

gcmfaces  
standard analysis of the solution in  
iter11/mat//

February 4, 2014

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**budgets : volume, heat and salt (top to bottom)**

**budgets : volume, heat and salt (100m to bottom)**

**mixed layer depth fields**

ECCO v4 ocean state estimate, release 1

estimate source : Gael Forget, MIT/AER/JPL ECCO-Production group

support contact : ecco@ocean.mit.edu

internal code : r4it11

estimate revision history :

r4it11 : halve background vertical viscosity

r4it10 : cleanup control vector adjustments

r4it9 : optim. global mean sea level alone

r4it0-8 : full adjoint iterations, omitting

global mean sea level altimetry constraint.

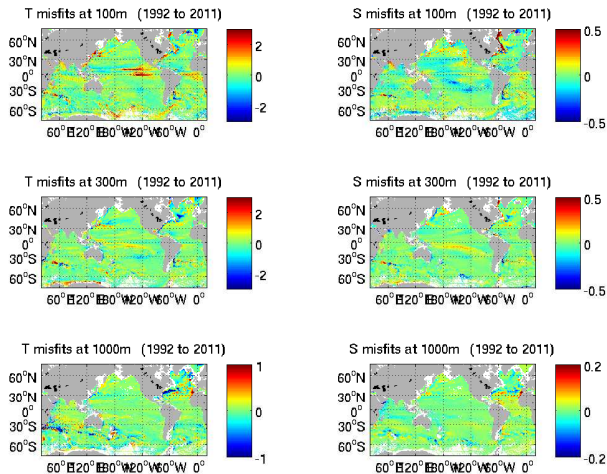
files revision history :

2014/02/04 : initial release of ECCO v4 (GF)

- domain decomposed in 90x90 tiles (13 of them)

- CF-1.6 ncetcdf files (using write

# fit to in situ data



**Figure:** Time mean misfit (model-data) for in situ profiles, at various depths (rows), for T (left; in K) and S (right; in psu).

# fit to in situ data

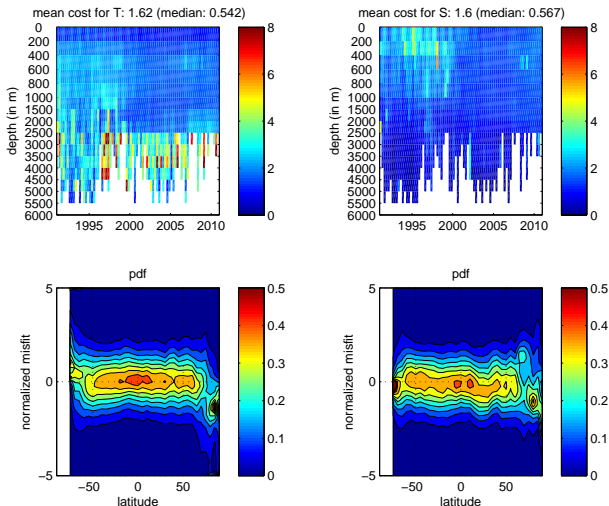


Figure: Cost function (top) for in situ profiles, as a function of depth and time. Distribution of normalized misfits (bottom) as a function of latitude. For T (left) and S (right).

# fit to in situ data

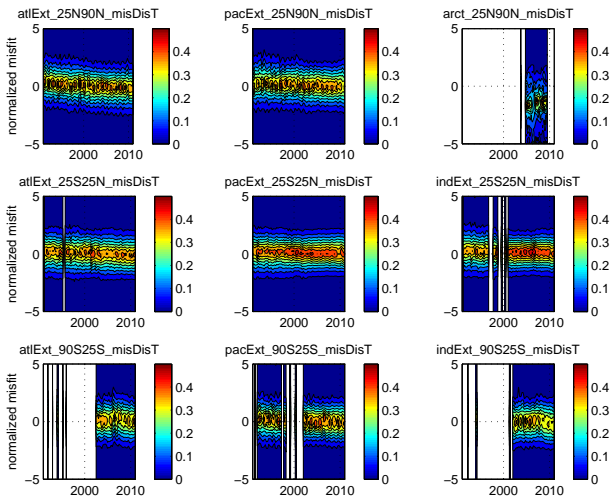


Figure: Distribution of normalized misfits per basin (panel) as a function of latitude, for T

# fit to in situ data

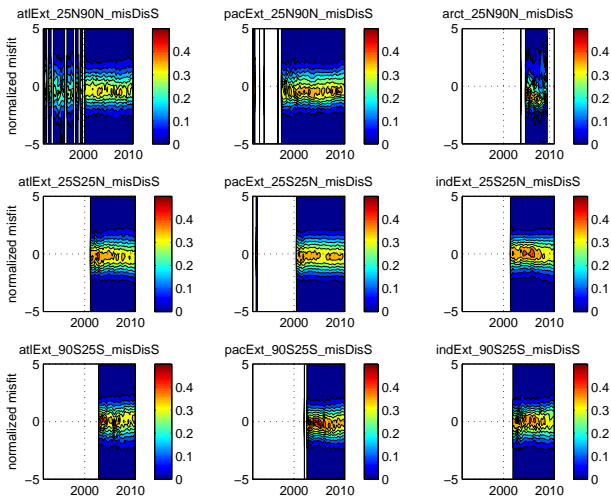


Figure: Distribution of normalized misfits per basin (panel) as a function of latitude, for S

# fit to altimeter data (RADS)

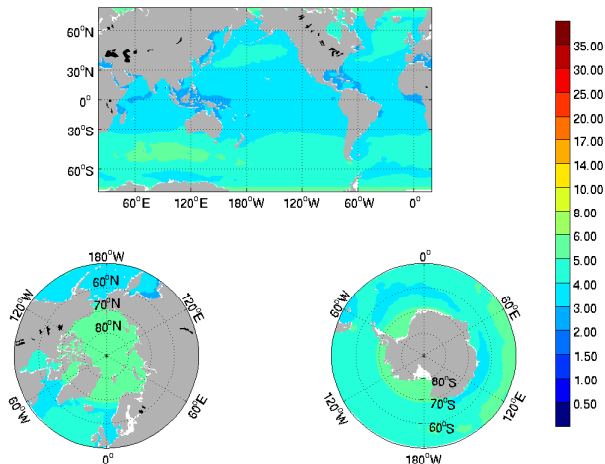


Figure: mean dynamic topography prior uncertainty (cm)



# fit to altimeter data (RADS)

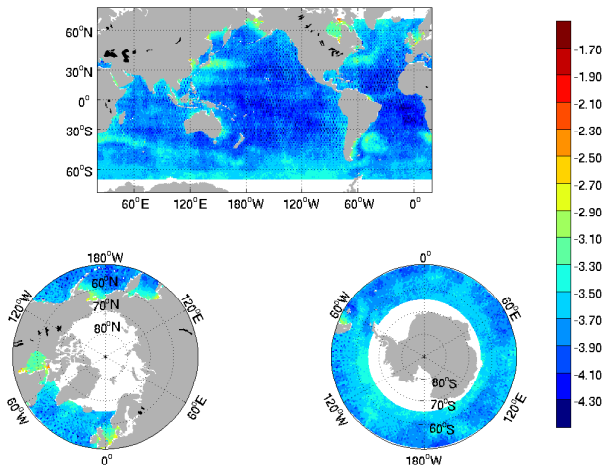


Figure: log(prior error variance) – sea level anomaly (m<sup>2</sup>) – large space/time scales

# fit to altimeter data (RADS)

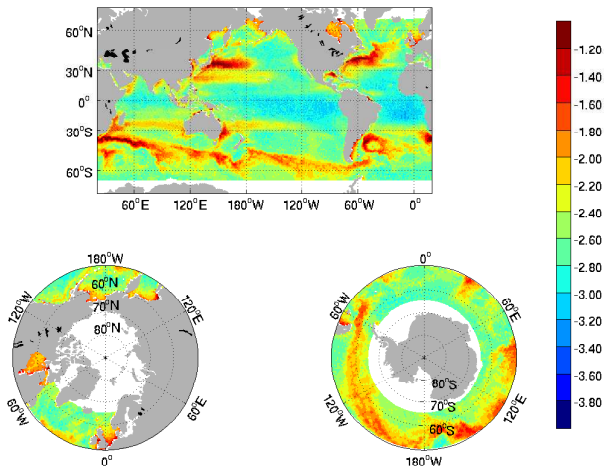


Figure:  $\log(\text{prior error variance}) - \text{sea level anomaly (m}^2\text{)}$  – pointwise

# fit to altimeter data (RADS)

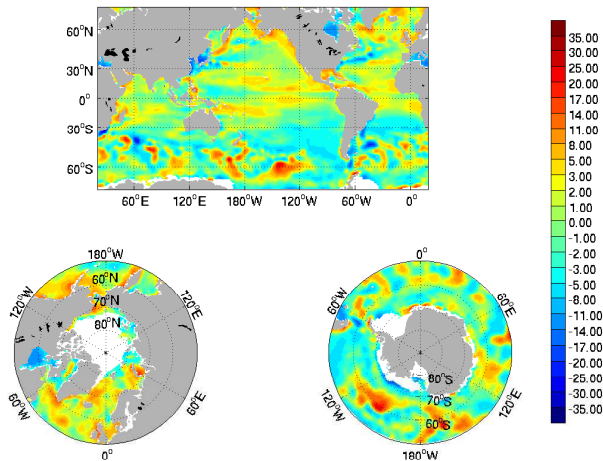


Figure: mean dynamic topography misfit (cm)

# fit to altimeter data (RADS)

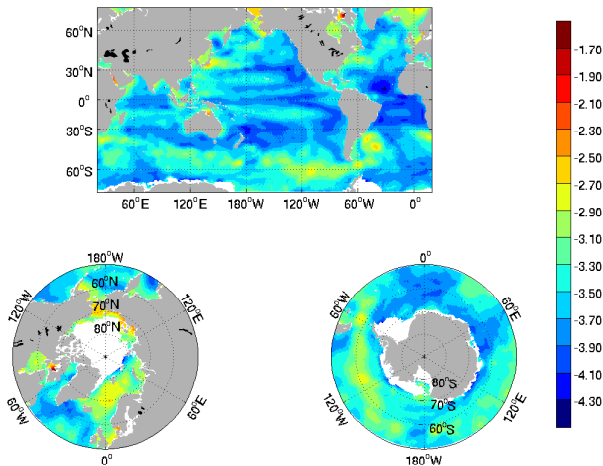


Figure: modeled-observed log(variance) – sea level anomaly (m<sup>2</sup>) – large space/time scales

# fit to altimeter data (RADS)

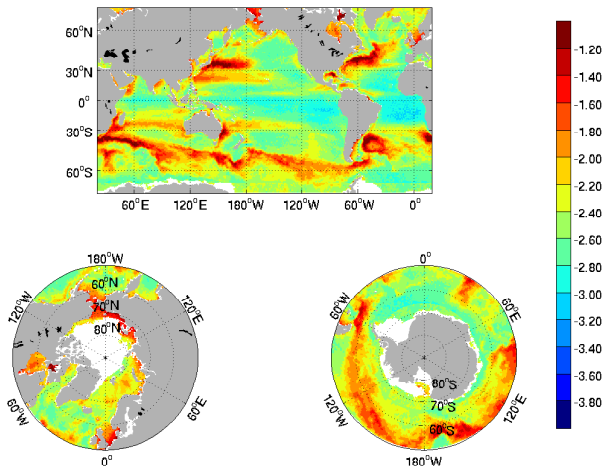


Figure: modeled-observed log(variance) - sea level anomaly (m<sup>2</sup>) - pointwise

# fit to altimeter data (RADS)

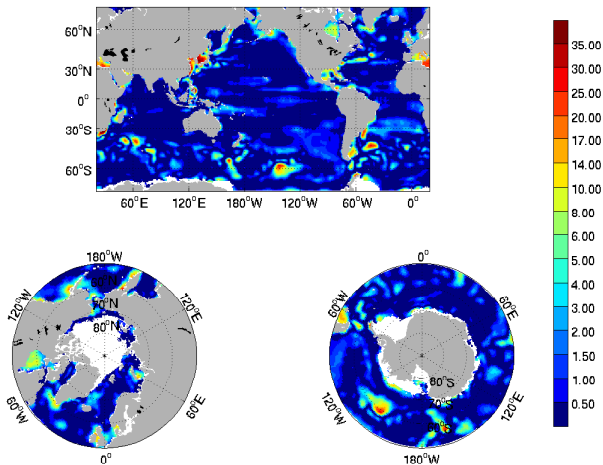
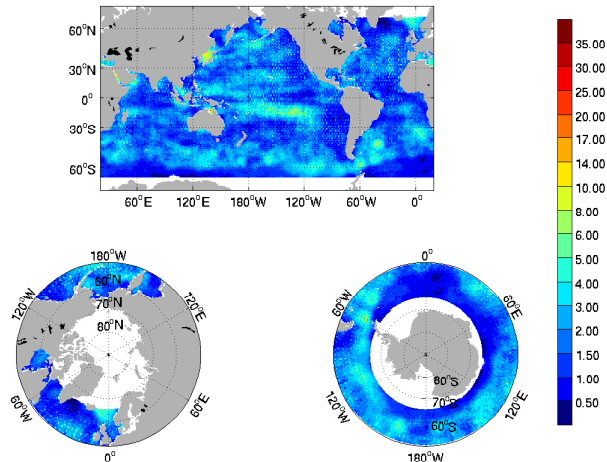


Figure: modeled-observed cost – mean dynamic topography

# fit to altimeter data (RADS)



**Figure:** modeled-observed cost – sea level anomaly  
– large space/time scales

# fit to altimeter data (RADS)

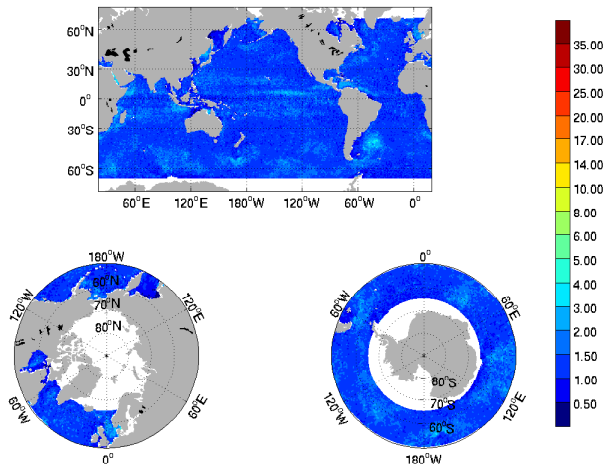


Figure: modeled-observed cost - sea level anomaly - pointwise



# fit to altimeter data (RADS)

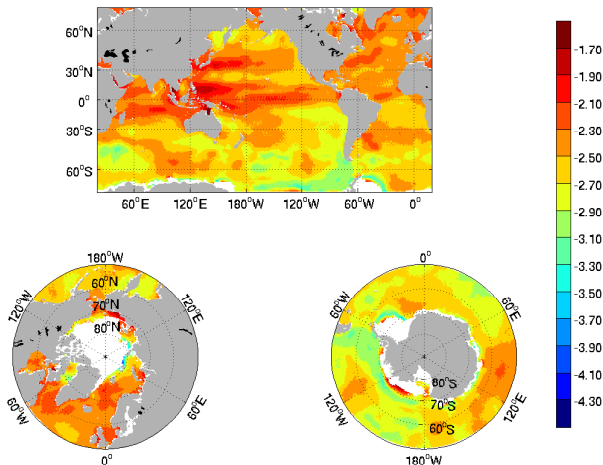


Figure: observed log(variance) - sea level anomaly ( $m^2$ ) - large space/time scales

# fit to altimeter data (RADS)

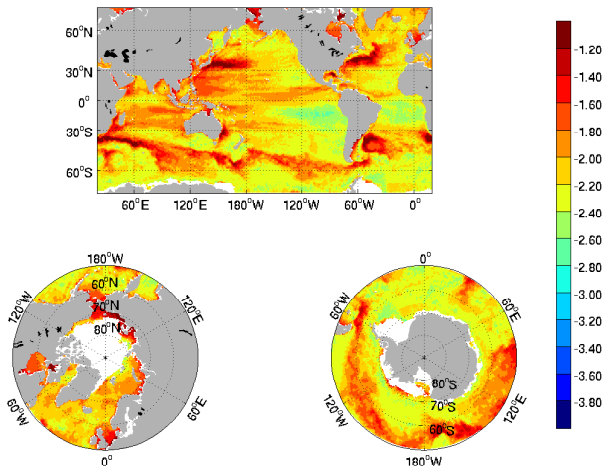


Figure: observed log(variance) - sea level anomaly (m<sup>2</sup>) - pointwise

# fit to altimeter data (RADS)

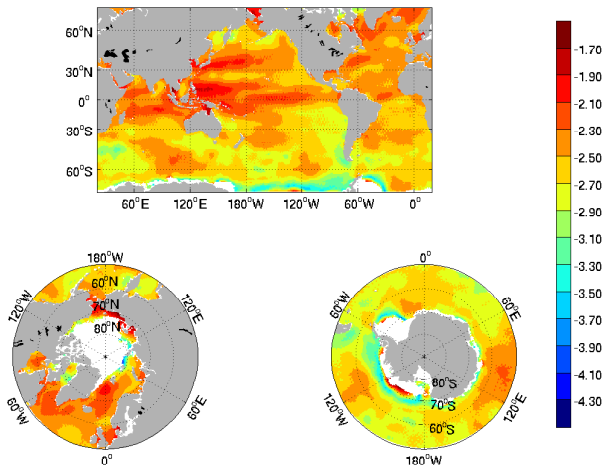


Figure: modeled log(variance) - sea level anomaly (m<sup>2</sup>) - large space/time scales

# fit to altimeter data (RADS)

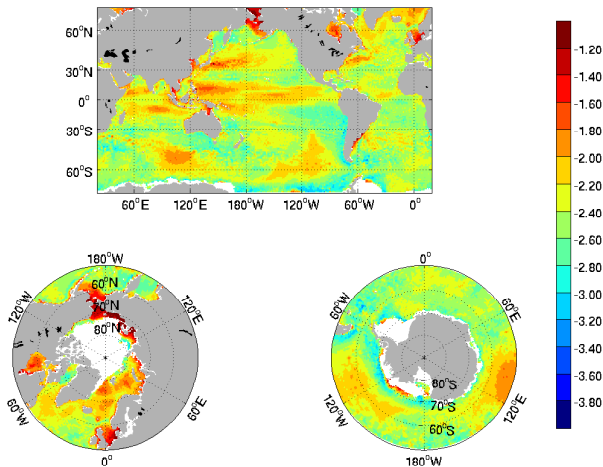


Figure: modeled log(variance) - sea level anomaly (m<sup>2</sup>) - pointwise

# fit to sst data

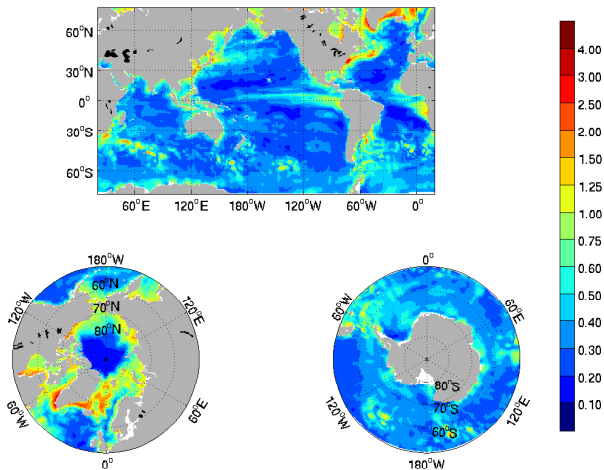


Figure: modeled-Reynolds rms - sea surface temperature (K)

