JERICO NEXT Malta Summer School 2018
EMODnet HF Radar Practical Session 5

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Research Group
University of Malta

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Background Information

Living on an island often gives us the naive perception that the surrounding capacity of the sea disperses and quickly washes away whatever we throw into it. The sea is indeed a medium in continuous movement, but patterns of motion constituting the sea currents greatly depend on meteorological and hydrological conditions and are in permanent evolution often driven by remote conditions. How much do we know about the circulation patterns of the sea in the area of the Maltese Islands? Do the general sea conditions really privilege us from the threat of oil spills originating away from our shores? Can we exploit technology to offer protection and response against marine hazards that can put at risk our essential economic assets? Which marine data is essential to local responsible entities in meeting such emergencies, and how can they be assisted to make timely informed decisions on the spot and whenever required?

Such questions are addressed by the CALYPSO HF Radar Network. Through the CALYPSO and the CALYPSO FollowOn projects, a permanent and fully operational system for the real-time measurement of sea surface currents and waves in the strip of sea between Malta and Sicily was set up. On the national level, this served to deliver another building block for the acquisition of essential routine marine data at the service of a number of stakeholders and local users. Currently, the radar network is composed of four radars at Ta' Sopu (Gozo), Ta' Barkat (Malta), Pozzallo Harbour (Sicily), and Marina de Ragusa (Sicily). The network was partly financed by the EU under the Operational Programme Italia-Malta 2007-2013.

KAPTAN, the Maltese word for 'Captain', is bringing this data on personal smartphones, making access to data easier and more direct, based on marine and weather prediction services, with higher resolution and local data. Just a few clicks on a phone app leads users to a suite of sea and weather data in the form of interactive spatial maps providing instantaneous user friendly and user defined access to prevailing conditions at sea as well as short term past and forecast information. Besides fishermen and sailing enthusiasts, KAPTAN also appeals to divers, surfers, beach tourists, and coastal users in general. The phone app can be downloaded for free for both Android and iOS devices. The same services are also available online at the project website.

The ongoing CALYPSO SOUTH project focuses on extending the HF radar network coverage to the western part of the Malta-Sicily Channel as well as to the southern approaches of the Maltese archipelago. This will be achieved through the installation of three new radars which are to be installed in Ghar Lapsi

(Malta), Ta' Cenc (Gozo), and Licata (Sicily). The enhanced network, which is to be in operation by the end of 2019, will allow for the development of new monitoring and forecasting tools and will deliver tailored operational downstream services to assist national responsible entities in their maritime security, rescue, and emergency response commitments. Funding is being provided through the Interreg VA Italia-Malta programme 2014-2020.

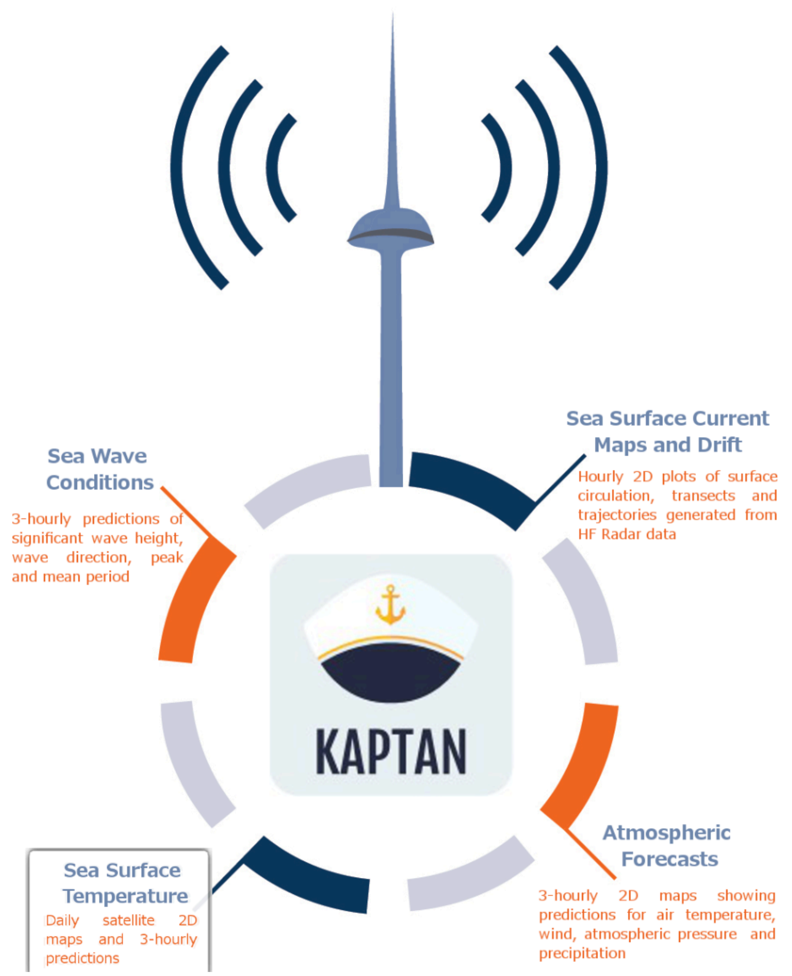


Figure 1: Services on CALYPSO Kaptan

Data Access

The Calypso Professional Data Interface consists of three main components, namely:

- The Data QuickView section;
- The Data Daily Download section; and
- The Data Aggregated Download section.

