

Analysis of a Mid-Atlantic Ozone

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Mentor: Dr. John Sullivan

PHYS 650: Atmospheric Measurement, 05/25/2022



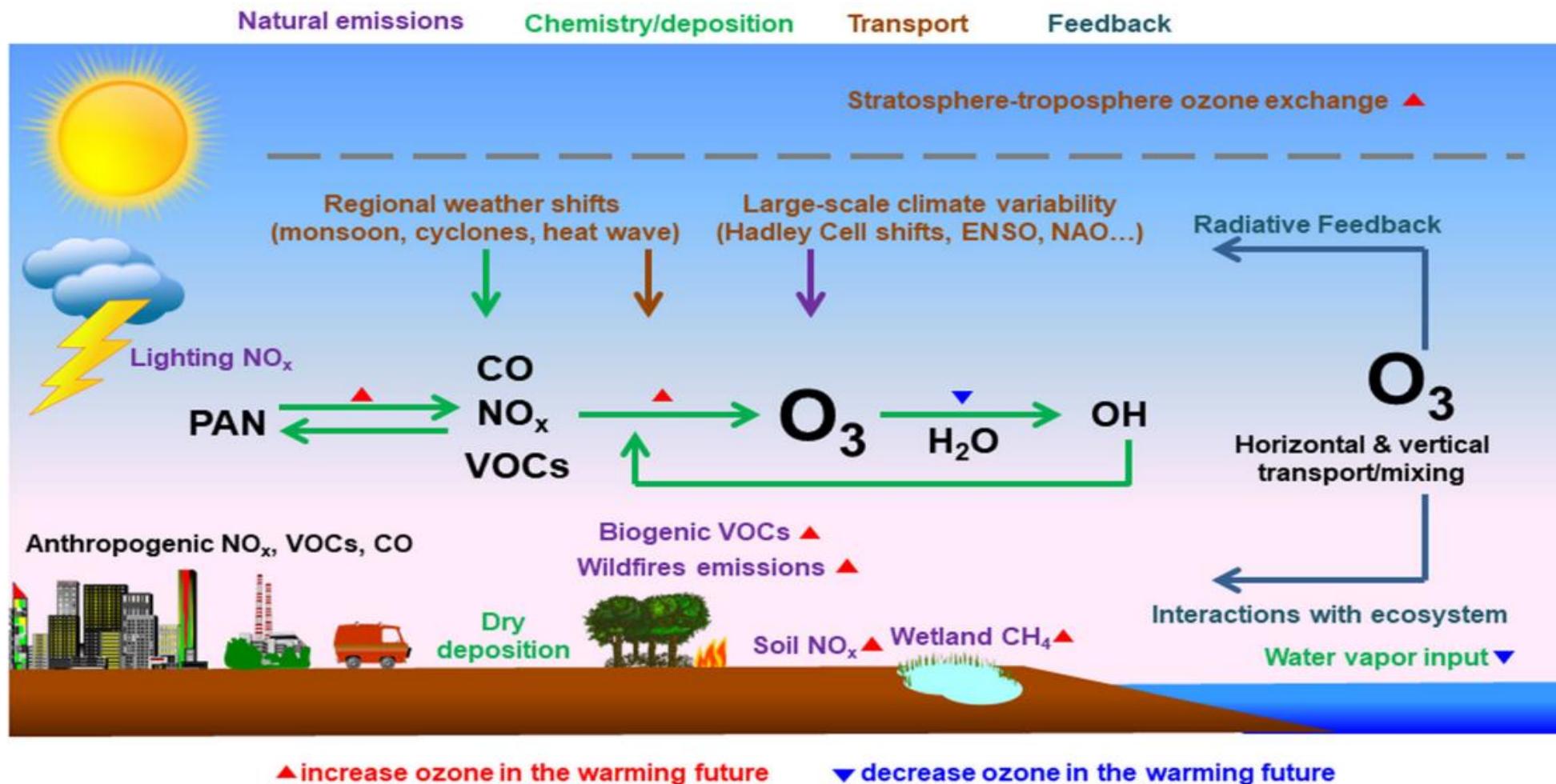
NCAS-M

NOAA COOPERATIVE SCIENCE
CENTER IN ATMOSPHERIC
SCIENCES AND METEOROLOGY



Goddard
SPACE FLIGHT CENTER

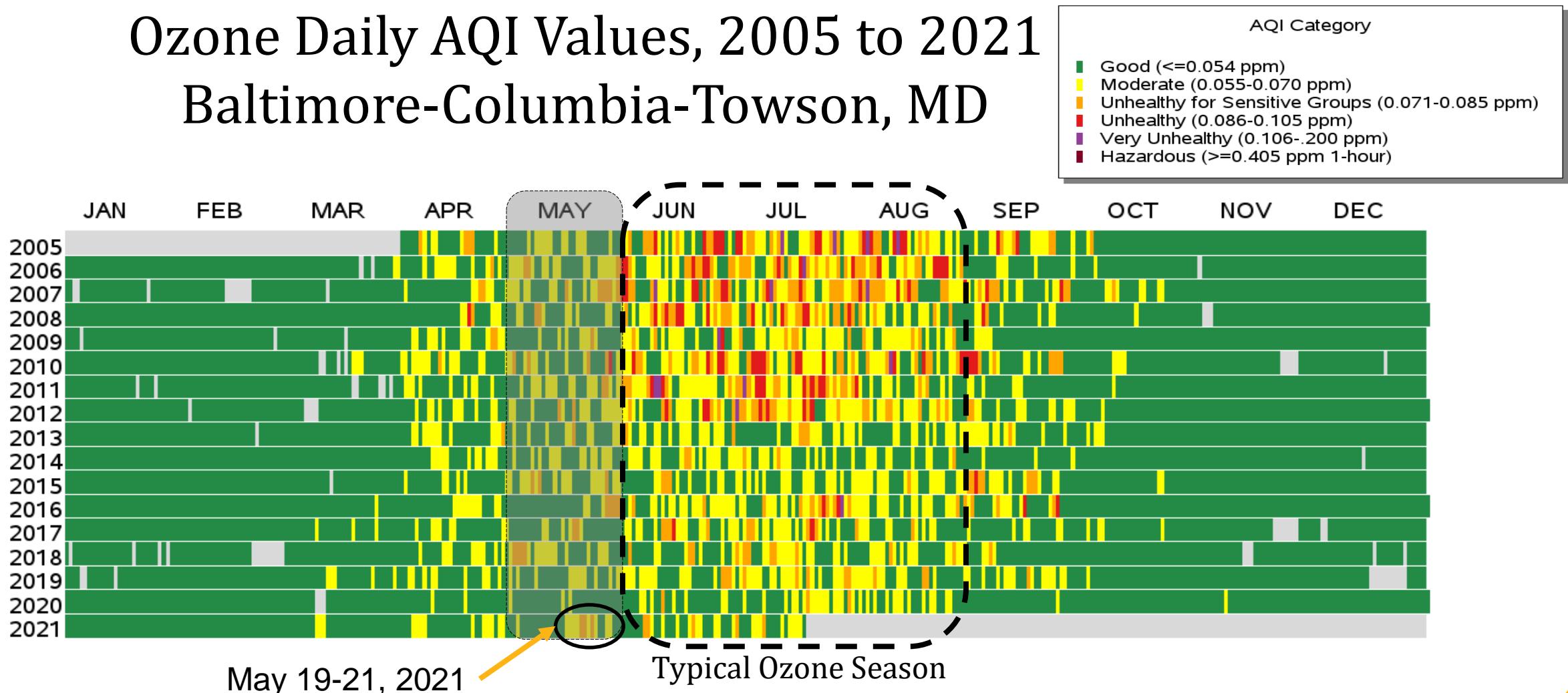
What is Ozone?

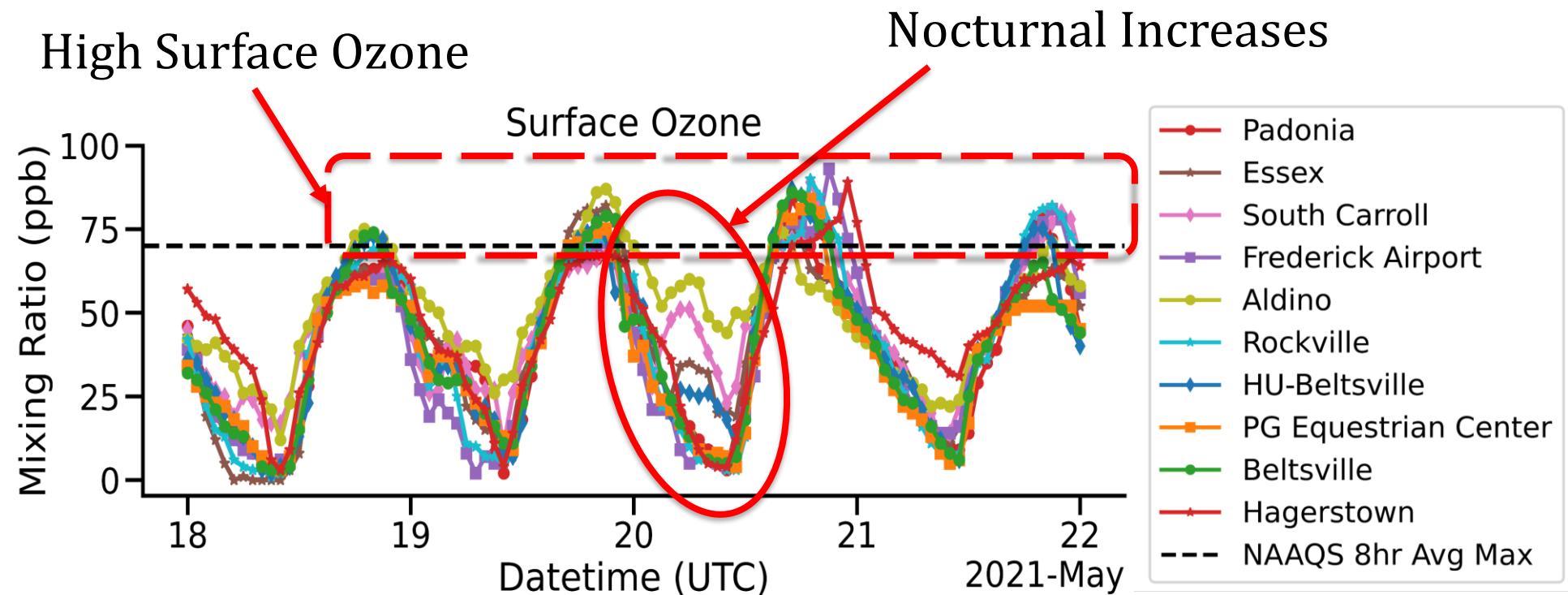


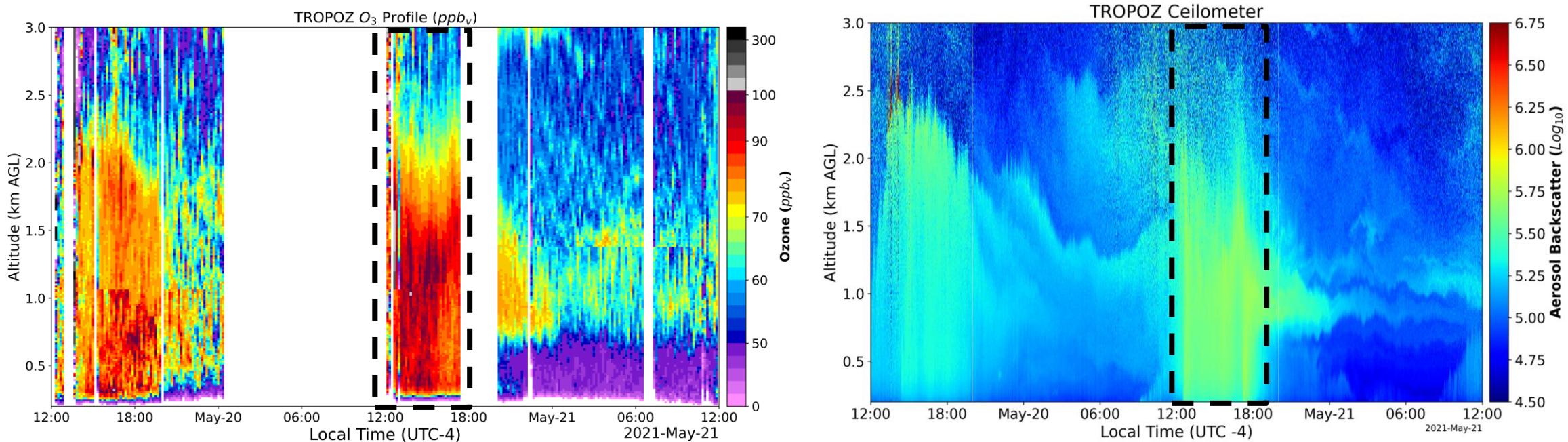
Lu et al., 2019

Ozone Daily AQI Values, 2005 to 2021

Baltimore-Columbia-Towson, MD







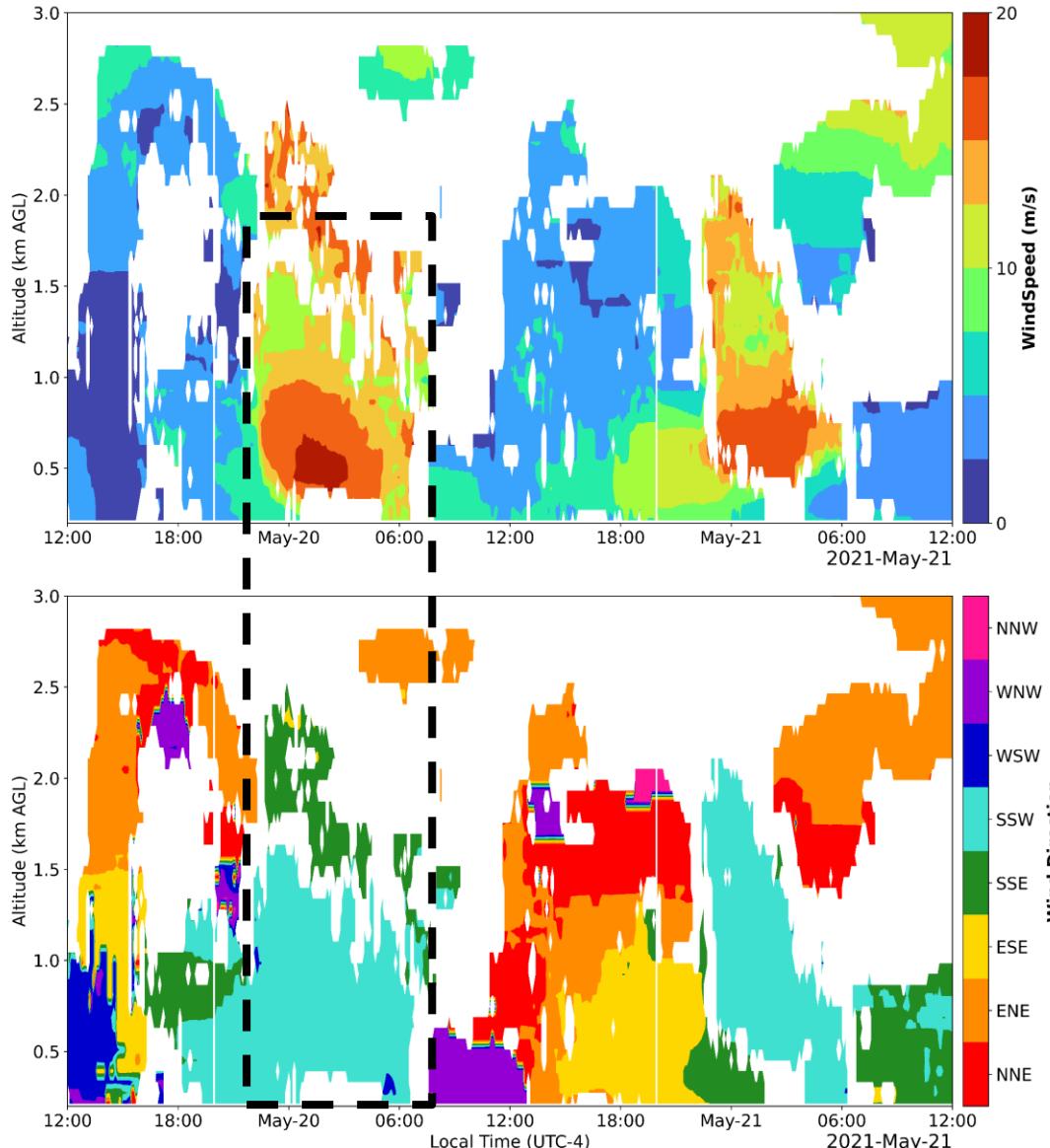
- Well-mixed polluted PBL seen from TROPOZ, Ceilometer, Sonde and surface
- Arrival of polluted air-mass marked by wind profile with
- Sonde observes over 10 m/s wind speeds at 02 LT (06 UTC) on 20th
- Wind, ceilometer, and ozone profiles indicate an air mass change occurring near 14 LT in the Beltsville, MD area marking the arrival well-mixed from the northeast.



