Continuity in Sounding Products from Multiple Platforms

Nadia Smith, Chris Barnet, Rebekah Esmaili and many others

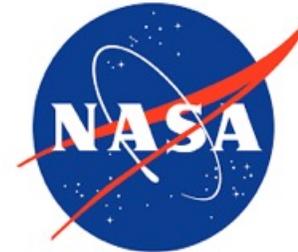# **NU**CAPS

NOAA-Unique Combined Atmospheric Processing System

Operational at **NOAA** (2006–) for National Weather Service forecasters

IASI/AMSU (Metop-A/B/C) and **CrIS/ATMS** (SNPP/NOAA-20)
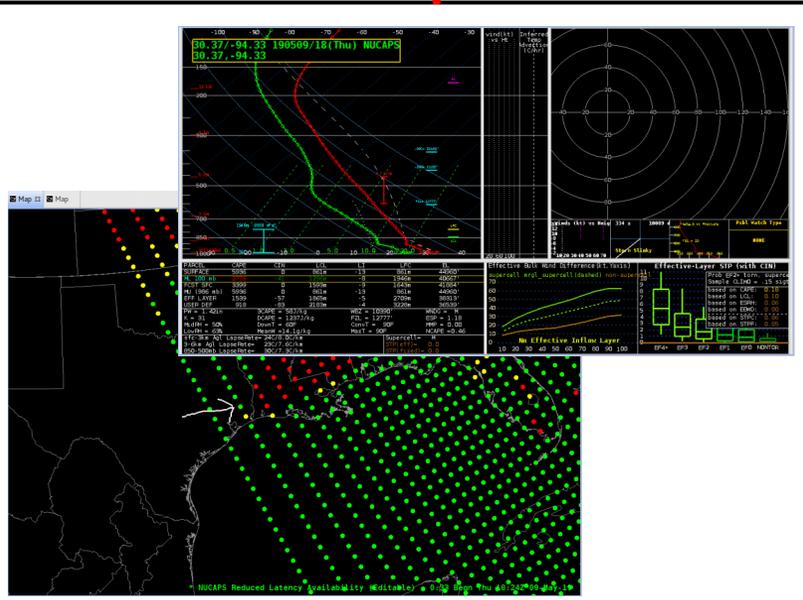
CLIMCAPS

Community Long-term Infrared Microwave Combined Atmospheric Processing System

Operational at **NASA** (2019–) for atmospheric research, studies and characterization

AIRS/AMSU (Aqua) and **CrIS/ATMS** (SNPP/NOAA-20)

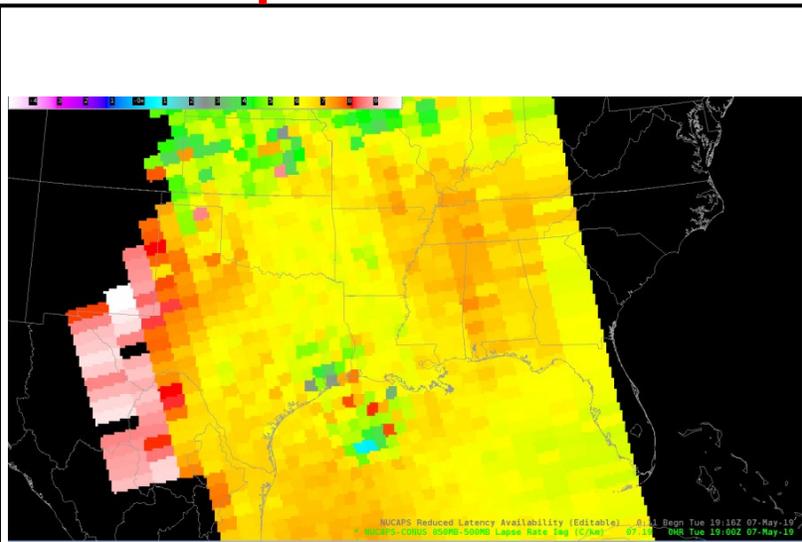# Forecaster evaluation of NUCAPS at the NOAA Hazardous Weather Testbed 2019

Hotspots

Post: Wherefore art thou Convection? (May 9)

- Forecaster used NUCAPS soundings to observing capping, which diagnosed why convection was delayed when compared to models in Houston, TX.
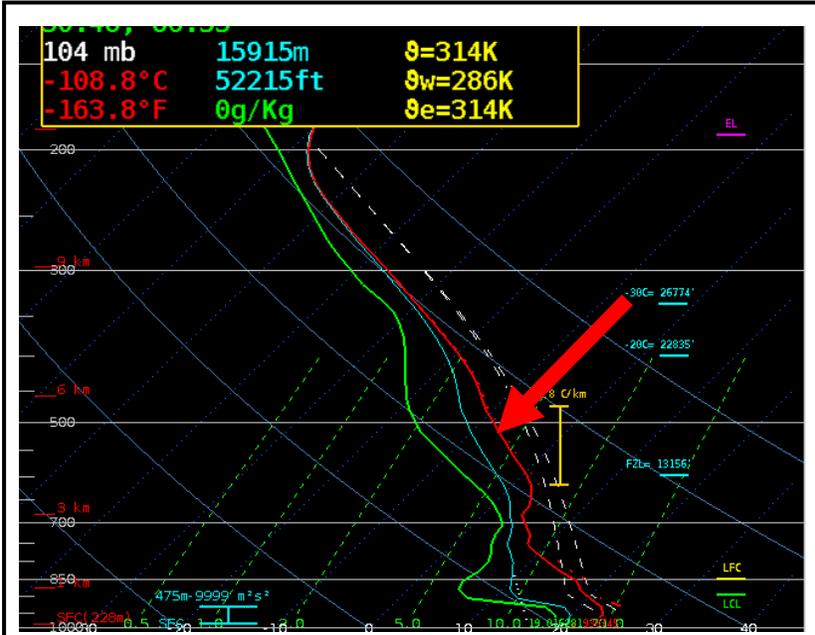
Spatial Gradients

Post: NUCAPS Lapse Rates (May 7)

- Forecaster used gridded NUCAPS to see mid-level Lapse Rate across West Texas, which indicates convective potential. Values above reflect the drier air advancing east leading to steeper lapse rates.

Vertical Structure

Post: TAE Mesoanalysis #1 (April 25)

- Forecaster diagnosed building instability ahead of a line of convective storms. The warm "nose" can impact storm intensity due to decreased CAPE.

NUCAPS in National Weather Service Operations

National Weather Service Feedback

What would make NUCAPS more useful to you in future?

- "Improve the temporal availability"

- "More frequent satellite passes"

- "Need additional satellites that can provide higher frequency of NUCAPS soundings"

Smith N., et al. 2019, *Why operational meteorologists need more satellite soundings*

"NUCAPS gradients are helpful for situational awareness prior to convective development"

"I used NUCAPS to show instability and overall moisture in the mid- to upper troposphere"

"NUCAPS is useful to evaluate the pre-convective environment"

"NUCAPS gave me confidence in the wind threat"
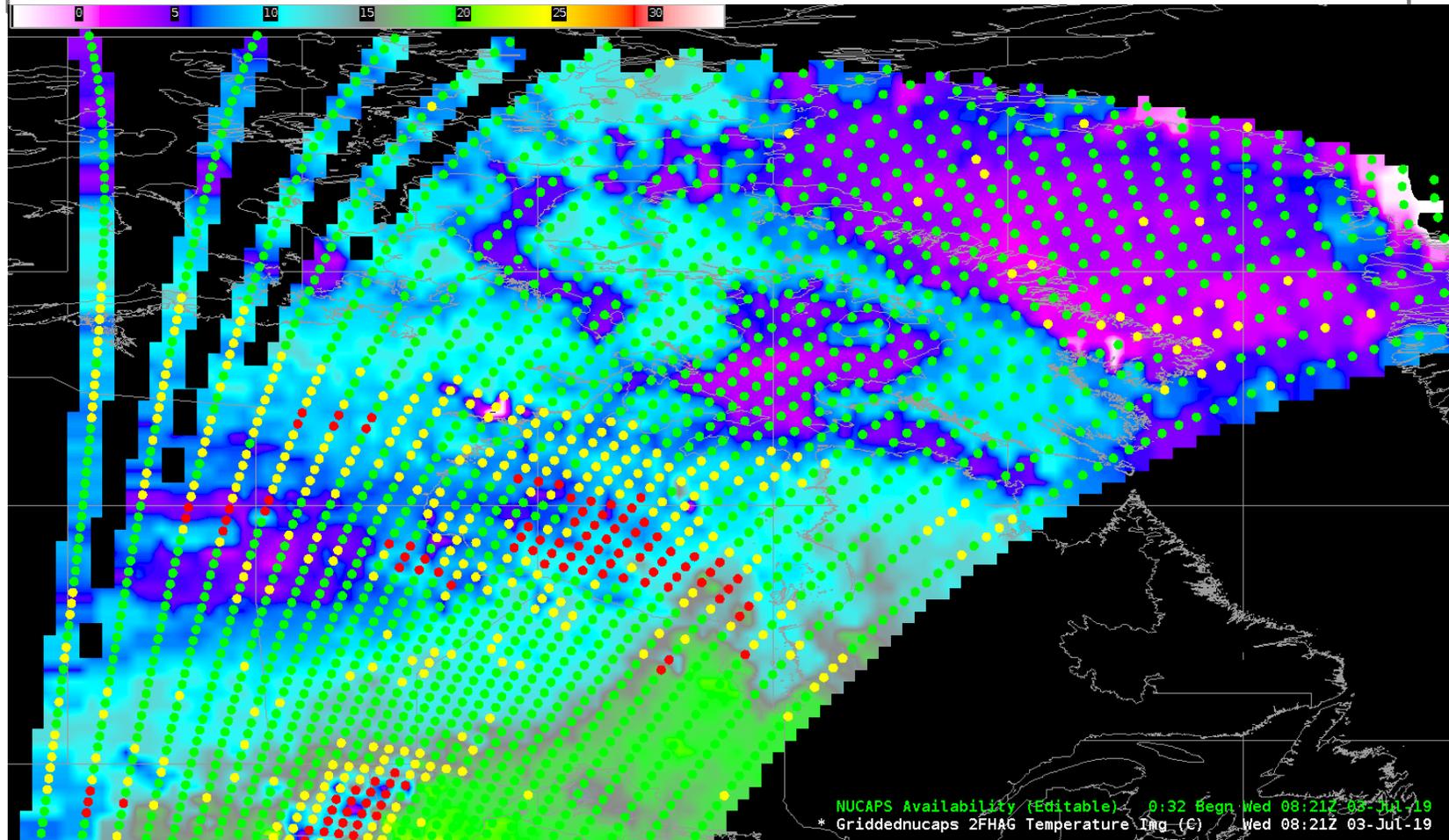
Creating a hyperspectral sounding continuity product

