Handout

RU 3

Research Unit 3

Operational Systems

Helmholtz-Zentrum Geesthacht

Centre for Materials and Coastal Research

Content:

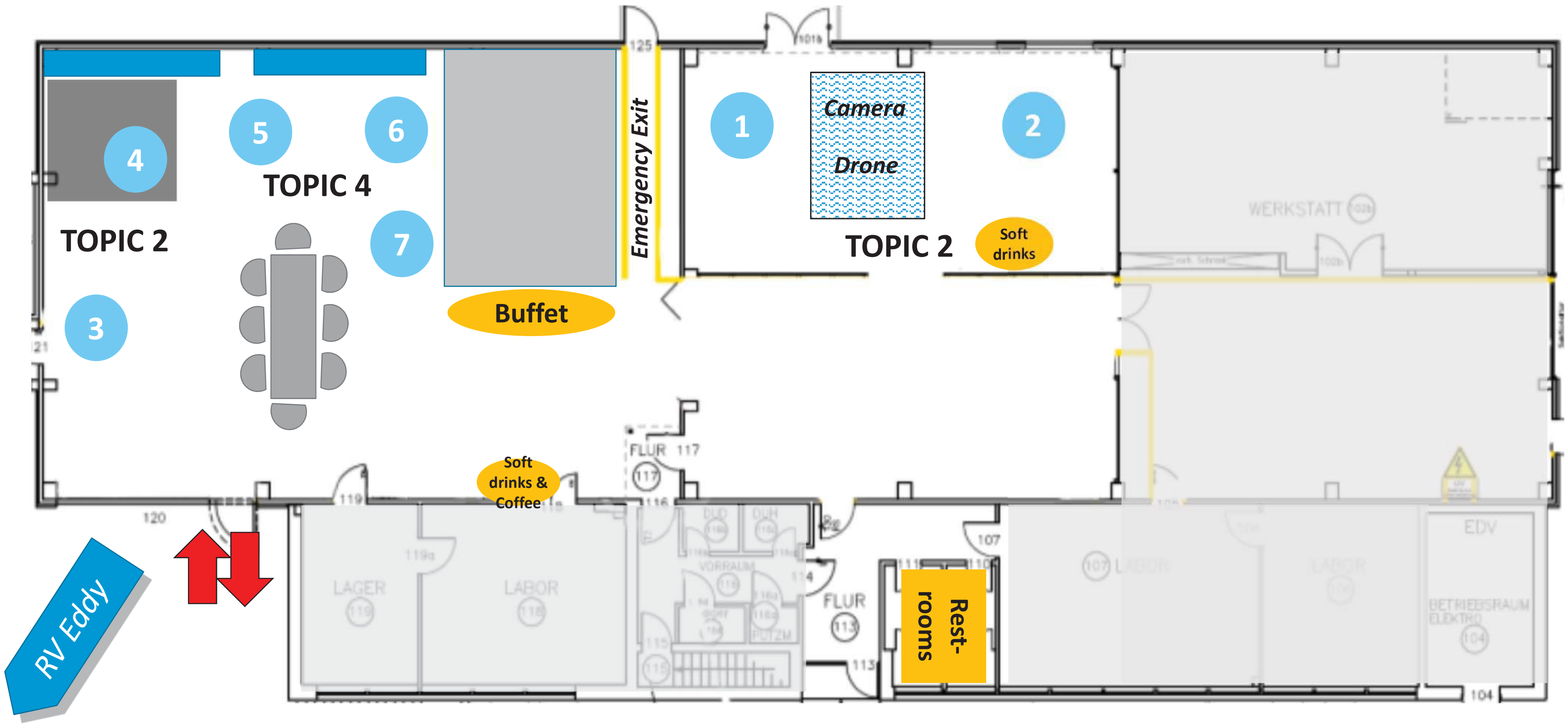
Hands-on presentations of instrument development and scientific applications:

- Small-scale physical processes
- COSYNA

Presentation COSYNA - Coastal Observing System for Northern and Arctic Seas

On-site visit RU3 *Operational Systems*

1. Submesoscale Turbulent Processes .... (Reiner Onken, Rüdiger Röttgers)
2. Sensing the Ocean with Marine Radars .... (Michael Streßer)
3. Glider observations .... (Lucas Merckelbach, Jeff Carpenter)
4. Sub-millimeter scale turbulent airflow .... (Marc Buckley)
5. FerryBox .... (Wilhelm Petersen)
6. High-Frequency Phytoplankton Observations .... (Jochen Wollschläger)
7. Coastal Suspended Particle Dynamics .... (Martin Hieronymi, Klas Ove Möller)



Observations and Modeling of Submesoscale Turbulent Processes

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Reiner Onken & Rüdiger Röttgers

The submesoscale wave band[1]

Properties
- between meso- and microscale
- forward energy cascade
- route to dissipation

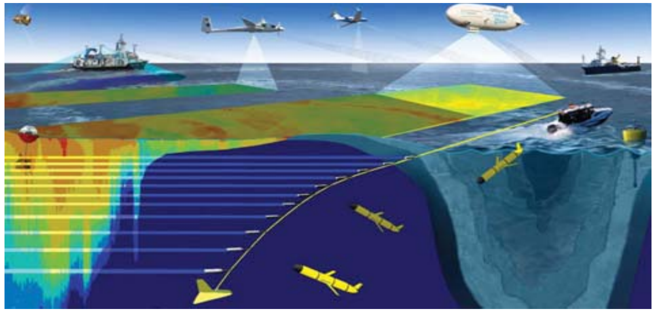
Features
- fronts, eddies, filaments
- various instability types
- internal waves

Scales and dynamics
- horiz. scales: 10 m → 10 km
- time scales: hours → days
- Ro 1 → 30

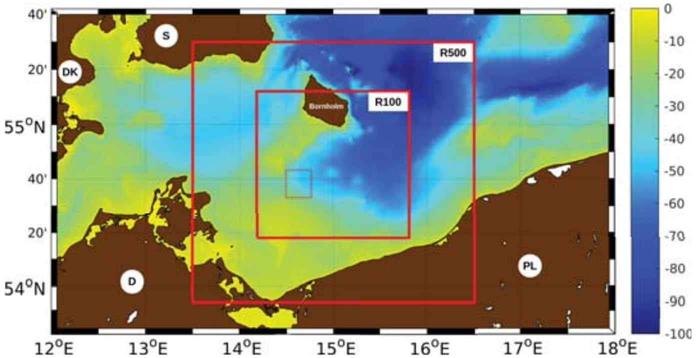
Relevance
- highly nonlinear
- strong vertical motion
- plankton growth

→ **submesoscale observations and modeling require high spatial and temporal resolutions**

Objectives and approach

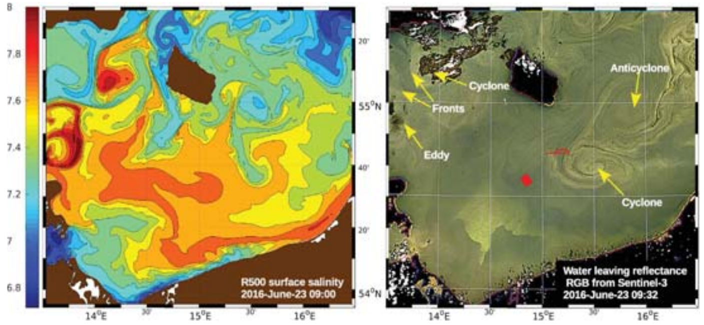


Expedition *Clockwork Ocean* (June 2016, Baltic Sea)
- advanced technology: CTD chain, zeppelin with cameras
- unprecedented spatial resolution: < 1m
- extremely high temporal resolution: 5 -50 Hz



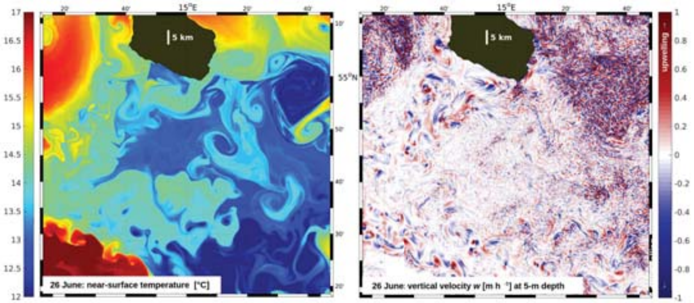
High–resolution numerical modeling: double – nesting[2]
- mesoscale environment: nest ROMS with 500-m resolution in operational model.
- submesoscale processes: second nest with 100-m resolution.

The mesoscale environment



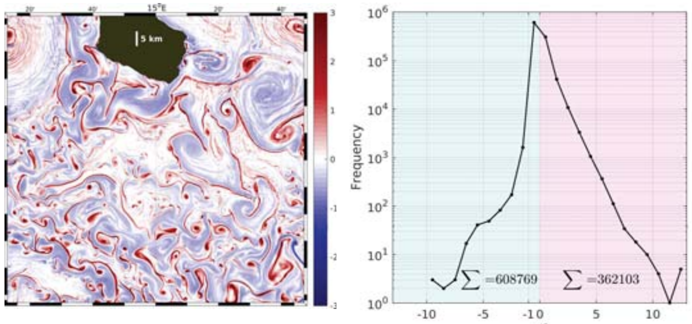
Good agreement between model and observations on 23 June 2016. Observed and modelled patterns are roughly in the same place.

Submesoscale processes



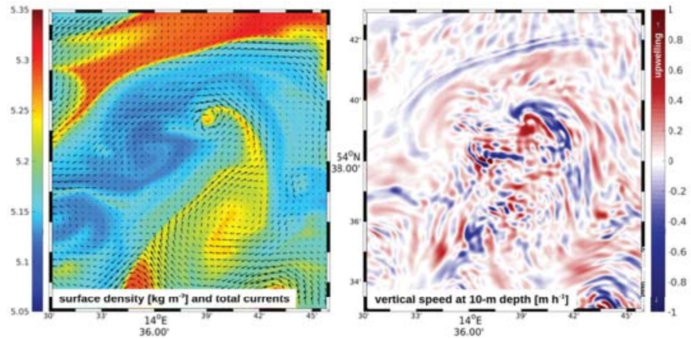
Tracer fields: resolution of narrow filaments (200 m) and small eddies (~ 1 km)

Vertical velocity: $-10 < w < 10$ m h^{-1} → plankton growth, nutrients



Relative vorticity
- biased distribution of relative vorticity
- $-17 < \zeta/f < 13$ → unbalanced flow, centrifugal instability

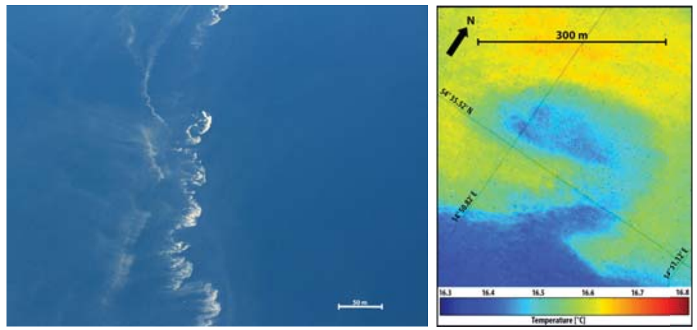
Life cycle of a submesoscale eddy



Successful modeling of the birth and decay of a 1-km eddy

Eddy-driven vertical motion creates stationary patchiness

Observations: fronts and submesoscale eddies



Cyanobacteria are aggregated at a submesoscale front

A very small eddy, observed by the zeppelin

Conclusion

- Unprecedented high-resolution observations and modeling of submesoscale processes with novel instrumentation
- First complete eddy life cycle from generation to decay
- Demonstrated coupling of physics and biogeochemistry

JPL · AWI · IOW · UCSB · UCLA · U.S. NAVAL RESEARCH LABORATORY

[1] McWilliams, 2016 [2] Berg, 2012

References

Observations and Modeling of Submesoscale Turbulent Processes

Reiner Onken, Rüdiger Röttgers

Berg, P. (2012) **Mixing in HBM**. *DMI Scientific Report*, 12-03, Danmarks Meteorologiske Institut, København, Denmark.

