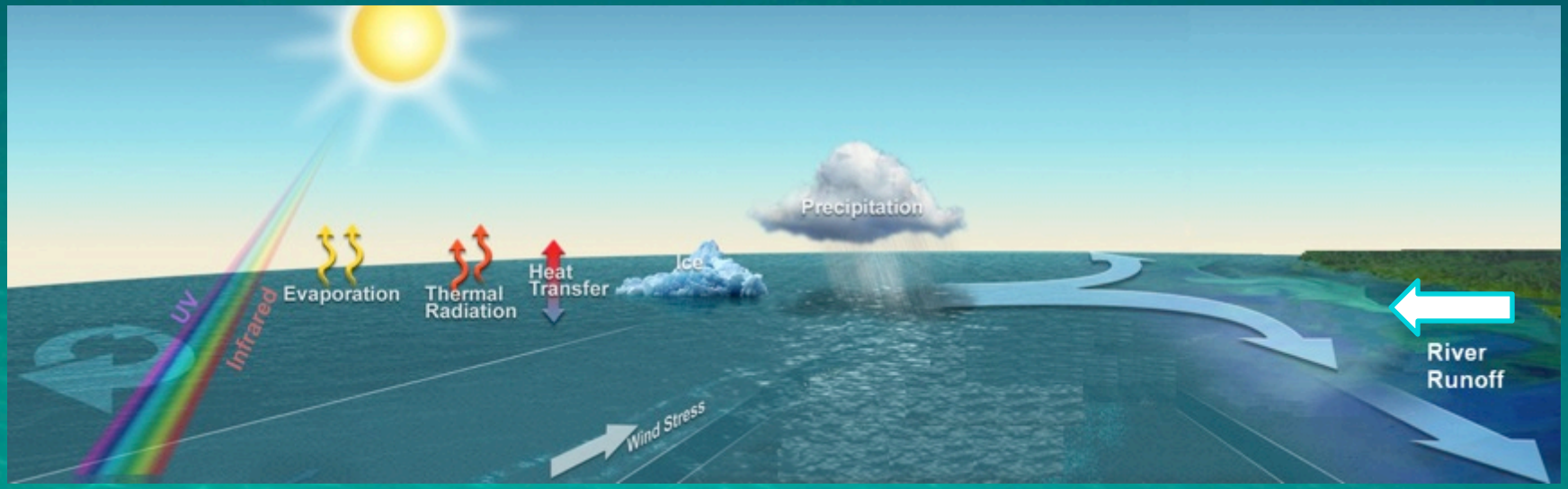
Ushakov K.V.
Ibrayev R.A.

Modeling the North Atlantic Ocean climate variability as a part of the CORE experiment

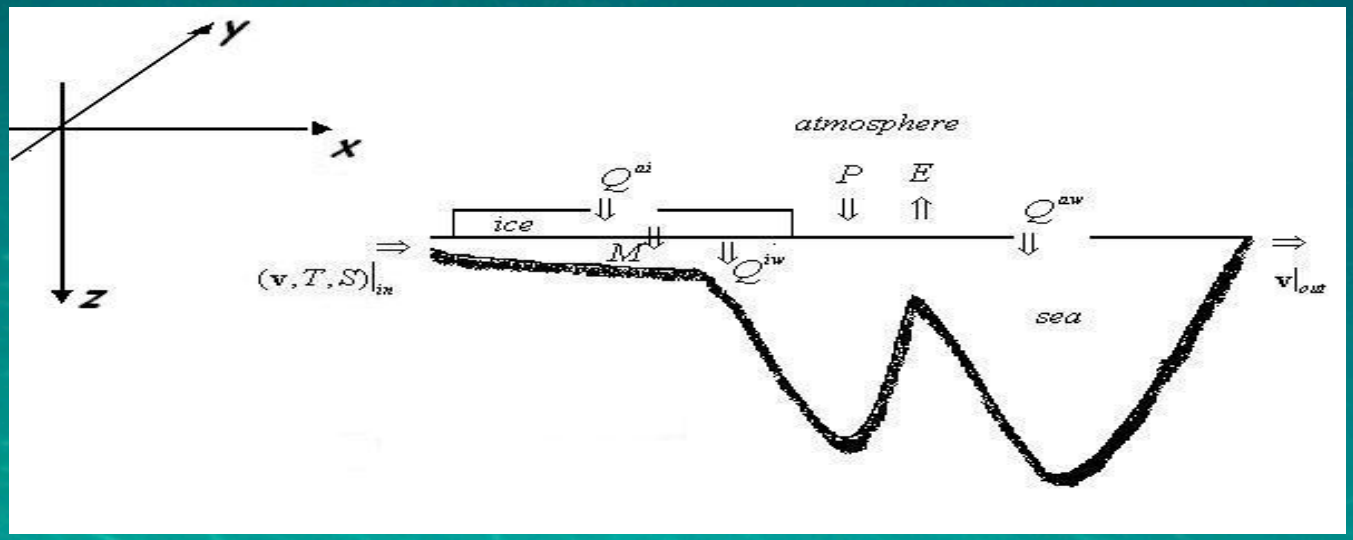
ENVIROMIS 2012

CORE-I experiment protocol



- Coupled ocean-ice model
- Climatological initial conditions
- Normal year forcing – 500 years
- CCSM atmospheric boundary layer
- Sea surface salinity relaxation
- Hydrology normalization

Model equations



$$u_t + (\vec{v}\cdot\nabla)u - fv = -\rho_o^{-1} p_x + (K_m u_z)_z + D_u$$
$$v_t + (\vec{v}\cdot\nabla)v + fu = -\rho_o^{-1} p_y + (K_m v_z)_z + D_u$$
$$p_z = \rho g$$
$$\nabla\cdot\vec{v} = 0$$
$$\zeta_t + \vec{v}\cdot\nabla(\quad \zeta) = \rho_f^{-1}(P + M - E)$$
$$T_t + (\vec{v}\cdot\nabla)T = (K_h T_z)_z + D_T + (\rho_o c_p)^{-1} I_z \cdot (1 - A)$$
$$S_t + (\vec{v}\cdot\nabla)S = (K_h S_z)_z + D_S$$
$$\rho = \rho(T, S)$$

Boundary conditions

Ω - 3-х мерная область

G_H - нижняя граница, $z - H(x,y) = 0$

G_ξ - верхняя граница, $z + \xi(x,y,t) = 0$

G_S - твердая боковая граница

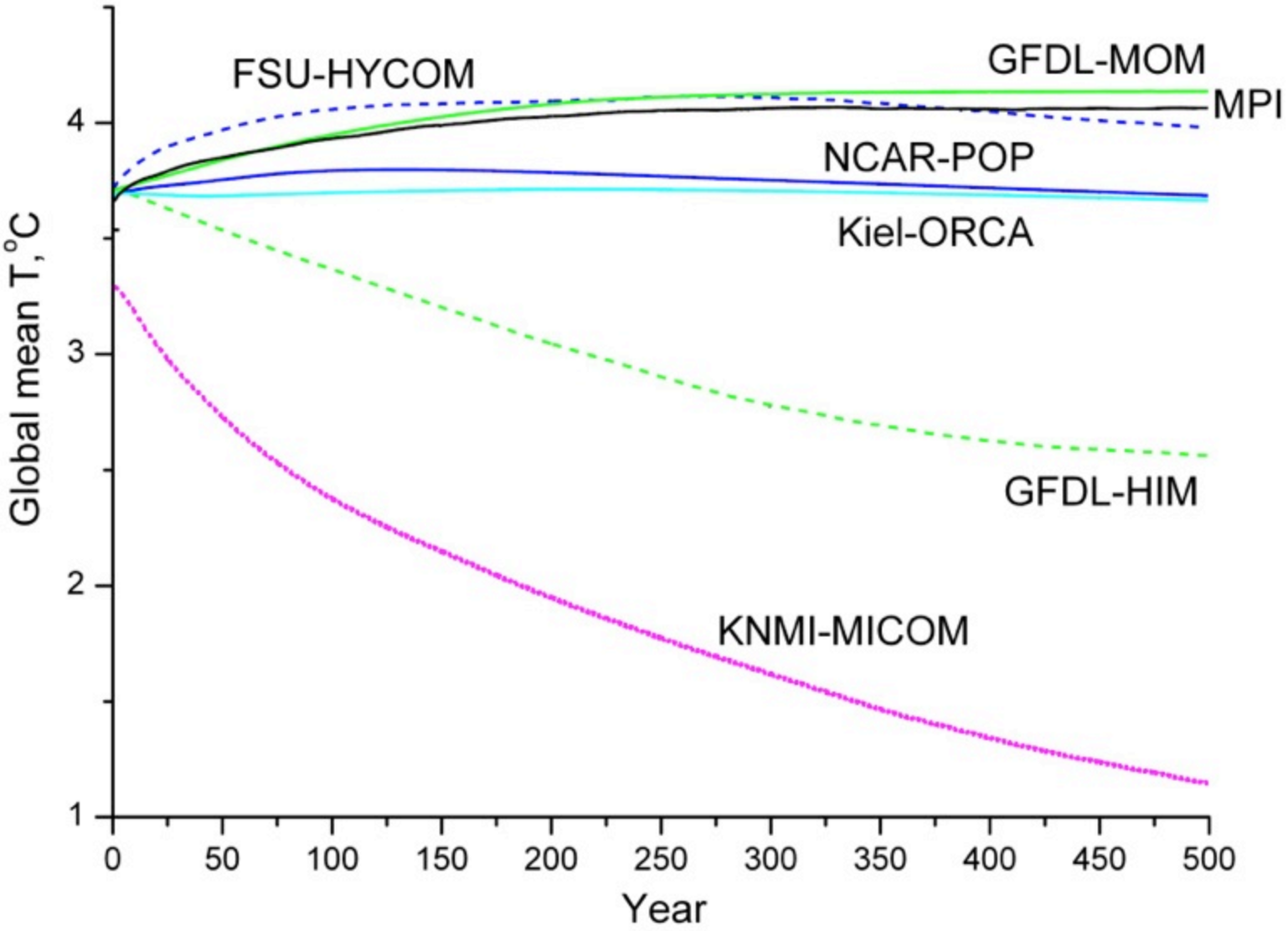
G_L - "жидкая" боковая граница

G_O - открытая боковая граница

$$G_\xi, z = -\xi(\lambda,\varphi,t): \begin{cases} -K_m(u_z, v_z) + (u,v)\cdot\rho_f^{-1}W = \rho_o^{-1}(1-A)(\tau^\lambda, \tau^\varphi) \\ p = p_a \\ -c_p K_h T_z + c_p T \rho_f^{-1} W = \rho_o^{-1}[Q_h^{aw}(1-A) + Q_h^{iw} A] \\ -K_h S_z + S\rho_f^{-1}W = \rho_o^{-1} S^{iw} MA \end{cases}$$