The Data QuickView section allows the viewing and downloading of data on an hourly basis for the entire domain. The user selects the date of interest and gets presented with set of images of the currents for the selected date-time. The user is allowed to download the data (as NetCDF or Ascii Columns file) for any specific hour. Apart from all this, the user may also view an animation of the currents for the selected day.

The Data Daily Download section presents the data for download for any month selected by the user. The data is aggregated on a daily basis. Hourly NetCDF files are concatenated together to create the daily files, whilst the Ascii files are aggregated as daily RAR archives. After the user selects the month of interest, the system shows the list of days for which there is data available. The data for each day may be downloaded in any format – i.e. NetCDF, Ascii Columns and Ascii Matrix Files.

The Data Aggregated Download section allows the aggregation and download of data over a range of days. The user selects the start date and the end date of the period of interest, and the desired data form (NetCDF, Ascii Columns or Ascii Matrix Files). The system performs the aggregation of data files between the start date and the end date provided that this period does not exceed 100 days. Once the aggregation is completed, the system outputs a link to the resulting aggregated file, and also informs the user of the days for which data is included in the aggregated file.

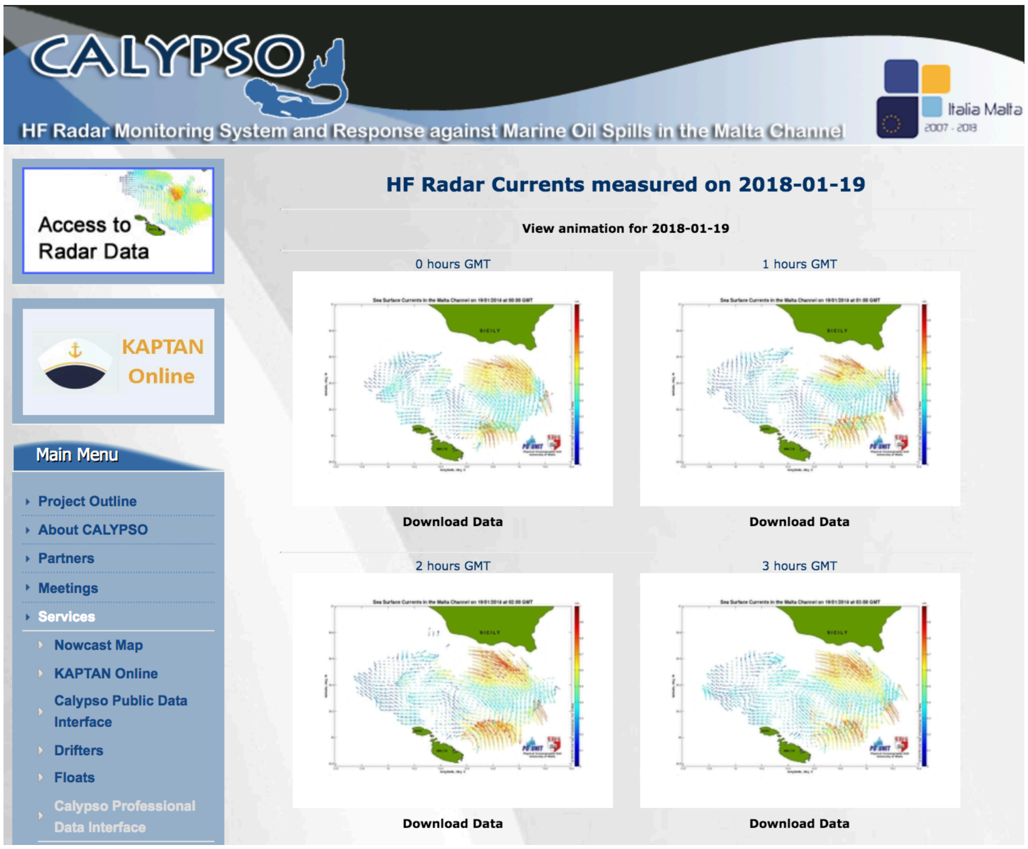


Figure 2: CALYPSO Professional Data Interface

Data Format

The Calypso HF-Radar Professional Data Interface disseminates real time currents data in three different formats.

