Arne Biastoch | Helmholtz Centre for Ocean Research Kiel

Modelling the Agulhas Current and its Coupling with the Atlantic Circulation

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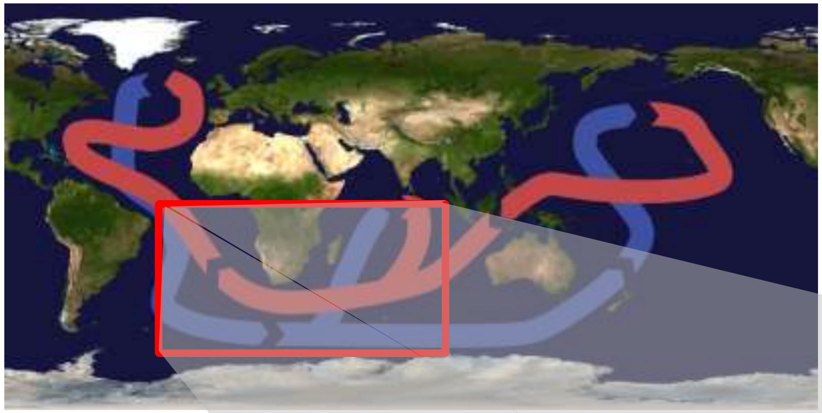
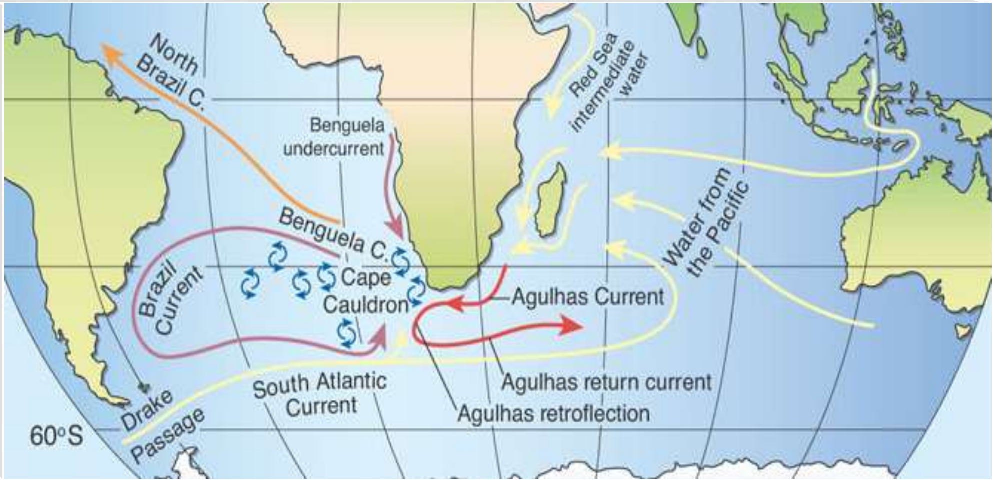
The Agulhas System as a Key Region of the Global Oceanic Circulation

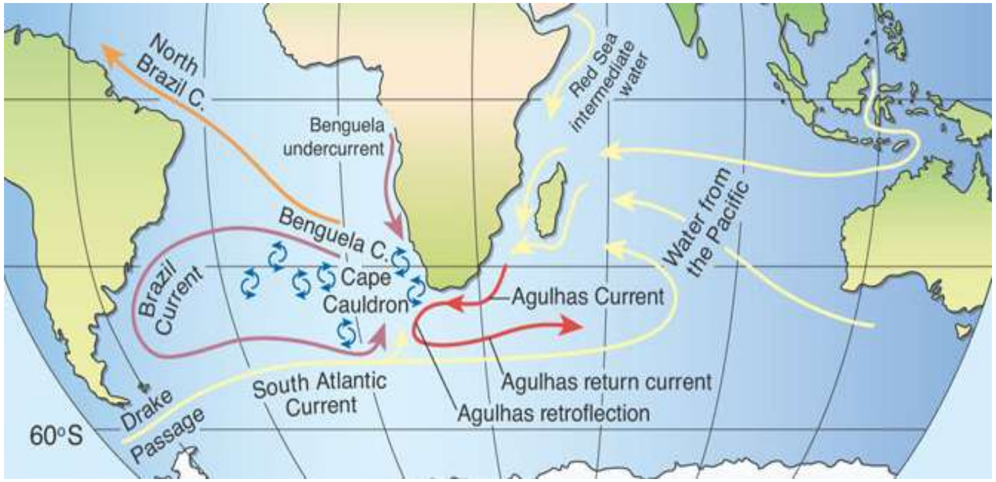




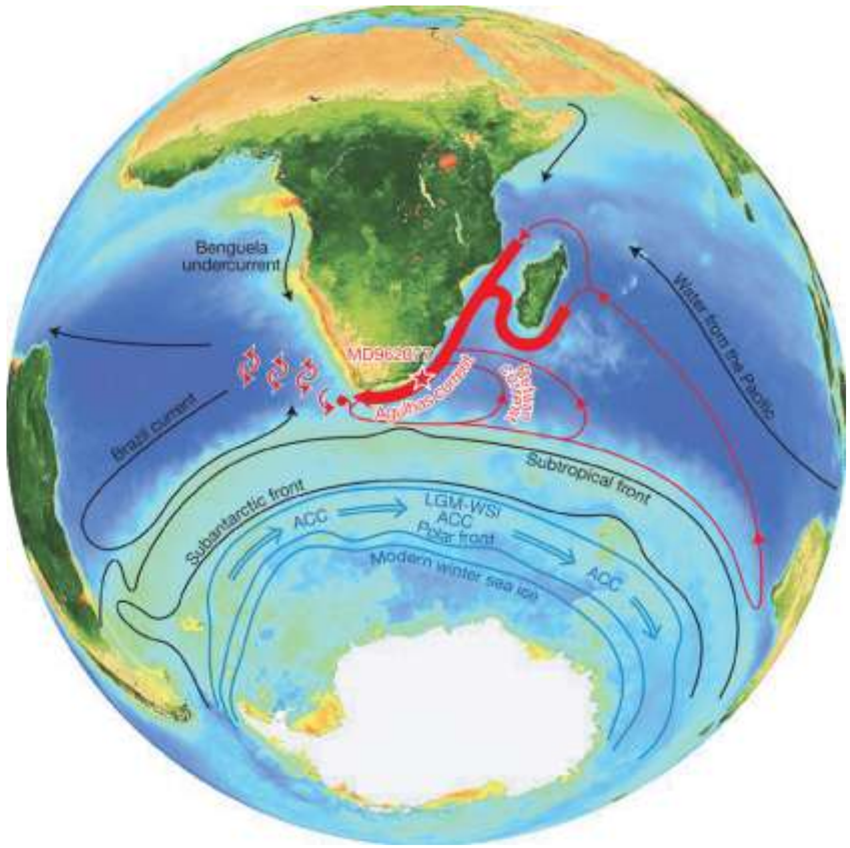
Gordon (*Nature*, 2003)

Structure

- Introduction
- Modelling the Agulhas Current
- Agulhas Leakage
- Large-Scale Response I: Waves
- Large-Scale Response II: Advection
- Summary and Perspective



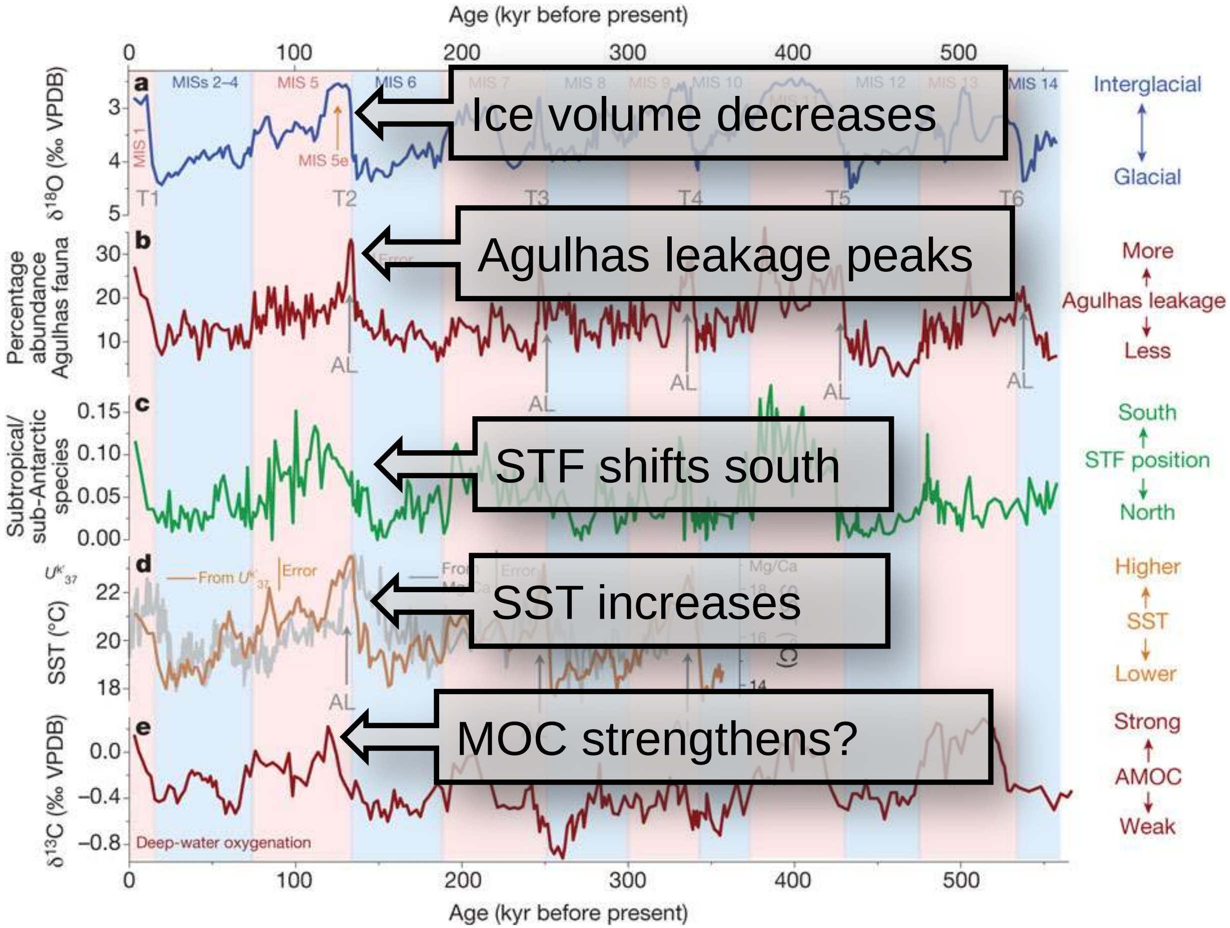
Gordon (*Nature*, 2003)



Satellite picture (SeaWiFS) of ocean colour

Palaeoceanography: Agulhas and Climate

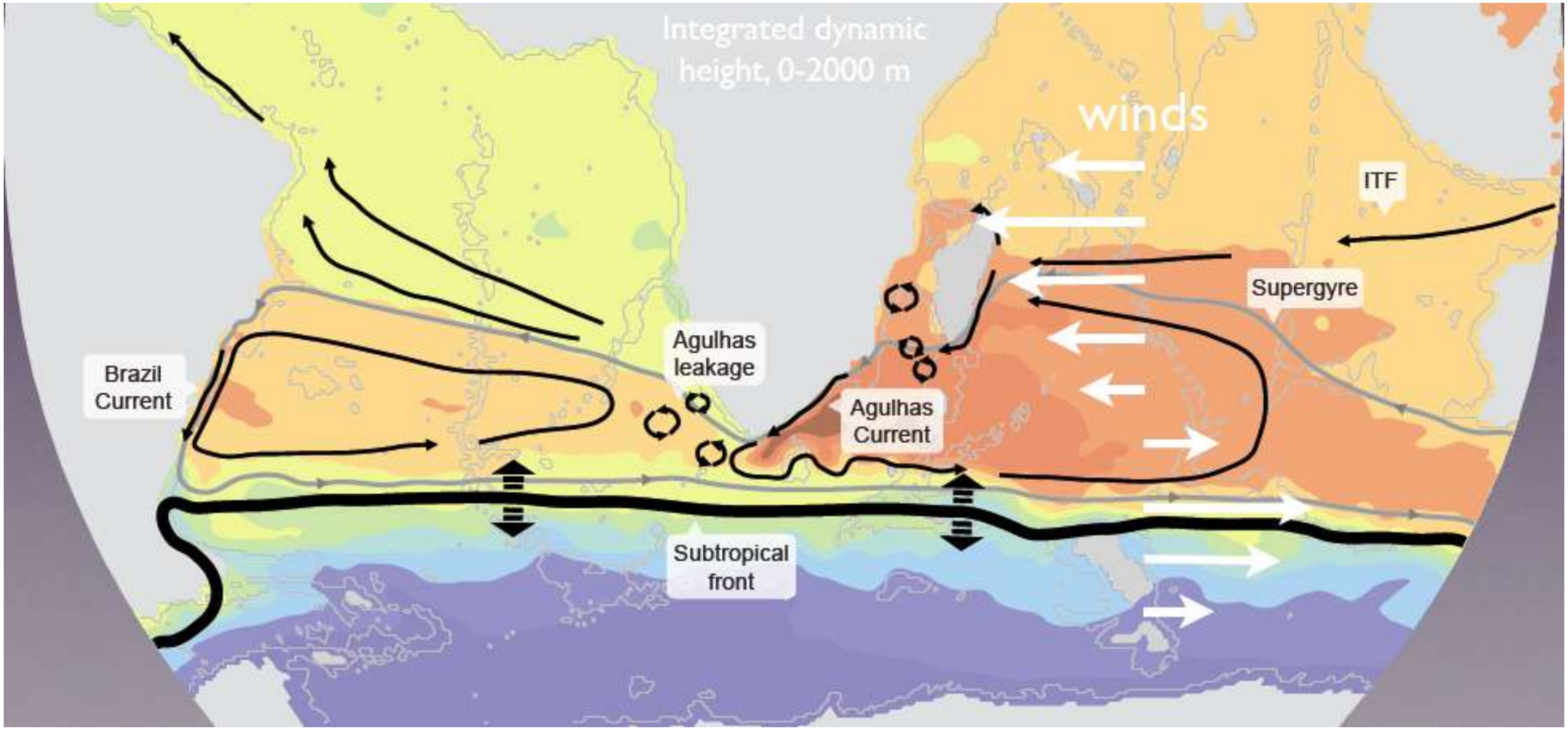
GEOMAR



Beal, de Ruijter, Biastoch, Zahn and SCOR WG 136 (Review in *Nature*, 2011)

