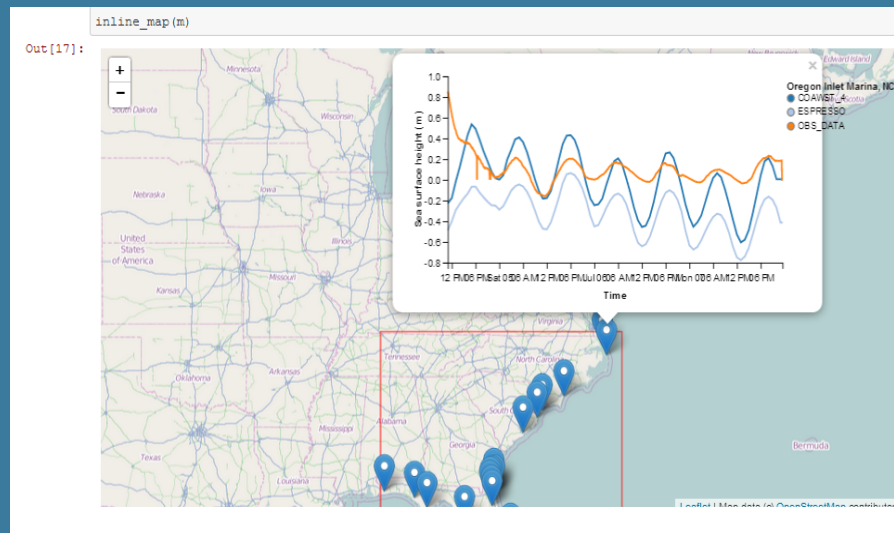
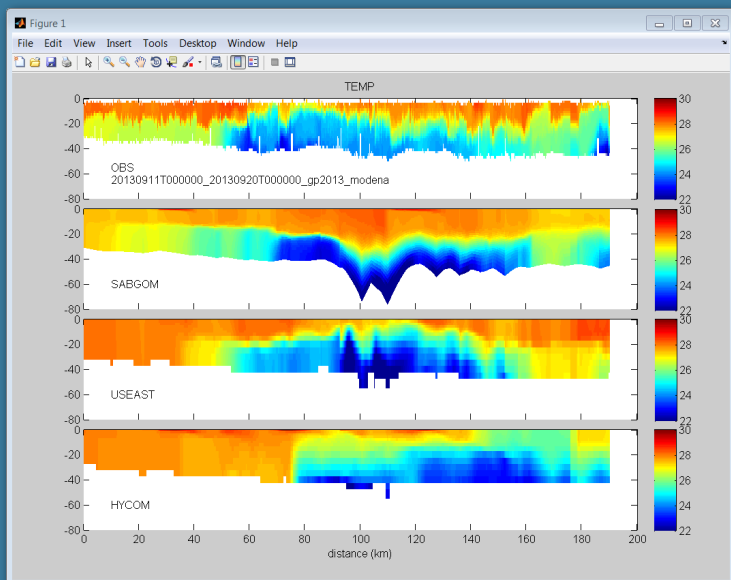


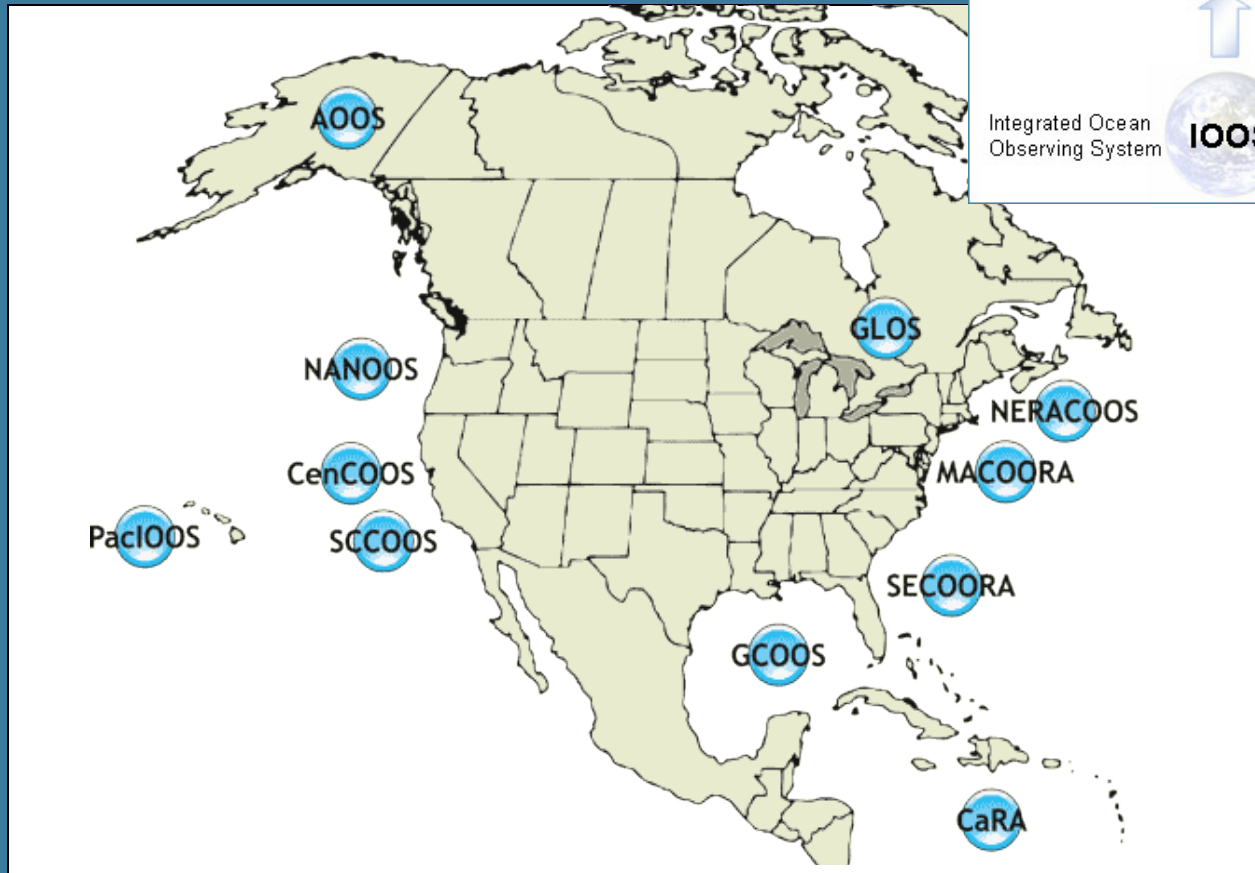
Tools for Ocean, Atmosphere & Climate Model Data Interoperability

Rich Signell (USGS-CMG)
 USGS Woods Hole, MA
 COAWST Training Workshop
 Woods Hole, MA: Aug 15-19, 2016



US Integrated Ocean Observing System (IOOS[®])

