

UNIVERSITY OF SOUTHAMPTON
FACULTY OF NATURAL AND ENVIRONMENTAL SCIENCES

Unravelling sub-seasonal to seasonal variability at key ocean circulation 'choke' points using gliders:
a case study from the Western Mediterranean Sea

The Quiet Revolution

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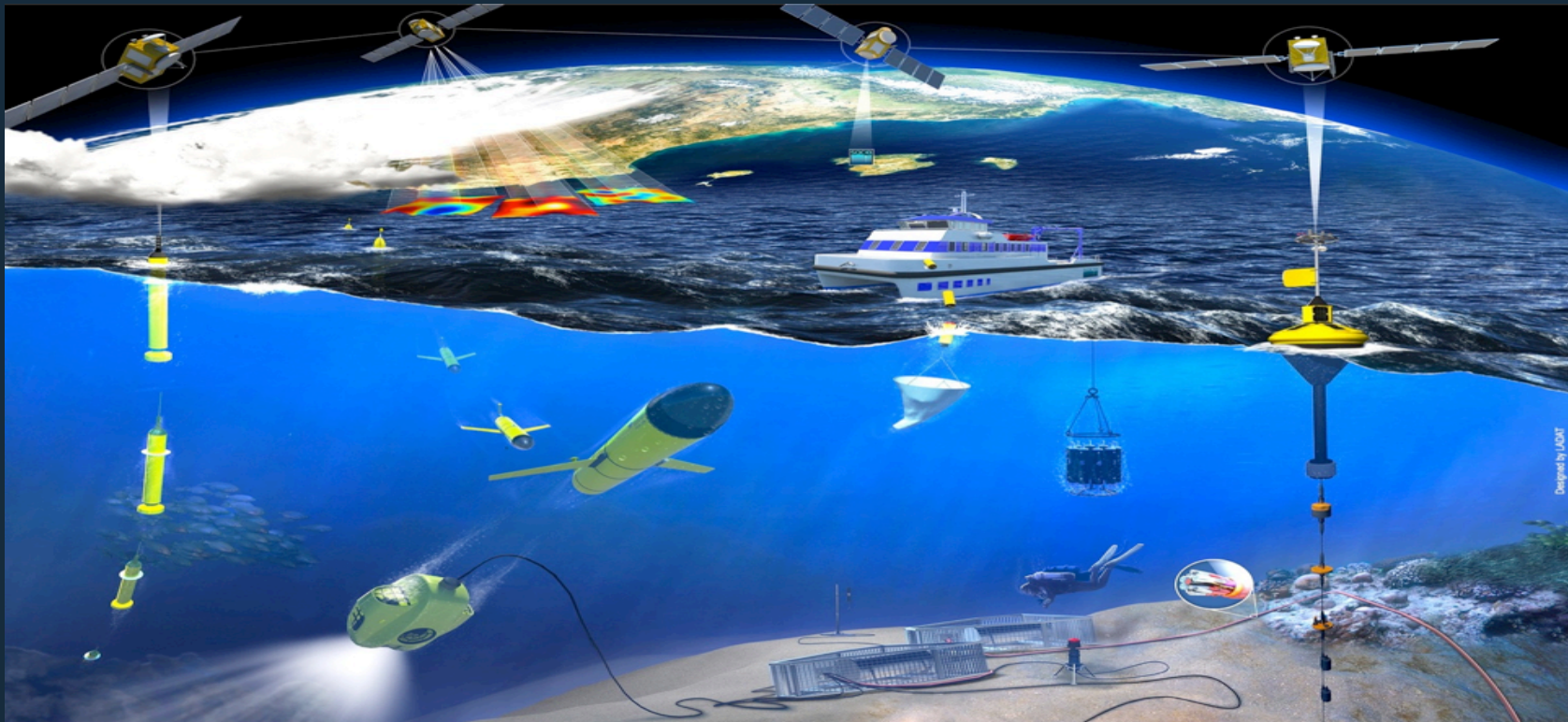
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NOCS
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The quiet revolution?

Evolution in ocean science:

- New multi-platform integrated ocean observatories - observing for long term/range of scales
- Monitor ocean state and ocean variability, now delivering results...
- Carefully and systematically improving our knowledge of ocean variability – a quiet revolution



Why study variability in ocean circulation?

