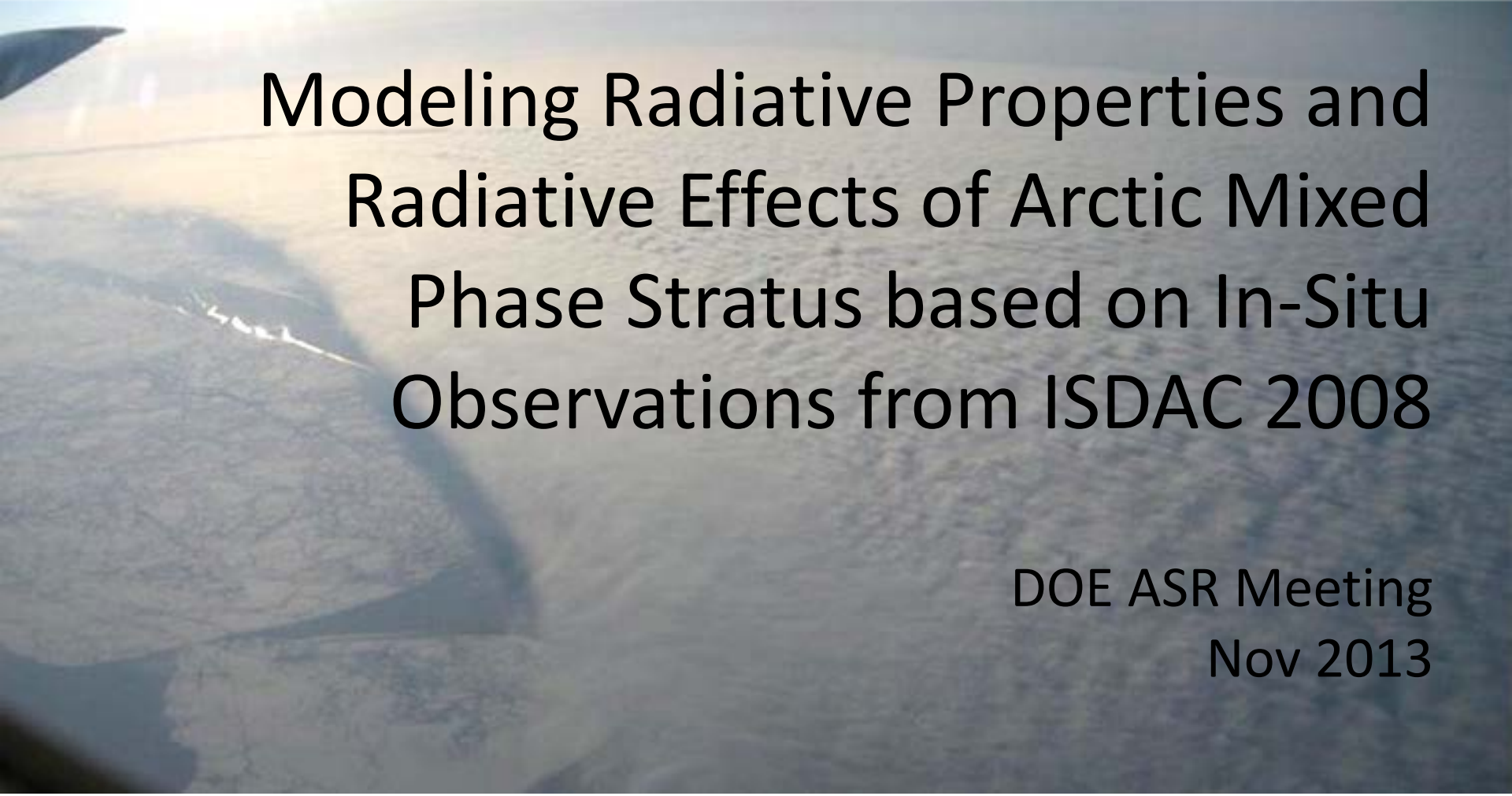


Modeling Radiative Properties and Radiative Effects of Arctic Mixed Phase Stratus based on In-Situ Observations from ISDAC 2008

DOE ASR Meeting
Nov 2013

Sara Lance

Paul Lawson, David Mitchell, Eric Jensen, Sebastian Schmidt

Climate Change in the Arctic

- Warming in the Arctic is amplified compared to other geographic locations on Earth, and some of that warming cannot be duplicated with climate models

- Potential under-attributed forcings include:
  - Elevated Surface Ozone and/or Methane
  - Black Carbon or dust deposited on snow
  - Cloud Radiative Effects (e.g. changes to emissivity)

In-Situ Cloud Observations (Ice & Water PSDs, Ice particle “shape recipe”) at multiple altitudes

↓

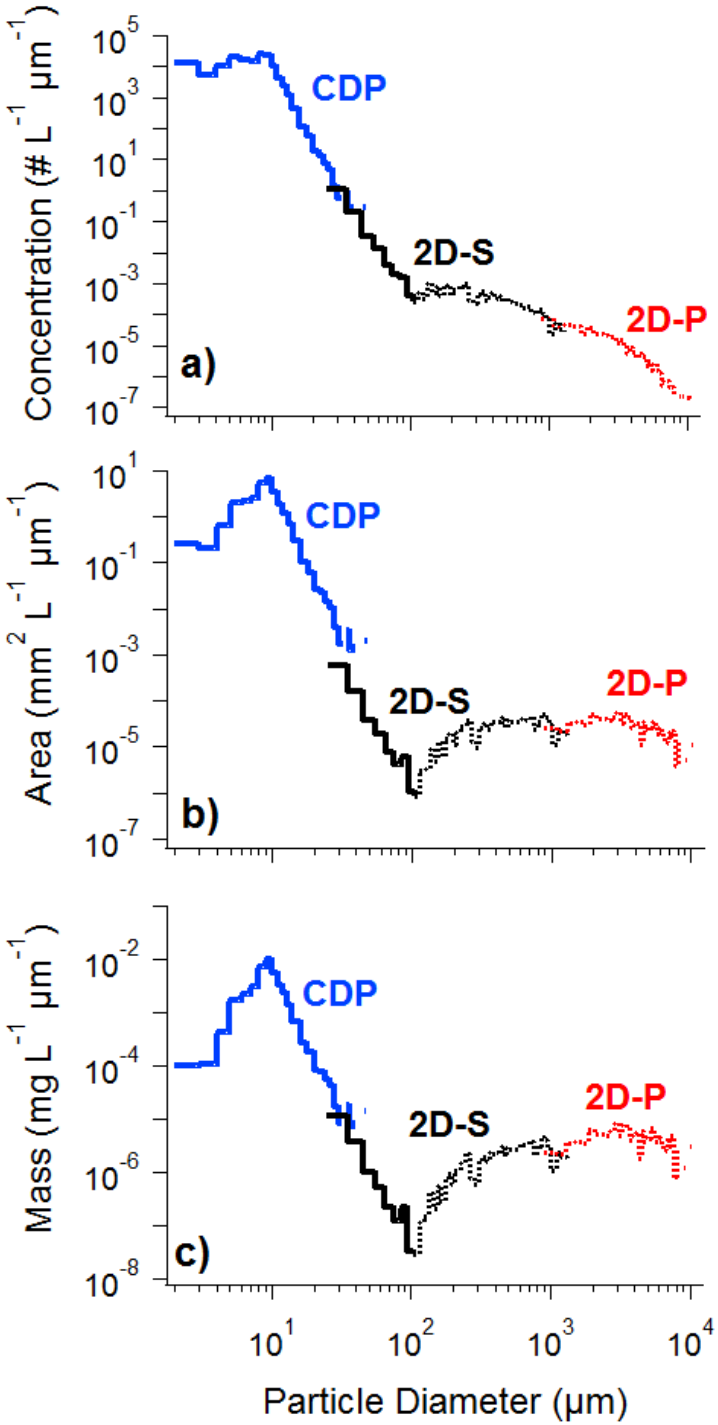
Modified Anomalous Diffraction Approximation (MADA) Code to produce Extinction, Single Scatter Albedo and asymmetry parameter

↓

Two-Stream Radiative Transfer Model(s)

