Observational Analysis of Atlantic Basin Tropical Cyclone Squall Lines and Relationship to the Diurnal Cycle

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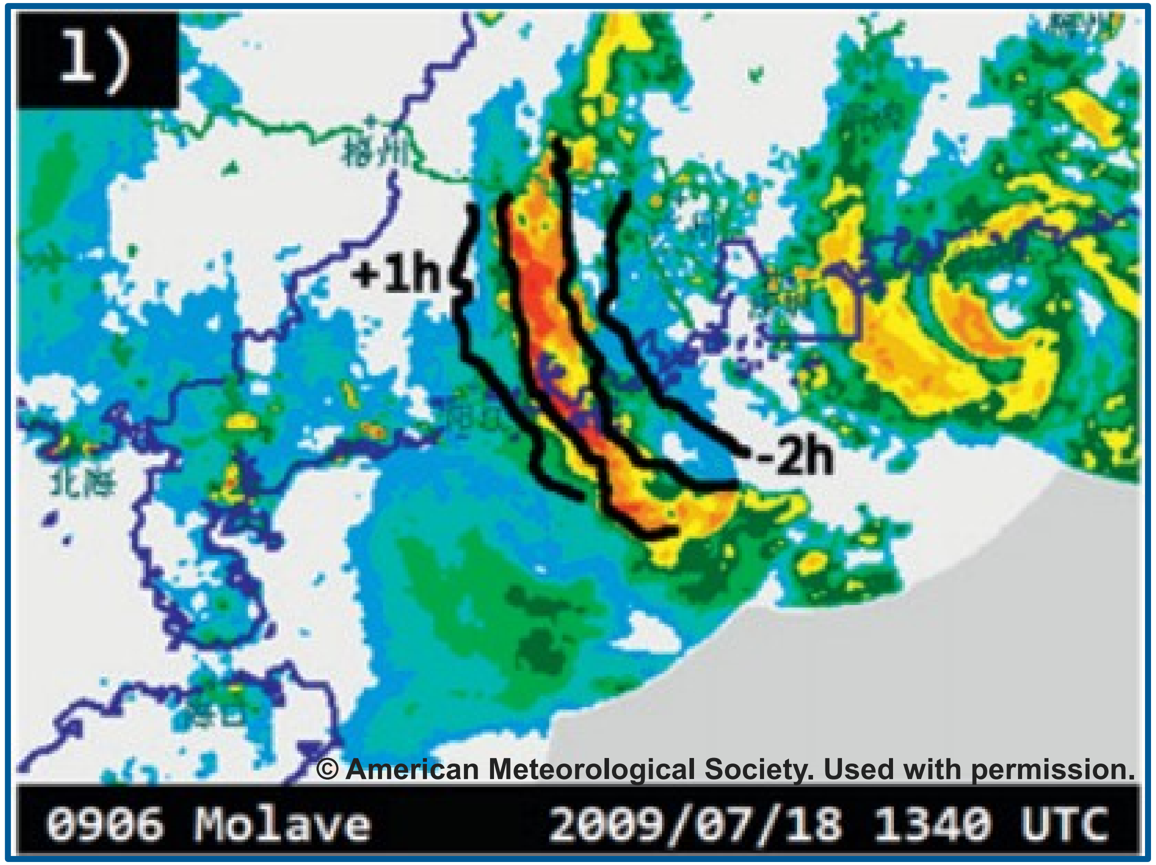
What is a Pre-TC Squall Line?

"Squall lines preceding landfalling tropical cyclones" (Meng & Zhang, 2012)

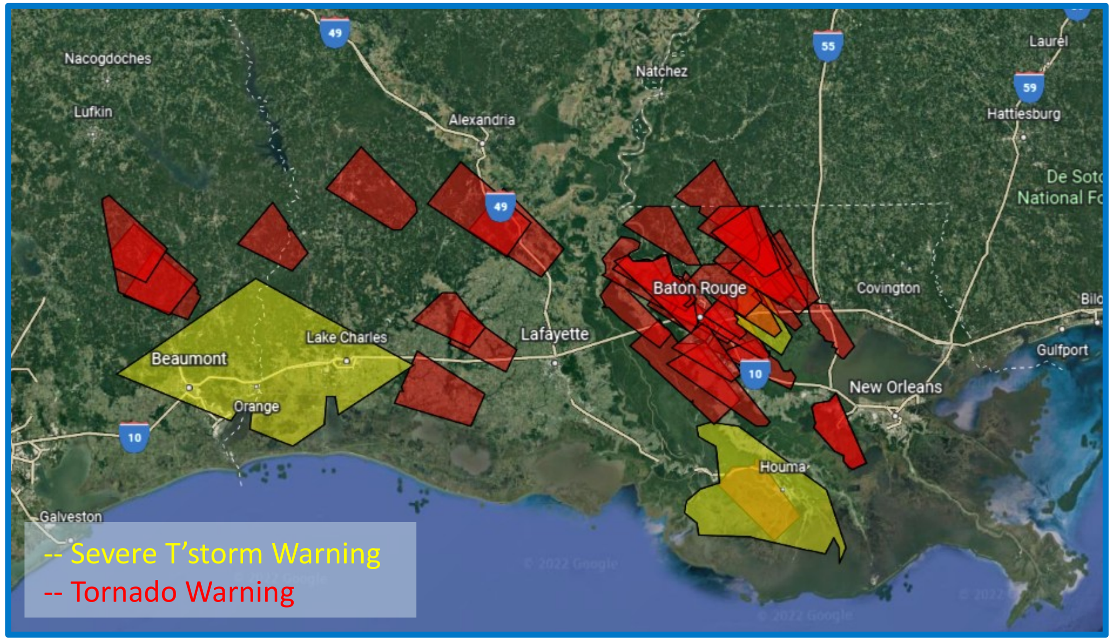
Most frequently form in a **broken-line mode** and a **trailing stratiform** organization

- Pre-TC squall lines have only been analyzed in the Atlantic in a limited number of studies (Ditchek et al. 2020; Dunion et al. 2019)
- They pose a threat well ahead of the main TC
  - Can affect land **12+ hours** before landfall
- Possible link between TC diurnal pulses and increased convection in outer TC region (Dunion et al. 2014)



Meng & Zhang (2012) Fig. 2L composite ref. of pre-TC squall line assoc. w/ Typhoon Molave

Research Motivation & Questions



Severe warnings for 8/26/2020 *prior* to Laura's landfall – courtesy of KLCH and KLIX NWS CWAs on Google Earth

Questions:

1. Do pre-TC squall lines have similar characteristics to midlatitude squall lines?
2. Are these pre-TC squall lines a type of outer rain band?
3. What type of environment are the pre-TC squall lines forming in?
4. Do these pre-TC squall lines form and propagate in a manner consistent with the diurnal pulses within the TC diurnal cycle?
5. How is the HRRR forecast model representing the pre-TC squall line?

Background

Pre-Squall Line Environment

Midlatitude Squall Lines:

