26 openair back trajectory functions

Back trajectories are extremely useful in air pollution and can provide important information on air mass origins. Despite the clear usefulness of back trajectories, their use tends to be restricted to the research community. Back trajectories are used for many purposes from understanding the origins of air masses over a few days to undertaking longer term analyses. They are often used to filter air mass origins to allow for more refined analyses of air pollution — for example trends in concentration by air mass origin. They are often also combined with more sophisticated analyses such as cluster analysis to help group similar type of air mass by origin.

Perhaps one of the reasons why back trajectory analysis is not carried out more often is that it can be time consuming to do. This is particularly so if one wants to consider several years at several sites. It can also be difficult to access back trajectory data. In an attempt to overcome some of these issues and expand the possibilities for data analysis, **openair** makes several functions available to access and analyse pre-calculated back trajectories.

Currently these functions allow for the import of pre-calculated back trajectories are several pre-define locations and some trajectory plotting functions. In time all of these functions will be developed to allow more sophisticated analyses to be undertaken. Also it should be recognised that these functions are in their early stages of development and will may continue to change and be refined.

This `importTraj` function imports pre-calculated back trajectories using the HYSPLIT trajectory model (Hybrid Single Particle Lagrangian Integrated Trajectory Model `http://ready.arl.noaa.gov/HYSPLIT.php`). Trajectories are run at 3-hour intervals and stored in yearly files (see below). The trajectories are started at ground-level (10m) and propagated backwards in time. The data are stored on web-servers at King's College London in a similar way to `importKCL`, which makes it very easy to import pre-processed trajectory data for a range of locations and years. **Note — the back trajectories have been pre-calculated for specific locations and stored as .RData objects. Users should contact David Carslaw to request the addition of other locations.** So far only a few receptors are available to users but in time the number will increase. It should be feasible for example to run back trajectories for the past 20 years at all the EMEP sites in Europe.[15]

Users may for various reasons wish to run HYSPLIT themselves e.g. for different starting heights, longer periods or more locations. Code and instructions have been provided in Appendix D for users wishing to do this. Users can also use different means of calculating back trajectories e.g. ECMWF and plot them in **openair** provided a few basic fields are present: `date` (POSIXct), `lat` (decimal latitude), `lon` (decimal longitude) and `hour.inc` the hour offset from the arrival date (i.e. from zero decreasing to the length of the back trajectories). See `?importTraj` for more details.

These trajectories have been calculated using the Global NOAA-NCEP/NCAR reanalysis data archives. The global data are on a latitude-longitude grid (2.5 degree). Note that there are many different meteorological data sets that can be used to run HYSPLIT e.g. including ECMWF data. However, in order to make it practicable to run and store trajectories for many years and sites, the NOAA-NCEP/NCAR reanalysis data is most useful. In addition, these archives are available for use widely, which is not the case for many other data sets e.g. ECMWF. HYSPLIT calculated trajectories based on archive data may be distributed without permission (see `http://ready.arl.noaa.gov/HYSPLIT_agreement.php`). For those wanting, for example, to consider higher resolution meteorological data sets it may be better to run the

[15] It takes about 15 hours to run 20 years of 96-hour back trajectories at 3-hour intervals.

OPENAIR MANUAL

http://www.openair-project.org/PDF/OpenAir_Manual.pdf df_bcn_cont.txt - Microsoft Excel

