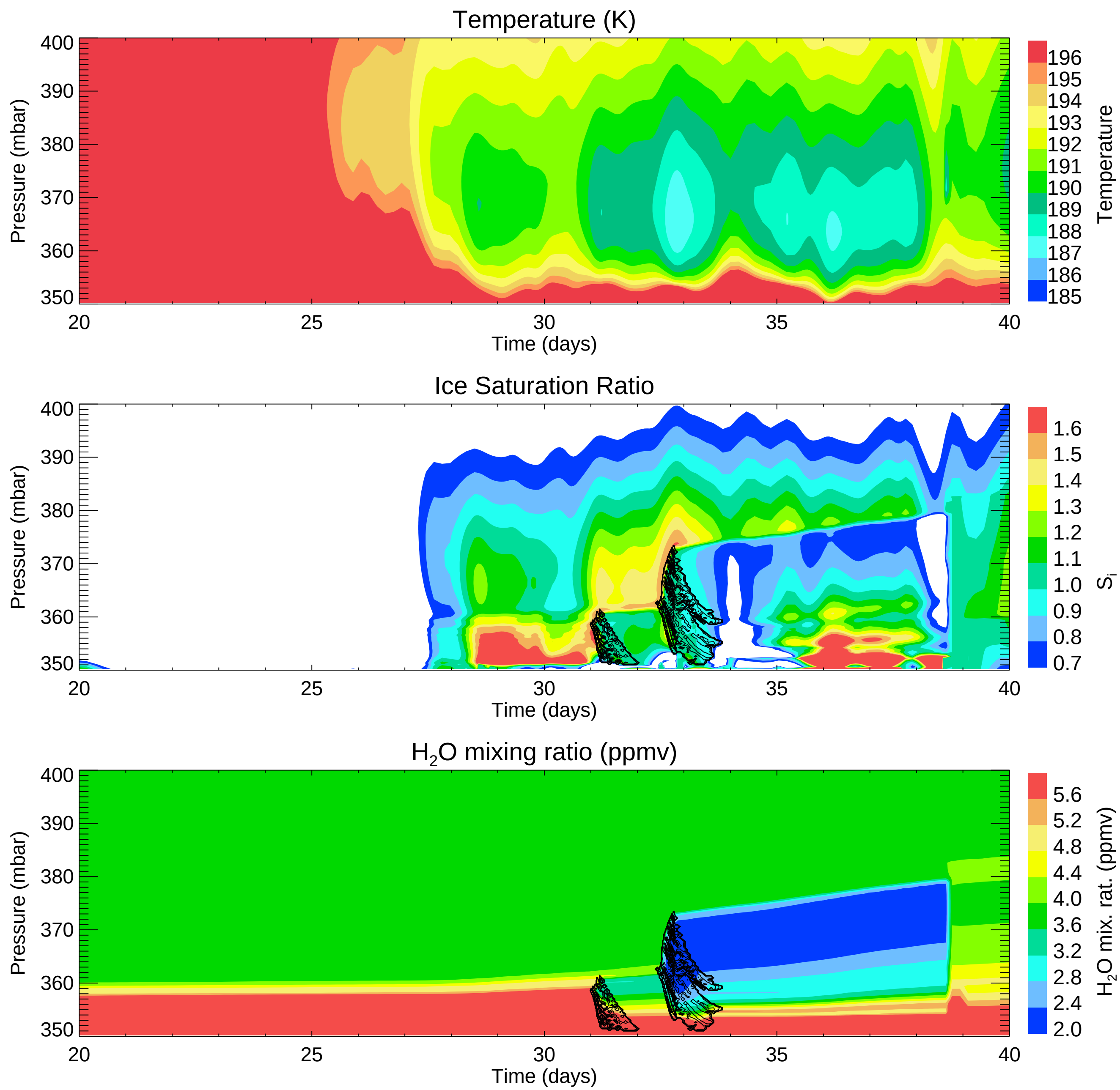
Sample hydration case



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