Observations of HDO/H_2O ratio in the ACCLIP campaign

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Photo: NASA (ISS)

Outline

- Background
- Planned Papers
  - NAM Case Studies
  - AM-NAM Isotopic Comparison and Summary
  - Microphysical Modeling of Water Isotopes
- Conclusions

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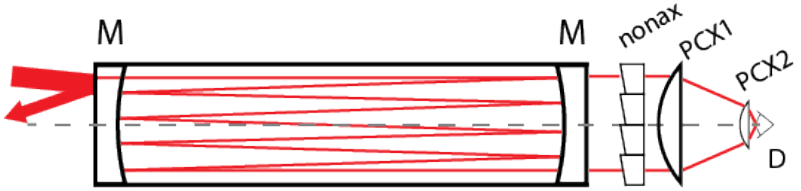
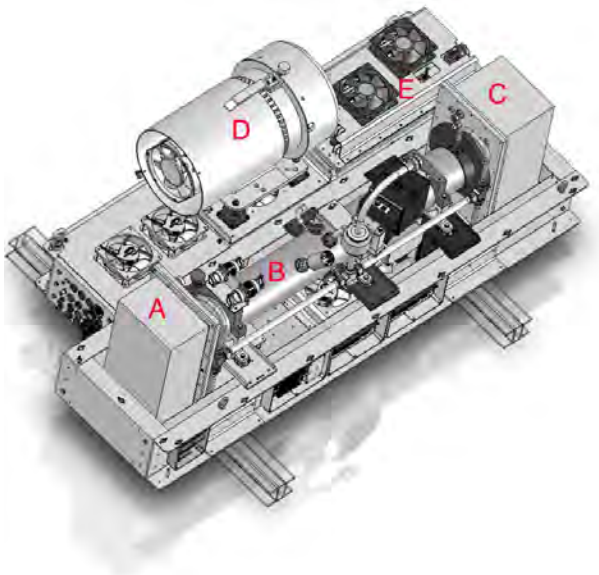
Instrument Performance

ChiWIS at a glance

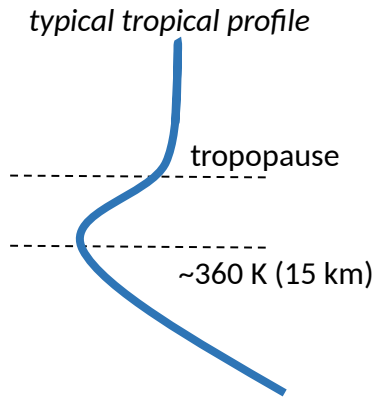




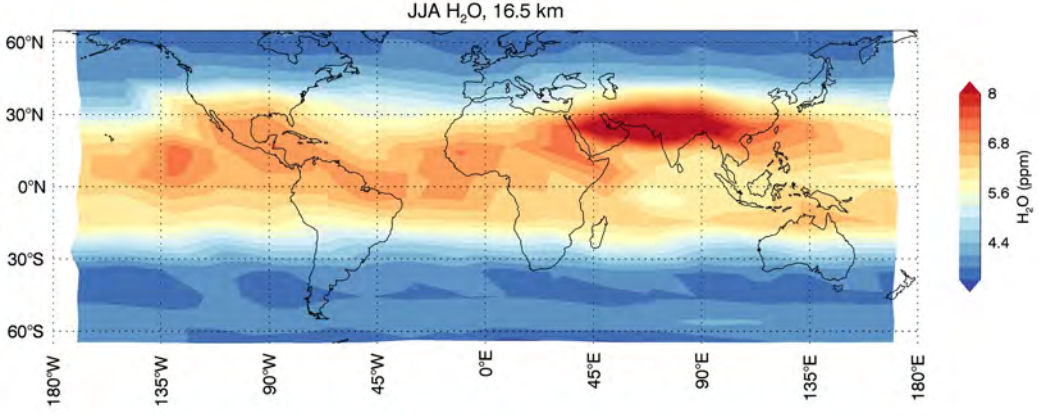
ACCLIP Configuration	
Technique	TDL OA-ICOS
Wavelength	2.65 µm
Scan Rate	75 Hz
Cavity Length	90 cm
Pathlength	**7+ km**
Target Molecules	H_2O, HDO
Dynamic range in H_2O	1-500+ ppm
Noise 1σ, 5 s.	6 x 10^{-4}
dD precision, 5 s.	80 ppm 3.5‰ 2.5 ppm 110‰
Cell pressure	40 hPa
Flush Time	~0.5 seconds

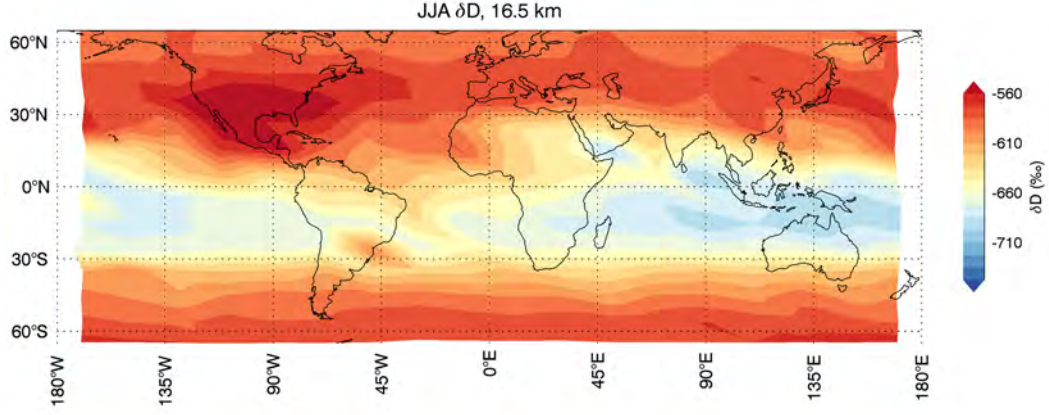
UT/LS science: Water isotopes trace convective origin of water

- depletion from condensation, enhancement from ice sublimation
- **core question: how does monsoon affect stratospheric H_2O?**
- N. American and Asian monsoons both associated with excess moisture, but have different isotopic signatures
- hypothesis for Asia : higher RH -> less ice sublimation at altitude



δD = per mil HDO/H_2O ratio rel. to standard ocean water





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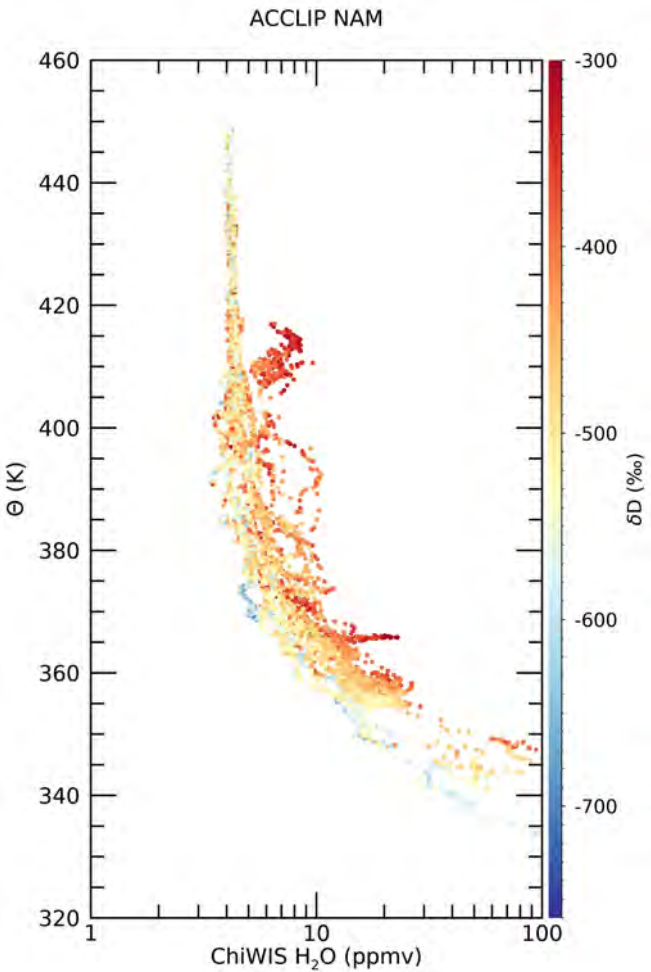
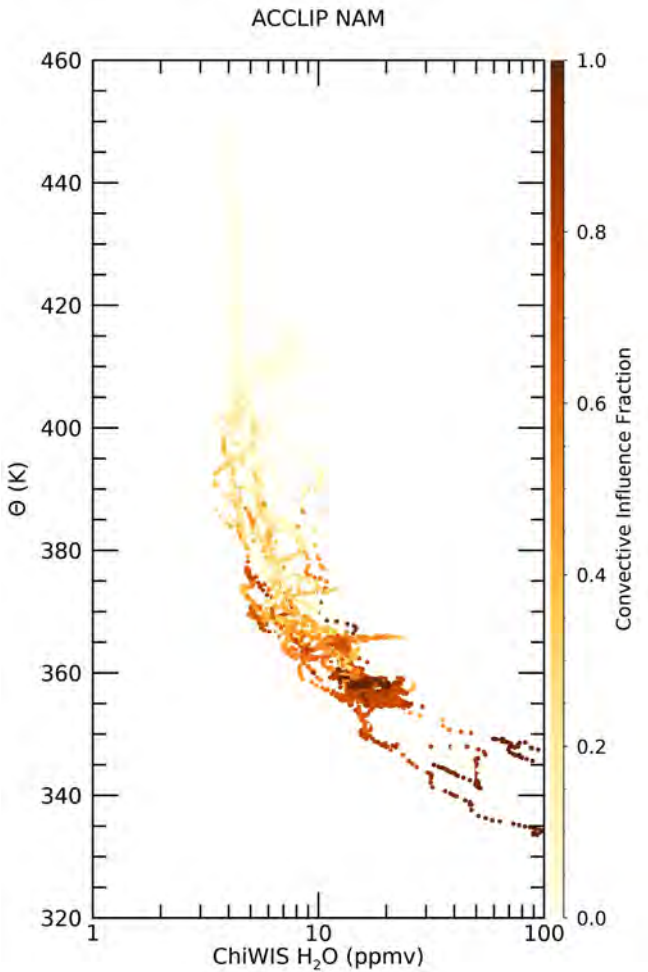
Water Isotopes in the North American Monsoon

