(Some) Challenges and Opportunities in Ocean Biogeochemistry

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2019 WDAC meeting

Input from Tobias Steinhoff, Toste Tanhua, Rik Wanninkhof, Nico Lange, Ricard Feely, Nancy Williams, Laura Juranek, Elise Droste and Nicholas Gruber

SOCONet, SOCAT, GLODAP & SOCOM >100 contributors worldwide

Challenges and Opportunities

Exclusive Economic Zone (EEZ) data recording of e.g. surface ocean CO_2. Need for an Argo-like solution. Discussion in WMO and IOC.

Reliable access to climate data, e.g. US government shutdown.

The next step for ICOS is to become operational with near-real time data transmission. (Tobias Steinhoff)

Undersampling of the temporal variability of the ocean carbon cycle. Need for improved temporal resolution, a niche that BGC Argo could fill. (Nicholas Gruber)

Increasing use of sensor data. Challenges for calibration, accuracy and links between data sets (e.g SOCAT, GLODAP, BGC Argo)

OceanObs’19 - Community White Papers

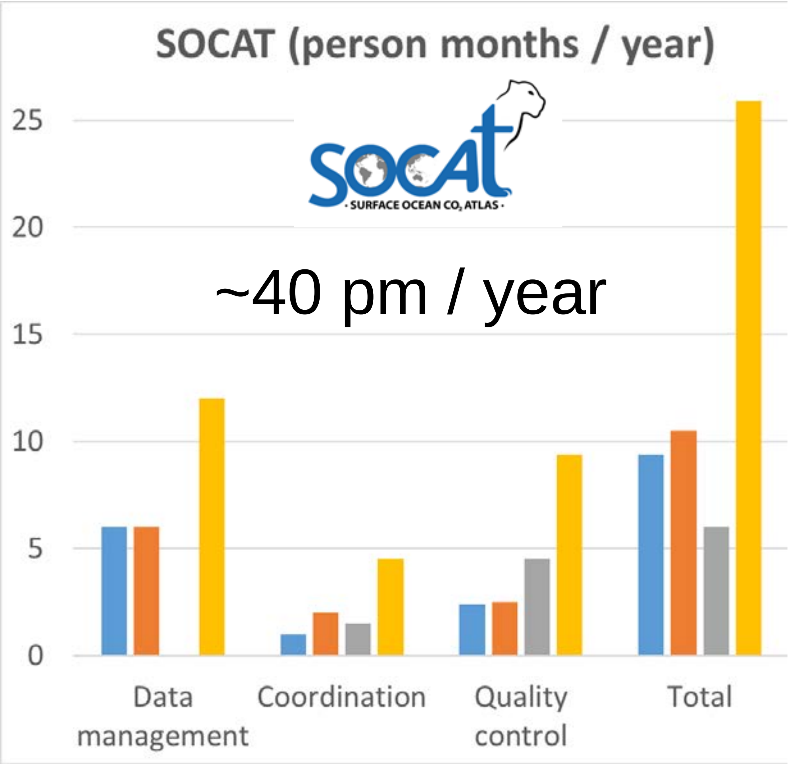
Challenges and Opportunities

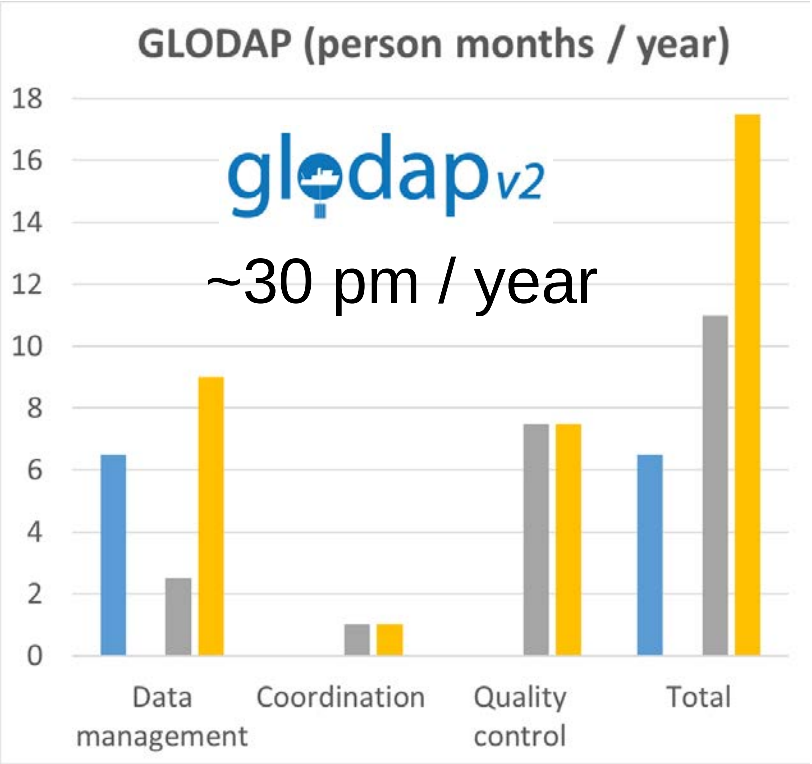
NEW
IOC Working Group on Integrated Ocean Carbon Research
Supported by IOC, IMBER, SOLAS, IOCCP and CLIVAR.

Members: Chris Sabine, Maciej Telszewski (IOCCP), Rik Wanninkhof, Parvadha Suntharalingam (SOLAS), Nicholas Gruber, Laurent Bopp (IMBER), Annalisa Bracco, Wenju Cai (CLIVAR), Salvatore Arico, Kirsten Isensee (IOC)

Discussion on a (kick-of) science workshop (in 2019 or 2020)

Funding challenges





- Underestimates. Partial response.
- 50% of SOCAT project funding ends in 2019.
- GLODAP heavily relies on one person.

