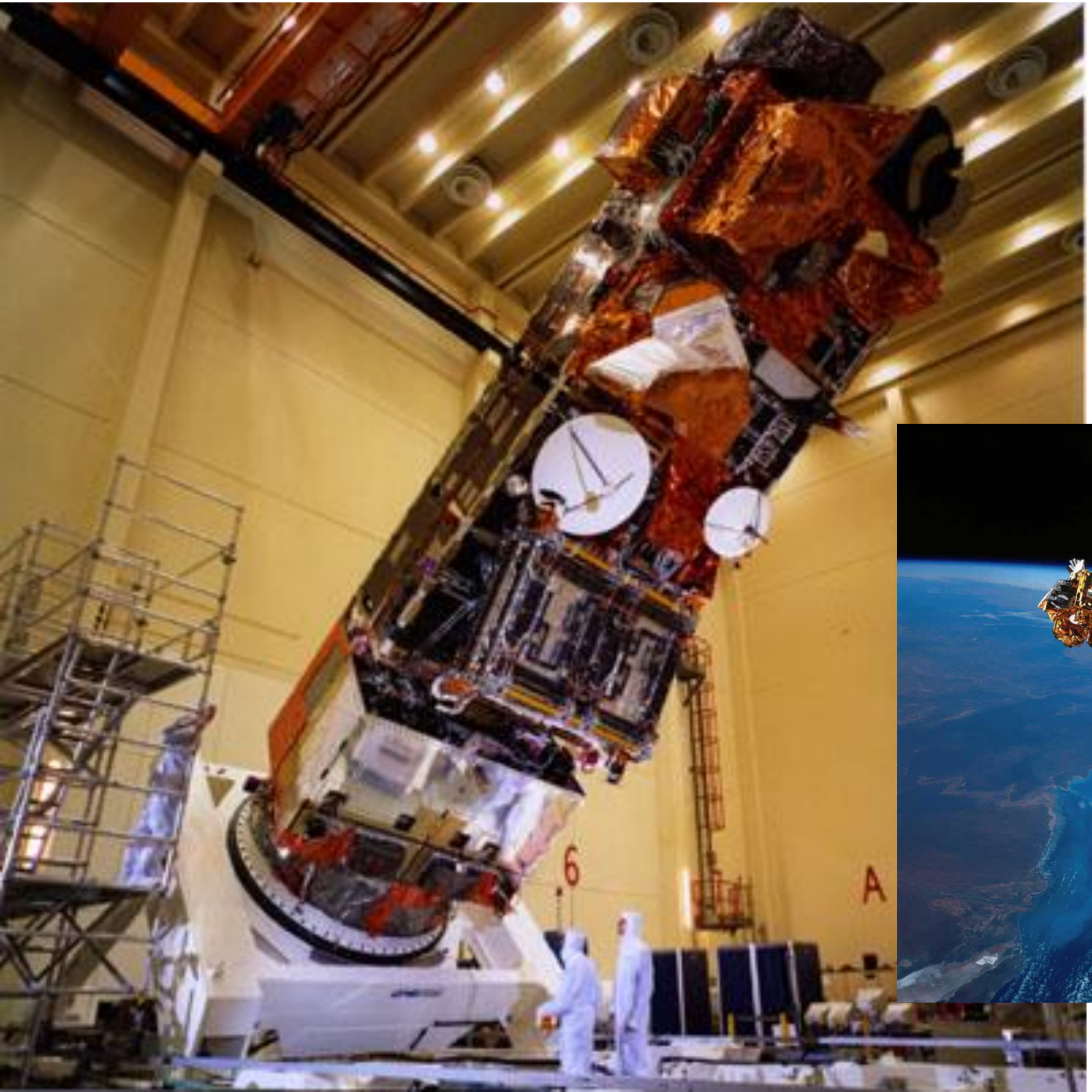
OceanFlux Greenhouse Gases Evolution

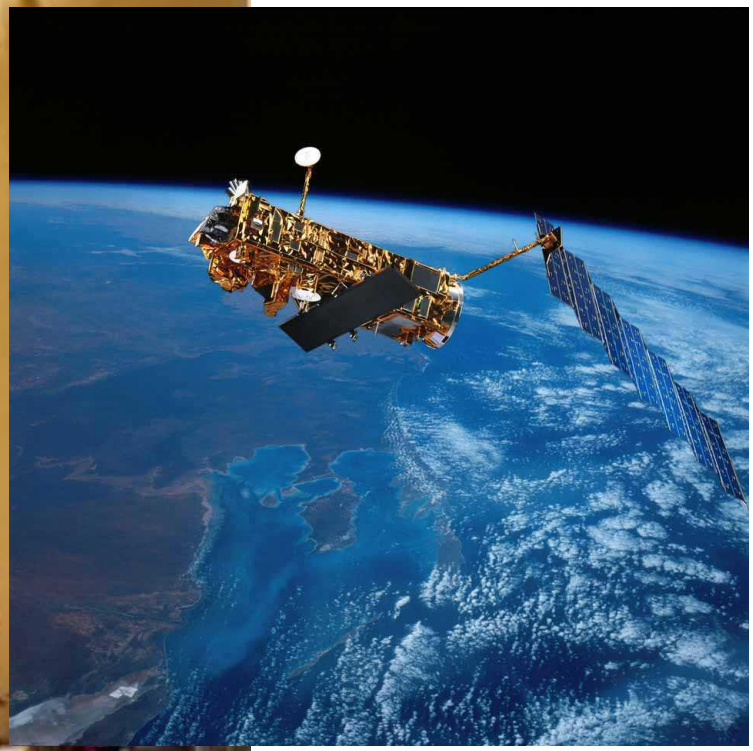
Jamie Shutler, David Woolf, Andy Watson, Jacek Piskozub, Bertrand Chapron, Phil Nightingale, Lonneke Goddijn-Murphy, Ute Schuster, Fanny Girard-Ardhuin, Jean-Francois Piolle, Mark Warren, Antoine Grouazel, Peter Land, Ian Ashton

