Thermodynamical anomalies in the upper troposphere and lower stratosphere above deep convective storms

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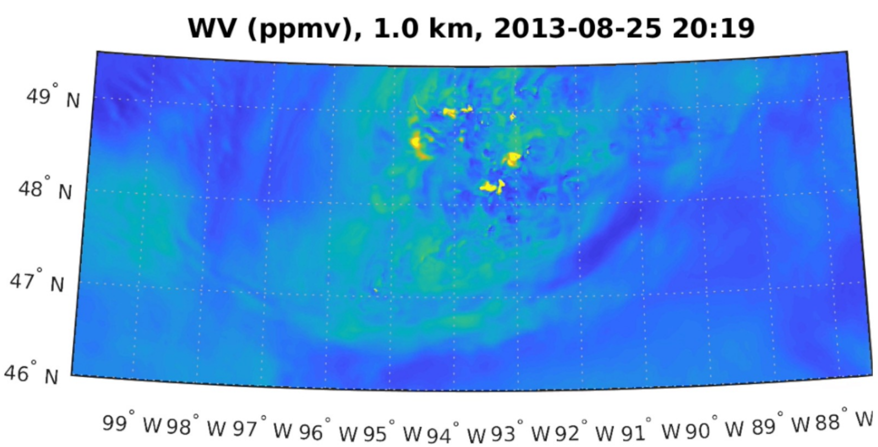
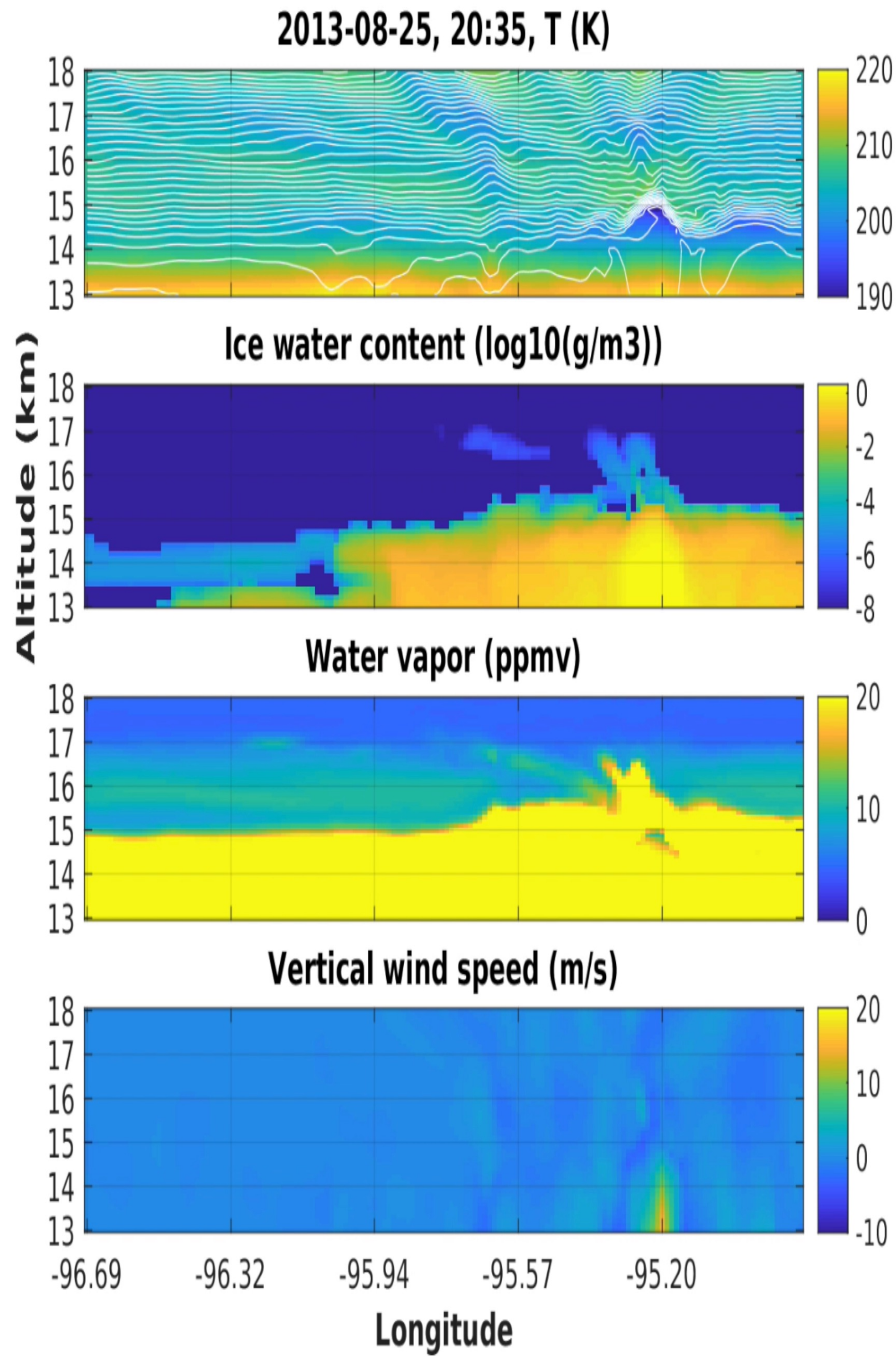
Convective impacts on UTLS

- Overshooting deep convections
  - Penetrate tropopause
  - Inject water substances
  - Perturb temperature fields

Water vapor field at tropopause (~16km)



