Airborne and in situ ground-based measurements of surface albedo, bidirectional reflectivity BRDF and snow properties on the Antarctic plateau

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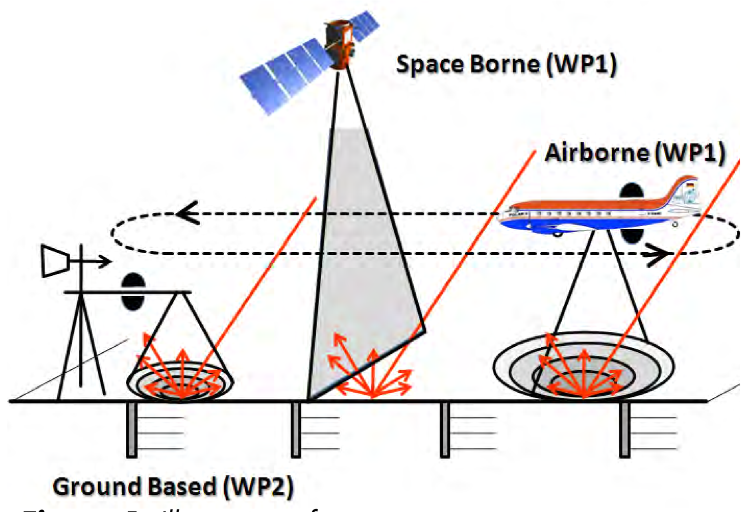
1. Motivation and Objectives



Satellite Data (WP1)	
Surface albedo	Retrieval
Airborne Data (WP1)	
Surface albedo	In situ
Surface BRDF	In situ
Surface roughness	Retrieval
Grain size	Retrieval
Ground Based Data (WP2)	
Surface albedo	In situ
Surface BRDF	In situ
Grain size profile	In situ
Surface roughness	In situ
Meteorology	In situ

Figure 1: *Illustration of measurement strategy*

MEASUREMENTS

Broadband and spectral radiation
Irradiance (↑, ↓), Radiance

+

Atmospheric properties
temperature, humidity, wind, clouds, precipitation, aerosol content

⬇

Snow radiative properties
surface albedo, BRDF

⬇

RETRIEVAL

Microphysical and macroscopic snow properties
specific surface area SSA (snow grain size), surface roughness

Coupling of…

- **Airborne** measurements of the **spatial variability** of surface albedo, BRDF, SSA and surface roughness
- **Ground-based** measurements of the **temporal variability** of surface albedo, BRDF and SSA

to improve prognostic snow models.

2. Campaign ANT-Land 2013/2014 – Kohnen Station

Kohnen - site conditions — Ground-based: temporal variability

75°00'S, 00°04'E, 2892m a.s.l.

Dry, nearly pollutant-free snow
Calm clear-sky periods
Episodes with precipitation and wind-induced horizontal transport of snow

Dronning Maud Land — Airborne: spatial variability

Pronounced roughness structures like sastrugi (higher wind speeds)
Changing type and amount of precipitation

