Impact of Overshooting Deep Convection on the Stratospheric Water Vapor: an A-Train Satellite View

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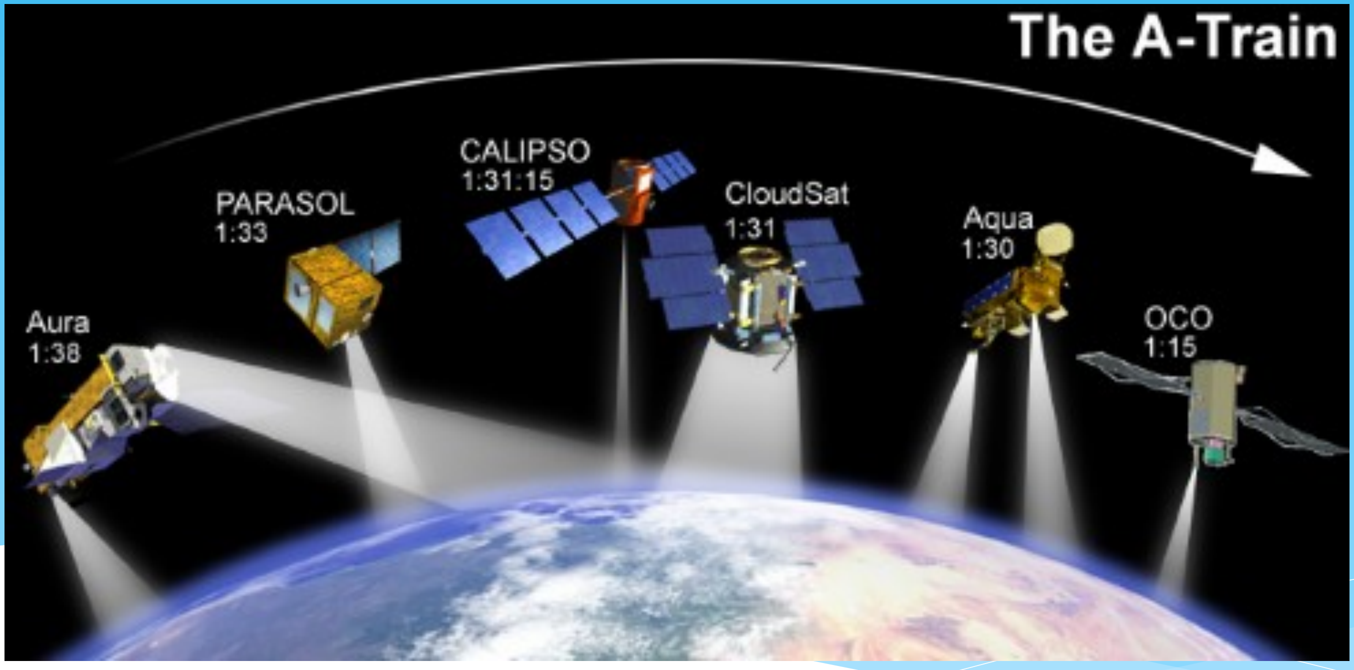


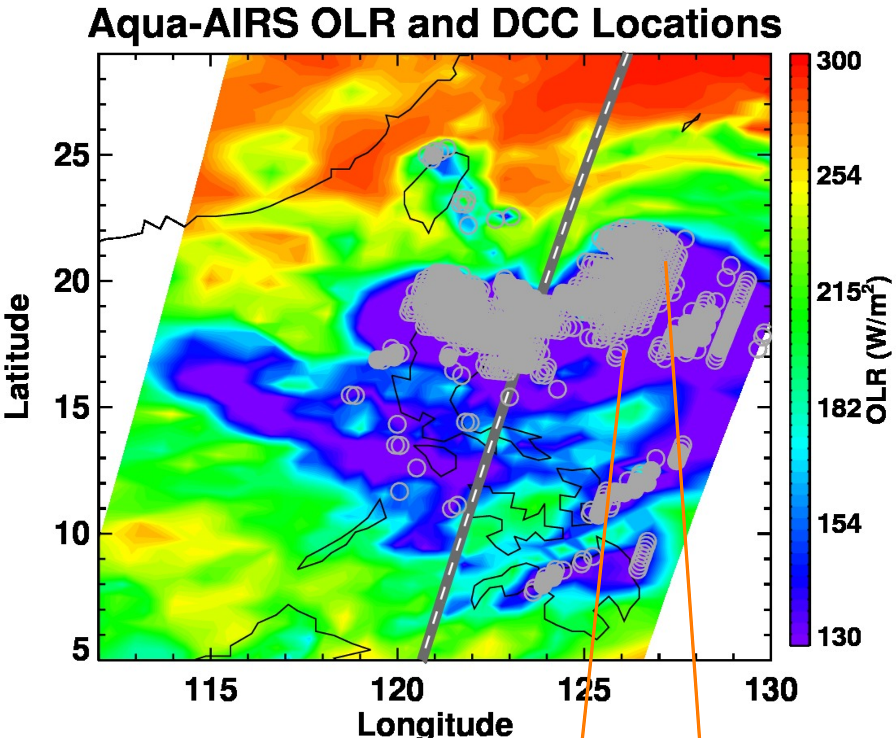
Composition and Transport in the Tropical Troposphere and Lower Stratosphere, July 20-23, 2015, Boulder, CO

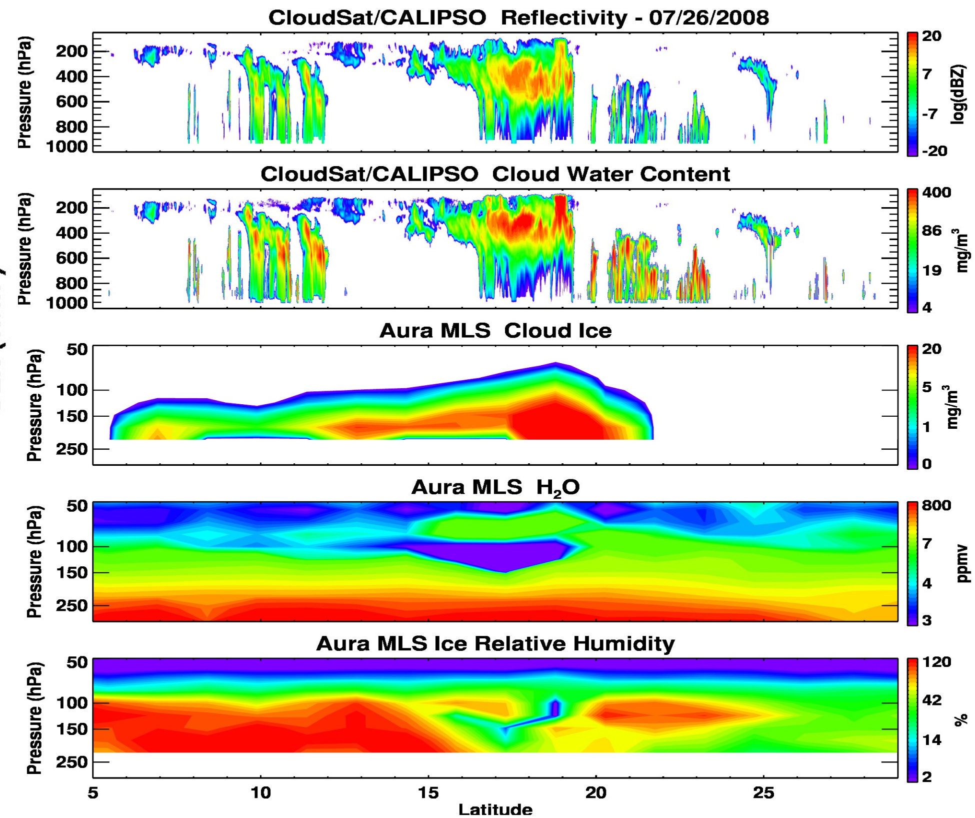
Objectives

- Does overshooting deep convection (ODC) hydrate or dehydrate the lower stratosphere and by how much?
- How does the convective influence on the stratosphere water vapor (SWV) evolve with climate change ?

- ❑ Combine deep convective clouds (DCC) measurements from CloudSat and Atmospheric Infrared Sounder (AIRS) on Aqua with the UTLS data from the Microwave Limb Sounder (MLS) on Aura.

