Using MODIS land surface temperatures and the Crocus snow model to understand the warm bias of ERA-Interim reanalysis at the surface in Antarctica

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• Introduction

• Data and Methods

• Evaluation results
  ▫ LST MODIS evaluation
  ▫ ERA-Interim and Crocus surface temperature analysis

• Conclusions
Introduction

*Use of remote-sensed surface temperature to evaluate the quality of reanalysis and snow model outputs in Antarctica.*

- Limited use of satellite observations for the evaluation of surface temperature simulations
- $T_s$ can be estimated from satellite observations under clear-sky conditions using the thermal emission of the surface in the infrared
- $T_s$ is more appropriate than $T_{2m}$ for investigating the energy budget of a snow-covered surface:
  - $T_s$: function of the surface energy budget
  - $T_{2m}$: diagnosis from the surface temperature and the air temperature at the lowest atmospheric vertical level
  - Large temperature gradients near the surface
Data and method

OBSERVATIONS:
MODIS surface temperatures
Clear-sky satellite observations
Hourly data; period: 2000-2011; Resolution ~1km

In situ observations
7 stations: Dome C, South Pole, Syowa, Kohnen, Plateau Station B, Pole of Inaccessibility and Princess Elisabeth.

MODELS:
ERA-Interim surface temperatures
ERA-i Ts is derived from the energy balance equation during the forecast step of IFS (Integrated Forecast Model)
3-hourly data; period: 2000-2011; Resolution: 80 km

Crocus snow model simulations
SURFEX/Crocus
ERA-Interim forcing data: T2m, HR2m, U10m, precipitation rate, LWdown, SWdown, Ps, extracted at 0.5° resolution 3H time step. Bilinear interpolation onto 25 km stereo grid
Hourly data; period: 2000-2011; Resolution ~ 25km

MODIS Ts and ERA-i Ts are projected onto a 25-km grid
MODIS Ts evaluation (1/2)

- **Availability**
  - Revisit time of MODIS
  - Cloudiness (West antarctica, coastal regions)

→ On average, 14 hourly Ts per day available around South Pole and more than 9 over the Antarctic Plateau.
MODIS Ts evaluation (2/2)

- Comparisons with in situ observations

Over the Antarctic Plateau:
- Biases from -1.8 to 0.1°C
- rmse from 2.2 to 4.8°C
- Comparisons with in situ observations

Over the Antarctic Plateau:
biases from -1.8 to 0.1°C
rmse from 2.2 to 4.8°C

Over the coastal regions :
Biases from -2.7 to -1.1°C
Rmse from 4.7 to 7.5°C
• Biases between ERA-i Ts/Crocus Ts and MODIS Ts

• ERA-Interim warm bias: +3 to +6°C (Plateau)
  Genthon et al, 2010:
  - underestimated albedo
  - attenuation of the nocturnal radiative cooling

• Crocus bias: -2 to +2°C (Plateau)
ERA-Interim Ts and Crocus Ts analysis (2/4)

- Comparison with in situ observations

**ERA-Interim**

<table>
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<tr>
<th>Condition</th>
<th>Bias</th>
<th>rmse</th>
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<tbody>
<tr>
<td>Dome C</td>
<td>3.20</td>
<td>5.78</td>
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<td>South Pole</td>
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**Crocus**

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<td>5.81</td>
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<td>South Pole</td>
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<td>Station B</td>
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<td>5.51</td>
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<tr>
<td>Pole of I.</td>
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<td>4.93</td>
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</tbody>
</table>

Bias and rmse values are shown for each condition.
ERA-Interim Ts and Crocus Ts analysis (3/4)

• Comparison between different Ts observations at South Pole

ERA-i warm bias during low LWdown → surface radiative cooling, stable atmospheric conditions

Same parameterization of the surface exchange between ERA-i (IFS) and ERA-i/land (HTESSEL)

Different parameterization of the surface exchange between ERA-i (IFS) and Crocus (SURFEX)
ERA-Interim Ts and Crocus Ts analysis (4/4)

- Averaged ERA-i sensible heat fluxes (August 2009)

- ERA-i overestimation:
  Over the plateau, $H_s > 20 \text{ W/m}^2$

Reijmer and Oerlemans, 2002:
$H_s \sim 12 \text{ W/m}^2$ in August (Kohnen)

ERA-i $H_s \sim 25 \text{ W/m}^2$ in August 2009 (Kohnen)

ERA-i warm bias:
Overestimation of the surface turbulent sensible heat fluxes in very stable conditions.
Conclusions

Great potential of MODIS in the Ts on the Antarctic Plateau under clear-sky conditions (availability, quality).
MODIS Ts: well suited for evaluating the Ts simulated by various types of models in Antarctica.

ERA-Interim warm bias on the Antarctic Plateau: +3 to +6°C
Overestimation of the surface turbulent sensible heat fluxes in very stable conditions.

Low Crocus Ts bias: -2 to +2°C
Limitation of the maximum Richardson number in SURFEX/Crocus
Changes in the turbulent flux parameterization strongly impact surface temperature
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Thanks for your attention