ICOS Ocean Thematic Center a tool to secure long term funding for ocean carbon (GHG) observation systems
The Oceanflux Greenhouse Gases Evolution meeting

Brest 06.09.2016
INFRAMER

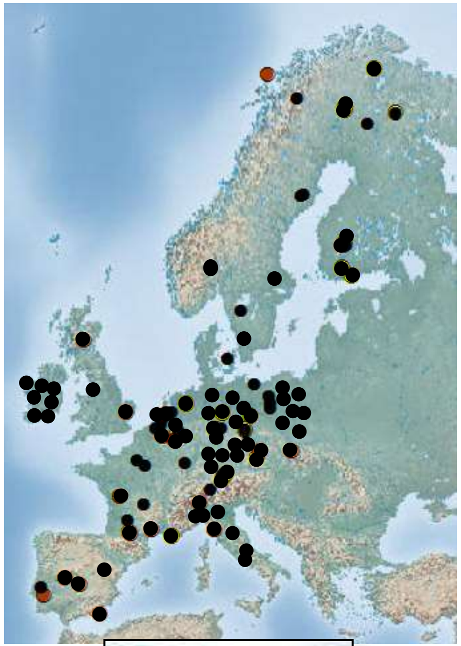
Truls Johannessen
Director of the OTC

PML

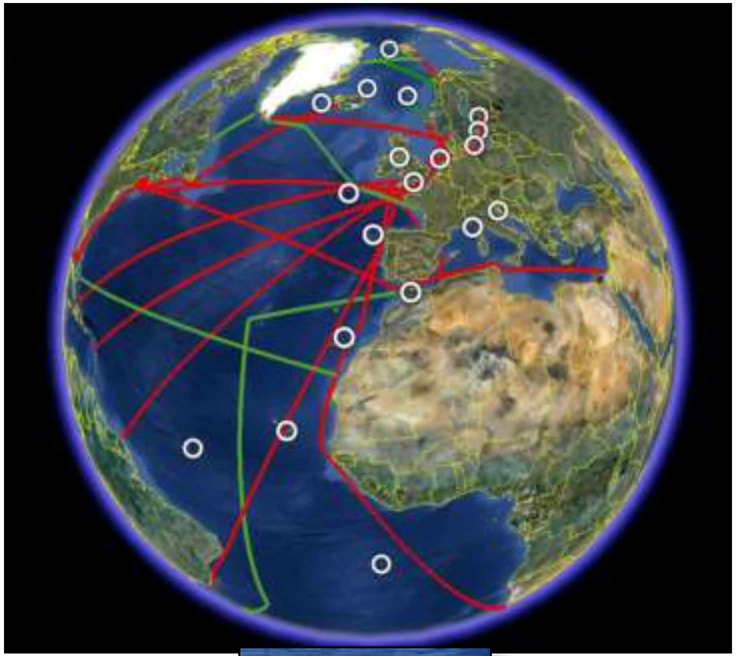
The potential ICOS station RI-network

Atmosphere

Ecosystems



Oceans



IMPORTANT RECENT EVENTS:

- ✓ **STATUS: ICOS ERIC accepted and signed by the EU and ICOS**
- ✓ **ICOS RI became an EU land mark**
- ✓ **ICOS Norway are now a full member of ICOS ERIC signed by the Ministry of Climate and Environment (August 2015)**
- ✓ **Kick off meeting of ICOS Norway and OTC, Bergen 11.04.2016**
- ✓ **July 2016 UK signed ICOS ERIC and are now ready to take formally a part of ICOS**

Home About Data Contact Documents

Welcome to the ICOS Ocean Thematic Centre (OTC)

The OTC is one of four central facilities within the European research infrastructure Integrated Carbon Observation System (ICOS RI). The marine elements of the ICOS RI provides the long-term oceanic observations required to understand the present state and predict future behaviour of the global carbon cycle and climate- relevant gas emissions. The oceanic sink currently offsets approximately 25% of CO_2 emissions from human activities. Oceanic net air-sea CO_2 fluxes of the Atlantic are a large proportion of the net global marine flux, together with CH_4 and N_2O fluxes.

OTC coordinate and support the European network of Monitoring Stations Assembly (MSA) in the North Atlantic, Nordic Seas, Baltic and the Mediterranean (Fig. 1). OTC cooperates with the International Ocean Carbon Coordination Project (IOCCP) to cover the global ocean observing systems, such as Voluntary Observing Ships (VOS), Fixed Ocean Stations (FOS), Repeat Ocean Sections (ROS), Marine Flux Towers (MFT) and new technologies.

OTC builds on expertise and results gained during previous and current EU-funded science projects (CAVASSOO, CARBOOCEAN, CARBOCHANGE, Euro-Sites, FixO3 and ATLANTOS). In addition, as the observation of marine carbon cycle is of global concern, OTC works with the global observing community to develop global monitoring (e.g. Pfeil et al., 2013; Bakker et al., 2014).

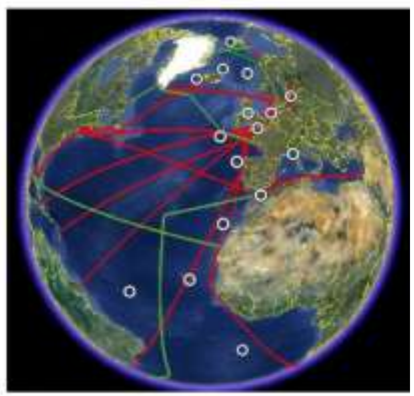
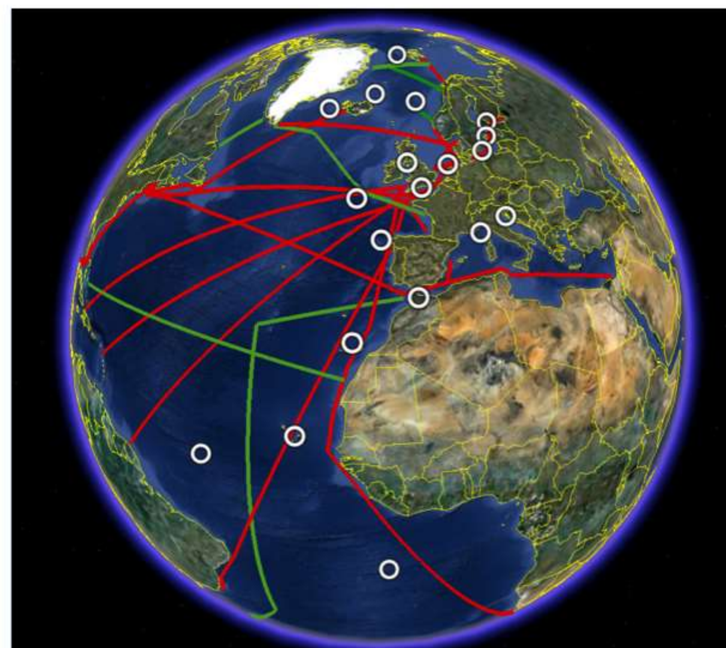


Fig. 1: The suggested network of stations for the ocean-netw Circles - Fixed Ocean Stations (FOS), Red lines – Volunta Observing Ships (VOS), and green lines – Repeat Ocean Se (ROS).

Marine observation routes and stations



The suggested network of stations for the ocean-network: Cicles - Fixed Ocean Stations, Red lines – Ships of Opertunites and Green lines – Repeat Section. In addition, new technologies like floats and gliders will be implement when relaiable and robust autonomious sensors for the purpose is developed.

http://icos-infrastructure.eu/

https://otc.icos-cp.eu/

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New acronyms: INTAROS, RINGO, SEACRIFOG

Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations

Readiness of ICOS for Necessities of Integrated Observations

Integrated Arctic observation system

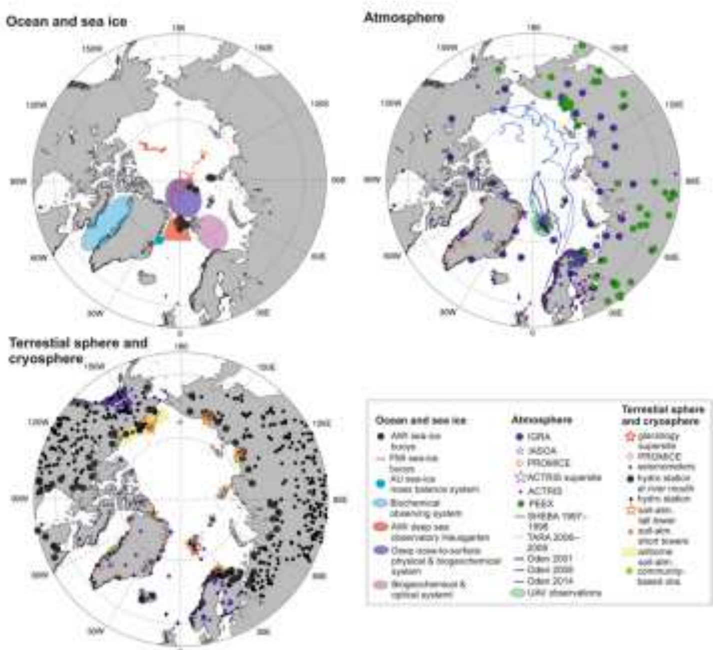
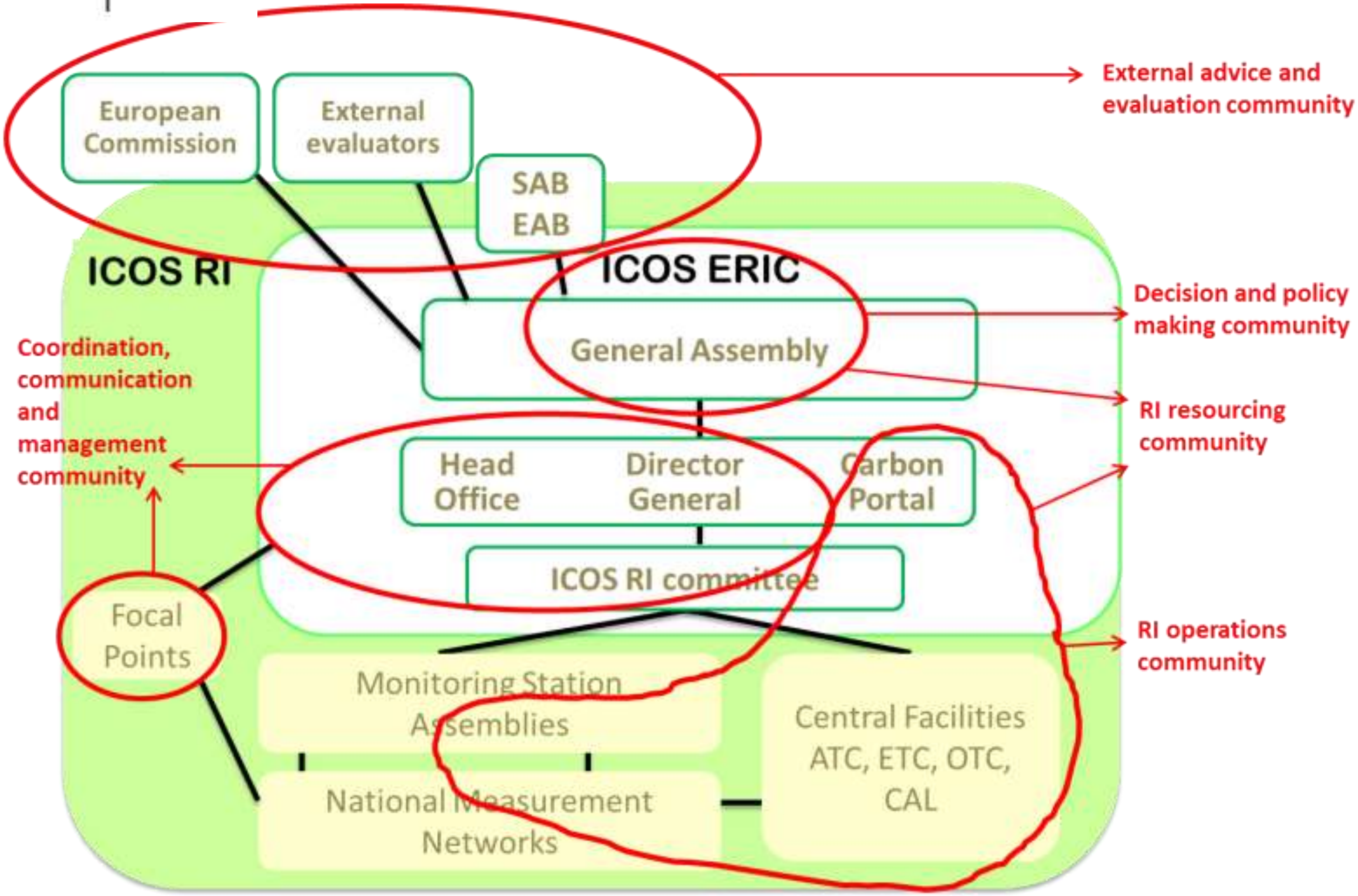


Figure 1. Example of existing observing systems in the Arctic (courtesy FMI).

