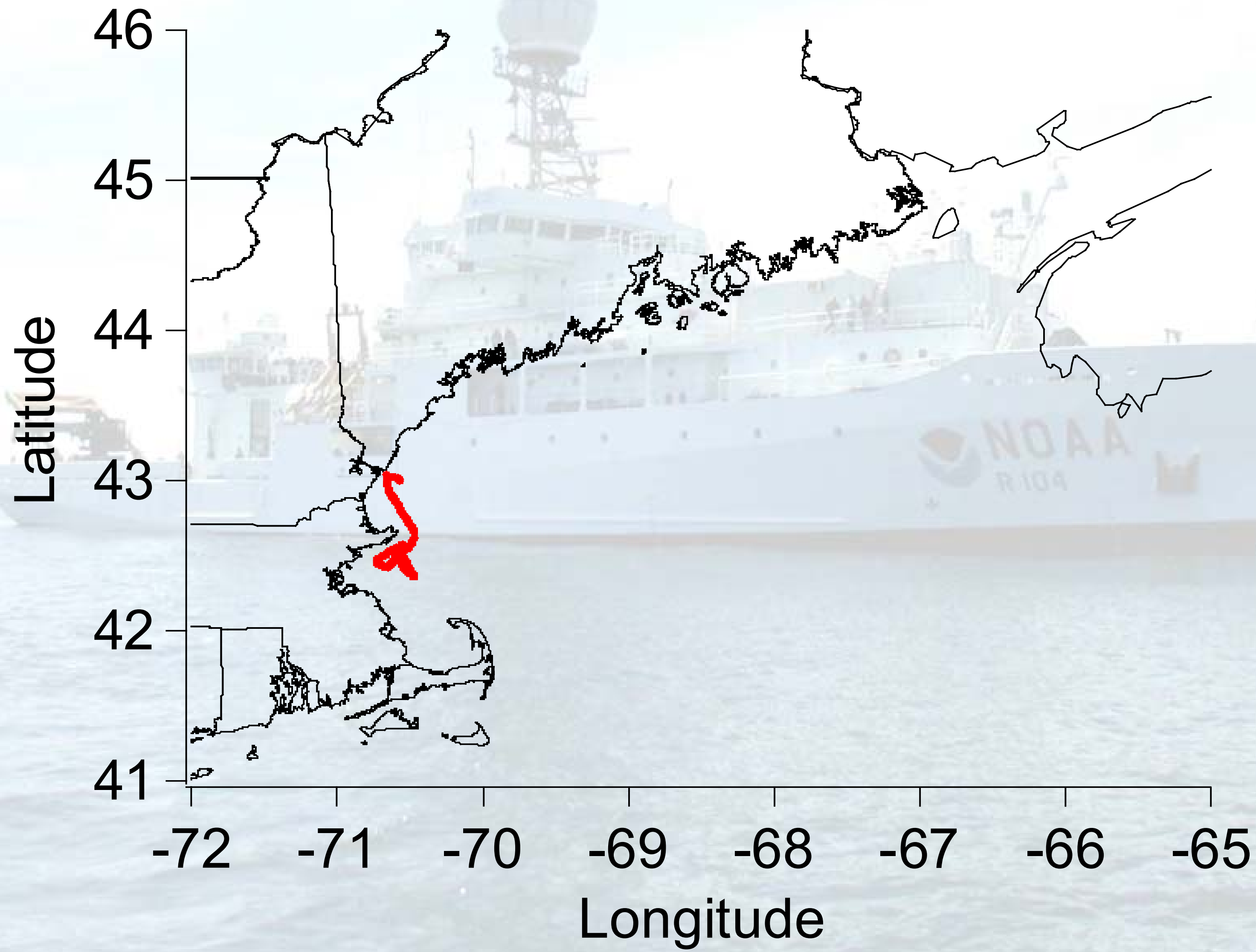
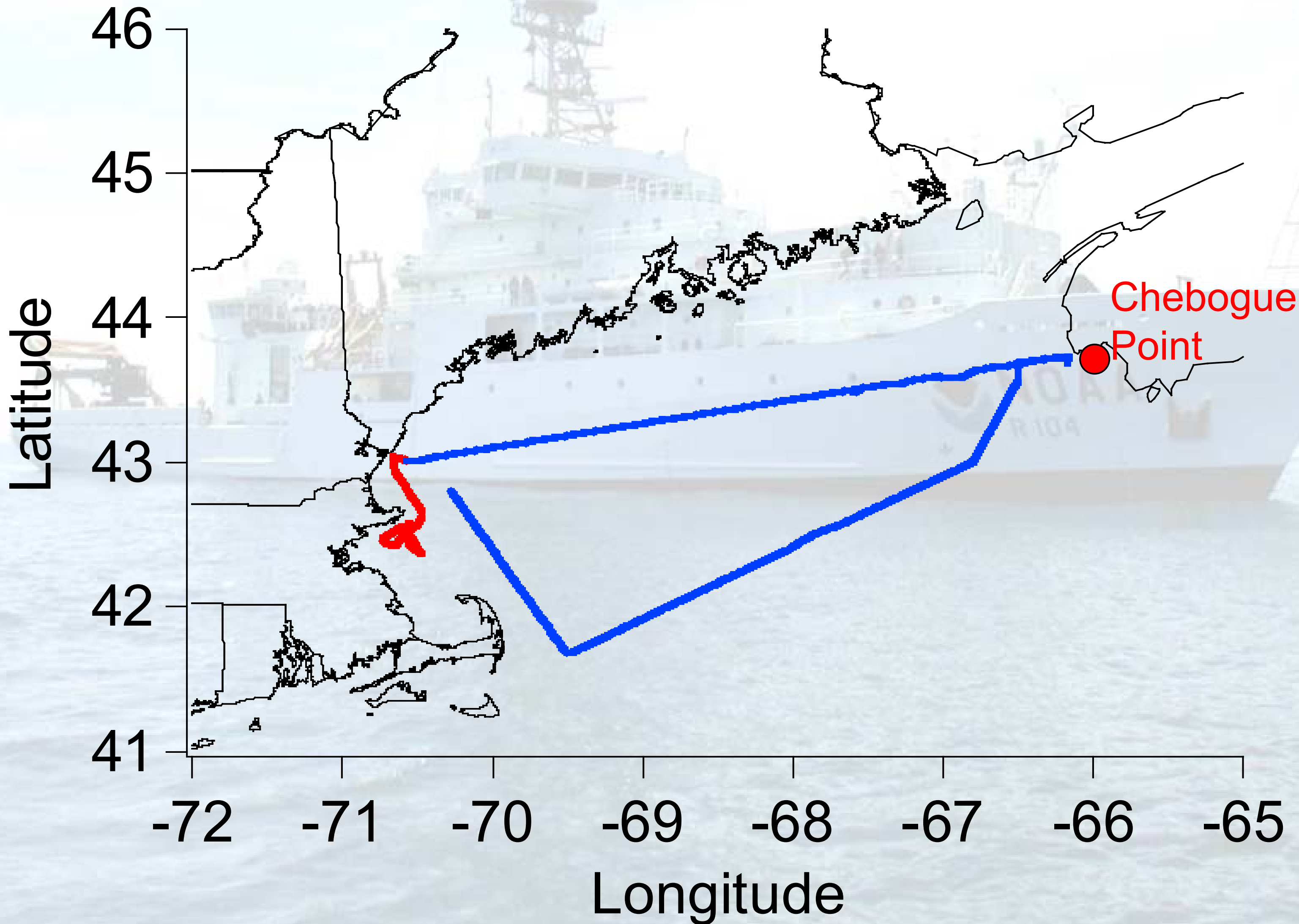
NEAQS – ITCT 2004

NOAA RV Ronald H. Brown
Leg 1, July 5 – 23, 2004

Ronald H. Brown Cruise Track
NEAQS – ITCT 2004, Leg 1

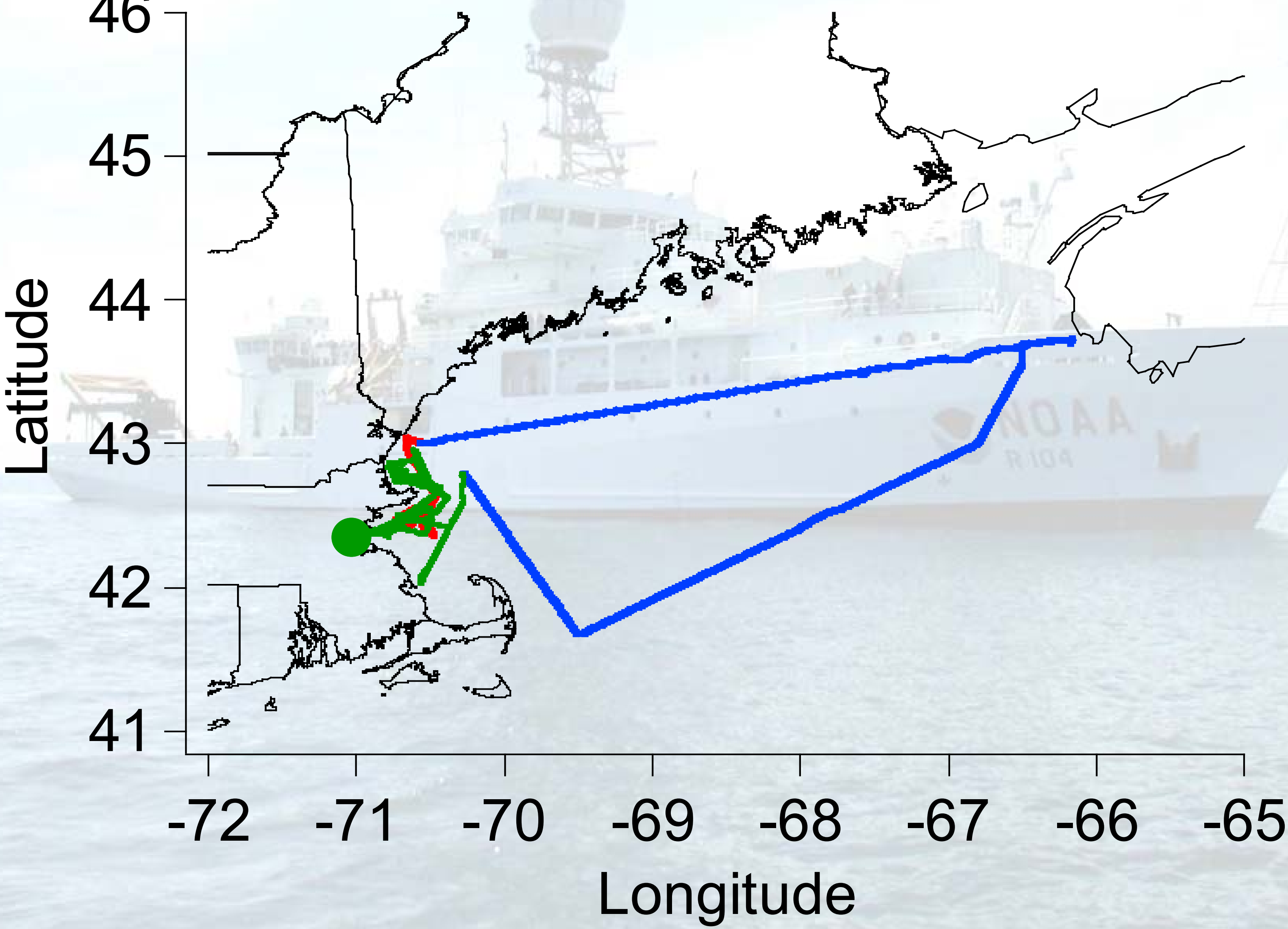


Ronald H. Brown Cruise Track
NEAQS – ITCT 2004, Leg 1

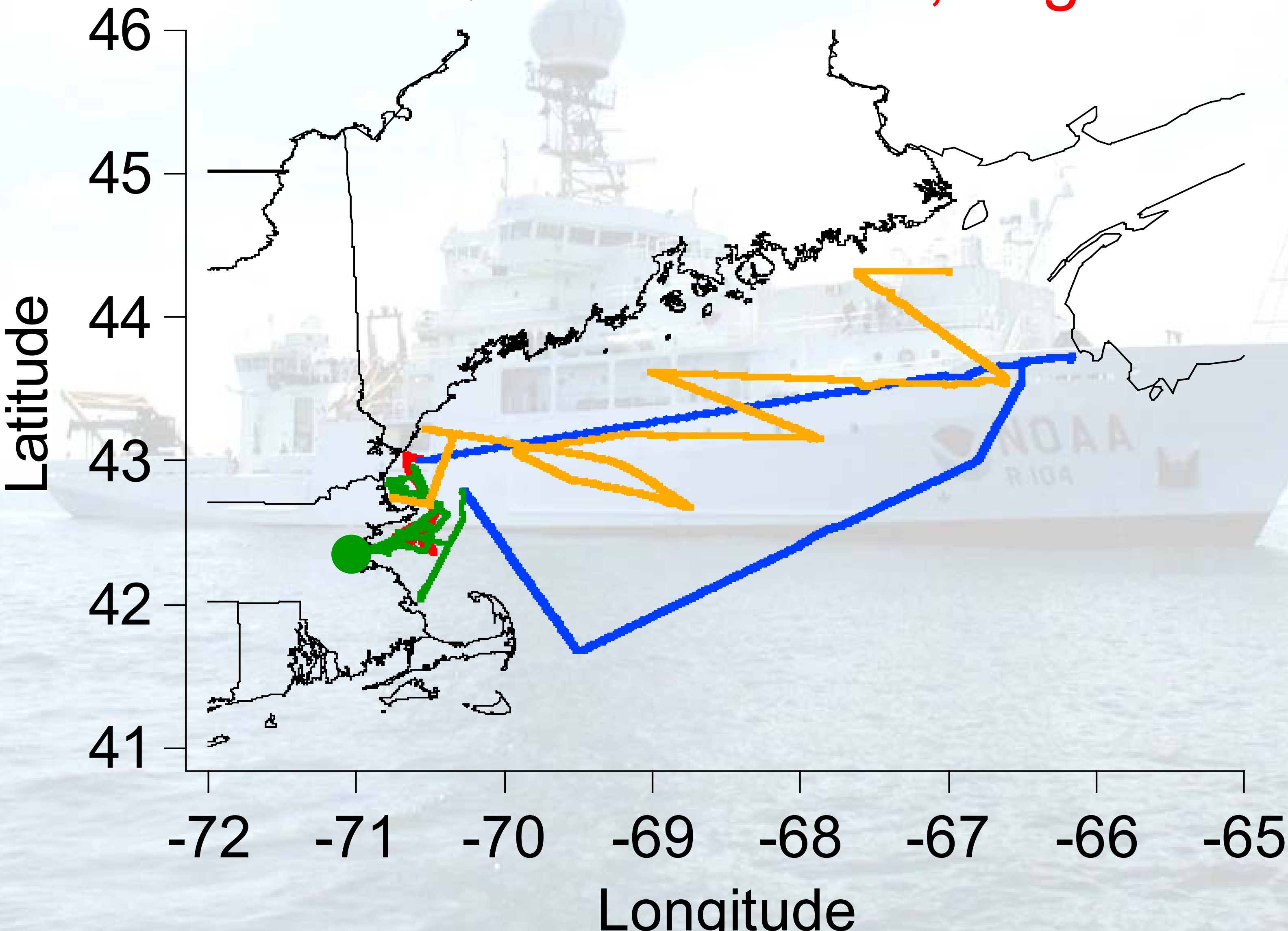



Chebogue
Point

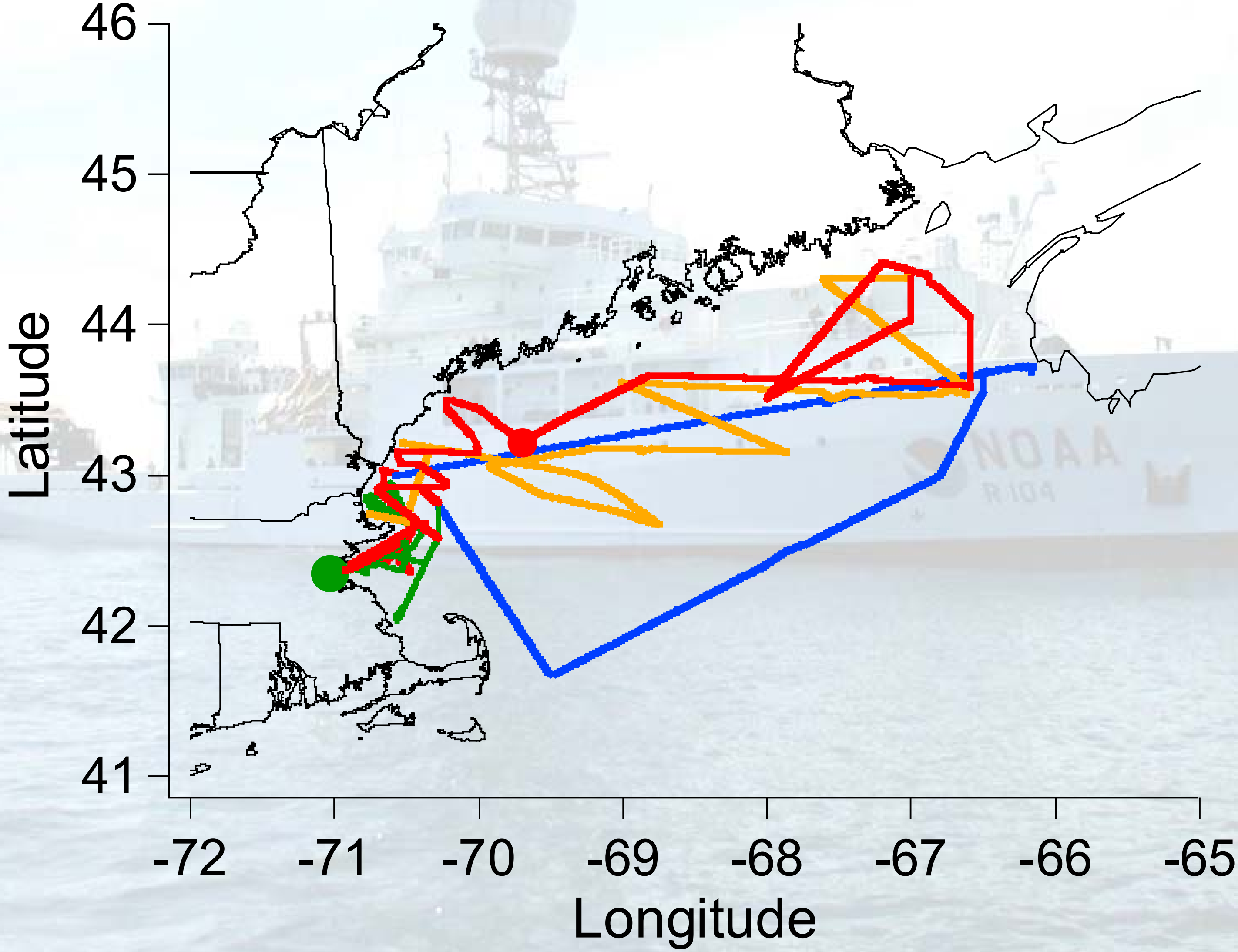
Ronald H. Brown Cruise Track
NEAQS – ITCT 2004, Leg 1



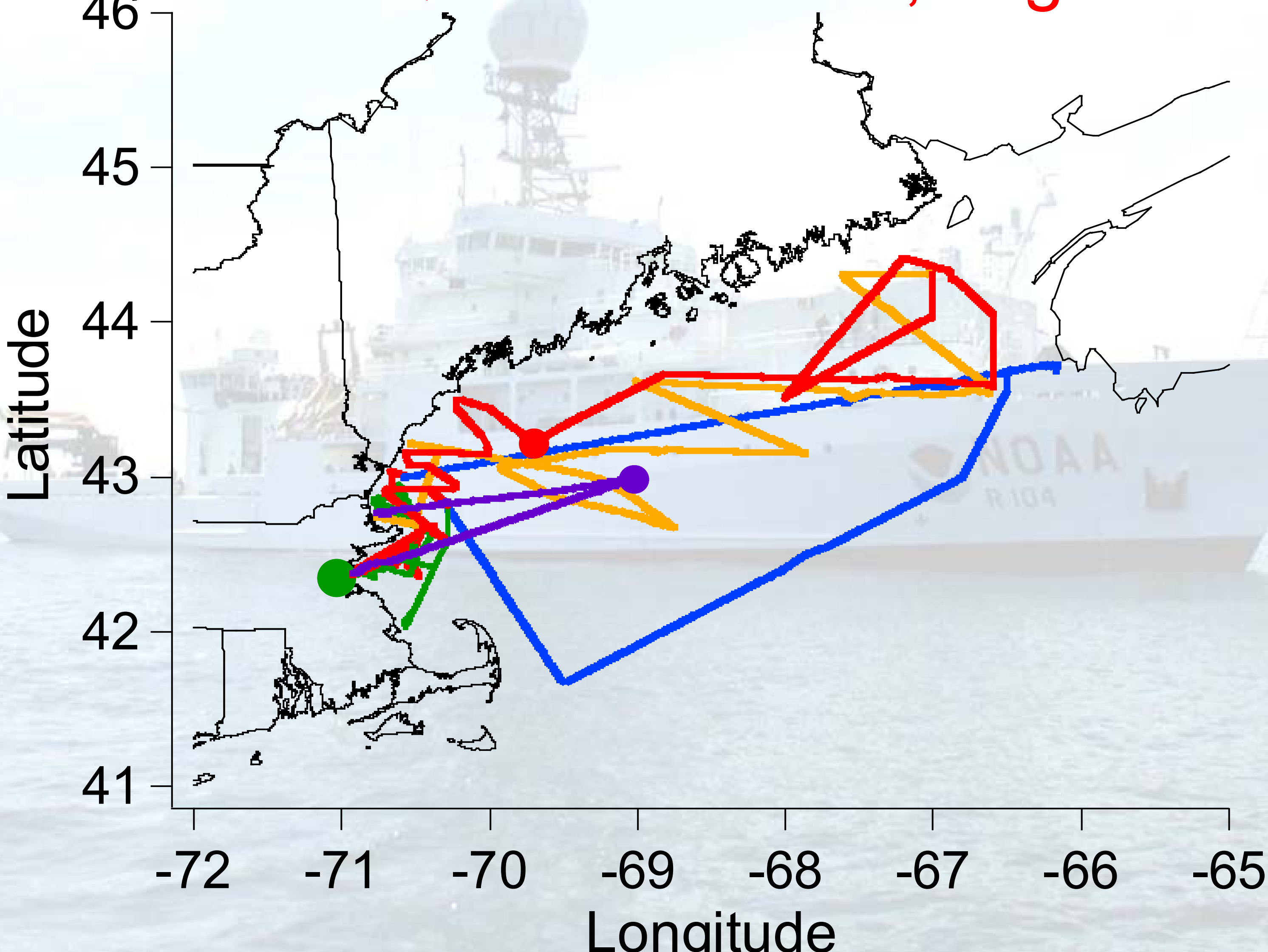
Ronald H. Brown Cruise Track
NEAQS – ITCT 2004, Leg 1



Ronald H. Brown Cruise Track
NEAQS – ITCT 2004, Leg 1



Ronald H. Brown Cruise Track
NEAQS – ITCT 2004, Leg 1



Objectives

★ Good Progress

? Needs High Priority

🚫 Finished

NEAQS/ITCT 2004 Field Study

Objectives/goals of the study (that include the ship)

1. How do gas and aerosol species from the urban corridor of New York and Boston evolve during transport over the Gulf of Maine?
2. How do gas and aerosol species from biogenic emissions evolve during transport over the Gulf of Maine?
3. How does the convectively turbulent continental boundary layer interact with the stable atmosphere over the Gulf of Maine? What is the effect on vertical mixing and transport of pollutants? What is the effect of the sea breeze circulation on their transport?
4. What is the total amount of nitrogen, sulfur, and carbon gases and aerosols emitted in the exhaust plumes from large ocean-going vessels? How do the emitted species evolve over time?

