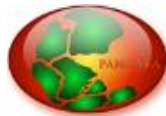


The Surface Ocean CO₂ Atlas enables quantification of the ocean carbon sink and ocean acidification



Dorothee Bakker (d.bakker@uea.ac.uk), Benjamin Pfeil, Karl Smith, Simone Alin, Kim Currie, Steve Jones, Alex Kozyr, Camilla Landa, Peter Landschützer, Siv Lauvset, Nathalie Lefèvre, Nicolas Metzl, Shin-ichiro Nakaoka, Yukihiro Nojiri, Kevin O'Brien, Are Olsen, Christian Rödenbeck, Ute Schuster, Maciej Telszewski, Bronte Tilbrook, Chisato Wada, Rik Wanninkhof and all >100 SOCAT contributors



Sources



Fossil fuel & cement sources
 $9.0 \pm 0.5 \text{ Pg C yr}^{-1}$ (91%)



Land-use change (9%)
 $0.9 \pm 0.5 \text{ Pg C yr}^{-1}$

Sinks



Atmosphere (44%)
 $4.4 \pm 0.1 \text{ Pg C yr}^{-1}$



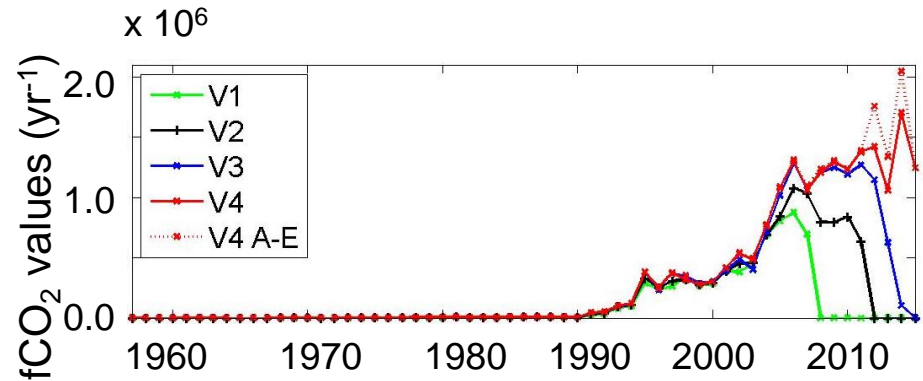
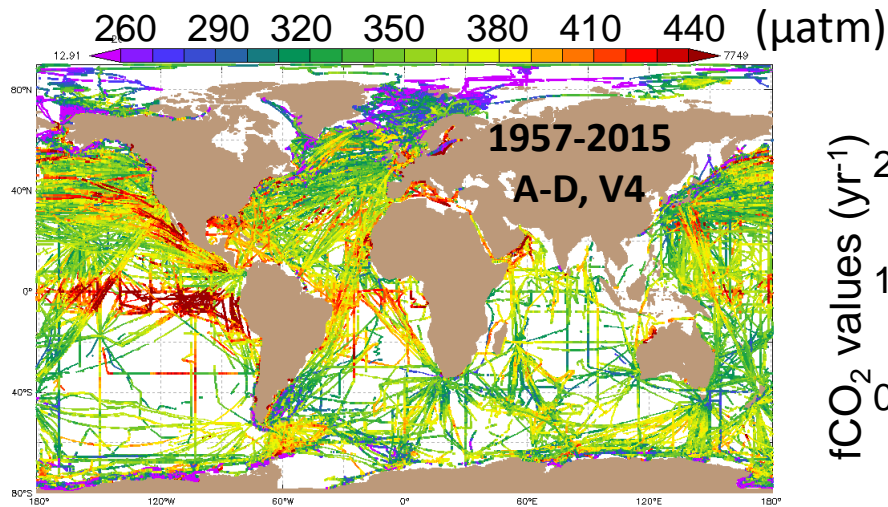
Ocean sink (26%)
 $2.6 \pm 0.5 \text{ Pg C yr}^{-1}$



Land sink (residual)
 $3.0 \pm 0.8 \text{ Pg C yr}^{-1}$
(30%)

Surface Ocean CO₂ Atlas (version 4)

public on 1 September 2016



Global synthesis and gridded products of surface ocean fCO₂ (fugacity of CO₂) in uniform format with quality control;

V4: 18.5 million fCO₂ values, accuracy < 5 μatm from 1957-2015 (flags of A-D);

Plus calibrated sensor data (< 10 μatm, flag of E);

Interactive online viewers;

