

# Analysis of a Mid-Atlantic Ozone Episode

Maurice E. D. Roots

*PHYS 650: Atmospheric Measurement*



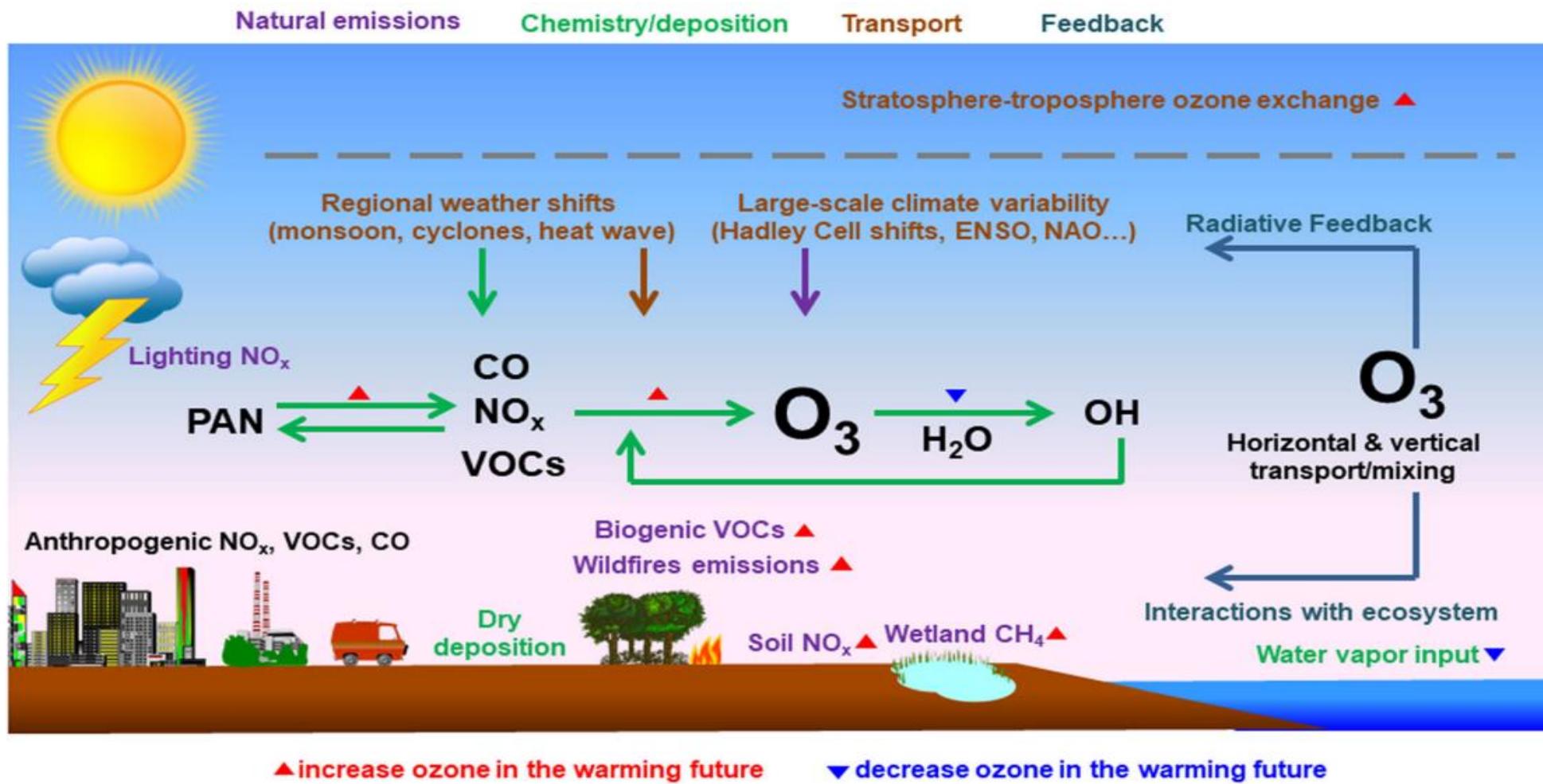
NCAS-M

NOAA COOPERATIVE SCIENCE  
CENTER IN ATMOSPHERIC  
SCIENCES AND METEOROLOGY



Goddard  
SPACE FLIGHT CENTER

# What is Ozone?

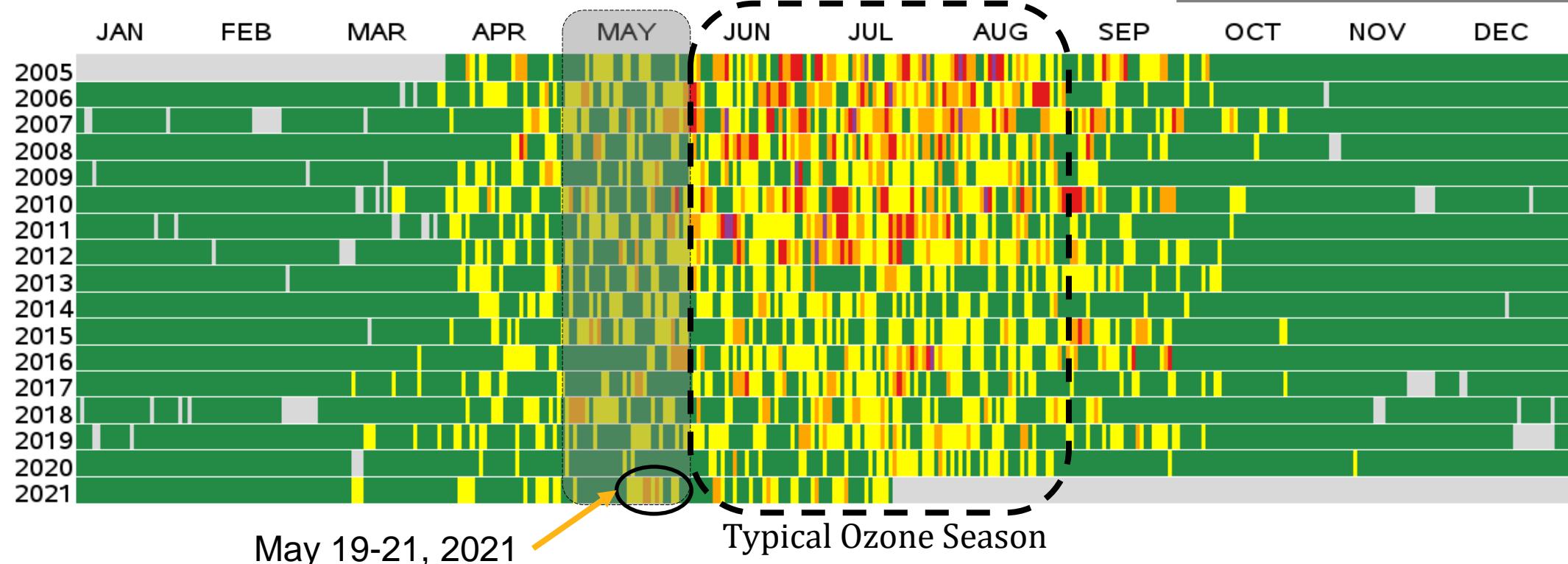


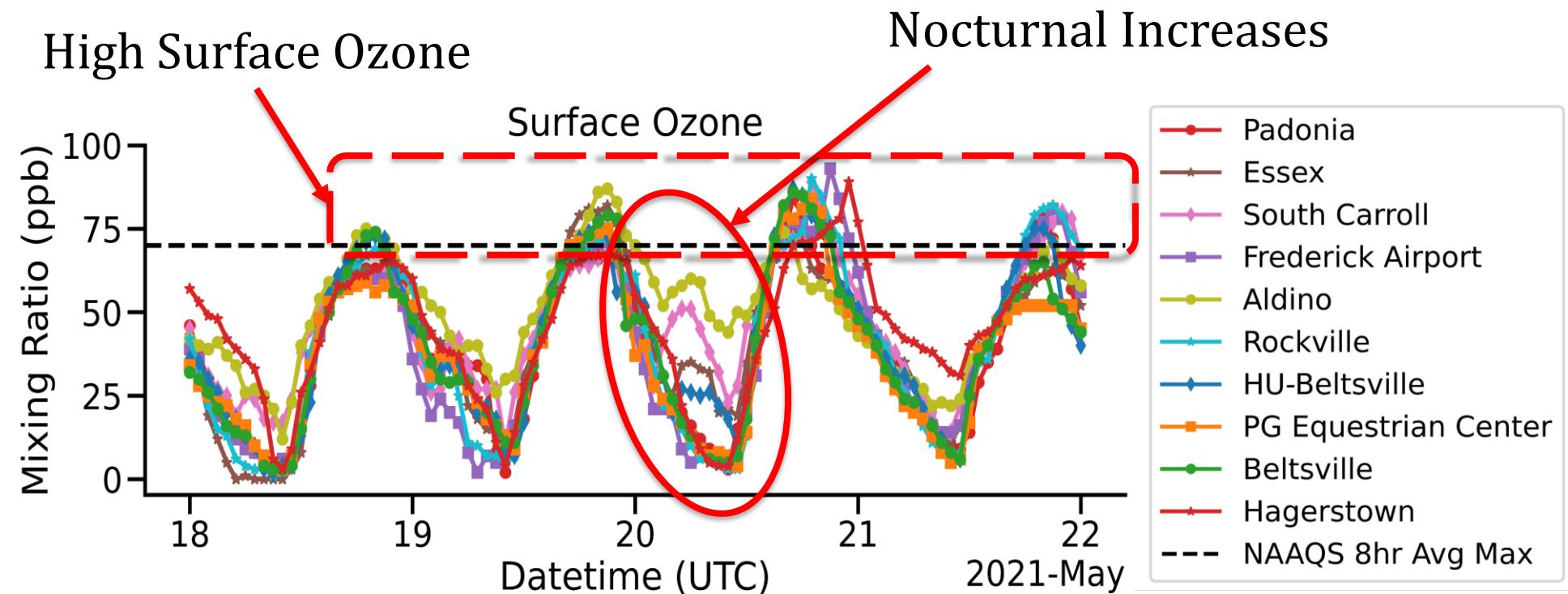
Lu et al., 2019

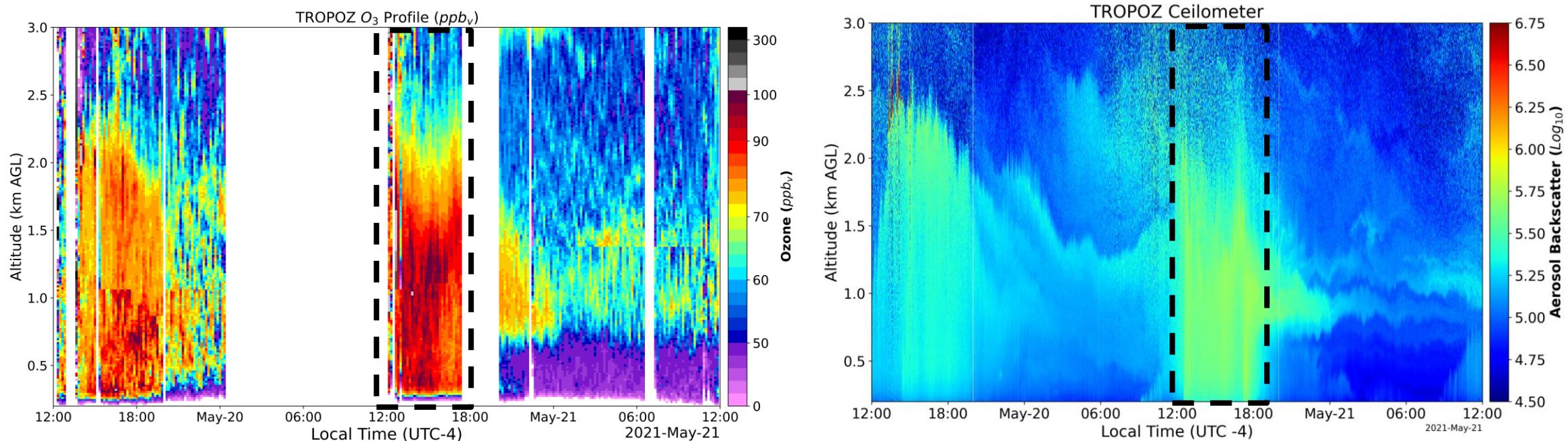
# Ozone Daily AQI Values, 2005 to 2021

## Baltimore-Columbia-Towson, MD

AQI Category
Good (<=0.054 ppm)
Moderate (0.055-0.070 ppm)
Unhealthy for Sensitive Groups (0.071-0.085 ppm)
Unhealthy (0.086-0.105 ppm)
Very Unhealthy (0.106-0.200 ppm)
Hazardous (>=0.405 ppm 1-hour)





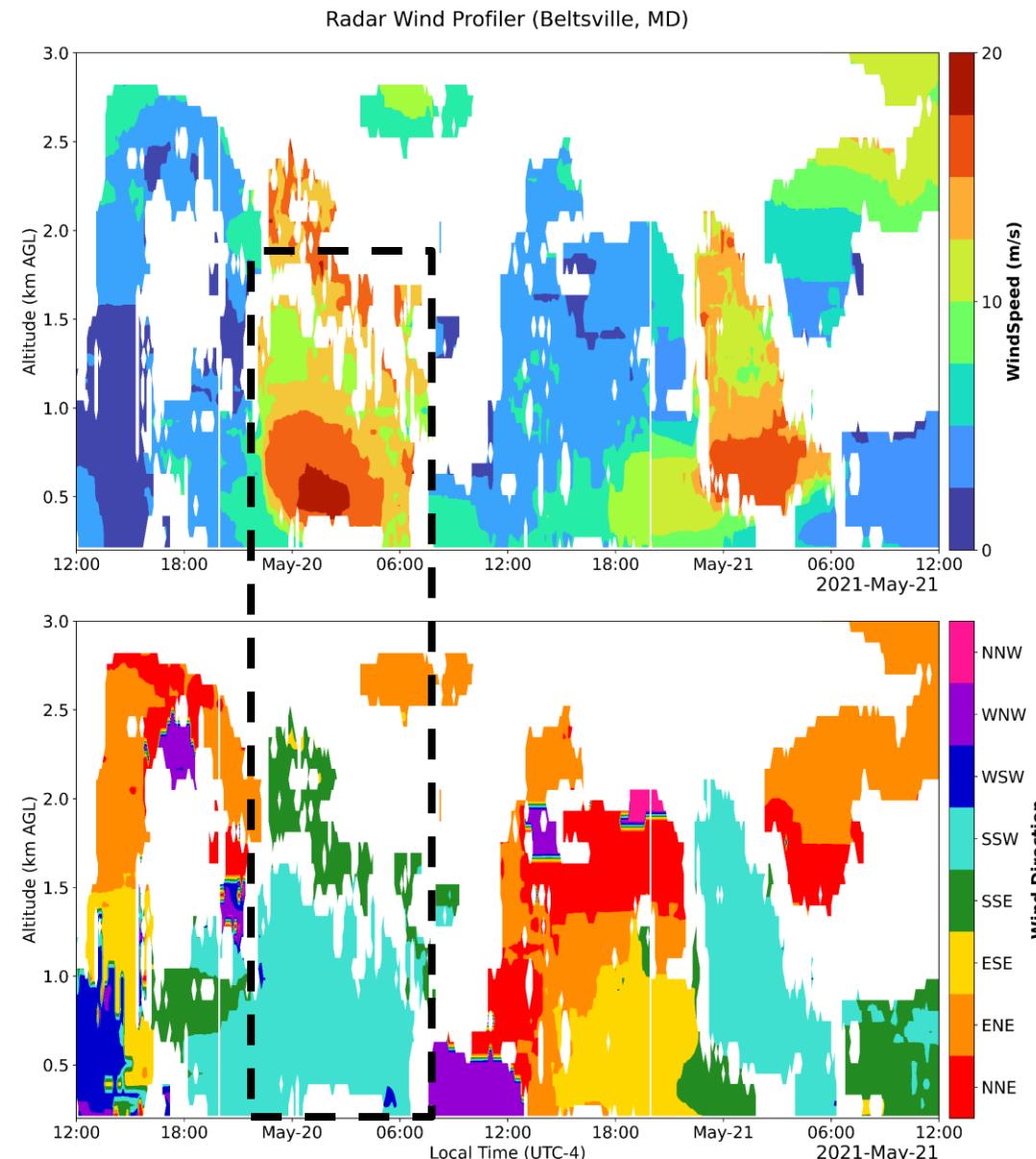


- Well-mixed polluted PBL seen from TROPOZ, Ceilometer, Sonde and surface
- Arrival of polluted air-mass marked by wind profile with
- Sonde observes over 10 m/s wind speeds at 02 LT (06 UTC) on 20th
- Wind, ceilometer, and ozone profiles indicate an air mass change occurring near 14 LT in the Beltsville,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