$$G_H, z = H(\lambda,\varphi): \begin{cases} w = u(a\cos\varphi)^{-1}\dfrac{\partial H}{\partial\lambda} + va^{-1}\dfrac{\partial H}{\partial\varphi} \\ -\rho_o K_m \dfrac{\partial(u,v)}{\partial z} = (\tau_B^\lambda, \tau_B^\varphi) \\ -\rho c_p K_h \dfrac{\partial T}{\partial z} = 0 \\ -\rho K_h \dfrac{\partial S}{\partial \mathbf{n}} = 0 \end{cases}$$

$$G_S: \begin{cases} (u,v)_n = 0 \\ \dfrac{\partial(u,v)_\tau}{\partial n} = 0 \\ \dfrac{\partial T}{\partial n} = 0 \\ \dfrac{\partial S}{\partial n} = 0 \end{cases} \text{ или } \begin{cases} u = 0 \\ v = 0 \\ \dfrac{\partial T}{\partial n} = 0 \\ \dfrac{\partial S}{\partial n} = 0 \end{cases} \qquad G_L: \begin{cases} u = u^{in} \\ v = v^{in} \\ T = T^{in} \\ T = T^{in} \end{cases} \text{ или } \begin{cases} u = u^{out} \\ v = v^{out} \\ \dfrac{\partial T}{\partial n} = 0 \\ \dfrac{\partial S}{\partial n} = 0 \end{cases}$$