McWilliams, J. C. (2016**) Submesoscale currents in the ocean**. *Proceedings of the Royal Society* A, 472: 20160117, doi: http://dx.doi.org/10.1098/rspa.2016.0117.

Hoskins, B. J. (1982) **The mathematical theory of frontogenesis**. *Annual Reviews of Fluid Mechanics,* 14, 131 – 151.

Sensing the Ocean with Marine Radars

Michael Streßer, Ruben Carrasco, Marius Cysewski, Jörg Seemann and Jochen Horstmann

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

HZG's X-Band Doppler Radar

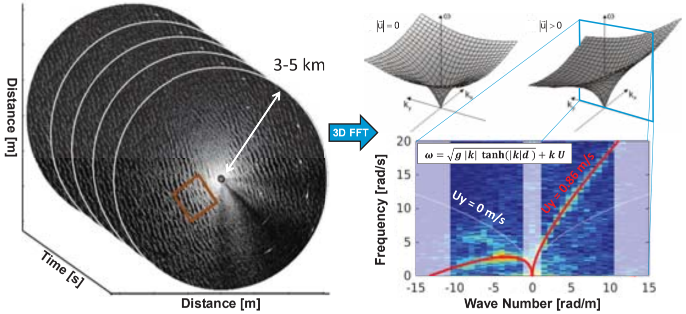

HZG's radar station at Sylt.

- A Dopplerized marine radar (X-Band) has been developed in collaboration with the Electrotechnical University of St. Petersburg, Russia
- Operation from platforms and moving vessels
- Simultaneous, remote measurements of surface winds, spectral wave parameters, surface currents[1] and coastal bathymetry.

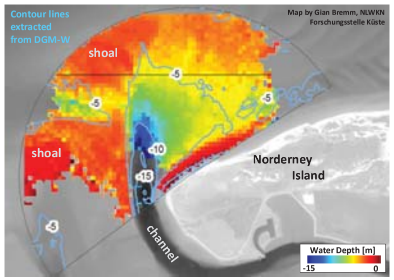
Surface Waves, Currents and Bathymetry

Spatio-temporal image sequence

Wavenumber-frequency spectrum



- Wave dispersion relationship depends on local water depth and local currents
- Long-term operational monitoring of waves[2,3] and currents[4,5] from land- or platform-based radar stations
- Doppler velocities are used to retrieve significant wave heights without external calibration[2,3]

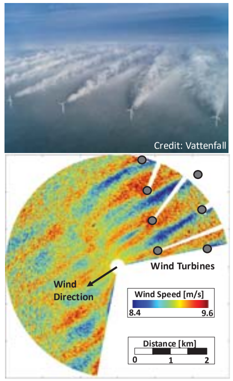


- Continuous monitoring of coastal erosion on time scales of hours to decades.
- Applicable from moderate wave conditions to severe storm conditions

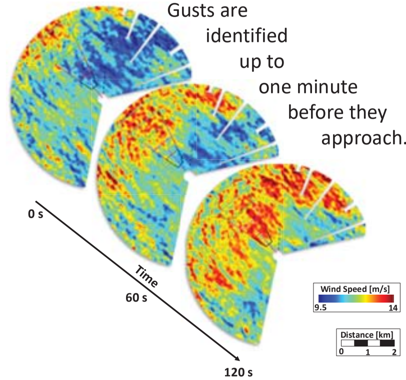
Surface Winds

- Surface winds are the main source of radar backscatter[6]
- Wind fields estimated in the spatial and temporal domain

Wind Farm Impacts



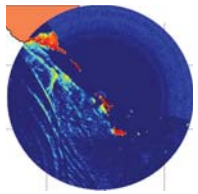
Wind Gusts



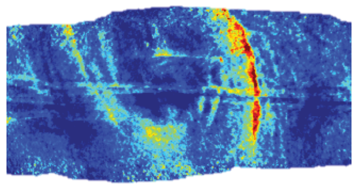
Surface Features

- Visualization of surface features via integration of geocoded radar backscatter intensity images
- Real-time locating and monitoring of e.g. internal waves or ocean fronts

Internal Waves

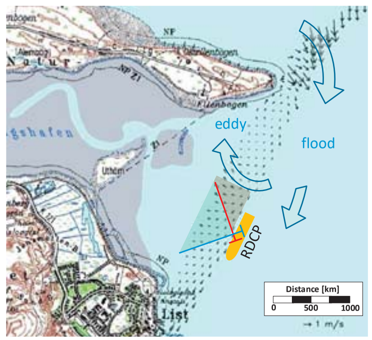


Submesoscale Eddy



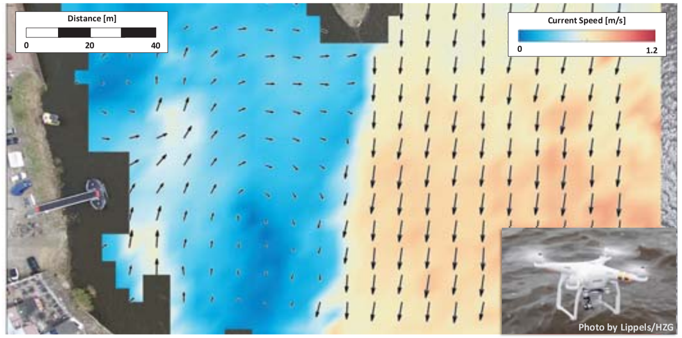
Radar Doppler Current Profiler (RDCP)

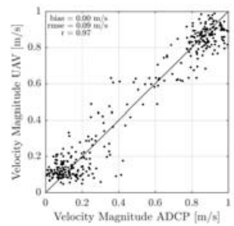

RV Ludwig Prandtl with two RDCP antennas.



- Velocity in line-of-sight
- Two radar antennas with fixed perpendicular view angles
- Current maps while vessel is moving

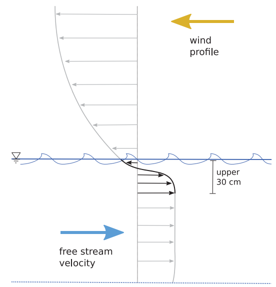
Application of Radar Methods to Airborne Video





- Radar methods for retrieving surface currents are applied to video imagery acquired by a quadcopter
- Proof-of-concept by comparisons to Acoustic-Doppler-Current-Profiler measurements[7]
- High-resolution current maps within minutes

- The upper water column is highly affected by wind shear, whereas acoustic instruments are usually "blind" near the boundary between water and atmosphere
- Vertical near-surface current shear deducted by analyzing different wave lengths



Conclusion

- **Successful development of a Dopplerized marine radar for ship- or land-based hydrography**
- **Measurements of waves, currents and bathymetry from platforms and moving vessels**
- **Locating and tracking of internal waves, ocean fronts and wind variations by real-time visualization of surface features**
- **Radar methods are applied to airborne video to retrieve high-resolution current maps**

Research Unit *Operational Systems*: Topic 2

[1]Horstmann et al. 2015, [2,3]Carrasco et al. 2017 a b, [4]Shen et al. 2016, [5]Huang et al. 2016, [6]Vicen-Bueno et al. 2013, [7]Streßer et al. 2017

References

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Michael Streßer, Ruben Carrasco, Marius Cysewski, Jörg Seemann, Jochen Horstmann

Horstmann, J., J.C. Nieto Borge, J. Seemann, R. Carrasco and B. Lund (2015) **Wind, Wave and Current retrieval utilizing X-Band Marine Radars**, Chapter 16 in Coastal Ocean Observing Systems, Elsevier, p.281-304.

Carrasco, R., Streßer, M., and Horstmann, J. (2017) **A simple method for retrieving significant wave height from Dopplerized X-band radar**. Ocean Sci., 13, 95-103, http://doi.org/10.5194/os-13-95-2017

Carrasco, R., J. Horstmann, and J. Seemann (2017) **Significant Wave Height Measured by Coherent X-Band Radar**. IEEE Trans. Geosci. Remote Sensing, 55(9), pp. 5355-5365, http://doi.org/10.1109/TGRS.2017.2706067.

Shen, C, W. Huang, E.W. Gill, R. Carrasco and J. Horstmann (2015) **An Algorithm for Surface Current Retrieval from X-band Marine Radar Images**. Remote Sens., Vol. 7, p. 7753-7767, http://doi.org/10.3390/rs70607753.

W. Huang, R. Carrasco, C. Shen, E. W. Gill and J. Horstmann (2016) **Surface Current Measurements Using X-Band Marine Radar With Vertical Polarization**, in IEEE Transactions on Geoscience and Remote Sensing, vol. 54, no. 5, pp. 2988-2997, http://doi.org/10.1109/TGRS.2015.2509781.

Vicen-Bueno, R., J. Horstmann, E. Terril, T. de Paolo, and J. Dannenberg (2013) **Real-Time Ocean Wind Vector Retrieval from Marine Radar Image Sequences Acquired at Grazing Angle**. J. Atmos. Oceanic Technol., Vol. 30, p. 127–139, http://doi.org/10.1175/JTECH-D-12-00027.1.

M. Streßer, R. Carrasco and J. Horstmann (2017) **Video-Based Estimation of Surface Currents Using a Low-Cost Quadcopter**, in IEEE Geoscience and Remote Sensing Letters, vol. PP, no. 99, pp. 1-5, http://doi.org/10.1109/LGRS.2017.2749120.

Turbulence observations from ocean gliders: Arctic Ocean heat fluxes

Lucas Merckelbach, Jeff Carpenter, Larissa Schultze, Benjamin Scheifele, Stephanie Waterman

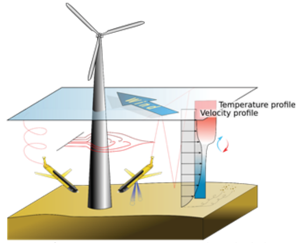
Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Turbulence in coastal oceans

Turbulence governs important processes in the coastal ocean:

- Heat fluxes and stratification
- Nutrient dynamics and phytoplankton growth
- Sediment resuspension and transport

Glider in the field



Schematic of processes investigated and glider sampling modes

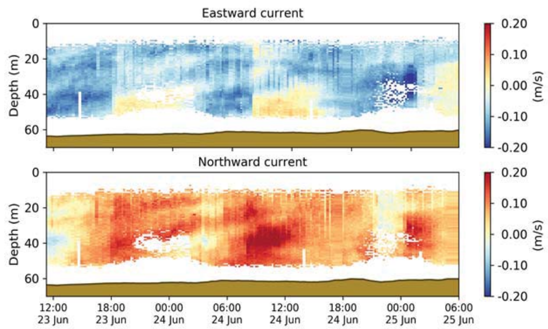
Glider technology

- Continuous, long-duration turbulence studies
- Sampling in stormy and extreme conditions
- Autonomously and remotely operated (→ cost reducing)

Development:

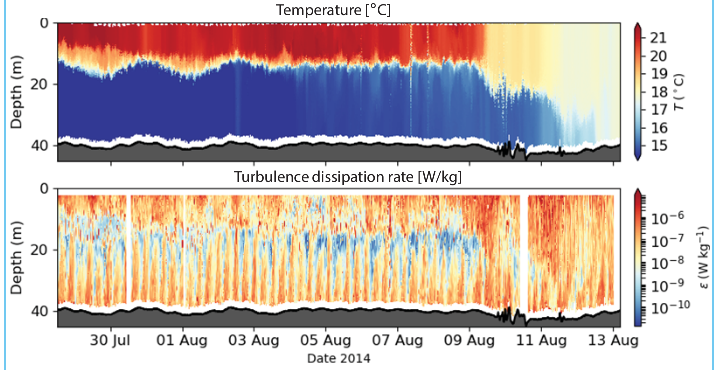
- Virtual AIS system for glider operations in the North Sea
- Developing artificial gills for glider powered by hydrogen fuel cells

Currents from glider mounted ADCP



Eastward and northward currents observed from a glider mounted Acoustic Doppler Current Profiler (ADCP) in the Baltic Sea in June 2016.

