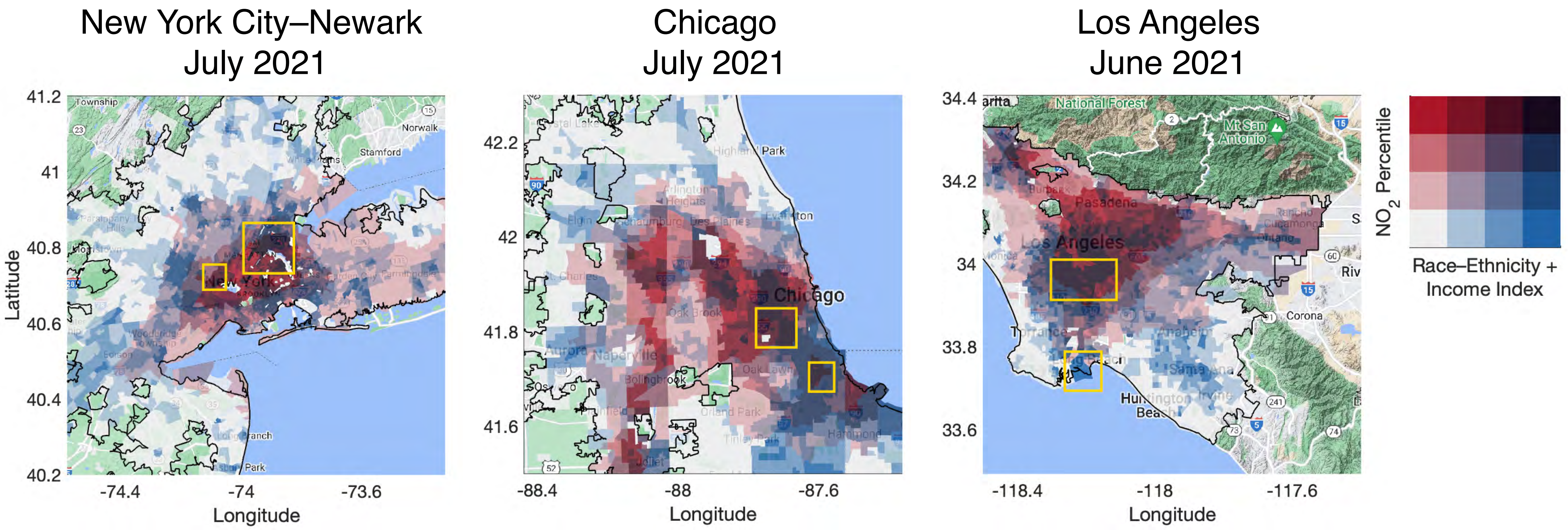
Flight Planning: Status and First Ideas

Everyone has 4 – 5 minutes:

- Sally Pusede (NO_2 inequality maps) - **Virtual**
- Becky Schwantes / Carsten Warneke (AEROMMA urban)
- Laura Judd (STAQS)
- John Mak (GOTHAAM)
- Sunil Baidar (CUPiDS)
- Xinrong Ren (ARL/UMD CESSNA)
- Andrew Rollins / Patrick Veres (AEROMMA marine)

Sally Pusede (NO_2 inequality maps)

New York City–Newark, Chicago, and Los Angeles



South Bronx, NY and Ironbound, NJ
Englewood, South Side, Mickinley Park, Little Village, and Austin, IL
Englewood, Huntington Park, and neighborhoods near the Port of Long Beach, CA

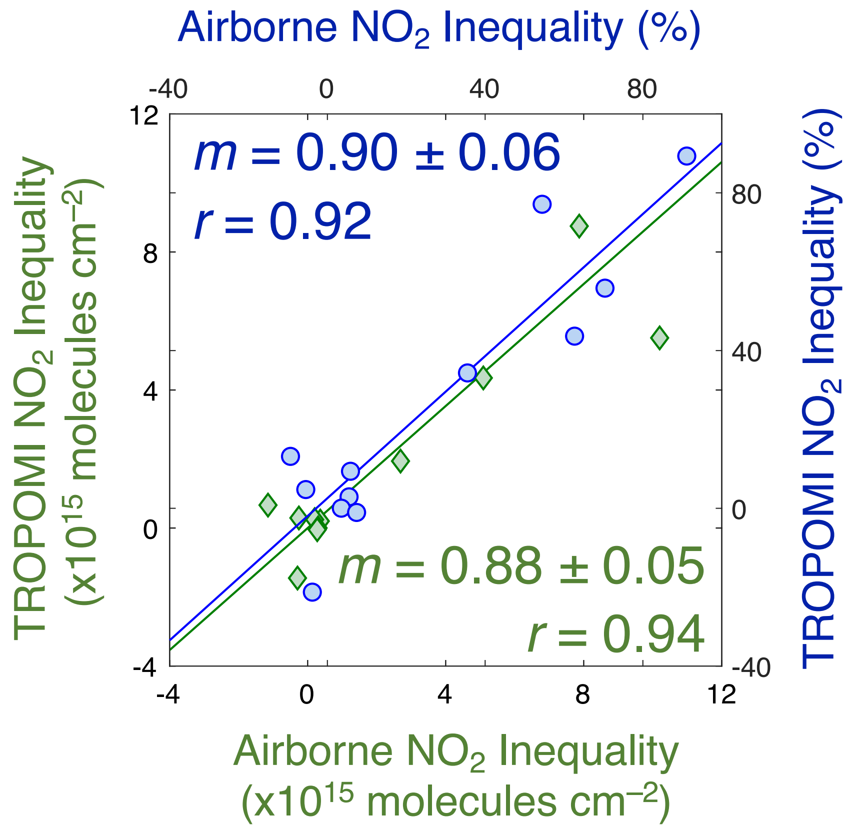
Figures created by Isabella Dressel

Sampling considerations: data density

Dressel et al., Daily Satellite Observations of Nitrogen Dioxide Air Pollution Inequality in New York City, New York and Newark, New Jersey: Evaluation and Application, ES&T, 2022

Meaningful information at coarser spatial resolutions. TROPOMI inequalities are largely insensitive to observation pixel area. In LA and Chicago, unpublished results are similar

LISTOS dataset:



Daily TROPOMI observations May 2018–September 2021:

	Mean of Daily Inequalities			Daily Inequalities		
	Relative Inequalities (%)			Coefficient of Variation		
Mean Pixel Area (km^2)	Black and African Americans	Hispanics + Latinos	People of Color in Low-Income Tracts	Black and African Americans	Hispanics + Latinos	People of Color in Low-Income Tracts
20–25	25 ± 2	24 ± 3	33 ± 3	0.78	0.83	0.67
25–30	23 ± 3	22 ± 3	31 ± 4	0.93	0.97	0.80
30–35	24 ± 3	24 ± 3	32 ± 4	0.76	0.76	0.70
35–45	25 ± 3	21 ± 3	32 ± 4	0.78	0.92	0.72
45–60	25 ± 3	22 ± 3	34 ± 4	0.81	0.87	0.79
>60	19 ± 3	19 ± 3	26 ± 4	0.91	0.97	0.86

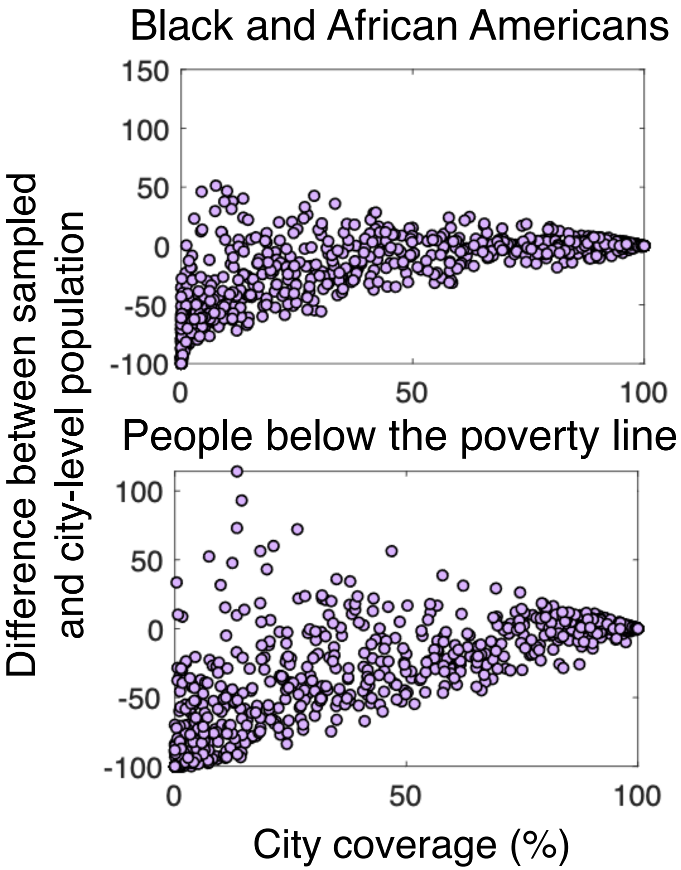
Sampling considerations: data extent

Dressel et al., Daily Satellite Observations of Nitrogen Dioxide Air Pollution Inequality in New York City, New York and Newark, New Jersey: Evaluation and Application, ES&T, 2022

Results are sensitive to how much of the city is sampled because key population groups may be missed

Daily TROPOMI observations May 2018–September 2021:

	Mean of Daily Inequalities			Daily Inequalities		
	Relative Inequalities (%)			Coefficient of Variation		
City coverage(%)	<30	30–60	>60	<30	30–60	>60
Black and African Americans	12 ± 2	30 ± 3	30 ± 1	1.99	0.64	0.40
Hispanics and Latinos	11 ± 2	29 ± 3	28 ± 1	2.00	0.62	0.53
Asians	10 ± 2	26 ± 3	28 ± 1	2.05	0.65	0.36
Below-poverty tracts	11 ± 4	25 ± 3	26 ± 1	2.47	0.66	0.45
People of color in low-income tracts	18 ± 4	37 ± 4	38 ± 1	1.81	0.65	0.36



Sampling considerations

For flight planning:

(1) Expansive city coverage is more important than high sampling density in small areas for city-wide inequality estimates

(2) Redundant sampling is low priority—TEMPO provides the continuity

(3) TEMPO evaluation will focus on morning and evening time periods and need to demonstrate:

(a) Measurements resolve neighborhood-level NO_2 differences (much progress already made here)
(b) Spatial patterns in the columns reflect pollutant patterns at the surface ⟵ vertical profiling

(4) Understanding air pollution in specific neighborhoods with EJ concerns is a different endeavor than describing inequalities city-wide and not well handled by aircraft, may be better achieved with ground monitoring. Community leaders and other representatives must be deeply involved at all stages

Becky Schwantes / Carsten Warneke
(AEROMMA urban)

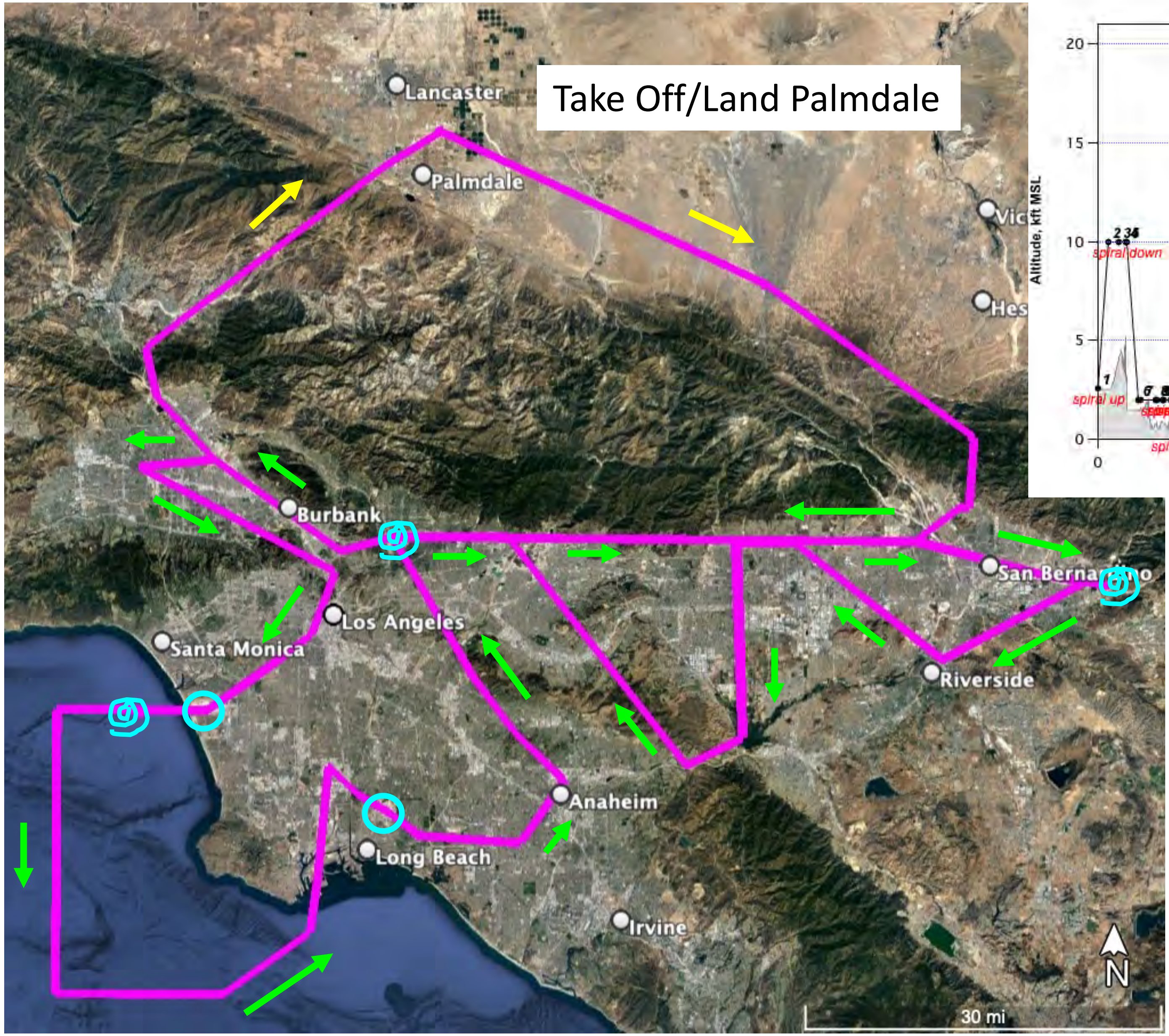
Preliminary Flight Plans for AEROMMA – Urban: Overview

