Adapting COSMO-CLM² for Antarctic climate representation

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The project website

1. Project

AEROCLOUD project:

- Collaboration between KU Leuven / Royal Meteorological Institute (RMI) and Royal Belgian Institute for Space Aeronomy (BIRA)
- What is the role of clouds and aerosols in the East Antarctic climate system?
- What is the relation between aerosols and clouds in East Antarctica?
- Achieve by using the observational framework at the Princess Elisabeth station in East Antarctica (Gorodetskaya et al., 2015) and climate modeling
- Role of KU Leuven: investigate clouds, precipitation and the surface mass balance using observations and COSMO-CLM².
- First step: Adapt COSMO-CLM² to represent Antarctic basic climate variables

2. Model setup

- COSMO-CLM²
  - Coupled to the Community Land Model
  - Boundary conditions: ERA-Interim
  - Horizontal resolution: 0.22°
  - 15 month runs (Oct 2011-Dec 2012)
  - Domain encompasses CORDEX domain
- Compare to RACMO (RCM)
  - State of the art climate model over Antarctica
  - Uses the same boundary conditions and horizontal resolution
- Compare to observations
  - Balloon measurements
  - Automatic Weather Stations
  - Scarce!

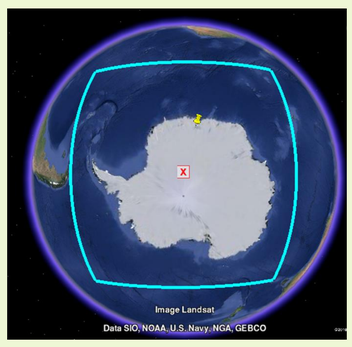

Figure 1: Model domain.

3. Default model run

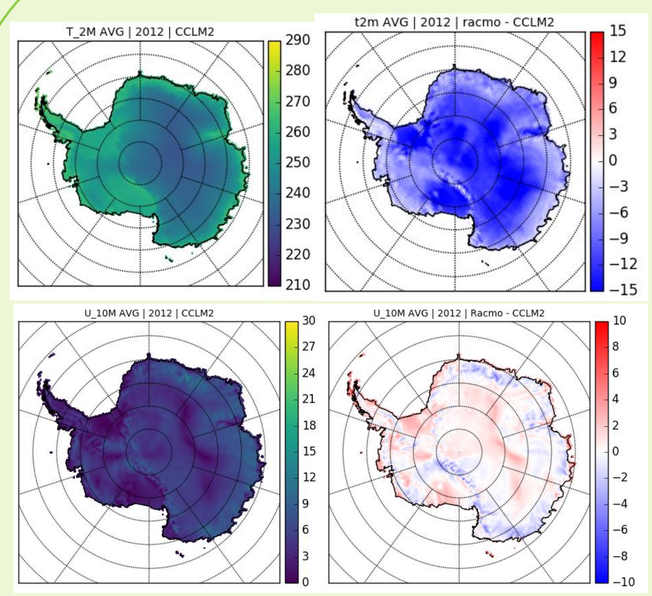

Figure 2: (left) Average temperature (up) and wind speed (down) for the year 2012. (right) Absolute difference with RACMO.

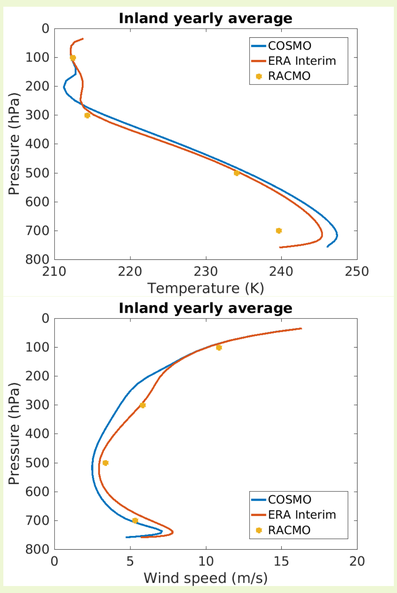

Figure 3: Upper air comparison of average temperature and wind speed for the year 2012.