A-Train Advantage



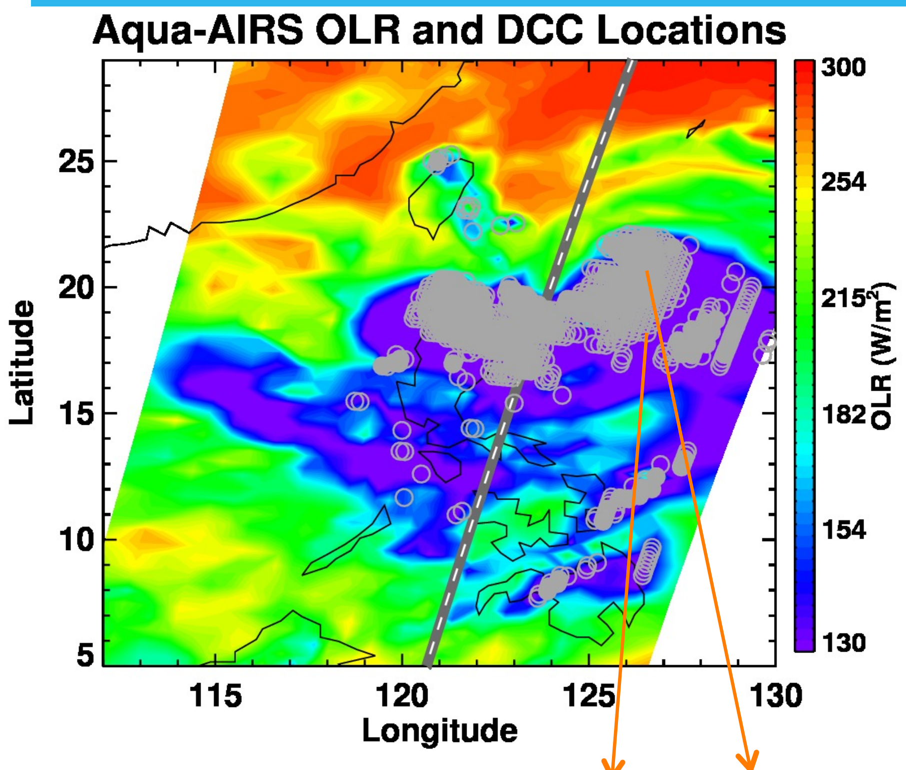


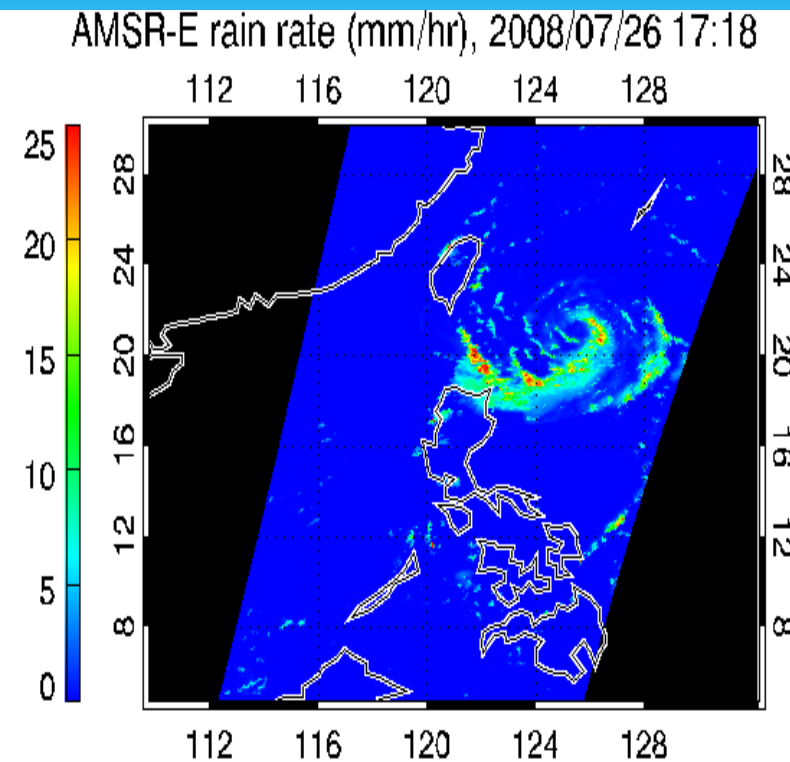
DTW = $BT_{1231} - BT_{1419} < 0$ or < -4

Aumann and Ruzmaikin (2013, ACP)

- AIRS: broad spatial coverage
- CloudSat: vertically resolved cloud structure
- MLS: vertical resolved water vapor and temperature profiles

AIRS DCC





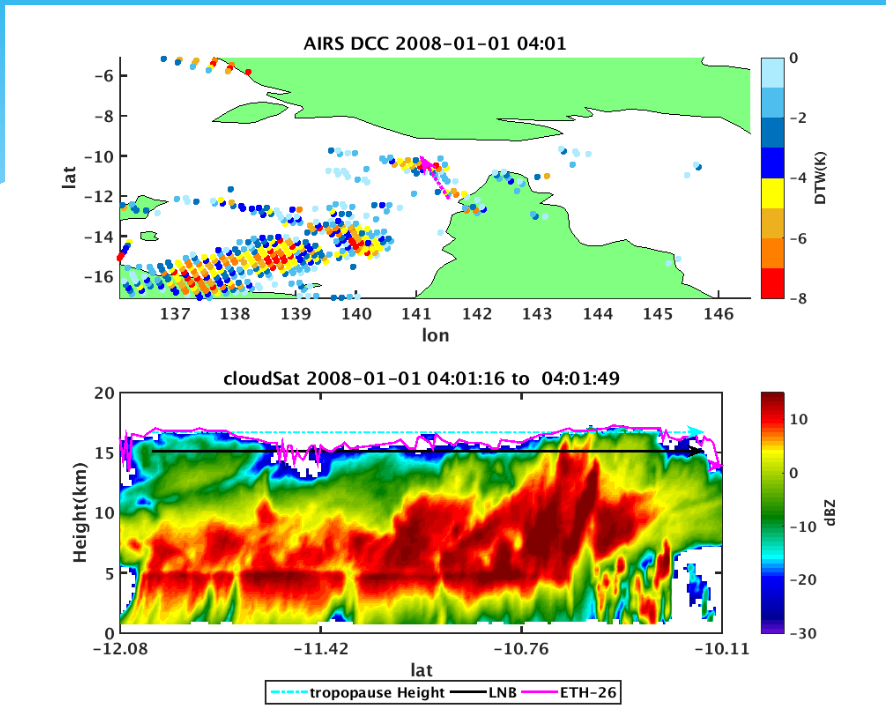
$DTW = BT_{1231} - BT_{1419} < 0$ or < -4

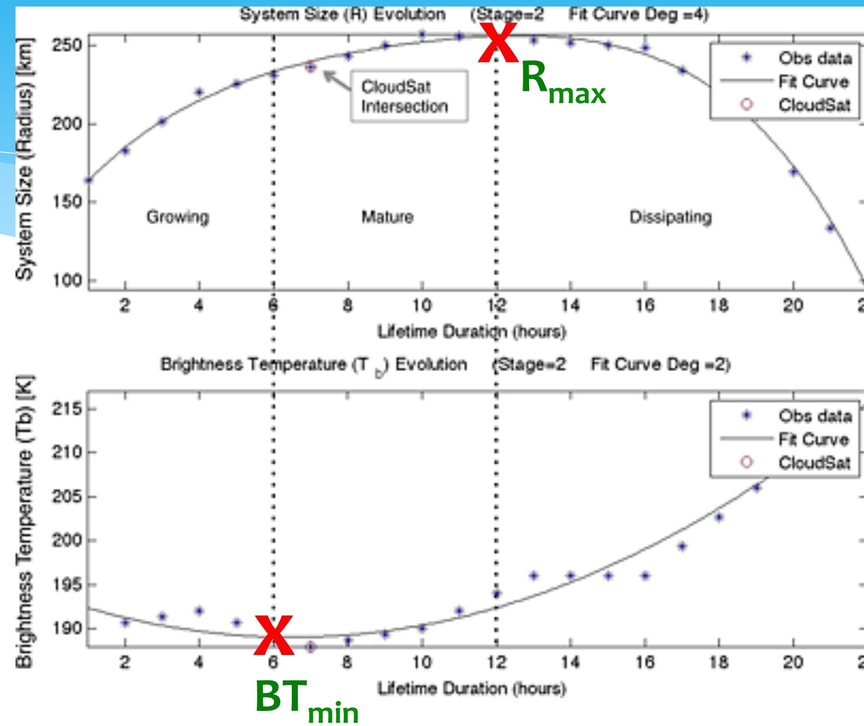
Aumann and Ruzmaikin (2013, ACP)

Table 1. Percent of DCCs identified with various IR brightness temperature thresholds and differences, segregated by surface type and time of day, from AIRS data in 2002–2012.