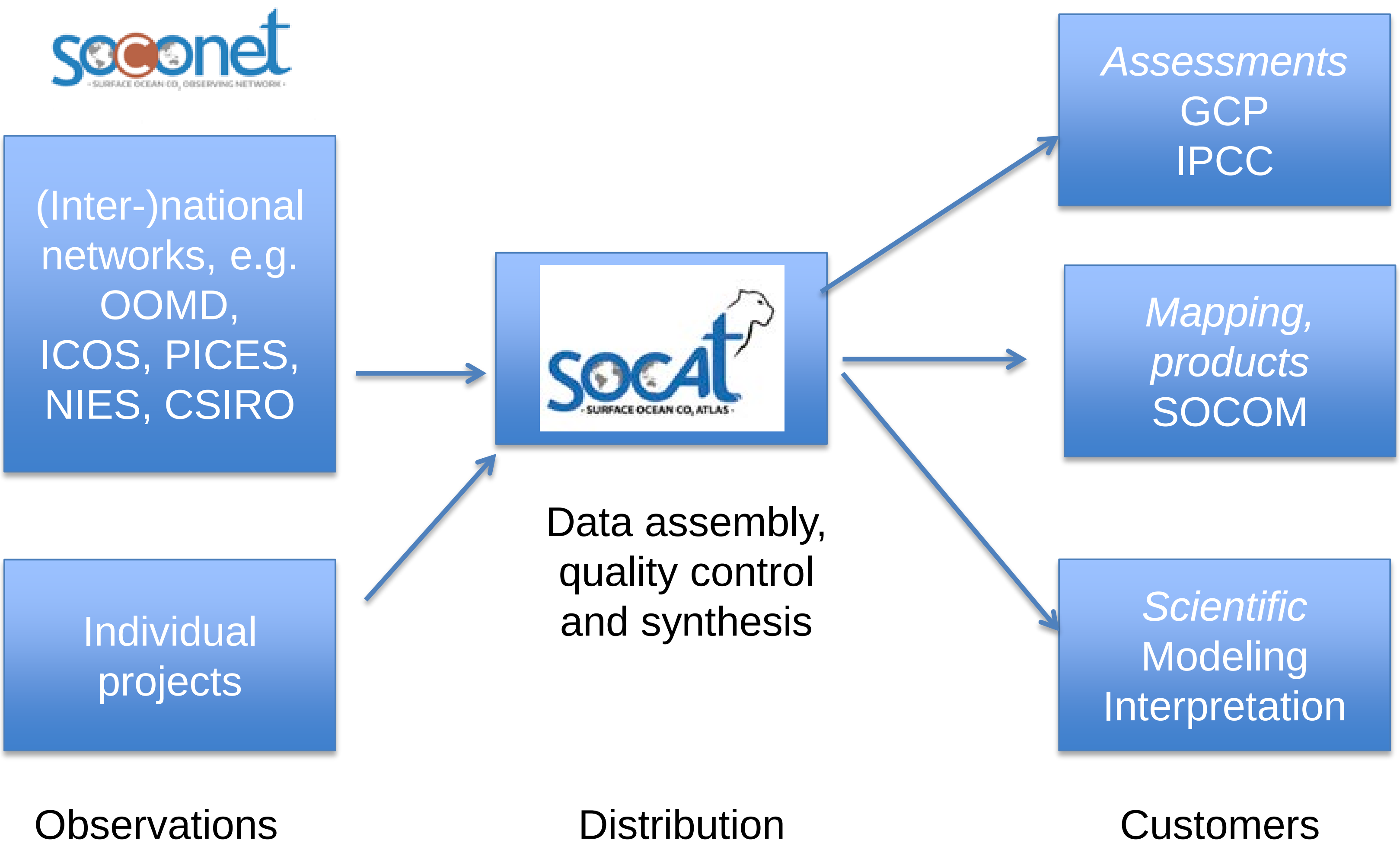
Project funding (national, EU)

NOAA OOMD/ base funding

Voluntary contributions (institution, other grants, overtime)

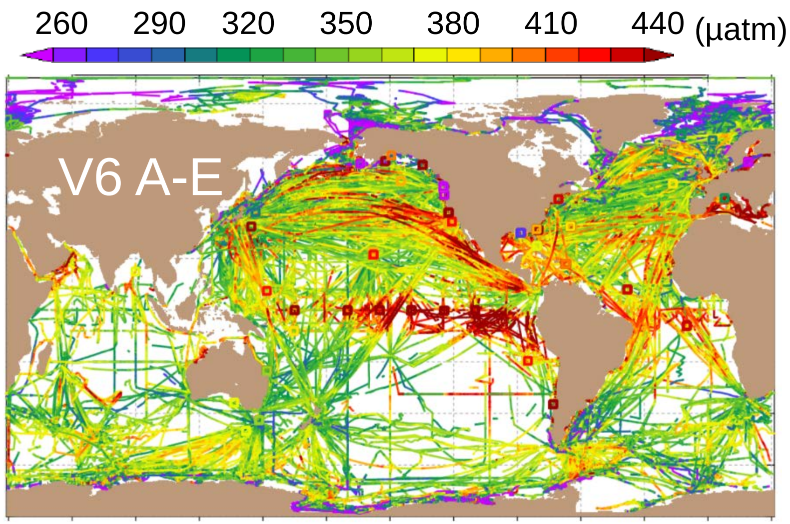
Total

Surface ocean CO_2 observations, data delivery and use



Surface Ocean CO_2 Atlas version 6

www.socat.info



Global synthesis products of surface ocean fCO_2 (fugacity of CO_2) in uniform format with quality control; No gap filling; Annual public releases; V6: 23.4 million fCO_2 values from 1957-2017, accuracy < 5 µatm (flags A-D); Plus calibrated sensor data (accuracy < 10 µatm, flag E);

SOCATv2019 (V7)

- Quality control ends 31 March 2019;
- Release on 18 June 2019.

SOCATv2020

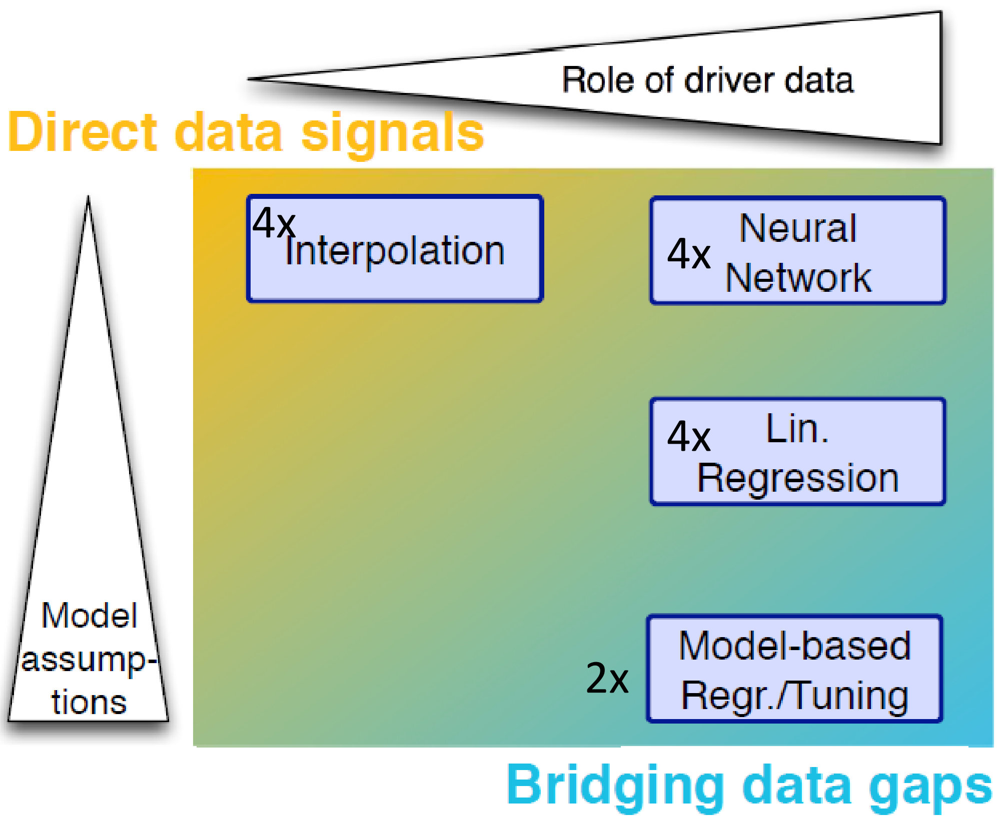
- Data submission ends 15 January 2020.