FSU-HYCOM
GFDL-MOM
MPI
NCAR-POP
Kiel-ORCA
GFDL-HIM
KNMI-MICOM
Global mean T, °C
Year
1
2
3
4
0
50
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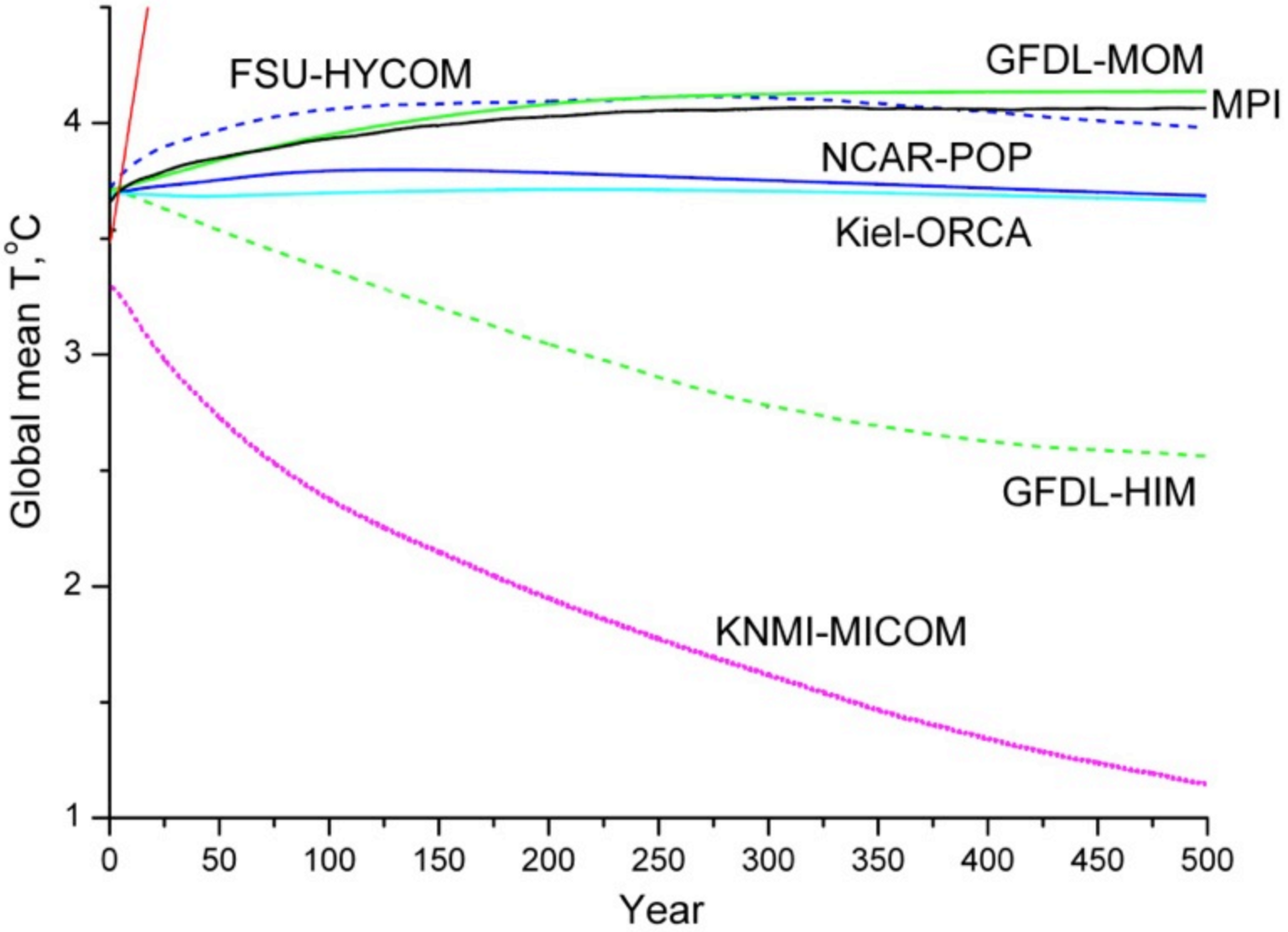
150
200
250
300
350
400
450
500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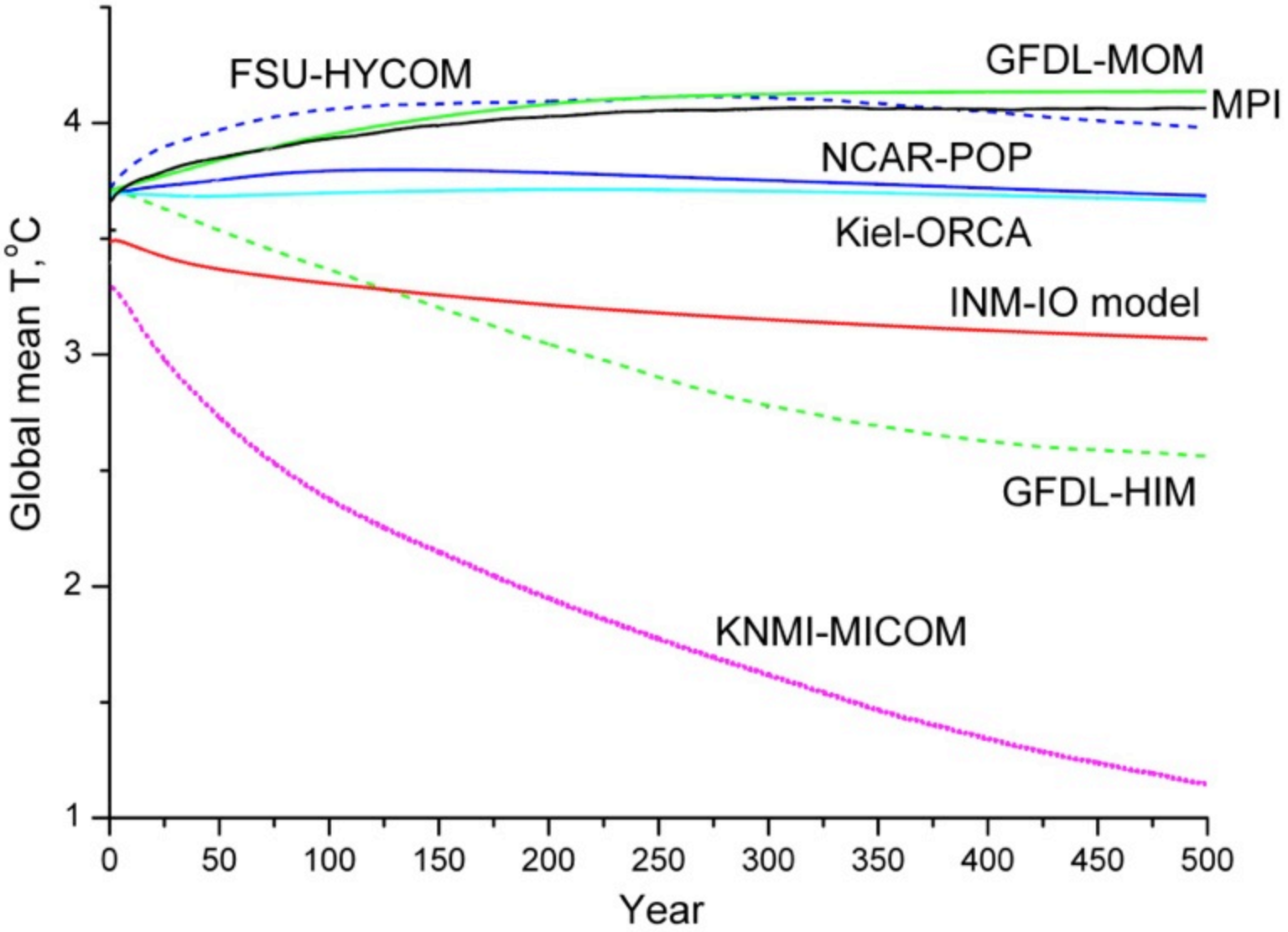
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INM-IO model
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Global mean T, °C
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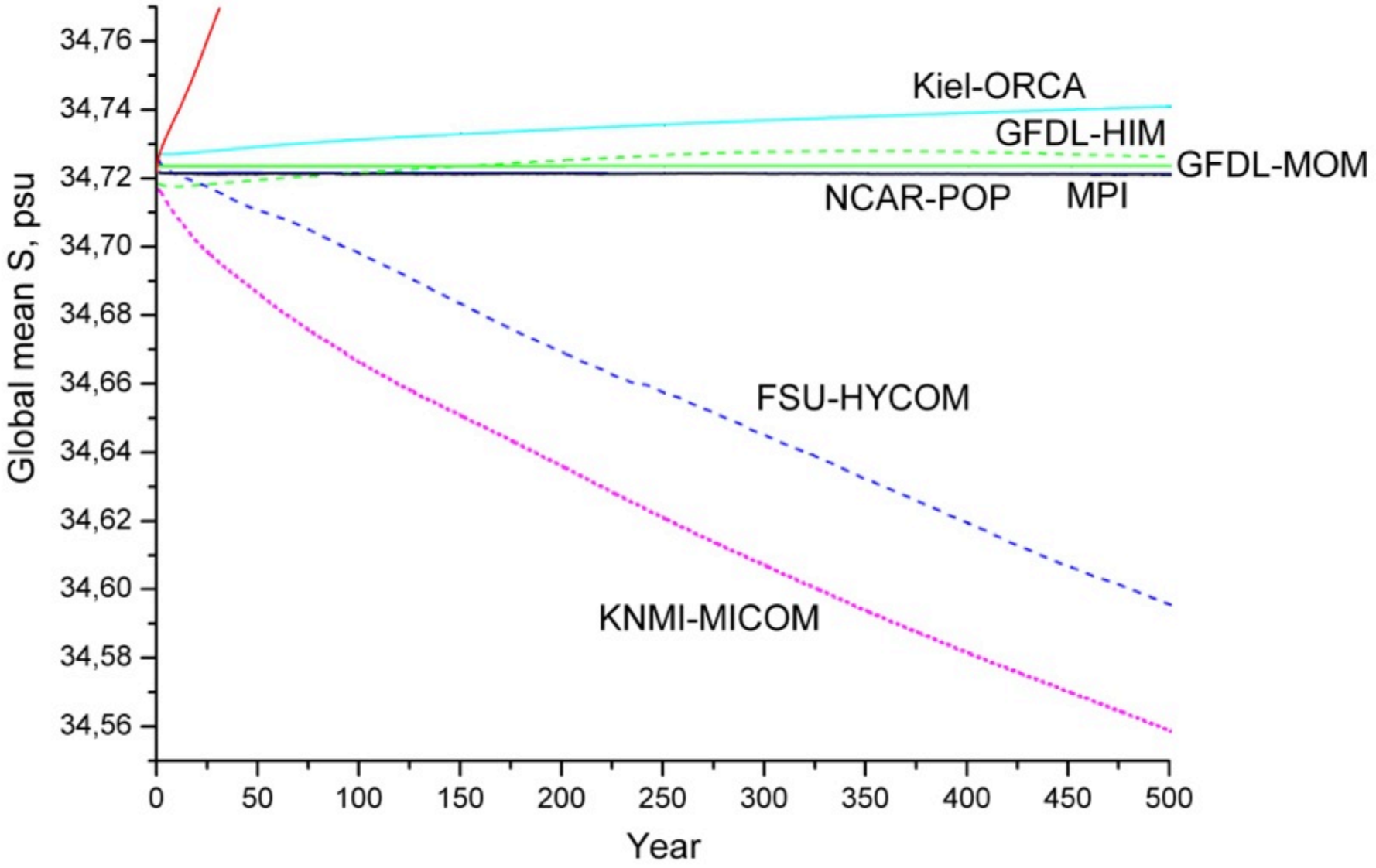
Global mean S, psu
34,76
34,74
34,72
34,70
34,68
34,66
34,64
34,62
34,60
34,58
34,56
0
50
100
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Year
Kiel-ORCA
GFDL-HIM
GFDL-MOM
NCAR-POP
MPI
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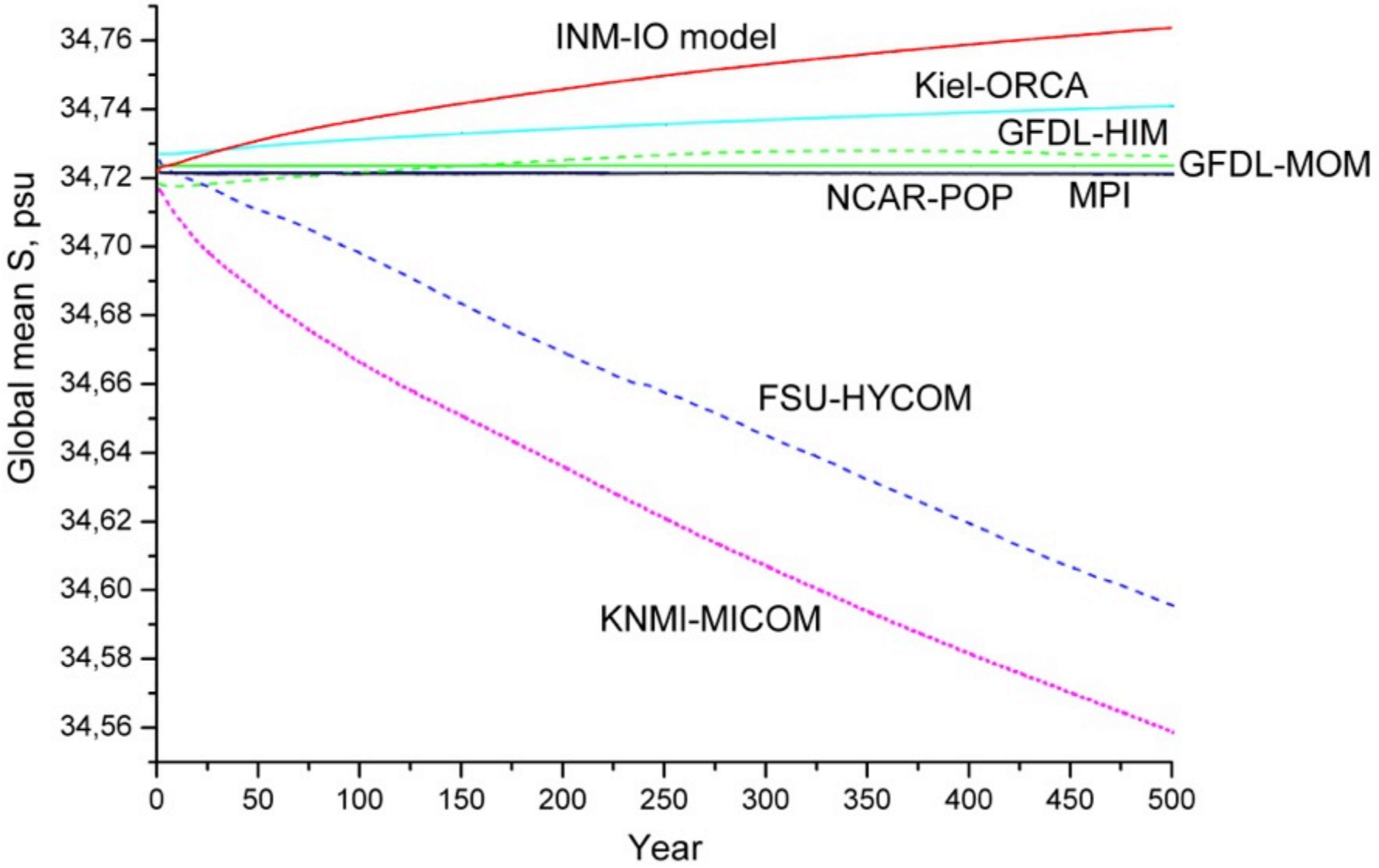
INM-IO model
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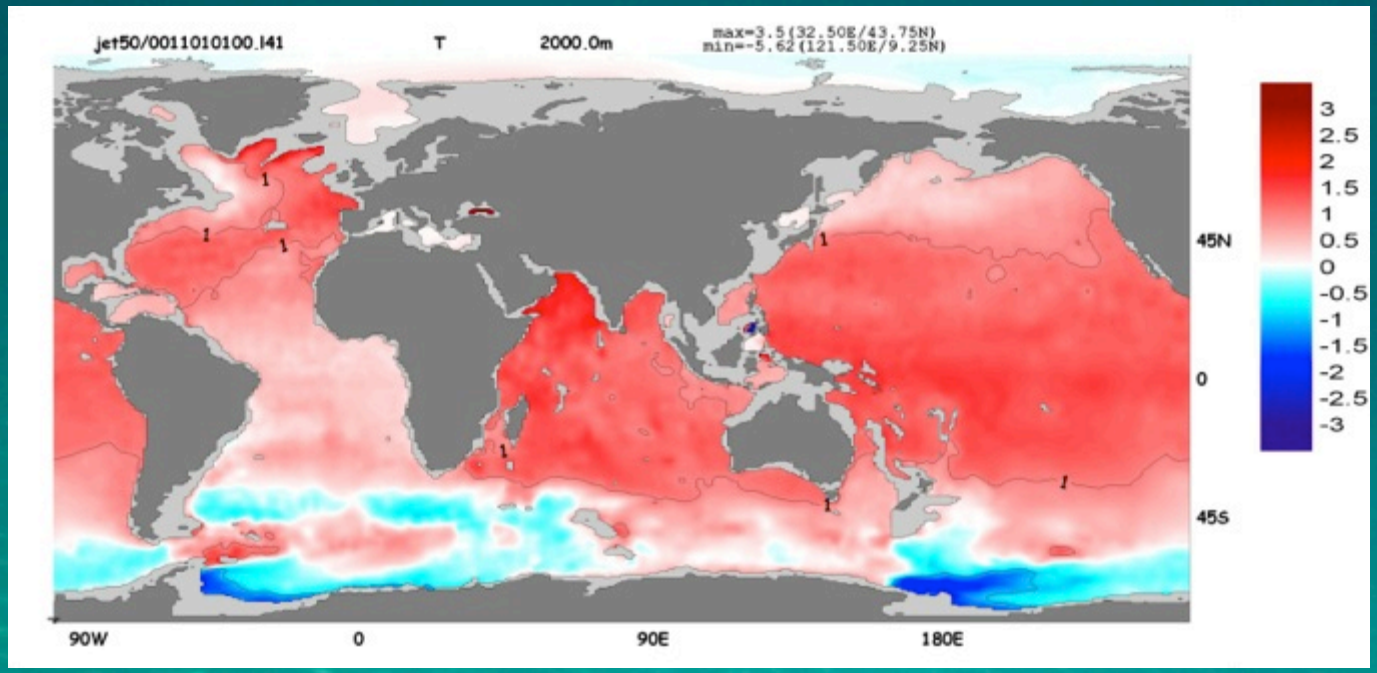
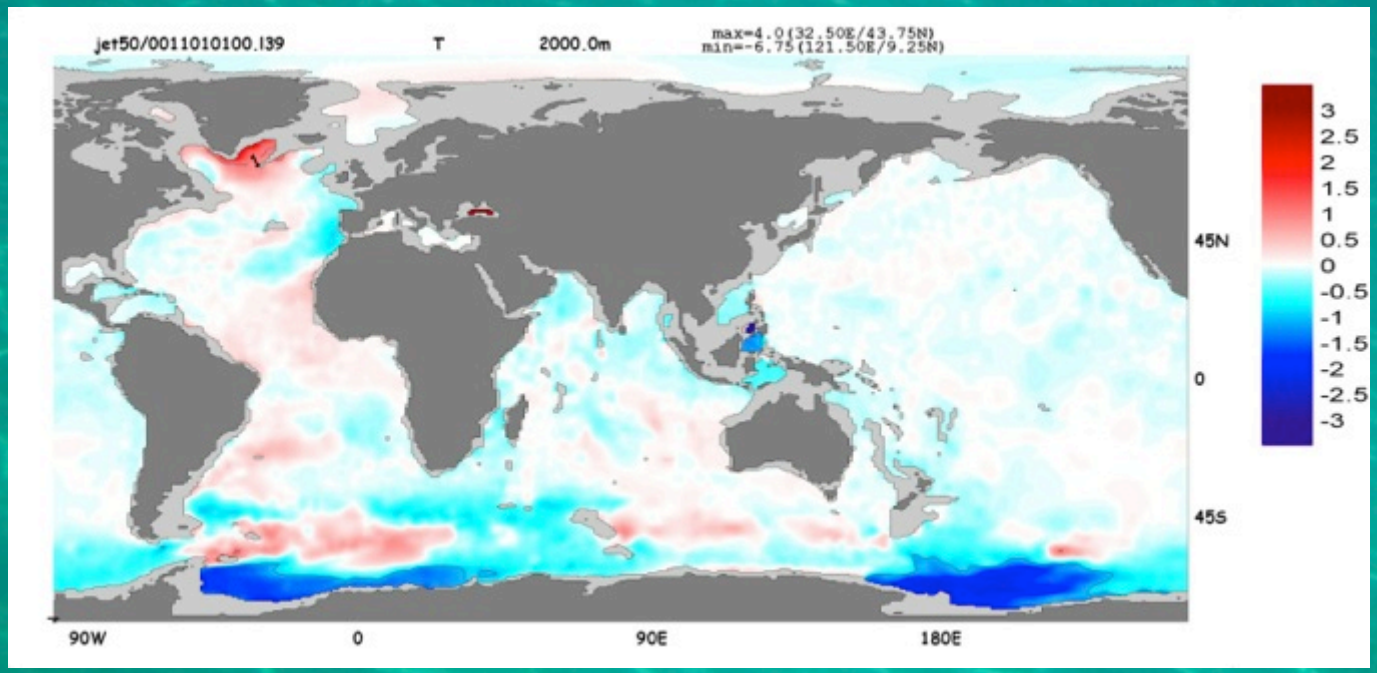
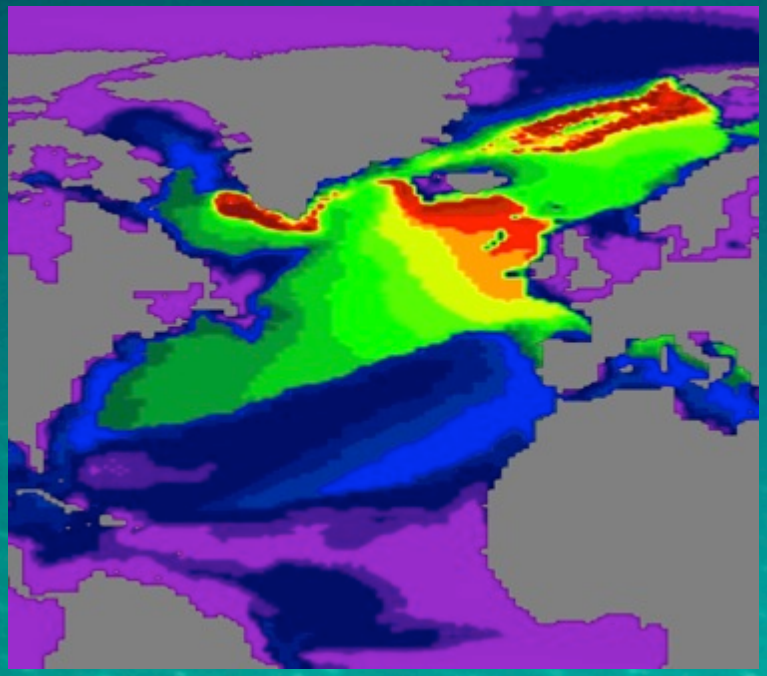