# fit to sst data

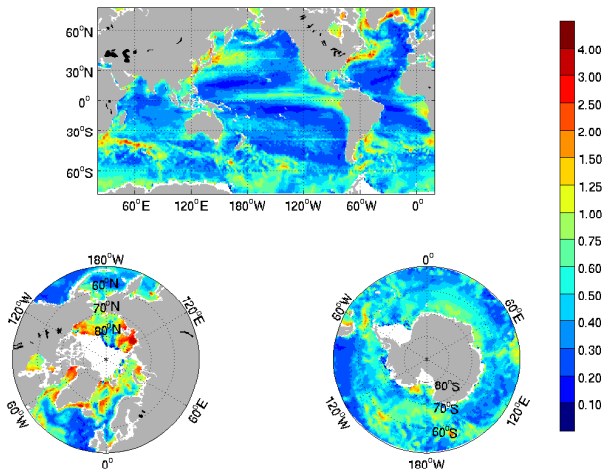


Figure: modeled-REMSS rms – sea surface temperature (K)

# fit to sst data

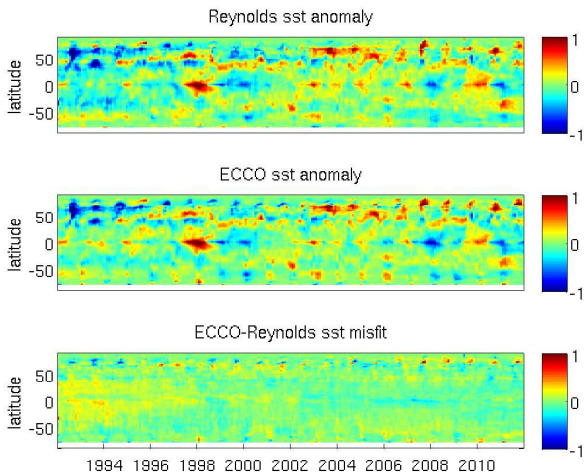


Figure: ECCO and Reynolds zonal mean sst anomalies (K)

# fit to sst data

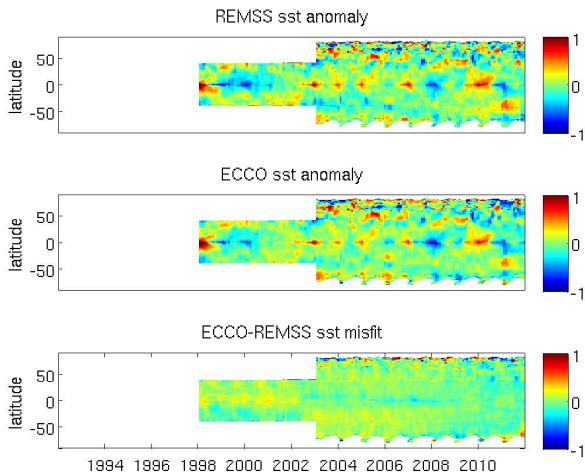


Figure: ECCO and REMSS zonal mean sst anomalies (K)



# fit to grace r4 data

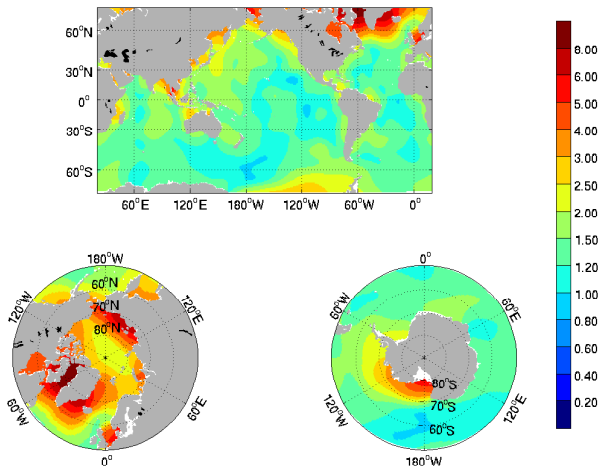


Figure: modeled-observed rms – bottom pressure (cm)

# fit to grace r4 data

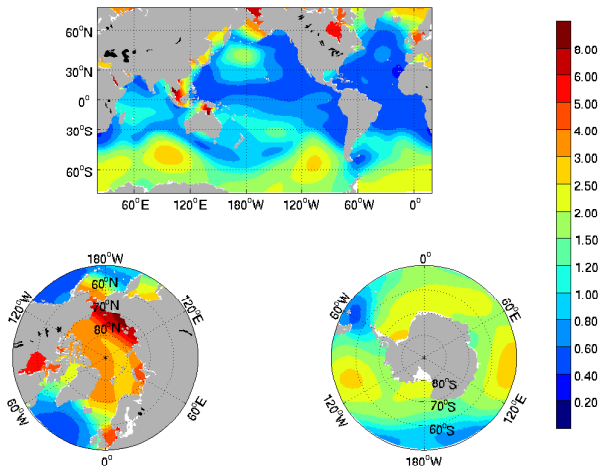


Figure: rms modeled – bottom pressure (cm)

# fit to grace r4 data

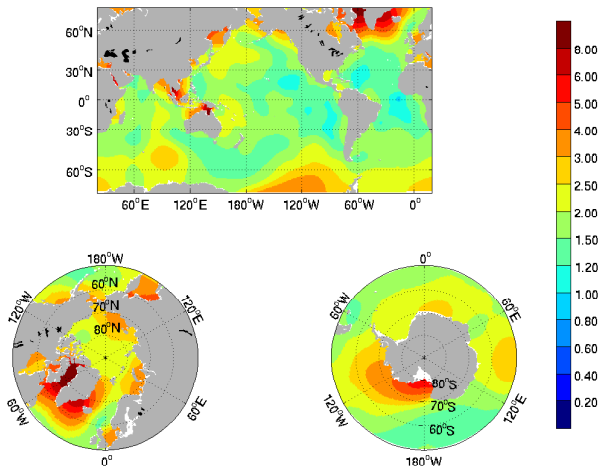


Figure: rms observed – bottom pressure (cm)

# fit to grace r4 data

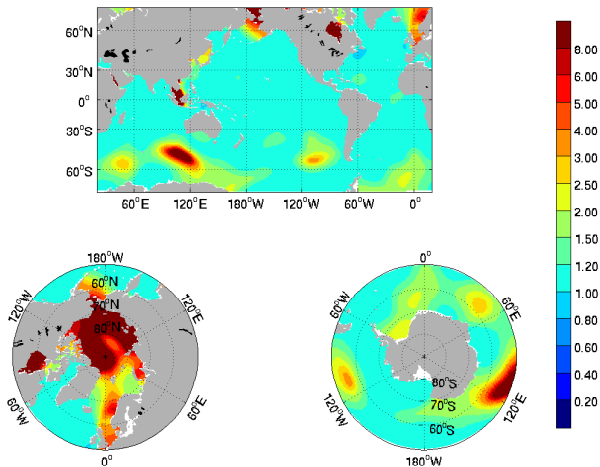


Figure: Cost function

# fit to seaice data

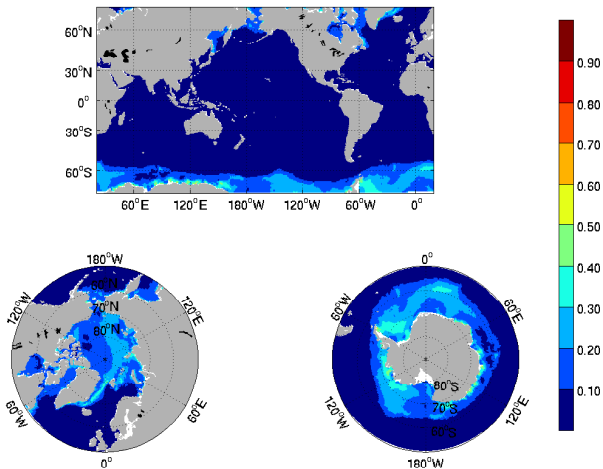


Figure: modeled-observed rms – sea ice concentration

# fit to seaice data

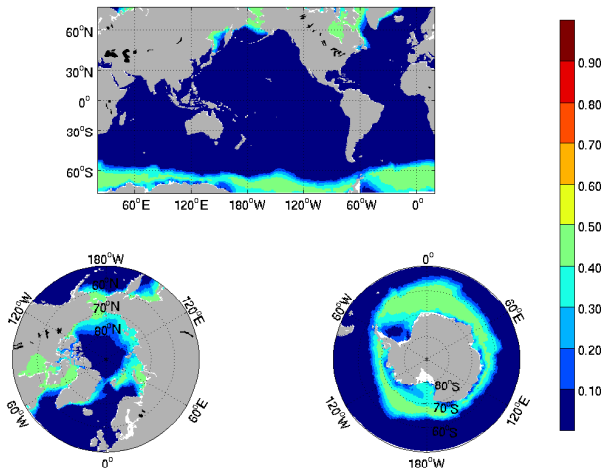


Figure: observed std – sea ice concentration

# fit to seaice data

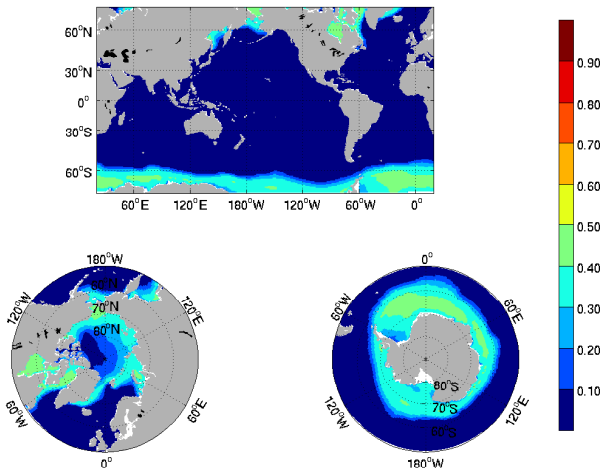


Figure: modelled std – sea ice concentration

# fit to seaice data

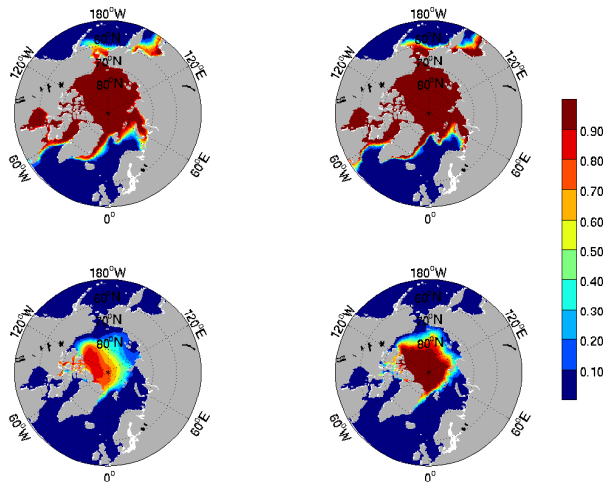


Figure: ECCO (left) and NSIDC (right, gsfc bootstrap) ice concentration in March (top) and September (bottom).



# fit to seaice data

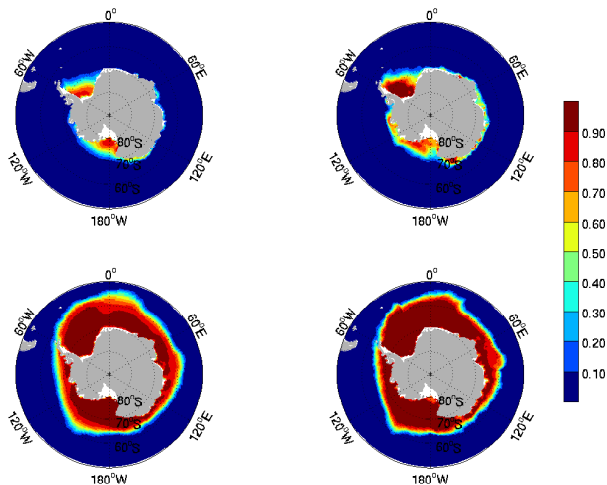


Figure: ECCO (left) and NSIDC (right, gsfc bootstrap) ice concentration in March (top) and September (bottom).

# fit to seaice data

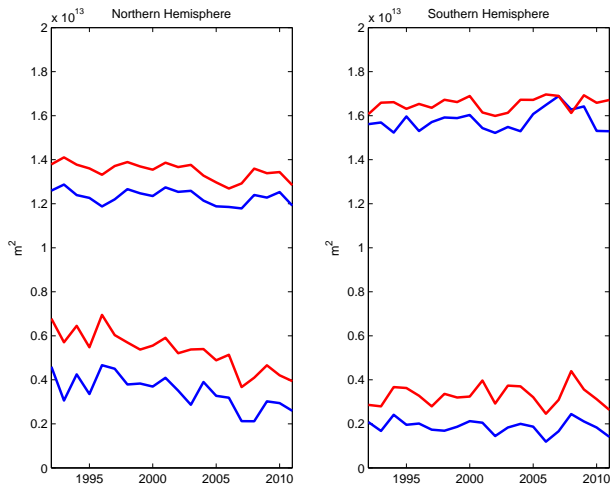


Figure: ECCO (blue) and NSIDC (red, gsfc bootstrap) ice concentration in March and September in Northern Hemisphere (left) and Southern Hemisphere (right)

# fit to seaice data

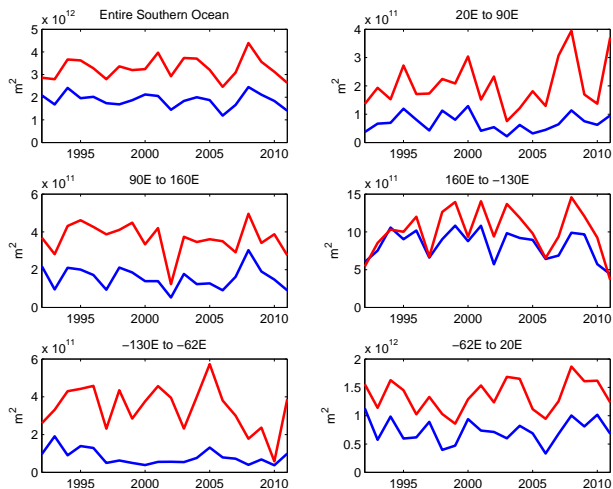


Figure: ECCO (blue) and NSIDC (red, gsfc bootstrap) ice concentration in March per Southern Ocean sector

# fit to seaice data

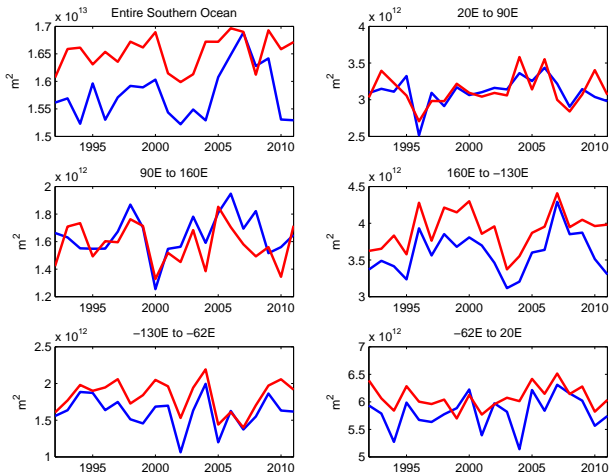


Figure: ECCO (blue) and NSIDC (red, gsfc bootstrap) ice concentration in September per Southern Ocean sector

# barotropic streamfunction

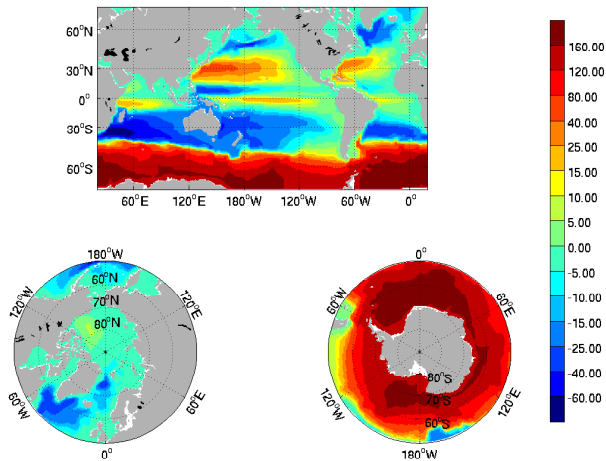


Figure: 1992-2011 mean – barotropic streamfunction (Sv)

# barotropic streamfunction

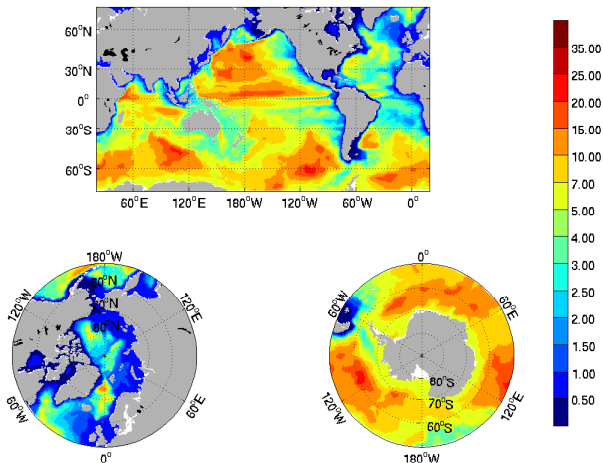


Figure: 1992-2011 standard deviation – barotropic streamfunction (Sv)

# meridional streamfunction

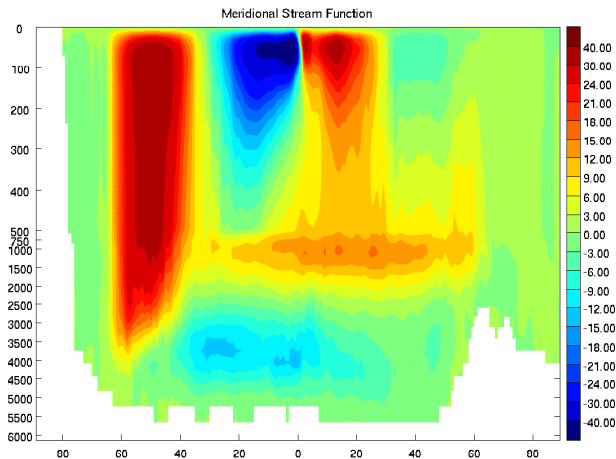


Figure: 1992-2011 mean – overturning streamfunction (Sv)

# meridional streamfunction

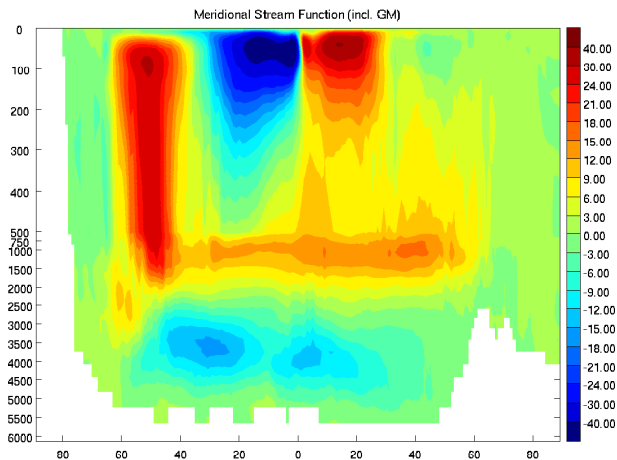


Figure: 1992-2011 mean – overturning streamfunction incl. GM (Sv)