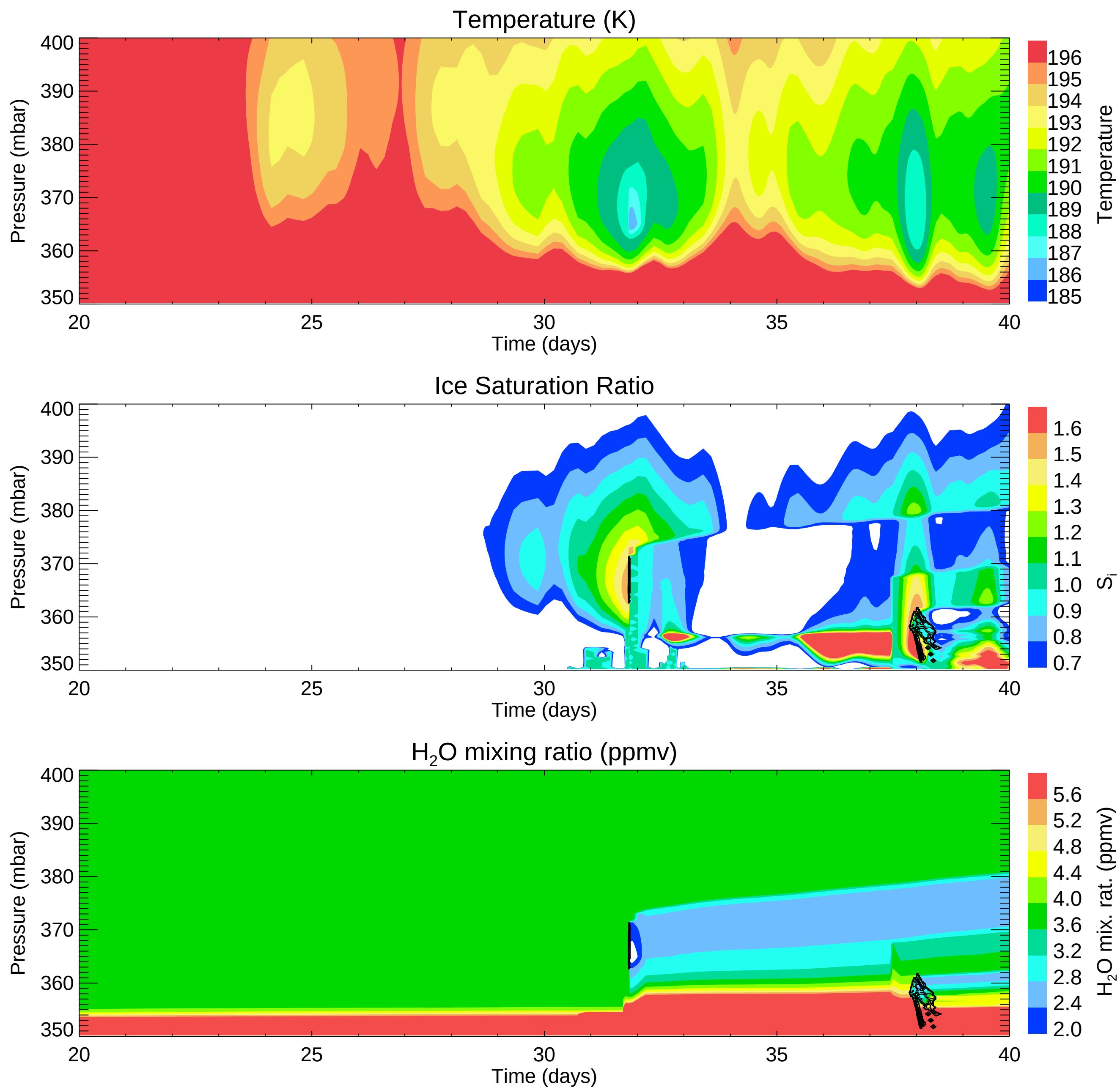
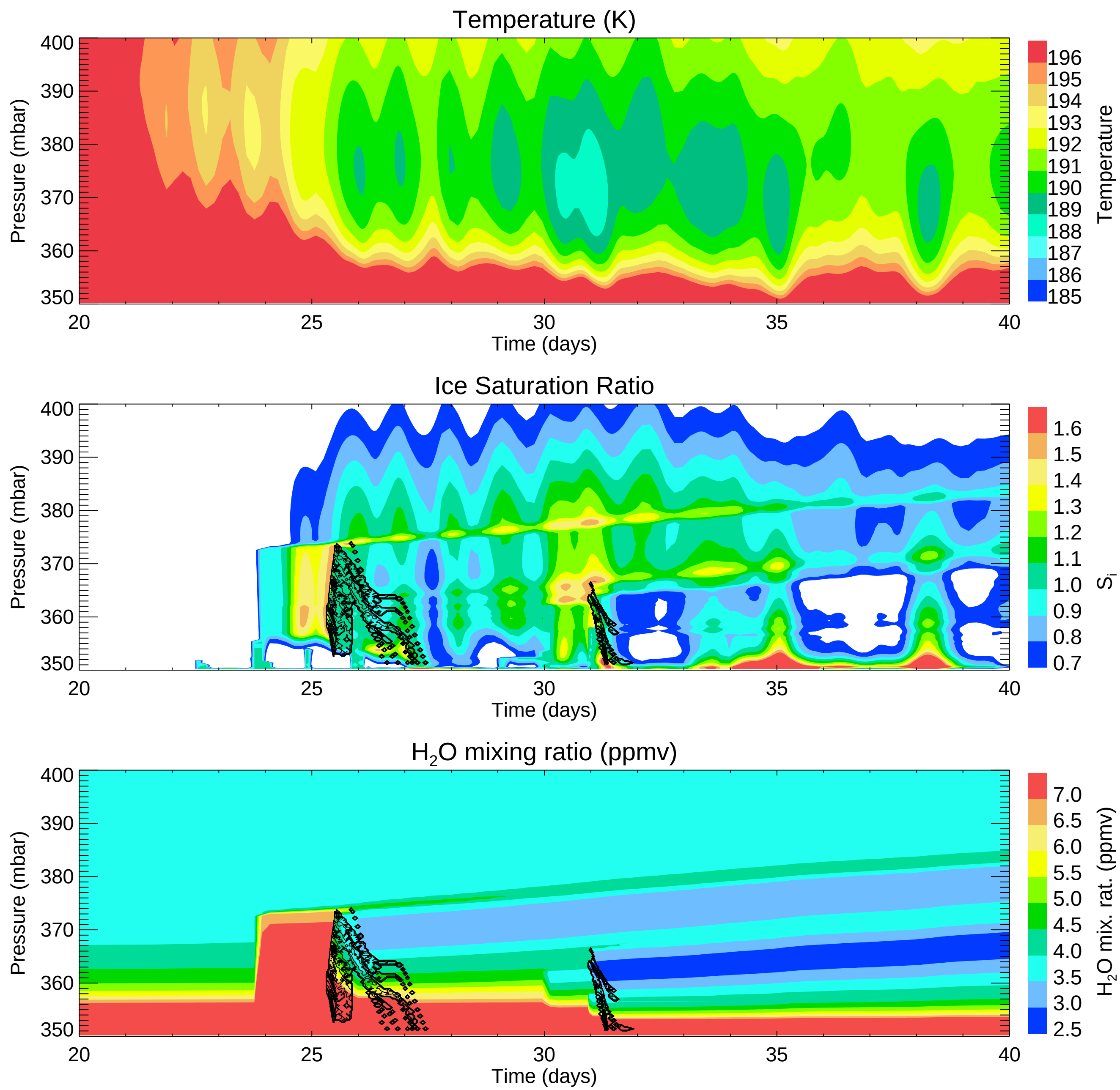
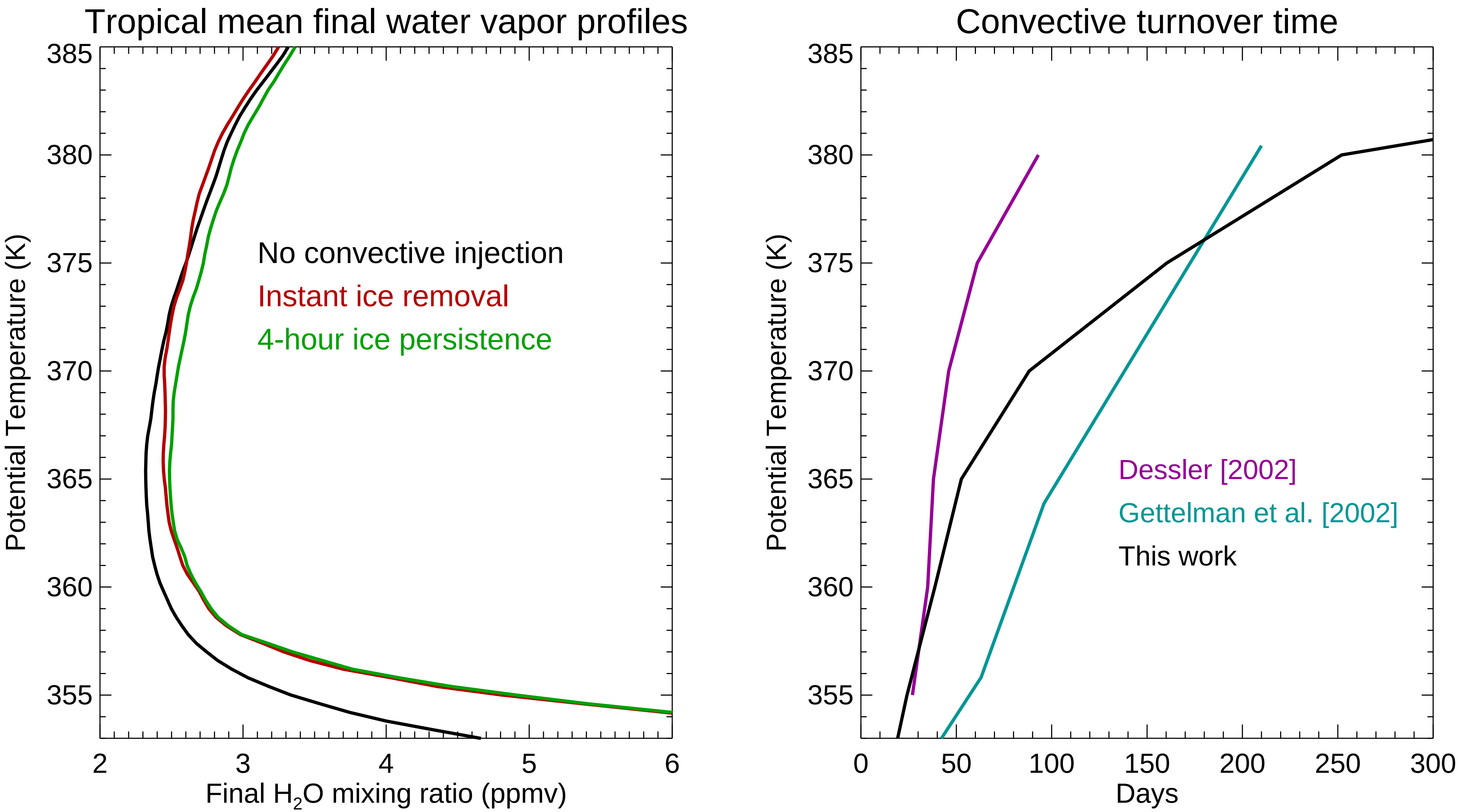