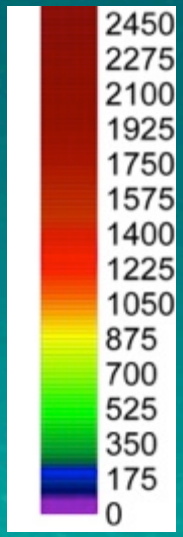


Temperature deviation from the WOA2001 data at 2000 m depth after 10 years:

upwind transport (top)

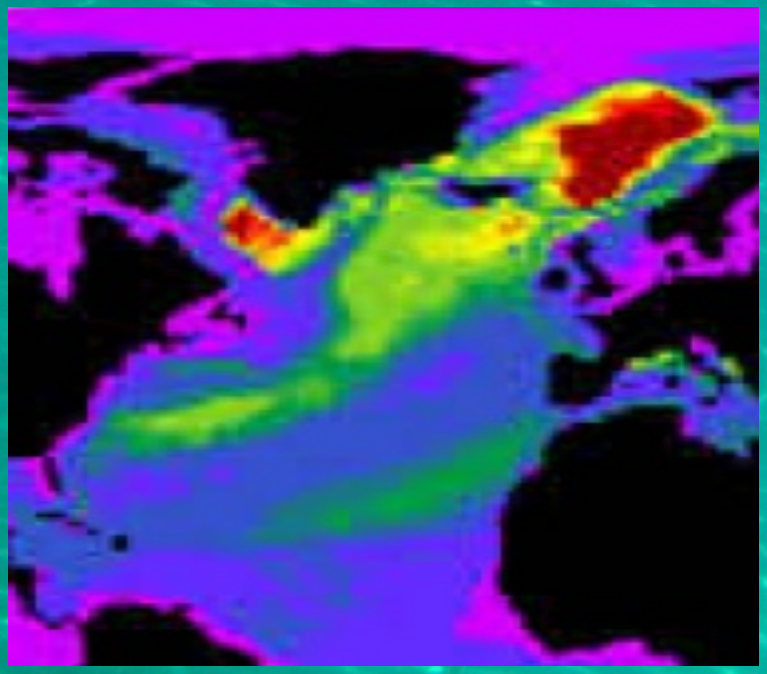
FCT Zalesak1979 (bottom)

