

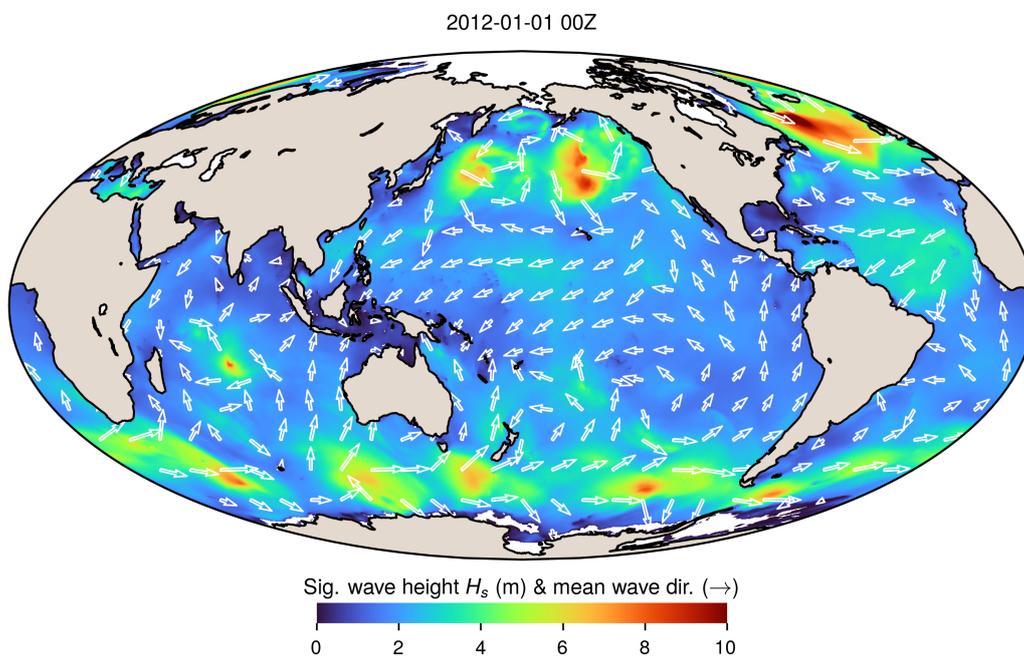
Product user guide for the WW3-ST6 global wave hindcasts

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1 Model setup

Global wave hindcasts are developed using the third generation spectral wave model WAVEWATCH III[®] (hereafter WW3, v6.07; The WAVEWATCH III[®] Development Group (WW3DG), 2019, hereafter WW3DG19) with the observation-based source terms (ST6; Liu et al., 2019) and the hybrid rectilinear-curvilinear, irregular-regular-irregular (IRI) grid system (approximately at $0.25^\circ \times 0.25^\circ$; Rogers and Linzell, 2018). Four distinct global hindcasts are produced, including i) a long-term hindcast (1979-2019) forced by the ERA5 (Hersbach et al., 2019) conventional winds U_{10} , ii) two short-term hindcasts (2011-2019) driven by the NCEP CFSv2 U_{10} (Saha et al., 2010, 2014) and the ERA5 neutral winds $U_{10,neu}$, respectively, and iii) another long-term run (1950-1978) using the ERA5 back extension data. For simulations since 1979, the input field for ice is sourced from Version 2 of the EUMETSAT OSI SAF sea-ice concentration climate data records (Lavergne et al., 2019).

Model physics selected include:

- ST6 package for wind input S_{in} , wave breaking S_{ds} and swell dissipation S_{swl} (Rogers et al., 2012; Zieger et al., 2015; Liu et al., 2019);
- DIA for the nonlinear four-wave interactions S_{nl} (Hasselmann et al., 1985);
- JONSWAP bottom friction S_{bf} (Hasselmann et al., 1973) with $\Gamma = -0.038 \text{ m}^2 \text{ s}^{-3}$;
- depth-induced wave breaking S_{db} (Battjes and Janssen, 1978) with the Miche-type criterion for the maximum individual wave height;
- partial-blocking approach (IC0) for ice-infested ocean (Tolman, 2003) with $C_{i,l} = 25\%$ and $C_{i,h} = 75\%$.

The external forcing data used are

- the ERA5 global reanalysis conventional wind data U_{10} (hourly, 0.25° ; 1979-2019) and neutral winds $U_{10,neu}$ (2011-2019) (Hersbach et al., 2019);
- the NCEP climate forecast system (CFS) winds (hourly, 0.5° ; 2011-2019) (Saha et al., 2010, 2014)
- the Global Sea Ice Concentration Climate Data Record v2 (OSI-450; 1979-2015) and Global Sea Ice Concentration Interim Climate Data Record v2 (OSI-430-b; 2016-present) - data are daily and archived on a $25 \times 25 \text{ km}$ grid (Lavergne et al., 2019).
- the ERA5 back extension data, including conventional wind data U_{10} (hourly, 0.25°) and ice concentration (daily, 0.25° ; 1950-1978) [See <https://confluence.ecmwf.int/display/CKB/The+family+of+ERA5+d datasets> for more details] - Note that the current ERA5 back extension appears to suffer from tropical cyclones that are sometimes unrealistically intense - this data stream should be updated once the corrected version of the ERA5 back extension is available (<https://confluence.ecmwf.int/display/CKB/ERA5+back+extension+1950-1978+%28Preliminary+version%29%3A+tropical+cyclones+are+too+intense>).