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1		date	receptor	year	month	day	hour	hour.inc	lat	lon	height	pressure	date2	VNi	Mineral	Marine	SSA	Industrial	Organic	RT	NSA	PM
2	1	01/01/2010 0:00	1	2010	1	1	0	0	41.4	2.15	65	956.6	01/01/2010 0:00									
962	961	01/01/2010 21:00	1	2009	12	28	4	-113	63.968	-13.358	42.5	993.6	28/12/2009 4:00									
963	962	01/01/2010 21:00	1	2009	12	28	3	-114	64.216	-13.116	36.6	994.9	28/12/2009 3:00									
964	963	01/01/2010 21:00	1	2009	12	28	2	-115	64.475	-12.905	31	996.2	28/12/2009 2:00									
965	964	01/01/2010 21:00	1	2009	12	28	1	-116	64.746	-12.721	25.8	997.3	28/12/2009 1:00									
966	965	01/01/2010 21:00	1	2009	12	28	0	-117	65.031	-12.554	21.2	998.5	28/12/2009 0:00									
967	966	01/01/2010 21:00	1	2009	12	27	23	-118	65.326	-12.39	17	1000.9	27/12/2009 23:00									
968	967	01/01/2010 21:00	1	2009	12	27	22	-119	65.632	-12.223	13.2	1003.4	27/12/2009 22:00									
969	968	01/01/2010 21:00	1	2009	12	27	21	-120	65.949	-12.065	9.8	1005.7	27/12/2009 21:00									
970	969	02/01/2010 0:00	1	2009	12	29	4	-92	61.829	-10.534	666.6	933.1	29/12/2009 4:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
971	970	02/01/2010 0:00	1	2010	1	1	7	-17	44.015	-2.962	465.3	908.5	01/01/2010 7:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
972	971	02/01/2010 0:00	1	2009	12	29	19	-77	58.603	-12.664	149.7	993.5	29/12/2009 19:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
973	972	02/01/2010 0:00	1	2010	1	1	0	-24	44.5	-4.994	401.9	932.3	01/01/2010 0:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
974	973	02/01/2010 0:00	1	2010	1	1	13	-11	43.36	-0.948	432.3	895.9	01/01/2010 13:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
975	974	02/01/2010 0:00	1	2009	12	29	21	-75	58.041	-13.41	93.4	999.9	29/12/2009 21:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
976	975	02/01/2010 0:00	1	2010	1	1	9	-15	43.77	-2.299	454.4	903.3	01/01/2010 9:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
977	976	02/01/2010 0:00	1	2009	12	30	19	-53	47.745	-15.782	31.7	993.7	30/12/2009 19:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
978	977	02/01/2010 0:00	1	2009	12	31	11	-37	44.687	-9.321	81.4	974.5	31/12/2009 11:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
979	978	02/01/2010 0:00	1	2010	1	1	11	-13	43.551	-1.609	441	899.6	01/01/2010 11:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
980	979	02/01/2010 0:00	1	2009	12	28	0	-120	69.11	-14.326	1241.2	859	28/12/2009 0:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
981	980	02/01/2010 0:00	1	2009	12	30	18	-54	48.271	-16.157	32.5	993.7	30/12/2009 18:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
982	981	02/01/2010 0:00	1	2010	1	1	6	-18	44.135	-3.255	464.2	911.9	01/01/2010 6:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
983	982	02/01/2010 0:00	1	2010	1	1	3	-21	44.4	-4.066	440.1	923.3	01/01/2010 3:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
984	983	02/01/2010 0:00	1	2010	1	1	1	-23	44.483	-4.66	415.5	929.5	01/01/2010 1:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
