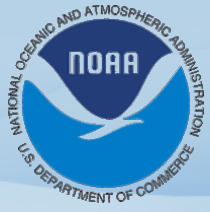
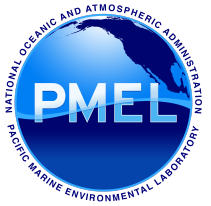


PMEL

Pacific Marine Environmental Laboratory

Ocean Tracers

John Bullister (NOAA-PMEL)
Dave Wisegarver (NOAA-PMEL)
Rolf Sonnerup (UW-JISAO)



Relevance

Tracers help you understand ocean circulation in ways that are fundamental to our understanding of the ocean's

- Uptake of anthropogenic heat and CO_2
- Changes in ocean interior circulation
- Changes in global climate
- Changes in ocean ecosystems

Relevance

NOAA goals:

- Understand oceanic uptake, storage and transport of heat, and impact on climate
- Ocean uptake of CO_2
- Changes in ecosystems

Background

- Man-made gases
- Inert in seawater
- Well-known history at sea surface

∴ Tracer in the ocean interior used to 'date' water masses

- High Signal-Noise

∴ See anthropogenic changes that are small relative to background variability

Background

Chlorofluorocarbons- CFCs

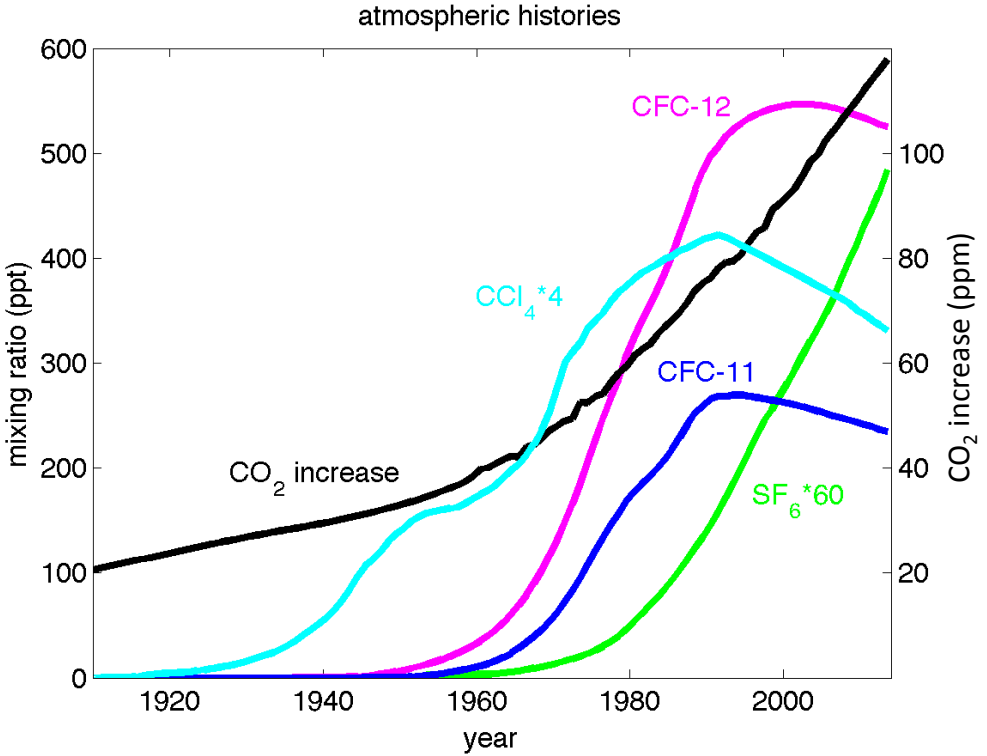
CFC-11 (F-11) - CCl_3F

CFC-12 (F-12) - CCl_2F_2

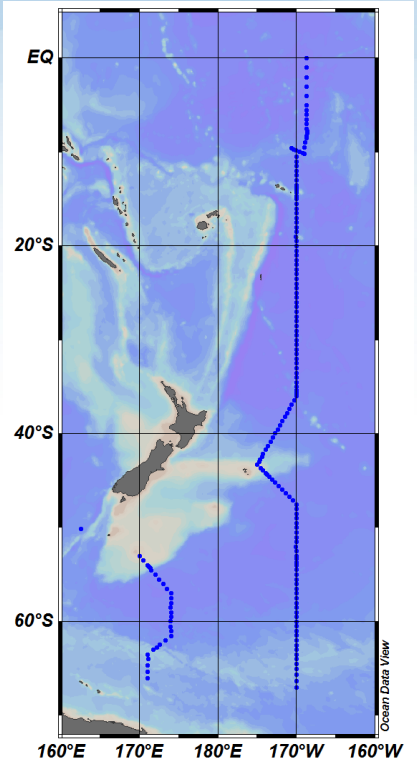
Carbon tetrachloride - CCl_4

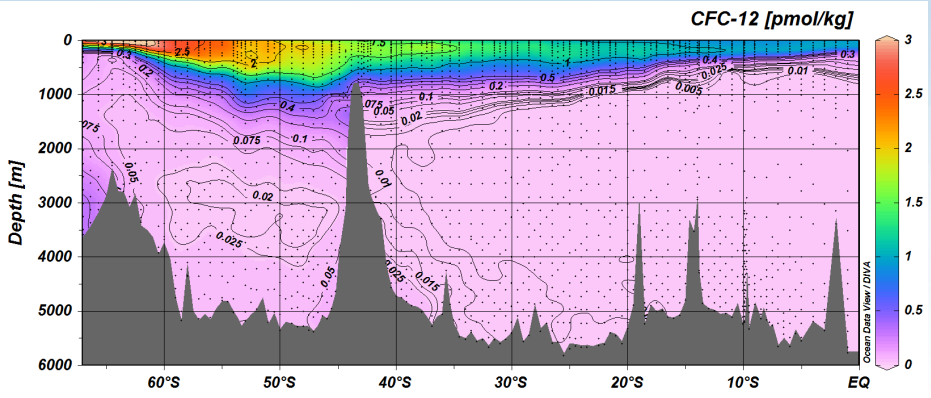
Sulfur Hexafluoride - SF_6

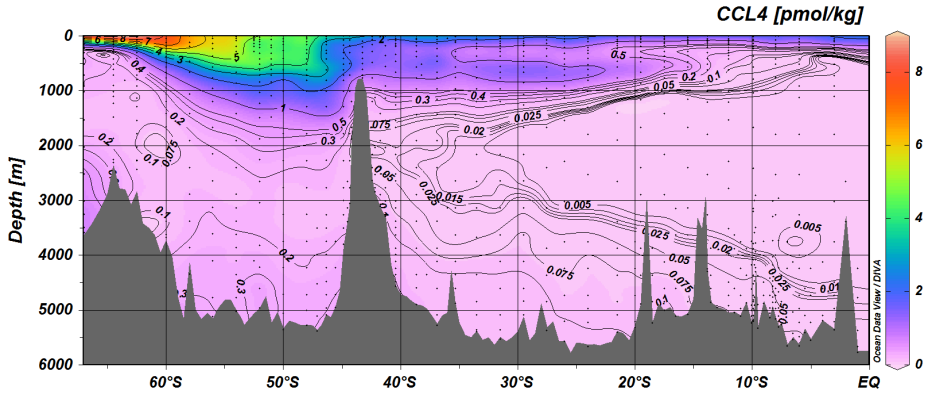
Nitrous Oxide - N_2O



Background

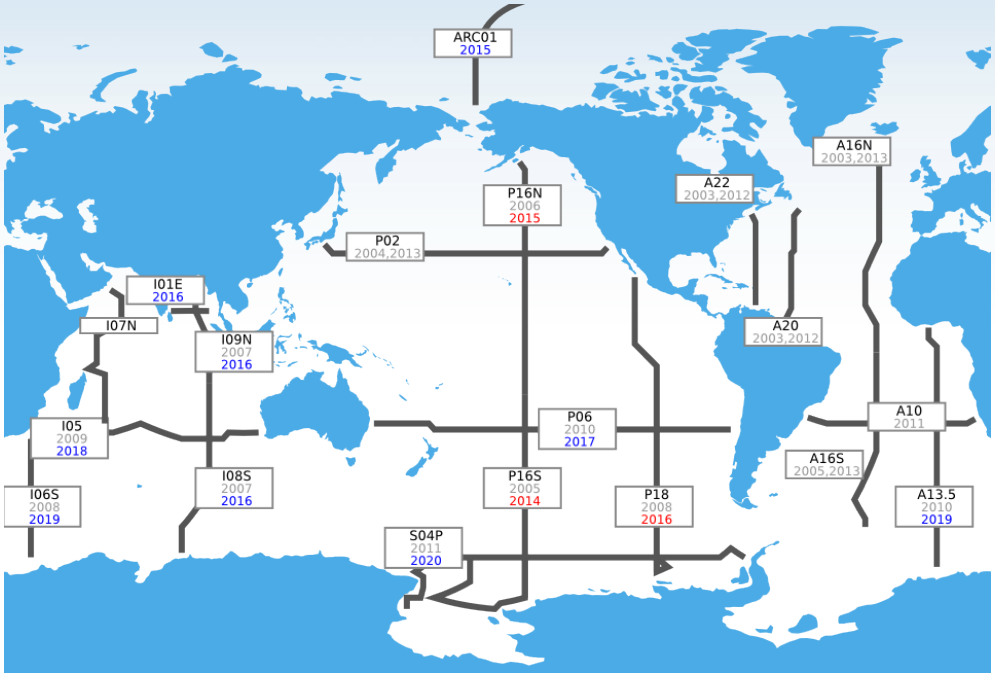

EQ
20°S
40°S
60°S
160°E
170°E
180°E
170°W
160°W
Ocean Data View


CFC-12 [pmol/kg]
Depth [m]
0
1000
2000
3000
4000
5000
6000
60°S
50°S
40°S
30°S
20°S
10°S
EQ
Ocean Data View / DIVA