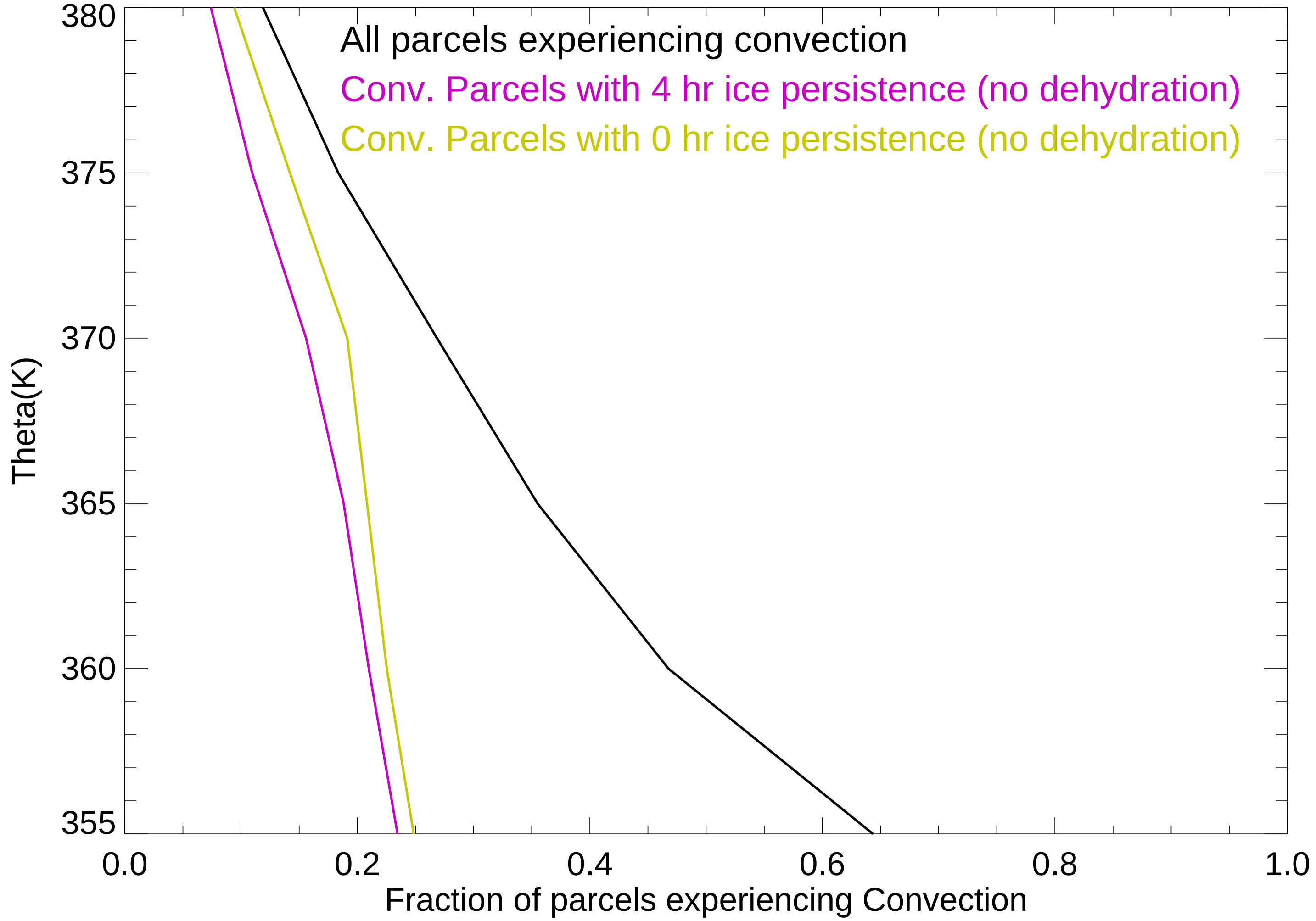
Sample hydration with subsequent nonconvective dehydration