NEAQS/ITCT 2004 Field Study cont…

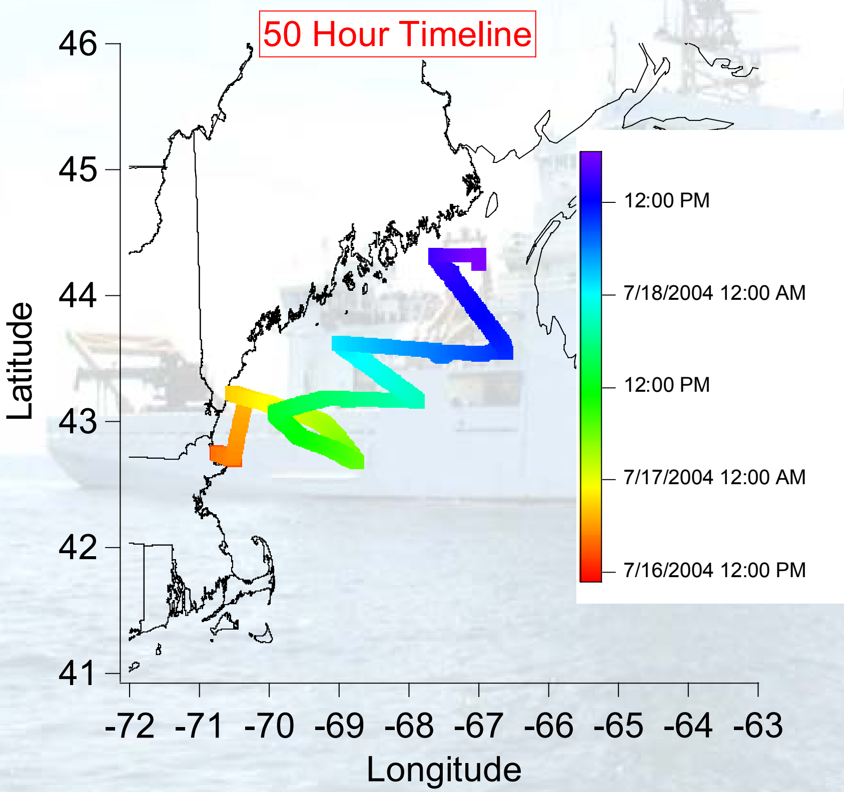
Objectives/goals of the study (that include the ship)

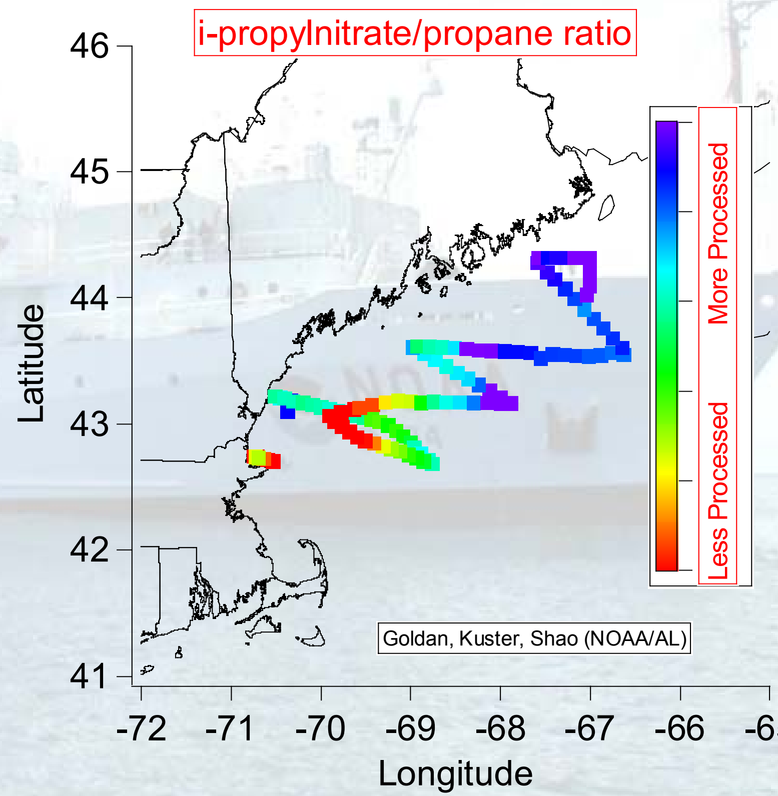
5. What is the clear-sky radiative impact of the aerosols advecting from North America out over the Northwestern Atlantic Ocean?
6. How do the continental aerosols over Northeastern North America and those advecting out over the Northwestern Atlantic Ocean affect cloud drop size distributions and cloud reflectance (first indirect effect)?
7. What is the composition of primary anthropogenic aerosol emitted from the urban NE?
8. What is the role of aerosol acidity in secondary aerosol formation (power plant plume within urban plume)?
9. What is effect of fog on gas and aerosol evolution?
10. How directly comparable are the measurements on the various platforms used during NEAQS/ITCT? (measurement intercomparisons)

NEAQS –ITCT 2004

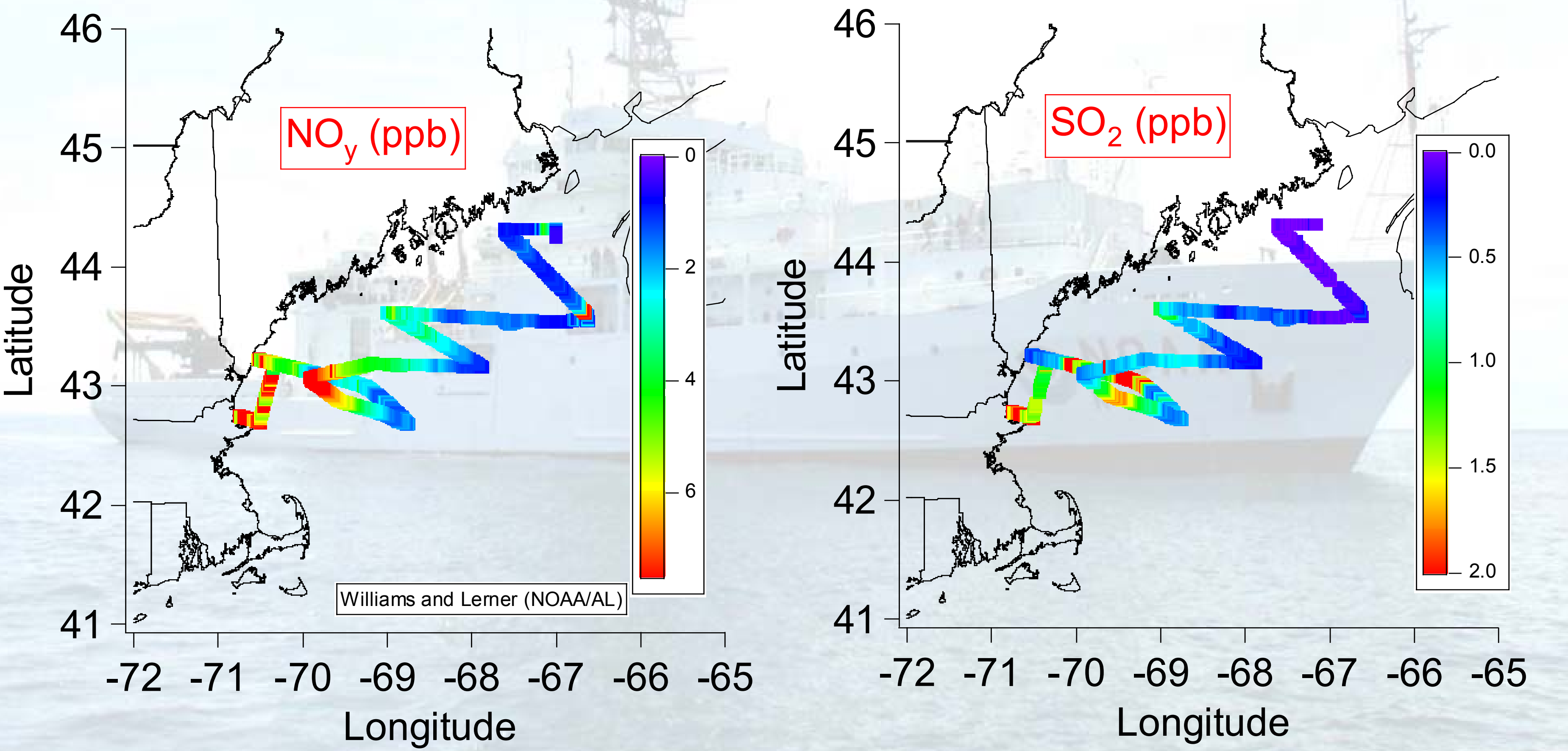
How do gas and aerosol species from the urban corridor of New York and Boston evolve during transport over the Gulf of Maine?

Chemical Processing of an Urban Plume

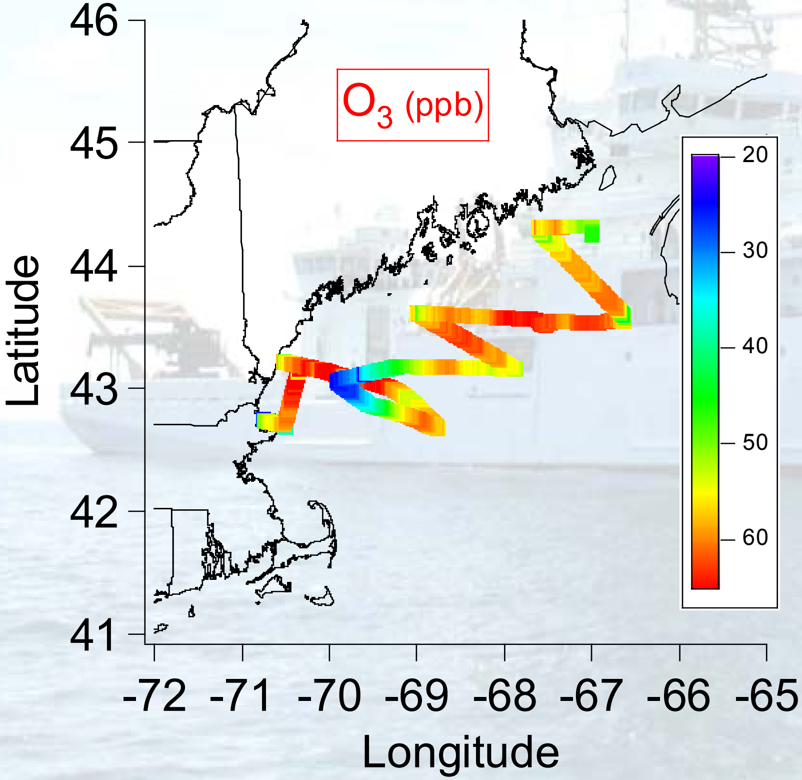


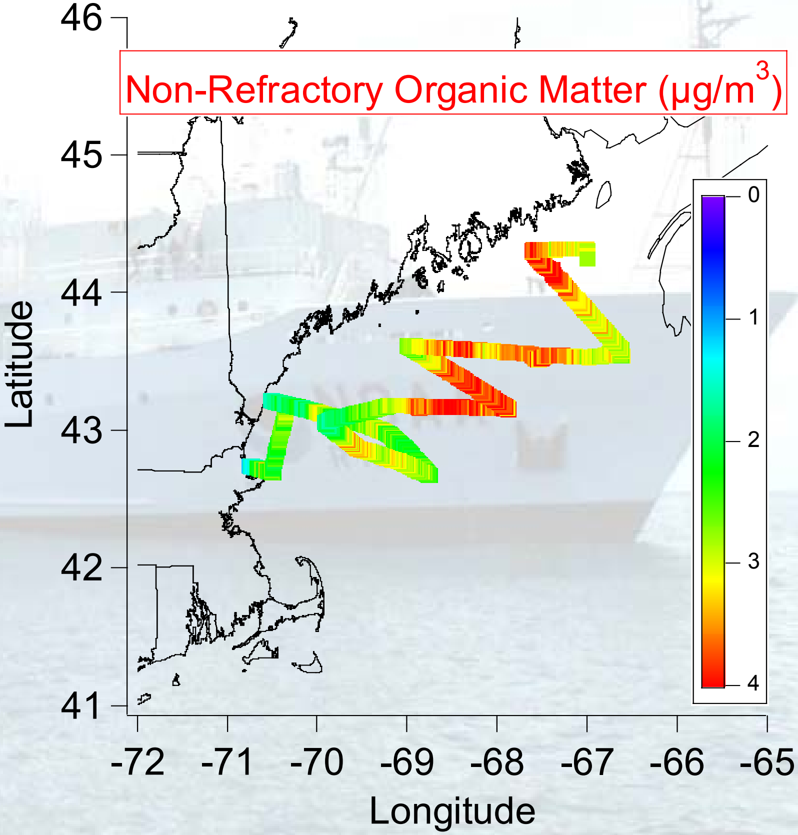


Chemical Processing of an Urban Plume

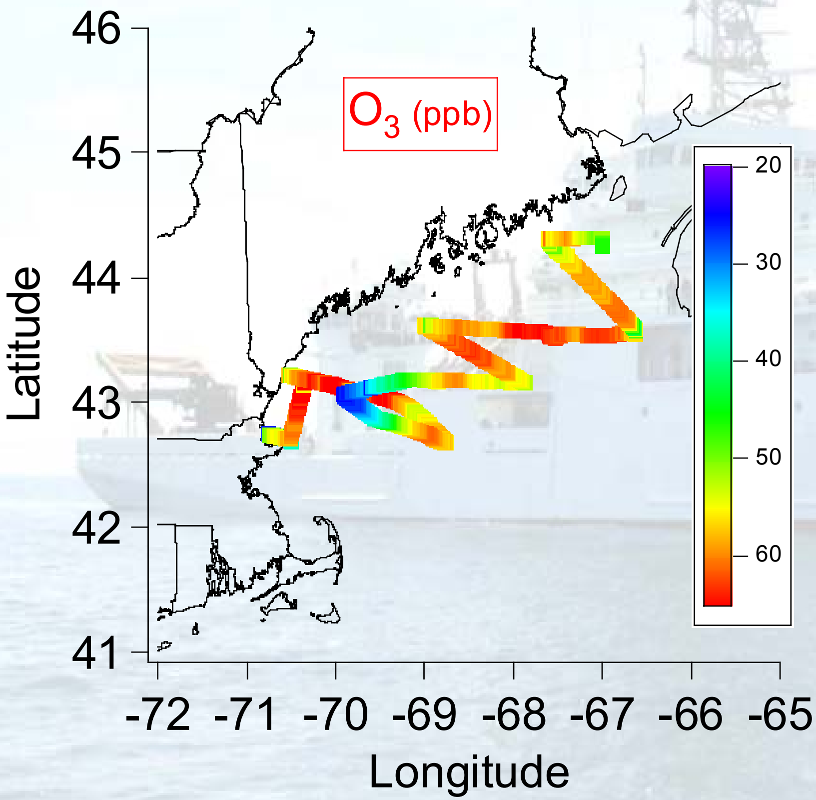


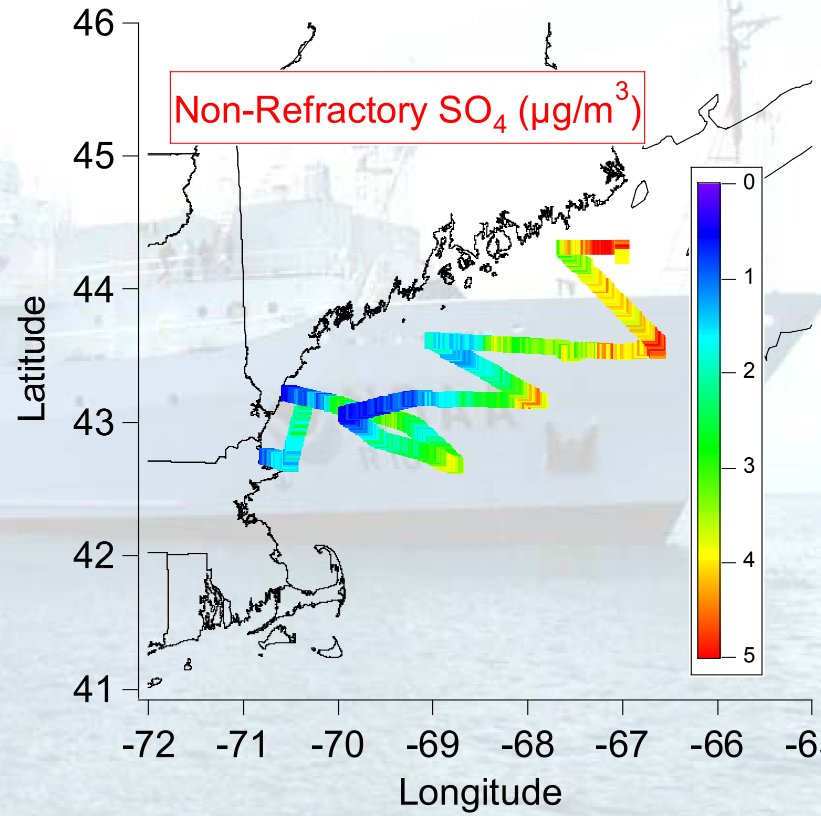
Chemical Processing of an Urban Plume



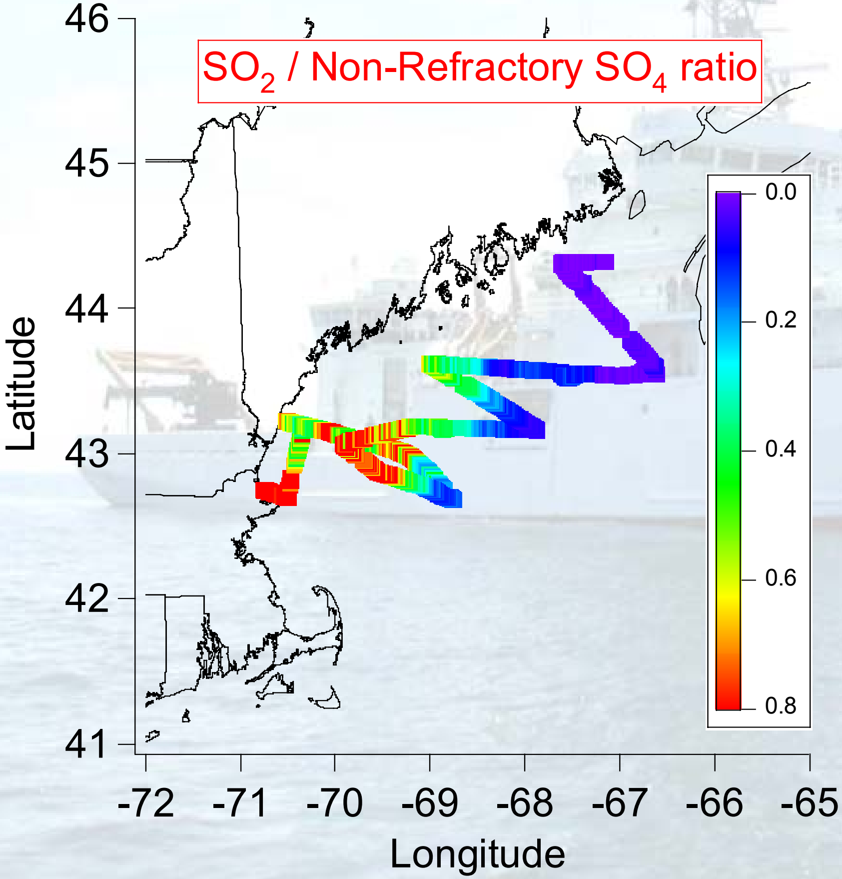


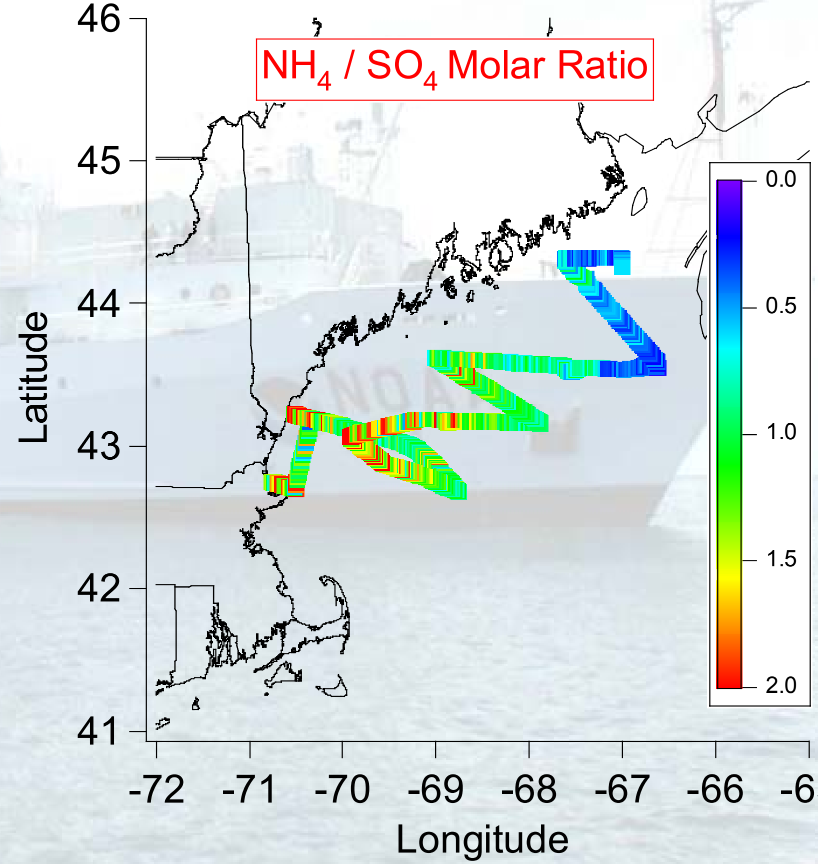
Chemical Processing of an Urban Plume



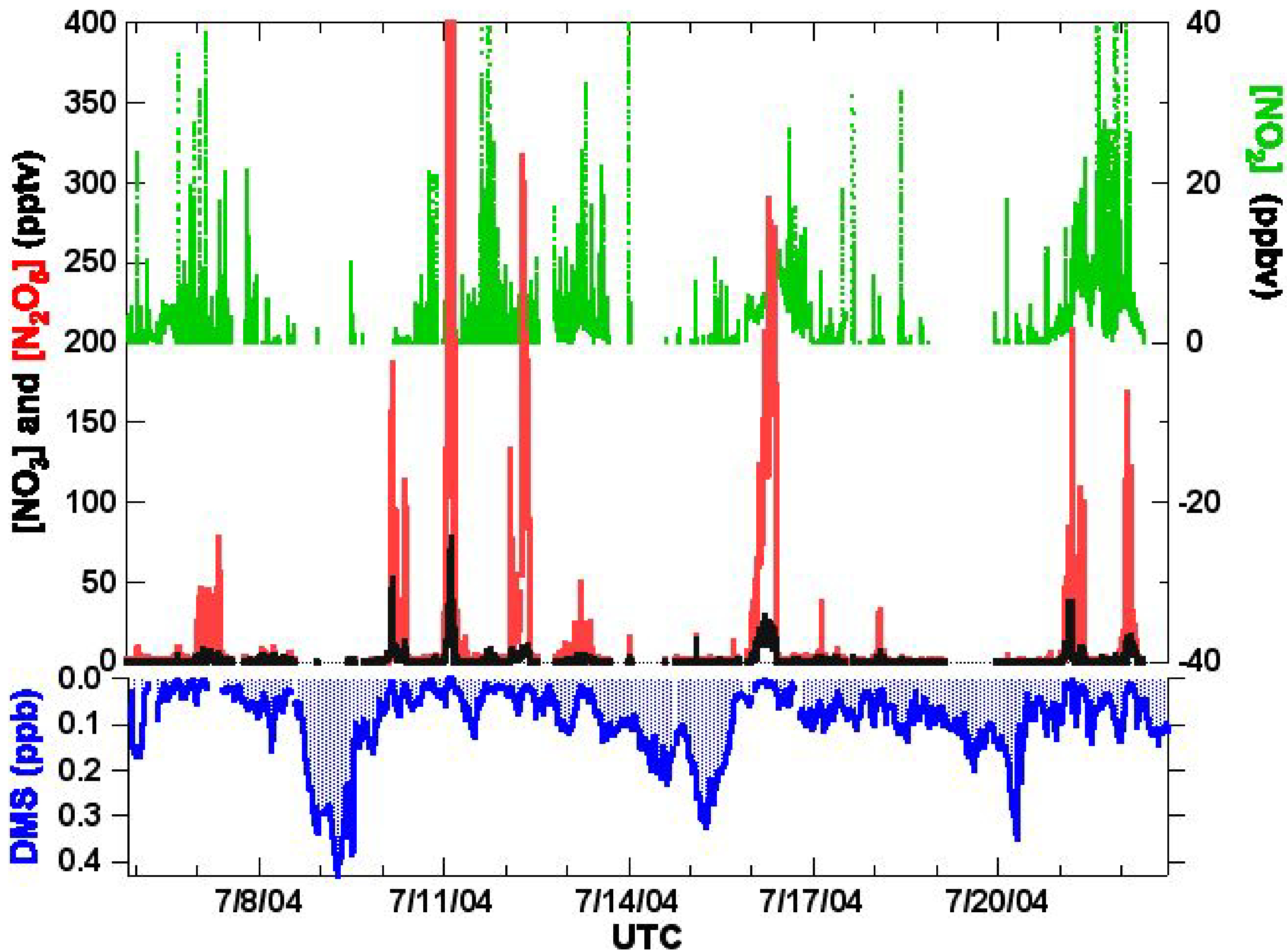


Chemical Processing of an Urban Plume





Night-time chemistry



NEAQS –ITCT 2004

How does the convectively turbulent continental boundary layer interact with the stable atmosphere over the Gulf of Maine? What is the effect on vertical mixing and transport of pollutants? What is the effect of the sea breeze circulation on their transport?