ICOS ledelse og organisering

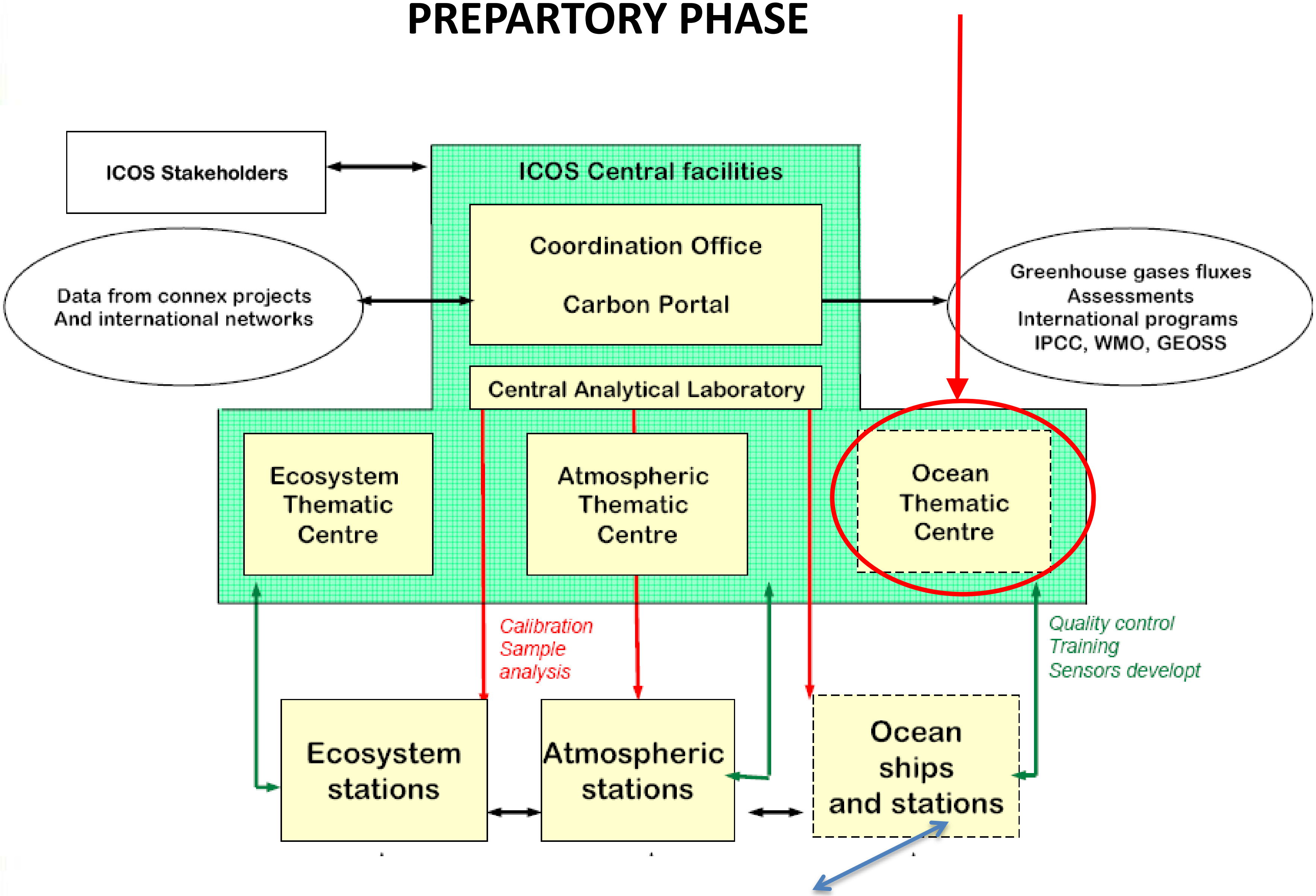


ICOS Norge og OTC vil være en aktiv del av denne strukturen og vil bruke sin innflytelse der det er mulig:

- ✓ ICOS MSA
- ✓ FOCAL POINT (ikke bestemt enda om nasjonale ”FOCAL POINTS” skal ha plass i generalforsamlingen
- ✓ Ledelse av OTC som også gir Norge en ekstra plass i generalforsamlingen

Norske ”stakeholders”, Forskningsrådet og Miljødirektoratet har plass i GA og kan direkte overvåke og påvirke beslutninger tilknyttet ICOS-Ri spesielt i saker som omhandler nasjonale ICOS-Norge og OTC

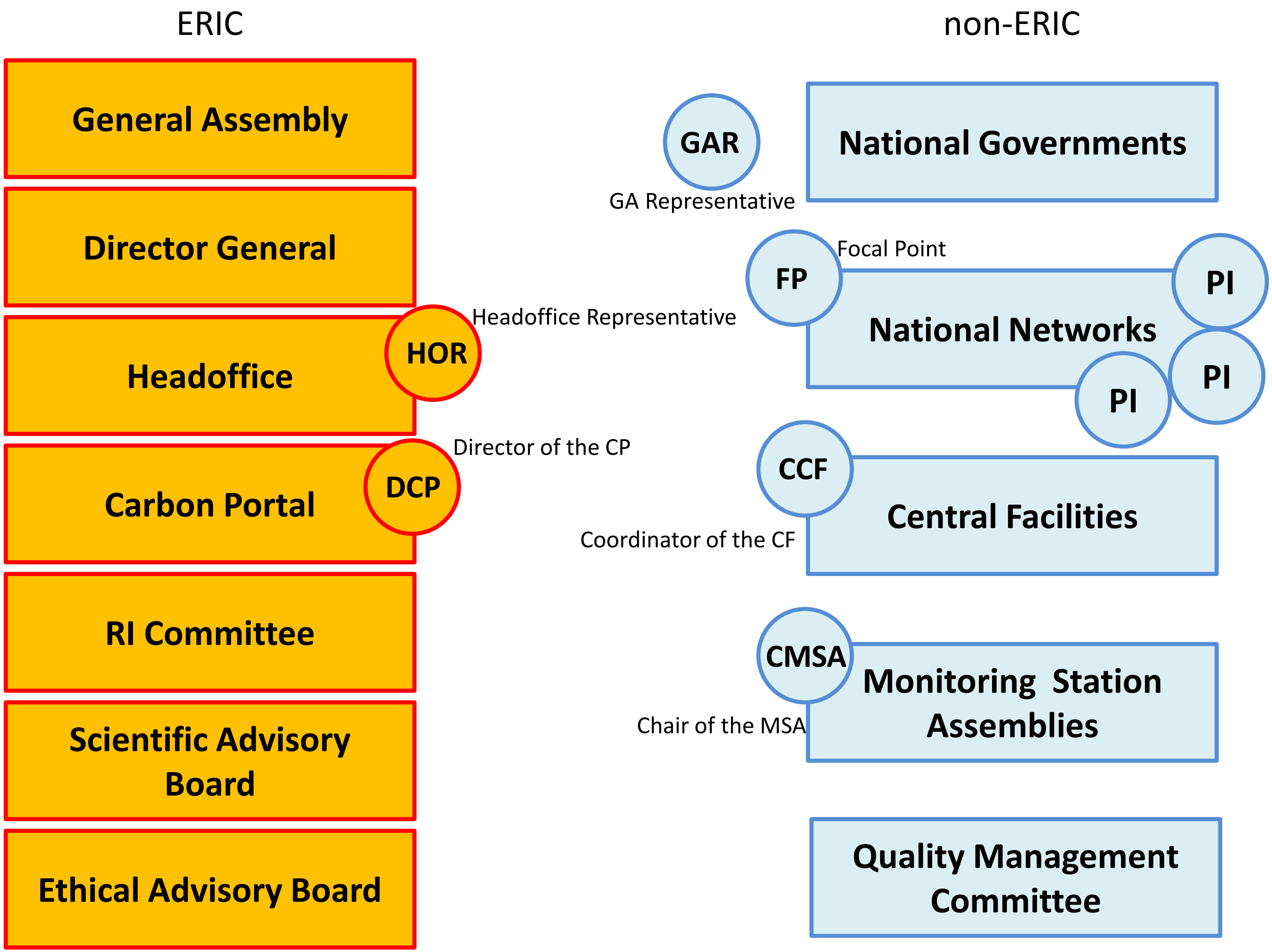
ICOS STRUCTURE DURING THE PREPARTORY PHASE



ICOS OCEAN MSA

Bodies and function owners in ICOS RI

ICOS ledelse og organisering



Prosjektets målsetninger

Mission ICOS RI:

- ✓ To enable research to understand the greenhouse gas (GHG) budgets and perturbations
- ✓ Provides the long-term observations required to understand the present state and predict future behaviour of the global carbon cycle and GHG emissions
- ✓ Technological developments and implementations, related to GHGs, will be promoted by the linking of research, education and innovation

The first objectives

- ✓ To provide effective access to a single and coherent data set to facilitate research into multi-scale analysis of GHG emissions and sinks, and the processes that determine their strength
- ✓ Aims to establish a template for the future development of similar integrated and operative GHG observation networks also outside Europe

The second objectives

- ✓ To provide vital information for current evaluation and future forecast of regional budgets of greenhouse gas sources and sinks, their human and natural drivers, and the controlling mechanisms
- ✓ Detect changes in regional greenhouse gas fluxes, early warning of negative developments and the response of natural fluxes to extreme climate events
- ✓ To reduce uncertainties in Earth System models and their predictions

Fate of anthropogenic CO_2 emissions (2005-2014 average)

