Characteristics of the Cloudy Atmosphere Observed by AIRS

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Procedure

- Overview of AIRS Products – Global Performance
- Use exemplar footprints to characterize dependence of product on cloudiness – 3 examples
  - Cloud-free
  - Low stratocumulus
  - Tropical cumulus convection
- Types of analyses - consistency between radiances
  - Observed (Obs)
  - Cloud-cleared (CC)
  - Calculated from ECMWF forecast ($Calc_{ECMWF}$)
  - Calculated from retrieved solutions ($Calc_{AIRS}$)
- Consistency of CC water vapor radiances and dynamics

Overview

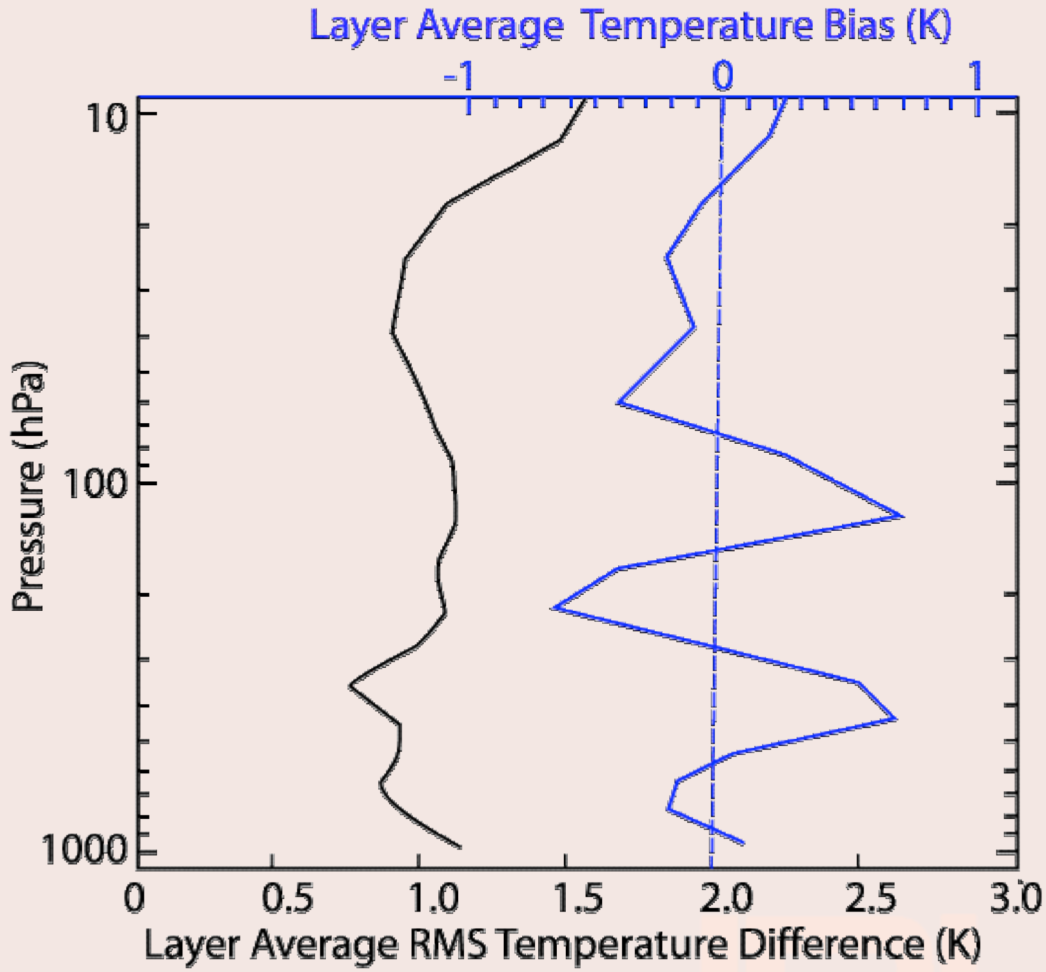
- 2002 September 9 (AIRS Focus Day 3)
  - Successful MW retrievals: 94%
  - Successful MW & cloud clearing: 93%
  - Full MW/IR Retrievals: 67%
  - Clear Retrieved Footprints (AIRS, AMSU):
    - NaF < 0.5: 0.2%
    - **Surface Channel Cloud Contamination < 0.1K**: 11% 5.0%

      $$\sum_i f_i \left\{ T_b^{Surf} - T_{b\,i}^{Cloud} \right\}$$

    - Total Cloudiness < 1%: 10% 3.8%

Temperature Profile Characteristics

- Comparison between AIRS retrievals and interpolated ECMWF
- RMS difference is an estimate of sum of forecast and retrieved errors (assumed uncorrelated)



Theoretical Basis for Cloud-Clearing

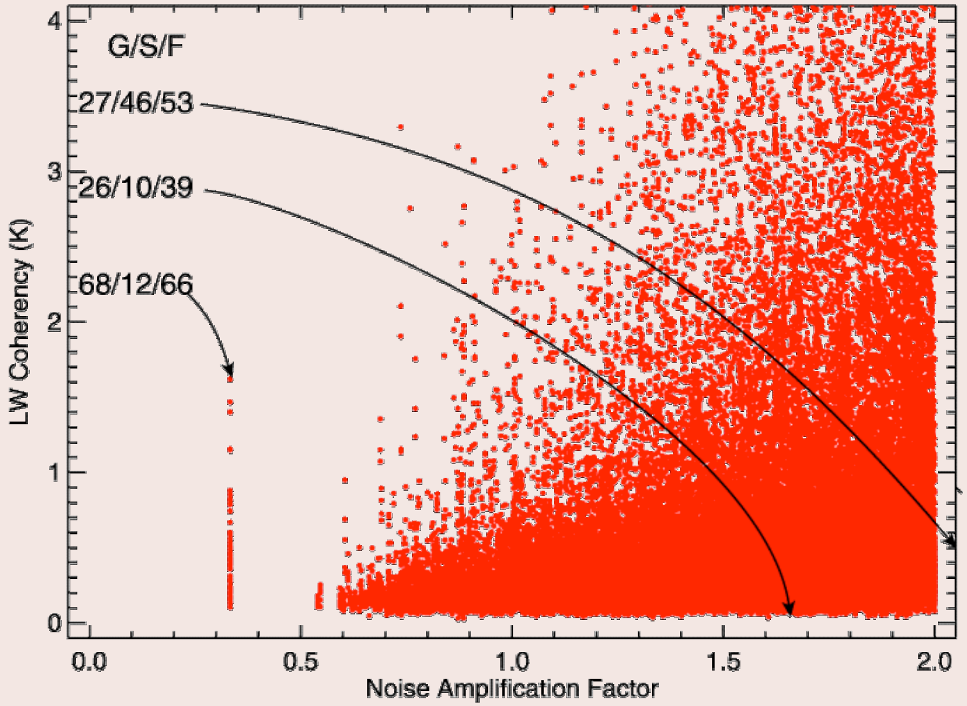
- Assumptions
  - Clouds are gray absorbers
  - Most parameters are homogeneous (independent of horizontal coordinates) within an AMSU footprint
    - Surface properties: emissivity, reflectivity, skin temperature
    - Profiles: temperature, water vapor, trace gases
    - Cloud properties: cloud top pressure, emissivity and reflectivity
  - Clouds are localized, i.e. cloud cover varies between AIRS footprints.

Characterization of Cloudiness

- Prediction of sea surface temperature
  - 21 LW channels (800 – 1000 cm^{-1}) SST
  - Cloud contamination characterized by departure from correlative SST
  - 0.8K precision
- Radiance coherency between adjacent footprint
  - Standard deviation of predicted SST in 3x3 AIRS footprints
  - 0.2K precision
- Noise amplification by cloud clearing

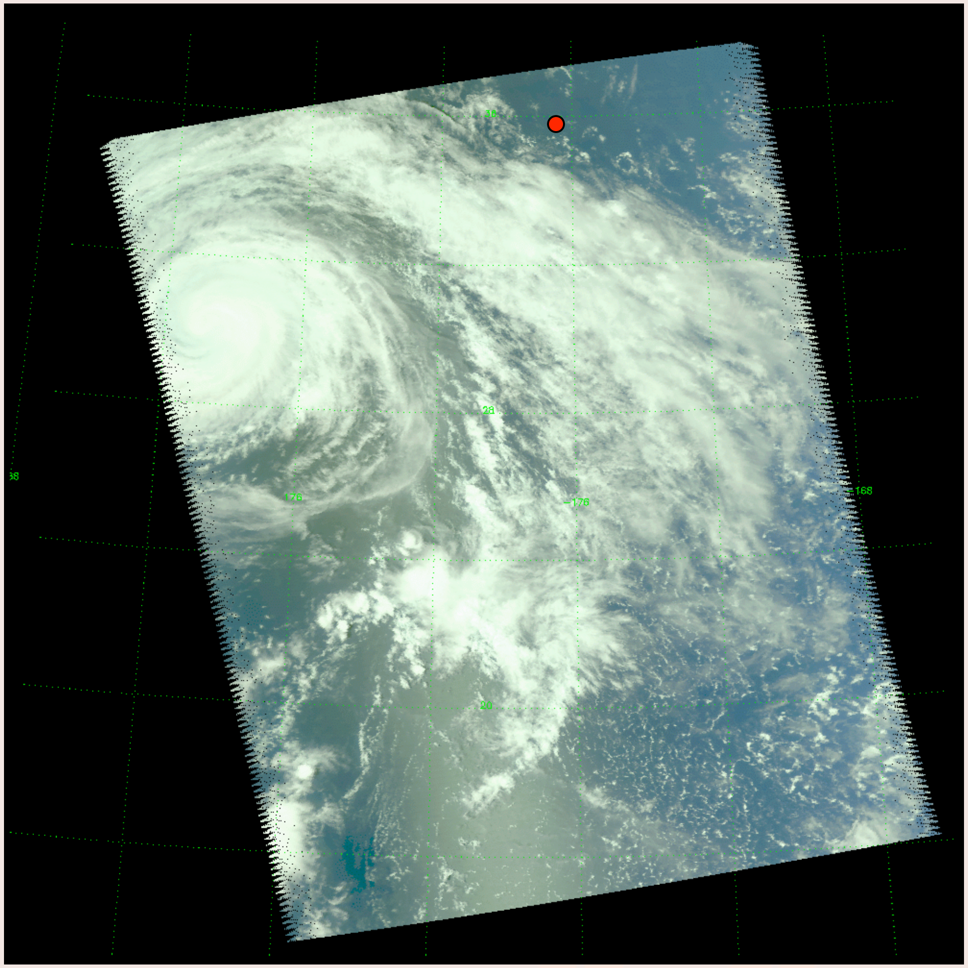
3 Study Footprints Presented

- 26/10/39
  - Low LW incoherency
  - Low SST discrepancy
  - Identified cloudy by retrieval
  - Thin cirrus
- 68/12/66
  - High LW incoherency
  - Identified clear by retrieval
  - Low stratocumulus
- 27/46/53
  - Moderate LW incoherency
  - Identified cloudy by retrieval
  - Tropical mesoscale cumulus systems