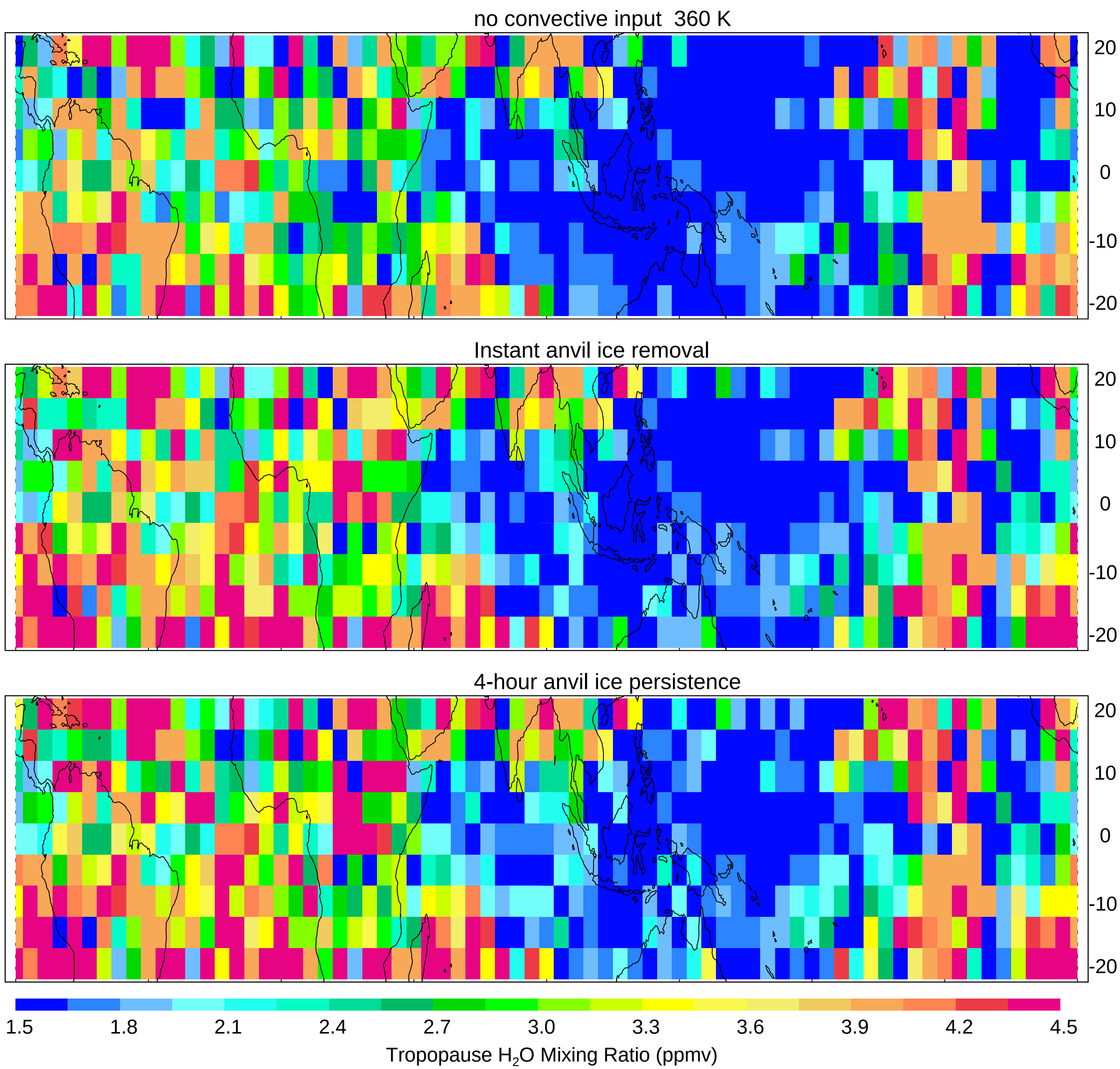
Overall effect on water vapor distribution