# meridional streamfunction

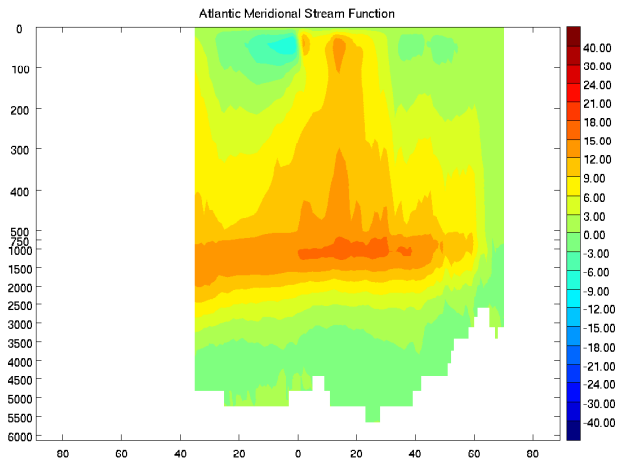


Figure: 1992-2011 mean – Atlantic overturning streamfunction (Sv)

# meridional streamfunction

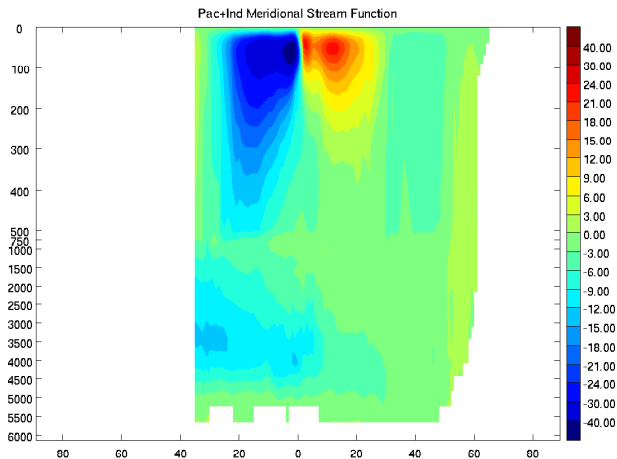


Figure: 1992-2011 mean – Pac+Ind overturning streamfunction (Sv)

# meridional streamfunction

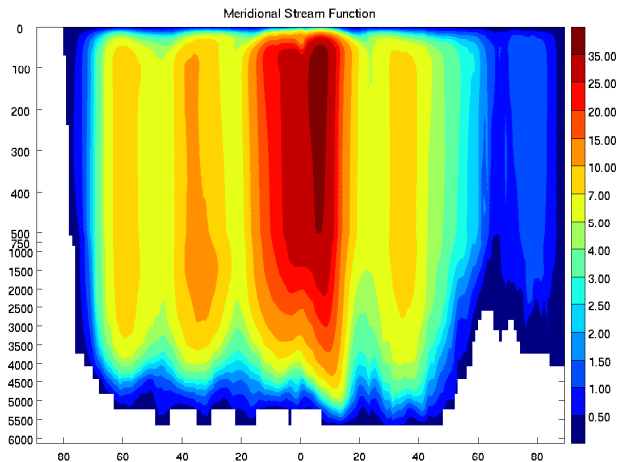


Figure: 1992-2011 standard deviation – overturning streamfunction (Sv)

# meridional streamfunction

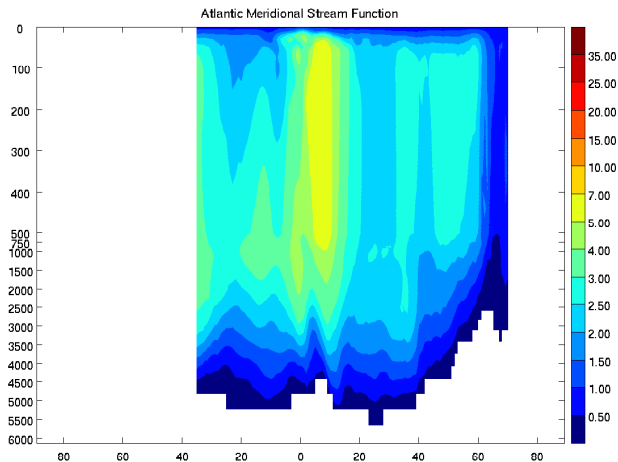


Figure: 1992-2011 standard deviation – Atlantic overturning streamfunction (Sv)

# meridional streamfunction (time series)

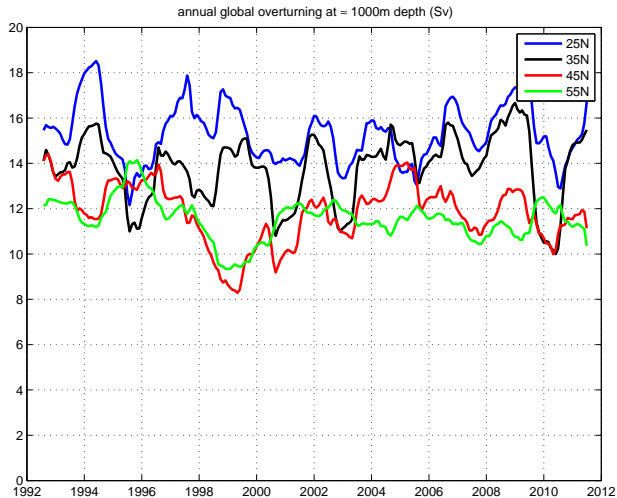


Figure: annual global overturning at select latitudes at  $\approx 1000\text{m}$  depth

# meridional streamfunction (time series)

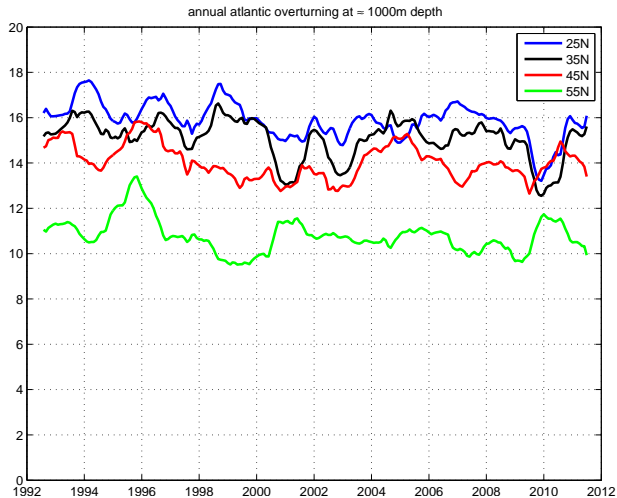


Figure: annual Atlantic overturning at select latitudes at  $\approx 1000\text{m}$  depth (Sv)

# meridional heat transport

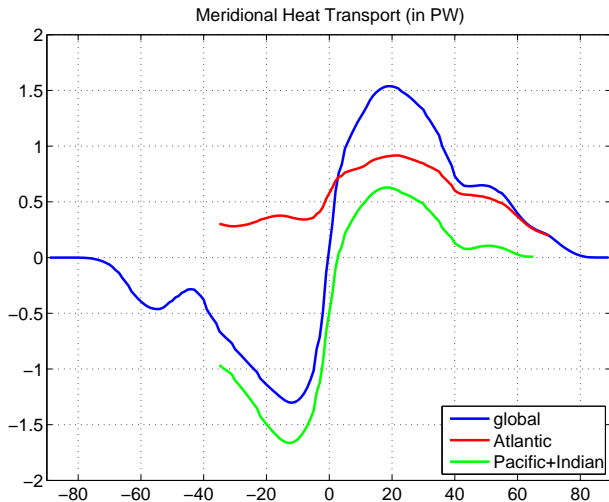


Figure: 1992-2011 mean – meridional heat transport (PW)

# meridional heat transport

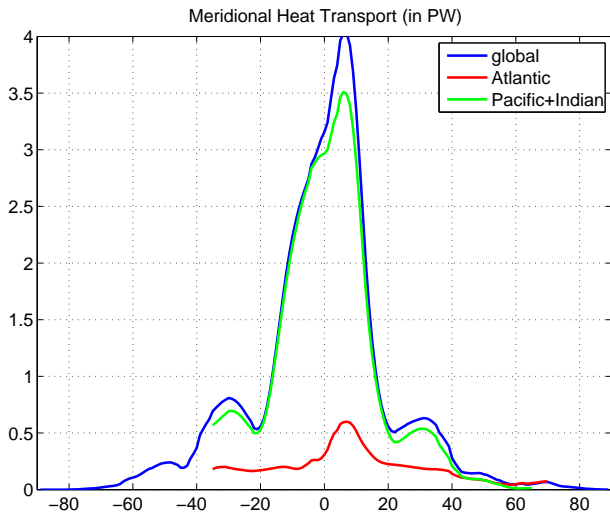


Figure: 1992-2011 standard deviation – meridional heat transport (PW)



# meridional freshwater transport

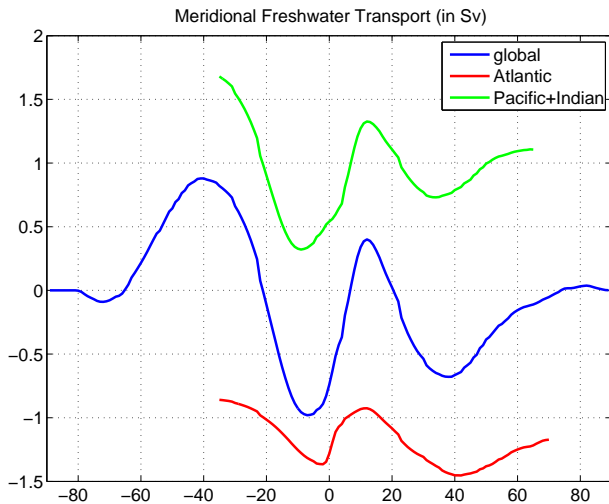


Figure: 1992-2011 mean – meridional freshwater transport (Sv)

# meridional freshwater transport

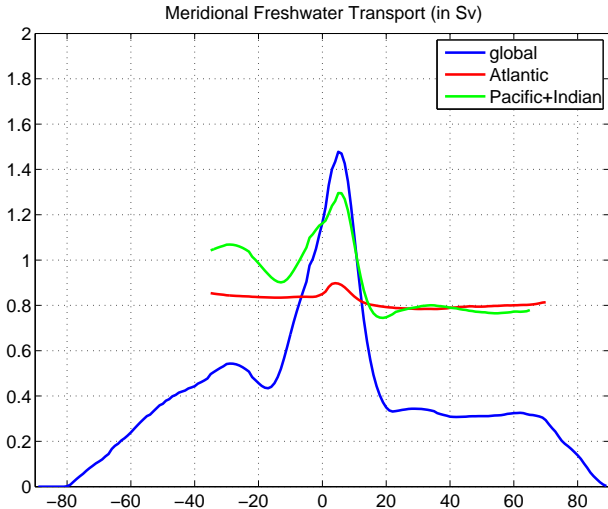


Figure: 1992-2011 standard deviation – meridional freshwater transport (Sv)

# meridional salt transport

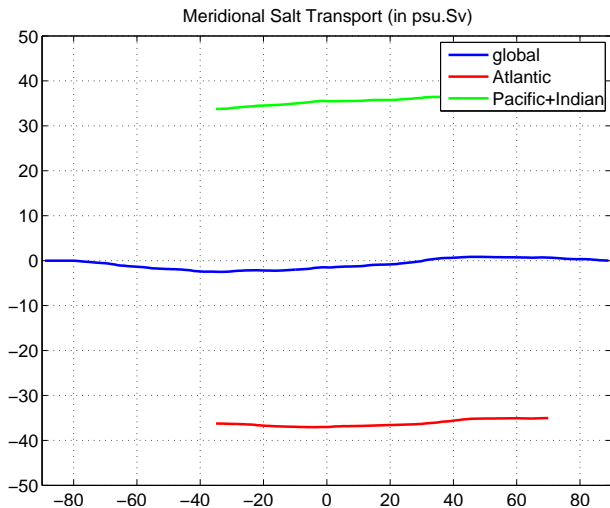


Figure: 1992-2011 mean – meridional salt transport (psu.Sv)

# meridional salt transport

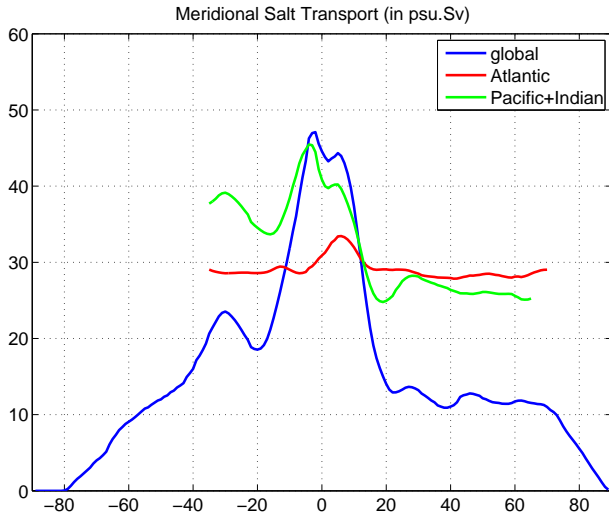


Figure: 1992-2011 standard deviation – meridional salt transport (psu.Sv)

# meridional transports (time series)

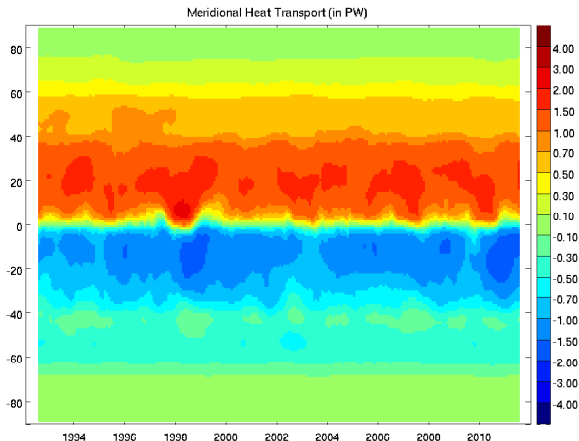


Figure: meridional heat transport (PW, annual mean)

# meridional transports (time series)

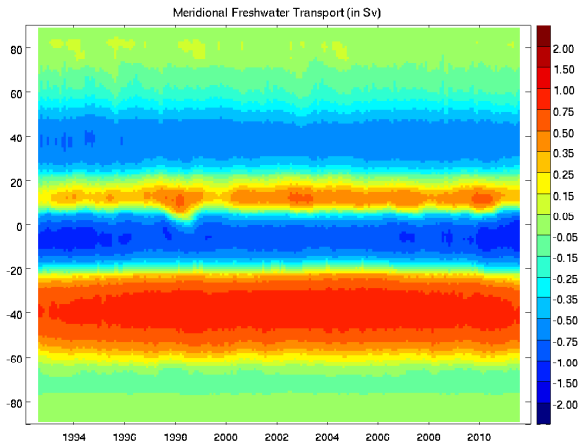


Figure: meridional freshwater transport (Sv, annual mean)

# meridional transports (time series)

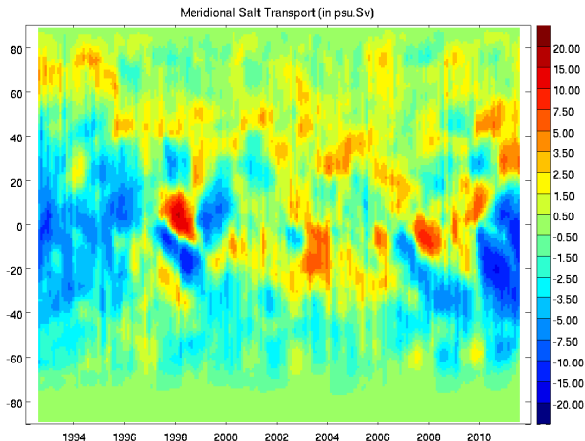


Figure: meridional salt transport ( $\text{psu}\cdot\text{Sv}$ , annual mean)

# transects transport

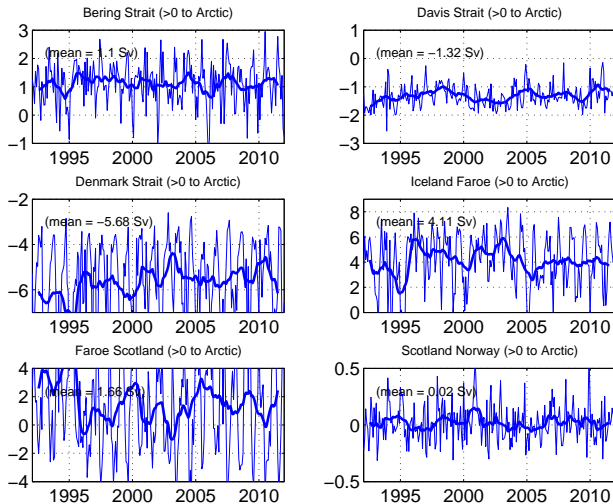


Figure: volume transports entering the Arctic (Sv, annual mean)



# transects transport

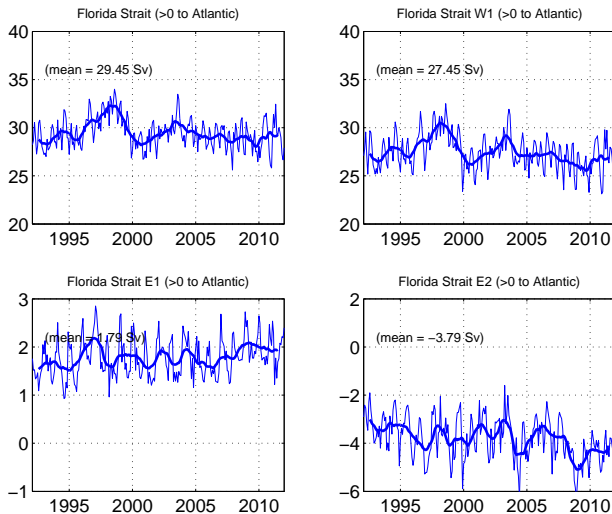


Figure: volume transports entering the Atlantic (Sv, annual mean)

# transects transport

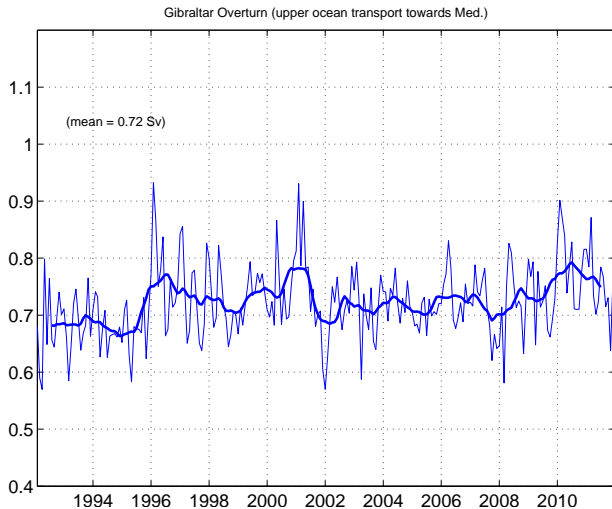


Figure: Gibraltar Overturn (Sv, annual mean)