oceanflux evolution
support to science element

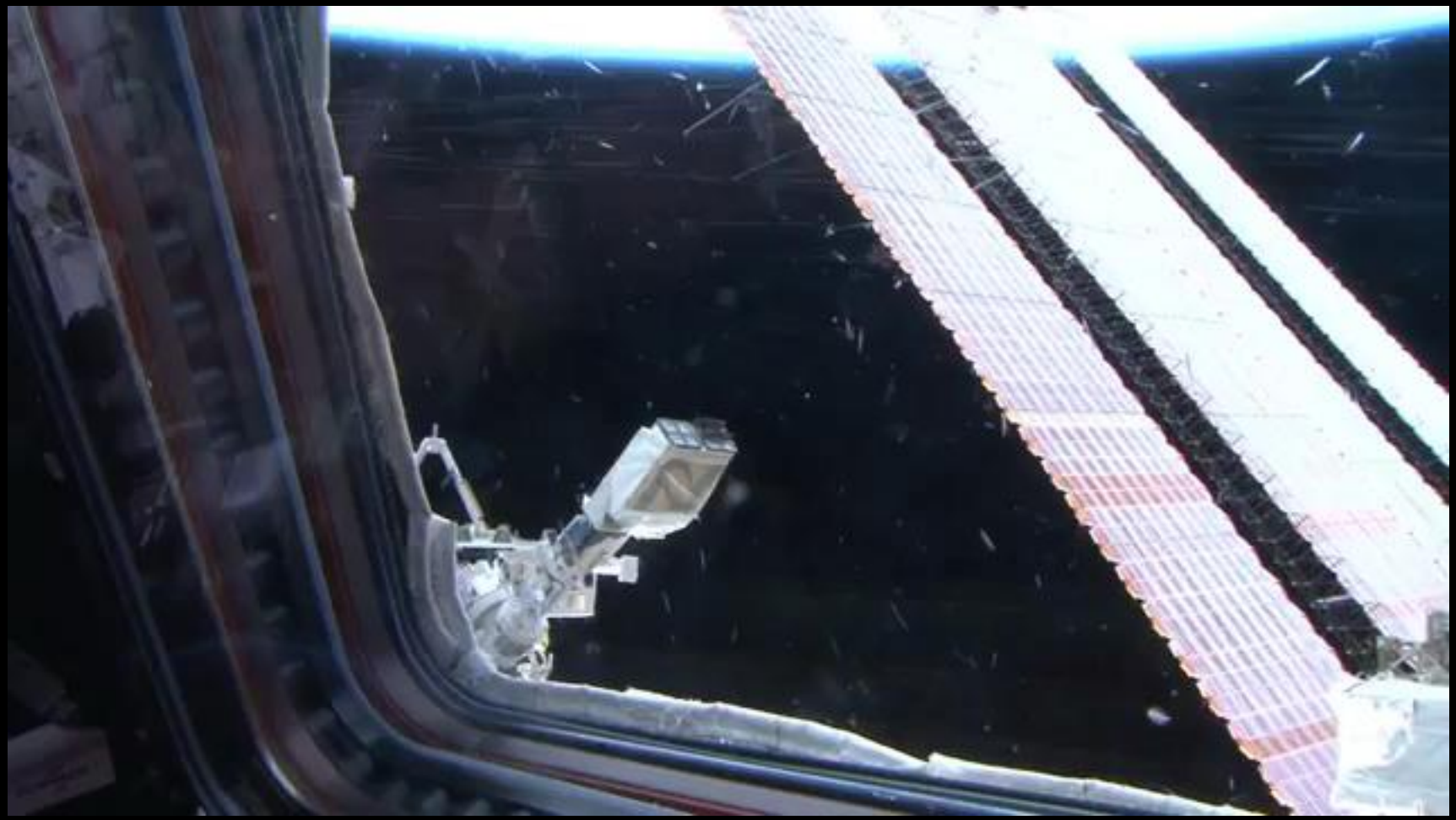
PML Plymouth Marine Laboratory

Project endorsed by






24
DTC-8



OceanFlux Initiative

Reinforce scientific collaboration between ESA and international SOLAS.

Fostering collaboration between different scientific communities.

First phase was developed in close collaboration with international SOLAS.

oceanflux evolution

support to science element

OceanFlux Initiative

Reinforce scientific collaboration between ESA and international SOLAS.

Fostering collaboration between different scientific communities.

First phase was developed in close collaboration with international SOLAS.

OceanFlux has two generic aims:

- Support development of novel products.

- Facilitate and advance integration of Earth observation data into SOLAS process studies.

oceanflux evolution

support to science element

OceanFlux Initiative

Reinforce scientific collaboration between ESA and international SOLAS.

Fostering collaboration between different scientific communities.

First phase was developed in close collaboration with international SOLAS.

OceanFlux has two generic aims:

- Support development of novel products.

- Facilitate and advance integration of Earth observation data into SOLAS process studies.