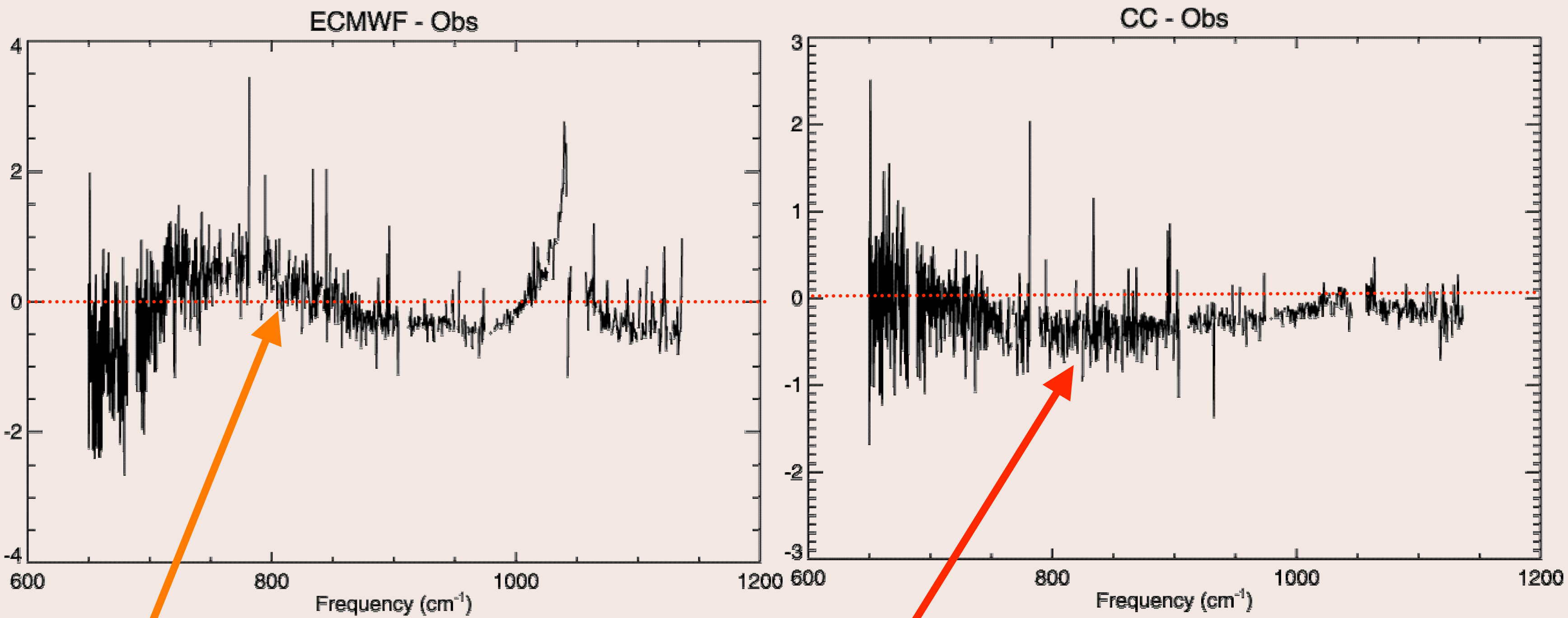


Cloud-Free Region (1)

- 6 September 2003
- G/S/F: 26/10/39
  (Granule/Scanline/Footprint)
- Noise Amplification Factor (NaF) 1.28
- LW Coherency: 0.05K
- LW SST Pred Err: 0.26K



Cloud Signatures



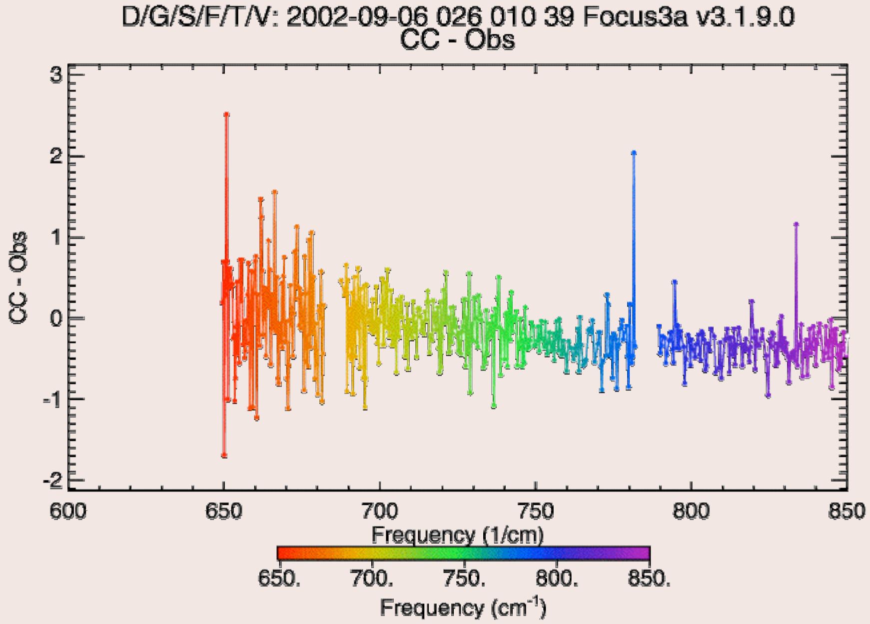
Surface Channels show droop indicative of cirrus

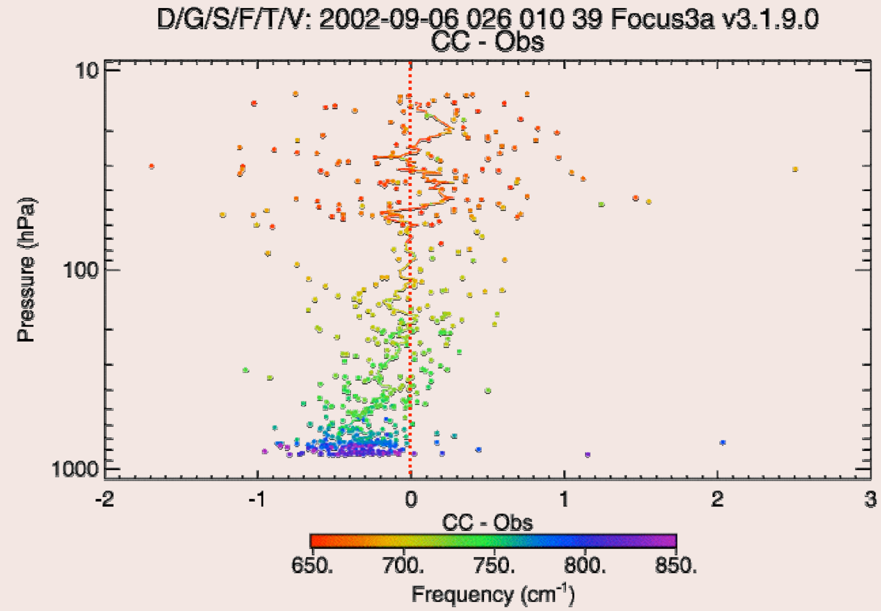
CC – Obs do not show removal of cirrus signature

CC are cooler than observed in window channels.

CC and ECMWF-calculated are within 0.4K in these surface channels

Cloud-Cleared – Obs



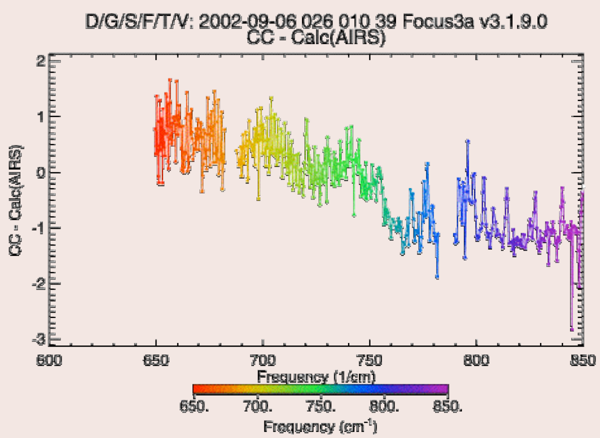


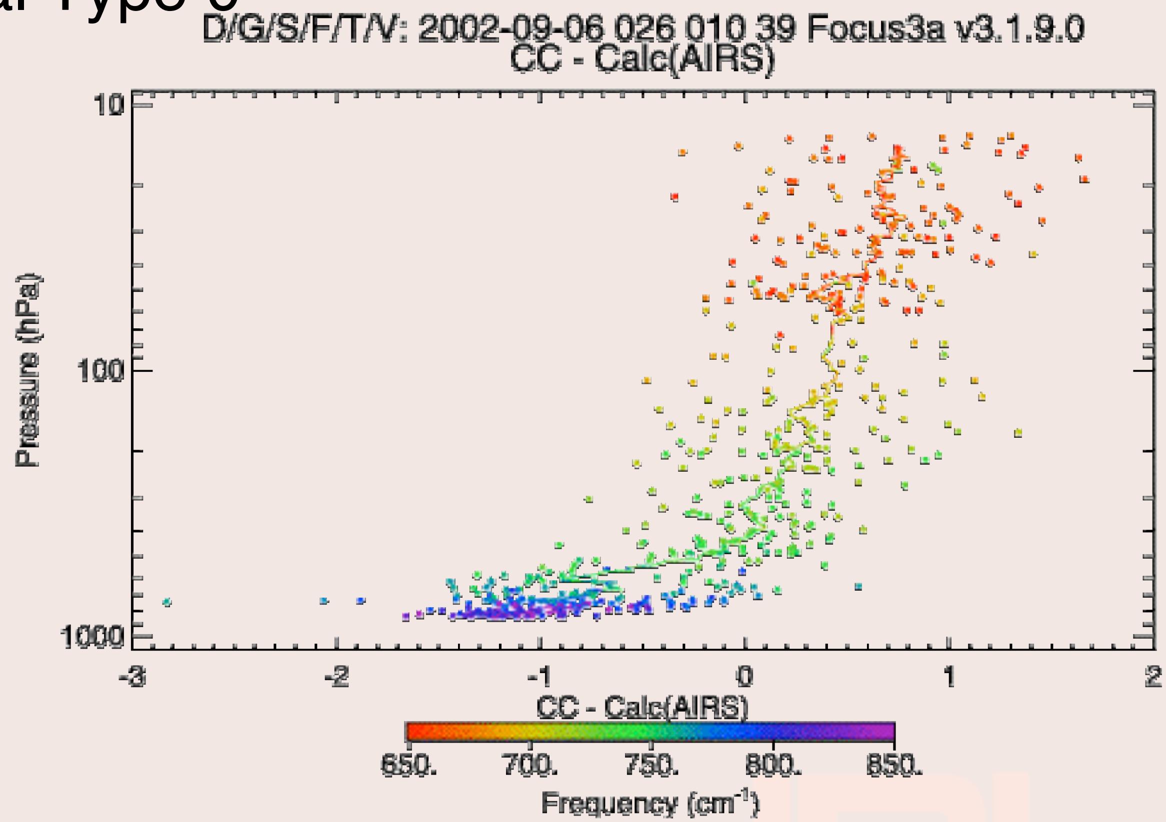
Map radiances onto pressure using P centroid of weighting functions.

