



# XCH<sub>4</sub>, Aerosol, and PBLH Measurements with the High-Altitude Lidar Observatory

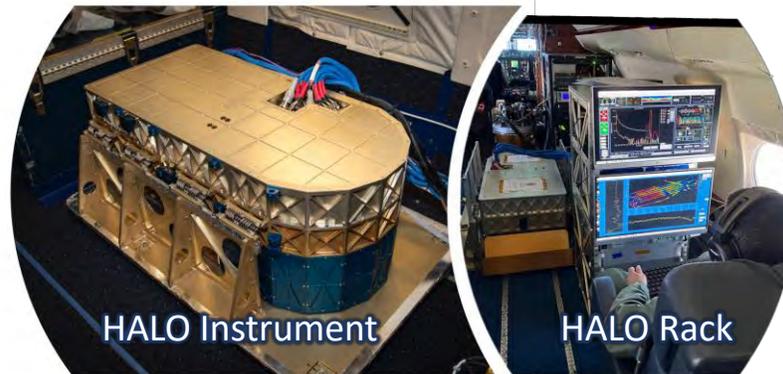
Amin Nehrir, Rory Barton-Grimley, Steven Wofsy, Sean Crowell, Roisin Commane  
and

HALO and MethaneAir Teams

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Langley  
Research  
Center



HALO Instrument

HALO Rack

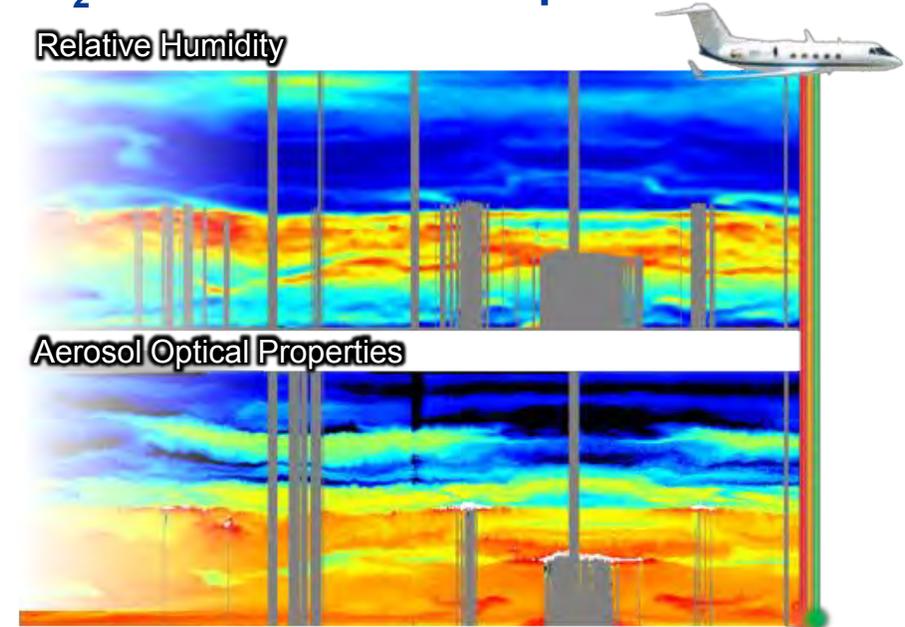


# HALO – Cross-Cutting DIAL and HSRL



## H<sub>2</sub>O Differential Absorption Lidar

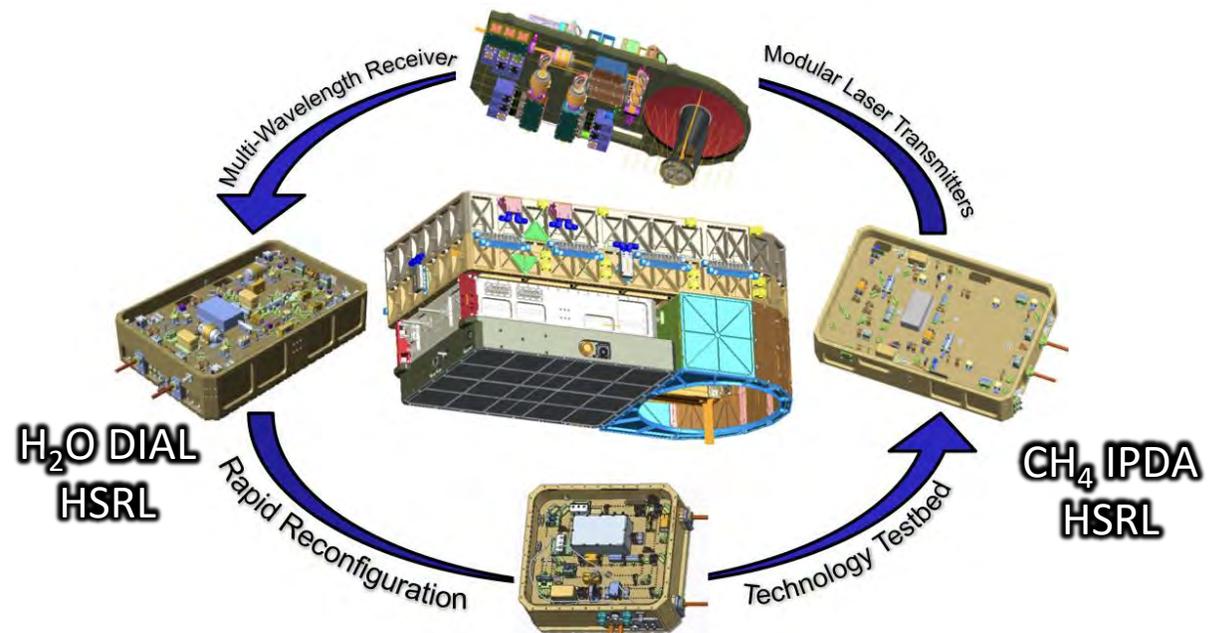
Relative Humidity



Aerosol Optical Properties

- $4\lambda$  935 nm water vapor differential absorption lidar (DIAL)
  - Carroll et al. 2022, AMT
- $2\lambda$  1645 nm methane integrated path DIAL (IPDA)
  - Barton-Grimley et al. 2022, AMT
- 532 nm high spectral resolution lidar (HSRL), 1064 nm backscatter
  - Hair et al. 2008, Applied Optics

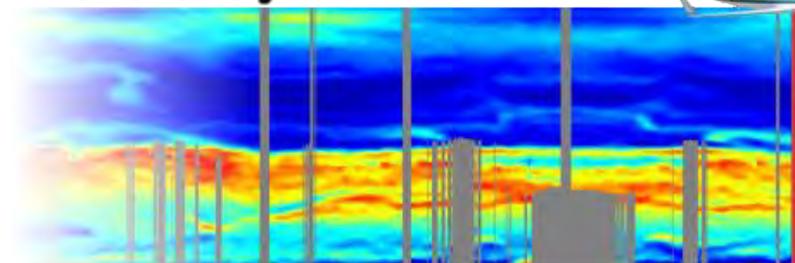
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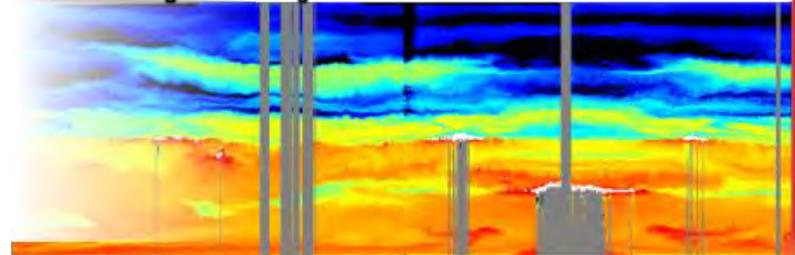
**CH<sub>4</sub> IPDA, H<sub>2</sub>O DIAL, Doppler Winds, HSRL**

## H<sub>2</sub>O Differential Absorption Lidar

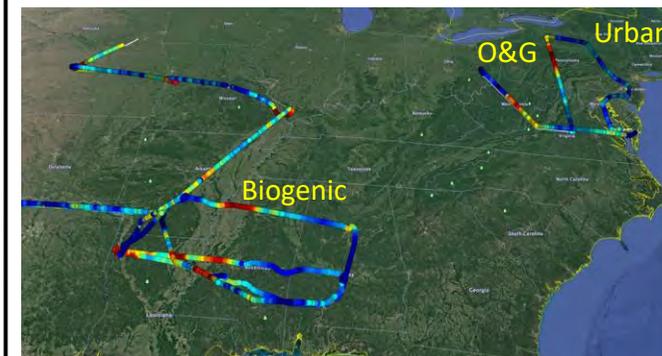
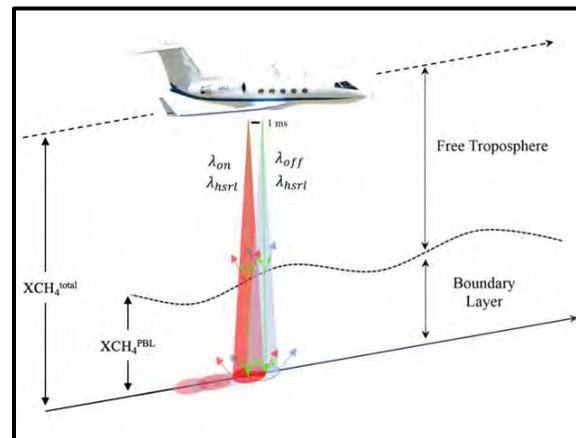
Relative Humidity



Aerosol Optical Properties



## CH<sub>4</sub> Integrated Path Differential Absorption (IPDA)

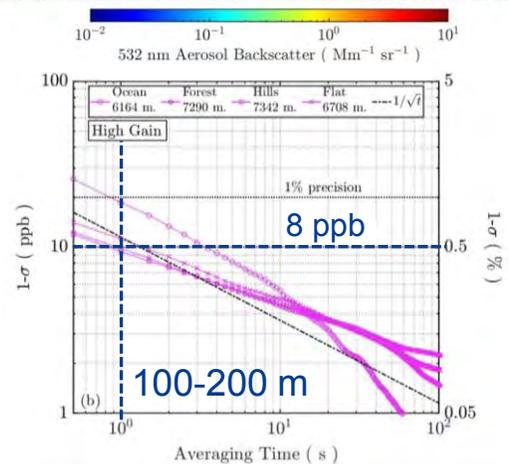
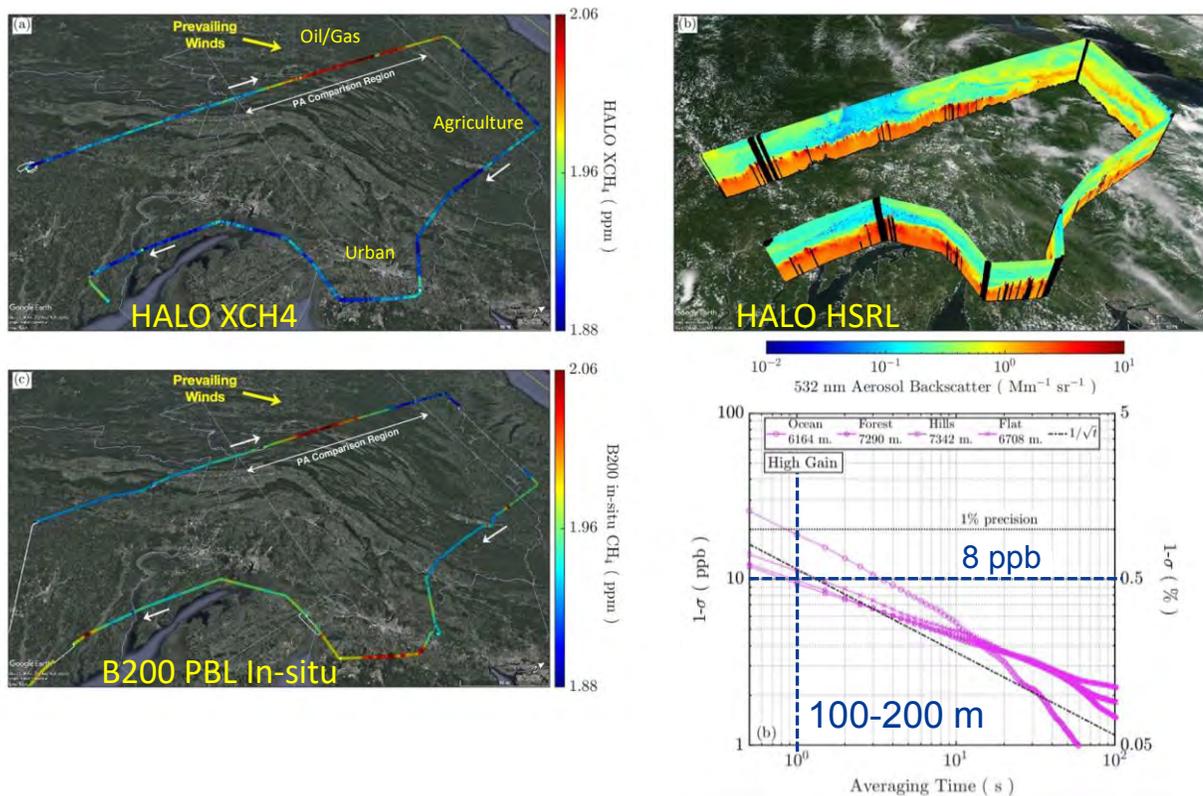


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# HALO validation during ACT-America and STAQS