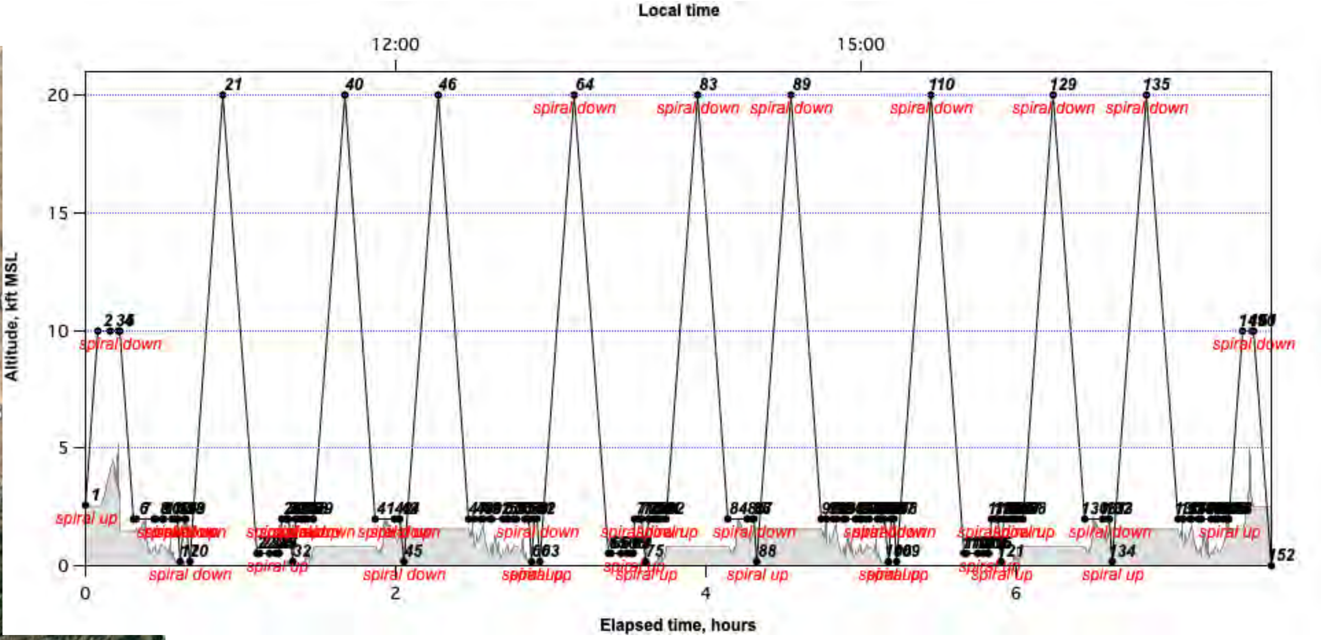
Becky Schwantes and Carsten Warneke

City	# of flights / city	# of 10 km profiles / flight	# of 6 km profiles / flight	Repeat Patterns / flight
Los Angeles (Tier 1)	3	0	9	3
New York (Tier 1)	4	2	6	2
Chicago (Tier 1)	4	2	6	2
Toronto (Tier 2)	2	2	6	2
Houston/Dallas (Tier 3)	Back-up	2	6	1
Atlanta (Tier 3)	Back-up	2	6	2
Transit	2	2		

Around 110 total flight hours + SARP

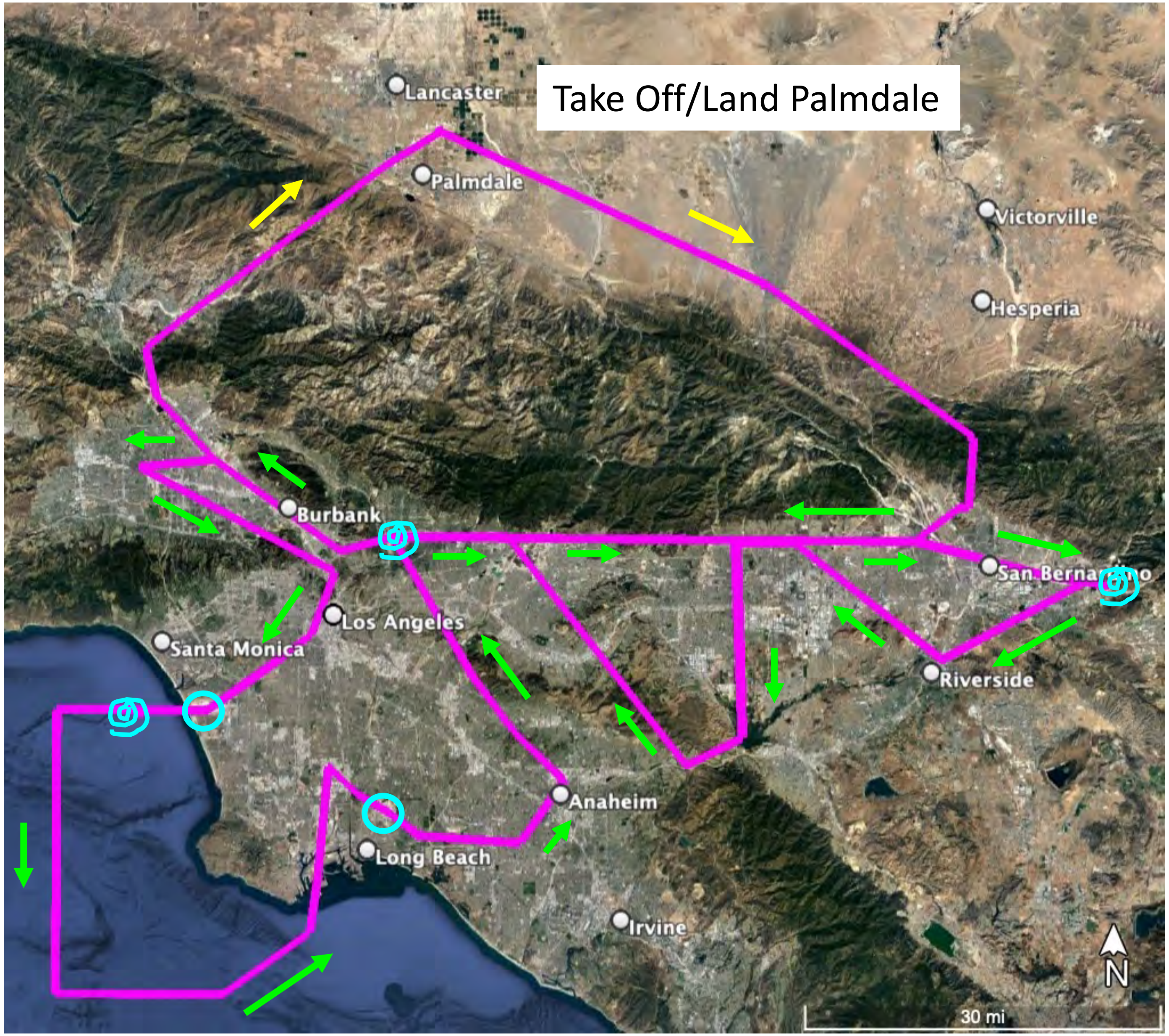
Preliminary Flight Plans for AEROMMA – Urban: Los Angeles





- Total flight time ~ 8 hrs
- Repeat the green arrow loop 3 times each flight to get diurnal information
- Three spirals up to 6 km – off coast, Pasadena, Redlands airport
- Two missed approaches – LAX and Long Beach airport
- Rest of the flight within the boundary layer

Preliminary Flight Plans for AEROMMA – Urban: Los Angeles

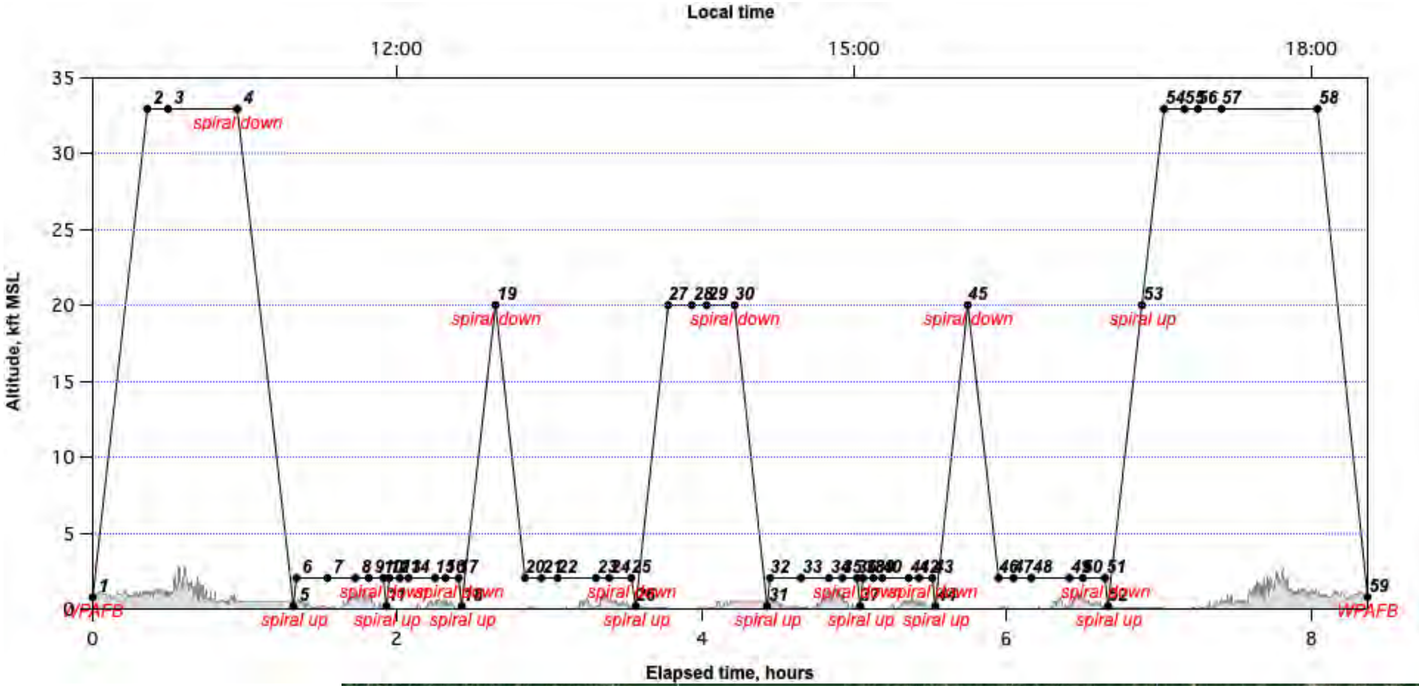


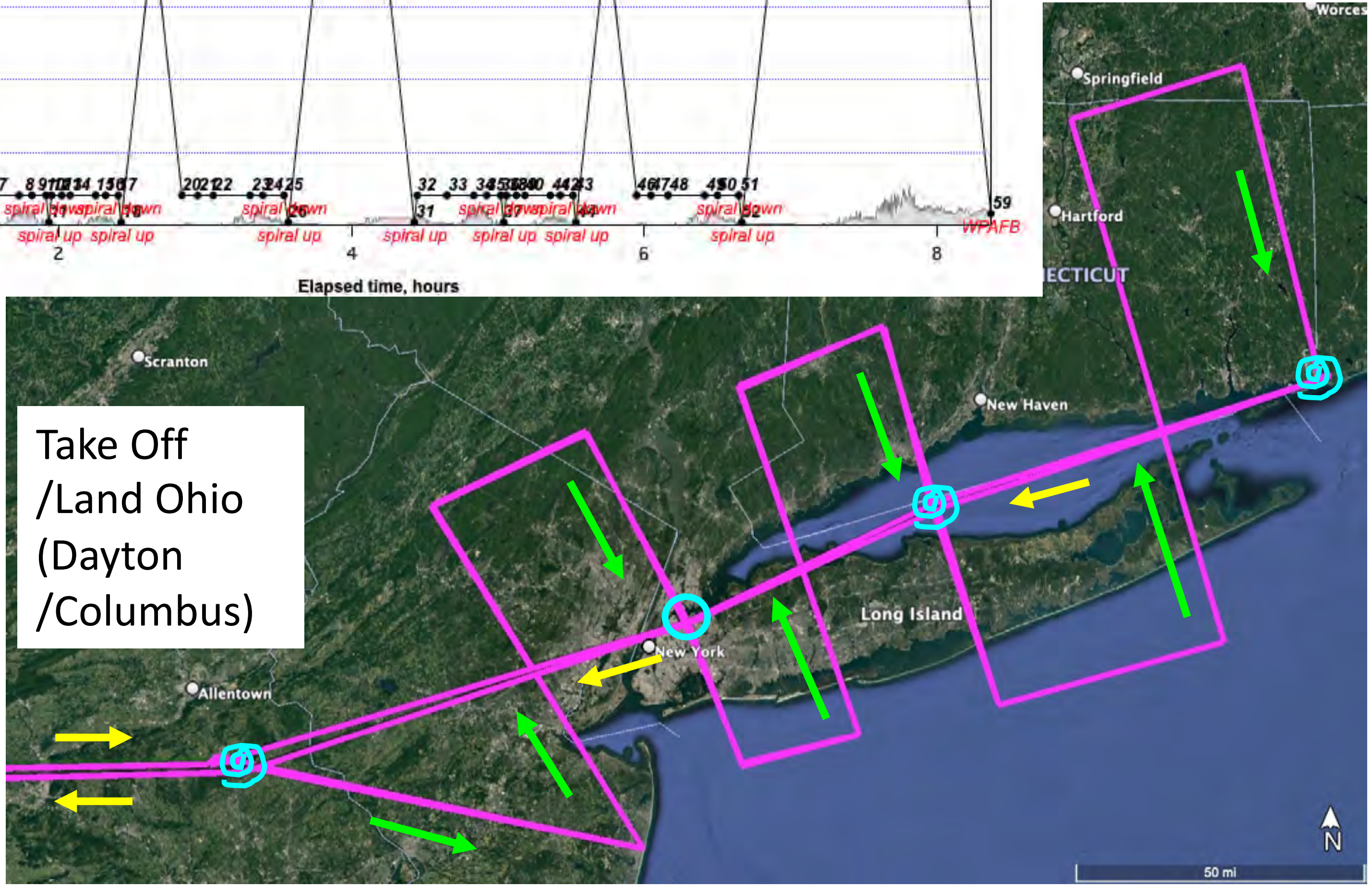
Goals:

- Repeat the magenta flight track three times
  - Weekday take off at 11 am
  - Weekday take off at 1 pm
  - Weekend take off at 11 am
- The repetition of the magenta flight track provides:
  - daily variability
  - diurnal variability
  - weekend/weekday impact
- The SARP flights (same payload as AEROMMA) greater coverage and more missed approaches around LA
  - Central Valley
  - Salton Sea

