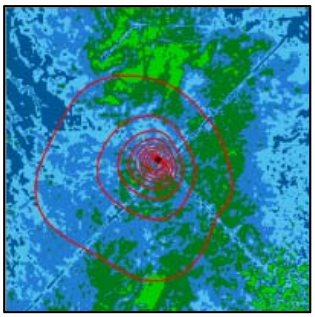
OPTIMISE Final Conference
21 - 23 February 2018

The Flux Footprint Prediction - Online Tool

Natascha Kljun (1), Enrico Tomelleri (2), Georg Wohlfahrt (3)

(1) Dept. of Geography, Swansea University, Swansea, United Kingdom, n.kljun@swansea.ac.uk;
(2) Faculty of Science and Technology, Free University of Bolzano-Bozen, Italy;
(3) Institute of Ecology, University of Innsbruck, Austria



Presentation type preference: oral

Session: 1 - Scientific Networking

We present FFPonline, a data processing tool initiated at the COST Optimise Footprint Modelling Expert Workshop at Innsbruck University in February 2017.

One of the main themes of OPTIMISE is linking eddy covariance (EC) flux measurements of, for example, carbon dioxide or water vapour with proximal optical sensing data. The key challenge in this context is the difference between the flux footprint of EC measurements, i.e. the area from which the measured flux originates, and the field-of-view of proximal sensing measurements. The footprint of EC measurements is typically hundreds of meters and is variable in time due to changing environmental conditions, while the field-of-view of proximal sensing measurements is a few meters and fixed in time. Placing proximal sensing instruments such that an area is sampled that contributes most to the flux footprint is hence of utter importance for interpretation of the collected data.

The footprint tool aims to support optimal placement of fixed spectrometers for continuous spectral information acquisition at EC sites and also supports combination of EC measurements with UAV-based spectral data.

FFPonline (http://footprint.kljun.net/ffp2d.html) allows uploading a time series of environmental data. For each time step of the input data, a footprint is calculated. The footprints for the time series are then aggregated to a so-called footprint climatology. The tool also derives an unsupervised land-cover classification for the footprint area based on a RGB and a Sentinel 2 map and overlays the footprint climatology with the land-cover classification. The key output is a graphical and tabular representation of what land-cover type contributes most to the measured fluxes and the location of the pixels for optimal proximal sensor placement.

Optimise Final Conference 2018

Swansea University
Prifysgol Abertawe

The Flux Footprint Prediction Online Tool

N. Kljun*, E. Tomelleri, T. El-Madany, G. Wohlfahrt

*Dept of Geography, College of Science, Swansea University, UK

n.kljun@swansea.ac.uk

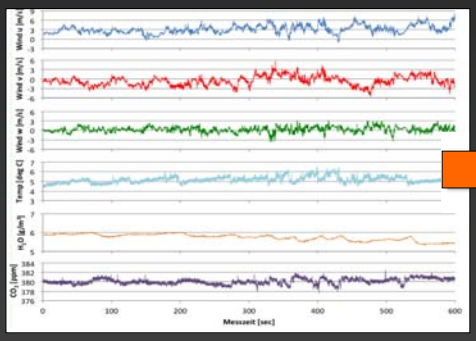
College of Science
Coleg Gwyddoniaeth

www.swansea.ac.uk/science

Area That Contributes to Measurement?

we measure

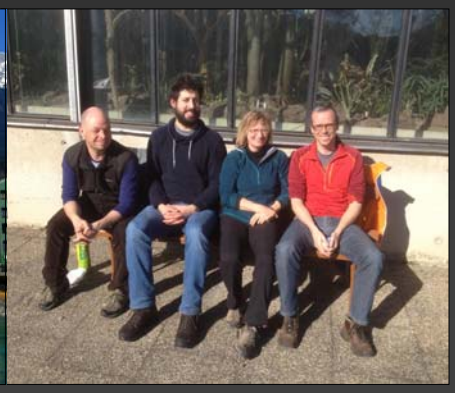
we look for



?

Optimise the Sensor Location

COST Optimise
Footprint Modelling Expert Workshop
Dept. of Ecology, Innsbruck University, Feb 2017



Flux Footprint Modelling

Flux footprint describes 'field of view' of EC system

Location and extent of a flux footprint depends on

- Height of measurement
- Surface properties
- Atmospheric flow characteristics (wind speed, wind direction, turbulence, ...)

⇨ variable in time!

Flux Footprint Estimates – Why?

- Describe main area of influence to EC measurements
  Support optimal placement of supplemental instruments / sensors (e.g. spectrometers)
- Flux time series interpretation
  Variability in flux introduced by shifts in field of view
  When does spectrometer probe same area as EC?
- Representativeness
  Mean composition of land cover that is probed
- Upscaling
  From plot measurement to local or regional scale

Flux Footprint Estimates

Footprint description

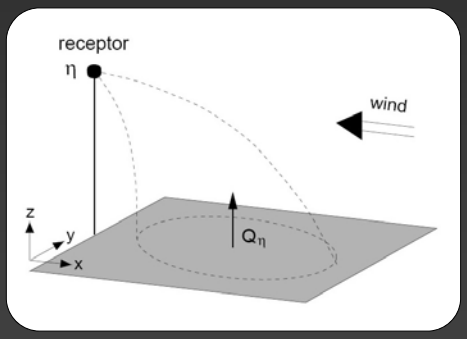
$$\eta(r) = \int_R Q_\eta(r + r')\, f(r, r')\, dr'$$