- High CAPE
- High LL wind shear

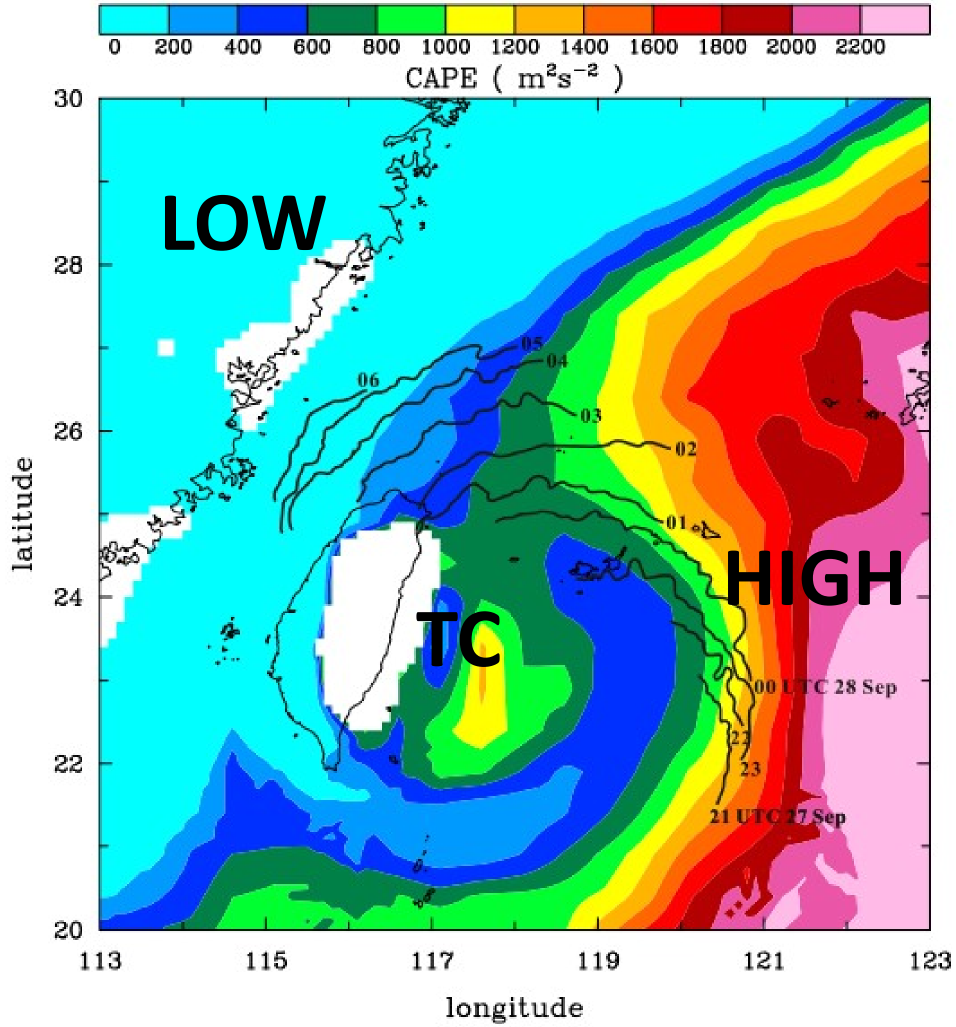
Tropical Cyclones:

- Higher CAPE outside core
- Low wind shear

(Bogner et al. 2000; Molinari et al. 2012)

Daytime heating over land may have an influence over the intensification of these pre-TC squall lines as well

Mean CAPE



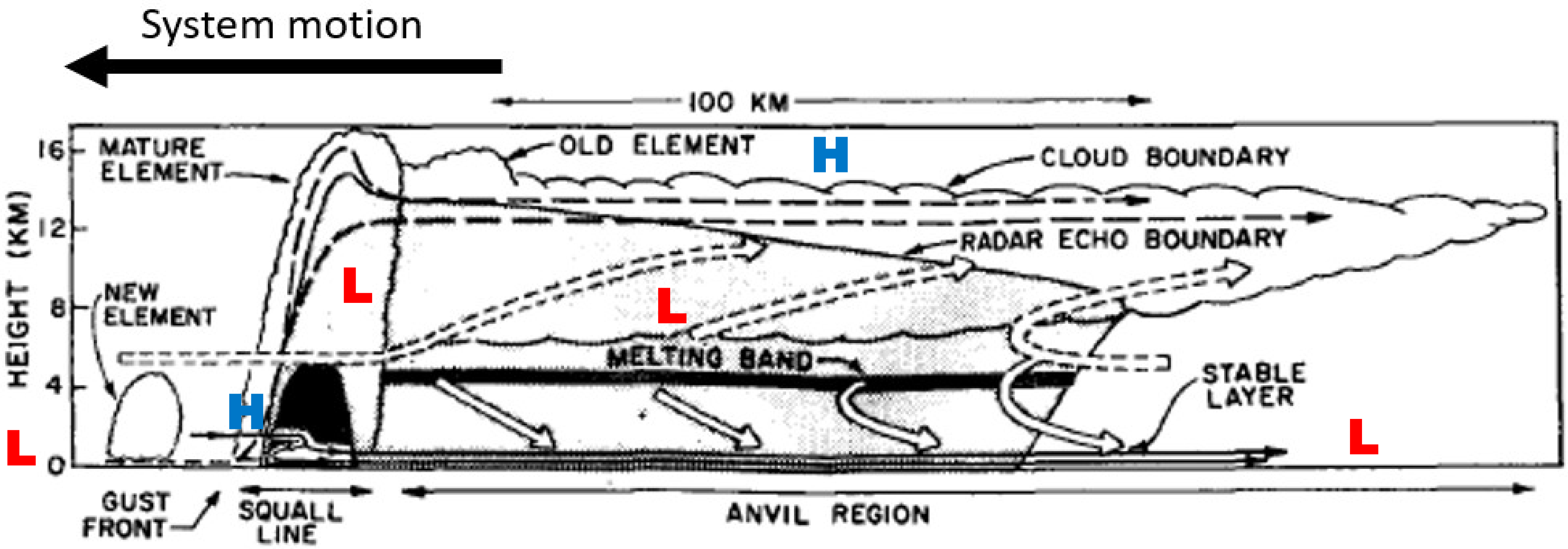
Yu, Lin, Luo (2019) – Mean CAPE assoc. w/ Typhoon Jangmi (2008) near Taiwan

Structure and Formation

Squall Line Definition:

- Linearly organized convection in a continuous or quasi-continuous band

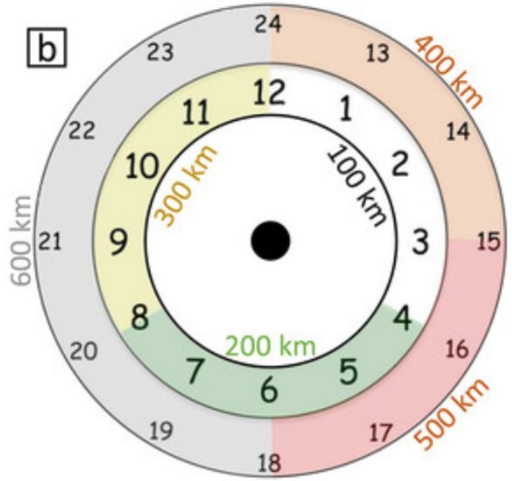
Key Structural & Surface Components of Midlatitude Squall Lines:



Gamache & Houze et al. (1989), Fig. 1

Tropical Cyclone Diurnal Cycle

- Recent interest in diurnal “pulses” as part of diurnal cycle
- **Diurnal pulse:** “cyclical pulses in the IR cloud field that regularly *propagate radially outward* from the storm.” (Dunion et al. 2014)
- Pulse begins traveling around sunset local time until the following afternoon following the Diurnal Clock
- Pulses have been classified as either a warming pulse or cooling pulse
- Pulses travel between **8** and **14 m/s**



(Left) Fig. 2b diurnal clock conceptual model from Ditchek et al. 2019
(Right) Fig. 1 from Dunion et al. 2014 GOES IR imagery and BT differences illustrating a diurnal pulse in Hurricane Felix (2007)