- 17 Federal Agencies
- 11 Regional Associations

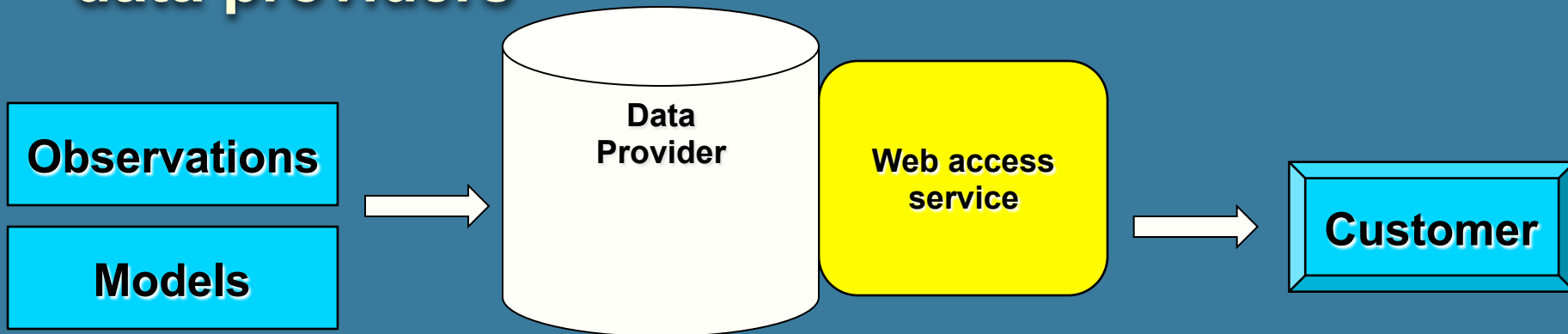


IOOS Core Principles

- Adopt open standards & practices



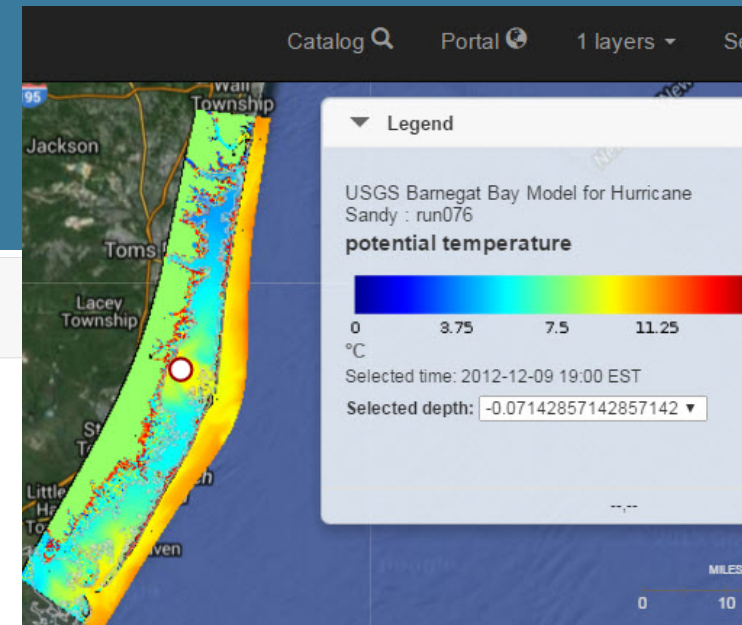
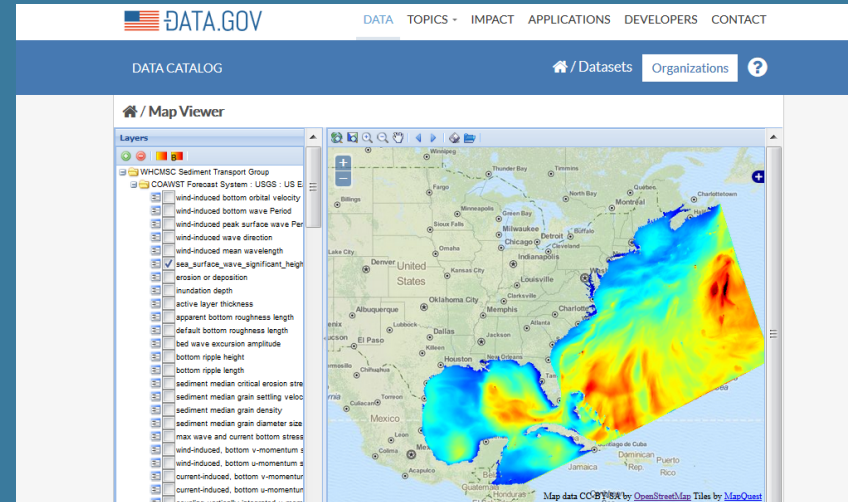
- Avoid customer-specific stovepipes
- Standardized access services implemented at data providers



From pile of files to interoperability

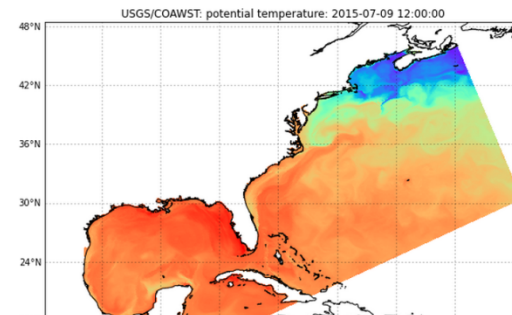
Raw Dataset files

Standardized
Search and
Browse



```
In [16]: model = 'USGS/COAWST'
url = 'http://geoport.whoi.edu/thredds/dodsC/coawst_4/use/fmrc/coawst_4_use_best.ncd'
var = 'sea_water_potential_temperature'
lev = -1
icube = var_lev_date(url=url, var=var, mytime=mytime, lev=lev, subsample=1)
map_plot(icube, model=model)

slice retrieved in 48.000320 seconds
```

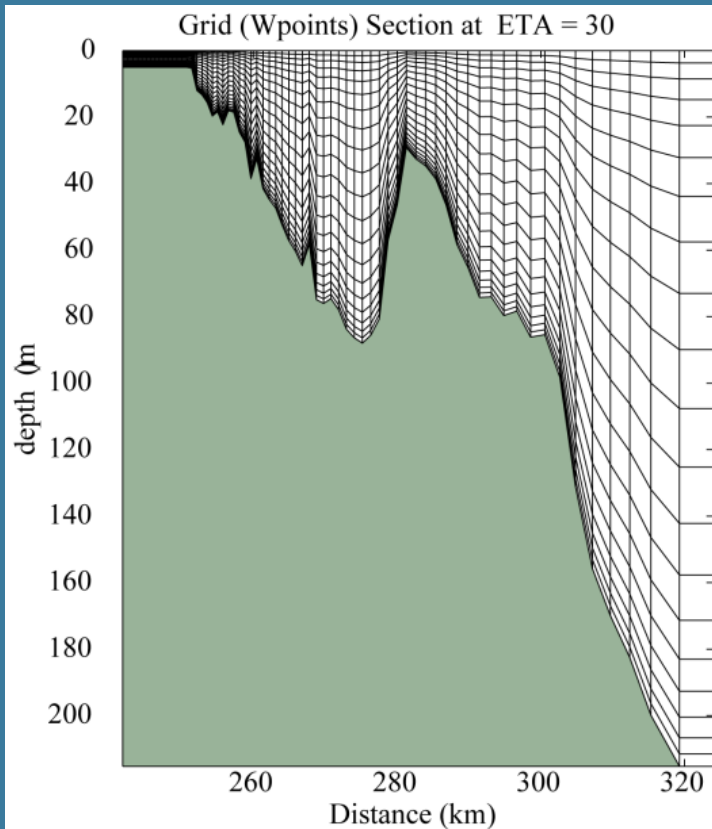


Standardized
Data Access

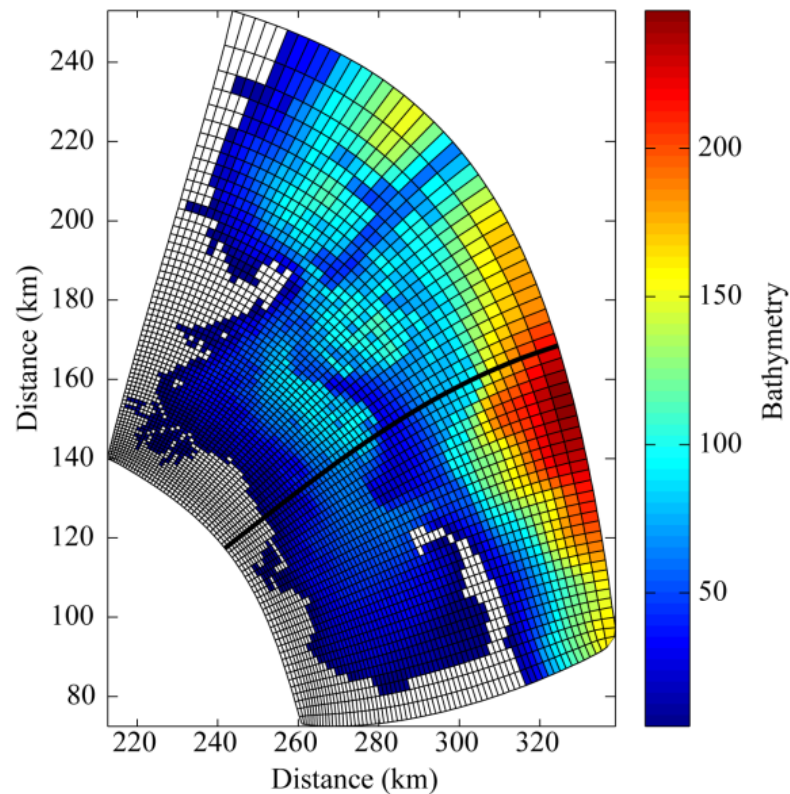


Ocean grids are often not regularly spaced!

