Decadal Variability in the Transient Tracer Distribution in the upper Arctic Ocean

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Background

- Arctic is warming strong and fast
- Water masses and ventilation processes are changing
- Transient anthropogenic gases (CFCs, SF_6) as tracer
- Well known atmospheric tracer concentrations [1]

Research Question

How did the distribution of transient tracer changed over time and what can tracers tell us about changing circulation and ventilation processes?

Atlantic Water along the transect

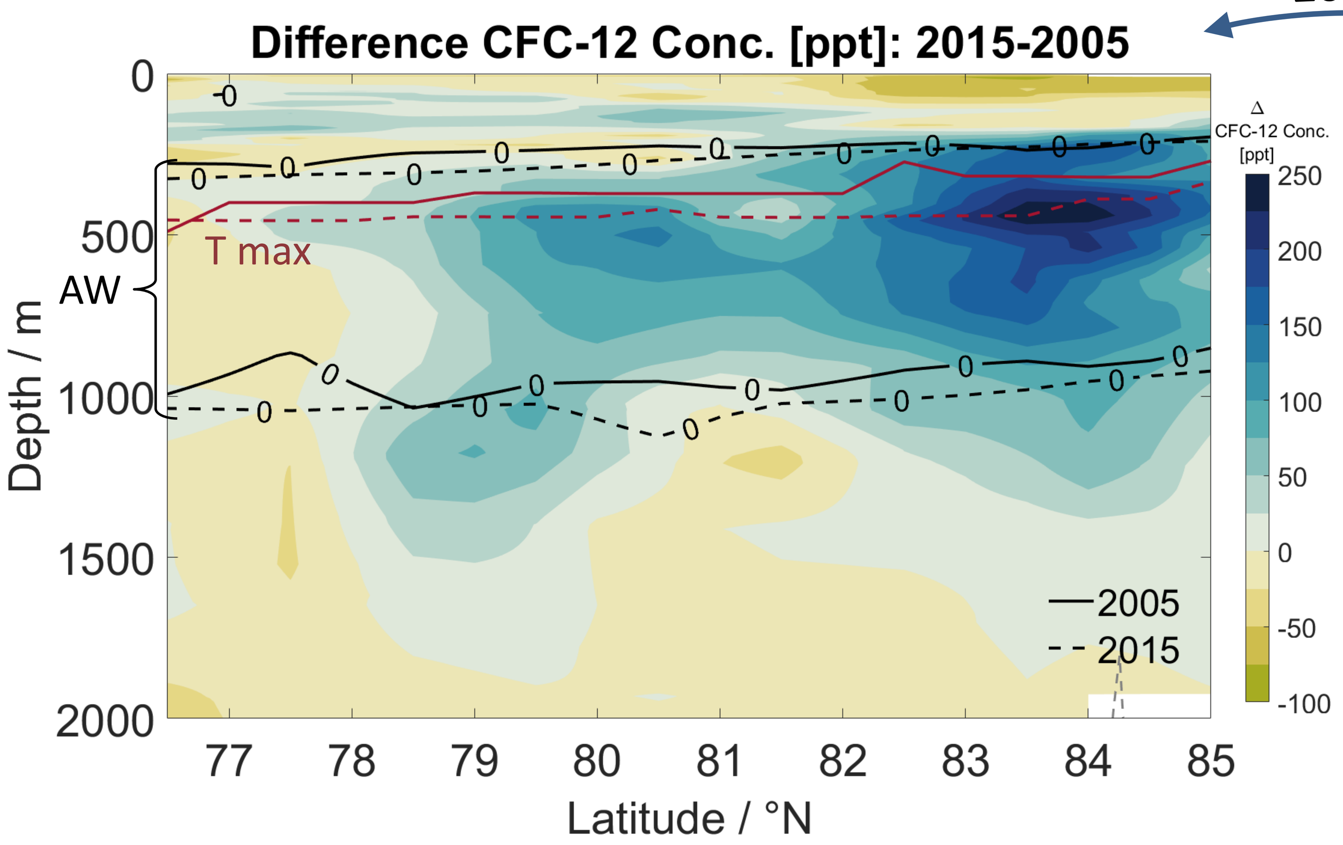


Fig. 1: Difference in CFC-12 concentration between 2015 and 2005. Black lines: 0°C isotherms as boundary of Atlantic Water (AW), red line temperature maximum.