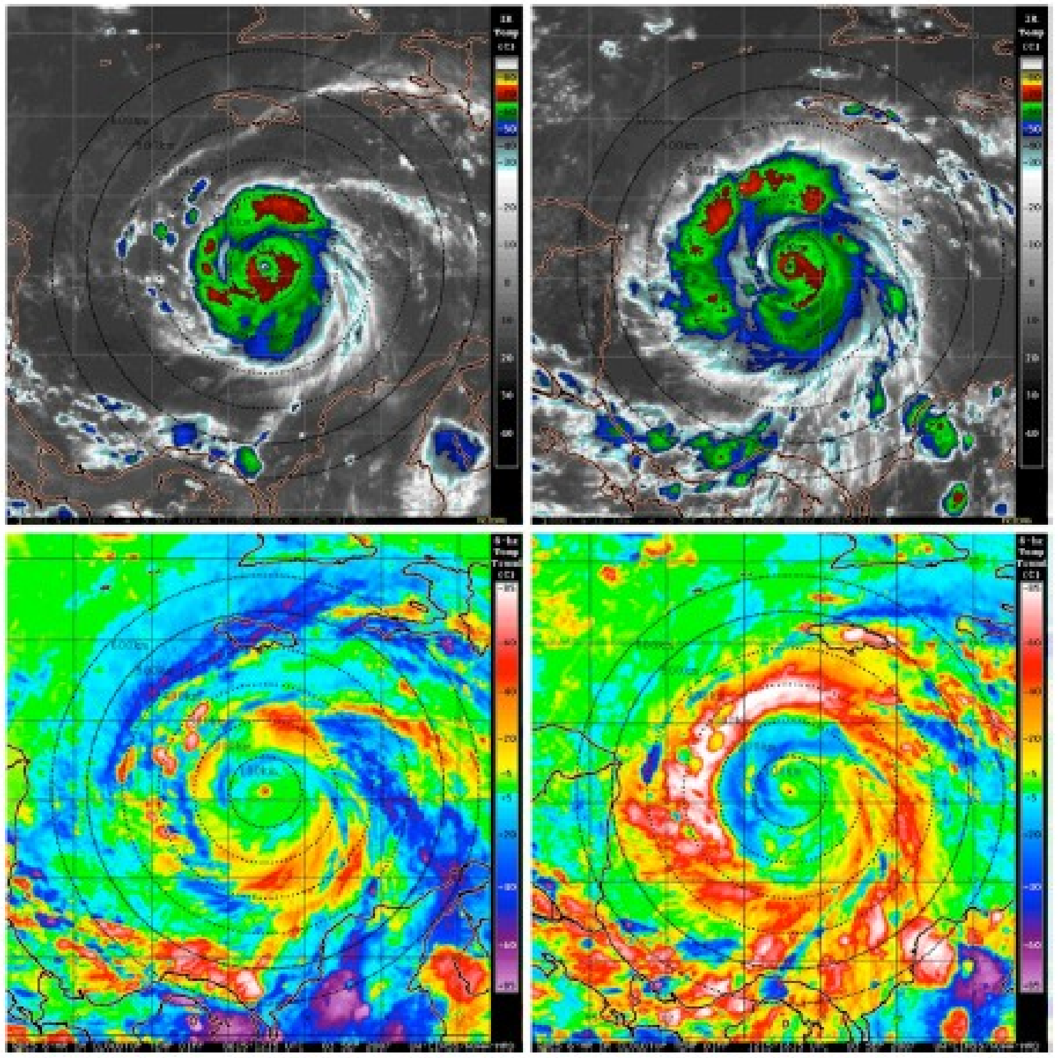
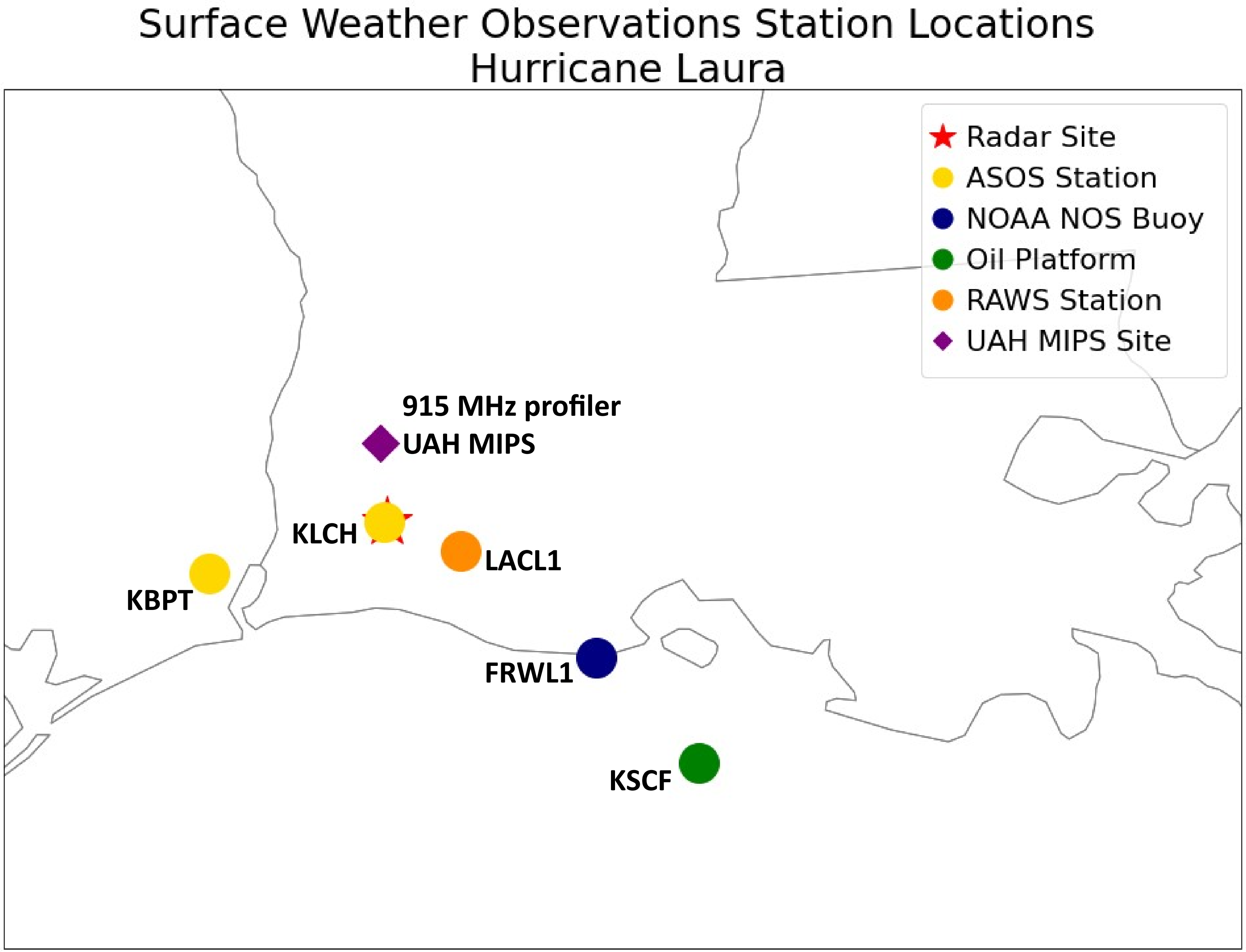


FIG. 1. (top) GOES IR imagery showing 2007 Hurricane Felix valid at (left) 1215 UTC (0715 LST) and (right) 1815 UTC (1315 LST) 3 Sep. (bottom) The corresponding 6-h GOES IR brightness temperature differencing images for these times . The yellow to pink shading (−10° to −85°C IR cooling tendencies) indicates a diurnal pulse propagating away from the storm during this period. The 100–600-km range rings (black dashed curves) from the TC center are overlaid on each of the satellite images. Lines of latitude and longitude are marked at 2° intervals.

Evaluation of:

- Surface observations
- Radar reflectivity structure
- Pre-squall environmental parameters
- The TC diurnal cycle pattern and propagation speed



