Atmospheric boundary layer observations at Dome C, Antarctica during the first winter-over

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OUTLINE OF THE PRESENTATION:

- **Scientific objectives of STABLEDC (STABLE boundary layer at Dome C)**
- **Experiment set up and measures**
- **Radiative budget and micrometeorological parameters**
- **PBL thermal structure**
- **Temperature, Wind speed and Richardson number profiles**
- **A possible contribution to astronomical "site testing"**

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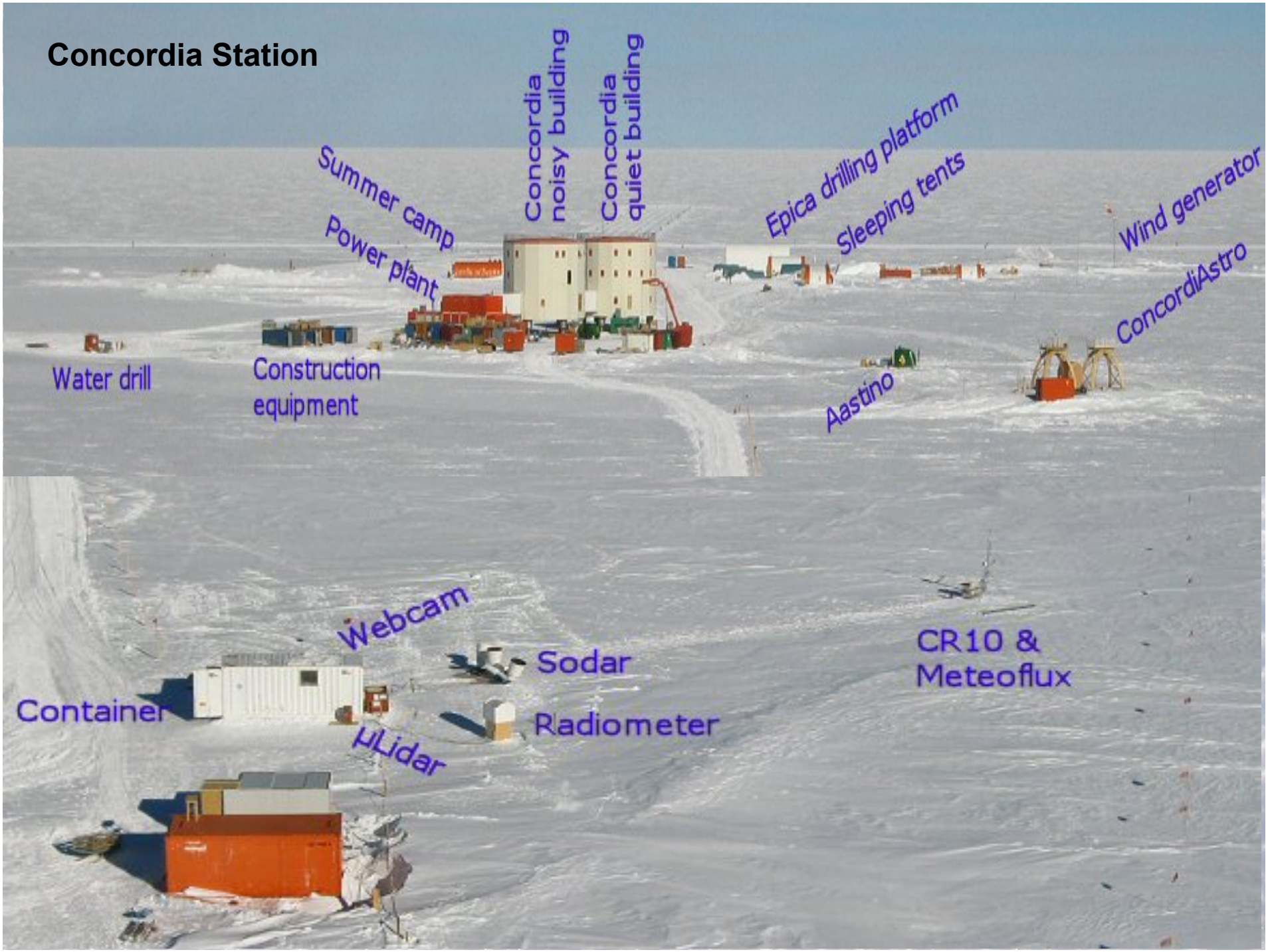
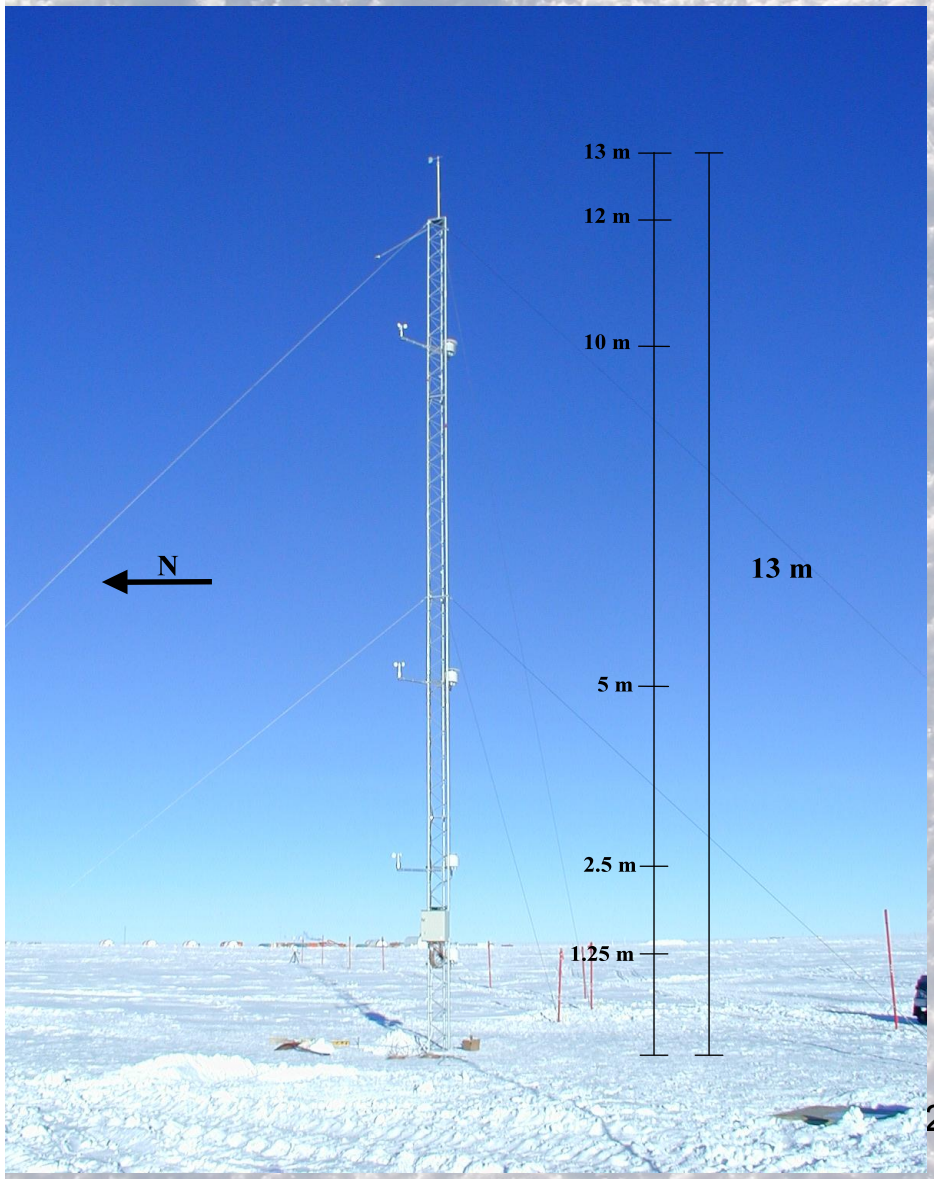
Scientific objectives of STABLEDC (STABLE boundary layer at Dome C)

Study of the PBL processes

- Thermal structure - turbulence
- Parameterization of the long - lived **stable** boundary layer
- Summer **weak convective** boundary layer
- Behavior of the temperature inversion
- Periodicity and occurrence of the warming events during the winter (*I. Petenko presentation*)
- Interaction between local and large scale circulation


Concordia Station
Concordia noisy building
Concordia quiet building
Summer camp
Power plant
Epica drilling platform
Sleeping tents
Wind generator
ConcordiAstro
Water drill
Construction equipment
Aastino
Webcam
Sodar
Container
Radiometer
µLidar
CR10 & Meteoflux

METEO TOWER



MEASUREMENTS

- 1.25 m Temperature
- 2.5, 5, 10 m Temperature - Wind Speed - Relative Humidity
- 12 m Net Radiometer
- 13 m Wind Direction

- **Surface Layer Profiles** (Wind, Temperature, Humidity)
- **Surface Layer Fluxes** (Heat and Momentum)

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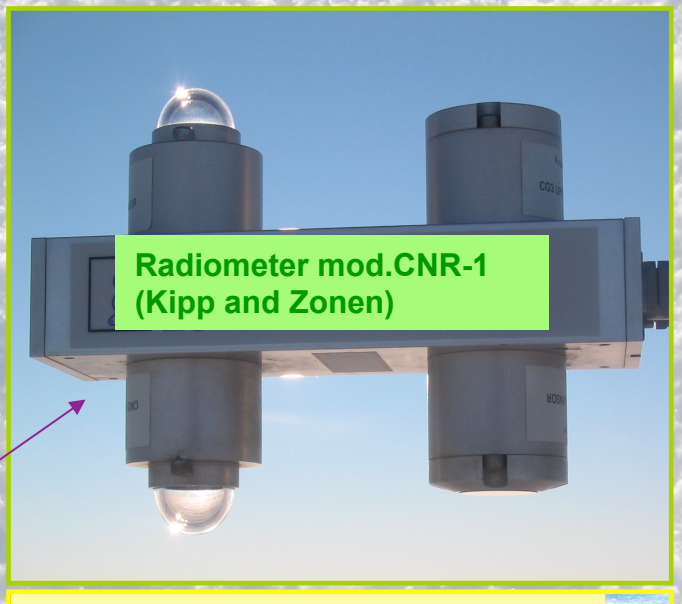
Surface Layer Turbulence and Radiation

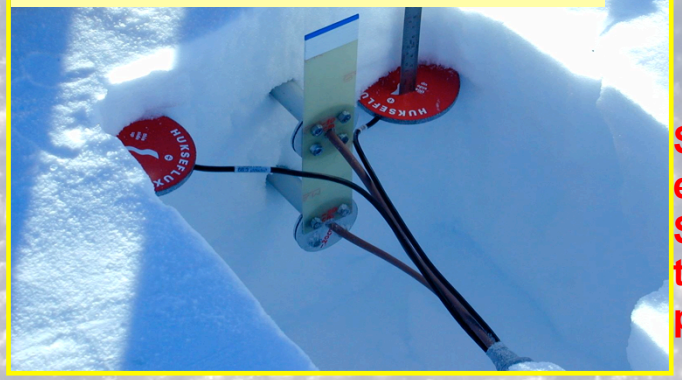
3 m- mast Sonic anemo-thermometer mod. USA - 1
(Metek GmbH) Maximum sampling frequency 20 Hz

u, v, Sonic Temperature,
Turbulent Fluxes (Heat, Momentum)
Turbulent Kinetic Energy



