

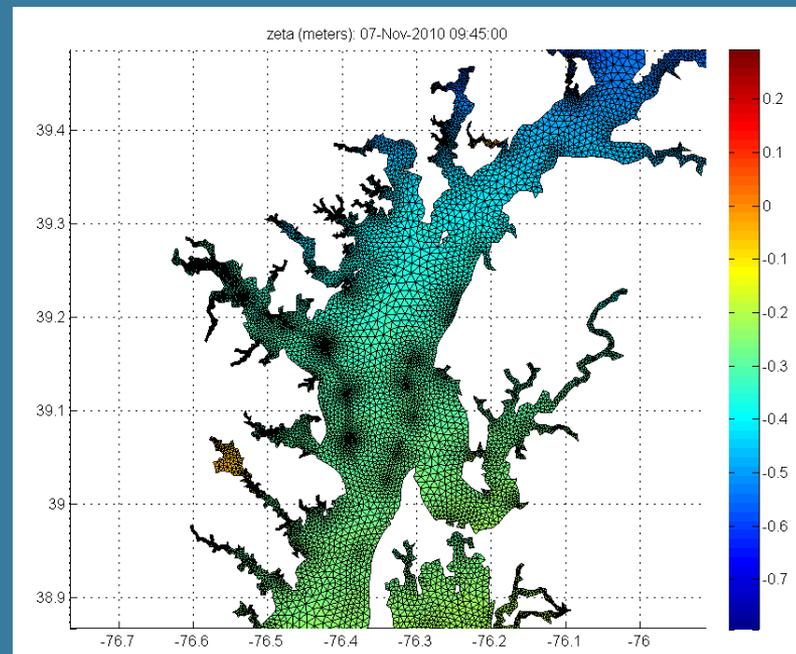
# The US-IOOS Modeling Testbed Cyberinfrastructure: Unstructured Grid Standards and Standards-Based Tools for Analysis of Ocean, Atmosphere & Climate Model Data

**Rich Signell, USGS, Woods Hole, MA**  
**GO-ESSP, May 11, 2011**

```
links = opensearch(q)
nc = ncugrid(links.dap{1})
z = nc.data('zeta',...)
grid = nc.grid('zeta',...)
```



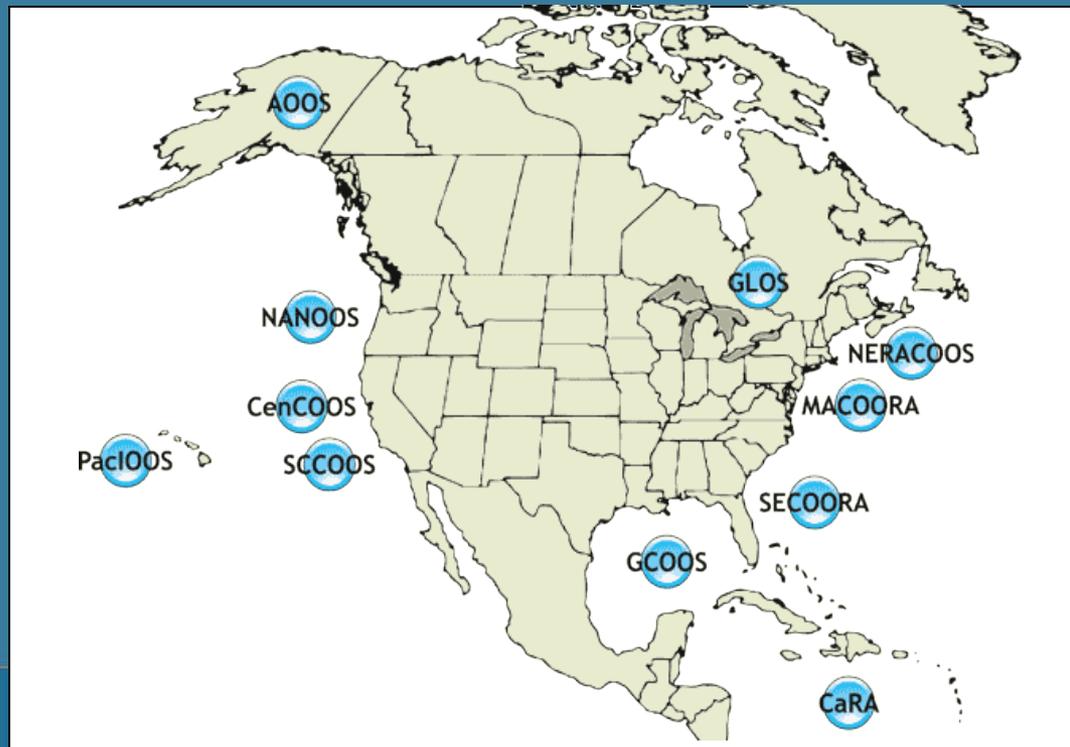
```
z = 26441x1 single
grid =
  lat: [26441x1 single]
  lon: [26441x1 single]
  time: 730970 (matlab datenum)
  connectivity: [52025x3 int32]
```



# US Integrated Ocean Observing System (IOOS<sup>®</sup>)

IOOS<sup>®</sup> Plan defines:

- Global Component
- Coastal Component
  - 17 Federal Agencies
  - 11 Regional Associations



# IOOS Modeling Testbed (testbed.sura.org)



**TESTBED**

- » [Publication Library](#)
- » [Presentation Library](#)
- » [Lessons Learned](#)

**USER LOGIN**

Username: \*

Password: \*

[LOG IN](#)

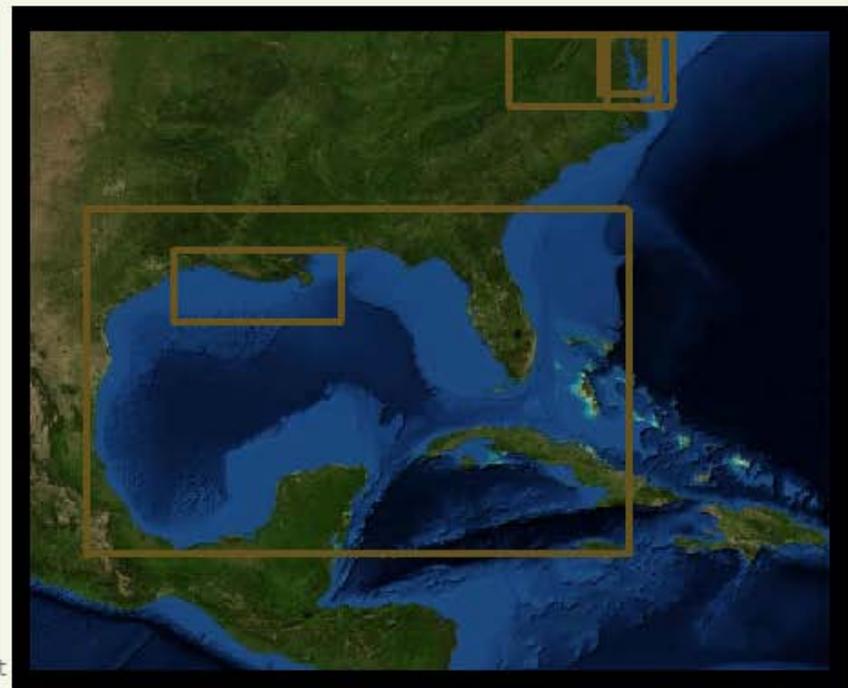
» [Request new password](#)