Proportions of parcels experiencing convection



Water Distribution



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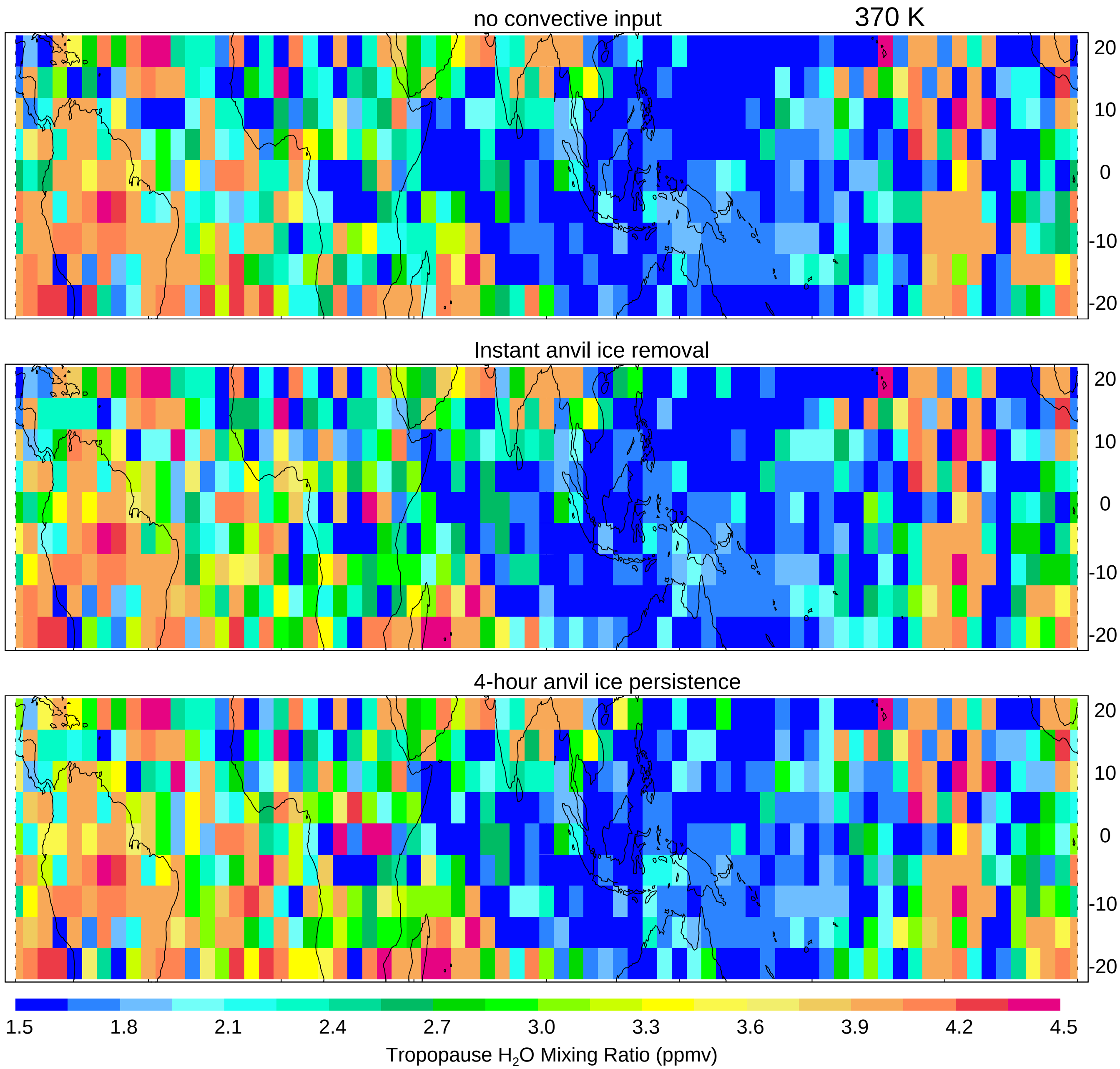

