Bridging Gas and Aerosol Properties between Northeast U.S. and Bermuda: Analysis of Eight Transit Flights

Cassidy Soloff[1], Taiwo Ajayi[1], Yonghoon Choi[2], Ewan C. Crosbie[2,3], Joshua P. DiGangi[2], Glenn S. Diskin[2], Marta A. Fenn[2,3], Richard A. Ferrare[2], Johnathan W. Hair[2], Miguel Ricardo A. Hilario[1], Chris A. Hostetler[2], Simon Kirschler[4,5], Richard H. Moore[2], Taylor J. Shingler[2], Kenneth L. Thornhill[2], Christiane Voigt[4,5], Edward L. Winstead[2,3], Luke D. Ziemba[2], Armin Sorooshian[1]

[1]University of Arizona, [2]NASA Langley Research Center, [3]Analytical Mechanics Associates, [4]DLR, [5]University Mainz

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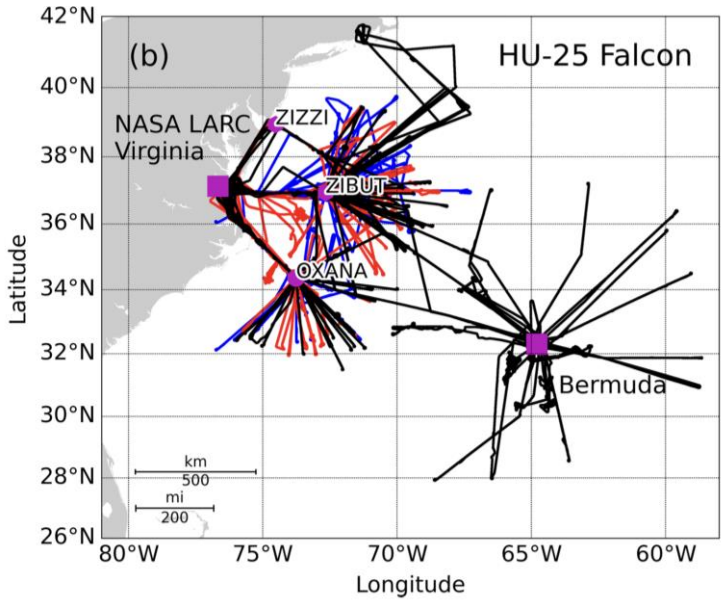
ACTIVATE STM

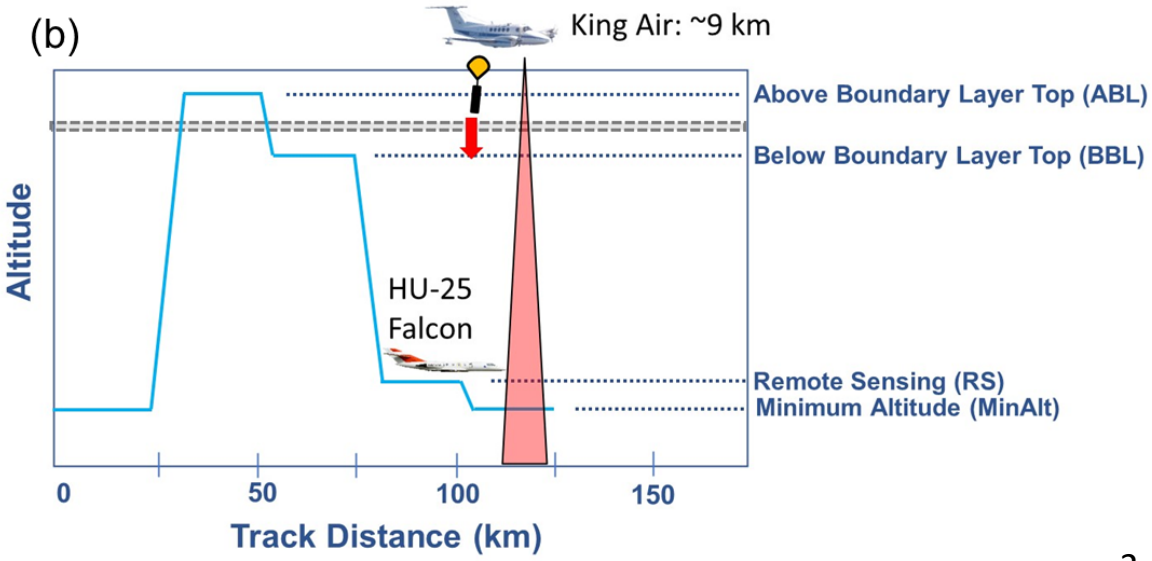
Contact: csoloff@arizona.edu

Motivation

- Rich history of studies near coast and Bermuda but scarcity of airborne studies bridging the two regions
- Out of ACTIVATE's 179 flights, eight transit flights help fill this gap
- Key questions:
  - How do trace gas and aerosol properties vary with offshore distance?
  - How do free troposphere (FT) and boundary layer (BL) measurements compare?