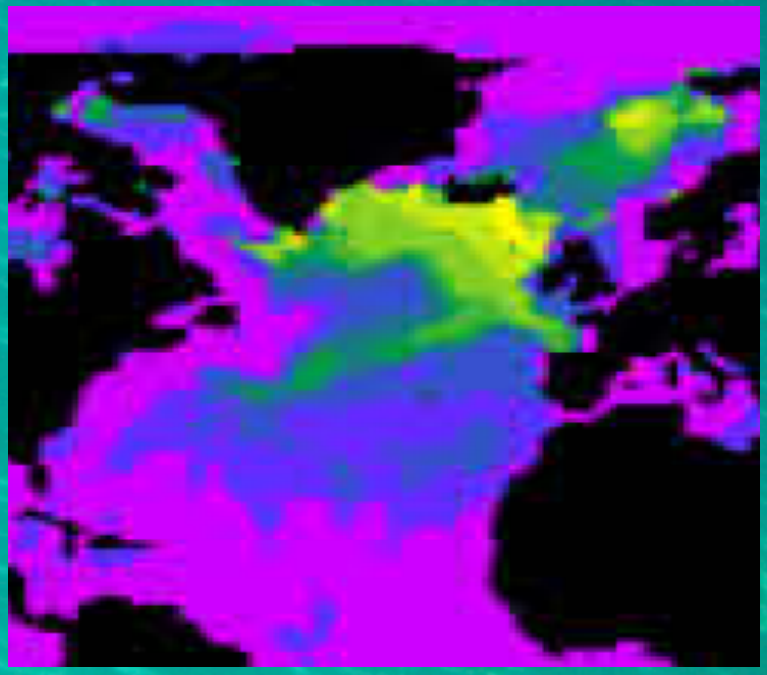


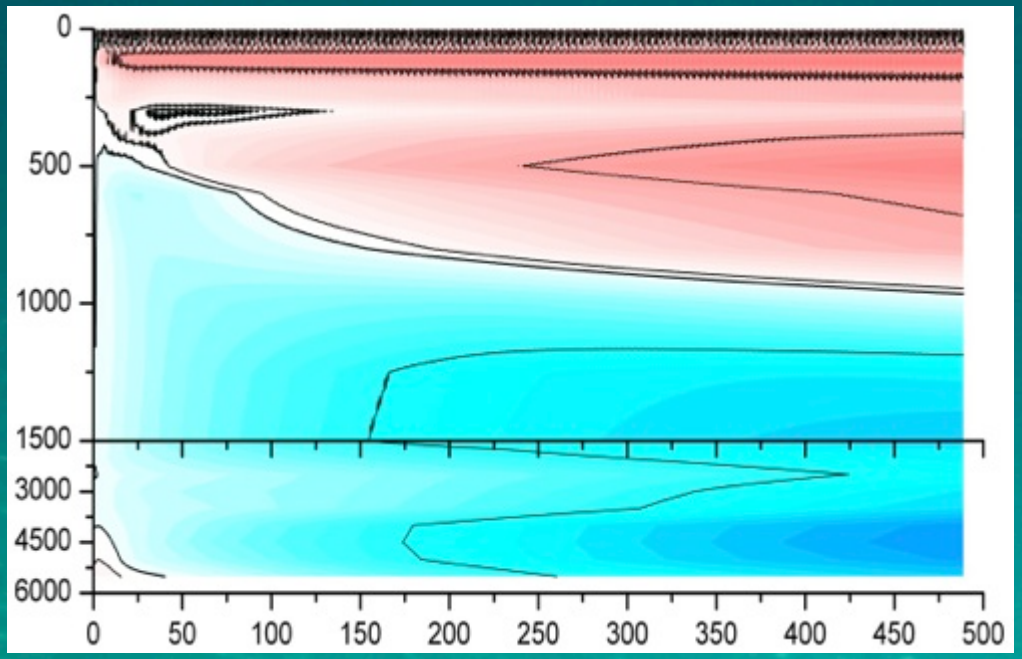


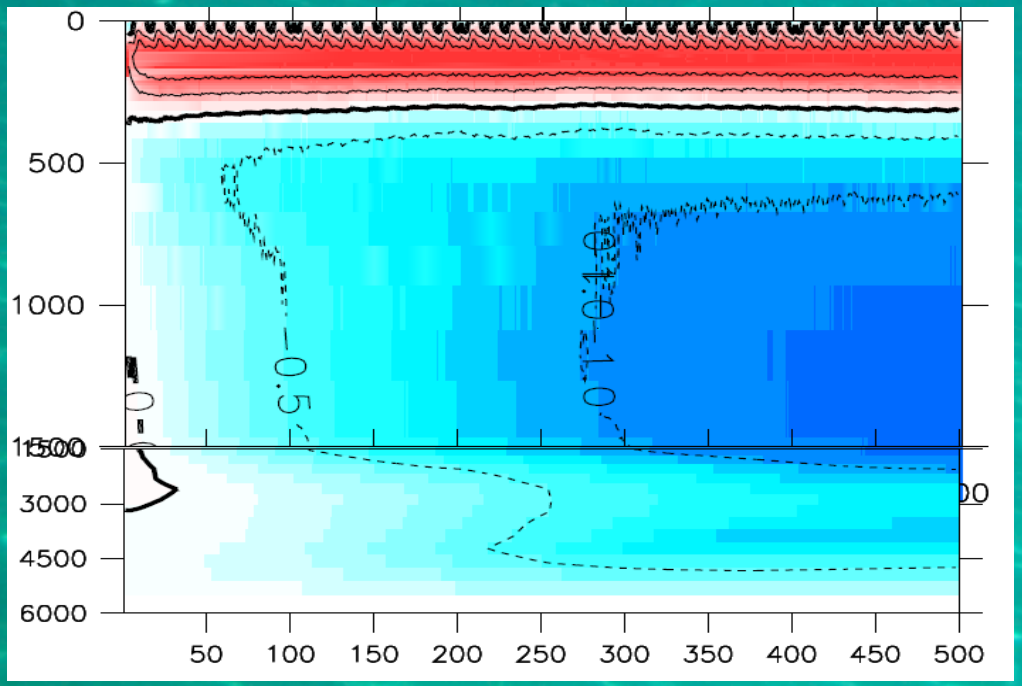
Mixed layer depth (m) :

- INM-IO model (left top)
- GFDL-HIM (left bottom)
- Climatological (right bottom)



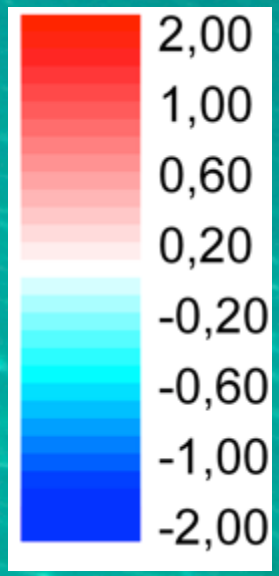




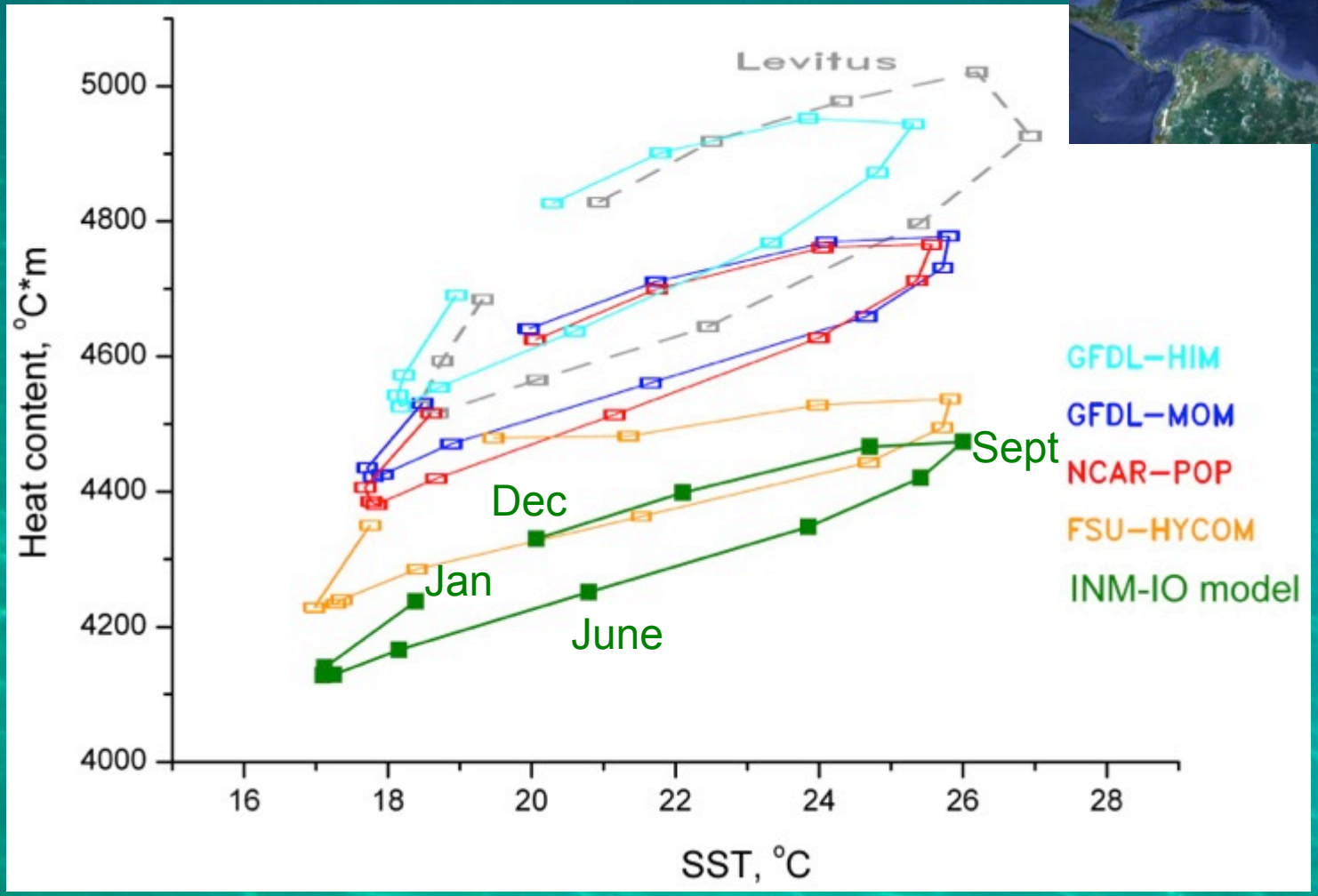


Globally averaged temperature drift (°C) as a function of depth (vertical, m) and time (horizontal, years)

INM-IO model (top)
GFDL-HIM (bottom)



Heat content over the upper 250 m versus SST at Ocean Weathership Echo (35°N, 48°W)



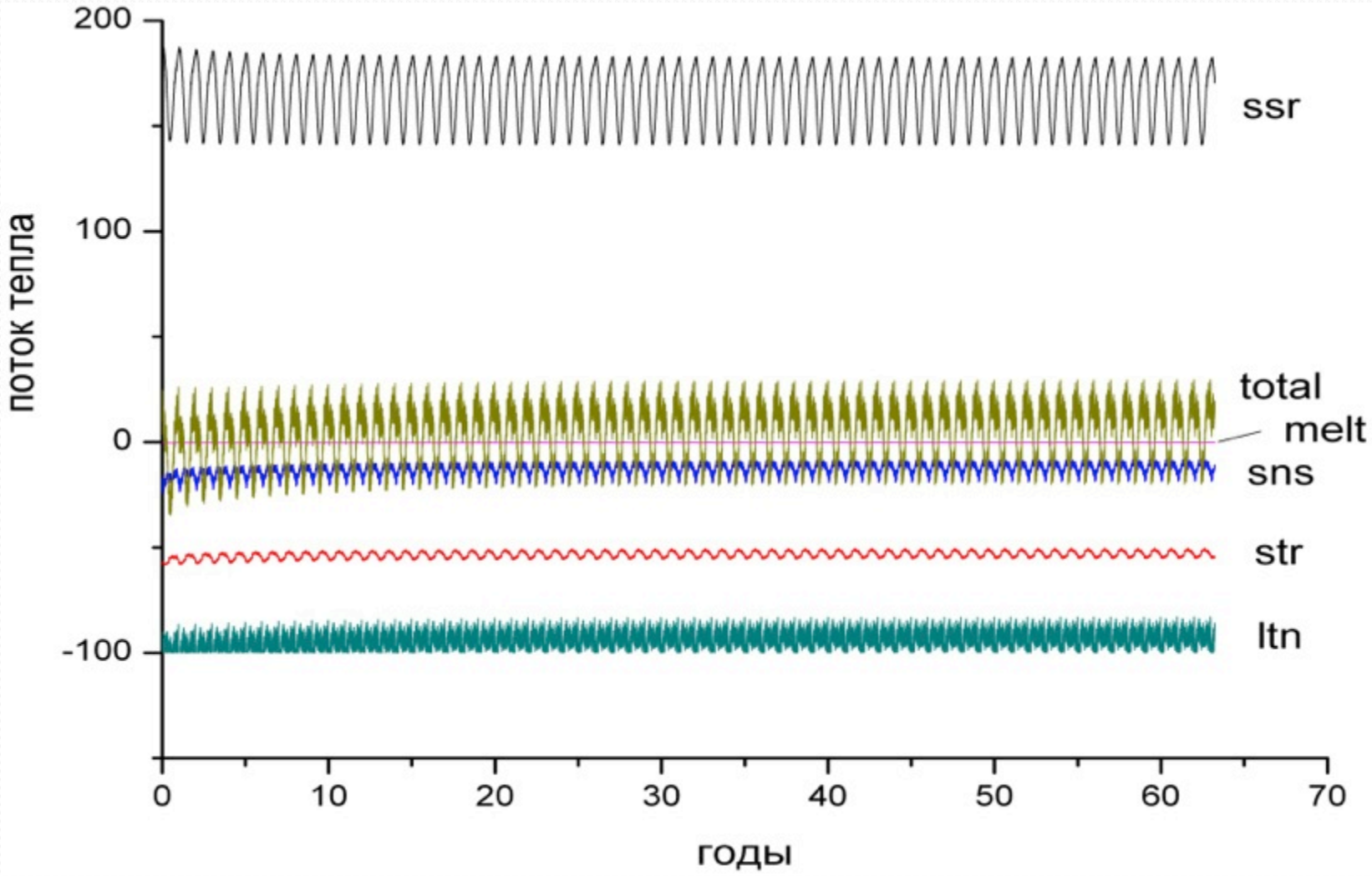
Thank you!