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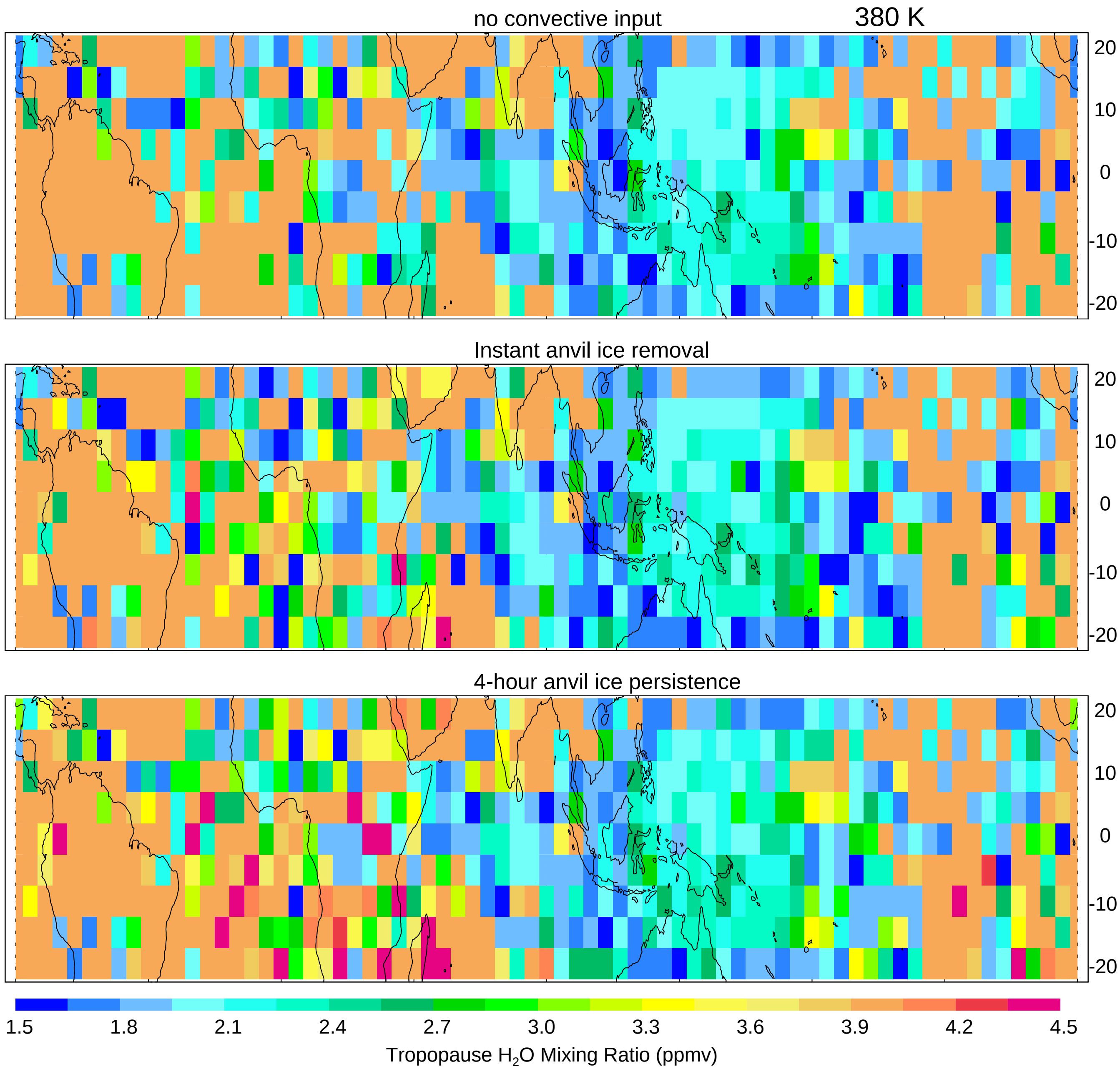
