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# Meteorological observations in Antarctic: over sea ice in winter 2013 and in Dronning Maud Land in summer 2014-2015

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10th Antarctic Meteorological Observation, Modeling, and Forecasting Workshop
Scott Polar Research Institute, Cambridge, UK 17-19 June 2019

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# Antarctic Meteorology and its Interaction with the Cryosphere and the Ocean (AMICO)

- AMICO is funded by the Academy of Finland (project duration 48 months, 2013-2016)
- Main objectives are to obtain a better knowledge on the Antarctic climate system and utilize this to develop numerical weather prediction and climate models.
- Principal Investigator: Dr. Timo Vihma
- Research team: 17 persons (FMI, HU)
- Collaboration with the Alfred Wegener Institute and TU of Braunschweig in Germany, CSIRO and University of Melbourne in Australia, Texas A&M University, Ohio State University, Brown University, University of California, University of Michigan in the USA, Stockholm University in Sweden, University of Innsbruck in Austria …

# Austral Winter 2013

## Objectives

This project aims at filling the gap of knowledge about the structure of the atmospheric boundary layer (ABL) over the sea ice covered Weddell Sea during winter. Observations were carried out to obtain a better understanding of the interaction between atmosphere, sea ice and ocean.

Joint work by groups from

- Finnish Meteorological Institute in Helsinki (FMI)
- Technische Universität Braunschweig (TU-BS)
- Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI).

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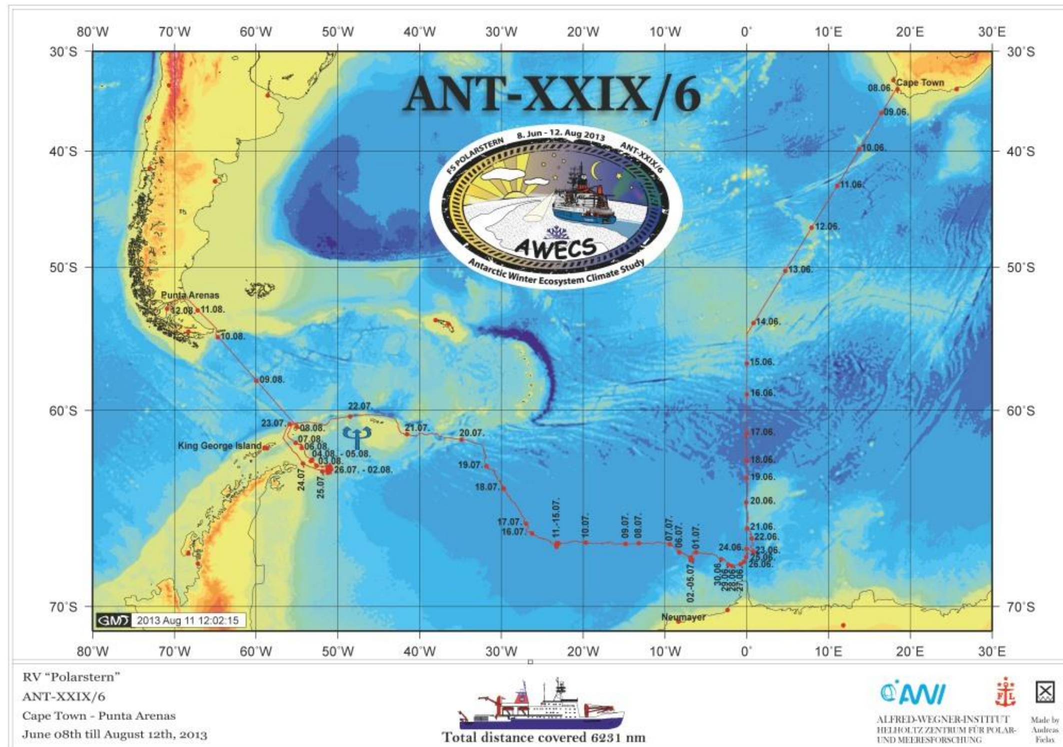
# Polarstern cruise

- RV Polastern Antarctic winter expedition ANT-XXIX/6
- Cape Town, 8 June 2013 – Punta Arenas 12 August 2013
- Altogether 8 ice stations with different duration
- First ice-station on 21 June, last one on 4 August
- Three different types of RPAS were used, SUMO, AMOR, MMAV
- Observations from 2m portable weather mast
- Regular Polarstern radiosonde soundings



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# FMI RPAS fleet

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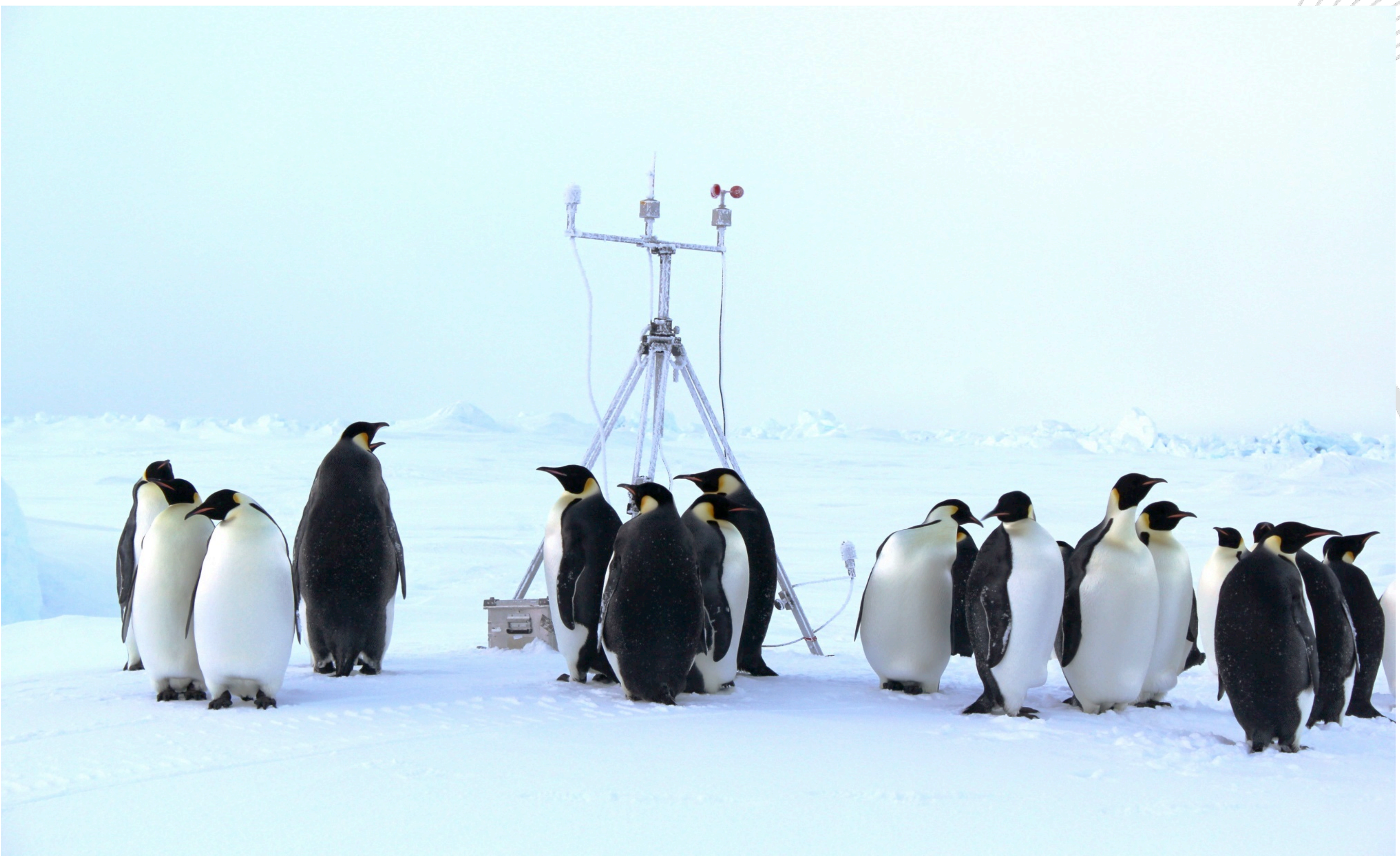

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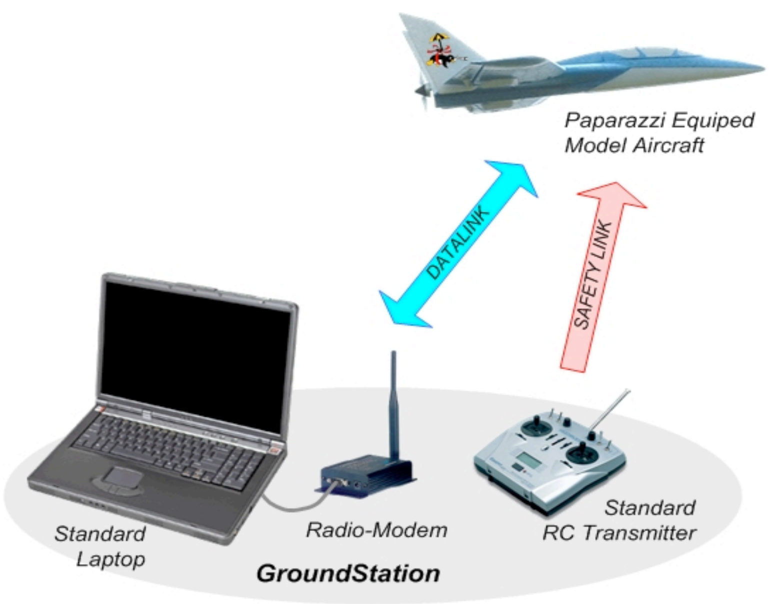
# RPAS SUMO