OPAL – Ozone Profiling Atmospheric Lidar :

Provide vertical profiles of Ozone and Aerosol

- Ozone 60m – 2km
- Aerosol backskatter 60m -10 km
- 10 minute resolution

HRDL – High Resolution Doppler Lidar

Provide vertical profiles of

- Low level wind speed and direction
- 15 minute / 5 m resolution

Provide information on :

- Turbulence / mixing
- Aerosol distribution
- Horizontal distribution of plumes for realtime tracking

ETL Lidar Systems aboard the Ronald H Brown

Christoph Senff
Richard Marchbanks
Alan Brewer

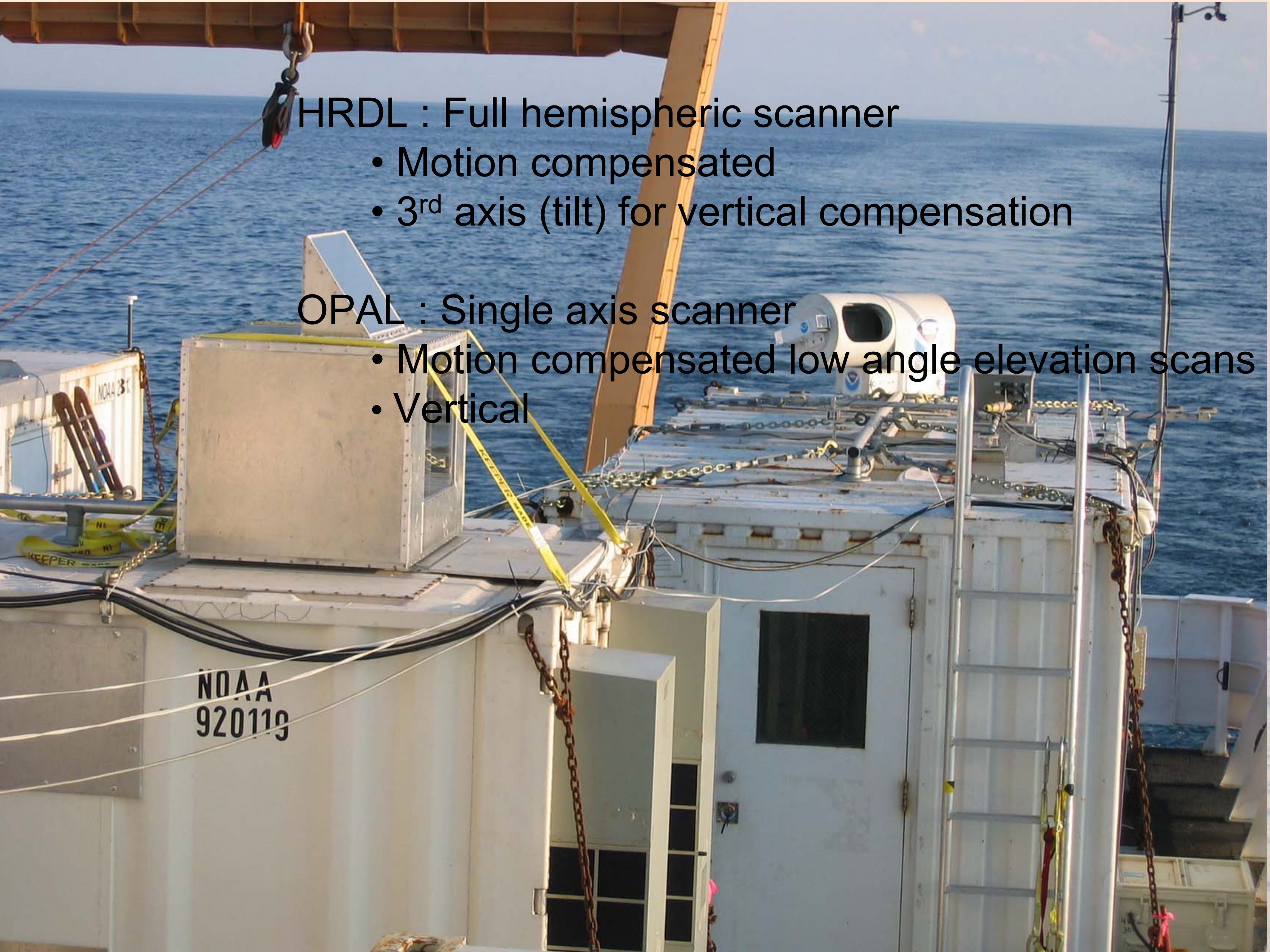
Located on the fantail

HRDL : Full hemispheric scanner

- Motion compensated
- 3rd axis (tilt) for vertical compensation

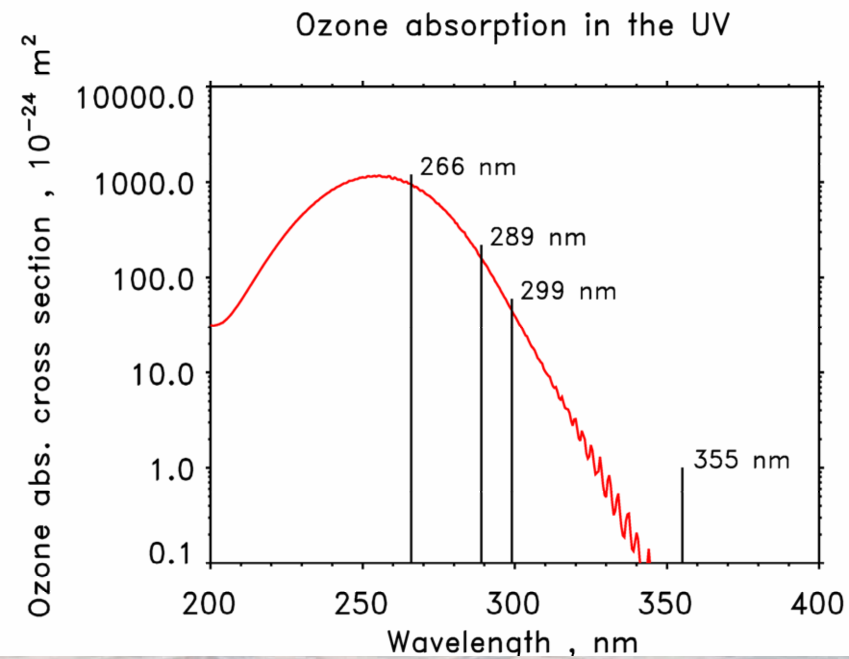
OPAL : Single axis scanner

- Motion compensated low angle elevation scans
- Vertical



OPAL measurement

Differential Absorption Lidar

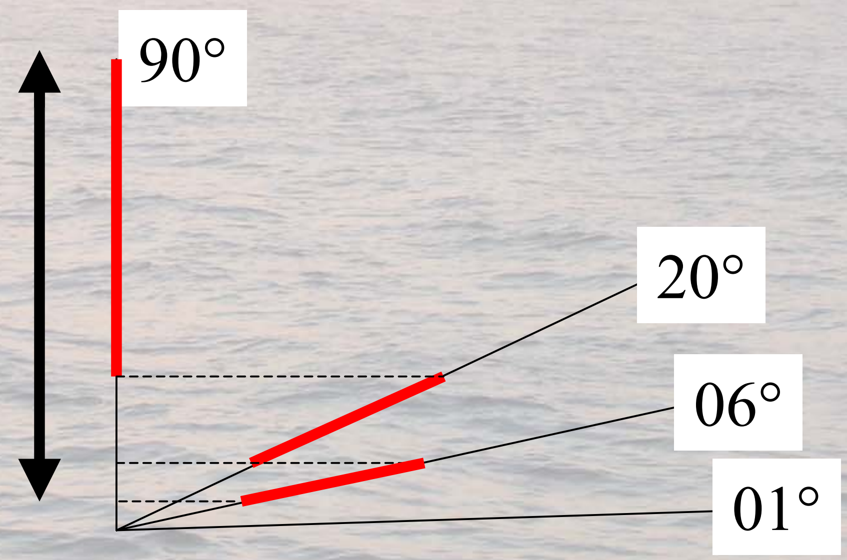


OPAL measurement

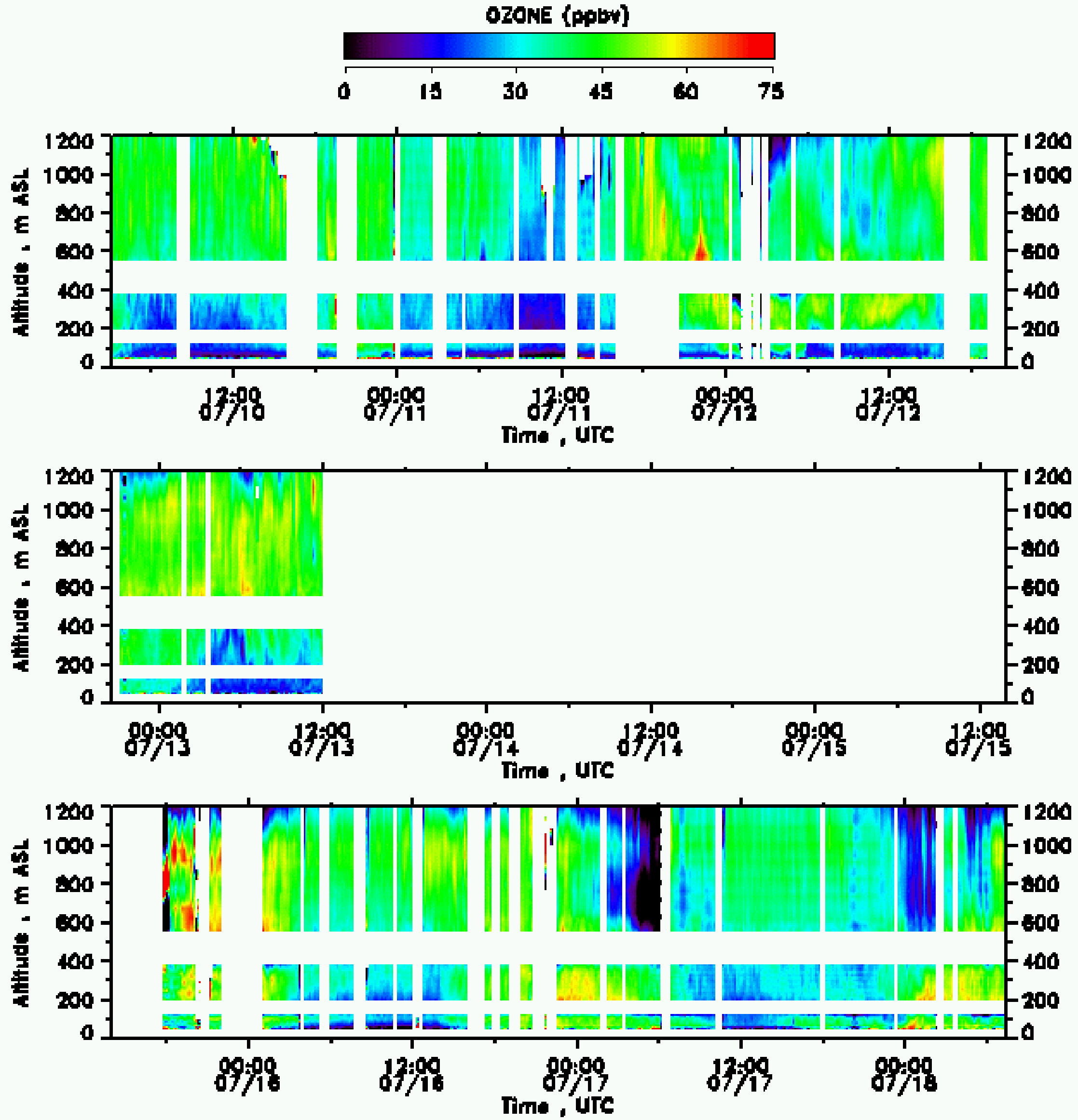
Scanning with altitude blending :

Ozone: 60 m – 2 km

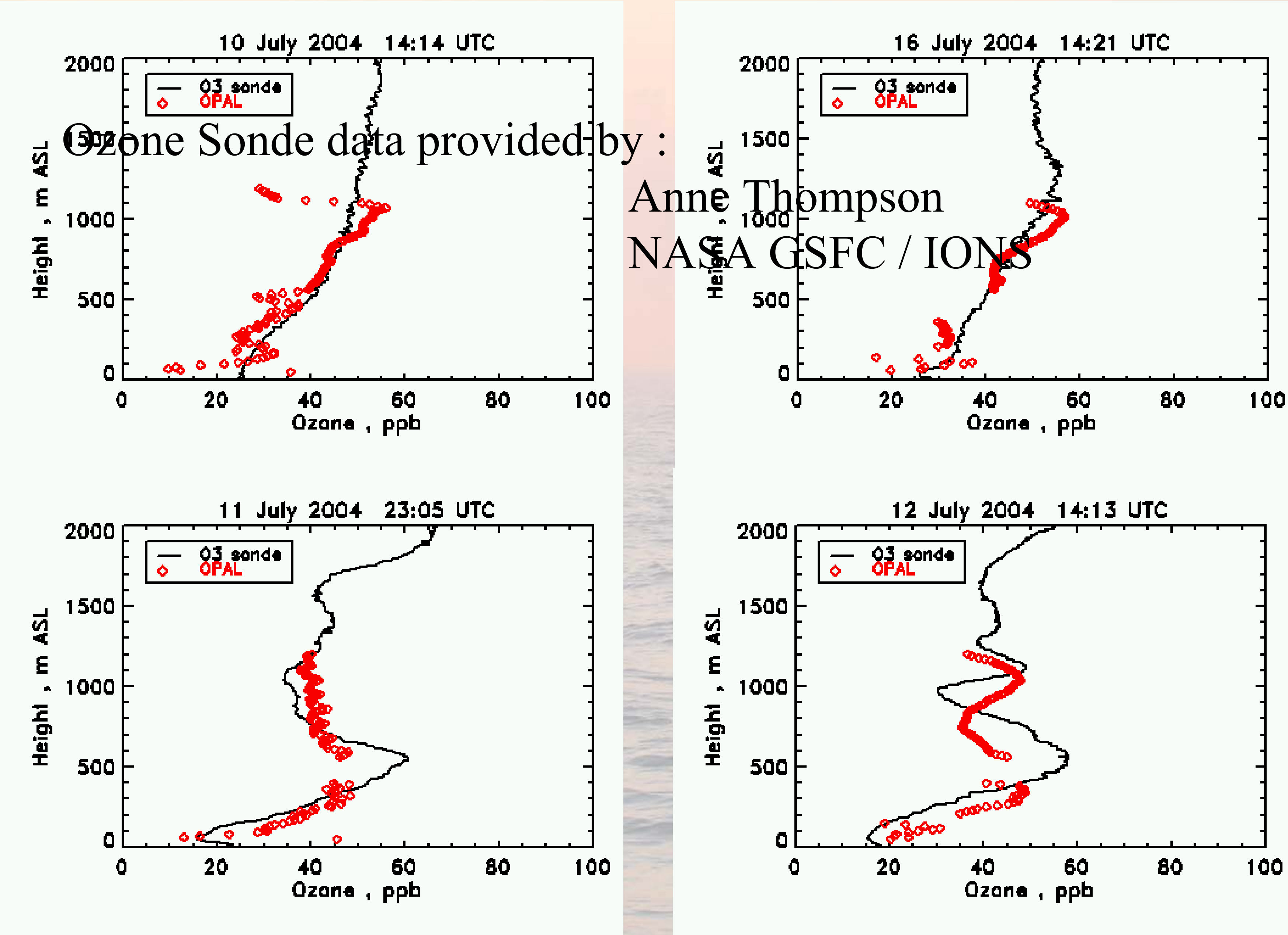
Aerosol: 60 m – 10 km



10 – 18 JUL 2004



Intercomparison w/ozone sondes

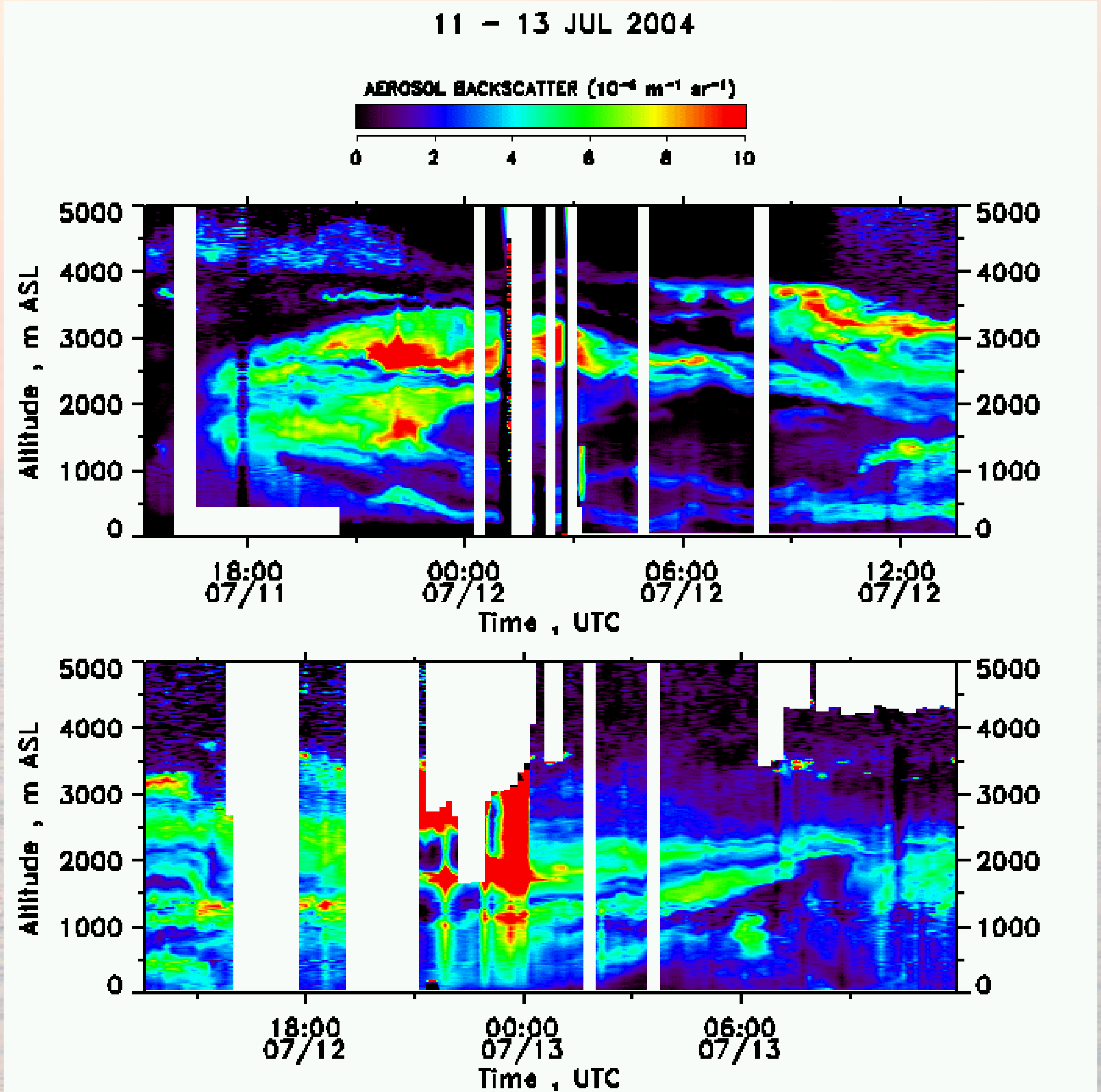


Ozone Sonde data provided by :

Anne Thompson

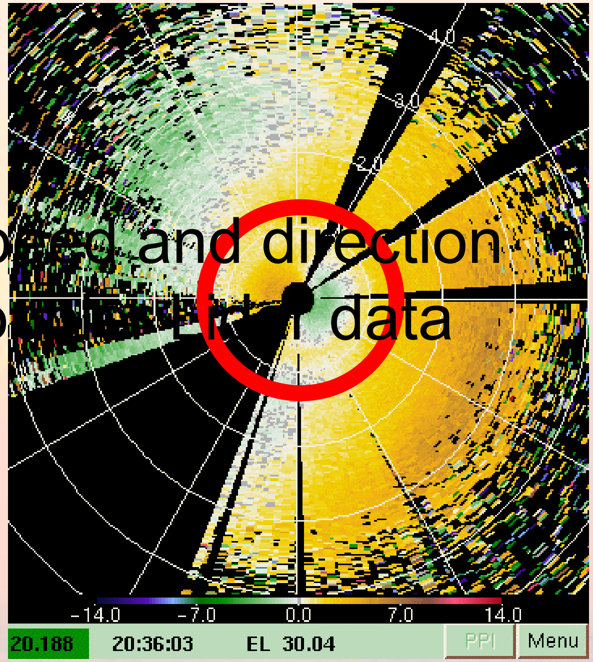
NASA GSFC / IONS

OPAL Observation of Forest Fire Plumes

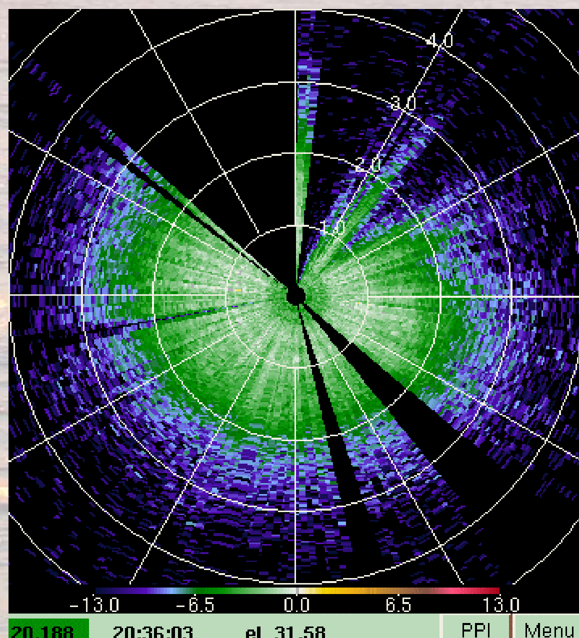


HRDL

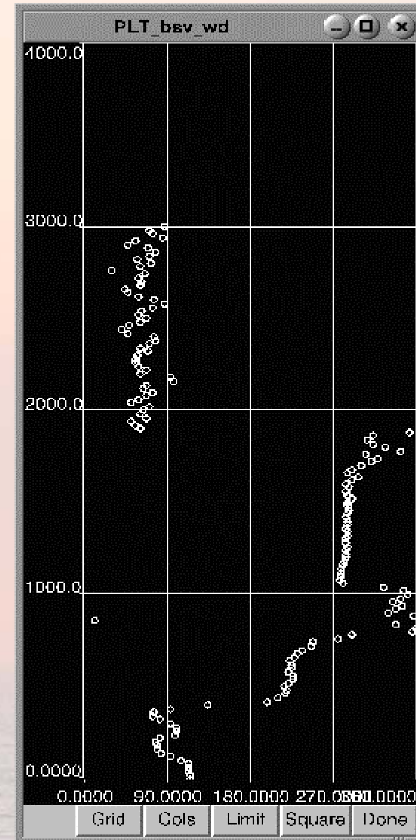
Wind speed and direction from Doppler Lidar data



