The Arctic boundary layer

Interactions with the surface, and clouds, as learned from observations (and some modeling)

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With the help of many: Ola Persson, Chris Fairall, Ian Brooks, Matthew Shupe, Thorsten Mauritsen, Joseph Sedlar, Cathryn Birch and many, many others

Context

- A few words about observations, or the lack thereof
- Boundary-layer structure
- Interaction with the surface: the seasonal story and what’s below
- Interactions with clouds
- Some modeling – here and there

A few words about observations

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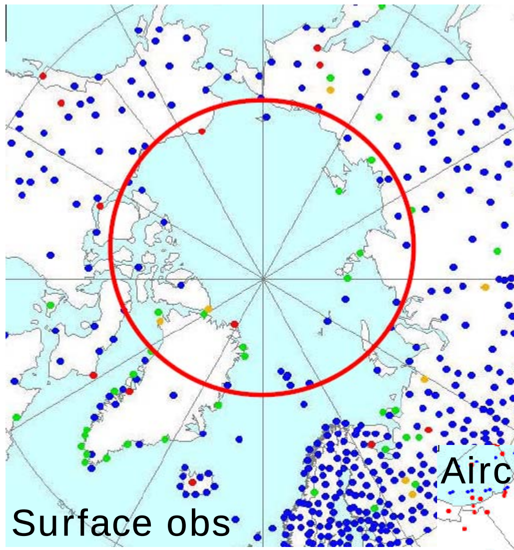

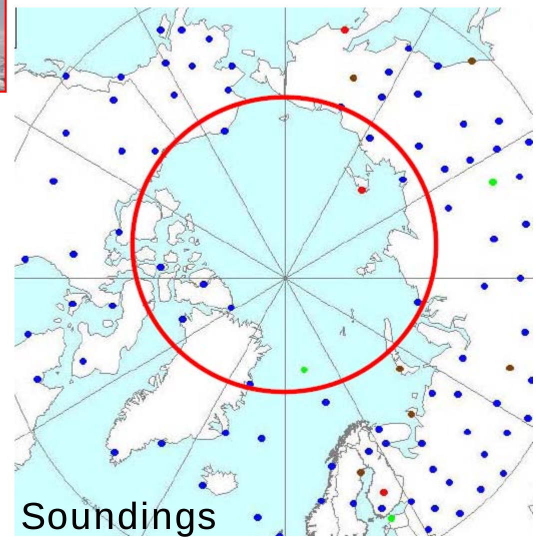

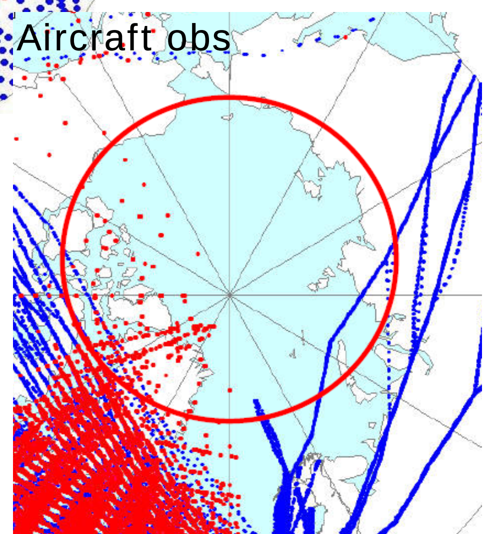

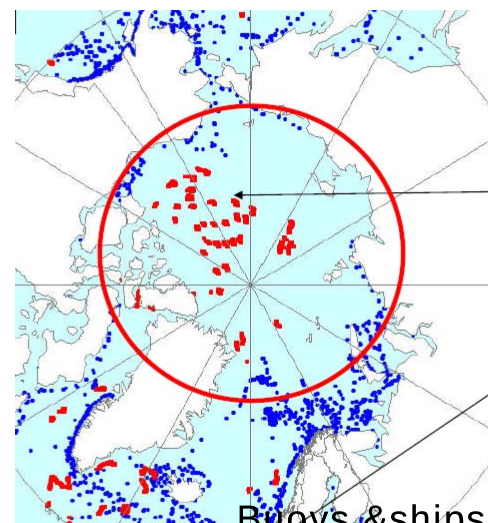

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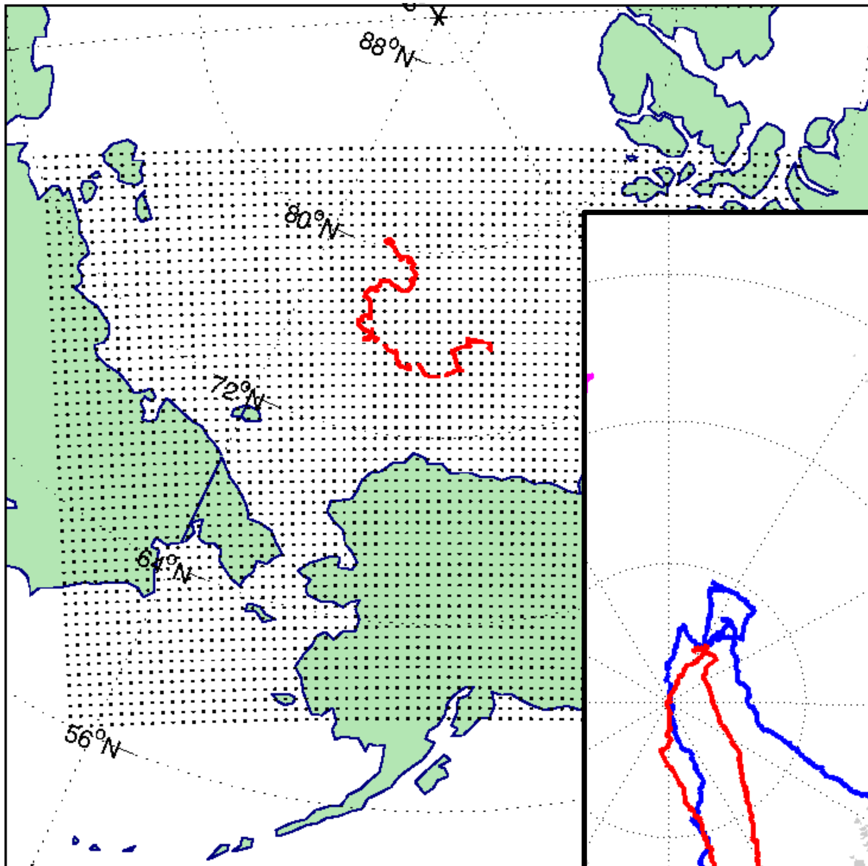
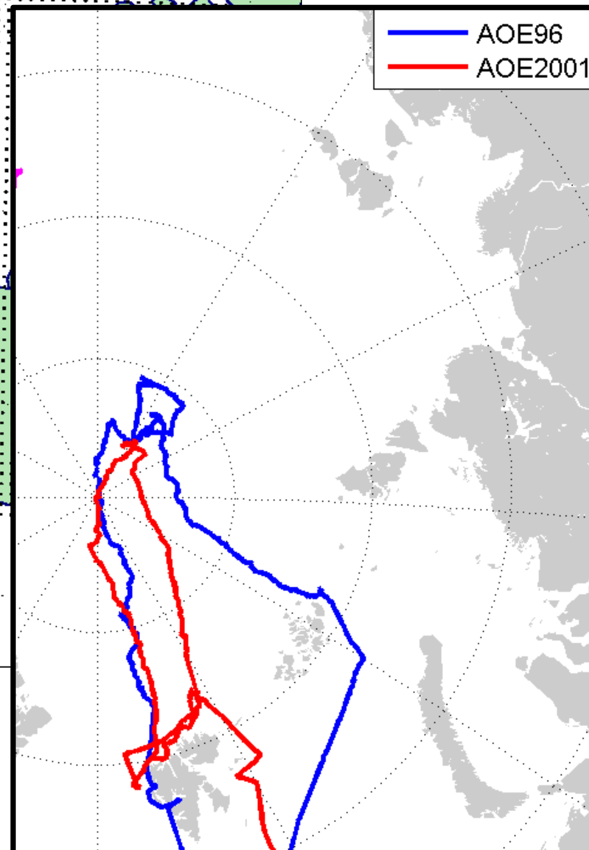
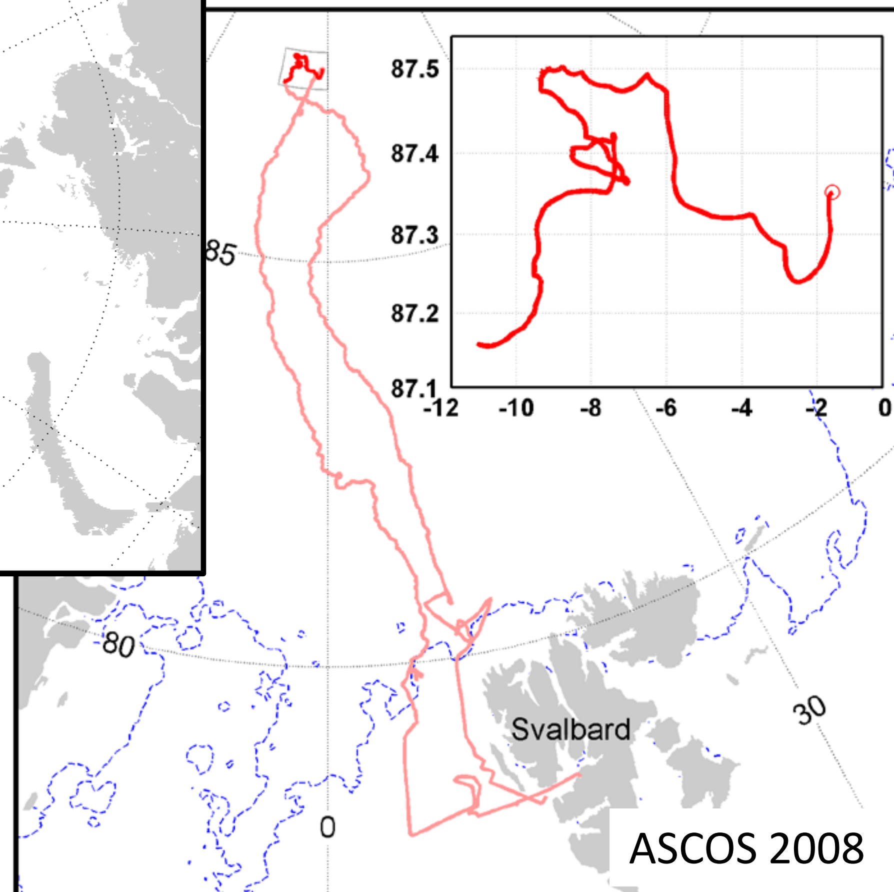
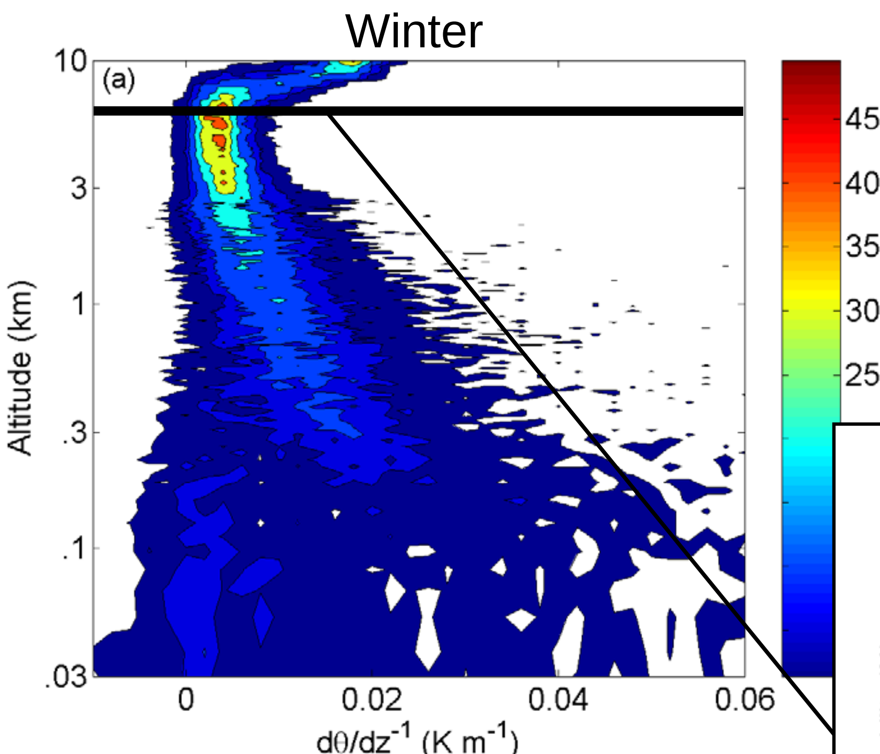


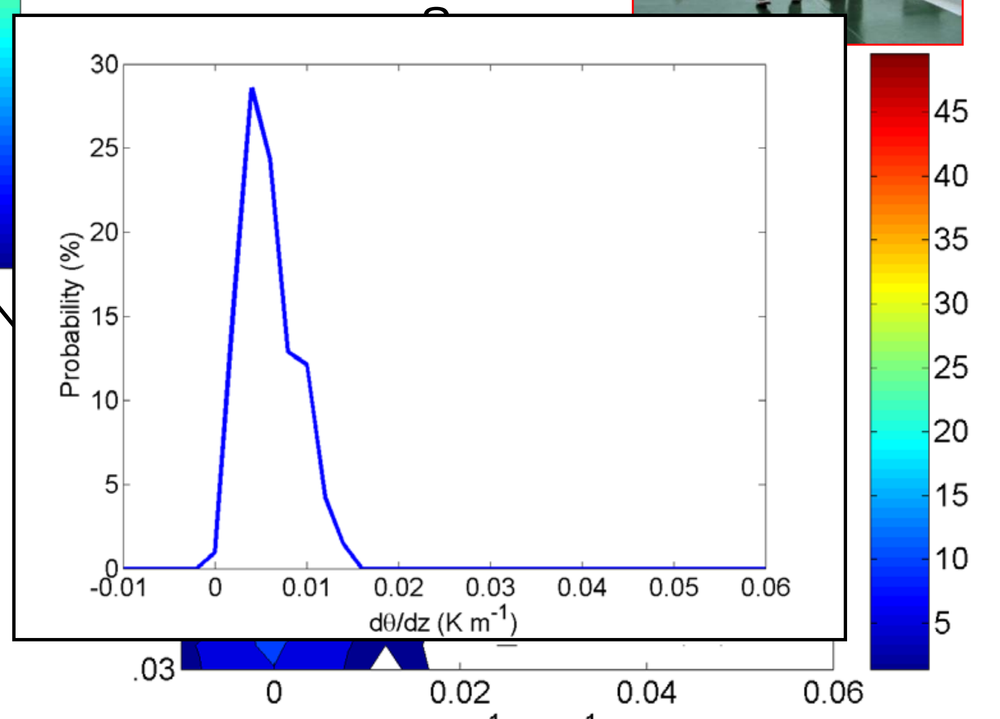




Arctic troposphere vertical structure

From SHEBA soundings





Tjernström & Graversen 2009

Arctic troposphere vertical structure

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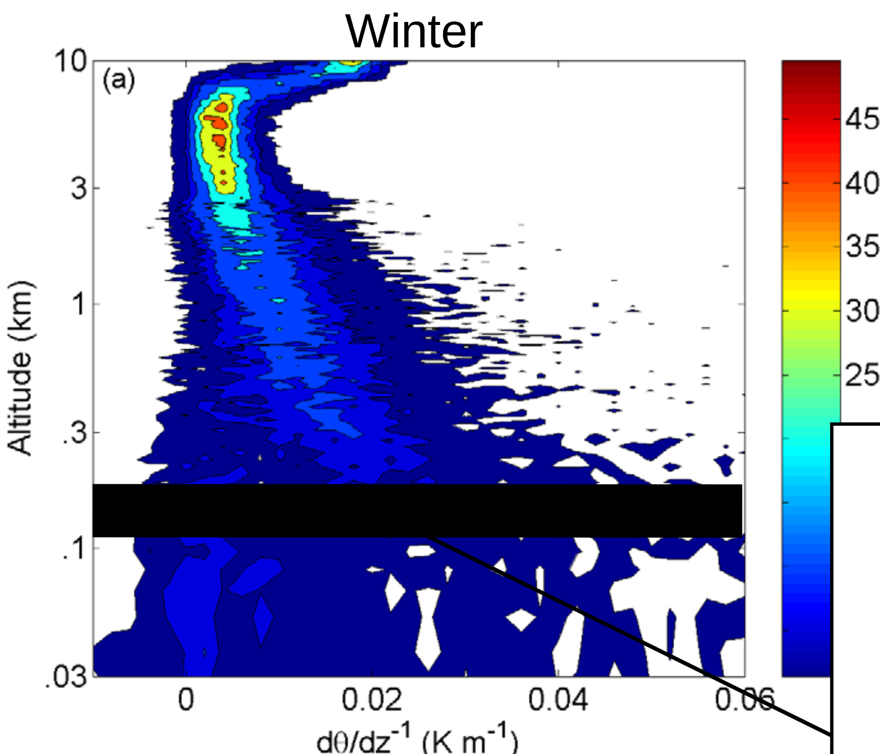

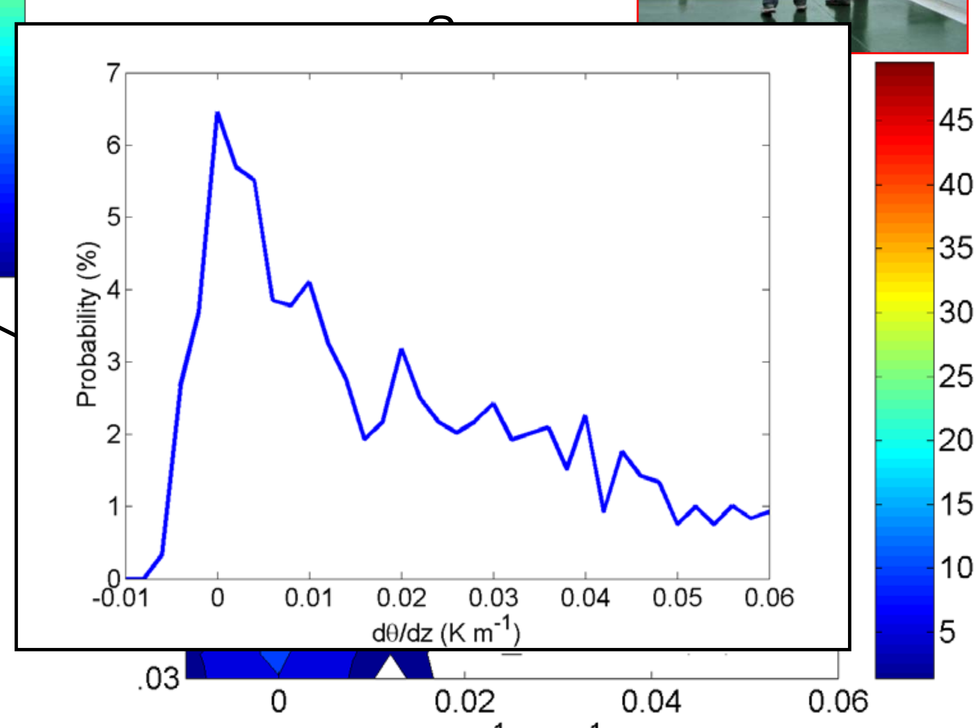

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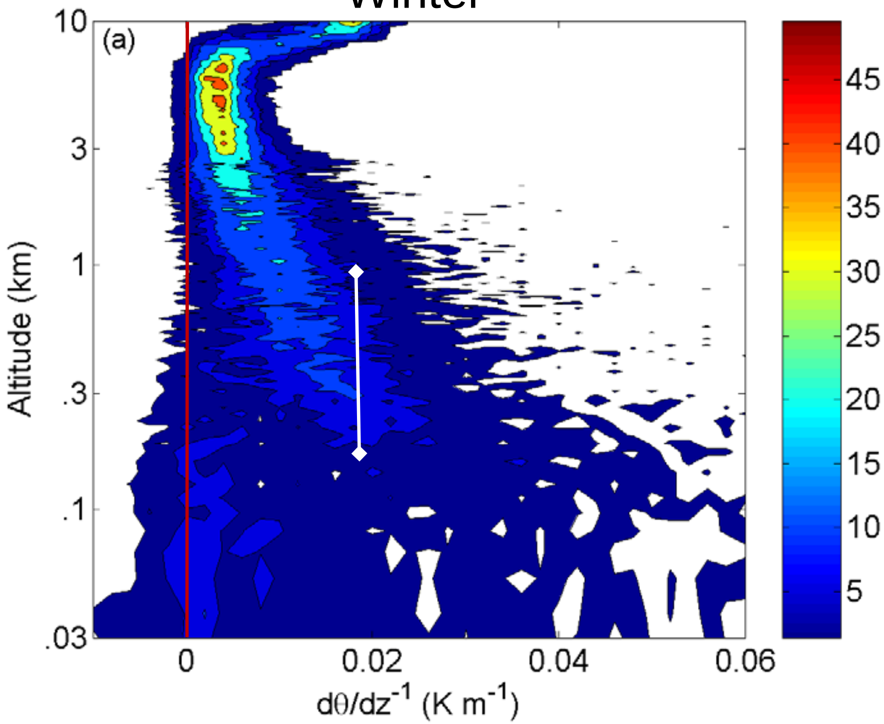
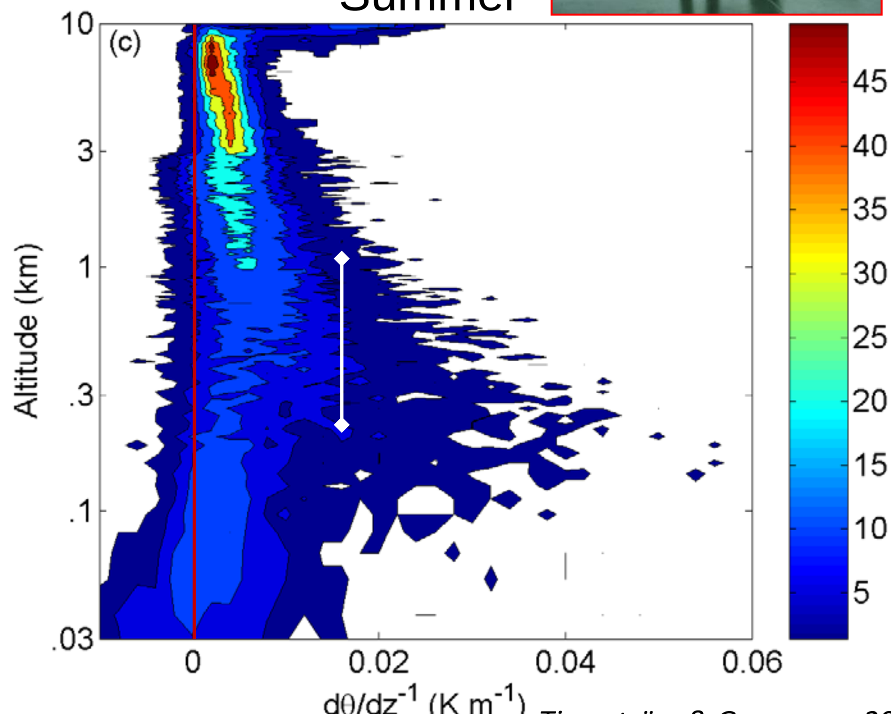
Arctic troposphere vertical structure

From SHEBA soundings

Winter



Summer



All seasons: Stable layer 200 m to ~2 km, near neutral 5-8 km & often near neutral PBL.