The ST6 source term package available in WW3 (v6.07) was initially calibrated with one-year CFS data in 2011 (Liu et al., 2019). It provokes a re-calibration of the tunable wind stress parameter, CDFAC, of the ST6 when different winds are adopted (Zieger et al., 2015). In our simulations, we used CDFAC of 0.98, 1.06 and 1.08 for the CFS U_{10} , ERA5 $U_{10,neu}$ and conventional U_{10} , respectively (Table 1). Once again, these values were calibrated based on a single-year model run for 2011, and then applied throughout the entire simulation period. The reader is referred to Liu et al. (2020) for further description and validation of these hindcasts against satellite altimeter and buoy observations.

Table 1: Summary of the WW3-ST6 global wave hindcasts with different wind forcings. Here CDFAC represents the tunable wind stress parameter of the ST6 package (Zieger et al., 2015).

Wind Forcing	CDFAC	Period	Folder name on Mediaflux
ERA5 U_{10}	1.08	1979-2019	ConvWnd
ERA5 $U_{10,neu}$	1.06	2011-2019	NeutWnd
CFS U_{10}	0.98	2011-2019	CFS2Wnd
ERA5 back extension U_{10}	1.08	1950-1978	BaExWnd

2 Wave parameters

2.1 Gridded output

The field wave parameters are stored on a global regularly-spaced, $0.25^\circ \times 0.25^\circ$ grid with a temporal resolution of 3 hours. Table 2 summarises all the wave parameters that are available in the hindcasts. The reader is referred to WW3DG19 (section 2.6; and references therein) and Liu et al. (2020) for detailed definitions of these wave parameters.

Table 2: Wave parameters available in the WW3-ST6 wave hindcasts

File name	Definition
<i>1) Forcing fields</i>	
wnd	wind speed u_{10}, v_{10} (m s^{-1})
ice	ice concentration c_i (-)
<i>2) Standard mean wave parameters</i>	
hs	significant wave height H_s (m)
lm	mean wave length L_m (m)
t02	wave period $T_{0,2}$ (s)
t0m1	wave period $T_{0,-1}$ (s)
t01	wave period $T_{0,1}$ (s)
fp	peak frequency f_p (Hz)
dir	mean wave direction θ_m ($^\circ$)
spr	directional spreading σ_θ ($^\circ$)

Continued on next page

Table 2 – Continued from previous page

File name	Definition
dp	peak direction θ_p ($^\circ$)
mxex	expected space-time extreme (STE) wave crest height $\overline{C_{\max}}$ (m)
mxes	standard deviation (std) of $\overline{C_{\max}}$ (m)
mxh	expected STE linear wave height $\overline{H_{\max}}$ (m)
sdmh	std of $\overline{H_{\max}}$ (m)
mxhc	wave height associated to the expected STE linear crest height $\overline{H_{\max,c}}$ (m)
sdmhc	std of $\overline{H_{\max,c}}$ (m)
wbt	dominant wave breaking probability b_T (-)
dsf	wave spreading factor ϕ (-)
uorb	significant surface orbital velocity u_{orb} (m) [$u_{orb} = \pi H_s / T_{0.2}$]

4) Spectral partition parameters for wind sea and up to 2 swell systems

“?” below represents the identifier number for a given partition, where ?=0, 1, 2 denote wind sea, primary swell and secondary swell, respectively.

phs?	significant wave height H_s (m)
ptp?	peak wave period T_p (s)
plp?	peak wave length L_p (m)
pdir?	mean direction θ_m ($^\circ$)
pspr?	directional spreading σ_θ ($^\circ$)
pws?	wind sea fraction of the given partition W (-)
pdp?	peak direction θ_p ($^\circ$)
ptm10c?	wave energy period T_E (s) (i.e., $T_{0,-1}$) (s)
pt01c?	wave period $T_{0,1}$ (s)
pt02c?	wave period $T_{0,2}$ (s)
panr?	directional narrowness A_d at the spectral peak (-)
pbf1?	1D Benjamin-Feir index (BFI) BFI_{1D} (-)
pbf2?	1D Benjamin-Feir index (BFI) BFI_{2D} (-)
ppi1?	1D PI number Π_{1D} (-)
pwbt?	dominant wave breaking prob. b_T (-)
tws	wind sea fraction of the entire spectrum (-)

