Geoscientific
Model Development

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Supplement of

ECCO version 4: an integrated framework for non-linear inverse modeling and global ocean state estimation

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Standard analysis for ECCO v4, release 1 state estimate.

September 28, 2015

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README

Depicted solution :
- name: ECCO v4, release 1 state estimate (1992–2011)
- source : Gaël Forget (MIT/AER/JPL ECCO group)
- reference : Forget et al., 2015 (doi:10.5194/gmdd-8-3653-2015)
- contact : ecco-support@mit.edu

Solution history :
- r4it11 : reduce background vertical viscosity (GF)
- r4it10 : cleanup control vector adjustments (GF)
- r4it9 : optimization of global mean sea level alone (GF)
- r4it0-8 : full adjoint iterations, omitting global mean
  sea level altimetry constraint (GF)

Release history :
- 2014/02/04 : initial release of ECCO v4, release 1 (GF)
    - domain decomposed in 90x90 tiles (13 of them)
    - CF-1.6 ncetcdf files (using write write_nctiles.m)
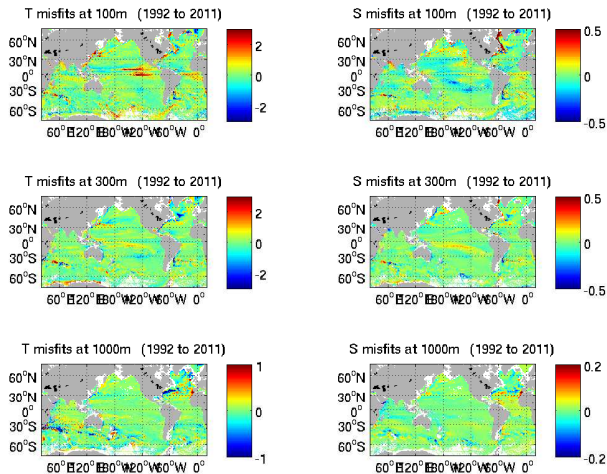
fit to in situ data

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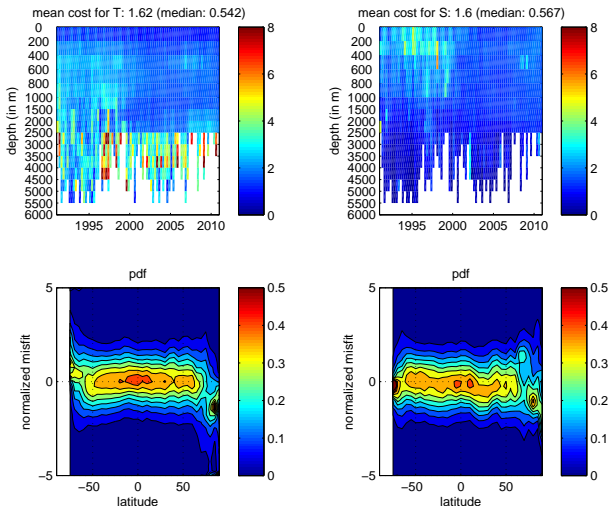
fit to in situ data

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).
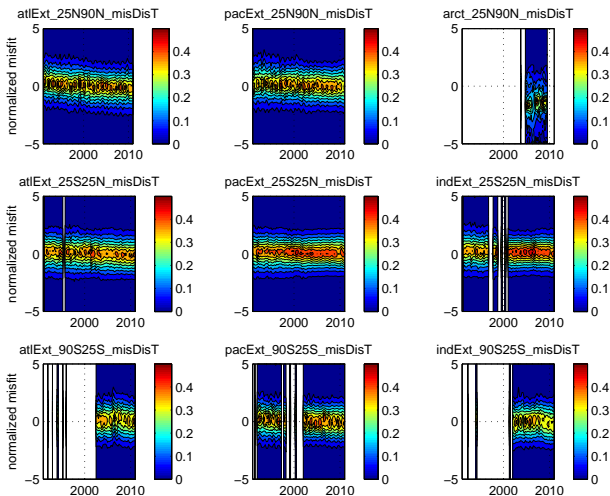
fit to in situ data

Figure : Distribution of normalized misfits per basin (panel) as a function of latitude, for T
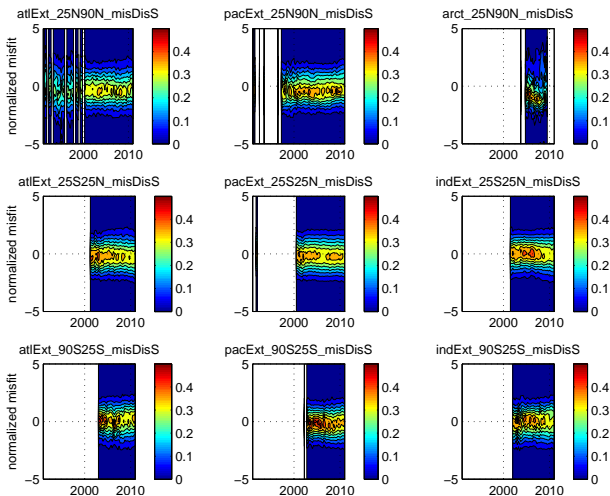
fit to in situ data

Figure : Distribution of normalized misfits per basin (panel) as a function of latitude, for S
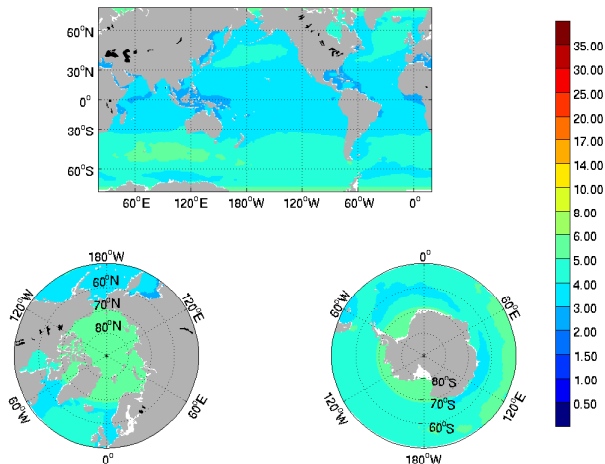
fit to altimeter data (RADS)

Figure : mean dynamic topography prior uncertainty (cm)
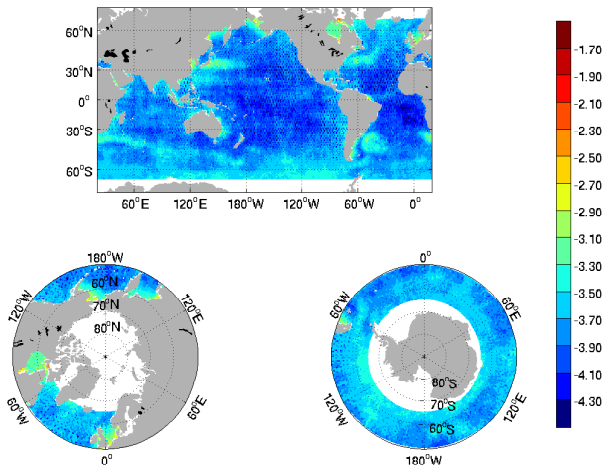
fit to altimeter data (RADS)

Figure : log(prior error variance) – sea level anomaly (m^2) – large space/time scales
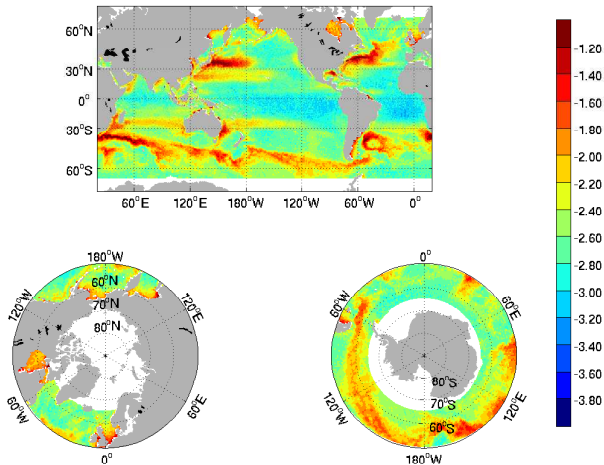
fit to altimeter data (RADS)

Figure : log(prior error variance) – sea level anomaly (m^2) – pointwise
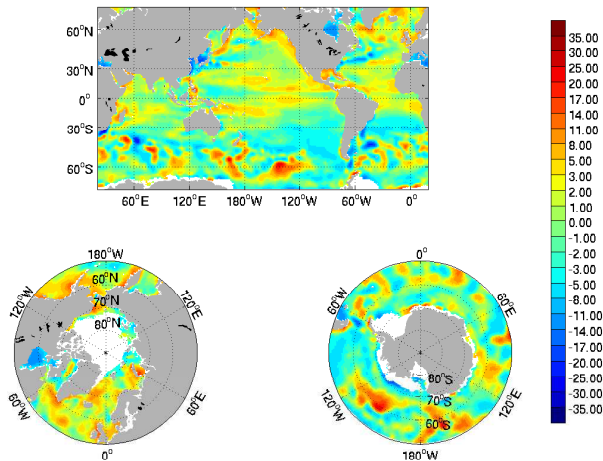
fit to altimeter data (RADS)

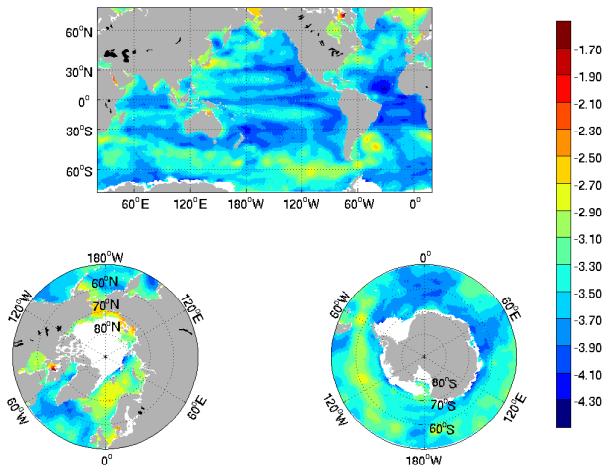Figure : mean dynamic topography misfit (cm)

fit to altimeter data (RADS)

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

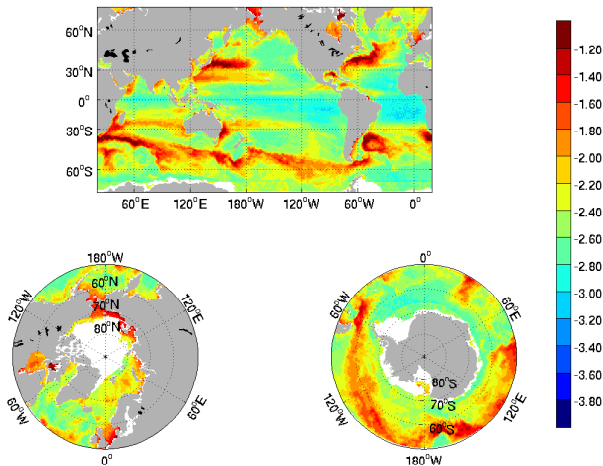# fit to altimeter data (RADS)

Figure : modeled-observed log(variance) – sea level anomaly (m^2) – pointwise
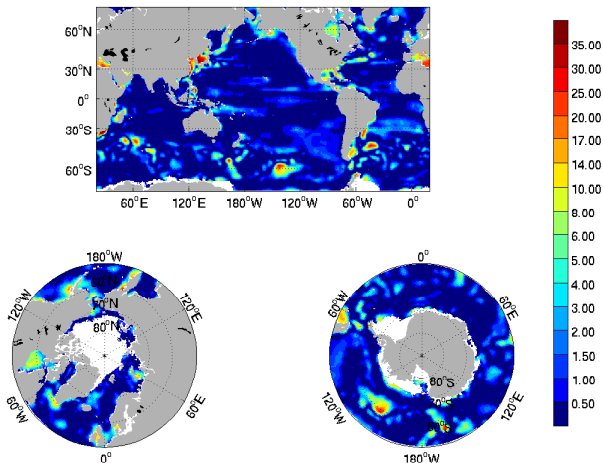
fit to altimeter data (RADS)

Figure : modeled-observed cost – mean dynamic topography
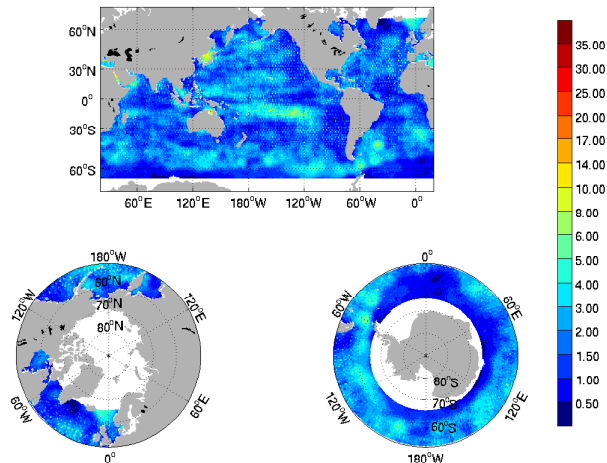
fit to altimeter data (RADS)

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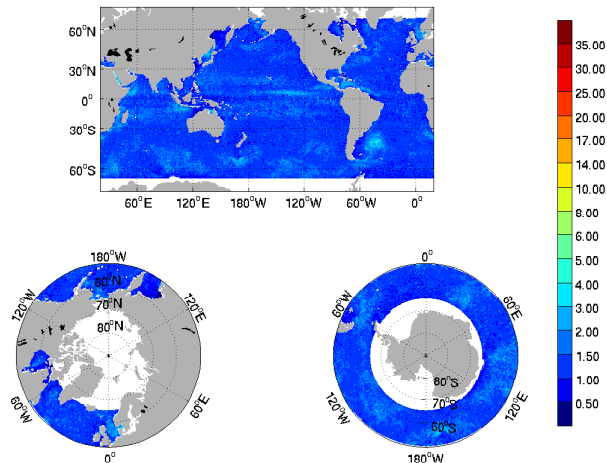– large space/time scales

fit to altimeter data (RADS)

Figure : modeled-observed cost – sea level anomaly – pointwise
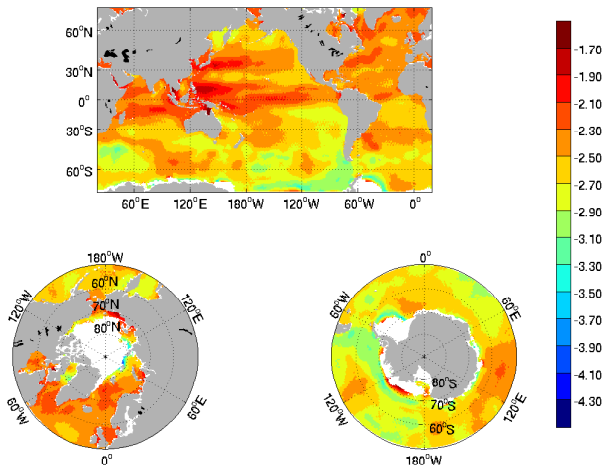
fit to altimeter data (RADS)

Figure : observed log(variance) – sea level anomaly (m^2) – large space/time scales
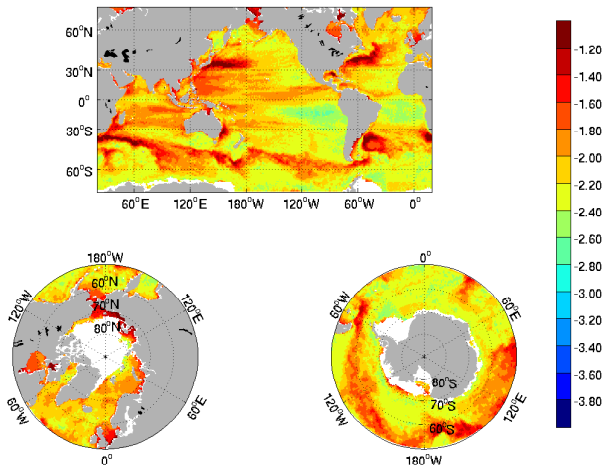
fit to altimeter data (RADS)

Figure : observed log(variance) – sea level anomaly (m^2) – pointwise
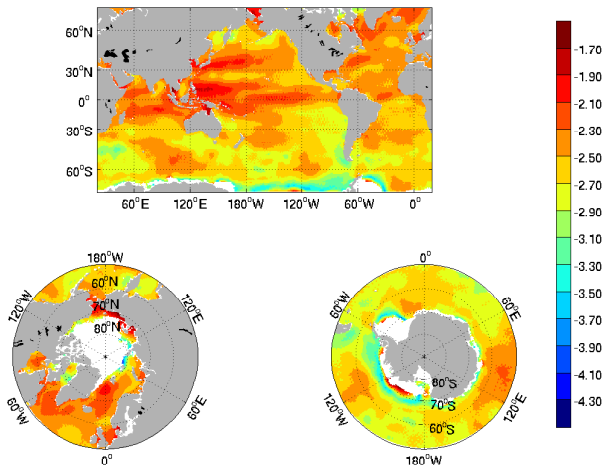
fit to altimeter data (RADS)

Figure : modeled log(variance) – sea level anomaly (m^2) – large space/time scales

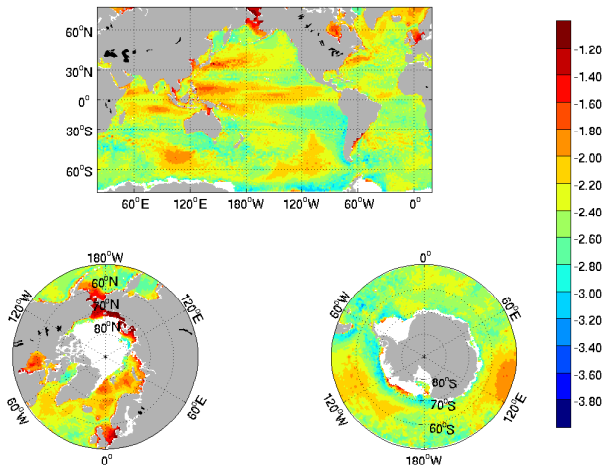# fit to altimeter data (RADS)