985	984	02/01/2010 0:00	1	2010	1	1	16	-8	43.04	-0.071	403.9	888.9	01/01/2010 16:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
986	985	02/01/2010 0:00	1	2010	1	1	10	-14	43.656	-1.952	447.1	901.4	01/01/2010 10:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
987	986	02/01/2010 0:00	1	2009	12	31	8	-40	44.927	-10.243	63.9	979.5	31/12/2009 8:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
988	987	02/01/2010 0:00	1	2009	12	30	17	-55	48.839	-16.483	32.8	993.4	30/12/2009 17:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
989	988	02/01/2010 0:00	1	2009	12	29	13	-83	59.965	-10.978	337.1	973.6	29/12/2009 13:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
990	989	02/01/2010 0:00	1	2009	12	31	23	-25	44.505	-5.329	383.5	933.5	31/12/2009 23:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
991	990	02/01/2010 0:00	1	2009	12	29	7	-89	61.107	-10.365	570.6	945.4	29/12/2009 7:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
992	991	02/01/2010 0:00	1	2010	1	1	2	-22	44.451	-4.352	428.3	926.6	01/01/2010 2:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
993	992	02/01/2010 0:00	1	2009	12	30	11	-61	52.512	-17.358	0	1000.1	30/12/2009 11:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
994	993	02/01/2010 0:00	1	2009	12	30	9	-63	53.583	-17.171	0	1003.2	30/12/2009 9:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
995	994	02/01/2010 0:00	1	2009	12	31	7	-41	45.029	-10.577	58.3	981.4	31/12/2009 7:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
996	995	02/01/2010 0:00	1	2009	12	28	4	-116	68.406	-13.327	1164.5	864.8	28/12/2009 4:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
997	996	02/01/2010 0:00	1	2009	12	30	15	-57	50.07	-16.998	26.7	994.5	30/12/2009 15:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
998	997	02/01/2010 0:00	1	2010	1	1	12	-12	43.454	-1.273	436.7	897.6	01/01/2010 12:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
999	998	02/01/2010 0:00	1	2010	1	1	18	-6	42.59	0.518	299.8	906.8	01/01/2010 18:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1000	999	02/01/2010 0:00	1	2009	12	30	7	-65	54.529	-16.732	0	1005.4	30/12/2009 7:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1001	1000	02/01/2010 0:00	1	2010	1	1	17	-7	42.855	0.215	366.6	900.1	01/01/2010 17:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1002	1001	02/01/2010 0:00	1	2010	1	1	4	-20	44.331	-3.793	450.5	919.8	01/01/2010 4:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1003	1002	02/01/2010 0:00	1	2009	12	29	16	-80	59.379	-11.694	232.7	984.4	29/12/2009 16:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1004	1003	02/01/2010 0:00	1	2009	12	29	17	-79	59.141	-11.995	203.4	988.1	29/12/2009 17:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1005	1004	02/01/2010 0:00	1	2009	12	29	20	-76	58.325	-13.032	121.8	996.4	29/12/2009 20:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1006	1005	02/01/2010 0:00	1	2009	12	30	8	-64	54.071	-16.974	0	1004.4	30/12/2009 8:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208
1007	1006	02/01/2010 0:00	1	2009	12	30	10	-62	53.064	-17.305	0	1001.8	30/12/2009 10:00	0.98467499	0.59328897	5.7603112	0.71496011	0.01414154	3.66640241	1.2192967	0.98887232	13.487208