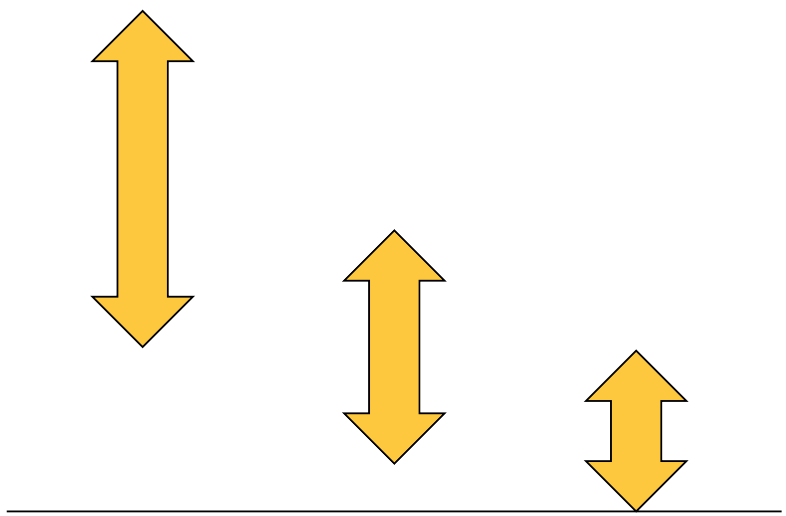
Small Unmanned Meteorological Observer

- Frame by Martin Müller and Christian Lindenberg
- Based on model airplane (FunJet by Multiplex)
- Length 75cm, wingspan 80 cm
- Weight appr. 600g
- Endurance up to 25 min
- Max speed 35 m/s
- Max altitude 3-4 km
- Max ascent rate 15 m/s
- Equipped for measuring temperature, pressure, humidity, airspeed, infrared radiation and estimating wind speed/direction (Pitot tube).
- IMU card and 5-hole probe for turbulence measurements

- It has a Paparazzi autopilot system that allows
  - stabilized aircraft
  - the operator to define complex autonomous missions while in flight to perform any task or adapt to any scenario.
- Hand launched
- Belly landing – manually or automatically (at the predefined point in flight plan)




# Altitude ranges and motivation for multicopter



Manned Aerial Vehicle: 200m - …

Small UAV: 30m - 3000m

Multicop-ter: 0m – 200m

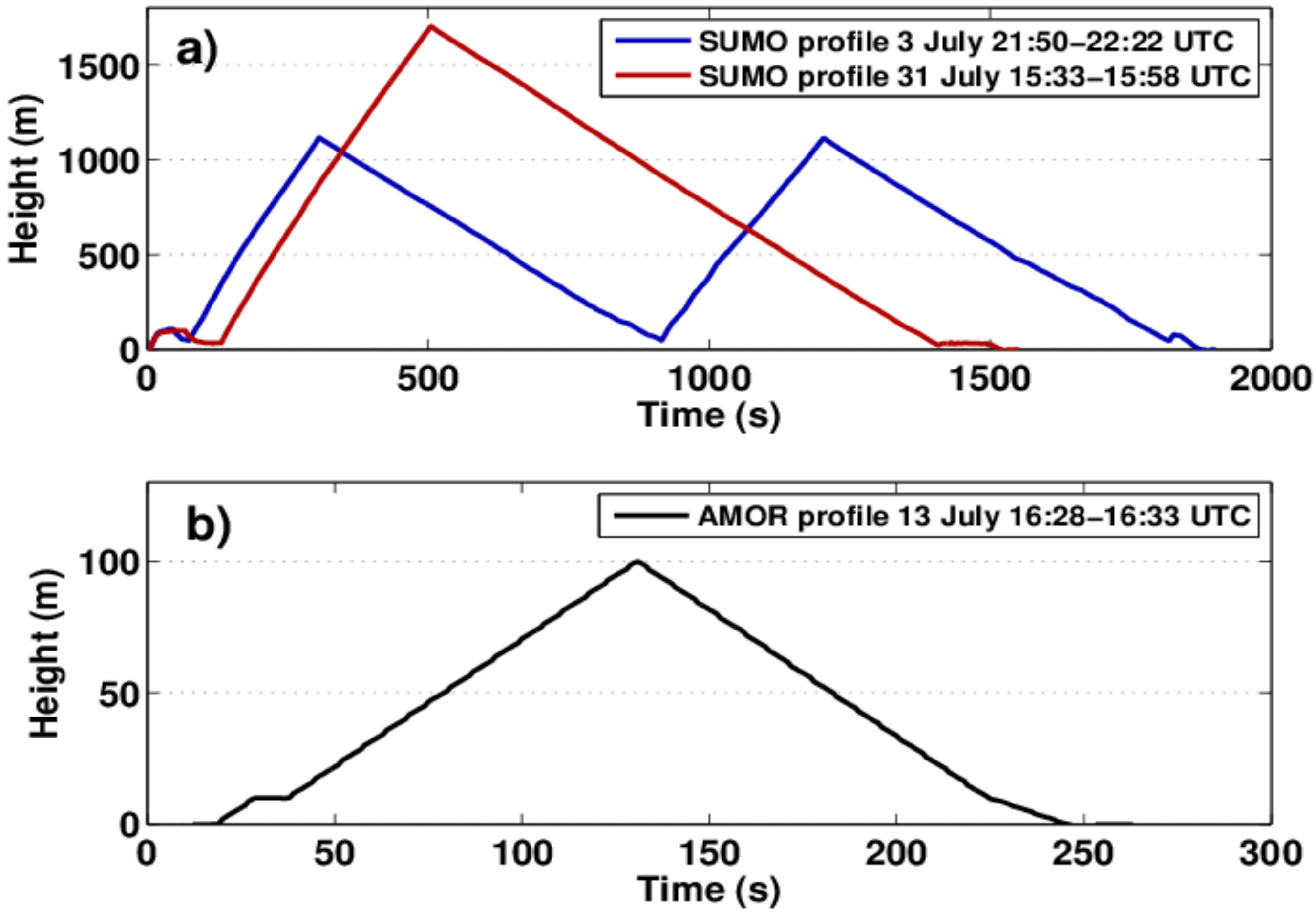
**Suitable tool for ultra-low ABL measurements**

# AMOR multicopter

**Advanced Mission and Operation Research**

- Quadrocopter with meteorological sensors
  - standard temperature and Rh sensor
  - fast temperature and Rh sensor
  - pressure sensor
  - surface temperature sensor
- Data acquisition system - enabling onboard data storage as well as continuous data monitoring on the ground control station during the flight
- Manual (stabilized), loiter and autonomous flight modes
- Fully autonomous mode was used in all flight missions, including predefined flight mission with automatic take-off and landing processes.
- Developed in Hochschule Ostwestfalen-Lippe - University of Applied Sciences

# Vertical profile strategy



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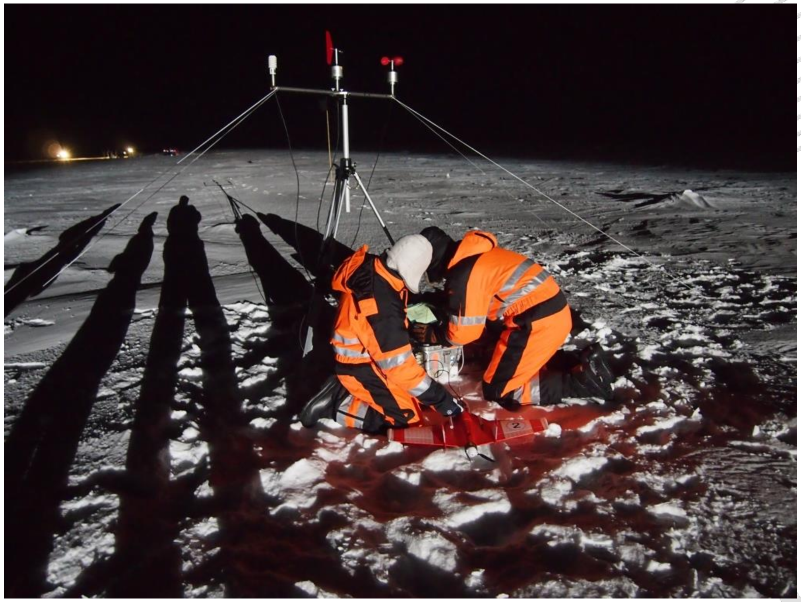
# Data collected

SUMO flights:
- Flights during 5 ice-station
- Max altitude between 1km and 1.7km
- 51 flights, 76 profiles

AMOR missions:
- Flights during 3 ice-stations
- 24 flights/profiles
- High quality profiles of T, Rh from the lowest 100m