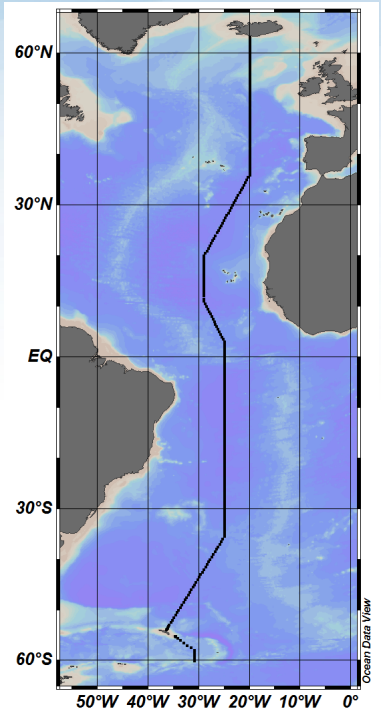

CCL4 [pmol/kg]
Depth [m]
0
1000
2000
3000
4000
5000
6000
60°S
50°S
40°S
30°S
20°S
10°S
EQ
Ocean Data View / DIVA

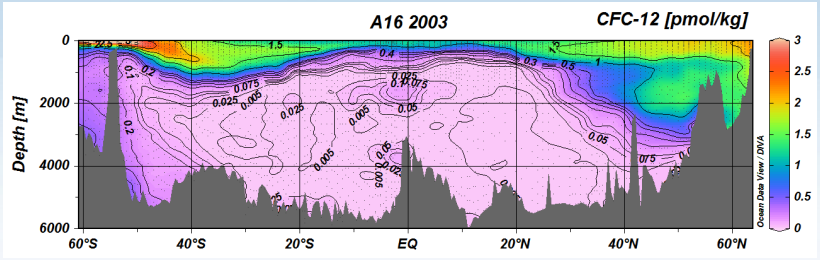
Background

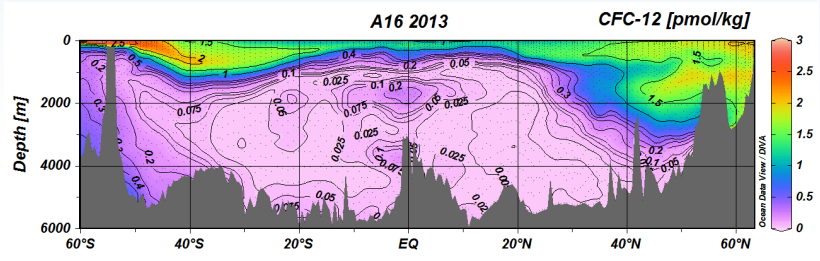
CLIVAR Hydrographic Program

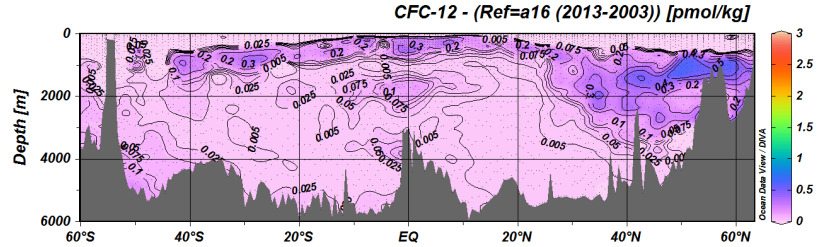


Performance









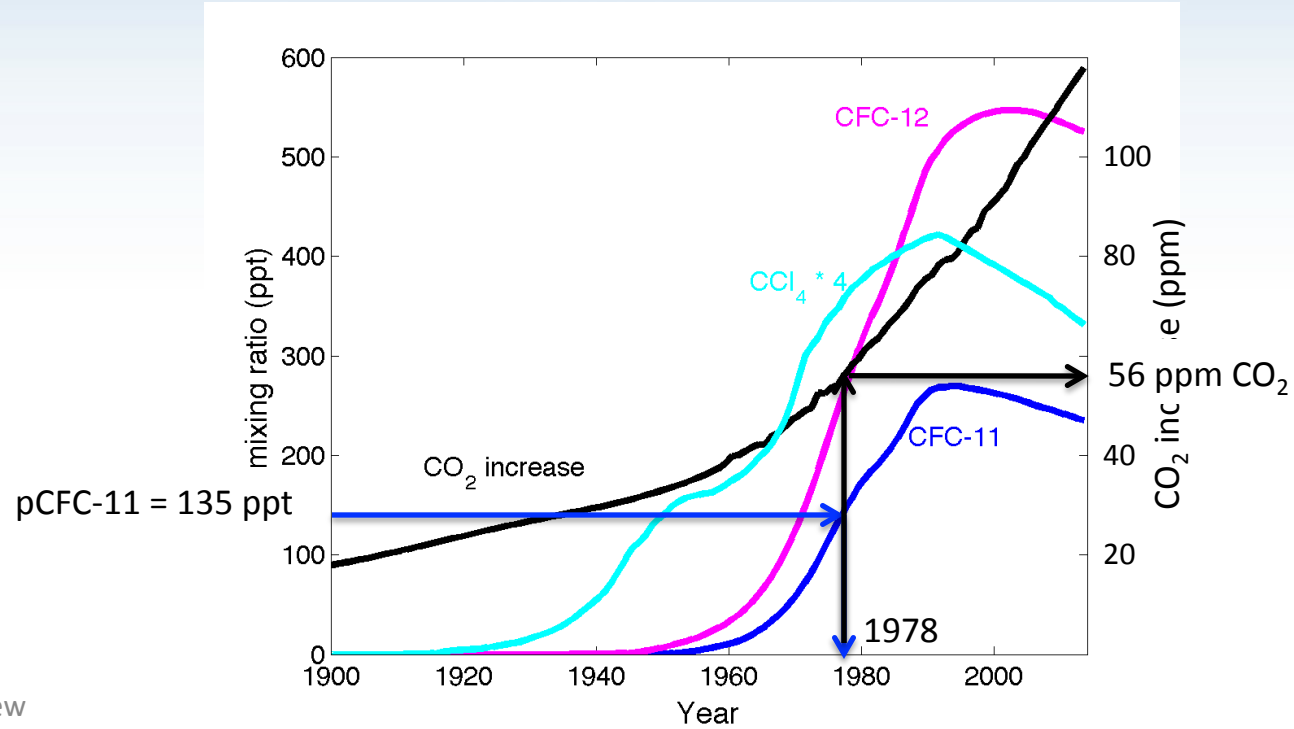
Background