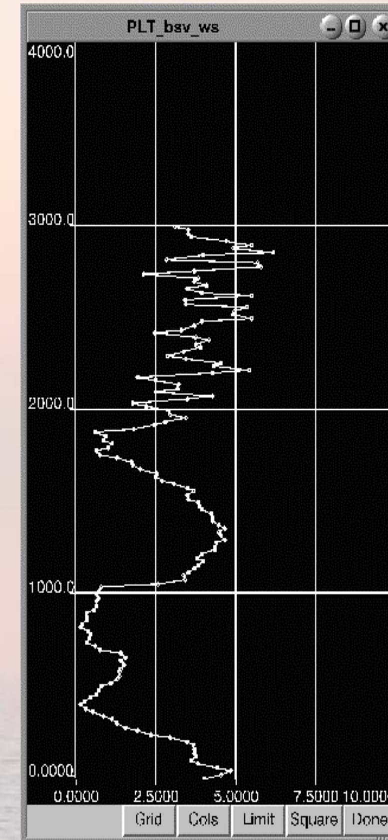
Radial Velocity



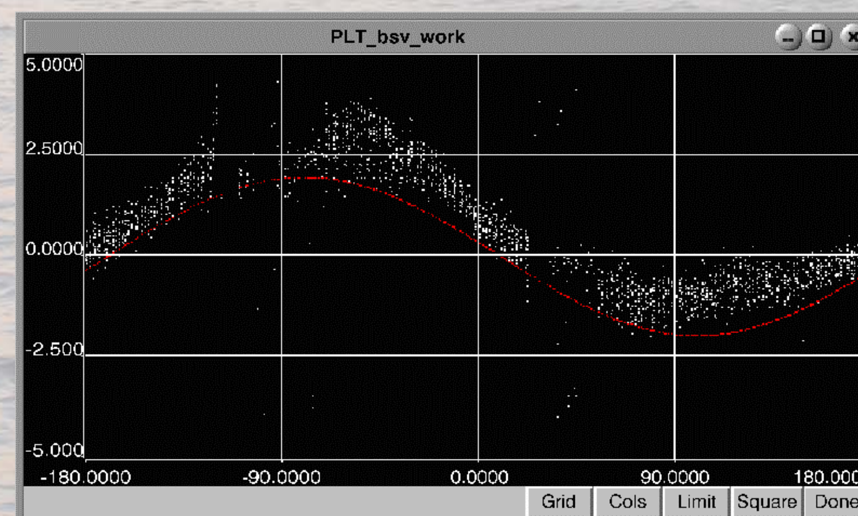
Intensity



Direction



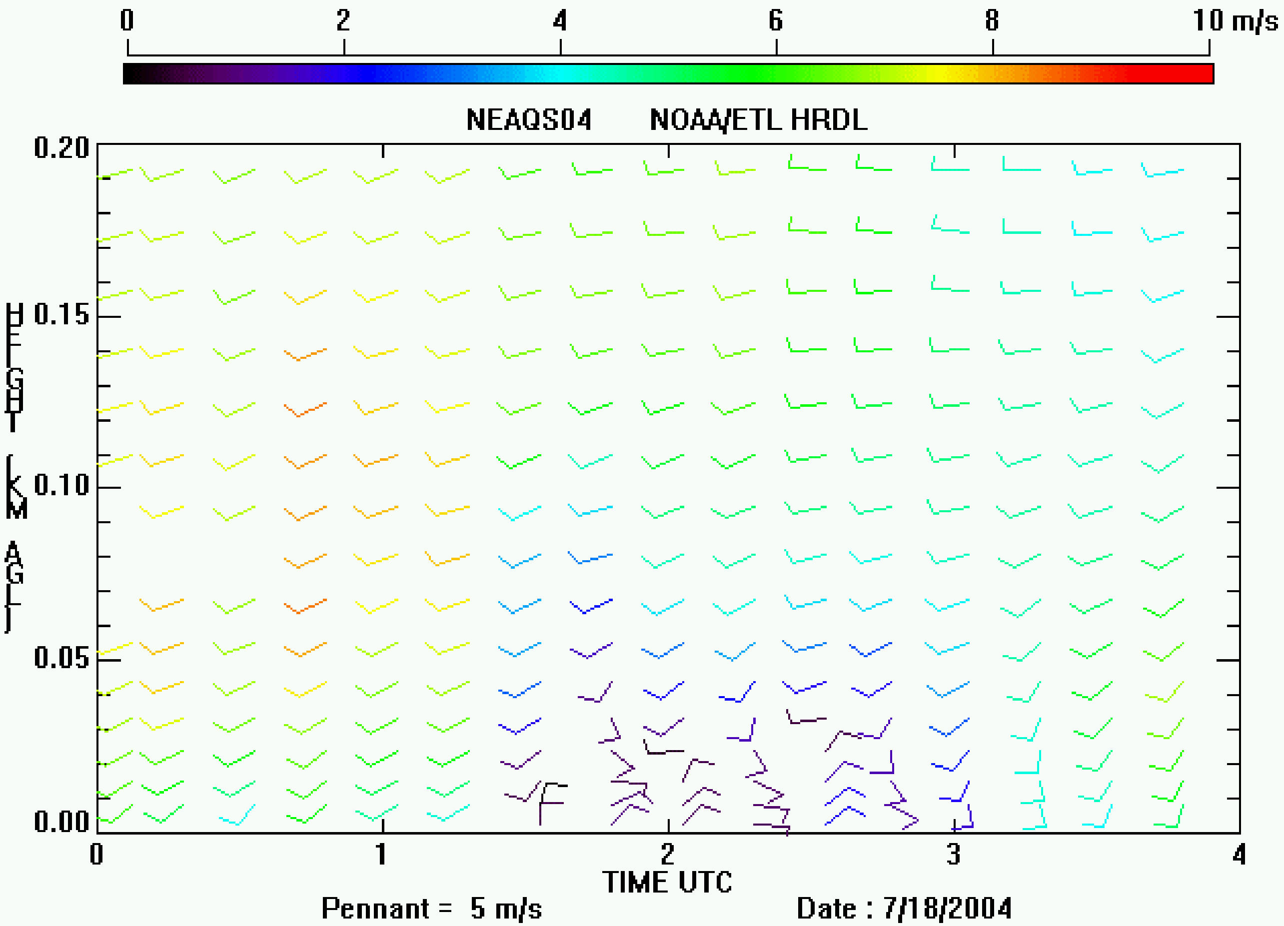
Speed



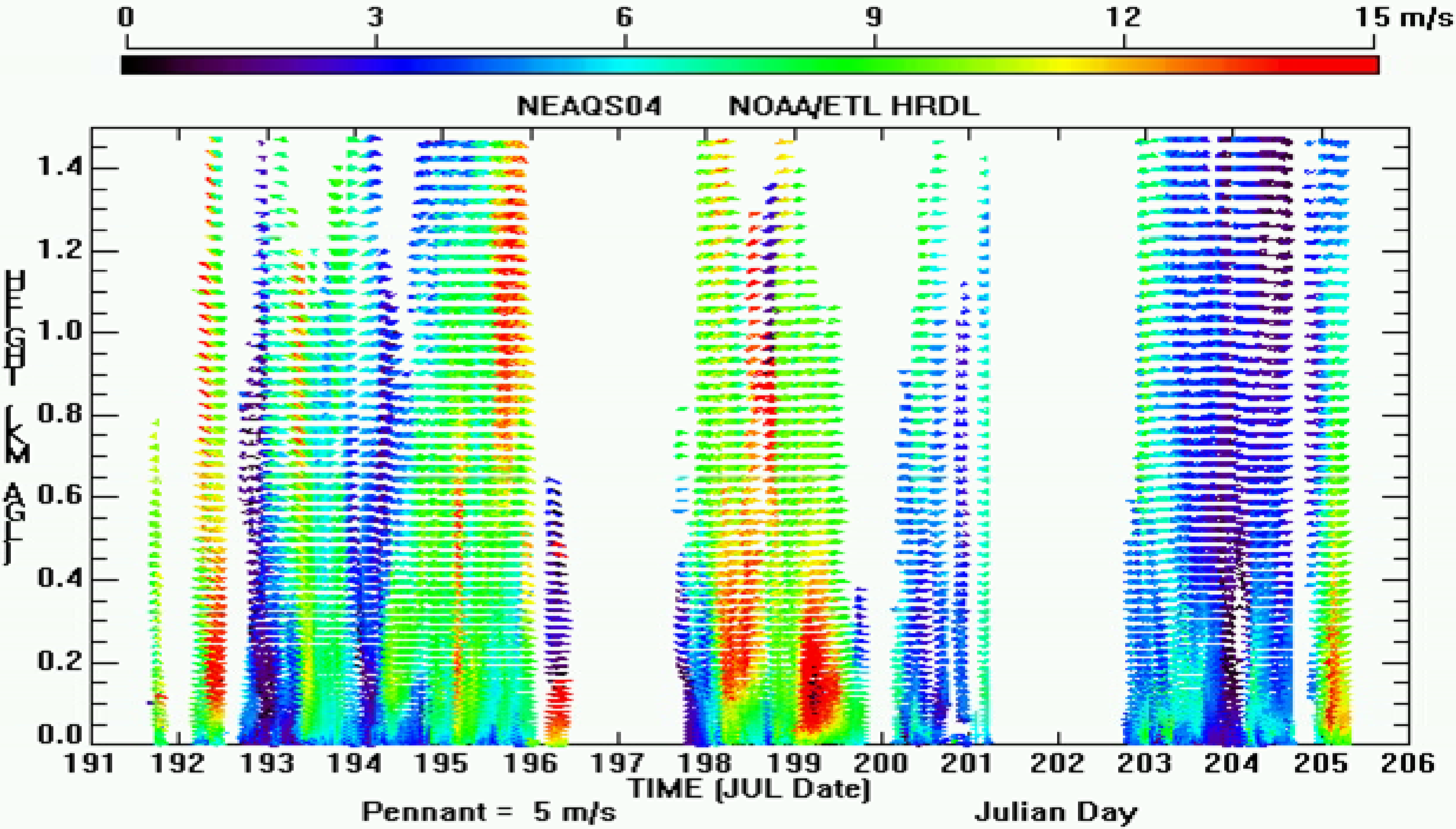
Vertical wind profiles every 15 min

Coherent extent of feature 30 m

Associated with sudden change in in chemical composition indicating another air mass

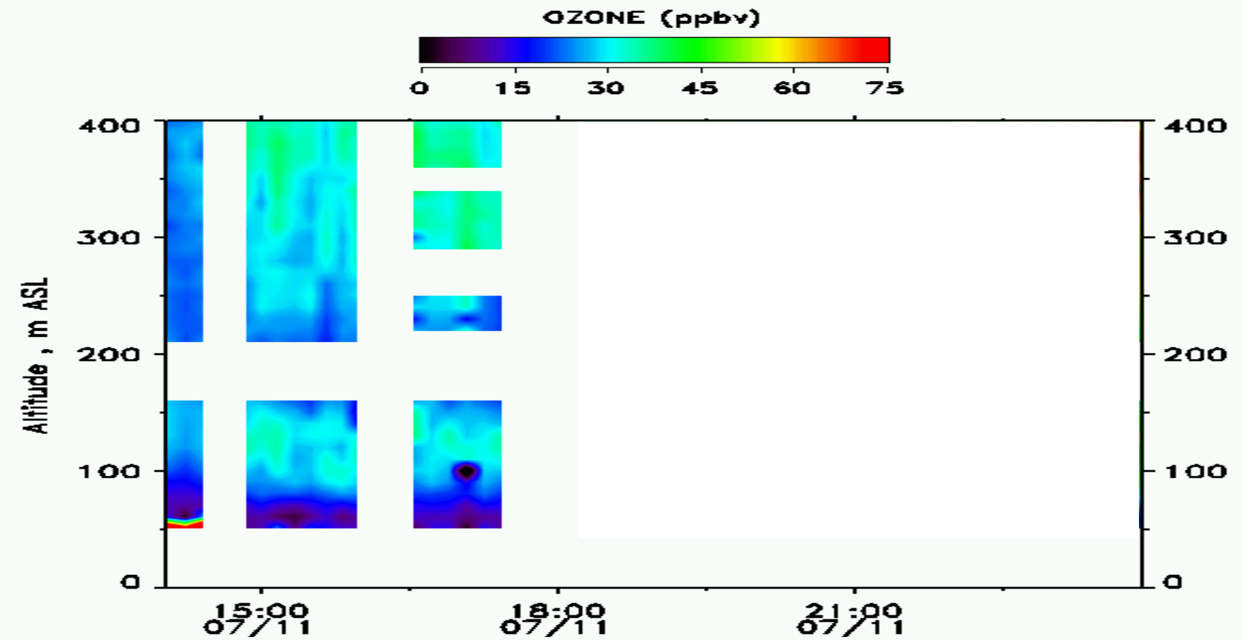


HRDL Winds July 11 – July 23 2004

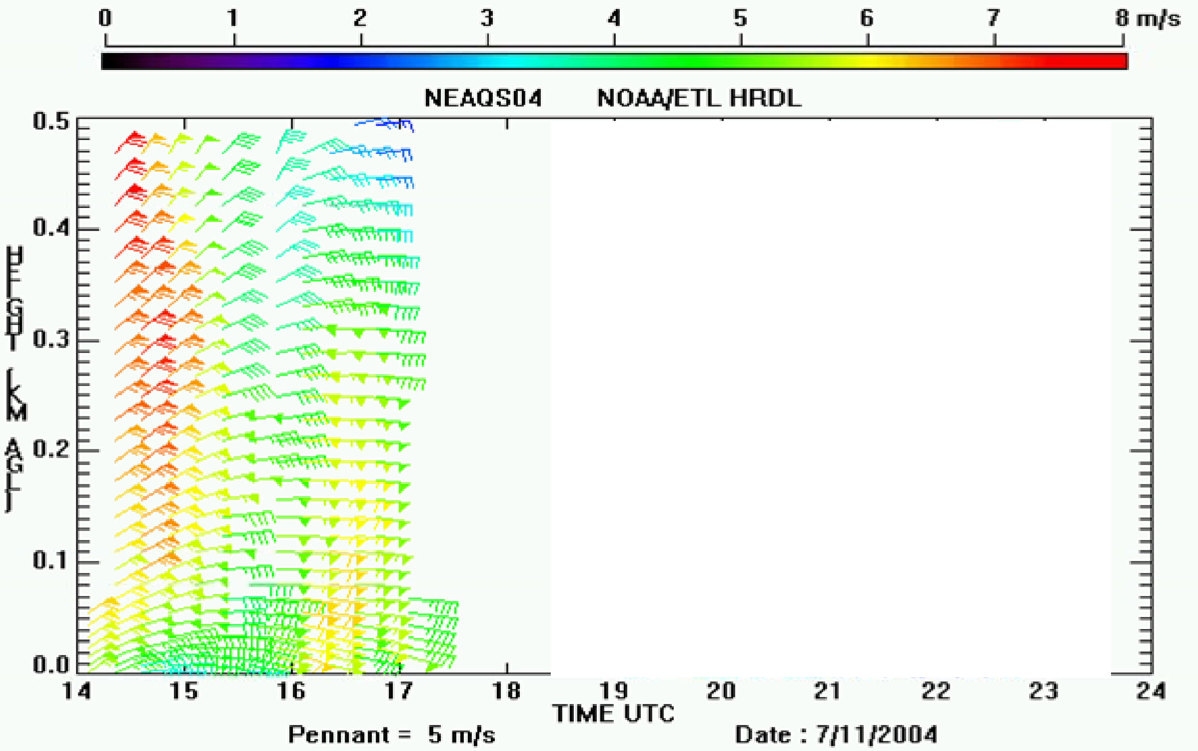


Boston Harbor Combined results :

OPAL Ozone



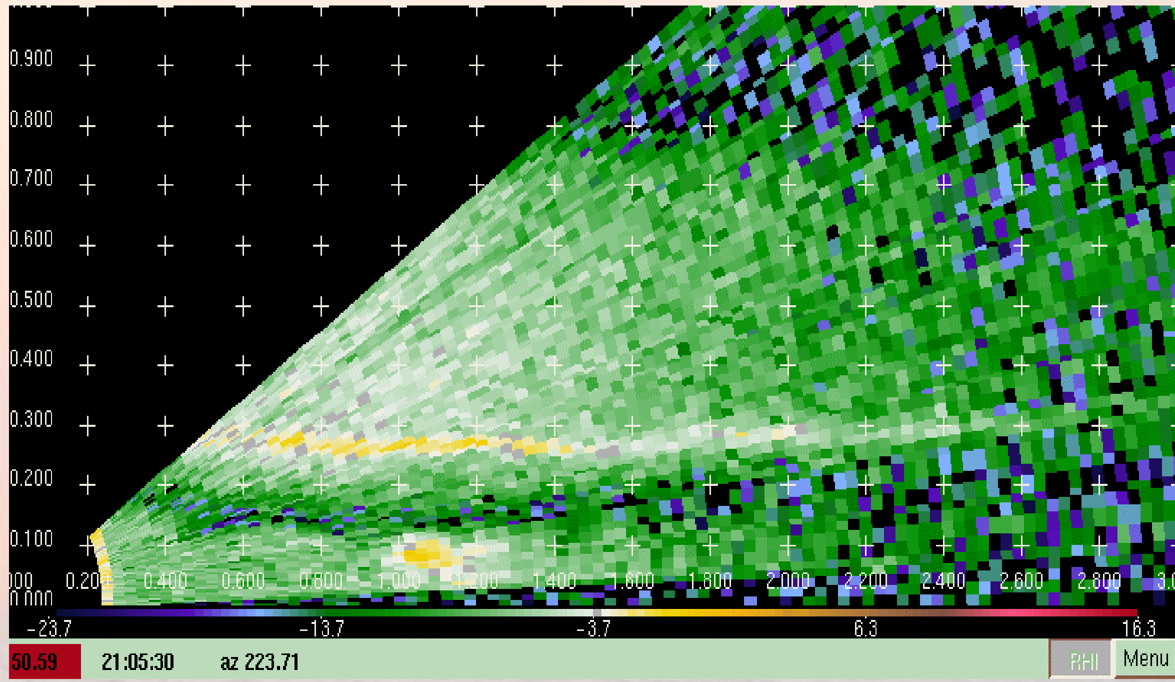
HRDL Winds



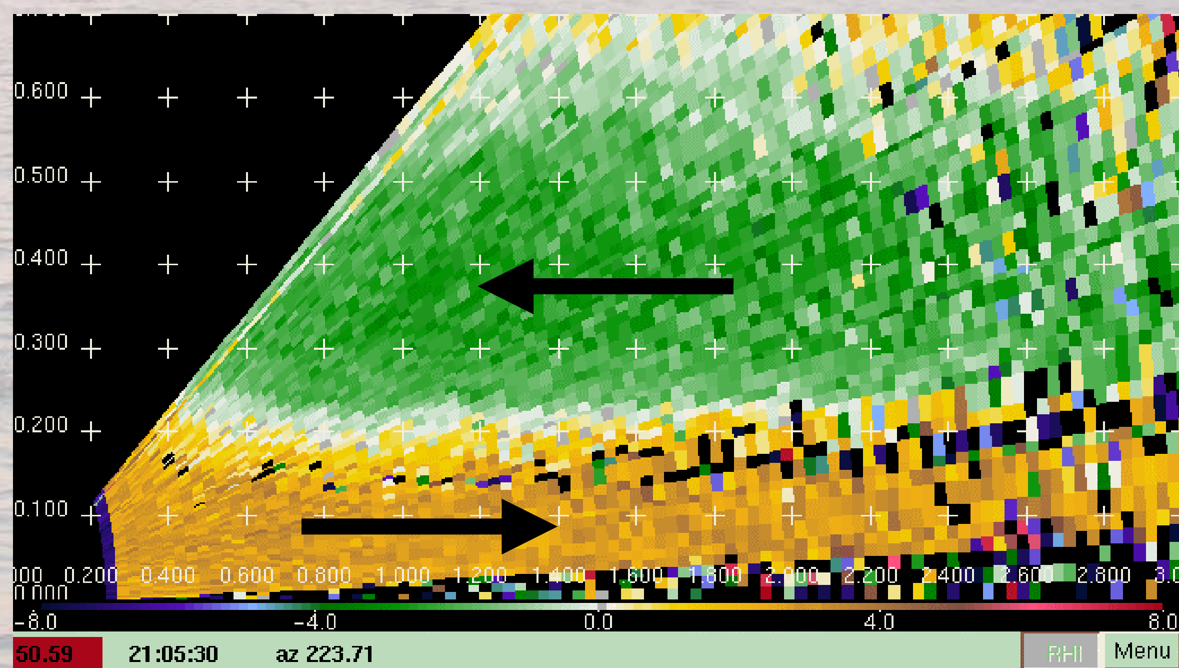
Boston Harbor :

Dynamics and ship plumes

HRDL Intensity



HRDL Radial Velocity



NEAQS –ITCT 2004

What is the total amount of nitrogen, sulfur, and carbon gases and aerosols emitted in the exhaust plumes from large ocean-going vessels? How do the emitted species evolve over time?

Marine Vessel Emission Characteristics

N emissions: mostly from combustion (temperature dependent)

S emissions: from fuel S-content (typically <1% to 5% by weight)

C emissions: virtually complete combustion!! (CO/CO_2 << 1%)

Particulate: soot; organic (unburned fuel; lube oils); some S

Global N-emissions: 3.08 TgN/yr (~14% of total fossil fuel source)
(~100% of U.S. mobile sources)

U.S. N-emissions: 0.25 TgN/yr (~7% of U.S. mobile source)

Global S-emissions: 4.24 TgS/yr (~5% of total fossil fuel source)
(~20% of global DMS source)

[Ref.: Corbett and Fishbeck, Science, 278, 31 Oct 97; and refs therein]

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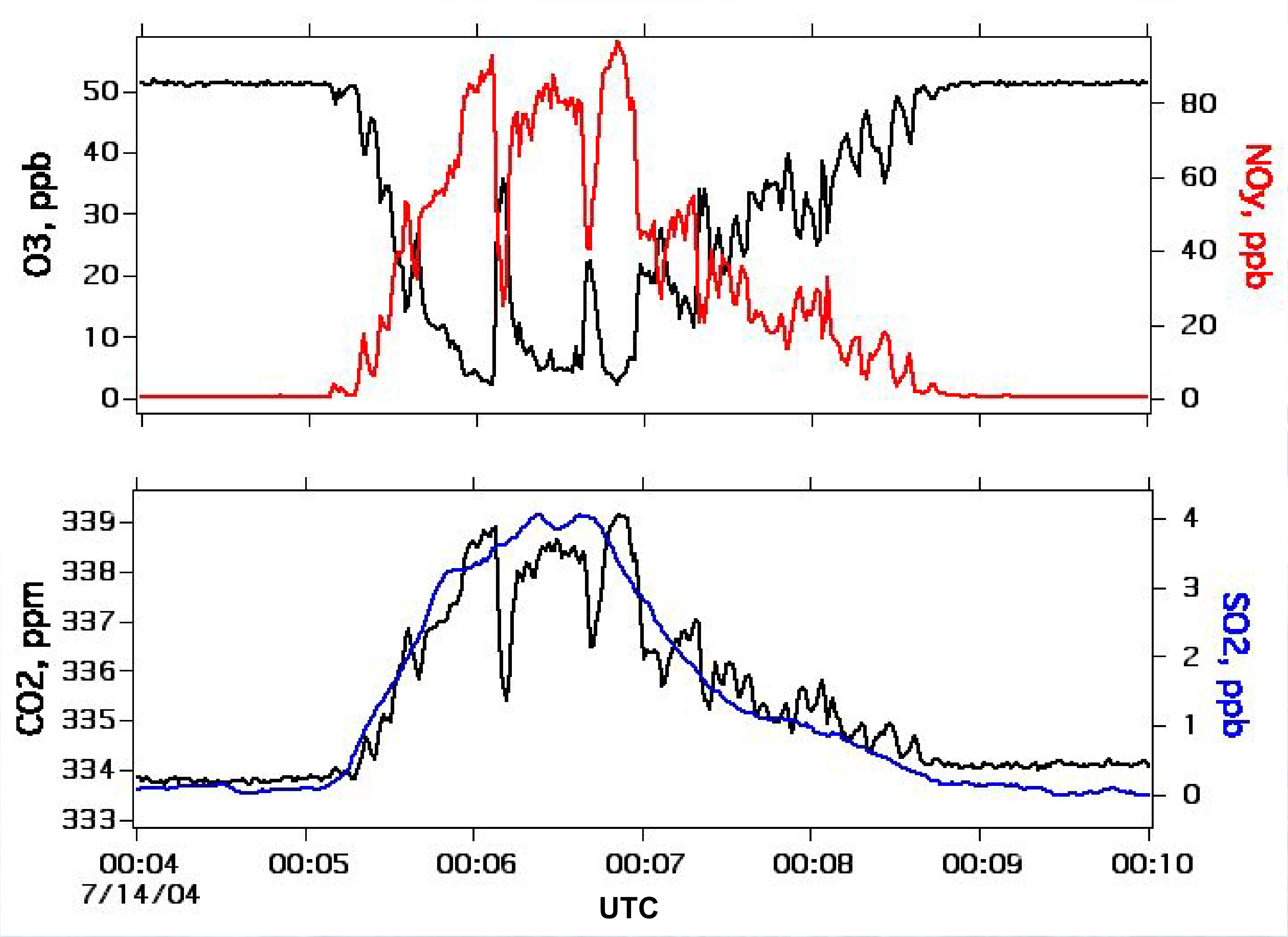
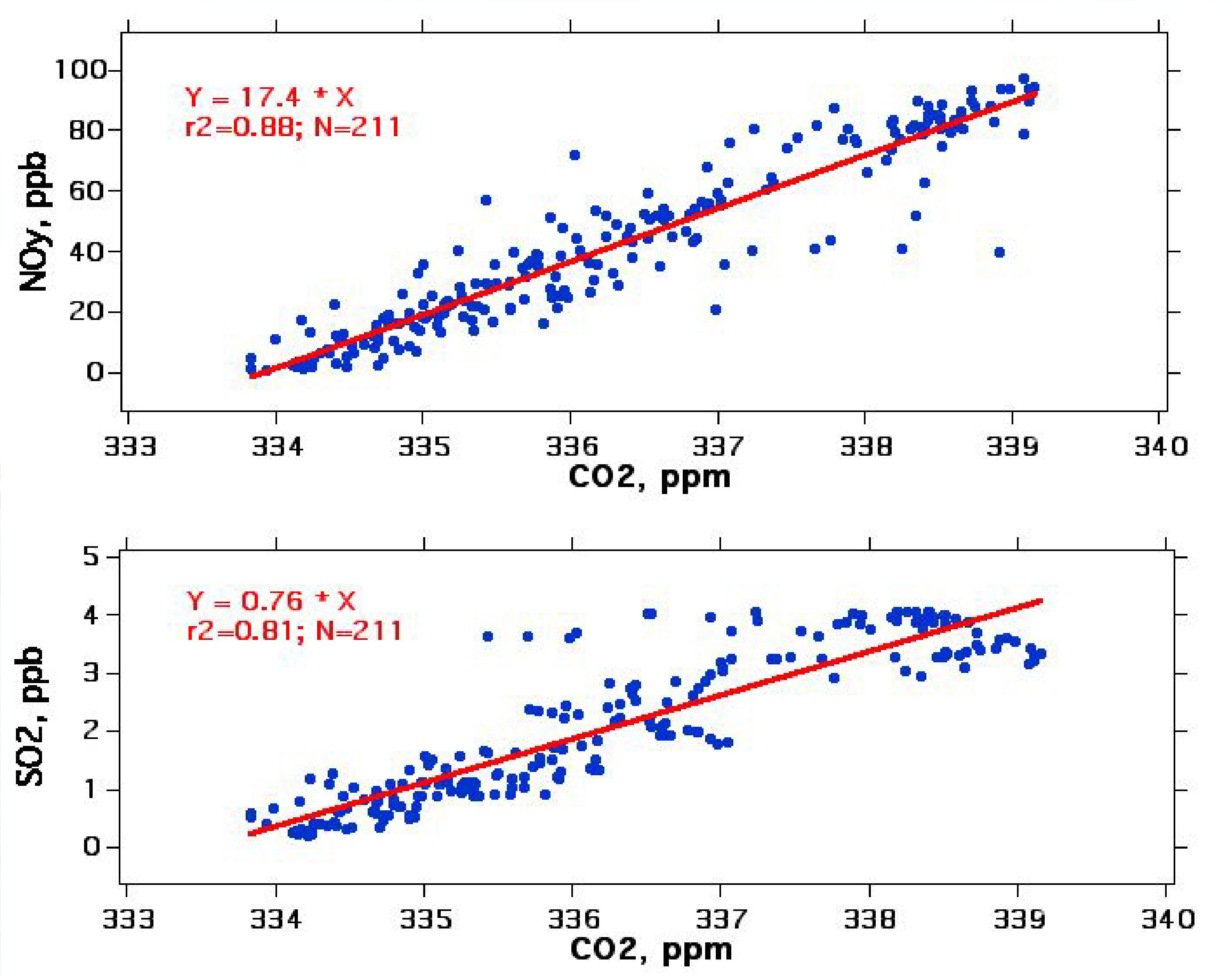
[Ref.: Corbett and Fishbeck, Science, 278, 31 Oct 97; and refs therein]