↓

Vertical Profile of Irradiances and Heating Rates

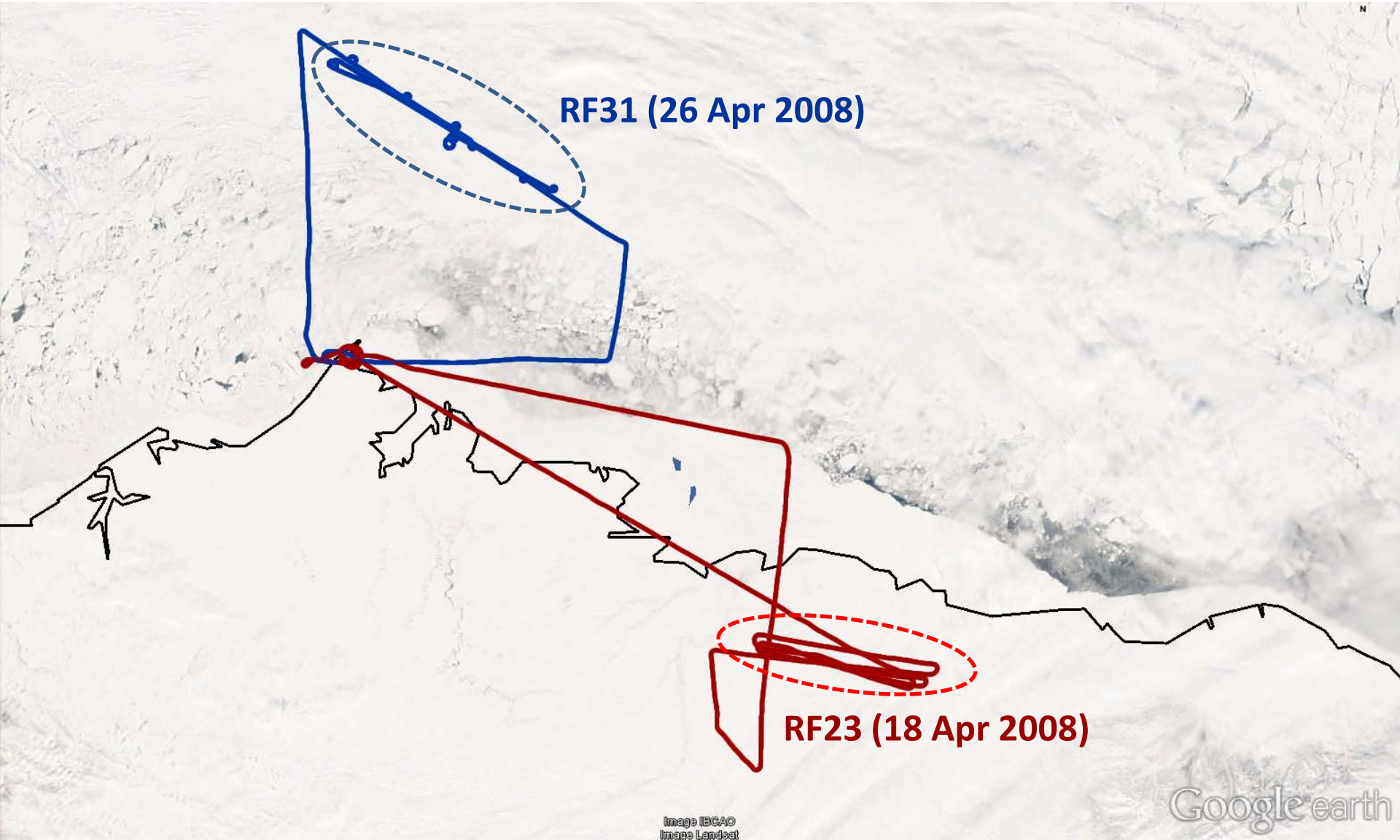


In-Situ Cloud Microphysics Observations

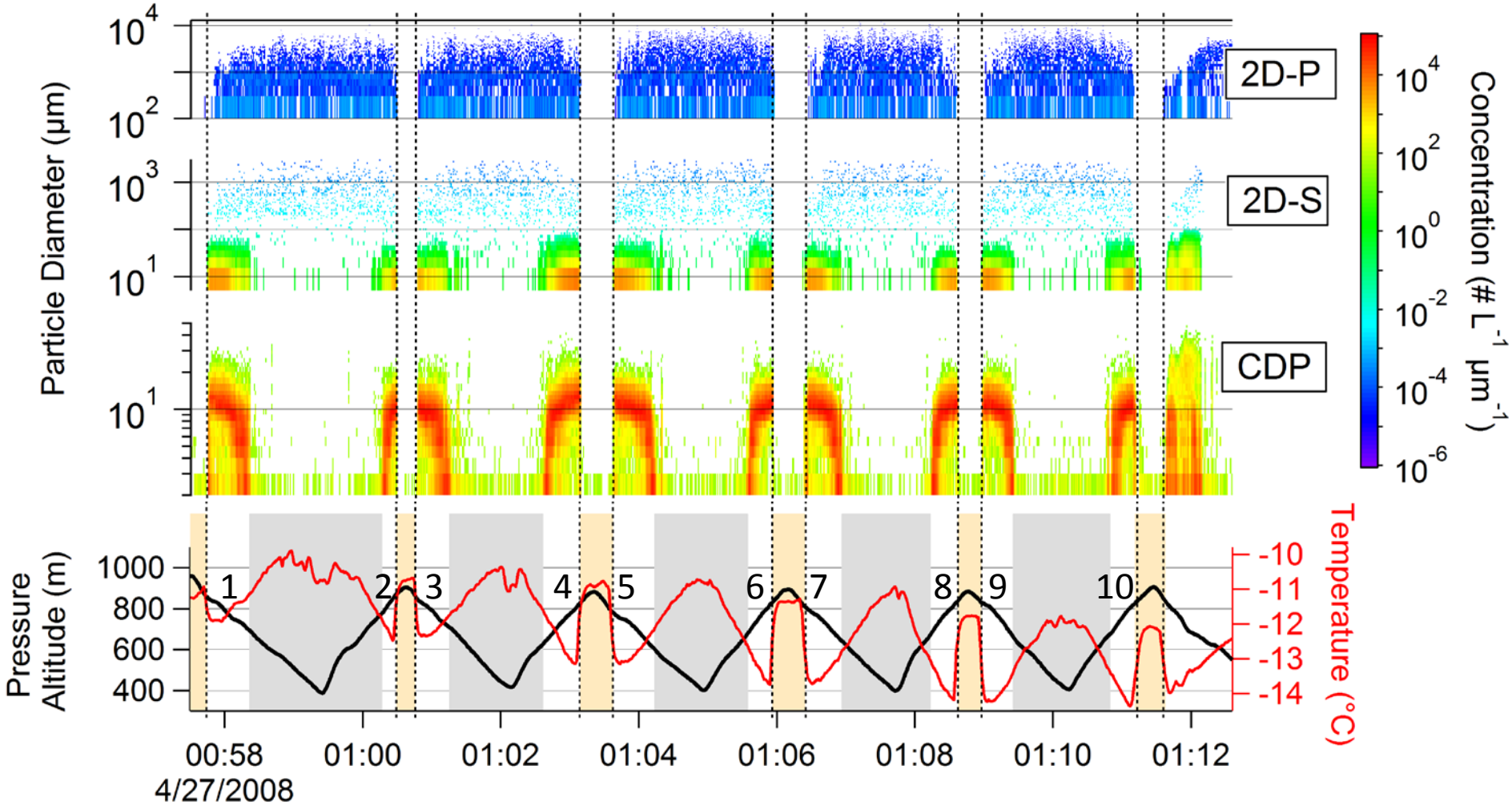
- **Ice** and **Liquid** particle size distributions obtained by combining CDP, 2D-S and 2D-P measurements

- CPI observations used to help classify ice particle shape, and a minimum ice particle diameter

Arctic mixed-phase stratus: Two ISDAC case studies



Case 1: Arctic Mixed-Phase Stratus over Sea-Ice (26 April: RF31)