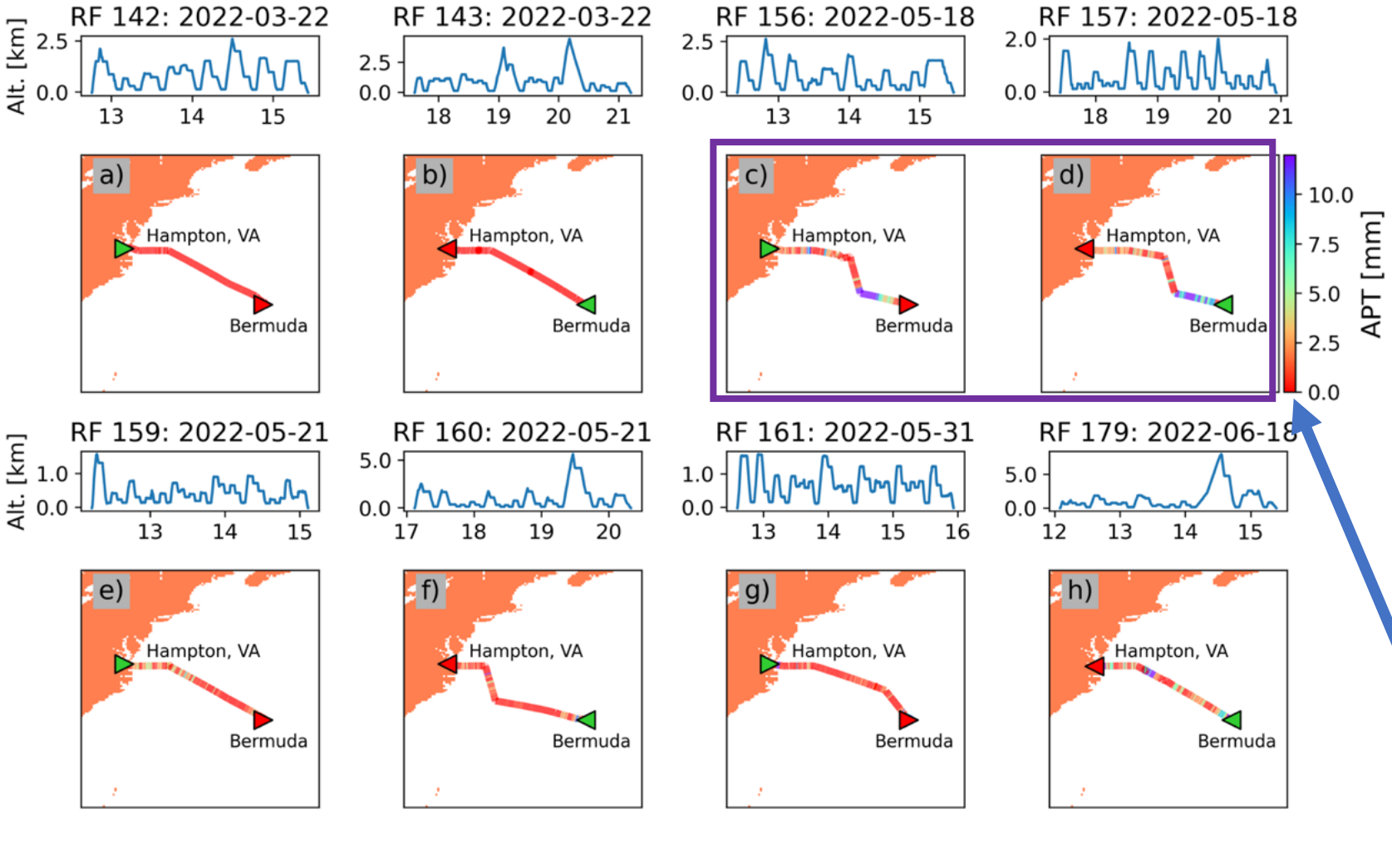


Sorooshian et al. 2023



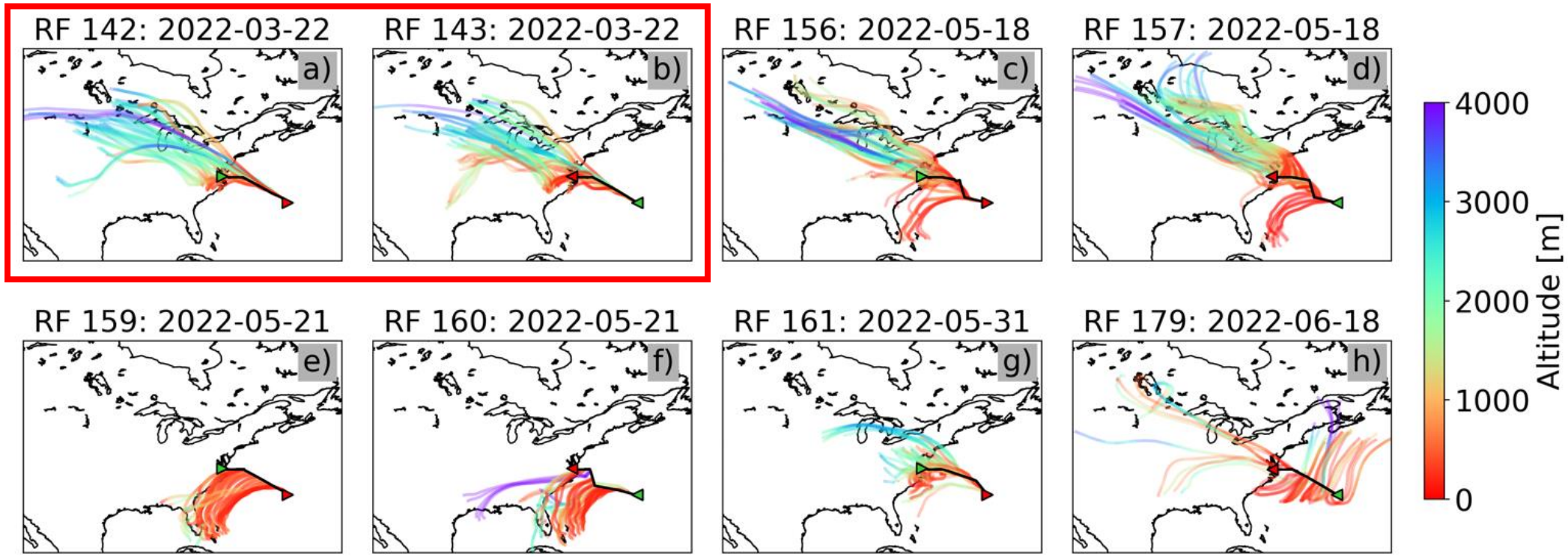
Acknowledgements:
- Funding support from NASA
- ACTIVATE Team

Flight Tracks



Accumulated Precipitation along the Trajectory (APT) highest on 18 May 2022 (C & D)

Air Mass Trajectories



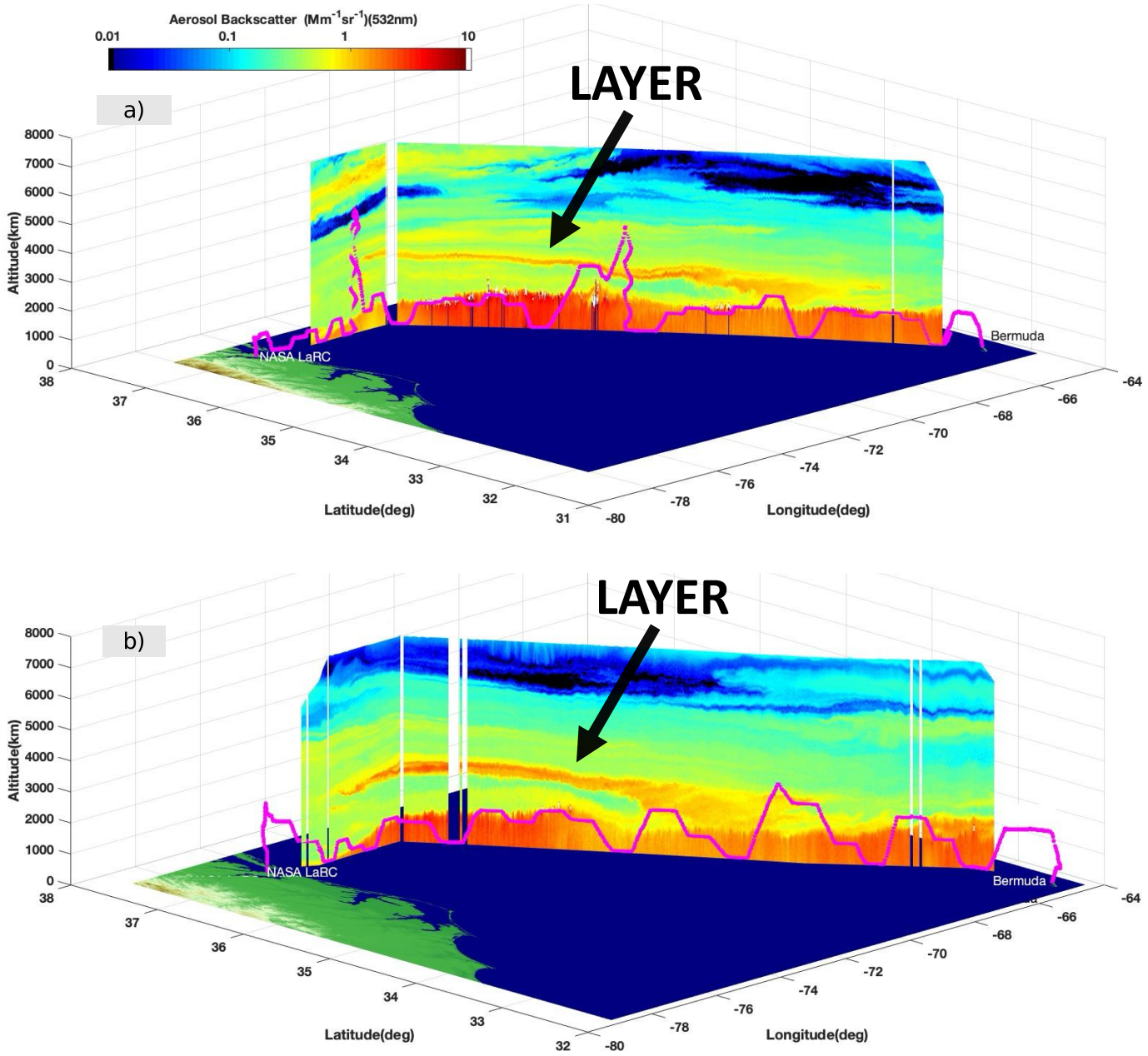
HYSPLIT 3-Day Back Trajectories

- "Golden Flights" RFs 142-143 on 3 May 2022 (A & B)
- Other flights had marine influence and continental outflow

HSRL-2 Lidar Curtains

“Golden Flights” 22 March 2022

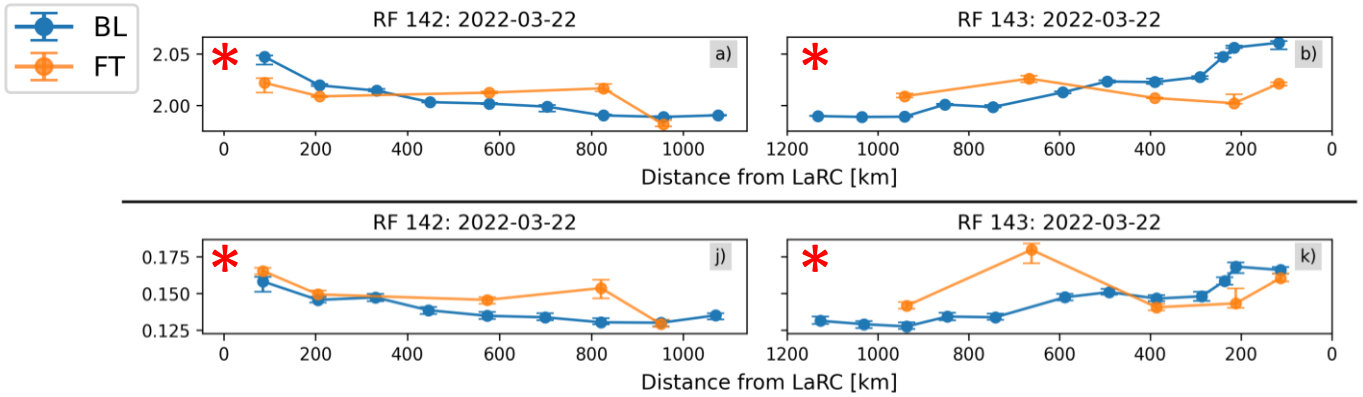
- Distinct aerosol layer aloft
  - Layer thickens in afternoon flight
- Shallow boundary layer by coast
- Other flights exhibit less distinct aerosol layering aloft



Trace Gas Concentrations

- CH_4 and CO concentrations generally decrease with offshore distance with strong trends in the BL
- CO is a good tracer for continental outflow (continental sources, sufficient lifetime)
- Golden flight BL levels off around 900 km

