Ocean Observatories Initiative

Global Array
Project Scientist Report

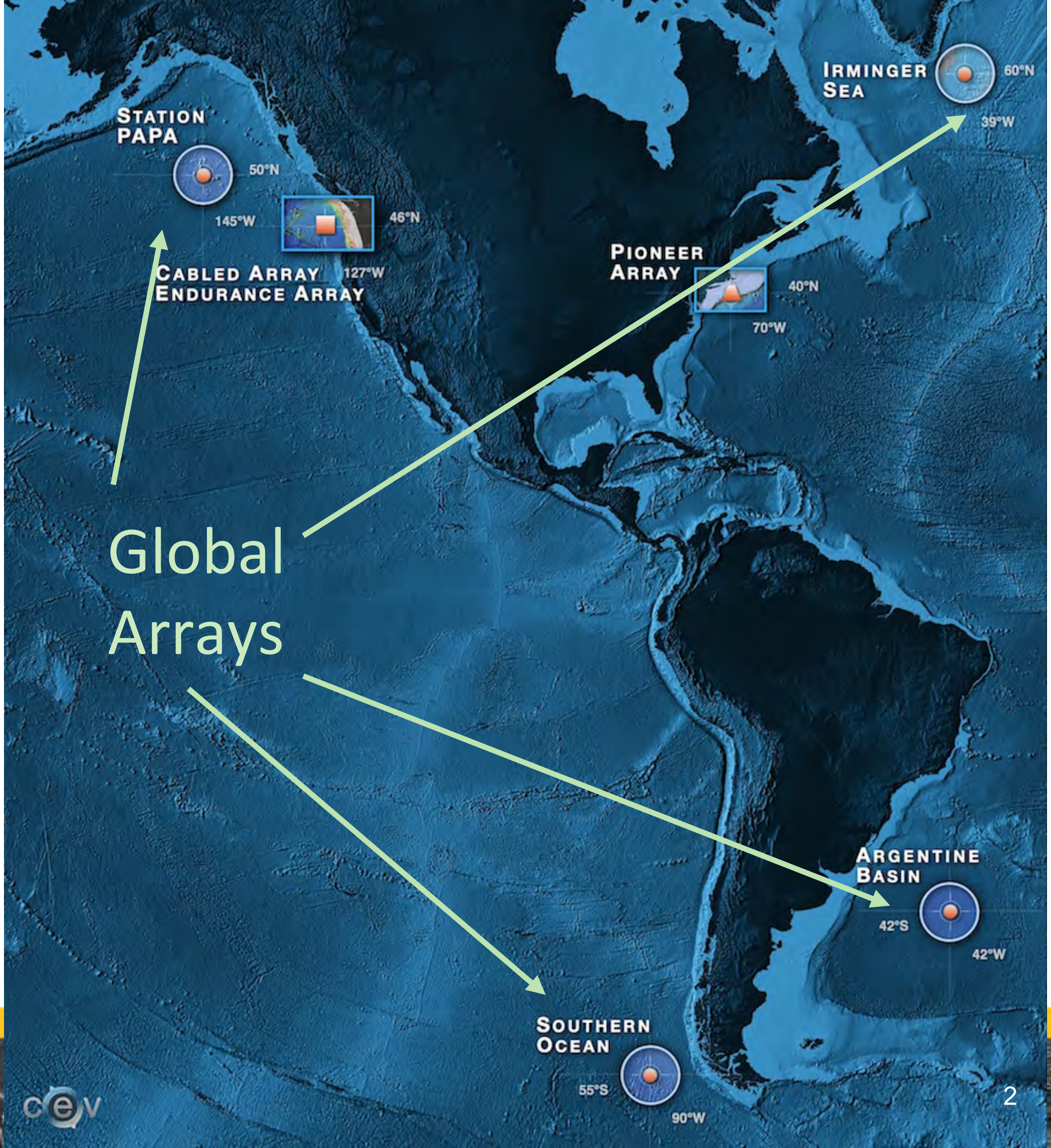
May 2018

Robert Weller
Woods Hole Oceanographic Institution

Global Arrays

Success stories
- Sampling data sparse regions
- Irminger Sea
- Assessing models
- Anchoring/validating global fields

Concerns
- Quantification of uncertainty in data
- Especially of met and fluxes
- Ship-based validation
- Cold weather capable sensors
- Technology refresh
- QA/QC and the operator
- Met and flux data files

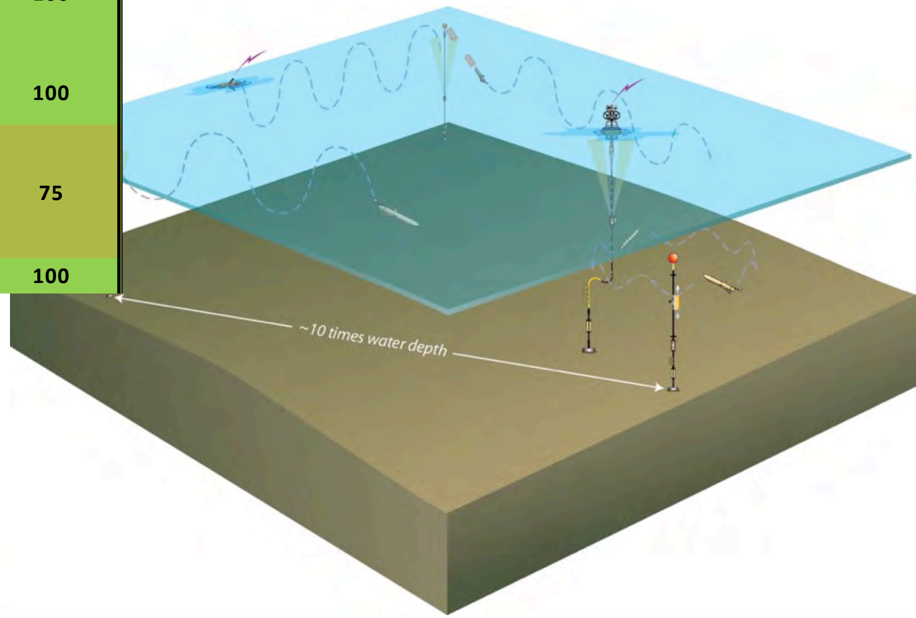


Southern Ocean 3

- **Southern Ocean 3 – Partial Recovery Dec 2017**
  - GSM 521 days, still 42% data return from 12 instruments
  - Power generation consistently reliable
  - Extended lifetime pending NSF/NERC re-deployment Fall 2018

Southern Ocean GSM Status

29-Apr-18	
	%good
Num Inst.	12
Inst. %	42
Data System	83
GPS	100
Power	99
Battery	100
PV	100
Wind Turbine	100
Telemetry	75
Beacon	100

