WW3 Tutorial 4.5: Wave System Tracking

Purpose

In this tutorial exercise we will go through the steps of performing the wave system tracking post-processing that is available in the WAVEWATCH III® v4.08 package. It will include instructions on producing partitioned wave output in a WAVEWATCH III® run, and how to process this output to obtain (i) spatially and temporally consistent fields and (ii) time series of all the component wave systems in the computational domain.

Input files

At the start of this tutorial exercise, the following list of files should reside in the exercise directory `~/day_4/tutorial_wavetracking/`:

```
partition.ww3
ww3_systrk.inp
plot_systrk.m
plot_systrk_pnt.m
coastal_bound_low.mat
```

The first of these, `partition.ww3`, is the raw spectral partition file. This file has been created using the algorithm of Tracy et al. (2007). This is done by requesting the output Type 6 in the programs `ww3_shel` and `ww3_multi`, for example (WW3 manual Chapter 4, see bold text):

```
...
$
$ Type 3 : Output along  track.
   19680606 000000   1800  19680606 013000
      T
$
$ Type 4 : Restart files (no additional data required).
   19680606 030000      1  19680606 030000
$
$ Type 5 : Boundary data (no additional data required).
   19680606 000000   3600  20010102 000000
$
$ Type 6 : Separated wave field data (dummy for now).
$          First line: Start time, increment (s) and end time of output
$          Second line: IX indices - First, last, increment; IY indices -
$          first, last, increment; flag for formatted file
   19680606 000000   3600  20010102 000000
      0 999 1 0 999 1 T
...
```

The user has the option of writing out the partition output data over only a sub-domain of the computational grid, if desired. Also, the wave system tracking operation can be computationally intensive, so the user can speed up the post-processing by de-refining the partition output file by skipping (IX, IY) grid points. We will not run the `ww3_shel` program here, but rather start from the point where the raw partition file has already been produced. Inspect the ASCII file `partition.ww3` (excerpt):

```
20091122 000000 -55.000   0.000  'grid_point'  5 2138.0  4.0 229.4 0.00   0.0
```

```
  0     2.80   15.45  372.70   256.47    49.27   0.04
  1     2.12    7.37   84.82   227.75    31.07   0.08
  2     1.33   15.46  372.93   270.18     9.31   0.00
  3     1.16    8.92  124.18   340.66    15.80   0.00
  4     0.51   10.22  162.96    45.97     8.21   0.00
  5     0.10   15.26  363.24   336.67     9.52   0.00
 20091122 000000 -55.000   1.000  'grid_point'  5 3286.3   4.3 226.7 0.00   0.0
  0     2.87   15.77  388.27   252.53    48.27   0.06
  1     2.28    7.52   88.25   228.66    30.67   0.09
  2     1.20   15.78  388.79   269.07     8.57   0.00
  3     1.15    8.97  125.62   338.86    15.83   0.00
  4     0.50   10.17  161.52    44.26     8.56   0.00
  5     0.10   15.27  363.96   337.34     8.18   0.00
 20091122 000000 -55.000   2.000  'grid_point'  5 2924.3   4.7 226.5 0.00   0.0
  0     2.93    8.07  101.62   249.99    46.72   0.08
  1     2.43    7.78   94.52   230.32    30.07   0.11
  2     1.13    9.01  126.66   337.41    15.18   0.00
  3     1.08   16.14  406.78   268.38     8.45   0.00
  4     0.48   10.11  159.58    42.45     8.77   0.00
  5     0.09   15.25  362.88   336.19     8.64   0.00
...
```

This file contains the spectral partition output at each geographical grid point for each model output time, as illustrated in Figure 1. Each combination of output time and output point has a unit data structure featuring a header line and a list of partitions. The header line contains: date, longitude, latitude, point name (string), number of partitions, local water depth, wind speed, wind direction (nautical convention), current speed and current direction. Below this, the partitions at this location and time are listed: the line with the index ‘0’ is the total wave field. The line with the index ‘1’ is the partition with wind sea, and the remaining partitions are the swell, from highest to lowest significant wave height.