Radiative budget:
- Incoming and outgoing shortwave and longwave radiation.
- Albedo

Conventional HFP01 heat flux plates at depth of 0, 5, 15, 30, 50 cm



Sub-surface energy fluxes
Snow temperature profiles

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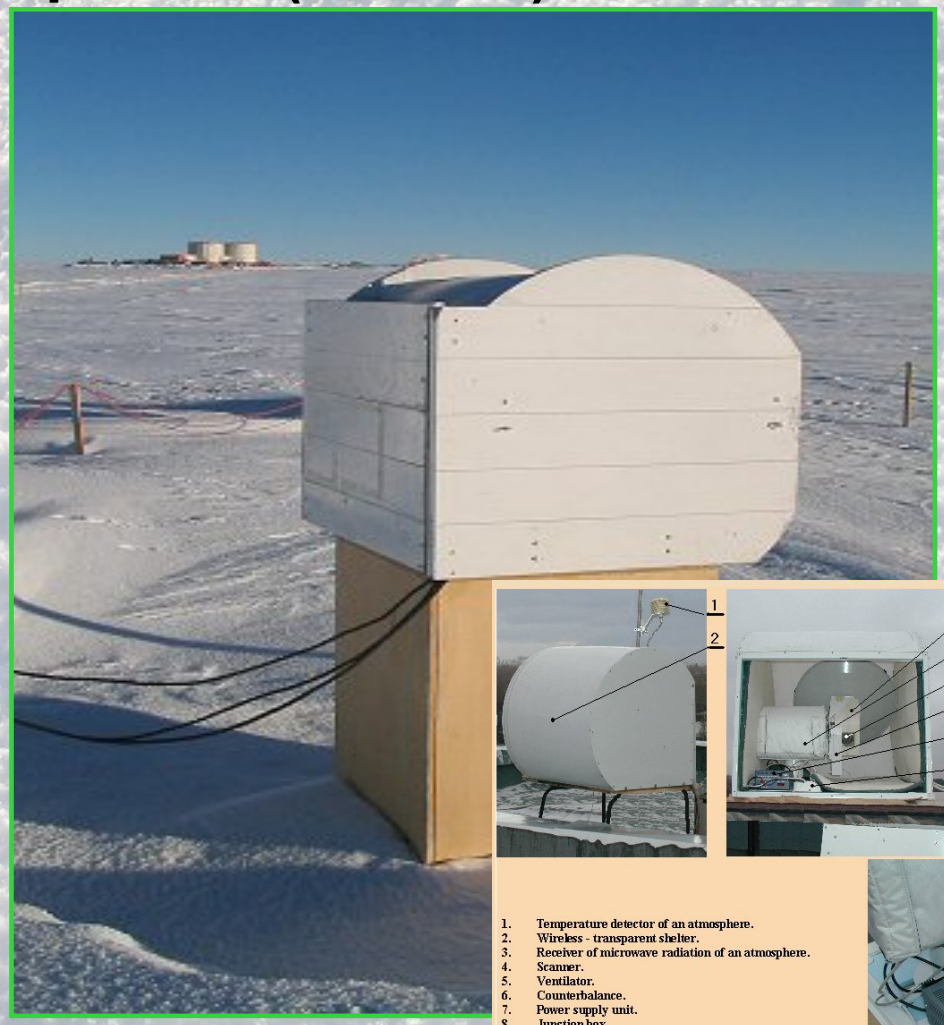
Ground based remote sensing : meteorological temperature profiler (MPT-5P)

Passive Microwave radiometer (MPT 5) by Kipp&Zonen.
Range 0-600 m

PBL Profile
-Development and break down of atmospheric inversions over the course of the time
-Temperature



1. Temperature detector of an atmosphere.
2. Wireless - transparent shelter.
3. Receiver of microwave radiation of an atmosphere.
4. Scanner.
5. Ventilator.
6. Counterbalance.
7. Power supply unit.
8. Junction box.
9. Cable the Scanner - RS232.
10. Cable ADC - RS232.
11. Feeding cable 220 v.
12. Parabolic- reflector.

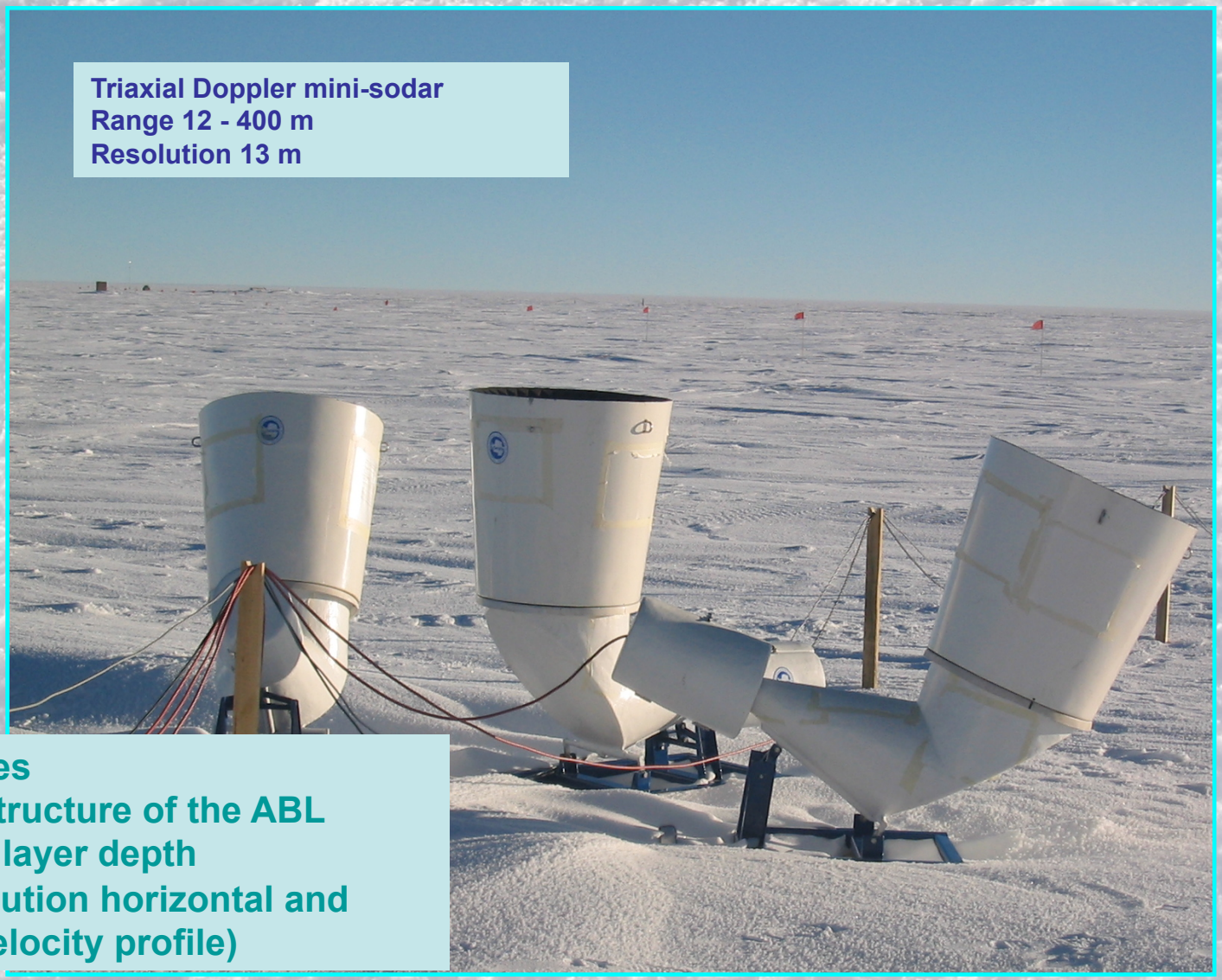
Fig. 1. A general view meteorological temperature profilers MTP5_5_pl.

Accuracy of temperature profile retrieval 0.5 C° (0-200m) 1C° (250-600m)
Range of measured atmospheric temperatures
-60°C + 20°C (relative humidity up to 90%)
Range 0 - 600 m with a resolution:

0-100 m – 10m
100-200 m – 15m
200-300 m – 20m
300-600 m – 50m

1 profile each 10 minutes

Ground based remote sensing : SODAR



PBL Profiles
- Thermal structure of the ABL
- Boundary layer depth
- High resolution horizontal and vertical velocity profile)


