



**ALFRED-WEGENER-INSTITUT**  
HELMHOLTZ-ZENTRUM FÜR POLAR-  
UND MEERESFORSCHUNG

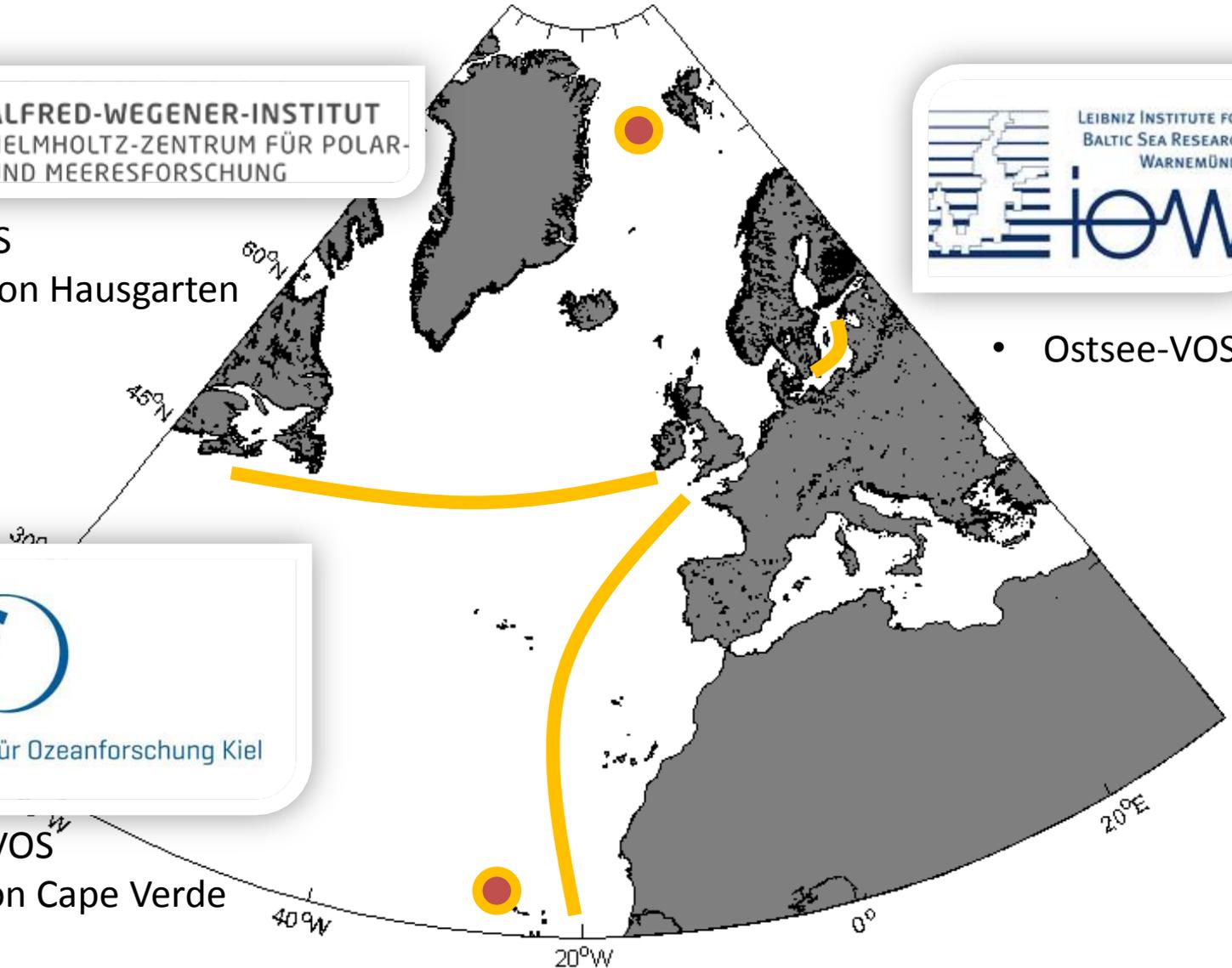
- Polarstern-VOS
- Zeitserienstation Hausgarten



- Ostsee-VOS



- Nord-Atlantik-VOS
- Zeitserienstation Cape Verde

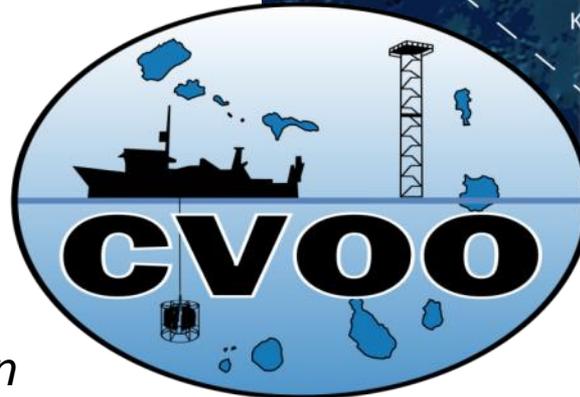
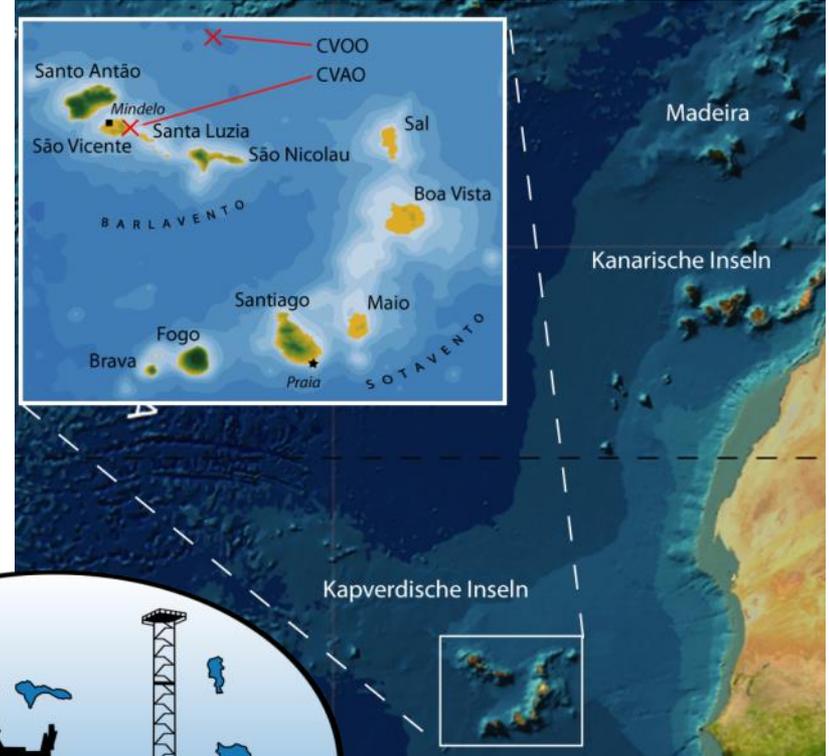


## North Atlantic VOS line (NA-VOS)

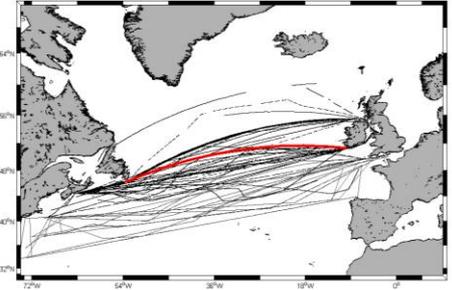
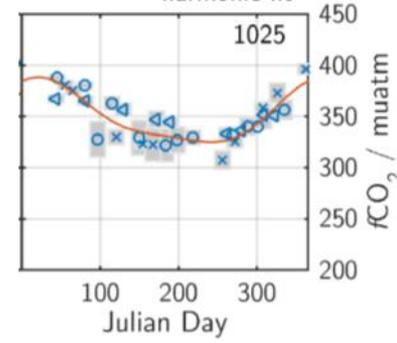


*Arne Körtzinger, Tobias Steinhoff,  
Björn Fiedler, Johannes Karstensen*

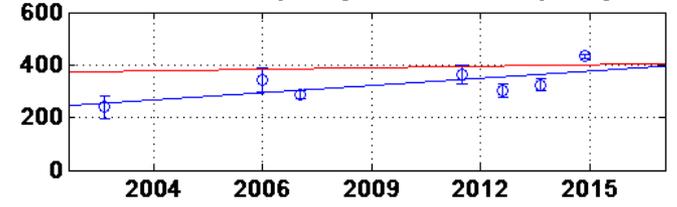
## Cape Verde Ocean Observatory (CVOO)