## A Super-Regional Testbed to Improve Models of Environmental Processes for the US Atlantic and Gulf of Mexico Coasts

A \$4 million grant from the National Oceanic and Atmospheric Administration is helping SURA evaluate the readiness of marine forecasts, such as flooding from storm surge or seasonal dead zones. Focused along the Atlantic and Gulf of Mexico coasts, the effort will improve those forecasts for use by emergency managers, scientific researchers and the general public.

The competitive grant was announced June 11 by NOAA's Integrated Ocean Observing System (IOOS®) program for fiscal year 2010. SURA is working with government agencies and researchers to advance information technology and improve understanding of coastal, ocean, and environmental phenomena.

Scientists will work to improve the precision of computer models that forecast chronic issues of high relevance in the Atlantic and Gulf regions – such as flooding from storm surge and seasonal depletion of oxygen in shallow waters. They will also explore methods for effectively delivering model results to regional centers, scientists and managers relying on IOOS. The



# IOOS Modeling Testbed Teams

## Testbed Management

Don Wright, SURA  
Liz Smith SURA  
Doug Levin, IOOS

## Cyber Infrastructure

25 members

Eoin Howlett, ASA

## Testbed Advisory Evaluation Group

9 members

Rich Signell, USGS

## Estuarine Hypoxia Chesapeake Bay

21 members

Carl Friedrichs, VIMS

## Shelf Hypoxia Gulf of Mexico

20 members

John Harding, MSU

## Inundation Gulf and East Coast

24 members

Rick Luettich, UNC-CH

# Analysis Toolboxes for Scientists

Scientists comparing models want powerful, flexible environments for analysis

Eventually we want toolboxes in all common scientific analysis environments: Python, R, IDL, but first we are focusing on **Matlab**.

Why **Matlab**?

- Used by 80% of the ocean modeling community
- Can directly use Java, so toolbox can use NetCDF-Java behind the scenes to enable high level CF functionality

# Model Data Interoperability Schematic

Nonstandard  
Output Files  
(distributed)

THREDDS Data Server

API

Standard  
Clients

ROMS

POM

ECOM

WW3

WRF

FVCOM

Standardized (CF)  
Virtual Datasets

NcML

NcML

NcML

NcML

NcML

NcML

NetCDF-Java  
Common Data  
Model = CF

Web Services

OPeNDAP

OGC WCS

NetCDF  
Subset  
Service

NetCDF  
-Java

Matlab

NcWMS

IDV

DIVE

ERDDAP

ArcGIS 9.3

*NcML, NetCDF-Java and THREDDS Data  
Server built and supported by Unidata  
under NSF-support*