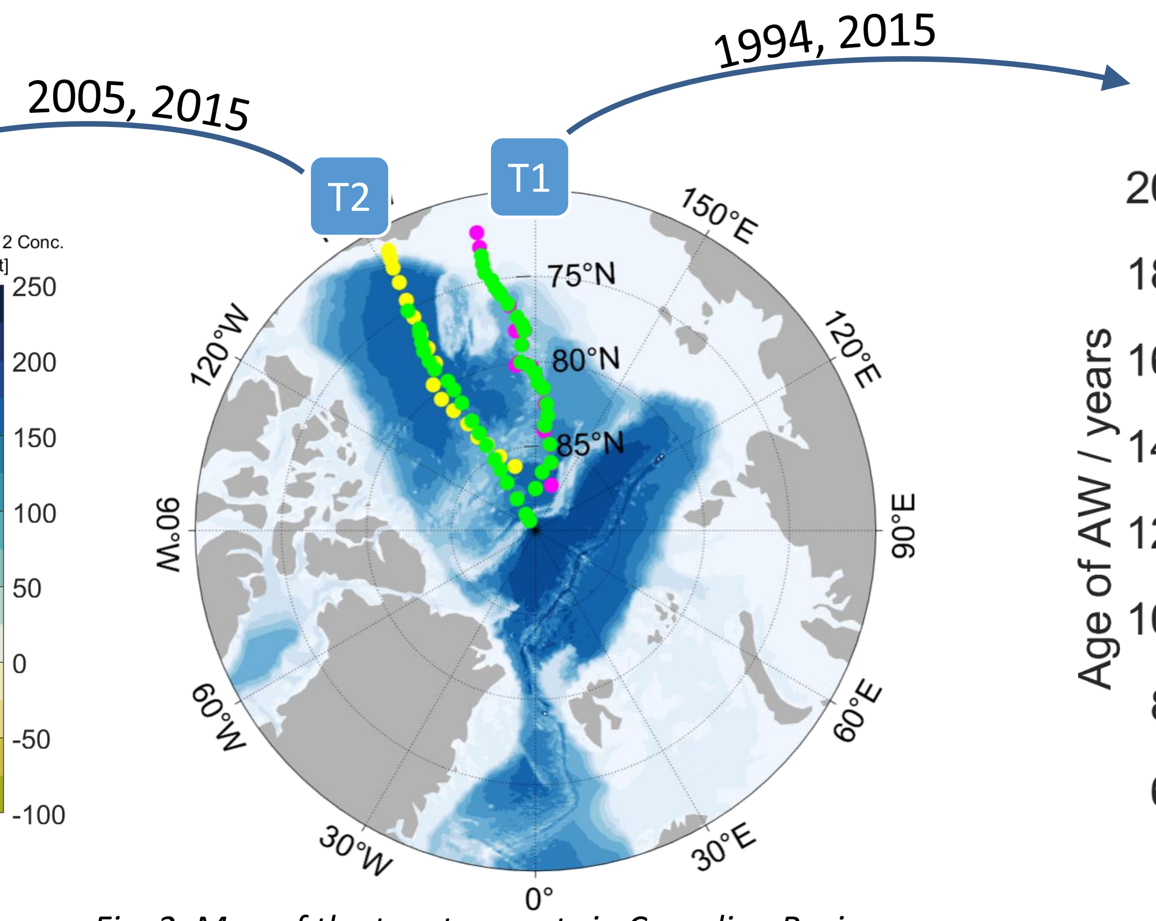


Fig. 2: Map of the two transects in Canadian Basin. Transect 1 (T1): 1994 (pink), 2015 (green); Transect 2 (T2): 2005 (yellow), 2015 (green).

