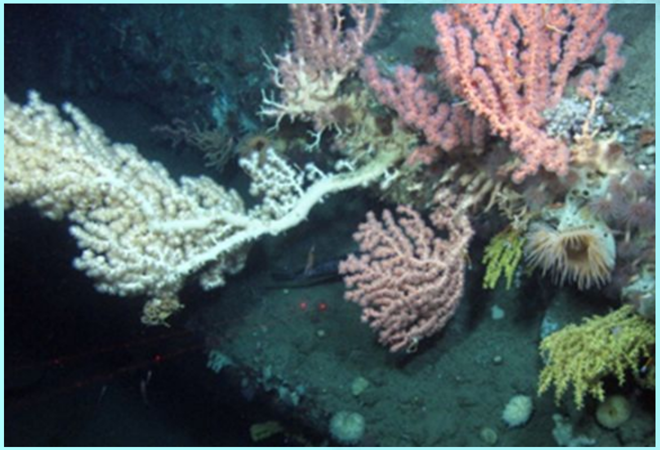
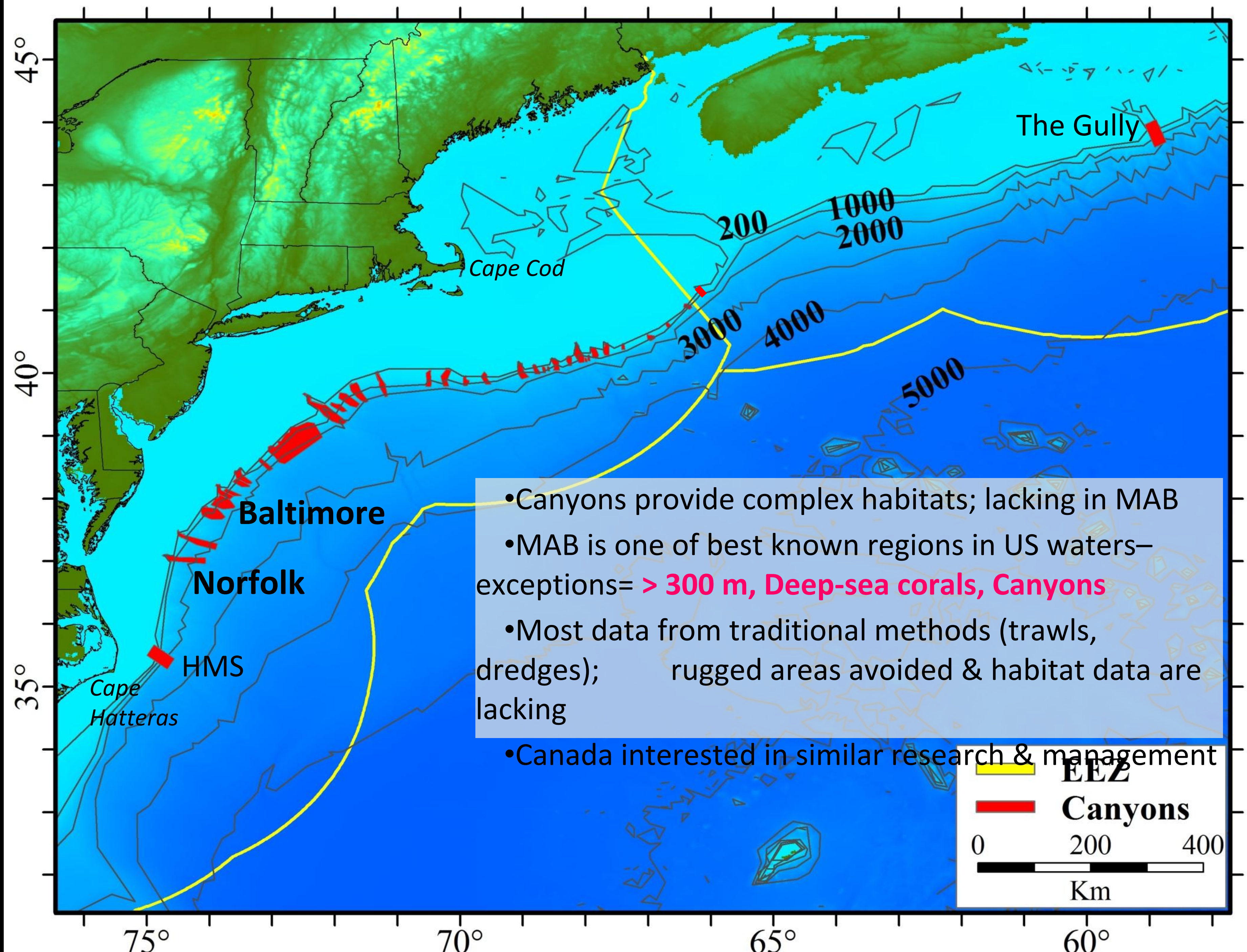
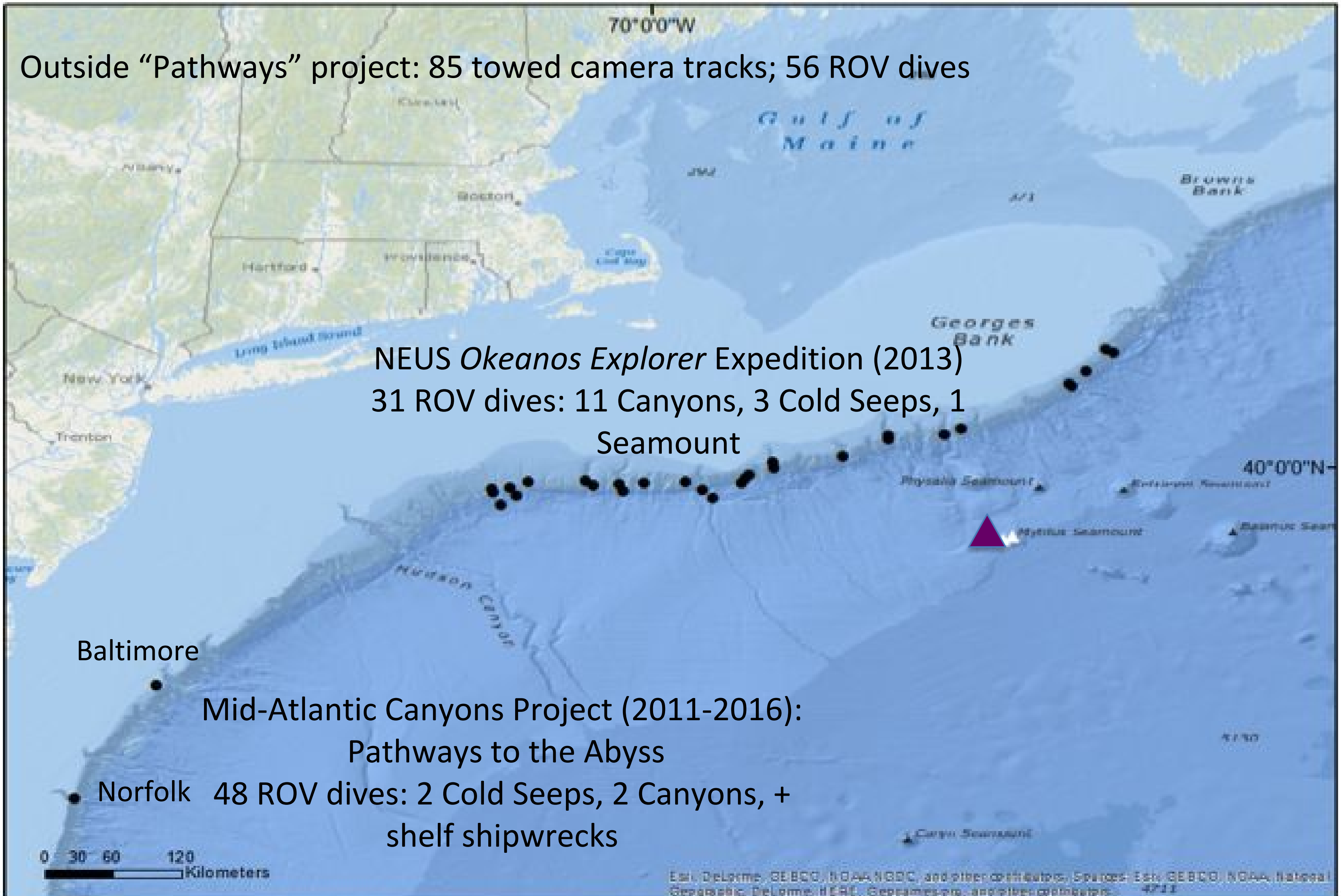
Mid-Atlantic Canyon Studies, Emphasizing Norfolk and Baltimore Canyons