Smoothed differences shown by line (method is dubious near surface)

Cloud-Cleared – Calc (AIRS)

- CC Radiances calculated from retrieved state, Retrieval Type 0





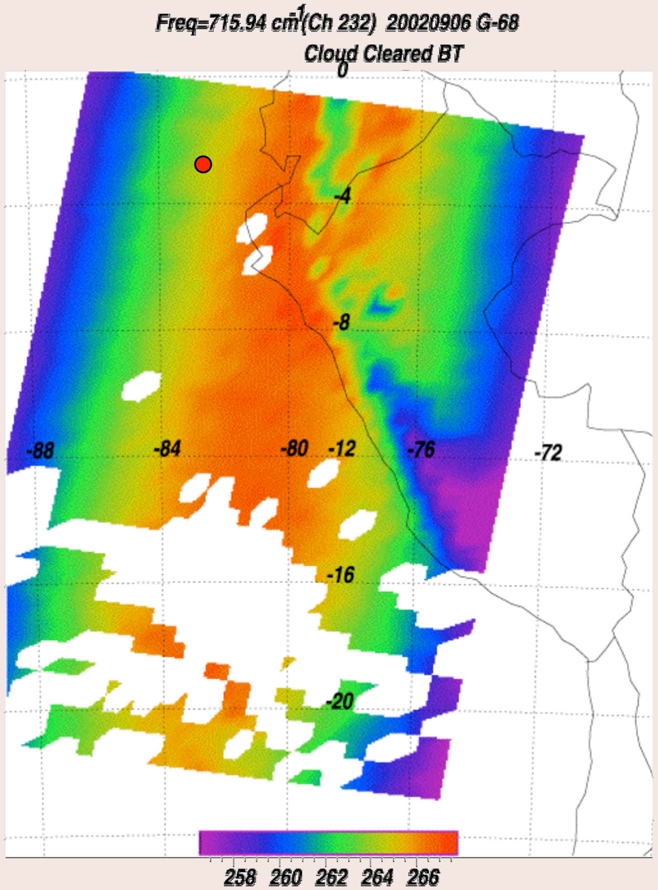
Summary for Example 1

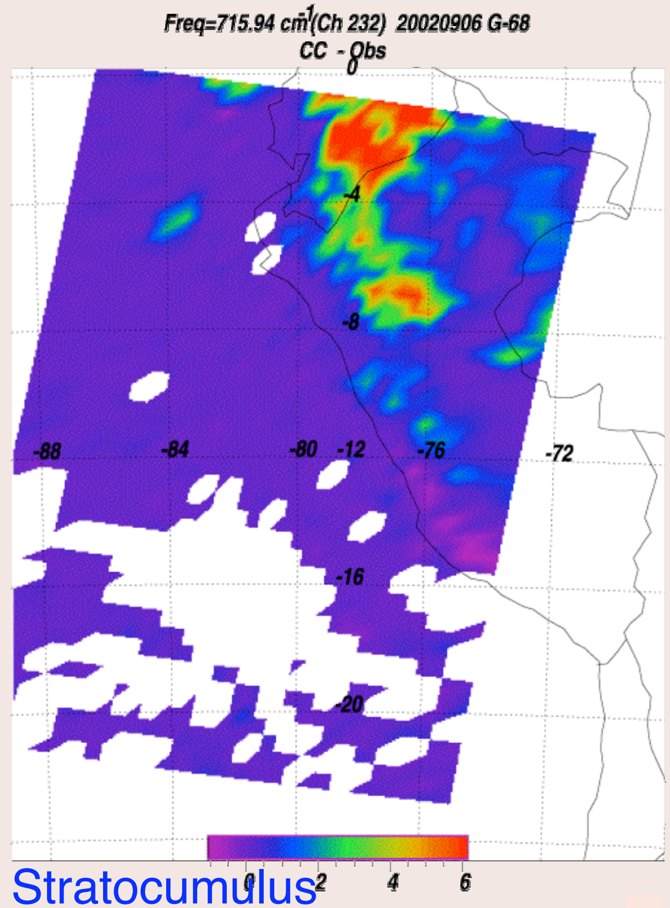
- Retrieval is detecting false cloud
  - Primitive cloud spectral model does not fit spectral shape of clouds
- Cloud-cleared - radiances calculated from solution
  - Poor in stratosphere and lower troposphere
  - Error propagates upward and downward through profile

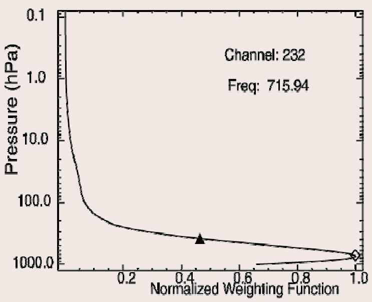
Cloudy Region Flagged Clear (2)

- Retrieval Set contains both G/S/F: 68/12/66 and 68/10/65 (Night)

  (Coherency employs moving window)



