

Regionale Ozeanographie

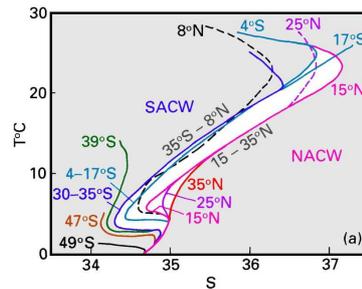
05 – Wassermassenanalyse

Literatur:

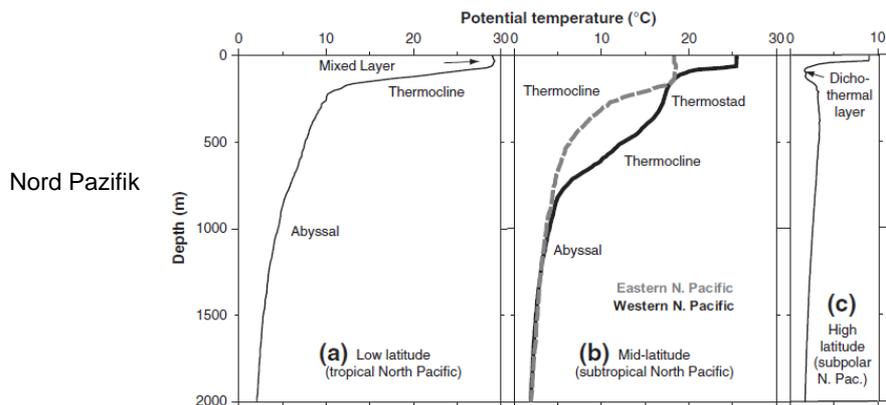
Emery, W.J. and R.E. Thomson (2001) *Data Analysis Methods in Physical Oceanography*. ELSEVIER, Amsterdam.

Karstensen, J. (1999) *Über die Ventilation der Thermokline des Indischen Ozeans*. Dissertation, Universität Hamburg

<http://www.sub.uni-hamburg.de/opus/volltexte/1999/74/html/node4.html>

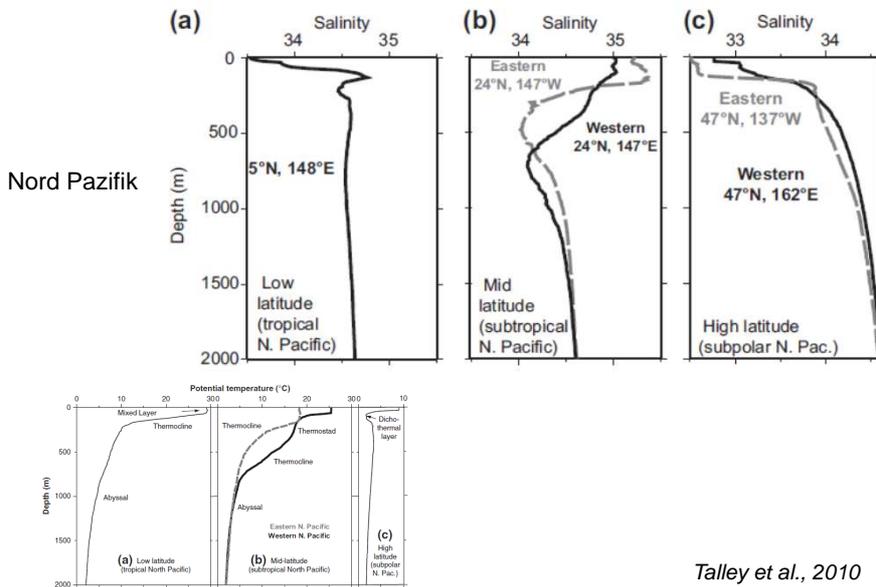


Schichtung

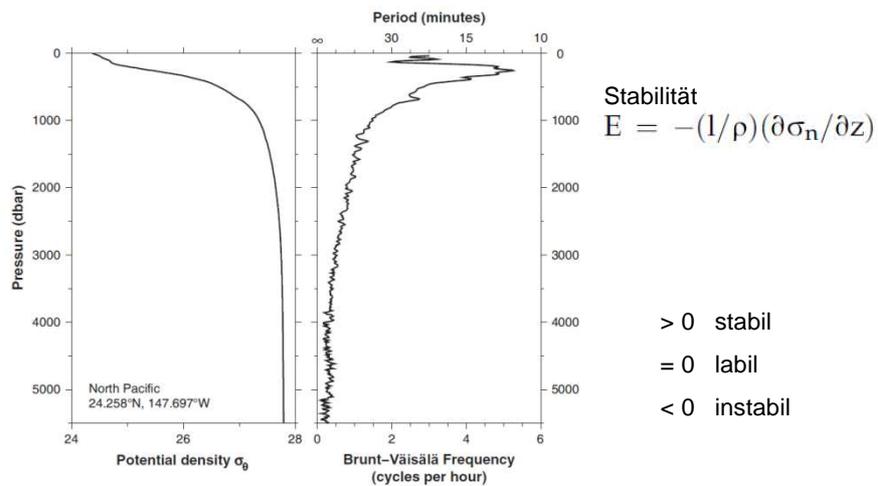


Talley et al., 2010

Schichtung



Stabilität der Wassersäule



Brunt-Väisälä Frequenz $N^2 = gE \approx g[-(1/\rho)(\partial\sigma_n/\partial z)]$