df_bcn_cont

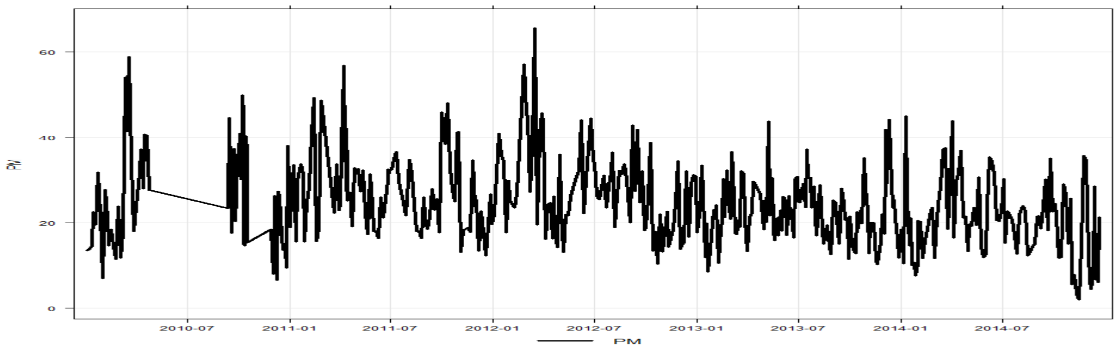
Upload OPENAIR and MAPS packages

Getting data in OPENAIR:

```
mydata=read.delim("clipboard",header=TRUE)
```

Plotting backtrajectories:

```
trajPlot(mydata)
trajPlot(selectByDate(mydata, start = "01/2/2012", end ="28/02/2012"))
trajPlot(selectByDate(mydata, start = "01/2/2012", end ="28/02/2012"),poll="PM",lwd=5)
trajPlot(selectByDate(mydata, start = "01/3/2013", end ="30/03/2013"),poll="PM",lwd=5)
```




```
trajPlot(selectByDate(mydata, start = "01/3/2013", end ="30/03/2013"),poll="SSA",lwd=5)
trajPlot(selectByDate(mydata, start = "01/3/2013", end ="30/03/2013"),poll="VNi",lwd=5)
trajPlot(selectByDate(mydata, start = "01/3/2013", end ="30/03/2013"),poll="Mineral",lwd=5)
```

Over the course of a year representing trajectories as lines or points results in a lot of over-plotting. Therefore it is useful to grid the trajectory data and calculate various statistics by considering latitude-longitude intervals. The first analysis considers the number of unique trajectories in a particular grid square. This is achieved by using the trajLevel function and setting the statistic option to “frequency”.

TrajLevel function:

```
trajLevel(selectByDate(mydata, start = "01/1/2013", end ="31/12/2013"),statistic="frequency")
trajLevel(selectByDate(mydata, start = "01/2/2013", end ="28/2/2013"),statistic="frequency")
```

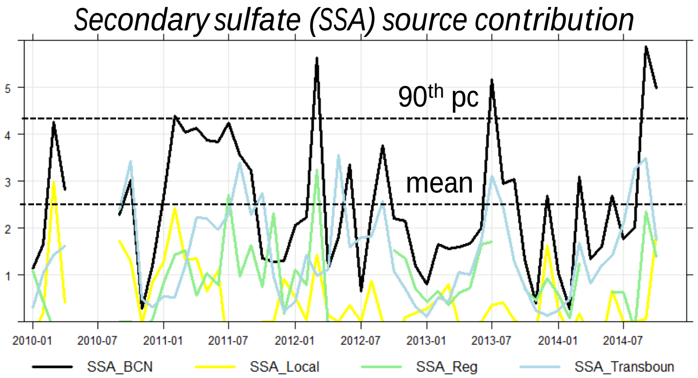
Frequency of back trajectory crossings for the BCN data. In this case it highlights that most trajectory origins are from the N and SE for 2013.

Back trajectories offer the possibility to undertake receptor modelling to identify the location of major emission sources. When many back trajectories (over months to years) are analysed in specific ways they begin to show the geographic origin most associated with elevated concentrations.
In particular, there is often interest in the origin of high concentrations for different pollutants. For example, compared with data over a whole year, how do the frequencies of occurrence differ?

```
trajLevel(mydata, pollutant = "SSA", statistic = "difference", col = c("skyblue", "white", "tomato"), min.bin = 3, border = NA)
```