- Seit 05/2012: CO<sub>2</sub>-Messung mit CRDS-System und NDIR-System;
- Seit 05/2012: δ<sup>13</sup>C-CO<sub>2</sub>-Messung mit CRDS-System (Picarro G2131-i),
- Seit 2012: **45** Transatlantikfahrten mit hochwertigen autonomen Messungen, davon **22** mit diskreter Probennahme;
- Abgabe der prozessierten und qualitätskontrollierten Daten bei SOCAT bis einschließlich **Dezember 2016**;
- Sommer/Herbst 2015: Installation neuer Geräte auf ACL-Schiff MS *Atlantic Cartier*, danach etliche Startschwierigkeiten mit verschiedenen Problemen; System seit April 2016 wieder operationell;
- Seit Herbst 2016: Installation eines EC Messmastes am Bug des Schiffes
- Erprobung der HydroFIA zur autonomen Messung der Alkalinität von Meerwasser als 2. Kohlenstoffparameter (Installation auf VOS Neubau);
- Mitte 2017: Wechsel auf ACL-Neubau MS *Atlantic Sail*;
- *Verbesserung der atmosphärischen CO<sub>2</sub> Messungen im Rahmen von RINGO.*



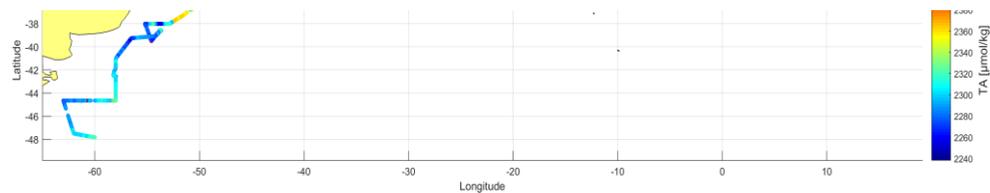
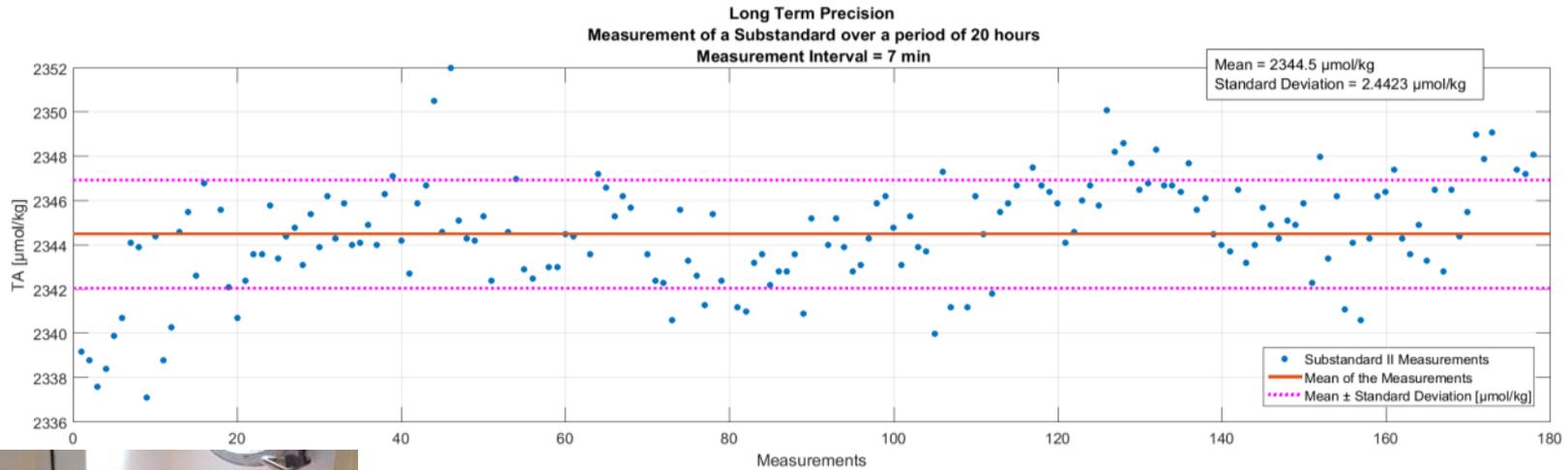
atm. CO<sub>2</sub>: 2.1  $\mu\text{atm/yr}$  sw. CO<sub>2</sub>: 1.9  $\mu\text{atm/yr}$



# NA-VOS: Autonome Alkalinitätsmessung

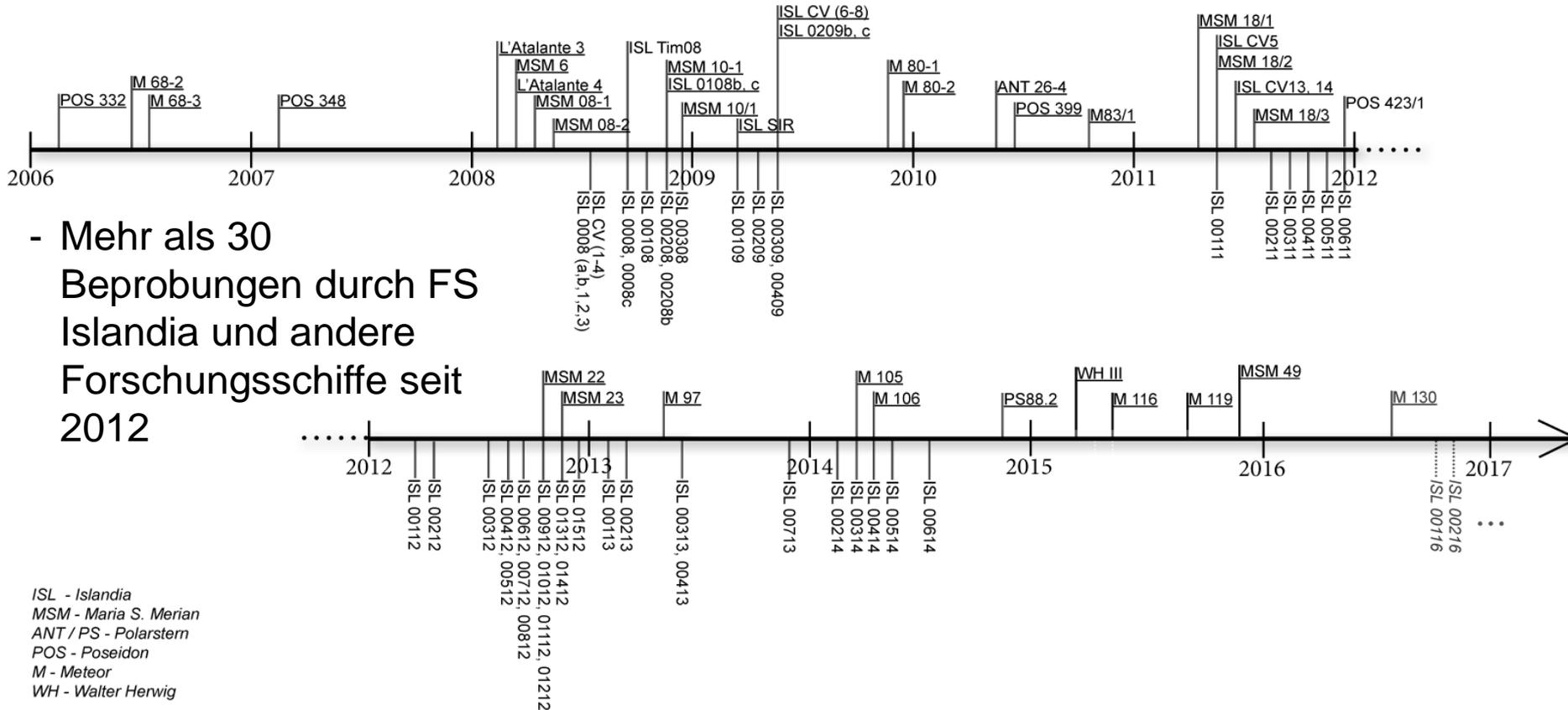
(Neuentwicklung geht in Routinebetrieb)