	Threshold	Tropical zone	Ocean day	Ocean night	Land day	Land night
DCC210	bt900 < 210K	0.800	0.557	0.650	0.932	1.09
DCCw0	bt1231 − bt1419 < 0	0.644	0.501	0.629	0.847	1.01
DCCw4	bt1231 − bt1419 < −4	0.158	0.107	0.184	0.235	0.165
DCC200	bt900 < 200K	0.140	0.092	0.161	0.197	0.139
DCCt2	bt900-T_{Trop} < 2	0.061	0.031	0.070	0.072	0.130

CloudSat ODC





CloudSat ODC selection criteria:

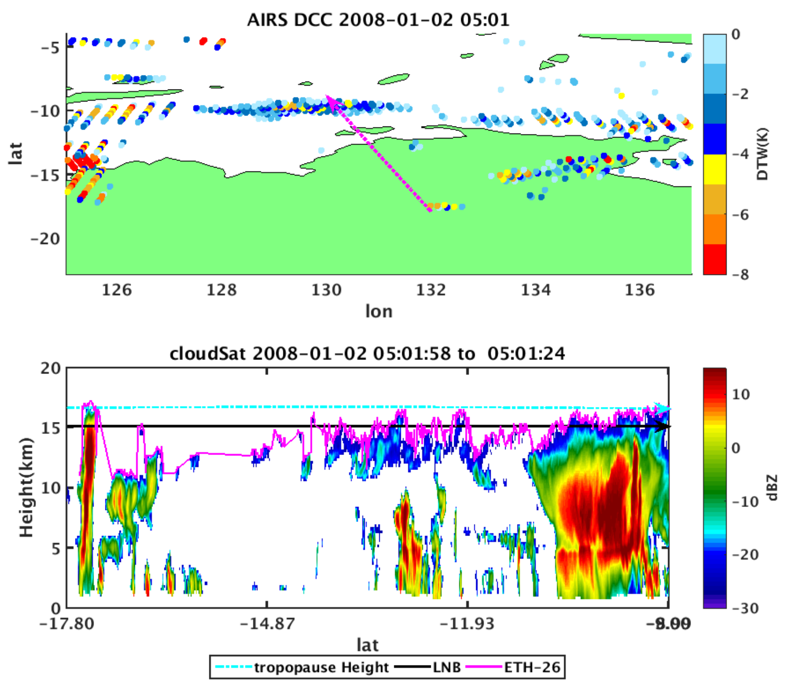
1. Cloud class: deep convection clouds
2. Cloud Top Height (CTH) ≥ 10 km
3. Cloud Base Height (CBH) ≤ 2 km
4. Continuous radar echo
5. CTH = LNB + δ (δ > 0)

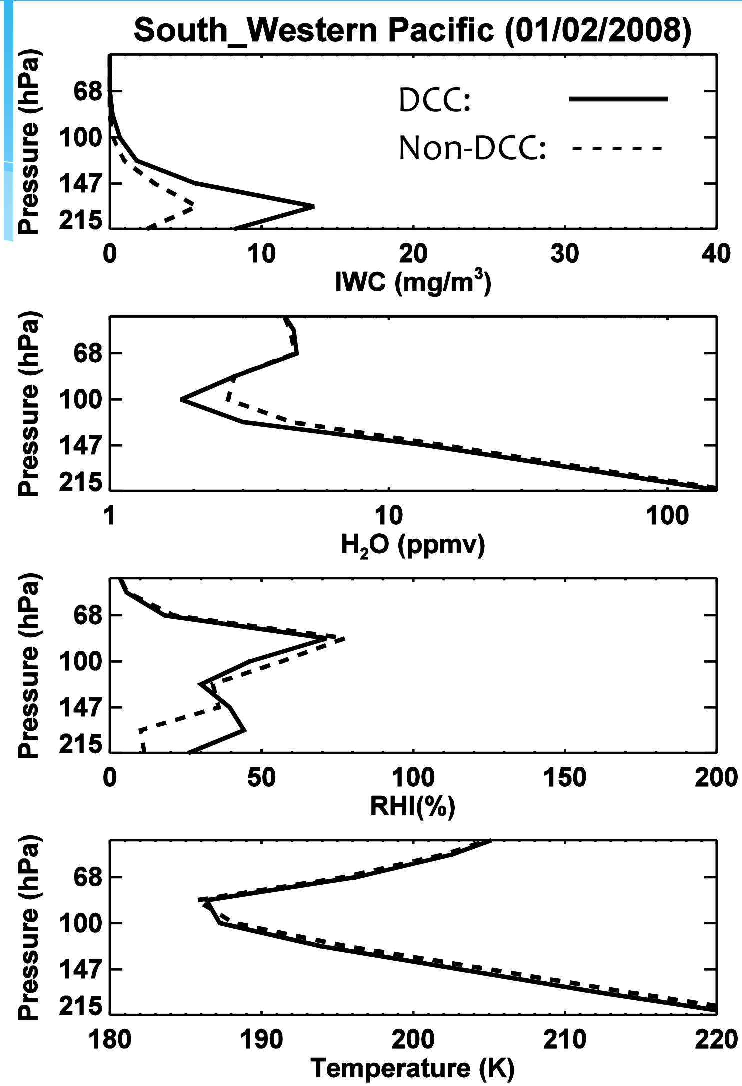
ISCCP-CT:

- Growing stage: before reaching BT_{min}
- Dissipating Stage: after reaching R_{max}
- Mature Stage: in-between growing and dissipating stages

Takahashi and Luo (2014)

A DCC in Western Pacific (winter)



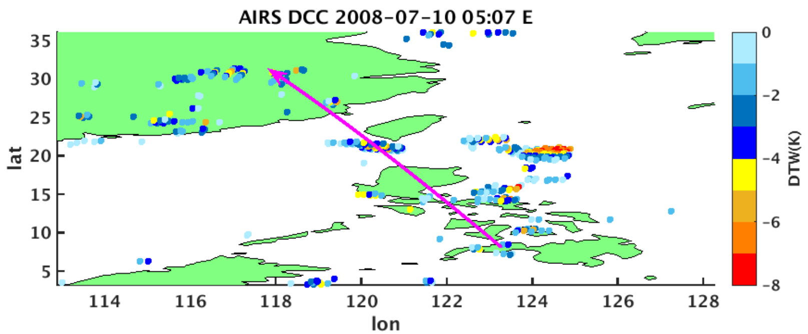


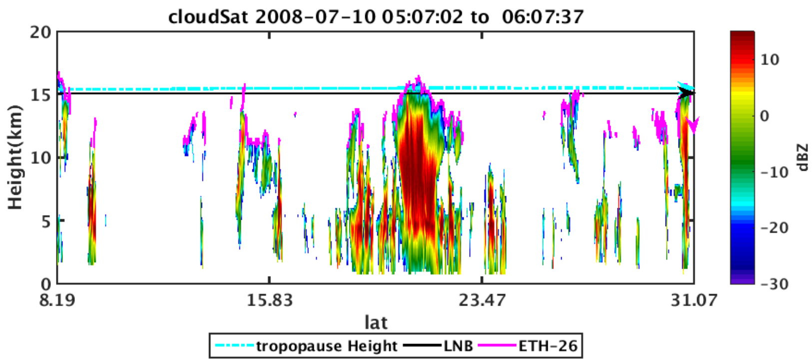
83 hPa H_2O
DCC: **2.8**
Non-DCC: **2.8**

DTW = −5.2 K
CTH = 17.3 km
TH = 16.7 km
TH: tropopause height

- Dehydration in the TTL, no difference in the LS

A DCC in Western Pacific (summer)

