Documentation – REMA topography and AntarcticaLC2000 landuse for WRF

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November 25, 2020

Abstract

Reference Elevation Model of Antarctica (REMA) topography and AntarcticaLC2000 landuse data are now available as static data input for the Weather Research and Forecasting model (WRF). Topography and landuse are made available at a spatial resolution of 1 km. This documentation describes the methods applied to convert REMA and AntarcticaLC2000 to WRF readable format and shows how this improves the representation of the Antarctic topography and landuse categories in particular at coastal Antarctic regions.

1 Introduction

This documentation provides information about a new topography dataset available to be used in the Weather Research and Forecasting model (WRF, Skamarock et al., 2008). While the standard orography in WRF is the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) at a horizontal resolution of 30 s (Danielson and Gesch, 2011), the BedMap2 (Fretwell et al., 2013) product with a spatial resolution of 1 km has been converted to WRF compatible binary files previously (Listowski and Lachlan-Cope, 2017). Although BedMap2 is aware of non-snow or non-ice covered coastal regions, there is no topography information available for these grid cells. Additionally, the standard Moderate Resolution Imaging Spectroradiometer (MODIS) landuse dataset (`modis_landuse_20class_30s_with_lakes` input in WRF) does not include any bare rock areas over Antarctica.

Therefore, Reference Elevation Model of Antarctica (REMA, Howat et al., 2019) topography with a spatial resolution of 8 m (bilinearly resampled at a 1 km resolution) is made available as WRF tiles. In accordance with the new topography a landuse dataset is provided based on the AntarcticaLC2000 landuse dataset (Hui et al., 2017) using MODIS landuse categories. The binary files required to run the WRF pre-processing for static data (`geogrid.exe`) are made available together with the corresponding index files.

Compared to previously available topography datasets for Antarctica, the new REMA topography shows an improved representation of coastal topography in non-ice-covered regions, e.g. the Vestfold hills. The landuse data includes the categories *snow and ice*, *bare rock* and optionally *lakes*. Alternatively, a version including *blue ice* as a separate new category is available together with the recently implemented WRF model version CRYOWRF, which includes the snow model SNOWPACK (Lehning et al., 1999) as a land surface model (Sharma, 2020).

Note

This document provides input data to run simulations with the Weather Research and Forecasting Model (WRF) and describes the process, how these files were produced. It does not claim to be complete. No responsibility will be taken in case of damage or loss of any kind.

2 Data

2.1 Reference Model of Antarctica (REMA) topography

The Reference Model of Antarctica (REMA) is a digital elevation model (DEM) based on satellite images collected between 2009 and 2017 but most date back to the summer season 2015/16 (Howat et al., 2019). REMA is available as heights above the WGS84 ellipsoid or as orthometric height above the EGM2008 geoid.

The new dataset is based on REMA data (Howat et al., 2019) with a spatial resolution of 8 m, bilinearly resampled at a 1 km resolution. For the heights we use the orthometric REMA data at a resolution of 8 m (https://www.arcgis.com/home/item.html?id=af22b667859b411993ac6094c1022ebc, downloaded: 23 May 2019), while for the extent of the continent the ellipsoidal mosaic 1 km filled dataset available on https://www.pgc.umn.edu/data/rema/ (downloaded: 1 May 2019) is used.

2.2 Landuse data

The landuse product is based on the AntarcticaLC2000 landuse dataset (Hui et al., 2017, available on: https://zenodo.org/record/826032#.X64_qlAo93g, accessed 13 November 2020), which has been produced by the use of Landsat Enhanced Thematic Mapper Plus (ETM+) data and MODIS. The state represented roughly corresponds to the year 2000. The dataset covers three categories, namely *bare rock*, *blue ice* and *snow/firn*. For the conversion to MODIS landuse categories (Table 1) the categories *blue ice* and *snow/firn* are merged to the category *snow and ice*. The category *bare rock* is translated to the MODIS category *barren or sparsely vegetated*. All grid cells over the sea are set to the landuse category *ocean*. An alternative version is produced for use in the recently implemented WRF model version CRYOWRF (Sharma, 2020), which includes a separate landuse category for *blue ice*. *Blue ice* has been introduced to be category 22.

2.3 Lakes

Optionally, the landuse data is augmented by an additional category for surface lakes (*Lakes*, Table 1). Lakes data is 'Produced using data from the SCAR Antarctic Digital Database' (downloaded from https://data.bas.ac.uk/items/8537f4c6-fc79-4d18-8877-dc2db9ee945e/#item-details-data, downloaded: 25 April 2019, no longer accessible. A newer version is available: https://data.bas.ac.uk/metadata.php?id=GB/NERC/BAS/PDC/01397, accessed: 13 November 2020). The 'High resolution Antarctic lakes dataset' is based on different sources (maps and remote sensing data) and is expected to be incomplete.