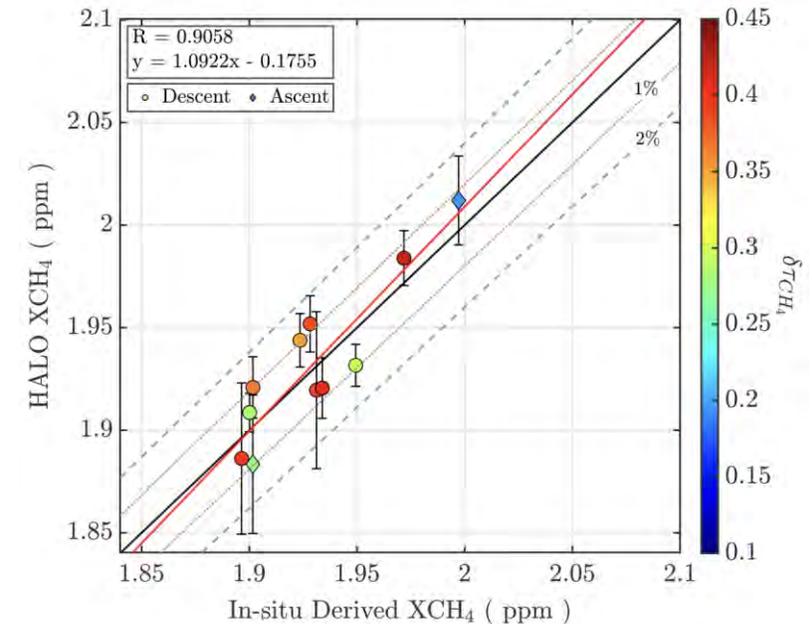
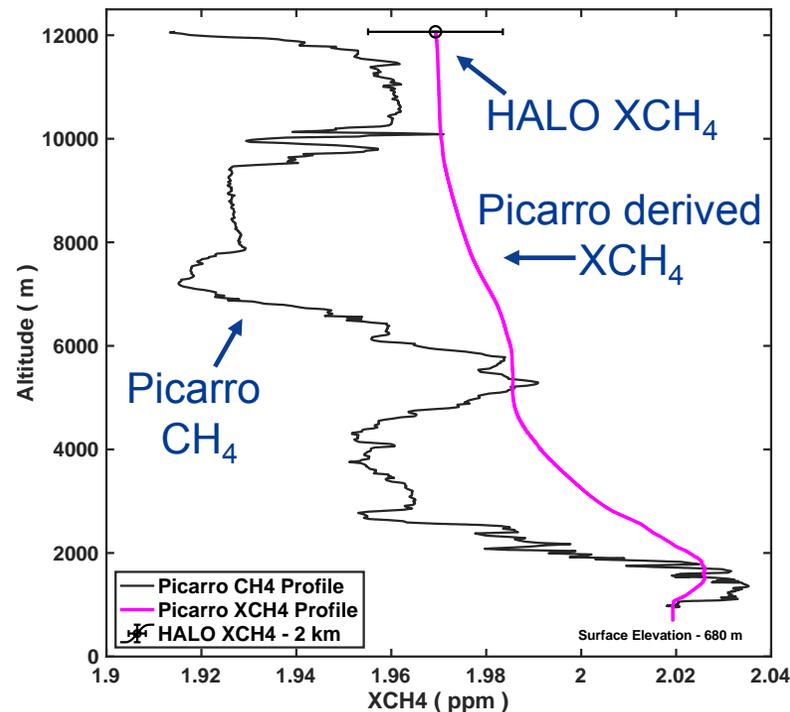
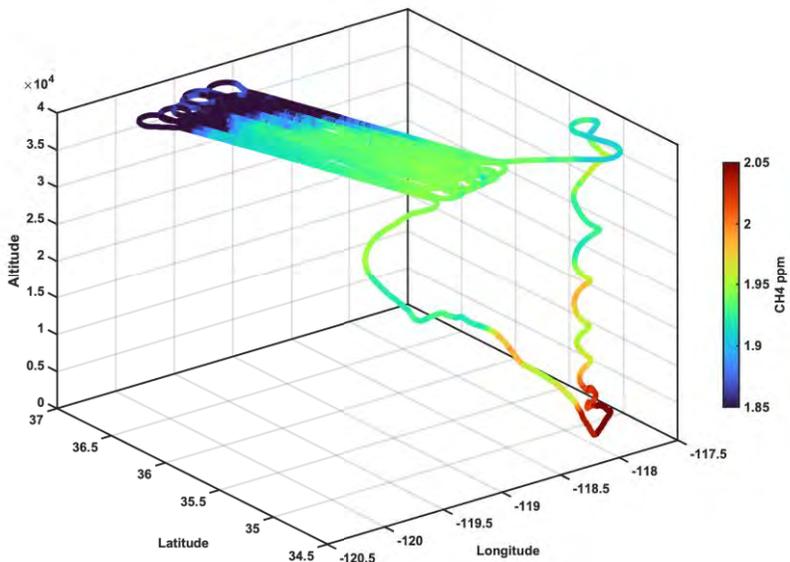
- Validated  $\text{CH}_4$  retrievals against co-located in-situ obs.
  - Excellent agreement with B200 in-situ, PBL sensitivity over the column
  - <1% bias, <.5% precision compared to vertical soundings
- First demonstrations of airborne range resolved profiling



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# Synergistic TEMPO Air Quality Science (STAQS)



- HALO flew on the NASA LaRC G-III during STAQS with AVIRIS-NG and PICARRO

## Flight Campaign Goals:

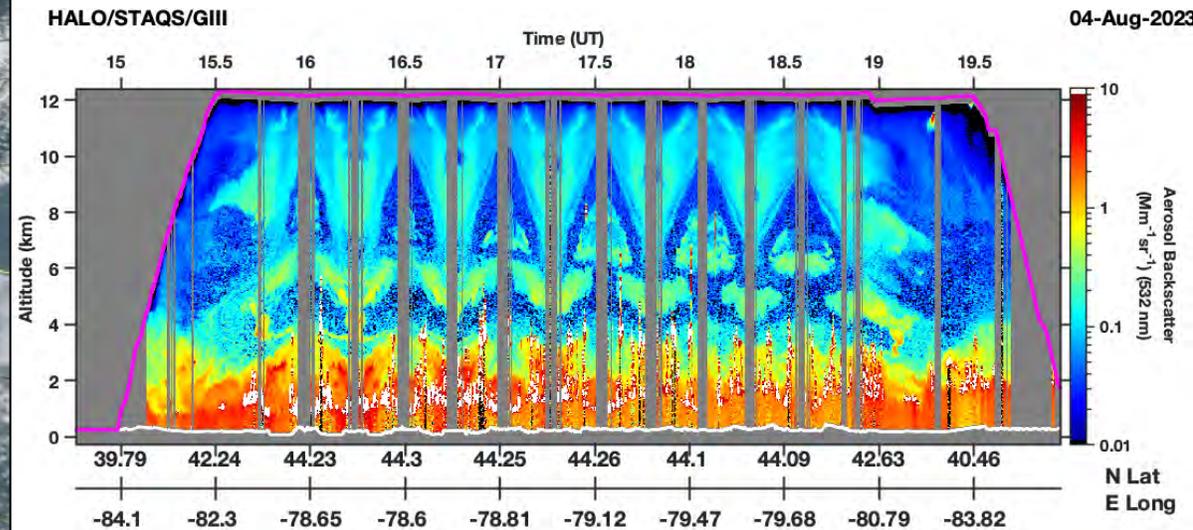
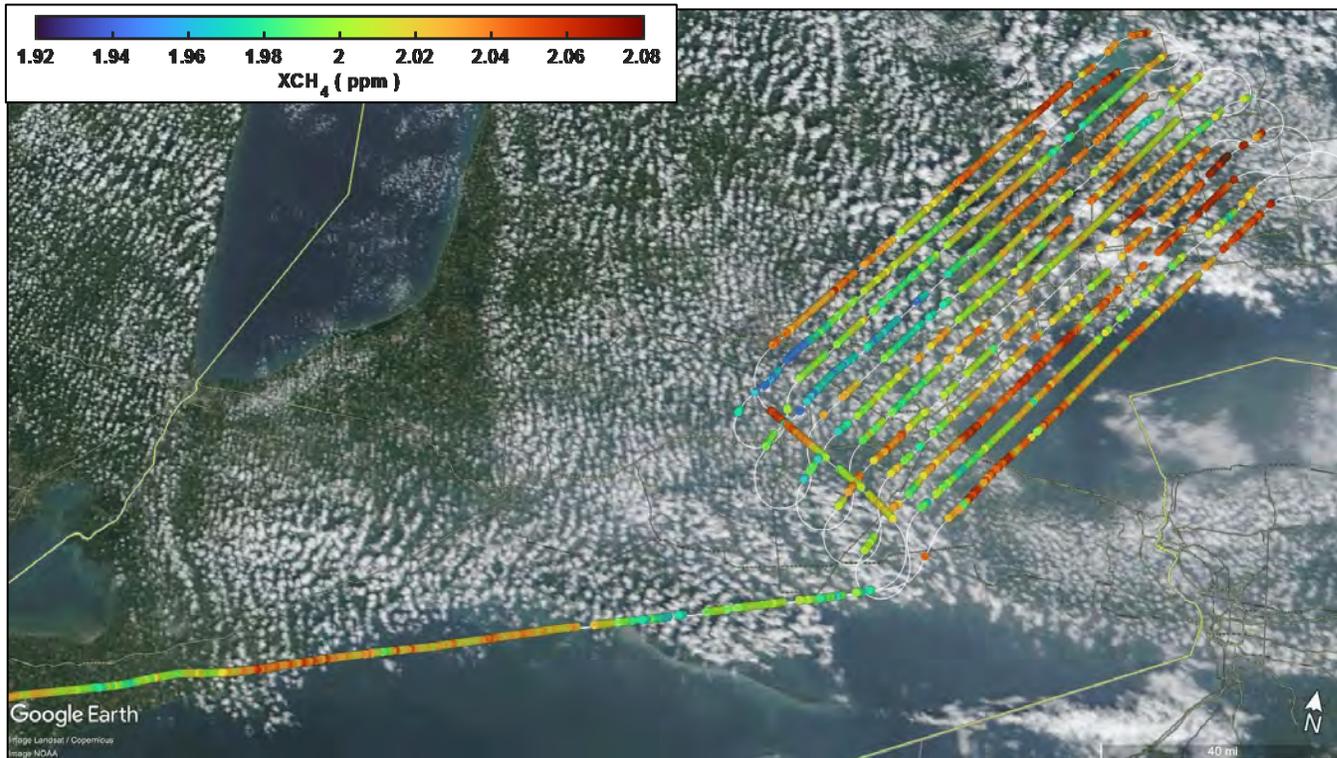
- Evaluate AM/PM lidar derived  $XCH_4$  variability across urban settings
- Evaluate active/passive synergies
- Evaluate HgCdTe detector  $CH_4$  profiling



