Taking the pulse of the Gulf Stream through variational inverse methods: is the North Atlantic Oscillation teasing it?

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26 apr 2018 - FOCUS Young Scientists Day

Background and motivation

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  - What about FRIA?

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  - FNRS?
    - "Very promising project! As a result, we decided to reject it."
  - What about FRIA?
    - Good things come in threes, didn't dare to check it!
  - Motivation:
    - Freedom of research
    - Transversal topic
    - Many trips abroad

My expectations with respect to FOCUS

- Job offers, job days?
- How to highlight PhD valuable experience (CV,...)?
- Make the PhD guidelines more accessible/visible (FOCUS website)?

Information about PhD spread among many websites

Centralise the information at http://www.focus.uliege.be ?

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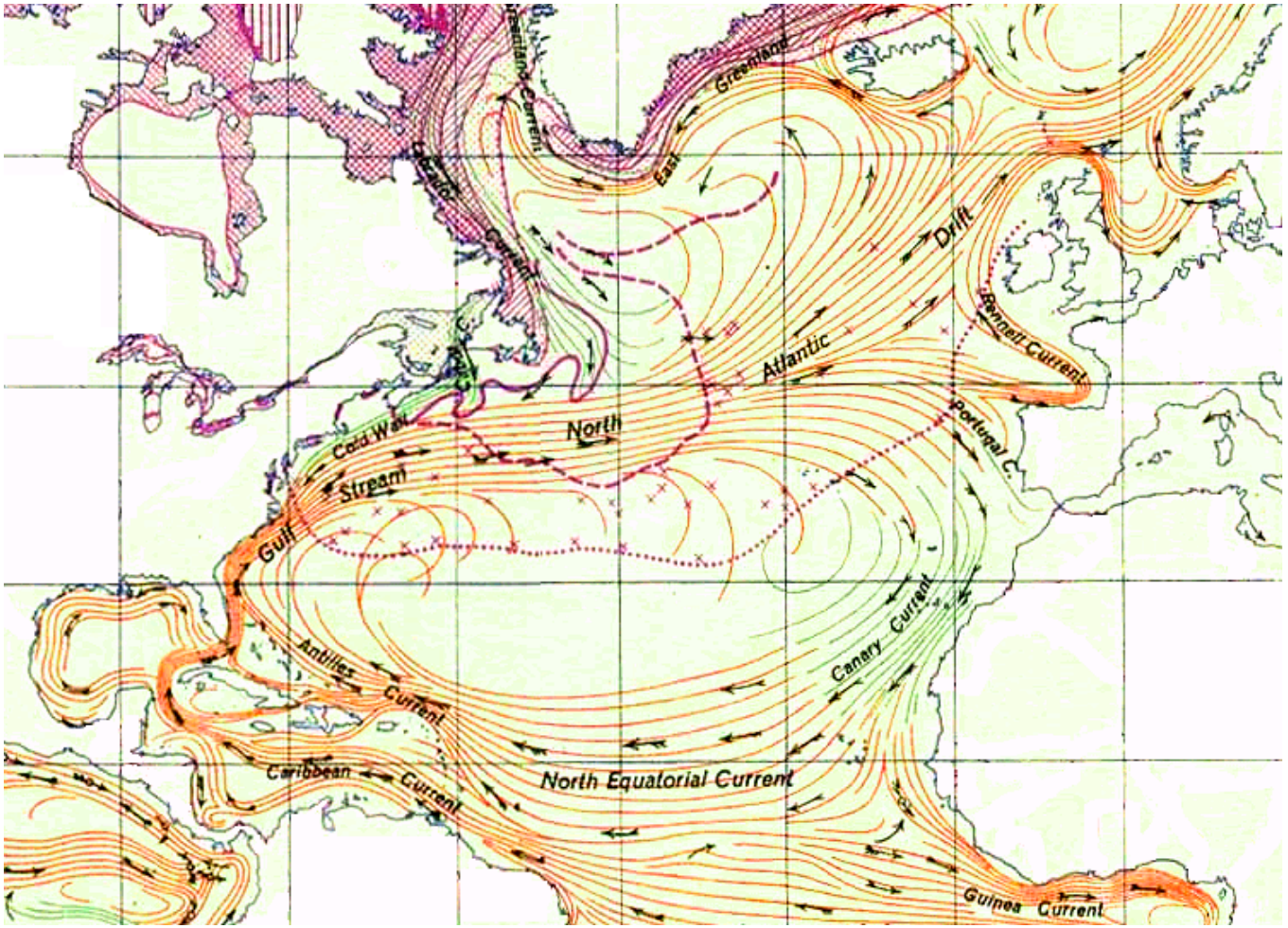
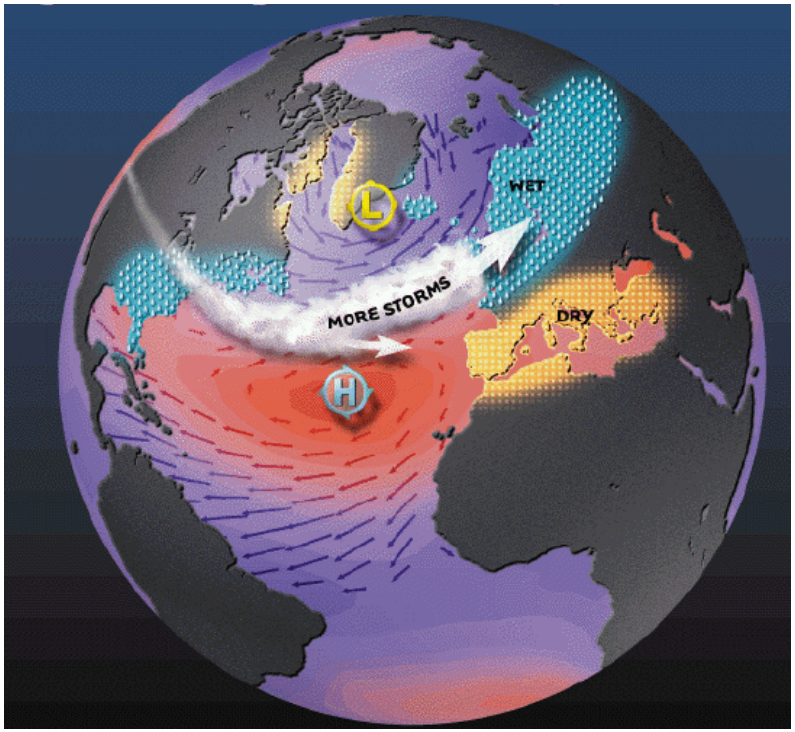
The Gulf Stream