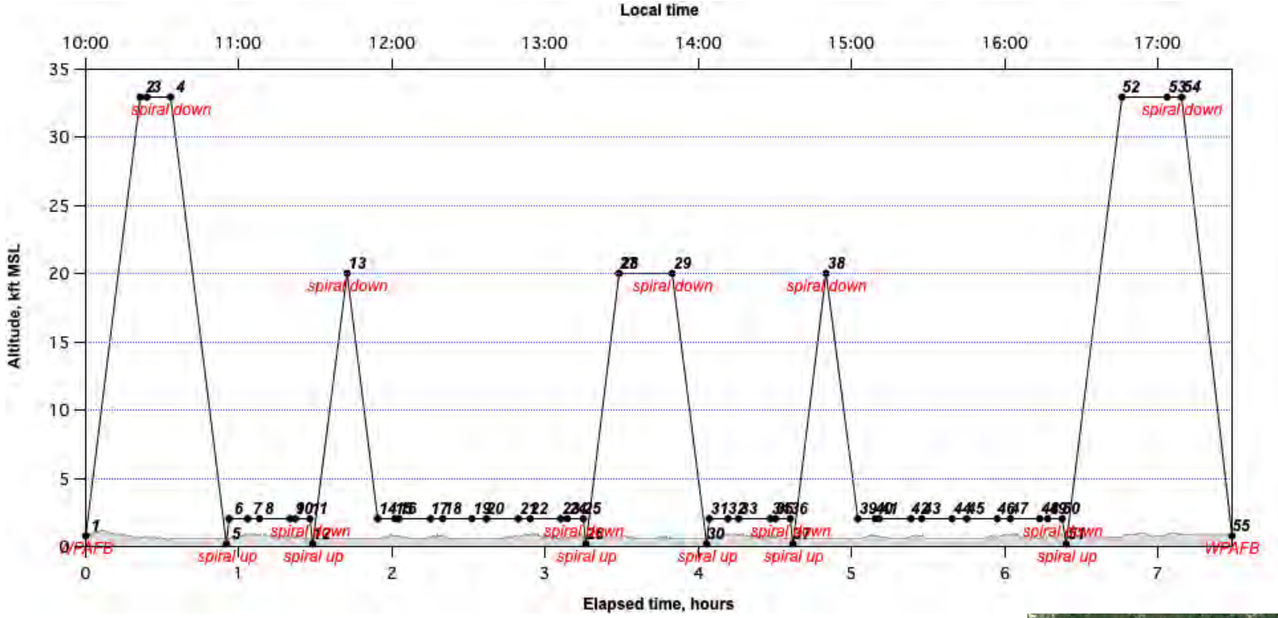
<u>Preliminary</u> Flight Plans for AEROMMA – Urban: New York City

- Total flight time ~ 8.5 hrs
- Repeat the green arrow raster 2 times each flight
- In between repeats fly at 6 km for Scanning-HIS
- Three spirals up to 6 km – Upwind, Long Island Sound, Downwind
- One missed approach – LaGuardia airport
- Rest of the flight tracks we stay within the boundary layer as much as possible
- **Goals:**
    - Pseudo-Lagrangian plumes
        - 1 weekday 10 am takeoff, 1 weekday noon takeoff, 1 weekend 10 am takeoff
    - 1 stagnation event

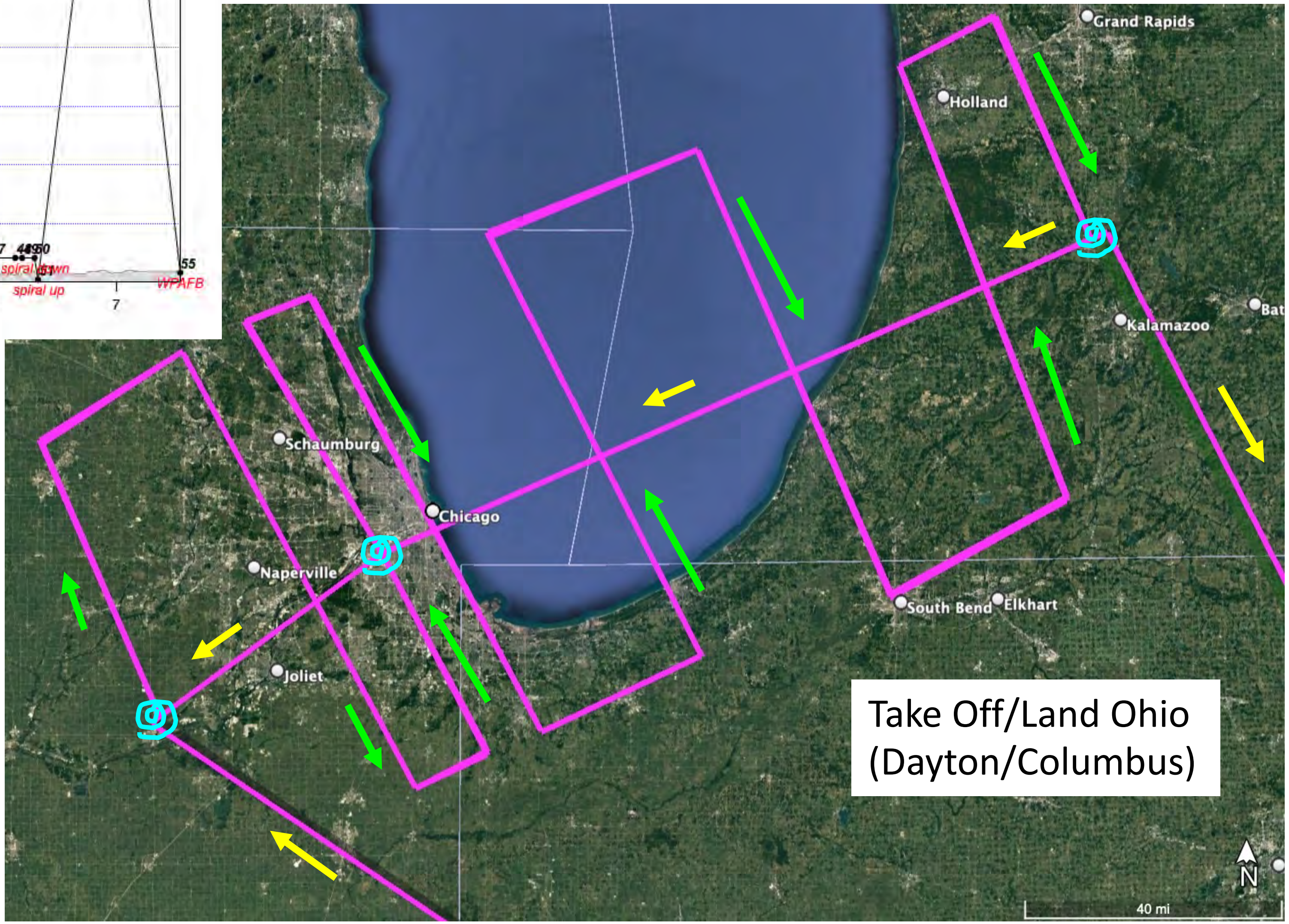




Preliminary Flight Plans for AEROMMA – Urban: Chicago



- Total flight time ~ 7.5 hrs
- Repeat the green arrow raster 2 times each flight to get diurnal information



- Three spirals up to 6 km – upwind, Midway airport or over Lake Michigan, downwind
- Missed approach – Midway airport
- Rest of the flight tracks we stay within the boundary layer as much as possible
- **Goals:** 2 weekday 10 am takeoff, 1 weekday noon takeoff, 1 weekend 10 am takeoff

Laura Judd (STAQS)

Synergistic TEMPO Air Quality Science

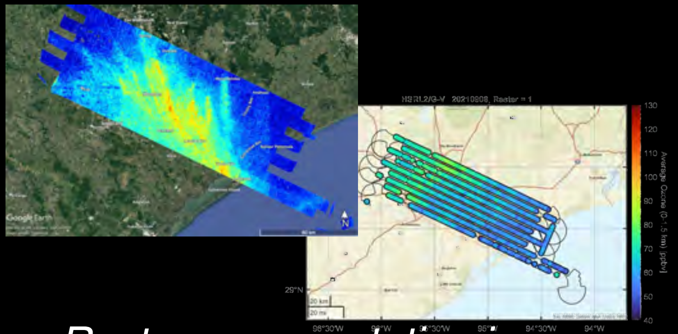
Gulfstream Flight Planning

	G-V: GCAS + HSRL2	G-III: AVIRIS-NG + HALO
Research flight hours	120	104
Targeted hours per flight	9-10	4
Flight-raster per day	1 flight – 3 rasters	2 flights-2 rasters
Nominal altitude	FL280	FL390
Primary Target Opportunities	4 days in each major city ~8 hours residual	

Prioritize systematic raster mapping of an ~56 x140 km area with the G-V 3x per day (morning-midday-afternoon) and G-III 2x per day (morning-afternoon) in primary target areas of LA, NYC, and Chicago

Forecasting priorities: clouds (especially cirrus)

Additional overflights will be considered secondarily and may include:
(1) extended legs to hit additional ground sites or source regions
(2) transecting of raster from a different direction overflying ground sites
(3) pollution plumes extending from urban cities before transiting to base



Raster representation in Houston during TRACER-AQ

Synergistic TEMPO Air Quality Science

Los Angeles- ascent/descent time (30 min):
🌞June 30th: 14:45-01:15 UTC(10.5 hour)

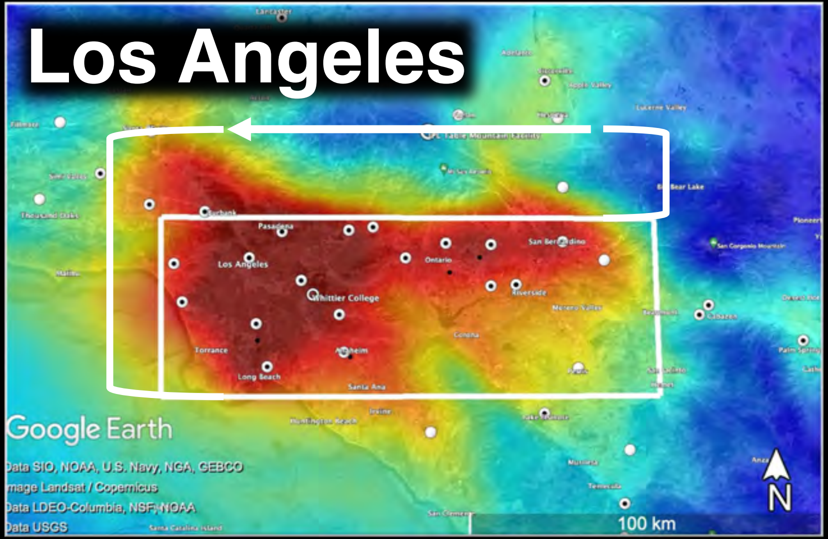
G-V: 3 rasters + ascent/descent + TMF x2 = 9h 20m
G-III:1 raster + ascent/descent + TMF x 1 = 3h 55m

NYC: transit of 1 hour one way
🌞 July 29: 11:45-22:15 UTC (10.5 hours)
🌞 August 29: 12:15-21:45 UTC (9.5 hours)

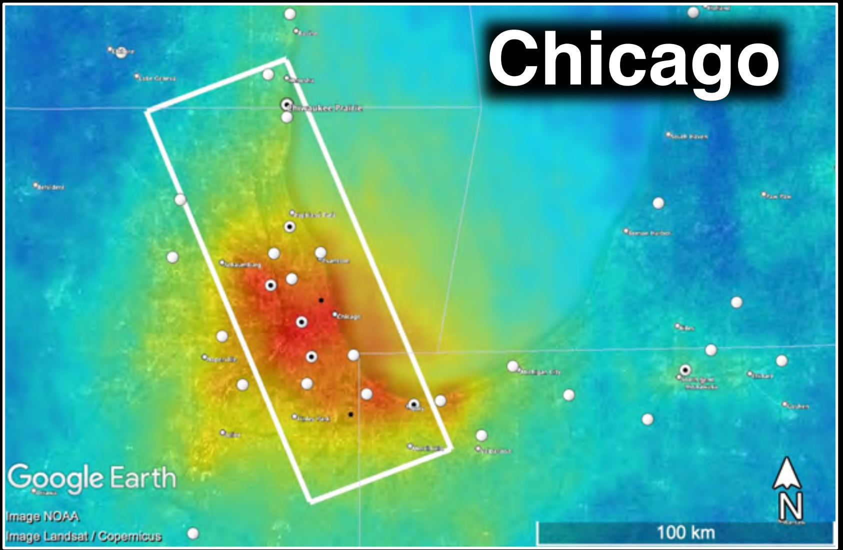
G-V: 3 rasters + transits + YCx2=10 h
G-III: 1 rasters + transit + local land + YCx1= 4h 15 m

Chicago: transit of 40 minutes one way
🌞 July 29: 12:45-23:15 UTC (10.5 hours)
🌞 August 29: 13:15-22:30 UTC (9.25 hours)

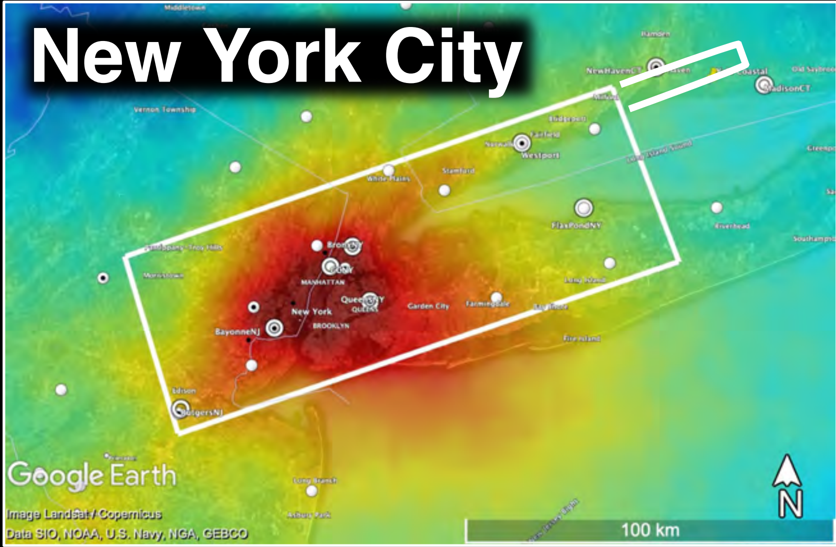
G-V: 3 rasters + transits = 8h 50m
G-III: 1 raster + transits = 3h 50m



- Overpassing TMF between rasters (25 minutes x1)
- Pollution over the water motivating small extended transect



- Targets of opportunities outside the raster?



