



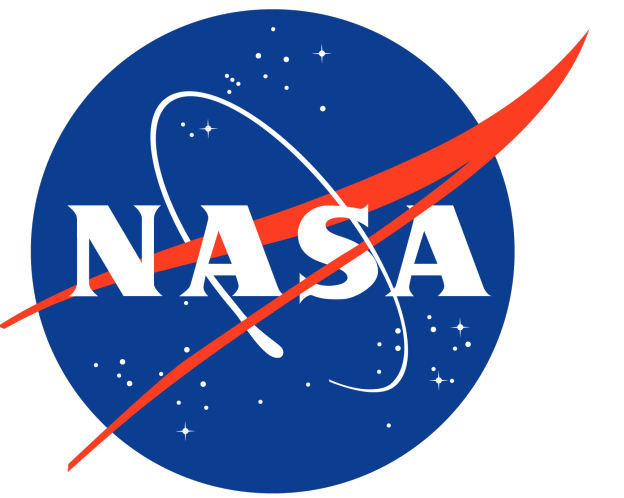
Model Evaluation and Intercomparison Using Data Collected by the Langley Mobile Ozone Lidar in Hampton, Virginia

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1 Introduction

Throughout the year 2022, the Langley Mobile Ozone Lidar (LMOL) has been frequently collecting ozone (O_3) measurements in the lower troposphere. The data was collected during a range of several distinct atmospheric conditions, including stratospheric intrusions, surface frontal passages, and long-range transported wildfire smoke plumes. We use this data to evaluate and intercompare the forecast accuracy of two atmospheric chemistry models: the GEOS Composition Forecasting model (GEOS-CF) and the Weather Research and Forecasting model with Chemistry (WRF-Chem). Both models make daily three-dimensional forecasts of many trace gases and species for the contiguous United States.

