Brine Rejection and Its Effect on the Arctic Halocline

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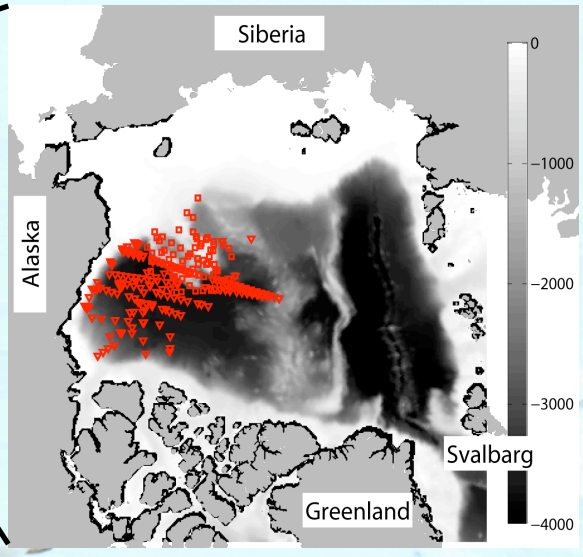
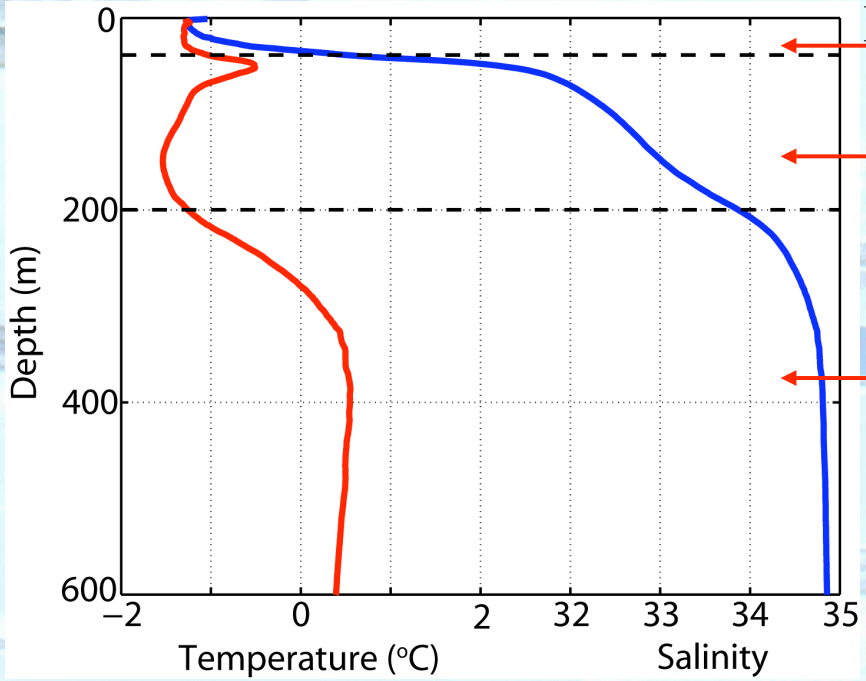
Outline

- Introduction
  - The Halocline
  - Problems in modeling
  - "Brine rejection scheme"
- Experiments
- Results
  - Halocline
- Final Remarks
  - Importance of brine rejection
  - Importance of halocline