ABL structure
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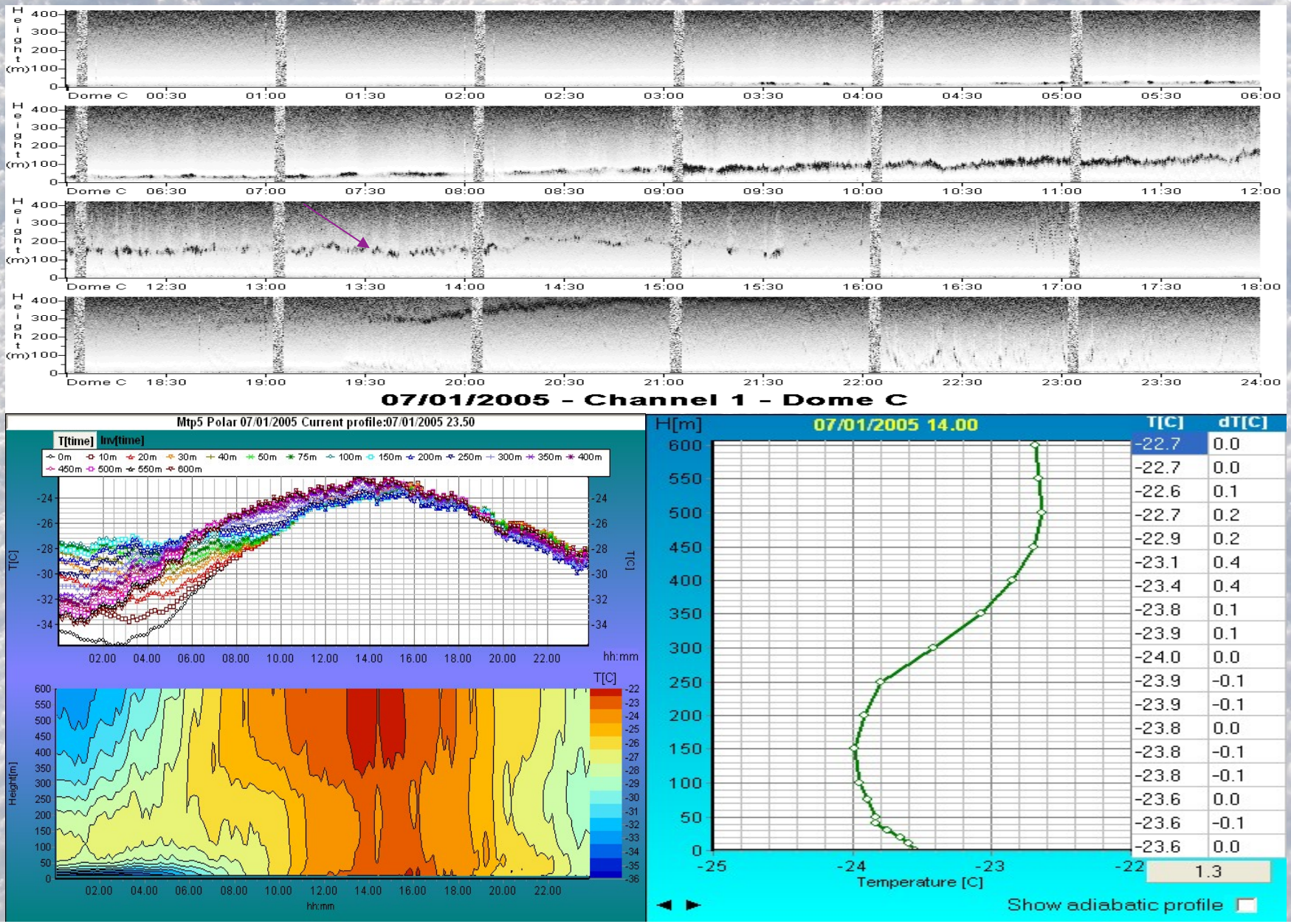
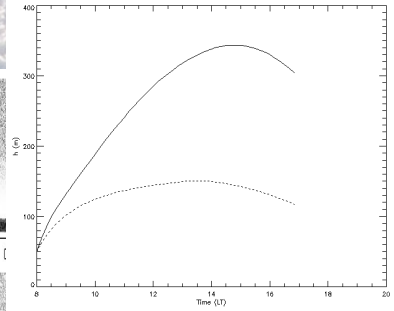
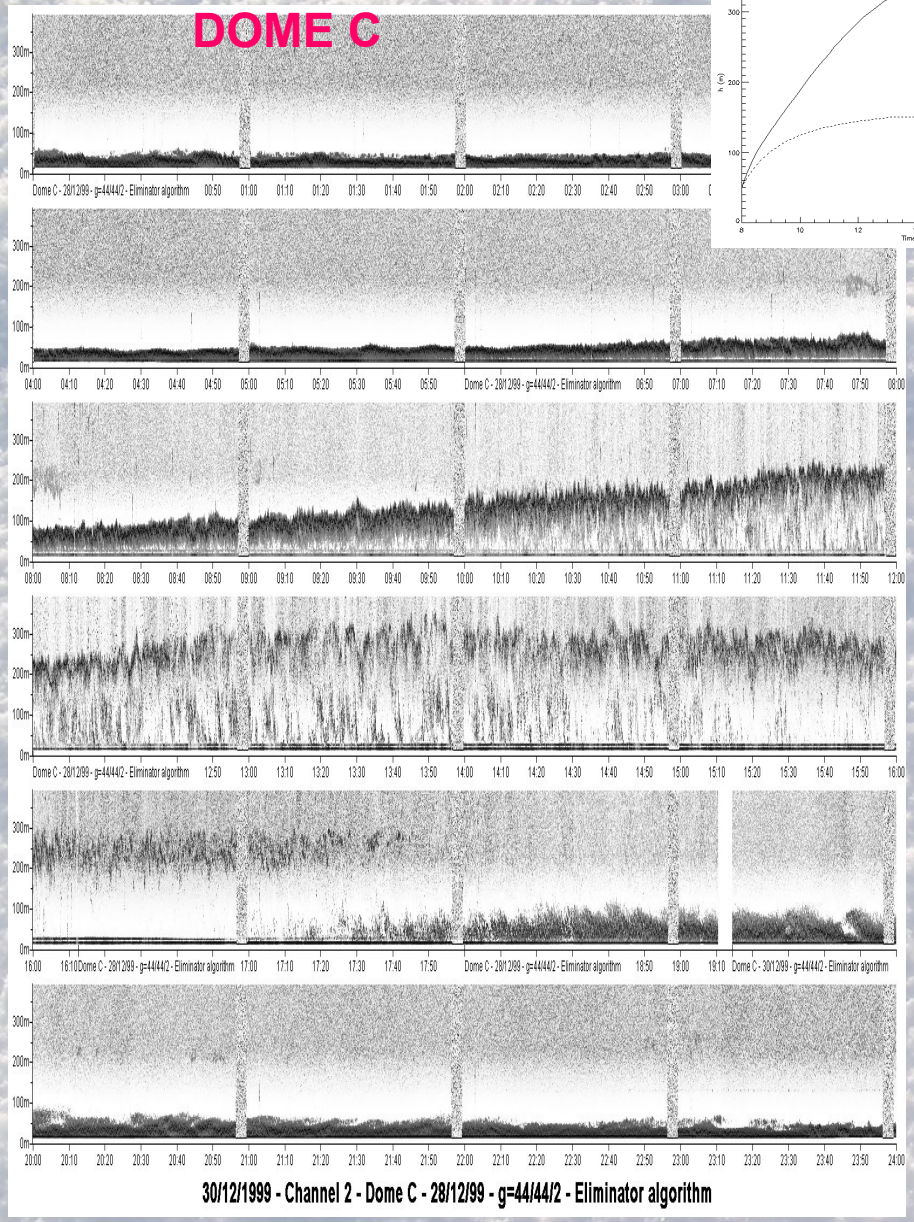
Convective Boundary Layer observed during the summer