North Sea turbulence and fluxes

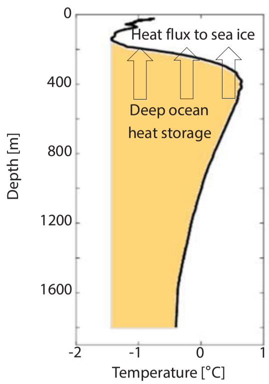


Ocean temperature (top) and turbulent dissipation rate (bottom) observed in the North Sea in summer 2014.

Arctic Ocean turbulence and heat fluxes

Motivating question:

Is there a significant ocean heat flux responsible for Arctic sea ice melt?

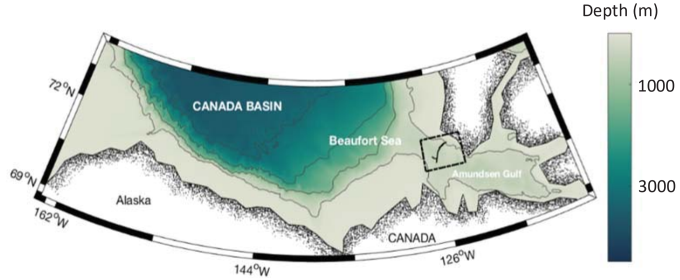


A quantification and under-standing of Arctic Ocean vertical turbulent heat fluxes is needed:

- Ocean's role in sea ice heat budget
- Mechanisms important for quantifying future changes in ice-free Arctic summers
- Arctic turbulence measurements are sparse and difficult

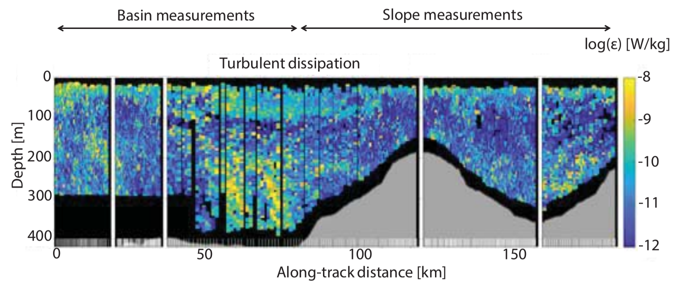
The Arctic study is a cooperation between HZG and the University of British Columbia

Turbulence in the Arctic Ocean



Glider turbulence transects across Amundsen Gulf, Arctic Ocean:

- Continuous 11-day turbulence measurements
- >400 individual profiles
- Identify extremely low background turbulence levels



Conclusions

- **Long-duration turbulence and current measurements from an autonomous platform**
- **Quantified turbulent vertical heat fluxes**
- **Densest measurements of Arctic turbulence to date**

Outlook

- **Identify physical mechanisms observed in Arctic Ocean turbulence**
- **Use gliders to study turbulence in extreme conditions**
- **Artificial gills for gliders powered by hydrogen**

Research Unit *Operational Systems*: Topic 2

References: Schultze et al. (2017); Scheifele et al. (submitted)

References

Turbulence observations from ocean gliders: Arctic Ocean heat fluxes

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Schultze, L. K. P., Merckelbach, L. M., & Carpenter, J. R. (2017) **Turbulence and mixing in a shallow shelf sea from underwater gliders**. Journal of Geophysical Research: Oceans, 122, https://doi.org/10.1002/2017JC012872.

Benjamin Scheifele, Stephanie Waterman, Lucas Merckelbach and Jeffrey Carpenter (2018). **Measuring the Dissipation Rate of Turbulent Kinetic Energy in Low Energy Environments: A Case Study from the Arctic Ocean**. Submitted to Journal of Geophysical Research – Oceans.

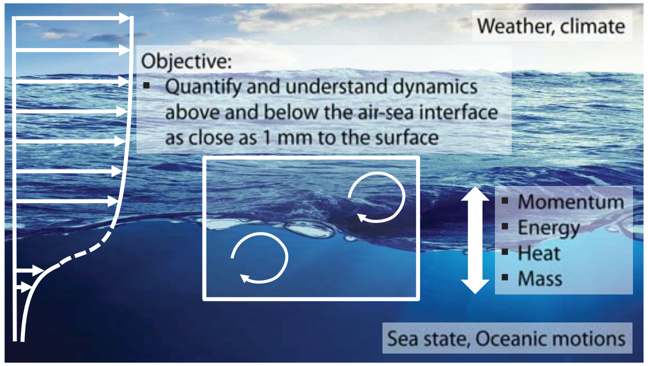
Sub-millimeter scale turbulent airflow dynamics above waves

Marc Buckley, Fabrice Veron, Jochen Horstmann, Jeff Carpenter

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Background

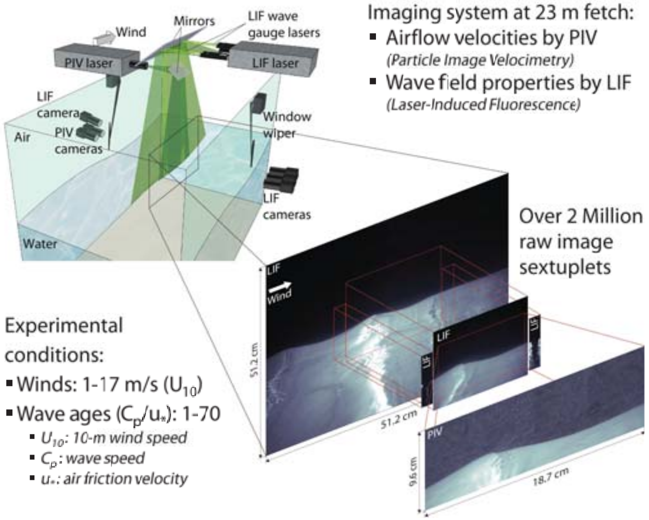
Momentum and energy fluxes across the ocean surface control sea state, coastal weather systems, and coupled atmospheric-oceanic processes. Small-scale dynamics control these fluxes. We present direct measurements of the structure of the airflow above ocean waves.



High-resolution airflow measurement system

Developed at University of Delaware's large (42m-long) Wind-Wave-Current Facility (USA)

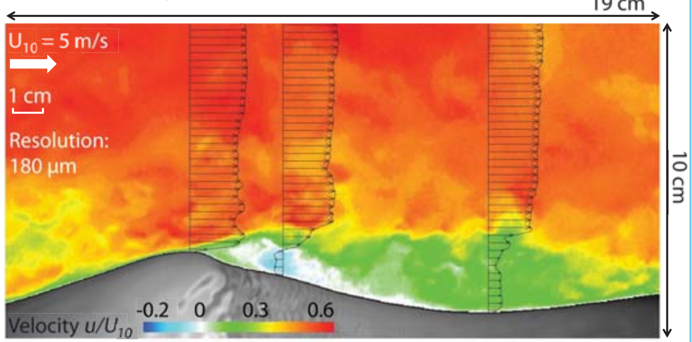
Imaging system at 23 m fetch:
- Airflow velocities by PIV *(Particle Image Velocimetry)*
- Wave field properties by LIF *(Laser-Induced Fluorescence)*

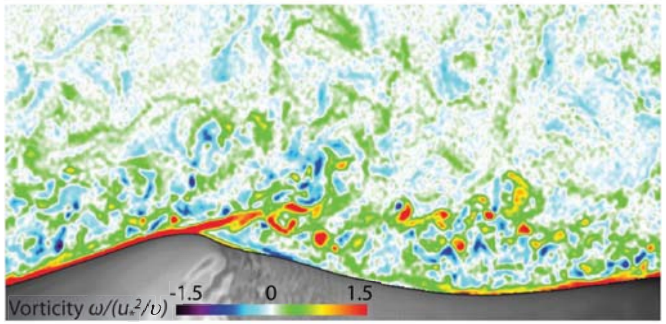


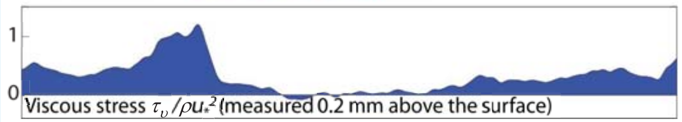
Experimental conditions:
- Winds: 1-17 m/s (U_{10})
- Wave ages (C_p/u_*): 1-70
  - *U_{10}: 10-m wind speed*
  - *C_p: wave speed*
  - *u_*: air friction velocity*

Structure of the airflow above waves

Instantaneous snapshots

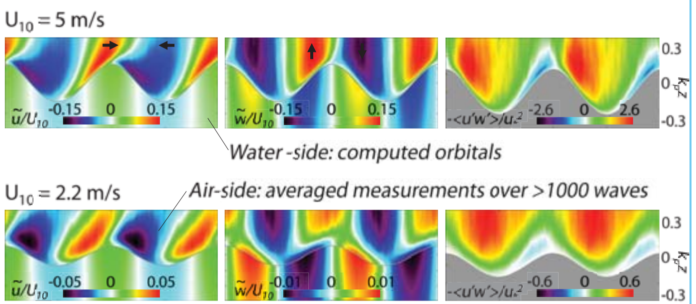






Buckley and Veron, 2017

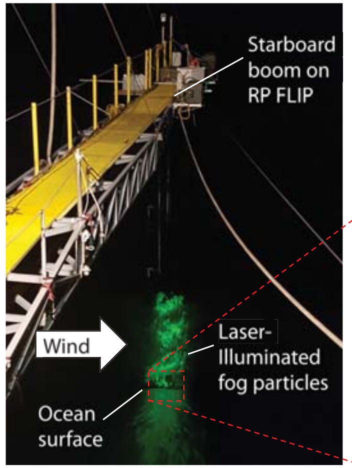
Phase-averaged motions and Reynolds stress



Buckley and Veron, 2016

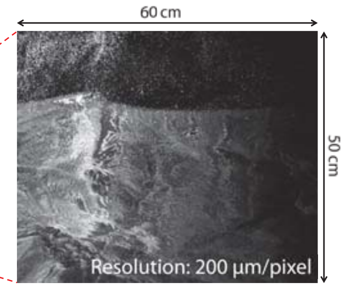
First airflow measurements as close as 1 mm above the ocean surface

Airflow PIV experiment on RP FLIP in the Pacific Ocean (October 2017)



Airflow PIV data acquisition from FLIP

- Winds from 3 to 17 m/s
- Airflow velocities captured between 1 mm and 2 m above the ocean surface



Example raw PIV image

Summary

University of Delaware · NSF · DFG Deutsche Forschungsgemeinschaft

- First sub-millimeter scale measurements of airflow kinematics over ocean surface waves
- Waves modulate the air-sea momentum flux through complex sheltering and orbital forcing mechanisms
- First simultaneous air-water measurements to be attempted in March 2018 in the Baltic Sea

References

Sub-millimeter scale turbulent airflow dynamics above waves

Marc Buckley, Fabrice Veron, Jochen Horstmann, Jeff Carpenter

Buckley, M.P. & Veron, F. Exp Fluids (2017) **Airflow measurements at a wavy air–water interface using PIV and LIF**, Experiments in Fluids, 58: 161, https://doi.org/10.1007/s00348-017-2439-2.

Buckley, M.P. and F. Veron, (2016) **Structure of the Airflow above Surface Waves.** J. Phys. Oceanogr., 46, 1377–1397, https://doi.org/10.1175/JPO-D-15-0135.1.