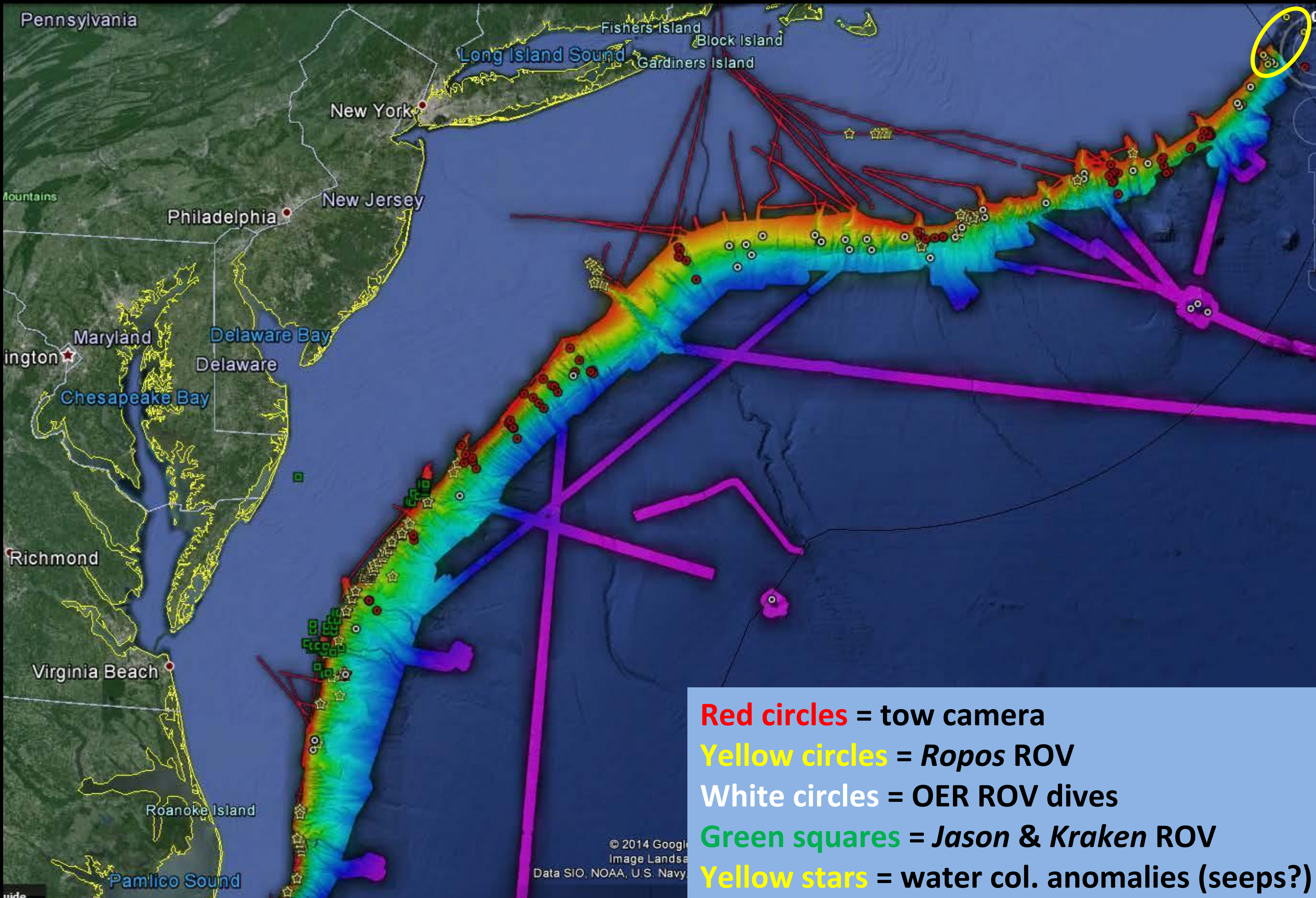


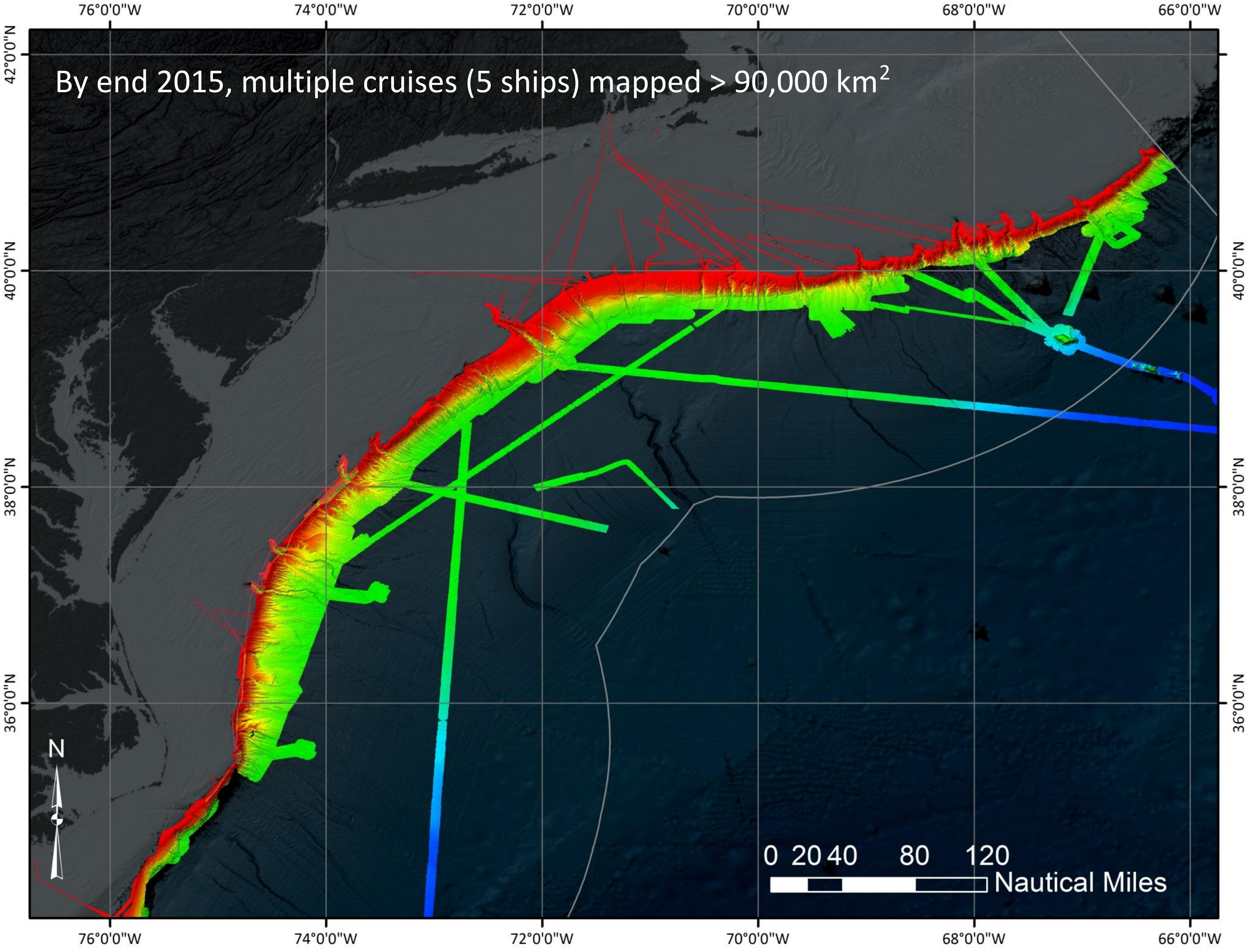
- Canyons provide complex habitats; lacking in MAB
- MAB is one of best known regions in US waters– exceptions= **> 300 m, Deep-sea corals, Canyons**
- Most data from traditional methods (trawls, dredges); rugged areas avoided & habitat data are lacking
- Canada interested in similar research & management