- Overpassing New Haven and Yale Coastal is key between Rasters
- Opportunities to transect pollution outside before transiting home

Will make some other flight plans for potential secondary target cities

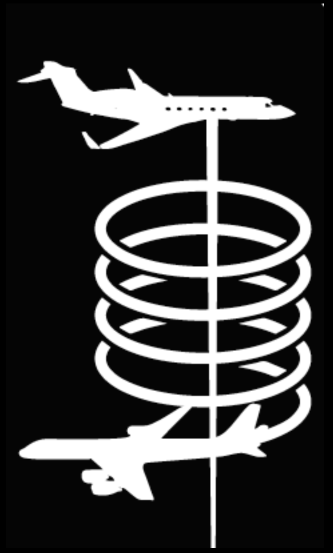
Synergistic
TEMPO
Air
Quality
Science

Additional thoughts:

→ Current thoughts are to have the G-III and G-V mapping the same flight lines spaced an appropriate distance apart to avoid direct under flights (laser operation rules) but to optimize synchronous measurements in morning & afternoon

- *Alternative idea: fly raster lines starting at opposing directions to increase the temporal frequency of HSRL data products from HSRL2 & HALO*

→ Remote sensing data will be even more informing when synchronized with other aircraft measuring profiles of NO_2, O_3, HCHO, methane, CO_2, and aerosol properties within raster areas.



→ Ask: If you have ideas of missing opportunities in these areas, please share (especially with geolocated information!)

John Mak (GOTHAAM)

GOTHAAM

GreaterNY Oxidant, Trace gas, Halogen and Aerosol Airborne Mission
Funded by the US National Science Foundation (ACP, GEO)

PIs: John E. Mak (lead PI), Daniel Knopf, Paul Shepson, Stony Brook University; AnnMarie Carlton, UC Irvine; Delphine Farmer, Colorado State U.; Roy Mauldin, U. Colorado; Kerri A. Pratt, U. Michigan; Joel Thornton and Lyatt Jaegle, U. Washington; Glenn Wolfe, U. Md/NASA

Location: ***Greater New York City***

Start-End Date:***July 1-August 12 2023***

NSF ***C-130 Aircraft (EOL)***

GOTHAAM

Deployment

PIs: John E. Mak (lead PI), Daniel Knopf, Paul Shepson, Stony Brook University; AnnMarie Carlton, UC Irvine; Delphine Farmer, Colorado State U.; Roy Mauldin, U. Colorado; Kerri A. Pratt, U. Michigan; Joel Thornton and Lyatt Jaegle, U. Washington; Glenn Wolfe, U. Md/NASA

Location: *Greater New York City*

Start-End Date:*July 1-August 12 2023*

NSF *C-130 Aircraft (EOL)*

Total DEPLOYMENT hours requested:	150
Est. number of flights:	18
Flight cruise altitude:	1000-1500’ AGL
Est length of flights	6-8 hours

Nighttime flights? YES, about 40% of flights will depart around 0200-0300 local time.

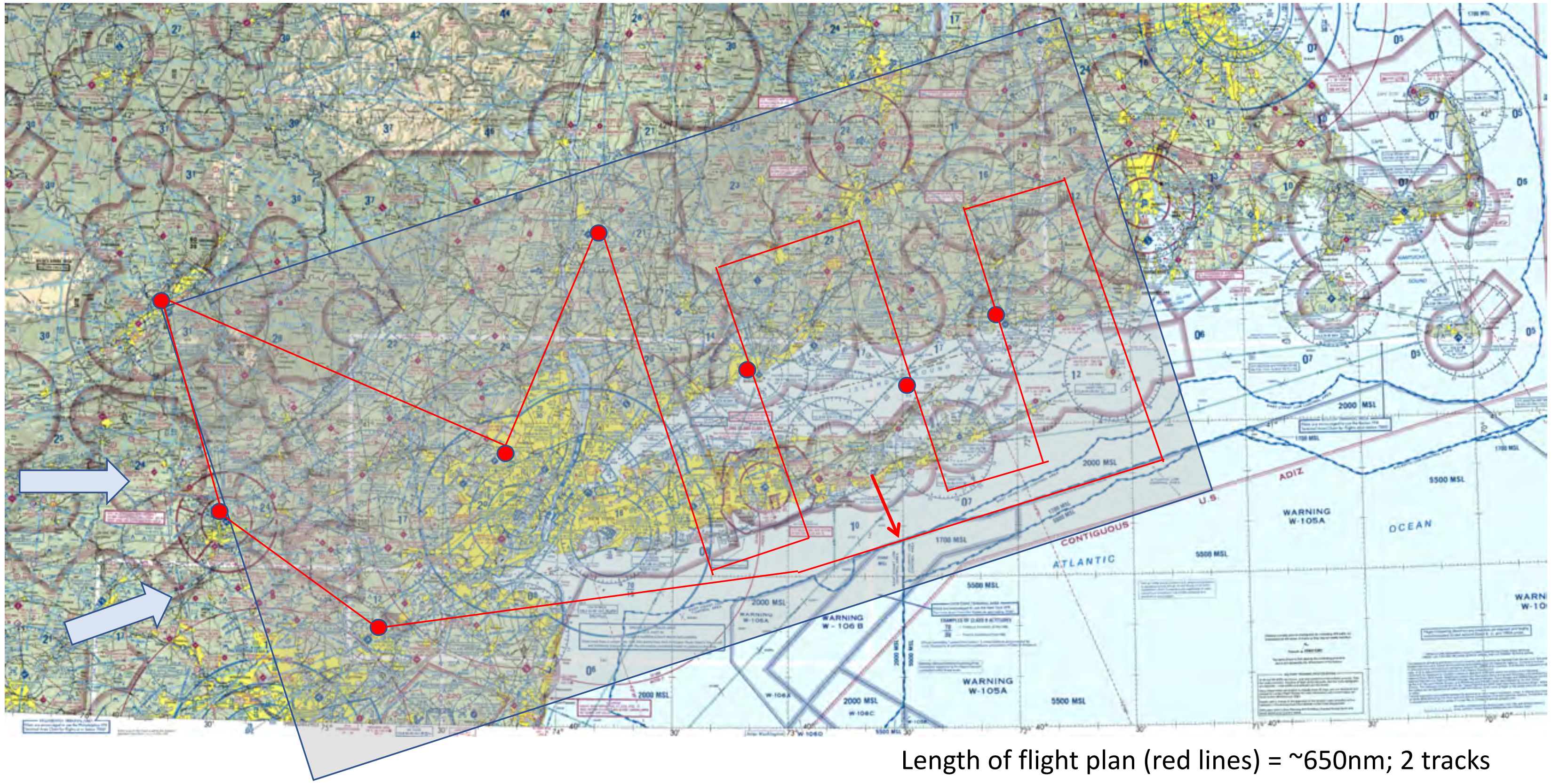
GOTHAAM

Deployment

- Flight planning approach:
- TBD. We will investigate Lagrangian flight planning (e.g., STILT), however because we are flying within the same space multiple times, we may also opt for fixed patterns to obtain composites. Still thinking about this.
- Lyatt Jaegle (UW, co-PI) will provide forecasts up to 5 days in advance.

Proposed flight plan 1, daytime, clear skies, E-W flow

Flight plan 1, daytime, W-SW flow, 1500’ AGL cruise alt, missed approaches/spiral climbs to ~6000’ at or between red dots



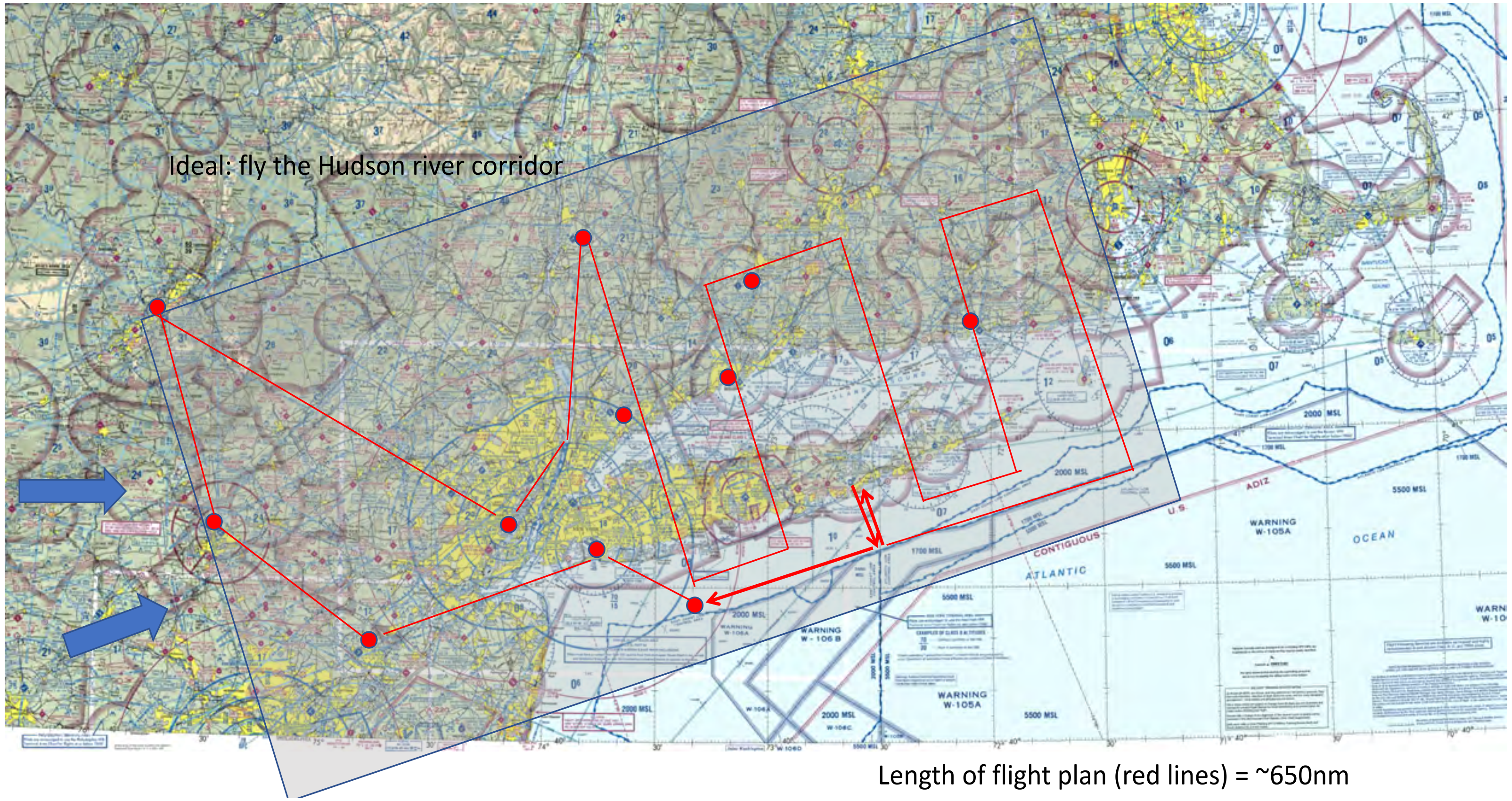
Length of flight plan (red lines) = ~650nm; 2 tracks

Specifics regarding missed approaches, climbs, etc. will be worked out in the field and will be subject to ATC, pilot discretion, traffic, etc.

Proposed flight plan 3, nighttime, clear skies

NOTE climbs are to a lower max altitude. More nighttime missed approaches are requested as a result of the very shallow boundary layer that we would like to sample. Missed approaches into Class B airports (KJFK, KEWR, KLGA) would be highly preferred.

Flight plan 3, night flight (0700 Z takeoff), W-SW flow, 1500’ AGL cruise alt, missed approaches/spiral climbs to ~3000’ near or between each red dot

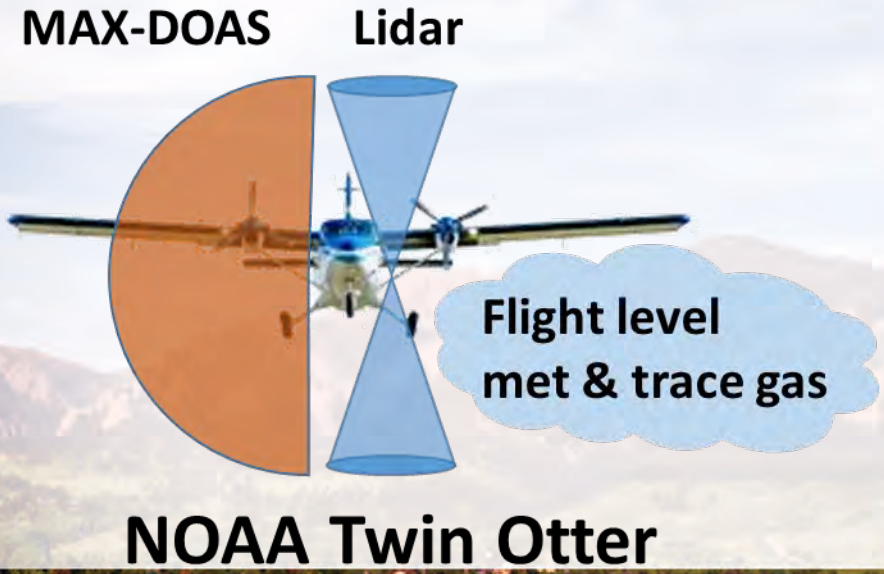


Length of flight plan (red lines) = ~650nm

Sunil Baidar (CUPiDS)