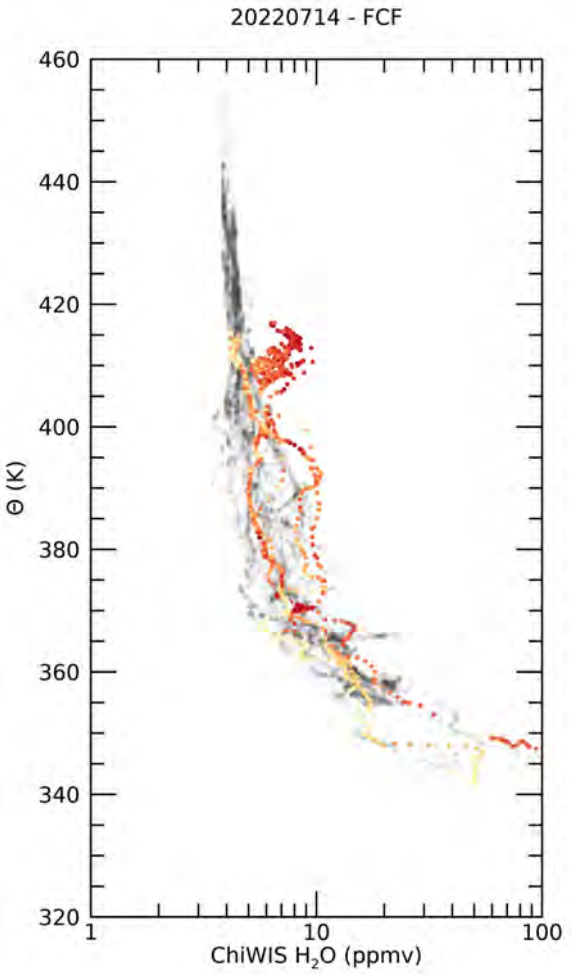




Seven flights with isotopic measurements out of Houston

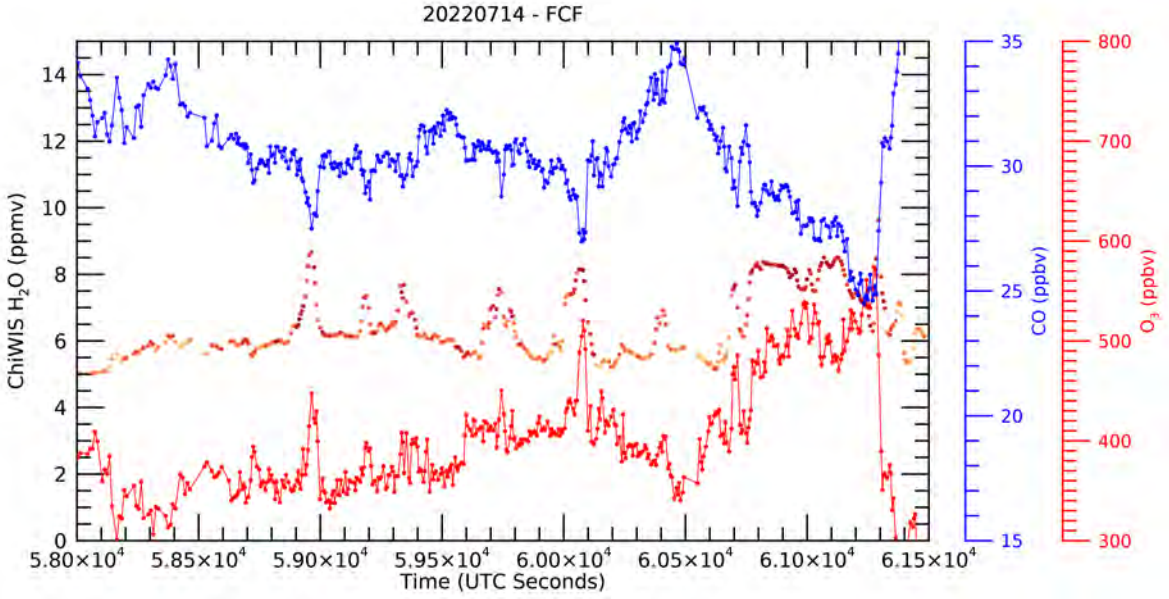
- Evidence of convective influence throughout UTLS up to 420 K
- Nearly all associated hydration events – sublimation of lofted ice
- Highest intervals of enhanced/enriched water not captured in 30 day CI

Water Isotopes in the North American Monsoon



Texas FCF, 2022-07-14: enhanced, enriched water up to 415 K

- Ozone positively correlated with water
- CO negatively correlated with water
- Suggests sublimation of overshoot ice+subsequent mixing



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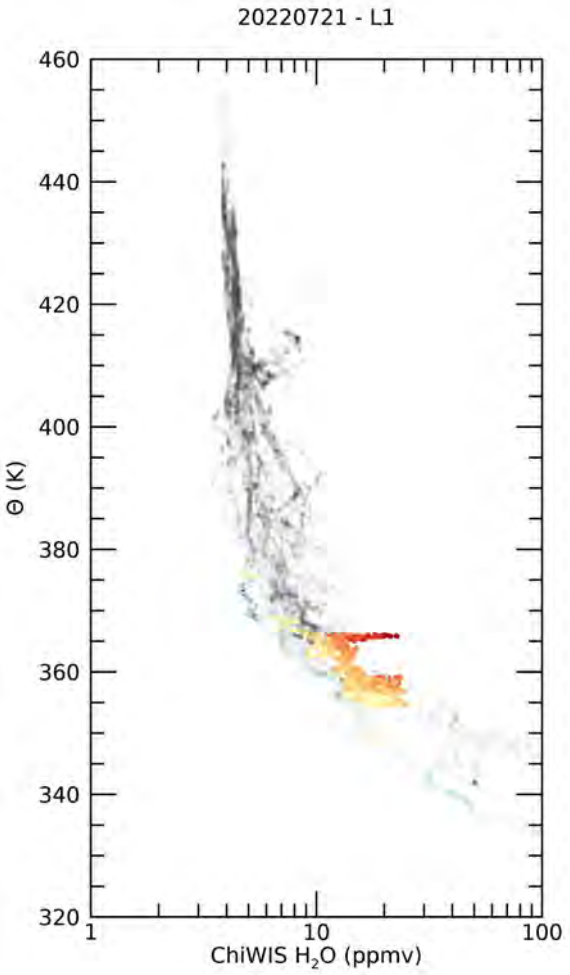
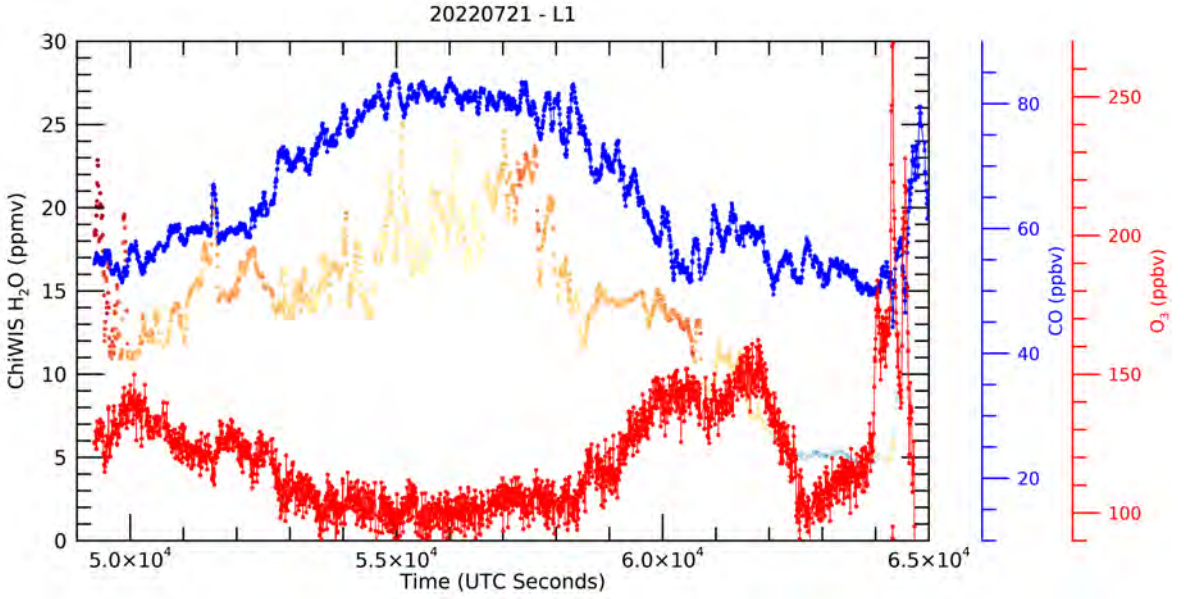


First Transit, 2022-07-21: Crossing the NAM

- CO shows both positive and negative correlations with H_2O
- Ozone shows weak correlation with water
- Isotopic depletion near center?



