Preliminary look at statistical distributions of cloud and aerosol properties over Southern Oceans during MARCUS

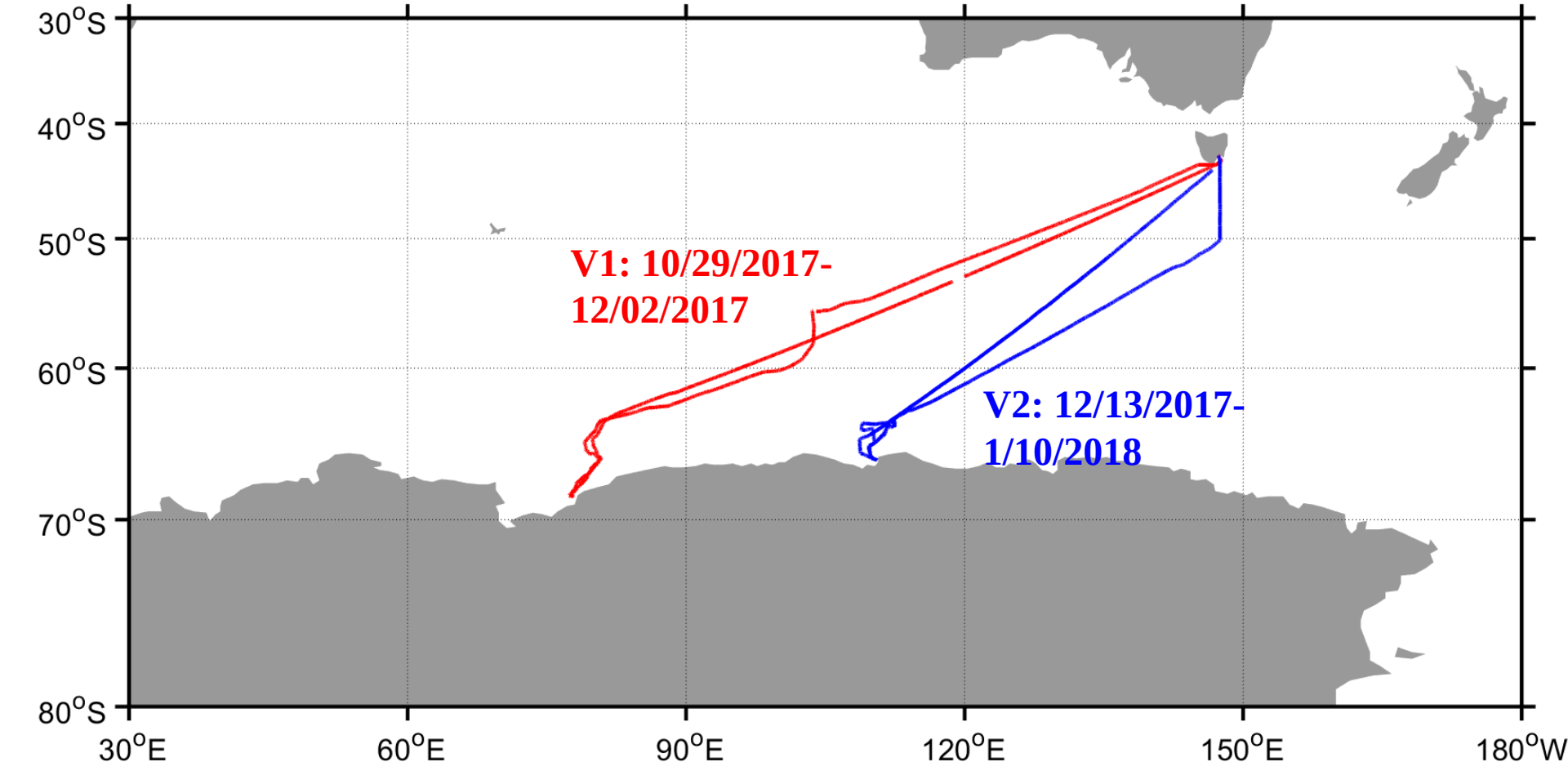
G. McFarquhar and MARCUS Science Team

DOE ASR Meeting, March 2018

MARCUS

- **What?** MARCUS targets observations of clouds, aerosols, precipitation and radiation over the Southern Ocean (SO)
- **Where?** The Australian Antarctic Division supply vessel Aurora Australis (AA) will make routine transits between Hobart, Australia and the Antarctic stations Mawson, Davis and Casey, and Macquarie Island.
- **How?** AMF-2 installed on AA will measure CCN and INPs at surface, retrieve profiles of macrophysical and microphysical properties of liquid and mixed-phase clouds, downwelling radiation, etc. , and launch soundings
- **When?** 21 October 2017 to 23 March 2018
- **Why?** Measurements in cold waters at latitudes poleward of 55˚S are sparse and climatologically important since there are large GCM biases in modeled SW absorption, and supercooled and mixed-phase clouds are frequent & not well retrieved

For more info see https://www.arm.gov/campaigns/amf2017marcus/


30°S
40°S
50°S
60°S
70°S
80°S
30°E
60°E
90°E
120°E
150°E
180°W
V1: 10/29/2017-
12/02/2017
V2: 12/13/2017-
1/10/2018

MARCUS Overarching objectives

(i) To **characterize physical properties of lower-tropospheric cloud systems** around mid-latitude cyclones over complete seasonal cycle;

(ii)To characterize microphysical and chemical properties of aerosols and aerosol precursor compounds, including DMS, that may play a role in regulating CCN and INPs over SO and to investigate their significance for cloud and precipitation formation, and radiative properties;

(iii)To assess quality of satellite cloud, aerosol, precipitation, and upper ocean products, to develop new ones, and to use these products to address the science questions;

(iv)To evaluate & improve skill of models at different scales to reproduce observed properties of SO cloud systems, aerosol physicochemical properties, and aerosol-cloud-precipitation interactions, and to use models to develop process-oriented understanding of mechanisms controlling properties of cloud systems.

Instrument Suite

AMF2 Instruments

Instrument	Measurement
Atmospheric Emitted Radiance Interferometer	Long-wave spectral radiance, spectral brightness temperature
Aerosol Optical Properties	Optical Properties
Aerosol Observing System	Aerosol Particle Size
Meteorological Measurements Associated with the Aerosol Observing System	P, T, Precip, RH, Wind, Wind speed, Rain Amount, etc.
Cloud Condensation Nuclei Particle Counter	Total Concentration and binned counts
Ceilometer	Backscattered radiation, cloud base height, planetary boundary layer height
Carbon Monoxide Analyzer	CO, N20 mixing ratios
Condensation Particle Counter	Aerosol Concentration (fine particle concn.)
Humidified Tandem Differential Mobility Analyzer	Aerosol particle size distribution and concentration
Infrared Thermometer	Surface skin temperature, Longwave narrow band brightness temperature

AMF2 Aerosol Instruments

Instrument	Measurement
Laser Disdrometer	LWC, PSD, Visibility
Marine Precipitation Instrumentation	Rain intensity and accumulated rain
Micropulse Lidar	Attenuated backscatter and polarization
Marine W-band (95 GHz) Cloud Radar	Mean doppler velocity, reflectivity and spectral width
Microwave Radiometer	Liquid water path, brightness temperature and precipitable water
Microwave Radiometer, 3 channel	Liquid water path, brightness temperature and precipitable water
Navigational Location and Attitude	Ship motion coordinates
Nephelometer	Aerosol scattering and backscattered radiation
Ozone Monitor	Ozone Concentration

AMF2 Lower Priority Instruments

Instrument	Measurement
Particle Soot Absorption Photometer	Aerosol absorption at 3 wavelengths
Radar Wind Profiler	Horizontal wind and vertical velocity
Balloon-Borne Sounding System	T, P, Td, wind speed and direction
Stabilized Platform	Pitch, roll angles, heading stabilizes platform
Total Sky Imager	Cloud amount and fraction
Ultra-High Sensitivity Aerosol Spectrometer	Aerosol particle size distribution

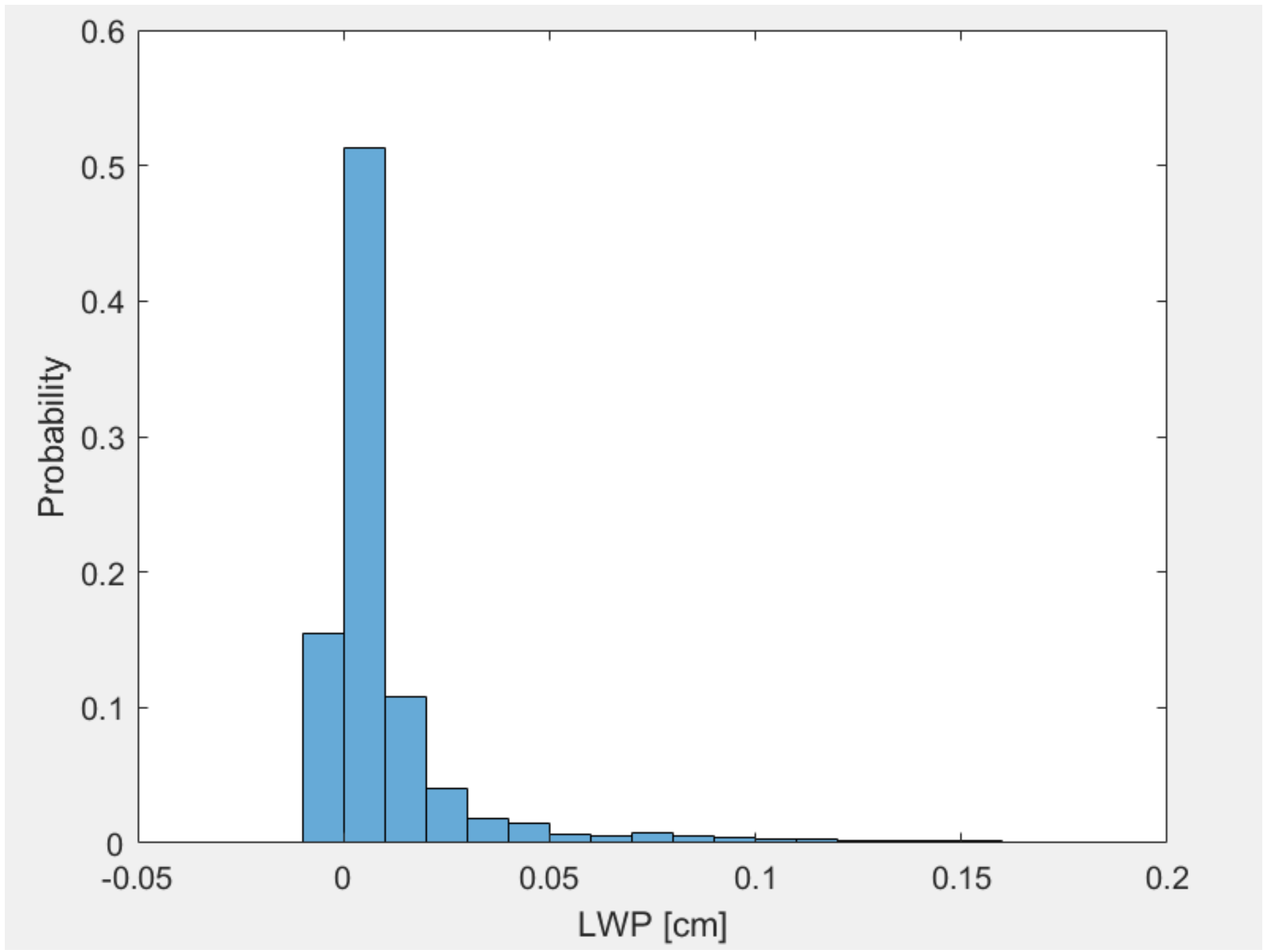
Theme 1: **Documenting the synoptically-varying vertical structure of Southern Ocean boundary layers and clouds**