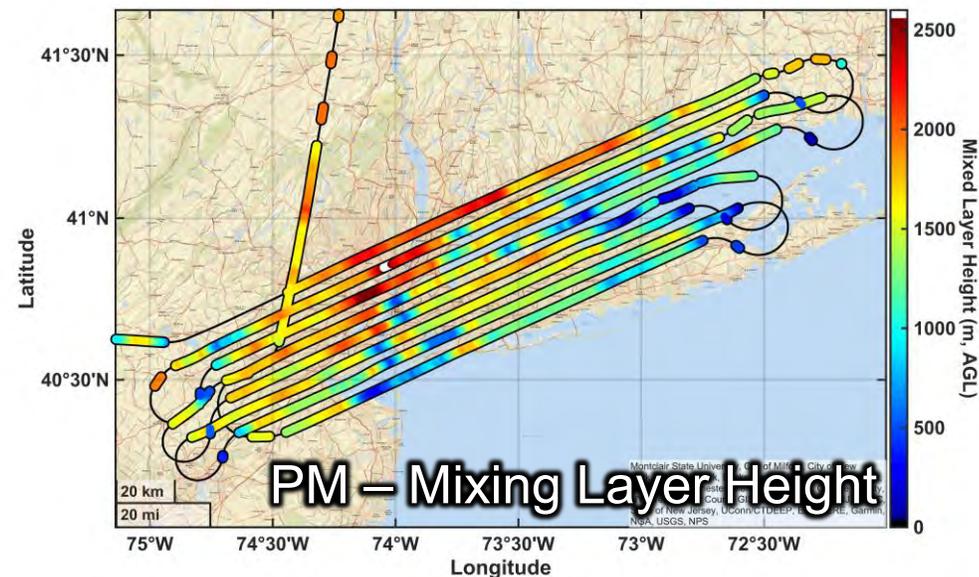
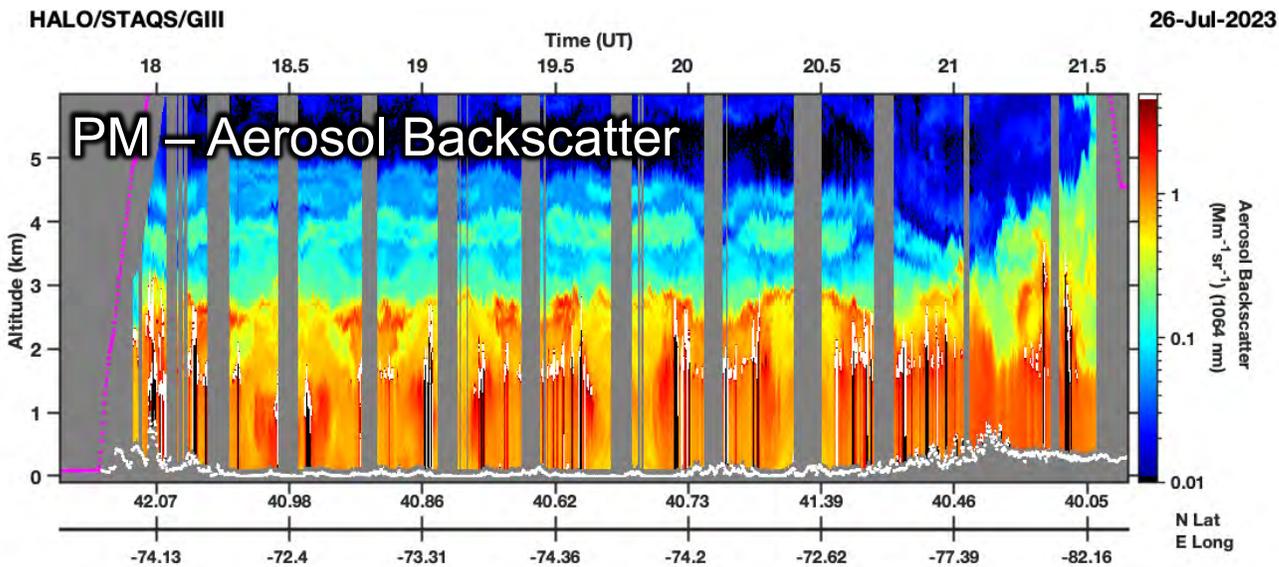
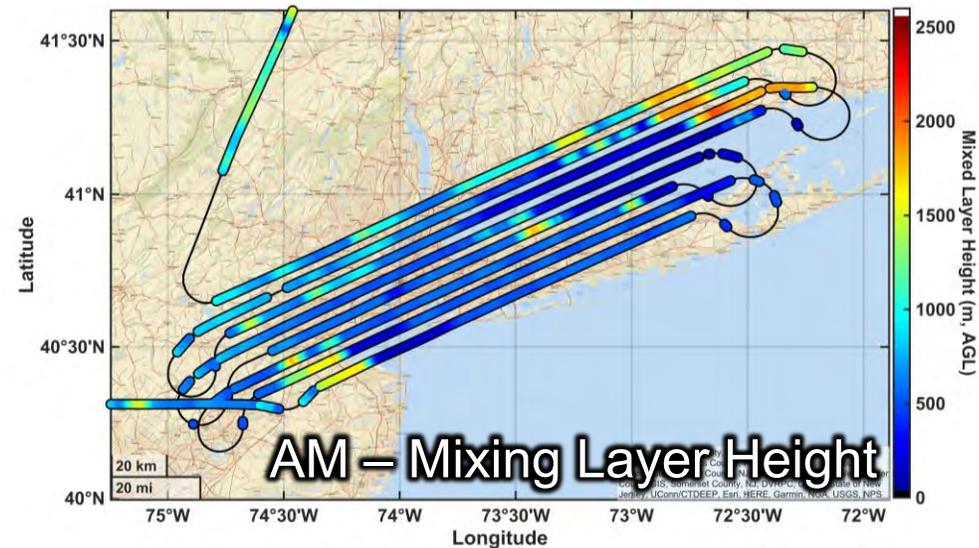
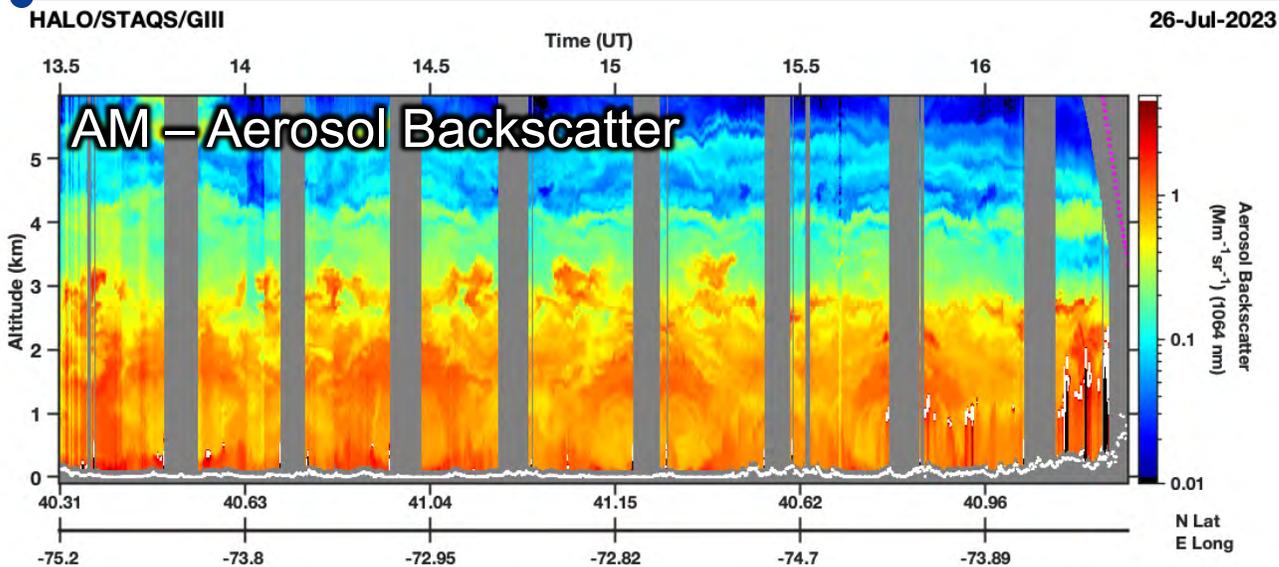
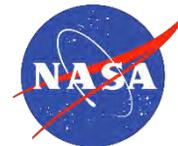
# STAQS – Toronto Cloudy/Smokey XCH<sub>4</sub> Retrievals



- Satellites alias observations towards clear sky conditions
- Clouds and aerosols confound retrievals of diffuse regional emissions
- Lidar offers excellent coverage through dense fair weather cumulus clouds and insensitive to aerosols within the column



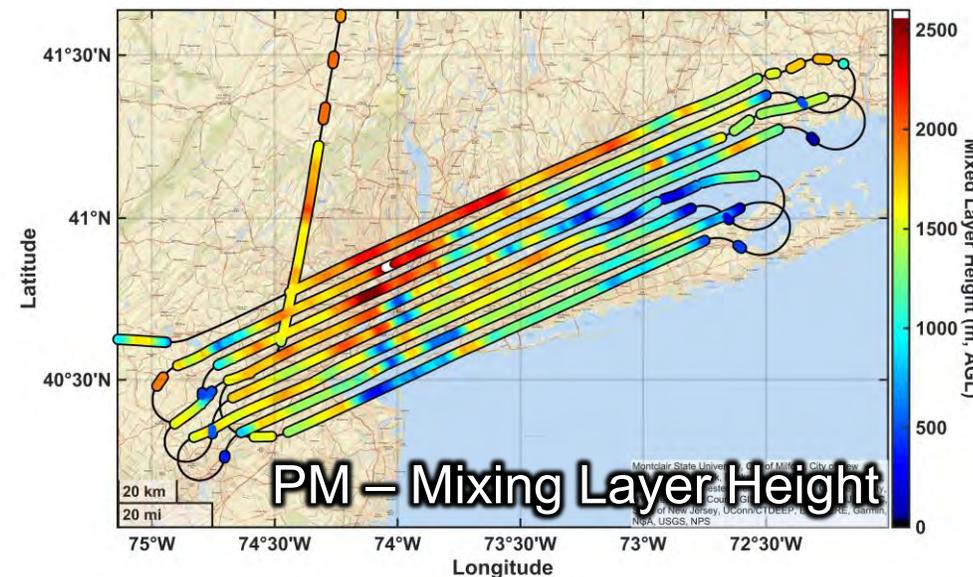
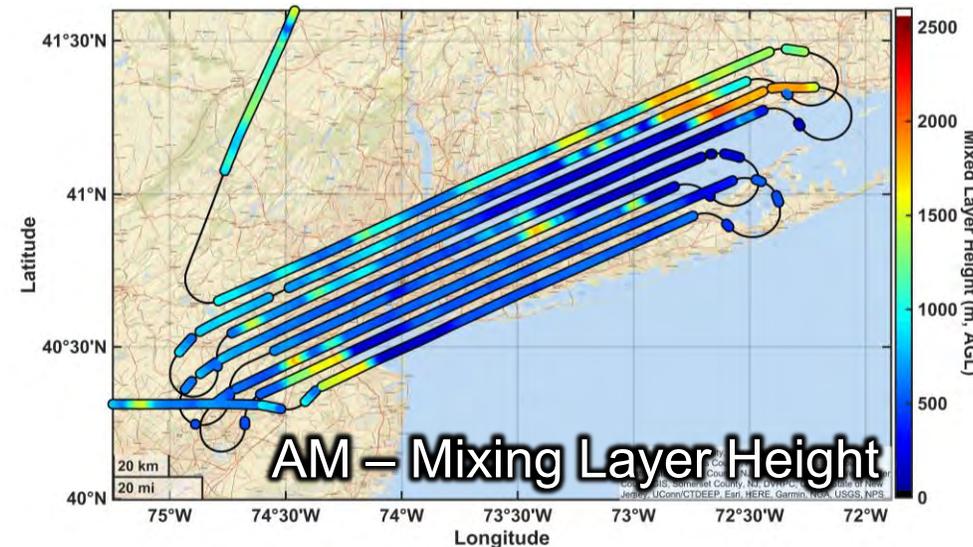
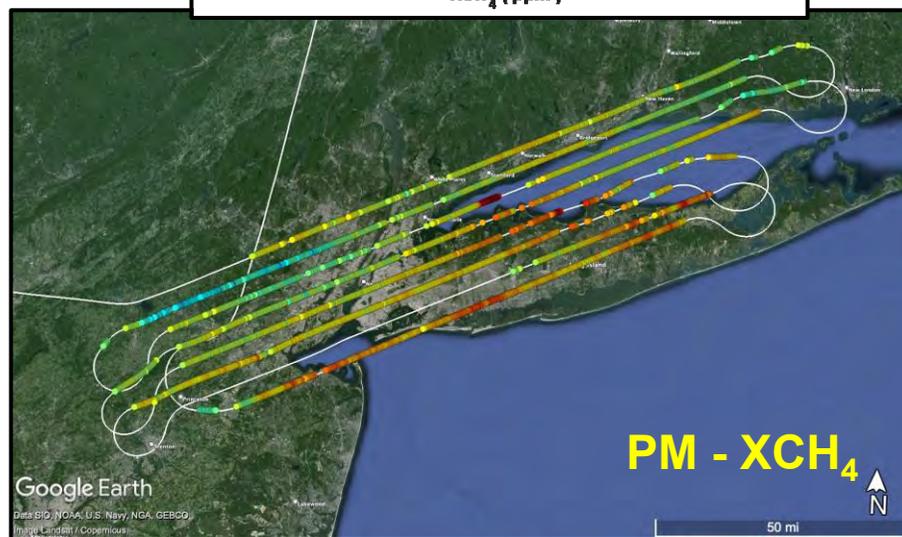
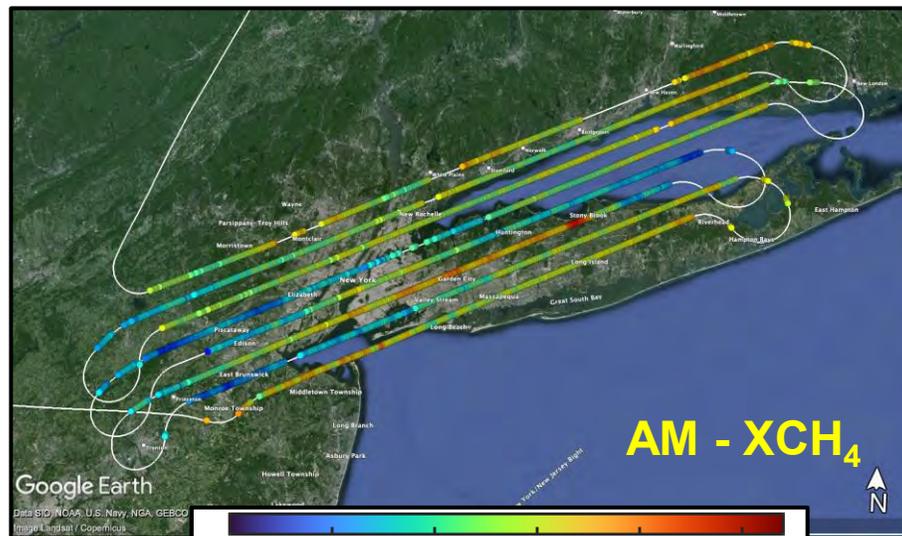
# STAQS – New York AM/PM Flights