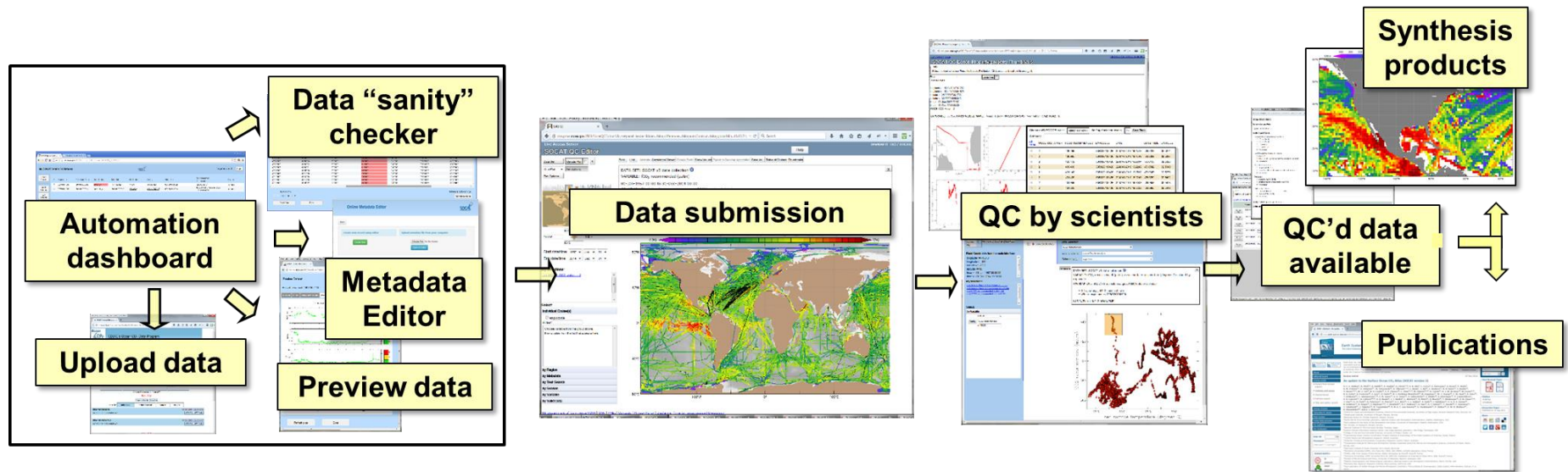
Downloadable (text, NetCDF, ODV, Matlab);

Documented in ESSD articles;

Fair Data Use Statement;

Community activity with >100 contributors worldwide.

Release of SOCAT version 4 – First annual release upon automated data upload



Automation of data upload, initial data checks speeds up data submission and enables annual, public releases of SOCAT.

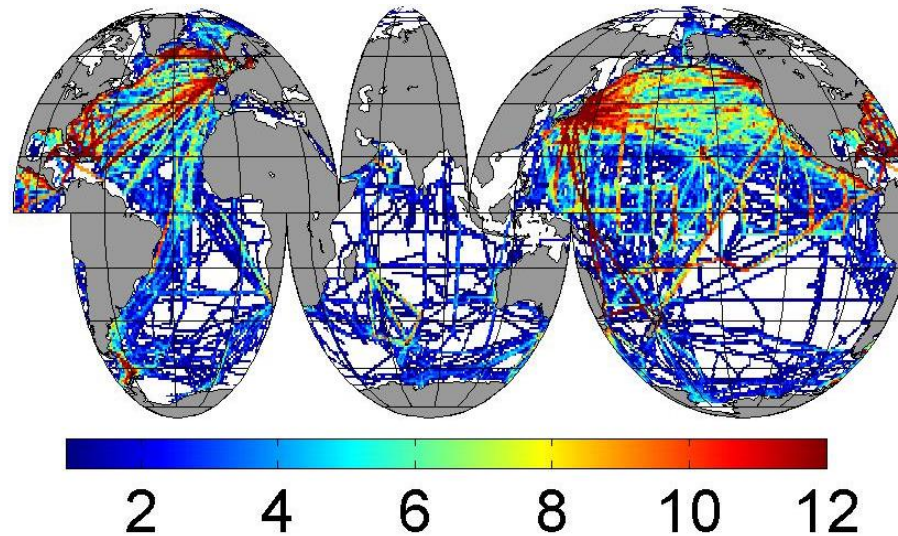
Online viewers.

SOCAT data is discoverable, accessible and citable.

Future: Automation of metadata upload.

(O'Brien et al., in prep.)

Future SOCAT versions



Months of the year
with fCO₂ values
(1970-2014) (V3)

- V5 Data upload ends 15 January 2017;
- V5 Quality control ends 31 March 2017;
- V5 Release in summer 2017;
- V6: V5 dates + 1 year

Sea surface temperature and salinity not QC-ed.