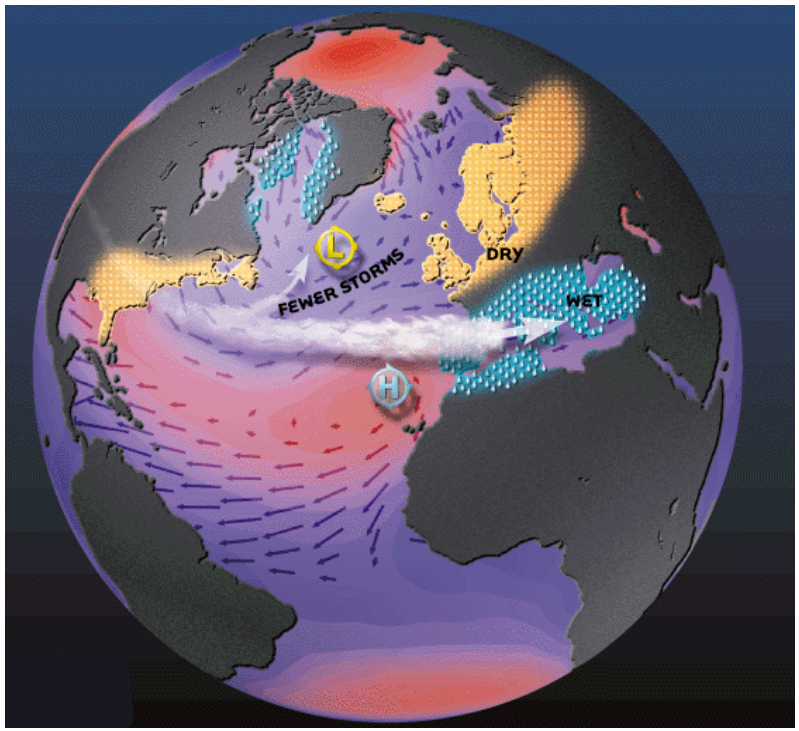


Source : Ocean Currents and Sea Ice from Atlas of World Maps, United States Army Service Forces, Army Specialized Training Division. Army Service Forces Manual M-101 (1943).