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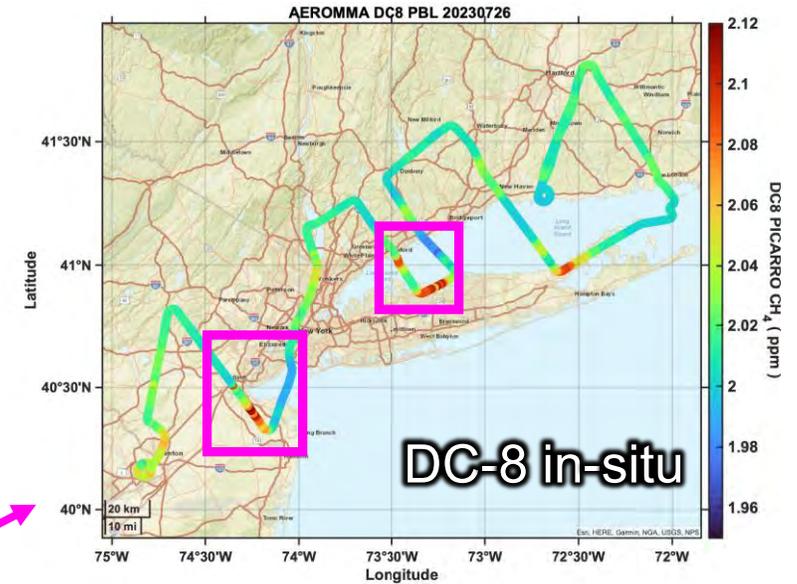
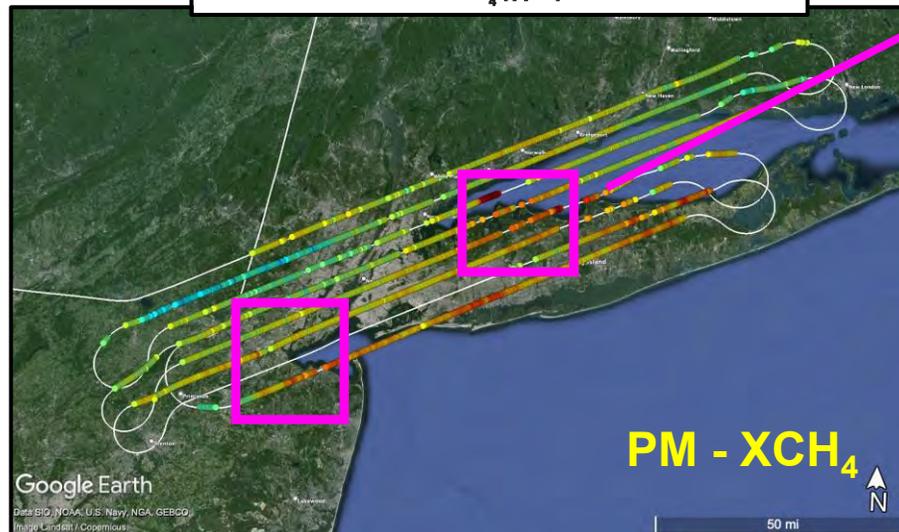
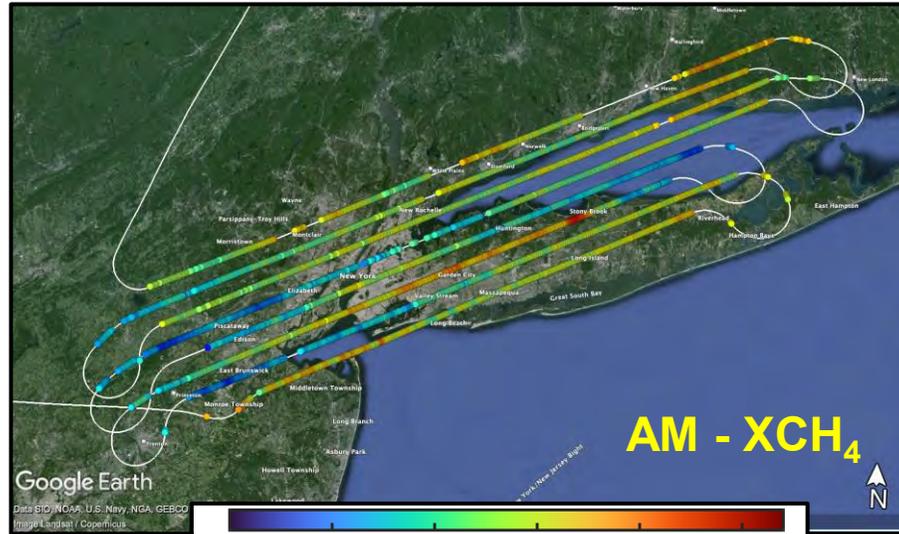
- Broad city scale enhancements observed between AM and PM flights
- Many small point sources identified from landfills, power plants, and wastewater plants
- Good correlation with in-situ CH<sub>4</sub> DC-8 observations



# STAQS – New York AM/PM Flights – DC-8 Synergy



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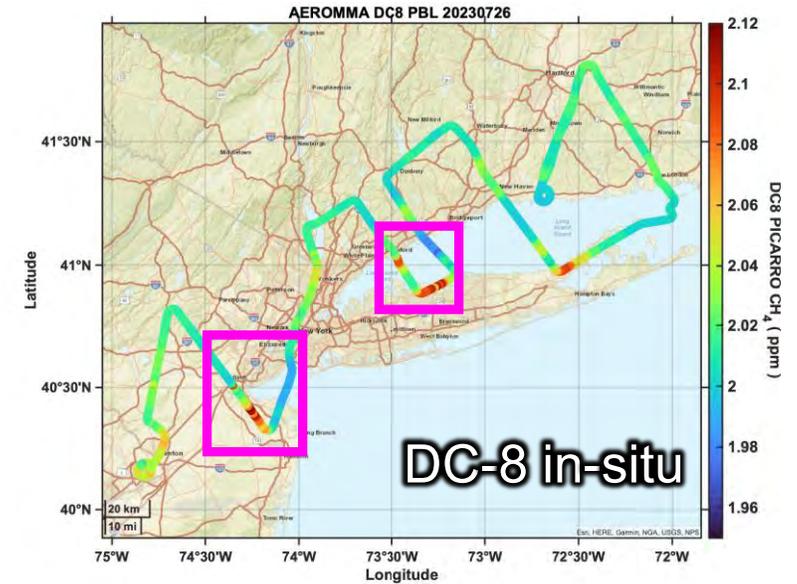
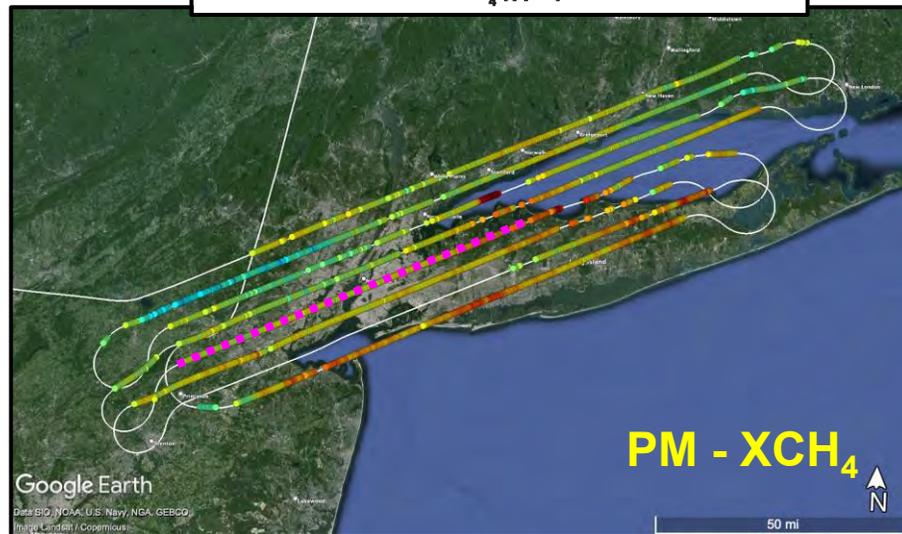
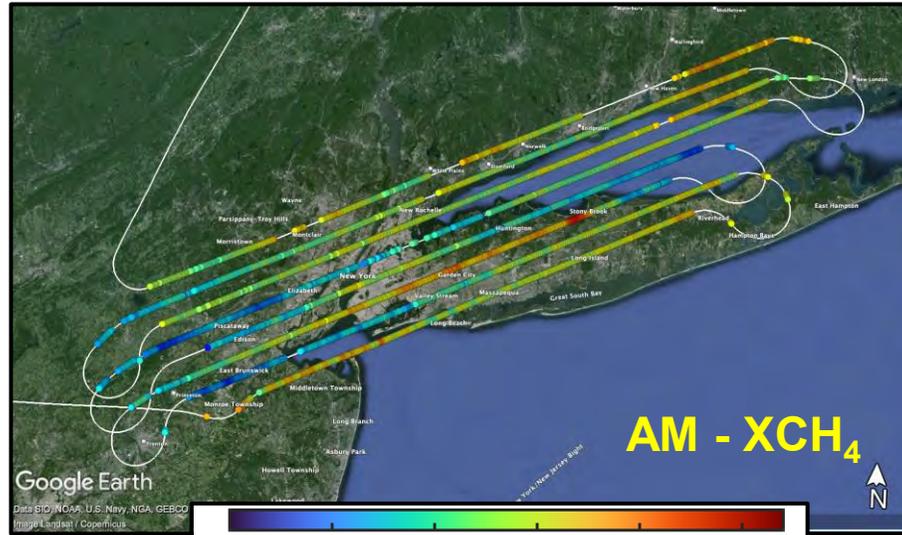


DC8 CH<sub>4</sub> Data – C/O NOAA CSL– AEROMMA 2023

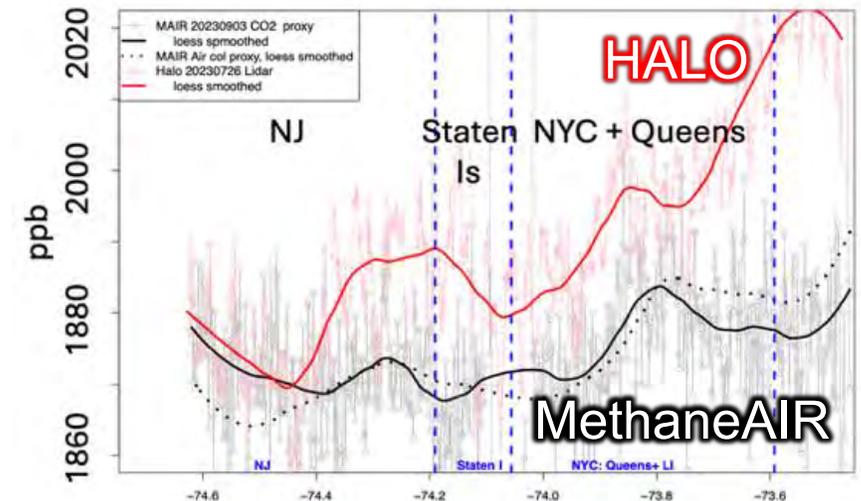
# STAQS – New York AM/PM Flights – MAIR Synergy