Характеристики и конфигурация моделей

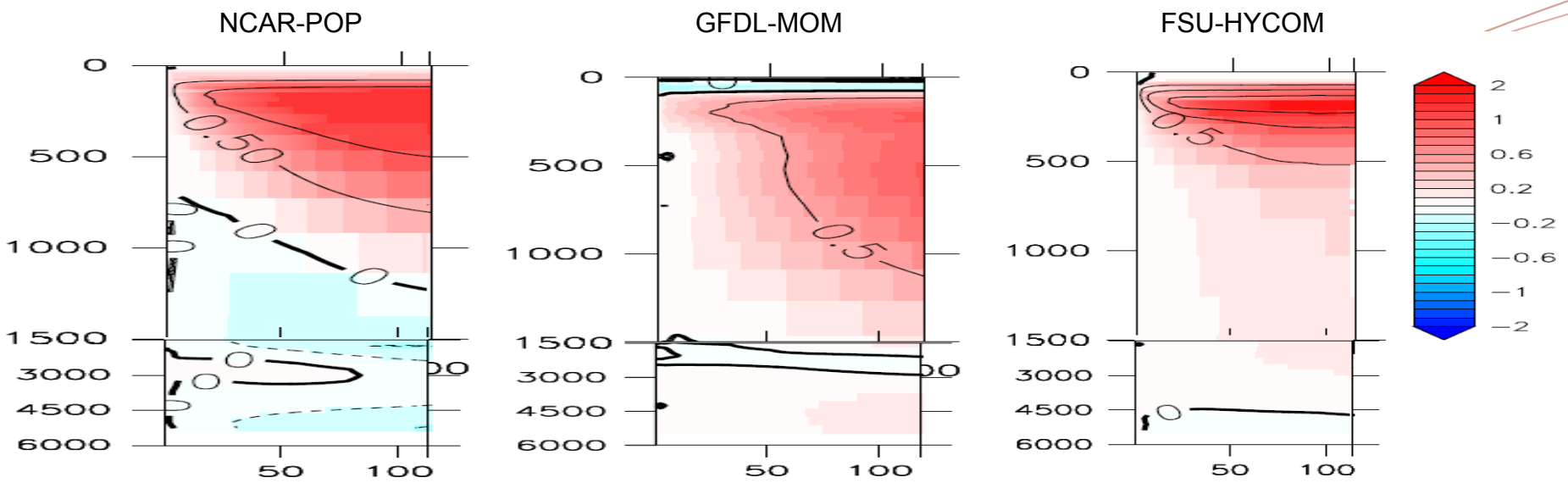
горизонтальная сетка	B (2)	C (5)		
гориз. разрешение			° (1)	2°×2° (1)
вертикальная сетка			ид (1)	
вертикальное разре			(2)	50 (2)
полюса				
основная переменн				
бароклинный шаг			' (3)	
баротропный шаг			еяв.(3)	
приближение Бусс				
поток пресной вод				
описание льда				
ледовые нач. услов			ств.(2)	
норм. гидрологии	есть (4)	нет (3)		
релаксация по соли	сильная (4)	слабая (3)		

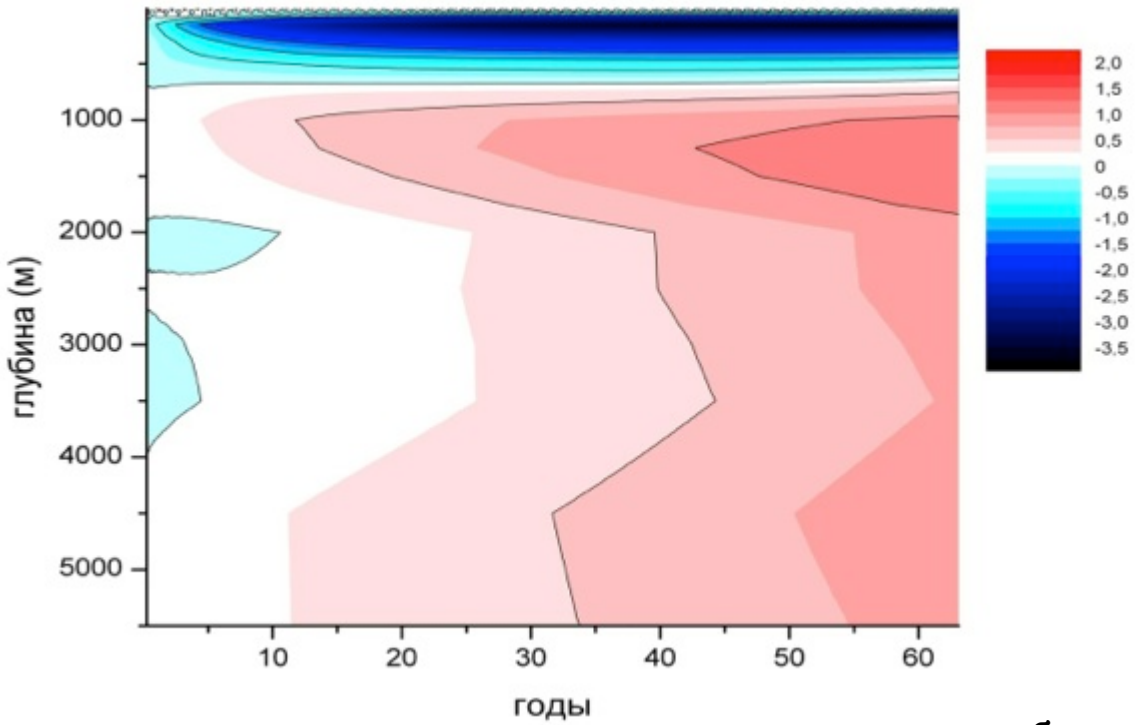
- NCAR-POP
- FSU-HYCOM
- GFDL-MOM
- GFDL-HIM
- KNMI-MICOM
- MPI
- Kiel-ORCA

модель, разработанная в ИВМ и ИО РАН

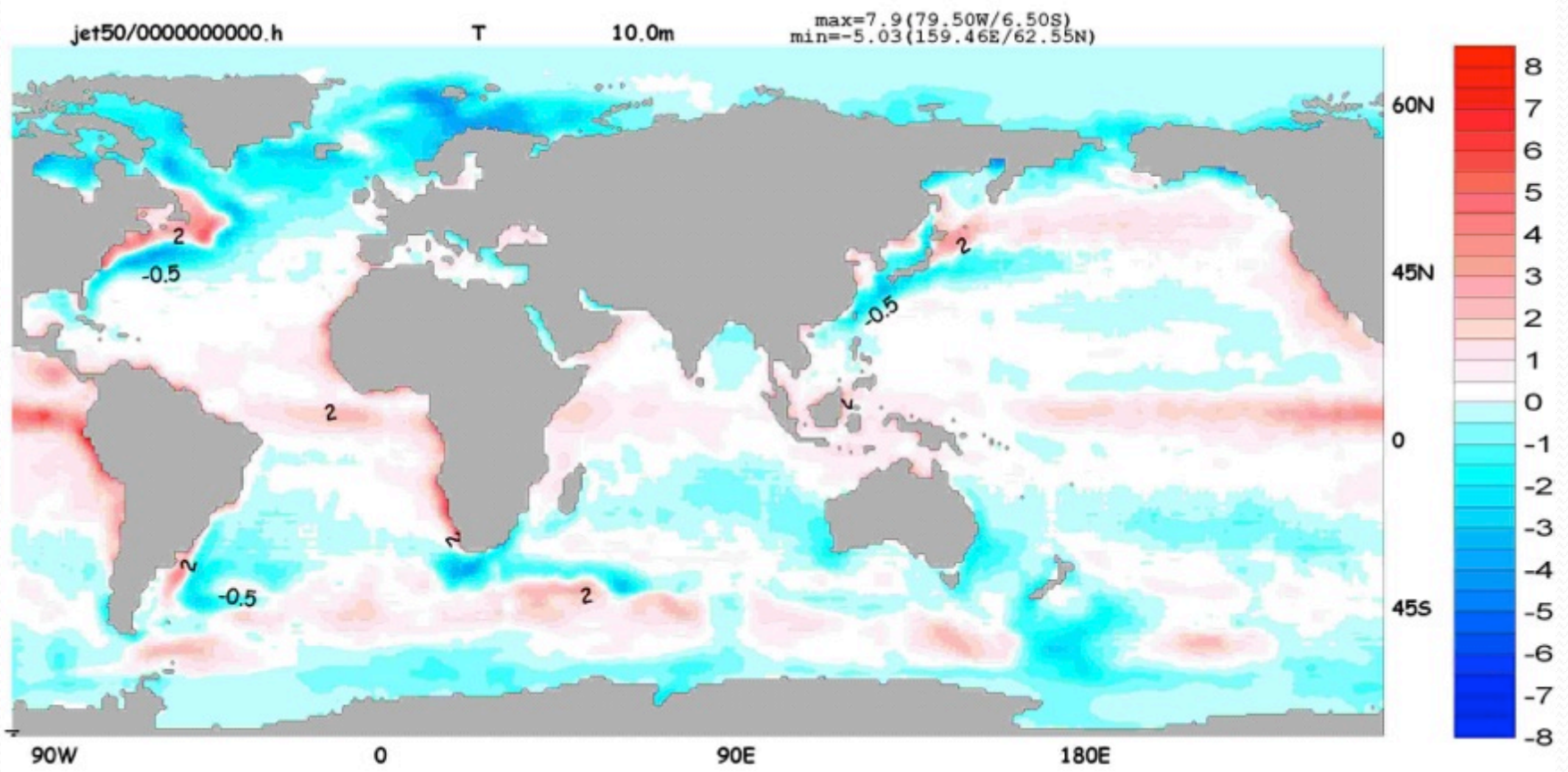


тепловые потоки на поверхности океана (Вт/м^2)