The GSFC TROPOZ DIAL deployed at Ft. Collins, CO for the 2014 DISCOVER-AQ campaign. [Source: [TOLNet - Tropospheric Ozone Lidar Network \(nasa.gov\)](#). Photo Credit: L. Twigg.]

Wind Profile

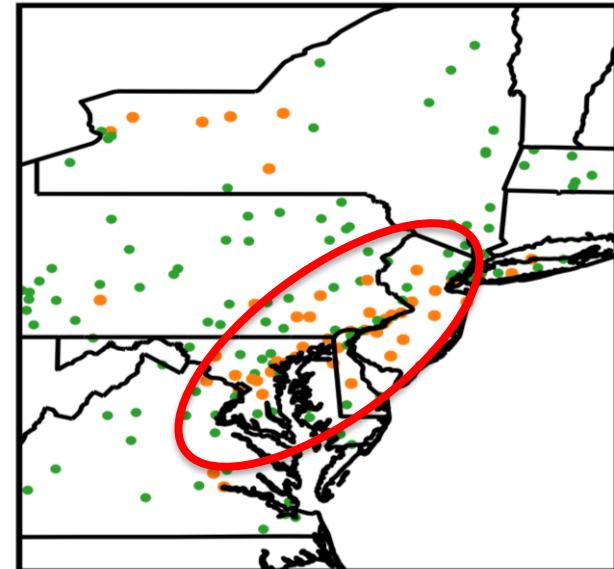
Radar Wind Profiler (Beltsville, MD)



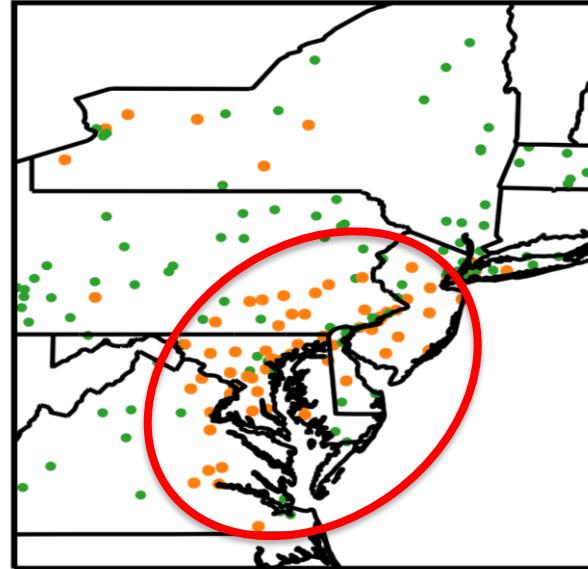
- HU-Beltsville RWP shows wind direction and magnitude change at time of polluted air-mass and cleaning it out.
- NLLJ at 0 - 6 LT on the 20th which preceding DSW and clean-out leading to next-day entrainment and transport



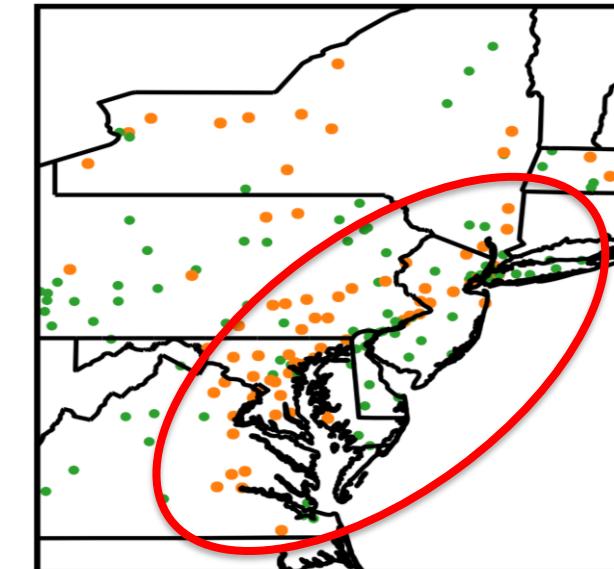
2021-05-18 : 2021-05-19



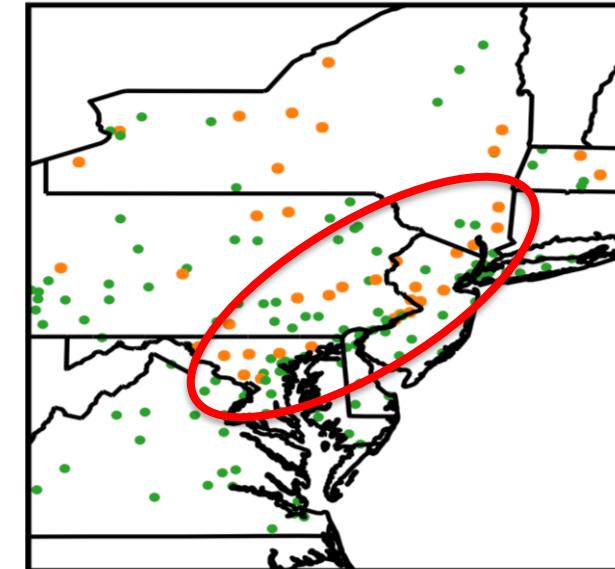
2021-05-19 : 2021-05-20



2021-05-20 : 2021-05-21

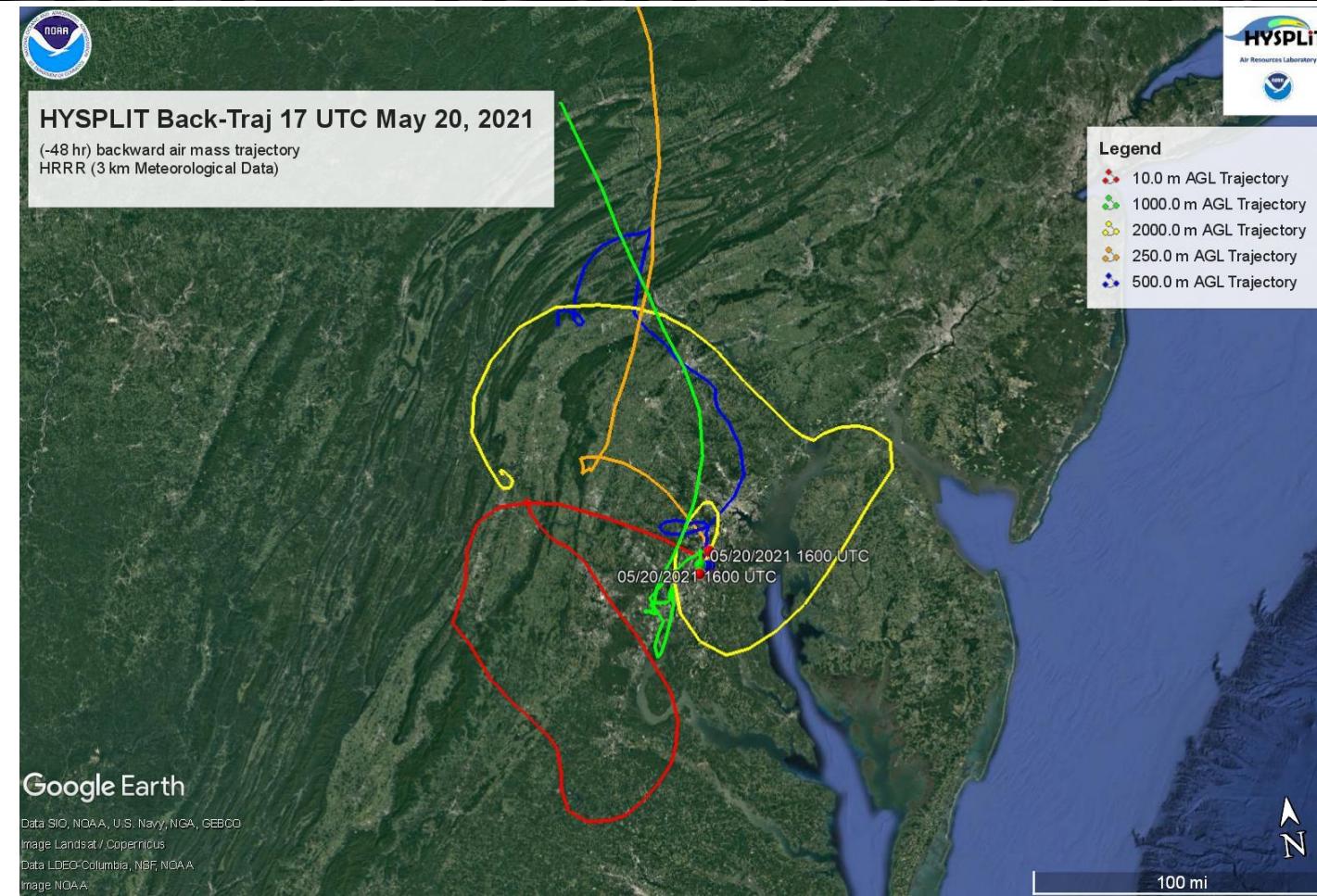
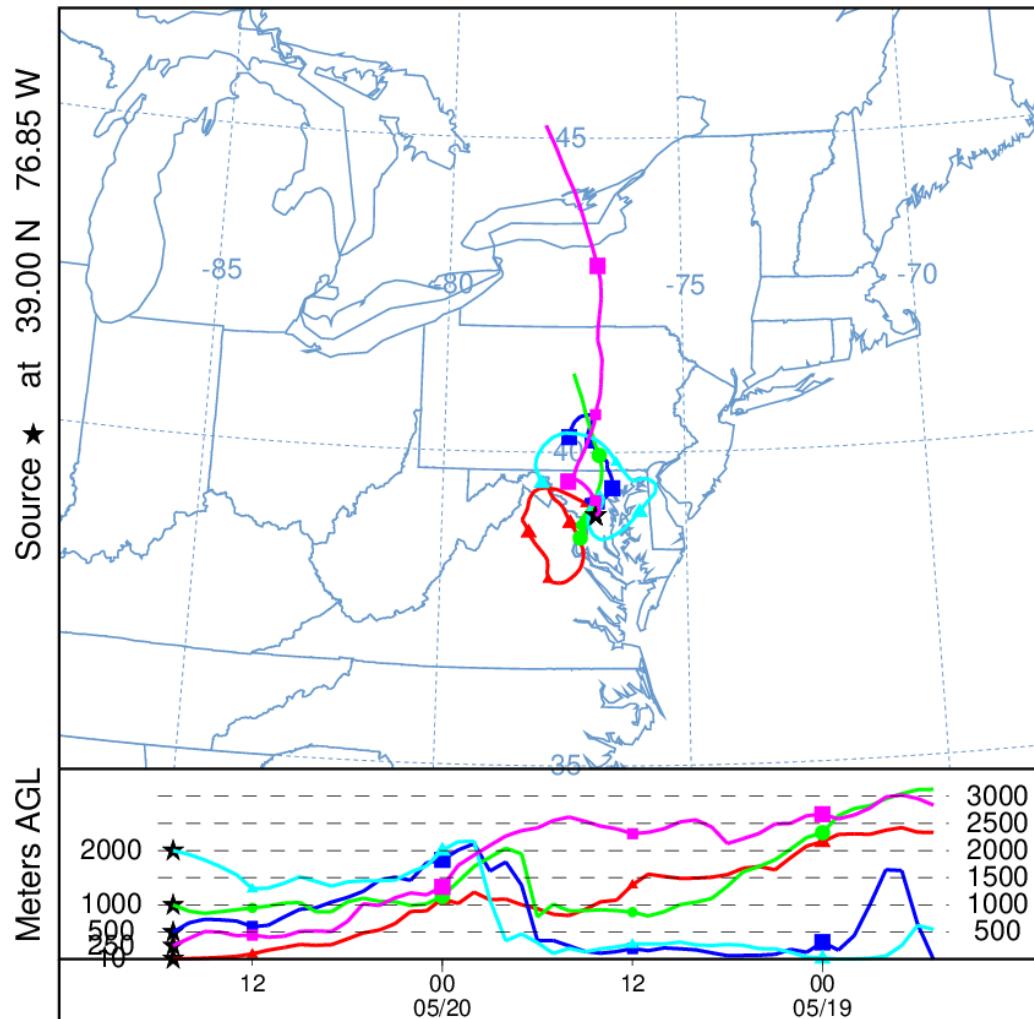


2021-05-21 : 2021-05-22



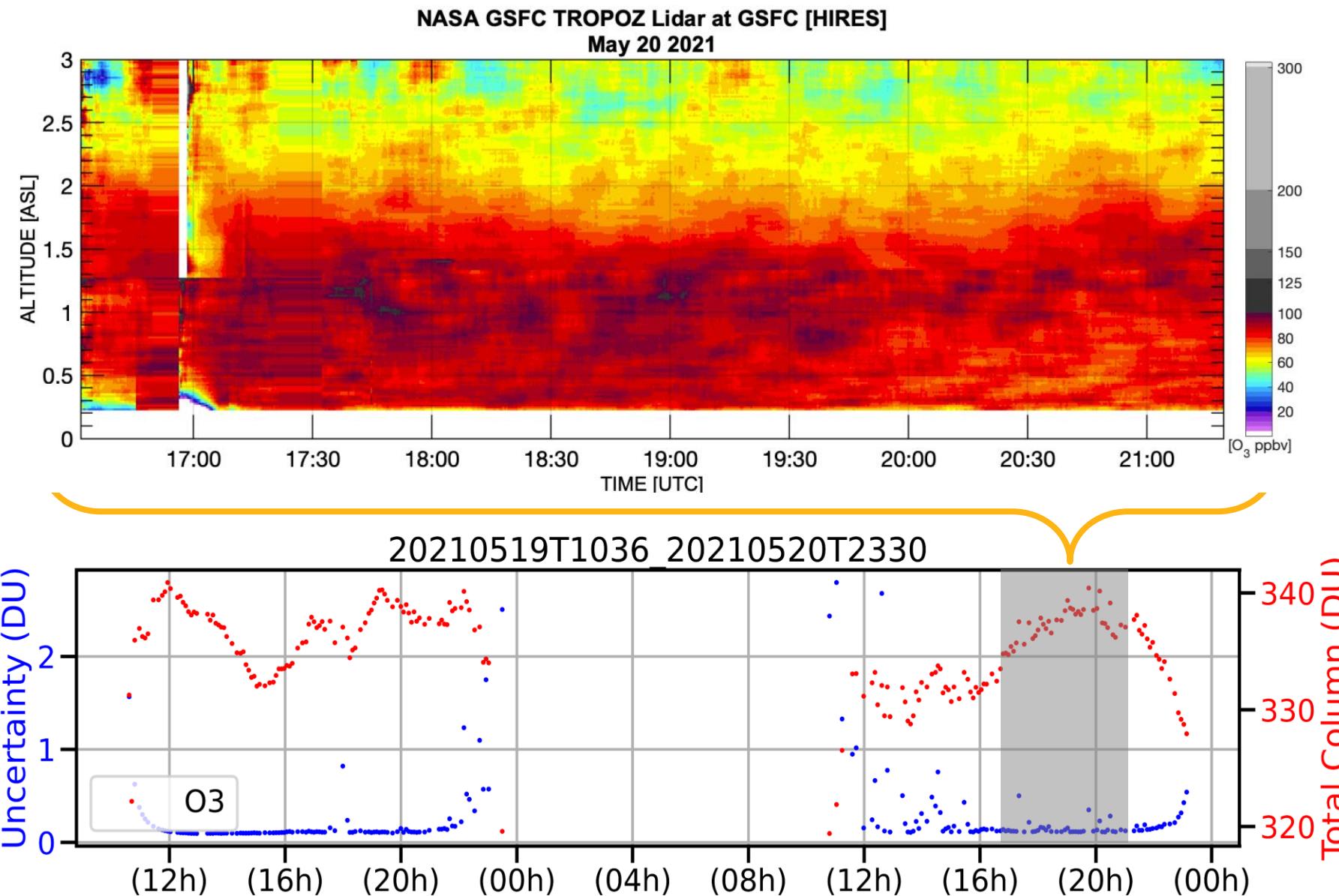
Orange circles are sites with >70 ppb surface ozone at **least once** in the time period. Green circles are <70ppb during the time period.