Three U.S. Mid-Atlantic Efforts Directed Towards Canyons ++



> 25 CRUISES (2011-2014)

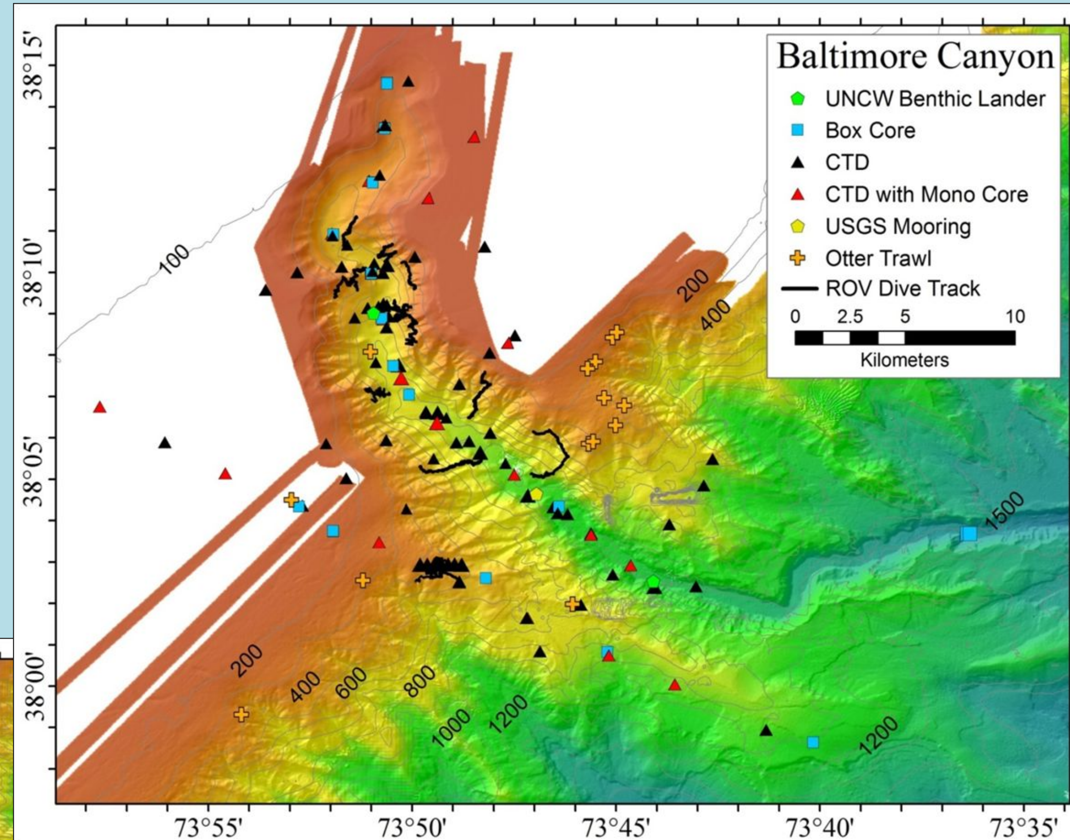


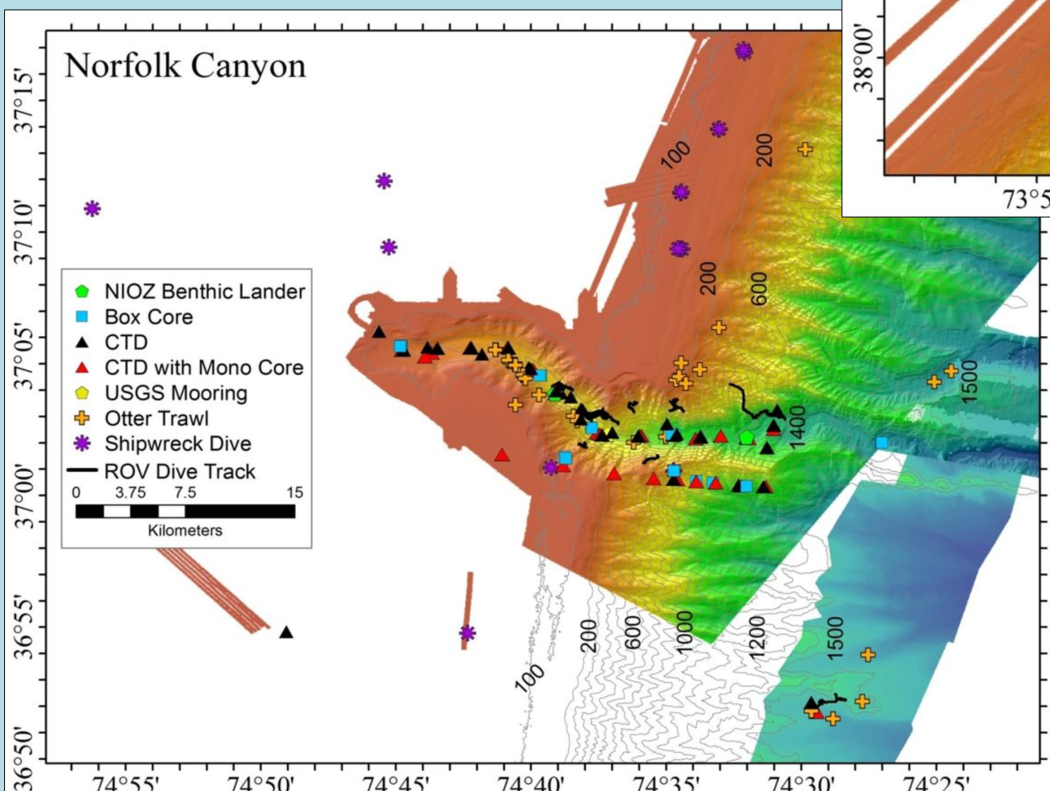


By end 2015, multiple cruises (5 ships) mapped > 90,000 km²
76°0'0"W
74°0'0"W
72°0'0"W
70°0'0"W
68°0'0"W
66°0'0"W
42°0'0"N
40°0'0"N
38°0'0"N
36°0'0"N
N
0 20 40 80 120
Nautical Miles

Pathways to Abyss FIELD METHODS

- One mapping cruise: 4-17 Jun 2011
- Two main cruises: 15 Aug - 2 Oct 2012 (3 Legs) and 2-18 May 2013 (2 Legs)
- One lander cruise: 21-27 Aug 2013
- Stations designed to compare between the two canyons and between canyons and open slope