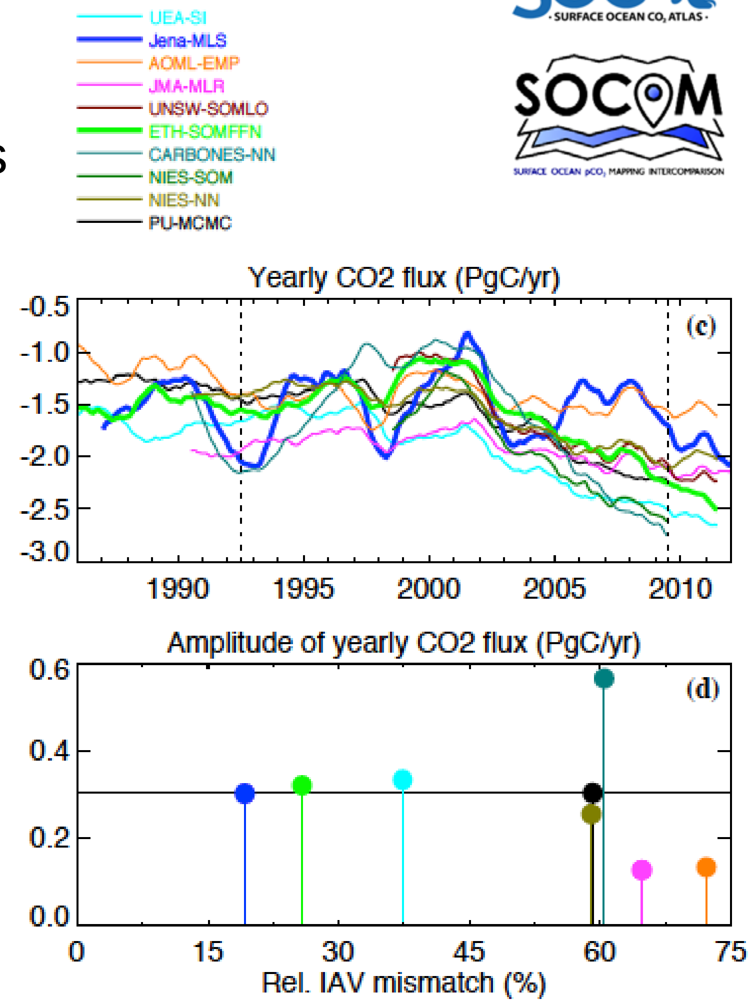
(Pfeil et al., 2013; Sabine et al., 2013; Bakker et al., 2014, 2016, ESSD)

Annual flux maps of ocean carbon sink

(data science)

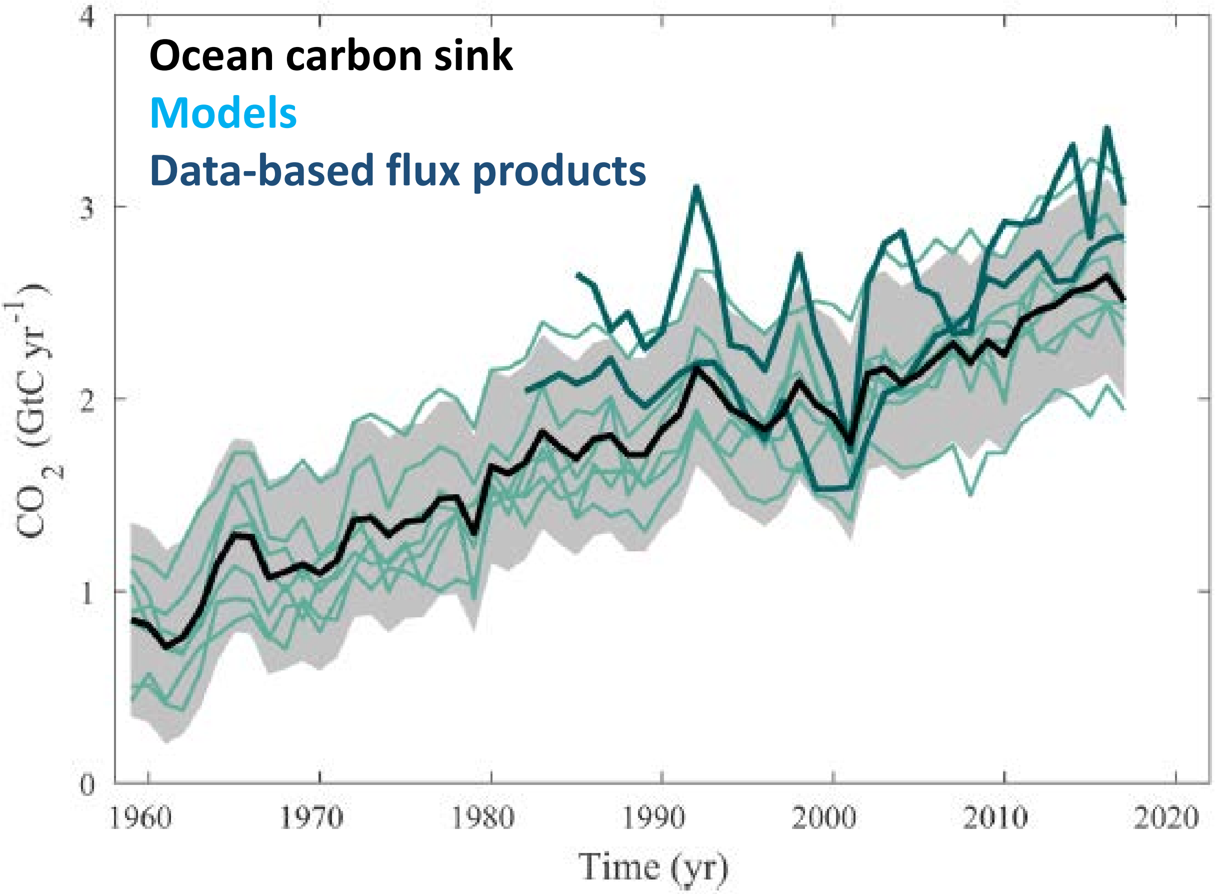
- Surface Ocean pCO_2 Mapping Intercomparison
- 14 data-based mapping methods
- Methods differ in forcing and driver data sets.
- Annual flux maps of global air-sea CO_2 fluxes

