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Documentation for MODIS Melt Pond Product

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1. Data Basis

The MODIS Melt Pond Product (MMPP) is based upon the *"MODIS Surface Reflectance 8-Day L3 Global 500m SIN Grid V005"* - product (MOD09A1) (available over the wist website: https://wist.echo.nasa.gov/api/ or http://reverb.echo.nasa.gov/reverb/). To cover the entire Arctic, the tiles h09v02 to h26-v02 are used to build up the MMPP (see figure 1).

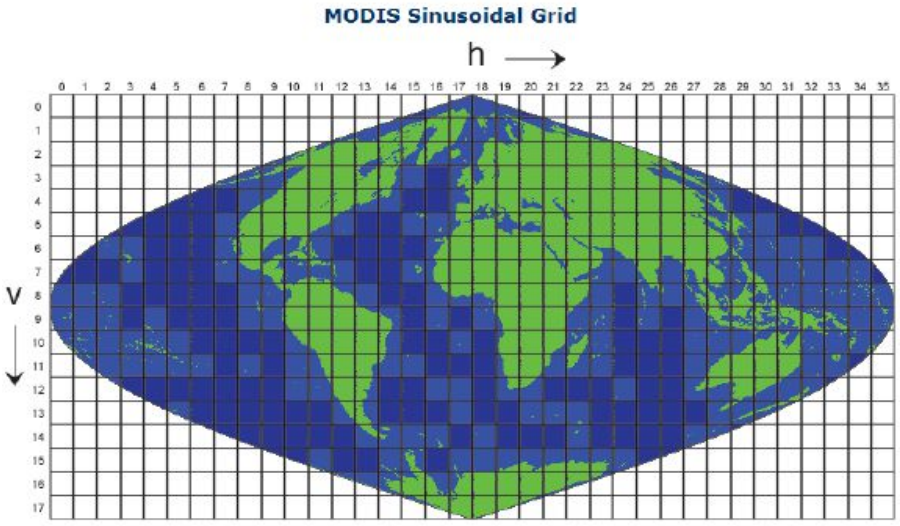

Illustration 1: MODIS sinusoidal grid

The date in the filename indicates the start of the 8-day period.

The MMPP data is available via http://icdc.cen.uni-hamburg.de/arctic_meltponds.html

2. Preprocessing

The MODIS tiles (from the daily and weekly product) are originally in sinusoidal projection. For a more comfortable processing the original MODIS *.hdf files are reprocessed band-wise to NetCDF-files on a polar stereographic grid with a grid resolution of 0.5 km. Additionally a land- and a cloud-mask are applied on the NetCDF-files (see figure 2). Land and cloud information are provided in the original MODIS product. Subsequently, all reprojected tiles are used to compose a complete Arctic mosaic, each band stored separately as NetCDF.

The band numbering is as follows:
band1: 459 nm - 479 nm
band3: 620 nm - 670 nm
band4: 841 nm - 876 nm

The date format is year_julday: yyyy_ddd (e.g. 2000_169)

For internal use only: Path: *snow:*
/scratch/clisap/seaice/OWN_PRODUCTS/MELT_PONDS/GRID_MOSAIC/[yyyy_ddd]/[1]

1 Preprocessed data not available anymore on snow due to resource problems – preprocessed data are stored on the tape archive of DKRZ. See documentation **"Documentation for MODIS Melt Pond Product Data Backup"**