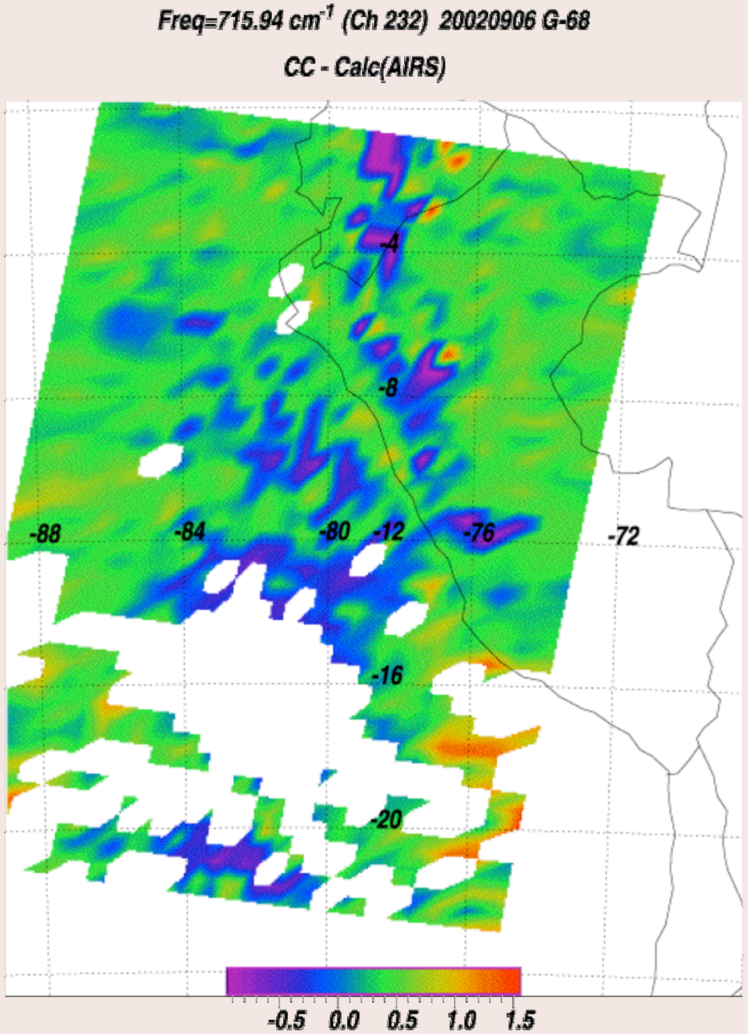


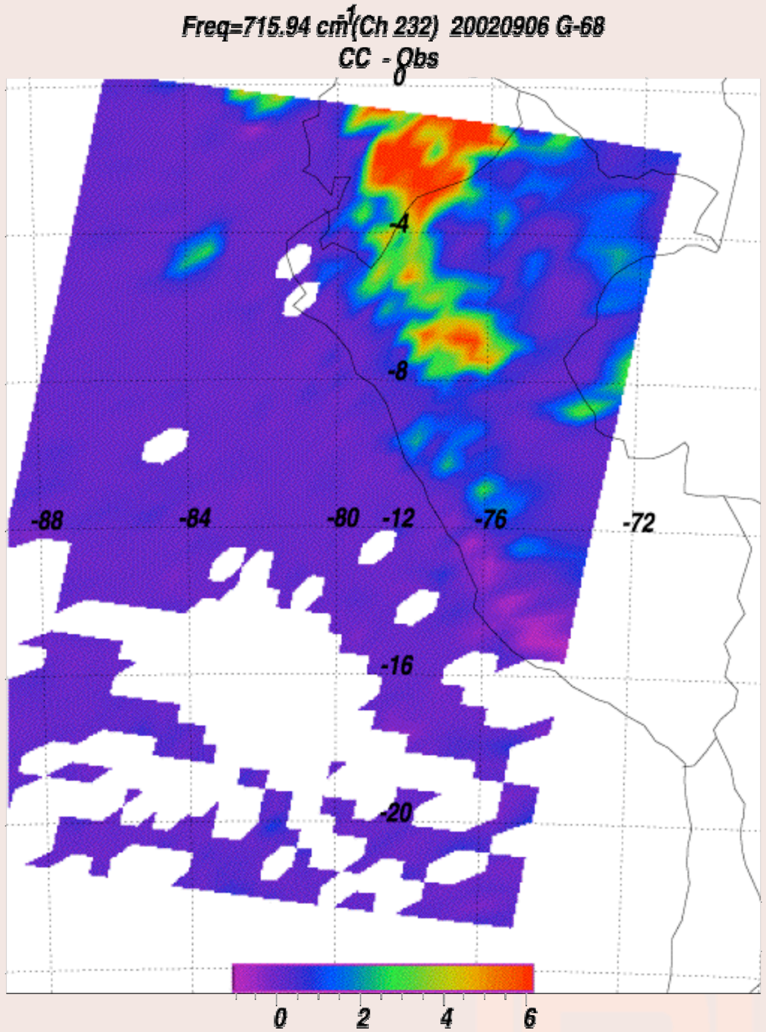


Low Stratocumulus

Coast of Peru

Consistency of Cloud-cleared and Calculated Radiances





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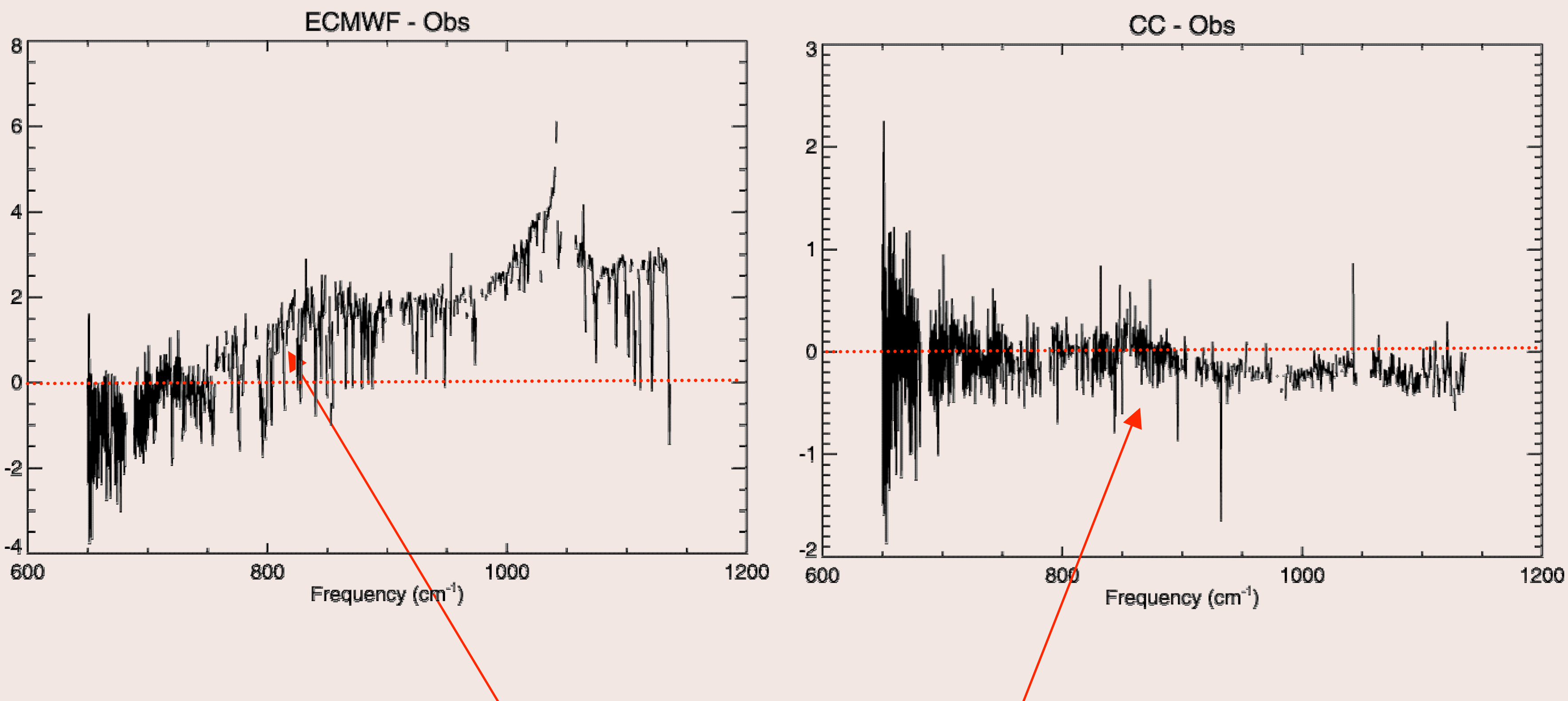
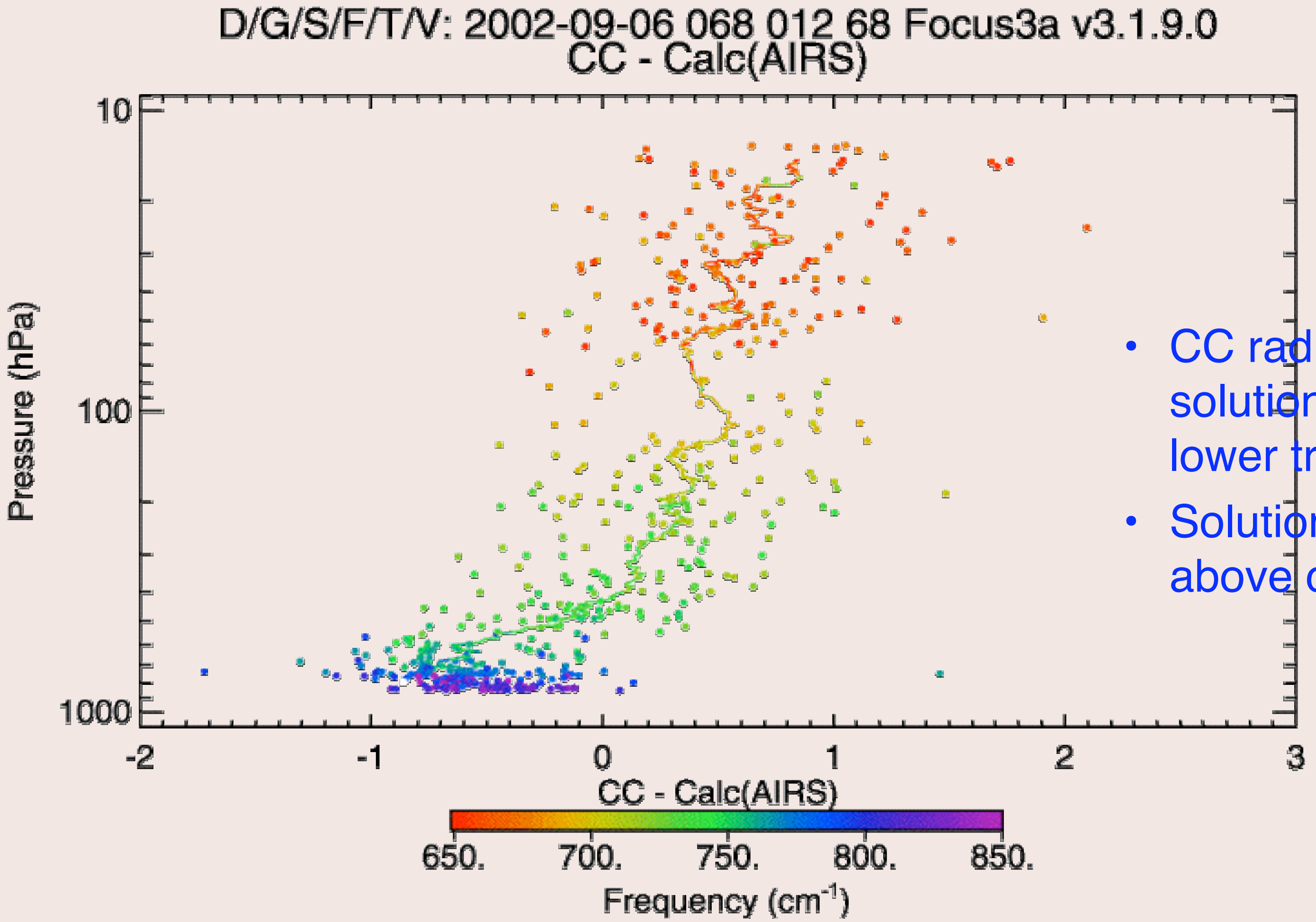
Cloud Signatures



Difference with ECMWF shows spectra signature of water clouds

Observed and Cloud-cleared radiances are the same

Consistency of Cloud-cleared and Fitted Radiances



- CC radiances are warmer than solution-derived radiances in lower troposphere
- Solution radiances are warmer above clouds

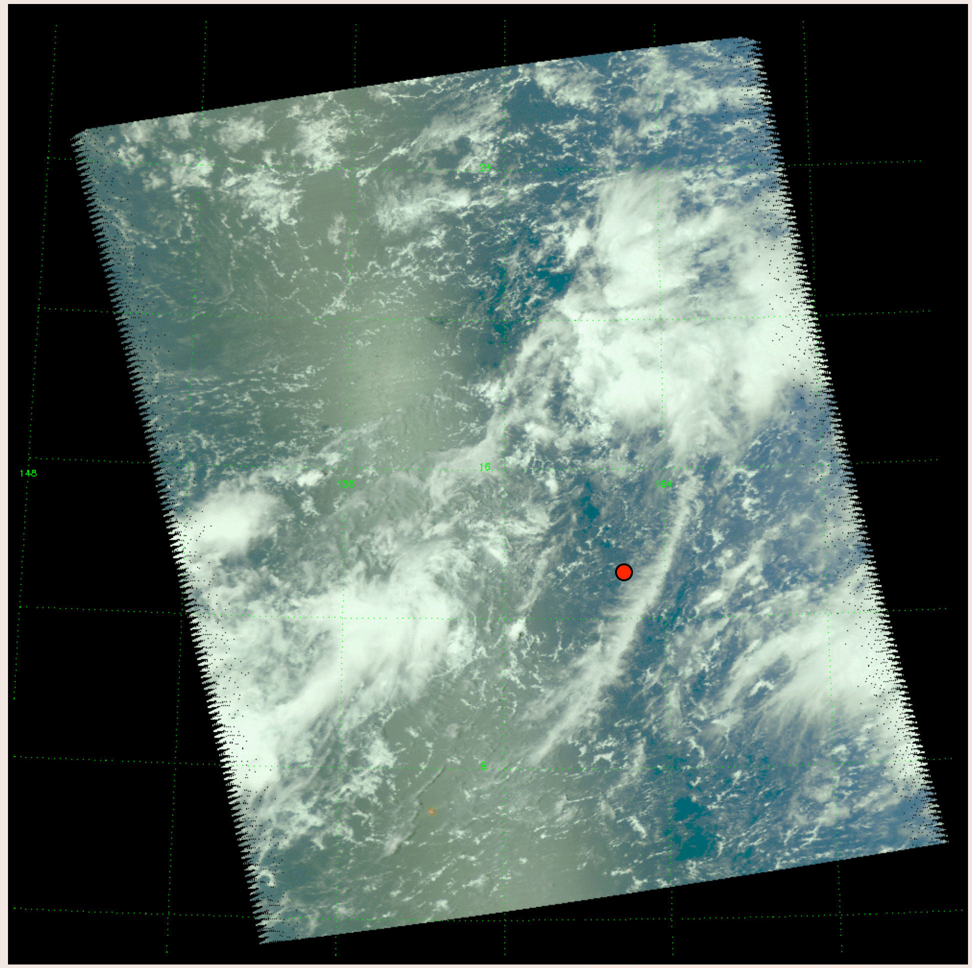
Summary of Example 2

- Low Stratocumulus not detected
  - Signature of liquid water clouds
- Fit to radiances within 1K in 1 km layers
  - Differences are correlated with height
- Radiances contain information not used by retrieval