Stretched surface and terrain following vertical coordinates



Curvilinear orthogonal horizontal coordinates



CF Conventions for met/ocean models

```
float temp(ocean_time, s_rho, eta_rho, xi_rho) ;  
    temp: standard_name = "sea_water_potential_temperature" ;  
    temp: units = "Celsius" ;  
    temp: coordinates = "lon_rho lat_rho s_rho ocean_time" ;  
  
double s_rho(s_rho) ;  
    s_rho: long_name = "S-coordinate at RHO-points" ;  
    s_rho: positive = "up" ;  
    s_rho: standard_name = "ocean_s_coordinate_g1" ;  
    s_rho: formula_terms = "s: s_rho C: Cs_r eta: zeta  
                           depth: h depth_c: hc "
```

Some of the groups using CF:

OGC: Open Geospatial Consortium

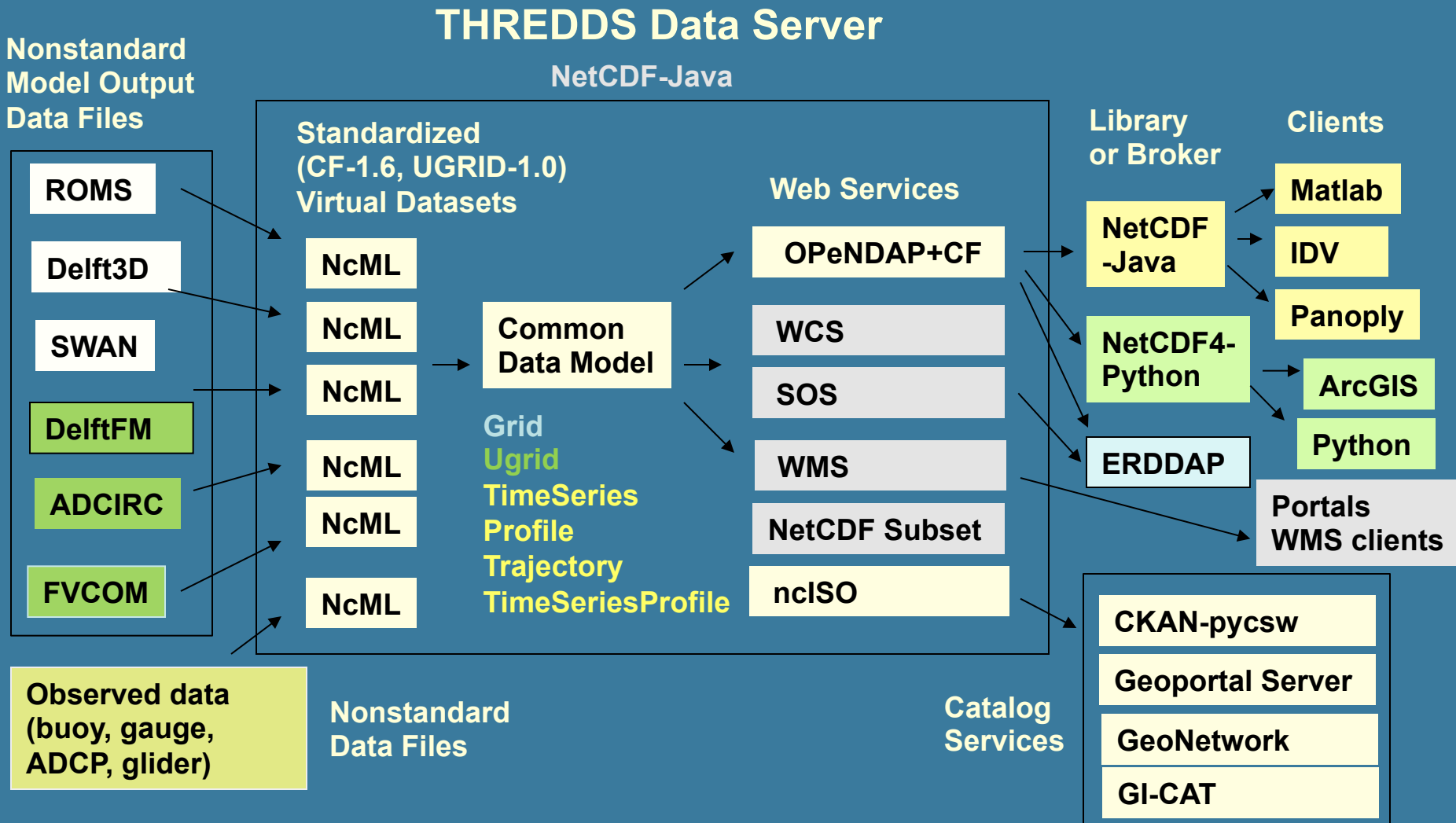
ODIP: Ocean Data Interoperability Platform

IOOS: Integrated Ocean Observing System

CMIP: Coupled Model Intercomparison Project (supporting IPCC)