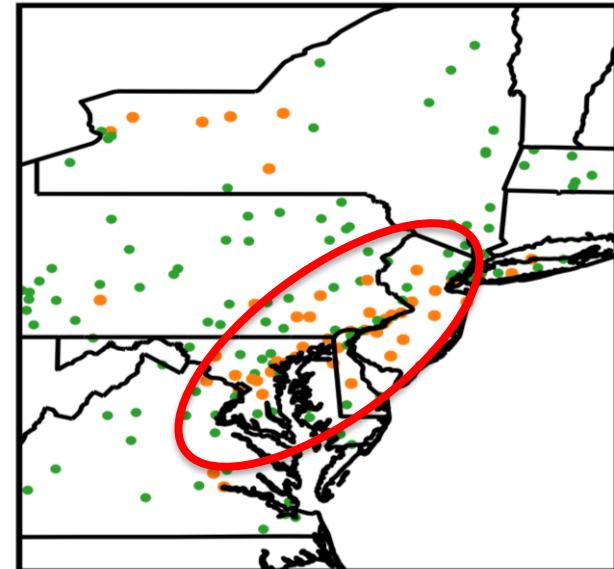


- HU-Beltsville RWP shows wind direction and magnitude change at time of polluted air-mass and cleaning it out.
- NLLJ at 0 - 6 LT on the 20th which preceding DSW and clean-out leading to next-day entrainment and transport

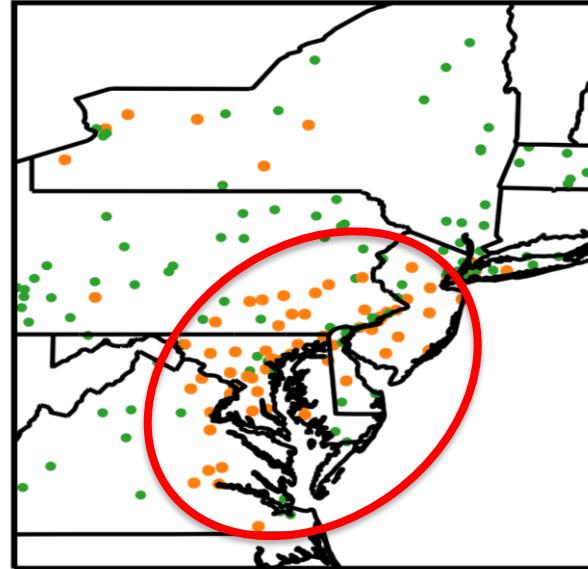


HU-Beltsville Wind Profiler

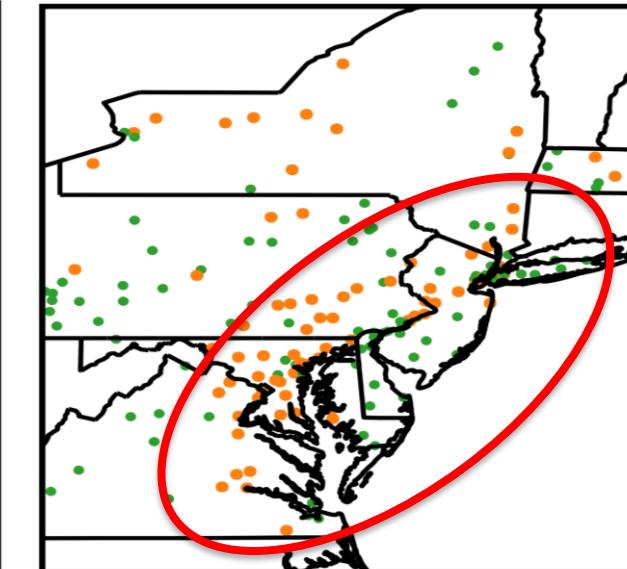
2021-05-18 : 2021-05-19



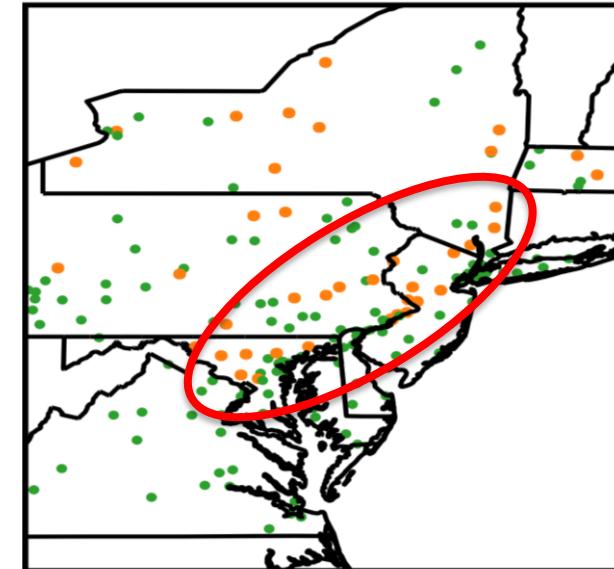
2021-05-19 : 2021-05-20



2021-05-20 : 2021-05-21

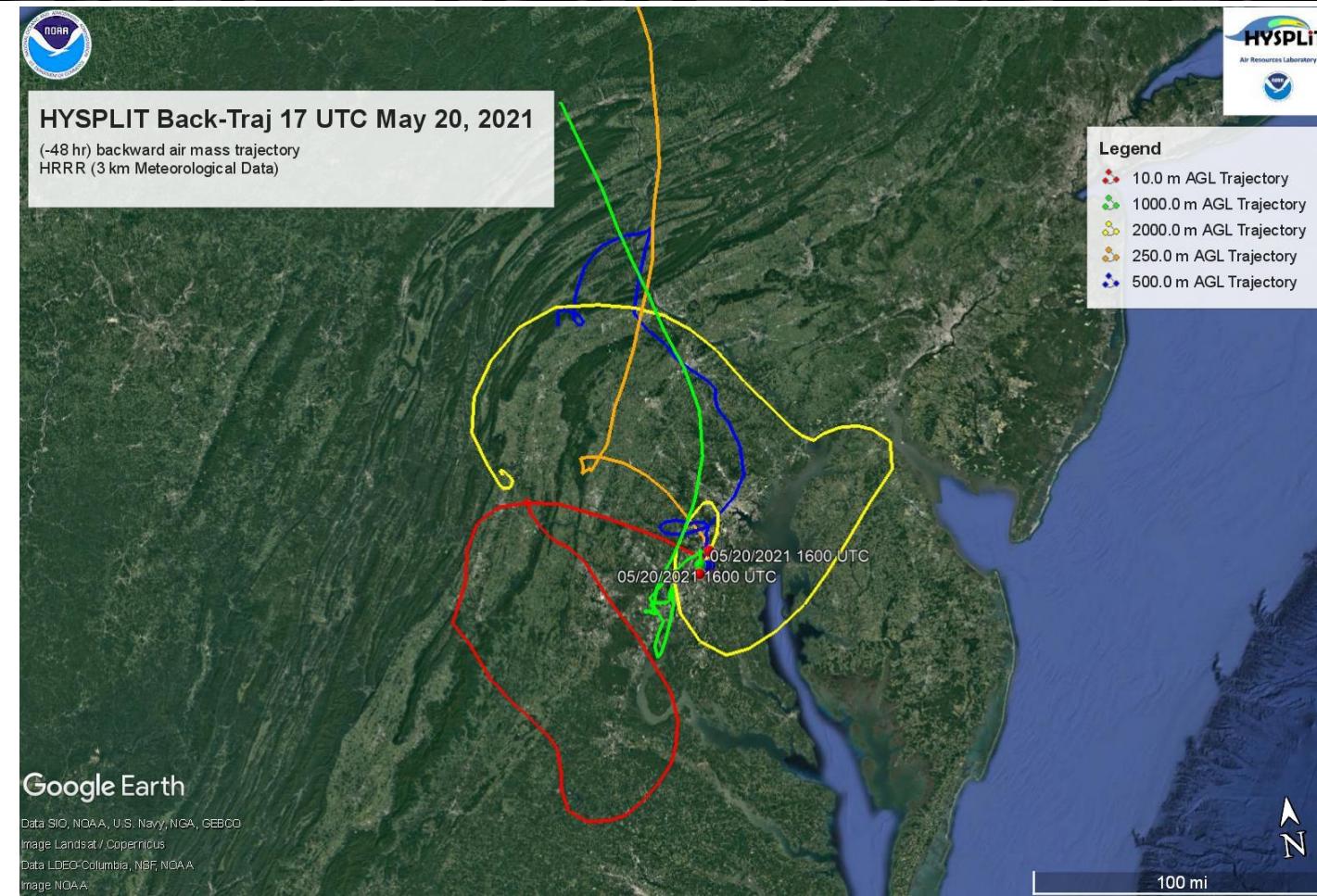
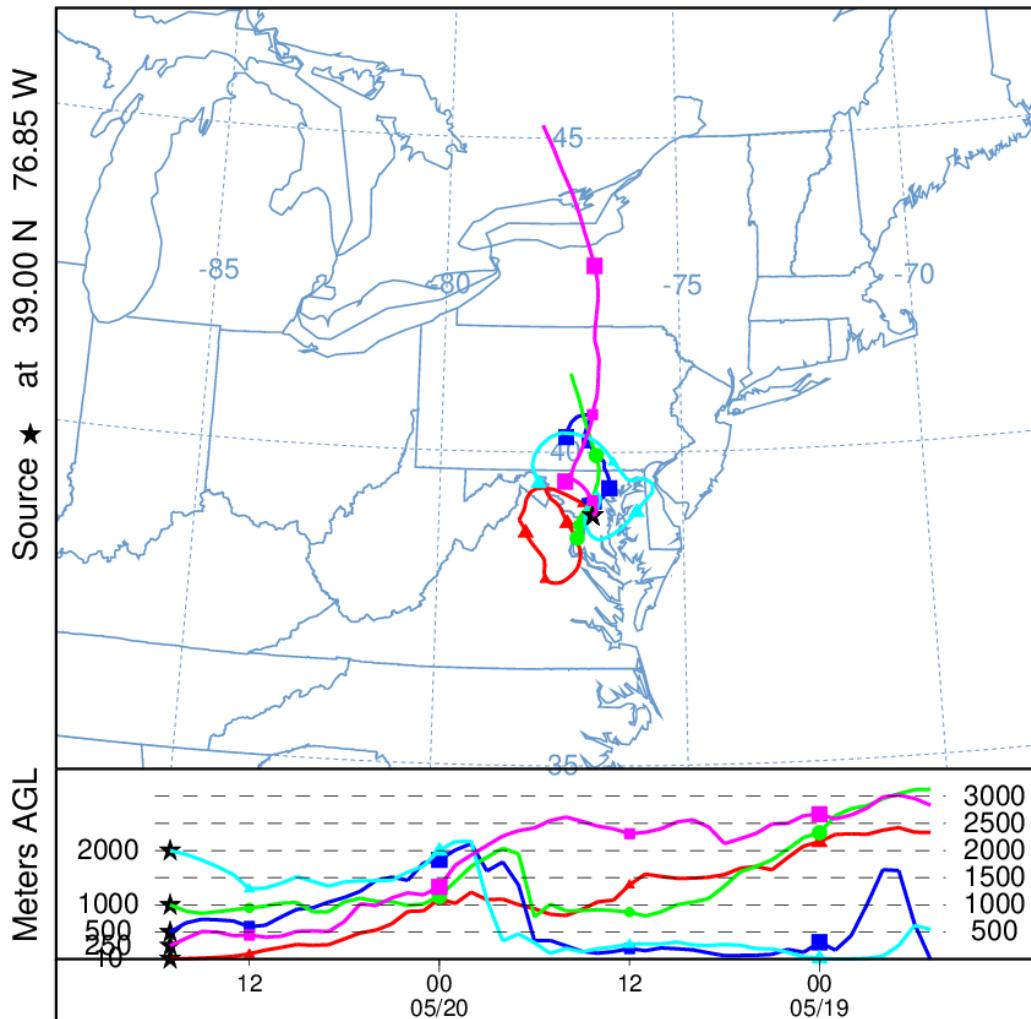


2021-05-21 : 2021-05-22



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

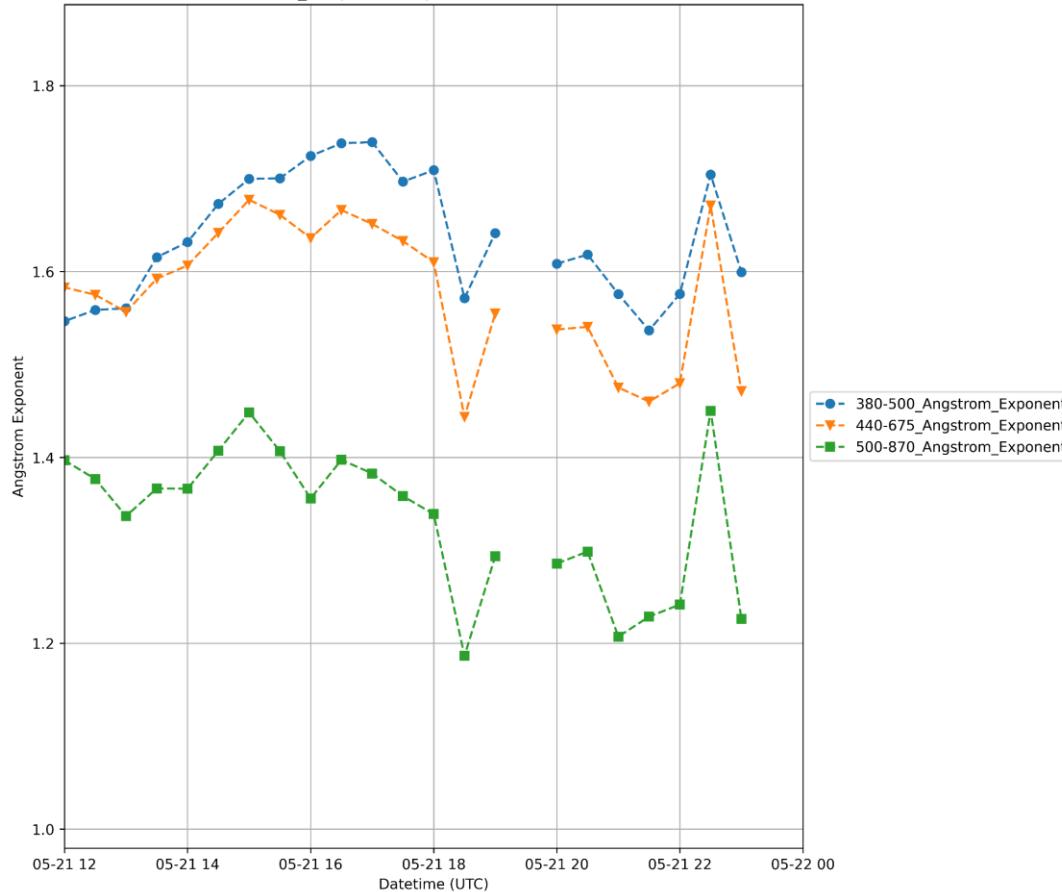
NOAA HYSPLIT MODEL  
Backward trajectories ending at 1700 UTC 20 May 21  
HRRR Meteorological Data