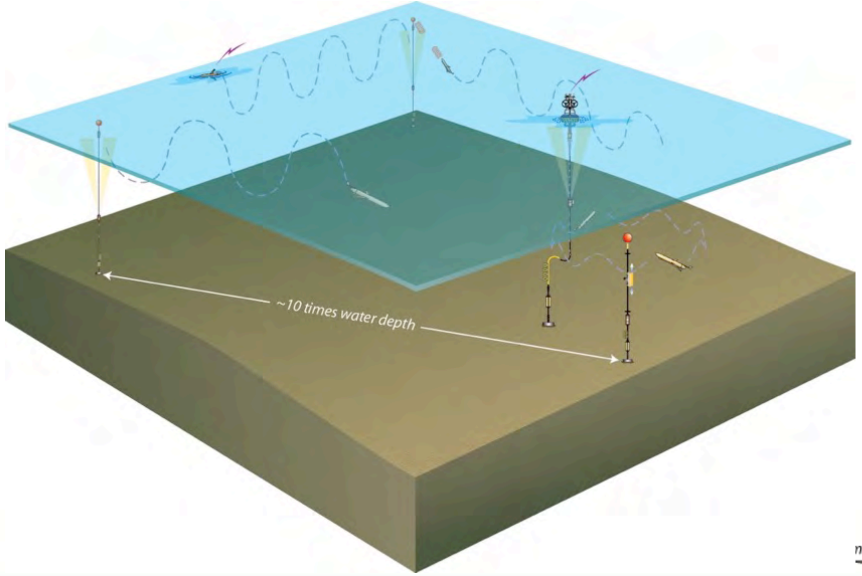


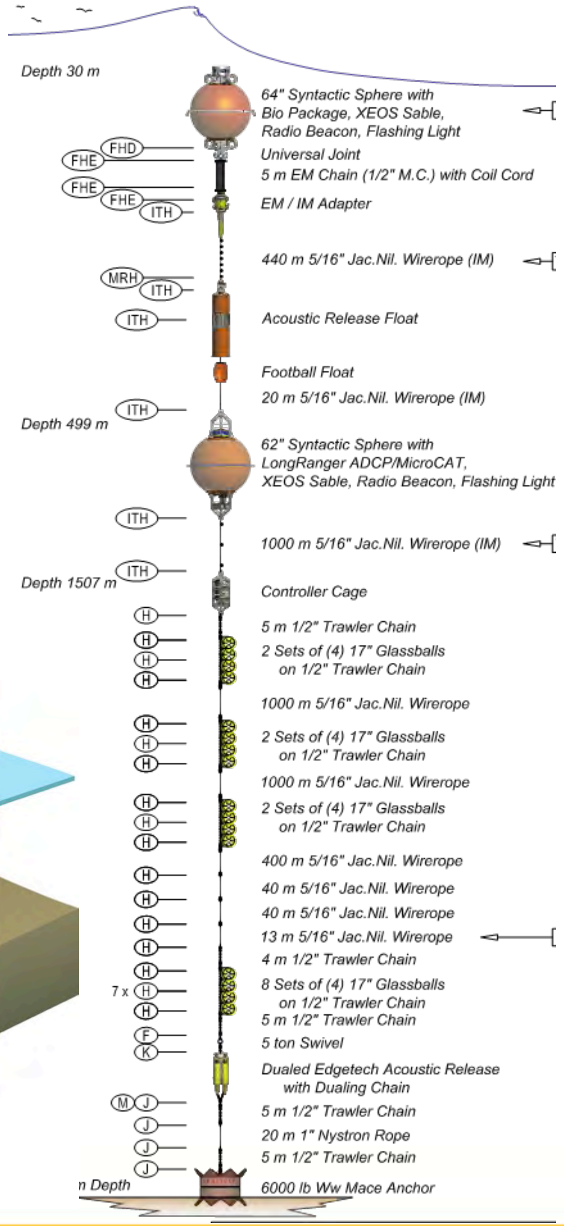
Challenges

- Southern Ocean weather prevented recovery of GSM and lower SSM sections Dec 2017
- Battery power limited for inductively-coupled sensors (365 day plan)

Argentine Basin 3

- **Full Recovery January 2018**
  - ➢ Cruise delayed. RV Atlantis diverted for Argentine Navy submarine search
  - ➢ Recovery of HYPM-2
  - ➢ Recovery of HYPM-3, FLMA/B-3
  - ➢ Equipment returned for refurbishment and re-use at Papa & Irminger





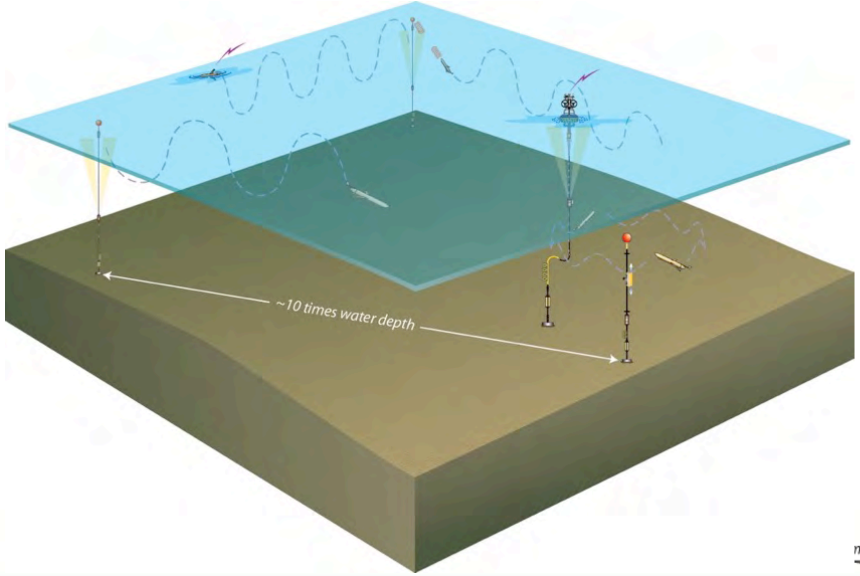
Irminger Sea 5

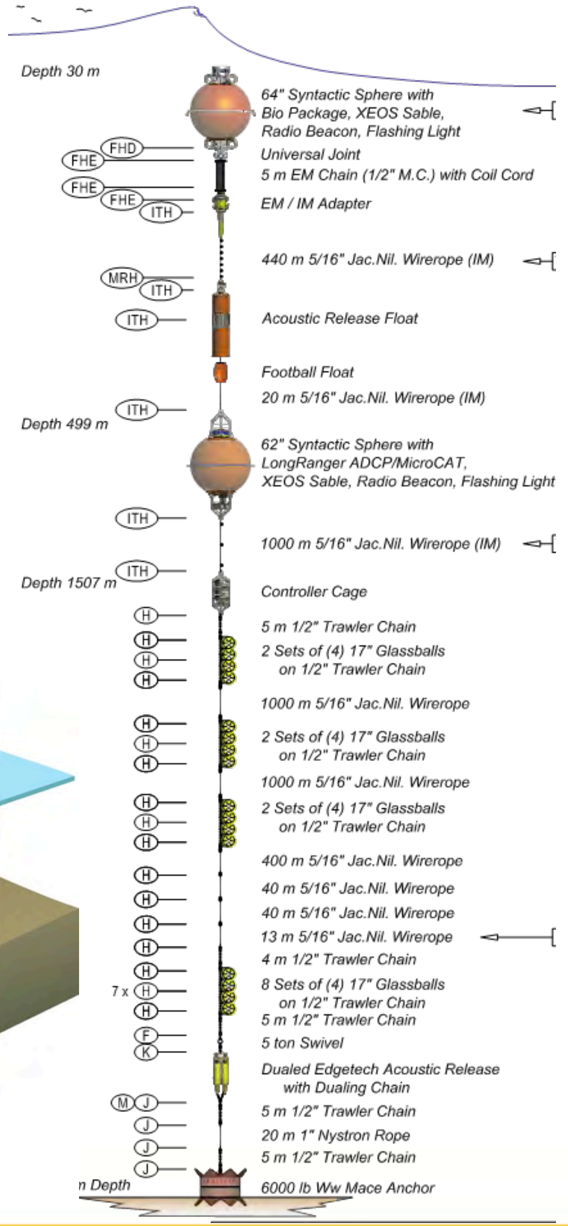
- **Scheduled Turn June 2018**

Challenges

- **GSM from Irminger 4 missing October 2017 – likely struck or trawled**
- **Air-search conducted**

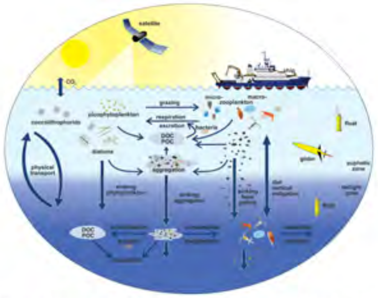
- **Modifications for Irminger 5**
  - ➢ **Tower camera**
  - ➢ **Heat elements to prevent tower icing**
  - ➢ **Universal joint engineering**
  - ➢ **Additional beacon on SUMO**
  - ➢ **Universal joint failure testing**





