Novel Application of NASA's GEOS-CF CO_2 Forecasting System to ACT-America Airborne Campaign

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Why do we need a real-time CO_2 forecasting product?

- Forecasting CO_2 for field campaigns.

- Given enough observations, forecasts allow for a quick real-time evaluation of known CO_2 sources.

- In theory, CO_2 forecasting products could assimilate CO_2 observations and perform inversions in near real-time. If we want to monitor CO_2 emissions at a policy level, such a step would be imperative.

The Atmospheric Carbon and Transport-America (ACT-America) NASA Campaign

C-130 aircraft.

B-200 aircraft.

- 2 aircraft (C-130 and B-200).
- 3 different regions in the Eastern United States: Gulf, Midwest, and Mid-Atlantic.
- 5 seasonal campaigns (2 summer campaigns) over 2016-2019 time period.
- Main mission goals are:
  1. Quantify and reduce atmospheric transport uncertainties.
  2. Quantify and reduce uncertainties in prior CO_2 and CH_4 flux estimates.

The CO_2 Forecasting Model Used: GEOS-CF

- The model used for ACT-America forecasting operated in two modes: GEOS-Chem and “GOCART”.
- GEOS-Chem operated in online mode providing CO and C_2H_6.
- “GOCART” simplified processes to generate CO and CO_2 forecasts.
- Meteorology was simulated with GEOS FP-IT.
- Resolution was 0.25 x 0.25 (~25 km).

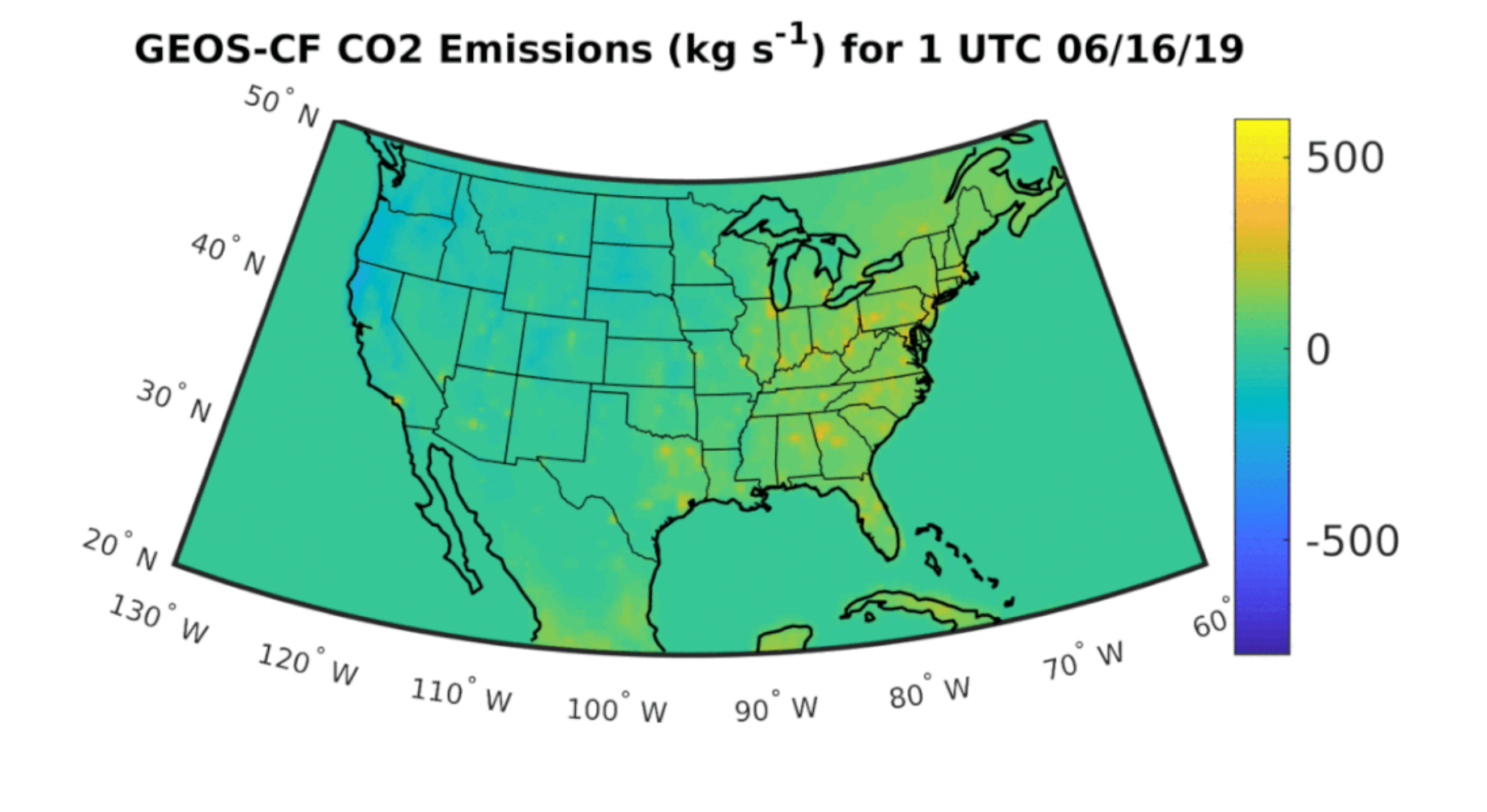
CO_2 from "GOCART"

- Near real-time CO_2 from GOCART (LoFi – Low-order Flux Inversion) is derived from several retrospective flux components.

- LoFi flux package adjusts land and ocean sinks to match global observed CO_2 growth rates.