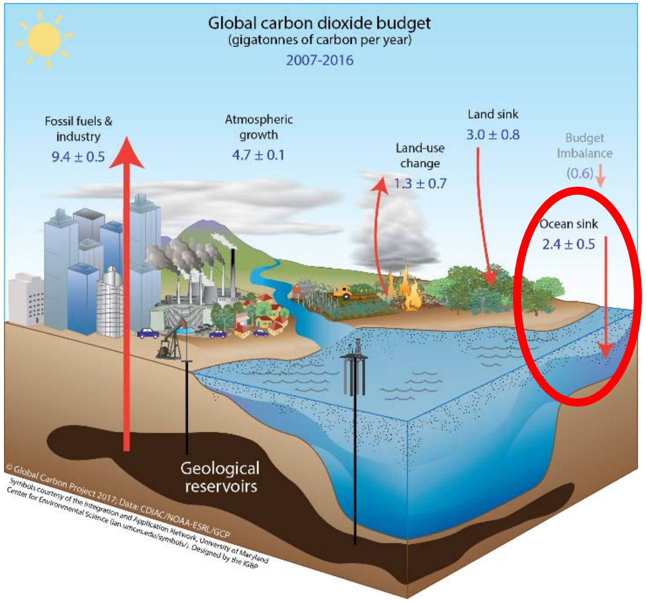




Rödenbeck et al. (2015) BG

Ocean carbon sink in the Global Carbon Budget





Year to year and long term variation on ocean carbon sink.
Models underestimate this variation

(Landschützer et al., 2016; Rödenbeck et al., 2015; Le Quéré et al., 2018a, b)

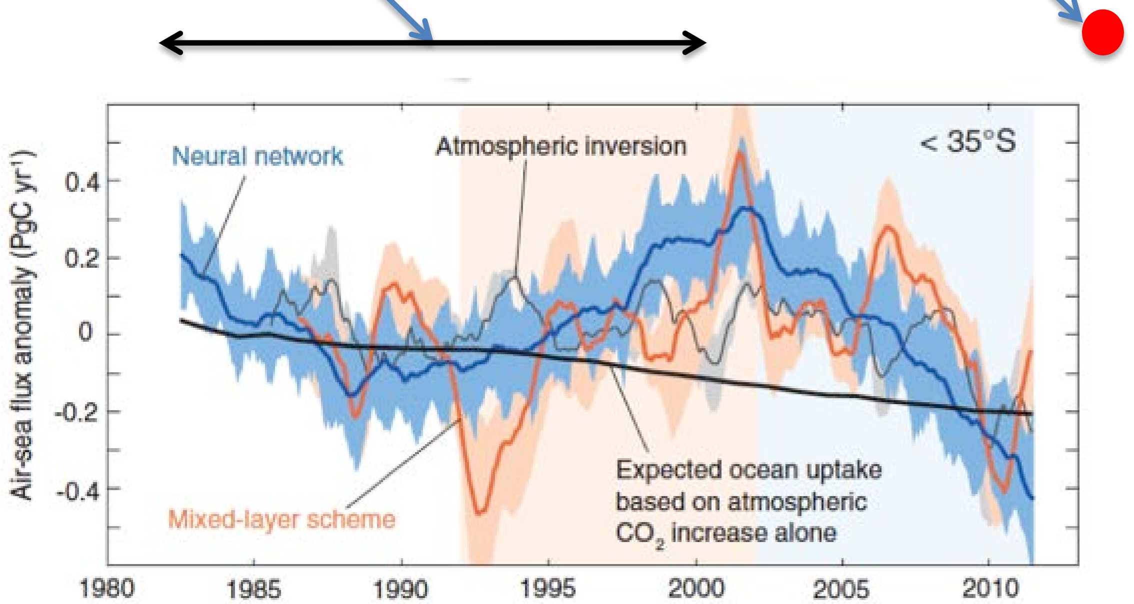
Uncertainty: Data coverage in space, time

The Southern, South Pacific, Indian and Arctic Oceans are undersampled.
Data quality and quantity are insufficient to validate the size and variation in the sink.
Air – sea ice – ocean CO_2 fluxes poorly constrained.

Southern Ocean (SO):

Saturation of the CO_2 sink Le Quéré et al. (2007)

The SO CO_2 source (0.8 Pg C / yr) (Gray et al. 2018 SOCCOM)

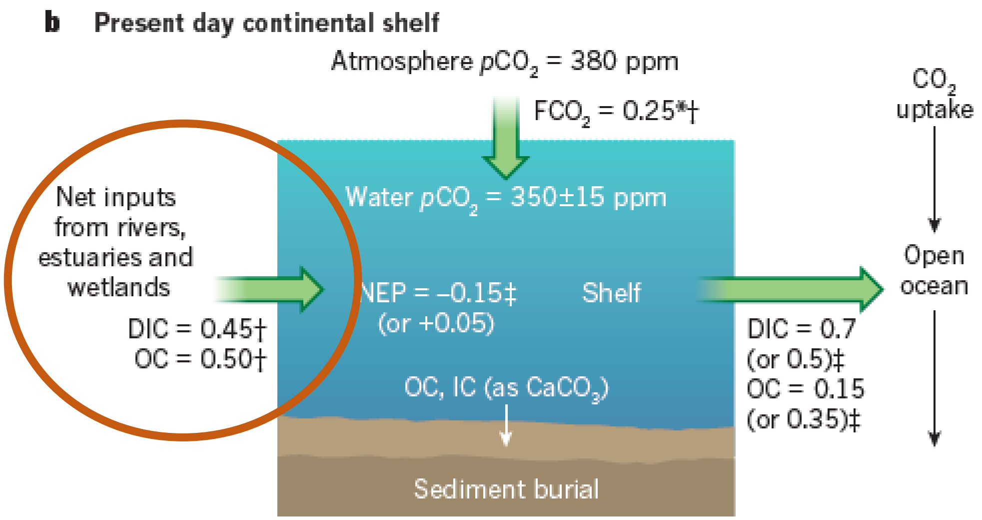


(Landschützer et al. 2015)

Uncertainty: Land - ocean interface and coastal seas

Organic and inorganic carbon transport from land to the ocean.