6) Wave-Ocean layer

tus	stokes volume transport ($\text{m}^2 \text{s}^{-1}$)
uus	stokes drift at sea surface (m s^{-1})

8) Spectrum parameters

mss	(down-wave & cross-wave) mean square slope $\langle s^2 \rangle$ (-)
msd	mean square slope direction ($^\circ$)
msc	Phillips tail constant (spectral tail level) (-)
mcd	tail slope direction ($^\circ$)

*) Derived parameters - will be calculated once the simulations are completed
- require sea surface temperature data

wmld	wave-induced mixed layer depth (m)
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2.2 Point output

The two-dimensional wave spectra at given wave buoy locations *during certain temporal periods* are also archived (Fig. 1), including buoys sourced from the U.S. National Data Buoy Center (NDBC; Meindl and Hamilton, 1992), Coastal Data Information Program (CDIP; Seymour et al., 1985), Canadian Marine Environmental Data Section (MEDS), ECMWF (Bidlot, 2017), Korea Meteorological Agency (KMA), Korea Hydrographic and Oceanographic Agency (KHOA; Ha et al., 2019), Australian Ocean Data Network (AODN) and Brazilian Navy PNBOIA (Pereira et al., 2017). A few buoys located in the Southern Ocean were sourced from Ocean Observatories Initiative (Trowbridge et al., 2019) and MetOcean Solutions (see also Young et al., 2020). The details of each buoy dataset, including the data duration, total number of stations, available wind and wave parameters, are summarized in Table 3. Some buoys may change their locations many times during their lifetime because of redeployment. Therefore, one should check the data files (i.e., `ww3_yyyyymm_spec.nc`) to get the specific locations and duration of each buoy.

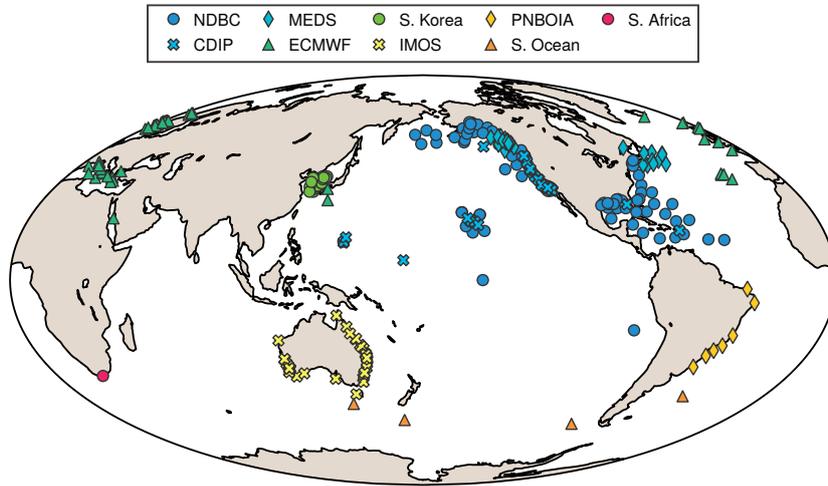


Figure 1: Locations of buoys selected to verify reanalysis winds and wave hindcasts (acronyms are introduced in Table 3).

3 Access to the hindcasts

The ST6 wave hindcasts are stored at the Mediaflux platform, maintained by the Research Computing Services (RCS) at the University of Melbourne (<https://wiki-rcs.unimelb.edu.au/display/RCS/Mediaflux>). The corresponding Mediaflux project is `proj-4320_ww3_st6_era5_hindcast-1128.4.274` and the full path to it in Mediaflux is `/projects/proj-4320_ww3_st6_era5_hindcast-1128.4.274`.

Table 3: Buoy datasets considered in our validation. Details presented include the operating agency or geographical region, duration of the entire dataset, total number of buoy stations ($\#$), minimum water depth d_{\min} used to filter buoys, available wind and wave parameters (U_z , wind speed at z m above the sea surface; θ_u , wind direction; H_s , significant wave height; $T_{0,2}$, mean zero-crossing period; T_p , peak period; θ_w , mean wave direction; θ_p , peak wave direction; $E(f)$, one-dimensional wave spectrum; $F(f, \theta)$, two-dimensional wave spectrum) and corresponding data source. U_x and T_x denote that the anemometer height and the definition of the reported wave periods are undocumented.