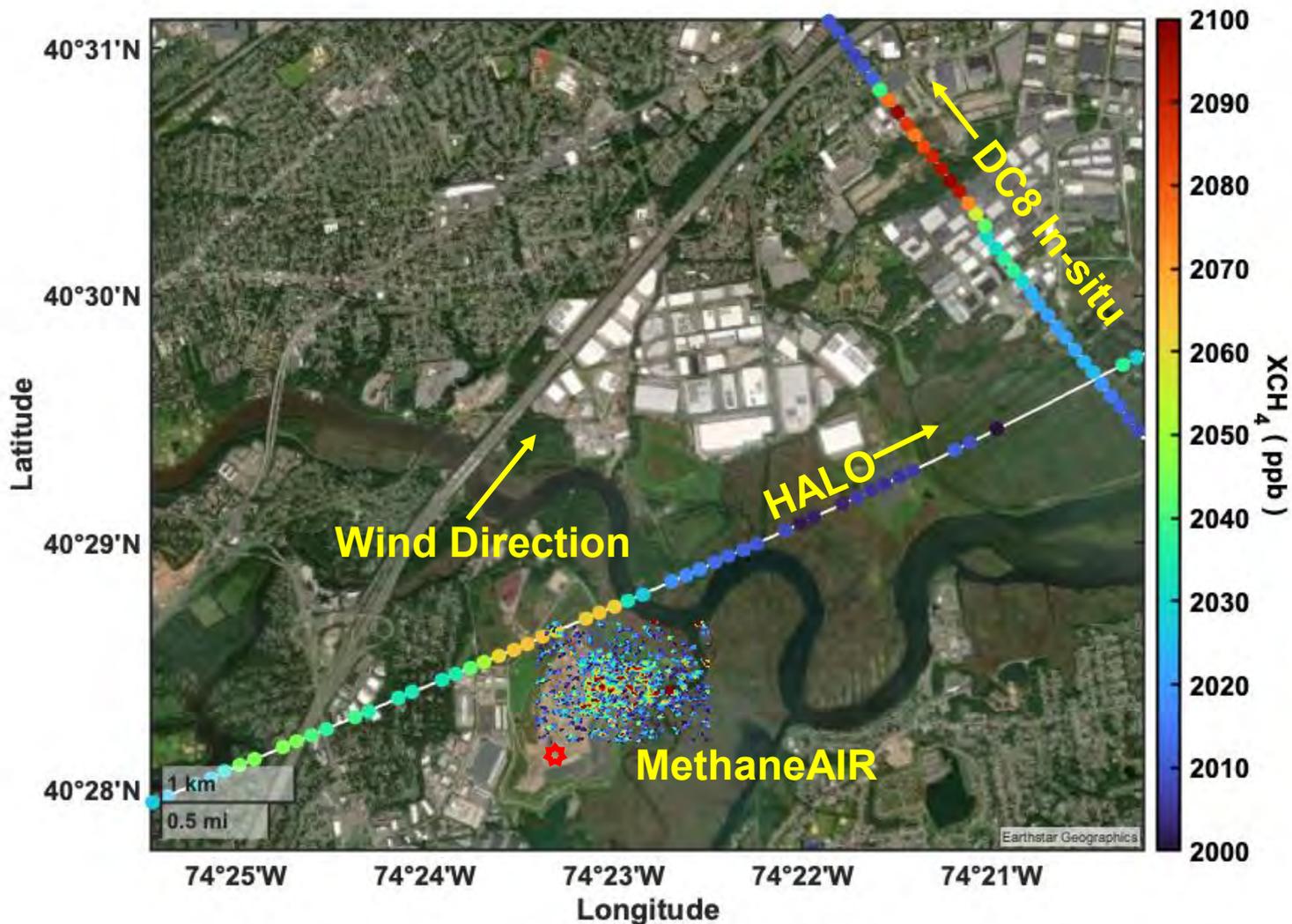
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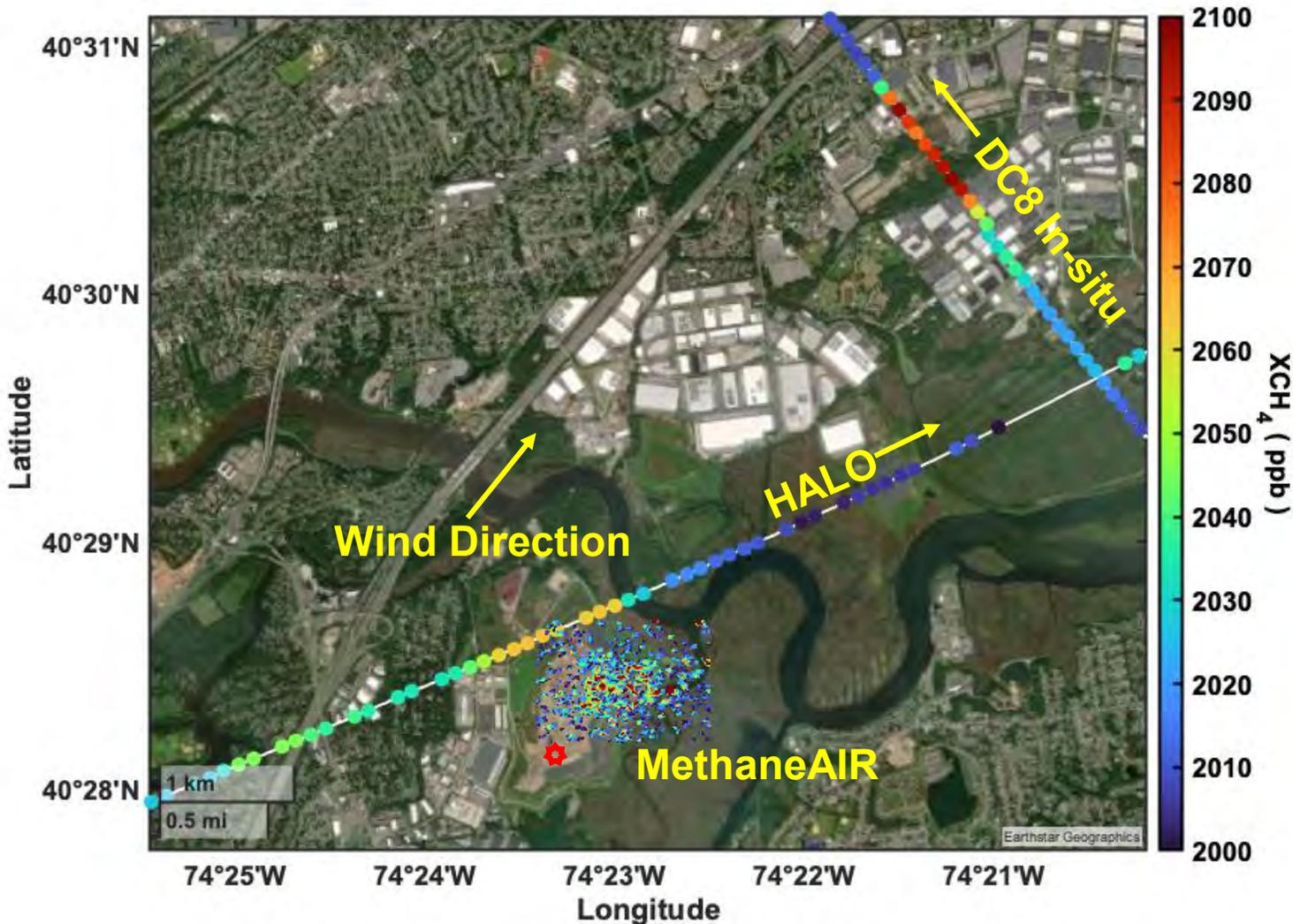
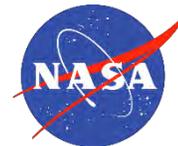


# Active/Passive Measurements & Synergies

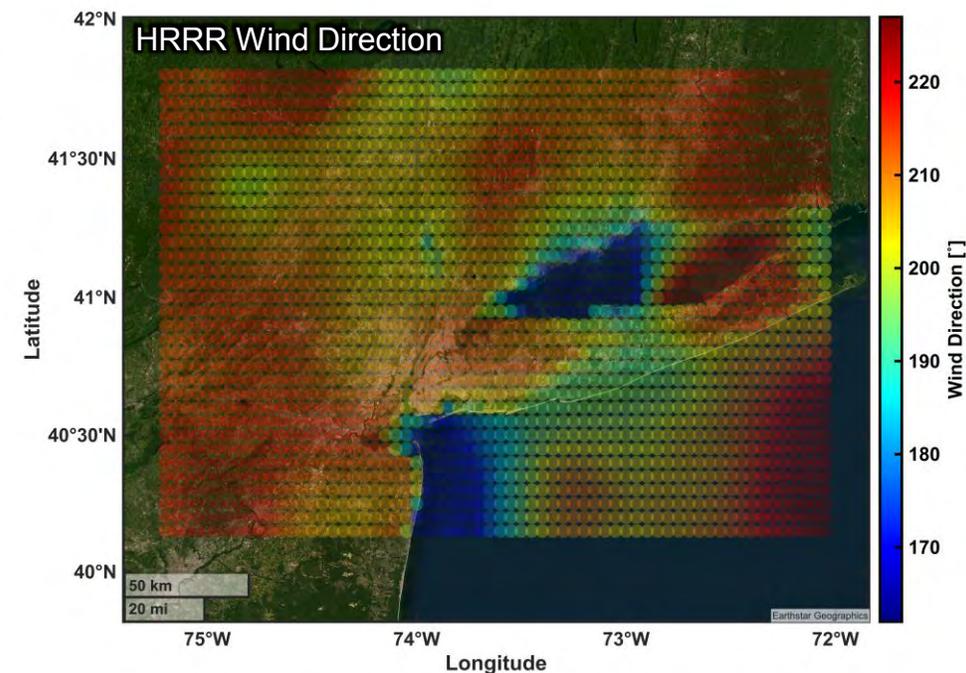


- ★ Middlesex County Landfill (East Brunswick, NJ)
- HALO GIII and DC-8 flight on 07/26/23 (afternoon)
- Methane Air flight on Lear Jet on 09/03/23

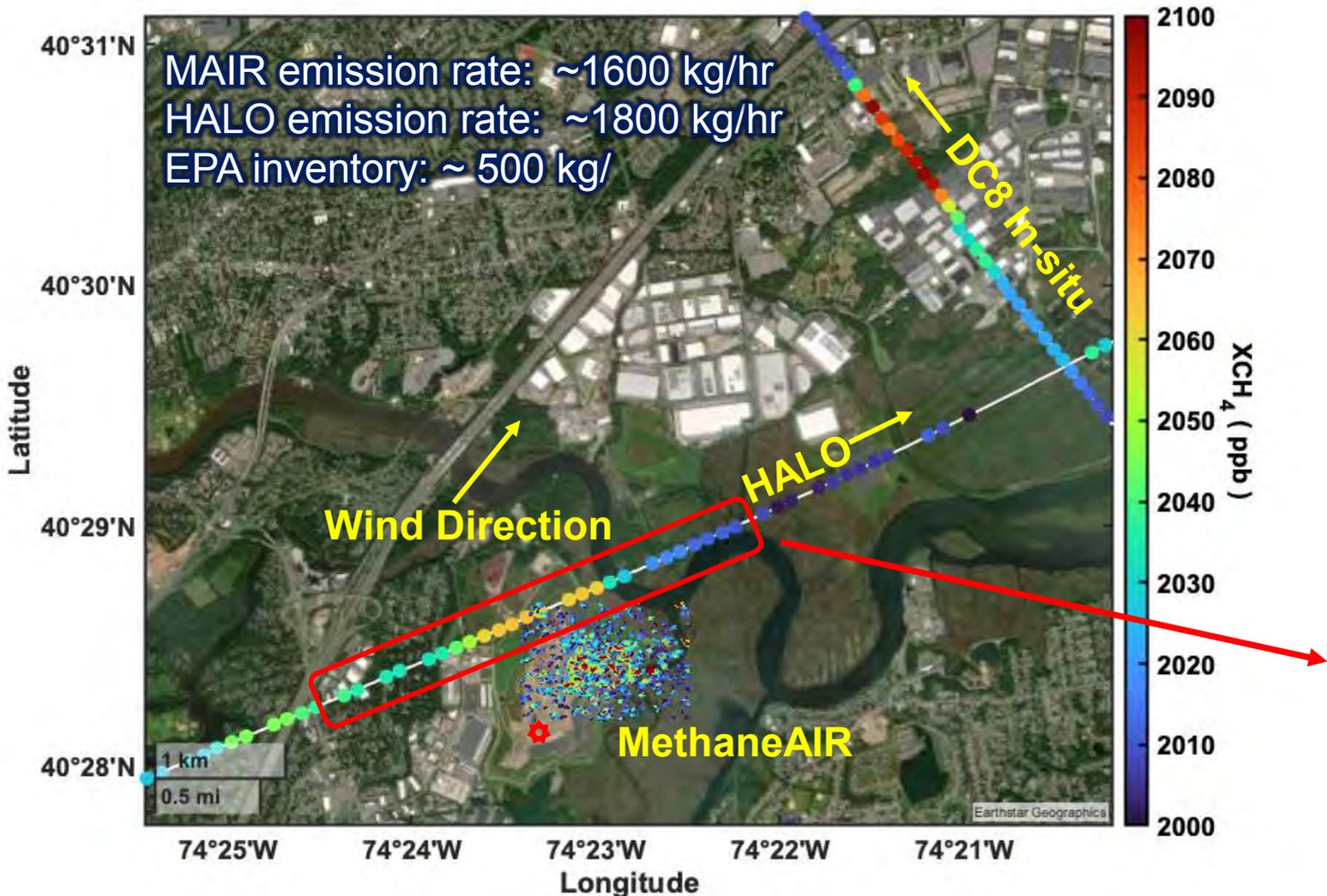
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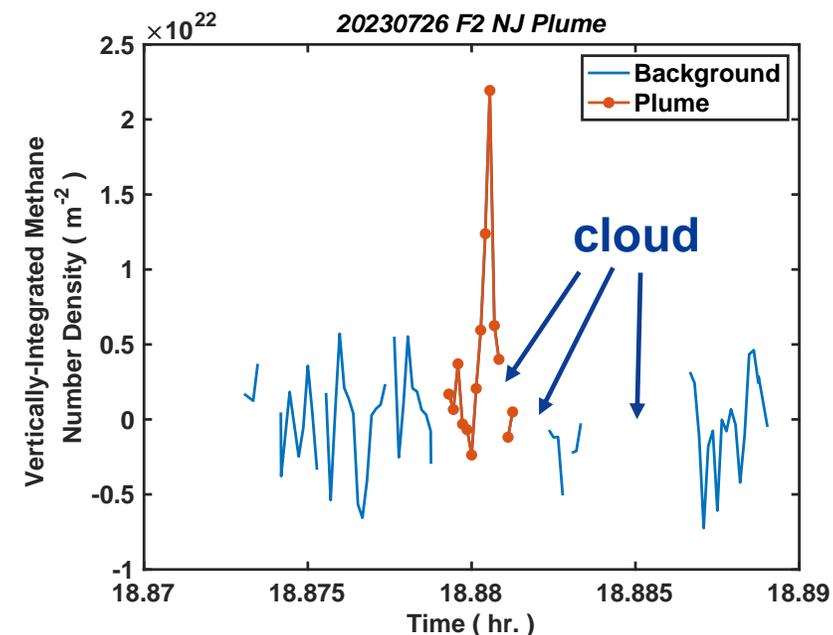
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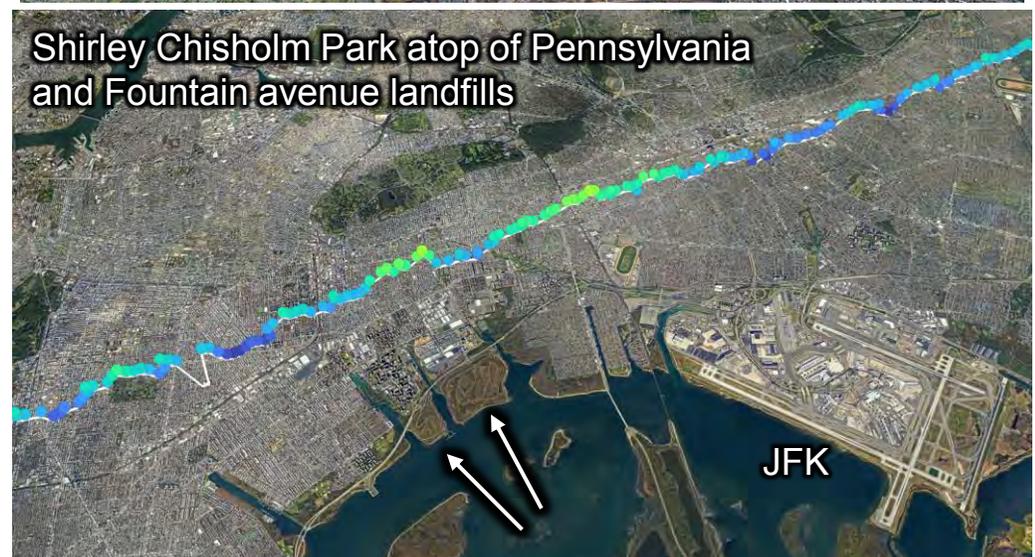
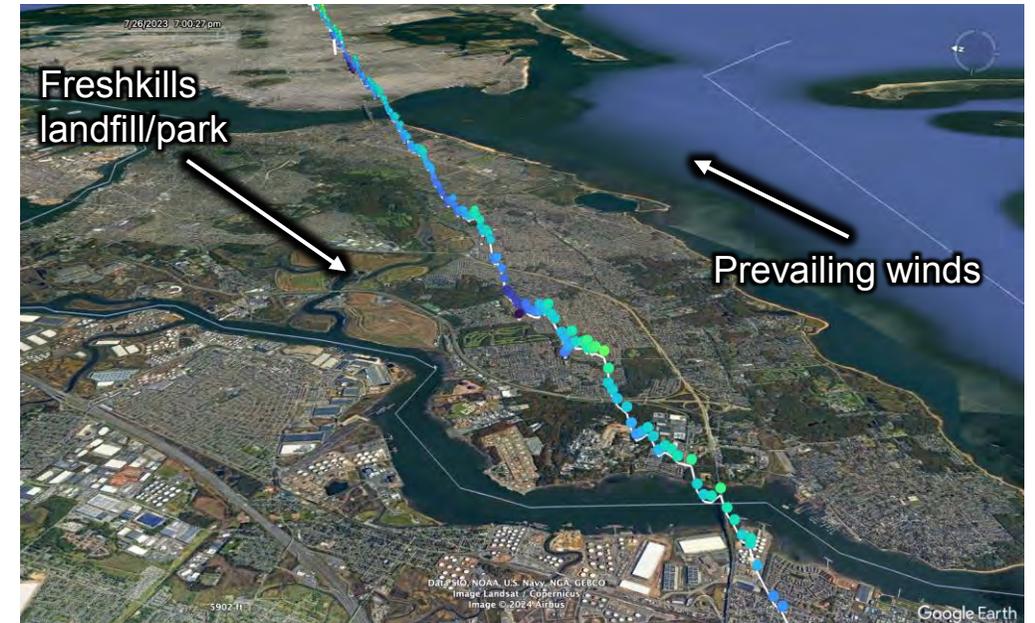
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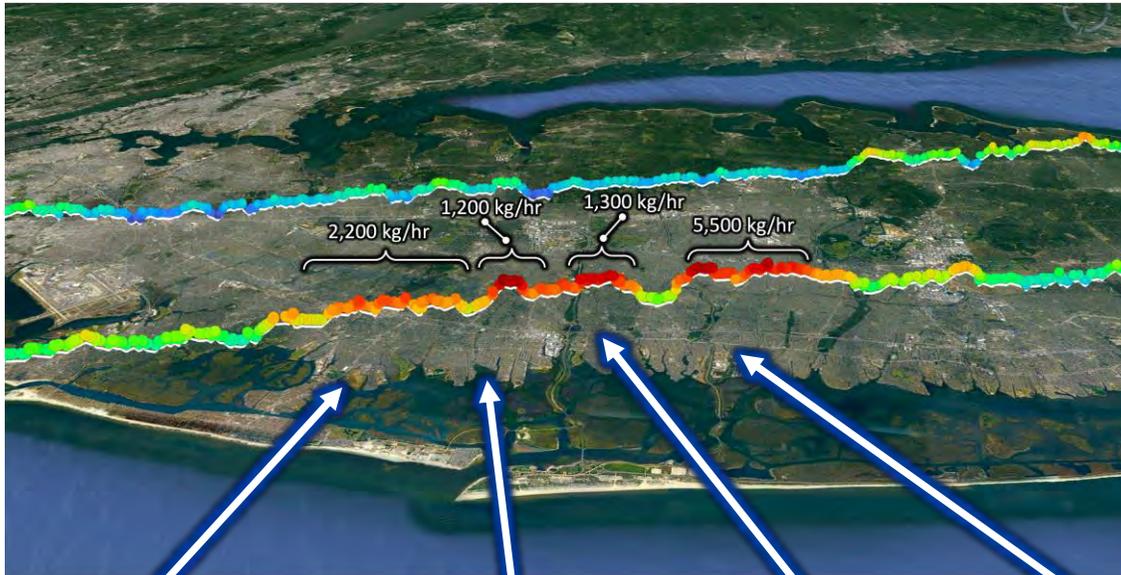
# Optimizing flight plans for active sounding