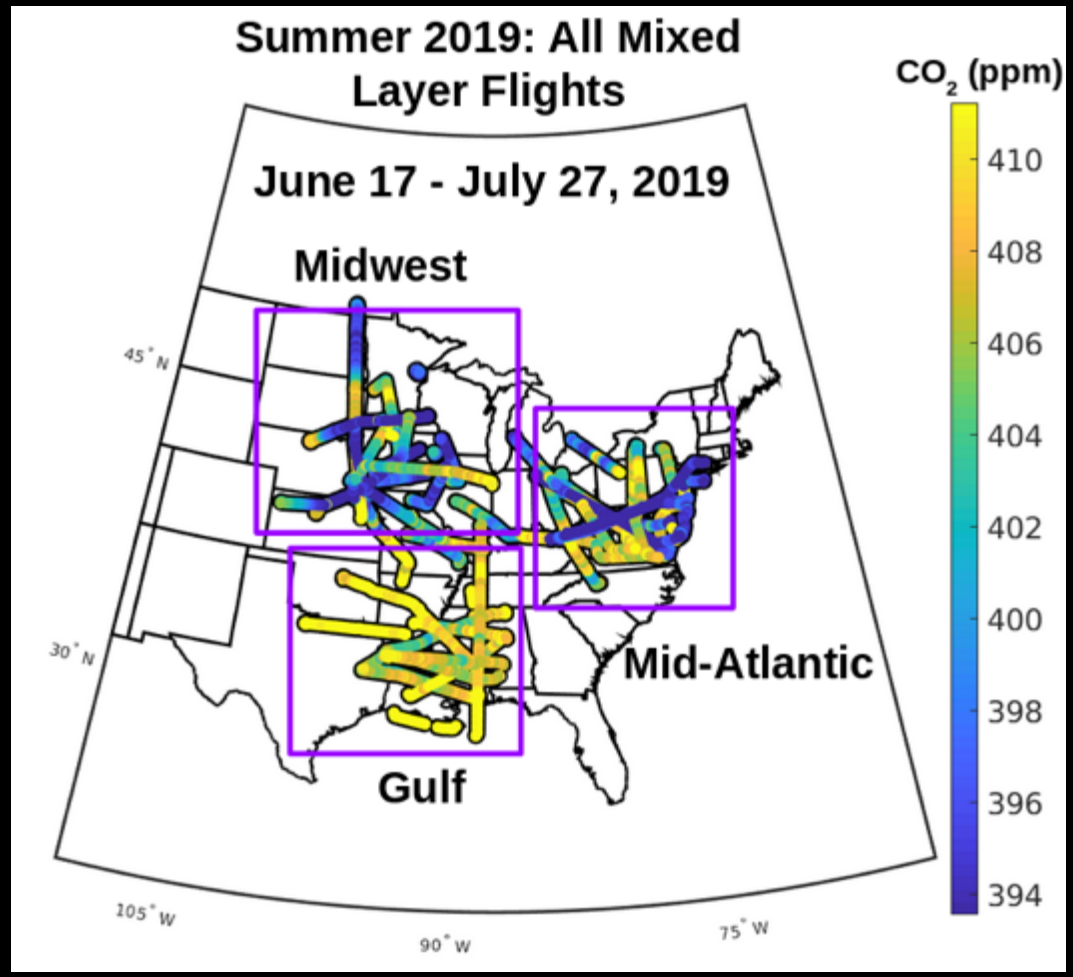
Flux Type	**Method**
NEE (Net Ecosystem Exchange) & Biofuel	LoFi CASA
Biomass Burning	QFED
Fossil Fuel	ODIAC
Ocean	LoFi Extension to Takahashi Climatology

Simulated CO_2 Flux

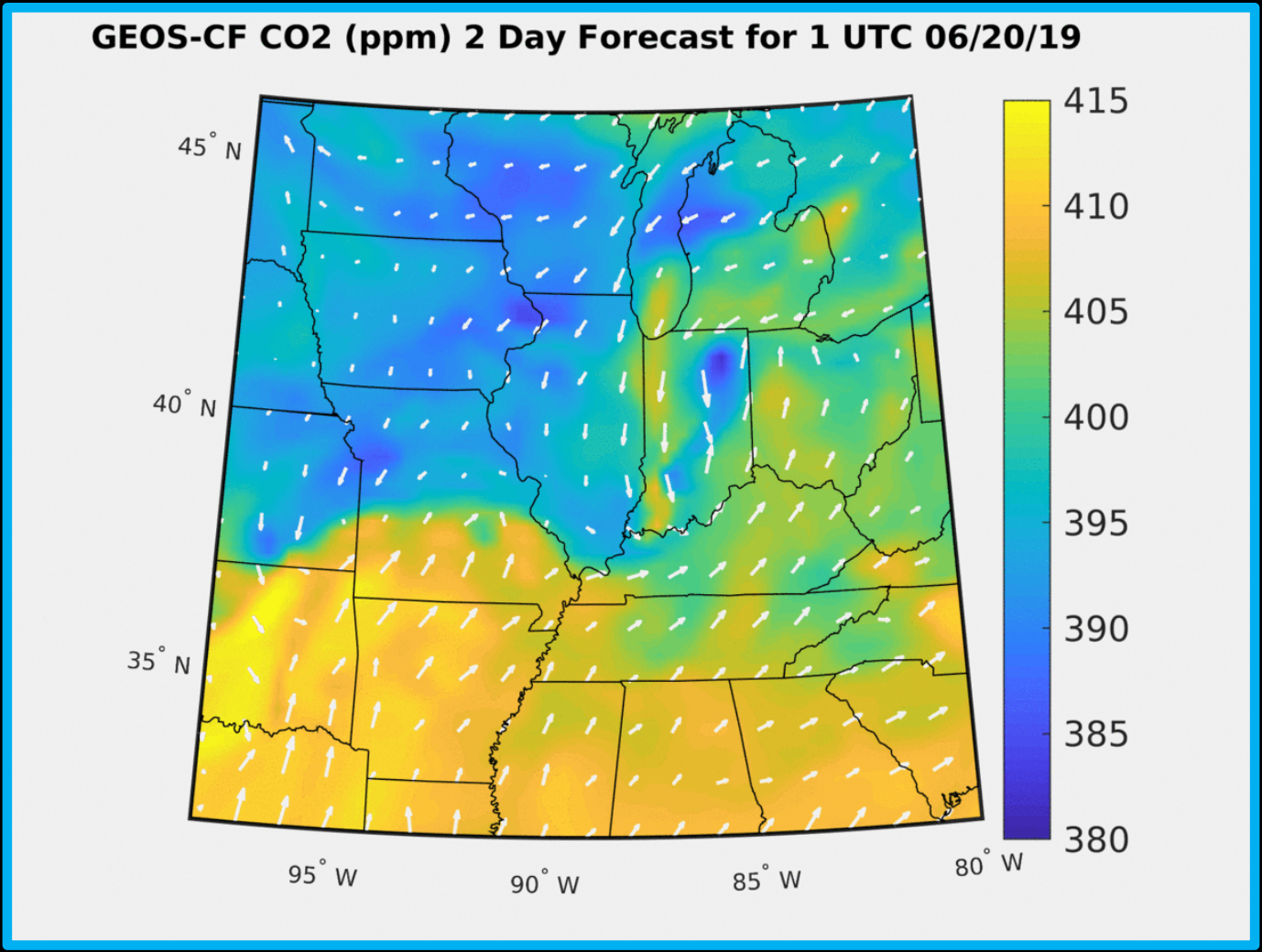


Forecasting for ACT-America Summer 2019 Campaign

- CO_2 forecasting was experimented with extensively only in 2019 summer campaign.
- The main goal was to help plan research flights.
- Forecasts were used to point out areas of CO_2 gradients.
- Studying these gradients with specific model studies could help better understand the uncertainty of modeled CO_2 due to errors in transport.