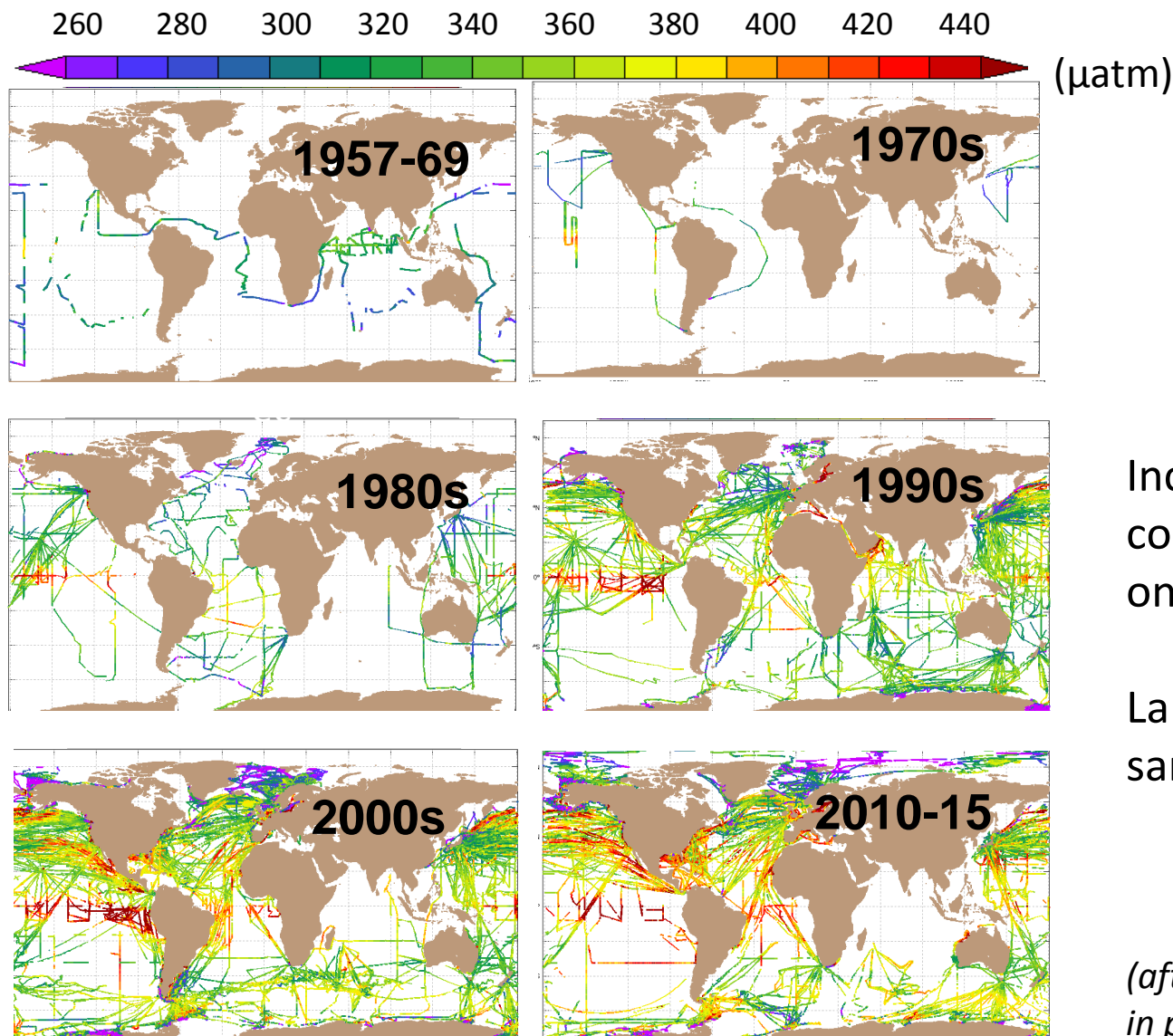
Atmospheric CO₂ measurements accepted (no QC yet);

Extra surface water parameters (DIC, TA, ...) accepted, but **no QC planned**.

SOCAT-MEMENTO working group on N₂O, CH₄.

(Bakker et al., 2016 ESSD in press)

Surface water fCO₂ per decade (v4)

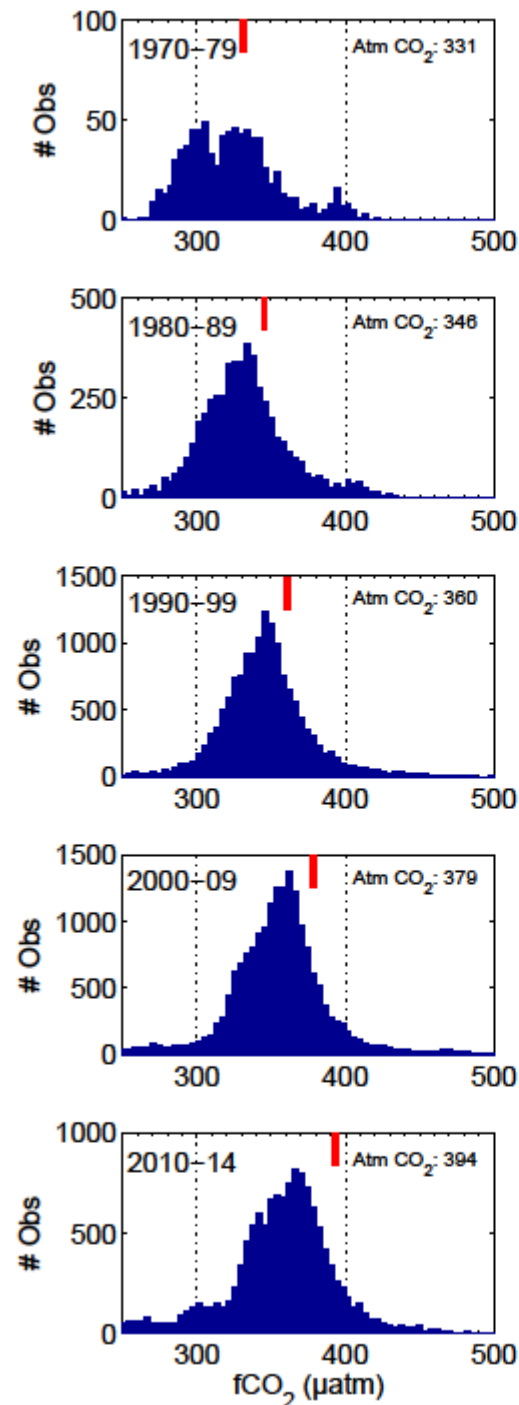


Increase in fCO₂ data collection from 1990s onwards.

Large regions are not sampled.

