Session H: Ocean Salinity

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Session H:
Ocean Salinity

Klaus-Dieter Sommer & Petra Spitzer

Outline:

- Introduction
- Relevant Measurands & Objectives
- The Papers & related Challenges
- Summary

The World of Oceans

- have 1100 times the heat capacity of the atmosphere
  (i.e. 99.9% of the heat capacity of the climate system)
- contain 96.5% of Earth's water
- experience 86% of global evaporation
  and 78% of global precipitation

Most research programs on the "Global Water Cycle" do not yet properly treat the ocean's role.

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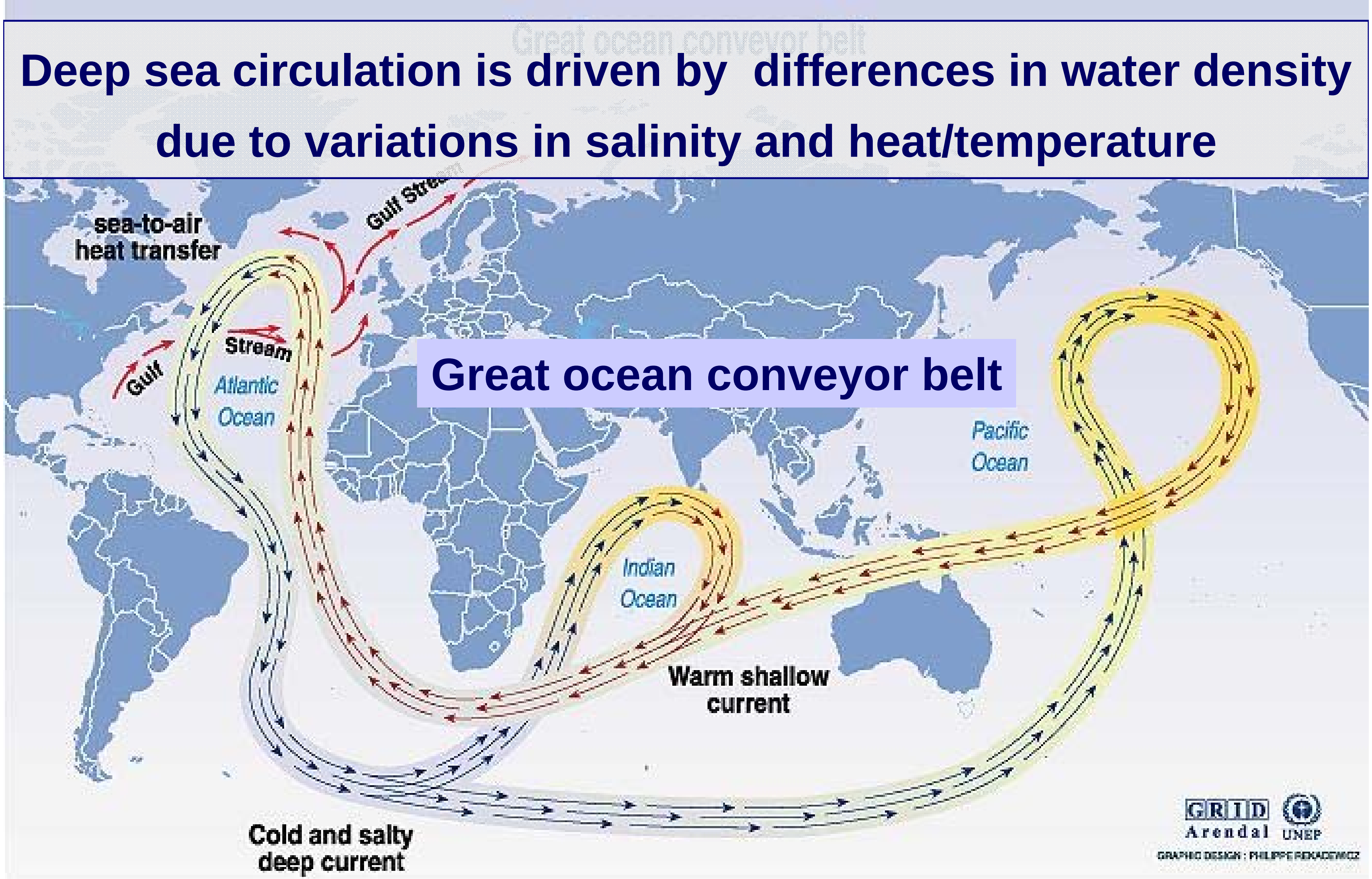
Deep sea circulation is driven by differences in water density due to variations in salinity and heat/temperature



Source: Broecker, 1991, in Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

GCOS Essential Climate Variables

…. for which international exchange is required for both current and historical observations

Oceanic climate variables:

Surface: Sea-surface temperature, **Sea-surface salinity**, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure**,** air-sea fluxes**,**

Sub-surface: Temperature, **Salinity**, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.