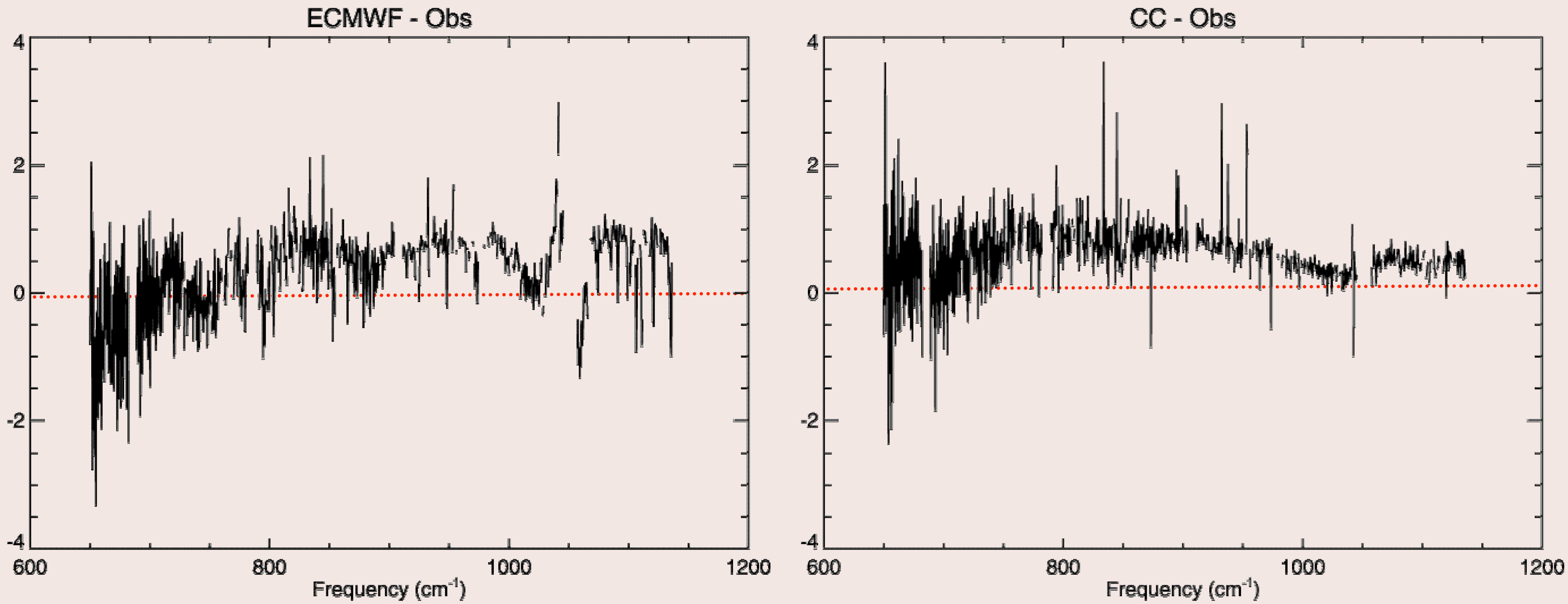
Tropical Cumulus

- Tropical Western Pacific
- GSF: 27/46/53
- 12.26 ° N, 161.7° E
- NaF: 3.1

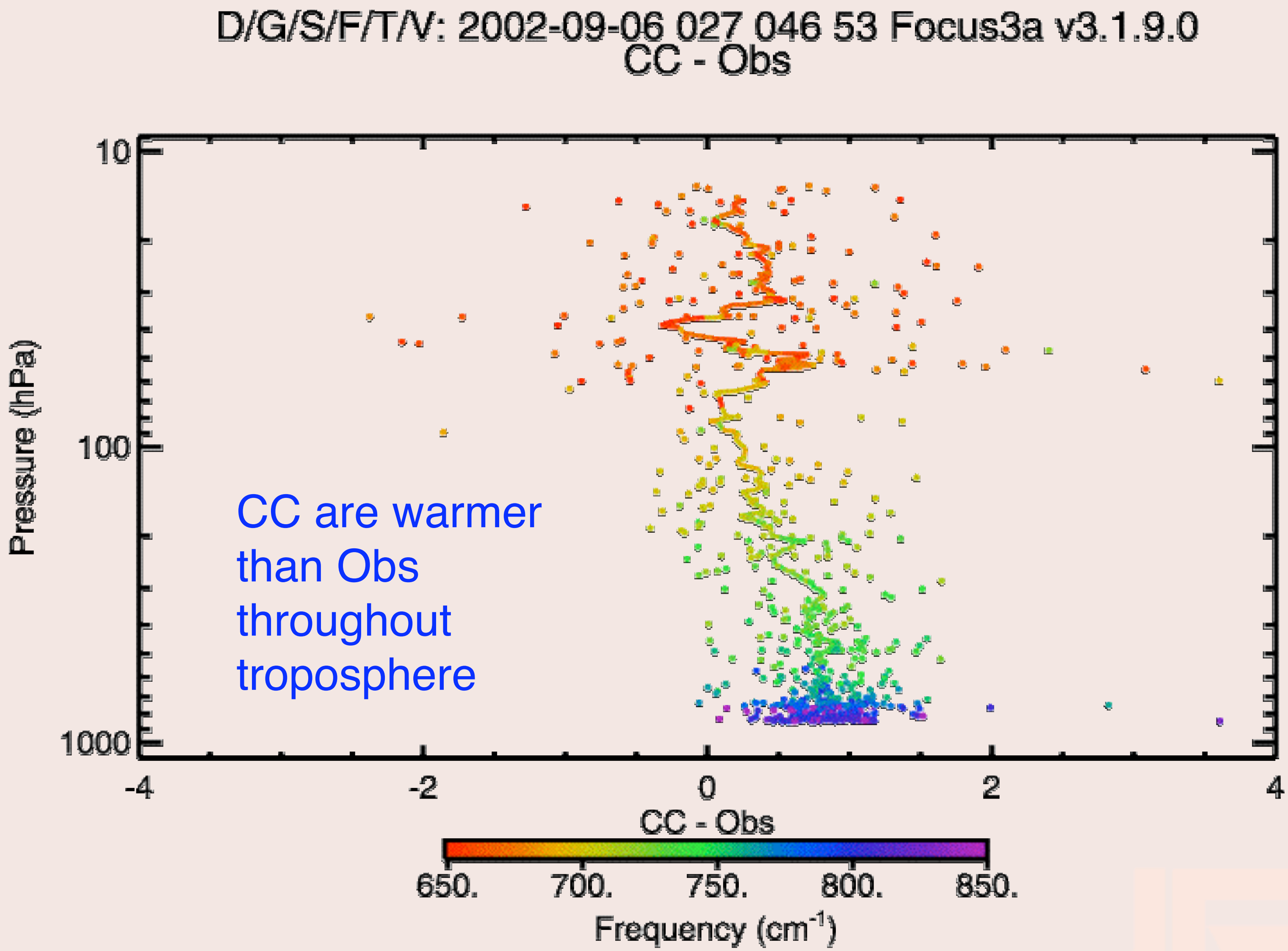
- Mesoscale Convective Systems



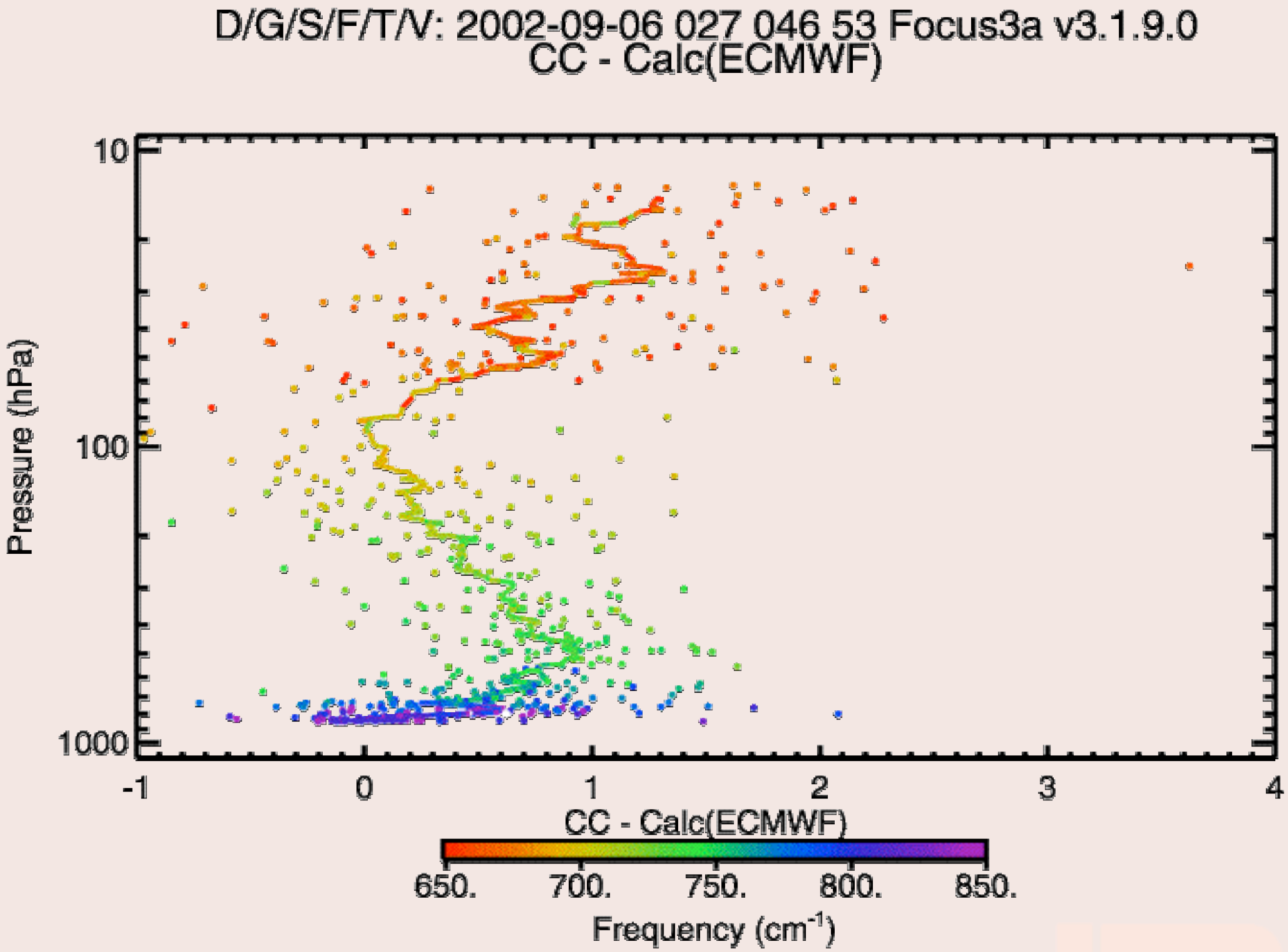
Cloud-cleared



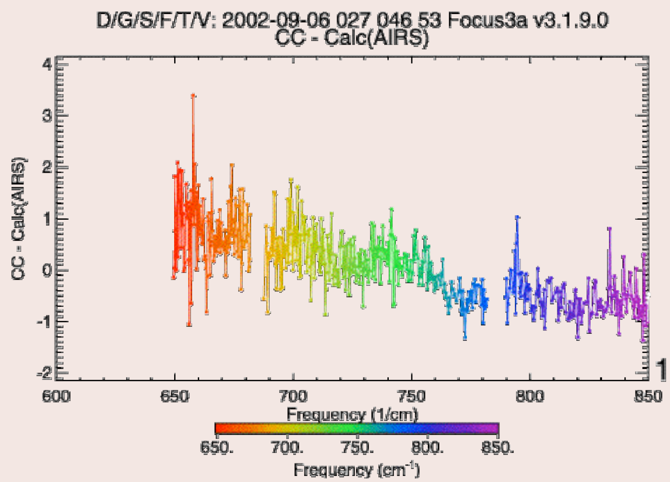
Cloud-cleared – Obs

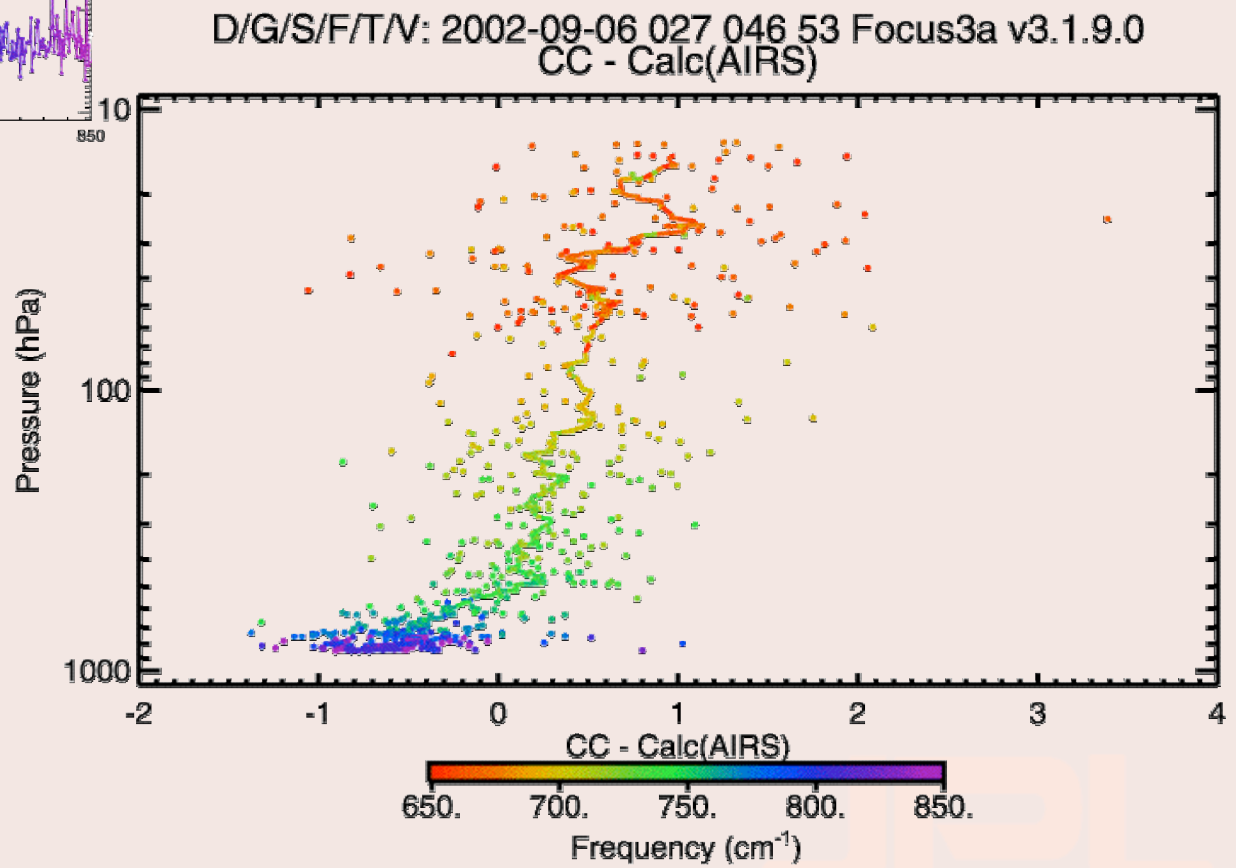


Cloud-cleared – Calc (ECMWF)