The North Atlantic Oscillation (NAO)



NAO +



NAO -

(Source : Martin Visbeck et Heidi Cullen, Lamont Doherty Earth Observatory, NOAA)

Is there a link?

- (Near-)consensus on
  - the influence of NAO on the GS
  - NAO+ $\Rightarrow$ stronger GS ; NAO– $\Rightarrow$ weaker GS
  - NAO+ $\Rightarrow$ GS shifts northward ; NAO– $\Rightarrow$ GS shifts southward
- No clear consensus on
  - the existence of a time lag between NAO and GS
  - the assessment of this lag
- Uncertainties due to
  - short time series
  - coarse resolution models
  - subjective methods
  - small data sets
  - absence of error estimates

Method - 1. Data acquisition

Variable	Database	No. of obs.	Total	No. of duplicates	Total without dup.
Temperature	WOD	24234836	40737763	13695754	27042009
	SeaDataNet	3778937			
	ICES	5810552			
	Hydrobase3	3962613			
	Argo	2950825			
Salinity	WOD	13468105	28363948	12560338	15803610
	SeaDataNet	2546423			
	ICES	5592437			
	Hydrobase3	3962613			
	Argo	2794370			

- Collecting a maximum of data (T/S)
- Duplicates handling & quality control
- Production of an homogeneous data base ($\sim$40 M)

- Production of a continuous field from discrete measurements

Variational Inverse Method (VIM)

φ is the analyzed field,
N_d the number of data points,
d_j the data value in (x_j, y_j),
D the region of interest.
We search for φ minimizing J on D :

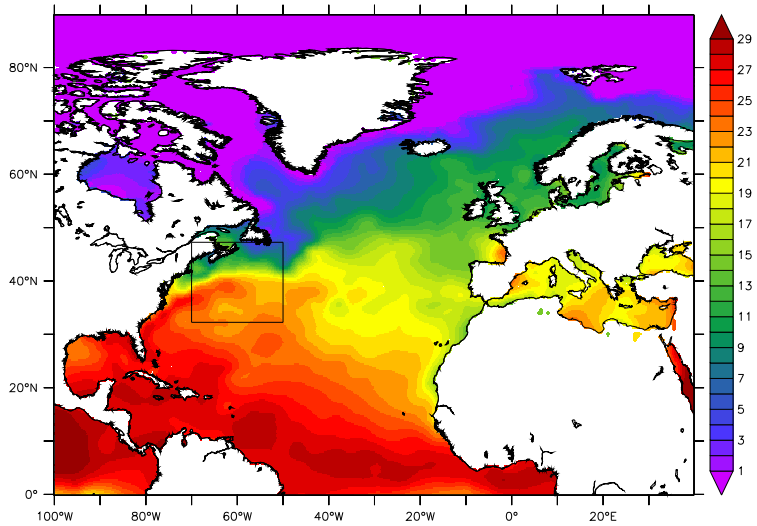
$$J[\varphi] = \sum_{j=1}^{N_d} \mu_j [d_j - \varphi(x_j, y_j)]^2 + \|\varphi\|^2$$