Changes by human activity unknown.

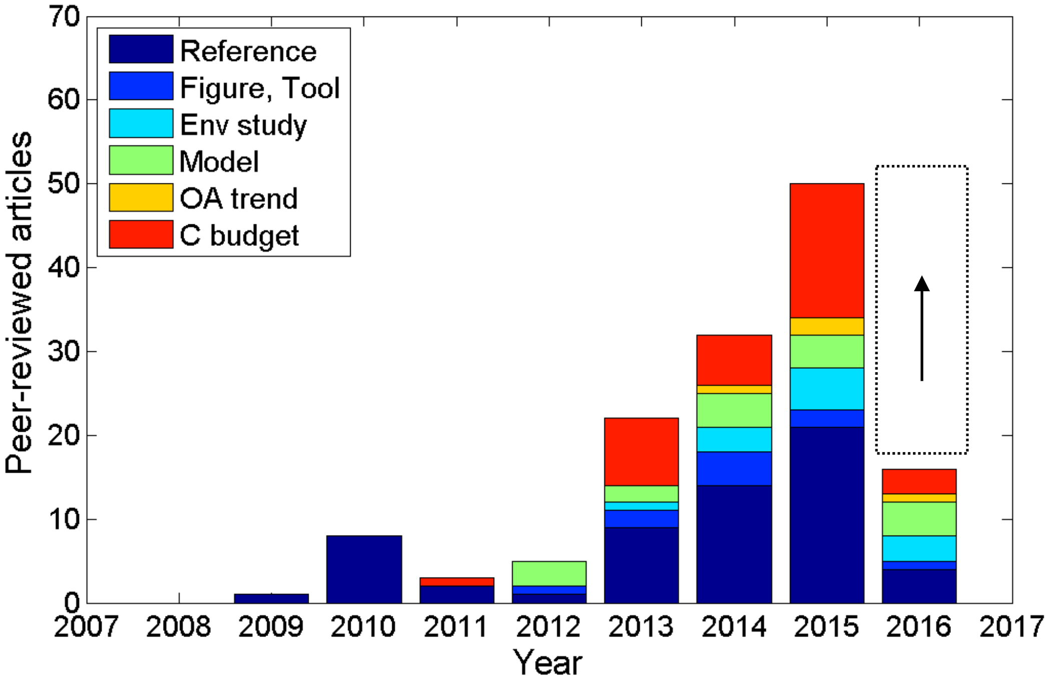


Organic carbon transport to the ocean (~0.78 Pg C yr^{-1}) is a major uncertainty in estimates of ocean uptake of anthropogenic carbon from pCO_2 maps, e.g. for Global Carbon Budget

Coastal ocean carbon sink not well constrained.

Jacobson et al., 2007; Bauer et al., 2013; Resplandy et al., 2018

Applications of SOCAT



SOCAT is cited in >>200 peer-reviewed articles and high-impact reports.

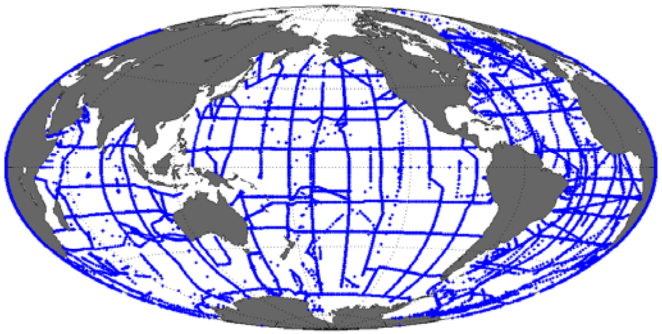
BAMS State of the Climate

- **Ocean carbon sink** (SOCOM, GCP, BAMS, SOCCR, IPCC)
- **Ocean acidification studies** (GOA-ON)
- **Model evaluation** (Obs4MIP, ESMVal, CMIP)
- Data products (e.g. Mercator Ocean)
- Calibration of sensors (BGC Argo, gliders)

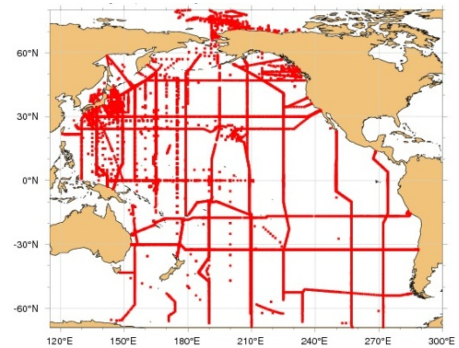
(Bakker et al., 2016)

Global Data Analysis Project Version 2
(<u>Interior ocean carbon</u> and other observations)

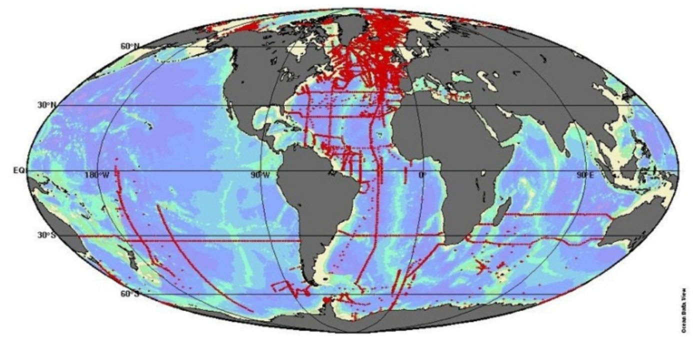
GLODAP (1985-1999)
(Key et al., 2004)

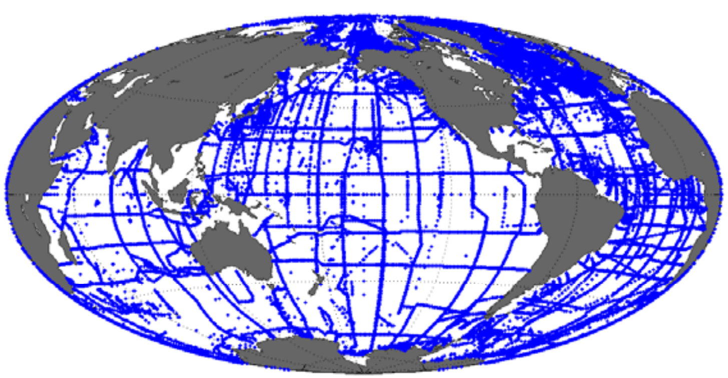


PACIFICA
(Suzuki et al., 2013)