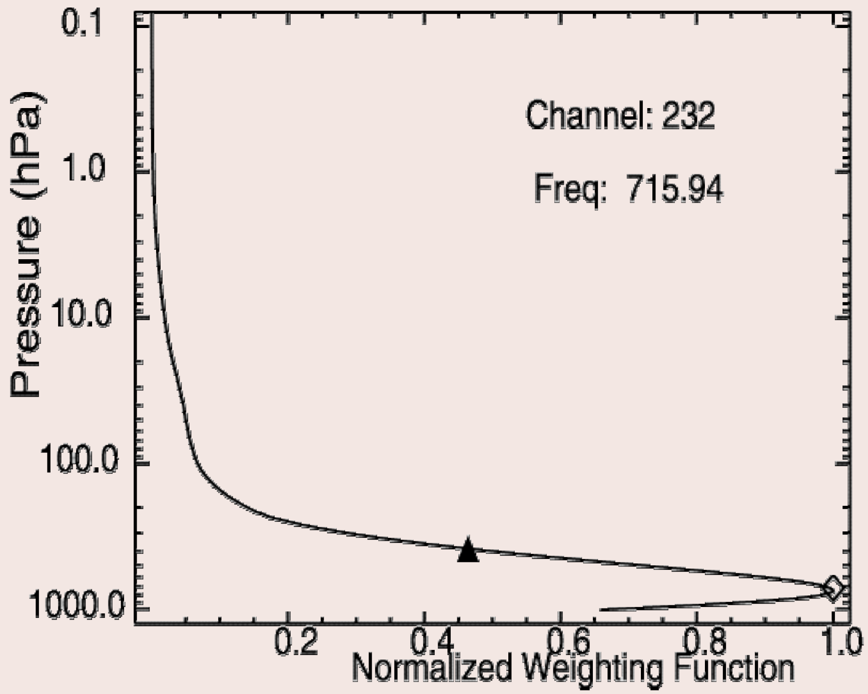
Cloud-cleared – Calc(Retrieval)

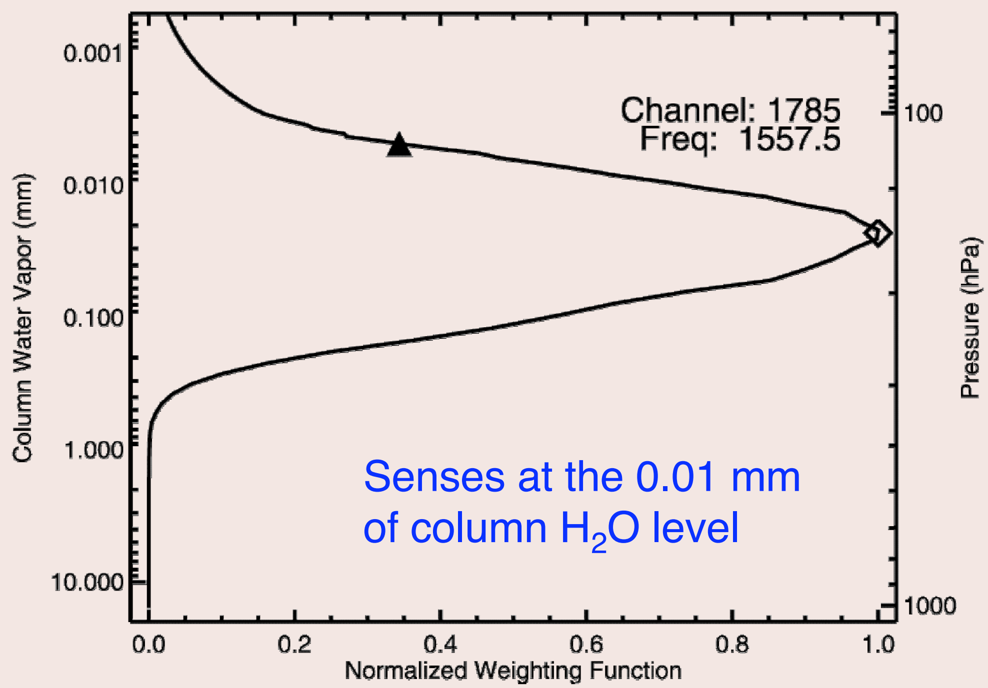




Fitted radiances match CC to 0.5K through mid and upper troposphere

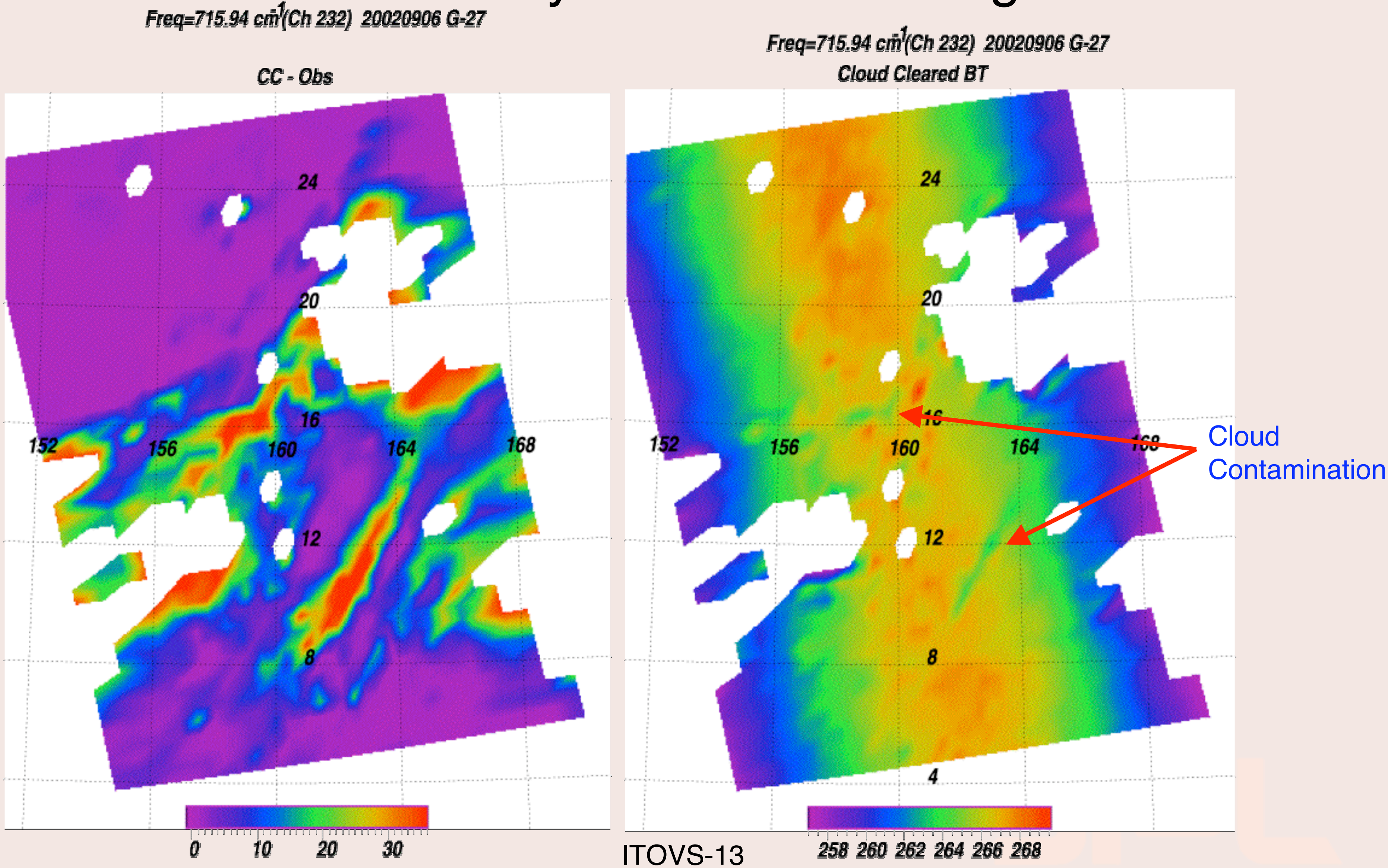
Spatial Variability of Temperature and Water Vapor