NetCDF Files – these are binary files that contain all the currents data collected by the Calypso HF-Radar Network. This includes: Time, Longitude, Latitude, Eastward (U) Water Velocity, Northward (V) Water Velocity, Standard Deviation of the Eastward (U) Water Velocity, Standard Deviation of the Northward (V) Water Velocity, and the Covariance. NetCDF files may be read by various readers (such as ncdump and panoply). More information about the NetCDF format may be found on:
http://www.unidata.ucar.edu/software/netcdf/

ASCII Column Files – these are ASCII text files that contain 4 columns, namely: Longitude (in degrees East), Latitude (in degrees North), Current Magnitude (in m/s), and Current Direction (in degrees from North). Data points for which there is no data are omitted from these files. These files may be read in any text editor, or standard spreadsheet software (such as MS Excel and/or LibreOffice Calc).

ASCII Matrix Files – these are tab-seperated ASCII files, where the Eastward (U) Current Velocities and the Northward (V) Current Velocities are stored as matrices in separate files. A single row in each of these matrix files corresponds to a single row of grid cells (i.e. cells with the same latitude), and the top row represent the grid row with the lowest latitude whilst the bottom row represents the grid row with the highest latitude. These files can be opened with any text editor. However, they are targeted to be processed similar to CSV files using spread-sheet software (such as MS Excel and/or LibreOffice Calc) and/or other data processing software such as R and Matlab.

The temporal resolution of the Calypso HF-Radar data is hourly. However, the system aggregates the data files into daily files, or into larger files according to the user requests. In case of the NetCDF files, the aggregation is performed by joining the hourly NetCDF files together along the time dimension. In the case of the ASCII files, the aggregation is performed by creating RAR archives containing the necessary ASCII hourly files.

Calculating current drift

The CurrentDrift.m function calculates locations of a floating object at every 10 minutes, starting from the specified time and the initial location. The particle locations are calculated taking into account surface currents only, using bilinear interpolation in space and 4th order Runge-Kutta integration scheme. Also, diffusion effect is neglected in this scheme.

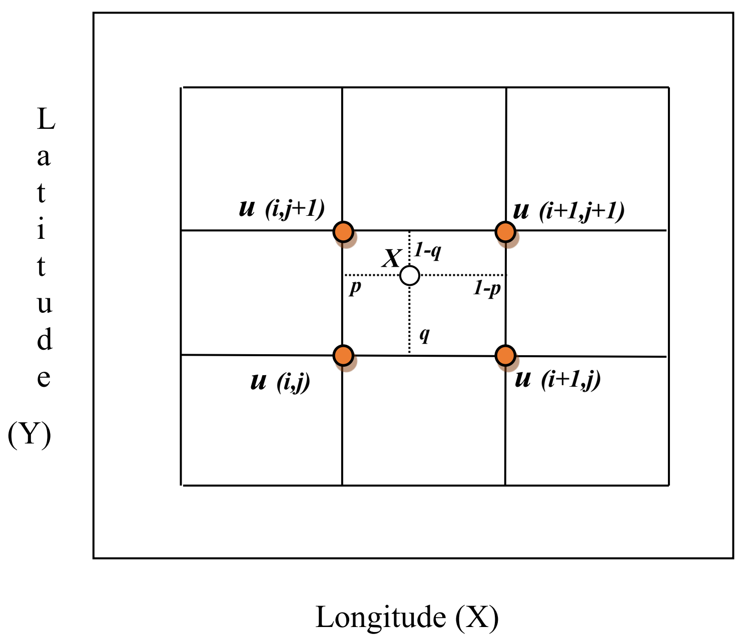


Figure 3: Visualisation of bilinear interpolation coefficients

The algorithm is the following:

1. Identifying u and v at the particle's initial location at the specified date and time using bilinear interpolation method.

2. Calculating 10 minute current fields by interpolating two closest hourly current fields.

3. Computing four intermediate points, called Runge-Kutta coefficients along both, X and Y axes.

$$u_x^n = (1-p)(1-q)u_{i,j} + p(1-q)u_{i+1,j} + pqu_{i+1,j+1} + (1-p)qu_{i,j+1}$$
$$v_x^n = (1-p)(1-q)v_{i,j} + p(1-q)v_{i+1,j} + pqv_{i+1,j+1} + (1-p)qv_{i,j+1}$$

where i is latitude and j is longitude and p and q are computed using same method.