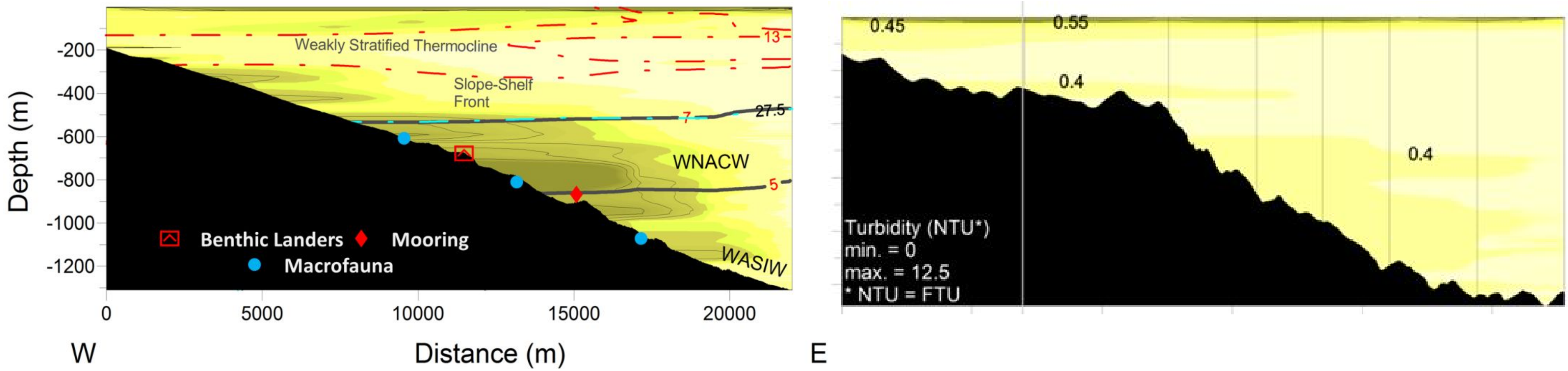
- 48 ROV dives (40-1612 m) using *Kraken II* (2012) & *Jason II* (2013)
- Video transects across all habitats
- 40, 30-min bottom trawl tows
- 157 Box and Mono cores
- 164 CTD stations
- 75 water samples (POM, Ω, nutrients)
- Landers & moorings (1 year duration) – 3 in each canyon

Not covered here

- Shallower study components (archaeology, shelf related)
- Fish
- Corals & Seeps
- Benthic Invertebrate Communities

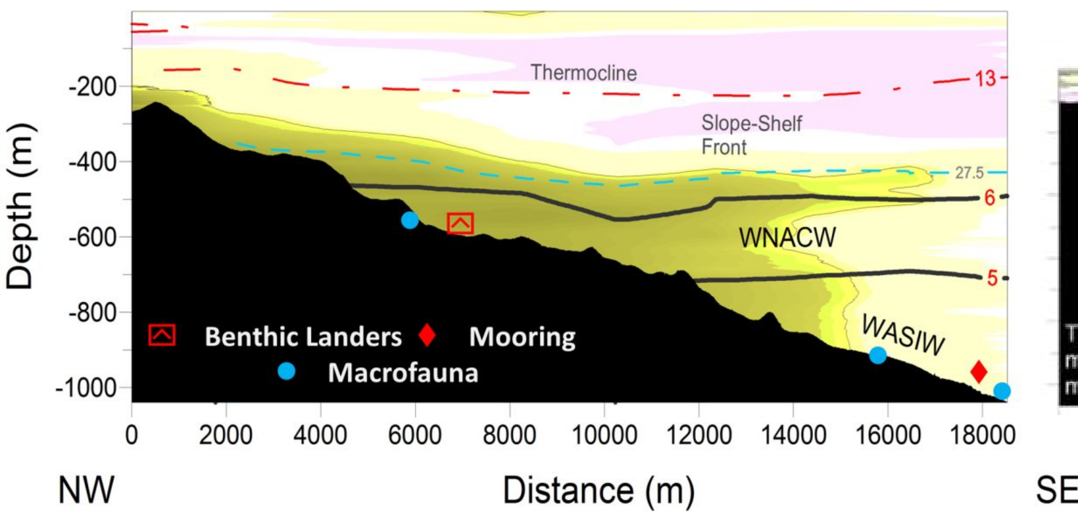
Physics

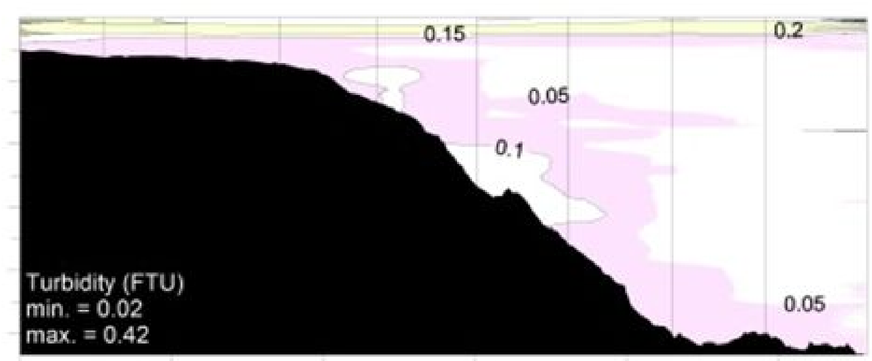
- Canyon temperature-salinity profiles differ from adjacent slopes (deep water masses penetrate up canyon, less so on slope)
- Strong up-canyon flows along most of canyon floors driven by semi-diurnal tidal pump
- Higher benthic current speeds in upper to mid-canyons than in deeper sections
- Higher current speeds in Norfolk Canyon axis often turbidity laden; correlated with surface storms (Hurricane Sandy = mass deposition event)
- Slower bottom currents in Baltimore; no turbidity events
- Persistent nepheloid layers in canyons, not on slope
- Deep water relatively isolated from surface



Norfolk: influenced by 3 water masses - the MAB shelf-slope front, WNACW and possibly deeper WASIW. Substantial nepheloid layers contact the canyon seabed between 200 and 1000 m.
Higher sediment accumulation rate than Baltimore Canyon and more uniform fine sediment drape, as well as high nitrogen and organic carbon enrichment throughout the canyon.

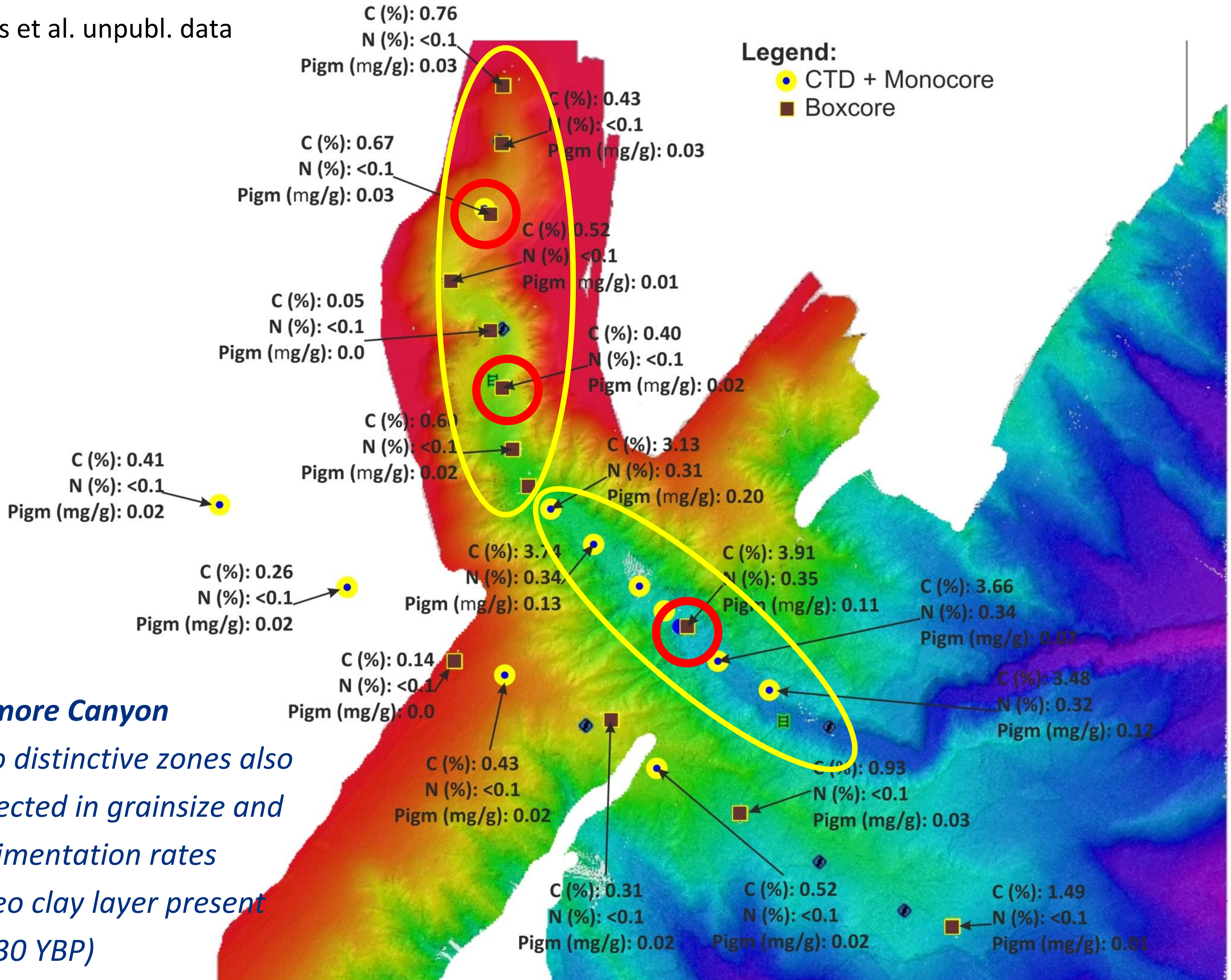
Baltimore: well developed nepheloid layer contacts the seabed, reaching 800 m depth, which was not present on the adjacent slope.
Three water masses influence the distribution of sediments and maintain the high levels of organic enrichment in the deposition zone > 800m.





