Gael Forget
MIT, Jan. 16th 2015

Independent Activities Period

Introduction to ocean data-model analysis

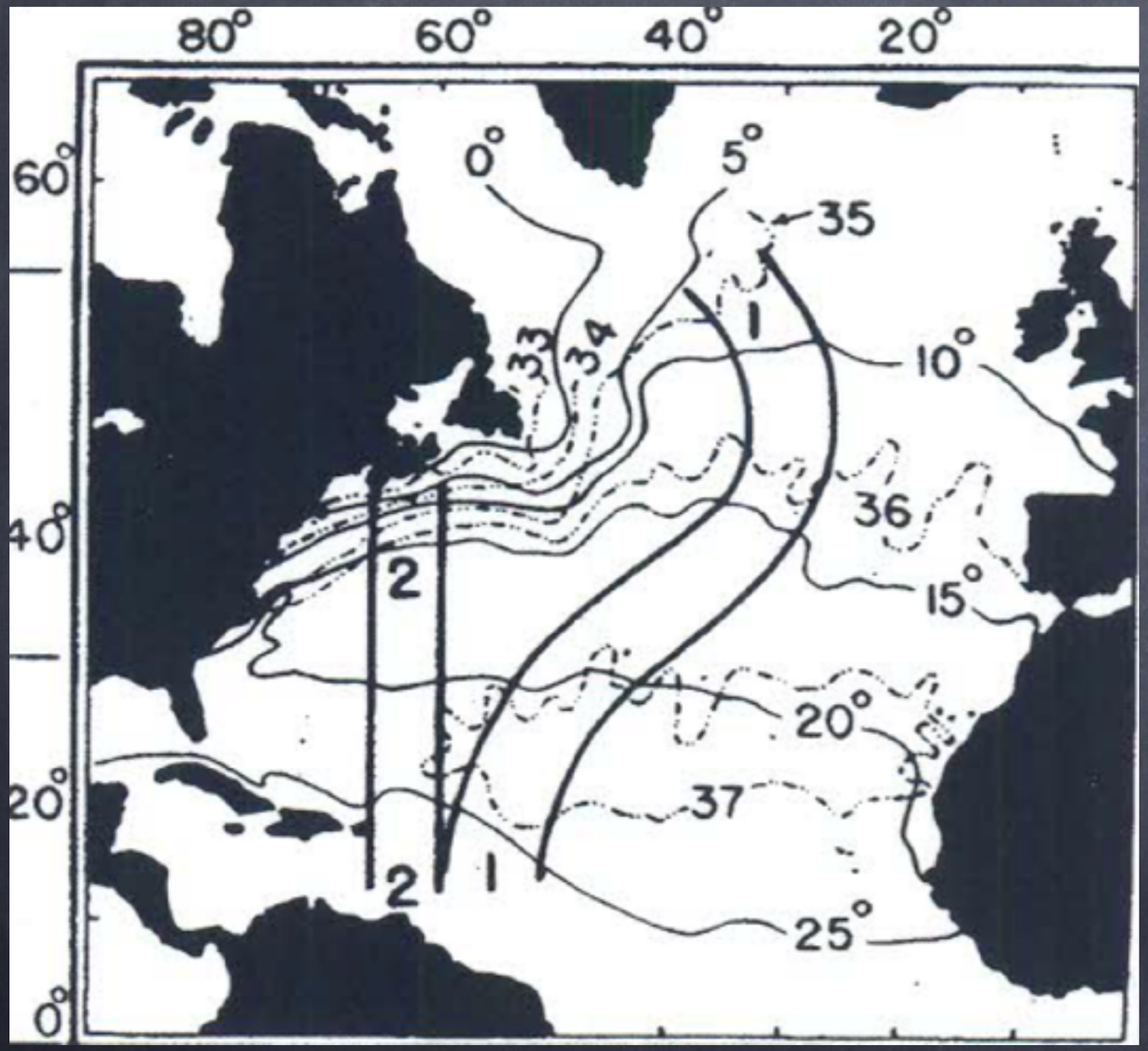
course 2 : interpolated and model data

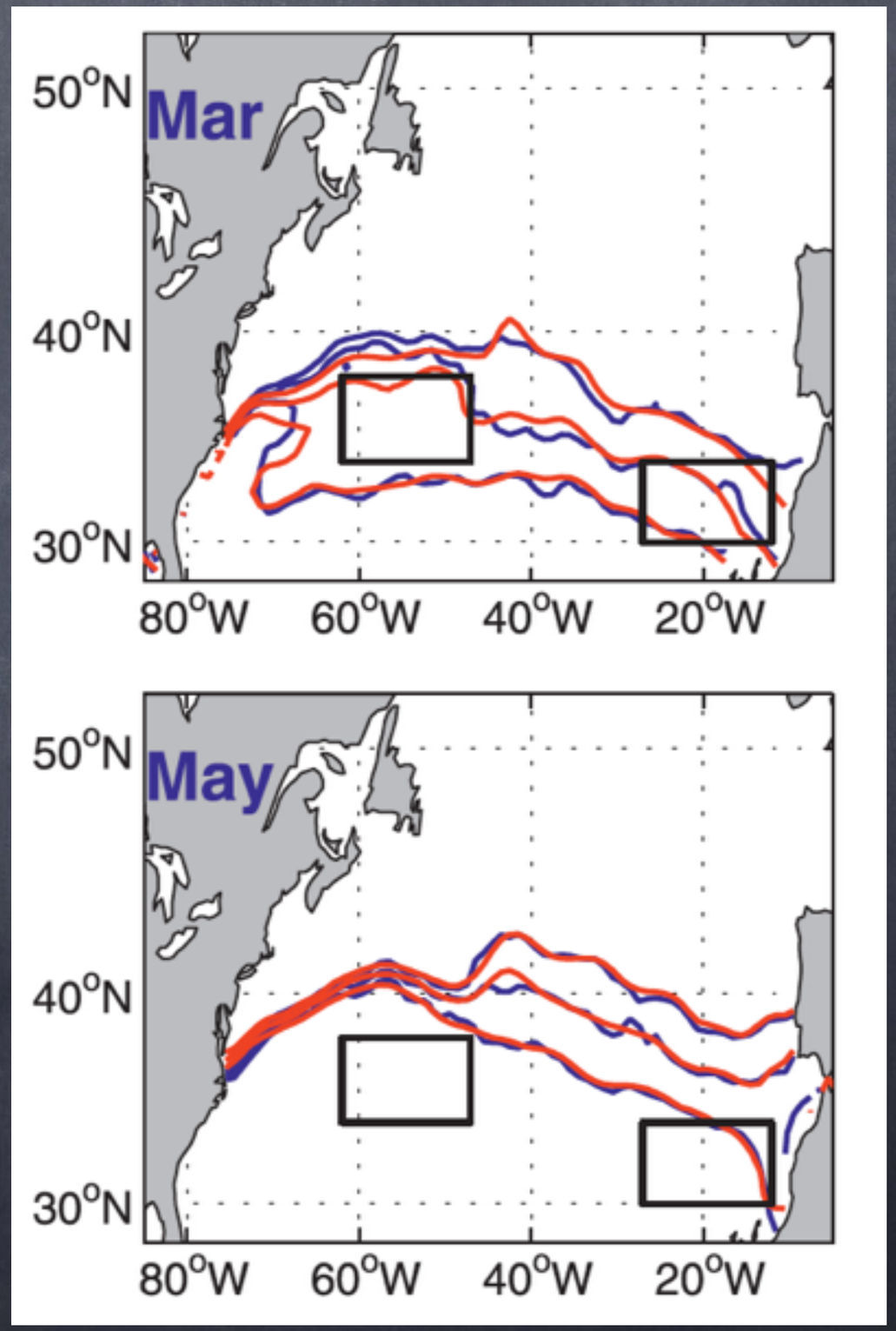
1. why interpolate data at all?
2. what is interpolated data?
3. gridding the earth (MITgcm, gcmfaces)
4. related considerations (budgets, transports)

5. interactive session : ECCO
6. resources, bibliography

… course 3 : state estimation

(1) why interpolate data at all?