The Runge-Kutta coefficients are computed for both, u and v components separated, as shown below:

$$k_1 = \Delta t * u(t^n, x_x^n)$$

$$k_2 = \Delta t * u\left(t^n + \frac{\Delta t}{2}, x_x^n + \frac{k1}{2}\right)$$

$$k_3 = \Delta t * u\left(t^n + \frac{\Delta t}{2}, x_x^n + \frac{k2}{2}\right)$$

$$k_4 = \Delta t * u(t^n + \Delta t, x_x^n + k3)$$

Thus, location of the particle at the point n+1 is

$$x_x^{n+1} = x_x^n + \frac{k_1}{6} + \frac{k_2}{3} + \frac{k_3}{3} + \frac{k_4}{6}$$

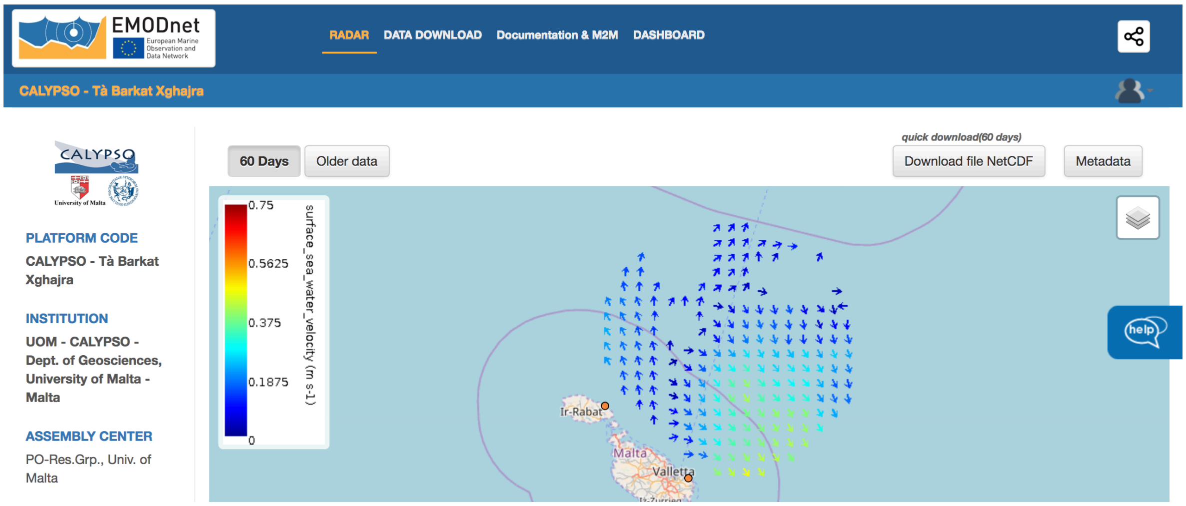
In order to compute coefficients k2 and k3, an intermediate current field is created by simple interpolation in between 10 minute current fields. Same procedure is repeated with the v component in order to compute the particle's location along Y axis (along latitude).

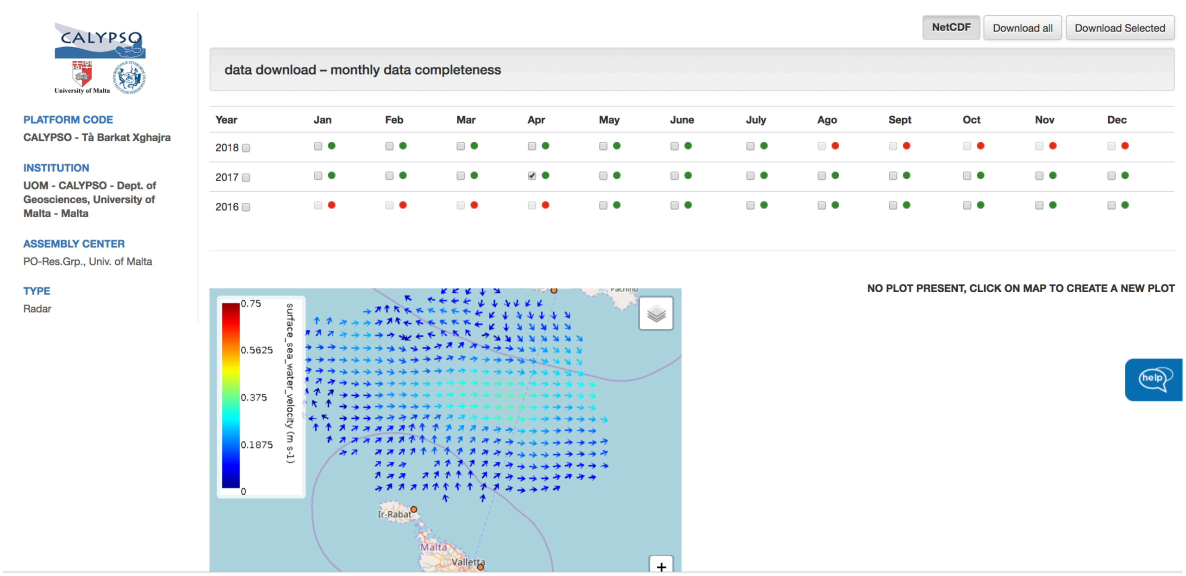
Filling data gaps due to changes in coverage is performed in order to improve availability of data and extend the run time of the function. A gap of up to 2 hours is filled with values interpolated between two closest available data frames. Interpolation in space is applied to a grid point when values for at least 4 out of its 8 closest neighbours are available. In that case, the grid point's value is computed as a simple average of the 4 to 8 neighbouring values.