FerryBox: Cost-Effective Tool for Coastal Ocean Observations

COSYNA

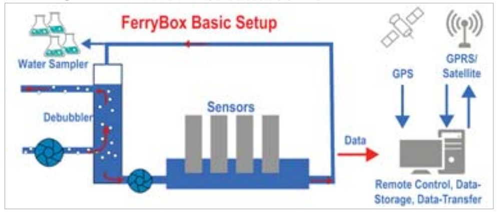
W. Petersen, Y. Voynova, M. Gehrung, H. Thomas, H. Rust, D. Blandfort and U. Callies

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Motivation:

- The ocean continues to be severely under-sampled
- FerryBoxes:
  - \+ ships-of-opportunity as a cost-effective research platform
  - \+ fewer limitations by space, power consumption, or harsh environment
  - \+ easier access for maintenance
  - \+ real-time data
  - \- only surface water measurements
  - \- depending on voluntary vessels

FerryBox System (developed at HZG)



Main Features:

- controlled by GPS
- automatic & remote-control
- automatic cleaning and rinsing
- automated safety mechanism for supervision of the system
- position-controlled automated water sampling
- easily expandable for new sensors (e.g. carbon sensors)

Parameters:

Basic Oceanography:

- water temperature
- conductivity/salinity
- turbidity
- dissolved oxygen

Biogeochemistry:

- chlorophyll-a fluorescence
- algal groups
- nutrients (NO_x, NH_4, o-PO_4, Si)
- pH
- alkalinity
- pCO_2

COSYNA FerryBox Installations:

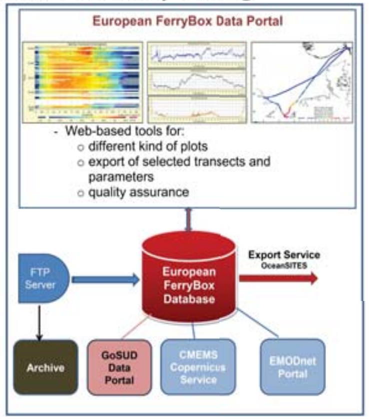
Fixed Routes: | Research Vessels and Cruise Liners:

Fixed Platforms:

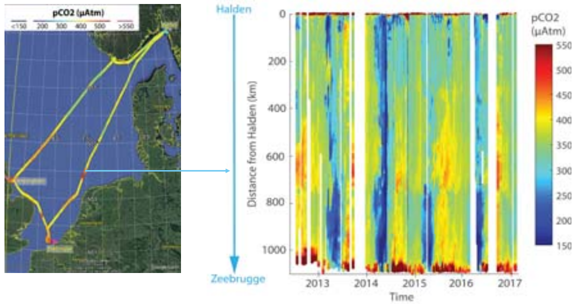
European FerryBox Community

(red lines: operated by HZG)

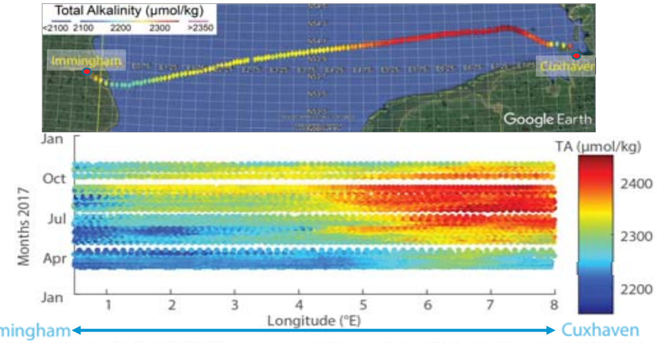
European FerryBox Database & Data Portal (*www.ferrybox.org*)



Carbon Cycle in the North Sea:

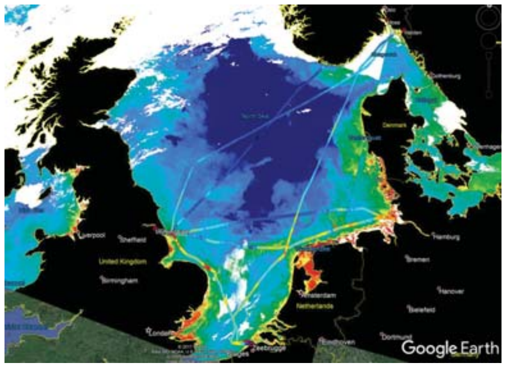


Long-term time series of pCO_2 measurements from 2012 to 2017 (data show transect from Halden to Zeebrugge)



Time series of **total alkalinity** (transect Immingham to Cuxhaven) in 2017 indicating alkalinity transport from the Wadden Sea to the open North Sea from spring to autumn

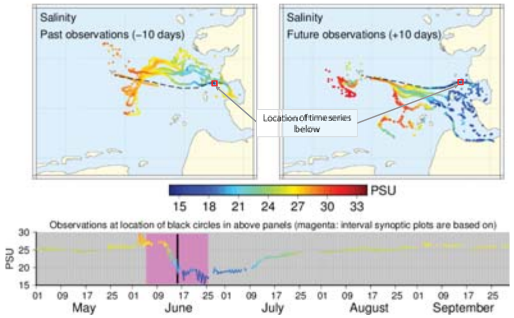
Chlorophyll-a Data from FerryBox and Satellite Images



Comparison of **chlorophyll-a** fluorescence (FerryBox) with chlorophyll-a from satellite (Sentinel-III) in June 2017

FerryBox Data and Advective Transport by Hydrodynamic Models

(provided by RU *Biogeochemistry in Coastal Seas*)



Extreme Elbe flood 2013: Synoptic plots of salinity showing advection of water masses 10 days before (left panel) to 10 days after (right panel) FerryBox transect from 15.06.2013

Conclusions

- **FerryBox - developed at HZG - is a well established and cost-effective tool for continuous observations of physical and biogeochemical parameters in coastal oceans**
- **HZG FerryBox database has been selected as the European FerryBox database**
- **High resolution in space and time enables new insights in biogeochemical processes such as the carbon cycle and extreme events →Contribution to ecosystem models (RU 1)**
- **Targeted sensor development for specific studies (e.g. carbon cycle, algae detection)**

Research Unit *Operational Systems*: Topic 4

Petersen (2014), Petersen & Colijn (2017), Voynova et al. (2017)

References

FerryBox: Cost-Effective Tool for Coastal Ocean Observations

Wilhelm Petersen, Yoana Voynova, Martina Gehrung, Henrike Thomas, Hendrik Rust, Daniel Blandfort, Ulrich Callies

Petersen, W. (2014) **FerryBox systems: State-of-the-art in Europe and future development**, Journal of Marine Systems, Volume 140, pp 4-12, ISSN 0924-7963, http://doi.org/10.1016/j.jmarsys.2014.07.003.

Petersen, W., Colijn, F. (Eds) (2017) **FerryBox White Paper**. EuroGOOS publication 2017, http://eurogoos.eu/download/publications/EuroGOOS_Ferrybox_whitepaper_2017.pdf.

Voynova, Y., Brix, H., Petersen, W., Weigelt-Krenz, S., Scharfe, M. (2017) **Extreme flood impact on estuarine and coastal biogeochemistry: The 2013 Elbe flood**. Biogeosciences, 14, 541-557, http://doi.org/10.5194/bg-14-541-2017.

Development of an Automated Hyperspectral Absorption Sensor –
High-Frequency Phytoplankton Biomass and Taxonomy

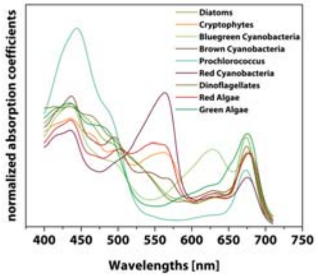
Jochen Wollschläger, Rüdiger Röttgers, Oliver Listing, Wilhelm Petersen

COSYNA

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

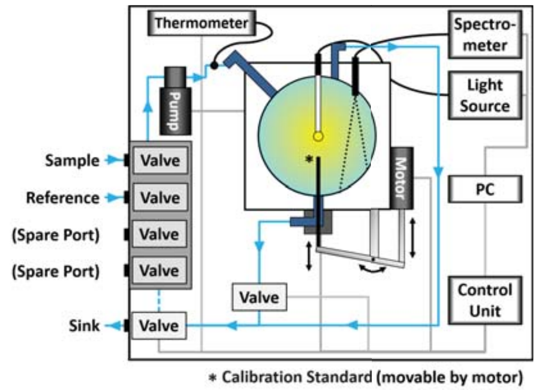
Motivation

- Absorption properties of water are influenced by phytoplankton pigments
- Absorption coefficient spectra of phytoplankton vary between groups
- Spectra contain information about phytoplankton biomass and composition
- Development of an automated system for long-term high-frequency measurement of absorption coefficient spectra

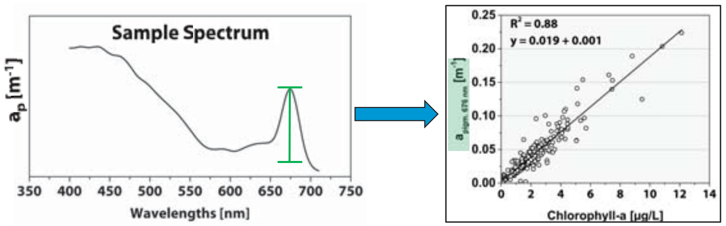


Principle of the Hyperspectral Absorption Sensor (HyAbS)

- Based on a point-source integrating cavity absorption meter (PSICAM), enabling
  - High sensitivity of measurements
  - No scattering errors
- Completely automated flow-through system, in contrast to other available systems
- Automated solid-standard calibration enables
  - Higher calibration frequency
  - Long-term operation over days
  - Independence of calibration liquids

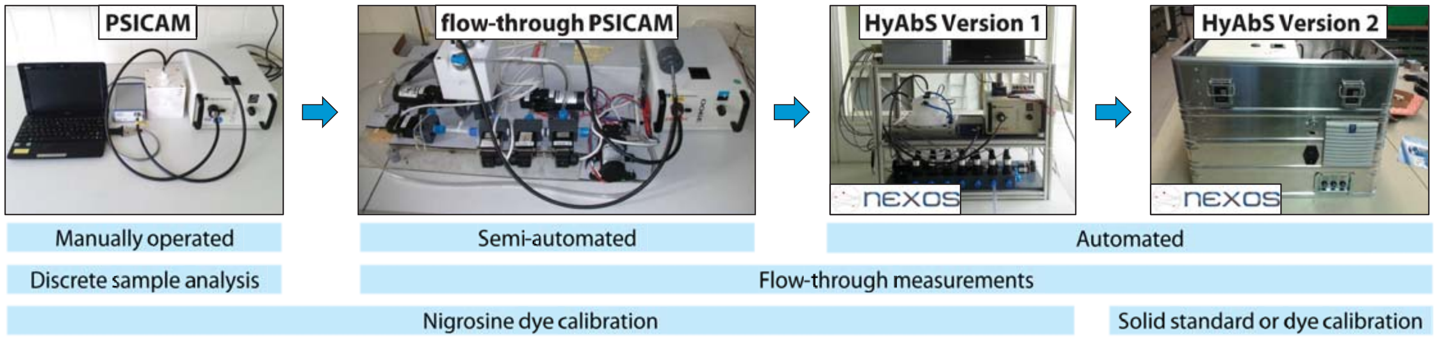


Biomass Estimation

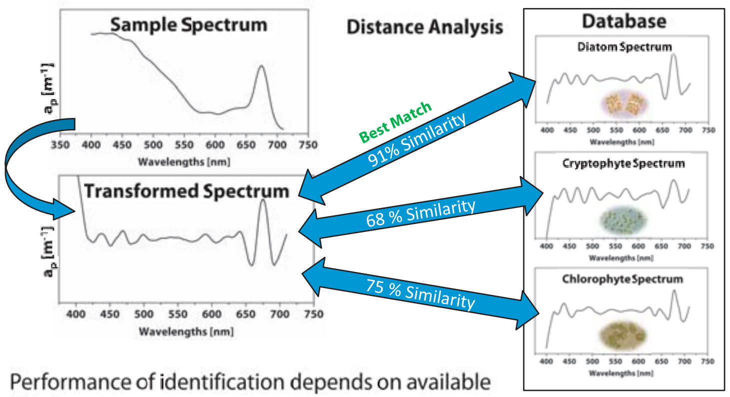


- No quenching effects like in fluorescence measurements
- More reliable chl-a proxy