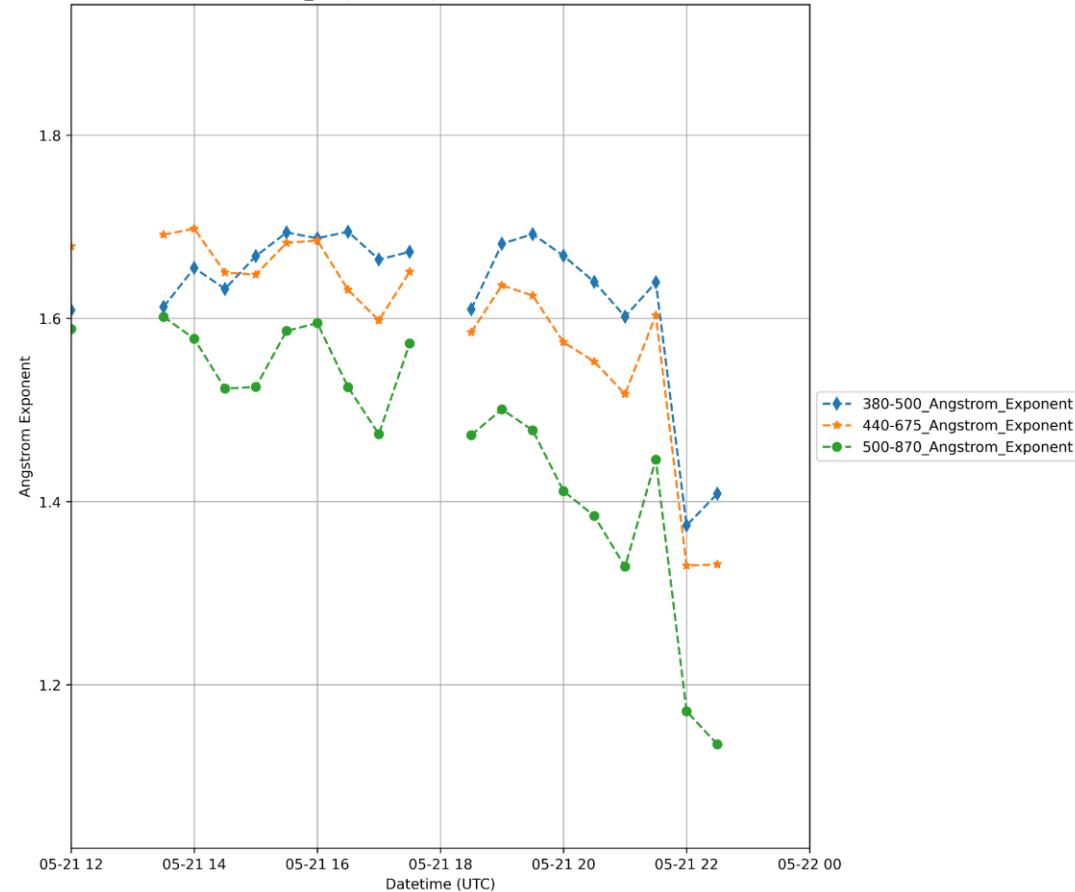
- Hybrid Sing Particle Lagranian Transport Model
  - Shows the air mass transport forwards or backwards

# AERONET Angstrom Exponent

Data Quality Level: lev15  
 AERONET\_Instrument\_Number: 1072  
 AERONET\_Site\_Name: GSFC  
 Site\_Latitude(Degrees): 38.9925  
 Site\_Longitude(Degrees): -76.839833

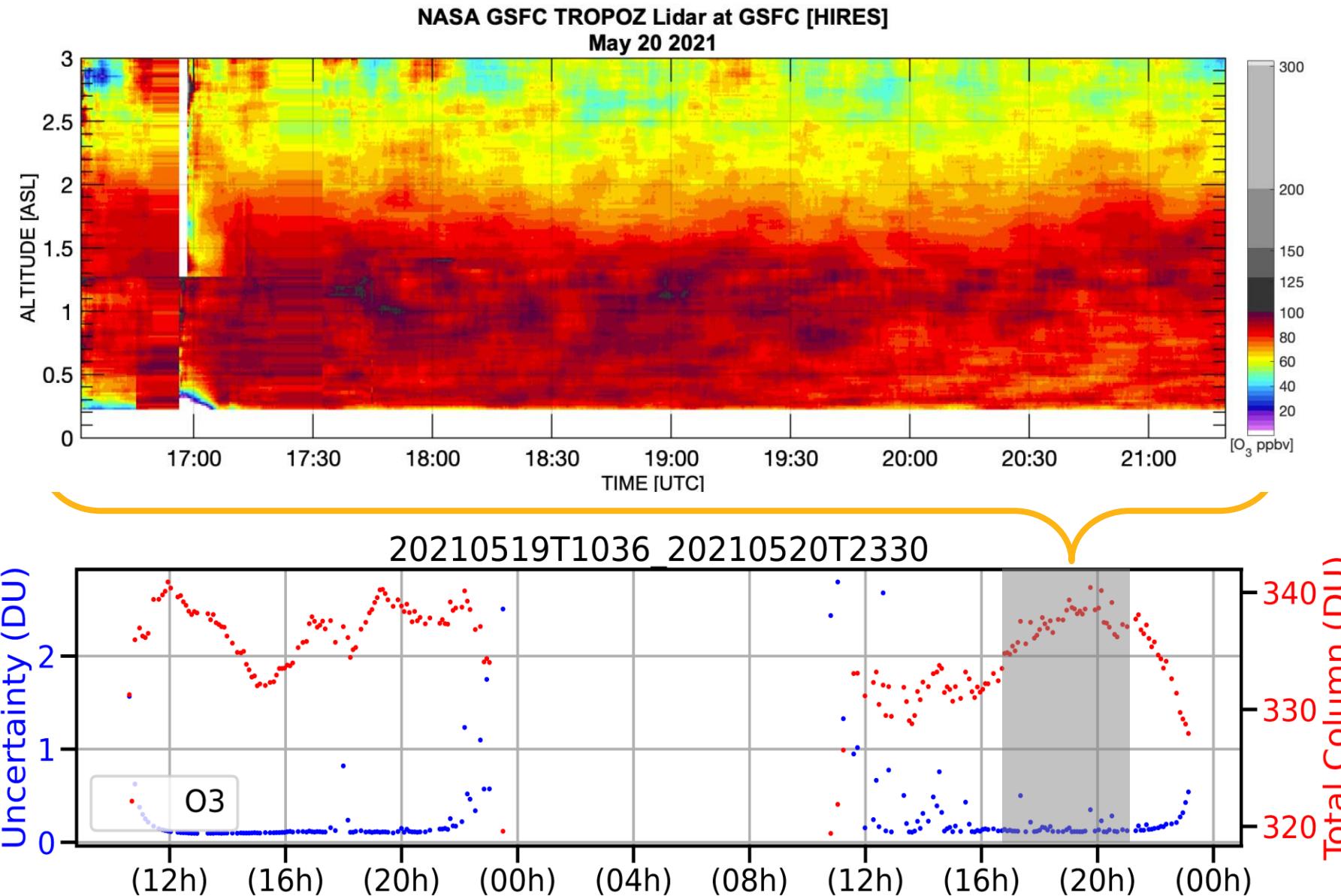


Data Quality Level: lev15  
 AERONET\_Instrument\_Number: 1040  
 AERONET\_Site\_Name: CCNY  
 Site\_Latitude(Degrees): 40.821313  
 Site\_Longitude(Degrees): -73.949036



Note that the temporal evolution is lead by CCNY and followed by GSFC indicated North to South transport of aerosols. Using Russel et al 2010 scheme for Aerosols classification by Angstrom Exponents we see that this is an influx of biomass burning aerosol ( $1 > \text{AAE} < 2$ ) from the North transported into the Baltimore, MD - Washington, DC region.

## Pandora with Ozone Lidar

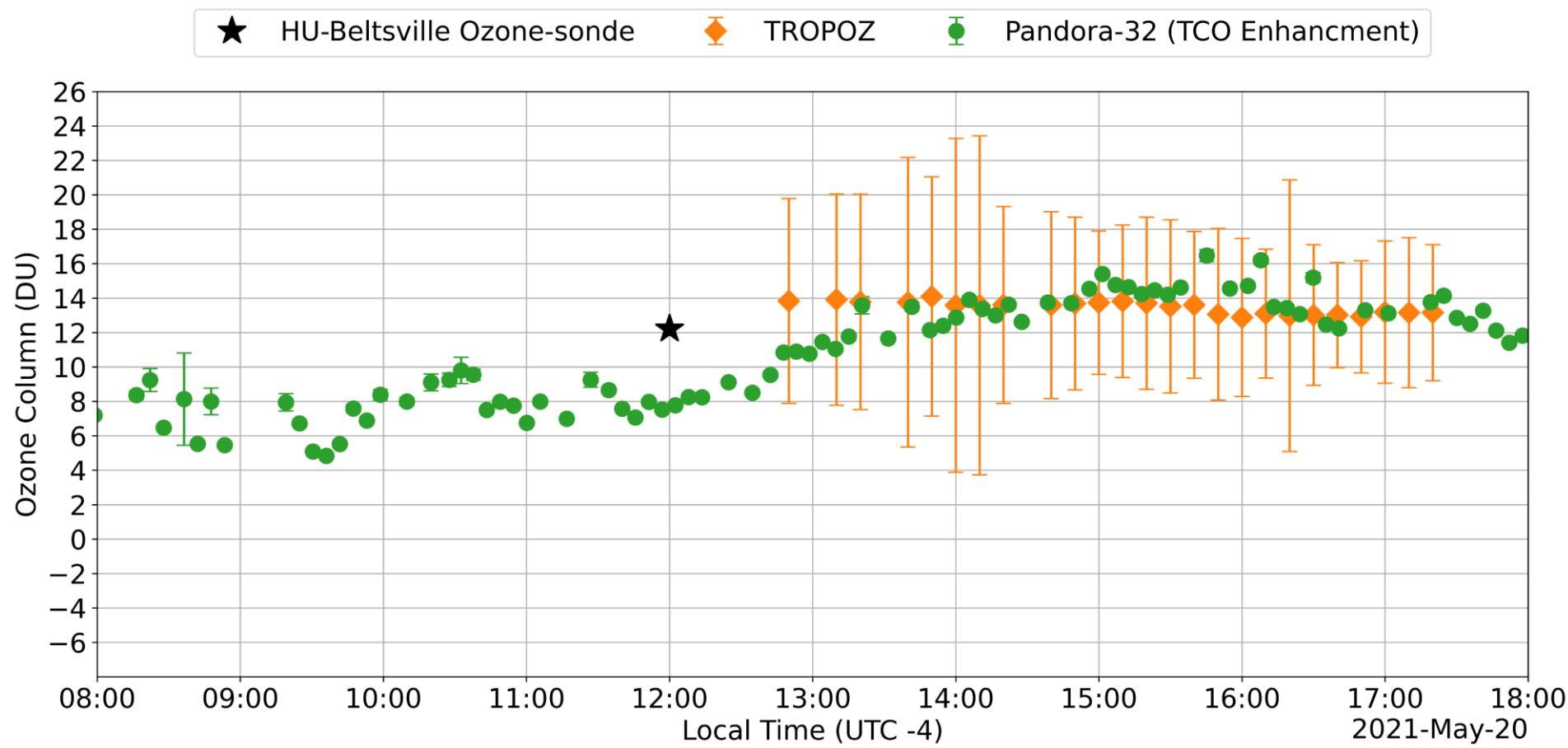


TCO<sub>3</sub> increase known in  
Pandora ~7 DU with Ozone  
lidar 0-2km ~14DU.

No known case study  
relating the Pandora (NASA  
Ground Based Dataset)  
TCO<sub>3</sub> 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<sup>[3]</sup>.
  - 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 & trajectory from GSFC at time of polluted air-mass
- Comparison of Surface, Pandora, and AERONET throughout the Mid-Atlantic

- Aerosol Analysis:

- Analysis of speciated surface PM

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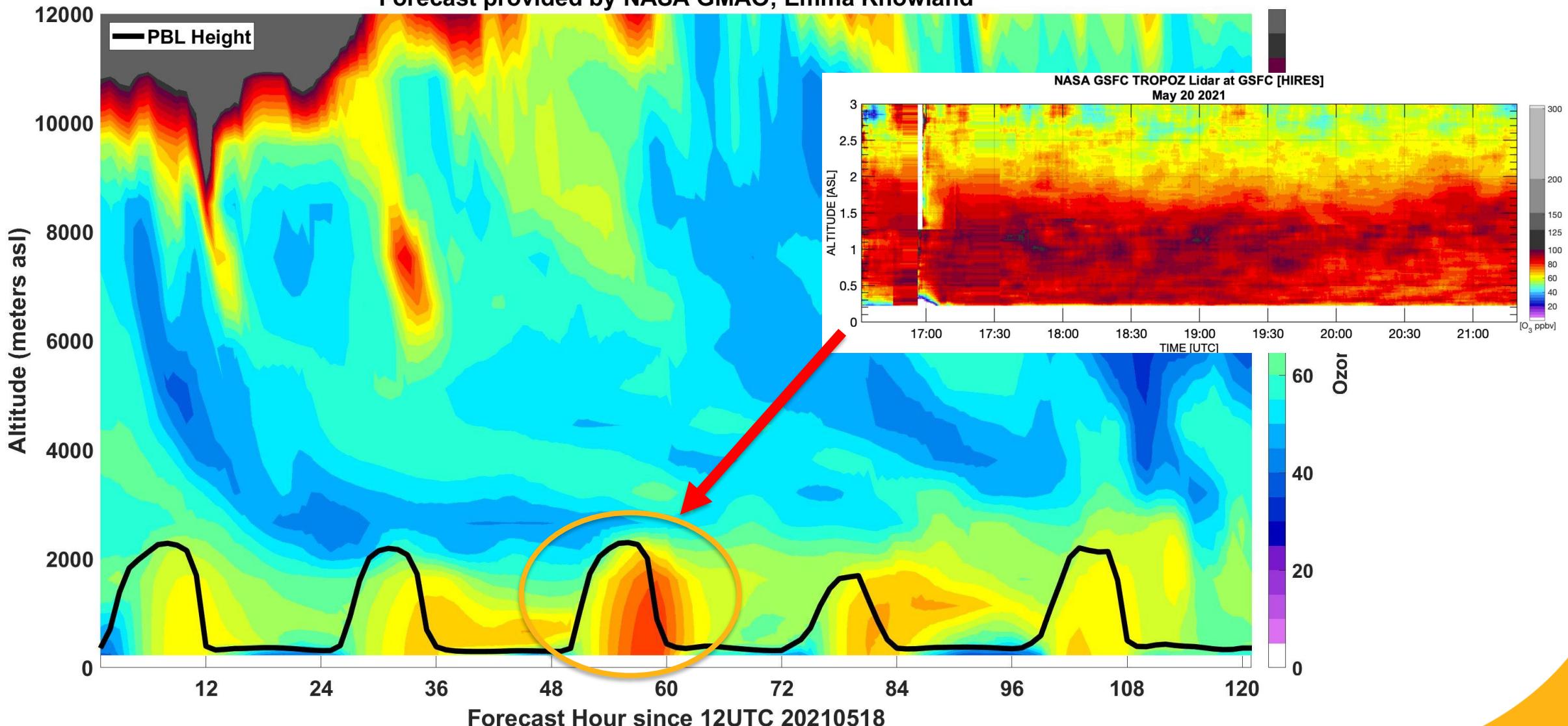
1. Dreessen, J., Sullivan, J., and Delgado, R.: Observations and impacts of transported Canadian wildfire smoke on ozone and aerosol air quality in the Maryland region on June 9–12, 2015, Journal of the Air & Waste Management Association, 66, 842–862, <https://doi.org/10.1080/10962247.2016.1161674>, 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 O<sub>3</sub> 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