CUPiDS: initial flight plan ideas

Sunil Baidar and the CUPiDS team



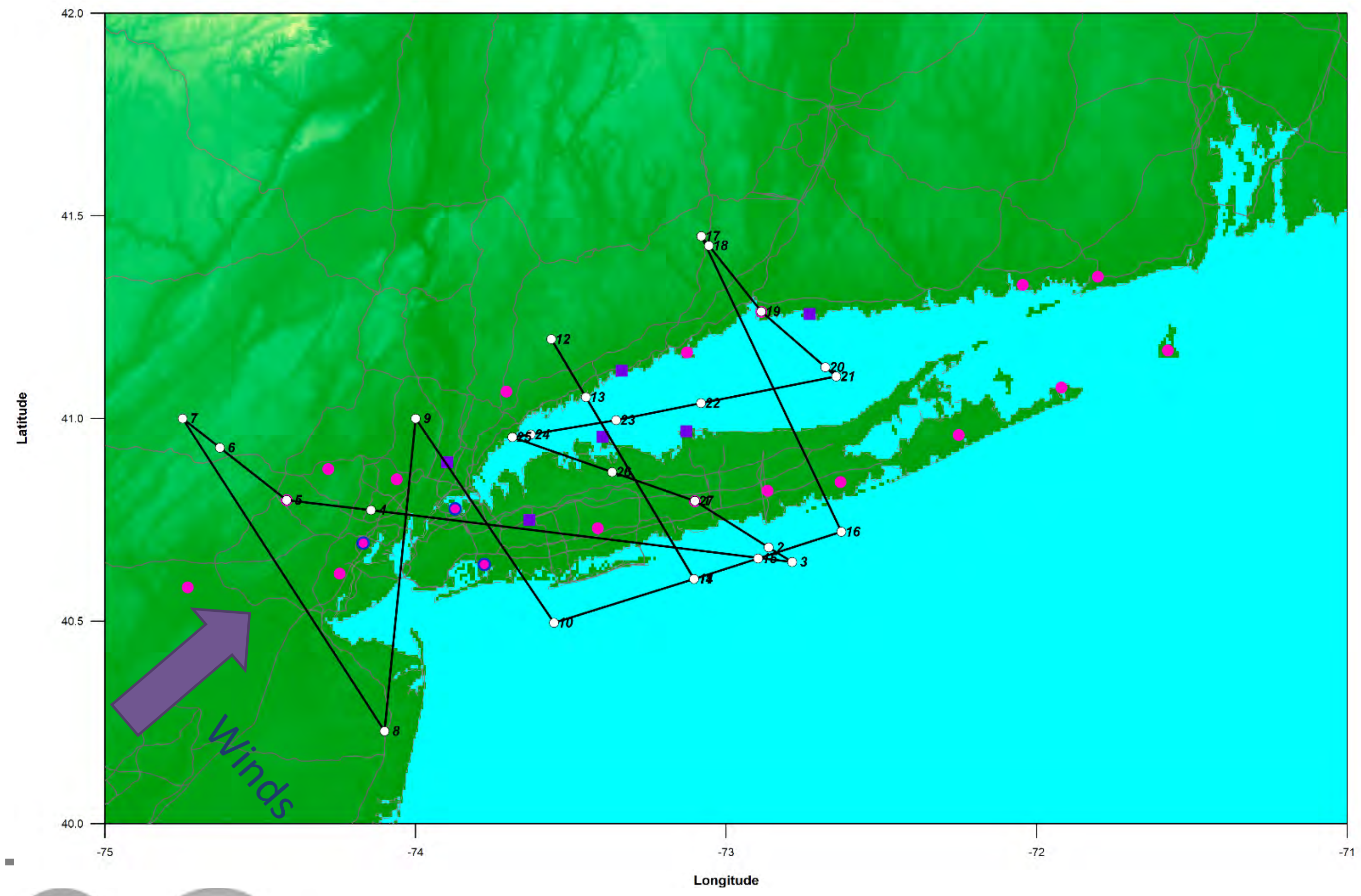
CUPiDS Coastal Urban Plume Dynamics Study 2023

NOAA CHEMICAL SCIENCES LABORATORY

CIRES

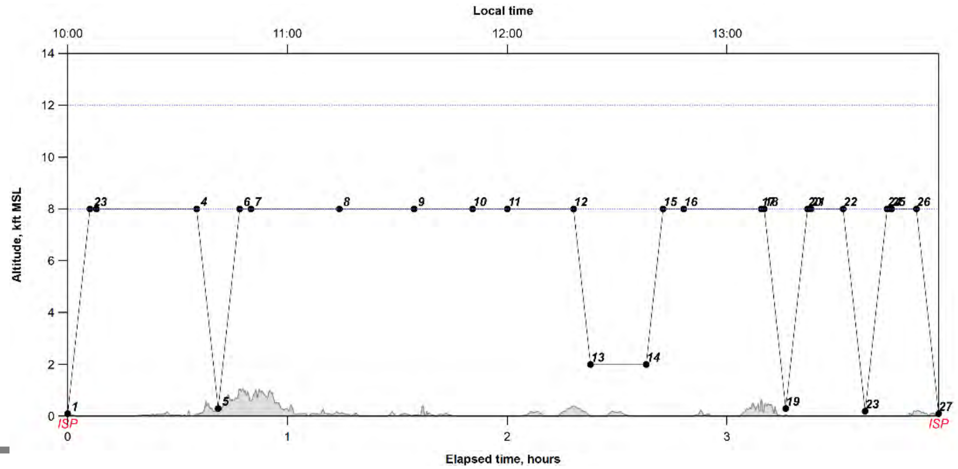
Pollution transport/ O_3 photochemistry

- Coordinated flight with DC-8



Features:

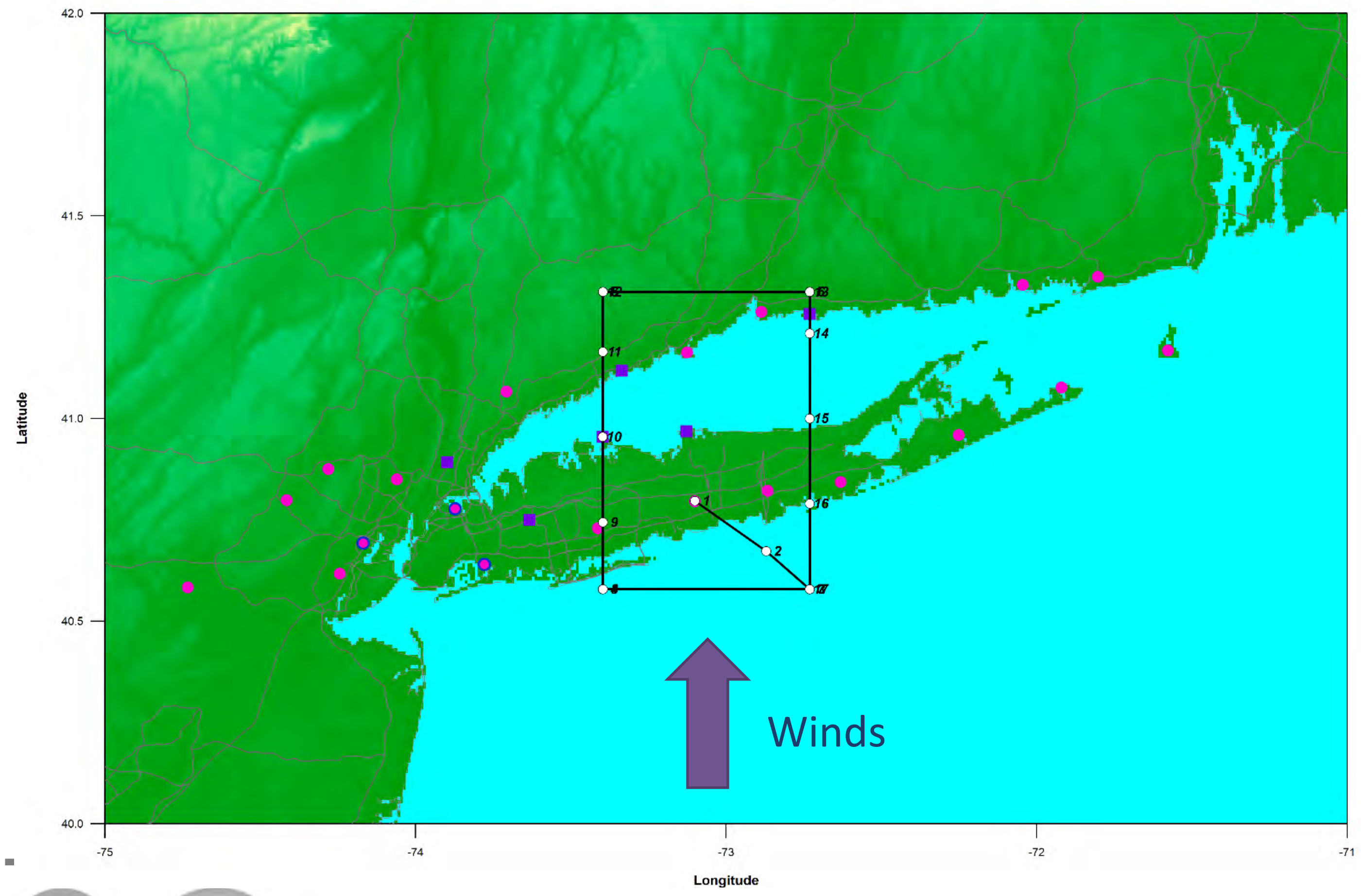
- Legs perpendicular to wind direction (SW).
- Flight legs upwind, over and downwind of the city.
- Profiles at 3 sites: upwind (Morristown), middle (TOPAZ) and downwind (New Haven, ground site)
- Stacked legs outside and inside BL
- Flight altitude: ~500 m above BL

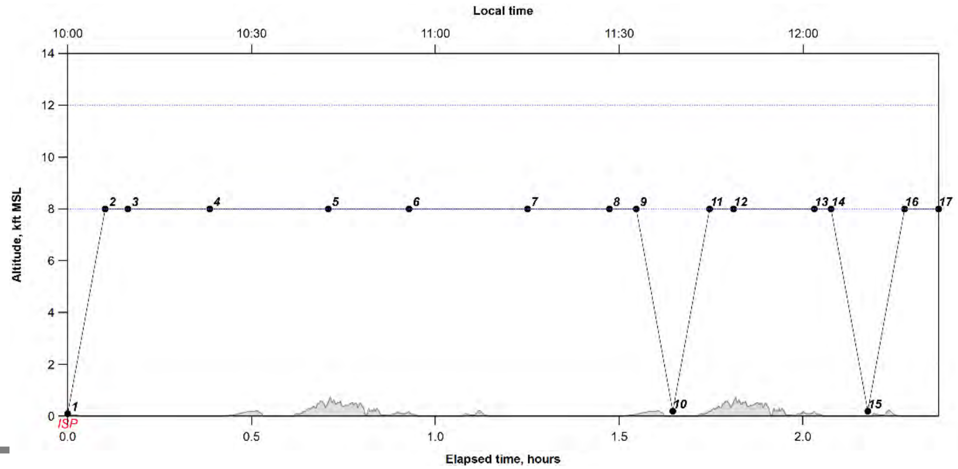


Temporal Evolution of Sea Breeze

Features:

- Repeat cycle: 1 hour
- Profiles at TOPAZ and ground site every other loop
- ~4 loops per flight
- Flight altitude: ~500 m above BL



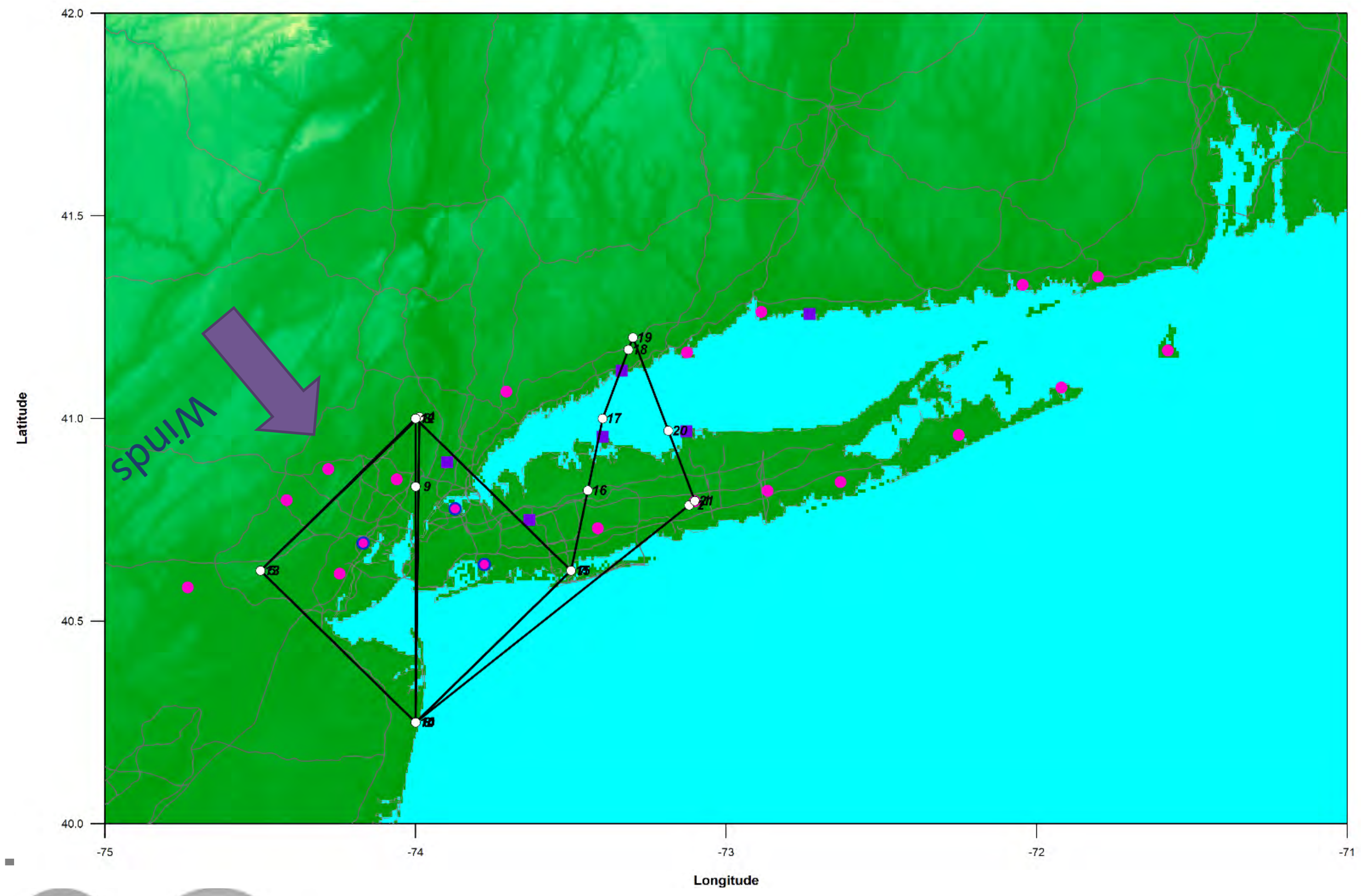


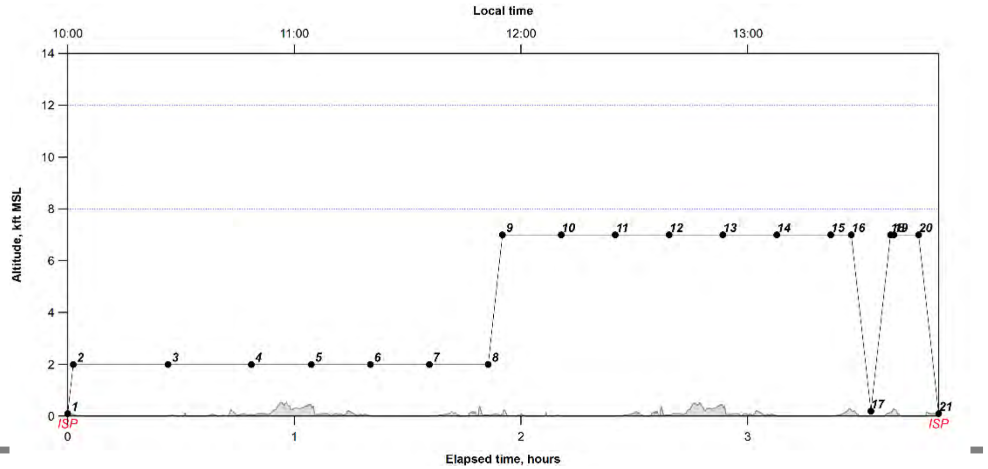
Quantify NY emissions

Features:

- Flight legs perpendicular and parallel to wind direction.
- One box inside the BL and one outside
- Flight leg along the Hudson

- Based on Twin Otter flight during ECO.