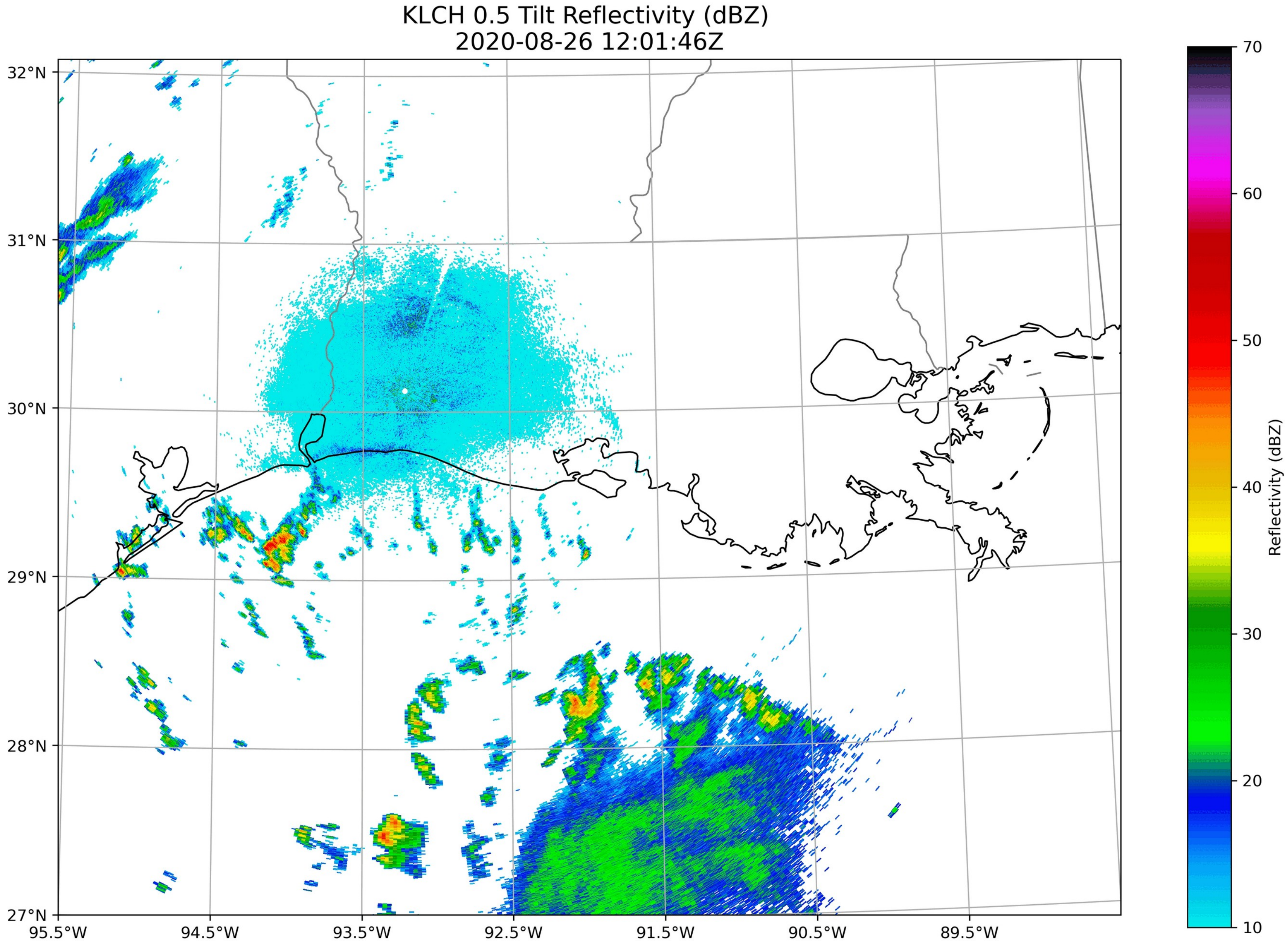
Results

HURRICANE LAURA (2020)

Image courtesy of NOAA via AP - LINK

Overview

- Made landfall in Cameron, LA on August 27th, 2020 as a **Category 4** Hurricane
- The pre-TC squall line passed through Lake Charles **13 hours** before Laura's landfall
- Time of interest: ~12Z to 21Z on August 26th
  - Formation over Gulf to dissipation over east TX
  - Passed through Lake Charles at about **1730Z** (12:30 PM)



Environmental Characteristics

12Z KLCH Sounding

Notable Observations:

Surface-based CAPE = **3462 J/kg**

ML CAPE = 1561 J/kg ▭ still high

0-1km Shear = **27 kts**

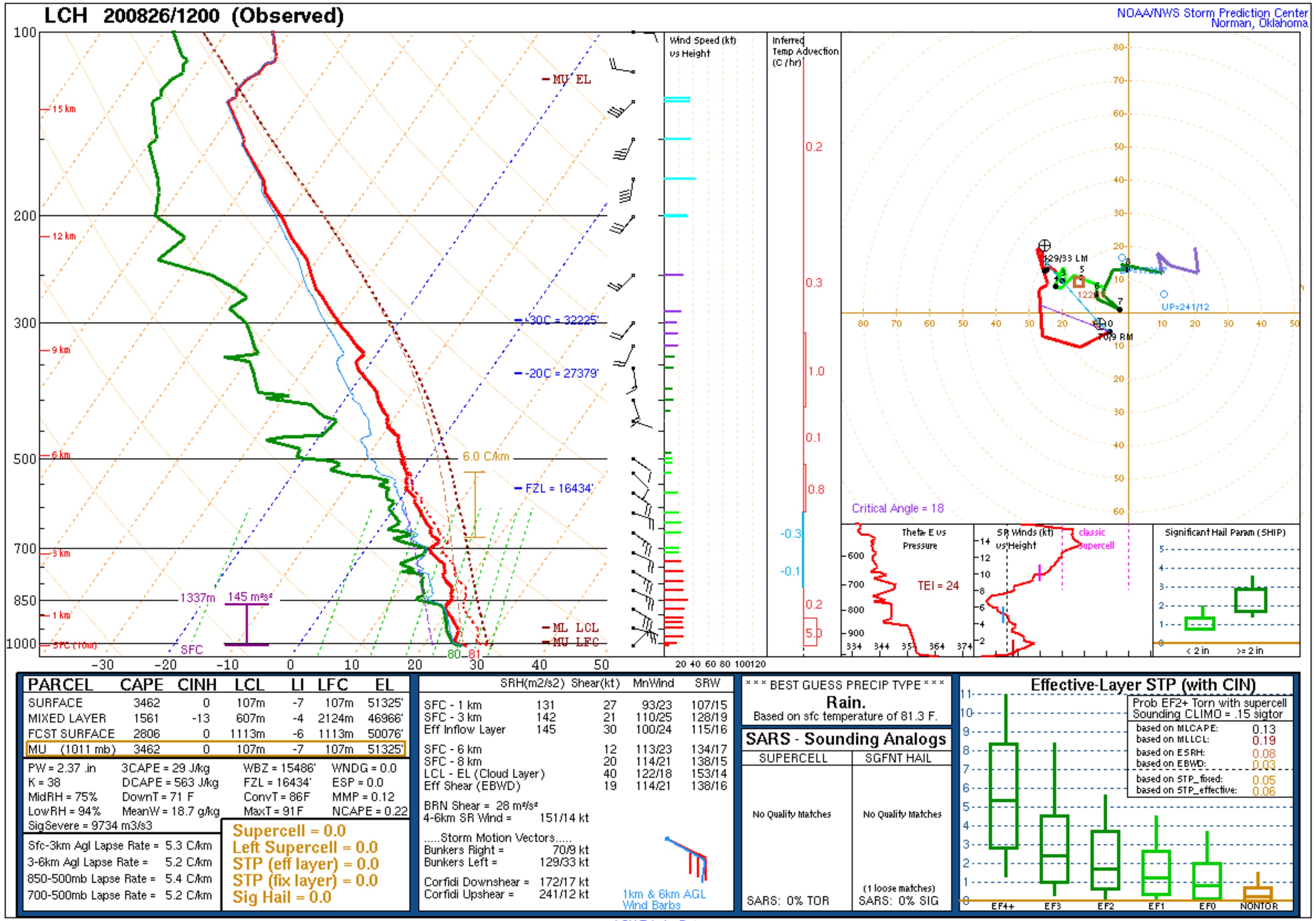
0-6km Shear = 12 kts

Surface CIN = 0 J/kg

BRN Shear = 28 m2/s2

✓ **High CAPE**

✓ **High LL wind shear**

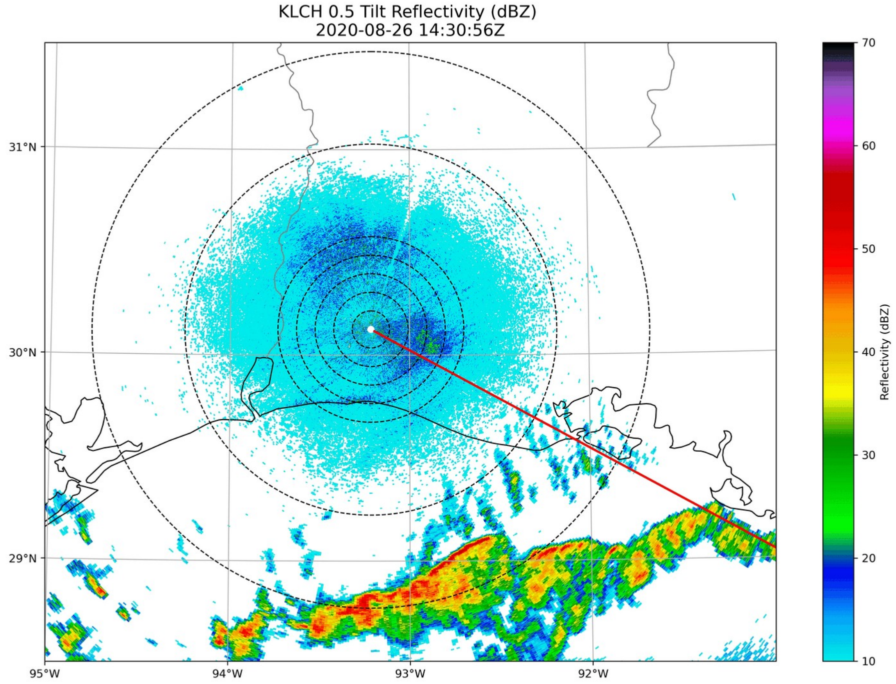


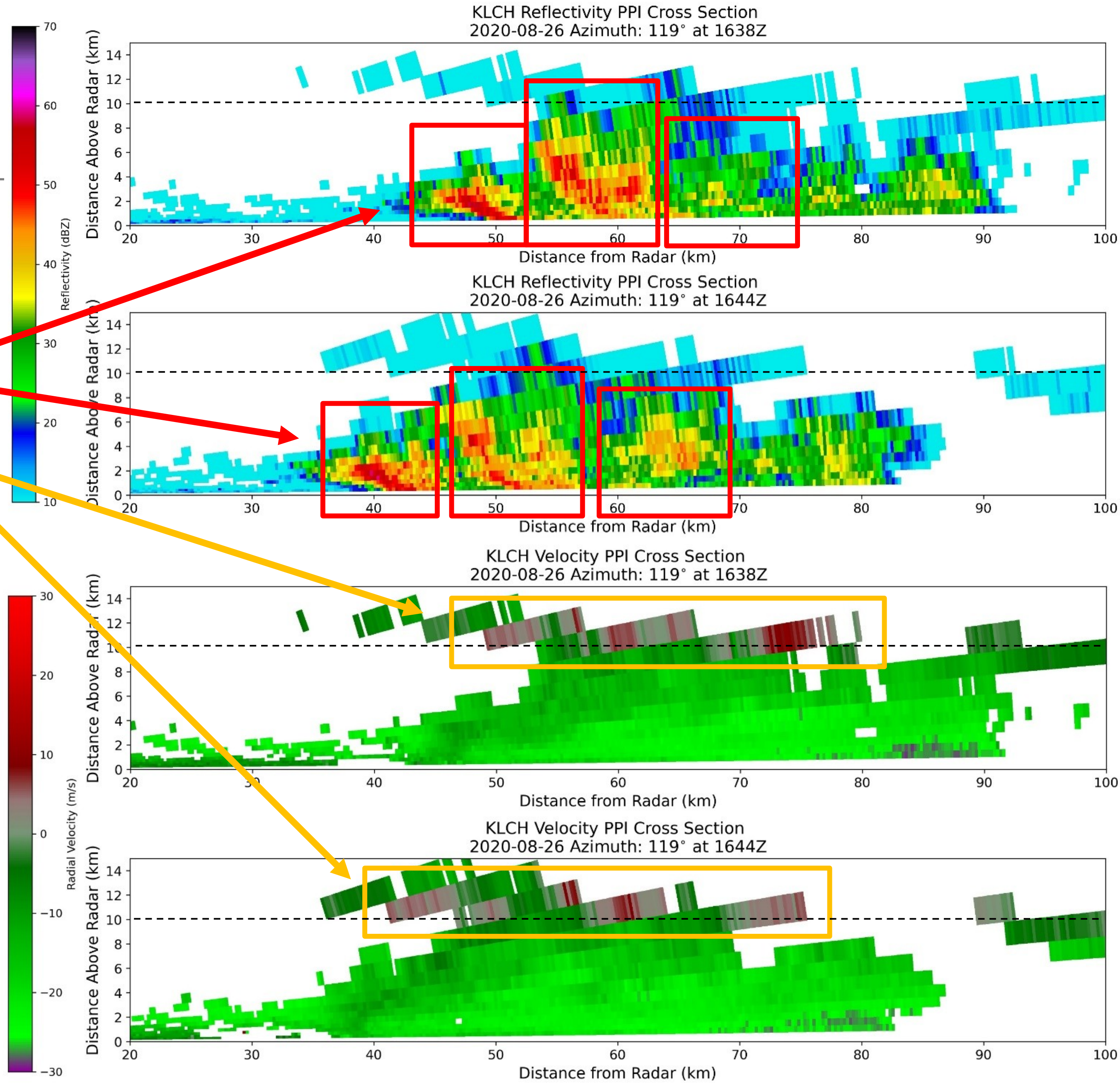
Structure and Evolution

- Maximum height of convection: ~10-12 km
- Horizontal width of squall line: 40-50 km

✓ Definitive multicellular structure observed

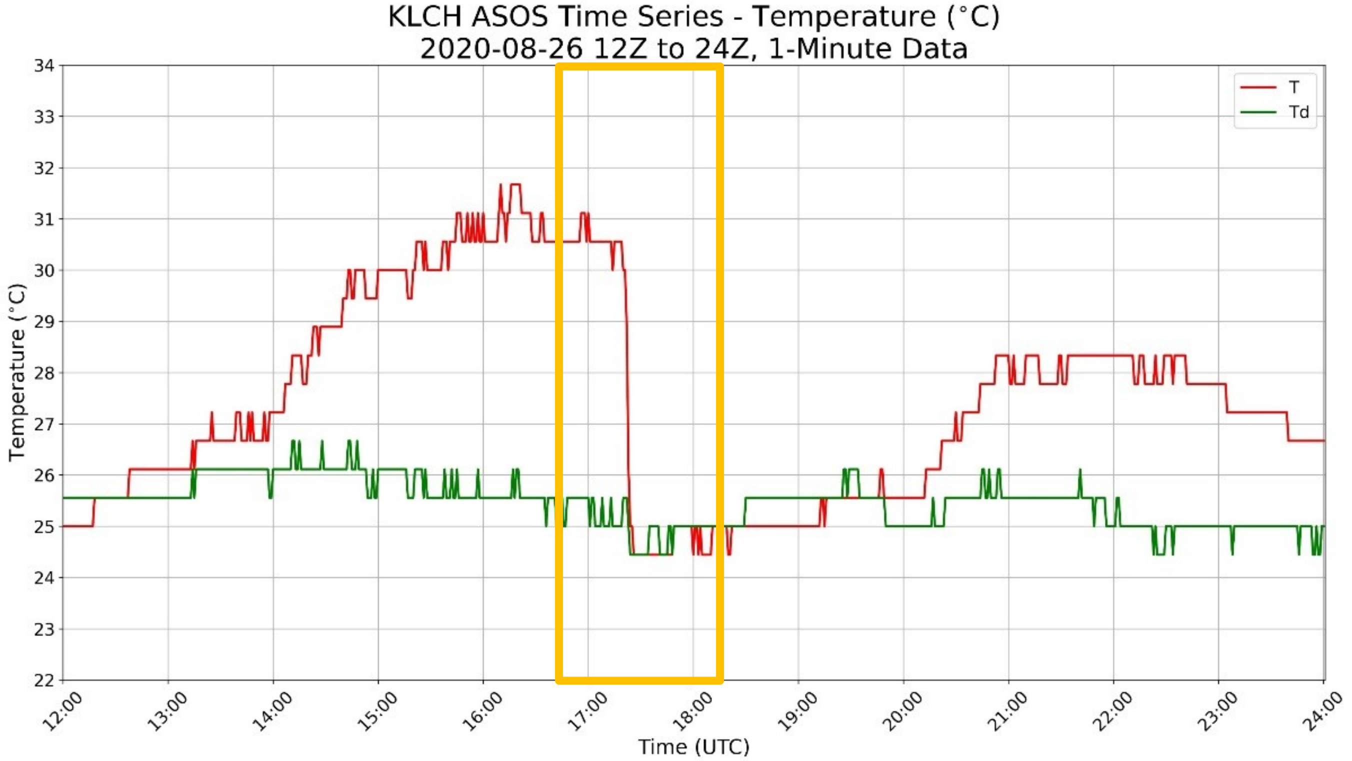
✓ Evidence of upper-level front-to-rear flow relative to the squall line