NOAA HYSPLIT MODEL
Backward trajectories ending at 1700 UTC 20 May 21
HRRR Meteorological Data



- Hybrid Sing Particle Lagranian Transport Model
 - Shows the air mass transport forwards or backwards

Pandora with Ozone Lidar

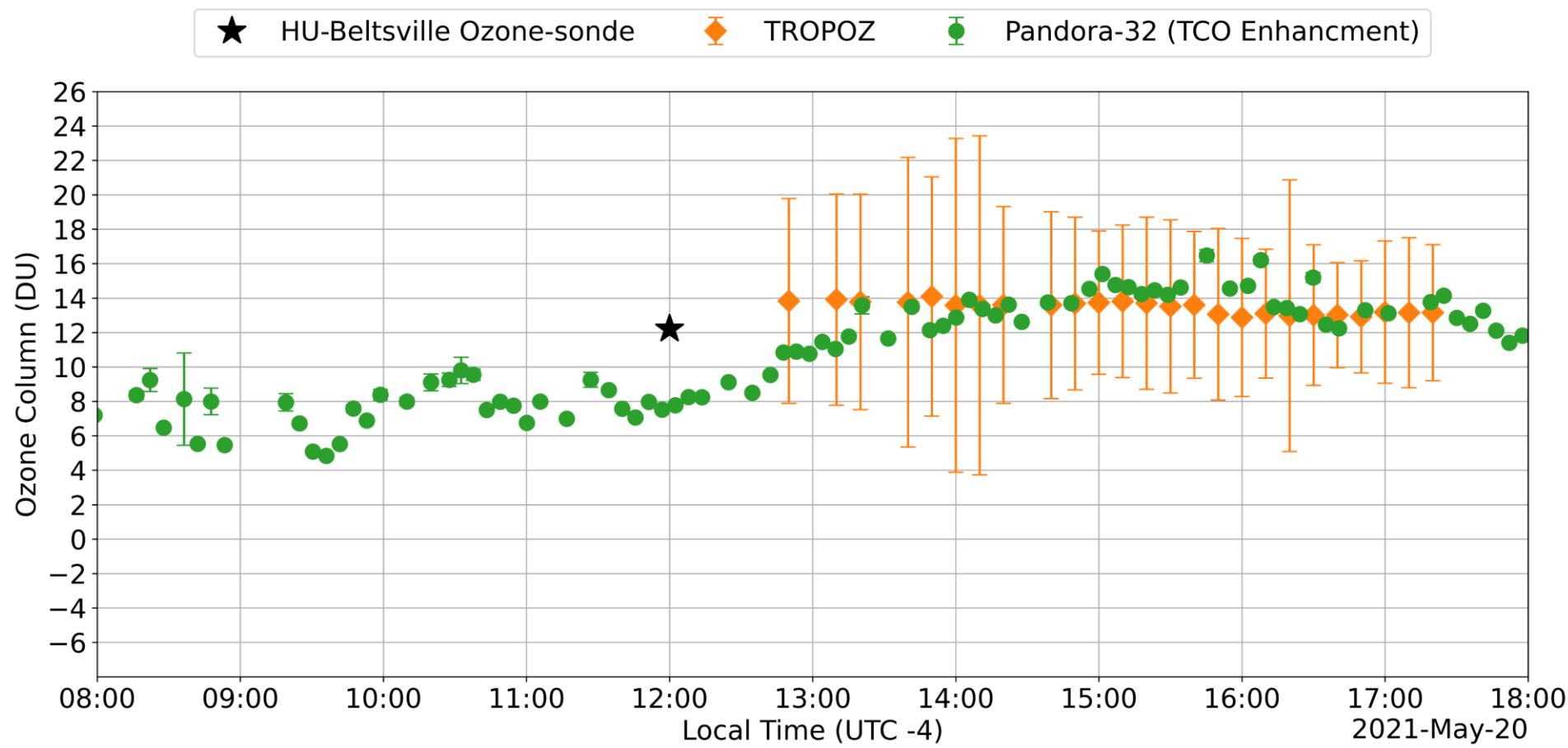


TCO₃ increase known in
Pandora ~7 DU with Ozone
lidar 0-2km ~14DU.

No known case study
relating the Pandora (NASA
Ground Based Dataset)
TCO₃ with O3 Lidar



Near Co-location 0 - 2 km Column Ozone



Ozone episode May is out of the norm for this location. The episode evolved from entrainment of a transported polluted air-mass then recirculation in the mid-atlantic on May 19 & 20, 2021 followed by quick lofting by DSW (as shown by ceilometer and wind) resulting in next-day entrainment.

- High resolution observations from active and passive remote sensors captured the evolution of the ozone episode.
- Pandora agrees with 0-2 km TROPOZ profile (TEMPO Ozone product)
 - This shows a potential for further usage in AQ event characterization
- The evolution of the PBL height from May 19 - 21 shows a clear relation to the 3-Stage Diurnal Boundary Model model^[3].
 - Increased surface ozone as result of local transport by dynamics
 - Decreasing height of the PBL each day -> Evidence of sinking layers
- This work also serves to demonstrate the usefulness of multi-instrument perspectives in air quality event analysis and study of spatio-temporal variability.

- Spatial Distribution:

- Forward dispersion modelling from GSFC at time of polluted air-mass
- Comparison of Surface, Sonde, and Pandora throughout the Mid-Atlantic

- Aerosol Analysis:

- Analysis of speciated surface PM and AERONET retrieval
- MAIAC aerosol comparison ground-based observations

- Model Comparisons:

- NASA GEOS-CF and GSFC near-collocation Observations

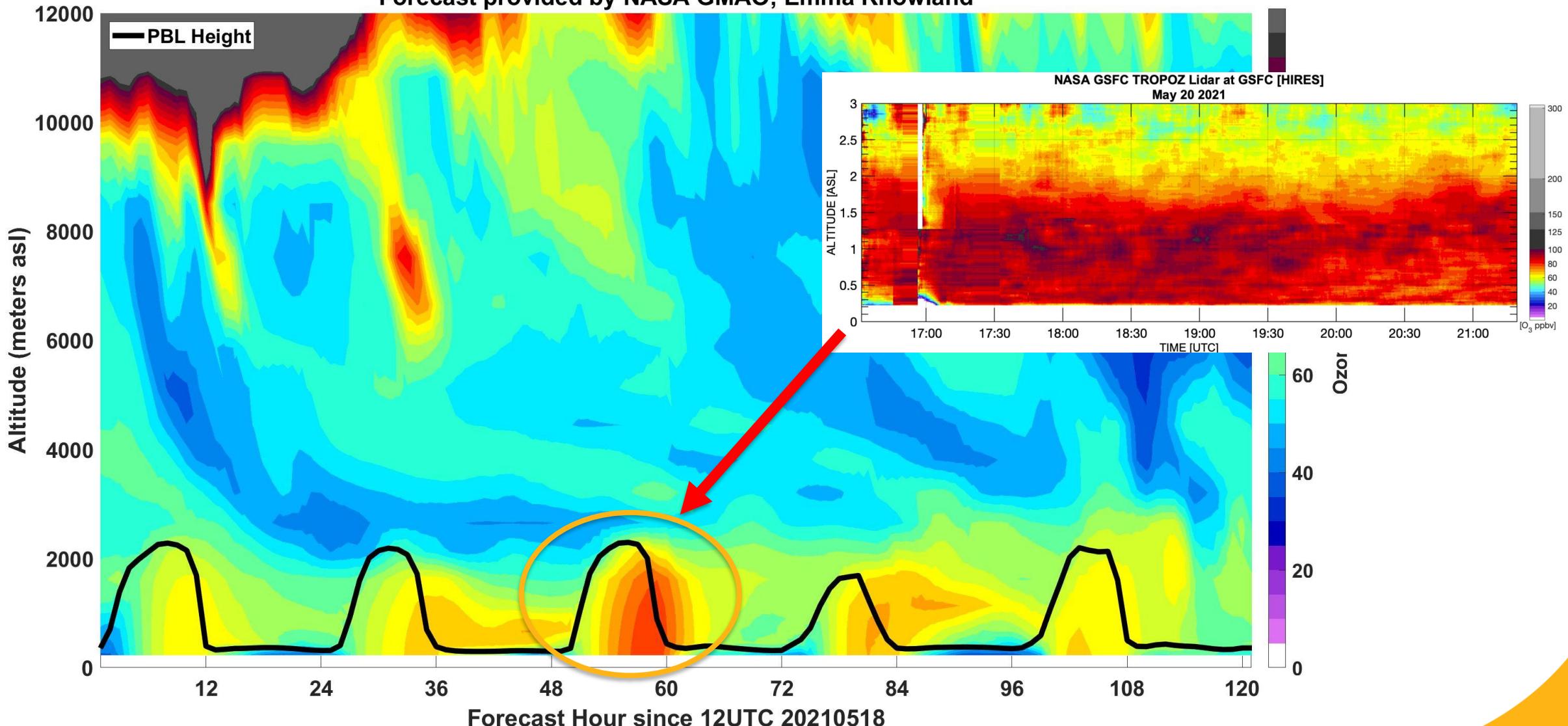
This material is based upon work supported by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Educational Partnership Program, under Agreement No. #NA16SEC4810006. The authors would like to thank Howard University National Center for Atmospheric Science and Meteorology (NCAS-M) program and NOAA Office of Education, Educational Partnership Program (NOAA EPP) for fellowship supporting Mr. Maurice Roots. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration. The authors would also like to thank that GEM consortium and NASA GSFC for funding this project and coordinating this collaboration.

1. Dreessen, J., Sullivan, J., and Delgado, R.: Observations and impacts of transported Canadian wildfire smoke on ozone and aerosol air quality in the Maryland region on June 9–12, 2015, Journal of the Air & Waste Management Association, 66, 842–862, <https://doi.org/10.1080/10962247.2016.1161674>, 2016.
2. Moghani, M., Archer, C. L., and Mirzakhalili, A.: The importance of transport to ozone pollution in the U.S. Mid-Atlantic, Atmospheric Environment, 191, 420–431, <https://doi.org/10.1016/j.atmosenv.2018.08.005>, 2018.
3. Rabenhorst, S., Whiteman, D. N., Zhang, D.-L., and Demoz, B.: A Case Study of Mid-Atlantic Nocturnal Boundary Layer Events during WAVES 2006, 53, 2627–2648, <https://doi.org/10.1175/JAMC-D-13-0350.1>, 2014.
4. Sullivan, J. T., McGee, T. J., Sumnicht, G. K., Twigg, L. W., and Hoff, R. M.: A mobile differential absorption lidar to measure sub-hourly fluctuation of tropospheric ozone profiles in the Baltimore–Washington, D.C. region, Atmos. Meas. Tech., 7, 3529–3548, <https://doi.org/10.5194/amt-7-3529-2014>, 2014.
5. Sullivan, J. T., Rabenhorst, S. D., Dreessen, J., McGee, T. J., Delgado, R., Twigg, L., and Sumnicht, G.: Lidar observations revealing transport of O₃ in the presence of a nocturnal low-level jet: Regional implications for “next-day” pollution, Atmospheric Environment, 158, 160–171, <https://doi.org/10.1016/j.atmosenv.2017.03.039>, 2017.
6. Tzortziou, M., Herman, J. R., Cede, A., and Abuhassan, N.: High precision, absolute total column ozone measurements from the Pandora spectrometer system: Comparisons with data from a Brewer double monochromator and Aura OMI: Pandora Total Column Ozone Retrieval, J. Geophys. Res., 117, <https://doi.org/10.1029/2012JD017814>, 2012.

Supplemental Slides

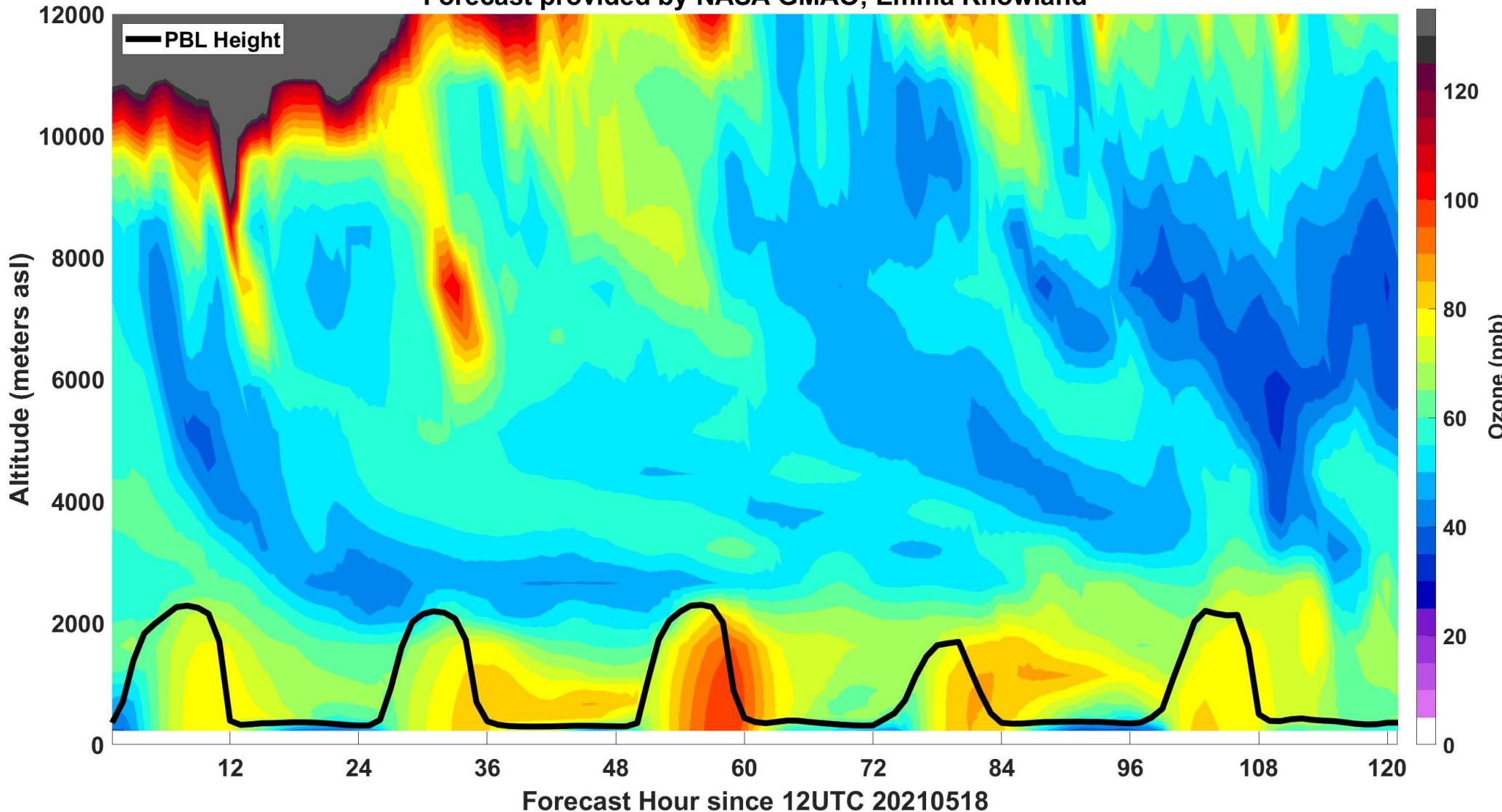
GEOS-CF Ozone (ppb) - TROPOZ - initialized 12UTC 20210518