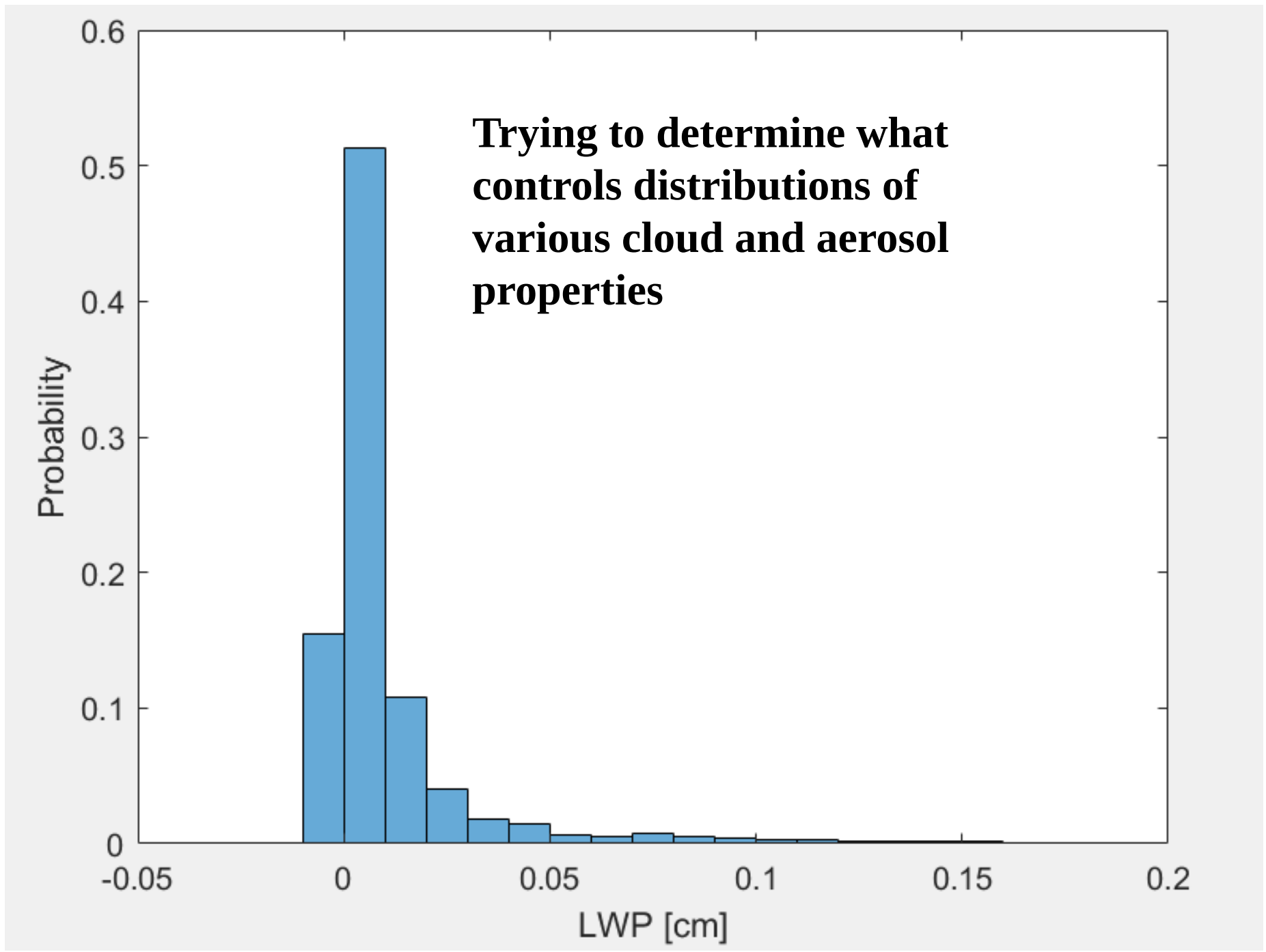
Theme 2: **Variability of sources and sinks of SO CCN and INPs and role of local biogenic sources over spring, summer and fall**

Theme 3: **Supercooled liquid clouds over the SO**

Theme 4: **Retrieving the properties of mixed-phase clouds**


P&O
AURORA AUSTRALIS


0.6
0.5
0.4
0.3
0.2
0.1
0
Probability
-0.05
0
0.05
0.1
0.15
0.2
LWP [cm]


Trying to determine what controls distributions of various cloud and aerosol properties
Probability
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.05
0
0.05
0.1
0.15
0.2
LWP [cm]

UO MARCUS Products

Catalogues of Cloud/Aerosol Data by Environmental, Meteorological and Geographic Condition