- HydroFIA TA System (KM Contros GmbH) zur autonomen Durchflussmessung der Alkalinität in Meerwasser
- Feldtest während Meteor Reise M133, ca. 2700 Messpunkte, 7 min Intervall
- Standardabweichung: „long term“: 2.4  $\mu\text{mol/kg}$ ; „short term“: 1.5  $\mu\text{mol/kg}$



# CVOO-Aktivitäten

(Durchgeführte Arbeiten & aktueller Stand)

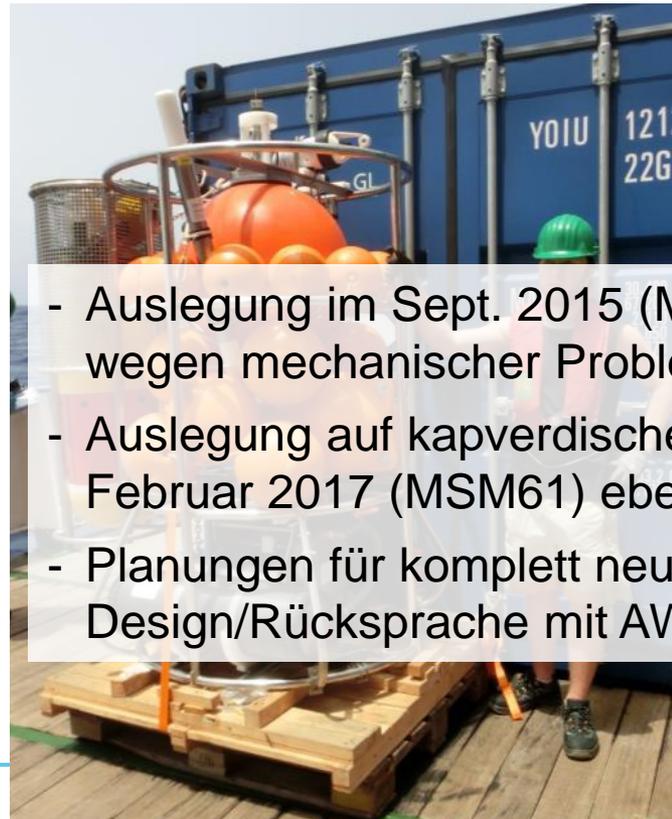
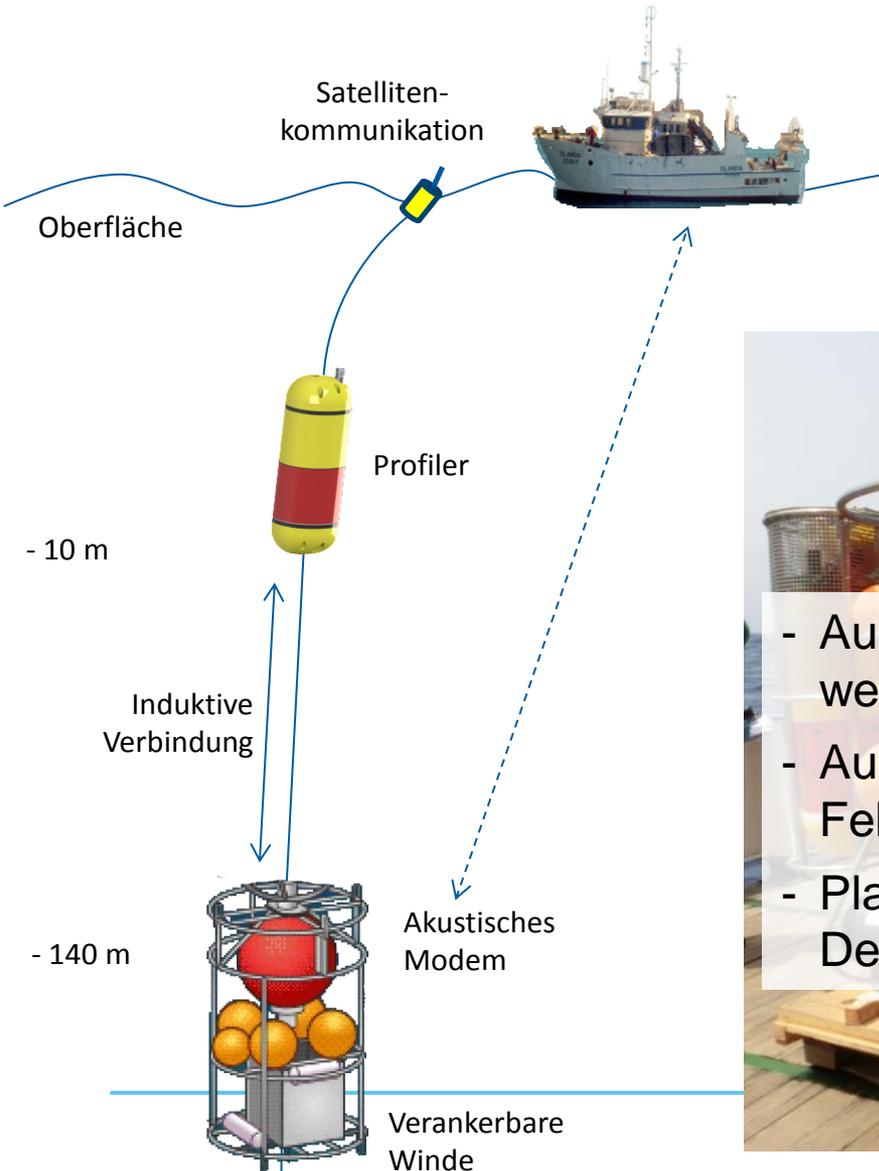


- Mehr als 30 Beprobungen durch FS Islandia und andere Forschungsschiffe seit 2012

- Verankerungsauslegungen in 2012, 2013, 2014, 2015, 2016 (Winde mit Profiler)
- Verankerte Sensoren: SAMI v2-CO<sub>2</sub>, AADI + KM Contros O<sub>2</sub>-Optoden
- Nächste Verankerungsauslegungen im Frühjahr 2018

# CVOO: Neue Beobachtungsansätze

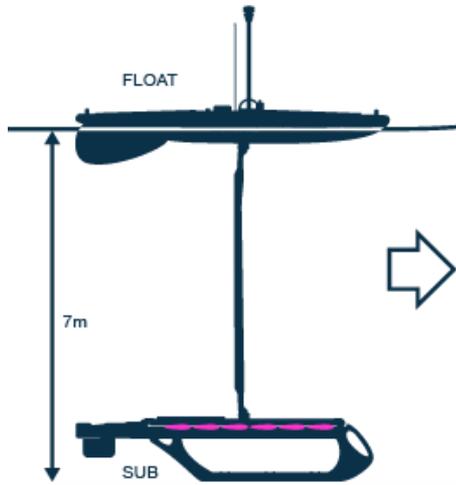
(Unterwasserwinde mit profilierendem Sensorträger)



- Auslegung im Sept. 2015 (Meteor-Reise M119) wegen mechanischer Probleme abgebrochen
- Auslegung auf kapverdischem Seamount im Februar 2017 (MSM61) ebenfalls abgebrochen
- Planungen für komplett neues Design/Rücksprache mit AWI