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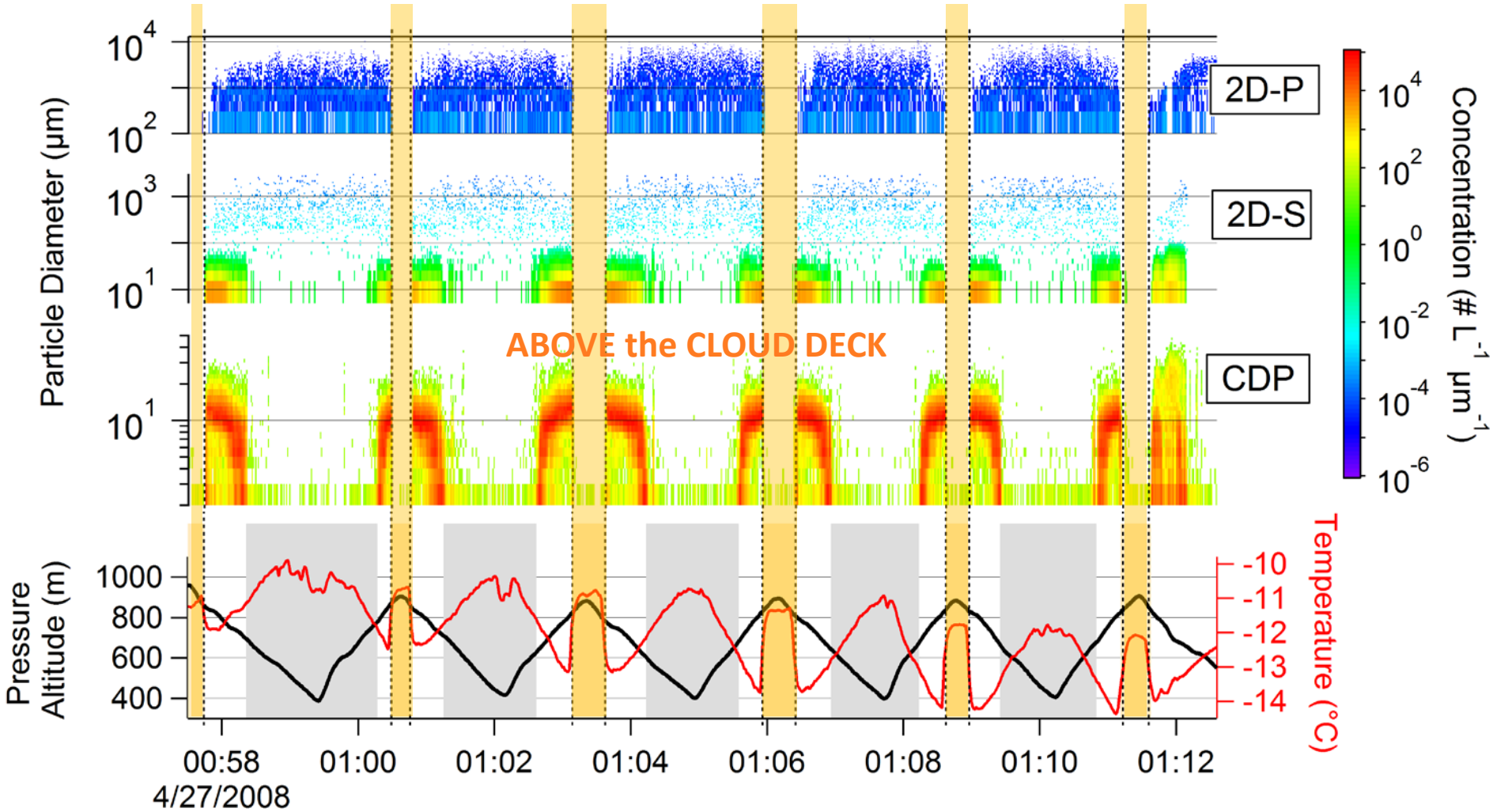

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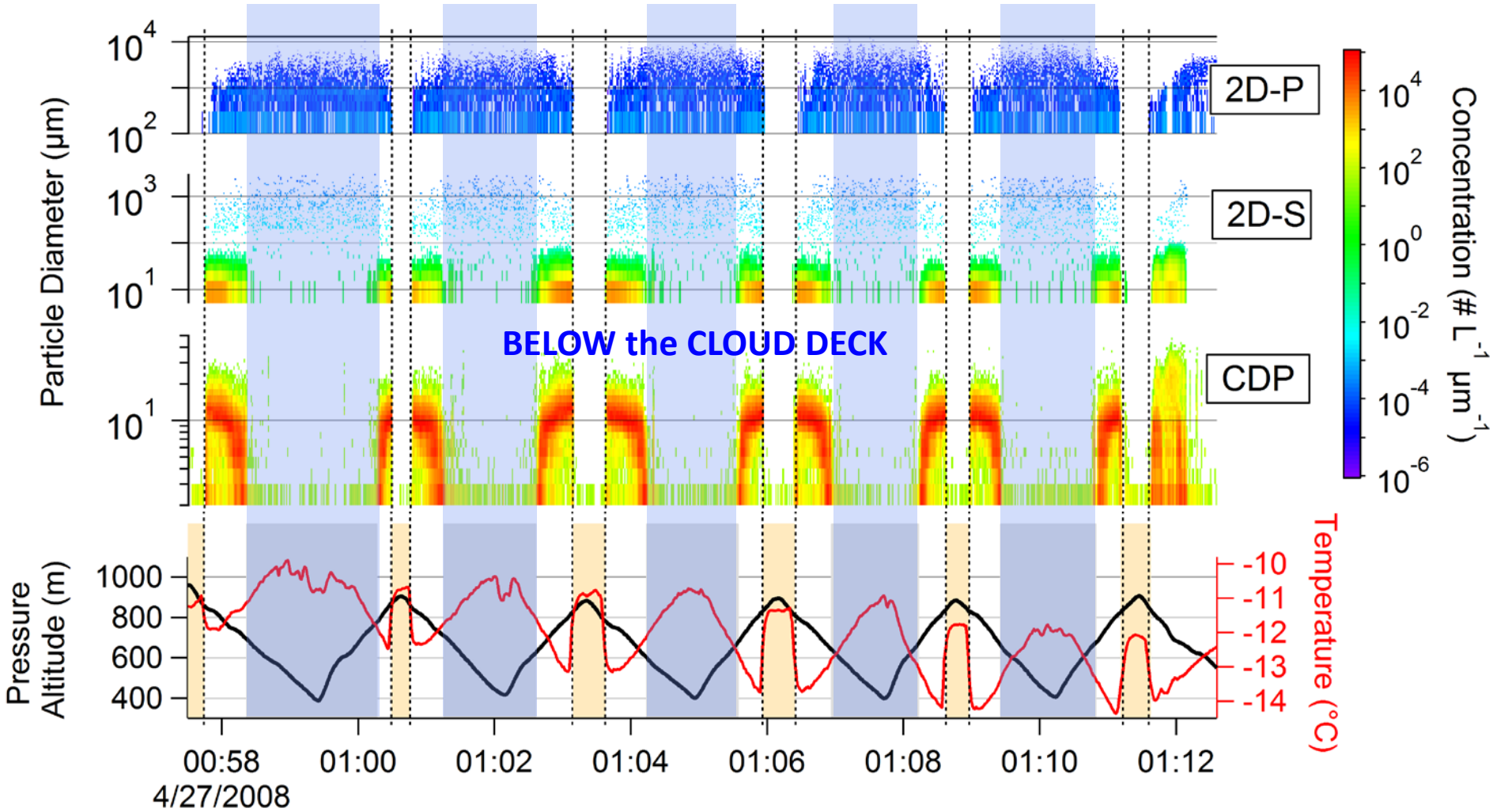
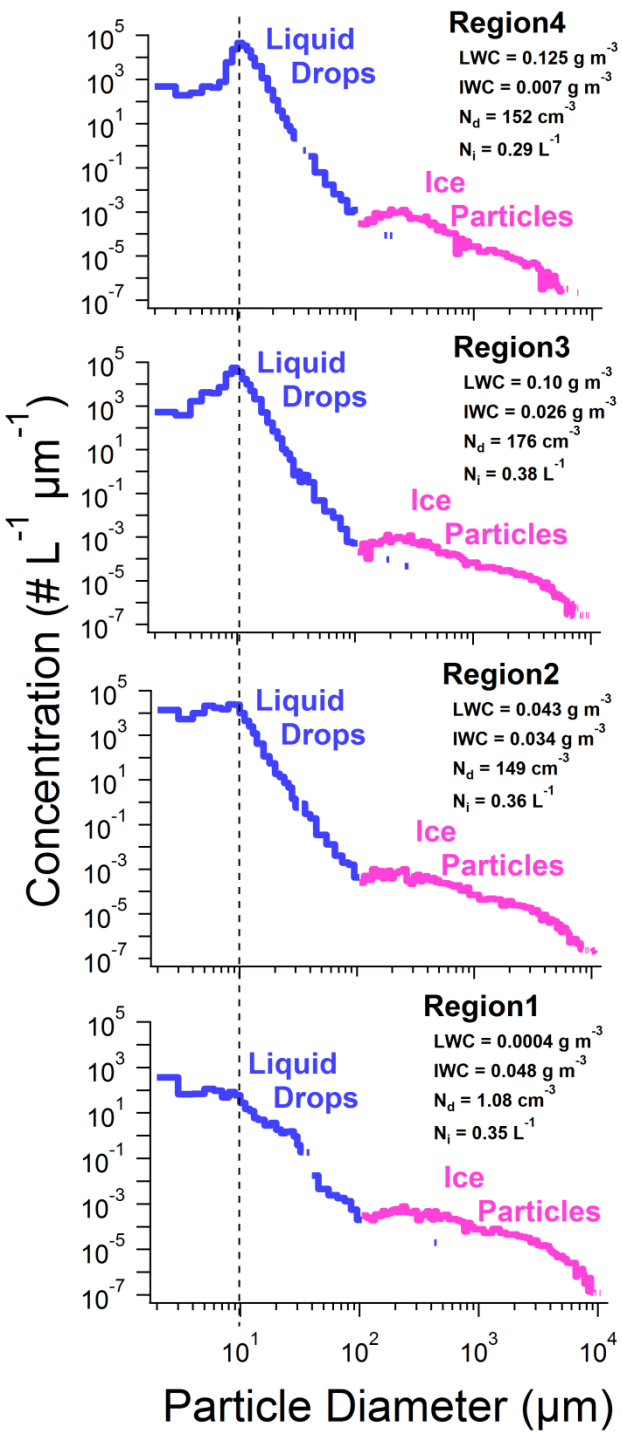
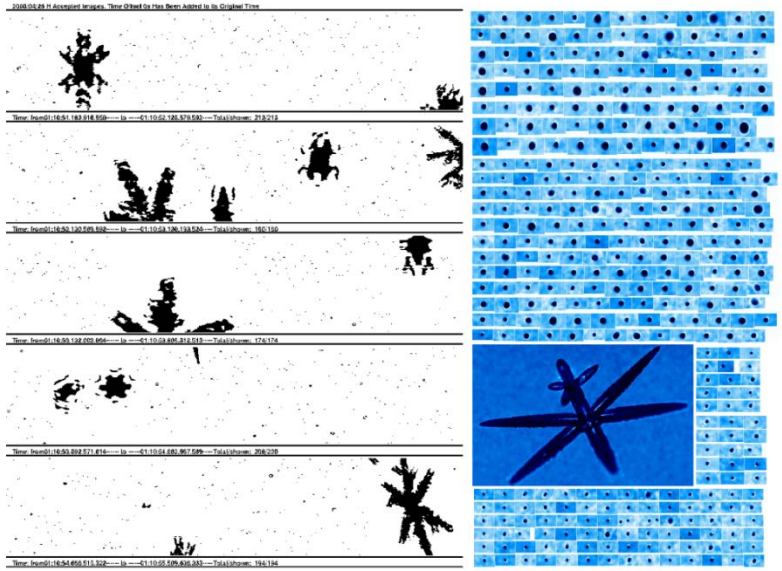
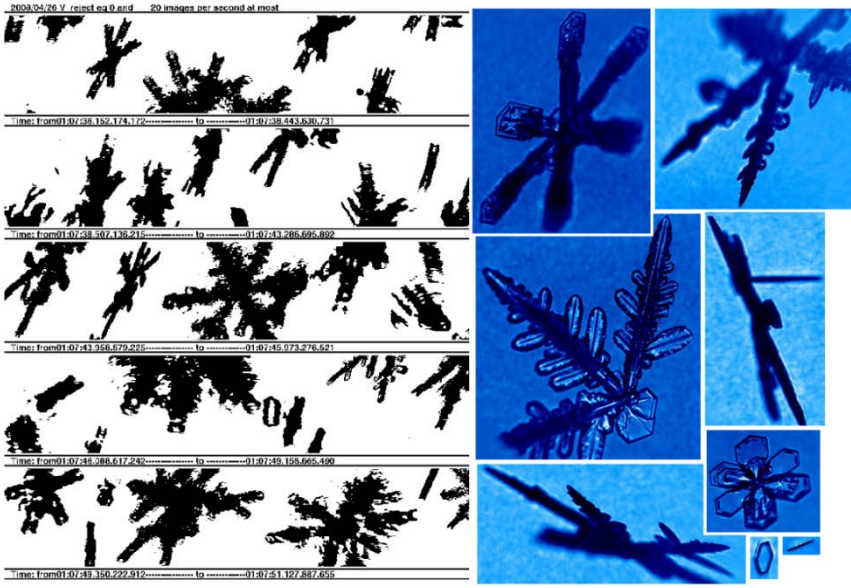