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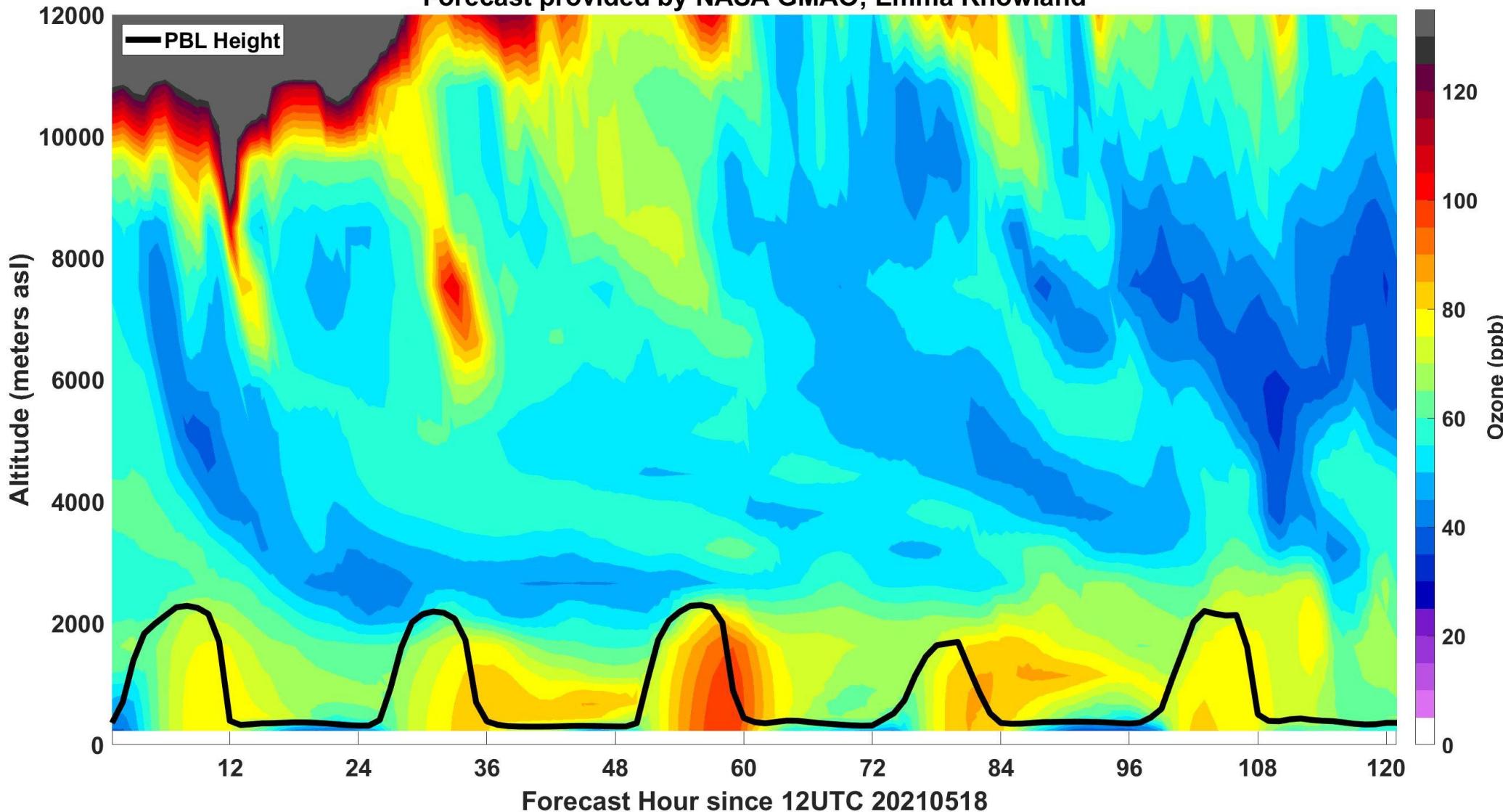
## GEOS-CF Ozone (ppb) - TROPOZ - initialized 12UTC 20210518

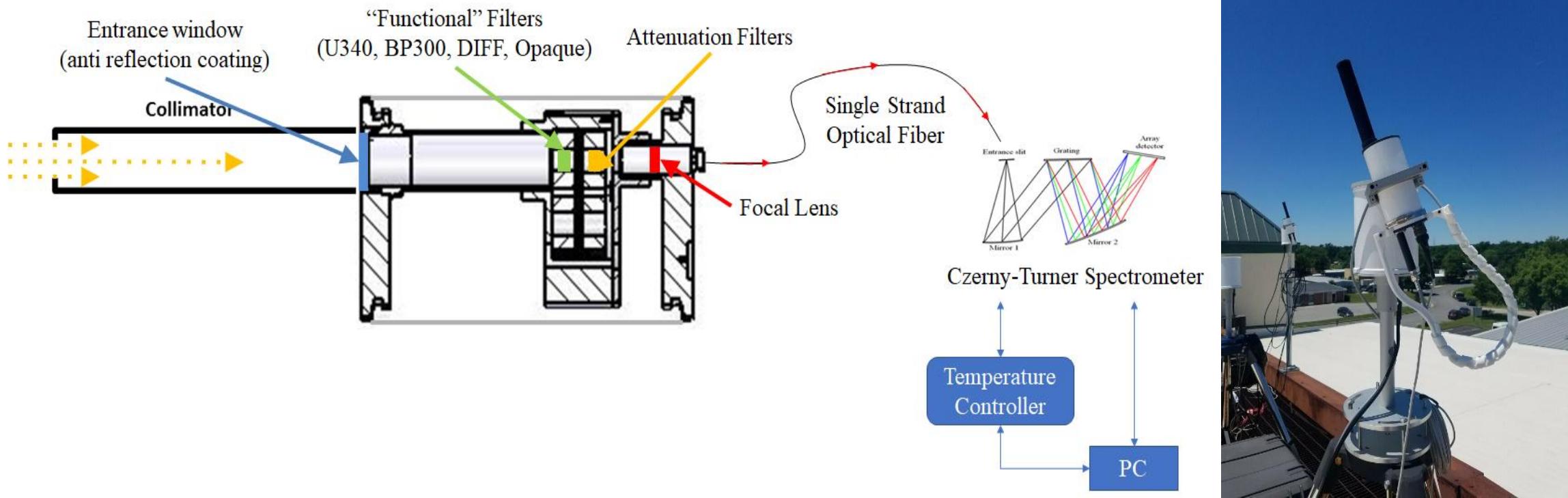
Forecast provided by NASA GMAO; Emma Knowland



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Forecast provided by NASA GMAO; Emma Knowland





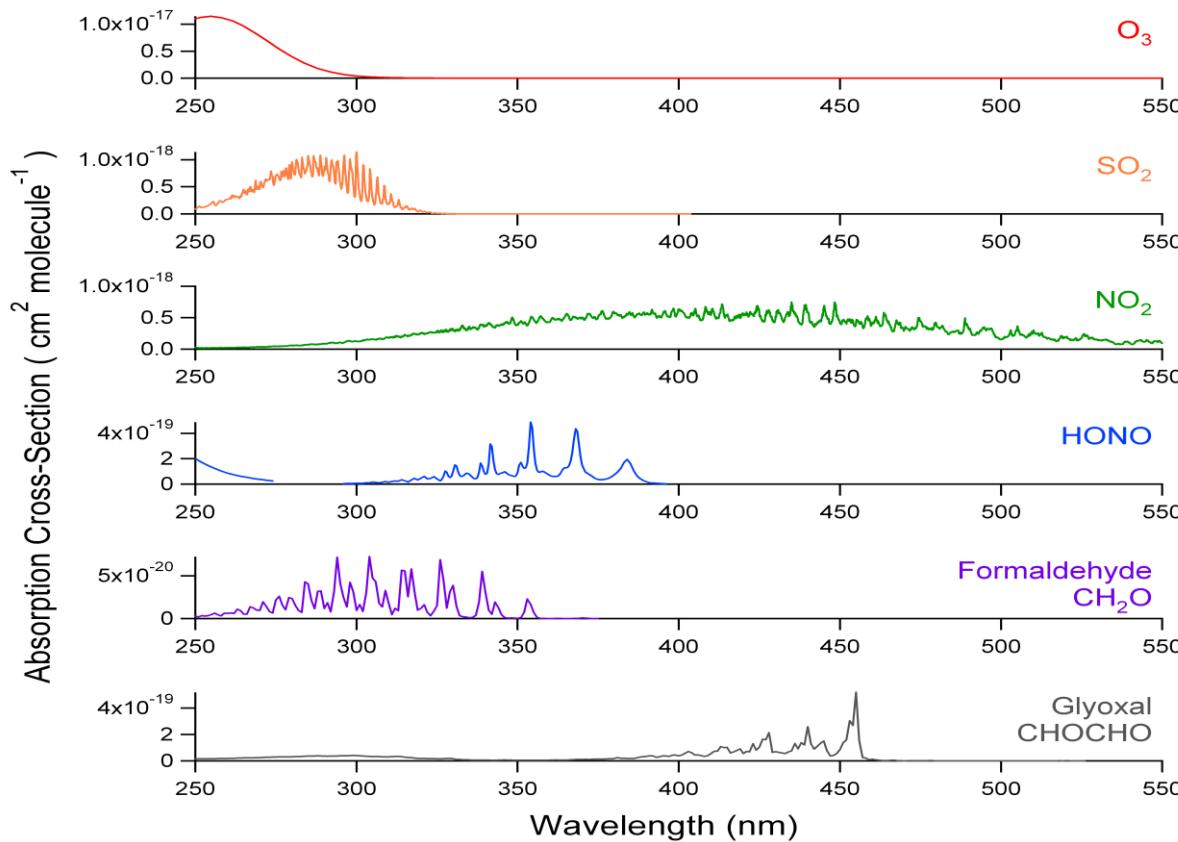
**Figure 6:** (a) Schematic view of Pandora version two (V2) and three (V3) sensor head configuration. (b) The Pandora-1S V3, equipped with; AvaSpec-ULS CCD spectrometer (Czerny-Turner optical design) with 2048 x 64 effective pixels, SciGlob-NASA tracker with 0.01° steps, and Cincoze DC-1100 R10 computer.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

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

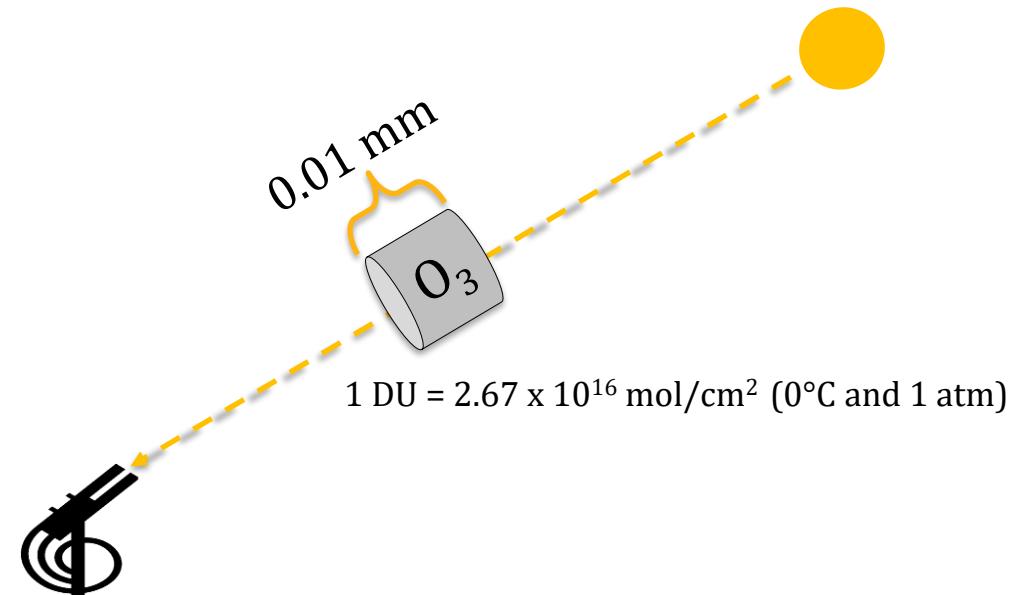
**Direct Sun Differential Optical Absorption Spectroscopy (DS-DOAS)**

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 x 0.01 mm thick

Total Column	NO <sub>2</sub>	O <sub>3</sub>	Research Quality
Precision (DU)	0.002	0.6	SO <sub>2</sub> , HCHO, BrO, H <sub>2</sub> O
Accuracy (DU)	0.05	15	

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

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 O<sub>3</sub> lidars
- ▶ 8 Pandora Spectrometers (O<sub>3</sub>, NO<sub>2</sub>, HCHO)
- ▶ Routine regulatory monitoring measurements
- ▶ 70 ozonesondes
- ▶ Boat measurements
- ▶ Mobile labs both supported by TRACER mission (July-August) and another pending NSF Support

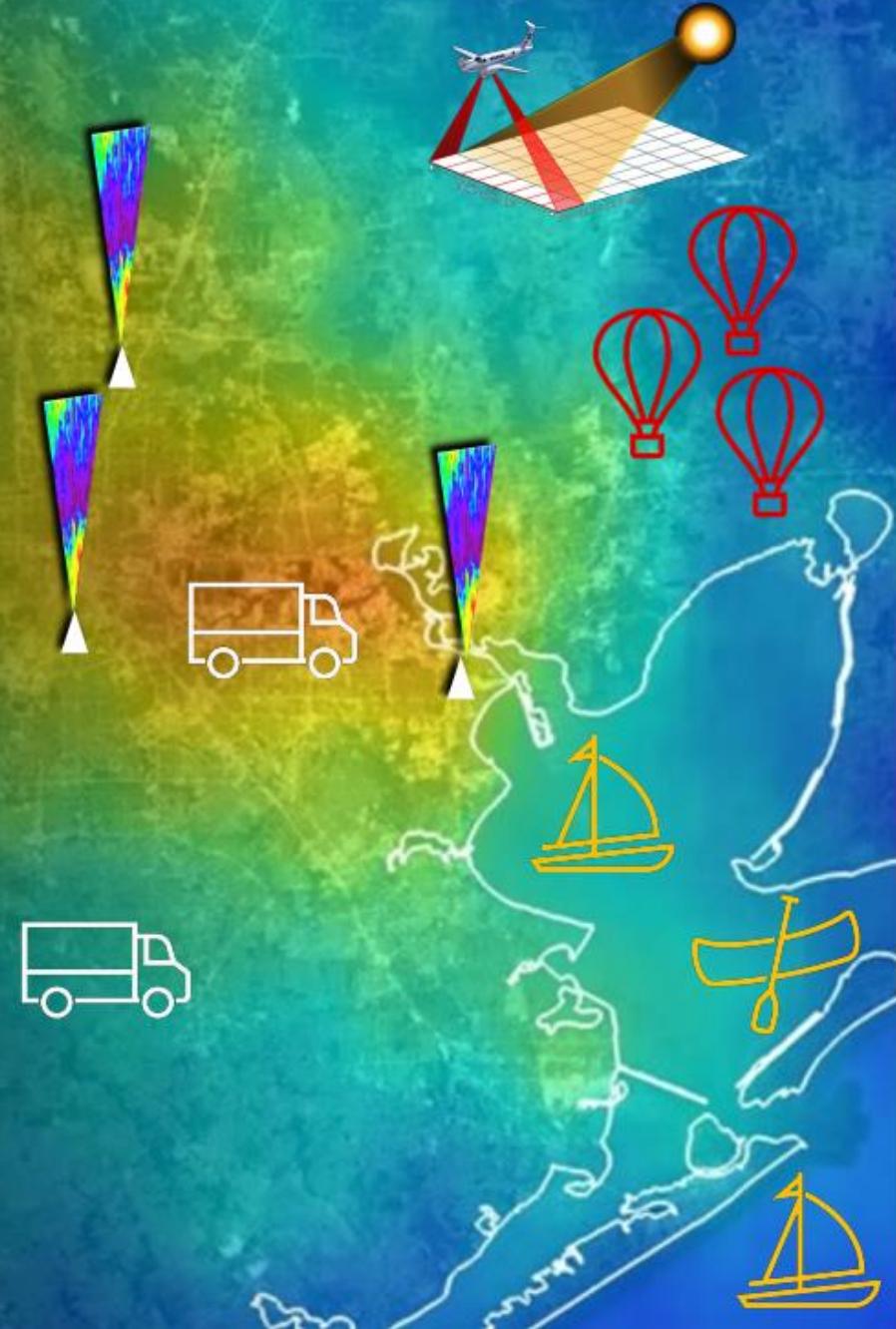
→ NASA JSC G-V Aircraft (77 flight hours)

- ▶ GCAS+HSRL2-DIAL (O<sub>3</sub>, NO<sub>2</sub>, 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!