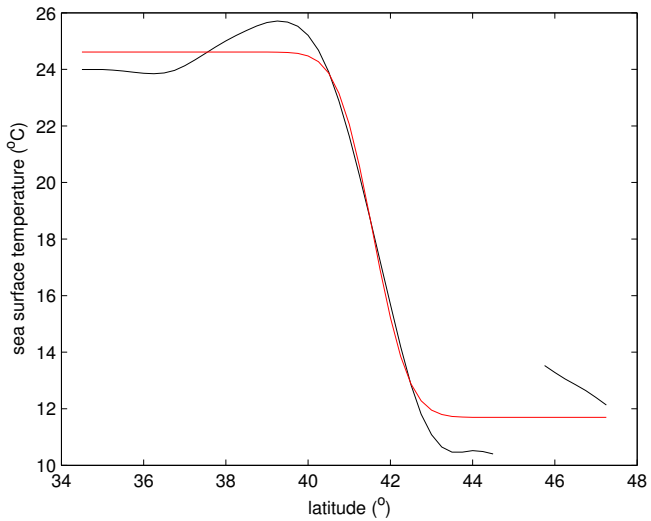
where $$\|\varphi\| = \int_D (\alpha_2 \nabla\nabla\varphi : \nabla\nabla\varphi + \alpha_1 \nabla\varphi \cdot \nabla\varphi + \alpha_0 \varphi^2) dD$$

Gulf Stream North Wall index

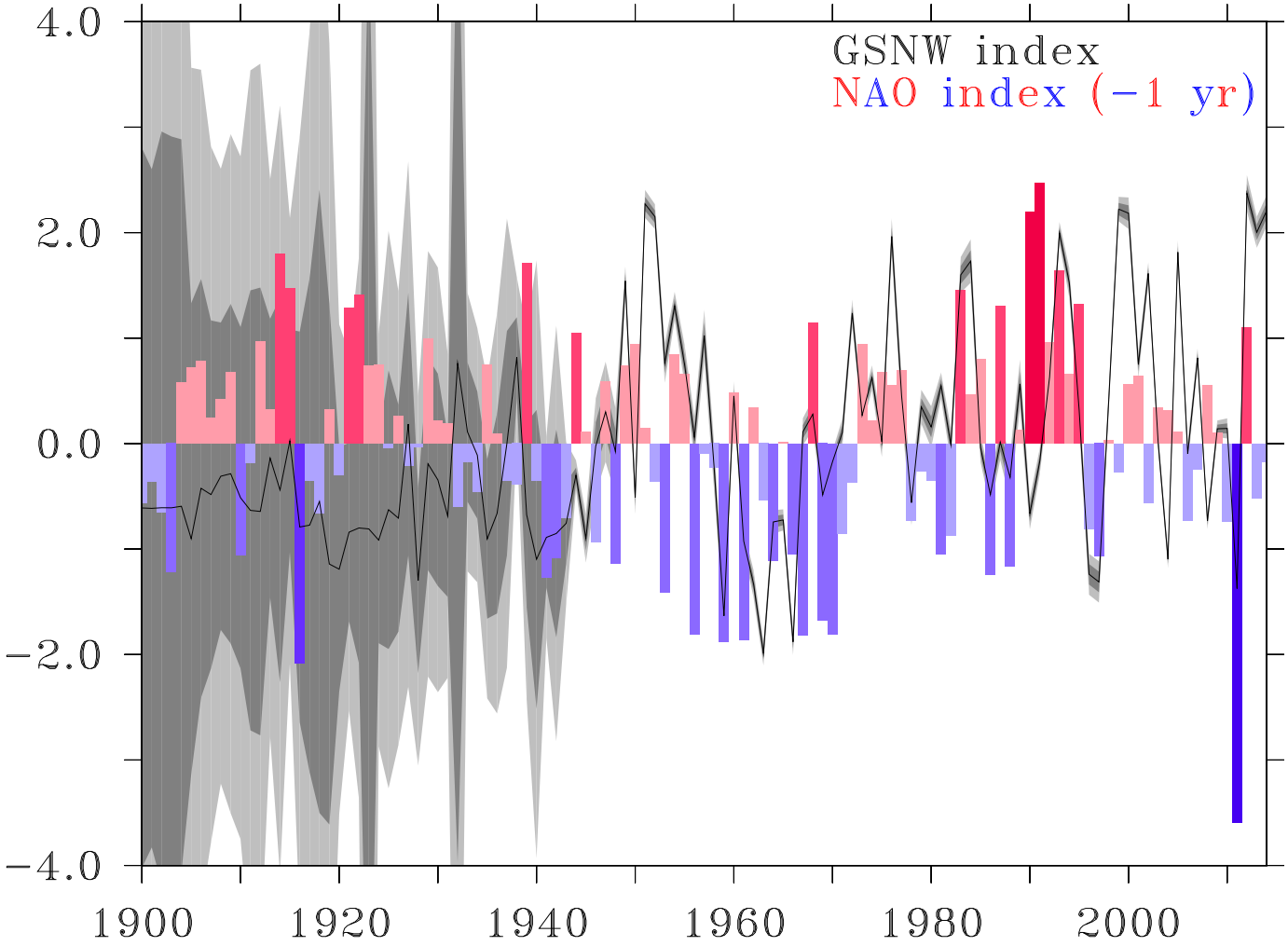
- Monthly diva analyses of SST since 1900