Development Steps of HyAbS

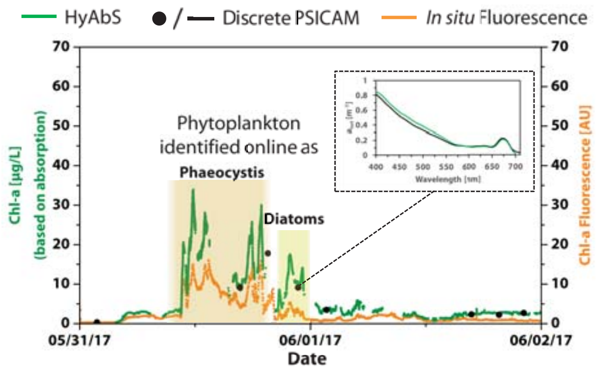


Taxonomic Identification



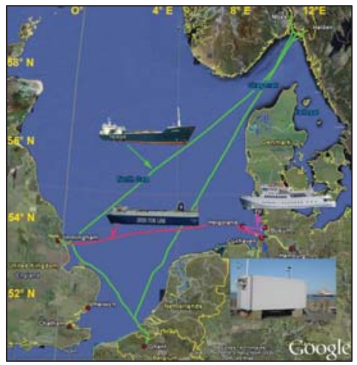
Performance of identification depends on available database

High Resolution Data from recent cruise



Online phytoplankton identification was in accordance with microscopy

Future prospects



Combining HyAbS with FerryBox

Conclusions

- HZG's HyAbS enables **automated**, **long-term** quantification and identification of phytoplankton
- High frequency data agree well with discrete data – potential for remote sensing validation
- More comprehensive understanding of biogechemical cycles by high frequency taxonomical information

Research Unit *Operational Systems*: Topic 4

Wollschläeger et al. (2013), Wollschläger et al. (2014), Wollschläger et al. (2016)

References

Development of an Automated Hyperspectral Absorption Sensor - High-Frequency Phytoplankton Biomass and Taxonomy

Jochen Wollschläger, Rüdiger Röttgers, Oliver Listing, Wilhelm Petersen

Wollschläger, J., Grunwald, M., Röttgers, R. and Petersen, W. (2013) **Flow-through PSICAM: a new approach for determining water constituents absorption continuously**. Ocean Dynamics 63(7): 761-775, http://doi.org/10.1007/s10236-013-0629-x.

Wollschläger, J., Röttgers, R., Petersen, W. and Wiltshire, K. H. (2014) **Performance of absorption coefficient measurements for the in situ determination of chlorophyll-a and total suspended matter**. Journal of Experimental Marine Biology and Ecology 453(0): 138-147, http://dx.doi.org/10.1016/j.jembe.2014.01.011

Wollschläger J., Voß D., Zielinski O. and Petersen W. (2016) **In Situ Observations of Biological and Environmental Parameters by Means of Optics—Development of Next-Generation Ocean Sensors With Special Focus on an Integrating Cavity Approach**. IEEE Journal of Oceanic Engineering, vol. 41, no. 4, pp. 753-762, http://doi.org/10.1109/JOE.2016.2557466

Coastal Suspended Particle Dynamics

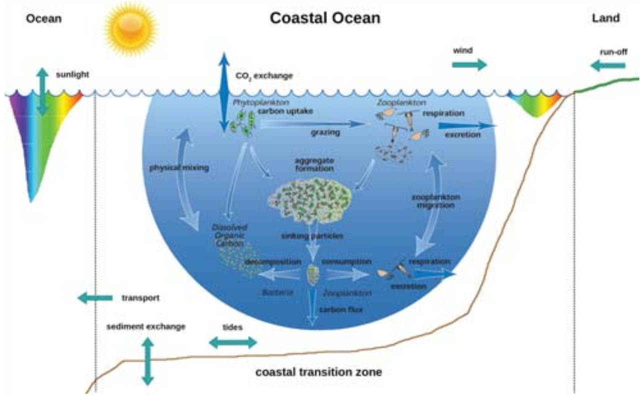
From the water sample to a large-scale view of coastal regions

Martin Hieronymi, Daniel Behr, Henning Burmester, Roland Doerffer, Kerstin Heymann, Hajo Krasemann, Dagmar Müller & Rüdiger Röttgers

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Motivation

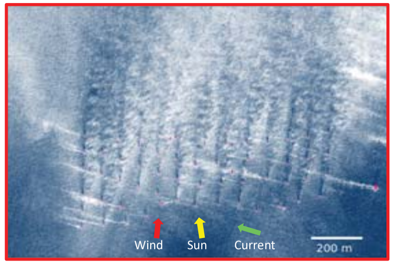
- Understanding dynamics and characteristics of organic and inorganic suspended particles
- Covering coastal areas from tidal catchment to shelf sea margin
- Elucidate mechanisms and quantify fluxes of the coastal particles on appropriate scales



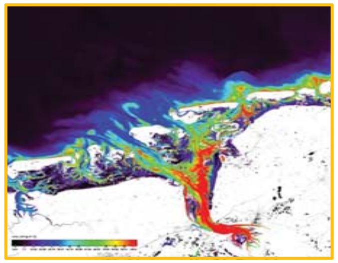
The context of research and main processes under investigation (adapted from JGOFS, 2001).

High resolution observations of the coasts

Sentinel-2 / MSI image with 10 m resolution.



Turbulent wind farm wakes (false colour image).

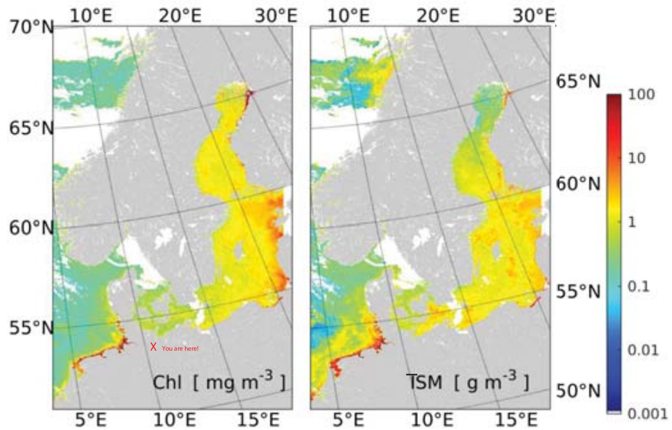


High TSM concentrations in the Wadden Sea.

CDOM from river mixes with turbid waters.

The coastal ocean and marginal seas: A great challenge

Sentinel-3 / OLCI Image of the Baltic and North Sea from June 2016 (swath width 1270 m, 300 m resolution).

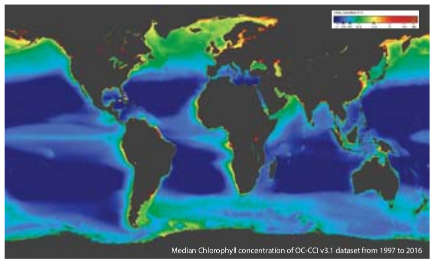


Estimated of chlorophyll and total suspended matter concentration. The OLCI Neural Network Swarm algorithm applies fuzzy logic water type classification with the aim to produce best possible products for open ocean, coastal, and inland waters [Hieronymi et al., 2017].

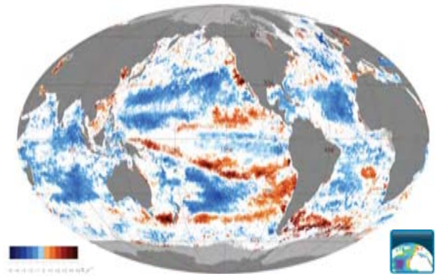
Stakeholders

- Remote sensing team of HZG developed the standard algorithm for coastal oceans
- Team provides operational algorithms for Baltic Sea
- Provides satellite data of the German Bight to data portal

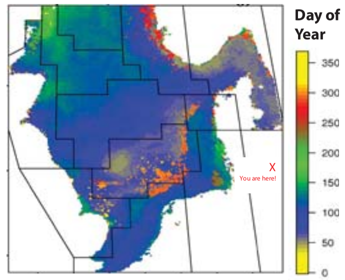
Global data for climate studies



HZG is partner of ESA's Ocean Colour – Climate Change Initiative, which provides consistent chlorophyll time series of global satellite data (4 km binning, daily to monthly means).



Global chlorophyll trends from 1997 to 2016. Up to now, there are no significant trends for the North Sea area detectable, but for some other regions (dataset to short for climate studies).



Phenology of maximum mean Chl concentration in the North Sea. Preliminary analysis shows change of timing of algae blooms.

Main co-operation partners

Conclusions

Our ocean color products deliver sufficiently precise data to investigate spatial and temporal variability of suspended particle concentration and phytoplankton.

Outlook

Combine satellite products with in situ data to investigate carbon related fluxes (PP, DOC, POC) and ecological functions of plankton and create new satellite products.

References

Coastal Suspended Particle Dynamics - From the water sample to a large-scale view of coastal regions

Martin Hieronymi, Daniel Behr, Henning Burmester, Roland Doerffer, Kerstin Heymann, Hajo Krasemann, Dagmar Müller, RüdigerRöttgers

Hieronymi, Martin, Dagmar Müller, Roland Doerffer (2017) **The OLCI Neural Network Swarm (ONNS): A Bio-geo-optical Algorithm for Open Ocean and Coastal Waters**. Frontiers in Marine Science 4, 140, https://doi.org/10.3389/fmars.2017.00140.

(Image: http://usjgofs.whoi.edu/)

Coastal Suspended Particle Dynamics

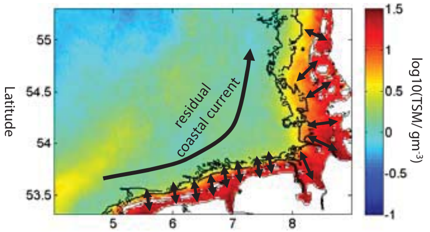
Resolving marine particle characteristics and variability

Klas Ove Möller, Rolf Riethmüller, Boris Cisewski, Philipp Fischer, Christian Möllmann, Götz Flöser, Markus Schartau, Kai Wirtz

COSYNA

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

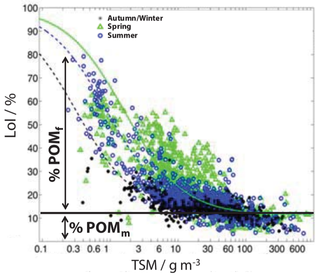
Exchange patterns of particulate matter



TSM concentration (2009 average) in the German Bight derived from MERIS with general transport patterns.

Analytical model of organic TSM fraction

- > 3000 water samples analysed to enhance information of statistical relationship between TSM concentration and organic fraction
- Analytical model further separates the organic component into "fresh" pelagic (**POM$_f$**) and mineral associated (**POM$_m$**) fractions

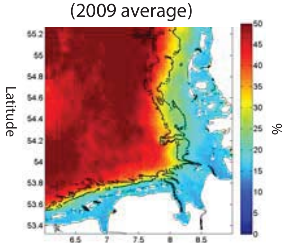


In cooperation with RU System Analysis and Modelling

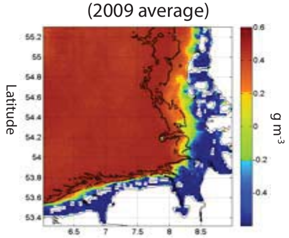
Loss on Ignition (LoI) vs. TSM from German Bight water samples taken between 2000 and 2014. Colors indicate season and lines represent the best model fit.

