README Gridded Hourly Temperature, Radiation and Makkink Potential Evaporation forcing for hydrological modelling in the Rhine basin

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1 General Information

```
file names:
temperature_hour_1.1.nc
makkink_potential_evaporation_hour_1.1.nc
global_radiation_hour_1.1.nc

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file type: netCDF4
```

2 General description

These datasets were created to provide forcing to a gridded hydrological model of the Rhine basin. These complement a precipitation dataset with the same resolutions and domain.

For more information please refer to the companion paper of this dataset: van Osnabrugge,B., Uijlenhoet, R., Weerts, A. Contribution of Potential Evaporation Forecasts to 10-day streamflow forecast skill for the Rhine river. (2018) Submitted to Hydrology and Earth System Sciences (HESS)

Below are short descriptions of each file seperately.

3 File Descriptions

3.1 temperature_hour_1.1.nc

3.1.1 Metadata

Metadata_Conventions: Unidata Dataset Discovery v1.0
title: Gridded air temperature dataset for the Rhine basin made with lapse rate corrected Inverse-Distance Squared Weighting
summary: A high resolution (1.2x1.2km) gridded air temperature dataset with hourly time step that covers the whole Rhine basin for the period 1997-2015. Made from gauge data with lapse rate corrected Inverse-Distance Squared Weighting
keywords: hourly air temperature,grid,Rhine basin,interpolation,climatology
cmd_data_type: Grid
crs: WGS 84/ UTM zone 32N EPSG:32632
institution: Deltares
creator_email: Bart.vanOsnabrugge@deltares.nl
acknowledgements: We thank the data providers: Koninklijk Nederlands Meteorologisch Instituut (KNMI); Deutscher Wetterdienst climate data center (DWD-cdc); Meteo Swiss, Service Publique de Wallonie, Departement des Etudes et de l Appui a la Gestion (SPW);Administration de la gestion de l eau Luxembourg; Meteo France
date_created: 07 march 2017
processing_level: final
project: IMPREX project funded by the European Commission under the Horizon 2020 framework programme (grant no. 641811)
companion_paper: Contribution of Potential Evaporation Forecasts to 10-day streamflow forecast skill for the Rhine river. Bart van Osnabrugge, Remko Uijlenhoet, Albrecht Weerts. 2018.
comment: Advice on use: This dataset was made as forcing for hydrological models. Care should be taken when using this data for other purposes, note that there are especially concerns when using this dataset for climate analysis. It is recommended to read the paper before using this dataset.
licence: Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA). Please refer to the companion paper when using this dataset

3.1.2 Structure of NETCDF file

```
netcdf file:/P:/1221519-imprex/004/Products/Temperature/temperature_hour_1.1.nc {
dimensions:
y = 540;
x = 420;
time = 172800;
variables:
double y(y=540);
```

```
:_FillValue = 9.96921E36; // double
:standard_name = "projection_y_coordinate";
:long_name = "y coordinate according to UTM32N";
:units = "m";
:axis = "Y";

double x(x=420);
:_FillValue = 9.96921E36; // double
:standard_name = "projection_x_coordinate";
:long_name = "x coordinate according to UTM32N";
:units = "m";
:axis = "X";

long time(time=172800);
:standard_name = "time";
:long_name = "time";
:axis = "T";
:units = "hours since 1996-05-02 01:00:00";
:calendar = "proleptic_gregorian";

double lat(y=540, x=420);

double lon(y=540, x=420);

int crs;
:long_name = "coordinate reference system";
:epsg_code = "32632";
:_CoordinateTransformType = "Projection";
:_CoordinateAxisTypes = "GeoX GeoY";

double t2m(time=172800, y=540, x=420);
:coordinates = "lat lon";
:_FillValue = NaN; // double
:least_significant_digit = 1; // int
:long_name = "air_temperature";
:units = "oC";
:grid_mapping = "crs";
:_ChunkSizes = 24, 540, 420; // int
```

3.1.3 Creation of file

Temperature observations (1996-2016) are interpolated on the same 1.2x1.2 km grid as the precipitation data (van Osnabrugge et al., 2017). Temperature is derived from interpolation of ground measurements with correction for height using the SRTM digital elevation model (Farr et al., 2007) and standard lapse rate as follows.