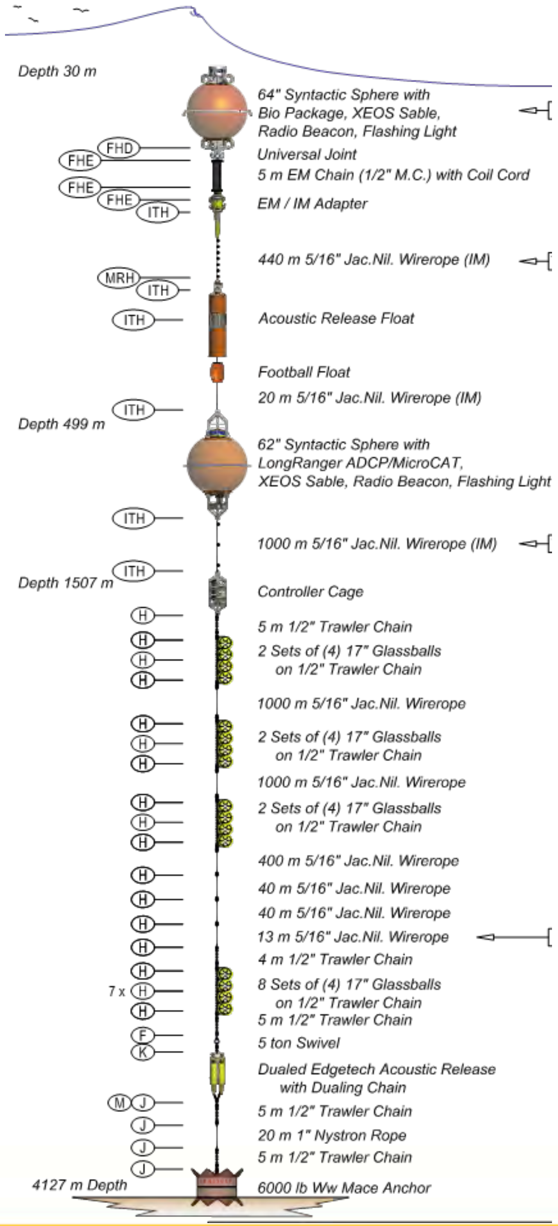
Global Papa 5

- **Scheduled Turn July 2018 RV Sally Ride**
  - ➢ **Recover Papa 4 SSM**
  - ➢ **Deploy Papa 5 SSM**



- **Coordination with NASA EXPORTS**
  - ➢ **Glider deployment**
  - ➢ **Sampling**

- **Coordination with NOAA PMEL**
  - ➢ **Turn Papa SUMO**



Global arrays – new knowledge of data sparse regions

Surface meteorology and air-sea fluxes at Global sites have drawn high interest:

- Extreme events and climatology of data sparse region
- Validating/anchoring remote sensing products
- Characterizing errors in model fields
- Validating/anchoring blended or hybrid air-sea flux products

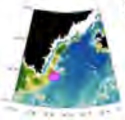
Weller (WHOI) inserted Southern Ocean met data on GTS

- To support Year of Polar Prediction Southern Ocean
- ECMWF showed improved forecast skill

Deep convection in the Irminger Sea observed with a dense mooring array

M. Femke de Jong[1] (femke.de.jong@nioz.nl), Marilena Oltmanns[2], Johannes Karstensen[2], Laura de Steur[1,3]

[1]Royal Netherlands Institute for Sea Research, [2]GEOMAR Helmholtz Centre for Ocean Research Kiel, [3]Norwegian Polar Institute



OOI Irminger Sea Array is located in a critical region for carbon uptake and export (the biological pump)

Hilary I. Palevsky and David P. Nicholson, Woods Hole Oceanographic Institution

hpalevsky@whoi.edu

Air-sea Interaction in the Irminger Sea: New Results from the OOI Mooring

OOI Southern Ocean air-sea heat fluxes and mixed layer variability

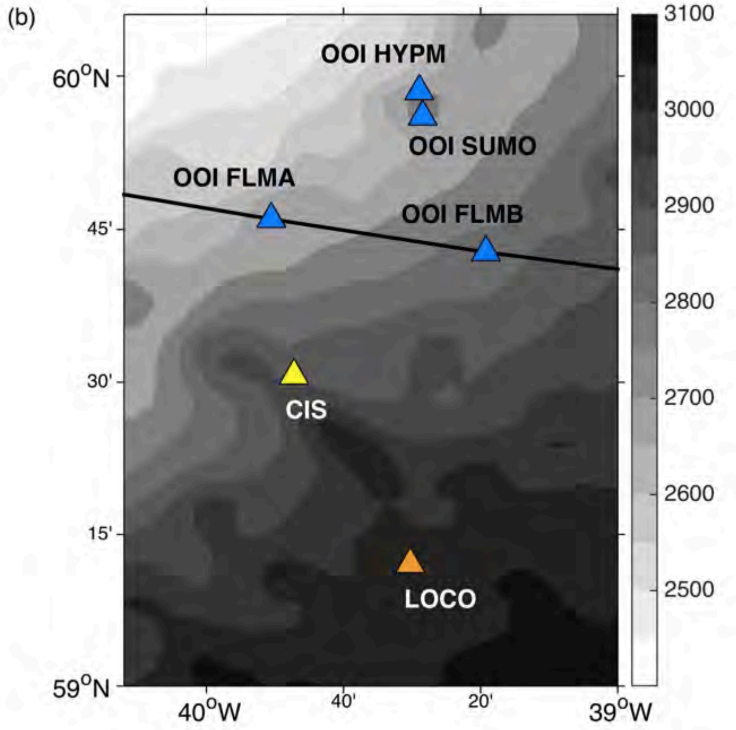
Veronica Tamsitt, Scripps Institution of Oceanography, vtamsitt@ucsd.edu

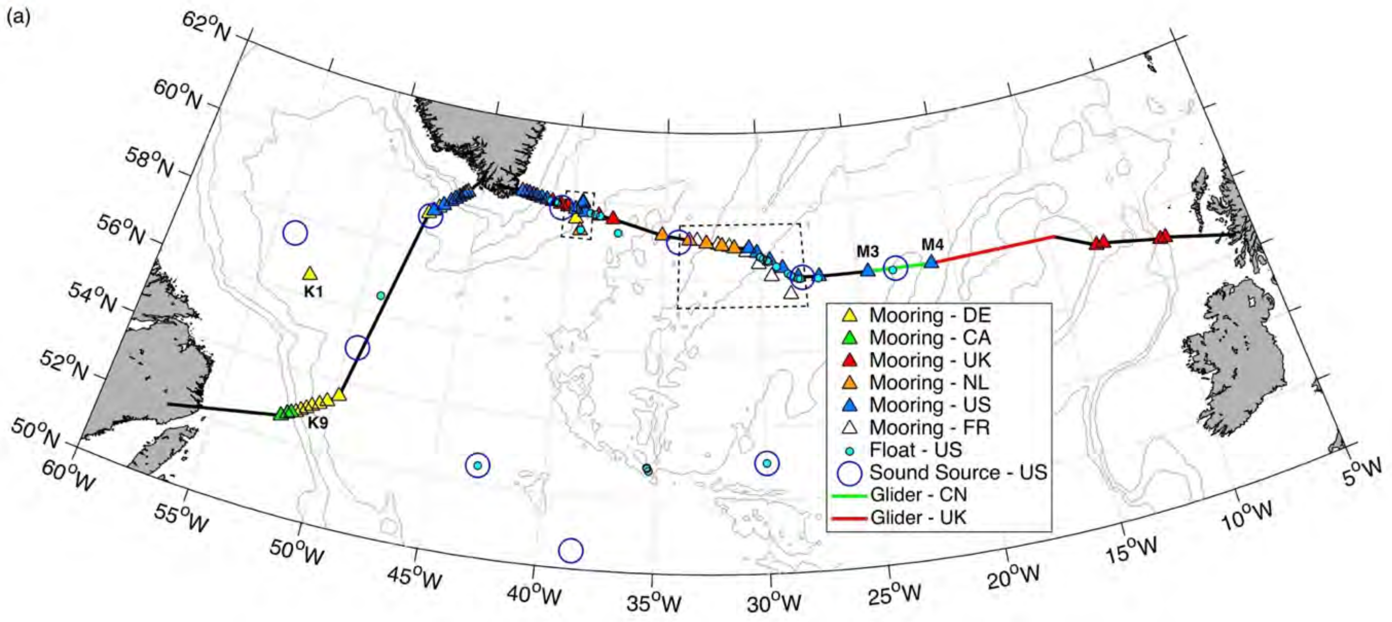
Poster AI24A-1604 4-6pm today

- The southernmost long-term open ocean mooring yields the first multi-year air-sea flux results south of 50°S.
- Extreme turbulent heat loss events occur year-round, and are driven primarily by cold, dry northeastward winds.
- Winter 2015 had more intense heat loss events, deeper mixed layers, and greater Subantarctic Mode Water formation than 2016.