Current project is called OceanFlux Greenhouse Gases Evolution

oceanflux evolution
support to science element

Aim

OceanFlux Greenhouse Gases *Evolution*:

- *Generate and demonstrate the impact of improved estimates of air-sea CO_2 and other atmosphere-ocean gas fluxes using EO data for use by SOLAS and other air-sea gas flux communities.*

- 22 specific requirements from ESA including software development, scientific studies and outreach.

oceanflux evolution
support to science element

Advancements in air-sea transfer relationships and understanding

JOURNAL OF GEOPHYSICAL RESEARCH
Oceans
AN AGU JOURNAL

JGR

Explore this journal >

Space-based retrievals of air-sea gas transfer velocities using altimeters: Calibration for dimethyl sulfide

Lonneke Goddijn-Murphy ✉, David K. Woolf, Christa Marandino

First published: 24 August 2012 Full publication history

DOI: 10.1029/2011JC007535 View/save citation

Cited by: 1 article Citation tools

View issue TOC
Volume 117, Issue C8
August 2012

Advancements in air-sea transfer relationships and understanding

JOURNAL OF GEOPHYSICAL RESEARCH

ELSEVIER

Remote Sensing of Environment

Volume 139, December 2013, Pages 1–5

Improvements to estimating the air–sea gas transfer velocity by using dual-frequency, altimeter backscatter

Lonneke Goddijn-Murphy[a], David K. Woolf[b], Bertrand Chapron[c], Pierre Queffeulou[c]

Show more

http://dx.doi.org/10.1016/j.rse.2013.07.026

Get rights and content

Highlights

Advancements in air-sea transfer relationships and understanding

JOURNAL OF GEOPHYSICAL RESEARCH
Oceans

JGR

ELSEVIER

Remote Sensing of Environment

Volume 139, December 2013, Pages 1–5

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

10.1002/2015JC011096

Key Points:

- The air-sea gas transfer model presented is consistent with data on a diverse set of gases
- Bubble-mediated air-sea gas transfer cannot be ignored in strong winds
- How the void fraction of bubble plumes could affect air-sea gas transfer velocity is discussed

A reconciliation of empirical and mechanistic models of the air-sea gas transfer velocity

Lonneke Goddijn-Murphy[1], David K. Woolf[2], Adrian H. Callaghan[3], Philip D. Nightingale[4], and Jamie D. Shutler[5]

[1]ERI, University of the Highlands and Islands, Inverness, UK, [2]ICIT, Heriot-Watt University, Stromness, UK, [3]Scripps Institution of Oceanography, La Jolla, California, USA, [4]Plymouth Marine Laboratory, Plymouth, UK, [5]Centre for Geography, Environment and Society, University of Exeter, Penryn, UK

Advancements in air-sea transfer relationships and understanding

JOURNAL OF GEOPHYSICAL RESEARCH
Oceans
JGR

Remote Sensing of Environment
Volume 139, December 2013, Pages 1–5

AGU PUBLICATIONS

AGU PUBLICATIONS
JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
10.1002/2013JC009412

Impact of wind waves on the air-sea fluxes: A coupled model

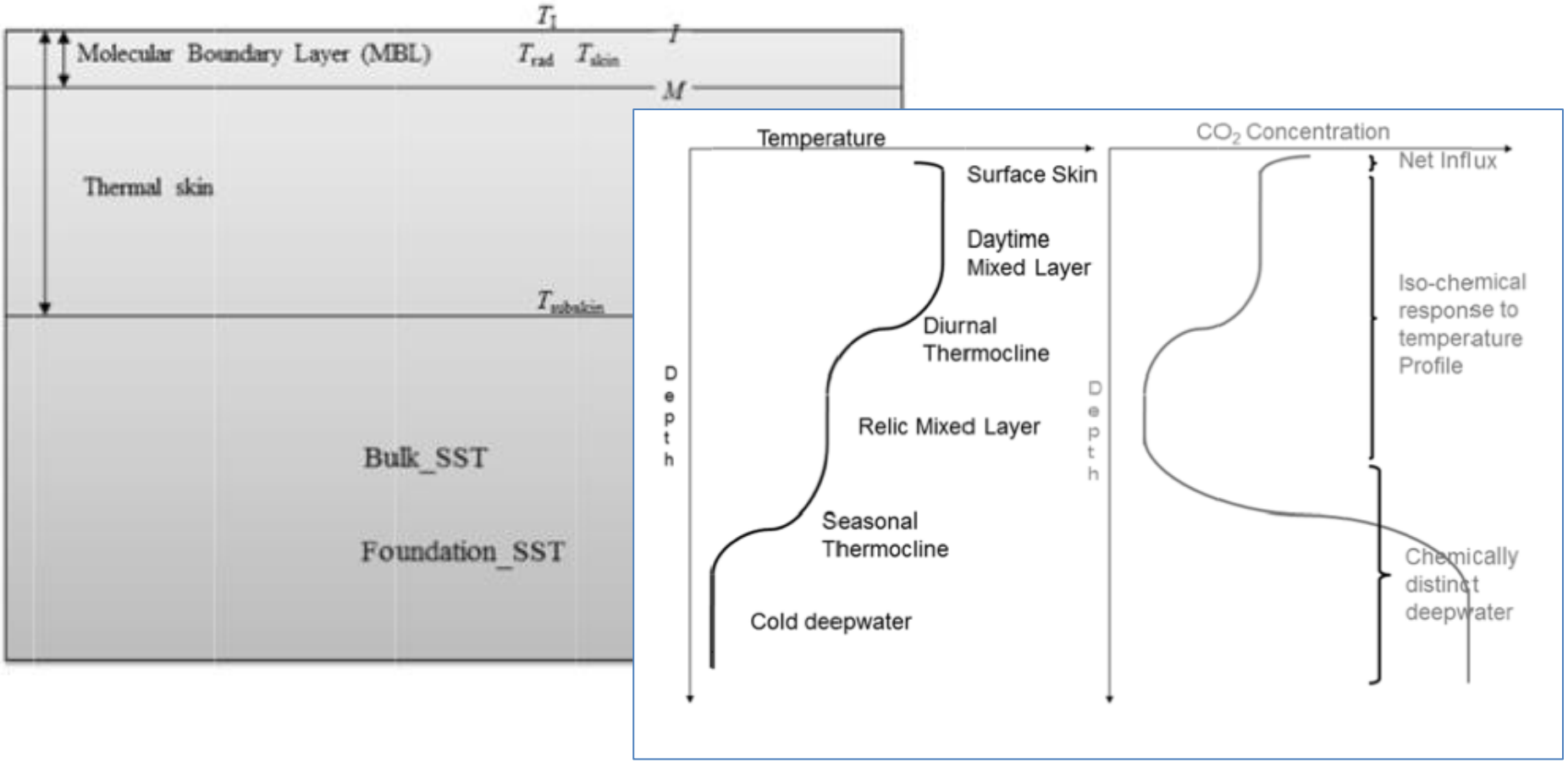
V. Kudryavtsev[1], B. Chapron[1,2], and V. Makin[3]