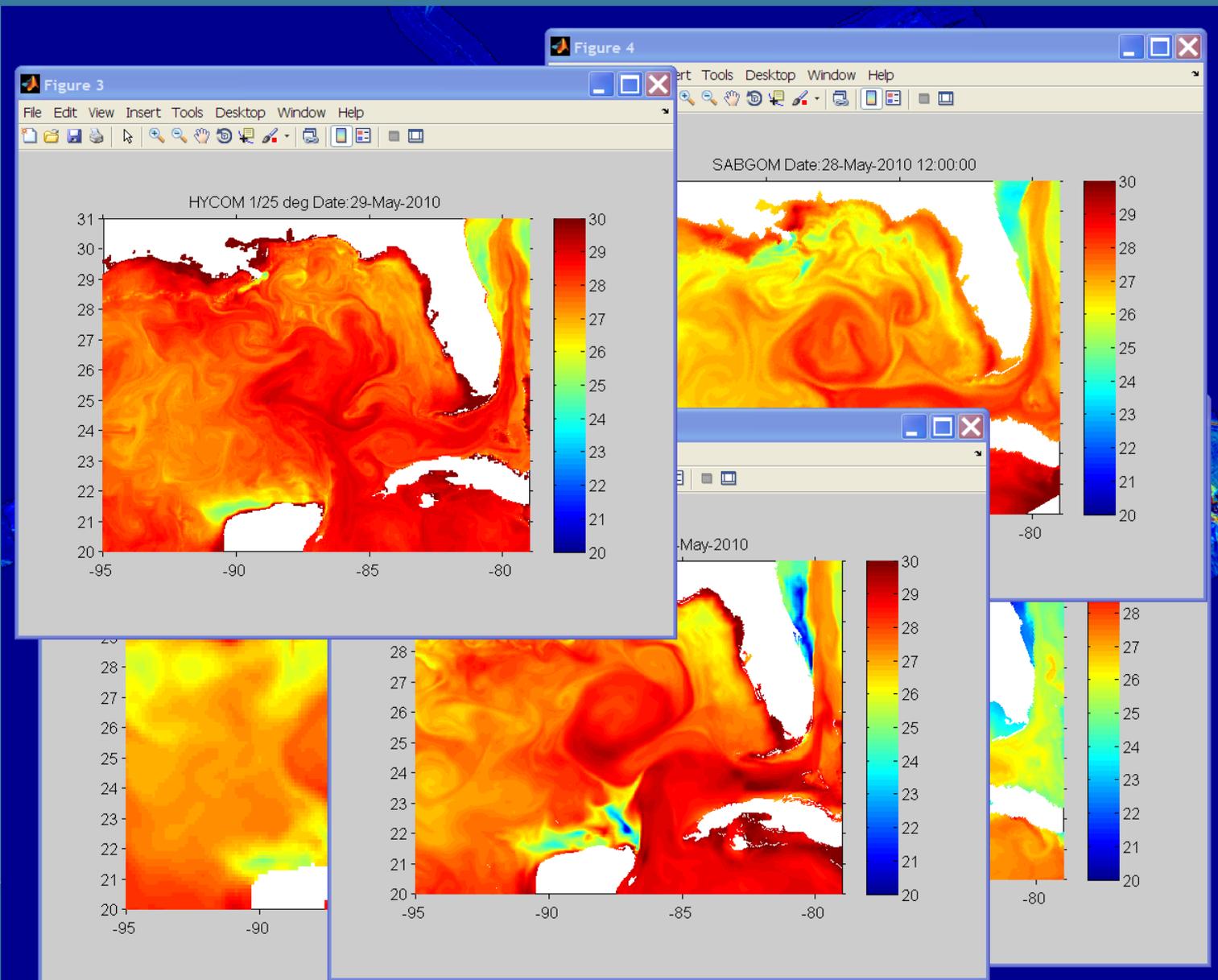
# NCTOOLBOX for Matlab

<http://code.google.com/p/nctoolbox>

Developers: Brian Schlining (MBARI); Alex Crosby (ASA)

- `nc=ncgeodataset(URL)`
- `ncvar=nc.variable('water_temp');`
- `t = ncvar.data(1,::,::,);`
- `grid = ncvar.grid(1,::,::,);`
- `t = 22x120x180 single`
- `grid =`
  - `lat: [120x180 single]`
  - `lon: [120x180 single]`
  - `z: [22x120x180 double]`
  - `time: 733582 (matlab datenum)`
- No model specific code!
- URL can be: local NetCDF, remote NetCDF, Grib, Grib2, NcML, OpenDAP...

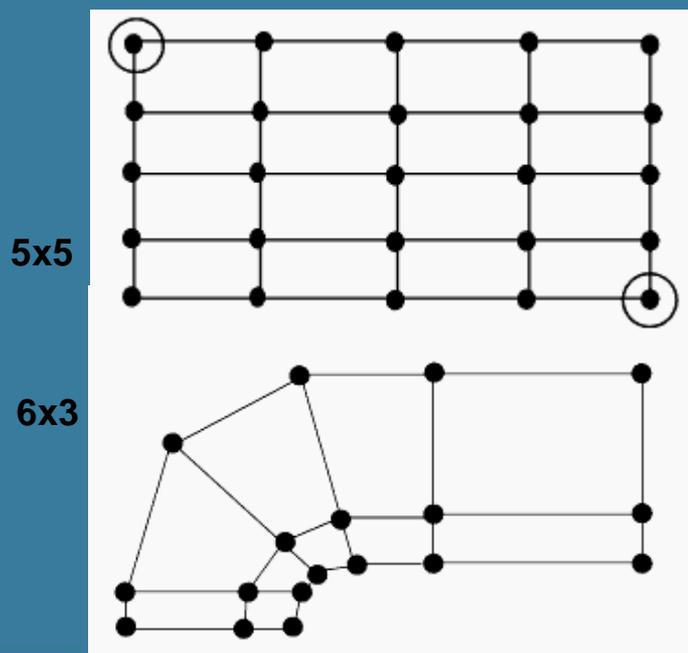
# Deep Water Horizon: Comparing 5 models on May 29, 2010



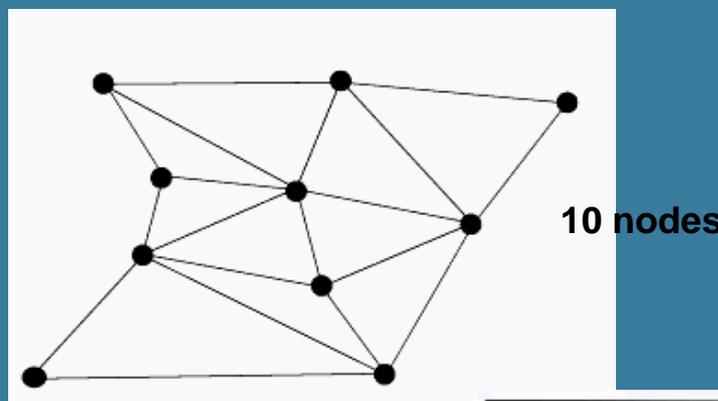
# Goal: A common cyberinfrastructure for accessing and analyzing ocean model data

Currently each modeling group has their own standards and toolsets for access, analysis and visualization