Satellite	Instruments	Overpass	Launch dates
Aqua	AIRS, AMSU	1:30	2002
Metop	IASI, AMSU, MHS	9:30	2008, 2012, …
S-NPP, JPSS	CrIS, ATMS	1:30	2011, 2017, …

Sensitivity to a-priori assumptions

- Sensitivity to meteorology (e.g., clouds at 9:30 vs 1:30 am/pm)
- Sensitivity to seasonal and climate changes

Instruments are different

- Spectral resolution, sampling and noise
- Spatial sampling & co-registration of channels
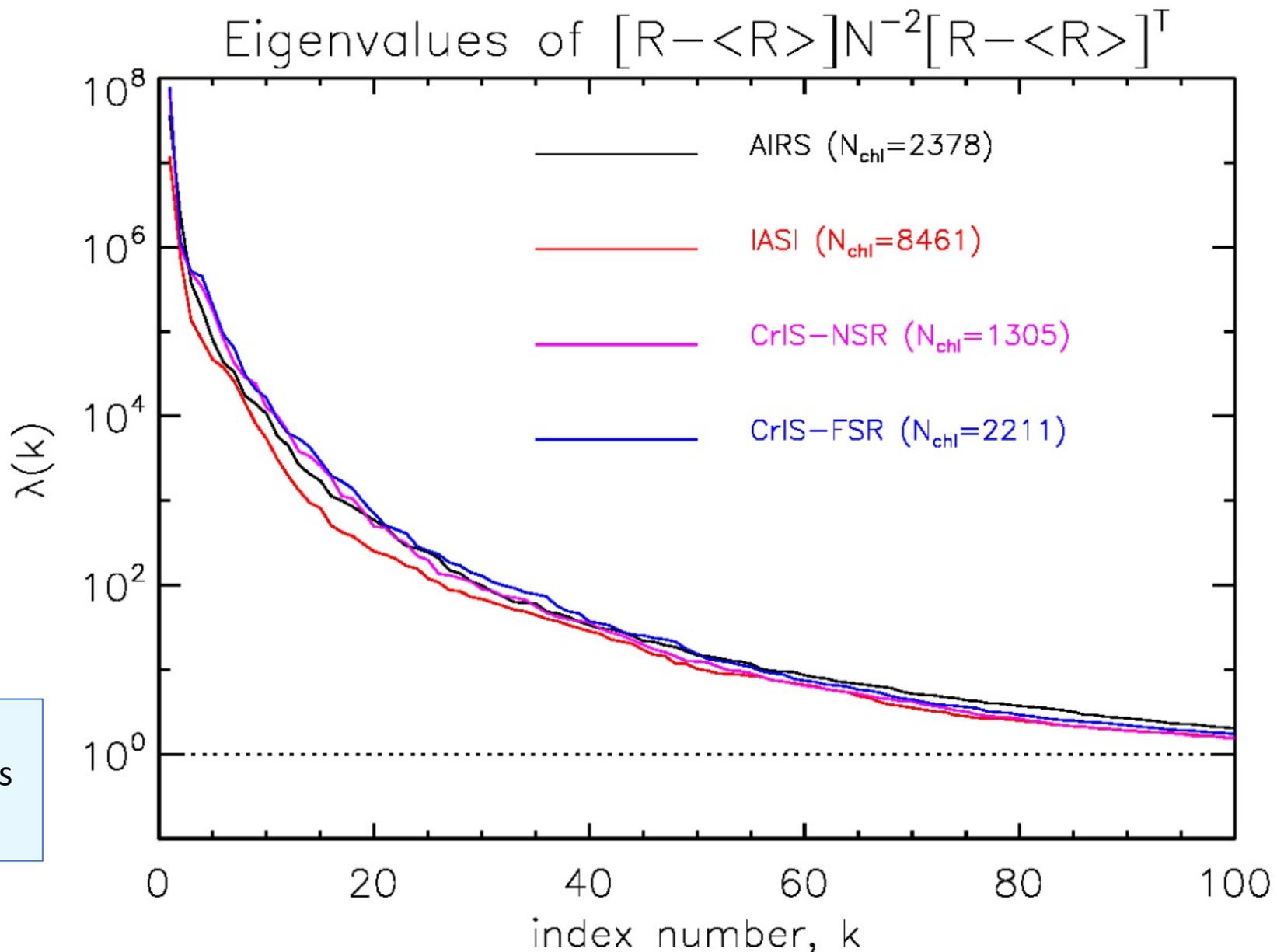- Degradation over time

Algorithm differences

- NOAA algorithms became operational ~1-2 year after launch and have asynchronous maintenance schedules (e.g., training datasets are different)
- 9:30/1:30 orbits co-location w/ in-situ is different (affects tuning/regression training and makes validation more difficult)

> Continuity was not the primary design criteria of the modern satellite sounding suite
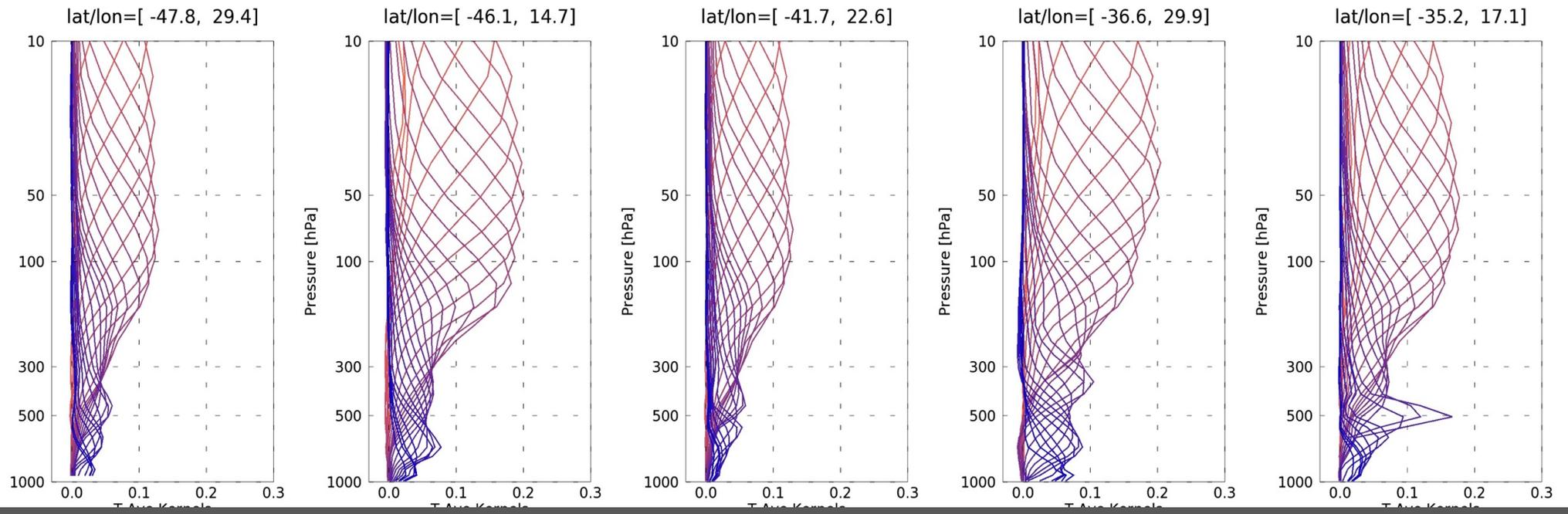
The information content of modern sounding instruments is _amazingly_ similar

- For a global ensemble, AIRS, IASI, and CrIS each have ~100 degrees of freedom

- Even though AIRS, IASI, and CrIS have different number of channels, ILS, noise, etc.

The 1st 100 significant eigenvectors of radiance covariance for a set of focus days normalized at $\lambda(k=200)$
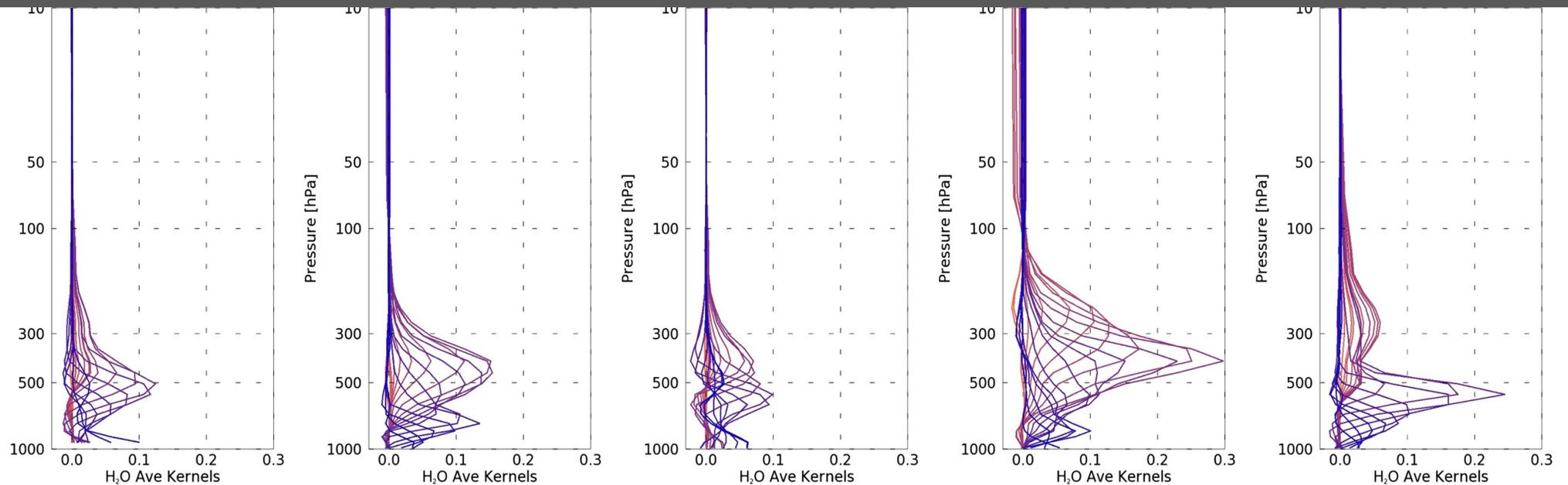

Eigenvalues of $[R-<R>]N^{-2}[R-<R>]^T$

AIRS ($N_{chl}=2378$)

IASI ($N_{chl}=8461$)