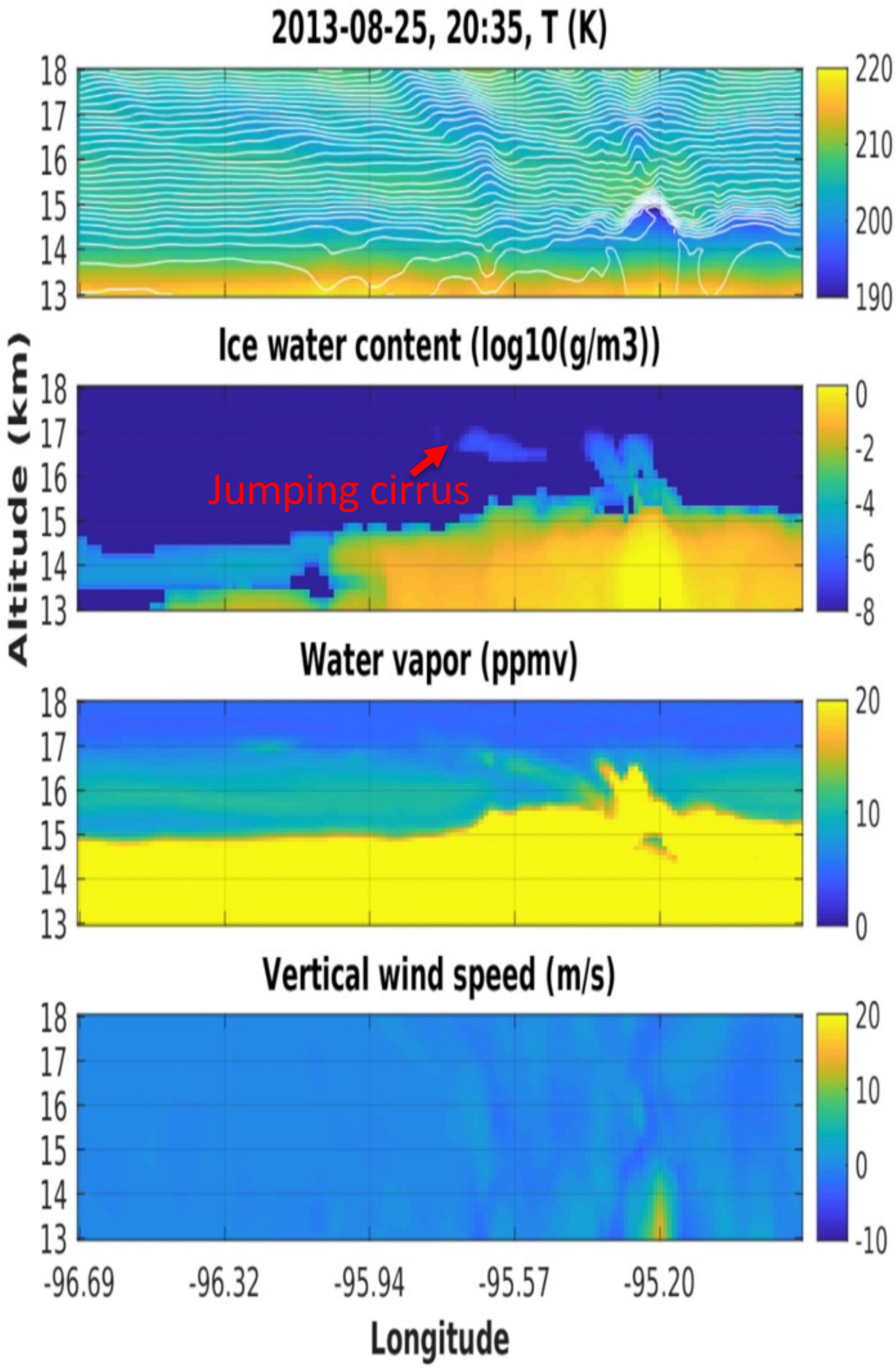
- Cloud-resolving (1-km) simulation of an overshooting convection (Qu et al. 2019)



Convective impacts on UTLS

- Consequences of Stratos. WV
  - Chemistry: e.g., ozone (Anderson 2010, 2017 vs. Robrecht 2021)
  - Radiative feedback (Forster&Shine 1999, Solomon 2010, Dessler et al. 2013, Banerjee 2019 vs. Huang 2016, 2020, Li&Newman 2020)
- Uncertainties concerning convections
  - Their trend under global warming?
  - Cooling/heating of tropopause? (Hartmann 2001, Corti 2006, Wright 2020,…)
  - Hydration/dehydration? (Danielsen 1993, Jensen 2007, …)

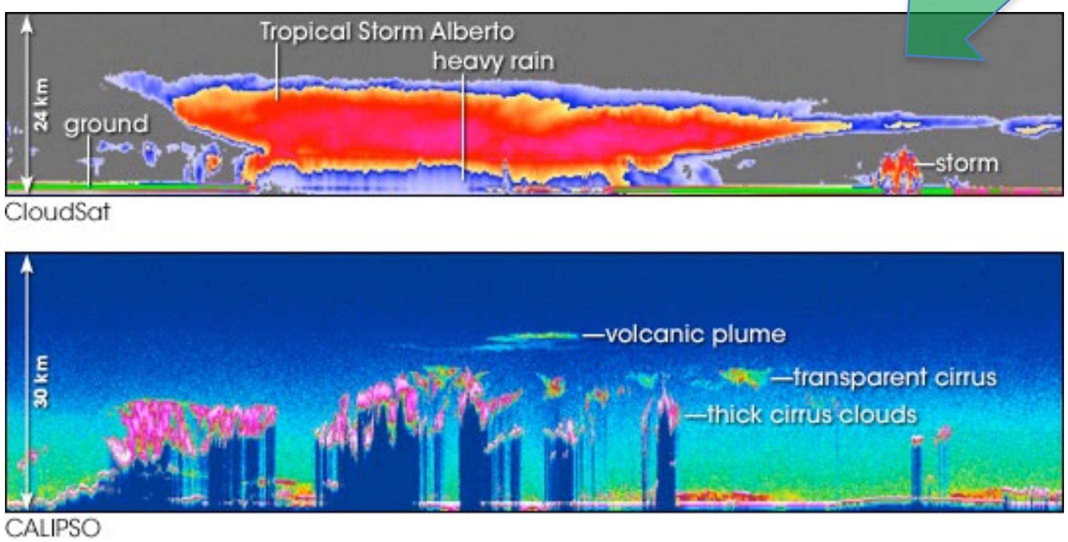
  => Need to observe collocated Cld/WV/Temp altogether!