IOOS Model Data Interoperability Design



Matlab NCTOOLBOX

<https://github.com/nctoolbox>

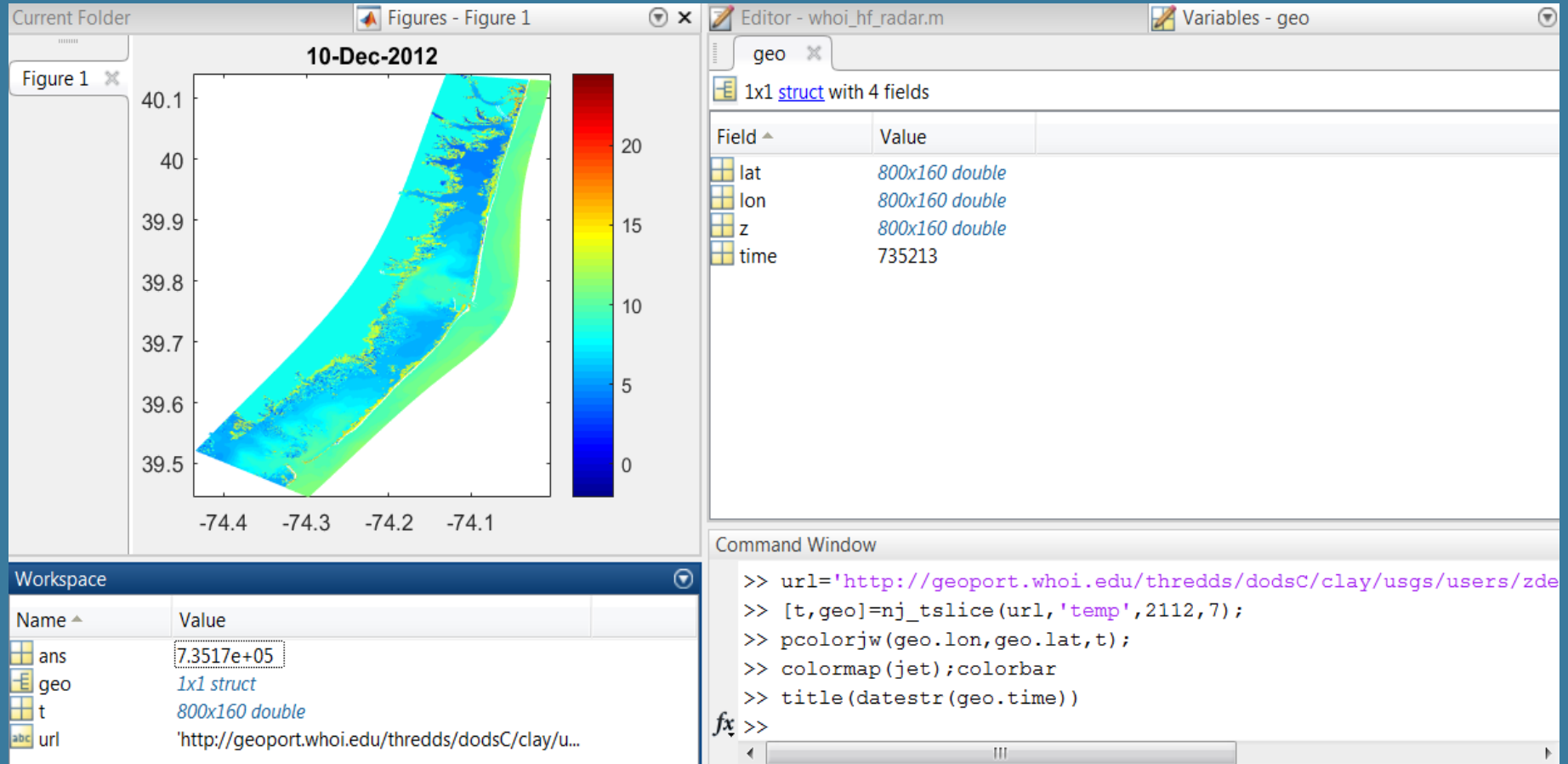
- Objective: Make it simple to access CF data
- Example function:
- `[t, geo]=nj_tslice(URL,'temp',1);`
- `t = 7x800x160 single`
- `geo =`
 - `lat: [800x160 single]`
 - `lon: [800x160 single]`
 - `z: [7x800x160 double]`
 - `time: 735169.0208 (matlab datenum)`
- `nj_tslice` works identically for COAWST/ROMS, WRF, HYCOM, Delft3D, Wavewatch3
- URL can be: local NetCDF, NcML, OpenDAP Data URL

1005

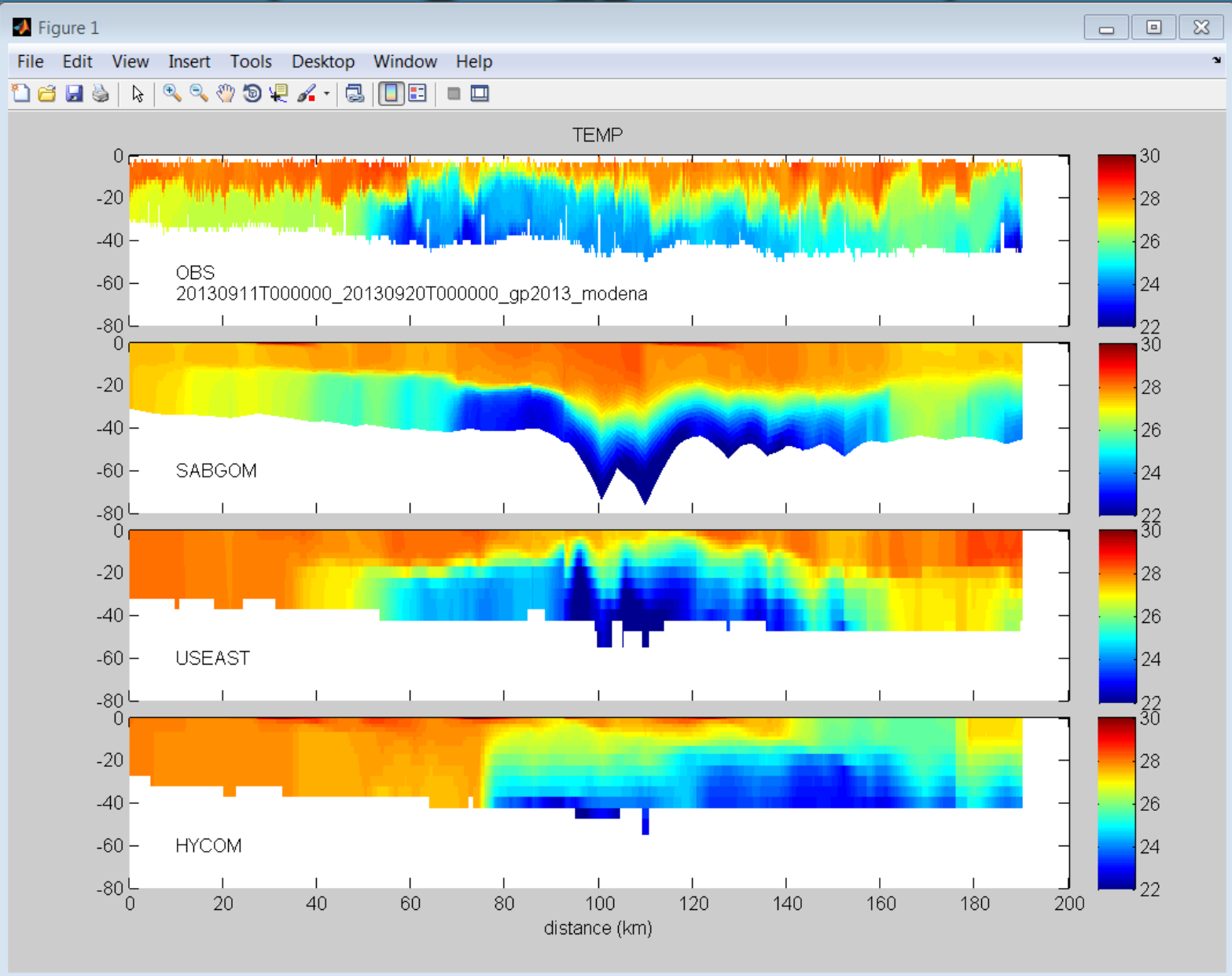


Matlab NCTOOLBOX

<https://github.com/nctoolbox>



compare_secoora_model_sections.m (using nc_genslice.m)



Approach for Small Research Groups



Ocean Science

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04 May 2016

Technical note

Technical note: Harmonising metocean model data via standard web services within small research groups

Richard P. Signell¹ and Elena Camossi²

¹USGS Woods Hole Coastal and Marine Science Center, Woods Hole, MA, USA
²NATO Science & Technology Organization, Centre for Maritime Research and Experimentation, La Spezia, Italy

Received: 17 Jul 2015 – Published in Ocean Sci. Discuss.: 05 Nov 2015
Revised: 22 Feb 2016 – Accepted: 21 Mar 2016 – Published: 04 May 2016

Abstract. Work over the last decade has resulted in standardised web services and tools that can significantly improve the efficiency and effectiveness of working with meteorological and ocean model data. While many operational modelling centres have enabled query and access to data via common web services, most small research groups have not. The penetration of this approach into the research community, where IT resources are limited, can be dramatically improved by (1) making it simple for providers to enable web service access to existing output files; (2) using free technologies that are easy to deploy and configure; and (3) providing standardised, service-based tools that work in existing research environments. We present a simple, local brokering approach that lets modellers continue to use their existing files and tools, while serving virtual data sets that can be used with standardised tools. The goal of this paper is to convince modellers that a standardised framework is not only useful but can be implemented with modest effort using free software components. We use NetCDF Markup language for data aggregation and standardisation, the THREDDS Data Server for data delivery, pycsw for data search, NCTOOLBOX (MATLAB®) and Iris (Python) for data access, and Open Geospatial Consortium Web Map Service for data preview. We illustrate the effectiveness of this approach with two use cases involving small research modelling groups at NATO and USGS.

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Short summary

A collection of tools and techniques are described which allow small research groups to deliver...