Region/Agency	Duration	$\#$ ¹	d_{\min} (m)	Parameters	Source
NDBC	01/1979 - 12/2018	102	100	$U_z, \theta_u, H_s, T_{0,2}, T_p, \theta_w, E(f), F(f, \theta)$	NOAA Marine Environmental Buoy Database
CDIP	09/1991 - 10/2019	47	100	$H_s, T_{0,2}, T_p, \theta_p, E(f), F(f, \theta)$	Coastal Data Information Program
MEDS	01/1979 - 10/2019	28	100	$U_x, \theta_u, H_s, T_p, E(f)$	Canadian Wave Data, Fisheries and Oceans Canada
ECMWF	08/1991 - 03/2019	78	100	$U_z, \theta_u, H_s, T_{0,2}, T_p, \theta_w$	J. Bidlot, G. Lemos, A. Semedo (only a subset of this dataset is used)
South Korea	01/1996 - 12/2019	30	0	$U_z, \theta_u, H_s, T_x, \theta_w$	Korea Meteorological Agency Korea Hydrographic and Oceanographic Agency Korea ocean research stations
Australia	01/1979 - 12/2018	41	0	$H_s, T_{0,2}, T_p, \theta_p$	AODN Integrated Marine Observing System
Brazil	04/2009 - 12/2018	7	100	$U_{10}, \theta_u, H_s, T_p, \theta_w$	Brazilian Navy PNBOIA
Southern Ocean	04/2010 - 12/2019	4	100	$U_z, \theta_u, H_s, T_{0,2}, T_p, \theta_w, E(f), F(f, \theta)$	Ocean Observatories Initiative (2) Australian Ocean Data Network (1) MetOcean Solutions (1)
South Africa	01/1998 - 12/2003	1	100	$H_s, T_{0,2}$	K. Machutcheon

¹A given buoy station may correspond to multiple geographical locations due to buoy redeployment.

3.1 Apply for an account

A granted account is desired to access the wave hindcasts. If you are interested in using our data for your research, please send us your name, email address and a few lines describing your research purpose briefly. We, with help of the RCS, will set up an account for you accordingly. For students and staff at the University of Melbourne, it is desired to use your [unimelb email](#) directly.

3.2 Login

There are multiple ways that we can choose to login the Mediaflux project, as explained in the [Mediaflux Wiki](#). For brevity, however, we present two methods only in the following sections, using the HTTPS protocol and sFTP, respectively.

3.2.1 Mediaflux Explorer (HTTPS Protocol)

It is recommended by the RCS that [Mediaflux Explorer](#) is the best starting place for working with Mediaflux data. The explorer for different systems (Windows, macOS and Linux) can be downloaded from <https://wiki-rcs.unimelb.edu.au/display/RCS/Mediaflux+Client+Downloads#MediafluxClientDownloads-explorer>.

Once you have the Mediaflux Explorer installed and started, follow the steps below to configure the server and to log in.

- (1) you must configure the Explorer to access the correct Mediaflux server. You just enter these into the appropriate entry boxes in the GUI that you see once you start the Explorer (Table 4 and Fig. 2).

Table 4: Configuration of the Mediaflux server

Entry	Box	Value
protocol	left-top	https
host	middle-top	mediaflux.researchsoftware.unimelb.edu.au
port	right-top	443

- (2) Mediaflux requires the triple of (domain, username and password) to log in (Fig. 2).

For [University of Melbourne Central \(Active Directory\) Account](#), you can login with your UoM credential (i.e., the account that you use routinely to login the unimelb laptop and desktop):

- Enter `unimelb` (staff accounts) or `student` (student accounts) into the Domain entry field
- Enter your usual institutional username (for the `user` field) and password (for the `password` field) and click Sign In .

For [local account](#) (e.g., non-institutional account or accounts for international users), you will have been provided by the RCS with the details for `domain`,



Figure 2: Mediaflux login GUI

user and password. Just enter them and click Sign In or Login. In this case, the domain field will be local.

3.2.2 sFTP (Secure File Transfer Protocol)

Mediaflux also supports the sFTP (Secure File Transfer Protocol), and hence you can use standard sFTP clients to login Mediaflux projects and download Mediaflux data. Here we choose the [FileZilla](https://filezilla-project.org/) client (a free software available for all desktop systems, i.e., Windows, macOS, and Linux; <https://filezilla-project.org/>) as an example.

Any sFTP tool needs to be configured with the details of the sFTP server that you are interacting with. The details for our Mediaflux sFTP service are

- protocol: sftp
- host/server: mediaflux.researchsoftware.unimelb.edu.au
- port: 22 or 9003

The service runs on port 9003 and port 22 is forwarded to 9003.

To proceed, start the FileZilla client, and configure the connection first:

- (1) From the File menu, click Site Manager, and then the New Site button;
- (2) Enter the connection details (host, port, protocol; see above and Fig. 3) on the General tab in the right hand pane;