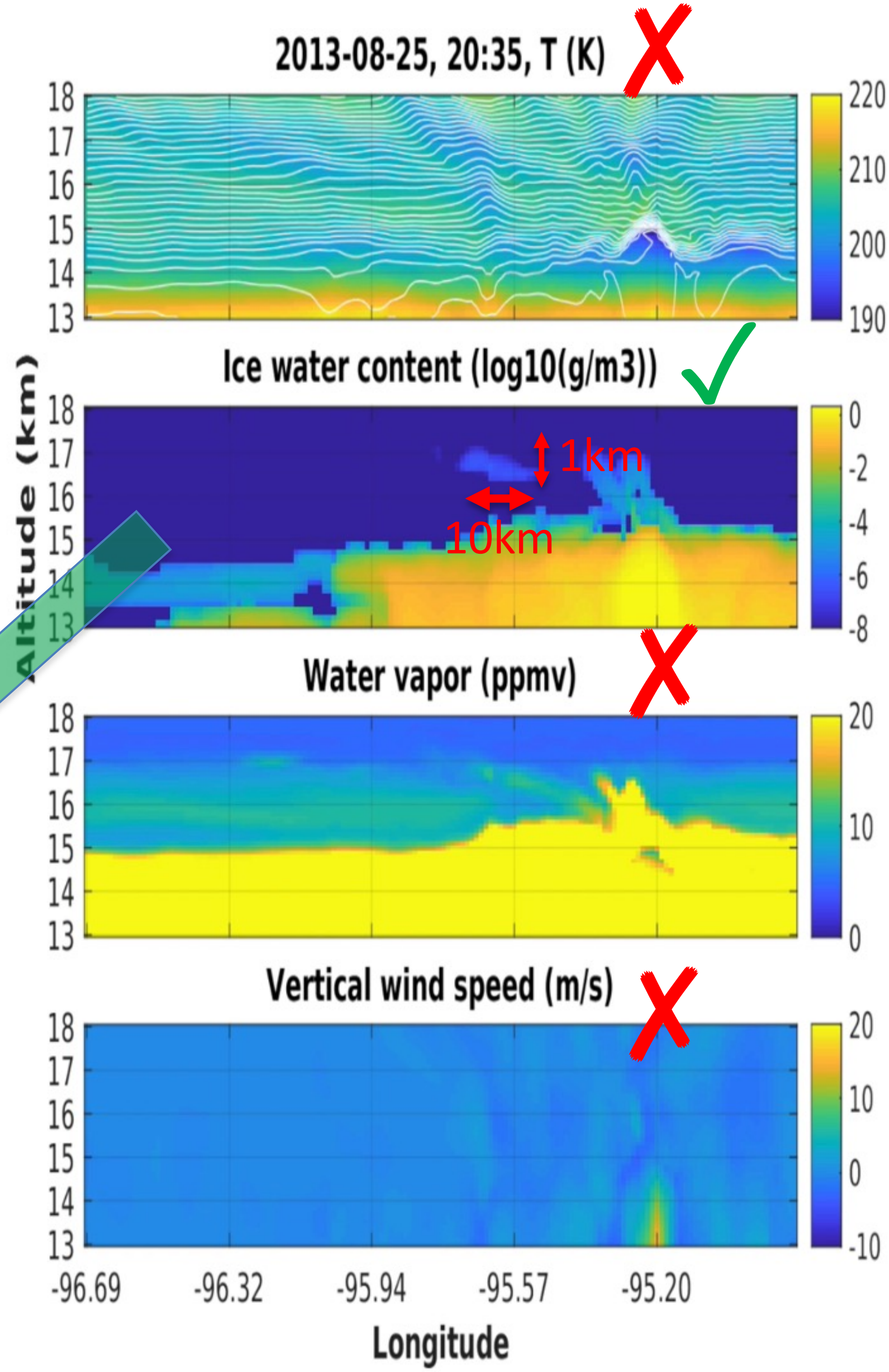


How well do we observe it?

- Hydrometeors: space lidar/radar
- Temperature?
- Humidity?
- Vacuum of thermodynamic data around convective tops!

CloudSat/CALIPSO curtain views



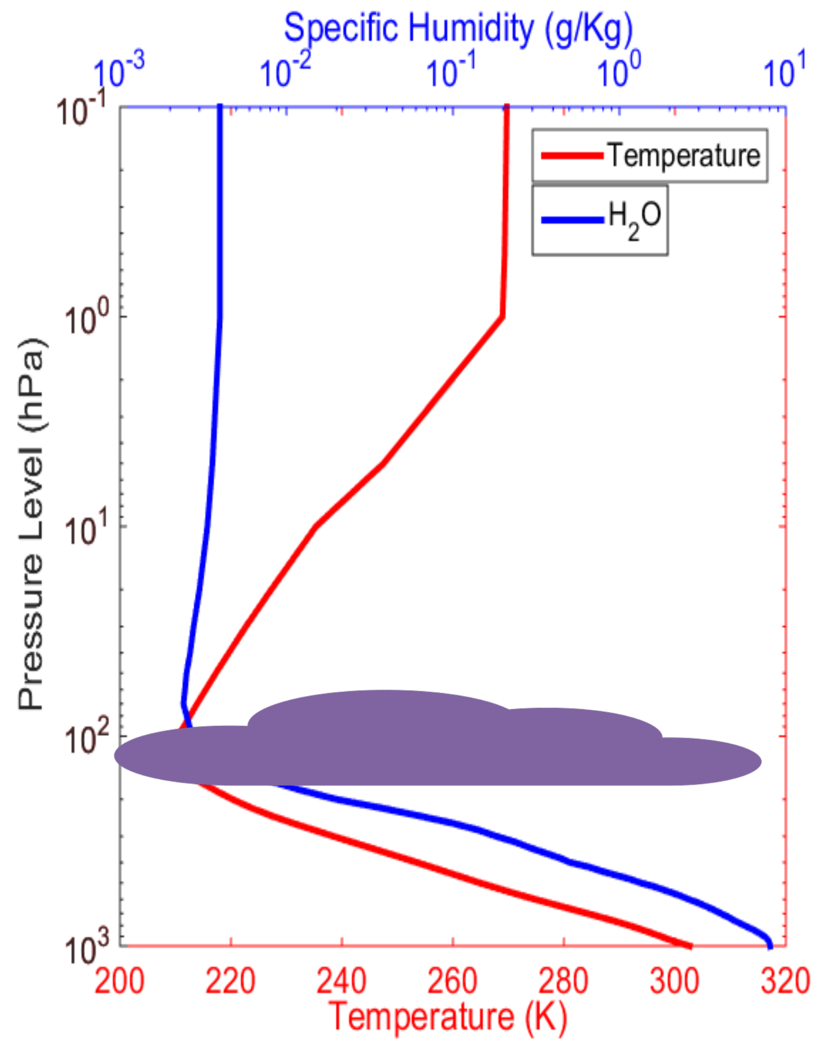


A “cloud-assisted” retrieval

- Two fundamental challenges for passive nadir sounding of UTLS WV
  - Greater WV concentrations at lower altitudes => Errors in UTLS from the smoothing effect of averaging kernel!
  - Non-monotonic temperature variation across tropopause – Errors due to ambiguity in relating radiance signal to temp/WV anomalies!