η: Measured value at r

$Q\eta$: Source emission rate at $r+r'$

R: Domain of integration

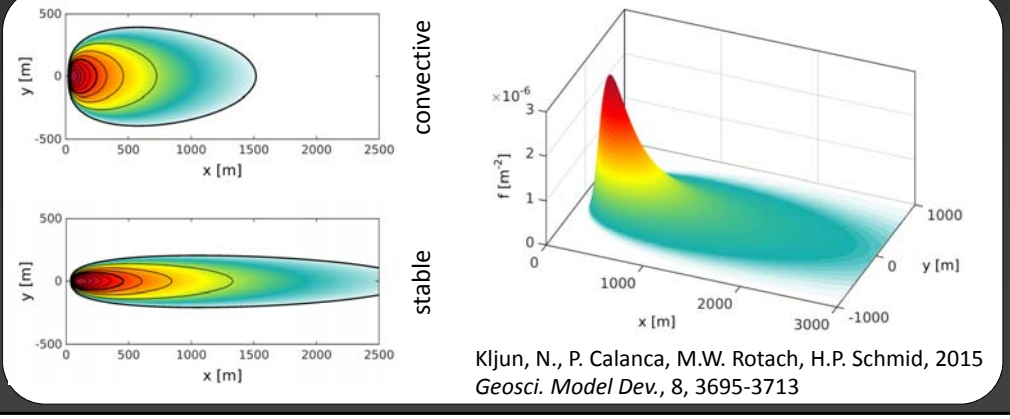
f: Transfer function (footprint function)



Flux Footprint Prediction FFP

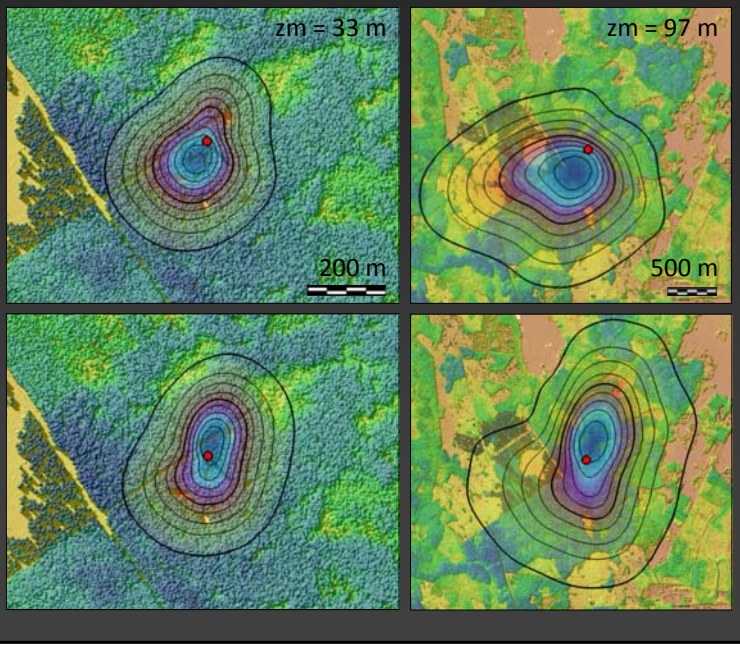
Valid for

- Convective to stable atmospheric conditions
- Measurement heights from close to the ground to high up in planetary boundary layer



Kljun, N., P. Calanca, M.W. Rotach, H.P. Schmid, 2015
Geosci. Model Dev., 8, 3695-3713

Example Footprint Climatology



Norunda
(ICOS Sweden)

May 2011

July 2011

Online Tool - Footprint Climatology

http://footprint.kljun.net

A simple two-dimensional parameterisation for Flux Footprint Prediction (FFP)

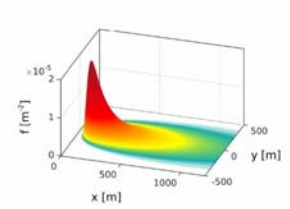
Home Online FFP 1D Online FFP 2D Downloads Contact

N. Kljun[1], P. Calanca[2], M. W. Rotach[3], and H. P. Schmid[4]

[1] Department of Geography, Swansea University, Swansea, United Kingdom
[2] Agroscope, Institute for Sustainability Sciences, Zurich, Switzerland
[3] Institute of Atmospheric and Cryospheric Sciences, Innsbruck University, Innsbruck, Austria
[4] KIT, Institute of Meteorology and Climate Research, Garmisch-Partenkirchen, Germany

www.geosci-model-dev.net/8/3695/2015/ doi:10.5194/gmd-8-3695-2015

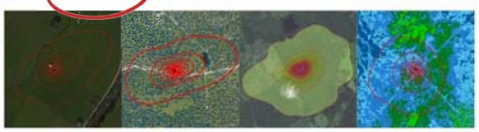
Citation: Kljun, N., Calanca, P., Rotach, M. W., and Schmid, H. P.: A simple two-dimensional parameterisation for Flux Footprint Prediction (FFP), Geosci. Model Dev., 8, 3695-3713, 2015.
BibTex EndNote



Online Tool - Footprint Climatology

Flux Footprint Prediction (FFP) online data processing

Home Register Sign in Contact



The FFPonline tool

FFPonline allows you to upload a time series of input data. For each time step of the input data, an FFP footprint is calculated. All footprints for the time series are aggregated to a footprint climatology. The tool also derives an unsupervised land cover classification for the footprint area and overlays the footprint climatology with the classification, providing you with a simple estimate of what land cover contributes most to the measured fluxes.