Forecast provided by NASA GMAO; Emma Knowland



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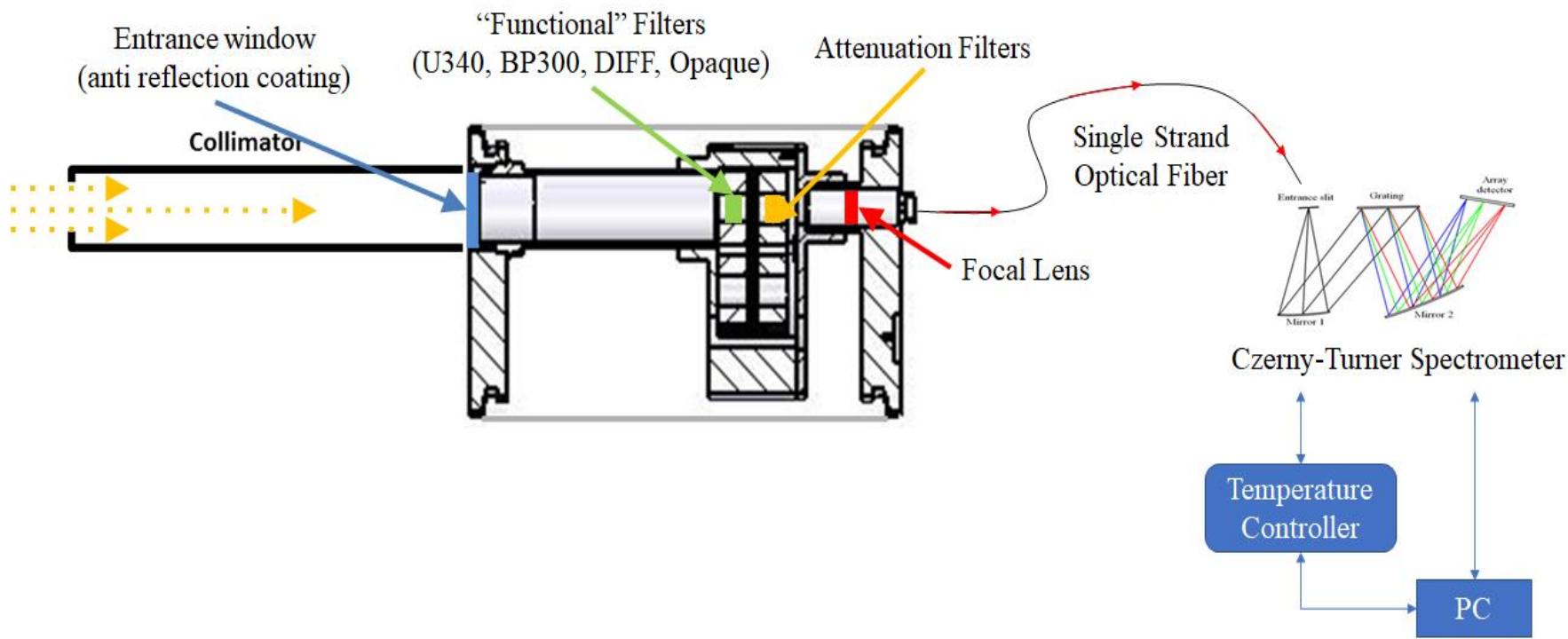


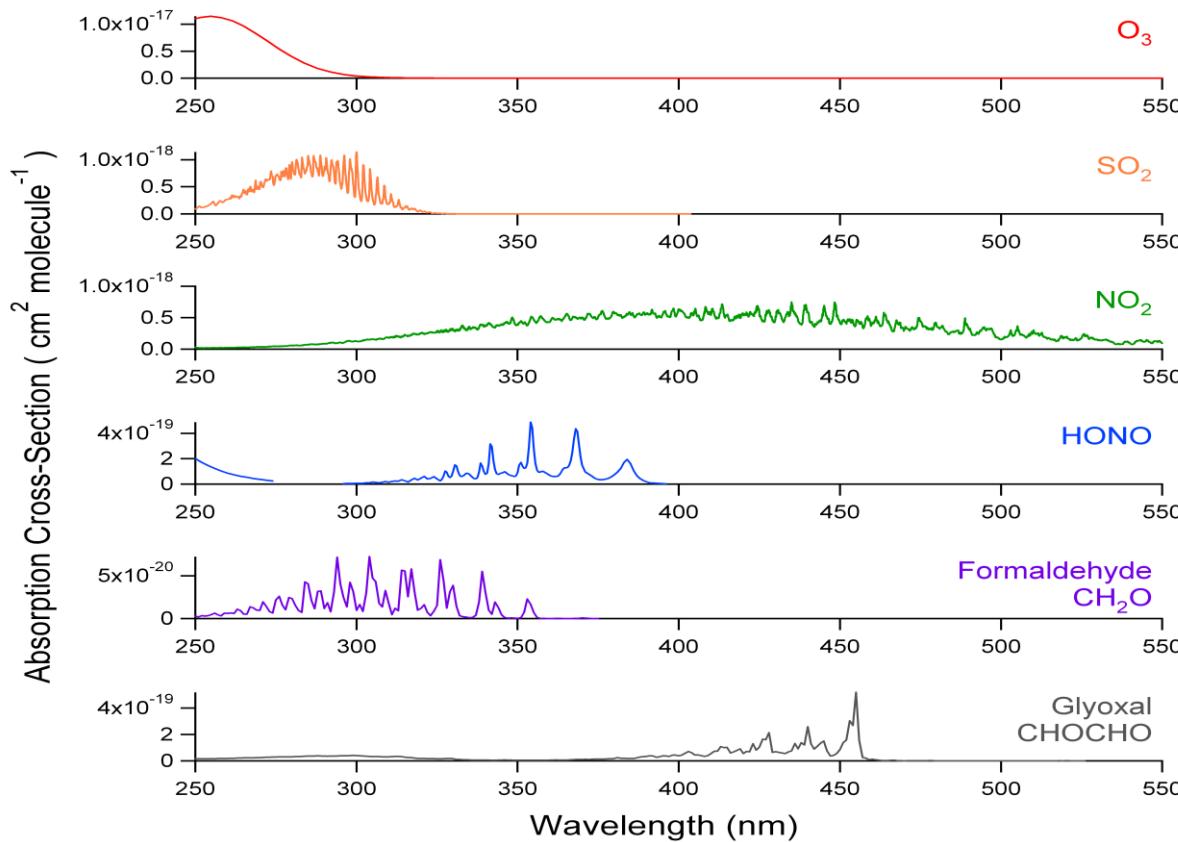
Figure 6: (a) Schematic view of Pandora version two (V2) and three (V3) sensor head configuration. (b) The Pandora-1S V3, equipped with; AvaSpec-ULS CCD spectrometer (Czerny-Turner optical design) with 2048 x 64 effective pixels, SciGlob-NASA tracker with 0.01° steps, and Cincoze DC-1100 R10 computer. Source NASA Pandora project.

Total Column Concentrations | Vertical Profiles in PBL | Tropospheric & Stratospheric Column | Near Surface Concentrations

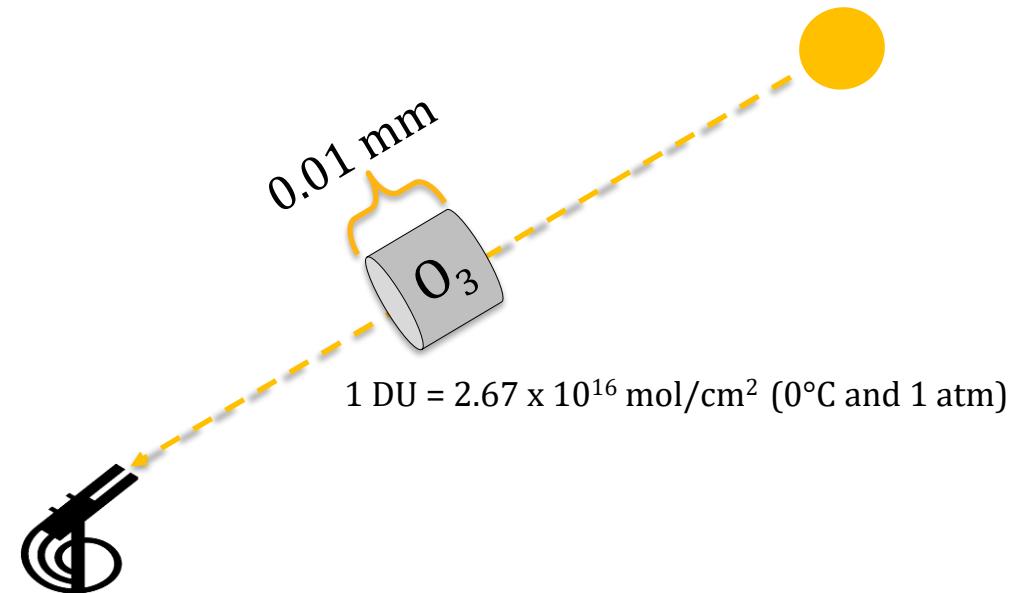
Direct Sun Differential Optical Absorption Spectroscopy (DS-DOAS)

Multiple attenuators in columnar of incoming solar radiation.

Full spectrum fit with all known absorption cross-sections.



Pandora's default is Dobson Units (DU)



Average 300 DU of Ozone = 300×0.01 mm thick

| Total Column | NO ₂ | O ₃ |
|----------------|-----------------|----------------|
| Precision (DU) | 0.002 | 0.6 |
| Accuracy (DU) | 0.05 | 15 |

Research Quality
SO₂, HCHO, BrO, H₂O

$$I(\lambda) = I_0(\lambda) \exp \left\{ -L \left(\sum_{j=1}^J \sigma_j(\lambda) C_j + \sigma_M(\lambda) C_M + \sigma_R(\lambda) C_R \right) \right\},$$

j - Species | M - Mie | R - Rayleigh

$$\sigma_j(\lambda) = \sigma_{j0}(\lambda) + \sigma'_j(\lambda),$$

$$\tau(\lambda) = \ln \left(\frac{I_0(\lambda)}{I(\lambda)} \right) = \left\{ L \left(\sum_{j=1}^J \sigma_j(\lambda) C_j + \sigma_M(\lambda) C_M + \sigma_R(\lambda) C_R \right) \right\}.$$

$$I(\lambda) = I_0(\lambda) \exp \left\{ -L \sum_{j=1}^J \sigma'_j(\lambda) C_j + \sum_p b_p \lambda^p \right\},$$

$$\ln(I(\lambda)/I_0(\lambda)) = -L \sum_{j=1}^J \sigma'_j(\lambda) C_j + \sum_p b_p \lambda^p.$$

$$S_k = \ln(I(\lambda_k)/I_0(\lambda_k)) = -L \sum_{j=1}^J \sigma'_j(\lambda_k) C_j + \sum_p b_p \lambda_k^p, \quad k = 1, n.$$

Planned Activities

Summer 2021: June-September IOP

→ **DOE Tracking Aerosol Convection interactions ExpeRiment**

*comprehensive in situ and remote sensing observations
of clouds, aerosols, precipitation, radiation and
meteorology*

TRACER-AQ: September 2021

→ Coordinated Ground Instruments

- ▶ 3 TOLNet O₃ lidars
- ▶ 8 Pandora Spectrometers (O₃, NO₂, HCHO)
- ▶ Routine regulatory monitoring measurements
- ▶ 70 ozonesondes
- ▶ Boat measurements
- ▶ Mobile labs both supported by TRACER mission (July-August) and another pending NSF Support

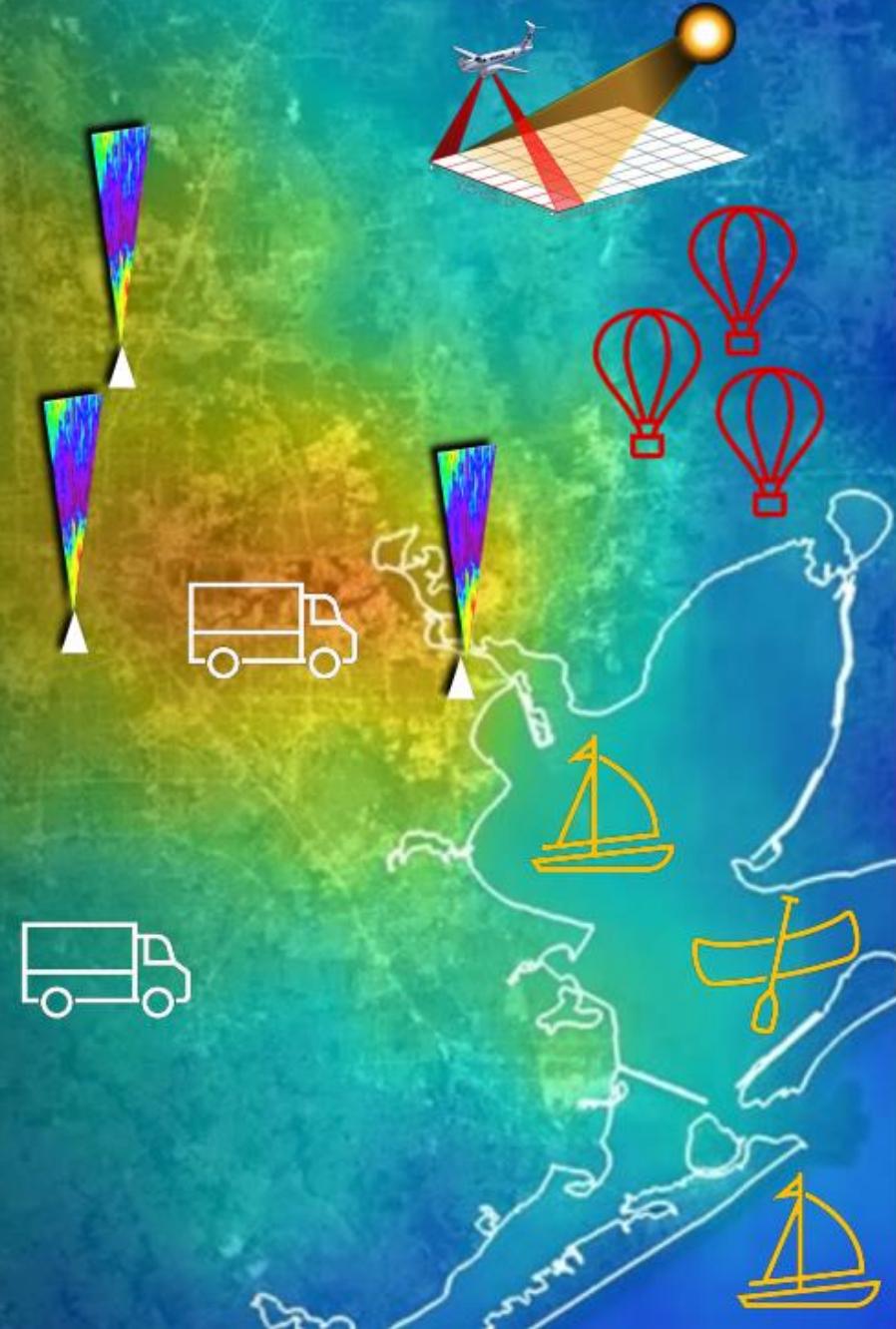
→ NASA JSC G-V Aircraft (77 flight hours)

- ▶ GCAS+HSRL2-DIAL (O₃, NO₂, HCHO, aerosols)

Science Plan Document will be available soon:

<https://www-air.larc.nasa.gov/missions/tracer-aq/index.html>

Study has room to grow in anyone has the support and desire to join!