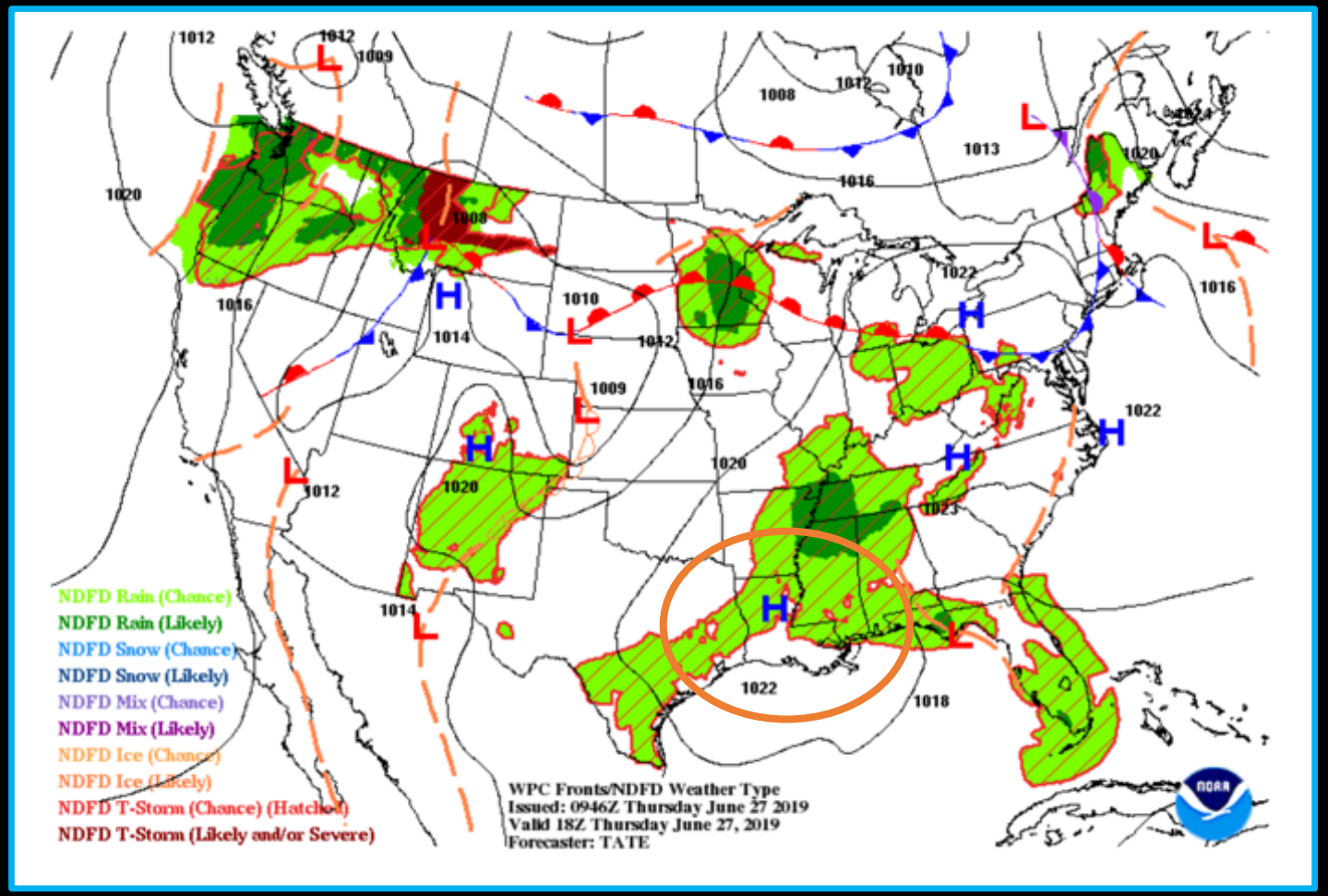


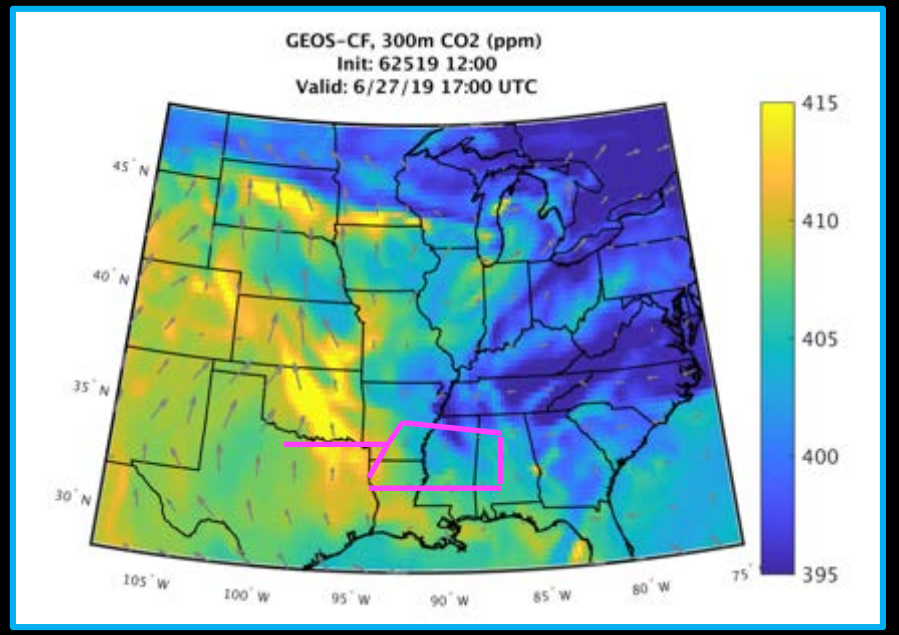
Sample of 2-Day Forecast



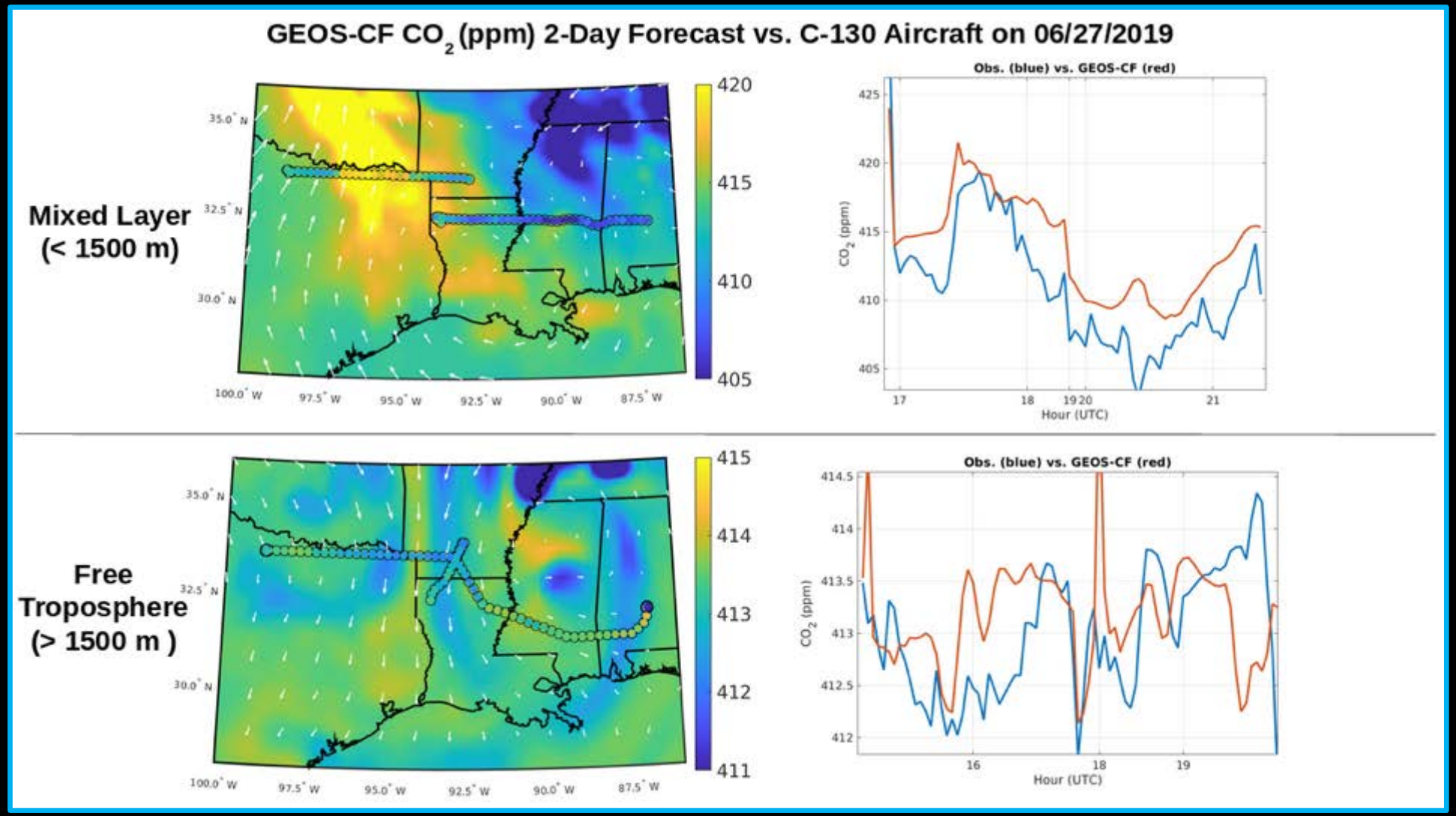