Exercise

1. From the EMODnet Physics portal, download the CALYPSO HF Radar data for April 2017. The platform can be accessed directly from: http://www.emodnet-physics.eu/Map/platinfo/piradar.aspx?platformid=13591

   Archived NetCDF data can be obtained by clicking on the 'Older data' button.

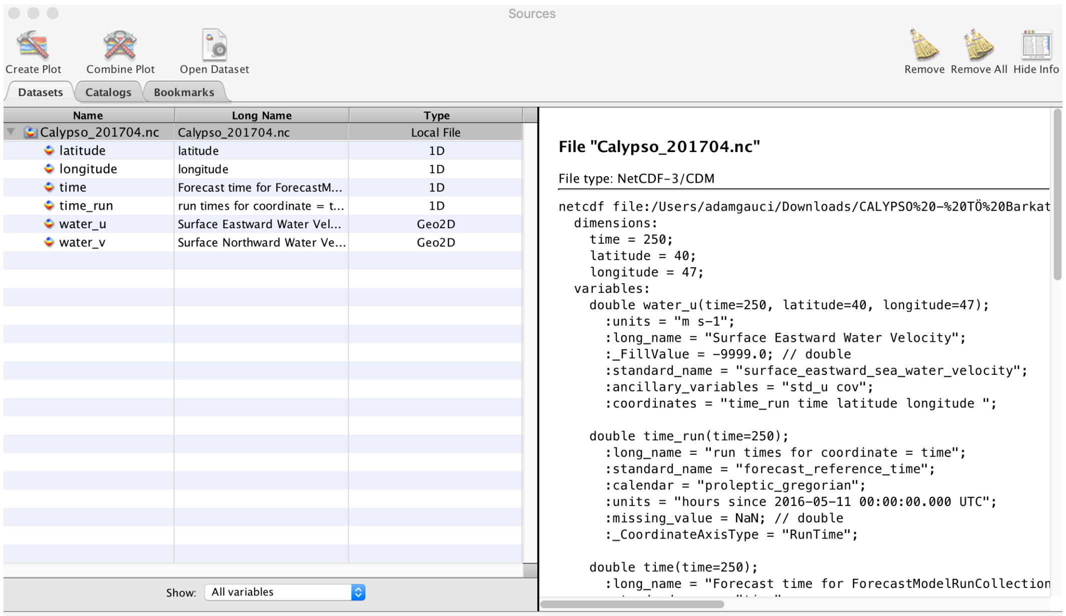




2. Visualize the NetCDF file in Panoply. Have a look at the metadata and check the parameter names.

Verify that there are 40 latitude points, and 47 longitude points.

See that the “time” field is stored as "hours since 2016-05-11 00:00:00.000 UTC".



Variable "time"

```
double time(time=250);
  :long_name = "Forecast time for ForecastModelRunCollection";
  :standard_name = "time";
  :calendar = "proleptic_gregorian";
  :units = "hours since 2016-05-11 00:00:00.000 UTC";
  :missing_value = NaN; // double
  :_CoordinateAxisType = "Time";
```

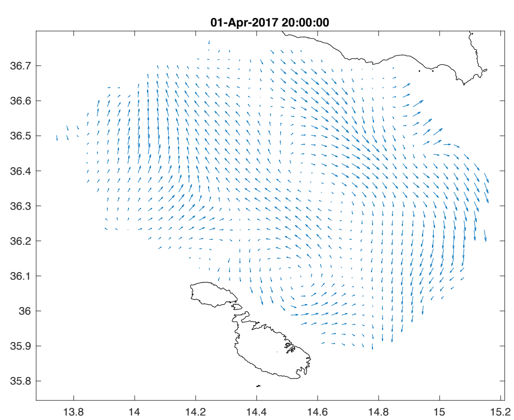
X-Axis: longitude (degrees_east); Y-Axis: latitude (degrees_north)