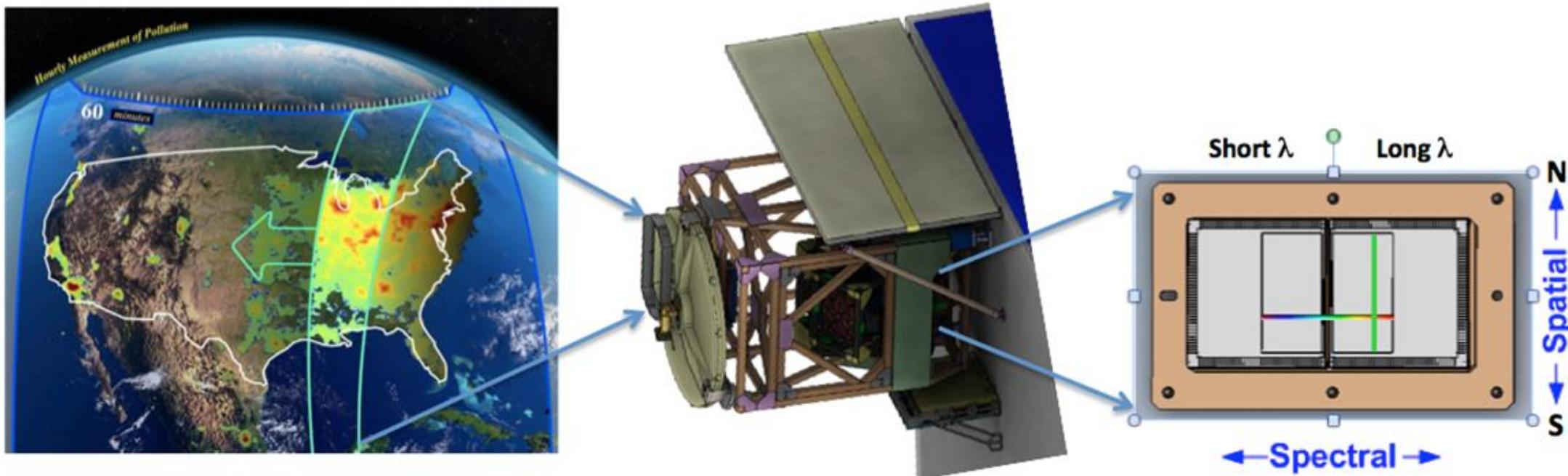


### Tropospheric Emissions Monitoring of POllution

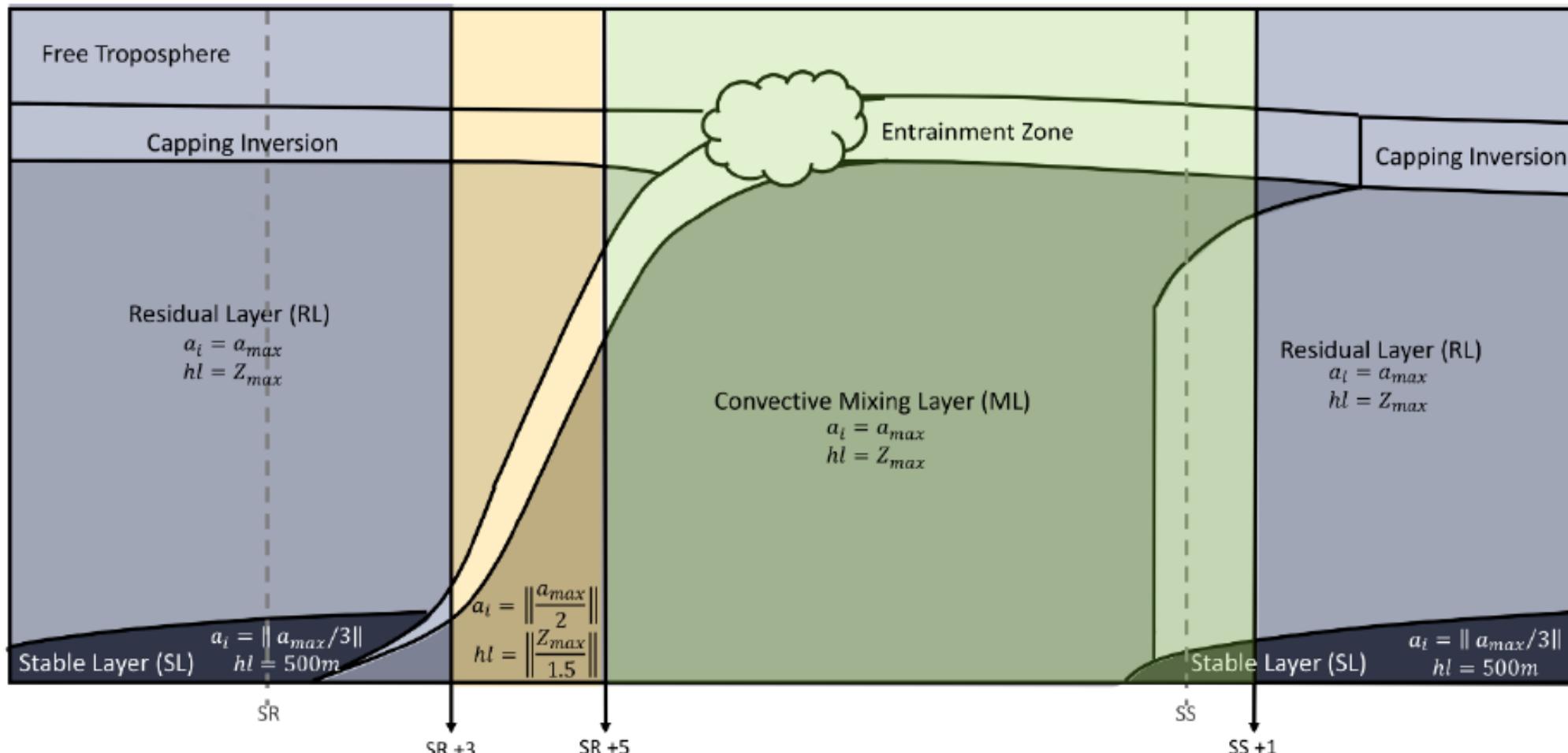
Spectral range: 290–740 nm (UV, VIS)   spectral sampling: 0.2 nm   spectral resolution: 0.6 nm

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  $36.5^{\circ}$  N,  $100^{\circ}$  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