2 Langley Mobile Ozone Lidar (LMOL)

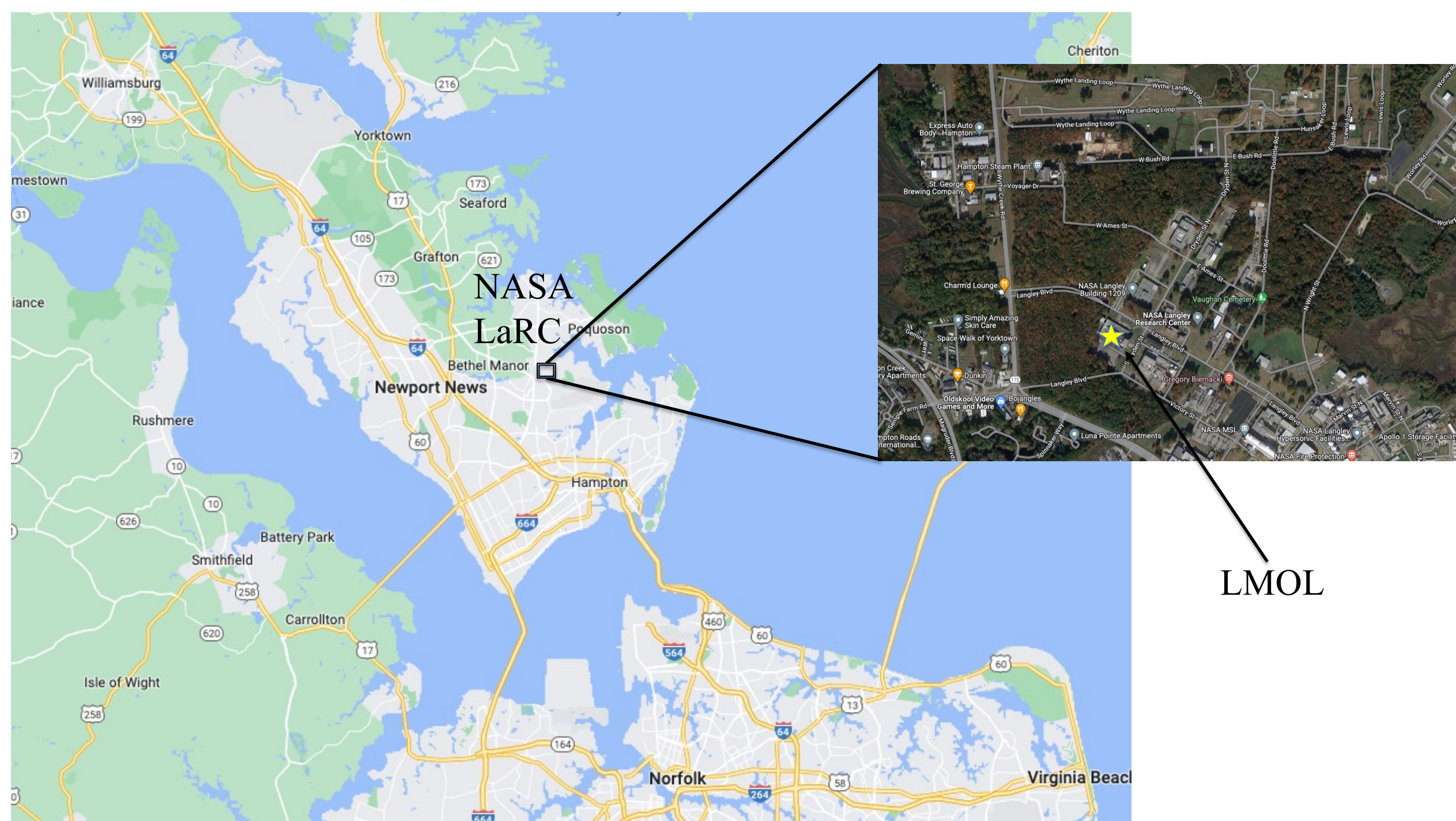
LMOL is a mobile ground-based O_3 differential absorption lidar (DIAL) system. The laser has a transmitter with a 1 kHz diode-pumped Q-switched Nd:YLF 527 nm laser to pump a Ce:LiCAF tunable UV laser for generating “on” and “off” wavelengths at 286 and 292 nm. A 40 cm diameter telescope is used to collect the backscatter signal for the far field, and a smaller-diameter wide-field off-axis parabolic mirror is used for the near-field return. LMOL is a part of the Tropospheric Ozone Lidar Network (TOLNet), a network of 7 operational ozone lidar systems across North America. Generally, O_3 vertical profiles range from 0.1-4 km during the daytime and up to 8 km above the surface at night with a 5-minute temporal resolution.