Weather mast deployed during 7 ice-stations



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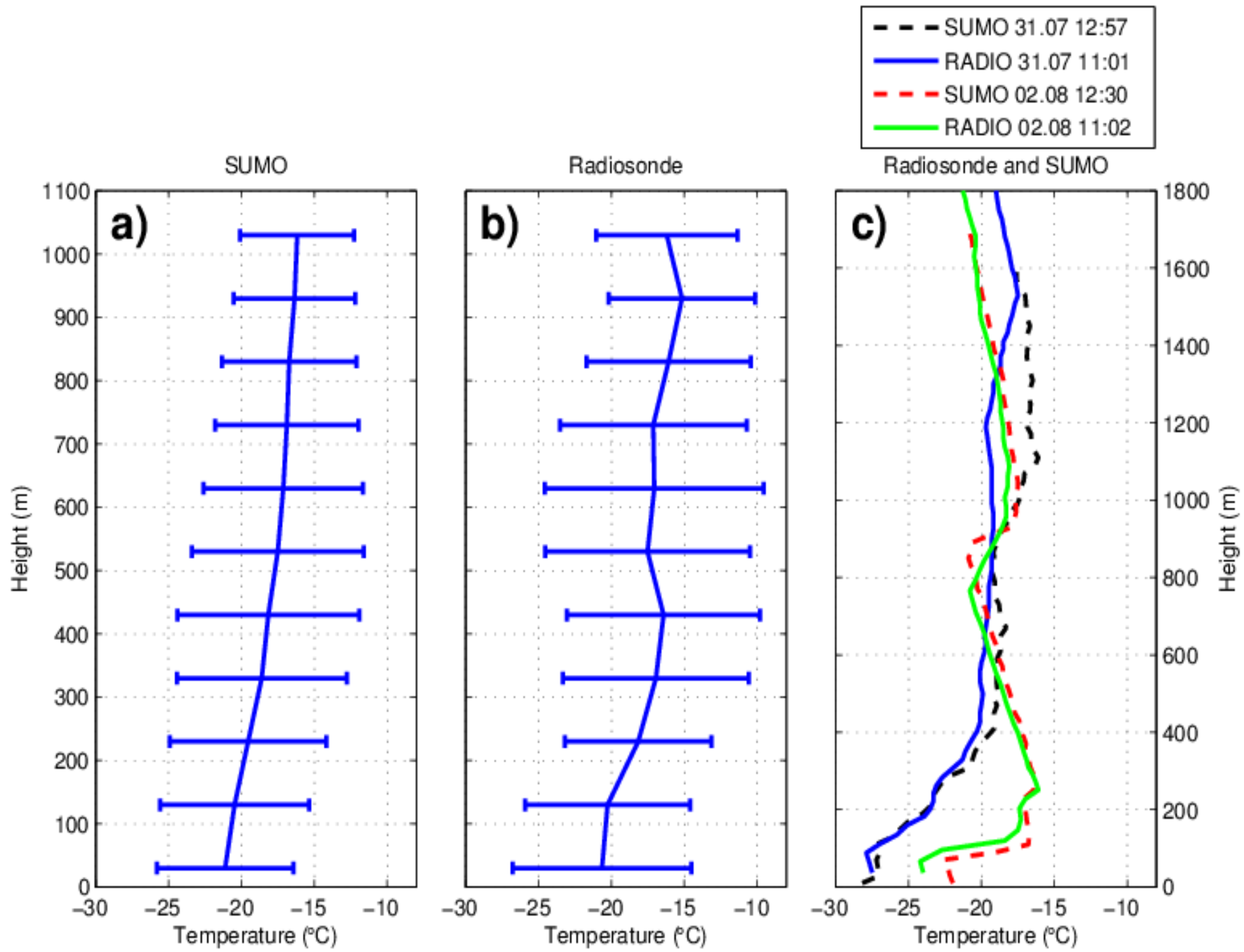
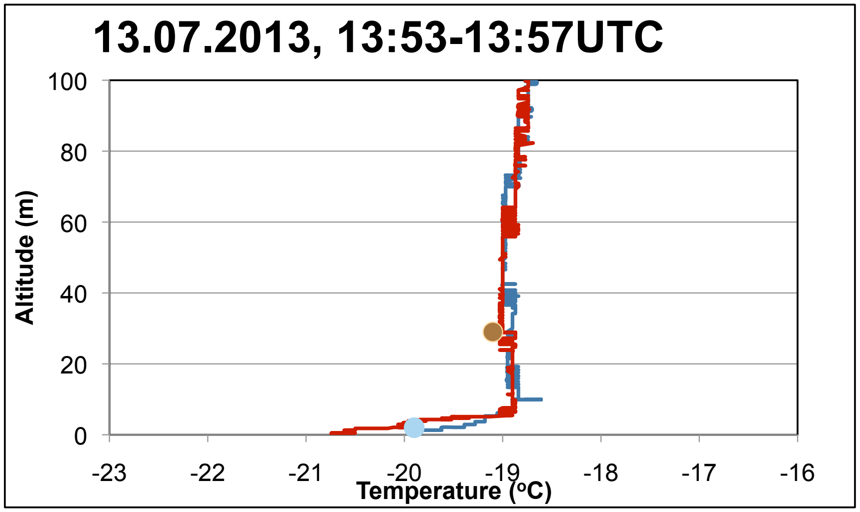
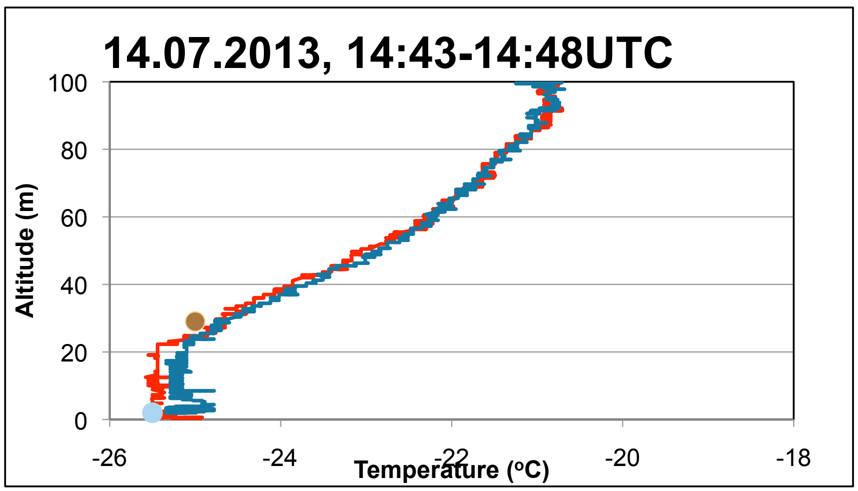
# SUMO vs. Polarstern radiosonde

- Average vertical profiles of T with standard deviations
- 69 SUMO profiles
- 10 radiosonde profiles (days when SUMO was operated)
- Radiosonde average profile less smooth than SUMO profile
- 2 single cases, 31 July and 2 August (timing error less than 2h)



# AMOR profiles




THT(up)
THT(down)
2m (Aanderaa mast)
29m (Ship)

# Flying lessons

- Strong wind (over 10m/s)
- Poor visibility due to low foggy clouds
- Ice formation on the UAVs' wings and propeller blades
- Finding suitable landing and take-off stripe on very rough sea ice
- Bigger plane – more requirements, less flexibility
- Obvious advantage of quadrocopter compared to SUMO and $M^2AV$, as it does not need large flat areas for landing and take-off
- Human mistakes

# Icing

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# Concluding remarks

- Observations over Antarctic sea-ice in winter
- Combined use of RPAS, ship observations and a small portable weather mast
- Advantages of AMOR comparing with fixed wing systems
    - faster temperature sensor
    - slower ascent and descent rate
    - temperature profiles more realistic under strong temperature stratifications
    - fully automatic take off and land on ridged sea ice
- Modern RPAS – easy to operate – utilization attractive in remote (polar) environments with limited infrastructure
- Notable cost-efficient performance
- Ongoing necessity in small and fast sensors, particularly whem humidity measurements are considered

# Objectives, Measuring Sites, Instruments …

**Period**:
December 2014 – February 2015.
**Field Group:**
Tisler, Kouznetsov, Leppänen, Lahtinen
**Objectives**:
- Physical processes in ABL
- Surface energy balance and albedo over different surface types
- Thermodynamics and structure of snow pack

**Observations**:
- Weather mast (2), surface energy budget, and snow measurements
- Spectral albedo measurements
- Sodar measurements
- UAV flights (SUMO + QC's)
- AWS deployment (2 tripods)
- SIMB deployment (sea ice)

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# DRONNING MAUD LAND AIR NETWORK (DROMLAN)

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# DRONNING MAUD LAND AIR NETWORK (DROMLAN)