[1]Satellite Oceanography Laboratory, Russian State Hydrometeorological University (RSHU), St. Petersburg, Russia, [2]Laboratoire d'Océanographie Spatiale, Ifremer, Plouzane, France, [3]Royal Netherlands Meteorological Institute, De Bilt, Netherlands

Key Point:
- New wind-over-wave-coupling model

Correspondence to:

Consolidated description of temperature and salinity handling within gas flux calculations



Woolf, D. K., Land, P. E., Shutler, J. D., Goddijn-Murphy, L. M., Donlon, C. J. (2016) On the calculation of air-sea fluxes of CO2 in the presence of temperature and salinity gradients, *Journal of Geophysical Research.*

Climatology of fCO_2 normalised to 2010

Ocean Sci., 11, 519–541, 2015
www.ocean-sci.net/11/519/2015/
doi:10.5194/os-11-519-2015

Ocean Science Open Access

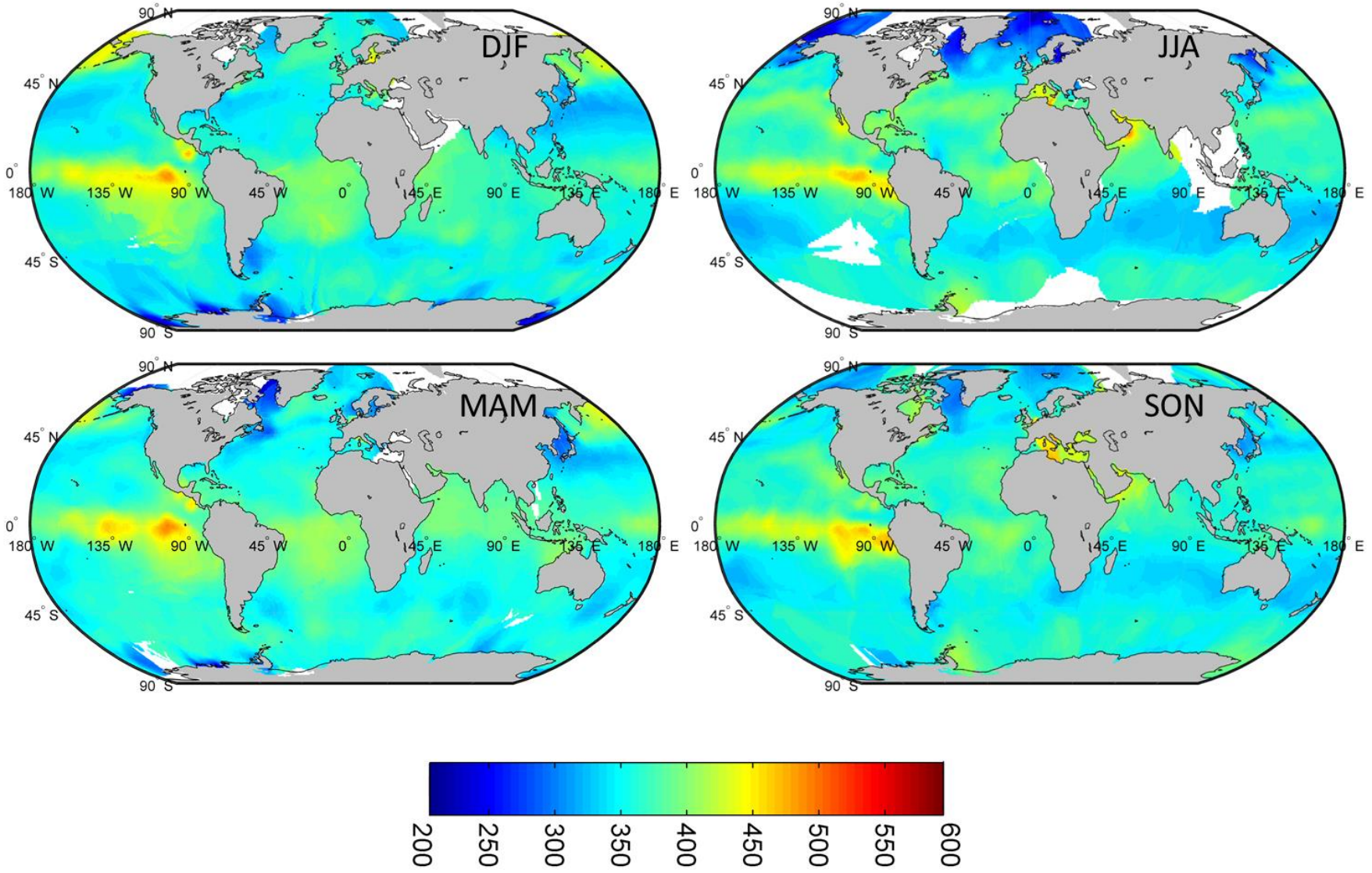
The OceanFlux Greenhouse Gases methodology for deriving a sea surface climatology of CO_2 fugacity in support of air–sea gas flux studies

L. M. Goddijn-Murphy[1], D. K. Woolf[2], P. E. Land[3], J. D. Shutler[4], and C. Donlon[5]

[1]ERI, University of the Highlands and Islands, Ormlie Road, Thurso, UK
[2]ICIT, Heriot-Watt University, Stromness, UK
[3]Plymouth Marine Laboratory, Prospect Place, Plymouth, UK
[4]University of Exeter, Centre for Geography, Environment and Society, Penryn, Cornwall, UK
[5]European Space Agency/ESTEC, Noordwijk, the Netherlands