(i) Air mass origin

(ii) Lower atmospheric stability

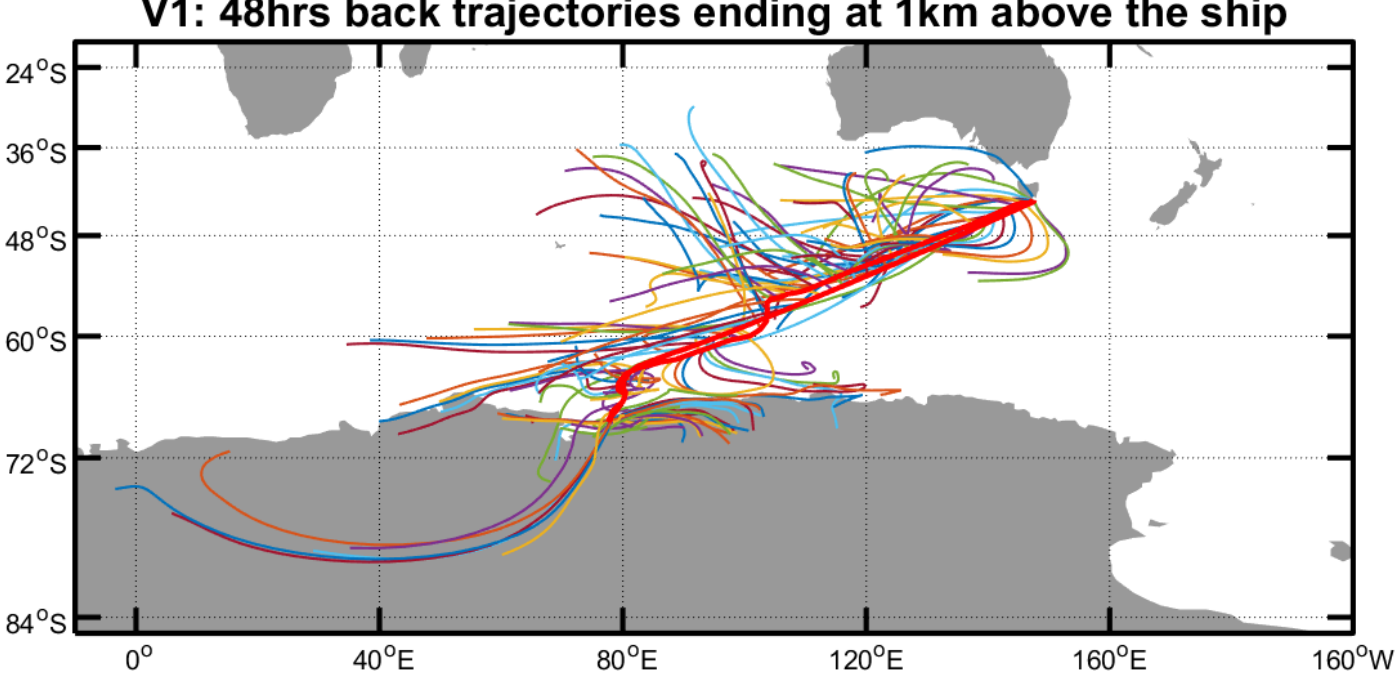
(iii) Wind speed and direction

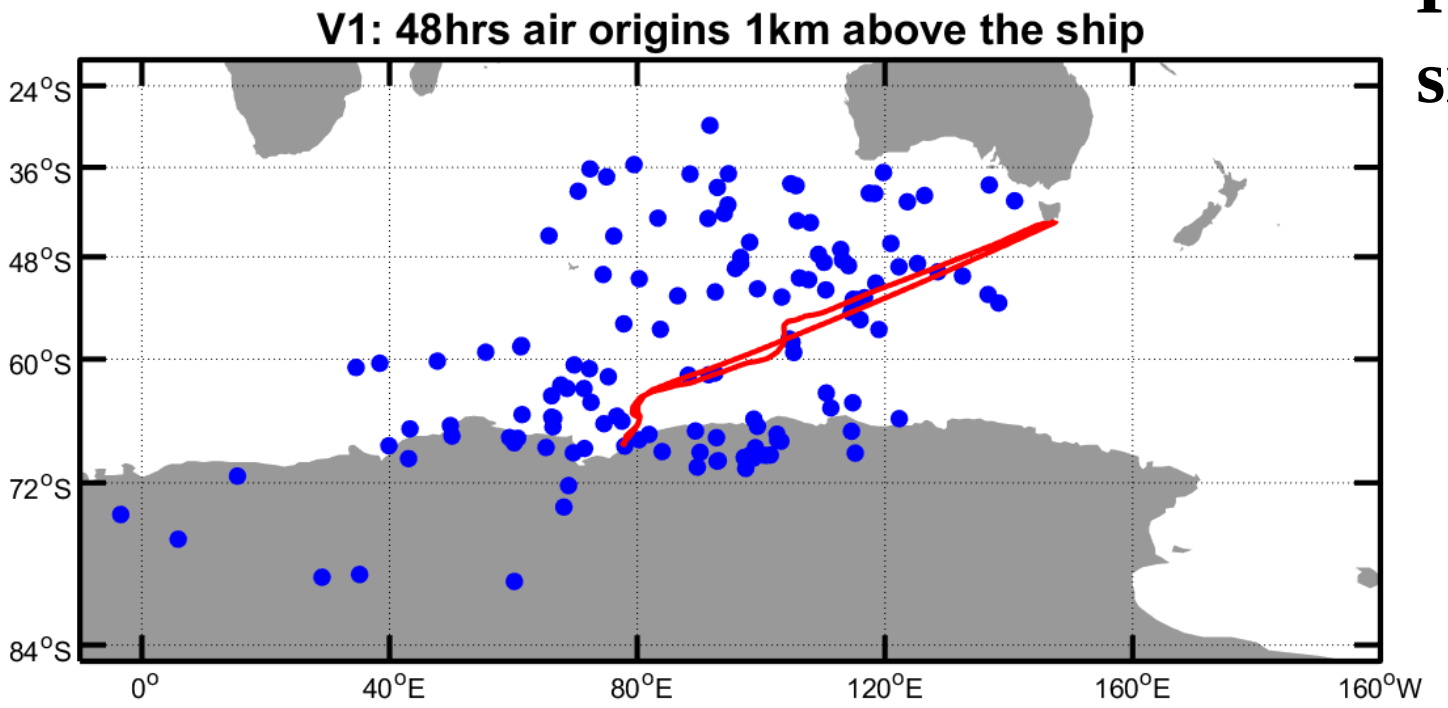
(iv) Location of observations within cyclone (i.e., what quadrant)

(v) Location relative to ocean polar front and sea surface temperature

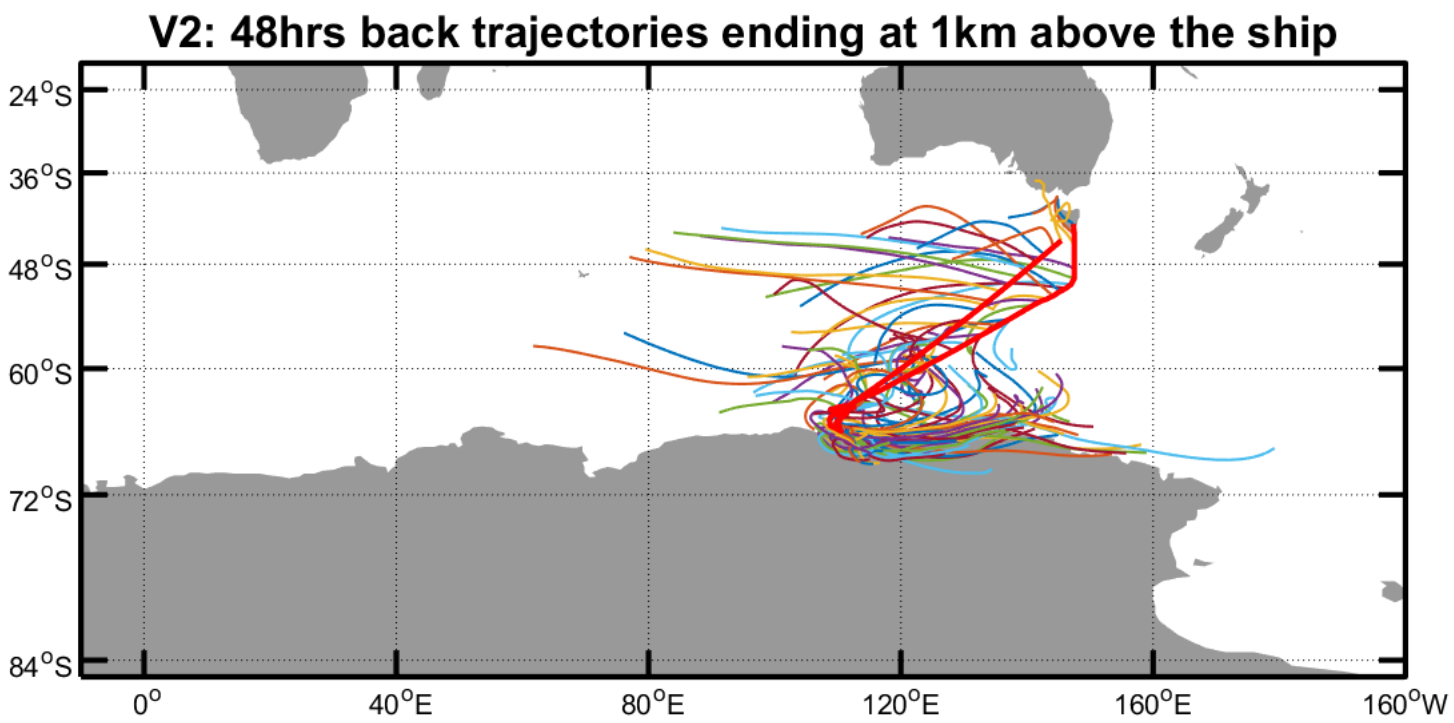
(vi) Precipitating vs. non-precipitating clouds

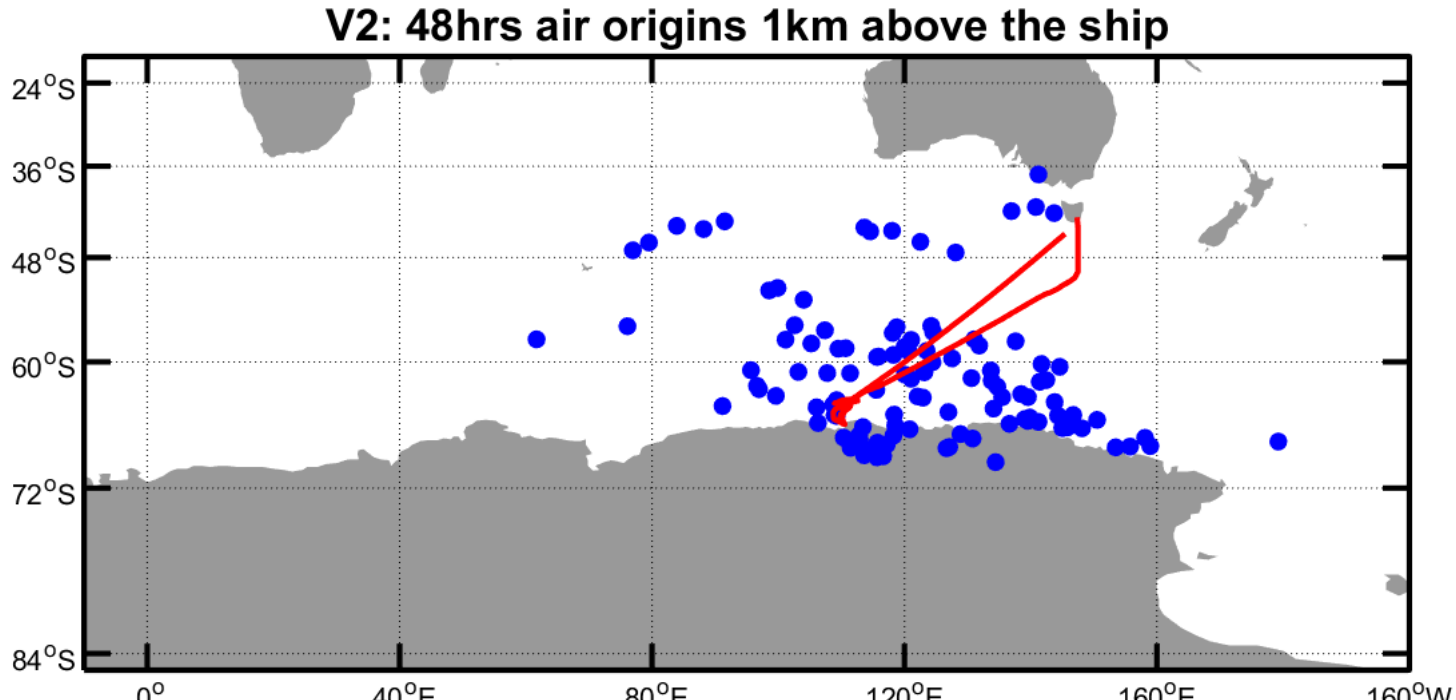
Also assessing consistency of multiple data sets