Table 1: *Landuse categories based on the MODIS categories.*

Landuse type	MODIS category
Snow and ice	15
Barren or sparsely vegetated	16
Ocean	17
Lakes	21
Blue ice*	22

*The category *blue ice* has been introduced for use with CRYOWRF, which is aware of different snow and ice types.

3 Methods

In this section the methods to produce the WRF input files are described. Technical details are given in box *REMA orthometric topography for WRF*.

3.1 Processing of topography data

The REMA topography provided as orthometric heights relative to the EGM2008 geoid with a resolution of 8 m is bilinearly resampled at a 1 km resolution. Holes in the topography, i.e. grid cells entirely surrounded by topography, are filled by interpolation to avoid missing data and enclosed ocean grid cells. The extent of the orthometric REMA dataset is larger than the REMA dataset referenced to the WGS84 ellipsoid. As negative topography values are not allowed in the WRF input tiles, all grid cells, with negative topography values are set to zero. Finally, as the extent of the landuse dataset (Section 3.2) fits better with the ellipsoidal REMA dataset, the orthometric REMA dataset is clipped by the extent of the ellipsoidal dataset.

3.2 Processing of landuse data

The landuse categories by AntarcticaLC2000, given as shape files, are rastered to the raster of the resampled orthometric REMA topography. For the dataset without lakes and blue ice, the rastered landuse categories are merged giving highest priority to *bare rock* [1], while all other grid cells (i.e. all grid cells with the category *blue ice*, remaining grid cells with the category *snow/firn* as well as grid cells without information from AntarcticaLC2000 but topography information from the orthometric REMA dataset) are set to the category *snow and ice*. Grid cells over the ocean are set to the landuse category *ocean*.

For the dataset with lakes, the lake data is rastered to the raster of the resampled orthometric REMA topography. When merging the categories, *lakes* get the highest priority followed by *bare rock*. All other grid cells over land are set to the category *snow and ice*, while grid cells over the ocean are set to the landuse category *ocean*. The dataset including *blue ice* is merged by the following decreasing priorities over land: *lakes*, *bare rock*, *blue ice*, *snow and ice*. Over the ocean the category *ocean* is set.

However, as the extent of the orthometric REMA topography is slightly larger than the extent for which AntarcticaLC2000 landuse information is available, this procedure results in some unrealistic *snow and ice* grid cells in the coastal area. To avoid this, both REMA orthometric topography and the AntarcticaLC2000 dataset are clipped by the extent of the ellipsoidal REMA topography dataset, which fits better to the extent of the available landuse data.

4 Creating WRF readable tiles

For WRF, the topography and landuse data needs to be transformed to a binary format. The WRF tiles need to be provided together with an `index` file, which contains the meta data (i.e. projection, reference coordinates, etc.). To create the WRF tiles FORTRAN scripts are available to convert the ascii files to the WRF binary format. To produce the index files, the reference coordinates of the lower left corner of the domain are required. Additionally, information about the WRF projection and grid cell size is needed. Furthermore, information about the new topography and landuse data needs to be added to `GEOGRID.TBL`, before running the preprocessing program (`geogrid.exe`).

REMA orthometric topography for WRF

Detailed description about resampling, whole filling and preparing of landuse data.

- **Download orthometric REMA data from GIS server**
  www.arcgis.com/home/item.html?id=af22b667859b411993ac6094c1022ebc
  (accessed: 23 May 2019)
  -> open in ArcGIS Desktop

- **Resample data**
  Arc Toolbox -> Data Management Tools -> Raster -> Raster Processing -> Resample

Output Cell Size:	X = 1000 m; Y = 1000 m
Resampling technique:	bilinear
Output file:	e.g. rema_1kmf8m

- **Save resampled data as TIFF**
  Right click on resampled layer -> Data -> Export Data ...

Extent:	Raster Dataset (original)
Spatial reference:	Raster Dataset (original)
Cell size:	1000 / 1000
Choose folder:	<REMA_folder_path>
Choose file:	<REMA_file_name>_orthometric.tif

- **Fill wholes in topography** Run python: `mask_topo_wholes_bygridfill.py`
  Output: `<REMA_file_name>_orthometricfilled.tif`

[1] When creating the rastered file from the shape file, a grid cell can have more than one classification, e.g. *bare rock* and *snow/firn*. In this case the cell will get the classification *bare rock* in the merged landuse raster as *bare rock* has the higher priority than *snow/firn*.