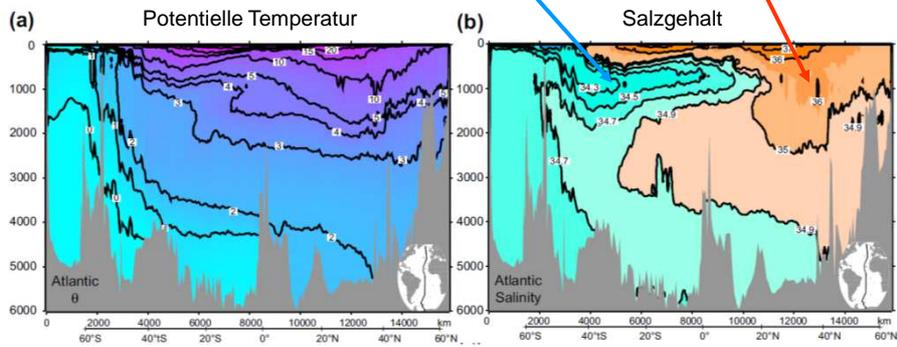
Talley et al., 2010

Vertikalschnitte

Atlantik

Antarktisches Zwischenwasser

Mittelmeerwasser

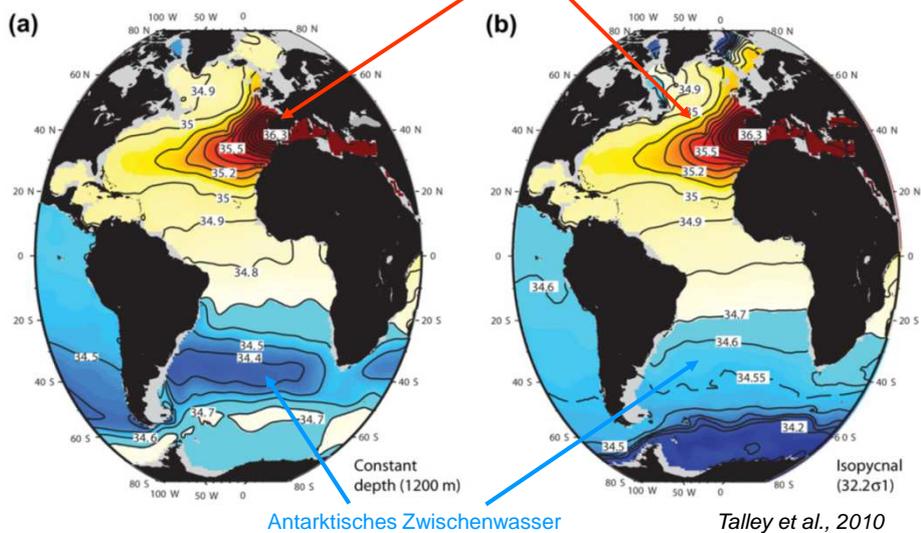


Talley et al., 2010

Horizontalverteilungen

Salzgehalt

Mittelmeerwasser



Talley et al., 2010

Temperatur-, Salzgehalts- und Dichte-Gleichung

$$\begin{aligned}
 DT/Dt &= \frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} && \text{zeitliche Variabilität} \\
 &+ w \frac{\partial T}{\partial z} && \text{Advektion/Konvektion} \\
 &= \frac{Q_H}{\rho c_p} + \frac{\partial}{\partial x}(\kappa_H \frac{\partial T}{\partial x}) && \text{Quellen/Senken} \\
 &+ \frac{\partial}{\partial y}(\kappa_H \frac{\partial T}{\partial y}) + \frac{\partial}{\partial z}(\kappa_V \frac{\partial T}{\partial z}) && \text{Mischung}
 \end{aligned}$$

$$\begin{aligned}
 DS/Dt &= \frac{\partial S}{\partial t} + u \frac{\partial S}{\partial x} + v \frac{\partial S}{\partial y} + w \frac{\partial S}{\partial z} \\
 &= Q_s + \frac{\partial}{\partial x}(\kappa_H \frac{\partial S}{\partial x}) \\
 &+ \frac{\partial}{\partial y}(\kappa_H \frac{\partial S}{\partial y}) + \frac{\partial}{\partial z}(\kappa_V \frac{\partial S}{\partial z})
 \end{aligned}$$

$$\rho = \rho(S, T, p) \quad \text{Zustandsgleichung}$$

$$\begin{aligned}
 D\rho/Dt &= \frac{\partial \rho}{\partial t} + u \frac{\partial \rho}{\partial x} + v \frac{\partial \rho}{\partial y} + w \frac{\partial \rho}{\partial z} \\
 &= (\frac{\partial \rho}{\partial S}) DS/Dt + (\frac{\partial \rho}{\partial T}) DT/Dt \\
 &+ (\frac{\partial \rho}{\partial p}) Dp/Dt
 \end{aligned}$$

Talley et al., 2010

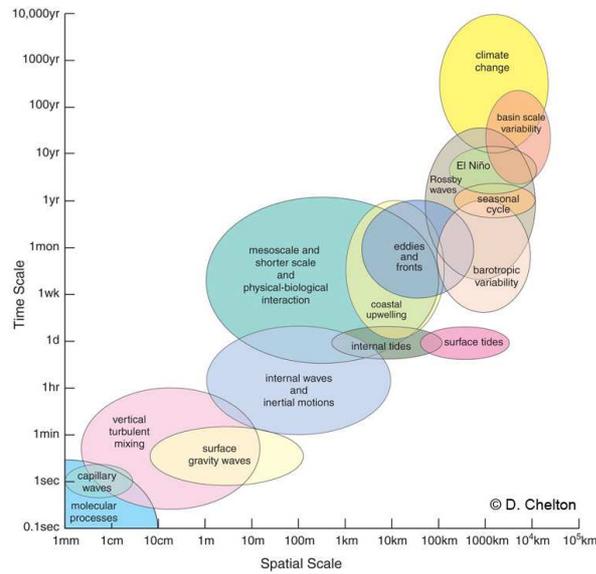
Diffusion κ

Molekulare Diffusion: κ – Wärme $\sim 1.3 - 1.5 \cdot 10^{-7} \text{ m}^2/\text{s}$
 κ – Salz $\sim 1.3 \cdot 10^{-9} \text{ m}^2/\text{s}$