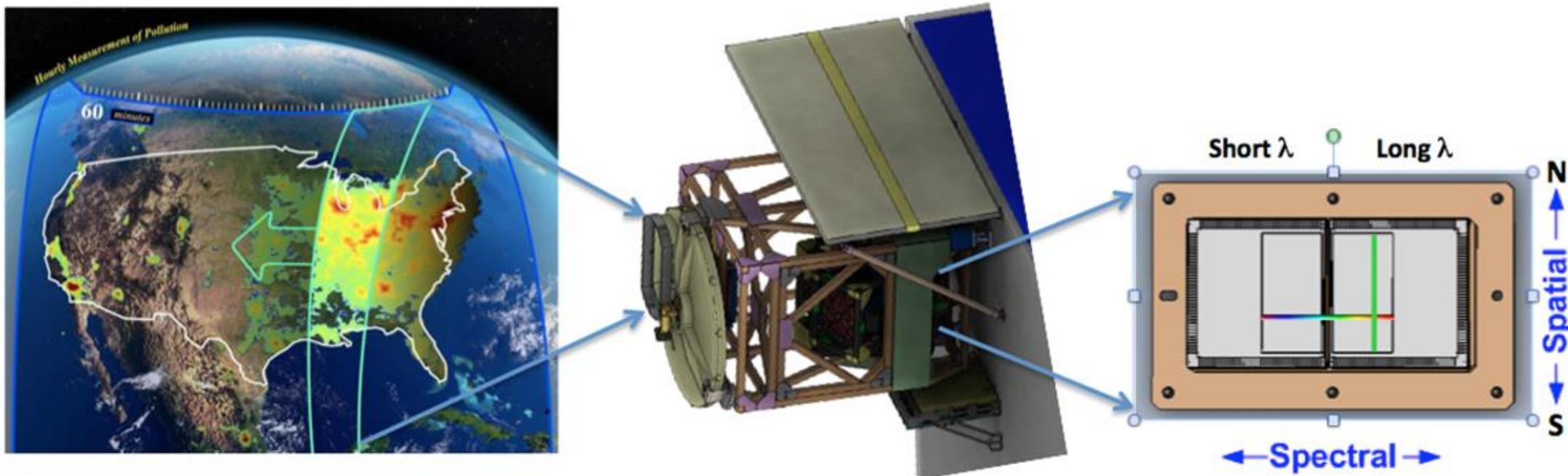


Tropospheric Emissions Monitoring of POllution

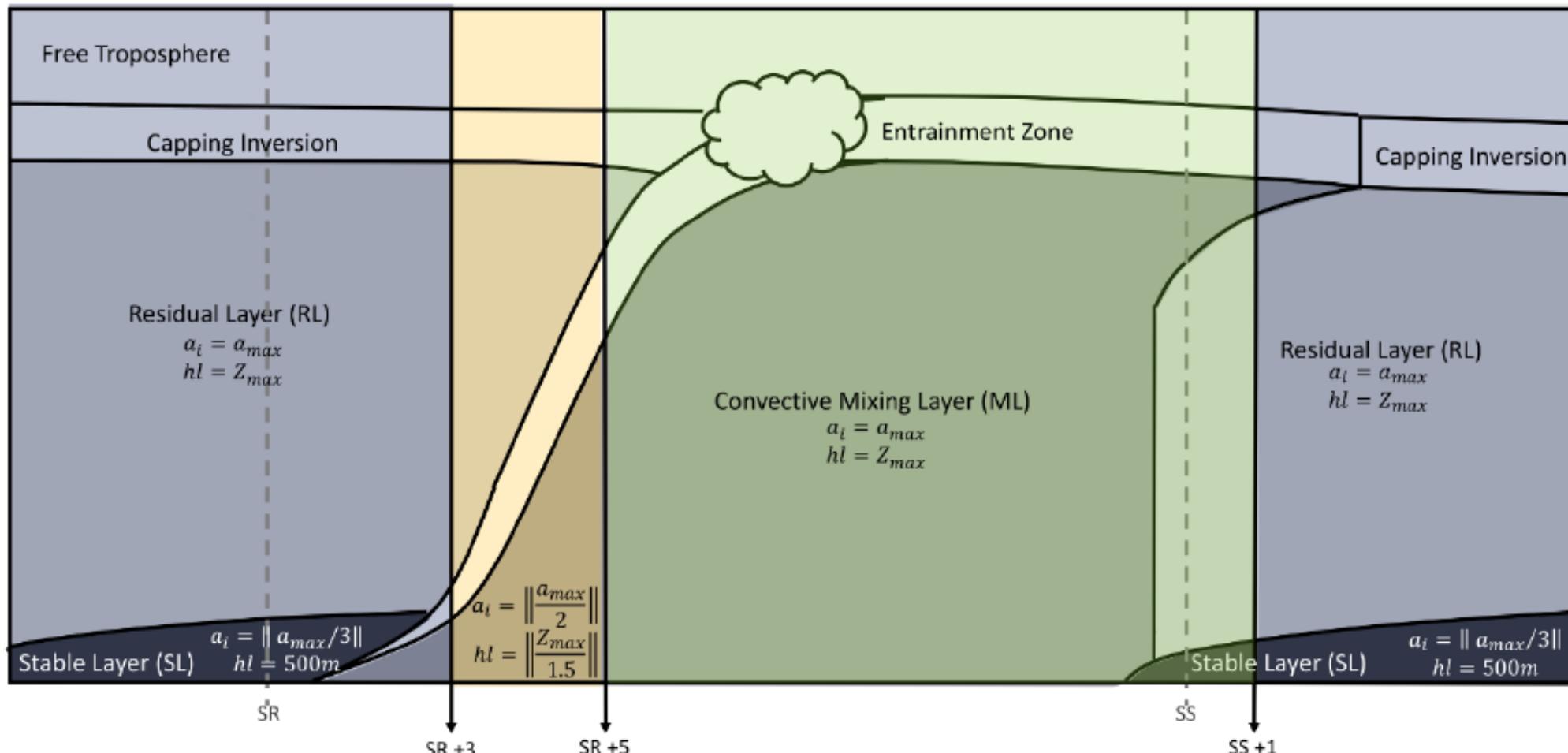
Spectral range: 290–740 nm (UV, VIS) spectral sampling: 0.2 nm spectral resolution: 0.6 nm

Spatial resolution: 2 km/pixel in the north-south direction, 4.5 km /pixel in the east-west direction at the center of the FOR (Field of Regard) which is desired to be 36.5° N, 100° W. Co-add/cloud clear as needed for specific data products

Two 2D detectors ($2\text{ k} \times 1\text{ k}$ pixels) images the full spectral range except for a gap from 490–540 nm for each geospatial scene

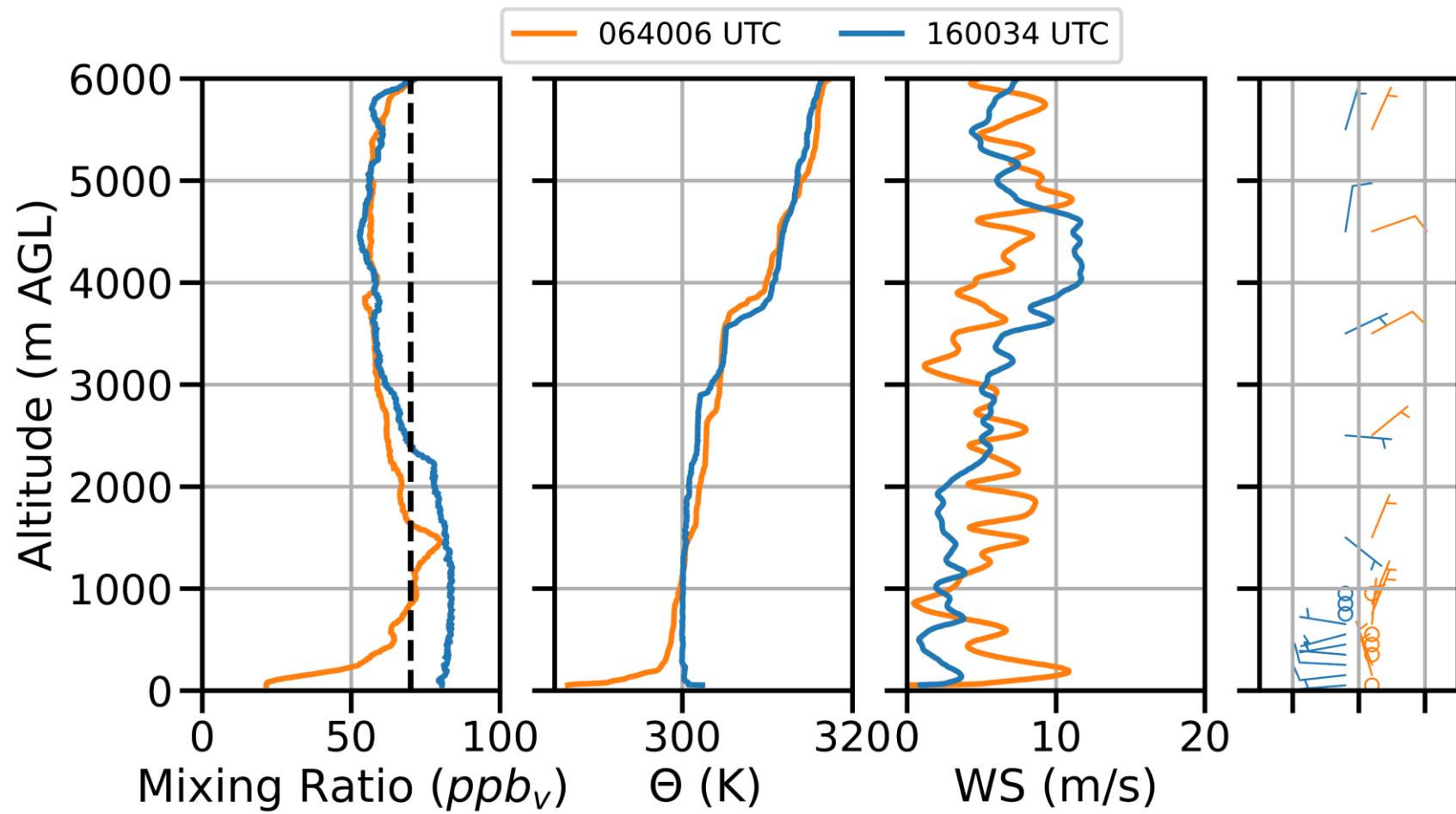


PBL Evolution (Adapted from Stull)

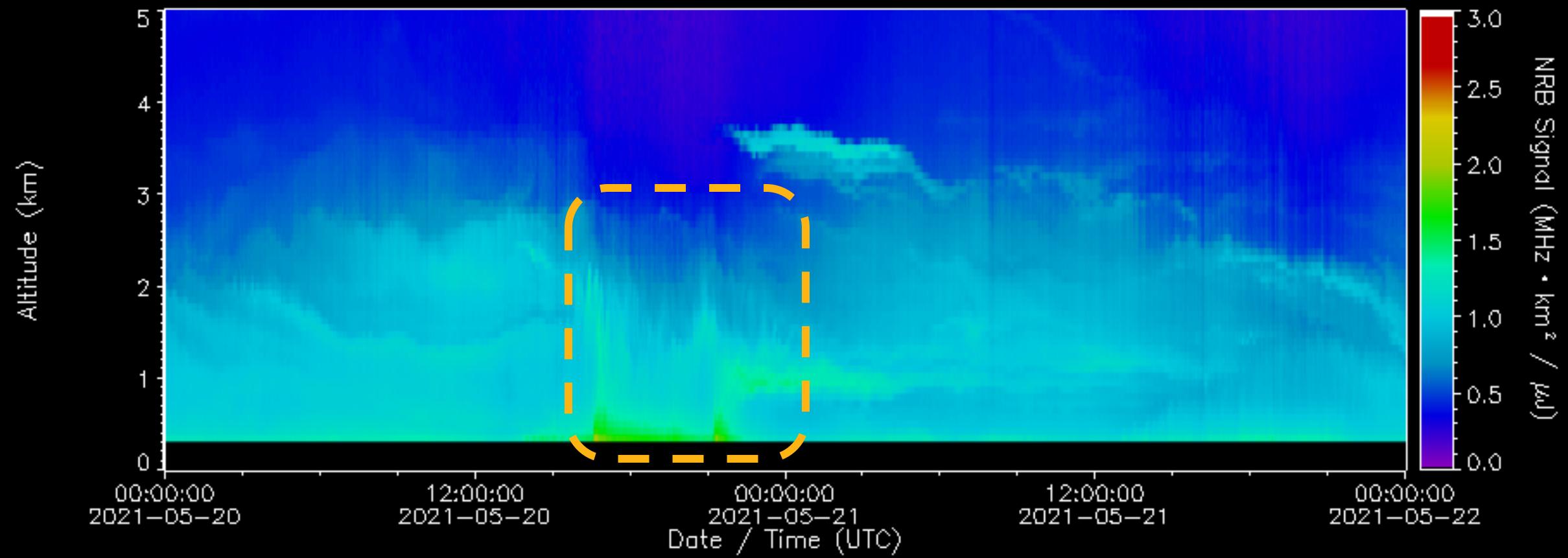




HUBV Ozone Sonde: 05/20/2021

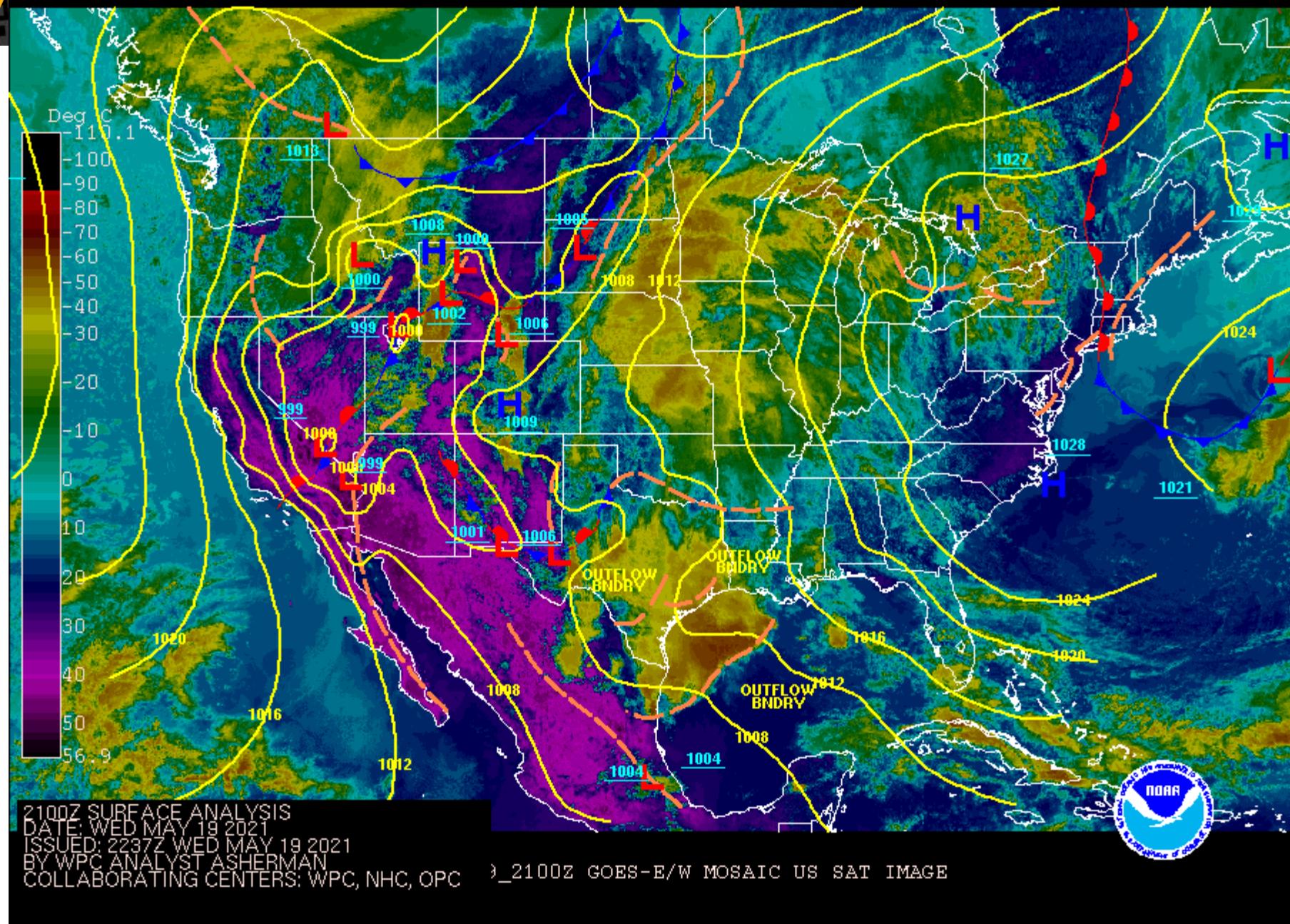


MPLNET GSFC 2021-05-20...2021-05-21: V3_1_NRB (MPL44258, 532.00 nm)