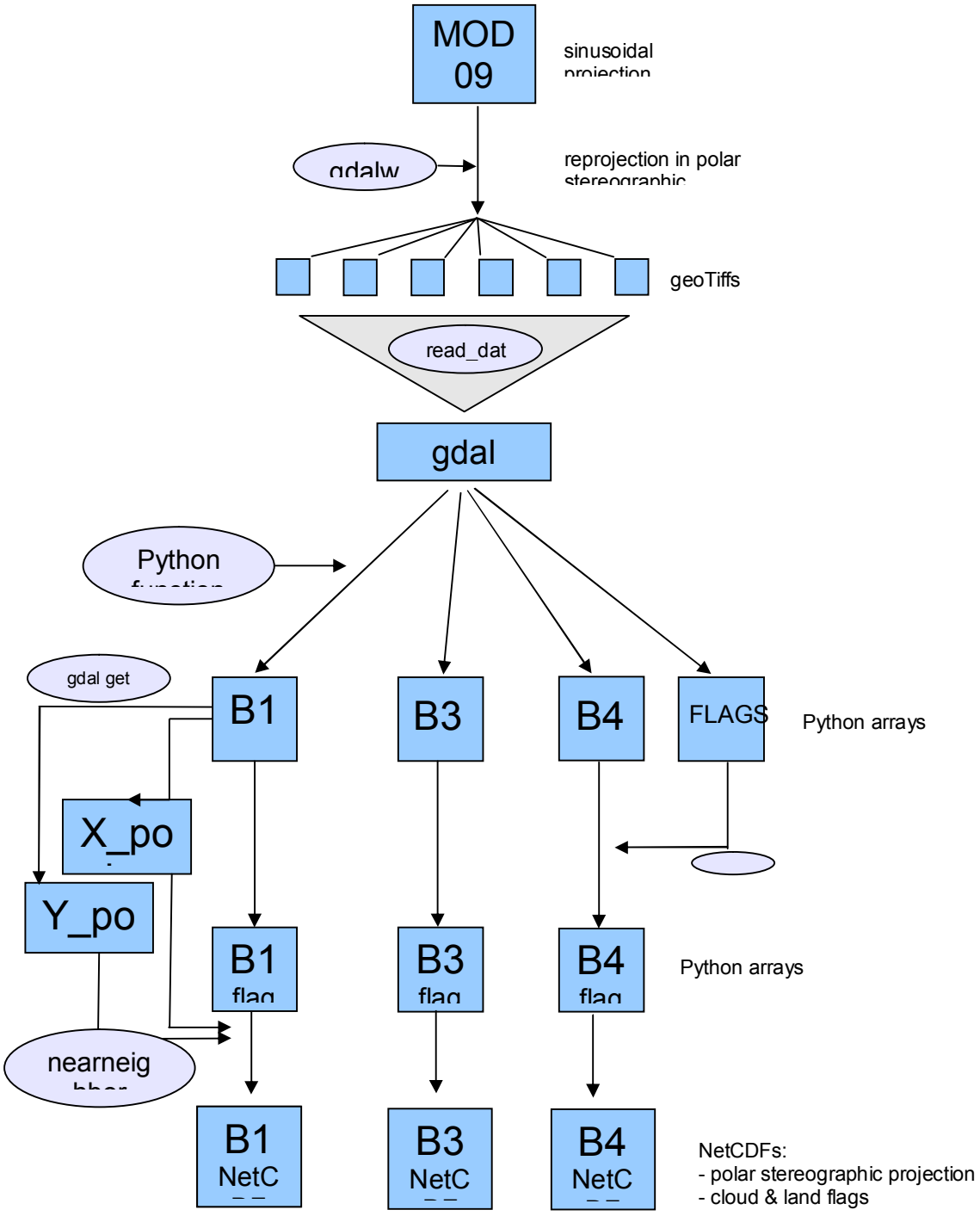

Illustration 2: MODIS processing chain

3. Production

The determination of melt ponds is based on the following equations:

$$[\sum a_i r_i = R]_k, \sum a_i = 1 \quad (1)$$

or

$$a_1 r_{11} \square a_2 r_{21} \square a_3 r_{31} = R_1$$

$$a_1 r_{13} \square a_2 r_{23} \square a_3 r_{33} = R_3$$

$$a_1 r_{14} \square a_2 r_{24} \square a_3 r_{34} = R_4$$

$$a_1 \square a_2 \square a_3 = 1$$

where R is the reflectance for each MODIS pixel for band k (k=1,3,4). r_i represents the spectral reflectance for each surface type.

The MMPP contains three surface types:

- open water
- snow/ice
- melt ponds

The spectral reflectance values of these surface types are taken over from Tschudi et al. (2008) (see table 1).

	open water	melt pond	snow/ice
band 1	0,08	0.22	0.95
band 3	0,08	0.16	0.95
band 4	0,08	0.07	0.87

Table 1: Surface reflectance values (Tschudi et al., 2008)

To solve the equations (1) an artificial neural network was build up, trained and applied. Details will not be given in this Documentation. For more information contact the authors.

The results (*mp[yyyy_ddd].data, ow[yyyy_ddd].data, snow[yyyy_ddd].data*) are stored as pickled python objects.

For internal use only: path: snow:
/scratch/clisap/seaice/OWN_PRODUCTS/MELT_PONDS/PRODUCTS/[yyyy_ddd]/[1]

1 Preprocessed data not available anymore on snow due to resource problems – preprocessed data are stored on the tape archive of DKRZ. See documentation **"Documentation for MODIS Melt Pond Product Data Backup"**

4. Final processing

For subsequent processing the pickled python objects were projected on a regular polar stereographic grid with a grid resolution of 0.5 km.

For internal use only: In further calculations, the following products were built (in brackets the according filename is given):

path: snow: */scratch/clisap/seaice/OWN_PRODUCTS/MELT_PONDS/PRODUCTS/[yyyy_ddd]/*

Melt pond products:

- melt pond fraction per 0.5 km grid cell (*path/[yyyy_ddd]_mp_05.nc)*

This is the base-product for further operations. This is NOT offered via ICDC or WCDC.

- melt pond fraction per 12.5 km grid cell (*path/[yyyy_ddd]_mp_125.nc)*

Spatial resolution of 12.5 km.

- melt pond fraction per 12.5 km grid cell (masked) (*path/[yyyy_ddd]_mp_masked125.nc)*

Spatial resolution of 12.5 km, data masked with the "weight-file" (see below) to eliminate cloudy artefacts on the edges of the cloud mask.