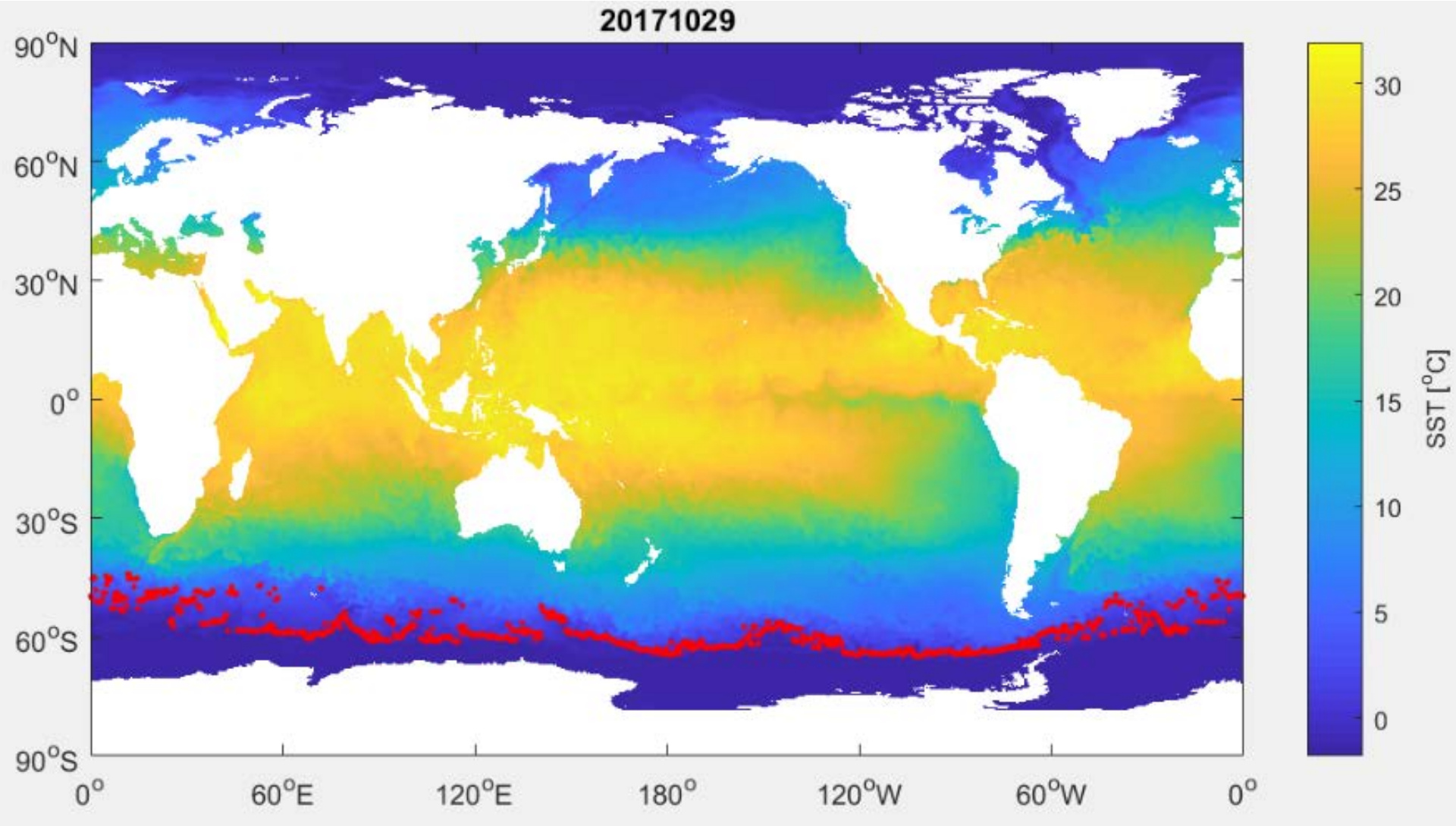




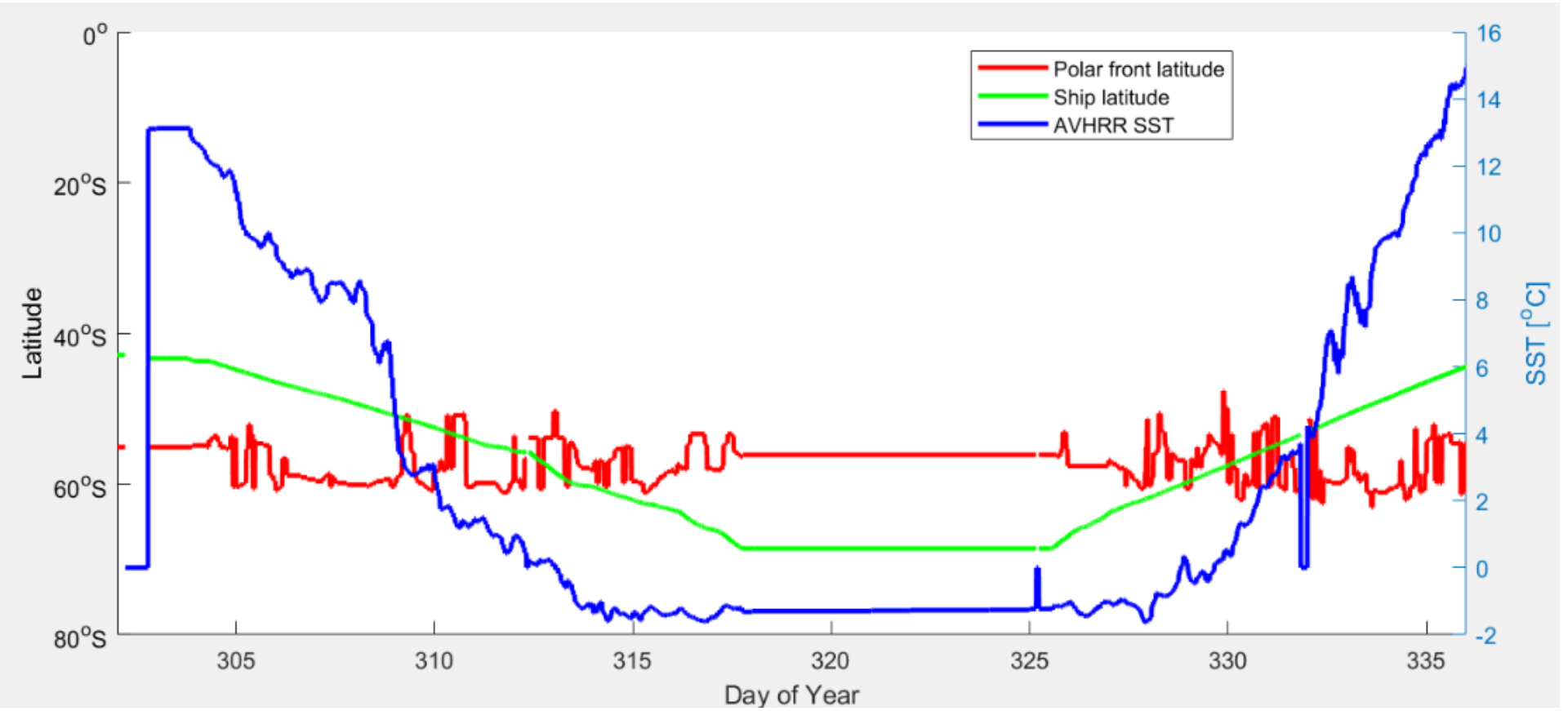
Back trajectories base on HYSPLIT simulations

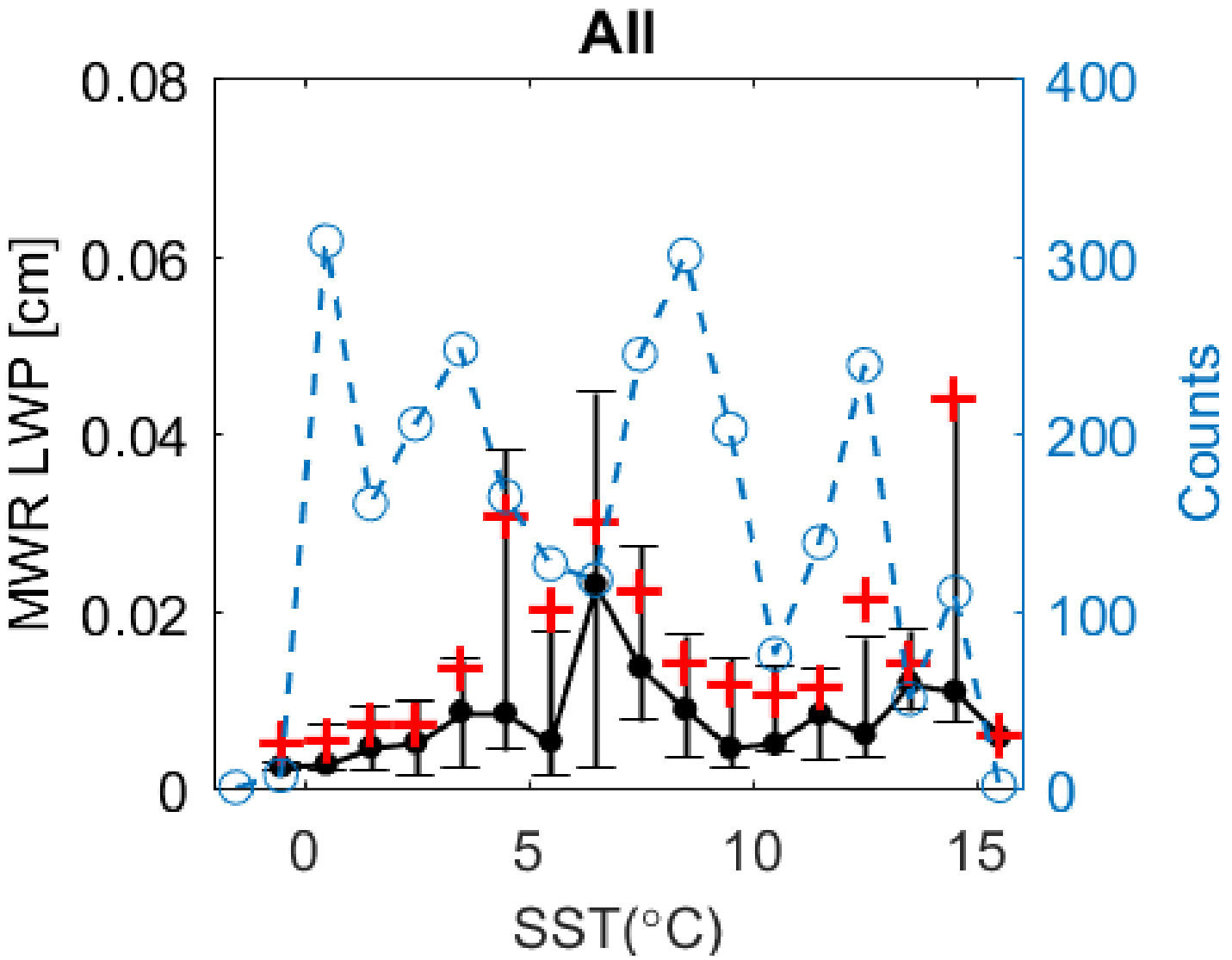

V2: 48hrs back trajectories ending at 1km above the ship
24°S
36°S
48°S
60°S
72°S
84°S
0°
40°E
80°E
120°E
160°E
160°W