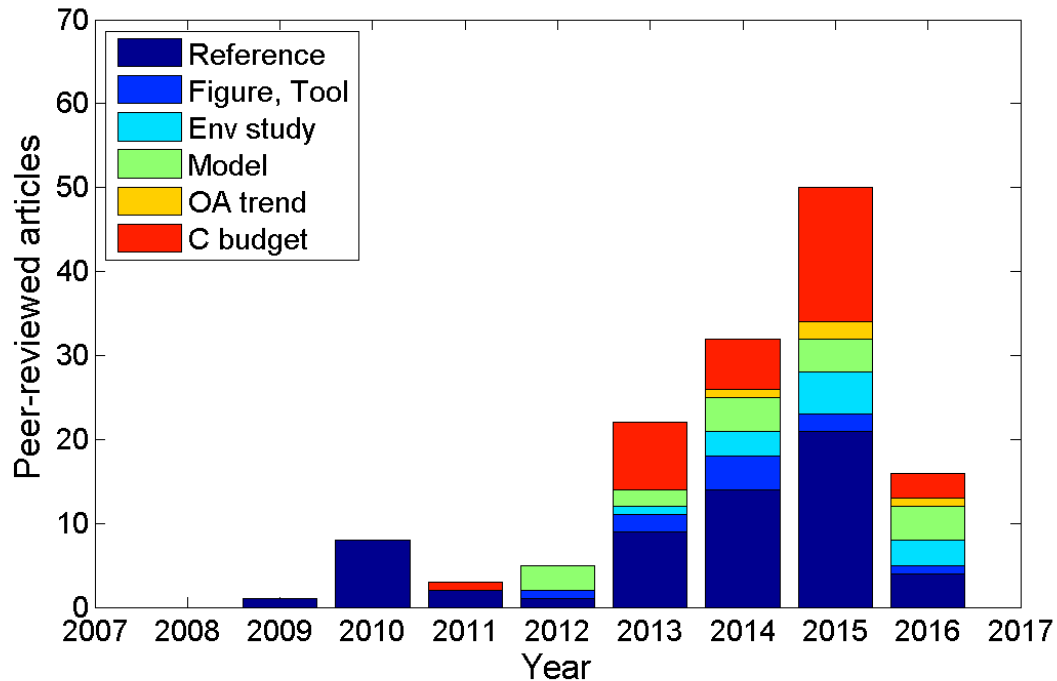
(after Bakker et al., 2016 ESSD in press)

Increasing surface water $f\text{CO}_2$ over time (v3)



(Bakker et al., 2016 ESSD in press)

Applications of SOCAT in peer-reviewed articles

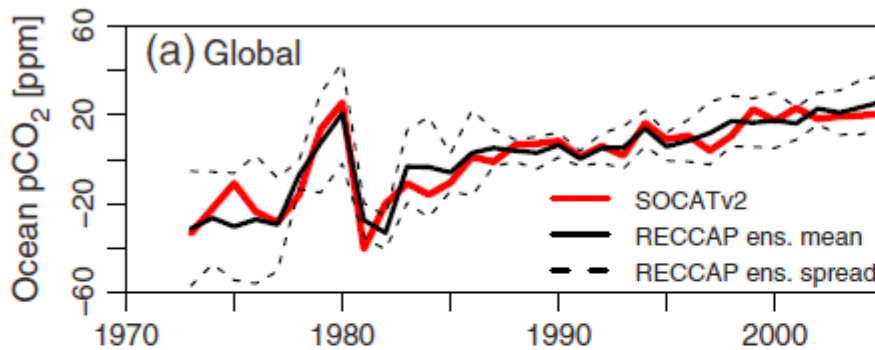


- SOCAT is named or cited in >>140 peer-reviewed articles:
- Reference to SOCAT,
 - Figures or tools,
 - Environmental studies,
 - Modelling,
 - Ocean acidification studies,
 - Carbon budgeting.