- Fit by err fct for 81 lon
- Longitudinal filtering acc. quality of fit
- 81 lat. of highest gradient
- 1st EOF (N-S movement)
- GSNW between 1900 and 2012
- Correlation with NAO (lag 0,1,2 years)



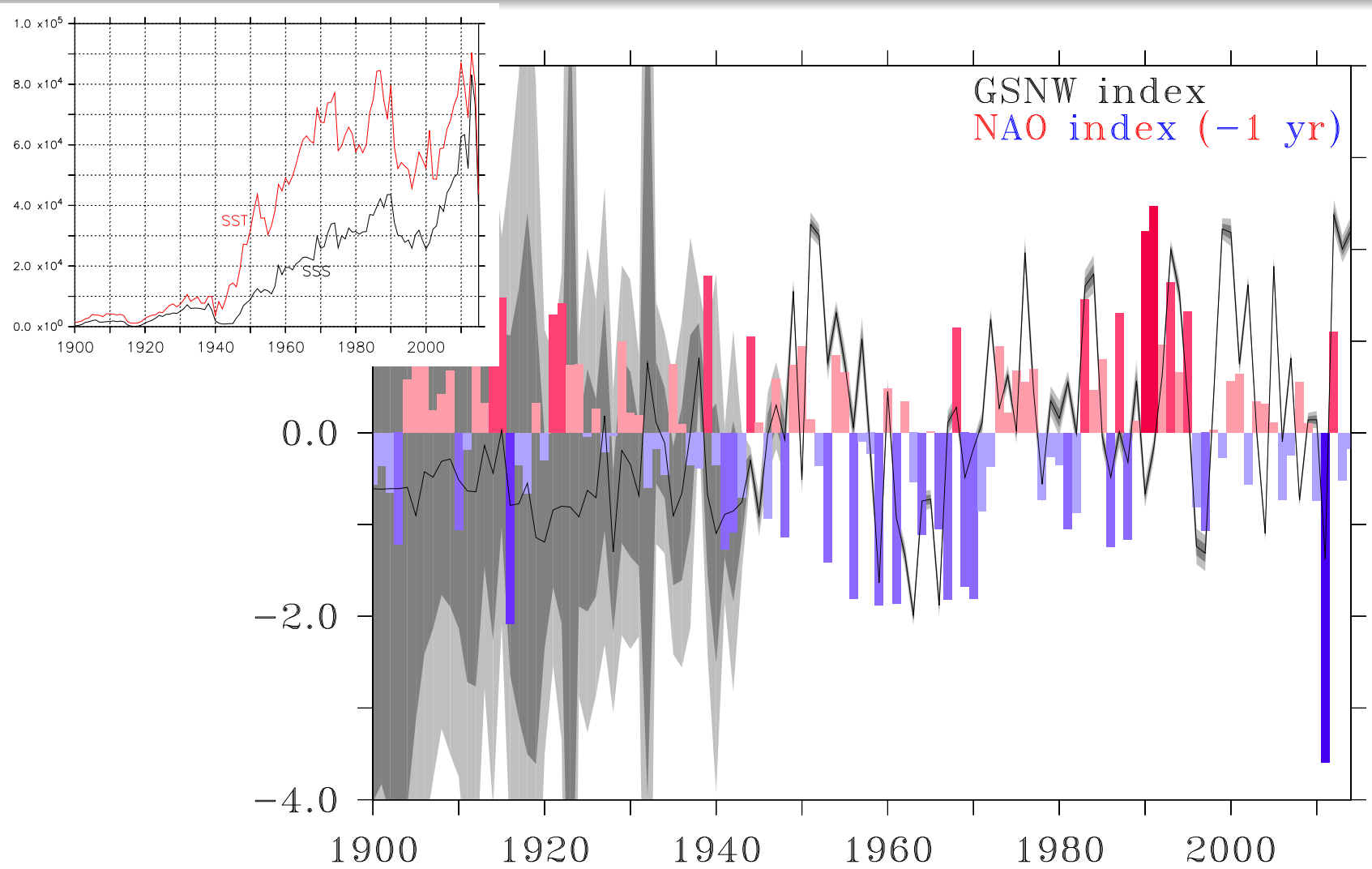


Correlations NAO-GSNW