Societies increasing need:

- Manage ocean resources based on knowledge and data
- Detect and understand climatic change

Need:

- Long time series
- Synoptic data

In 2009, the RAPID array records a 30% drop in average current strength, that lasted a year

"We need data, ... models are becoming untestable" (Carl Wunsch, 2010)

>> Variability in ocean circulation affects the distribution of heat and salt, also biological nutrients and marine organisms

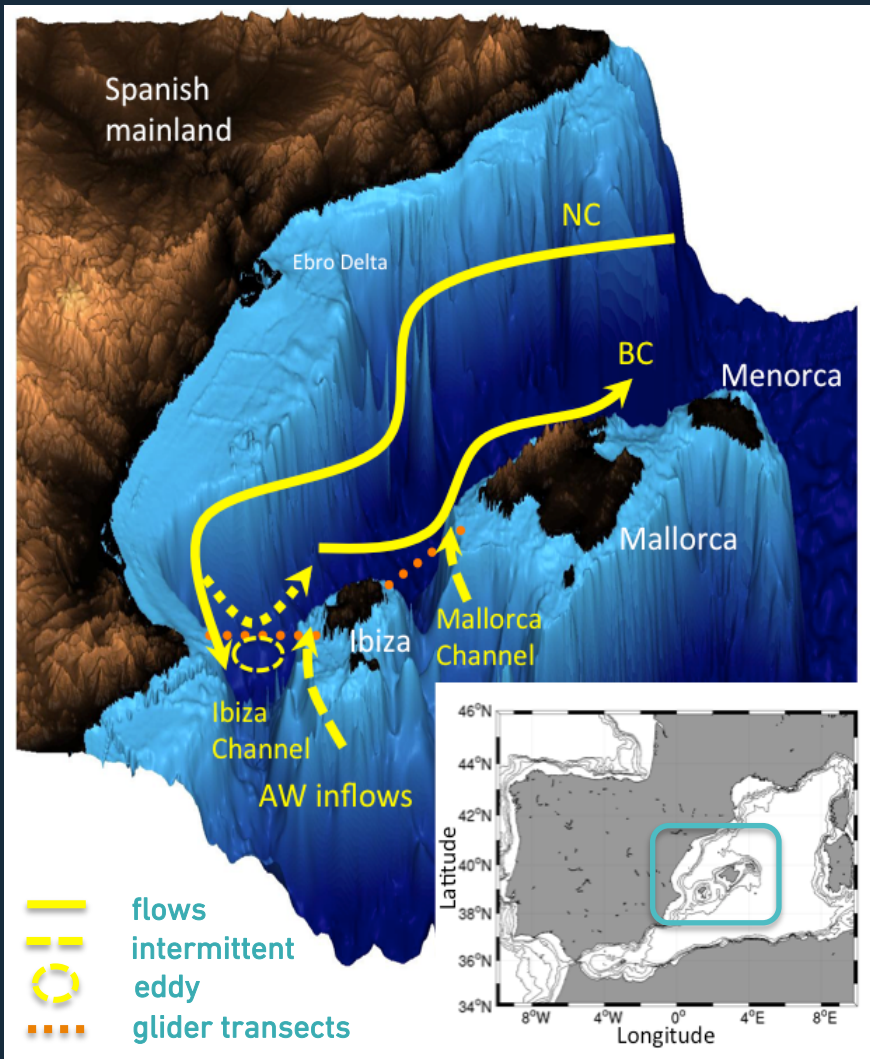
- Improved knowledge of variability:
 - increase model forecast skill
 - link physical processes to ecosystem response
 - detect future climatic change