Furthermore: Ocean boundary currents and overflow

(green: other key variables not yet established)

Target: holistic understanding of gobal water cycle, ocean circulation and climate variability

http://www.wmo.ch/pages/prog/gcos

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Background on Salinity

Absolute Salinity (g/kg) is defined as the **mass fraction of dissolved material in seawater**. Hardly to determine experimentally!

Mass fractions of the various ions are assumed to be constant in seawater
Conductivity is proportional to the total amount of ions
Conductivity can be measured direct in the sea as ⇒ **Practical salinity**

Practical Salinity PSS-78 (unit less ratio) referred to a potassium chloride solution via IAPSO Standard Seawater
International accepted standard since 1978
NOT traceable to SI

PSS-78 is limited to the salinity range 2 to 42

PSS-78 does not account for composition anomalies

Major scientific needs highlighted in the Sydney Report:

Knowing ocean initial conditions
is essential for decadal forecasts and projections:

- requires observations through full depth of ocean
- ocean **sub-surface observation** of temperature, salinity, carbon
- ensuring **argo network being maintained** for more than 50 years
- homogeneous, **well-calibrated data sets** from both, **sea level and sattelites**
- more **systematic treatment of biases** supported by reference measurements

Target: holistic understanding gobal water cycle, ocean circulation and climate variability

http://www.wmo.ch/pages/prog/gcos

Challenges in Ocean Salinity Measurement I

- **To identify key measurement and calibration issues** which metrology support is required for, related to sea-surface and sub-surface poperties (coposition, thermal state, flux)

- **To implement the new (thermodynamic) equation of state** TEOS-10 (absolute salinity employed)

- To discuss and **develop new approaches to measure (absolute) salinity traceable to the SI** (promising: density, refractive index, speed of sound); additionally: **accounting for ocean diversity** („matrix effects“ from nutrients etc.)

- Generally: to ensure traceability, **long-term reliability and compa-tibility of measured data**

- **Methods and standards to be developed** to meet ocean community needs

Challenges in Ocean Salinity Measurement II

- In particuar: Systematically **modelling the ocean measurements and more reliably evaluating the associated measurement uncertainty**

- **Cross-linking the measurements,** inparticular of in-situ measurements and sattelite-based results by modern data fusion methods

  Only smart measuring (sensor) networks offer the full performance needed for ocean and climate research

- To identify future requirements for improved underpinning metrology in sustainable ocean observation and monitoring

- To drive road-mapping within NMIs to ensure that measurement methods and standards are developed to meet ocean community needs

Presentations in the Ocean-Salinity Session

▪ Rainer Feistel:	TEOS-10: The new thermodynamic definition of seawater
▪ Birgit Klein:	Salinity calibration standards adopted in the international Argo programme
▪ Rainer Feistel:	Sea-Salt Composition and Oceanographic Salinity Scales
▪ Martin Visbeck:	Global climate and ocean observing systems, opportunities and challenges
▪ Thierry Delcroix:	The sea-surface salinity observation system
▪ Petra Spitzer:	Traceable salinity measurement
▪ Chen-Tung Arthur Chen:	Role of the oceans in global cycles of carbon and nutrients

The Oceans and the Global Climate System

Ocean

- is the main regulator of the global climate system
- is a sink for anthropogenic carbon dioxide
- is in its dynamics strongly relying on the properties of seawater

A major factor of ocean dynamics are spatio-temporal variations in absolute salinity (mass fraction of dissolved material in seawater)

Therefore, „absolute salinity“ traceable to SI is the appropriate measurand to characterize this property