- Flight plans optimized for for swath of passive imagers
  - HALO lidar sounder often sampled upwind of major sources
  - High sensitivity still allow for identification of enhancement despite missing the primary 'plume'
- Many sources identified that are no longer reporting to the EPA
  - Parks/sanctuaries atop of capped landfills
  - Golf courses atop of capped landfills
- Methane enhancements observed near power plants?



# Disentangling Sources



- Work ongoing with Sean Crowell and Roisin Commane to compare observations with different inventories (Crowell) and historic surface observations (Commane)
- Preliminary results show good agreement at city scale
- Emission rate discrepancies relative to inventories from individual sources



Oceanside  
Capped, not reporting



Hempstead  
Capped, not reporting

?



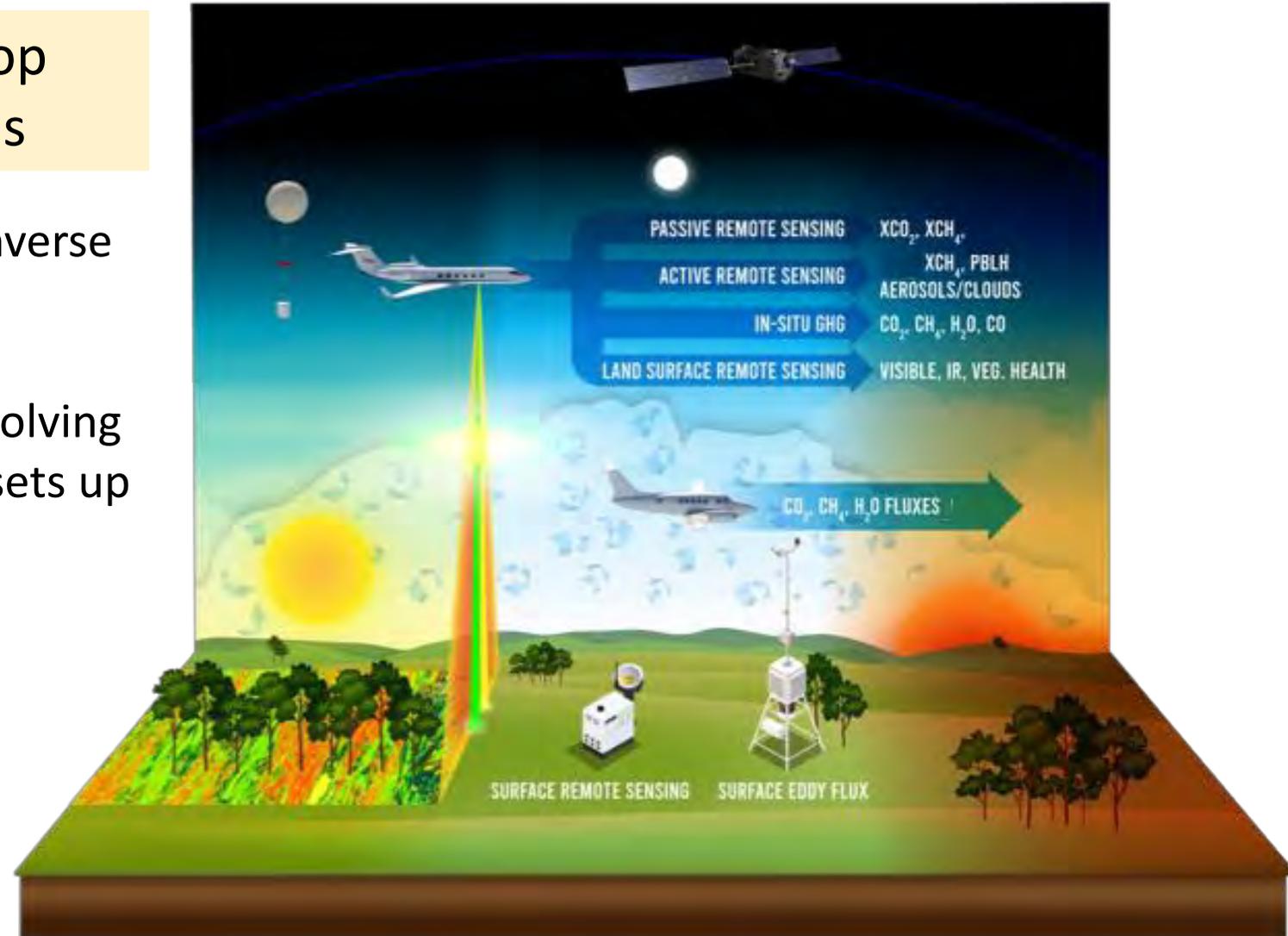
Cedar Creek  
Waste water  
treatment plant

# Summer 2025 - Benchmarking Methane Area Emissions with MethaneAIR and HALO



Goal: provide rigorous test of "top down" regional area flux models

- There is currently no way to validate inverse models
- Designed to tightly constrain inverse models by spatially and temporally resolving atmospheric burden of methane as it sets up and evolves over a 2-day period

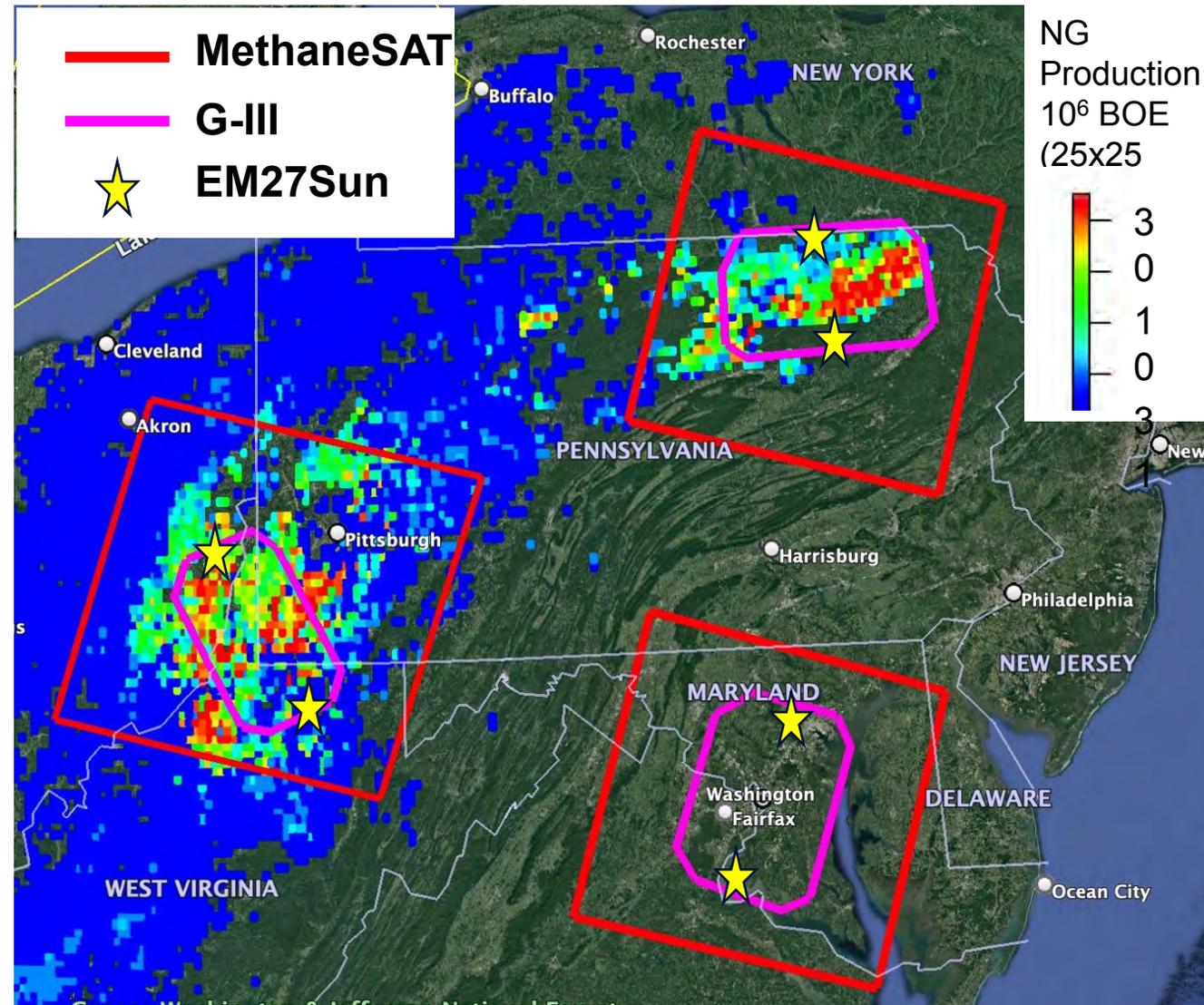


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- Create a high-resolution map of methane over several large (80 x 120 km) regions, oversampling in time spanning several days
- Repeat experiment at 3 sites – 2 areas of Appalachian basin + Washington DC/Baltimore urban area