CrIS−NSR ($N_{chl}=1305$)

CrIS−FSR ($N_{chl}=2211$)

$\lambda(k)$

index number, k

Strong scene dependence of information content – CLIMCAPS NOAA-20

Top row (T(p)): lat/lon=[-47.8, 29.4], lat/lon=[-46.1, 14.7], lat/lon=[-41.7, 22.6], lat/lon=[-36.6, 29.9], lat/lon=[-35.2, 17.1]

Averaging Kernels for all retrieval parameters – CLIMCAPS NOAA-20

CLIMCAPS-N20 20180701 pm mean averaging kernels for N-MidLat zone

T   H$_2$O   O$_3$ CO   CH$_4$ CO$_2$ HNO$_3$
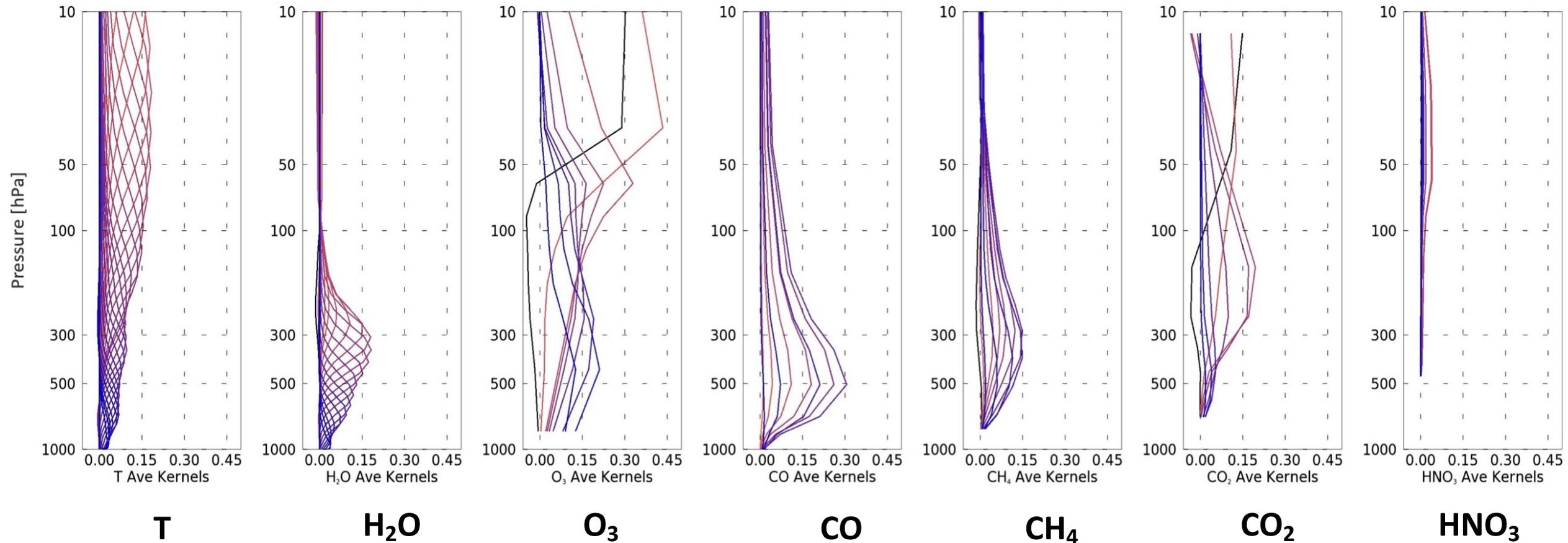
Sequential physical retrieval approach with channel selection allows us to decompose the spectrum into atmospheric parameters with uncorrelated information content

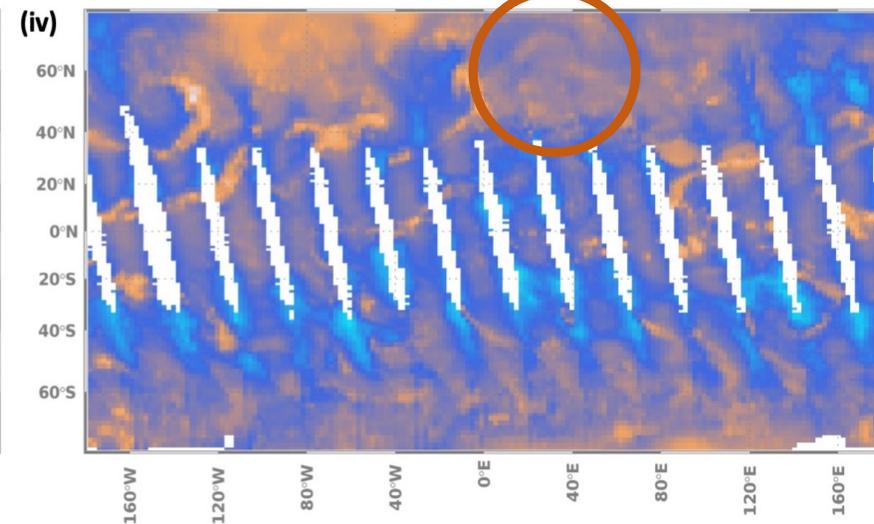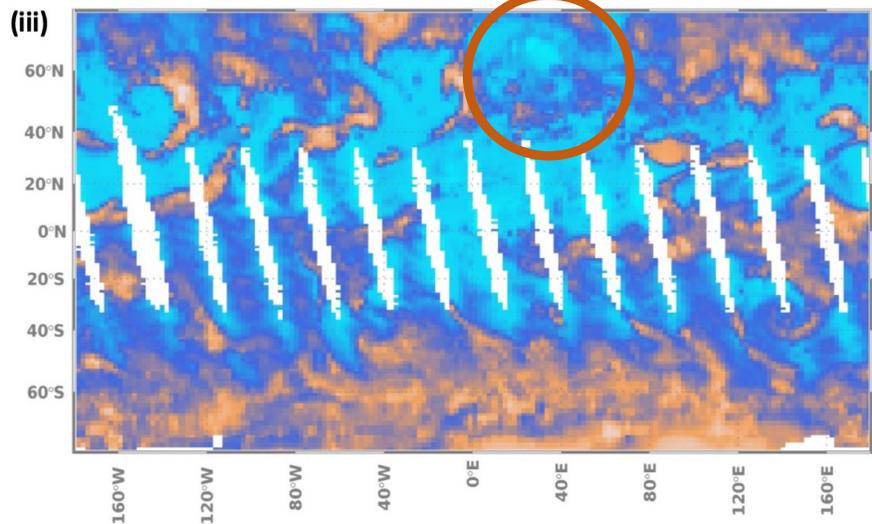Smith and Barnet, 2019, *Uncertainty characterization and propagation in CLIMCAPS,* doi.org/10.3390/rs11101227
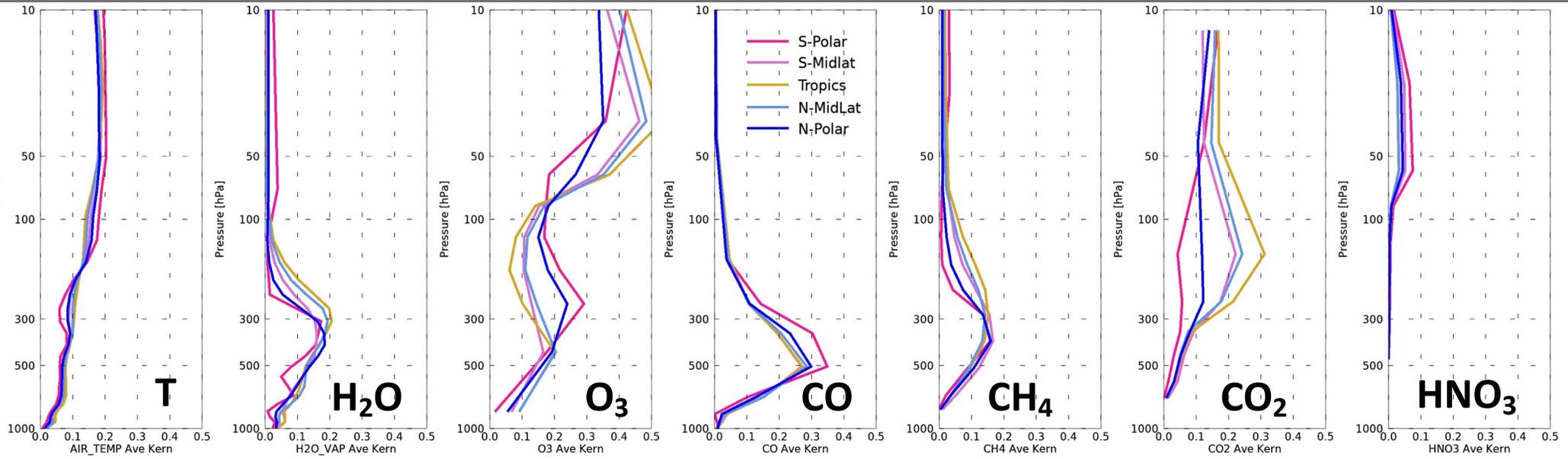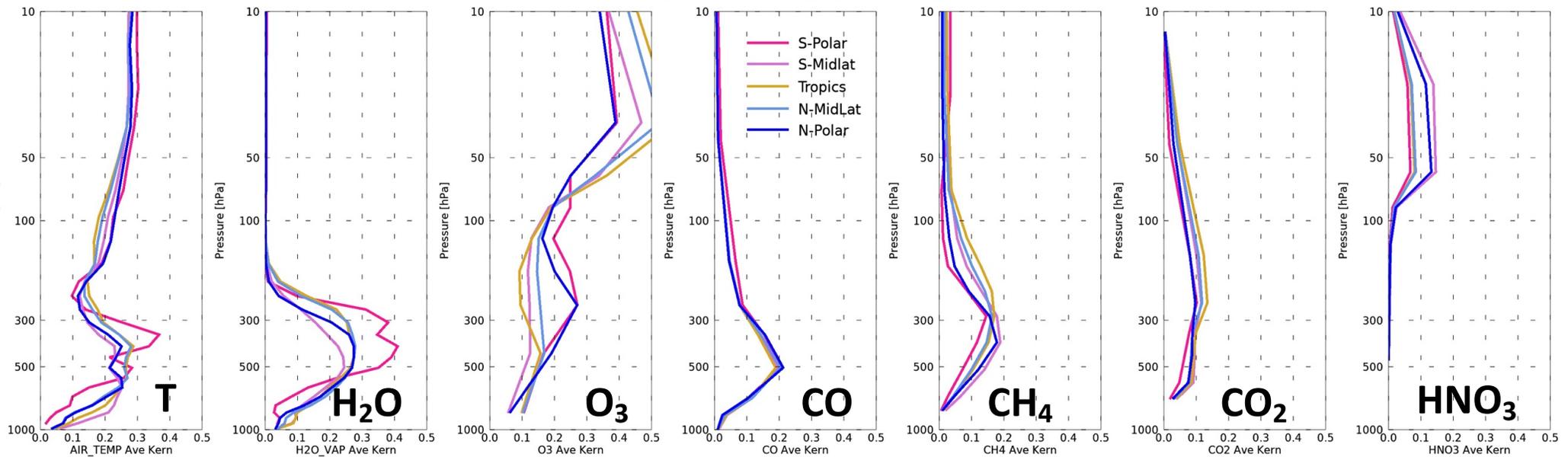
Degrees of Freedom – CLIMCAPS NOAA-20
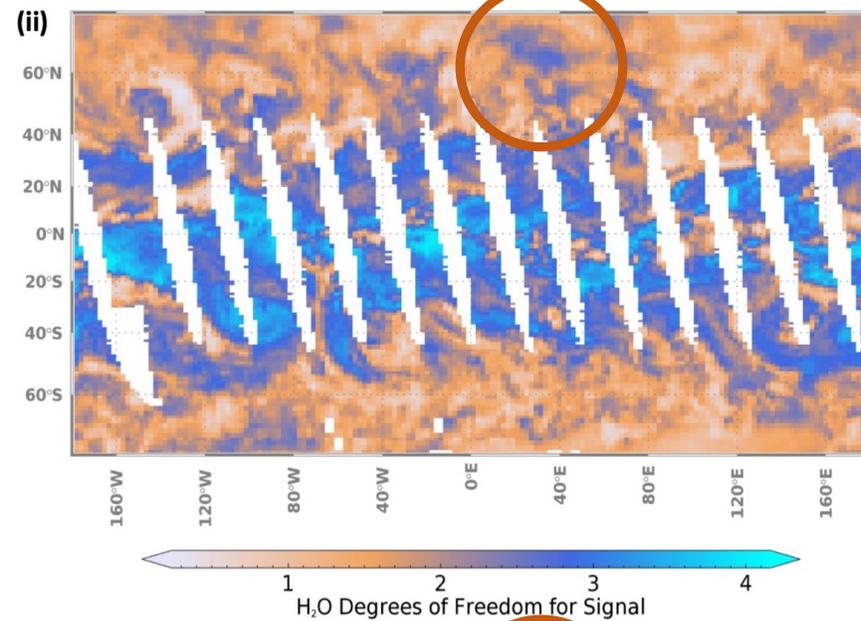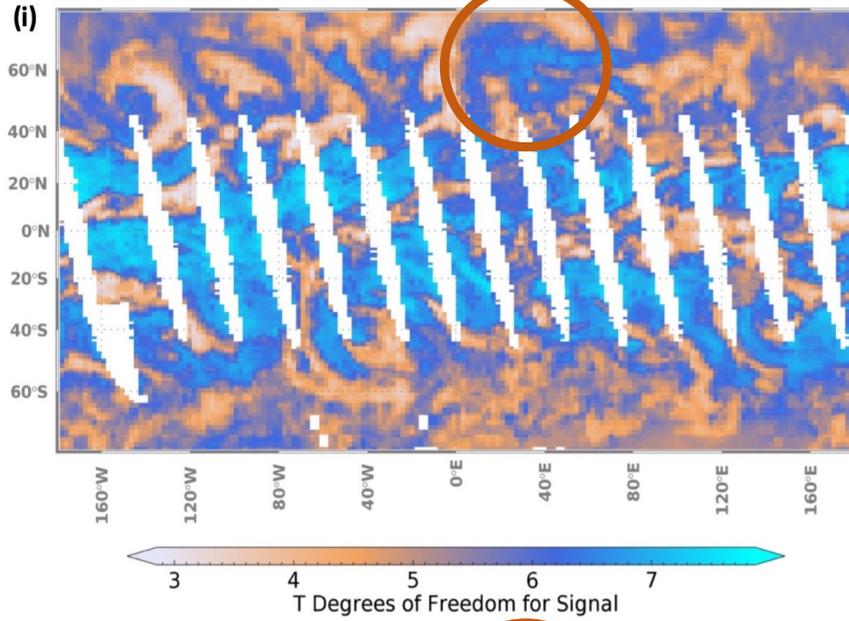
We are able to remove/reduce spectral correlation of information content in retrieval parameters