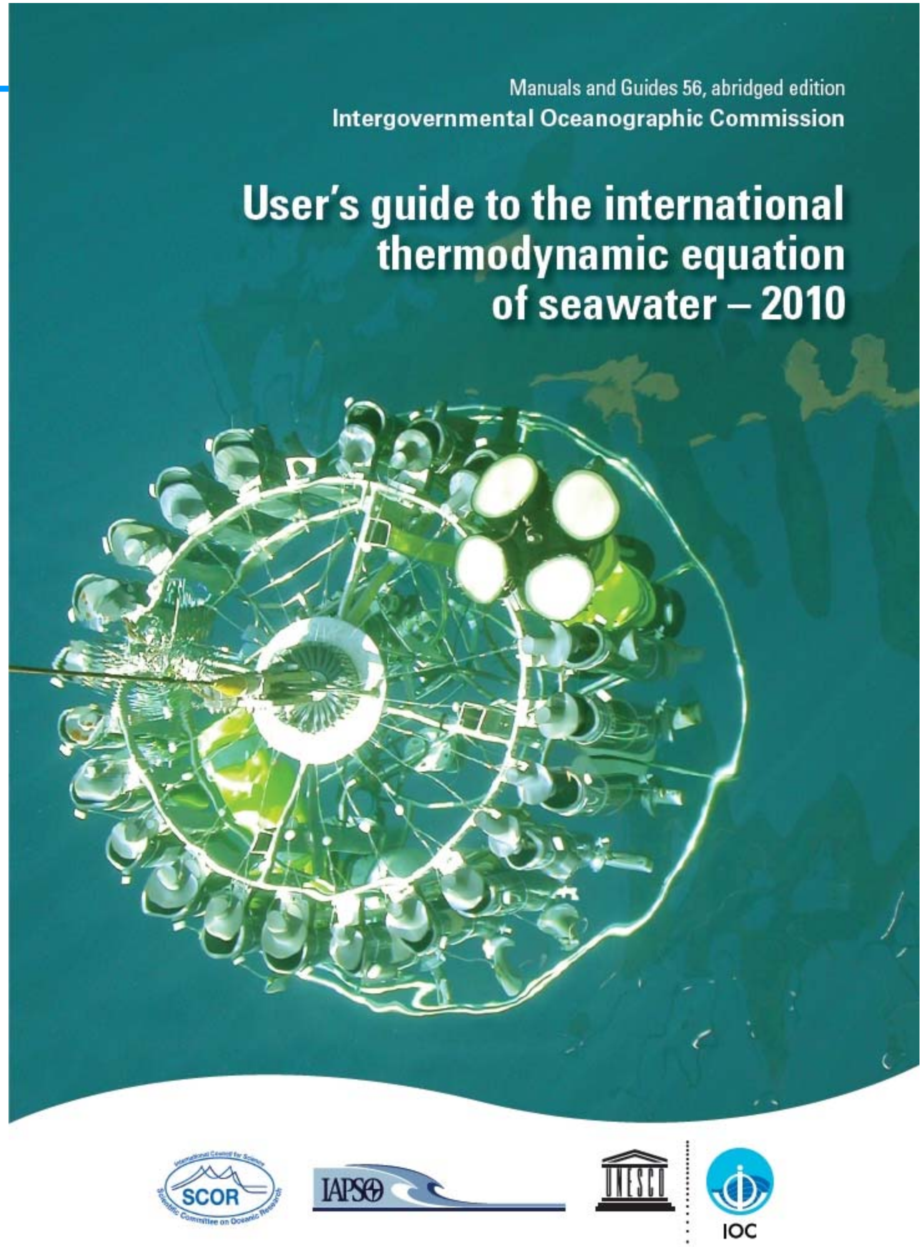
Unfortunately, it cannot be measured in accordance with its definition.

TEOS-10

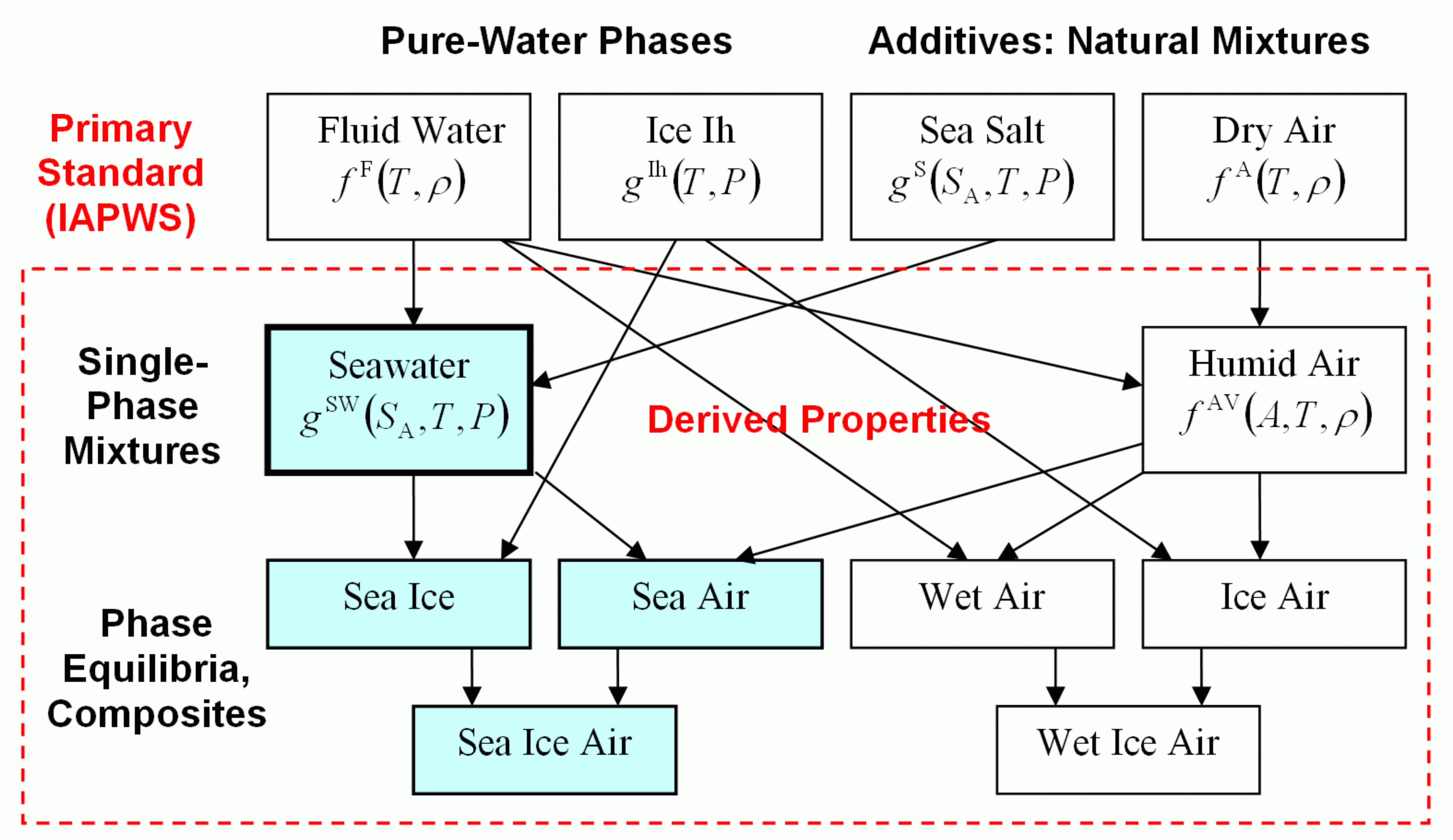
Rainer Feistel:
TEOS-10:
The new thermodynamic definition of seawater