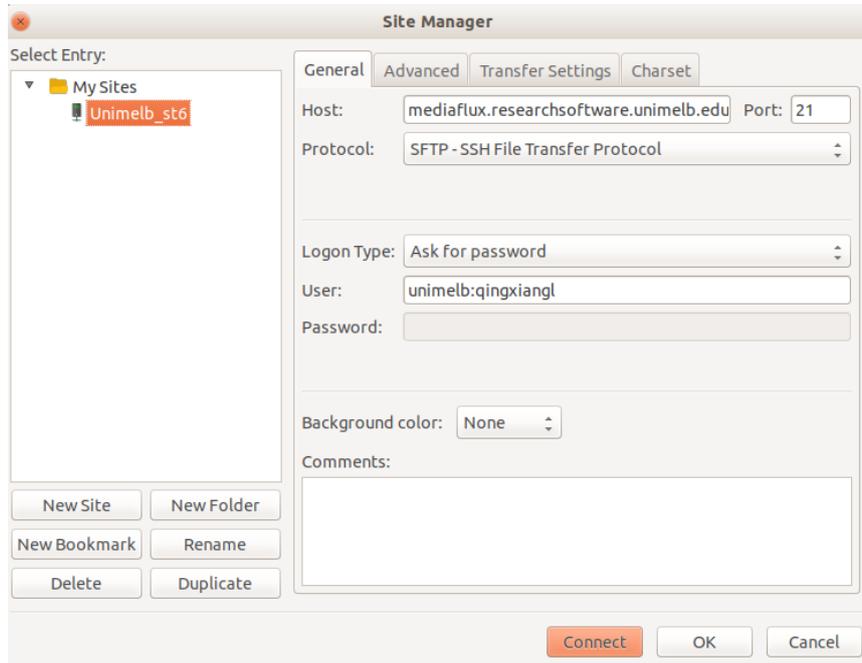


Figure 3: Configure connection in FileZilla (note that this screenshot is outdated, and therefore it is better to use 22 for port rather than 21.)

- (3) By selecting a login type of **Ask for password**, FileZilla will prompt for the password each time we connect. You can choose the **Normal** login type if you wish to save your password.
- (4) Click **Connect** and a new window will ask for your password. Enter it and click **OK**. As you have never connected to this host before, you will be prompted about an **Unknown host key**. If you tick **Always trust this host** you will not be prompted next time.

Note that the SFTP user name is a combination of the Domain and Username of the Mediaflux account (Fig. 3).

- **University of Melbourne Central (Active Directory) Accounts:**
 - Staff accounts: `unimelb:username`
 - Student accounts: `student:username`
- **Local accounts:** `domain:username`

3.3 Download data

3.3.1 Mediaflux Explorer

Once you login successfully, you will be able to see the main interface for the ST6 wave hindcasts. Click `projects/proj-4320_ww3_st6_era5_hindcast-1128.4.274` (Fig. 4)

and go through the file/folder (called as asset/collection in the Mediaflux terminology) as you wish.

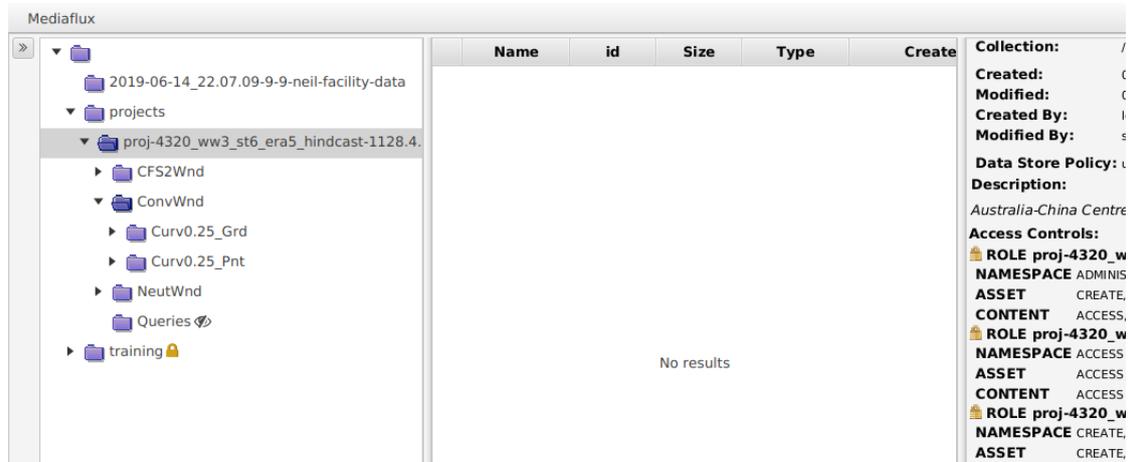


Figure 4: The main interface for the ST6 project shown in the Mediaflux Explorer.

Figure 4 illustrates how the hindcast data are archived. The folder (sub-collection) `proj-4320_ww3_st6_era5_hindcast-1128.4.274/ConvWnd` holds all the WW3 data that we currently have completed (1979-2019) using the ERA5 conventional winds U_{10} . Similarly, `NeutWnd`, `CFS2Wnd` and `BaExWnd` hold the run forced by the ERA5 neutral winds $U_{10,neu}$, the CFS winds and the ERA5 back extension data, respectively (Table 1). The sub-folder `Curv0.25_Grd` contains the gridded wave parameters over the whole global ocean; `Curv0.25_Pnt` consists of wave spectra at selected points only.