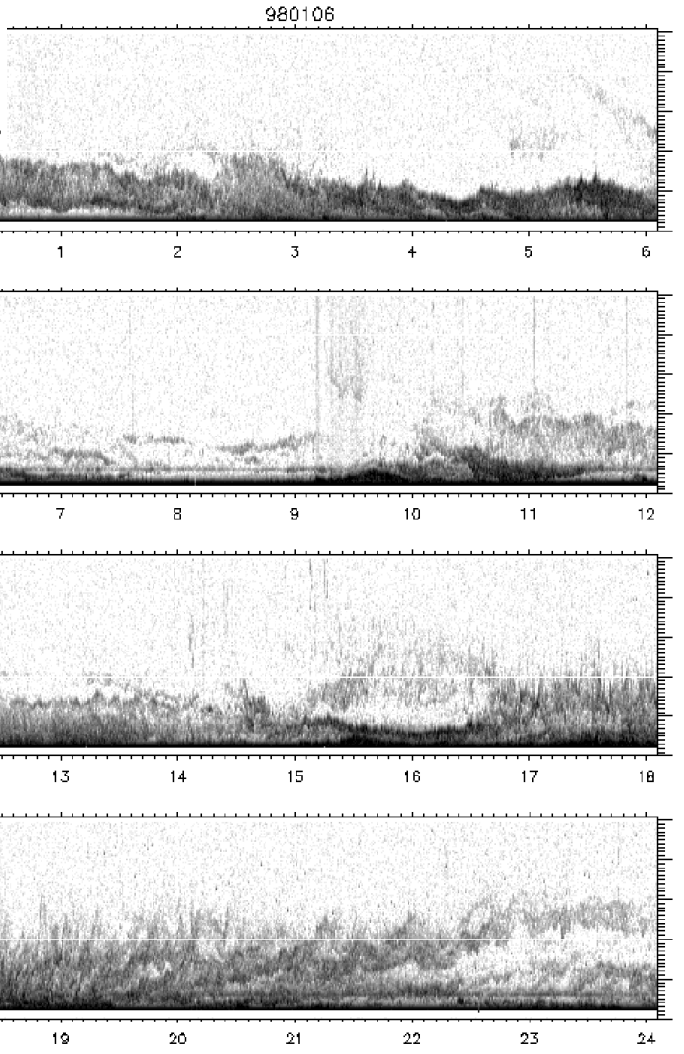


DOME C



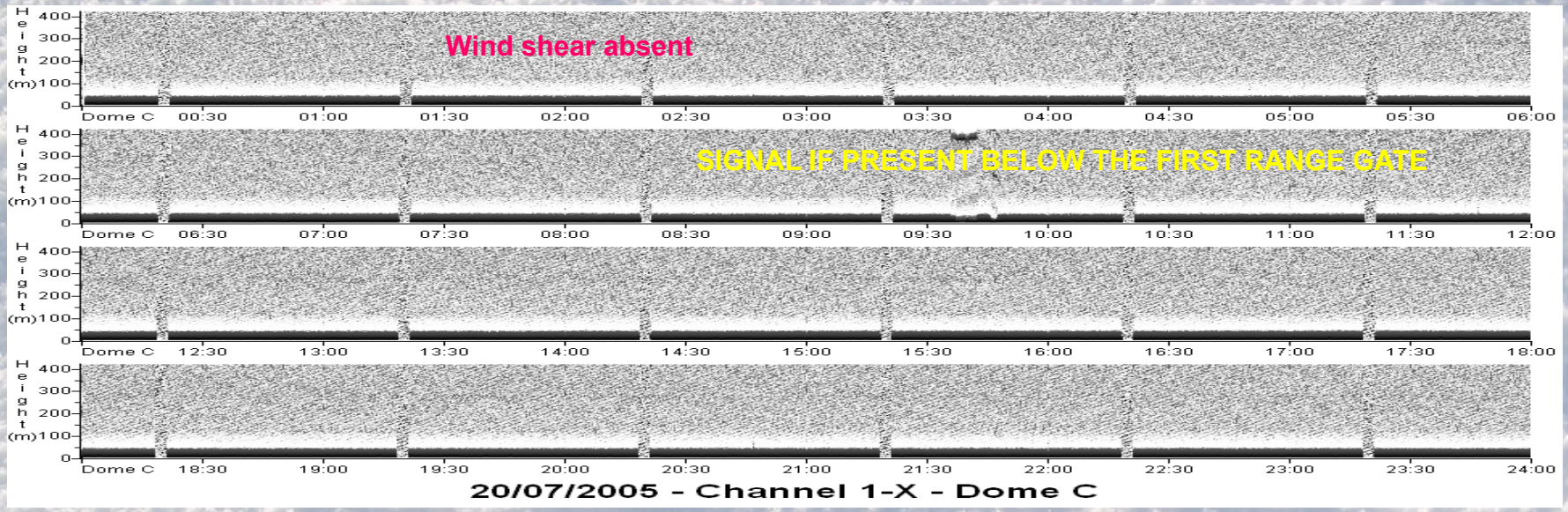


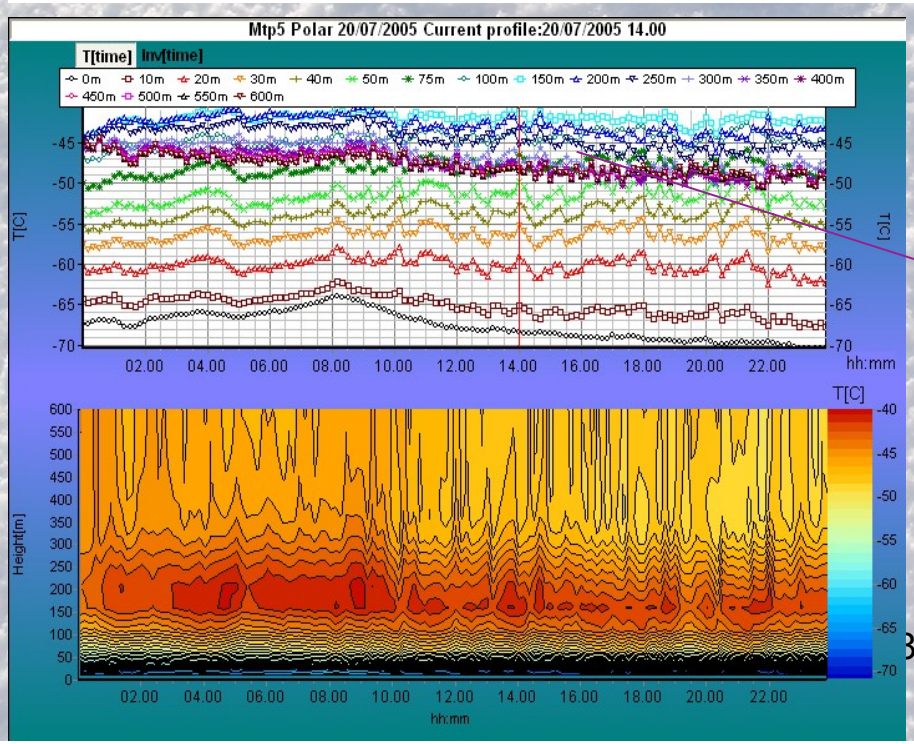
HALLEY

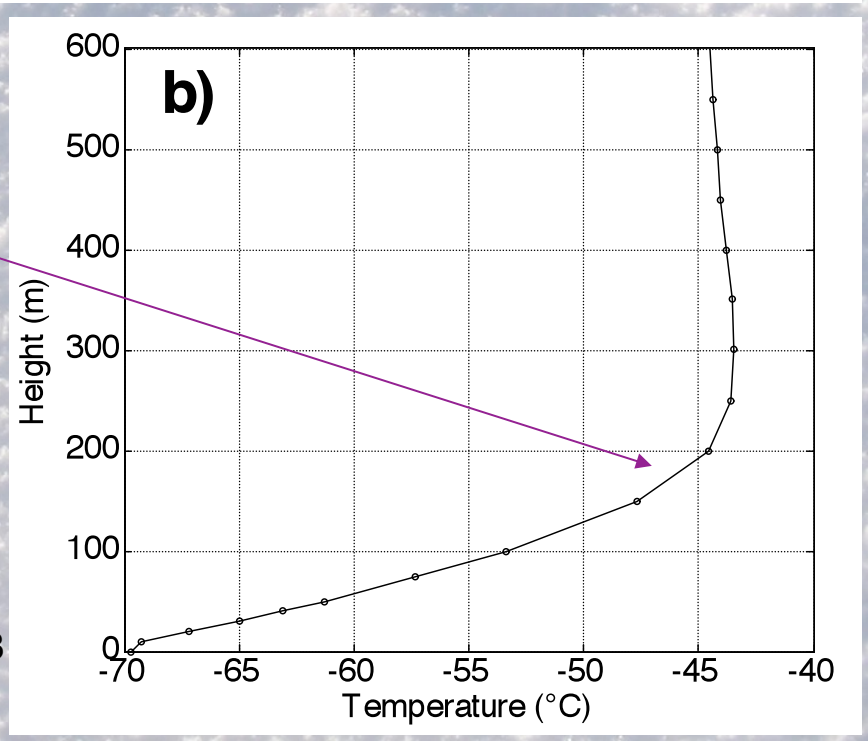


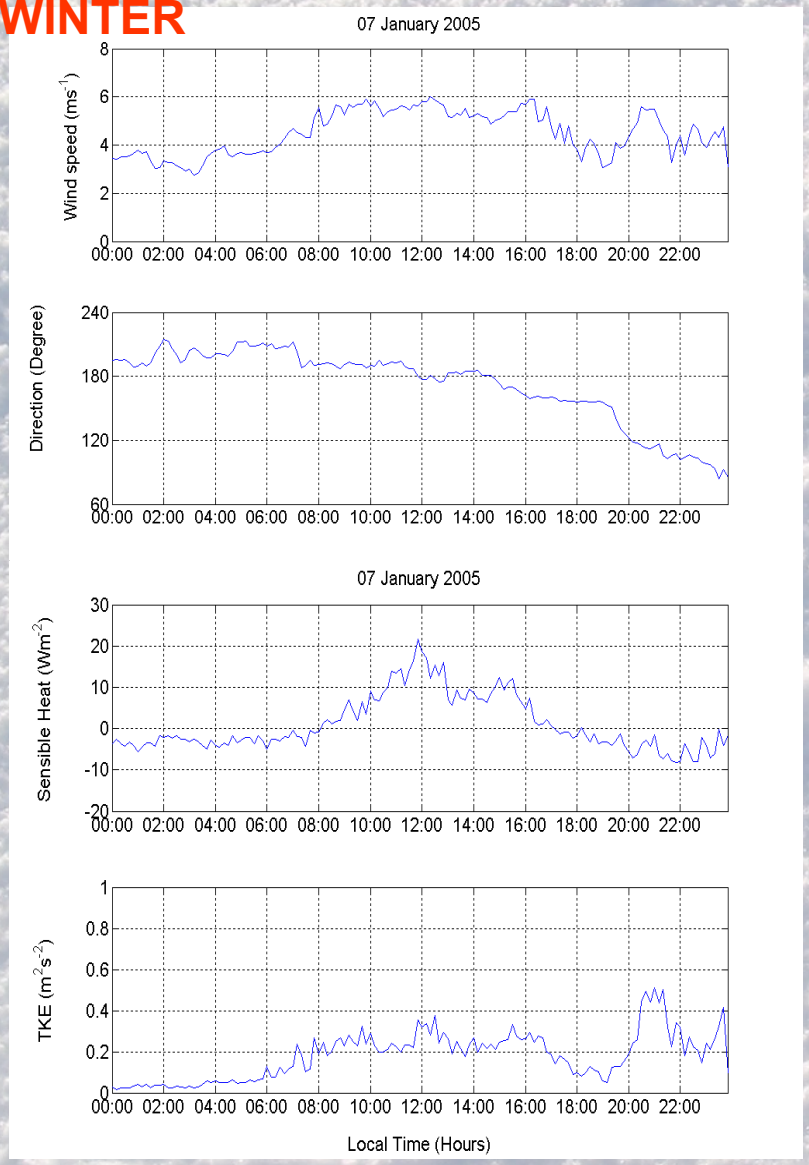
King J.C., Argentini S., P. Anderson, 2006. Contrasts between the summertime surface energy balance and boundary layer structure at Dome C and Halley stations, Antarctica. J. of Geophysical Research Vol. 3 D02105

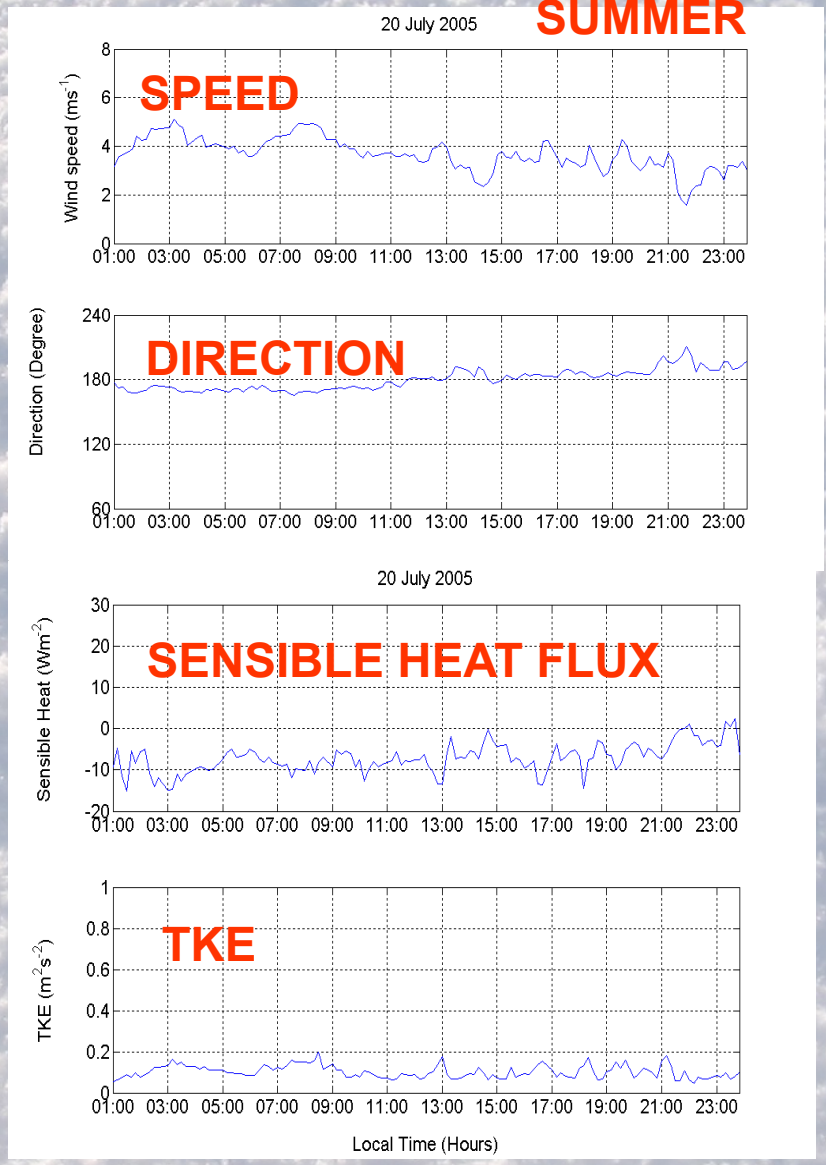
Stable Boundary Layer observed during the winter