Correspondence to: L. M. Goddijn-Murphy (lonneke.goddijn-murphy@uhi.ac.uk)

Climatology of fCO_2 normalised to 2010



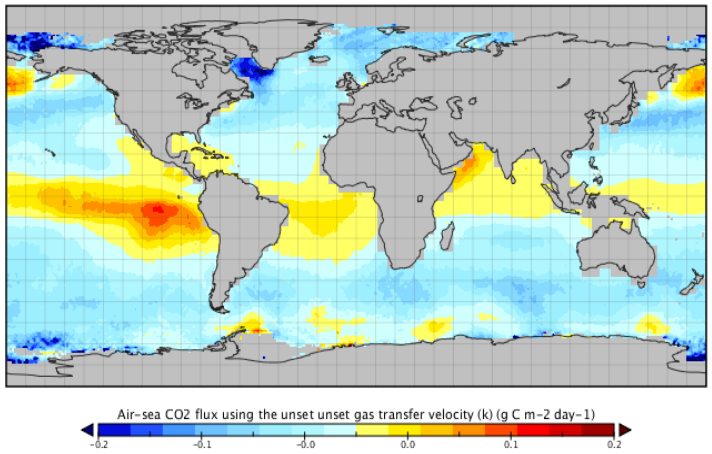
mean $f_{CO2,cl}$ (µatm) from SOCAT V2 (std of monthly mean < 25)

FluxEngine – air-sea gas flux toolbox

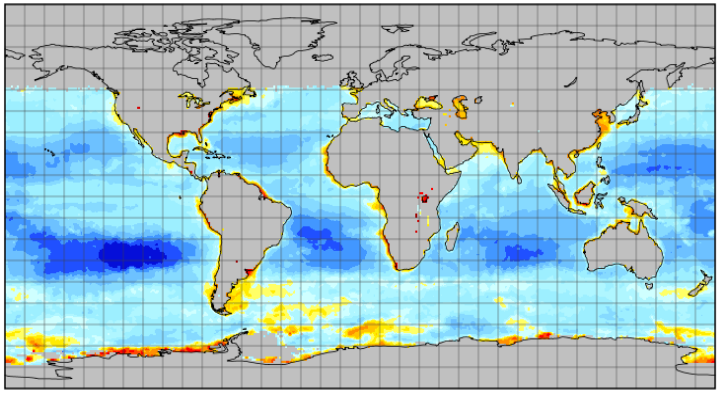
Toolbox developed for community use:

- Open source license (python and PERL based).
- Standard NetCDF data input and output.
- Net flux tool with traceable land/ocean/basin templates.
- User configurable gas flux calculation.
- Extensively verified using published data.

oceanflux evolution
support to science element



Example mean daily flux output



Example process indicator layer output using ESA Climate Change Indices chl-a

Shutler, J. D., Piolle, J-F., Land, P., Woolf, D. K., Goddijn-Murphy L.,, Paul, F., Girard-Ardhuin, F., Chapron, B., Donlon, C. J., (2016) Flux Engine: A flexible processing system for calculating air-sea carbon dioxide gas fluxes and climatologies, *Journal of Atmospheric and Oceanic Technology.*