2010 IOC endorsed new
Thermodynamic Equation of Seawater – 2010 (TEOS-10)
from which accurate algorithms for calculating density and many other thermodynamic properties (e.g. heat capacity) of seawater are available

Part of the new thermodynamic treatment of seawater involves
adopting Absolute Salinity



Modular architecture of the TEOS-10 standard for seawater



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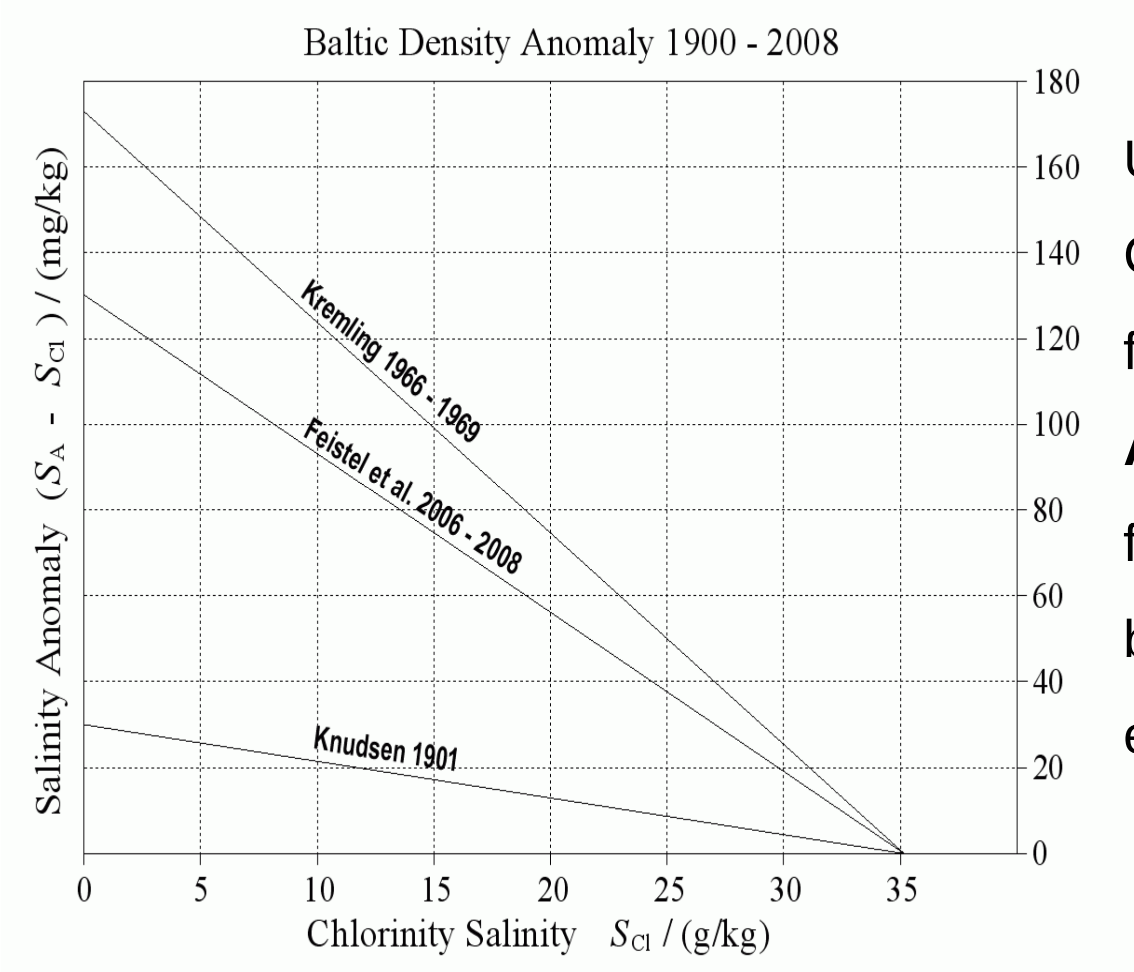
Sea-Salt Composition and Oceanographic Salinity Scales