Forecasting Example 1

NWS Fronts for 18Z Thursday 06/27/19

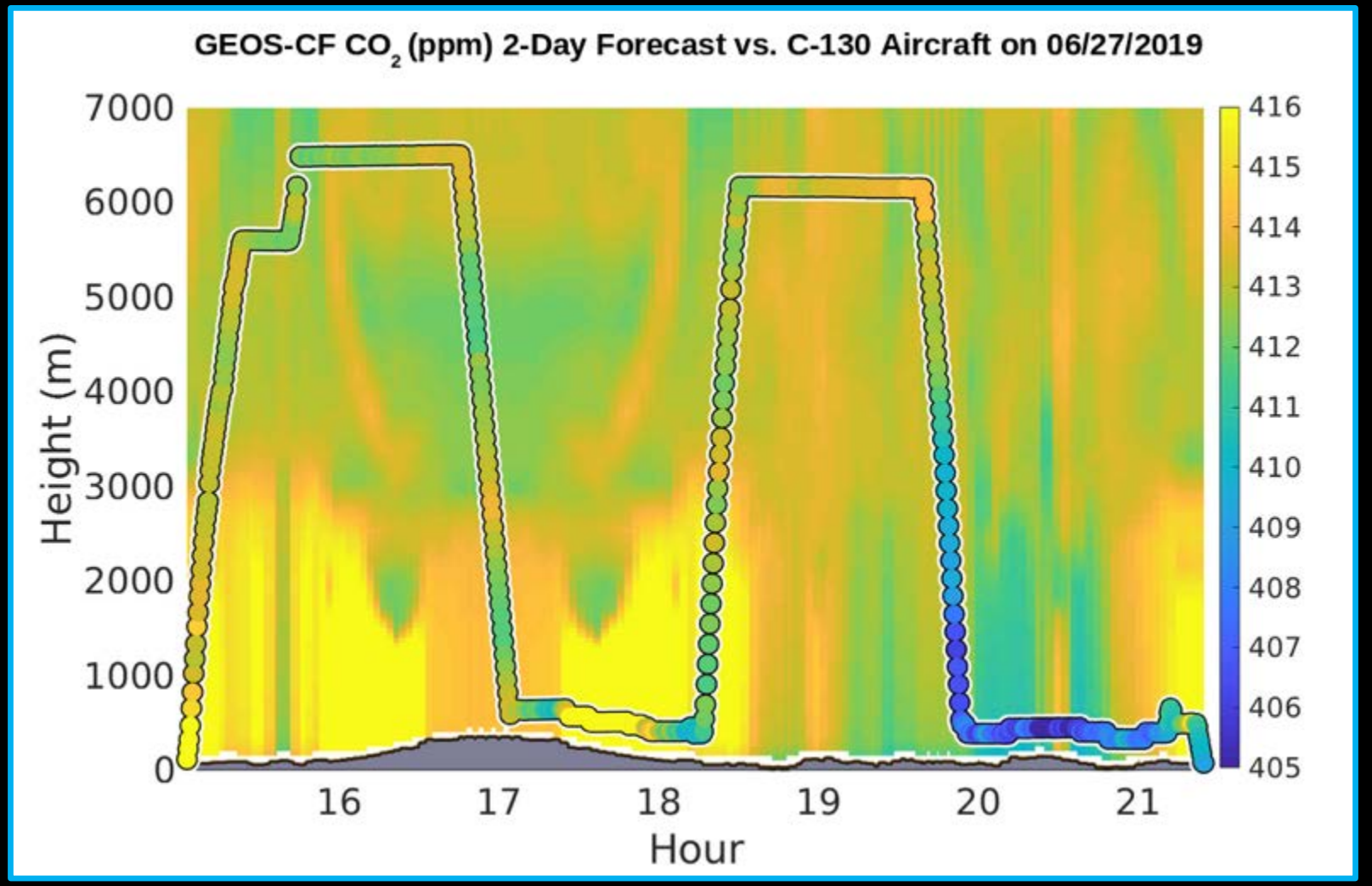




Forecasting Example 1 (cont.)

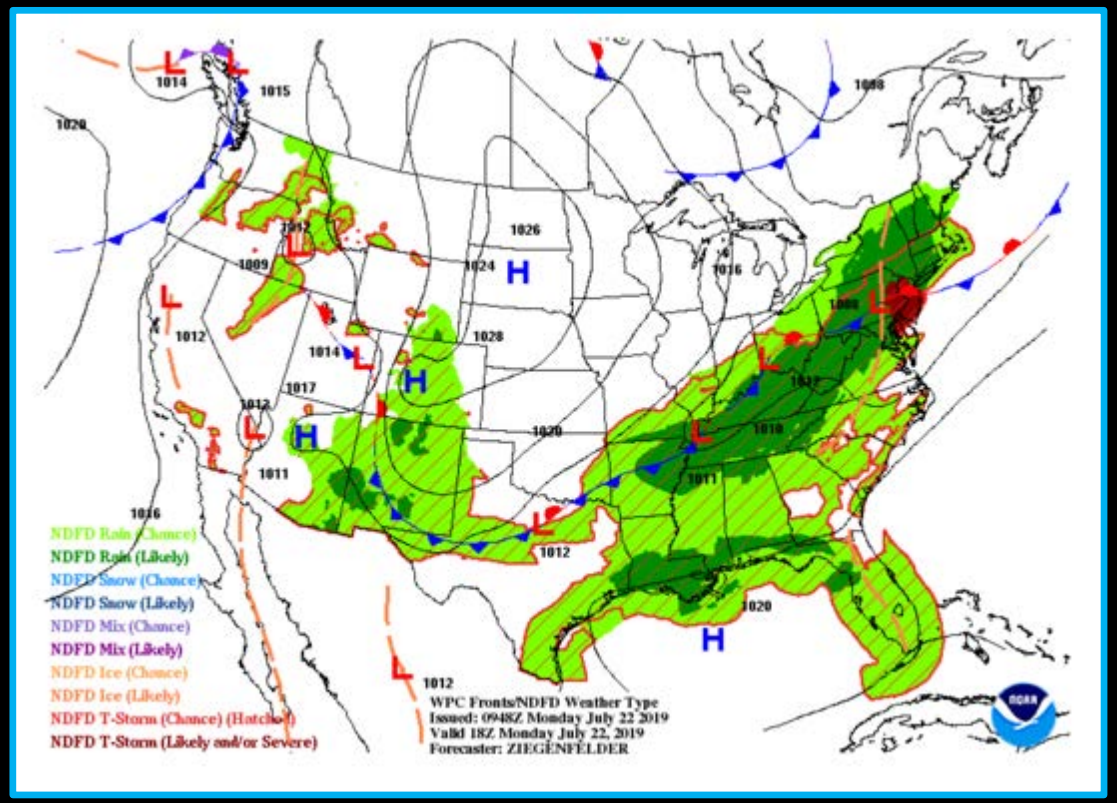