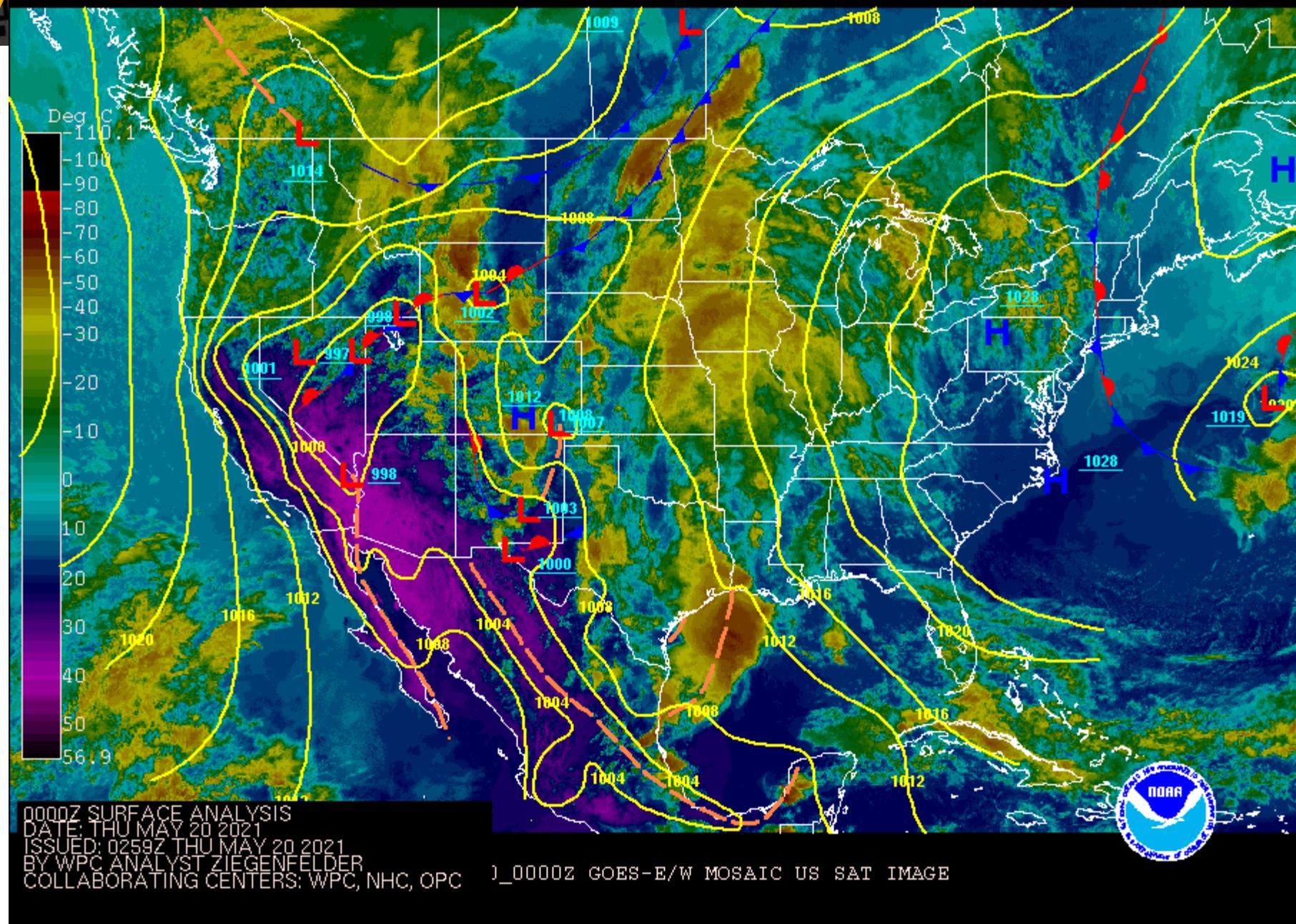


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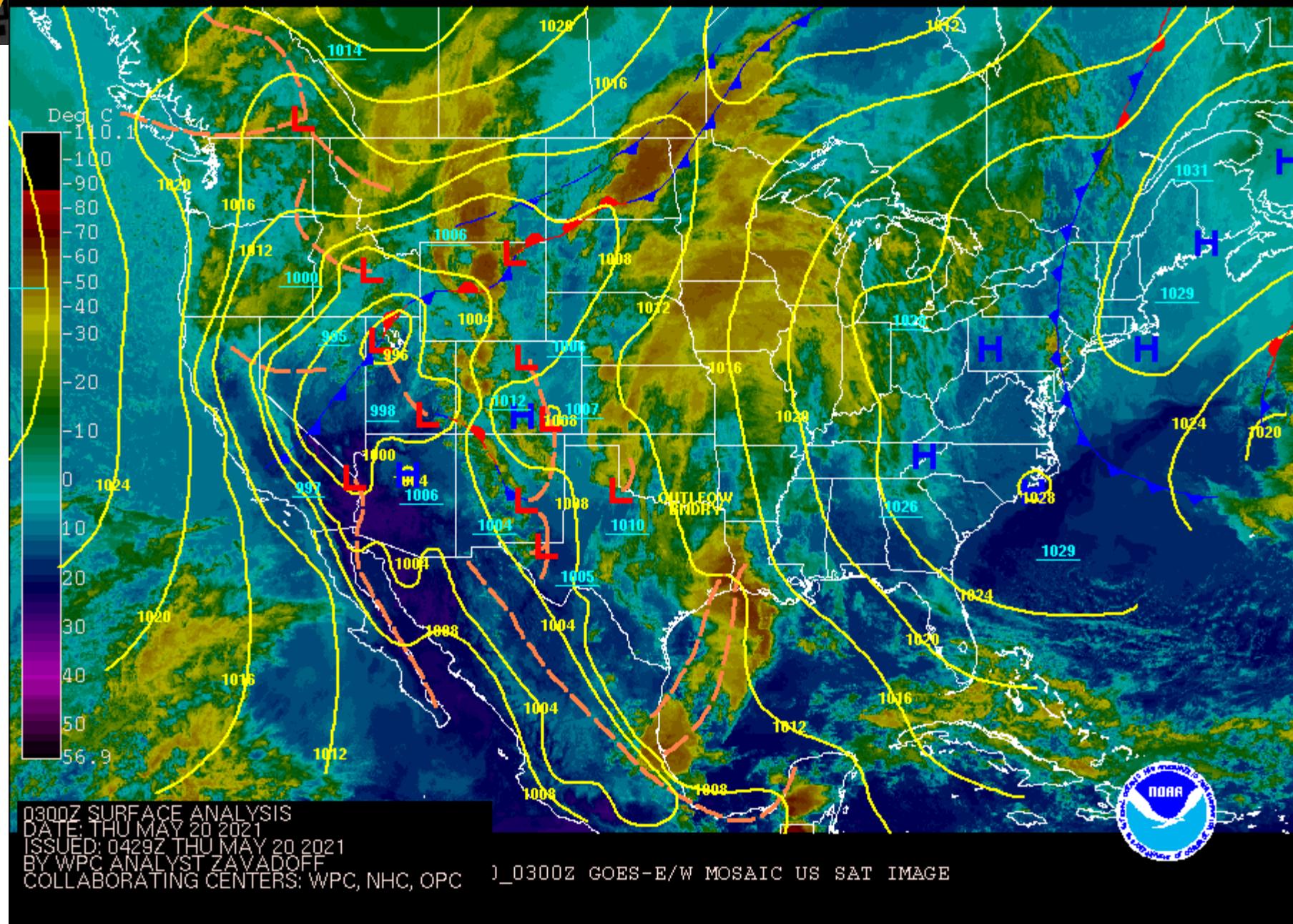


UMD



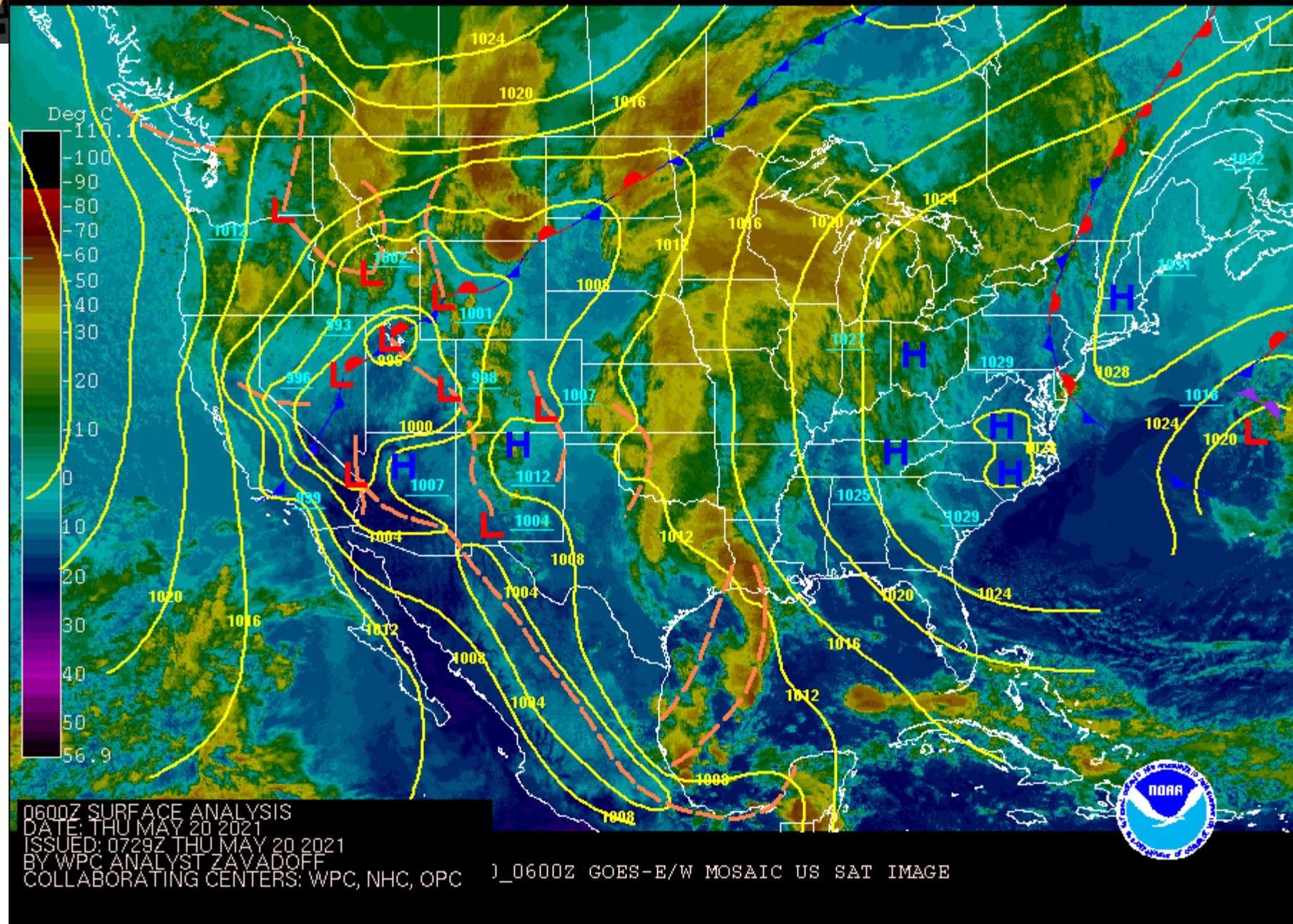


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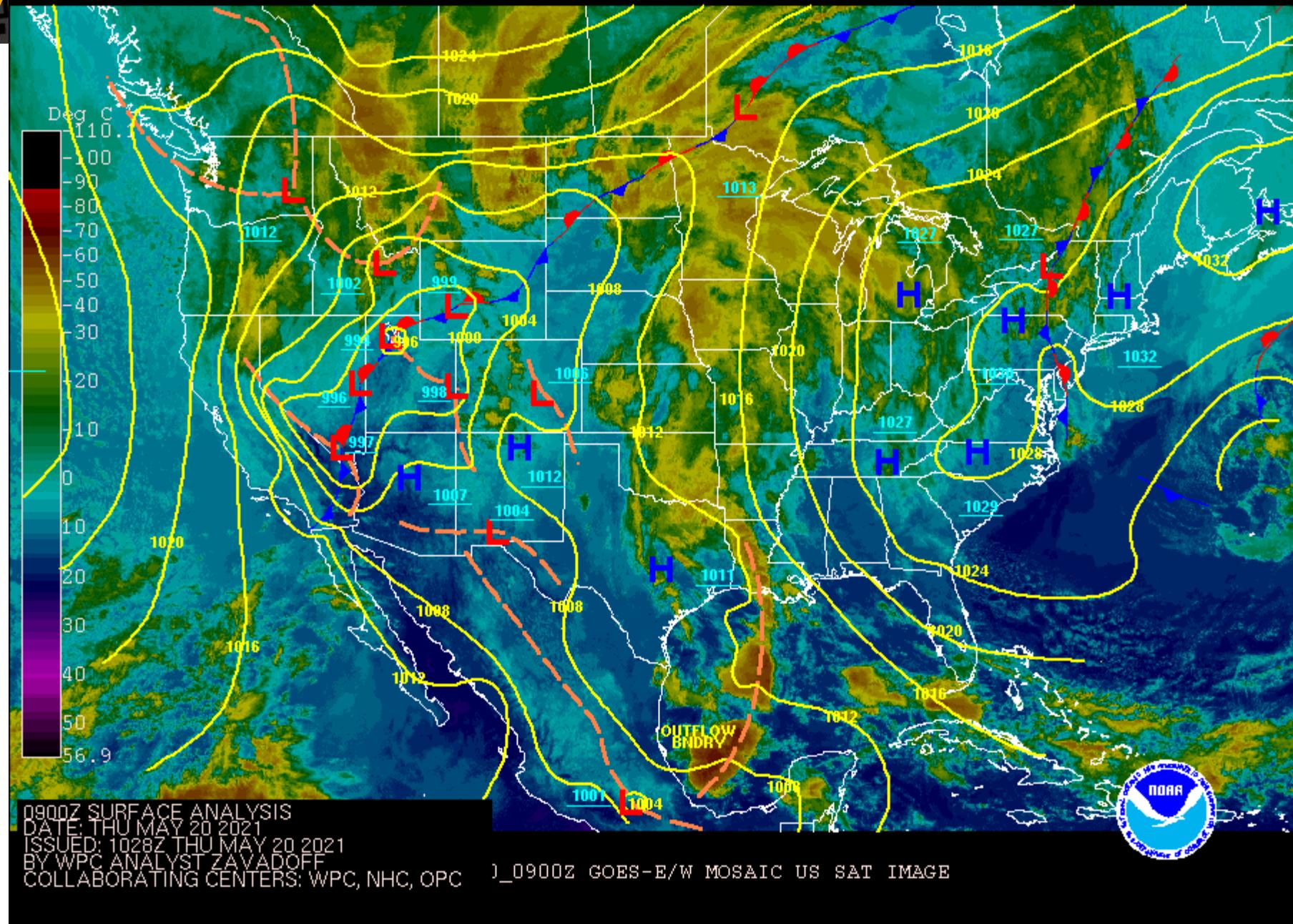