CARINA (1977-2006)
(Tanhua et al. 2009)





GLODAPv2.2019 (1972-2017), 840 cruises;
GLODAPv2 (1972-2013) (Olsen et al., 2016)

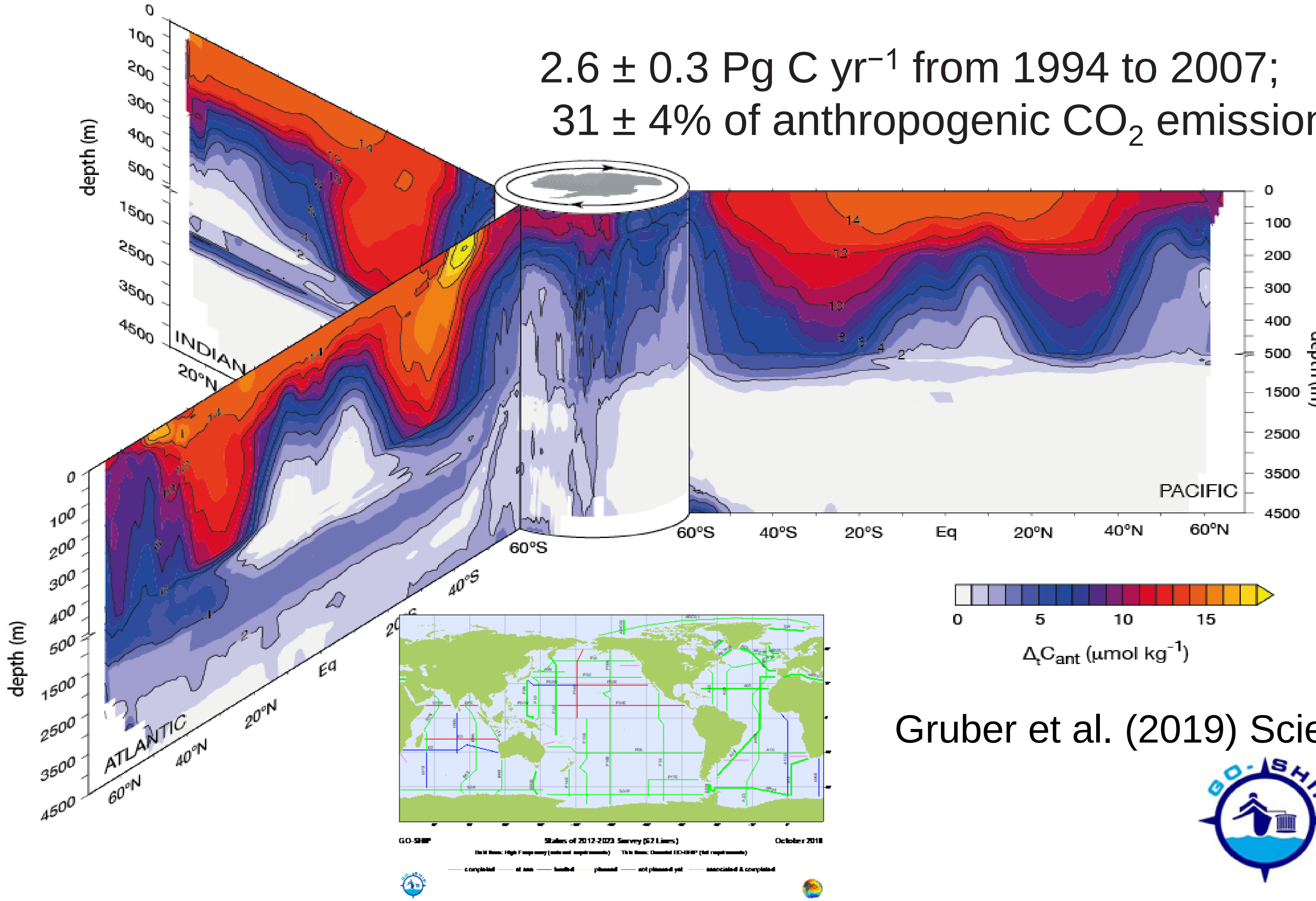
Release on 26 March 2019

- Uniform, bias corrected;
- Core: T, S, DIC, Alk, oxygen, nutrients, freons;
- Also: pH, carbon isotopes, organic carbon and nitrogen, tritium, helium;
- Bi-annual updates, decadal releases.

Anthropogenic carbon uptake

32 ± 4 Pg C from 1994 to 2007
160 ± 20 Pg C from 1800 to 2010

2.6 ± 0.3 Pg C yr^{-1} from 1994 to 2007;
31 ± 4% of anthropogenic CO_2 emissions



Gruber et al. (2019) Science

Global Data Analysis Project Version 2
(**Interior ocean carbon** and other observations)

Dissolved Inorganic Carbon (µmol/kg) on WOCE Section A16

Evidence for substantial anthropogenic ocean biogeochemical change

Provides insight into:

- Ocean biogeochemical change and variation
- Air-sea CO_2 flux
- Ocean acidification

A reference product for e.g.

- Climate related studies (biogeochemistry)
- Quality control of sensor data (e.g. BGC Argo)
- Model evaluation