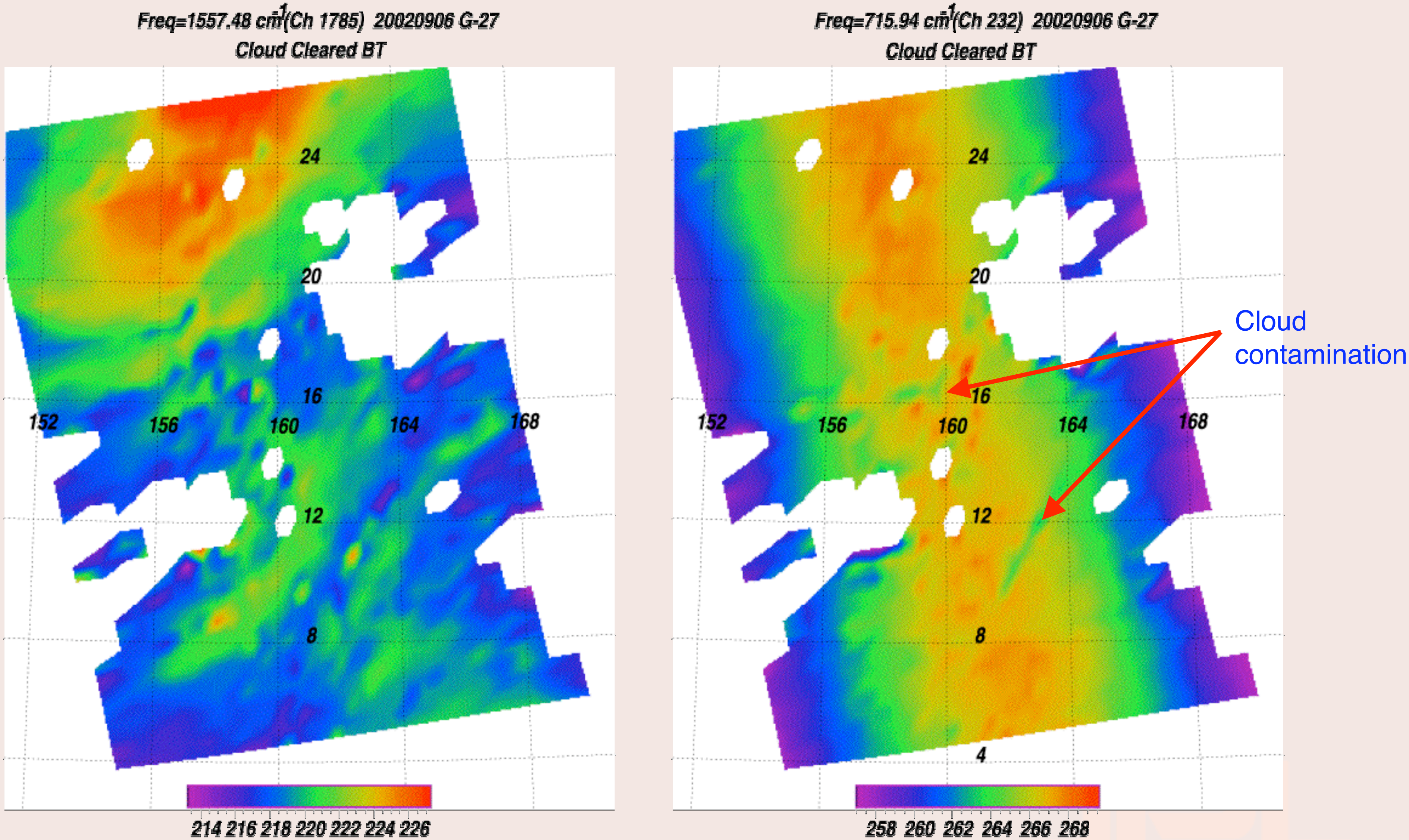
Spatial Variability

Accuracy of Cloud Clearing



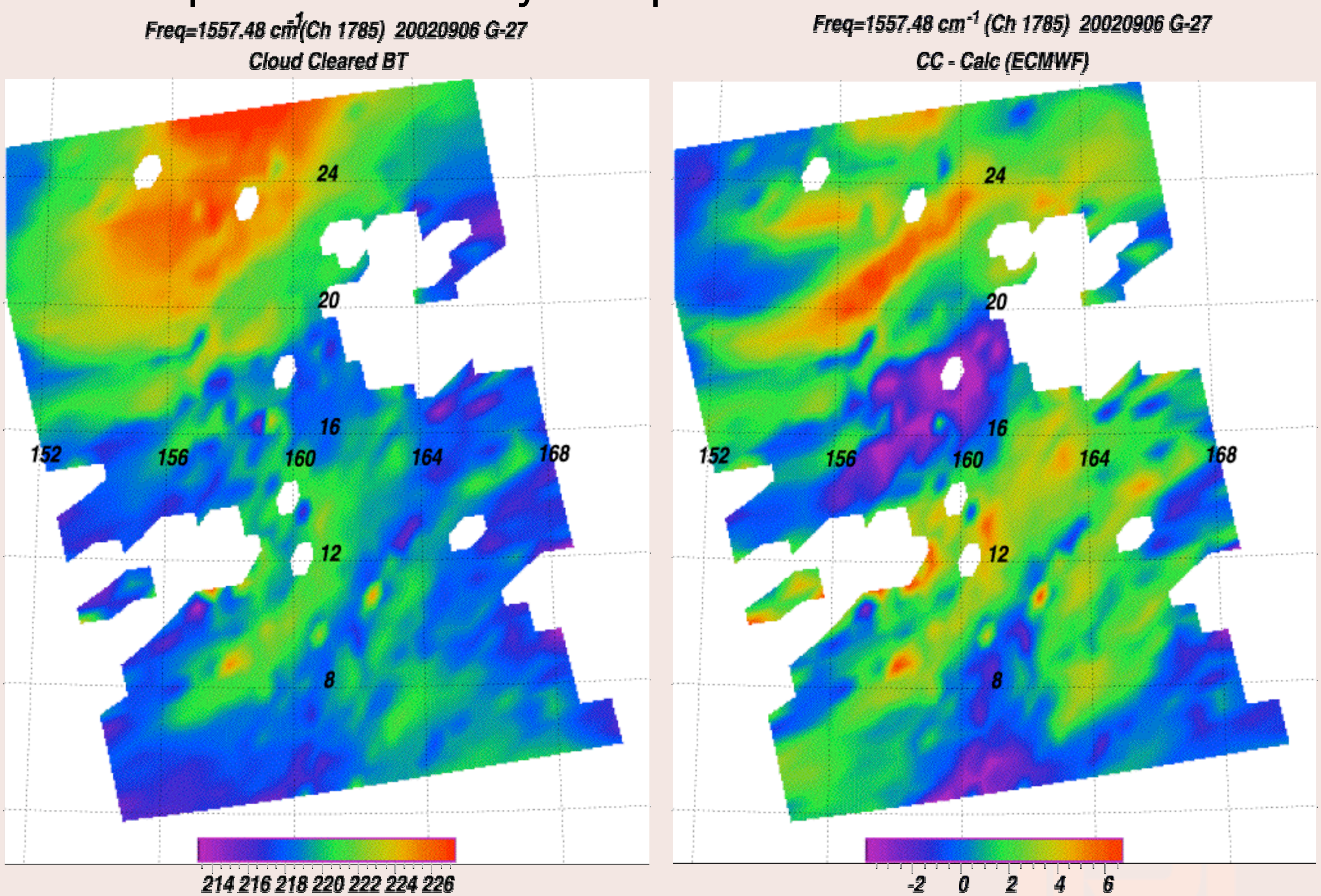
Upper-Trop Water Sounding Channel

Correlation with Clouds



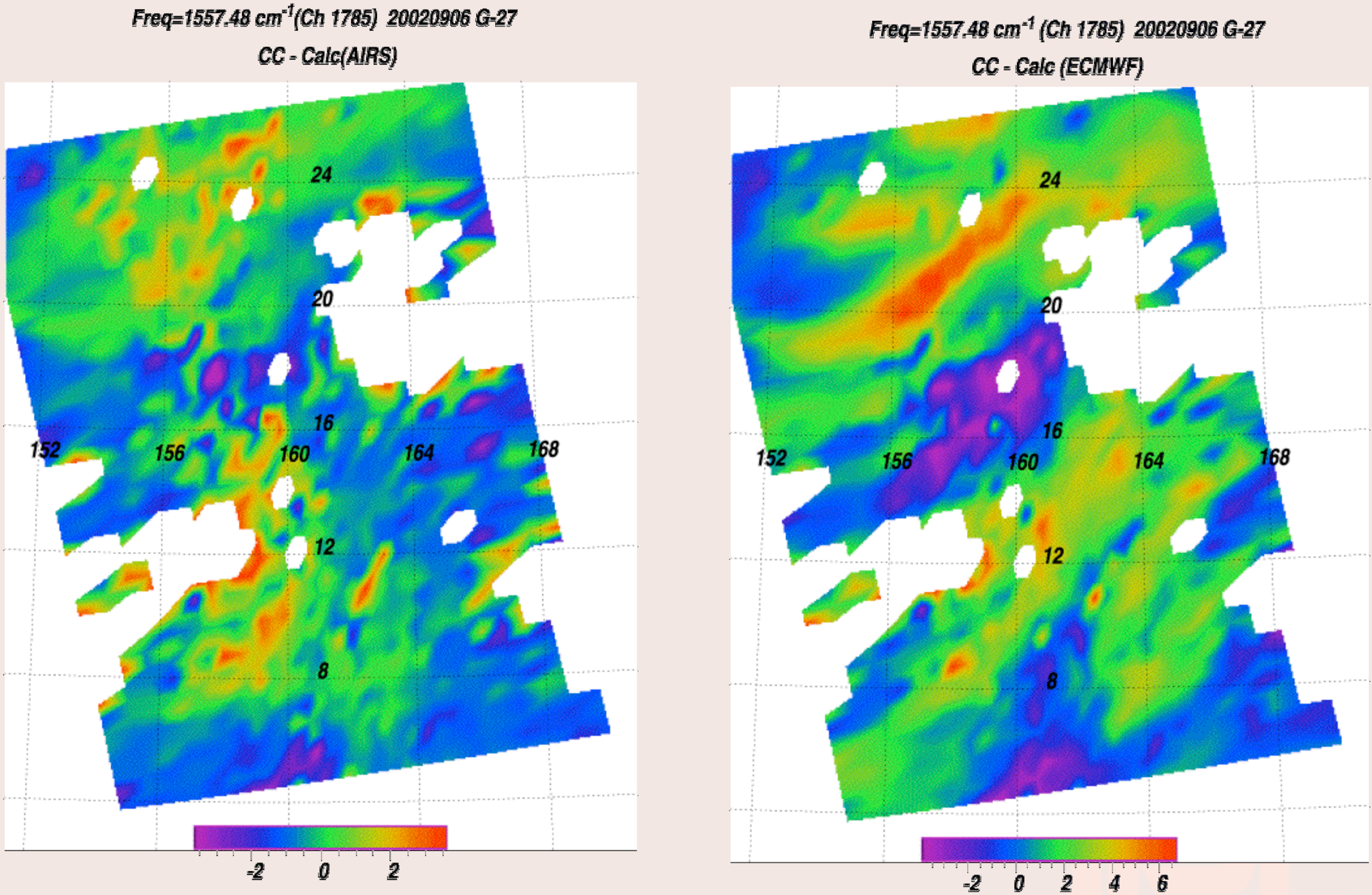
Upper-Trop Water Sounding Channel

Spatial Variability compared with ECMWF



Upper-Trop Water Sounding Channel

Radiance Closure



Water Vapor Spatial Variability

- Water vapor CC radiance shows greater variability then temperature
- Increases mixing ratio uplifts the 0.01 column water vapor surface,
  - 1557 cm^{-1} radiances is cooler
- Variability is correlated with clouds, but
- Radiance is consistent with:
  - vertical transport in squall
  - subsidence forward of squall

Conclusions

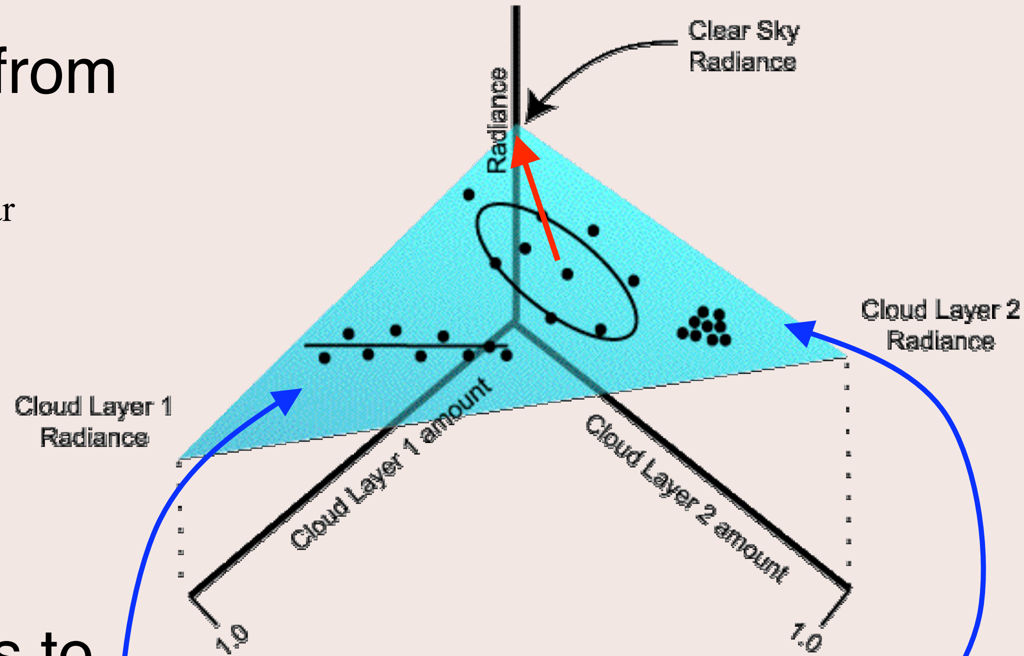
- Algorithms have difficulty detecting low clouds (previously known)
- Calculated radiances from solution do not agree with cloud-cleared radiances when low clouds are present
  - Implies more information can be extracted from measurement
- Algorithms appeared to be optimized for high clouds, e.g. tropical cumulus
- Mid through upper tropospheric cloud-cleared water vapor radiances show variability consistent with dynamics
- Studies of individual footprints elucidate algorithmic improvements and limitation