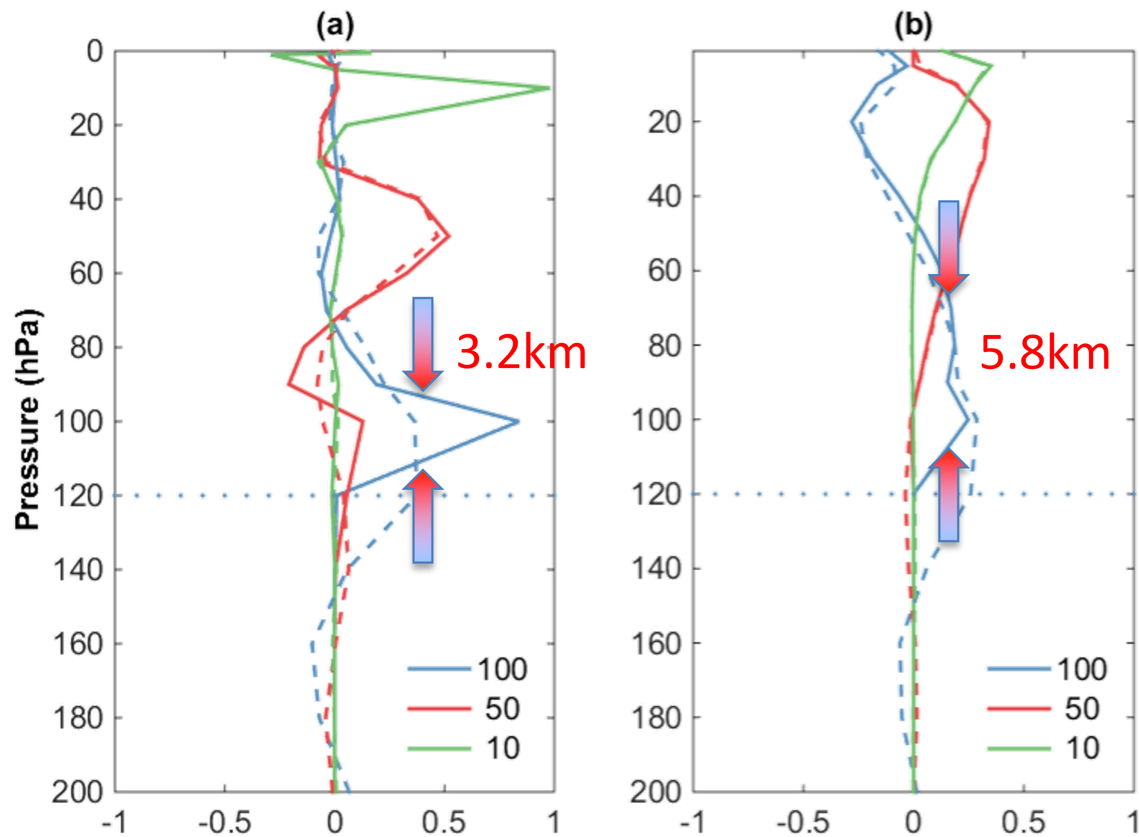
- A dense cloud layer at tropopause
  - Mitigate both issues!

    => Cloud-assisted retrieval!



Cloud-assisted retrieval

- IR hyperspectrometer-only (Feng&Huang 2018)
  - Forward model: MODTRAN
  - Inverse method: Optimal estimation (Rodgers 2000)
  - Validations: against aircraft data
  - Slab cloud assumption limits retrieval accuracy near cloud top
- Synergistic: IR+active cloud sensors (Feng et al. 2021; Feng&Huang 2021)
  - CloudSat/CALIPSO=>cloud top location=>cloud emission=>improved T, q retrieval



Averaging kernels of a) temp and b) WV at three levels. Dash: clear-sky; solid: cloud-assisted. (Feng & Huang 2018)