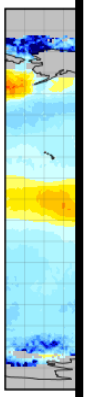
Flux

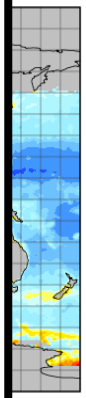
Toolbo

- Op
- Sta
- Net
- Use
- Ext

flux evolution

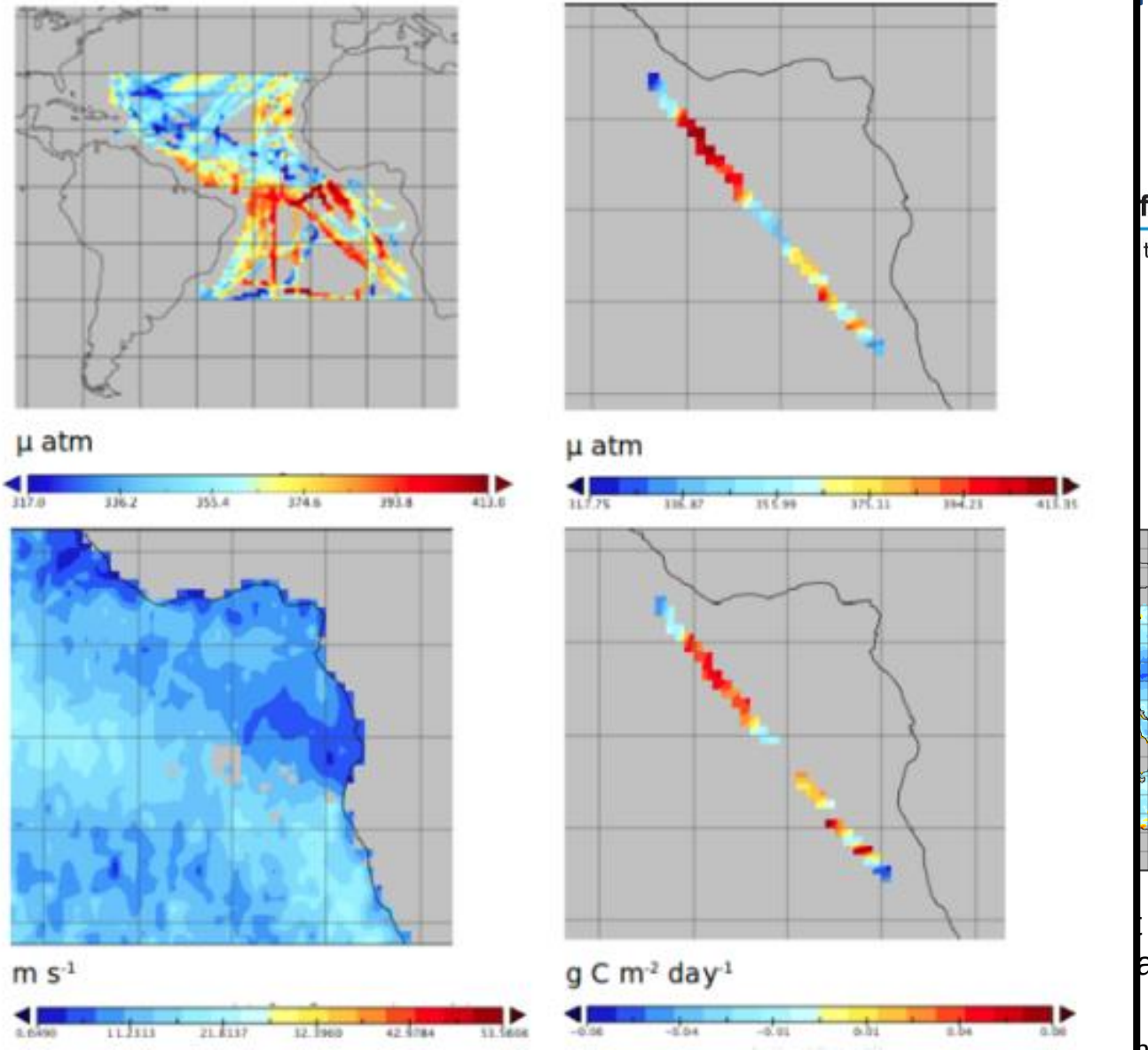
to science element





using

a



Shutler, J. , B., Donlon, C. J., (201 nd climatologies, *Journal of Atmospheric and Oceanic Technology.*

FluxEngine – air-sea gas flux toolbox

Toolbox developed for community use:

Software toolbox available for free on github

Now being used for:

1. Research:
   - Two ESA projects.
   - Three PhD projects (2xUK, 1xPoland).
   - Three UK funded research projects (2xNERC, Royal Society Fellowship).
   - To be used to support ICOS (within EU H2020 RINGO).
1. Teaching:
   - One undergraduate degree (Computer Science at Maastricht University, The Netherlands).

Example mean daily flux output

ESA Climate Change Indices chl-a

Shutler, J. D., Piolle, J-F., Land, P., Woolf, D. K., Goddijn-Murphy L.,, Paul, F., Girard-Ardhuin, F., Chapron, B., Donlon, C. J., (2016) Flux Engine: A flexible processing system for calculating air-sea carbon dioxide gas fluxes and climatologies, *Journal of Atmospheric and Oceanic Technology.*

FluxEngine – air-sea gas flux toolbox

Toolbox developed for community use:

Software toolbox available for free on github

Now being used for:

1. Research:
   - Two ESA projects.
   - Three PhD projects (2xUK, 1xPoland).
   - Three UK funded research projects (2xNERC, Royal Society Fellowship).
   - To be used to support ICOS (within EU H2020 RINGO).
1. Teaching:
   - One undergraduate degree (Computer Science at Maastricht University, The Netherlands).

http://www.oceanflux-ghg.org/Products/FluxEngine

climatologies, *Journal of Atmospheric and Oceanic Technology.*

Involvement and provided data for the SOCOM community inter-comparison

Biogeosciences, 12, 7251–7278, 2015
www.biogeosciences.net/12/7251/2015/
doi:10.5194/bg-12-7251-2015

Biogeosciences Open Access EGU

Data-based estimates of the ocean carbon sink variability – first results of the Surface Ocean pCO_2 Mapping intercomparison (SOCOM)

C. Rödenbeck[1], D. C. E. Bakker[2], N. Gruber[3], Y. Iida[4], A. R. Jacobson[5], S. Jones[6], P. Landschützer[3], N. Metzl[7], S. Nakaoka[8], A. Olsen[9], G.-H. Park[10], P. Peylin[11], K. B. Rodgers[12], T. P. Sasse[13], U. Schuster[6], J. D. Shutler[6], V. Valsala[14], R. Wanninkhof[15], and J. Zeng[8]

Assessing the importance on rain on global and regional air-sea gas fluxes

Use FluxEngine to estimate the impact of rain on global estimations of CO2 exchange between the ocean and the atmosphere.

Enhanced gas transfer, *k*, and **Direct deposition**, F_{DIC} applied to multi-year global analysis.

Effective transfer rate calculated using a non-linear relationship with wind:

$$k_{total} = k_{wind} + [1 - exp(a\beta)]\, k_{rain}$$

Transfer depends on rain rate, Rn and the partial pressure of CO_2 in the air, pCO_{2A}

$$F_{DIC} = Rn\ \alpha\ pCO_{2A}$$

Rain terms increase the annual global net CO_2 sink by up to 6%.

Regionally it can larger (e.g. 15% increase in Pacific annual net sink).

Monthly regional net fluxes can be modulated by > ±50%.