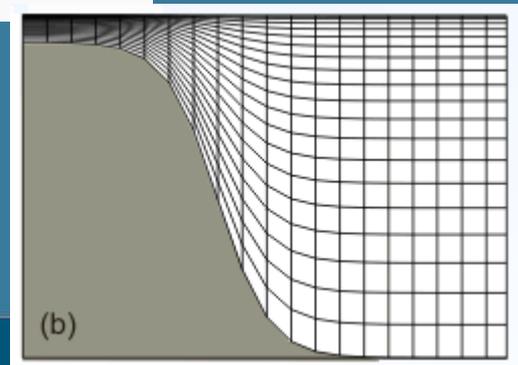
Structured Grids



Unstructured Grid

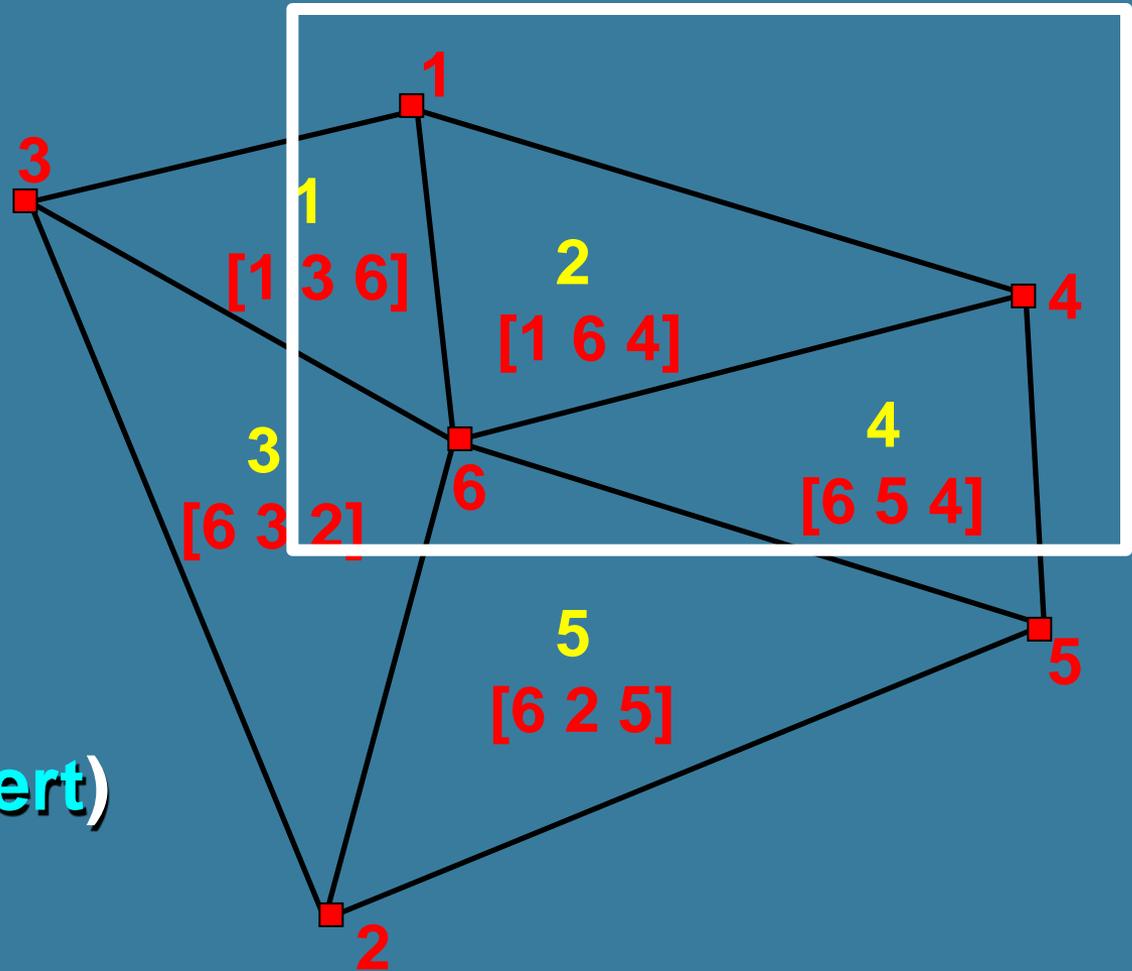


Variety of Stretched Vertical Coordinates



# Unstructured Grid Topology

- **node** = 6
- **nele** = 5
- **nvert** = 3
- lon(**node**)
- lat(**node**)
- int ele(**nele**,**nvert**)



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*NcML, NetCDF-Java and THREDDS Data  
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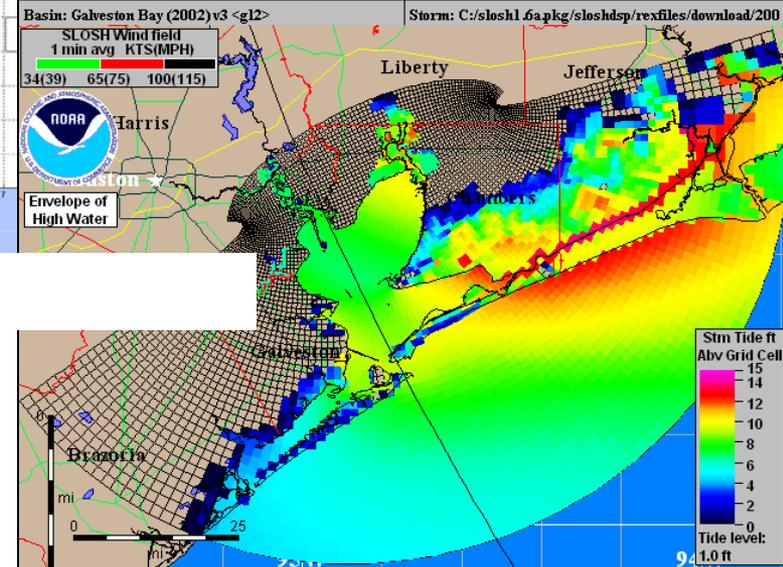
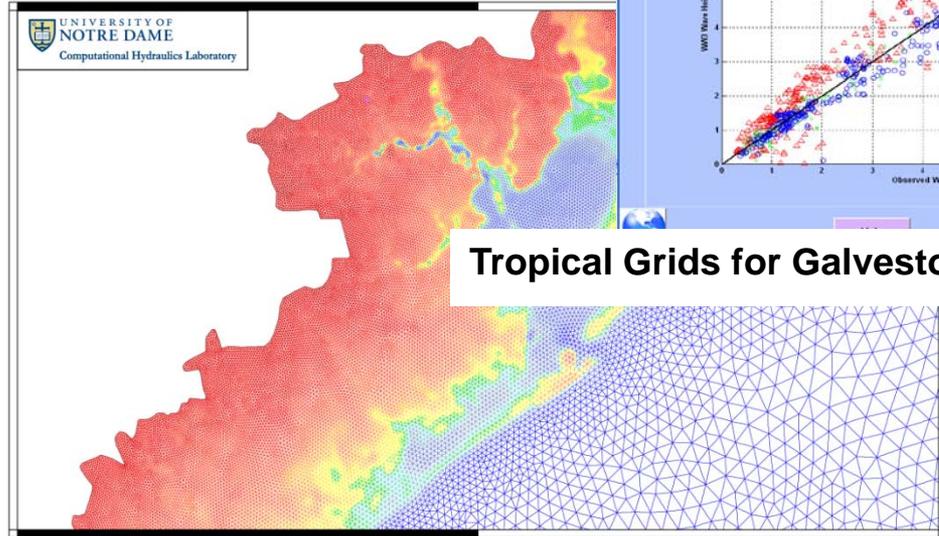
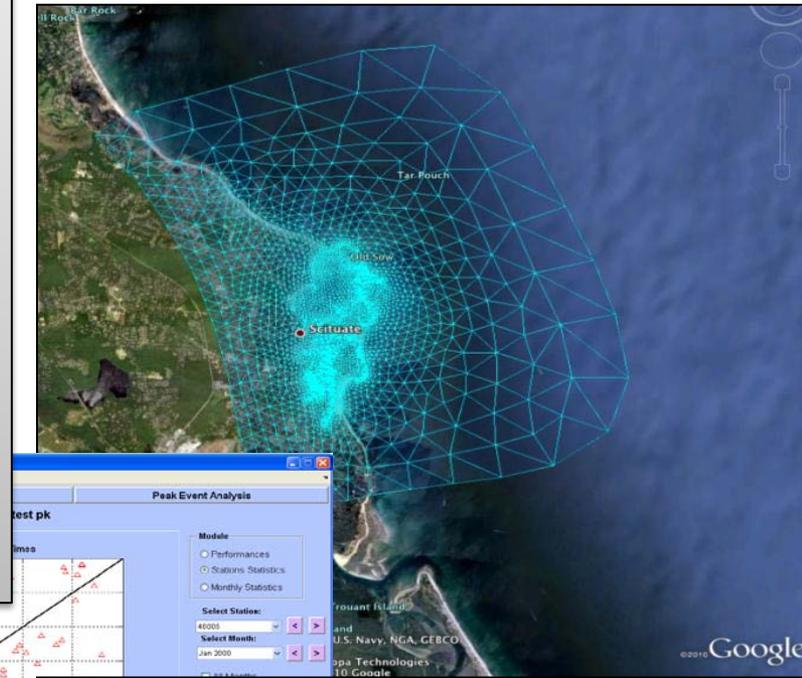
# Inundation