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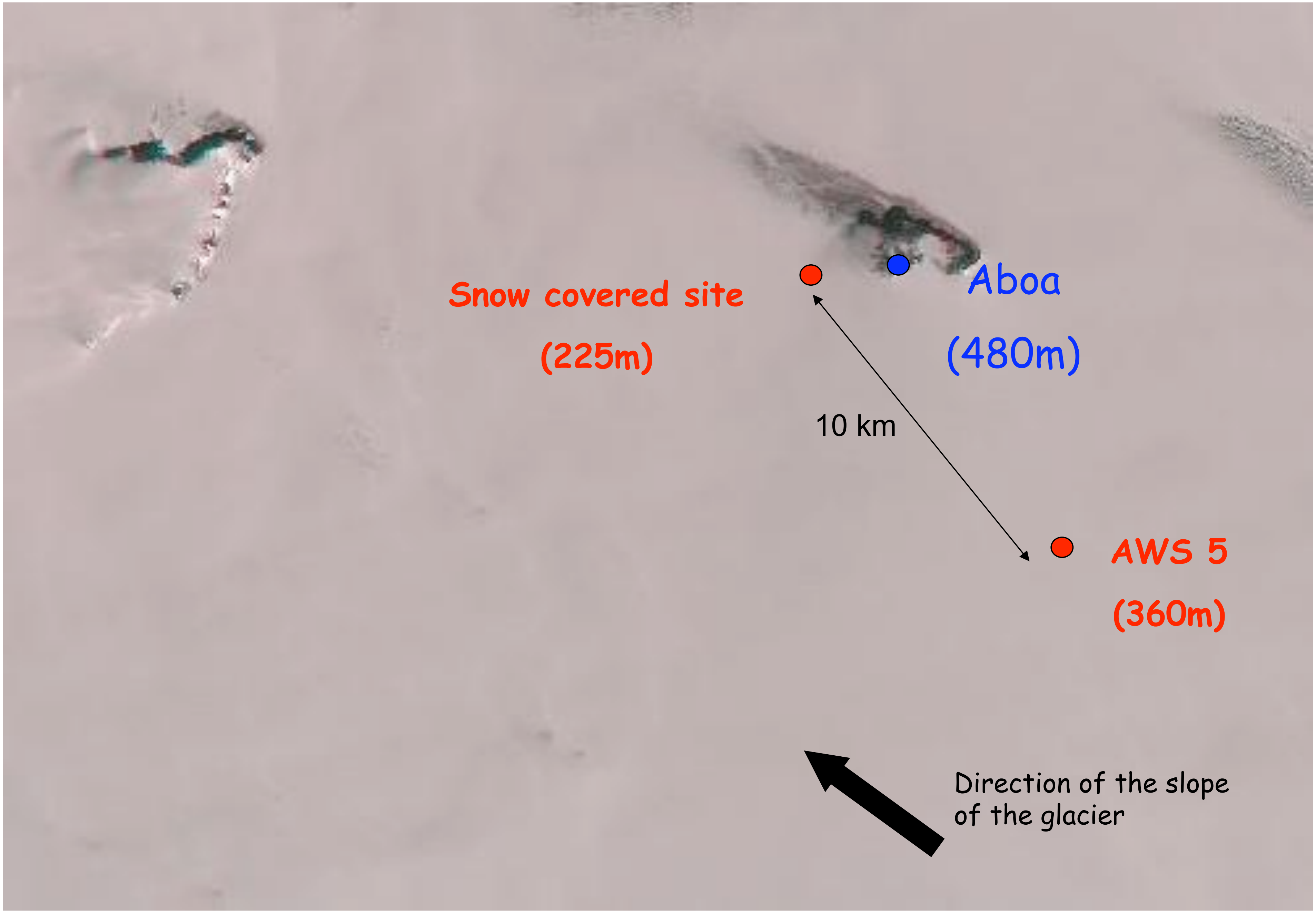
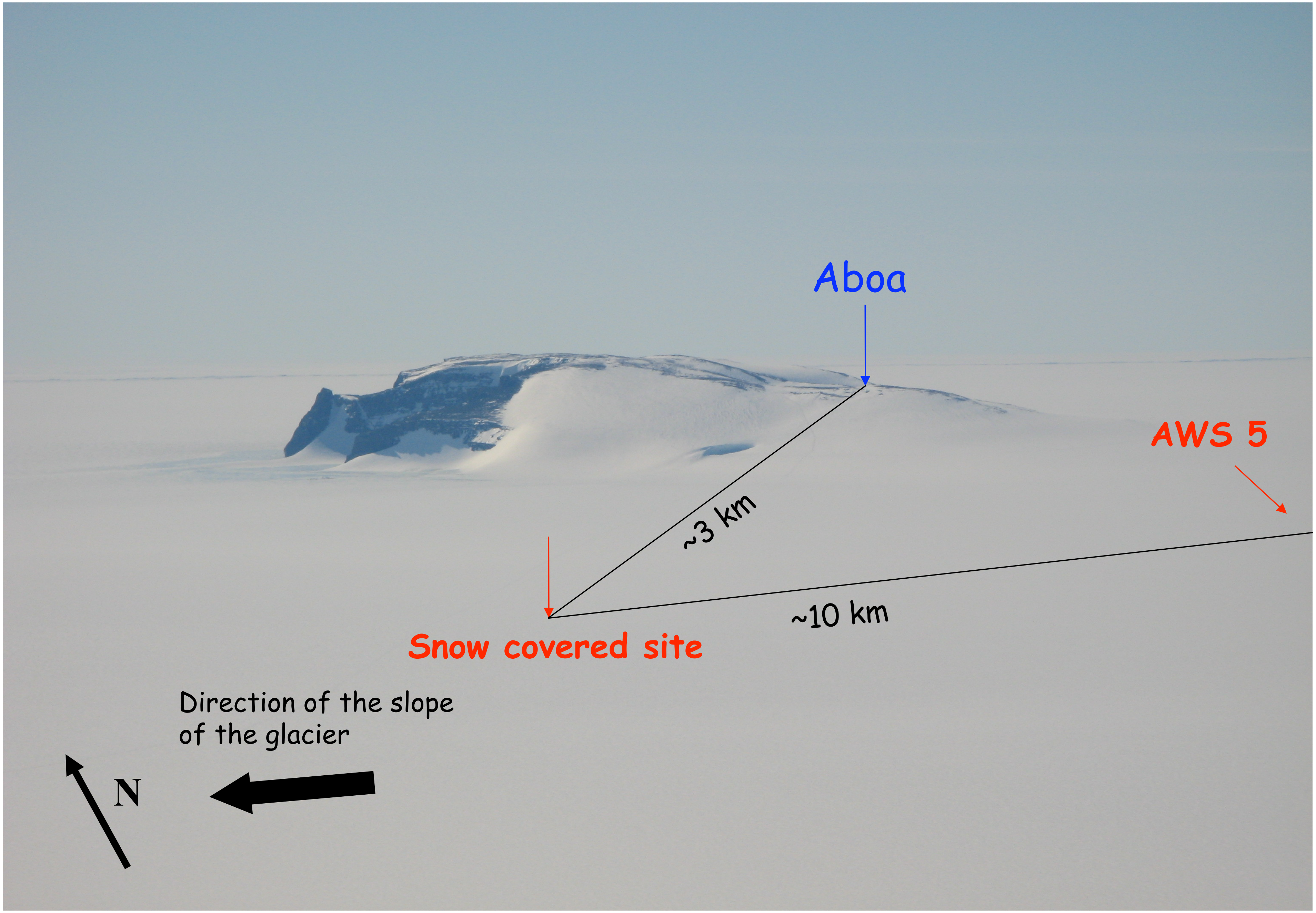
- The Finnish Antarctic research station Aboa (73°03'S, 13°25'W) was built in 1988 - 89.
- The Swedish research station Wasa is located only 200 m from Aboa (together the two stations form the Nordenskiöld Base Camp).
- Aboa was enlarged and renovated during the summer 02-03. (New block for sauna and bathroom, new block for radio room and for station manager, new accommodation containers for the scientists etc.)
- Aboa is now designed to provide for expeditions sized from about 12 even to 18 persons.
- The station consists of a main building, 2 laboratory containers, 3 containers for accommodation, one of which being medical doctor's container.
- The research station is occupied during the Antarctic summer only.


Snow covered site
(225m)
Aboa
(480m)
10 km
AWS 5
(360m)
Direction of the slope
of the glacier


Aboa
AWS 5
~3 km
~10 km
Snow covered site
Direction of the slope
of the glacier
N

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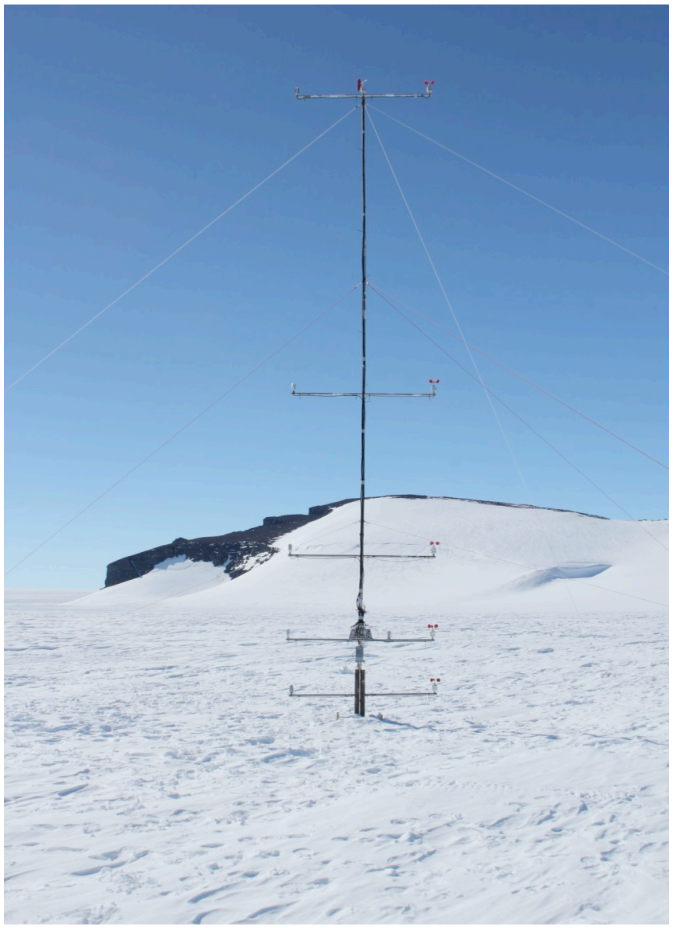
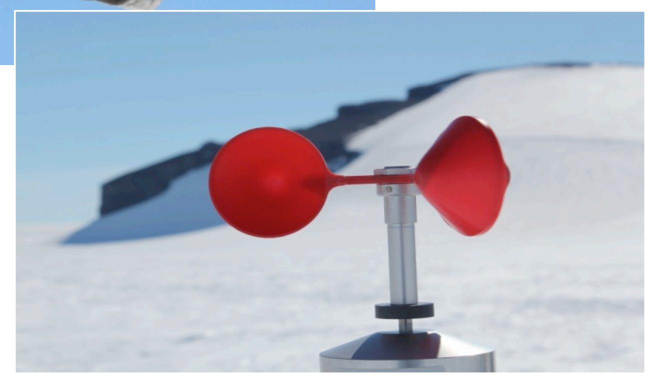
# 10m weather mast at the Snow-covered Site