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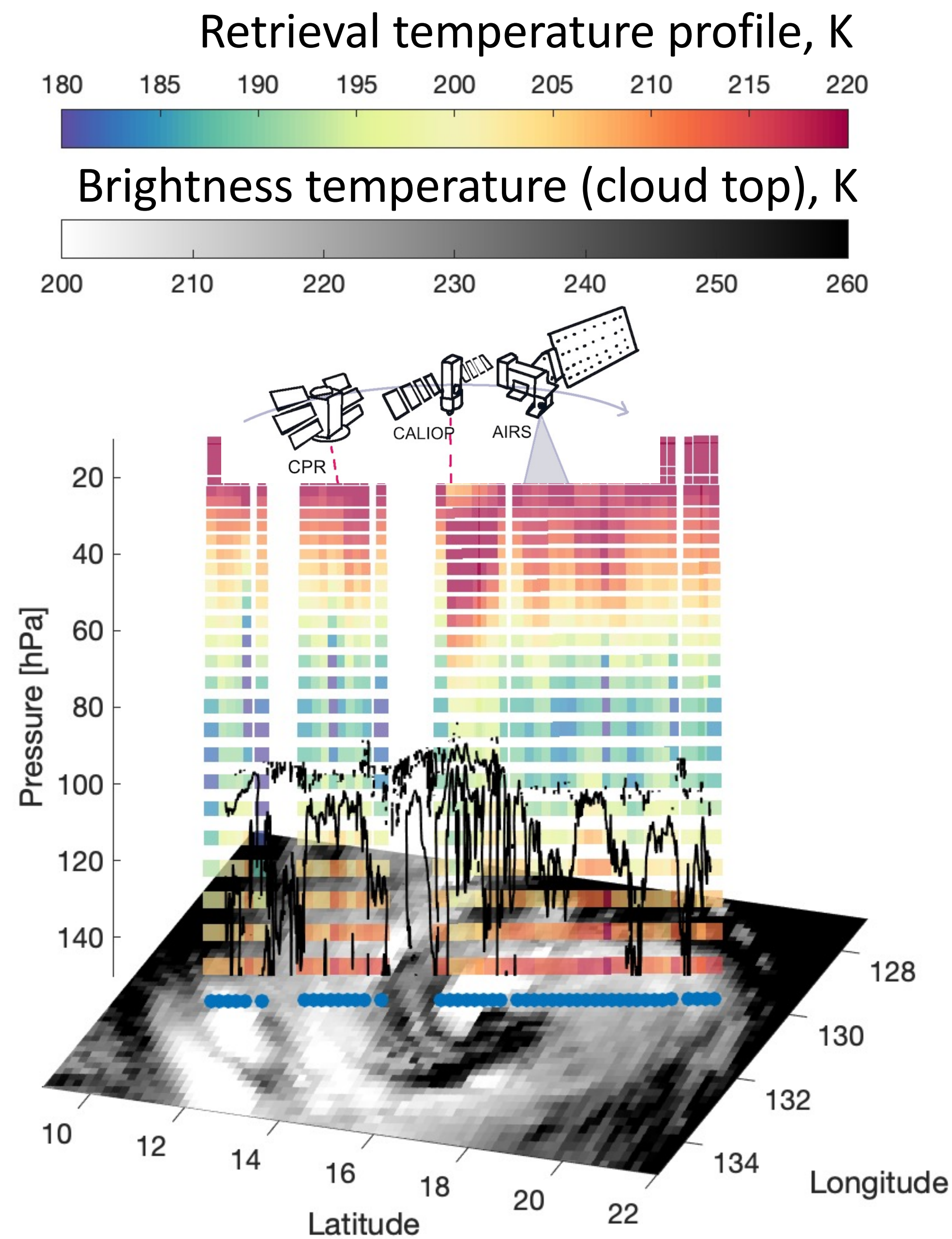
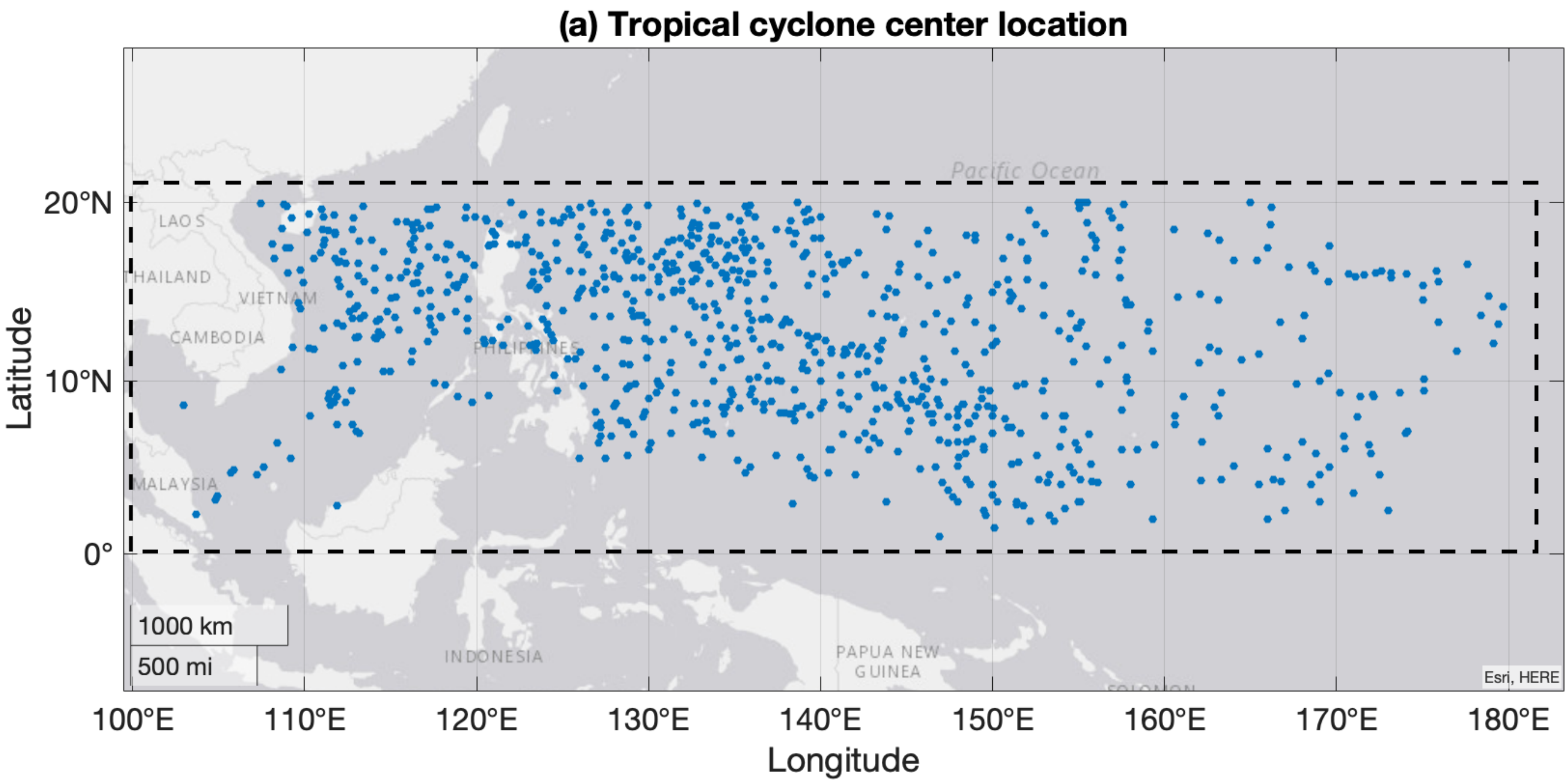