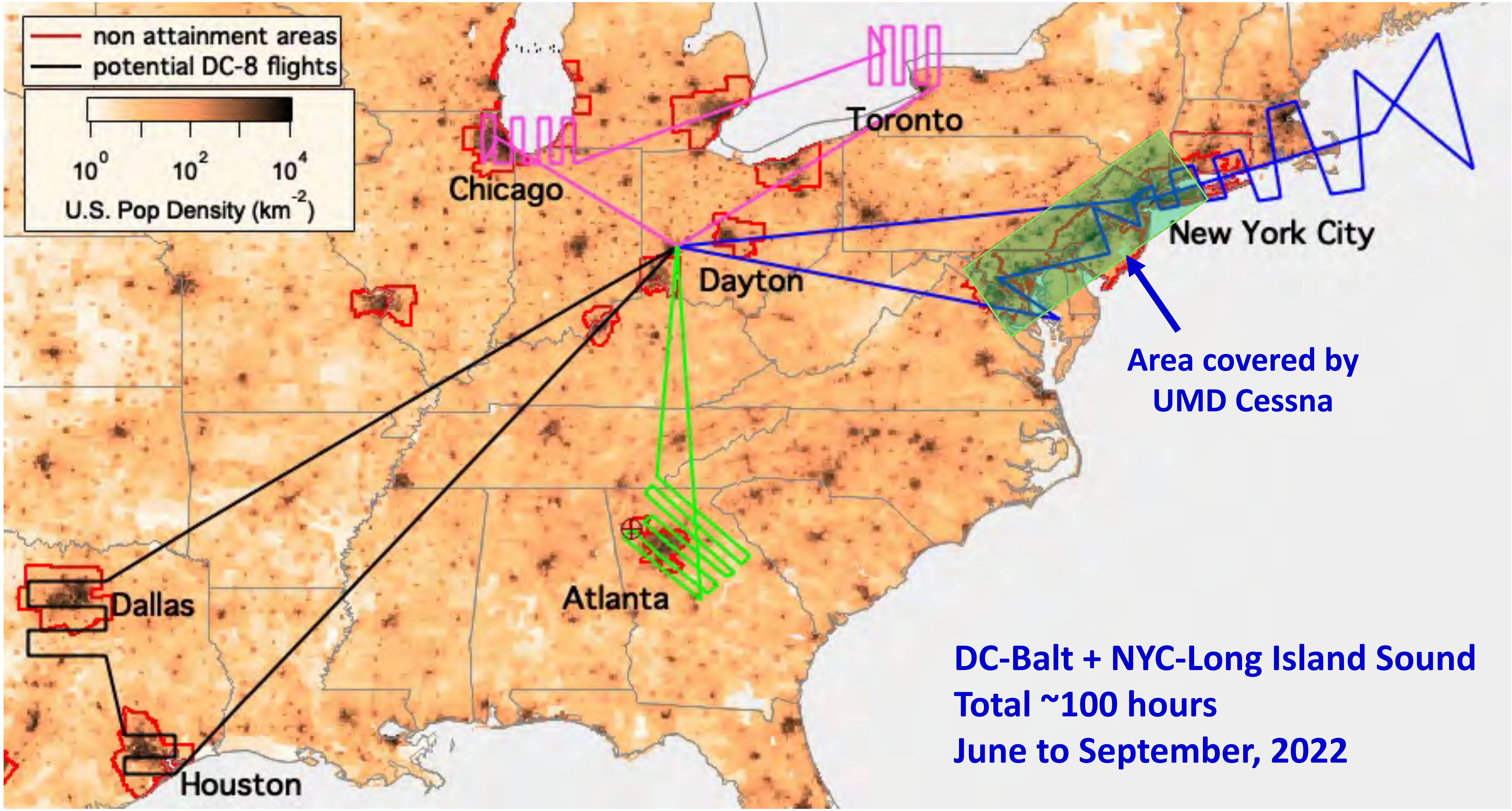




Xinrong Ren (ARL/UMD CESSNA)

NOAA-ARL/UMD Cessna: Readiness and Flight Plans

Xinrong Ren[1], Phil Stratton[1,2], Paul Kelley[1,2], Winston Luke[1], Russ Dickerson[2], and Pete DeCarlo[3]
[1]NOAA Air Resources Laboratory (ARL) [2]University of Maryland [3]Johns Hopkins University



NOAA-ARL/UMD's Aircraft Measurements during AEROMMA 2023

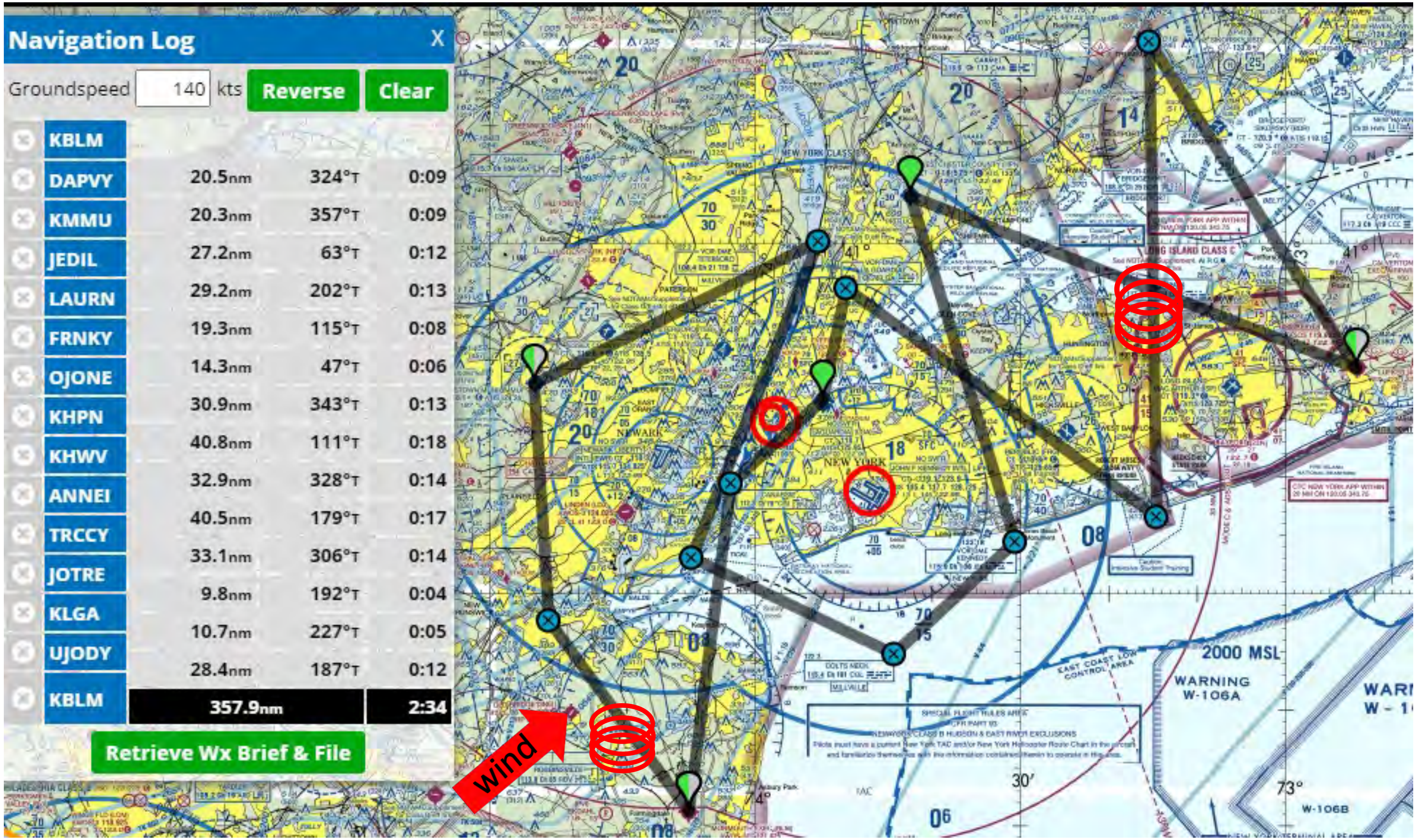
Cessna 402 Research Aircraft

Cessna Research Aircraft Instrumentation

Variable	Method
Position	GPS
Meteorology (T, RH, P, 2-D Wind)	Thermistor Hygristor, Capacitance Manometer, Differential GPS
Fast Greenhouse Gas Analyzer (CH_4/CO_2/CO/H_2O)	Cavity Ring Down Spectroscopy Picarro Model G2401-m
Ethane Detector	Mid-IR Absorption, Aeris Ultra
Ozone (O_3)	UV Absorption
Nitrogen Dioxide (NO_2), Nitric Oxide (NO) Nitrogen Oxides (NOy)	CAPS, Teledyne Chemiluminescence, Thermal dissociation to NO
Black Carbon (7 wavelengths at 370, 470, 520, 590, 660, 880, 950 nm)	Aethalometer, AE43
VOCs*	TofWerk PTR-Tof-MS

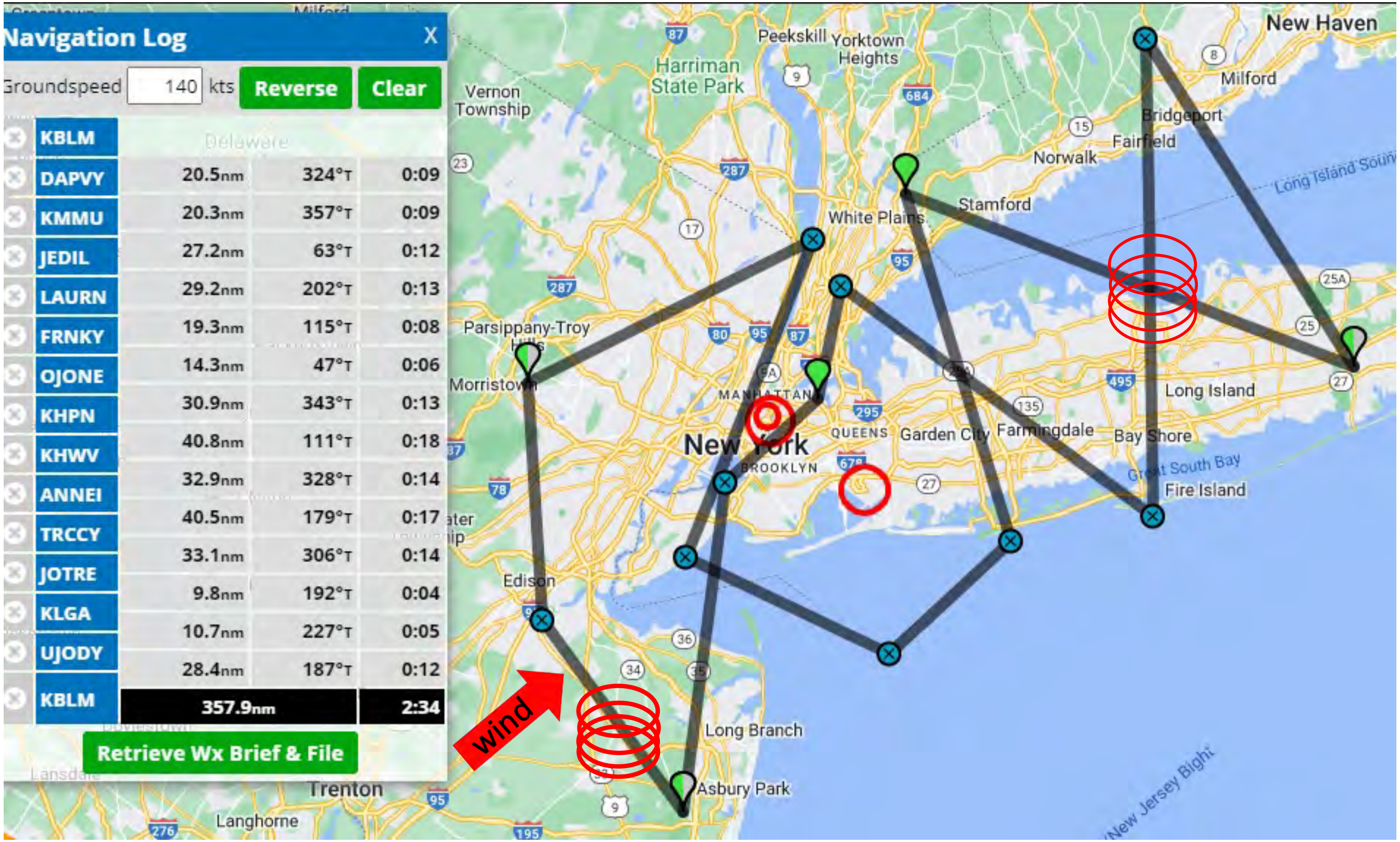
* Support is needed for PTR-ToF-MS (PI: Pete DeCarlo, Johns Hopkins). **All other instruments will be ready.**