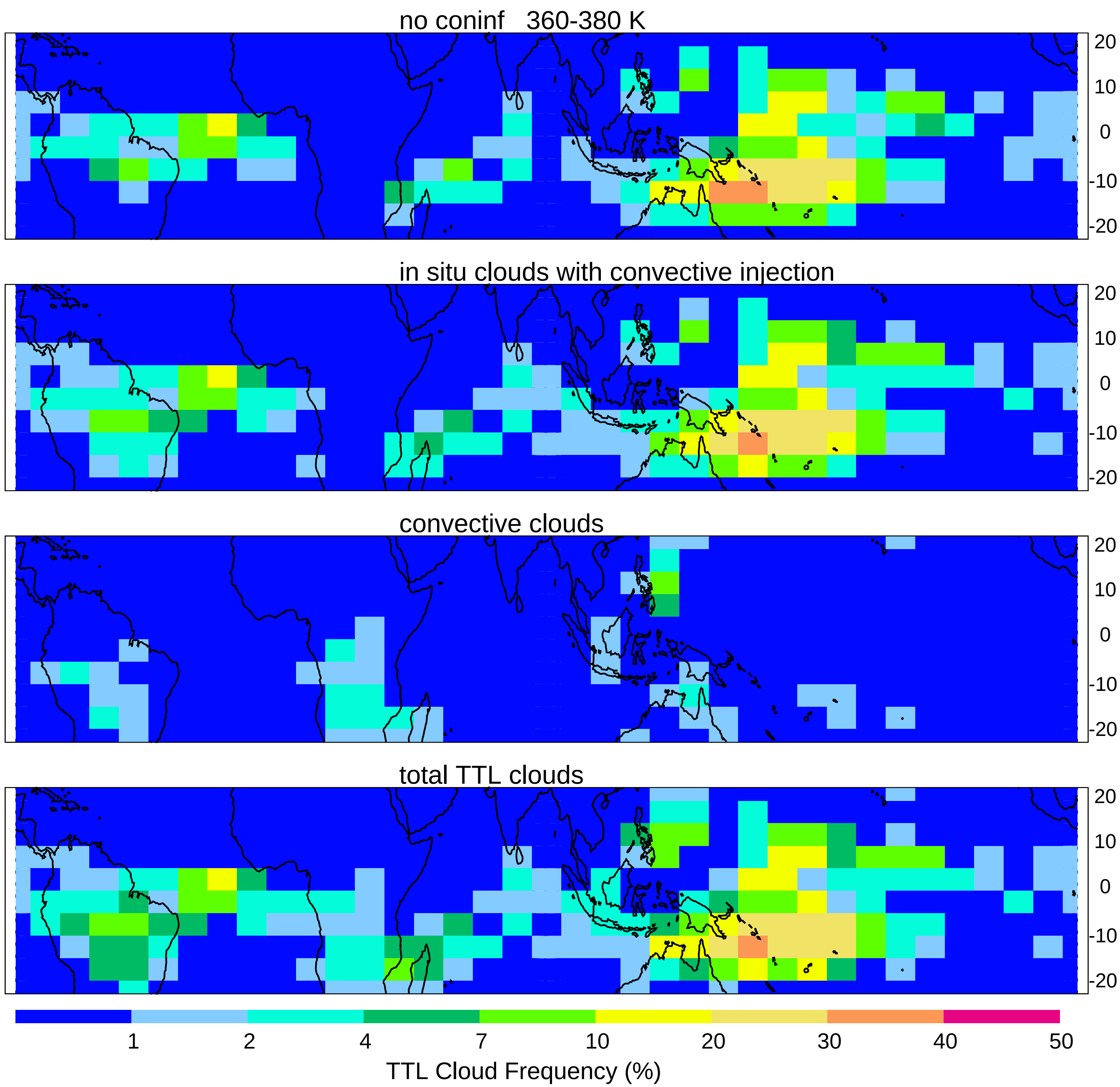
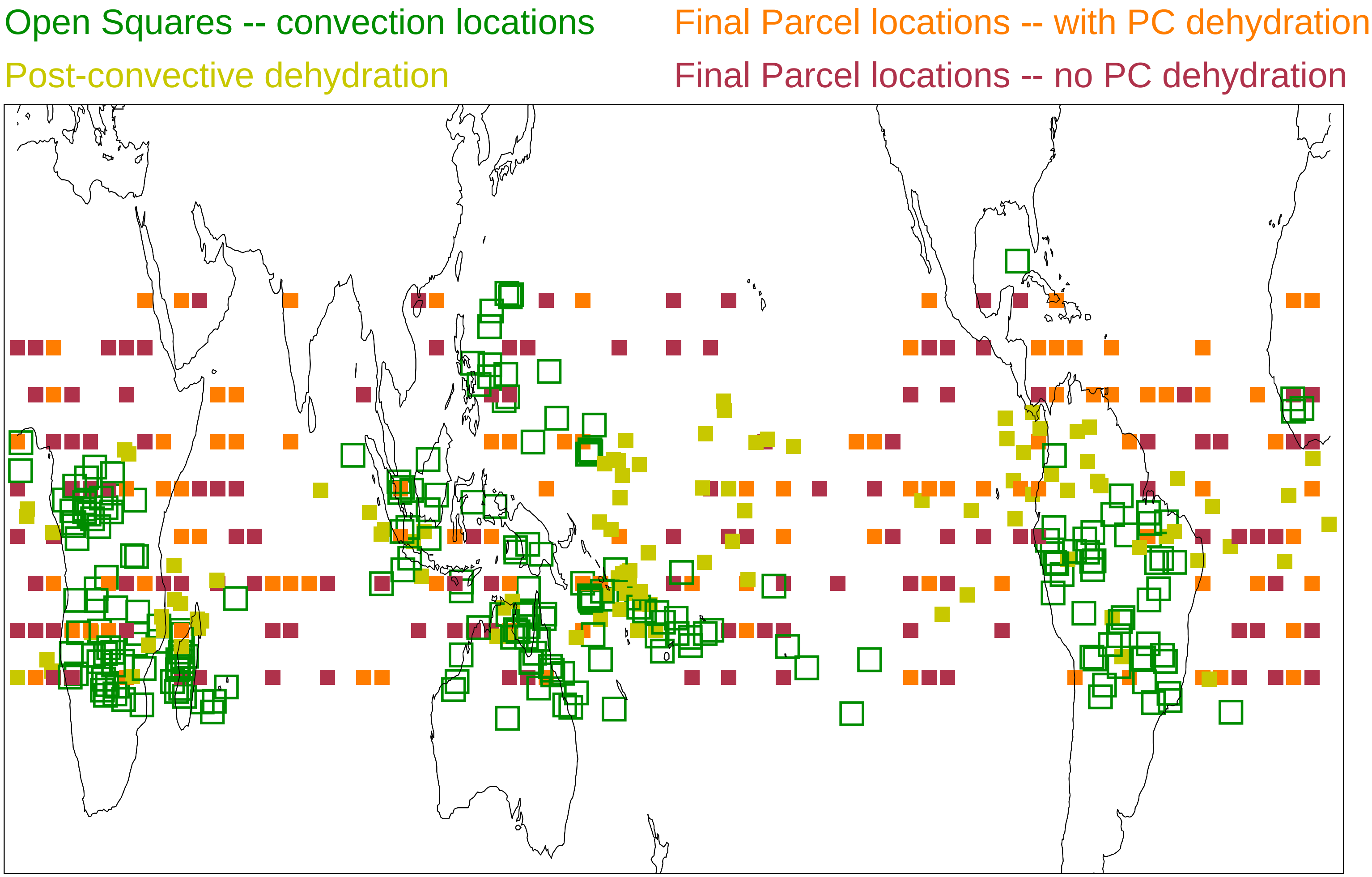