Scientific work

2013/12/10 – 2014/01/31: Observations and measurements

Research flights with Polar6

16 flights, 60 flight hours

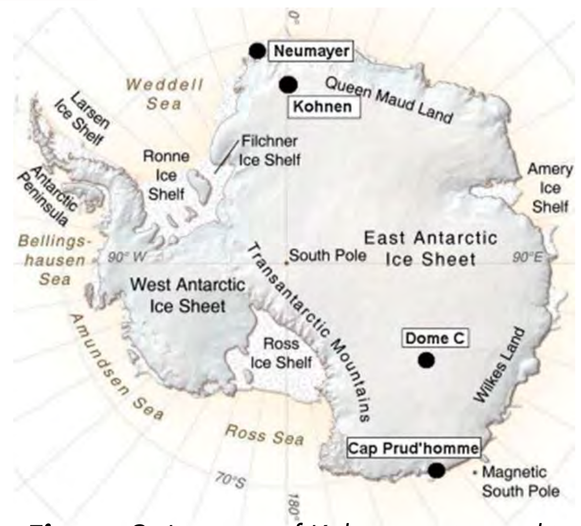


Figure 2: *Location of Kohnen station within Antarctica*

Date	Comments
2013/12/24	Radiation squares
2013/12/25	Grid Kohnen
2013/12/27	Triangle Northeast
2013/12/28	Diurnal variations (5 flights)
2013/12/29	Ice divide
2013/12/30	Jutulstraumen glacier
2013/12/31	Recisl-FD-81
2014/01/02	Neumayer via Jutulstraumen Neumayer-Kohnen
2014/01/04	Kohnen-Halley-Kohnen
2014/01/05	North-South lines West

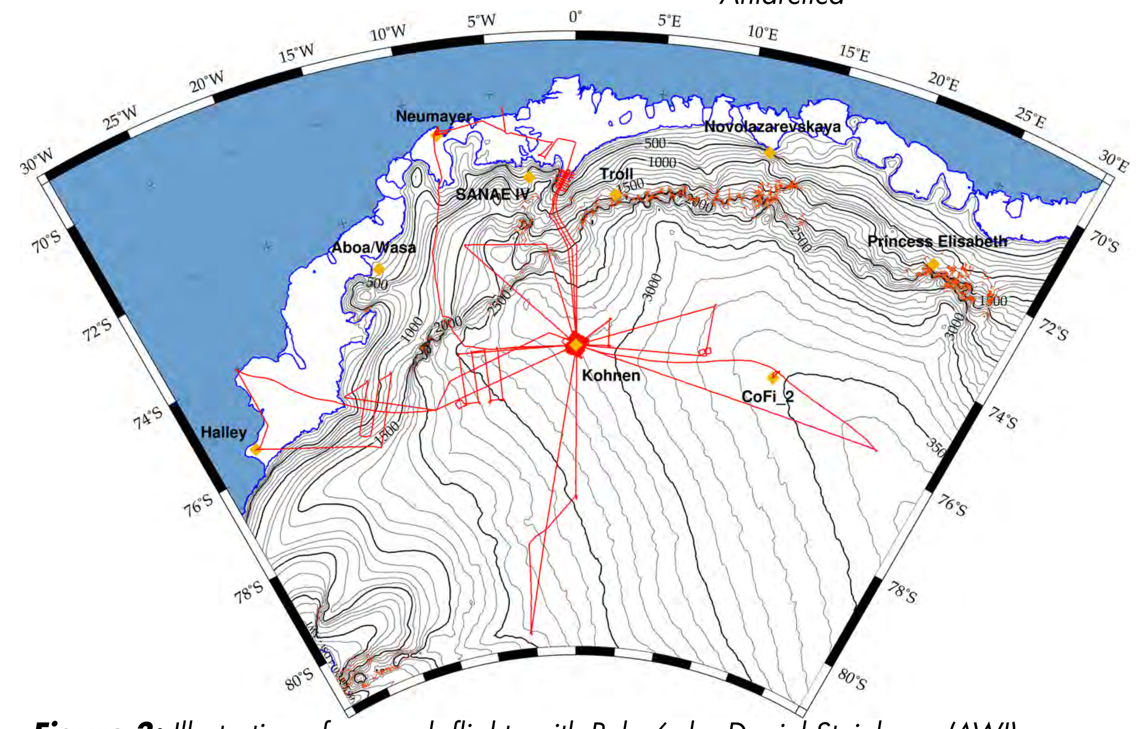


Figure 3: *Illustration of research flights with Polar6, by Daniel Steinhage (AWI)*