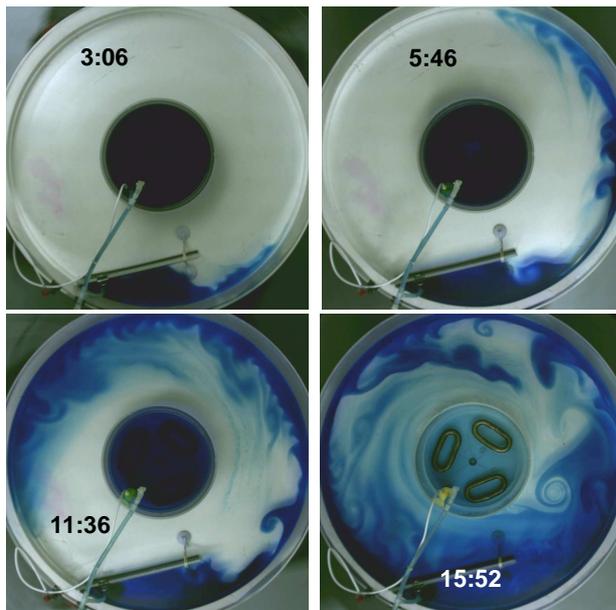
Turbulente Diffusion ist keine Eigenschaft des Meerwassers sondern hängt von den betrachteten Skalen ab

κ – Wärme/Salz horizontal $\sim 10^2 - 10^4 \text{ m}^2/\text{s}$
 κ – Wärme/Salz vertikal $\sim 10^{-5} \text{ m}^2/\text{s}$

Skalen ozeanischer Prozesse



Tracerausbreitung



Advektion im geostrophischen Randstrom

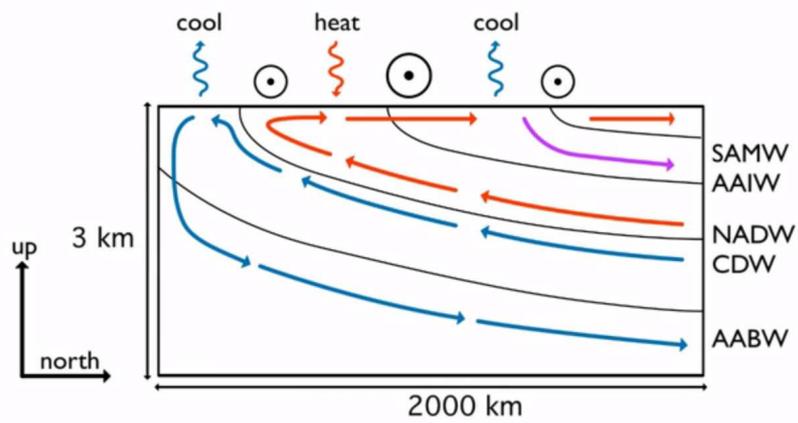
Wirbeldiffusion zum Zentrum des Beckens

Diffusion durch submesoskalige Prozesse

Molekulare Diffusion

Rotierender Tank. Einleitung von gefärbtem Süßwasser in Salzwasser. Seepraktikum Prandtl 2014.

Wärmetransporte im südlichen Ozean



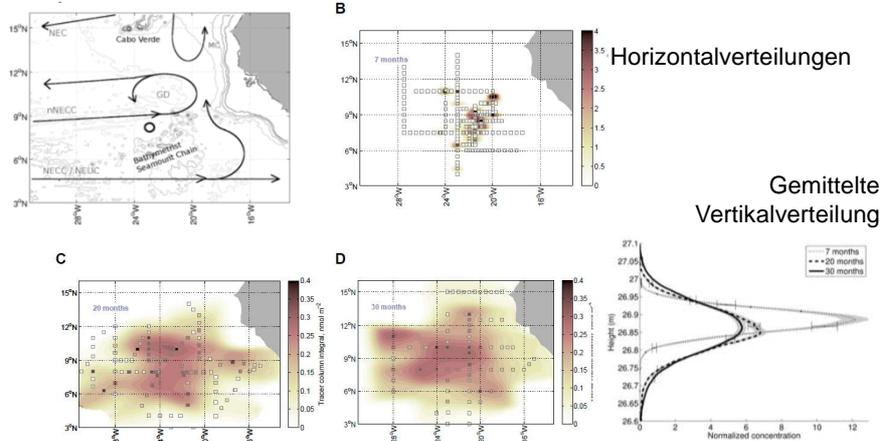
Ryan Abernathey
<https://vimeo.com/17822148>