- High overestimation of surface temperature over the whole of Antarctica (Figure 2; top)
- Surface wind speed is reasonably represented apart from the coasts (Figure 2; bottom)
- Small differences between CCLM², RACMO and ERA INTERIM is found for upper air temperatures and wind speeds
- The main upper air bias is present around 200hPa, where CCLM² depicts the tropopause at the wrong height level. This problem is only present in austral summer.

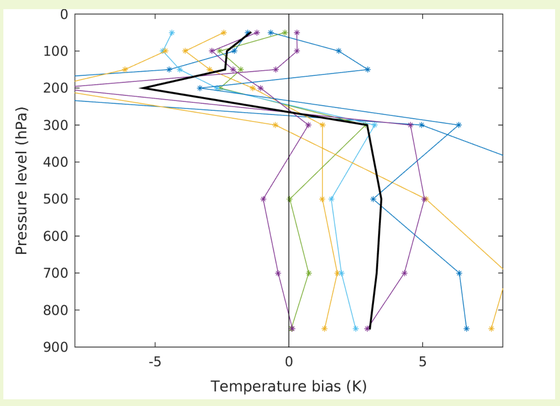

Figure 4: Temperature bias between balloon soundings averaged for January 2012 for eight stations (depicted by thin lines; figure 5) and the corresponding pixel in CCLM². The average bias is depicted in black.

4. Upper atmosphere

- The upper atmosphere is reasonably represented apart from the wrong height of the tropopause (in austral summer)
  - Increasing vertical model levels or assimilating ozone levels did not improve the bias
  - Spectral nudging is applied, depicting the location of the tropopause at the right level in austral summer months

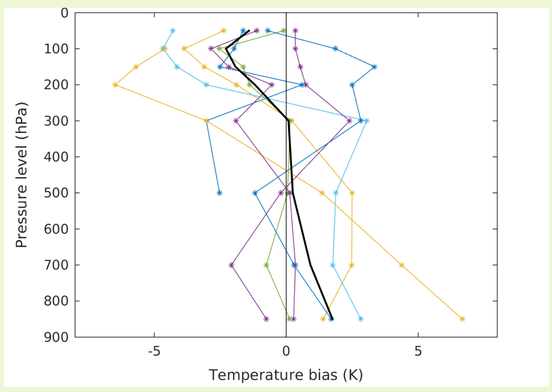

Figure 5: Temperature bias between balloon soundings averaged for January 2012 for eight stations (depicted by thin lines; figure 5) and the corresponding pixel in CCLM². The average bias is depicted in black.

5. Surface albedo

- Surface temperature bias is huge (up to 10K; Figure 2) and is even bigger in January (more than 15K; Figure 6)
- Community Land Model does not consider Antarctica as an ice sheet, but as bare soil (!)
  - Furthermore, no snow layer is initialized at the start of the simulation
  - Surface albedo is very low, absorbing too much radiation and attributing for high surface temperatures
- The surface dataset has been adapted: Antarctica is now considered a land-based glacier with albedo values ranging between 0,8 and 0,9.
- This reduces the bias in temperatures substantially for the month of January
- However, CCLM² still has a warm bias in austral summer.

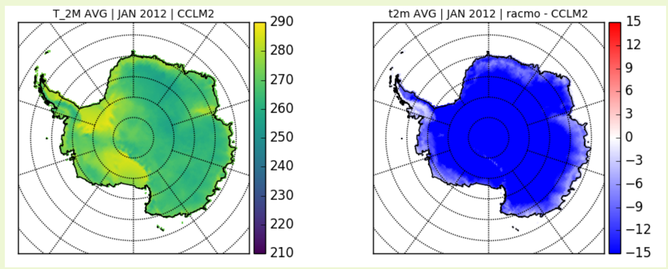

Figure 6: (left) Average surface temperature for January 2012 in CCLM². (right) Temperature bias between RACMO and CCLM² for January 2012.