Please register or sign in to use the FFPonline tool. Information on input data requirements and formatting, as well as on the result files can be found here.

For details on the footprint parameterisation and its limitations see Kljun, N., P. Calanca, M.W. Rotach, H.P. Schmid, 2015: A simple two-dimensional parameterisation for Flux Footprint Prediction (FFP). Geosci. Model Dev., 8, 3695-3713. doi:10.5194/gmd-8-3695-2015.

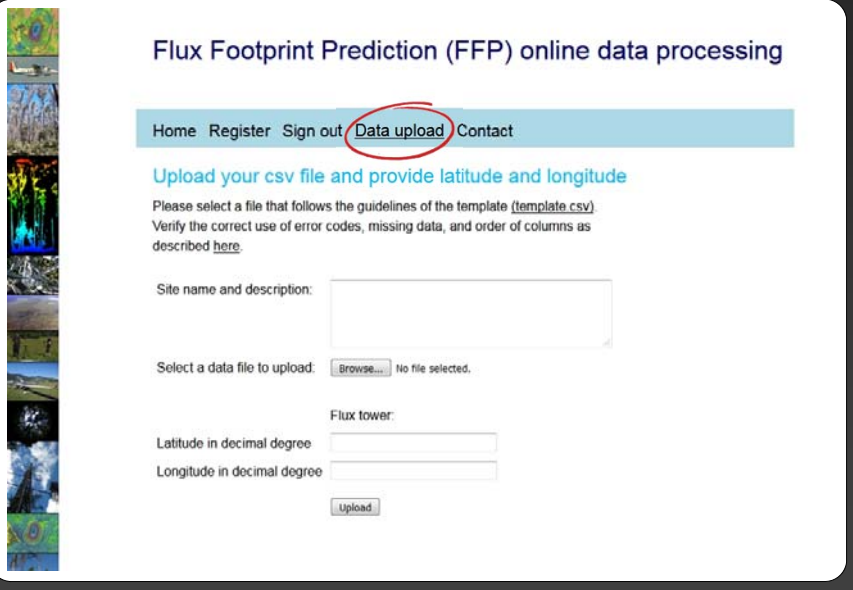
Please acknowledge the source of your footprint estimates by citing the above article. Thanks!
BibTex EndNote

For customised simulations, for example for using your own maps or to design your own figures, you can download the FFP code (Matlab, Python, R) at http://footprint.kljun.net.

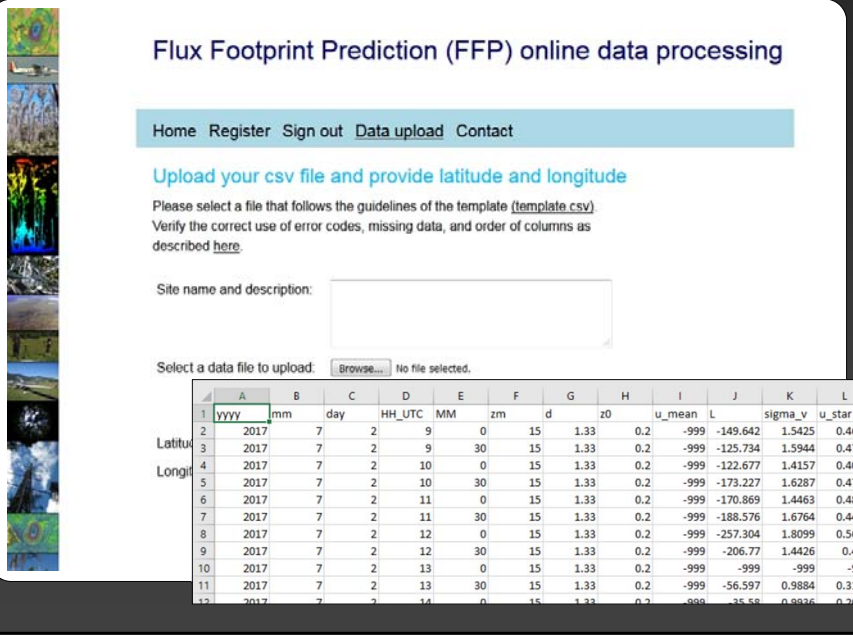
This webtool has been initiated by the COST action Optimise ES1309. COST is supported by the EU Framework Programme Horizon 2020.