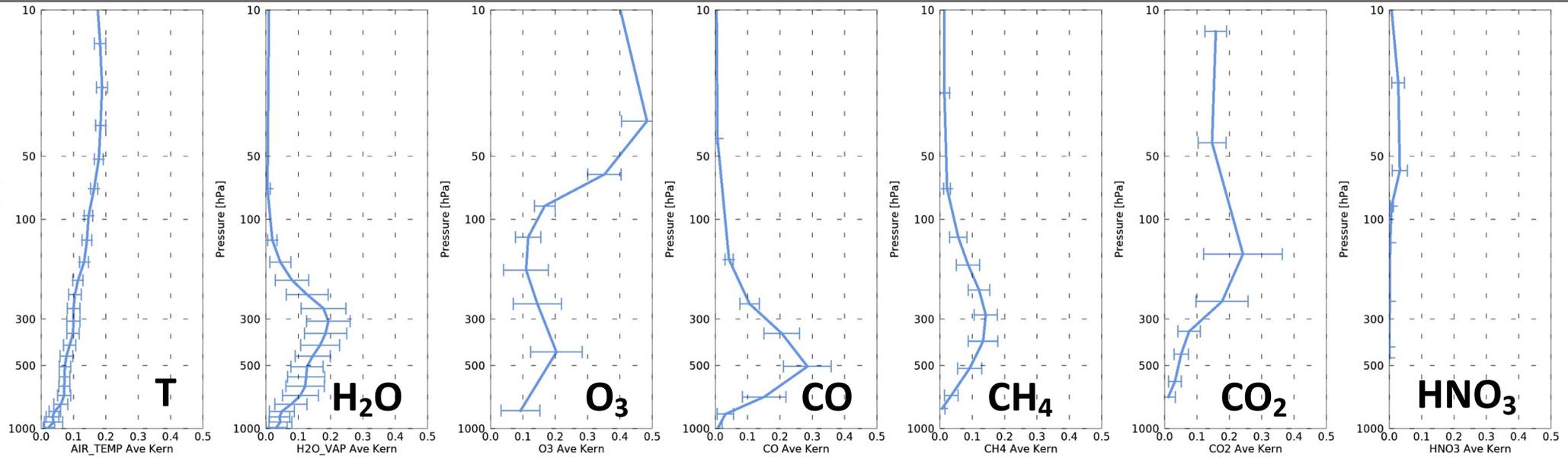Spatial patterns of information content from four retrieval parameters

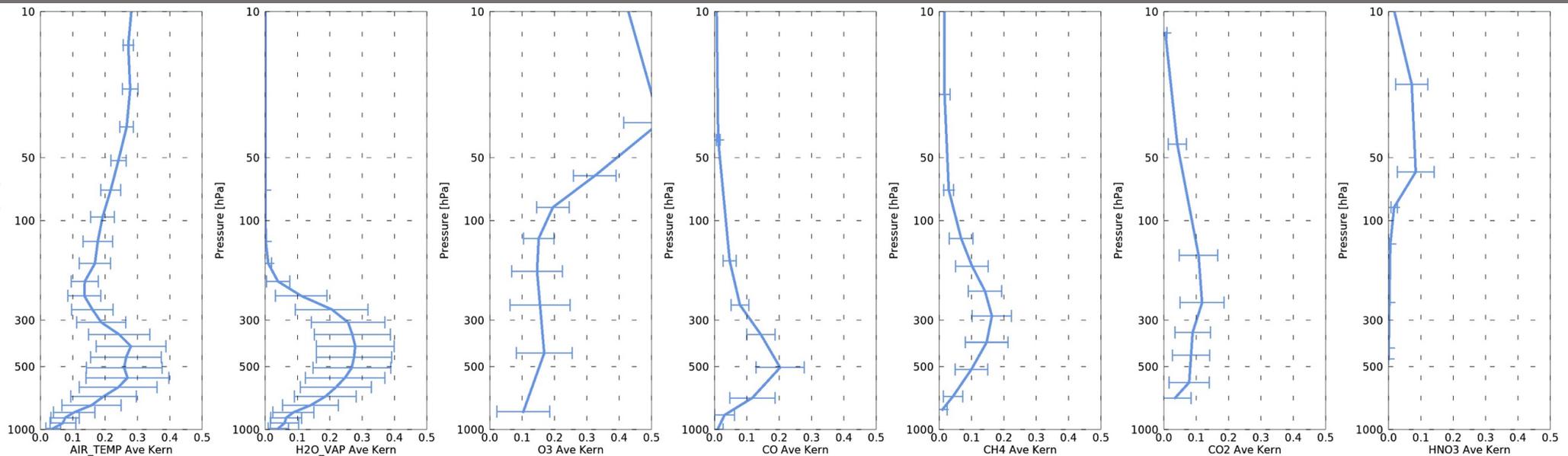CLIMCAPS NOAA-20 AK diagonals Summer Daytime 5 Global Zones