Organic particulate matter distribution

Organic fraction of TSM (2009 average)



POM$_f$ – POM$_m$ (2009 average)

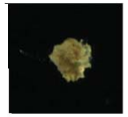


- Rapid transition from POM$_m$ (Wadden Sea) to POM$_f$ (German Bight)
- Zone of intense interaction between fresh off-shore and hydrolised mineral associated organic matter

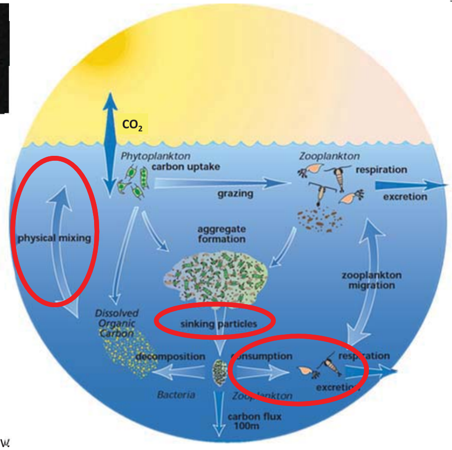
Marine snow: undersampled & underrated

Marine aggregates and particles of biogenic origin (marine snow) play a major role in the oceans particle flux as *the* major vector of carbon transport.

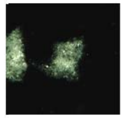
Fecal pellet



Regular snow



Phaeocystis snow

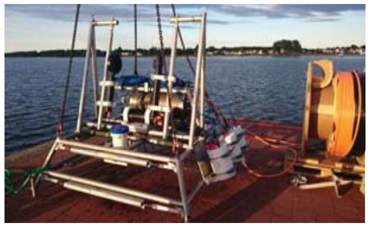


Diatom snow

Diagram of the biological carbon pump and the important role of marine snow (adapted from JGOF)

Key processes Physical: passive sinking, vertical transport, lateral advection
Biological: active feeding, vertical migration, fragmentation

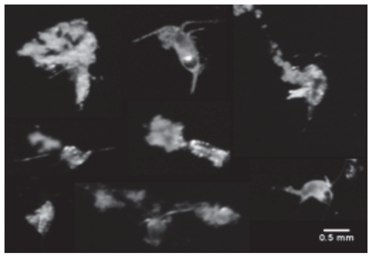
Plankton and particle observatory



The COSYNA underwater observatory

- Continuous automatic small-scale observations in real-time
- Particles, plankton & hydrography
- Temporal scales: 1s – months
- Provides unique time-series

Elucidate trophic role of marine snow



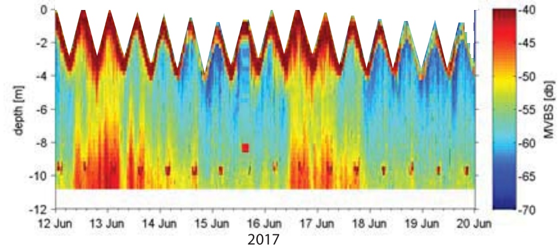
Copepods indicating particle feeding behavior

- Estimate remineralisation vs. sinking / transport
- Translation of optical measurements into particle content, aggregation & transfer
- Determine carbon flux and export

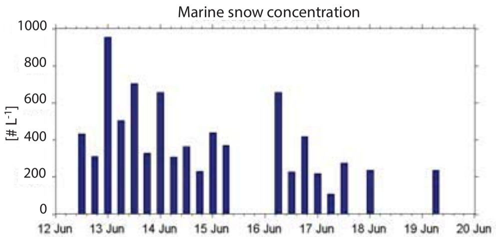
High-resolution marine snow observations

First permanent observations resolving dynamic pulses and high variability of marine snow occurence potentially linked to primary production, tidal cycle and turbulence.

Acoustic backscatter intensity



No. of particle images



Particle distribution observed with the ADCP (upper panel) and marine snow concentration from images (lower panel) during a one week period in June 2017.

TOMCAT FROM OPTICS TO EXPORT · SCOR · AWI · GEOMAR · THÜNEN · UHH

Conclusion

- Combination of satellite data and analytical model reveals a pronounced transition zone that keeps particulate matter in the Wadden Sea.
- First optical long-term observation and quantification of key processes influencing carbon flux and zooplankton - marine snow interactions.
- Unique high-resolution time-series of coastal marine snow abundance reveals high variability and dynamic pulses of aggregate concentration.

Outlook

- Investigate features (e.g. aggregation, settling, flow patterns) of the transition zone in front of the Wadden Sea and in other coastal areas.
- Estimate carbon fluxes and trophic importance of organic particles in coastal areas by extending *in-situ* optical sampling.
- Elucidate and quantify potential links of the shelf to the ocean's biological carbon pump by combining large-scale satellite observation, high-resolution *in-situ* time series and bio-geochemical models.

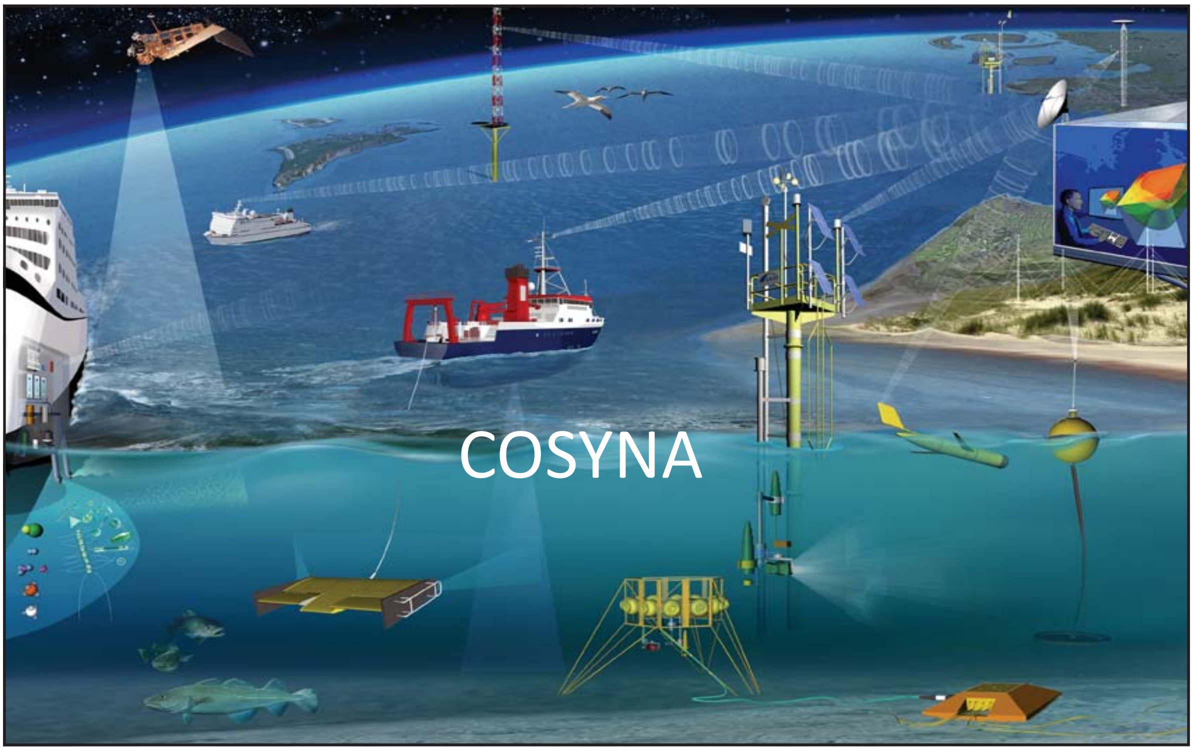
References

Coastal Suspended Particle Dynamics - Resolving marine particle characteristics and variability

Klas Ove Möller, Rolf Riethmüller, Boris Cisewski, Philipp Fischer, Christian Möllmann, Götz Flöser, Markus Schartau, Kai Wirtz

Giering, S. L. C., R. Sanders, A. P. Martin, C. Lindemann, K. O. Möller, C. J. Daniels, D. J. Mayor, *and* M. A. St. John (2016) **High export via small particles before the onset of the North Atlantic spring bloom.** J. Geophys. Res. Oceans, 121, 6929–6945, http://doi.org/10.1002/2016JC012048.

Moeller, K. O., St John, M., Temming, A., Floeter, J., Sell, A. F., Herrmann, J.-P., et al. (2012) **Marine snow, zooplankton and thin layers: indications of a trophic link from small-scale sampling with the Video Plankton Recorder**. MARINE ECOLOGY PROGRESS SERIES, 468, 57-69, http://doi.org/10.3354/meps09984.



COSYNA: HZG and Partners

Topic 4

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Research Unit 3: *Operational Systems*

AWI

LKN.SH

HPA Hamburg Port Authority

BAW

CAU Christian-Albrechts-Universität zu Kiel

Ludwig-Franzius-Institut

marum

ICBM

GEOMAR

NLWKN

RU1: *System Analysis and Modelling*

RU2: *Biogeochemistry in Coastal Seas*

COSYNA: Structure and Numbers

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Lead Helmholtz-Zentrum Geesthacht – Centre for Materials and Coastal Research

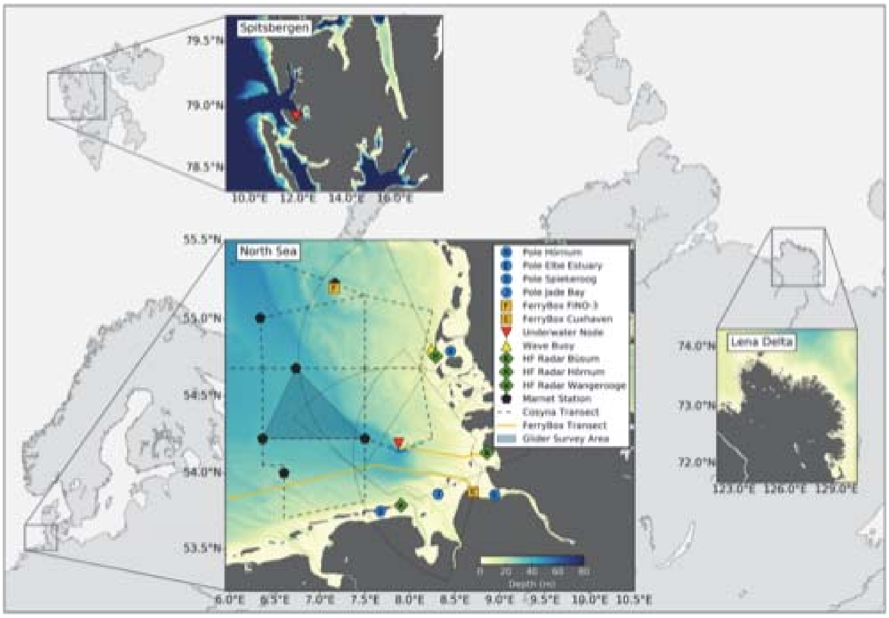
BSH – AWI – LKN.SH – CAU – HPA – BAW – marum – Ludwig-Franzius-Institut – GEOMAR – NLWKN – ICBM

- Lead HZG (Director B. Baschek, Project Manager: H. Brix)
- Initial funding: M€ 9.25
- ACROSS funding: M€ 1.7 (2015-17)
- Instruments also provided to partners

Operational Effort (FTEs)	HZG	Partners
Operation	6	7
Data Management	5	3
Outreach and Management	2	0
Operational costs (T€/year)	300	
Personnel (T€/year)	780	
New instrument systems	ACROSS, MOSES	