Extra-tropical – Gulf of Maine

Tropical – Gulf of Mexico

- 4 models: 3 unstructured grid +1 structured grid
- Coupled wave-storm surge-inundation (TWL)
- Consistent forcing, validation and skill assessment using existing IMEDS tool
- Extensive observational data sets for historical storms like, Rita and Gustav in standard formats
- SURA has provided supercomputer resources

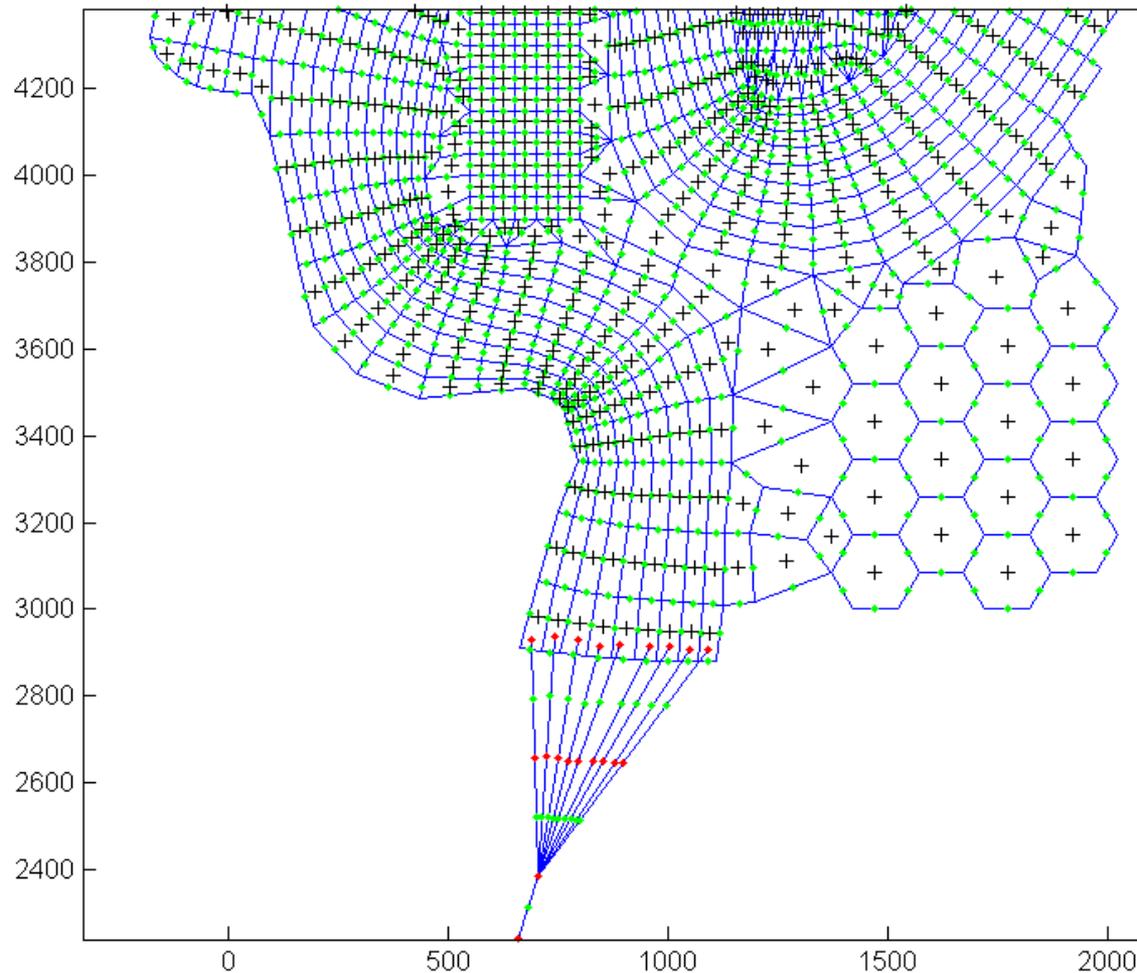
## Extratropical Grid



# Progress on UGRID standard

- Standard discussed on UGRID Google Group (45 members from FVCOM, SELFE, ADCIRC, ELCIRC, DELFT3D (Deltares), ICOM modeling groups, NOAA/ERD, NOAA/PMEL, NOAA/GFDL, USGS, UNIDATA, OOI, IOOS, ... )  
[http://bit.ly/ugrid\\_group](http://bit.ly/ugrid_group)
- UGRID standards document  
[http://bit.ly/ugrid\\_cf](http://bit.ly/ugrid_cf) (Bert Jagers, DELTARES)
- New UGRID class in NetCDF-Java
- [http://bit.ly/ugrid\\_git](http://bit.ly/ugrid_git) (Kyle Wilcox, ASA)
- New UGRID class in Matlab NCTOOLBOX  
[http://bit.ly/ugrid\\_m](http://bit.ly/ugrid_m) (Alex Crosby, ASA)