33.0 ± 1.8 $GtCO_2/yr$ 91%

Sources

3.4 ± 1.8 $GtCO_2/yr$ 9%

16.0 ± 0.4 $GtCO_2/yr$
44%

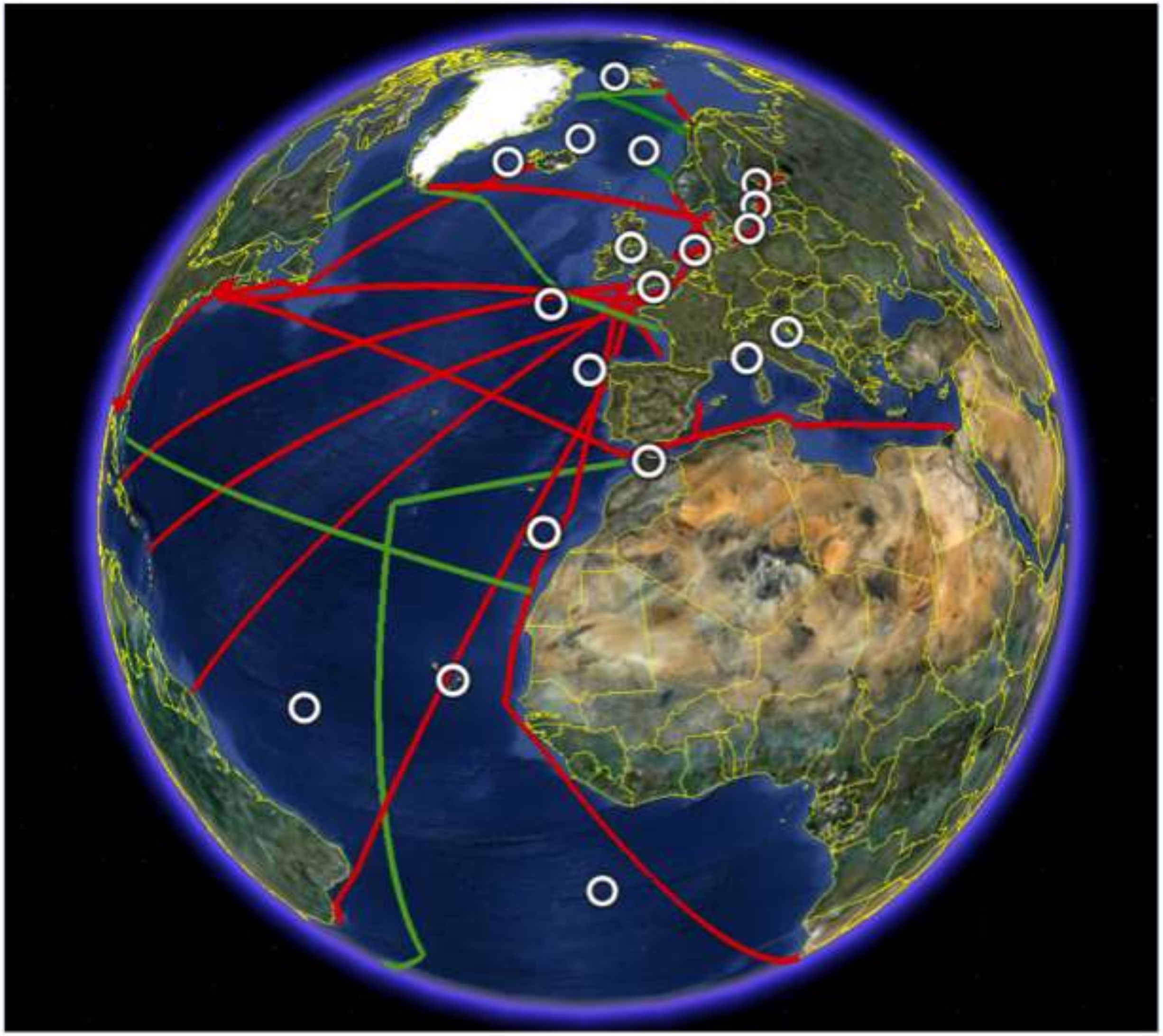
Partitioning

10.9 ± 2.9 $GtCO_2/yr$
30%
Calculated as the residual of all other flux components

26%
9.5 ± 1.8 $GtCO_2/yr$

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Marine observation routes and stations



The suggested network of stations for the ocean-network: Cicles - Fixed Ocean Stations, Red lines – Ships of Opertunites and Green lines – Repeat Section. In addition, new technologies like floats and gliders will be implement when relaiable and robust autonomious sensors for the purpose is developed.

Contributions to the Ocean Thematic Centre

	SOC	Exeter	PML	Bergen	Kiel
Leadership		X		**X**	
VOS	X	**X**	X	X	
Fixed stations	X	X	X	**X**	
Repeat sections	X	X	X	**X**	
Coastal	X	X	**X**	X	
Liaison with Shipping Industry	**X**			X	
Technological development (sensors)	**X**	X	X	X	**x**
New platforms (floats, gliders etc.)	**X**	X	X	X	
Data Centre				**X**	
Flux calculations		**X**	X	X	

Activity leaders suggested in the OTC proposal:

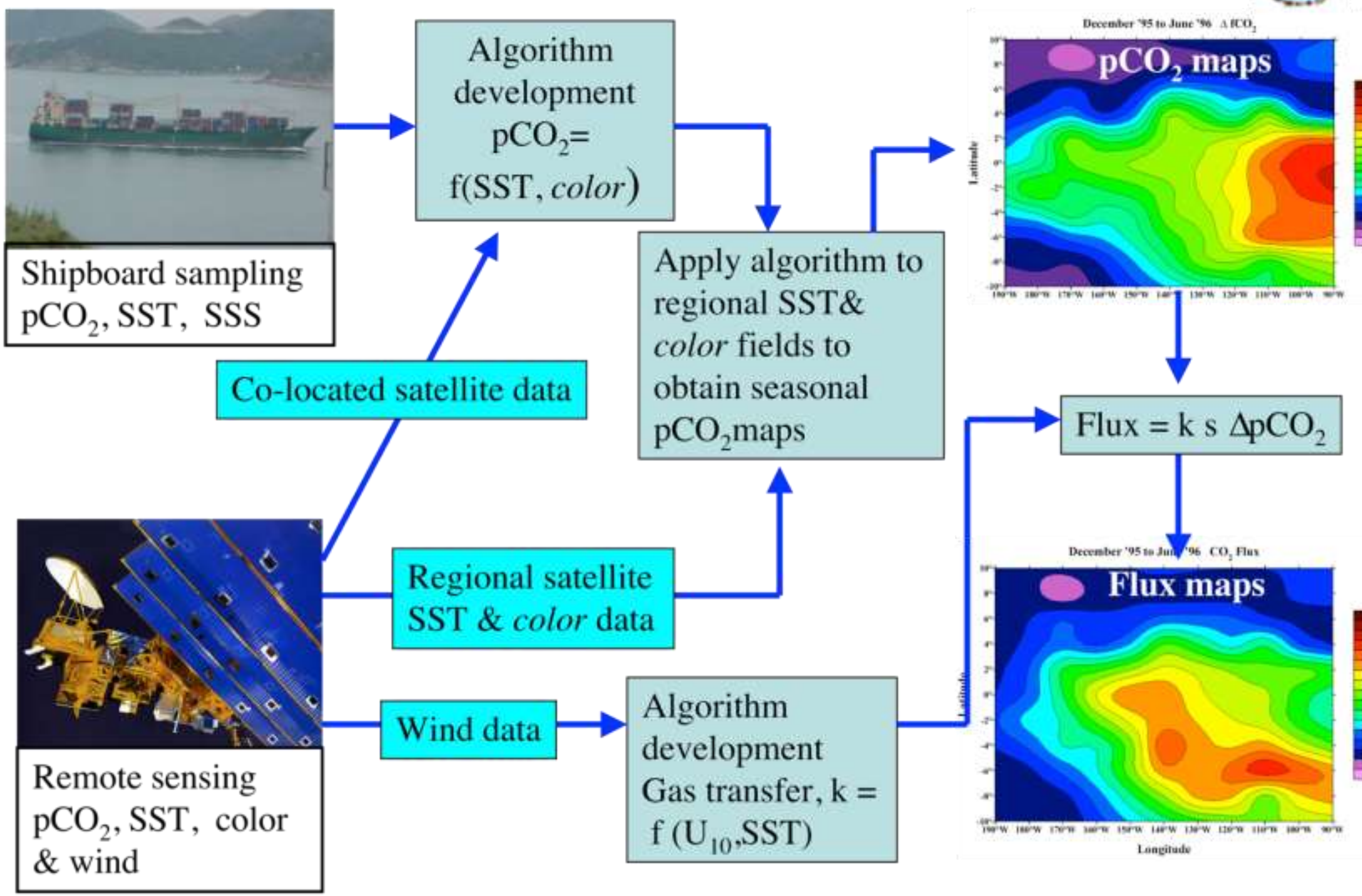
OTC Director and Vice Director:	*Johannessen/Watson*
VOS:	*Ute Schuster*
Fixed Stations:	*Ingunn Skjelvan*
Repeat Sections:	*Emil Jeansson*
Coastal:	*Vassillis Kitidis*
Liaison with Shipping Industry:	*Richard Sanders*
Technology development (Sensors):	*N.N. Southampton*
New platforms: (floats, Gliders etc.):	*N.N. Southampton*
Data Centre:	*Benjamin Pfeil*
Flux Calculations:	*Andrew Watson, Phil Nightingale, Truls Johannessen*

The team selected will most likely continue for the whole 5 years period

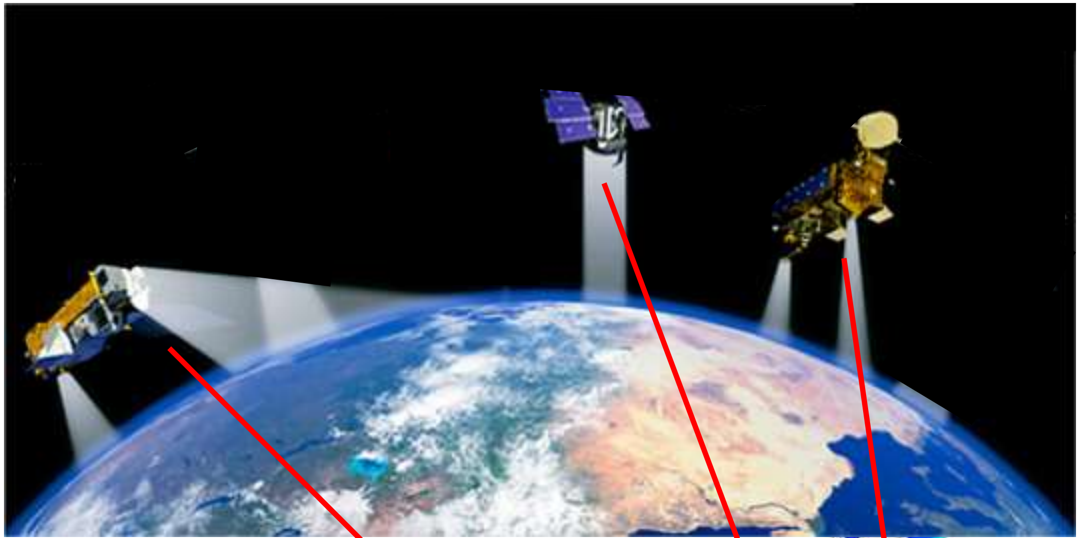
Proposed Ships of opportunity

Denmark to Greenland line - Norway
Germany to Canada line – Germany
Germany to Antarctica, Polarstern, Germany
UK to Caribbean line - UK
France to French Guiana line - France
France to Brazil line – Spain
Iceland to USA line - France
UK to Spain line – Spain
Nordic Sea –Lines - Norway
Norway to Netherlands line Norway
North Sea to Spain line Netherland
North Sea line UK
Baltic Sea line from Germany to Finland – Germany
Iberian Peninsula line Spain
France-UK line (Western English channel) UK
France to Spain line (Bay of Biscay) France
Belgium announced 2 lines
AT THE MOMENT 18 LINES