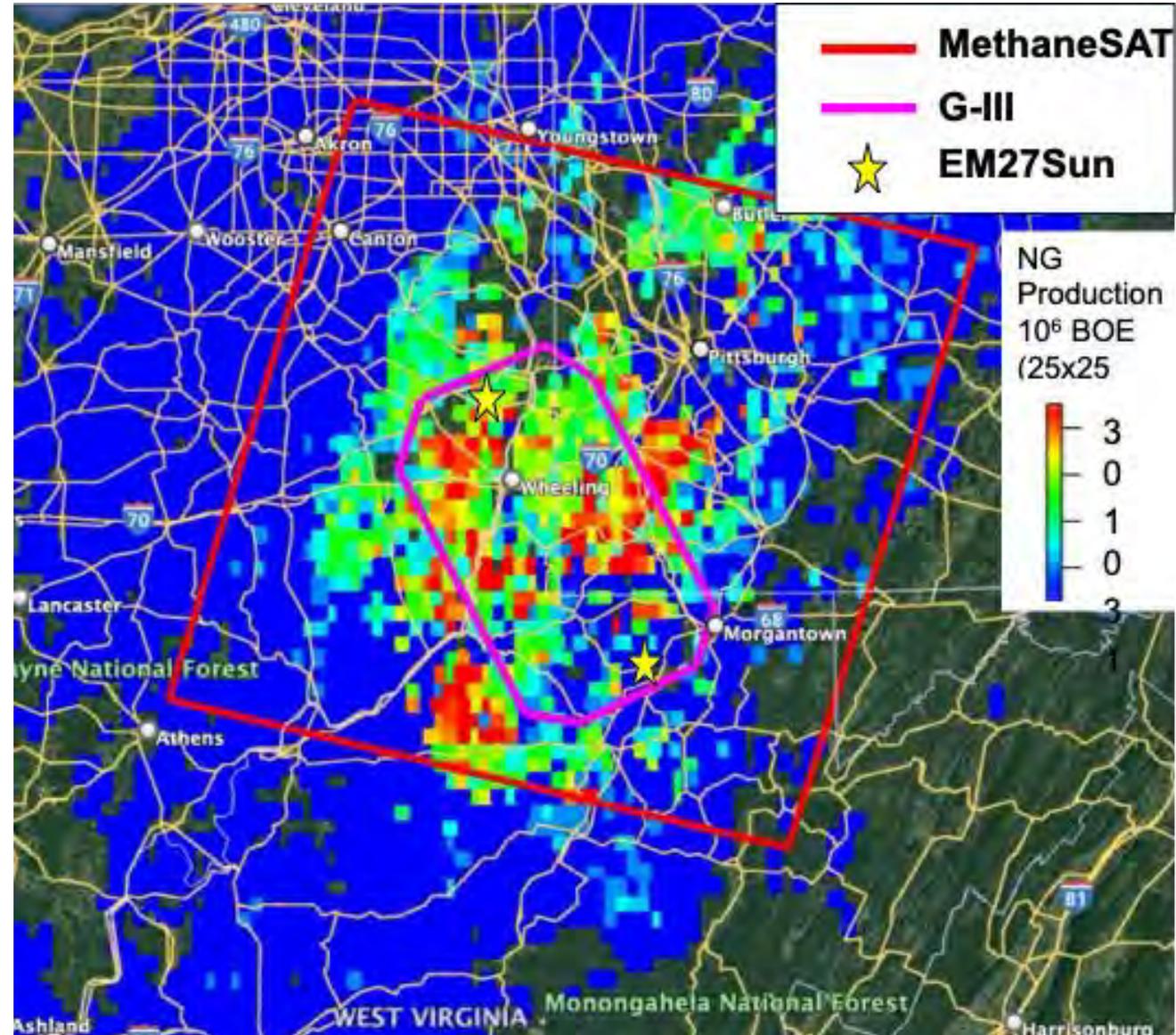


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## Strategy:

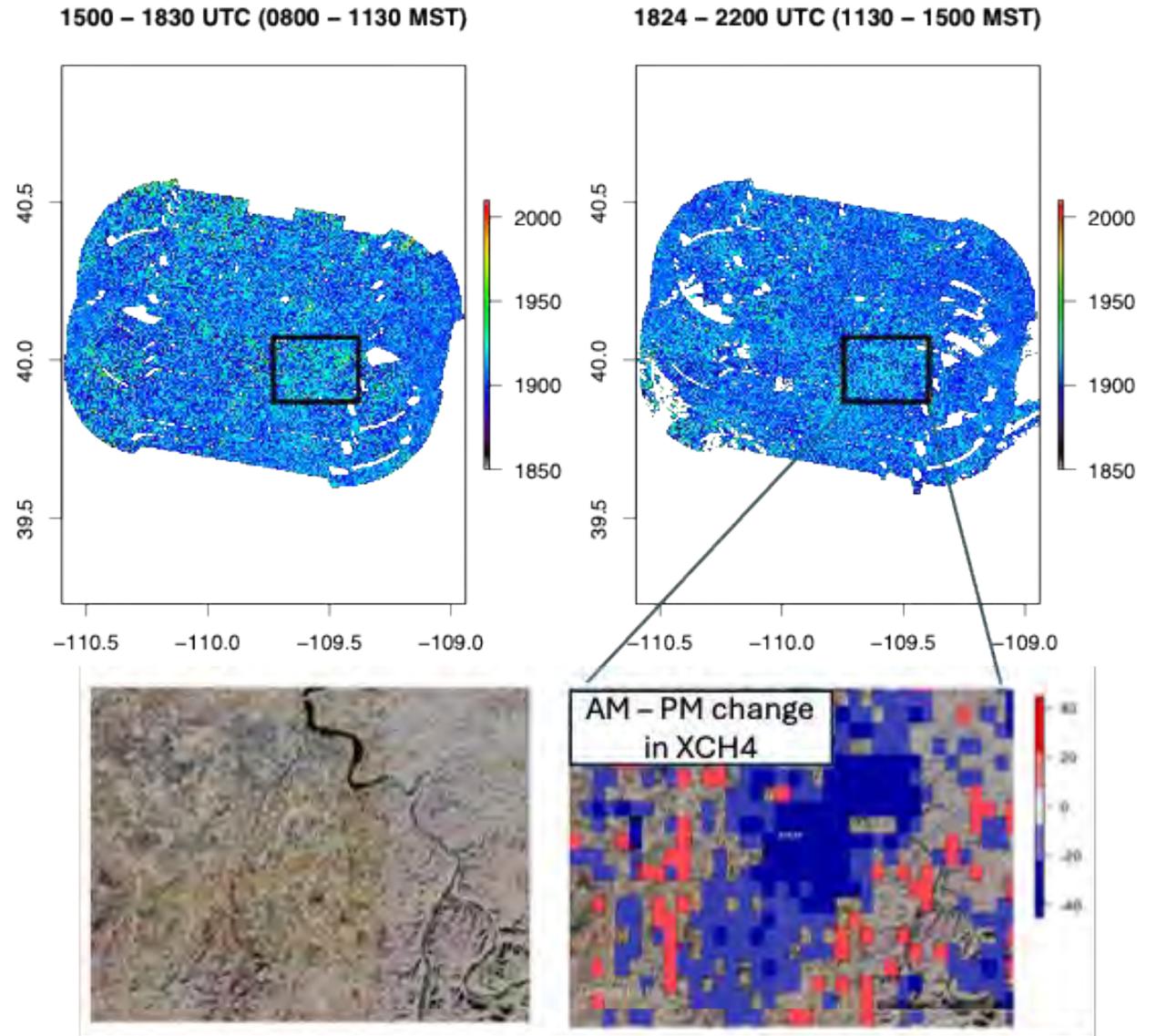
- HALO methane lidar on NASA G-3 will fly target area overnight on NASA G-3
- MethaneAIR and HALO methane lidar on NASA G-3 will then fly two sorties covering target region (80 x 120 km)
- Repeat for 2 consecutive days
- MethaneSAT will target same region (200 km x 200 km)
- A network of EM27Sun spectrometers distributed around study area for additional ground truth and temporal variability



# 2024 MethaneAIR Benchmark Flights: Uinta Basin UT



- Example of morning (left) and afternoon (right) repeats of Uinta basin
- Methane bulge (bottom) seen in early/mid morning, near O&G infrastructure in a low-lying area near a river valley; likely accumulated overnight
- In the afternoon map, the bulge has spread out and attenuated
- Multiple passes per day (in 2025, 4 including HALO overnight and MSAT) allow for distinguishing between emitted and transported methane





Data:

<https://www-air.larc.nasa.gov/missions/staqs/>

#### Contacts

- *Amin Nehrir* ([amin.r.nehrir@nasa.gov](mailto:amin.r.nehrir@nasa.gov))
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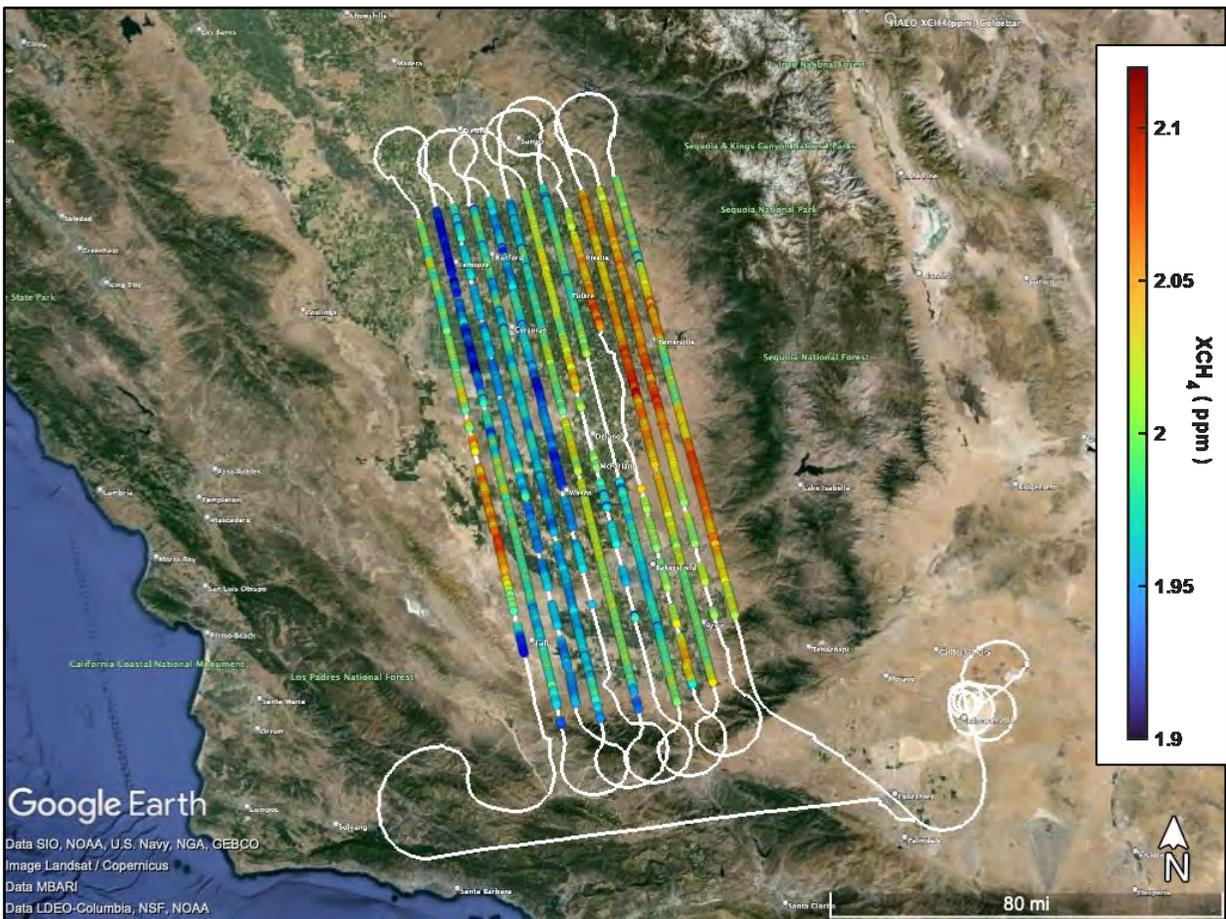


Thanks to GHG center, Tropospheric Composition, Earth  
Science Technology Office, SBIR, LaRC, GSFC ....