Basic meteorological data

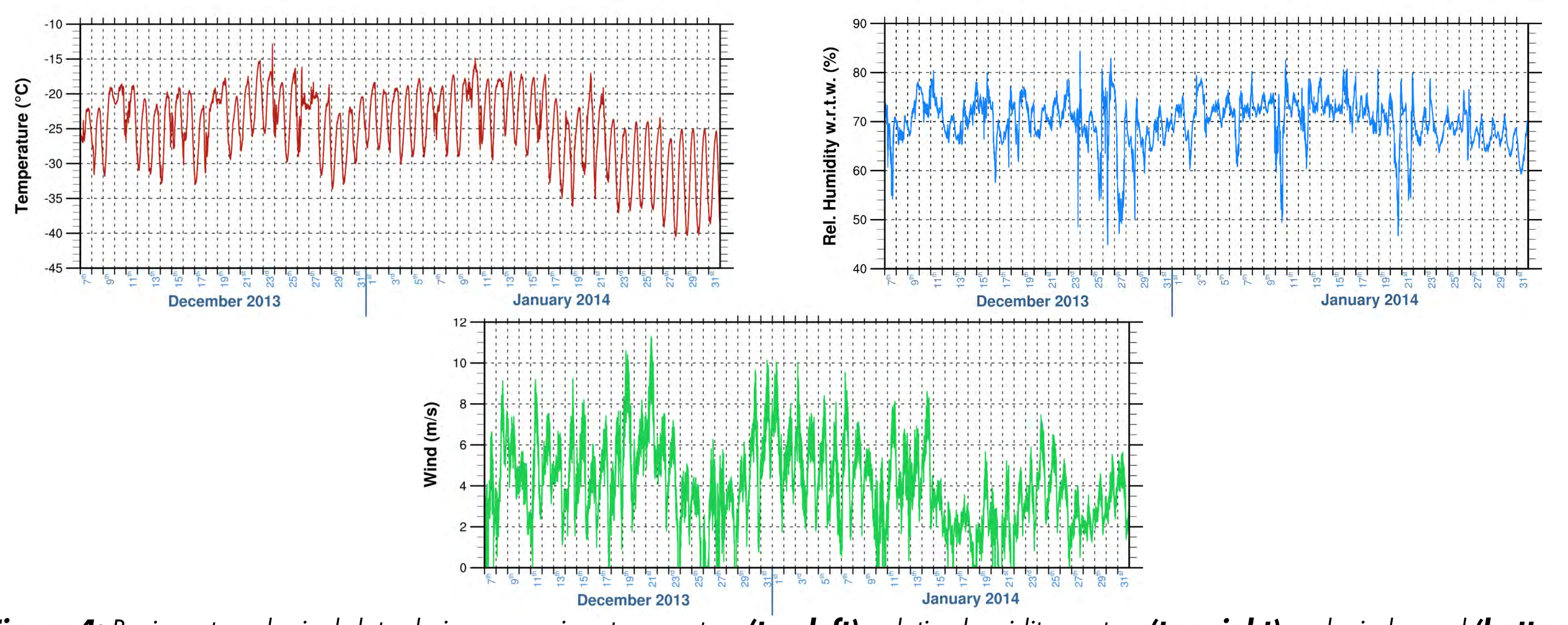


Figure 4: *Basic meteorological data during campaign: temperature **(top left)**, relative humidity w.r.t.w. **(top right)** and wind speed **(bottom)***