Winter: Additionally strong surface inversions ~ 50% of the time

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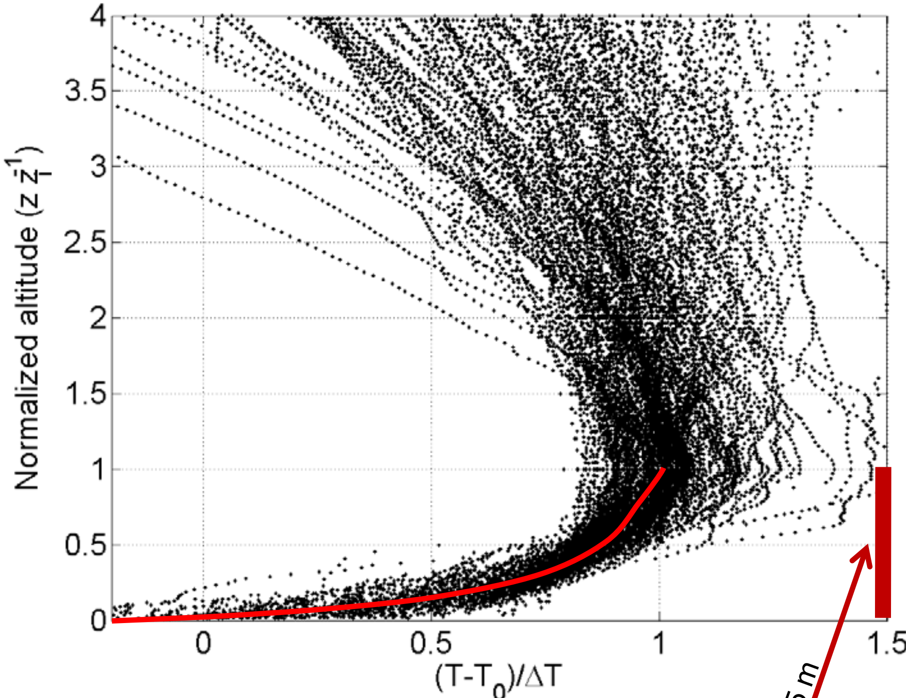
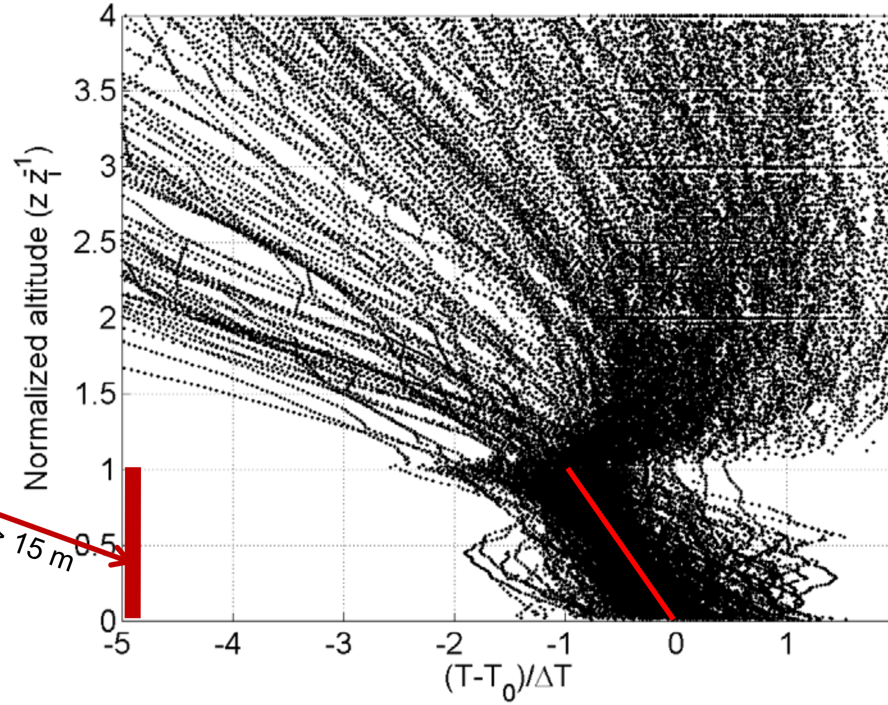
Surface inversion



	Winter	Spring	Summer	Autumn
Surface	53%	15%	9%	61%
Lifted	47%	85%	91%	39%

Lifted inversion



"Boundary layer"

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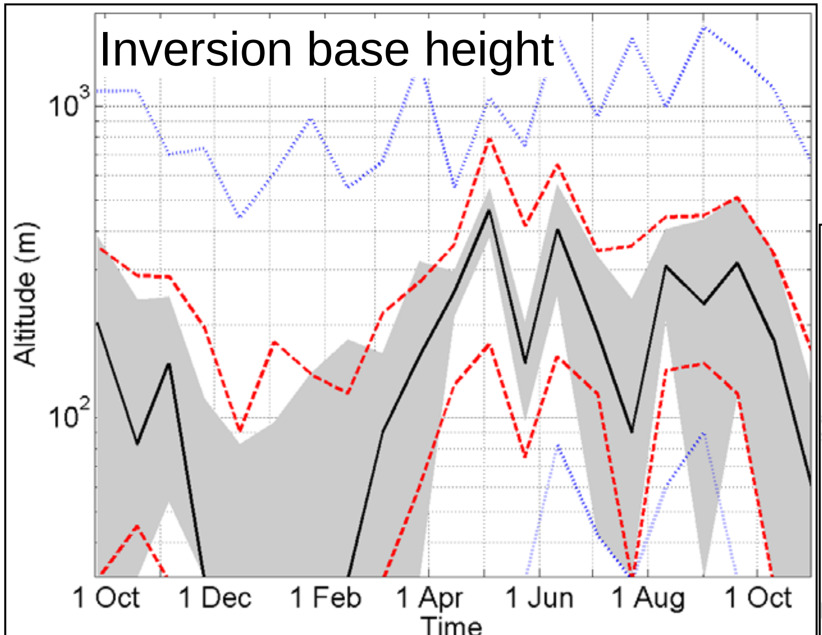
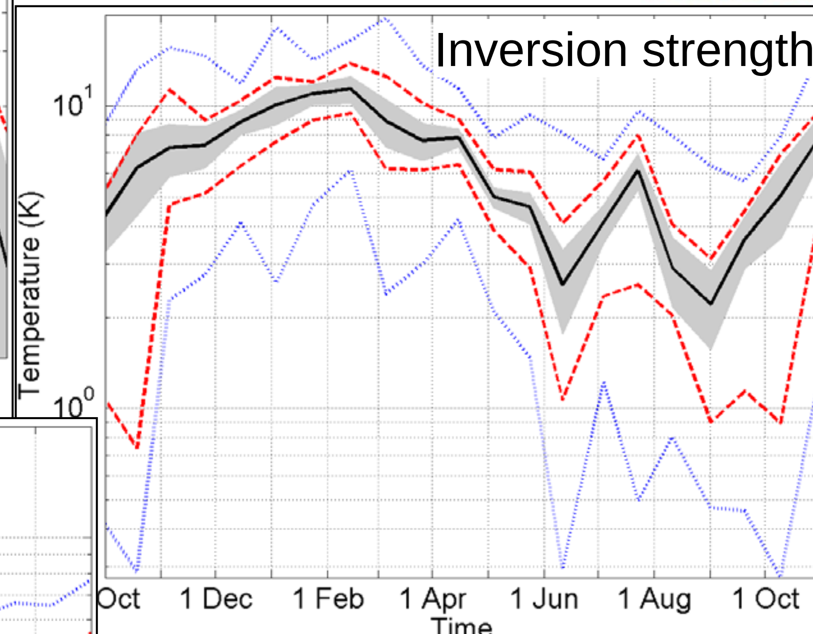
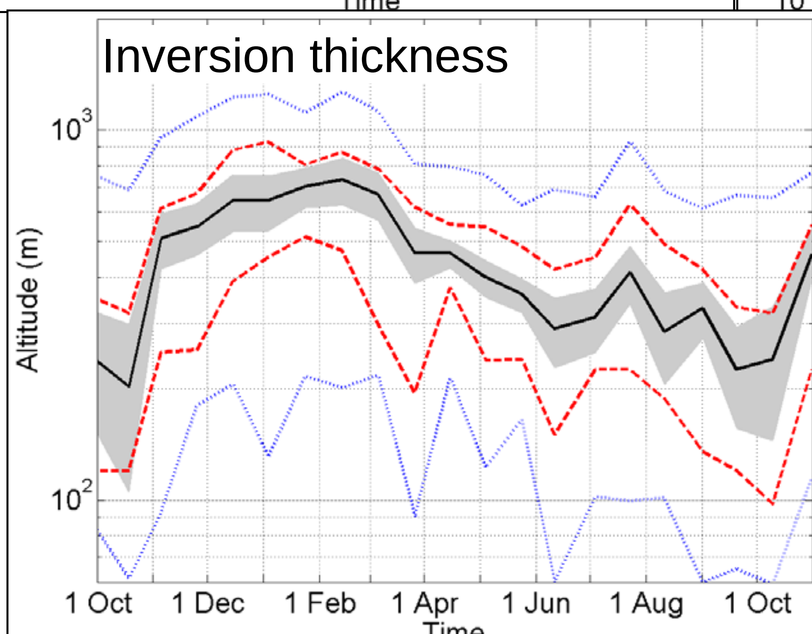
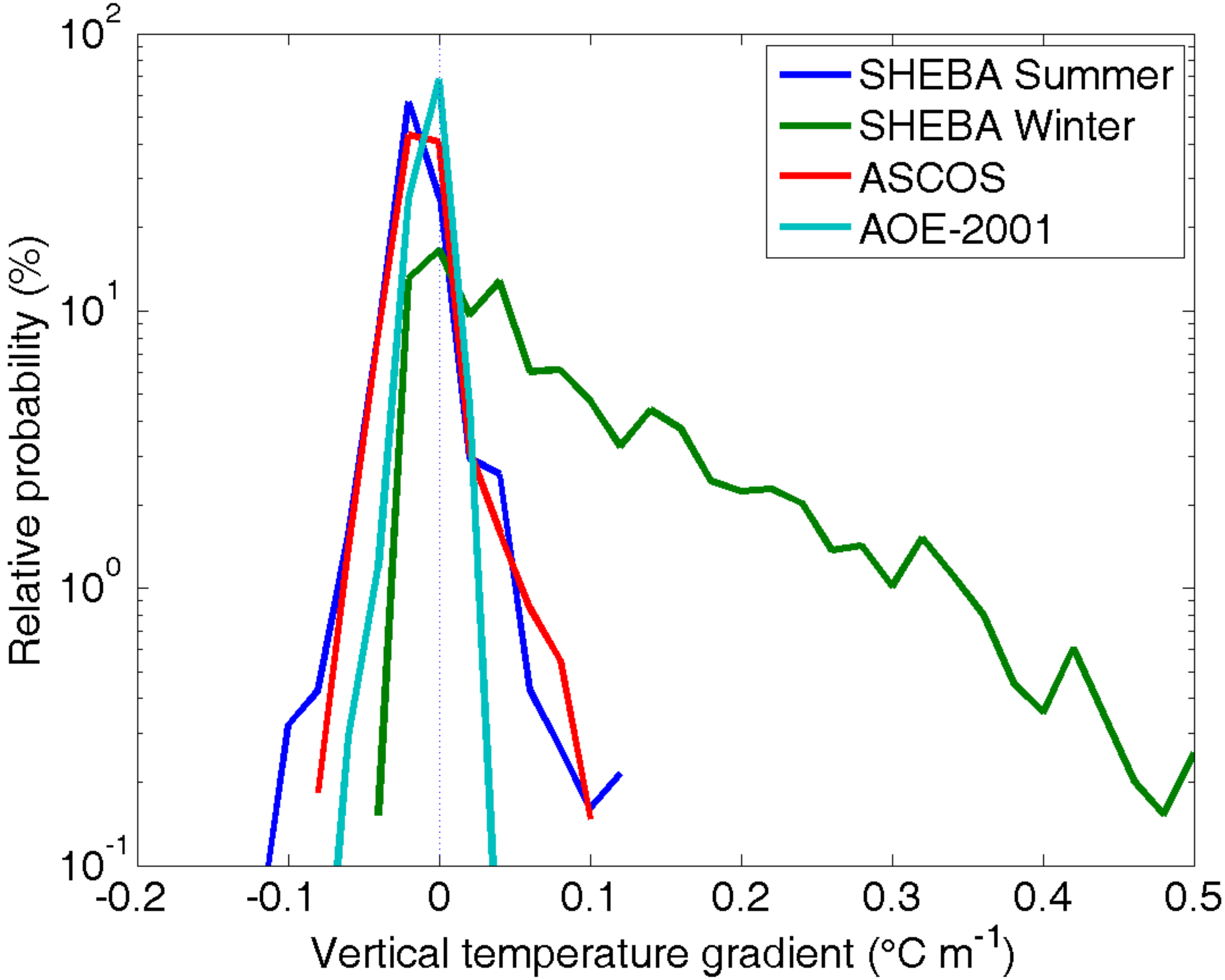