CFC tracers provide rates…

1) Ocean circulation and mixing
2) Water mass formation and changes
3) Uptake of anthropogenic CO_2
4) Rates of key biogeochemical processes
    -Biological production rates
5) Test of numerical ocean models' uptake of the anthropogenic perturbation

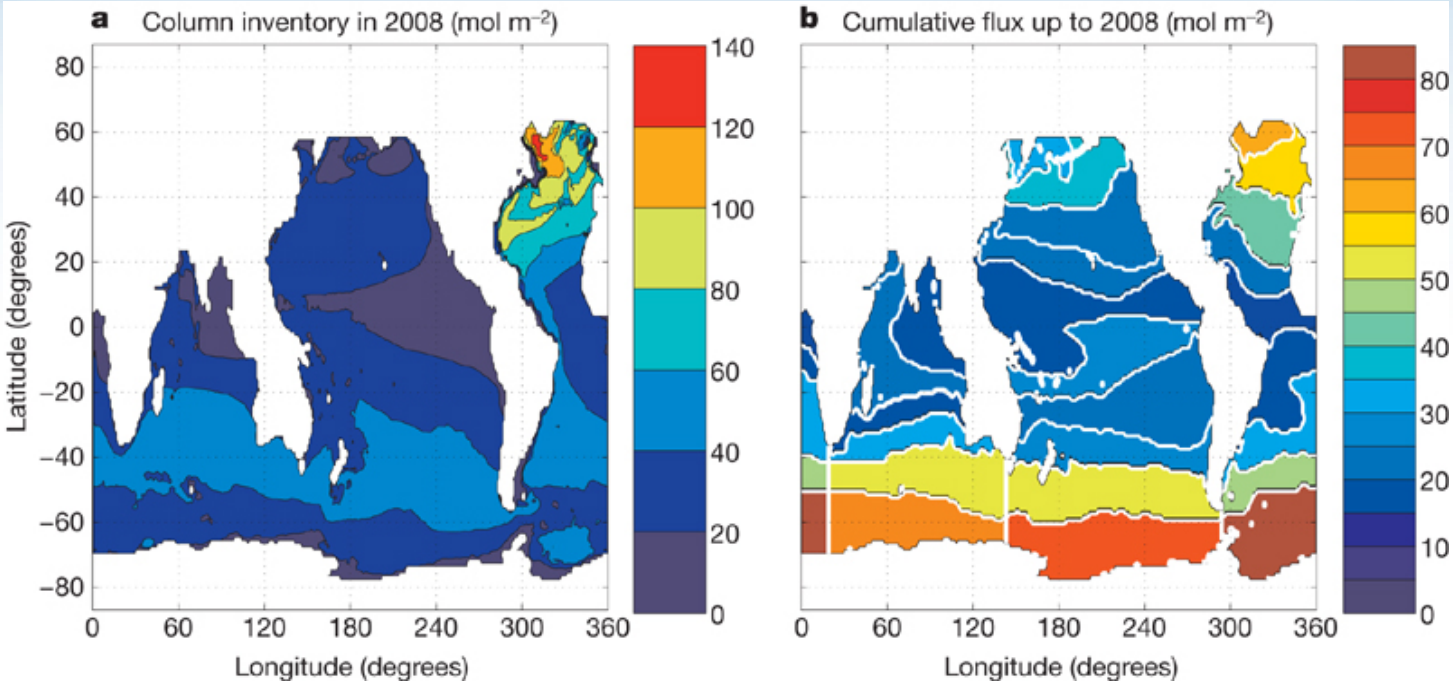
Performance

Atmospheric Histories of trace gases (ppt) and CO_2 (ppm)