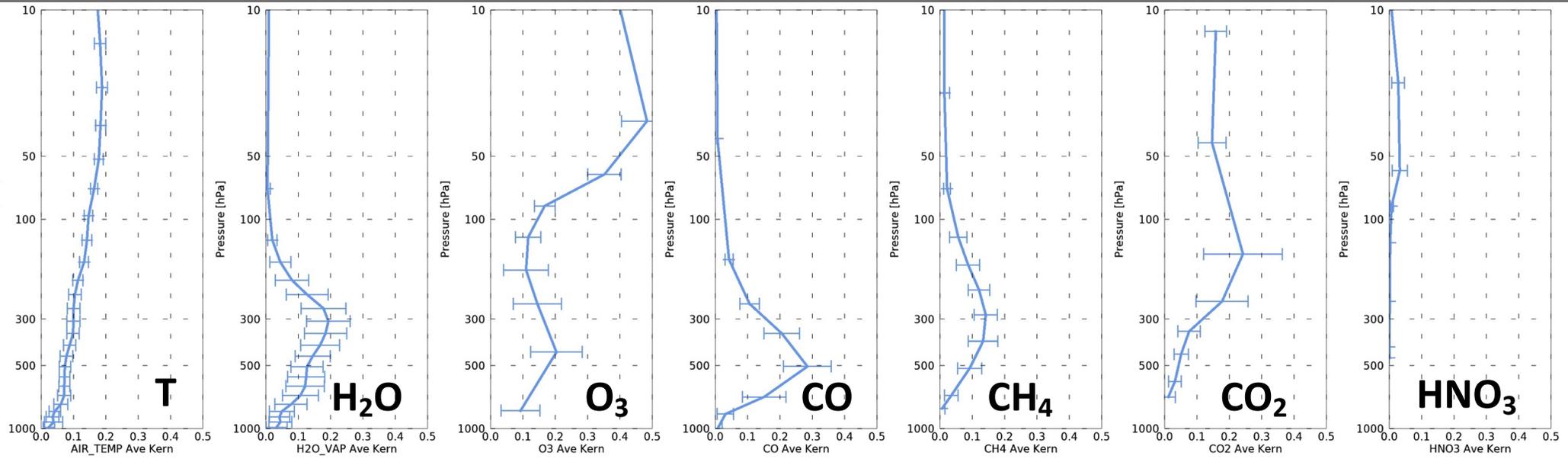CLIMCAPS Aqua AK diagonals Summer Daytime 5 Global Zones
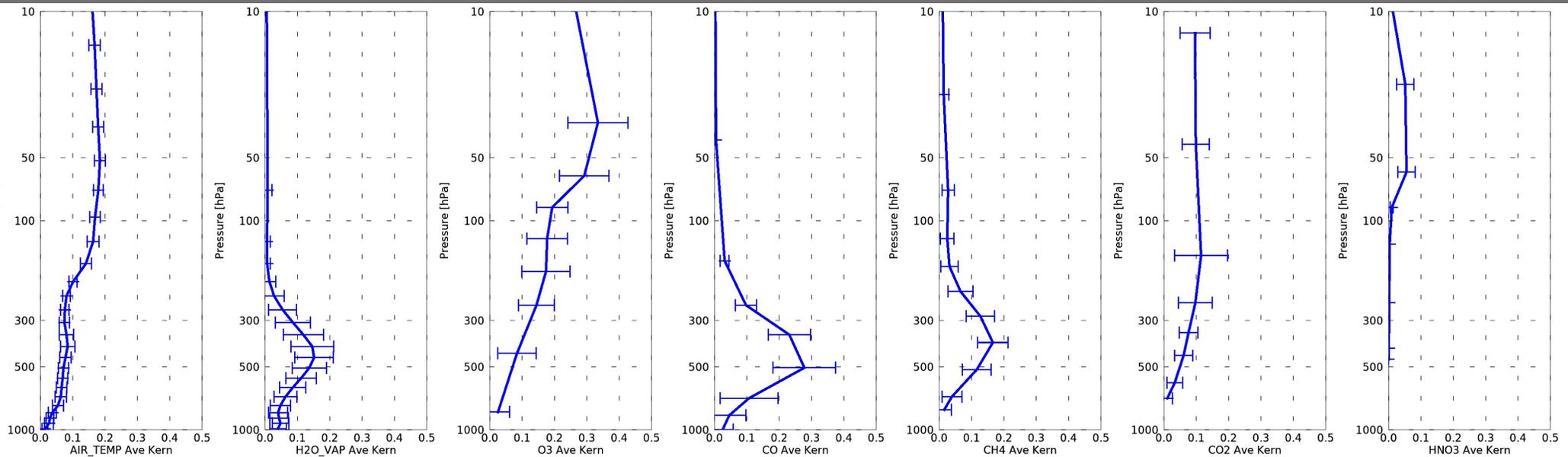
CLIMCAPS NOAA-20 Summer Daytime North Mid-Lat

CLIMCAPS Aqua Summer Daytime North Mid-Lat

CLIMCAPS NOAA-20 Summer Daytime North Mid-Lat

T H_2O O_3 CO CH_4 CO_2 HNO_3

AIR_TEMP Ave Kern   H2O_VAP Ave Kern   O3 Ave Kern   CO Ave Kern   CH4 Ave Kern   CO2 Ave Kern   HNO3 Ave Kern

CLIMCAPS NOAA-20 Winter Daytime North Mid-Lat

AIR_TEMP Ave Kern   H2O_VAP Ave Kern   O3 Ave Kern   CO Ave Kern   CH4 Ave Kern   CO2 Ave Kern   HNO3 Ave Kern

CLIMCAPS NOAA-20 Summer Daytime Tropics

T   H₂O   O₃   CO   CH₄   CO₂   HNO₃
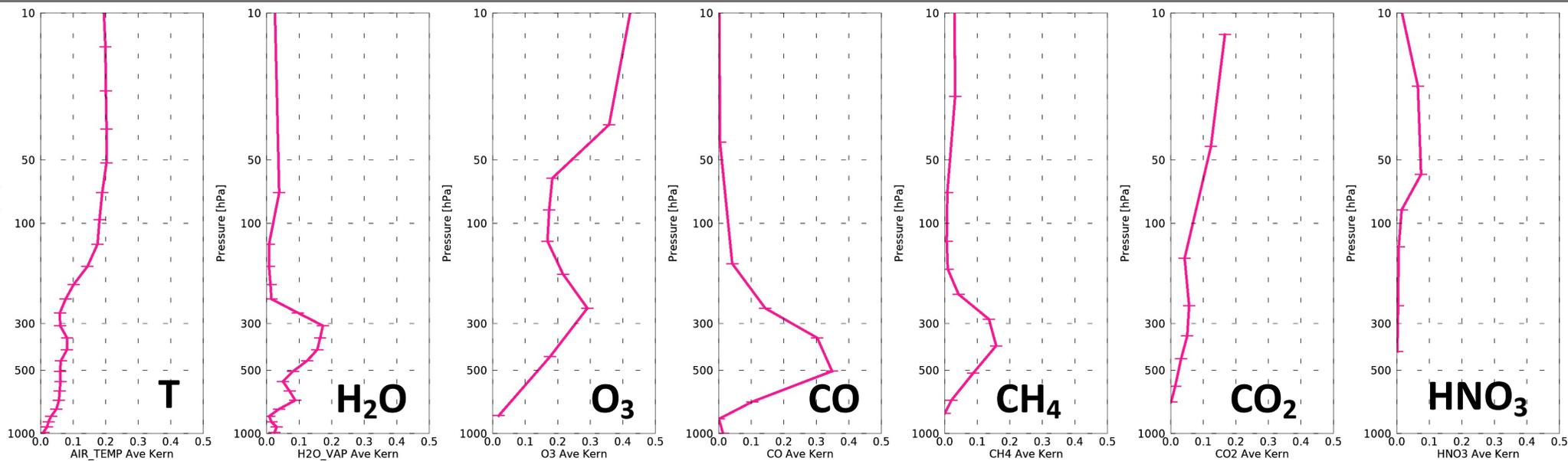
CLIMCAPS NOAA-20 Summer Daytime South Pole
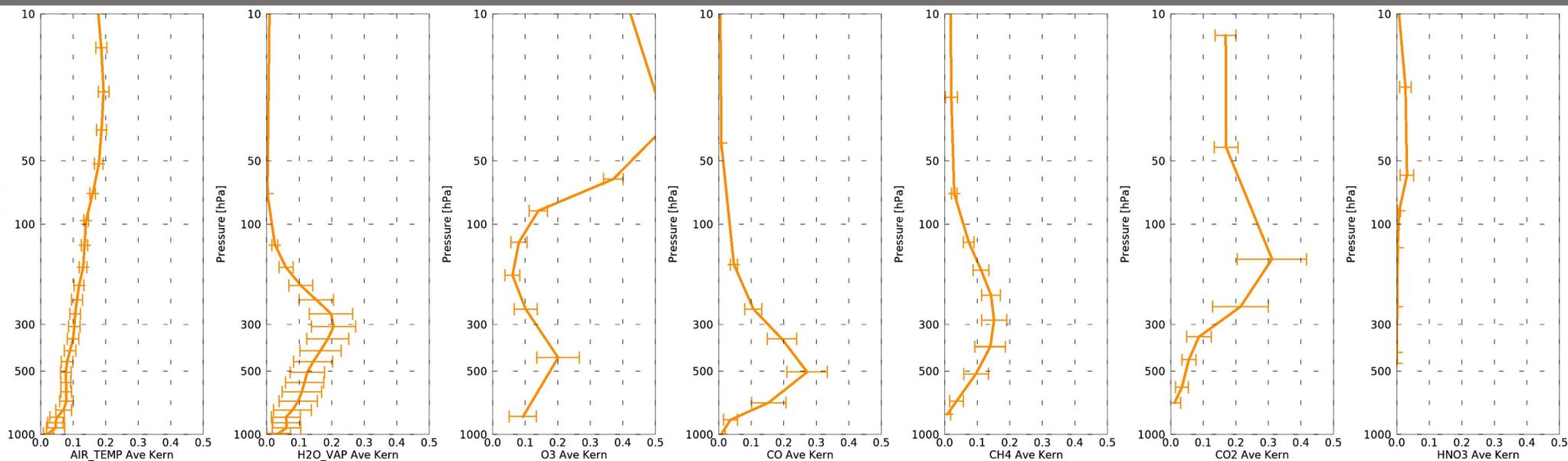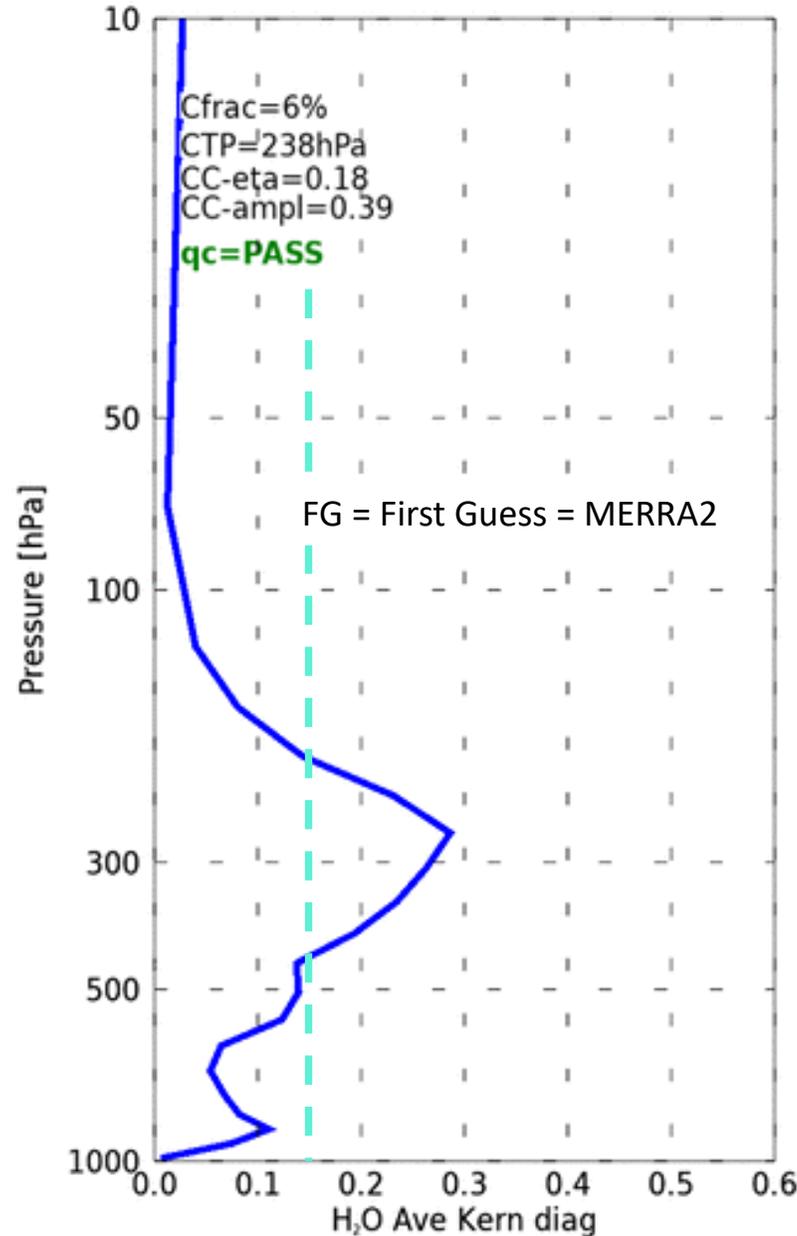
(1)