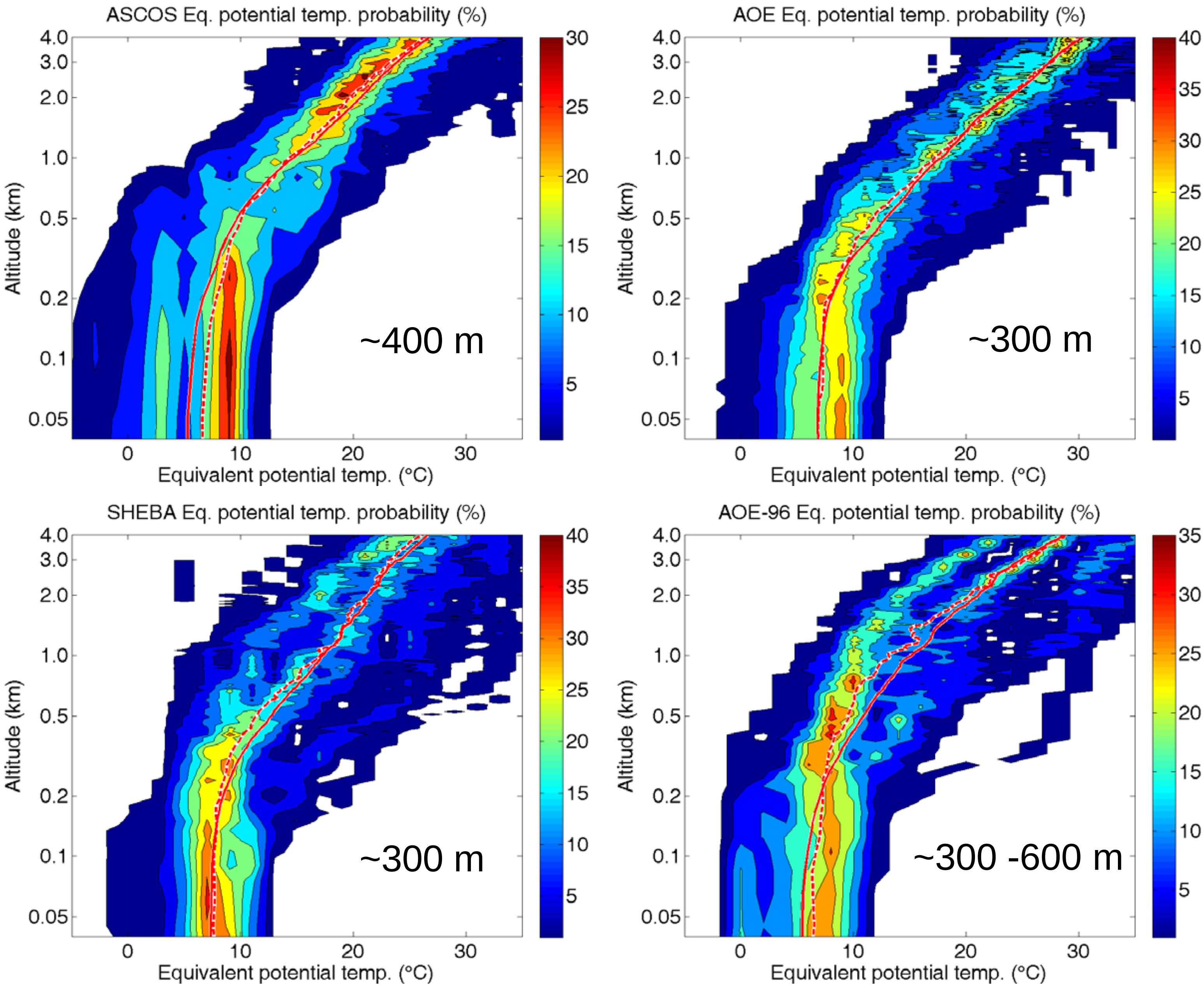




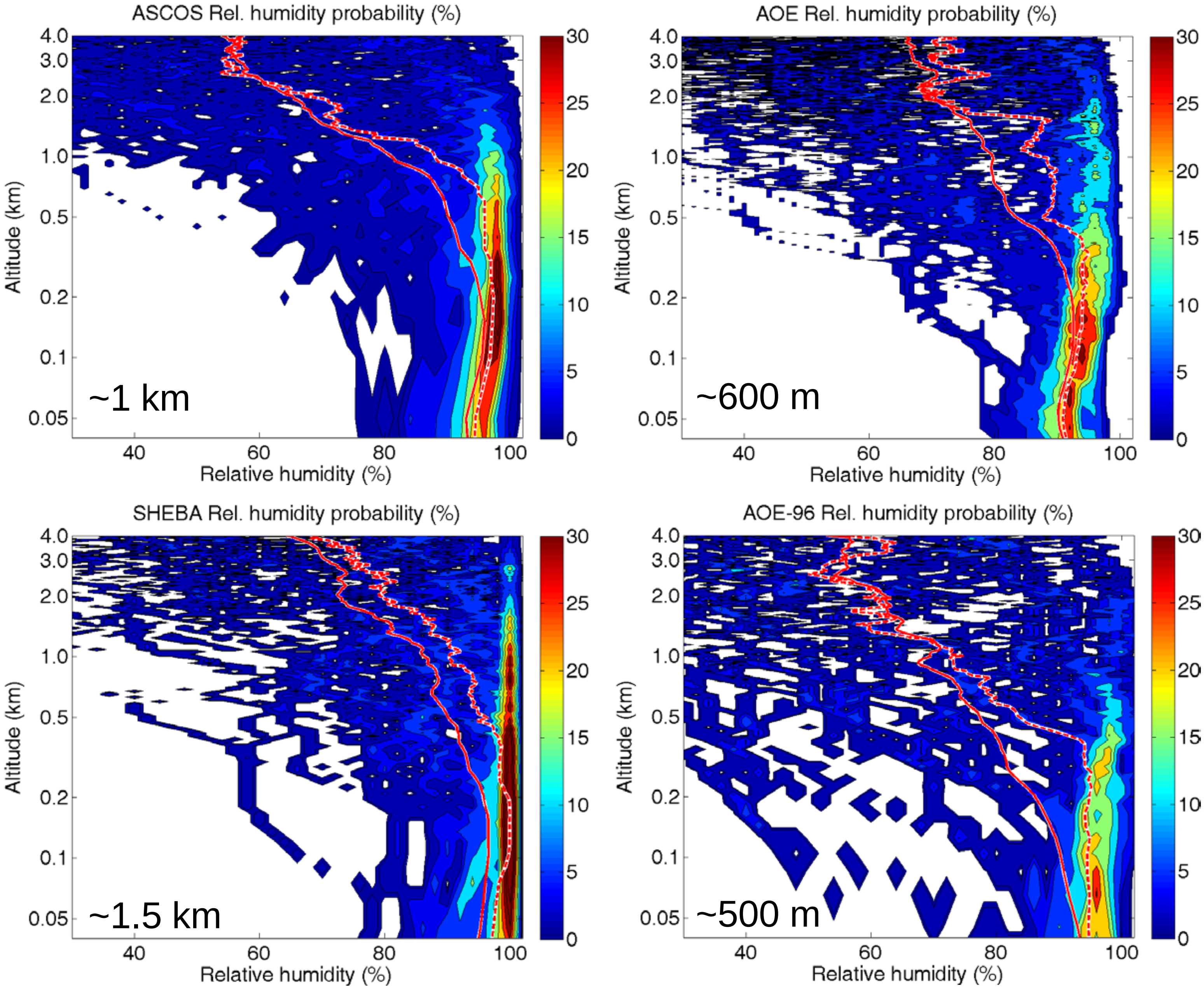
Near-surface stability



Vertical thermal structure



Vertical moisture structure



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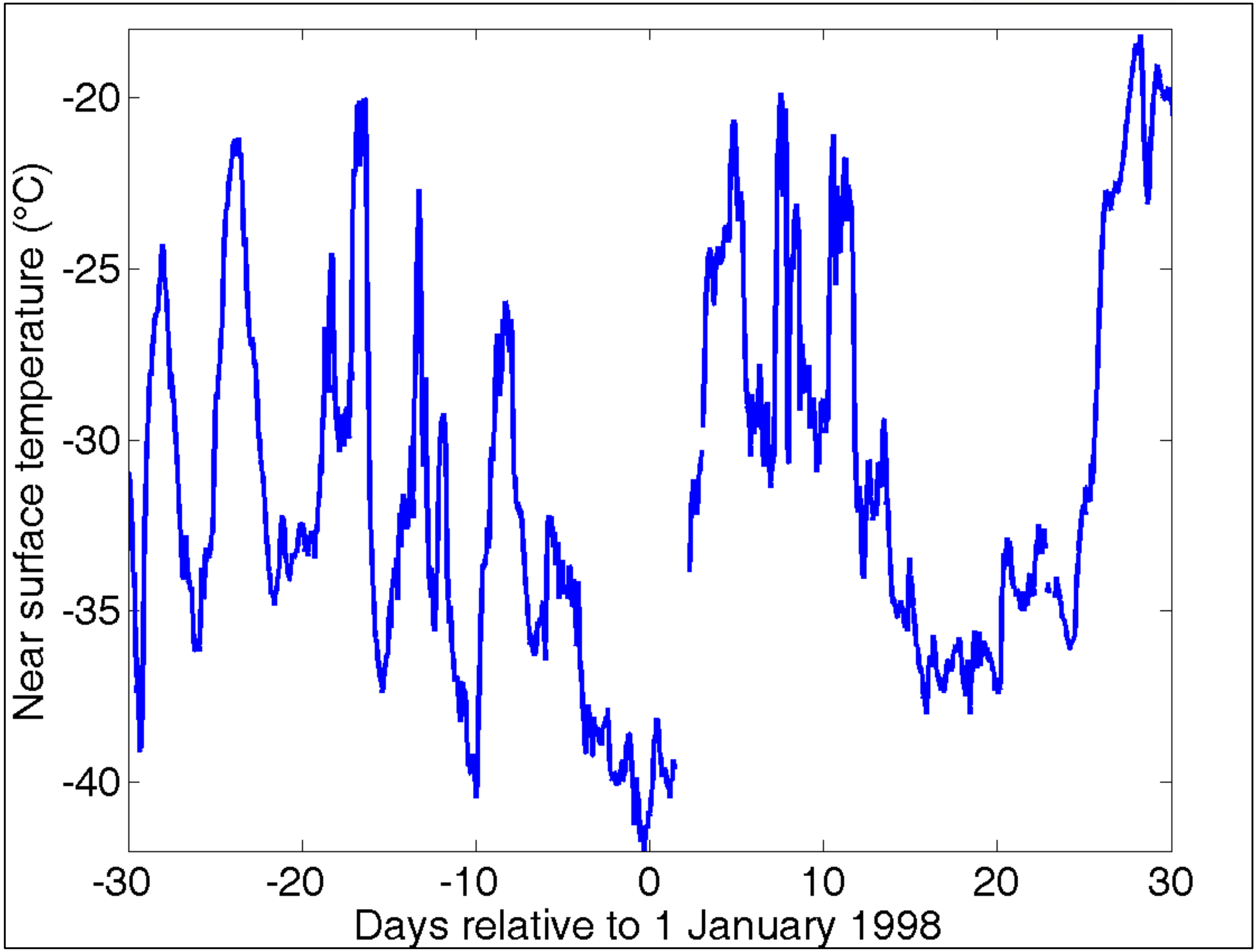
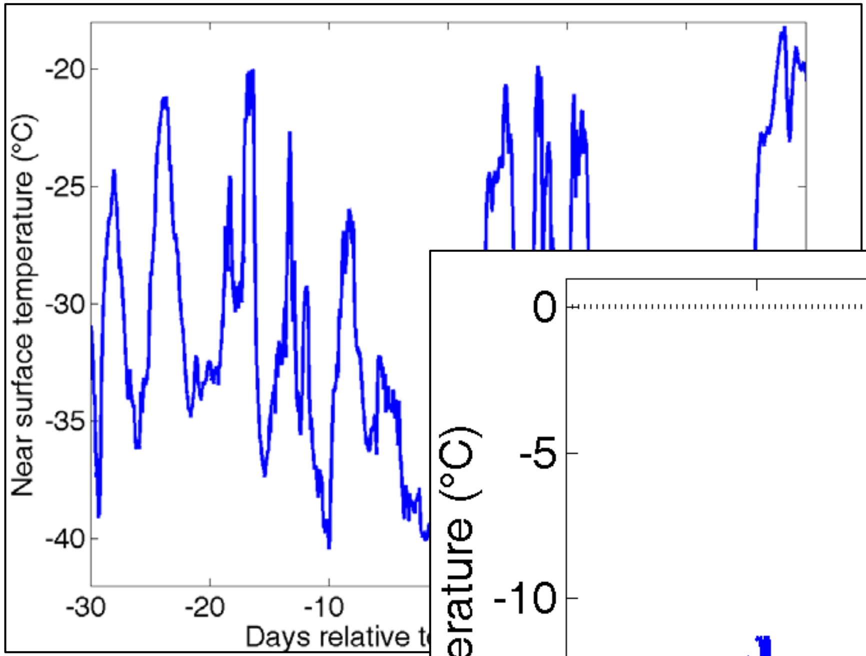
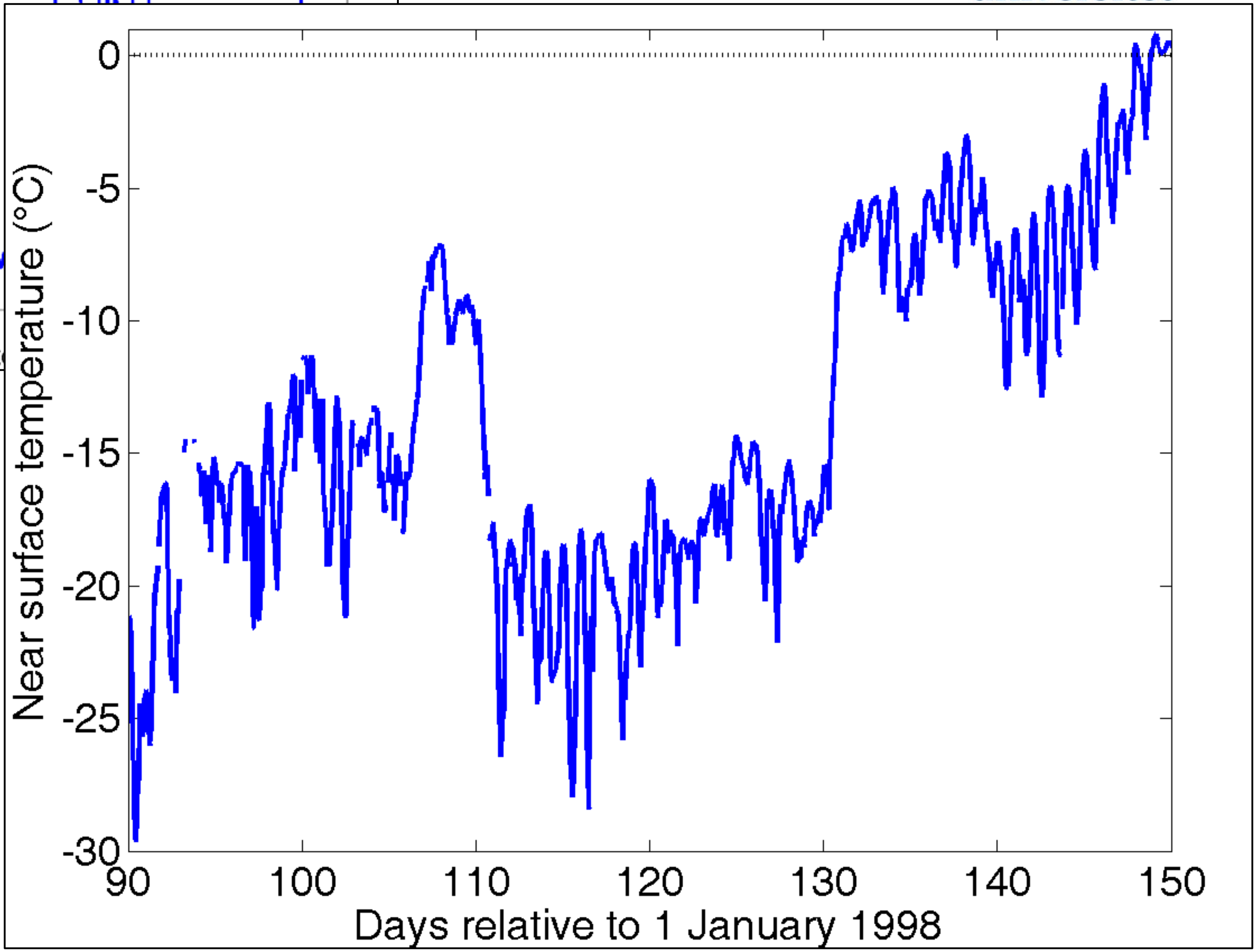


Near surface temperature (°C)
-20
-25
-30
-35
-40
-30
-20
-10
0
10
20
30
Days relative to 1 January 1998





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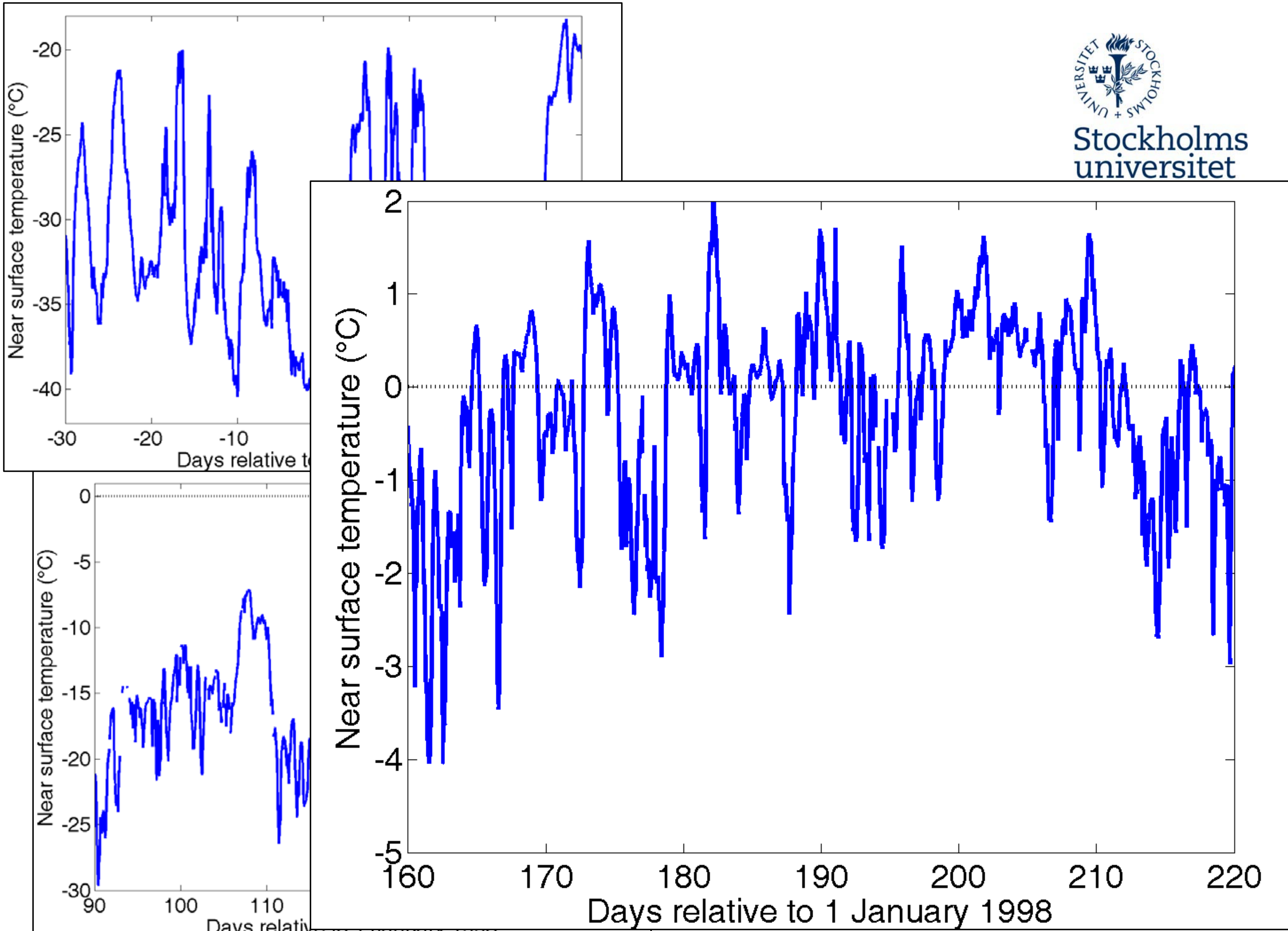
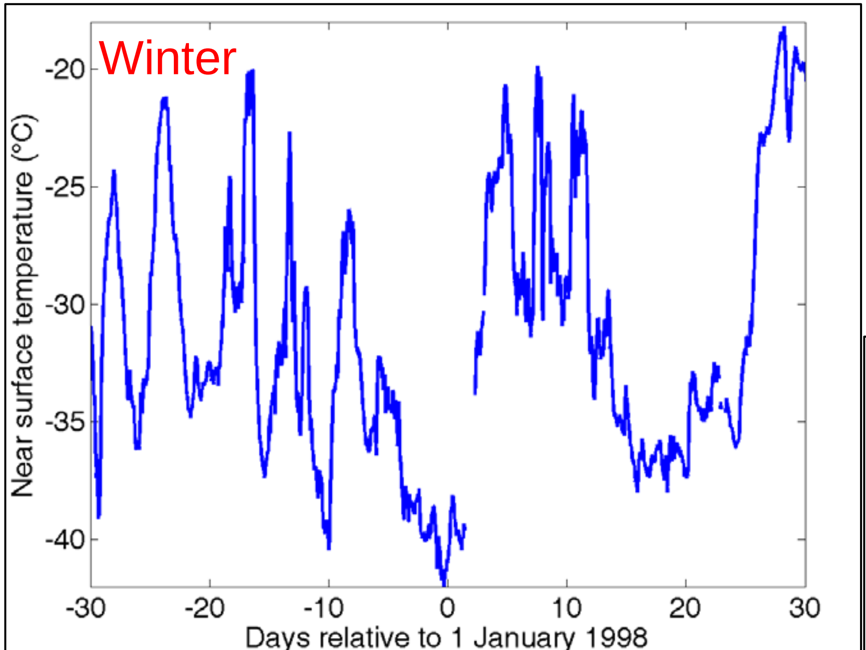
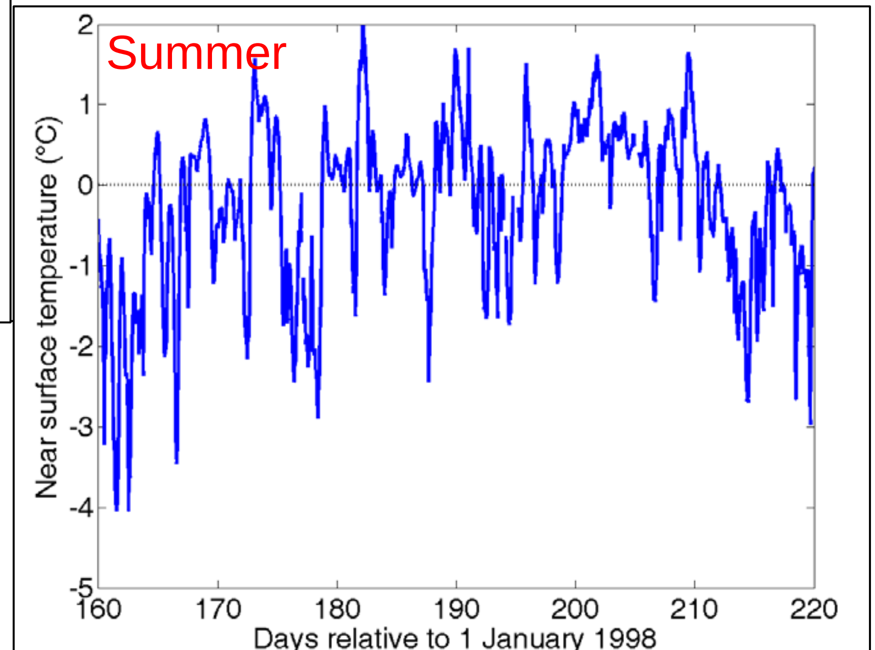
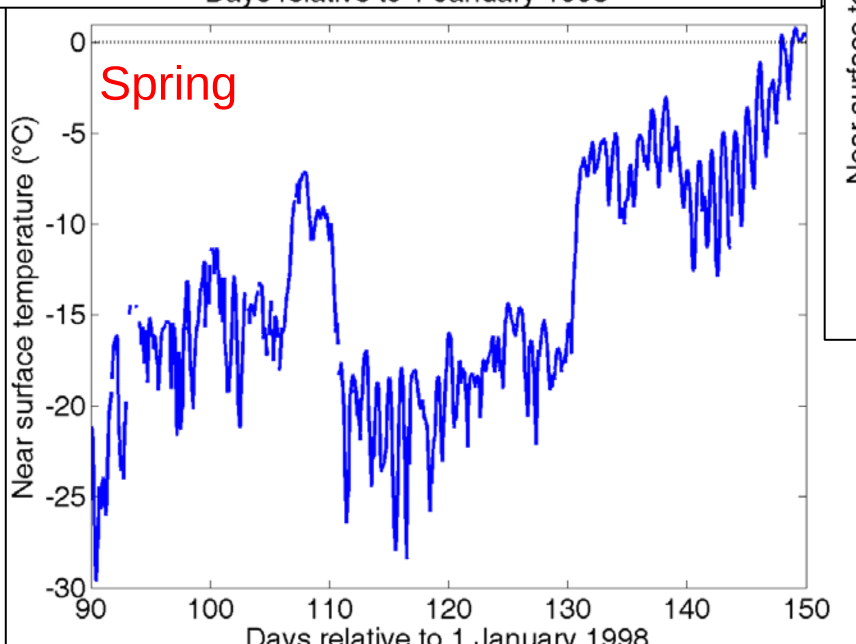

Near surface temperature (°C)
-20
-25
-30
-35
-40
-30
-20
-10
Days relative t
0
-5
-10
-15
-20
-25
-30
90
100
110
Days relativ
2
1
0
-1
-2
-3
-4
-5
160
170
180
190
200
210
220
Days relative to 1 January 1998