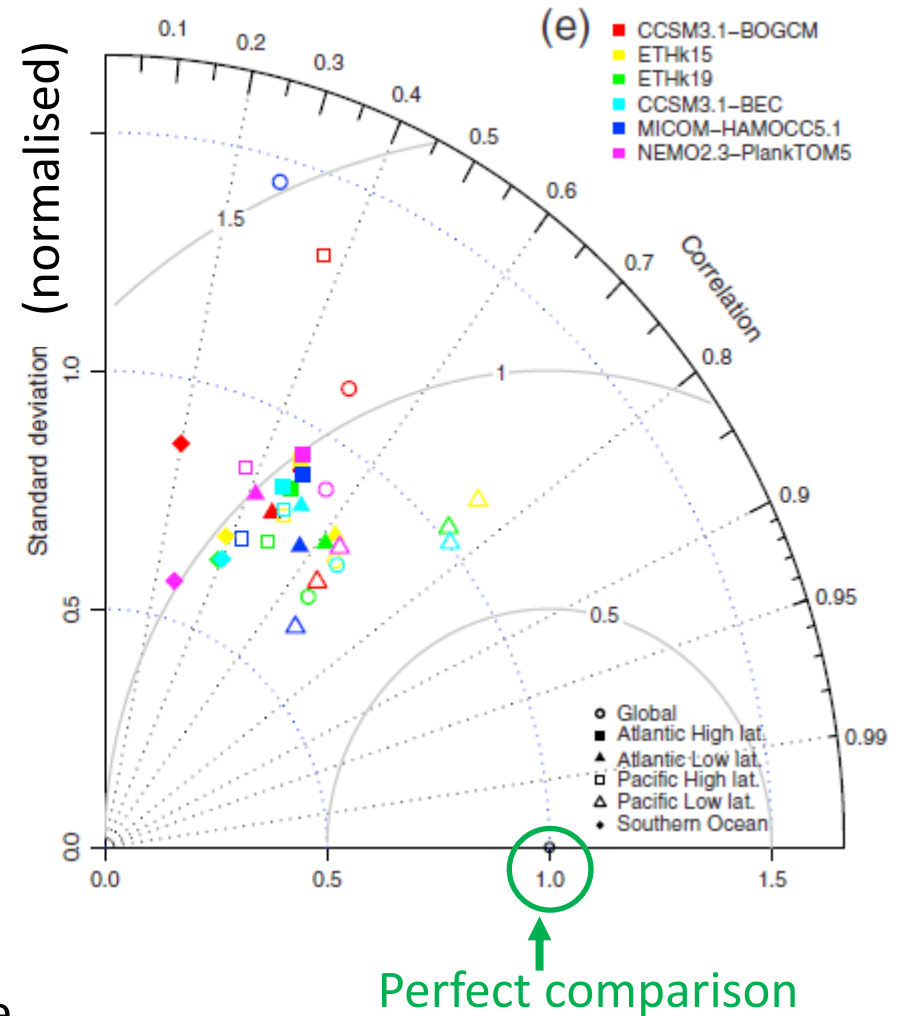
Figure of 22 April 2016

(Bakker et al., 2016 ESSD in press)

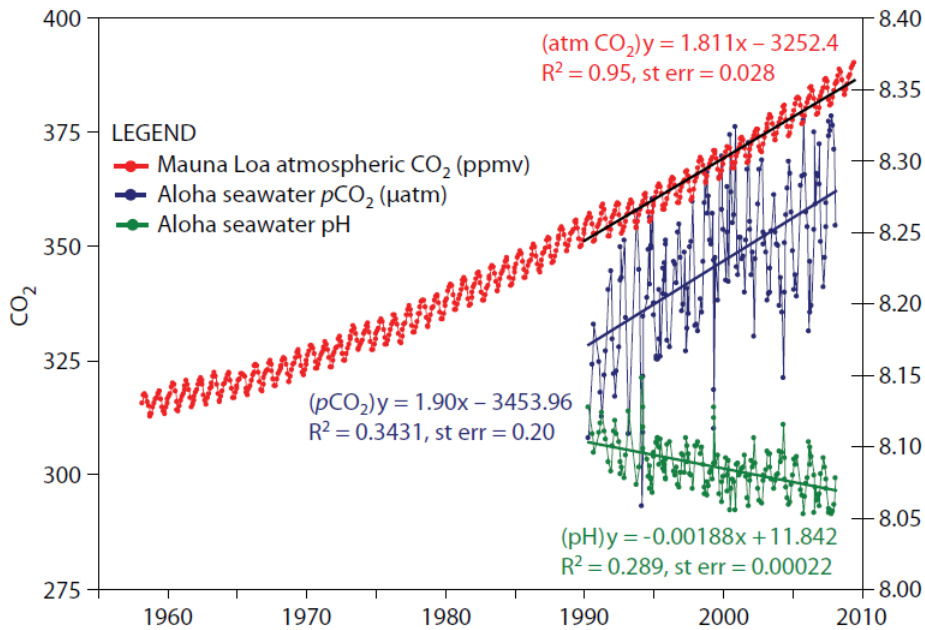
Model evaluation



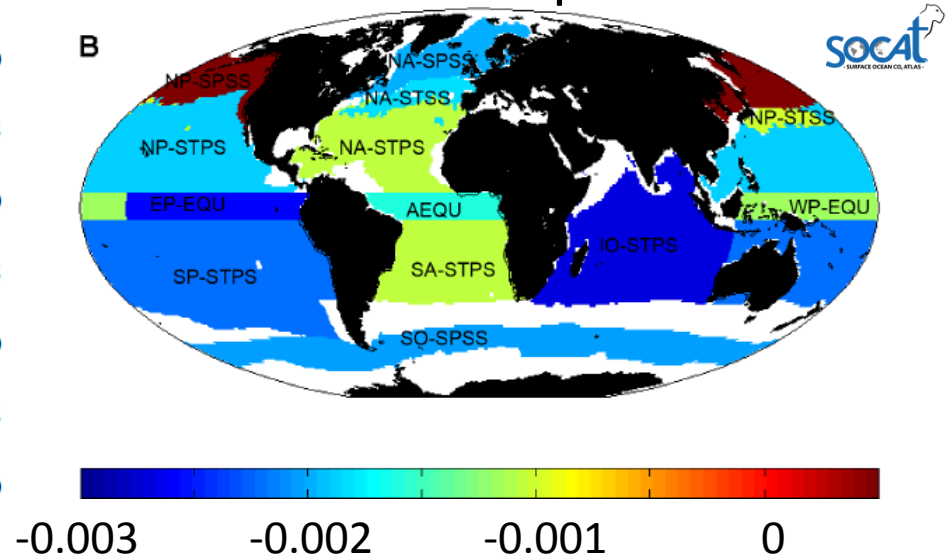
- Subsampling of 6 ocean-only CMIP5 models to SOCAT v2 $f\text{CO}_2$ values;
- Comparison of annual mean anomalies;
- **Models underestimate the variation in surface ocean $p\text{CO}_2$.**
- SOCAT in Obs4MIP now a CMIP reference (for next IPCC report).