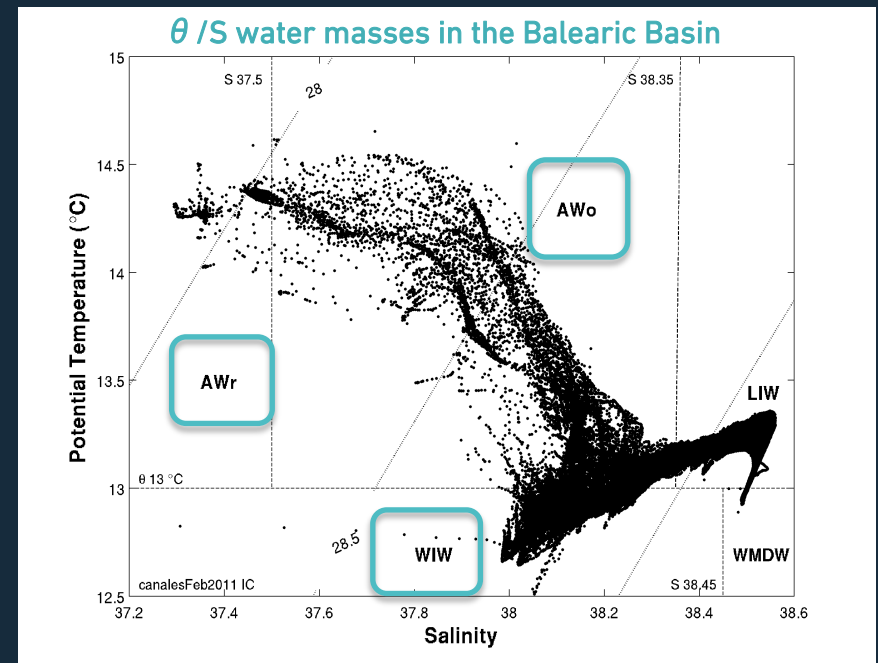
Nature May 2013

Importance of the Ibiza Channel

Narrow 'choke' point in the basin scale circulation



- Northern Current transport more saline AW south
 - Inflows of less saline, warmer AW 'recent'
 - Fresh inflows affect spawning grounds bluefin tuna
 - Eddies 'block' channel
 - Role of winter mode water (WIW) – cold eddy cores
- >> Governs important N/S exchange of water mass



Local definitions after López- Jurado et al. (2008)

What known about variability previously?

Seasonal strengthening of Northern Current in winter (Astraldi et al. 1989)
'large cruise-to-cruise variability in transport' (Pinot and Ganachaud 1999)

The CANALES experiment - (Pinot et al. 2002)

- 1990's 2.5 year program seasonal ship sampling to resolve variability
- Seasonal maximum/minimum in transport through IC

Reference	Date	Survey	South (Sv)		North (Sv)		Net (Sv)	
			Winter	Summer	Winter	Summer	South	North
Ibiza Channel								
Font, Salat and Tintoré, (1988)	historical data	Ships CTD	-1.00	-0.50				
Castellon et al., (1990)	May - June 1989	Ships ADCP		-0.24				
López-Jurado and del Rio, (1994)	Nov 1990 - May 1991	Ships CTD	-0.65	-0.56	+1.08	+0.51		
Pinot et al., (1995)	May - June 1991	Ships CTD		-0.20		+0.50		
Pinot and Ganachaud, (1999)	June 1993	Ships CTD		-0.55		+0.55		
Pinot et al., (2002)	Mar 1996 – Jun 1998	Ships CTD	-1.20	-0.30	+0.20	+0.70	-1.05	+0.35
Mallorca Channel								
Pinot et al., (2002)	Mar 1996 – Jun 1998	Ships CTD					-0.30	+0.05

Historical 'seasonal' estimates of transport through the IC and MC, most cruises in summer

Glider and ship datasets

Glider CTD Data 2011 - 2013:

- 3 years quasi-continuous monitoring
- Repeat transects IC (2 – 3 days), full channel depth
- Profile resolution 300 m to ~2.7 km (deep channel)

3 years - 66 IC transects, 22 MC transects

~13,000 profiles

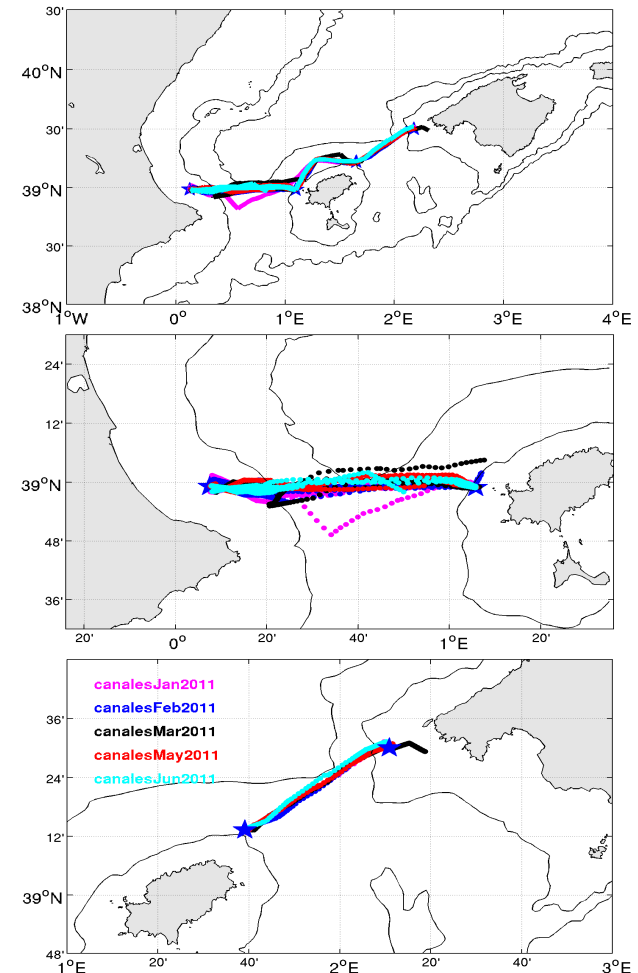
Ship CTD data 1996 – 2013:

- 18 years 'seasonal' ship campaigns
- Primarily from IEO (IBAMar dataset)
- 2 SOCIB and 1 Catholic University of Valencia
- Station resolution 10 km

18 years - 54 IC transects, 48 MC transects

~ 1100 profiles

>> Temperature and salinity used to
calculate geostrophic velocity and
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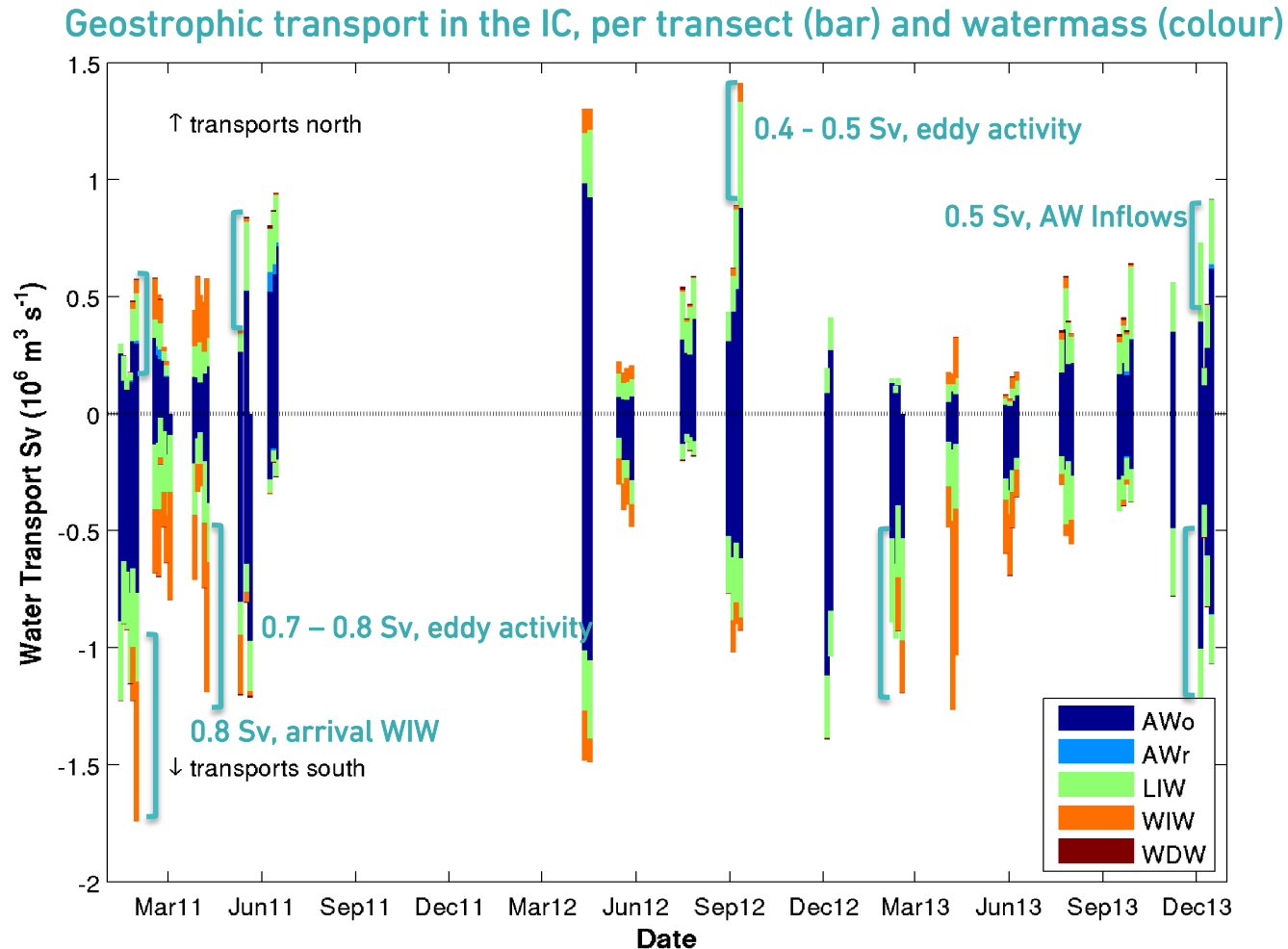
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>> Temperature and salinity used to calculate geostrophic velocity and transport of watermass