Figure : modeled log(variance) – sea level anomaly (m^2) – pointwise
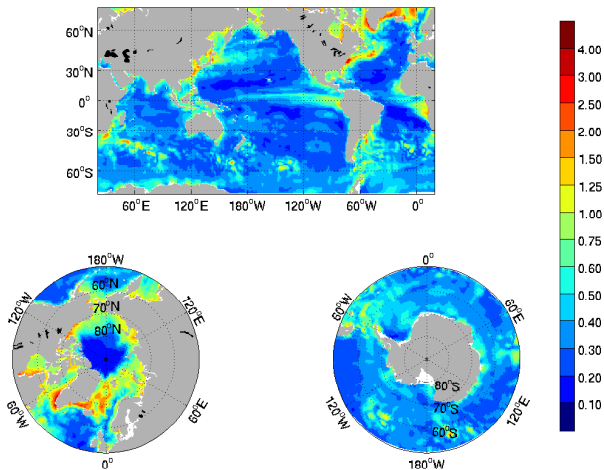
fit to sst data

Figure : modeled-Reynolds rms – sea surface temperature (K)
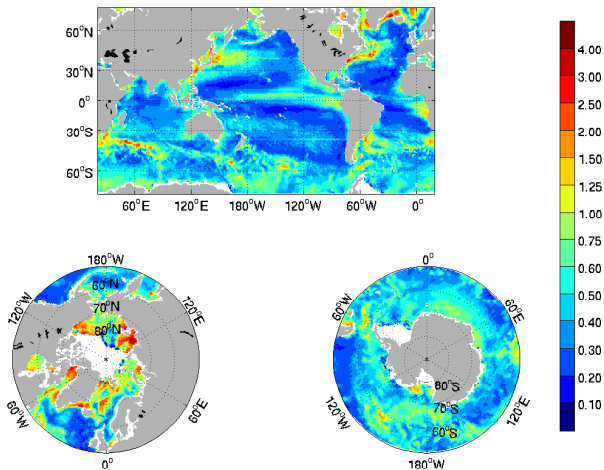
fit to sst data

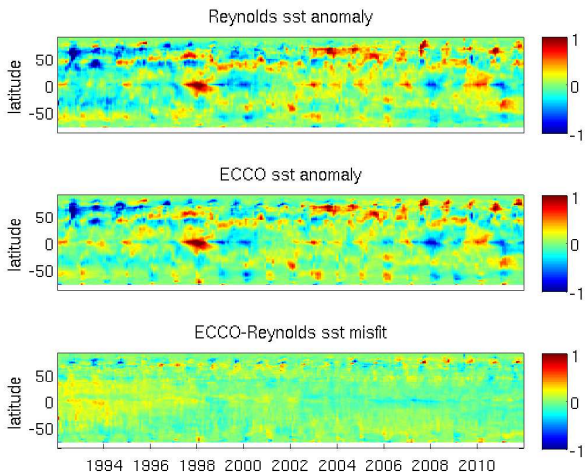Figure : modeled-REMSS rms − sea surface temperature (K)

fit to sst data

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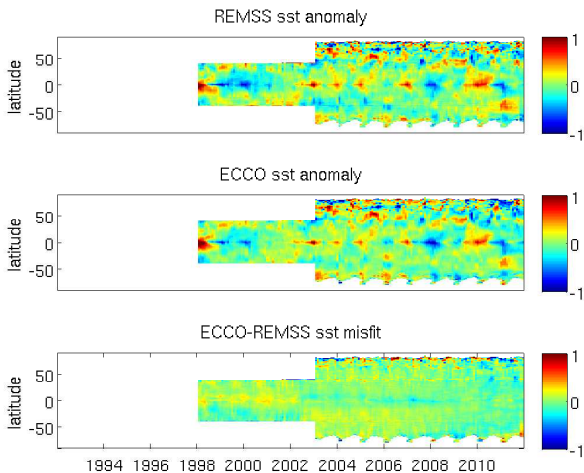
fit to sst data

Figure : ECCO and REMSS zonal mean sst anomalies (K)
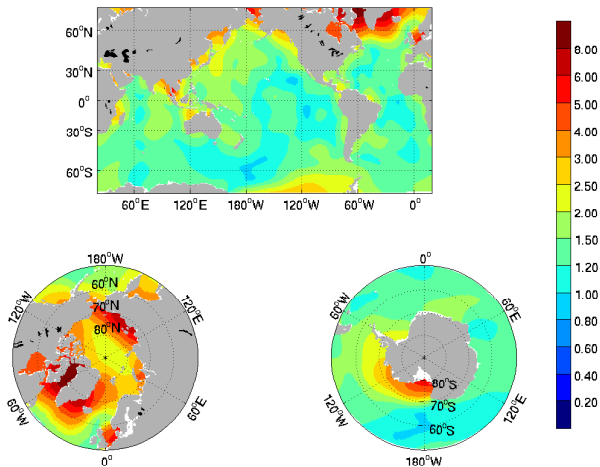
fit to grace r4 data

Figure : modeled-observed rms – bottom pressure (cm)
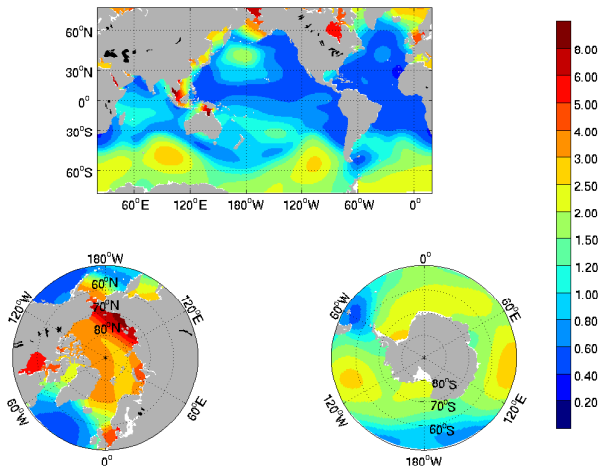
fit to grace r4 data

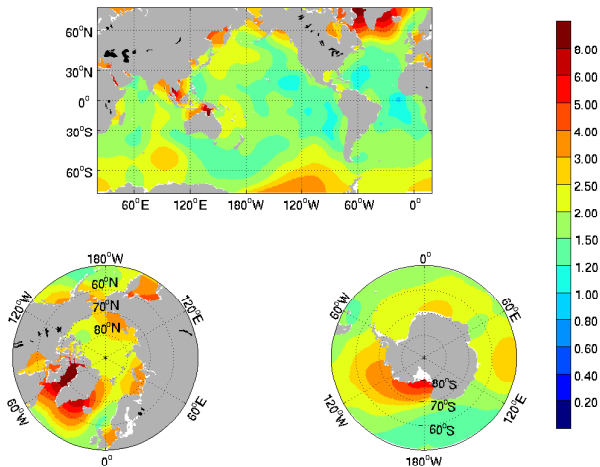Figure : rms modeled – bottom pressure (cm)

fit to grace r4 data

Figure : rms observed – bottom pressure (cm)
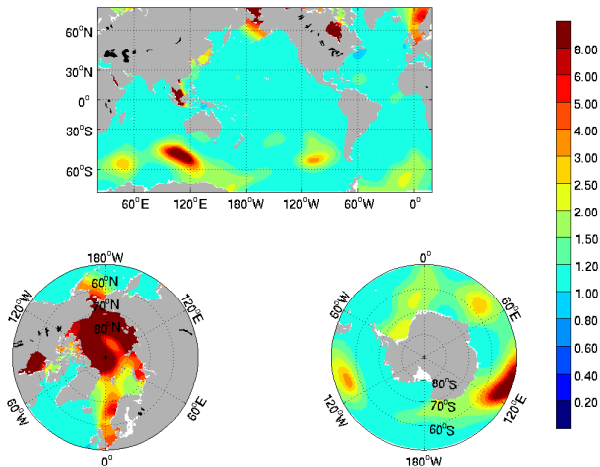
fit to grace r4 data

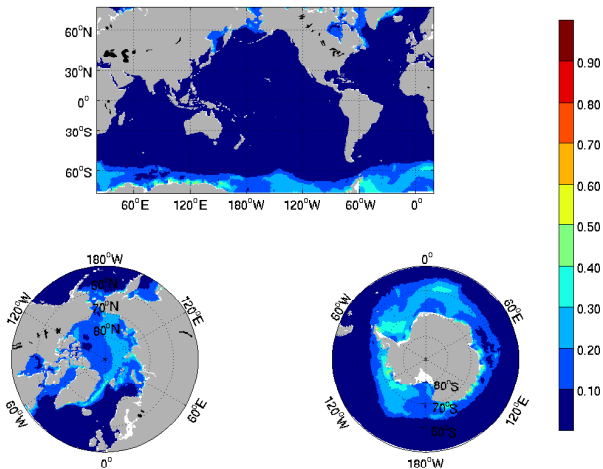Figure : Cost function

fit to seaice data

Figure : modeled-observed rms – sea ice concentration
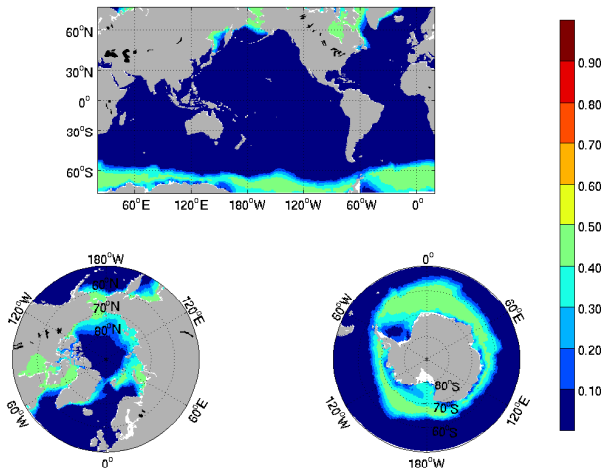
fit to seaice data

Figure : observed std – sea ice concentration
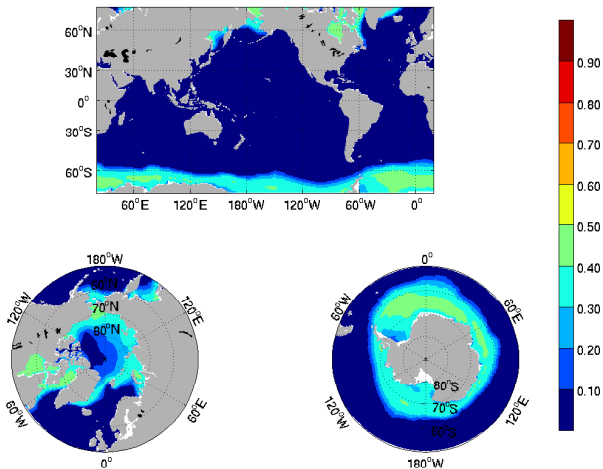
fit to seaice data

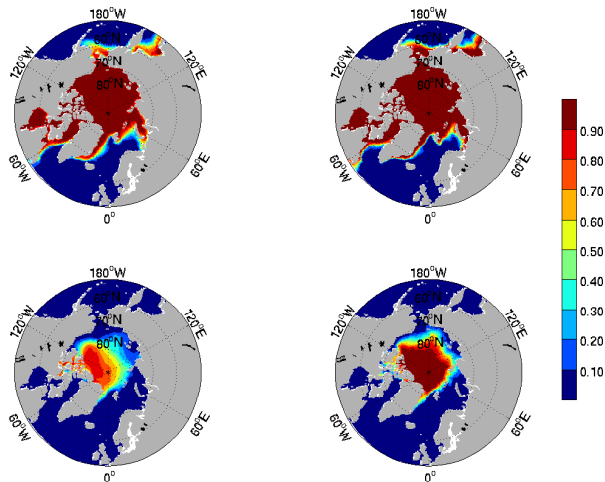Figure : modelled std – sea ice concentration

fit to seaice data

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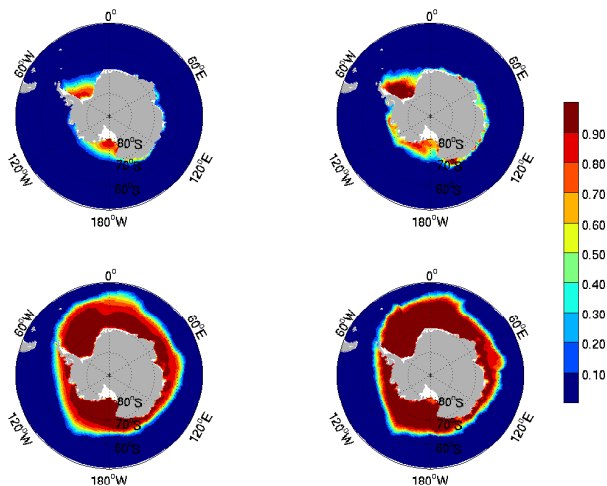
fit to seaice data

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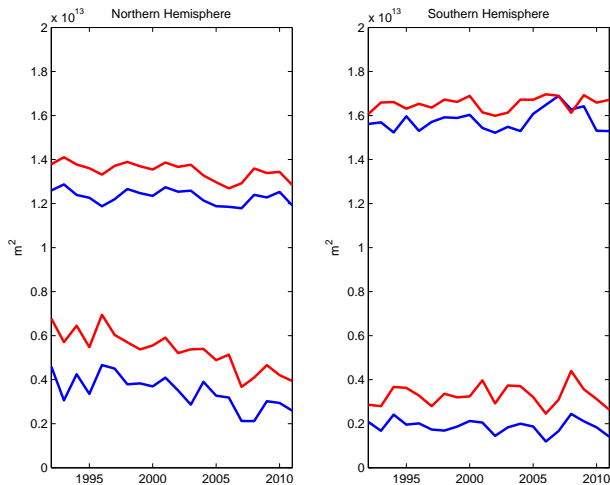
fit to seaice data

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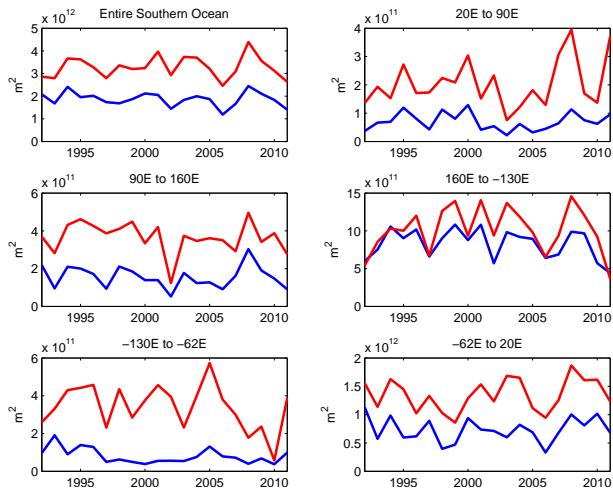
fit to seaice data

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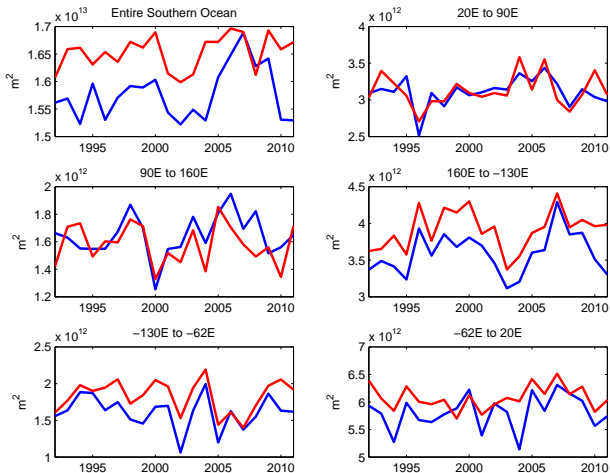
fit to seaice data

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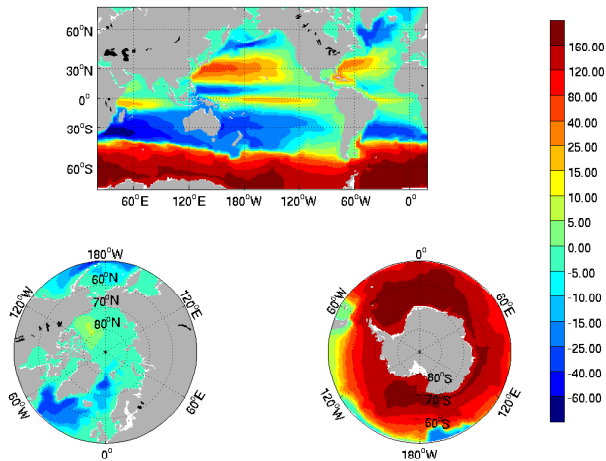
barotropic streamfunction

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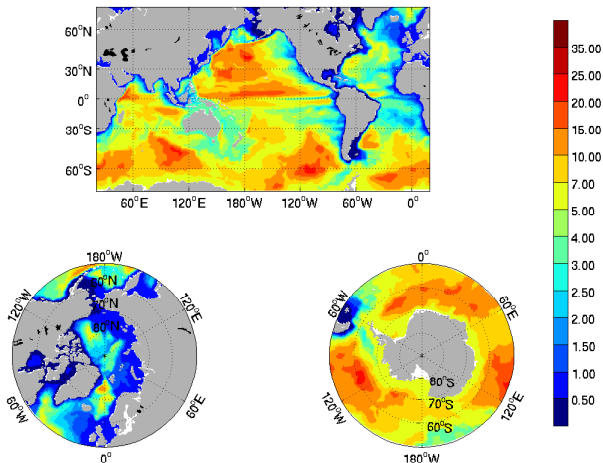
barotropic streamfunction

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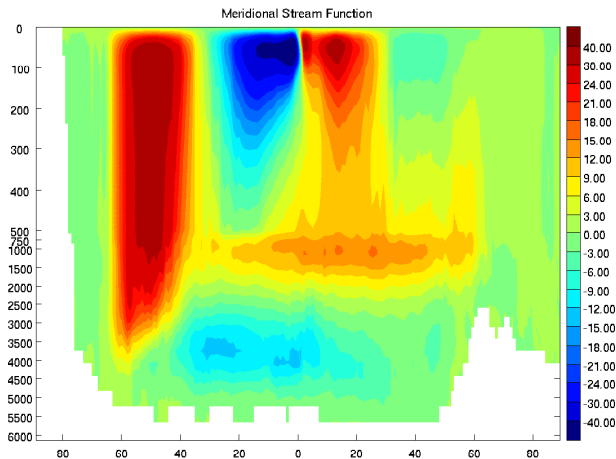
meridional streamfunction