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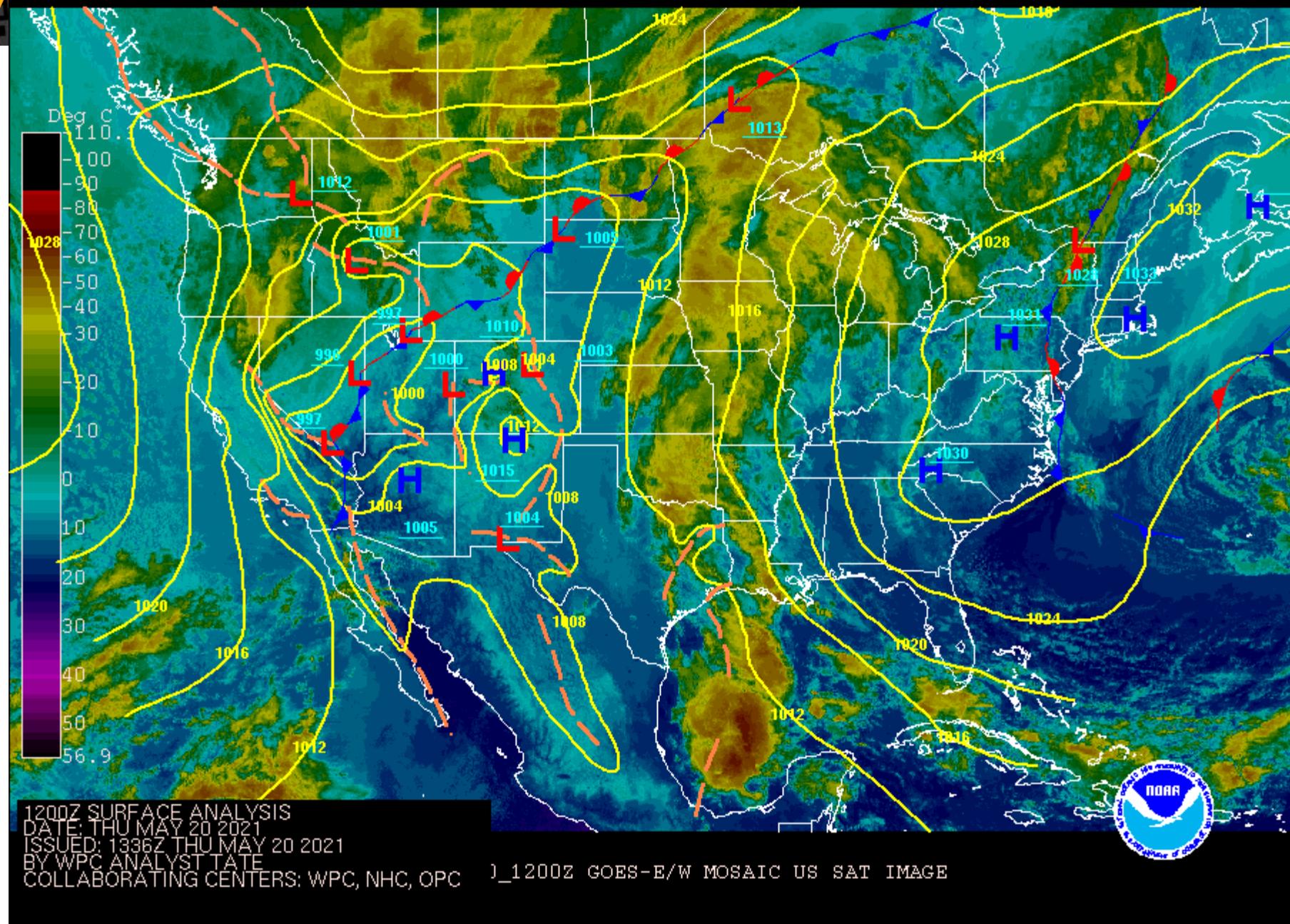


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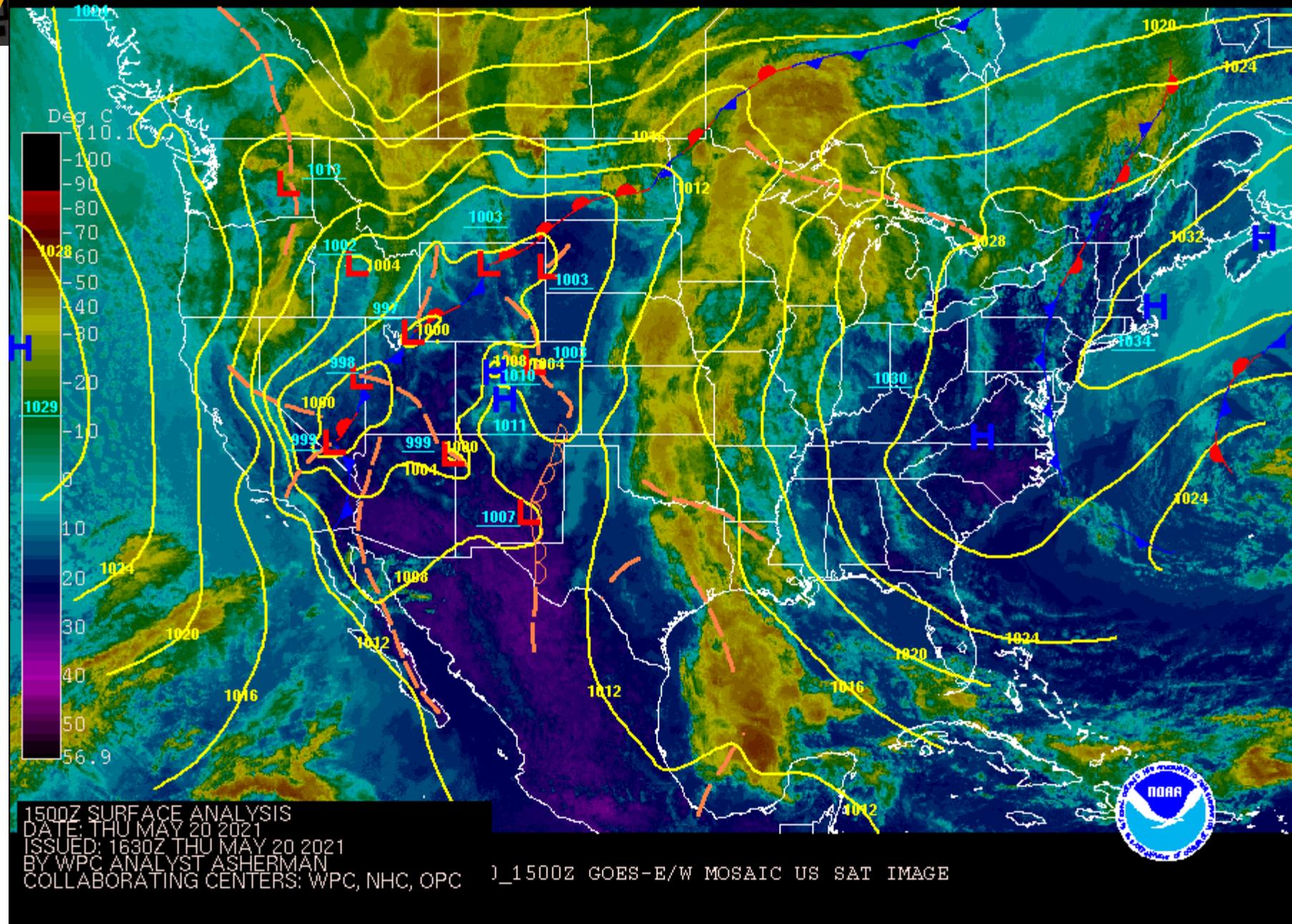


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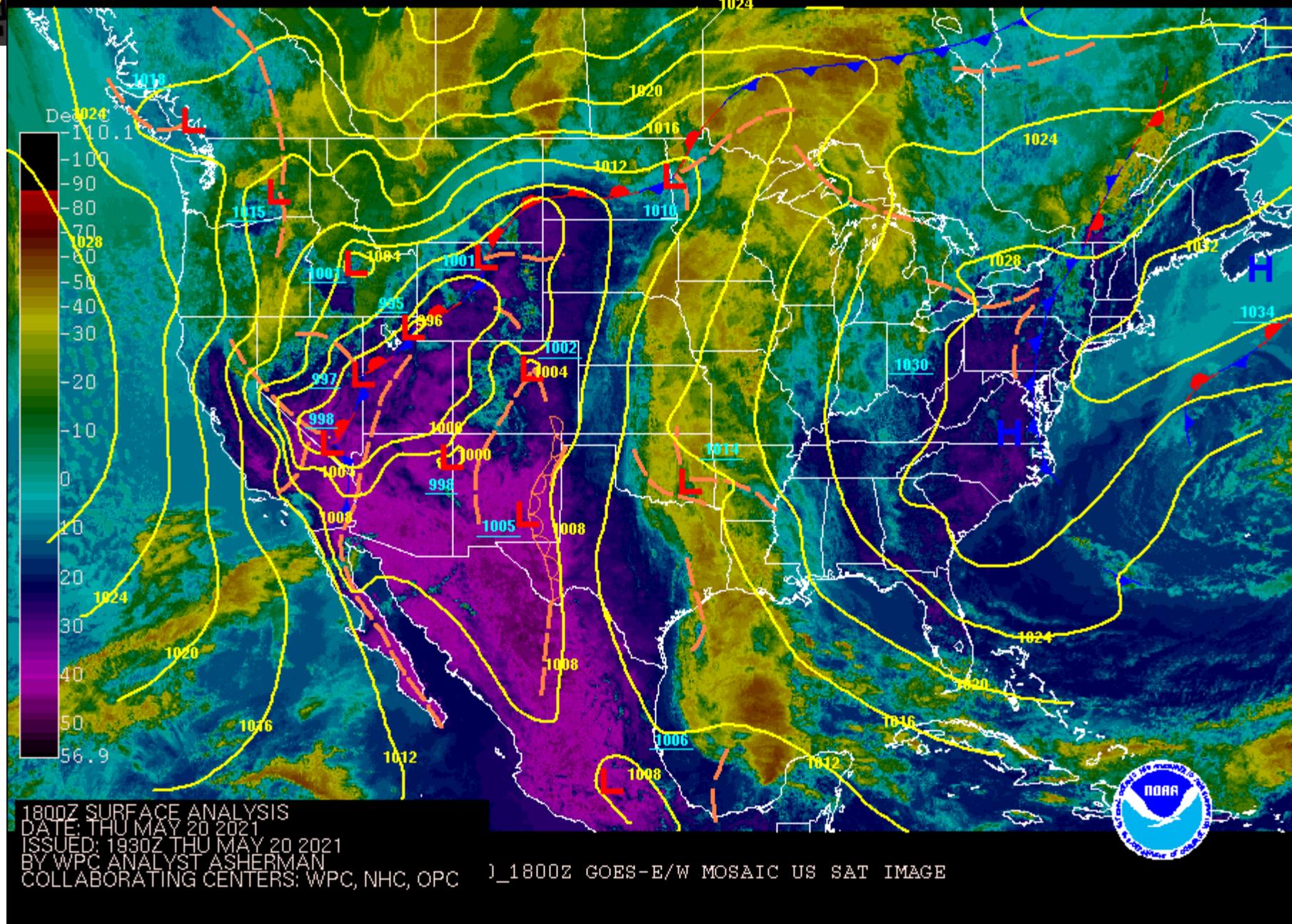


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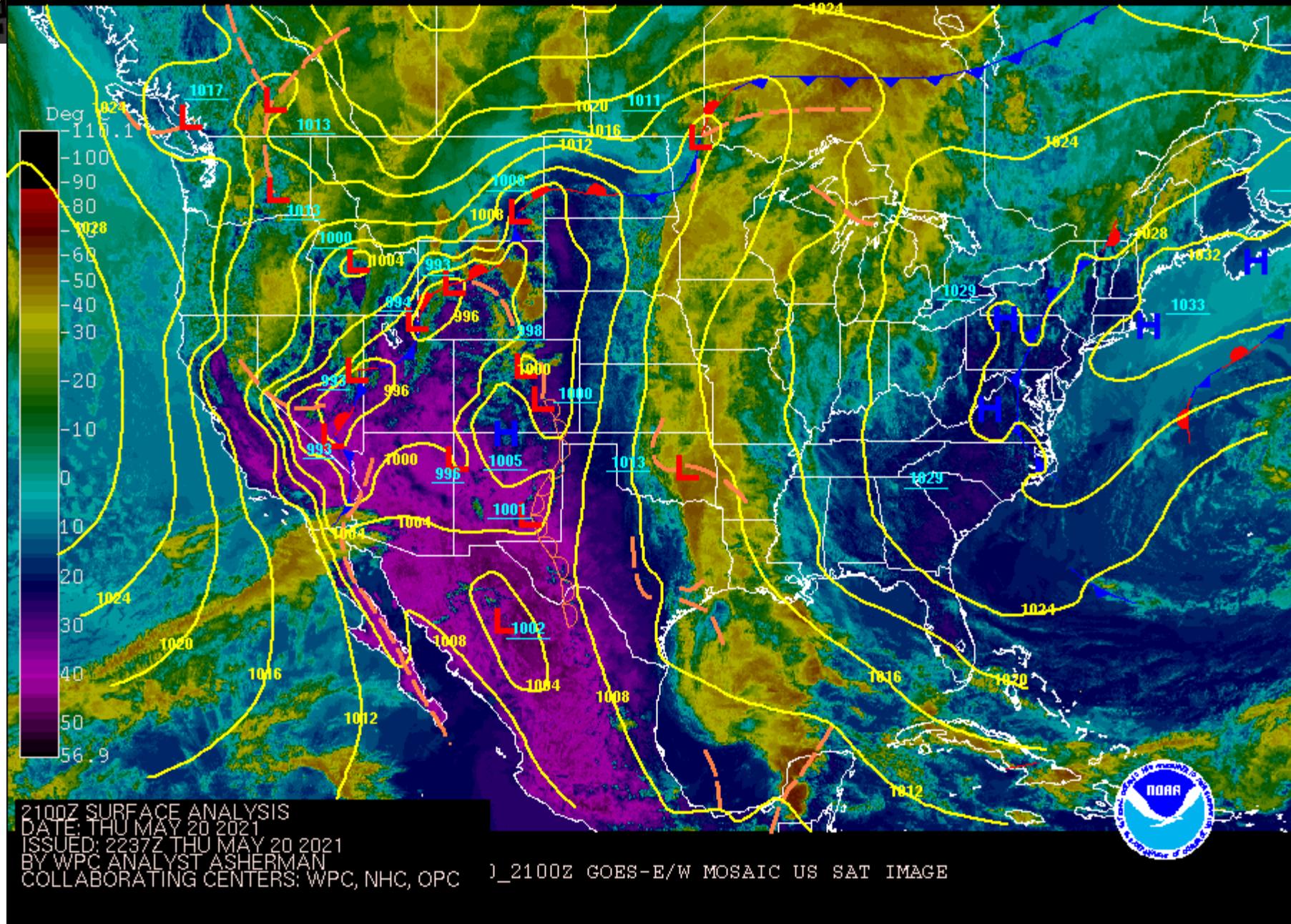


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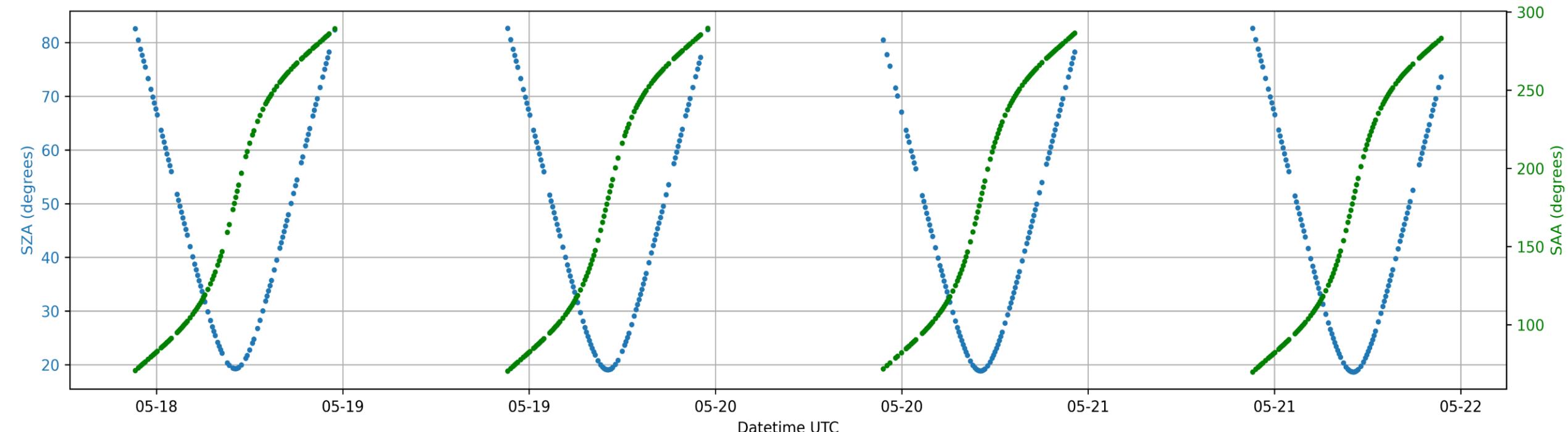
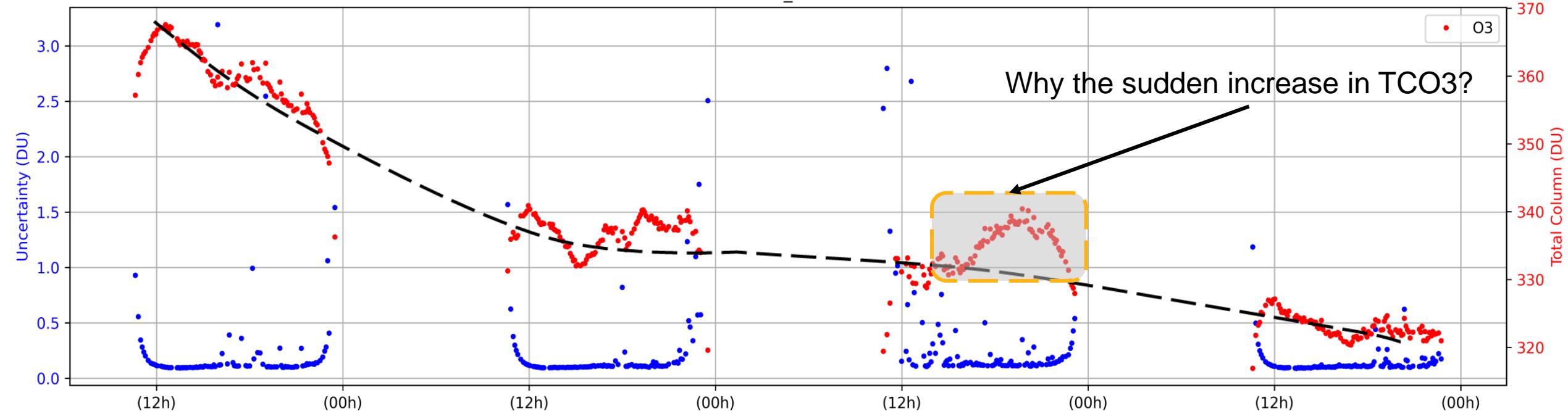