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SNIP 0.940

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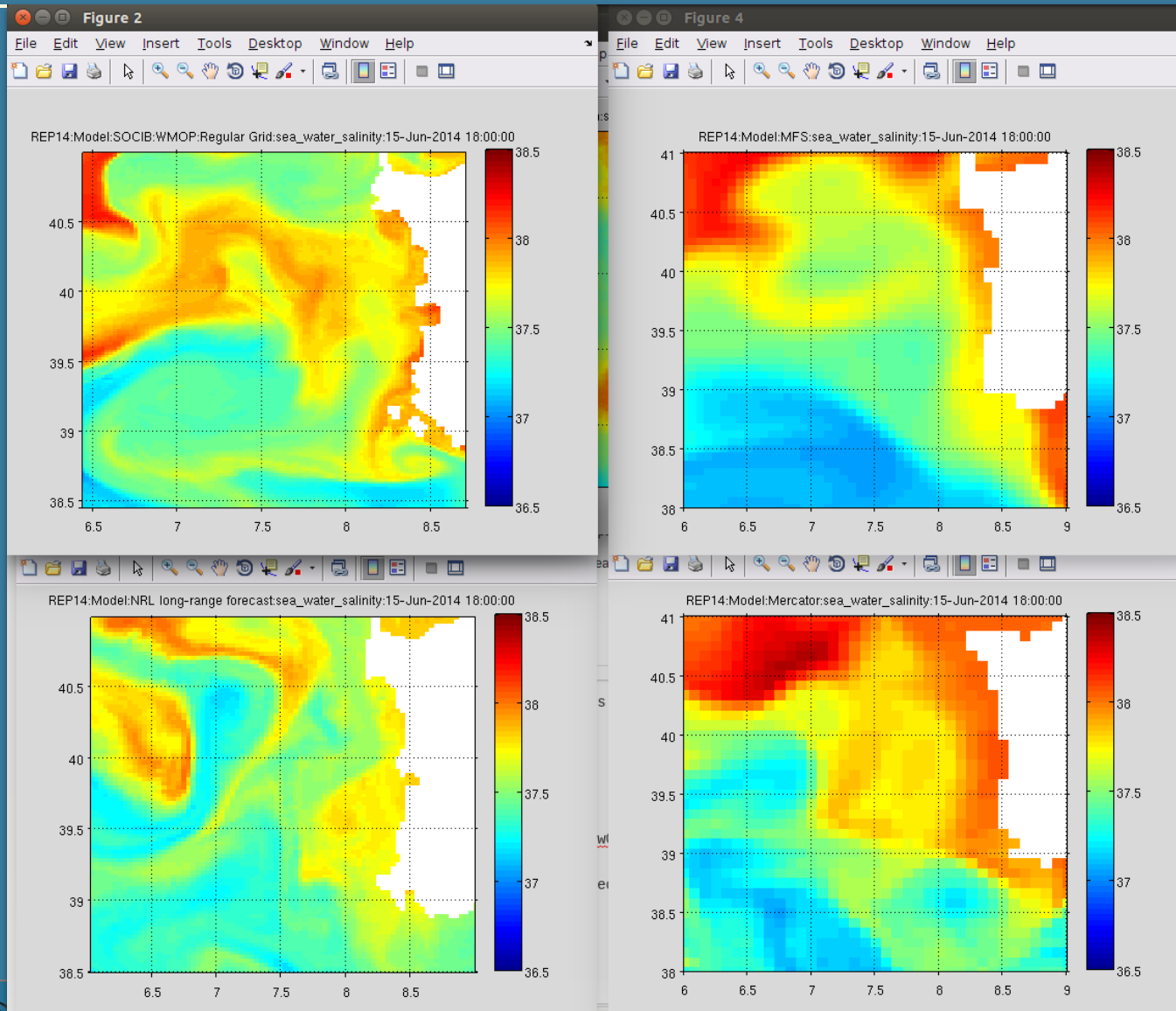
For reviewers

User ID

Password

New user? Lost login?

Deployment at NATO



Automated model comparison

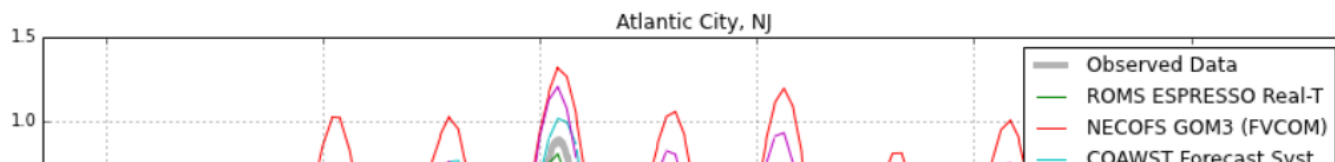
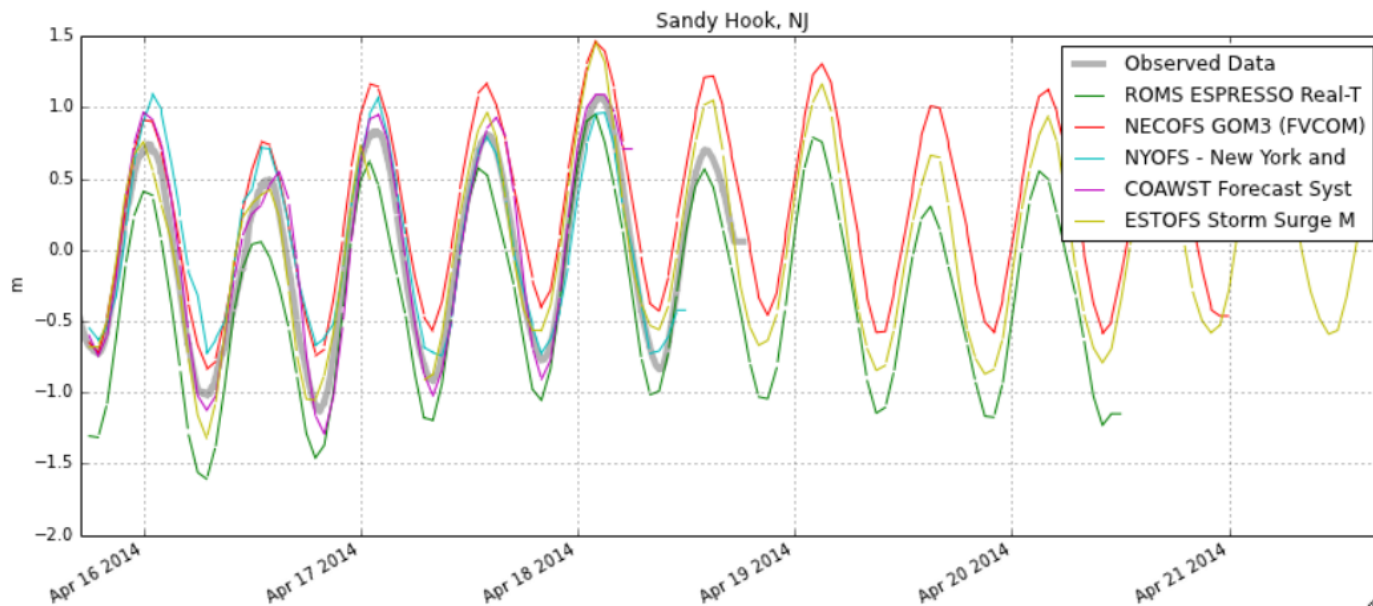
IP[y]: Notebook

IOOS_inundation Last Checkpoint: Mar 15 16:08 (autosaved)

File Edit View Insert Cell Kernel Help

Code Cell Toolbar: None

```
In [45]: for df in obs_df:
          df.plot(figsize=(14,6),title=df.name)|
          ylabel('m')
```



Catalog Search



[DATA](#) [TOPICS](#) [IMPACT](#) [APPLICATIONS](#) [DEVELOPERS](#) [CONTACT](#)