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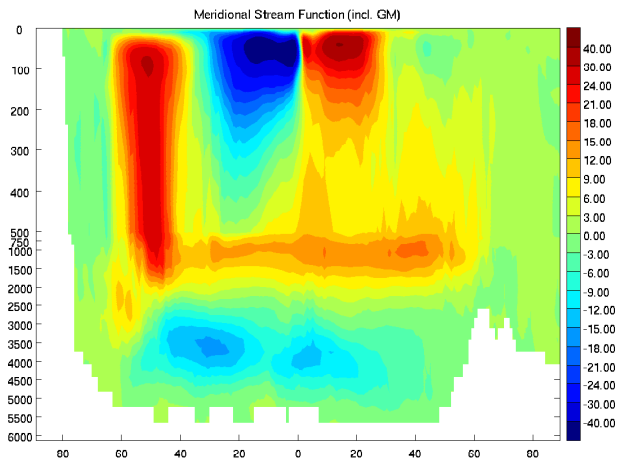
meridional streamfunction

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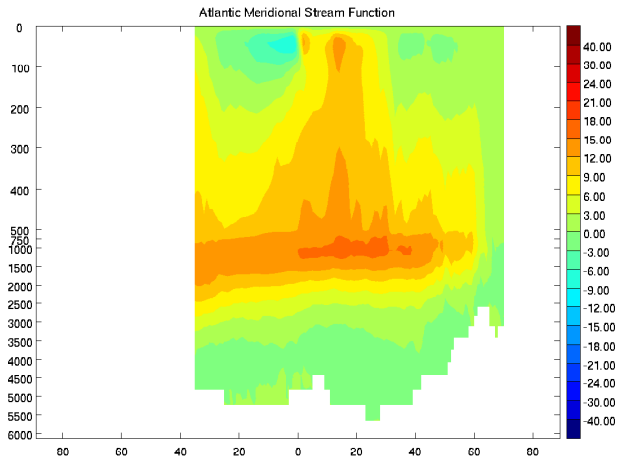
meridional streamfunction

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

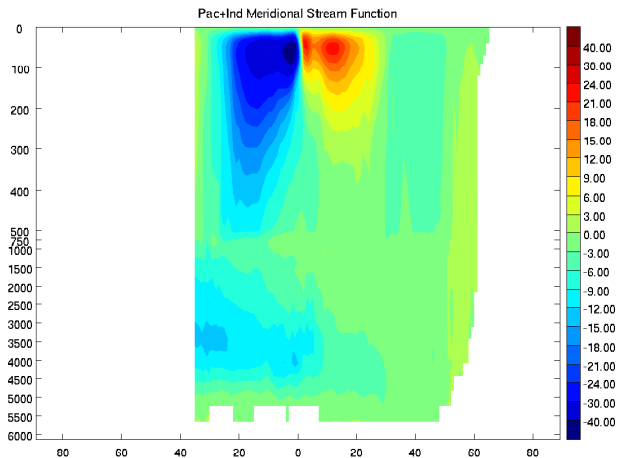# meridional streamfunction

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

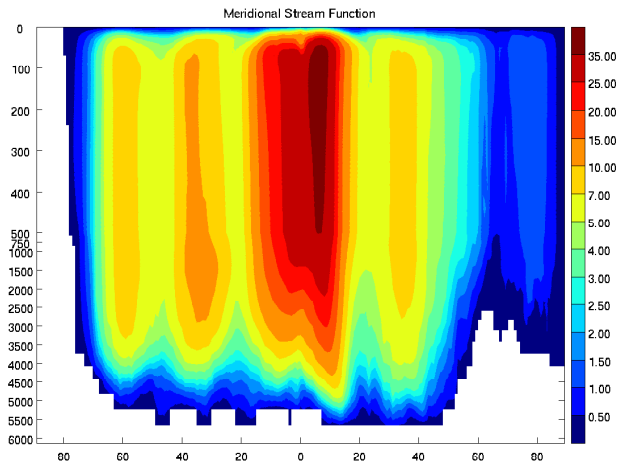# meridional streamfunction

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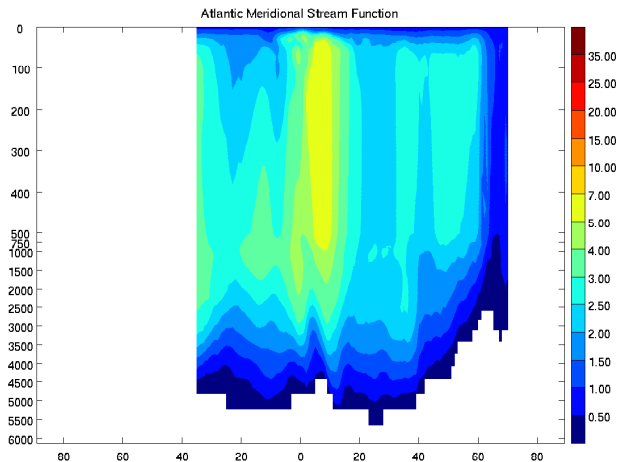
meridional streamfunction

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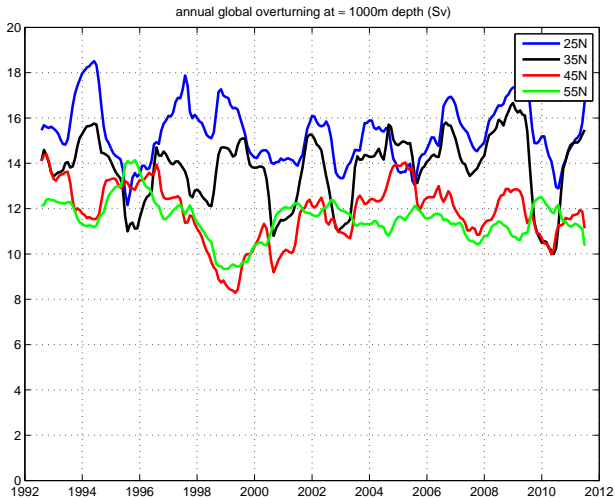
meridional streamfunction (time series)

Figure : annual global overturning at select latitudes at $\approx$ 1000m depth
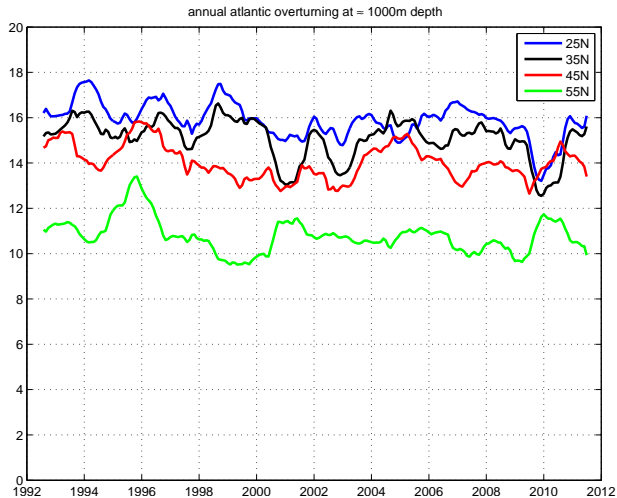
meridional streamfunction (time series)

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

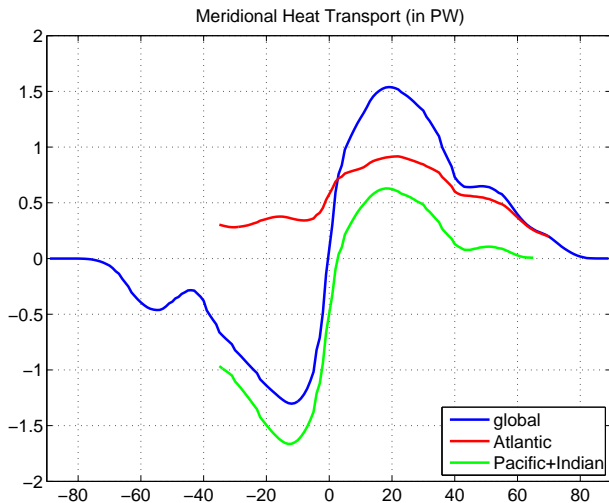# meridional heat transport

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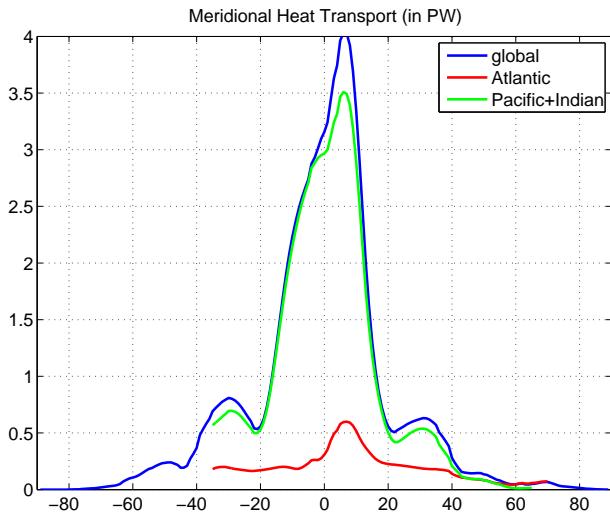
meridional heat transport

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

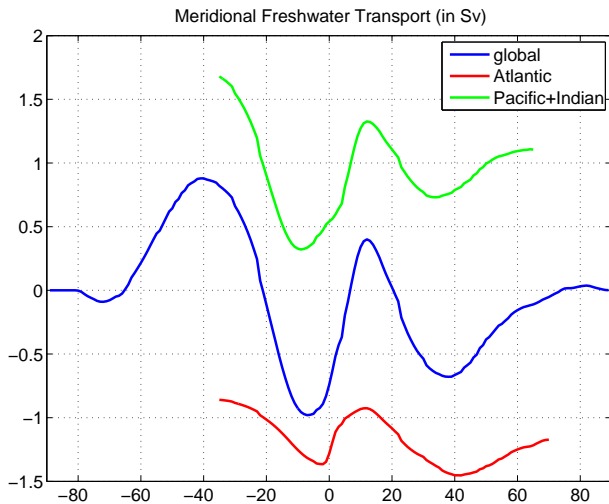# meridional freshwater transport

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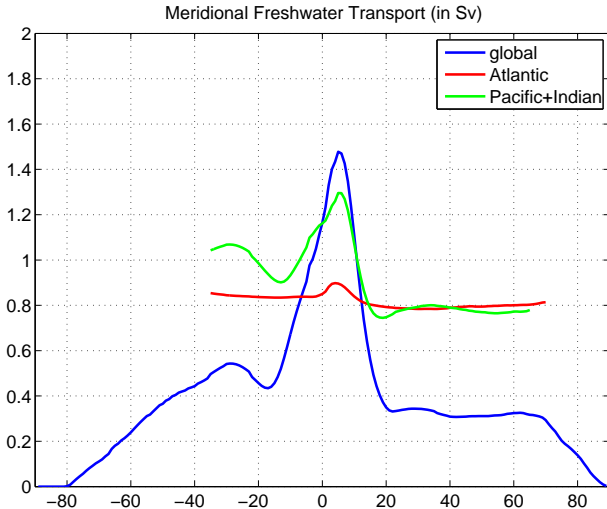
meridional freshwater transport

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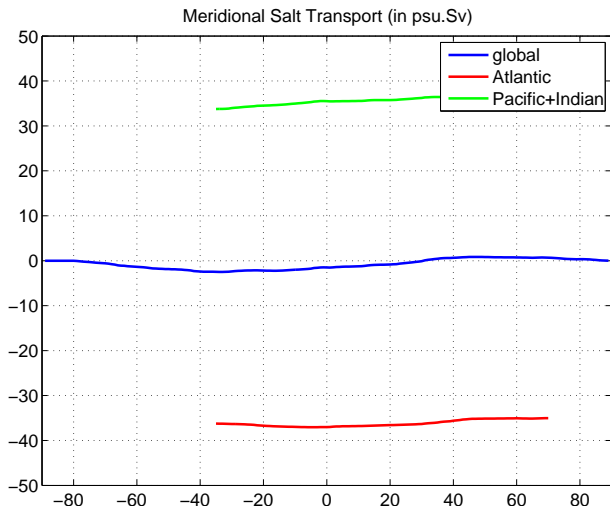
meridional salt transport

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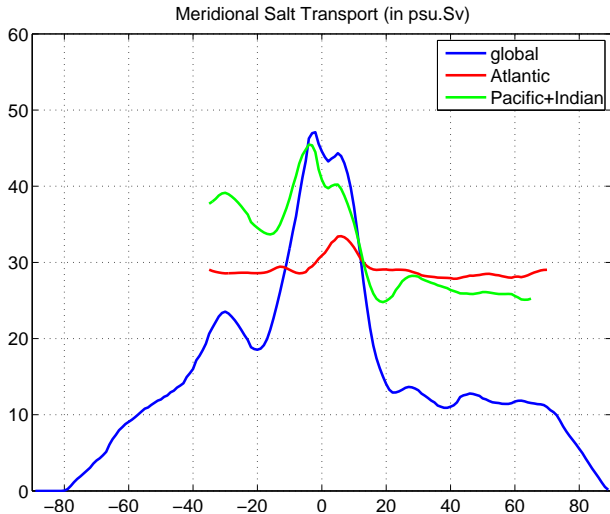
meridional salt transport

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

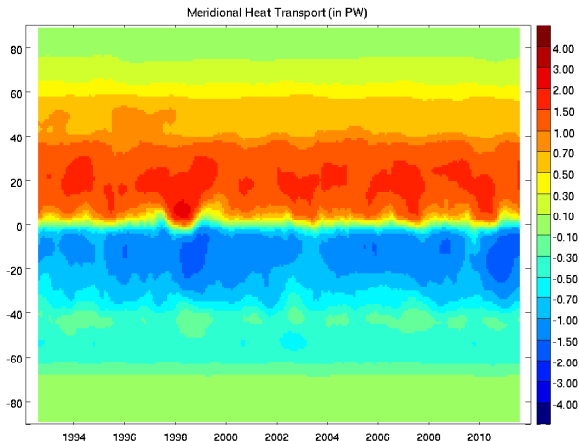# meridional transports (time series)

Figure : meridional heat transport (PW, annual mean)
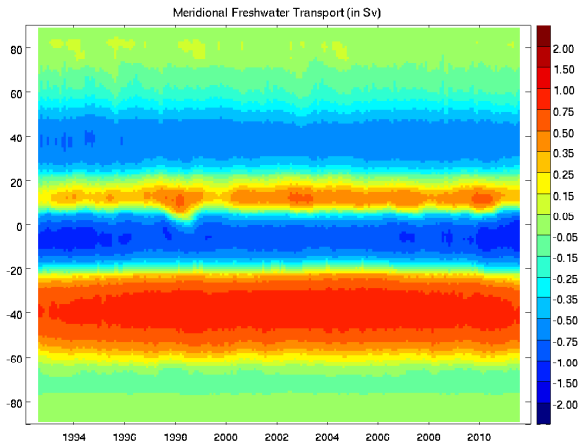
meridional transports (time series)

Figure : meridional freshwater transport (Sv, annual mean)

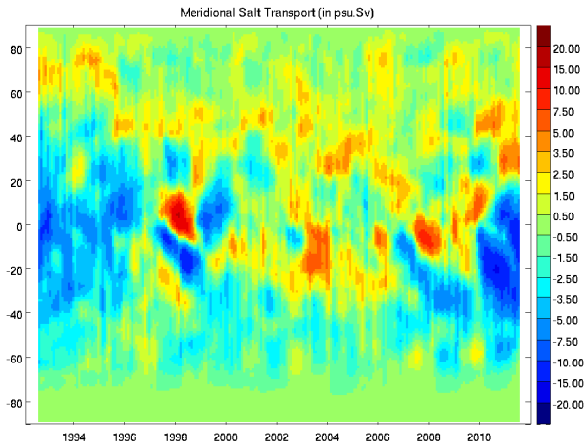# meridional transports (time series)

Figure : meridional salt transport (psu.Sv, annual mean)
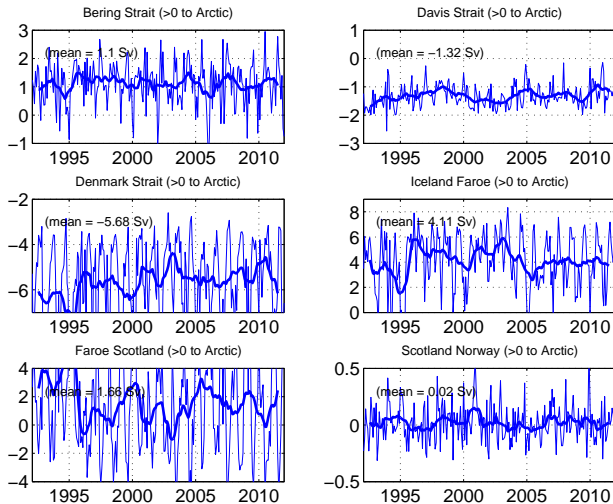
transects transport

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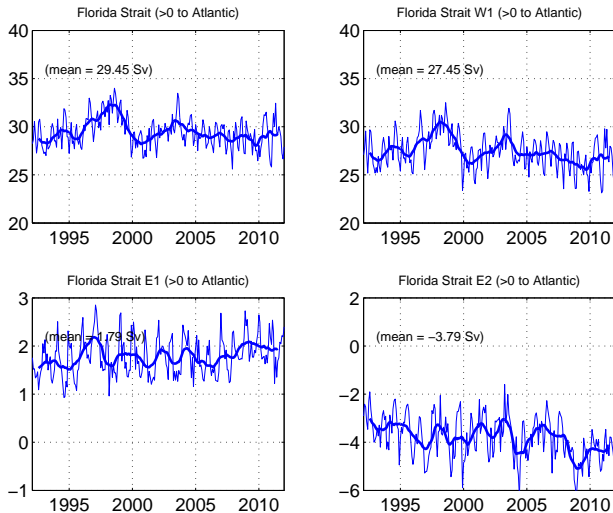
transects transport

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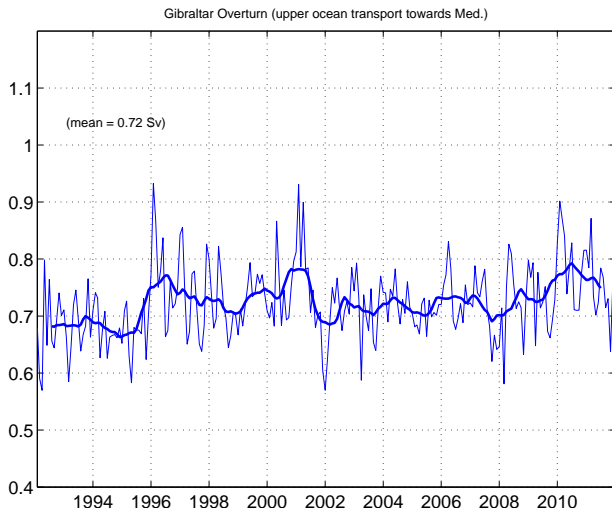
transects transport