GRL papers, TOS Oceanography, AGU Town Hall, EGU talks, papers in progress……

Irminger Sea





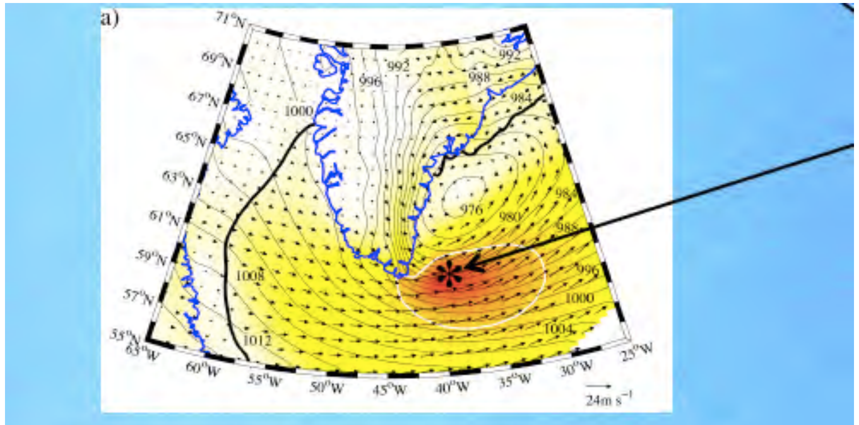
OOI Irminger mooring array design was finalized in collaborations with OSNAP at First Irminger Sea workshop.

Second Irminger Sea workshop saw strong support for and utilization of OOI Irminger.

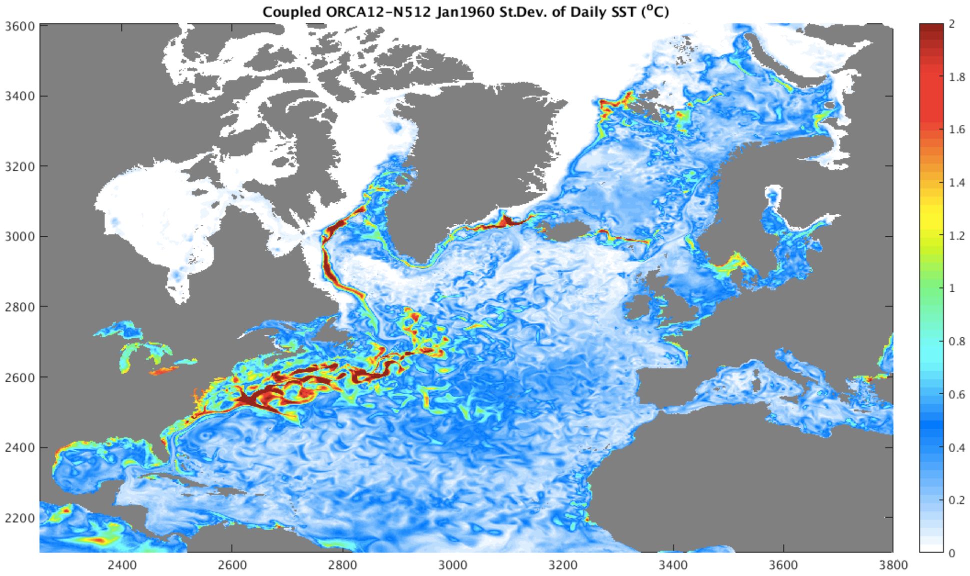
Surface piercing German Central Irminger Sea (CIS) and Dutch profiling LOCO moorings to be discontinued, look to OOI to sustain sampling.

Strong pulls for: surface mooring, full depth profiler, multidisciplinary sampling including on gliders, and mesoscale sampling.

Irminger Sea



South-westerly TJ composite : SLP (contours mb), 10-m wind direction (vectors) and speed (shading, m s^{-1}). Thick white curves show speed > 17 m s^{-1} .



Std deviation of Jan daily SST, 1/12° ocean from NEMO model, Andrew Coward NOC via Simon Josey

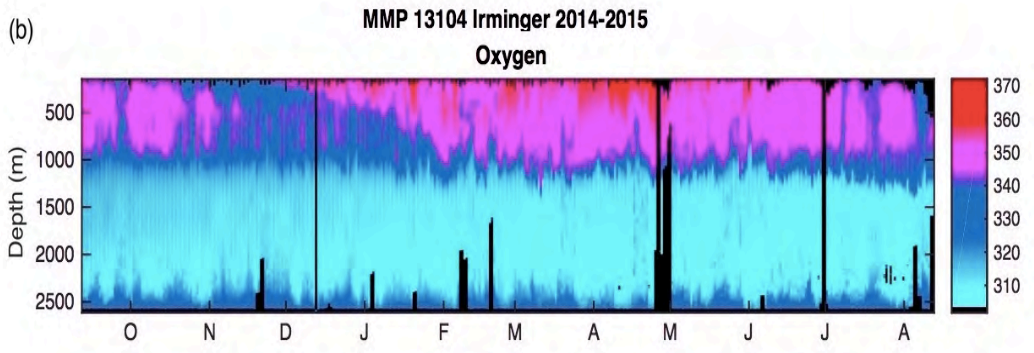
Simon Josey (NOC) EGU talk – OOI Irminger ideally placed to sample Tip Jet

OOI Irminger – the right place, samples full water column, samples the mesoscale, samples meteorology and fluxes, multidisciplinary

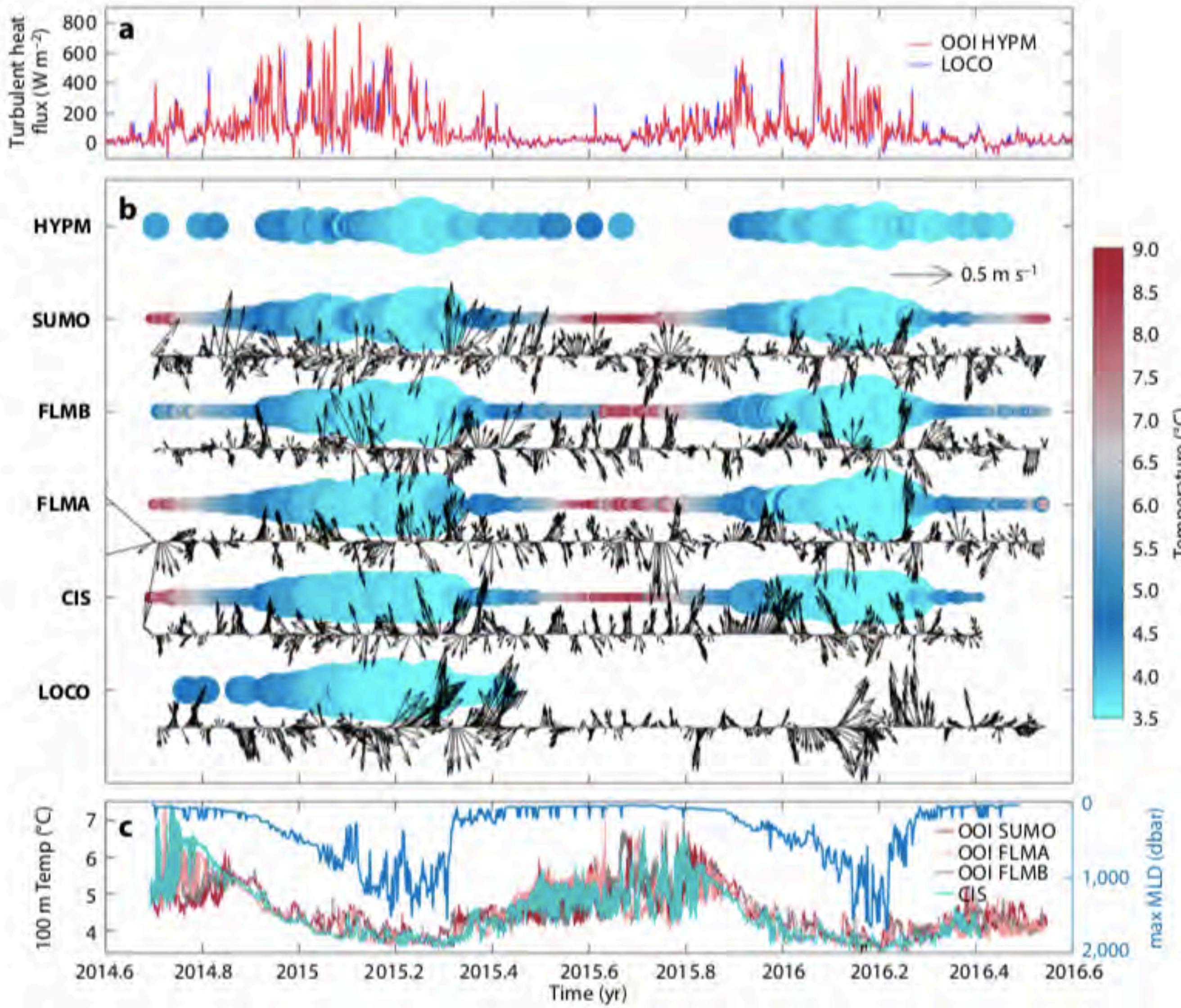
Irminger Sea – research foci

- What are the air-sea fluxes?
- Role of air-sea fluxes in convection?
- What sets space/time scales of deep convection?
- The role of the ocean mesoscale?
- Year to year variability, pre-conditioning?
- Links between physics and biology - blooms