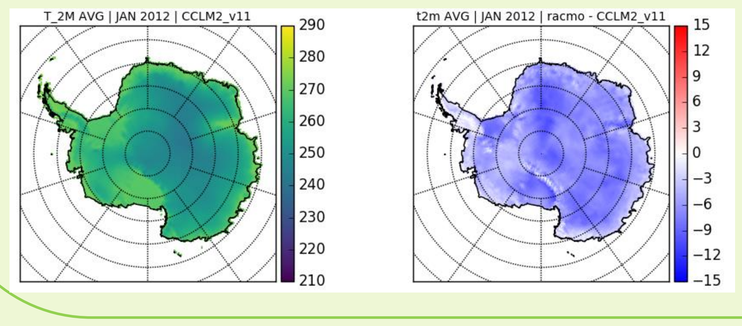

Figure 7: (left) Average surface temperature for January 2012 in CCLM² with adapted surface dataset. (right) Temperature bias between RACMO and CCLM² with adapted surface dataset for January 2012.

6. Boundary layer

- Over Antarctica, a stable boundary layer is often present. In the default model setup, stable boundary layers are not well represented, often attaining for too much mixing.
- Adapted the turbulence parameters to create less turbulence
- Tkhmin, tkmmin, patlen are lowered following Cerenzia et al. (2014).
- This attributes for lower surface temperatures over inland Antarctica and the ice shelves, decreasing the bias of figure 7 even further.

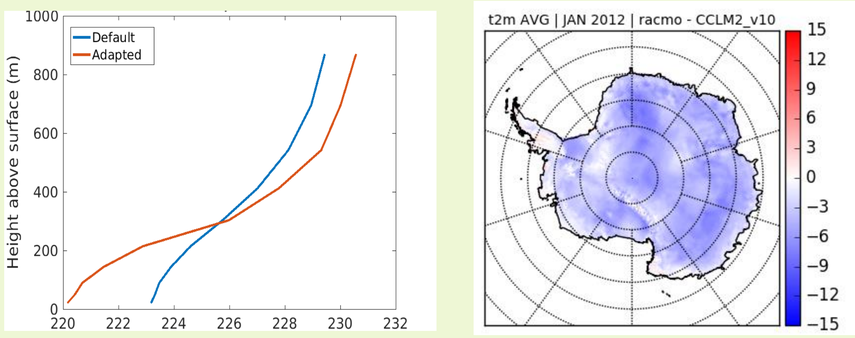

Figure 8: (left) Example of the average temperature profile of the boundary layer for Dome C. A run for January 2012 with adapted turbulence parameters and the setup of section 5 are compared. (right) The temperature bias between RACMO and CCLM² (with modification of section 5 and 6 included).

7. Conclusions and future work

- The default COSMO-CLM² simulation is not able to correctly represent the Antarctic climate
- Several modifications to the original set-up are executed
  - Spectral nudging has been applied to get the correct location of the tropopause
  - The surface temperature bias is mainly caused by a wrong representation of the Antarctic ice sheet in the Community Land Model, attaining for too low albedo values.
  - The high turbulence mixing rates in the stable boundary layer are counteracted by decreasing the turbulence parameters, attaining for lower surface temperatures.
- The performance of COSMO-CLM² is improved but not yet optimized:
  - Fine-tuning of albedo and turbulence parameters is needed
  - By increasing stability, a decline in wind speed is observed. Surface roughness values will be tuned to obtain a better estimate of surface winds.
  - The snow layer properties will be analyzed in order to get better estimates of blowing snow and the metamorphism of snow particles.

References:

- Cerenzia, I., Tampieri, F. and Tesini, M.S., 2014. Diagnosis of Turbulence Schema in Stable Atmospheric Conditions and Sensitivity Tests. COSMO Newsletter 14.
- Gorodetskaya, I. V., Kneifel, S., Maahn, M., Van Tricht, K., Thiery, W., Schween, J. H., Mangold, A., Crewell, S. and Van Lipzig, N. P. M., 2015. Cloud and precipitation properties from ground-based remote sensing instruments in East Antarctica. The Cryosphere 9, 285-304.