Natural Variability in Nordic Seas Overflows: Toward a Mechanistic Understanding of Proxy Signals

U. Ninnemann,


Bathymetry Nordic Seas

Western overflow

Iceland

Gardar Drift

Eastern overflow

Norway

Scotland
Observed pattern

Model variability (70-180 band)
Simulate AMO features w/prescribed OHT
Atmospheric forced
Ocean may be response to, not driver of, AMO
models (yes), reconstructions (?)
Q’s remain unanswered:

Mechanisms (is the ocean overturning involved, which elements)?

Robustness (persistence? presence and timescale of the change…aspects that bear on predictability of the system)

Do the overflows vary? (Mainly ISOW)
   On what timescales?
   What aspects (velocity, density etc.)
   Effects (e.g. relationship to ventilation and ocean carbon chemistry)
   Why
Latitude: 60° 19’ N
Longitude: 23° 58’ W
Depth: 2081 m
Sed. Rate: \( \approx 50 \text{ cm ka}^{-1} \)

Modified after Faugères et al. 1999
Deeper/southern site = smaller grain size mean and variability.
Similar frequencies suggest ocean role/response on AMO timescales.

[AMO from: Enfield et al., 2001; Gray et al., 2004b; Mann et al., 2009; Svendsen et al., 2014; Mjell et al., 2016]
certain-phasing

Ocean could either drive or be driven by climate.

to determine phase helps differentiate mechanisms

Requires absolute age of ash peaks (Irvali et al in prep.)
Variability in bottom flow (ISOW):

Largest magnitude on millennial timescales but also variations on multidecadal-centennial timescales over past 10 kyr.

Knight & Sutton, 2005

Mjell et al., 2015
How does bottom flow south of ridge relate to ISOW?

Langehaug et al., 2016

Use a fully coupled global climate model – Bergen Climate Model (BCM)

The model has produced a 500-yr long simulation which includes historical solar irradiance and volcanic aerosol variations.

The ocean part of BCM is an isopycnal model, i.e., z-coordinate is defined on density surfaces.
• Downstream velocity not simple metric for overflow transport (density more important)

Conversely, processes controlling FSC overflow transport are not necessarily those that drive flow along the GD (important how one up-scales the significance of proxy signals using models)

Using FSC density and transport we are able to explain (r=0.87) ~ 76% of variability in the downstream velocity at the Gardar Dam
Increased bottom flow = decrease overflow (density & transport) & flow shoals (shallower isopycnals thicken and increase in velocity).

Implications for proxy records, location vital, around axis of flow (could vary on long timescales Thornally et al., 2013).
Mechanisms—modulation by SPG circulation (or LSW formation)?

GD & BTSF

Variance  BTSF

FSC density & BTSF

Not the (direct) mechanisms driving GD in BCM.

Major circulation modes not correlated with strength of GD operates independently of gyre circulation.

Driven by changes further upstream.

FSC density-BTSF relation similar to GD-BTSF relation.

Langehaug et al., 2016
Mechanisms—modulation by Nordic Seas surface conditions and circulation and pressure gradients across ridge. (see also K. Lohmann et al., 2015)

Weak overflow (and GD flow) related to negative SST and SSS anomalies drive negative density anomalies—decreasing convection and the cross ridge pressure gradient.

Composite of weak flow states

Low SST  Low SSS  Decrease MLD

A overflow (and GD flow) related to negative SST and SSS anomalies drive negative density anomalies—decreasing convection and the cross ridge pressure gradient.
Overflows varying vertically may be hard to metric with one or a few grain size records however, may leave a fingerprint in other water mass/ventilation (test with $\delta^{13}C$)
Changes in ventilation ($\delta^{13}C$) uniformitarianism problematic upper ocean $\delta^{13}C$ altered by invasion of light anthropogenic
Recovering the natural \( \delta^{13}C \) pre-Anth distribution

**uncorrected**

- Homogeneous/small gradients
- Absent or low values
- Highest values >2km
- No clear signal of overflows

**corrected**

- Larger vertical and horizontal gradients
- Related to specific water masses
- NB LSW

Changes in ventilation (using \( \delta^{13}C \))
uncorrected

Homogeneous/small gradients

Near Holocene midpoint
  - both +/- ventilated
  - more/less carbon uptake?

Requires preformed $\Delta$
  - How to increase decrease?
corrected

freq. “chatter” makes sense
E.g. Δ (decreases) in LSW
As a template for interpreting the past, corrected

High freq. “chatter” makes sense. E.g. $\Delta$ (decreases) in LSW

Yashayaev, 2008
As a template for interpreting the past

corrected

In the N.Atl. Near Holocene max

- Natural variability—decreased ventilation (not +/-)

Large decreases

- associated w/cooling

require additional $\Delta$

- not just short term LSW
  - SSW
  - Persisting LSW $\Delta$?
Curry & Mauritzen, 2005

15 yrs sample resolution, 13 AMS 14C dates

DSOW bottom water flow and ventilation covary
C. wuellerstrofi 3 pt smooth
Mean Sortable silt (10-63 micron)

More NADW

C. wuellerstrofi δ^{13}C (%)

Less NADW

BW flow speed (mean sortable silt)

BW ventilation (benthic δ^{13}C)

Mean sortable silt

Covariance consistent with vertical movement of DSOW

Kleiven, Rosenthal & Ninnemann, in prep
...climate-circulation phasing TBD

- BW flow on Gardar (model) related to ISOW (density&transport)

- BW flow (model GD) migrates vertically and driven by Nordic Seas changes (e.g., X-ridge density gradients) [Lohmann et al., 2015; Langehaug et al, 2016]

- BW ventilation varies on decadal-centennial timescales (DSOW&ISOW)
  SPG cold, fresh, lower density = weaker BW ventilation & flow (LSW?)
  (salinity dominance for buoyancy)

- Modern BW ventilation ($\delta^{13}C$) near its Holocene peak
  - Recent natural variability marked by decreases from modern state.

- Multidecadal BW variability through Holocene (intermittent strength), larger variability on centennial and millennial timescales.
  - Millennial most prominent (esp. last 8 kyr)
  - Prominent variability (centennial events) early Interglacials