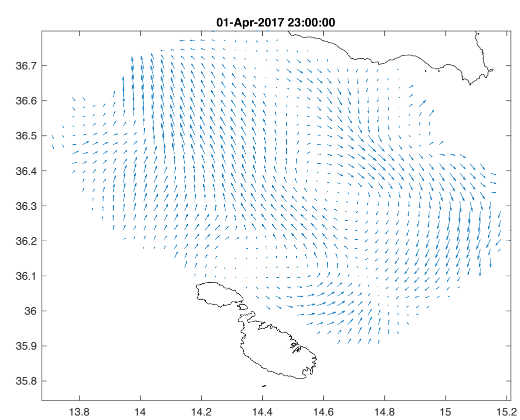
	13.977	14.011	14.044	14.078	14.111	14.144	14.178	14.211	14.245	14.278	14.311	Avg.
36.150	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.08118	0.05294	0.03587
36.177	NaN	NaN	NaN	NaN	NaN	NaN	0.08375	0.13856	0.13863	0.12476	0.13378	0.03294
36.204	NaN	NaN	NaN	NaN	NaN	0.08908	0.15458	0.22108	0.19424	0.18288	0.19104	0.04952
36.231	NaN	NaN	NaN	NaN	0.14908	0.17864	0.17054	0.21239	0.29563	0.21905	0.24160	0.07597
36.258	NaN	-0.01733	0.00495	0.08246	0.13438	0.19689	0.25478	0.23069	0.23727	0.23853	0.24686	0.07324
36.285	NaN	-0.01780	-0.00976	0.02770	0.11358	0.17453	0.26375	0.26375	0.18927	0.13310	0.11738	0.06385
36.312	-0.00861	-0.03449	-0.01245	0.01150	0.08114	0.16552	0.21139	0.19124	0.12809	0.04869	0.01531	0.05475
36.340	0.03157	0.00618	-0.01173	0.01283	0.06704	0.13722	0.17113	0.12423	0.02969	-0.02370	-0.04250	0.07075
36.366	0.01680	0.06352	0.04563	0.03584	0.06077	0.09846	0.11114	0.06804	-0.01169	-0.05213	-0.08199	0.08953
36.394	0.04665	0.05322	0.07580	0.06858	0.07041	0.06384	0.06787	0.01978	-0.05116	-0.07923	-0.08820	0.10288
36.421	0.05207	0.06592	0.08141	0.07222	0.05189	0.03447	0.00574	-0.02650	-0.05927	-0.08998	-0.10886	0.08714
36.448	0.06708	0.07034	0.05884	0.05550	0.03464	0.01806	-0.01486	-0.06080	-0.08830	-0.10101	-0.11478	0.07272
36.475	0.05344	0.06281	0.05712	0.03998	0.02783	0.00779	-0.02400	-0.06950	-0.09753	-0.11393	-0.12347	0.04121
36.502	0.05765	0.04182	0.04150	0.04487	0.03387	0.01162	-0.02279	-0.07277	-0.11505	-0.11728	-0.13822	0.02714
36.529	0.05808	0.03776	0.03168	0.02948	0.03229	0.01110	-0.00984	-0.05662	-0.12646	-0.14465	-0.13557	0.02761
36.556	0.00286	0.02071	0.03376	0.03232	0.02503	0.02125	-0.01772	-0.04715	-0.10764	-0.15593	-0.16818	0.02549
36.583	-0.00568	-0.00840	0.01224	0.03417	0.02606	0.01598	-0.00600	-0.04571	-0.08791	-0.12337	-0.15531	0.04060
36.610	NaN	-0.00014	0.00956	0.02872	0.02444	0.00367	-0.01346	-0.02908	-0.06511	-0.09292	-0.12065	0.06547
36.637	NaN	NaN	NaN	0.01377	0.01749	-0.01279	-0.02553	-0.02772	-0.03706	-0.05505	-0.08001	0.09101
36.664	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	-0.02449	0.17509

3. Load the HF Radar data in Matlab using the ‘ncread’ command.

Visualise the data using the ‘quiver’ command.

```
dataLat = ncread('Calypso_201704.nc', 'latitude');
dataLon = ncread('Calypso_201704.nc', 'longitude');
dataTime = ncread('Calypso_201704.nc', 'time');
dataWaterU = ncread('Calypso_201704.nc', 'water_u');
dataWaterV = ncread('Calypso_201704.nc', 'water_v');


coast = dlmread('mapcoast.dat');


dataBase = datenum([2016 5 11 0 0 0]);


for t = 1:1:numel(dataTime)
      dataTime(t) = addtodate(dataBase, dataTime(t), 'hour');
end


for t = 1:1:numel(dataTime)
      clf()
      plot(coast(:,1), coast(:,2), 'k-'); hold on;
      quiver(dataLon, dataLat, dataWaterU(:,:,t)', dataWaterV(:,:,t)')
      axis([min(dataLon) max(dataLon) min(dataLat) max(dataLat)]);
      title(datestr(dataTime(t), 0));
      waitforbuttonpress;
end
```