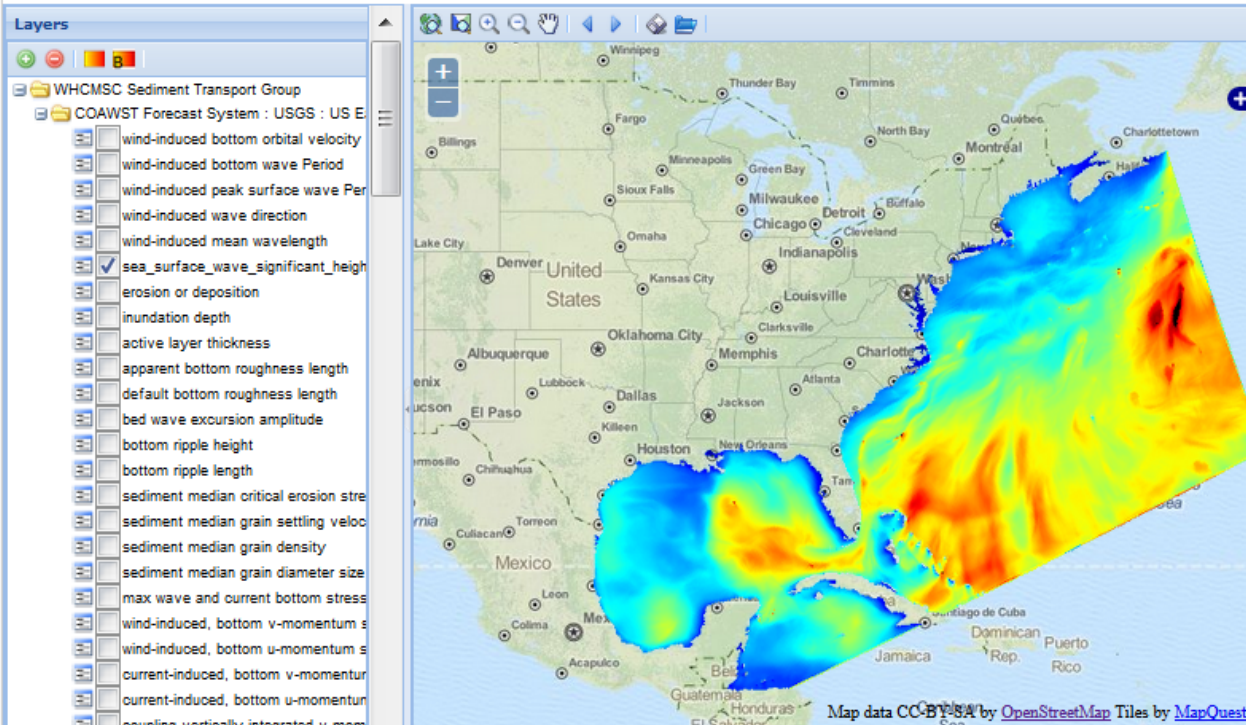
DATA CATALOG

[/ Datasets](#)

[Organizations](#)



[/ Map Viewer](#)



Catalog services can be federated via
OGC CSW (Catalog Service for the Web)

WMS Browsing with THREDDS/ncWMS

← → ↺ geoport.whoi.edu/thredds/godiva2/godiva2.html?server=http://geoport.whoi.edu/thredds/wms/clay/usgs/users/zdfne/ru

☒ Auto-zoom on select

WHCMSC Sediment Transport Group

- USGS Barnegat Bay Model for Hurricane Sandy : run076
 - wet/dry mask on V-points
 - barotropic_y-sea_water_velocity
 - bottom v-momentum stress
 - bathymetry at RHO-points
 - Coriolis parameter at RHO-points
 - curvilinear coordinate metric in XI
 - curvilinear coordinate metric in ETA
 - angle between XI-axis and EAST
 - mask on RHO-points
 - sea_water_potential_temperature
 - sea_water_salinity
 - suspended noncohesive sediment, size class 01
 - suspended noncohesive sediment, size class 02
 - suspended noncohesive sediment, size class 03
 - suspended noncohesive sediment, size class 04
 - density anomaly
 - wet/dry mask on RHO-points
 - sea_surface_height_above_datum

Layer: WHCMSC Sediment Transport Group > USGS Barnegat Bay Model for Hurricane Sandy : run076 > sea_water_potential_temperature
Units: degree_Celcius
Depth (l): 0.07142857142857142 ▾
Date/time: 10 Dec 2012 00:00:00 ▾ UTC [first frame](#) [last frame](#)

[Fit layer to window](#)

December, 2012
« < Today > »
Sun Mon Tue Wed Thu Fri Sat
1
2 3 4 5 6 7 8
9 10 11 12 13 14 15
16 17 18 19 20 21 22
23 24 25 26 27 28 29
30 31
Select date

15
10.00
0

boxfill ▾
linear ▾
[auto](#)
[lock](#)

0

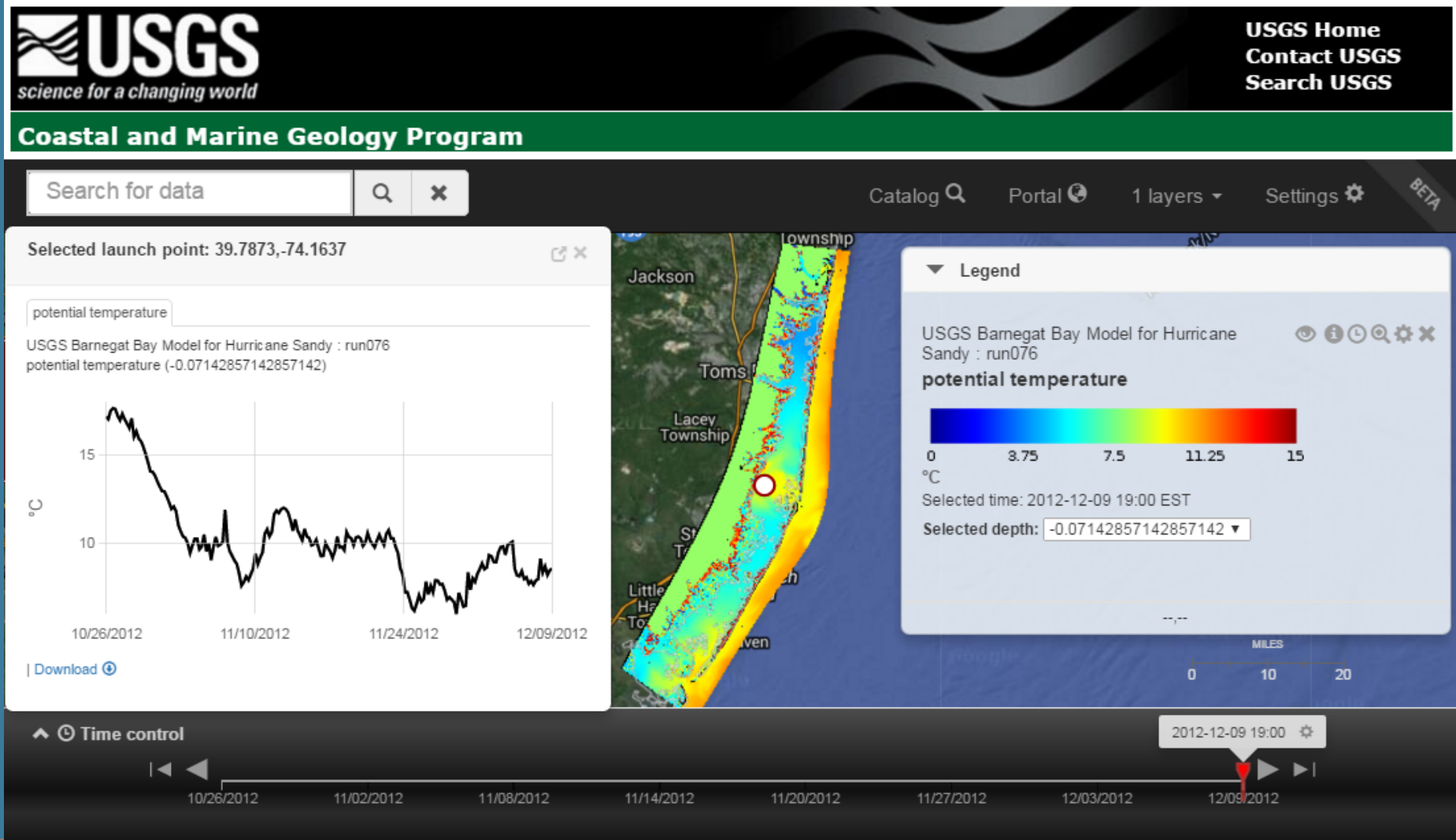
Overlay opacity: 100% ▾

[User guide](#)