- **Cup anemometers and thermal sensors at 0.5m 1.2m, 2.5m, 5m and 10m.**
- **Wind direction sensor at 10m.**
- **MSR145**

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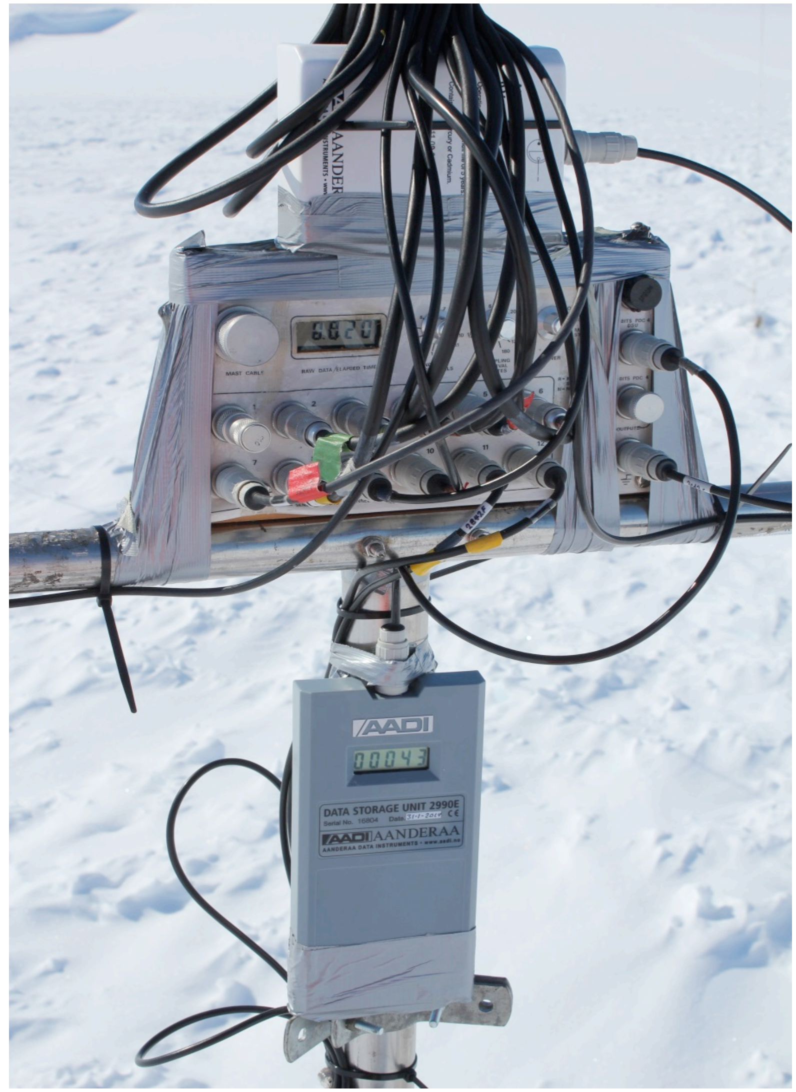
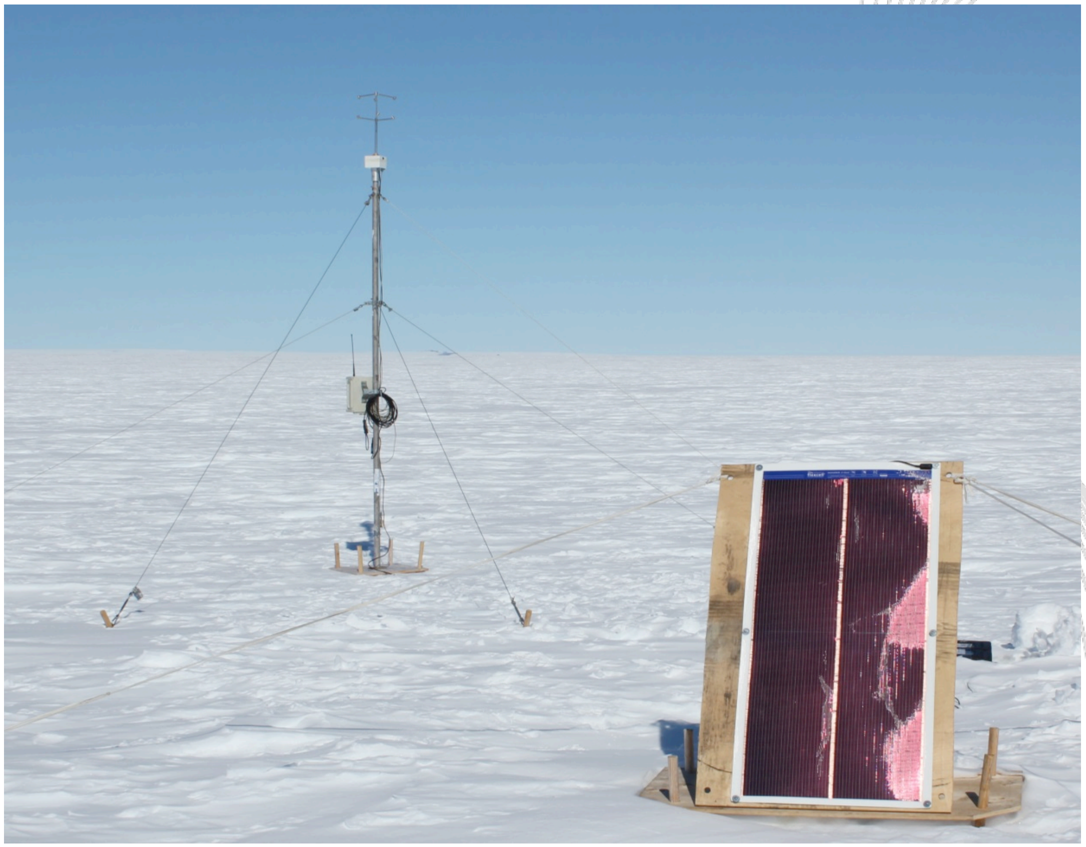
- Aanderaa battery + logger + DSU (10m weather mast at the Snow-covered Site)
- Sampling interval 1min (min interval for logger to acquire all sensors)

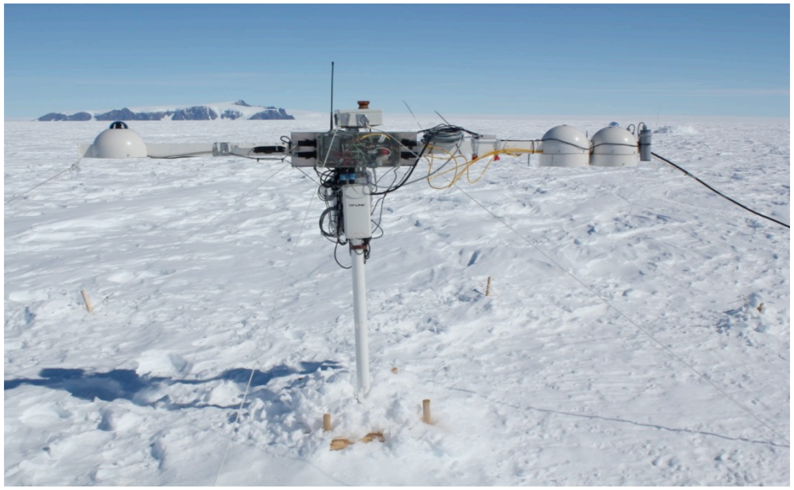


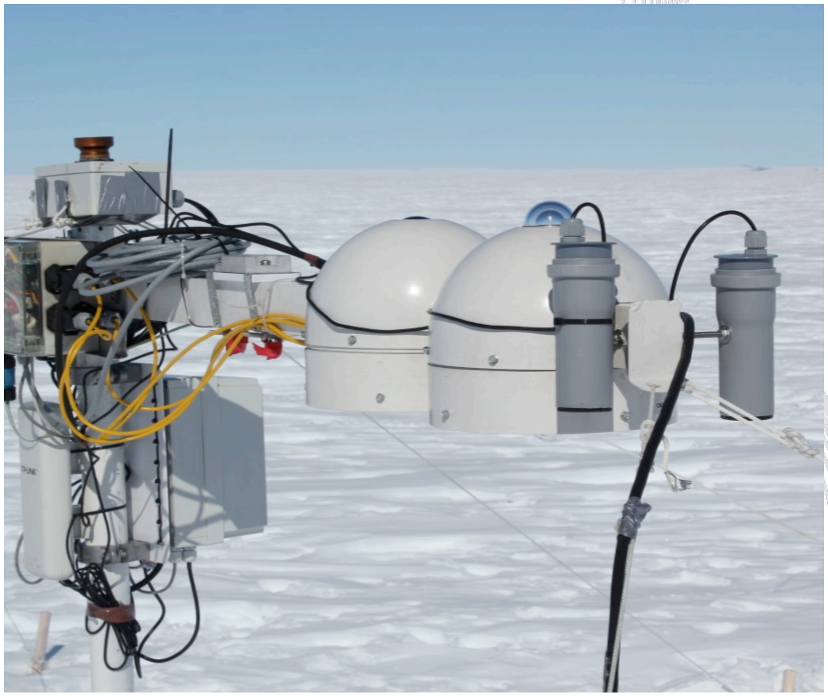
# Sonic anemometer at the Snow-covered Site