LMOL parked behind the Atmospheric Science building (B1250) at NASA Langley Research Center

2.1 LMOL Site Location

The lidar is located in the parking lot behind the Atmospheric Sciences building at NASA Langley Research Center in Hampton, Virginia, approximately 37.095 N, -76.389 W. The Hampton Steam Plant is located 600-m to the NNE of LMOL, which frequently emits SO_2 into the lower troposphere. The Newport News/Hampton peninsula is bordered by the James River to the west and south, and Chesapeake Bay to the east, creating a land-sea gradient which impacts local meteorology and atmospheric composition.



3 Forecast Models

GEOS-CF

- Global 5-day forecasts of atmospheric composition
- 25-km horizontal resolution, 72 hybrid eta levels
- Physics package comparable to MERRA-2
- GEOS-Chem chemistry
- Physics coupled to GOCART aerosols
- HTAP anthropogenic emissions

WRF-Chem

- Regional forecasts for the contiguous United States
- 12-km horizontal grid spacing, 11 model levels between 0-1 km
- Thompson MP, YSU PBL
- MOZART gas phase chemistry, GOCART aerosols
- GFS (meteorology) and WACCM (chem) IC and BC
- NEI 2014 anthropogenic emissions

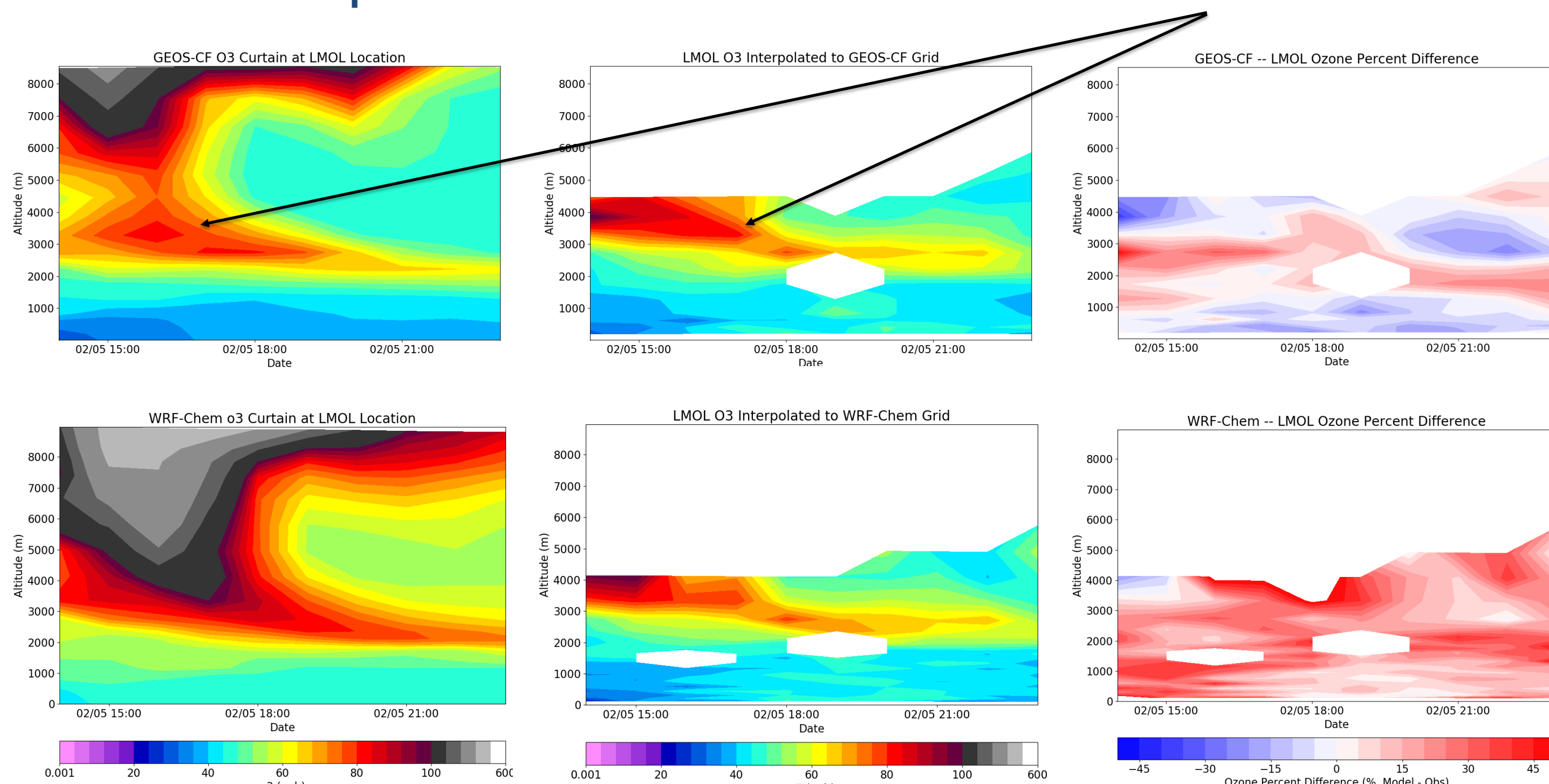
4 Model Forecast Evaluation at LMOL Location

LMOL has been collecting data over the past 12 months and has observed several different types of atmospheric events:

1. Stratospheric intrusions
2. Clear/calm days
3. Surface fronts
4. Long-range smoke transport

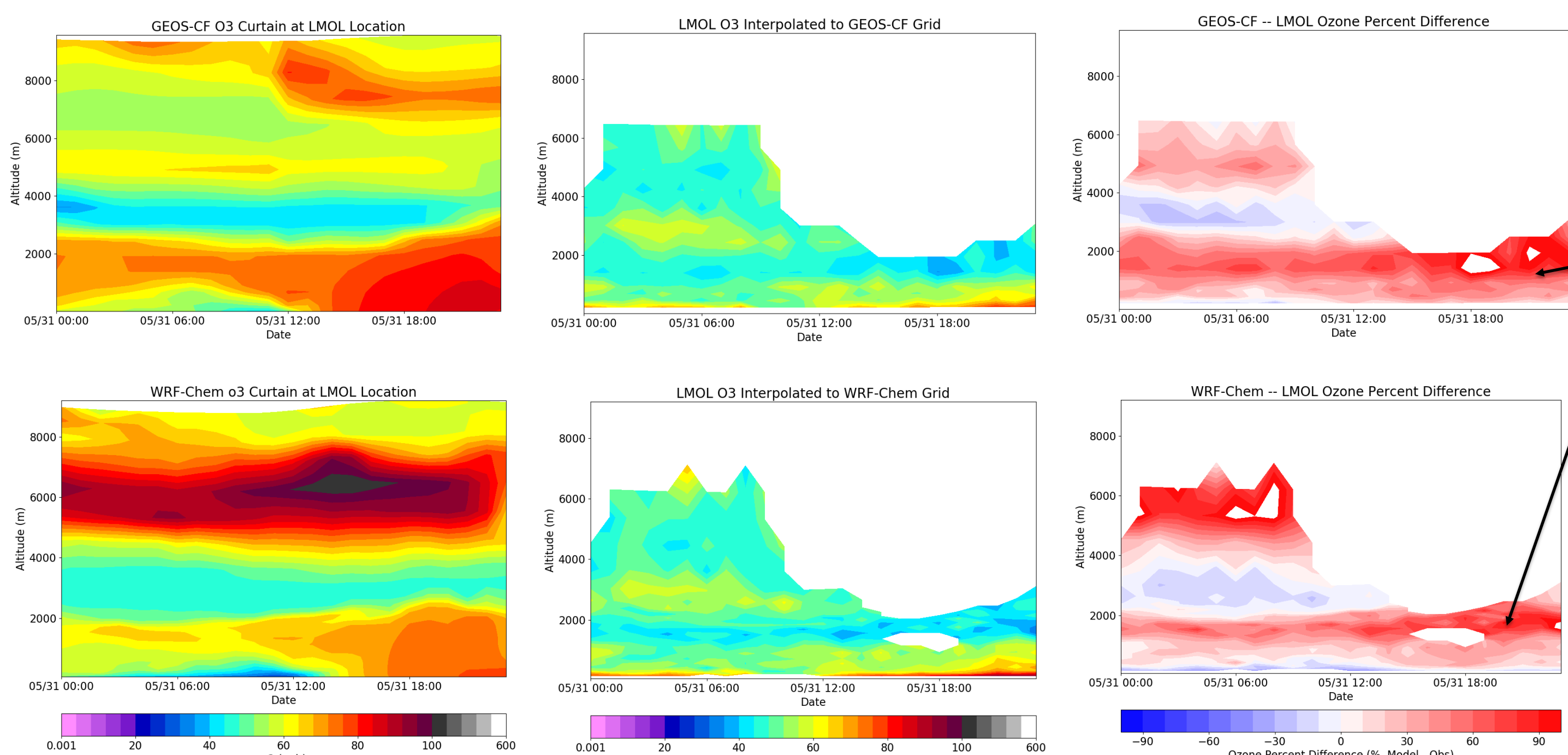
We utilize this data to evaluate the performance of the two air quality forecast models. To do so, the LMOL profiles are mapped onto the models' vertical grids and then we calculate the percent difference in the ozone profiles.