Introduction





Mixed layer

Halocline

Atlantic Water

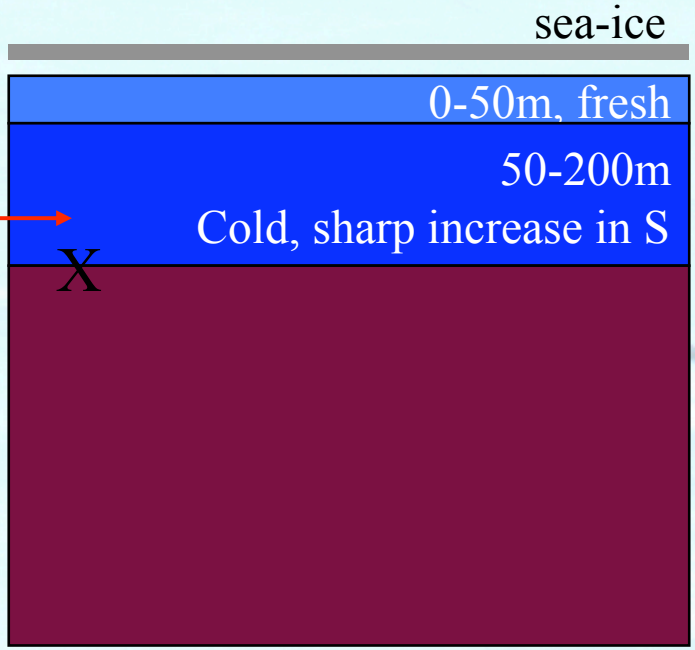
0-50m, fresh

50-200m
Cold, sharp increase in S

- > 200m
- Warm
- Salty

Introduction

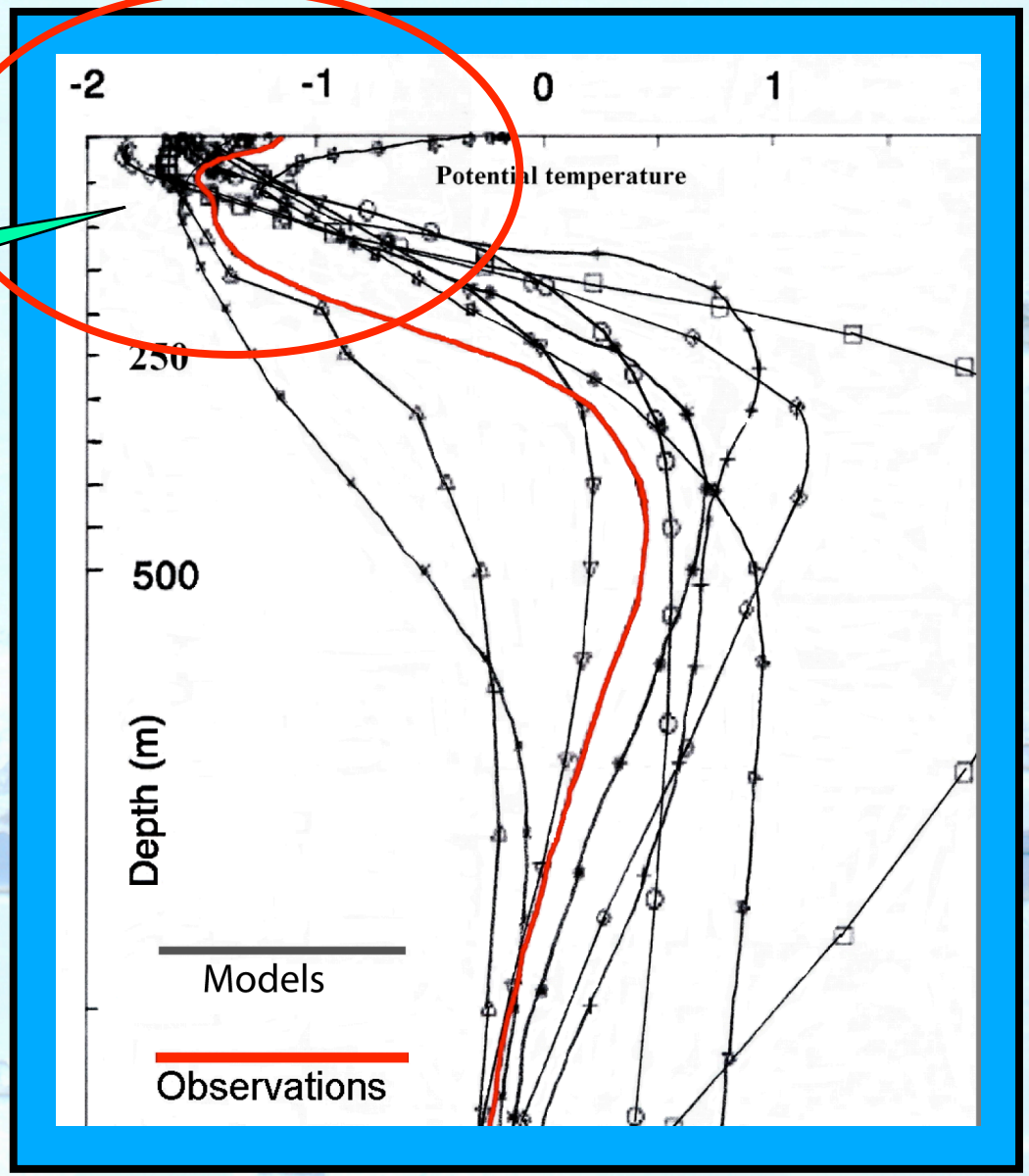
- **The Halocline:**



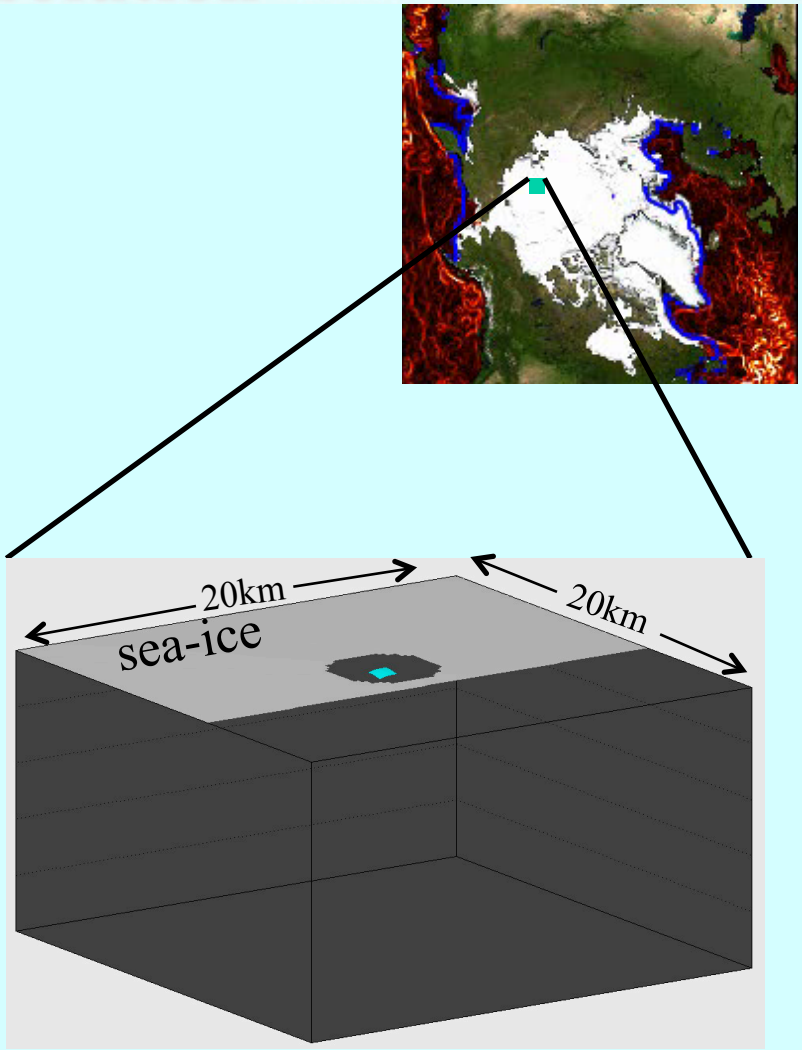
- **Insulator → prevents sea-ice melting**
- **Important to sea-ice stability**

Current State-of-the-Art Models:

Halocline missing



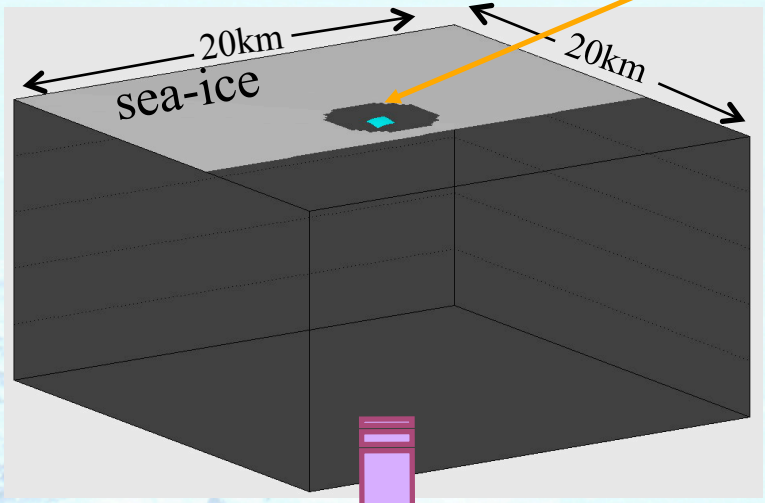
Problem: resolution

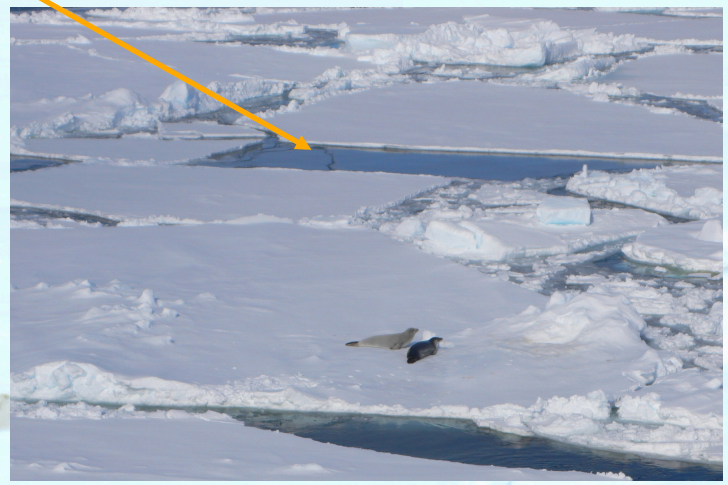


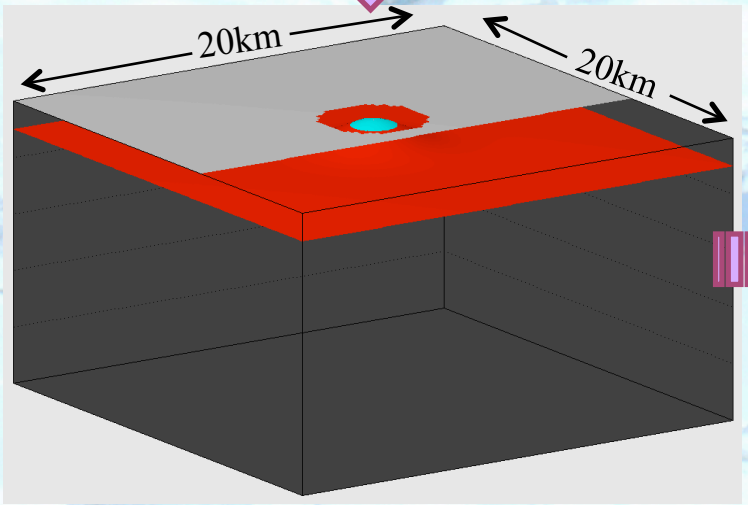
ECCO2: High-Resolution Global-Ocean and Sea-Ice Model