Irminger Sea



Irminger Moored Profiler Dissolved Oxygen



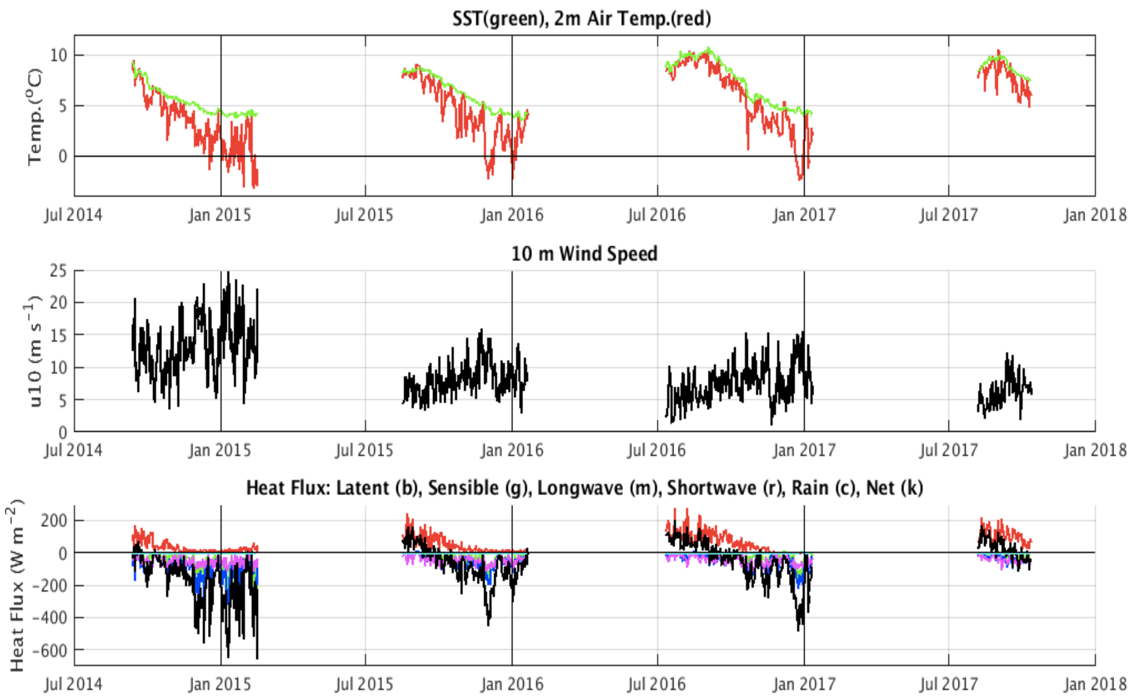
From Femke de Jong: Surface fluxes(ERA) and mixed layer depth (size of circle) and temperature (color) with hourly velocity vectors.

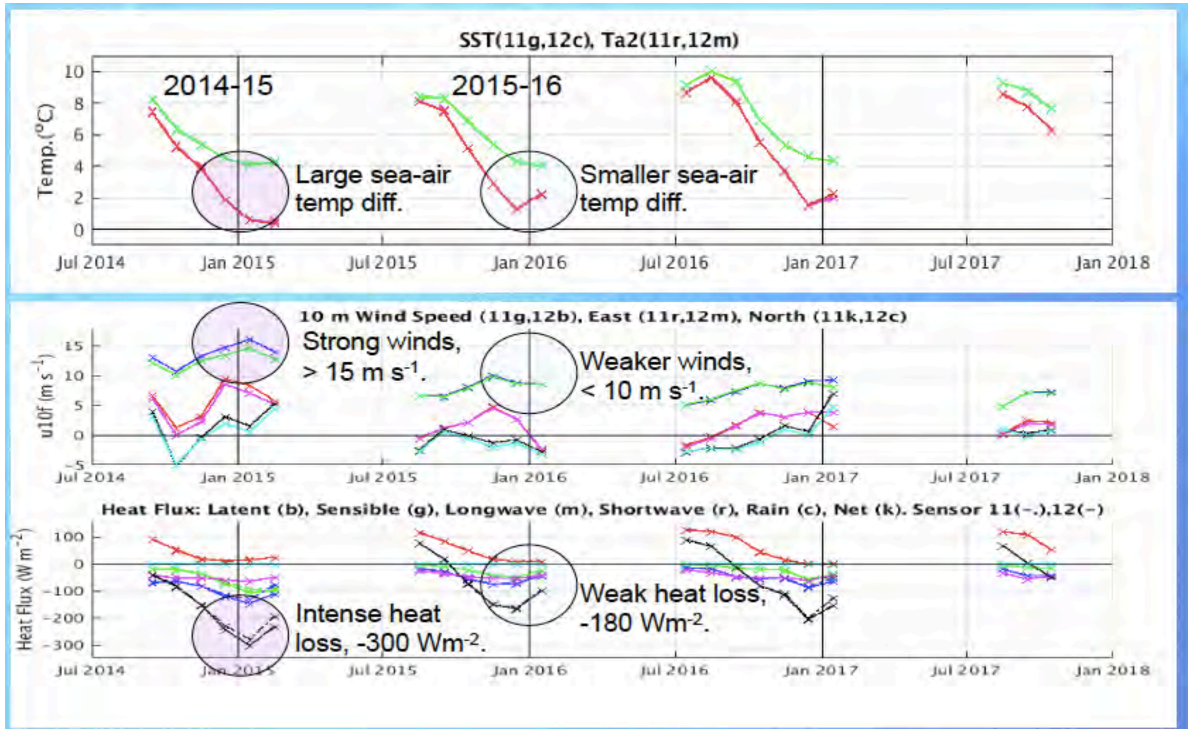
Variability in MLD and deep convection across the array?

- surface forcing
- eddy variability
- properties of water advected in

Irminger Sea

From Simon Josey (NOC)





Left: Air temperature (top), 10 m wind speed (middle) and heat flux components (bottom) for OOI Irminger surface mooring.
Right: Overplotting monthly means from both bulk met systems on buoy, air temp (top), wind speed (middle), heat flux (bottom). Note year to year variability.

Question: Two systems agree, but what are the accuracies?

Anchoring global fields – validating models

Surface meteorology and air-sea fluxes at Global sites have drawn high interest:

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- Validating/anchoring remote sensing products
- Characterizing errors in model fields
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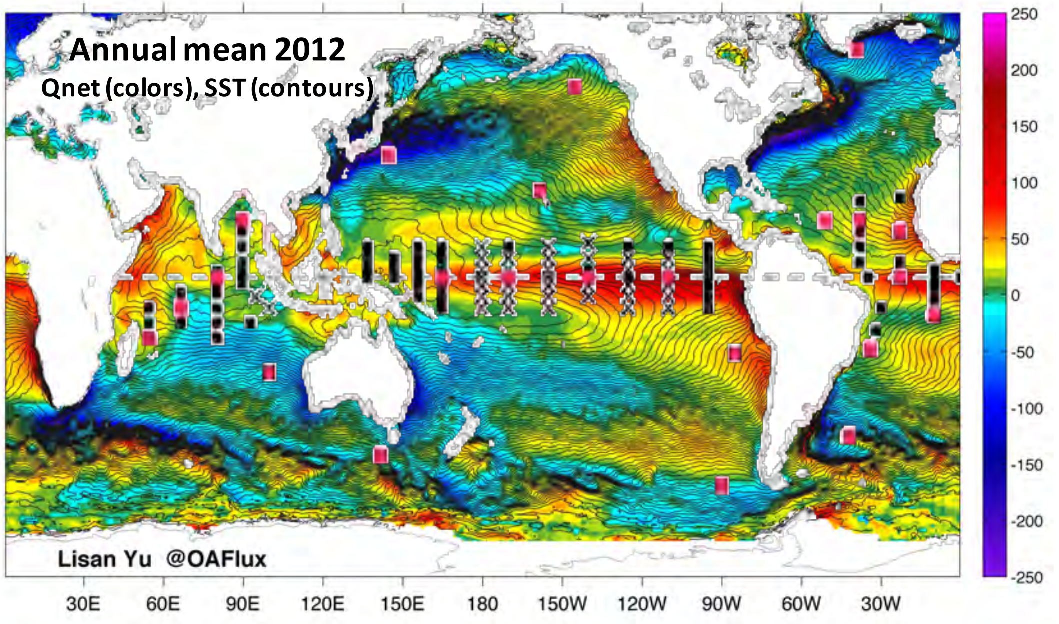