OBJECTIVES:
1) Survey/compilation of emission factors
2) Examine chemistry of plume aging

Exhaust Emissions from a Container Ship: MSC Nuria



Container Ship Exhaust Emission Component Relationships



Emission Factor Calculations

Assume: 1. Complete combustion (all fuel C goes to CO_2)

2. Average fuel C content: 86±0.5% C or 13.9±0.1 g fuel/mole C

[Average fuel N content: 0.3±0.2%]

[Average fuel S content: 1.5±1.2%]

[Source: Lloyd's Register, 1995]

E.F. (NO_x)

$$E.F._{(NO_x)} = \frac{\text{ppmv } NO_y \text{ * 46e-3 kg } NO_x\text{/mole } NO_y \text{ * 1000 kg}}{\text{ppmv } CO_2 \text{ * 13.9e-3 kg fuel/mole } CO_2 \text{ * tonne fuel}} = \text{Slope * 3.31}(\pm 0.02)$$

E.F. (SO_2)

$$E.F._{(SO_2)} = \frac{\text{ppmv } SO_2 \text{ * 64e-3 kg SO2/mole } SO_2 \text{ * 1000 kg}}{\text{ppmv } CO_2 \text{ * 13.9e-3 kg fuel/mole } CO_2 \text{ * tonne fuel}} = \text{Slope * 4.60}(\pm 0.03)$$

Information about fuel consumption (e.g., from tax records) combined with emission factors provides emission estimates of N and S from marine vessels

Marine Vessels: Emission Factor Data

(per 1000kg [tonne] fuel)

Date	Time	kg NO_x	kg SO_2	Vessel type
18Jul02	1035	49(±2)	~5	Cruise ship
19Jul02	1055	83(±4)	0.7(±0.09)	Fishing vessel
30Jul02	2230	75(±2)	0.7(±0.04)	Casino boat
6Aug02	1155	60(±1)	19(±1)	Tanker
8Aug02	2335	67(±7)	11(±2)	Container
11Jul04	2115-2215	74(±12)	9(±6)	Cruise ship
14Jul04	0015	58(±1)	4(±0.1)	Container ship

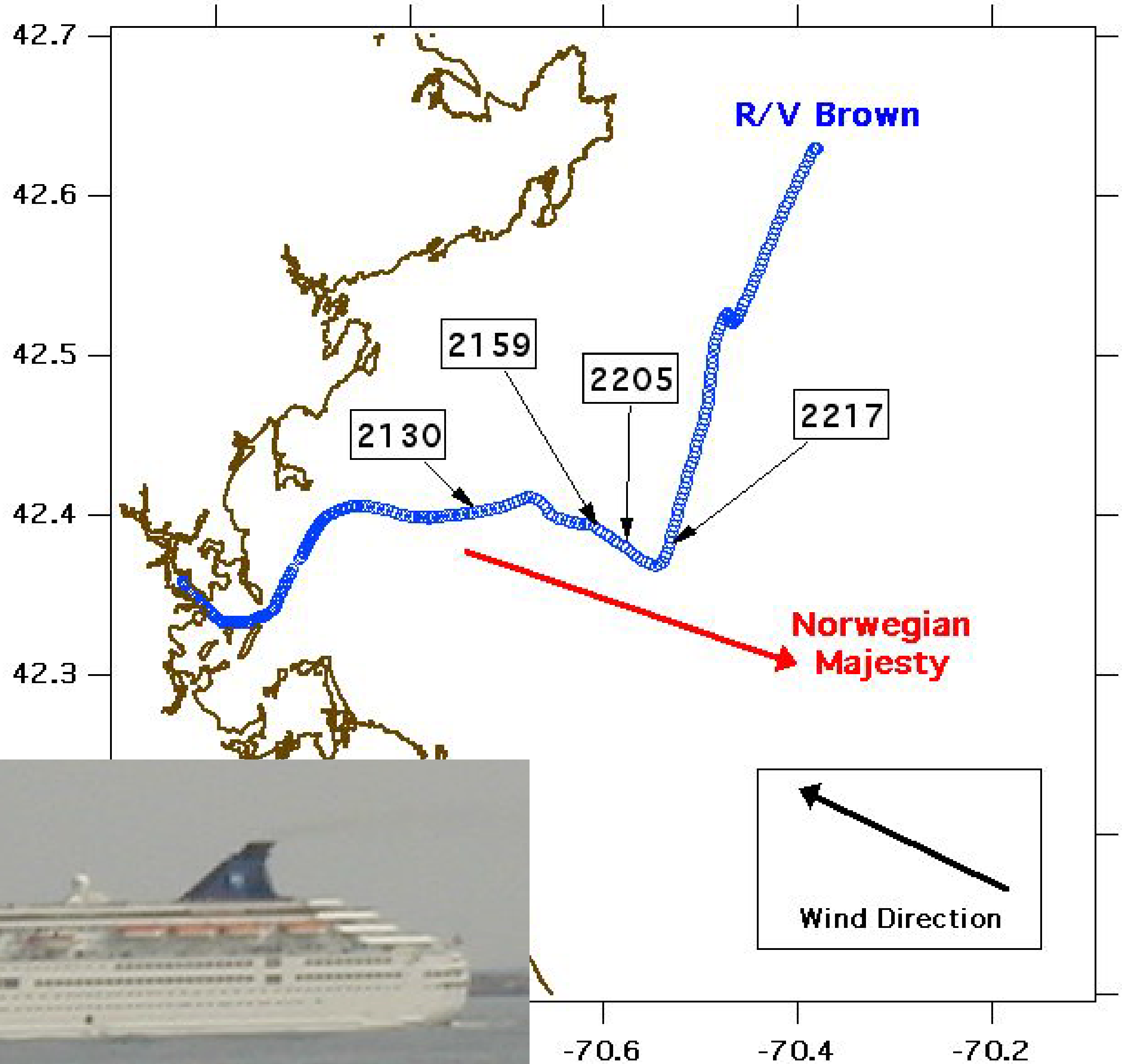
Encounter with a Cruise Ship: Norwegian Majesty

Blue dots:
R/V Brown course

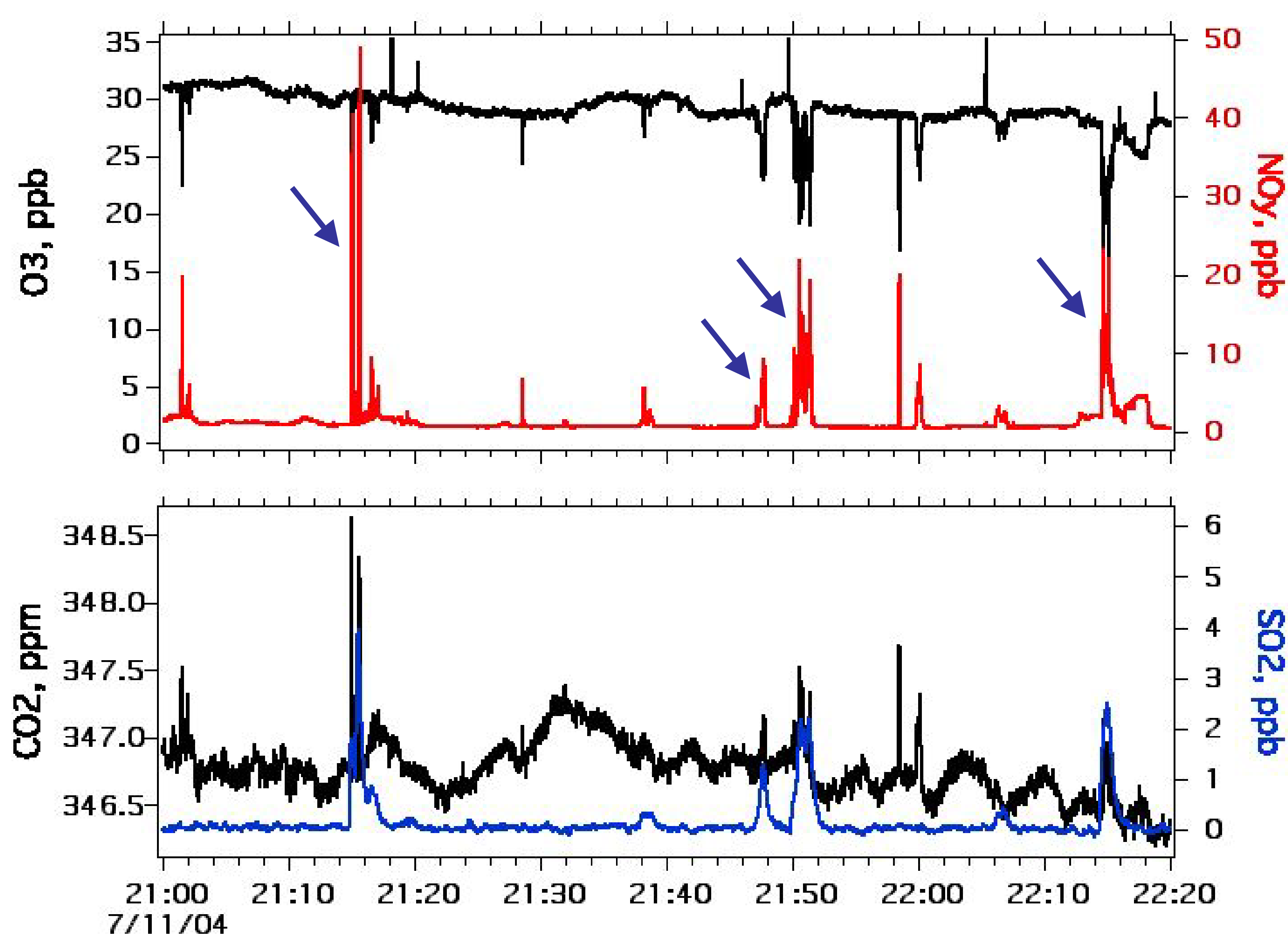
Red arrow:
approximate track of cruise ship

Numbered boxes:
UTC times of lidar scans

Black arrow:
approximate wind direction

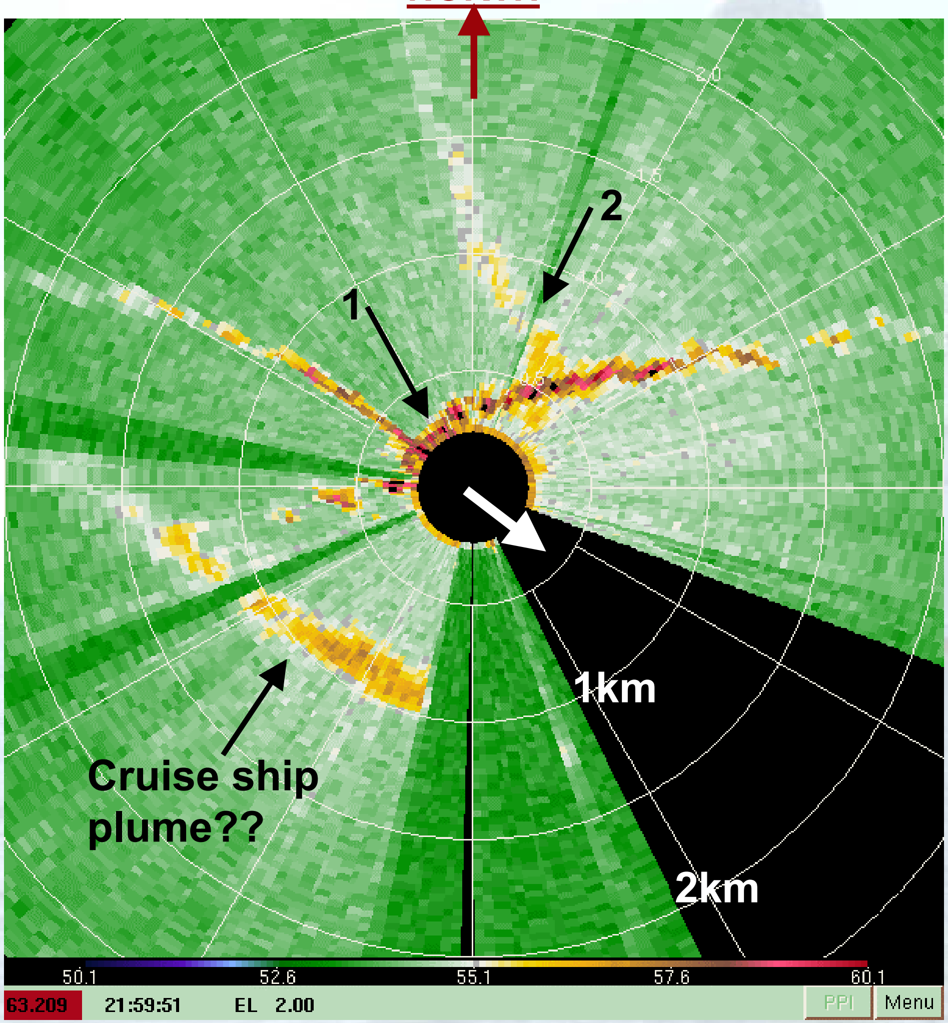


Cruise Ship Exhaust Emission Plume Tracking



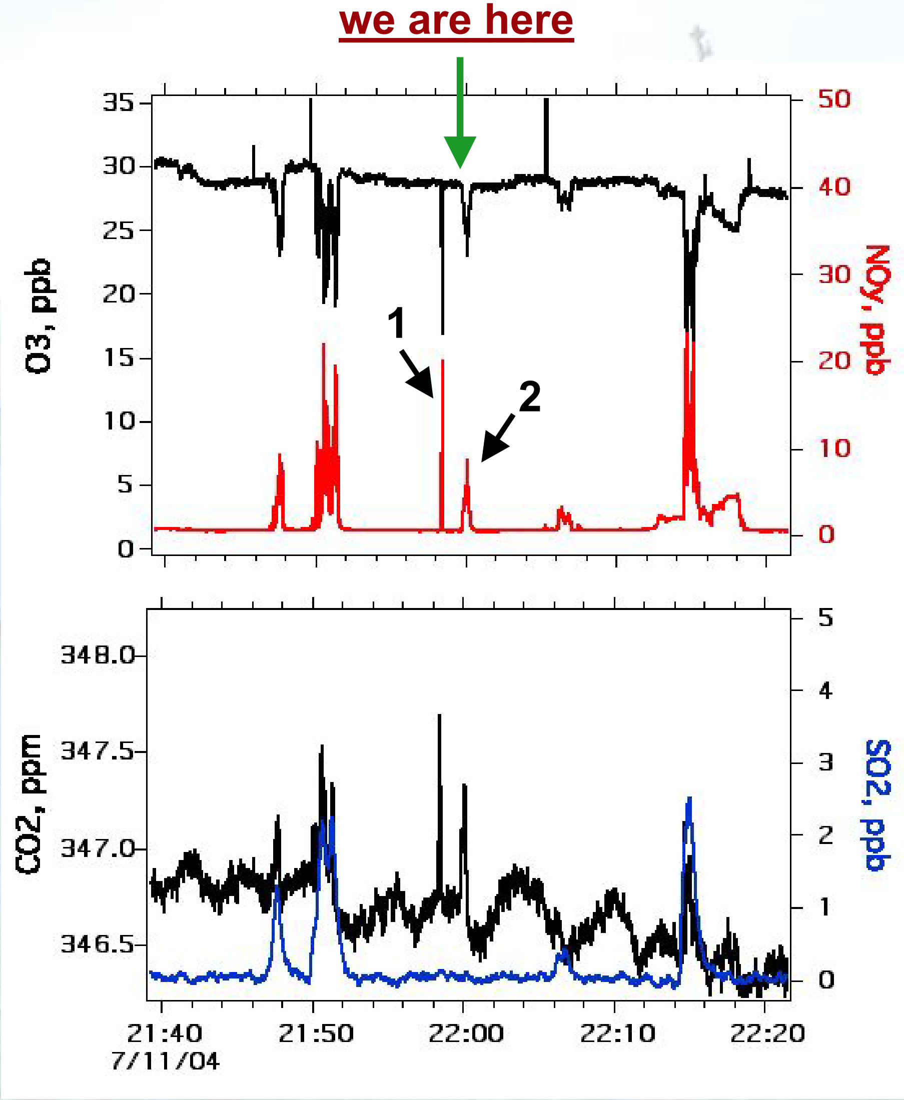
Ship Exhaust Plume Encounters - Mass. Bay; 11 July 04

HRDL Azimuth Scan; 21:59:51 UTC



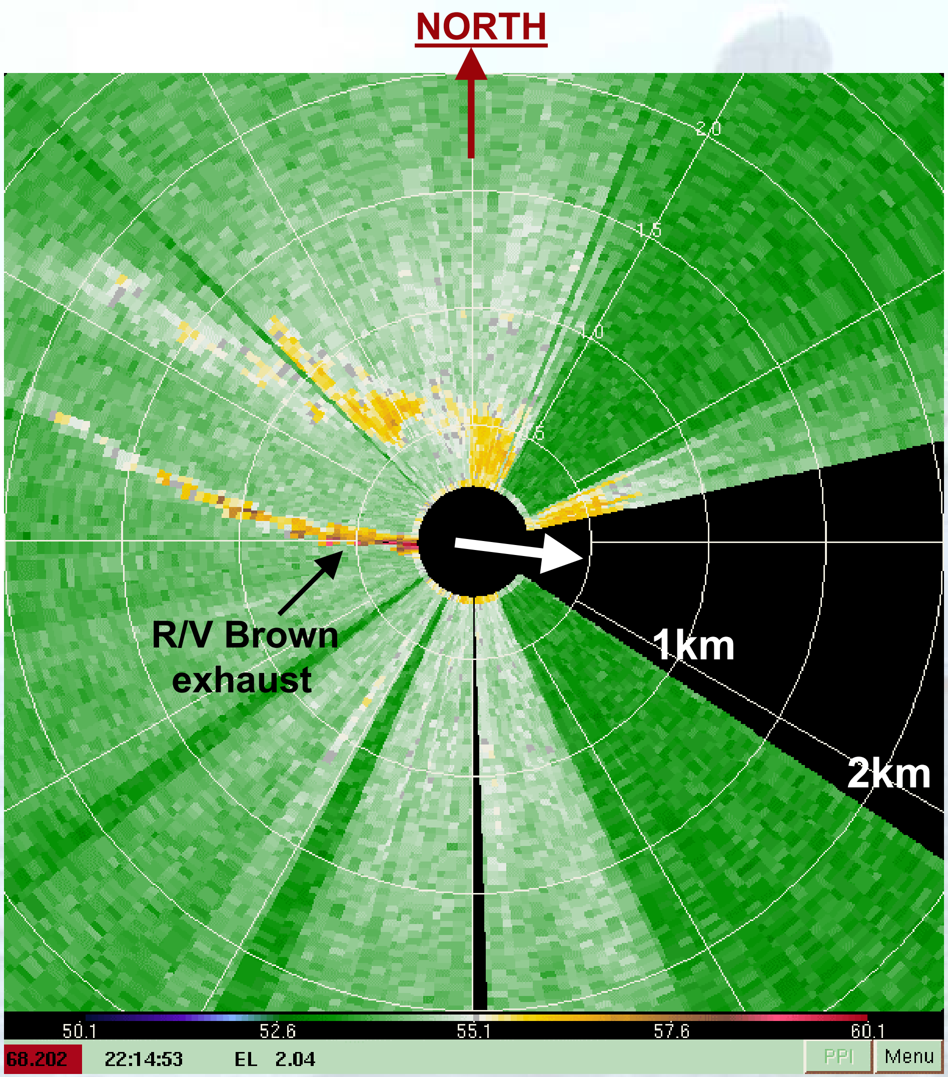
2-degree Elevation Angle (0.5 km ht.: ~ 24m)

O_3, NO_y, SO_2, CO_2 Time Series



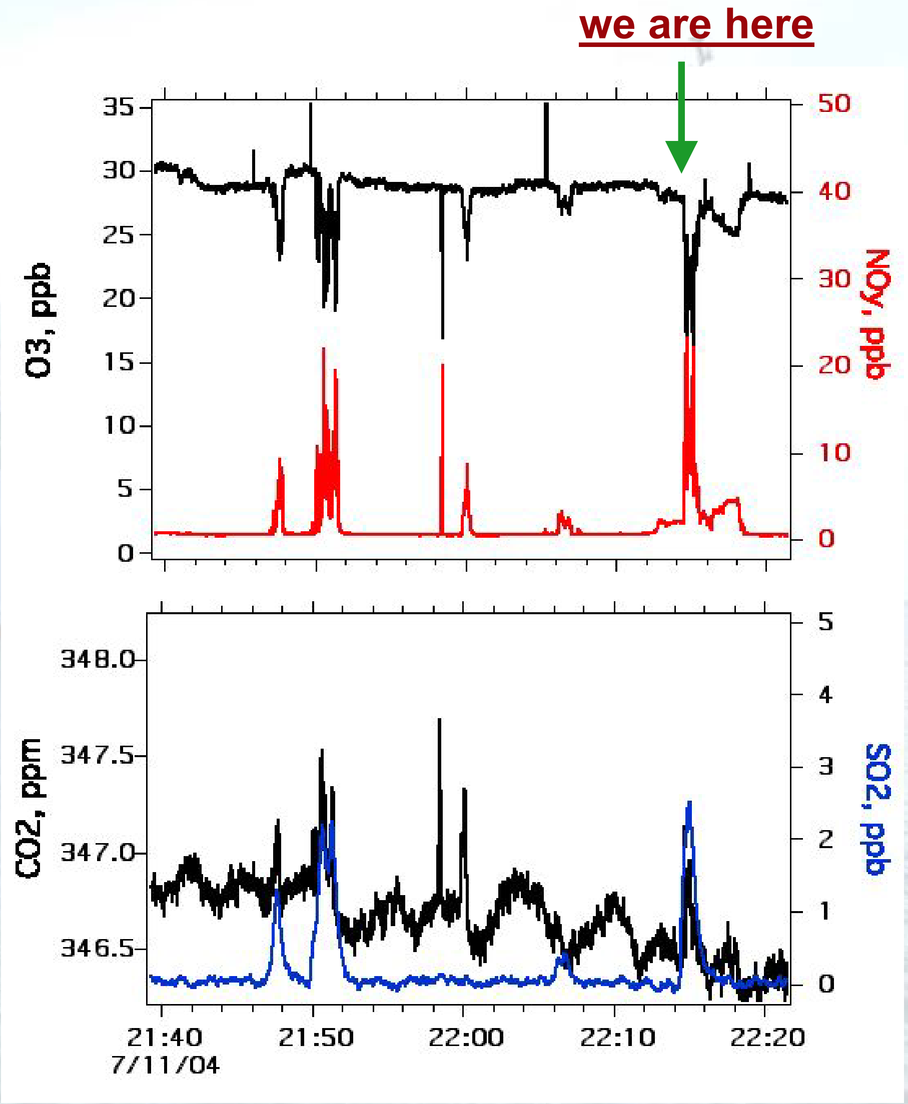
Ship Exhaust Plume Encounters - Mass. Bay; 11 July 04

HRDL Azimuth Scan; 22:14:53 UTC



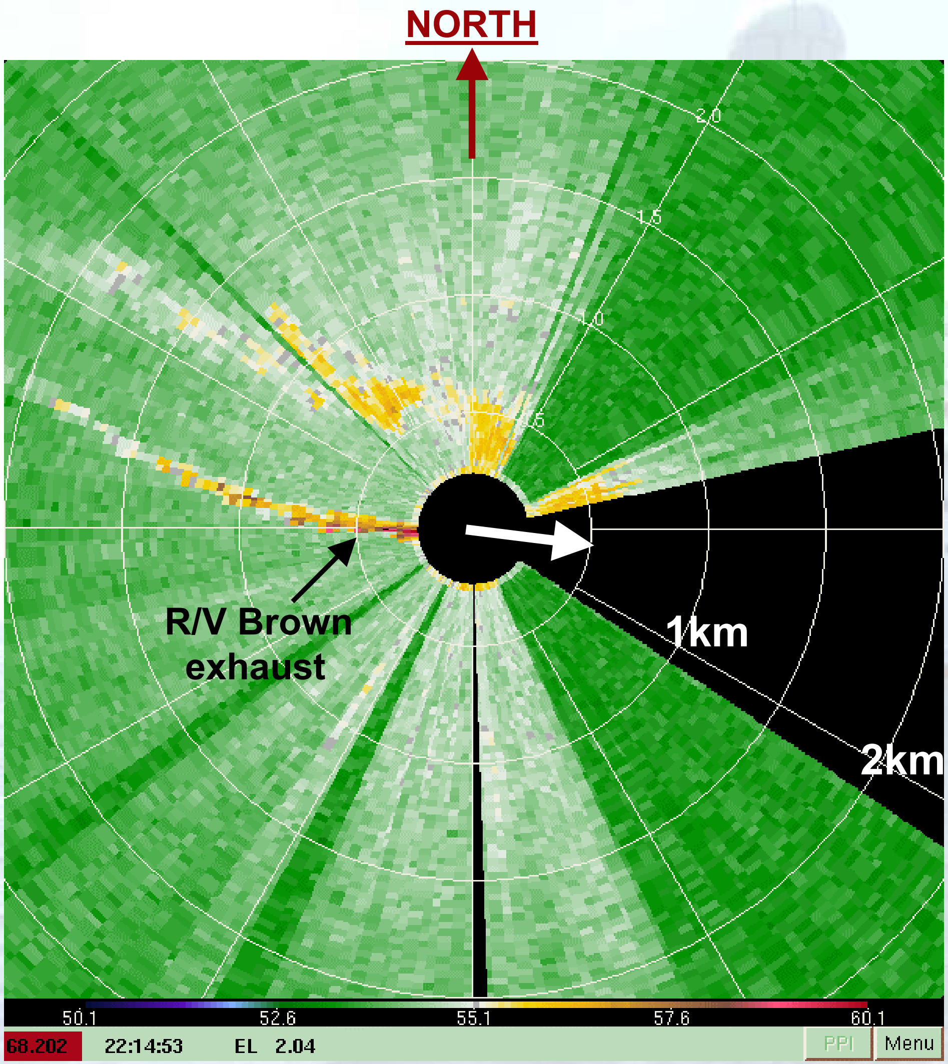
2-degree Elevation Angle (0.5 km ht.: ~ 24m)