Flight Plan Example: NYC-Long Island Sound



- Based on air quality forecast
- To coordniate with other aircraft

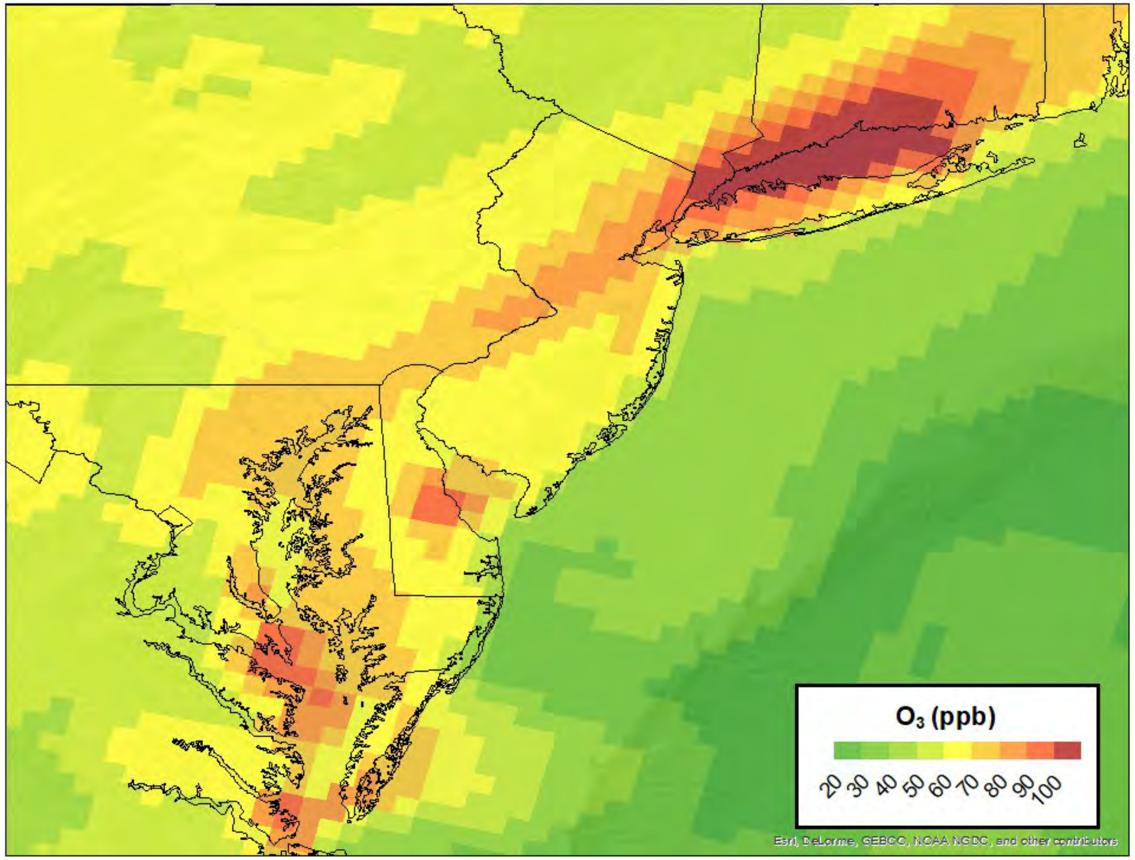
Flight Plan Example: NYC-Long Island Sound



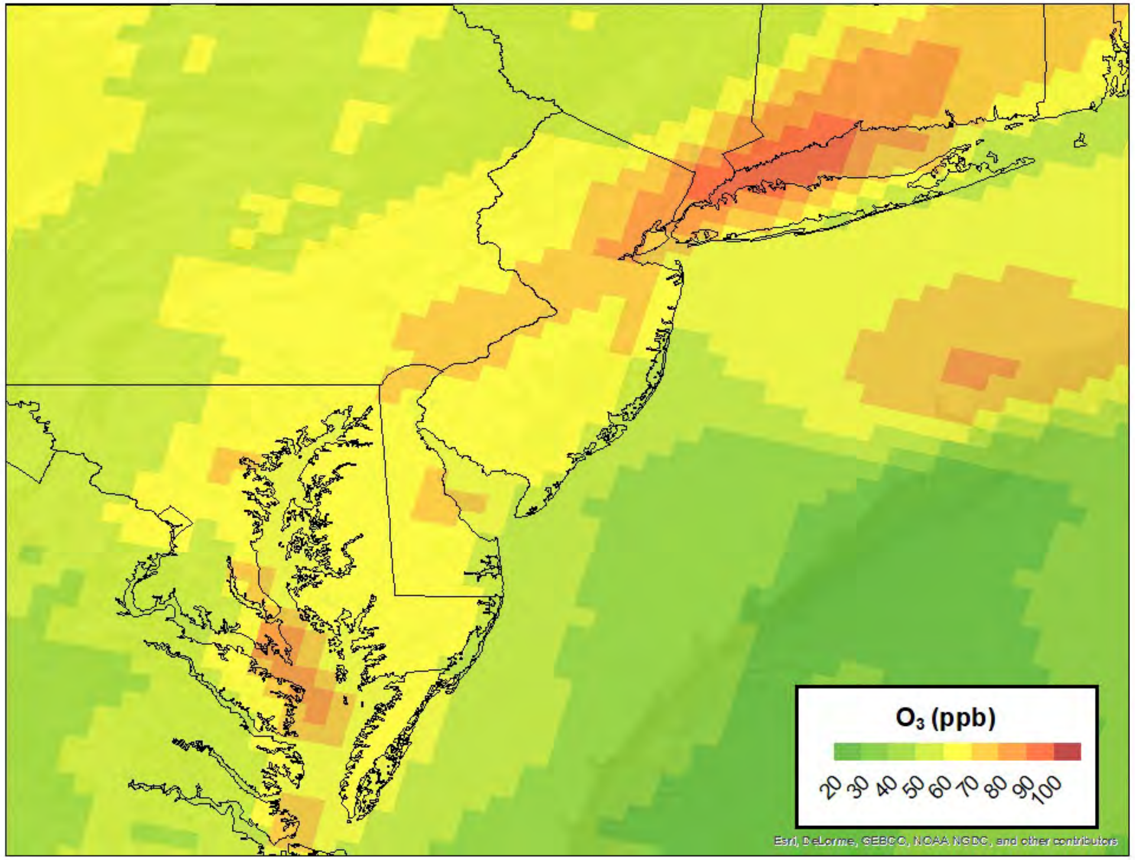
Morning & afternoon flights

Ozone forecast, Sunday, 7/19/20

1-hour Ozone, Sunday (7/19) @ 2 PM EDT



8-hour Ozone, Sunday (7/19)



Meteorology initialized in WRF-Chem utilizing NAM 7/18 00Z forecast, FIVE-VCP 2019 inventory

Go-No Go decisions: based on the latest forecast (i.e., 24 hr)

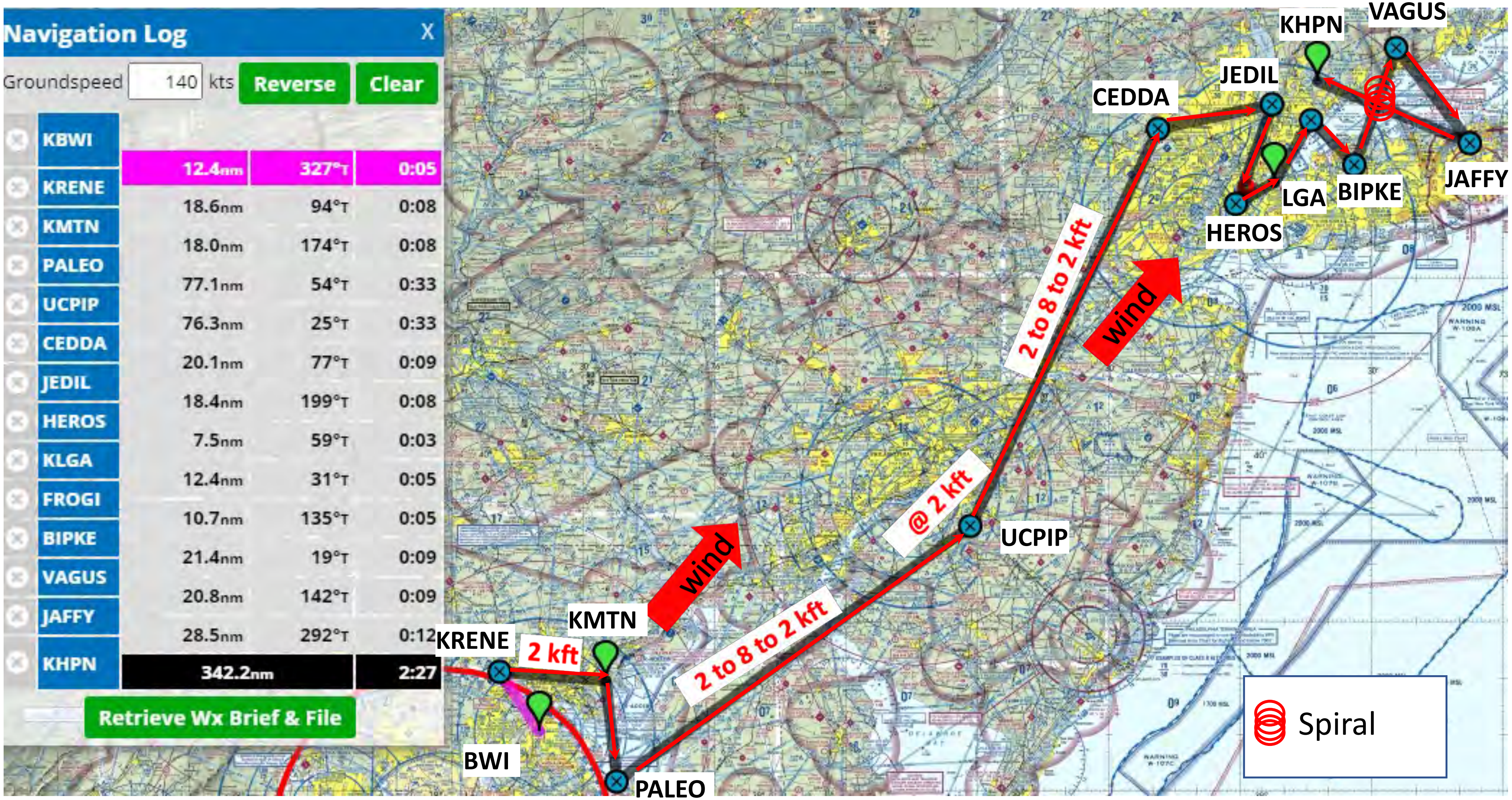
Forecast timing: 3-day AQ forecast with daily updates.