Ocean acidification from SOCAT

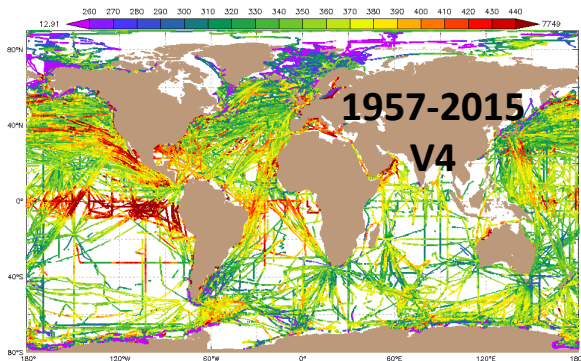


Surface ocean pH change for 1991 to 2011 per biome



- Combine SOCAT fCO₂ with salinity-derived alkalinity.
- Mean pH decrease of 0.002 units per year from 1991 to 2011.
- SOCAT enables quantification of regional trends in surface ocean pH.

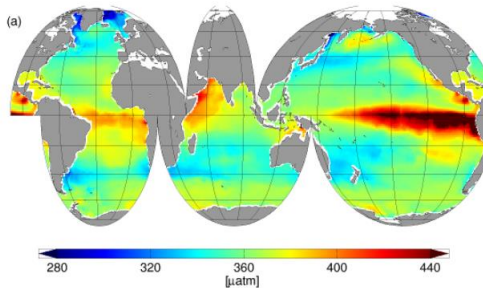
Mapping (gap filling) of surface ocean pCO₂ observations



A synthesis data product
(here SOCAT v4)



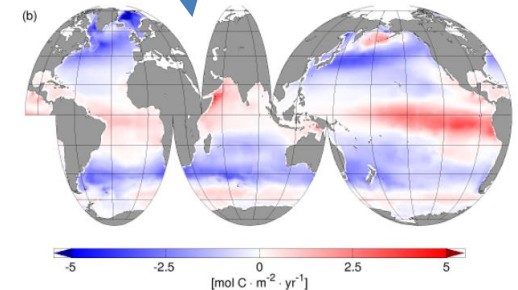
Mapping technique



Surface water pCO₂
(here 1998-2011)



Flux = $k * \Delta pCO_2(w-a)$
Gas transfer parameterisation,
wind speed product

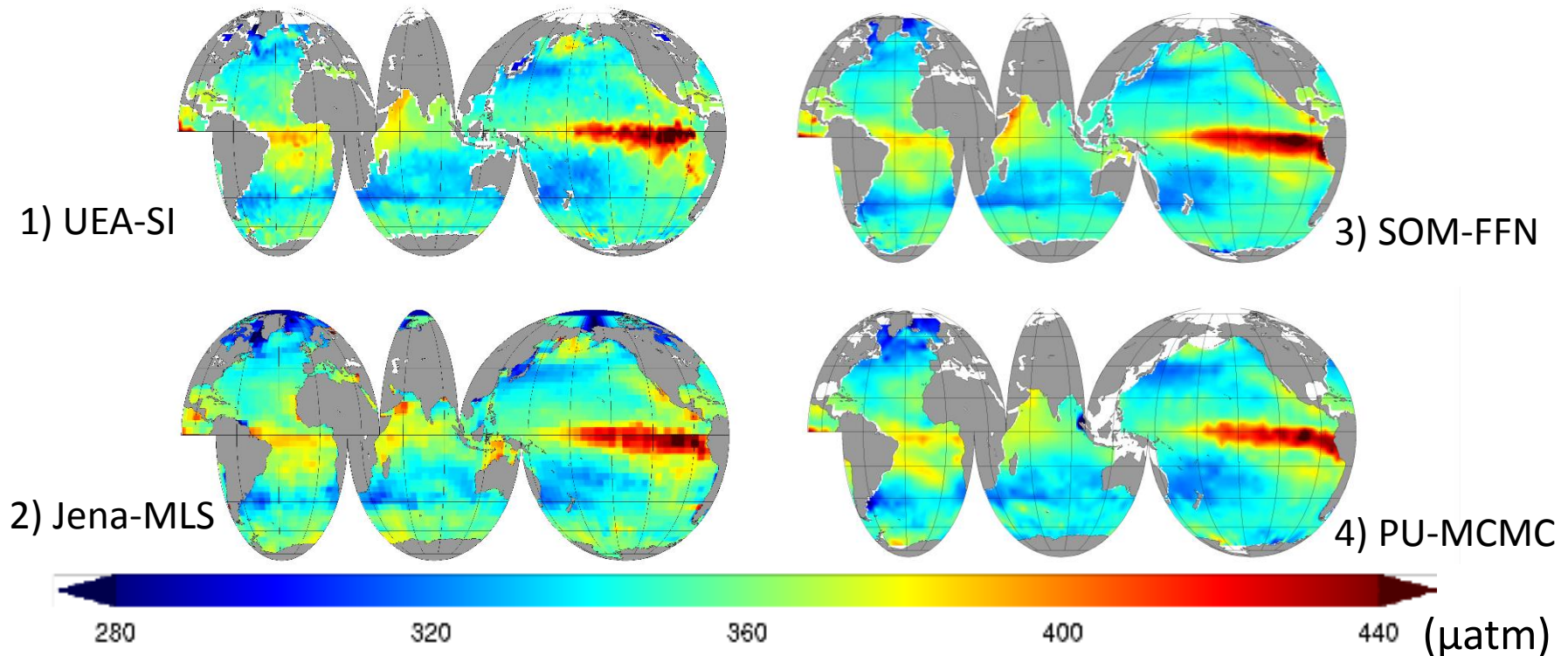


Air-sea CO₂ flux
(here 1998-2011)

Talk by Christian Rödenbeck

(Bakker et al., 2016 ESSD in press; Landschützer et al., 2014 GBC; Rödenbeck et al., 2015, BG)

