Hyperspectral Data Applications: Convection & Turbulence

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- Overview: Application Research for MURI
- Atmospheric Boundary Layer Turbulence
- Convective Initiation Studies

Hyperspectral Data Applications: Convection & Turbulence

- Questions:
  - How can high-temporal resolution soundings of water vapor and temperature (derived from hyperspectral measurements) be used to assess boundary layer turbulent/moisture patterns?
  - What is the value of hyperspectral satellite data for evaluating cloud growth, cloud microphysics, and the variability of water vapor for studying convective cloud formation?
- Data:
  - AERI (and Raman LIDAR) atmospheric profiles
  - GIFTS data cubes

Turbulence Applications

Purpose:

- To evaluate from hyperspectral data the atmospheric turbulence features that can result in hazardous conditions for landing aircraft.

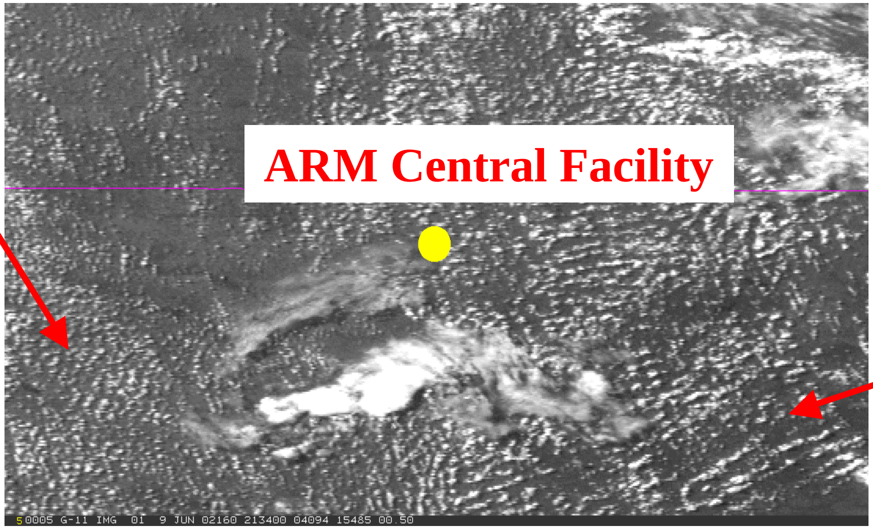
- To demonstrate the means by which high-temporal, high-spectral resolution data may be used to observe “wave” and “roll” patterns of turbulence in the atmospheric boundary layer (ABL).

- To eventually relate ABL turbulence to larger scale mixing phenomena, i. e., deep, moist convection (e.g., thunderstorms).

Characterizing the CBL using Profiling Instruments

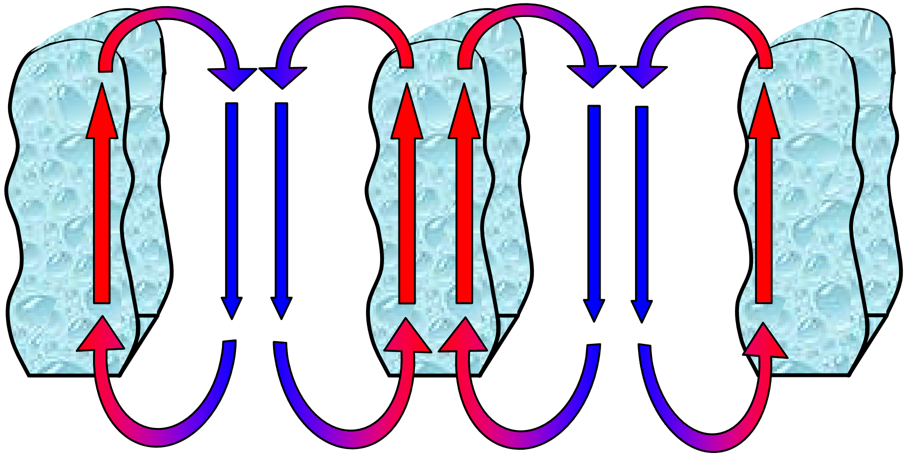
Convective Rolls & Waves Lamont, OK (yellow) GOES-11: 2134 UTC

Rolls

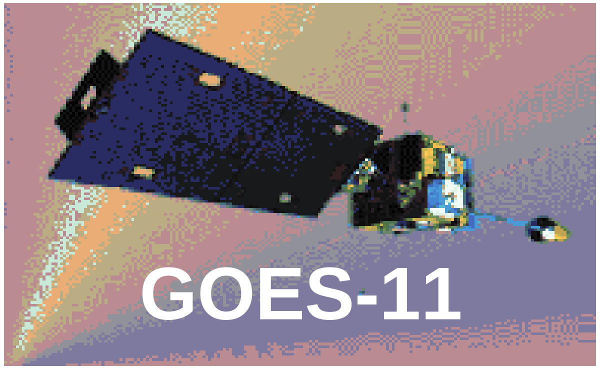


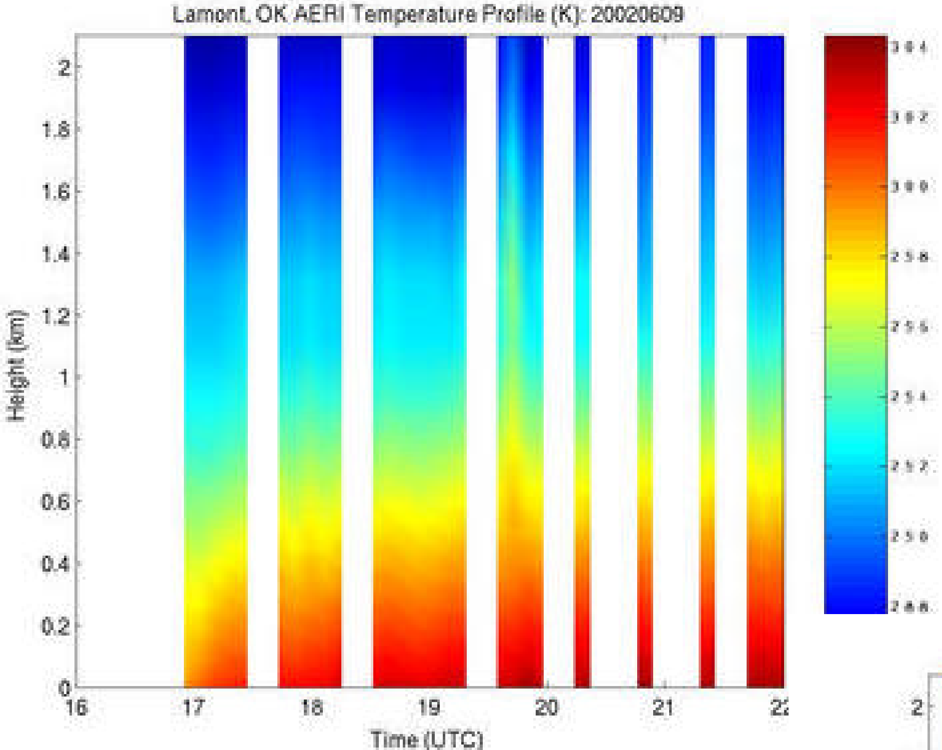
R_B, Monin-Obukhov Length, ABL depth

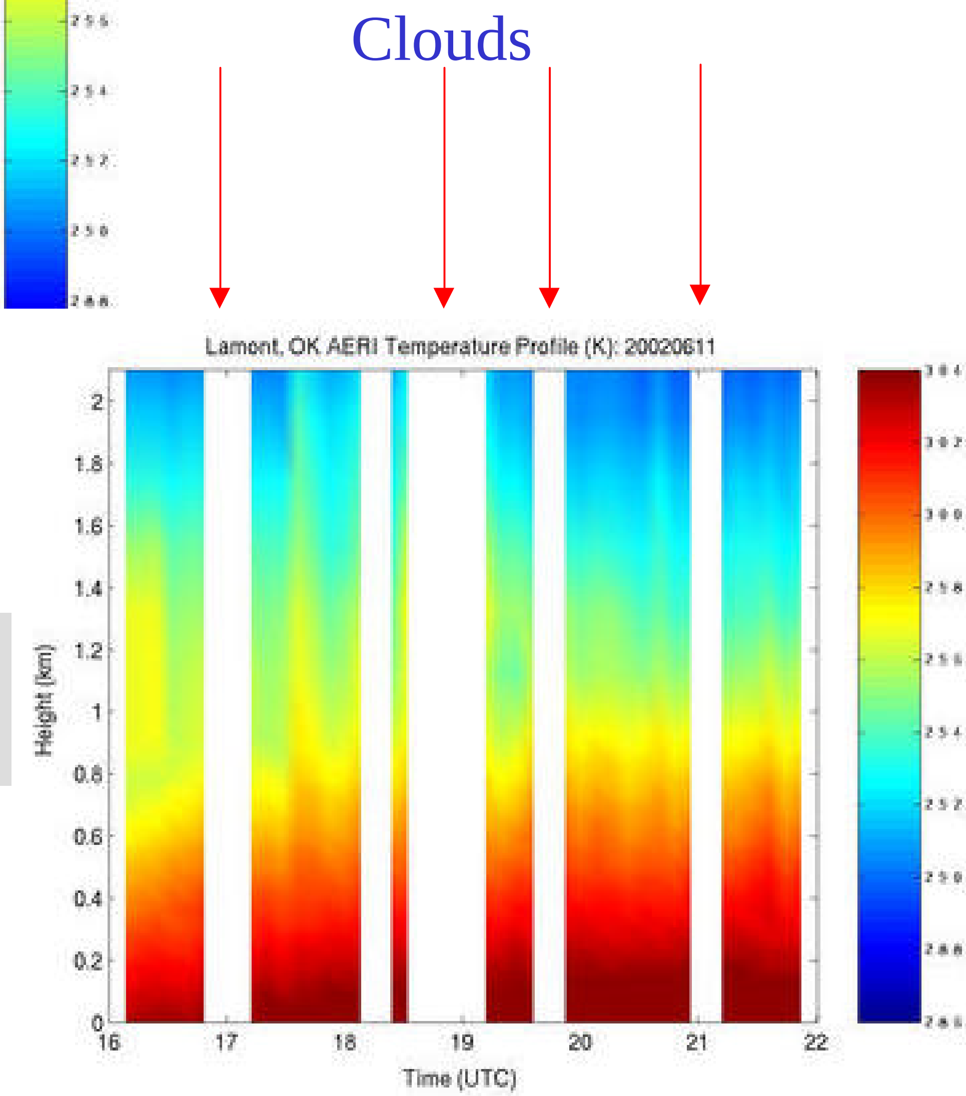
Waves atop the CBL



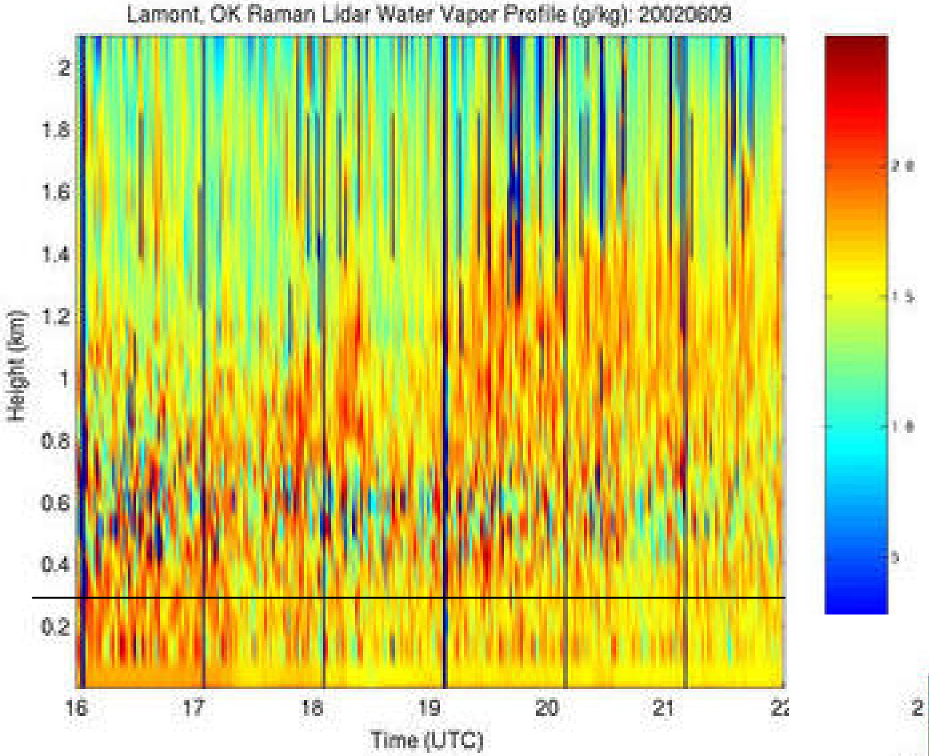
"Truth Data" – GOES-11 and S-Pol Radar (IHOP)