UMD Cessna Flight Plan for Sunday AM, 7/19/20

Objective: Photochemistry/emission flight over Baltimore/Philly/NYC

Waypoints: KBWI KRENE KMTN PALEO UCPIP CEDDA JEDIL HEROS KLGA FROGI BIPKE VAGUS JAFFY KHPN

Takeoff: ~11 AM EDT, Duration: ~3 hrs

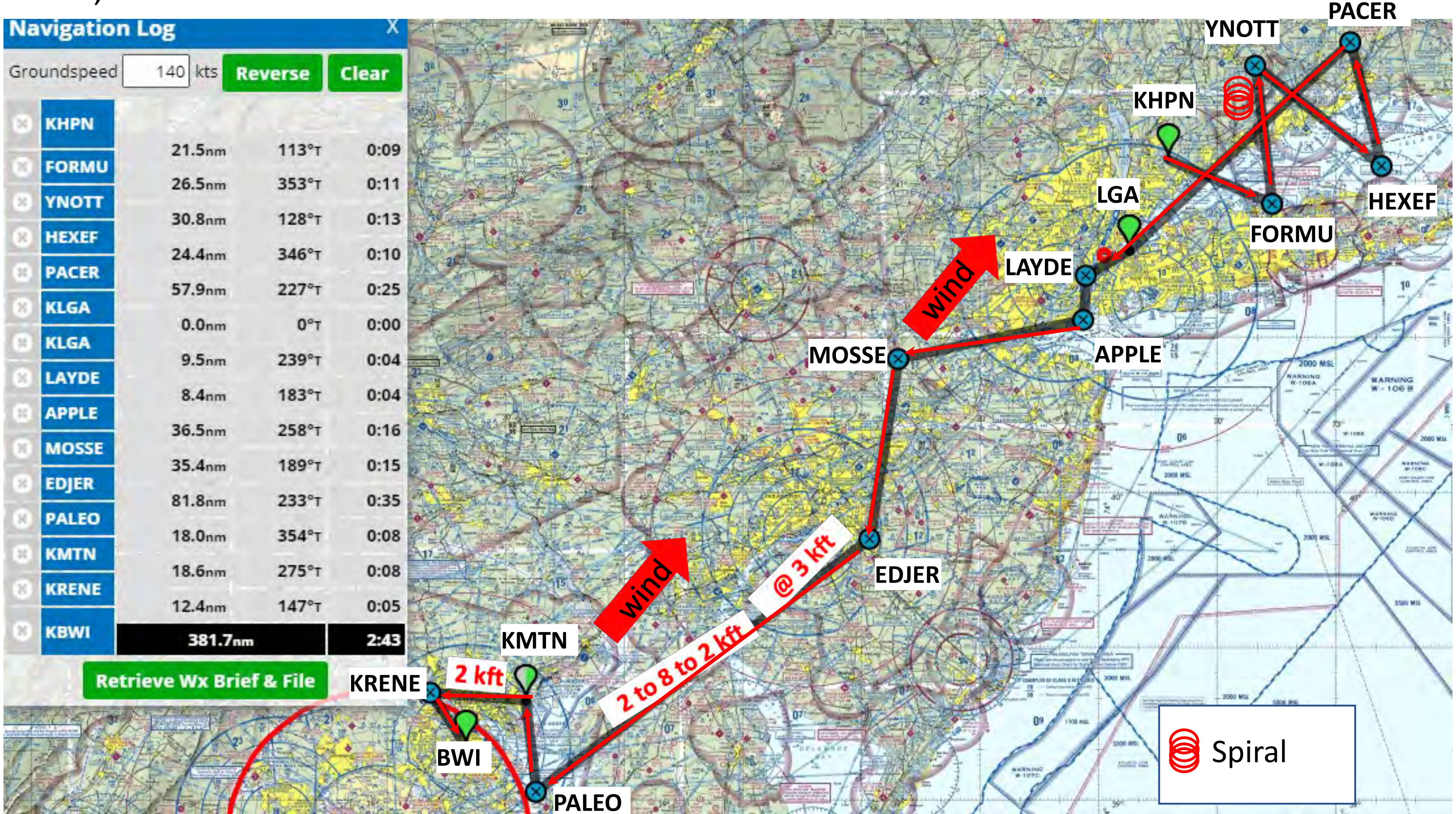


UMD Cessna Flight Plan for Sunday PM, 7/19/20

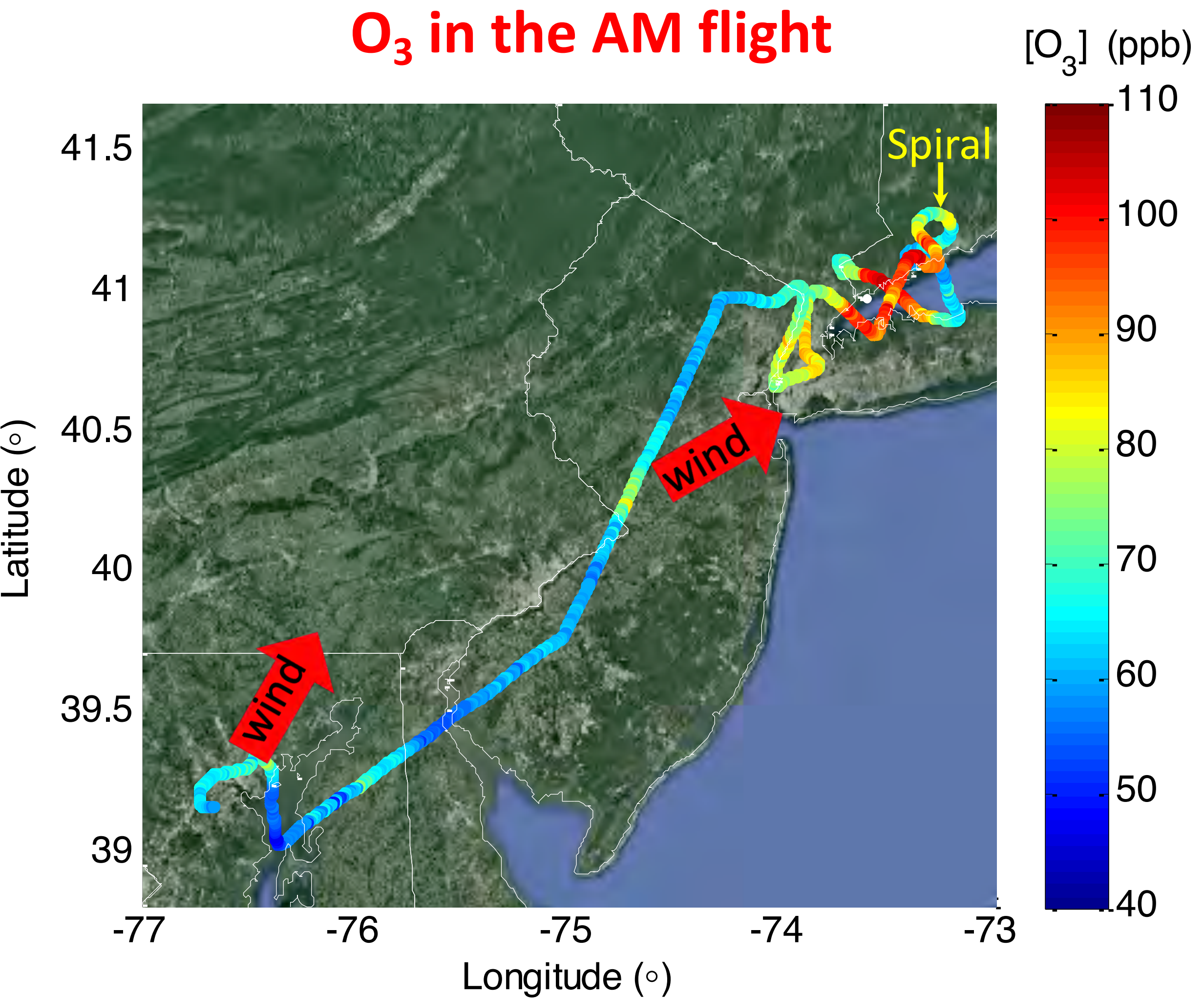
Objective: Photochemistry/emission flight over Baltimore/Philly/NYC

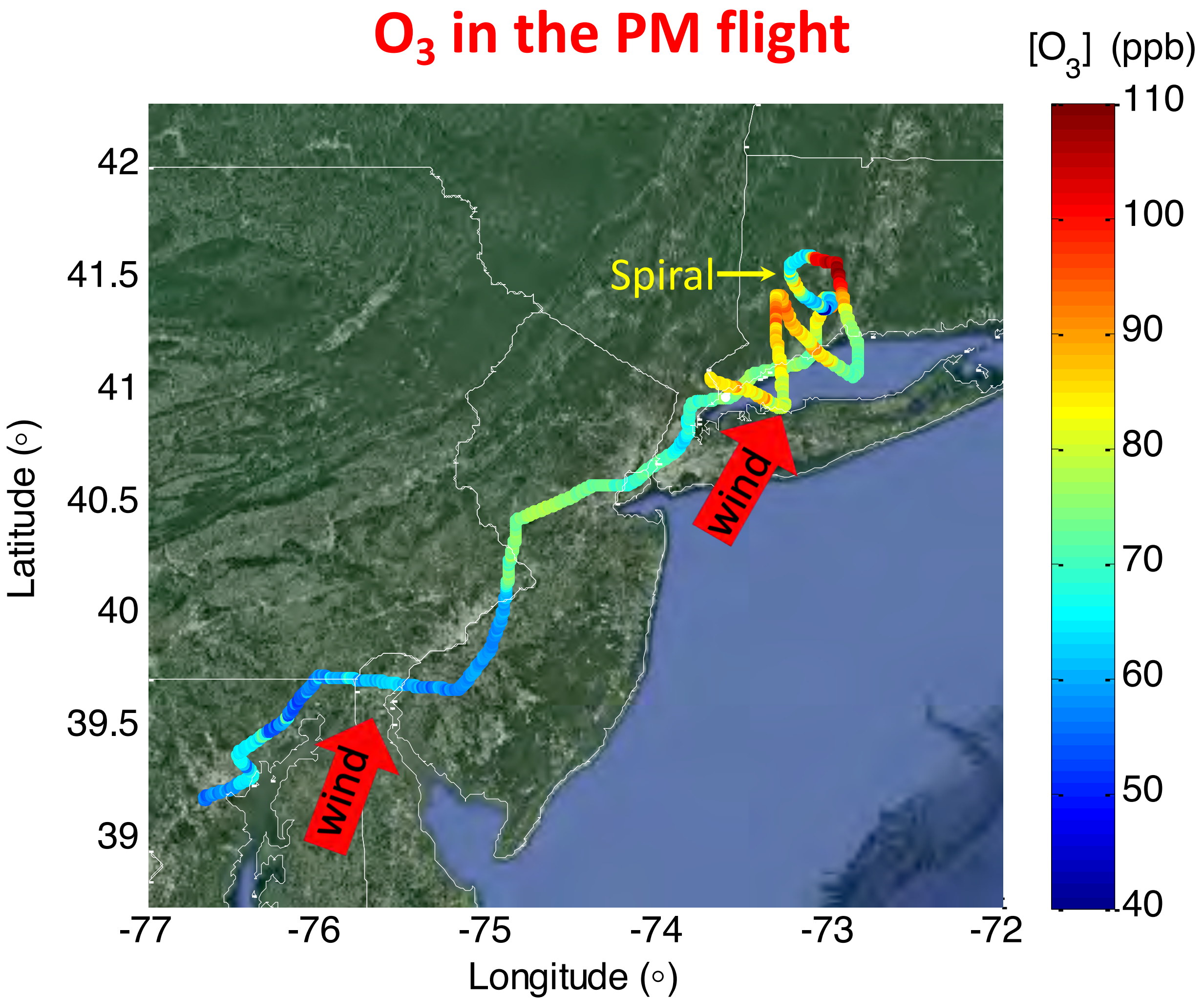
Waypoints: KHPN FORMU YNOTT HEXEF PACER KLGA LAYDE APPLE MOSSE EDJER PALEO KMTN KRENE KBWI

Takeoff: ~3 PM EDT, Duration: ~3 hrs



O_3 on the flight track





- Max. O_3 over the LIS in the early afternoon.
- SSW wind in the afternoon pushed the NYC downwind plume toward CT inland.

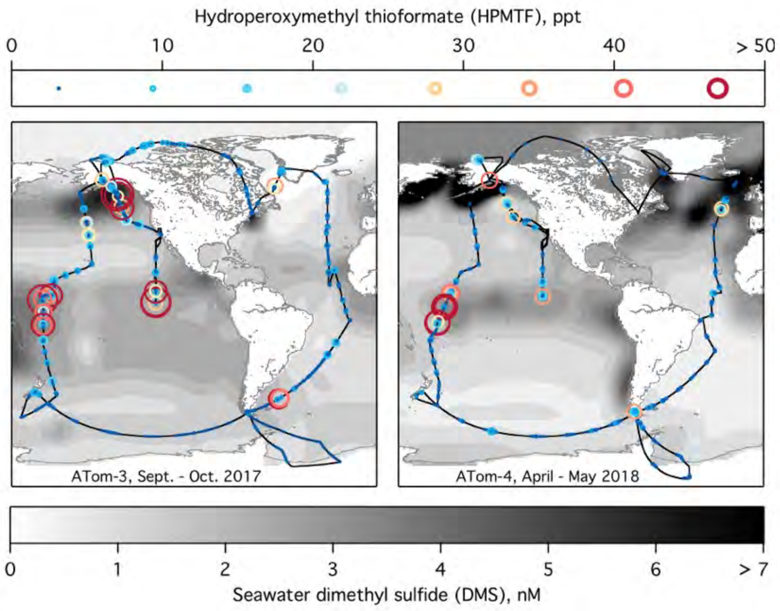
Andrew Rollins/Patrick Veres (AEROMMA marine)

Sampling Strategy 1: Low latitude marine fluxes

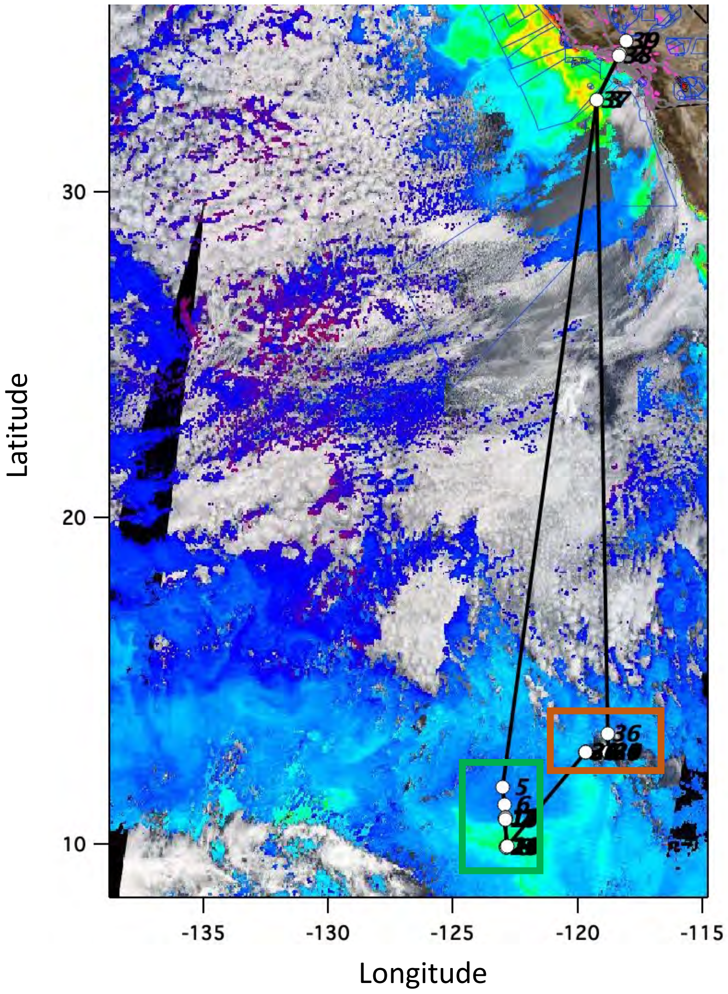
Target flux sampling opportunities in tropical and mid-latitude Pacific where important fluxes of key species are inferred to occur

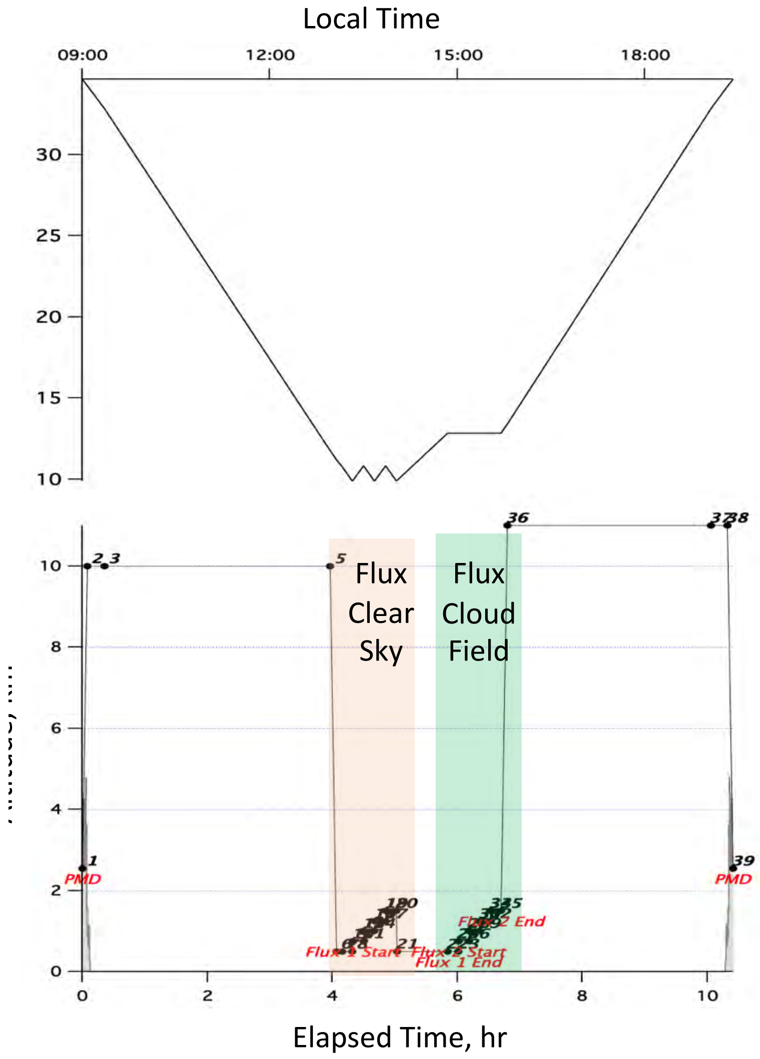
Location determined by several variables:

- Cloud fields
- DMS climatology
- NO_x abundance
- Wind speed
- Dissolved O_2



Veres et al., 2020





Sampling Strategy 2: Chasing New Particle Formation from DMS

1. Targeted sampling and extended dwell in and around regions with higher likelihood of NPF

2a. NPF Identified – Sample within region to observe evolution of NPF events

2b. No NPF identified - Divert to secondary goals of flux sampling in variable cloud and cloud free fields (as in example)