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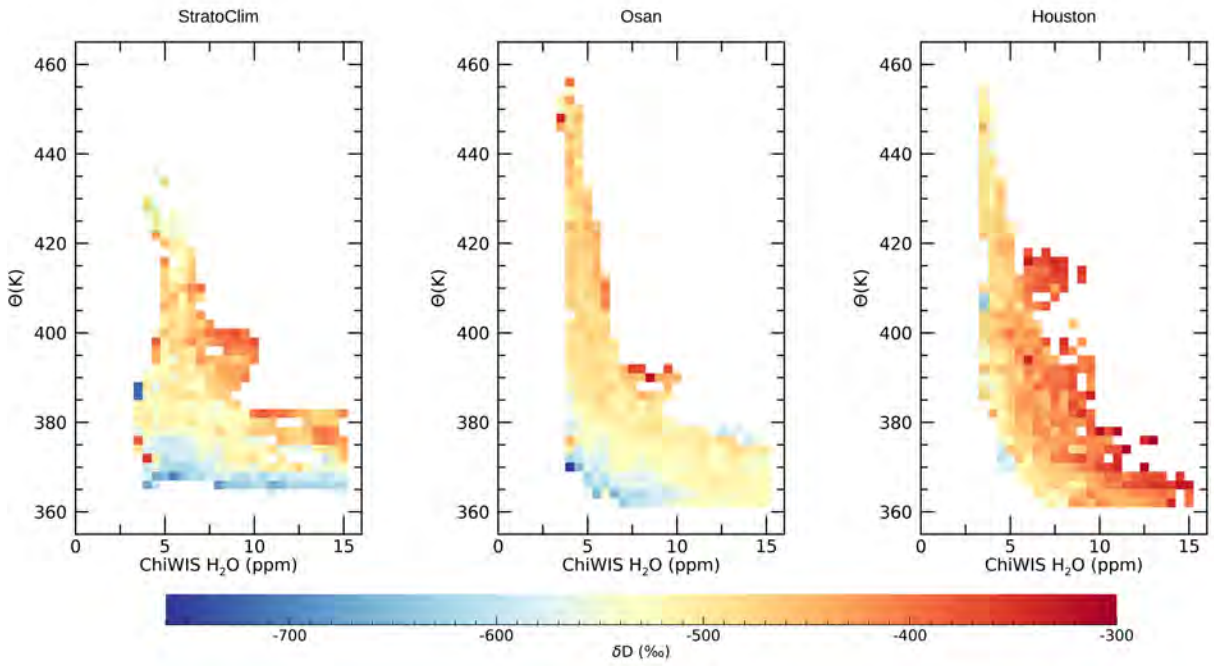
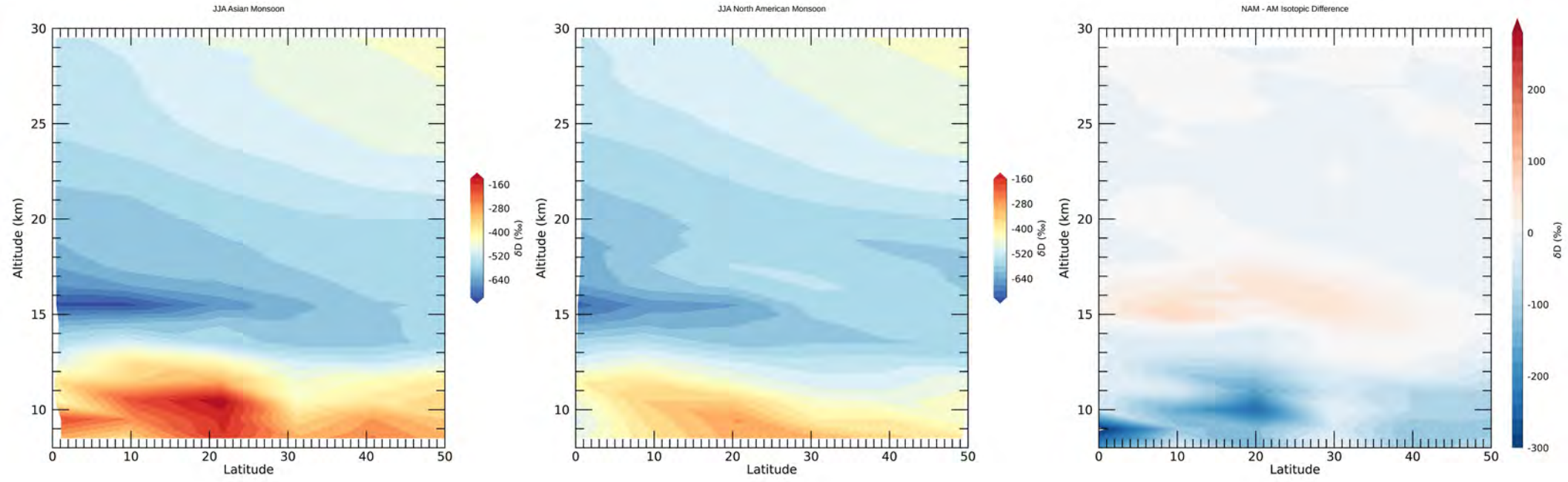
Water Isotopologue Observations by Region

- Data rebinned into 2x0.5 bins, colored by avg. deltaD
- Khaykin et al., 2021 show that convection can both deplete and enhance.



Water Isotopologue Observations by Region

- ACE-FTS data binned over 0-50 N and 8-30 km for NAM and AM regions
- Right panel is NAM-AM Isotopic Difference



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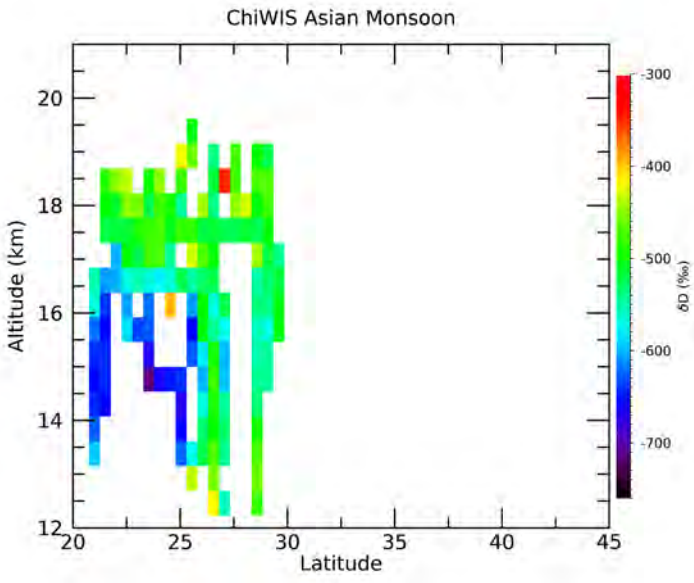
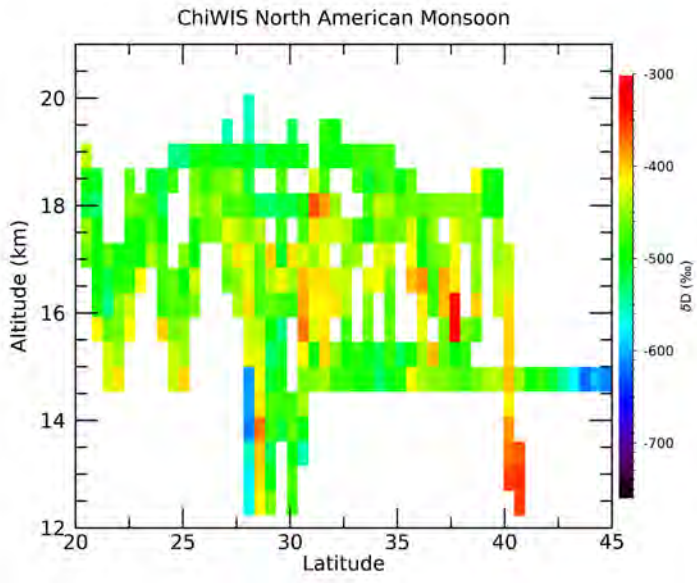
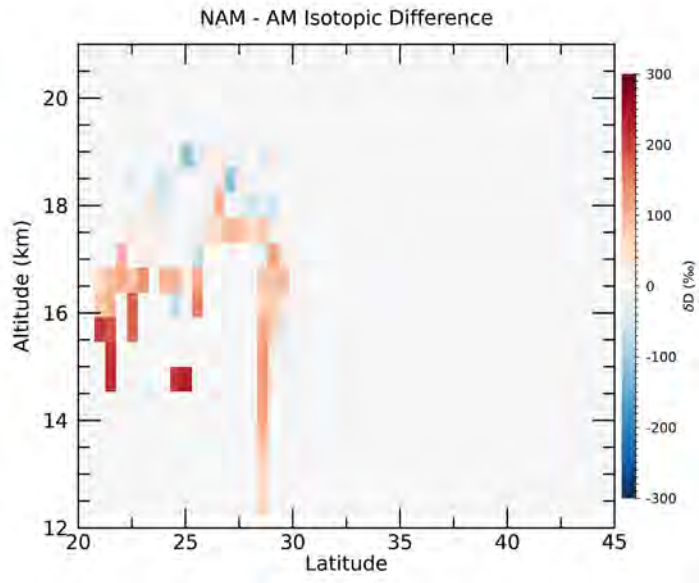