*Golden Flights



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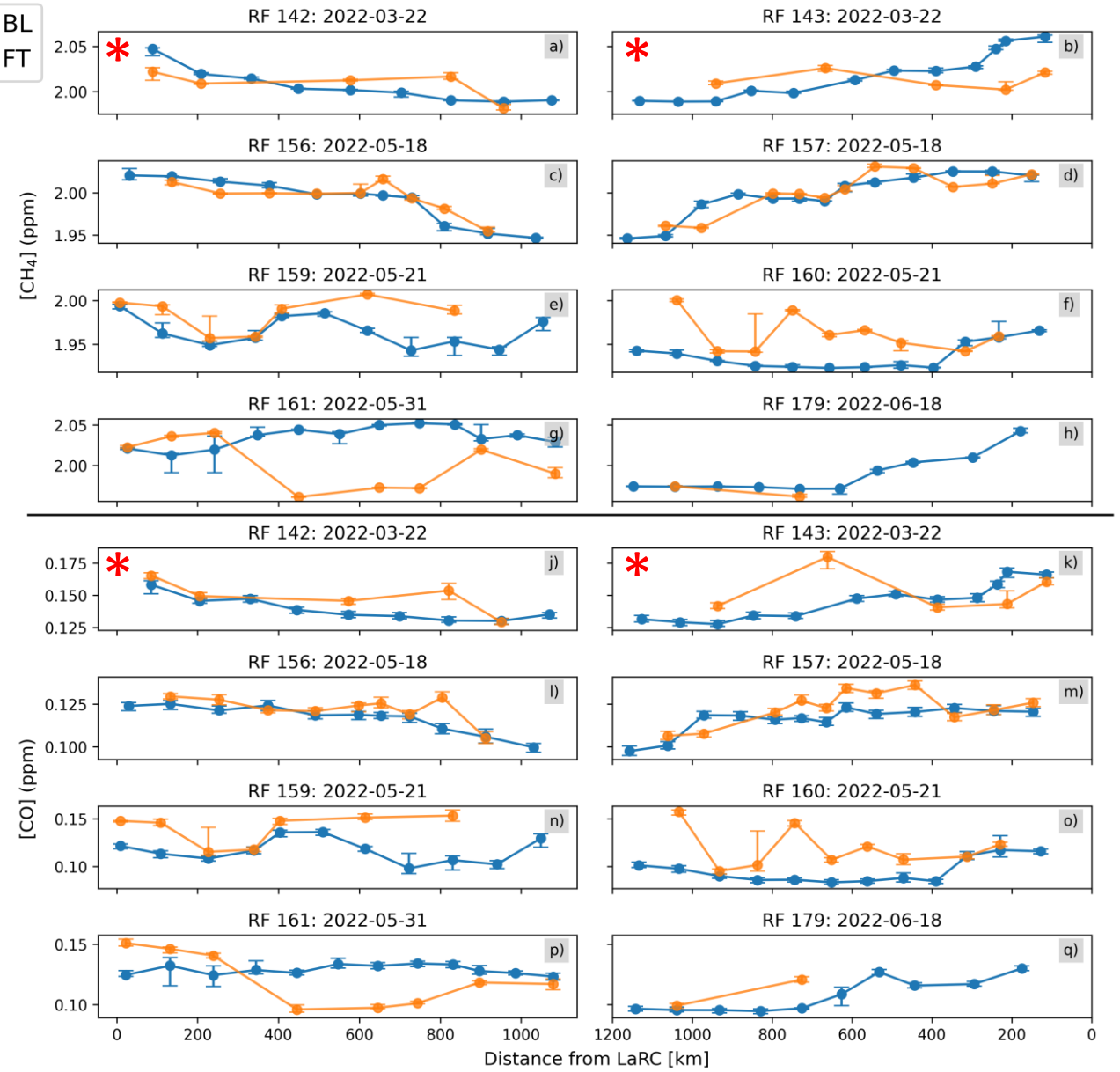
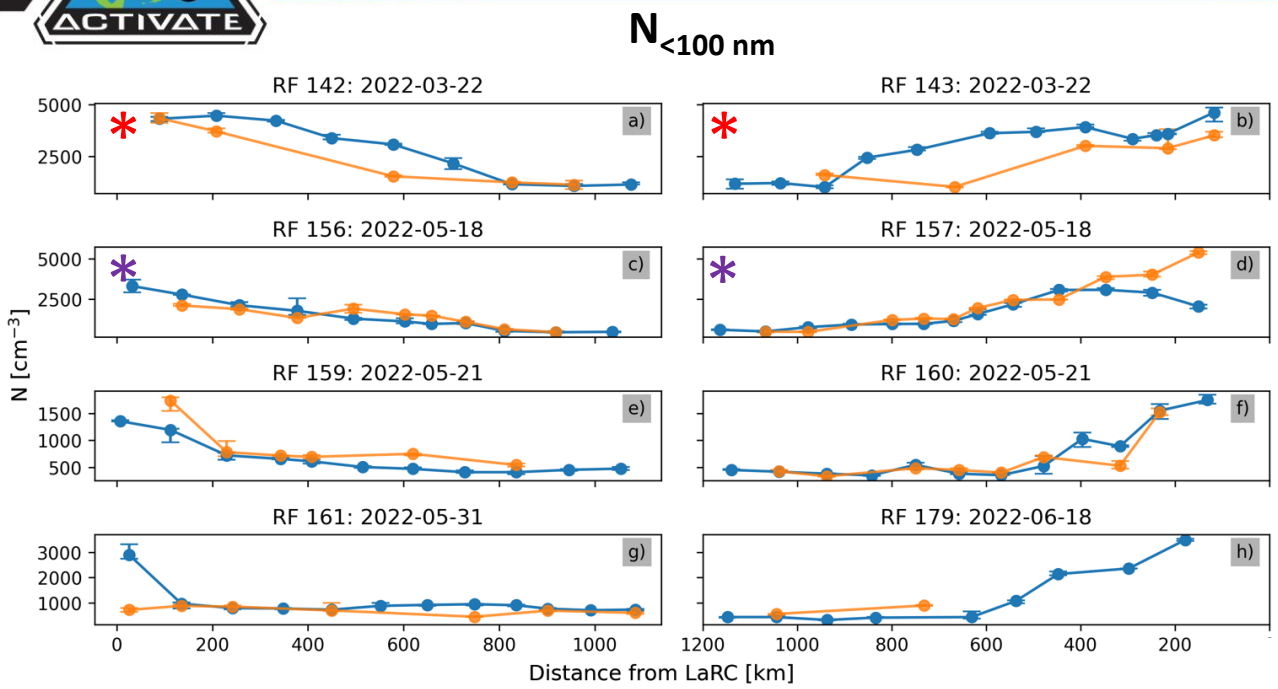


Aerosol Number Concentrations



*Golden Flights

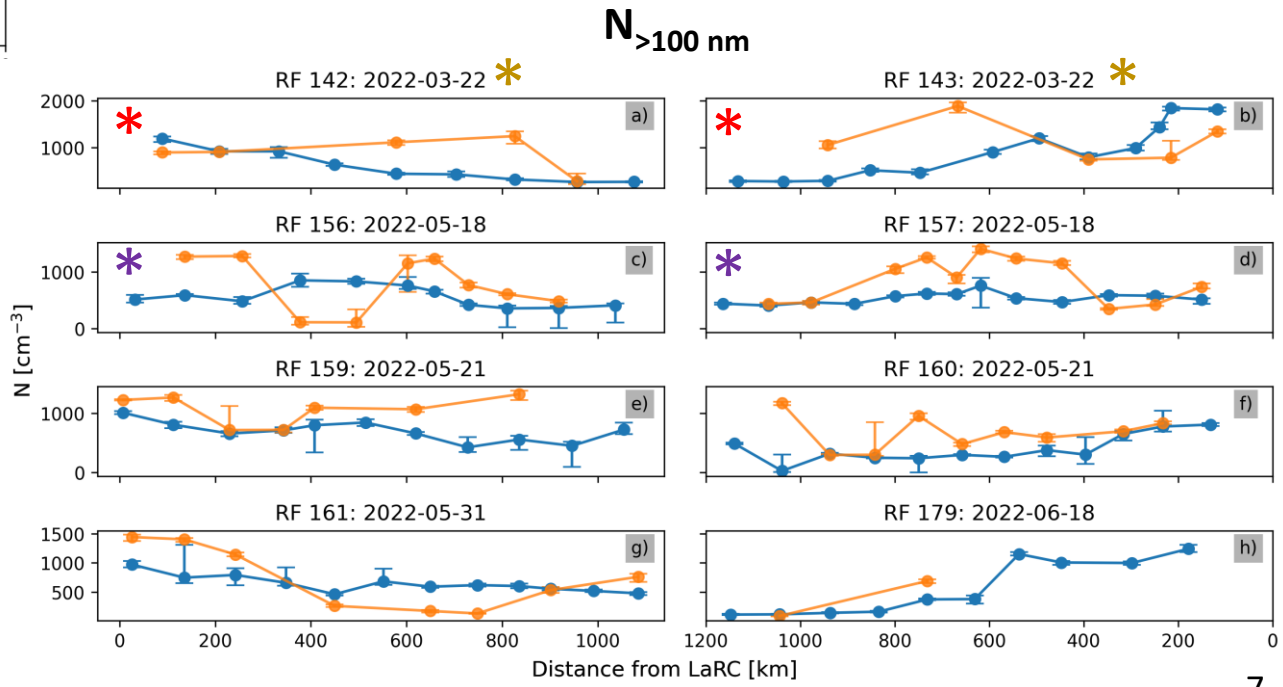
*High APT

$N_{<100\ nm}$ (SMPS)