To calculate temperature T_x at a given grid cell x from a number of n surrounding gauges, determine a set of weights based on inverse-distance squared weighting between all gauges (typically the n closest gauges) and the grid cell. This step can have a threshold for maximum distance. $d_{i,x}$ is the distance between gauge i and cell x:

$$w_{i,x} = \frac{\frac{1}{d_{i,x}^2}}{\sum_{i=1}^{n} \frac{1}{d_{i,x}^2}} \tag{1}$$

Second, calculate the temperature lapse correction term $T_{\gamma,x}$ as the weighted difference between the height of the grid cell H_x and the height of the considered gauges H_i multiplied with the lapse rate γ.

$$T_{\gamma,x} = \gamma \left(\sum_{i=1}^{n} (H_i - H_x) w_{i,x} \right) \tag{2}$$

Note that $T_{\gamma,x}$ is static for a fixed configuration of the measurement network if γ is taken to be a constant. In this study the configuration of the measurement network changed based on the number of reporting stations at each time step. A constant lapse rate was assumed: $\gamma = 0.0066[°C/m]$

Third, interpolate the measured temperature $T_{m,i}$ with the weights as with standard inverse-distance squared interpolation:

$$T_{m,x} = \sum_{i=1}^{n} T_{m,i} w_{i,x} \tag{3}$$

The final temperature estimate for grid cell x is obtained by adding $T_{\gamma,x}$ and $T_{m,x}$:

$$T_x = T_{\gamma,x} + T_{m,x} \tag{4}$$

3.2 global_radiation_hour_1.1.nc

3.2.1 Metadata

Metadata_Conventions: Unidata Dataset Discovery v1.0
title: Gridded global radiation dataset for the Rhine basin resampled from LSA SAF and CM SAF radiation products for hydrological modelling purposes
summary: A high resolution (1.2x1.2km) gridded global radiation dataset with hourly time step that covers the whole Rhine basin for the period 1997-2015. Radiation is resampled and merged from two satellite products: LSA SAF DSSF and CM SAF SIS and gap filled with ERA5 (ssrd).
keywords: global radiation,grid,hourly,Rhine,transnational,hydrological modelling
cmd_data_type: Grid
crs: WGS 84/ UTM zone 32N EPSG:32632
institution: Deltares
creator_email: Bart.vanOsnabrugge@deltares.nl

acknowledgements: We thank the data providers: Land Surface Satellite Application Facility (LSA SAF) and Climate Monitoring Satellite Application Facility (CM SAF)
date_created: 28 june 2018
processing_level: final
project: IMPREX project funded by the European Commission under the Horizon 2020 framework programme (grant no. 641811)
companion_paper: Contribution of Potential Evaporation Forecasts to 10-day streamflow forecast skill for the Rhine river. Bart van Osnabrugge, Remko Uijlenhoet, Albrecht Weerts. 2018.
comment: Advice on use: This dataset was made as forcing for hydrological models. It is recommended to read the paper before using this dataset.
project: IMPREX project funded by the European Commission under the Horizon 2020 framework programme (grant no. 641811) licence: Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA). Please refer to the companion paper when using this dataset

3.2.2 Structure of NETCDF file

```
netcdf file:/P:/1221519-imprex/004/Products/Evaporation/global_radiation_hour_1.1.nc {
dimensions:
time = 182160;
y = 540;
x = 420;
variables:
double lat(y=540, x=420);

double time(time=182160);
:calendar = "proleptic_gregorian";
:units = "hours since 1996-06-01 01:00:00.0 +0000";
:standard_name = "time";
:long_name = "time";
:axis = "T";

int crs;
:long_name = "coordinate reference system";
:epsg_code = "32632";
:_CoordinateTransformType = "Projection";
:_CoordinateAxisTypes = "GeoX GeoY";

double y(y=540);
:standard_name = "projection_y_coordinate";
:long_name = "y coordinate according to UTM32N";
:axis = "Y";
:units = "m";
```

```
double dssf(time=182160, y=540, x=420);
:_FillValue = -999.0; // double
:least_significant_digit = 2; // int
:units = "W/m2";
:coordinates = "lat lon";
:grid_mapping = "crs";
:long_name = "downward surface shortwave flux";
:_ChunkSizes = 1, 540, 420; // int

double lon(y=540, x=420);

double x(x=420);
:standard_name = "projection_x_coordinate";
:long_name = "x coordinate according to UTM32N";
:units = "m";
:axis = "X";
```

3.2.3 Creation of file

Downward shortwave radiation is resampled and merged from the EUMETSAT Surface Incoming Solar Radiation (SIS) (Mueller et al., 2009) and Downward Surface Shortwave Flux (DSSF) (Trigo et al., 2011) products from the Climate Monitoring Satellite Application Facility (CM-SAF) and the Land Surface Analysis Satellite Application Facility (LSA-SAF), respectively. Gaps in the satellite data are filled with the ERA5 Surface solar radiation downwards (ssrd) parameter from the 4d-var reanalysis (Copernicus Climate Change Service, 2018).