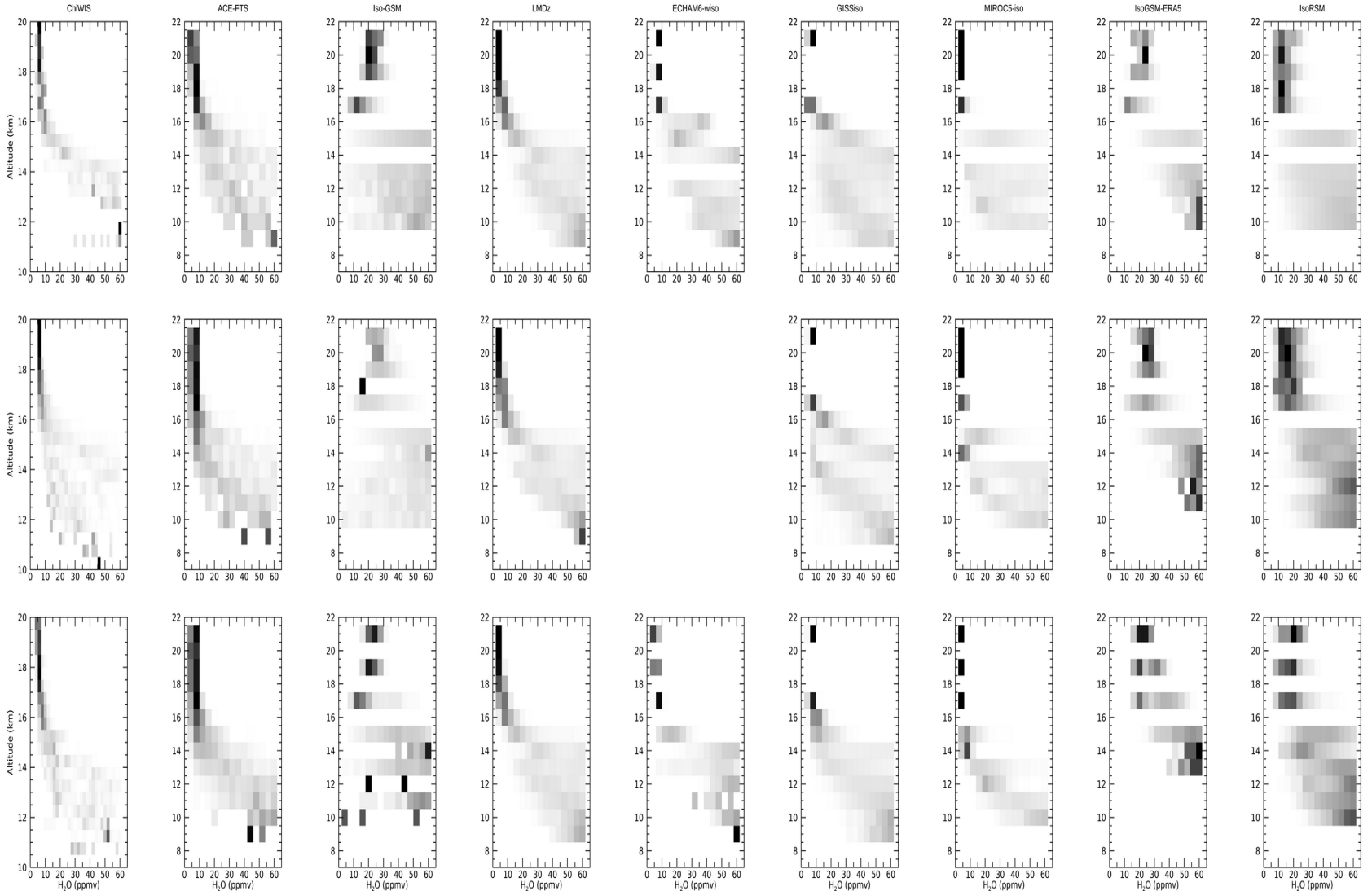
Models show a variety of disagreements with observation

StratoClim
Kathmandu

ACCLIP
Korea

ACCLIP
Houston

1 km x 5 ppm bins



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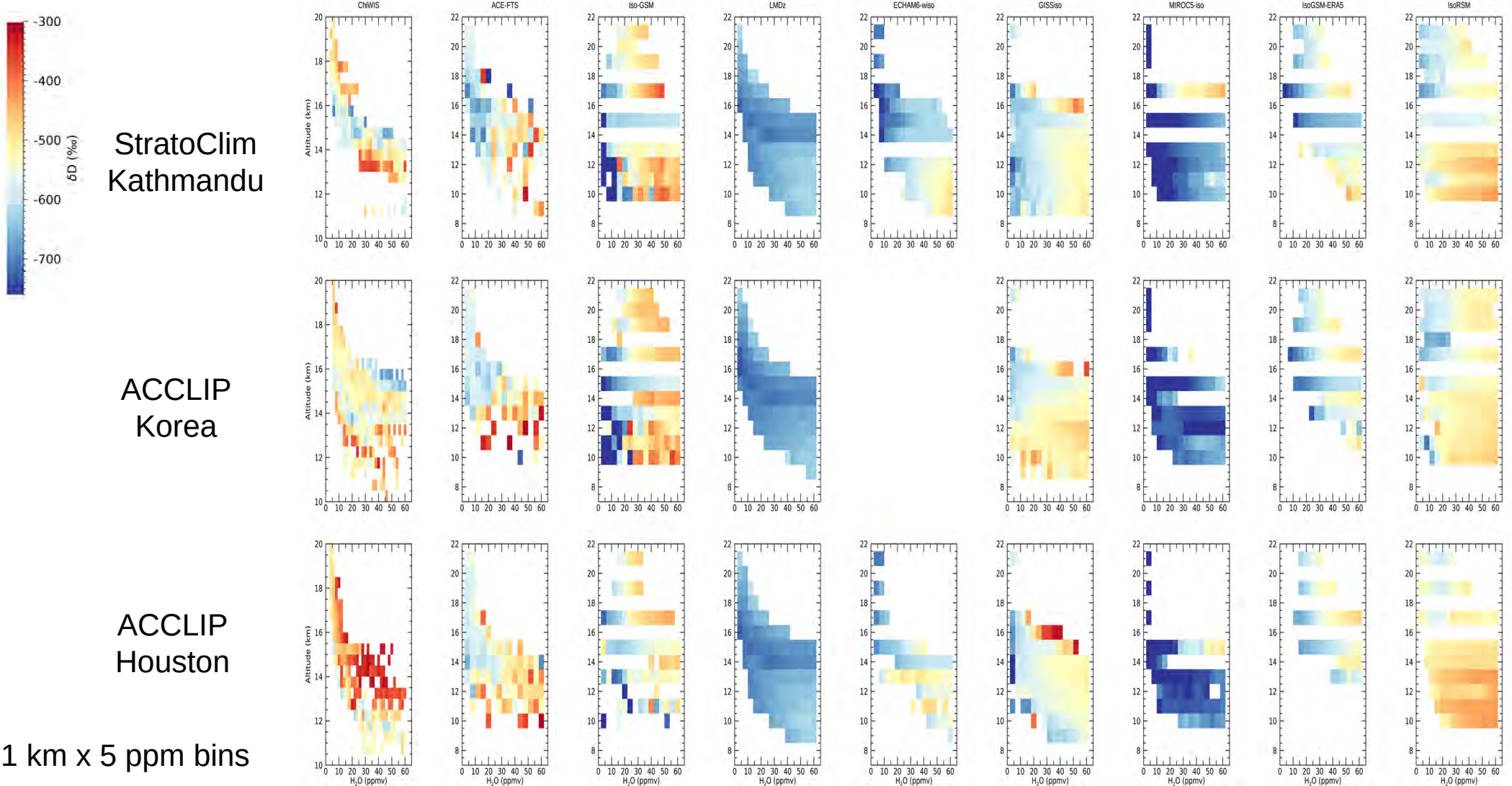

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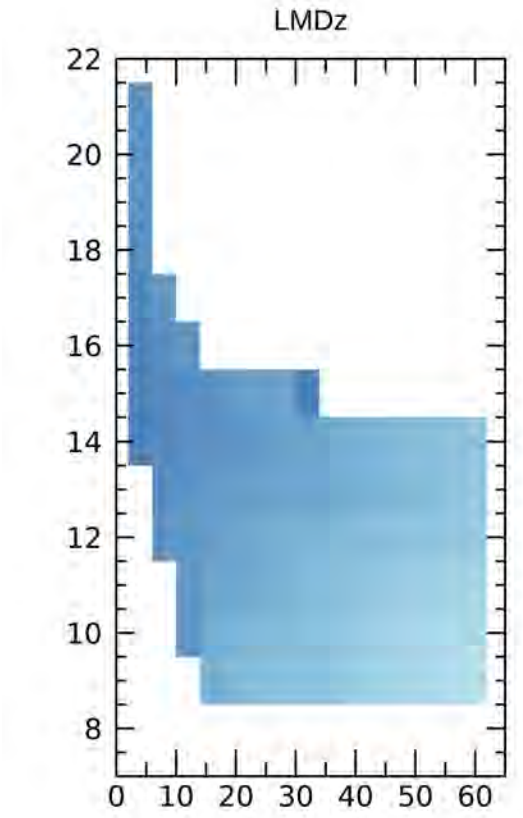
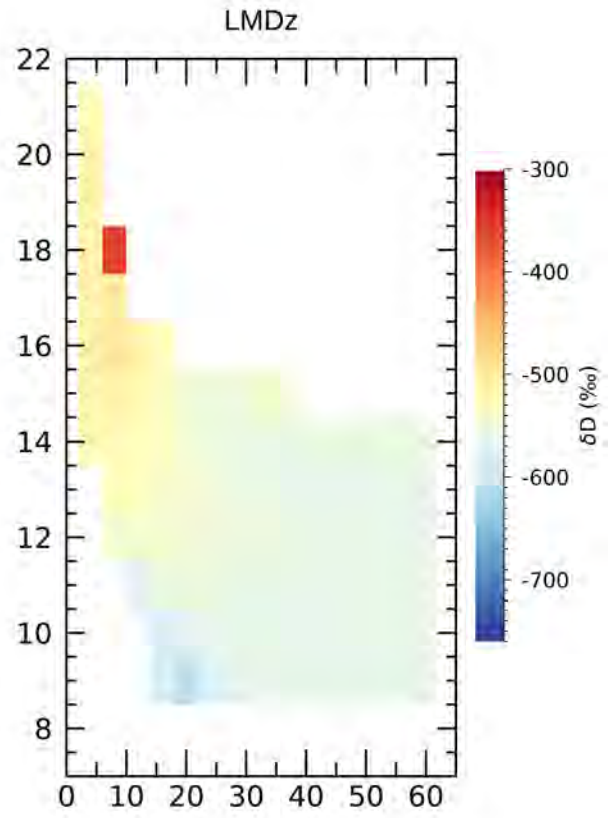
Observational Feedback into Models