- **Metek USA-1 sonic anemometer**
- **3 orthogonal wind components and air temperature were measured (sampling rate of 20Hz)**
- **Battery box (buried in the snow) + 30W solar panel**
- **Drift of calibration parameters – broken fixation of one upper arm (glued/fixed according manufacturers recommendations)**



# Kipp & Zonen radiation sensors at Snow Site





- Two CMP pyranometers, two CGR pyrgeometers, SPN1 sunshine pyranometer
- Warm weather – severe melting – stabilization challenges and regular leveling (digital inclinometer – resolution 0.01 degrees)
- Down-looking cameras (series of images acquired every 5 min)
- Fisheye skycamera (Canon PowerShot, cloud cover monitoring, 5 min interval)
- Power supply by batteries + 30W solar panels

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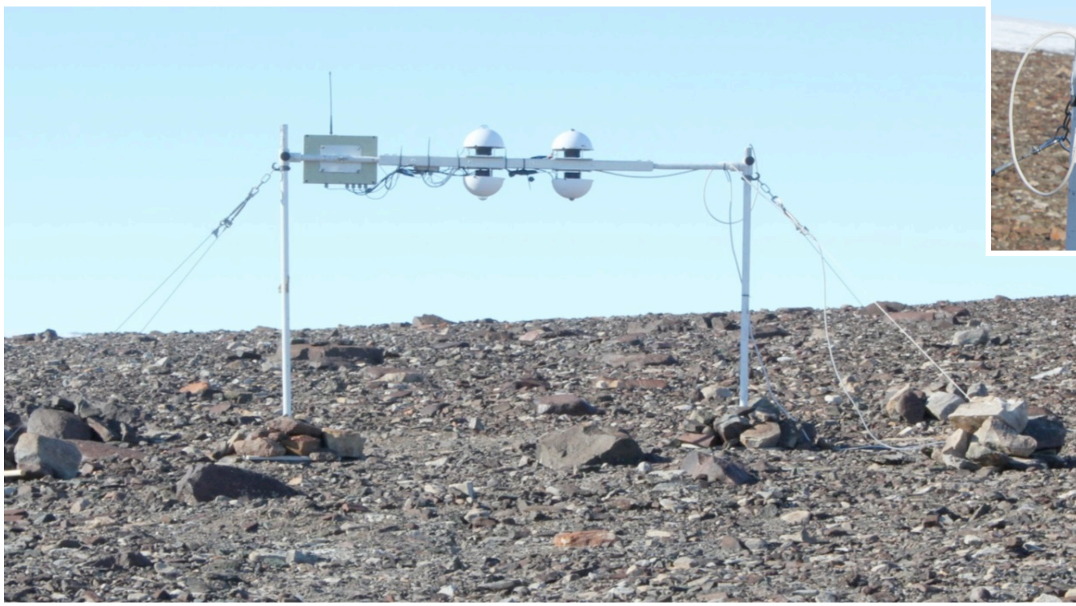
# Eppley radiation sensors at Basen nunatak



- On the rocky surface near Aboa station
- Similar set to Kipp&Zone radiation sensors, except it does not include the sensor for global+diffuse radiation
- Data logger + UHF radio link
- Batteries + solar panels

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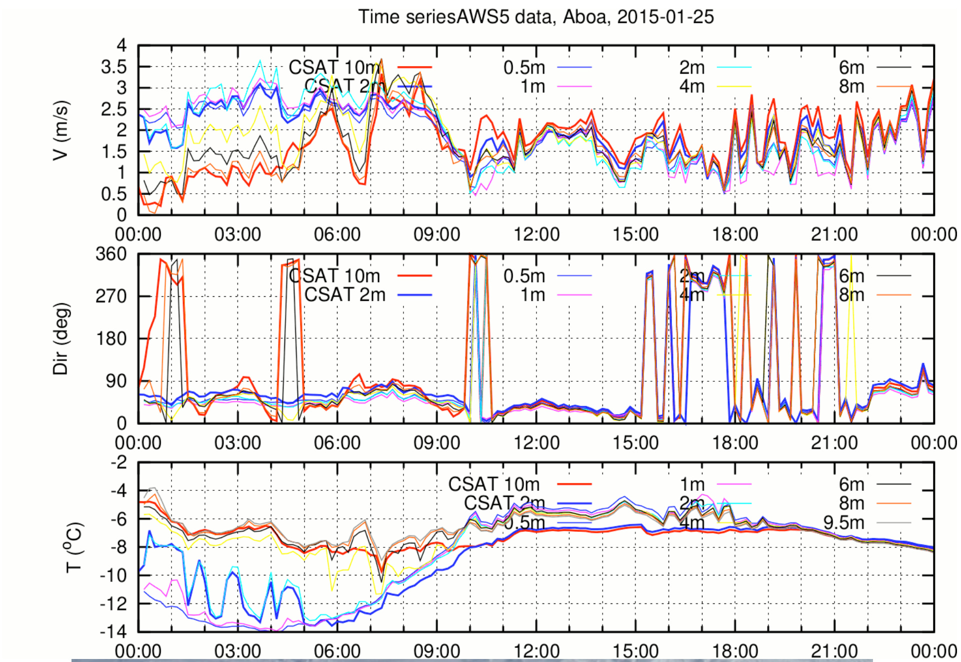
# Campbell weather mast (10m) at AWS5

- Upgraded setup compared to 2010-11
- Campbell 107-type temperature probes at 7 levels
- 2D Gill WindSonic anemometers at 6 levels
- Kipp&Zone  CNR4 radiation budget probe
- Vaisala HMP45AC temperature and humidity probe
- Two Campbell CSAT3 3D sonic anemometers
- WiFi connection instead of UHF radio link

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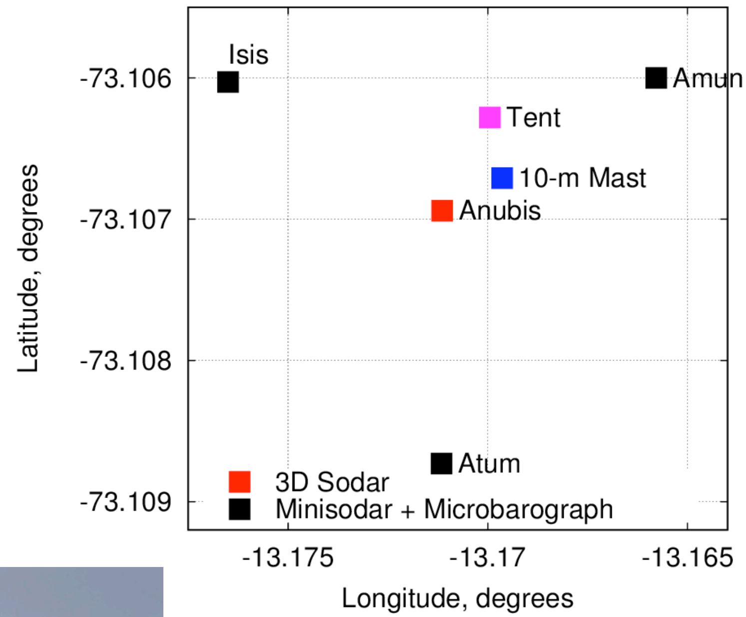
## Sodar measurements

### Set of several sodar dishes and microbarographs at different locations




- 3D sodar LATAN3 “Anubis”: wind profiles and echogrammes
- 3 vertical minisodars LATAN3m: triangle 350m (each at 200m from Anubis)

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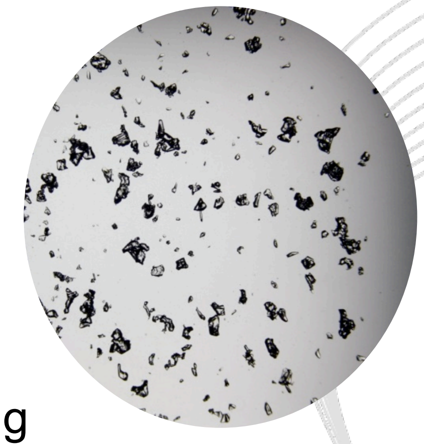
# Snow-radiation measurements