O_3, NO_y, SO_2, CO_2 Time Series



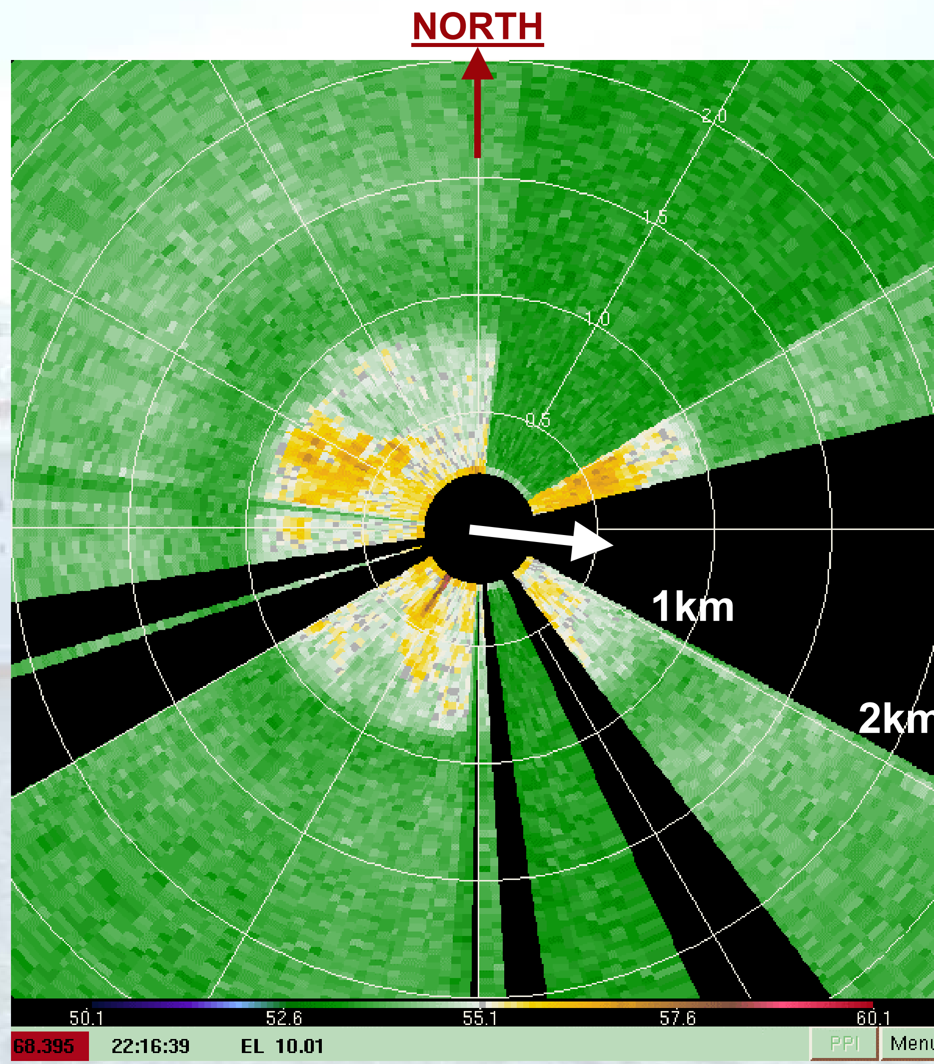
Ship Exhaust Plume Encounters - Mass. Bay; 11 July 04

HRDL Azimuth Scan; 22:14:53 UTC



2-degree Elevation Angle (0.5 km ht.: ~ 24m)

HRDL Azimuth Scan; 22:16:39 UTC



10-degree Elevation Angle (0.5 km ht.: ~ 94m)

NEAQS –ITCT 2004

- What is the clear-sky radiative impact of the aerosols advecting from North America out over the Northwestern Atlantic Ocean?
- How do the continental aerosols over Northeastern North America and those advecting out over the Northwestern Atlantic Ocean affect cloud drop size distributions and cloud reflectance (first indirect effect)?

Ron Brown Aerosol Optical Properties
NEAQS – ITCT 2004
Leg 1

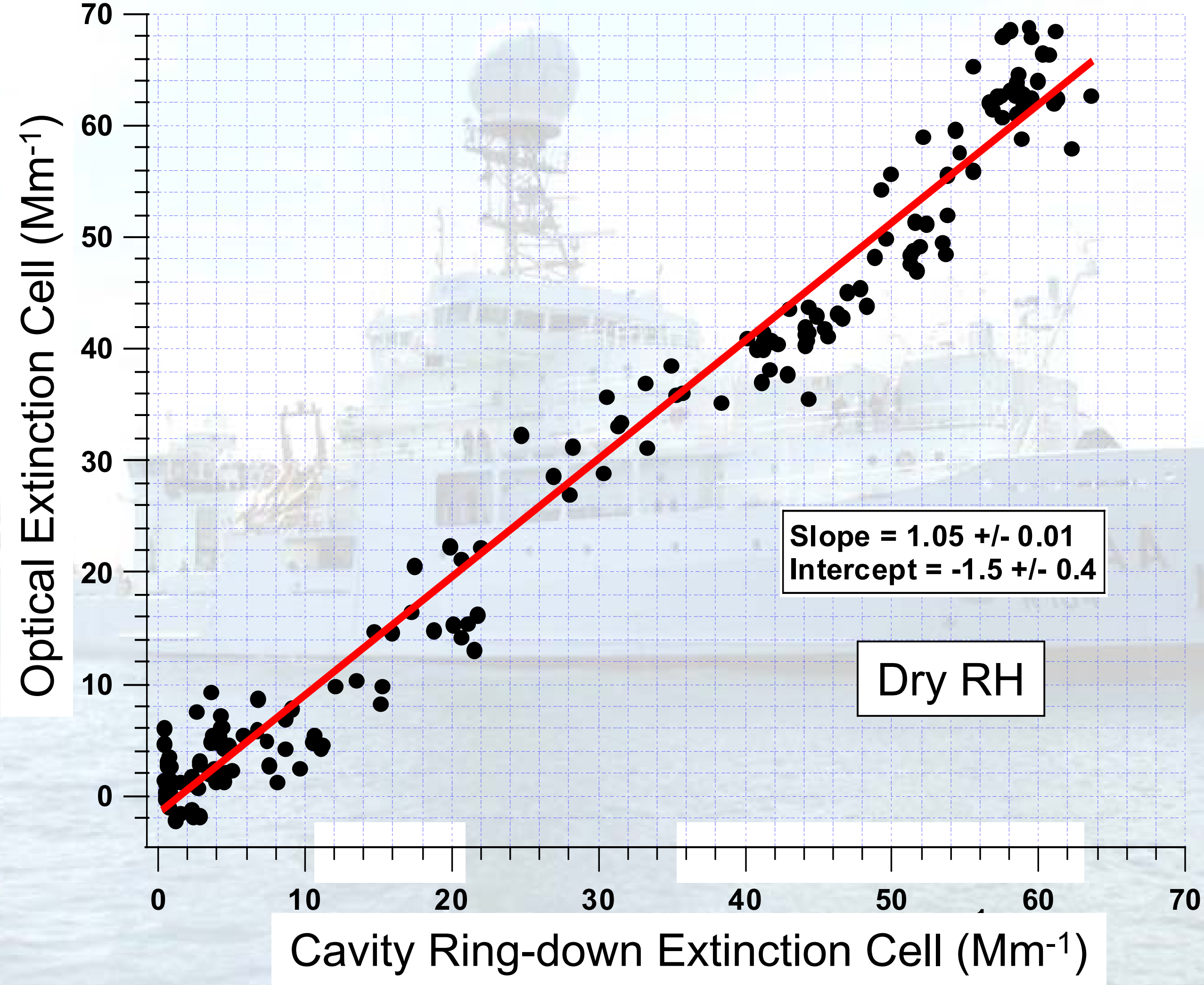
Input from T. Baynard, D. Covert, P. Kollias,
T. Onasch, A. Petterson, C. Senff, W. Wang

Aerosol Direct Radiative Forcing

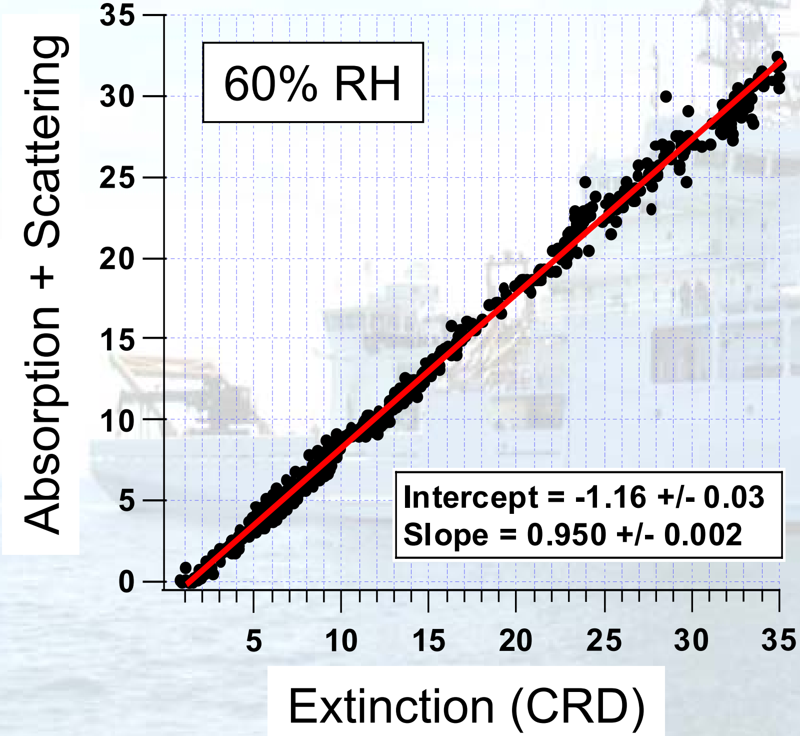
Approaches

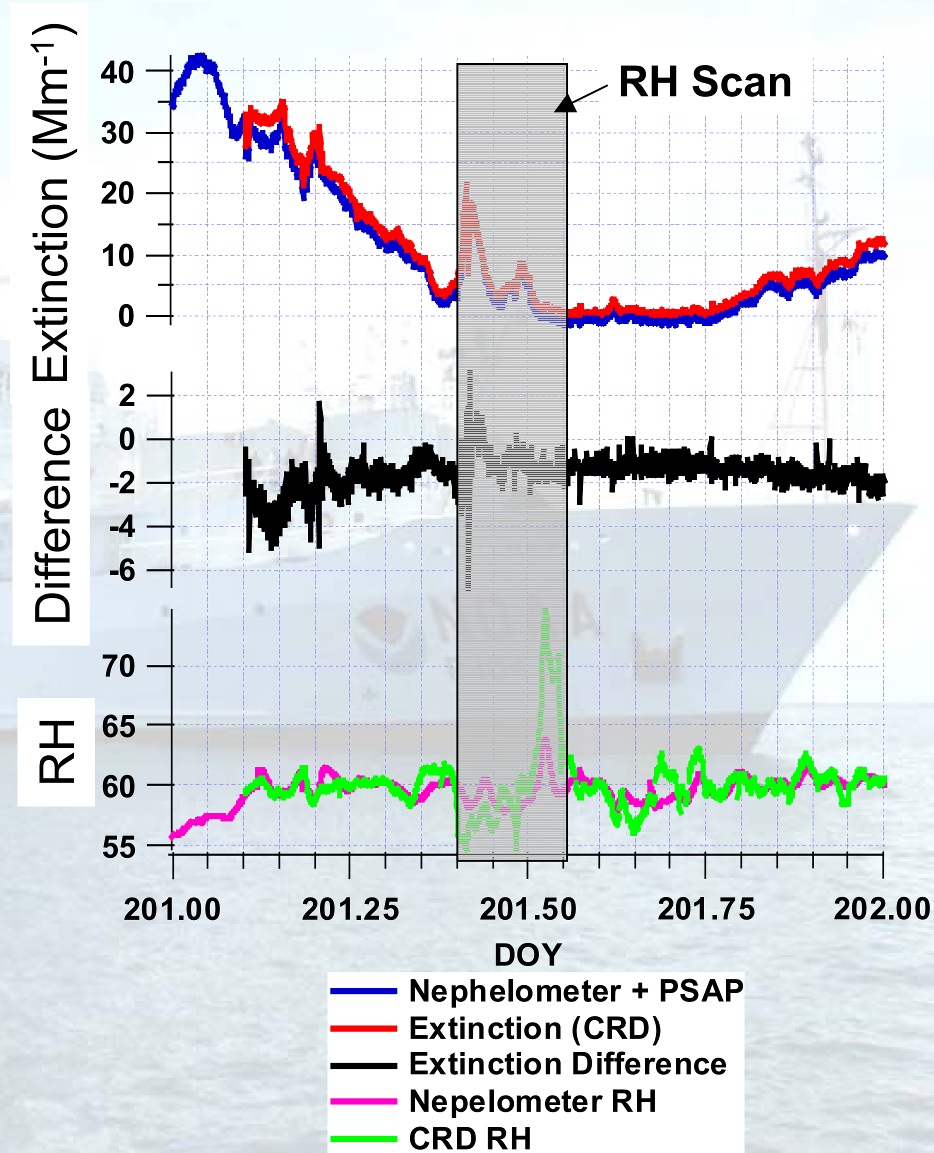
- Column Closure
- Local Closure
  - Extinction
    - Optical Extinction Cell
    - Cavity Ring-down Extinction Cell
    - OPAL – horizontal scanning mode
    - Nephelometer + PSAP
  - Hygroscopic Growth Dependence of Scattering and Extinction
    - Nephelometer
    - Cavity Ring-down Extinction Cell
- Determination of Relationships Between Aerosol Scattering and Chemistry
- Regional Sensitivity of Forcing to Variability in Backscattered Fraction of Light, Single Scattering Albedo, and Aerosol Optical Depth

Comparison of Extinction Measured by Optical Extinction Cell And Cavity Ring-down Extinction Cell (Jul 16 – Jul 22)

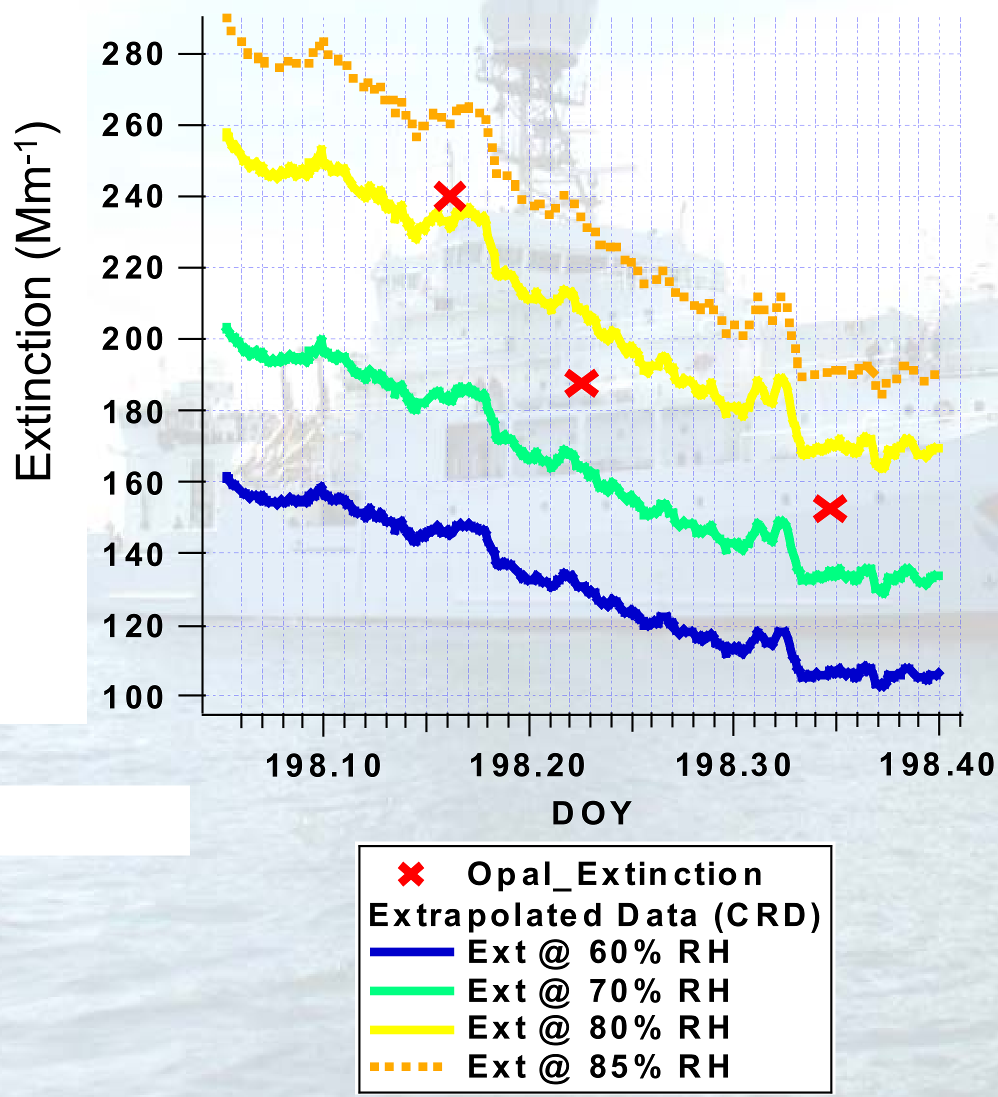


Comparison of Extinction Measured by Neph + PSAP And Cavity Ring-down Extinction Cell



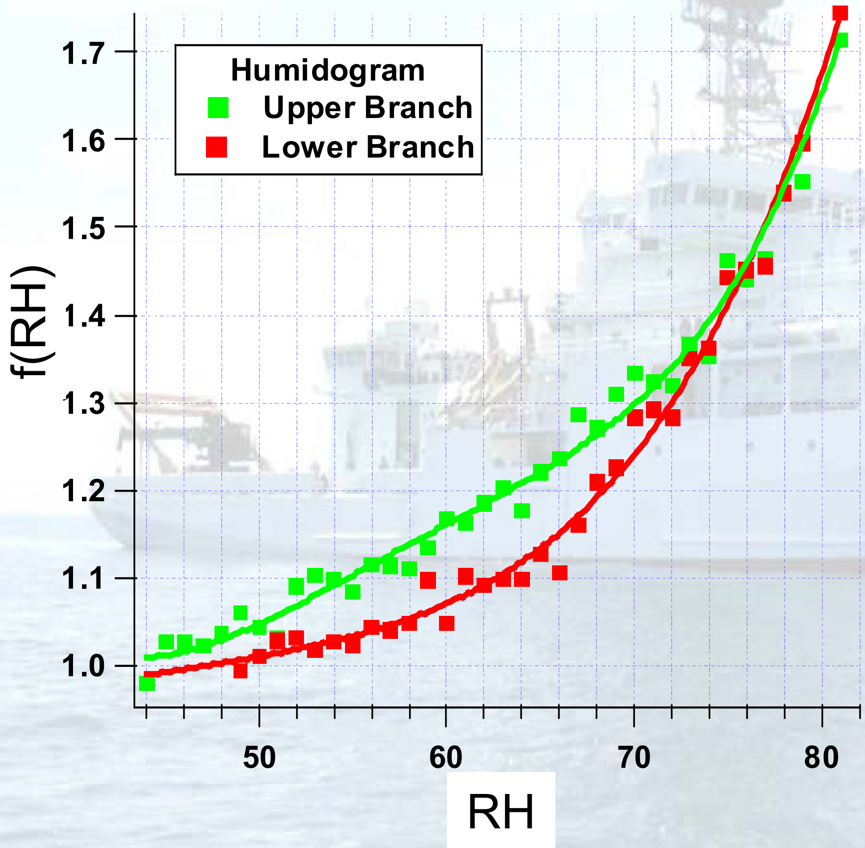


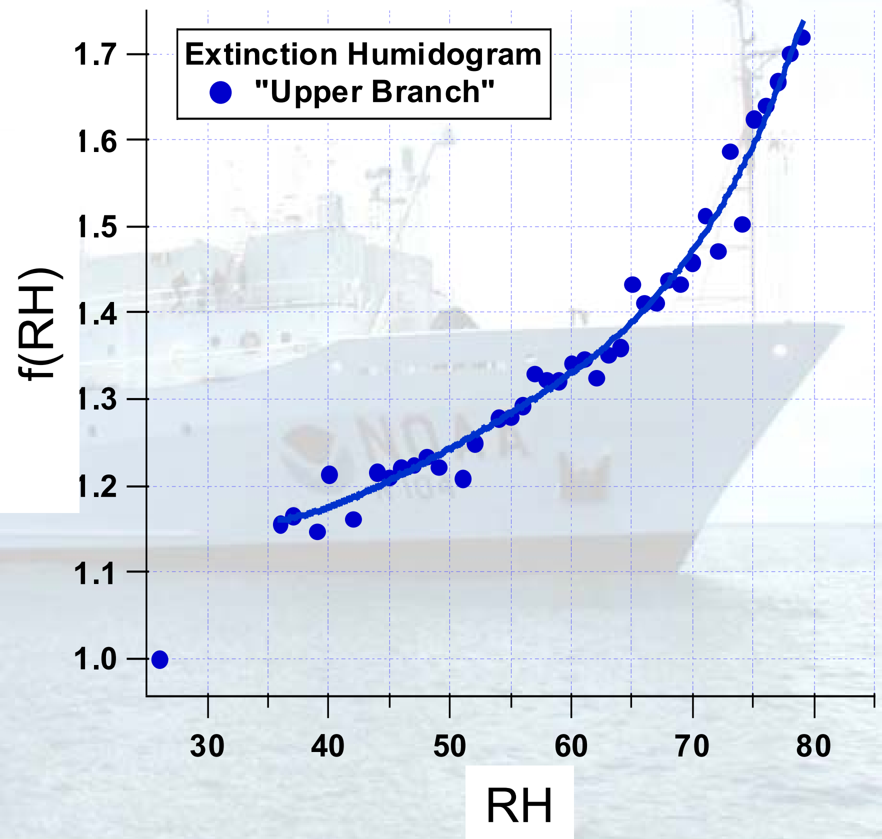
Comparison of Extinction Measured by Cavity Ring-down Extinction Cell and OPAL (LIDAR) at λ = 355 nm



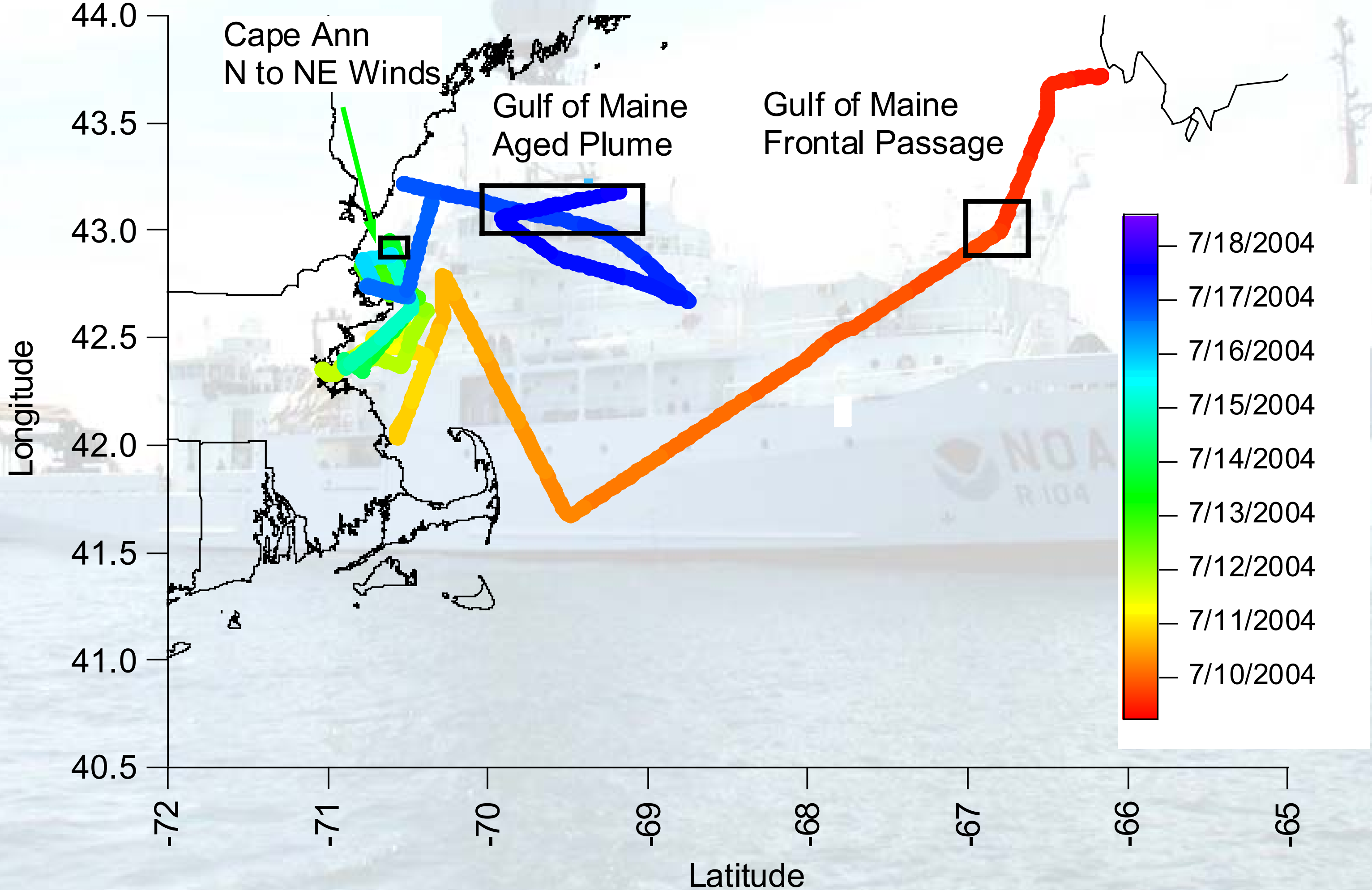
Ambient RH = 80 to 90%

Comparison of Hygroscopic Growth Dependence of Aerosol Scattering from Humidified Nephelometer and Extinction from CRD DOY 203 (12:00 UTC)