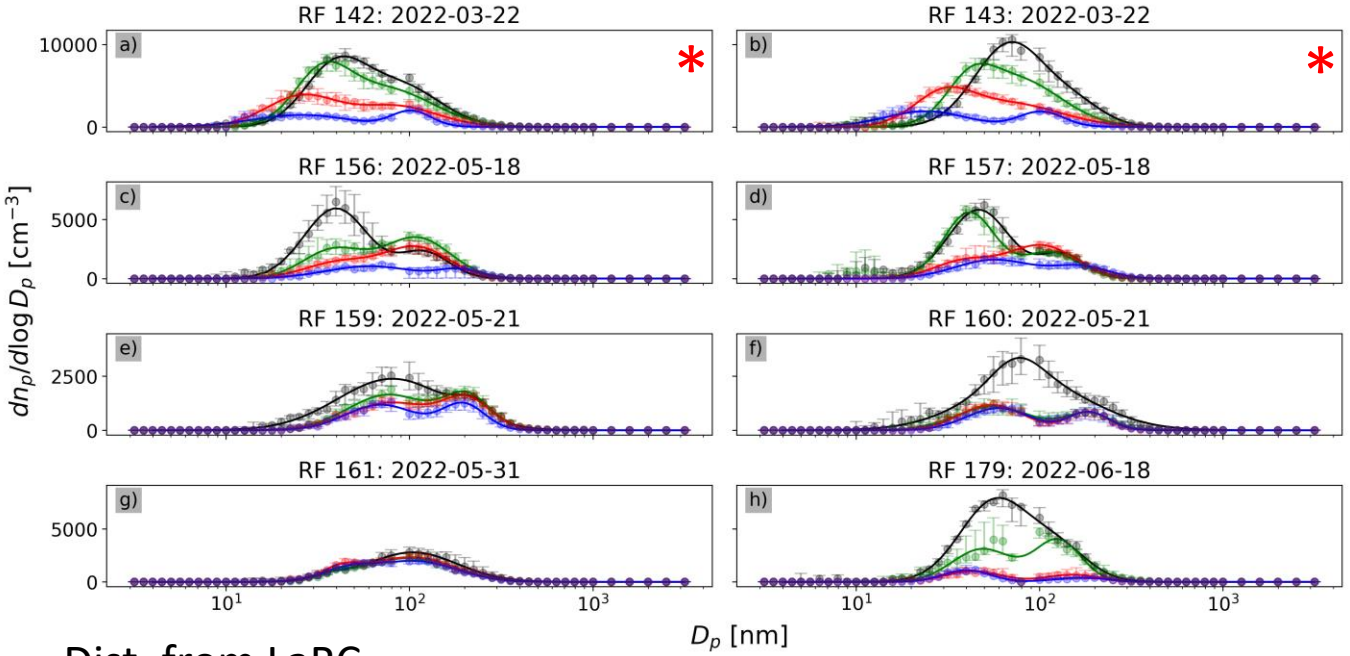
- Offshore reduction in number in FT and BL

$N_{>100\ nm}$ (LAS)

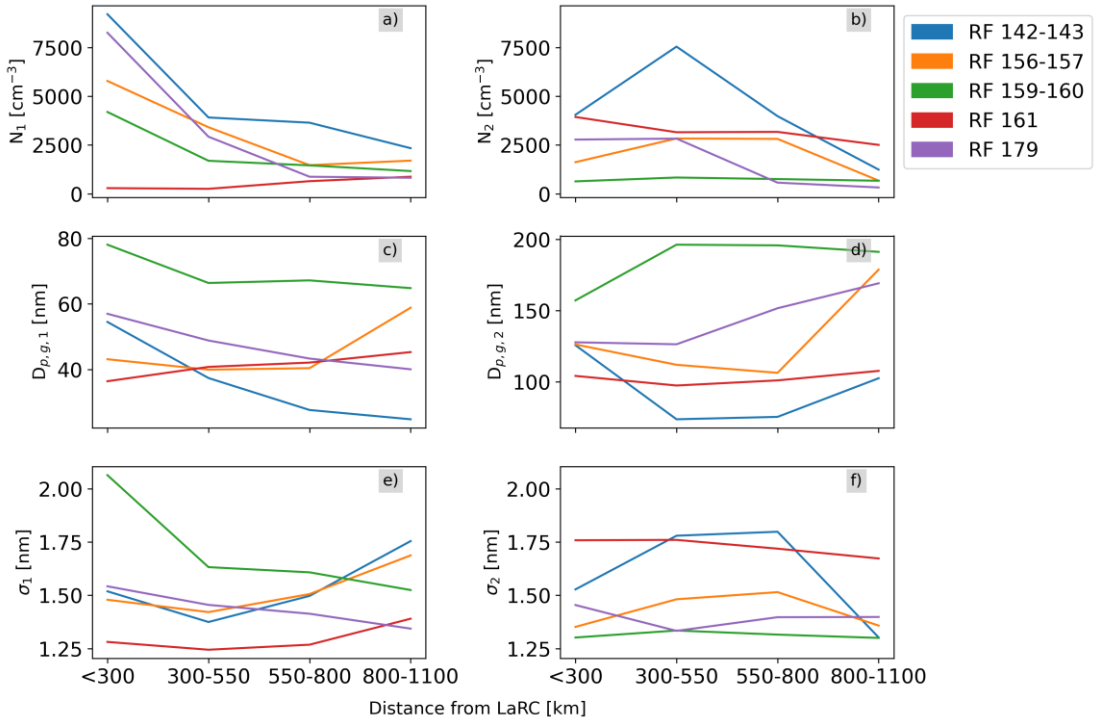
- Less prominent offshore reduction in number in BL
- No clear trend in FT
- Lower BL concentrations on high APT days



Size Distributions



*Golden Flights



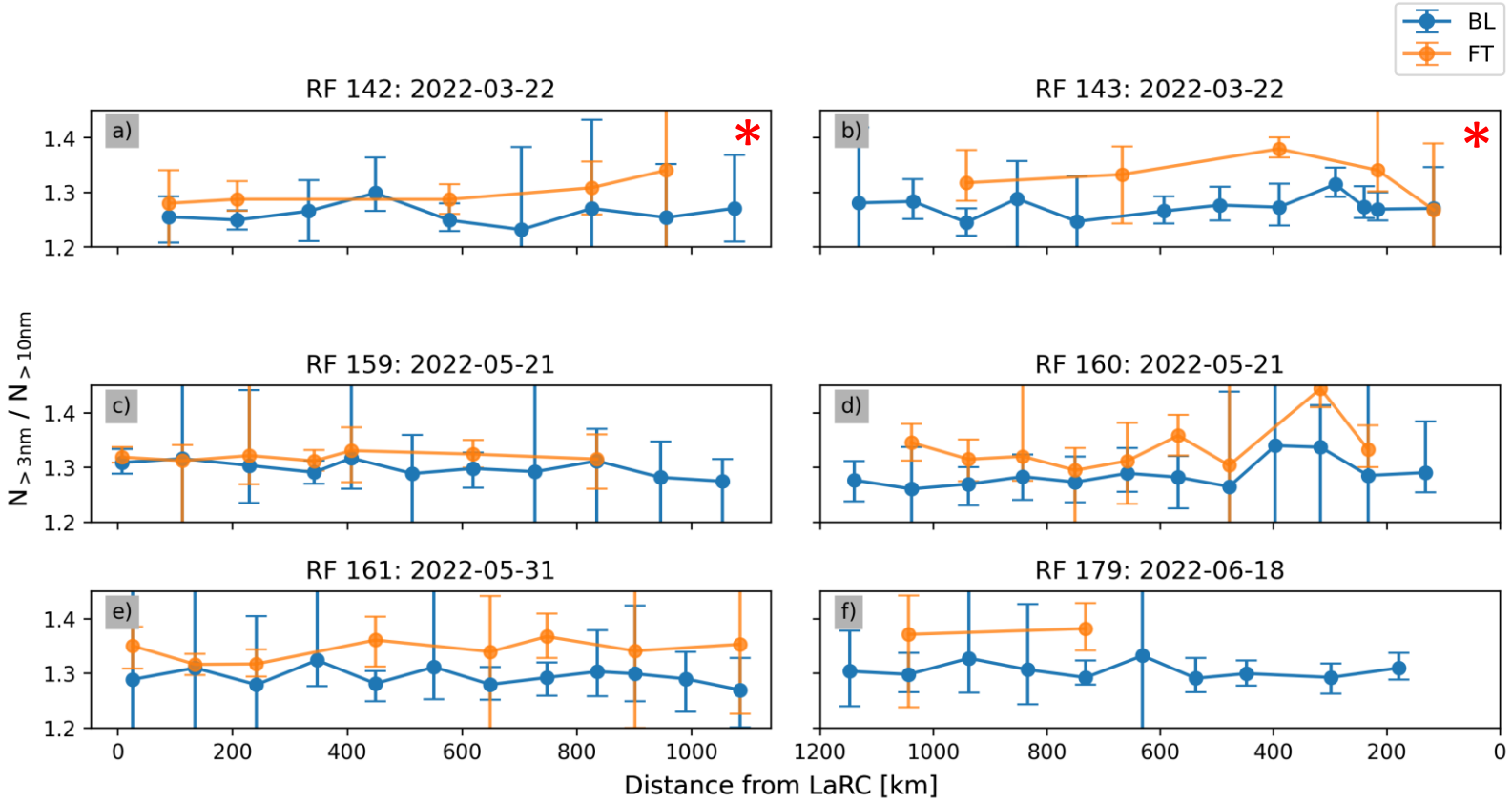
Dist. from LaRC

- < 300 km
- 300 - 550 km
- 550 - 800 km
- 800 - 1100 km

- Boundary layer:
  - "Golden Flights" showed a decrease in Aitken mode N & $D_{p,g}$ with offshore distance
  - Aitken mode N generally decreased with offshore distance (4 of 5 days)
  - Aitken mode $D_{p,g}$ decreased 3 of 5 days
  - Accumulation mode N and $D_{p,g}$ have no clear trend
  - σ for both modes show no clear trend
- No clear trend in FT