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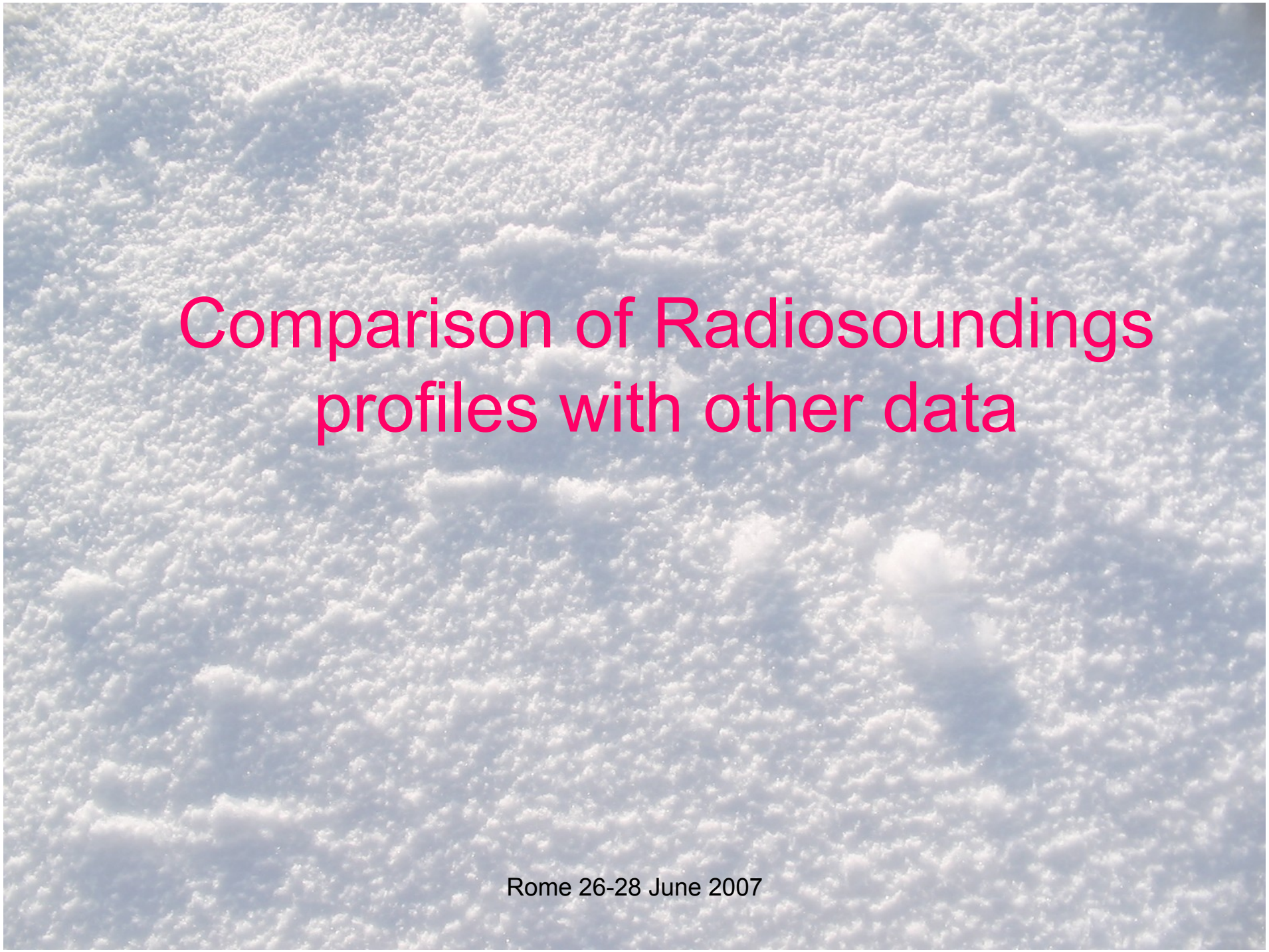
Comparison of Radiosoundings profiles with other data
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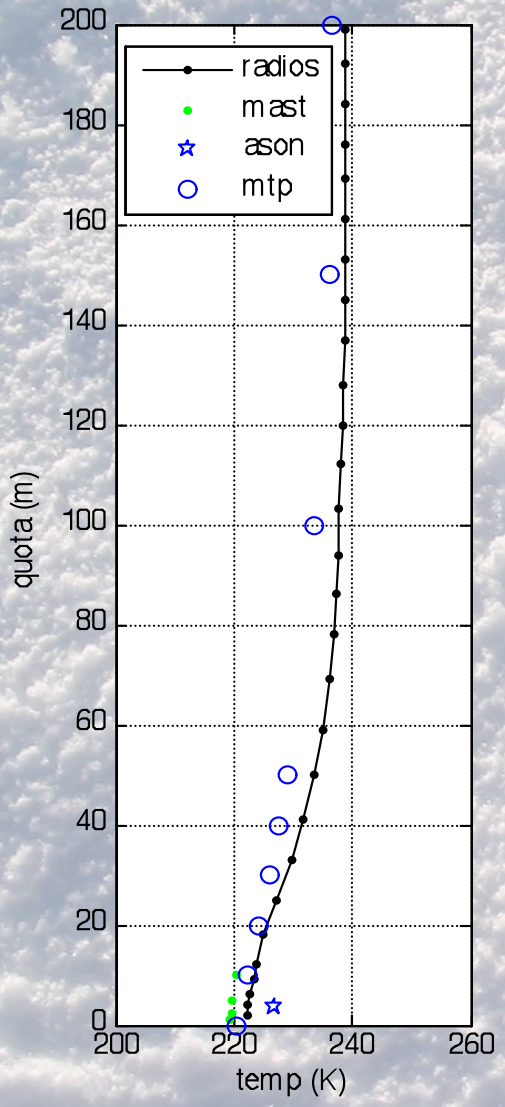
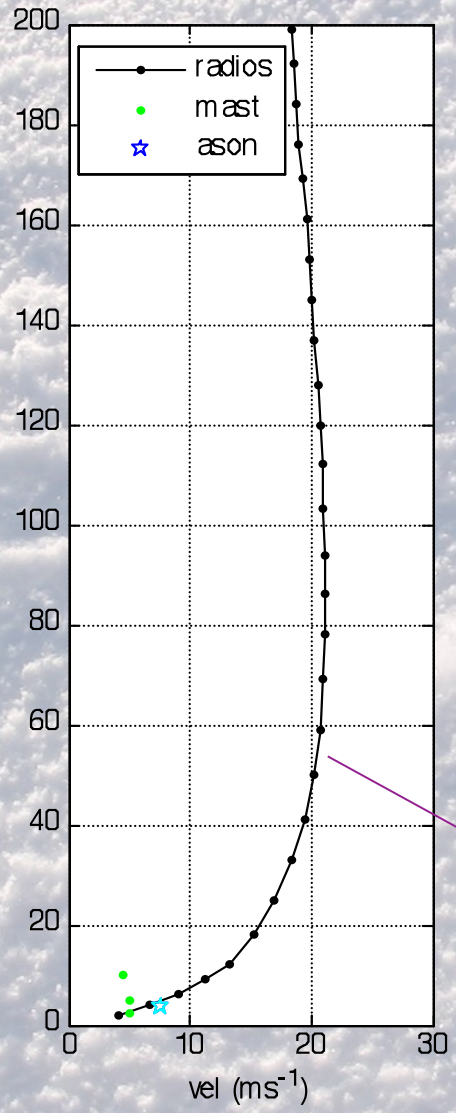
WINTER

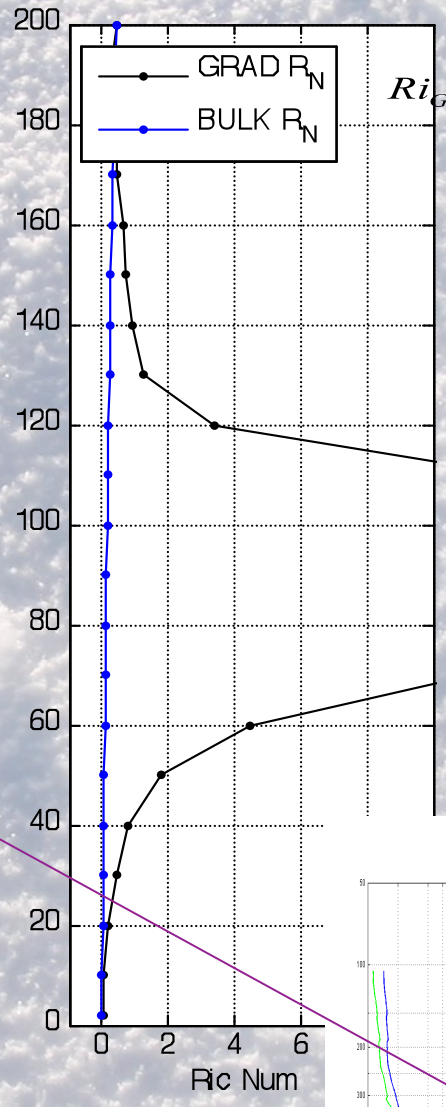
10-Jun-2005 - h(RiG=.25)= 30 - h(RiG=1)= 50

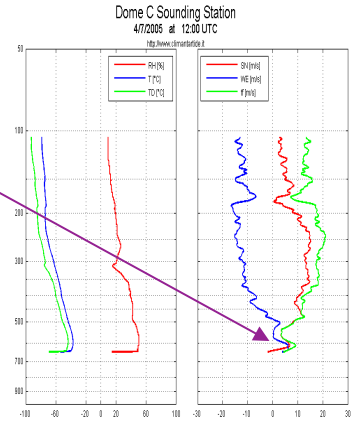
$$R_{BULK} = \frac{g(\vartheta - \vartheta_0)}{\vartheta(u^2)} z$$

$$Ri_{GRAD} = \frac{g\frac{d\vartheta}{dz}}{\vartheta_m\left(\frac{du}{dz}\right)^2}$$









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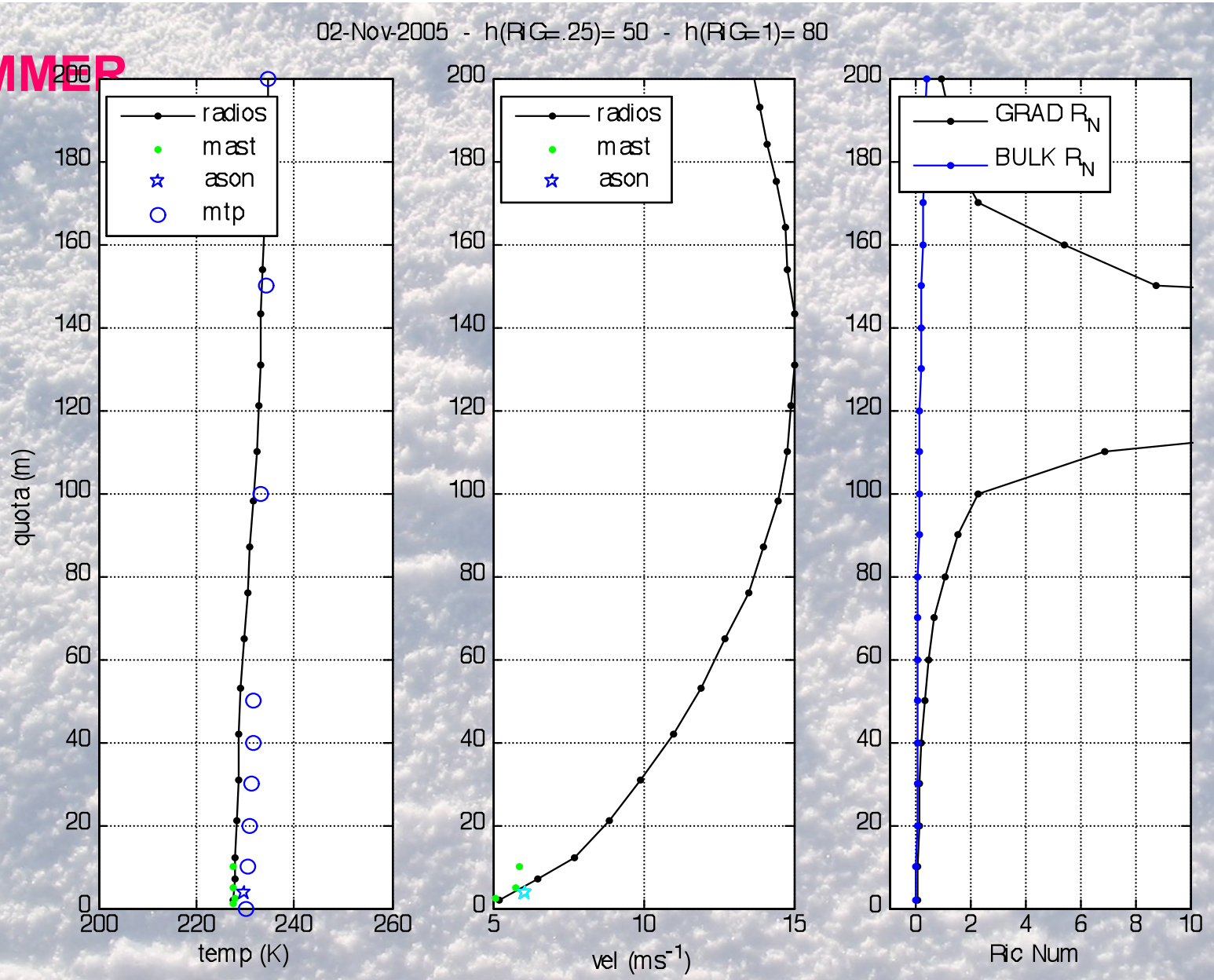
During the winter the surface cools down in response to longwave radiation and a surface inversion begins to form and develop.