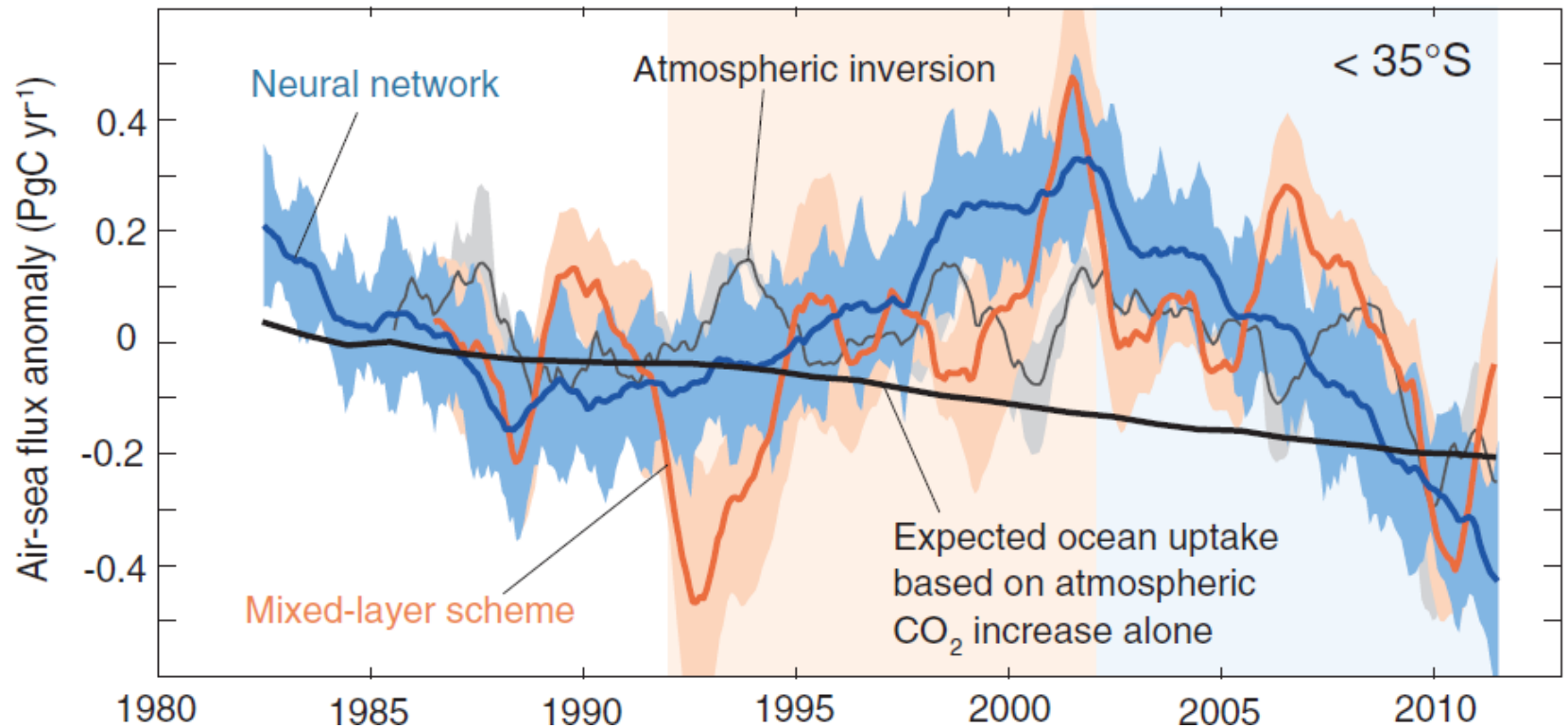
Mean surface ocean pCO₂ (2000-2009)



Data-based mapping of the ocean carbon sink provides **priors for atmospheric inversion, thus aiding quantification of the land sink**

(Van der Laan et al., 2014; Jones et al., 2015; Rödenbeck et al., 2014, 2015).