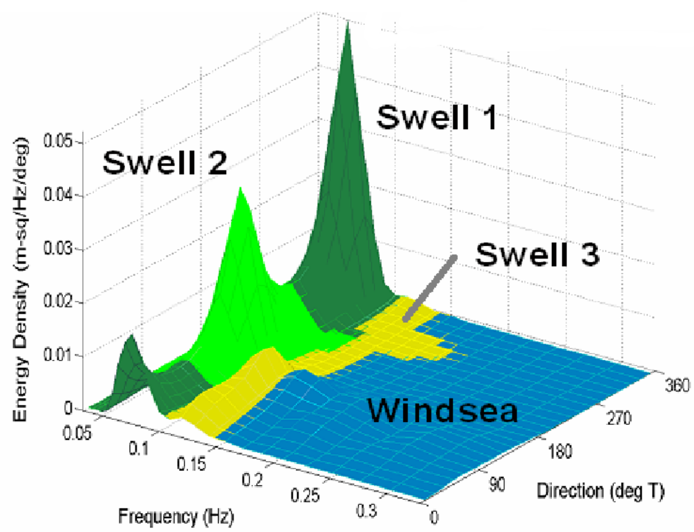

Figure 1: Illustration of spectral partitioning, showing a wind sea partition and a number of swell partitions (Tracy et al. 2007).

Within each line, the following parameters are found: significant wave height of partition, peak wave period of partition, wave length of partition, peak direction of partition, directional spread of partition and the wind fraction. The latter indicates the fraction of that partition that is actively being forced by the wind. This is the primary input data file used by the program `ww3_systrk`.

Program settings

The wave tracking procedure is configured using the input file `ww3_systrk.inp`. The WW3 manual Chapter 4 provides an overview of the available options. The file has the following format:

```
$ File name for raw partition data
$
  'partition.ww3'
$
$ First time level (yyyymmdd hhmmss), time increment and number of
$ time levels to process.
$
  20091122 000000  3600  4
$
$ Domain over which tracking is to be performed. First line: longitude
$ limits; second line: latitude limits. For entire domain, use -999. 999
$
   100. 275.
     0.  55.
$
$ Parameters of tracking algorithm ---------------------------------- $
$   - dirKnob (deg), perKnob (s), hsKnob (m), wetPts (frac),
$     dirTimeKnob (deg), perTimeKnob (s)
$   - seedLat, seedLon
$
 10. 1. 0.25 0.1 10. 1.
  0. 0.
$
$ Output points --------------------------------------------------- $
$ Longitude, latitude. End with 0. 0. string on last line.
$
  222.54  40.75
  199.42  19.02
  205.94  23.55
  290.35  31.98
  347.60  48.70
  337.00  21.00
  197.94  24.32
  206.10  23.56
    0.    0.
```

The first line specifies the input data, namely the spectral partition file `partition.ww3` discussed above. In the second line, the start date of the wave tracking post-processing, the time increment and the number of time steps to process are given. The third and fourth lines specify the geographic domain to consider. Note that both the time interval and geographic domain over which wave systems are tracked can be subsets of the data contained in the file `partition.ww3`. This is useful, because sometimes one is interested in analyzing output over only a part of the model domain. The combining parameters `dirKnob` and `perKnob` are used to influence the strictness of the system combining algorithm in geographic space, and `dirTimeKnob` and `perTimeKnob` are the corresponding parameters in temporal space. Lower values imply stricter criteria, which typically results in a larger number of wave systems, each with a smaller spatial extent. This also typically increases the processing time. Conversely, higher values tend to fuse wave systems together. Recommended values are given above.

The parameters `hsKnob` and `wetPts` are a low-energy and small-system filters - all wave systems with an average H_{m0} below `hsKnob` or with a size of less than `wetPts`*100% of the overall domain size are purged. Parameters `seedLat` and `seedLon` influence the origin of the wave system search spiral, with default at the center of model domain (indicated by 0. 0.). At the end of a tracking run, the end state of system memory is stored in `sys_restart1.ww3`. This file, renamed as `sys_restart.ww3`, can be used to restart a tracking sequence from this previous system memory state.