Since buoyancy inhibits vertical momentum exchanges in the inversion layer, significant wind speed and direction shears develop in this layer.

The wind speed profile is generally characterised by a low – level jet in which winds are often supergeostrophic.

Internal gravity waves can also develop in such stratified environment; such waves frequently appear mixed with turbulence.

SUMMER



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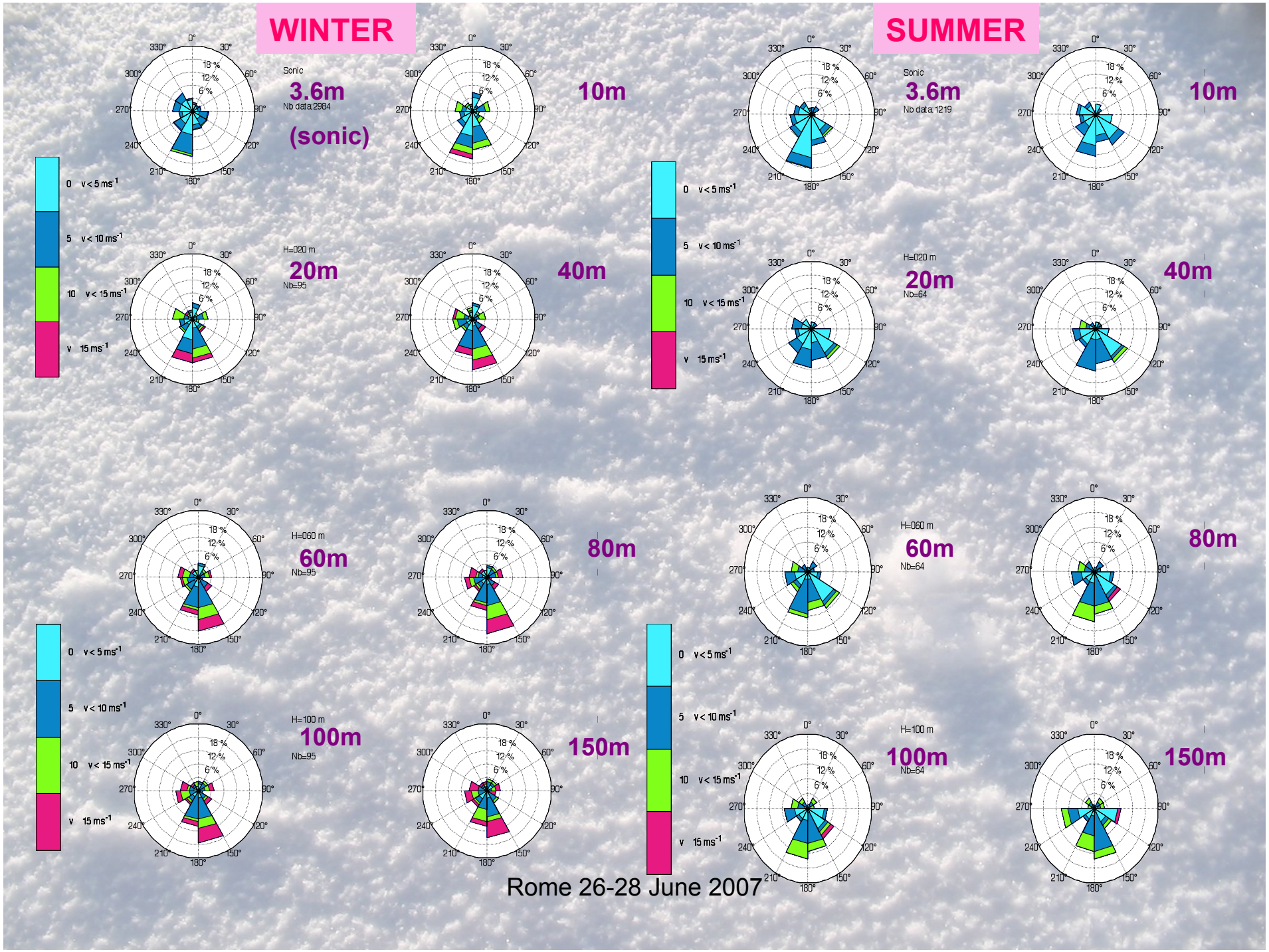
WINTER
SUMMER
Sonic
3.6m
Nb data:2984
(sonic)
10m
Sonic
3.6m
Nb data:1219
10m
0 v < 5 ms-1
5 v < 10 ms-1
10 v < 15 ms-1
v 15 ms-1
H=020 m
20m
Nb=95
40m
H=020 m
20m
Nb=64
40m
H=060 m
60m
Nb=95
80m
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Nb=64
80m
H=100 m
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Nb=95
150m
H=100 m
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Nb=64
150m
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Typical temperature profiles
in the PBL
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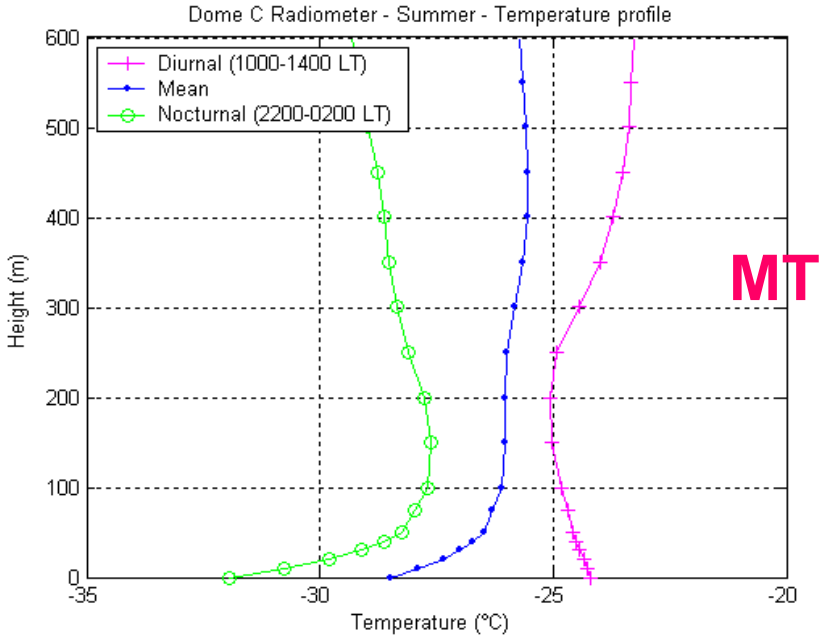
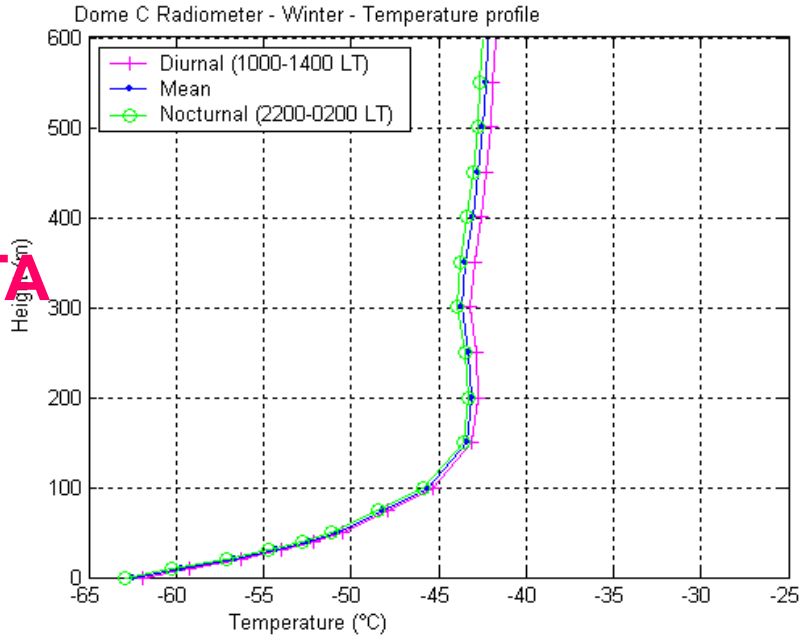
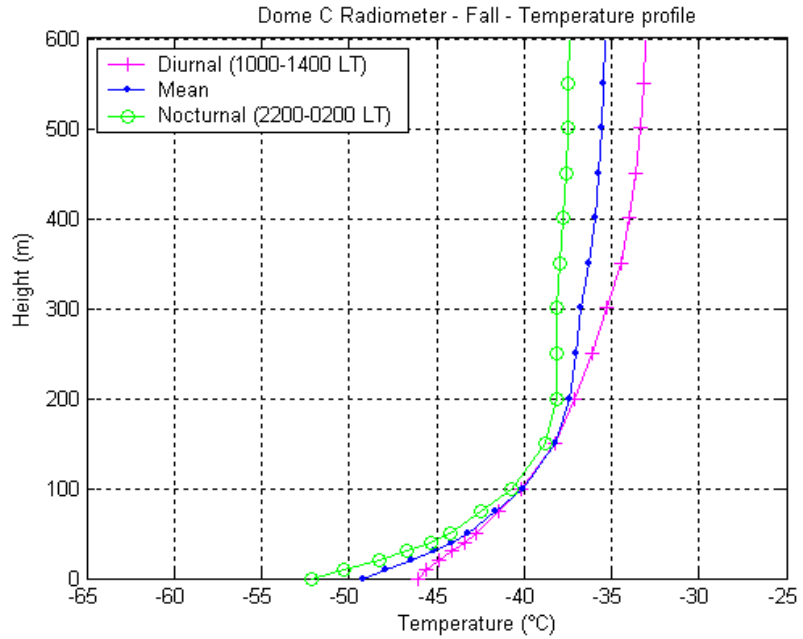
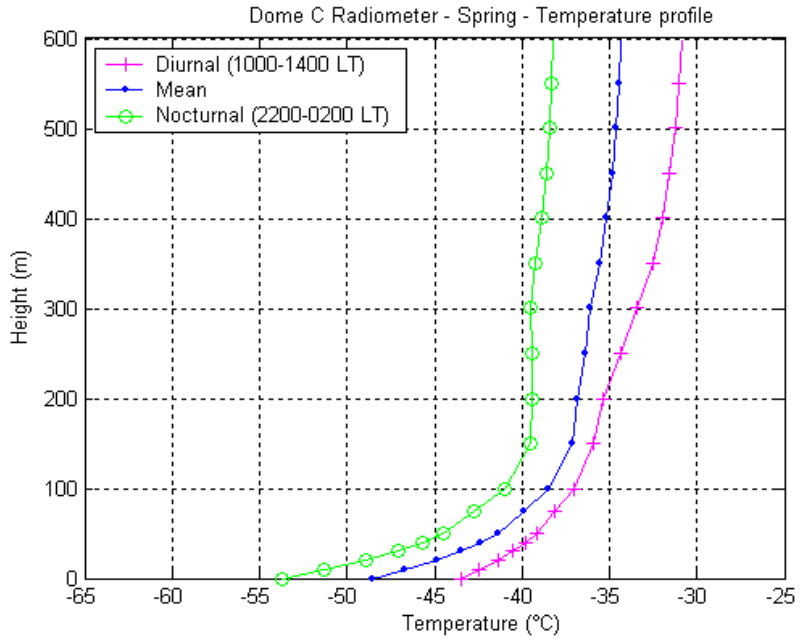
Boundary Layer temperature profiles



