Eddy-covariance flux footprint overview for the MOSAiC expedition.

This documentation provides a brief overview of the eddy covariance (EC) flux footprints, calculated for the bow tower EC system (located on the bow tower of the Polarstern), as well as the EC systems operating at Met City at three heights. Within can be found overview descriptions of the input data, the footprint calculations and the output data formats. References to the footprint calculation code will additionally be provided.

Data Inputs

These footprints are derived for data collected during the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition (https://mosaic-expedition.org/). All data are stored in persistent repositories and will be available to the general public from January 2023 onwards. Briefly, two data sets are utilised for these footprint calculations. The first is from the EC system placed on the bow tower of the Polarstern, at approximately 20 m. height. This system was installed primarily in order to investigate the air—surface exchange of the trace greenhouse gases (GHG) carbon dioxide (CO_2), methane (CH_4), dimethyl-sulfide (DMS) and ozone (O_3). All data utilised for these footprint calculations were collected using a (XX) sonic anemometer. Further details, along with the data, can be found in the Arctic Data Center repository (XX ref).

The Met City tower was installed on the sea ice within the Central Observatory (CO) of the MOSAiC expedition. The primary purpose of this tower was to investigate the turbulent parameters of the lower boundary layer above the sea ice, though a secondary purpose was also to record a second set of GHG measurements, excluding DMS. Sonic anemometers of type (XX) were installed at nominal heights of 10 m., 6 m. and 2 m. Due to movement of the sea ice surface, the relative location of this tower to the Polarstern changes throughout the campaign. Further details, along with the data, can also be found in the Arctic Data Center repository (XX ref).

The Polarstern operates a GPS receiver and gyroscopic compass. These were used to derive the ship location (latitude and longitude), as well as the ship's compass heading. Additionally, a GPS receiver was placed at the Met City tower, also providing its latitude and longitude. The relative latitude/longitude between the Met City tower and Polarstern were used to derive the relative location of the tower, and the ship heading and distance from the bridge to bow tower, were used to derive the relative location of the bow tower. Polarstern GPS/gyroscope compass data are available (XX ref).

Radiosondes were launched from the helicopter deck ($z \approx$ XX) every 6 hours throughout the campaign. Data from these launches were used to estimate the planetary boundary layer (PBL) height, using the method of XX ref. Linear interpolation between the calculated PBL heights was used in order to obtain a 1 h. sample rate to match that of the turbulent parameters captured by the towers.

Footprint Calculations

The two-dimensional flux footprint prediction (FFP) is calculated using the method developed and reported by Kljun *et al.*, 2015 (doi: 10.5194/gmd-8-3695-2015). Specifically, the function calc_footprint_FFP.m, provided alongside this documentation, was written by Kljun *et al*. and is publicly available via https://footprint.kljun.net/index.php. Briefly, the FFP calculation is based on a parameterisation of an earlier large eddy simulation model developed by Kljun and others. This parameterisation was quite unique at the time, as it allows for a two-dimensional estimation of the footprint contribution (rather than the traditional 1D in the direction of wind flow), at a relatively low computational cost. For further details please see Kljun *et al.*, 2015 and references within.

Quality control of the input data was restricted mainly to that which had been implemented by the original publishers of the input data (see section above and references within). The only additional quality control step implemented consisted of limiting input data to only those where the computed bulk Richardson number (see XX ref for details of the bulk parameter modelling) was below 0.2. Values above this threshold were interpreted as periods when the measured flow at the height of the sonic anemometer was decoupled from the turbulent surface layer, hence rendering the concept of a surface footprint invalid.

Output data

The output data are stored and available in netCDF4 format, with one file for each tower/height combination. A brief overview of each follows.

base_time

Set for UNIX time, *i.e.* 1st January 1970 00:00 UTC.

time

Seconds since base time. Each time step refers to the beginning of the hour-long averaging period.

latitude

Taken directly from the Polarstern GPS receiver. Averaged across the hour.

longitude

Taken directly from the Polarstern GPS receiver. Averaged across the hour.

1D footprints

These one-dimensional footprints are more representative of traditional footprint calculations, in that they are estimates of the relative contribution to the flux in one direction only, rotated in the direction of the oncoming wind. These have been included primarily for comparison with outputs from other footprint models. Note that these are calculated independently of the 2D footprints. Note also that all distances are relative to the GPS sensor on the Polarstern, not from the tower in question. This is to allow for direct comparisons between all tower footprints.

north_dist_1d

North-south coordinate grid location for each point in the footprint calculation. North positive.

east_dist_1d

Same as above, for east-west grid location. East positive.

contr_1d

Relative contribution of each point to the overall calculated 1D footprint.

2D footprints

Surface two-dimensional estimation of the flux footprint. As with the 1D footprint, all distance values are relative to the Polarstern GPS receiver. Unlike the 1D footprints, each point given by a north-east-contribution value has an associated area, the dimensions of which are given by dxy_2d. All coordinates are for the southernmost (westernmost) edge of the associated area. Note that these have all been interpolated from the original FFP calculation onto a regular-spaced grid that is held constant for all 2D footprints. This is in contrast to the 1D footprints, where the coordinates are simply rotated into mean wind direction and translated according to tower location, with no interpolation onto a regular grid.

The 2D coordinates are saved in a coordinate (COO) format representation of a sparse matrix, rather than a full matrix for each footprint. Conversion to a full matrix may be necessary for visualisation.

dxy_2d

Linear distance along both the north and east axes associated with each footprint coordinate. All areas are square, thus total area for each coordinate contribution equals dxy_2d^2.

north_dist_2d

North-south coordinate grid location for each area point in the footprint calculation. North positive.

east_dist_2d

Same as above, for east-west grid location. East positive.

contr_2d

Interpolated relative contribution of each point to the overall calculated 1D footprint.

rXX contours

The rXX contours relate only to the 2D footprints and give contour outlines of surface areas representing XX% of the total calculated footprint contribution. Unlike the 2D footprints themselves, these have not been interpolated onto a regularly-spaced grid.

rXX_north_dist

North-south coordinate grid location for each point in the XX% contour. North positive.

rXX_east_dist

Same as above, for east-west grid location. East positive.

Figures

The below figures show 1D, 2D and contour outputs for a single example footprint. Note the difference in distance scales for the 1D and 2D footprints. This is due to the varying outputs of the calc_footprint_FFP.m function. Please see the documentation and Kljun *et al.*, 2015 for further information. Note also that the contours shown in the lower panel represent 20%, 40%, 60% and 80% of the total calculated 2D footprint.