Wärmetransporte im südlichen Ozean



Ryan Abernathey
<https://vimeo.com/17822148>

Tracerexperiment

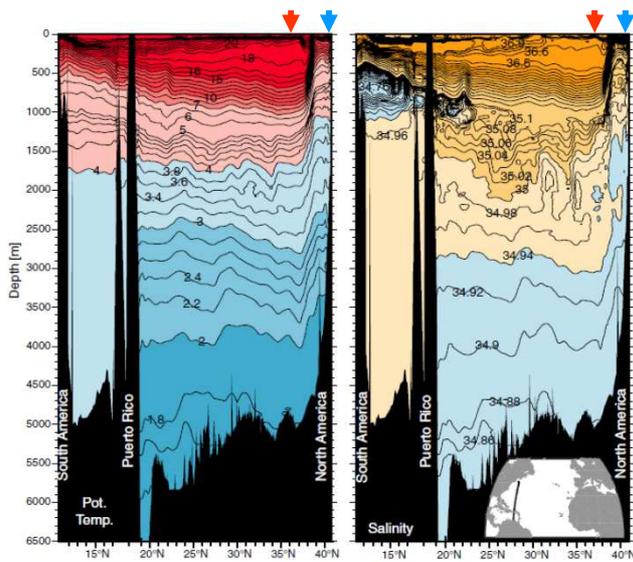


$$K_H \sim 3 - 5 \cdot 10^3 \text{ m}^2/\text{s}$$

$$K_V \sim 1.7 \cdot 10^{-5} \text{ m}^2/\text{s}$$

Banyte et al., 2013

Westlicher Atlantik - Golfstrom



Talley et al., 2010

Temperatur-Salzgehalts Diagramm

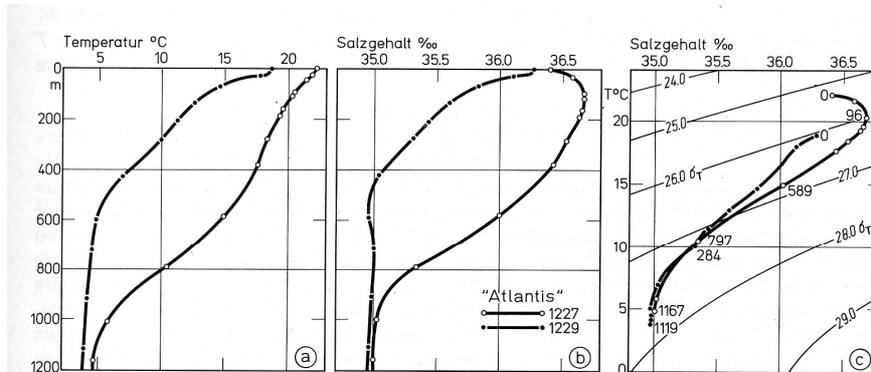
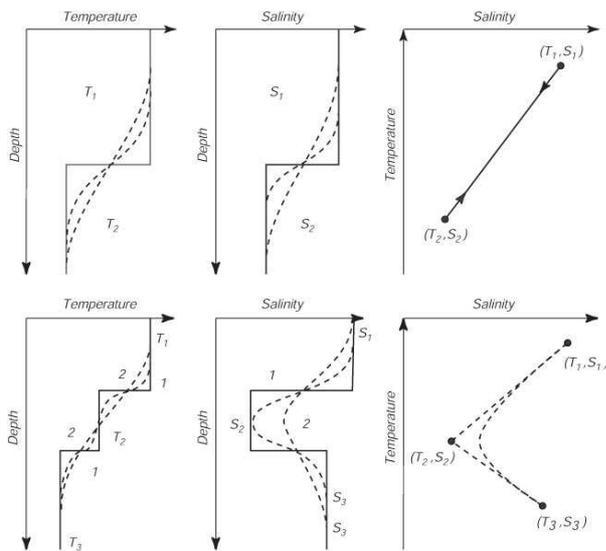


Abb. 5.16. Beziehung zwischen Temperatur und Salzgehalt auf den beiden benachbarten Stationen „Atlantis“ 1227 und 1229 im Golfstrom östlich von Kap Hatteras. Stationslage s. Abb. 10.42. a) Vertikale Temperaturverteilung; b) vertikale Salzgehaltsverteilung; c) TS -Beziehung. Ziffern an den Meßpunkten: Meßtiefen in m.

Dietrich et al, 1975

Vertikale Vermischung



Dietrich et al, 1975

Einige Definitionen und Begriffe

Wassermasse

Wasserkörper, der die gleiche oder ähnliche Bildungsgeschichte seiner Bestandteile besitzt.

Wassertyp

Funktionaler Zusammenhang seiner charakteristischen Parameter und deren Varianz (Punkte im Parameterraum)

Quellwassertyp

Wassertypen in den Quellregionen

Einige Definitionen und Begriffe

Wassermassentracer

konservative Tracer

nahezu konstante Eintragsfunktion an der Grenzfläche Ozean-Atmosphäre

nicht-konservative Tracer

nahezu konstante Eintragsfunktion, zeitlich variable Quellen und Senken

transiente Tracer

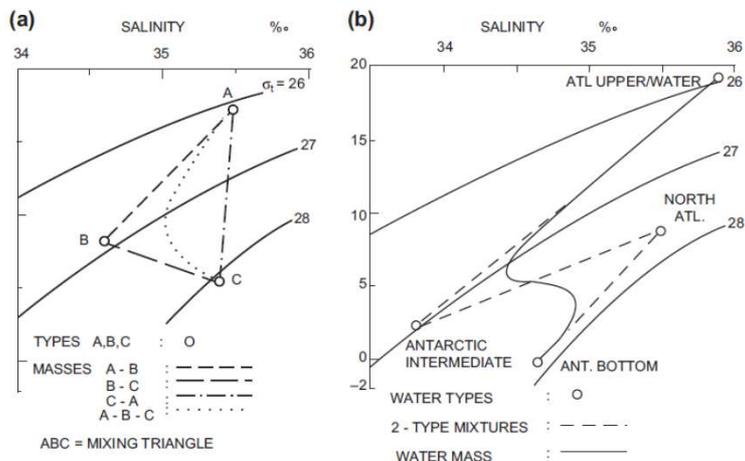
variable Eintragsfunktion, zeitlich variable Quellen und Senken

Redfield Verhältnis

Verhältnis der Nährstoffkonzentrationen im Plankton zueinander

1 Mol P : 16 Mol N : 106 Mol C

Klassische Wassermassenanalyse



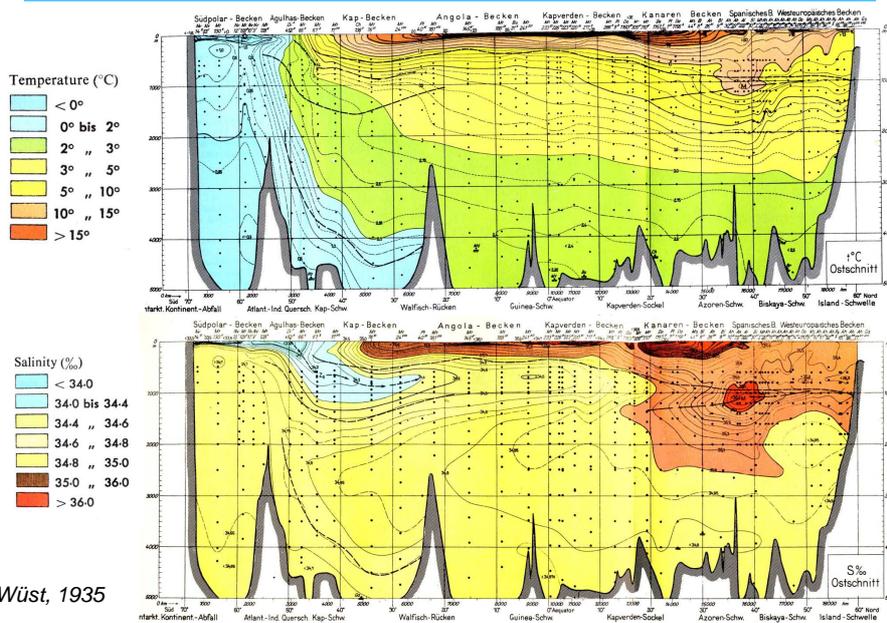
$$x_a T_a + x_b T_b + x_c T_c = T_{obs}$$