# transects transport

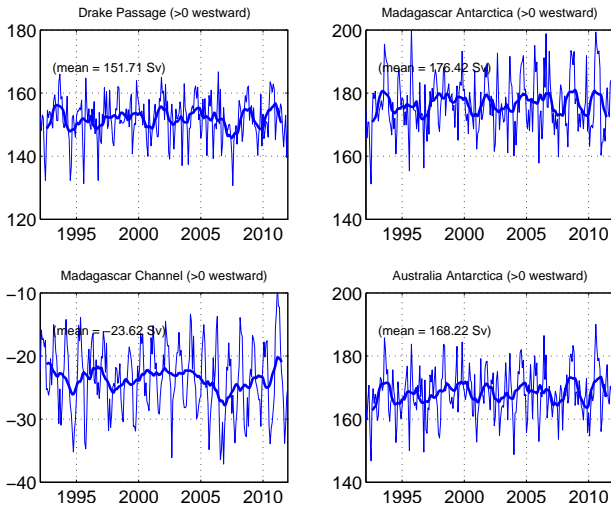


Figure: ACC volume transports (Sv, annual mean)

# transects transport

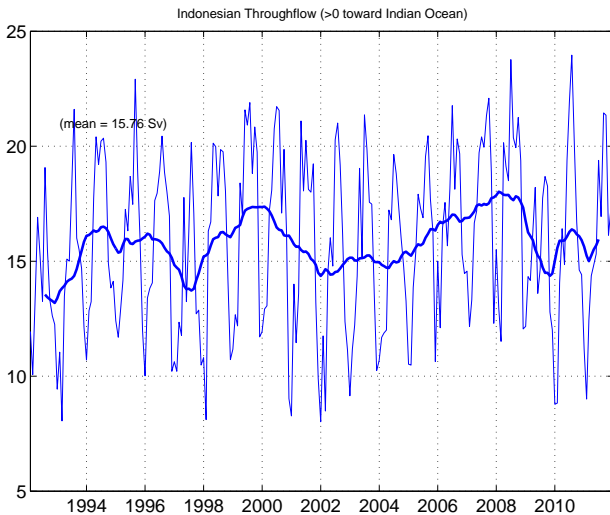


Figure: Indonesian Throughflow (Sv, annual mean)

# sea surface height

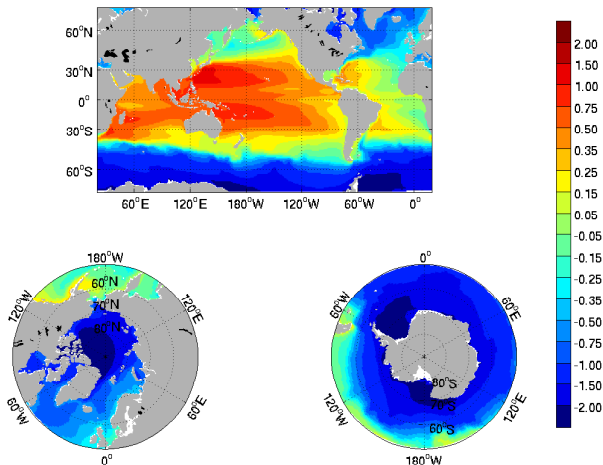


Figure: 1992-2011 mean – sea surface height (EXCLUDING ice, in m)

# sea surface height

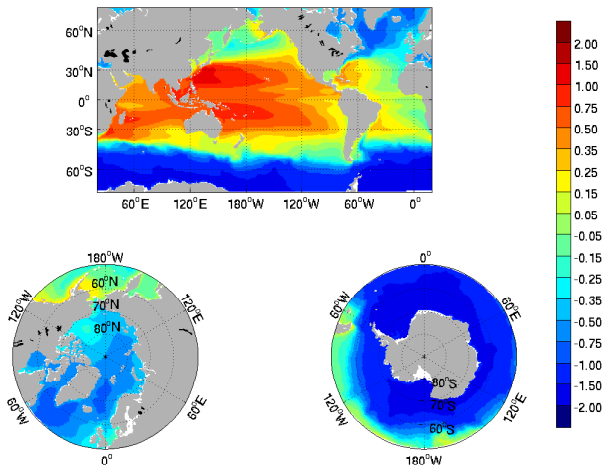


Figure: 1992-2011 mean – sea surface height (INCLUDING ice, in m)

# sea surface height

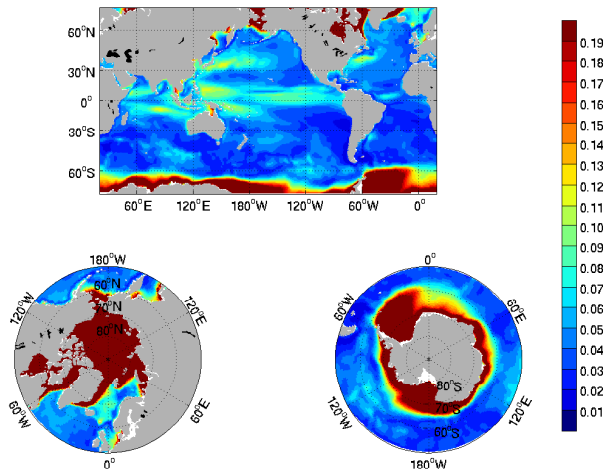


Figure: 1992-2011 standard deviation – sea surface height (EXCLUDING ice, in m)

# sea surface height

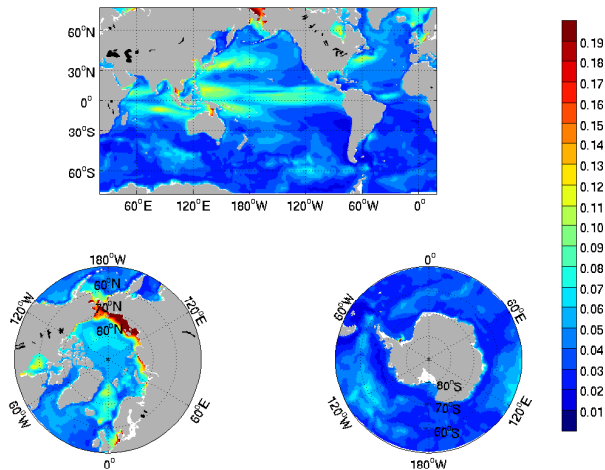


Figure: 1992-2011 standard deviation – sea surface height (INCLUDING ice, in m)