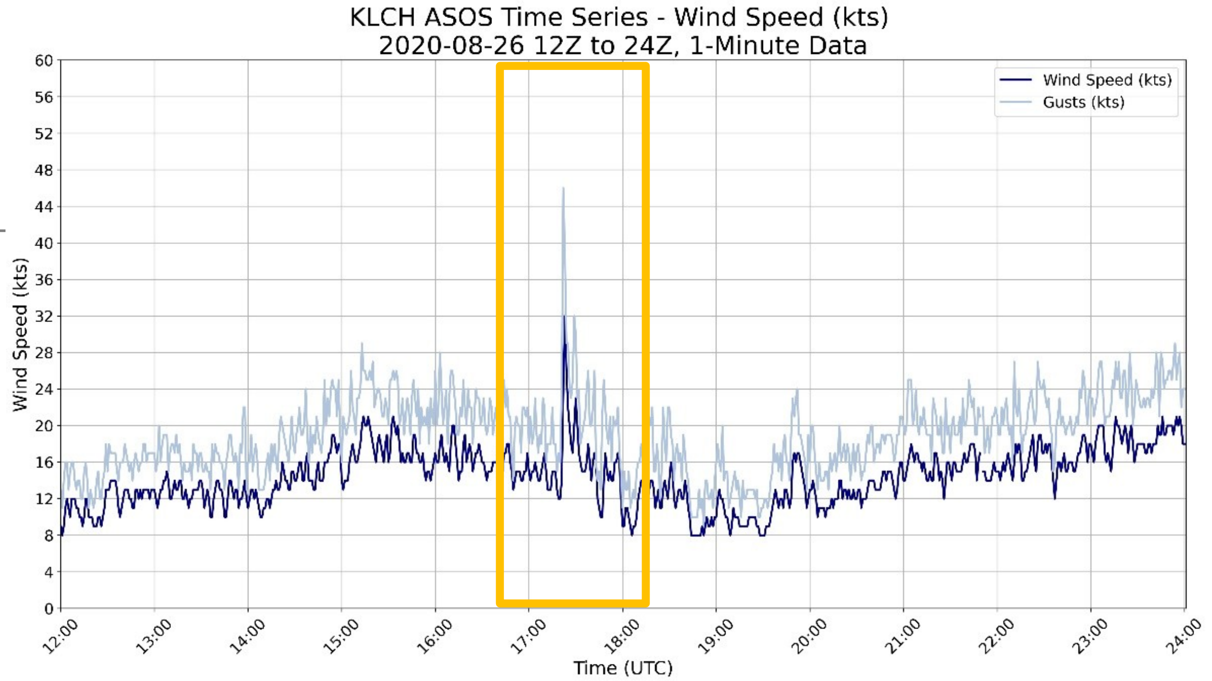


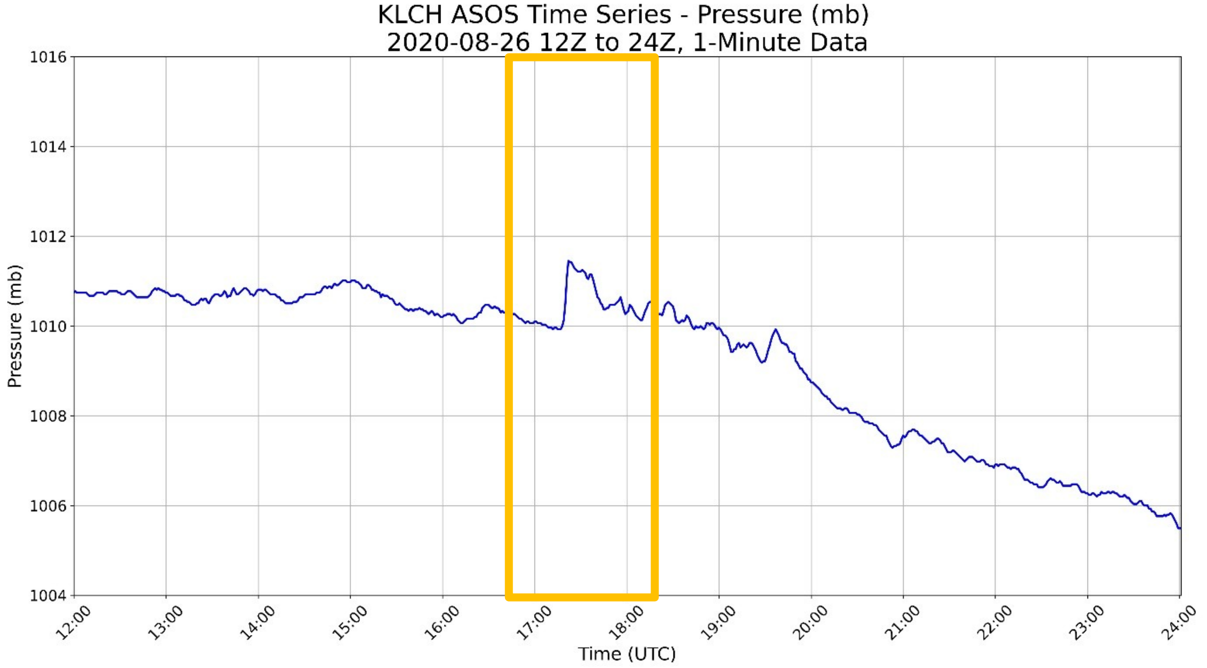


MOTION

Surface Observations



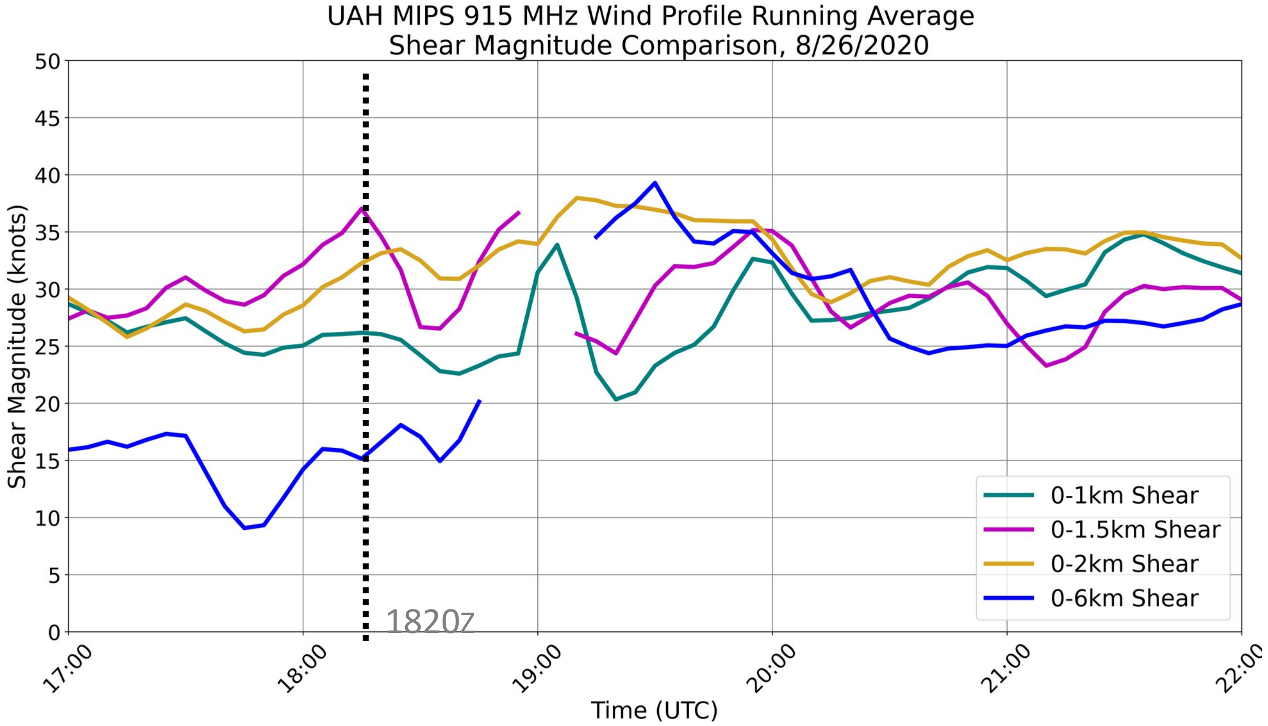


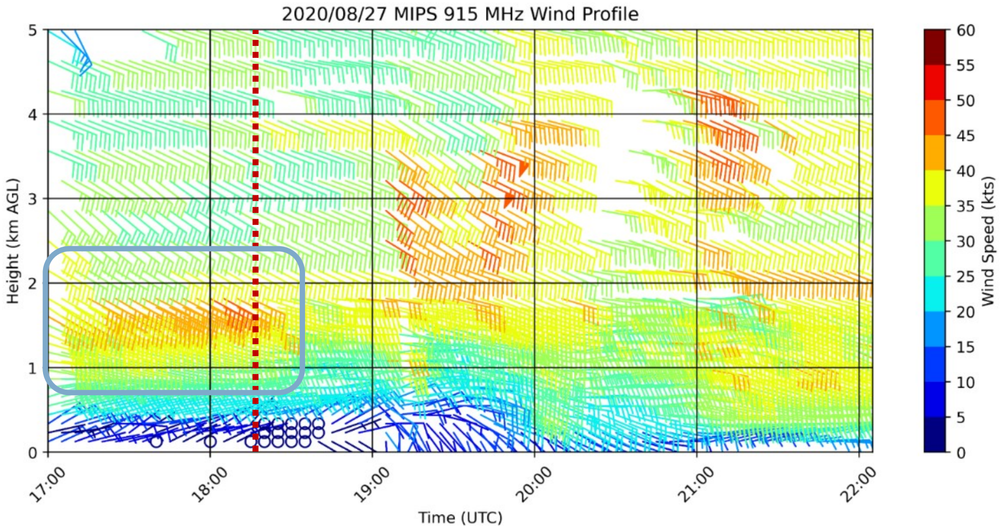


- ✓ **-6.1°C** Temperature Drop in **7** minutes
- ✓ **+1.42 mb** Pressure Rise in **9** minutes
- ✓ **46 kt** gust during passage (32 kt 1-min avg.)