$$x_a S_a + x_b S_b + x_c S_c = S_{obs}$$

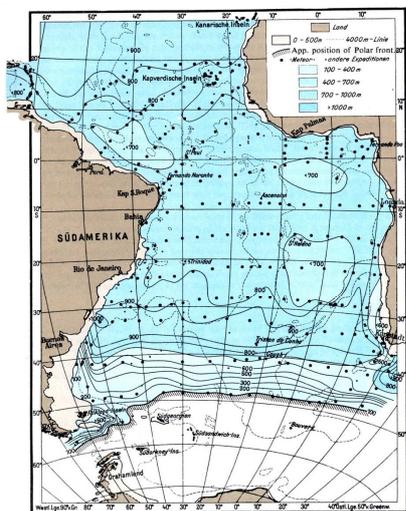
$$x_a + x_b + x_c = 1$$

Helland-Hansen, 1918
 aus Talley et al., 2010

Wüst's core layer method - section

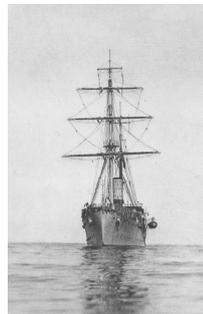


Wüst's core layer method – depth of core layer

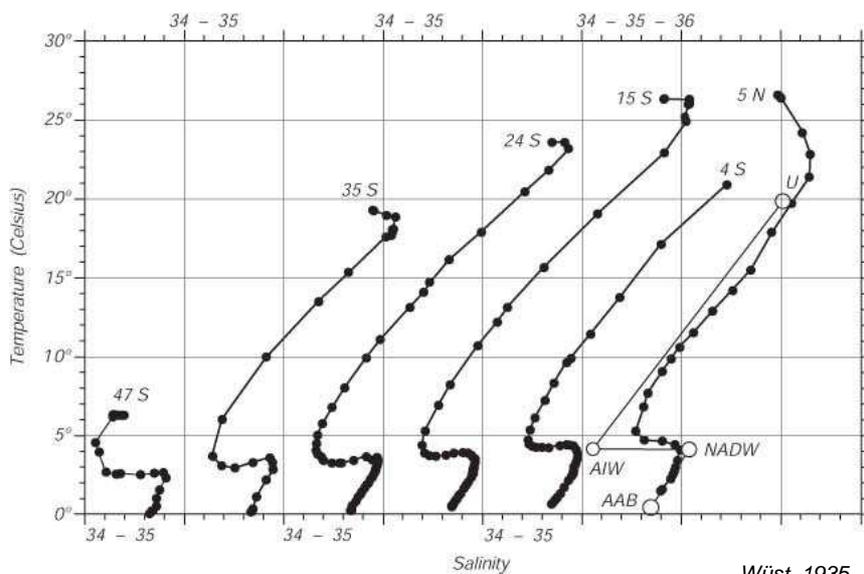


Wüst, 1935
 Depth of the core layer (intermediate salinity minimum) of the Subantarctic Intermediate Water.
 Maßstab 1:60 MILL.

METEOR Expedition

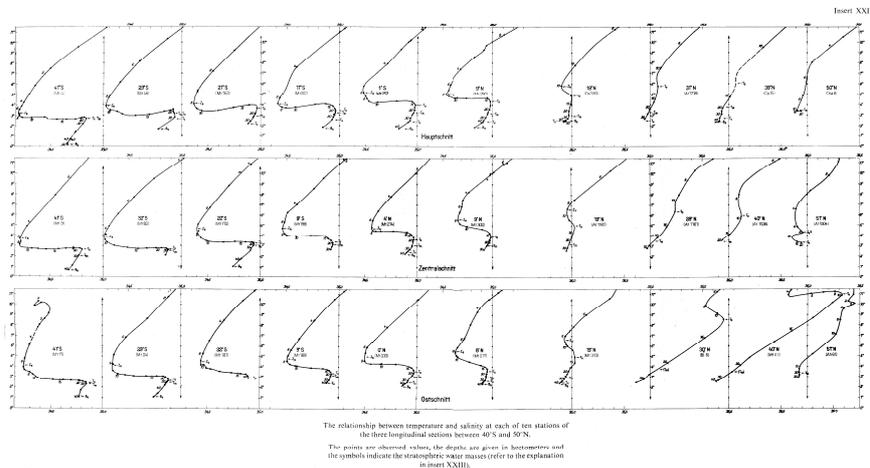


Wüst's core layer method – TS diagrams



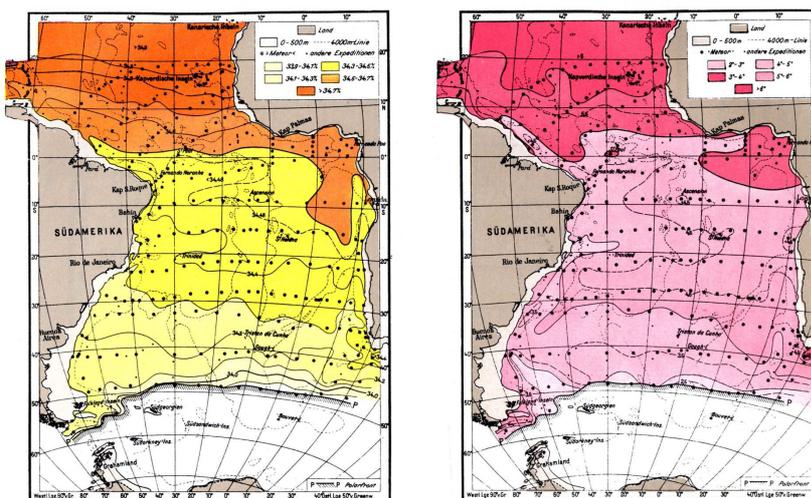
Wüst, 1935

Wüst's core layer method – TS diagrams



Wüst, 1935

Wüst's core layer method – T & S in core layer



a) Salinity (‰) of the core layer (intermediate salinity minimum) of the Subantarctic Intermediate Water.