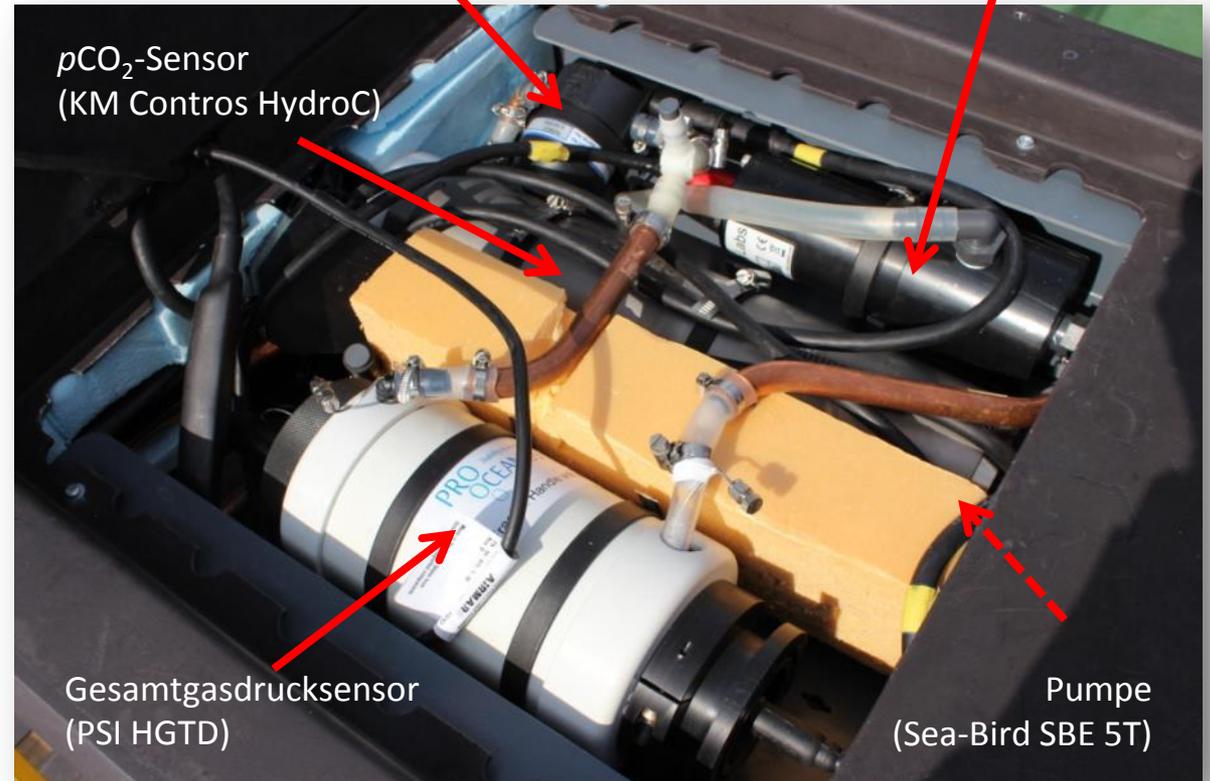
# CVOO: Neue Beobachtungsansätze

(Wave Glider als Mini-Forschungsschiff)



O<sub>2</sub>-Optode  
(Sea-Bird SBE 63)

Chlorophyll/Trübungssensor  
(Wetlabs FLNTURT)



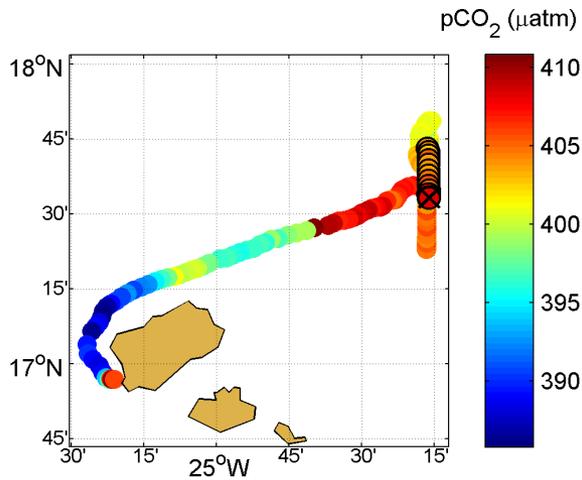
pCO<sub>2</sub>-Sensor  
(KM Contros HydroC)

Gesamtgasdrucksensor  
(PSI HGTD)

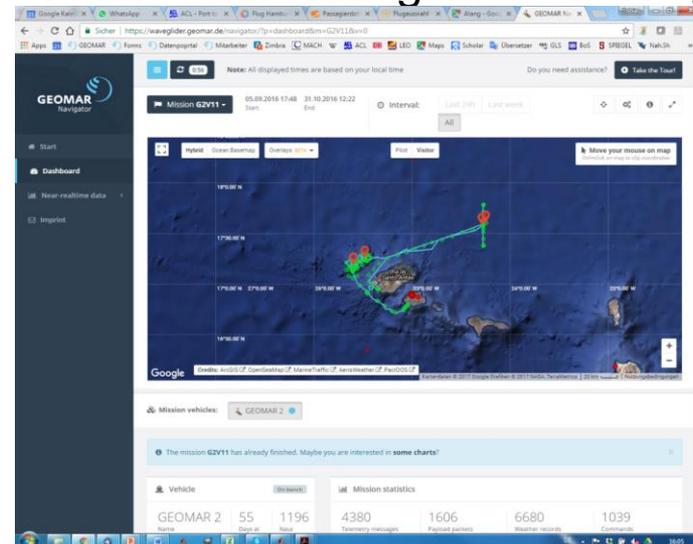
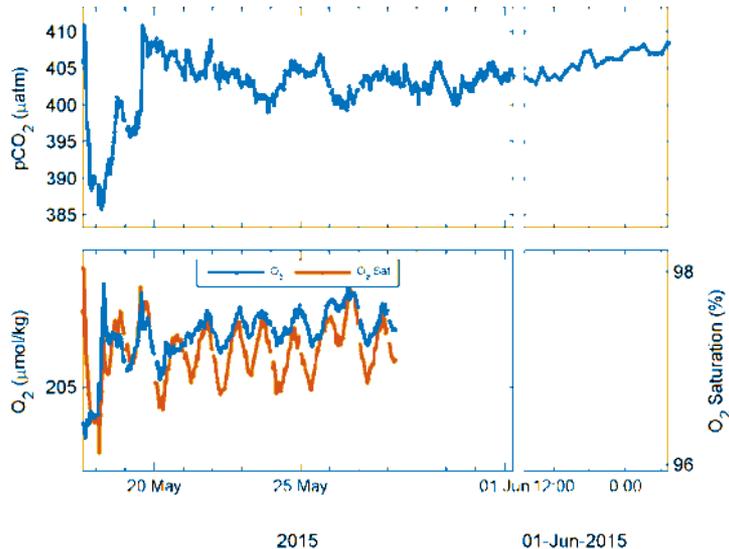
Pumpe  
(Sea-Bird SBE 5T)

# CVOO: Neue Beobachtungsansätze

(Wave Glider als Mini-Forschungsschiff)



- Dreiwöchiger Feldtest bei Kapverden/CVOO im Mai 2015
- Mai/Juni 2016: Felderprobung in Eckernförder Bucht
- Sep.-Nov. 2016: Einsatz bei Kapverden und während MSM61
- Zurzeit Überarbeitung von Navigationskomponenten
- Geplant ist die Erweiterung der Messungen um TA



# Ocean Science Center Mindelo (OSCM)



- Biological and chemical laboratories
- Workshop for construction and maintenance
- Large hall with crane for installation of laboratory containers and maintenance a large seagoing equipment
- Storage facilities (incl. cool & freeze storage)
- Conference room
- Guest offices
- Technical facilities

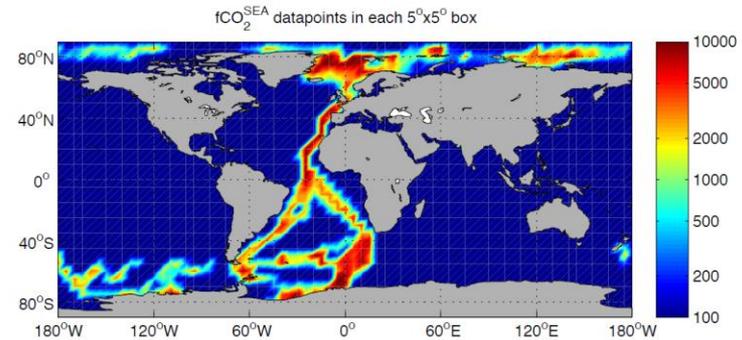


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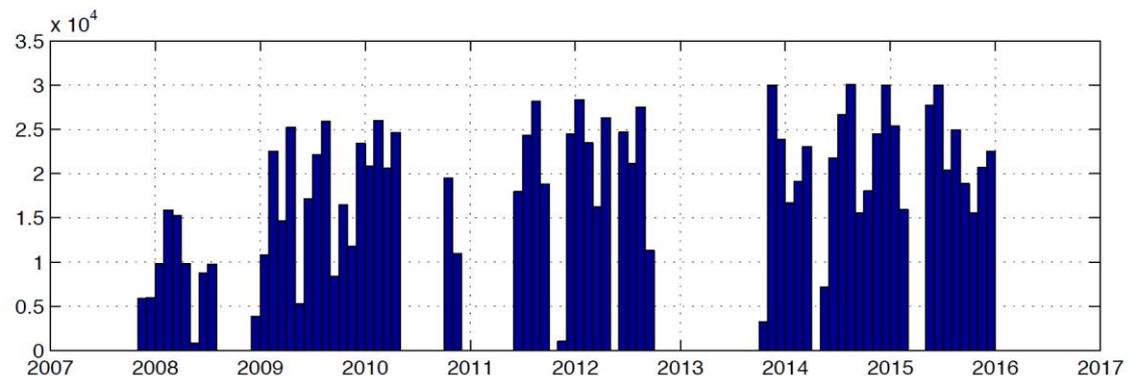