- JJA 2017 tropical averages of LMDz Isotopic Ratio



- Rerun with slightly decreased precip. efficiency

$\varepsilon_p^{max} = 0.999$ → $\varepsilon_p^{max} = 0.99$



=> Easy to tune δD in UT/LS. Increase of 150‰ above 300 hPa, preserves specific humidity envelope

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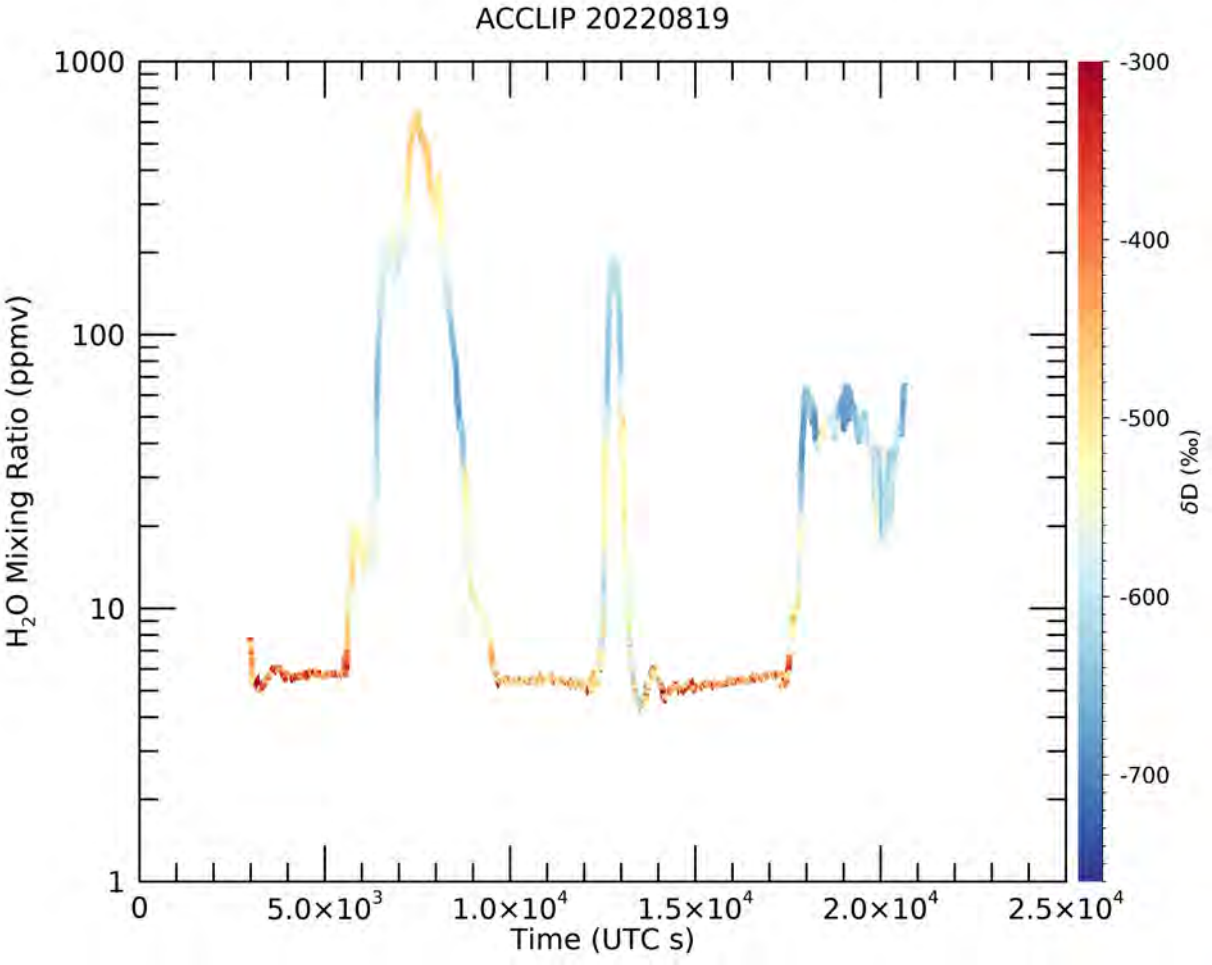
Case study from ACCLIP 2022-08-19 – Simple freezing model

Can a simple freezing model estimate our observed isotopic ratios?

- Following Sayres et al., 2010
- **For convective hits:** Initialize w/ saturation value of H_2O and δD=-300‰.
- **No hits:** Initialize at saturation value of H_2O and δD based on Rayleigh distillation
- If water is greater than saturation along trajectory, parcel is brought to 100% RH and fractionation occurs.
- Values from each 1k bundle of trajectories are averaged and compared to our data at observation point.



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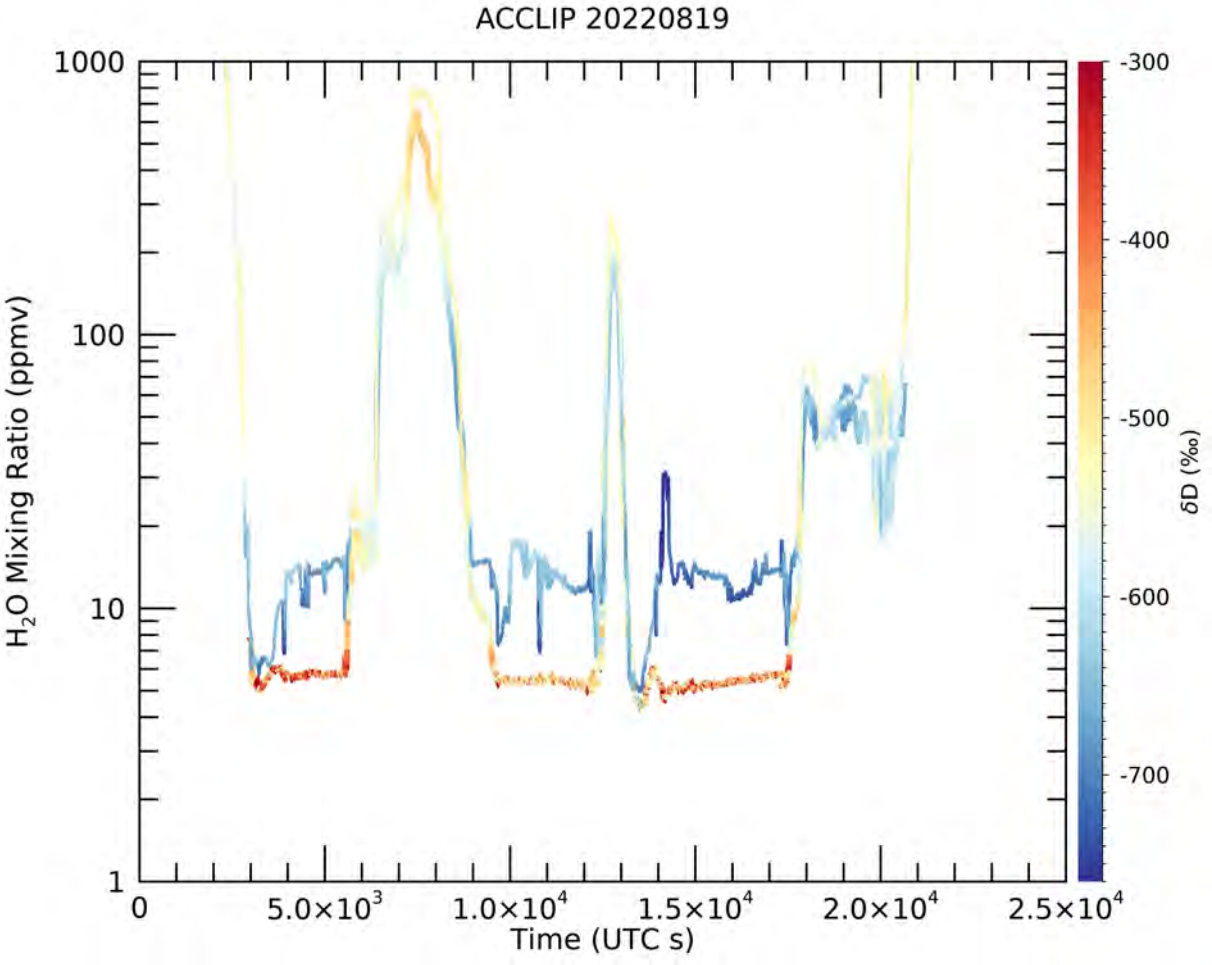