Within Mixed-phase stratus deck



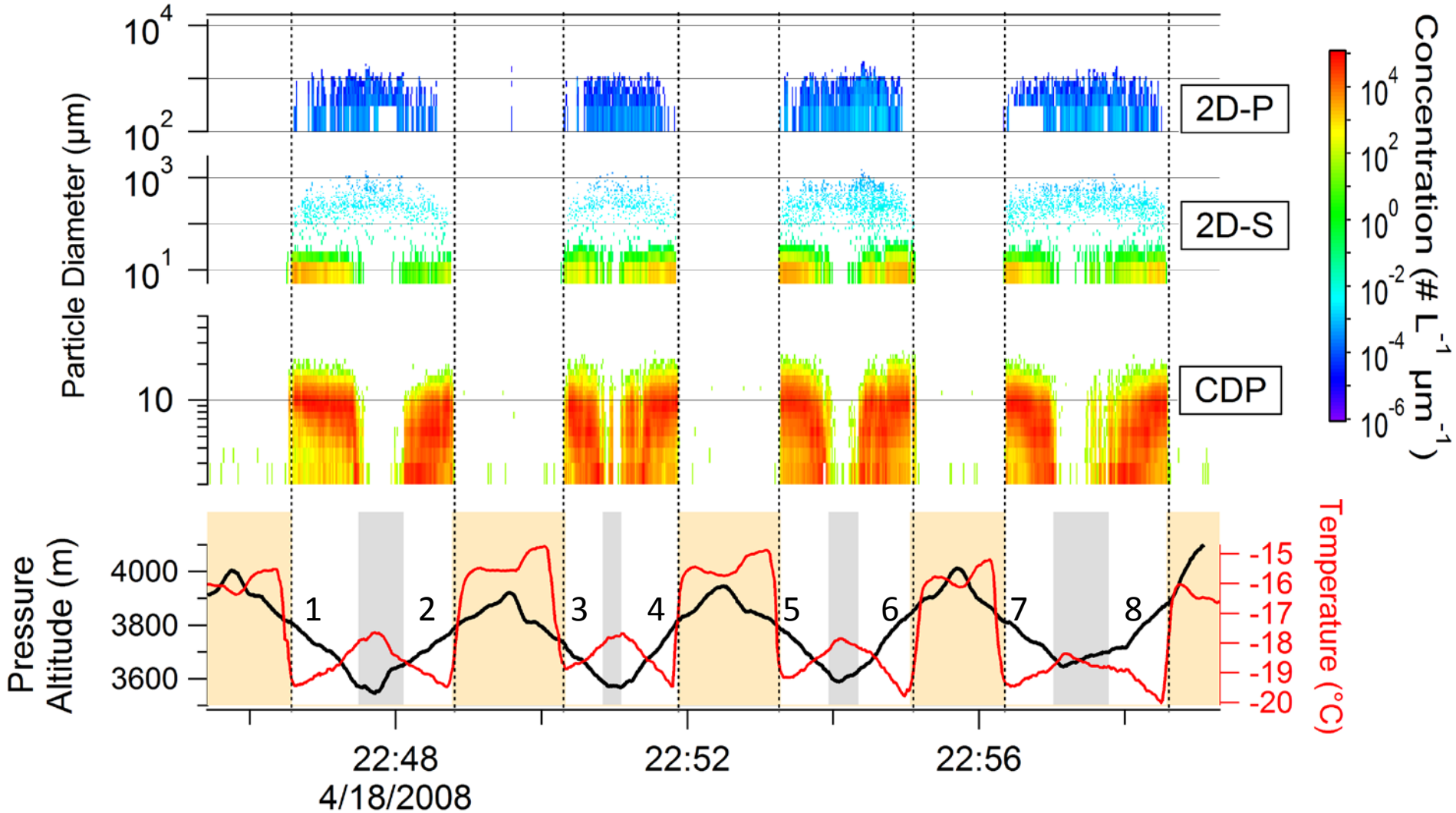
Below Mixed-phase stratus deck



640 μm

500 μm

Case 2: Arctic Mixed-Phase Stratus over the North Slope (18 April: RF23)