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SHEBA surface temperatures

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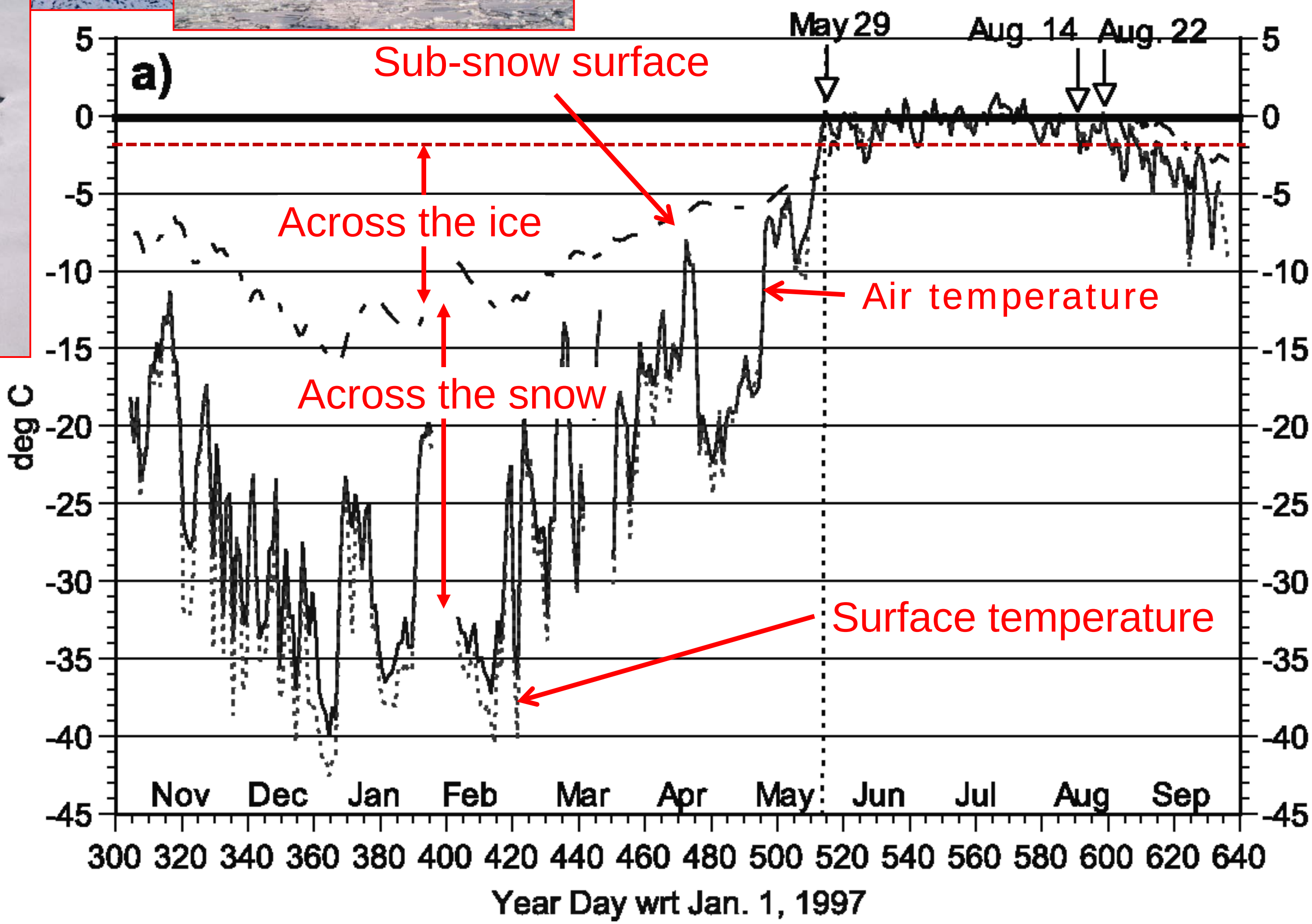
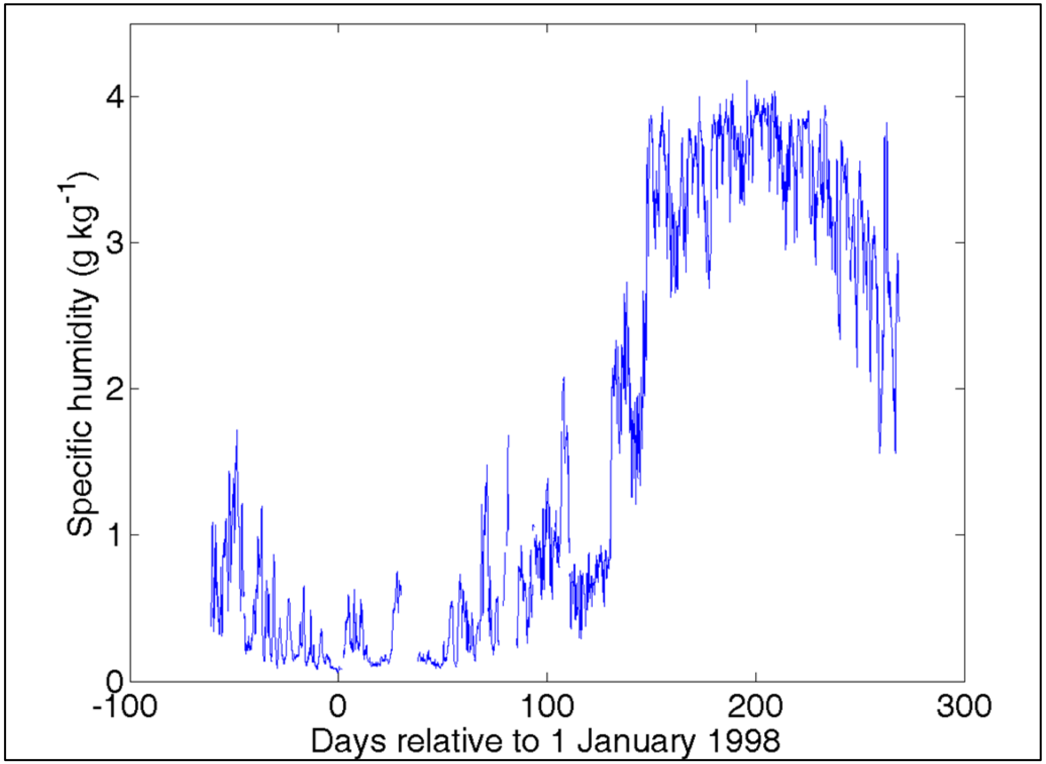
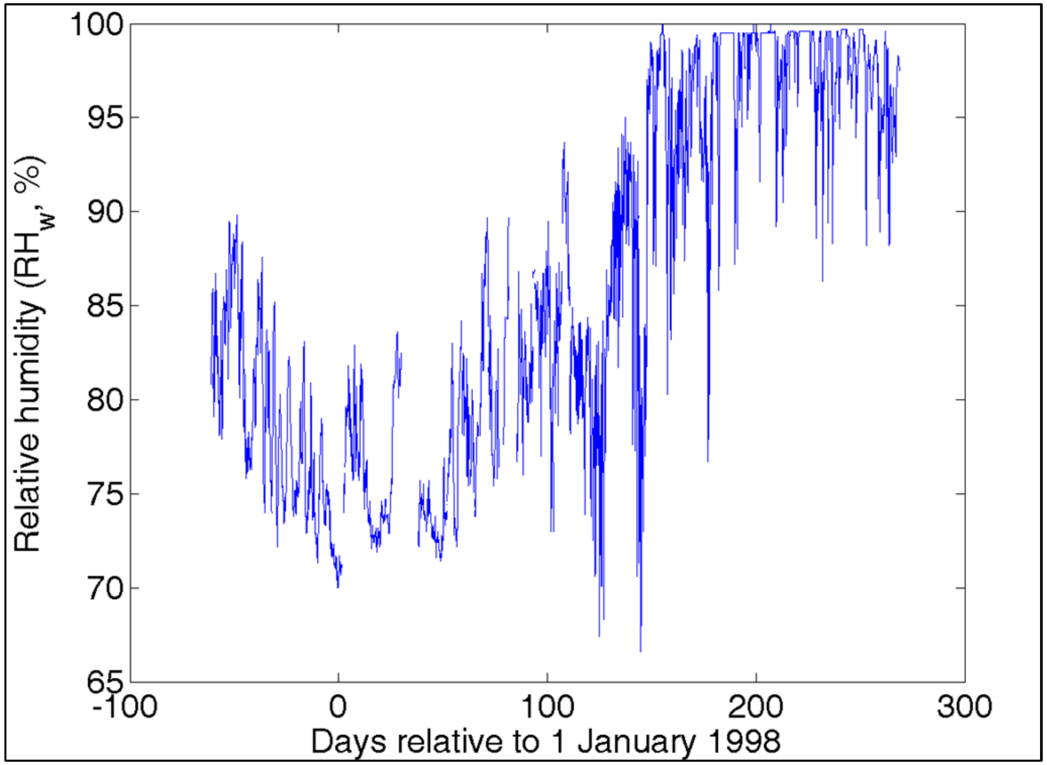


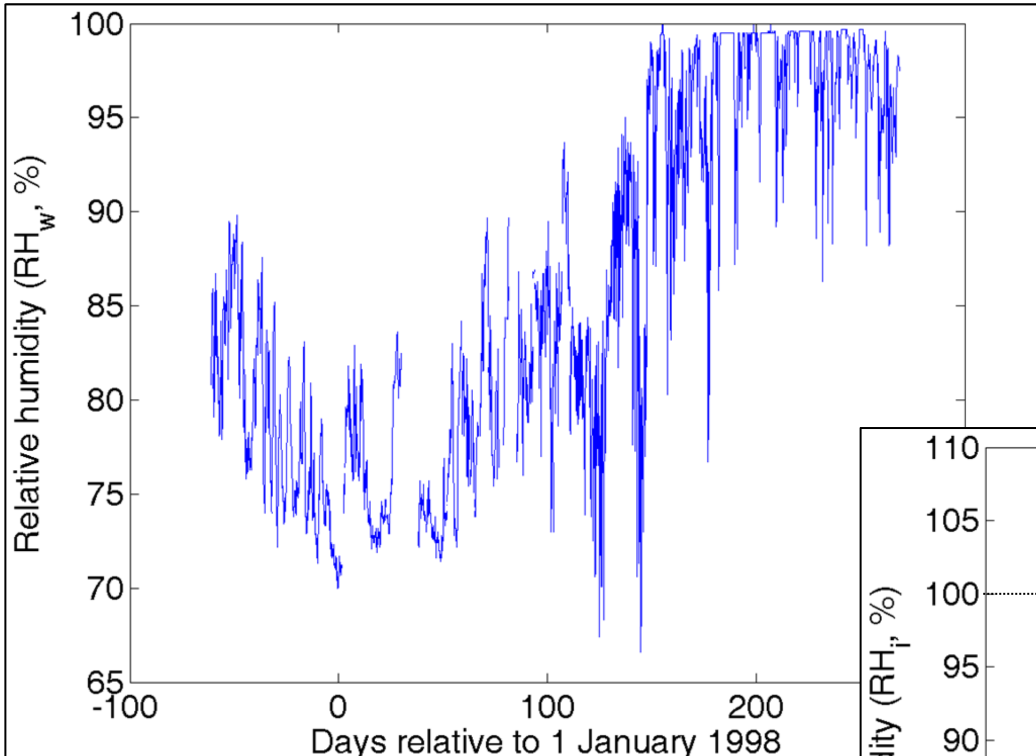


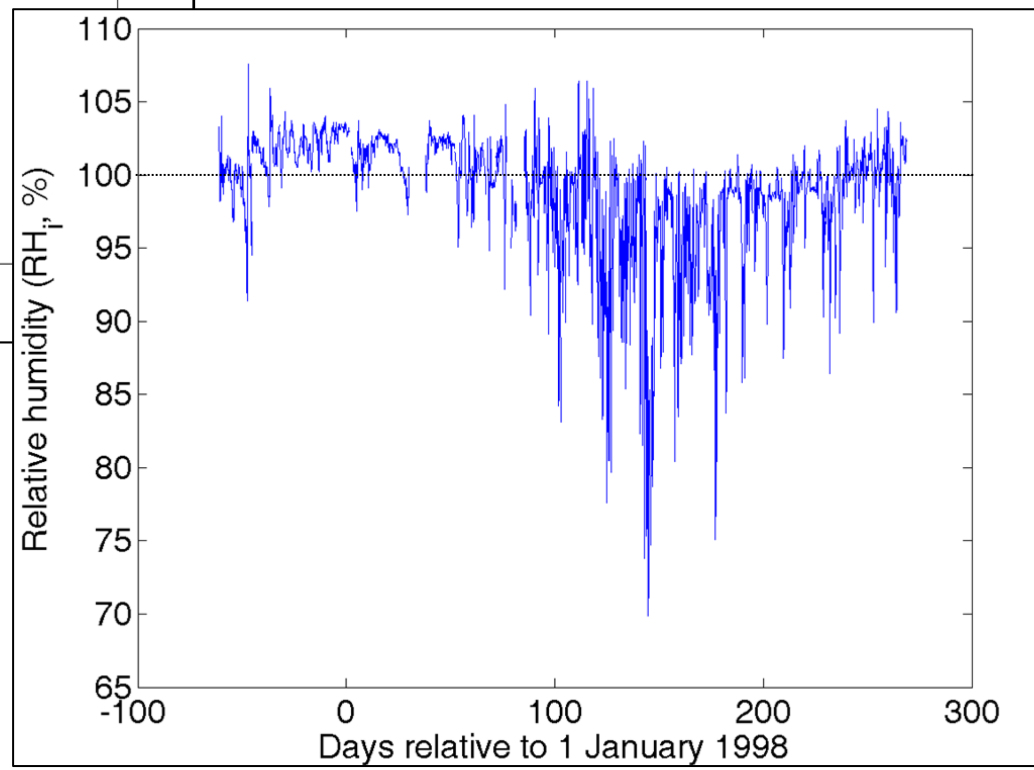
Specific humidity (g kg-1)
4
3
2
1
0
-100
0
100
200
300
Days relative to 1 January 1998

SHEBA Relative humidity



SHEBA Relative humidity





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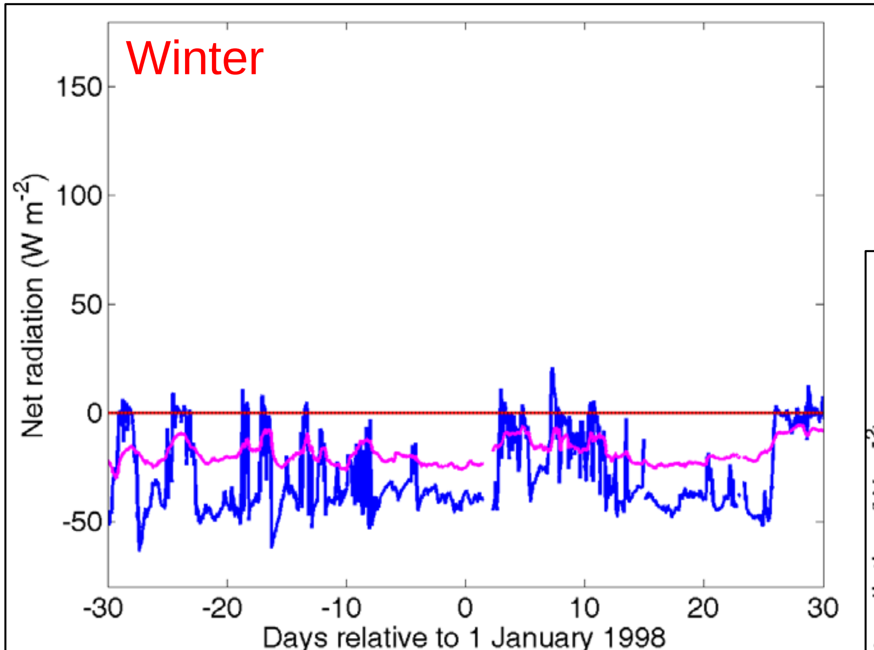

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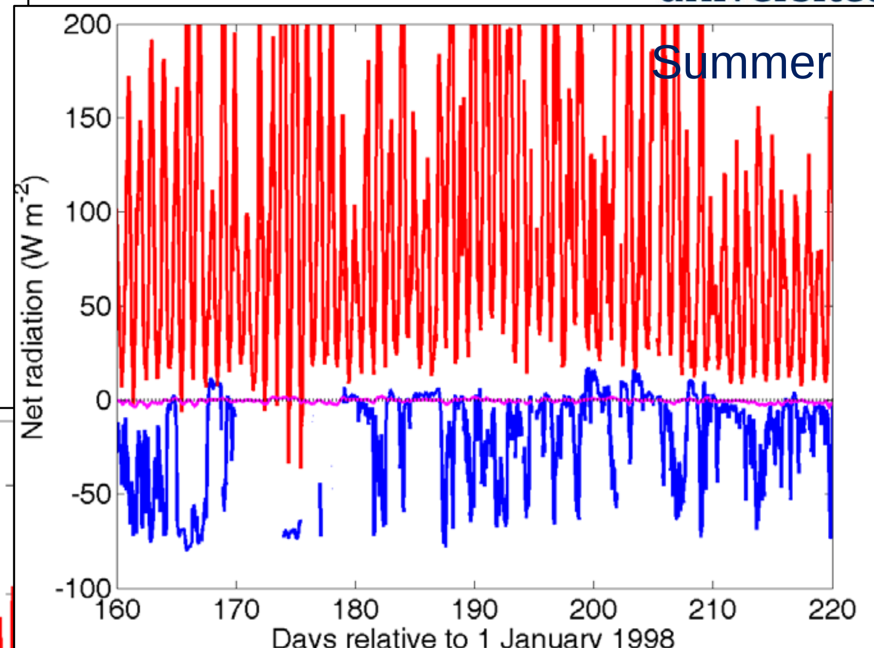

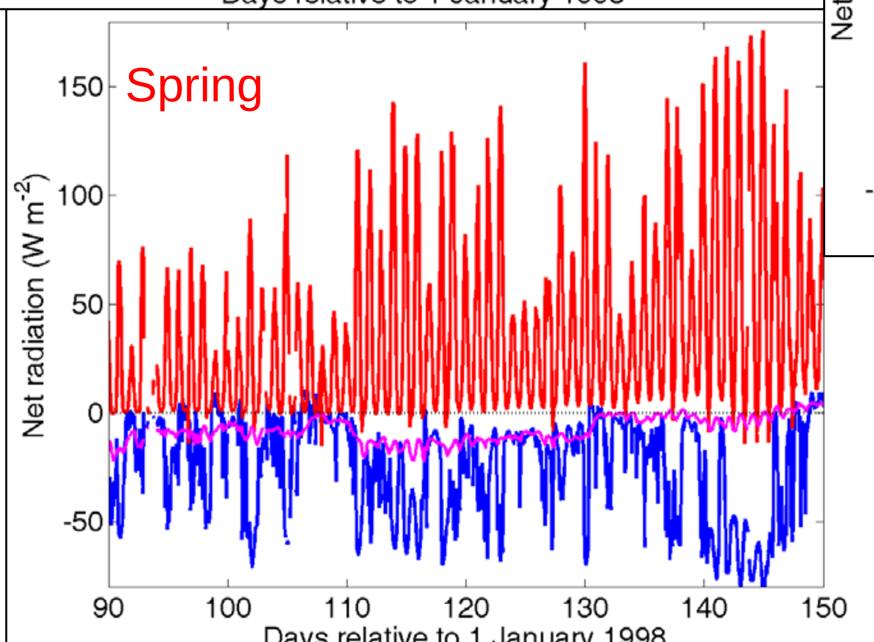

SHEBA stability

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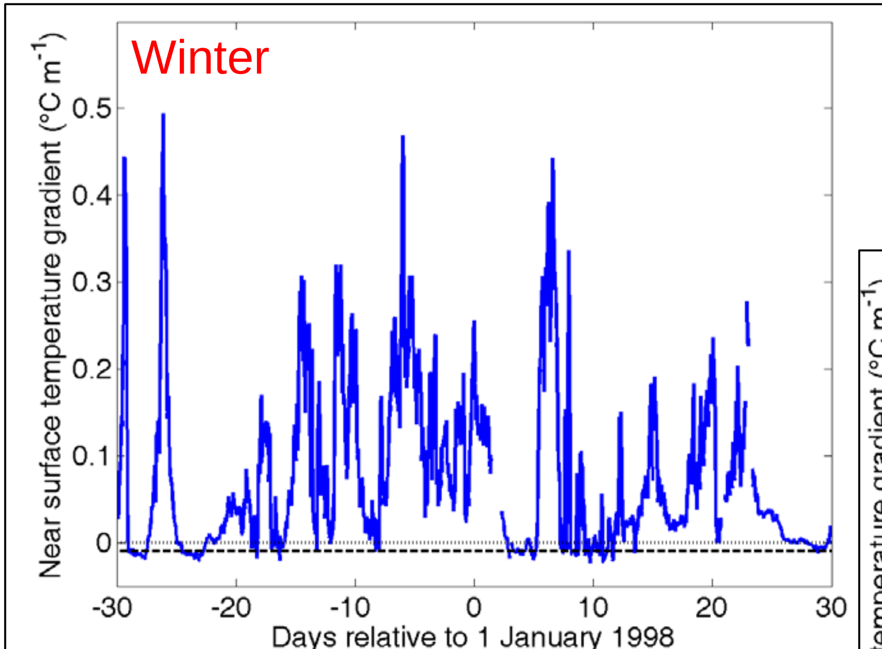