High SNR
Small Departure

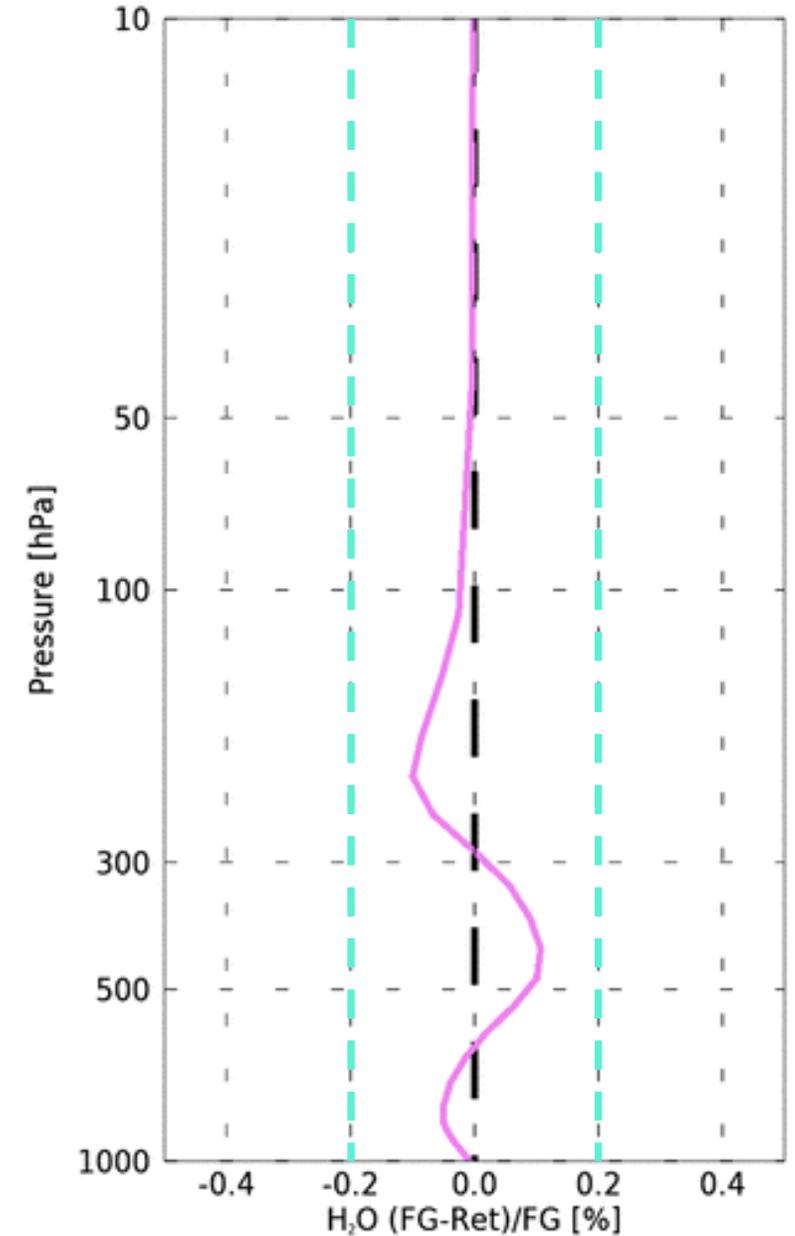**> 0.15 Ave Kern**
< 20% departure

CLIMCAPS made a SMALL change to FG water vapor profile (MERRA2) because the FG agreed with the measurements.

Here, we can **have confidence in FG** as approximation of true atmospheric state.

CLIMCAPS-N20 H$_2$O 20180701PM Gran#15 FOR#122

Cfrac=6%
CTP=238hPa
CC-eta=0.18
CC-ampl=0.39
qc=PASS

FG = First Guess = MERRA2

Pressure [hPa]

H$_2$O Ave Kern diag

FG departure, lon/lat=[150.25, 23.98]
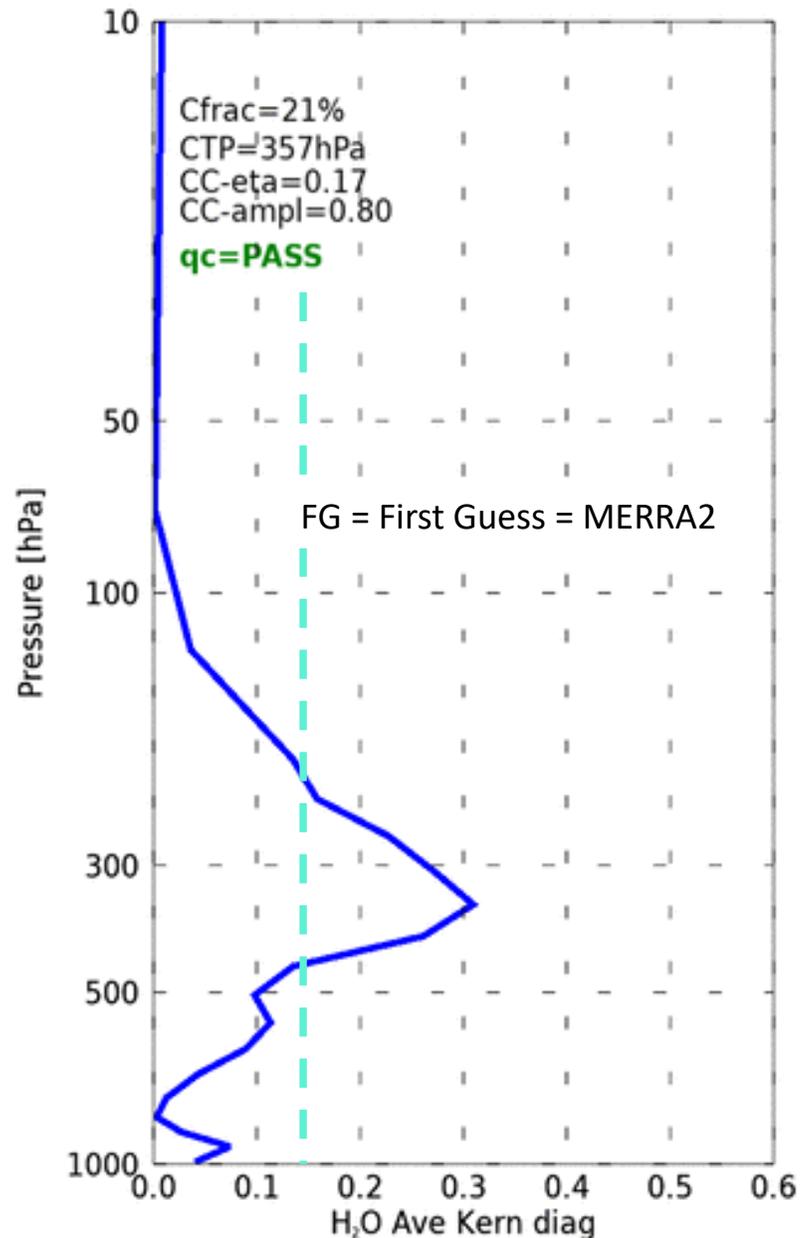
Pressure [hPa]

H$_2$O (FG-Ret)/FG [%]

(2)

**High SNR
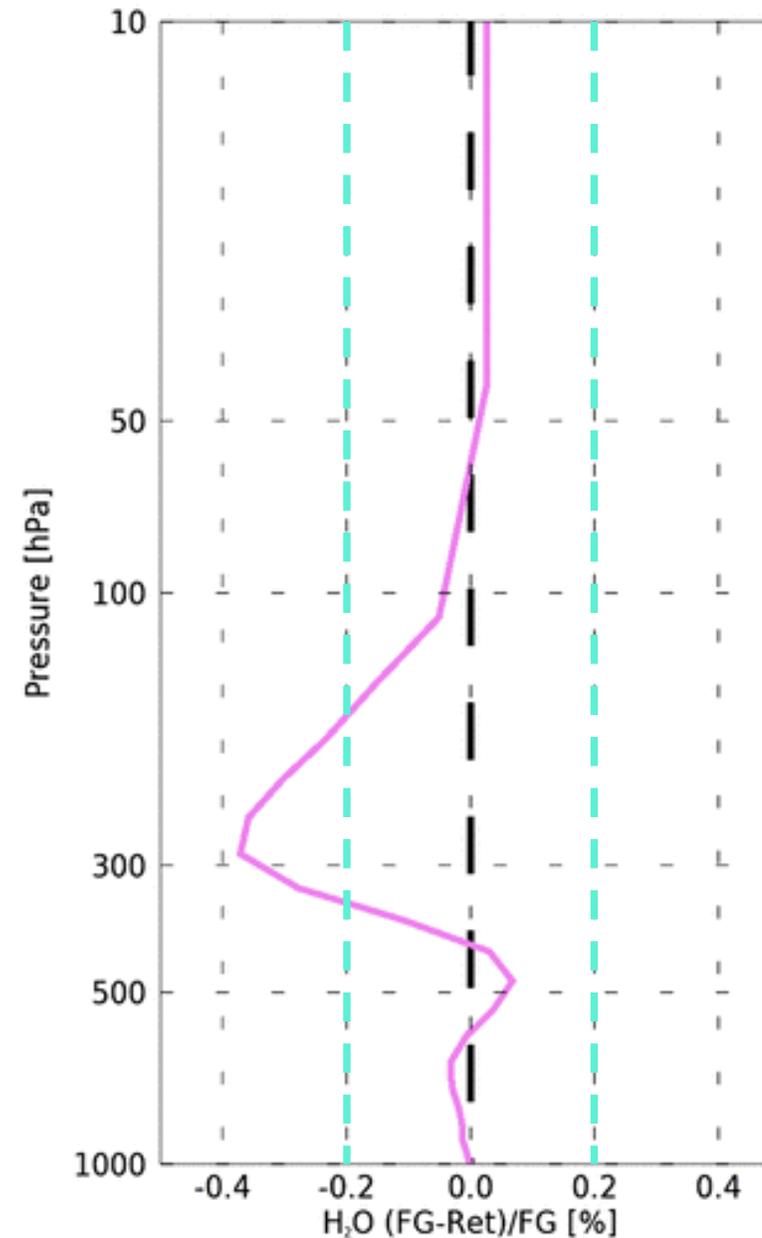Large Departure**

> 0.15 Ave Kern
> 20% departure

CLIMCAPS made a significant change to FG water vapor profile (MERRA2) because it did not agree with the measurements.