Mienis et al. unpubl. data

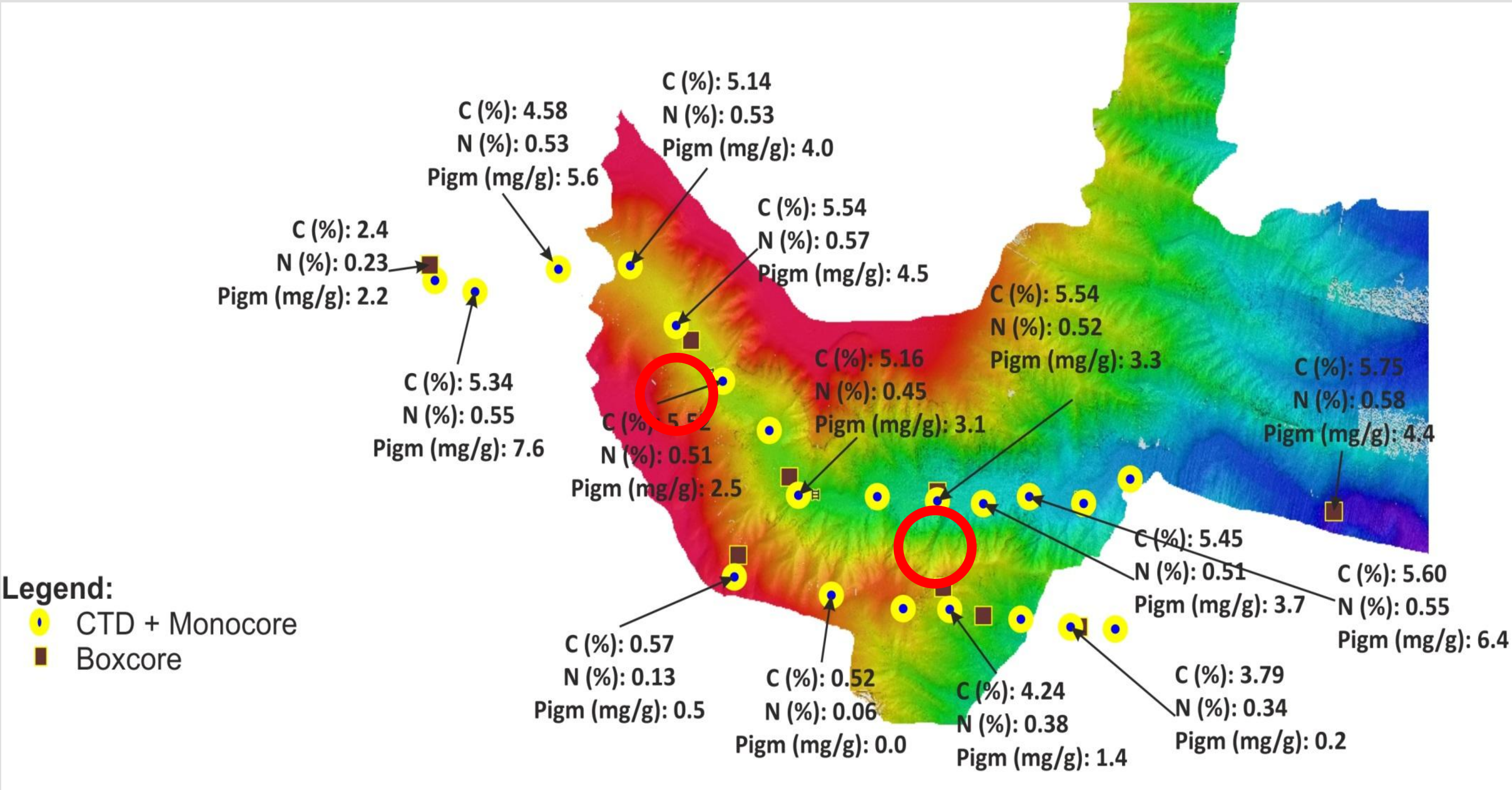
Mienis et al. unpubl. data



Baltimore Canyon

- *Two distinctive zones also reflected in grainsize and sedimentation rates*
- *Paleo clay layer present (9730 YBP)*

Mienis et al. unpubl. data



Norfolk Canyon

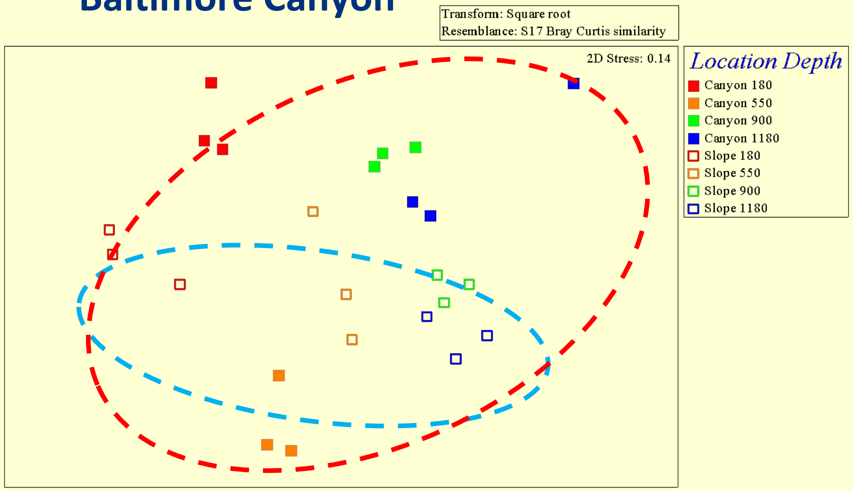
- *Homogenous distribution*
- *High accumulation rates*

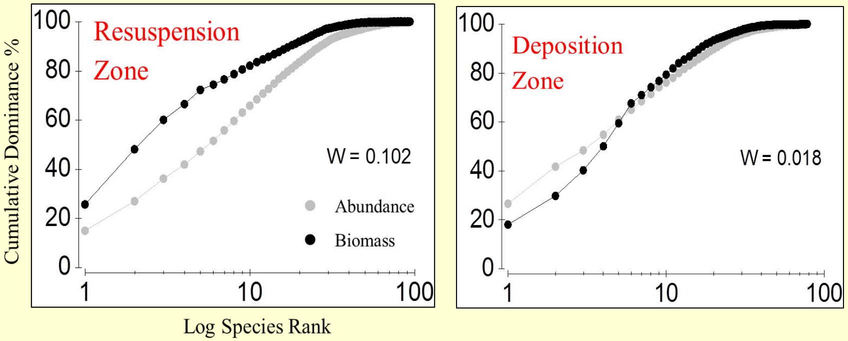
Geology

- Canyons differ in sediment regimes
  - two zones in BC (course in upper & fine in lower)
  - BC zonation linked to internal bores and mid-canyon convergent zone
  - one zone in NC
  - sedimentation rates higher in NC
- Both canyons organically enriched compared with slope
  - Conduits for sediment and organics
- Differences probably linked to morphology (BC more complex, NC more orthogonal = stronger tides) & its interaction with hydrography