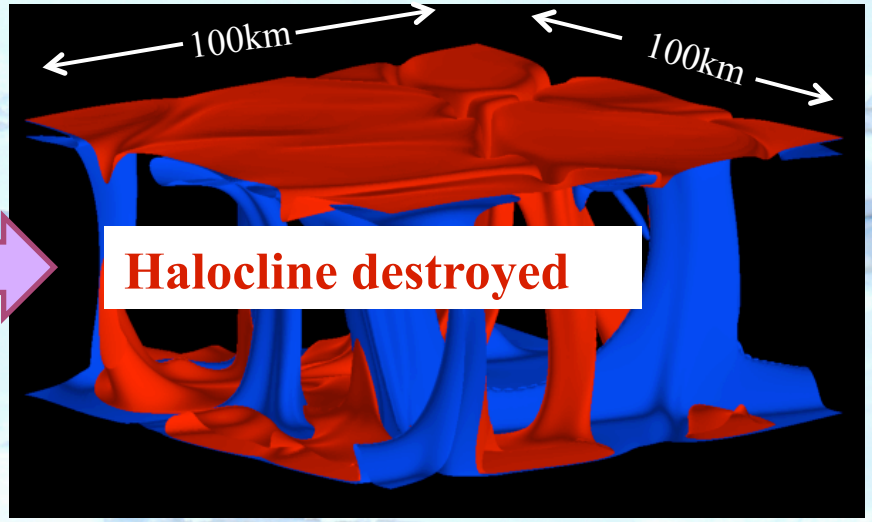
Problem: resolution

rejected salt



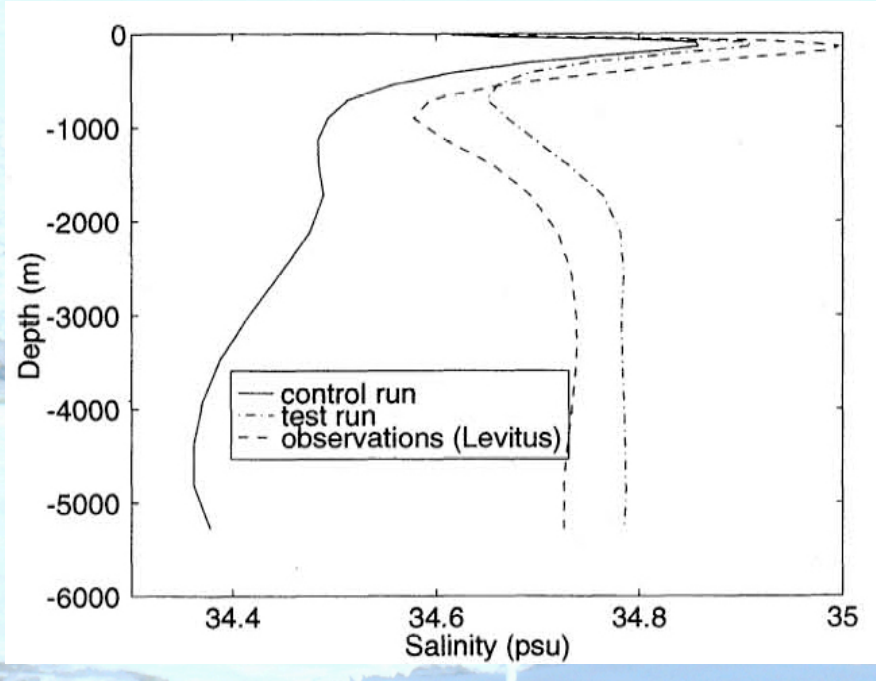


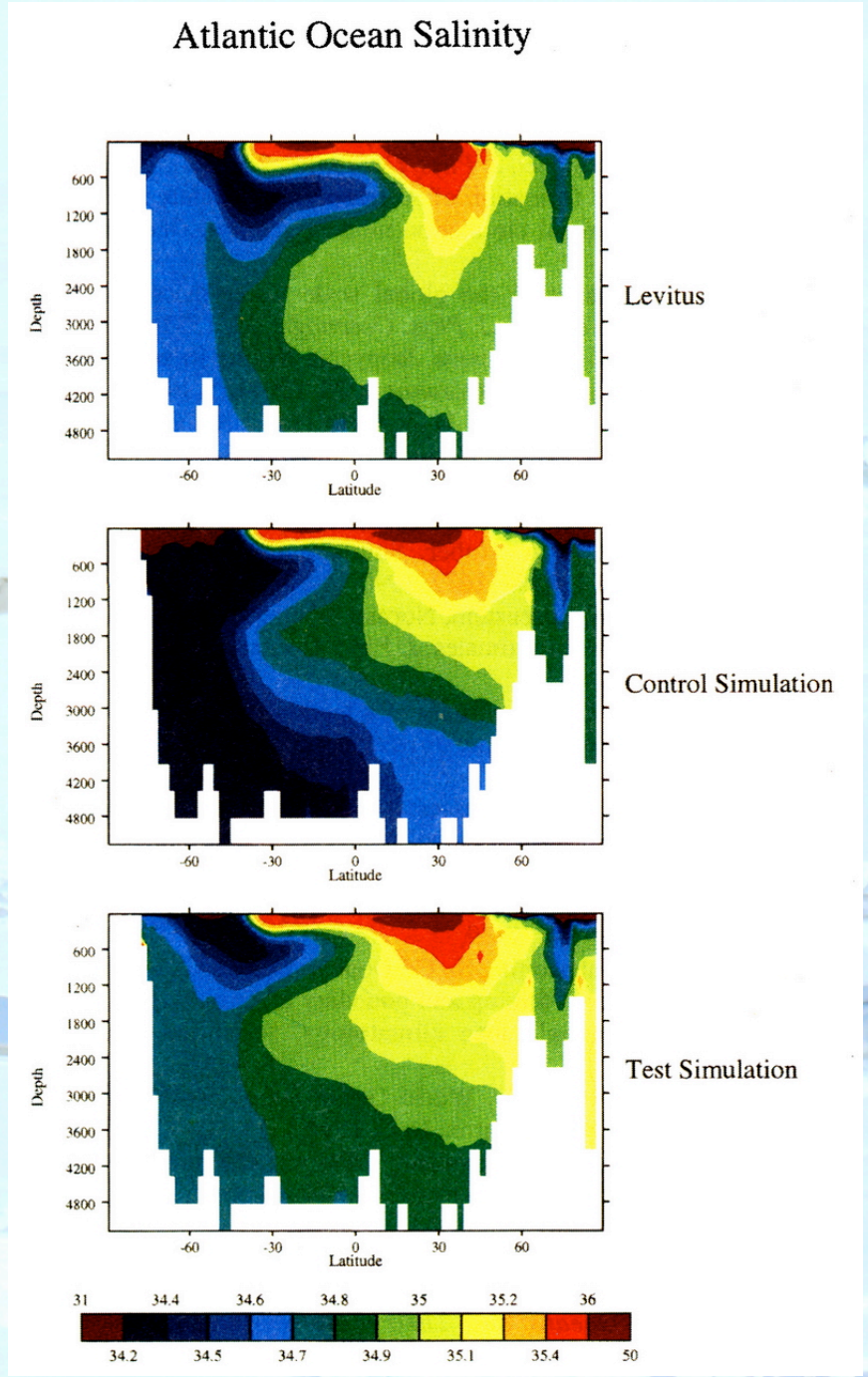




Salt plume scheme:

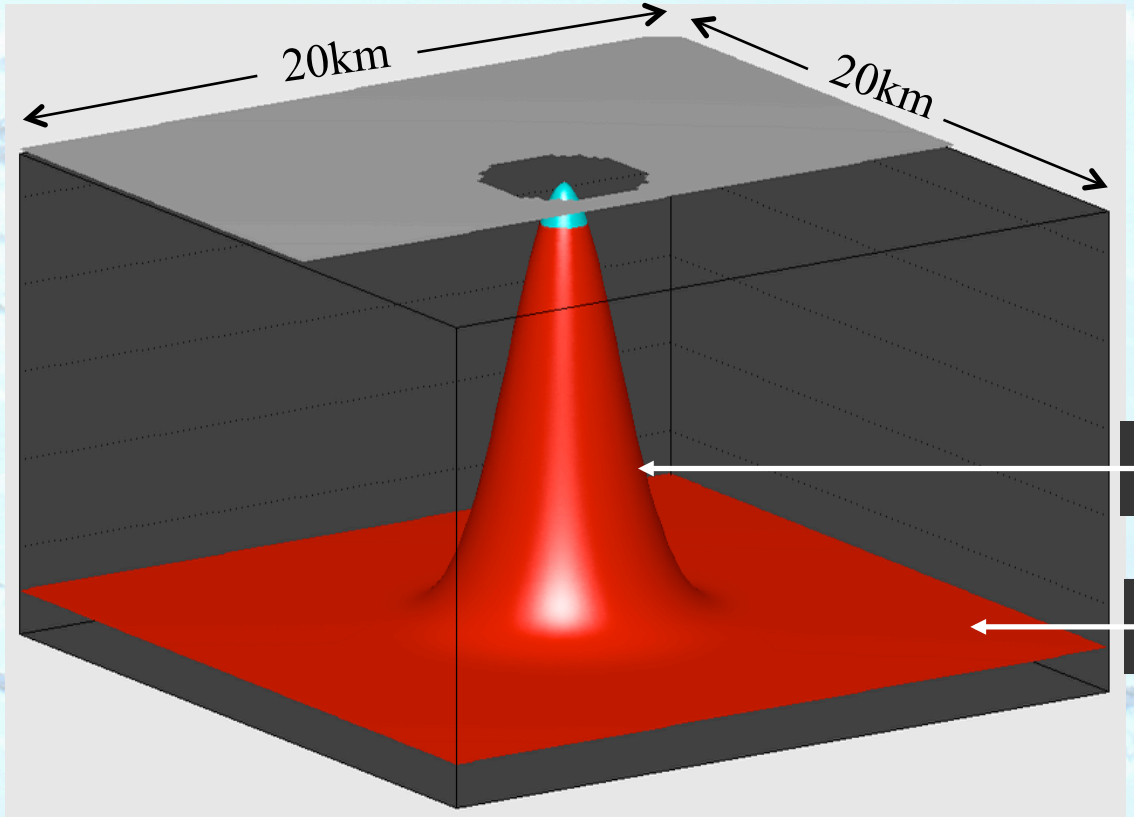
1. Duffy et al. [1997, 1999] in the Southern Ocean





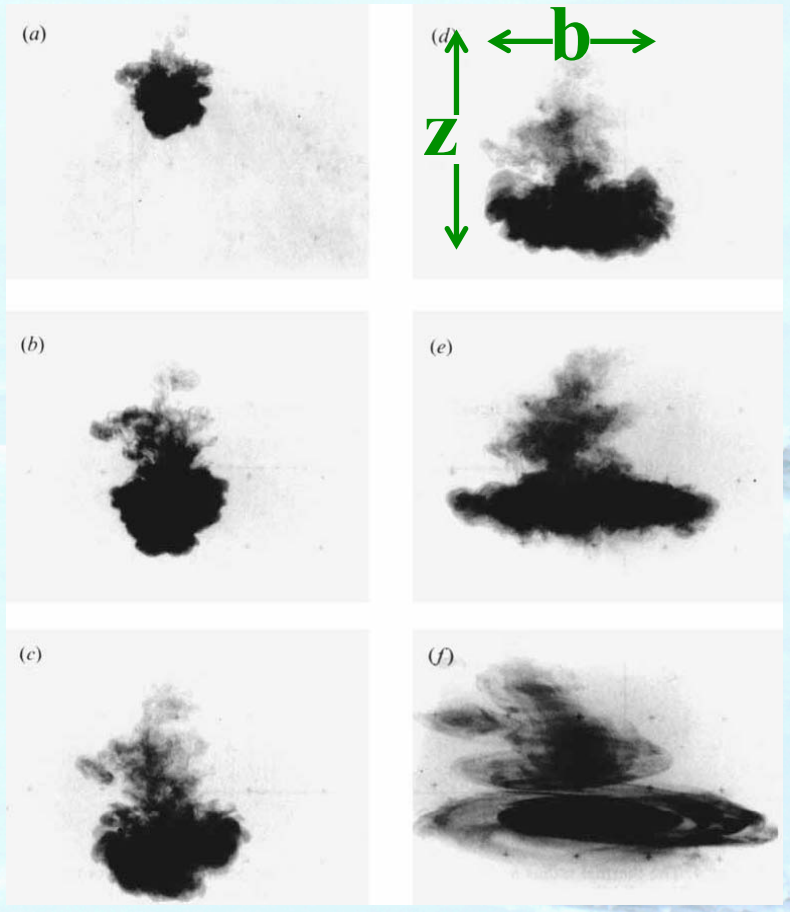
Hypothesis: **Sub-grid-scale Salt Rejection**