# 3D state variables

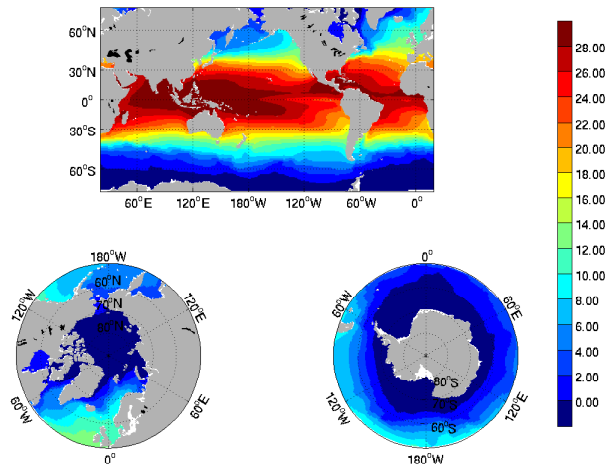


Figure: 1992-2011 mean – temperature (in degC) at 5m

# 3D state variables

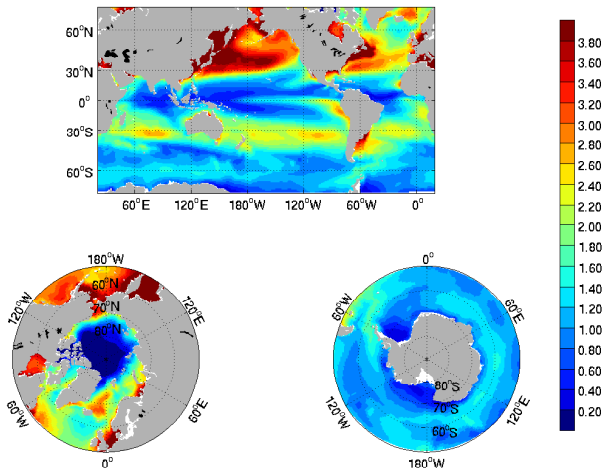


Figure: 1992-2011 standard deviation – temperature (in degC) at 5m

# 3D state variables

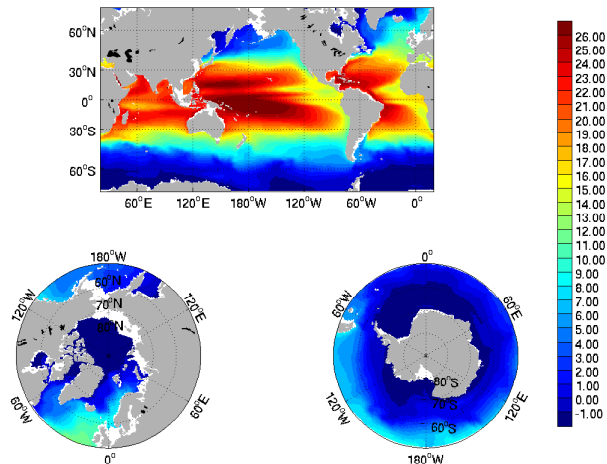


Figure: 1992-2011 mean – temperature (in degC) at 105m

# 3D state variables

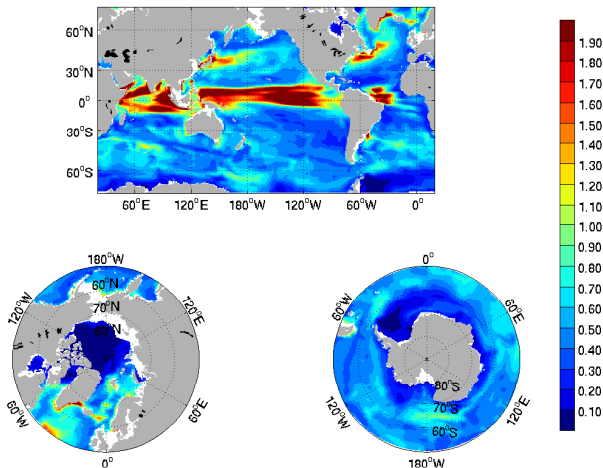


Figure: 1992-2011 standard deviation – temperature (in degC) at 105m

# 3D state variables

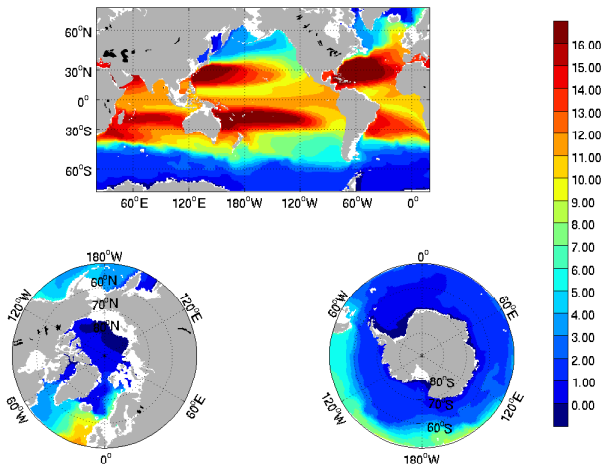


Figure: 1992-2011 mean – temperature (in degC) at 300m

# 3D state variables

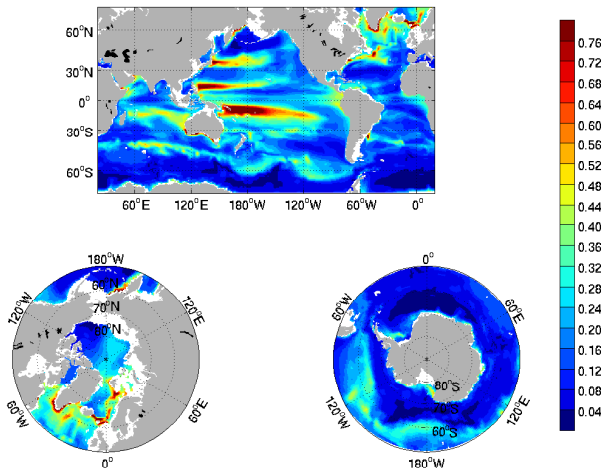


Figure: 1992-2011 standard deviation – temperature (in degC) at 300m

# 3D state variables

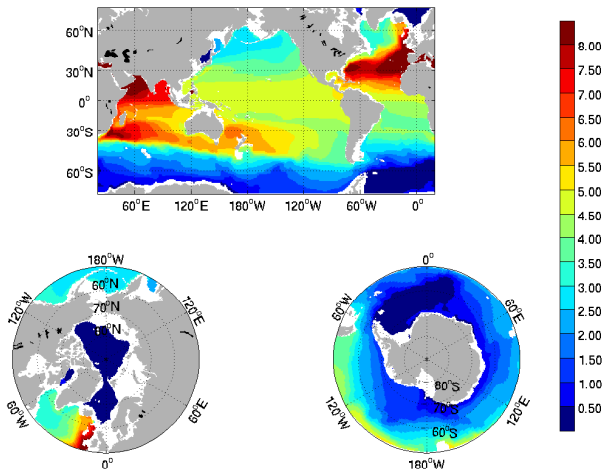


Figure: 1992-2011 mean – temperature (in degC) at 910m

# 3D state variables

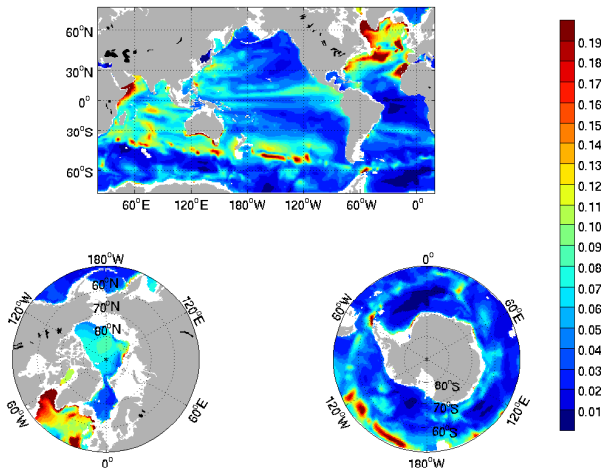


Figure: 1992-2011 standard deviation – temperature (in degC) at 910m



# 3D state variables

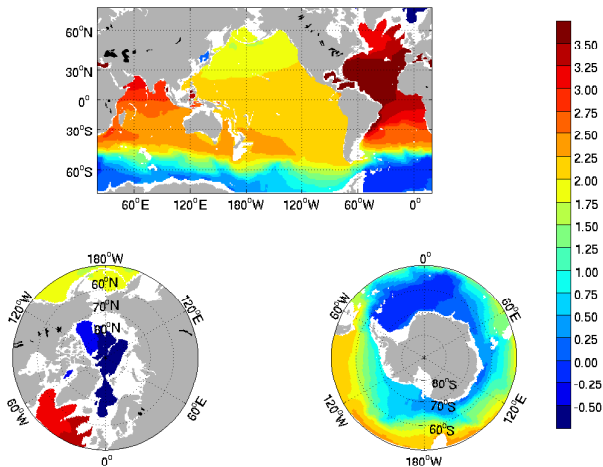


Figure: 1992-2011 mean – temperature (in degC) at 1914m

# 3D state variables

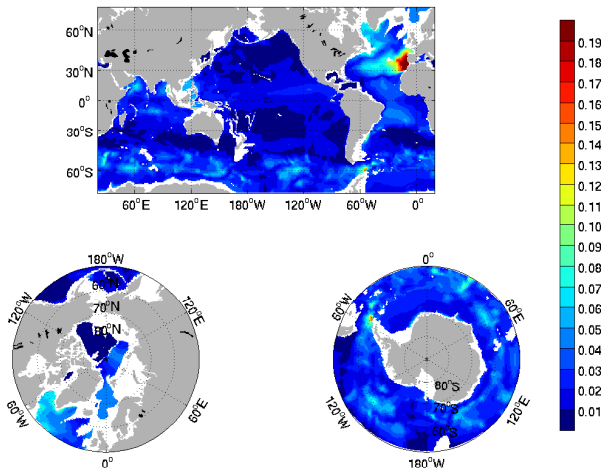


Figure: 1992-2011 standard deviation – temperature (in degC) at 1914m

# 3D state variables

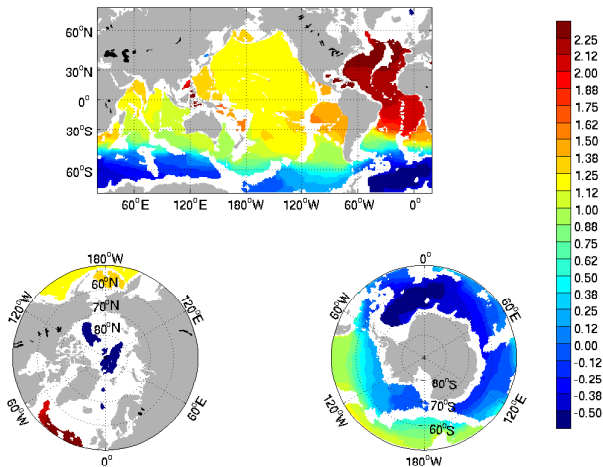


Figure: 1992-2011 mean – temperature (in degC) at 3581m

# 3D state variables

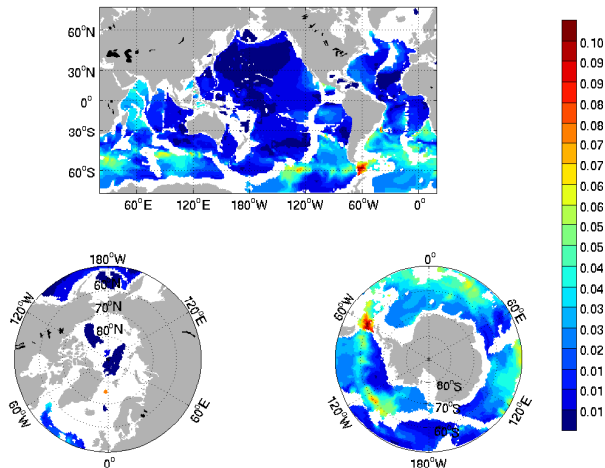


Figure: 1992-2011 standard deviation – temperature (in degC) at 3581m

# 3D state variables

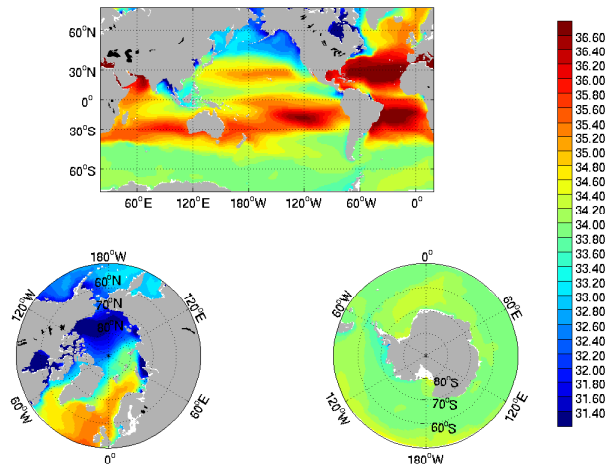


Figure: 1992-2011 mean – salinity (in psu) at 5m

# 3D state variables

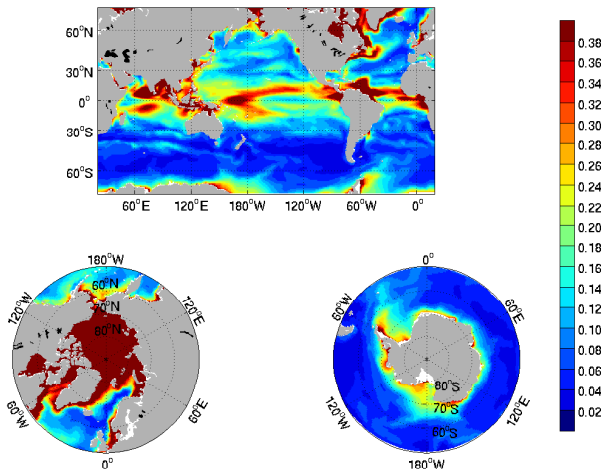


Figure: 1992-2011 standard deviation – salinity (in psu) at 5m

# 3D state variables

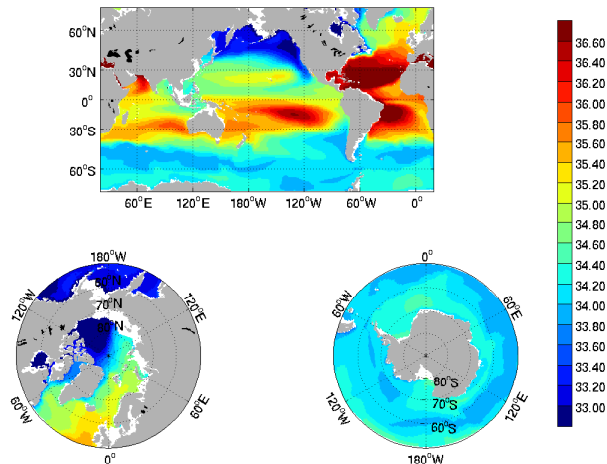


Figure: 1992-2011 mean – salinity (in psu) at 105m

# 3D state variables

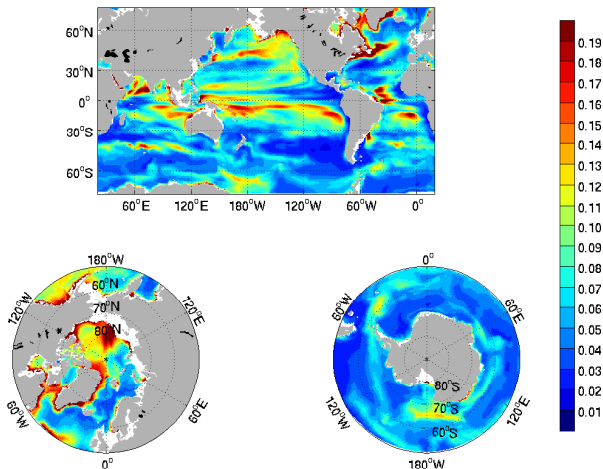


Figure: 1992-2011 standard deviation – salinity (in psu) at 105m



# 3D state variables

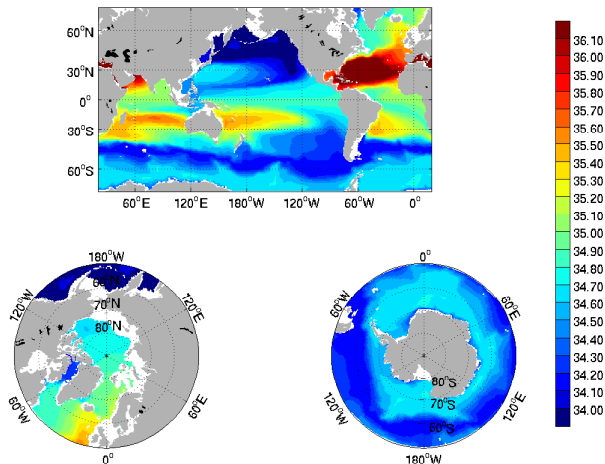


Figure: 1992-2011 mean – salinity (in psu) at 300m

# 3D state variables

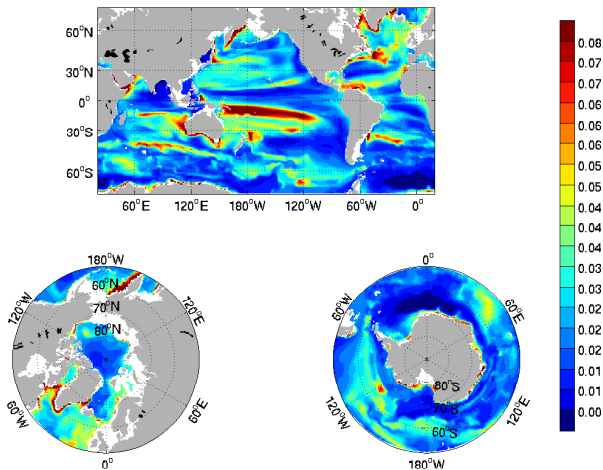


Figure: 1992-2011 standard deviation – salinity (in psu) at 300m

# 3D state variables

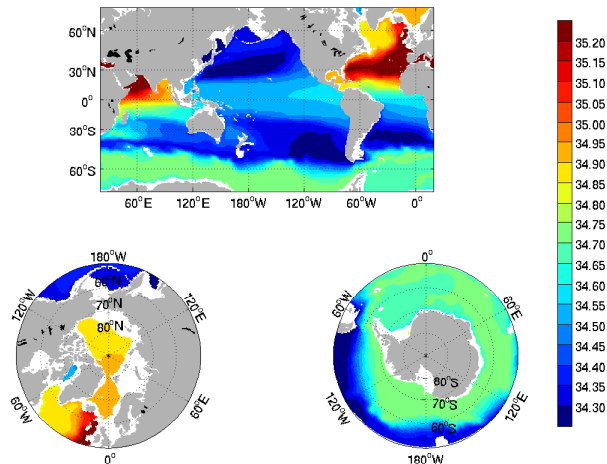


Figure: 1992-2011 mean – salinity (in psu) at 910m

# 3D state variables

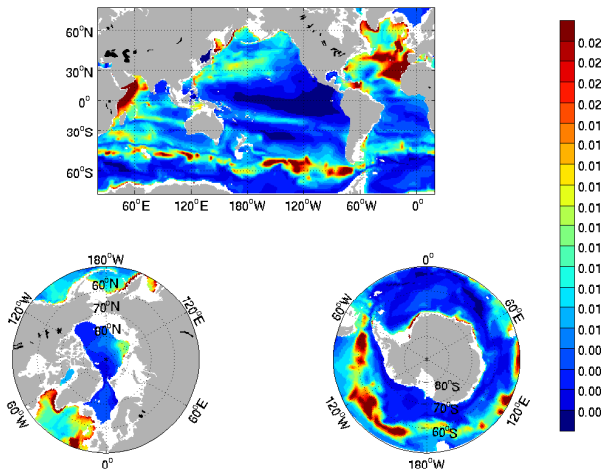


Figure: 1992-2011 standard deviation – salinity (in psu) at 910m

# 3D state variables

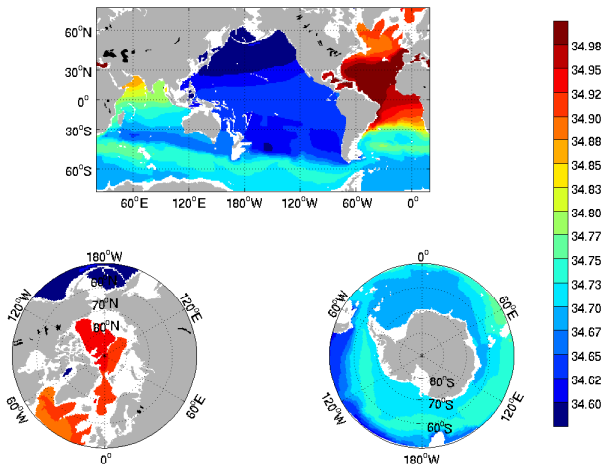


Figure: 1992-2011 mean – salinity (in psu) at 1914m

# 3D state variables

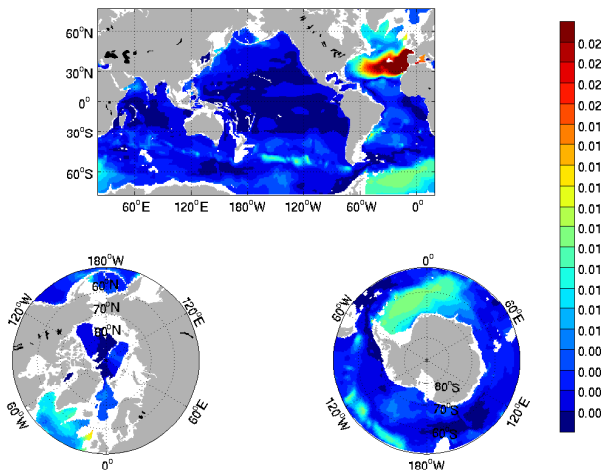


Figure: 1992-2011 standard deviation – salinity (in psu) at 1914m

# 3D state variables

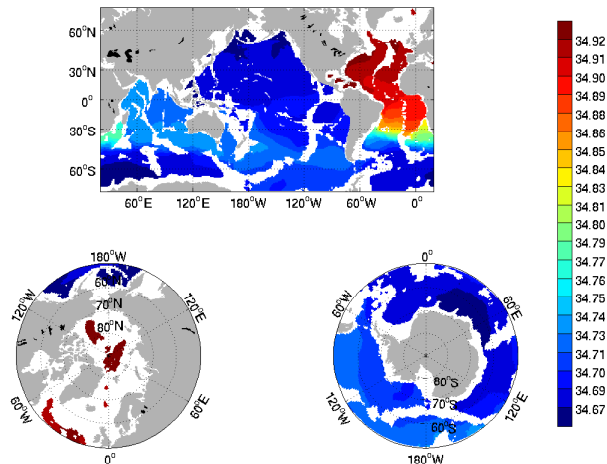


Figure: 1992-2011 mean – salinity (in psu) at 3581m

# 3D state variables

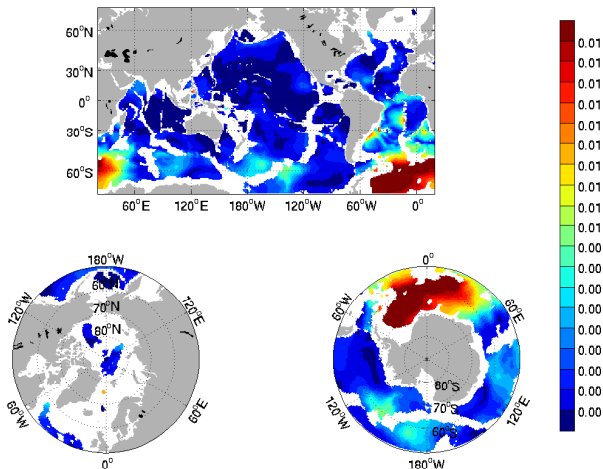


Figure: 1992-2011 standard deviation – salinity (in psu) at 3581m



# 3D state variables

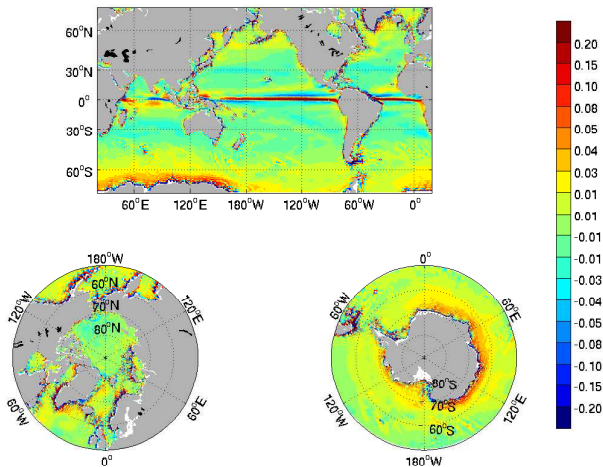


Figure: 1992-2011 mean – vertical velocity (in mm/year) at 15m

# 3D state variables

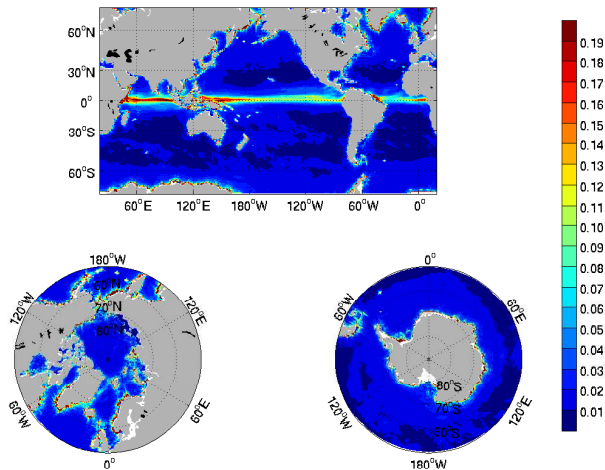


Figure: 1992-2011 standard deviation – vertical velocity (in mm/year) at 15m

# 3D state variables

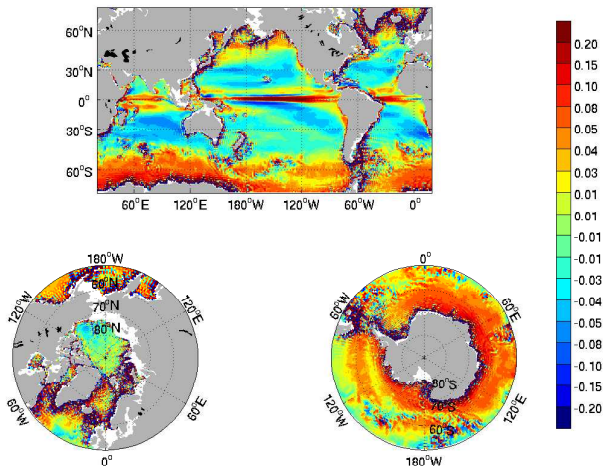


Figure: 1992-2011 mean – vertical velocity (in mm/year) at 105m

# 3D state variables

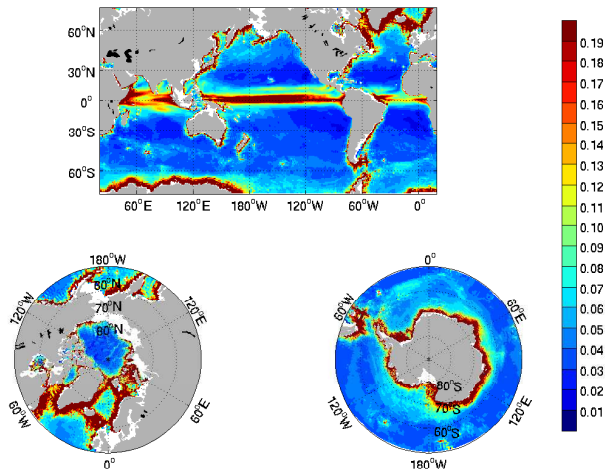


Figure: 1992-2011 standard deviation – vertical velocity (in mm/year) at 105m

# 3D state variables

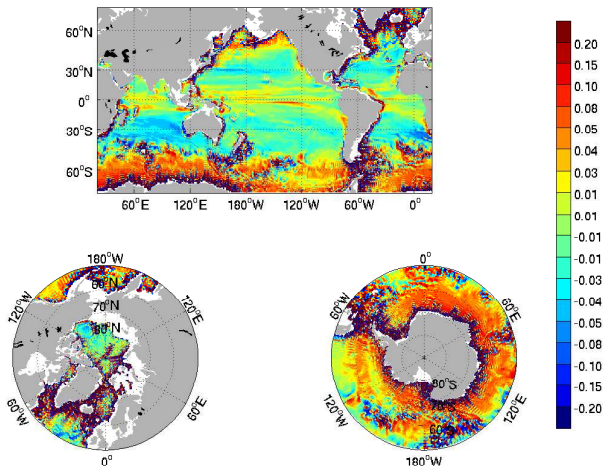


Figure: 1992-2011 mean – vertical velocity (in mm/year) at 300m

# 3D state variables

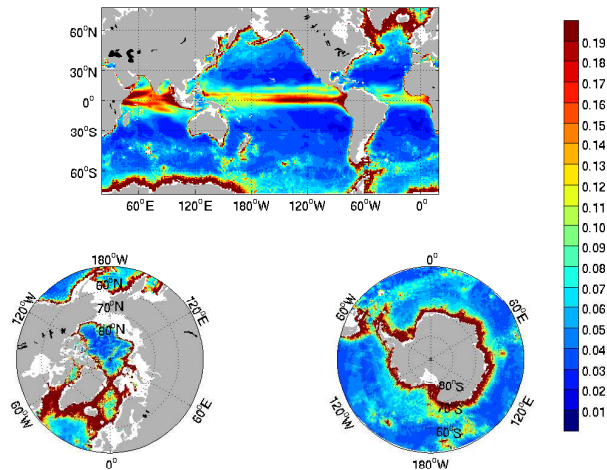


Figure: 1992-2011 standard deviation – vertical velocity (in mm/year) at 300m

# 3D state variables

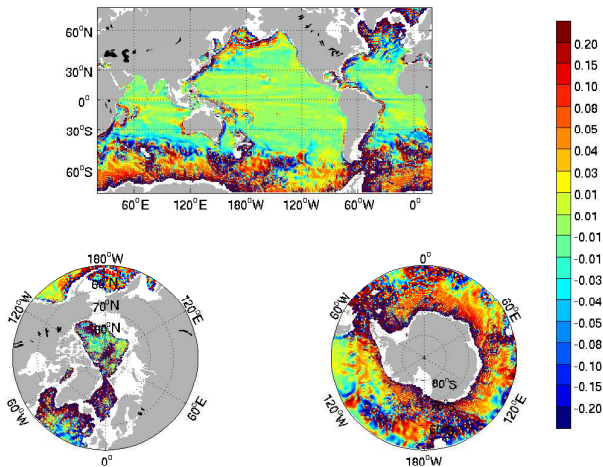
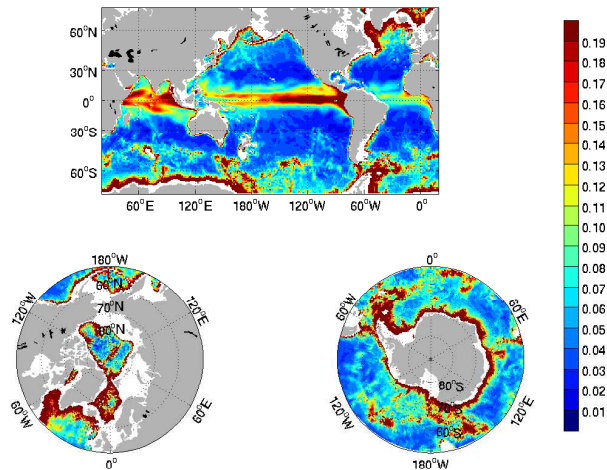