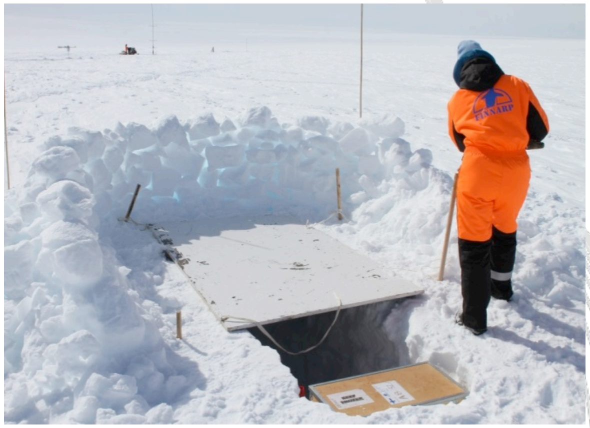


## Snow measurements

- Snow pits: stratigraphy (ice layering, grain type, wetness, hardness), vertical profile of snow density and temperature
- Macro-photos of snow particles (in snow lab)
- Surface roughness (with blackboard and infrared cameras)
- Snow accumulation/ ablation

## Radiation measurements

- Broadband shortwave and longwave fluxes (downwelling and upwelling)
- Direct/diffuse shortwave components
- Surface spectral albedo
- Surface spectral nadir reflectance
- Vertical profile of snow reflectance
- Test flight with drone equipped with broadband and spectral (350-1100nm) albedometres



# RPAS flights

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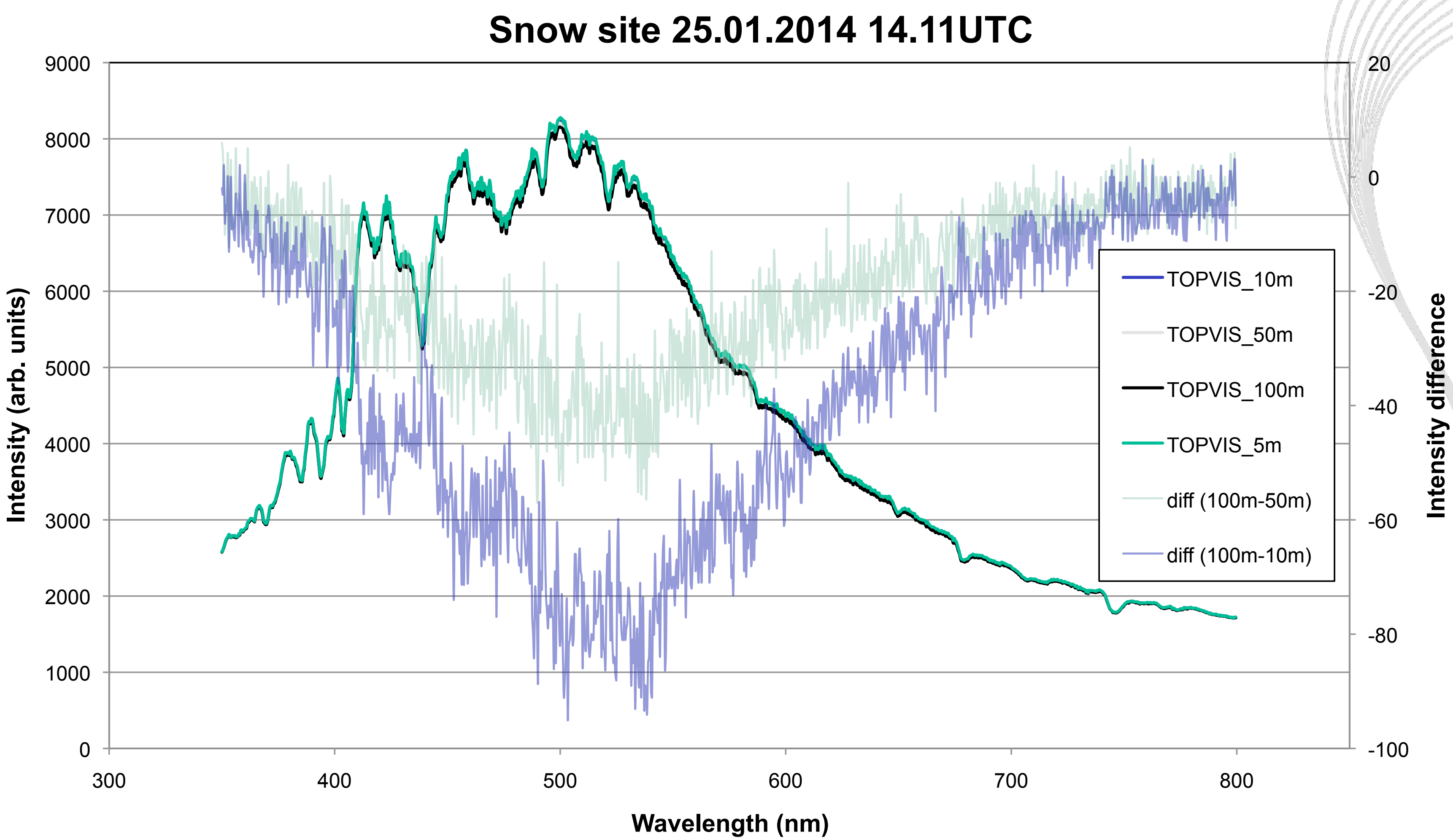

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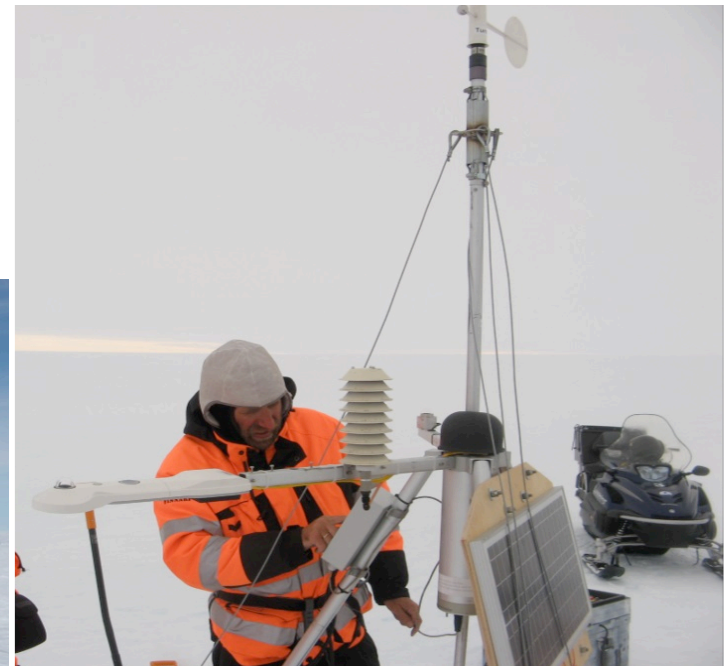
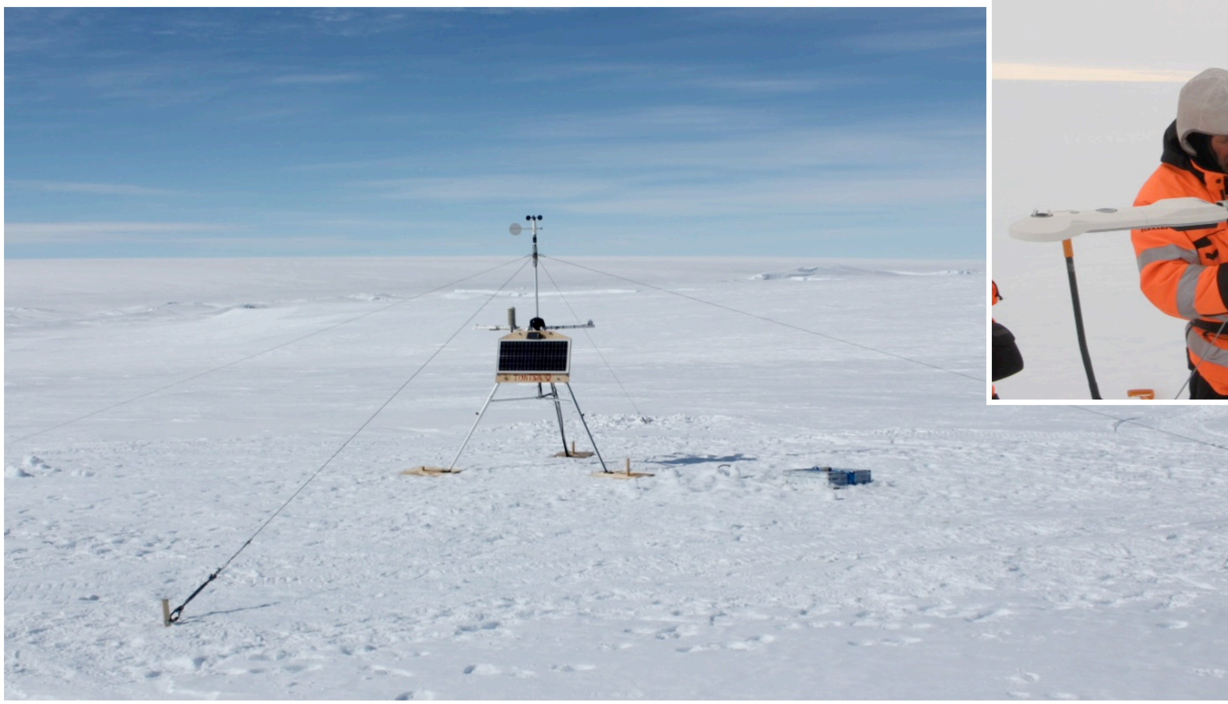
# Vaisala automatic weather stations (old FMI MAWS)