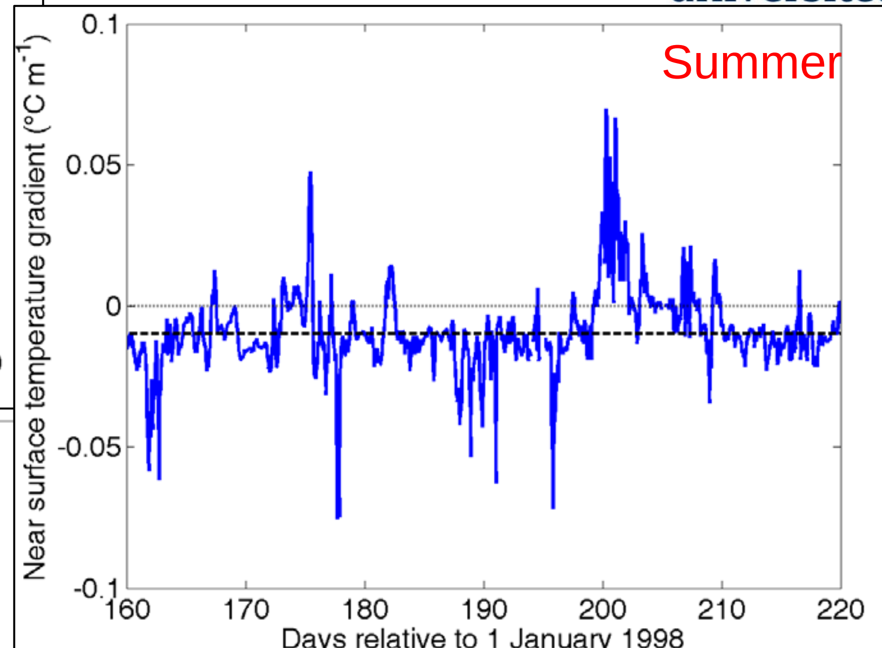

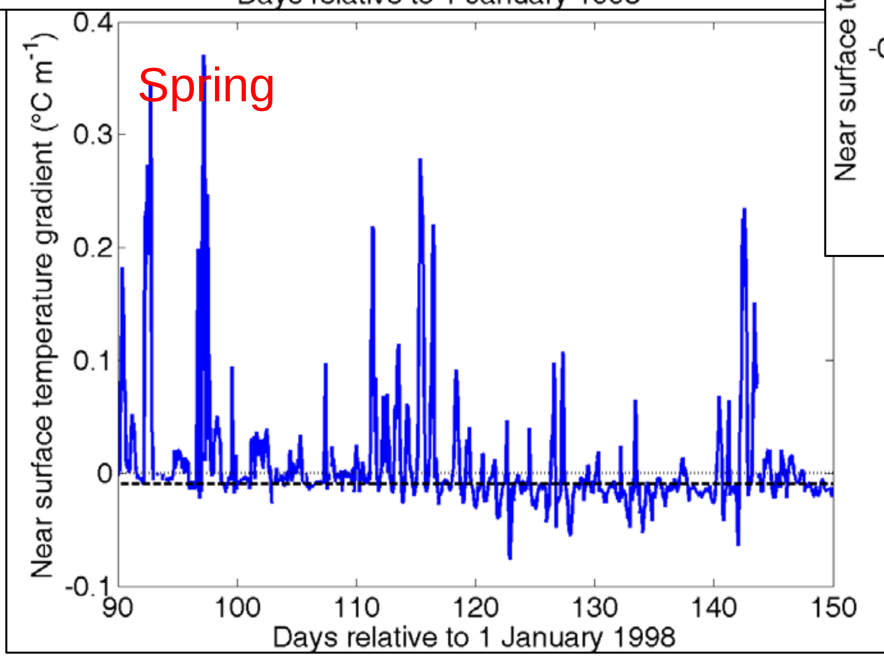

SHEBA sensible heat flux

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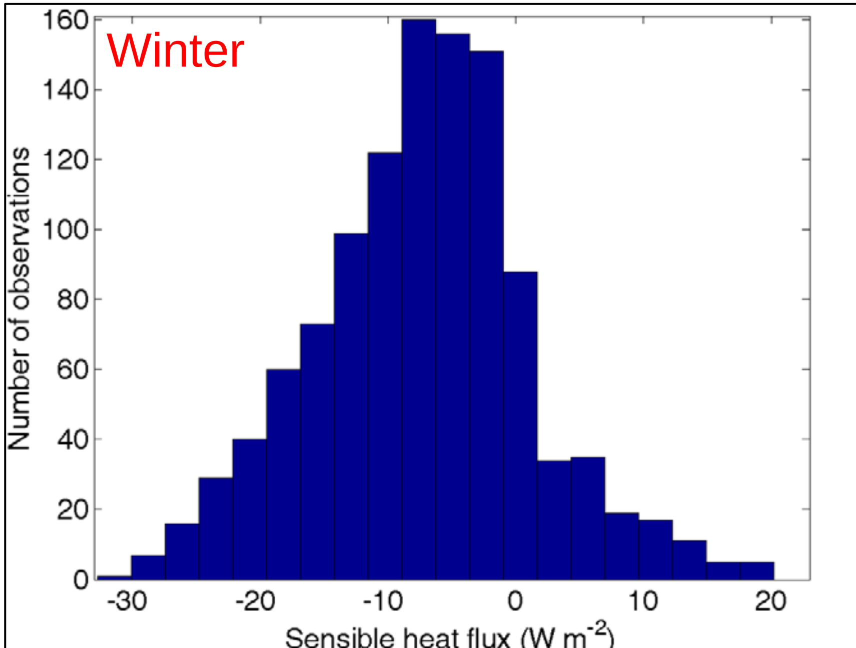
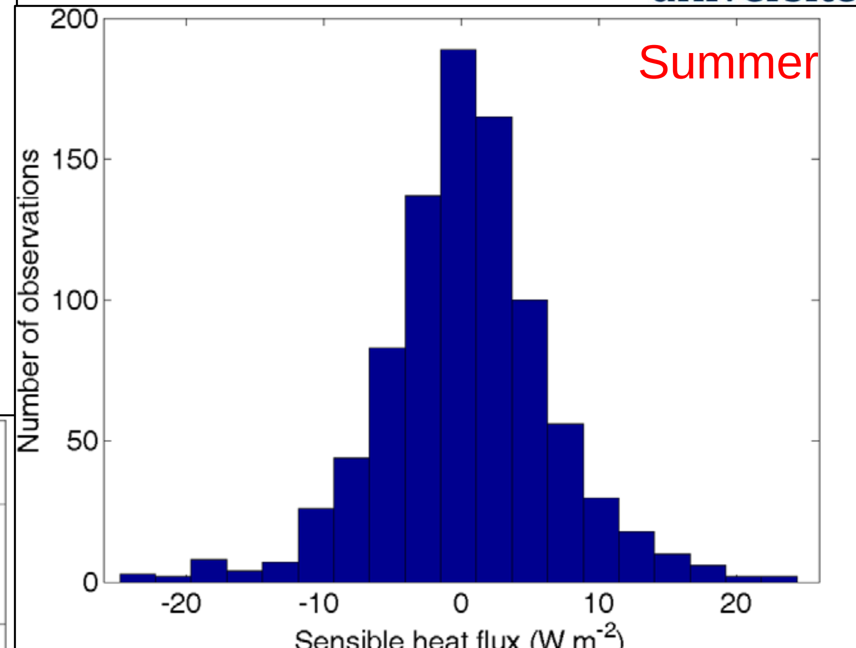
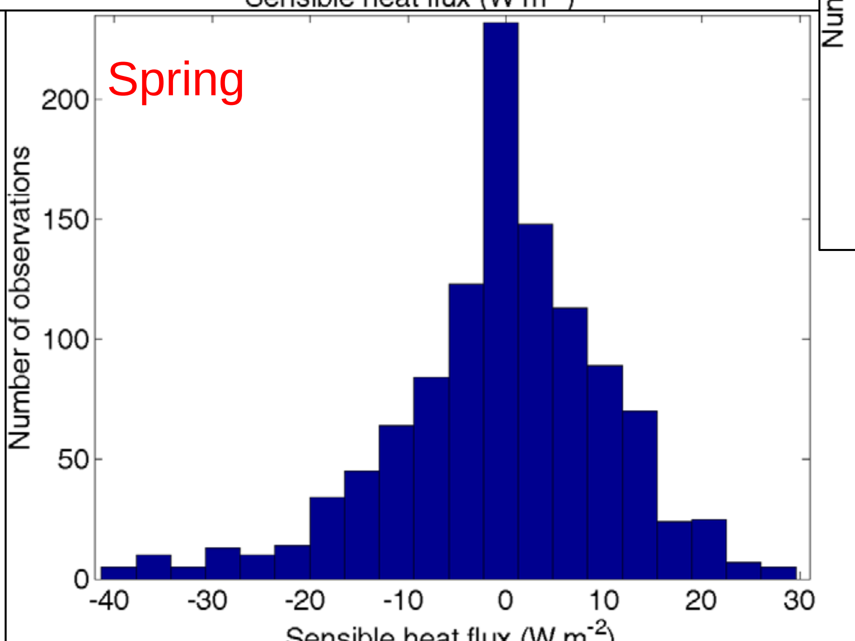
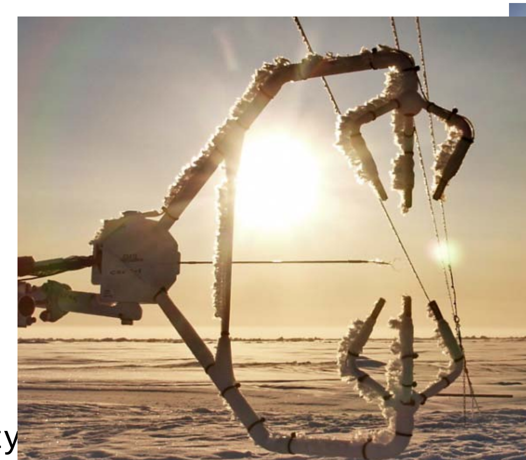
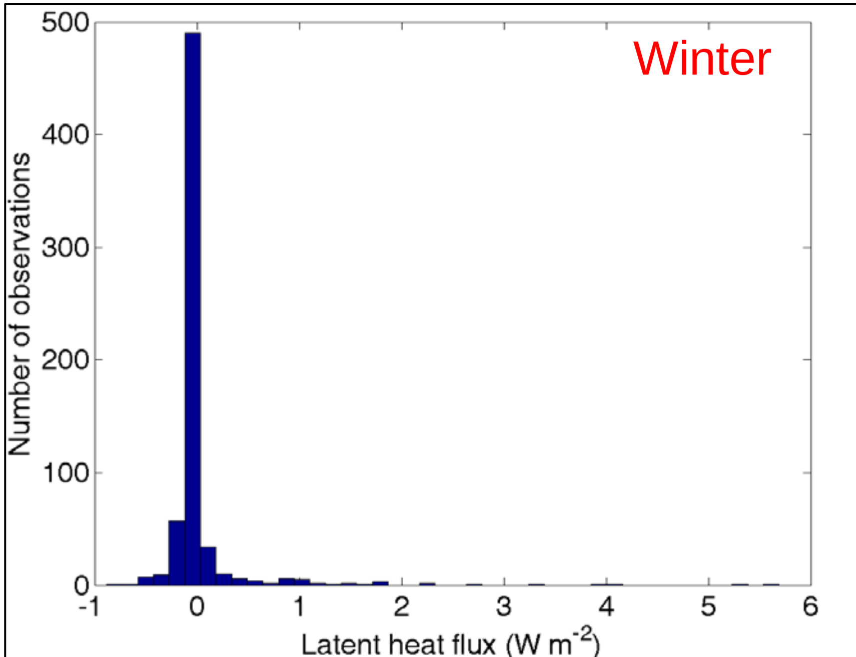