3. Instrumentation

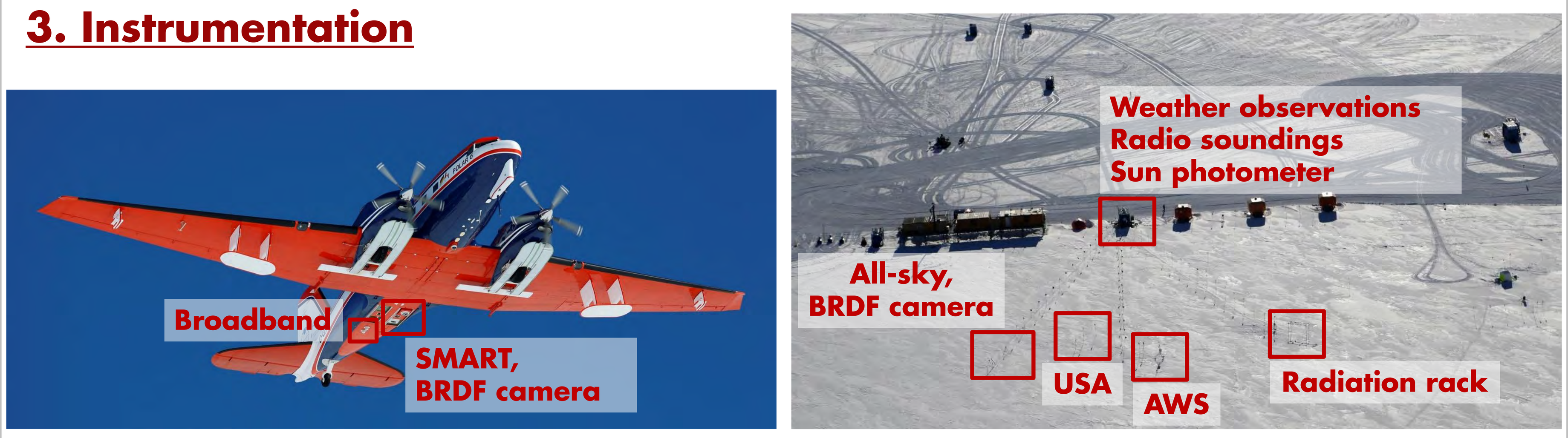


Figure 5: *Overview of the instrumentation during ANT-Land 2013/2014 on Polar 6 research aircraft **(left)** and Kohnen station **(right)***

Broadband radiation sensors — Airborne

Pyranometer: Kipp & Zonen CMP22
Pyrgeometer: Kipp & Zonen CGR4

Measured quantity: **Irradiance** (F↑ and F↓), Wm^{-2}
Temporal resolution: 50ms
Response time: CMP22: 5s, CGR4: 18s
Wavelength range: CMP22: 0.2-3.6μm, CGR4: 4.5-42μm
Stabilization: none

Broadband radiation sensors — Ground-based

Pyranometer: Kipp & Zonen CM22
Pyrgeometer: Eppley Precision Infrared Radiometer

Measured quantity: **Irradiance** (F↑ and F↓), Wm^{-2}
Temporal resolution: 1min
Response time: CM22: 5s , PIR: 2s
Wavelength range: CM22: 0.2-3.6μm, PIR: 3.5-50μm

SMART albedometer — Airborne

(Spectral Modular Airborne Radiation measurements sysTem)

Measured quantities: **Irradiance** (F_λ↑ and F_λ↓), **Radiance** (I_λ↑ and I_λ↓), $Wm^{-2}nm^{-1}$, $Wm^{-2}nm^{-1}sr^{-1}$
Temporal resolution: 1s
Stabilization: Active, range: ±6°, accuracy: 0.2°
Wavelength range: 0.3-2.1μm
Spectral resolution: 2-3nm (0.3-1.0μm), 9-16nm (1.0-2.1μm)

CORAS — Ground-based

(COmpact RAdiation measurement System)

Measured quantity: **Spectral irradiance** (F_λ↑ and F_λ↓) $Wm^{-2}nm^{-1}$
Temporal resolution: 15s
Wavelength range: 0.2-2.2μm
Spectral resolution: Full width at half maximum: 2-16nm
Mount: Kohnen station, radiation rack

Figure 6: *Optical inlet of SMART **(top)**, irradiance as flux of radiation incident from total hemisphere **(bottom)***

BRDF camera — Airborne/Ground-based

CANON EOS 1D Mark III/CANON EOS 6D

Measured quantity: **Radiance** (I↑)
Spectral resolution: 3 channels (RGB)
Temporal resolution: 4s/1h
Specifics: 180° fish-eye lense