8 minute AERI profiles from 16-22 UTC on June 9th, 11th



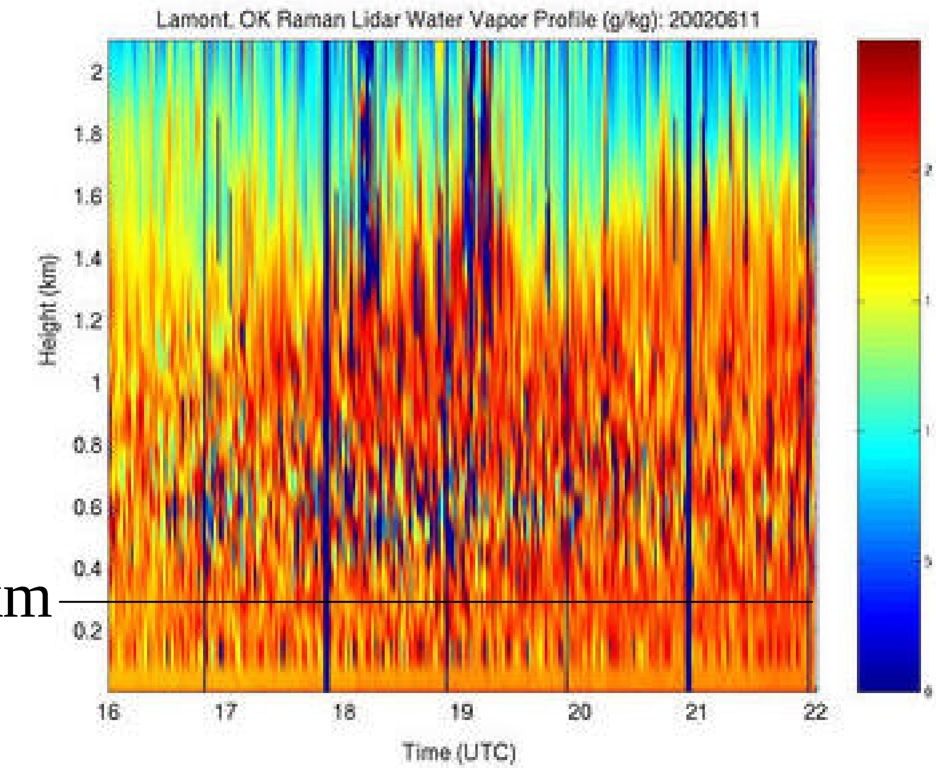
Used:

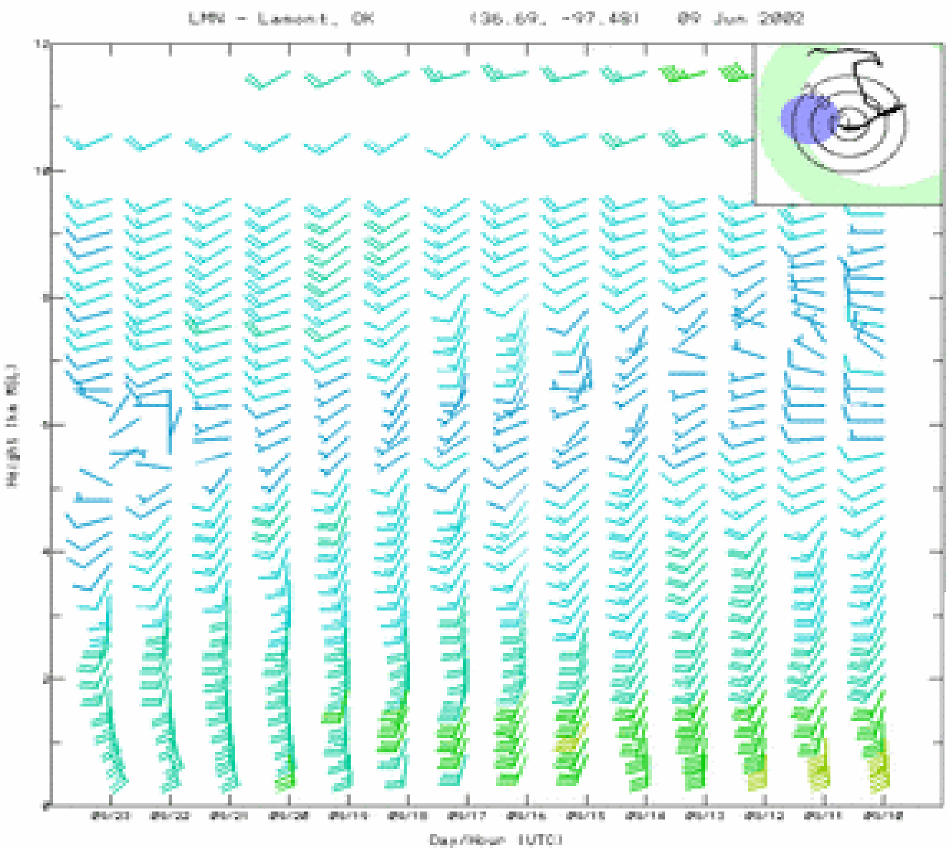
→ Moisture at 0.31 km

→ Daytime information

1 minute Raman LIDAR profiles from 16-22 UTC on June 9th, 11th

0.312 km

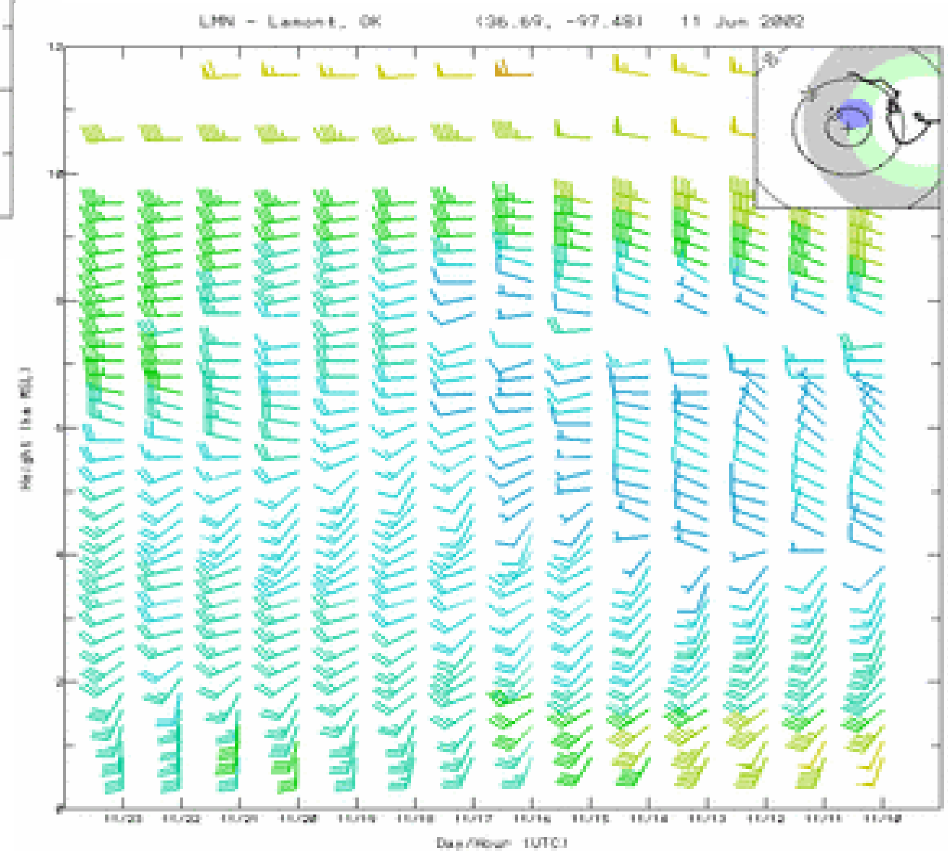




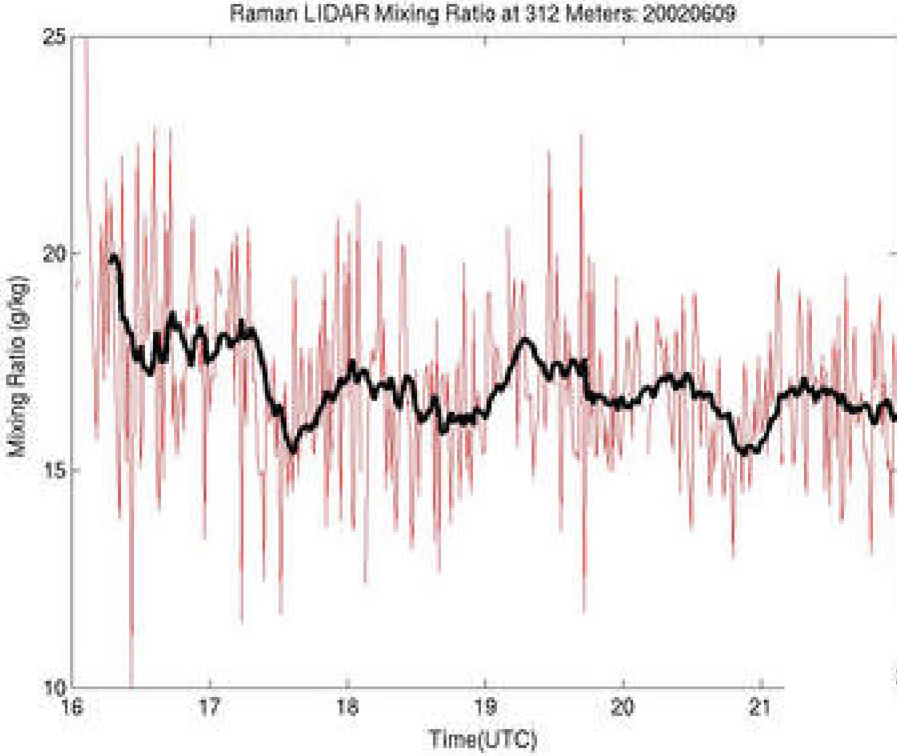
Used to Evaluate:

→ CBL wind shear

→ Turbulent organization



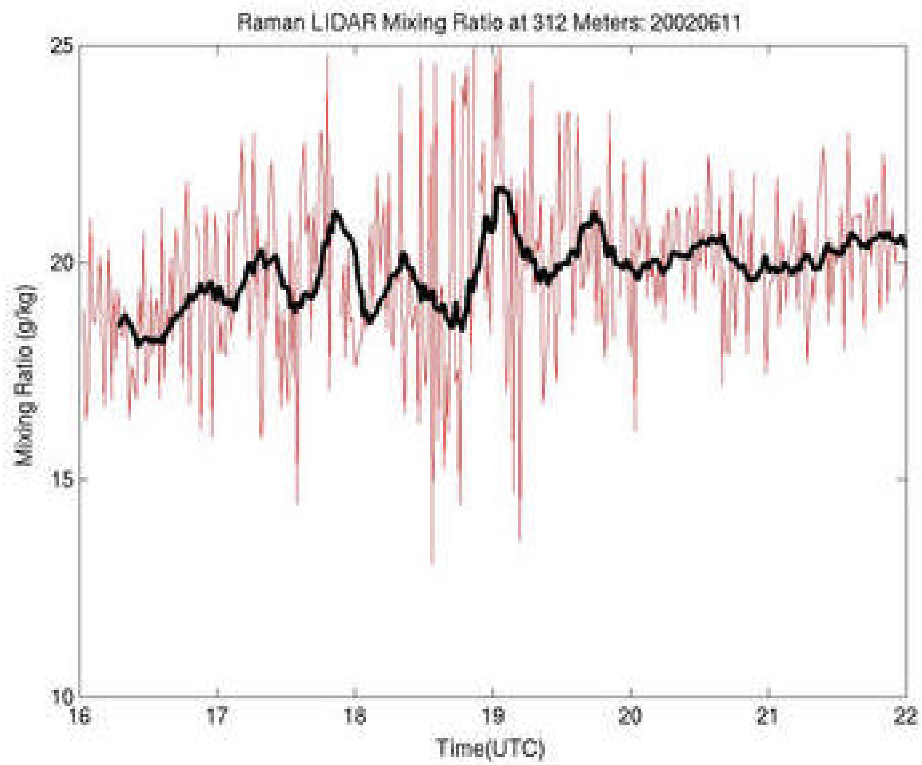
915 Mhz Wind Profiler at Lamont, OK on June 9th, 11th

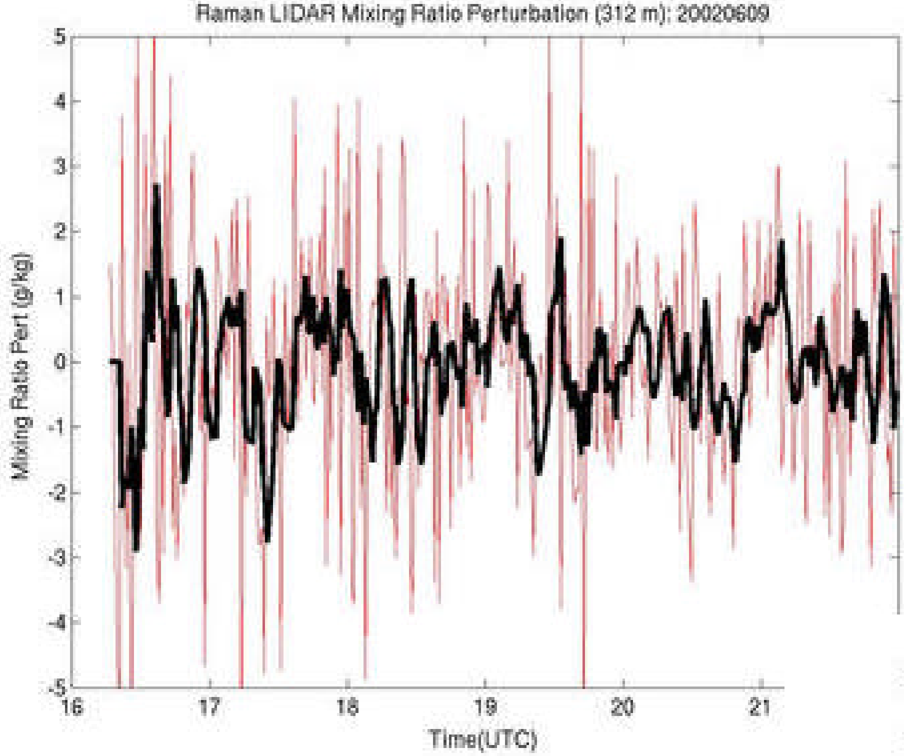


Scales of high-q_e "plumes" making convective clouds:

- → 10 km length scales
- → Moisture fluxes
- → ABL overturning

15 min running mean of q_v raw signal at 312 meters; from Raman LIDAR



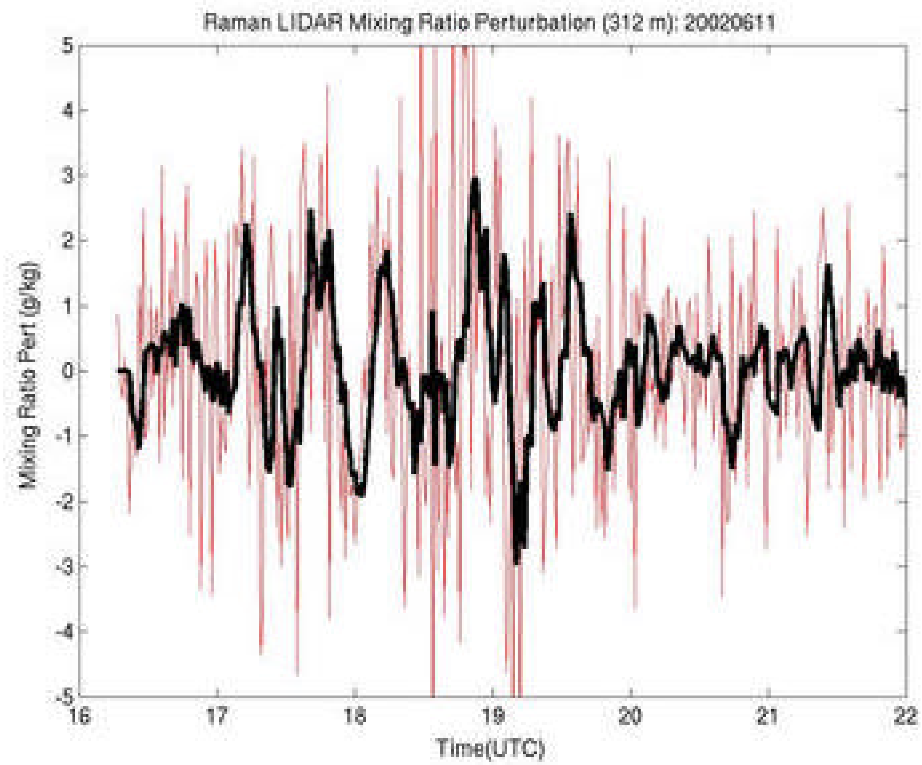


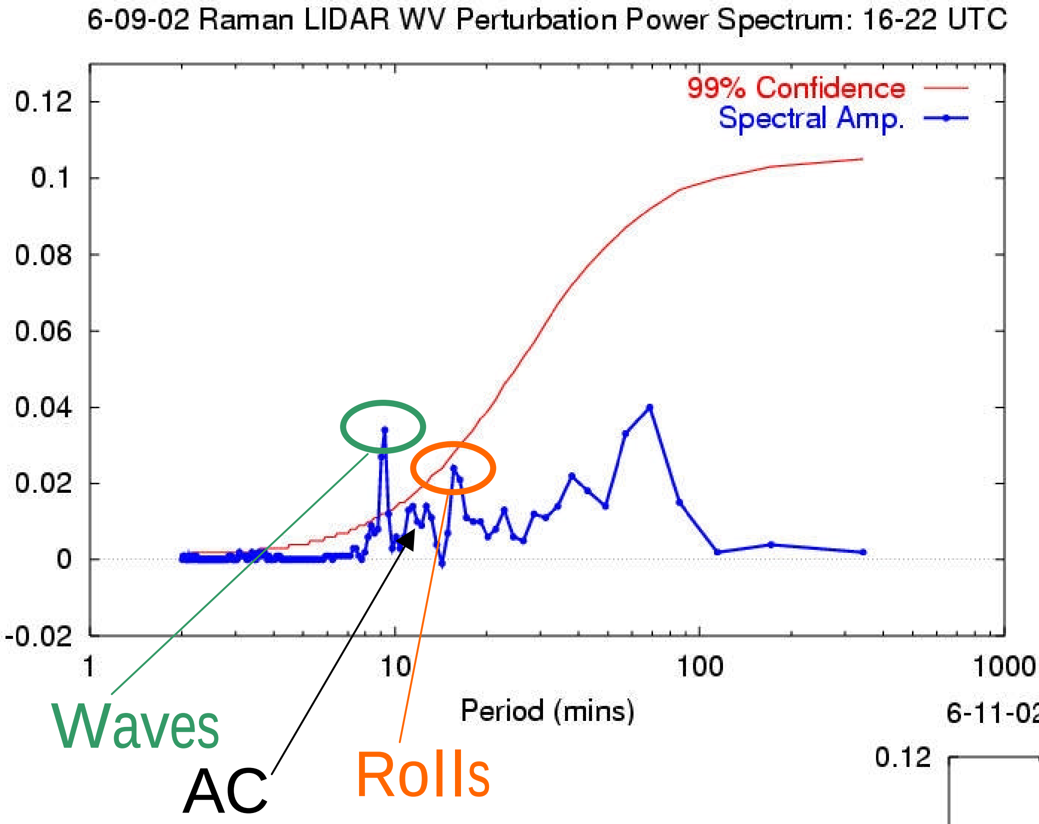
Scales of high-q_e "plumes" making convective clouds:

→ 3 km length scales

→ Cumulus clouds

5 min running mean of q_v perturbations at 312 meters: from Raman LIDAR

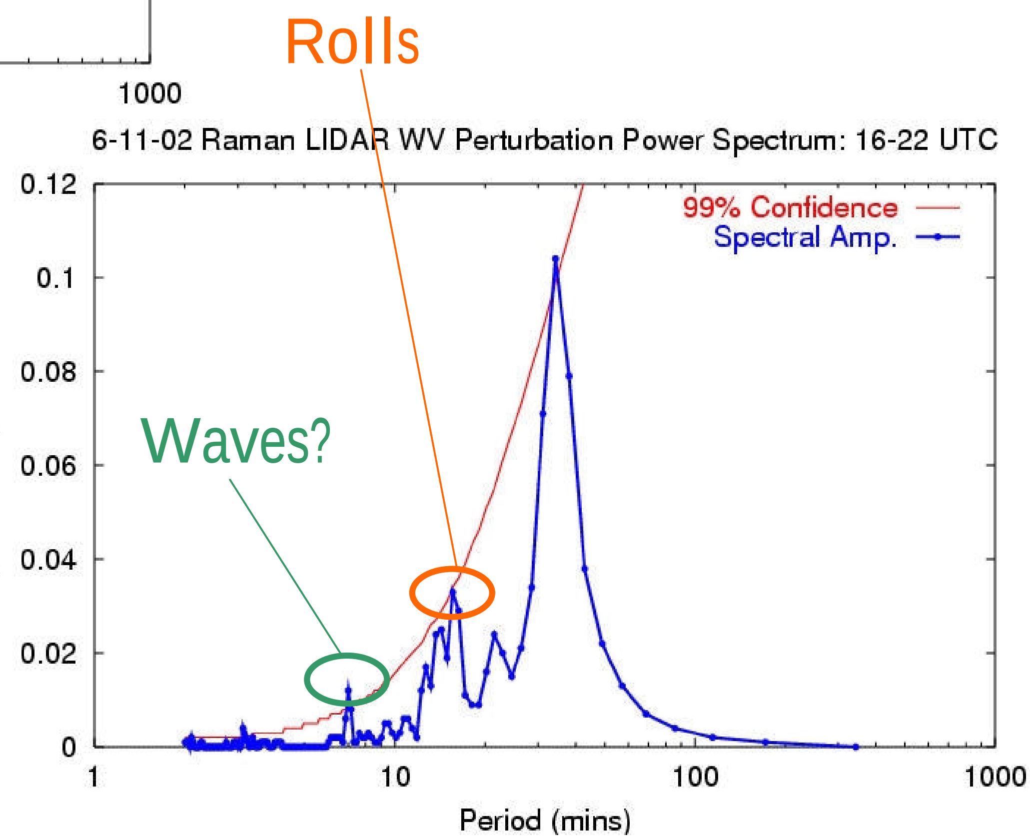


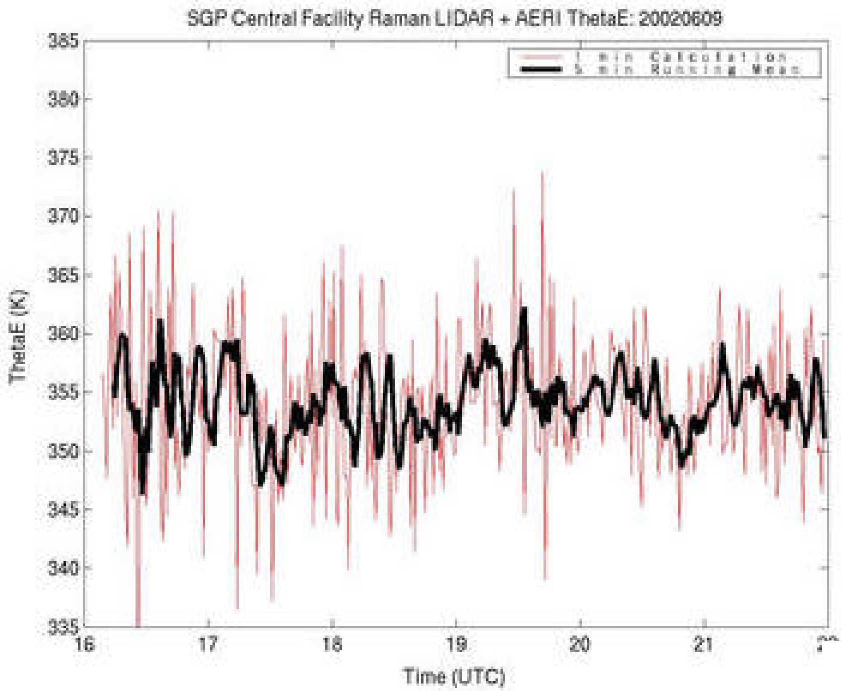


- A satellite analysis reveals that convective cloud wave structures passed over Lamont with a frequency of 6 to 9 minutes from 1915-2200 UTC. CBL roll patterns were observed at 16-21 minute frequencies.

- This frequency closely corresponds to the periodicity derived from the Raman LIDAR WV perturbation power spectrum

- Quantitative analysis of the GOES-11 imagery via a 2-D Fourier transform





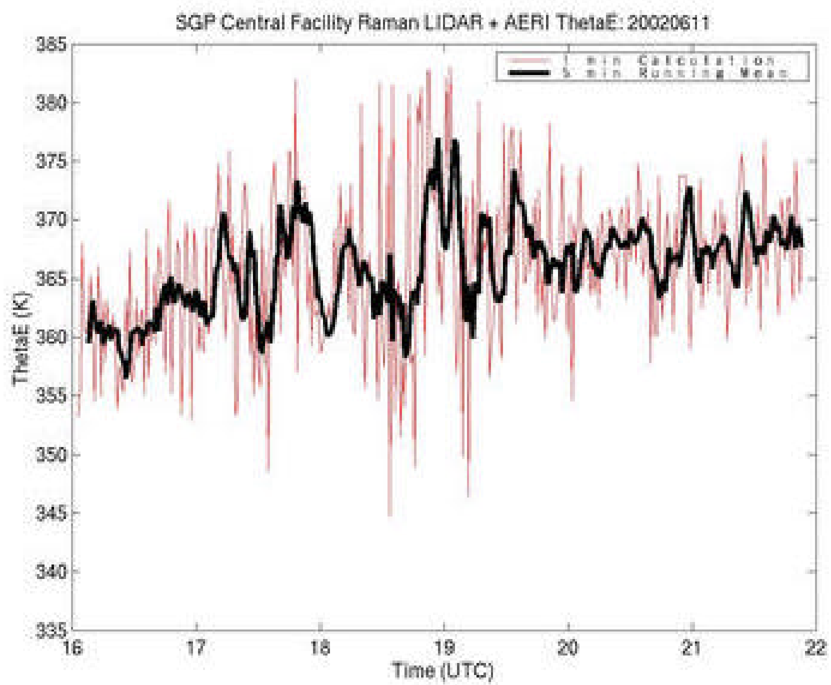
Scales of high-q_e “plumes” making convective clouds:

→ 3 km length scales

→ Cumulus clouds

Use 40 s AERI from CRYSTAL experiment in Florida (2002)

Raman LIDAR q_v + AERI T to form q_e every 1 minute

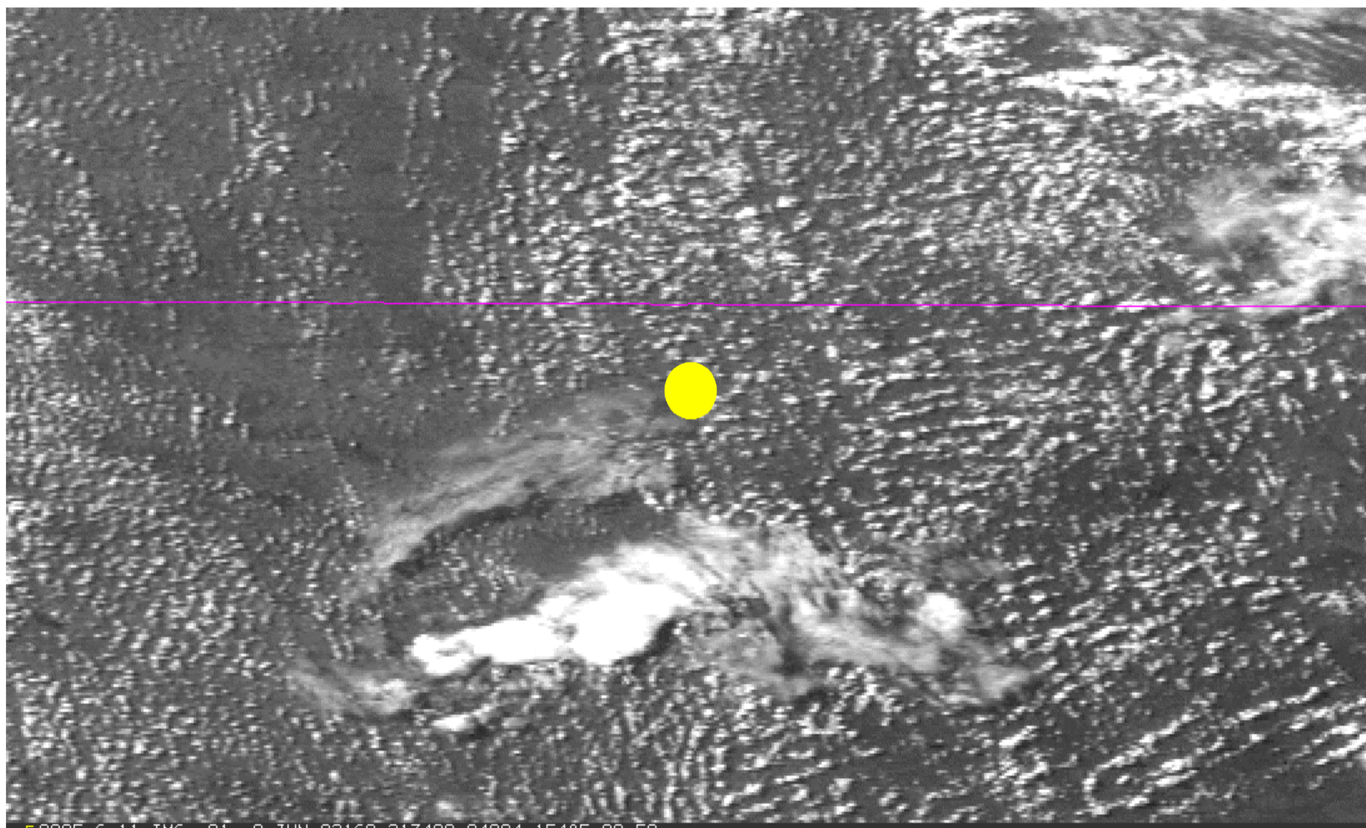


Comparison to original GOES-11 Imagery (or Radar) plus PBL Turbulence Theory

Theory (e.g., use of R_B):

$$R_B = \frac{g \Delta \overline{?_v} \Delta z}{\overline{?_v} \left[\Delta \overline{U}^2 + \Delta \overline{V}^2 \right]}$$

Satellite Data (2d Fourier Transform):



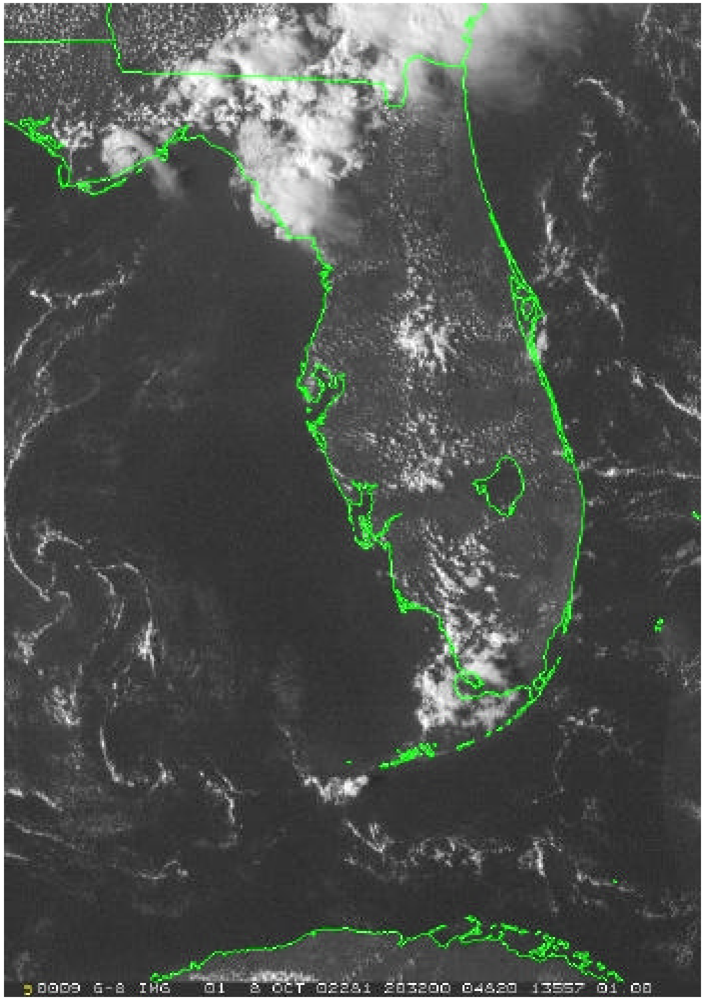
Convective Initiation Research

Purpose:

- To assess the sensitivity brought by hyperspectral data for studying atmospheric convection.
- GIFTS should do a better job identifying low-level water vapor/temperature gradients as precursors to cloud development.
- To assess the ability of GIFTS in evaluating cloud microphysics, temperature and water vapor patterns in terms of assessing CI ?