Feng & Huang 2020, 2021

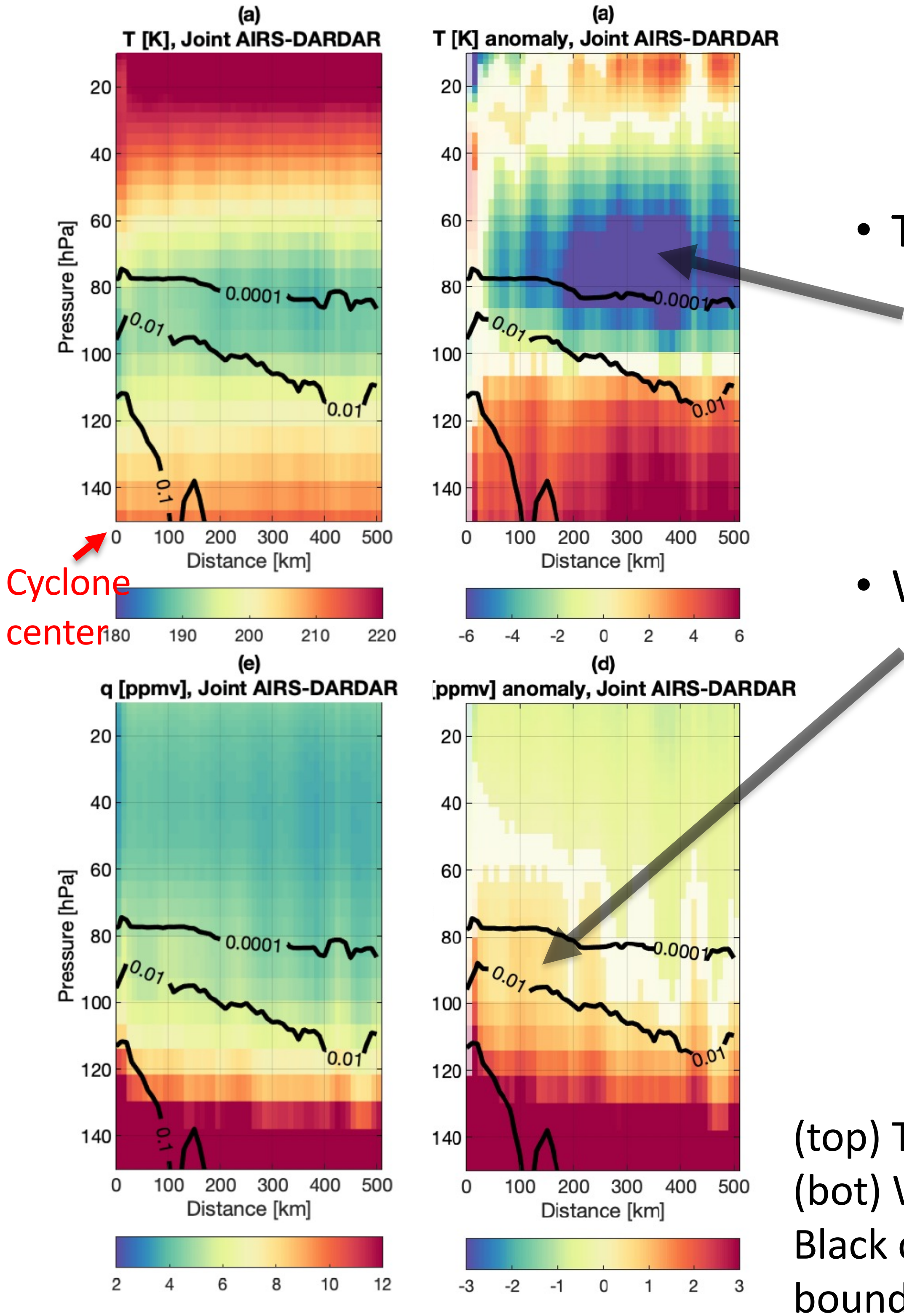
Application: Retrieval of thermodynamical fields above tropical cyclones



Distributions of cyclone centers passed over by A-Train from 2006 to 2016 over the northern part of the West-Pacific region

947 cyclone overpasses, 2735 profiles retrieved

(Feng & Huang 2021)



T, q retrieval

- Temperature
  - Cold anomaly above cyclones, in agreement with radio occultation results (e.g., Rivoire et al. 2016)

    => Cloud top rad cooling?
- WV
  - Moist anomaly near the center (<=200km)