# Designed to handle existing models, but also this: Bert Jagers' complex grid!

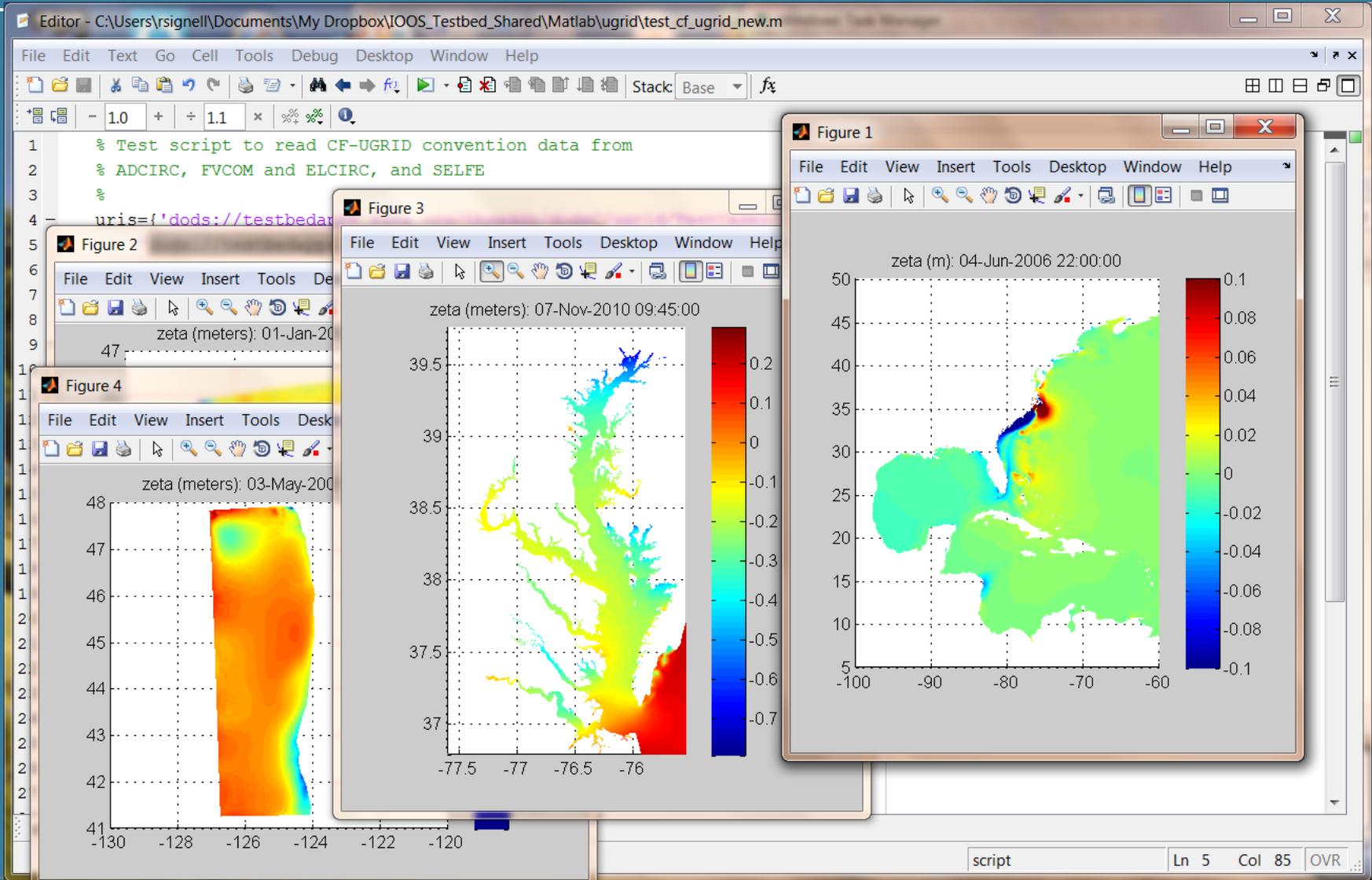


# NCTOOLBOX for Matlab

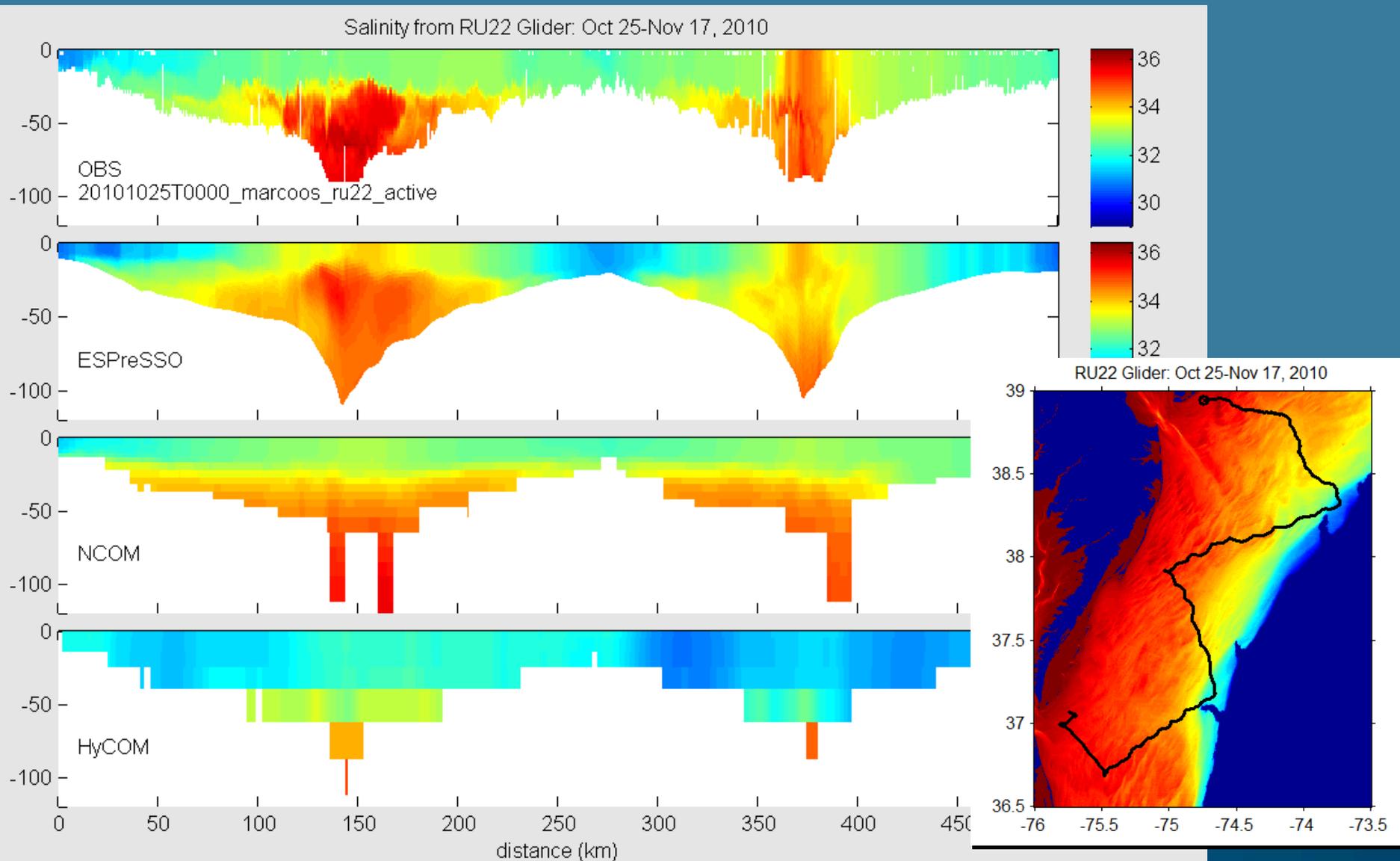
<http://code.google.com/p/nctoolbox/>

- Objective: Make it simple to access CF data
- `nc = ncugrid(URL)`
- `z = nc.data('zeta',...)`
- `grid = nc.grid('zeta',...)`
- `z = 26441x1 single`
- `grid =`
  - `lat: [26441x1 single]`
  - `lon: [26441x1 single]`
  - `time: 730970 (matlab datenum)`
  - `connectivity: [52025x3 int32]`
- works identically for FVCOM, ADCIRC, SELFE, ELCIRC
- URL can be: local NetCDF, remote NetCDF, NcML, OpenDAP Data URL

# UGRID interoperability in Matlab



# Virtual Ocean Glider Function from NCTOOLBOX



# Single point of access catalogs are good, but...

Tools Help

Data Choosers Field Selector Displays

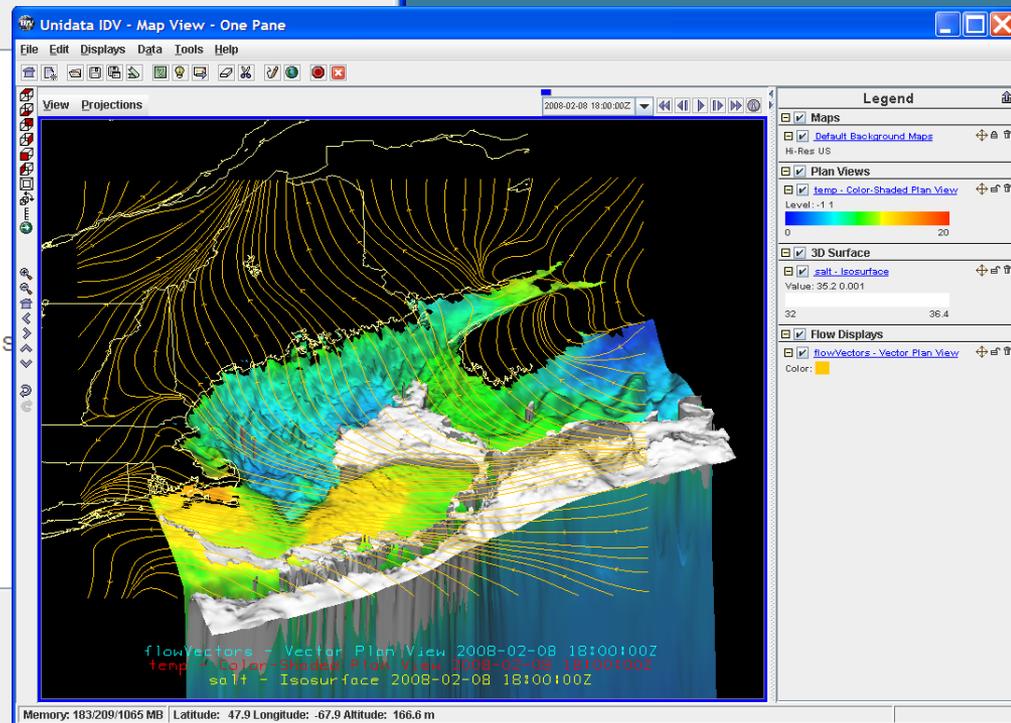
Catalogs:

Data Source Type:

- GEO-IDE
  - NOAA
    - NOAA-Affiliated
      - IOOS Regions
        - AOS
        - NANOS
        - CENCOOS
        - SCCOOS
        - PACIOOS
        - GLOS
        - NERACOOS
          - Northeastern Regional Association of Coastal Ocean Observing S
          - UMaine THREDDS Data Server →
          - USGS Woods Hole THREDDS Data Server 1
          - USGS Woods Hole THREDDS Data Server 2
          - WHOI McGillicuddy Group THREDDS Data Server
          - UMASSD Chen Group THREDDS Data Server
          - UNH JCOOT Group THREDDS Data Server →
        - MACOORA
        - SECOORA
        - CARICOOS

Please select a dataset from the catalog



GEO-IDE Web Site: <http://geo-ide.noaa.gov>

# THREDDS ncISO metadata service (Habermann, Neufeld) <http://bit.ly/nciso-group>



Testbed - App Server

THREDDS Data Server

Catalog <http://testbedapps.sura.org/thredds/clean.html>

Dataset: NOAA IOOS Testbed THREDDS Server/Estuarine Hypoxia/CH3D - Synoptic - Agg

- *ID:* [estuarine\\_hypoxia/ch3d/agg](#)