Here, we can **have confidence in Retrieval** as approximation of true atmospheric state.

CLIMCAPS-N20 H$_2$O 20180701PM Gran#15 FOR#101

Cfrac=21%
CTP=357hPa
CC-eta=0.17
CC-ampl=0.80
qc=PASS

FG = First Guess = MERRA2

Pressure [hPa]

H$_2$O Ave Kern diag

FG departure, lon/lat=[156.25, 24.72]

Pressure [hPa]

H$_2$O (FG-Ret)/FG [%]
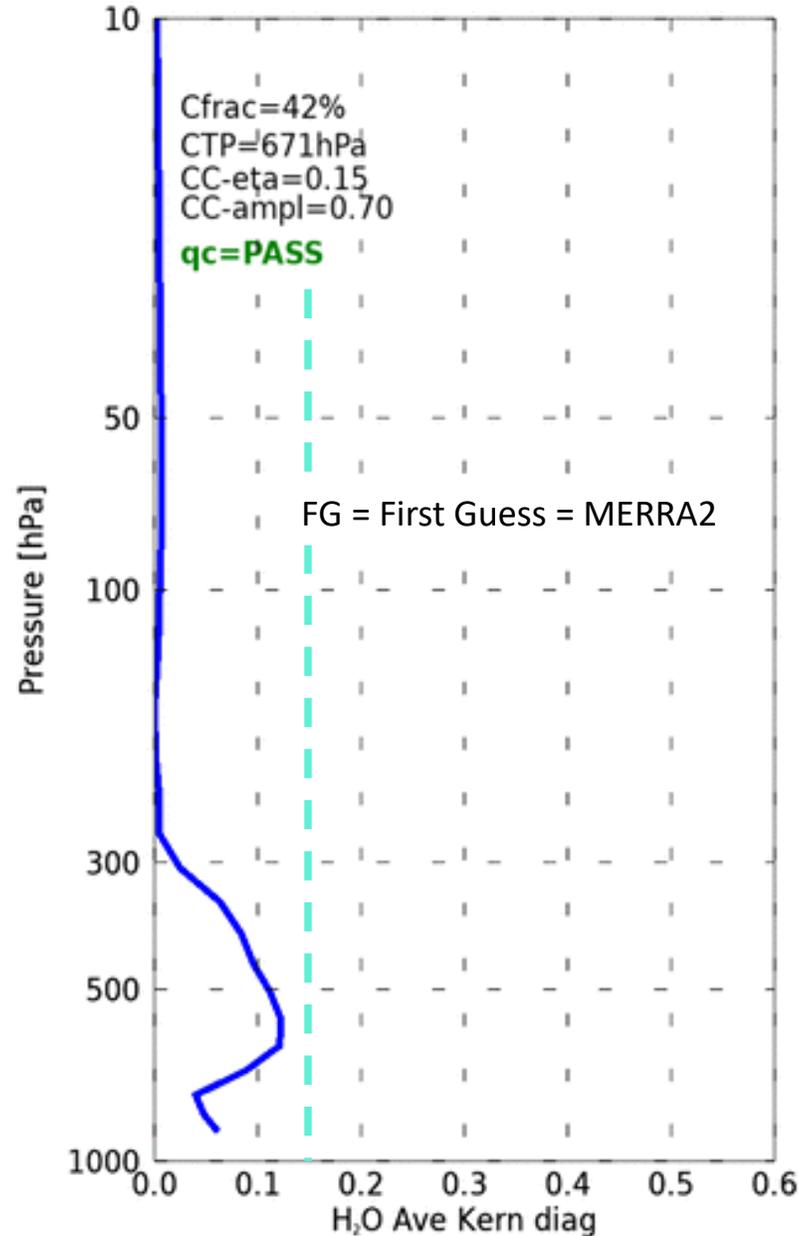
(3)
Low SNR
Small Departure

< 0.15 Ave Kern
<= 20% departure

CLIMCAPS made a SMALL change to FG water vapor profile (MERRA2) and measurement information content is low for this scene.
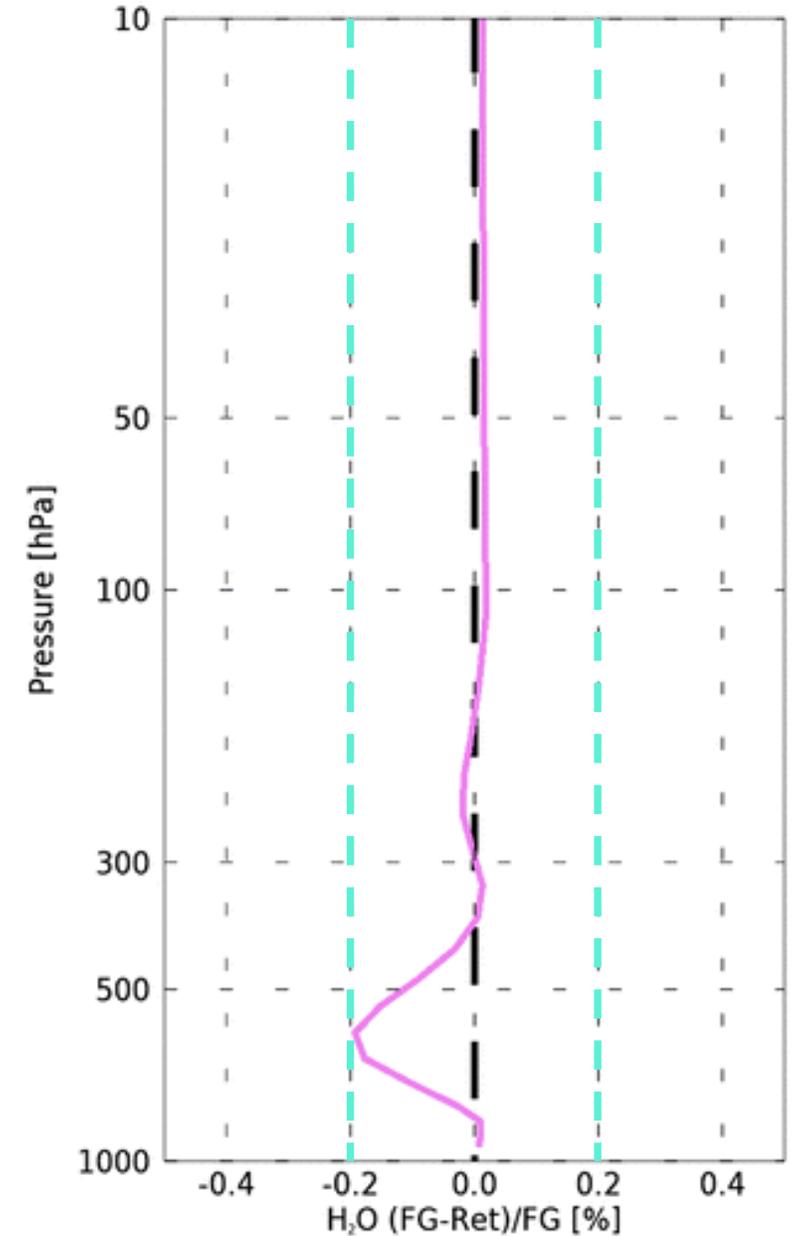
Here, we should **interpret both FG and Retrieval with caution** since we have limited knowledge of true state.

These cases typically occur in **polar regions**

CLIMCAPS-N20 H$_2$O 20180401PM Gran#10 FOR#318

Cfrac=42%
CTP=671hPa
CC-eta=0.15
CC-ampl=0.70
qc=PASS

FG = First Guess = MERRA2

Pressure [hPa]

H$_2$O Ave Kern diag

FG departure, lon/lat=[-144.58, -76.18]

Pressure [hPa]