Natascha Kljun, Claudio D'Onofrio, Tarek El-Madany, Enrico Tomelleri, Georg Wohlfahrt

Online Tool - Footprint Climatology



FFP Online Tool - Input



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	yyyy	mm	day	HH_UTC	MM	zm	d	z0	u_mean	L	sigma_v	u_star	wind_dir
2	2017	7	2	9	0	15	1.33	0.2	-999	-149.642	1.5425	0.4604	8.05
3	2017	7	2	9	30	15	1.33	0.2	-999	-125.734	1.5944	0.4774	19.96
4	2017	7	2	10	0	15	1.33	0.2	-999	-122.677	1.4157	0.4078	14.58
5	2017	7	2	10	30	15	1.33	0.2	-999	-173.227	1.6287	0.4737	22.56
6	2017	7	2	11	0	15	1.33	0.2	-999	-170.869	1.4463	0.4801	6.1
7	2017	7	2	11	30	15	1.33	0.2	-999	-188.576	1.6764	0.4497	14.13
8	2017	7	2	12	0	15	1.33	0.2	-999	-257.304	1.8099	0.5639	12.73
9	2017	7	2	12	30	15	1.33	0.2	-999	-206.77	1.4426	0.455	6.21
10	2017	7	2	13	0	15	1.33	0.2	-999	-999	-999	-999	-999
11	2017	7	2	13	30	15	1.33	0.2	-999	-56.597	0.9884	0.3153	95.18

FFP Online Tool - Input

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1															
2		yyyy	mm	day	HH_UTC	MM	zm	d	z0	u_mean	L	sigma_v	u_star	wind_dir	
3		2017	7	2	9	0	15	1.33	0.2	-999	-149.642	1.5425	0.4604	8.05	
4		2017	7	2	9	30	15	1.33	0.2	-999	-125.734	1.5944	0.4774	19.96	
5		2017	7	2	10	0	15	1.33	0.2	-999	-122.677	1.4157	0.4078	14.58	
6		2017													
7		2017													
8		2017													
9		2017													
10		2017													
11		2017													
12		2017													

2) FFP input

To calculate a footprint climatology based on FFP, the input parameters listed below are needed. Upload a time series of input data as csv-file. The first row is treated as header line. See FFPonline_template.csv for an example.

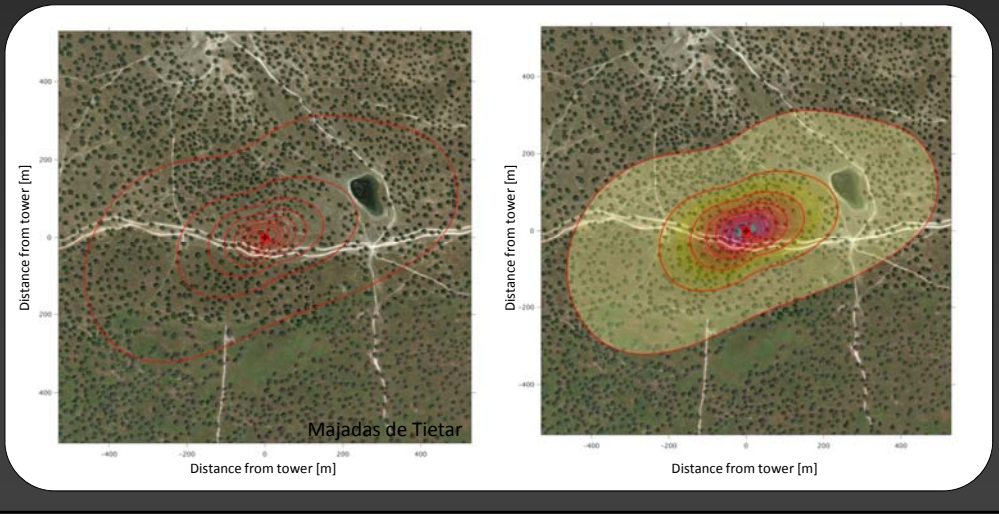
yyyy	= Year
mm	= Month [1-12]
day	= Day of month [1-31]
HH	= Hour [0-23] or [1-24] – has to be in UTC, NOT local time
MM	= Minutes, for example [0 30]
zm	= Measurement height above ground [m]
d	= Displacement height [m]
z0	= Roughness length [m] - enter [-999] if not known
u_mean	= Mean wind speed at zm [ms-1] - enter [-999] if not known
L	= Obukhov length [m]
sigma_v	= Standard deviation of lateral velocity fluctuations after rotation [ms^{-1}]
u_star	= Friction velocity [ms^{-1}]
wind_dir	= Wind direction in degrees (of 360) for rotation of the footprint

Input parameters available from EC data processing software

FFP Online Tool - Output

You will receive an email with a link to download:

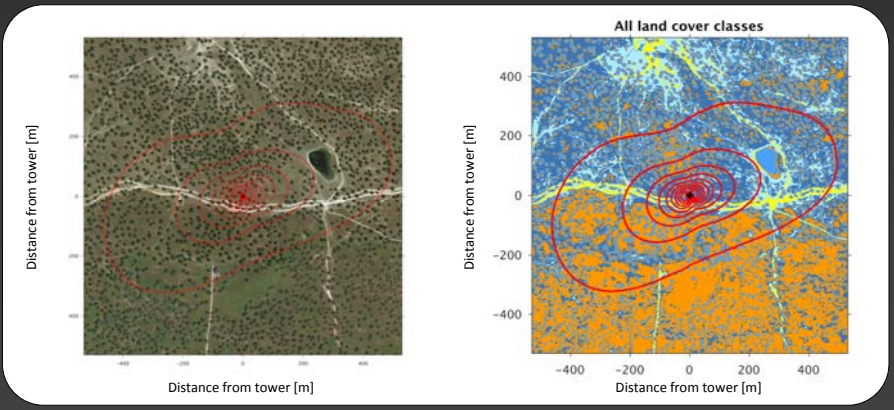
1) Bing or Google map images with footprint climatology