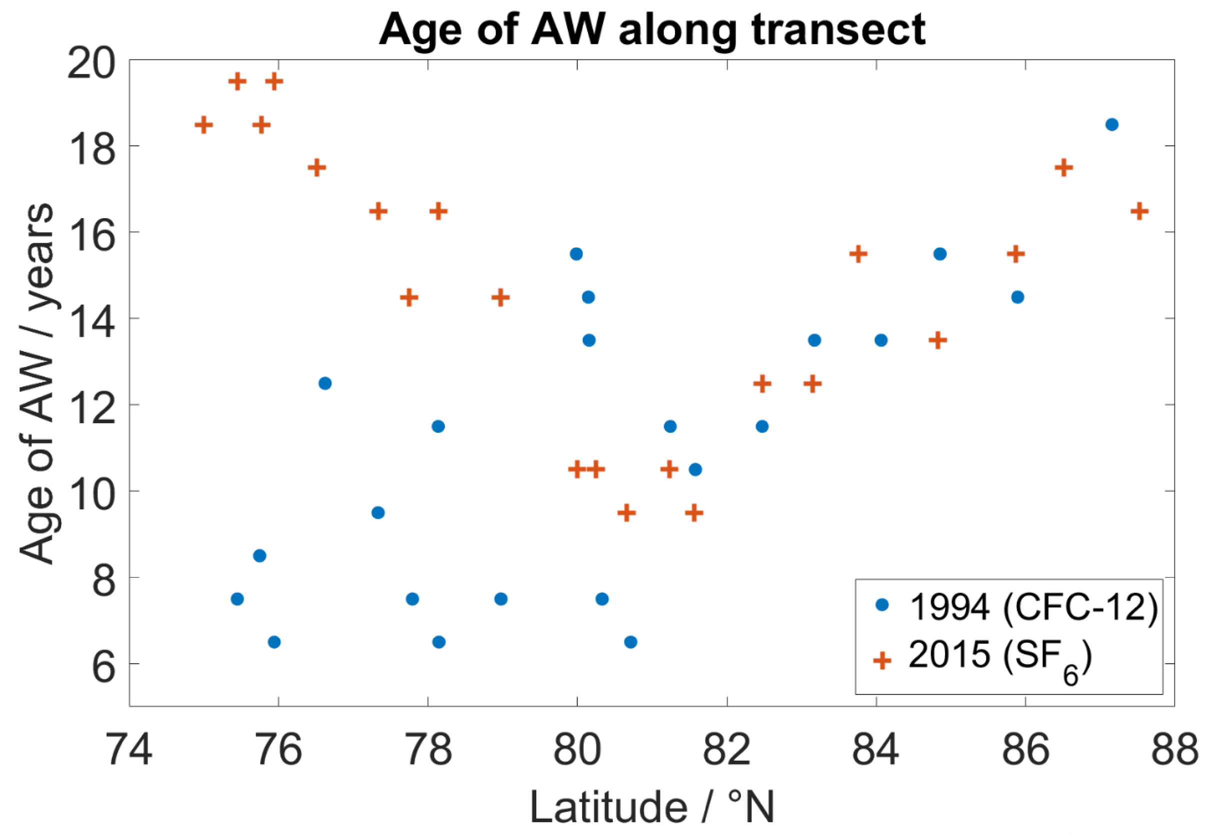


Fig. 3: Age of Atlantic Water for 1994 using CFC-12 (blue circles) and 2015 using SF_6 (red crosses)

- Largest difference in CFC-12 between 2015 and 2005 is found in high latitudes in the Atlantic Water (AW)
- The high difference indicates a change in water mass properties
- Similar situation found along T1

- Creation of tracer data set [2, 3, 4]
- T1: 1994: July, August (Louis St. Laurent)
  2015: August, September (Healy)
- T2: 2005: August, September (Oden)
  2015: September (Healy)

- Higher tracer ages are found in lower latitudes in 2015 compared to 1994, similar in higher latitudes
- A difference in age of more than 2 years indicates change in circulation / ventilation processes [6]
- Along T2 the Atlantic Water age is also higher in 2015