Running the program

At the start of this exercise you should have the program executable `ww3_systrk` available in the `~/wwatch3/exe/` folder of your WW3 directory tree (see Day 1 Tutorial on compilation). This executable directory should also be included in your PATH variable (see your .cshrc profile file). Test this by navigating to the work directory ~/`day_4/tutorial_wavetracking/` and typing

```
which ww3_systrk
```

We will start by running the code with the default settings provided in the tutorial input file `ww3_systrk.inp` (based on Van der Westhuysen et al., 2013). The most important of these are the parameters for the tracking algorithm itself:

```
$ Parameters of tracking algorithm ----------------------------------- $
$   - dirKnob (deg), perKnob (s), hsKnob (m), wetPts (frac),
$     dirTimeKnob (deg), tpTimeKnob (s)
$   - seedLat, seedLon
$
 10. 1. 0.25 0.1 10. 1.
  0. 0.
```

Run the wave tracking program (in parallel, with 2 processors) by typing the following on the command line in the work directory `day_4/tutorial_wavetracking/`:

```
mpirun –np 2 ww3_systrk
```

The after completing this post-processing, the following output files will have been created in the run directory:

```
sys_log0000.ww3        (log file parallel processor No. 1)
sys_log0001.ww3        (log file parallel processor No. 2)
sys_coord.ww3          (field output file: coordinates)
sys_hs.ww3             (field output file: significant wave height)
sys_tp.ww3             (field output file: peak period)
sys_dir.ww3            (field output file: peak direction)
sys_dspr.ww3           (field output file: directional spreading)
sys_pnt.ww3            (point output file: all prameters)
sys_restart1.ww3       (hotstart file)
```

First, we are going to visualize the field output using the Matlab script `plot_systrk.m`. This script uses the files `sys_coord.ww3`, `sys_hs.ww3`, `sys_tp.ww3`, as well as a landboundary file `coastal_bound_low.mat`. Make sure to configure the work directory in the section "User Configurable Parameters" at the top of the script. The following four .png files will be created, one for each time step being processed:

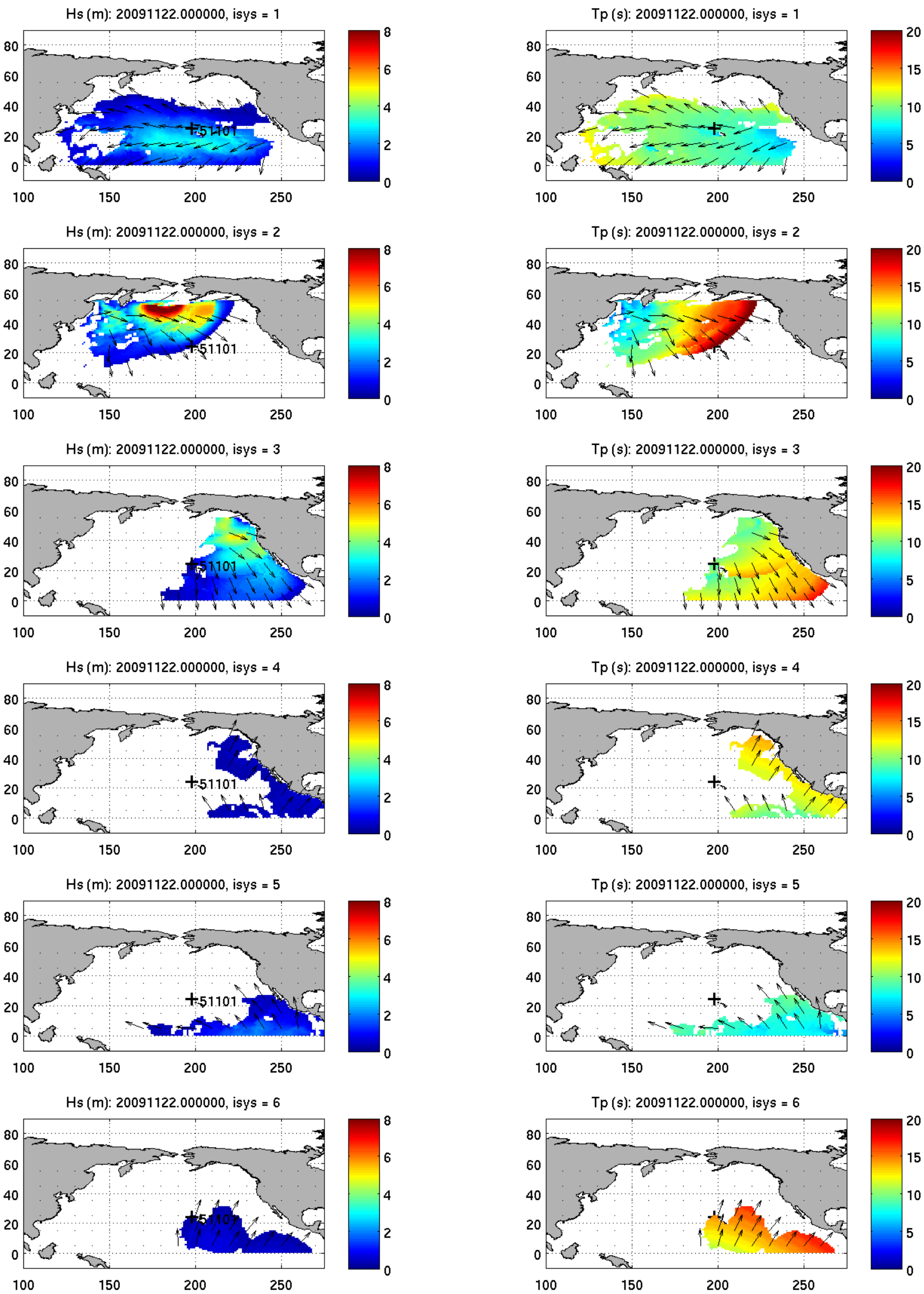

Figure 2: Wave system output over N. Pacific for 2009/11/22 00:00 UTC, incl. location of NDBC 51101.