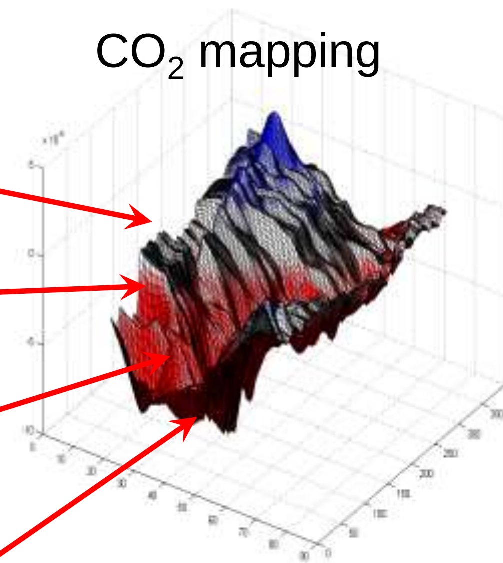
Producing Seasonal CO_2 Flux Maps



Satellite SST, chl, winds can be used to interpolate the network observations accurately, to create mappings

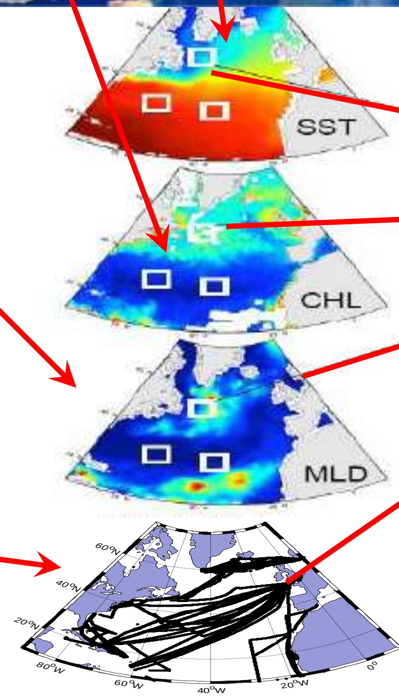


CO_2 mapping



CO_2 measurement network

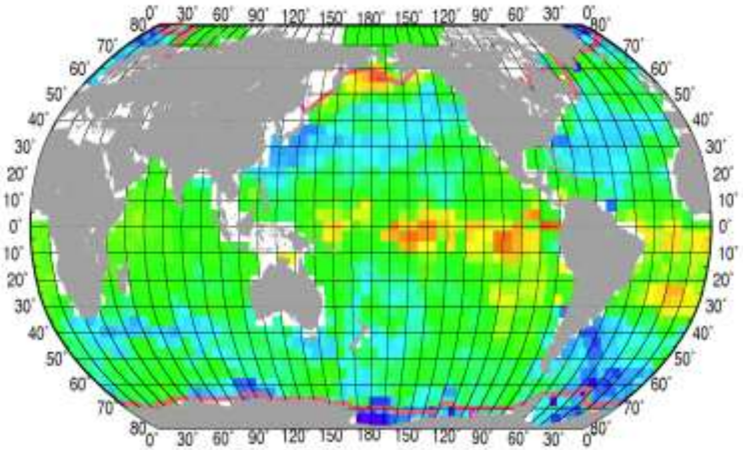
Floats??



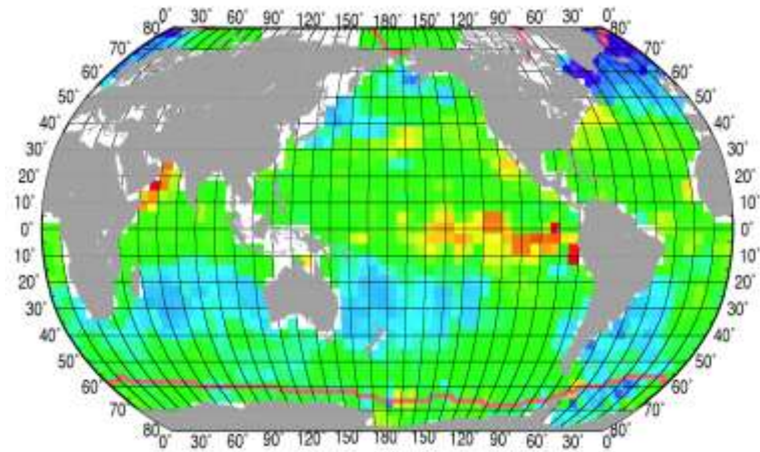
Spot CO_2 values

Global CO_2 fluxes: From global climatology to seasonal fluxes

Climatological pCO_2 in Surface Water [940K] for February 1995

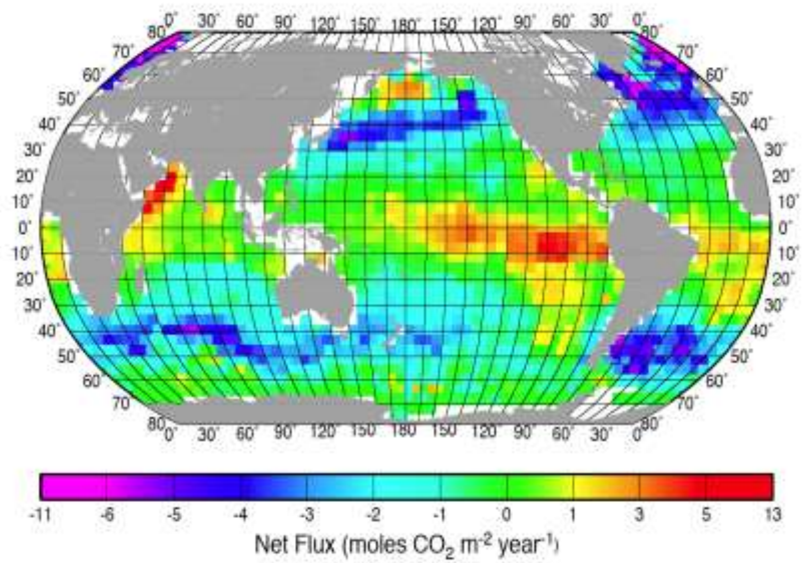


Climatological pCO_2 in Surface Water [940K] for August 1995



Global average $\Delta pCO_2 \approx$ -7 µatm

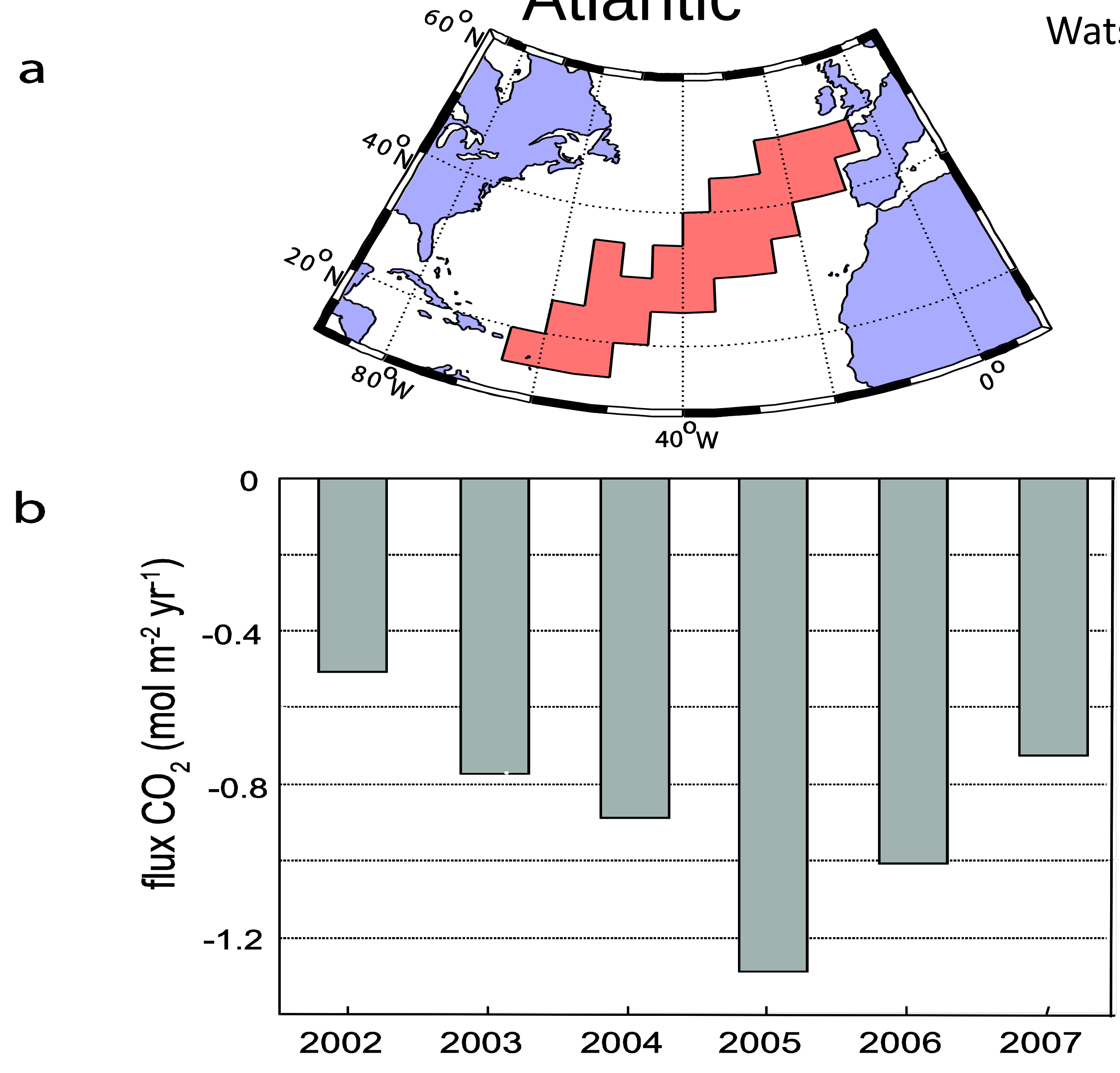
Flux:
On first-order controlled by ΔpCO_2 but strongly influenced by wind



Uptake $\approx$-1.6 Pg C yr^{-1}

Time series of annual mean fluxes in central N. Atlantic

Watson et al. 2009



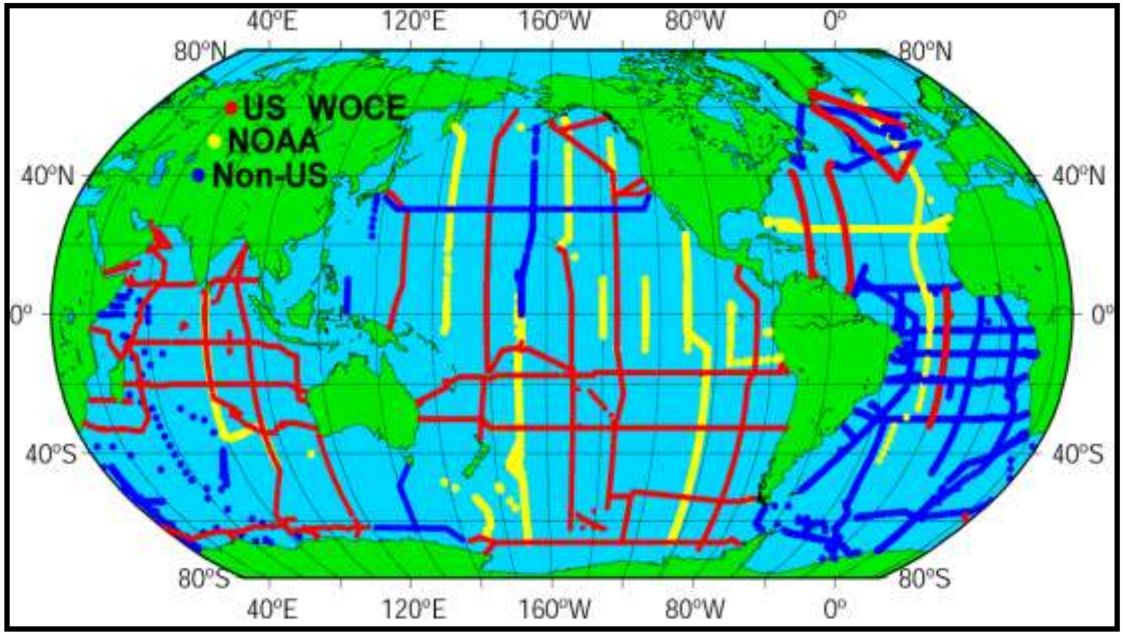
Repeat hydrographic sections from the north to the south

75ºN – Norway
Gimsøy-Greenland - Norway
Svinøy Section - Norway
PRIME - UK
OVIDE - Spain
24ºN - UK
A17- Spain
Weddell- Germany
More lines might be added at the OTC .

