

Shifting surface currents in the northern North Atlantic Ocean

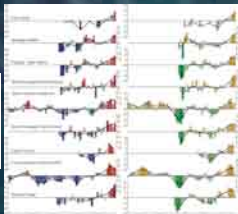
Sirpa Häkkinen (1) and Peter Rhines (2)
 (1) NASA Goddard Space Flight Center, Greenbelt, MD, USA
 (2) University of Washington, Seattle, WA

ABSTRACT

Analysis of surface drifter tracks in the North Atlantic Ocean from the time period 1990 to 2007 provides the first evidence that the Gulf Stream waters can have direct pathways to the Nordic Seas. Prior to 2000, the drifters entering the channels leading to the Nordic Seas originated in the western and central subtropical region. Since 2001 several paths from the western subtropics have been present in the drifter tracks leading to the Rockall Trough through which the most saline North Atlantic Waters pass to the Nordic Seas. This reorganization of surface circulation is analyzed using several altimetry related products: (1) drift trajectories of synthetic drifters in the AVISO 1/3 geostrophic velocity field, (2) eddy kinetic energy from altimetry and (3) altimetric velocities combined with Ekman transport estimates (NOAA-OSCAR product). All these products support the surface drifter findings and reflect NE flow anomaly since 2001. These near surface circulation changes have taken effect while the altimetry shows a continual westwarding of the subtropical gyre. These findings highlight the changes in the vertical structure of the northern North Atlantic Ocean, its dynamics and exchanges with the higher latitudes, and show how pathways of the thermohaline circulation can open up and maintain or increase its intensity even as the basin-wide circulation spins down.

BACKGROUND

- Increasing salinity and temperature of the Atlantic flow in the channels leading to the Nordic Seas since 1996 with a steep increase since 2002 (Holliday et al 2008)
- Expansion of the subtropical gyre - SEAWIFS (McClain et al 2004)
- Weakening subpolar gyre - altimetry (TOPEX/Poseidon, Jason, ERS-1/2, Envisat) -> westward shift of the subpolar front (Bersch 2002)
- Large fluctuations in the NAO index
- Brambilla and Talley, JGR 2006: essentially no (one) drifters escaping from below 45N to the Nordic Seas

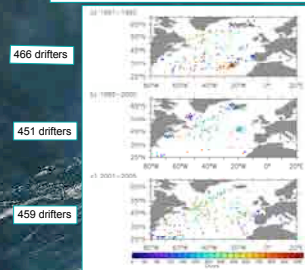


Warming and salinization of the Atlantic water path in the Nordic Seas since the late 1990s -> Holliday et al. GRL 2008
 The sudden salinization and warming difficult to explain by changes in surface fluxes

DATA

- SURFACE DRIFTERS DROGUE AT 15m ; available since 1989 (NOAA GLDP)
- EKE, Vg, from merged multi-mission altimetry 1992- (AVISO)
- 1x1 altimetric SSH (Brian Beckley/GSFC)
- NOAA OSCAR surface current product based on altimetric geostrophic velocities + Ekman drift computed from various remote sensing wind product (1992-)
- data divided to 3 (4) 5-year periods to reflect different NAO phases : 1991-1995 NAO+; 1996-2000 mainly NAO-; 2001-2005 a weak fluctuating NAO index

SURFACE DRIFTER LAUNCHES AND LIFESPAN (color, days)



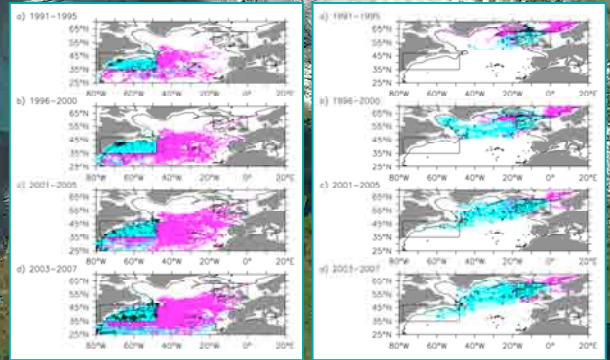
466 drifters

451 drifters

459 drifters

SURFACE DRIFTER TRACKS PASSING THROUGH THE GULF STREAM REGION ; Cyan for tracks before entering; magenta after leaving

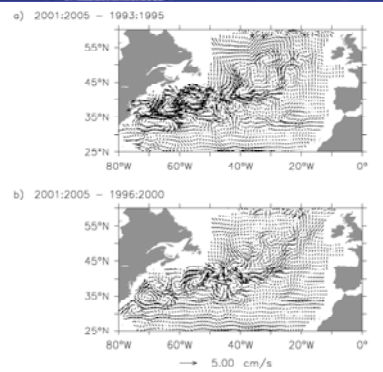
FOR PERIODS 1991-1995; 1996-2000; 2001-2005; 2003-2007



SURFACE DRIFTER TRACKS ENTERING THE ROCKALL TROUGH; Cyan for tracks before entering; magenta after leaving