- Tripod Vaisala MAWS
- CNR4 net radiometer
- Battery box (Sunica 85 Ah Ni-Cd) + solar panel
- Basen nunatak + Rampen





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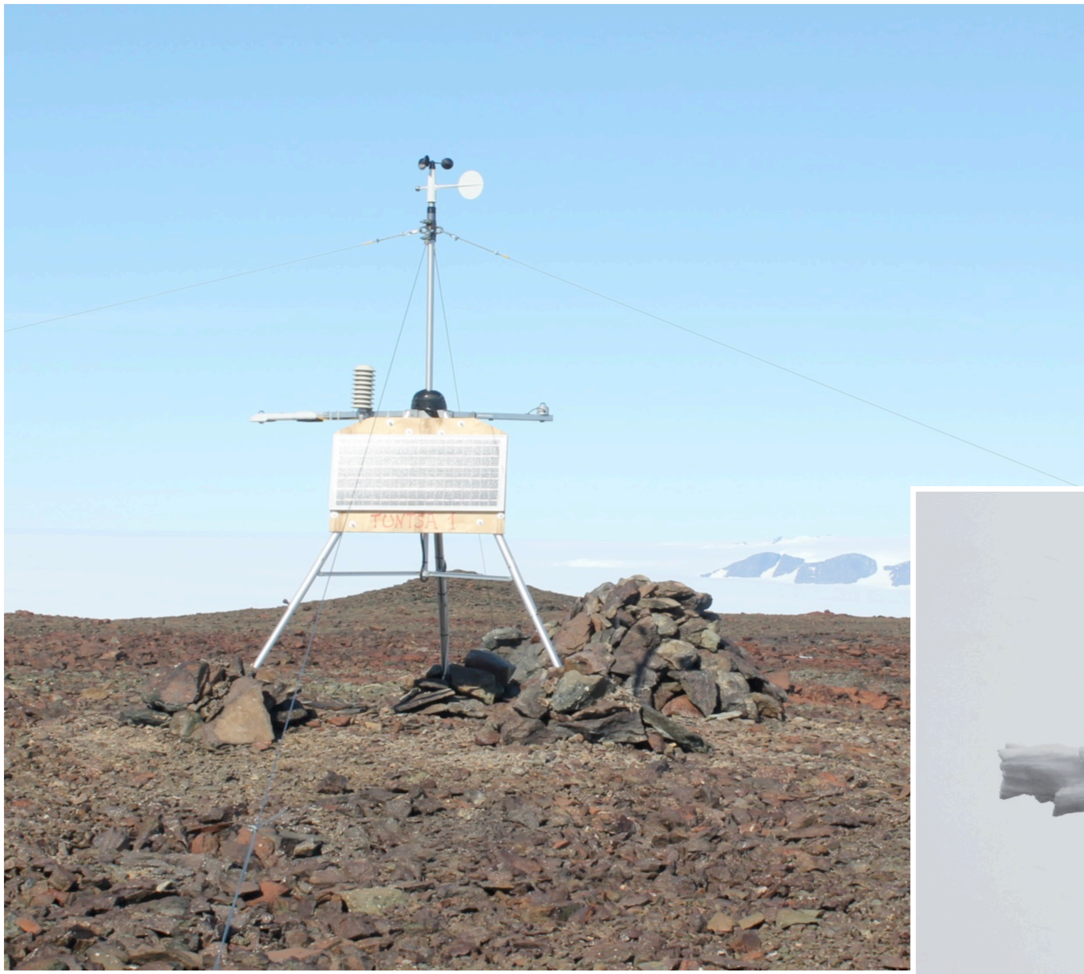

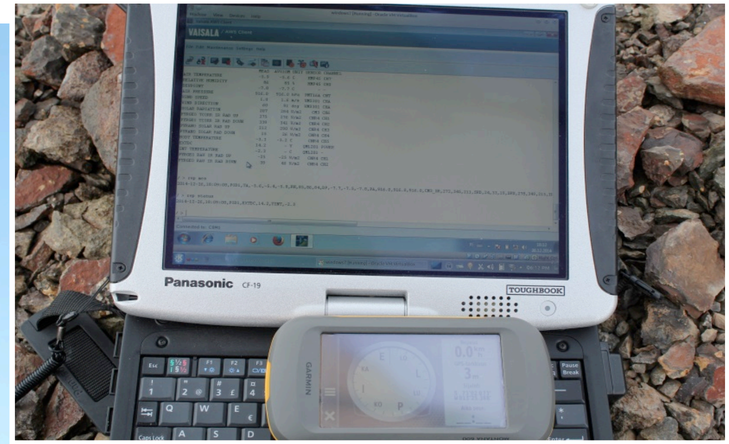


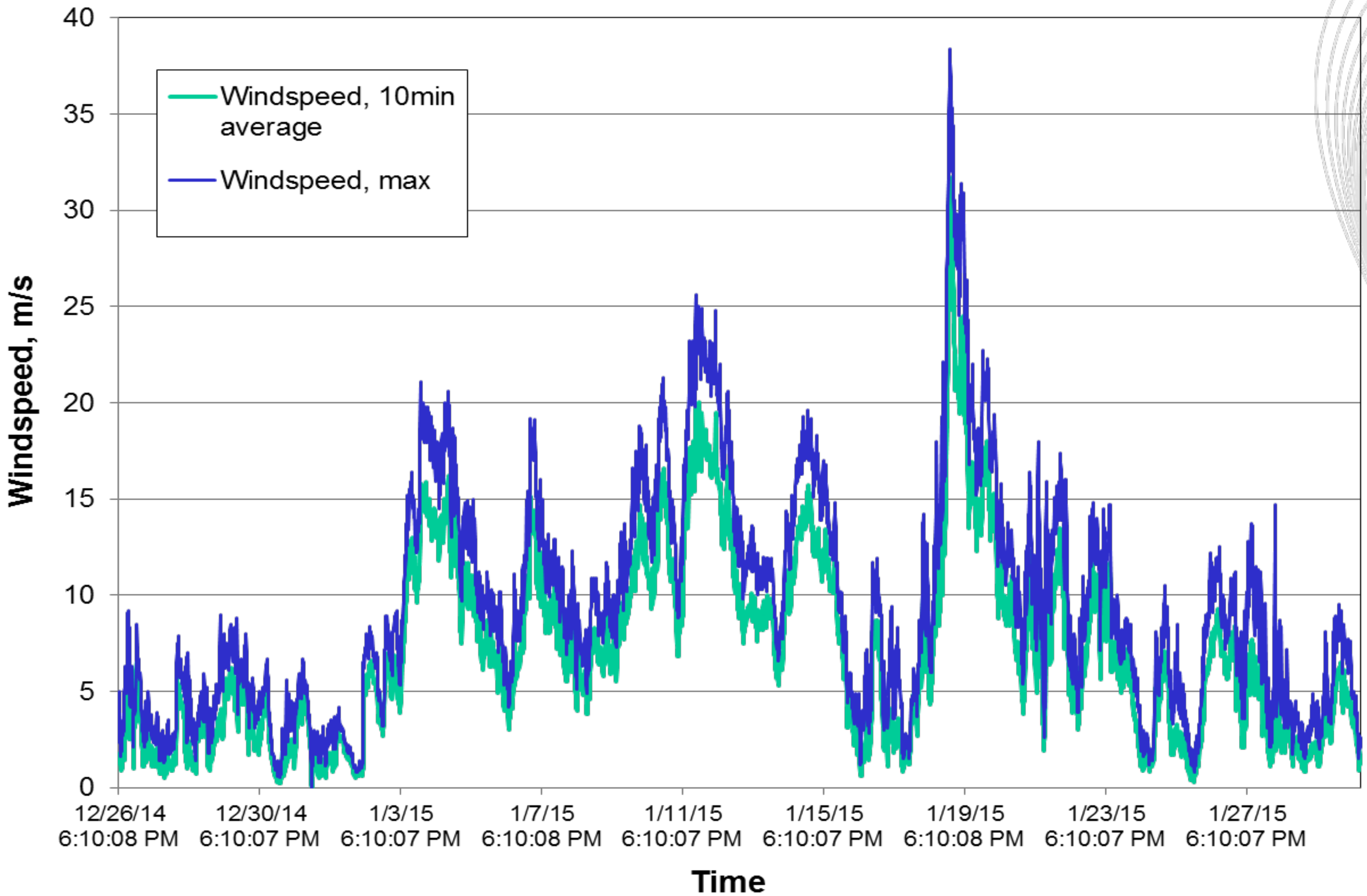
Windspeed, 10min average
Windspeed, max
Windspeed, m/s
40
35
30
25
20
15
10
5
0
12/26/14 6:10:08 PM
12/30/14 6:10:07 PM
1/3/15 6:10:07 PM
1/7/15 6:10:08 PM
1/11/15 6:10:07 PM
1/15/15 6:10:07 PM
1/19/15 6:10:08 PM
1/23/15 6:10:07 PM
1/27/15 6:10:07 PM
Time

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