IC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996			s	s	s	s		s				
1997		s		s	s		s	s				
1998	s					s						
1999					s							
2000									s		s	
2001			s			s					s	
2002			s		s				s			
2003			s			s				s		
2004			s		s					s		
2005			s			s				s		
2006				s		s						
2007							s			s		
2008		s		s			s			s		
2009					s							
2010				s								
2011	gggg gg	s gg gggg	gg	ggg	s ggg	s ggg	s					
2012				gg	gggg		gggg	g	ggg			gg
2013		gggg		s gggg	g	s ggg	gggg		ssss gggg		g	gggg ss
MC	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996			s	s	s	s		s				
1997	s			s	s		s	s				
1998	s			s		s						
1999					s							
2000											s	
2001				s	s	s					s	
2002			s		s				s			
2003					s					s		
2004			s		s					s		
2005			s			s			s			
2006				s		s				s		
2007							s			s		
2008		s			s		s				s	
2009					s		s					
2010				s								
2011		gg	g		s g	g	s					
2012			s g		g		gg	g		g	g	g
2013	g		s		g	s g	g		g	g	g	s

High frequency variability Ibiza Channel

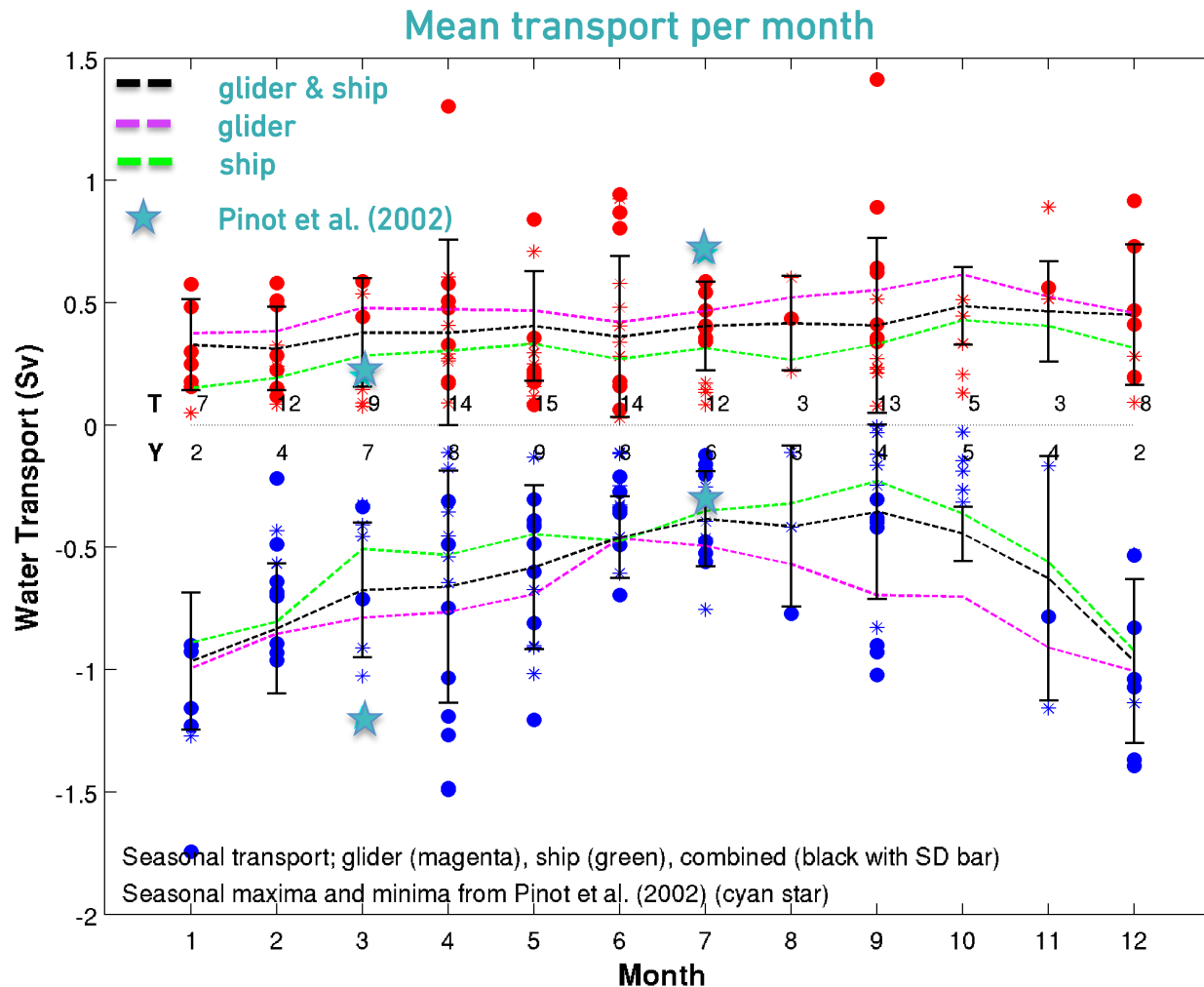
Gliders observe high frequency variability in the transport of watermass