CI Interest Field: GOES Data

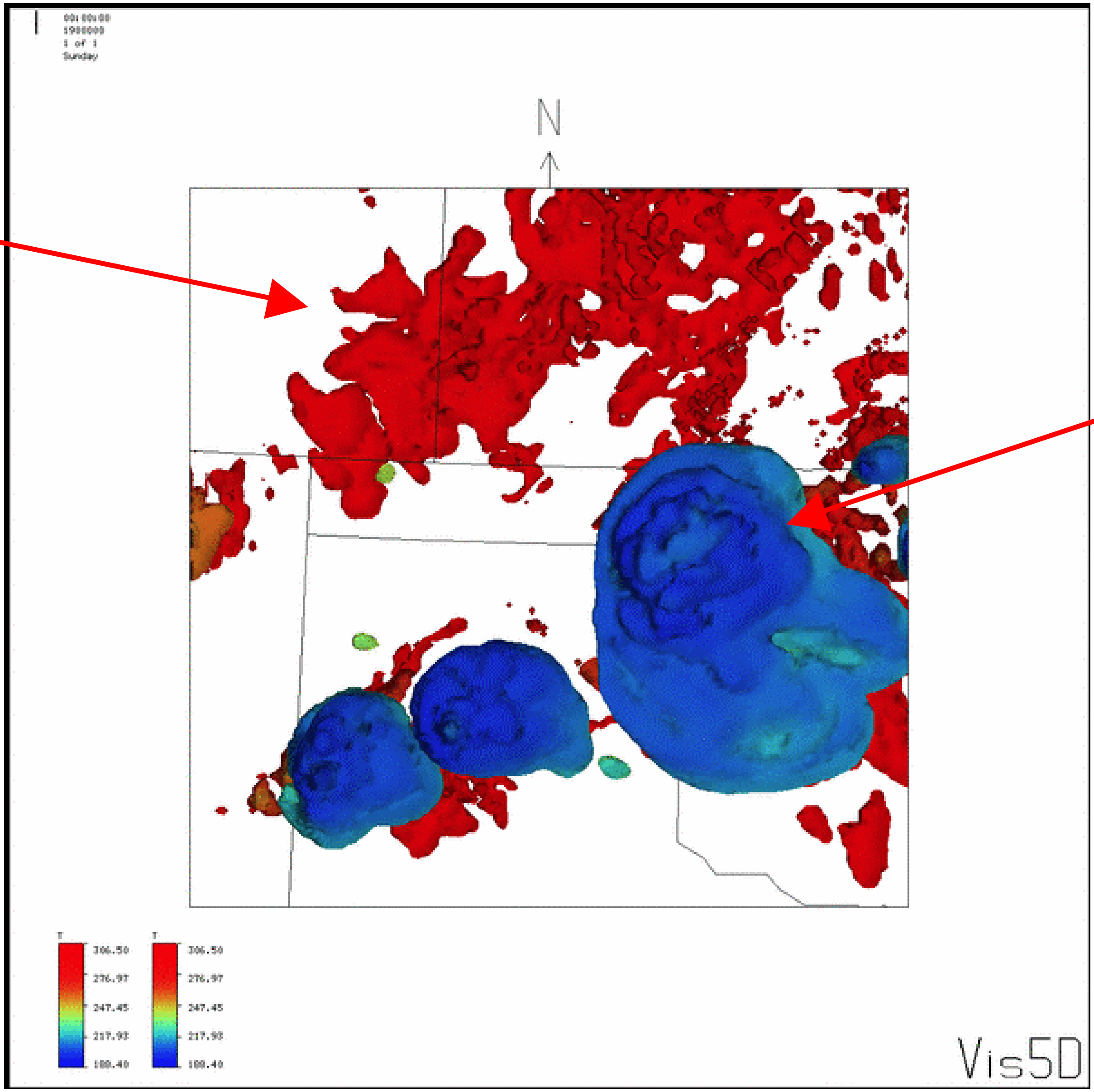
20:32 UTC 8 October 2002



- 6.7–10.7 μm: Deepening cumulus into dry troposphere/stratosphere (Schmetz et al. 1997; *Adv. Space Res.*)
- 3.9–10.7 μm: Low (liquid) versus high (ice) cloud delineation ("fog product")
- 12.0–10.7 μm: Optically thin (cirrus) versus optically thick (cumulus) clouds

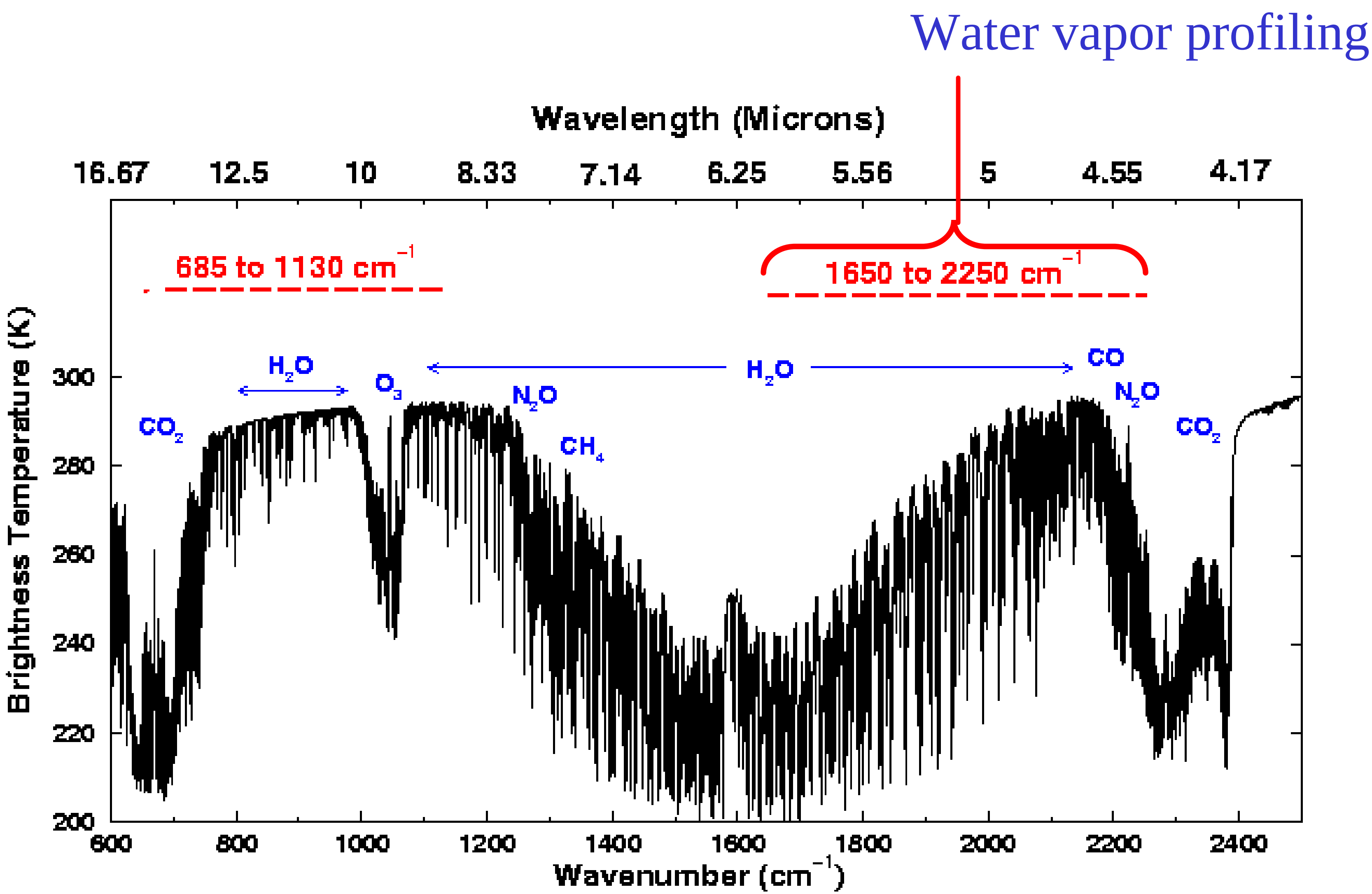
Overview: MM5 Simulation (Cloud-top Temperature) at 22 UTC