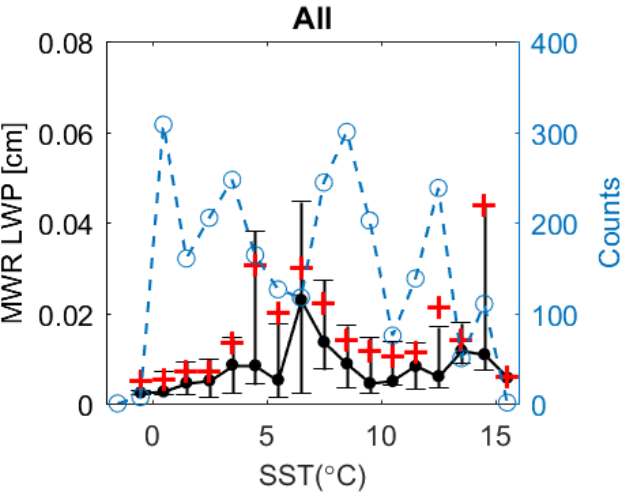

V2: 48hrs air origins 1km above the ship
24°S
36°S
48°S
60°S
72°S
84°S
0°
40°E
80°E
120°E
160°E
160°W

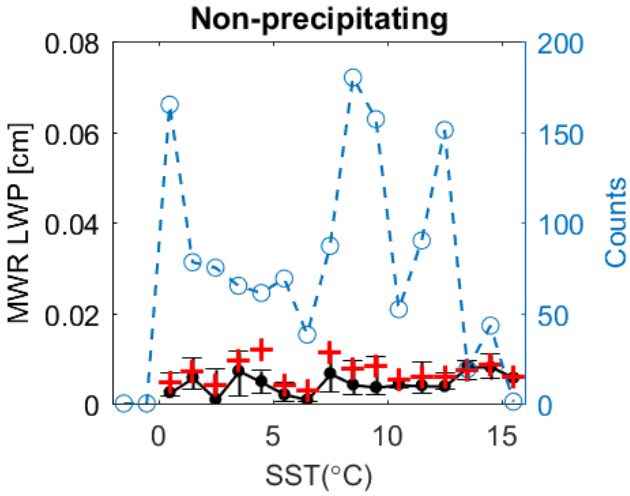


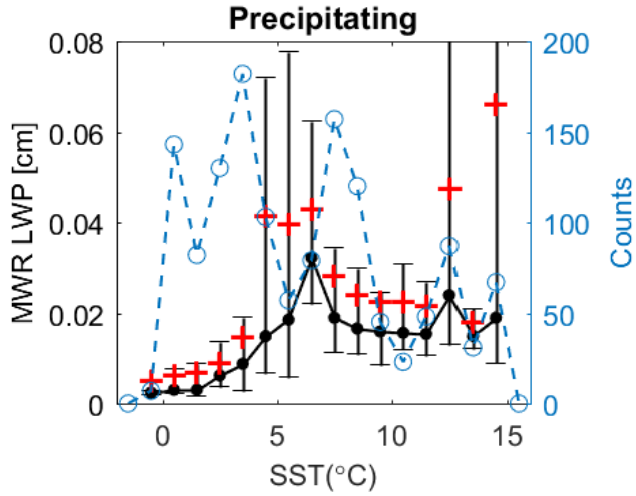
- **NOAA 1/4° satellite SSTs from AVHRR**
- **Red points: Polar front defined as southern location where absolute SST gradient exceeds 0.015°C/km (Dong et al. 2006)**

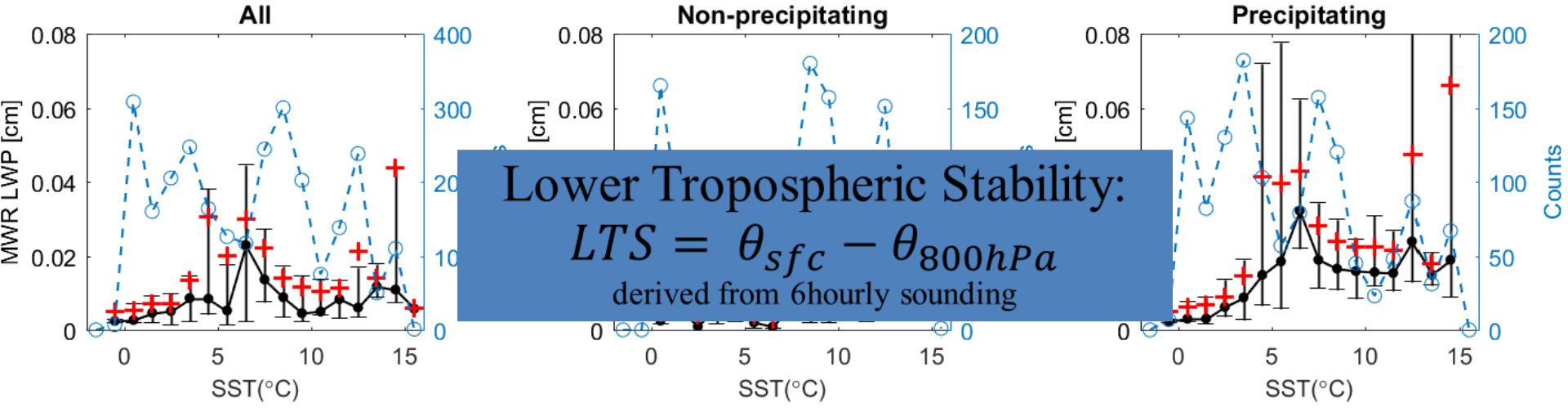

Polar front latitude
Ship latitude
AVHRR SST
0°
20°S
40°S
60°S
80°S
Latitude
16
14
12
10
8
6
4
2
0
-2
SST [°C]
305
310
315
320
325
330
335
Day of Year


All
0.08
0.06
0.04
0.02
0
MWR LWP [cm]
400
300
200
100
0
Counts
0
5
10
15
SST(°C)


All
MWR LWP [cm]
Counts
SST(°C)
0.08
0.06
0.04
0.02
0
400
300
200
100
0
0
5
10
15


Non-precipitating
MWR LWP [cm]
Counts
SST(°C)
0.08
0.06
0.04
0.02
0
200
150
100
50
0
0
5
10
15

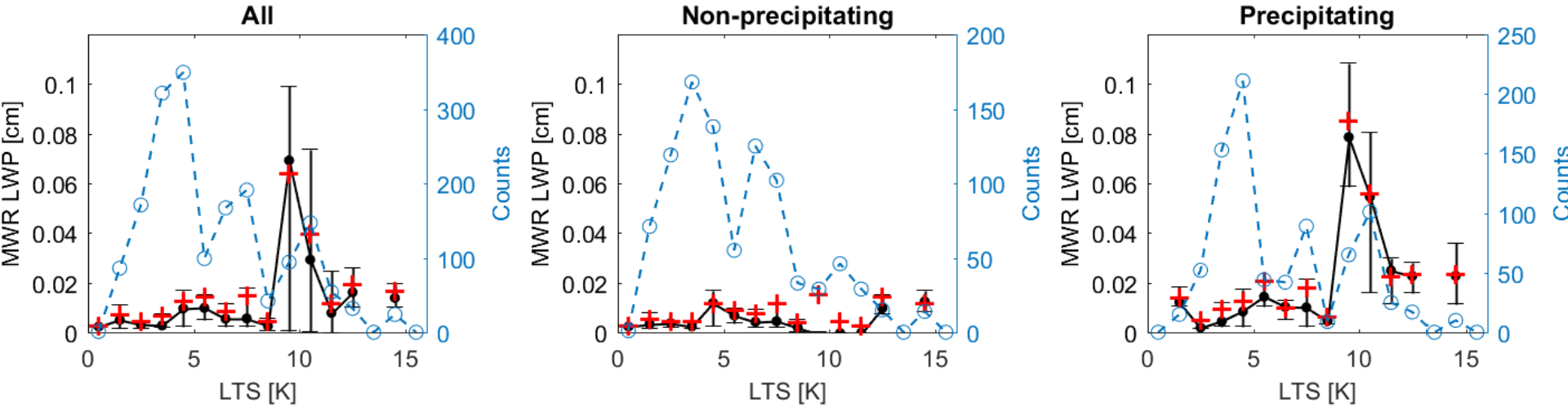

Precipitating
MWR LWP [cm]
Counts
SST(°C)
0.08
0.06
0.04
0.02
0
200
150
100
50
0
0
5
10
15