- **Download landuse data**
  AntarcticaLC2000: https://zenodo.org/record/826032#.X64_qlAo93g, accessed: 13 November 2020
  Lakes: https://data.bas.ac.uk/full-record.php?id=GB/NERC/BAS/PDC/01397, accessed: 13 November 2020
  Note: The lakes dataset used for the provided tiles is from a older versions and was downloaded on the 25 April 2019.
- **Raster landuse** Run python: `landuse_shape_to_raster.py`
  Output: Rastered (`.tif`) files for each landuse category
- **Merge landuse categories** Run python: `landuse_merge.py`
  Output: Rastered landuse file (`.tif`)

Note: Using this procedure quite many coastal grid cells get the landuse category Snow or ice, because the shape file does not cover these cells.

Steps to get the extent of the ellipsoidal referenced dataset:

1. Prepare REMA ellipsoidal dataset
   - **Download ellipsoidal REMA data from REMA webpage,** 1 km **resolution**
     https://www.pgc.umn.edu/data/rema/ (downloaded: 1 May 2019)
   - **Fill wholes in topography** Run python: `mask_topo_wholes_bygridfill.py`
     Output: `<REMA_file_name>_filled.tif`
2. Clip REMA orthometric data and landuse data to the extent of the REMA ellipsoidal dataset
   - **Clip data** Run python; `clip_topo_landuse.py`
     Output: `.tif` and `.txt` files of the area generated.
     Note: `clip_topo_landuse.py` does not do any regridding but clips the grid cells based on the indexing, i.e. the two datasets need to have the same extent.

Get reference coordinates (lower left (ll) corner):

- Add clipped dataset to ArcGIS
- Create point shapefile -> choose coordinate system
- Add shapefile to ArcMap
- Change projection to projection of layer (`WGS_1984_Stereographic_South_Pole`)
- Draw point with ll corner coordinates:
  Coordinates of ll corner -2699999.4723
  -2200000.4172
- Project new point to WGS84 lat/lon
  Coordinates in WGS84: -58.715136
  -129.173669

Create binary files for WRF:

- Export files as ascii (-> or `.txt` directly from python: produced when clipping dataset)
- **Run FORTRAN90** `ascii_to_bin_topo.f90` and `ascii_to_bin_landuse.f90`
  Note: Filename is not allowed to be too long.
  Note: Recently wordsize has to be changed from 2 to 1 in `ascii_to_bin_landuse.f90`.
- **Create index files** (requires information about reference coordinates)
- **Adapt `GEOGRID.TBL.ARW`**: Include information about the new datasets for topography and landuse.
  Note: When including the new dataset with priority 2, WRF will use the new dataset wherever it is available and the default (or specified) for all other grid cells.
- **Adapt `namelist.wps`**: Chose name of new datasets in `geog_data_res`.