- High frequency changes - on a par with seasonal signal
- Occurring over days to weeks
- Causes:
 - arrival of WIW
 - eddies
 - strong AW inflow

Seasonal variability Ibiza Channel

Interannual mean seasonal cycle of transport

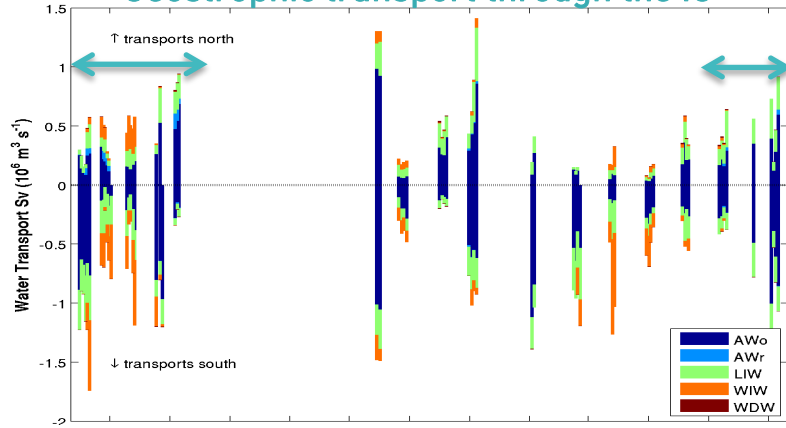


- Seasonal cycle in transport S
- None in transport N
- Agreement glider/ship data
- Changes our view of exchange
- Different drivers to N and S combine through the IC

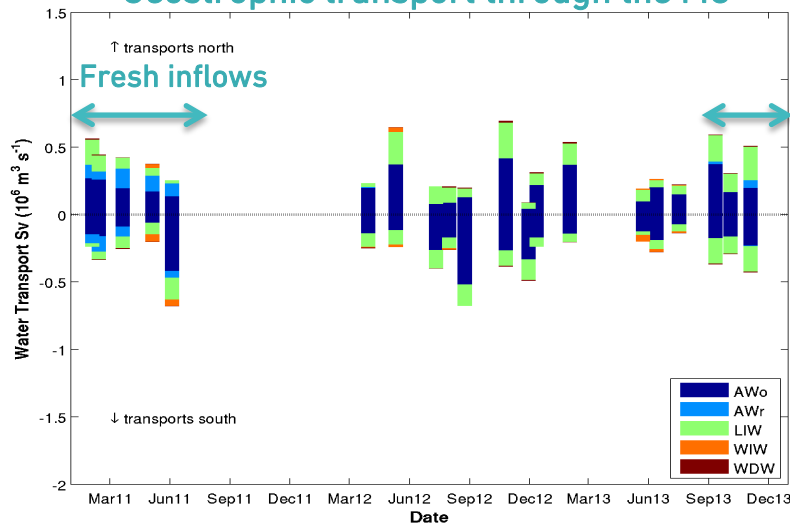
Insight into AW Inflows

Fresher AW inflows (light blue)

