Understanding outgoing long-wave radiation from the Antarctic atmosphere

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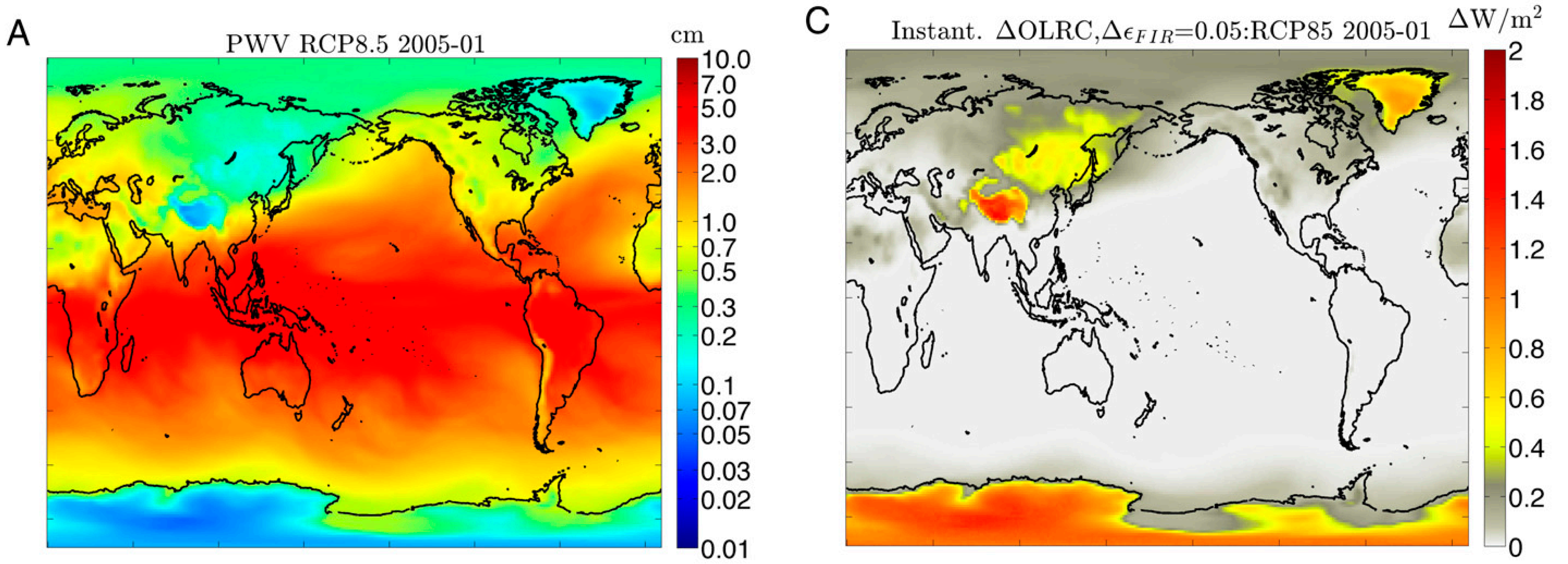
Motivation

Antarctica's heat budget defines how it will respond to climate change. Antarctica's surface cools itself mainly by emitting infrared radiation. Approximately 50% of the emission happens at wavelengths beyond $15\mu m$. Most parts of the planet are opaque at these far-infrared wavelengths. However, where the total column water vapour is below $1\,mm$, the atmosphere becomes transparent to far-infrared radiation, see Fig.1 and [2]. This causes an inverted greenhouse effect over vast parts of the continent, which is an Antarctic specific feature [4]. Currently, there are no global measurements constraints on far-infrared radiation, i.e. from space-based far-infrared sensors, and therefore the far-infrared surface emissivity is estimated from other wavelength bands. Due to the lack of knowledge, it is not possible to model with confidence the response of Antarctica to changes in climate.



(a) Monthly averaged Precipitable Water Vapour from Community Earth System Model integration of RCP8.5 for January 2005. Figure from [2].

(b) Instantaneous change in clear-sky OLR based on a spectrally uniform perturbation of far-infrared surface emissivity of 0.05. Figure from [2].

Figure 1: Implications for climate models: The magnitude of change in outgoing longwave radiation (OLR) caused by reasonable perturbation of the far-infrared surface emissivity is comparable to the effect a surface temperature change of 2 K would have on OLR.

Two-step approach to improve our knowledge about far-infrared surface emissivities

1. Robustly estimate the sensitivity of Antarctica's far-infrared radiation budget to changes in the far-infrared surface emissivity
   - Use measurements of the AWARE campaign on the West Antarctic Ice Sheet [3]
   - Robustly determine the uncertainties on radiosonde profiles using GRUAN methodology [1]
   - Combine measurements of multiple instruments from AWARE into Site Atmospheric State Best Estimates (SASBEs, [5]). SASBEs contains all available knowledge of the state of a target variable at that site and includes an estimate of the uncertainty on each value
   - Use SASBEs to constrain radiative transfer model → calculate top-of-the-atmosphere (TOA) radiance and associated uncertainties [6]
   - Test the sensitivity of TOA radiance to changes in the surface emissivity → for each investigated surface emissivity spectrum a Monte-Carlo simulation of the TOA radiances and their uncertainties will be performed → sensitivity of TOA to changes in the far-infrared surface emissivity gives a robust estimate of effects our current lack of knowledge has on the Antarctic radiation budget
   - This project would support deployment of the FORUM (Far-infrared Outgoing Radiation Understanding and Monitoring) instrument which, if funded, will be deployed on ESA Earth Explorer 9
2. Perform measurements with an aircraft or balloon-borne far-infrared spectrometer above Antarctica
   - Following robust determination of effects that lack of knowledge about far-infrared emissivity has → measurement campaign
   - If FORUM mission goes ahead, such a campaign could also support validation purposes
   - If FORUM does not go ahead, such a campaign could provide the required far-infrared measurements for parts of Antarctica

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