Correlation	NAO	NAO (-1 yr)	NAO (-2 yr)
GSNW (1940-2014)	0.1812	0.3692 (S)	-0.02329

Correlations NAO-GSNW



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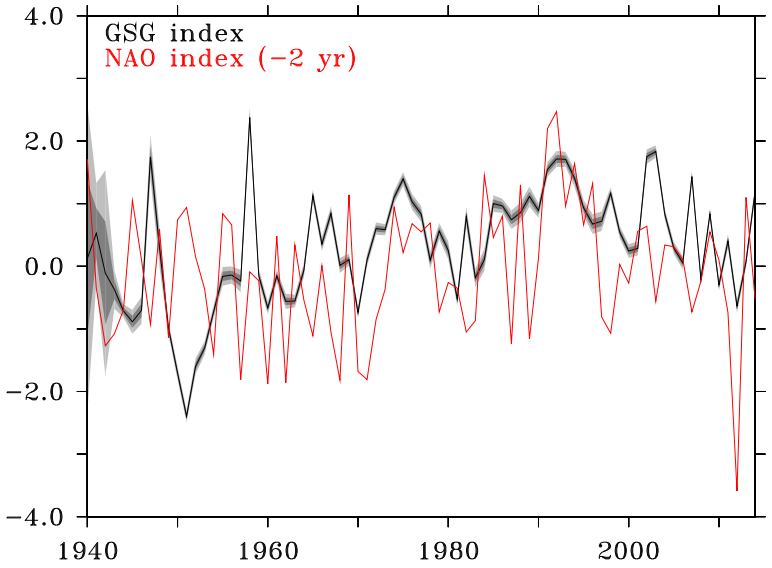
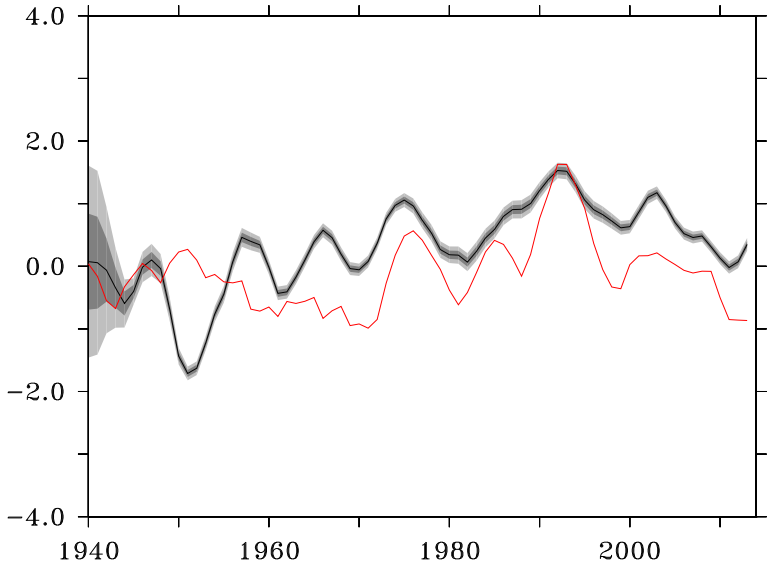
Correlation NAO-GSD