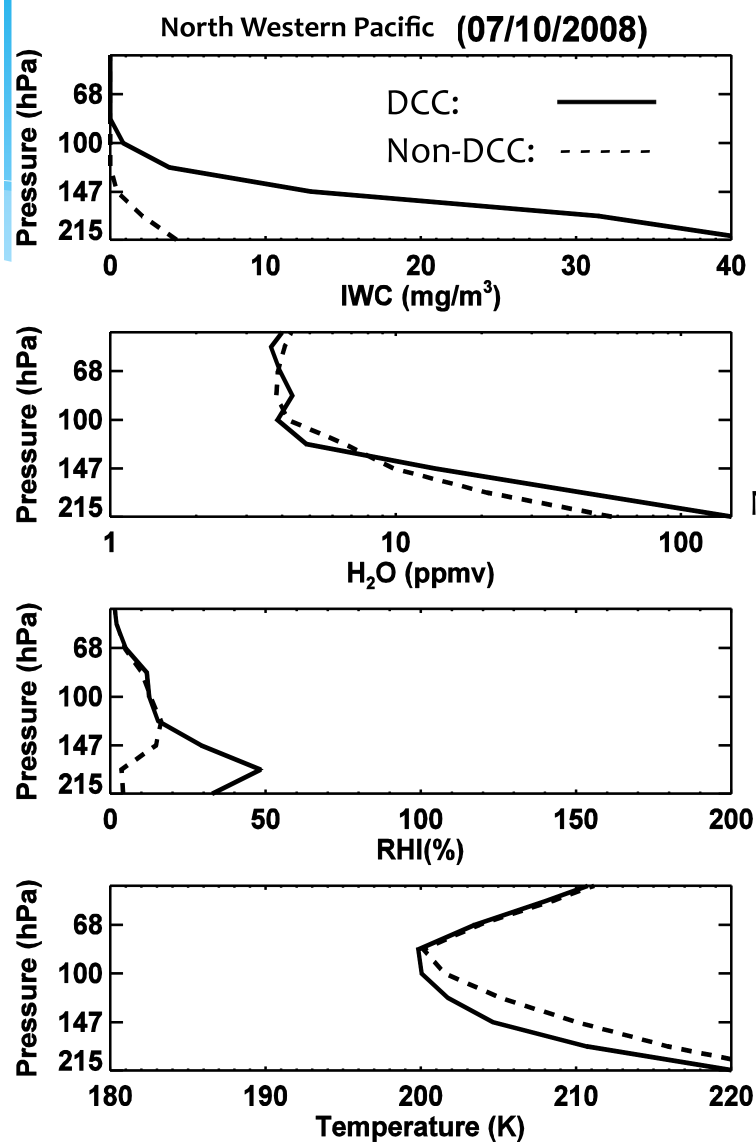




DTW = −5.2 K

CTH = 16.5 km

TH = 15.5 km



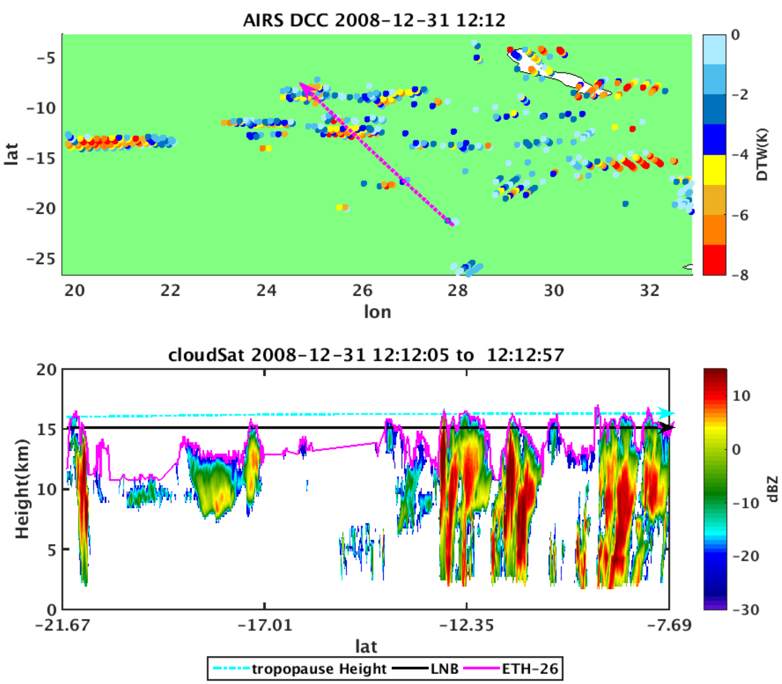
83 hPa H_2O

DCC: 4.3

Non-DCC: 3.8

- Dehydration in the TTL, hydration in the LS by 0.5 ppmv

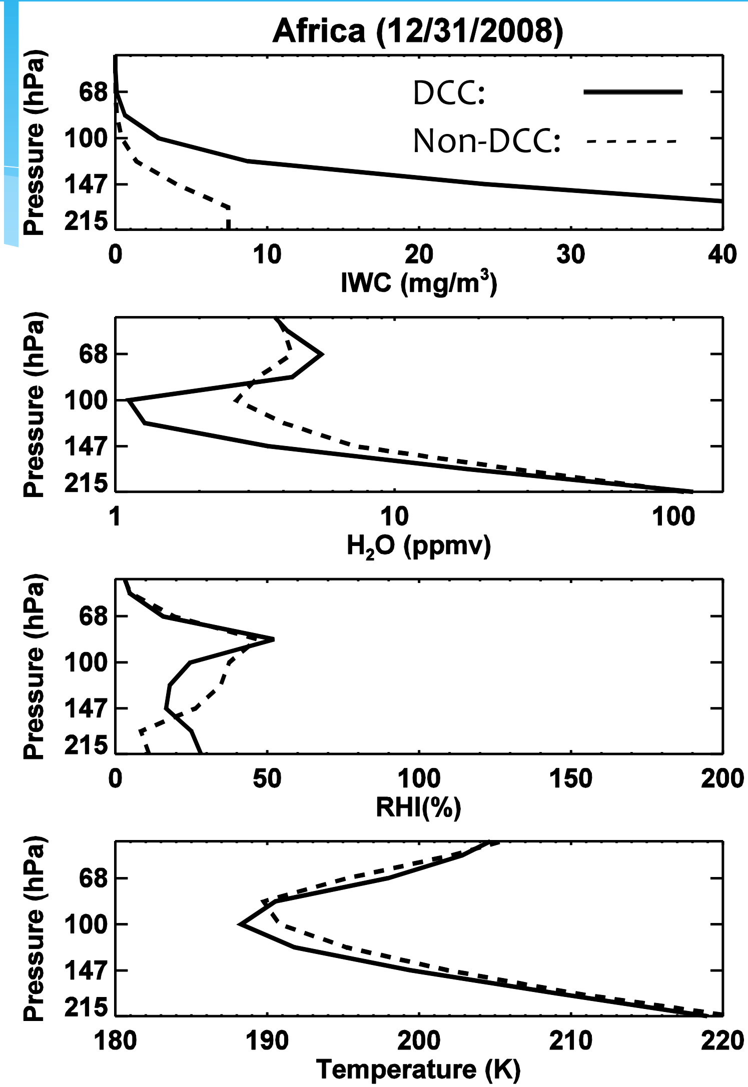
A DCC in Central Africa (austral summer)