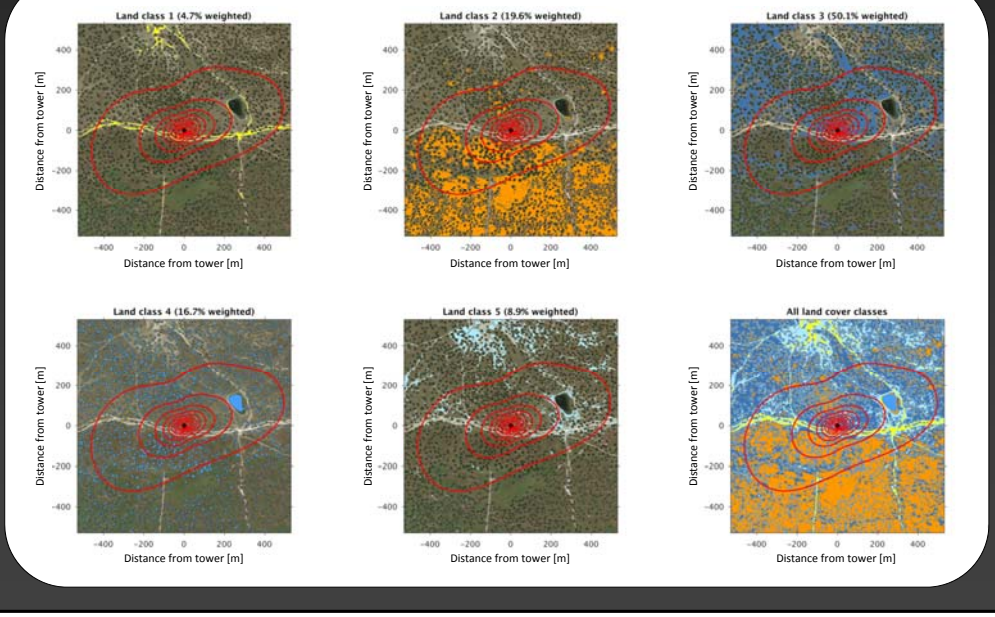
FFP Online Tool - Output

2) Land classification maps with footprint climatology

⇨ unsupervised land classification (kmeans) based on RGB maps (Bing or Google)



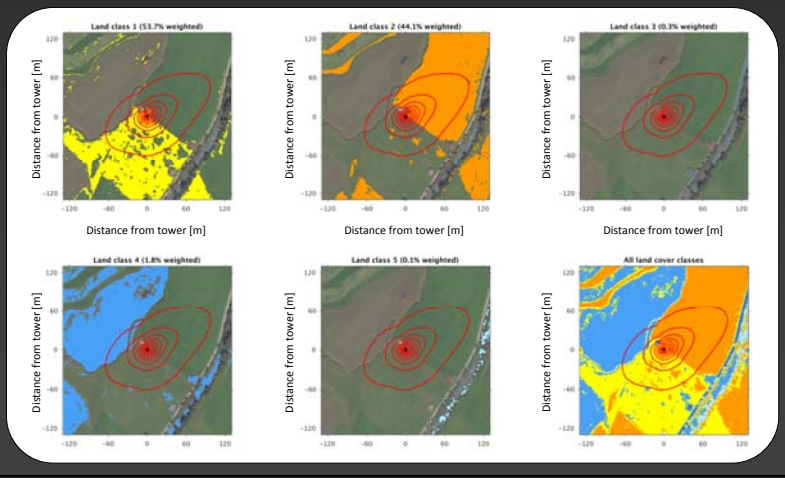
FFP Online Tool - Output



FFP Online Tool - Output

You will receive an email with a link to download:

3) Summary table with relative contribution of each land cover class to measured flux (footprint-weighted)



FFP Online Tool - Output

You will receive an email with a link to download:

3) Summary table with relative contribution of each land cover class to measured flux (footprint-weighted)

Area	Class=1 footprint-weighted	Class=2 footprint-weighted	Class=3 footprint-weighted	Class=4 footprint-weighted	Class=5 footprint-weighted
10%	0.927	0.073	0	0	0
20%	0.717	0.283	0	0	0
30%	0.687	0.313	0	0	0
40%	0.679	0.321	0	0	0
50%	0.648	0.352	0	0	0
60%	0.619	0.378	0	0.003	0
70%	0.592	0.398	0.004	0.006	0
80%	0.567	0.421	0.004	0.009	0
90%	0.537	0.441	0.003	0.018	0.001
Domain	0.526	0.438	0.004	0.03	0.003

FFP Online Tool - Output

You will receive an email with a link to download:

4) Footprint matrix to overlay with your own map

1752e-06	7.1213297e-06	7.6260347e-06	8.1768707e-06	8.7790214e-06	9.4383661e-06	1.016
6311e-05	1.1831238e-05	1.2796348e-05	1.3863107e-05	1.5044729e-05	1.6356493e-05	1.781
4223e-05	2.1264889e-05	2.3306343e-05	2.5601794e-05	2.8190475e-05	3.1118930e-05	3.444
7917e-05	4.2554691e-05	4.7519508e-05	5.3239804e-05	5.9859192e-05	6.7554209e-05	7.654
4213e-05	9.9542680e-05	1.1430943e-04	1.3194526e-04	1.5318057e-04	1.7897986e-04	2.106
6810e-04	2.9789377e-04	3.5779313e-04	4.3370659e-04	5.3175567e-04	6.6078159e-04	8.331
2443e-03	1.3449496e-03	1.7344466e-03	2.2885501e-03	3.0150328e-03	3.7839940e-03	4.334
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2888e-03	1.2480090e-03	1.0361628e-03	8.5983889e-04	7.1606001e-04	5.9947294e-04	5.047
9529e-04	3.6459412e-04	3.1282059e-04	2.6994891e-04	2.3419446e-04	2.0419633e-04	1.788
2818e-04	1.3913424e-04	1.2346522e-04	1.0998369e-04	9.8335167e-05	8.8230196e-05	7.943
7468e-05	6.4986360e-05	5.9038835e-05	5.3779625e-05	4.9112700e-05	4.4957925e-05	4.124
6175e-05	3.4943873e-05	3.2259658e-05	2.9837875e-05	2.7647769e-05	2.5662733e-05	2.385
8532e-05	2.0721766e-05	1.9354067e-05	1.8102008e-05	1.6953788e-05	1.5899009e-05	1.492
4082e-05	1.3208580e-05	1.2445558e-05	1.1739290e-05	1.1084661e-05	1.0477097e-05	9.912
1642e-06	8.8977930e-06	8.4413903e-06	8.0152573e-06	7.6169532e-06	7.2442677e-06	6.895
9161e-06	6.2607718e-06	5.9722538e-06	5.7009854e-06	5.4457092e-06	5.2052754e-06	4.978
8108e-06	4.5629290e-06	4.3721713e-06	4.1917891e-06	4.0210925e-06	3.8594460e-06	3.706
0009e-06	3.4231592e-06	3.2922737e-06	3.1679149e-06	3.0496842e-06	2.9372117e-06	2.830
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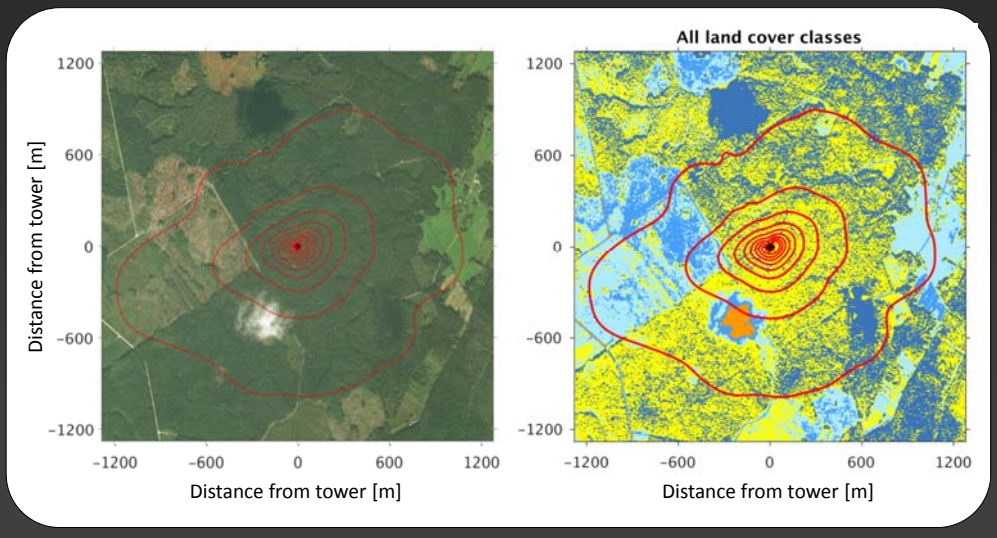
4302e-06	1.6482672e-06	1.5982026e-06	1.5501326e-06	1.5039595e-06	1.4595912e-06	1.416
9269e-06	1.3364719e-06	1.2985028e-06	1.2619510e-06	1.2267511e-06	1.1928418e-06	1.160
6645e-06	1.0982893e-06	1.0689894e-06	1.0407180e-06	1.0134305e-06	9.8708485e-07	9.616
6054e-07	9.1330773e-07	8.9034809e-07	8.6814895e-07	8.4667925e-07	8.2590941e-07	8.058