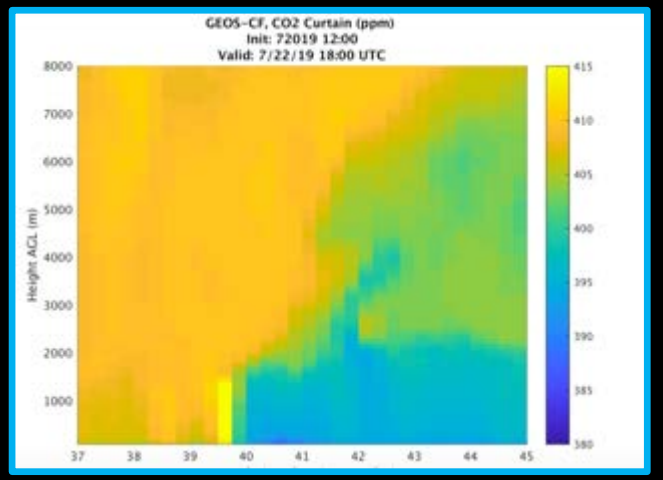
Forecasting Example 1 (cont.)

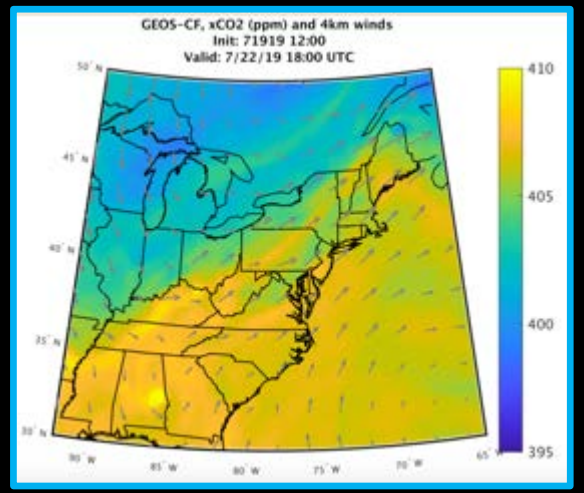


Forecasting Example 2 (cont.)