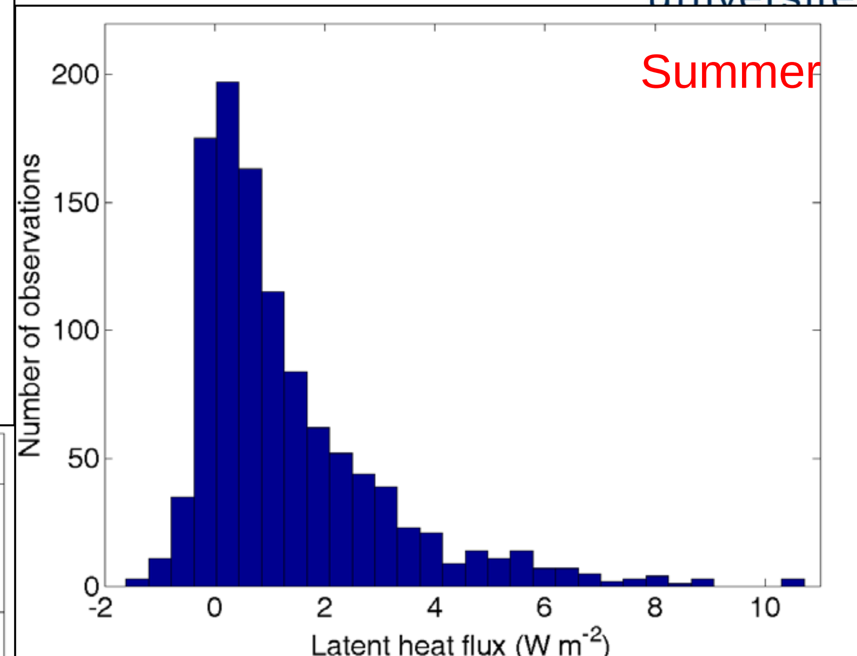


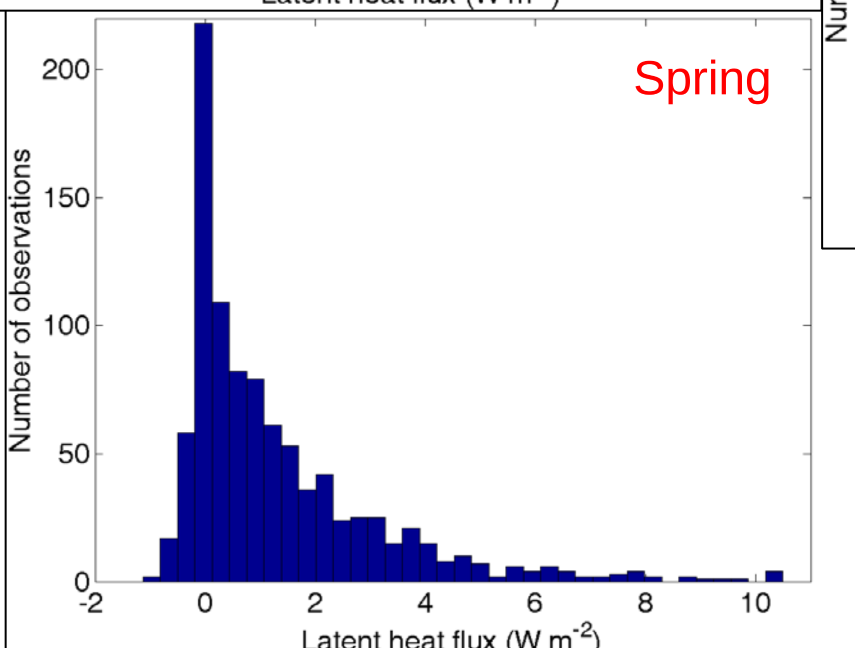




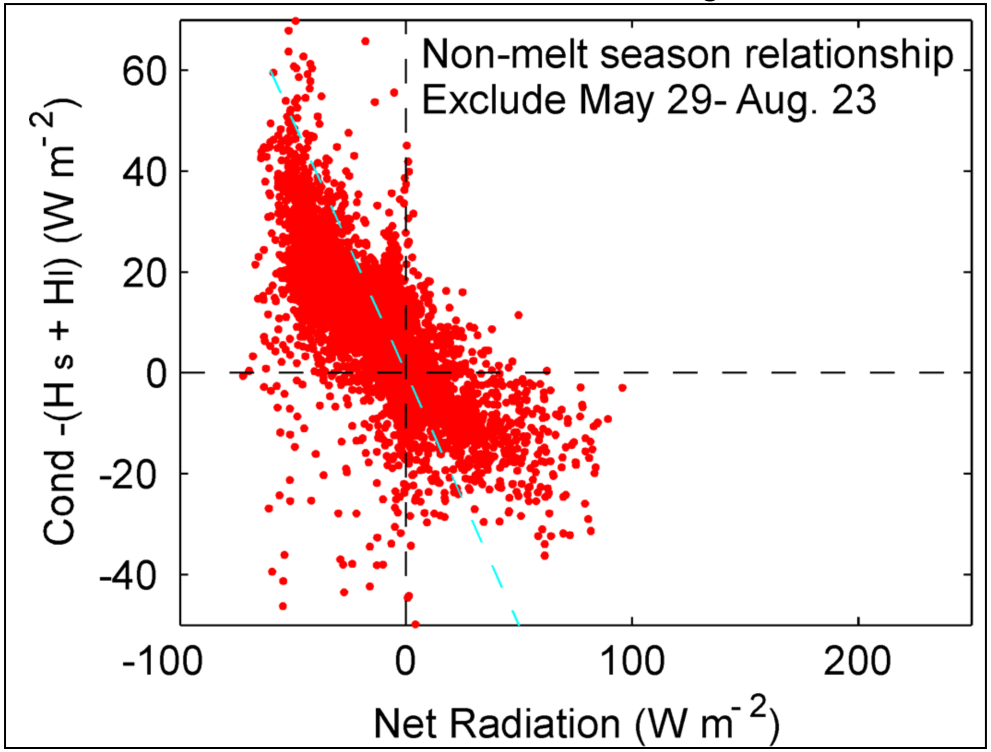
SHEBA latent heat flux



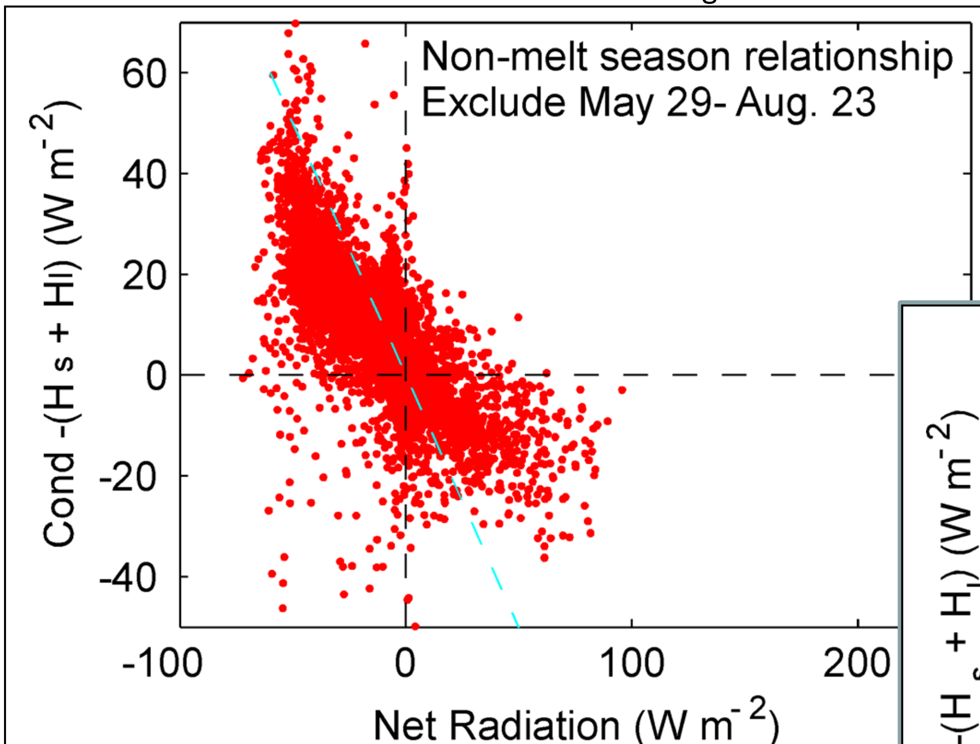




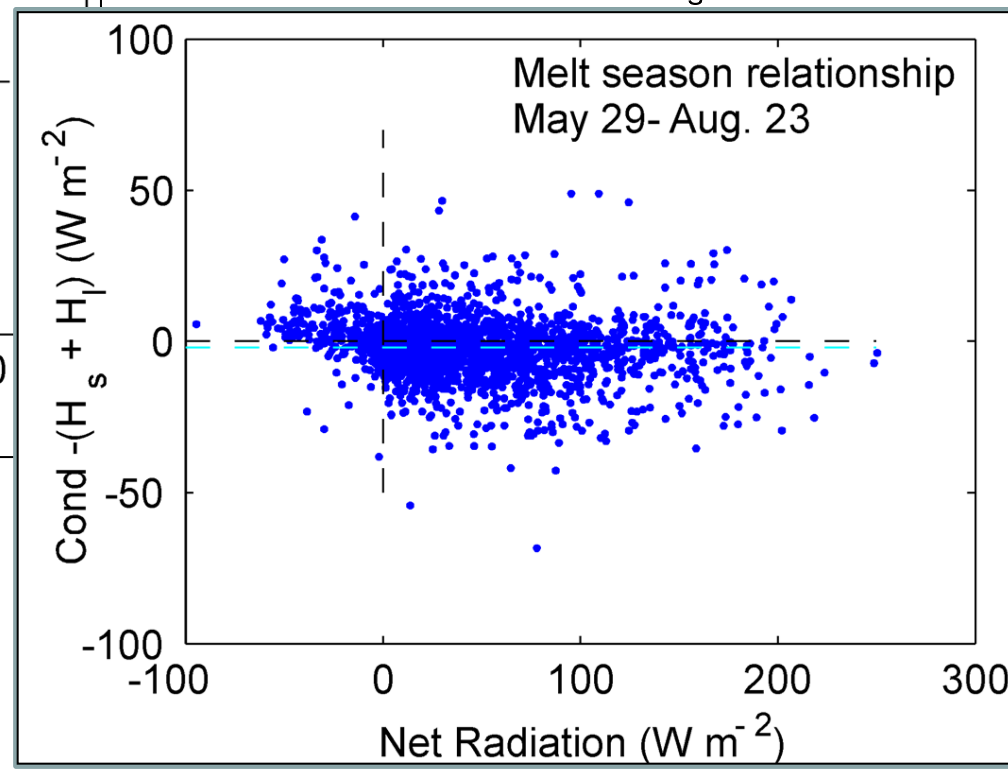
Non-melt season: Variable $T_s < 0° C$



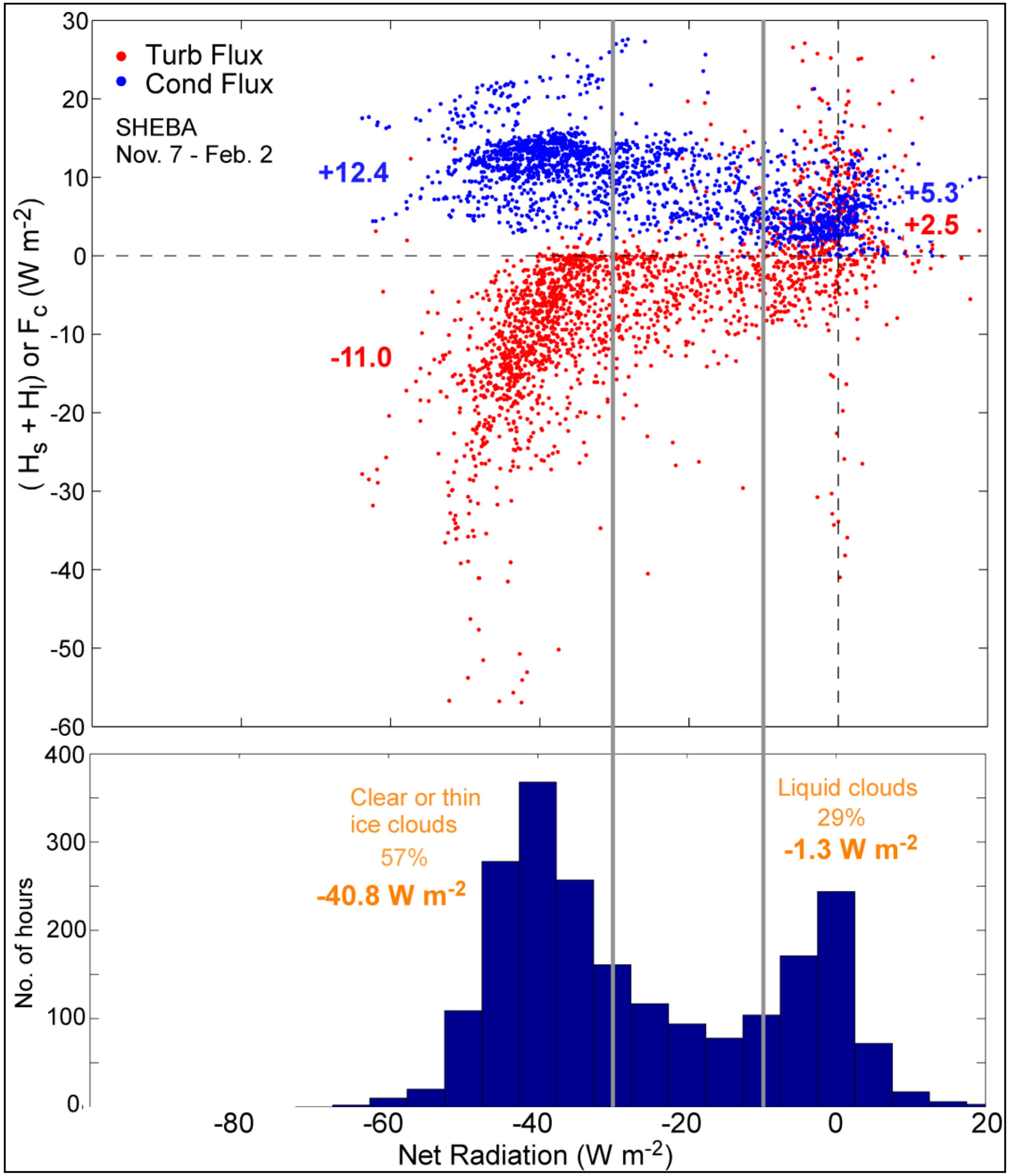
Non-melt season: Variable $T_s < 0°$ C



Melt season: Fixed $T_s \approx 0°$ C



SHEBA Polar Night



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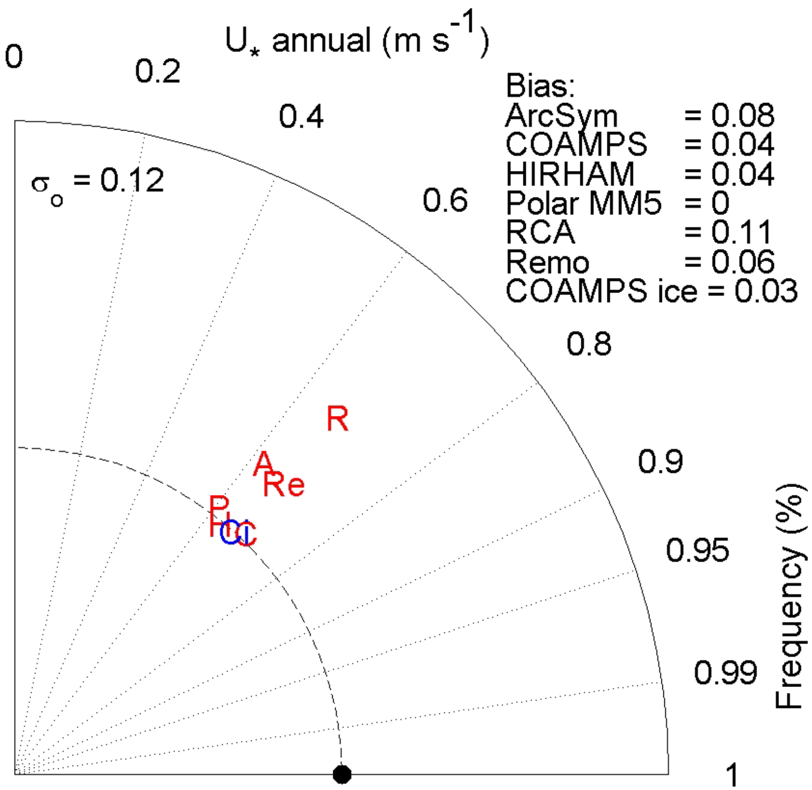
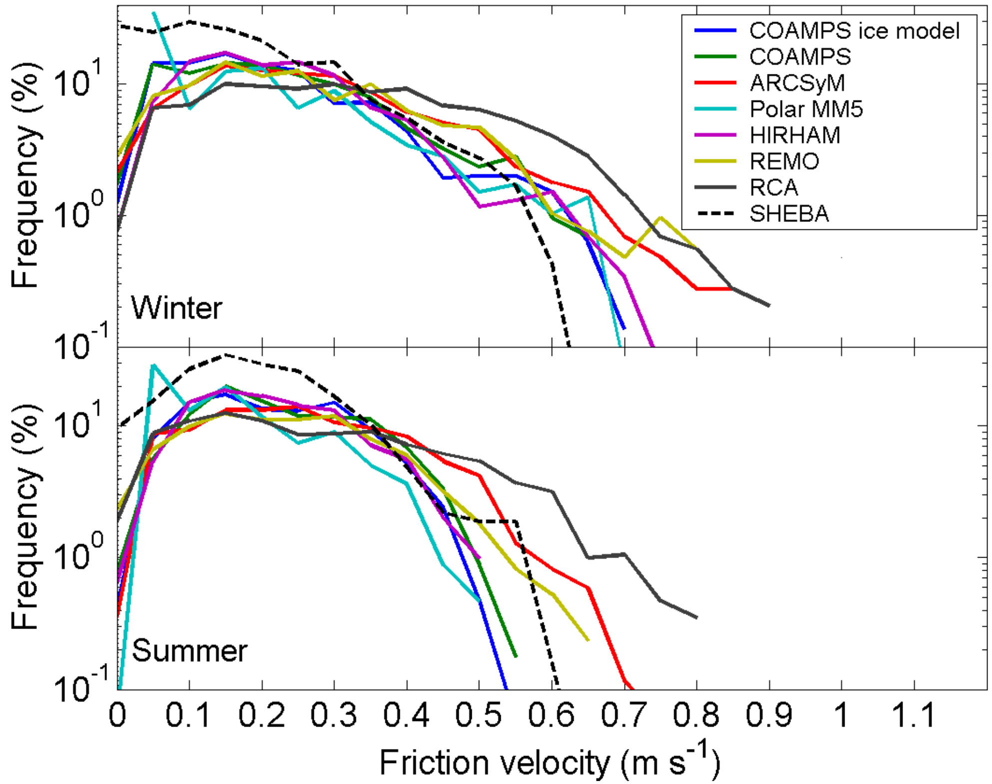
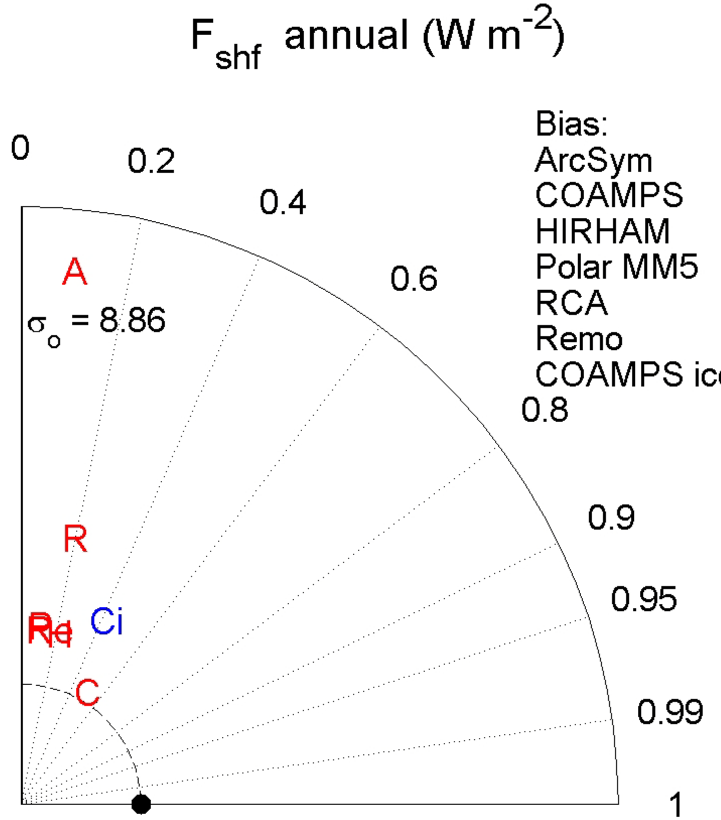
Momentum transfer to the surface