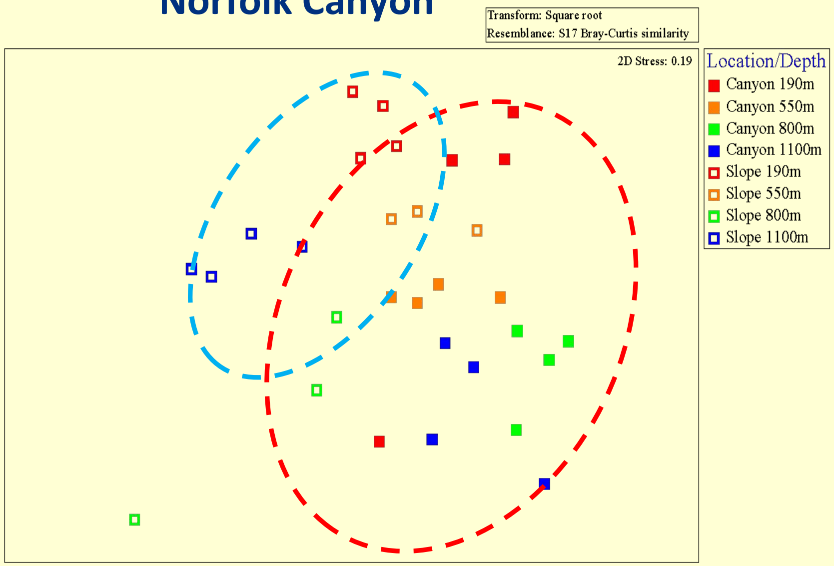
Macrofaunal patterns and environmental drivers

Baltimore Canyon





Norfolk Canyon



- Upper BC macrofaunal communities enhanced by nepheloid layer and increased canyon flushing.
- Lower BC communities dominated by opportunistic species, resilient to high levels of organic enrichment.

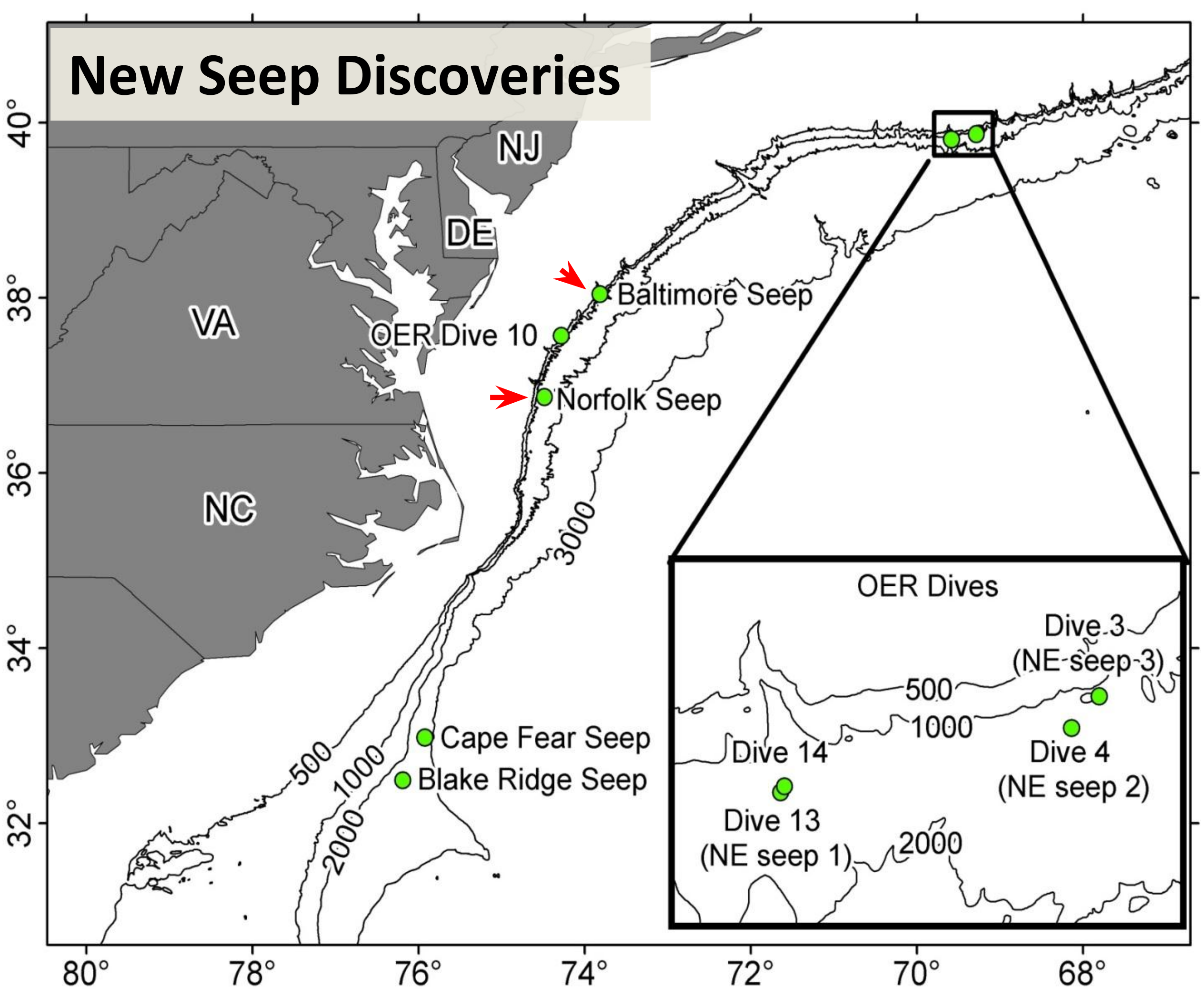
•Community assemblages differed significantly between canyon and slope habitats.

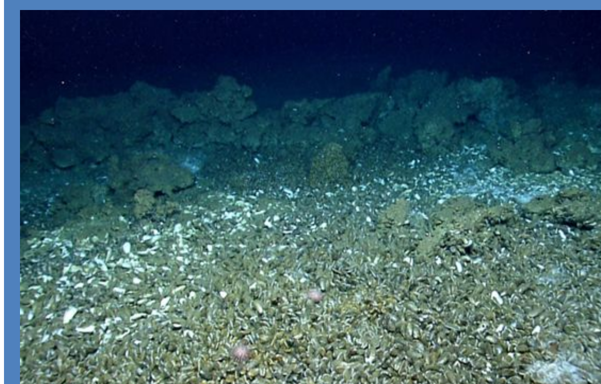
•Baltimore and Norfolk canyon communities were significantly different from each other.

•Depth, % sand, and organic enrichment best explain differences between canyon and slope.

Robertson et al., unpubl. data

New Seep Discoveries





Two seeps mapped and surveyed in detail near Baltimore Canyon & Norfolk Canyon.
As many as **560+** seeps remain to be explored.
Huge impact on benthic habitats and fauna.