8 Full depth Hydrographic Sections

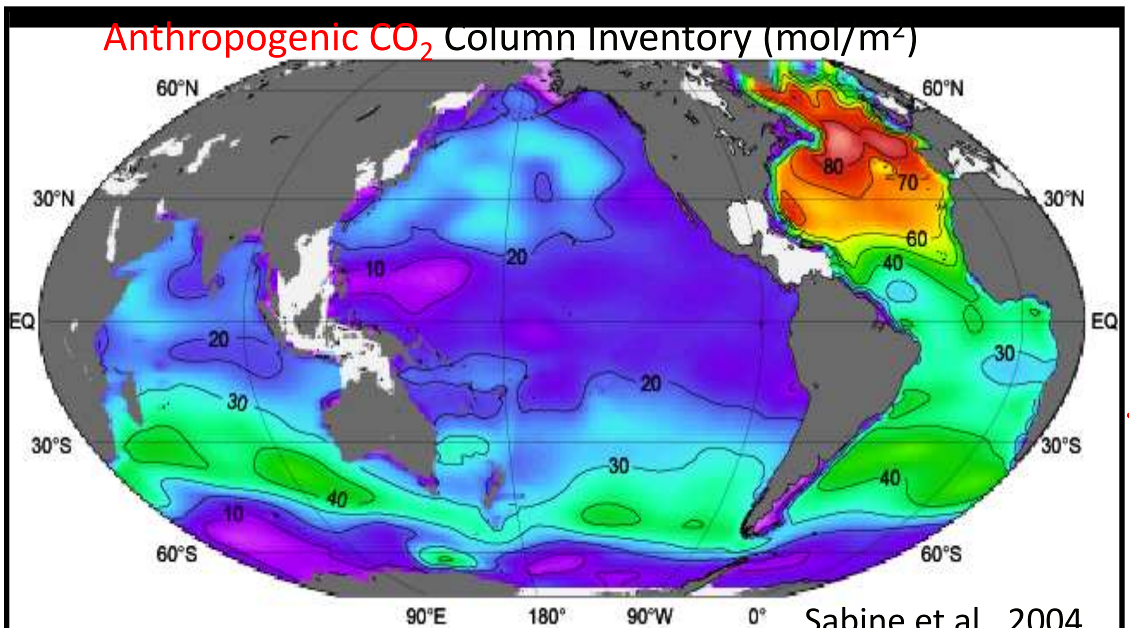
WOCE/JGOFS/OACES Global CO_2 Survey (1995)

http://cdiac.esd.ornl.gov/oceans/glodap/Glodap_home.htm



~72,000 sample locations collected in the 1990s

DIC ± 2 μmol kg^{-1}
TA ± 4 μmol kg^{-1}



Mapped Inventory = 106±17 Pg C

\+ marginal seas = 6± 6 Pg C

\+ Arctic Ocean = 6± 6 Pg C

Total Inventory = 118±19 Pg C

ICOS
INTEGRATED CARBON OBSERVATION SYSTEM
NORWAY'

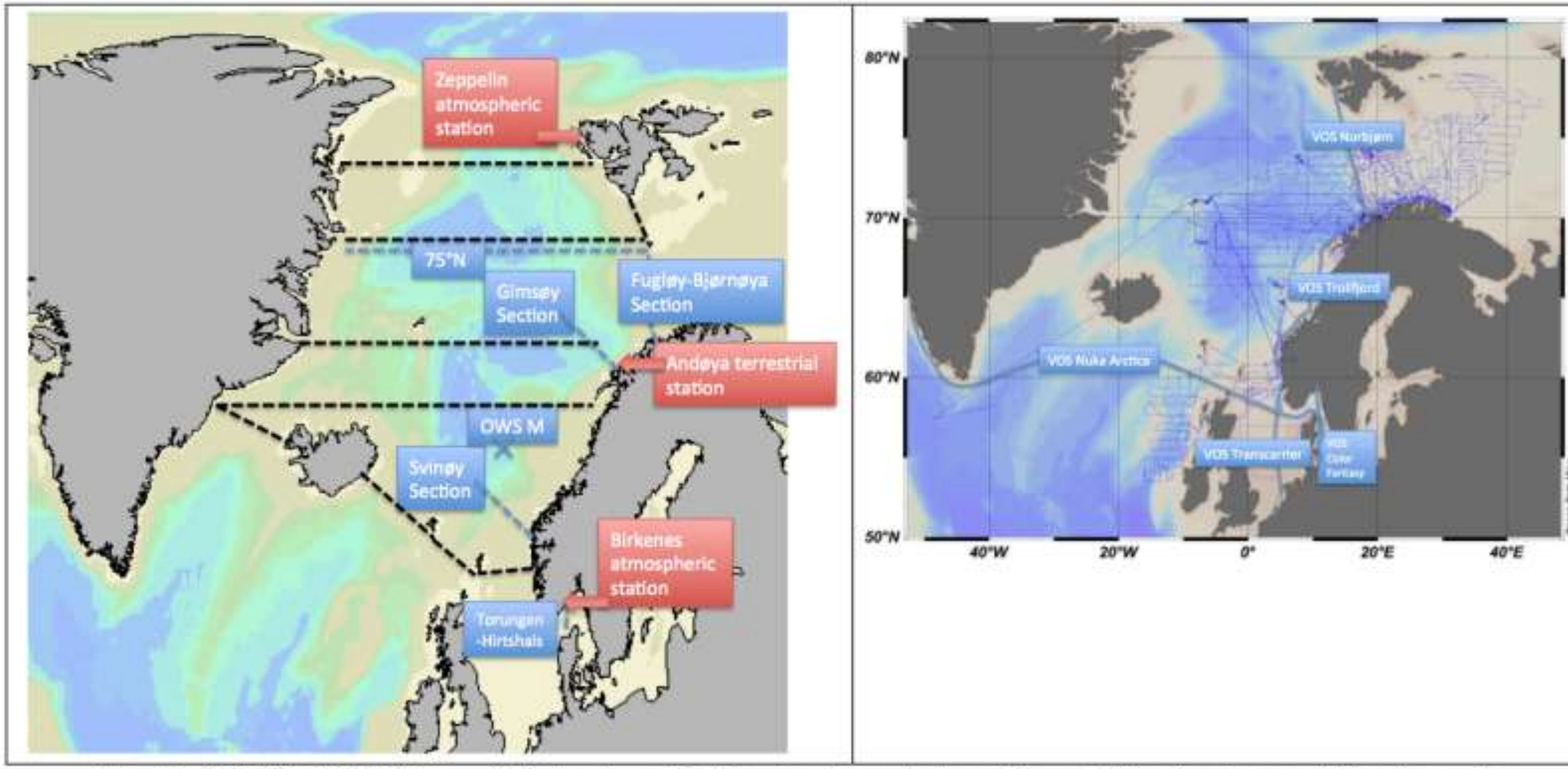


Fig. 4.2: (left) The ICOS-Norway infrastructure. Red denotes atmospheric and terrestrial subsystems and blue the marine subsystems. Dashed blue lines are repeat hydrography lines (IMR: Fugløya-Bjørnøya, Gimsøy, Svinøy, Torungen-Hirtshals; BCCR: 75°N, OWS M), and dashed black lines represent carbon inventory cruises (see Table 4.1). (right) Area coverage of VOS lines in the marine network. Blue thin lines represent, as an example, data collected by G.O. Sars between 2005 and 2007 (BCCR). The suggested VOS Johan Hjort will give similar coverage (increasing the time resolution). VOS Nuca Arctica and VOS Transcarrier are existing BCCR VOS lines, and VOS Norbjørn, VOS Color Fantasy, and VOS Trollfjord are existing NIVA VOS lines.

Variables to be measured

Solstrand meeting outside Bergen, 2010

Type	Parameters	Frequency	Accuarcy and precision
Core	Atmospheric pCO_2	Continuous (30 min)	Essential to within 1 µatm Desirable to within 0.1 µatm
Core	Sea surface pCO_2	Continuous (30 min)	To within 1 µatm
Core	Barometric pressure	Continuous (30 min)	To within 0.5 mbar
Core	Sea surface temperature	Continuous (30 min)	To within 0.05 ^oC
Core	Sea surface salinity	Continuous (30 min)	To within 0.1 units
Core	Nutrients (NO_3 + NO_2, PO_4, SiO_4)	Periodical, water sampling	To within 1 µM
Core	Dissolved inorganic carbon	Periodical, water sampling	Desirable to within 1 µmol kg^{-1}
Core	Total alkalinity	Periodical, water sampling	Desirable to within 1 µmol kg^{-1}
Additional	Atmospheric flask samples for CO_2, CH_4, N_2O, SF_6, CO, H_2, O_2/N_2, ^{13}C, ^{18}O, ^{14}C in CO_2	As determined by central analytical facility	As determined by the central analytical facility
Additional	Chlorophyll-fluorescence		
Desirable	pH	Continuous (30 min)	To within 0.001 units
Desirable	Total dissolved gas pressure	Continuous (30 min)	
Desirable	Meteorological parameters	Continuous (30 min)	