MTP DATA







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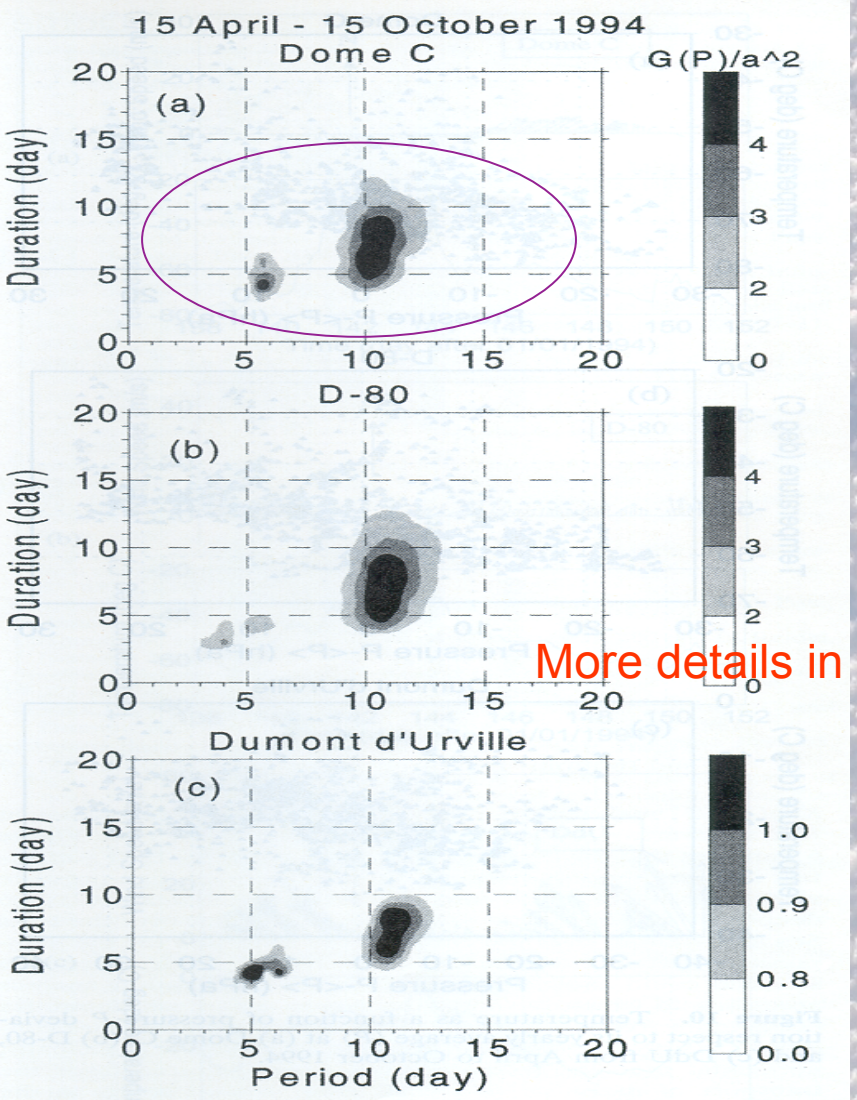
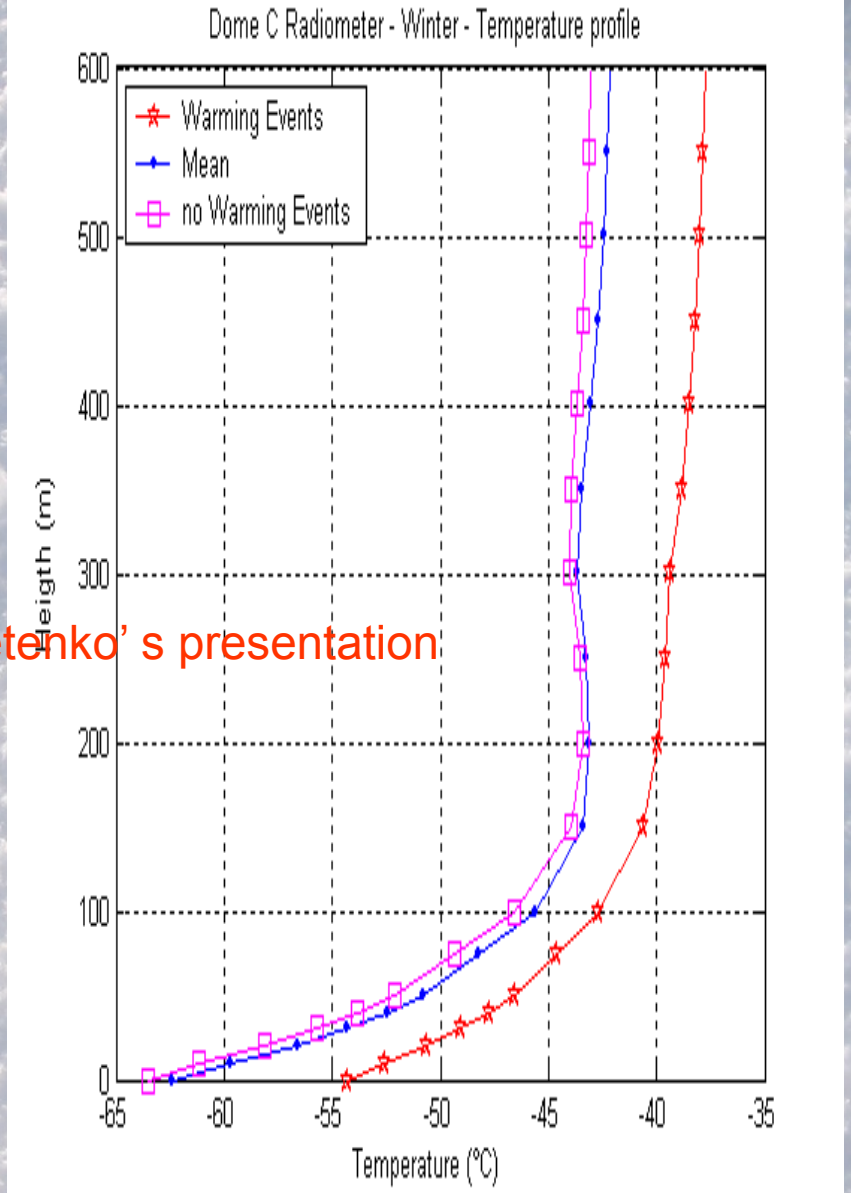


Figure 9. Spavelet diagrams showing spectral density of wavelet transform coefficients versus period and duration of irregularities in the temperature time series for Dome C, D-80, and DdU from April 15 to October 15, 1994. $G(P)$ is the spectral density, and a is the wavelet temporal scale attributed to the duration of irregularities. See text more details.

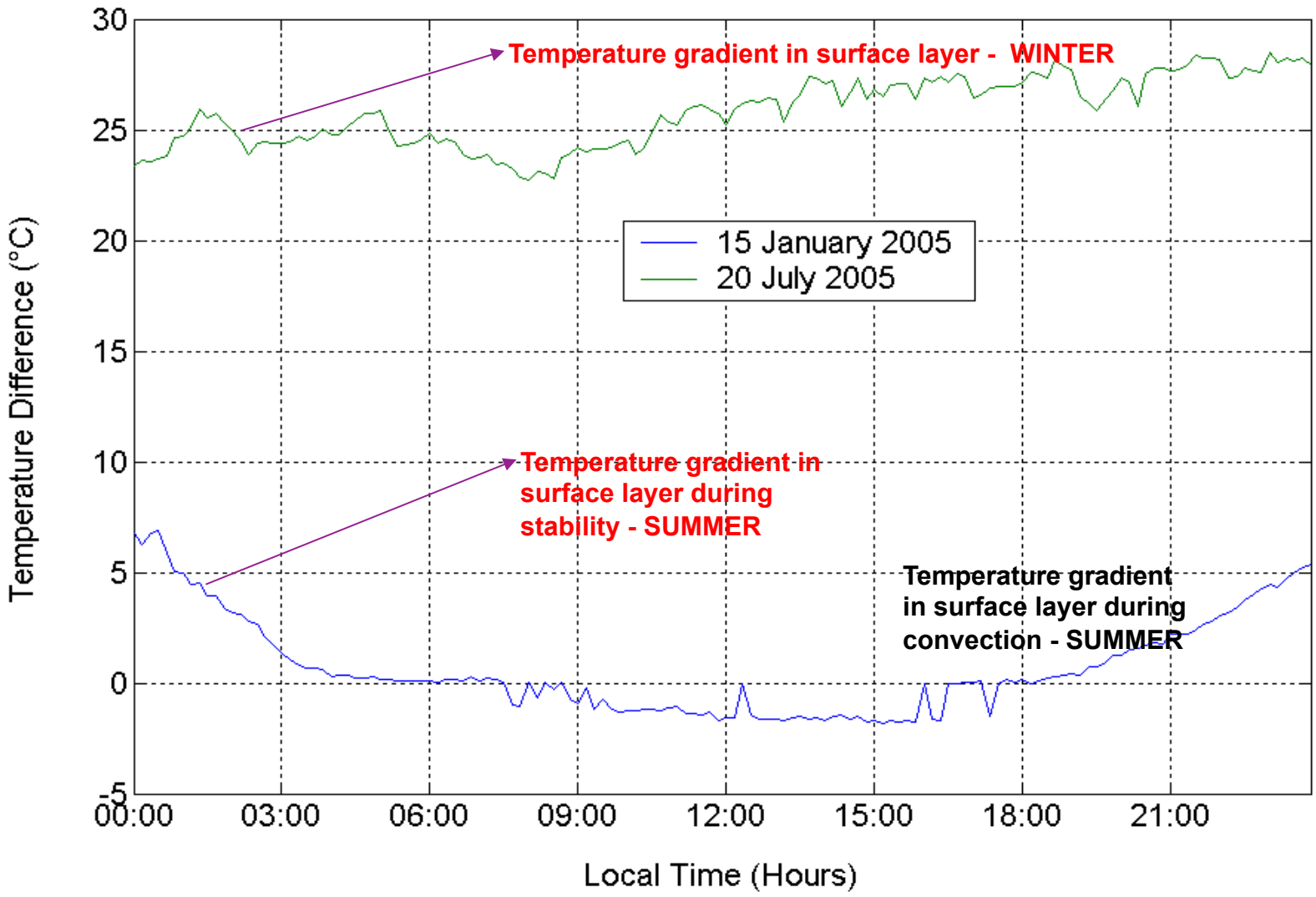


More details in Petenko' s presentation

Argentini S. , I. V. Petenko, G. Mastrantonio, V. A. Pavlyukhin, and A. Viola, 2001; Spectral characteristics of East Antarctica Meteorological Parameters during 1994. *J. of Geophysical Research, Vol* 106, N° D12, p. 12463-12476.