Figure : Gibraltar Overturn (Sv, annual mean)
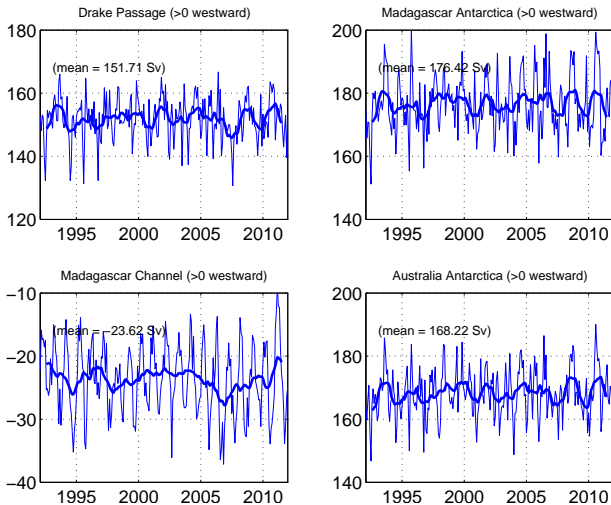
transects transport

Figure : ACC volume transports (Sv, annual mean)
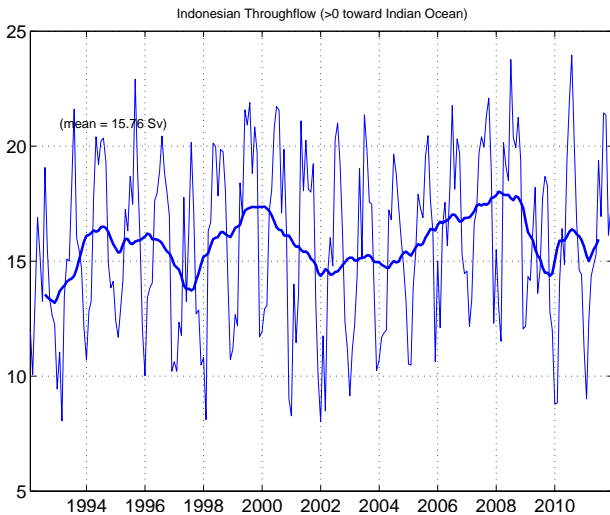
transects transport

Figure : Indonesian Throughflow (Sv, annual mean)
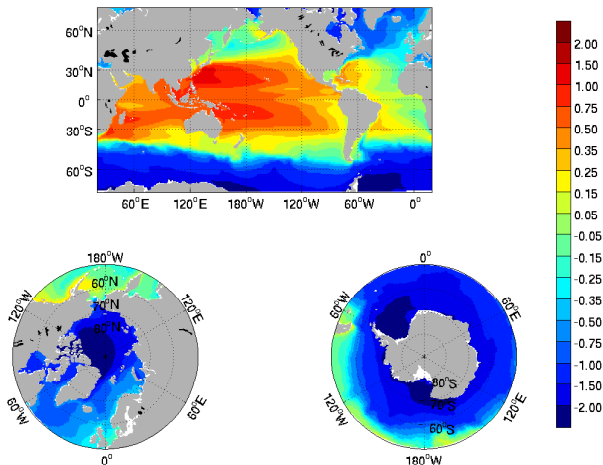
sea surface height

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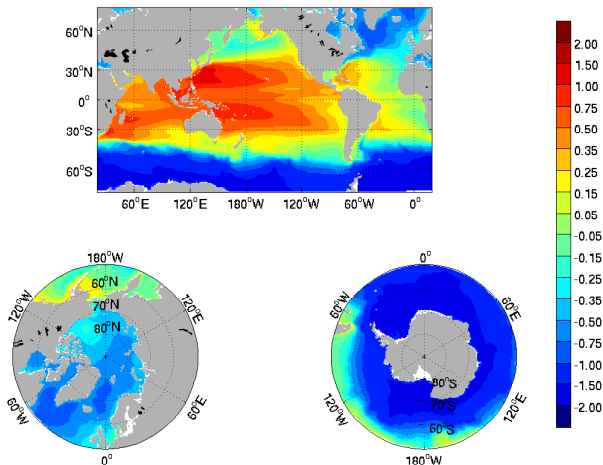
sea surface height

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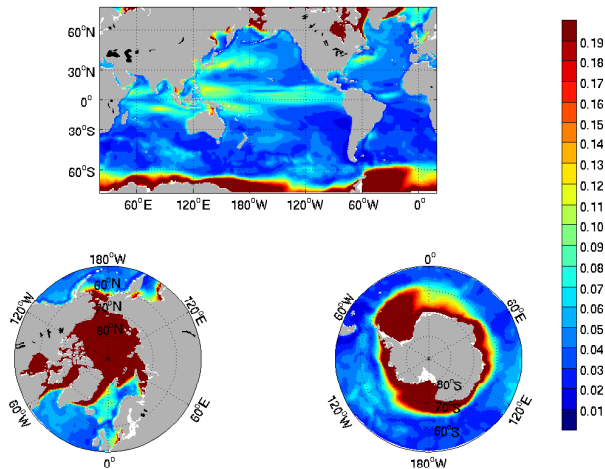
sea surface height

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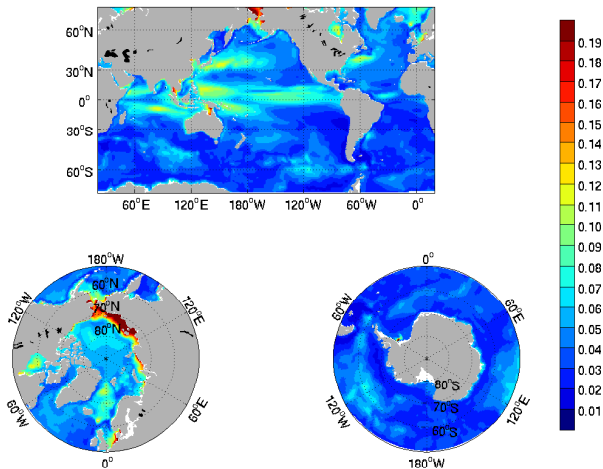
sea surface height

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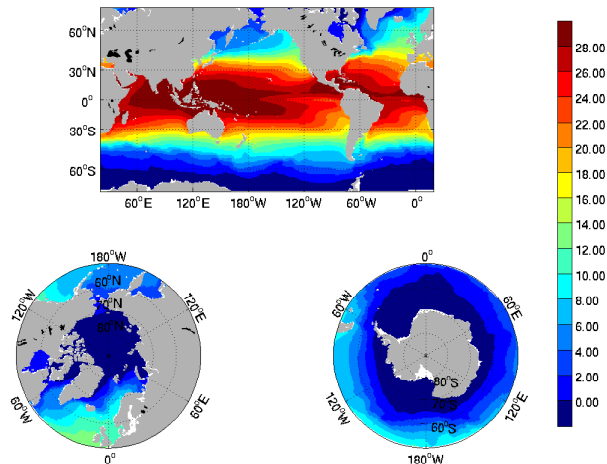(INCLUDING ice, in m)

3D state variables

Figure : 1992-2011 mean – temperature (in degC) at 5m
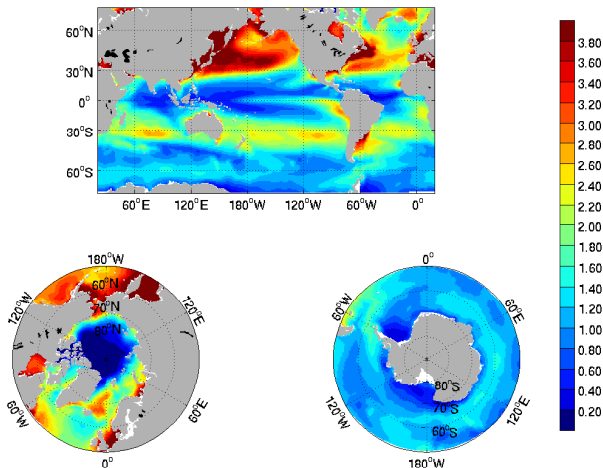
3D state variables

Figure : 1992-2011 standard deviation – temperature (in degC) at 5m
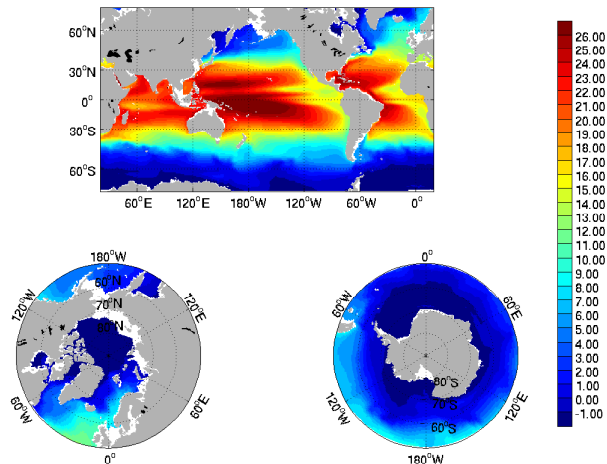
3D state variables

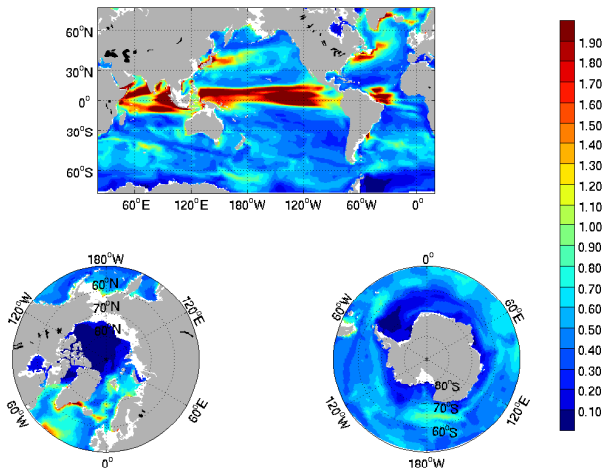Figure : 1992-2011 mean – temperature (in degC) at 105m

3D state variables

Figure : 1992-2011 standard deviation – temperature (in degC) at 105m
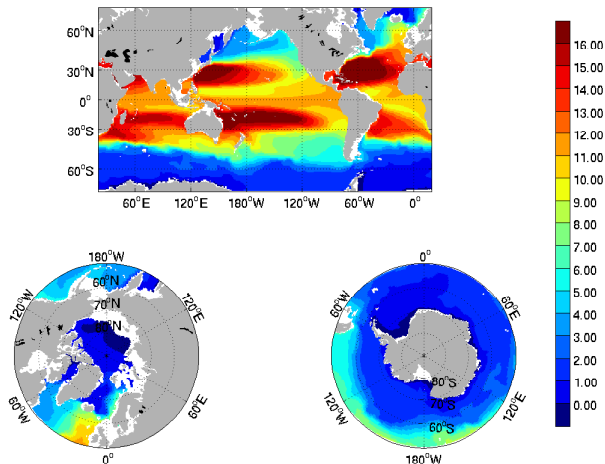
3D state variables

Figure : 1992-2011 mean – temperature (in degC) at 300m
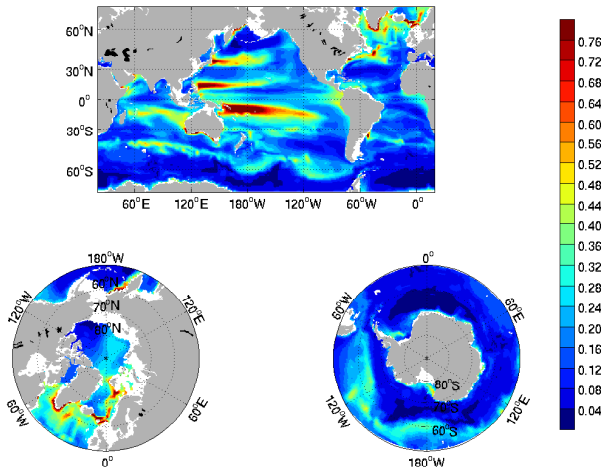
3D state variables

Figure : 1992-2011 standard deviation – temperature (in degC) at 300m
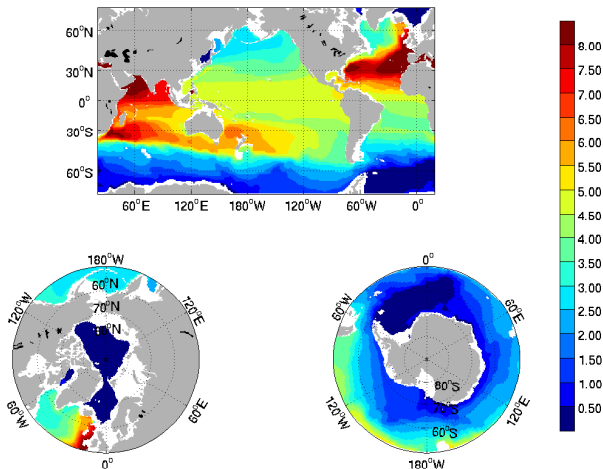
3D state variables

Figure : 1992-2011 mean – temperature (in degC) at 910m
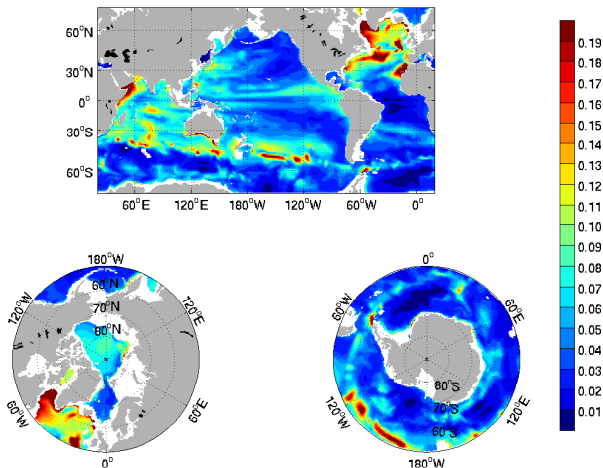
3D state variables

Figure : 1992-2011 standard deviation – temperature (in degC) at 910m
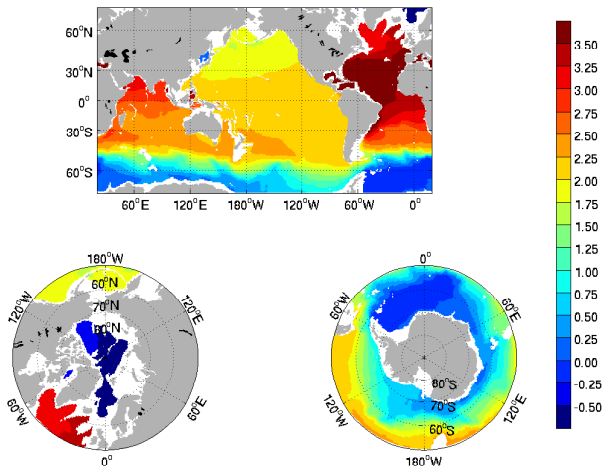
3D state variables

Figure : 1992-2011 mean – temperature (in degC) at 1914m
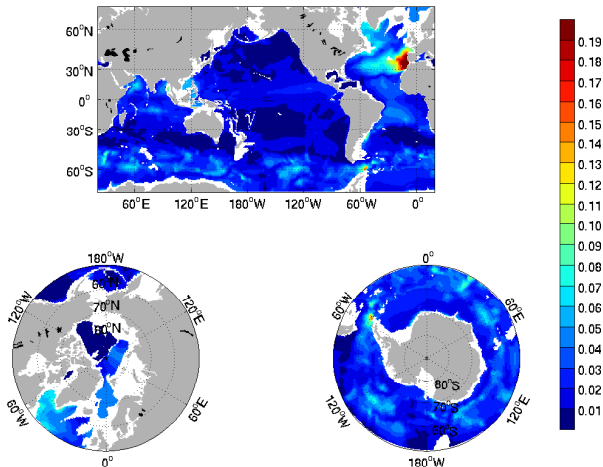
3D state variables

Figure : 1992-2011 standard deviation – temperature (in degC) at 1914m
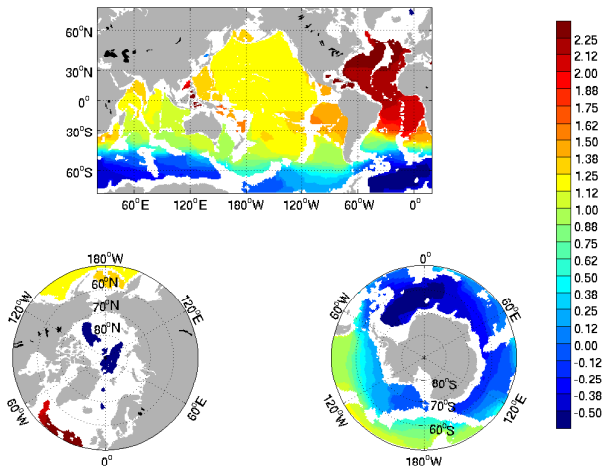
3D state variables

Figure : 1992-2011 mean – temperature (in degC) at 3581m
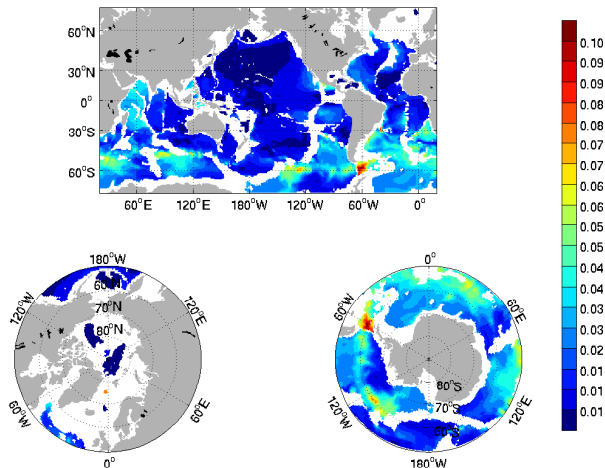
3D state variables

Figure : 1992-2011 standard deviation – temperature (in degC) at 3581m
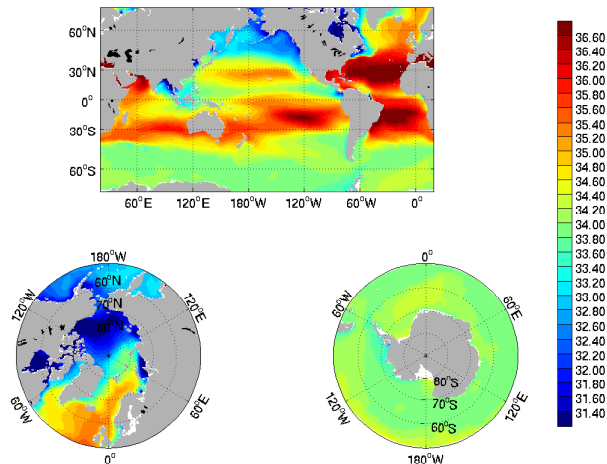
3D state variables