Performance

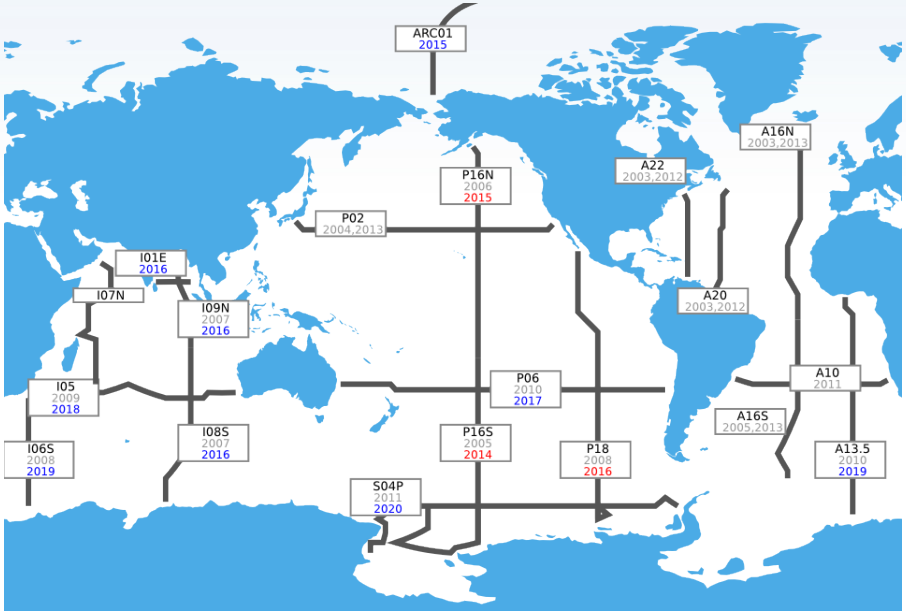
Anthropogenic carbon in the ocean



Khatiwala et. al., (2009)

Quality

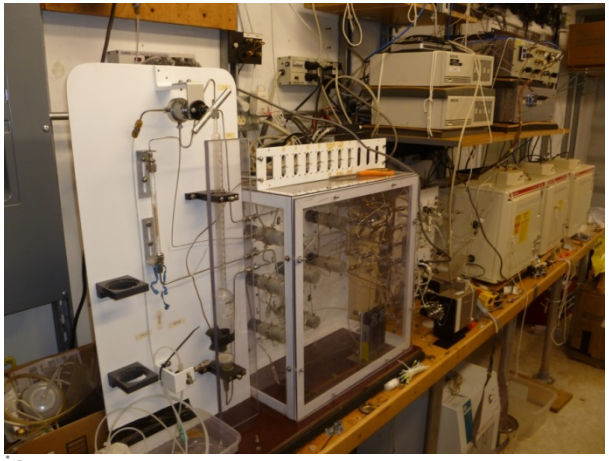
- Recognized as a world leader in the accurate, ultra-low level measurements of these compounds
- CLIVAR I5, I8S/I9S, P16N, P18, A16N, A16S, A10, A13.5 cruises

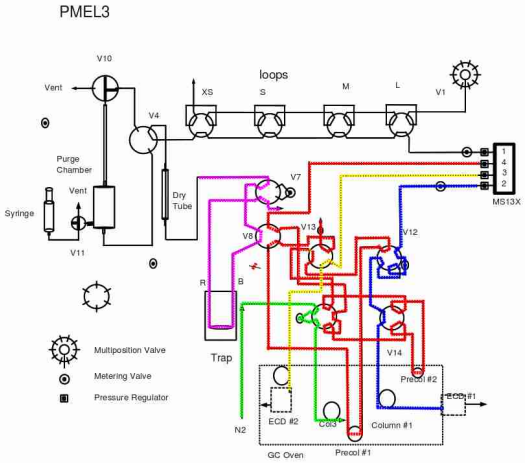


Quality

PMEL has led in development of tracer techniques

- Pioneered ocean CFC observations (1980s and 1990s)
- Developed SF_6, N_2O methods in past 5 years
- Designed and built analytical systems for academic laboratories (U. Washington, U. Texas)
- Developed water sampling bottles and sampling gear widely used on CLIVAR expeditions