Figure 7: *BRDF camera*

Automatic Weather Station — Ground-based

Vaisala HMP155, Young Wind Monitor MA 05106-5

Measured quantities: **p, T, u, F↑, F↓, wind, snow accumulation**
Temporal resolution: 1min averages

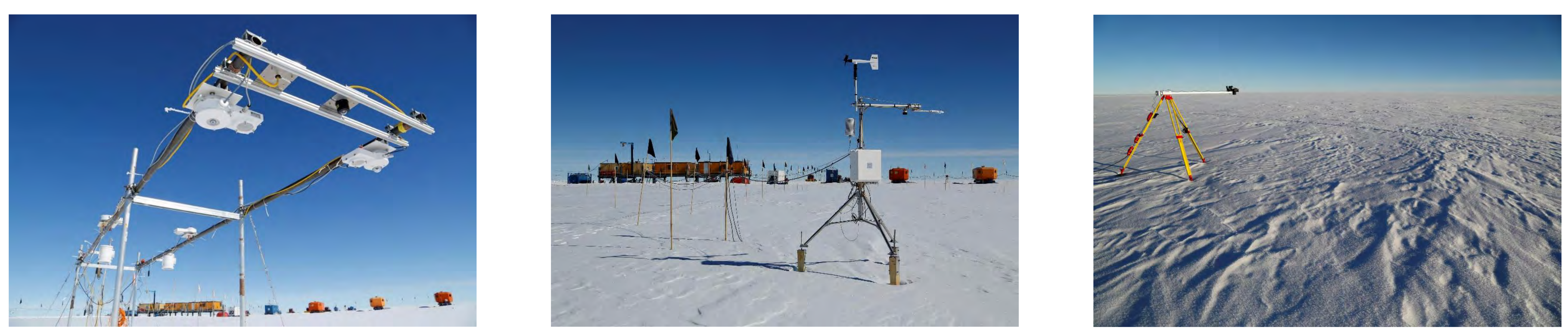


Figure 8: *Radiation rack with CORAS and broadband radiation sensors **(left)**, automatic weather station **(centre)** and BRDF camera **(right)***