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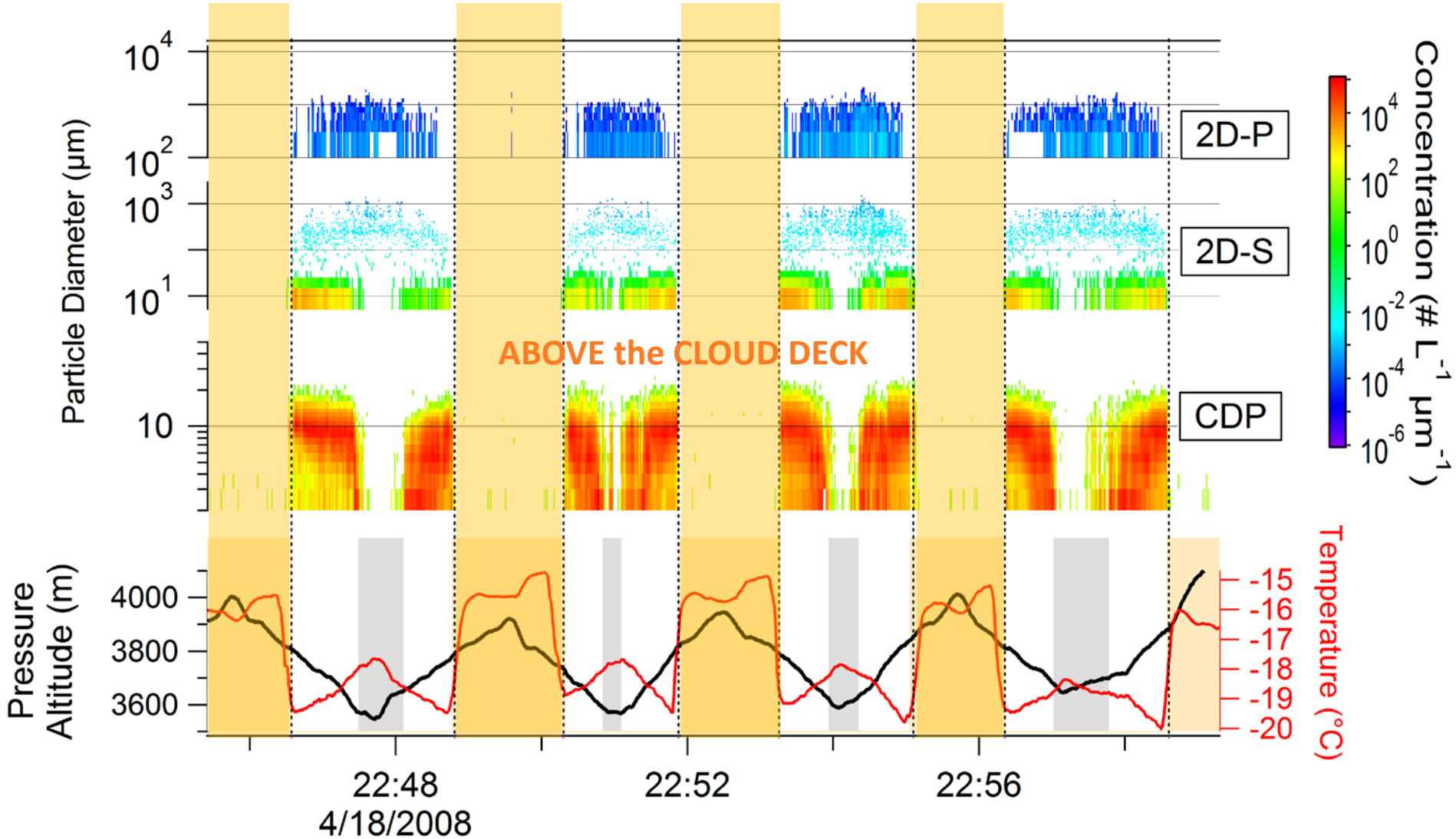

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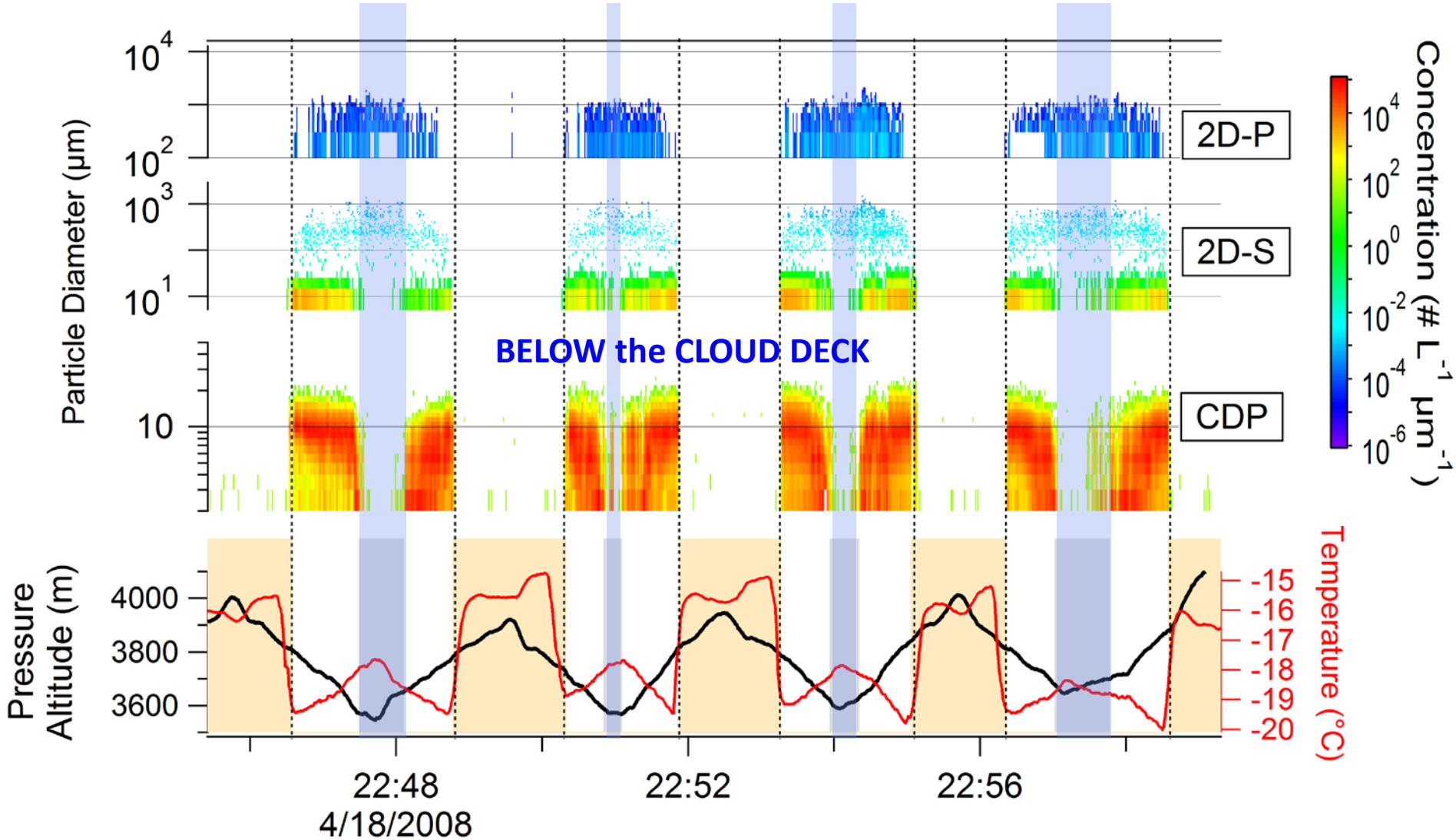
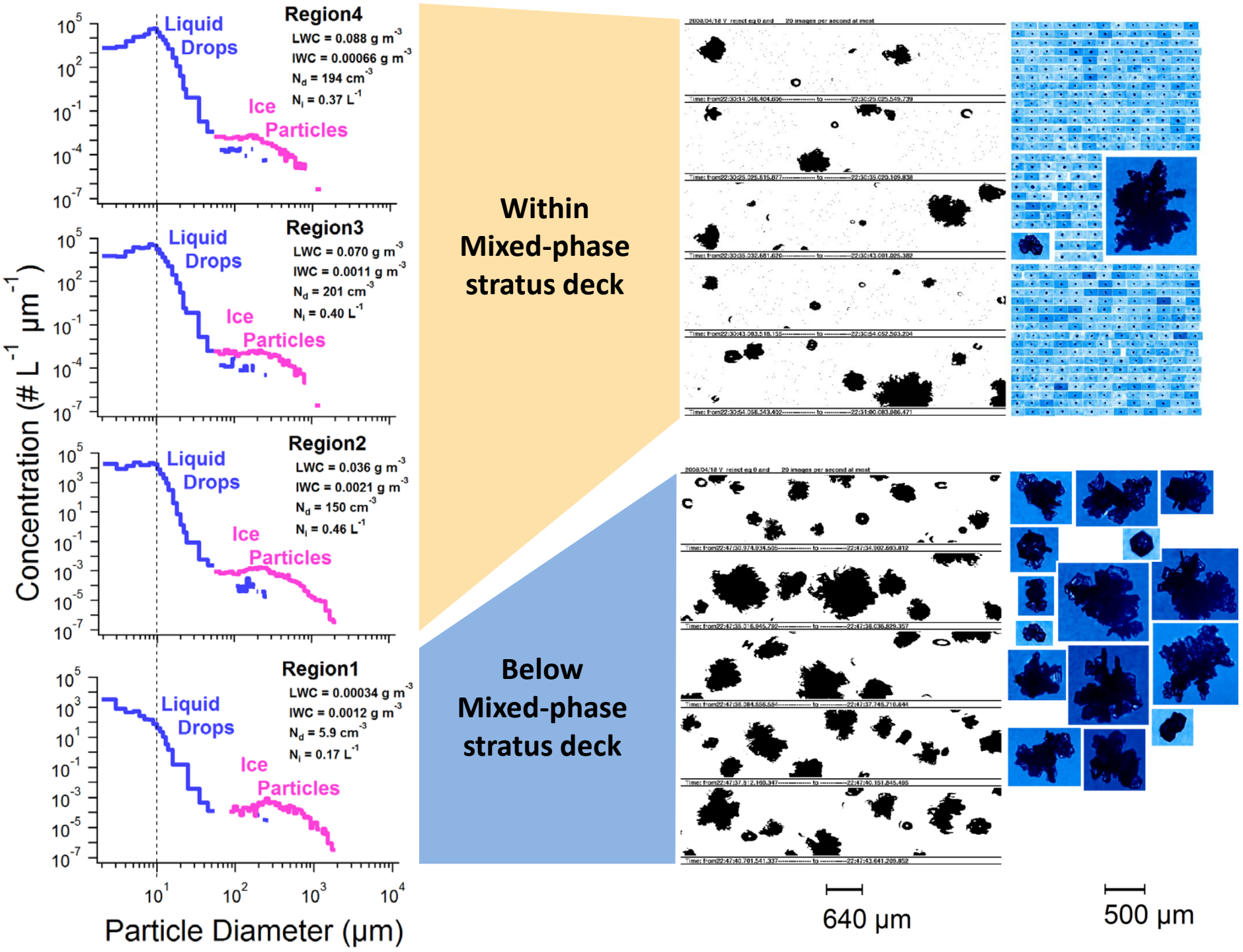
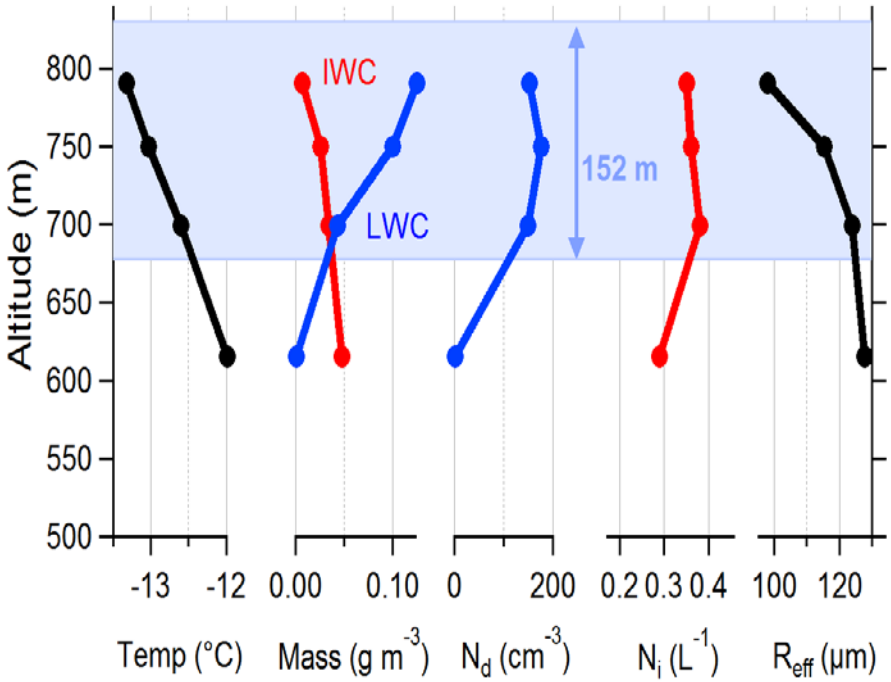
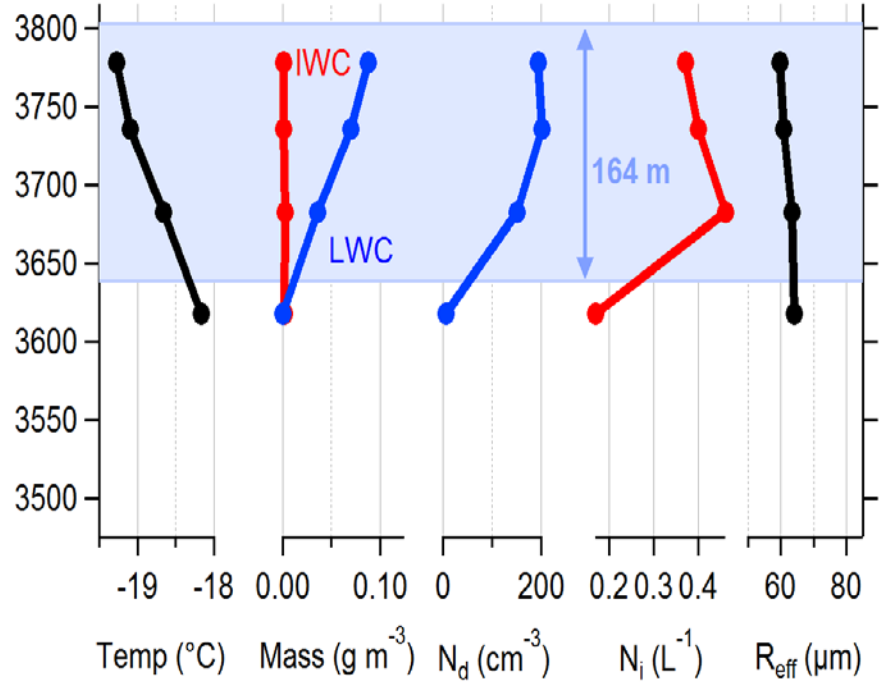