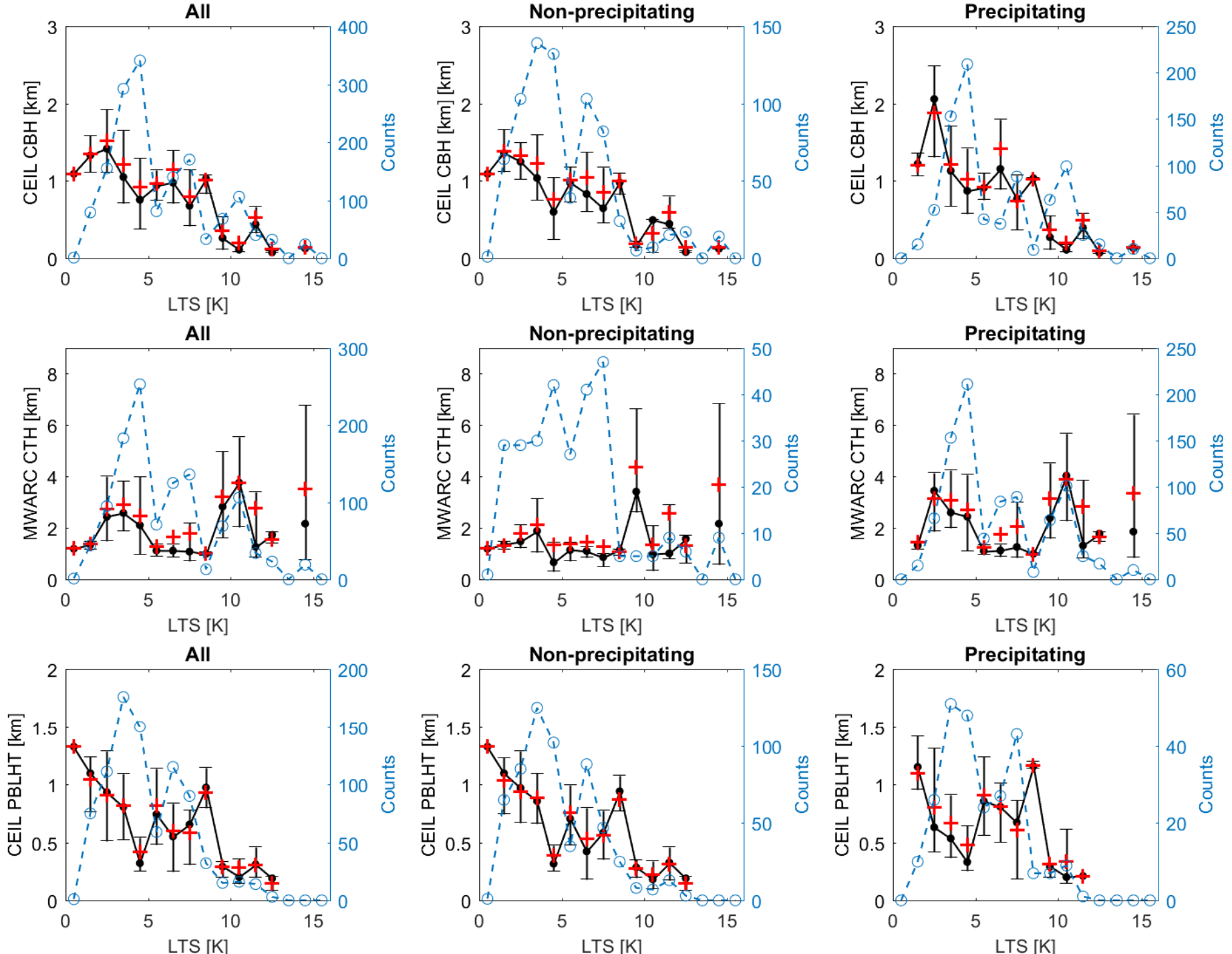


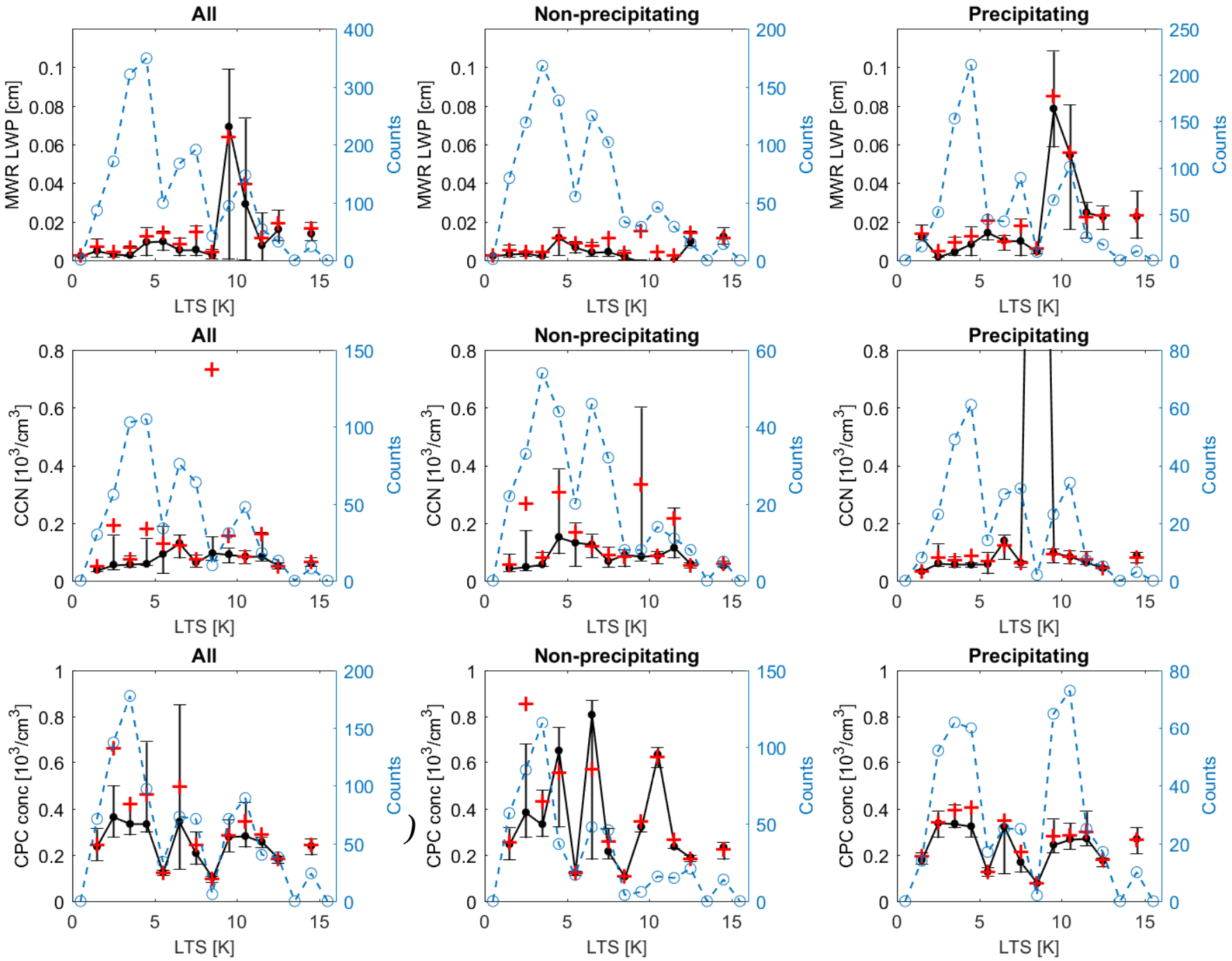
Lower Tropospheric Stability:

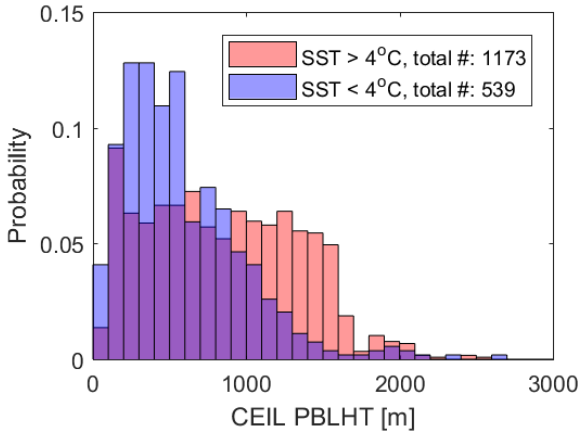
$$LTS = \theta_{sfc} - \theta_{800hPa}$$

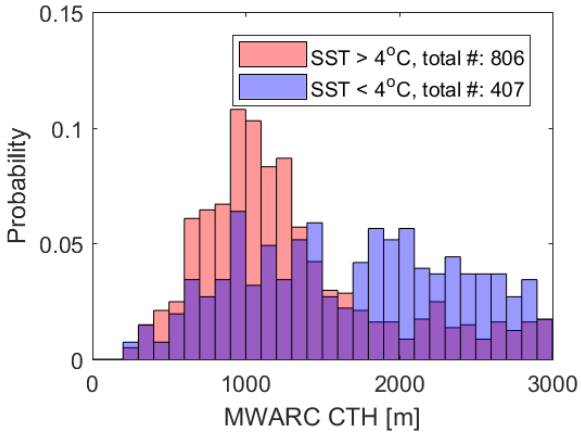
derived from 6hourly sounding

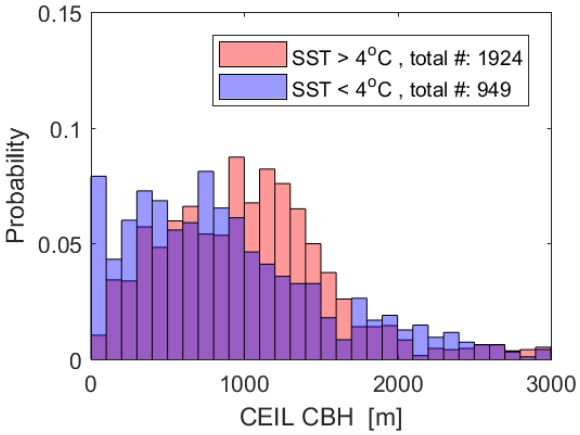


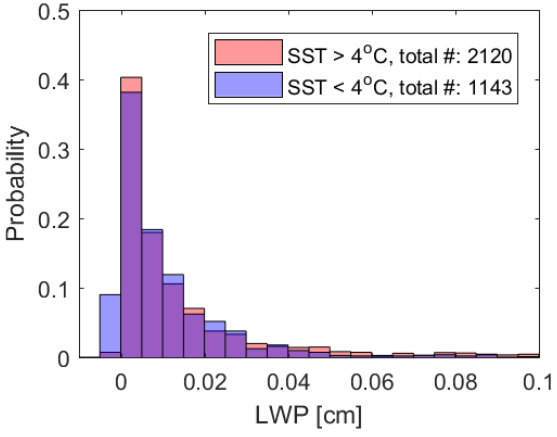

All
Non-precipitating
Precipitating
CEIL CBH [km]
MWARC CTH [km]
CEIL PBLHT [km]
Counts
LTS [K]