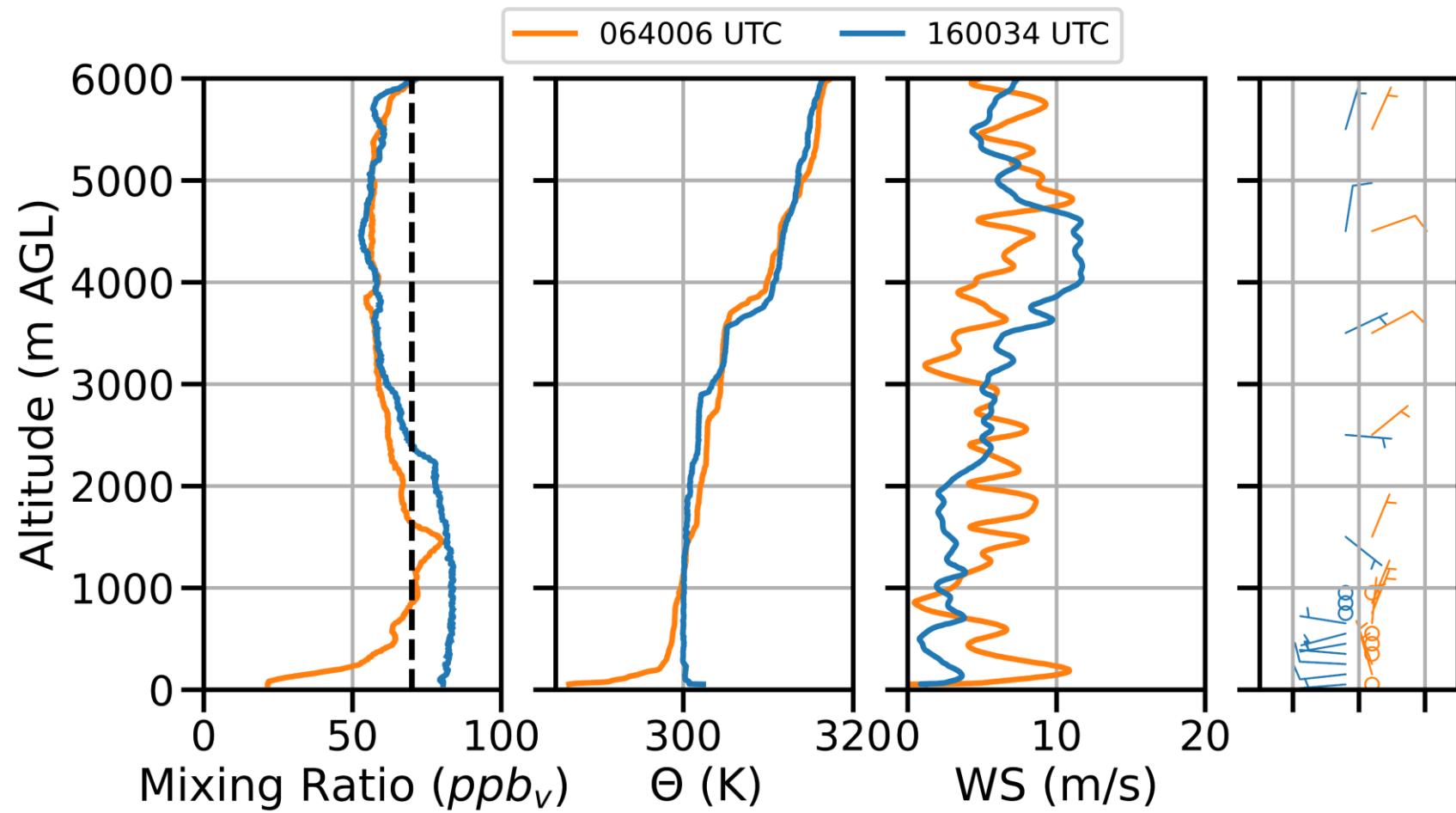


# PBL Evolution (Adapted from Stull)

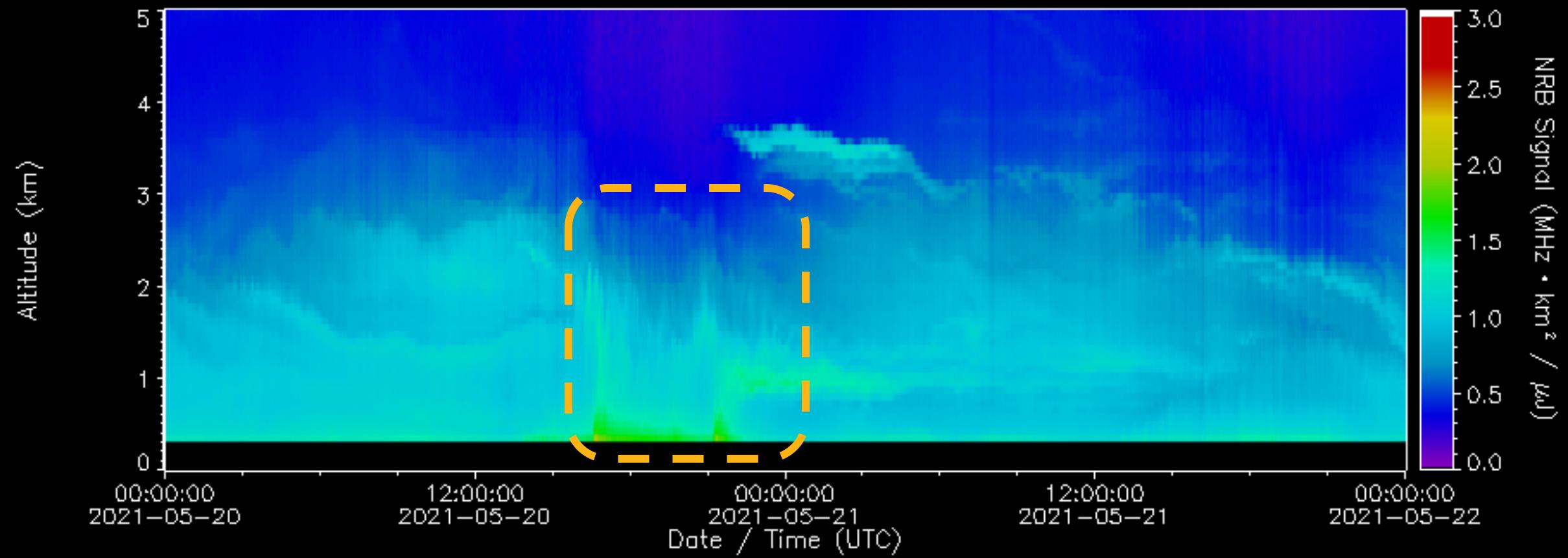




HUBV Ozone Sonde: 05/20/2021

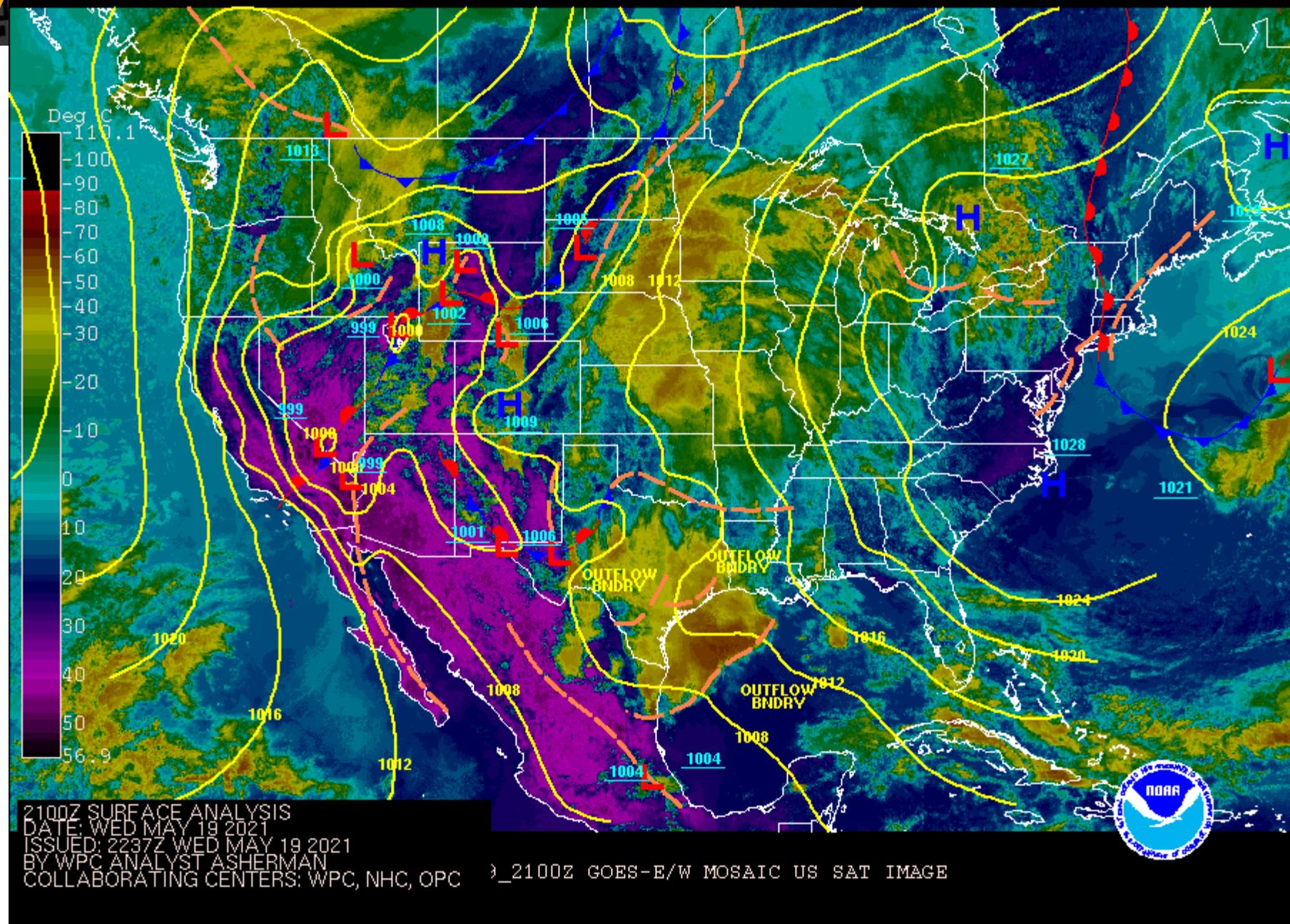


MPLNET GSFC 2021-05-20...2021-05-21: V3\_1\_NRB (MPL44258, 532.00 nm)



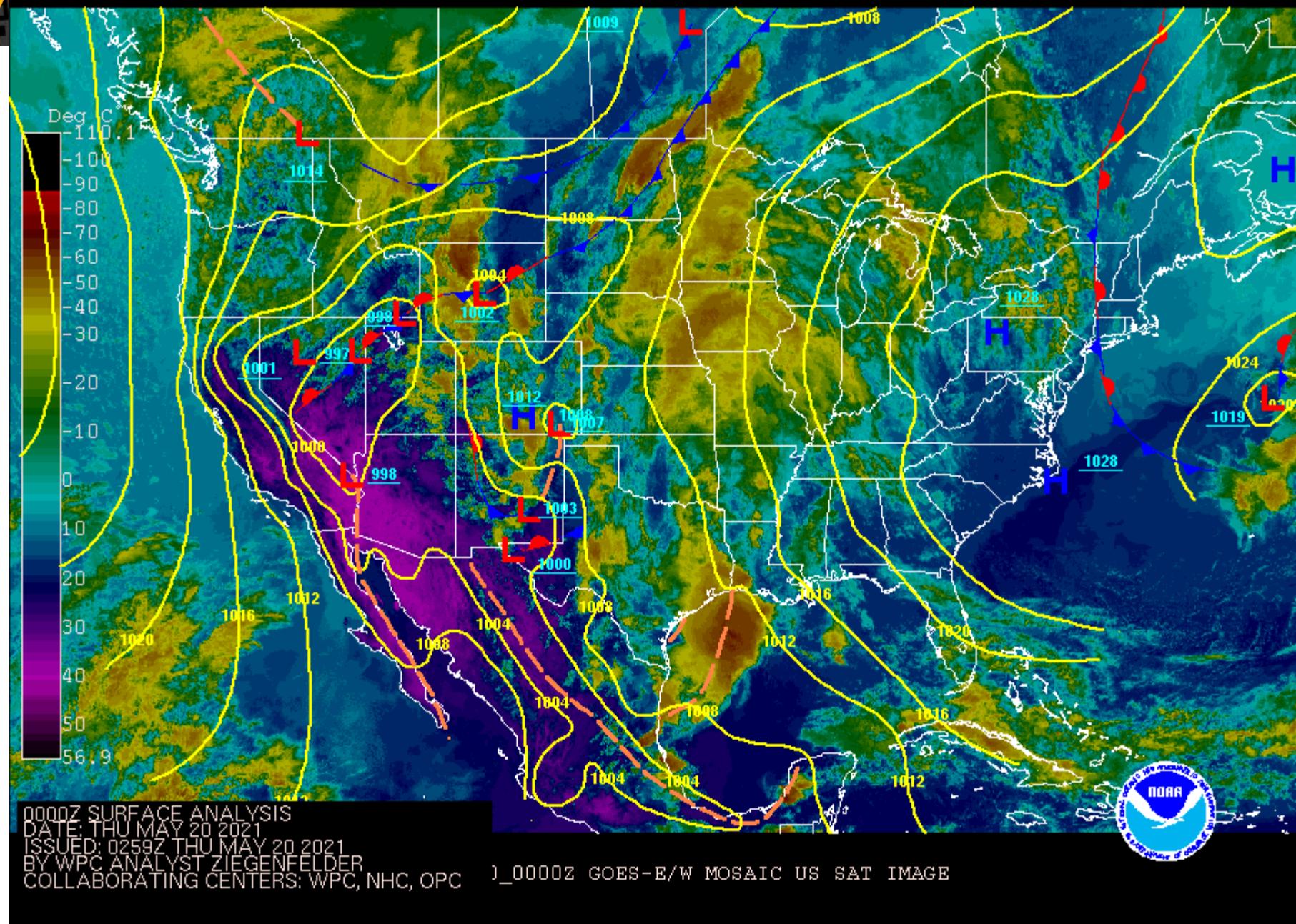


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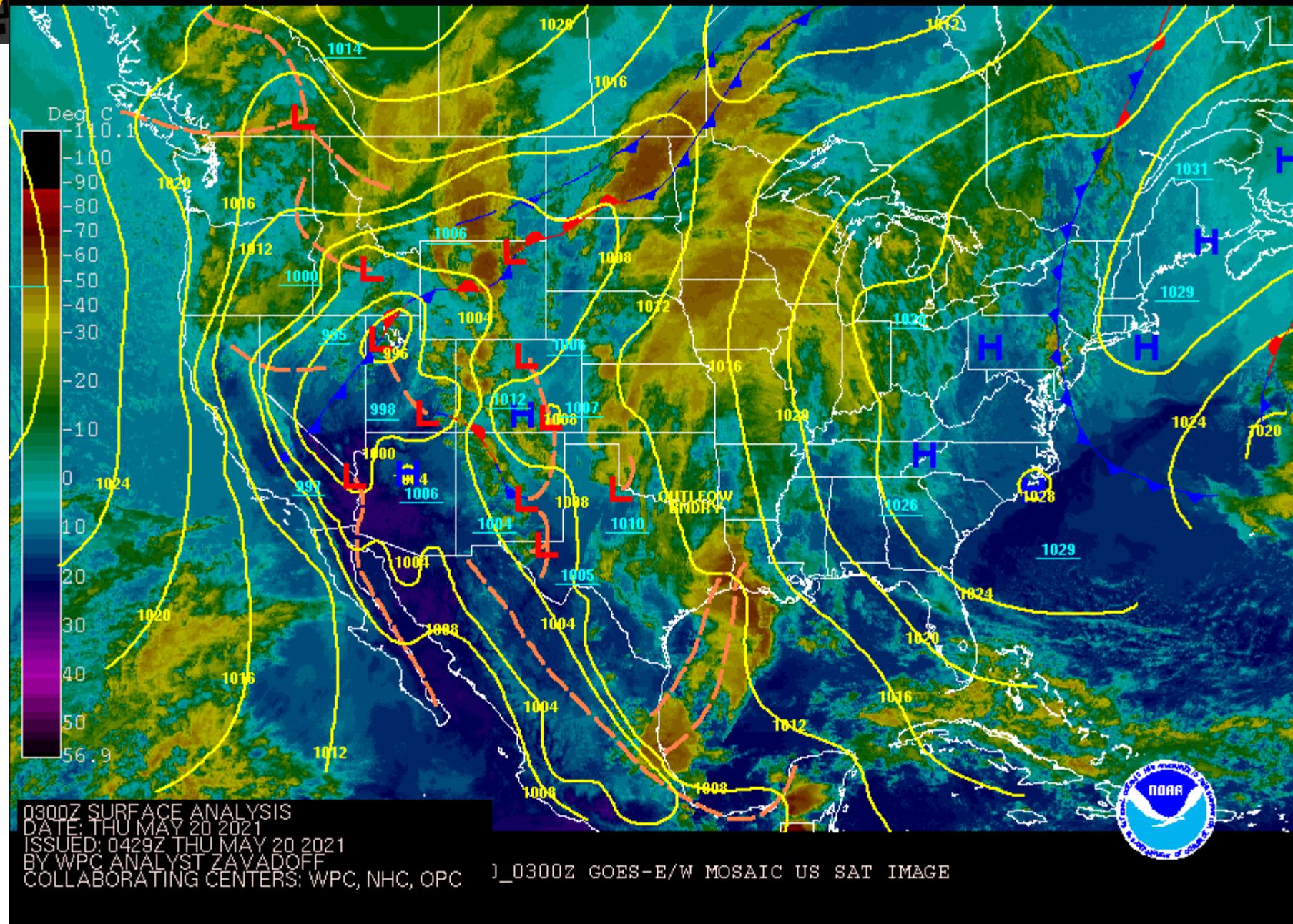


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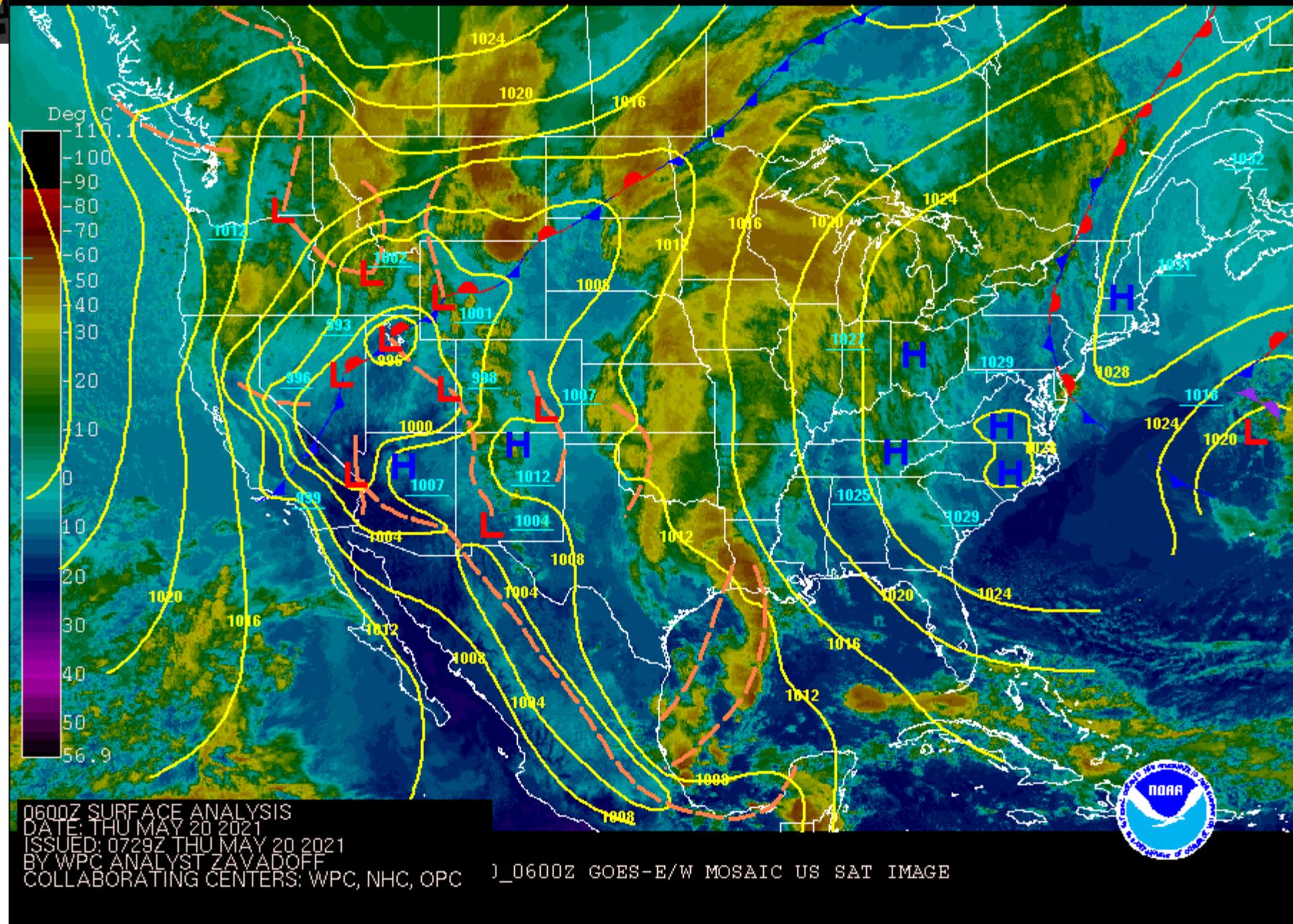