[test image](#)

Reading e-Science Centre

WMS Browsing with CMG Oceanographic Portal



NetCDF Subset Service to CSV



[WHCMSC Sediment Transport Group](#)

[THREDDS Data Server](#)

Catalog http://geoport.who.edu/thredds/catalog/coawst_4/use/fmrc/catalog.html

Dataset: coawst_4_use/Best Time Series

- *Data format:* netCDF
- *Data type:* GRID
- *Naming Authority:* gov.usgs.er.whsc
- *ID:* coawst_4/use/fmrc/coawst_4_use_best.ncd

Documentation:

- **summary:** Best time series, taking the data from the most recent run available.
- **summary:** ROMS USE Output from COAWST
- [Carolinas Coastal Change Program](#)
- [ReadMe.txt](#)

Access:

1. **OPENDAP:** /thredds/dodsC/coawst_4/use/fmrc/coawst_4_use_best.ncd
2. **NetcdfSubset:** /thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd
3. **WMS:** /thredds/wms/coawst_4/use/fmrc/coawst_4_use_best.ncd
4. **ISO:** /thredds/iso/coawst_4/use/fmrc/coawst_4_use_best.ncd
5. **NCML:** /thredds/ncml/coawst_4/use/fmrc/coawst_4_use_best.ncd
6. **UDDC:** /thredds/uddc/coawst_4/use/fmrc/coawst_4_use_best.ncd



NCSS Grids As Point Data (Gridded Dataset)



Dataset: /thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd (Gridded Dataset Description)

Base Time: 2012-06-25T01:00:00Z

You must select at least one Variable and a Lat/Lon location.

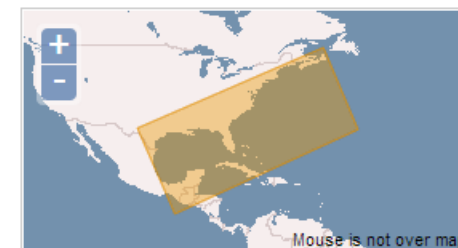
Select Variable(s):

- ☐ angle = angle between XI-axis and EAST
- ☐ f = Coriolis parameter at RHO-points
- ☐ h = bathymetry at RHO-points
- ☐ mask_psi = mask on psi-points
- ☐ mask_rho = mask on RHO-points
- ☐ mask_u = mask on U-points
- ☐ mask_v = mask on V-points
- ☐ pm = curvilinear coordinate metric in XI
- ☐ pn = curvilinear coordinate metric in ETA

Variables with Time coordinate time

- ☐ Dwave = wind-induced wave direction
- ☒ Hwave = wind-induced significant wave height
- ☐ Lwave = wind-induced mean wavelength
- ☐ Pwave_bot = wind-induced bottom wave Period
- ☐ Pwave_top = wind-induced peak surface wave Period
- ☐ Uwave_rms = wind-induced bottom orbital velocity
- ☐ Uwind = surface u-wind component
- ☐ Vwind = surface v-wind component
- ☐ Zo_app = apparent bottom roughness length
- ☐ Zo_def = default bottom roughness length
- ☐ bed_wave_amp = bed wave excursion amplitude
- ☐ bedload_Usand_01 = bed load flux of sand in U-direction, size class 01
- ☐ bedload_Usand_02 = bed load flux of sand in U-direction, size class 02
- ☐ bedload_Usand_03 = bed load flux of sand in U-direction, size class 03
- ☐ bedload_Usand_04 = bed load flux of sand in U-direction, size class 04
- ☐ bedload_Usand_05 = bed load flux of sand in U-direction, size class 05
- ☐ bedload_Usand_06 = bed load flux of sand in U-direction, size class 06

Choose Lat/Lon Location:



Latitude: 39.5
Longitude: -69.5
Within Bounding Box:
north
48.4639
west -101.7498 -53.2530 east
11.8884
south

Choose Time Subset:

Time range Single time

Starting: 2014-08-27T01:00:00Z

Ending: 2014-08-28T00:00:00Z

[reset to full extension](#)

Choose Vertical Level:

Level:

Choose Output Format:

Format: CSV

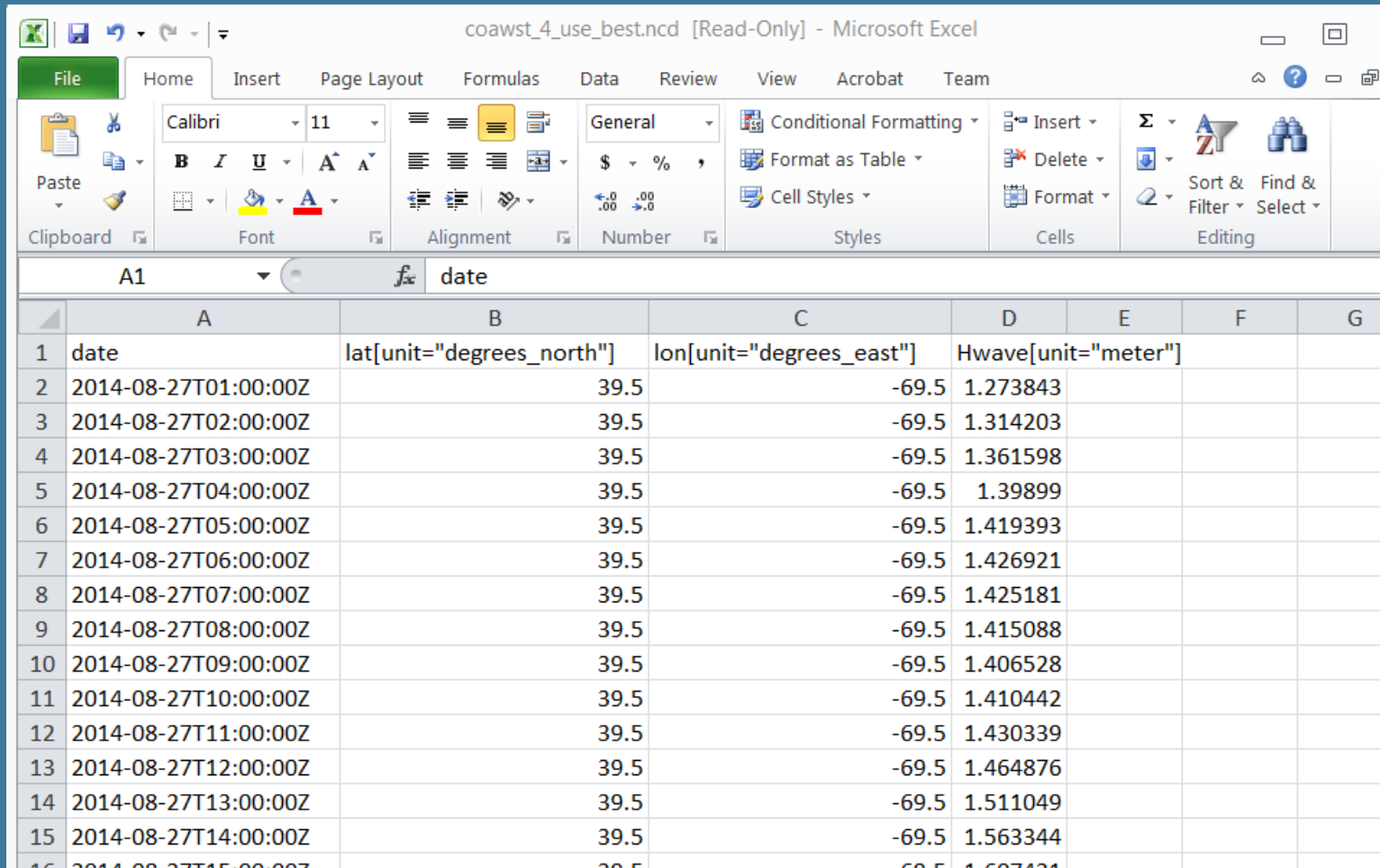
CSV Time Series from Subset Service

```
date,lat[unit="degrees_north"],lon[unit="degrees_east"],Hwave[unit="meter"]
2014-08-27T01:00:00Z,39.5,-69.5,1.273842692375183
2014-08-27T02:00:00Z,39.5,-69.5,1.3142027854919434
2014-08-27T03:00:00Z,39.5,-69.5,1.3615976572036743
2014-08-27T04:00:00Z,39.5,-69.5,1.398990273475647
2014-08-27T05:00:00Z,39.5,-69.5,1.419392704963684
2014-08-27T06:00:00Z,39.5,-69.5,1.426921010017395
2014-08-27T07:00:00Z,39.5,-69.5,1.4251813888549805
2014-08-27T08:00:00Z,39.5,-69.5,1.4150882959365845
2014-08-27T09:00:00Z,39.5,-69.5,1.406528115272522
2014-08-27T10:00:00Z,39.5,-69.5,1.4104422330856323
2014-08-27T11:00:00Z,39.5,-69.5,1.4303393363952637
2014-08-27T12:00:00Z,39.5,-69.5,1.4648756980895996
2014-08-27T13:00:00Z,39.5,-69.5,1.5110485553741455
2014-08-27T14:00:00Z,39.5,-69.5,1.5633442401885986
2014-08-27T15:00:00Z,39.5,-69.5,1.6074210405349731
2014-08-27T16:00:00Z,39.5,-69.5,1.6265686750411987
2014-08-27T17:00:00Z,39.5,-69.5,1.6184144020080566
2014-08-27T18:00:00Z,39.5,-69.5,1.5933209657669067
2014-08-27T19:00:00Z,39.5,-69.5,1.5608850717544556
2014-08-27T20:00:00Z,39.5,-69.5,1.527510643005371
2014-08-27T21:00:00Z,39.5,-69.5,1.5050616264343262
2014-08-27T22:00:00Z,39.5,-69.5,1.5094025135040283
2014-08-27T23:00:00Z,39.5,-69.5,1.5698728561401367
2014-08-28T00:00:00Z,39.5,-69.5,1.7087903022766113
```