Figure: 1992-2011 mean – vertical velocity (in mm/year) at 910m

# 3D state variables



**Figure:** 1992-2011 standard deviation – vertical velocity (in mm/year) at 910m



# 3D state variables

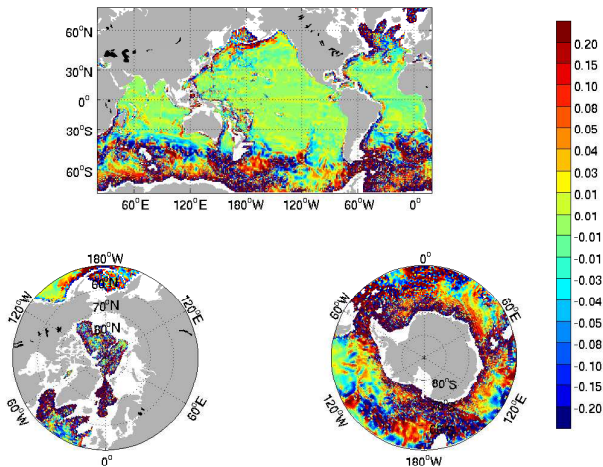


Figure: 1992-2011 mean – vertical velocity (in mm/year) at 1914m

# 3D state variables

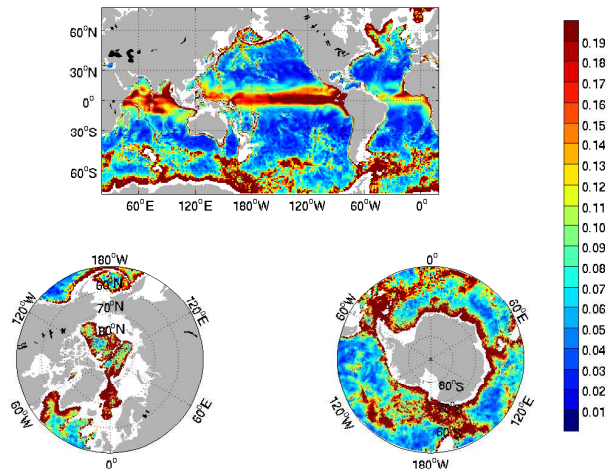


Figure: 1992-2011 standard deviation – vertical velocity (in mm/year) at 1914m

# 3D state variables

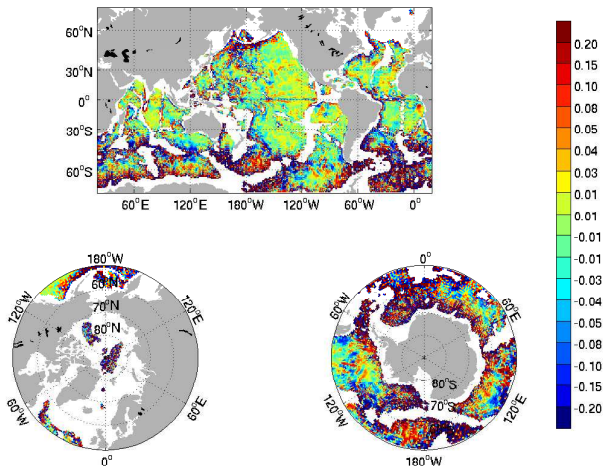
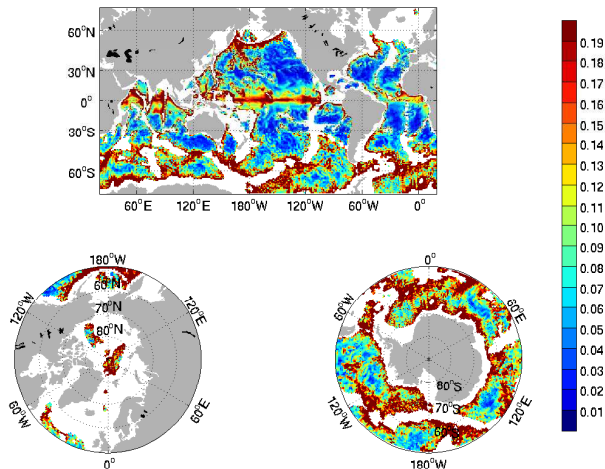


Figure: 1992-2011 mean – vertical velocity (in mm/year) at 3581m

# 3D state variables



**Figure:** 1992-2011 standard deviation – vertical velocity (in mm/year) at 3581m

# air-sea heat flux

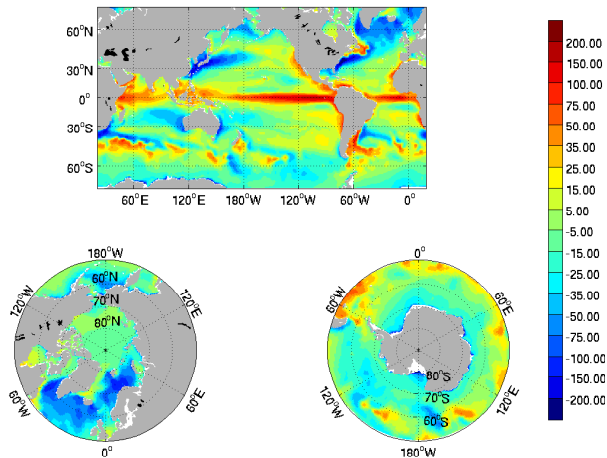


Figure: 1992-2011 mean – QNET to ocean+ice ( $\text{W/m}^2$ )

# air-sea heat flux

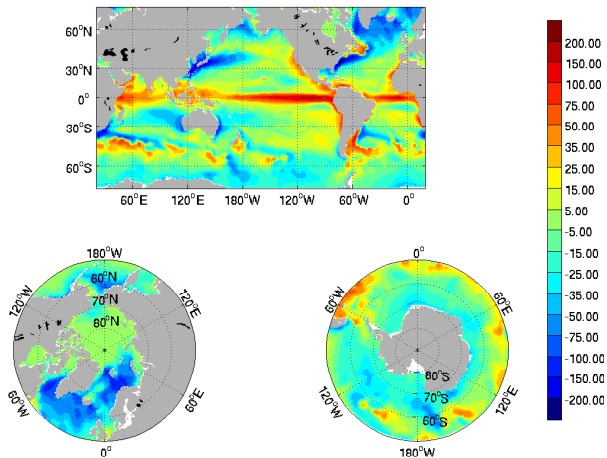


Figure: 1992-2011 mean – QNET to ocean ( $\text{W/m}^2$ )

# air-sea heat flux

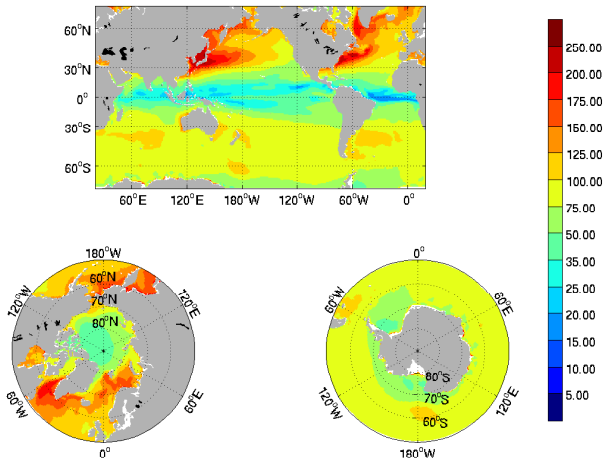


Figure: 1992-2011 standard deviation – QNET to ocean+ice ( $\text{W/m}^2$ )

# air-sea heat flux

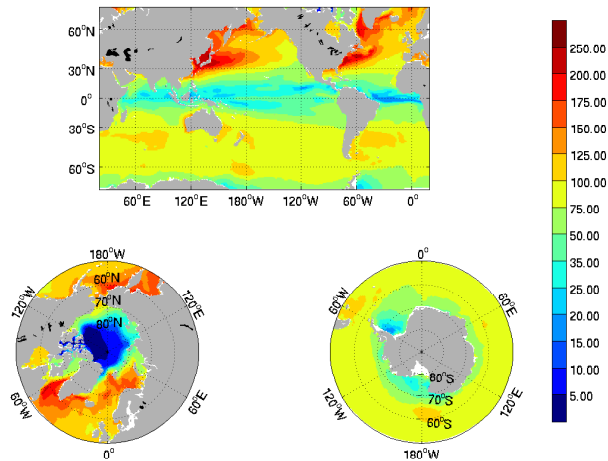


Figure: 1992-2011 standard deviation – QNET to ocean ( $\text{W/m}^2$ )



# air-sea freshwater flux

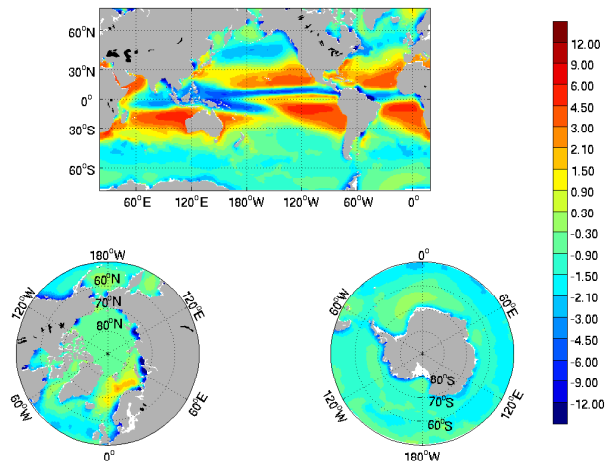


Figure: 1992-2011 mean – E-P-R from ocean+ice (mm/day)

# air-sea freshwater flux

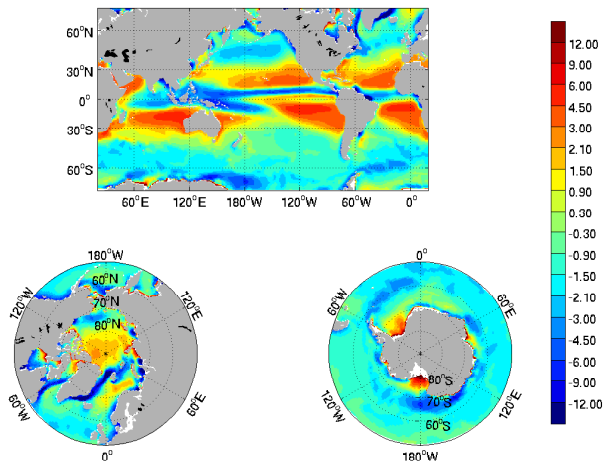


Figure: 1992-2011 mean – E-P-R from ocean (mm/day)

# air-sea freshwater flux

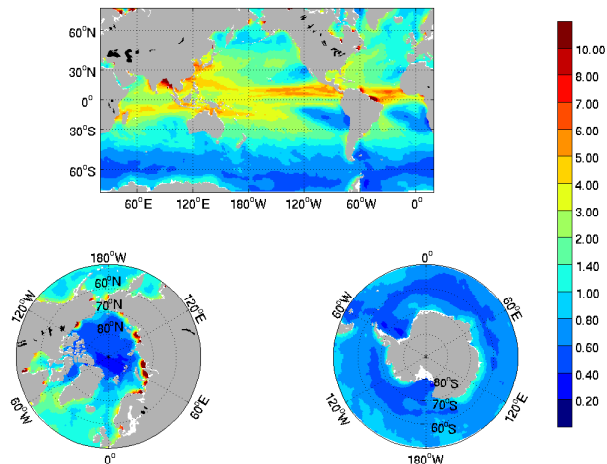


Figure: 1992-2011 standard deviation – E-P-R to ocean+ice ( $\text{W}/\text{m}^2$ )

# air-sea freshwater flux

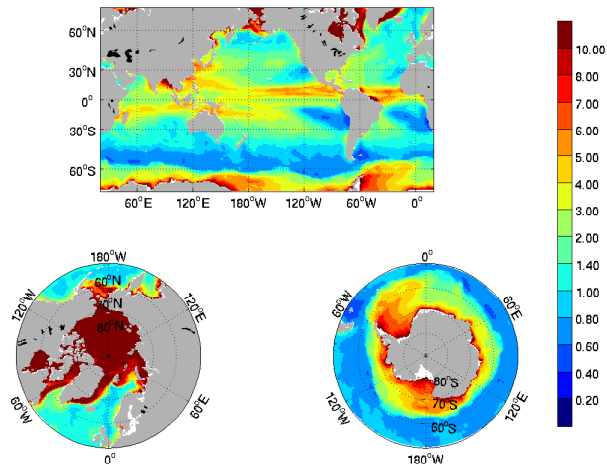


Figure: 1992-2011 standard deviation – E-P-R to ocean ( $\text{W/m}^2$ )

# surface wind stress

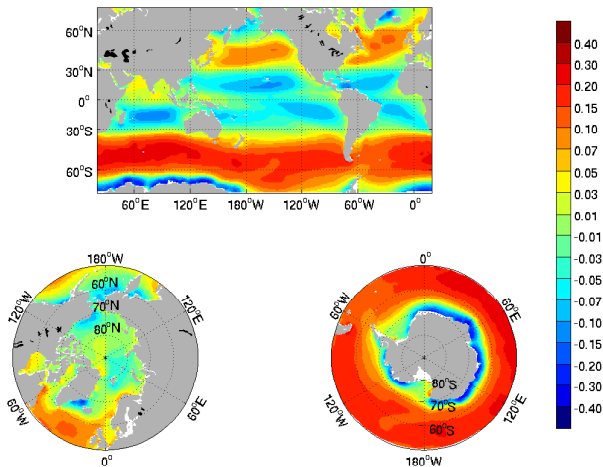


Figure: 1992-2011 mean – zonal wind stress ( $\text{N/m}^2$ )

# surface wind stress

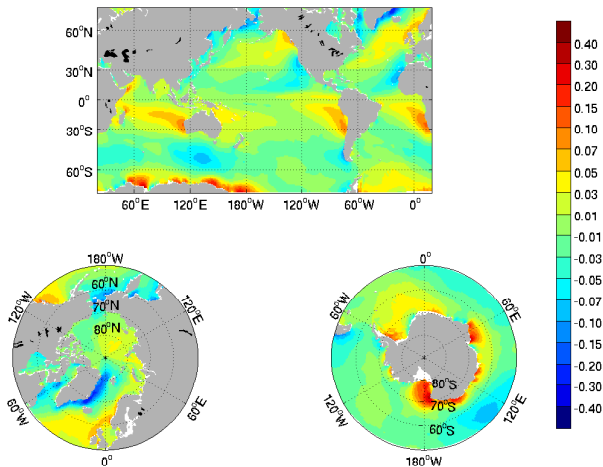


Figure: 1992-2011 mean – meridional wind stress ( $\text{N/m}^2$ )

# surface wind stress

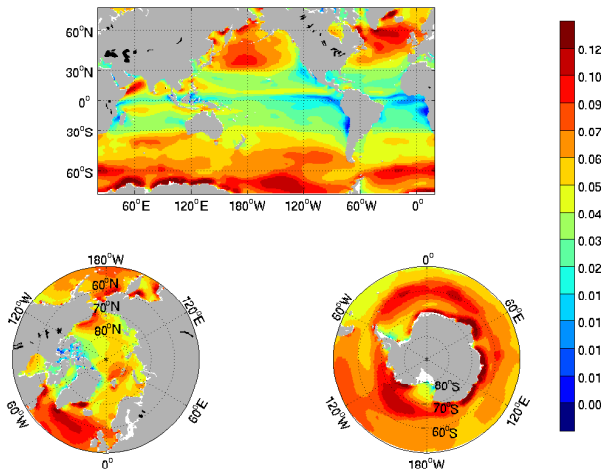


Figure: 1992-2011 standard deviation –  $\tau_Z$  ( $\text{W/m}^2$ )

# surface wind stress

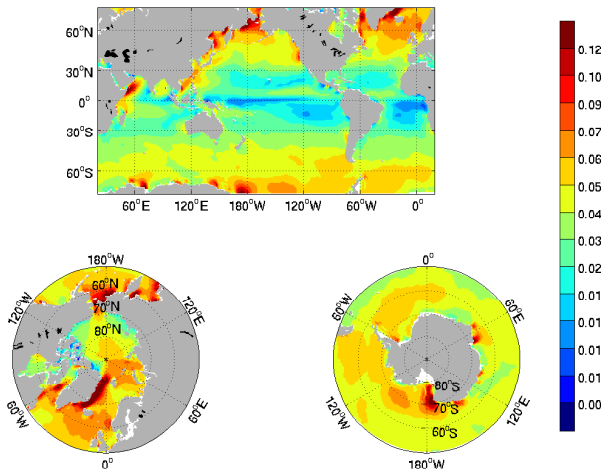


Figure: 1992-2011 standard deviation –  $\tau_M$  ( $\text{W/m}^2$ )



# zonal mean tendencies

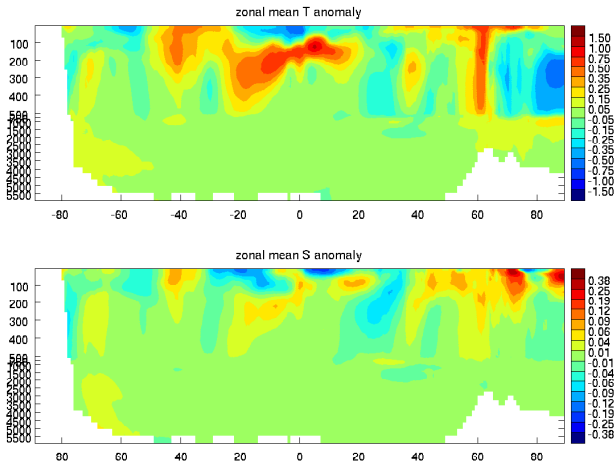


Figure: 1992-2011 , last year minus first year – zonal mean temperature (degC; top) and salinity (psu; bottom)

# equatorial sections

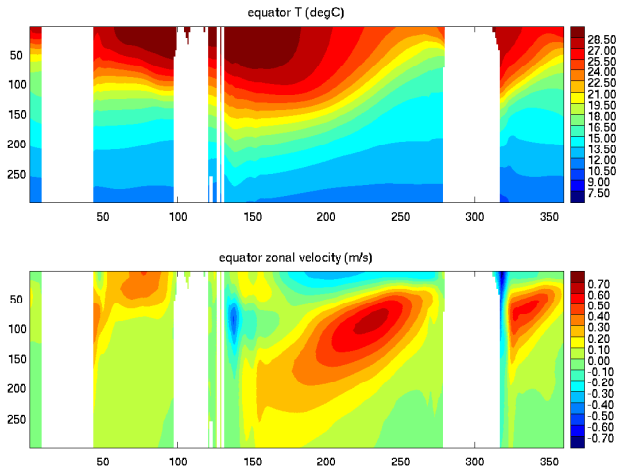


Figure: 1992-2011 mean – equator temperature (degC;top) and zonal velocity (m/s;bottom)

# global mean properties

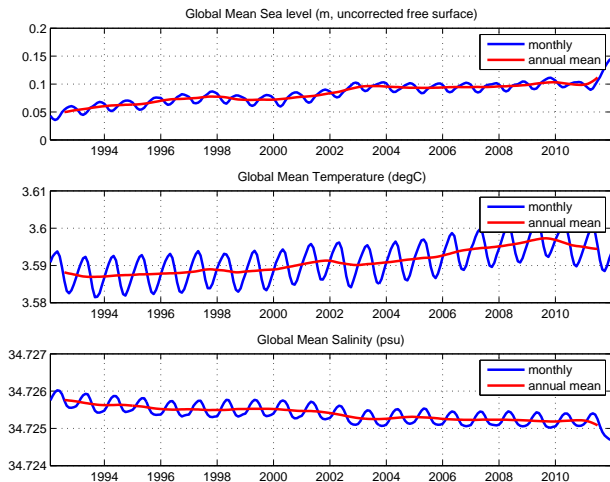


Figure: global mean T (degC; top) and S (psu; bottom)