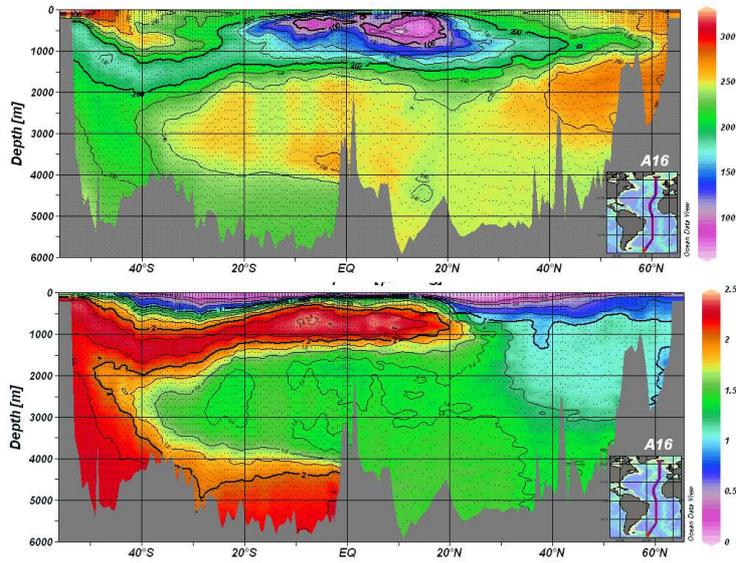
Maßstab 1:80 Mill.

b) Temperature (°C) of the core layer (intermediate salinity minimum) of the Subantarctic Intermediate Water.

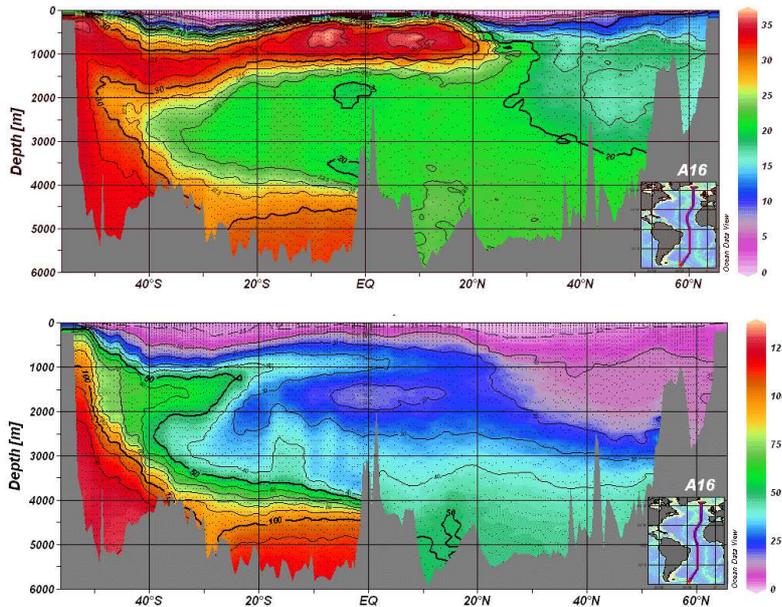
Maßstab 1:80 Mill.