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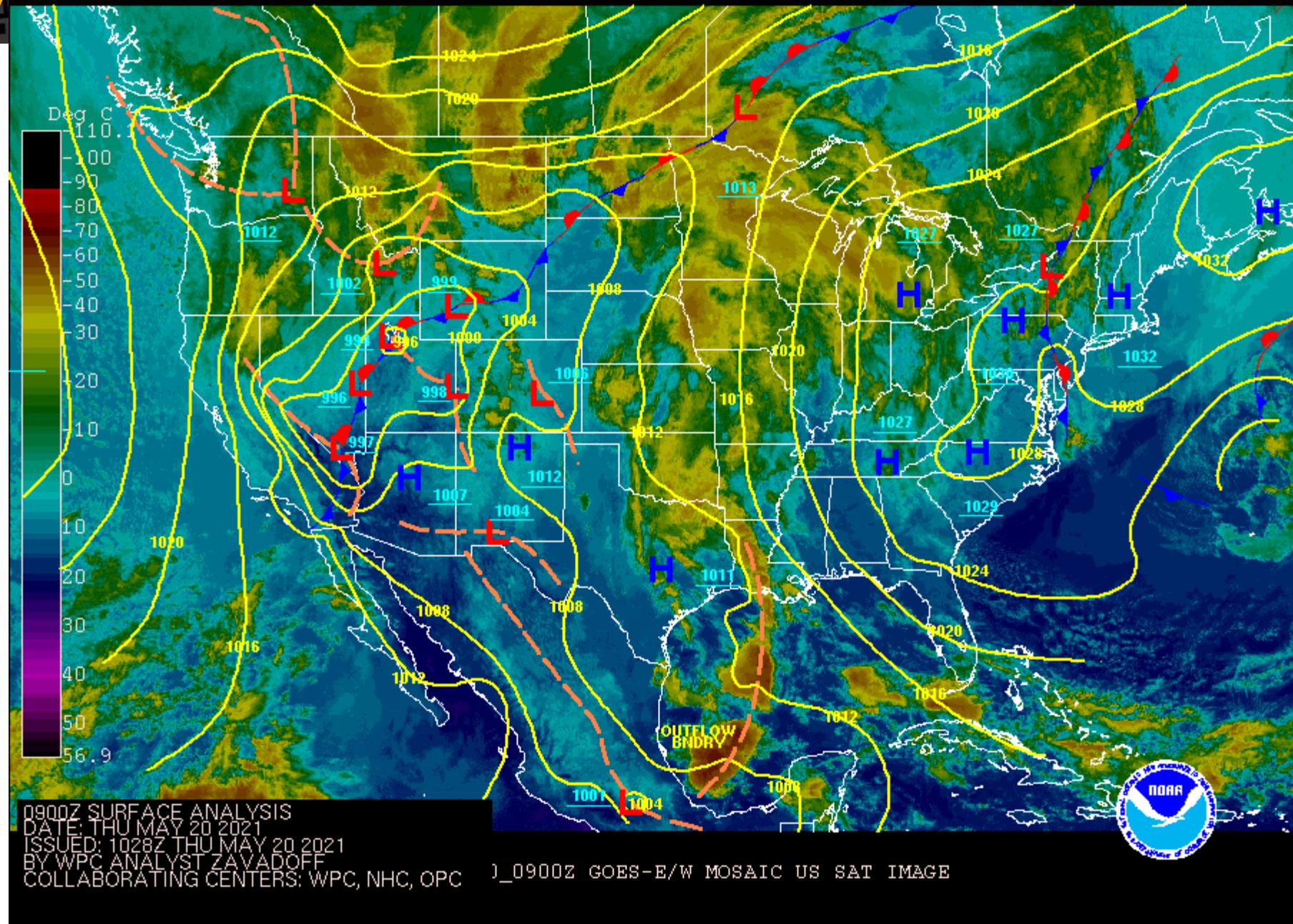


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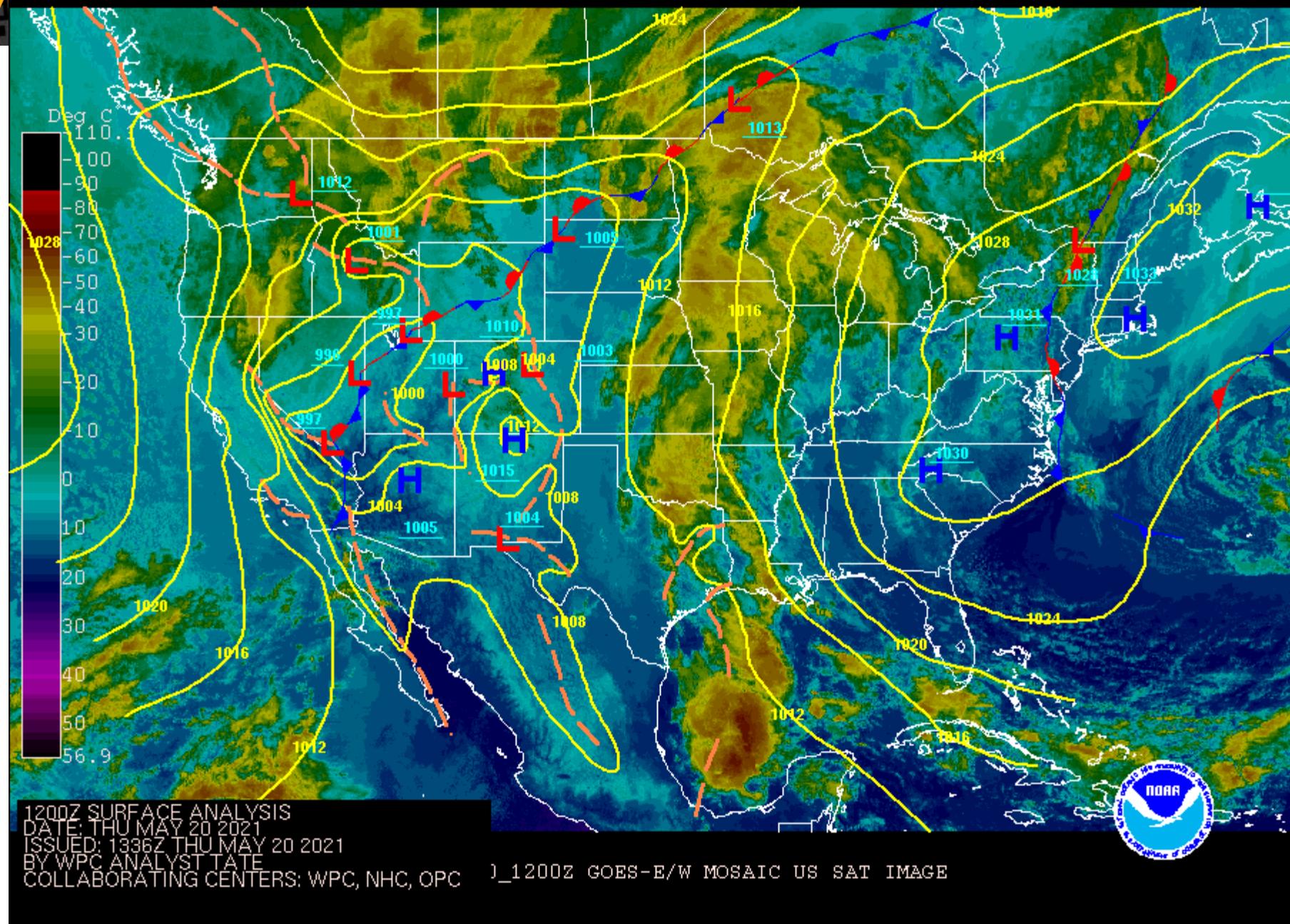


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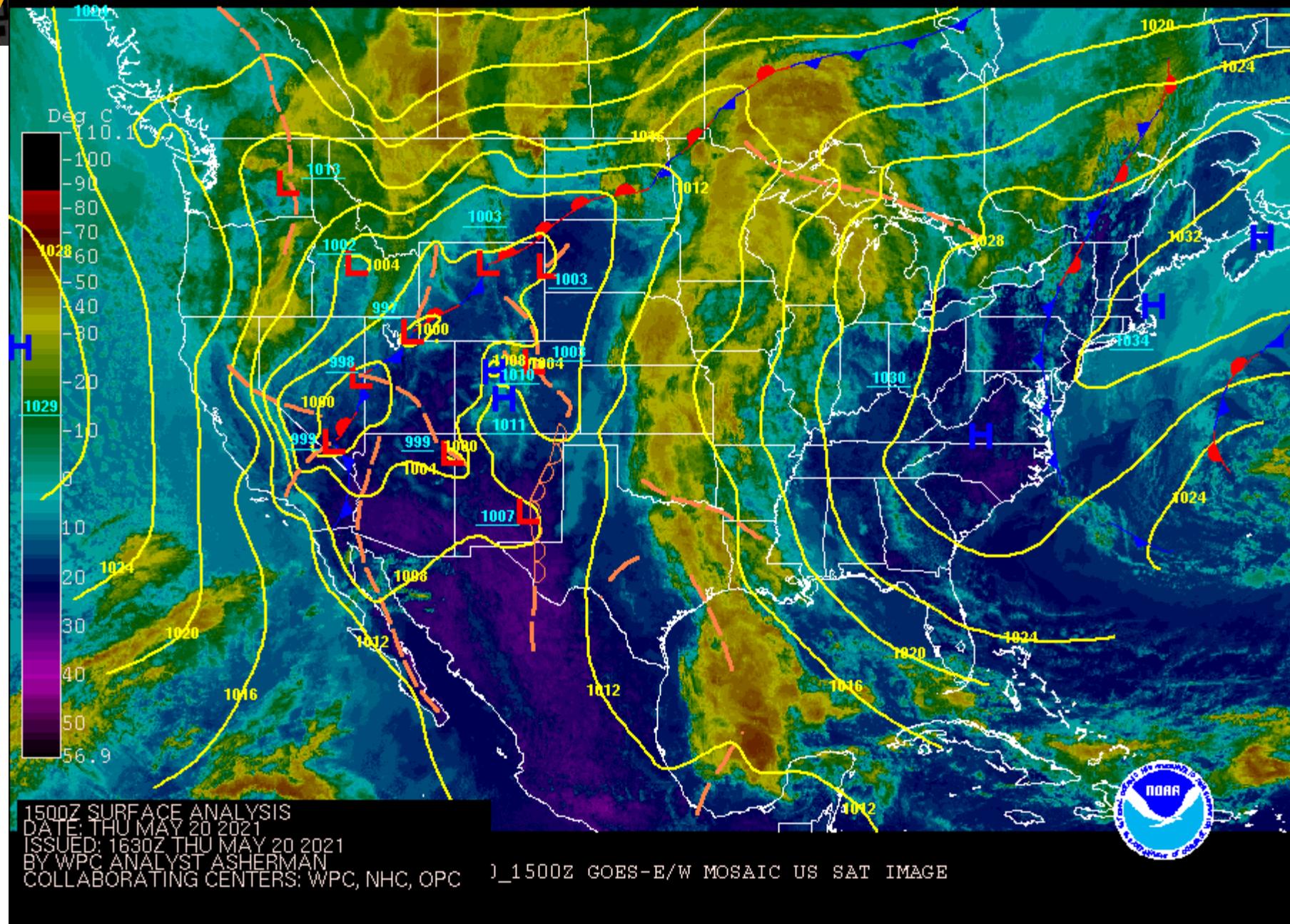


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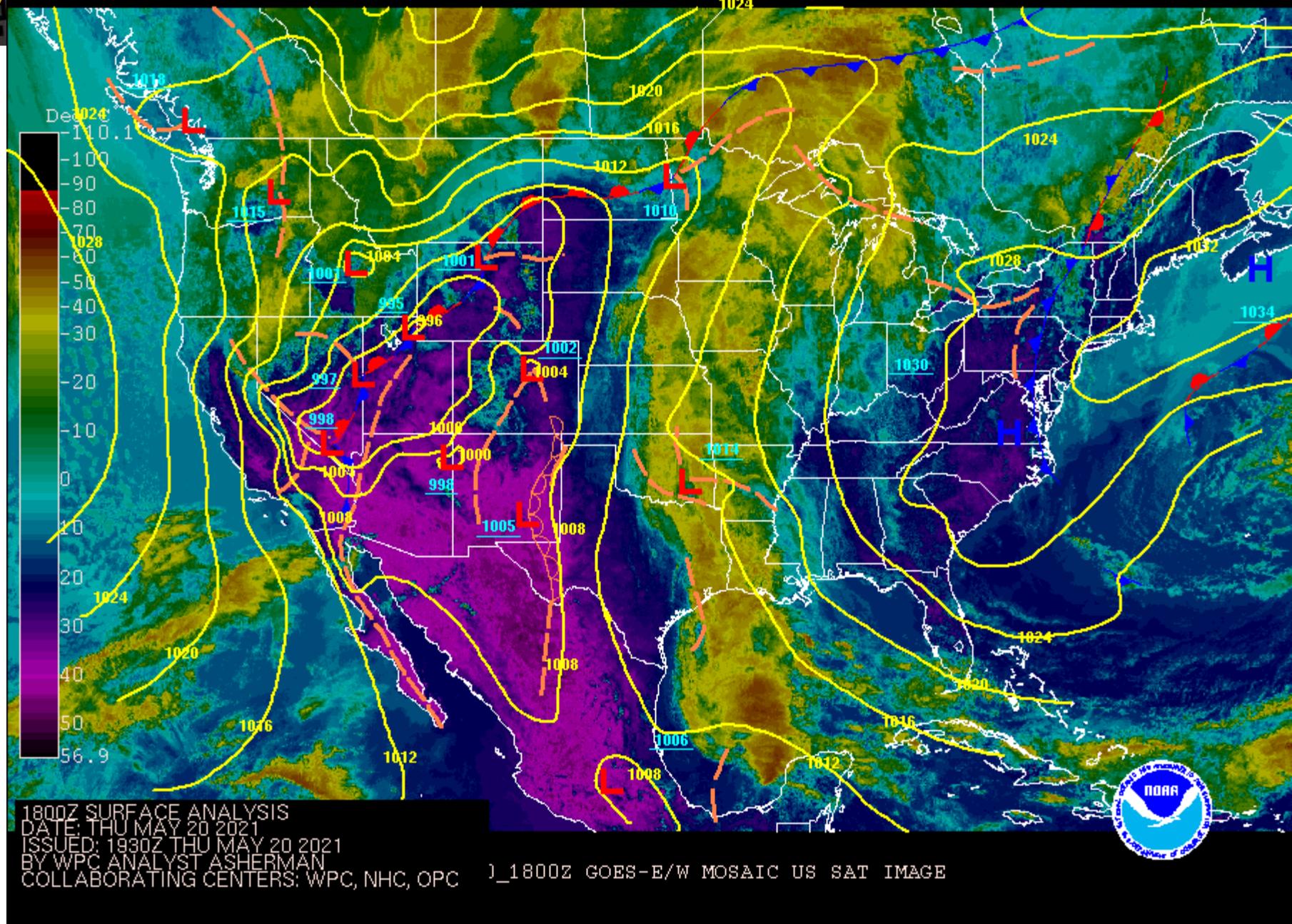


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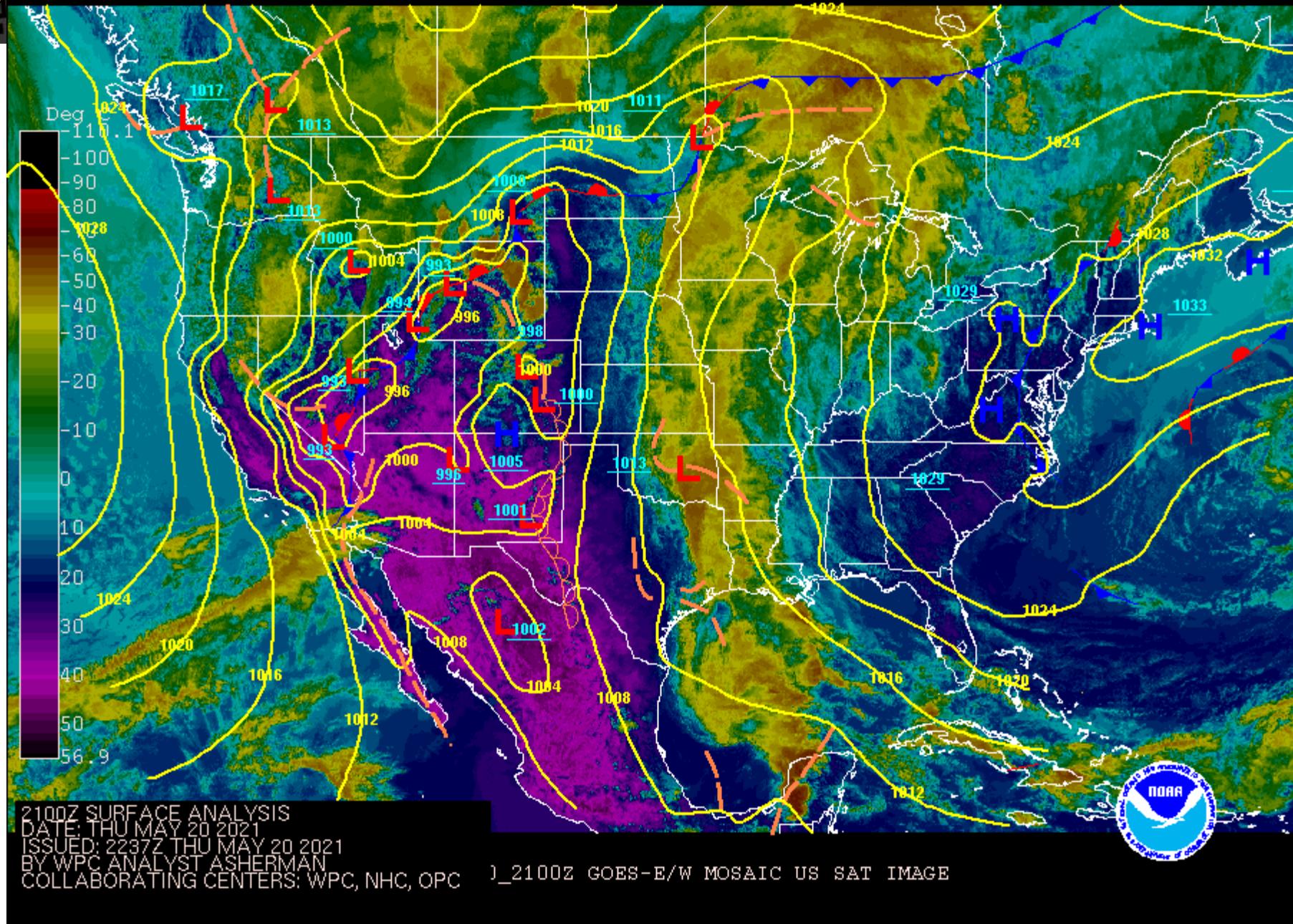