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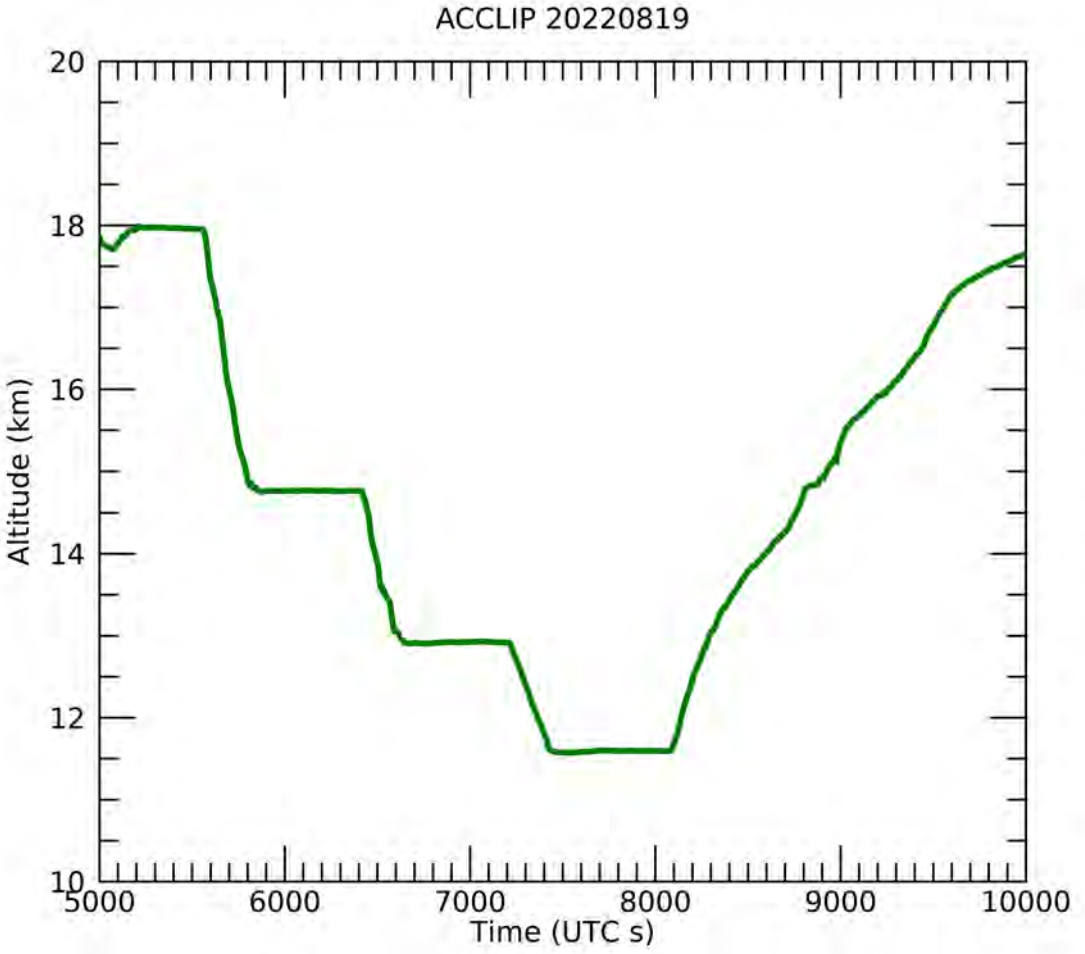


Case study from ACCLIP 2022-08-19 – Simple freezing model

Can a simple freezing model estimate our observed isotopic ratios?

This procedure captures the broad features of the water distribution but:

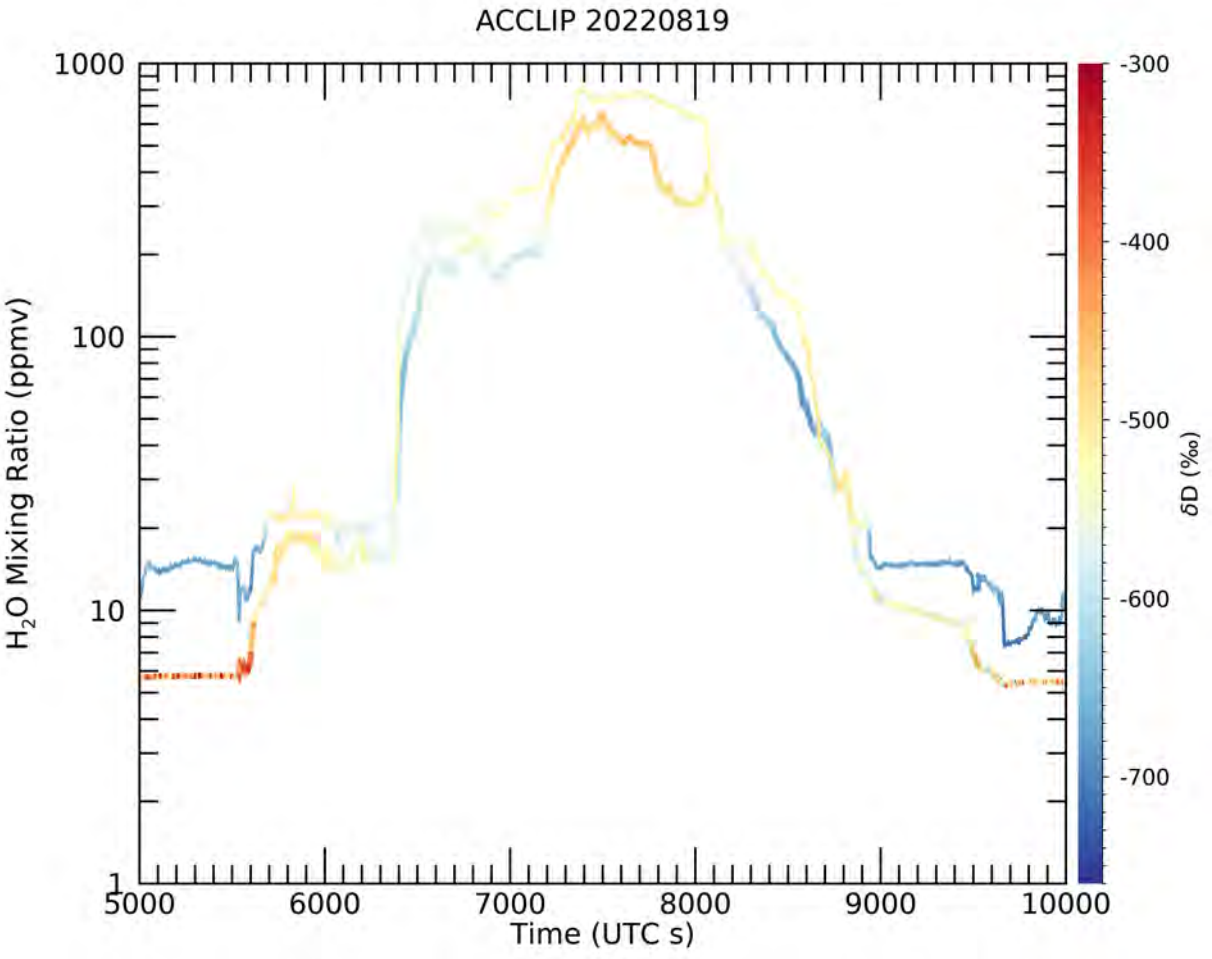
-Too wet almost everywhere

-Far too depleted at the highest altitudes

-Generally too enriched around 100 ppm of water vapor

-Move to 0.25x0.25 ERA5 in backtrajectories

-More complicated freezing model?



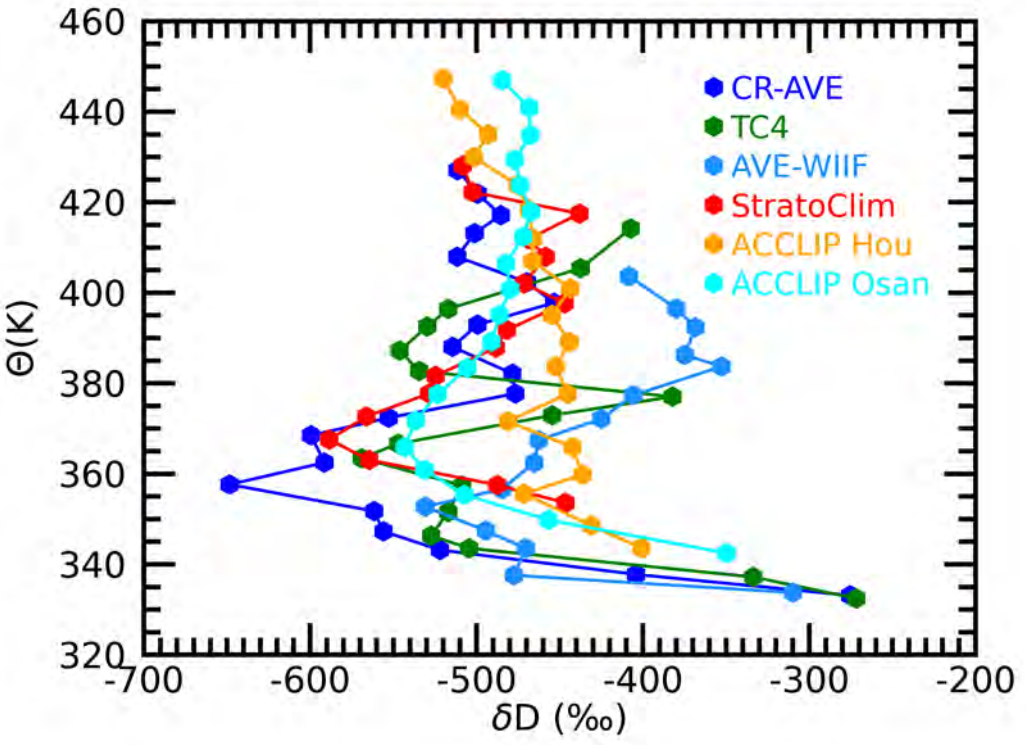
Conclusions and Future Work

- Houston, Kathmandu, and Osan all have unique isotopic profiles, although broad features are consistent with influence of deep convection
- Vertical profiles of water isotopic composition in NAM demonstrate substantial convective influence up to 415 K
- Combine backtrajectories with, e.g., GridRad to identify episodes of strong convective influence and overshooting tops – sources of NAM convection

In situ profiles show convective influence, but have unique features

Comparison to in situ measurements

- UTLS measurements in StratoClim similar to CR-AVE (Feb.) & TC-4 (Jul.) made from Costa Rica.
- AVE-WIIF measurements from Houston are 100-150 per mil enriched over the other measurements
- ACCLIP Osan and StratoClim very similar, SC slightly more depleted