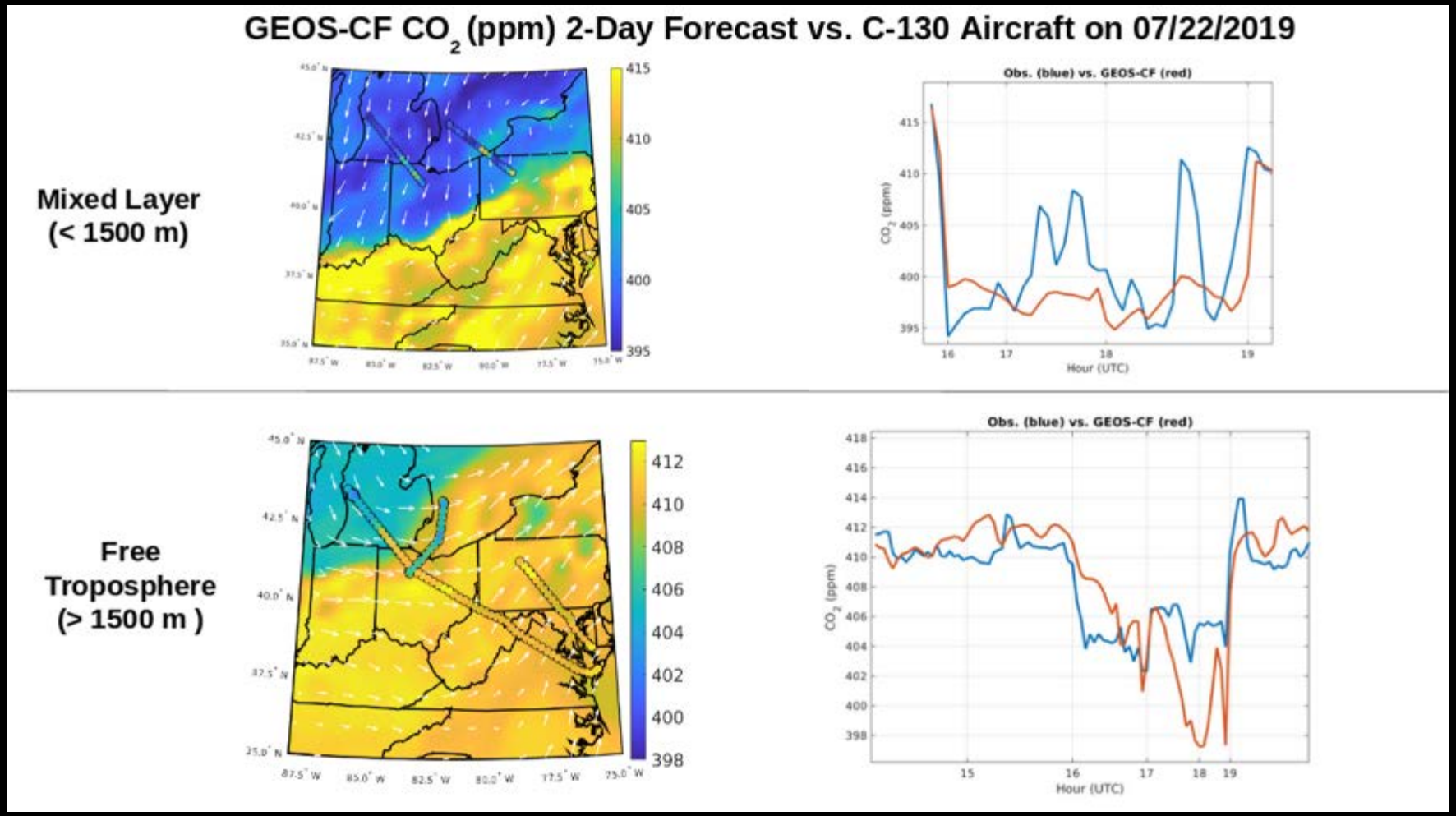
NWS Fronts for 18Z Monday 07/22/19



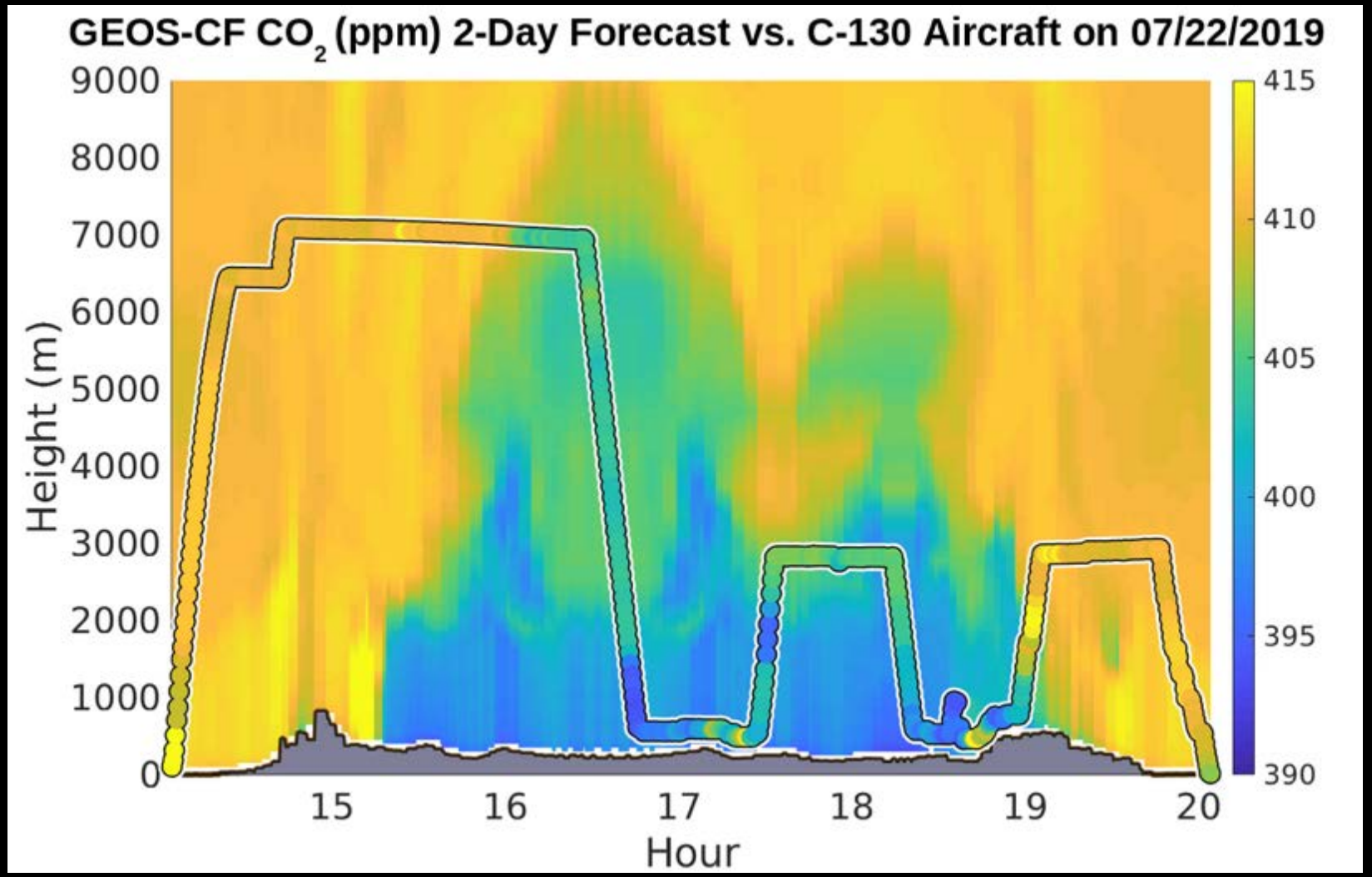




Forecasting Example 2 (cont.)



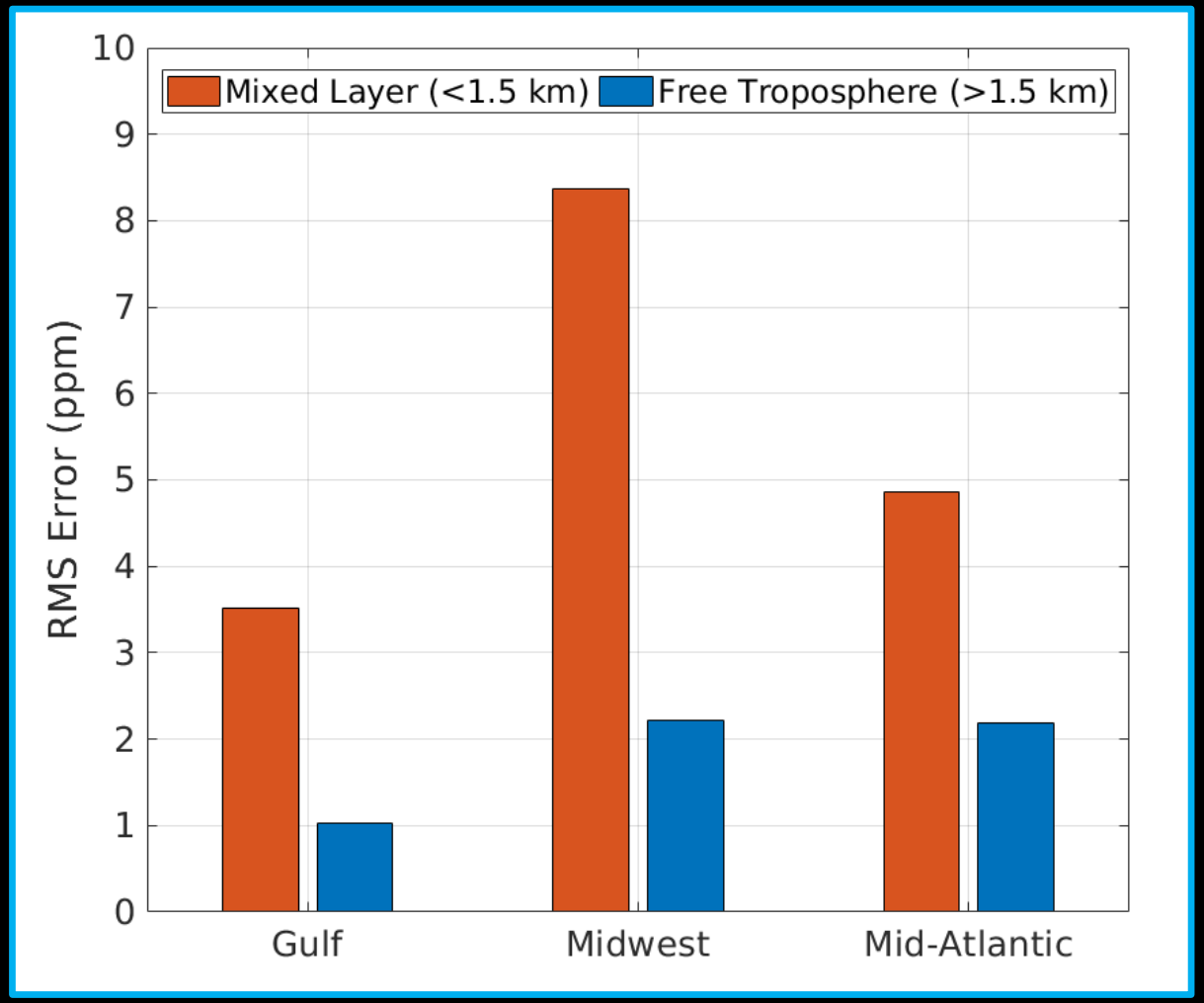
Forecasting Example 2 (cont.)



Results 1

- The model performs much better in the free troposphere than in mixed layer.
- This implies that flux errors are larger than transport errors.
- Extreme flooding of 2019 in the Midwest significantly affected CO_2 sink for the duration of the ACT-America campaign.