## CO<sub>2</sub> measurements on board the Voluntary Observing Ship (VOS) RV „Polarstern“

**PI's:** Mario Hoppema & Steven van Heuven  
**system:** General Oceanics GO8050  
**data:** fCO<sub>2</sub><sup>SEA</sup>, xCO<sub>2</sub><sup>atm</sup>, Ferrybox, Meteo  
**region:** Arctic - transit - Antarctic vv  
**uptime:** ~67%  
 ~422 weeks on board (from Nov '07)  
 ~365 weeks at sea  
 ~246 weeks of successful data  
 (~1.2 million two-minute fCO<sub>2</sub><sup>sea</sup> samples)



total of 14 cruise legs submitted to SOCATv2  
 total of 28 cruise legs (re-)submitted to SOCATv3  
 total of 39 cruise legs (re-)submitted to SOCATv4



### CO<sub>2</sub> measurements on board the Voluntary Observing Ship (VOS) RV „Polarstern“

- ❖ GO system for pCO<sub>2</sub> working properly and reliable.
- ❖ **Polarstern VOS is fully functional ICOS platform**
- ❖ pCO<sub>2</sub> systems were moved to deeper in ship, closer to water inlet
- ❖ Many high quality data collected, processed and submitted to SOCATv5
- ❖ Contribution to Global Carbon Budget 2016 (Le Quéré et al. ESSD 2016)

### Outlook

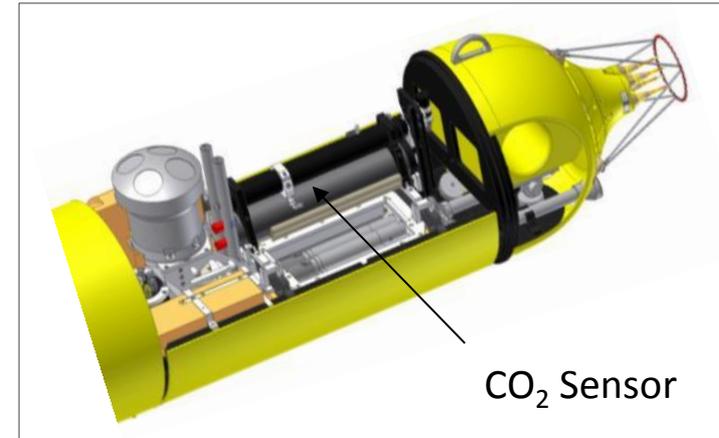
- Installation of a HydroFIA TA (for underway Total Alkalinity measurement); this enables to determine the complete CO<sub>2</sub> system
- Further comparisons of the GO and Oceanpack pCO<sub>2</sub> systems
- Contributions to SOCAT and quality controlling of SOCAT data



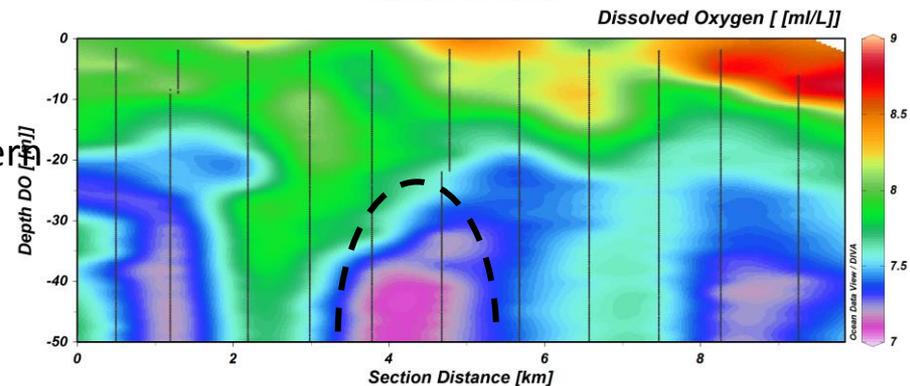
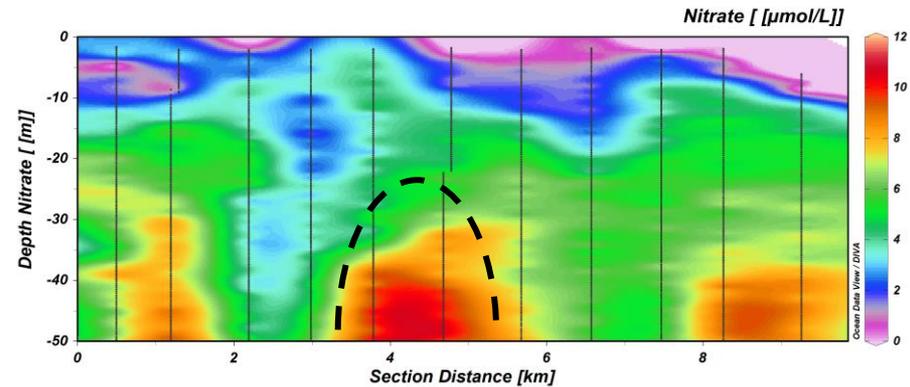
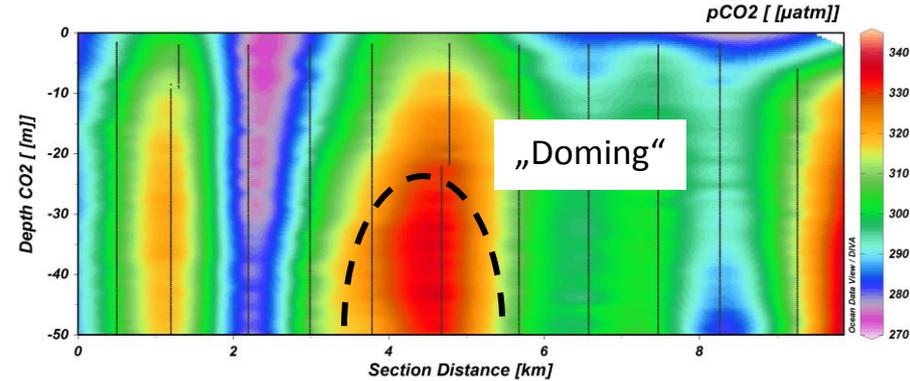
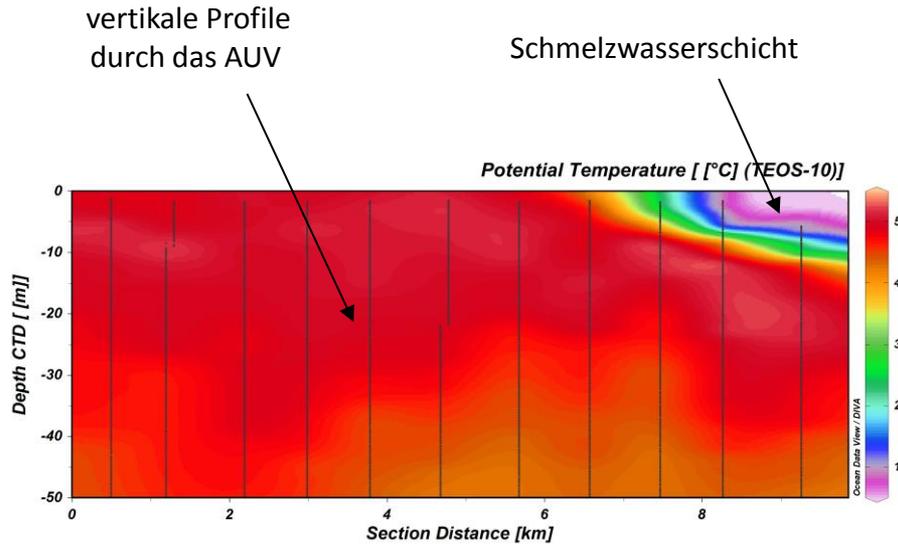
## Integration eines CO<sub>2</sub> Sensors in das autonome Unterwasserfahrzeug (AUV)