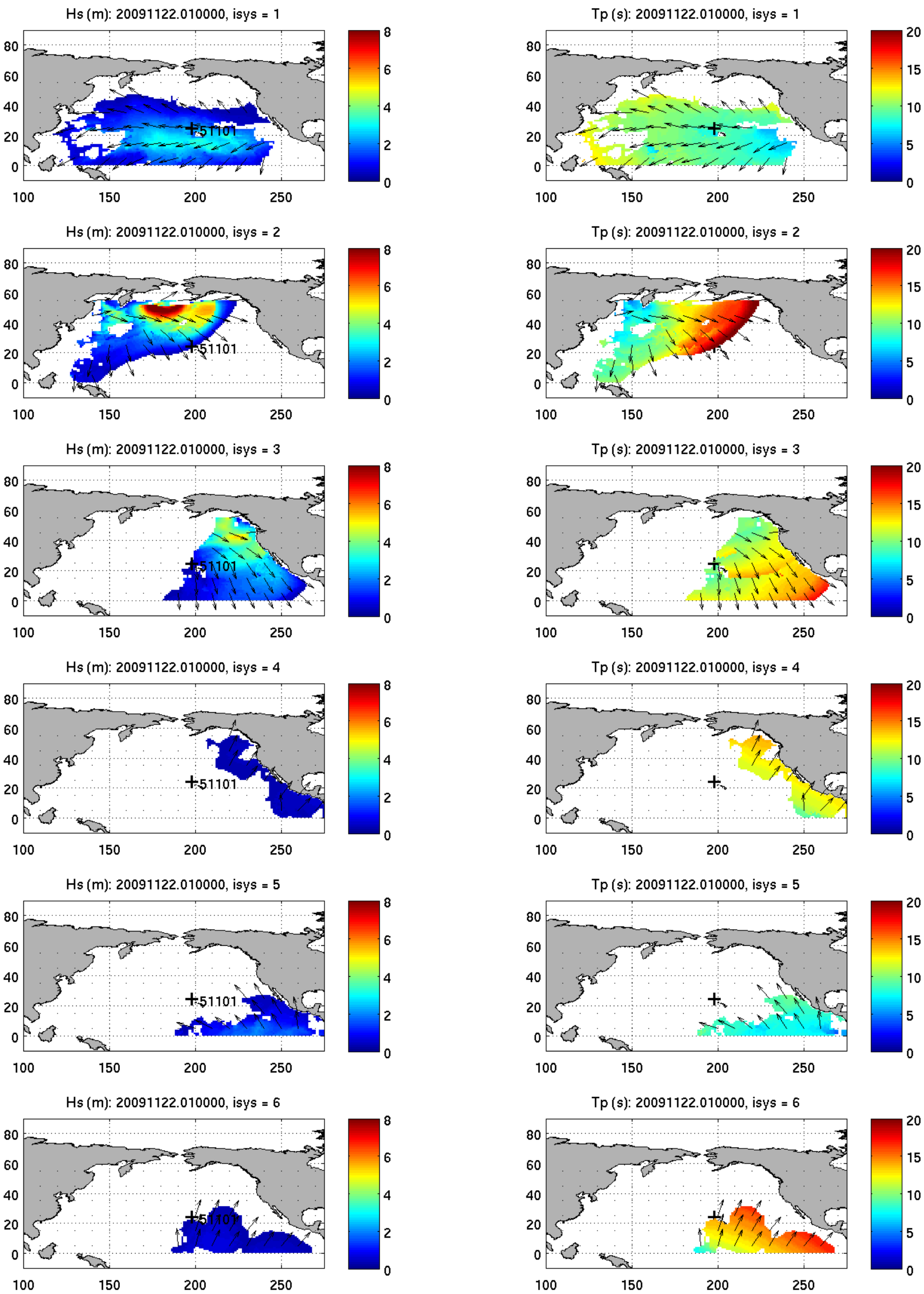

Figure 3: Wave system output over N. Pacific for 2009/11/22 01:00 UTC, incl. location of NDBC 51101.