FFP Online Tool - Output

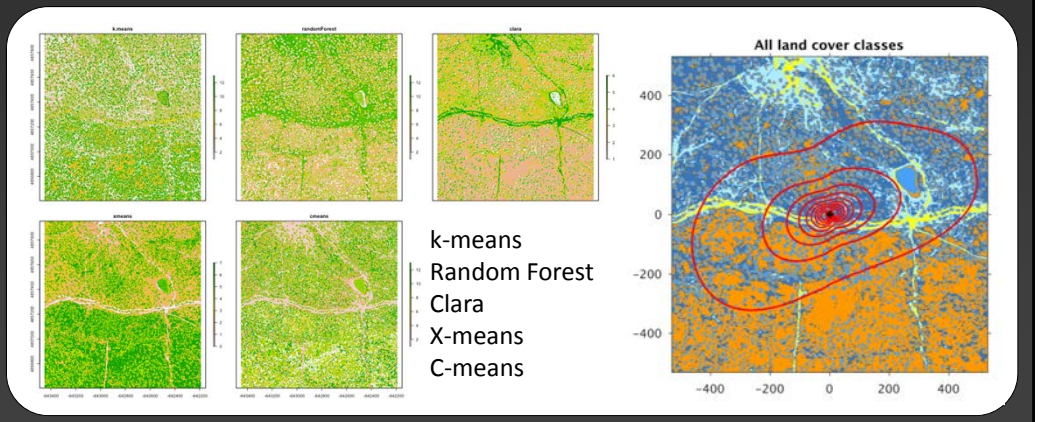
Unsupervised classification in some cases problematic...



FFP Online Tool - Outlook

In progress:

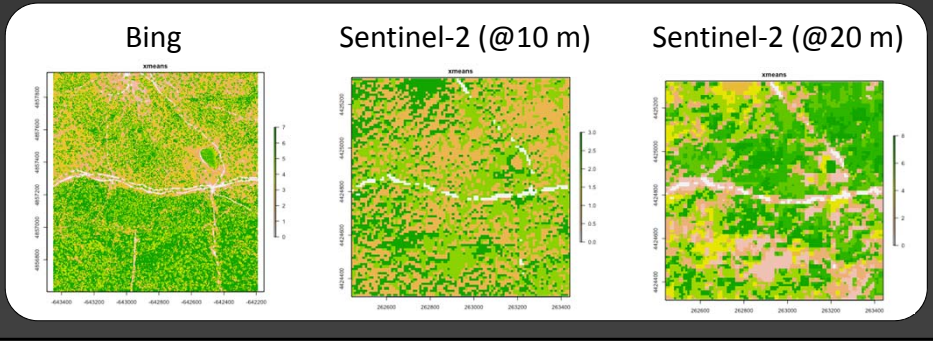
- Combination of approaches for land cover classification



FFP Online Tool - Outlook

In progress:

- Combination of approaches for land cover classification
- Application of above using RGB imagery and Sentinel-2 data

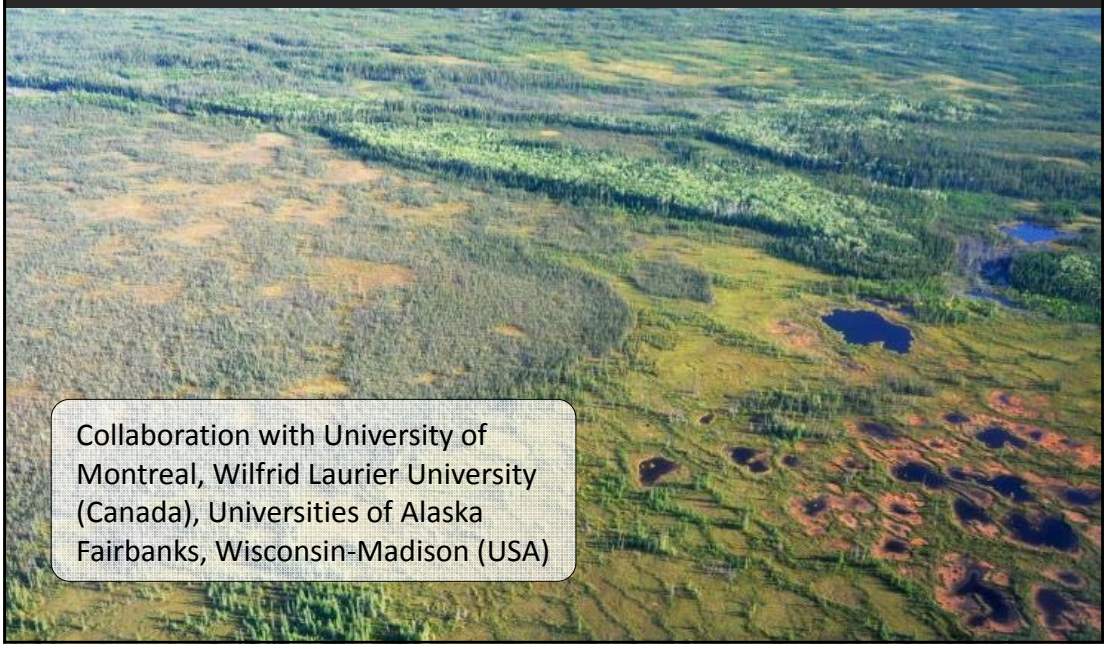


FFP Online Tool - Outlook

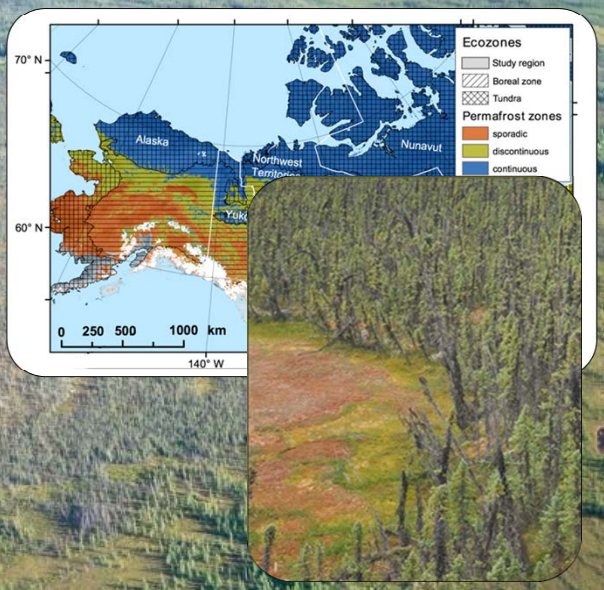
In progress:

- Combination of approaches for land cover classification
- Application of above using RGB imagery and Sentinel-2 data
- Selection of imagery depending on time stamp of your input data

Example Application FFP

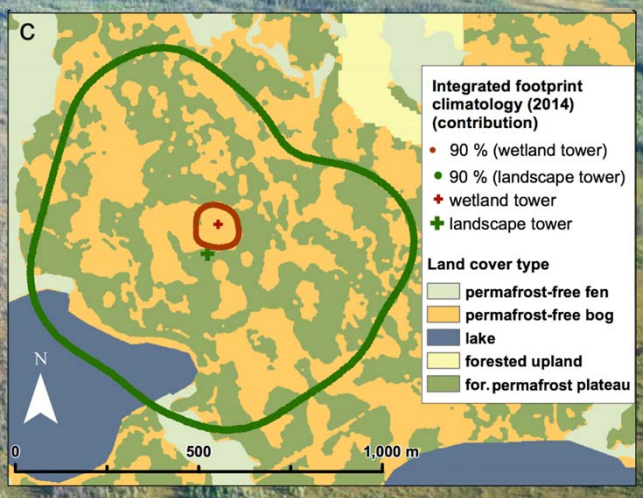


Scotty Creek, Northern Canada

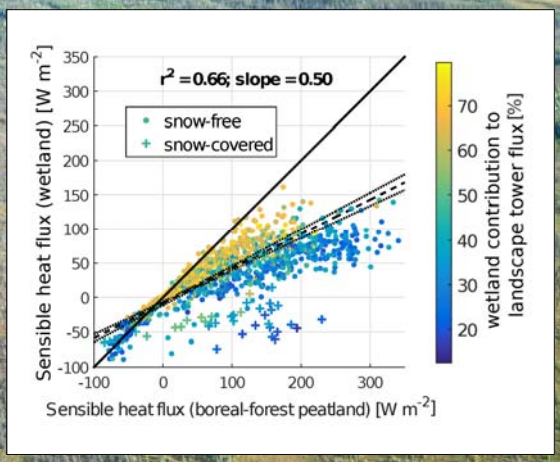


- Permafrost thawing
- Expansion of permafrost-free wetlands
- Declining tree cover, i.e. partial loss of boreal forest

Example Application FFP



Example Application FFP



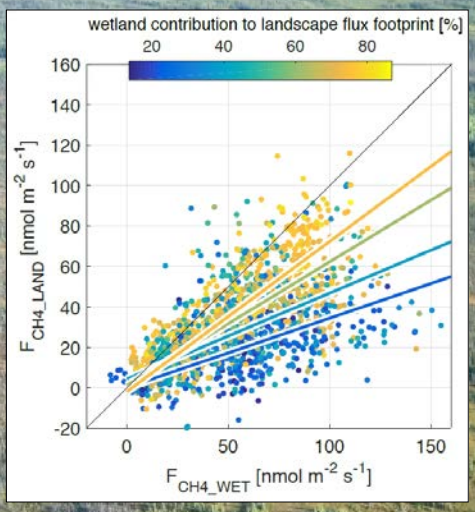
Large decrease in turbulent sensible heat flux

⇩

Regional cooling effect due to boreal forest loss

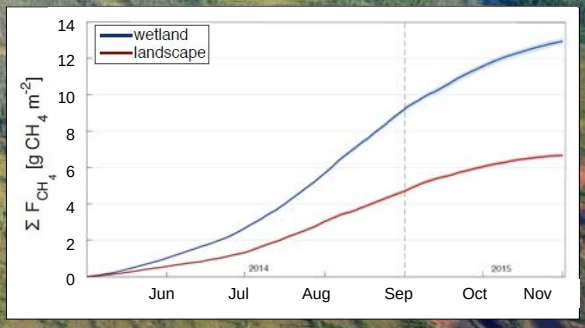
Helbig et al. 2016
GCB 22, 4048-4066

Methane Release Due to Permafrost Thawing



Wetland contributes strongly to landscape CH_4 fluxes

Helbig et al. 2017, GCB 23, 2413-2427



Take-Home Message

- Online tool 2D flux footprint parameterisation FFP

✓ Simple to apply
✓ Fast, valid for most atmospheric conditions
✓ Provides information for best suitable sensor location
✓ Supports interpretation of measurements

- Online Tool access and FFP Code available: http://footprint.kljun.net
- Kljun et al. 2015, Geosci. Model Dev. 8, 3695–3713

Take-Home Message

- Online tool 2D flux footprint parameterisation FFP

✓ Simple to apply
✓ Fast, valid for most atmospheric conditions
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