DTW = −6.0 K

CTH = 16.5 km

TH = 16.3 km



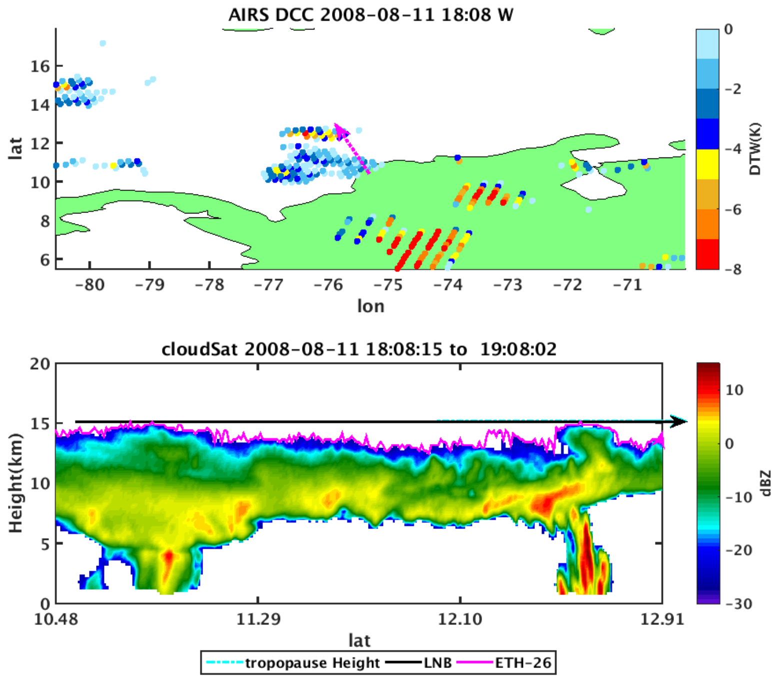
83 hPa H_2O

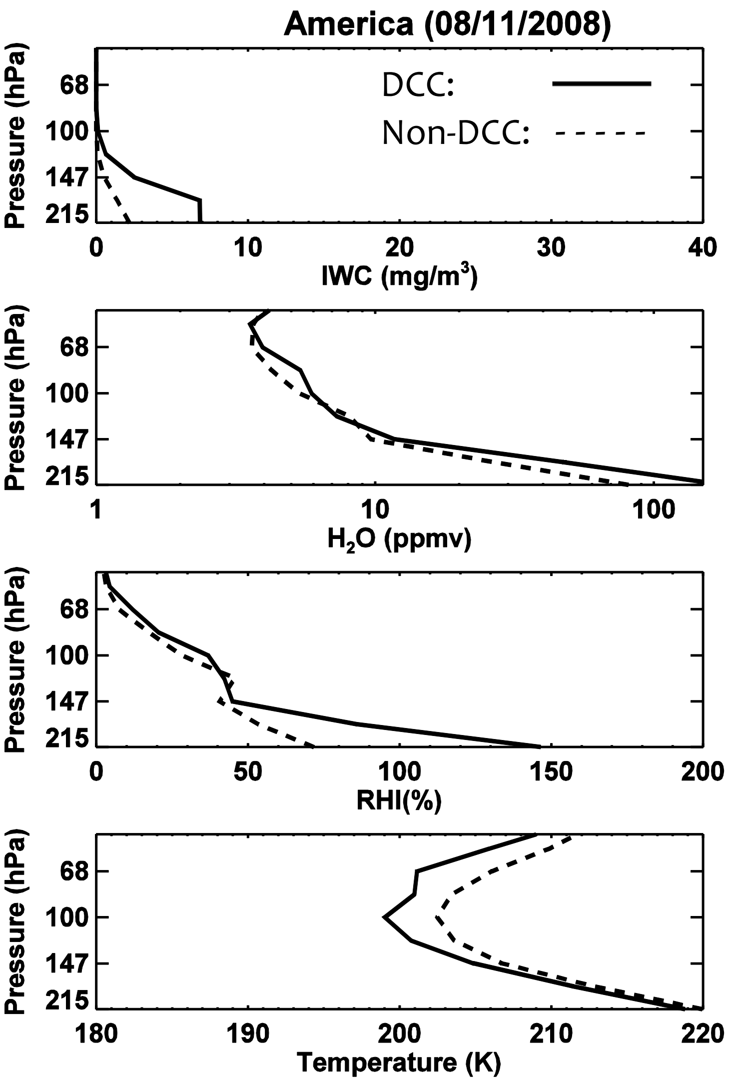
DCC: **4.3**

Non-DCC: **3.2**

- Dehydration in the TTL, hydration in the LS by 1.1 ppmv

A DCC in Central America (summer)





83 hPa H_2O

DCC: 5.4

Non-DCC: 4.3

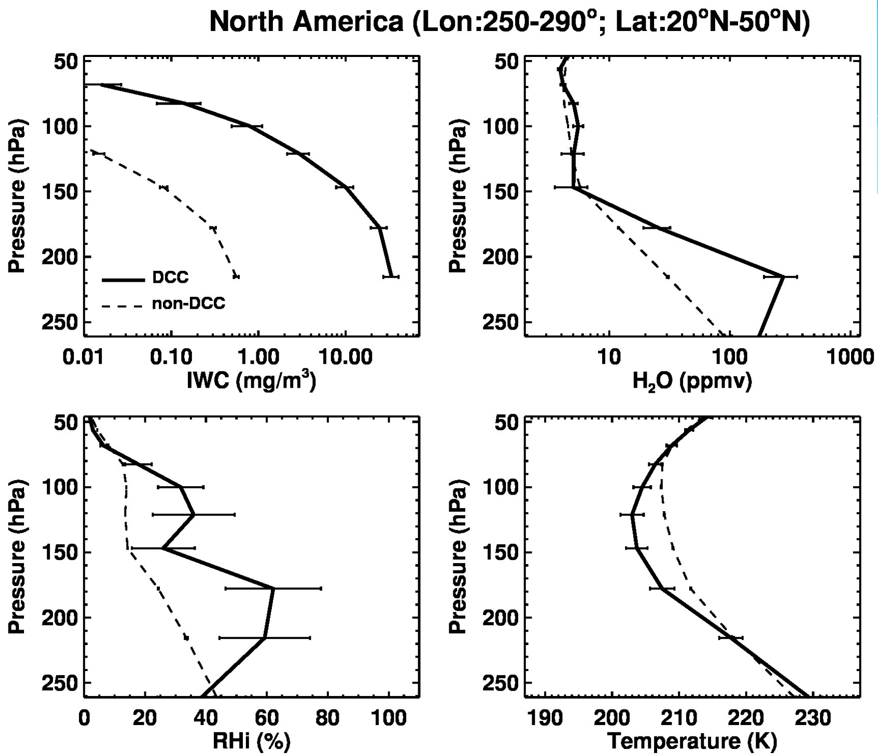
DTW = −2.0 K

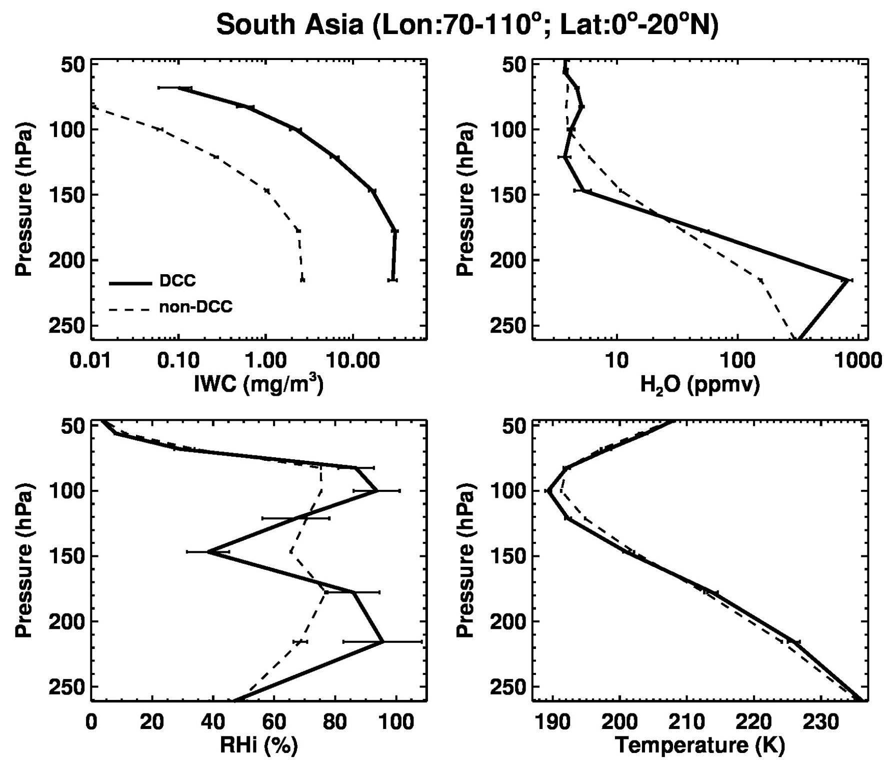
CTH = 15.1 km

TH = 15.2 km

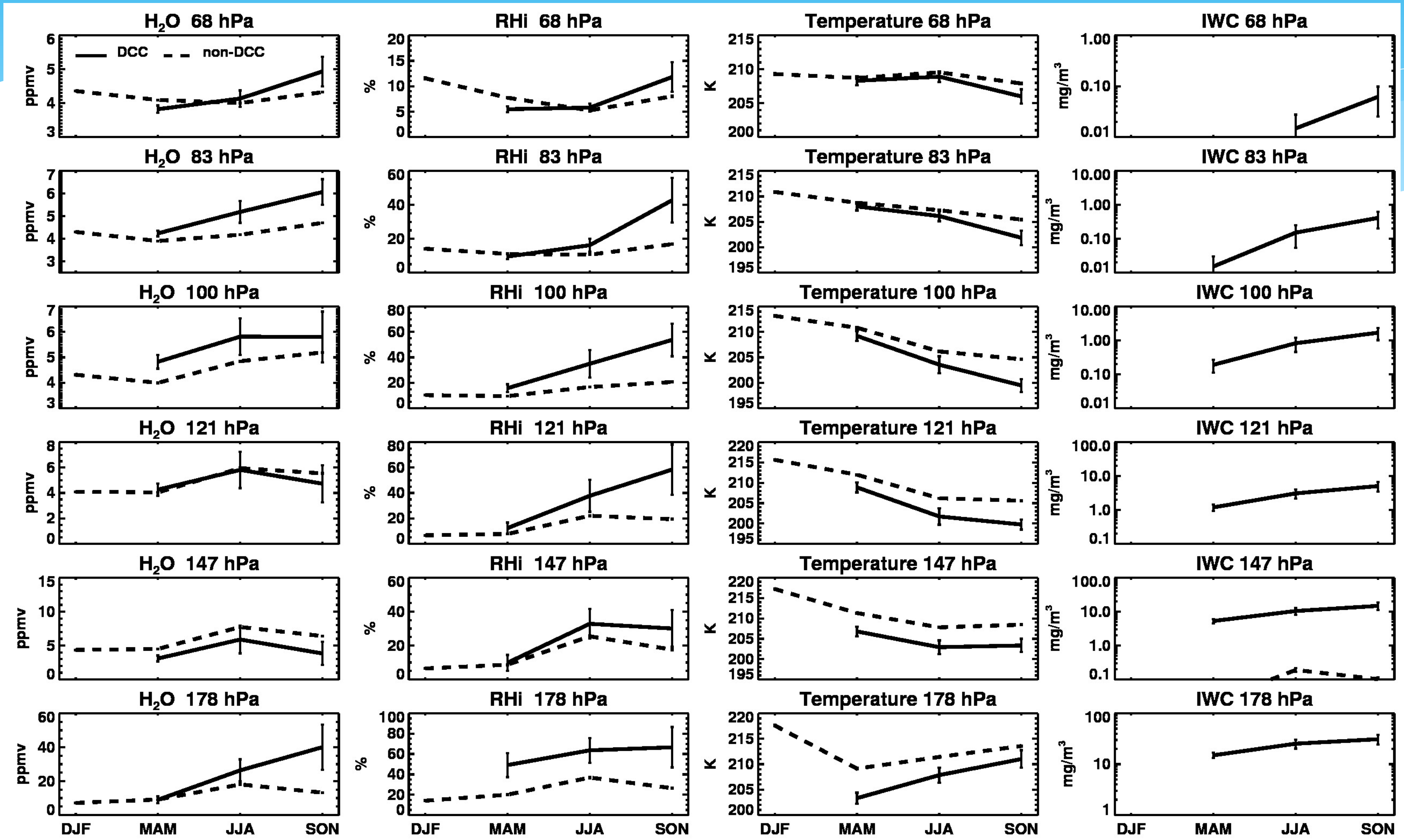
- No dehydration in the TTL, hydration in the LS by 1.1 ppmv