Figure : 1992-2011 mean – salinity (in psu) at 5m
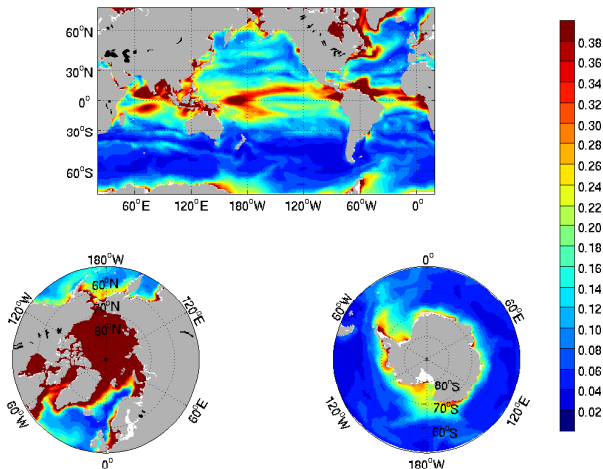
3D state variables

Figure : 1992-2011 standard deviation – salinity (in psu) at 5m
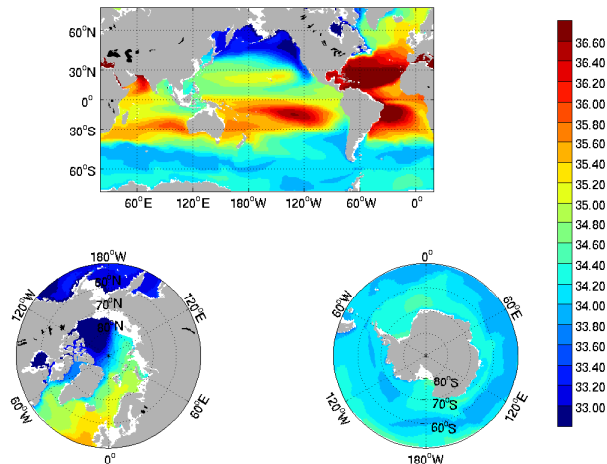
3D state variables

Figure : 1992-2011 mean – salinity (in psu) at 105m
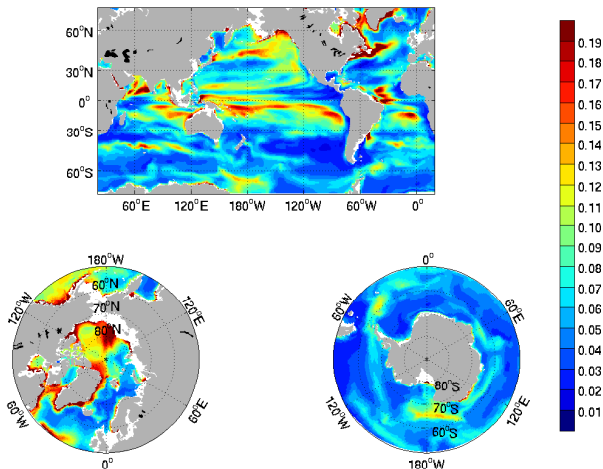
3D state variables

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
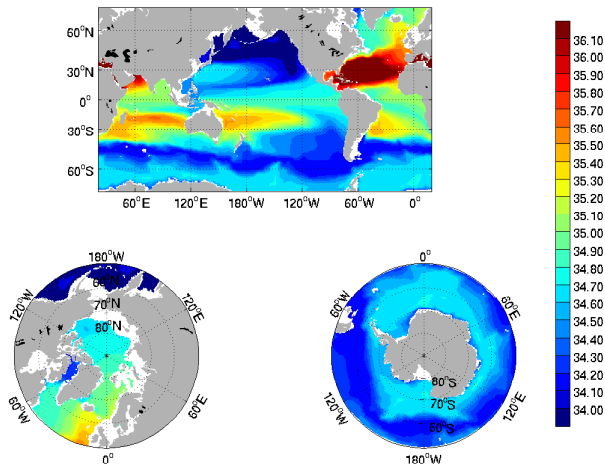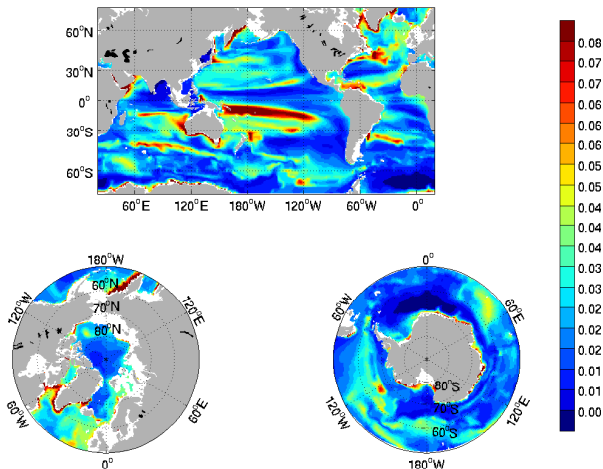
3D state variables
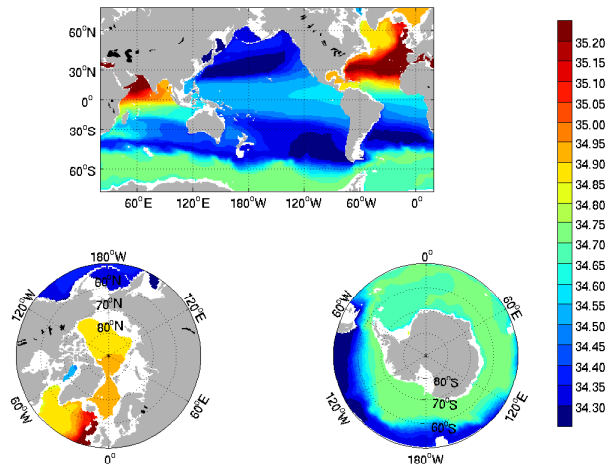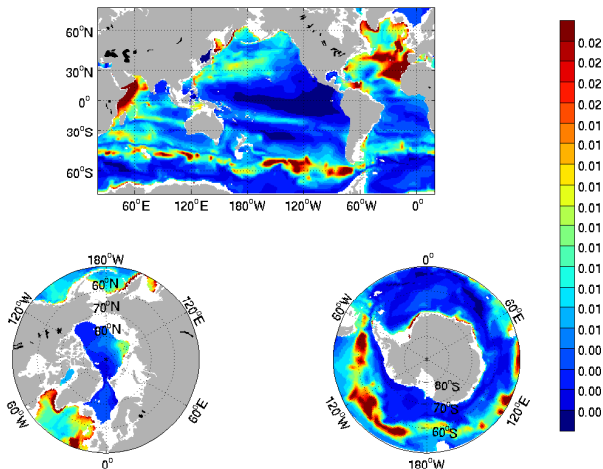

Figure : 1992-2011 mean – salinity (in psu) at 1914m

3D state variables

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

3D state variables
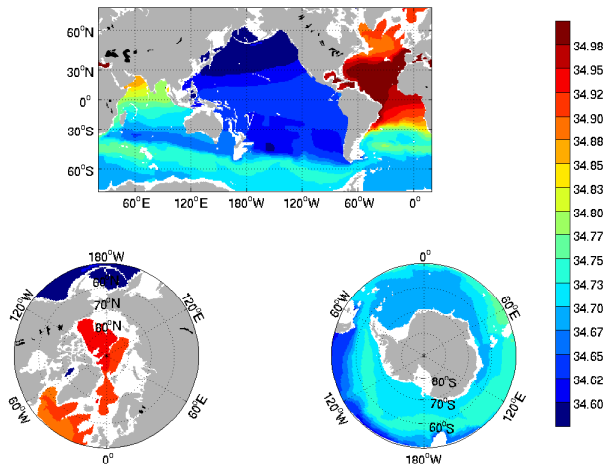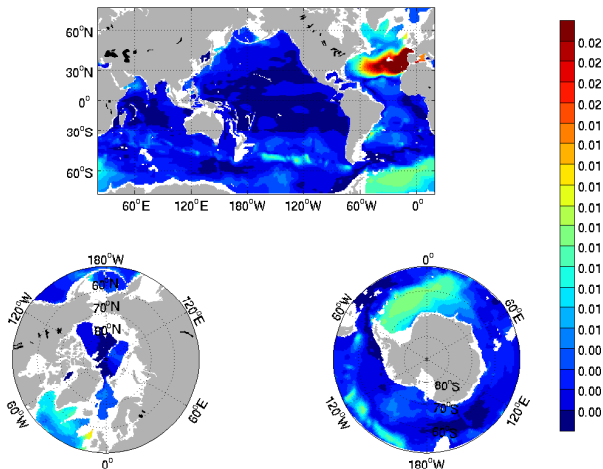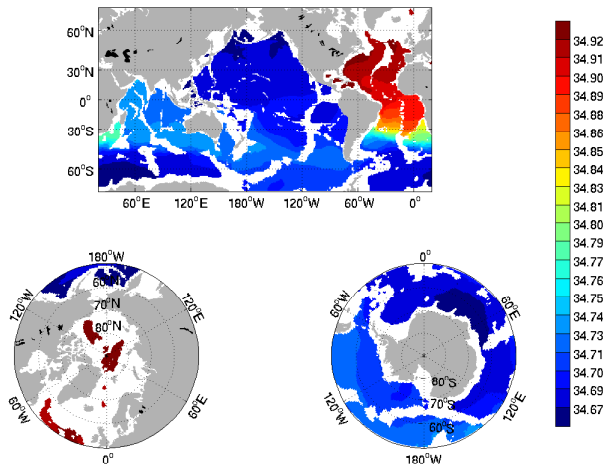

Figure : 1992-2011 mean – salinity (in psu) at 3581m
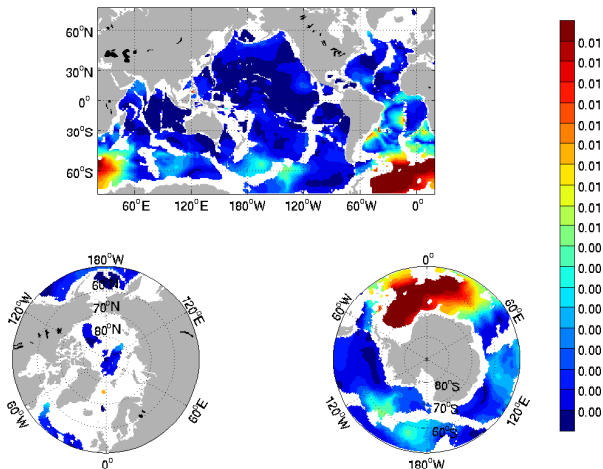
3D state variables

Figure : 1992-2011 standard deviation – salinity (in psu) at 3581m
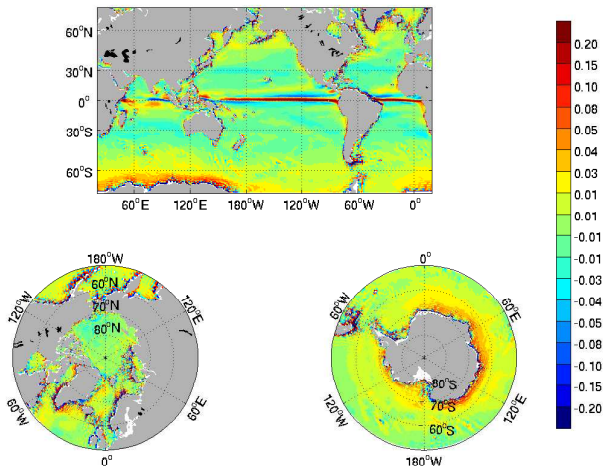
3D state variables

Figure : 1992-2011 mean – vertical velocity (in mm/year) at 15m
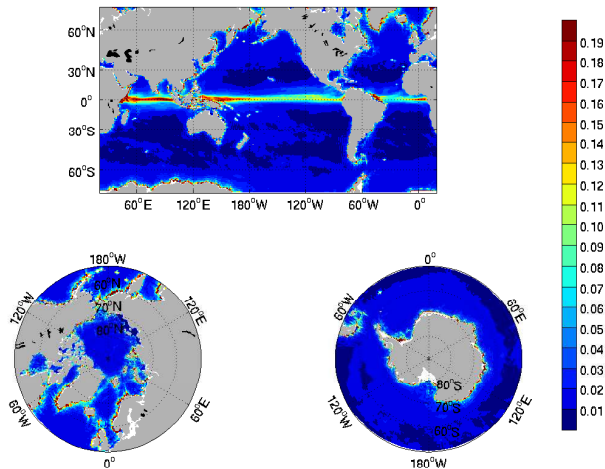
3D state variables

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
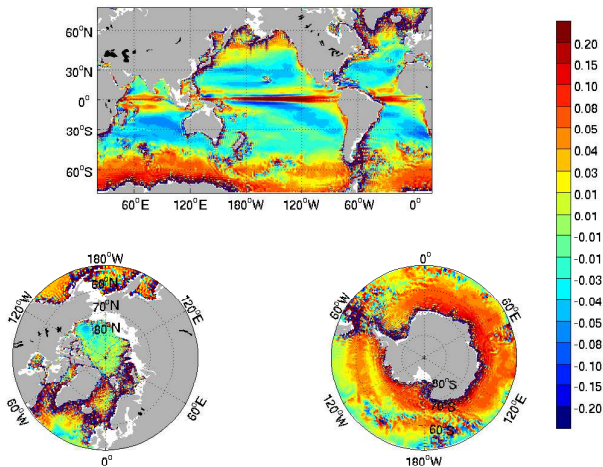
3D state variables

Figure : 1992-2011 mean – vertical velocity (in mm/year) at 910m
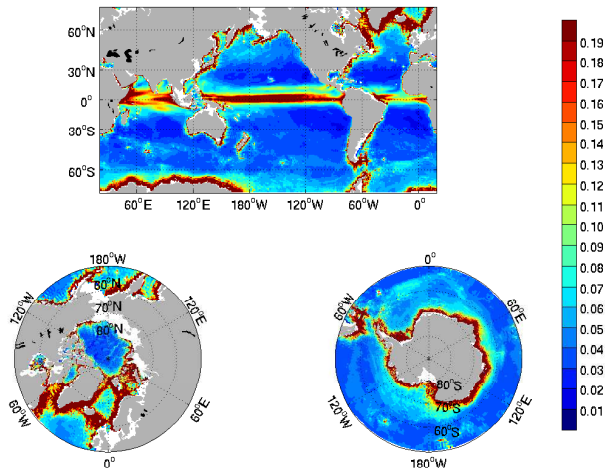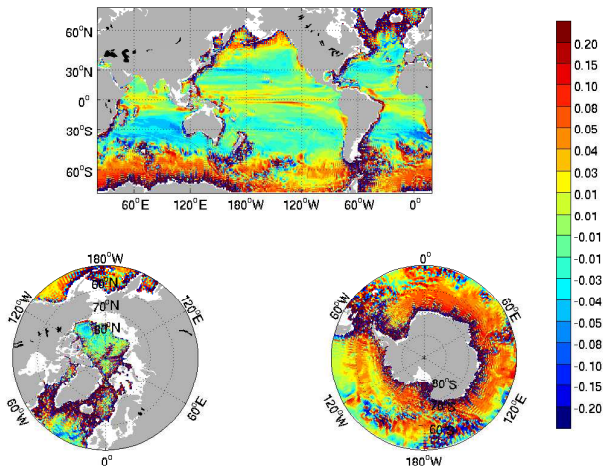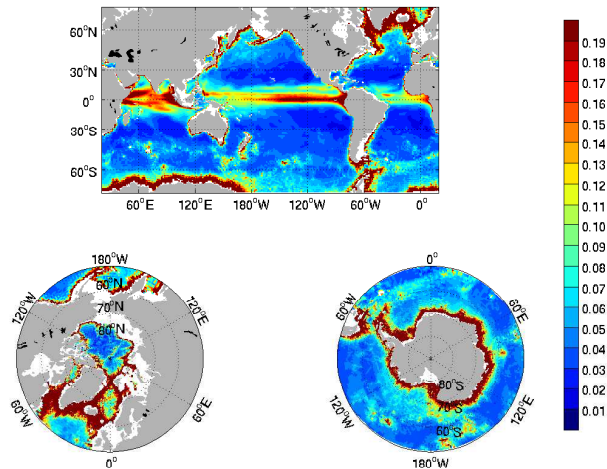
3D state variables

Figure : 1992-2011 standard deviation – vertical velocity (in mm/year) at 910m
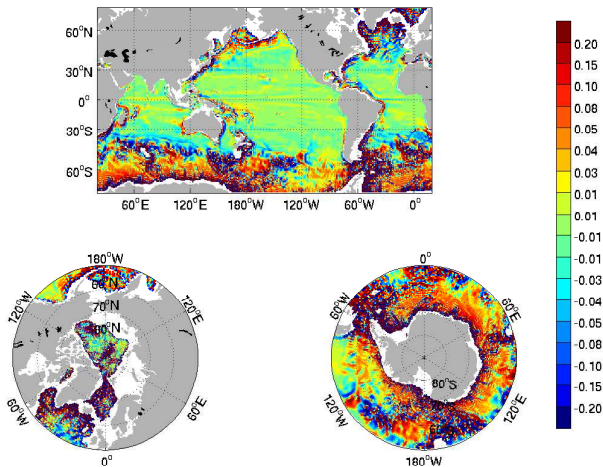
3D state variables

Figure : 1992-2011 mean – vertical velocity (in mm/year) at 1914m
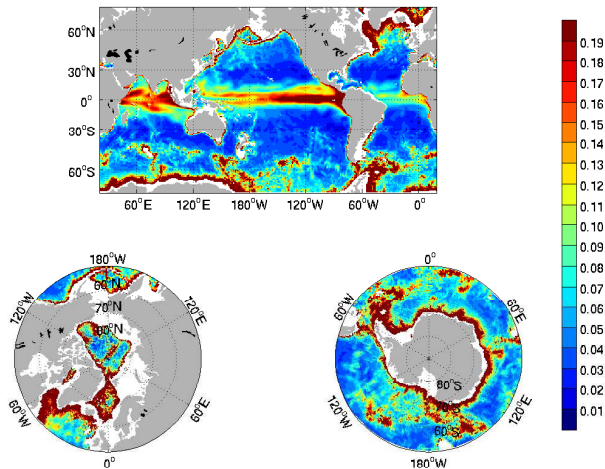
3D state variables