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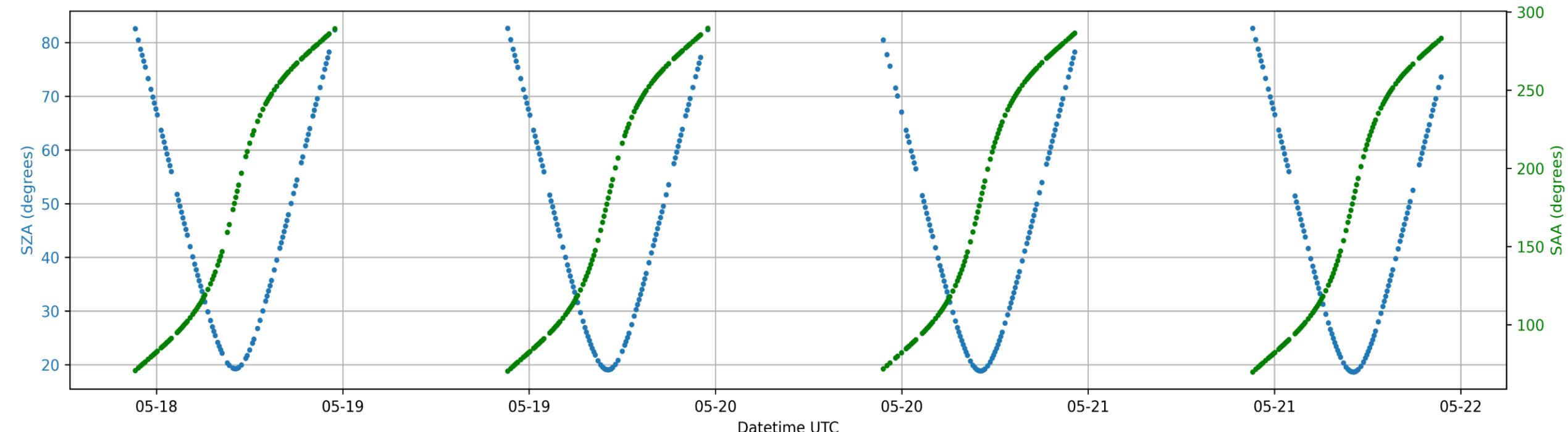
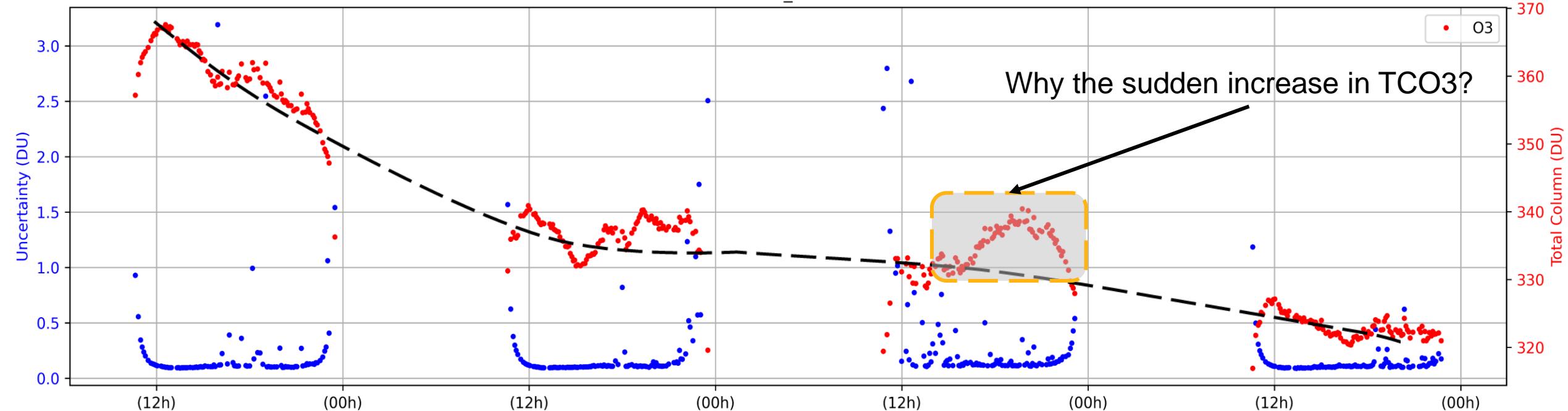




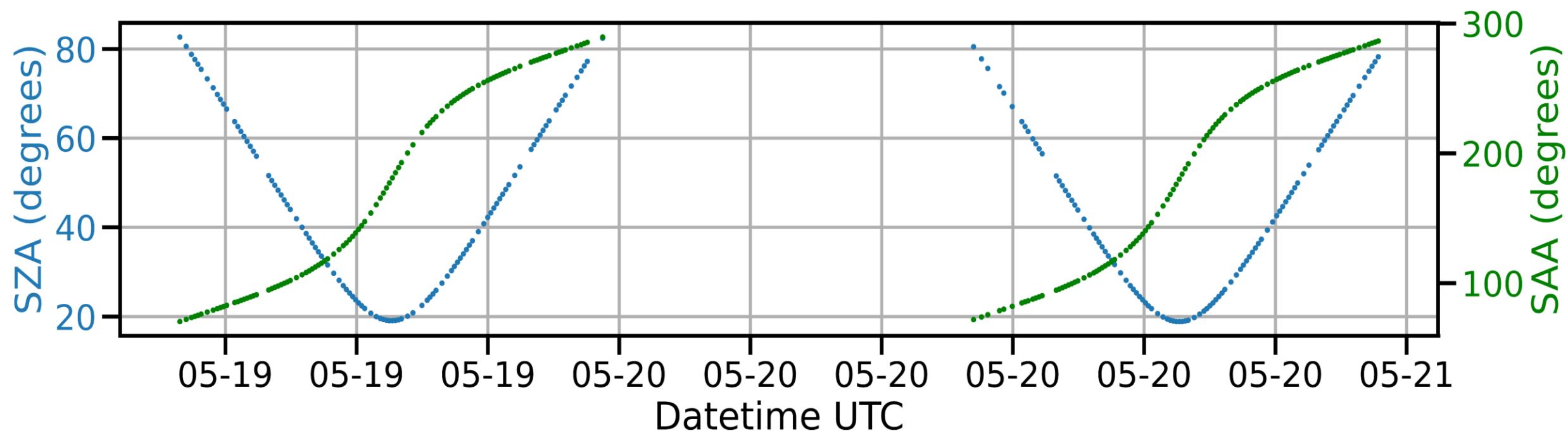
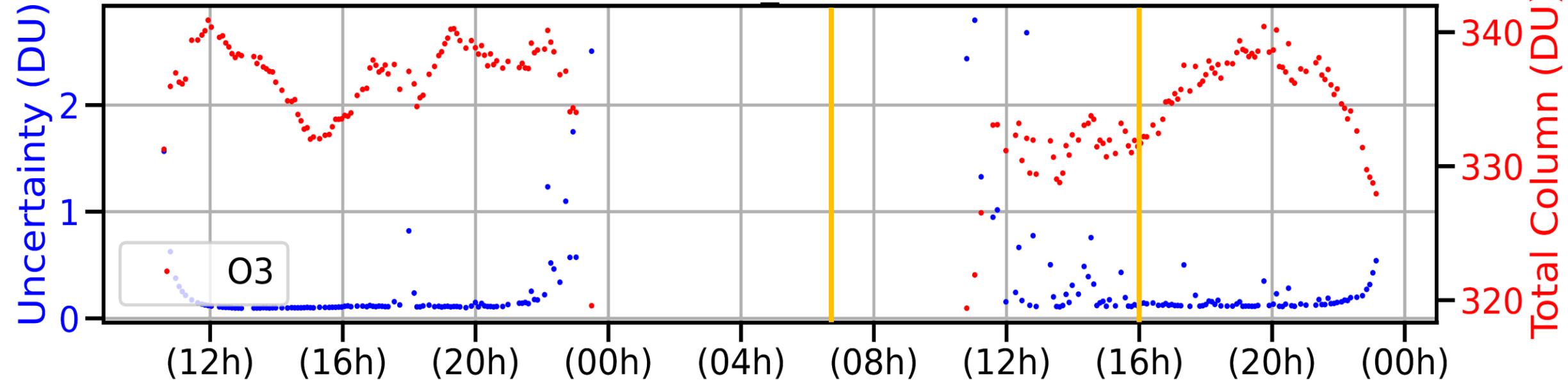
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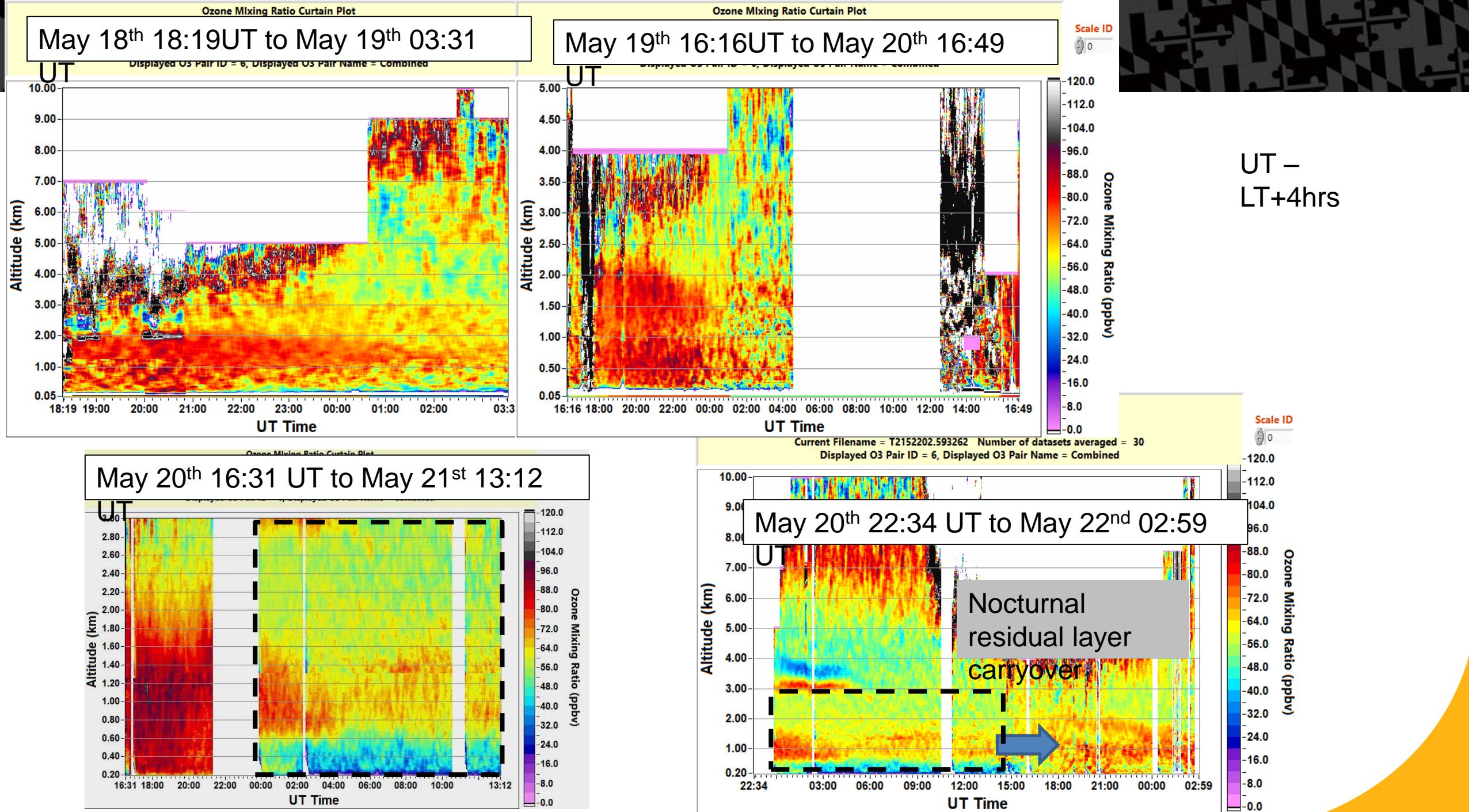


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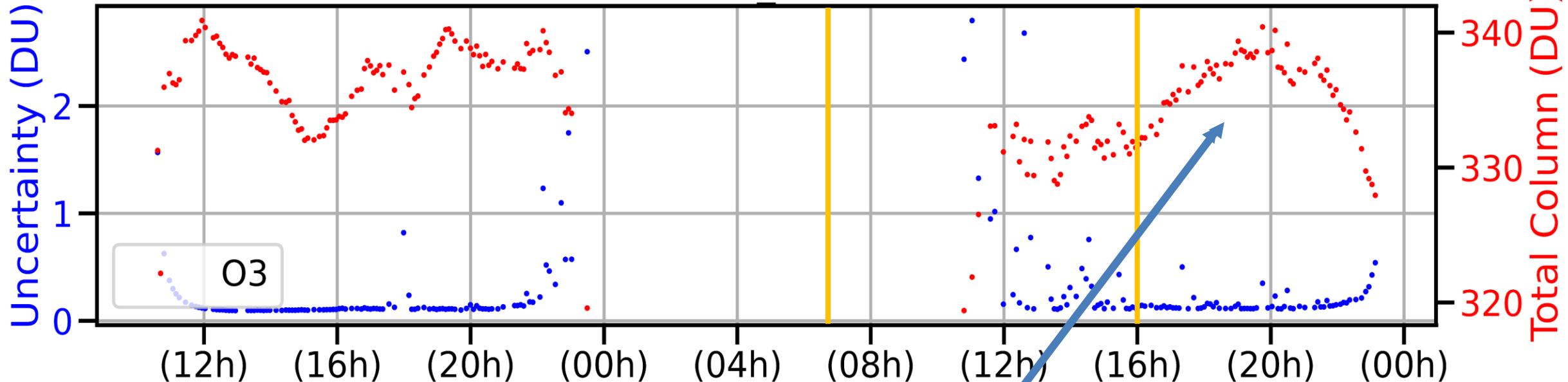


20210519T1036 20210520T2330





20210519T1036 20210520T2330



O3

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