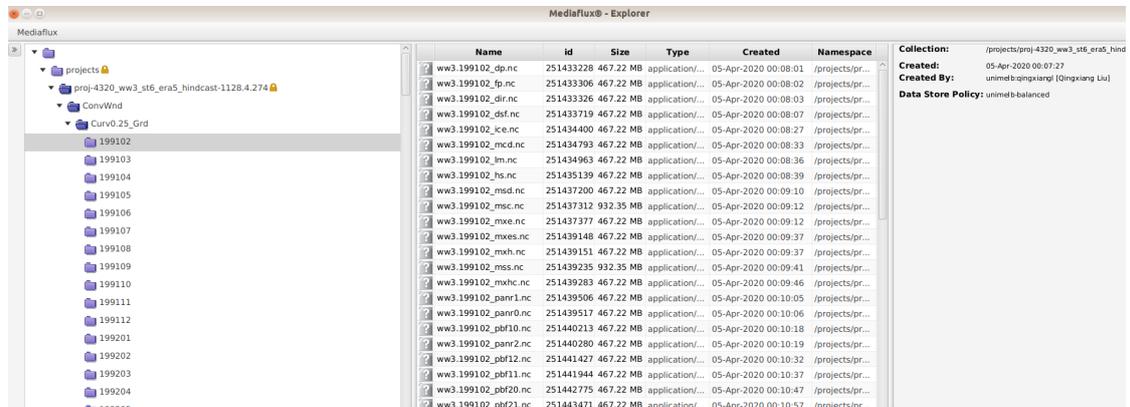


Figure 5: NC files under the folder (sub-collection) `projects/proj-4320_ww3_st6_era5_hindcast-1128.4.274/ConvWnd/Curv0.25_Grd/199102`.

Under the folder `Curv0.25_Grd`, wave data are stored by year and month with a folder name like `yyyymm` (left window in Fig. 5), and under a given month folder (e.g., `199102`), wave parameters presented in Table 2 are all archived in the netCDF4 format. Each

wave parameter corresponds to one netCDF file, which is named as `ww3.yyyyymm.xxx.nc` (middle window in Fig. 5). Here `xxx` denotes the short name for the given wave parameter (see 1st column of Table 2).

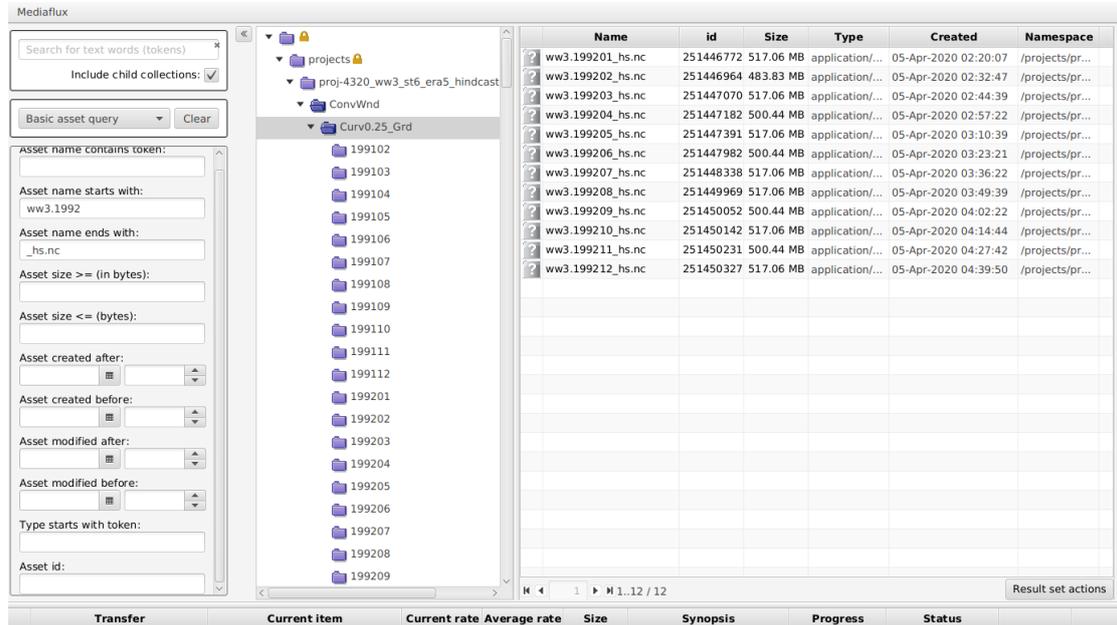


Figure 6: Illustration of the searching feature of the Explorer, where all the files for significant wave height H_s in the year 1992 are located.