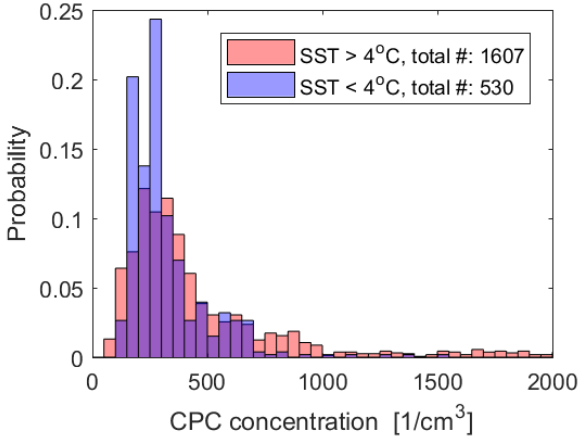

All
Non-precipitating
Precipitating
MWR LWP [cm]
CCN [10^3/cm^3]
CPC conc [10^3/cm^3]
Counts
LTS [K]

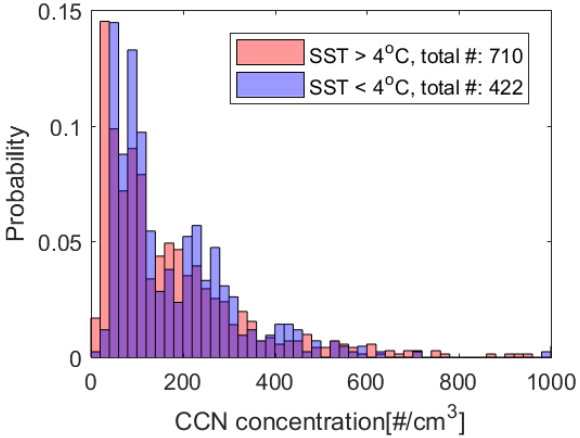

SST > 4°C, total #: 1173
SST < 4°C, total #: 539
Probability
CEIL PBLHT [m]

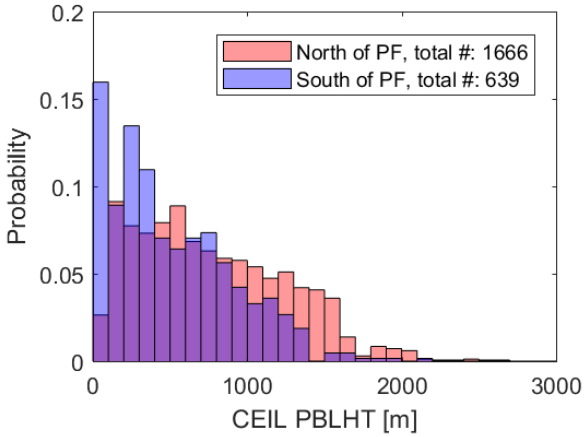

SST > 4°C, total #: 806
SST < 4°C, total #: 407
Probability
MWARC CTH [m]

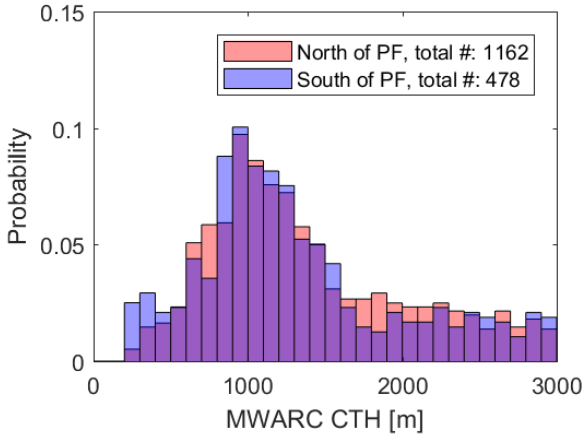

SST > 4°C , total #: 1924
SST < 4°C , total #: 949
Probability
CEIL CBH [m]

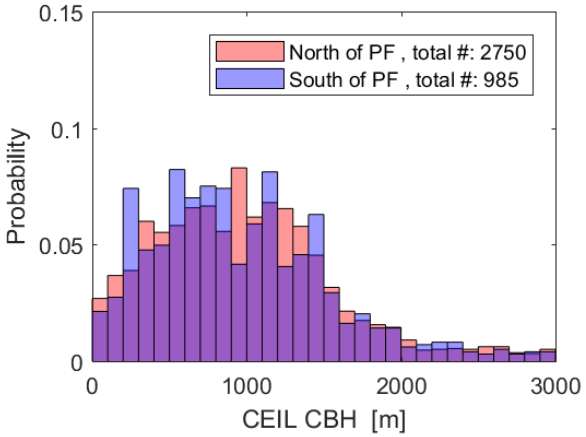

SST > 4°C, total #: 2120
SST < 4°C, total #: 1143
Probability
LWP [cm]

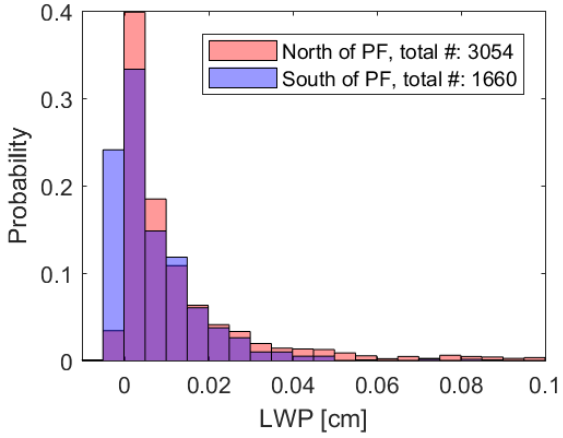

SST > 4°C, total #: 1607
SST < 4°C, total #: 530
Probability
CPC concentration [1/cm3]

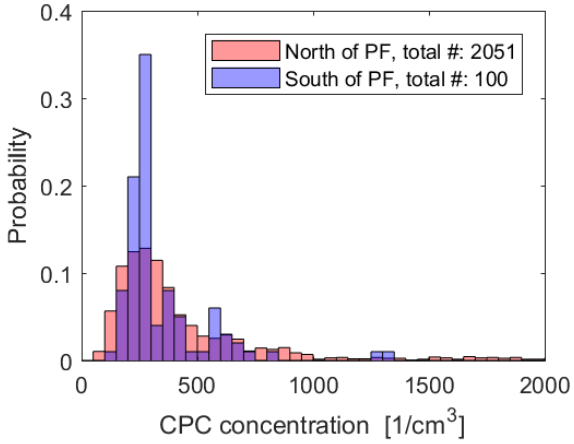

SST > 4°C, total #: 710
SST < 4°C, total #: 422
Probability
CCN concentration[#/cm3]

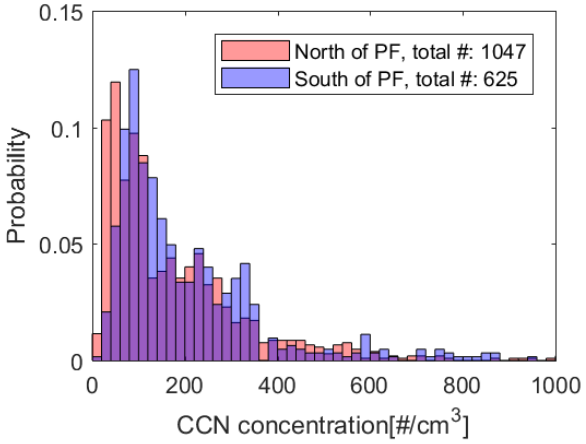

North of PF, total #: 1666
South of PF, total #: 639
Probability
CEIL PBLHT [m]

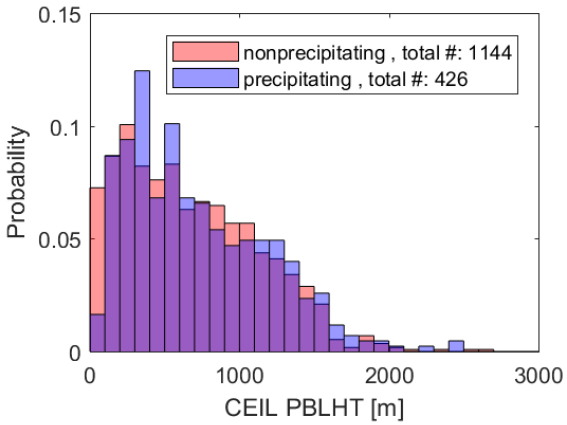

North of PF, total #: 1162
South of PF, total #: 478
Probability
MWARC CTH [m]