Instrument status during campaign

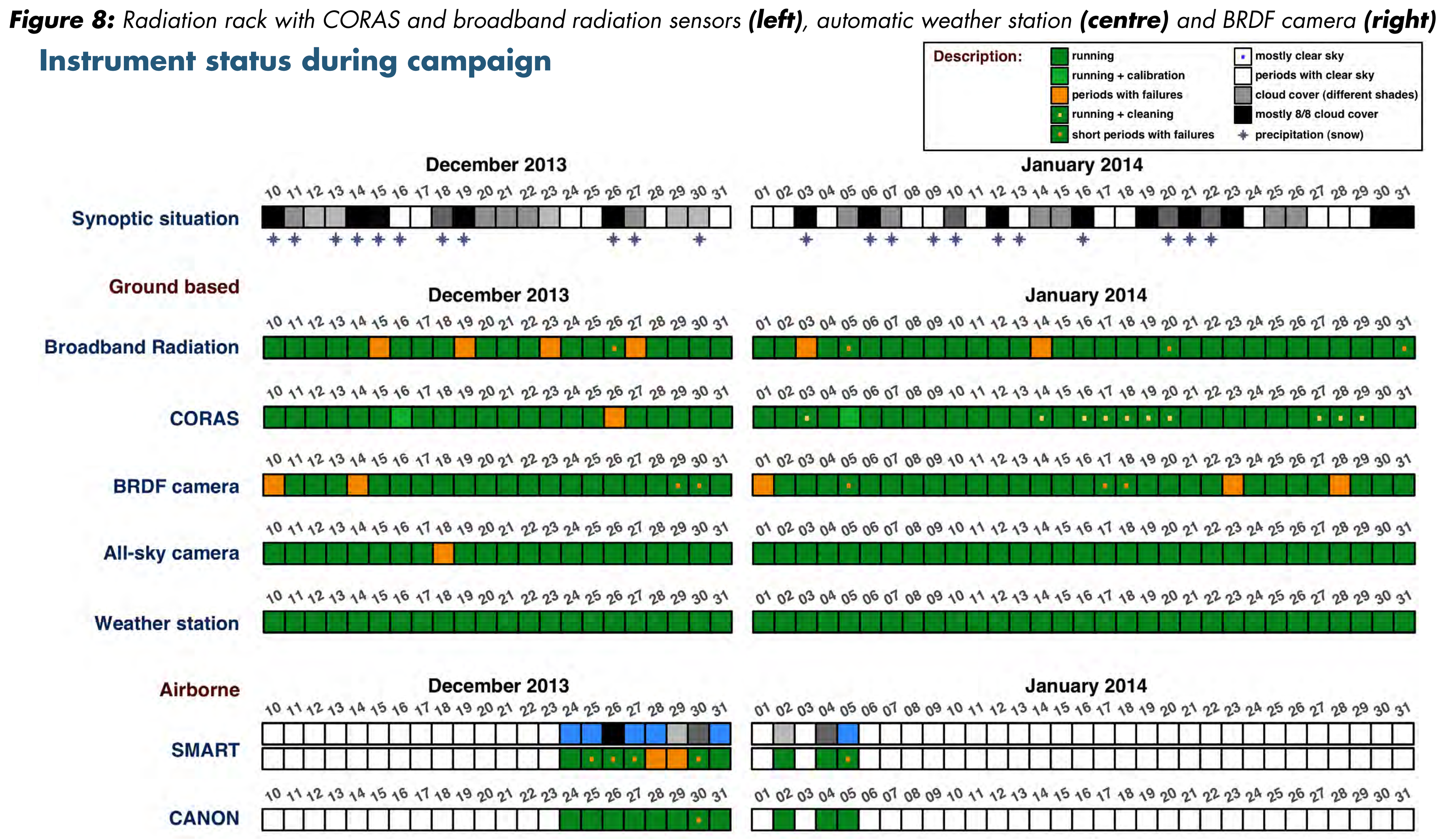


Figure 9: *Synoptic situation and status of ground-based and airborne instruments during observation period (2013/12/10-2014/01/31)*