### Zusammenfassung der Arbeiten:

- Sensor: HydroC CO<sub>2</sub> (Contros, Kiel)
- strukturelle Integration in das AUV
- Einbau unterstützender Geräte  
(Pumpe, Elektronik für einen langsamen Anlauf der Pumpen)
- Anpassung der Stromversorgung der Nutzlast aufgrund des hohen Strombedarfs des Sensors
- Neuauslegung der Auftriebsverteilung des Fahrzeugs aufgrund des relativ hohen Sensorgewichts



## AUV-Tauchgänge in Eisrandbereichen



- $\text{CO}_2$  ist wichtiger Parameter um die Dynamik der Eisrandzone zu verstehen
- Korrelationen zwischen verschiedenen Parametern
- kleinskalige Messungen werden durch langsame Ansprechzeit der Sensoren verhindert

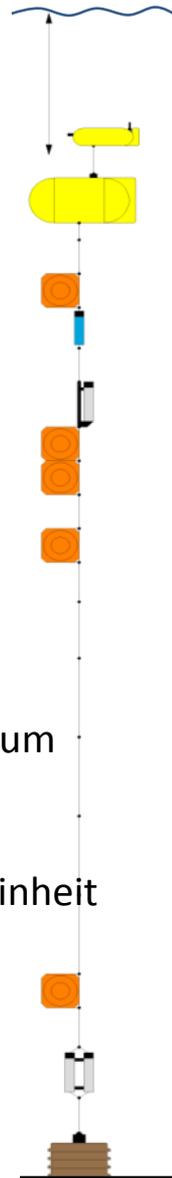
## Entwicklung einer Unterwasser-Winde mit profilierendem Sensor-Träger

### Zusammenfassung der Arbeiten 2016-2017

- Kurzzeit-Tests des Systems in Tjärnö, Schweden
- Vorbereitungen für den Langzeit-Einsatz (1 Jahr)

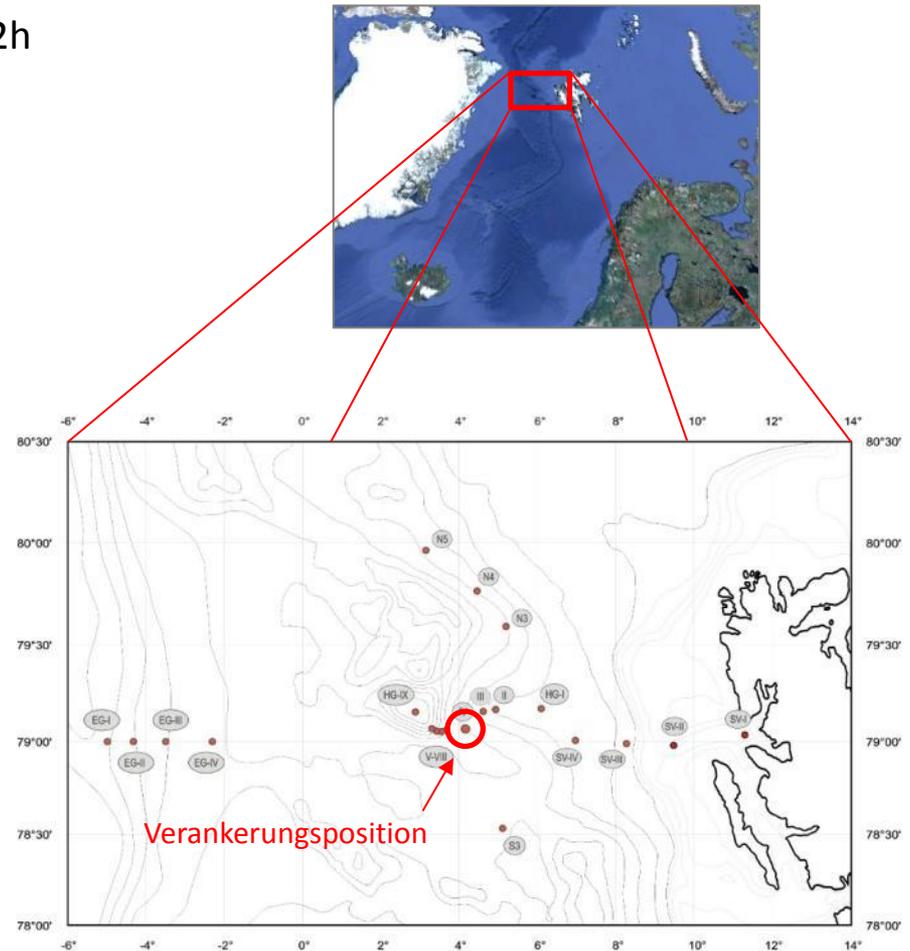


- Ausbringung des Systems am LTER Observatorium HAUSGARTEN in der östlichen Framstraße
- Beginn des Baus einer weiteren, optimierten Einheit des Unterwasserwinden-Systems



## Einsatz des Systems während der *Polarstern* Expedition PS99.2 im Sommer 2016

- Ausbringung im Bereich des Tiefsee-Observatoriums HAUSGARTEN
- Profil-Länge nominal 135 m, Profil-Intervall 72h
- Bergung geplant für den Sommer 2017



# Trace Gas measurements on board VOS Finnmaid

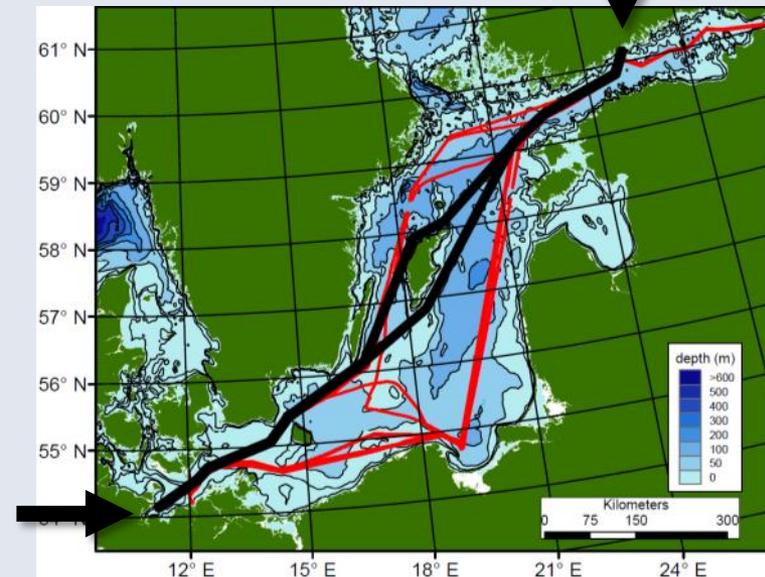
- **Current status of instrumentation**
  - $p\text{CO}_2$ ,  $p\text{O}_2$ , and  $p\text{CH}_4$
- **Some results of the last year(s)**
  - Statistics
  - Overview
- **Status versus plan”**



Helsinki  
(Finland)



Top: The “BALTIC VOS”  
Voluntary observing ship M/S Finnmaid, run  
by Finnlines,  
Right: possible cruise tracks, main tracks east  
and west of Gotland highlighted

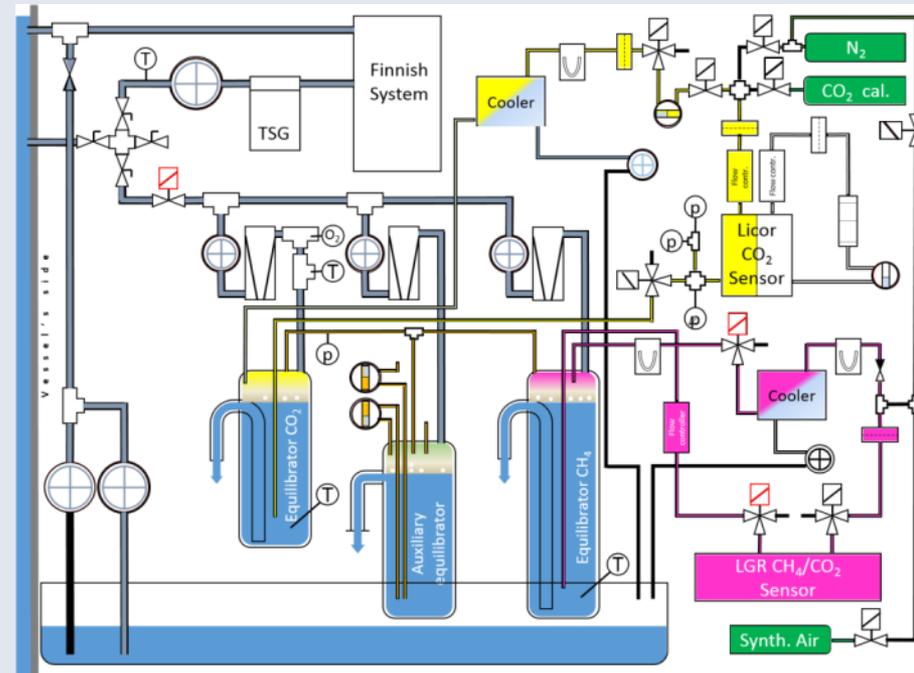


Lübeck  
(Germany)