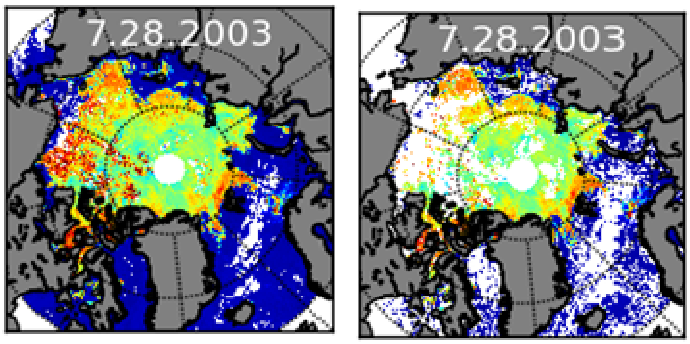

Illustration 3: Melt-pond fraction without (left) and with 50% cloud cover threshold applied (right.)

It is recommended – and actually the product offered via ICDC and WCDC offers this – to use an even higher threshold of 90% - that means only grid cells that contain 90% of the base-product's 0.5 km resolution pixel are selected for this product.

- number of pixel for 12.5 km-grid-product (*path/[yyyy_ddd]_mp_125WEIGHT.nc)*

Amount of pixel used for building the mean value in the gridding routine. In cloudy regions it can be possible, that only a few pixel go into the coarse grid product – if these pixel are "faulty", they can highly influence the result. This product can be used to mask the melt-pond fraction 12.5 km-product for further analysis and can be used as a kind of "indicator" how trustful is the result of the coarse grid.

- standard deviation for 12.5 km-grid-product (*path/[yyyy_ddd]_mp_125SD.nc)*

Standard deviation of a 12.5 km grid-cell according to the 0.5 km base-product.

Sea ice concentration products:

Sea ice concentration is defined as 1 minus open-water (ow) fraction (see below). These are NOT included in the product offered via ICDC and WCDC.

All sea ice concentrations products are not validated until now!

- sea ice concentration 0.5 km (*path/[yyyy_ddd]_ice_05.nc)*

Sea ice concentration with a spatial resolution of 0.5 km.

- sea ice concentration 12.5 km (*path/[yyyy_ddd]_ice_125.nc)*

Sea ice concentration with a spatial resolution of 12.5 km.

Open water concentration products:

All open water concentrations products are not validated until now!

- Open water concentration 0.5 km (*path/[yyyy_ddd]_ow_05.nc)*

Open water concentration with a spatial resolution of 0.5 km – NOT offered via ICDC or WCDC.

- Open water concentration 12.5 km (*path/[yyyy_ddd]_ow_125.nc)*

Open water concentration with a spatial resolution of 12.5 km.

5. Data Volume

The data volume of all products listed in Section 4 for the melt seasons 2000-2011 amounts to in total 636 GB, the product offered via ICDC / WCDC has a size of 3.7 GB.

6. Missing Data

The MMPP contains data gaps due to missing initial MODIS MOD09A1 data.
The following datasets are completely missing (c) or have missing tiles (m) -
(maily the tiles northwards 80° are missing):

2000_129 (m)	2001_129 (m)	2002_129 (m)	2003_177 (m)	2007_129 (m)
2000_137 (m)	2001_137 (m)	2002_137 (m)		2007_137 (m)
2000_145 (m)	2001_145 (m)	2002_145 (m)		2007_145 (m)
2000_153 (m)	2001_153 (m)	2002_153 (m)		2007_153 (m)
2000_177 (m)	2001_161 (m)	2002_161 (m)		2007_161 (m)
2000_185 (m)	2001_169 (c)	2002_193 (m)		
2000_193 (m)	2001_177 (m)	2002_201 (m)		
2000_209 (m)	2001_185 (m)			
2000_217 (m)	2001_193 (m)			
2000_225 (m)	2001_201 (m)			
2000_233 (m)	2001_209 (m)			
2000_241 (m)	2001_217 (m)			
2000_249 (m)	2001_225 (m)			
	2001_233 (m)			
	2001_241 (m)			

Additionally, data gaps occur due to cloud-masking.

All data gaps are filled with nan. In the product offered via ICDC and WCDC land is set to 101, data gaps appear as 103.

7. Accuracy

See:

Tschudi, M. A. et al (2008): *Derivation of melt pond coverage on Arctic sea ice using MODIS observations,* **Remote Sensing of Environment.** 112, pp. 2605-2614, doi:10.1016/j.rse.2007.12.009

Rösel, A., Kaleschke, L. and Birnbaum, G. (2012): *Melt ponds on Arctic sea ice determined from MODIS satellite data using an artificial neural network.* **The Cryosphere.** doi:10.5194/tc-6-431-2012.

Rösel, A. and Kaleschke, L. (2012): *Exceptional melt pond occurrence in the years 2007 and 2011 on the Arctic sea ice revealed from MODIS satellite data.* **Journal of Geophysical Ressearch**. 117, C5, doi:10.1029/2011JC007869.