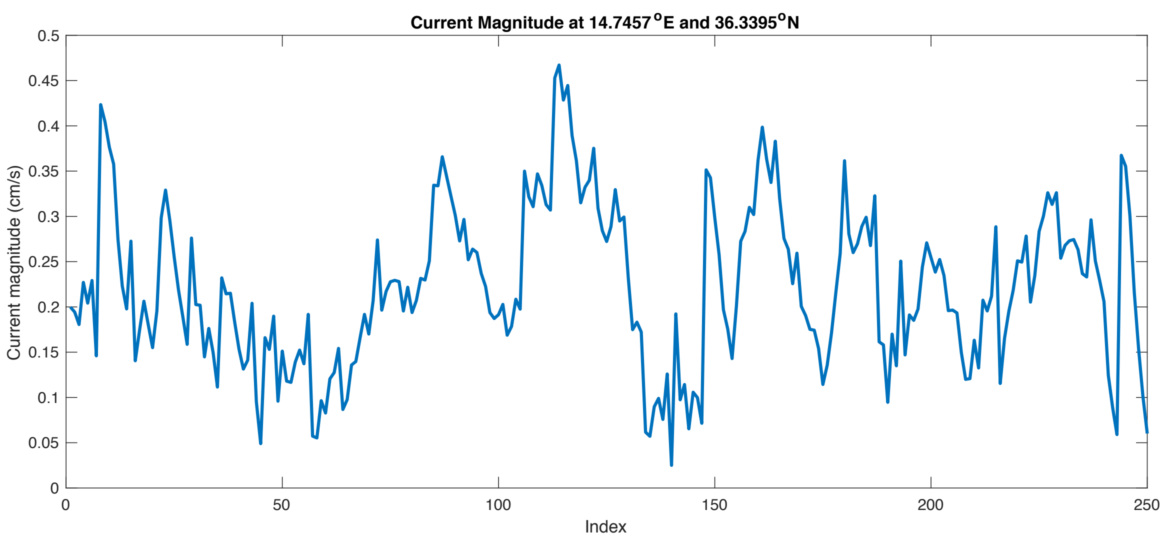


4. Produce a time series of the sea surface current magitude observed at a particular longitdue and latitude. Try to select a point in the center of the CALYPSO HF Radar coverage to avoid having gaps due to interference. Remember that the magnitude of a vector is computed as follows:

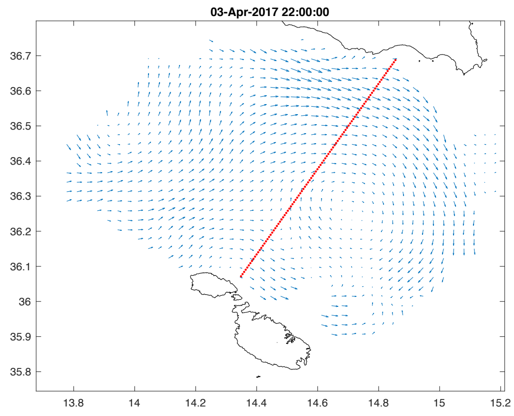
$$M = \sqrt{u^2 + v^2}$$

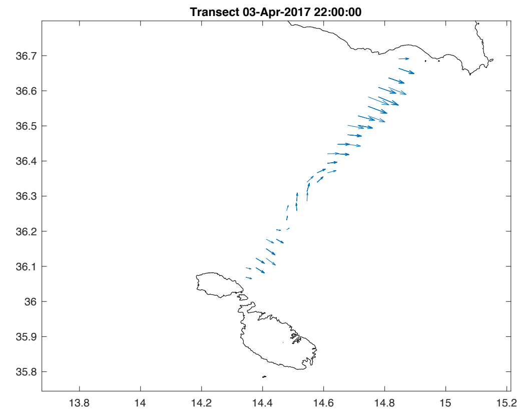
Display the result for *i* = 33 and *j* = 23. Such a coordinate corresponds to 14.7457°E in longitude and 36.3395 °N in latitude.

```
i = 33; %longitude index
j = 23; %latitdue index

dataMag = sqrt(squeeze(dataWaterU(i, j,:).^2)
     + squeeze(dataWaterV(i, j,:).^2));

plot(dataMag, 'LineWidth', 2);
title(['Current Magnitude at ', num2str(dataLon(i)), '^oE and ',
num2str(dataLat(j)), '^oN']);
xlabel('Index');
ylabel('Current magnitude (cm/s)');
```



5. Plot a transect of current vectors between two selected waypoints for a particular time frame. Allow the user to specify the start and end points and then visualize all the vectors in between.