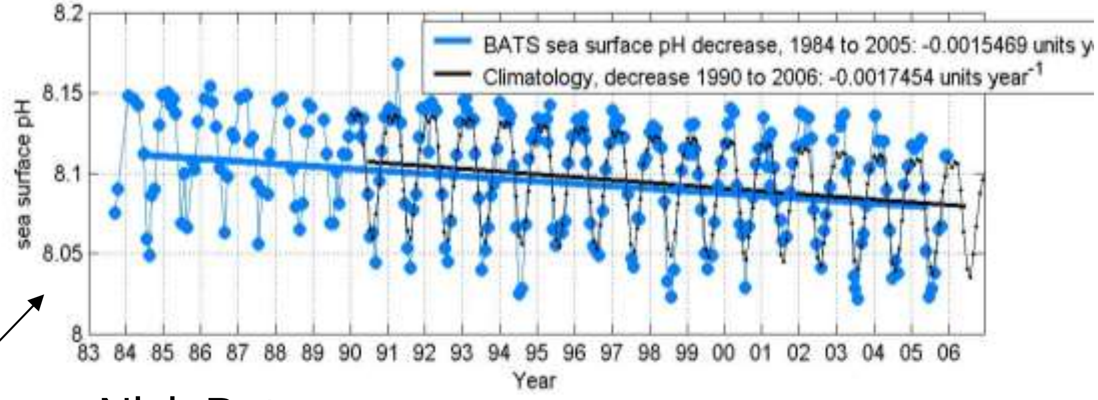
Proposed Fixed Time Series Stations

21 stations suggested

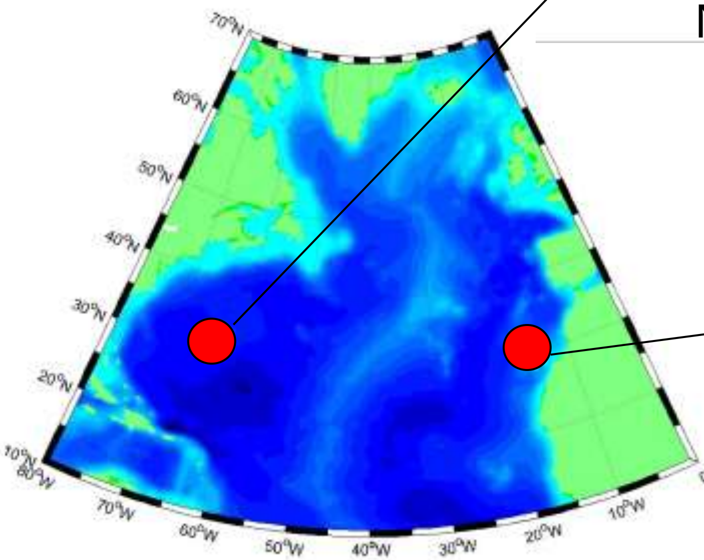
Hausgarten, Fram Strait - Germany
Ocean Weather Station M, 66^{o}N / 2^{o}E - Norway
Irminger Sea, 64.33^{o}N / 28.00^{o}W - Iceland
Iceland Sea, 68.00^{o}N / 12.67^{o}W - Iceland
Östergarnsholm, Baltic Sea – Sweden
Utö, Baltic Sea – Finland
Marsdiep, North Sea – Nederlands
Liverpool Bay, Irish Sea - UK
L4, western English Channel - UK
E1, western English Channel- UK
Station Pap, 49^{o}N / 16^{o}W - UK
MINAS, off Spain, 43^{o}N / 11^{o}W - Spain
MOOSE, Mediterraenean, 43^{o}N / 7.9^{o}E – France
PALOMA – Italy
ODAS – Italy
ENEA – Italy
GIFT, Gibraltar, 35^{o}N / 5^{o}W - Spain
ESTOC, Canary Island, $29^{o}10'$ N / $15^{o}30'$ W - Spain
Cap Verde Islands - Germay
PIRATA 6^{o}S / 10^{o}W tropical Atlantic - France
PIRATA 8^{o}N / 38^{o}W tropical Atlantic – France

Time series of pH – Ocean Acidification

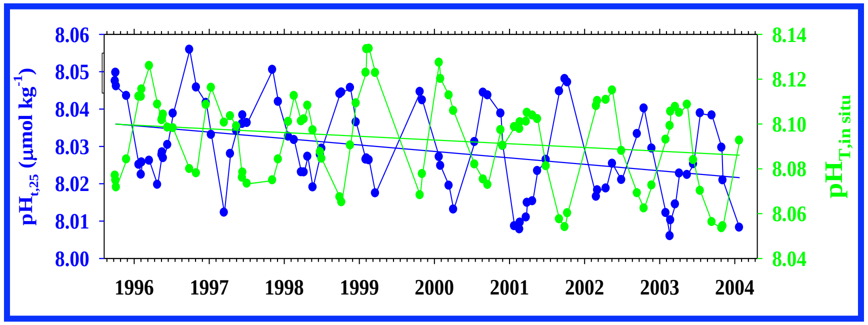
Bermuda time-series



Nick Bates



Canary Islands time-series



Melchor González-Dávila and J. Magdalena Santana-Casiano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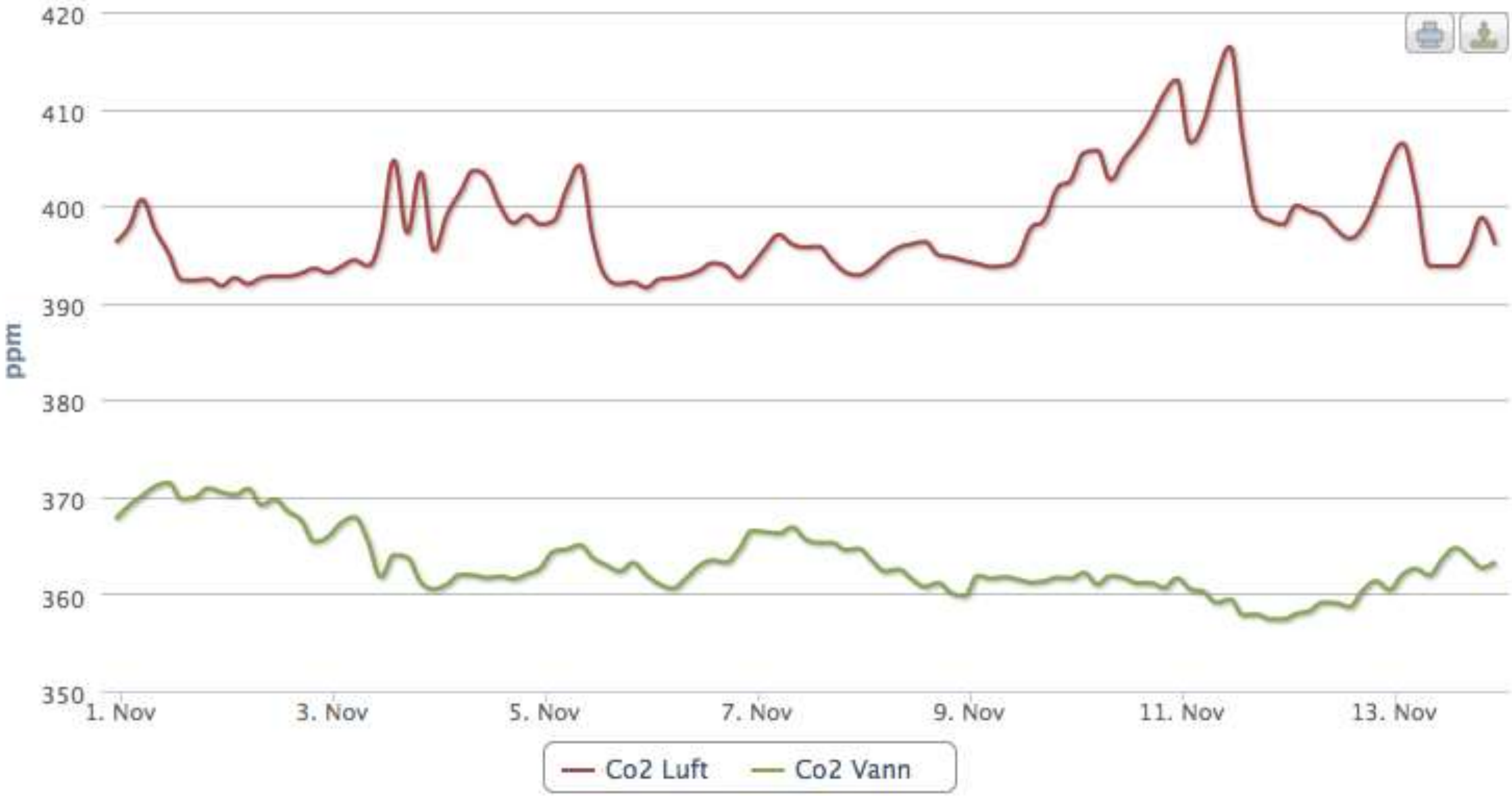
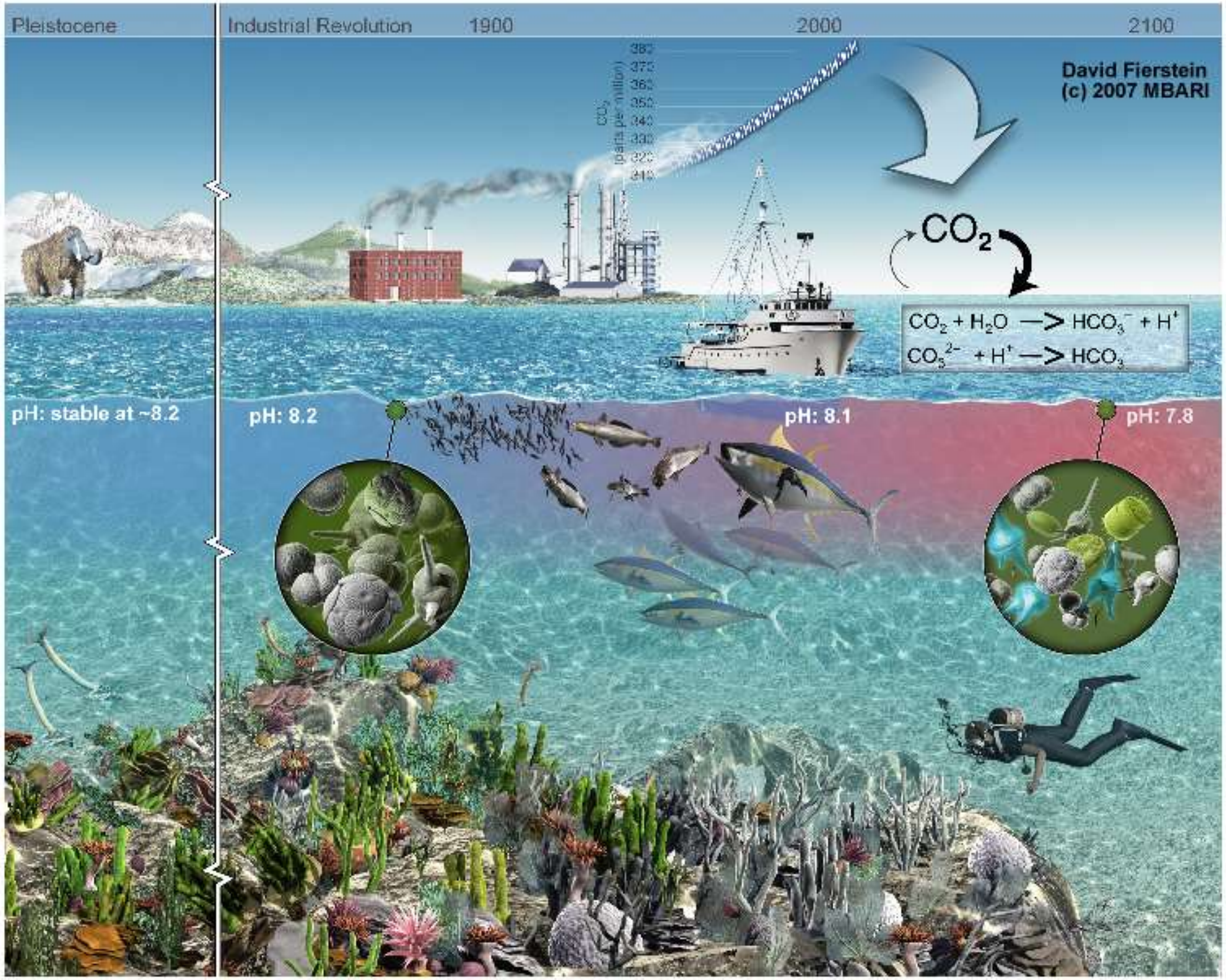
DATA from New Station MIKE (Polar Buoy)