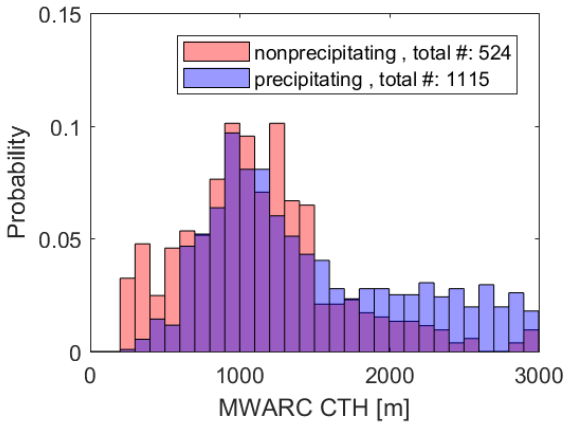

North of PF , total #: 2750
South of PF , total #: 985
Probability
CEIL CBH [m]

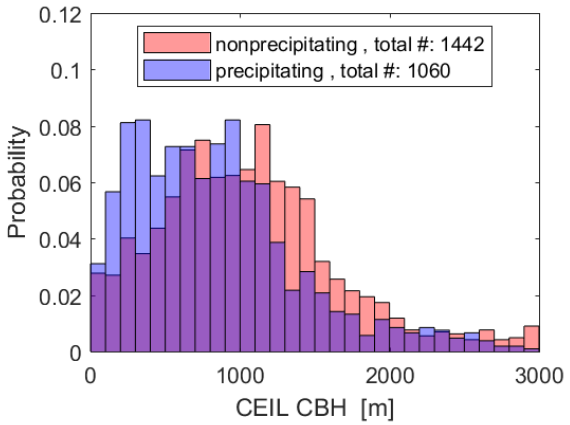

North of PF, total #: 3054
South of PF, total #: 1660
Probability
LWP [cm]

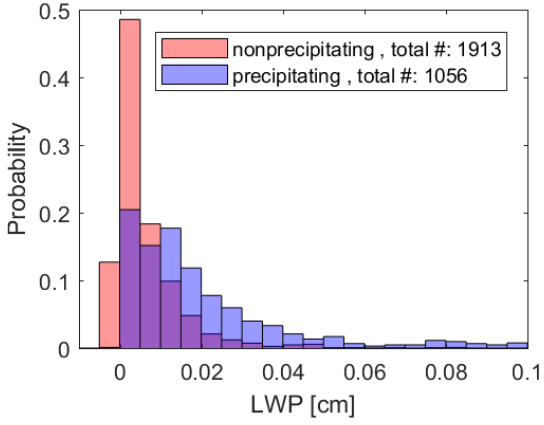

North of PF, total #: 2051
South of PF, total #: 100
Probability
CPC concentration [1/cm3]

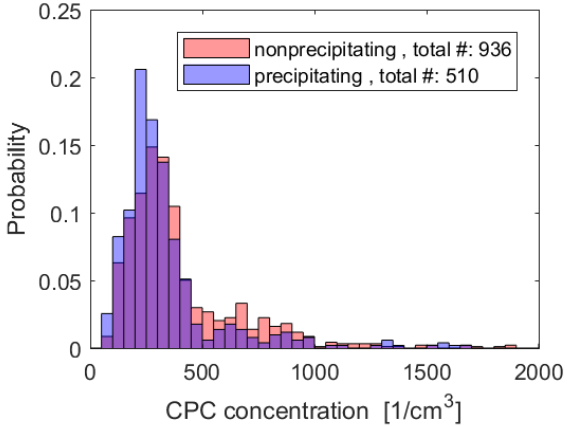

North of PF, total #: 1047
South of PF, total #: 625
Probability
CCN concentration[#/cm3]

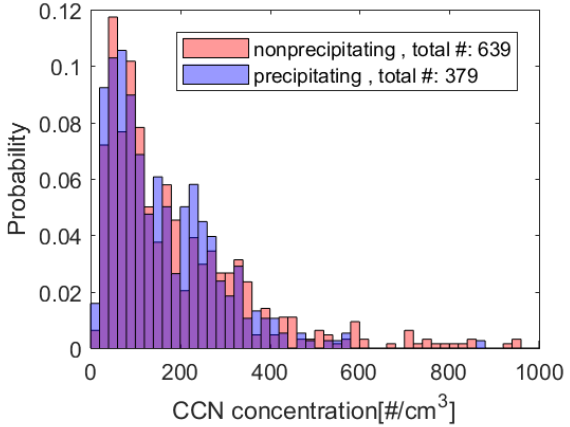

nonprecipitating , total #: 1144
precipitating , total #: 426
Probability
CEIL PBLHT [m]

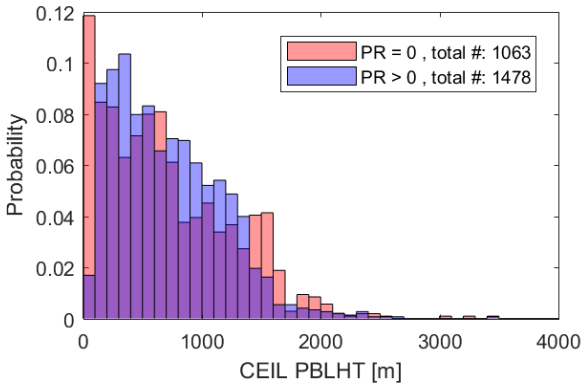

nonprecipitating , total #: 524
precipitating , total #: 1115
Probability
MWARC CTH [m]

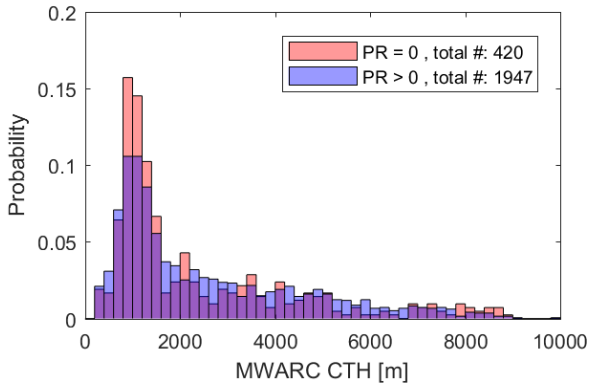

nonprecipitating , total #: 1442
precipitating , total #: 1060
Probability
CEIL CBH [m]

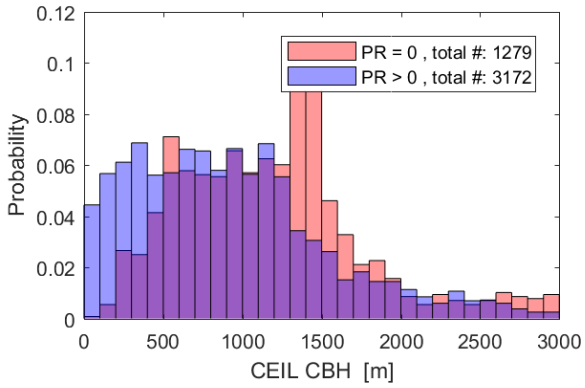

nonprecipitating , total #: 1913
precipitating , total #: 1056
Probability
LWP [cm]

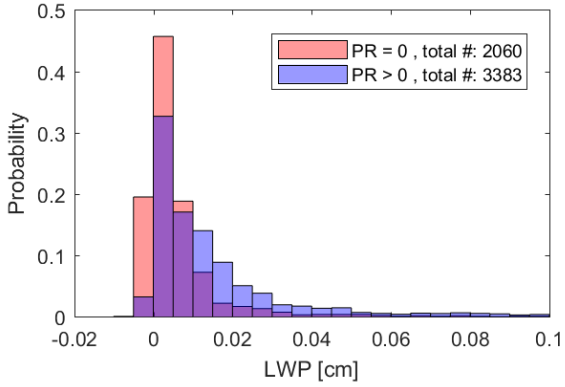

nonprecipitating , total #: 936
precipitating , total #: 510
Probability
CPC concentration [1/cm3]

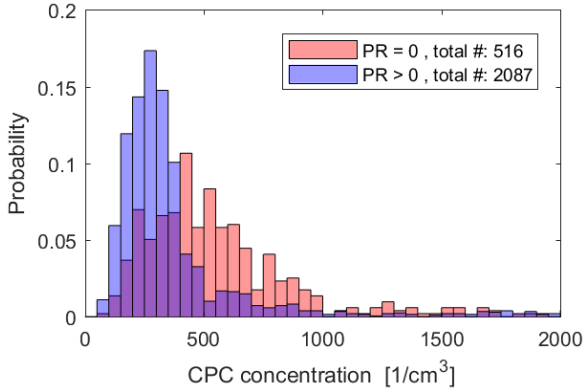

nonprecipitating , total #: 639
precipitating , total #: 379
Probability
CCN concentration[#/cm3]

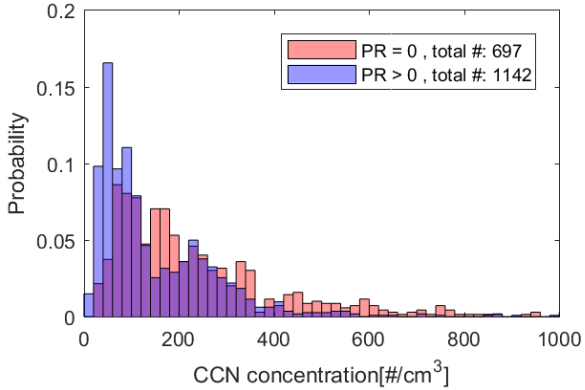

PR = 0 , total #: 1063
PR > 0 , total #: 1478
Probability
CEIL PBLHT [m]


PR = 0 , total #: 420
PR > 0 , total #: 1947
Probability
MWARC CTH [m]


PR = 0 , total #: 1279
PR > 0 , total #: 3172
Probability
CEIL CBH [m]


PR = 0 , total #: 2060
PR > 0 , total #: 3383
Probability
LWP [cm]


PR = 0 , total #: 516
PR > 0 , total #: 2087
Probability
CPC concentration [1/cm3]


PR = 0 , total #: 697
PR > 0 , total #: 1142
Probability
CCN concentration[#/cm3]