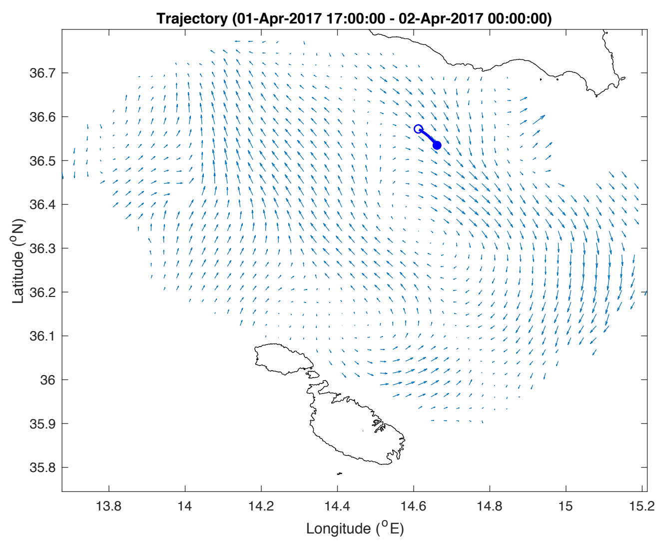


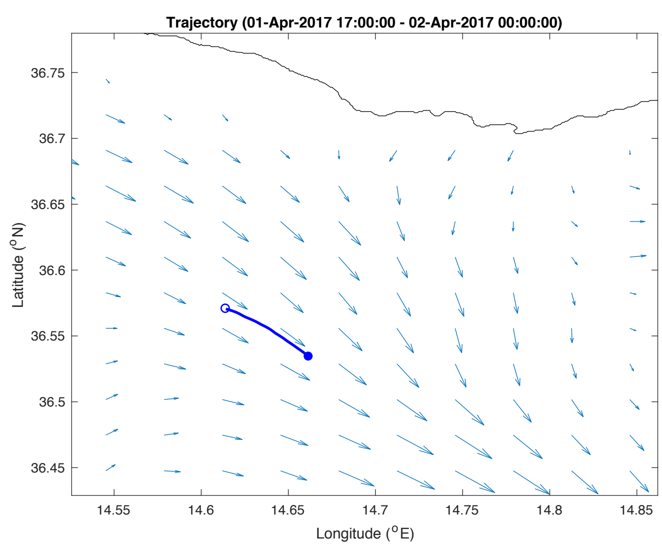



```
t = 20;
plot(coast(:,1), coast(:,2), 'k-'); hold on;
quiver(dataLon, dataLat, dataWaterU(:,:,t)', dataWaterV(:,:,t)')
axis([min(dataLon) max(dataLon) min(dataLat) max(dataLat)]);
title(datestr(dataTime(t), 0));
[x y] = ginput(2);
[xFill yFill] = fillline([x(1) y(1)], [x(2) y(2)], 100);
plot(xFill, yFill, 'r.')

dataIdx = [];
for i = 1:1:numel(yFill)
    [xMinVal xMinIdx] = min(abs(dataLon - xFill(i)));
    [yMinVal yMinIdx] = min(abs(dataLat - yFill(i)));
    dataIdx(i, :) = [xMinIdx yMinIdx dataLon(xMinIdx) dataLat(yMinIdx)
dataWaterU(xMinIdx, yMinIdx, t) dataWaterV(xMinIdx, yMinIdx, t)];
end

figure;
plot(coast(:,1), coast(:,2), 'k-'); hold on;
quiver(dataIdx(:,3),dataIdx(:,4),dataIdx(:,5),dataIdx(:,6));
axis([min(dataLon) max(dataLon) min(dataLat) max(dataLat)]);
title(['Transect ', datestr(dataTime(t), 0)]);
```

6. Apply `currentdrift.m` to superimpose over HF radar fields a drifting particle from an initial user selected position. This function takes 10 parameters as follows:

`dataLon`	– list of longitude coordinates (N x 1)
`dataLat`	– list of latitude coordinates (M x 1)
`dataWaterU`	– 3D matrix with water velocities (N x M x t)
`dataWaterV`	– 3D matrix with water velocities (N x M x t)
`dataTime`	– list of timestampls (t x 1)
`year`	– the year of the start of trajectory as a string value
`month`	– the month of the start of trajectory as a string value
`day`	– the day of the start of trajectory as a string value
`hour`	– the hour of the start of trajectory as a string value
`length`	– the length of trajectory as a string value






```
CurrentDrift (dataLon, dataLat, dataWaterU, dataWaterV, dataTime,
    '2017', '4', '1', '17', '7')
```