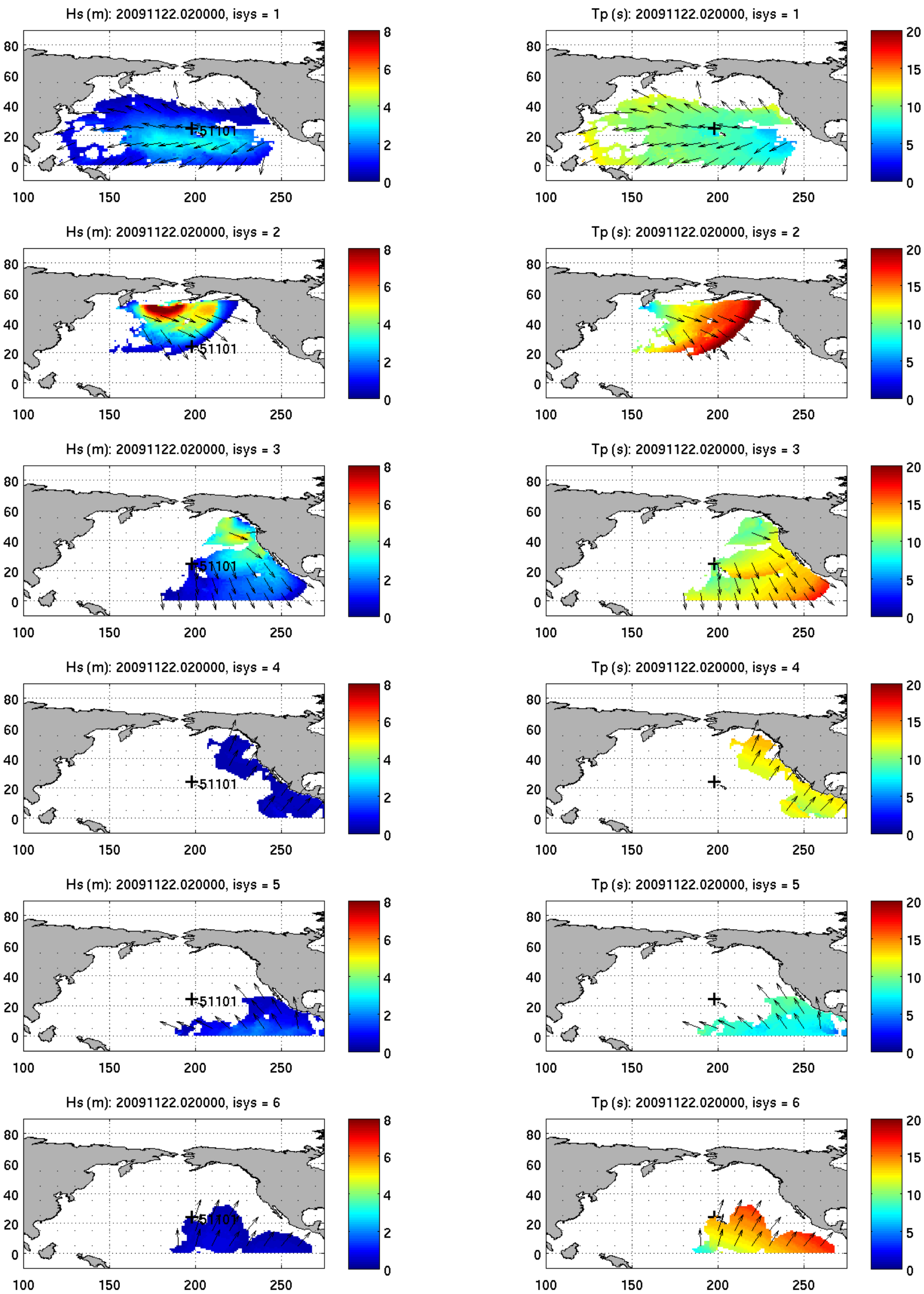

Figure 4: Wave system output over N. Pacific for 2009/11/22 02:00 UTC, incl. location of NDBC 51101.