High saturation due to events

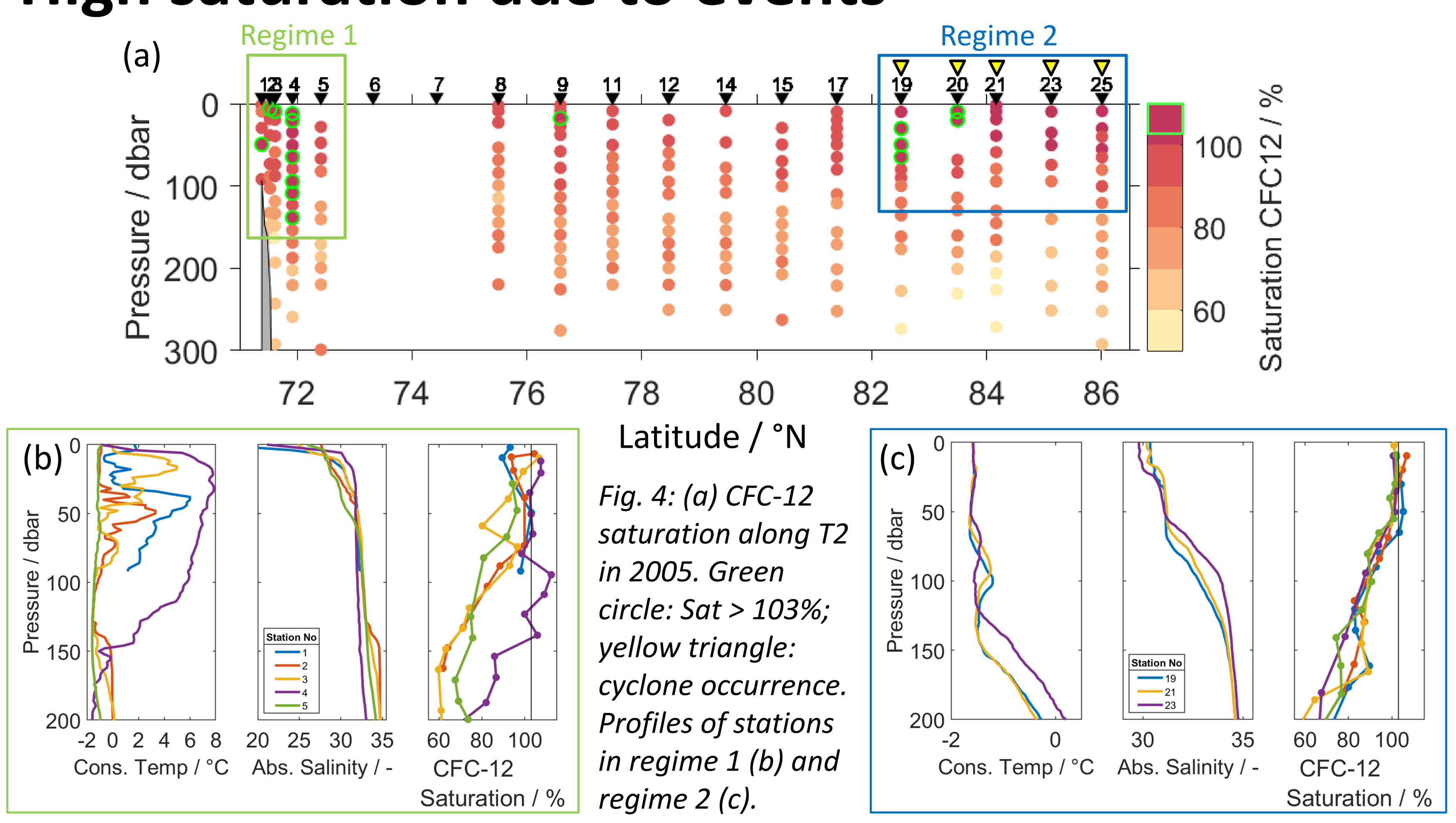
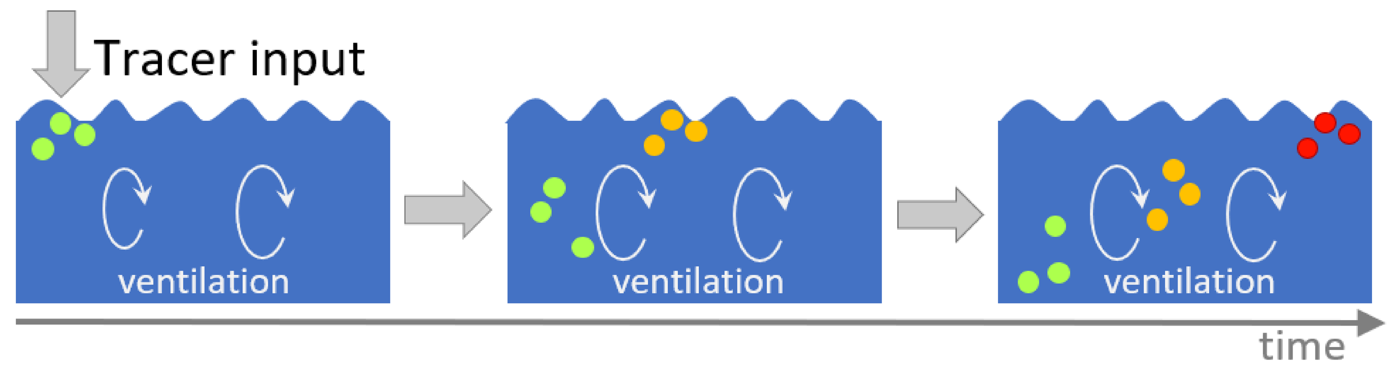
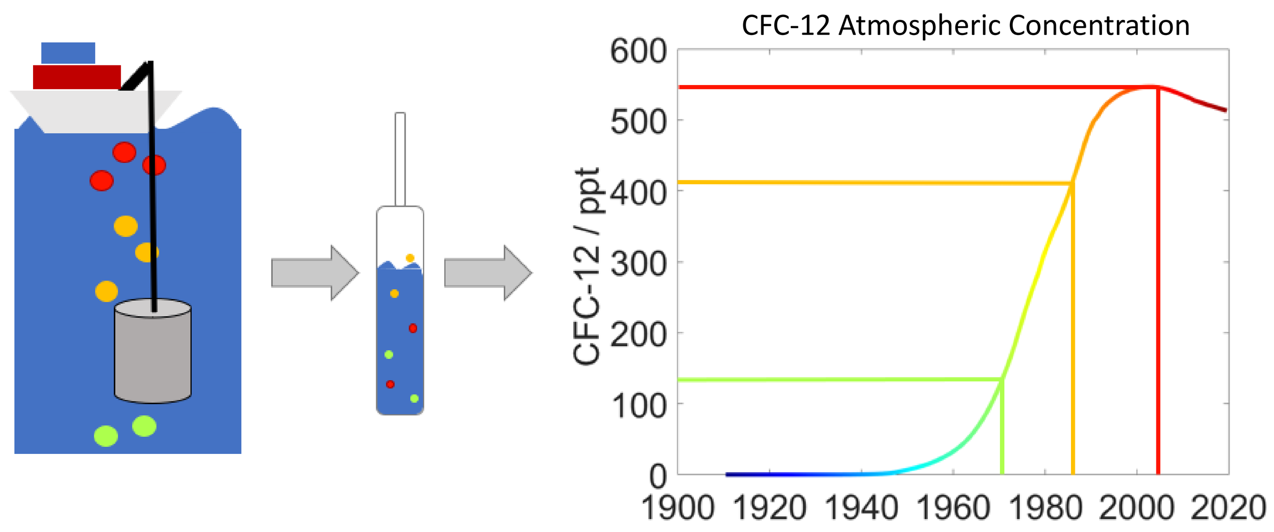