Talk of Rainer Feistel:

TEOS-10 permits to account for regionally anomalous solutes

- **silicates in North Pacific**
- **lime in Baltic Sea**

Decadecal variability of the baltic Sea composition anomaly



Using TEOS-10 equations, Chlorinity-Salinity computed from measured chlorinity and **Absolute Salinity**, estimated from density parameterized by linear correlation (Feistel et al 2009)

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Absolute Salinity

Absolute Salinity:

- is a **key variable not only for monitoring/modelling ocean circulation**
- **but also biodiversity in aquatic ecosystems** depends on salinity

To understand the impact of anthropogenic carbon dioxide on the ocean and to quantify the acidification process in more detail, metrological references for pH and salinity are needed

Arthur Chen Talk:

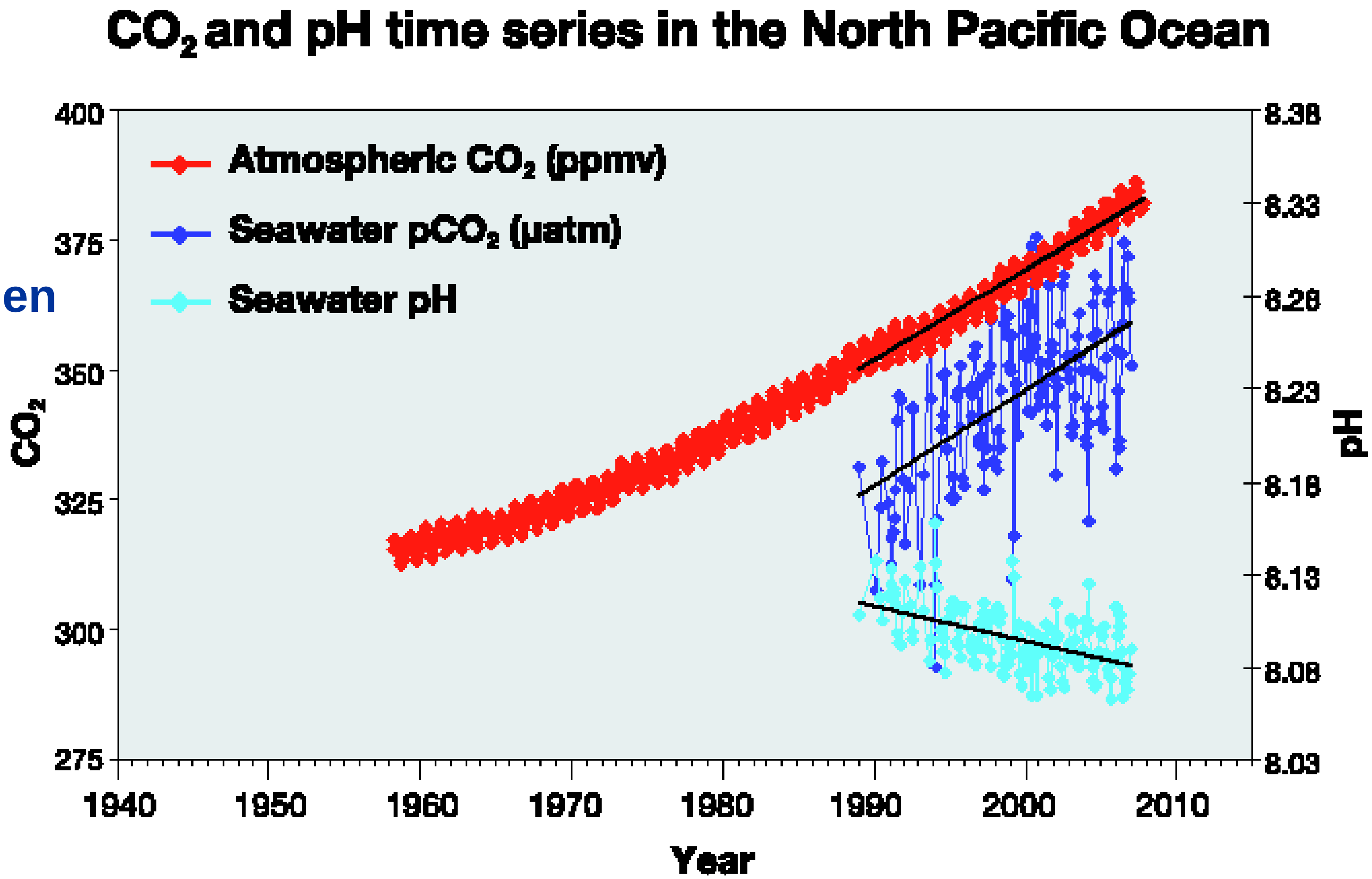
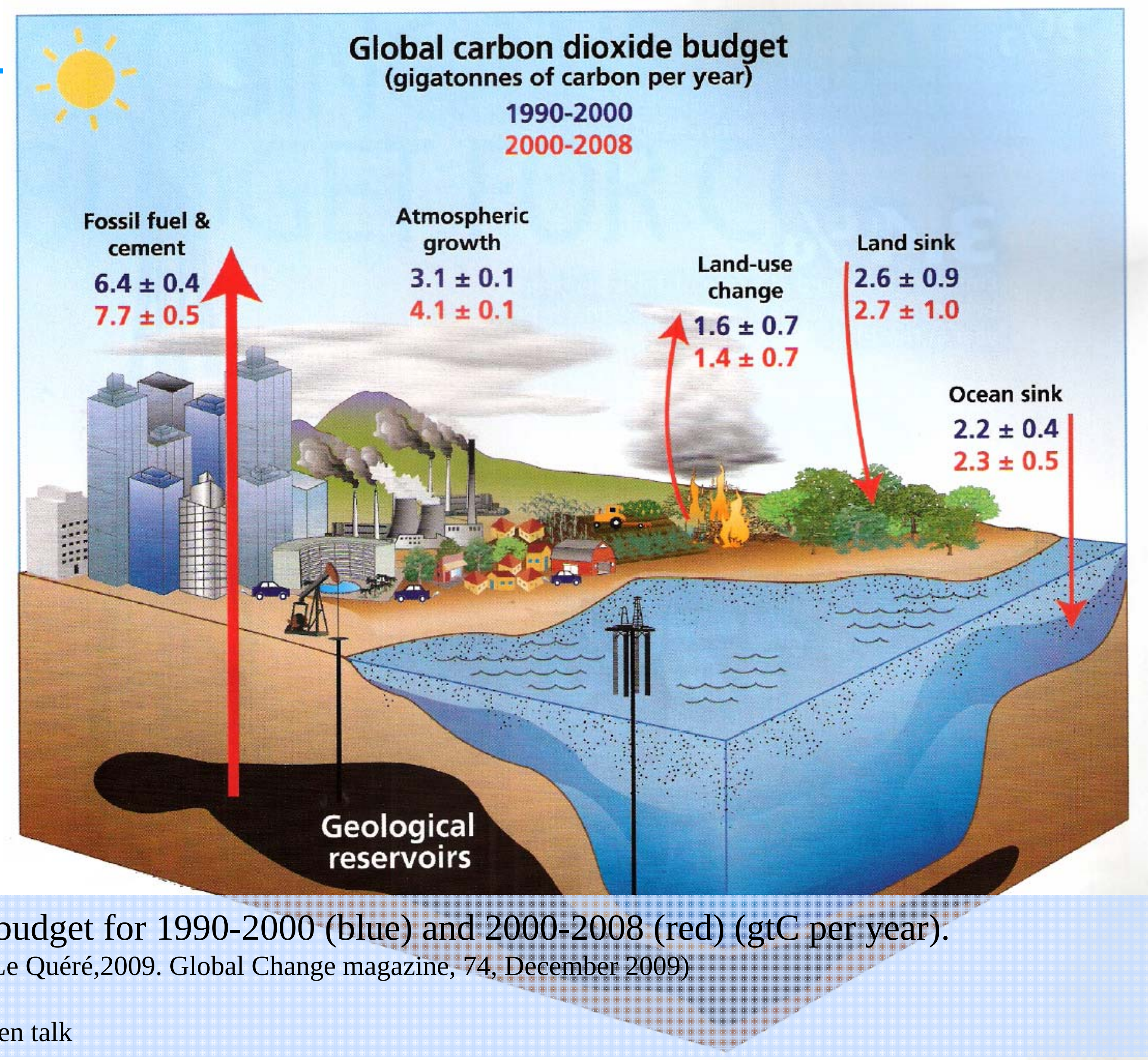