Geostrophic transport through the IC

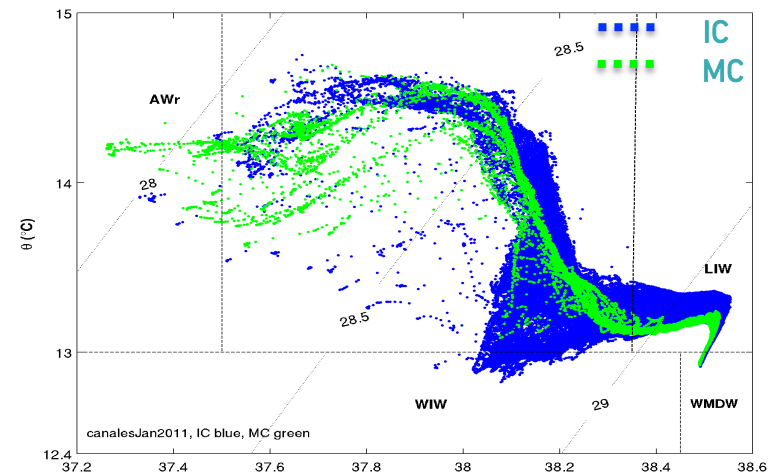


Geostrophic transport through the MC



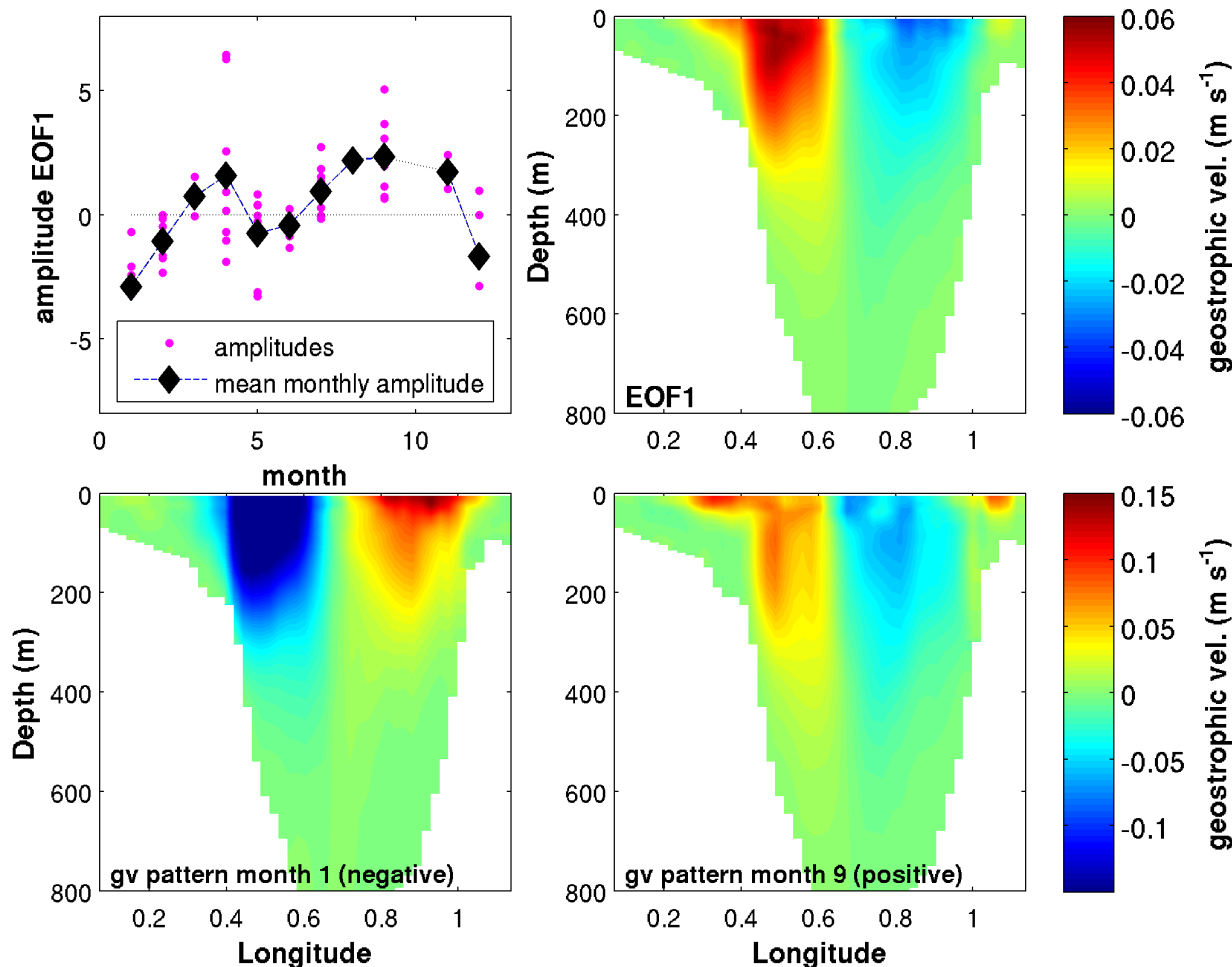
- Synchronous through IC/MC
- Episodic
- Several months duration
- MC slightly fresher
- Inflow events influenced gyre patterns to S
- Operational alerts

Water masses 'canalesJan2011'



Seasonal interplay between basin and mesoscale

First EOF of geostrophic velocity in the Ibiza Channel



- First EOF:
 - 42%
 - Seasonal pattern amplitude
- negative amplitude
 - Winter/early summer
 - Negative strong NC
- positive amplitude
 - Spring/autumn
 - Anticyclonic eddy
- Preliminary seasonal cycle for eddy activity