Region4
LWC = 0.088 g m-3
IWC = 0.00066 g m-3
Nd = 194 cm-3
Ni = 0.37 L-1
Region3
LWC = 0.070 g m-3
IWC = 0.0011 g m-3
Nd = 201 cm-3
Ni = 0.40 L-1
Region2
LWC = 0.036 g m-3
IWC = 0.0021 g m-3
Nd = 150 cm-3
Ni = 0.46 L-1
Region1
LWC = 0.00034 g m-3
IWC = 0.0012 g m-3
Nd = 5.9 cm-3
Ni = 0.17 L-1
Liquid Drops
Ice Particles
Concentration (# L-1 µm-1)
Particle Diameter (µm)
Within Mixed-phase stratus deck
Below Mixed-phase stratus deck
640 µm
500 µm





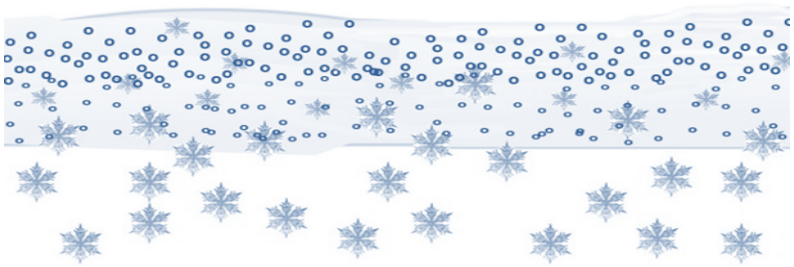
26 Apr (RF31)

- Cloud thickness ~150m
- T ~ -13°C
- N_d ~ 200 cm^{-3} (max)
- R_e ~ 110µm

18 Apr (RF23)

- Cloud thickness ~160m
- T ~ -19°C
- N_d ~ 200 cm^{-3} (max)
- R_e ~ 60µm

0.6 K/day surface warming



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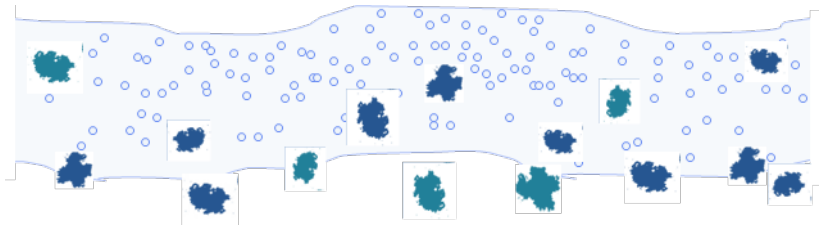
0.2 K/day surface warming