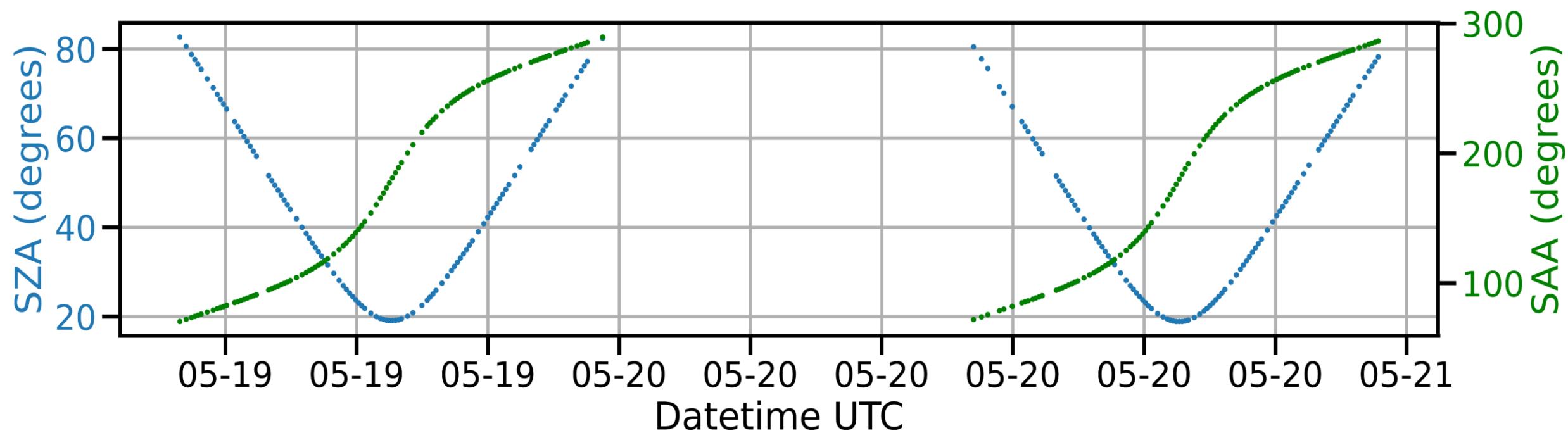
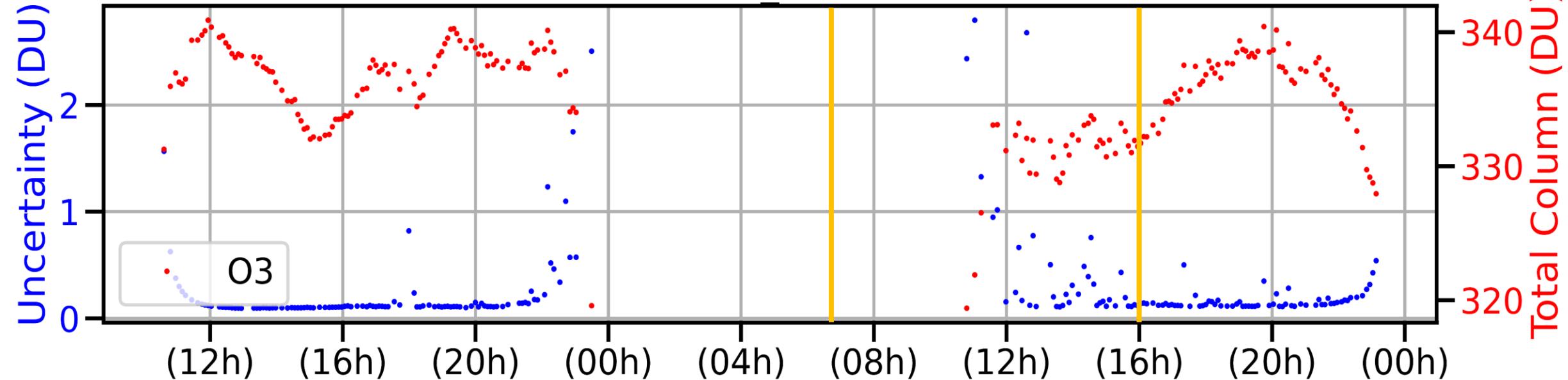
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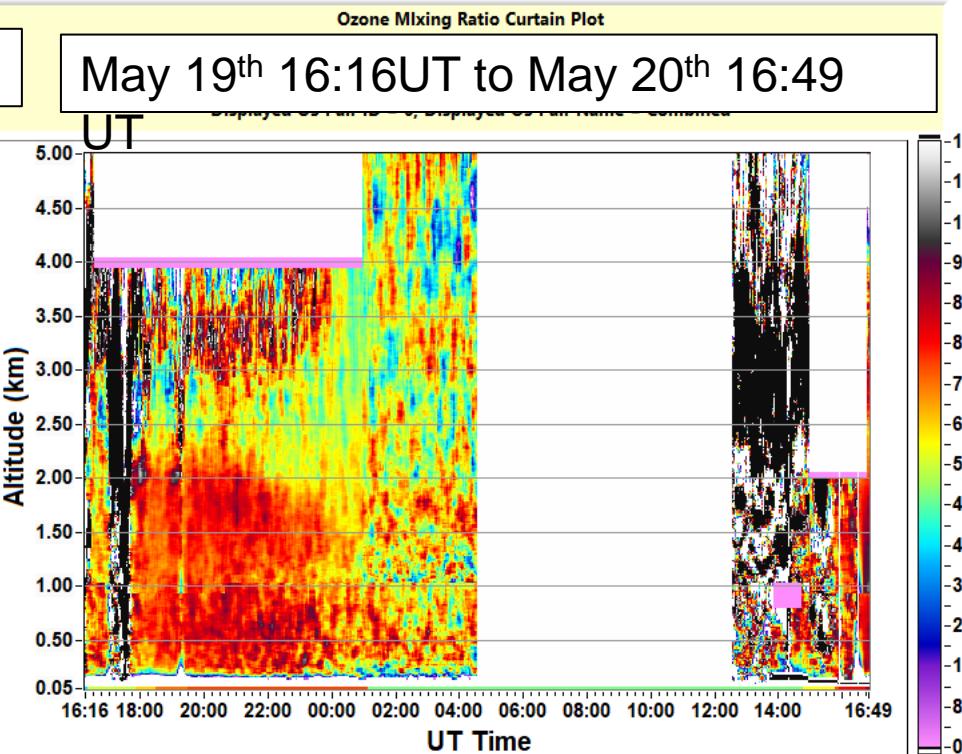
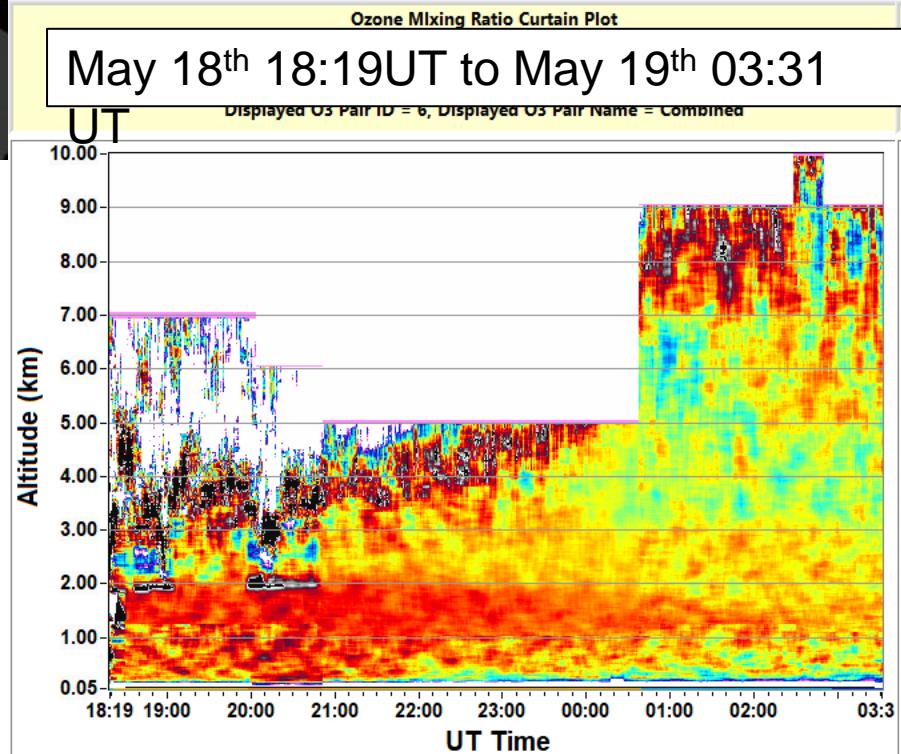


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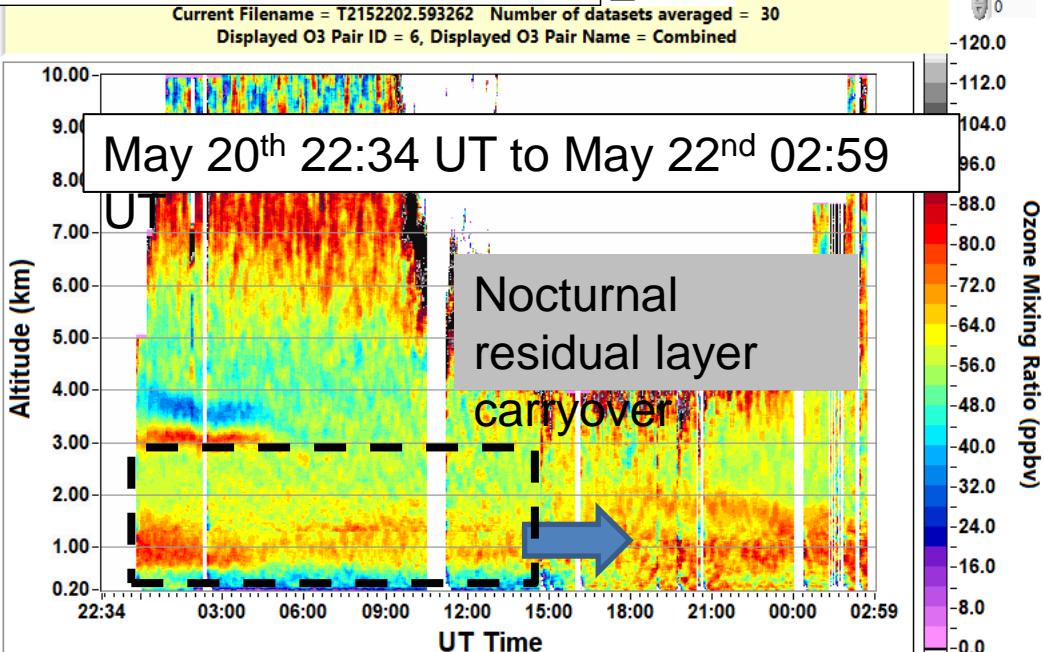
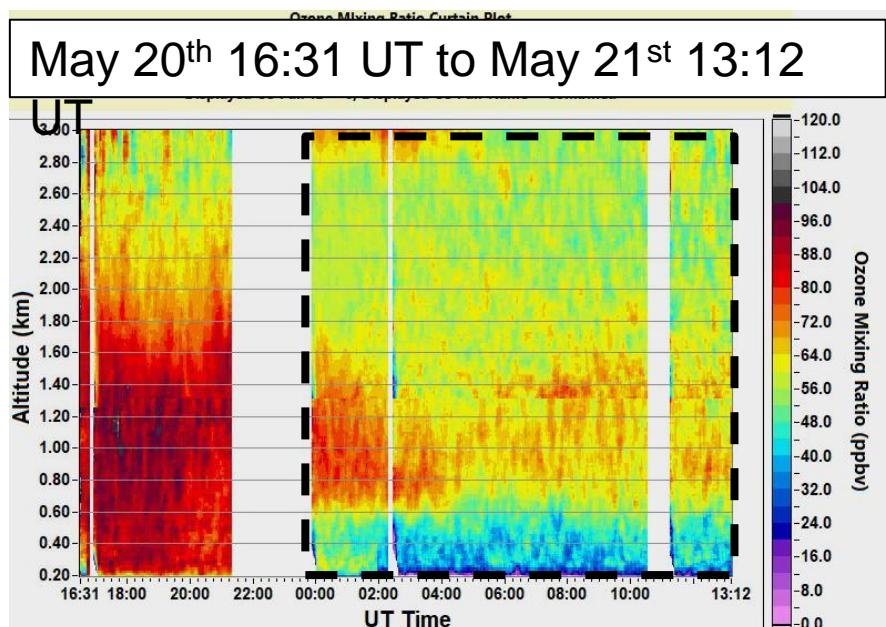


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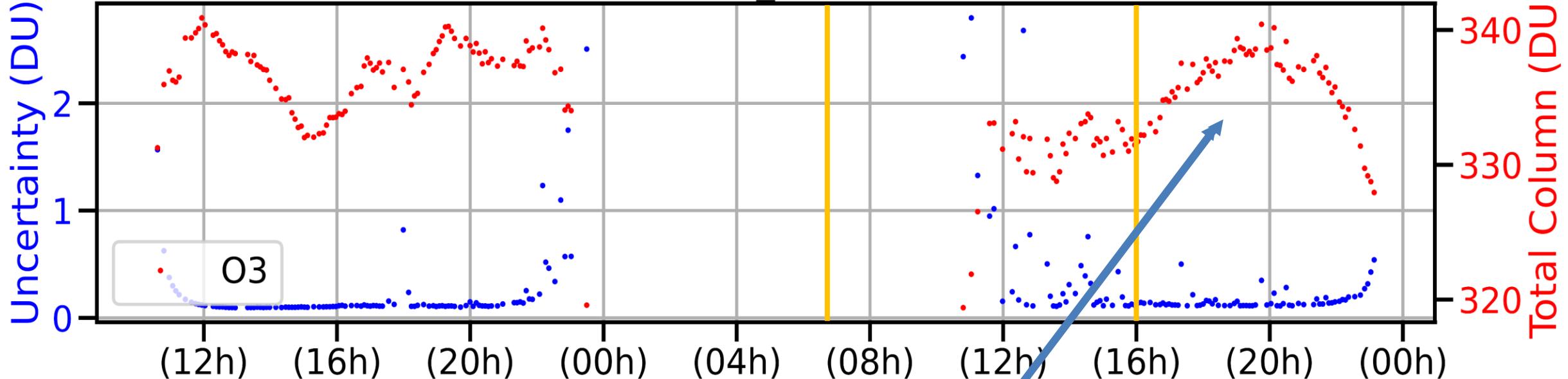




UT –
LT+4hrs



20210519T1036 20210520T2330



Is the high density of O3 the causation for this spike?