Two Summer Monsoon Regions

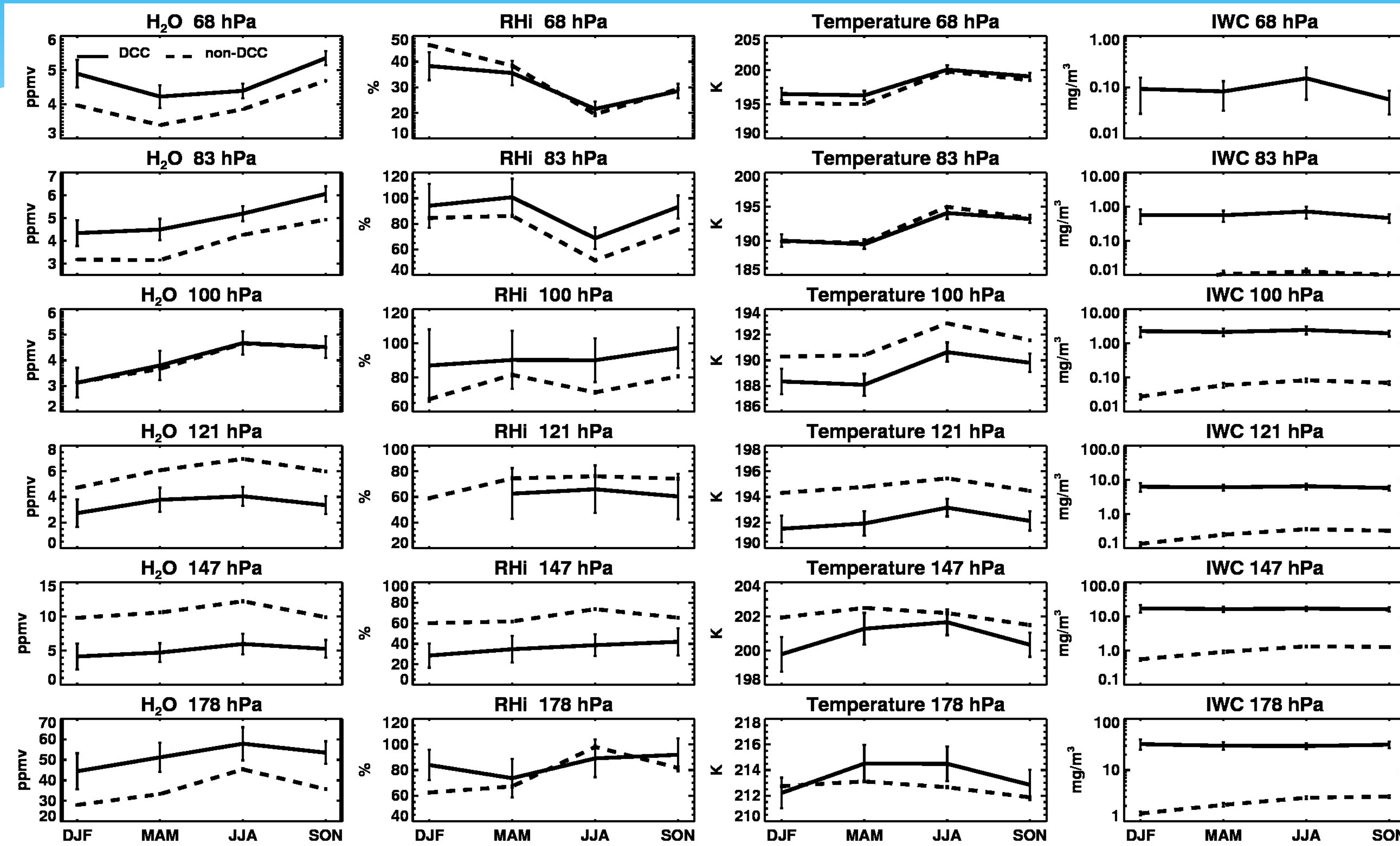




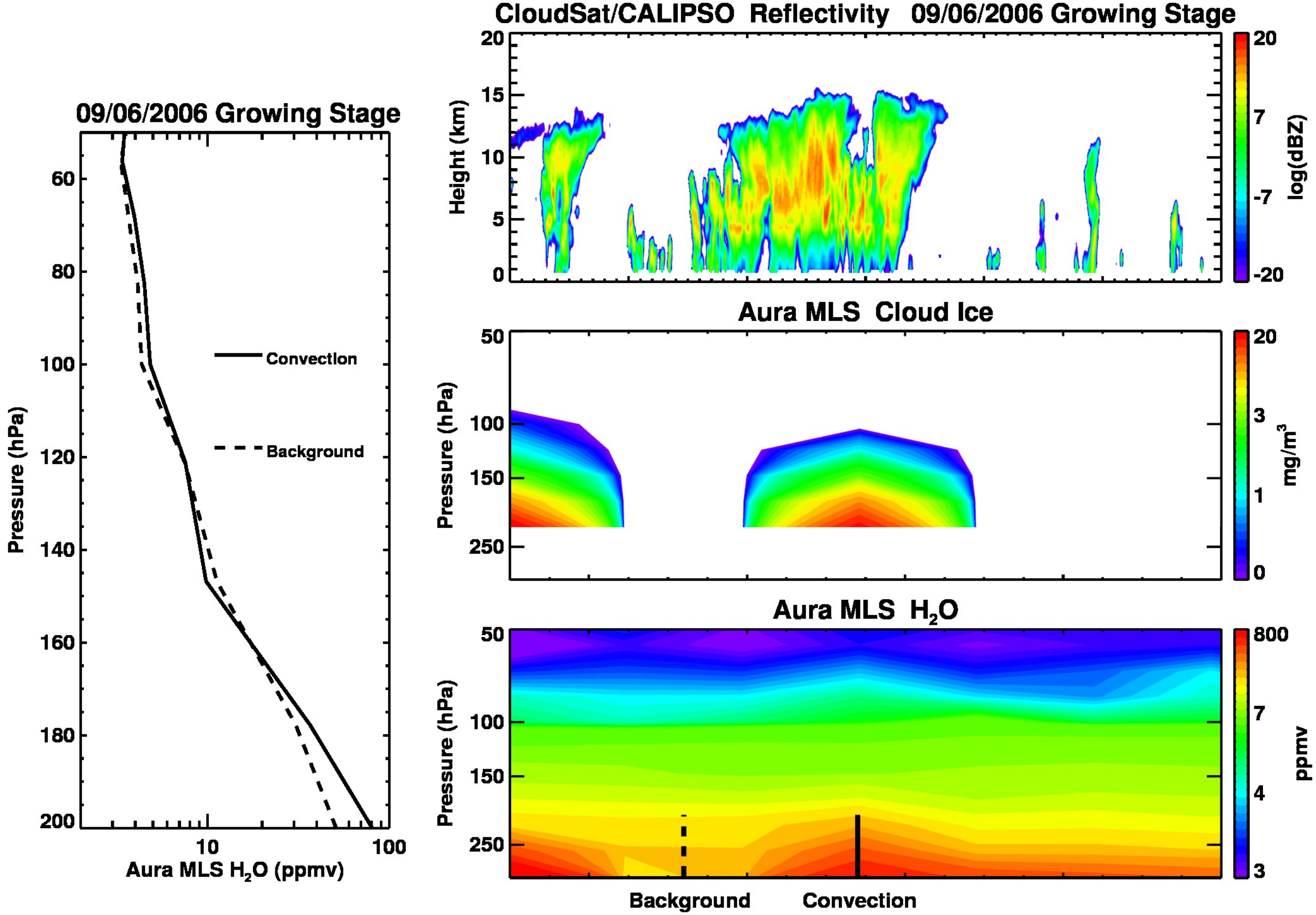
Seasonal Variation (North America)