Figure credit:
Richard A. Feely, Pacific Marine Environmental Laboratory,
National Oceanic and Atmospheric Administration, USA,
with atmospheric data from Pieter Tans and seawater data from David Karl.
Adapted from Feely (2008) in Levinson and Lawrimore (eds),
Bull. Am. Meteorol. Soc. 89(7): S58.

Taken from Ocean Acidification, 2009

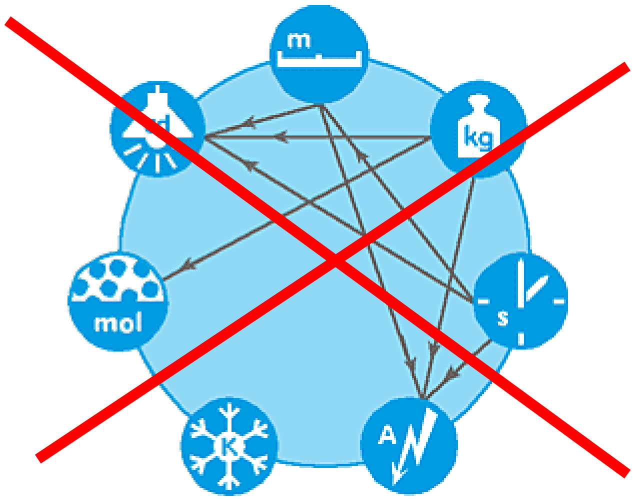


Global CO_2 budget for 1990-2000 (blue) and 2000-2008 (red) (gtC per year).
(Taken from C. Le Quéré,2009. Global Change magazine, 74, December 2009)