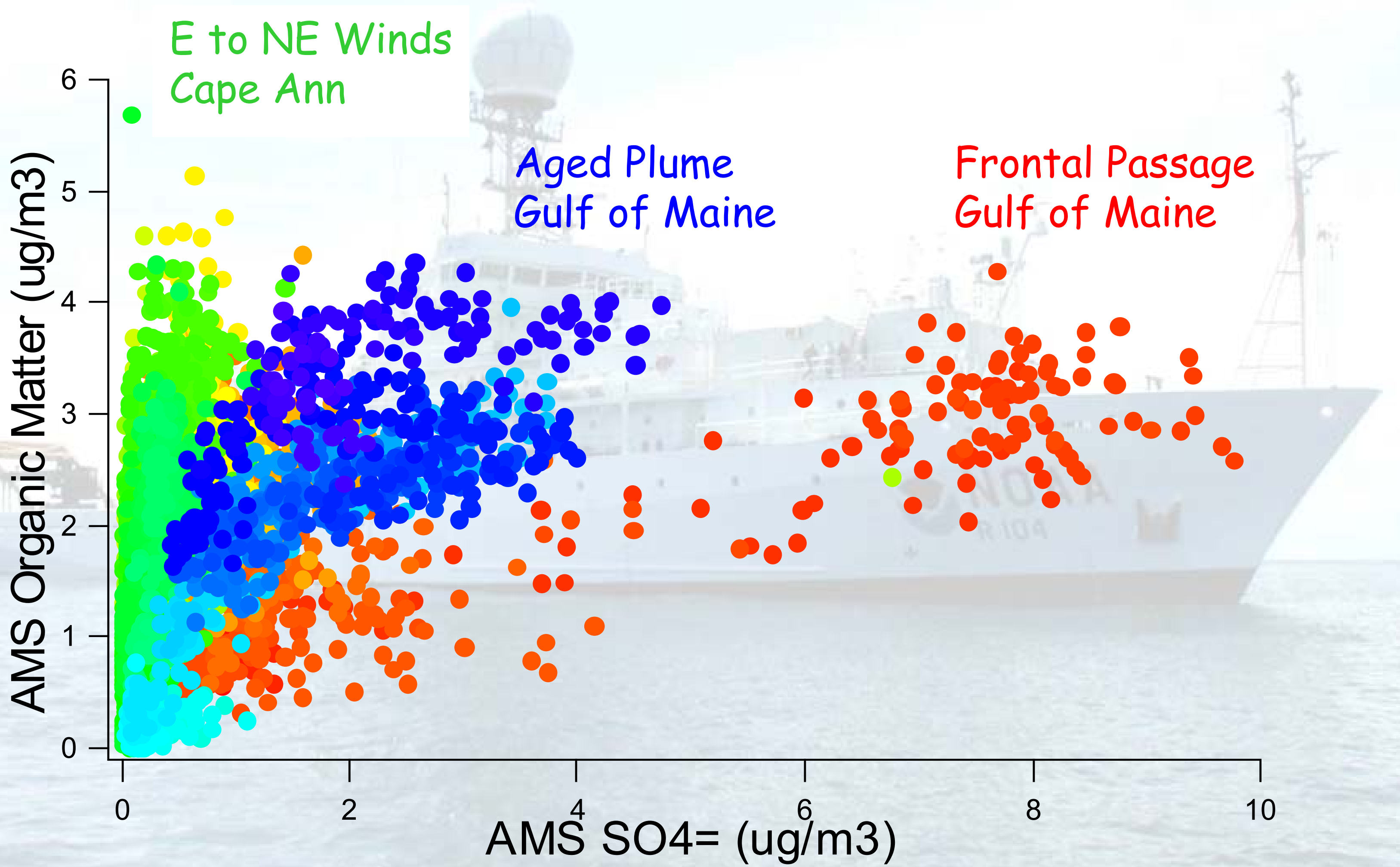




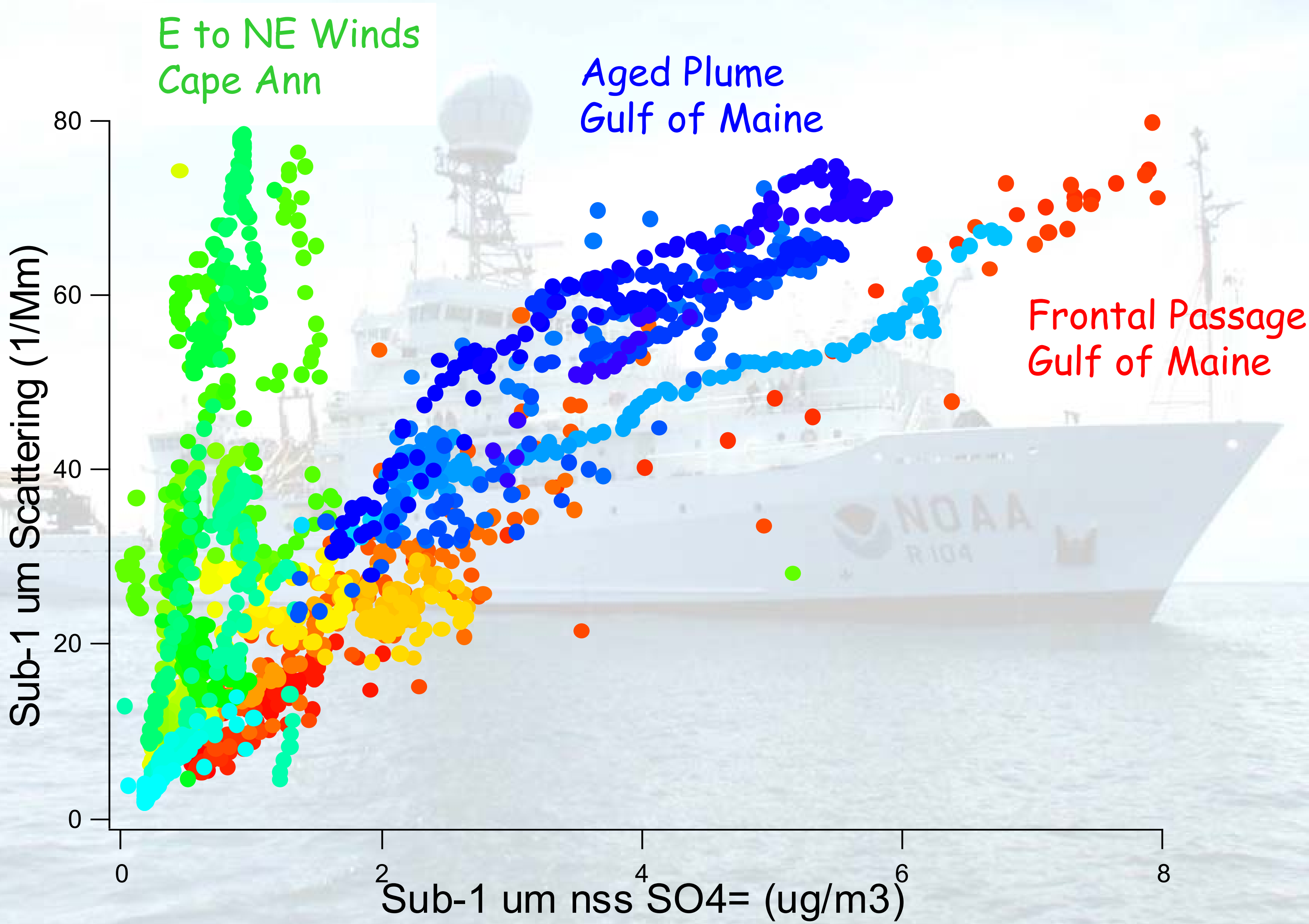
Relationships Between Aerosol Chemistry and Scattering for Three Plumes



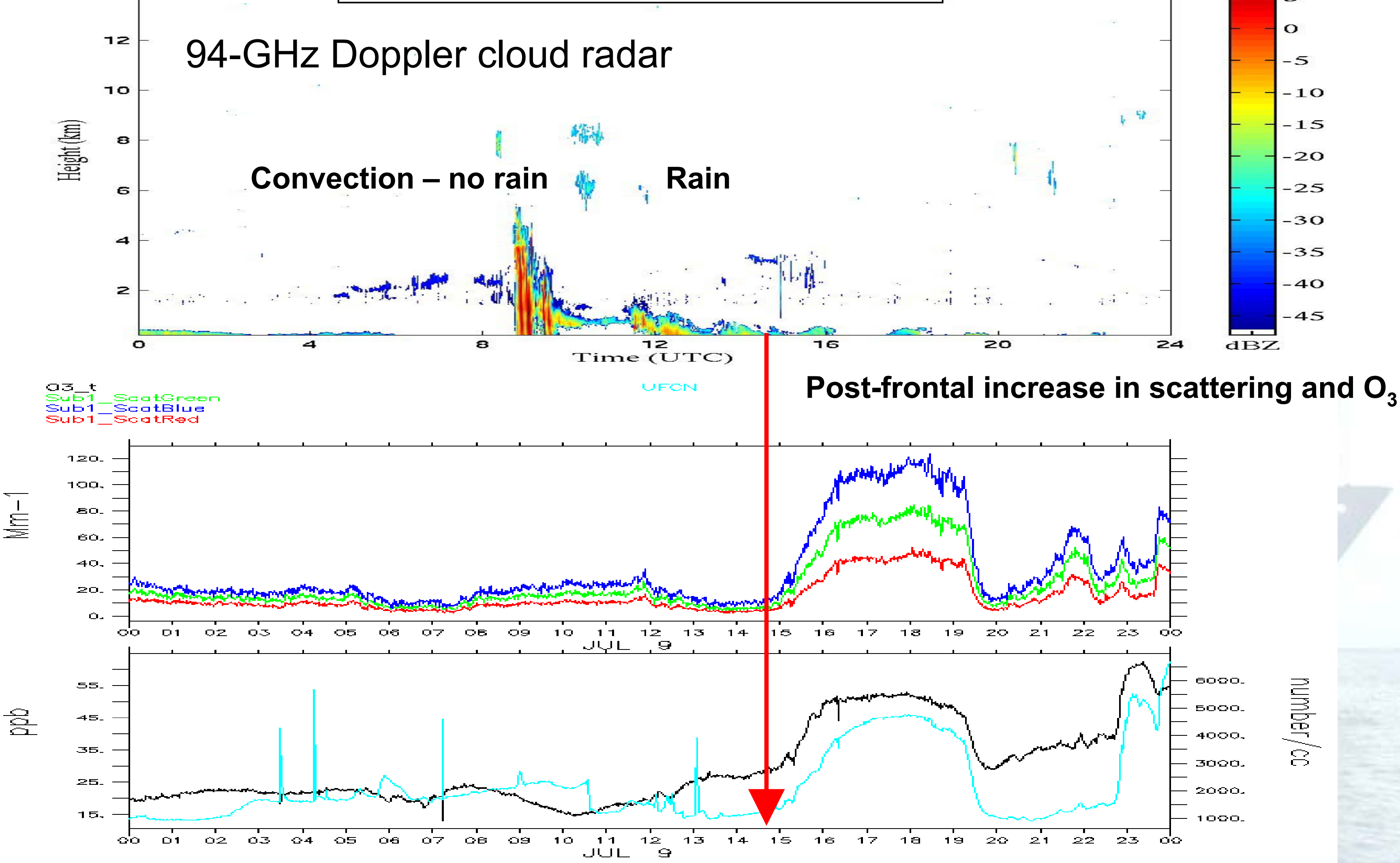
Aerosol Sulfate versus Organics for Jul 9 to Jul 18
(color coded with time)



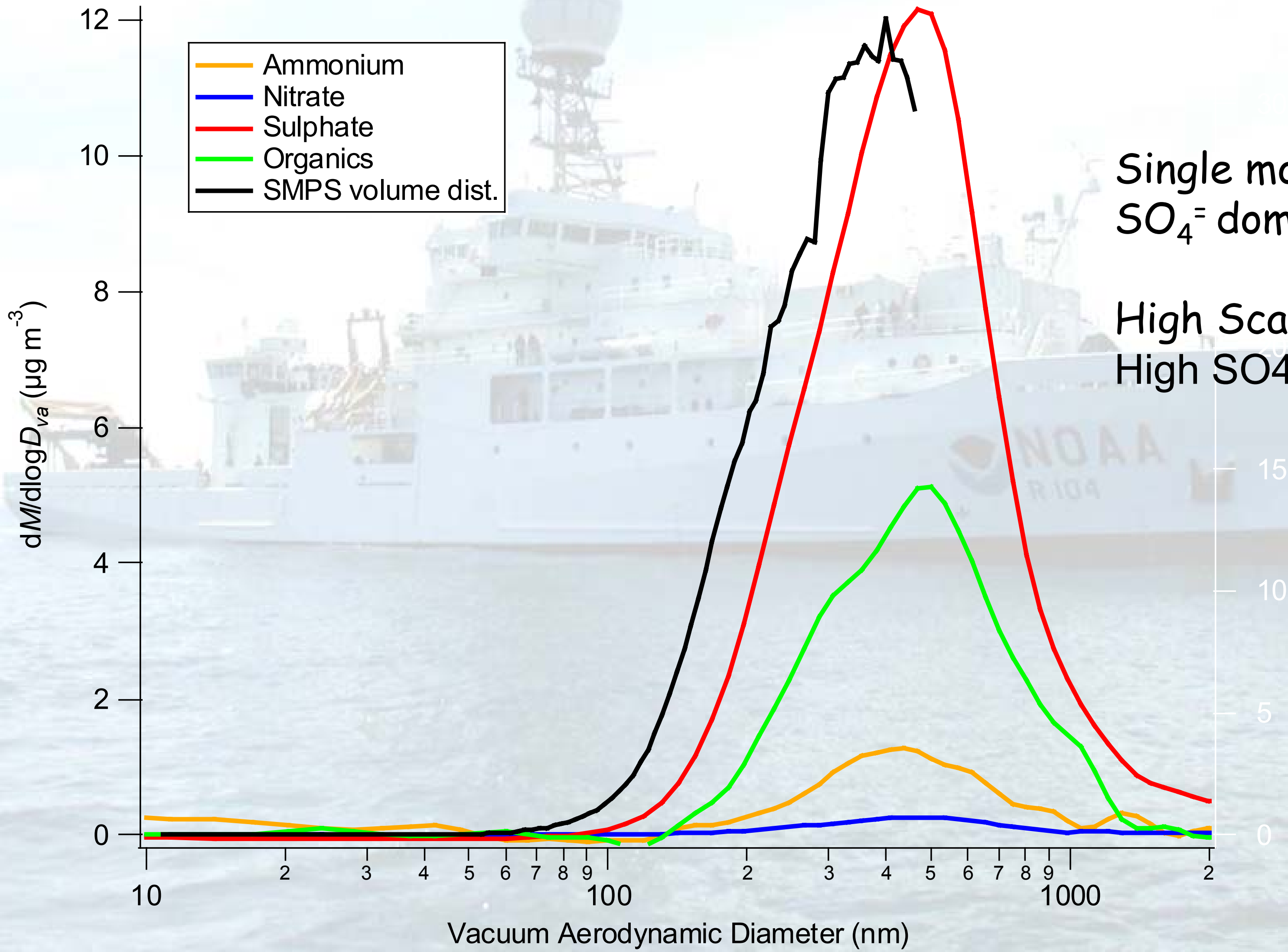
Submicron Aerosol Sulfate versus Scattering for Jul 9 to Jul 18



Frontal Passage - Gulf of Maine



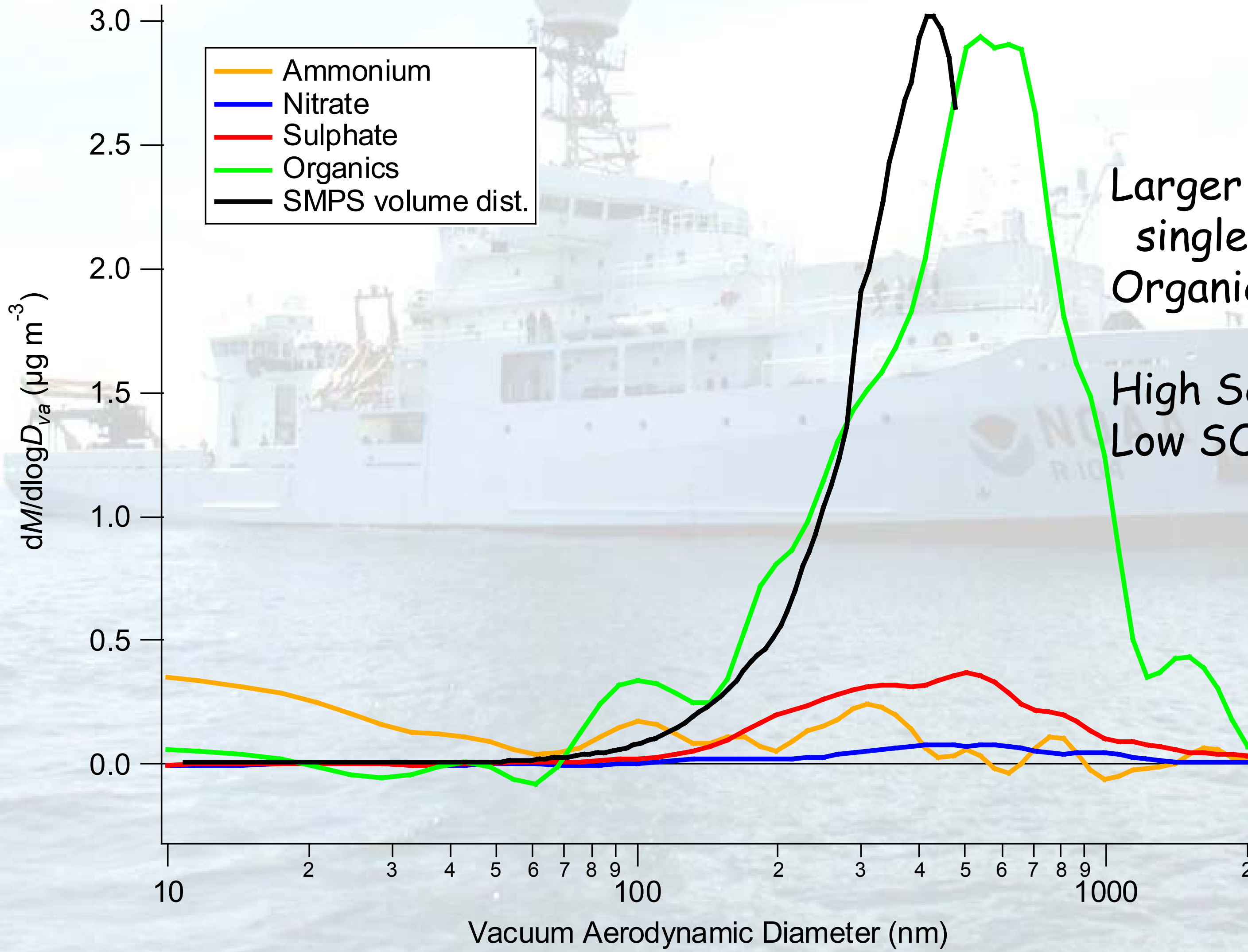
Frontal Passage – Gulf of Maine
Chemically Speciated Mass Distribution



Single mode
$SO_4^=$ dominates

High Scattering
High SO4=

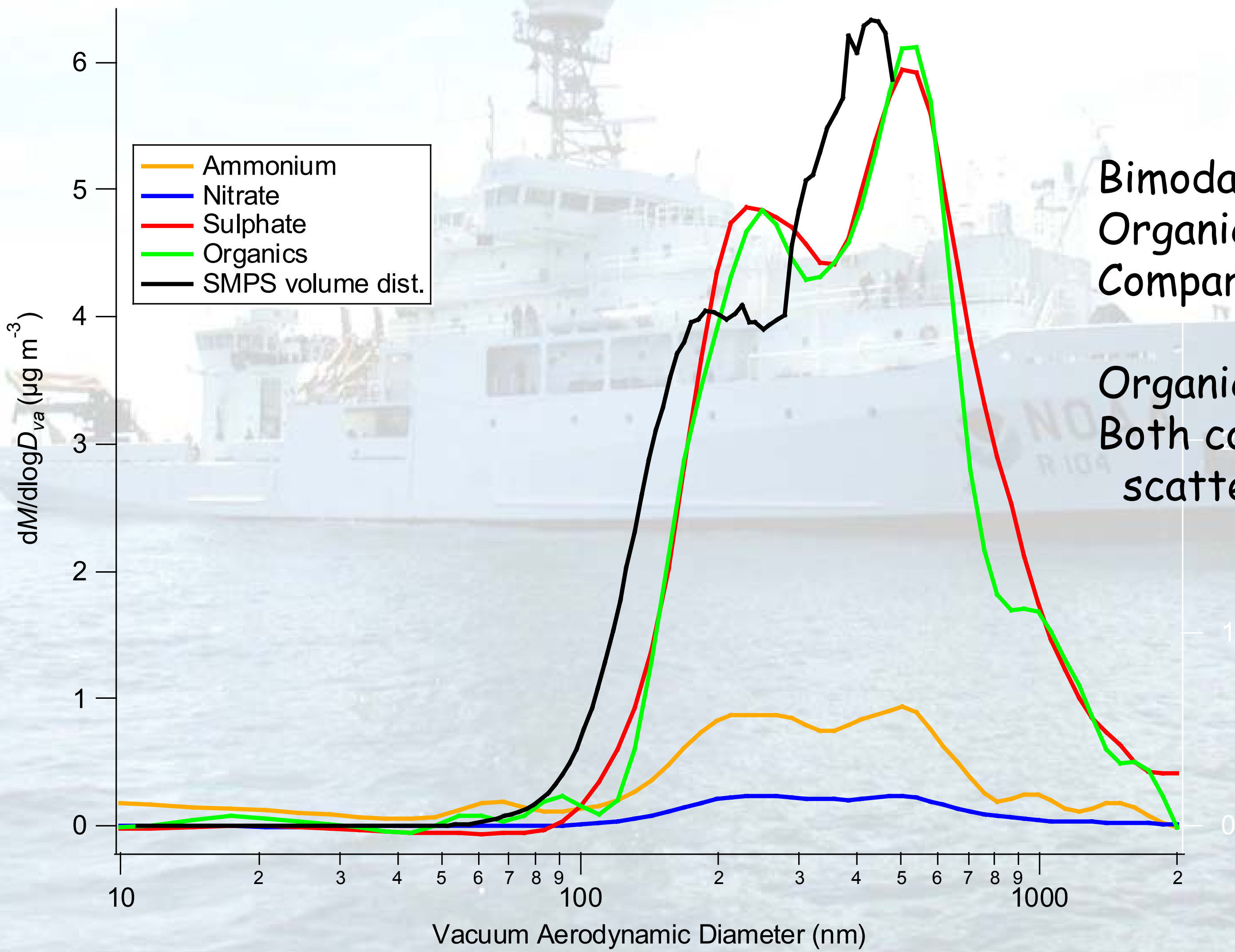
Cape Ann – E to NE Winds
AMS Chemically Speciated Mass Distributions