Future perspectives

Artist's rendition of anthropogenic CO_2 and the resulting ocean acidification



DATA PRODUCTS – that in the future might have the ICOS label on the European level:

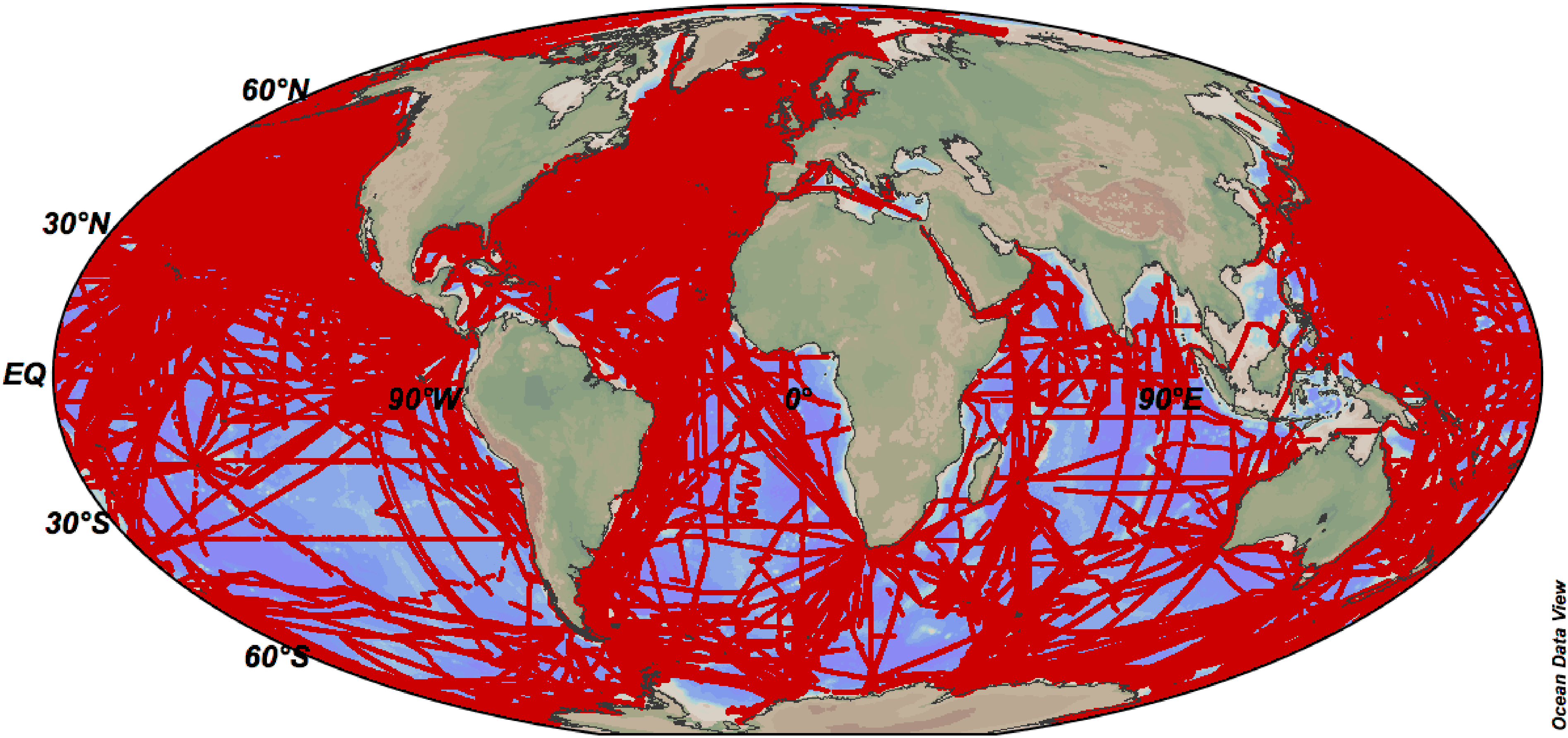
Pfeil, B., Olsen, A., Bakker, D. C. E., Hankin, S., Koyuk, H., Kozyr, A., Malczyk, J., Manke, A., Metzl, N., Sabine, C. L., Akl, J., Alin, S. R., Bates, N., Bellerby, R. G. J., Borges, A., Boutin, J., Brown, P. J., Cai, W.-J., Chavez, F. P., Chen, A., Cosca, C., Fassbender, A. J., Feely, R. A., González-Dávila, M., Goyet, C., Hales, B., Hardman-Mountford, N., Heinze, C., Hood, M., Hoppema, M., Hunt, C. W., Hydes, D., Ishii, M., Johannessen, T., Jones, S. D., Key, R. M., Körtzinger, A., Landschützer, P., Lauvset, S. K., Lefèvre, N., Lenton, A., Lourantou, A., Merlivat, L., Midorikawa, T., Mintrop, L., Miyazaki, C., Murata, A., Nakadate, A., Nakano, Y., Nakaoka, S., Nojiri, Y., Omar, A. M., Padin, X. A., Park, G.-H., Paterson, K., Perez, F. F., Pierrot, D., Poisson, A., Ríos, A. F., Santana-Casiano, J. M., Salisbury, J., Sarma, V. V. S. S., Schlitzer, R., Schneider, B., Schuster, U., Sieger, R., Skjelvan, I., Steinhoff, T., Suzuki, T., Takahashi, T., Tedesco, K., Telszewski, M., Thomas, H., Tilbrook, B., Tjiputra, J., Vandemark, D., Veness, T., Wanninkhof, R., Watson, A. J., Weiss, R., Wong, C. S., and Yoshikawa-Inoue, H.: A uniform, quality controlled Surface Ocean CO2 Atlas (SOCAT), Earth Syst. Sci. Data, 5, 125-143, doi:10.5194/essd-5-125-2013, 2013. http://www.earth-syst-sci-data.net/5/125/2013/essd-5-125-2013.pdf

Sabine, C. L., Hankin, S., Koyuk, H., Bakker, D. C. E., Pfeil, B., Olsen, A., Metzl, N., Kozyr, A., Fassbender, A., Manke, A., Malczyk, J., Akl, J., Alin, S. R., Bellerby, R. G. J., Borges, A., Boutin, J., Brown, P. J., Cai, W.-J., Chavez, F. P., Chen, A., Cosca, C., Feely, R. A., González-Dávila, M., Goyet, C., Hardman-Mountford, N., Heinze, C., Hoppema, M., Hunt, C. W., Hydes, D., Ishii, M., Johannessen, T., Key, R. M., Körtzinger, A., Landschützer, P., Lauvset, S. K., Lefèvre, N., Lenton, A., Lourantou, A., Merlivat, L., Midorikawa, T., Mintrop, L., Miyazaki, C., Murata, A., Nakadate, A., Nakano, Y., Nakaoka, S., Nojiri, Y., Omar, A. M., Padin, X. A., Park, G.-H., Paterson, K., Perez, F. F., Pierrot, D., Poisson, A., Ríos, A. F., Salisbury, J., Santana-Casiano, J. M., Sarma, V. V. S. S., Schlitzer, R., Schneider, B., Schuster, U., Sieger, R., Skjelvan, I., Steinhoff, T., Suzuki, T., Takahashi, T., Tedesco, K., Telszewski, M., Thomas, H., Tilbrook, B., Vandemark, D., Veness, T., Watson, A. J., Weiss, R., Wong, C. S., and Yoshikawa-Inoue, H.: Surface Ocean CO2 Atlas (SOCAT) gridded data products, Earth Syst. Sci. Data, 5, 145-153, doi:10.5194/essd-5-145-2013, 2013. http://www.earth-syst-sci-data.net/5/145/2013/essd-5-145-2013.html

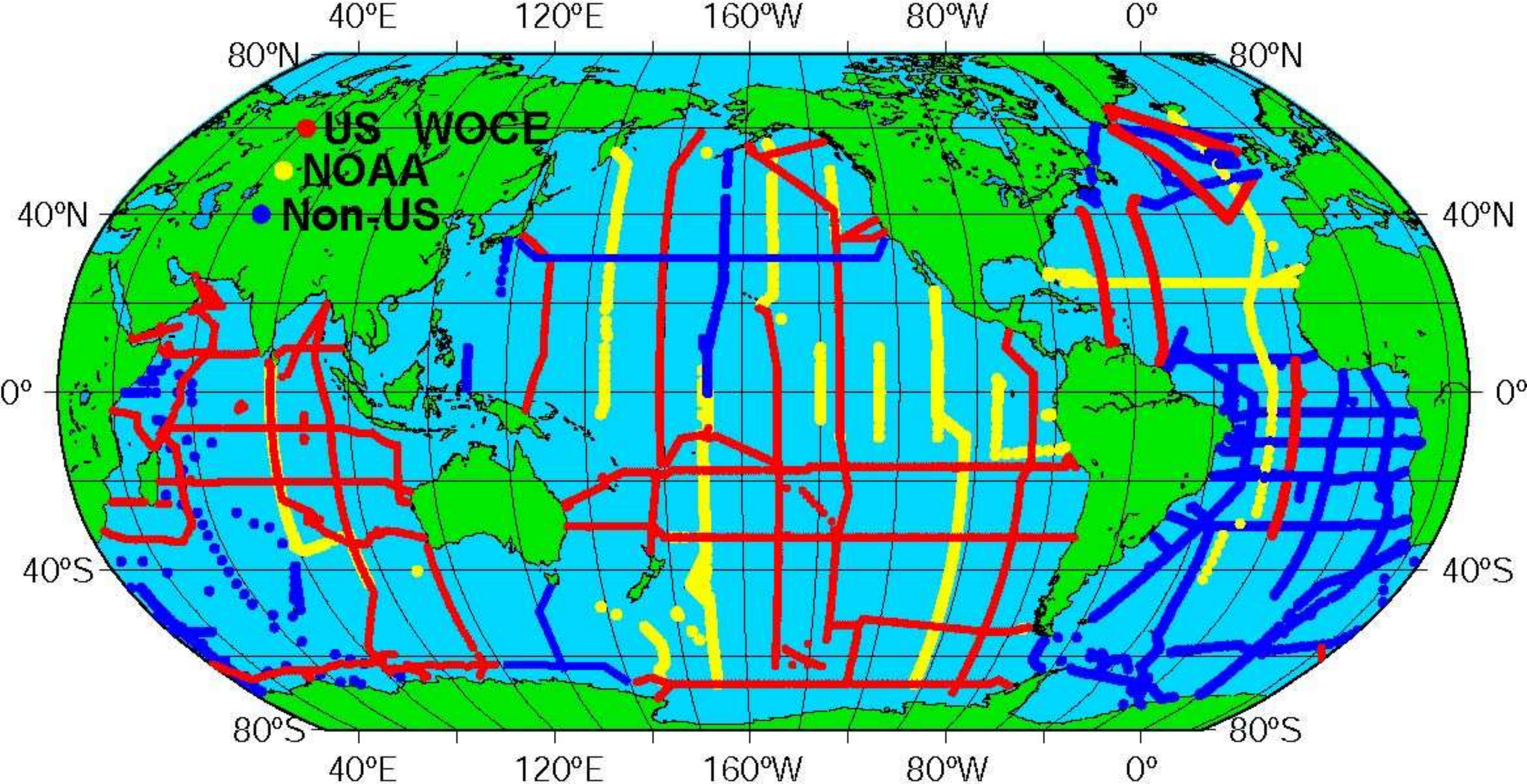
Release of the Surface Ocean CO2 Atlas version 3