Seasonal Variation
(South Asia)

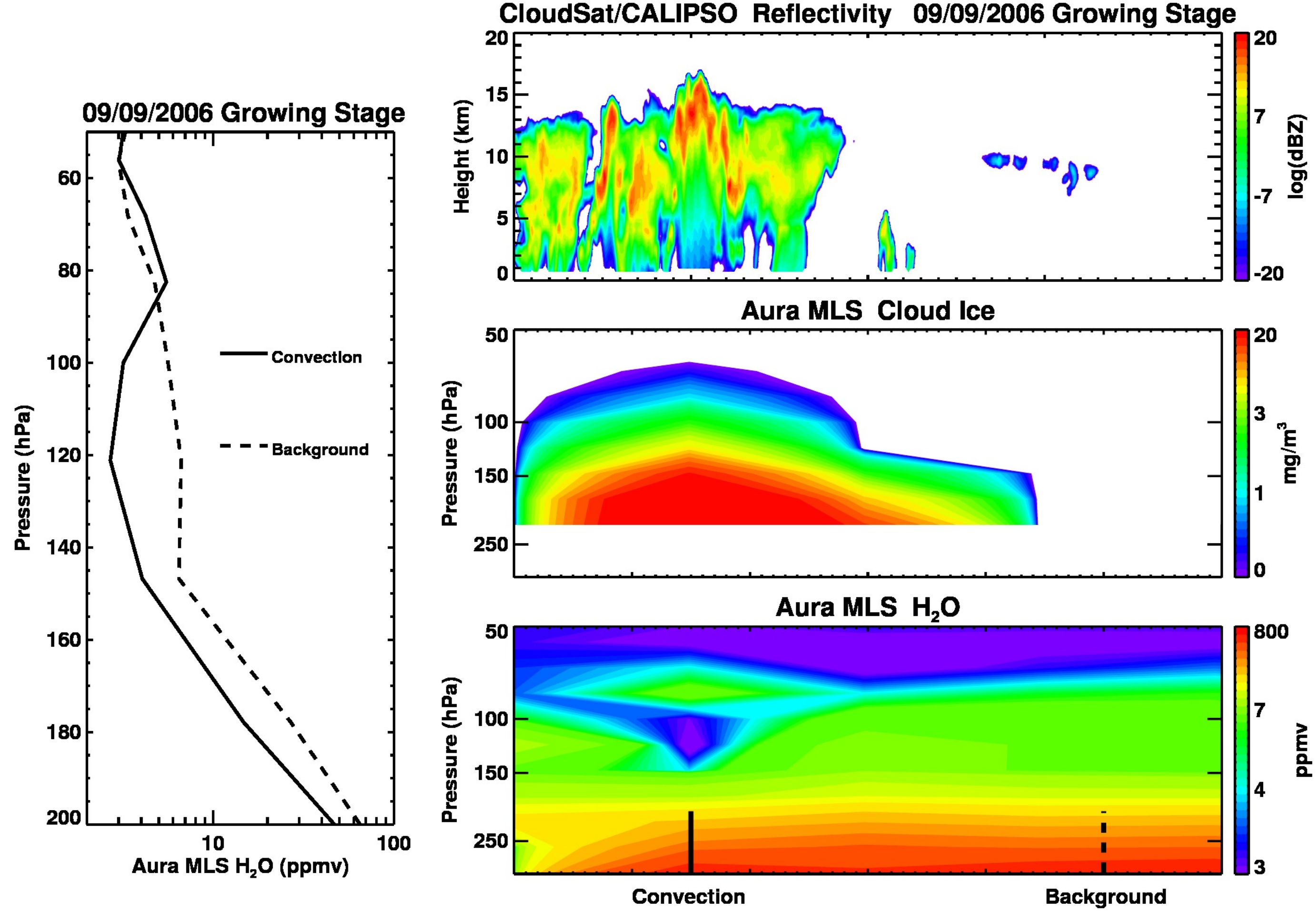


A Growing Stage ODC



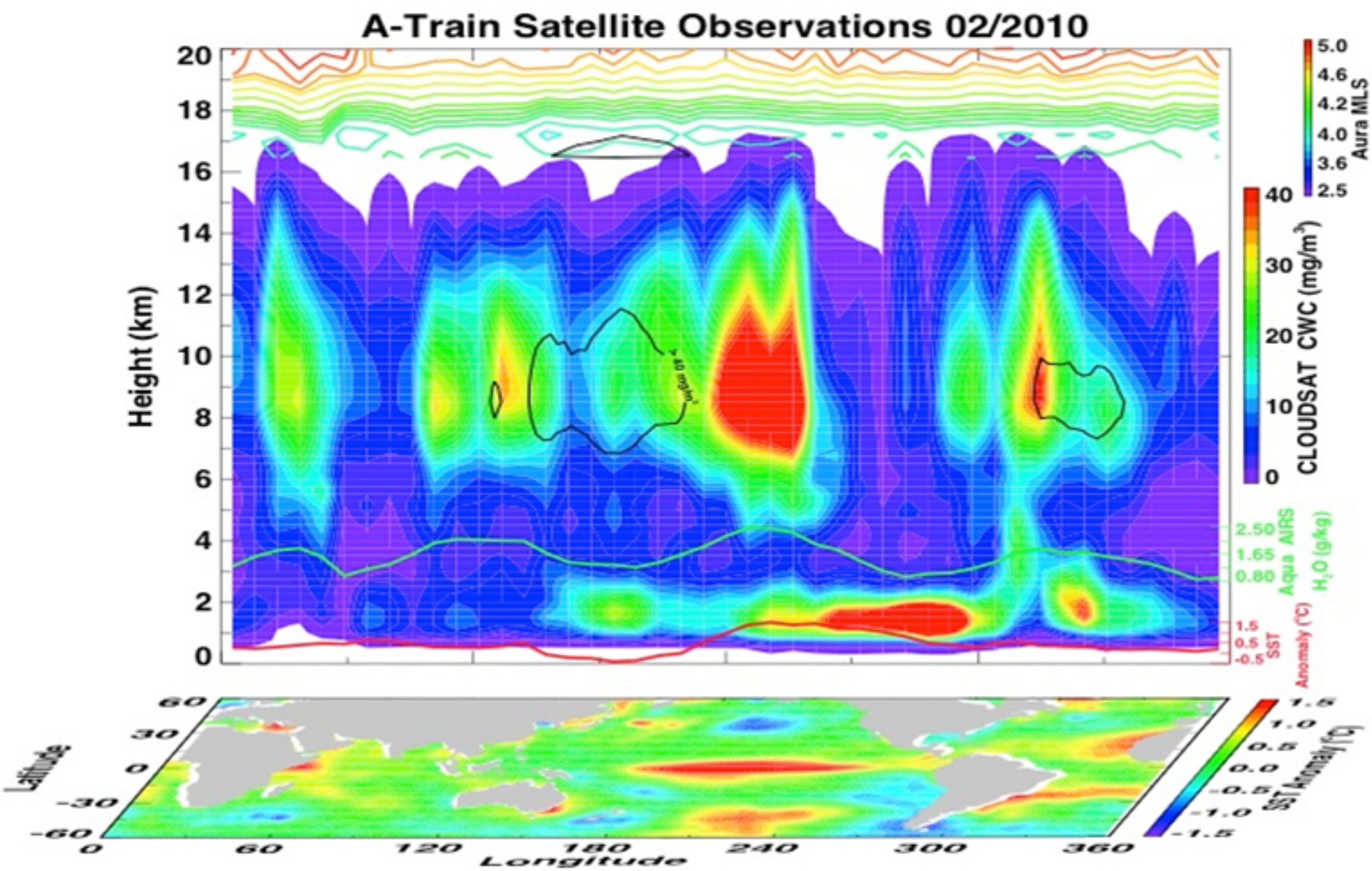
Overshooting Deep Convection at (4.33°N, 156.06°E)