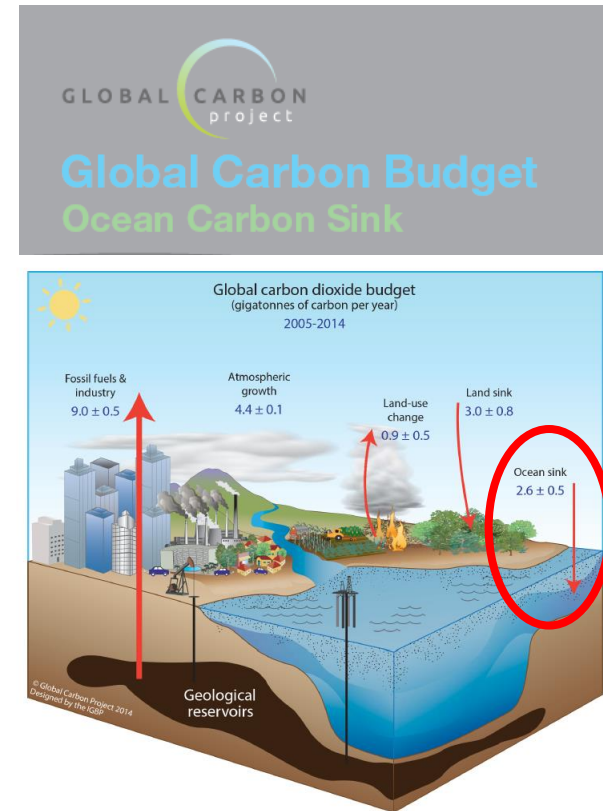
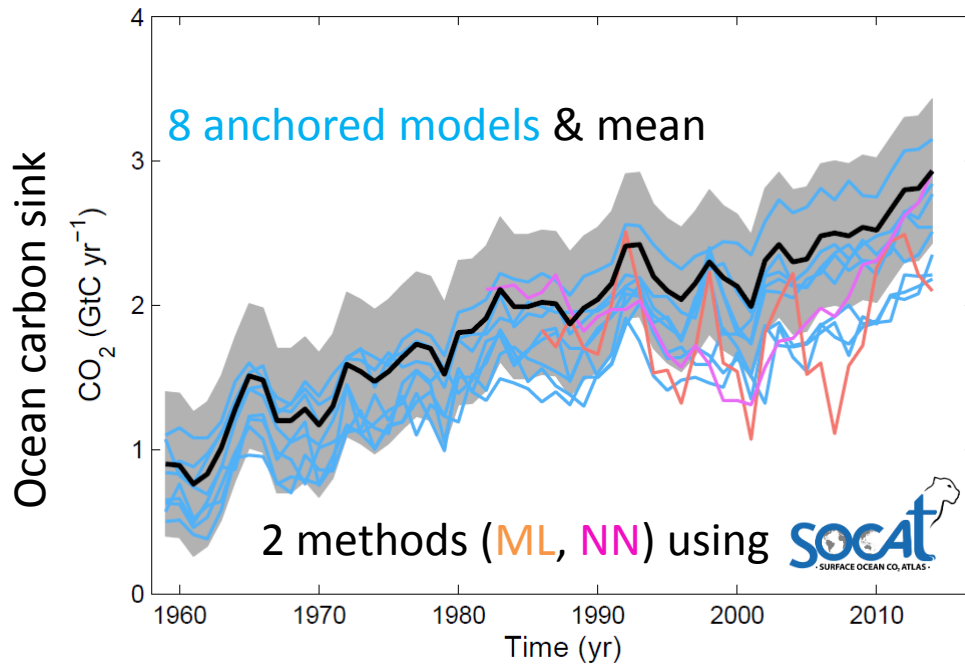
Reinvigoration of the Southern Ocean carbon sink



2 methods using SOCAT v2;
 $\Delta p\text{CO}_2$ trends dominate the sink variability;
 $\Delta p\text{CO}_2$ trends lead to a sink increase of >0.5 PgC/yr.

(Landschützer et al., 2015, Science 349 (6253): 1221-1224)

Ocean carbon sink in Global Carbon Budget



- Quantification of trends in the ocean carbon sink and ocean acidification,
- Quantification of the land carbon sink,
- Evaluation of ocean carbon models (Obs4MIP for CMIP),
- Large year-to-year variation in the ocean carbon sink,
- Models underestimate the variation in the ocean carbon sink.

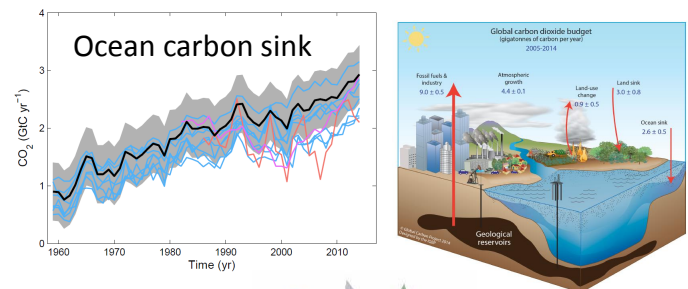
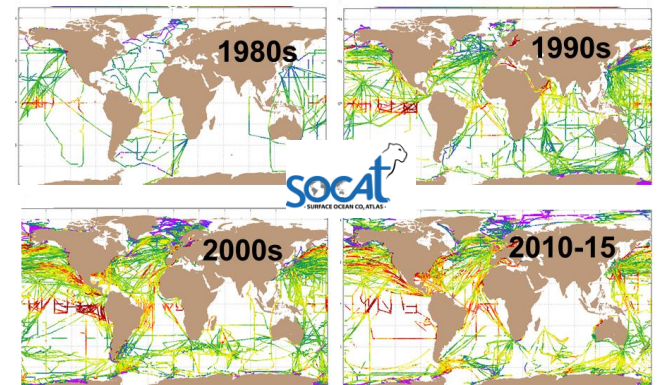
(Landschützer et al., 2014; Rödenbeck et al., 2014, 2015; Le Quéré et al., 2015)

Long-term in situ ocean carbon observations

‘No substitute exists for **adequate observations**.’

‘Models will evolve and improve, but, without data, will be untestable, and observations not taken today will be lost forever.’

‘Today’s climate models will likely prove of little interest in 100 years. **But adequately sampled, carefully quality controlled and archived data** for key elements of the climate system will be useful indefinitely.’



Wunsch et al. (2013) PNAS 110 (12) 4435-4436;
Bryden, H., 2014 Challenger Medal Lecture;
Bakker et al., 2016 in press; Le Quéré et al., 2015.



COP21

Acknowledgements

SOCAT has >> 100 contributors and numerous funding agencies. Contribute to and/or use these products.

Acknowledge the **contribution of the data providers**, e.g. by invitation to co-authorship, notably in **regional studies**, and by citation of relevant scientific publications.

V5 Data upload ends 15 January 2017 & V5 QC ends 31 March 2017.

SOCAT needs **quality controllers!**

User feedback essential.

Sustained funding for data collection and synthesis is key. d.bakker@uea.ac.uk