It is pretty straightforward to download files from a particular folder on the Mediaflux platform, and [the video here](#) nicely demonstrates how to do this. It is a bit tricky, however, to download some particular wave parameters only across multiple folders (i.e., years and months). In this case, we need to use the searching feature of Mediaflux Explorer; please see [the video](#) for example. Note that the GUI shown in the video is slightly outdated. As an another example, Fig. 6 presents how to locate all the netCDF files for significant wave height H_s in 1992. This is achieved in 3 steps:

- (1) Choose a primary folder under which the files will be searched (e.g., the folder `ConvWnd` or the folder `Curv0.25_Grd`);
- (2) Activate the searching window by clicking the button  (to the leftmost-top of the Explorer) and pick the option “Include child collections” (watch [this video](#) if you could not find the button);
- (3) Use the field “Asset name starts with” (e.g., `ww3.1992` in Fig. 6) and the field “Asset name ends with” (e.g., `_hs.nc` in Fig. 6) – this will show all the `*_hs.nc` available for 1992. One can leave the field “Asset name starts with” empty if `*_hs.nc` files are needed for all the forty years. Note that it may take a few minutes for all the relevant files being searched and finally loaded.

3.3.2 sFTP

When using sFTP, the full path for the ST6 wave hindcast project becomes `/Volumes/proj-4320_ww3_st6_era5_hindcast-1128.4.274/`. Click the folder `ConvWnd/Curv0.25_Grd` to get the gridded wave parameters, or `ConvWnd/Curv0.25_Pnt` for point output. The organization of the data is described in the previous section, and therefore we will not repeat it here. Figure 7 illustrates the folder tree of the hindcast dataset in FileZilla.

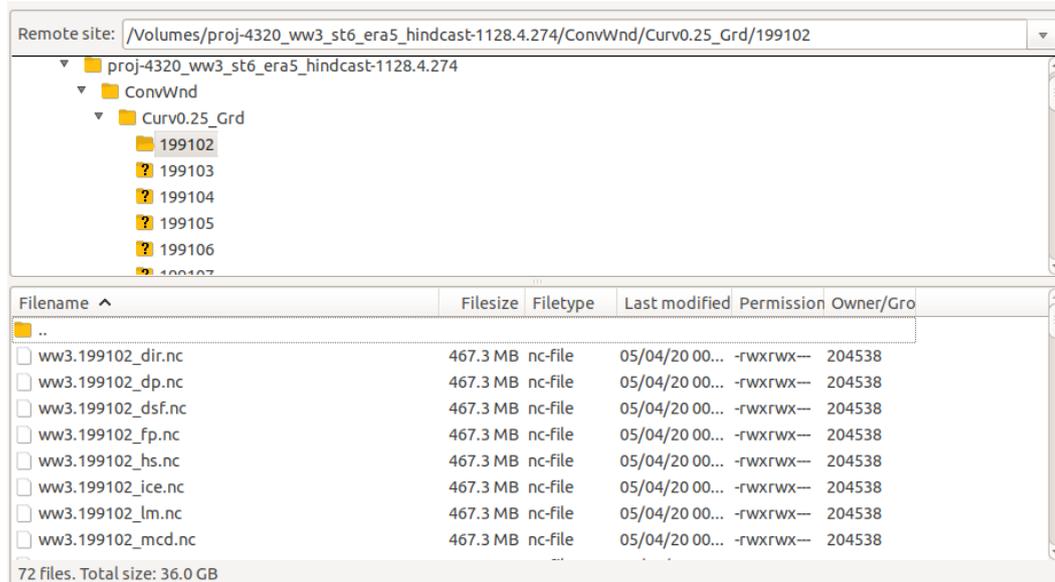
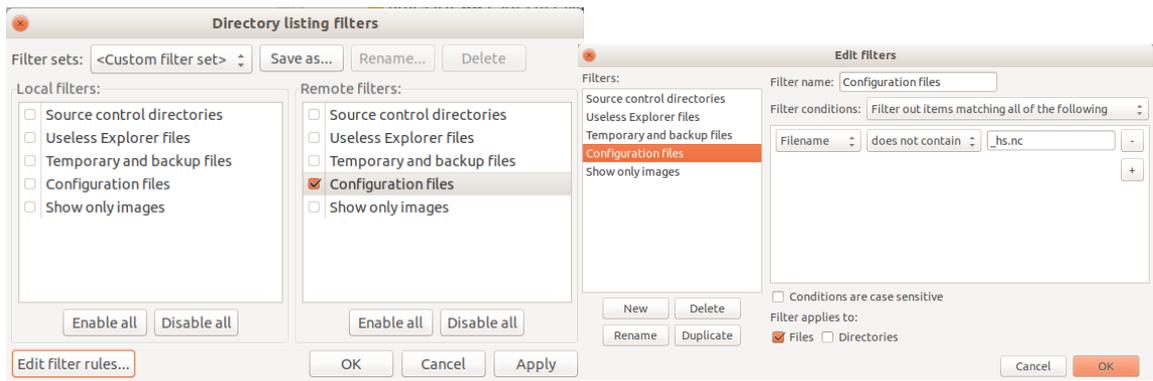


Figure 7: Illustration of the ST6 wave data shown in FileZilla.