New Particle Formation

- $N_{>3\ nm}$/ $N_{>10\ nm}$ is commonly used to indicate new particle formation (NPF)
  - Doesn't mean it occurred at the measurement site
- Relatively consistent with offshore distance and generally higher in the FT



*Golden Flights

Aerosol Composition

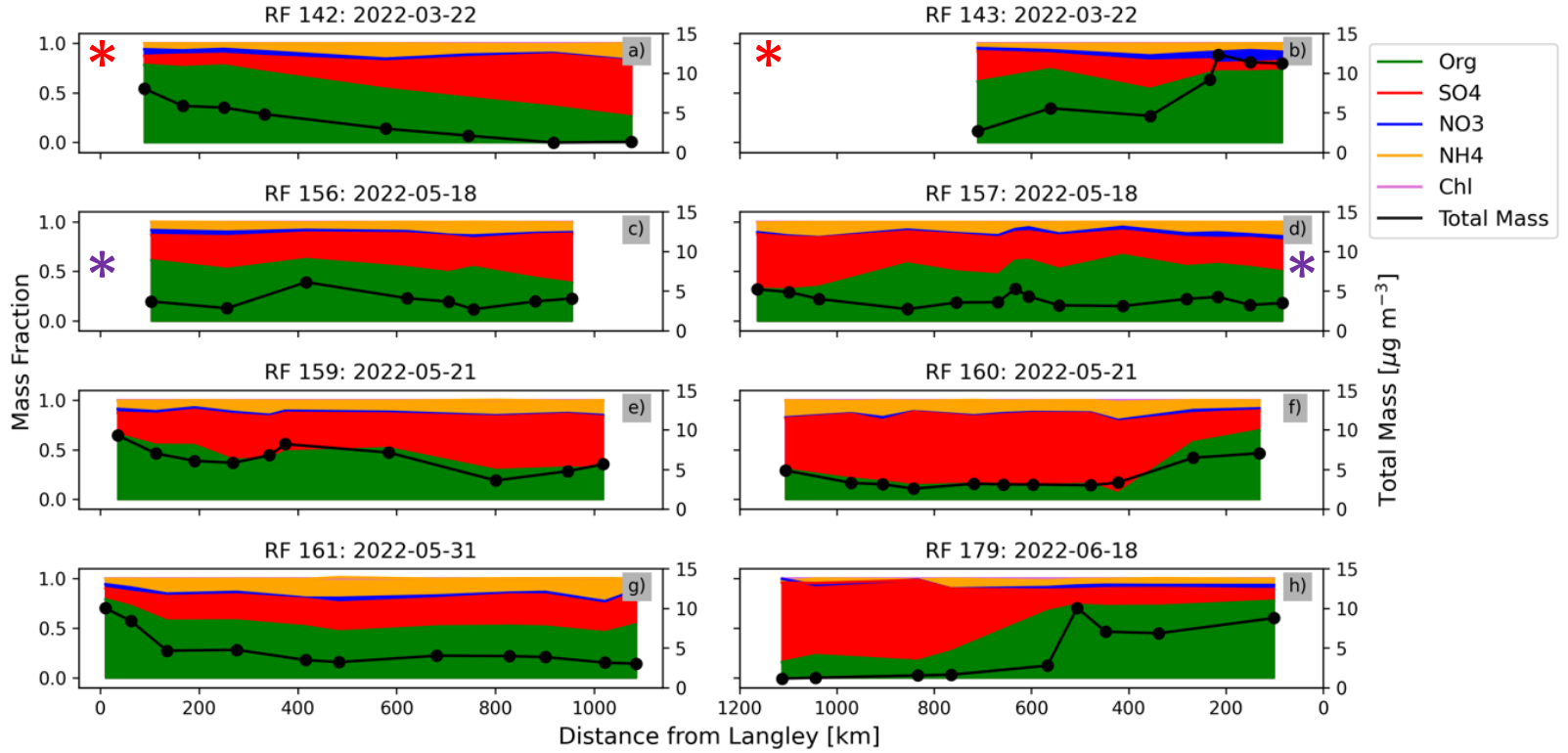
*Golden Flights

In BL:

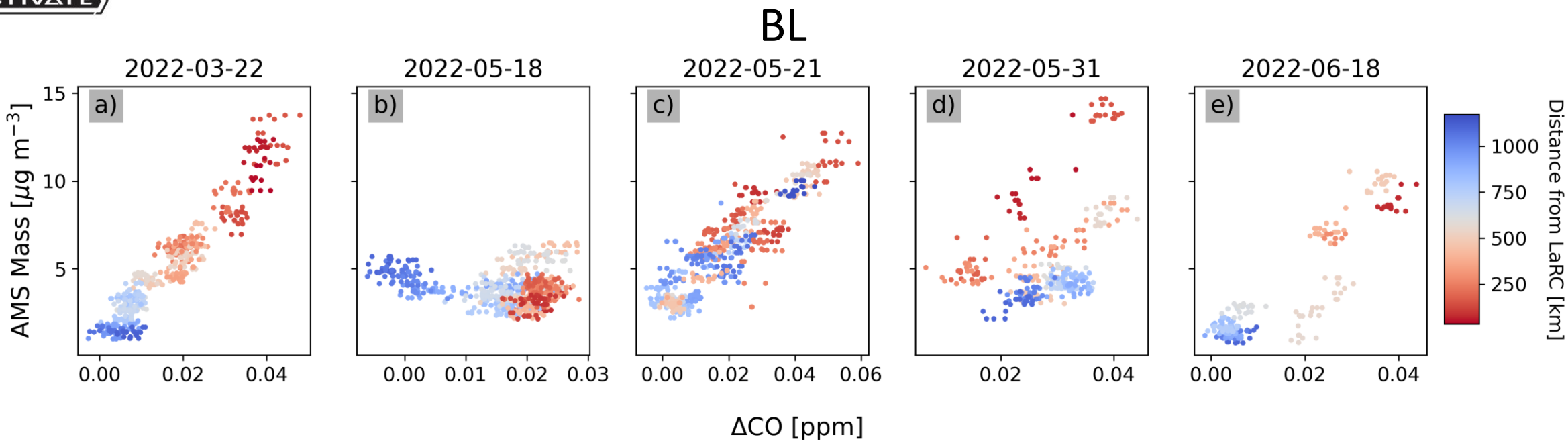
- Offshore reduction in AMS total mass – most prominent for “Golden Flight”
- Offshore reduction of organic fraction and increase in sulfate mass fraction

No clear trend in mass fractions in FT

BL



Mass Concentration Along Outflow

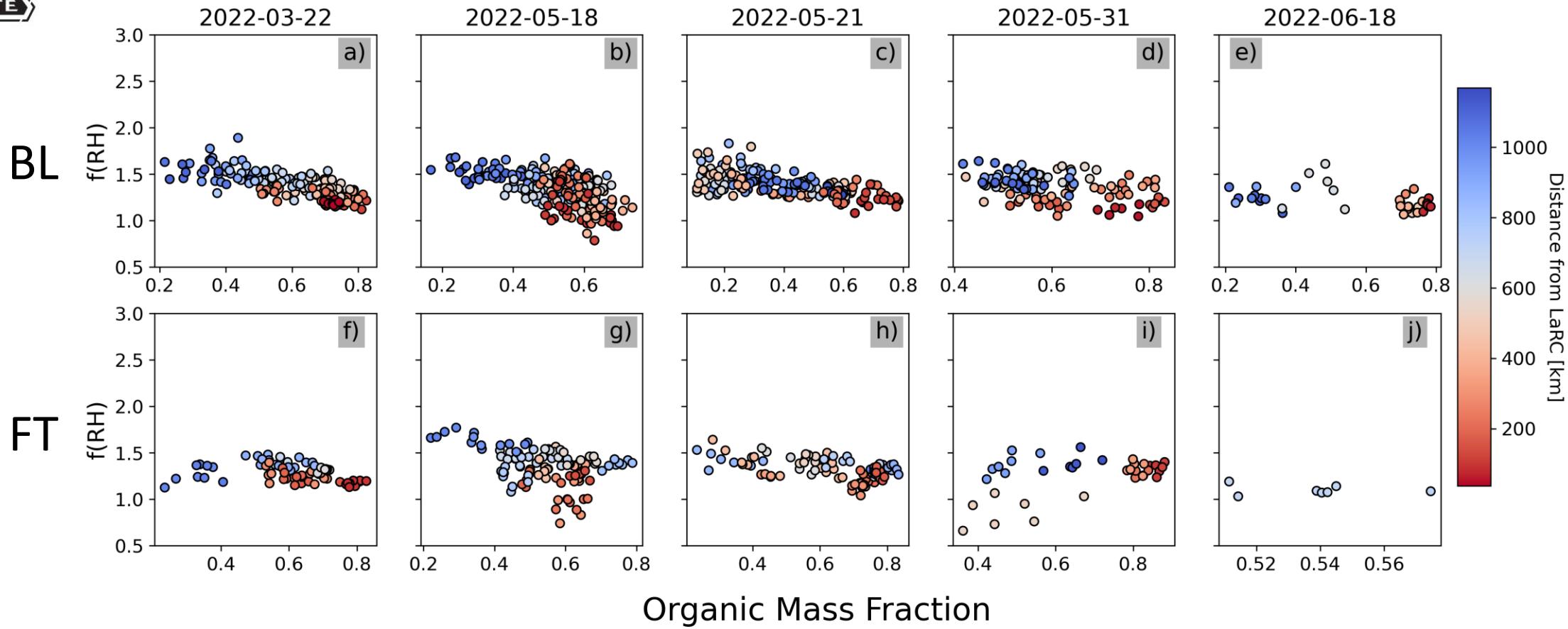


Tracer of continental outflow: $\Delta CO_i = [CO]_i - [CO]_{p5}$

In BL:

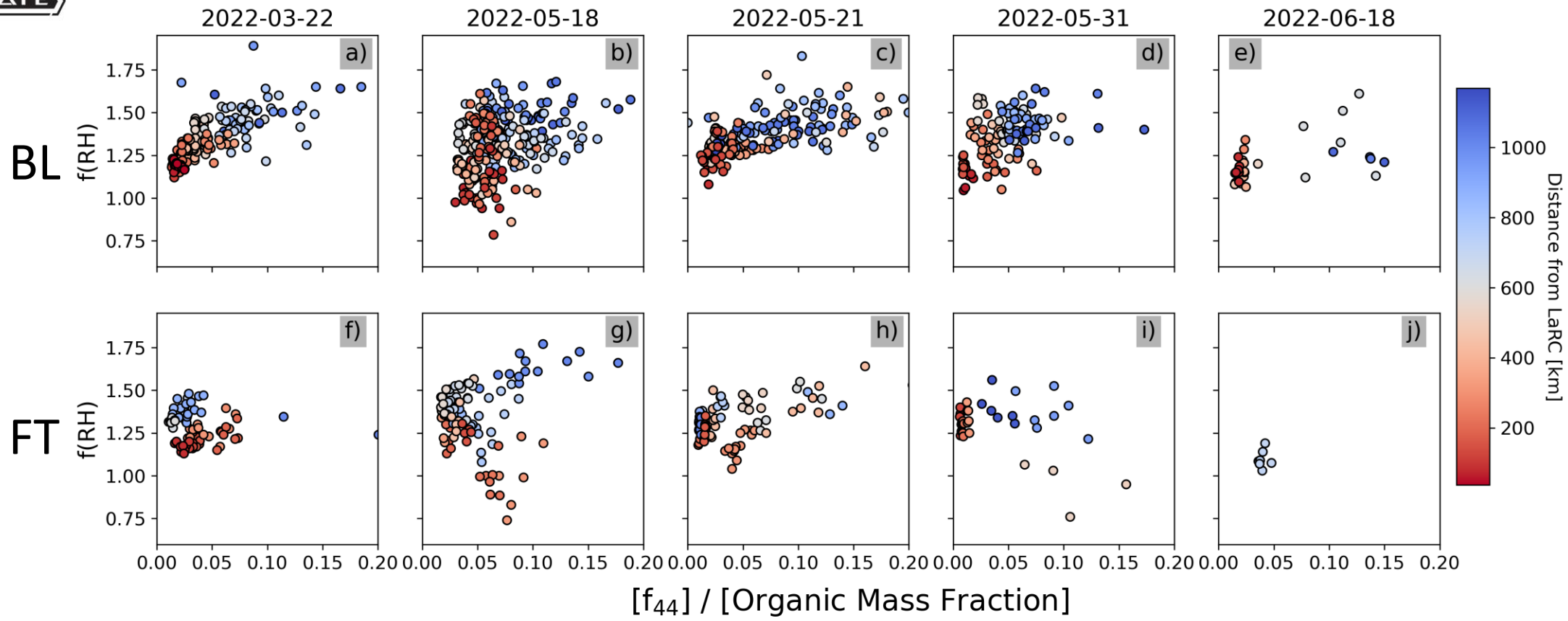
- "Golden flights" (A) show dilution of aerosol mass concentration with continental outflow
- 18 May 2022 flights (B) show low concentrations (higher APT) and enhancements near Bermuda

Hygroscopicity



- f(RH) generally increases with offshore distance and decreases with organic mass fraction
- Stronger trend in BL

Hygroscopicity



- f_{44}: relative amount of carboxylic acids contributing to total organic mass
- BL f(RH) increases with f_{44} for fixed organic mass fraction
- No clear trend in FT

Conclusions

Offshore Gradient	No Clear Trend
- Decreasing CH_4 and CO concentrations	
- Decreasing BL & FT $N_{<100\ nm}$	
- Decreasing BL $N_{>100\ nm}$	- FT $N_{>100\ nm}$
- Decreasing BL Golden flight Aitken mode N & $D_{p,g}$ - Decreasing BL Aitken mode $D_{p,g}$ (3 of 5 days) - Decreasing BL Aitken mode N (4 of 5 days)	- BL and FT accumulation mode $D_{p,g}$, N - σ for both modes
- Constant $N_{>3\ nm}$/ $N_{>10\ nm}$, higher in FT	
- Decreasing (increasing) BL organic (sulfate) mass fraction	- Mass fractions in FT
- Increasing BL f(RH)	- FT f(RH)

- Enhanced APT coincides with decreased AMS mass and $N_{>100\ nm}$
- BL f(RH) decreased with organic mass fraction
- BL f(RH) increased with f_{44} for fixed organic mass fraction
- Golden flights and BL measurements generally showed the clearest trends

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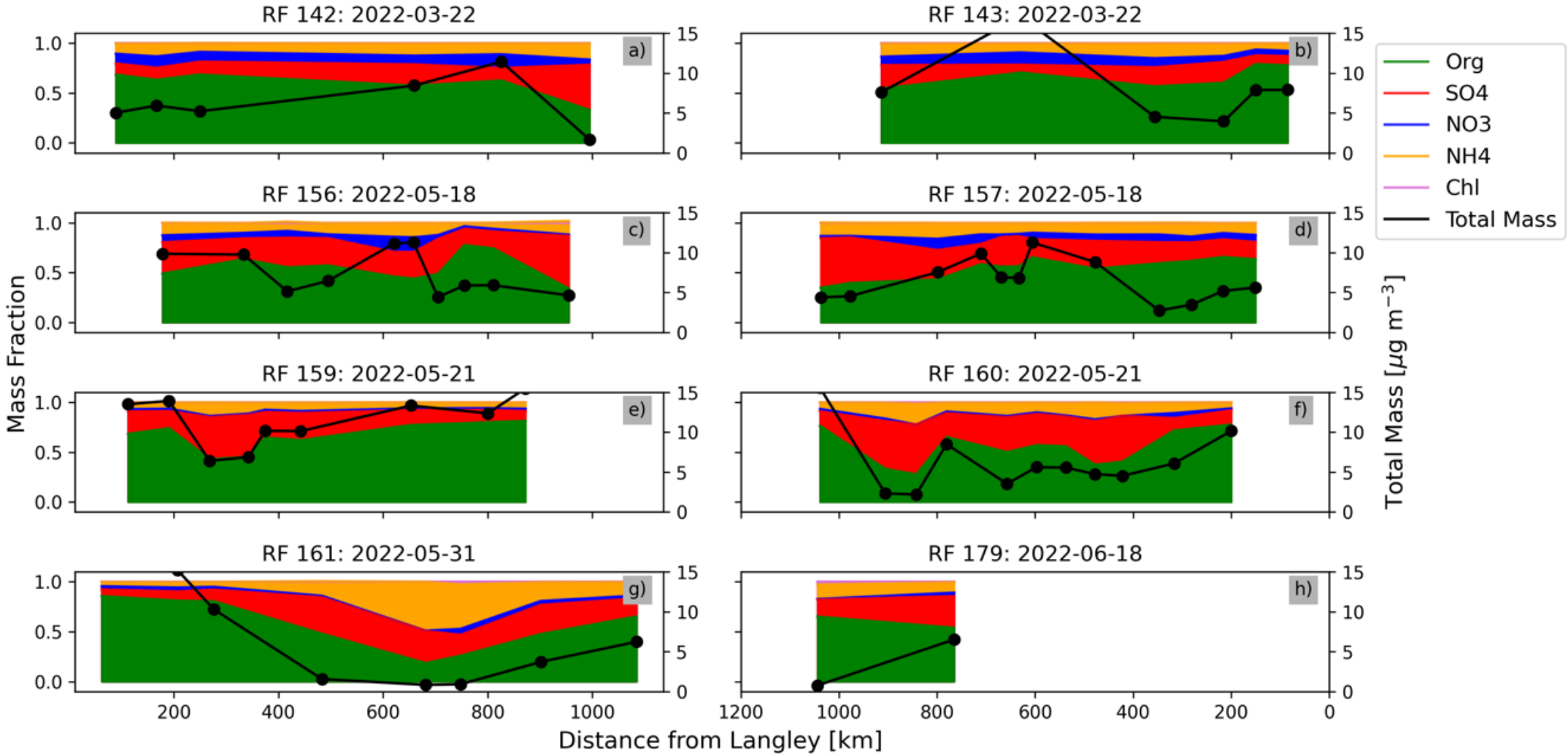
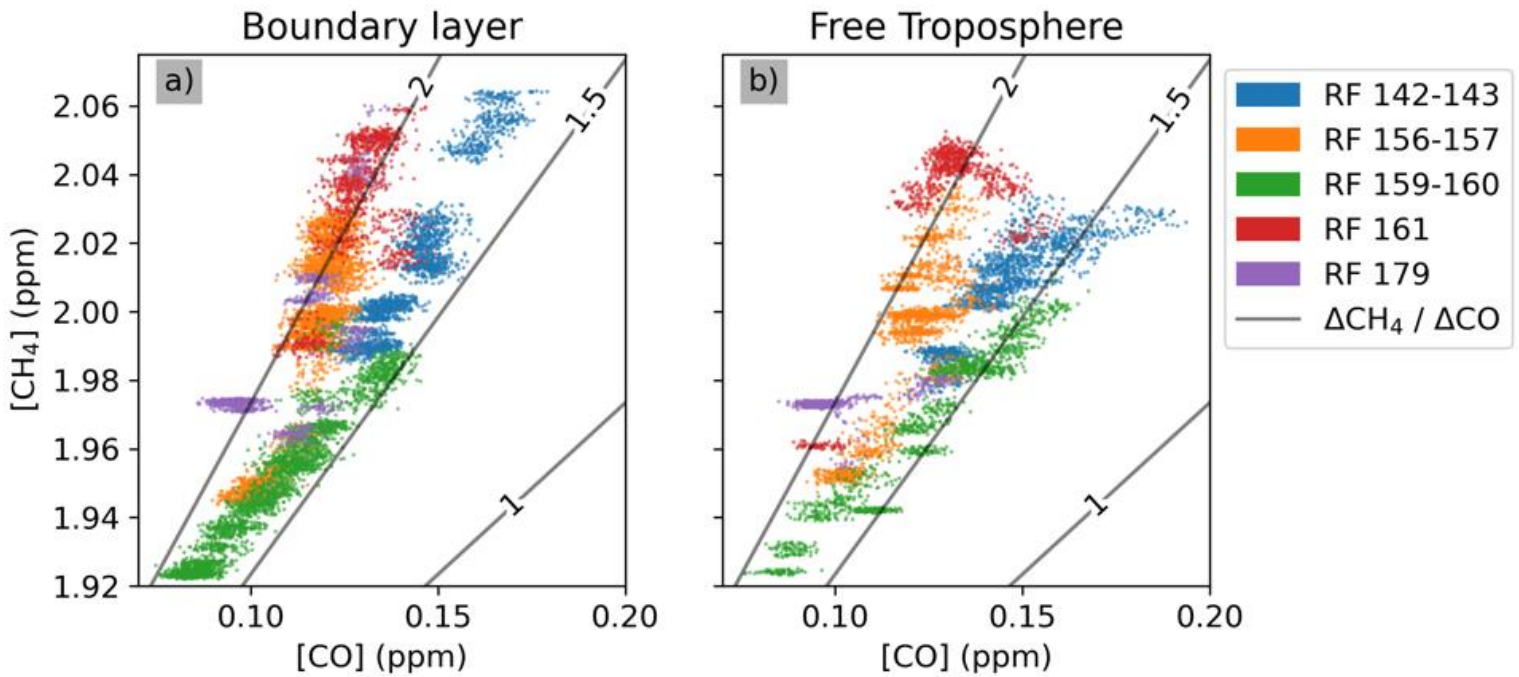
Aerosol Composition