    => Overshooting injection
  - Dry anomaly further away

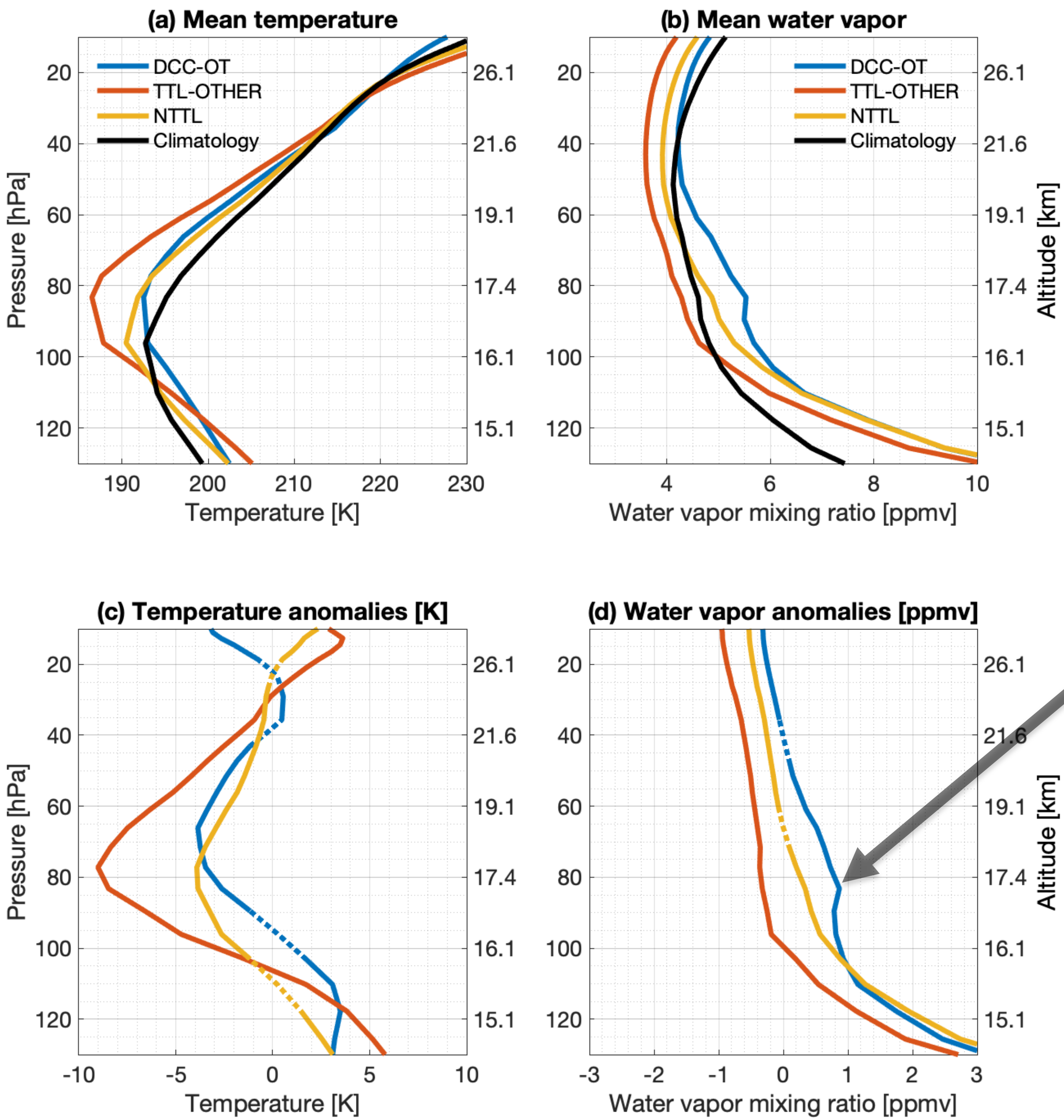
    => Dehydration induced by cooling?

(top) Temperature and anomaly

(bot) WV and anomaly

Black contours: ice concentrations – cloud boundaries (Feng & Huang 2021)

Characteristic T, q in diff situations

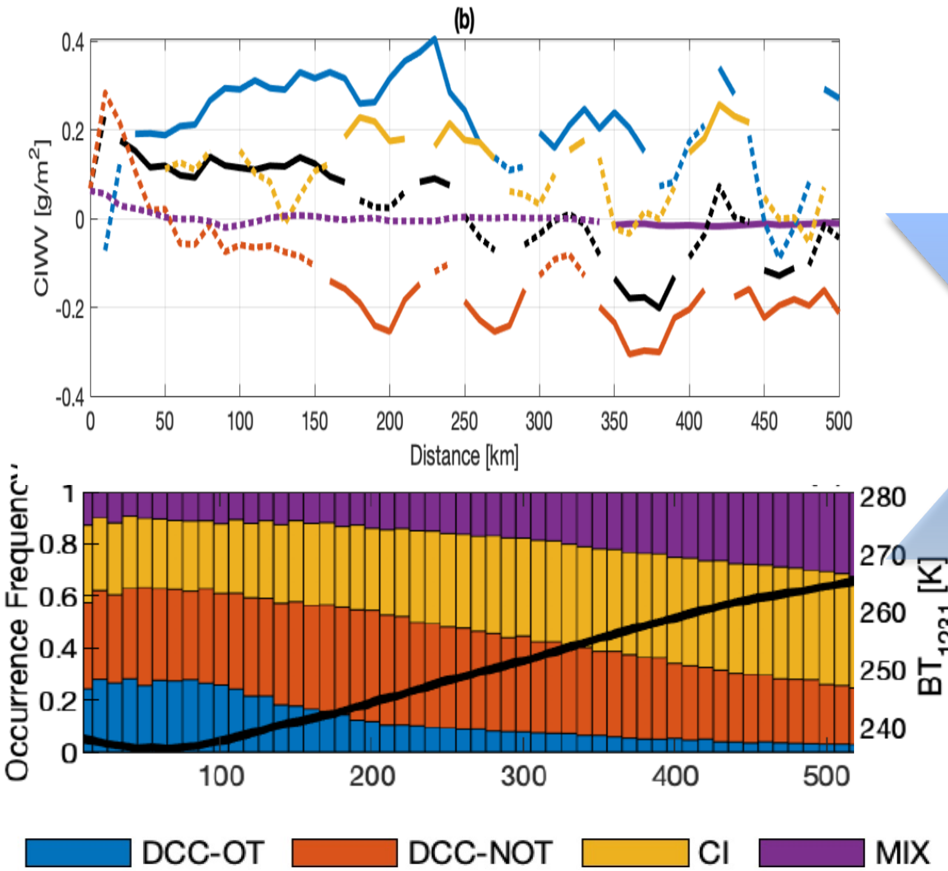


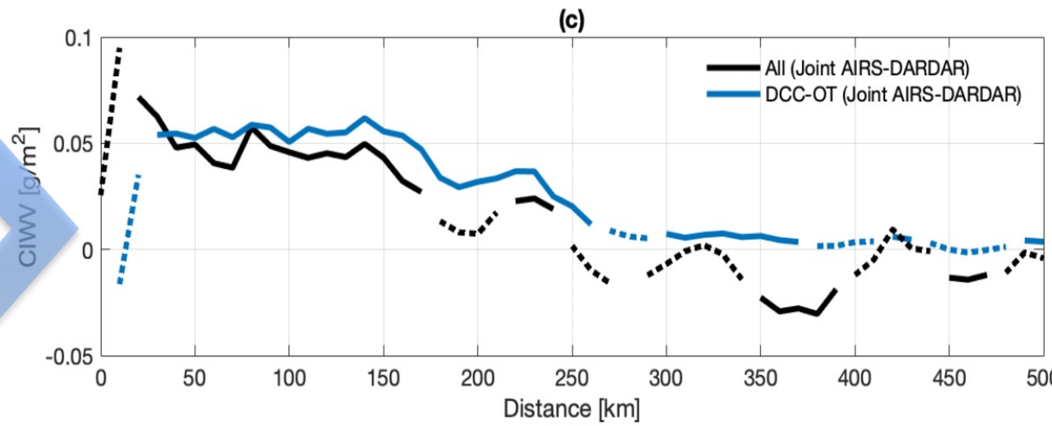
- DCC-OT: overshooting convection
- TTL-Other: non-OT clouds in TTL
- NTTL: no cloud in TTL