3.3 makkink_potential_evaporation_hour_1.1.nc

3.3.1 Metadata

Metadata_Conventions: Unidata Dataset Discovery v1.0
title: Gridded potential evaporation dataset for the Rhine basin calculated with Makkinkś formula
summary: A high resolution (1.2x1.2km) gridded potential evaporation dataset with hourly time step that covers the whole Rhine basin for the period 1997-2015. Potential evaporation is calculated with the Makkinkś formula.
keywords: potential evaporation,grid,hourly,Rhine,transnational,hydrological modelling,Makkink
companion_paper: van Osnabrugge,B., Weerts, A., Uijlenhoet, R. Contribution of Potential Evaporation Forecasts to 10-day streamflow forecast skill for the Rhine river cmd_data_type: Grid
crs: WGS 84/ UTM zone 32N EPSG:32632
institution: Deltares
creator_email: Bart.vanOsnabrugge@deltares.nl

date_created: 29 june 2018
processing_level: final
project: IMPREX project funded by the European Commission under the Horizon 2020 framework programme (grant no. 641811)
comment: Advice on use: This dataset was made as forcing for hydrological models. It is recommended to read the paper before using this dataset.
project: IMPREX project funded by the European Commission under the Horizon 2020 framework programme (grant no. 641811) licence: Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA). Please refer to the companion paper when using this dataset

3.3.2 Structure of NETCDF file

```
netcdf file:/P:/1221519-imprex/004/Products/Evaporation/makkink_potential_evaporation_hour_1
dimensions:
x = 420;
y = 540;
time = 172080;
variables:
double x(x=420);
:standard_name = "projection_x_coordinate";
:long_name = "x coordinate according to UTM32N";
:units = "m";
:axis = "X";

double lat(y=540, x=420);

double y(y=540);
:standard_name = "projection_y_coordinate";
:long_name = "y coordinate according to UTM32N";
:units = "m";
:axis = "Y";

double pet(time=172080, y=540, x=420);
:long_name = "makkink potential evaporation";
:_FillValue = -999.0; // double
:least_significant_digit = 2; // int
:coordinates = "lat lon";
:grid_mapping = "crs";
:units = "mm";
:_ChunkSizes = 1, 540, 420; // int

double time(time=172080);
:calendar = "proleptic_gregorian";
:units = "hours since 1996-06-01 01:00:00.0 +0000";
```

```
:standard_name = "time";
:long_name = "time";
:axis = "T";

int crs;
:long_name = "coordinate reference system";
:epsg_code = "32632";
:_CoordinateTransformType = "Projection";
:_CoordinateAxisTypes = "GeoX GeoY";

double lon(y=540, x=420);
```

3.3.3 Creation of file

The potential evaporation is calculated based on air temperature T [$°C$] and downward shortwave radiation Rg [$\frac{W}{m^2}$] for accumulation period t [s] (Hiemstra and Sluiter, 2011):

$$PET = 1000 \cdot 0.65 \frac{\Delta}{\Delta + \gamma} \cdot \frac{tR_g}{\lambda \rho_w} [mm] \tag{5}$$

with,

$$\gamma = 0.646 + 0.0006T [hPa/°C] \tag{6}$$

$$\lambda = 1000(2501 - 2.38T) [J/kg] \tag{7}$$

$$\Delta = \frac{6.107 \cdot 7.5 \cdot 273.3}{(273.3 + T)^2} e^{\frac{7.5T}{273.3+T}} [hPa/°C] \tag{8}$$

$$\rho_w = 1000 [kg/m^3] \tag{9}$$

References

Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., and Alsdorf, D. E.: The shuttle radar topography mission, Rev. Geophys., 45, RG2004, https://doi.org/10.1029/2005RG000183, URL http://doi.wiley.com/10.1029/2005RG000183, 2007.

Hiemstra, P. and Sluiter, R.: Interpolation of Makkink evaporation in the Netherlands, Tech. rep., KNMI, De Bilt, URL http://bibliotheek.knmi.nl/knmipubTR/TR327.pdf, 2011.

Mueller, R., Matsoukas, C., Gratzki, A., Behr, H., and Hollmann, R.: The CM-SAF operational scheme for the satellite based retrieval of solar surface irradiance — A LUT based eigenvector hybrid approach, Remote Sens. Environ., 113, 1012–1024, https://doi.org/10.1016/J.RSE.2009.01.012, URL http://www.sciencedirect.com/science/article/pii/S0034425709000224, 2009.

Trigo, I. F., Dacamara, C. C., Viterbo, P., Roujean, J.-L., Olesen, F., Barroso, C., Camacho-de Coca, F., Carrer, D., Freitas, S. C., García-Haro, J., Geiger, B., Gellens-Meulenberghs, F., Ghilain, N., Meliá, J., Pessanha, L., Siljamo, N., and Arboleda, A.: The Satellite Application Facility for Land Surface Analysis, Int. J. Remote Sens., 32, 2725–2744, https://doi.org/10.1080/01431161003743199, URL `http://www.tandfonline.com/doi/abs/10.1080/01431161003743199`, 2011.

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