Figure : 1992-2011 standard deviation – vertical velocity (in mm/year) at 1914m
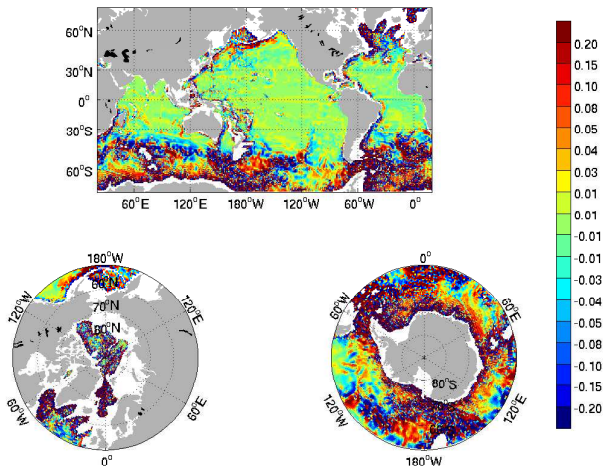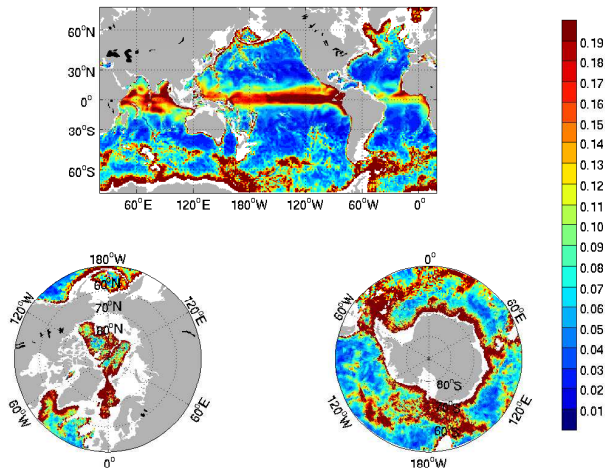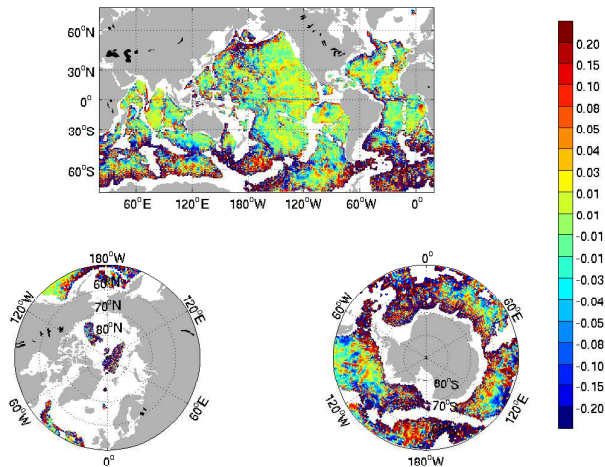
3D state variables

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

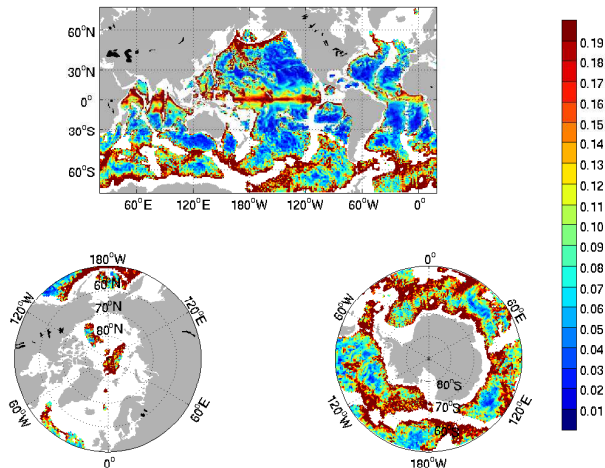# 3D state variables

Figure : 1992-2011 standard deviation – vertical velocity (in mm/year) at 3581m
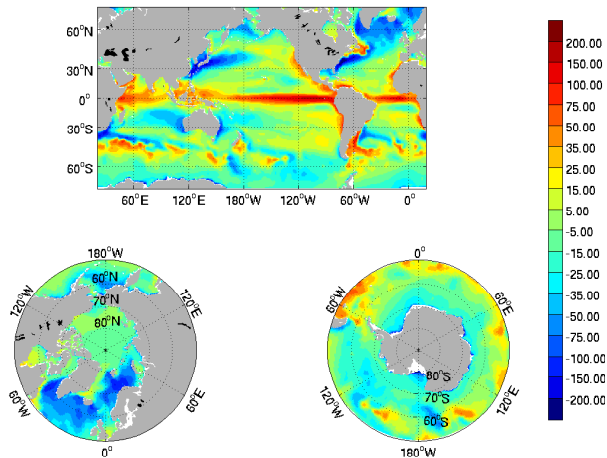
air-sea heat flux

Figure : 1992-2011 mean – QNET to ocean+ice (W/m^2)

air-sea heat flux

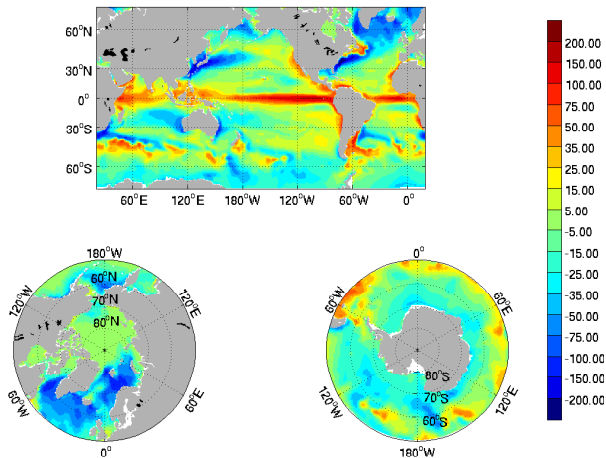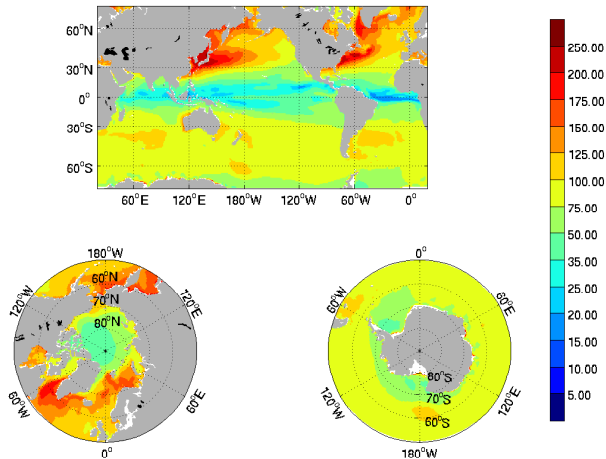Figure : 1992-2011 mean – QNET to ocean (W/m²)

air-sea heat flux

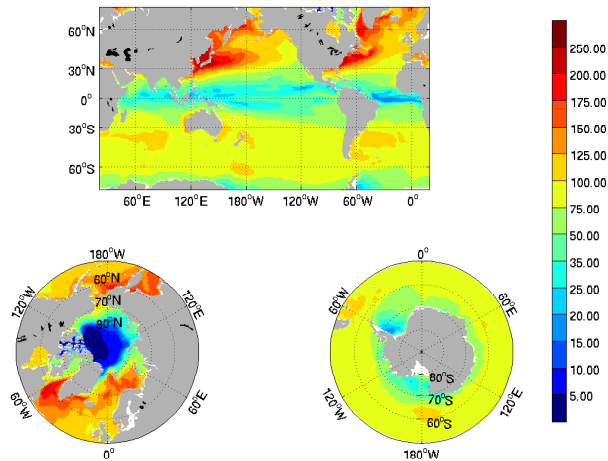Figure : 1992-2011 standard deviation – QNET to ocean+ice (W/m^2)

air-sea heat flux

Figure : 1992-2011 standard deviation – QNET to ocean (W/m^2)
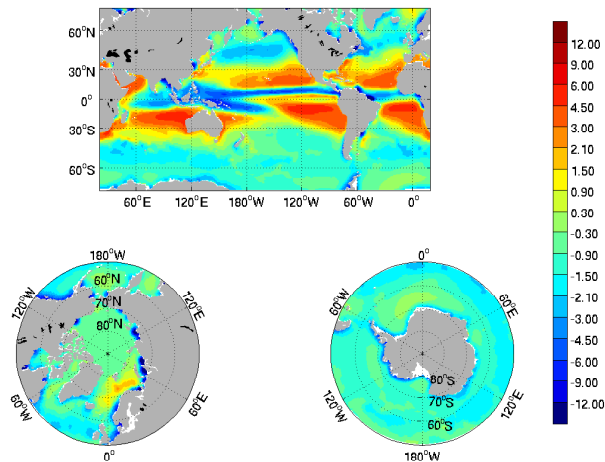
air-sea freshwater flux

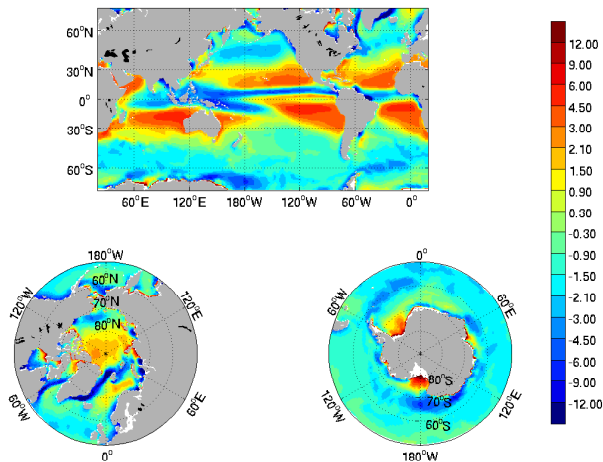Figure : 1992-2011 mean – E-P-R from ocean+ice (mm/day)

air-sea freshwater flux

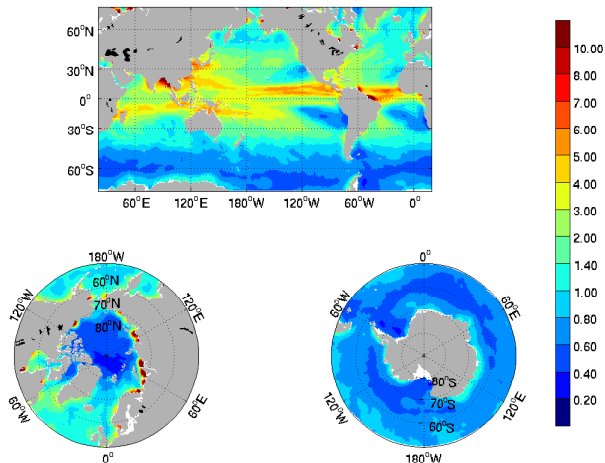Figure : 1992-2011 mean – E-P-R from ocean (mm/day)

air-sea freshwater flux

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

air-sea freshwater flux
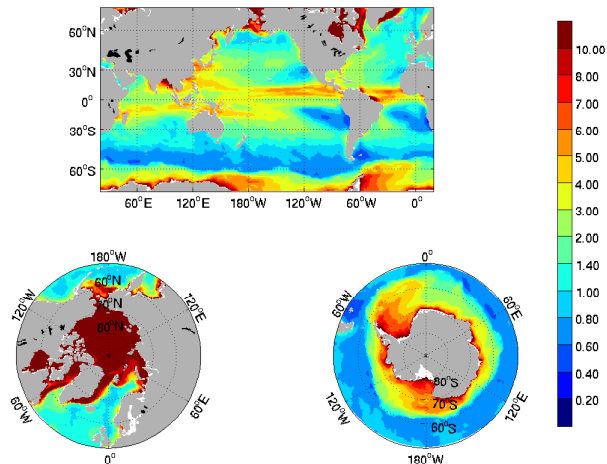

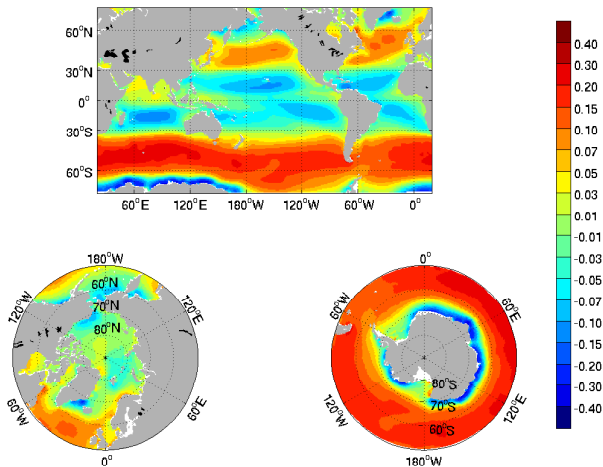Figure : 1992-2011 standard deviation – E-P-R to ocean (W/m^2)

surface wind stress

Figure : 1992-2011 mean – zonal wind stress (N/m^2)

surface wind stress
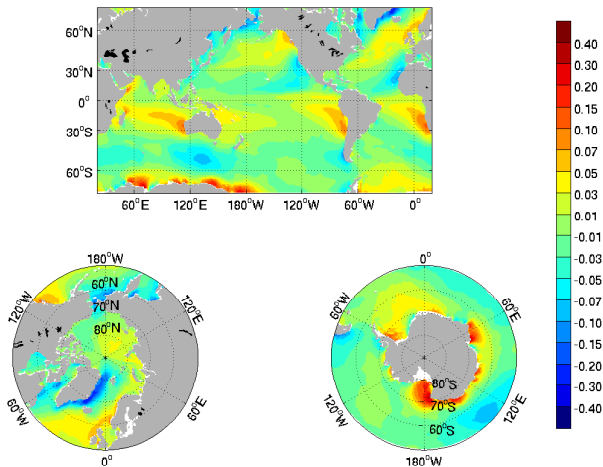

Figure : 1992-2011 mean – meridional wind stress (N/m^2)

surface wind stress
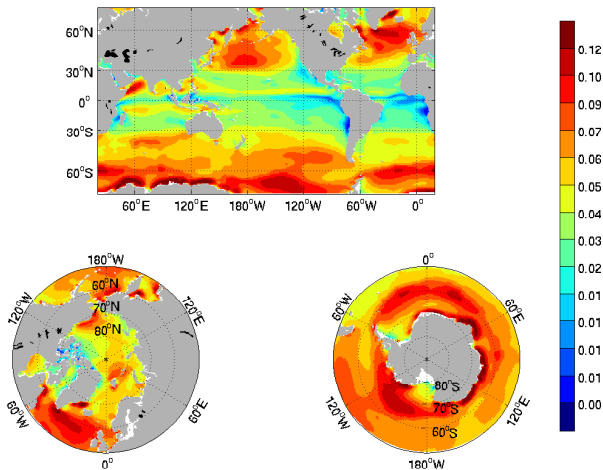

Figure : 1992-2011 standard deviation – tauZ (W/m^2)

surface wind stress
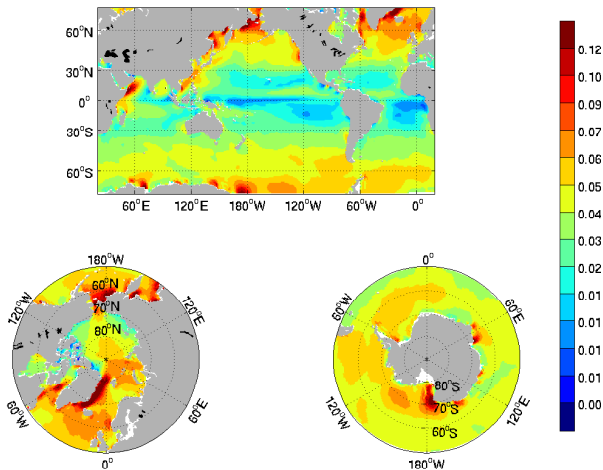

Figure : 1992-2011 standard deviation – tauM (W/m^2)

zonal mean tendencies

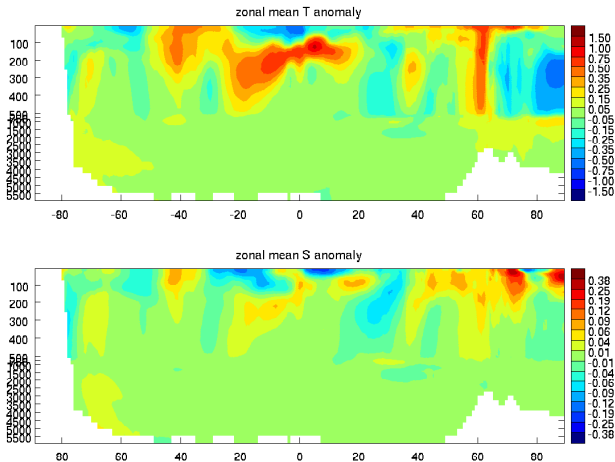Figure : 1992-2011 , last year minus first year – zonal mean temperature (degC; top) and salinity (psu; bottom)

equatorial sections

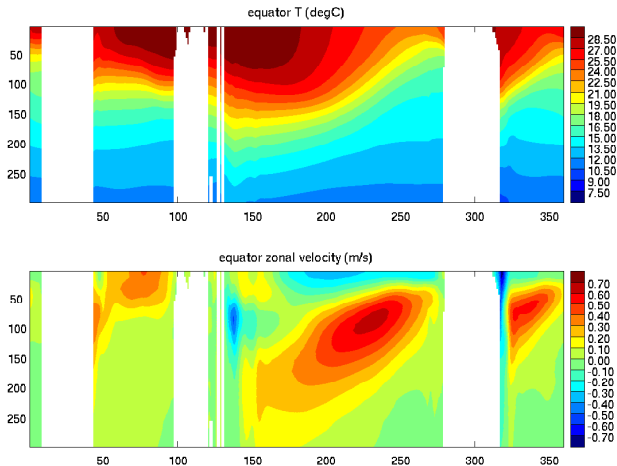Figure : 1992-2011 mean – equator temperature (degC;top) and zonal velocity (m/s;bottom)

global mean properties

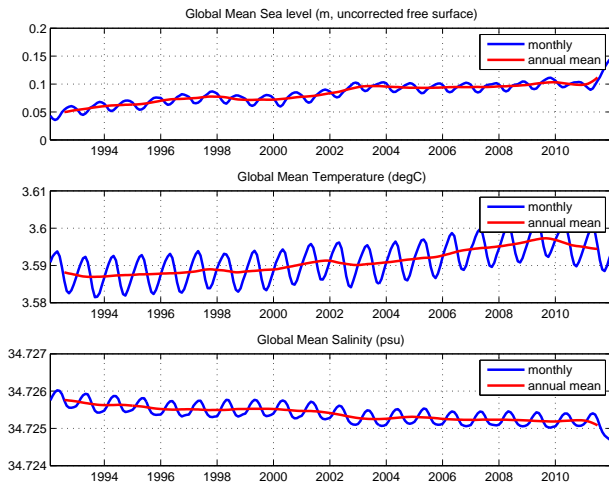Figure : global mean T (degC; top) and S (psu; bottom)