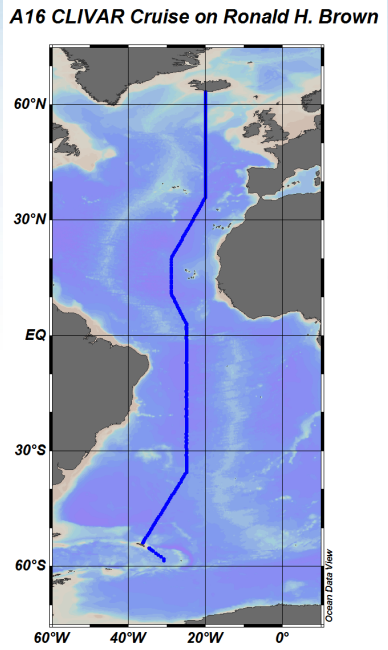


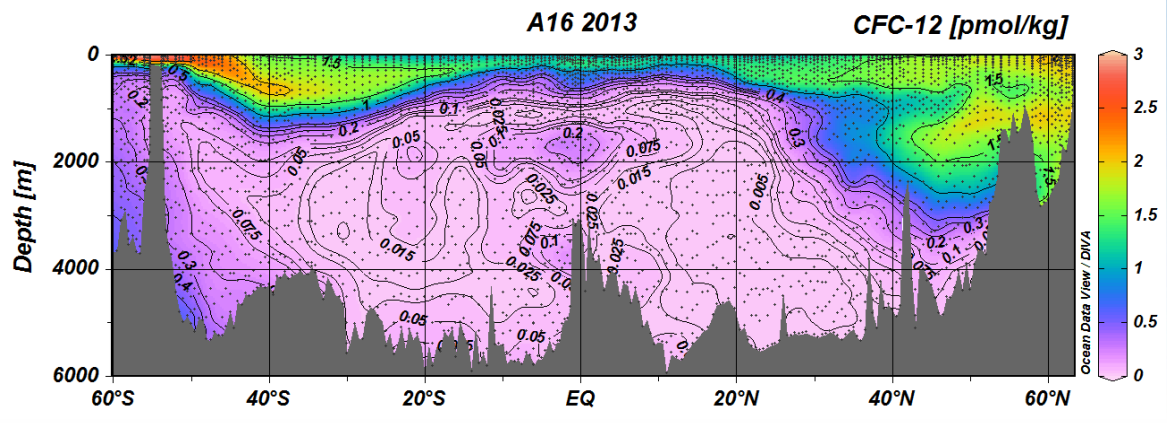


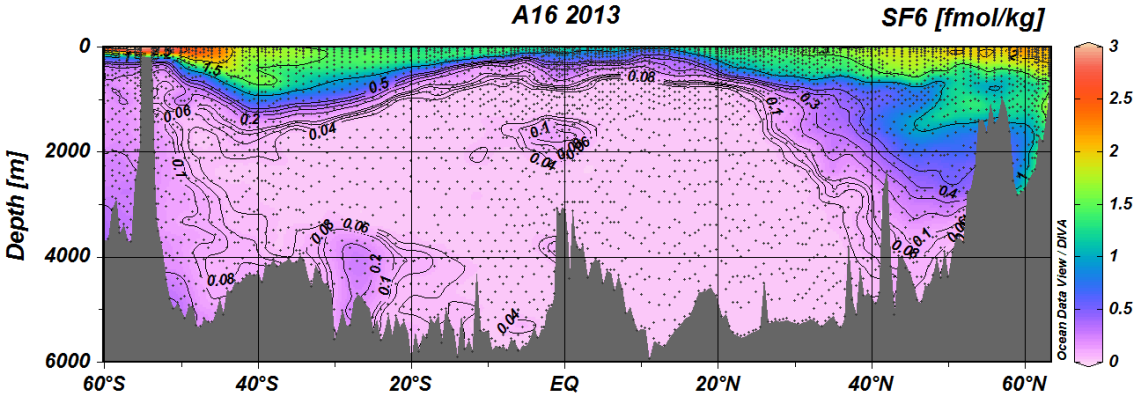
Quality/Relevance

- CFC and SF_6 calibration standards for International CLIVAR groups
- N_2O and CH_4 standards for SCOR

Quality/Performance





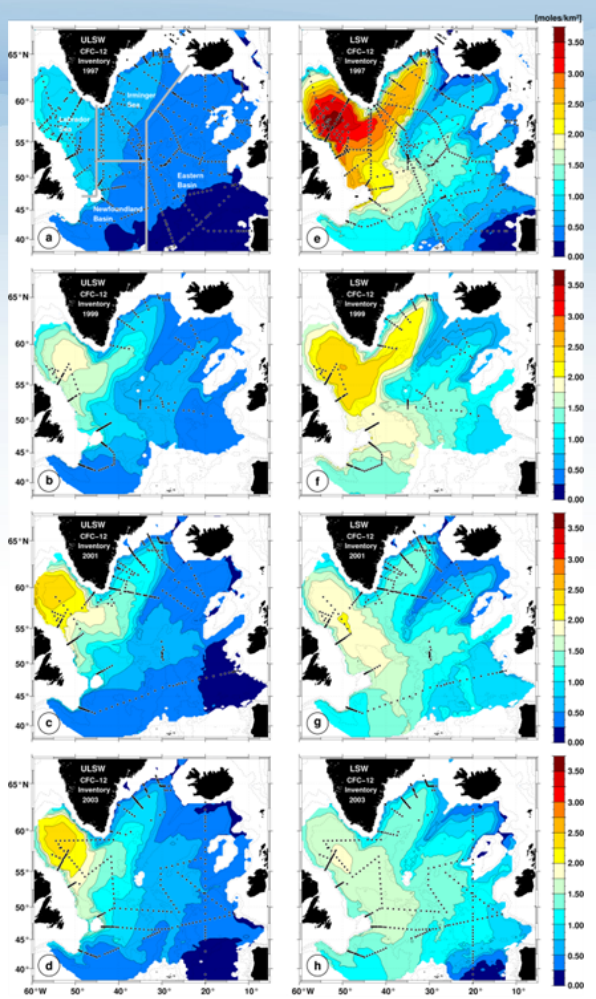


Quality

- Water Mass Formation Rates from CFC Inventories
- *Inventory = formation rate * CFC in surface waters*