Form Arthur Chen talk

Traceable measurement of salinity

In oceanography conductivity measurements are used as a practical measure for salinity:
Practical Salinity S



Measurement results are not traceable to the SI

Practical salinity	comparable for	within a rel. uncertainty (CCQM-P111 study)
current traceability	some years	5×10^{-5}
traced to SI	centuries	**3×10^{-4} (Problem)**

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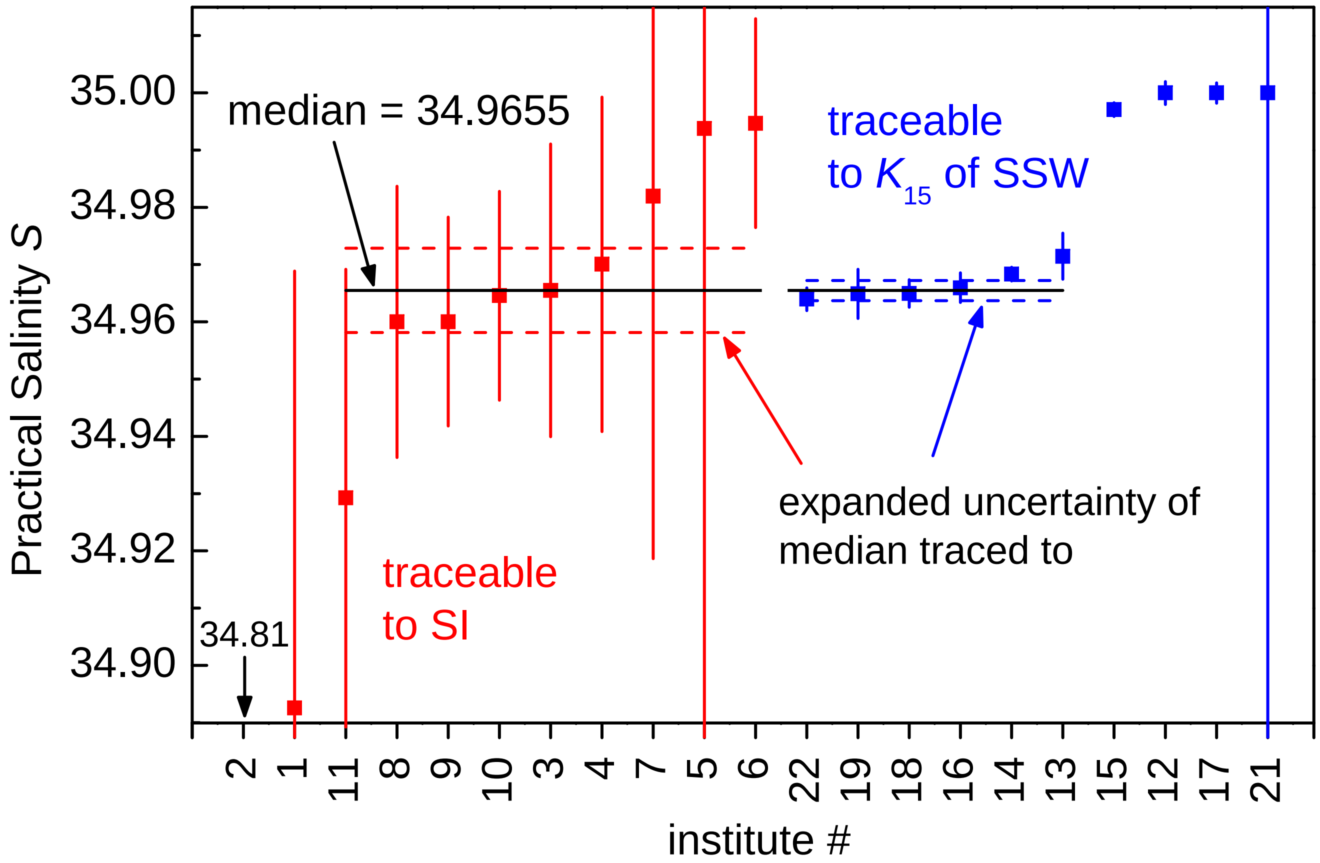
Evaluation of CCQM-P111 results



$$S_{SI} = S(R = \frac{\kappa_{SI-traced}}{\kappa_{scale}})$$

κ_{scale} = 4.29104 S/m

chosen such that medians matches

<u>relative uncertainties of medians</u>

traceable to SI: 3×10^{-4} to K_{15} (rel. conductivity) of SSW: 5×10^{-5}

Conductivity & Salinity Problems

Way out? Density as the Composition Measurand

(rather than Practical Salinity)