Low Clouds: *water*



CB's: *ice*

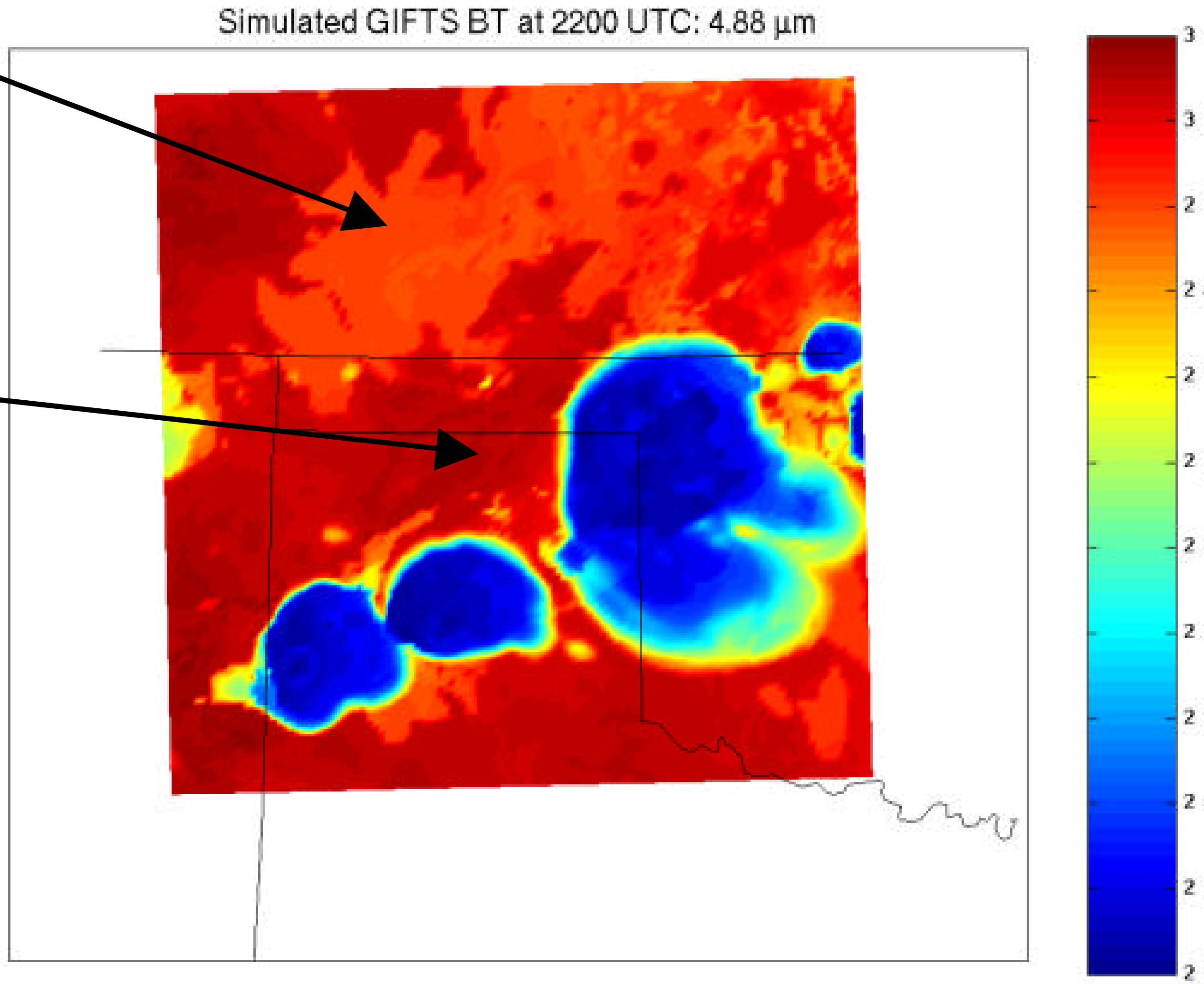
GIFTS Spectral Coverage

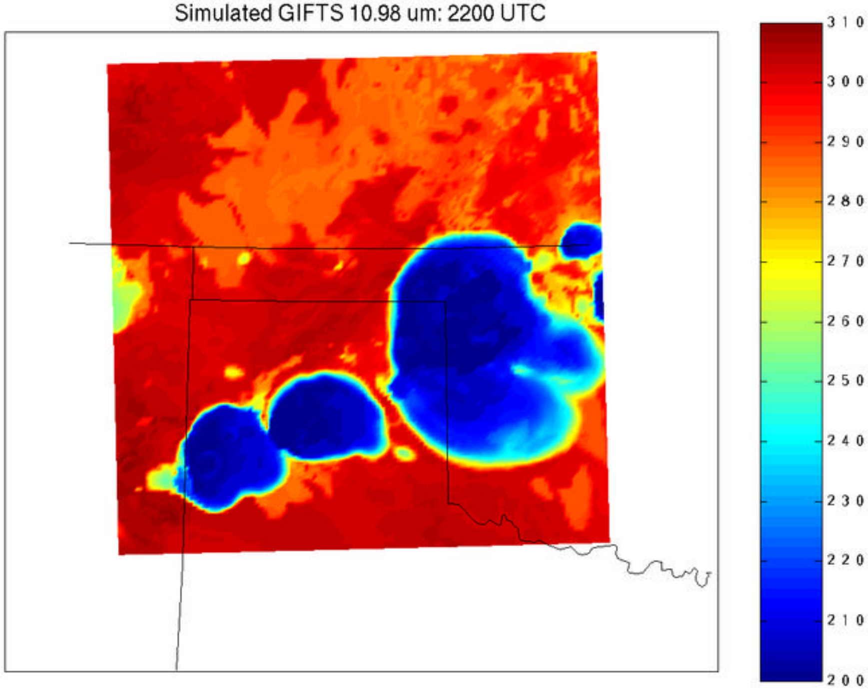


<u>Sensitivity:</u> A Vertical Trip through the Atmosphere via the Water Vapor Absorption Bands (4.88-6.06 μm, every 50 cm^{-1})

Low clouds

Dry air



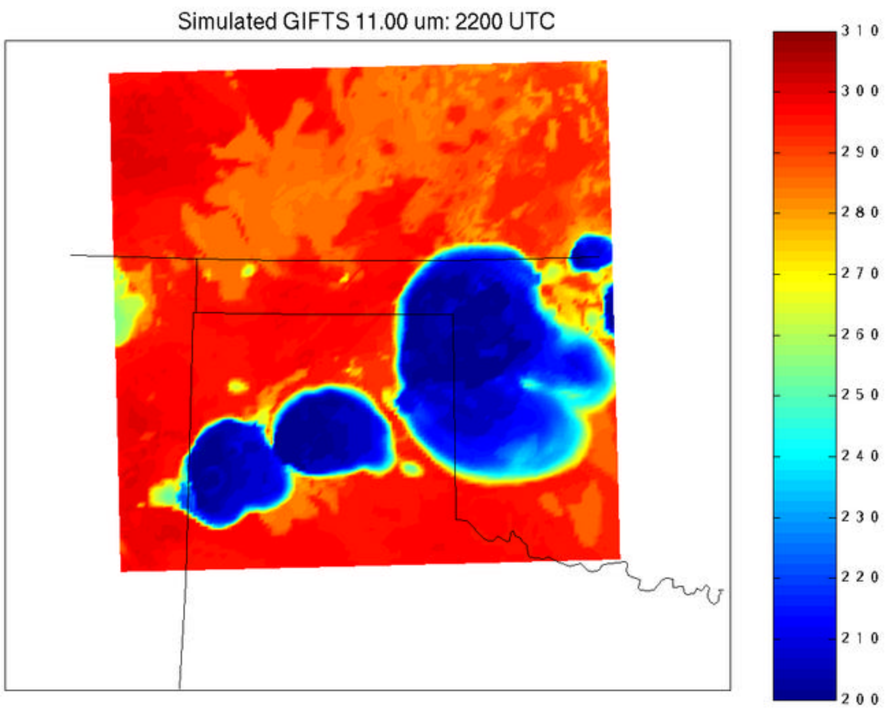


Small wavenumber change results in significant changes in view:

→ Low-level water vapor

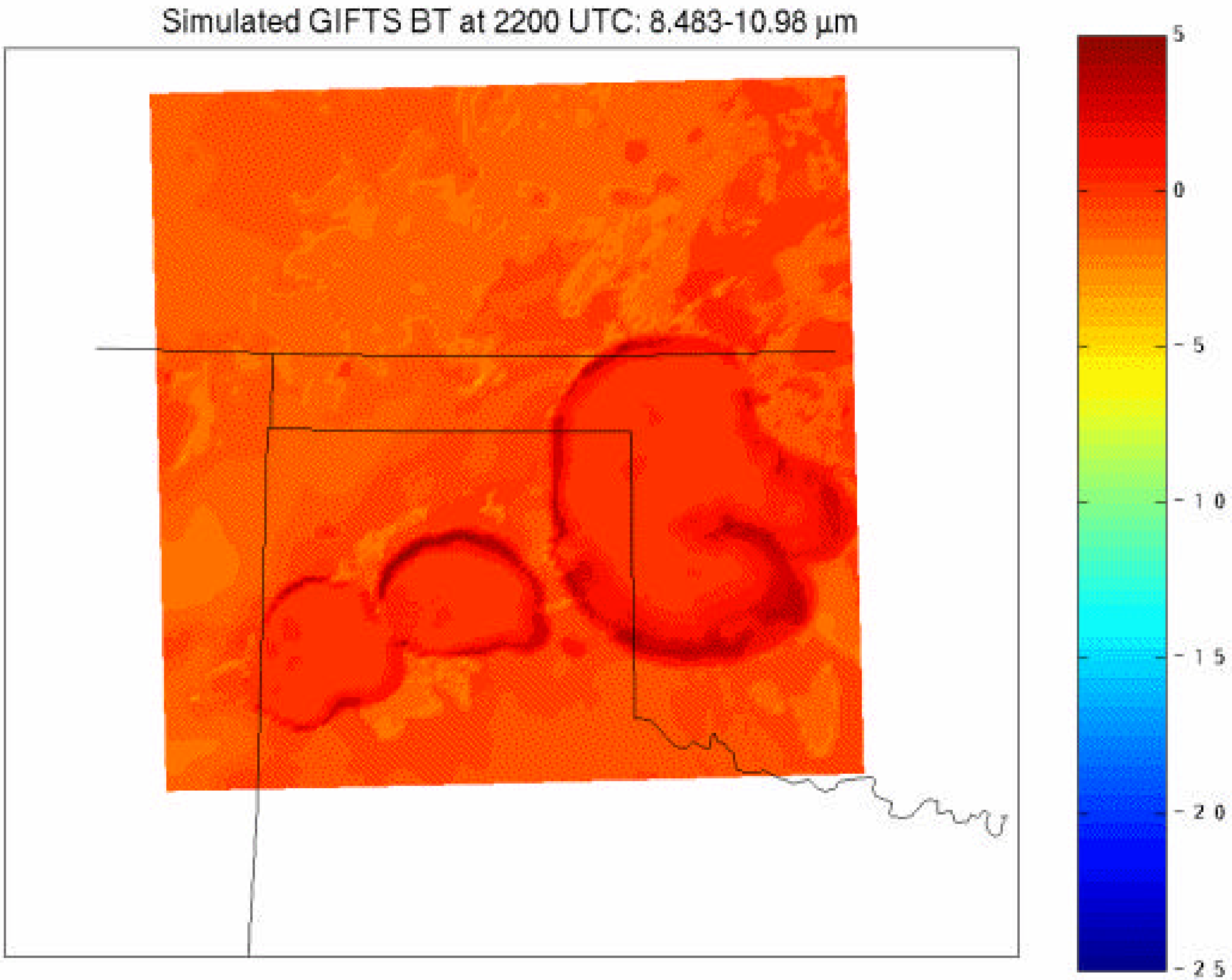
→ Surface temperature

Surface moisture

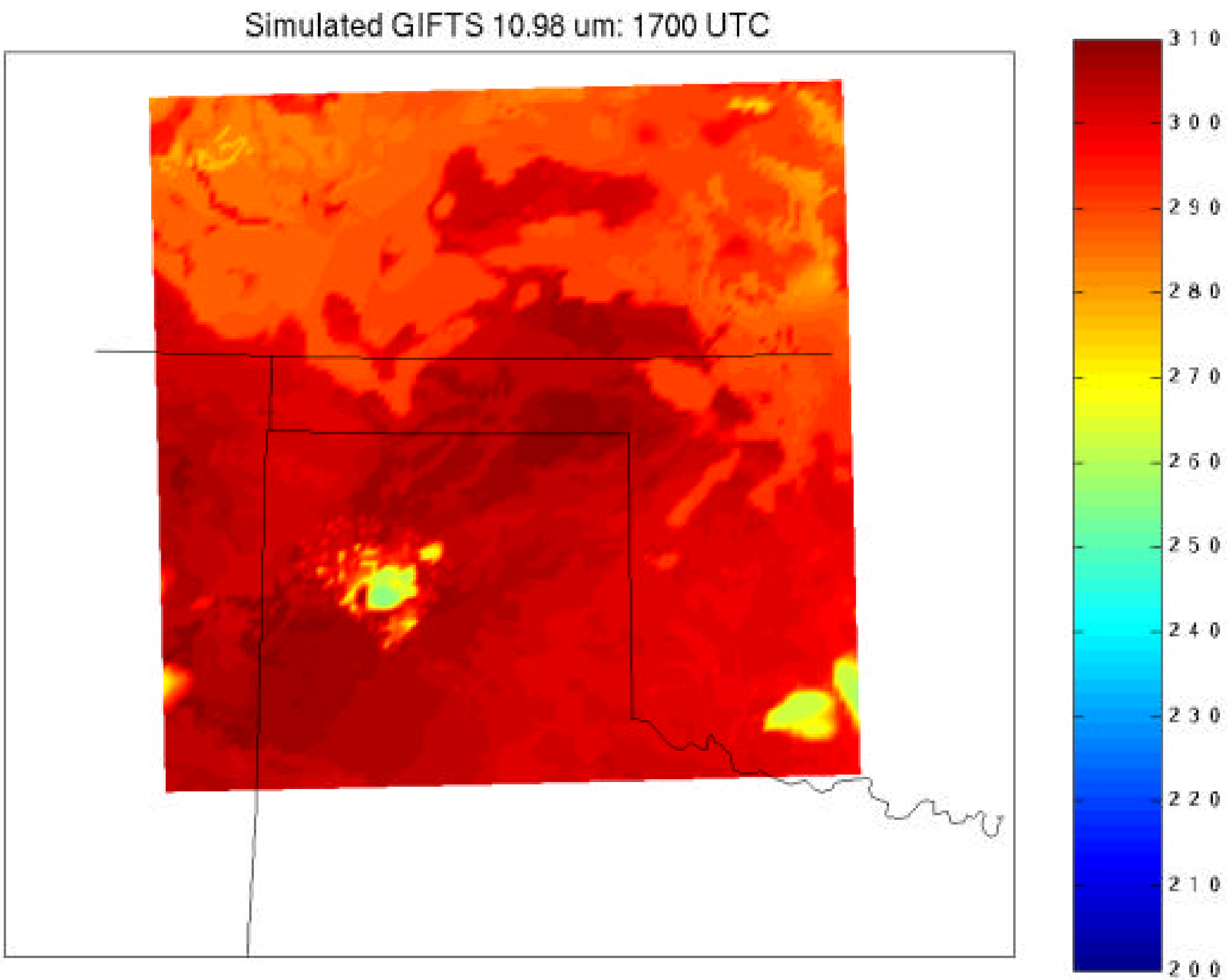


Comparison between the 10.98 µm (left) and 11.00 µm (right) bands at 22 UTC

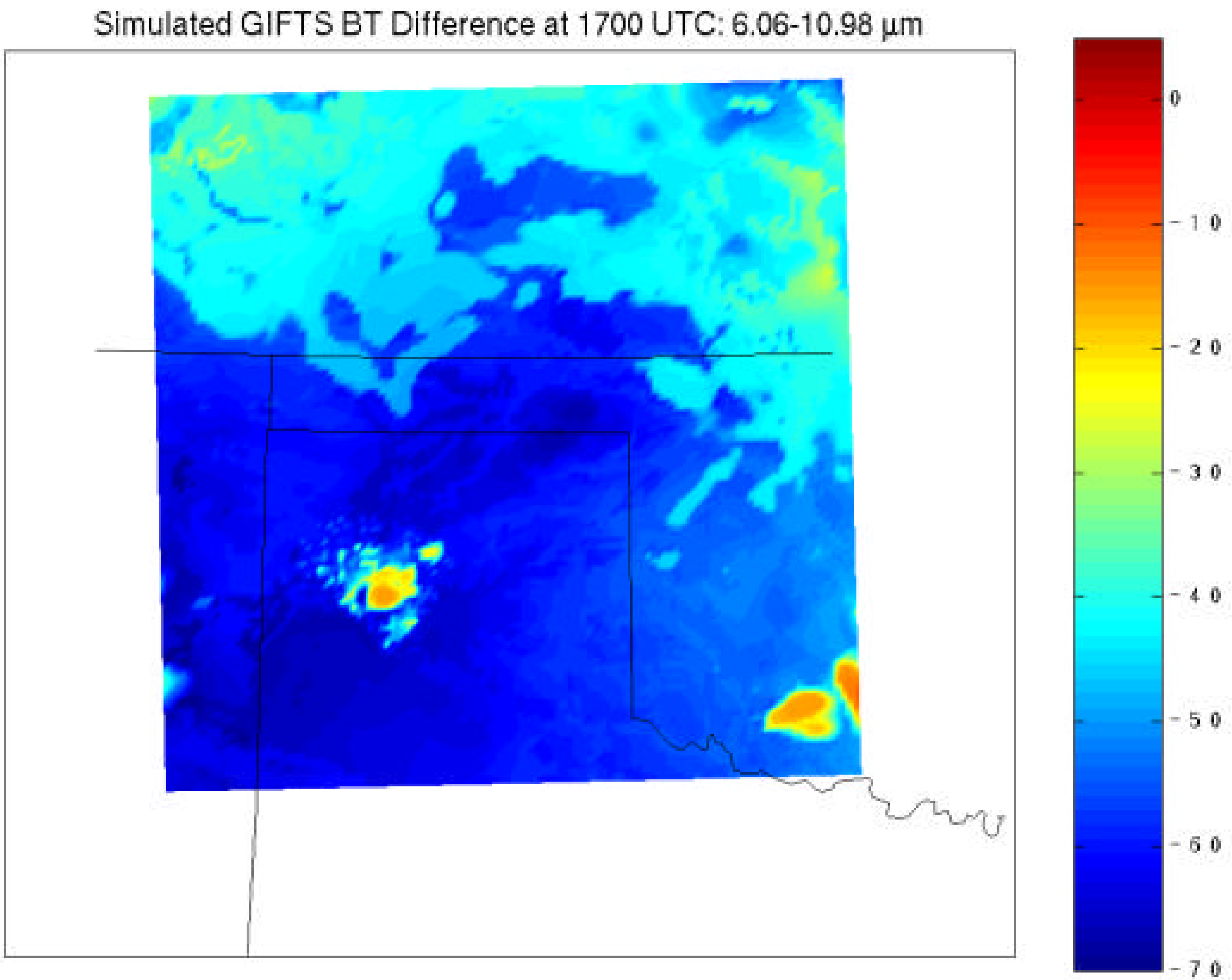
Illustration of the High Sensitivity to Selected wavenumbers in the ~8.5-10.98 μm difference (1 cm^{-1} increments)



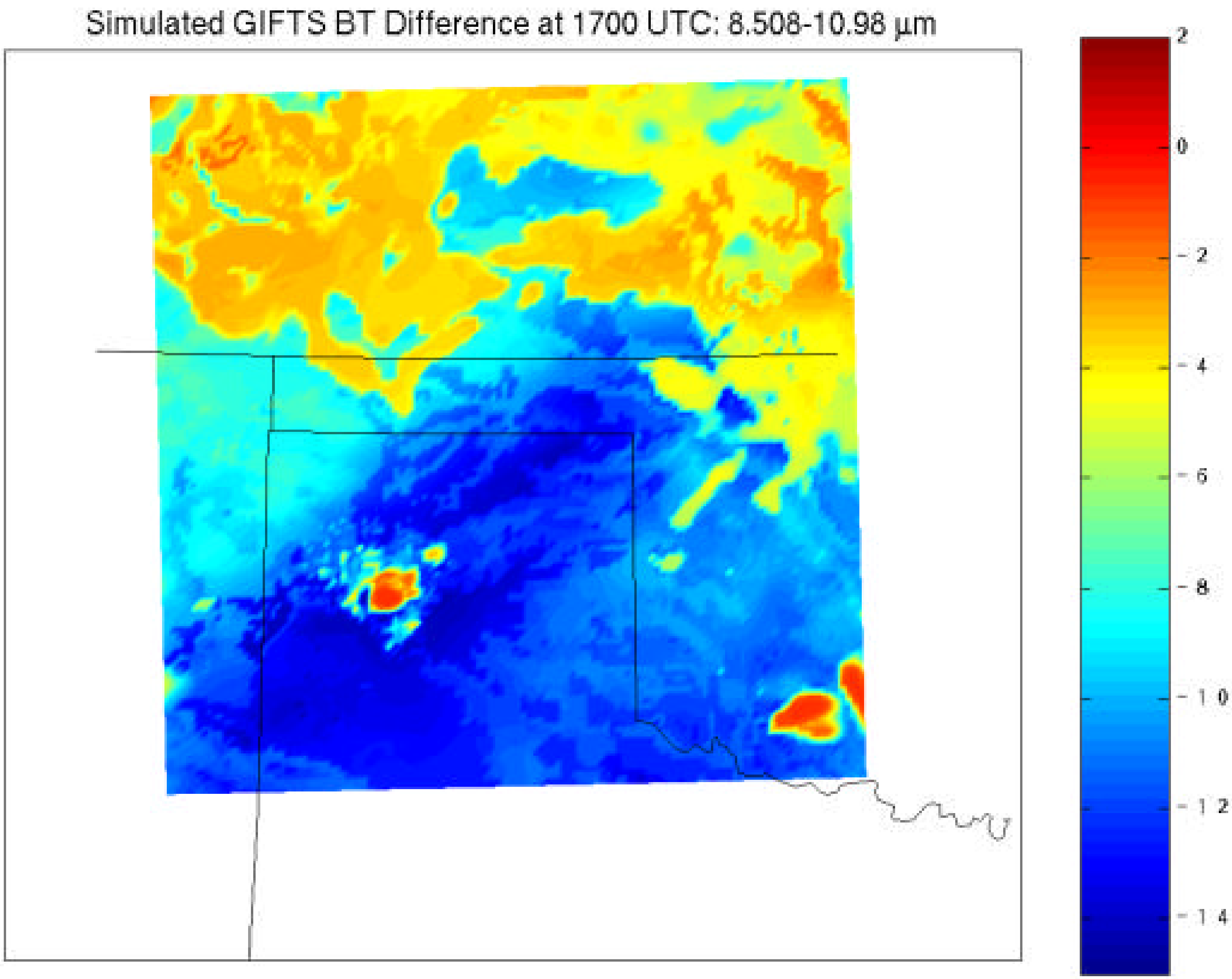
Convective Evolution: 10.98 μm Animation: 17-22 UTC