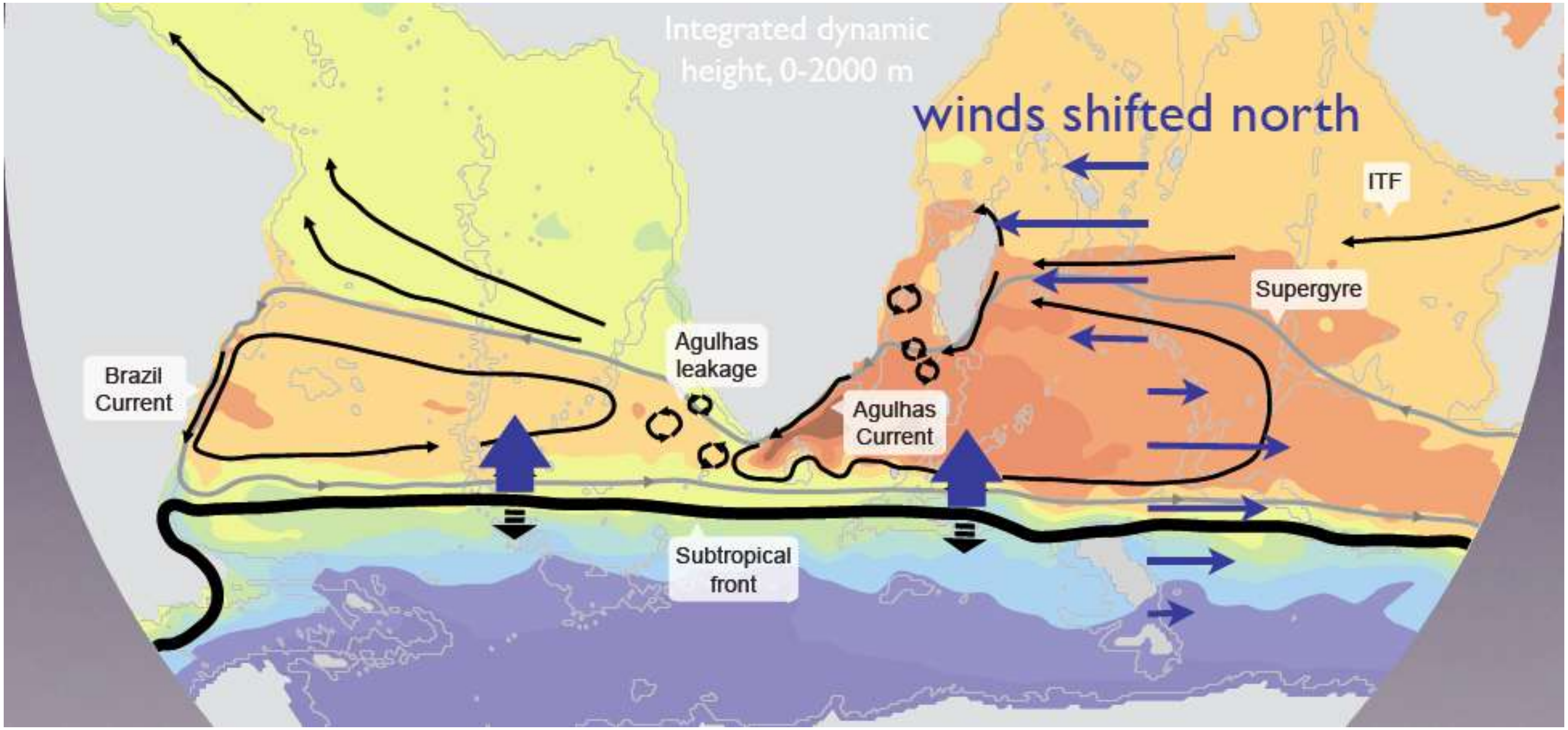
HELMHOLTZ ASSOCIATION

Dynamical Controls on Agulhas Leakage



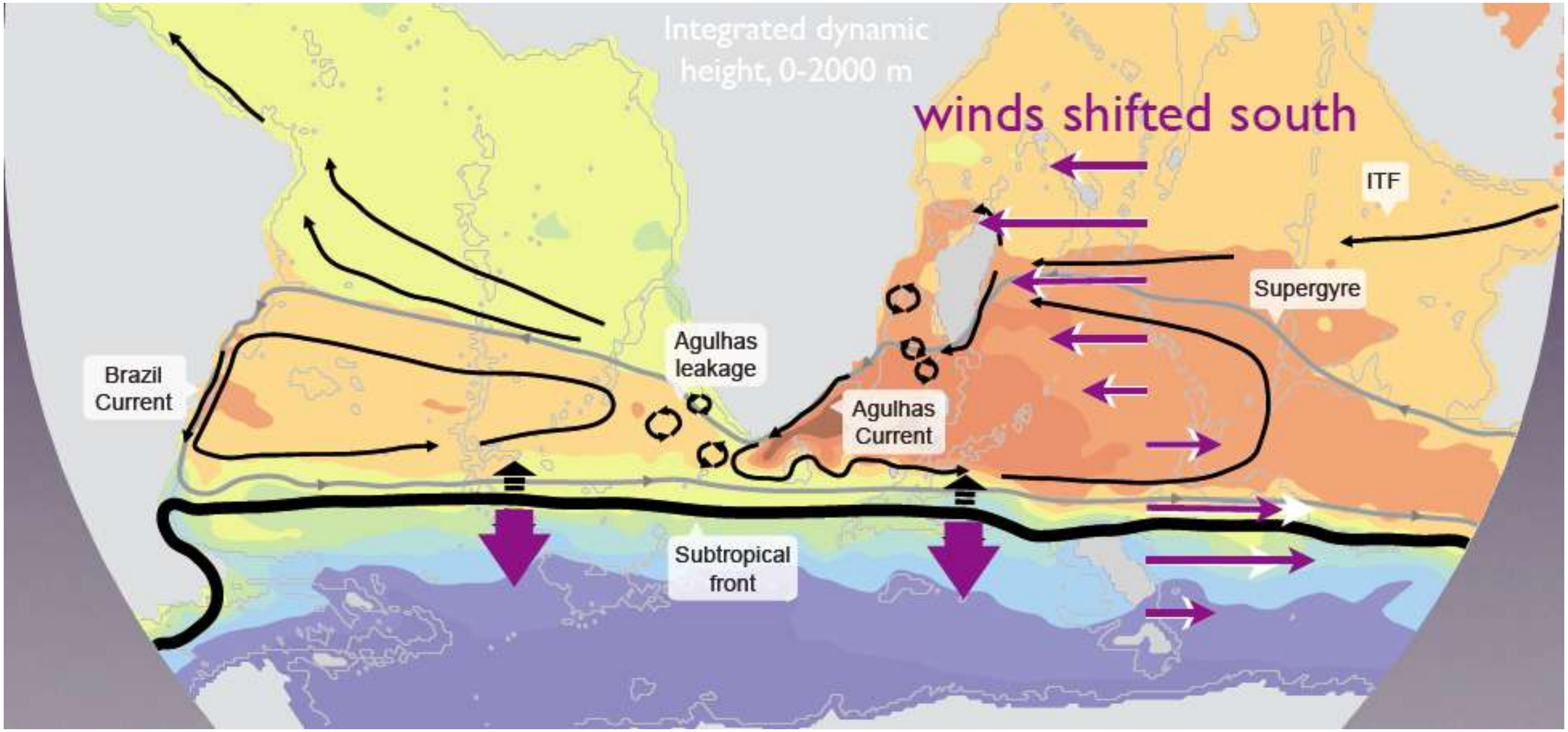
Beal, de Ruijter, Biastoch, Zahn and SCOR WG 136 (Review in *Nature*, 2011)

Dynamical Controls on Agulhas Leakage



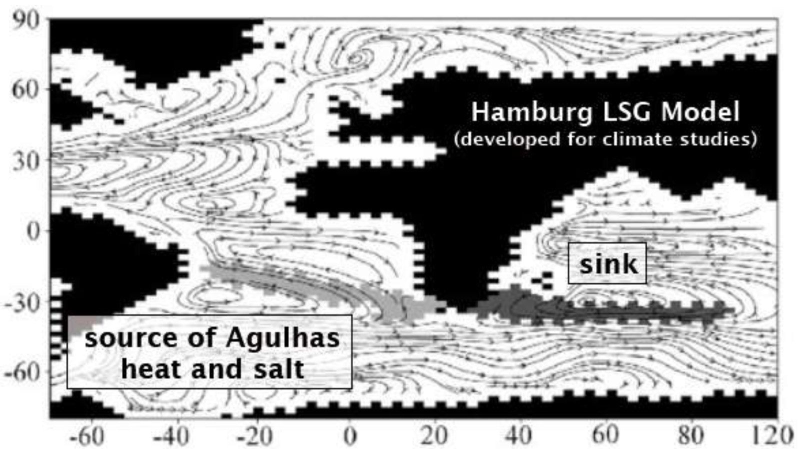
Beal, de Ruijter, Biastoch, Zahn and SCOR WG 136 (Review in *Nature*, 2011)

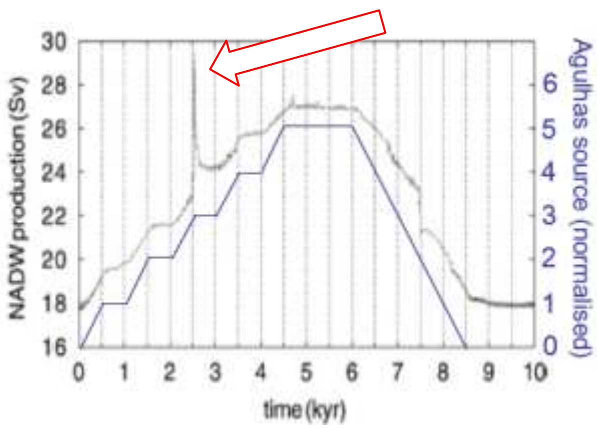
Dynamical Controls on Agulhas Leakage



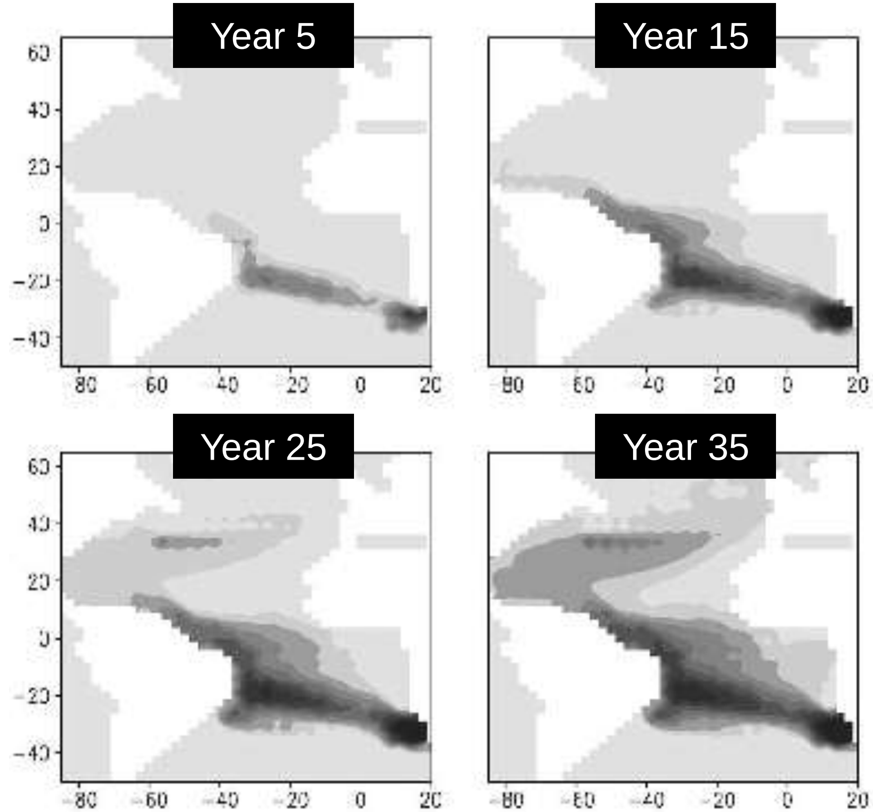
Beal, de Ruijter, Biastoch, Zahn and SCOR WG 136 (Review in *Nature*, 2011)

Response of the North Atlantic to South Atlantic Buoyancy Input





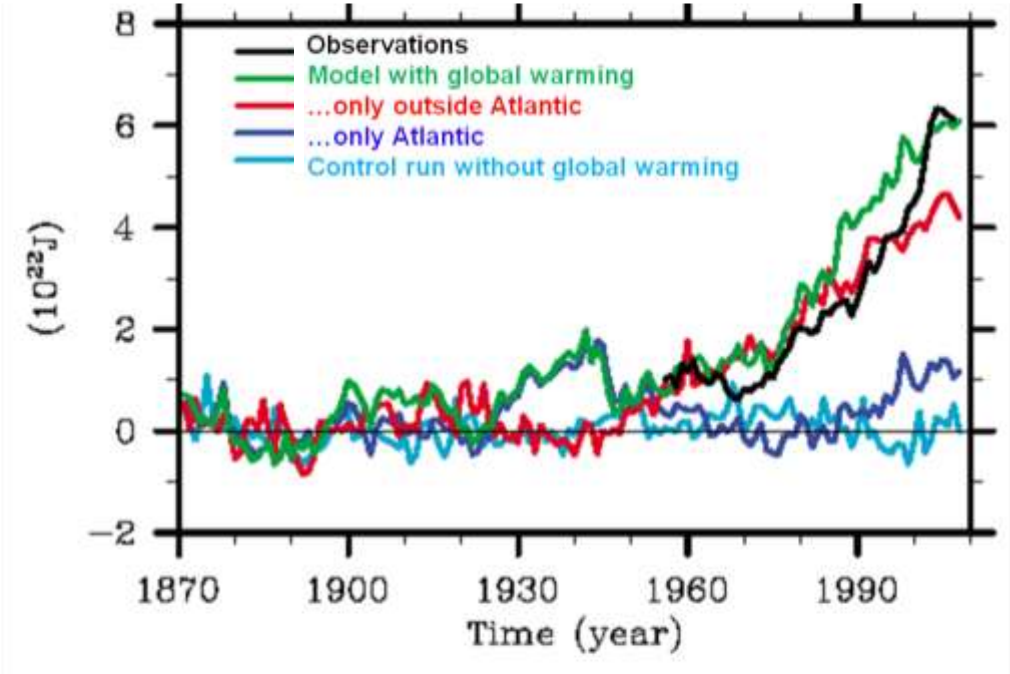
Input and NADW response



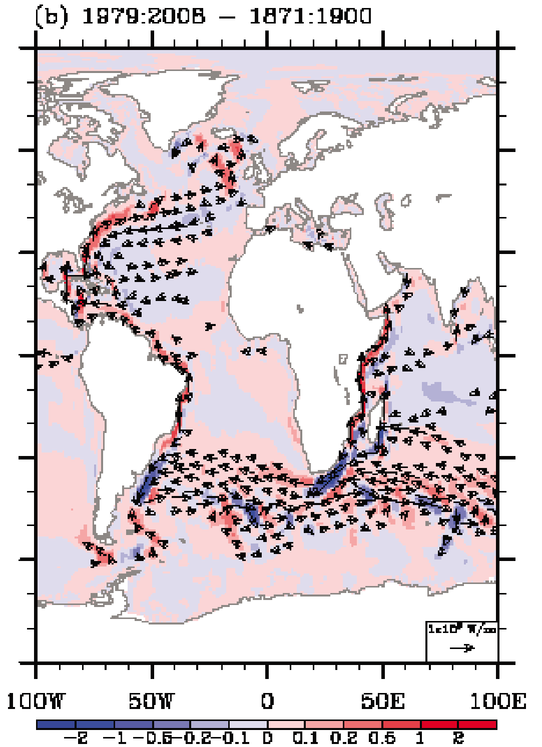
Spreading of salt anomaly at 250 m depth

Weijer et al. (2002)