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 ≈ -75

zonal mean properties

Figure : mean temperature (top; K) and salinity (bottom; psu) minus first year at lat ≈ -65
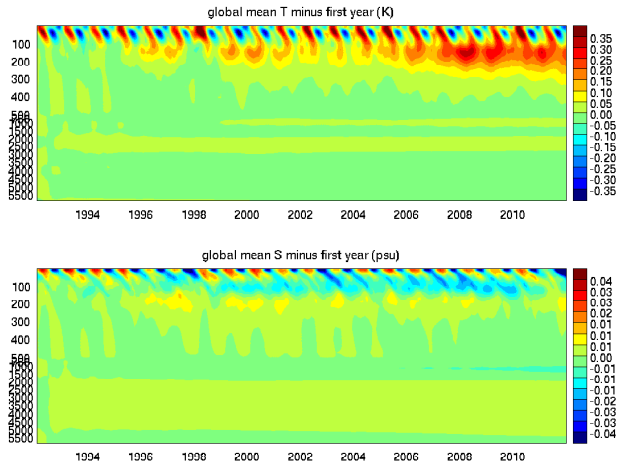
zonal mean properties

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

zonal mean properties

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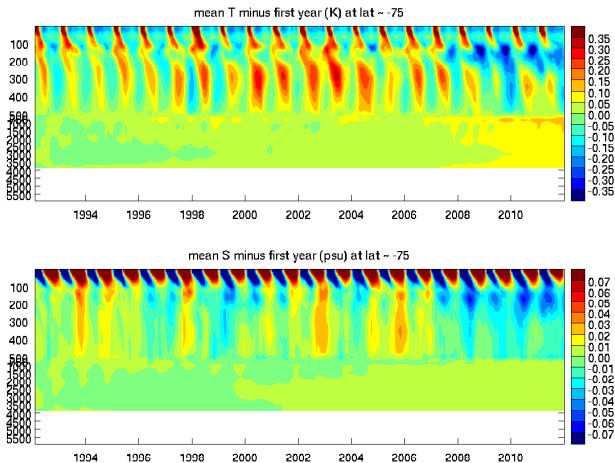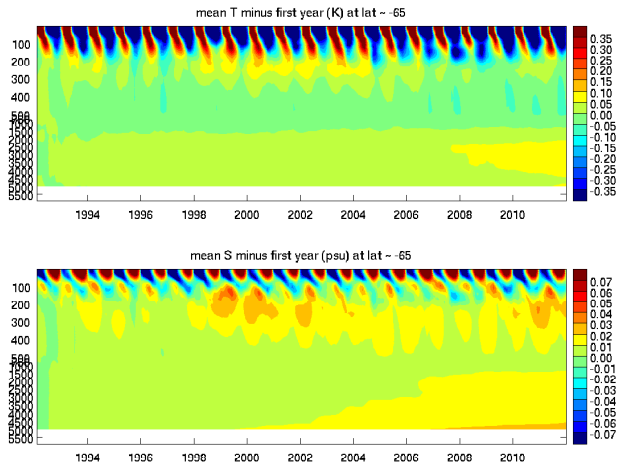minus first year at lat ≈ -25

zonal mean properties

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

zonal mean properties

Figure : mean temperature (top; K) and salinity (bottom; psu) minus first year at lat ≈ 65
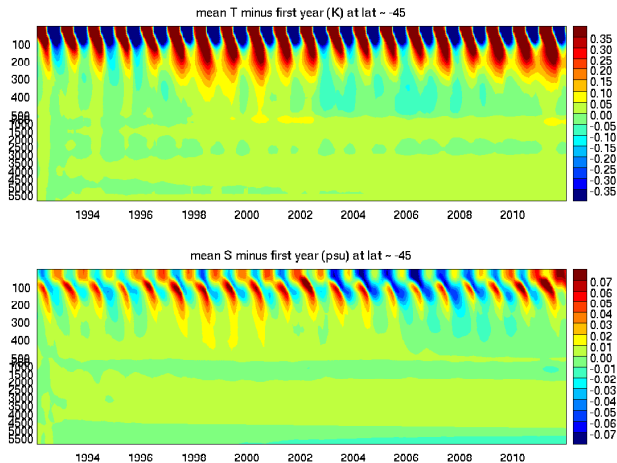
zonal mean properties

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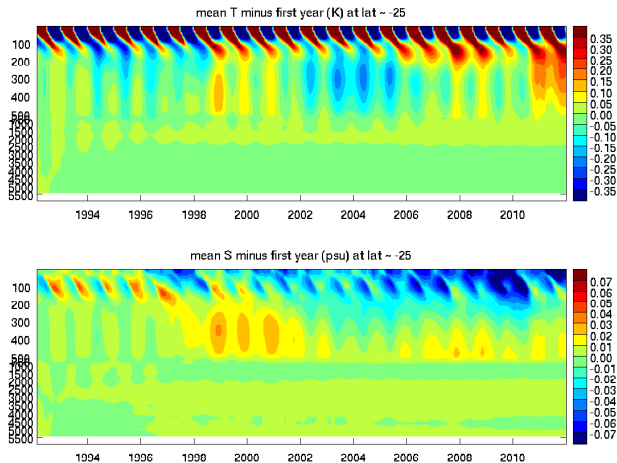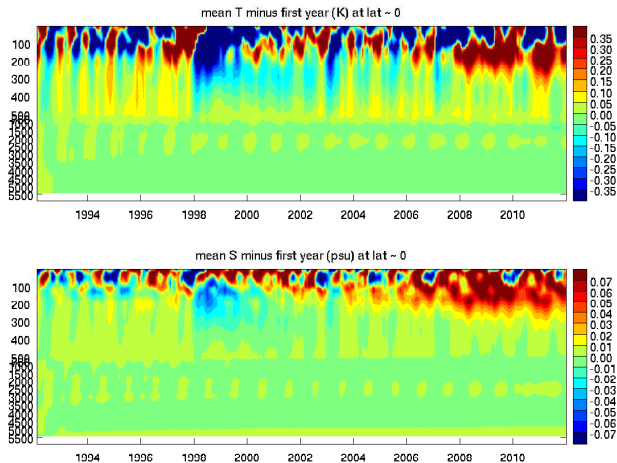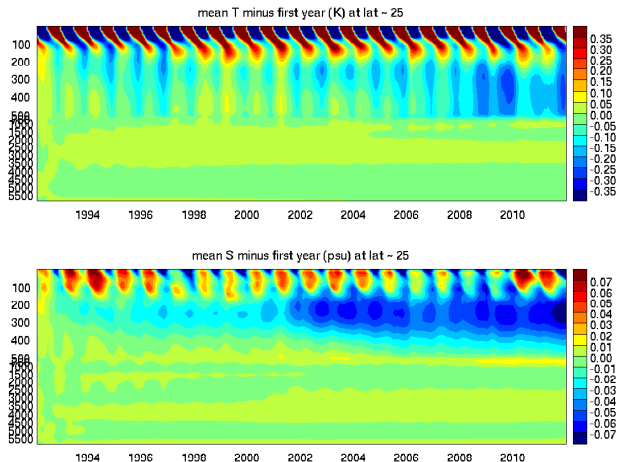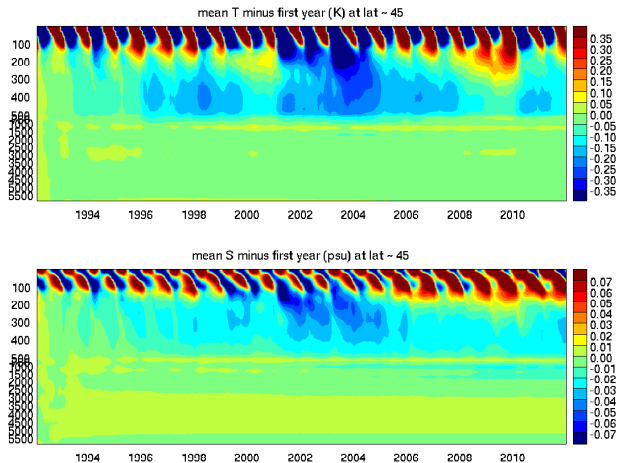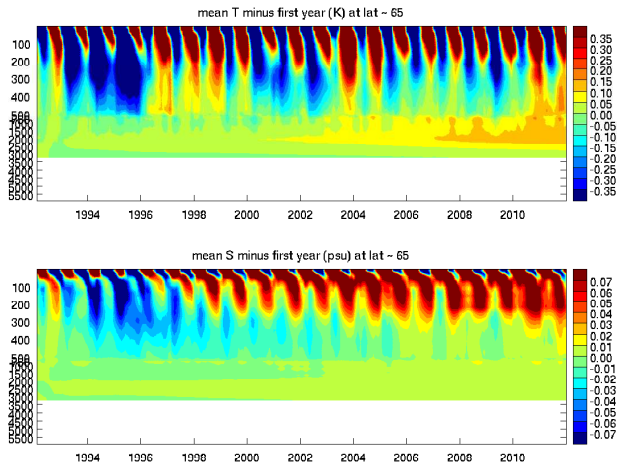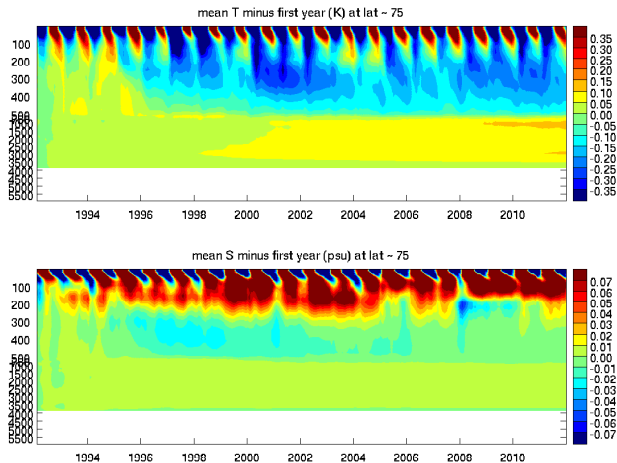
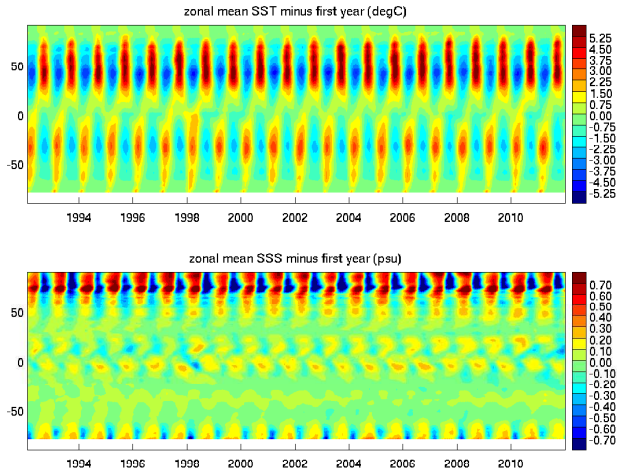# zonal mean properties (surface)

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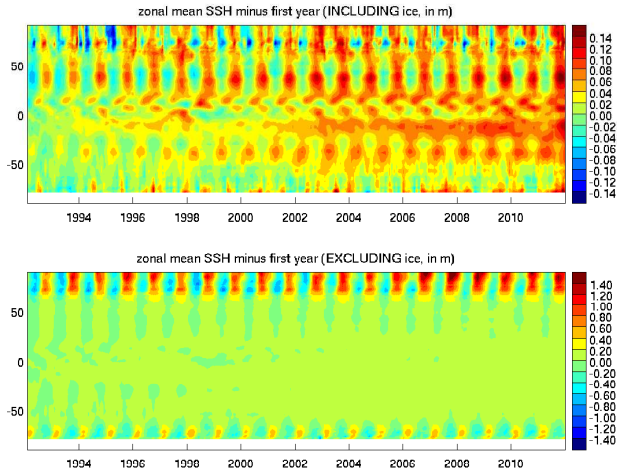
zonal mean properties (surface)

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

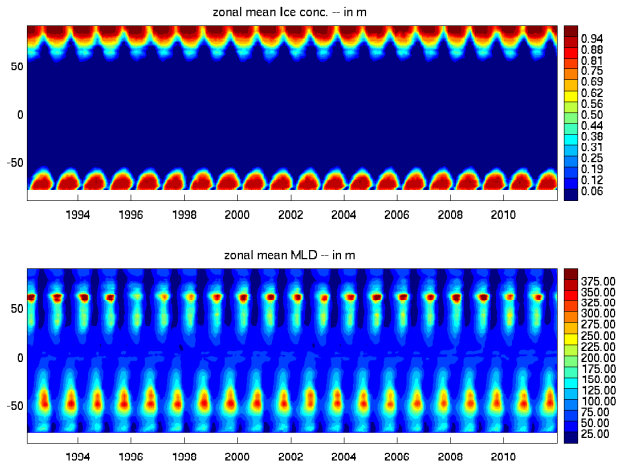# zonal mean properties (surface)

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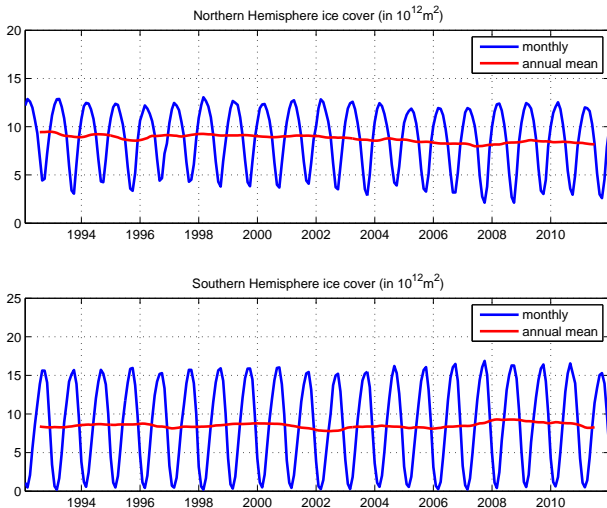
seaice time series

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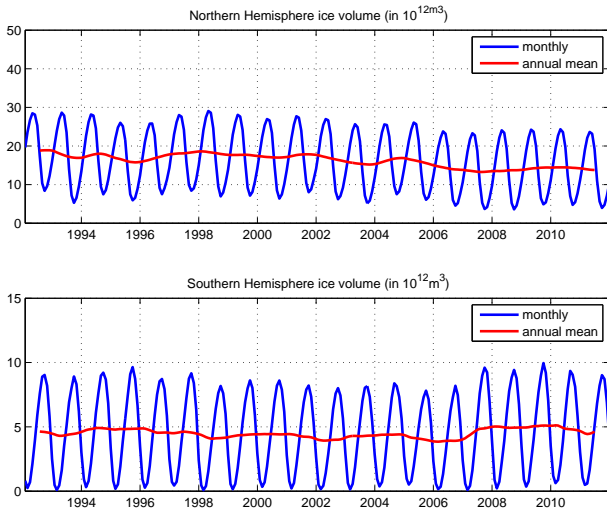
seaice time series

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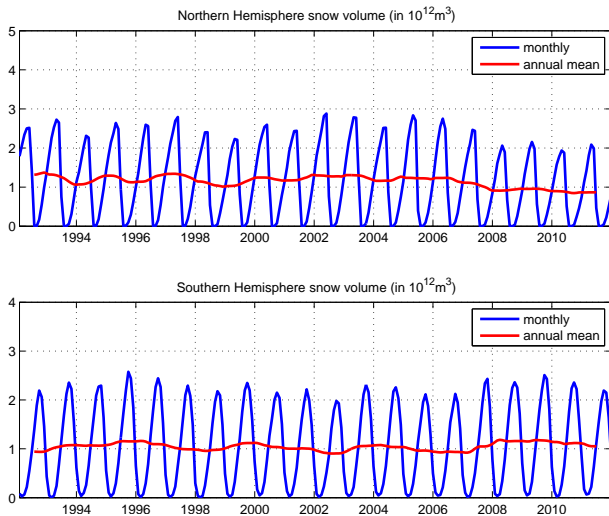
seaice time series

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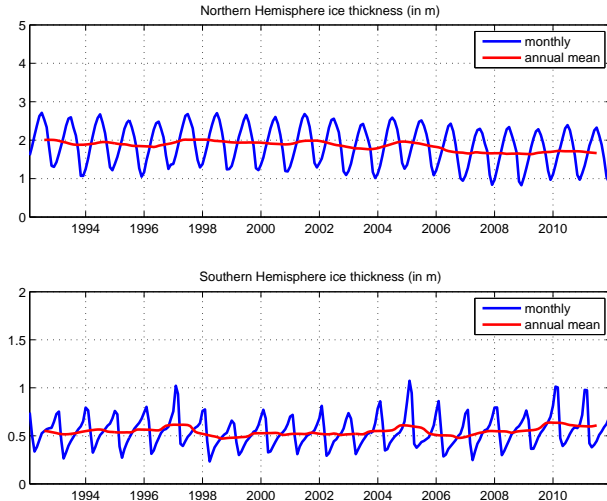
seaice time series

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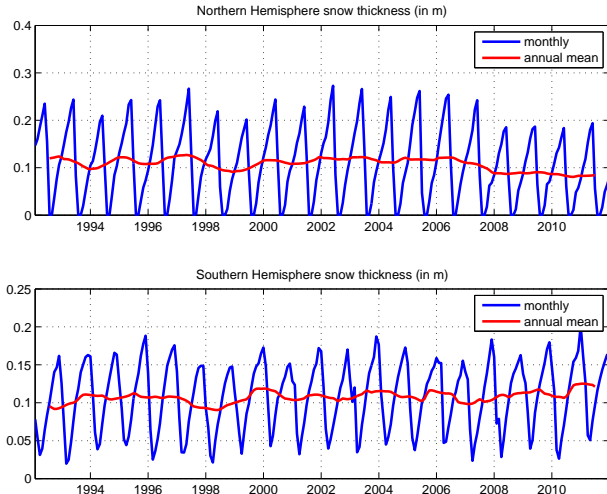
seaice time series

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

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

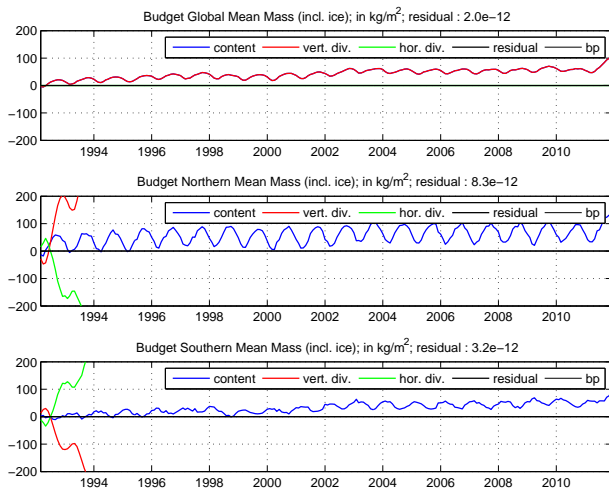Figure : 1992-2011 global (upper) north (mid) and south (lower),
mass budget (ocean+ice) in kg/m^2.