4. Diurnal cycle of broadband radiation and snow shortwave albedo

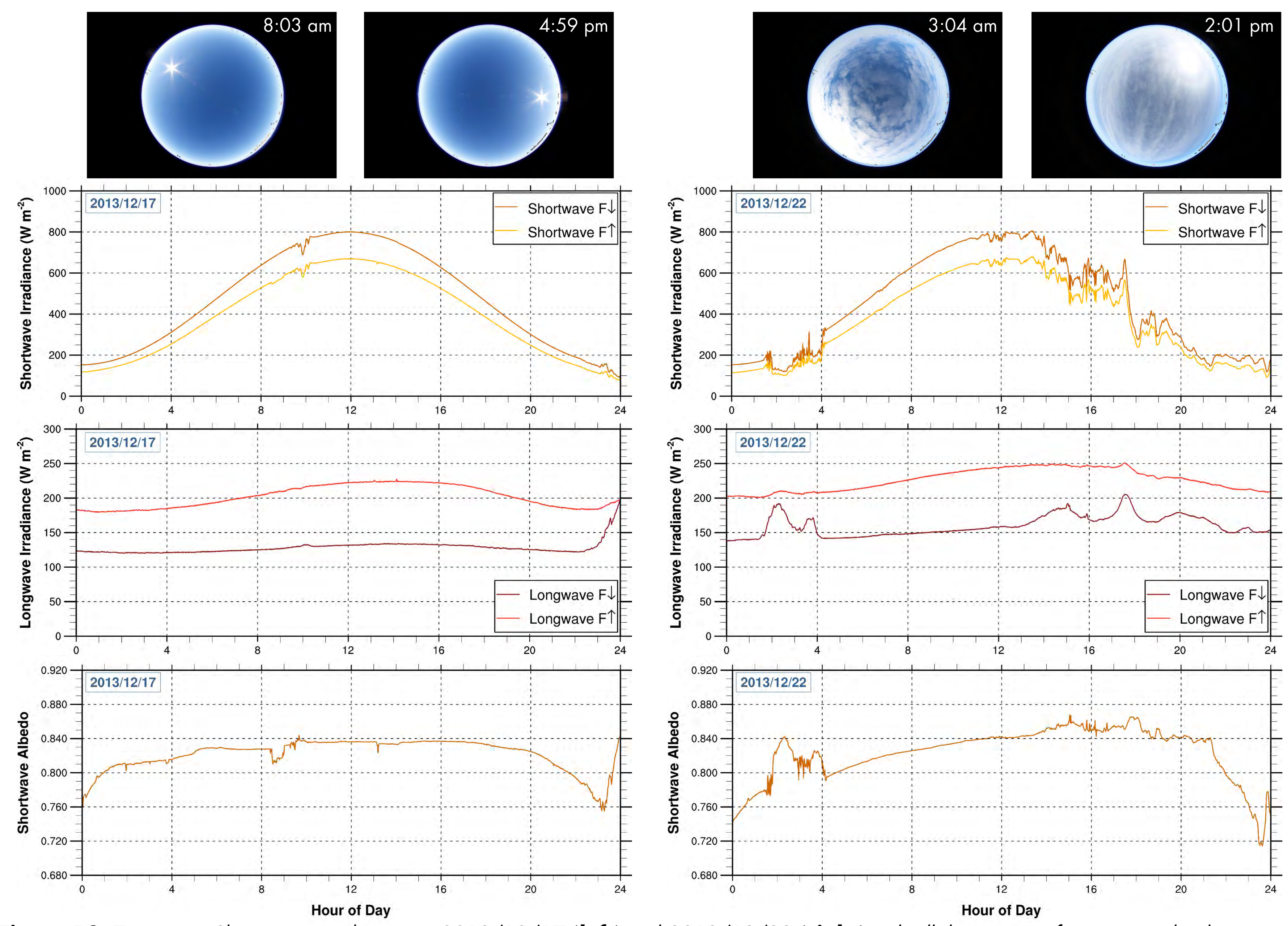


Figure 10: ***Top row:*** *Shortwave irradiance on 2013/12/17 **(left)** and 2013/12/22 **(right)** with all-sky images of respective cloud situation,*
Middle row: *Longwave irradiance on 2013/12/17 **(left)** and 2013/12/22 **(right)**,*
Bottom row: *Corresponding shortwave albedo on 2013/12/17 **(left)** and 2013/12/22 **(right)***

First interpretation:

- **Clear-sky irradiance** measurements (2013/12/17) show almost undisturbed diurnal cycle, during night only shortly affected by instrument shadow
- Single **cloud** event also visible in **albedo** time series
- **Influence of clouds** depend on cloud optical thickness and cloud cover (2013/12/22):
  - Isolated Cirrus may increase downward shortwave irradiance through increased scattering
  - Thicker clouds decrease downward shortwave irradiance through higher absorption and increase downward longwave irradiance due to cloud temperature
- **Increased** shortwave **albedo** at **larger** solar **zenith angles** in contradiction to theoretical behaviour of plane snow surface, may be due to **shadows** of textured surface (e.g. sastrugi, ripples,…)

5. Outlook

I. **Retrieval** of snow properties from remote sensing (SSA, surface roughness)
II. **Comparison** with in situ measurements of snow properties
III. **Simulation** and **validation** of temporal variability of snow optical properties by prognostic snow models (SCIATRAN, SNICAR, Crocus)

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