- Gulf Stream Delta index: measures the T diff. across GSNW



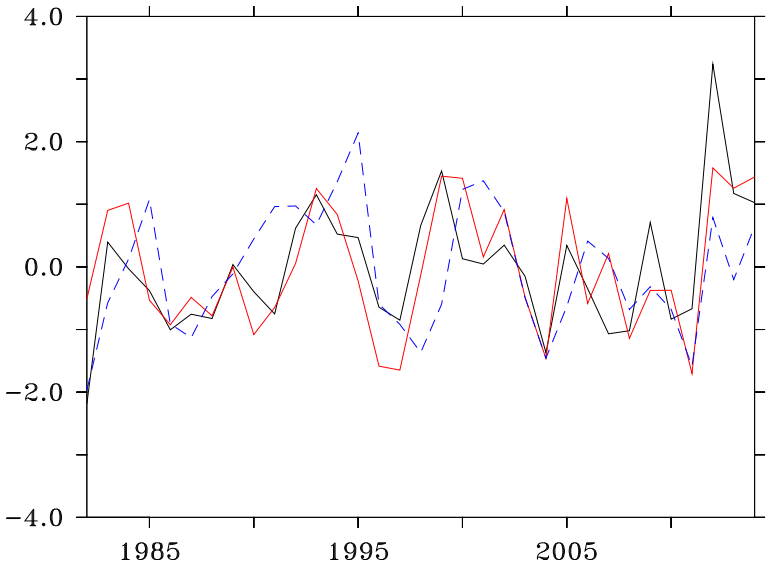
GSD (black) and NAO with 2 year lag (red)



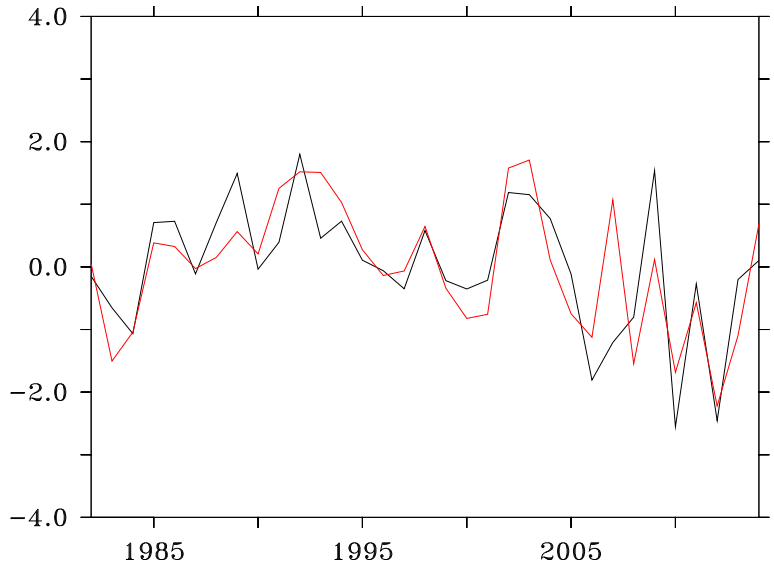
Running averages of GSD and NAO ; 4-yr basis

Correlation	NAO	NAO (-1 yr)	NAO (-2 yr)
GSG (1940-2014)	0.2077	0.1667	0.2069
GSG (1960-2014)	0.4964 (S)	0.2838	0.4297 (S)

Comparison with satellite data and Taylor GSNW index



GSNW Diva (red), GSNW sat (black), Taylor (blue)

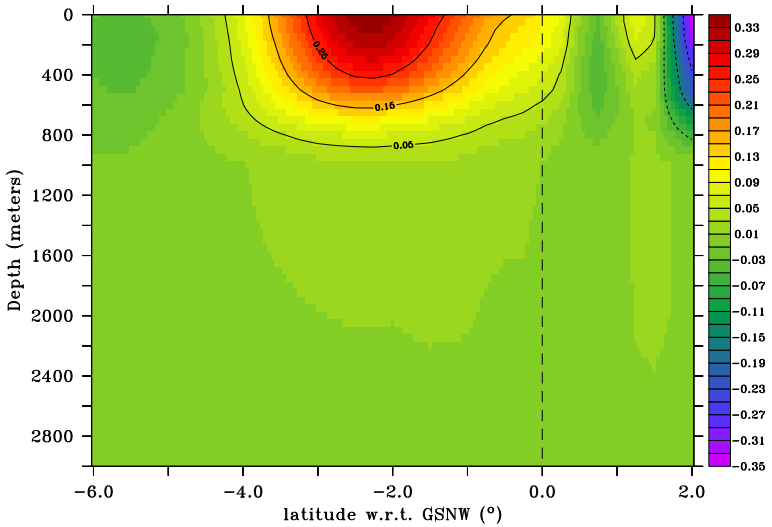


GSD Diva (red), GSD sat (black)