Diurnal Behaviour of

Temperature gradient -------- T(H=inflection height) – T(ground)



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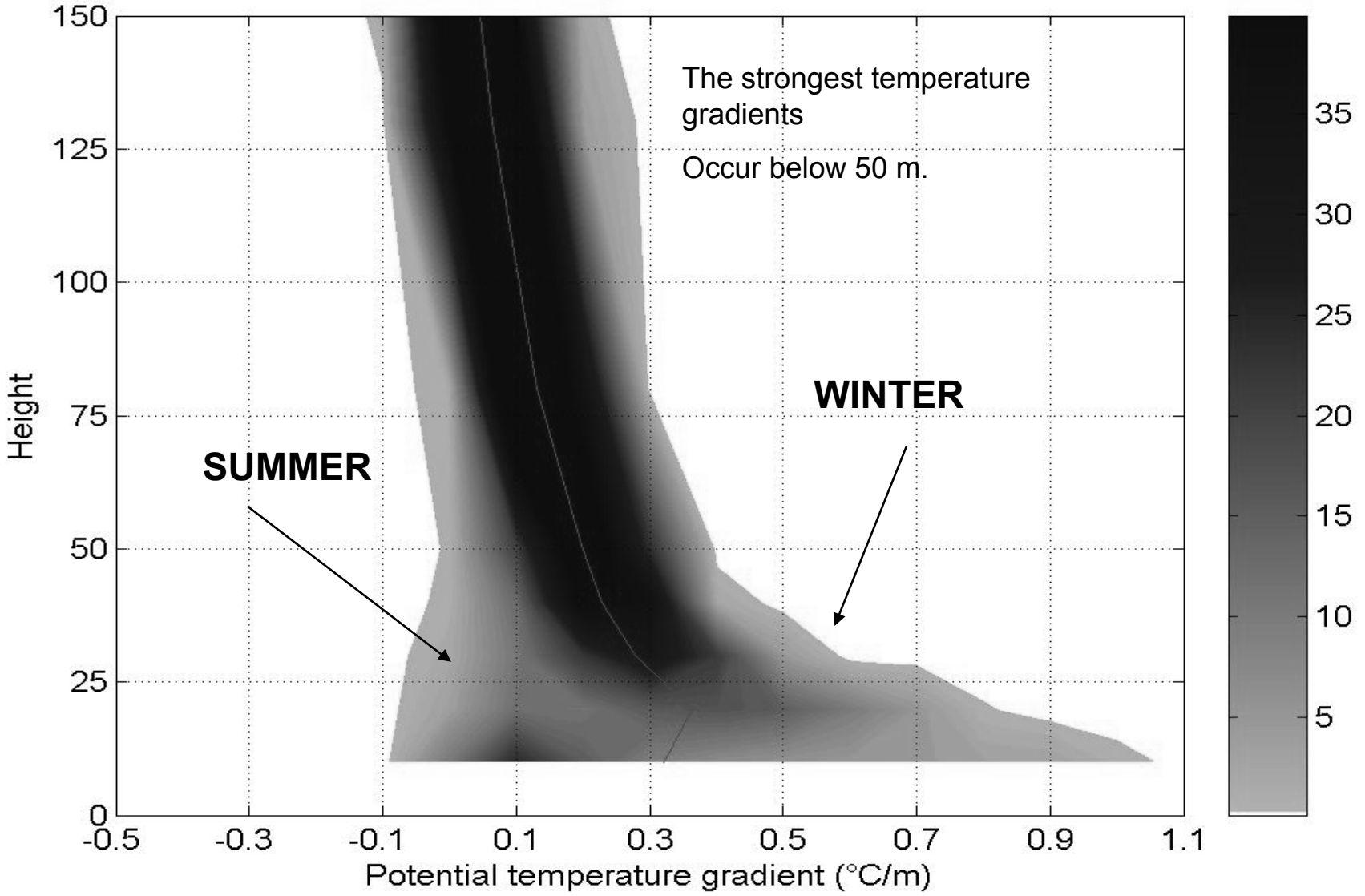
Colour zone graphic of potential temperature gradient



Richardson Number

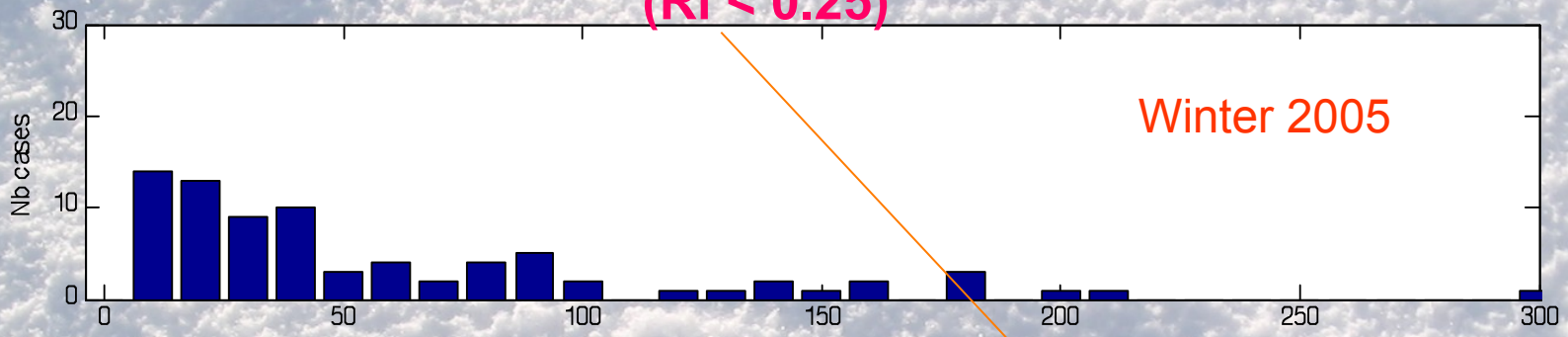
•The Richardson number is a measure of the intensity of mixing (turbulence) and provides a simple criterion for the existence or non-existence of turbulence in a stably stratified environment.

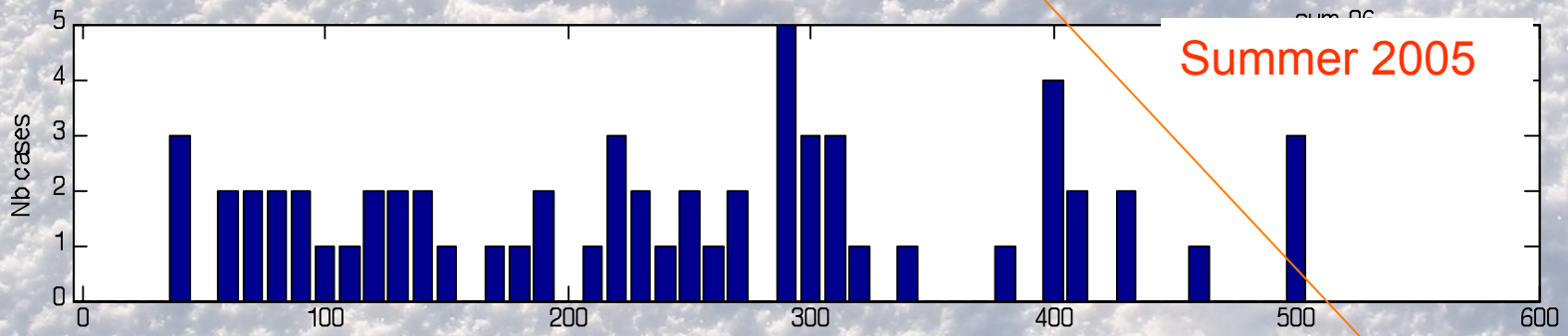
•Large positive value of Ri (greater than 0.25) are indicative of weak and decaying turbulence or a completely non-turbulent environment.

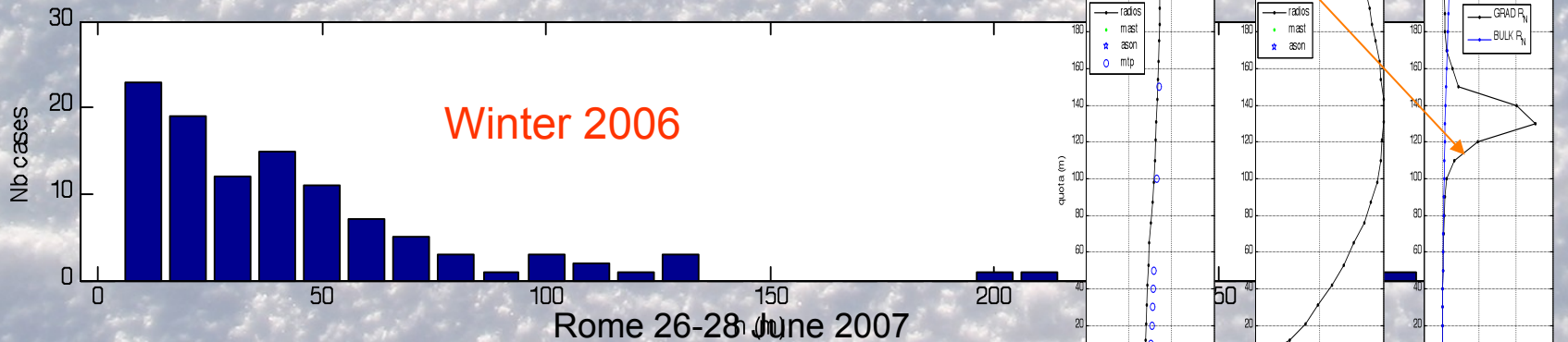
•Stably stratified flows with weak negative density gradients and/or strong velocity gradients can also become dynamically unstable, if the Richardson number is less that its critical Value Ric = 0.25

DISTRIBUTION OF TURBULENT LAYER with RICHARDSON NUMBER

(Ri < 0.25)







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FUTURE WORK

- Continue PBL monitoring at Dome C
  - PNRA Proposal
  - IPY Proposal
- Coordination of Atmospheric activities at Concordia (COCOA = COncordia Common Observatory of the Atmosphere)
- Contribution to atmopheric “site testing”

Monitor, understand and model the PBL-CI system during winter :

- **Sodar measurements needed to obtain a general picture of the temperature fluctuation field within and above the stable PBL and to estimate the PBL height (however they cannot cover all possible cases).**

- **MPT5 Measurements : high resolution temperature profiles to monitor the temperature gradient**

- **Real-time numerical large eddy simulation (LES) study of the PBL-CI system covering the entire autumn-winter period over Dome C – focused on the vertical / temporal distribution of the TPE (then squared temperature fluctuations, then CN2) and other required parameters.**

- **Measurements - complementary to currently performed:**

  Basic turbulence measurements at 1 level (3 m)

  Mean profiles of wind and temperature in the lower 50 m (7-8 levels) - needed

  (i) to understand if Katabatic winds occur and

  (ii) to compute Richardson numbers close to the surface

Experimental data and LES would complement each other and allow quantifying mechanisms of generation and maintaining of TKE / TPE over Dome C and giving reliable scenario of typical winters – for use in optimal planning of the construction work and future astronomical observations.

SODAR (Sound Detection and Ranging)

Using acoustic waves the sodar gives a picture of the thermal structure of the atmosphere.

Setting of the sodar antennas vertically pointing one (up to 3) transmitting and one receiving; height resolution 5 m, first range gate 5 m; maximum reached height 100 m. To be tested and run at Dome C by ISAC.

The high resolution needed in the near proximity of the ground and the very narrow layer of interest (about 150 m) suggest the use of high acoustic frequencies.
In order to monitor the winter as well the summer boundary layer structure we plan to develop a new high resolution mini-Sodar system which can work in two modes:

- very high resolution (resolution 2.5 meters – first range gate 5 m – maximum range 150 m) during the winter
-High resolution (resolution 5meters – first range gate 10 m – maximum range 300 m) during the summer

This system will be used in a configuration which will use 3 emitting antennas and one receiving antenna in order to increase the signal to noise ratio.

The new mini-sodar has been done in a way to minimize all the hardware parts which at low temperature are those which give the major problems.


THANK YOU
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