# global mean properties

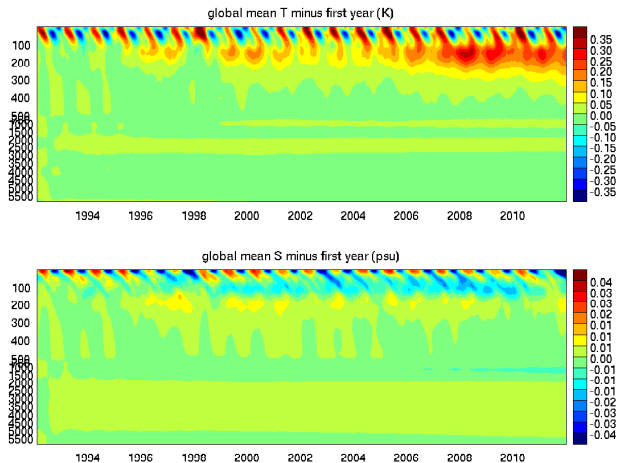


Figure: global mean temperature (K; top) and salinity (psu; bottom) minus first year

# zonal mean properties

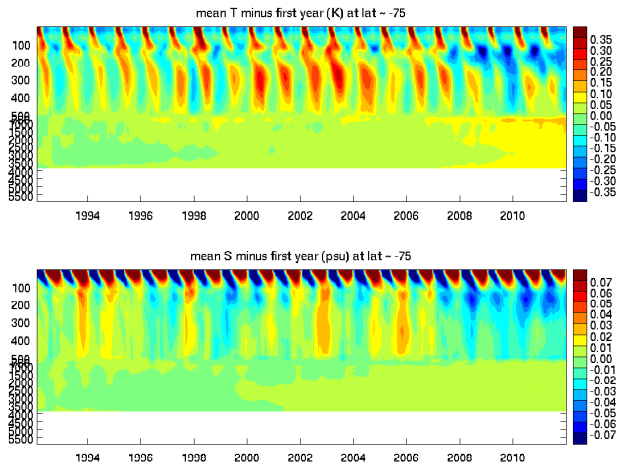


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx -75$

# zonal mean properties

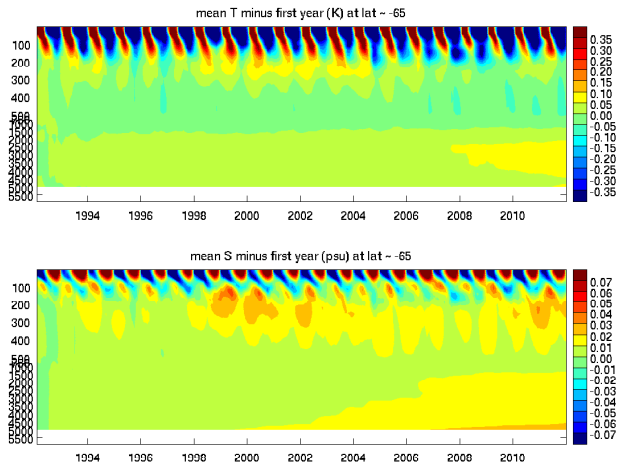


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx -65$

# zonal mean properties

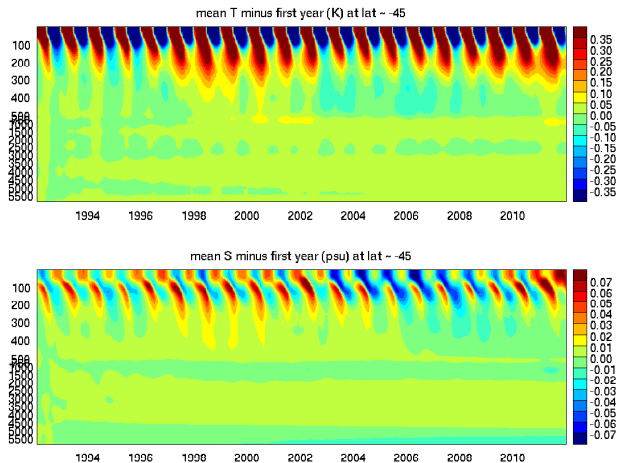


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx -45$

# zonal mean properties

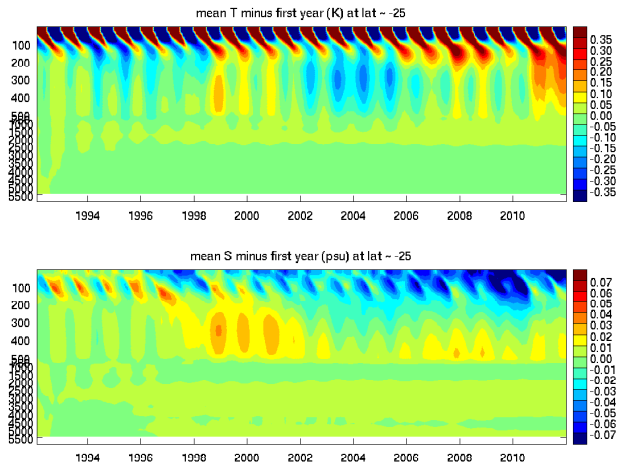


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx -25$



# zonal mean properties

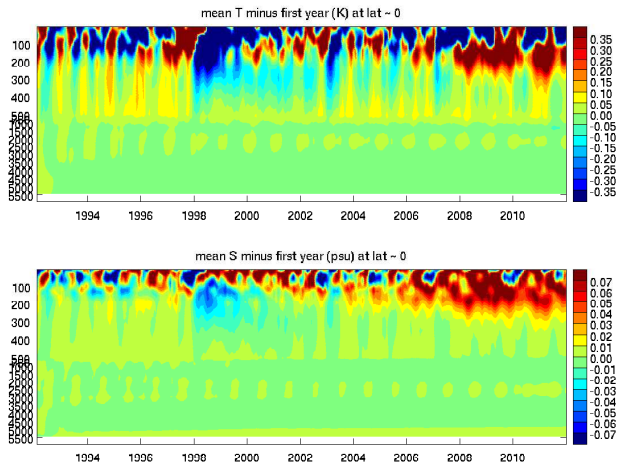


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx 0$

# zonal mean properties

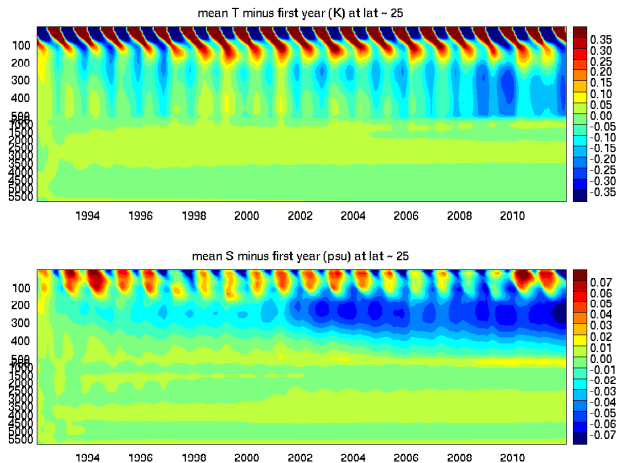


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx 25$

# zonal mean properties

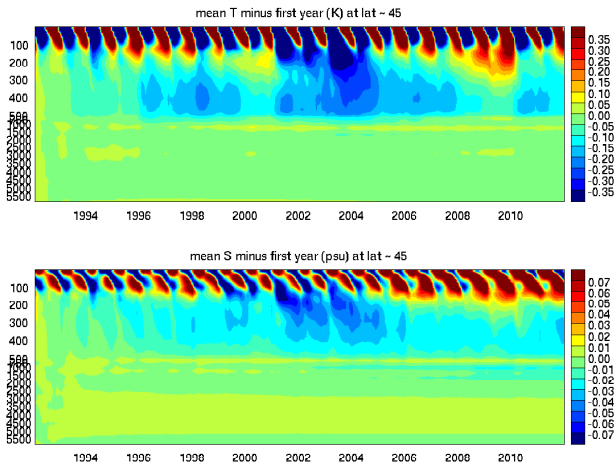


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx 45$

# zonal mean properties

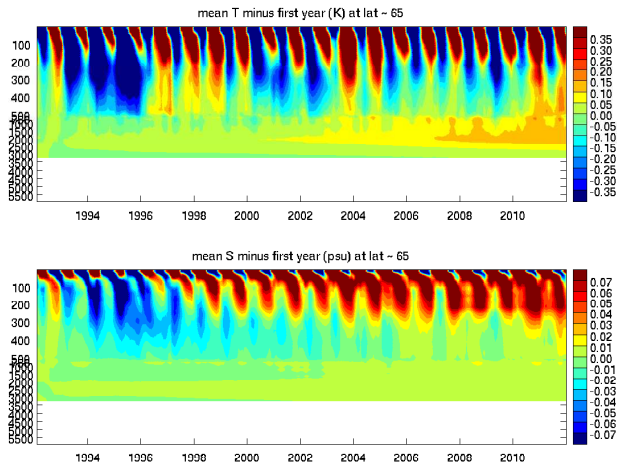


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx 65$

# zonal mean properties

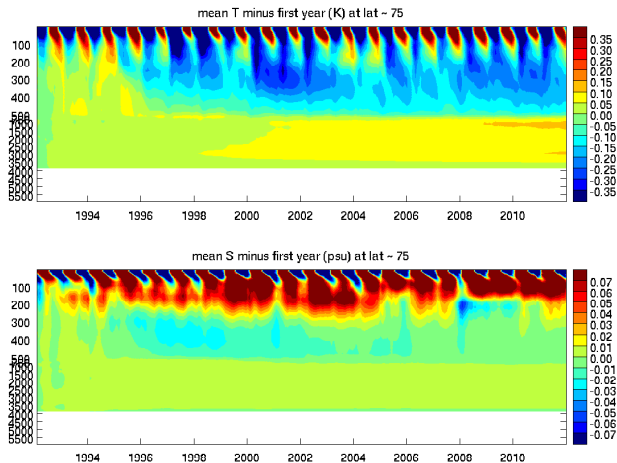


Figure: mean temperature (top; K) and salinity (bottom; psu) minus first year at lat  $\approx 75$

# zonal mean properties (surface)

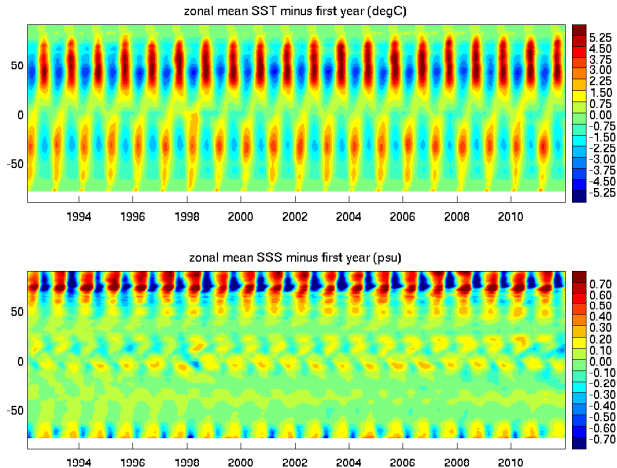
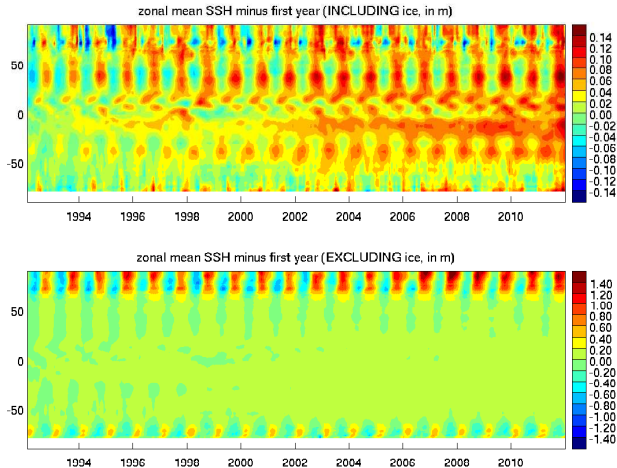


Figure: zonal mean temperature (degC; top) and salinity (psu; bottom) minus first year (psu) at 5m depth

# zonal mean properties (surface)



**Figure:** zonal mean SSH (m, uncorrected free surface) minus first year, including ice (top) and below ice (bottom)

# zonal mean properties (surface)

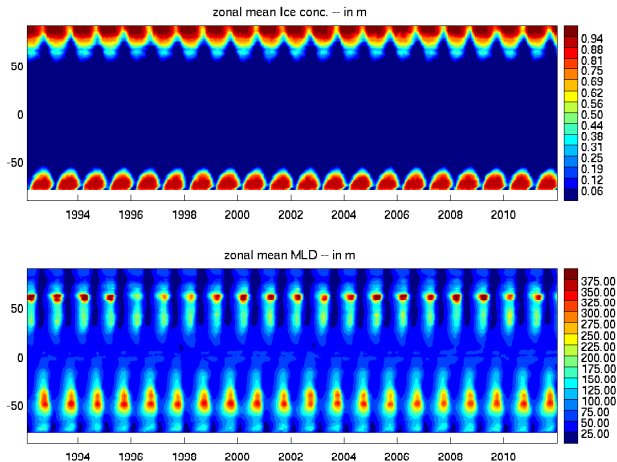


Figure: zonal mean ice concentration (no units) and mixed layer depth (m)



# seaice time series

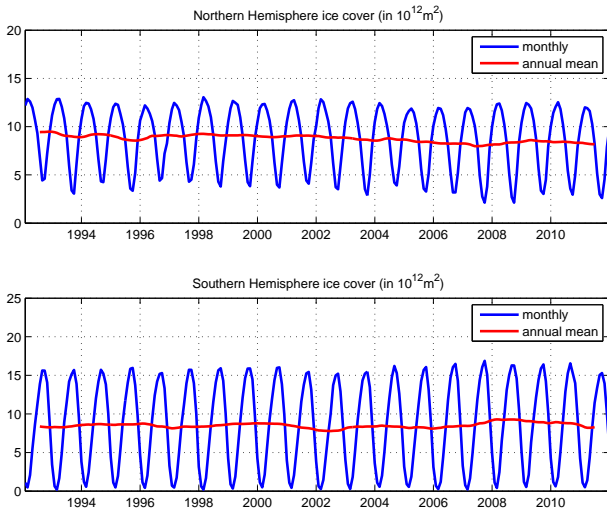


Figure: sea ice cover (in  $10^{12}m^2$ ) in northern (top) and southern (bottom) hemisphere

# seaice time series

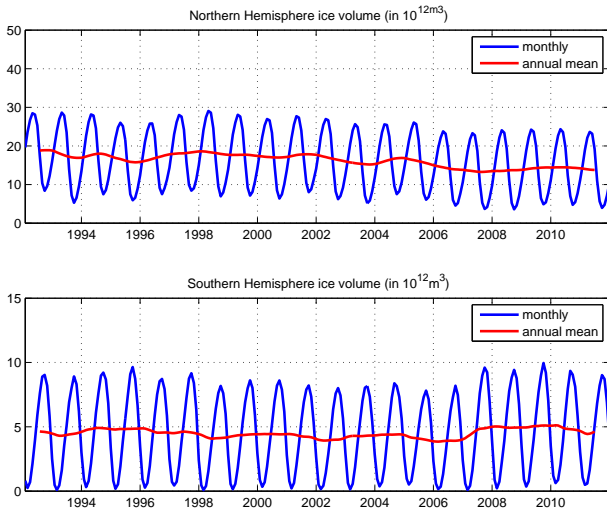


Figure: sea ice volume (in  $10^{12}m^3$ ) in northern (top) and southern (bottom) hemisphere

# seaice time series

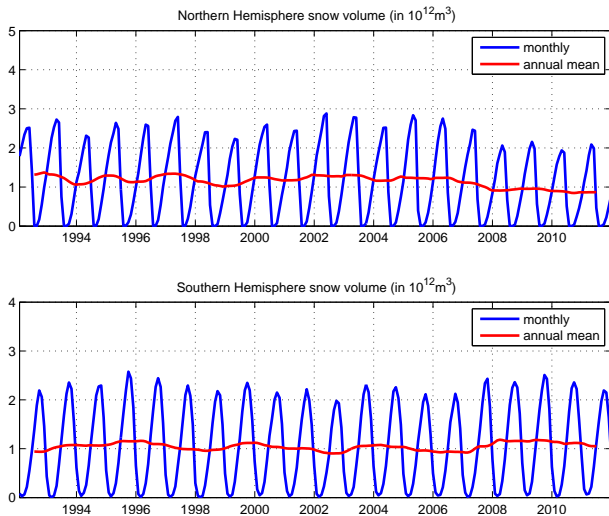


Figure: snow volume (in  $10^{12}m^3$ ) in northern (top) and southern (bottom) hemisphere

# seaice time series

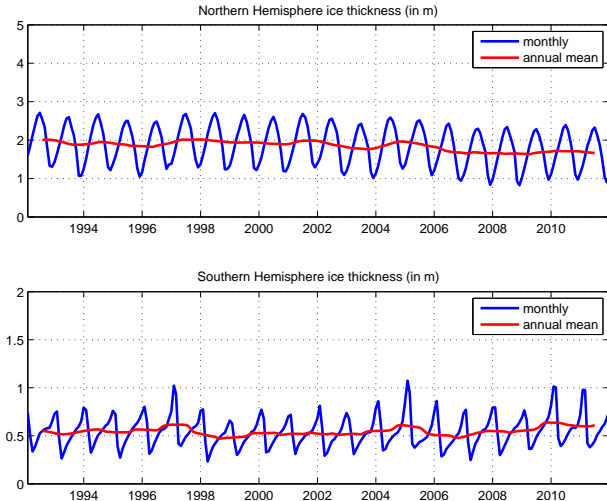


Figure: sea ice thickness (in m) in northern (top) and southern (bottom) hemisphere

# seaice time series

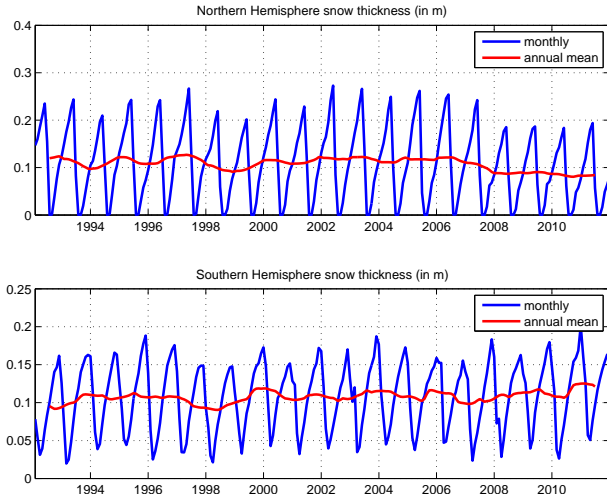


Figure: snow thickness (in m) in northern (top) and southern (bottom) hemisphere

# budgets : volume, heat and salt (top to bottom)

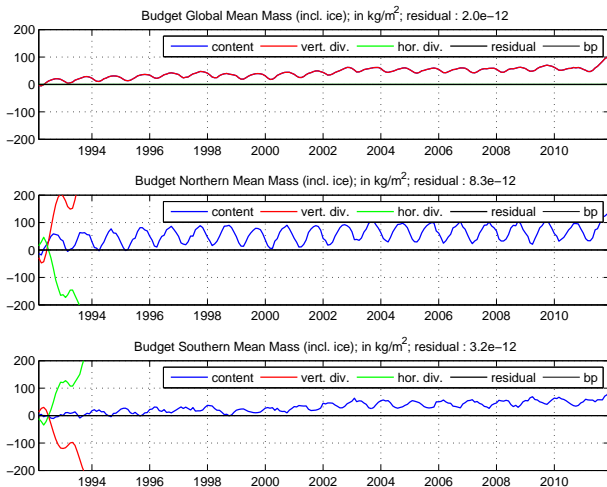


Figure: 1992-2011 global (upper) north (mid) and south (lower), mass budget (ocean+ice) in kg/m<sup>2</sup>.