Far-field Influence on North Atlantic Climate

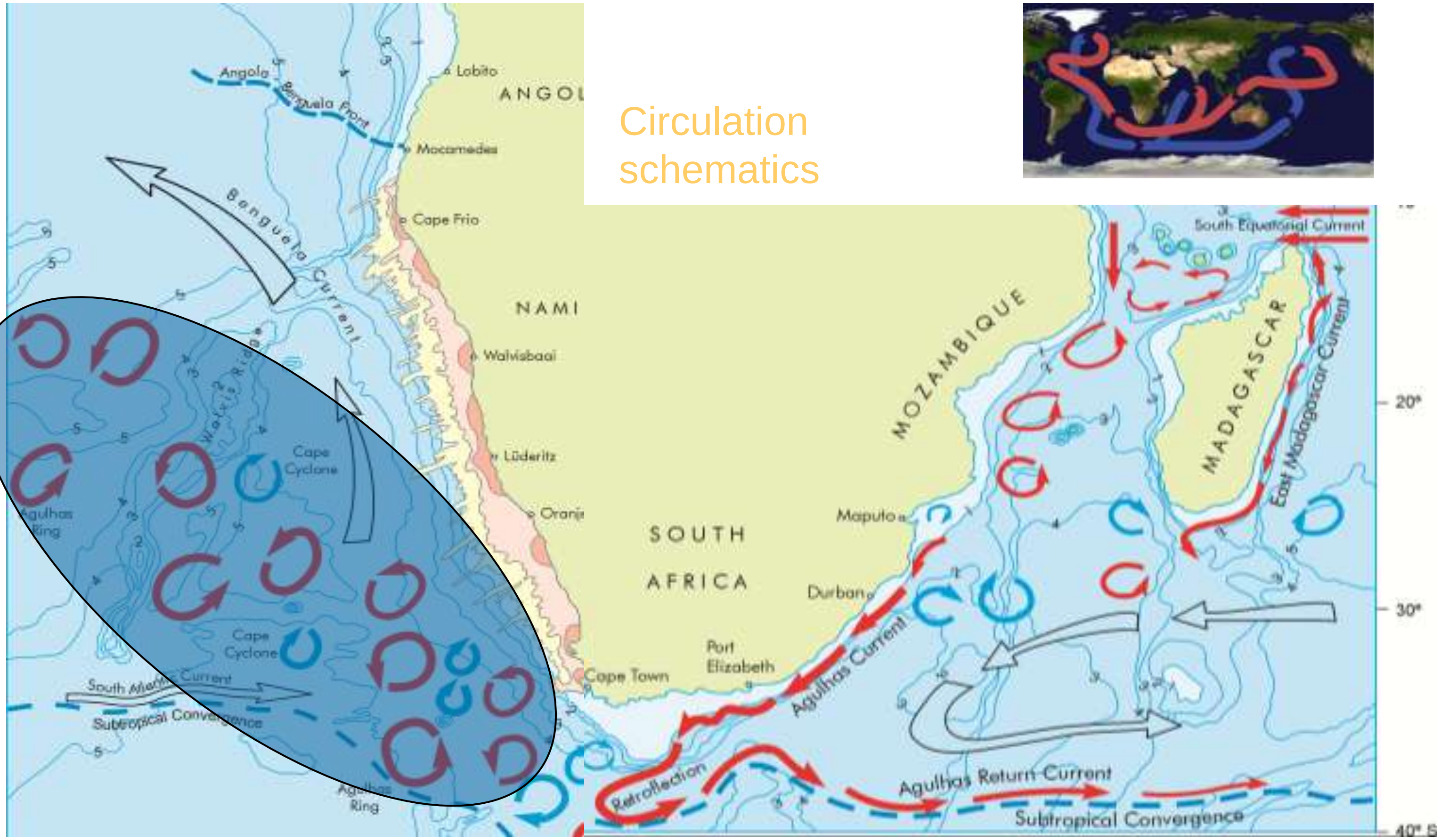


Atlantic Ocean heat content



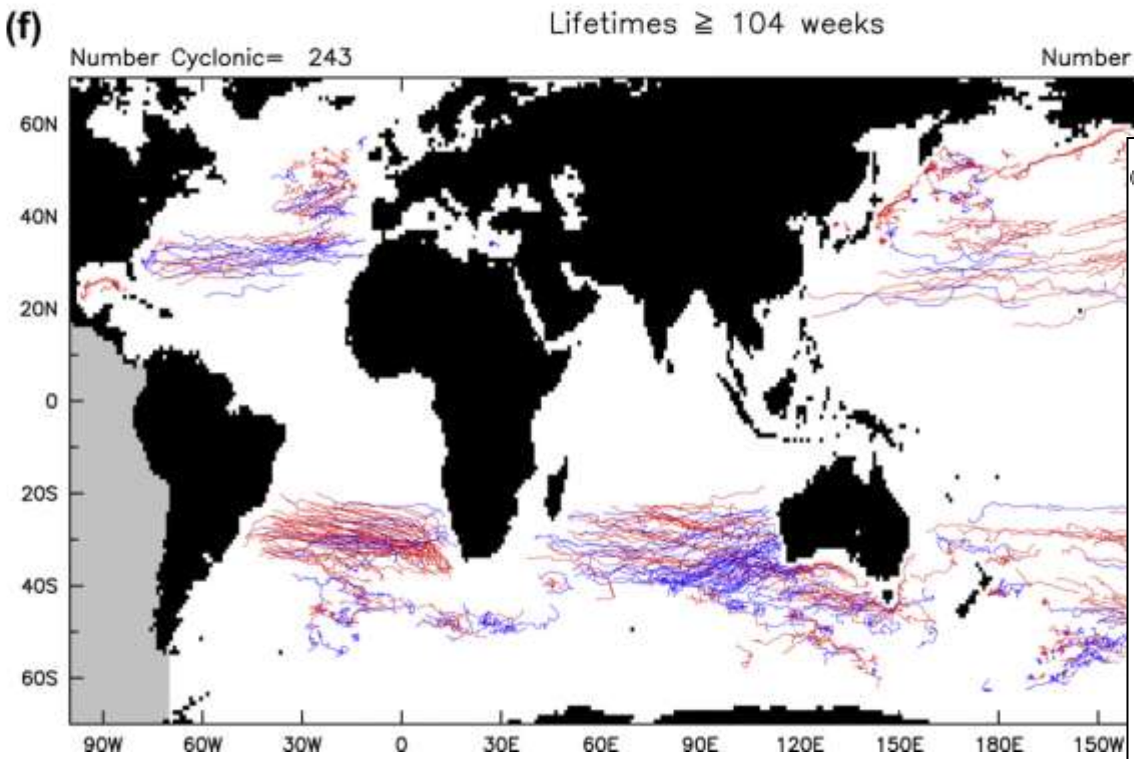
Spreading of heat anomalies under global warming

Mesoscale Variability up- and downstream of the Agulhas Current

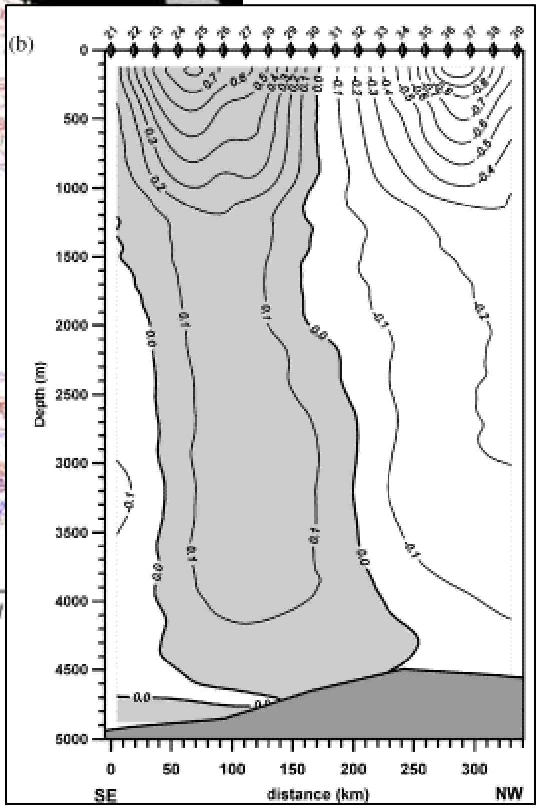


Lutjeharms and Ansorge (2007)

Agulhas Rings

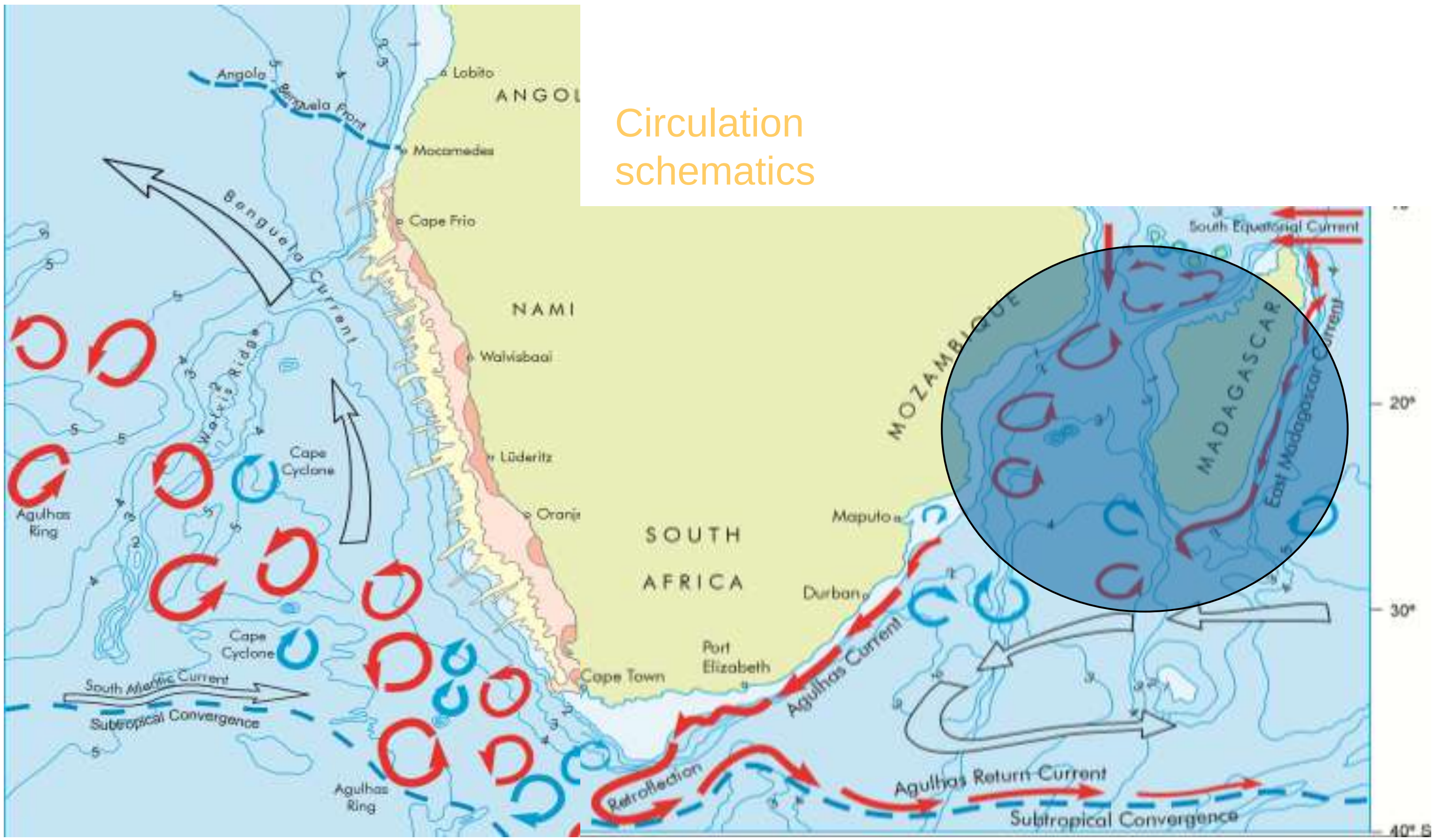


Trajectories of long-lasting eddies



Velocity structure of an Agulhas ring

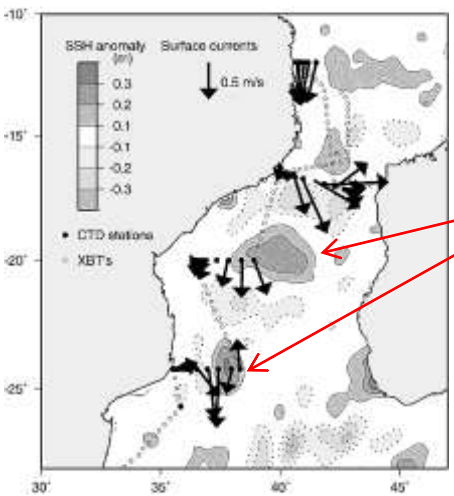
Mesoscale Variability up- and downstream of the Agulhas Current



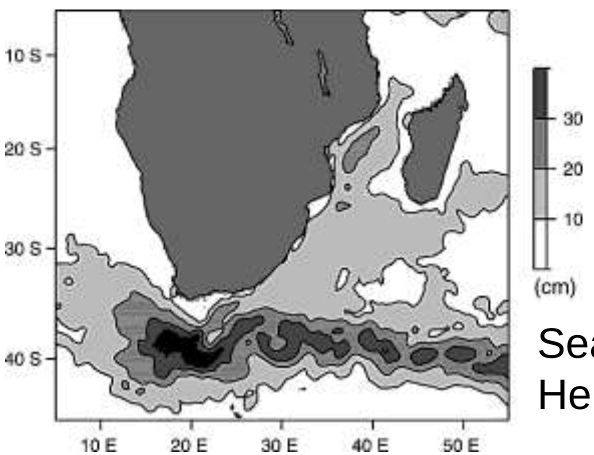
Circulation schematics

Lutjeharms and Ansorge (2007)

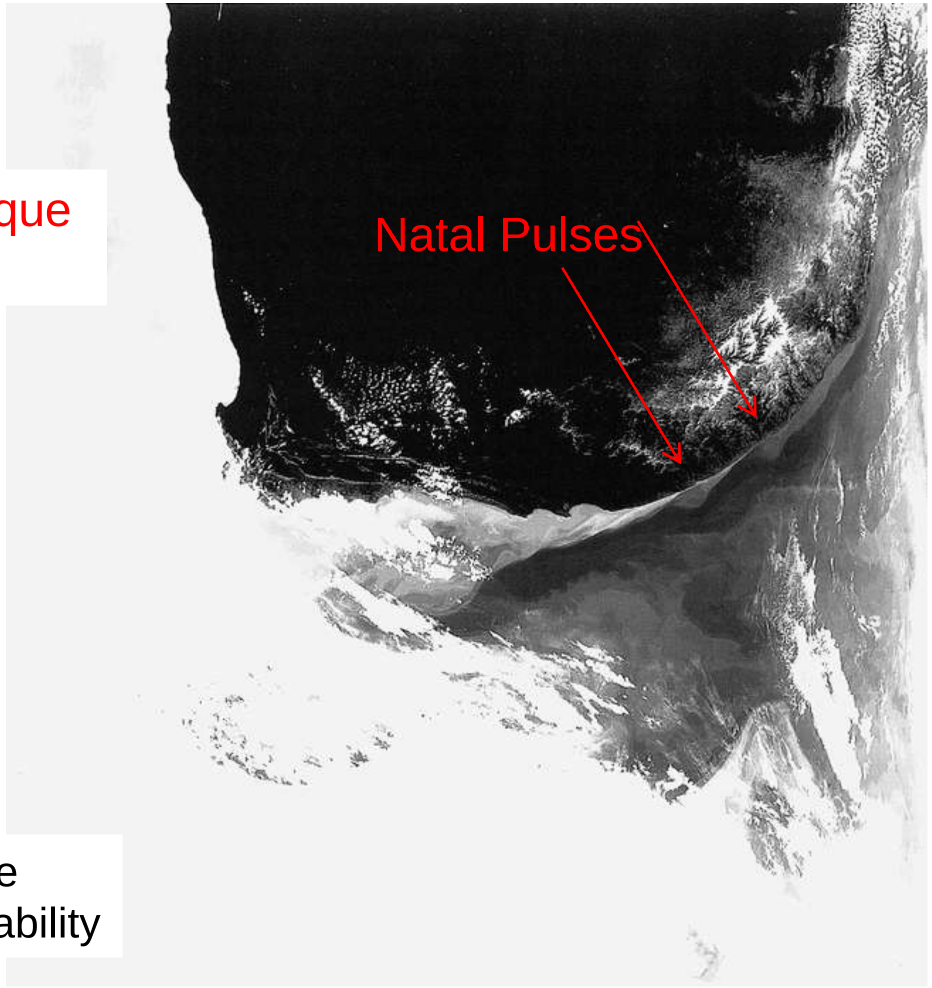
Mesoscale Dynamics in the Source Regions



Mozambique Eddies



Sea Surface Height Variability



Natal Pulses

De Ruijter et al. (1999; 2002); Schouten et al. (2002)

Modelling the Agulhas Current

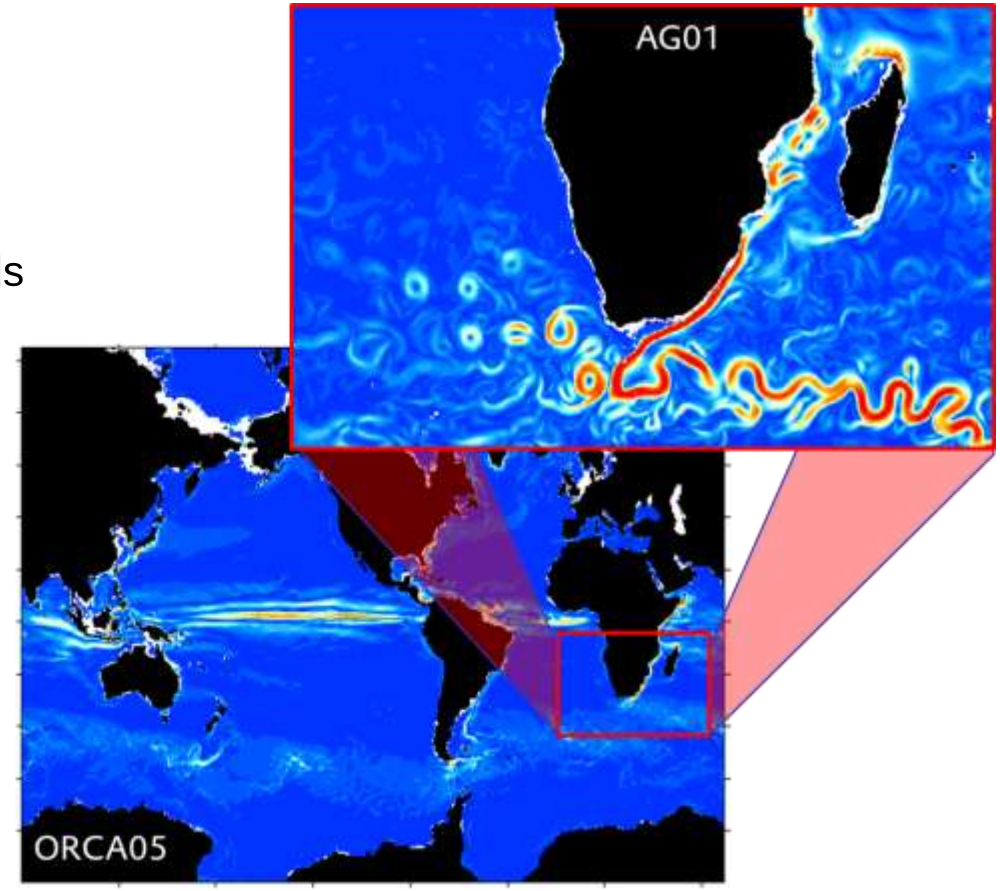
… and its Embedding in the Large-scale Circulation