4.1 Stratospheric Intrusions



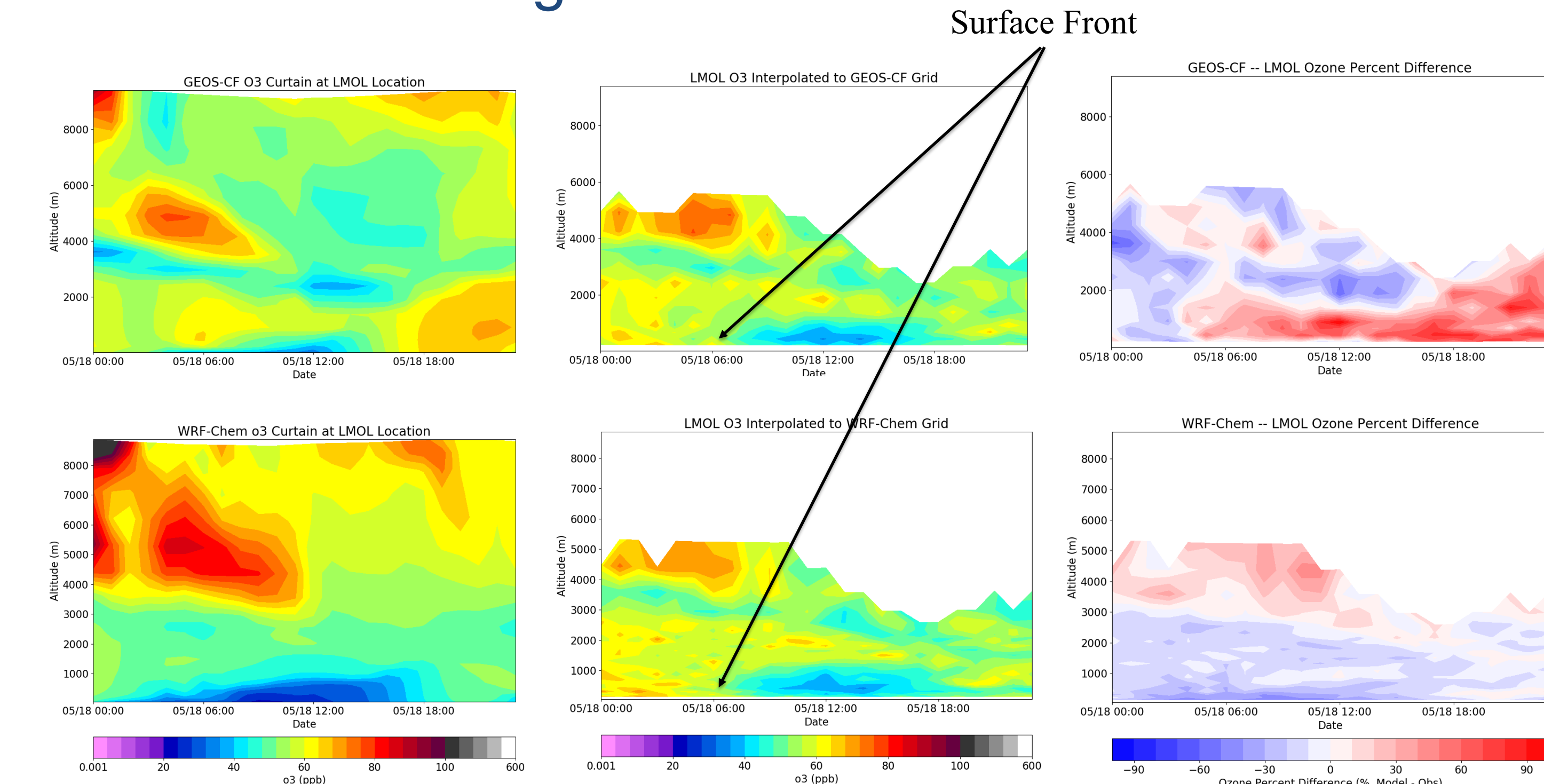
- Stratospheric Intrusions (SI) of O_3 -rich air can potentially elevate surface O_3 mixing ratios if sufficient downward transport is present.
- O_3 in SI is well represented in models, though there are slight differences in timing and extent of transport, as well as the magnitude of the O_3 mixing ratio in the SI feature.
- The LMOL measurements also demonstrate the lidar's capability in measuring SI events.