# budgets : volume, heat and salt (top to bottom)

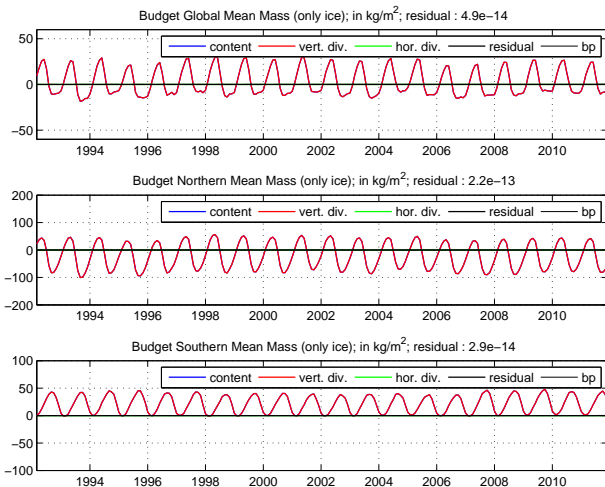


Figure: 1992-2011 global (upper) north (mid) and south (lower), mass budget (ice only) in  $\text{kg/m}^2$ .

# budgets : volume, heat and salt (top to bottom)

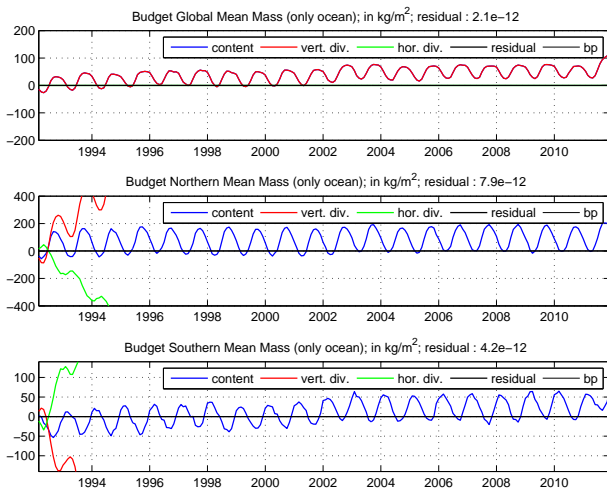


Figure: 1992-2011 global (upper) north (mid) and south (lower), mass budget (ocean only) in  $\text{kg/m}^2$ .



# budgets : volume, heat and salt (top to bottom)

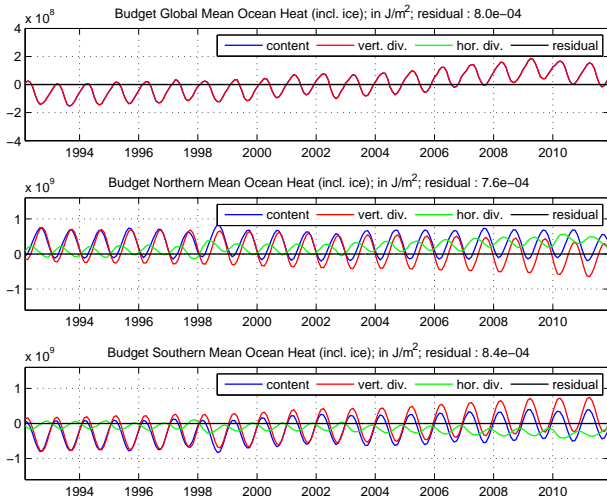


Figure: 1992-2011 global (upper) north (mid) and south (lower), heat budget (ocean+ice) in  $\text{J/m}^2$ .

# budgets : volume, heat and salt (top to bottom)

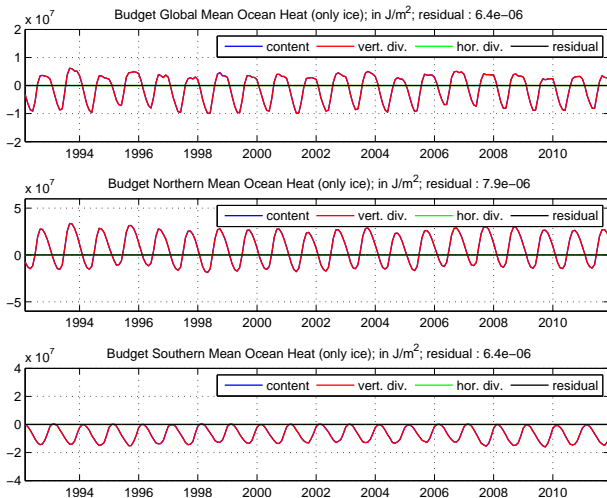


Figure: 1992-2011 global (upper) north (mid) and south (lower), heat budget (ice only) in  $\text{J/m}^2$ .

# budgets : volume, heat and salt (top to bottom)

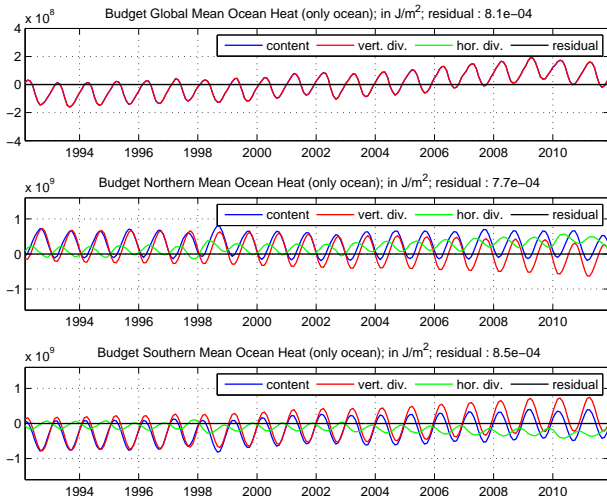


Figure: 1992-2011 global (upper) north (mid) and south (lower), heat budget (ocean only) in  $\text{J/m}^2$ .

# budgets : volume, heat and salt (top to bottom)

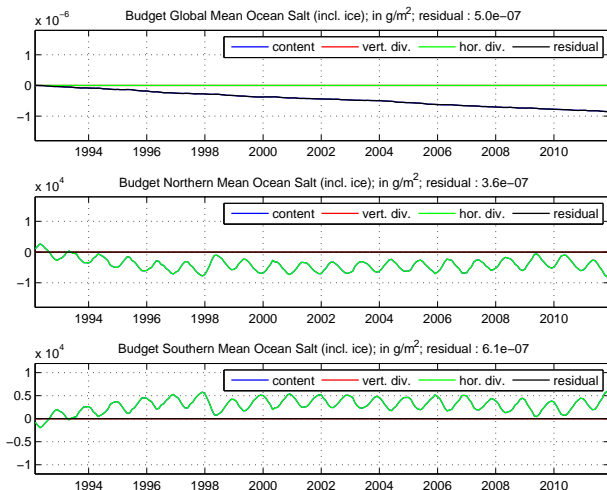


Figure: 1992-2011 global (upper) north (mid) and south (lower), salt budget (ocean+ice) in  $\text{g/m}^2$ .

# budgets : volume, heat and salt (top to bottom)

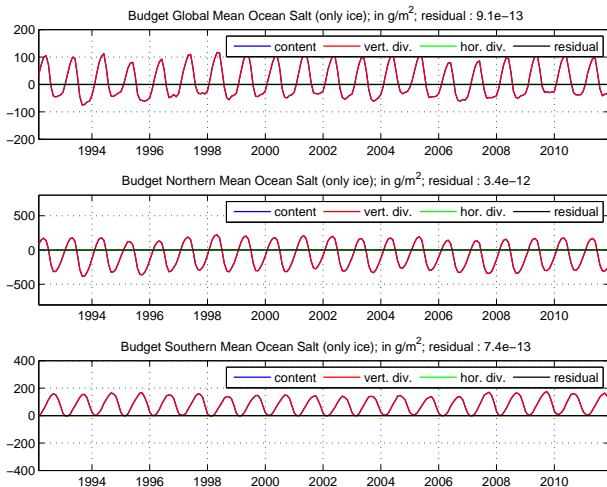


Figure: 1992-2011 global (upper) north (mid) and south (lower), salt budget (ice only) in  $\text{g/m}^2$ .

# budgets : volume, heat and salt (top to bottom)

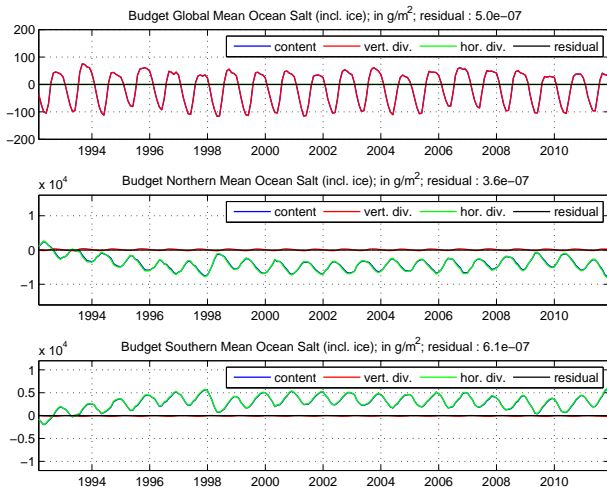


Figure: 1992-2011 global (upper) north (mid) and south (lower), salt budget (ocean only) in  $\text{g/m}^2$ .

# budgets : volume, heat and salt (100m to bottom)

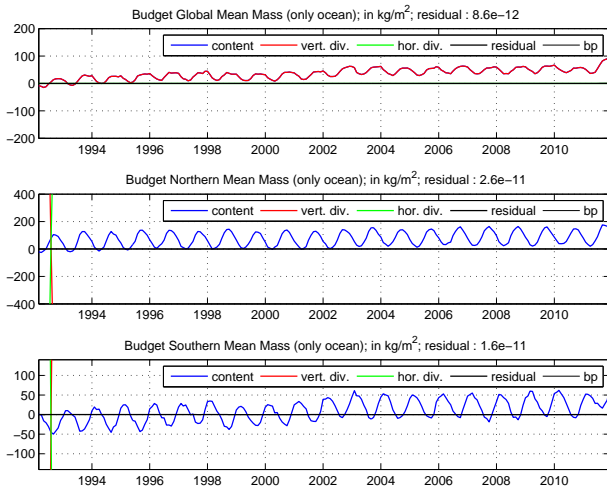


Figure: 1992-2011 global (upper) north (mid) and south (lower), mass budget (ocean only) in  $\text{kg/m}^2$ .

# budgets : volume, heat and salt (100m to bottom)

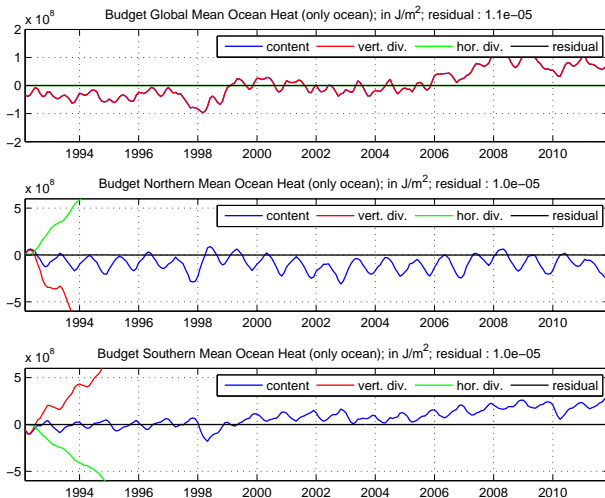


Figure: 1992-2011 global (upper) north (mid) and south (lower), heat budget (ocean only) in  $\text{J/m}^2$ .



# budgets : volume, heat and salt (100m to bottom)

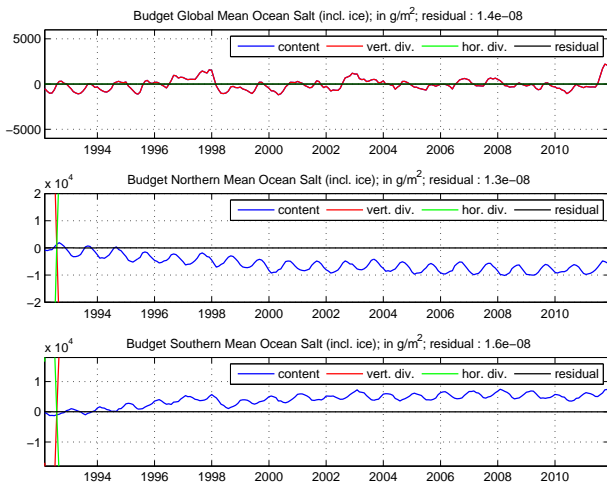


Figure: 1992-2011 global (upper) north (mid) and south (lower), salt budget (ocean only) in  $\text{g/m}^2$ .

# mixed layer depth fields

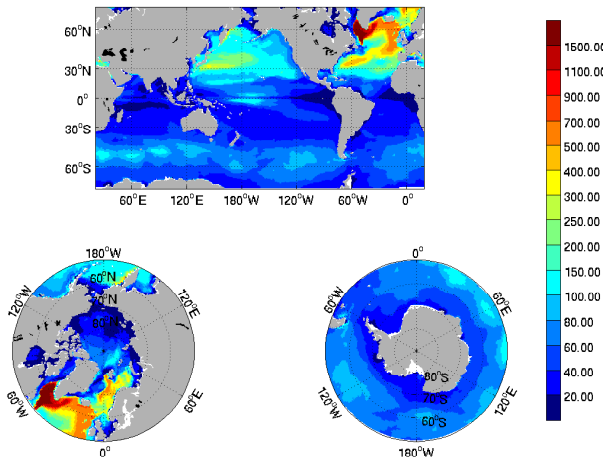


Figure: 1992-2011 March mean – mixed layer depth per Kara formula (m)

# mixed layer depth fields

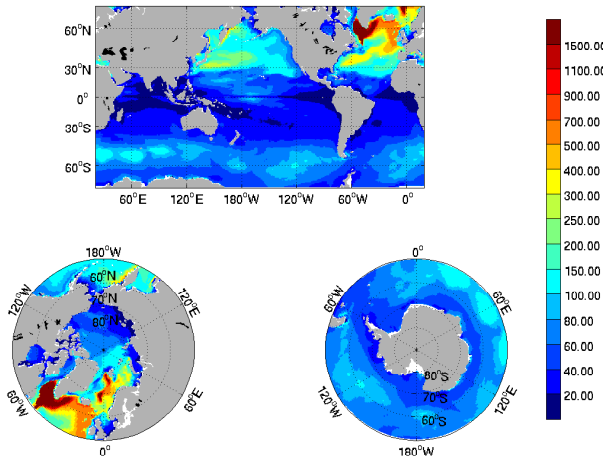


Figure: 1992-2011 March mean – mixed layer depth per Suga formula (m)

# mixed layer depth fields

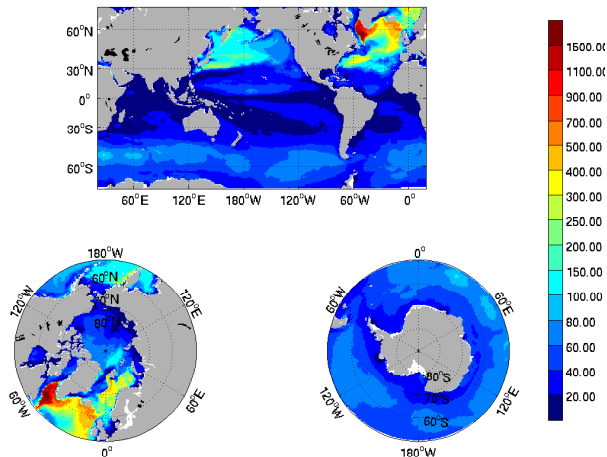


Figure: 1992-2011 March mean – mixed layer depth per Boyer M. formula (m)

# mixed layer depth fields

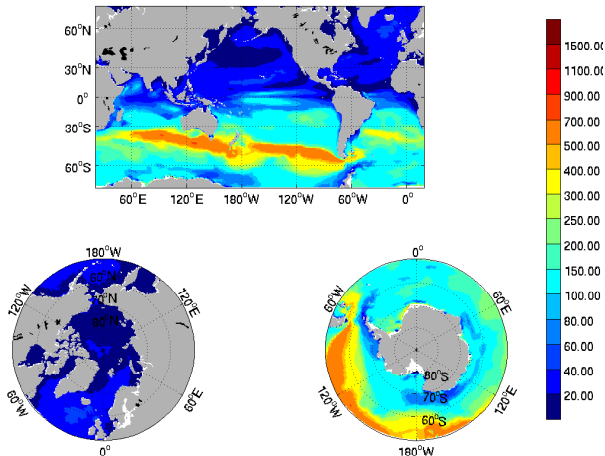


Figure: 1992-2011 September mean – mixed layer depth per Kara formula (m)

# mixed layer depth fields

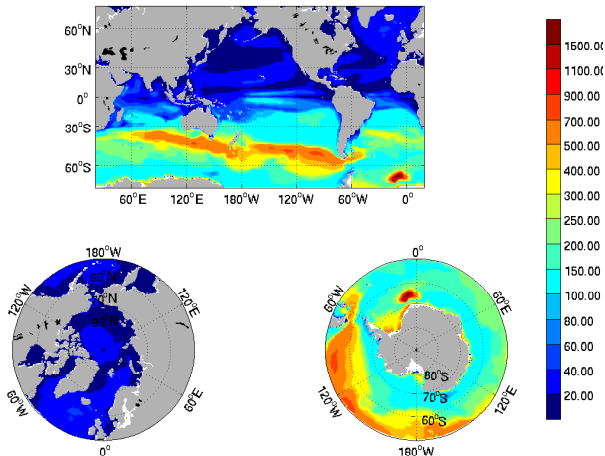


Figure: 1992-2011 September mean – mixed layer depth per Suga formula (m)

# mixed layer depth fields

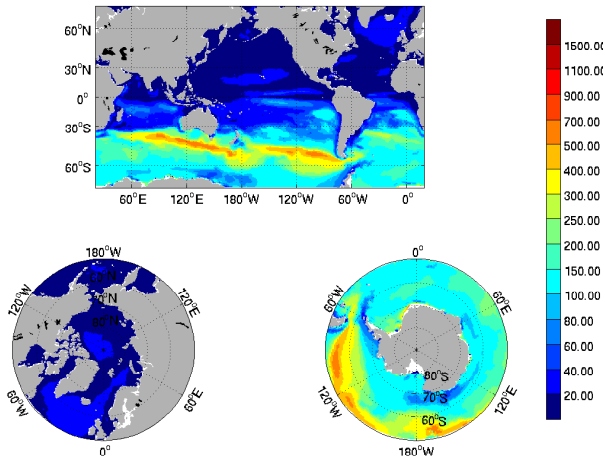


Figure: 1992-2011 September mean – mixed layer depth per Boyer M. formula (m)