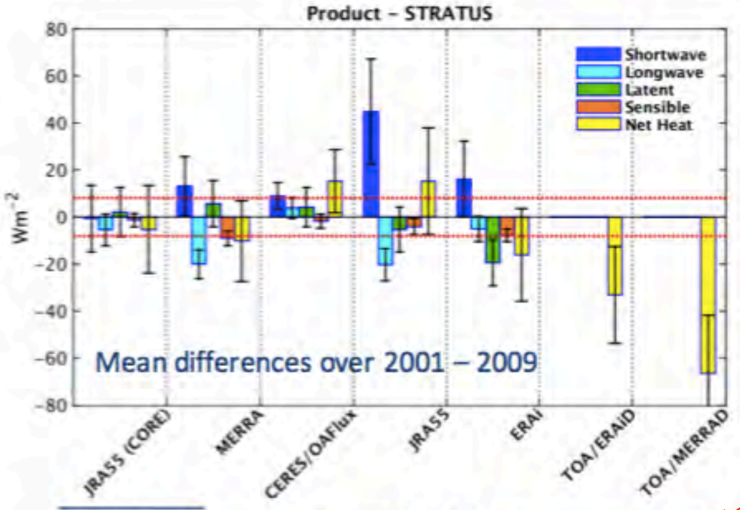
All components	■ Full-flux	
Partial components	■ LH, SH, SW. **No LW**	✖ LH, SH. **No LW & SW**

Figure from Lisan Yu (WHOI) – data from OOI Global arrays provides unique cold, dry regime data that are needed to tune hybrid fluxes in those regions.

Southern Ocean and Argentine Basin data of high value in tuning updated OA Flux products.

Air-sea fluxes – surface heat flux and wind stress on a global basis:
elements of the strategy – sustained benchmark sites for comparisons

Net heat flux (Wm⁻²)	Mean (2001 – 09)	Product – Buoy Mean DIFF (RMSE)
STRATUS	**37 ± 61**	–
ERAi	21 ± 71	-16 (25)
MERRA	27 ± 54	-10 (20)
JRA55	52 ± 71	15 (27)
OAFlux/CERES	52 ± 64	15 (20)
TOA/ERAiDIV	4 ± 72	-33 (39))
TOA/MERRADIV	-30 ± 74	-66 (71)
JRA55 (CORE)	**32 ± 62**	**-5 (19)**



- Products are ordered according to their agreement with the buoy net fluxes, from the best to the worst
- The red horizontal lines indicate the buoy standard error in net fluxes

The value of the in-situ surface meteorology and fluxes depends on knowing the uncertainties of the buoy time series.

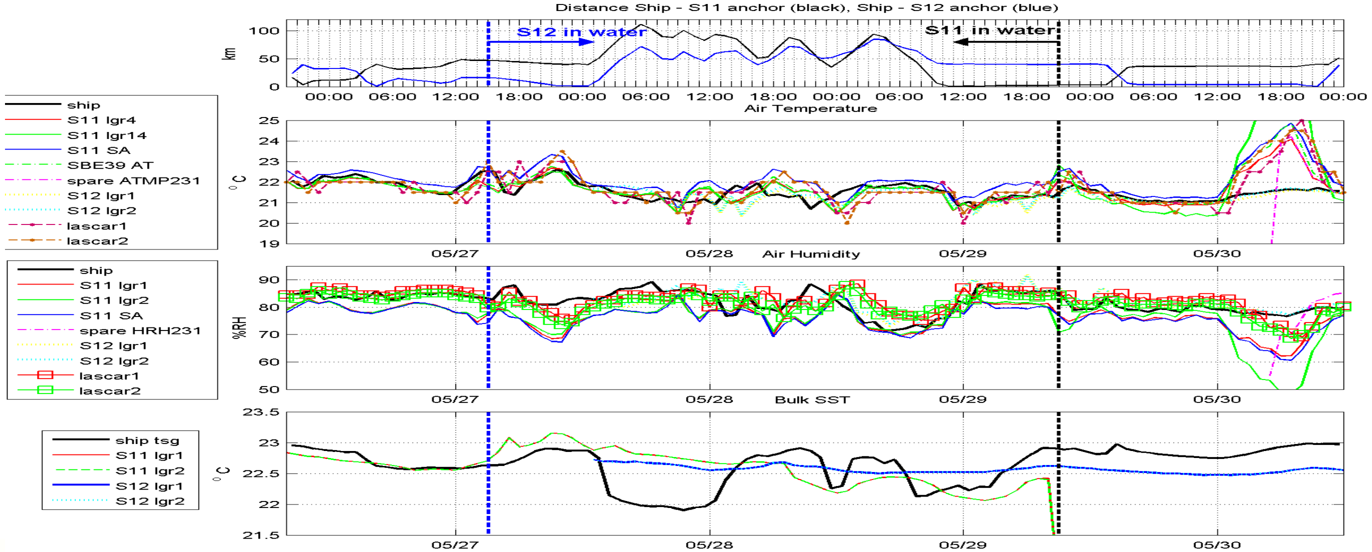
In-situ data with well-known accuracies are key to anchoring global air-sea flux fields.

The planned life of the OOI Global arrays was exciting as long time series are key to assessing and validating model, remote sensing, and hybrid products. These figures from Maria Valdivisio, Univ. of Reading, looking at validation and assessment using buoy data. These figures use WHOI ORS Stratus data, a 17 year time series.

High demand for and use of surface meteorology and air-sea flux data has been accompanied by demand for quantification of uncertainties in these data.

Concern: Dedicated in the field intercomparisons are critical to identify drift, bias in sensors after a year deployment.

Ideally, ship has bow tower with freshly calibrated, climate quality set of meteorological and flux sensors. Ideally, overlapping buoy data, and intercomparison should last 2-3 days.