COSYNA Locations

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



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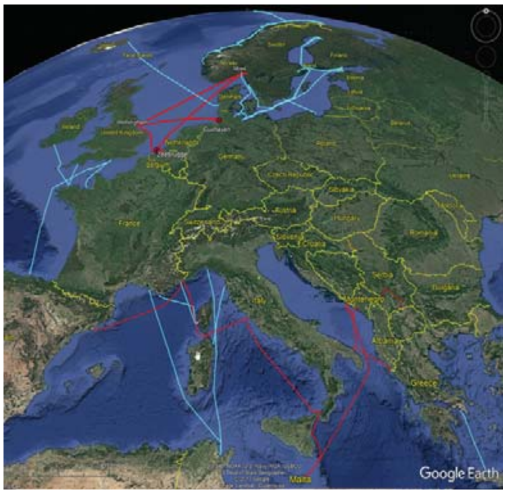
FerryBoxes

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

- HZG development
- Autonomous
- Self-cleaning
- New focus: carbon cycle variability
- Common European FerryBox Database at HZG



Parameters:

- Standard COSYNA parameters
- turbidity, chlorophyll-a fluorescence, pH, pCO_2, alkalinity, algal groups, nutrients

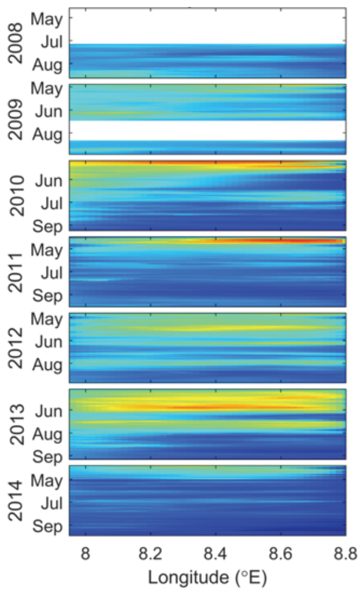
COSYNA

FerryBoxes - Application

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Multiyear Time-Series

pH ferry data between Büsum and Helgoland for each summer between 2008 and 2014 from M/V Funny Girl (Voynova et al., 2017).



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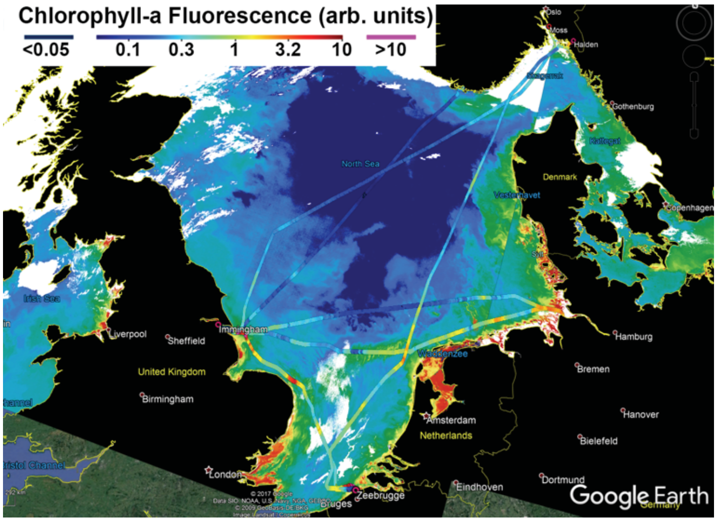
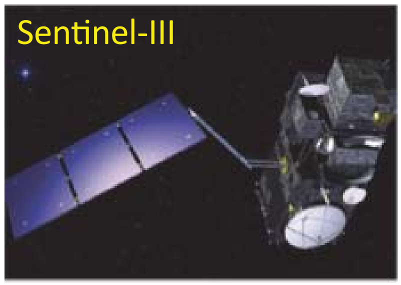
Combining Satellite and FerryBox



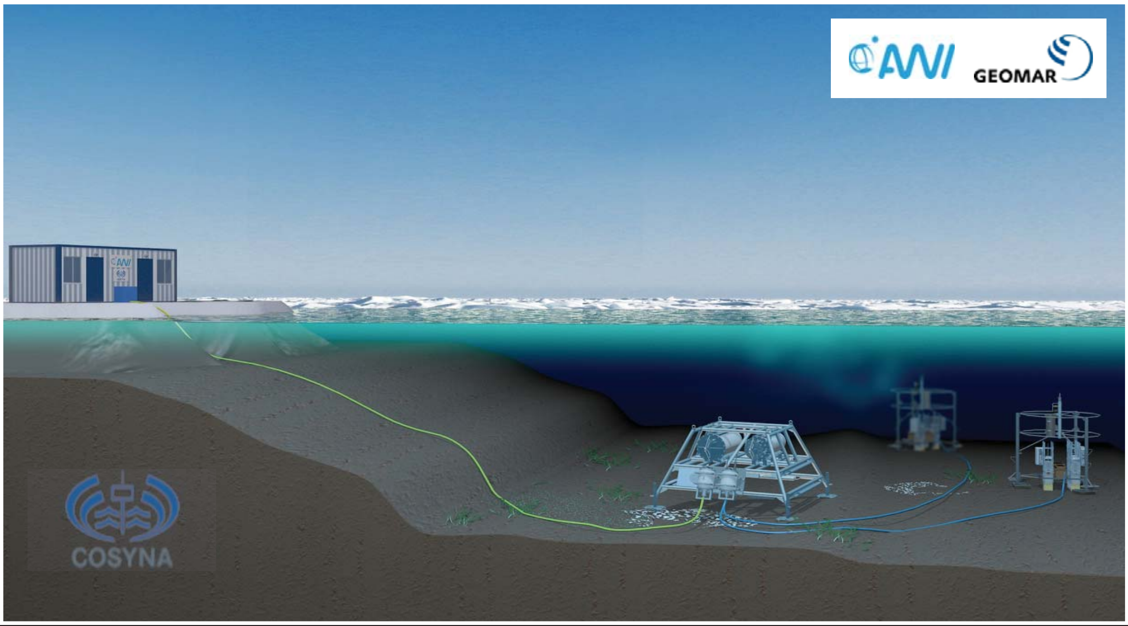


- Coastal water algorithm for ESA
- Long-time chlorophyll time-series

COSYNA

Underwater Node System

AWI GEOMAR



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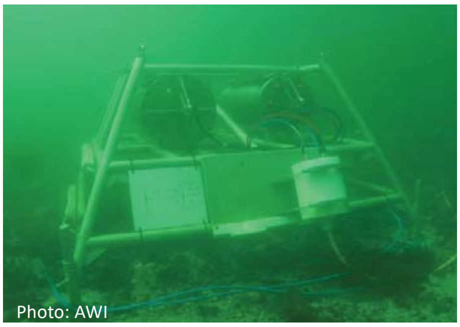
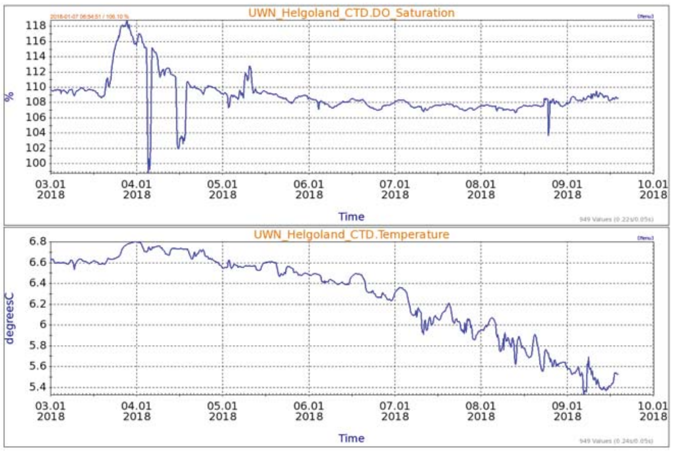
Underwater Node System

- Robust flat water system
- Live access
- Near real-time data
- Community usage





More instrument developments:

See posters in building 34

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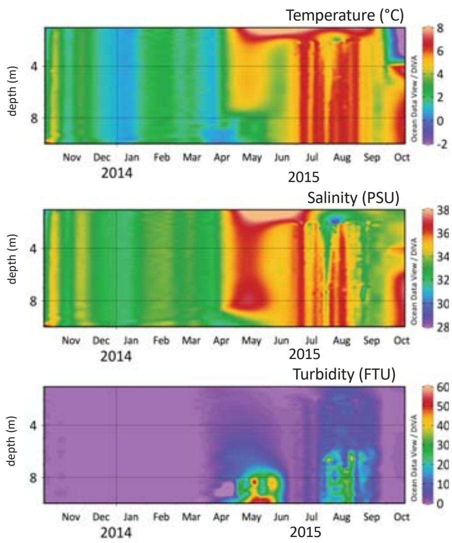
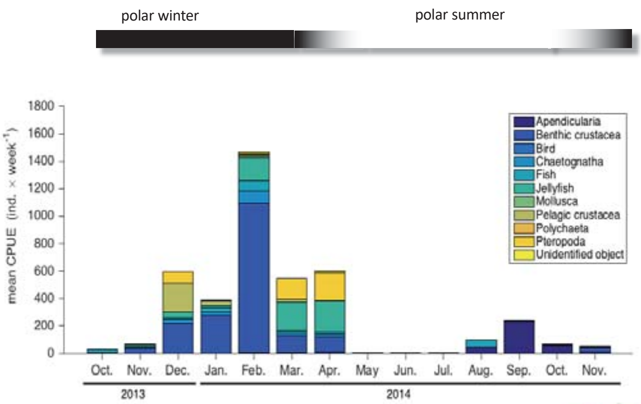
Centre for Materials and Coastal Research

Underwater Node System Svalbard



First ever measurement of seasonal cycle of species composition changes AWI's measurement campaigns to winter

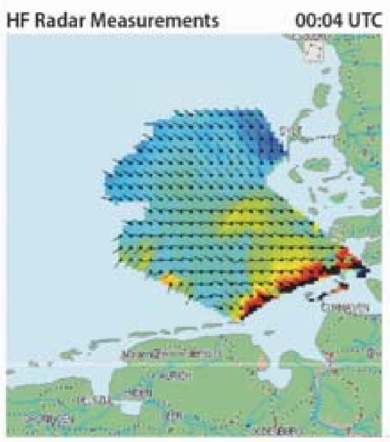


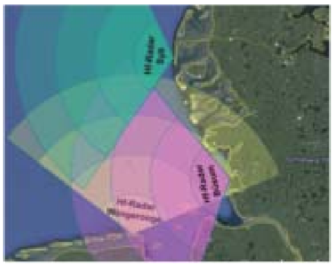
Fischer et al. (2017)

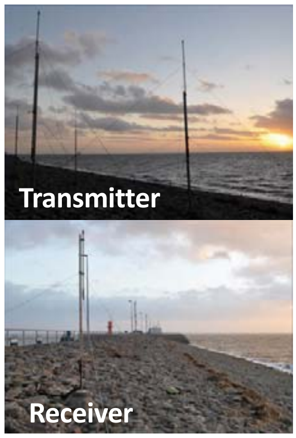
AWI COSYNA

HF-Radar Currents

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research





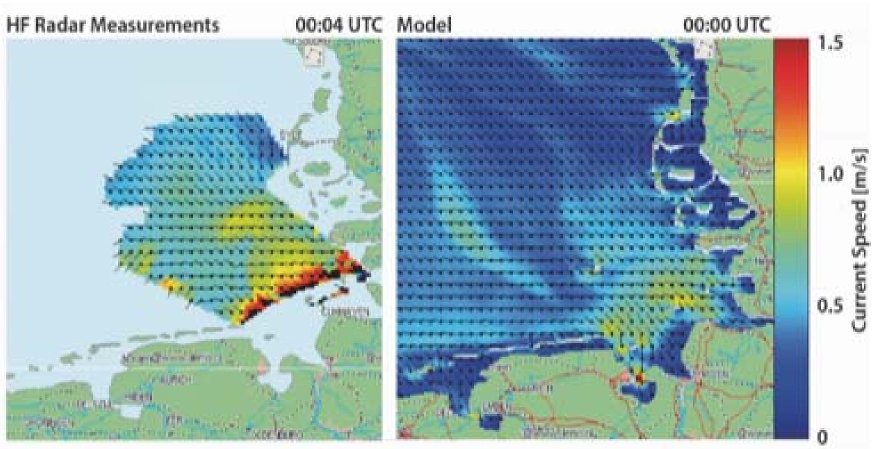


COSYNA

HF-Radar Currents

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Assimilation of Currents
into a 3D Circulation Model
by Research Unit 1