Nested Ocean Model

NEMO ocean/sea-ice model within

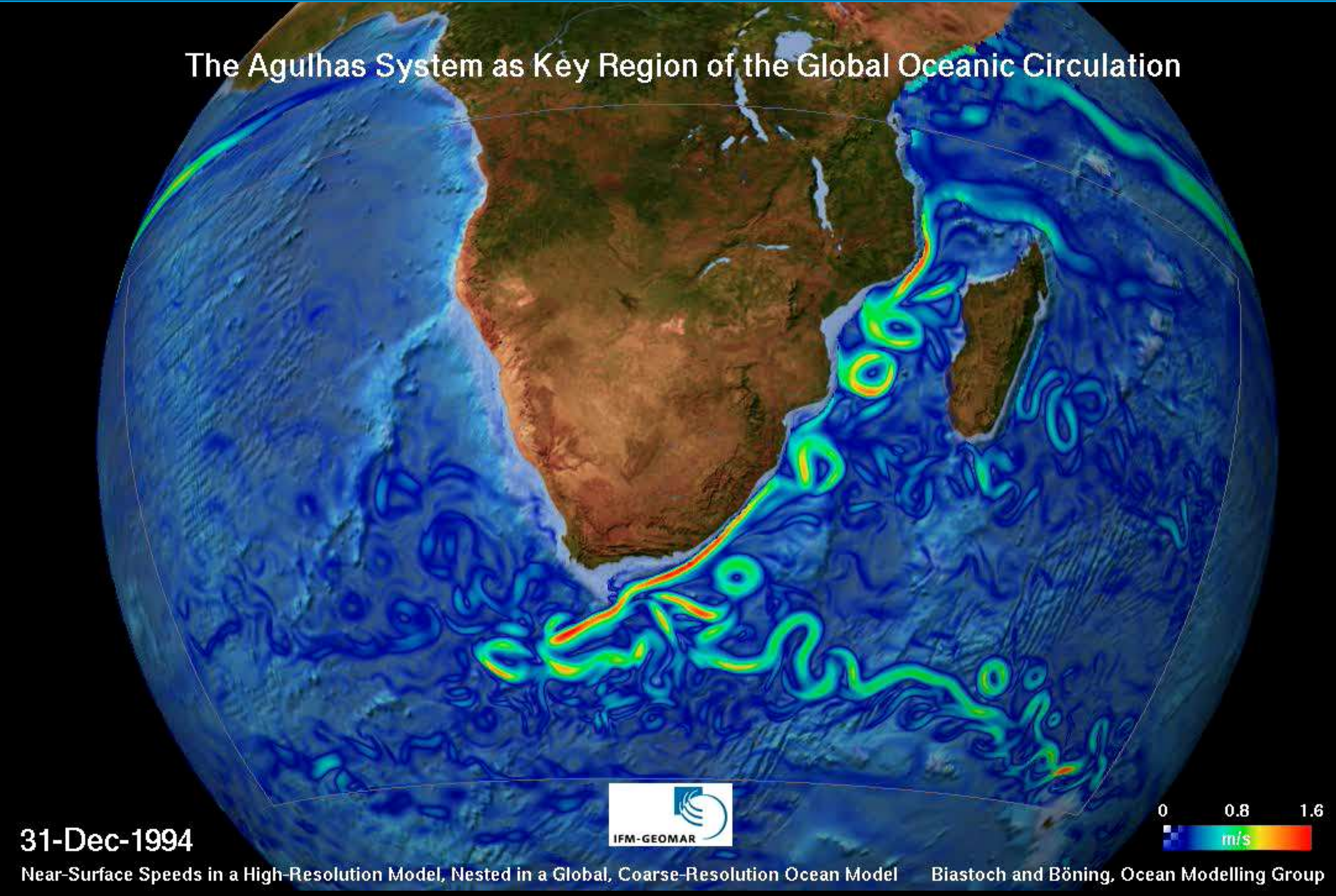
European DRAKKAR collaboration

- Nested configuration with 2-way interaction (AGRIF) between both grids
  - Global coarse-resolution (1/2°)
  - High-resolution Agulhas (1/10°)
- 46 vertical levels
- Sea-ice model
- Atmospheric forcing (CORE): Bulk formulae at 6h/1d-resolution, inter-annual variability (1958-2004)

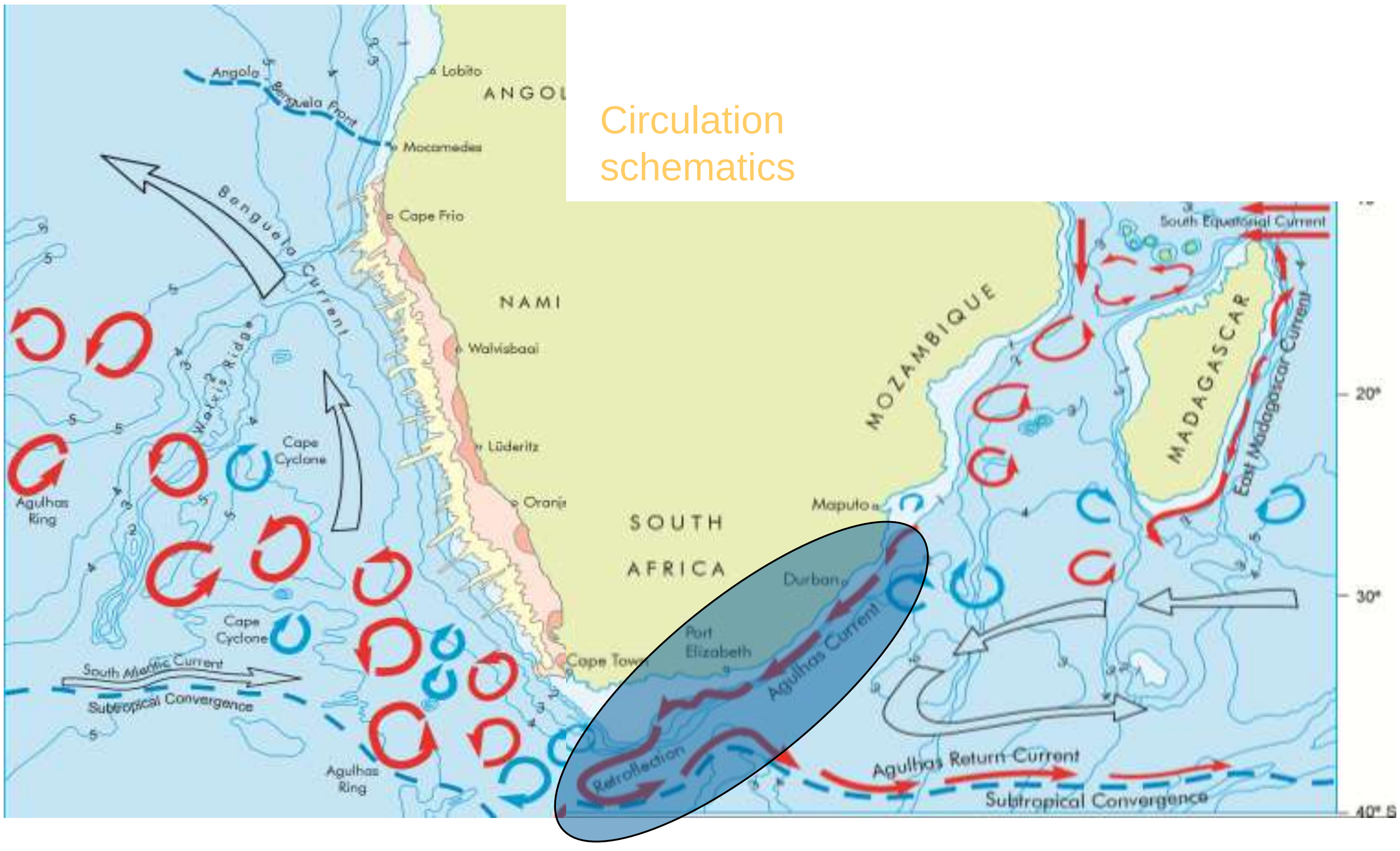


Madec (2006); Barnier et al. (2006); Debreu et al. (2008)

Animation of Near-Surface Speed



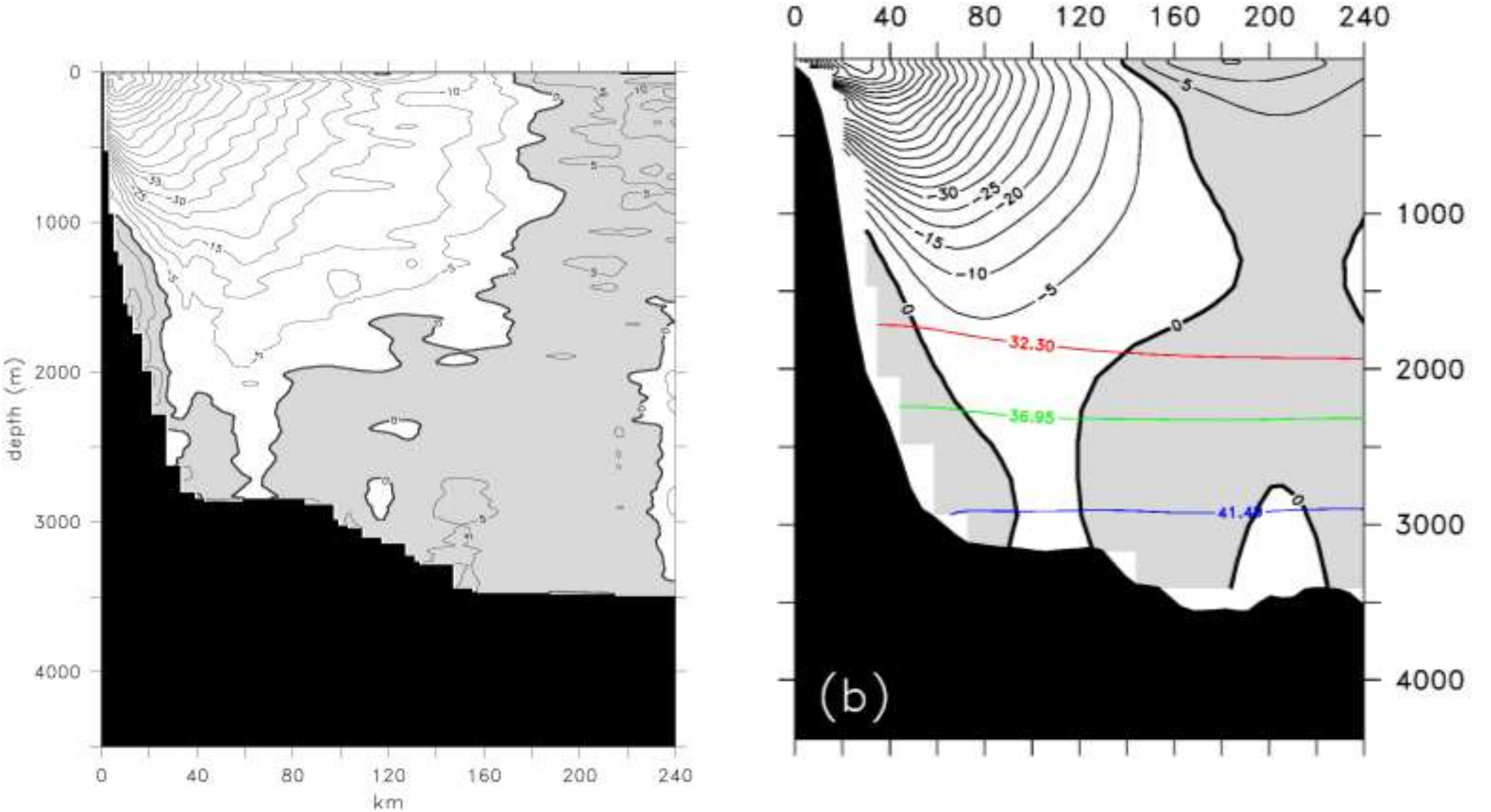
Agulhas Current



Circulation schematics

Lutjeharms and Ansorge (2007)