(less than 20km)



Parameters:

- depth
- shape

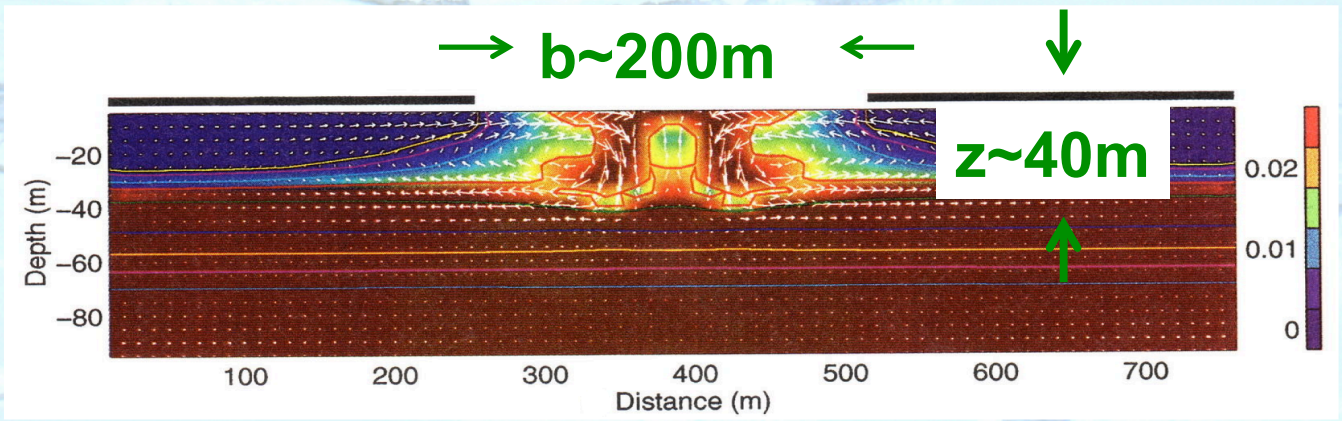


a) **Laboratory Experiments**

[Helfrich, 1994]:

b) Numerical Experiments:

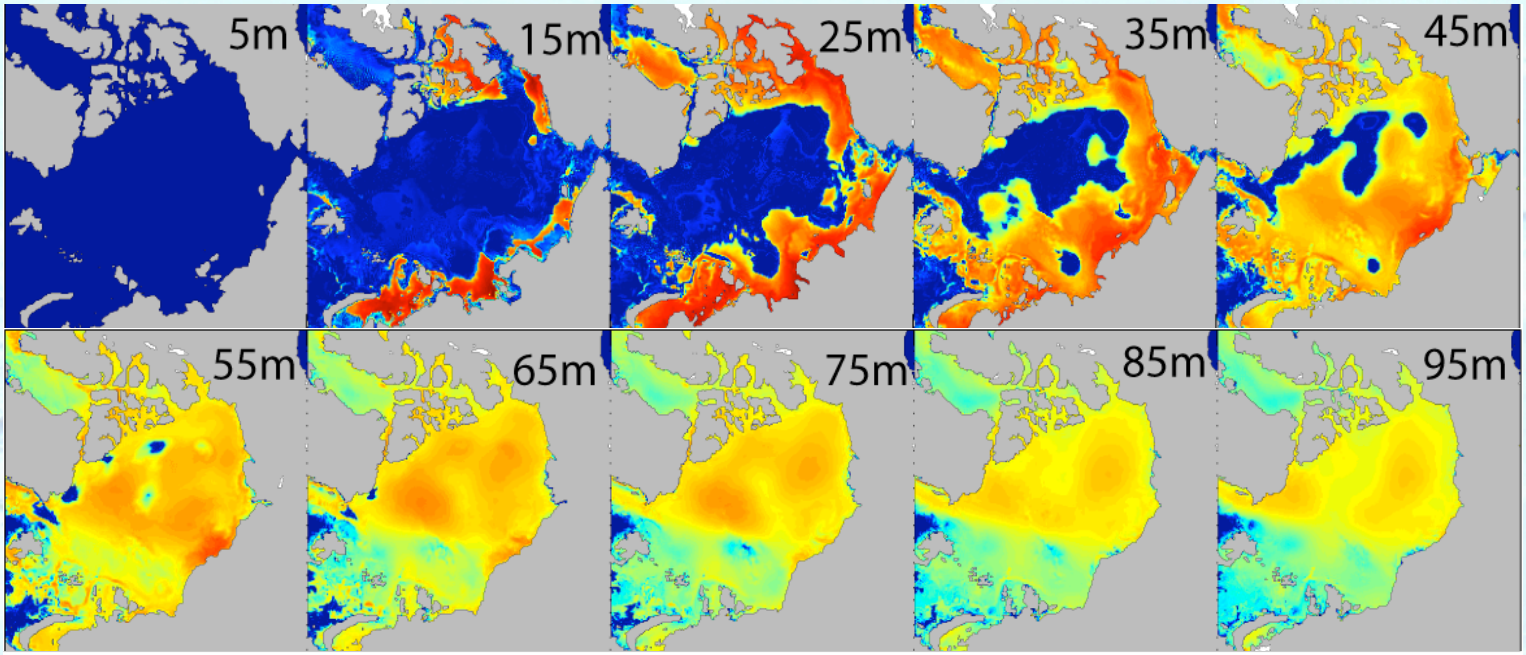
[Smith and Morison, 1998]:



Salt plume:

Brine Rejection Parameterization: Depth

04 Feb 1992

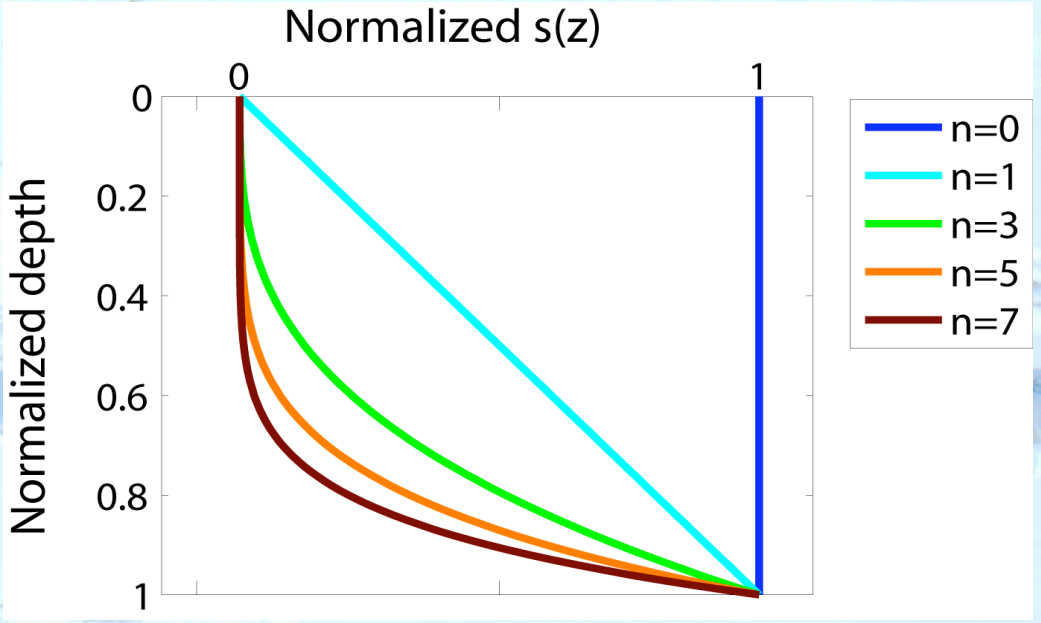


- Density structure:
  - dρ/dz in mixed layer:
    10^{-6} to 10^{-4} kg/m^3/m
  - dρ/dz @ top of halocline
    ~ 10^{-2} to 10^{-1} kg/m^3/m

Parameterization

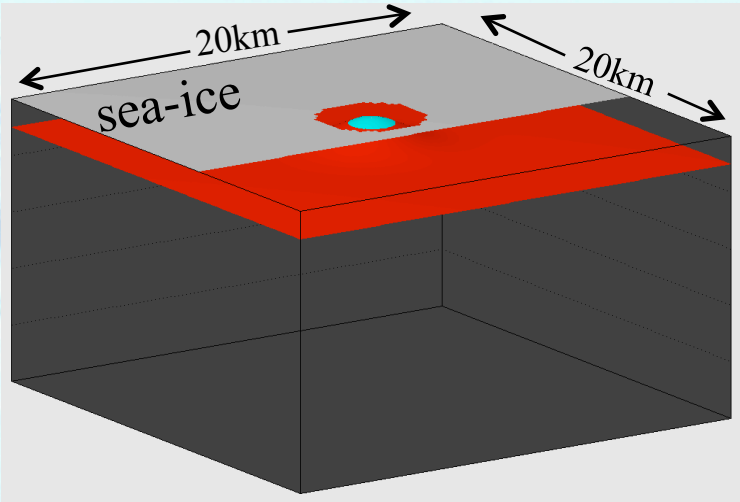
- **Brine Rejection Parameterization: Shape**
  - **Sea-ice retains 33% of salt**
  - **67% of salt rejected back to the ocean**
  - **Rejected salt *s(z)* is distributed down to bottom of mixed layer *z=D* according to:**

$$s(z) = \begin{cases} Az^n, |z| \le |D| \\ 0, |z| > |D| \end{cases}$$

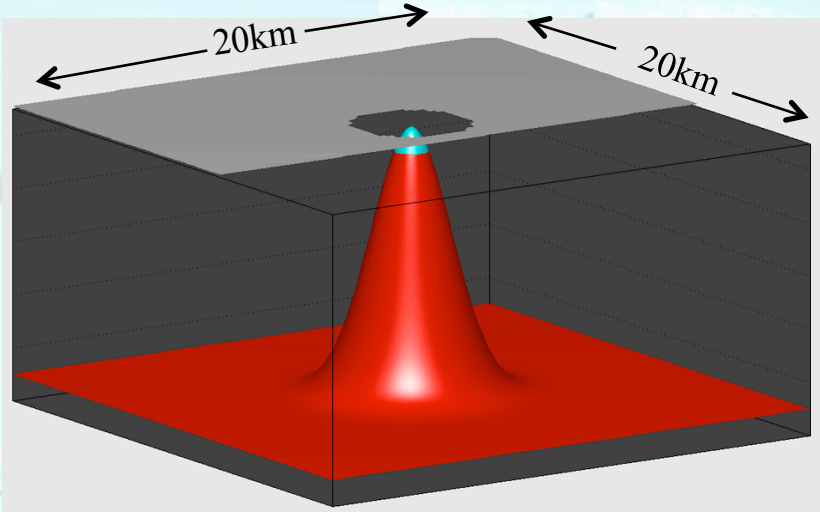


Results:

A0:
without salt-rejection scheme

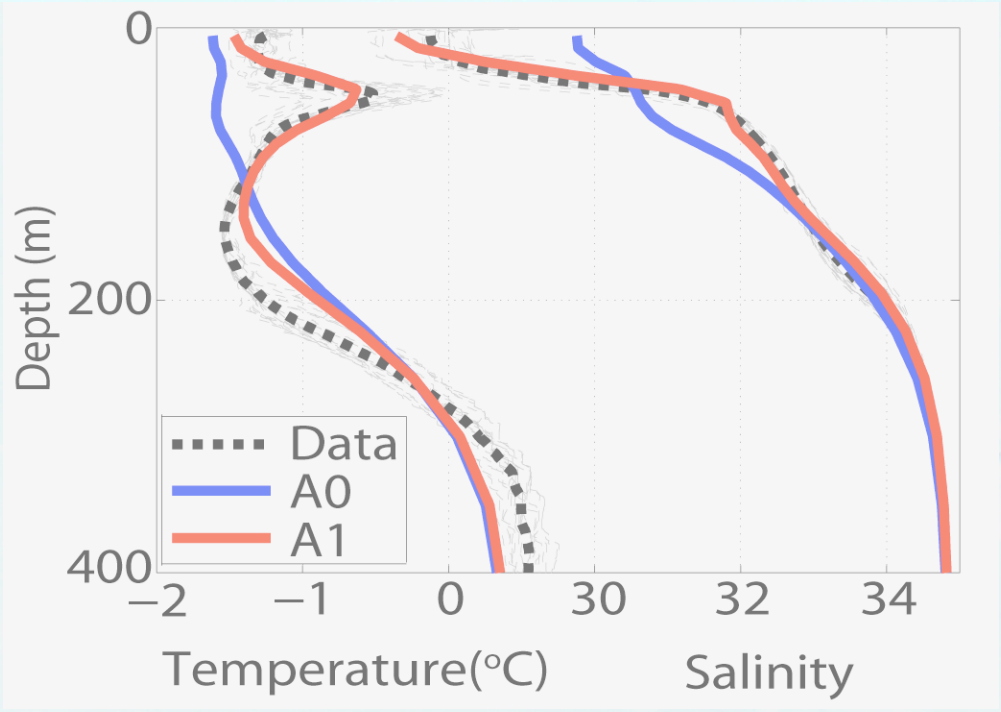


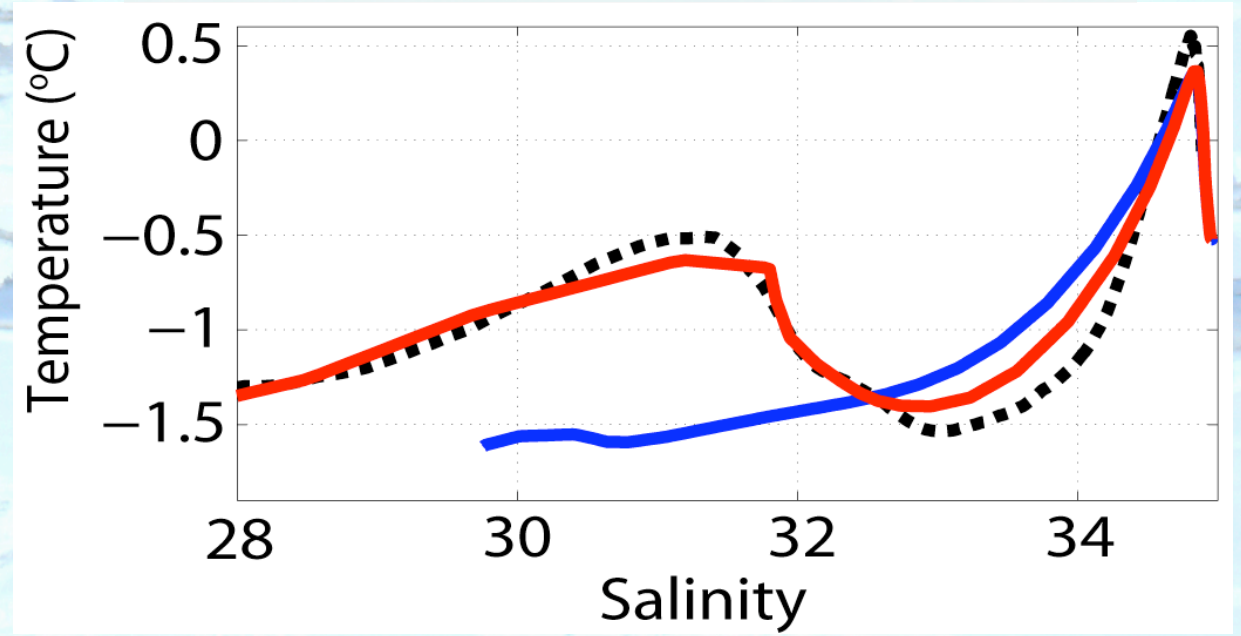
A1:
with salt-rejection scheme



Results:

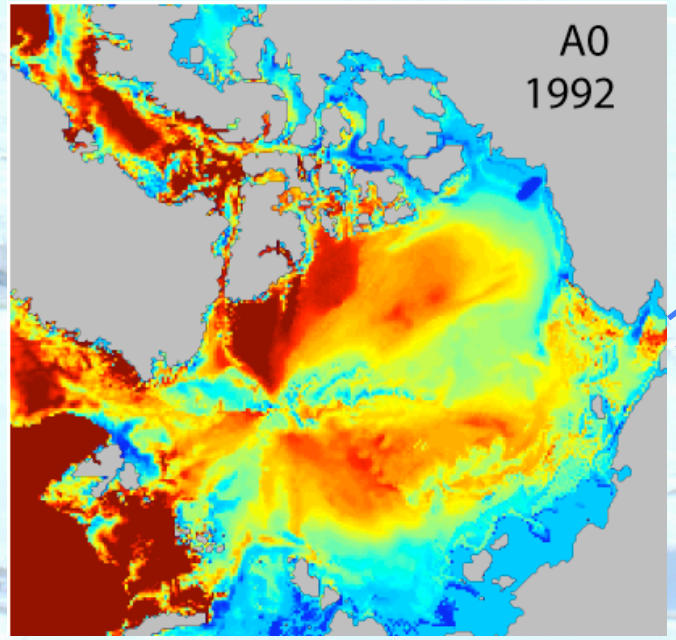
- Temperature
- Salinity



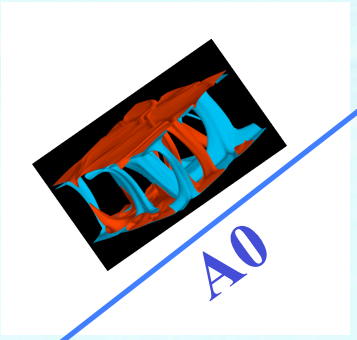


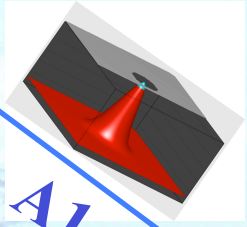
Results:

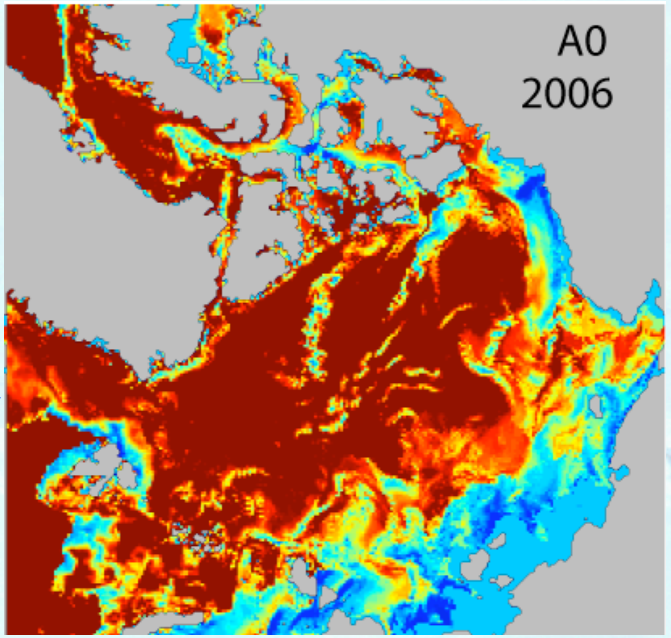
- **Mixed layer**

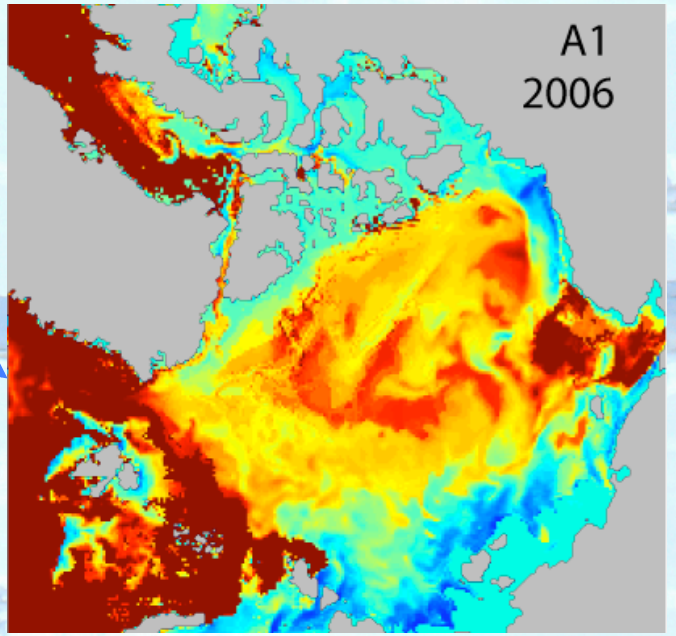


0m 50m









Conclusion:

- Successfully reproduce Halocline

- resolution problem: salt rejection occurs at < 20km scale
  → common practice in ocean & atmosphere models

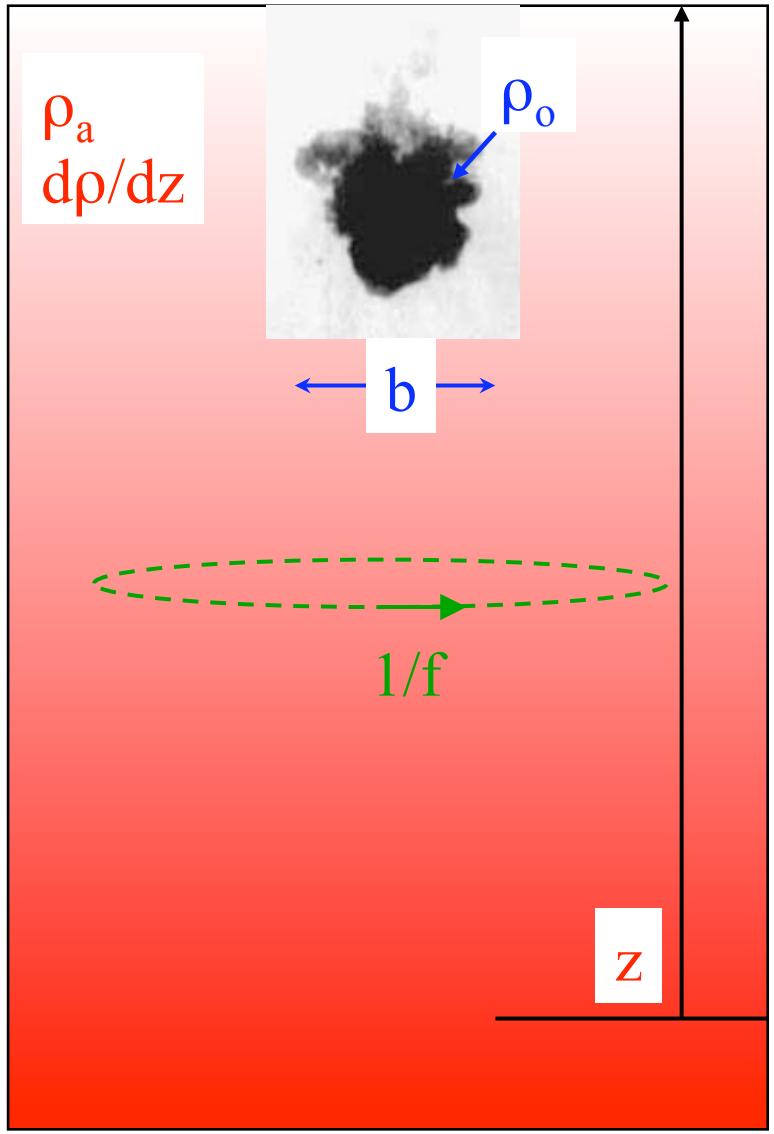
- halocline: → prevents heat in Atlantic Water from melting sea-ice
  → important to sea-ice stability & climate change studies

➢ Nguyen et al., 2008, submitted to JGR - Oceans


END

Salt plume scheme:

2. Laboratory experiments:
   Morton et al., [1956], Helfrich, [1993],
   Bush and Woods, [1999]



Parameters:

$$F_o = V_o \cdot g \frac{\rho_a - \rho_o}{\rho_a}$$ F_o: initial buoyancy

$$N^2 = -\frac{g}{\rho_o}\frac{d\rho}{dz}$$ N^2: buoyancy frequency

$$t_f \sim \frac{1}{f}$$ f: Coriolis frequency

Scalings:

Rotation unimportant	Rotation important
$(1/f)/(1/N) = N/f > 0.6$	$N/f < 0.6$
$z_M \approx 2.66\left(F_o N^{-2}\right)^{1/4}$	$z_R \approx 3.6\left(F_o f^{-2}\right)^{1/4}$
$b_M \approx 0.25 \cdot z_M$	$b_R \approx 0.25 \cdot z_R$

Assessment:

- **Data (Fig.1):**

  Conductivity-Temperature-Depth (CTD) profiles:

  a) Scientific Ice Expeditions 1995-2000 [SCICEX].

  b) Beaufort Gyre Exploration Project 2003-2004 [WHOI]

- **Measure of Improvements:**

  Improvements are measured in reduction of sum-of-squares (*SSQ*) of model minus data:

$$I = \frac{\left(SSQ_{A0} - SSQ_{A[1,2]}\right)}{SSQ_{A0}} \times 100$$

***I* > *0* when $SSQ_{A[1,2]} < SSQ_{A0}$ ➔ Solution *A[1,2]* is better**

***I* < *0* when $SSQ_{A[1,2]} > SSQ_{A0}$ ➔ Solution *A[1,2]* is worse**

Table.2: **Relative Improvements *I (%)* for experiments A1 and A2 with respect to A0 for the years 1995-2004.**

	Data							
	SCICEX						BGEP	
Experiment	1995	1996	1997	1998	1999	2000	2003	2004
A0	0	0	0	0	0	0	0	0
A1	27	16	39	12	28	9	62	68
A2	-15	6	45	27	30	11	118	79