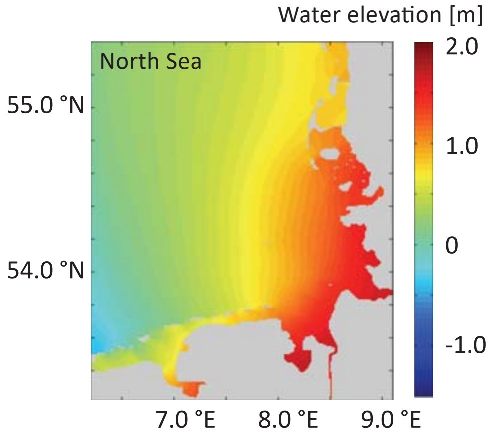
COSYNA

COSYNA Modeling and Forecasts

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Nested modeling system

- Pre-operational 72-h forecasts
- 3D-fields
  - Currents
  - Salinity
  - Temperature
- 2D-fields:
  - Water elevation
  - Wave parameters



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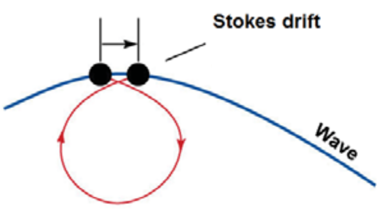
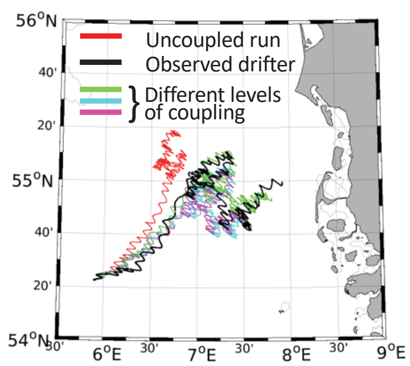
COSYNA Modeling System

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

- Ongoing developments
  - Coupling of waves and circulation models
  - Improving drift simulations





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COSYNA Data Products

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

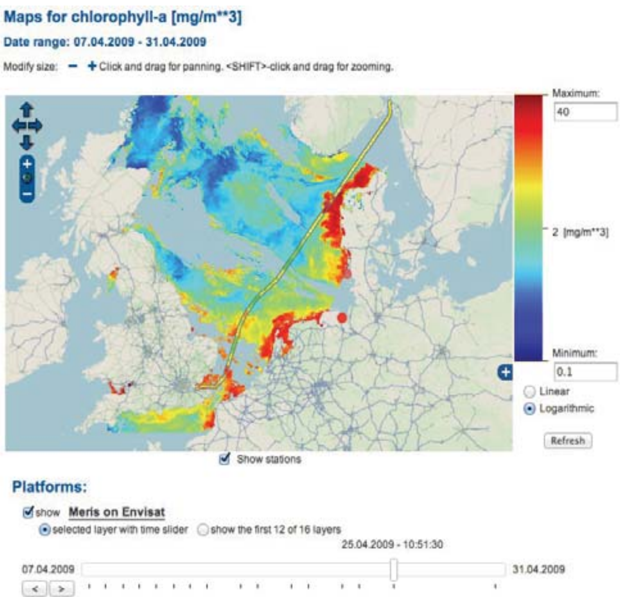
COSYNA Products

- Currents
- Waves
- Temperature
- Chlorophyll
- Ship-tracking

COSYNA

COSYNA Data Portal

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

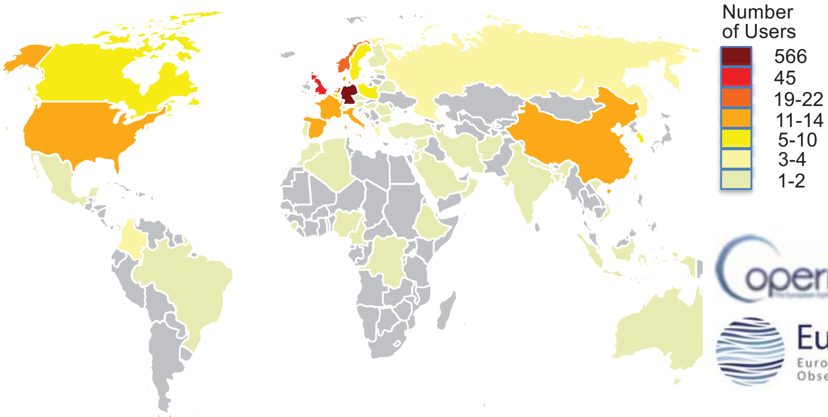


- Free data access
- Near real-time availability
- Combination of different measurements for easy analysis

COSYNA

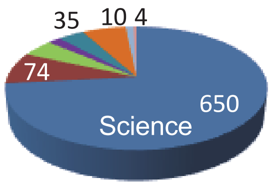
COSYNA Users

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



Copernicus

EuroGOOS European Global Ocean Observing System

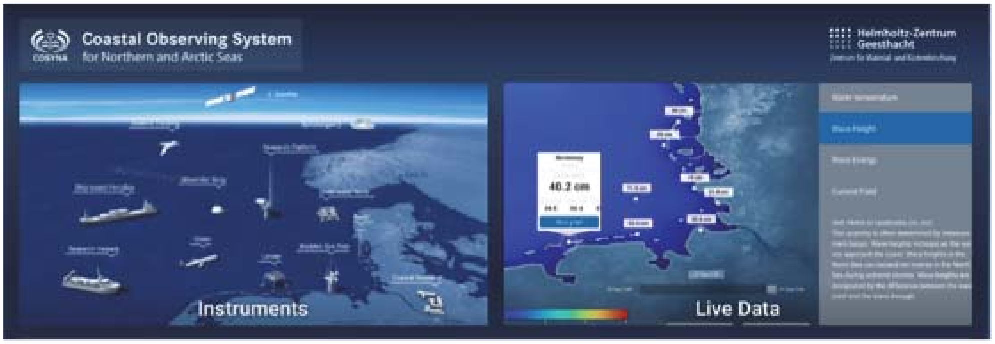


- 140 scientific COSYNA publications
- COSYNA Special Issue (OS, BGS)
- Lead publication: Baschek et al.(2017)
- 12 data publications
- 5 data products

COSYNA

COSYNA Outreach

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

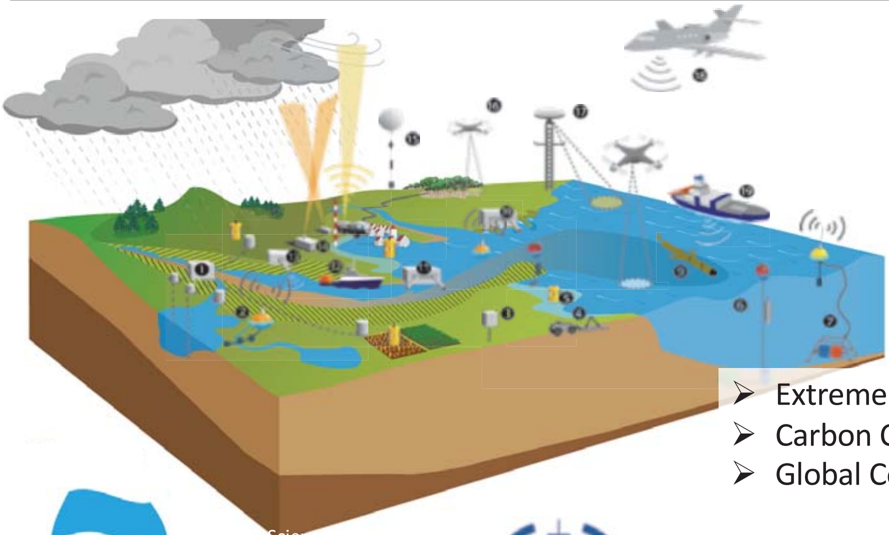


- COSYNA App
- Website
- Exhibitions
- Print products
- Workshops
- Showroom
- Earth System Knowledge Platform

COSYNA

COSYNA‘s Future

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



- Extreme Events
- Carbon Cycle Variability
- Global Coast

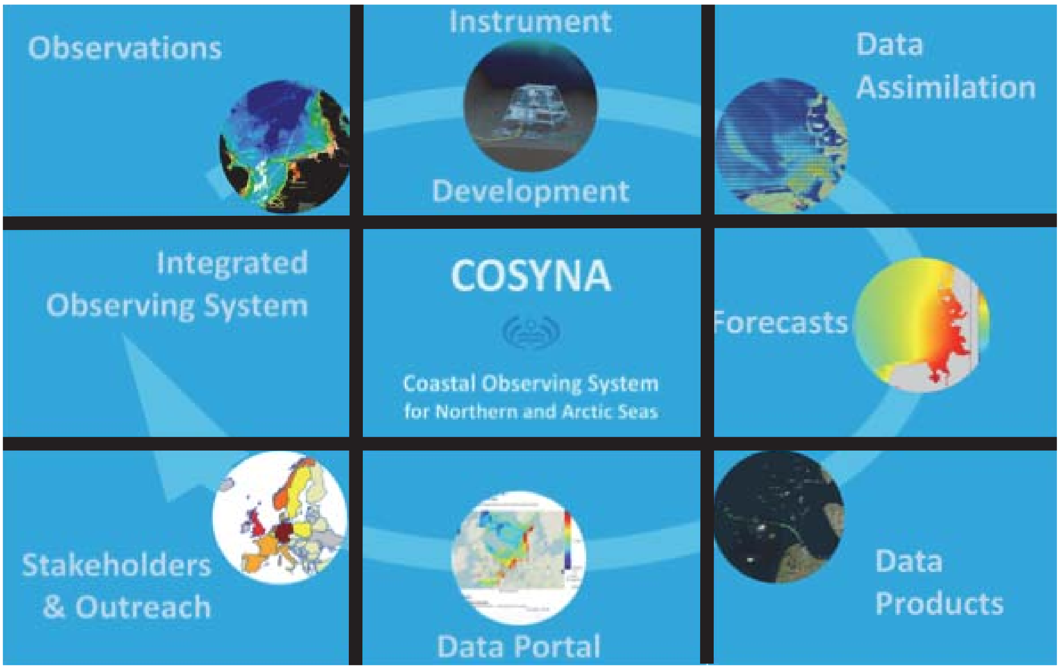
DANUBIUS-RI ⟷ COSYNA ⟷ MOSES

COSYNA‘s Achievements

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

- Created an integrated and one of the most comprehensive coastal observing systems worldwide
- Community-wide use of platforms, sensor technology and tools developed
- Fostering understanding of North Sea and Arctic coastal systems
  - Long-term monitoring enables evaluation of extreme events (e.g., Elbe flood) and system changes (e.g., chlorophyll maxima)
  - Asymmetry of Wadden Sea exchange processes shown
  - Winter observations crucial for fish stock assessment at Svalbard
  - Changed seabird flight patterns due to wind farms

COSYNA



Observations
Instrument
Development
Data
Assimilation
Integrated
Observing System
COSYNA
Coastal Observing System
for Northern and Arctic Seas
Forecasts
Stakeholders
& Outreach
Data Portal
Data
Products