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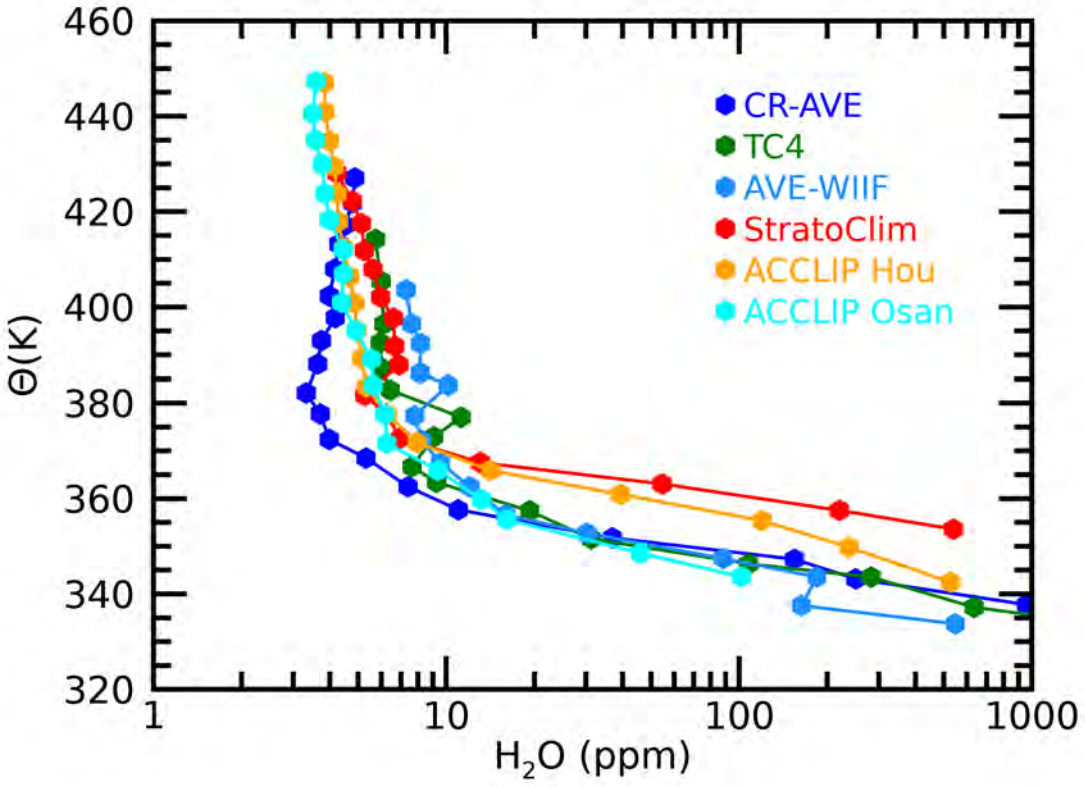
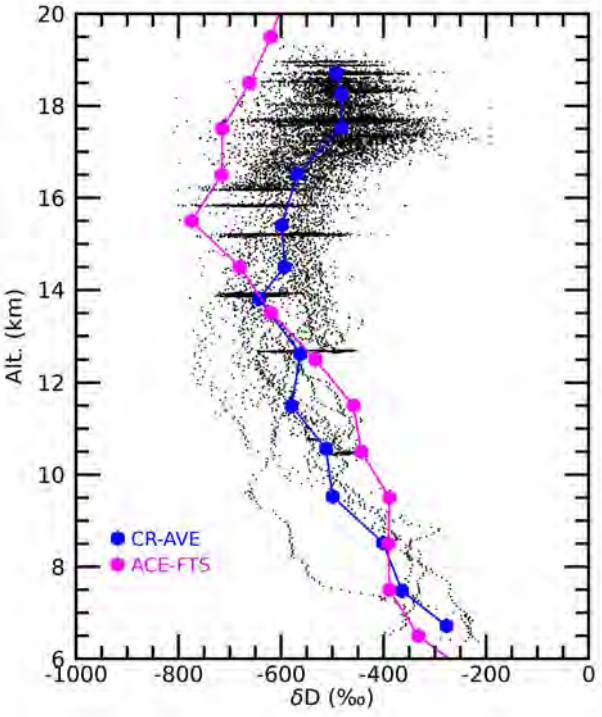
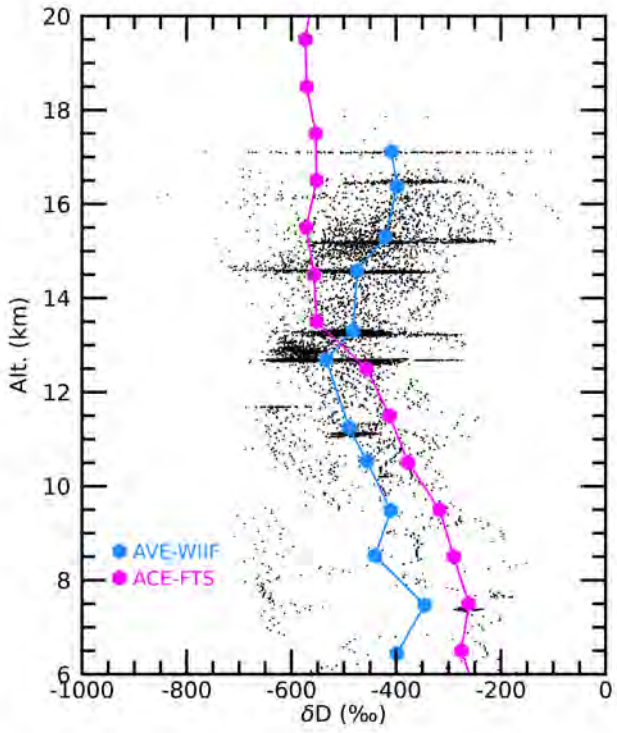
- **AM wetter than NAM (AVE-WIIF) and NA Tropics (CR-AVE & TC4) up to UT/LS base**
- **StratoClim measurements ~10 degrees warmer through tropopause than CR-AVE, ~10 degrees cooler than AVE-WIIF**