Larger diameter single mode Organics dominate

High Scattering
Low $SO_4^{=}$

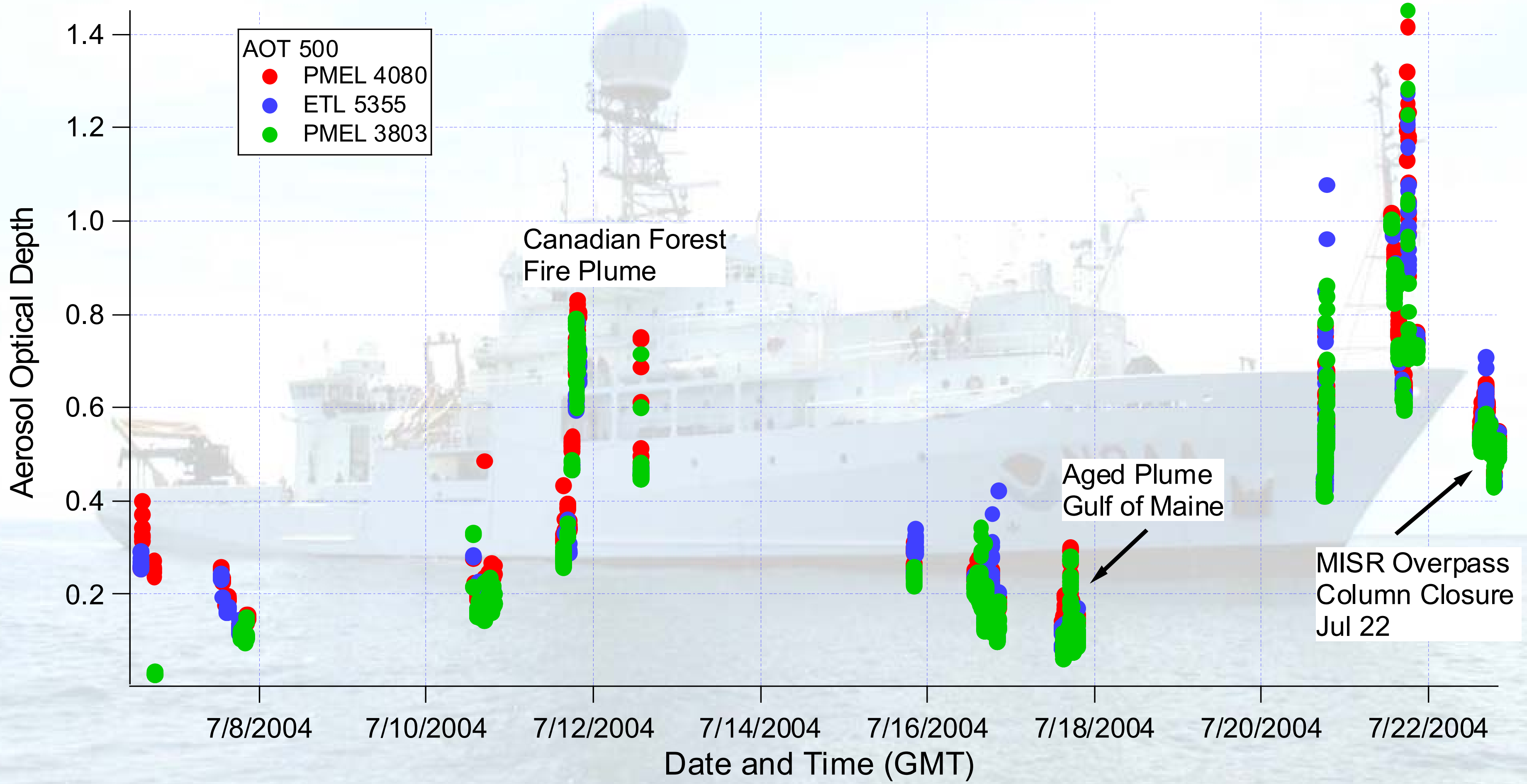
Gulf of Maine – Aged Plume
AMS Chemically-speciated Mass Distributions



Bimodal
Organics and $SO_4^=$
Comparable

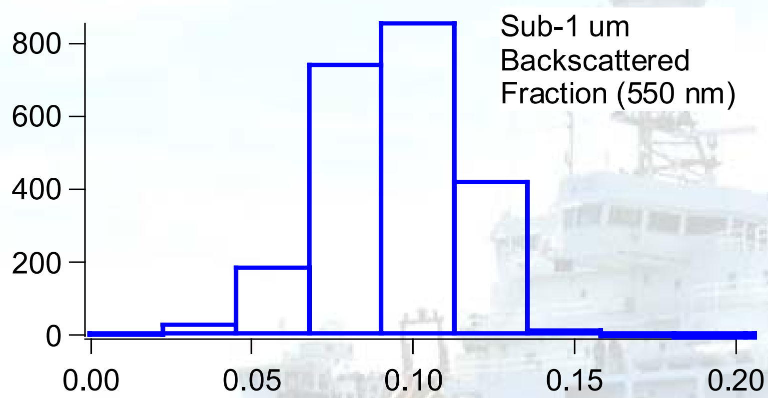
Organics and $SO_4^=$
Both control
scattering

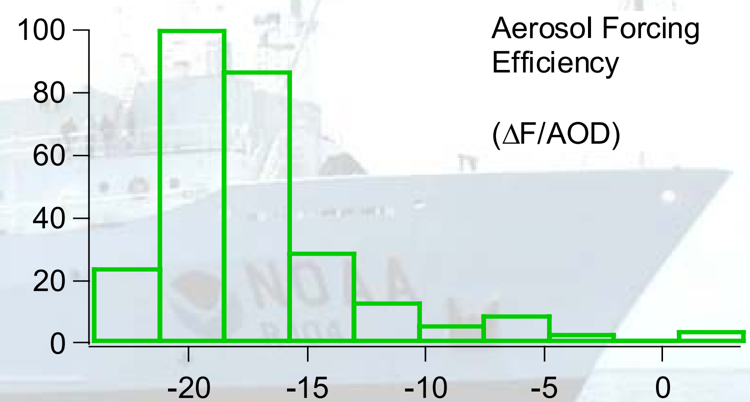
Aerosol Optical Depth (500 nm)

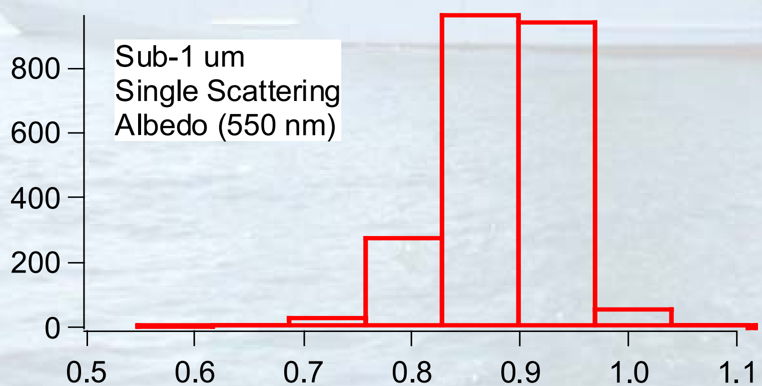


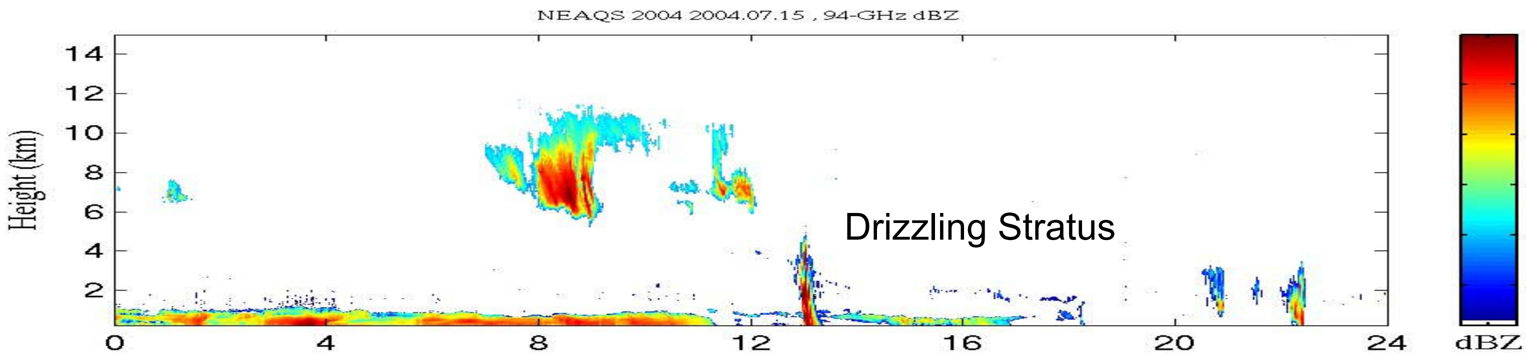
Variability in observed Sub-1 um Backscattered Fraction and Single Scattering Albedo for the Three Plumes

Resulting Variability in Estimated Aerosol Forcing Efficiency









Aerosol Indirect Radiative Forcing

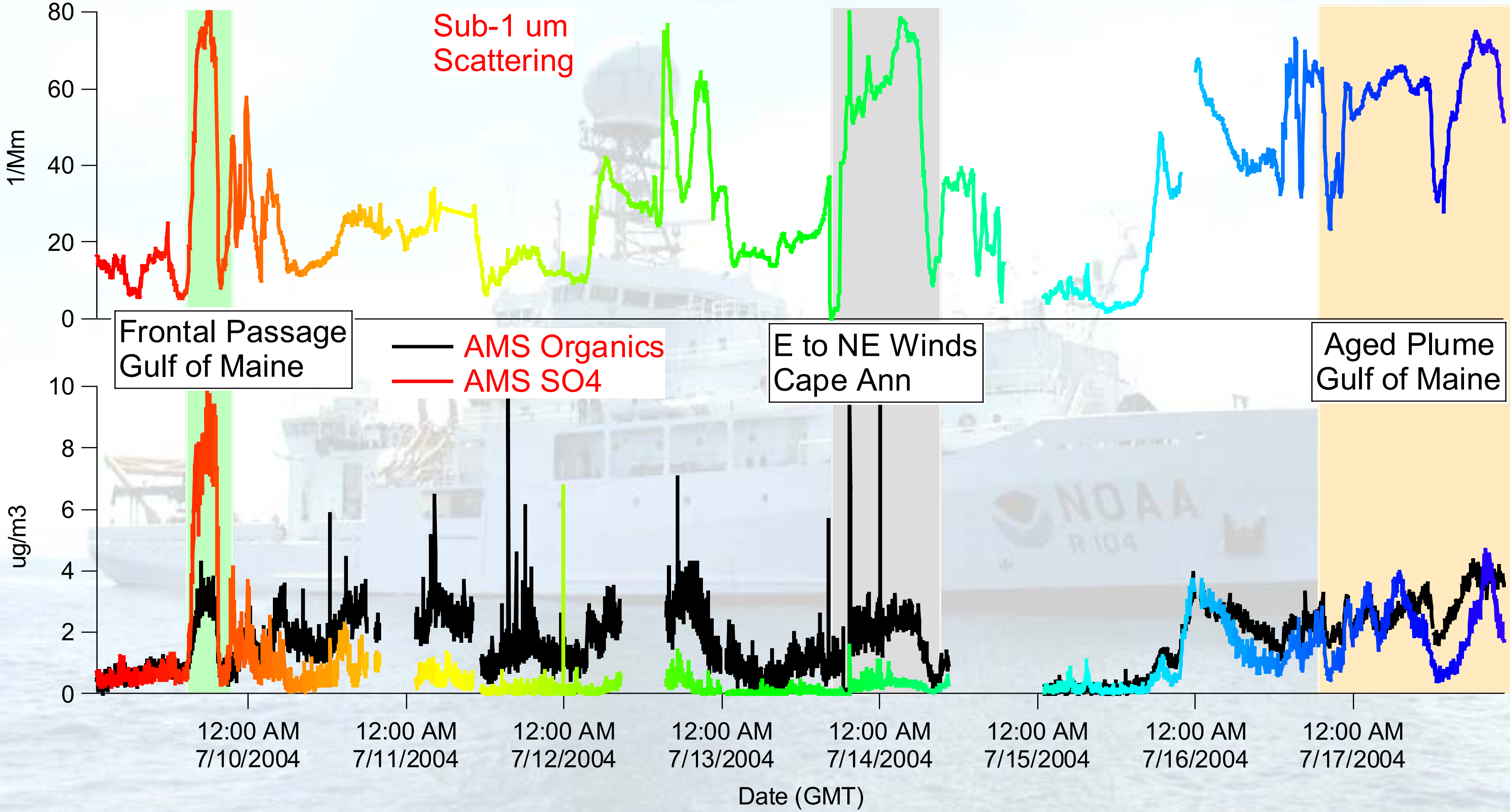
Approach

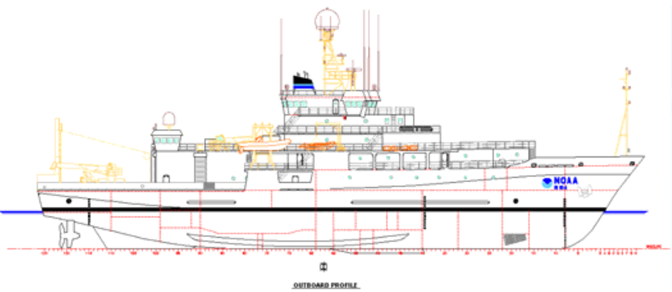
- 94-GHz Doppler Cloud Radar and 2 Channel Microwave Radiometer for retrieval of:
    - Cloud optical depth (τ)
    - Liquid water content (LWC)
    - Droplet concentration (N_d)
    - Effective Radius (r_e)

- Determine the range of LWC, N_d, τ, in boundary layer clouds and how they vary under different aerosol conditions.
- Determine how the lifecycle and cloud fraction of liquid water clouds is affected by different aerosol loadings.

NOAA
R104

Sub-1 um Scattering and Concentrations of Organics and Sulfate

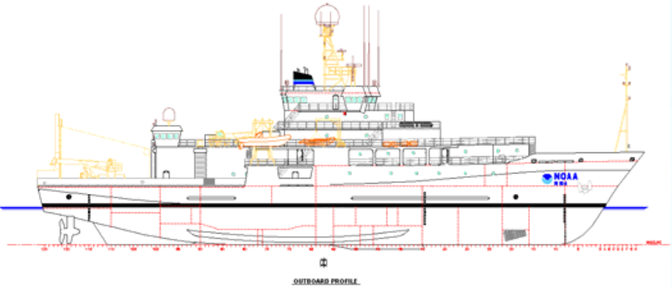




Measurements

http://saga.pmel.noaa.gov/NEAQS-ITCT/

Parameter	Method	Laboratory	PI
Ozone	UV absorbance	AL/PMEL	Williams/Johnson
Ozone	NO chemiluminescence	AL	Williams
Ozone vertical dist	Ozonesonde	NASA	Thompson
Ozone vertical dist	Lidar (OPAL)	ETL	Senff
Carbon monoxide	UV fluorescence	AL	Lerner
Carbon dioxide	Non-dispersive IR	AL	Lerner
Water vapor	Non-dispersive IR	AL	Lerner
Sulfur dioxide	Pulsed fluorescence	AL/PMEL	Williams/Bates
Nitric oxide	Chemiluminescence	AL	Lerner
Nitrogen dioxide	Photolysis cell	AL	Lerner
Total N oxides	Au tube reduction	AL	Williams
PANs	GC/ECD	AL	Roberts
Alkyl nitrates	GC/MS	AL	Goldan
NO3/N2O5	Cavity ring-down spect.	AL	Osthoff
Nitric acid/NH3	Mist Chamber.IC	UNH	Dibb
Photolysis rates	Spectral radiometer	AL	Jakoubek

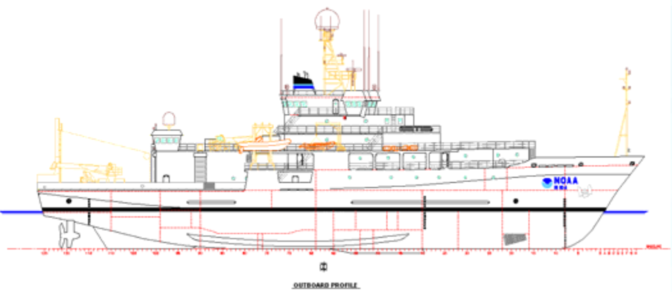


Measurements

Parameter	Method	Laboratory	PI
Continuous speciation of VOCs	PTR-MS/CIMS	AL	Warneke
VOC speciation	GC/MS	AL	Goldan/Kuster
Seawater & atmospheric pCO2	NDIR	AOML	Wanninkhof
Seawater DMS	S chemiluminesence	PMEL	Bates/Johnson
Radon	Radon gas decay	PMEL	Johnson
Wind/Temp/RH Profiles	Wind profiler	ETL	White
Temp/RH profiles	Sondes	ETL	White
LWP	Microwave radiometer	ETL	Fairall
Cloud drop size, updraft velocity	3mm radar	UM	Albrecht
Cloud height	Ceilometer	ETL	Fairall
Turbulent fluxes	Bow-mounted EC flux	ETL	Fairall
High resolution turbulence	Mini-sodar -	ETL	Fairall
Wind profiles/microturbulence	C-band radar	ETL	Fairall
Aerosol vertical profiles	OPAL	ETL	Senff
BL wind/aerosol profiles	Doppler lidar (HRDL)	ETL	Brewer

Measurements

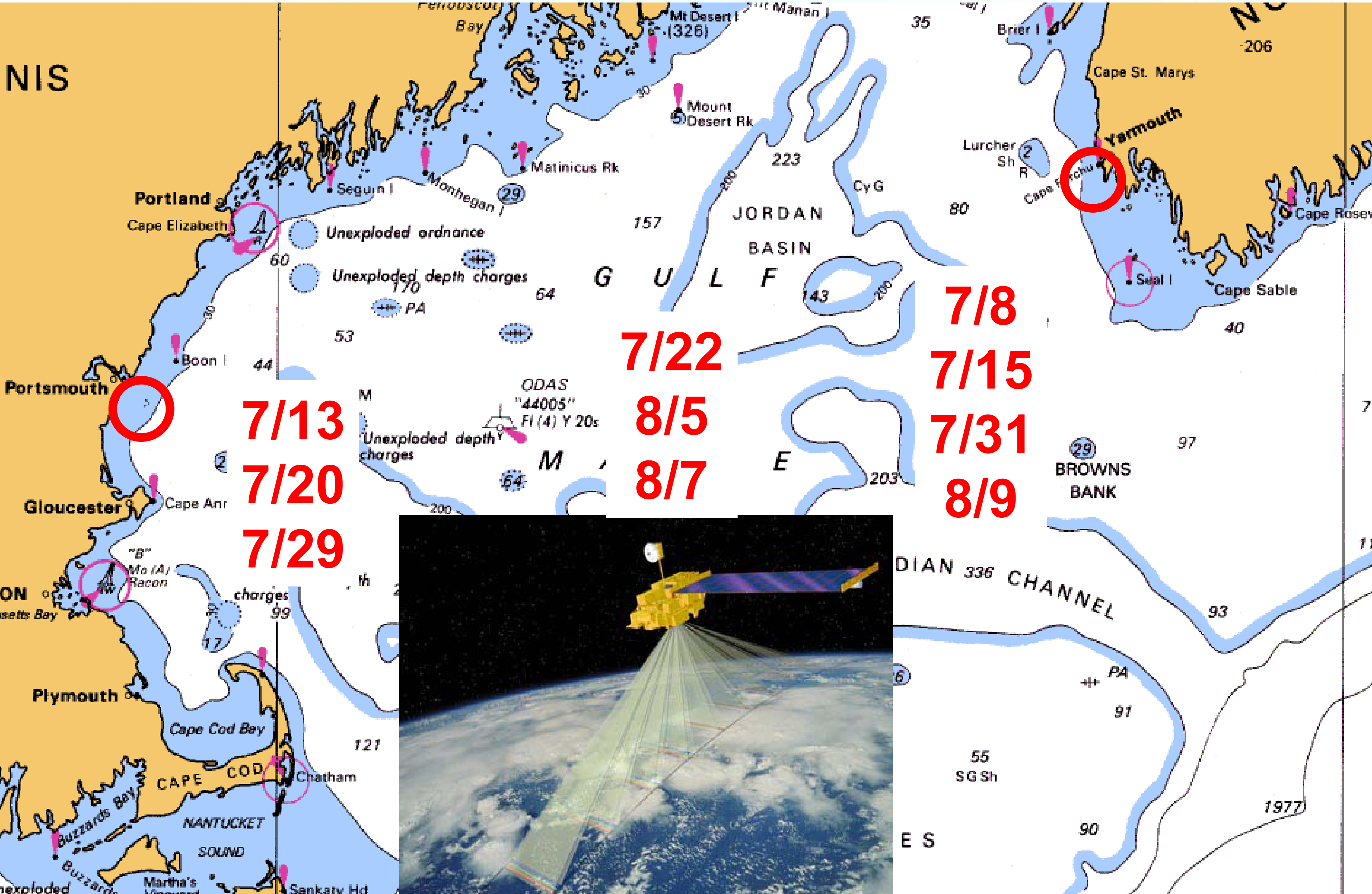
Parameter	Method	Laboratory	PI
Aerosol ionic composition	PILS-IC	PMEL	Quinn
Aerosol WSOC	PILS-TOC	PMEL	Quinn/Bates
Organic aerosol speciation	PILS-LCMS	PMEL	Quinn
Aerosol size and composition	Aerosol mass spectrometer	PMEL/ Aerodyne	Bates/Worsnop
Aerosol OC/EC	On-line thermal/optical	PMEL	Bates
Aerosol composition 2 stage (sub/super micron) & 7 stage at 60% RH	Impactors (IC, XRF and thermal optical OC/EC, total gravimetric weight)	PMEL	Quinn/Bates
Aerosol functional groups	FTIR	SIO	Russell
Total & sub micron aerosol scattering &backscattering (450, 550, 700 nm) at 60%RH	TSI nephelometers (2)	PMEL	Quinn
Total & sub-micron aerosol absorption (450, 550, 700 nm) dry	PSAPs (2)	PMEL	Quinn

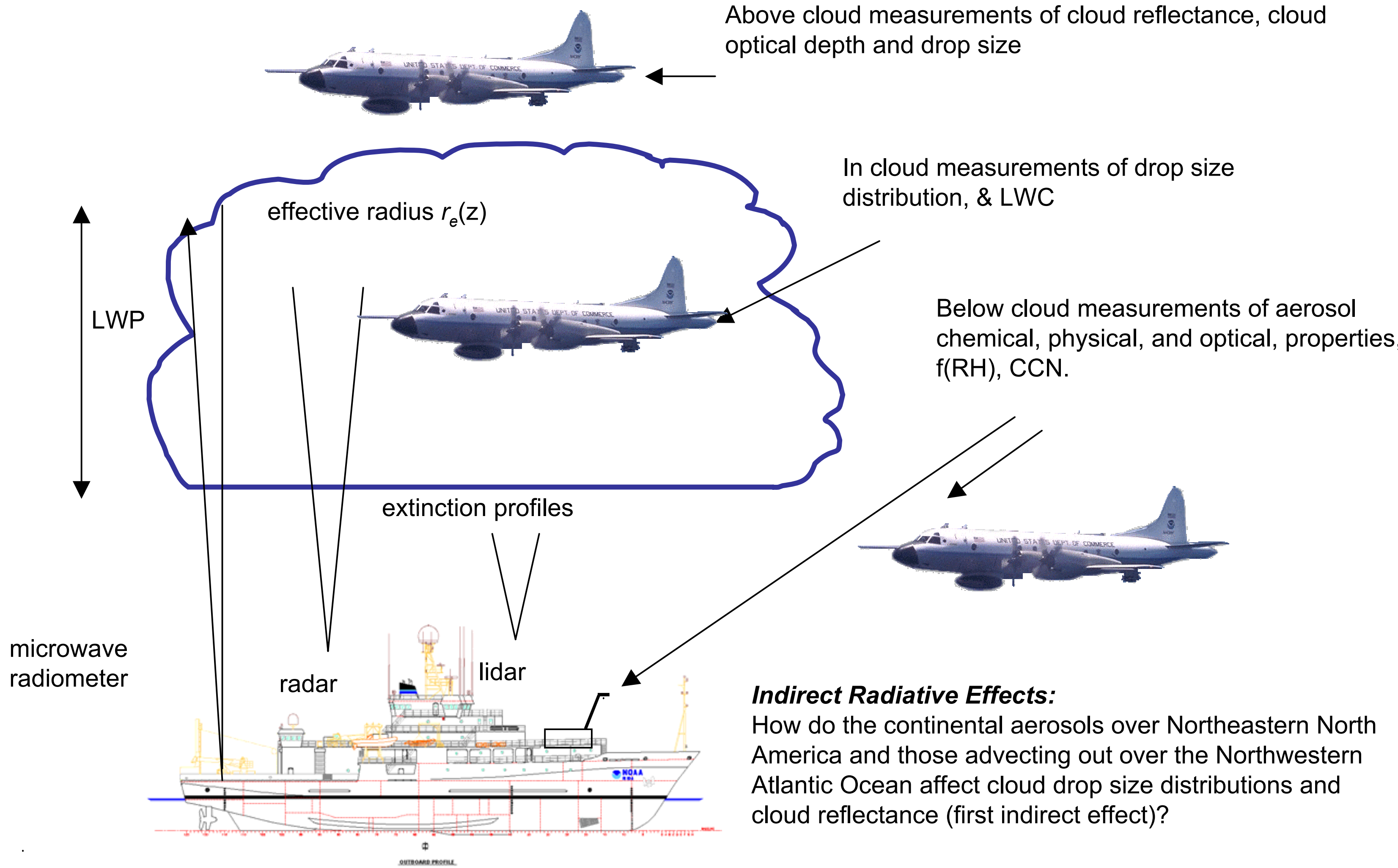


Measurements

Parameter	Method	Laboratory	PI
Sub-micron aerosol extinction	Extinction cell	UW	Covert
Total & sub-micron aerosol extinction	Cavity ring-down spectrometer	AL	Baynard
Aerosol number	TSI 3010 3025	UW/PMEL	Covert/Bates
Aerosol size distribution 5-10,000 nm at 60% RH	DMA, OPC and APS	UW/PMEL	Covert/Bates
Total & sub-micron aerosol light scattering hygroscopic growth	Twin TSI 3563 nephelometers	UI	Rood
Irradiance	PRP	BNL	Reynolds
AOD	microtops	PMEL	Quinn

Operations Area





Indirect Radiative Effects:
How do the continental aerosols over Northeastern North America and those advecting out over the Northwestern Atlantic Ocean affect cloud drop size distributions and cloud reflectance (first indirect effect)?


NOAA R/V *RONALD H. BROWN*
NOAA
R 104
NEAQS/ITCT 2004