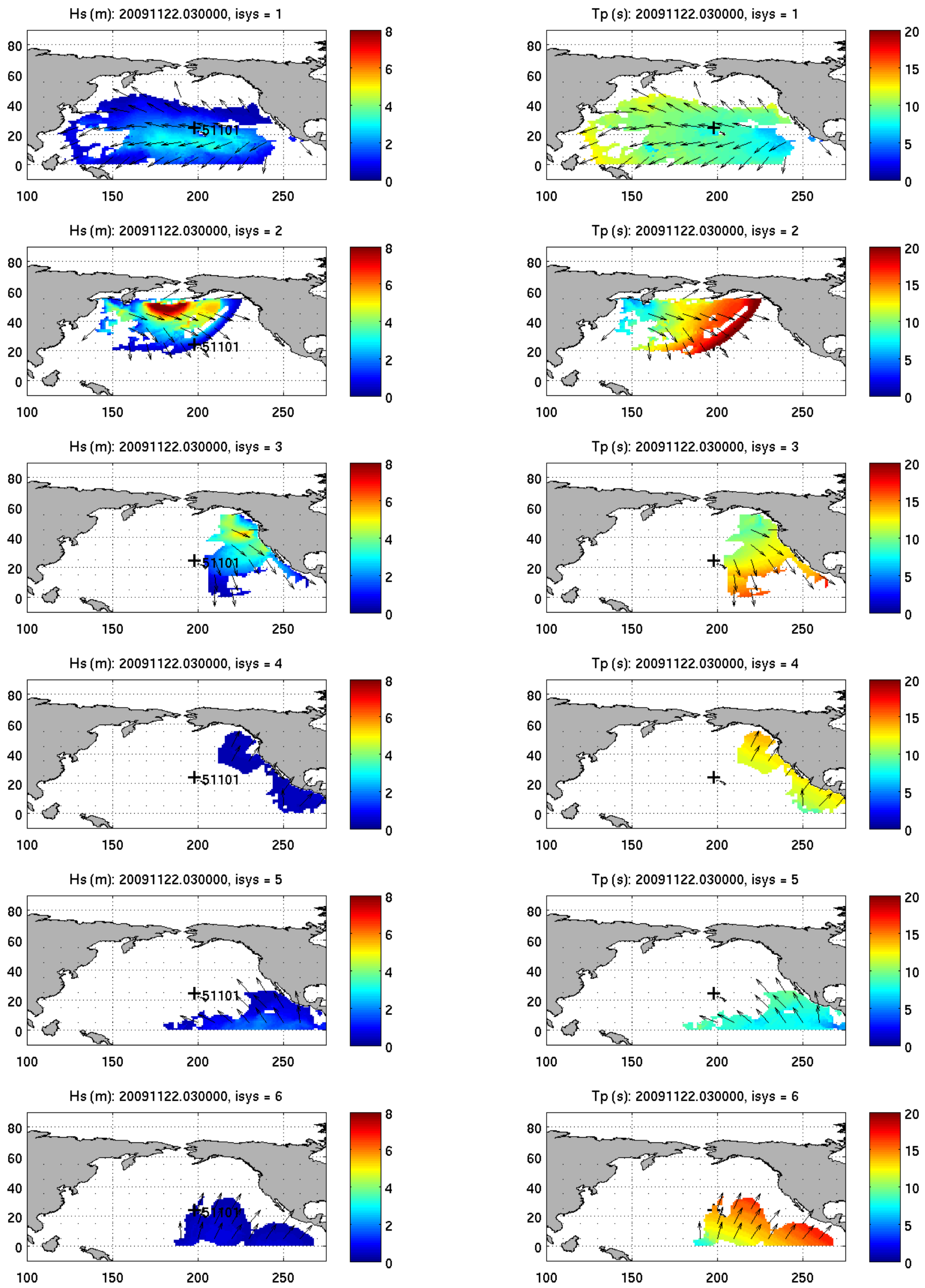

Figure 5: Wave system output over N. Pacific for 2009/11/22 03:00 UTC, incl. location of NDBC 51101.

Second, we are going to visualize the time series output of the file `sys_pnt.ww3`, using the Matlab script `plot_systrk_pnt.m`. Again, specify your work directory in the section "User Configurable Parameters" at the top of the script. The script yields the following time series plot:

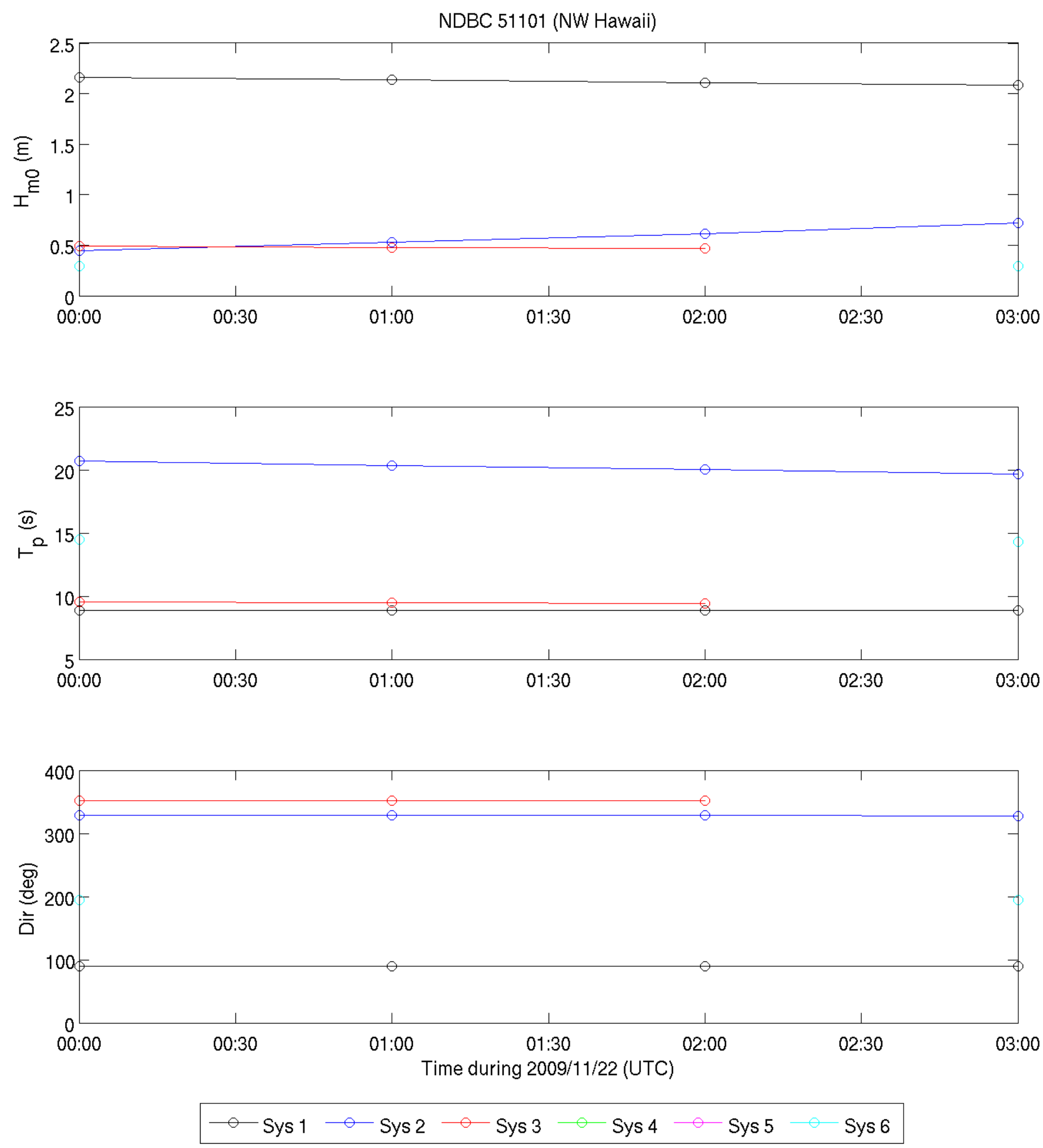

Figure 6: Time series output of partitioned and tracked wave systems at NDBC buoy 51101.

Figure 6 shows the time series output of all component wave systems that pass through the location of the NDBC buoy 51101 (see Figs 2-5) during the simulation time considered. It can be seen that a persistent E wind sea (Sys 1), a mature NW swell (Sys 2) and a NW wind sea/young swell (Sys 3) pass through this point. Regarding the latter, its presence at NDBC 51101 extends only up to 2009/22/11 02:00 UTC. Other output points can also be selected for plotting. These are first specified in the input file `ww3_systrk.inp`, and then in the user section of the script `plot_systrk_pnt.m`.

Additional exercise

We can investigate the sensitivity of the wave tracking post-processing by changing the values of the tracking algorithm. For example, try the settings:

```
$ Parameters of tracking algorithm ---------------------------------- $
$   - dirKnob (deg), perKnob (s), hsKnob (m), wetPts (frac),
$     dirTimeKnob (deg), tpTimeKnob (s)
$   - seedLat, seedLon
$
 30. 3. 0.25 0.1 30. 3.
  0. 0.
```

You will see that the wave systems tend to be more combined that in the example above.

Conclusion

In this exercise, we have studied the `ww3_systrk` post-processing program that performs spatial and temporal tracking of wave systems. This can be applied to the Type 6 (partition) field output from WAVEWATCH III. In a practical case, a longer time series of simulation output would be considered, for example a 5-day forecast.

References

Tracy, B, E.-M. Devaliere, J. L. Hanson, T. Nicolini and H. L. Tolman, 2007. Wind sea and swell delineation for numerical wave modeling, Proc. 10th Int. Workshop on Wave Hindcasting and Forecasting, Paper P12

Van der Westhuysen, A. J., J. L. Hanson and E.-M. Devaliere, 2013. Spatial and temporal tracking of wave fields from ocean basin scales to coastal waters, J. Atmos. and Oceanic Tech., in review.

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