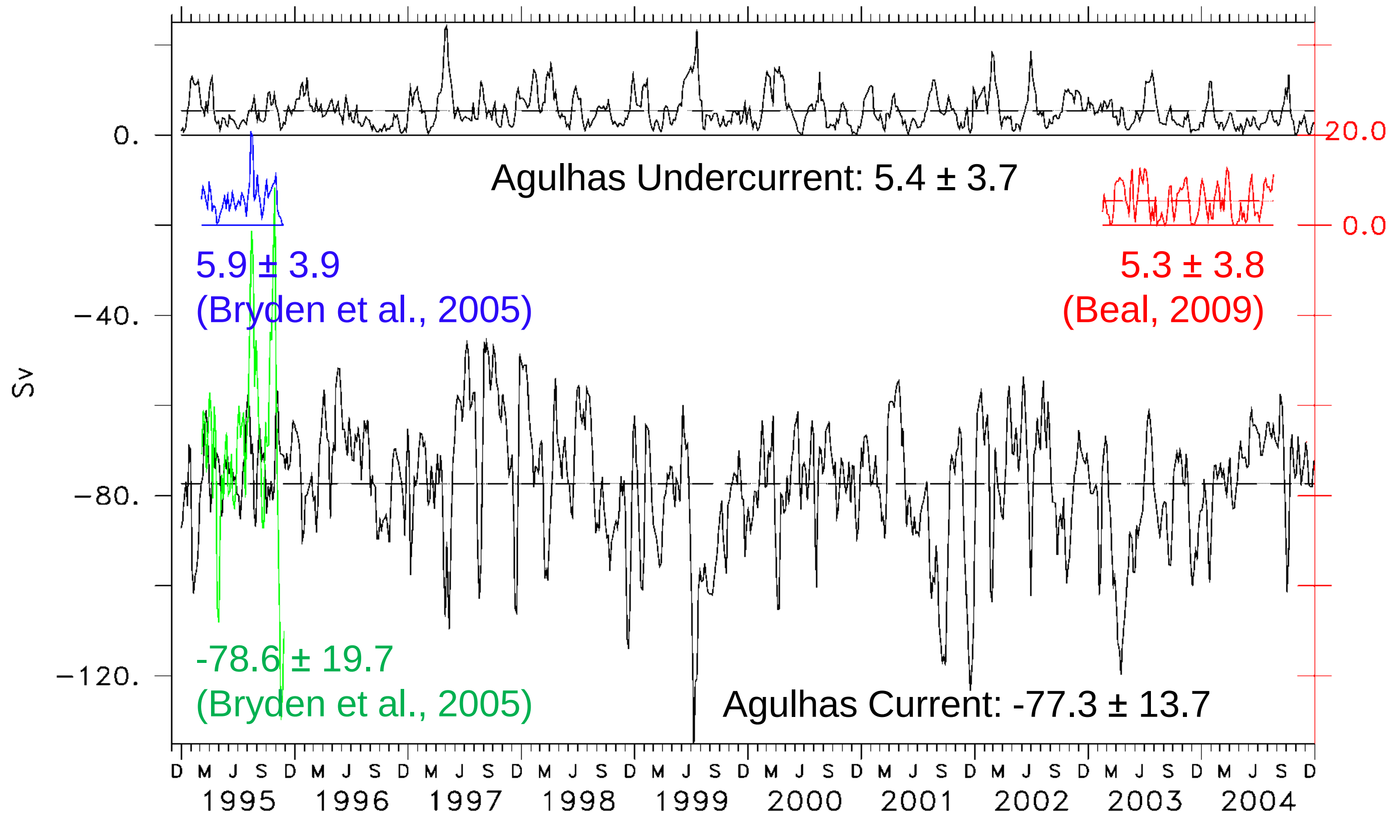
Agulhas Current



Observations (composite section) and model off Port Shepstone

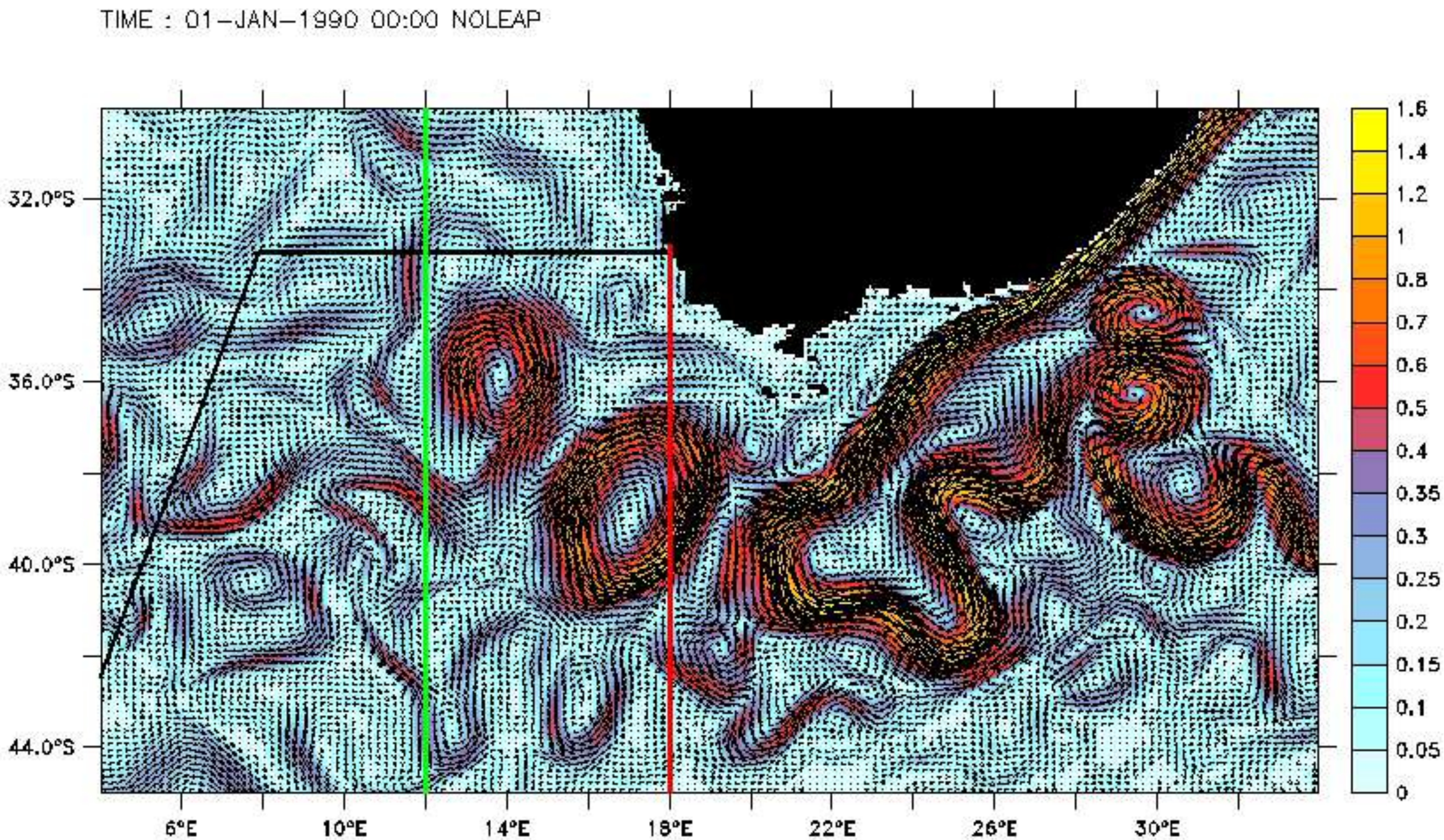
Beal (2009); Biastoch et al. (*J. Phys. Oceanogr.*, 2009)

Agulhas Current Variability



Modelled and observed Agulhas Current and Agulhas Undercurrent

Retroflection of the Agulhas Current

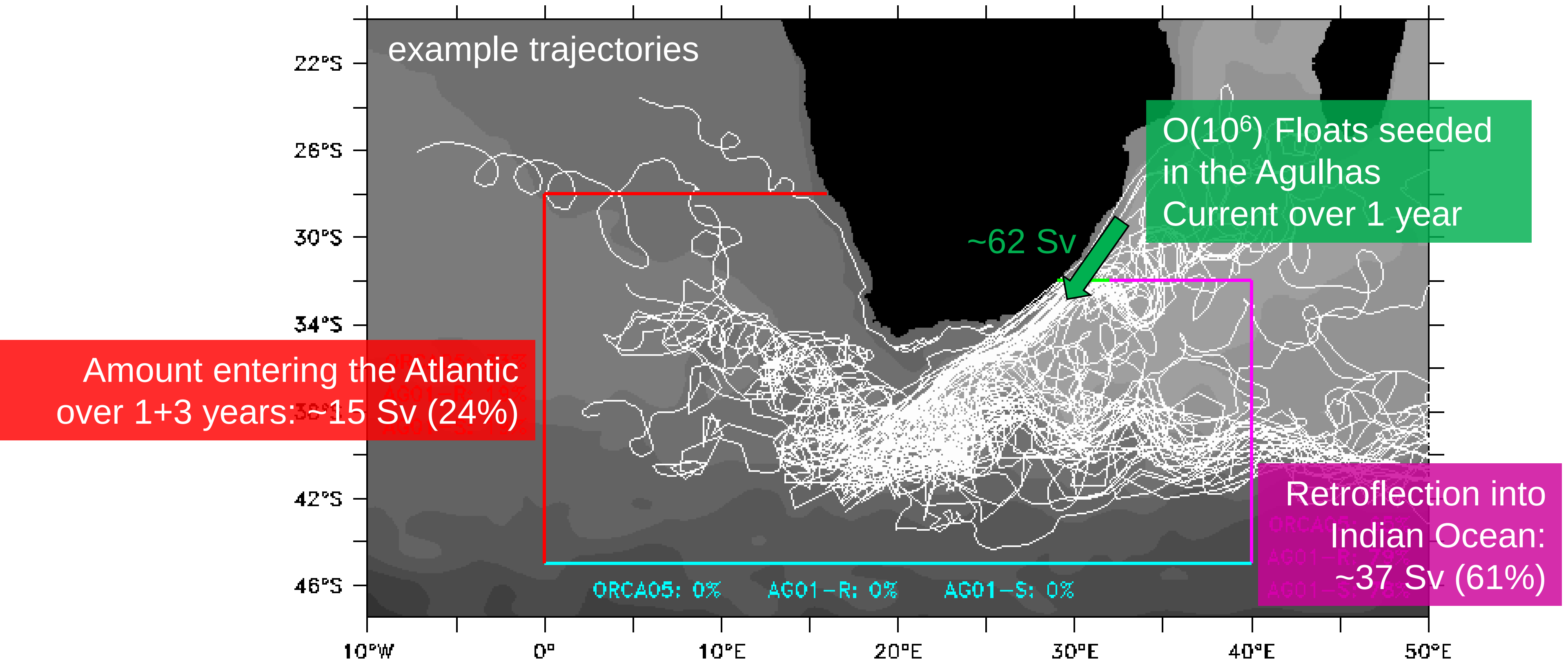


Speed and velocity at 100 m depth

Agulhas Leakage

Interoceanic Transfer of Mass, Heat and Salt

Quantification of Agulhas Leakage



„**Agulhas Leakage**“ = amount of Agulhas Current that flows into the Atlantic

Biastoch et al. (*Geophys. Res. Lett.*, 2008); ARIANE (Blanke, Univ. Brest)

The Importance of Model Resolution

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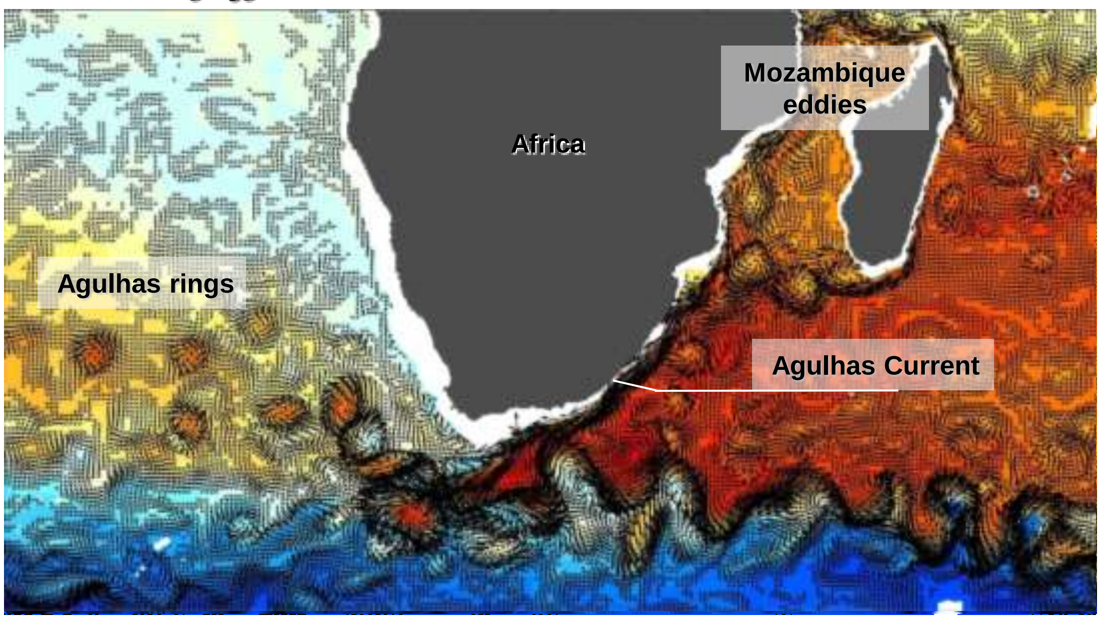

Temperature and velocity at 450m depth (snapshot)

Resolution	Agulhas Leakage
ORCA05 (50 km)	29.6 ± 6.0 Sv
ORCA025 (25 km)	16.2 ± 4.9 Sv
AG01 (10 km)	14.8 ± 2.6 Sv

Observations (Richardson, 2007): ~15 Sv

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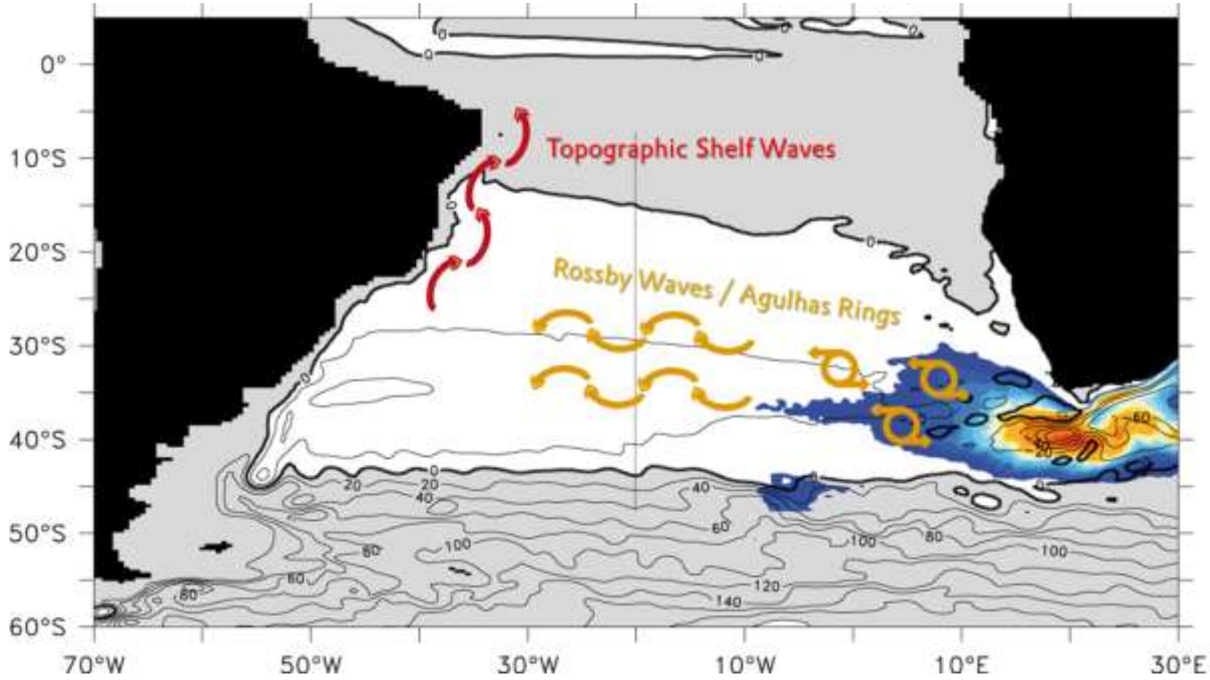
Large-scale Response I

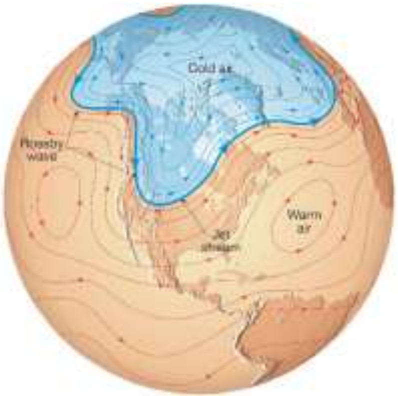
Wave Effect on the Atlantic MOC

Wave Response:
Dynamical Effect of Agulhas Mesoscale on MOC



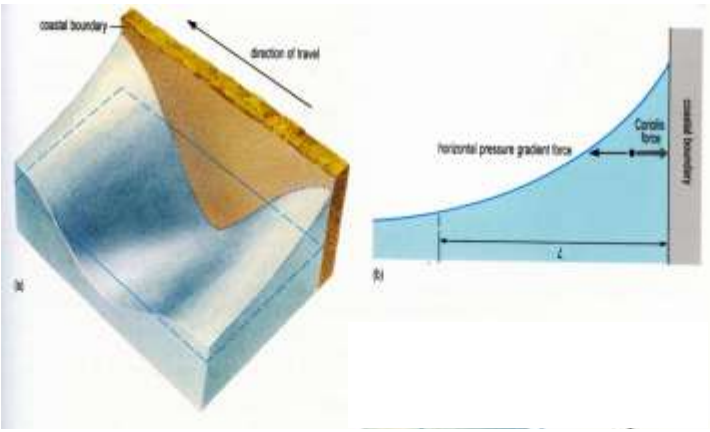
Biastoch et al. (*Nature*, 2008)