Distance to buoy

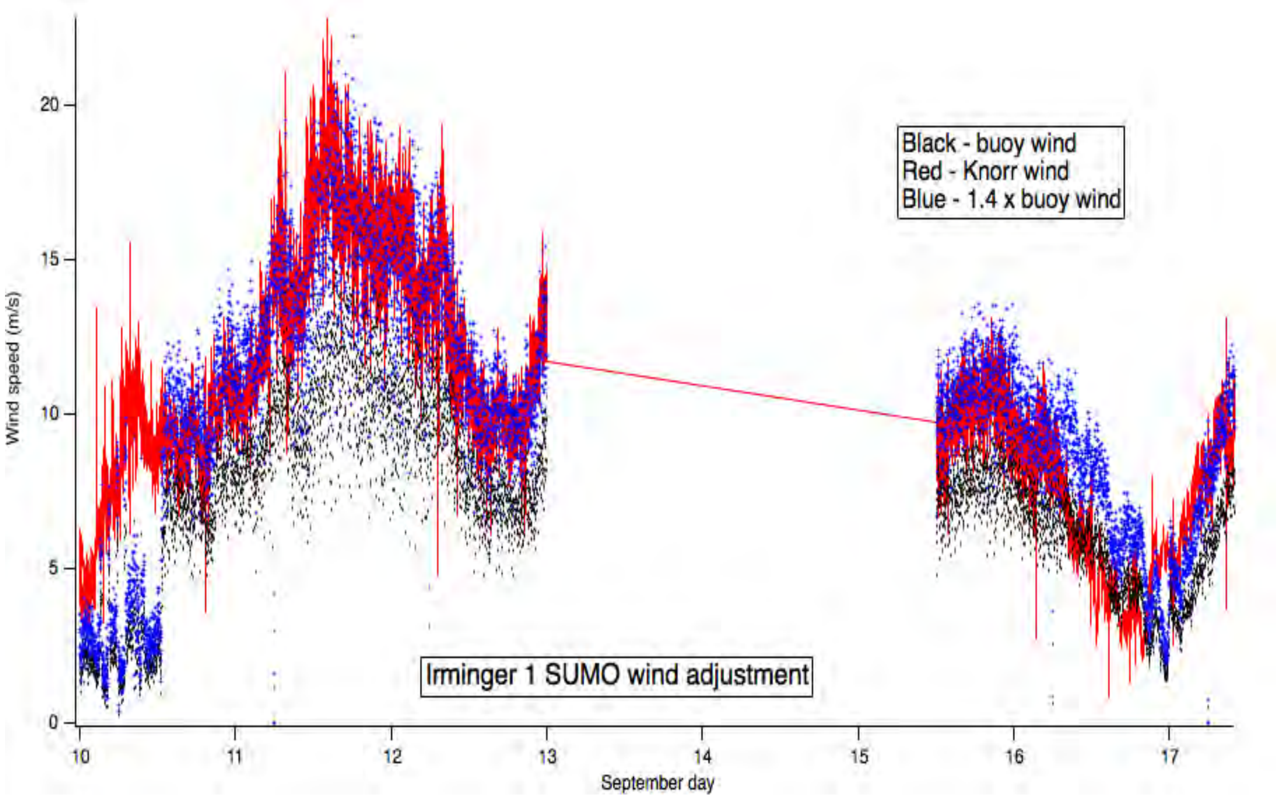
Air T

RH

SST

Example: S12 surface buoy deployed to overlap with S11 surface buoy, buoys intercompared to each other and to shipboard sensors.

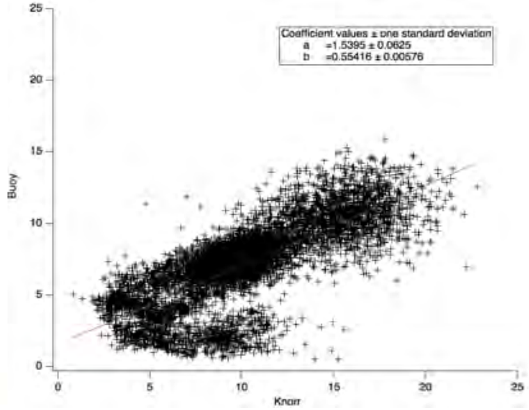
Concern: OOI surface buoys not fully qualified as observational platforms for surface meteorology and air-sea fluxes.



Buoy wind (black); Knorr wind (red); adjusted buoy (blue). One-minute data.

In the first Global surface buoy deployment, at Irminger Sea in Sept, 2014, OOI SUMO winds were observed to be too low. A comparison with ship winds indicated a ~40% under – measurement. This was due to flow blockage by buoy structures (antennae, mounts, tower).

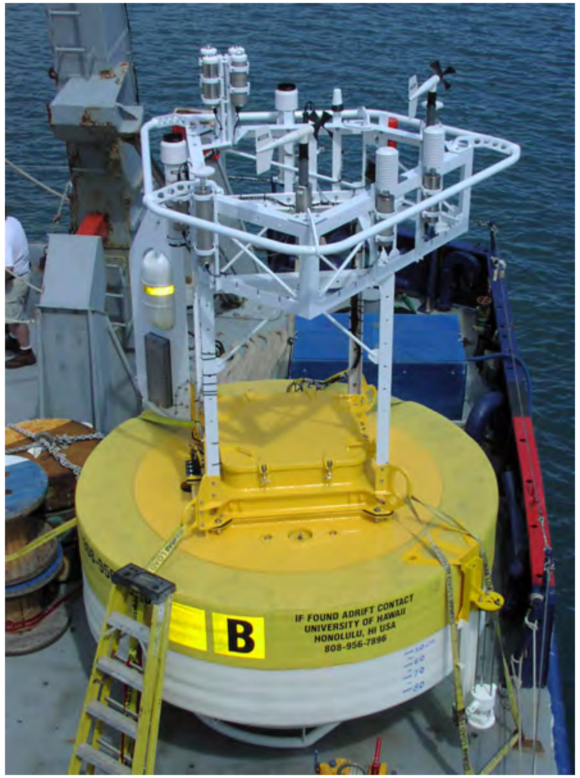
Linear fit – suggests 40% error

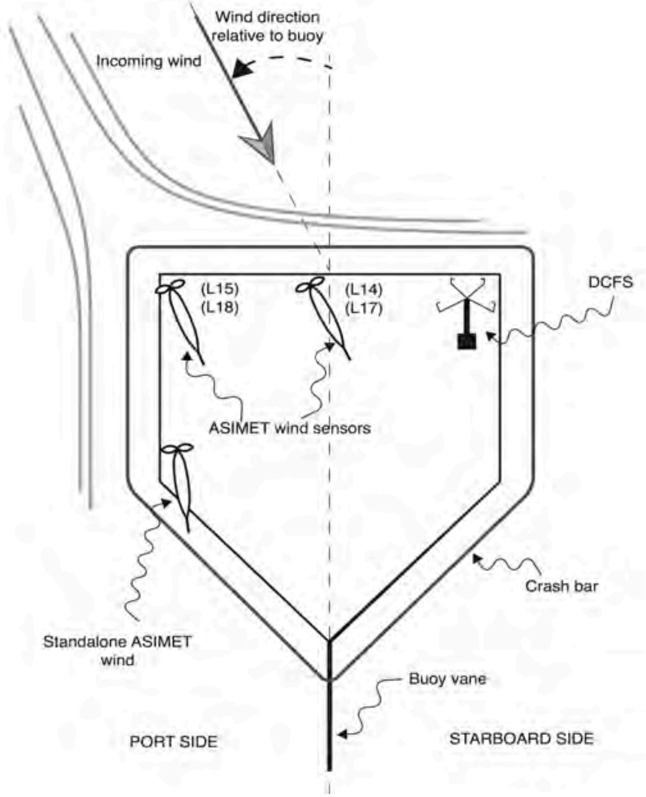


Concern: Investigator at NOC offered to do computational fluid dynamic (CFD) study of flow around OOI surface buoy – CGSN did not take this opportunity.

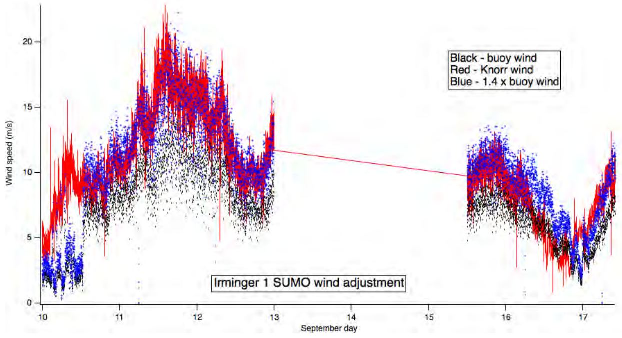
Surface buoy in use by WHOI Upper Ocean Processes Group.

Work to understand and characterize observational accuracies has included CFD study or air flow around buoy superstructure and sensors.





Concern: High demand for and use of surface meteorology and air-sea flux data has been accompanied by demand for quantification of uncertainties in these data.



Buoy wind (black); Knorr wind (red); adjusted buoy (blue). One-minute data.

Based on initial findings, the two anemometers were moved higher in their mounting brackets.

Studies show that upwind effects of cylindrical bodies extend out ~ 10 diameters, so sensor environment at halo level remains a concern.

Impacts of buoy hull, well structure, solar panels, wind generators should be investigated.

Concern: New understanding of sites such as Irminger with periods of freezing conditions point to the need to evolve to meteorological sensors designed for cold weather use.

HEATED FOR HIGH DATA AVAILABILITY, FEATURING NEW RVHTM TECHNOLOGY

High data availability is attained by heating of the outer dome using ventilation between the inner and outer dome. RVHTM - Recirculating Ventilation and Heating - technology, developed by Hukseflux, suppresses dew and frost deposition and is as effective as traditional ventilation systems, without the maintenance hassle and large footprint.

compliant with IEC 61724-1:2017 Class A

The dome of SR30 pyranometer is heated by ventilating the area between the inner and outer dome. RVHTM is much more efficient than traditional ventilation, where most of the heat is carried away with the ventilation air. Recirculating ventilation is as effective in suppressing dew and frost deposition at 2 W as traditional ventilation is at 10 W. RVHTM technology also leads to a reduction of zero offsets.