Again, if you would like to download some particular wave parameters only across multiple years and months, follow the steps below:

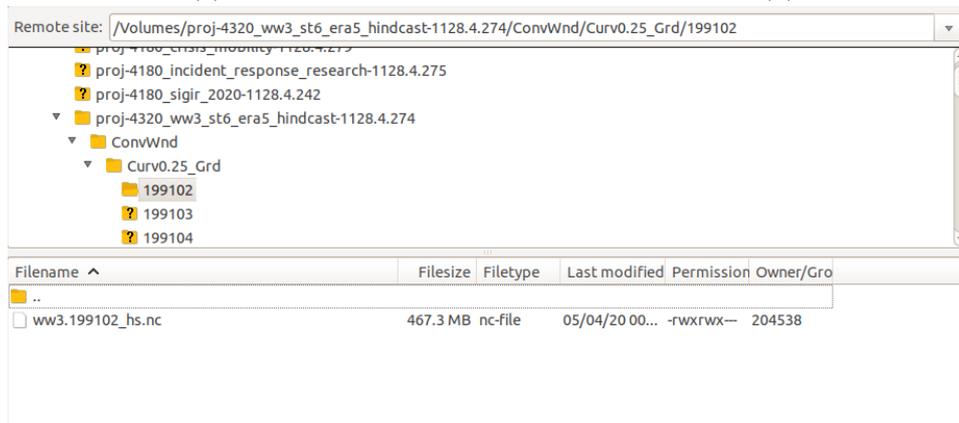
- (1) From the View menu, click “Directory listing filters ...”, the window shown in Fig. 8a will pop up.
- (2) Choose the option “Configuration files” on the Remote filters tab (Fig. 8a), and then “Edit filter rules ...” – another window shown in Fig. 8b will pop up.
- (3) Click “Configuration files” and edit the respective filter conditions as you wish. When all the filters are setup properly, click “OK” and then go back to the main interface of FileZilla. As ruled by the filter shown in Fig. 8b, now only netCDF files for wave height (`*_hs.nc`) will be displayed in the FileZilla folder tree (Fig. 8c).

It is worth mentioning that it is possible to set up multiple filters so that we can get multiple wave parameters. Figure 9 provides another example which uses 3 filters to download wave height H_s , peak frequency f_p and mean wave direction θ_m .



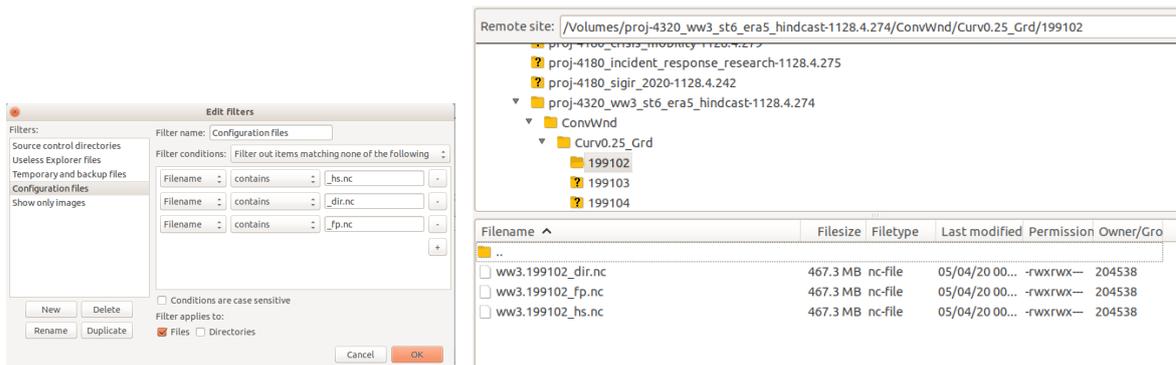
(a)

(b)



(c)

Figure 8: Directory list filters in FileZilla.



(a)

(b)

Figure 9: Another example for using directory list filters in FileZilla.

4 Report problems

To this point, we think we have provided necessary details for accessing the data and for the WW3-ST6 hindcast dataset itself. But if you find anything unclear or any problems in the dataset, feel free to contact us [email: qingxiang.liu@unimelb.edu.au (Q. Liu); a.babanin@unimelb.edu.au (A. Babanin)].

For problems related to your Mediaflux account (i.e., login, connection, etc.), please report your issue to

- UoM Staff: <http://go.unimelb.edu.au/or96>;
- UoM Students: <http://go.unimelb.edu.au/4exr>;
- External Users: <http://go.unimelb.edu.au/s6qr>.

When reporting issues, please mention explicitly the name of the ST6 project, that is, `proj-4320_ww3_st6_era5_hindcast-1128.4.274`.

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