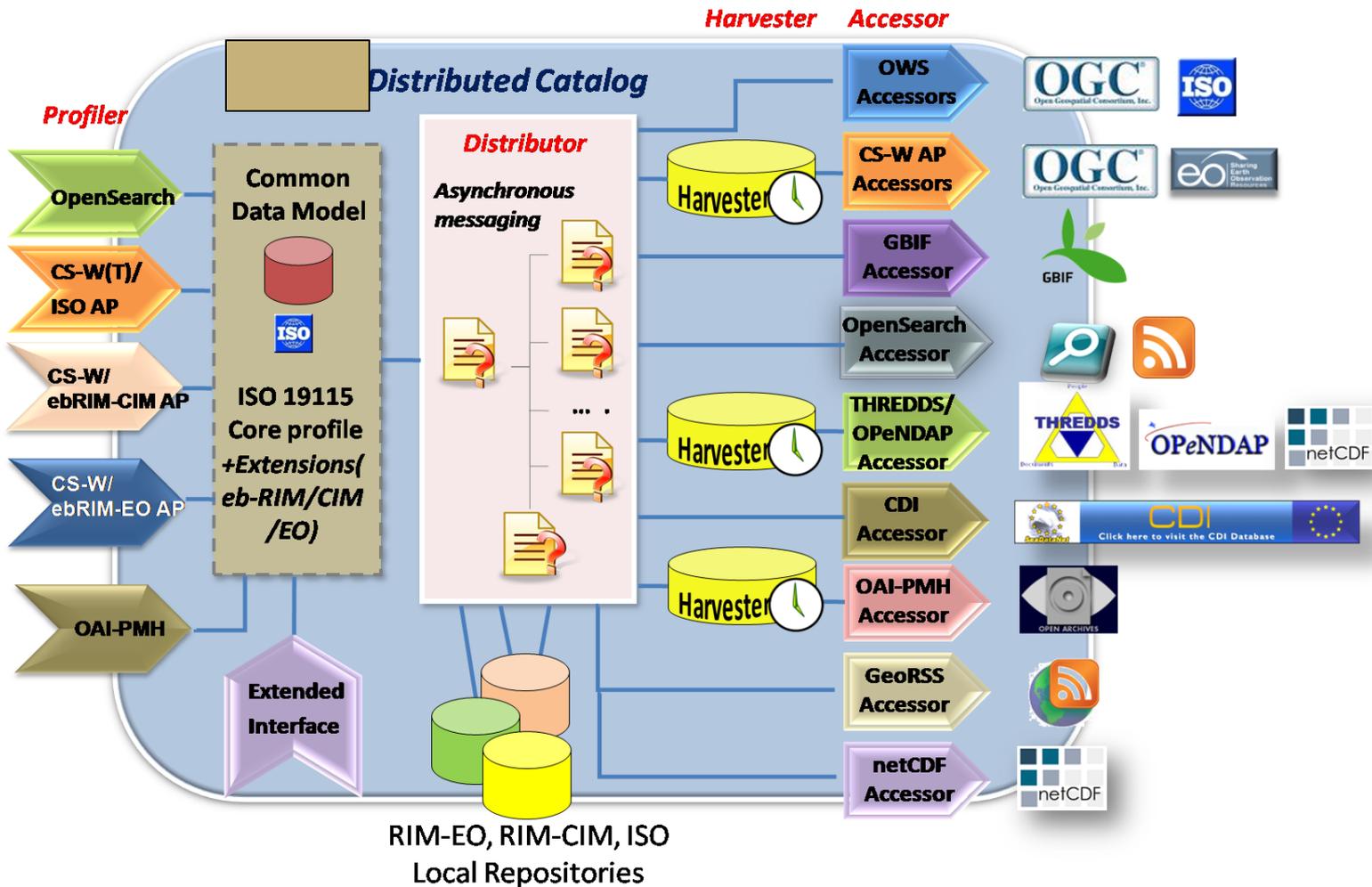
## Access:

1. **OPENDAP:** [/thredds/dodsC/estuarine\\_hypoxia/ch3d/agg.nc](#)
2. **WCS:** [/thredds/wcs/estuarine\\_hypoxia/ch3d/agg.nc](#)
3. **WMS:** [/thredds/wms/estuarine\\_hypoxia/ch3d/agg.nc](#)
4. **NetcdfSubset:** [/thredds/ncss/estuarine\\_hypoxia/ch3d/agg.nc](#)
5. **NCML:** [/thredds/ncml/estuarine\\_hypoxia/ch3d/agg.nc](#)
6. **UDDC:** [/thredds/uddc/estuarine\\_hypoxia/ch3d/agg.nc](#)
7. **ISO:** [/thredds/iso/estuarine\\_hypoxia/ch3d/agg.nc](#)

# GI-CAT Catalog Service

## Boldrini, Nativi

Harvesting THREDDS-NcISO from Testbed and OceanNOMADS TDS servers



## Search

\*salinity\* from:2001-01-01T23:00:00 to:2009-12-3

[Search](#)

[+](#) **Records shown from: IOOS Modeling Testbed**

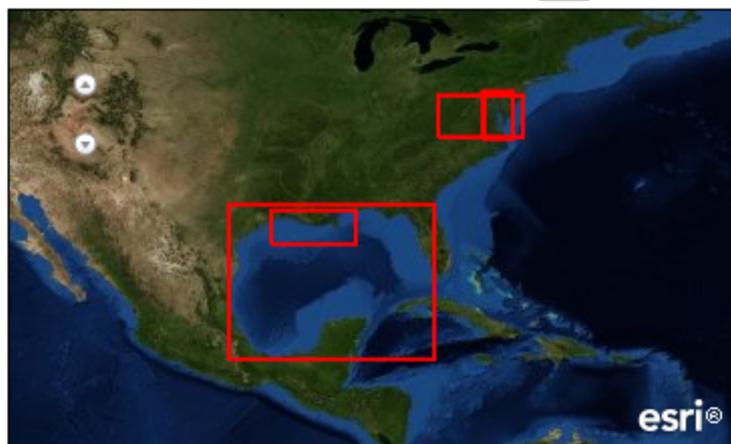
[Click here to select different site or configure search.](#)

### [Additional Options](#)

[Clear](#)

### WHERE

Anywhere  Intersecting  Fully within



### [My Saved Searches](#)

Results 1-6 of 6 record(s)

[Expand results](#) [Zoom To Results](#) [Zoom To Searched Area](#)

 [UMCESRoms \(UMCES\) - ROMS](#)

 [ROMS \(TAMU\) - ROMS-3.0](#)

 [CBOFS2 \(NOAA\) - ROMS-3.0](#)

 [t3d\\_2009123112](#)

 [CBOFS2-1TDO \(NOAA\) - ROMS-3.0](#)

 [UMCESRoms \(UMCES\) - ROMS](#)

See results through REST

API: [GEORSS](#) [ATOM](#) [HTML](#) [FRAGMENT](#) [KML](#) [JSON](#)

# OpenSearch query in Matlab

```
q.endpoint = 'http://testbedapps.sura.org/gi-  
cat/services/opensearch';  
q.string_text = 'sea_water_salinity';  
q.Bbox = '-82,36,-73,40';  
q.time_start = '2000-06-20T04:33:45Z';  
q.time_end = '2006-08-01T00:00:00Z';  
[links,params] = opensearch(q);  
dap = links2dap(links);  
dap{1}  
ans =  
    http://testbedapps.sura.org/thredds/dodsC/estuarine  
_hypoxia/ch3d/agg.nc
```

# Next Steps

- **Harmonize with ESMF Unstructured Mesh format (Bob Oehmke), OPeNDAP.org UGRID work (James Gallagher), GridSpec (Balaji)**
- **Server-side subsetting with TDS (Rtree-based subsetting has been added to NetCDF-Java)**
- **Server-side regridding with TDS (ESMF?, GridFields?)**
- **More UGRID methods for NJ/Matlab (arbitrary vertical slicing)**
- **We welcome participation!! (Google groups, testing, coding....)**
- **Can also demo later today, if interested...**