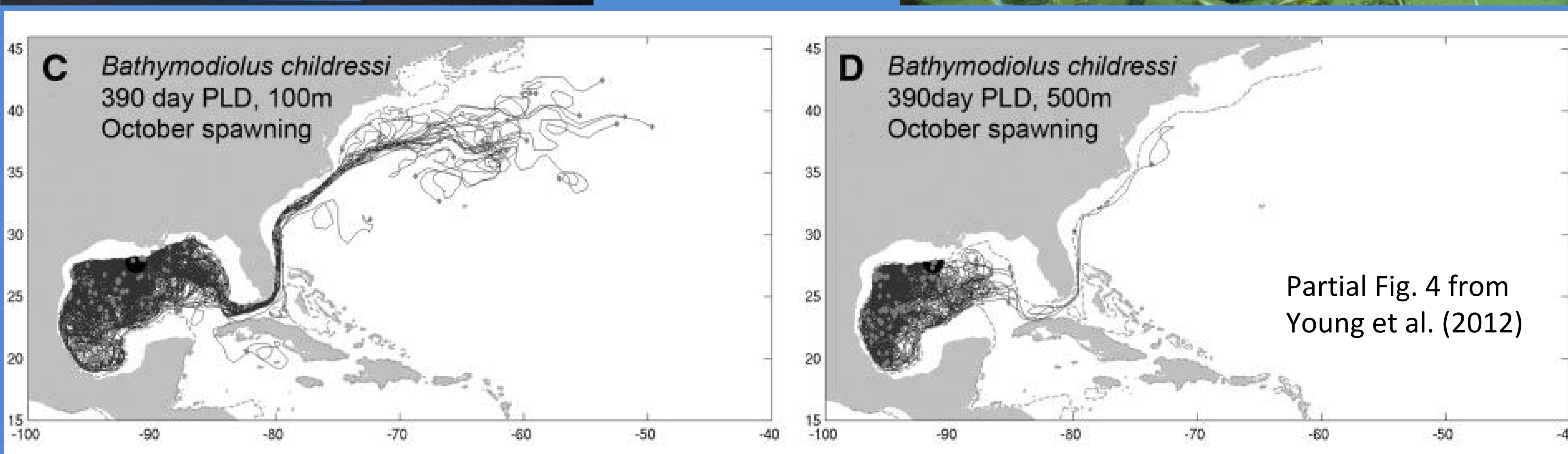
Genetics Overview

- New species discovered (*Anthothela* & *Acanella* octocorals; *Pagurus & Munidopsis*)
- Octocorals had distinct genus level bacterial communities
- No differences in coral bacteria between canyons
- No differences in *A. grandiflora*, *P. resedaeformis*, or *P. arborea* between canyons
- *Paramuricea placomus* differed between Baltimore Canyon and the Gulf of Maine
- *Desmophyllum dianthus* similar between canyons, but differed between shallow (650 m) & deep (1320 m)
- *Lophelia pertusa* similar between canyons, but differed from GOM & SEUS populations. But, some colonies exhibited affinity with GOM.
- High population connectivity in *Eumunida picta* (GOM to MAB)

Seep mussels identified (sequencing cytochrome oxidase gene) as *Bathymodiolus childressi* (Coykendall et al.; Johnson et al., unpubl. data.).

Previously known only from the northern Gulf of Mexico, 528-3000 m. Our records from Baltimore Canyon represent a huge range extension (~ 3,065 km) as well as shallowest depths (380 m) yet recorded.

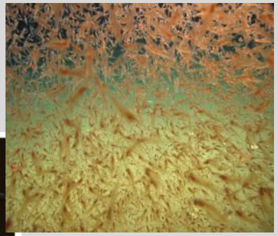
Live mussel densities at least to ~ 181 m^{-2}



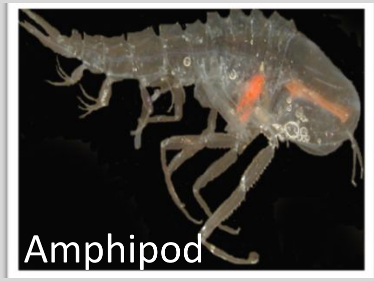
Partial Fig. 4 from Young et al. (2012)

Trophics

- Complex food webs with multiple trophic levels
- Stable isotope patterns similar between two canyons, but differed from slope, suggests different reworking of basic food (POM) input
- Substrate type and resuspension events influence trophic web
- Some species use of chemosynthetic sources
- Fish diets (generalist) similar between canyons



Common food items



Paleoecology

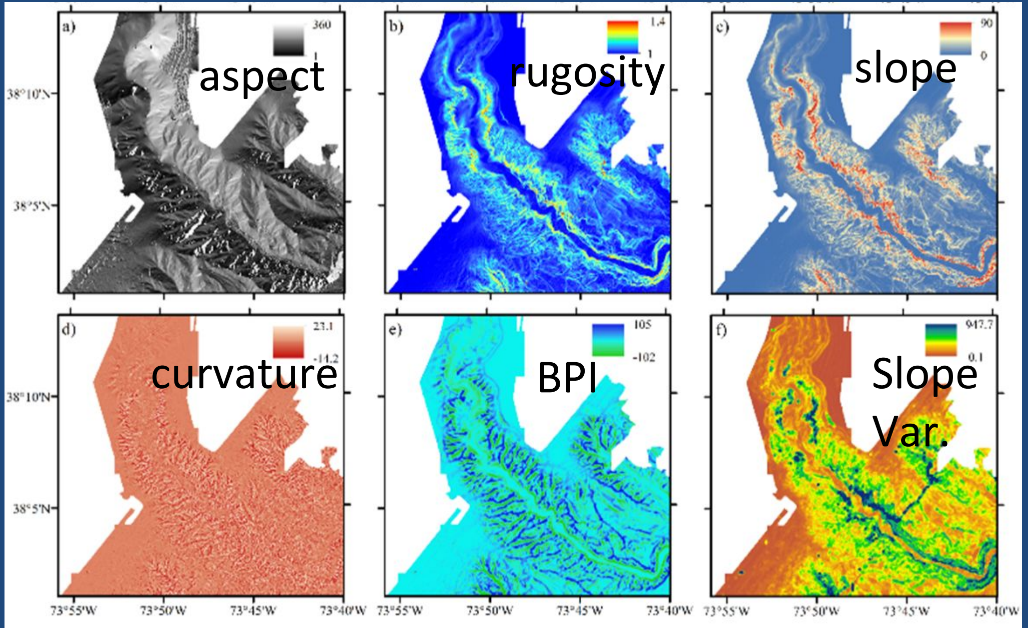
- Living & sub-fossil *D. dianthus* corals allow 700 yrs of environmental reconstruction
- Little change in nutrient flux, carbonate ion system, or pH in canyons over last 700 yrs; relatively stable environment
- Hydrocarbon seepage relatively recent (15Ka at Baltimore & 3Ka at Norfolk)