Cloud Distribution



Location and Effects of Convection reaching 365K



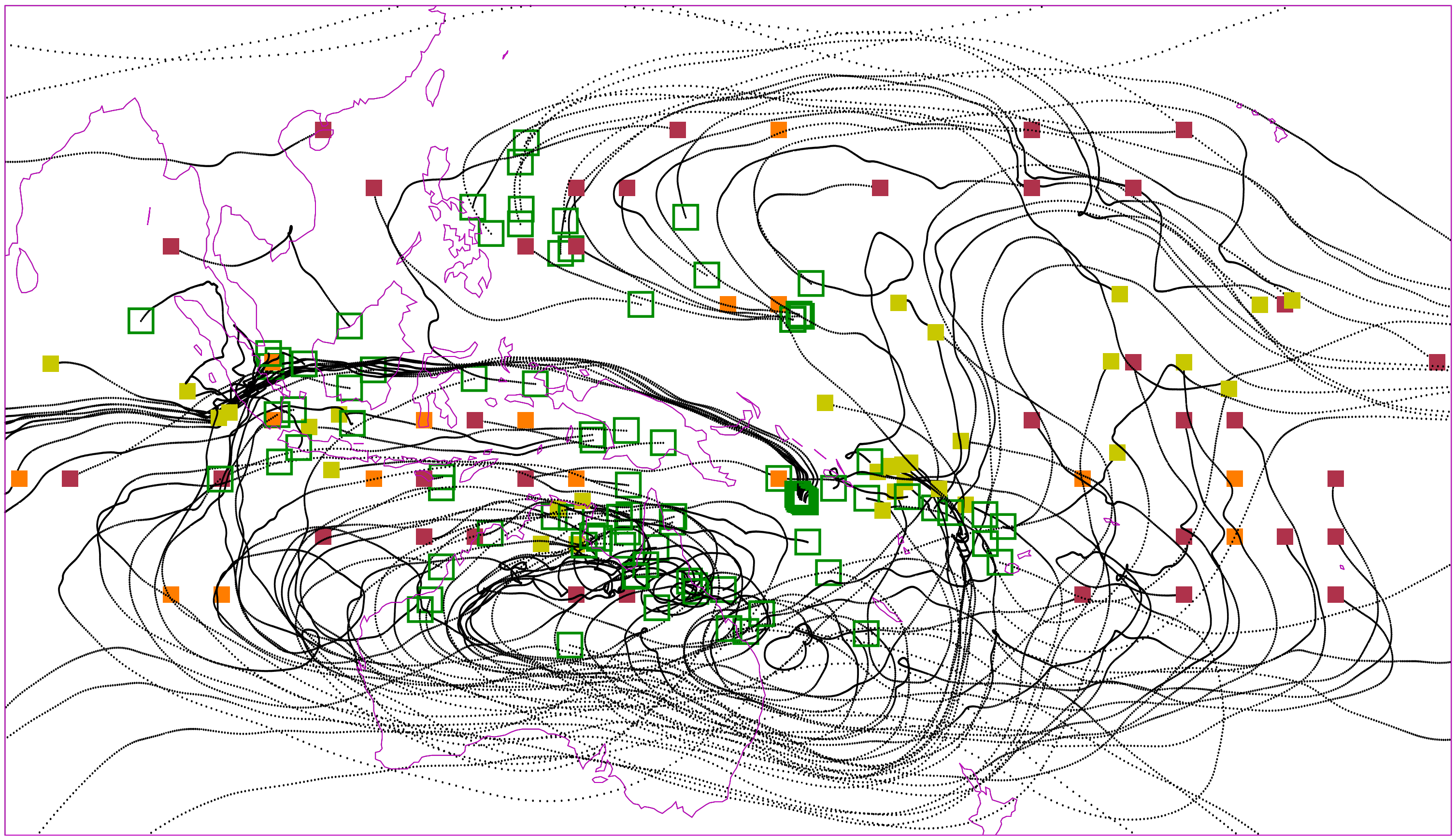
Circulation of Convective Parcels reaching 365K

Open Squares -- convection locations

Post-convective dehydration

Final Parcel locations -- with PC dehydration

Final Parcel locations -- no PC dehydration



Conclusions

- Effect of direct convective injection on water vapor distribution
  - Significant hydration below temperature minimum (20%)
  - Slight dehydration if instant anvil ice removal assumed
  - 10% hydration if anvil ice persists for 4 hours
  - Convective effects limited by subsequent dehydration

- Convective hydration is reasonably well distributed in tropics

- Cloud enhancement is confined to convective areas

- How can Aura help?
  - Simple water vapor comparison for overall features
  - Convective output – water and temperature downstream of clouds
  - Gravity wave temperature perturbations abv T minimum
  - Cloud altitude distributions