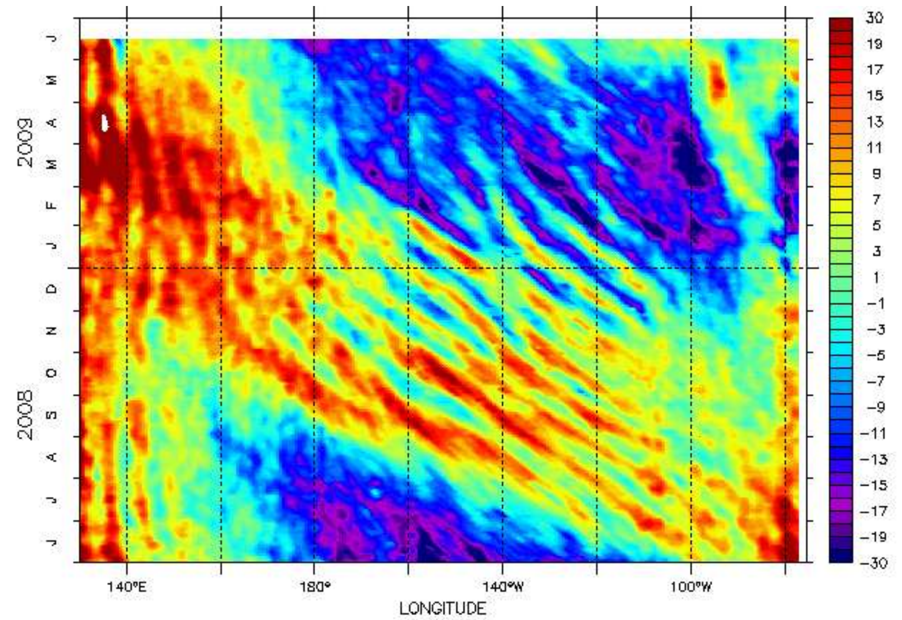
Rossby and Kelvin Waves



Rossby waves

Kelvin waves

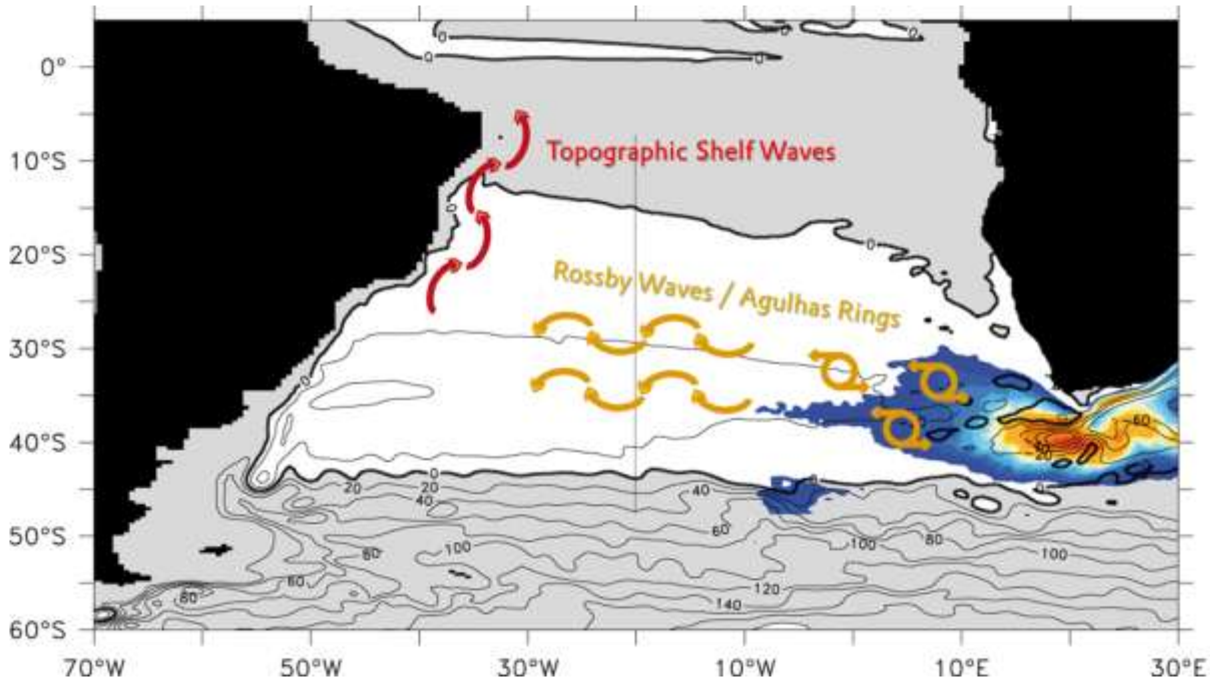




Hovmoeller diagram of sea level anomalies (cm) in the tropical Pacific

T. Walter (CUNY); Open University Textbook; AVISO

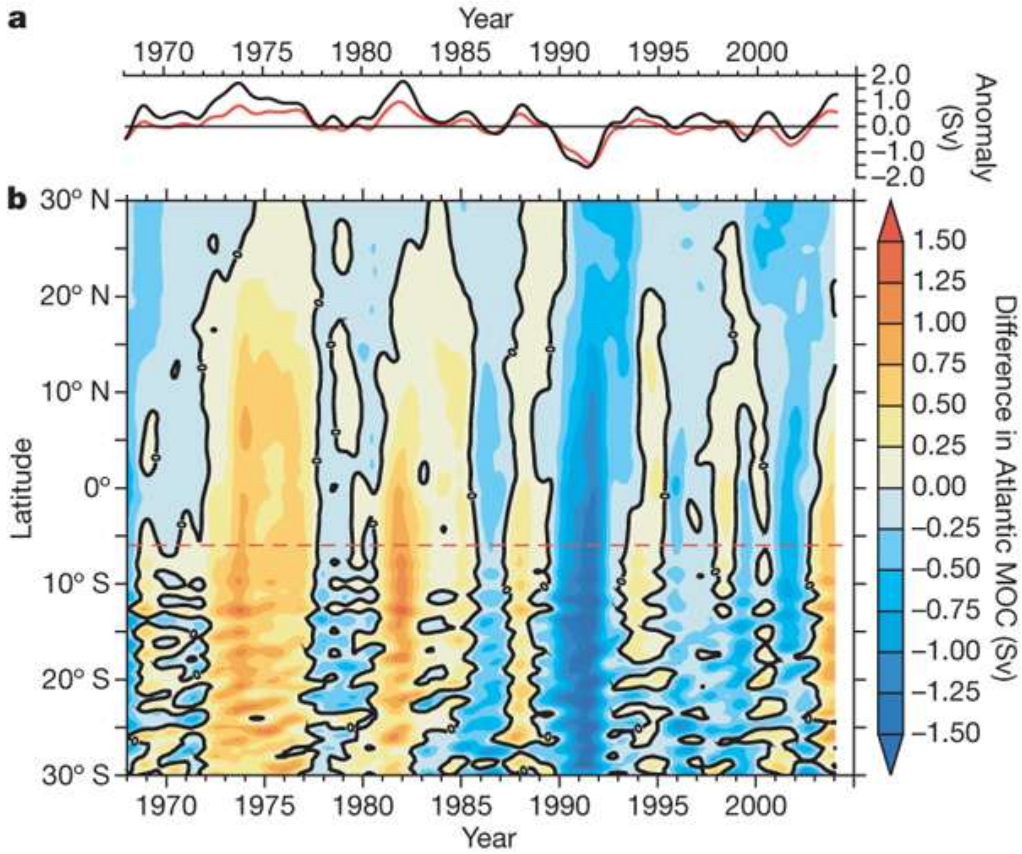
Wave Response:
Dynamical Effect of Agulhas Mesoscale on MOC



Biastoch et al. (*Nature*, 2008)

Wave Response:
Dynamical Effect of Agulhas Mesoscale on MOC

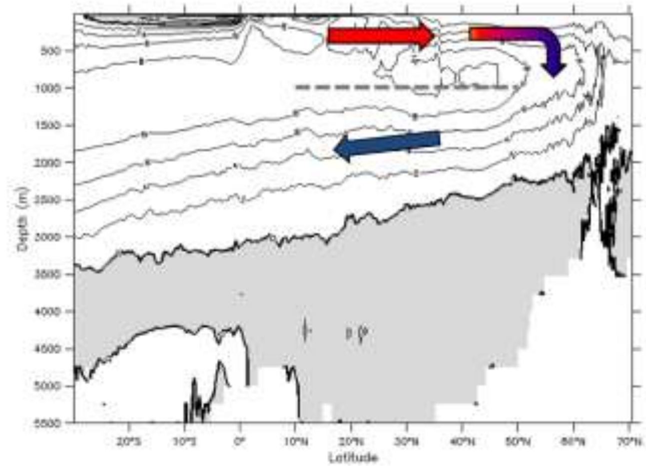
GEOMAR



Interannually filtered MOC-difference at 1000 m due to Agulhas mesoscale

Difference in MOC and

North Brazil Current at 6°S



Mean MOC

Biastoch et al. (*Nature*, 2008)

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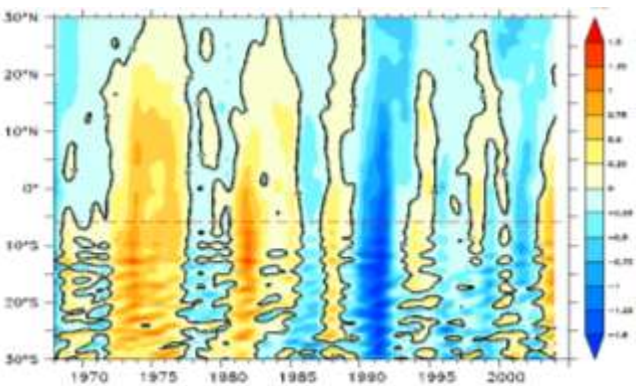
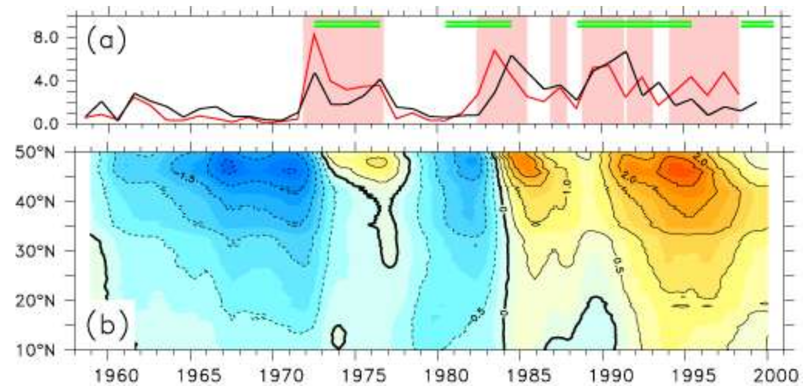
Wave Response:
Northern vs. Southern Influences

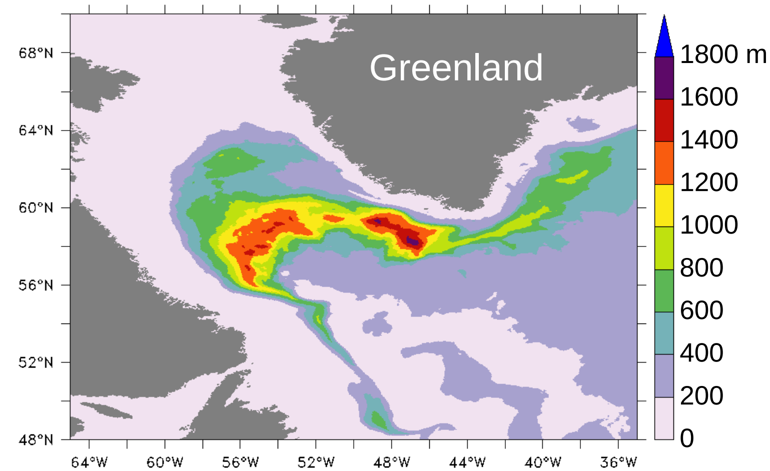


MOC anomalies due to Agulhas mesoscale



NAO and LSW formation

MOC anomalies due to Labador Sea convection



Winter value of (modelled) mixed layer depth in the Labrador Sea

Biastoch et al. (*Nature*, 2008); Biastoch et al. (*J. Clim*., 2008)

Wave Response:
Northern vs. Southern Influences

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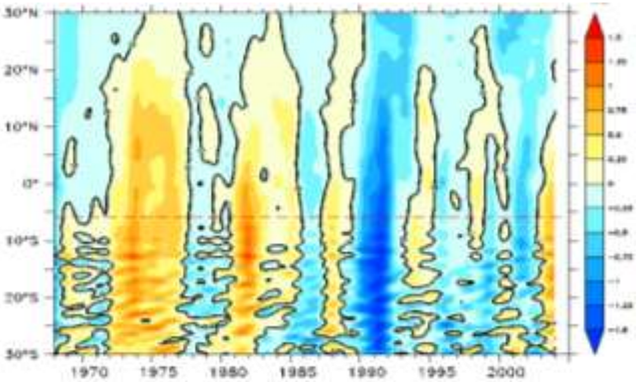
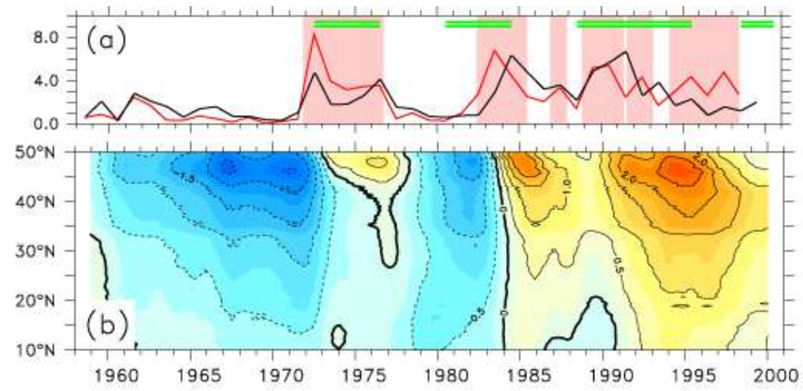
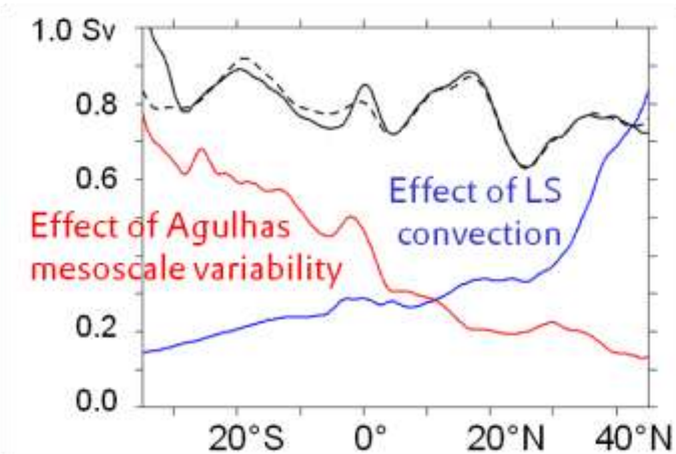




LSW formation

MOC anomalies due to Agulhas mesoscale

MOC anomalies due to Labador Sea convection



Standard deviation of <u>interannual</u> MOC strength

Biastoch et al. (*Nature*, 2008); Biastoch et al. (*J. Clim.*, 2008)

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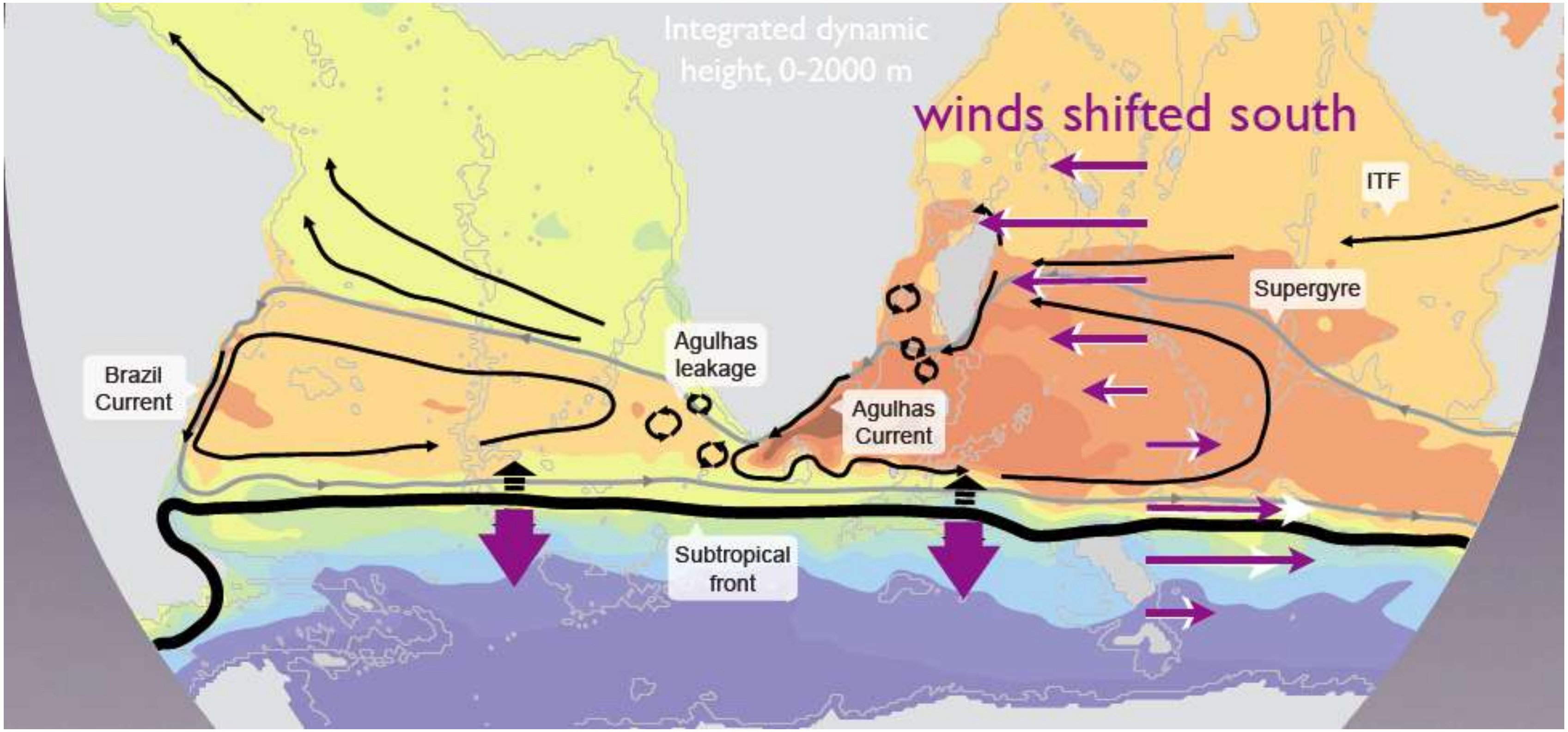
Large-scale Response II