H$_2$O (FG-Ret)/FG [%]
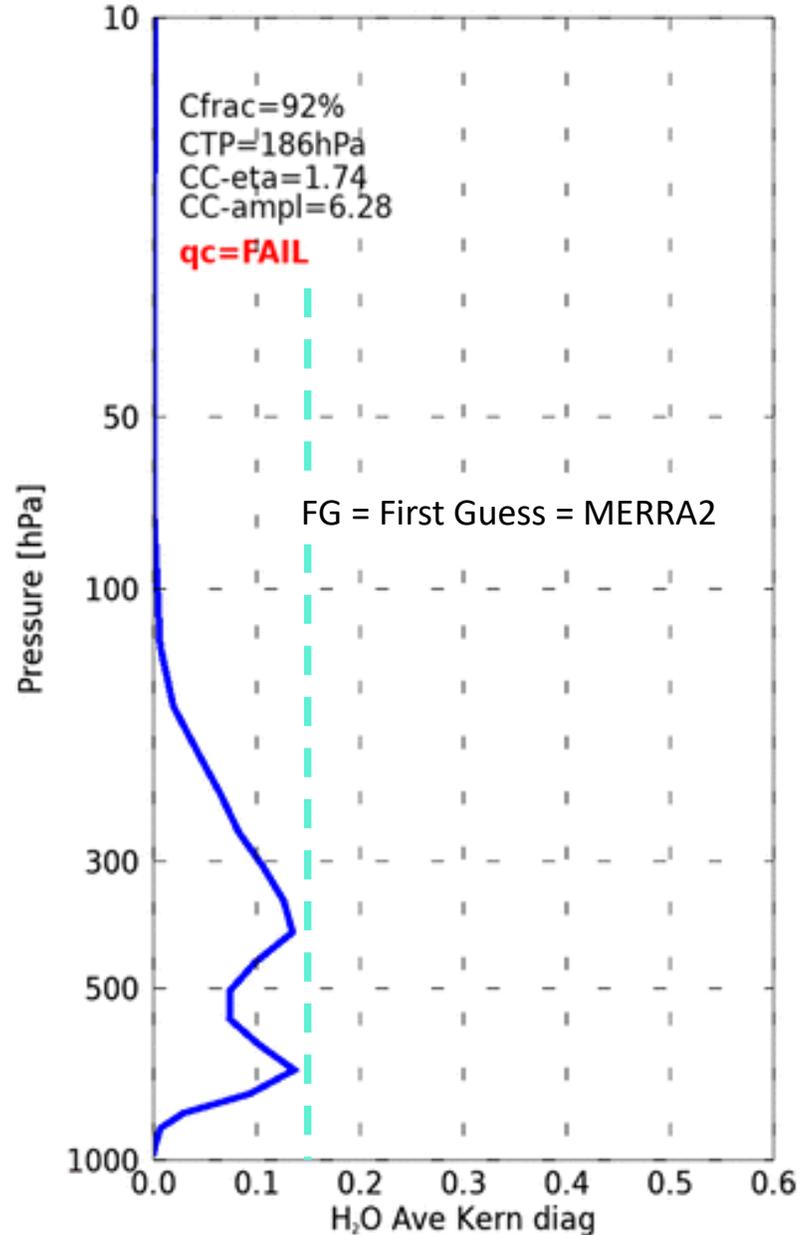
(4)
Low SNR
Large Departure

< 0.15 Ave Kern
> 20% departure

CLIMCAPS made a LARGE change to FG water vapor profile (MERRA2) despite low measurement information content for this scene.
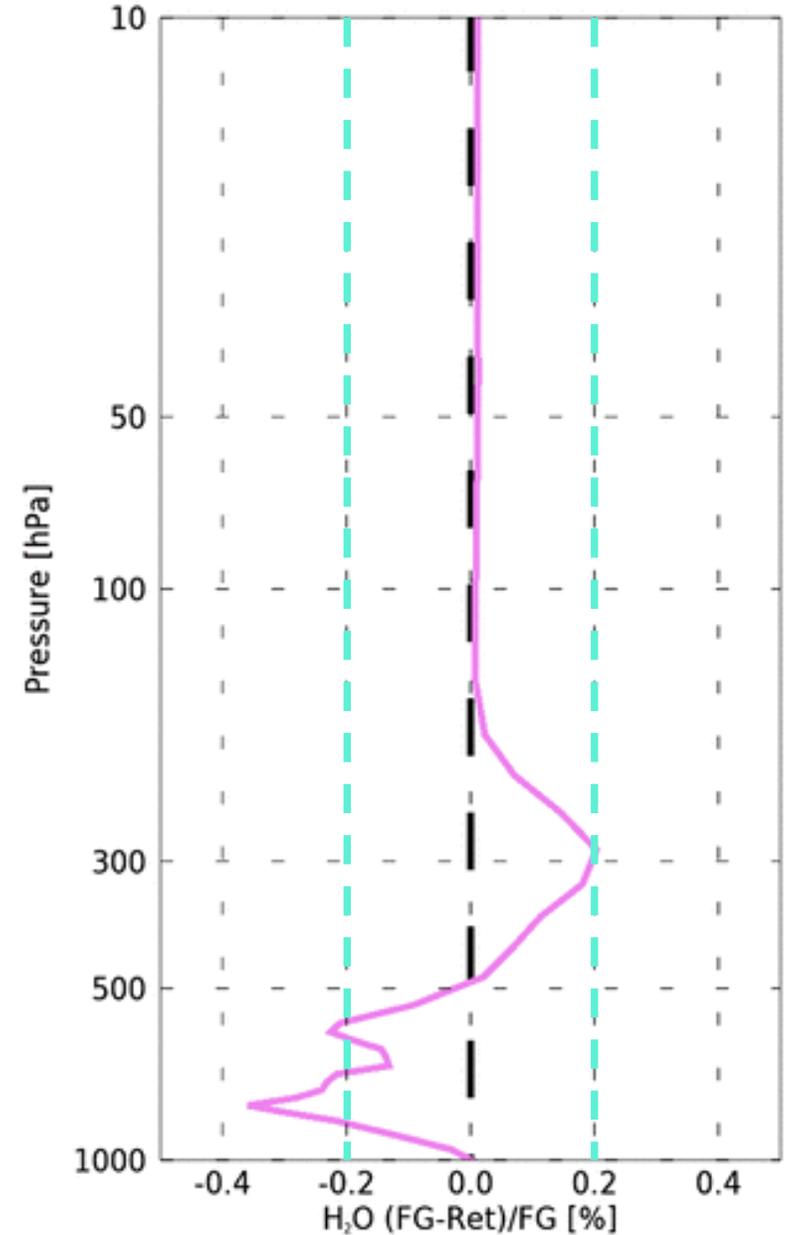
Here, we should **reject** **Retrieval** since FG departure is NOT based on knowledge of true state.
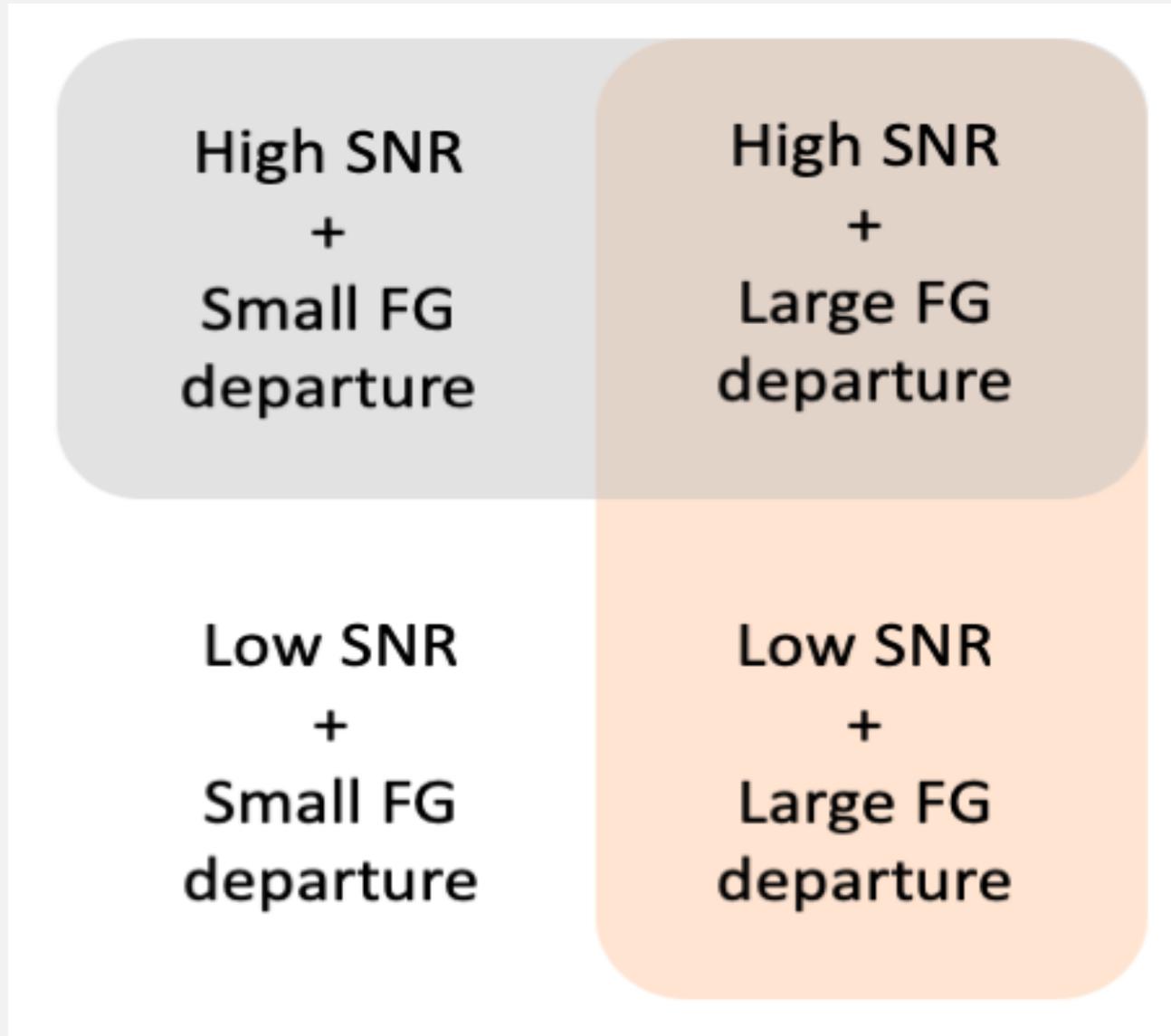
These cases are typically rejected by QC filters

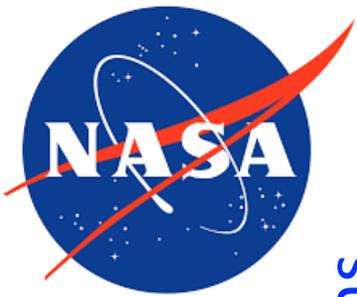

CLIMCAPS-N20 H_2O 20180701PM Gran#40 FOR#310

Cfrac=92%
CTP=186hPa
CC-eta=1.74
CC-ampl=6.28
qc=FAIL

FG = First Guess = MERRA2

Pressure [hPa]

H_2O Ave Kern diag

FG departure, lon/lat=[82.81, 12.12]

Pressure [hPa]

H_2O (FG-Ret)/FG [%]

Smith and Barnet, 2019, *Diagnosing satellite sounding observations from multiple satellite platforms*, <u>in prep</u>

In summary…

NUCAPS

IASI/AMSU on **MetOp-A/B/C** + CrIS/ATMS on **SNPP+NOAA20**

AIRS/AMSU on **Aqua** + CrIS/ATMS on **SNPP+NOAA20**

CLIMCAPS

Research to Operations

Operations to Research

Multi-platform product continuity with scene-dependent uncertainty characterization, propagation and reporting to separate instrument effects, a-priori assumptions and real geophysical change