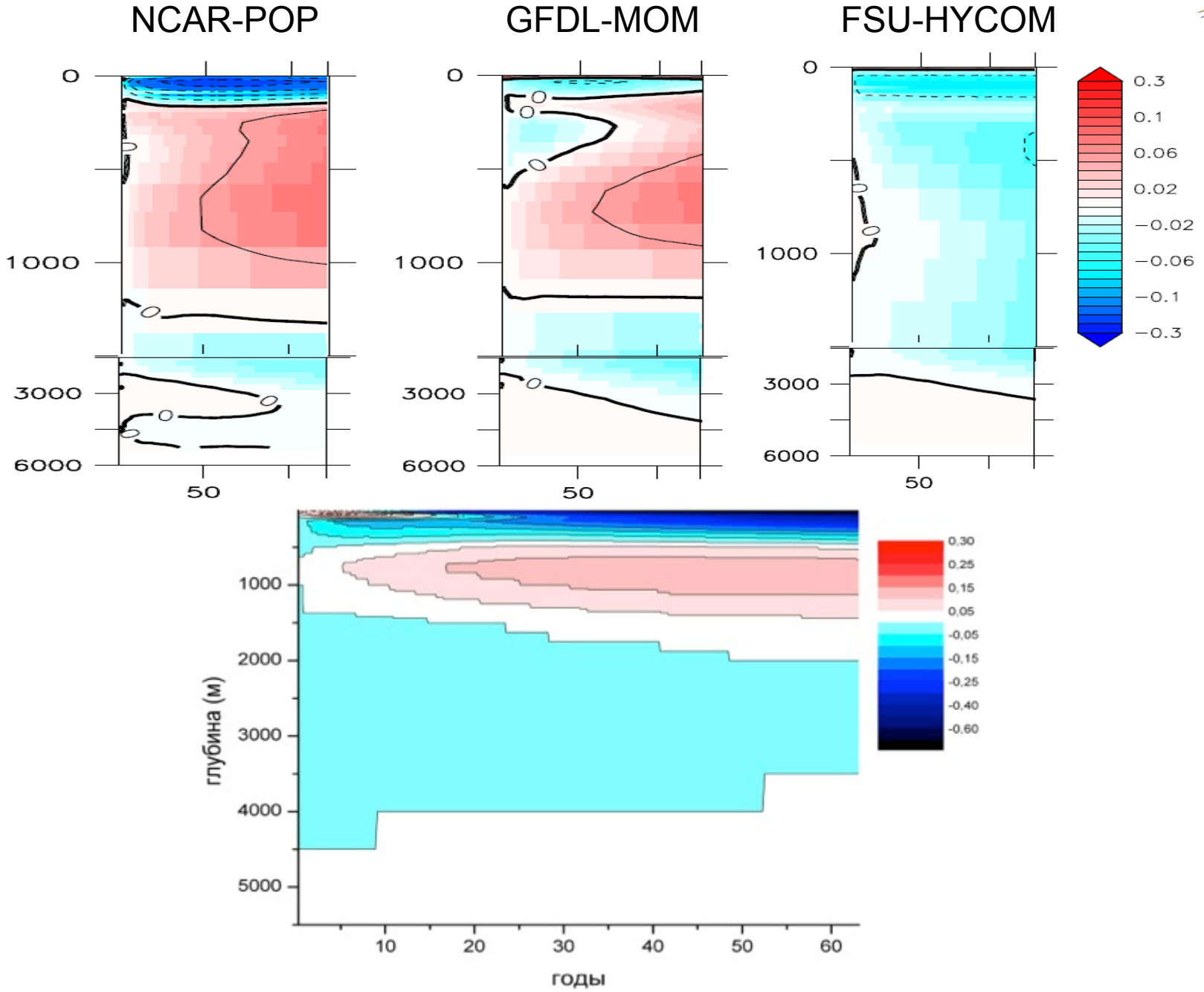




аномалия температуры как функция времени и глубины

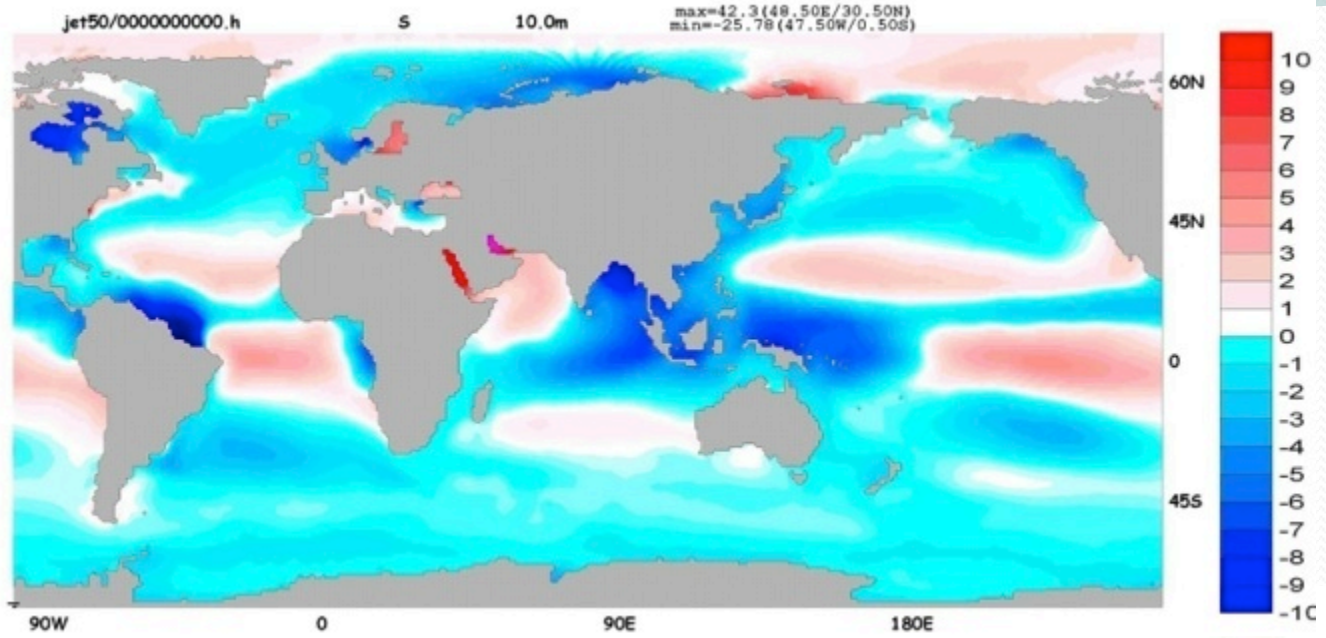


аномалия поверхностной температуры океана (ºС,осреднение за 54-58 годы) по сравнению с климатологическими начальными условиями