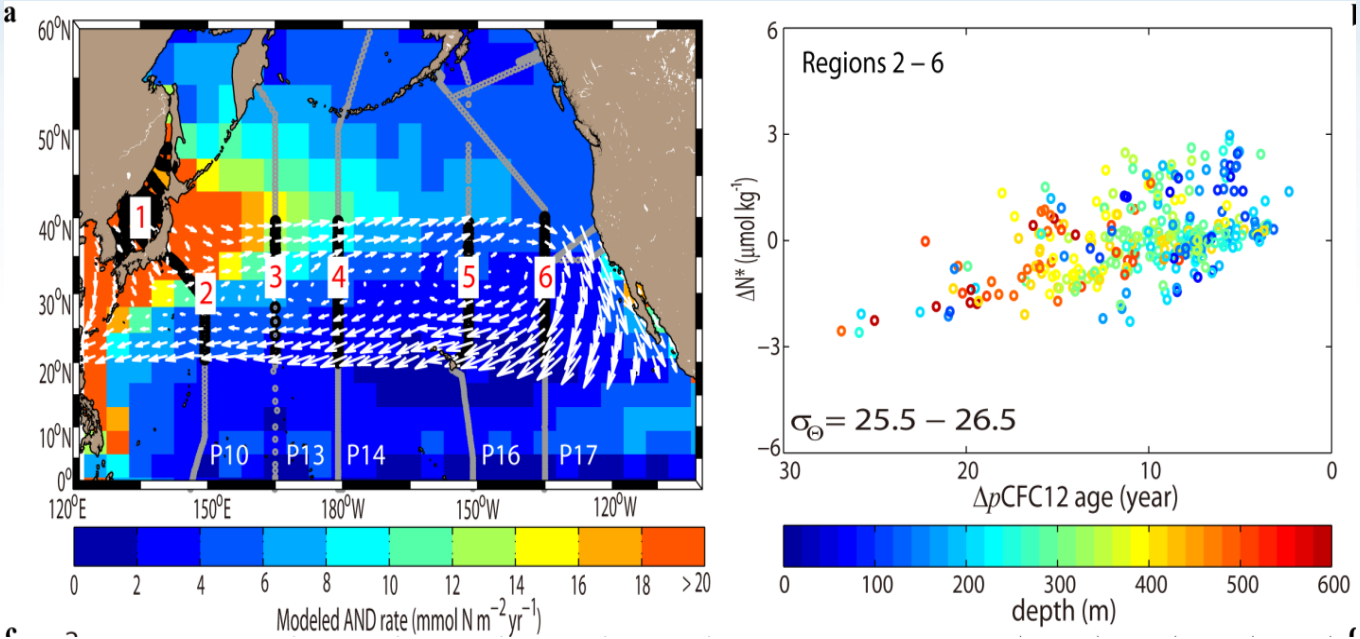
- *Water Mass formation rates have been determined for AABW, GSDW, LSW, NADW*

CFCs document changes in Labrador Sea water over time [*Kieke et al.*, 2008]



Performance

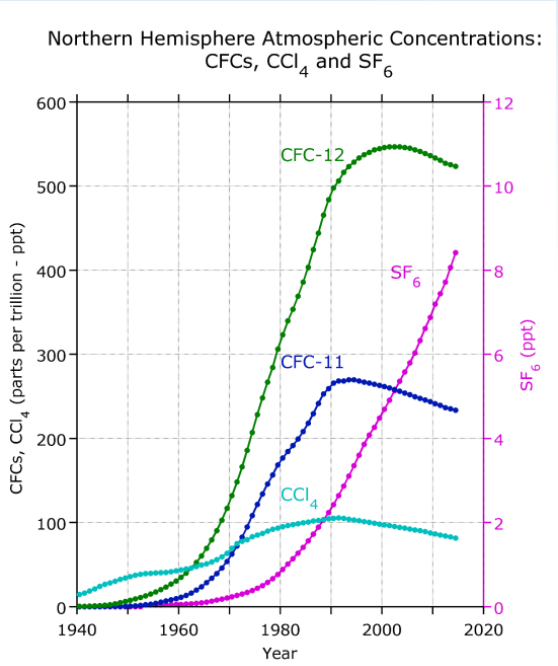
CFCs a tool to directly assess rate of change of nitrogen levels in the ocean