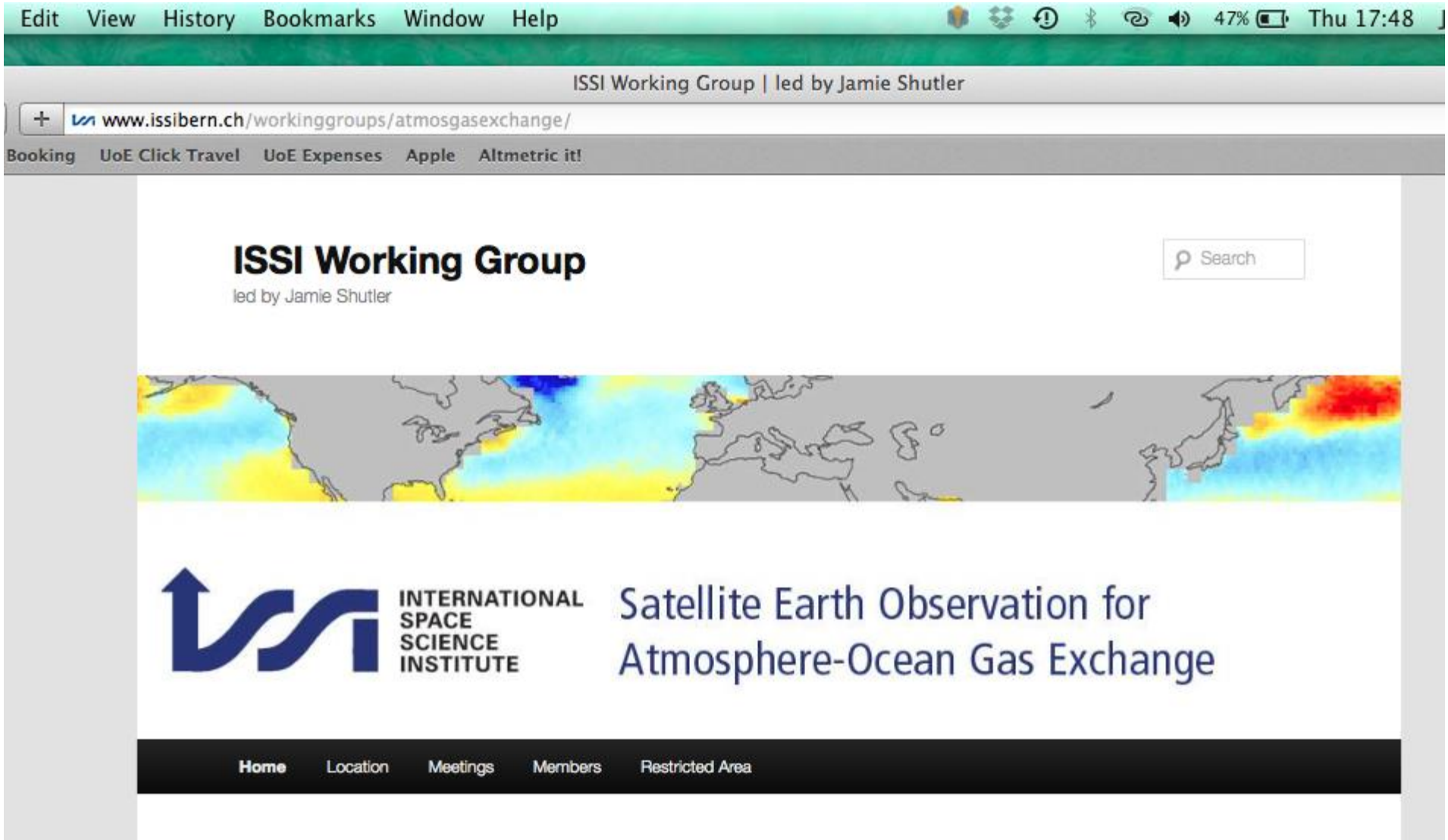
Ashton, I. G., Shutler, J. D., Land, P. E., Woolf, D. K., Quartly, G. (in-press) A sensitivity analysis of the impact of rain on regional and global sea-air fluxes of CO_2, *PlosOne.*

Other recent progress and current research

- FluxEngine version 2 software now released:
  - Now includes CH_4, N_20, rain parameterisations and handling for polar stereographic data.
- Re-analysed SOCATv3 dataset to a common SST.
  - Software and data will become available later this year.

- Initial results from an Arctic study using new satellite capabilities – between ice gas exchange.
- Developing a calibrated bubble-mediated gas transfer relationship.

International Space Science Institute (ISSI) Working Group



sentinel-3

esa

ESA | OBSERVING THE EARTH | COPERNICUS | SENTINEL-3

The bigger picture
· Introducing Sentinel-3

Applications
· Oceans of change
· Over land

About the mission
· Facts and figures
· Satellite constellation
· Instruments
· About the launch

• Meet the team

Operations and data
· Data flow
· Data products

Multimedia

ESA > Our Activities > Observing the Earth > Cop

Carbon flux

Access the video

SENTINEL-3 AND THE OCEAN CARBON CONU

BBC | Sign in | News | Sport | Weather | iPlayer | TV

NEWS

Home | UK | World | Business | Politics | Tech | Science | Health | Education | E

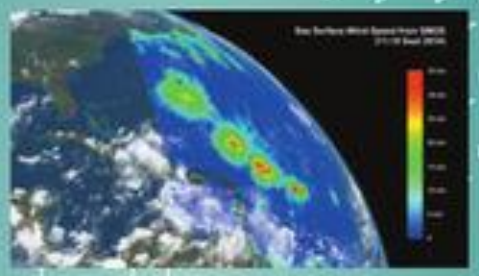
Science & Environment

How Northern European waters soak up carbon dioxide

By Jonathan Amos
BBC Science Correspondent

25 February 2016 | Science & Environment

Colder, stormy waters at higher latitudes tend to take up most carbon dioxide



SCIENCE WORKSHOP

6 - 9 Sept. 2016

BREST | FRANCE

Scientists and engineers are invited to attend the Science Workshop which will allow the project and other international teams to present their recent advances, it will also provide a forum for the community to plan future aims and collaborations.

EVOLUTION

The OceanFlux Greenhouse Gases project

Aims to improve the quantification of air-sea exchanges of greenhouse gases, of prime importance in the climate system.

esa stse

oceanflux evolution

support to science element

Published OceanFlux advances

Advances in methods, tools, assessment, community partnerships and data provision.