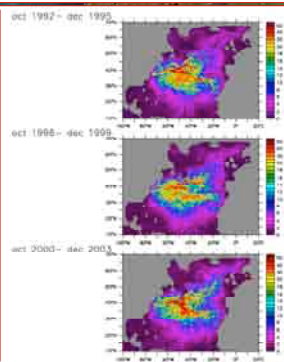
REPRESENTATIVENESS OF THE DRIFTER TRACKS ? ALL SURFACE DRIFTER TRACKS LAUNCHED SOUTH OF 45N (left), AND NORTH (right) OF 45N DURING PERIODS 1991-1995, 1996-2000 AND 2001-2005

OSCAR SURFACE CURRENT ANOMALIES



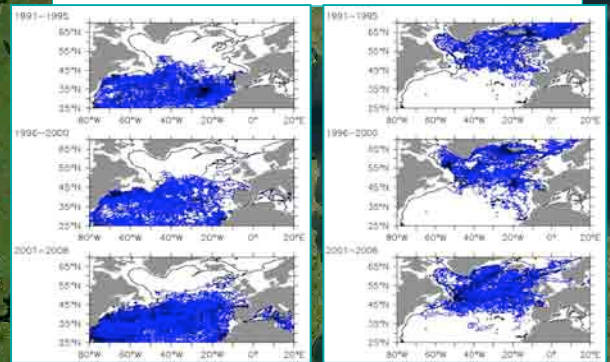
SYNTHETIC DRIFTERS IN THE 7-DAY AVISO GEOSTROPHIC VELOCITY FIELD

652 drifters released Oct 1 each period in the Gulf Stream box (see above); color refers to how many drifters passed the same AVISO 1/3deg grid box. In the last period 15% of the drifters cross 55N, compared to about 9% in the two earlier periods.



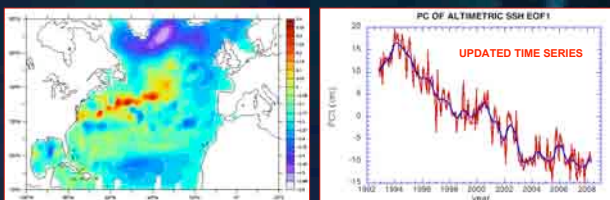
TRACER ADVECTION IN THE AVERAGE 5-YEAR SURFACE DRIFTER VELOCITY FIELD

(tracer inserted to the Gulf Stream box with value of 100 and kept constant)

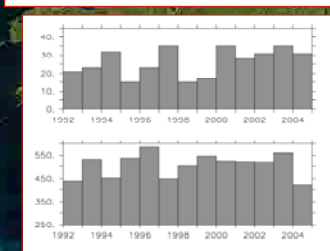


ALTIMETRIC SSH CHANGES

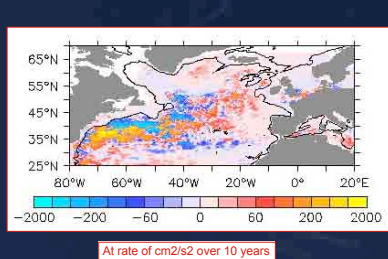
(update using only TOPEX/Poseidon and Jason-1 data, time period covered: October 1992 to April 2008) (Häkkinen and Rhines, 2004)



NUMBER OF SYNTHETIC DRIFTERS IN AVISO Vg FIELD THAT PASS 55N AND THEIR AVERAGE TIME WHEN 250 DRIFTERS ARE RELEASED IN THE GULF STREAM BOX OCT 1 EACH YEAR

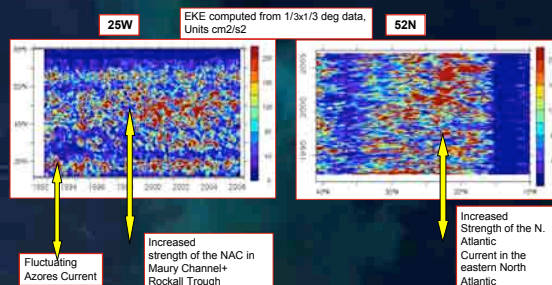


TREND IN EKE FROM OCT 1992 TO SEP 2006



At rate of cm2/s2 over 10 years

LOW-PASS FILTERED ALTIMETRIC EKE FLUCTUATIONS ALONG LONGITUDE (25W) AND LATITUDE (52N) SECTIONS



Fluctuating Azores Current

Increased strength of the NAC in Maury Channel+ Rockall Trough

Increased strength of the N. Atlantic Current in the eastern North Atlantic

SUMMARY

- Before 2001 the warmest NAC branches turn south-eastward in the eastern North Atlantic, since 2001 these warm water pathways shift to north-eastward towards the Nordic Sills:
 - Drifters are able to overcome Ekman drift (← weak NAO)
 - A signal of increased salt to the Nordic Seas
- Synthetic drifters in the 7-day AVISO Vg support the enhancement of the Rockall branch of the North Atlantic Current
- The surface currents carrying high salinity waters to the Nordic Seas will support the stabilizing effect of salinity on the thermohaline circulation