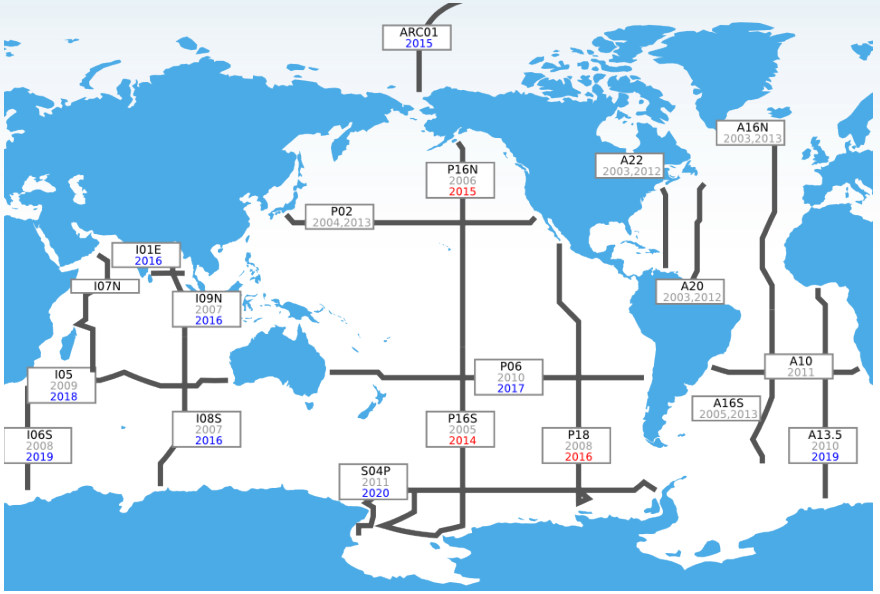


Kim et al., *Science*, in review

Future Directions

SF_6 observations concurrent with CFCs on ~ 1/3 of repeat hydrography cruises



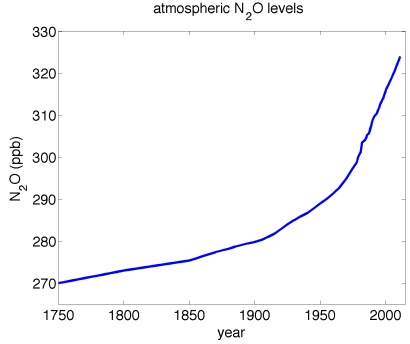


Future Directions

- Model-data comparisons
- Mixing in the ocean interior from CFCs and SF_6
- Oxygen and nitrogen cycling rates in the ocean
- Anthropogenic CO_2 uptake from CFCs
- Nitrous oxide observations

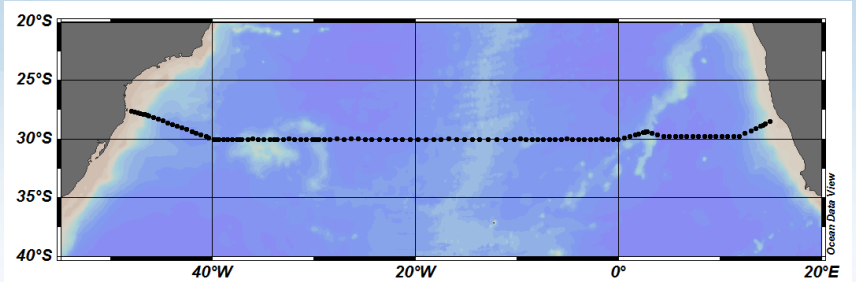
Future Directions

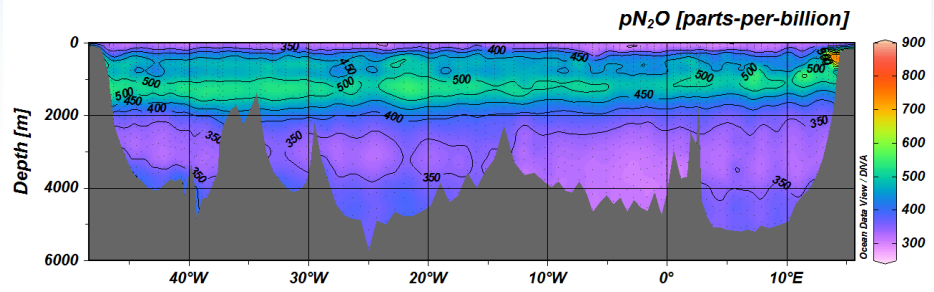
Nitrous oxide (N_2O) is an important greenhouse and ozone depleting gas.

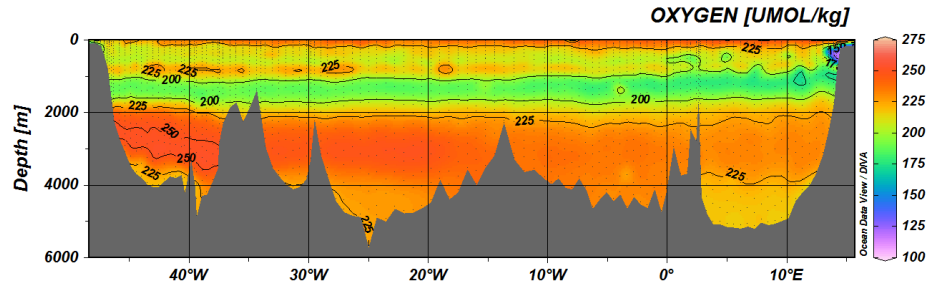


The strength of the ocean source may be linked to changes in dissolved oxygen

Pursuing Isotopic (^{15}N, and ^{18}O) N_2O measurements to understand sources and sinks in the ocean







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