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

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

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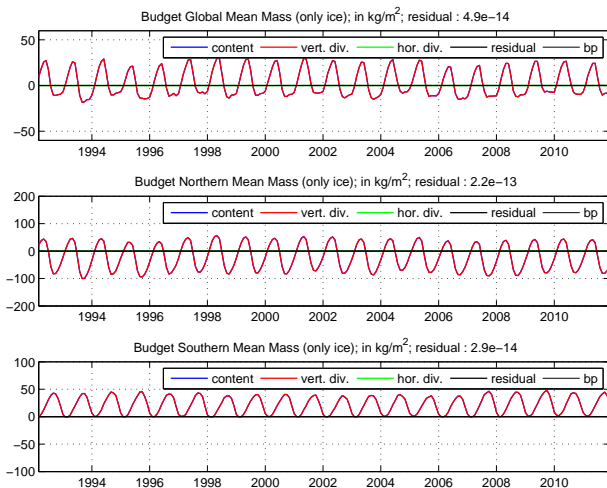

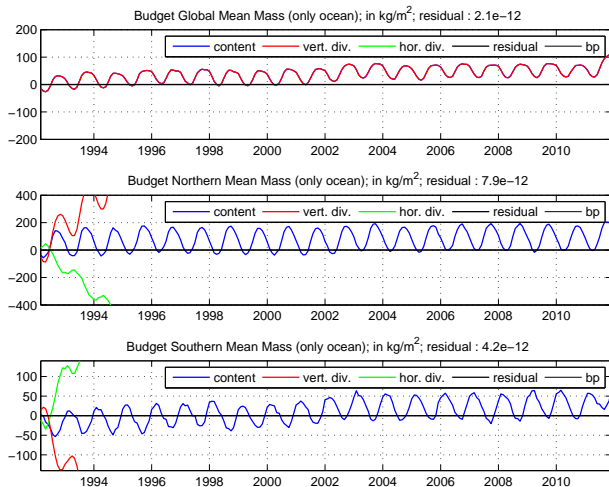Figure : 1992-2011 global (upper) north (mid) and south (lower), mass budget (ocean only) in kg/m^2.

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

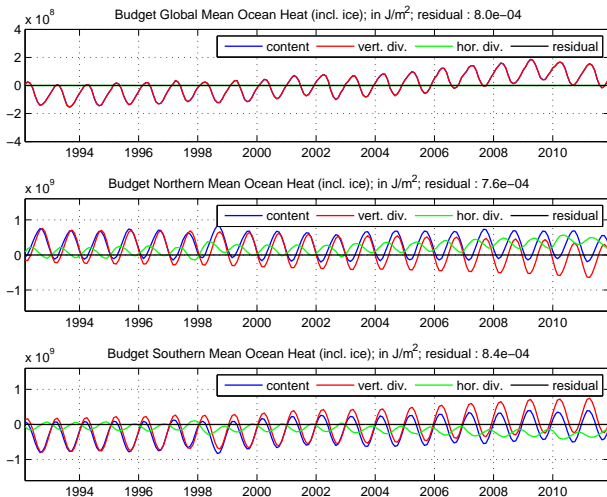Figure : 1992-2011 global (upper) north (mid) and south (lower), heat budget (ocean+ice) in J/m^2.

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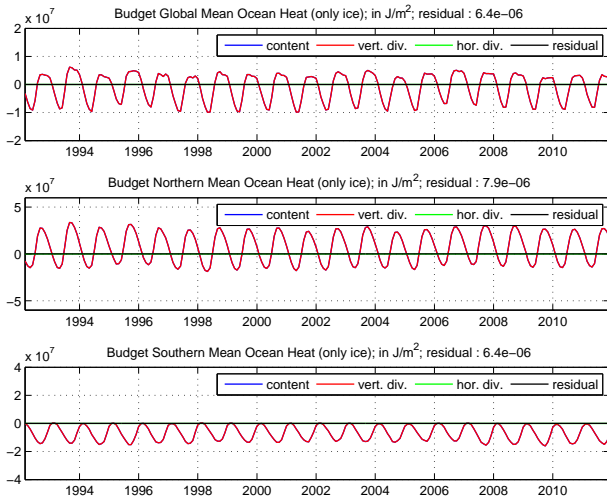

Figure : 1992-2011 global (upper) north (mid) and south (lower), heat budget (ice only) in J/m^2.

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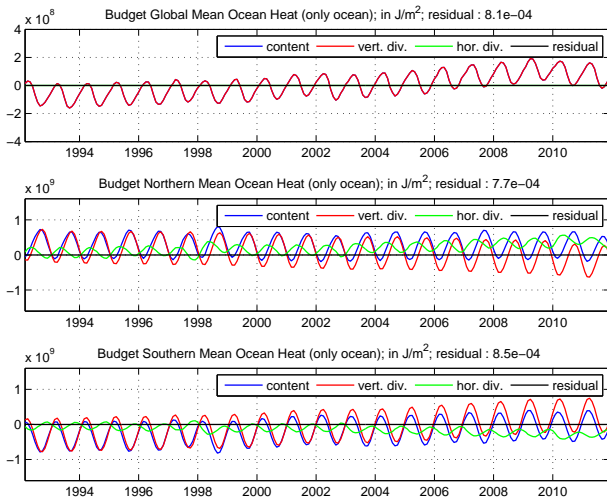

Figure : 1992-2011 global (upper) north (mid) and south (lower), heat budget (ocean only) in J/m^2.

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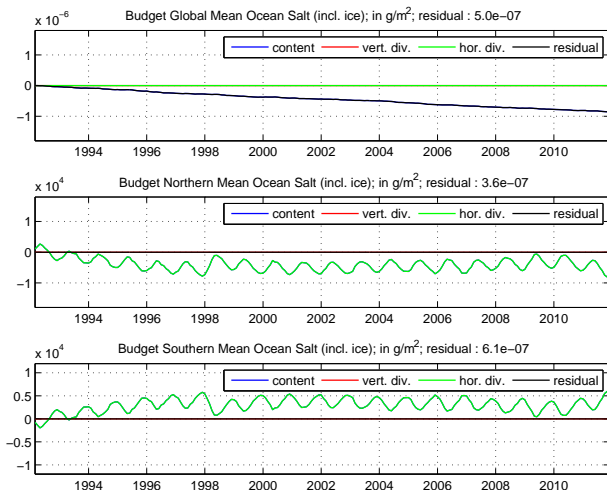

Figure : 1992-2011 global (upper) north (mid) and south (lower), salt budget (ocean+ice) in g/m^2.
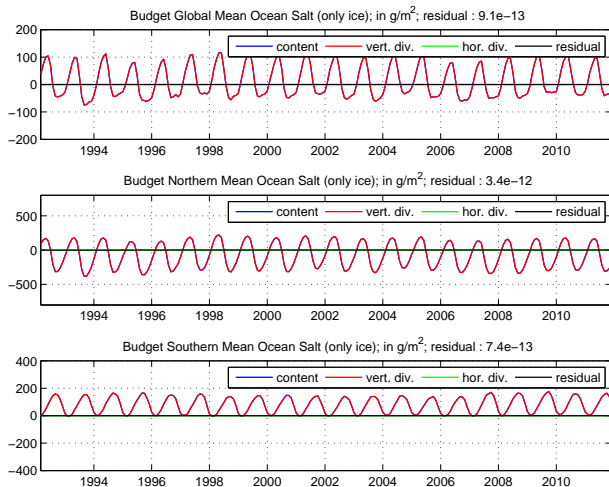
budgets : volume, heat and salt (top to bottom)

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

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

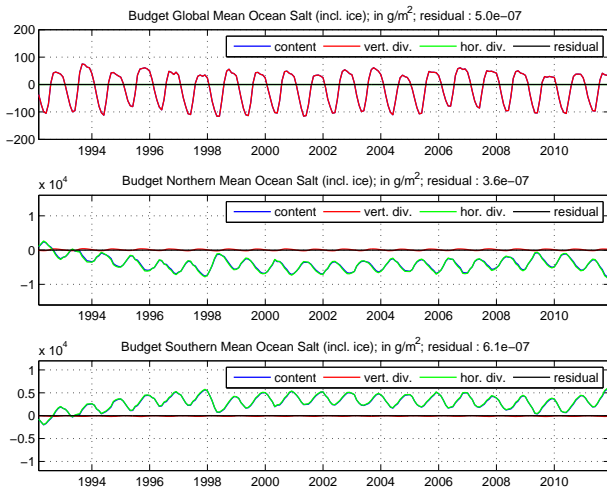

Figure : 1992-2011 global (upper) north (mid) and south (lower), salt budget (ocean only) in g/m^2.
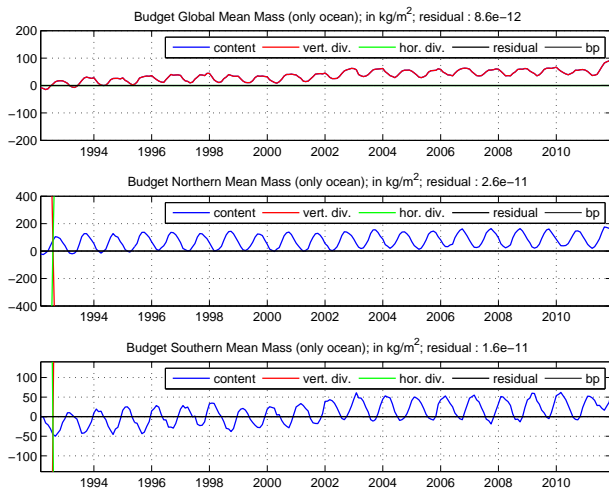
budgets : volume, heat and salt (100m to bottom)

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

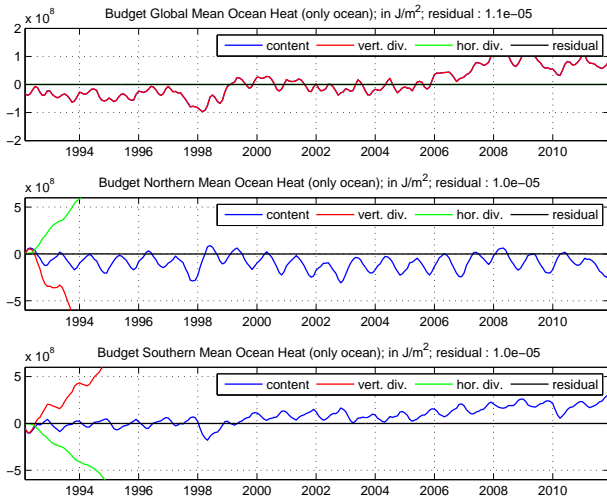# budgets : volume, heat and salt (100m to bottom)

Figure : 1992-2011 global (upper) north (mid) and south (lower), heat budget (ocean only) in J/m^2.
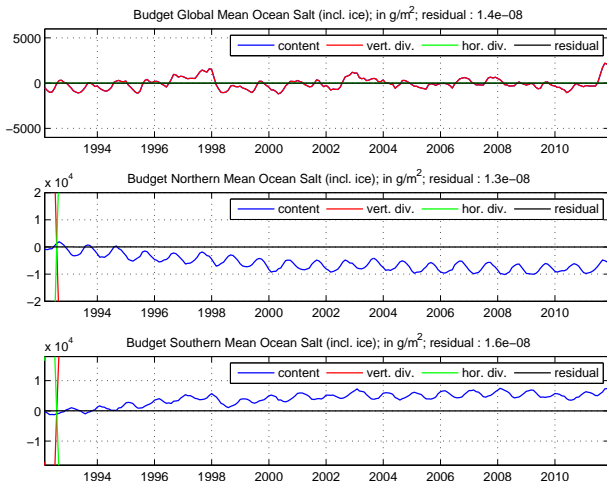
budgets : volume, heat and salt (100m to bottom)

Figure : 1992-2011 global (upper) north (mid) and south (lower), salt budget (ocean only) in g/m^2.
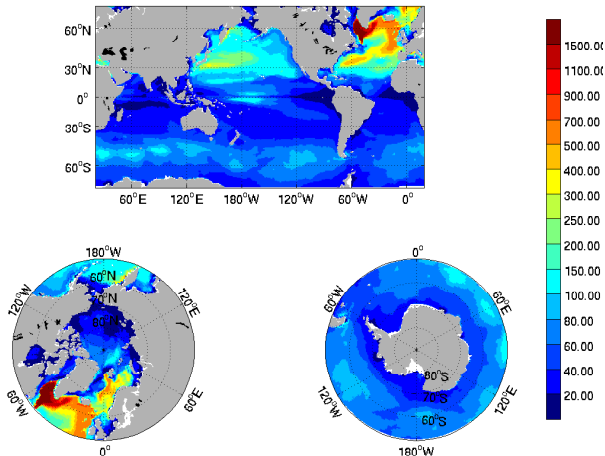
mixed layer depth fields

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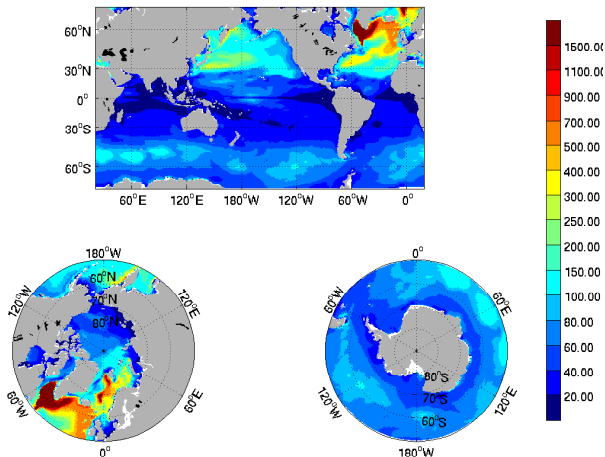
mixed layer depth fields

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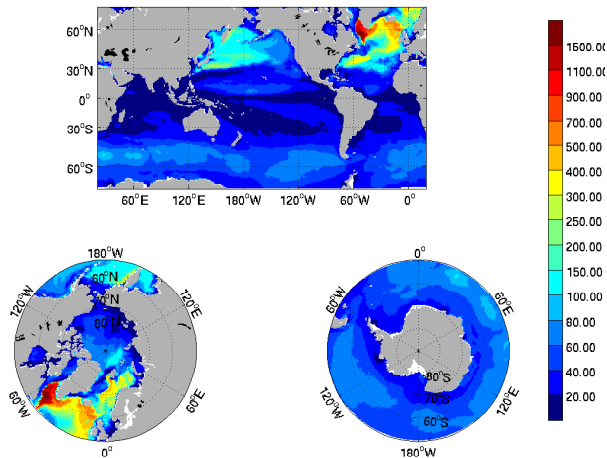
mixed layer depth fields

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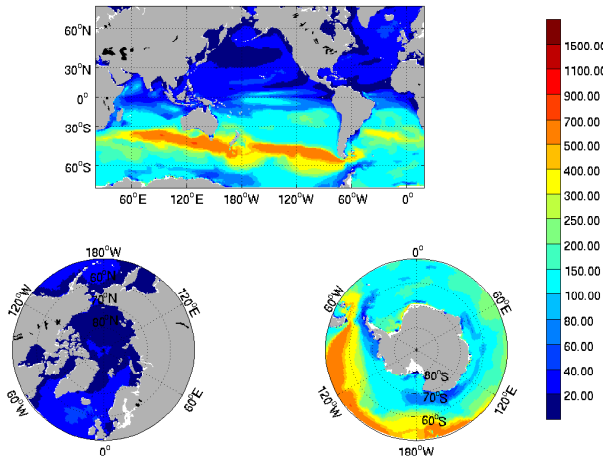
mixed layer depth fields

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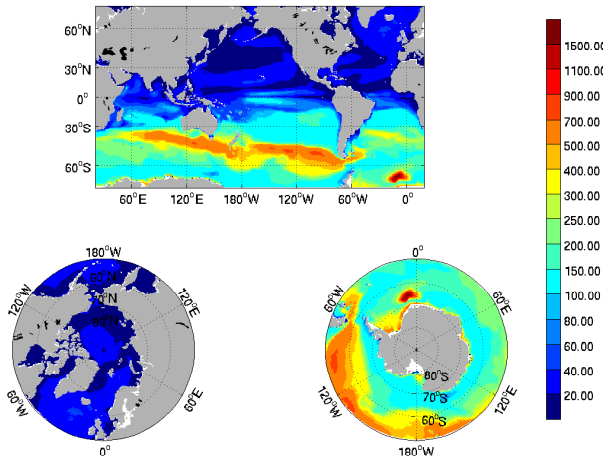
mixed layer depth fields

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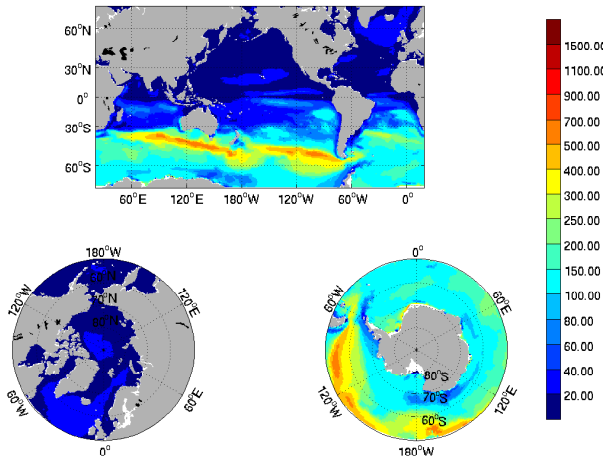
mixed layer depth fields

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