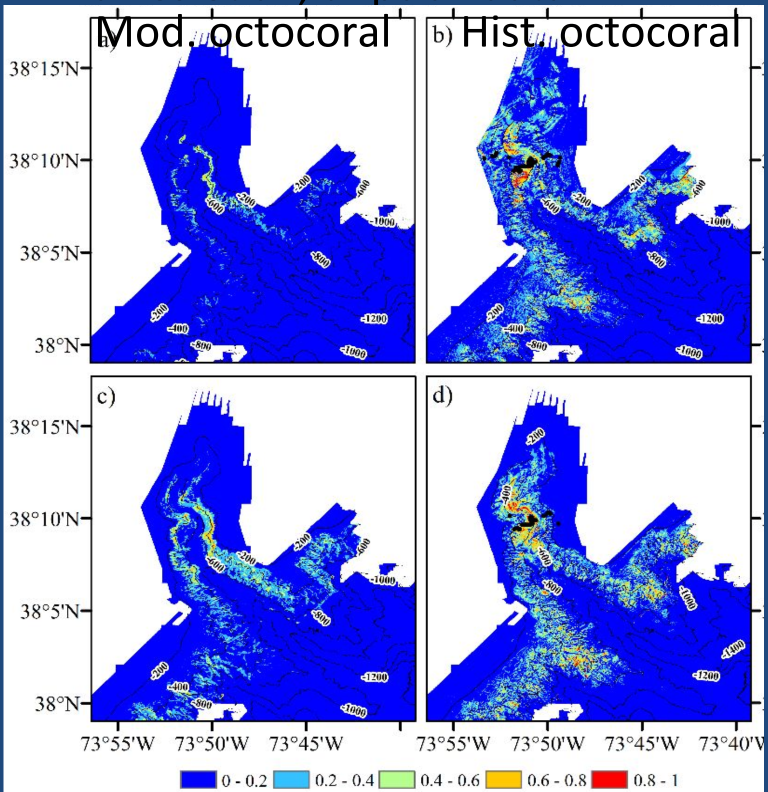
Habitat Modeling

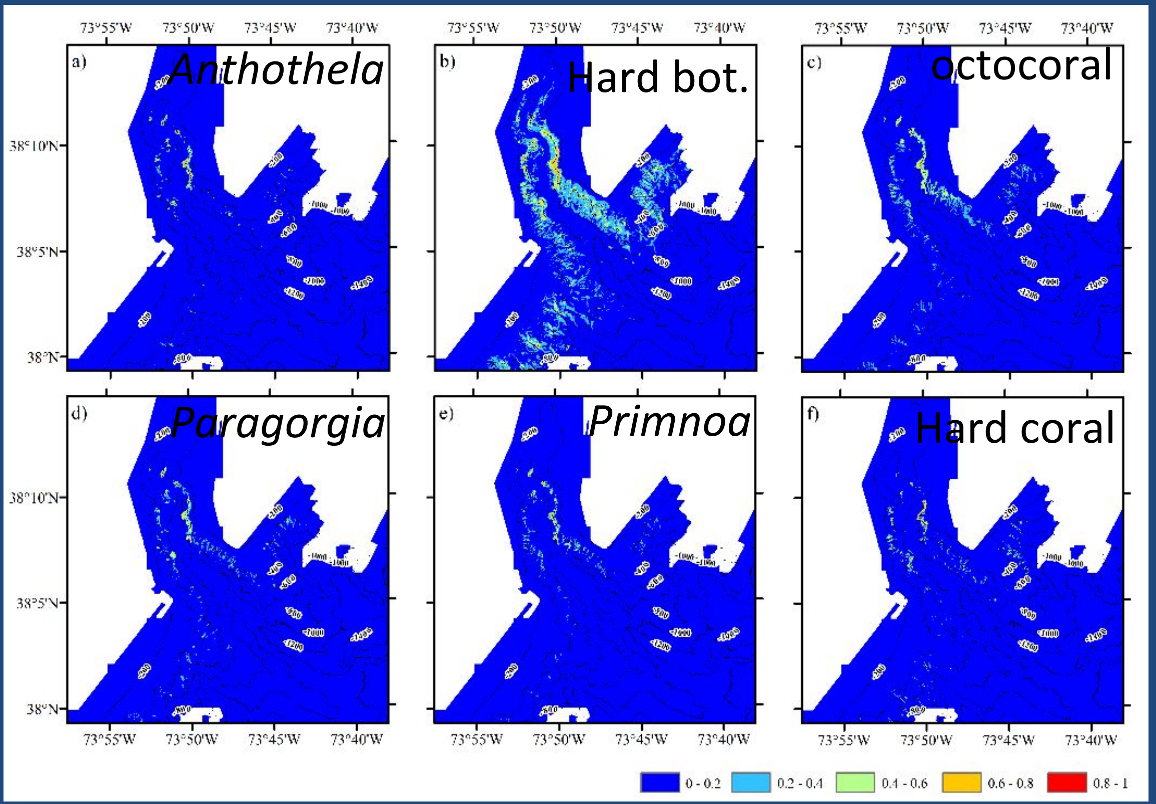
- Terrain & environmental data, + tolerance data
- Historical vs modern data

  (high quality obs. critical)

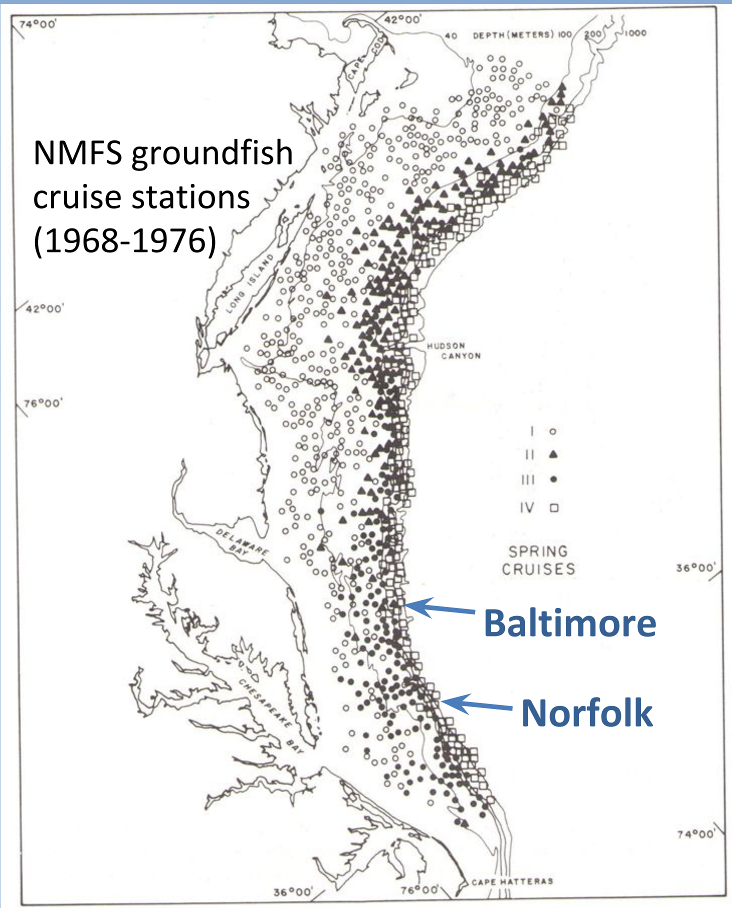
Davies et al., unpubl. data

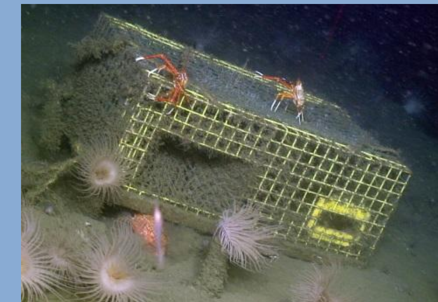


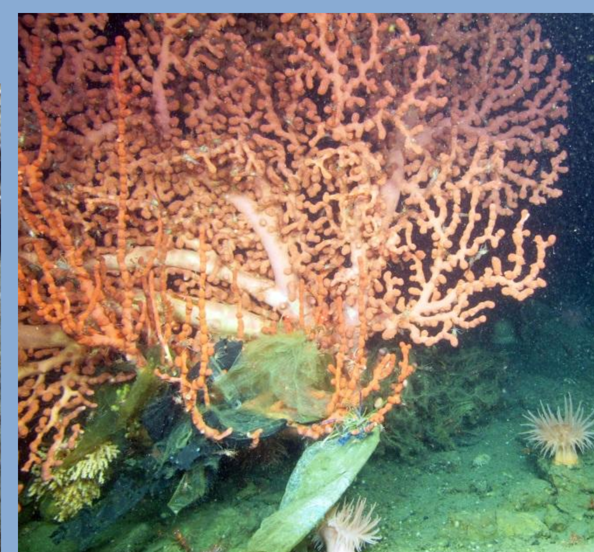




Anthropogenic impacts common: lost fishing gear, trash, lesions on fishes







Summary

- Oceanography different in several regards between the two canyons; canyon morphology & orientation may play roles
- Canyons typified by regular disturbance events as well as persistent phenomena (e.g., nepheloid layers)
- Infauna between canyons differs because of physical differences leading to different organic regimes
- Other sessile fauna (corals, sponges, etc.) may be affected also, but less clear
- Mobile fauna keys on habitat, but only in depths < ~1400 m
- Complex habitats important hotspots & support unique assemblages; structure more important than substrata type

Recommendations

- Fill in multibeam gaps ($\geq$ 100 m)
- Studies of similar detail in a few other different canyons (physics, geology, habitat-fauna, genetics)
- More detailed & focused seep studies
- Benthic/pelagic coupling
- Anthropogenic impacts (plastics, chemical, abandoned gear, fishing & refugia)
- Link with wider area efforts (ATLAS, Canada, SponGES)
- Better coordination