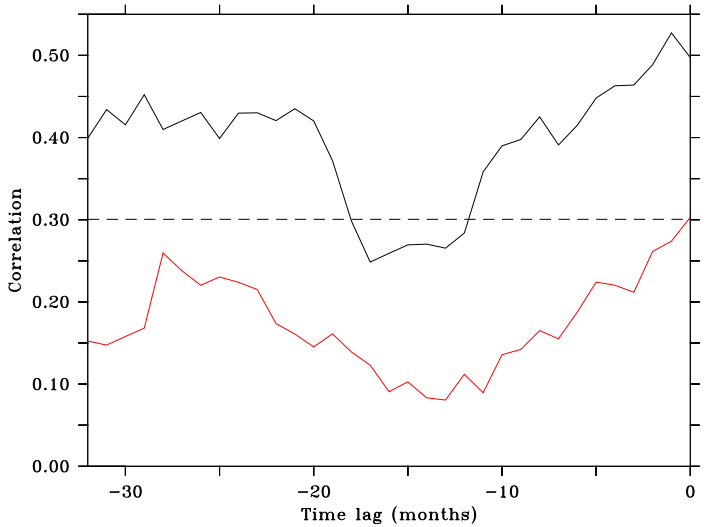
Correlation	GSNW Diva	GSNW sat	GSD sat
GSNW Diva		0.7336	
Taylor GSNW	0.4331	0.4458	
GSD Diva			0.7559

GS speed and transport

- T and S diva maps at 15 depths (0-3000 m)
- Speeds from geostrophic equilibrium



Average speeds (ms^{-1}) along the GS in March 2014



Correlations between NAO-GSD (black) and between NAO–GST (red) on 1960–2014

GST	NAO	NAO (-1 yr)	NAO (-2 yr)
1940-2014	0.3476 (S)	0.1620	0.2202
1960-2014	0.3030 (S)	0.1119	0.2239

Working plan

1. Extend the GSG index to a real transport index (3D)
2. Increase the reliability of DIVA analyses
    1. Weighting too close data
    2. Use of variable correlation length (from sat. data)
3. Other developments of DIVA (eg. detrending option)
4. Other variables (salinity, currents)
5. ...

Thank you for your attention !

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GSG index

- Monthly diva analyses of SST since 1900
- Fit by err fct for 81 lon
- Longitudinal filtering acc. quality of fit
- 81 values of highest gradient
- Average
- GSG index between 1900 and 2012
- Correlation with NAO (lag 0,1,2 years)

Sensitivity to reference field

- From 1st analyses err fct fits, creation of new ref monthly fiels
- New estimation of parameters CL & SN
- Analyses
- => GSNW index not affected

Handling of duplicates

1. Immediate removal of exact duplicates
2. Longer procedure for near duplicates :
   - $\triangle lon < 0.1^{\circ}$
   - $\triangle lat < 0.1^{\circ}$
   - $\triangle time < 1h$

$\Rightarrow$ candidates duplicates

1. If $\triangle val < 0.1$ then
   - averaging the candidates
2. else
   - averaging + low weight on this observation

Handling of sea ice cover

1. Sea ice concentration since 1870 from Walsh and Chapman (2013)
2. Average on 1900-2011 & interpolation on DIVA grid
3. hshs

Pixels $> 15\%$ of sea ice are replaced by Levitus (2010) climatology (1°)

Variational Inverse Method (VIM)

Parameters :

1. α_0 penalizes the field itself (anomalies)
2. α_1 penalizes the gradients
3. α_3 penalizes the variability
4. μ penalizes the error of the analysis