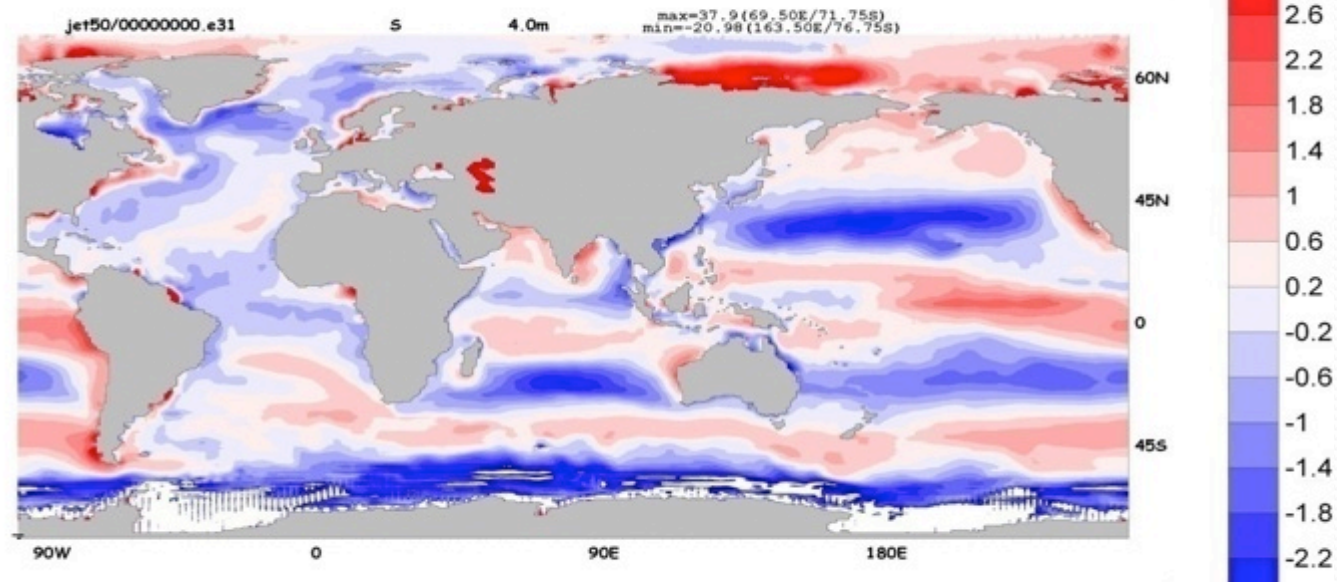


аномалия солёности как функция времени и глубины

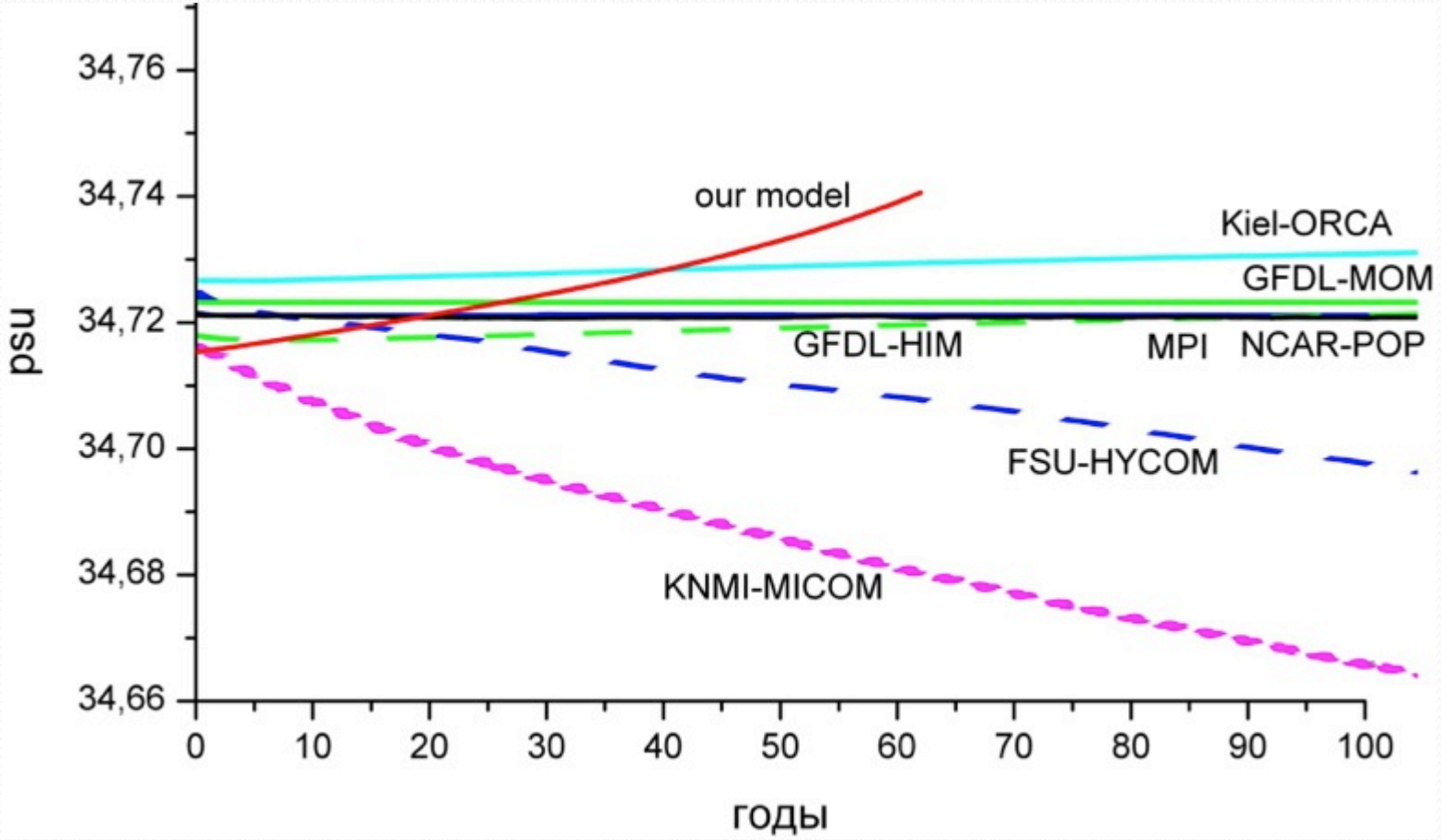
аномалия поверхностной солёности (осреднение за 5 лет)



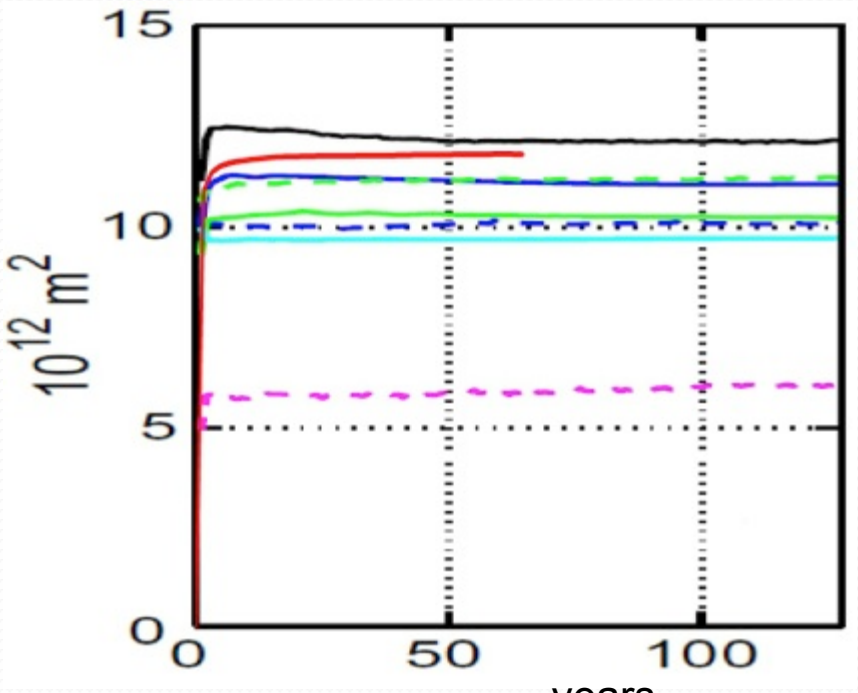
без релаксации



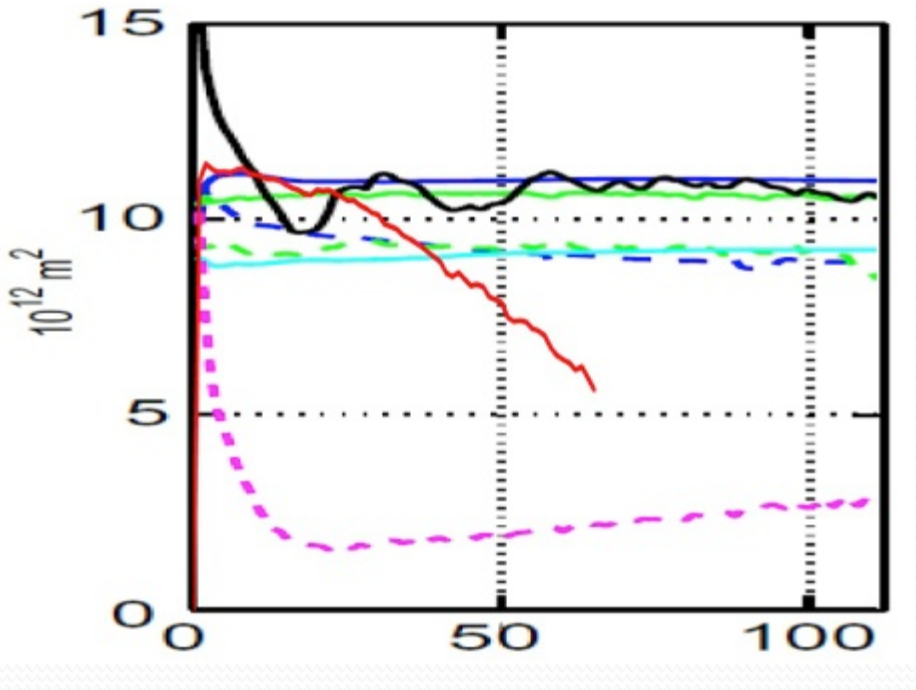
с сильной релаксацией



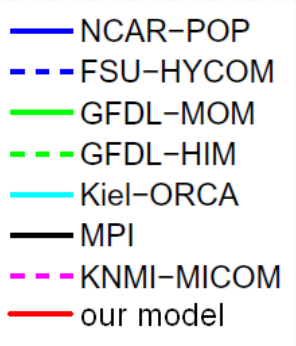
глобальная средняя солёность океана в эксперименте с релаксацией



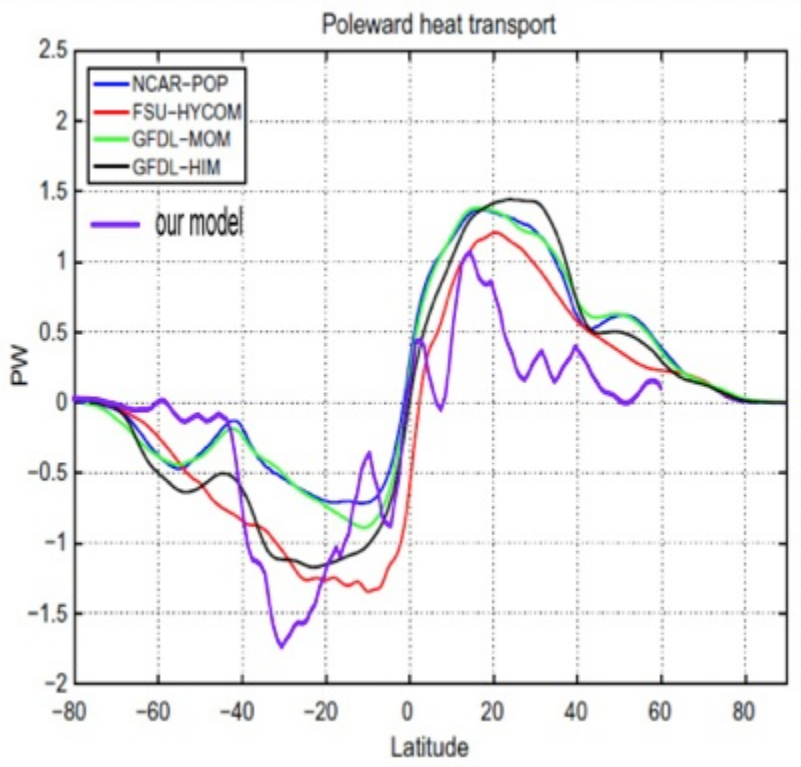
(а)

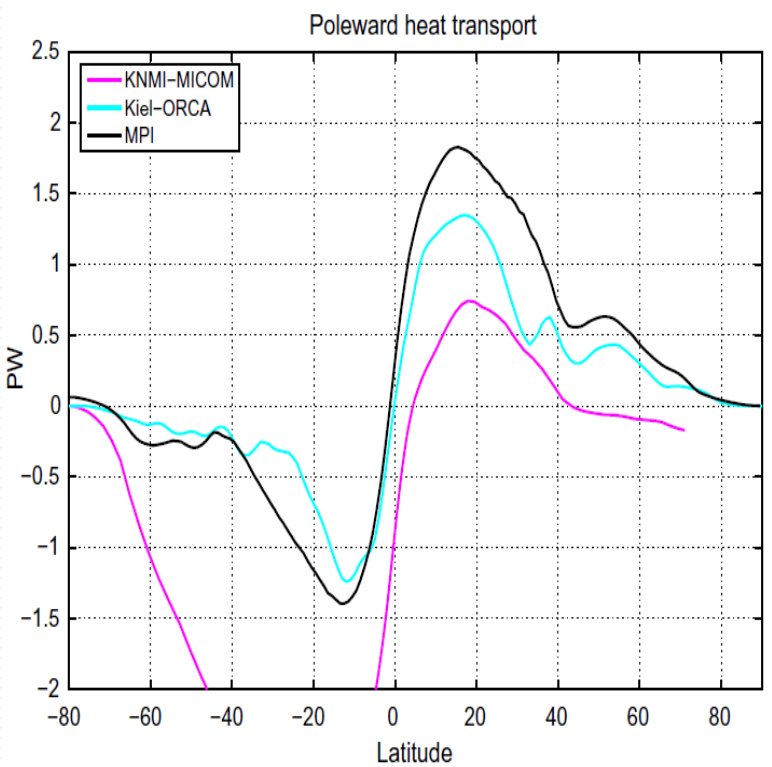


(б)



Эволюция площади льда
в северном (а) и южном (б) полушариях





среднегодовой меридиональный перенос тепла в северном направлении (петаватт) по результатам различных моделей