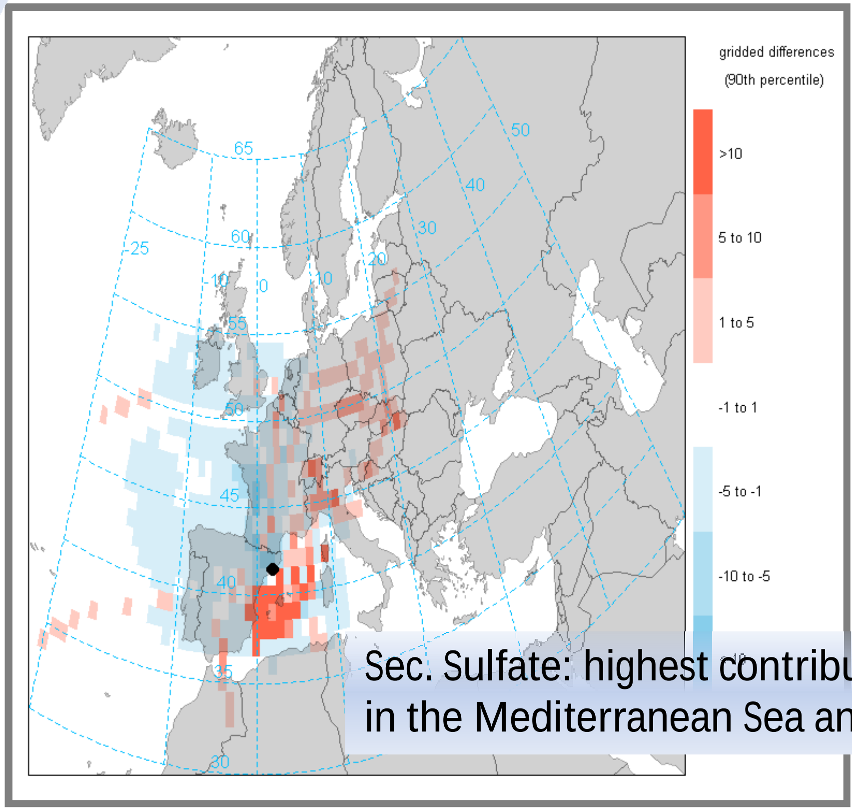
5-days back

PMF source contributions
+
Backtrajectory analysis



SSA Barcelona (SPAIN)

The Figure shows that compared with the whole year, high SSA concentrations (>90th percentile) are more prevalent when the trajectories originate from the Mediterranean Basin and from East EU, which is seen by the positive values in the plot.