## Current Installation on “BALTIC VOS”

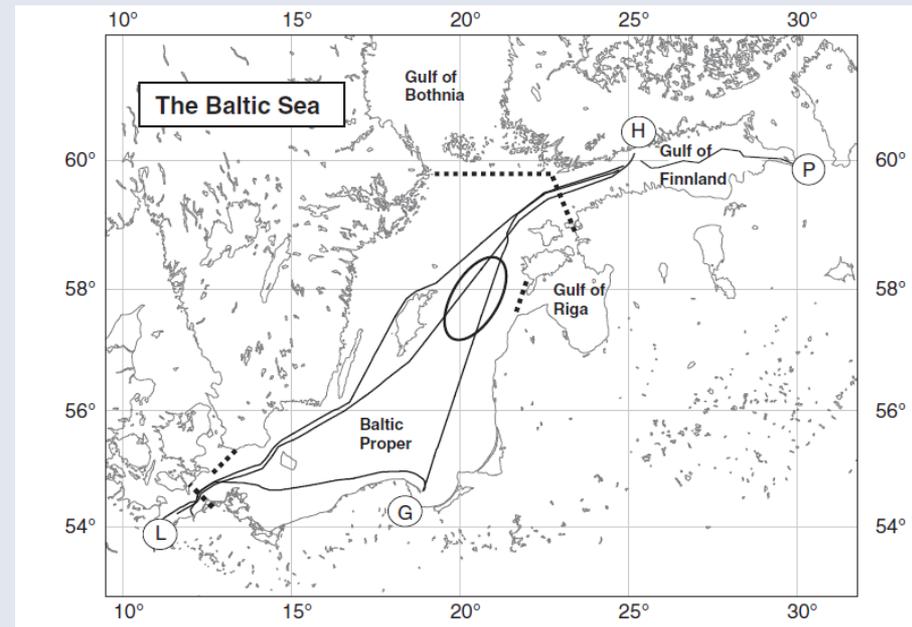


- Greenhouse gas measurements: **pCO<sub>2</sub>** and **CH<sub>4</sub>**
- Installed alongside preexisting Finnish Alg@line system (Real time algal monitoring in the Baltic Sea)



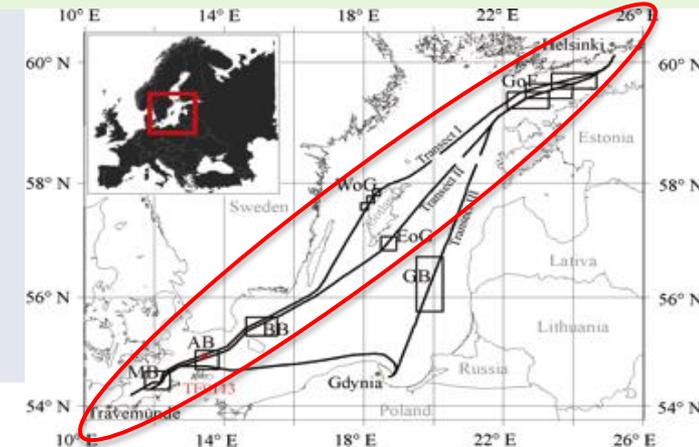
## Some performance statistics (2016)

- 187 (CO<sub>2</sub>) / 167 (CH<sub>4</sub>) ship transects with validated data (out of 213)
- 284.461 (CO<sub>2</sub>) / 258.749 (CH<sub>4</sub>) valid data (note redundant set up for pCO<sub>2</sub> based on LICOR and LOS GATOS oa-ICOS instrument)
- Ship heading approx. once per month to Skt. Petersburg for bunkering,
- **Data gaps and failure**
  - Shipyard stay
  - Air leakage ( LGR air pump)
  - Single component failure
  - discrepancy between the two independent pCO<sub>2</sub> systems



## Overview ( $p\text{CO}_2$ )

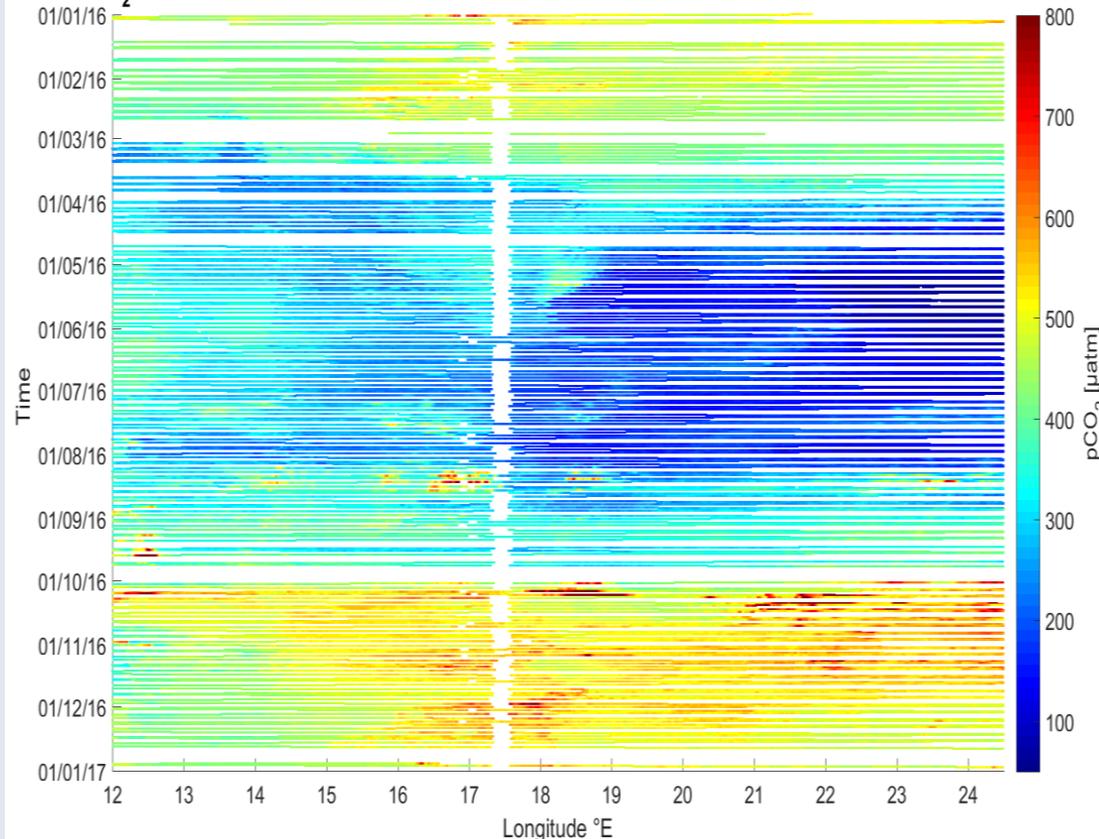
- Quantification of productivity and interannual drivers
- Seasonal switch of strong atmospheric source-sink behaviour



Surface  $p\text{CO}_2$  based on all data for 2016 on cruise tracks passing close to Gotland (Strong seasonal fluctuations between  $\text{CO}_2$ -oversaturation and undersaturation, most pronounced in the Gulf of Finland ( $22^\circ \text{ E}$ - $26^\circ \text{ E}$ )).