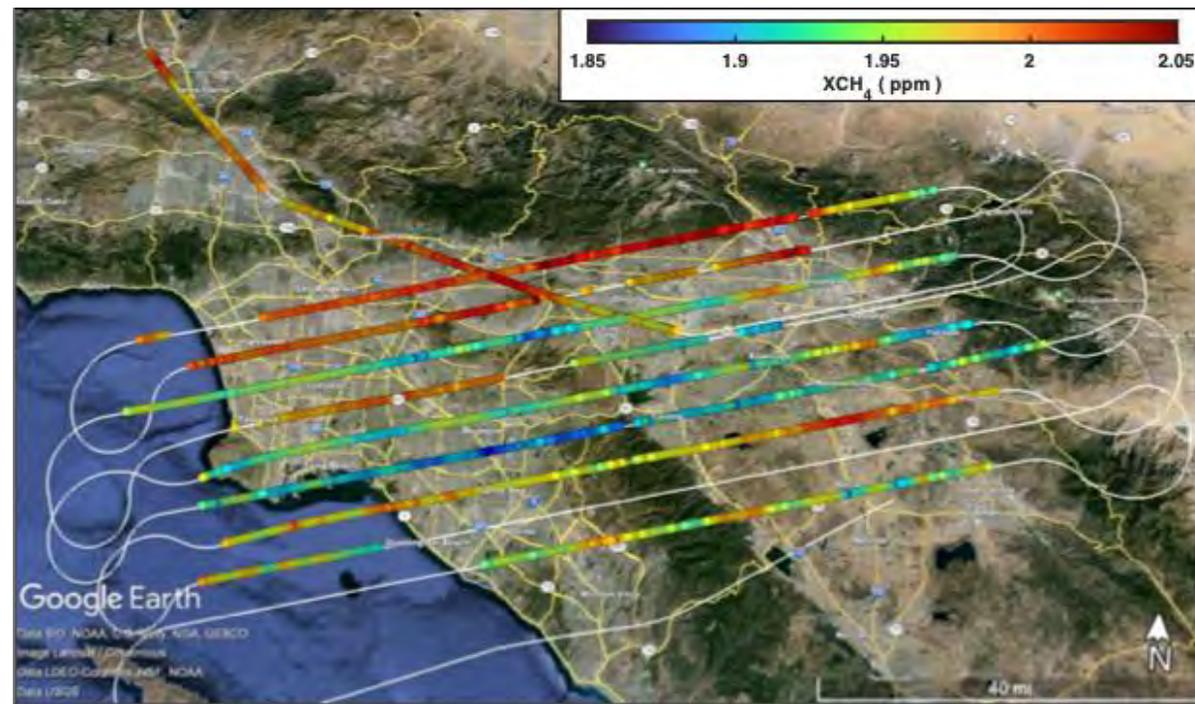
# STAQS – Central Valley and LA Basin



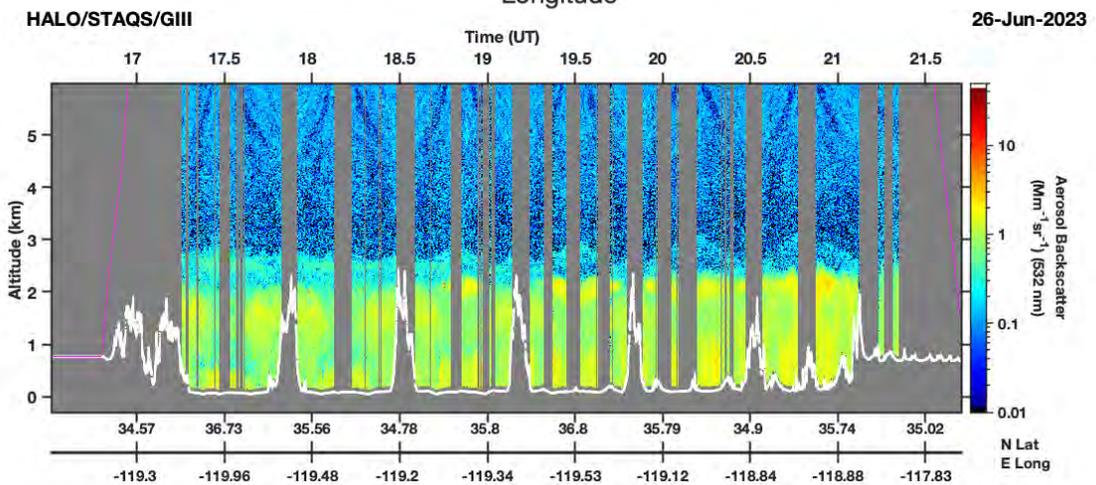
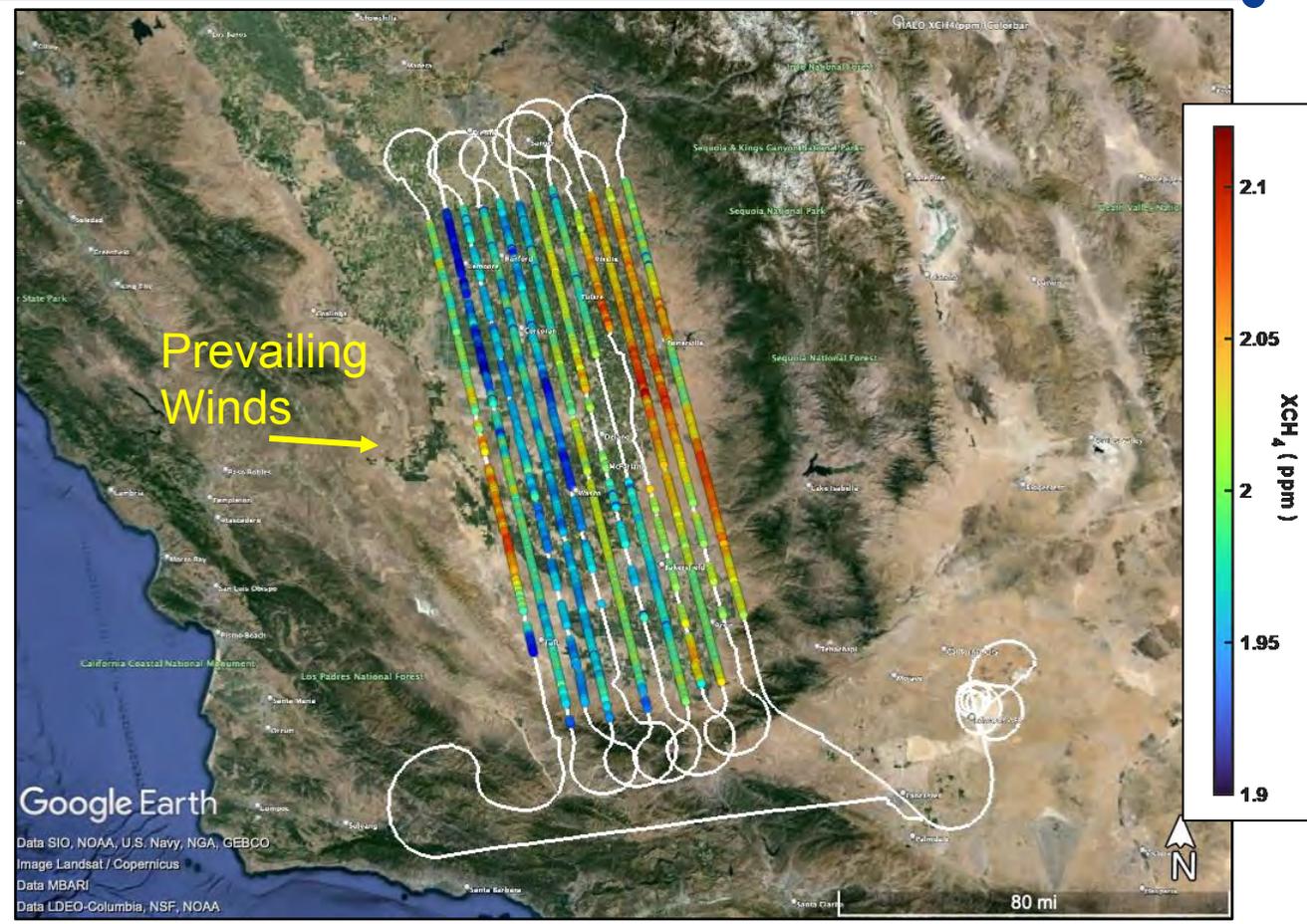
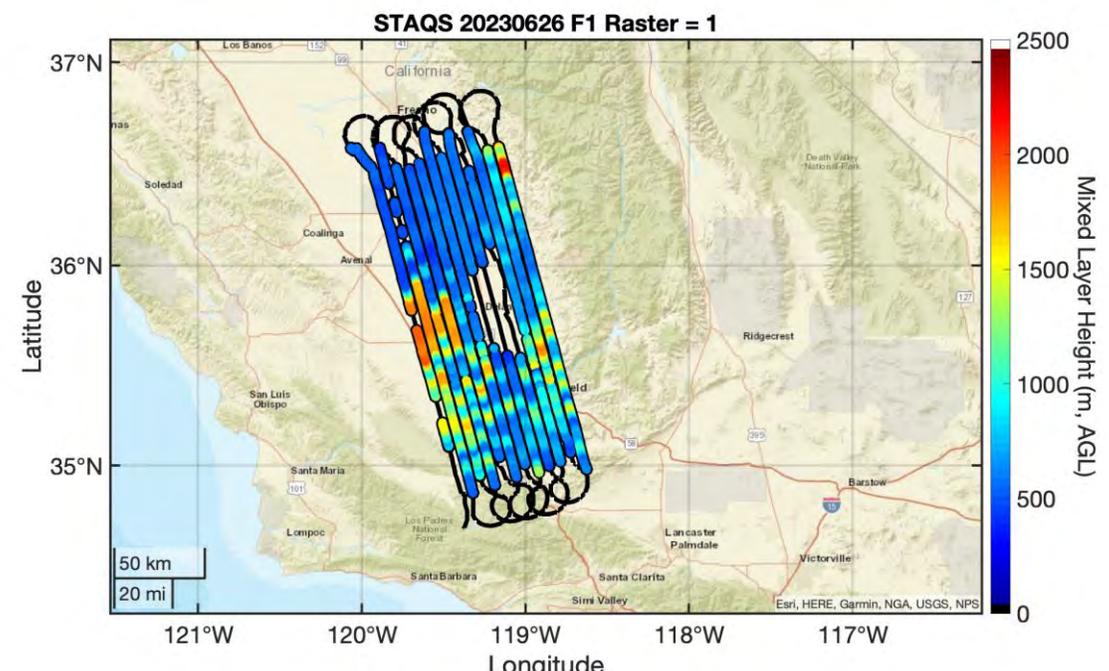
## Central Valley



## LA Basin

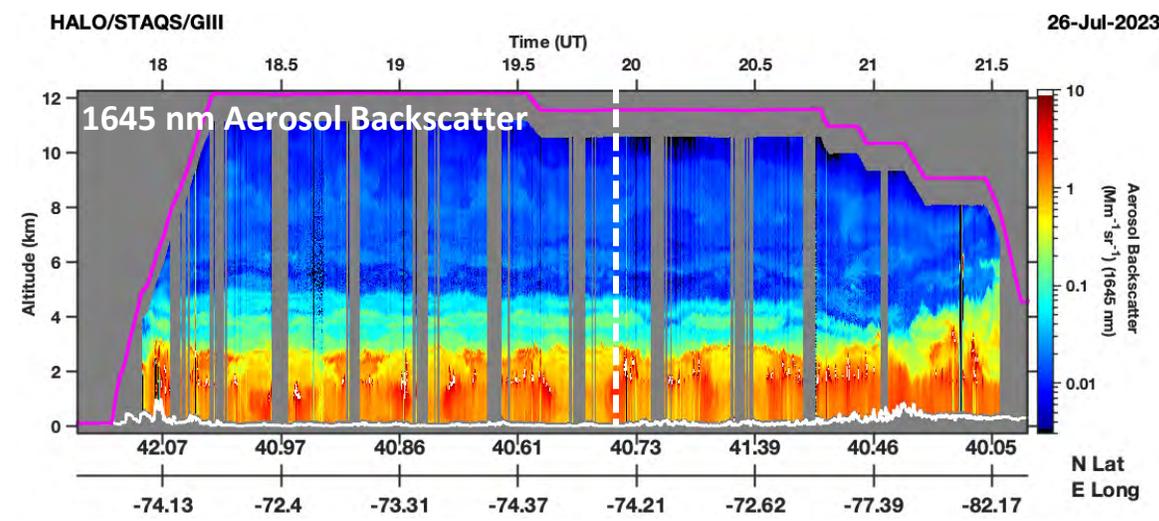
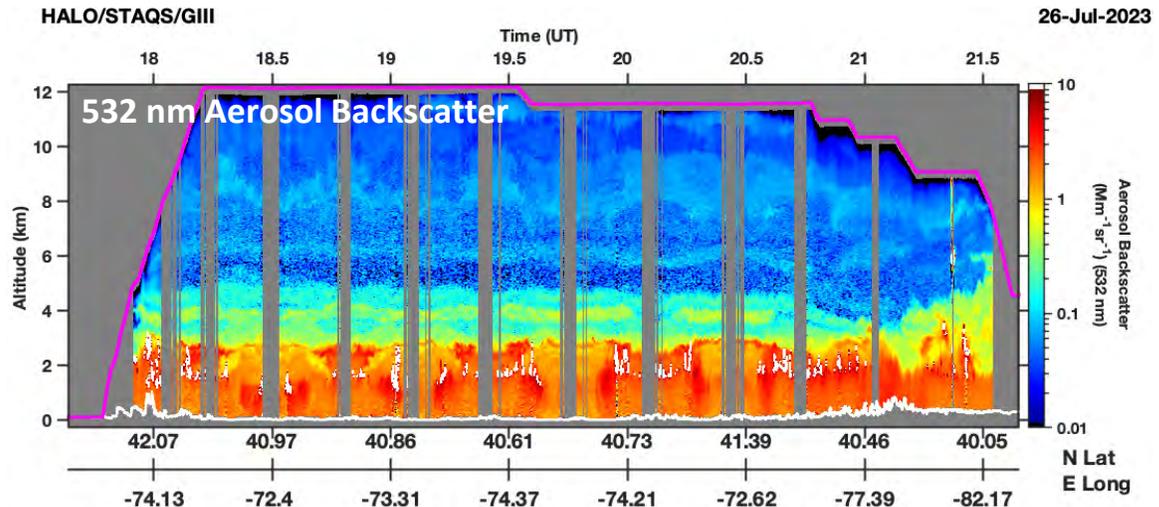


# STAQS – Central Valley XCH<sub>4</sub> and PBLH Distributions



- Enhancements from agriculture and O&G observed throughout the central valley
- HALO observed pooling of CH<sub>4</sub> on the western side of the valley, consistent with prevailing winds and in-situ DC-8 observations

# Complementing Cloud Slicing With Clear Air Profiling



- Integrated and flew a sensitive HgCdTe detector previously used for column measurements from strong surface echo to evaluate range resolved profiling (FT and PBL columns in clear air)
- Building on the first airborne demonstration of range resolved  $\text{CH}_4$  profiles from LISTOS and ACT-America (Barton-Grimley et al. 2022)