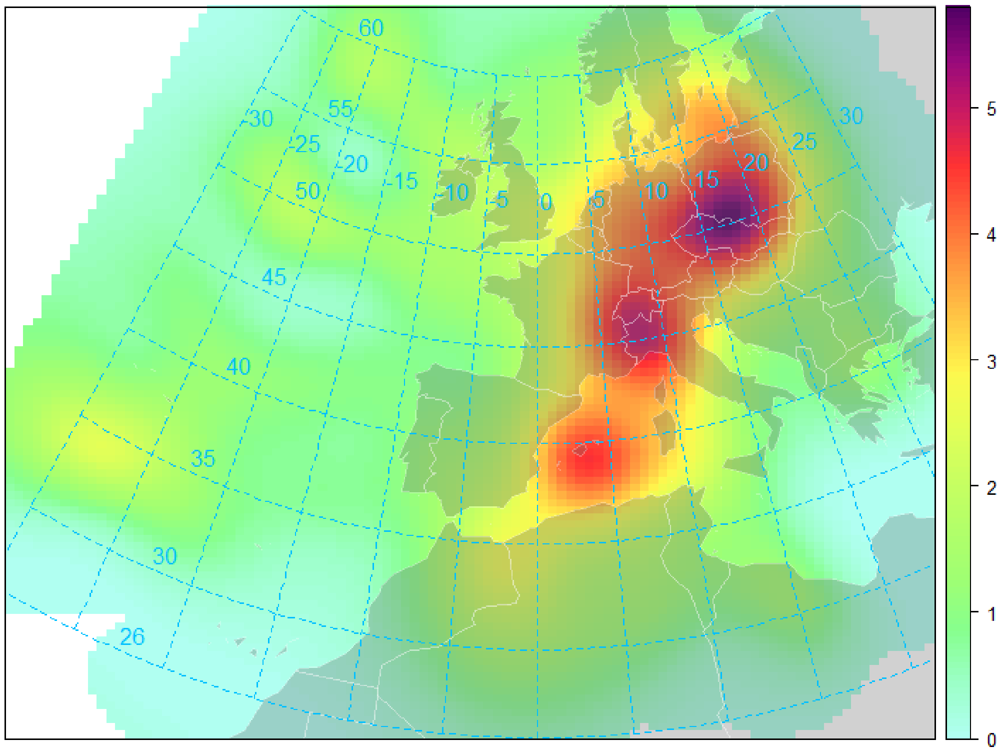


Sec. Sulfate: highest contributions from vessel traffic in the Mediterranean Sea and Central/eastern EU

Concentration Weighted Trajectory (CWT)

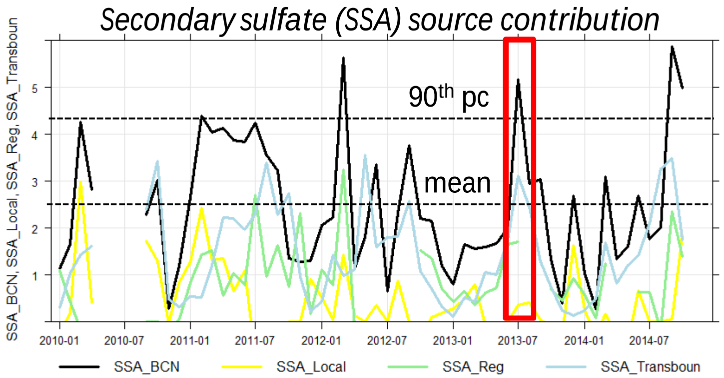
Seibert et al. (1994) computed concentration fields to identify source areas of pollutants. This approach is sometimes referred to as the CWT or CF (concentration field). For each grid cell, the mean (CWT) or logarithmic mean (used in the Residence Time Weighted Concentration (RTWC) method) concentration of a pollutant species is calculated (check OPENAIR manual for details).

```
trajLevel(subset(mydata, lat > 20 & lat < 60 & lon >-30 & lon <30), pollutant ="SSA", statistic = "cwt",
smooth = TRUE, col = "increment")
```