Propagation of spring bloom from SW to NE

Valid  $p\text{CO}_2$  [ $\mu\text{atm}$ ] data from Baltic Sea of IOW Equilibrator-Sensor-System (VOS FINNMAID) 01.01.2016 - 31.12.2016



## Status – On track versus not on track

### ON TRACK

- Data retrieval throughout the ICOS funding phases (2012-2016)
- pCO<sub>2</sub>-data delivered to SOCAT
- Station labeling process started
- New instruments (N<sub>2</sub>O, ICOS-funded) and  $\delta^{13}\text{C}_{\text{CO}_2}$  inhouse, Aandera weather station, ICOS-funded) tested and in preparation for installation

### PENDING

- New components in extended set up not installed on board VOS Finnmaid yet

### OTHER THINGS WORTHWHILE MENTIONING

- **RINGO** subproject funded (installation of **ATC-conform atm. data acquisition on VOS Finnmaid**)
- **BONUS INTEGRAL** under negotiation (tentative start July 1st, talk tomorrow)
- **SCOR 143 Intercalibration cruise** completed in October 2016 (non-CO<sub>2</sub> continuous surface Greenhouse gas measurements)



Earth Syst. Sci. Data, 5, 125–143, 2013  
www.earth-syst-sci-data.net/5/125/2013/  
doi:10.5194/essd-5-125-2013  
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A uniform, quality controlled Surface Ocean  
CO<sub>2</sub> Atlas (SOCAT)

## SOCAT v1, v1 gridded, v2, v3, v4, v5

A. Nakadate<sup>1</sup>, Y. Nakano<sup>2</sup>, S. Nakasaka<sup>3</sup>, Y. Nojiri<sup>4</sup>, A. M. Omar<sup>5,6</sup>, X. A. Padu<sup>7</sup>, G.-H. K. Paterson<sup>8,9</sup>, F. F. Perez<sup>10</sup>, D. Pierrot<sup>11</sup>, A. Pisoni<sup>12</sup>, A. F. Rios<sup>13</sup>, J. M. Santana-Cast  
J. Salisbury<sup>14</sup>, V. V. S. S. Sarma<sup>15</sup>, R. Schlitzer<sup>16</sup>, B. Schneider<sup>17</sup>, U. Schuster<sup>18</sup>, R. Sieg  
I. Skjelvan<sup>19</sup>, T. Steinhoff<sup>20</sup>, T. Suzuki<sup>21</sup>, T. Takahashi<sup>22</sup>, K. Tedeo<sup>23</sup>, M. Telszewski  
H. Thomas<sup>24</sup>, B. Tilbrook<sup>25,26</sup>, J. Tjiputra<sup>27</sup>, D. Vandemark<sup>28</sup>, T. Venzke<sup>29,30</sup>, R. Wannin

A multi-decade record of high-quality fCO<sub>2</sub> data  
version 3 of the Surface Ocean CO<sub>2</sub> Atlas (SOC)

D. C. E. Bakker, B. Pfeil, C. S. Landa, N. Metz, K. M. O'Brien, A. Olsen, K. Smith, C. Cosca, S. Harasawa, S.-I. Nakaoka, Y. Nojiri, U. Schuster, T. Steinhoff, C. Sweeney, T. Takahashi, B. Tilbrook, C. Wada, R. W. R. Alin, C. F. Balestrini, L. Barbero, N. R. Bates, A. A. Bianchi, T. Bonou, J. Boutin, Y. Bozec, E. F. Burger, D. Castle, L. Chen, M. Chierici, K. Currie, W. Evans, C. Featherstone, R. A. Feely, A. Fransson, C. G. Greenwood, L. Gregor, S. Hankin, N. J. Hardman-Mountford, J. Harley, J. Hauck, M. Hoppema, M. P. Hu, W. Hunt, B. Huss, J. S. P. Ibarra, T. Johannessen, R. Keeling, V. Kitis, A. Körtzinger, A. Kozyr, E. Kra, A. Kuvata, P. Landschützer, S. K. Lauvset, N. Lefèvre, C. Lo Monaco, A. Manke, J. T. Mathis, L. Merlivat, P. M. S. Monteiro, D. R. Munro, A. Murata, T. Newberger, A. M. Omar, T. Ono, K. Paterson, D. Pearce, D. Robbins, S. Saito, J. Salisbury, R. Schlitzer, B. Schneider, R. Schweitzer, R. Siegel, I. Skjelvan, K. F. Su Sutherland, A. J. Sutton, K. Taddoko, M. Telszewski, M. Tuma, S. M. A. C. Van Heuven, D. Vandemark, E. Watson, and S. Xu

Earth System  
Data  
www.earth-syst-sci-data.net/5/145/2013/  
doi:10.5194/essd-5-145-2013  
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Surface Ocean CO<sub>2</sub> Atlas (SOCAT) gridded data products

C. L. Sabine<sup>1</sup>, S. Hankin<sup>2</sup>, H. Kozyr<sup>3</sup>, D. C. E. Bakker<sup>4</sup>, B. Pfeil<sup>5,6</sup>, A. Olsen<sup>7</sup>, N. Metz<sup>8</sup>, A. Kozyr<sup>9</sup>,

www.earth-syst-sci-data.net/6/69/2014/  
doi:10.5194/essd-6-69-2014  
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An update to the Surface Ocean CO<sub>2</sub> Atlas (SOCAT  
version 2)

D. C. E. Bakker<sup>1</sup>, B. Pfeil<sup>2,3</sup>, K. Smith<sup>4,5</sup>, S. Hankin<sup>6</sup>, A. Olsen<sup>7,8</sup>, S. R. Allin<sup>9</sup>, C. Cosca<sup>10</sup>, S. Harasawa<sup>11</sup>, A. Kozyr<sup>12</sup>, Y. Nojiri<sup>13</sup>, K. M. O'Brien<sup>14</sup>, U. Schuster<sup>15</sup>, M. Telszewski<sup>16</sup>, B. Tilbrook<sup>17,18</sup>, C. Wada<sup>19</sup>, J. Aki<sup>20</sup>, L. Barbero<sup>21</sup>, N. R. Bates<sup>22</sup>, J. Boutin<sup>23</sup>, Y. Bozec<sup>24,25</sup>, W.-J. Cai<sup>26</sup>, R. D. Castle<sup>27</sup>, E. P. Chavez<sup>28</sup>, L. Chen<sup>29,30</sup>, M. Chierici<sup>31,32</sup>, K. Currie<sup>33</sup>, H. J. W. de Baar<sup>34</sup>, W. Evans<sup>35</sup>, R. A. Feely<sup>36</sup>, A. Fransson<sup>37</sup>, Z. Gao<sup>38</sup>, B. Hales<sup>39</sup>, N. J. Hardman-Mountford<sup>40</sup>, M. Hoppema<sup>41</sup>, W.-J. Huang<sup>42</sup>, C. W. Hunt<sup>43</sup>, B. Huss<sup>44</sup>, T. Ichikawa<sup>45</sup>, T. Johannessen<sup>46</sup>, E. M. Jones<sup>47</sup>, S. D. Jones<sup>48</sup>, S. Jutterström<sup>49</sup>, V. Kitis<sup>50</sup>, A. Körtzinger<sup>51</sup>, P. Landschützer<sup>52</sup>, S. K. Lauvset<sup>53</sup>, N. Lefèvre<sup>54,55</sup>, A. B. Manke<sup>56</sup>, J. T. Mathis<sup>57</sup>, I. Merlivat<sup>58</sup>, N. Metz<sup>59</sup>, A. Murata<sup>60</sup>, T. Newberger<sup>61</sup>, A. M. Omar<sup>62,63</sup>, T. Ono<sup>64</sup>, G.-H. Park<sup>65</sup>, K. Paterson<sup>66</sup>, D. Pierrot<sup>67</sup>, A. F. Rios<sup>68</sup>, C. L. Sabine<sup>69</sup>, S. Saito<sup>70</sup>, J. Salisbury<sup>71</sup>, V. V. S. S. Sarma<sup>72</sup>, R. Schlitzer<sup>73</sup>, R. Siegel<sup>74</sup>, I. Skjelvan<sup>75,76</sup>, T. Steinhoff<sup>77</sup>, K. F. Sullivan<sup>78</sup>, H. Sun<sup>79</sup>, A. J. Sutton<sup>80</sup>, T. Suzuki<sup>81</sup>, C. Sweeney<sup>82</sup>, T. Takahashi<sup>83</sup>, J. Tjiputra<sup>84</sup>, N. Tsurushima<sup>85</sup>, S. M. A. C. van Heuven<sup>86</sup>, D. Vandemark<sup>87</sup>, P. Vlahos<sup>88</sup>, D. W. R. Wallace<sup>89</sup>, R. Wanninkhof<sup>90</sup>, and A. J. Watson<sup>91</sup>



Global Carbon Budget 2013

Global Carbon Budget 2014

Global Carbon Budget 2015

Global Carbon Budget 2016