Wüst, 1935

Non-conservative tracers – Oxygen & phosphate

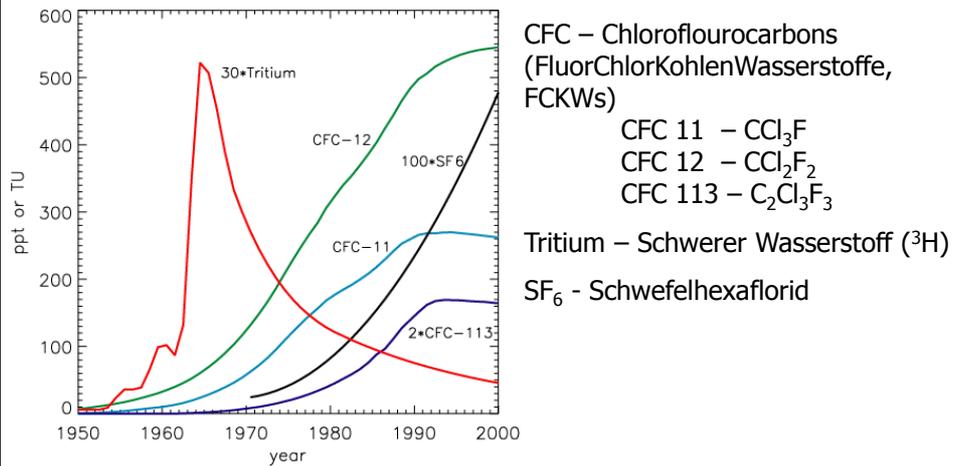


Non-conservative tracers – Nitrate & Silicate

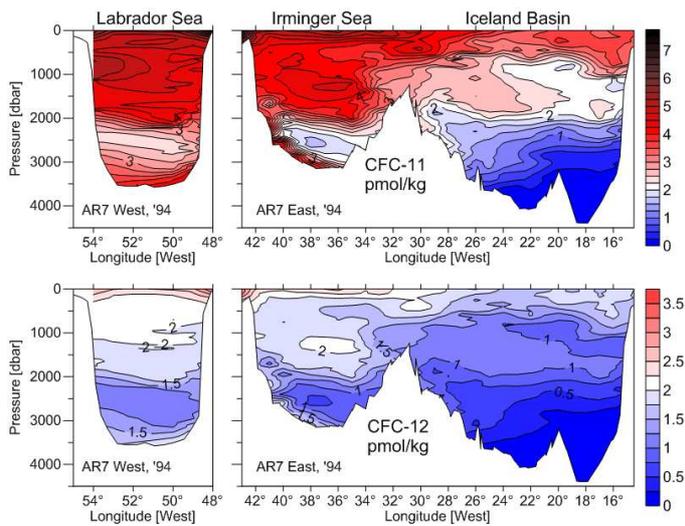


Transient tracers

Tracer mit zeitabhängigen Quellen oder Senken

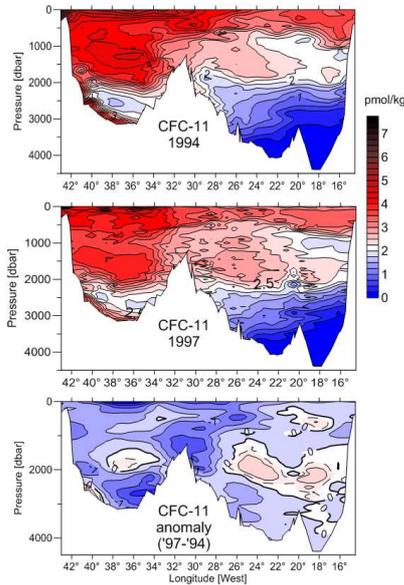


Transient tracer CFCs



De Jong, 2011

Changes in CFC-11

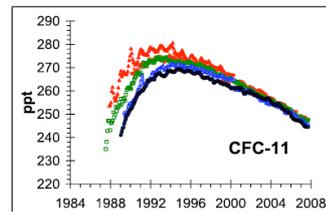


Change in CFC-11 between 1994 and 1997.

Similar changes.

But the increase is not as strong.

Due to earlier start of the CFC-11 decrease in the atmosphere compared to CFC-12.



De Jong, 2011

Subduktion

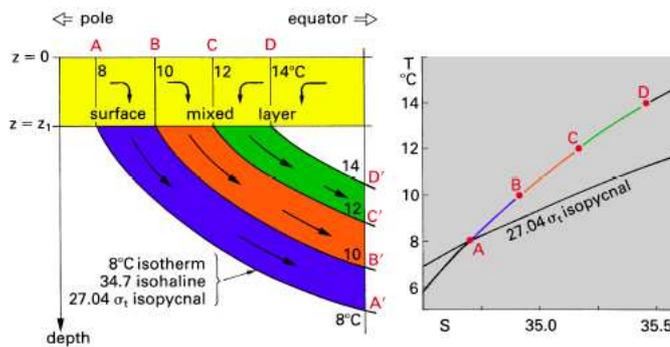


Fig. 5.3. Sketch of water mass formation by subduction in the Subtropical Convergence. The T-S diagram shows both the meridional variation of temperature and salinity between stations A and D, and the vertical variation equatorward of station D from the surface down along the line A'B'C'D'. For more detail, see text.

Price, 2001

Central Waters

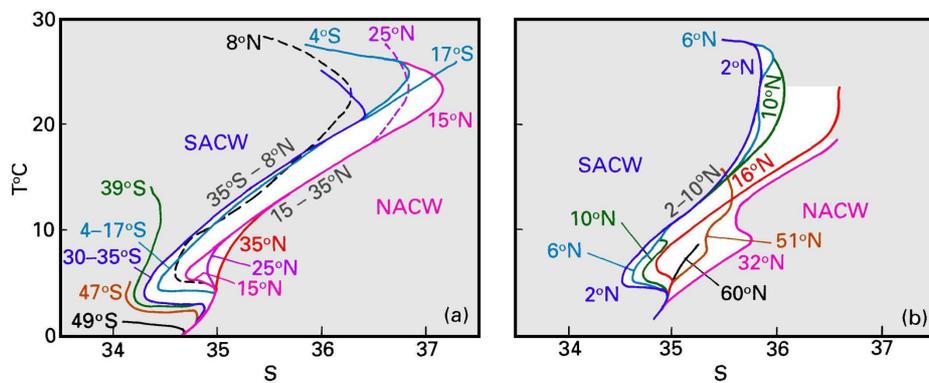


Fig. 15.9. T-S diagrams for stations along two meridional sections. (a) Western basins, (b) eastern basin (northern hemisphere). Note the northward weakening of the AAIW salinity minimum, the deep salinity maximum produced by the inflow of Eurafriean Mediterranean Water (most prominently at 32°N in the east), and the sudden transition from SACW to NACW south of 15°N. Data from Osborne *et al.* (1991).

Optimum Multi Parameter Analysis

$$\begin{aligned}
 x_1 T_1 + x_2 T_2 + x_3 T_3 + x_4 T_4 &= T_{\text{obs}} + R_T \\
 x_1 S_1 + x_2 S_2 + x_3 S_3 + x_4 S_4 &= S_{\text{obs}} + R_S \\
 x_1 O_{2,1} + x_2 O_{2,2} + x_3 O_{2,3} + x_4 O_{2,4} &= O_{2,\text{obs}} + R_{O_2} \\
 x_1 PO_{4,1} + x_2 PO_{4,2} + x_3 PO_{4,3} + x_4 PO_{4,4} &= PO_{4,\text{obs}} + R_{PO_4} \\
 x_1 NO_{3,1} + x_2 NO_{3,2} + x_3 NO_{3,3} + x_4 NO_{3,4} &= NO_{3,\text{obs}} + R_{NO_3} \\
 x_1 Si_1 + x_2 Si_2 + x_3 Si_3 + x_4 Si_4 &= Si_{\text{obs}} + R_{Si} \\
 x_1 + x_2 + x_3 + x_4 &= 1 + R_{\Sigma}
 \end{aligned}$$

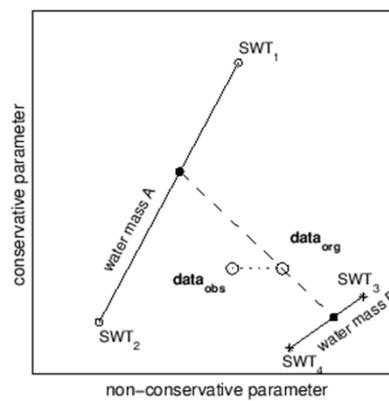
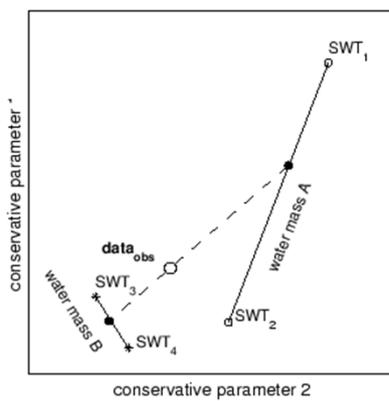
Residuen ΣR_i^2 werden minimiert