4.2 Clear/Calm Days



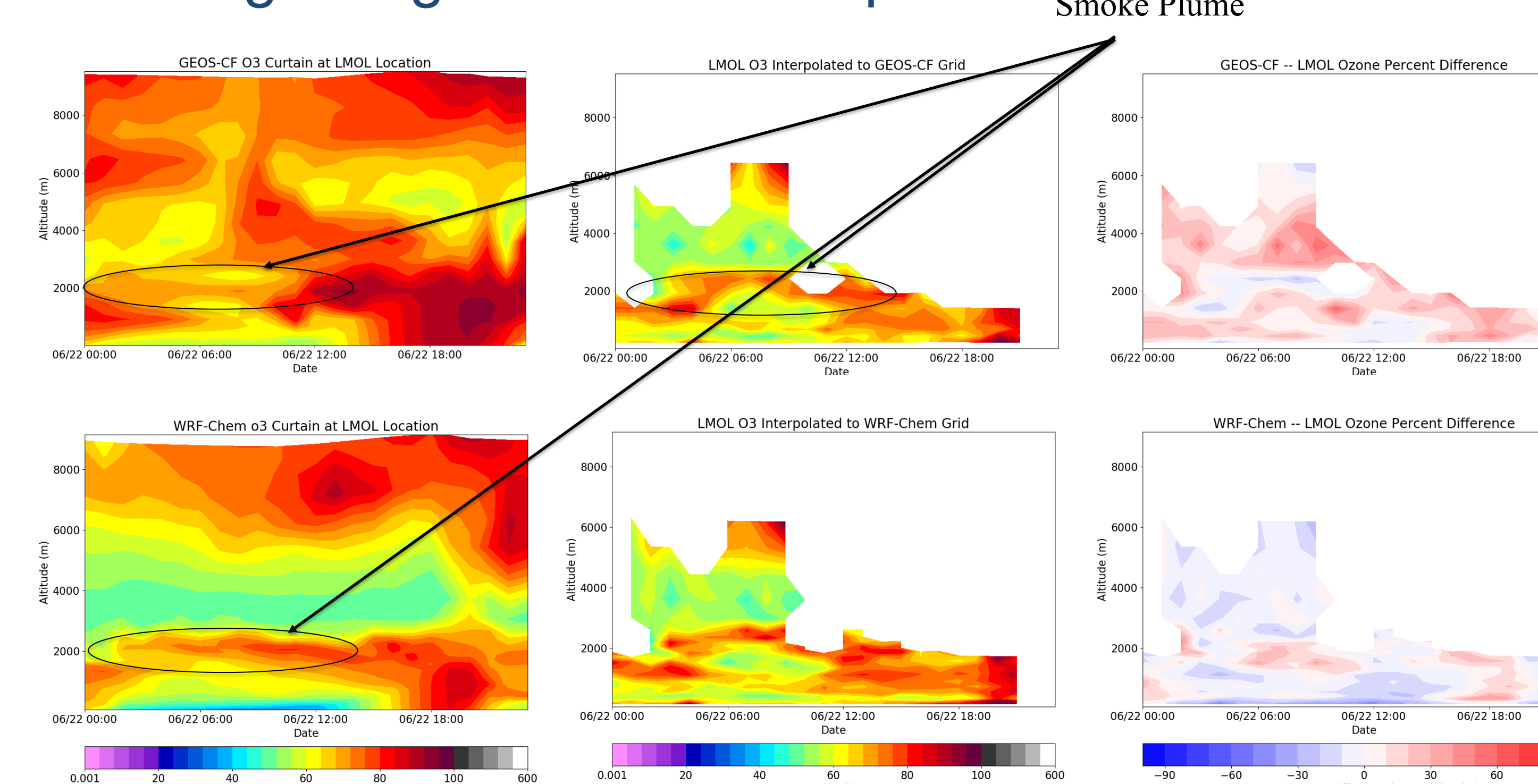
- Boundary layer O_3 is generally overpredicted by both models, potentially due to too much lofting of near-surface O_3 .
- LMOL measurements also show high near-surface O_3 that is not always predicted by the forecast models (e.g., 00-06 UTC).