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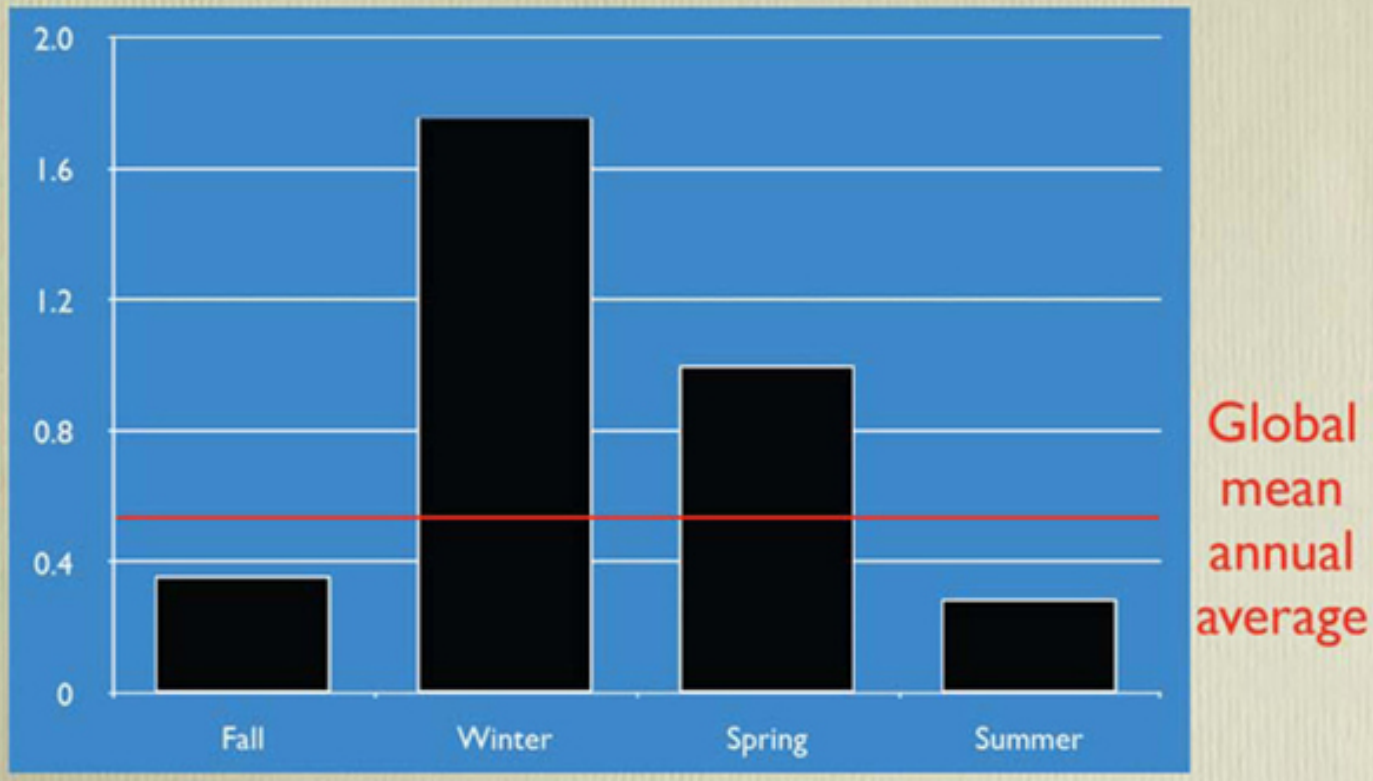
20th century Arctic warming