Cited in >823 peer-reviewed articles

Slide by Nico Lange

Biogeochemical (BGC) Argo floats

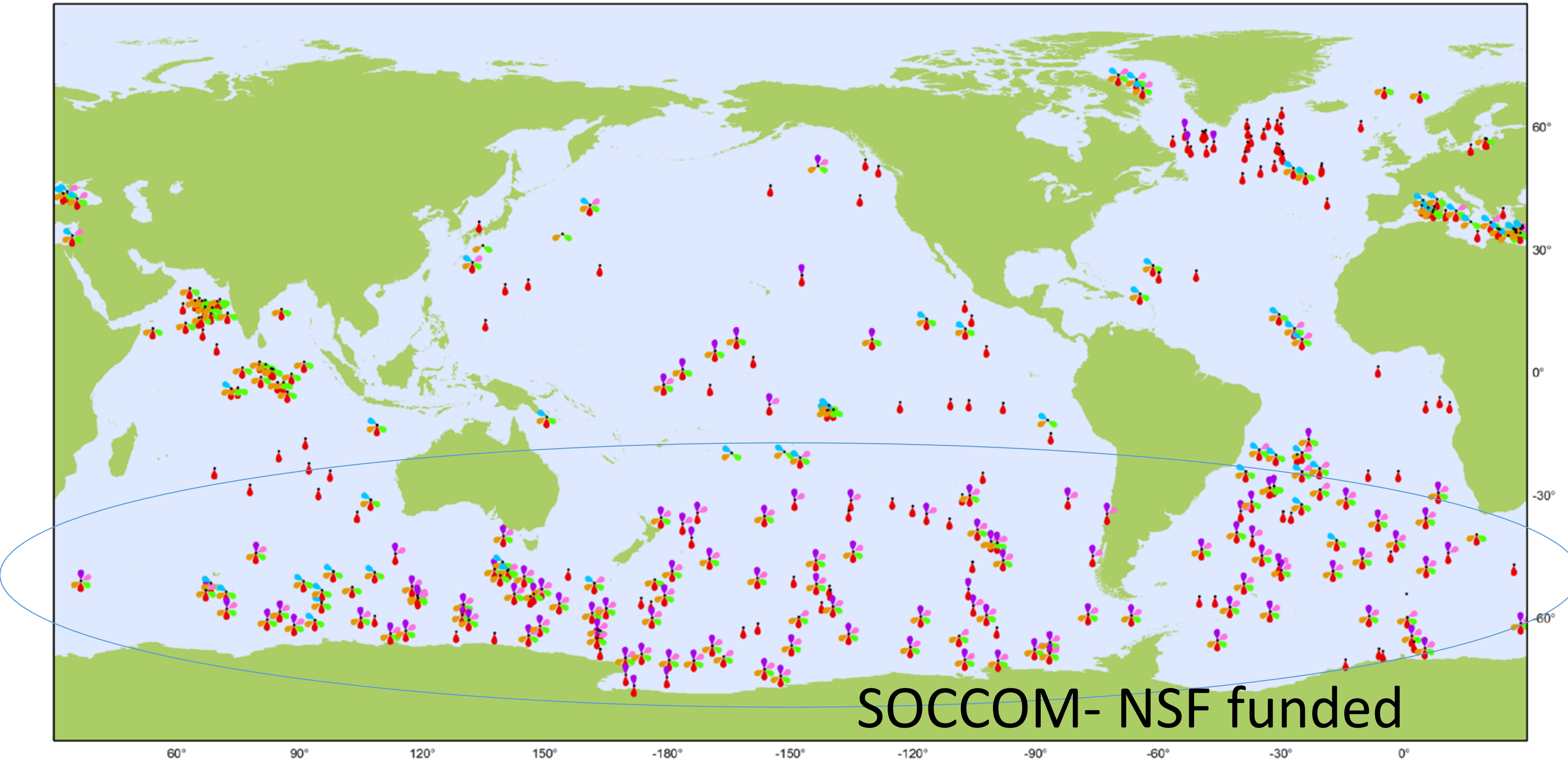
Argo sensors:
Temperature
Salinity
Pressure

Biogeochemical sensors, e.g.
Oxygen
Nitrate
pH
Fluorescence
Backscatter
CDOM

Ice avoidance

Profiling between 0 and 2000 m depth
Send data back via satellite; lifetime up to 5 years
Calibration samples for all parameters taken as a float is deployed.
SOCCOM is a large US NSF program using BGC Argo floats.

Biogeochemical Argo floats



Biogeochemical Argo

Sensor Types

Latest location of operational floats (data distributed within the last 30 days)

February 2019

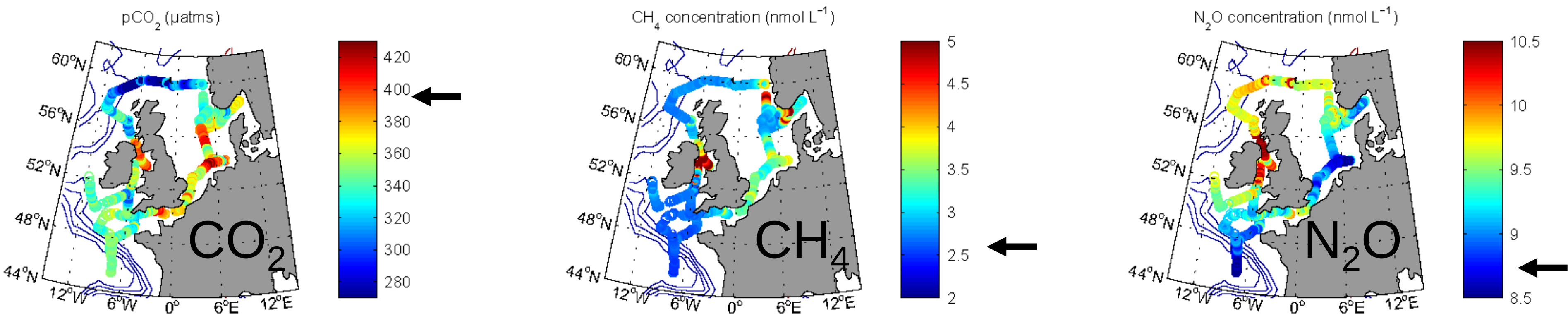
- Operational Floats (338)
- Suspended particles (199)
- Downwelling irradiance (64)
- pH (118)
- Nitrate (128)
- Chlorophyll a (199)
- Oxygen (321)

Generated by www.jcommops.org, 08/03/2019

pH results from SOCCOM / GO-SHIP Intercomparison

New technologies: Autonomous surface vessels

Uncertainty: Air-sea fluxes of CH_4 and N_2O, their variation, trends and drivers



Air-sea fluxes of the long-lived greenhouse gases methane and nitrous oxide, their variation, trends and drivers are poorly known.