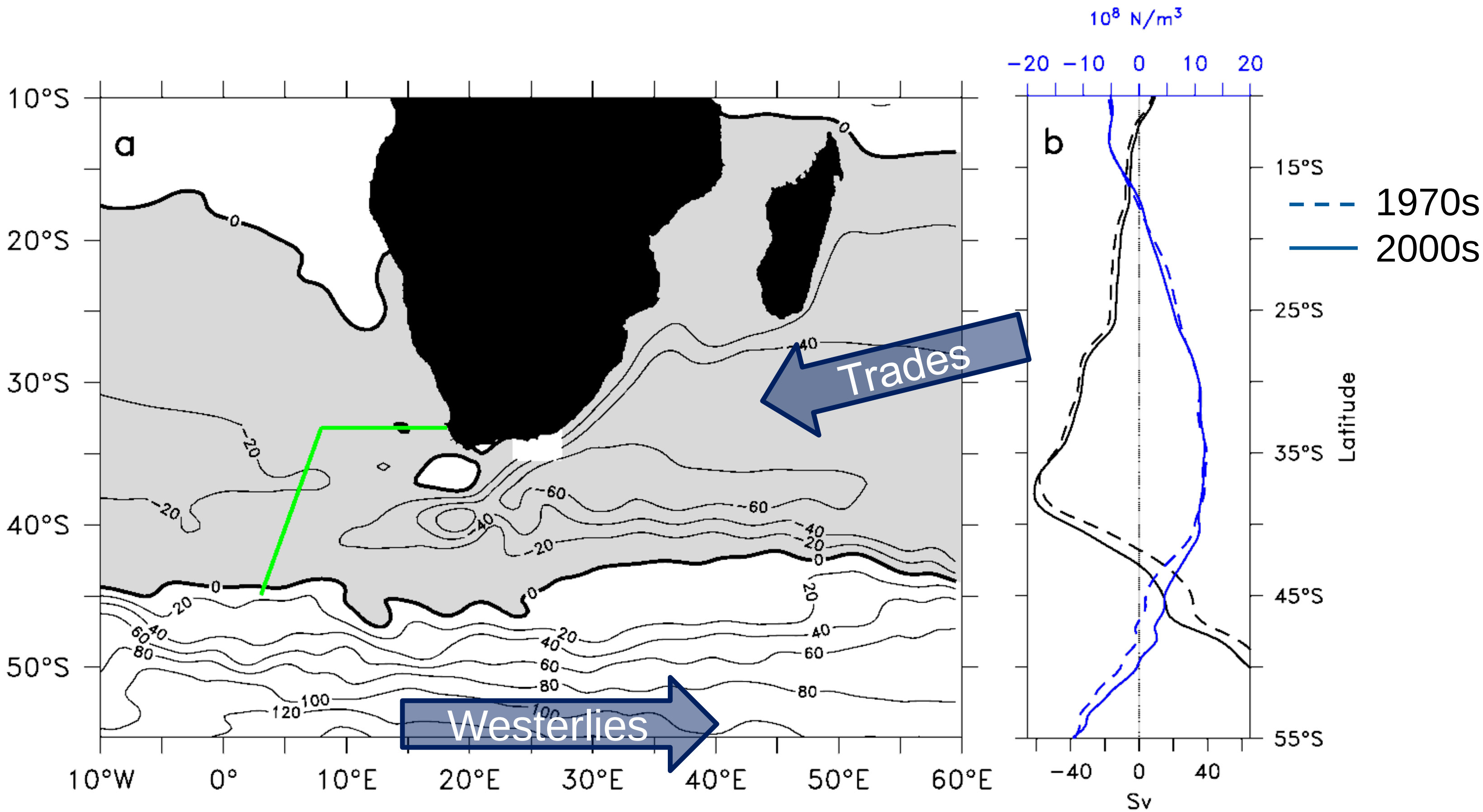
Advective Effect on Thermohaline Circulation

Dynamical Controls on Agulhas Leakage



Beal, de Ruijter, Biastoch, Zahn and SCOR WG 136 (Review in *Nature*, 2011)

Advective Response: Agulhas Leakage and Thermohaline Circulation

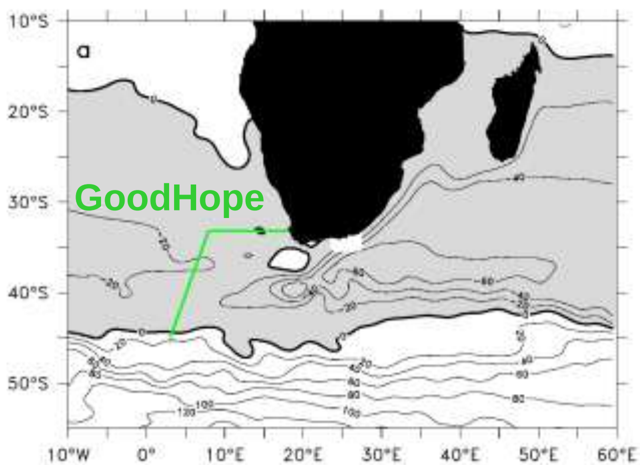


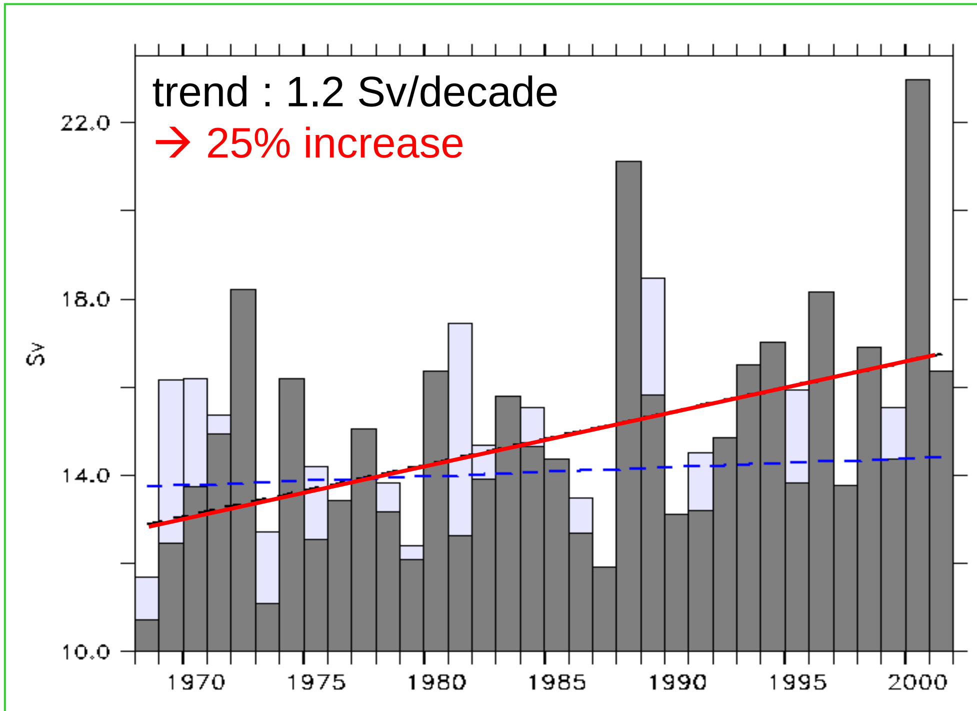
Horizontal Circulation (streamfunction)

Zonal averages of stream-function and wind stress curl

Biastoch et al. (*Nature*, 2009)

Advective Response:
Agulhas Leakage and Thermohaline Circulation

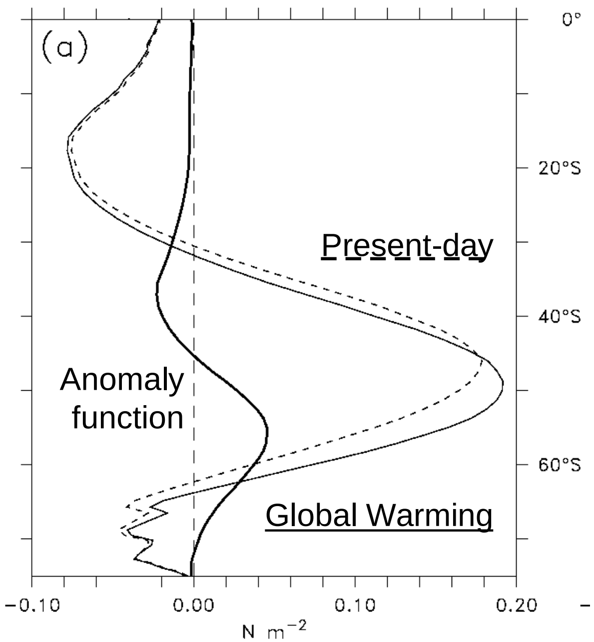




Agulhas leakage
(fractional Agulhas transport crossing GoodHope section)

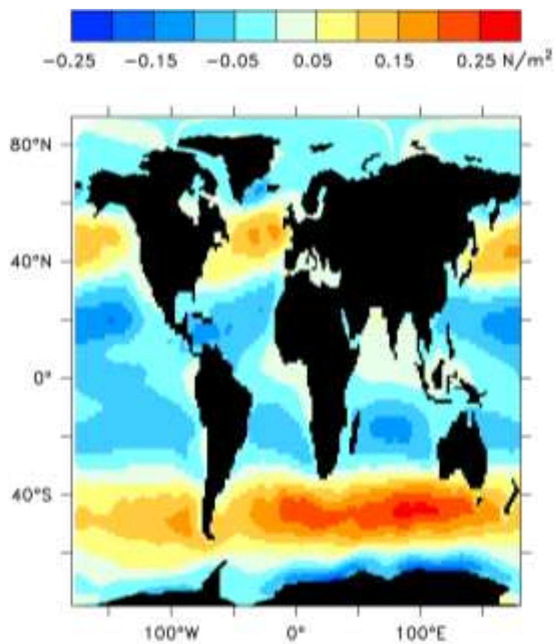
Biastoch et al. (*Nature*, 2009)

Agulhas Leakage under Global Warming

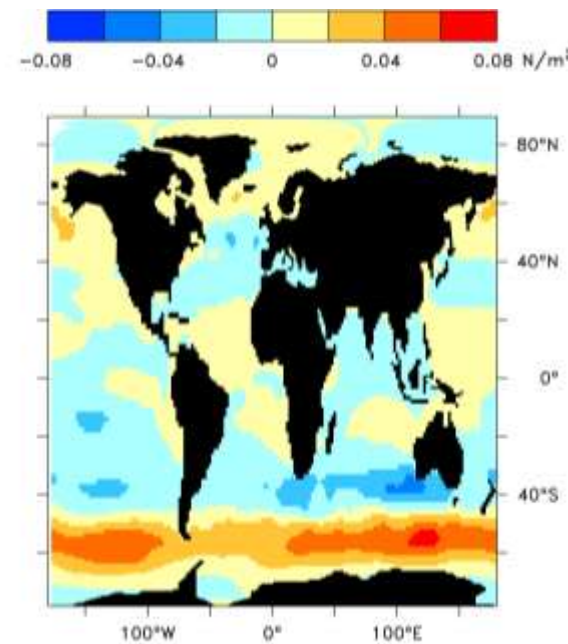


Zonally averaged wind stress

Zonal wind stress in the Kiel Climate Model (KCM)



Present-day experiment

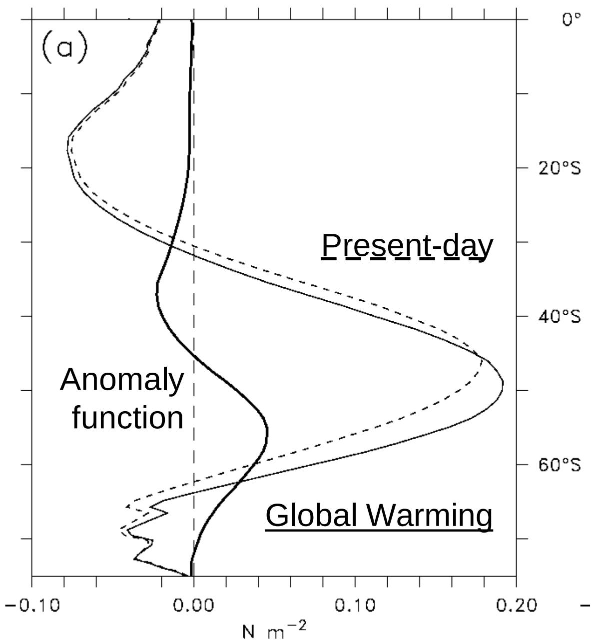


Difference due to global warming

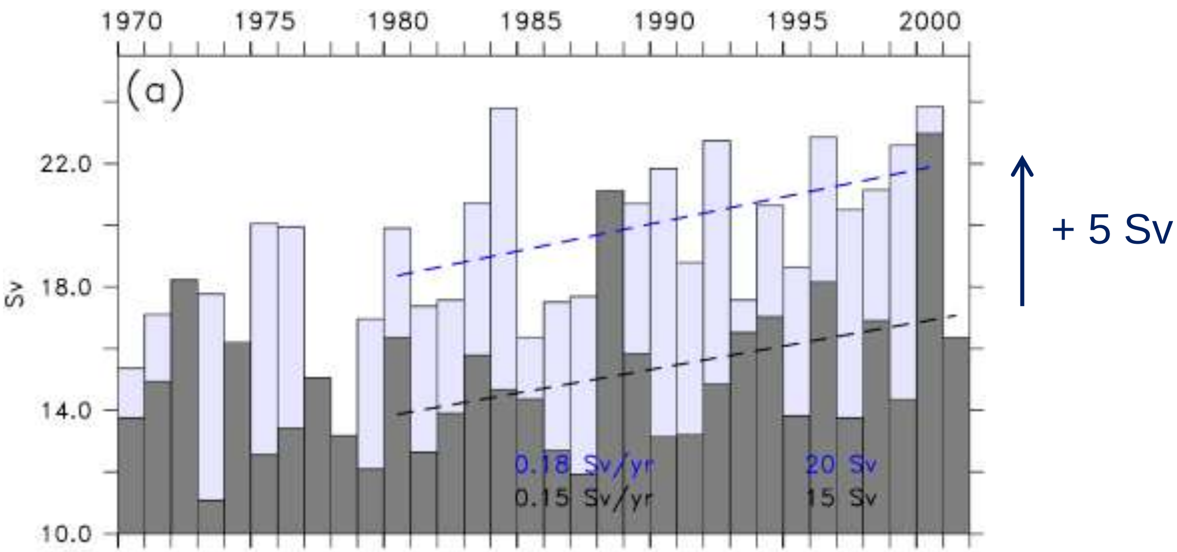
Park et al. (2008); Biastoch and Böning (2012, in prep.)

Agulhas Leakage under Global Warming

GEOMAR



Zonally averaged wind stress



Agulhas leakage for reference (dark gray bars) and shifted wind (light gray) experiments

Park et al. (2008); Biastoch and Böning (2012, in prep.)