Optimum Multi Parameter Analysis

$$\begin{aligned}
 x_1 T_1 + x_2 T_2 + x_3 T_3 + x_4 T_4 &= T_{\text{obs}} + R_T \\
 x_1 S_1 + x_2 S_2 + x_3 S_3 + x_4 S_4 &= S_{\text{obs}} + R_S \\
 x_1 O_{2,1} + x_2 O_{2,2} + x_3 O_{2,3} + x_4 O_{2,4} &= O_{2,\text{obs}} + R_{O_2} \\
 x_1 PO_{4,1} + x_2 PO_{4,2} + x_3 PO_{4,3} + x_4 PO_{4,4} &= PO_{4,\text{obs}} + R_{PO_4} \\
 x_1 NO_{3,1} + x_2 NO_{3,2} + x_3 NO_{3,3} + x_4 NO_{3,4} &= NO_{3,\text{obs}} + R_{NO_3} \\
 x_1 Si_1 + x_2 Si_2 + x_3 Si_3 + x_4 Si_4 &= Si_{\text{obs}} + R_{Si} \\
 x_1 + x_2 + x_3 + x_4 &= 1 + R_\Sigma
 \end{aligned}$$

Residuen ΣR_i^2 werden minimiert

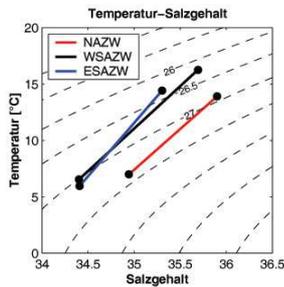
Optimum Multi Parameter Analysis



Karstensen, 1999

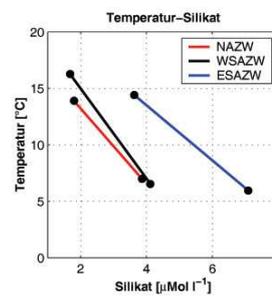
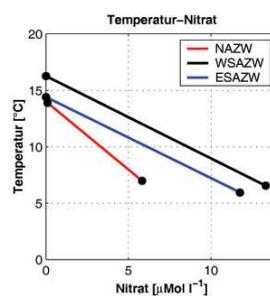
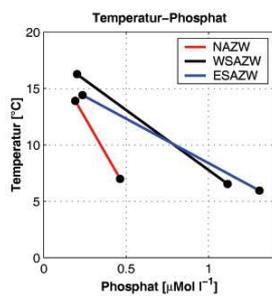
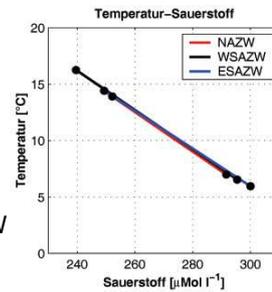
OMP Central Waters

Karstensen, 1999



Beispiel: Eigenschaften von Zentralwassermassen (ZW) im Atlantik.

NAZW – Nordatlantisches ZW
WSAZW – Westsüdatlantisches ZW
ESAZW – Ostsüdatlantisches ZW



Extended OMP

$$\begin{array}{rcccccccl}
 x_1 T_1 & + & x_2 T_2 & + & x_3 T_3 & + & x_4 T_4 & + & 0 & = & T_{\text{obs}} + R_T \\
 x_1 S_1 & + & x_2 S_2 & + & x_3 S_3 & + & x_4 S_4 & + & 0 & = & S_{\text{obs}} + R_S \\
 x_1 O_{2,1} & + & x_2 O_{2,2} & + & x_3 O_{2,3} & + & x_4 O_{2,4} & - & \Delta P_{r_{O/P}} & = & O_{2,\text{obs}} + R_{O_2} \\
 x_1 PO_{4,1} & + & x_2 PO_{4,2} & + & x_3 PO_{4,3} & + & x_4 PO_{4,4} & + & \Delta P & = & PO_{4,\text{obs}} + R_{PO_4} \\
 x_1 NO_{3,1} & + & x_2 NO_{3,2} & + & x_3 NO_{3,3} & + & x_4 NO_{3,4} & + & \Delta P_{r_{N/P}} & = & NO_{3,\text{obs}} + R_{NO_3} \\
 x_1 Si_1 & + & x_2 Si_2 & + & x_3 Si_3 & + & x_4 Si_4 & + & \Delta P_{r_{Si/P}} & = & Si_{\text{obs}} + R_{Si} \\
 x_1 & + & x_2 & + & x_3 & + & x_4 & + & 0 & = & 1 + R_{\Sigma}
 \end{array}$$

Berücksichtigung des Redfield - Verhältnisses

Anwendung OMP

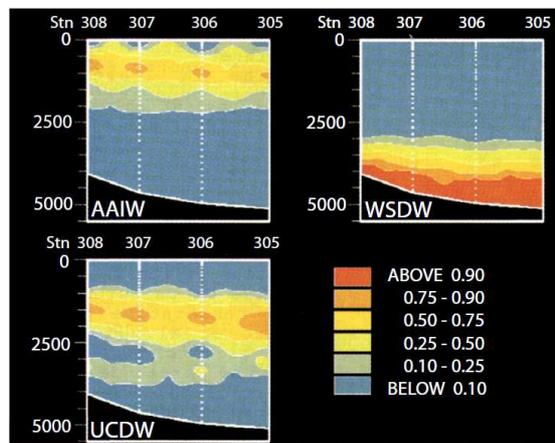


FIGURE 6.17 Example of optimum multiparameter (OMP) water mass analysis. Southwestern Atlantic about 36°S, showing the fraction of three different water masses. Antarctic Intermediate Water, AAIW; Upper Circumpolar Deep Water, UCDW; and Weddell Sea Deep Water, WSDW. Source: From Maamaatuaiahutapu et al. (1992).

title