(Wager, PhD thesis 2016)

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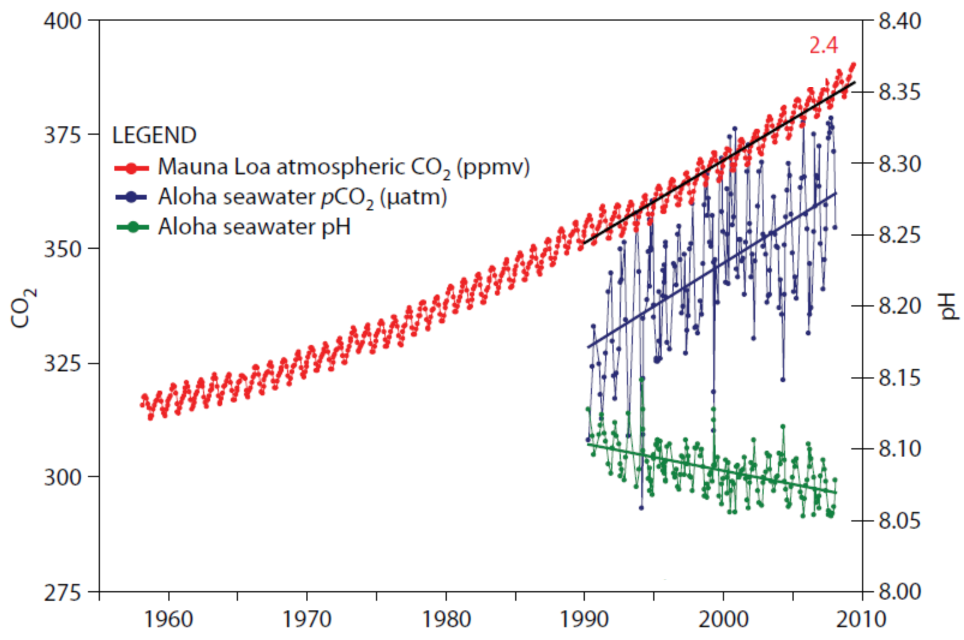
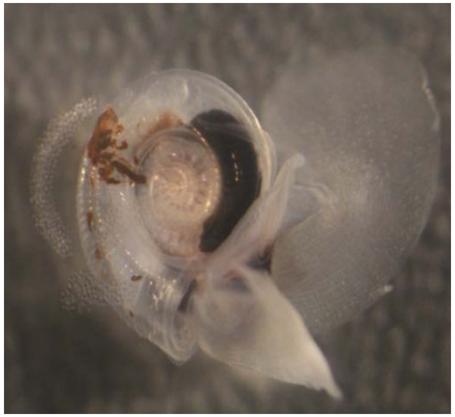
Progression and impacts of ocean acidification (OA) by ocean CO_2 uptake

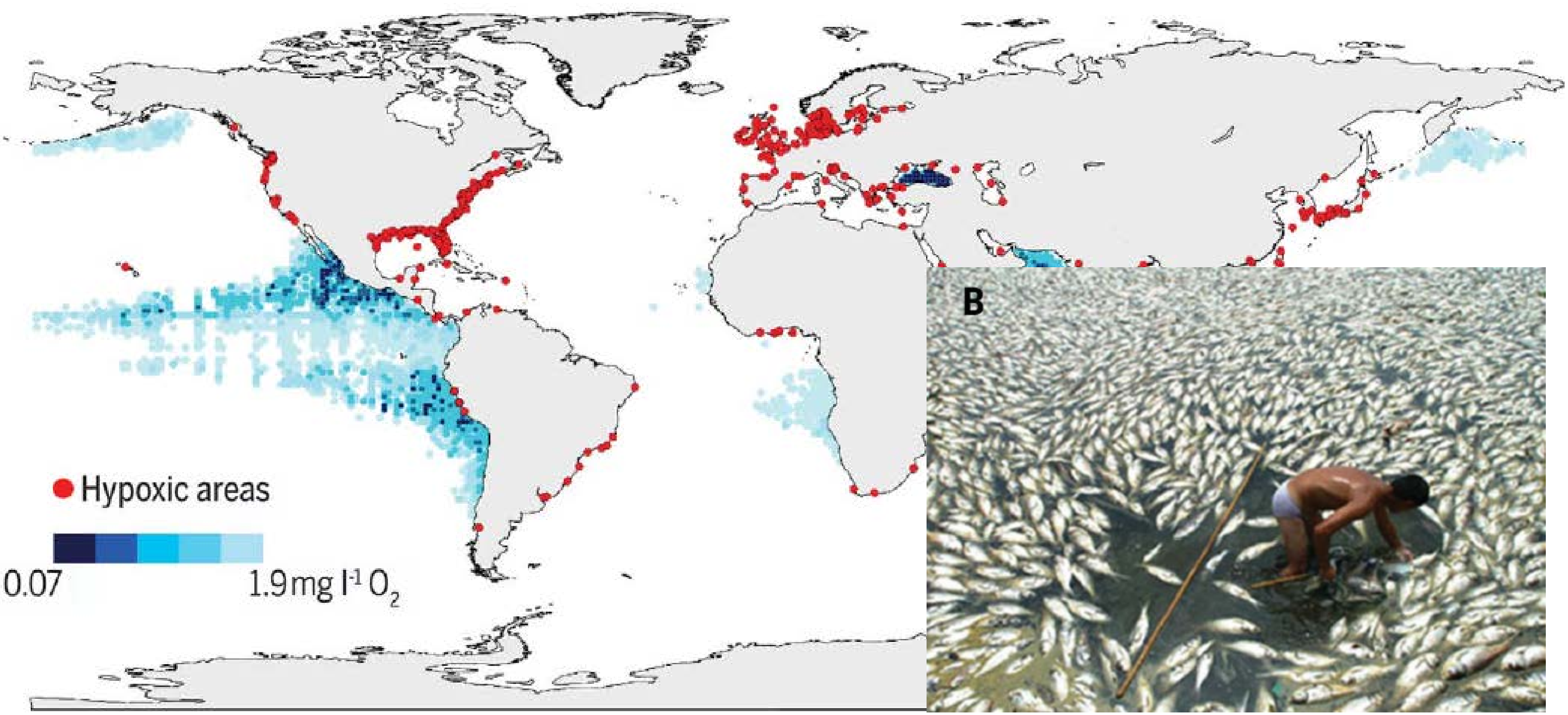




(Caldeira and Wickett, 2003; Feely et al., 2009; Gardner et al., 2018)

- Ocean CO_2 uptake decreases pH and the saturation state Ω for calcium carbonates ($CaCO_3$).
- pH has decreased by 0.1 pH unit since 1750.
- pH will decrease by 0.3 pH units by 2100 ('business as usual').
- OA will continue long after CO_2 emissions stop. OA will continue under geo-engineering, unless these reduce CO_2 emissions.
- Uncertainty on impact of OA on marine organisms and ecosystems.

Low and declining oxygen levels



Red: Hypoxic areas – O_2 concentrations < 63 µmol L^{-1} (or 2 mg L^{-1}).
Blue: Oxygen minimum zones at 300 m depth

Breitburg et al., 2018. Science 359 (46): 1-11

Challenges and Opportunities in Ocean Biogeochemistry

Human activity impacts ocean biogeochemistry worldwide

Many challenges and opportunities for assessing such impacts

Photo by Brian Ward, taken in the remote Indian Ocean