4.2 Frontal Passages



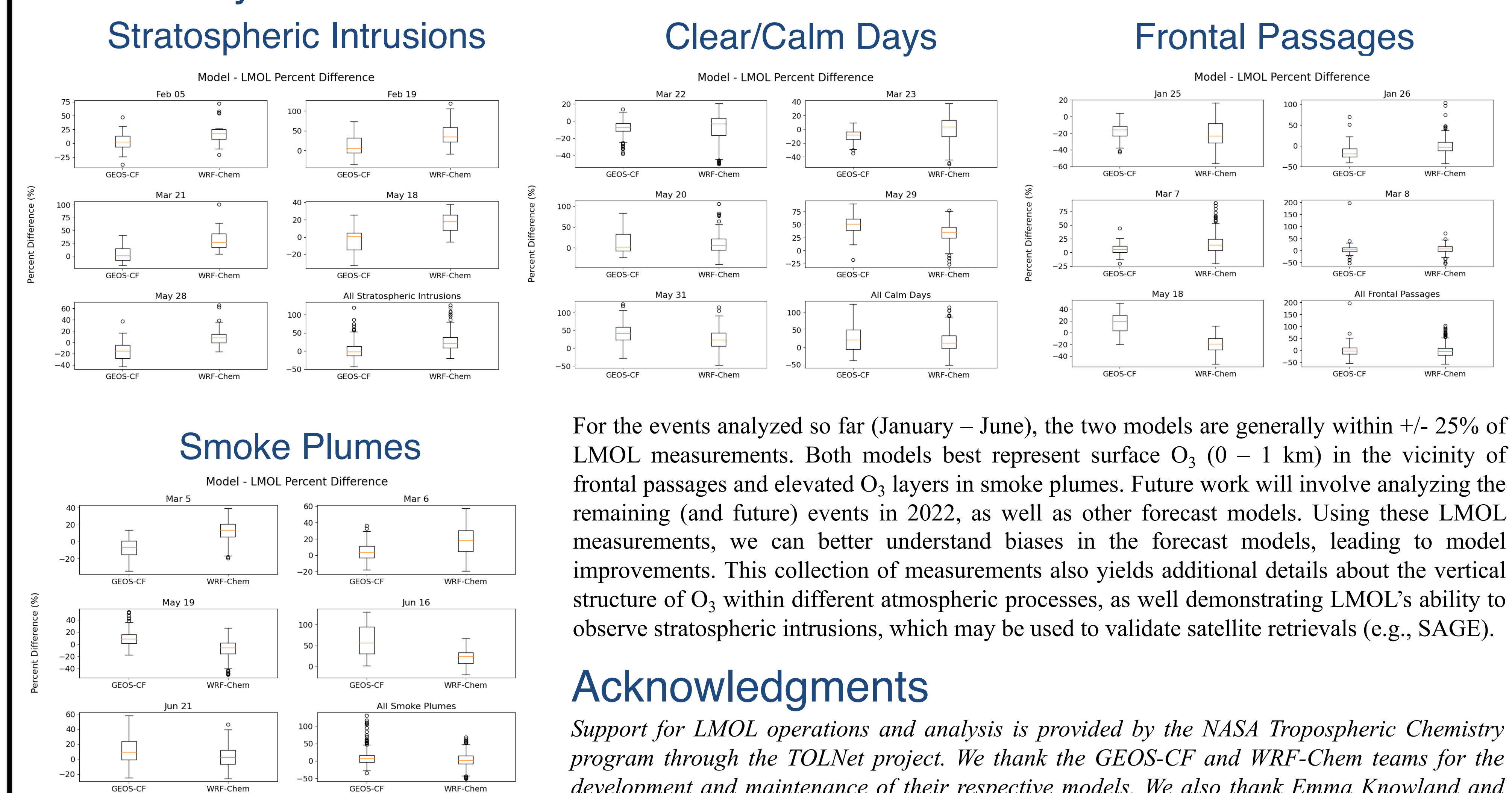
- The difference in the timing of the frontal passage and its associated effect on near-surface trace gas composition is within ~1-2 hours in the models, compared to LMOL.
- In general, WRF-Chem O_3 is lower than the measured O_3 following the passage of the cold front; GEOS-CF tends to overpredict surface O_3 .

4.3 Long Range Smoke Transport



- Both models forecast the timing of the smoke plume with reasonable accuracy but slightly overestimate both the O_3 mixing ratio in the smoke plume as well as the height of the smoke plume.
- LMOL curtains also provide additional details in the vertical structure of the smoke plumes that are not captured by the models.

5 Summary of Events



For the events analyzed so far (January – June), the two models are generally within +/- 25% of LMOL measurements. Both models best represent surface O_3 (0 – 1 km) in the vicinity of frontal passages and elevated O_3 layers in smoke plumes. Future work will involve analyzing the remaining (and future) events in 2022, as well as other forecast models. Using these LMOL measurements, we can better understand biases in the forecast models, leading to model improvements. This collection of measurements also yields additional details about the vertical structure of O_3 within different atmospheric processes, as well demonstrating LMOL's ability to observe stratospheric intrusions, which may be used to validate satellite retrievals (e.g., SAGE).

Acknowledgments

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