Aquarius brightness temperature variations at Dome C and snow metamorphism at the surface

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Motivations

The Antarctic ice sheet is both an **actor** in the climate system and an **indicator** of its evolution.

Ice sheet area $\sim 14 \times 10^6 \text{ km}^2$

Antarctica contains $\sim 90\%$ of total ice on Earth

Number of Automatic Weather Station $\sim 100$
Motivations

The Antarctic ice sheet is both an **actor** in the climate system and an **indicator** of its evolution.

- Ice sheet area $\sim 14.10^6 \text{ km}^2$
- Antarctica contains $\sim 90\%$ of total ice on Earth

How to monitor ice temperature?

$\implies$ climate models (global, or regional)

$\implies$ reanalysis (ERA-interim, MERRA...)

$\implies$ remote sensing
Motivations

Motivated by L-band deep-penetration observations over Antarctica to:

- Analyze their spatial distribution
- Assess the observations’ stability
- Contribute to define cal/val and intercalibration experiments

Important initial tasks toward retrieving snow & ice properties
The current 1.4 GHz (L-band) space-borne radiometers

Aquarius

SMOS
The current 1.4 GHz (L-band) space-borne radiometers

Aquarius

Designed for sea surface salinity retrievals
Operates 3 non-scanning radiometers

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<th>3</th>
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<td>Incidence angle (°)</td>
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Large footprint sizes, but Excellent sensitivity of 0.2 K
The current 1.4 GHz (L-band) space-borne radiometers

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- Large footprint sizes, but
- Excellent sensitivity of \(0.2\) K

**SMOS**

- Designed for moisture & salinity
- Radiometer with aperture synthesis

- Multiple incidence angles (0–65°)
- Finer spatial resolution (30–90 km)
- Coarser sensitivity (2–2.5 K)
Outline

1. Spatial distribution of Aquarius TB in Antarctica

2. Temporal Aquarius TB variations at Dome C

3. Impact of snow surface state
   3.1 Comparison with AMSU-B grain index
   3.2 Comparison with surface-based IR surface pictures

4. Conclusion
Antarctica
Weekly mean brightness temperature (vertical polarization, radiometer 3 $\theta_{\text{inc}} \sim 46.3^\circ$)

Winter
Cycle 098

Summer
Cycle 080

Coastal open water/sea ice modifies Aquarius TB

(Brucker et al., 2014 TC)
East Antarctica

Annual mean and standard deviation TB (radiometer 1, $\theta_{\text{inc}} \sim 29.2^\circ$)

Areas where melt events occurred since August 1, 2000 were masked.

There are grid cells (36 km) without observations.
Dome C, Antarctic Plateau (3240 m)

Snow temperature below 15 m: 218.42±0.07 K (Brucker et al., 2011)

Snow accumulation: 8–10 cm of snow (Urbini et al., 2008)

Ideal site to study the relationship: microwave observations – ice properties
Dome C – TB timeseries

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Sensitivity $\sim 0.2$ K
Dome C – TB angular diagram

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3 $209.50 \pm 0.26$
2 $206.79 \pm 0.25$
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Beam H (K)
1 $189.97 \pm 0.44$
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3 $181.39 \pm 0.72$

Sensitivity $\sim 0.2$ K
Dome C – TB timeseries

Fast variations $\leadsto$ surface changes?
Dome C – TB H/V timeseries

Focus on $\frac{TB_H}{TB_V}$.

- Removes the dependency on the physical temperature
- Highlights emissivity variations
Dome C – TB H/V timeseries

Focus on $\frac{TB_H}{TB_V}$, which removes the dependency on the physical temperature and highlights emissivity variations.

Variation $> 0.001$ is above the radiometric noise.

The largest variations are observed by radiometer 3.

Radiometer 1 ($\theta_{inc} \sim 29.2^\circ$)
Radiometer 2 ($\theta_{inc} \sim 38.4^\circ$)
Radiometer 3 ($\theta_{inc} \sim 46.3^\circ$)
Satellite monitoring of the snow surface at Dome C

AMSU-B grain index derived from AMSU-B (Picard et al., 2012), with shallow penetration (few cm) channels
Satellite monitoring of the snow surface at Dome C

**AMSU-B grain index** derived from AMSU-B (*Picard et al., 2012*), with shallow penetration (few cm) channels

\[ \text{GI} = 1 - \frac{\text{TB}_{150}}{\text{TB}_{89}} \]

**Typical penetration depths in ice**

- 89 GHz $\approx <0.2$ m
- 37 GHz $\approx <1$ m
- 19 GHz $\approx 3-5$ m
- 10 GHz $\approx 10-15$ m
- 6.9 GHz $\approx >20$ m

**L-band observations have a large penetration in ice**
Satellite monitoring of the snow surface at Dome C

AMSU-B grain index derived from AMSU-B (Picard et al., 2012), with shallow penetration (few cm) channels

\[ GI = 1 - \frac{TB_{150}}{TB_{89}} \]

Good synchronization of the variations in summer
Surface-based monitoring of the snow surface at Dome C

Near IR camera
2 m high
imaged area $\sim 4 \text{ m}^2$

(Champollion et al., 2013)
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(Champollion et al., 2013)
Aquarius and hoar crystal on the surface

No hoar

Hoar

L-band TB variations at Dome C and snow metamorphism
Aquarius and hoar crystal on the surface

L-band observations are sensitive to surface snow properties
A simple calculation with Fresnel’s reflection coefficients at the air/snow interface

![Graph showing density variation of 75 kg m\(^{-3}\) could explain the largest change in TB H/V (in Dec. 2011)]
Aquarius radiometers have an excellent sensitivity (0.2 K), are thus appealing to study the ice sheets.

TB variability at H polarization is larger than at V polarization, increases as $\theta_{inc}$ increases, is larger than the sensors’ sensitivity.

L-band radiation has a deep penetration, but is sensitive to surface snow properties.

Hoar crystals on the surface may influence cal/val experiments.

Dome C
Wind direction

Hoar crystals present

Hoar crystals disappear

(Champollion et al., 2013)

See also: Gallet et al. (2014), The growth of sublimation crystals and surface hoar on the Antarctic plateau, The Cryosphere.