## Impact of Seawater Nonlinearities on the Nordic Seas Circulation U.S.NAVAL Robert W. Helber, Jay F. Shriver, David A. Hebert, Alan J. Wallcraft, and James D. Dykes Naval Research Laboratory, Code 7321, Stennis Space Center, MS RESEARCH LABORATORY

Denmark Strait

#### Abstract

The Nordic Seas (Greenland, Iceland, and Norwegian Seas) are important for Arctic-midlatitude climate linkages. Cold fresh water from the Arctic Ocean and warm salty water from the North Atlantic Ocean meet in the Nordic Seas, where the balance between temperature and salinity variability has been evolving during recent decades. Greenland Sea, deep convection has ceased, allowing the intermediate depth water mass to grow. Present Naval Research Laboratory (NRL) ocean forecast systems, however, do not capture the details of this subsurface ocean structure. The goal of this research is to improve NRL ocean forecast capabilities in the Nordic Seas.

### **The Larger Context**

As described by Carmack (Deep Sea Research II, 2007), "higher long-term mean steric height in the Pacific and subsequent 'downhill' transport of Pacific Water (PW) into the Arctic Ocean and then North Atlantic" results in a "supply of freshwater [from the Pacific that] must return equatorward;" ... "as intermediate water (IW) and deep water (DW) in " the Nordic Seas (Figure 1). We are interesting in the water mass modification processes in the Nordic Seas.



Figure 1. From Carmack, E. C. (2007) "The alpha/beta ocean distinction: A perspective on freshwater fluxes, convection, nutrients and productivity in high-latitude seas." Deep-Sea Research Part li-Topical Studies in Oceanography 54(23-26): 2578-2598.

# NRL Global Ocean Forecasting System (GOFS) Capabilities

A recent global reanalysis has incorrect deep, water masses at 75N in the Greenland Sea. The global Hybrid Coordinate Ocean Model (HYCOM), used in GOFS (Metzger et al. 2017) does not utilize the layered capability of the model.



#### Area of Interest

## **New High Resolution Nordic Seas Regional Domain:** Under Development

Realistic, high resolution (1/25° 1351x1555), Nordic Seas regional HYCOM simulations will be configured such that the layered coordinates follow the water mass structure in Denmark Strait and over the Iceland-Faroe ridge.



## **New Paradigm for Seawater State**

Present numerical ocean modeling utilizes the derived variables of potential temperature and density ignoring a more complete description of seawater thermodynamics (e.g. Feistel R. Prog. In Oceangr., 2003).



### **Thermobaric Instability**

Envision an ocean condition where potential density is constant everywhere, but potential temperature and salinity are not.





- thermodynamics
- parameterization

Studies in Oceanography 54(23-26): 2578-2598. (GDEM) Version 4, NRL/MR/7330—10-9271. Oceanography, 58, 43–114. NRL/MR/7320--17-9722.

#### **Conclusions:**

• Water masses in the Greenland Sea are evolving on intra- annual time-scales (not shown, Rudels et al. 2012) so climatology needs to be updated

• Present general ocean circulation models are missing aspects of non-linear ocean

• The non-linear effect of thermobaricity exists in present regional ocean models without

• The impact of the thermobaricity is to weaken (strengthten) stratification when cool (warm) water overlays warm (cool) water.

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