CSV request is a “RESTful” URL:

**[http://geoport.whoi.edu/thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd?](http://geoport.whoi.edu/thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd?var=Hwave&latitude=39.5&longitude=-69.5&time_start=2014-08-27T01:00:00Z&time_end=2014-08-28T00:00:00Z&vertCoord=&accept=csv)
[var=Hwave&latitude=39.5&longitude=-69.5&time_start=2014-08-27T01:00:00Z&time_end=](http://geoport.whoi.edu/thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd?var=Hwave&latitude=39.5&longitude=-69.5&time_start=2014-08-27T01:00:00Z&time_end=2014-08-28T00:00:00Z&vertCoord=&accept=csv)
[2014-08-28T00:00:00Z&vertCoord=&accept=csv](http://geoport.whoi.edu/thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd?var=Hwave&latitude=39.5&longitude=-69.5&time_start=2014-08-27T01:00:00Z&time_end=2014-08-28T00:00:00Z&vertCoord=&accept=csv)**

Accessing the CSV data in Excel



The screenshot shows the Microsoft Excel interface with the file 'coawst_4_use_best.ncd' open in Read-Only mode. The ribbon is set to 'Home', and the 'Data' tab is active. The data is imported as a table with the following columns:

	A	B	C	D	E	F	G
1	date	lat[unit="degrees_north"]	lon[unit="degrees_east"]	Hwave[unit="meter"]			
2	2014-08-27T01:00:00Z	39.5	-69.5	1.273843			
3	2014-08-27T02:00:00Z	39.5	-69.5	1.314203			
4	2014-08-27T03:00:00Z	39.5	-69.5	1.361598			
5	2014-08-27T04:00:00Z	39.5	-69.5	1.39899			
6	2014-08-27T05:00:00Z	39.5	-69.5	1.419393			
7	2014-08-27T06:00:00Z	39.5	-69.5	1.426921			
8	2014-08-27T07:00:00Z	39.5	-69.5	1.425181			
9	2014-08-27T08:00:00Z	39.5	-69.5	1.415088			
10	2014-08-27T09:00:00Z	39.5	-69.5	1.406528			
11	2014-08-27T10:00:00Z	39.5	-69.5	1.410442			
12	2014-08-27T11:00:00Z	39.5	-69.5	1.430339			
13	2014-08-27T12:00:00Z	39.5	-69.5	1.464876			
14	2014-08-27T13:00:00Z	39.5	-69.5	1.511049			
15	2014-08-27T14:00:00Z	39.5	-69.5	1.563344			
16	2014-08-27T15:00:00Z	39.5	-69.5	1.607431			

Access the CSV data in Python, R, etc

Wakari RESTful_model_assessment

View Other Bundles by rsignell Download Entire Bundle Download This Notebook Run/Edit this Notebook

```
var=%lat=42.801000&longitude=-70.169000&time_start=2014-08-23T16:01:13Z&time_end=2014-08-28T16:01:13Z&rtCoord=&accept=csv' % (var,lat,lon,start,stop)
print(url)

http://geoport.whoi.edu/thredds/ncss/grid/coawst_4/use/fmrc/coawst_4_use_best.ncd?var=Hwave&lat=42.801000&longitude=-70.169000&time_start=2014-08-23T16:01:13Z&time_end=2014-08-28T16:01:13Z&rtCoord=&accept=csv
```

In [11]: #load model data CSV into Pandas DataFrame

```
df_mod = pd.read_csv(url,index_col='date',parse_dates=True)
```

Plot the time series

In [12]:

```
fig, ax = plt.subplots(figsize=(12, 4))
ax = df_mod['Hwave[unit="meter"]'].plot(ax=ax, legend=True)
df_obs['wvht'].plot(ax=ax, legend=True)
ax.set_title('Wave Height at Station %s' % station);
```

Wave Height at Station 44098

Legend: Hwave[unit="meter"] (blue line), wvht (green line)

Y-axis: 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4

X-axis: 24 Aug 2014, 25, 26, 27, 28

Service-based Framework Components

- Common data models for “feature types” (structured and unstructured grids, time series, profiles, swaths) (Unidata CDM)
- Standard web data services for delivering these common data model “feature types” (OPeNDAP, SOS)
- Standard catalog services for the metadata
- Tools to search, access and process these services in common analysis environments: R, Matlab, Python, ArcGIS, JavaScript

Getting model data connected

- Find someone with a THREDDS Data Server or [install your own](#)
- Drop your files in a directory, and add an NcML file that starts with “00_dir” (e.g. “00_dir_roms.ncml”) to aggregate, standardize and describe the dataset:
[Sample ROMS NcML file](#)
- If you want your data to end up in the portal, add “CMG_Portal” to the “project” attribute:
`<attribute name=“project”value=“CMG_Portal”/>`
- If you want your datasets to be discoverable, edit the list of thredds catalogs on CMG github repo, submit PR
- Full instructions on the [USGS-CMG Portal Github Wiki](#)

Framework benefits

- Lots of choices for data access (Browser, Matlab, Python, R, Excel)
- Less time wasted messing with data, more time spent on science
- Less time responding to data requests
- Easy development of portals
- More usage of products
- Faster feedback to modelers, improved models