Journal publications

1. Shutler JD, Quartly GD, Donlon CJ, Sathyendranath S, Platt T, Chapron B, Johannessen JA, Girard-Ardhuin F., Nightingale PD, Woolf DK, Høyer JL (2016), Progress in satellite remote sensing for studying physical processes at the ocean surface and its borders with the atmosphere and sea ice, *Progress in Physical Geography*, 40: 215-246, doi:10.1177/0309133316638957. link
2. Shutler JD, Land PE, Piolle J-F, Woolf DK, Goddijn-Murphy L, Paul F, Girard-Ardhuin F, Chapron B, Donlon CJ (2016), FluxEngine: a flexible processing system for calculating atmosphere-ocean carbon dioxide gas fluxes and climatologies, *Journal of Atmospheric and Oceanic Technology*, doi: 10.1175/JTECH-D-14-00204.1. link
3. Woolf DK, Land PE, Shutler JD, Goddijn-Murphy LM, Donlon CJ (2016), On the calculation of air-sea fluxes of CO2 in the presence of temperature and salinity gradients, *Journal of Geophysical Research-Oceans*, doi: 10.1002/2015JC011427. link
4. Goddijn-Murphy L, Woolf DK, Callaghan AH, Nightingale PD, Shutler JD (2015), A reconciliation of empirical and mechanistic models of the air-sea gas transfer velocity, *Journal of Geophysical Research-Oceans*, doi:10.1002/2015JC011096. link
5. Goddijn-Murphy, L.M., D.K. Woolf, P.E. Land, J.D. Shutler, C.J. Donlon (2015), The OceanFlux Greenhouse Gases methodology for deriving a sea surface climatology of CO_2 fugacity in support of air-sea gas flux studies, *Ocean Science*, 11, 519-541, doi:10.5194/os-11-519-2015. link
6. Rödenbeck, C., Bakker, D. C. E., Gruber, N., Iida, Y., Jacobson, A. R., Jones, S., Landschützer, P., Metzl, N., Nakaoka, S., Olsen, A., Park, G.-H., Peylin, P., Rodgers, K. B., Sasse, T. P., Schuster, U., Shutler, J. D., Valsala, V., Wanninkhof, R., and Zeng, J. (2015) Data-based estimates of the ocean carbon sink variability – first results of the Surface Ocean pCO2 Mapping intercomparison (SOCOM), *Biogeosciences*, 12, 7251-7278, doi:10.5194/bg-12-7251-2015. link
7. Kudryavtsev, V., B. Chapron, and V. Makin (2014), Impact of wind waves on the air-sea fluxes: A coupled model, *Journal of Geophysical Research - Oceans*, 119, 1217–1236, doi:10.1002/2013JC009412. link
8. Land, P.E., J.D. Shutler, R.D. Cowling, D.K. Woolf, P. Walker, H.S. Findlay, R.C. Upstill-Goddard, C.J. Donl (2013) Climate change impacts on sea–air fluxes of CO_2 in three Arctic seas: a sensitivity study using Ea observation, *Biogeosciences*, 10, 8109-8128, doi:10.5194/bg-10-8109-2013. link
9. Goddijn-Murphy, L., D.K. Woolf, B. Chapron, P. Queffeulou (2013) Improvements to estimating the air–sea g transfer velocity by using dual-frequency, altimeter backscatter, *Remote Sensing of Environment*, 139, 1· doi:10.1016/j.rse.2013.07.026. link
10. Goddijn-Murphy, L., D.K. Woolf, C. Marandino (2012) Space-based retrievals of air-sea gas transfer velocities using altimeters: Calibration for dimethyl sulfide, *Journal of Geophysical Research*, 117, C08028, doi:10.1029/2011JC007535. link

oceanflux evolution

support to science element

Published OceanFlux advances

Advances in methods, tools, assessment, community partnerships and data provision.

Journal publications

1. Shutler JD, Quartly GD, Donlon CJ, Sathyendranath S, Platt T, Chapron B, Johannessen JA, Girard-Ardhuin F., Nightingale PD, Woolf DK, Høyer JL (2016), Progress in satellite remote sensing for studying physical processes at the ocean surface and its borders with the atmosphere and sea ice, *Progress in Physical Geography*, 40: 215-246, doi:10.1177/0309133316638957. link
2. Shutler JD, Land PE, Piolle J-F, Woolf DK, Goddijn-Murphy L, Paul F, Girard-Ardhuin F, Chapron B, Donlon CJ

That's it!

All of this work was only possible through collaborating with international community and through using EO, models and in situ in synergy.

All publications and data are freely available on the project website: wwww.oceanflux-ghg.org

Journal of Geophysical Research - Oceans, 119, 1217–1236, doi:10.1002/2013JC009412. link

8. Land, P.E., J.D. Shutler, R.D. Cowling, D.K. Woolf, P. Walker, H.S. Findlay, R.C. Upstill-Goddard, C.J. Donl (2013) Climate change impacts on sea–air fluxes of CO_2 in three Arctic seas: a sensitivity study using Ea observation, *Biogeosciences*, 10, 8109-8128, doi:10.5194/bg-10-8109-2013. link
9. Goddijn-Murphy, L., D.K. Woolf, B. Chapron, P. Queffeulou (2013) Improvements to estimating the air–sea g transfer velocity by using dual-frequency, altimeter backscatter, *Remote Sensing of Environment*, 139, 1· doi:10.1016/j.rse.2013.07.026. link
10. Goddijn-Murphy, L., D.K. Woolf, C. Marandino (2012) Space-based retrievals of air-sea gas transfer velocities using altimeters: Calibration for dimethyl sulfide, *Journal of Geophysical Research*, 117, C08028, doi:10.1029/2011JC007535. link

oceanflux evolution

support to science element

International Space Science Institute (ISSI) Working Group