6.06-10.98 μm Band Difference: Red (Diff's > 0) = Clouds Near/Above Tropopause



8.508-10.98 μm Band Difference: Red (Δ's > 0) = Ice

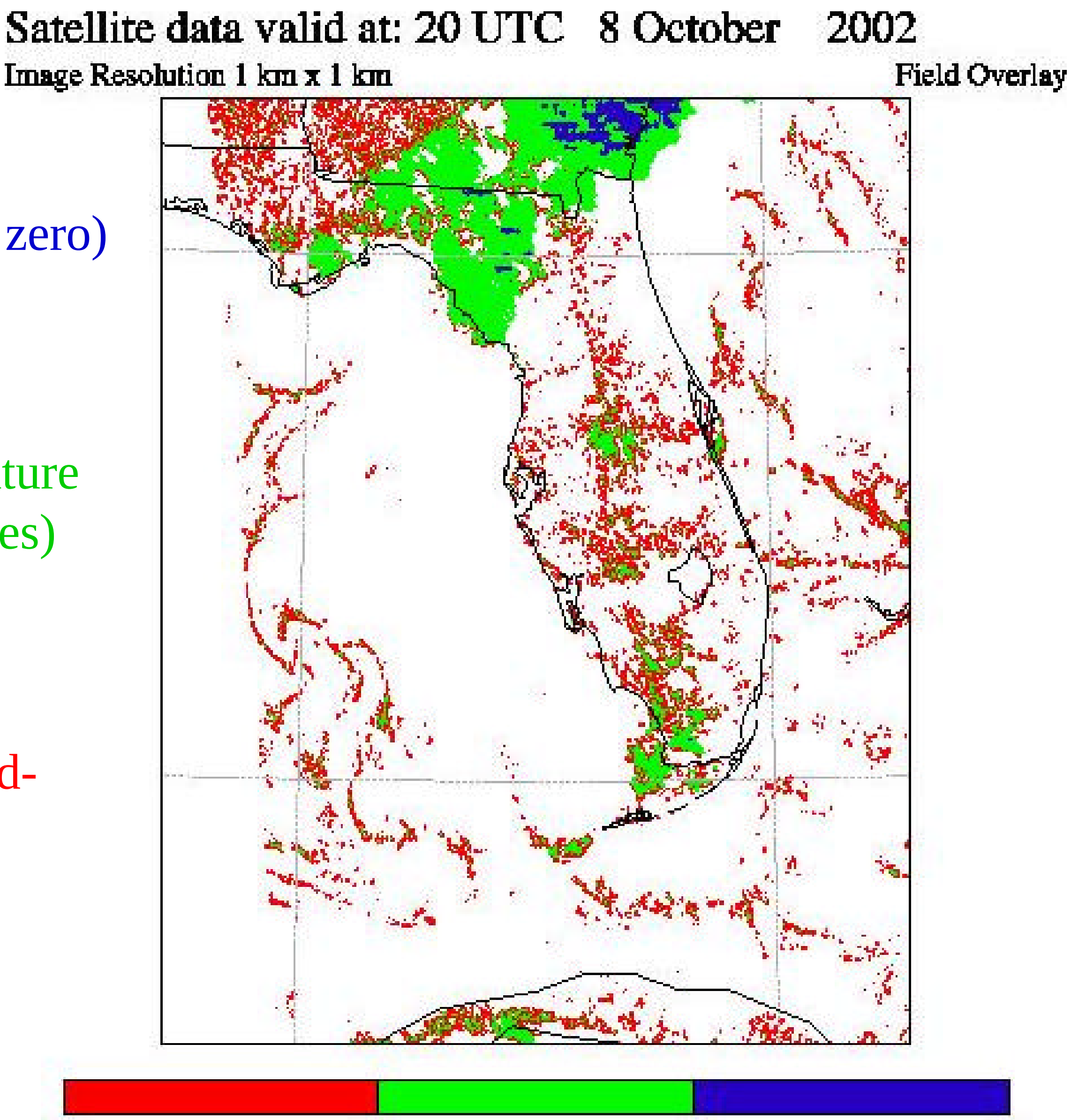


Overlaying GOES Infrared & Visible Fields

- Channel Differencing:
  6.7–10.7 µm (values near zero)

- Visible:
  Brightness Threshold (mature mesoscale cumulus features)

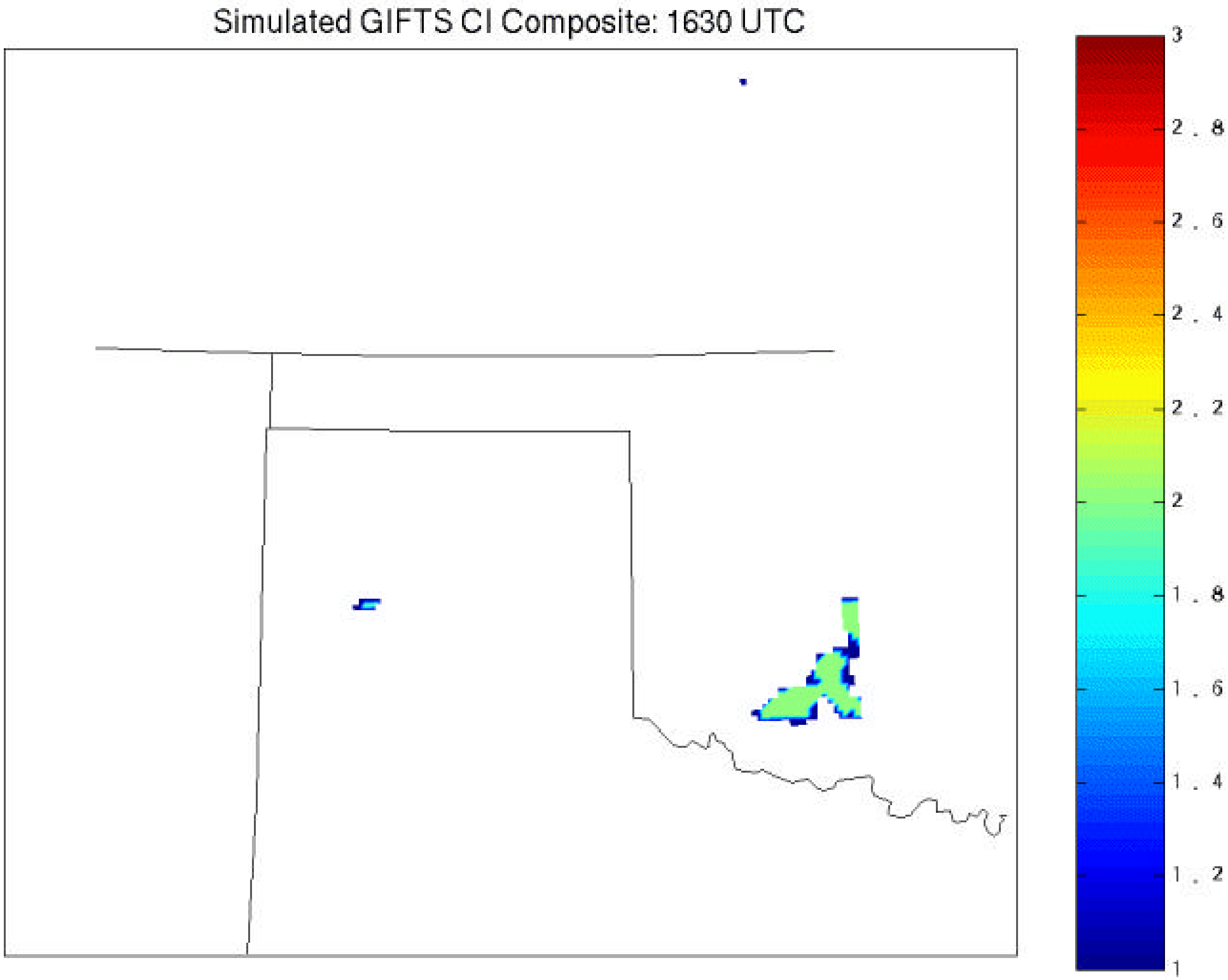
- Visible:
  Gradient Technique (cloud-scale cumulus features)

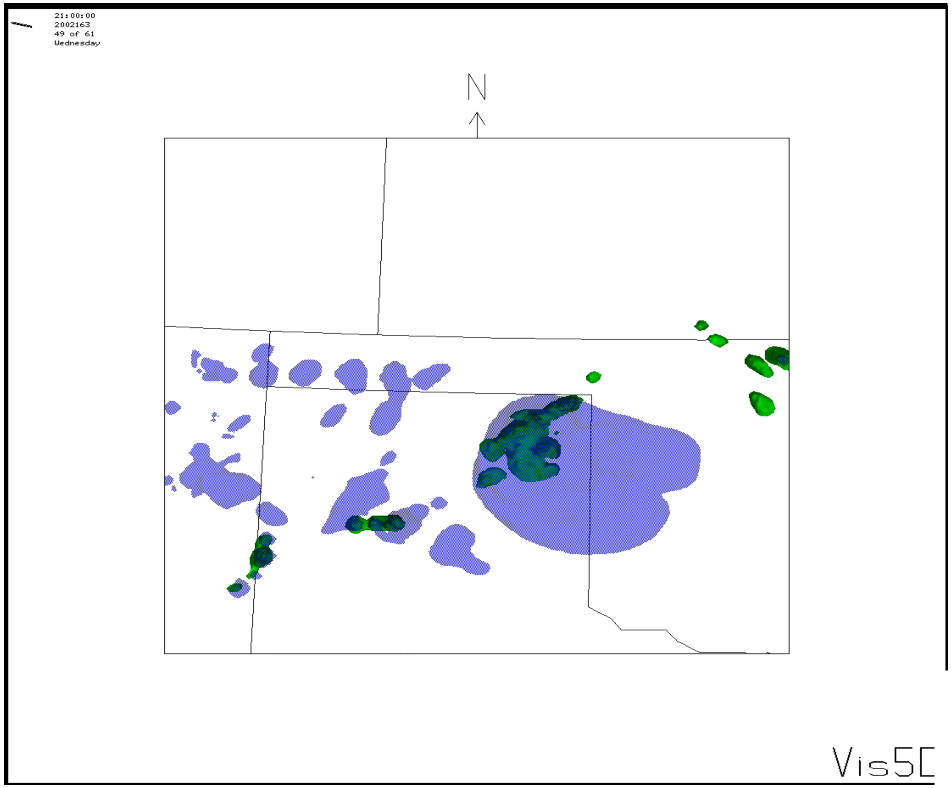


CI composite: Blue - 10.98 μm BT < 273.2

Green - 8.512-10.98 μm (Δ's > -1 → ice)

Red - 6.06-10.98 μm (Δ's > 0 → high clouds)

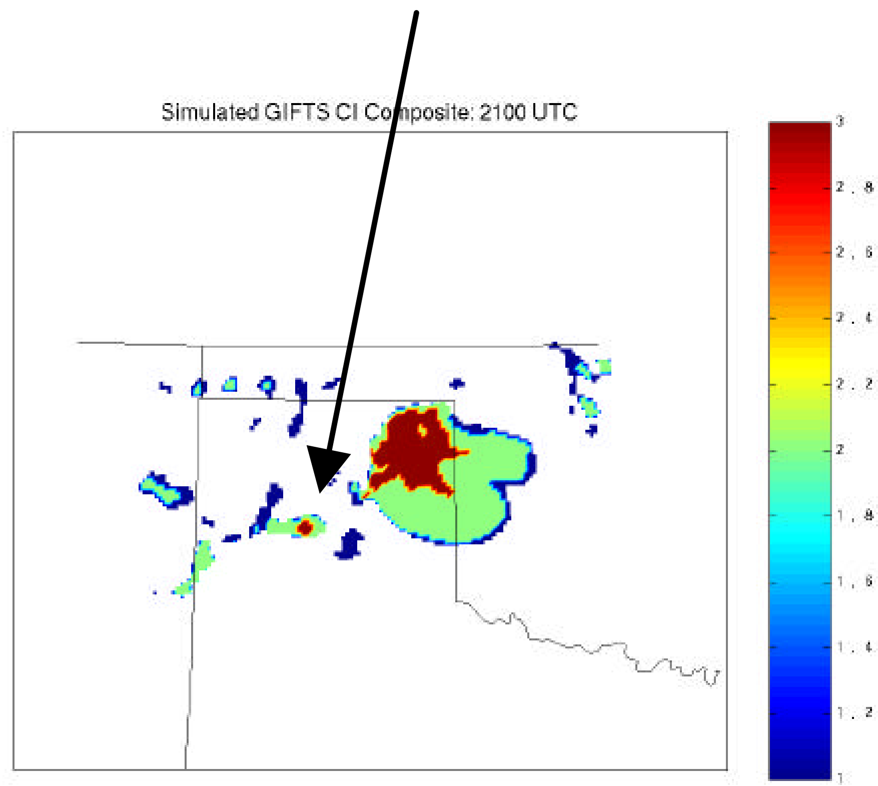




Blue - 10.98 µm BT < 273.2

Green - 8.512-10.98 µm (Δ's > -1 ice)

Red - 6.06-10.98 µm (Δ's > 0 high clouds)



Comparison of Simulated GIFTS CI Composite and MM5 simulated rain and cloud ice fields

Overview

- GIFTS/hyperspectral data offer us an improved ability to assess cloud properties (e.g., growth & phase).

- GIFTS should do a better job identifying low-level water vapor/temperature gradients as precursors to cloud development.

- Seek other new methods of using GIFTS to assess CI other than evaluating cloud microphysics, temperature and water vapor patterns.

Overview

- First look at S-HIS and NAST-I for performing these analyses.

- Use of other validation data sets (other than IHOP); THOR*pex* (with AIRS, NAST-I, etc.).