A Mature Stage DCC

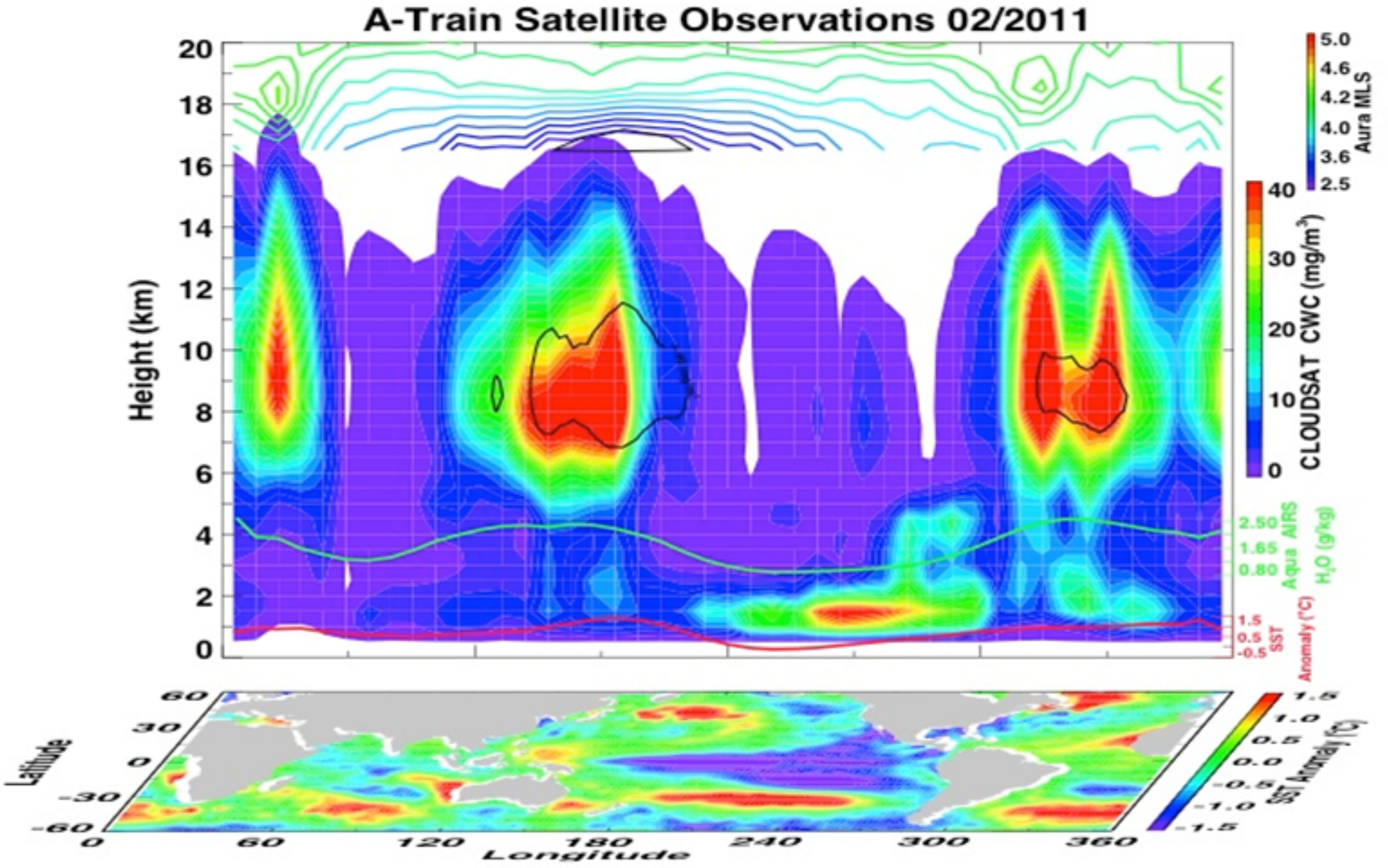


Overshooting Deep Convection at (5.0°N, 173.20°E)

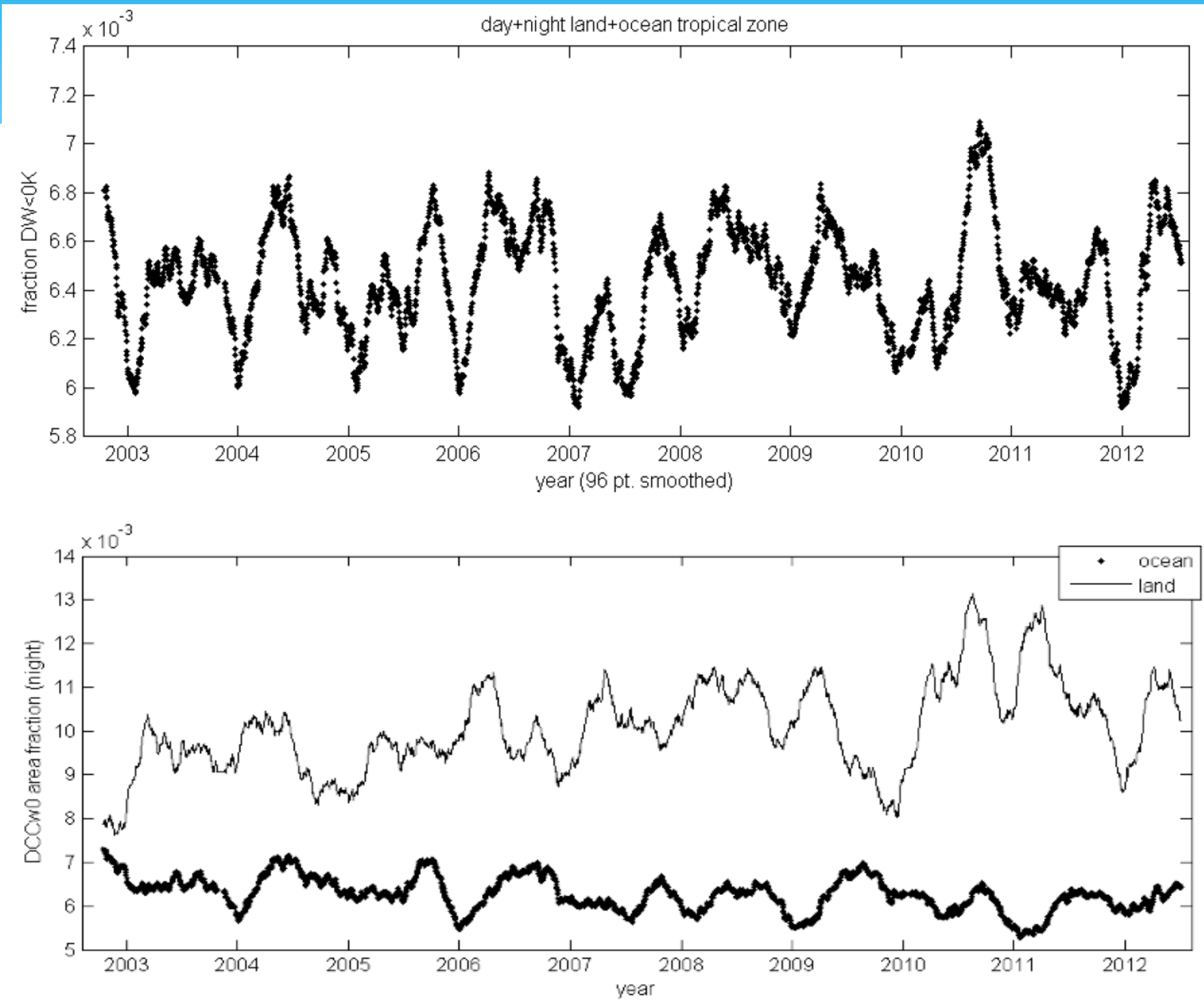
Interannual Variations



Interannual Variations



Ten-Year Trends



Aumann and Ruzmaikin (2013, ACP)

Summary

- We find that ODC tends to cool and dehydrate the TTL, but can moisten the lower stratosphere up to 30%. However, large regional and seasonal differences exist for the deep convective impact on the SWV.
- The convective influence on the SWV also depends on the life cycles of ODC.
- Interannual variations of the SWV are influenced by the coupling between deep convection and tropopause temperature.
- Although ODC could moisten the lower stratosphere, its rarity makes the overall convective moistening effect quite small on the annual mean water vapor budget (< 0.2%), but it may play a significant role in the SWV variabilities.
- Whether the ODC influence on the SWV would strengthen under global warming is still an open question.