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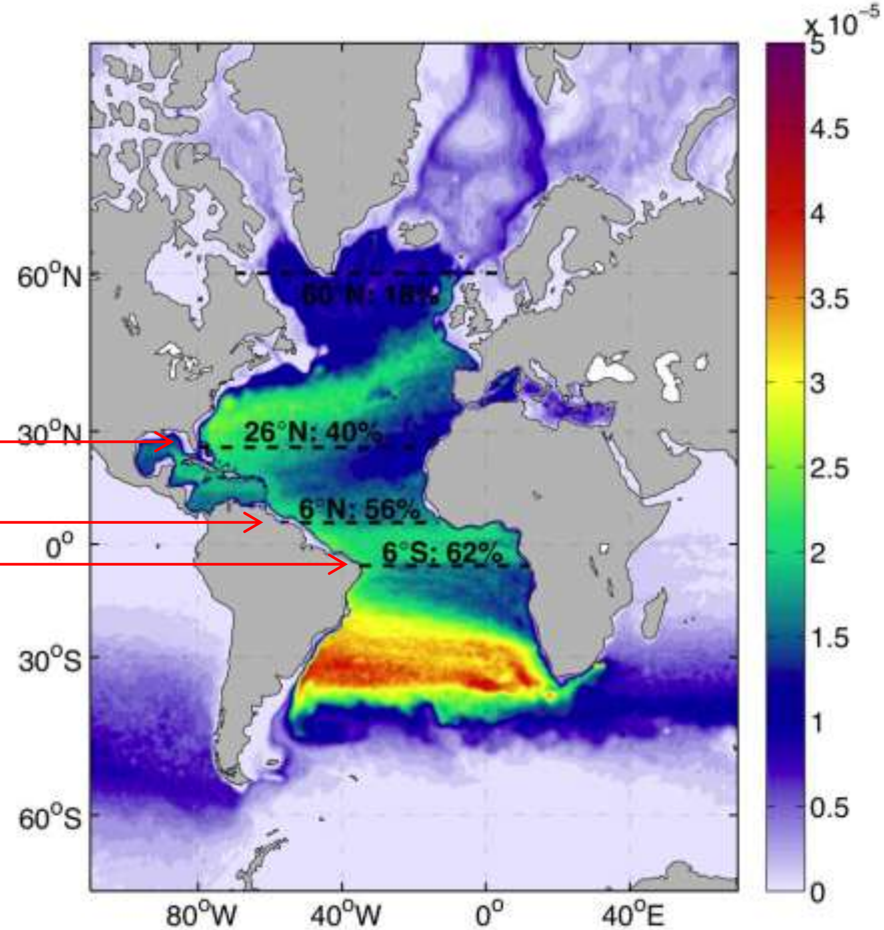
Spreading of Agulhas Leakage

Typical
Spreading Rates

~14 Years

~8 Years

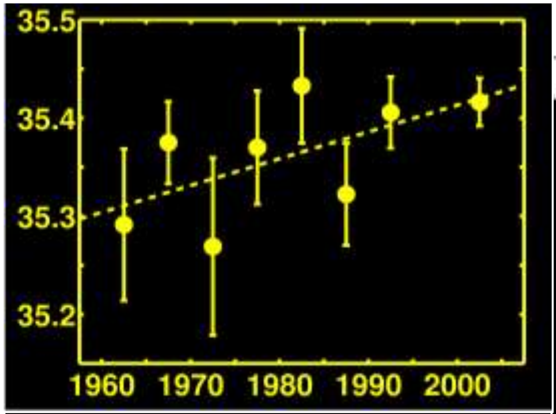
~6 Years



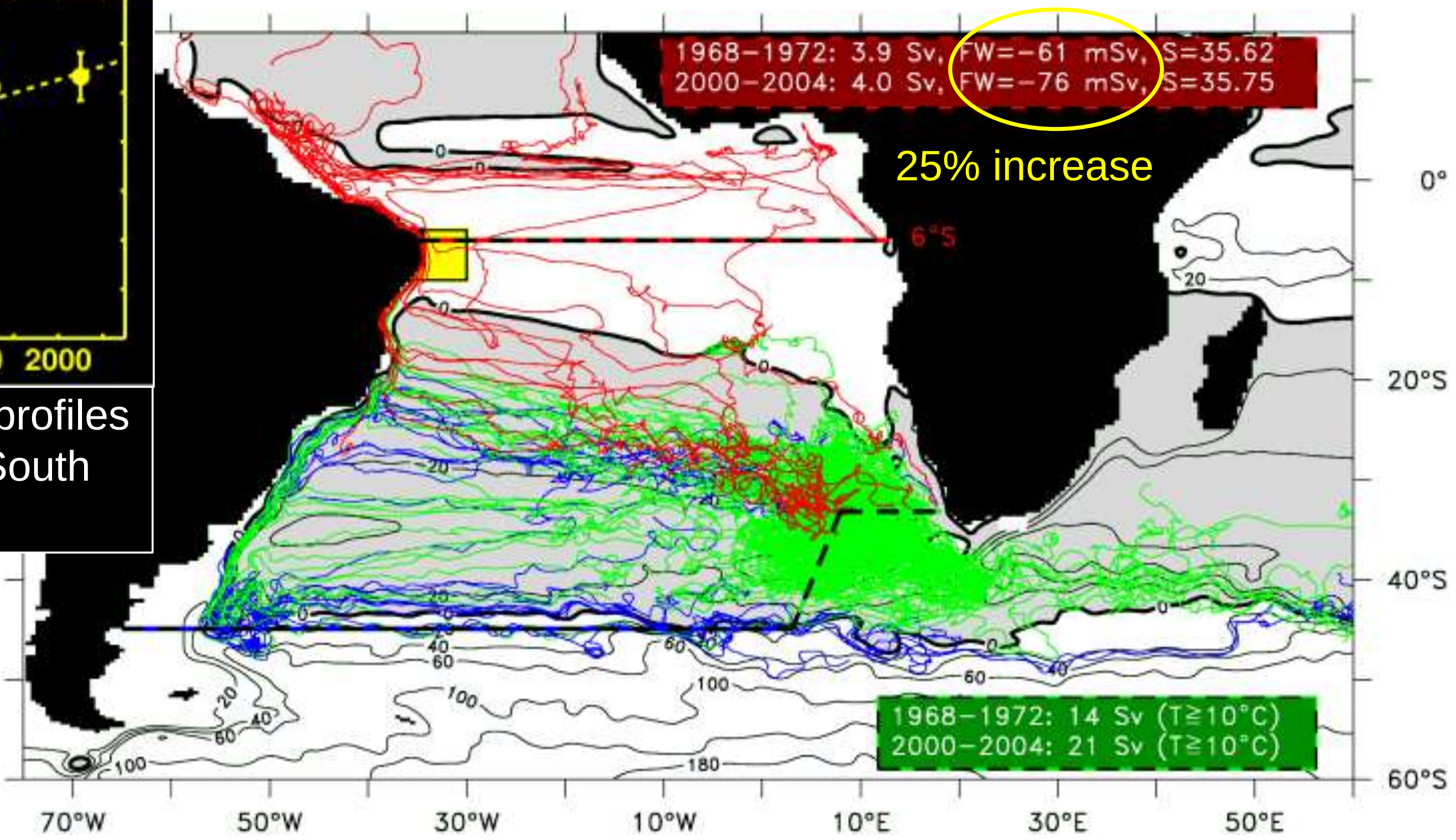
Probability density map of Agulhas leakage floats

Rühs, Biastoch, Durgadoo, Behrens (2012, in prep.)

Advective Response:
Agulhas Leakage and Thermohaline Circulation



Analysis of historic profiles in NBC core off South America

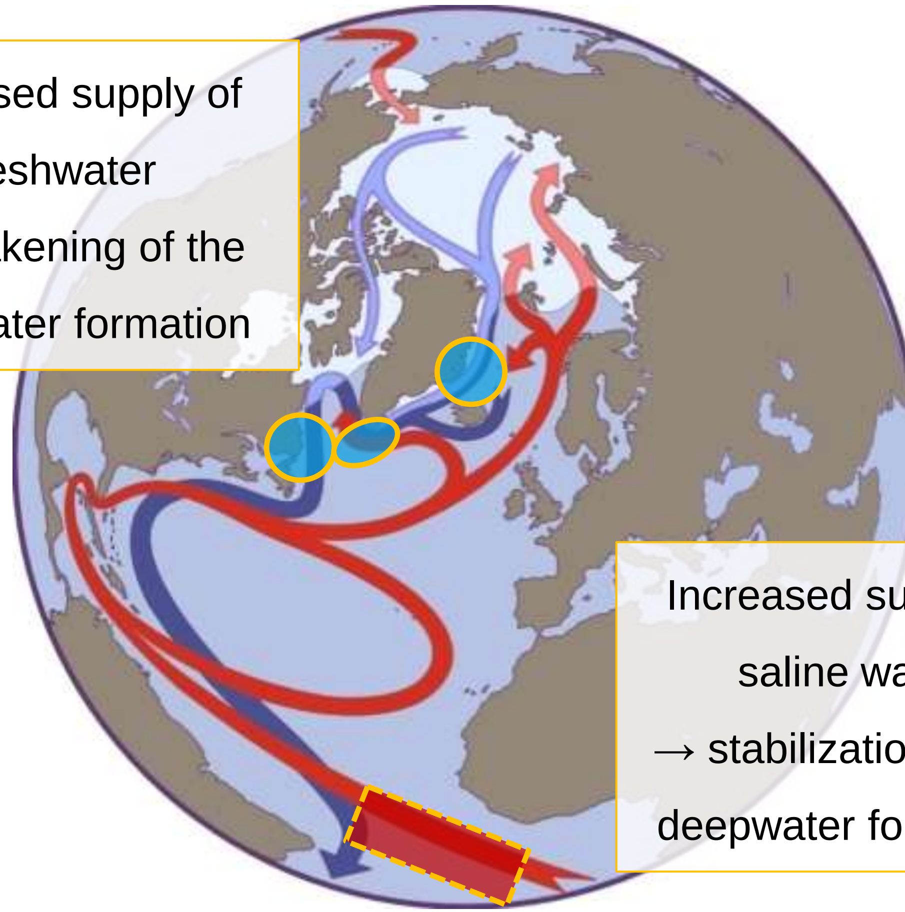


Example trajectories of virtual floats released along the GoodHope section

Biastoch et al. (*Nature*, 2009)

Northern vs. Southern Influences on the Atlantic Thermohaline Circulation

GEOMAR



Increased supply of freshwater

→ weakening of the deepwater formation

Increased supply of saline water

→ stabilization of the deepwater formation

Nature cover pages 2008 and 2009, schematics by G. Holloway

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Summary and Perspective

- High-resolution model needed to realistically represent the Agulhas system and Agulhas leakage

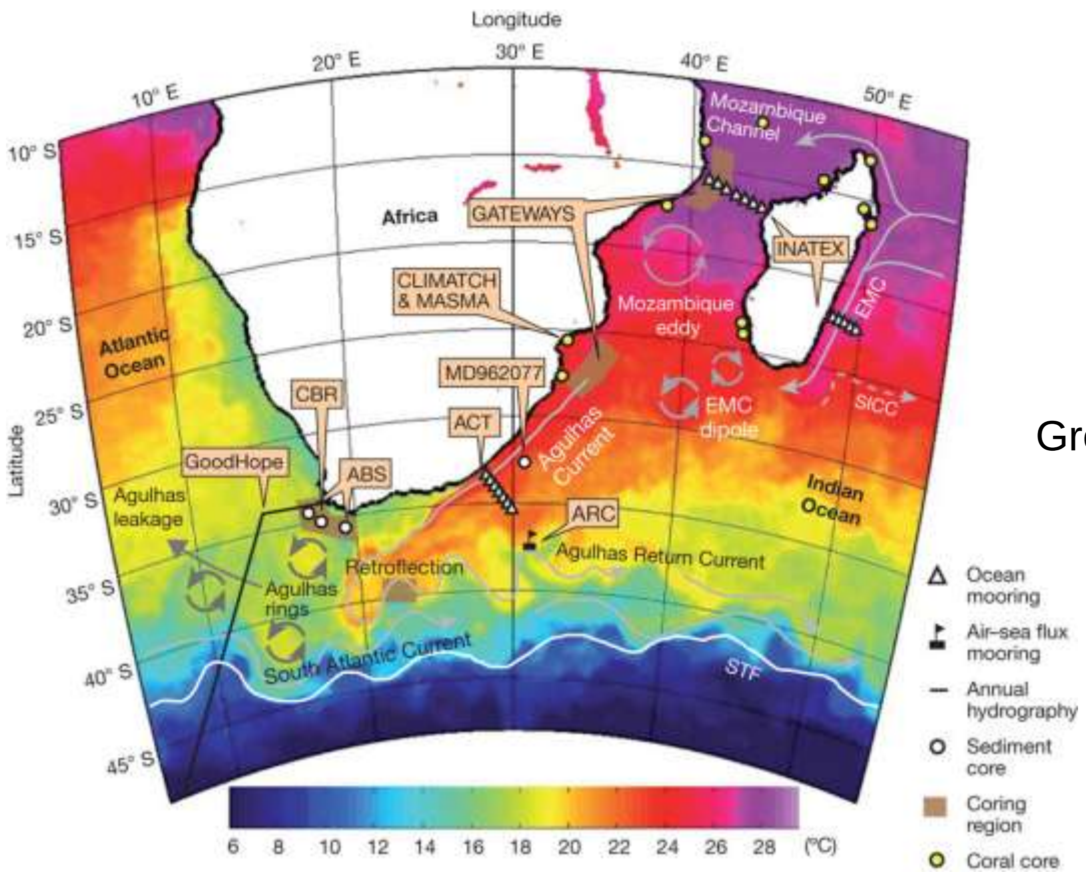
(I) Wave process

- Mesoscale Agulhas leakage dynamics introduces decadal MOC variations of ±1.5 Sv quickly propagating into northern hemisphere
- What causes the decadal variations?
- How important are these for the (interpretation of) North Atlantic circulation variability?

(II) Advective process

- Supergyre has extended due to poleward shift/intensification of SH westerlies
- The Agulhas Leakage has increased → 25% increase in salt export towards the north
- Climate models project a further increase in Agulhas leakage
- How does the timing and strength compare to the (Sub-)Arctic freshening?
- How do other sources (Drake Passage, Southern Ocean) contribute?

Increasing Awareness of Agulhas Regime



SCOR Working Group136
“Climatic Importance of the
Greater Agulhas Current System”

Beal, de Ruijter, Biastoch, Zahn and SCOR WG 136 (Review in *Nature*, 2011)

Increasing Awareness of Agulhas Regime

GEOMAR

International Council for Science
SCOR
Scientific Committee on Oceanic Research

SCOR Working Group136
“Climatic Importance of the
Greater Agulhas Current System”

CHAPMAN CONFERENCE

The Agulhas System and its Role in Changing Ocean Circulation, Climate, and Marine Ecosystems
Spier Hotel, Stellenbosch, Western Cape, South Africa
8–12 October 2012

De Ruijter, Zahn, Biastoch, Beal, and SCOR WG 136

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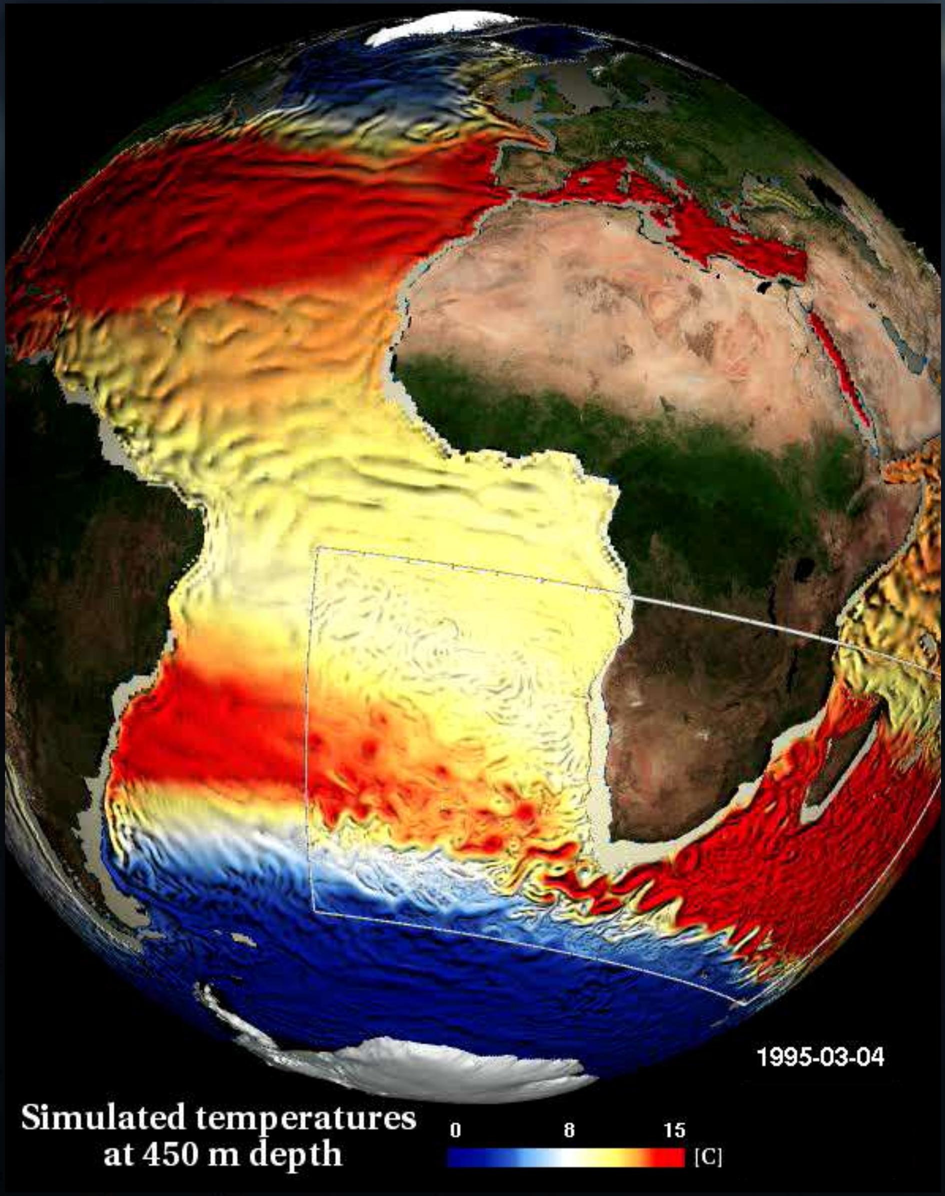

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