70-90 N, C/century, GISS observations

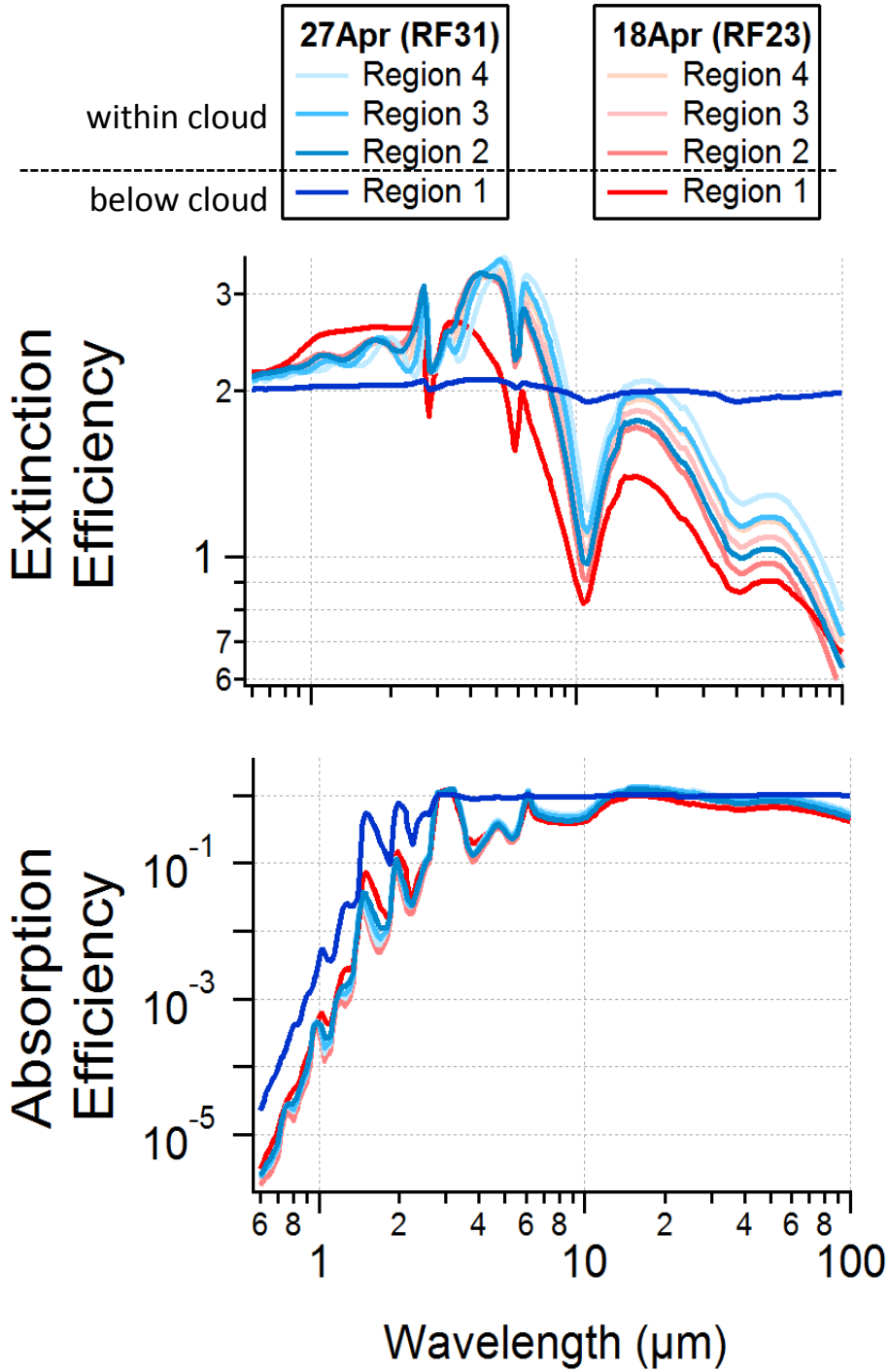


AMS congressional briefing, D. Shindell, May 31, 2006

Summary

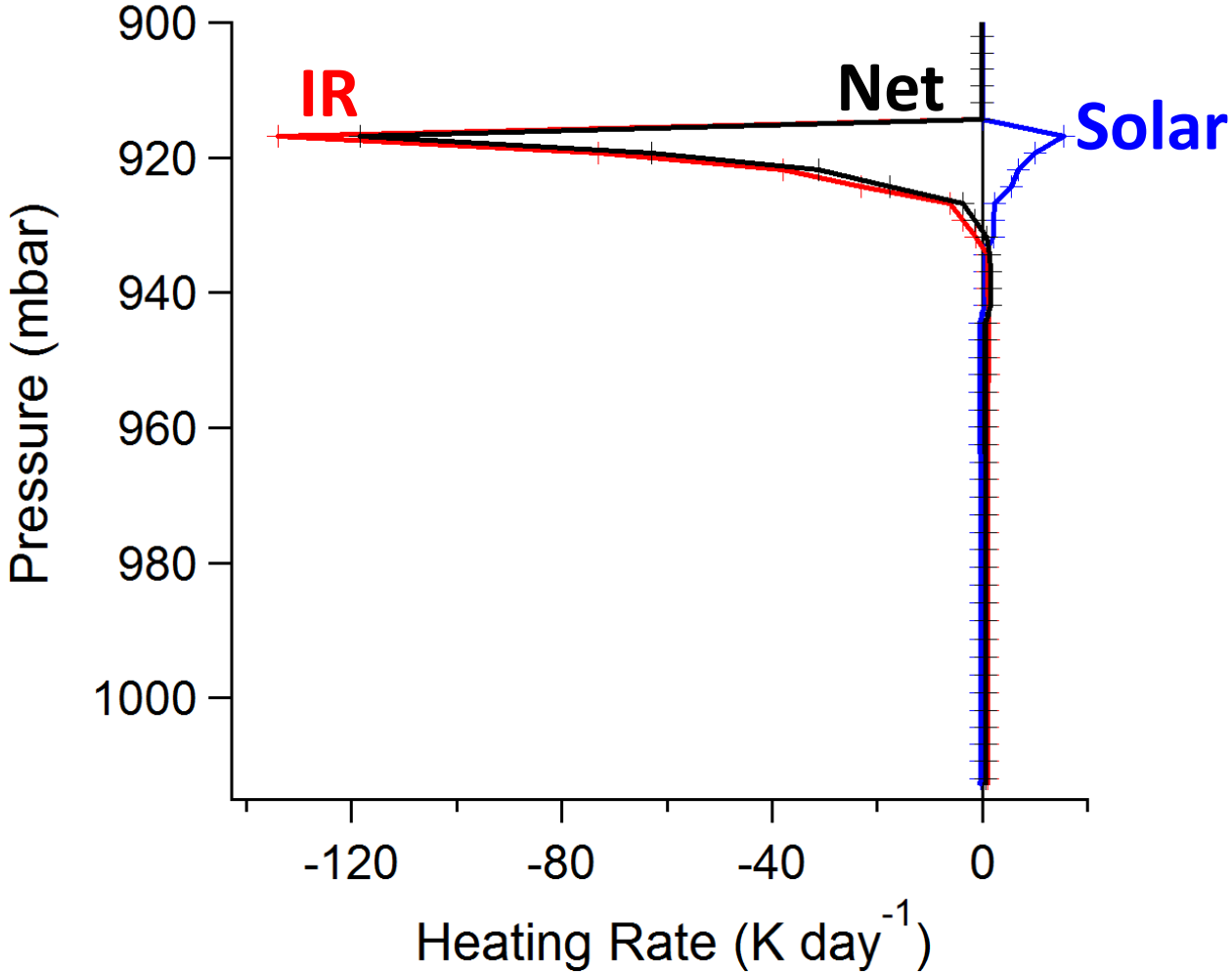
- Surface warming < 1 K/day due to radiative effects of thin Arctic mixed-phase stratus

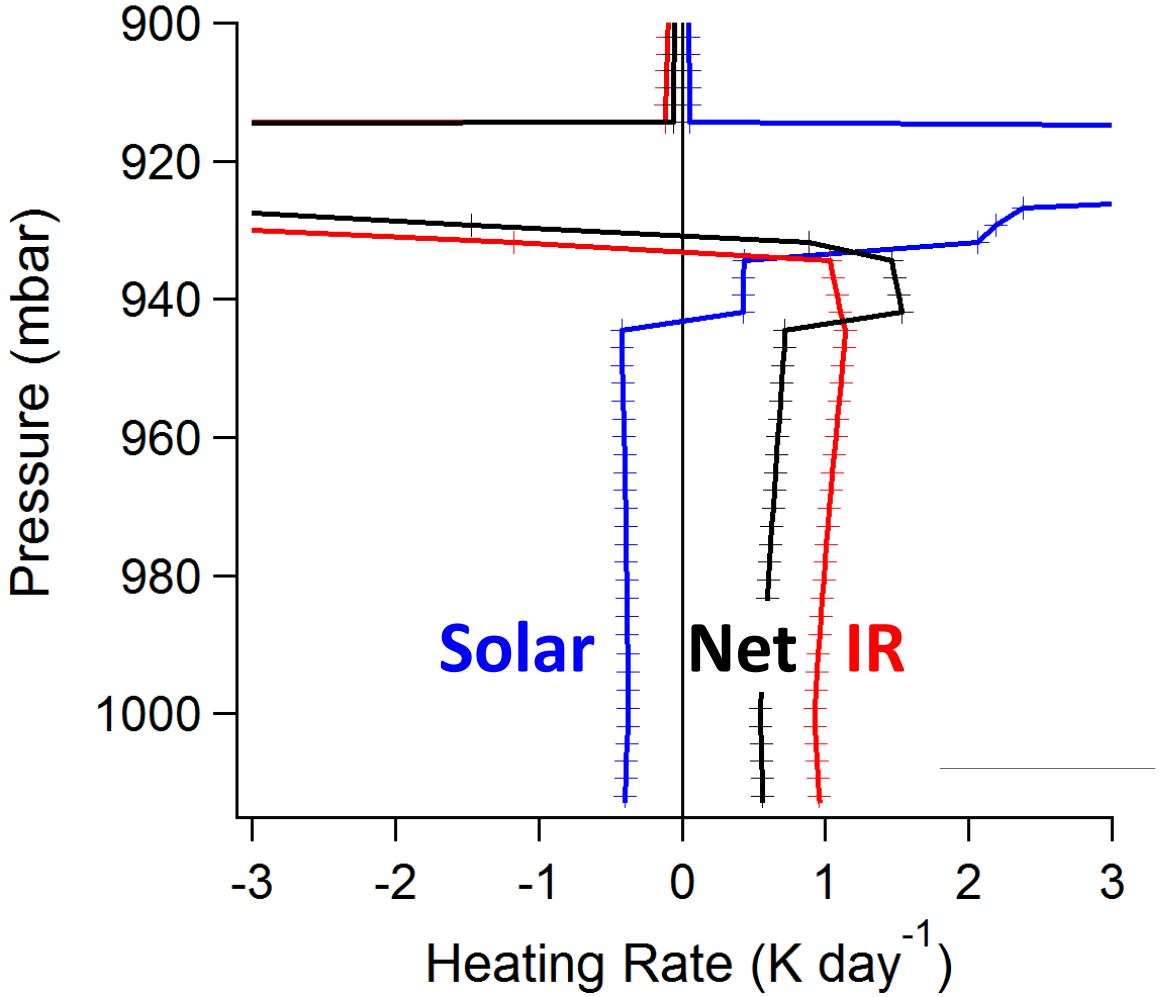
- Factor of 3 difference, for clouds with different microphysical properties



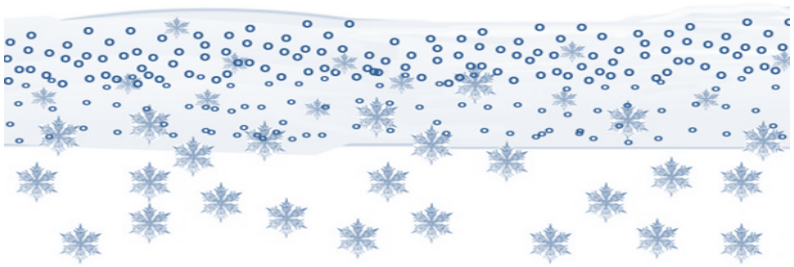
Modified Anomalous Diffraction Approximation (MADA)

- Inputs
  - Ice and water PSDs for several altitude levels
  - Ice Crystal "shape recipe"
- Outputs
  - Extinction Coefficient
  - Single Scatter Albedo
  - Asymmetry Parameter


IR
Net
Solar
900
920
940
960
980
1000
Pressure (mbar)
-120
-80
-40
0
Heating Rate (K day^{-1})


900
920
940
960
980
1000
Pressure (mbar)
Solar
Net
IR
-3
-2
-1
0
1
2
3
Heating Rate (K day^{-1})

0.6 K/day surface warming



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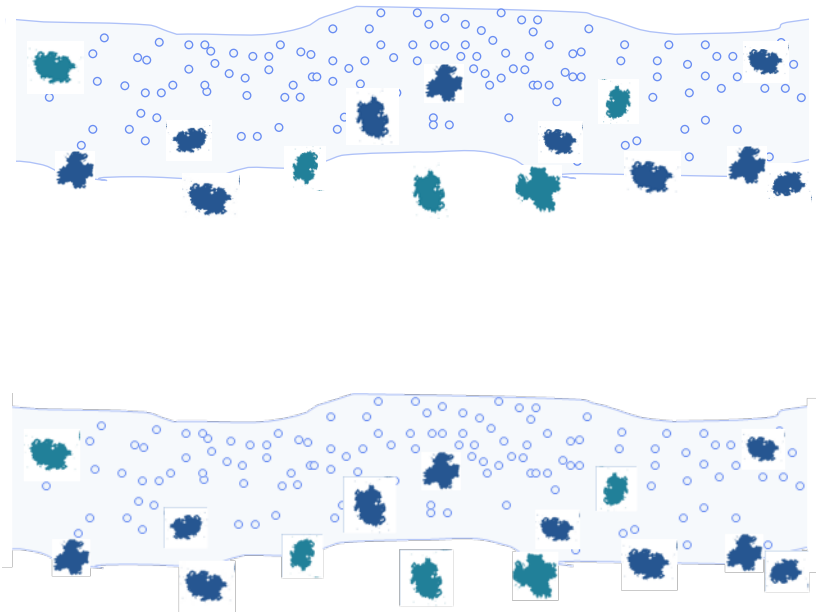

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