- SI-traceable to 2-3 ppm uncertainty, no artefacts
- Most relevant quantity for oceanography
- Permits computation of absolute salinity
- Detects non-conducting chemical species

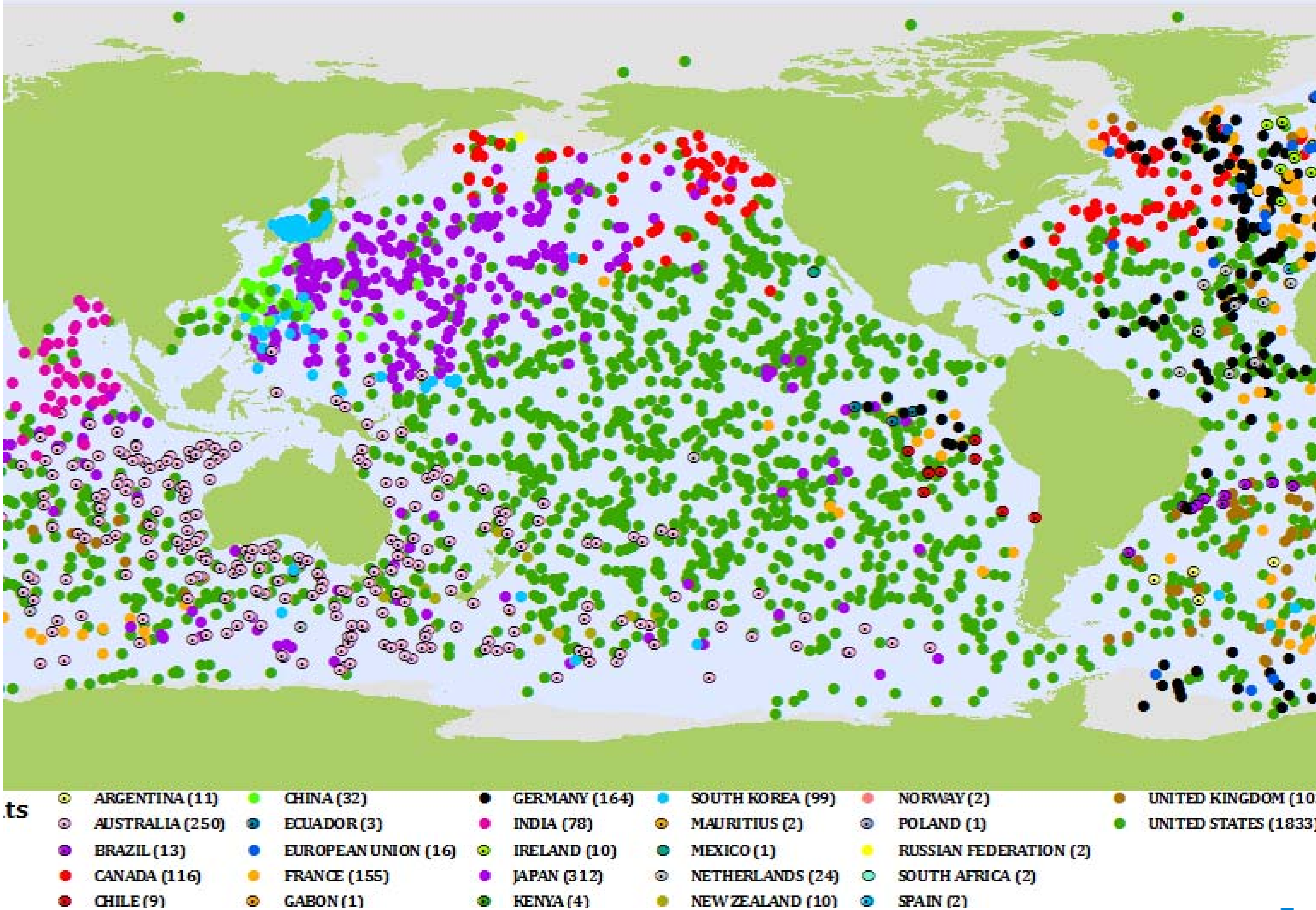
Discussion:
Standard seawater (SSW) also calibrated for density, to indicate Absolute Salinity
Need research in seawater standard stability; Influence of species (silicate, nitrate, nutrients, DIC, traces on SSW)

International Argo program to measure salinity

Talk of Birgit Klein:

Argo program operates an autonomous in-situ observing network of more than 3000 drifting instruments
Contributions from 23 different countries
To create a unified data set, it is essential to standardize quality control and data processing

Status of Argo Network



Talk of Martin Visbeck: Reports on OceanObs´09
Global climate and ocean observing systems, opportunities and challenges

Vision: Provision of routine and sustained global information on the marine environment sufficient to meet society's needs for describing, understanding and forecasting marine variability (including physical, biogeochemical, ecosystems and living marine resources), weather, seasonal to decadal climate variability, climate change, sustainable management of living marine resources, and assessment of longer term trends


Thank you