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 $\sim 14 \times 10^6$ km$^2$

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

**Number of Automatic Weather Station** $\sim 100$
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Number of Automatic Weather Station $\sim 100$

How to monitor ice temperature?

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

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

$\Rightarrow$ 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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<td>Footprint size (km x km)</td>
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Large footprint sizes, but Excellent sensitivity of 0.2 K
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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 $\theta_{\text{inc}} \sim 46.3^\circ$)

Coastal open water/sea ice modifies Aquarius TB

*(Brucker et al., 2014 TC)*
East Antarctica

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

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 \cite{Brucker2011}

Snow accumulation: 8–10 cm of snow \cite{Urbini2008}

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

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<td>186.22 ± 0.53</td>
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Sensitivity $\sim 0.2 \text{ K}$
Dome C – TB angular diagram

Beam | TB V (K) |
---|---------|
3  | 209.50±0.26 |
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Beam | TB H (K) |
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Sensitivity $\sim 0.2$ K
Dome C – TB timeseries

Fast variations \(\rightsquigarrow\) 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 $\frac{TB_H}{TB_V}$. removes the dependency on the physical temperature. highlights emissivity variations.

Variation $> 0.001$ is above the radiometric noise.
The largest variations are observed by radiometer 3.
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

\[ GI = 1 - \frac{TB_{150}}{TB_{89}} \]
Satellite monitoring of the snow surface at Dome C

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

Typical penetration depths in ice:
- 89 GHz \( \sim \) <0.2 m
- 37 GHz \( \sim \) <1 m
- 19 GHz \( \sim \) 3-5 m
- 10 GHz \( \sim \) 10-15 m
- 6.9 GHz \( \sim \) >20 m

L-band observations have a large penetration in ice

(Surdyk, 2002)
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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No hoar
Surface-based monitoring of the snow surface at Dome C

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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
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

Radiometer 1 ($\theta_{\text{inc}} \sim 29.2^\circ$)

Radiometer 2 ($\theta_{\text{inc}} \sim 38.4^\circ$)

Radiometer 3 ($\theta_{\text{inc}} \sim 46.3^\circ$)

A 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). They are thus appealing to study the ice sheets.

TB variability at H polarization is larger than at V polarization. It increases as $\theta_{inc}$ increases and 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

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

(Champollion et al., 2013)