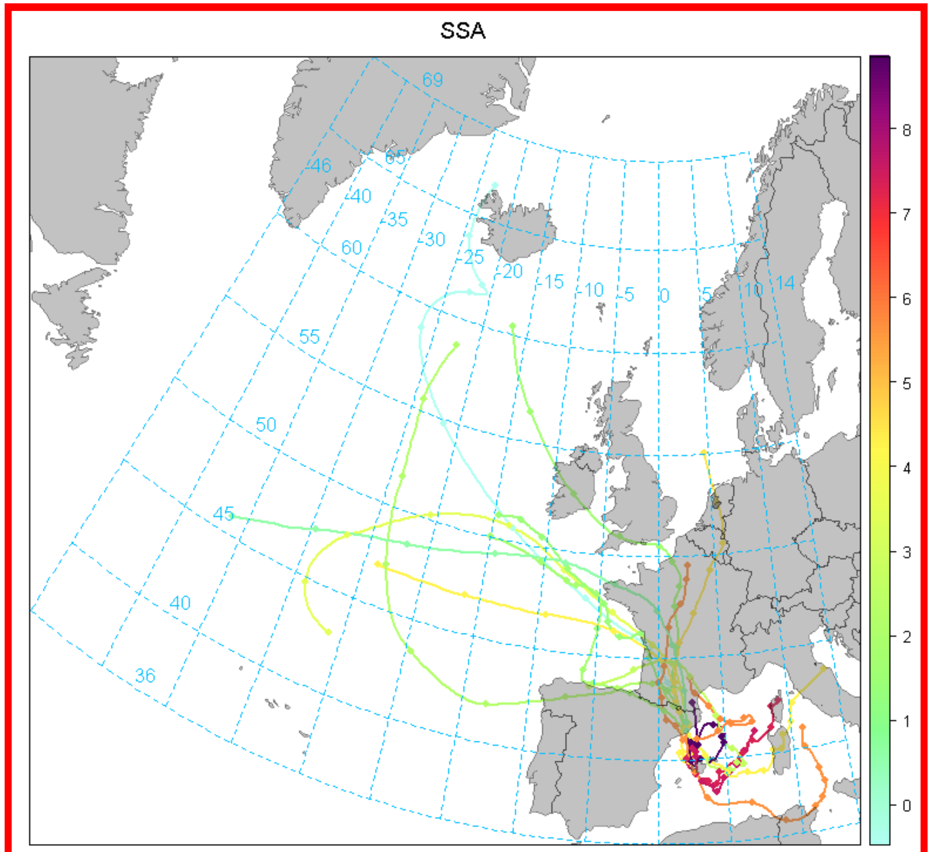
5-days back

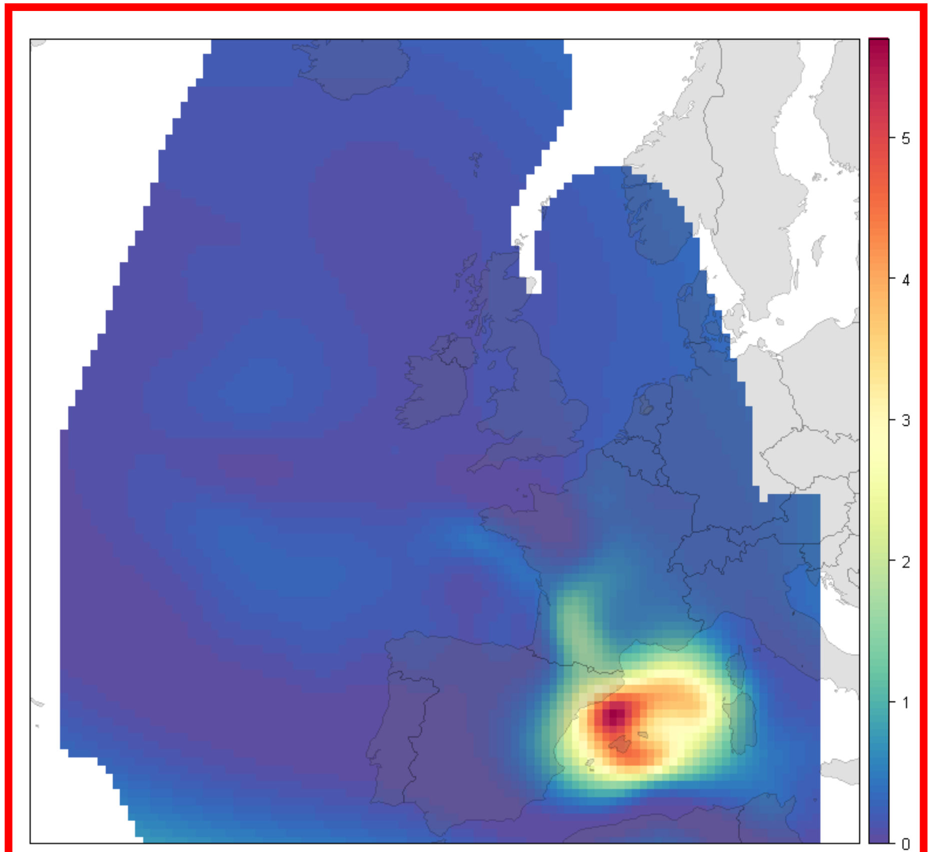
trajLevel(subset(mydata, lat > 20 & lat < 60 & lon >-30 & lon <30,start="25/06/2013",end="12/08/2013"), pollutant ="SSA", statistic = "cwt", smooth = TRUE, col = "increment")



SSA Barcelona (SPAIN)

25/06/2013-12/08/2013





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