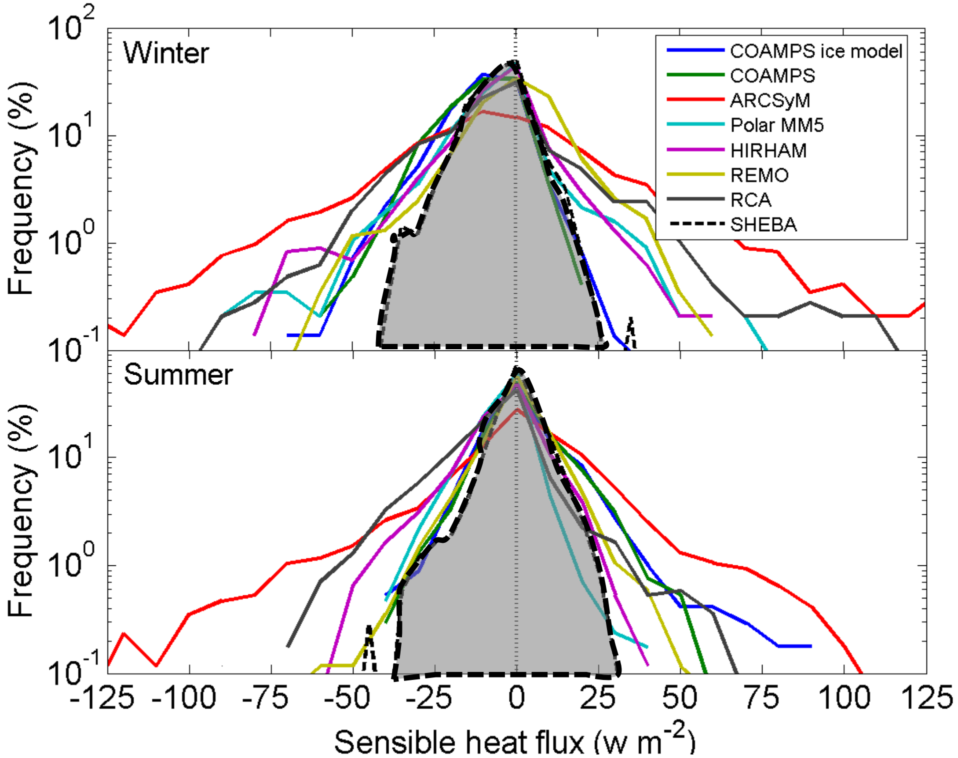




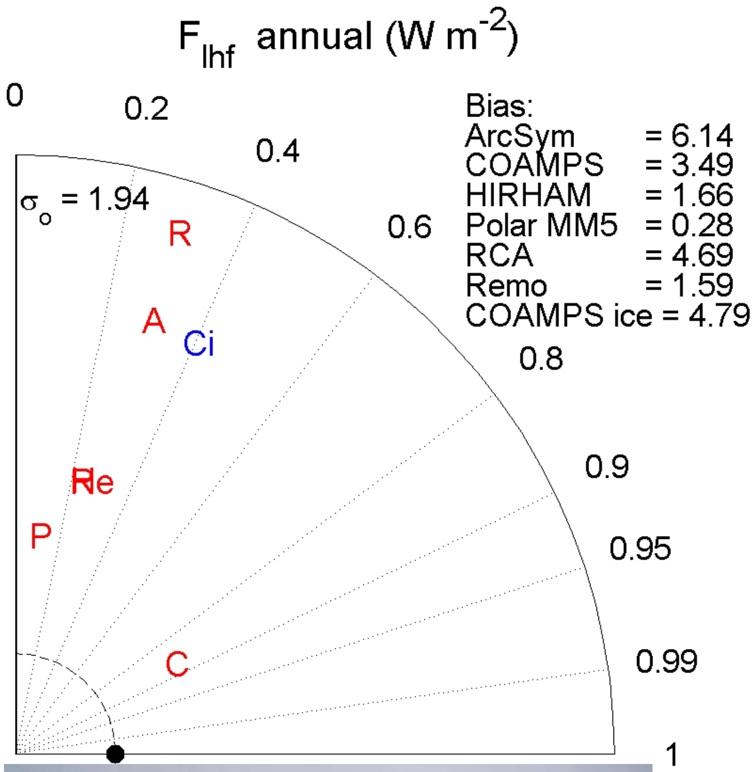
Tjernström et al. 2008

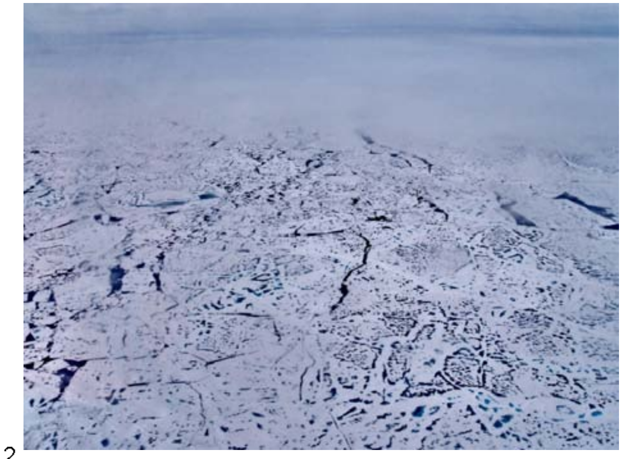
Surface sensible heat flux

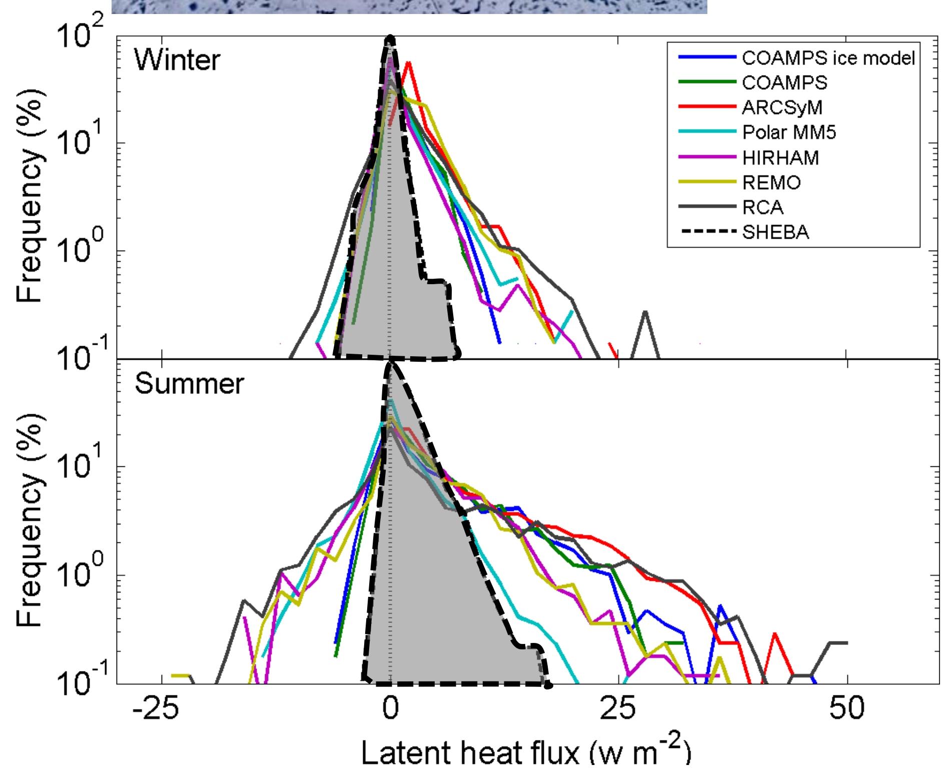




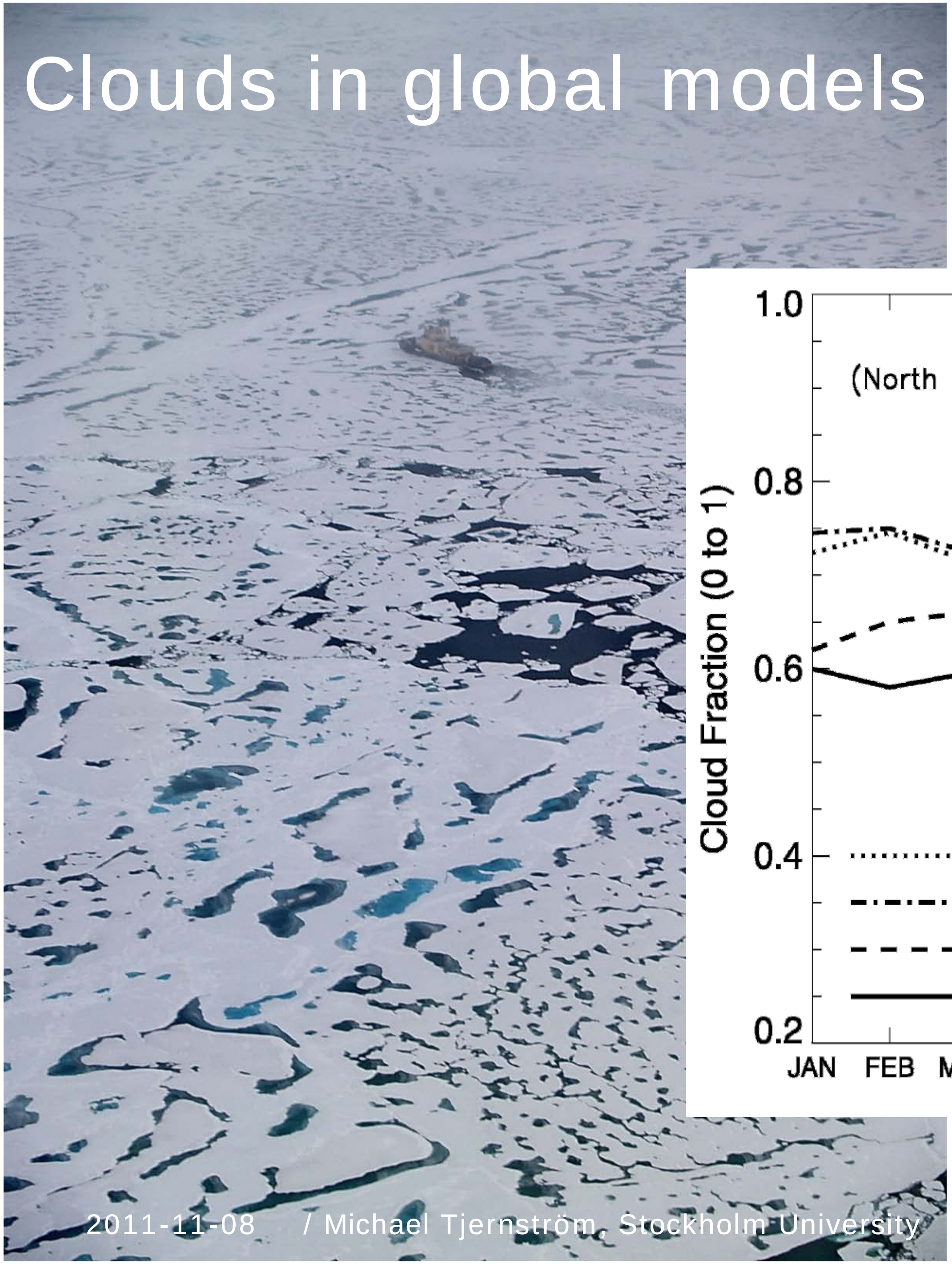
Surface latent heat flux

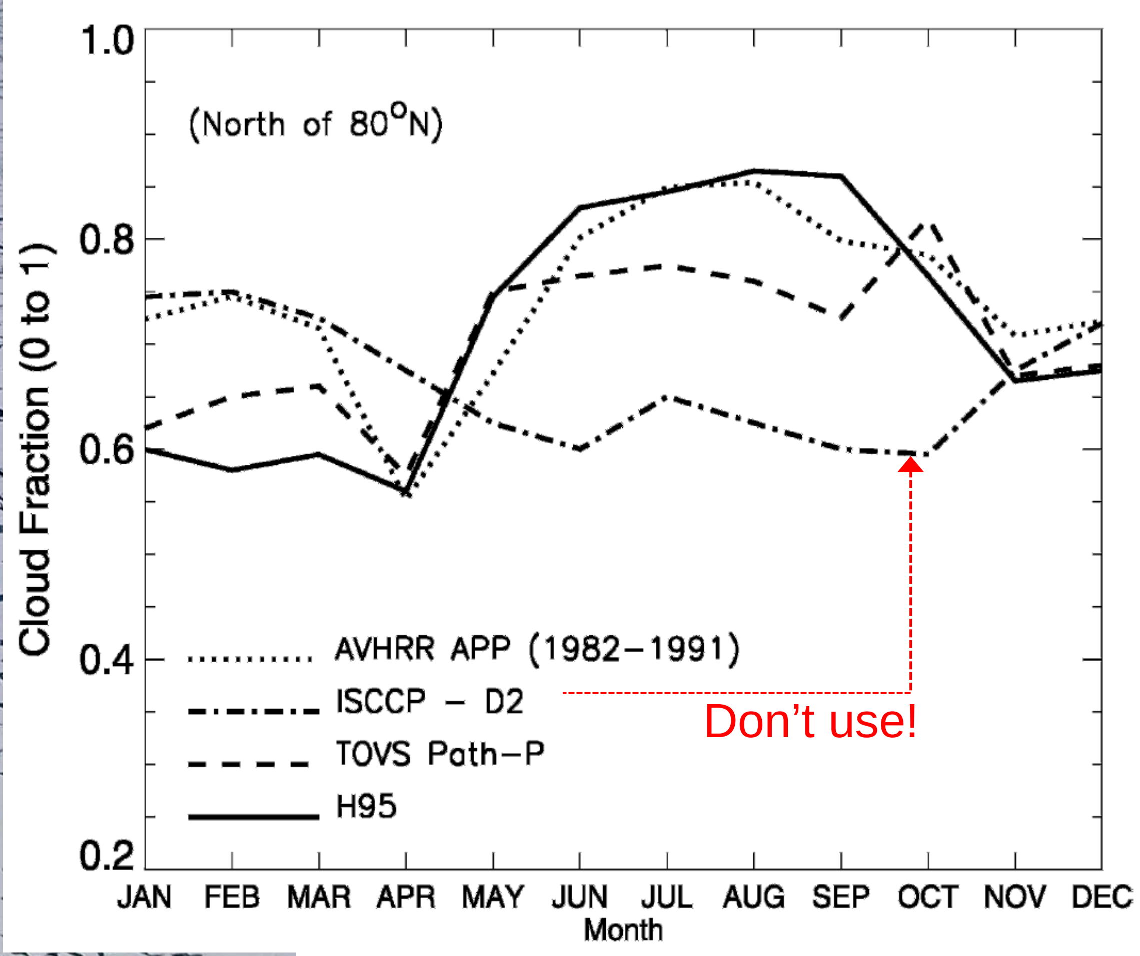




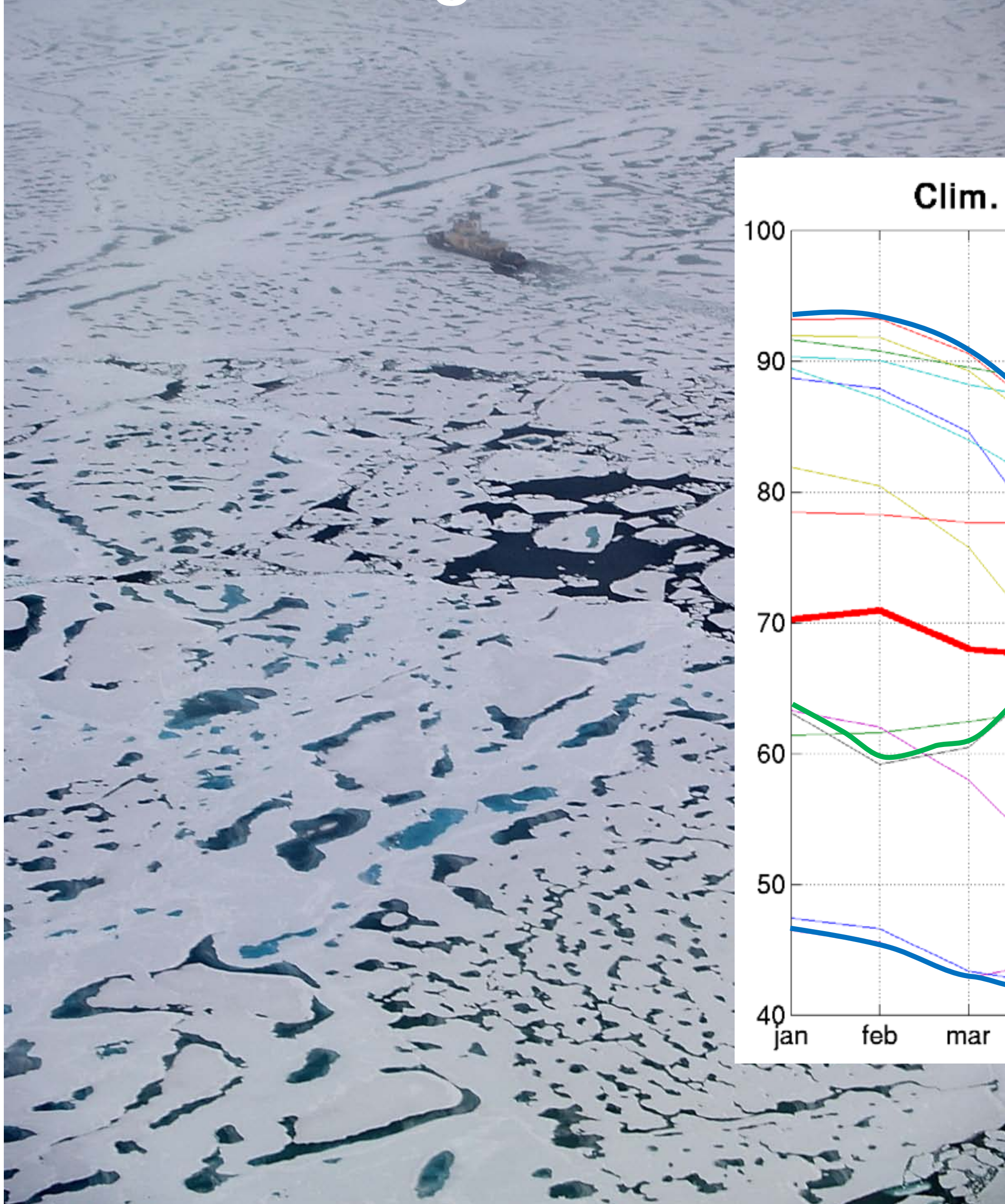


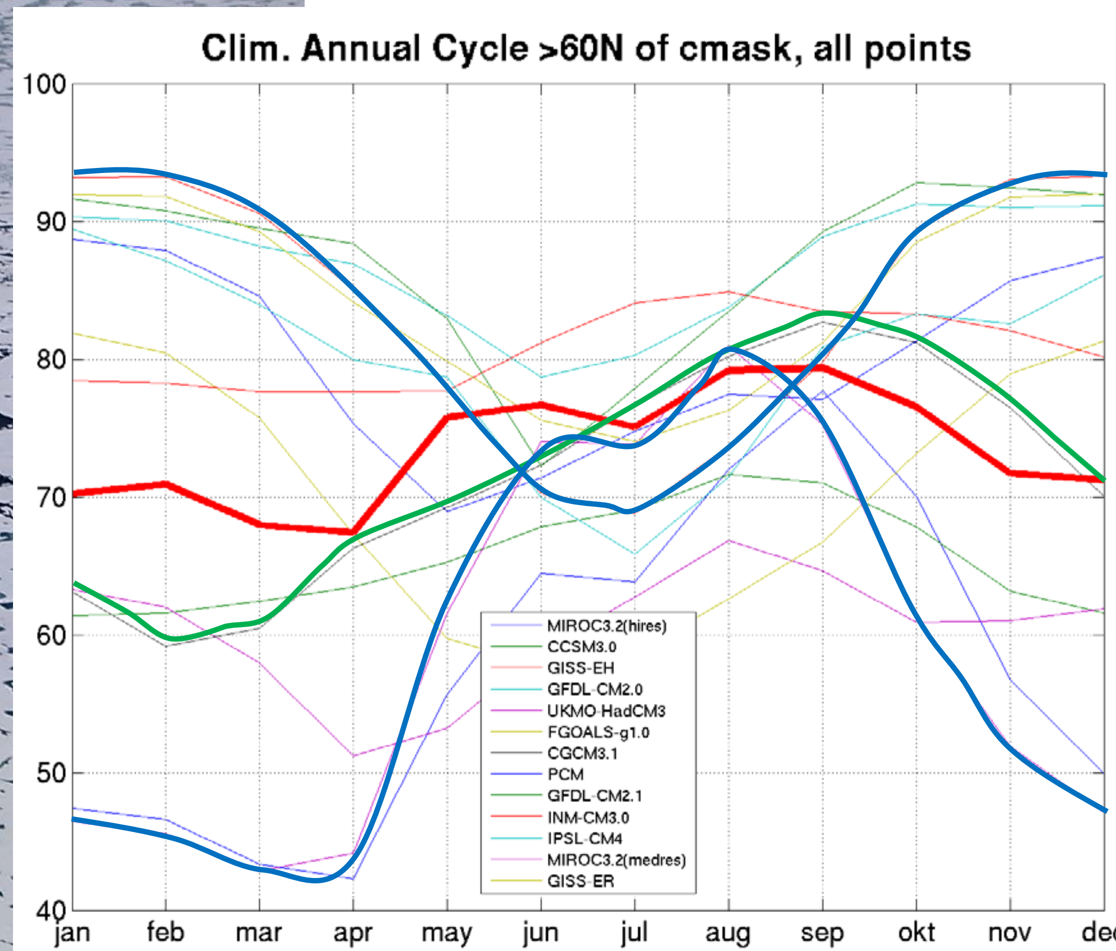
Clouds in global models





Clouds in global models





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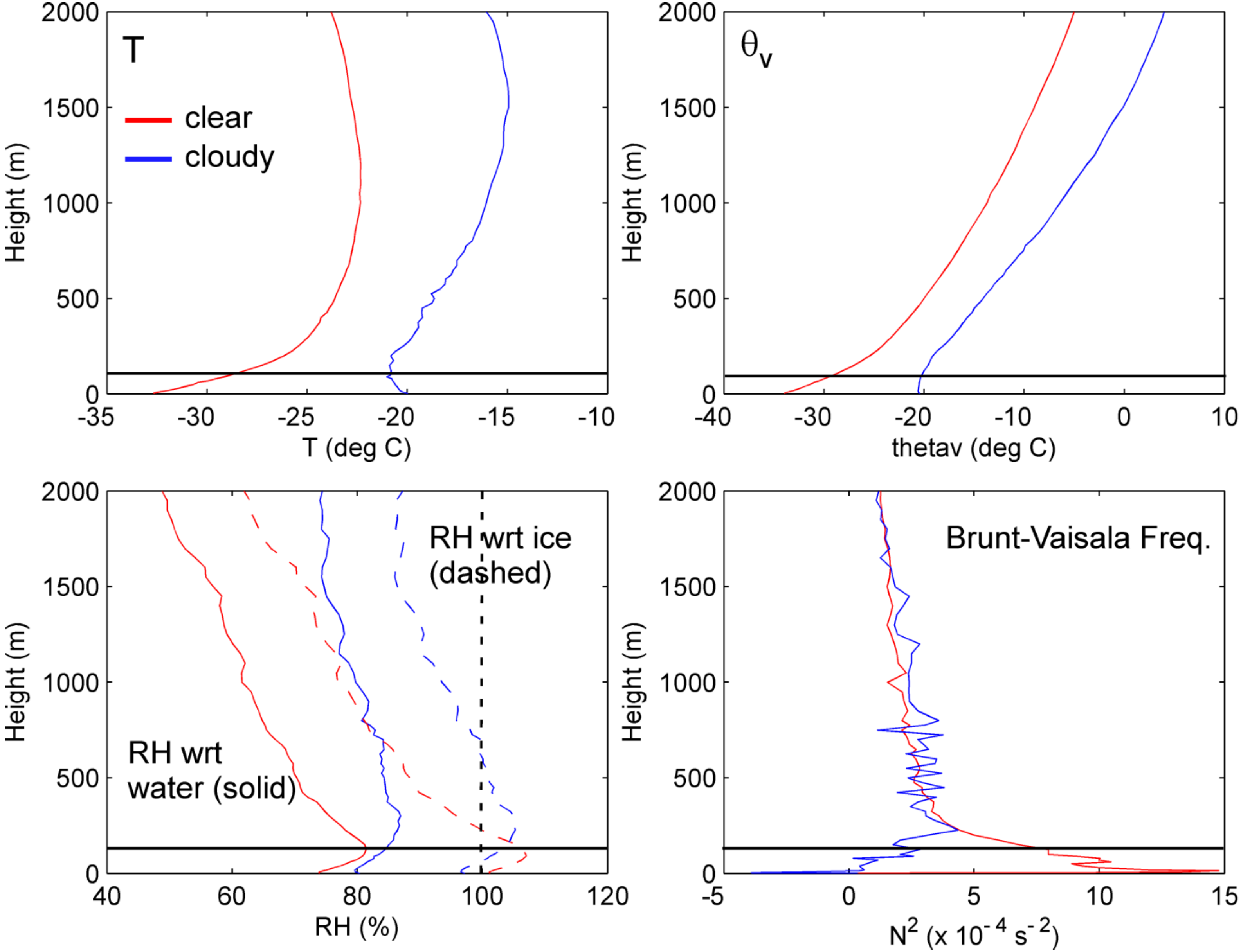
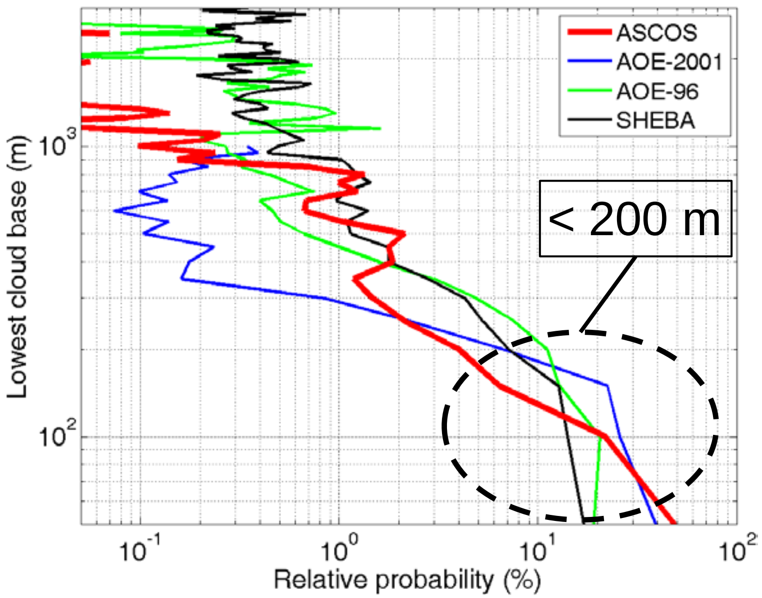
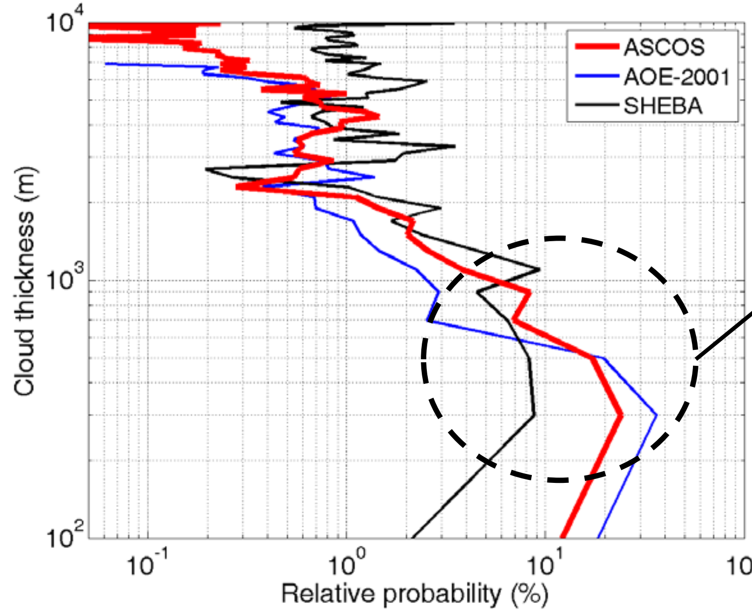


Winter conditions





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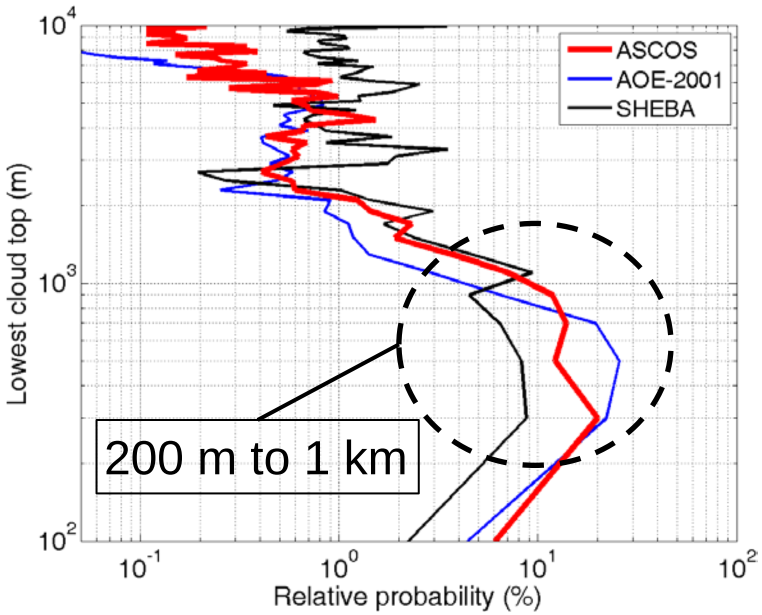

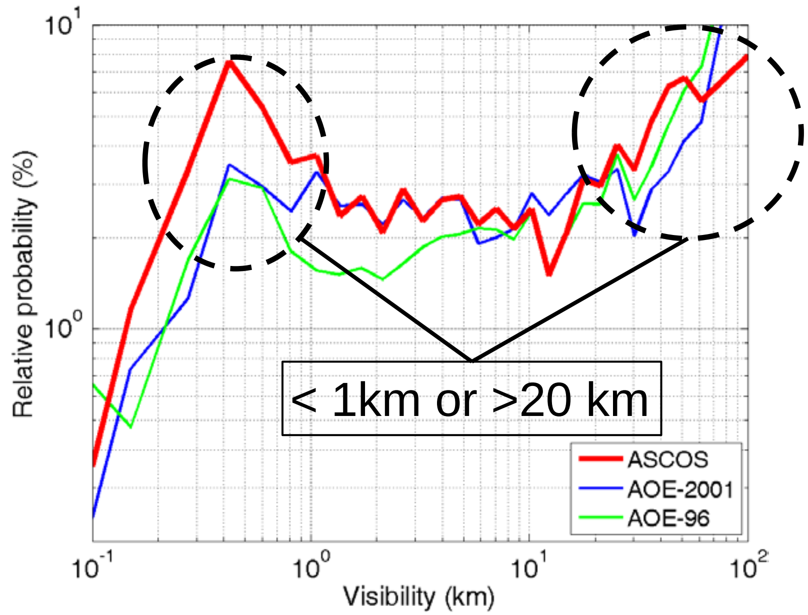

Summer conditions

Clouds in regional models

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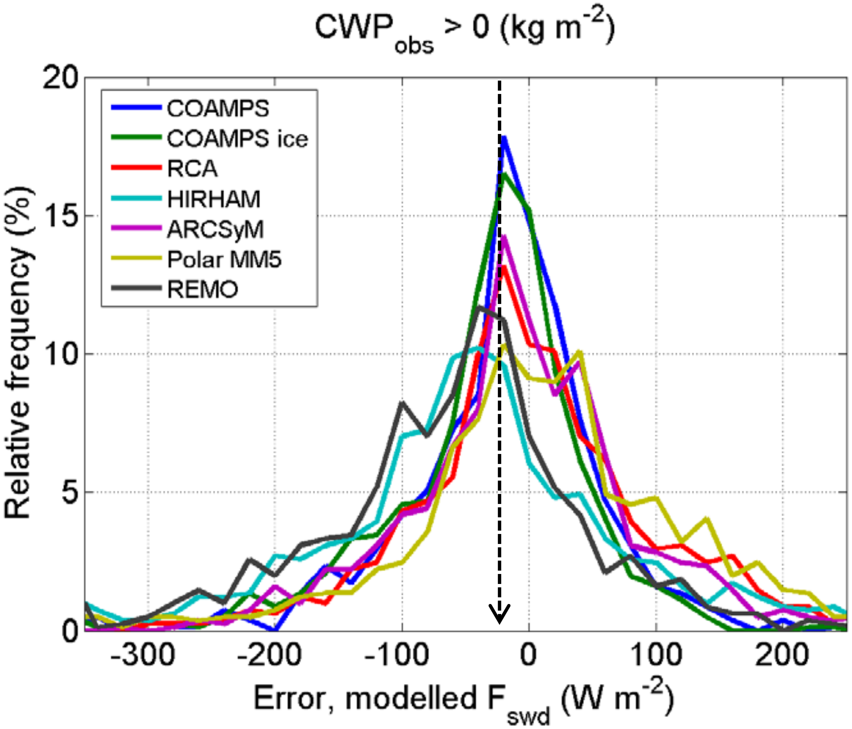