Example: Huskeflux SR30

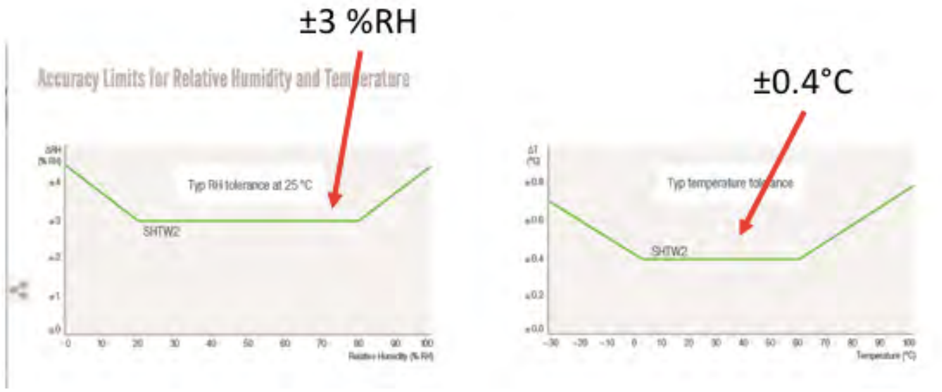
- Heat, ventilated
- Measures tilt
- 1.2% for radiometer
- 1° for tilt

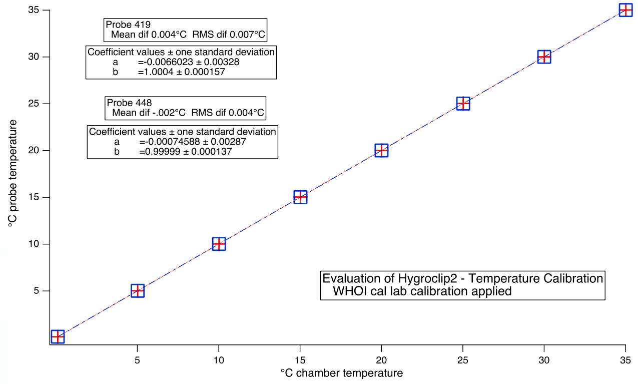
Deals with ice and frost

Reduces thermal offsets

Quantifies tilt related error

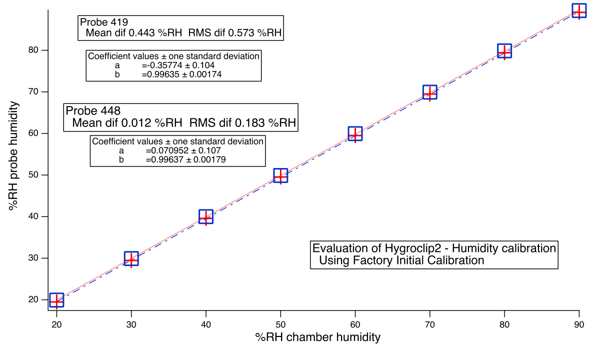
Concern: Ongoing evolution of the state of the art of surface buoy meteorological sensors should be reflected in technology refresh of the surface buoys. Since bulkmet instrument was specified, there have been improvements.





Mean DT = 0.003 °C, RMS DT = 0.005 °C

New Rotronic Hygroclip2 RH/AT sensor



Older, RH/AT sensor developed for HVAC use has modest accuracy, tuned for ~20°C

Humidity check , factory calibration

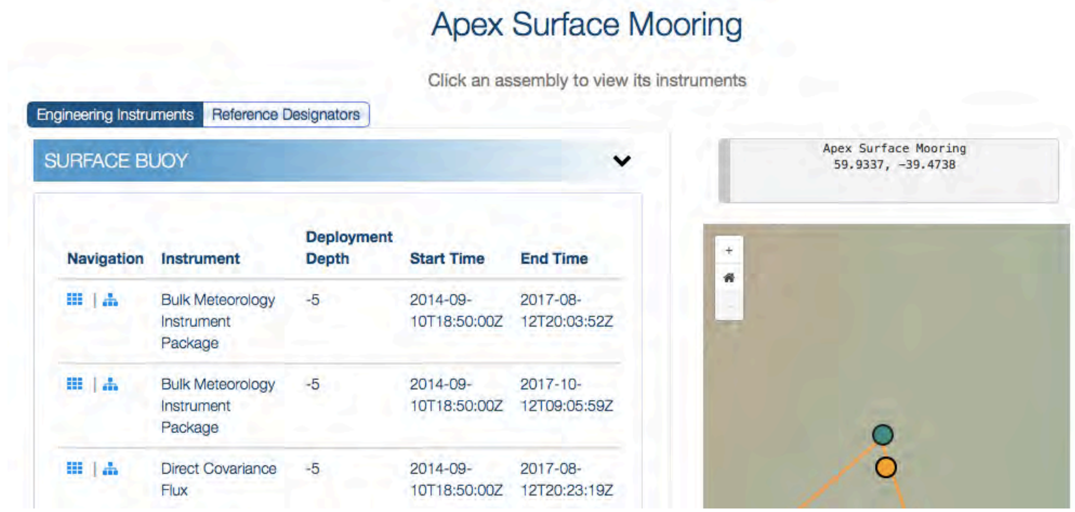
Mean DRH = 0.453 %RH. RMS DRH = 0.573 %RH

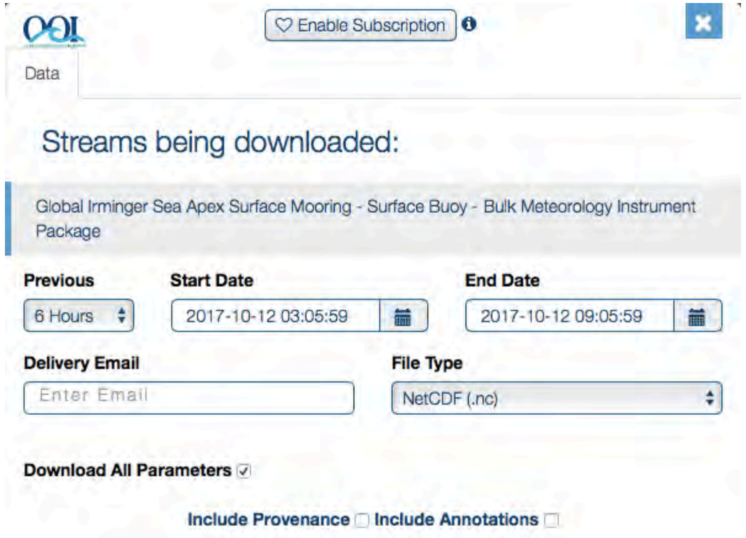
Mean DRH = 0.012 %RH. RMS DRH = 0.183 %RH

Concern: QA/QC of surface meteorology and air-sea fluxes should be linked to operator.

- Buoy assembly and burn-in at WHOI: sensor calibration, compare 2 systems, check RFI, magnetic influences
- Buoy assembly in port: check two systems
- Ship versus buoy: dedicated in the field intercomparisons; high quality shipboard system
- Overlap new/old buoys or short gap: intercompare old/new for biases, drift
- Use two and three redundant sensors to assess performance
- Compare to ECMWF model on the fly and in post-assessment
- Post-recovery calibration
- Assembly of continuous, long time series: examine deployment by deployment performance
- Flag sensors with issues, diagnose, recalibrate
- Apply new understanding retroactively
- Test and evaluate new sensors; check for aging and degradation of operational sensors

Concern: Users finding retrieving air-sea flux time series challenging. We should improve data serving.





Desired flux file:

- All variables together
- Wind stress mag, east and north stress
- Latent, sensible, incoming SWR and LWR, net SWR and LWR
- Settings for COARE algorithm
- Air temp, humidity at 2 m; wind velocity at 10 m
- Surface reference current

Global Arrays

Status

Strong data utilization

Research and publication underway

Irminger Sea workshop catalyzed efforts

Especially surface meteorology and air-sea fluxes

Concerns

- Quantify accuracies
  - CFD study of surface buoys
  - In-situ validation with dedicated ship intercomparisons
- Migrate to more suitable, improved sensors
- Better integration of operator in QA/QC
- Improve data access