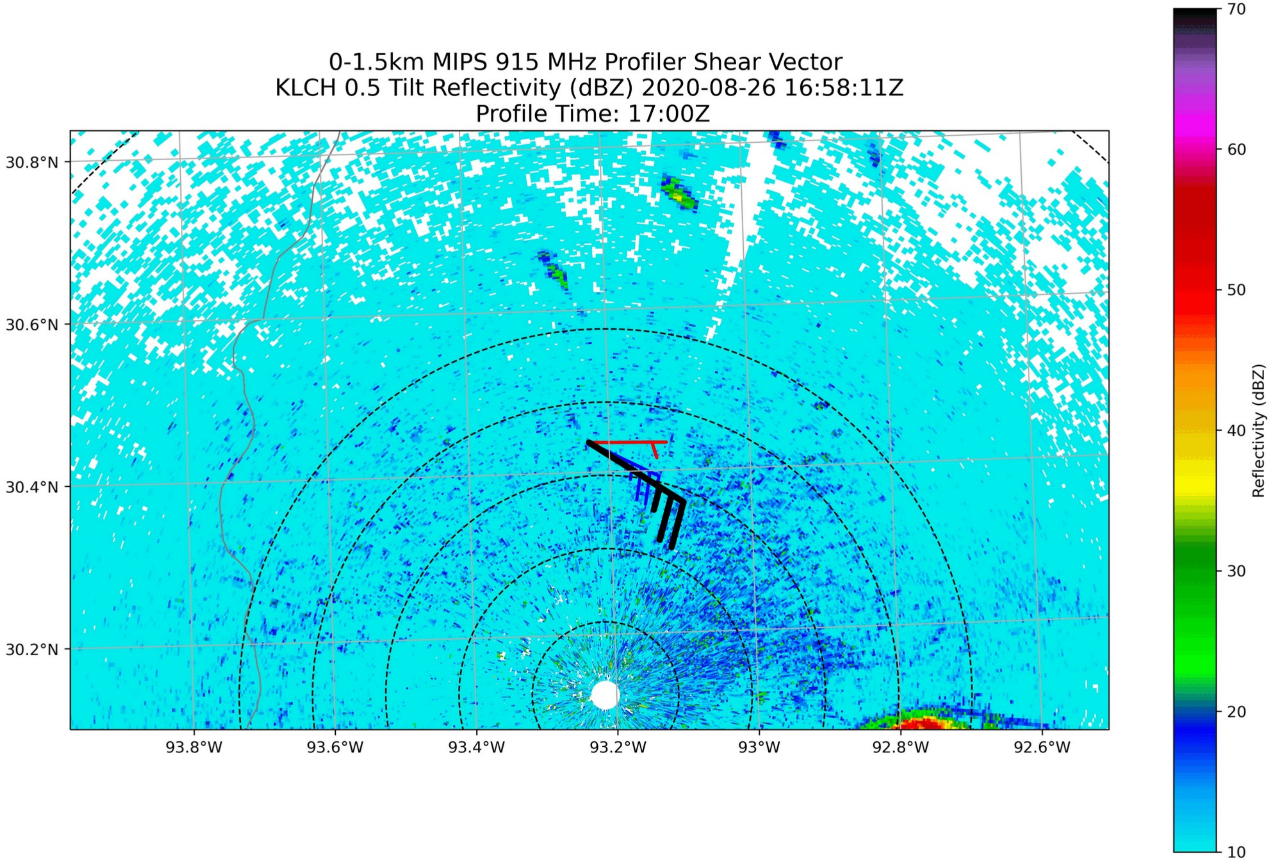
➢ **Suggests cold pool-driven feature**

915 MHz Wind Profile – Shear Analysis





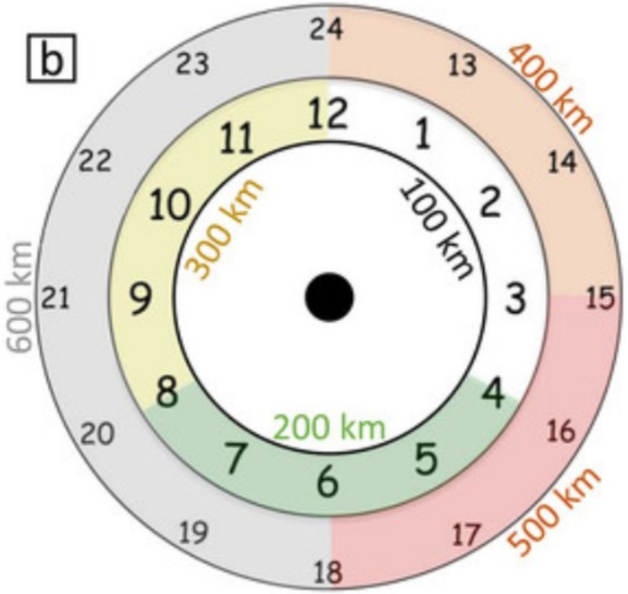
- ✓ Low-level shear is the largest in the layer prior to gust front passage
- Gust front passage at approximately **1820Z**

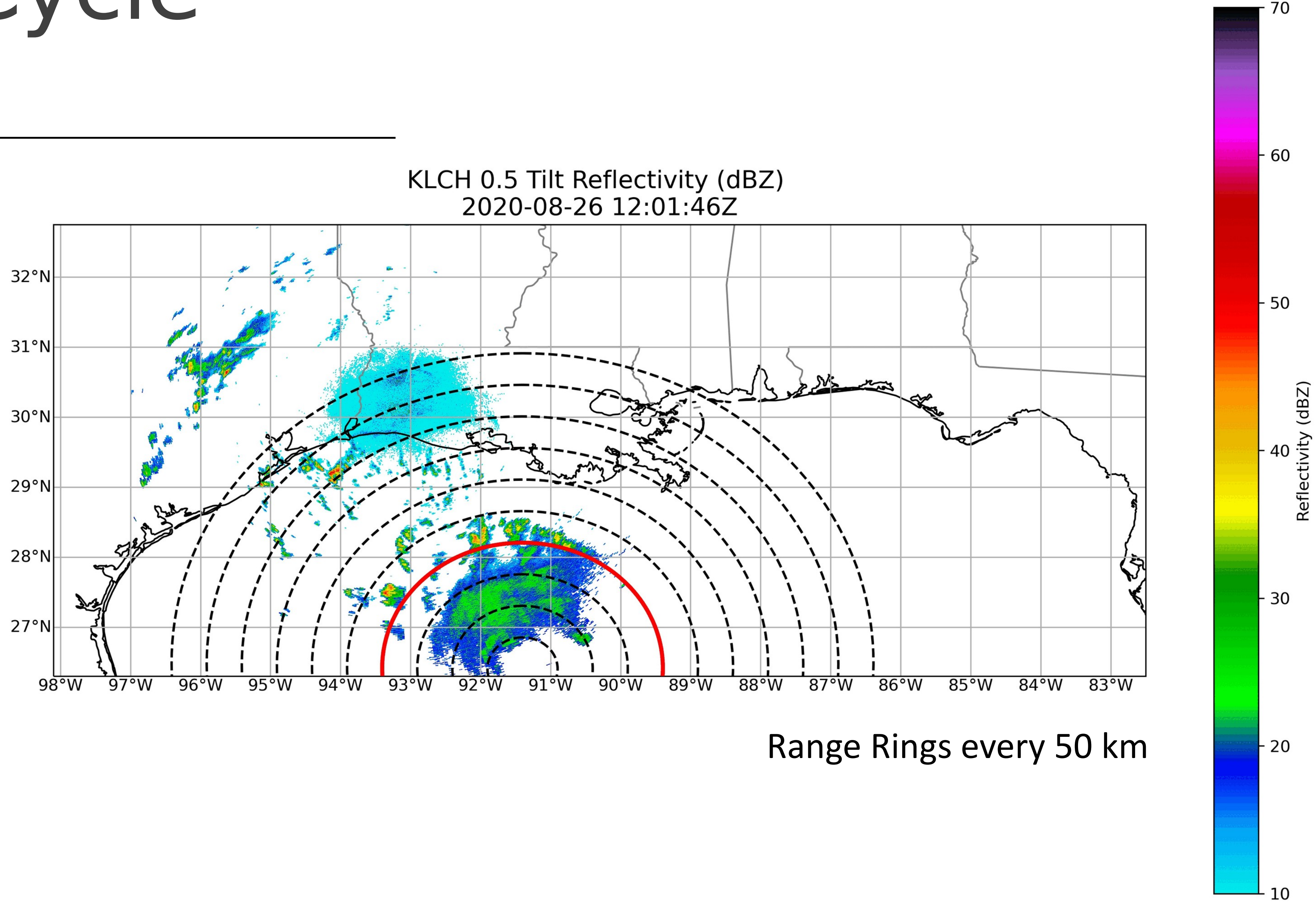


Diurnal Cycle Analysis

Mean Propagation Speed for 12-20Z:

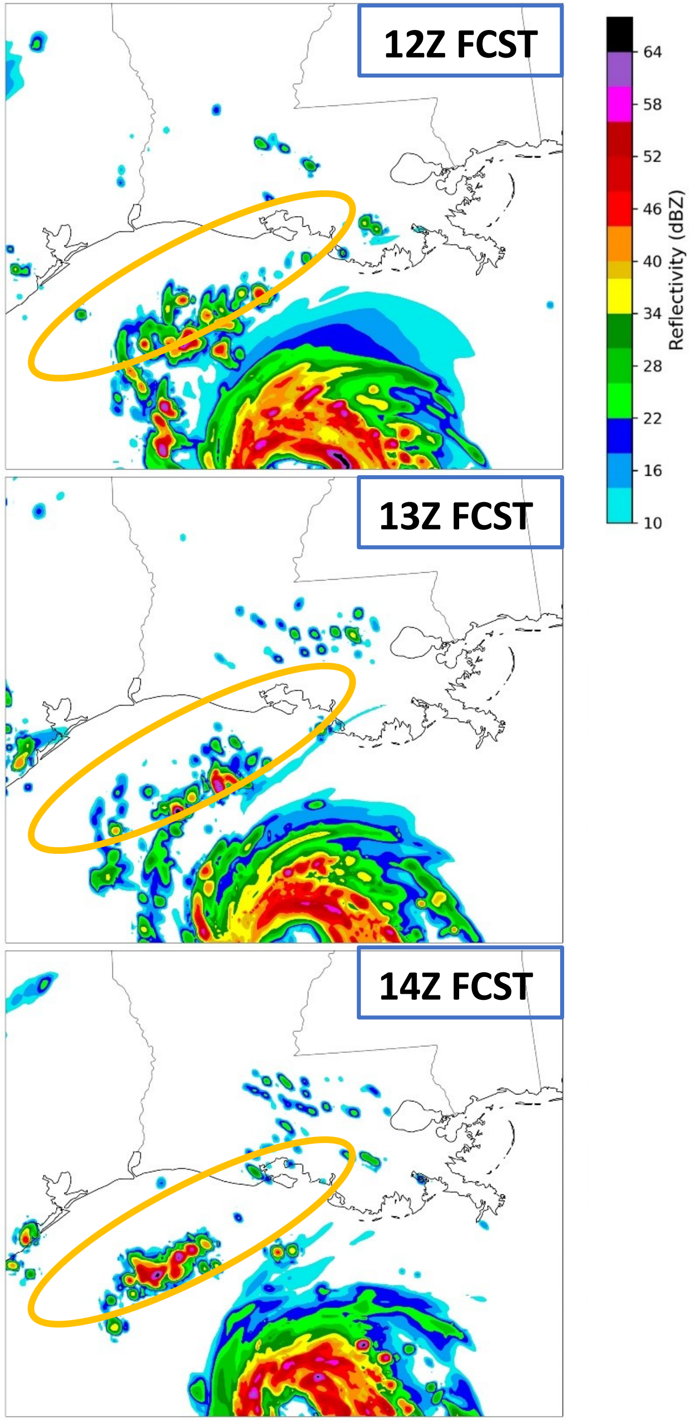
6.2 m/s, with a maximum at 16Z of **9.2 m/s**



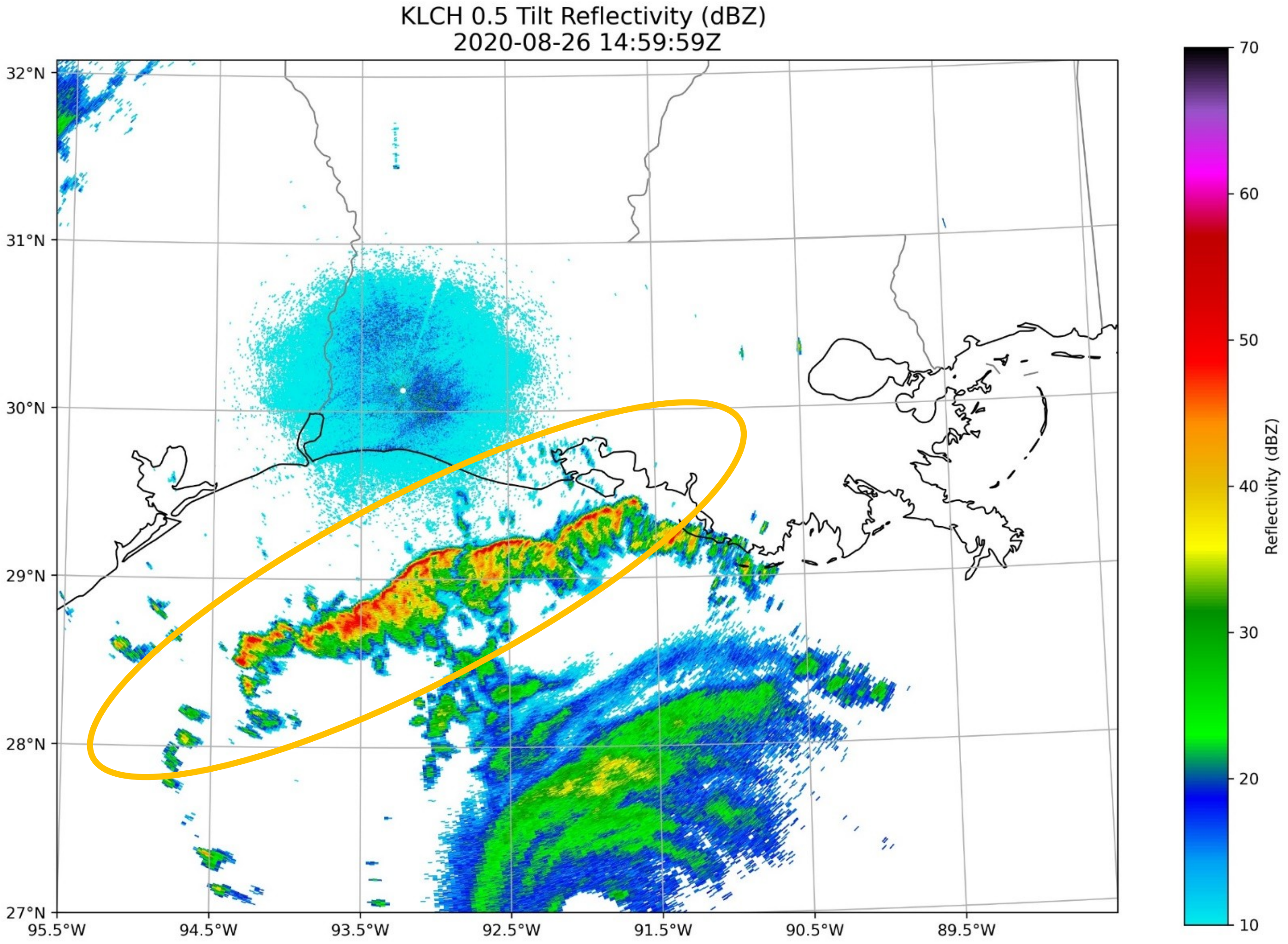


Range Rings every 50 km

HRRR Forecast Model



HRRR Composite Reflectivity 12Z run – 14Z run for 15Z (left)
KLCH 0.5⁰ Observed Reflectivity, 1459Z (below)



Conclusions

- Formed in high CAPE, high LL shear environment
  - Closer to that of a midlatitude squall line environment
- Structure and organization of pre-TC squall line distinct from outer TC rain band
  - Trailing stratiform
  - Multicellular structure, rear outflow
  - Surface characteristics, cold pool, meso-high
- Propagation follows timing of TC diurnal clock
- HRRR forecast model failed to represent the feature as observed
  - Even 5 hours out from observations, it was not shown in model
  - Hypothesis: lack of surface obs. over Gulf kept model from resolving cold pool

Questions and Contact:

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Thank you!

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SPORT Short-term Prediction Research and Transition Center

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