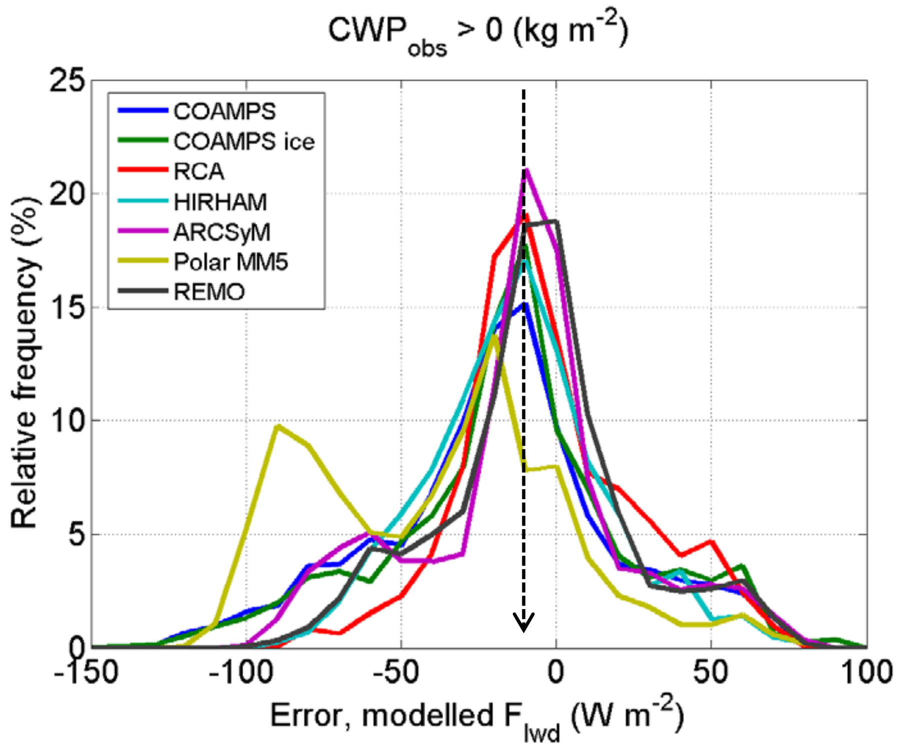

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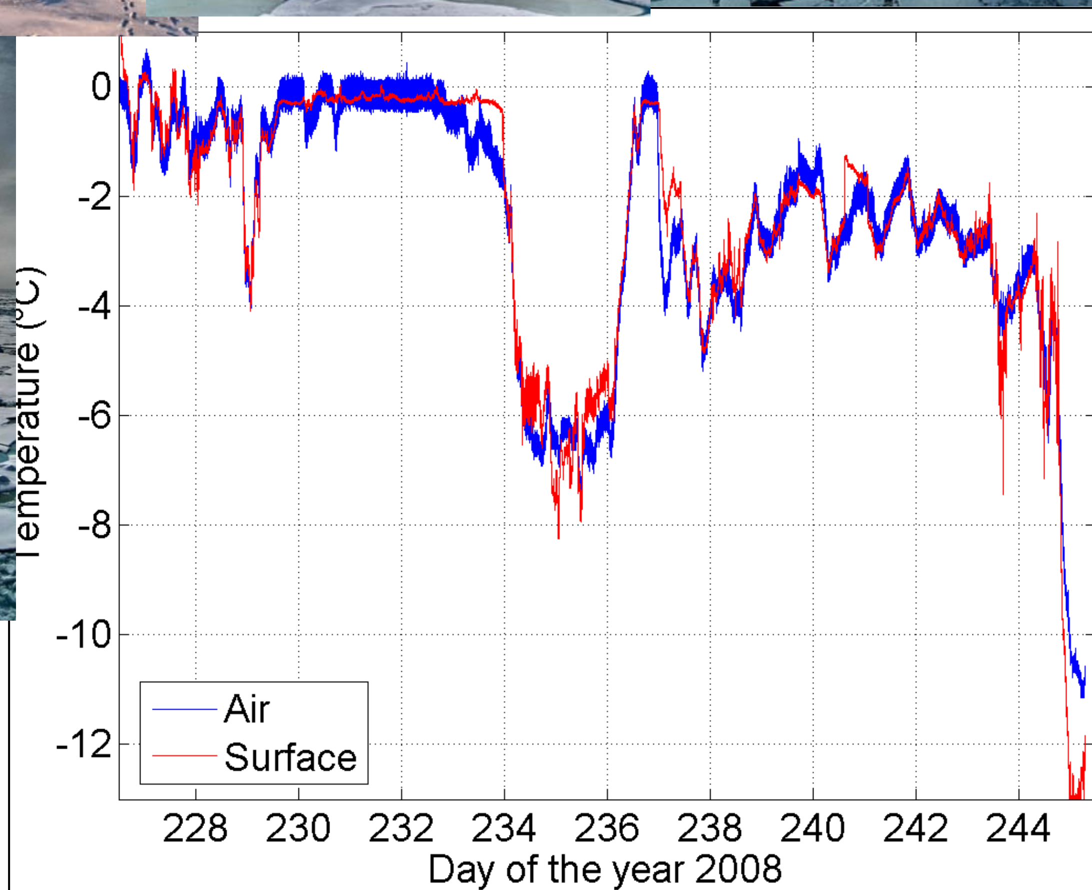
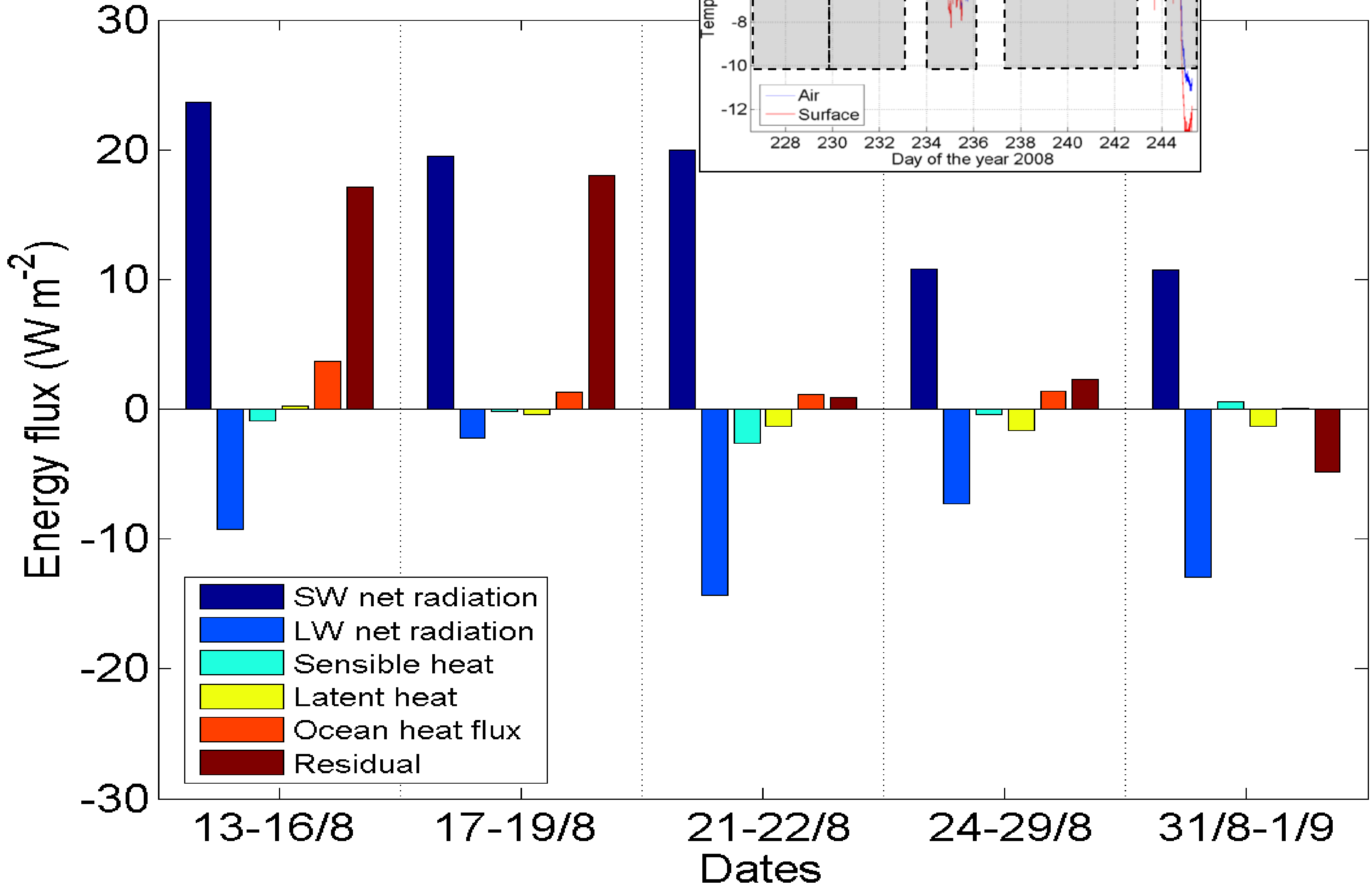
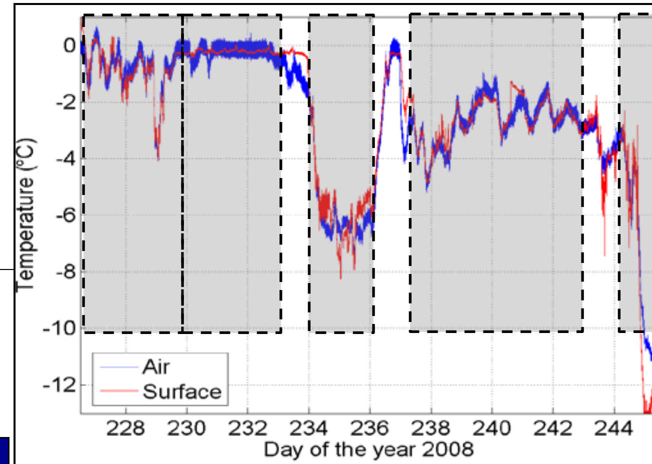


Surface energy balance





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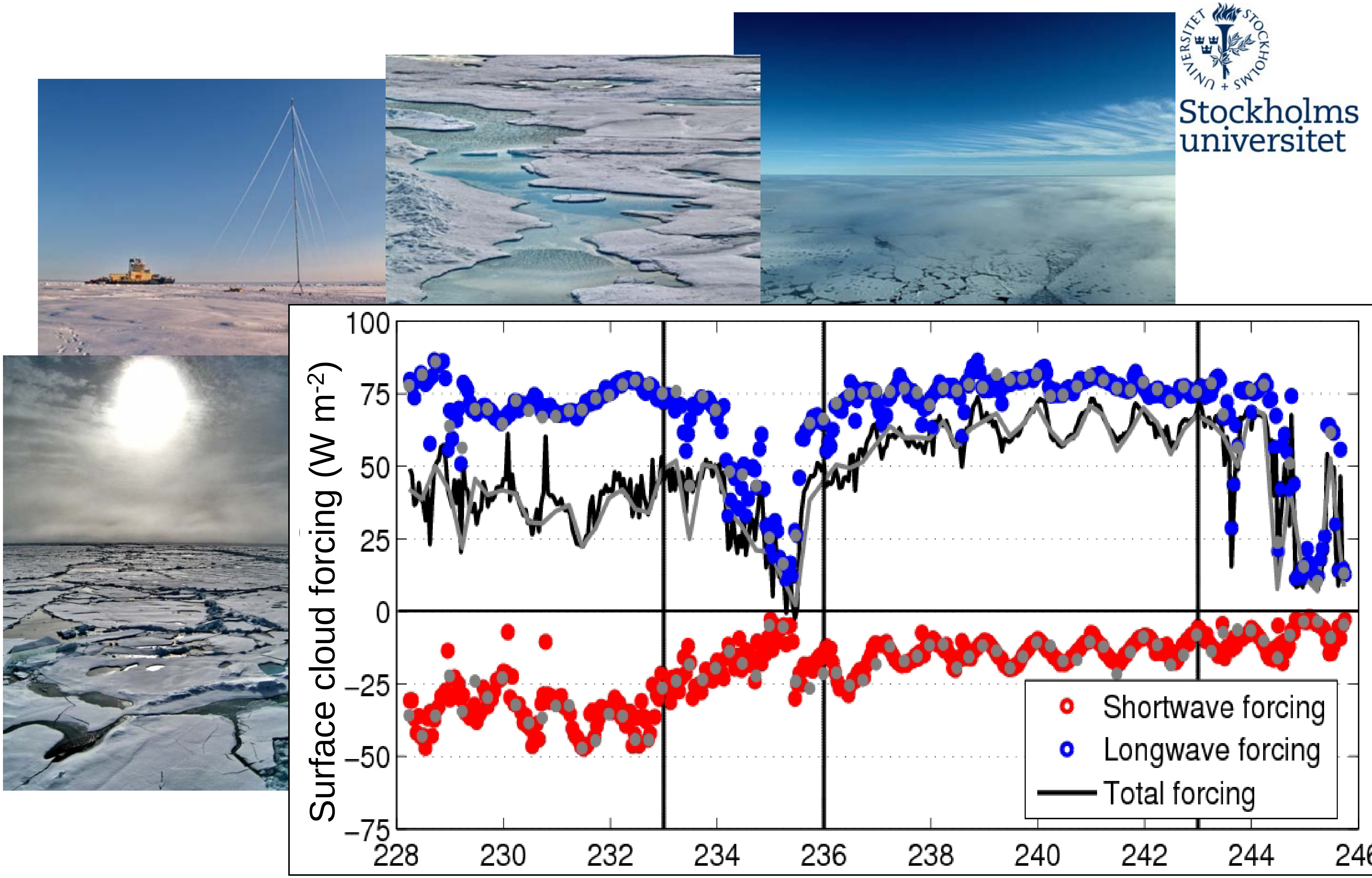
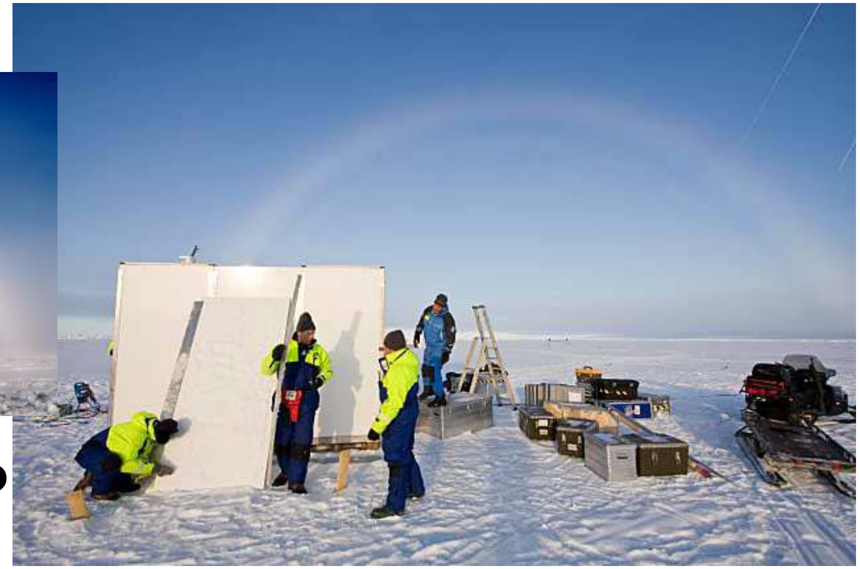
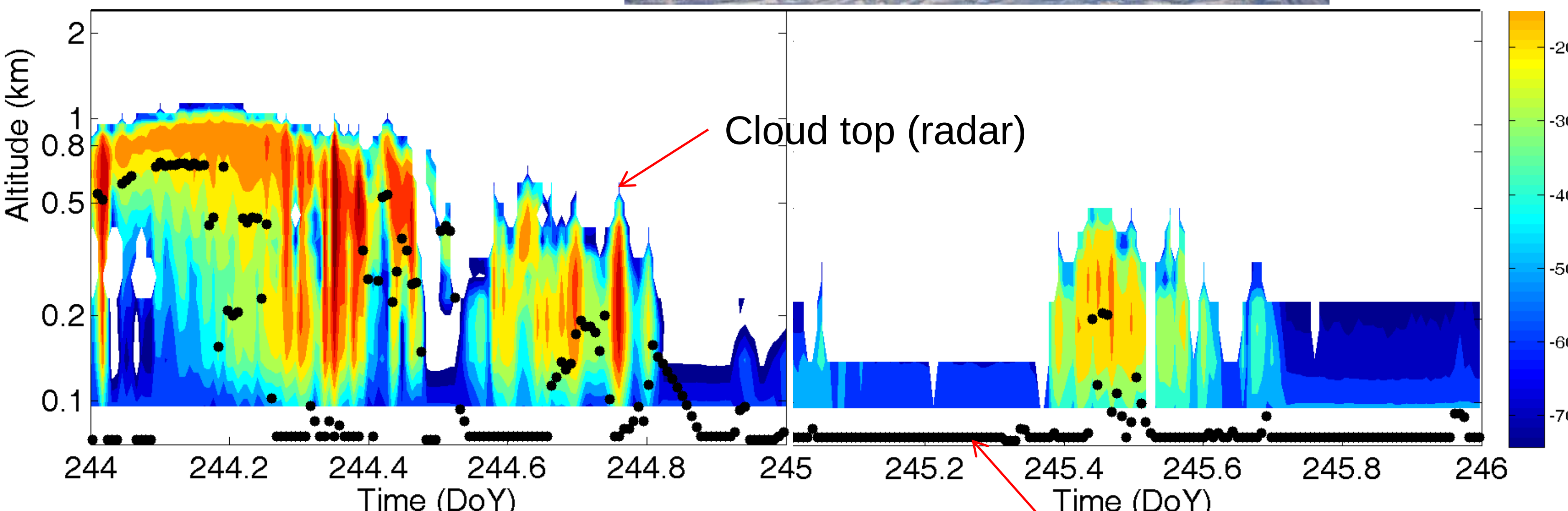




What is a cloud?



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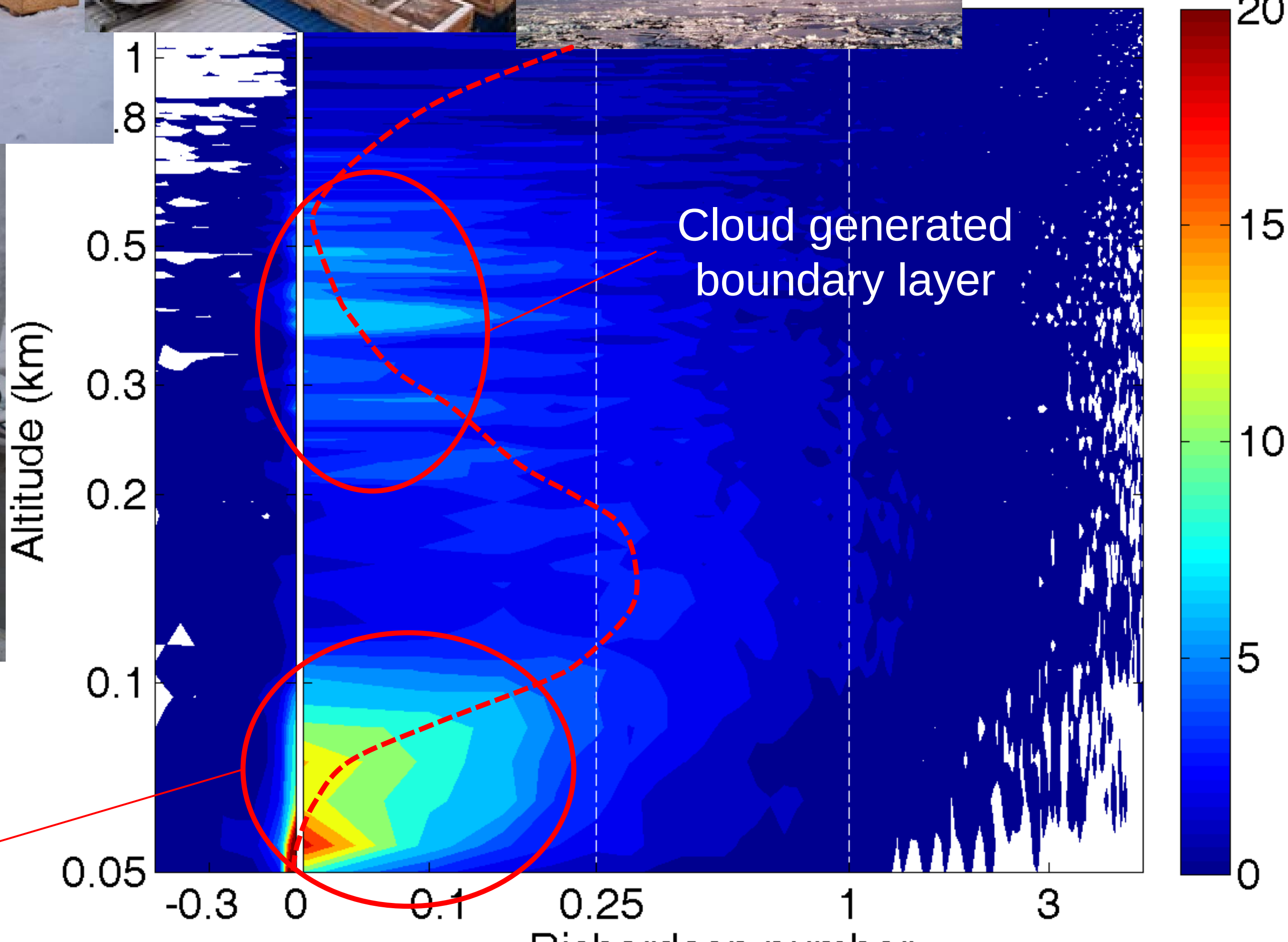

Some reflections…

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- What we think we know about small scale features such as low-troposphere vertical structure, clouds and surface fluxes rests on very "thin ice". As a consequence modeling with out observational constraints is problematic; even reanalysis is difficult
- Some things stand out:
  - The over-all boundary-layer structure is dominated by near-neutral conditions, but strong lasting surface inversions do occur in winter
  - Three surface coupling regimes: melt (summer, fixed T_s), non-melt (spring, responsive T_s) and polar night (winter, no sun).
  - Near-surface moisture remains close to saturation – almost always!
  - In winter, conduction through ice & snow is as important as sensible heat flux and snow thickness is critical
  - Low clouds dominate, but clouds are sometimes optically thin. In summer this is because of sometimes very low aerosol concentrations while cloud-water phase is also important, especially in winter
  - Surface energy balance is dominated by (LW) radiation while turbulent heat fluxes are small $\Rightarrow$ focus more on the momentum flux?