B. Pfeil, D. Bakker, A. Olsen, K. O’Brien, K. Smith, C. S. Landa, S. Jones, A. Kozyr, N. Metzl, M. Telszewski, D. Pierrot and the SOCAT community

Issues during the making of SOCATv3



Hydrographic sections: GLODAP - ocean interior data from the 90's – very US dominated



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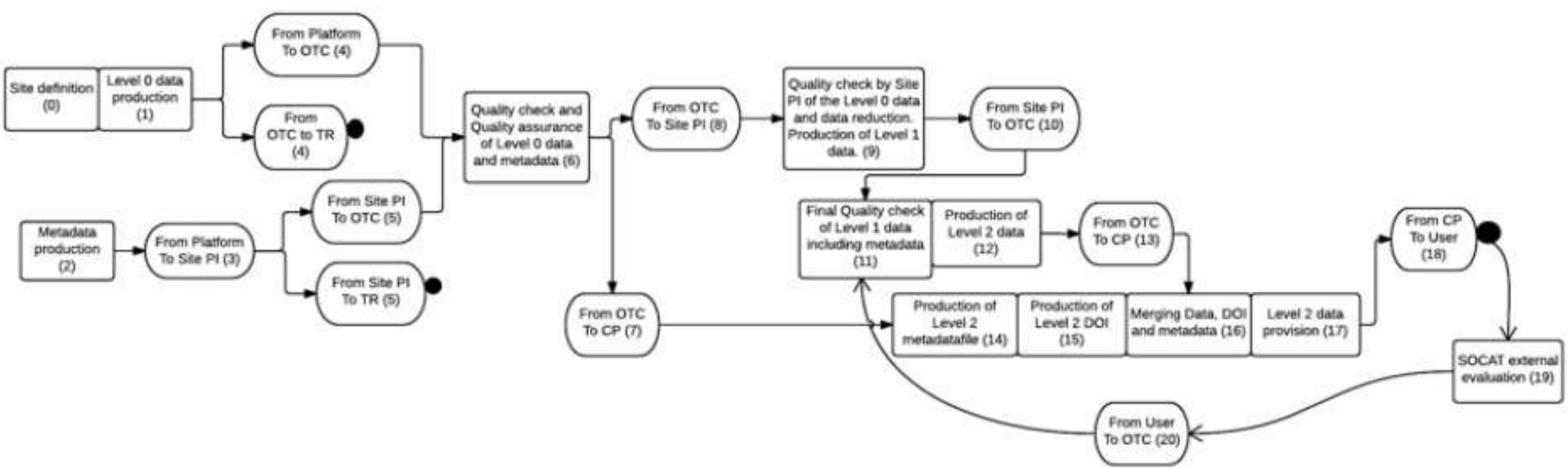
Data management

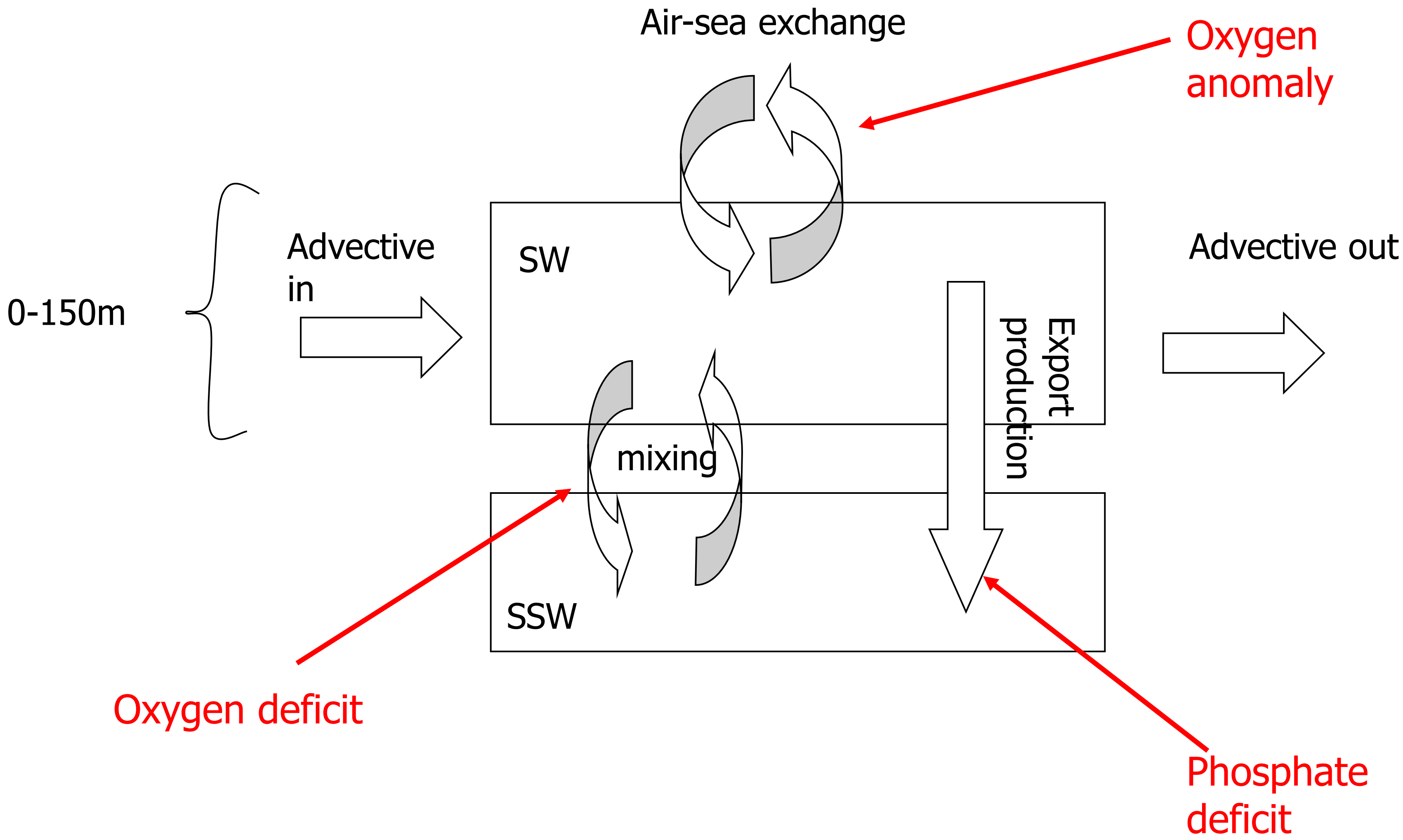
Backbone of ICOS (>50 % of the OTC deliverables)

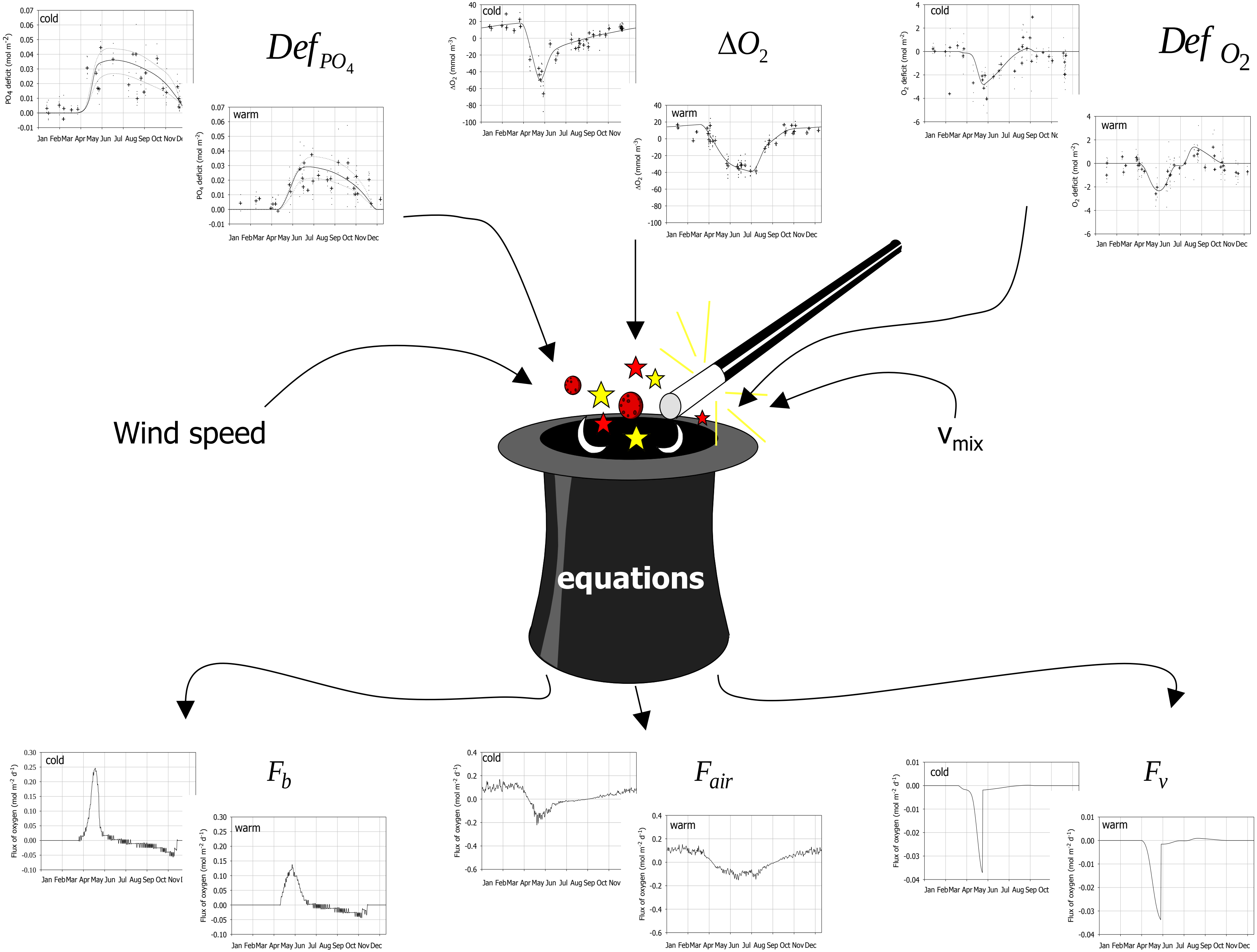
ICOS data policy, ICOS data lifecycle and OTC deliverables ensure:

- Free and open access without any restrictions (data exchange with national data centres)
- 100 % alliance with modern data management plans e.g



Oxygen fluxes to surface layer





Def_{PO_4}
ΔO_2
Def_{O_2}
Wind speed
v_{mix}
equations
F_b
F_{air}
F_v
cold
warm

SOBER

Surface Ocean Biogeochemical and Ecological Research

CO_2 Uptake estimates on short time and regional space scales:

Air-water CO_2 fluxes

Objective:

Constrain the exchange of CO_2 between ocean and atmosphere in order to improve prediction of future CO_2 levels

Goal:

"Determine **regiona**l air-sea CO_2 fluxes on **seasonal** timescales to 0.2 Pg yr^{-1}"

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Thank You!