The quiet revolution

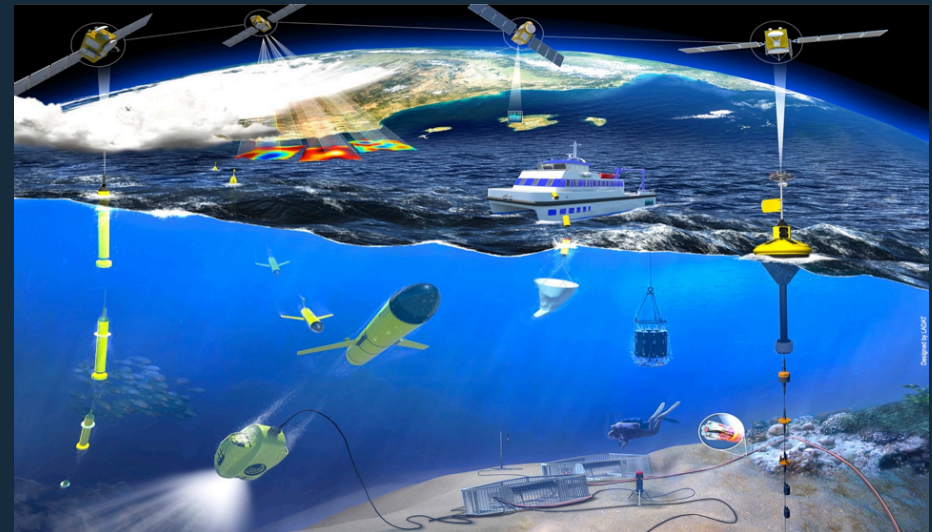
- Gliders, as a part of a multi-platform integrated ocean observing
- Unravel variability at a range of scales and has changed our view of exchange and the drivers
- At an important circulation 'choke' point – ecosystem and completion basin scale circulation

How have gliders changed our view and what does this mean:

- First time glider observe high frequency variability – place seasonal cycles in context
- Seasonality - NC and eddies – drivers of which are to the north - atmospheric exchange.... but more than deep water formation drives the NC flows, eddies and NC linked
- No seasonality Inflows have – fresh inflows likely driven by some specific events in Alboran Sea, IC and MC linked
- Gliders capable of delivering high quality data, ship missions required to calibrate but challenge is to further leverage/enhance ship time observations

How can we use this knowledge:

- Verify models and improve forecasting capability
 - Investigate interannual variability and the drivers of variability
- >> Potential products for society
- RT 'inflow alerts' - SOCIB operational network
 - Inflow prediction - from altimetry (gyre patterns)



OBJECTIVES

1. GENERAL OBJECTIVES: PhD - study variability ocean circulation sub-seasonal to seasonal timescales – 'proof of concept' for glider monitoring ocean variability, generally assist SOCIB where needed and I can help
2. MAJOR ACOMPLISHMENTS SO FAR 2013-2014: Submitted thesis – passed viva!
3. OBJECTIVES FOR 2015:
 - Take the 'proof of concept' further, advance research (modelling/drivers/prediction), automate metrics for key glider monitoring (inflows, NC strength....), develop products for society
 - Automate in-situ calibration methodology (across platforms)
 - Publish another paper on results AND 'proof of concept'.
 - SOCIB: Development SOCIB products - cross platform, integrated and predictive
 - SOCIB: Expand monitoring integrated strategy (sensors/locations/platforms) to meet future observing needs (MFSD, blue growth, models, science questions) – cross platform
 - SOCIB: Take same approach for other platforms (e.g. moorings, drifters) other students
4. MAJOR NEEDS – cross platform view, closer to end users, expand to meet future observing needs (MFSD, blue growth, models), SOCIB team not bad at working together, just encourage people to see this as important, continue to improve working environment

SUMMARY/IDEAS

5. SUMMARY/IDEAS:

- Products: brainstorm product ideas, take decisions, execute well (market testing). Attract funding for additional products (sponsorship/links). Promote outside product development – competitions.
- Science & data for QC & calibration: 2 person team responsible
- Use PhD/MSc project studies: depth data understanding platforms/variables, deliver QC, understand our product, generate ideas
- Identify cross facility issues: meet to resolve (calibration, expansion, data management), Data Centre/ETD?
- Identify clear opportunities for open access – promote
- Keep innovating - learning, development and inspiration (visits, courses, conferences, read more, internal knowledge transfer), and environment/working space (ad hoc meeting points, working standing up, different seating)

Notes for discussion - day 2

I would like to see clear themes and excitement:

- 1. Products; for society (clear ideas exist within SOCIB on how to achieve this), for science (we have them, we need to promote them and get feedback on what required)
- 2. Expand our observing capability - this is a huge challenge because of resources, but I think we need this ambition, it is exciting and it should be a focus (Benja's fixed station an example), what does society and science need out of a network in 5 years time, more biogeochemistry? transects for models (Mercator - funds??), biology...fish tag listening devices (other acoustics), more local bouys with different sensors (port authorities?? - just guesses) - we could invite experts to SOCIB to meet with the facilities to say what they need?
- 3. Technology - identify 2 or 3 areas for new technology development - big data analytics for a hoc enquiry example, our brilliant visualisations, help with sensor testing and development on our network (forge a relationship with someone - PAL for gliders....) SOCIB to get together and brainstorm this too?? to have an idea for each facility - we do not have to do them all just a few.