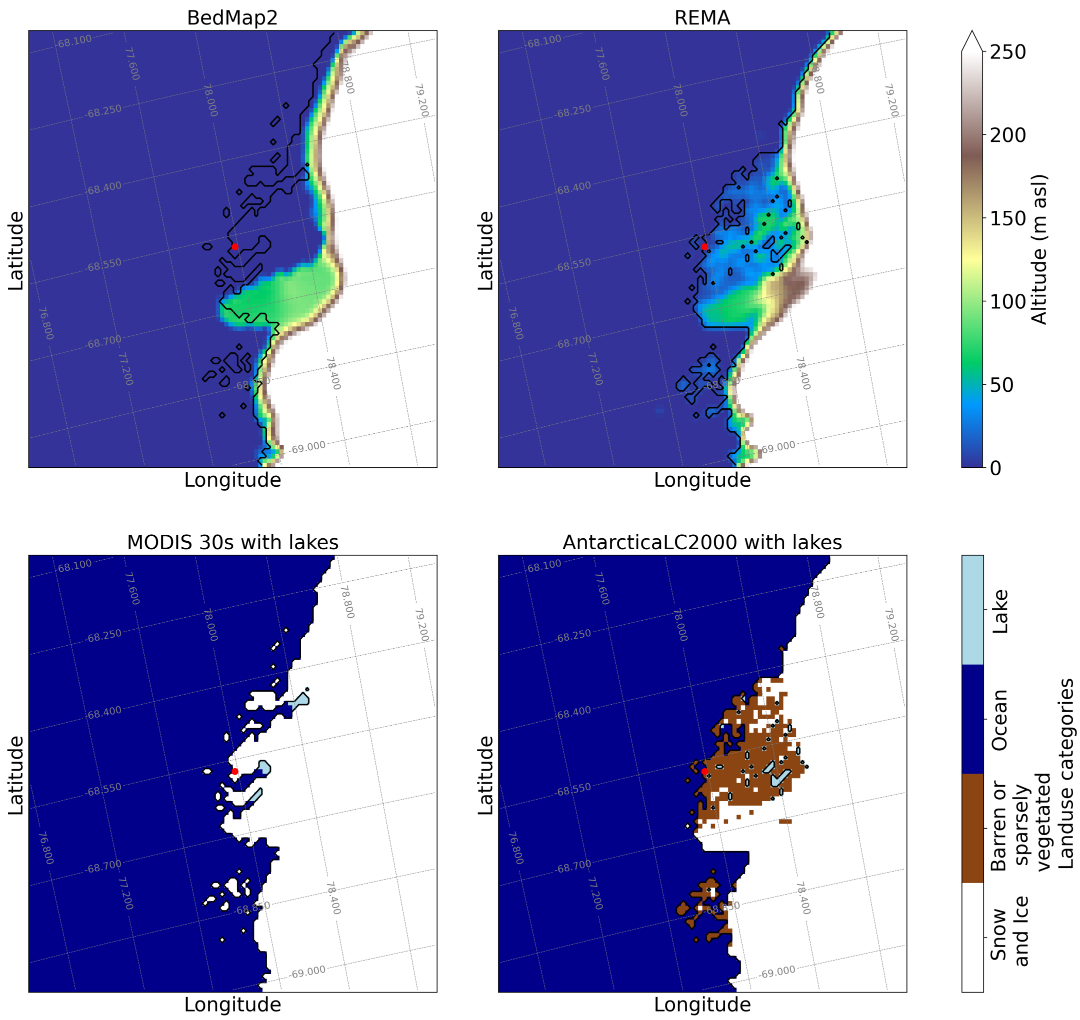

Figure 1: *Comparison of BedMap2 and REMA toporgraphy (top) for the region of the Vestfold hills. The bottom row shows the WRF standard MODIS 30s with lakes and AntarcticaLC2000 with lakes landuse coverage for the same region. The red dot marks the coordinates of the research station Davis by the Australian Antarctic Division (AAD).*

5 Comparison to existing datasets

As an example, the terrain and landuse information from REMA and AntarcticaLC2000 is compared to the previously existing topography from BedMap2 and the standard WRF MODIS landuse data (Figure 1). For the illustration the region of the Vestfold hills is chosen, which is a region of rocky terrain with lakes, which has a seasonal snow cover compared to the major part of the Antarctic continent, which has a perennial ice cover. BedMap2 does not include any topographic information for the region of the Vestfold hills. The standard MODIS dataset includes lakes but no barren or sparsely vegetated landuse grid cells. Compared to these previously available datasets, the presented dataset includes topography for snow and ice free terrain around the Antarctic coast and explicitly specifies grid cells of exposed bedrock as barren or sparsely vegetated. An additional dataset including blue ice areas is provided (Figure 2). Blue ice areas are present in extended parts of coastal Antarctica. The recently implemented coupled model CRYOWRF (Sharma, 2020) is capable to take blue ice into account by the use of an initial snow profile with snow characteristics of very dense snow, i.e. ice.

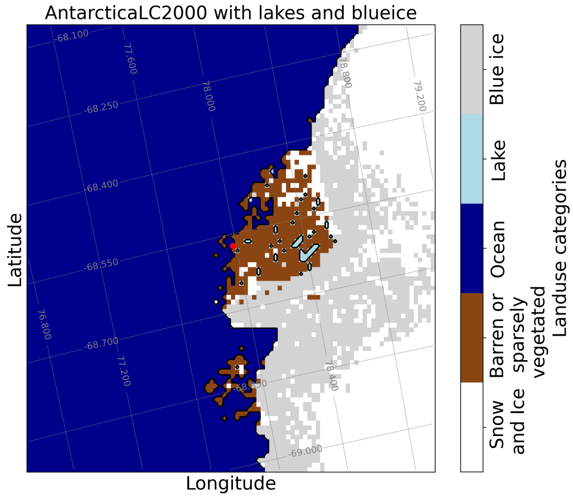

Figure 2: *AntarcticaLC2000 with lakes and blue ice landuse coverage. The red dot marks the coordinates of the research station Davis by AAD.*

Acknowledgements

This work is funded by the EPFL project "Local surface mass balance processes in East Antarctica" (LOSUMEA) and the Swiss National Science Foundation project "From Cloud to Ground: Snow Accumulation in Extreme Environments" (200020_179130). For fruitful discussion we would like to thank Varun Sharma, Étienne Vignon, and Alexis Berne. Additionally, many thanks go to Étienne Vignon for testing the newly produced surface input data. DEMs (REMA) provided by the Byrd Polar and Climate Research Center and the Polar Geospatial Center under NSF-OPP awards 1543501, 1810976, 1542736, 1559691, 1043681, 1541332, 0753663, 1548562, 1238993 and NASA award NNX10AN61G. Computer time provided through a Blue Waters Innovation Initiative. DEMs produced using data from DigitalGlobe, Inc. For the data access of REMA data, we thank the Geospatial support provided by the Polar Geospatial Center under NSF-OPP awards 1043681 and 1559691. Lakes information is 'Produced using data from the SCAR Antarctic Digital Database'.

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