Fig. 4: (a) CFC-12 saturation along T2 in 2005. Green circle: Sat > 103%; yellow triangle: cyclone occurrence. Profiles of stations in regime 1 (b) and regime 2 (c).

- Two regions of very high CFC-12 saturations along T2 in 2005
- Regime 1: Nonlinear mixing between water masses (with different T, S) can lead to local oversaturations in the interior
- Regime 2: Cyclone event present during days of measurement and before [7], lead to deep mixed layer and additional air input

Methods





Assumptions:

- Equilibrium concentration reached
- No exchange with surrounding

Fig. 5: Conceptual model of tracer age calculation over time.

- Solubility of tracer depends on local temperature and salinity
- Using solubility function f(c,T,S) excludes effect of temperature and salinity
- Tracer saturation regards atmospheric partial pressure of that year
- Calculation of tracer age using time dependent source function [5]
- Combination of SF_6 and CFC-12 possible [6], is needed due to decreasing CFC-12 concentration after 2003/04

Work in progress

Beaufort Gyre

- T1: 2015 larger extent reaching transect in contrast to 1994
- T2: larger extent in 2015 than 2005, but both in transect

Arctic Oscillation

- 1994: positive/high phase: cyclonic circulation pattern
- 2005: negative/low before: anticyclonic circulation pattern
- 2015: mixed phase: still more anticyclonic [8]

Impact of Atlantification

- More and warmer AW reaching Arctic Ocean
- More mixing due to weaker halocline possible

Conclusion

- Changes of tracer concentration and age are present along both transects. This change indicates a change in the circulation and/or ventilation pattern of the Atlantic Water.
- For the changes in the higher latitudes along the transect, a change in the recirculation pathway of the Atlantic Water is likely.
- The higher ages along T1 in the lower latitudes in 2015 compared to 1994 might be connected to the size change of the Beaufort Gyre or to any other change in the pathway of the Atlantic Water leading to a higher age of the water.
- High saturations near the surface can be attributed to different regimes: cyclone (or any wind events) and non-linear mixing.

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