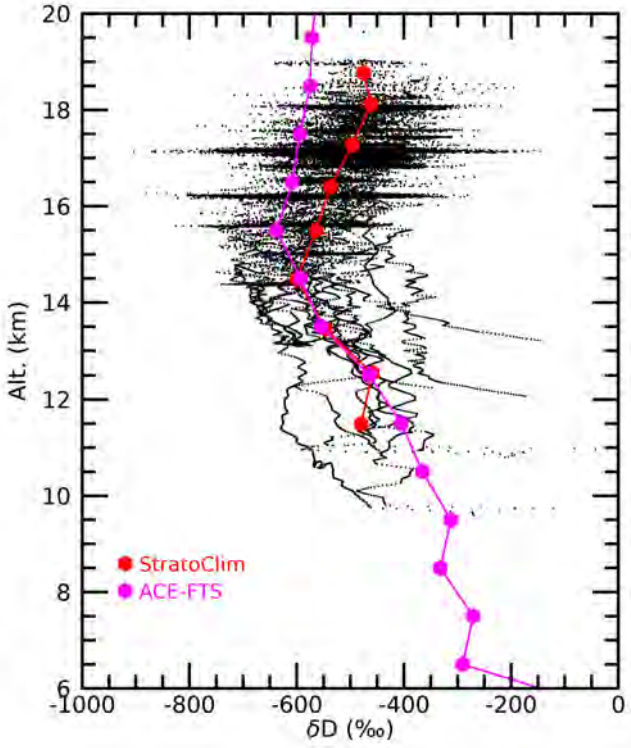


In situ vs. ACE show consistent deviation at ~14 km

In situ measurements all 100-200 per mil heavier than ACE, origin unclear







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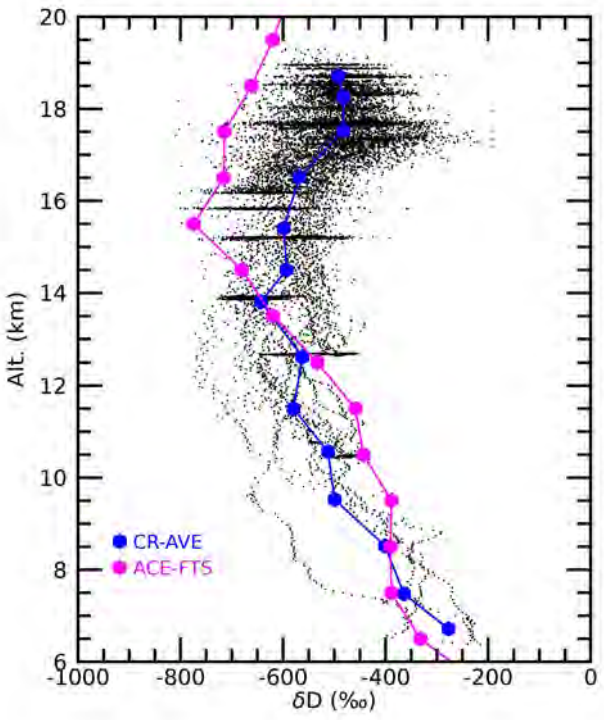
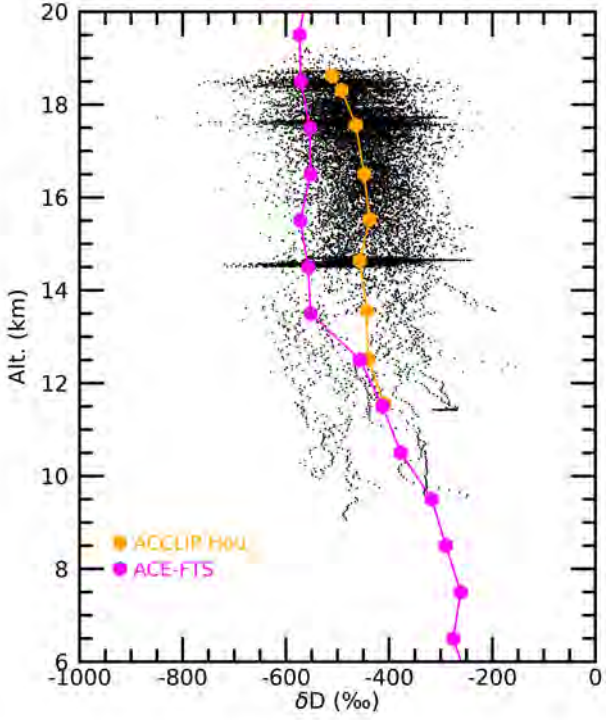
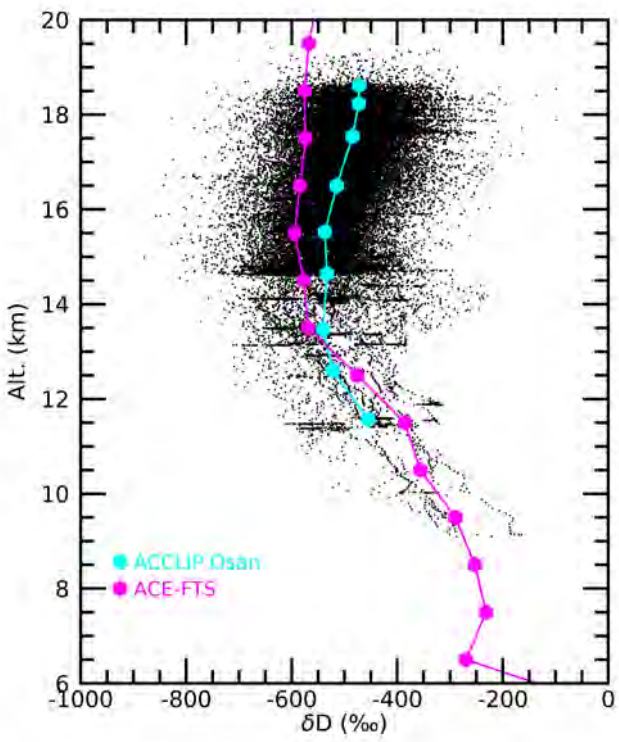
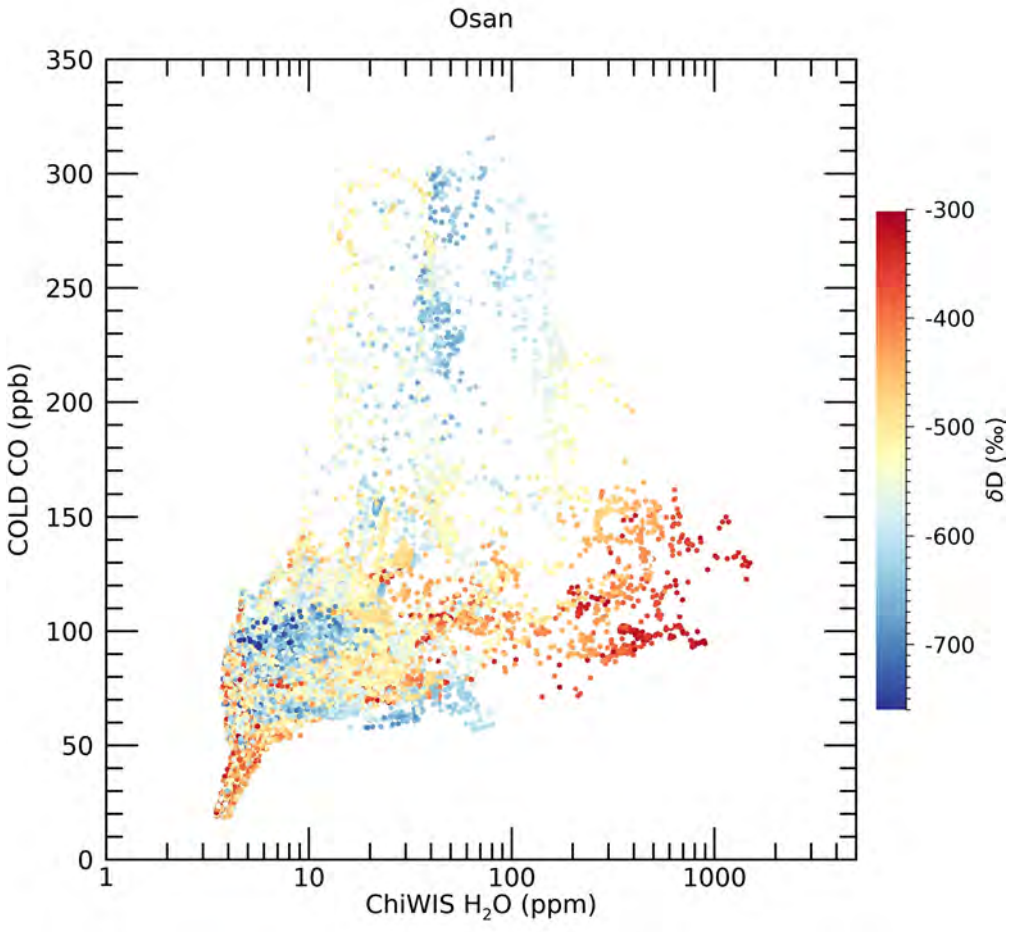






Water Isotopologue Observations by Region

- COLD2 CO vs ChiWIS water, colored by deltaD
- 8/19 feature stands out, high CO with some fairly strong depletion. Hinnanmor shows low CO with strong depletion.



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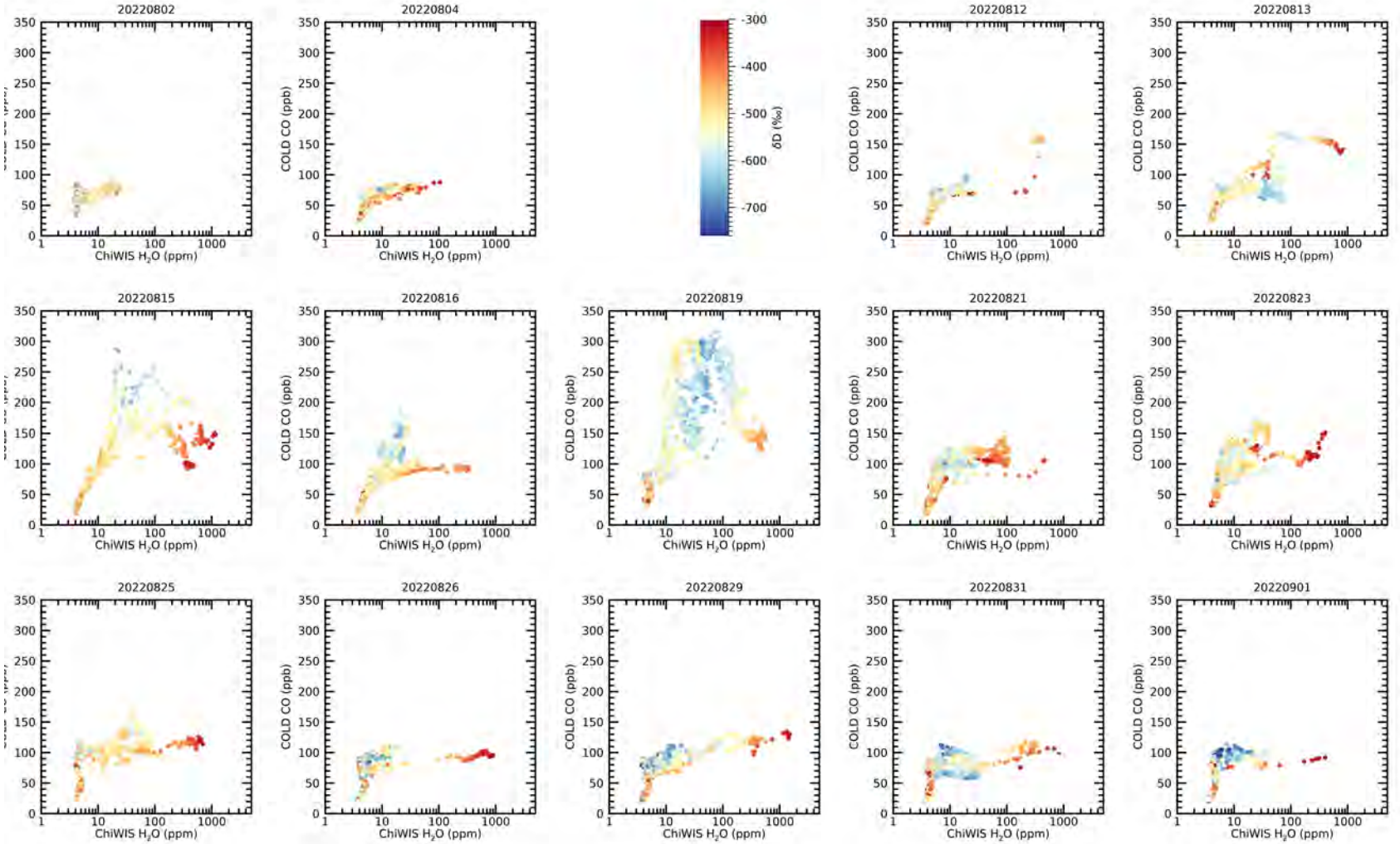

Water Isotopologue Observations by Region

- Data rebinned into 0.1x1 bins, colored by avg. deltaD
- In situ measurements by ChiWIS support satellite observations of enhanced deltaD at 16.5 km in the NAM