- Colder/higher CPT

- Hydration near/above overshooting clouds
- Dehydration above cirrus (anvil) clouds

Assessment of moistening effect



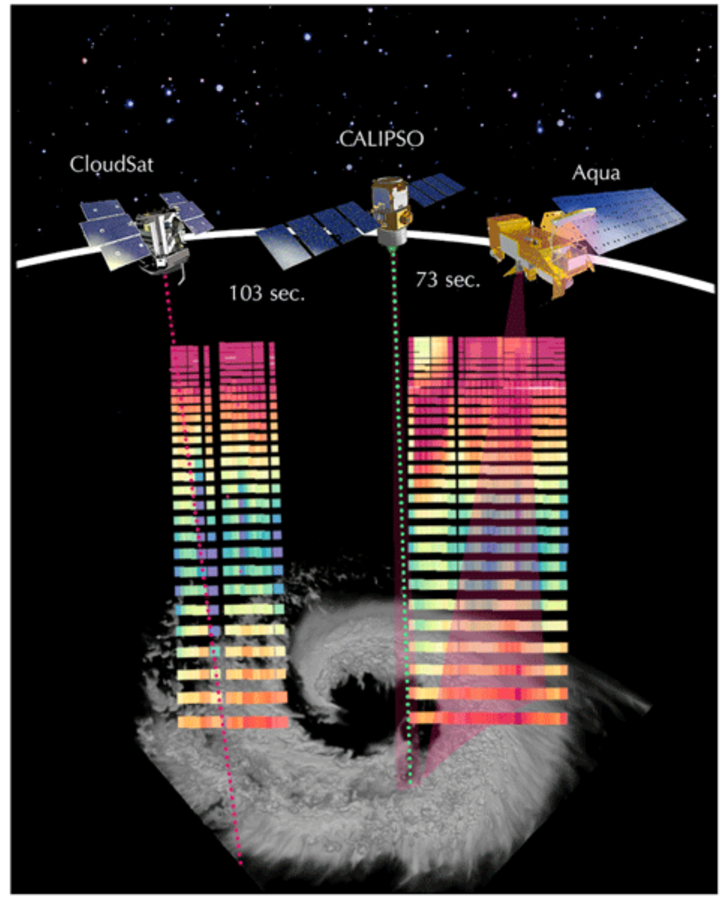


- DCC-OT: overshooting convections
  - Can increase CIWV by up to 0.4 g m^{-2} (+25%)
  - Convoluted with its occurrence freq, this translates to a 0.024 g m^{-2} (+0.7%) moistening above the cyclones.

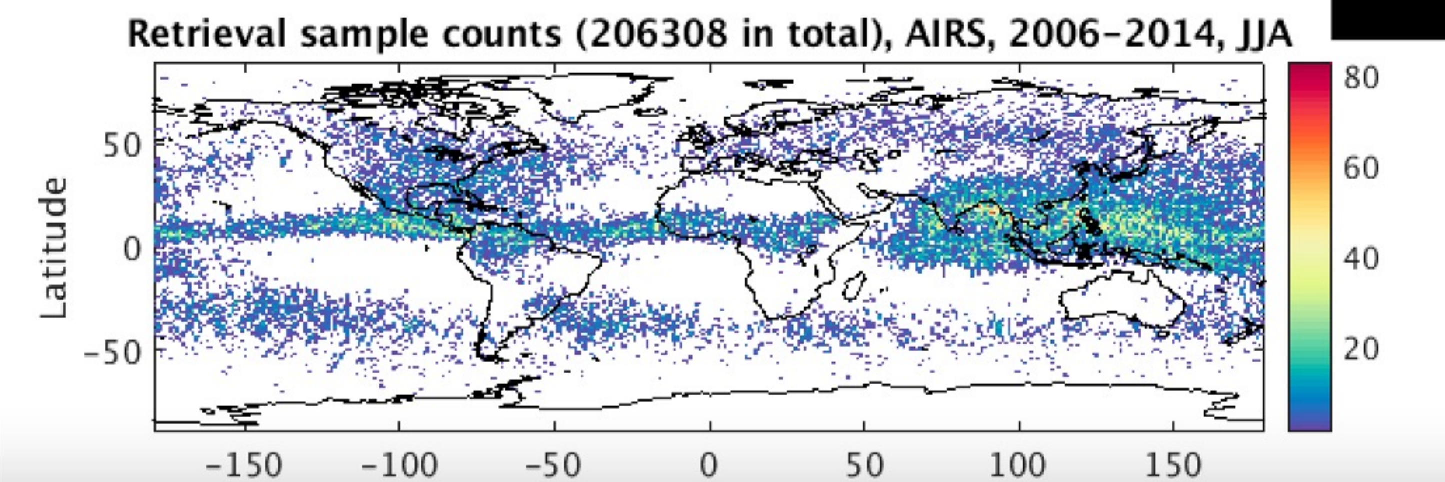
Top: anomalies in column integrated WV above cloud associated with diff cloud types
Bot: occurrence freq of diff clouds
(Feng & Huang 2021)

Take-home messages

- A new nadir IR hyperspectral retrieval technique is probing the thermodynamic fields in the lower stratosphere, filling the data vacuum near and above deep/overshooting convection tops. [Feng et al. 2021 Atm. Meas. Tech., Feng & Huang 2021 Atmos. Chem. Phys.]



- Future work



Potential A-train samples for the synergistic cloud-assisted retrieval
Next aim: extratropical deep convections, IASI, FORUM (?)