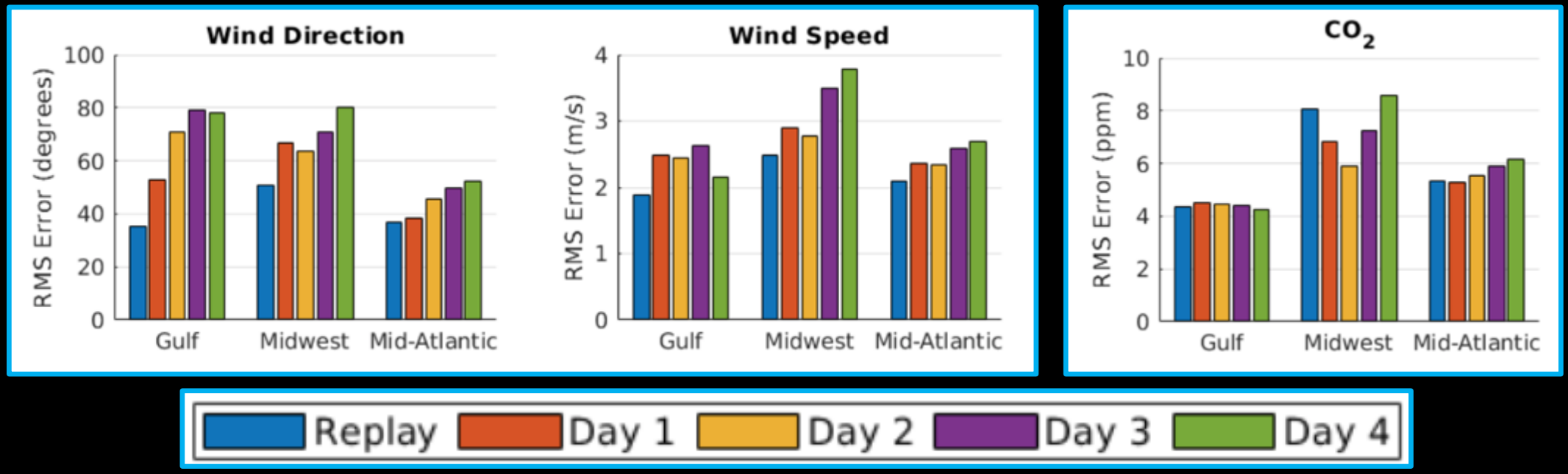
RMS Error for Model vs. Aircraft Observations



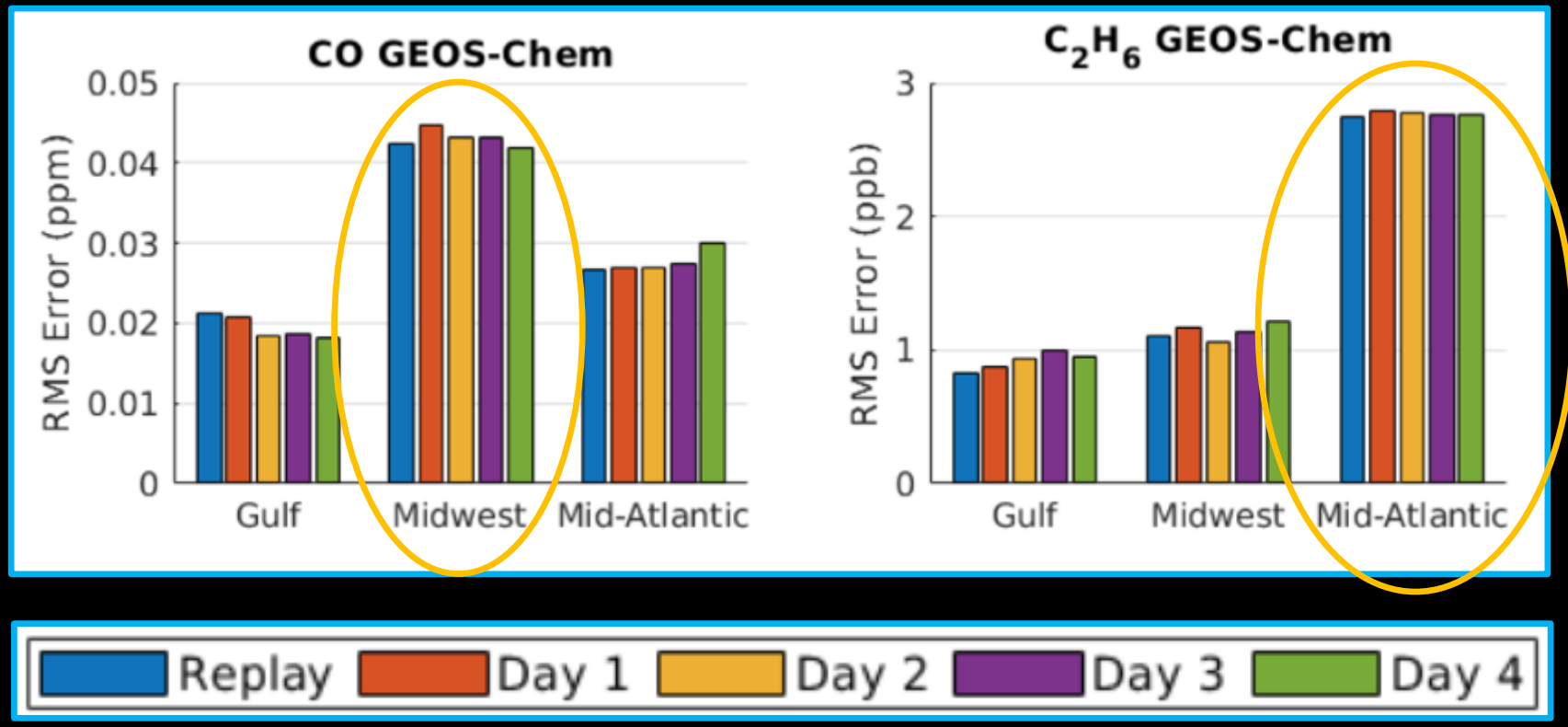
Results 2

- Forecasts from different lead times indicate that skill in transport prediction is decreasing, while CO_2 forecast skill is relatively consistent.

- This implies that the main source of error in the CO_2 stems from the emissions input (flux) of the CO_2 (at least in Gulf and Mid-Atlantic).



Results 2 (cont.)



Conclusions

- The forecasting of CO_2 is useful when planning flight missions (such as ACT-America) by helping to identify interesting CO_2 features such as gradients.
- The model is much more accurate in the free troposphere than in mixed layer.
- The NASA GEOS-CF model's skill of predicting CO_2 remains relatively similar when considering lead times of 1 to 4 days for Gulf and Mid-Atlantic regions.
- Given current analysis, emissions seem to contribute more to CO_2 modeling errors than transport.

Acknowledgments

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