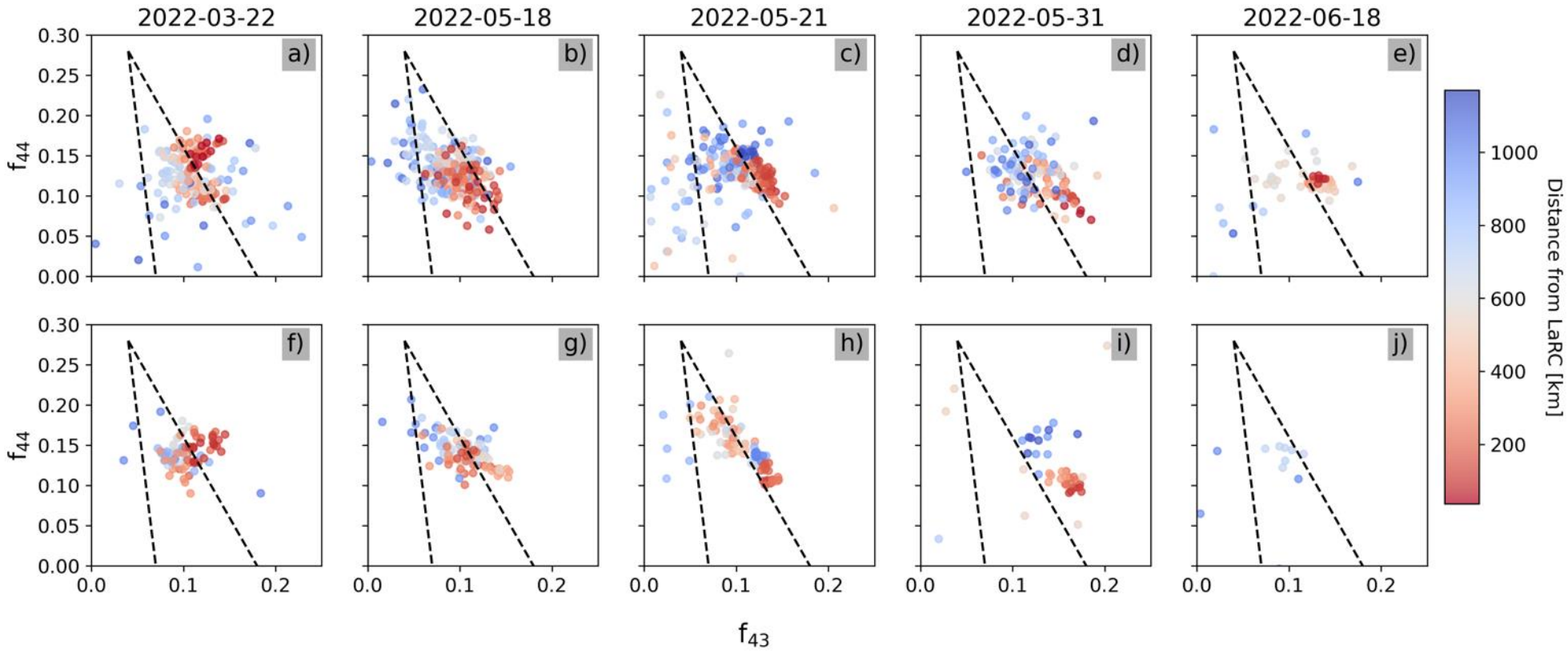
FT



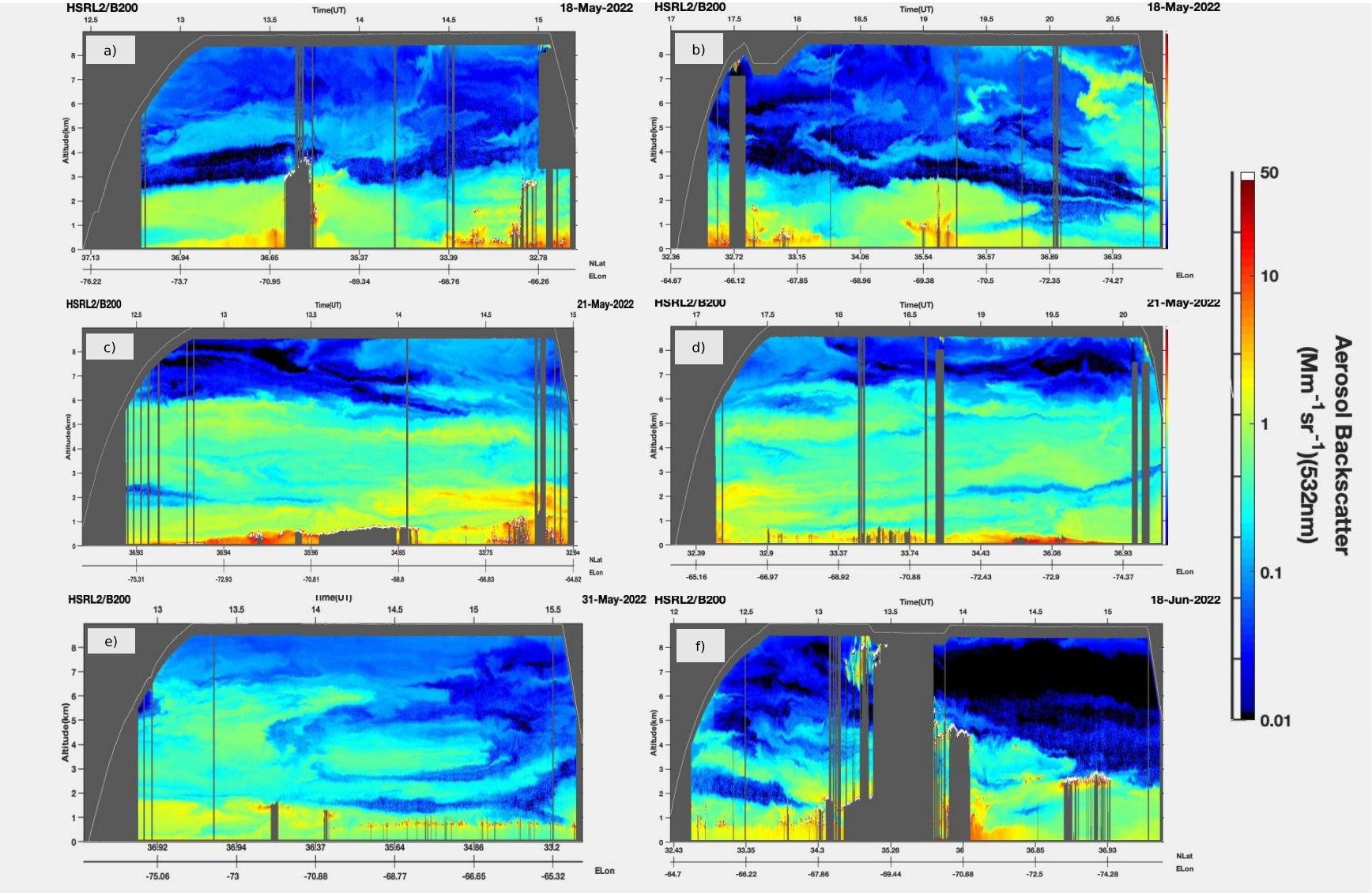
No clear trend in FT

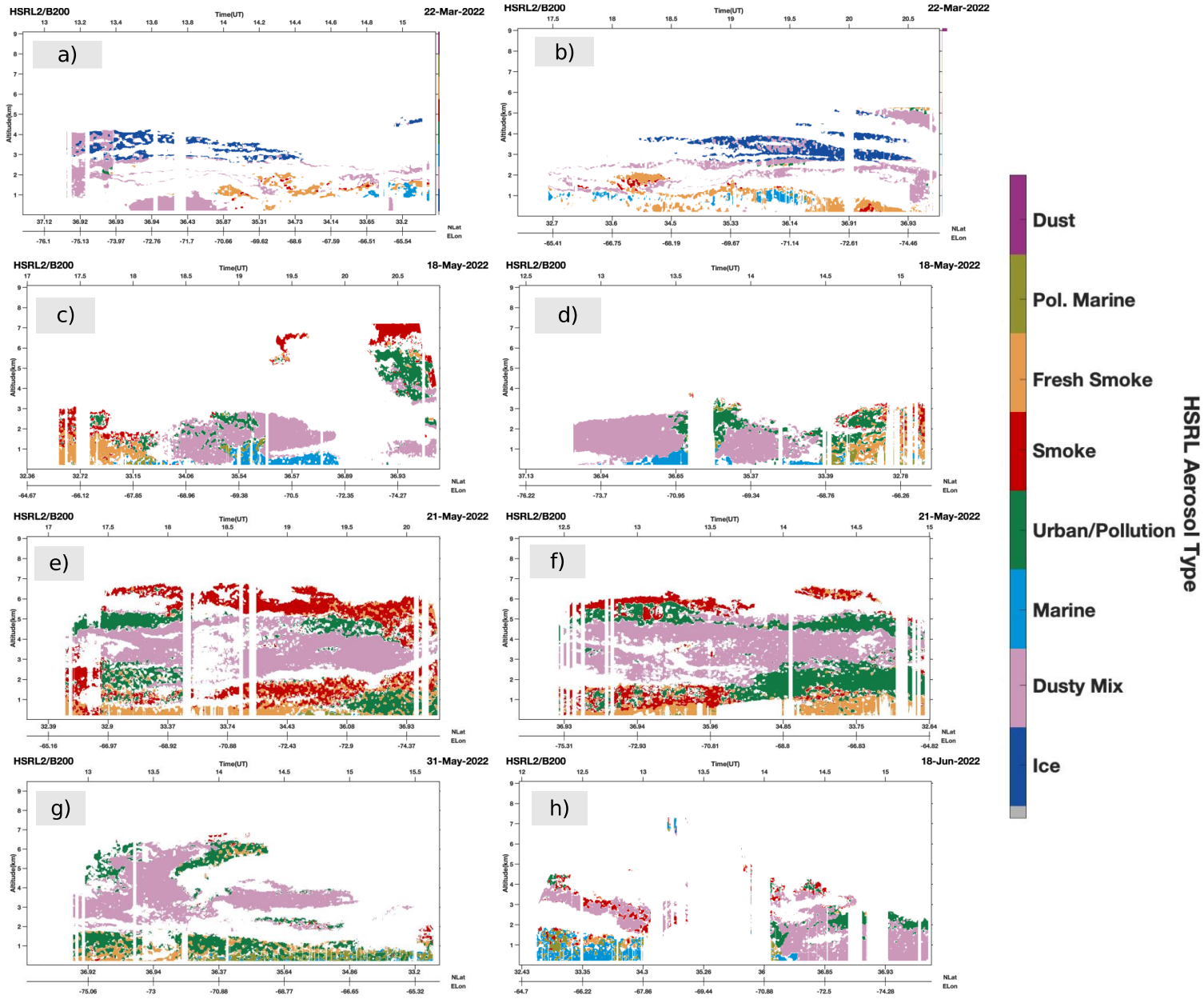

Boundary layer
Free Troposphere
a)
b)
2
1.5
1
2.06
2.04
2.02
2.00
1.98
1.96
1.94
1.92
[CH4] (ppm)
0.10
0.15
0.20
[CO] (ppm)
RF 142-143
RF 156-157
RF 159-160
RF 161
RF 179
ΔCH4 / ΔCO

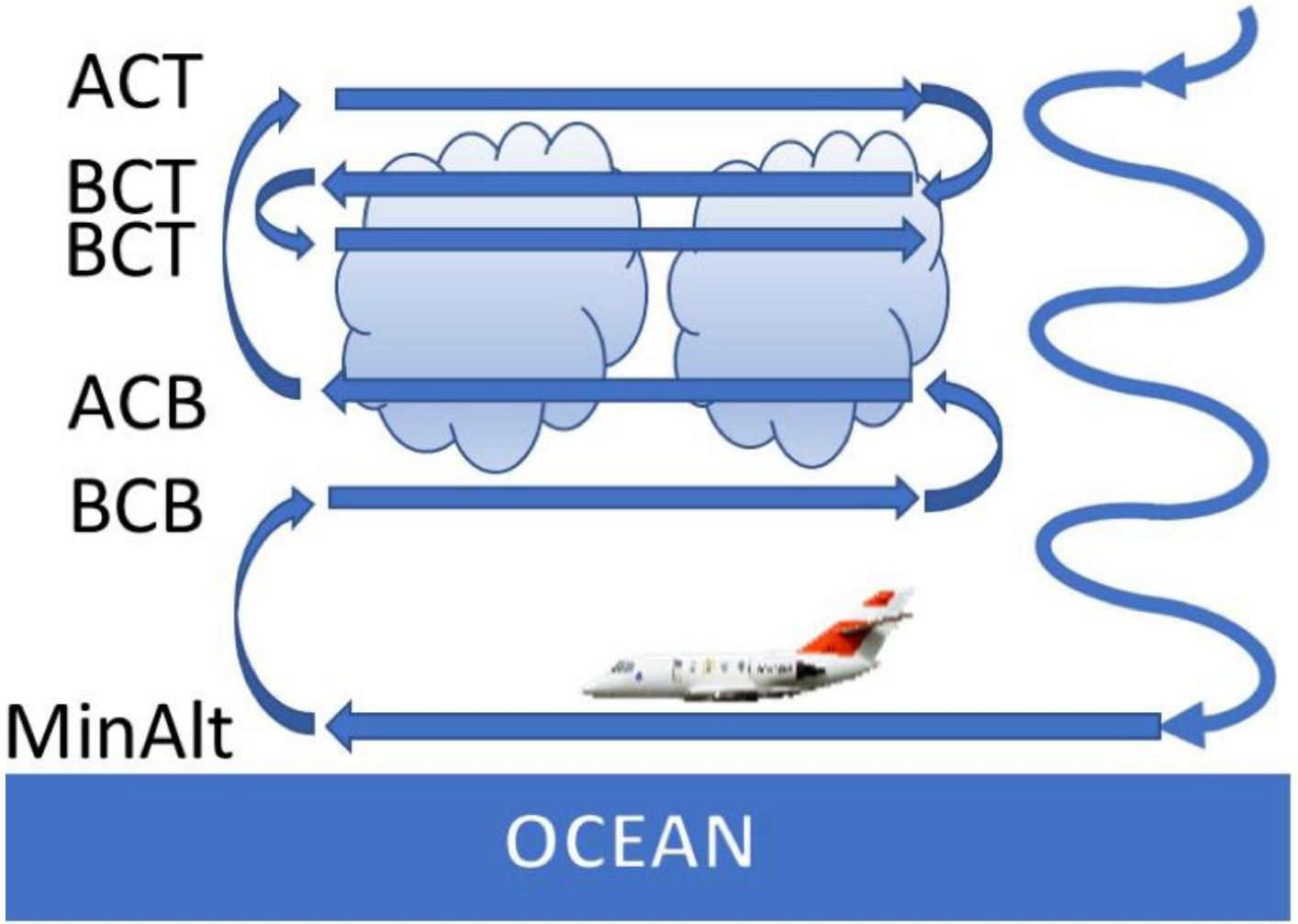
Particle Aging



More highly aged particles towards top left


HSRL2/B200
18-May-2022
a)
b)
21-May-2022
c)
d)
31-May-2022
e)
18-Jun-2022
f)
Time(UT)
Altitude(km)
NLat
ELon
Aerosol Backscatter
(Mm-1 sr-1)(532nm)
50
10
1
0.1
0.01


HSRL2/B200
22-Mar-2022
a)
b)
18-May-2022
c)
d)
21-May-2022
e)
f)
31-May-2022
g)
18-Jun-2022
h)
Time(UT)
Altitude(km)
NLat
ELon
Dust
Pol. Marine
Fresh Smoke
Smoke
Urban/Pollution
Marine
Dusty Mix
Ice
HSRL Aerosol Type


ACT
BCT
BCT
ACB
BCB
MinAlt
OCEAN