Cloud–Clearing Procedure

- Predict clear radiances from microwave radiances

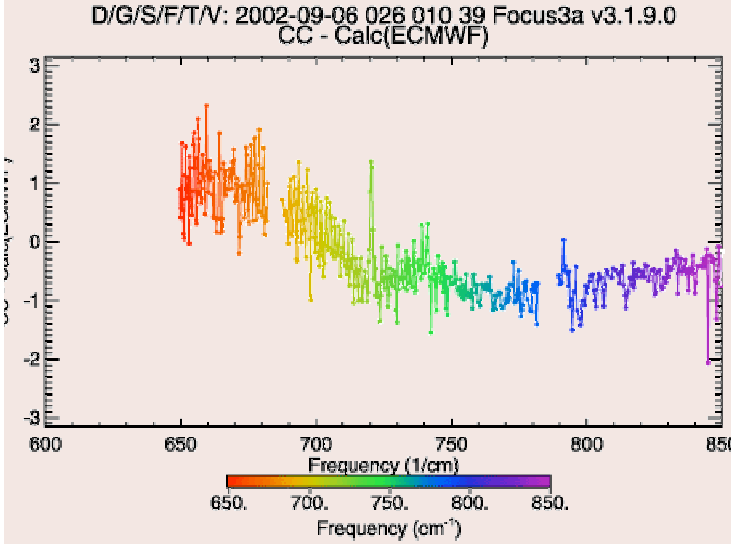
$$R_{\mu\text{wave}} \; \square \; T, q \; \square \; R_{\text{IR}}^{\text{Clear}}$$

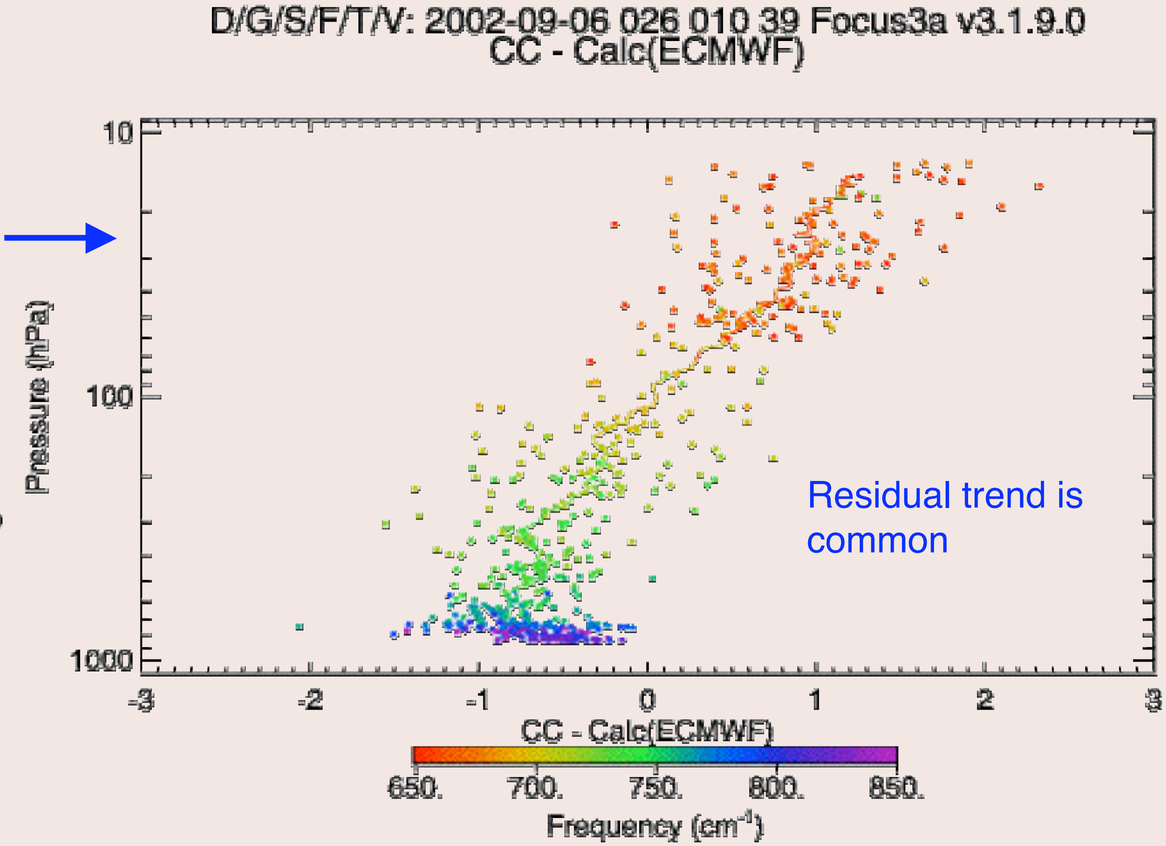
- Estimate cloud fractions from cloudy and pre-dicted clear radiances (predictor channels)
- Extrapolate all radiances to clear conditions
  - Noise amplification



Two unsolvable conditions
- Homogenous clouds
- Correlated clouds

Cloud-Cleared – Calc(ECMWF)





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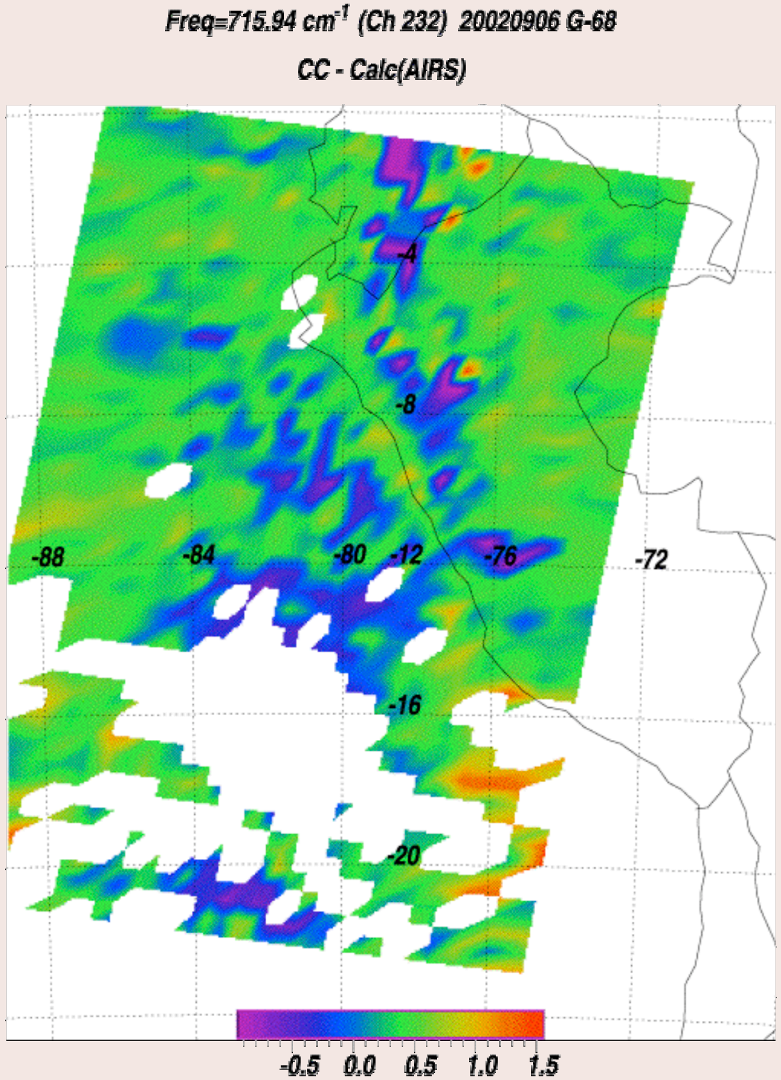

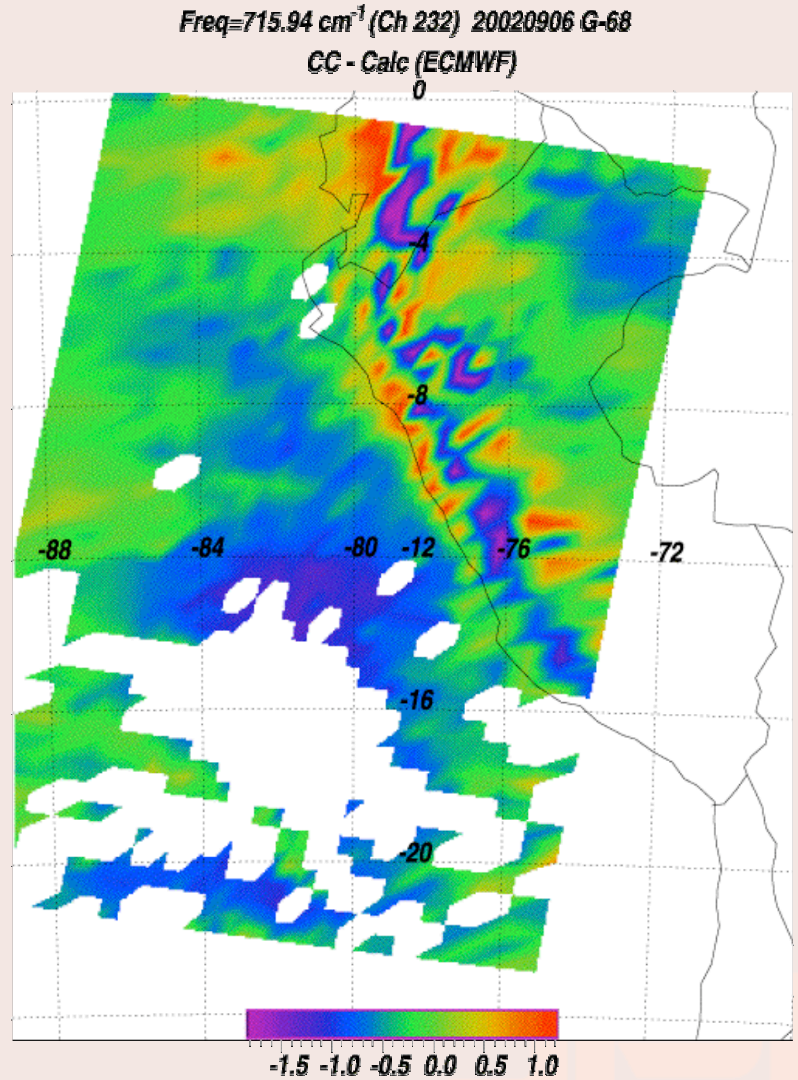

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