Ocean, Climate have geography

(1) why interpolate data at all?

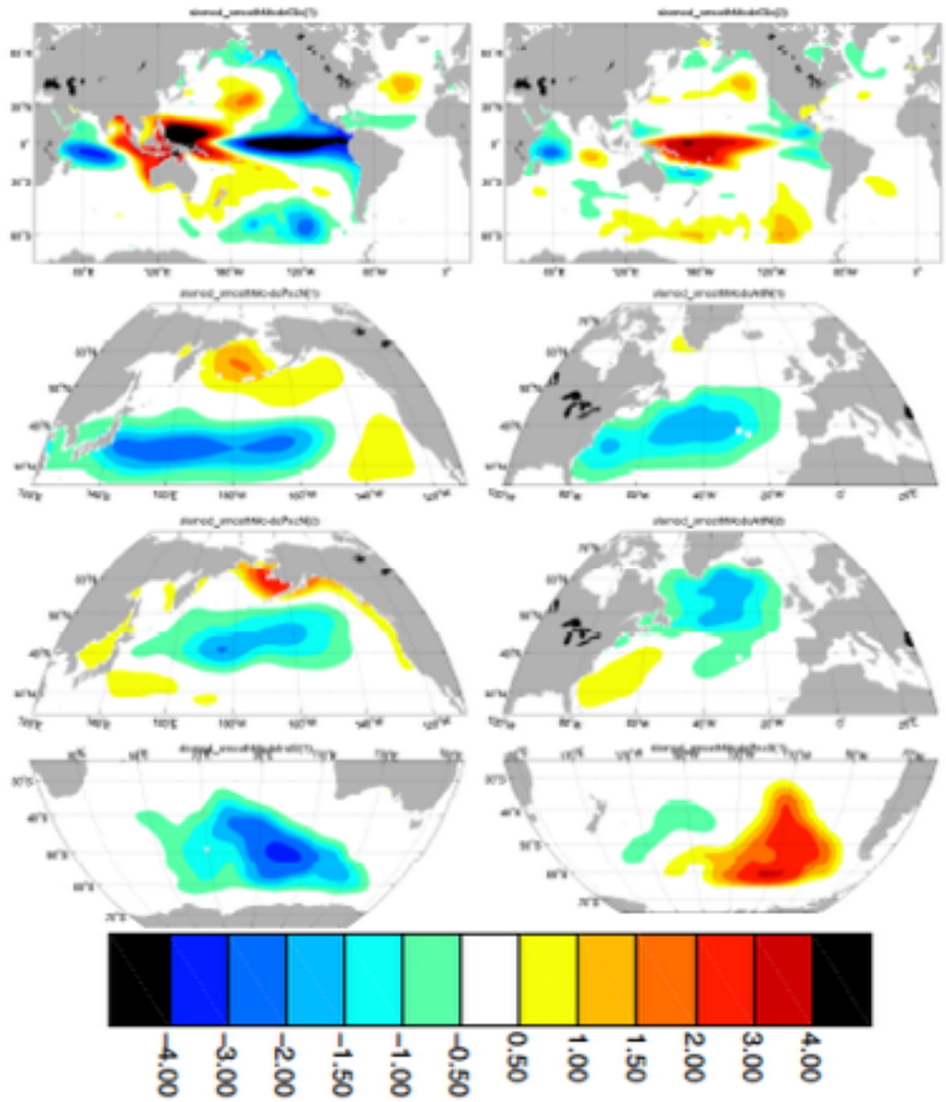


Figure 14: Spatial patterns of ζ variability (in cm) identified by EOF analysis of ζ_e (see Appendix B for algorithmic details). Principal component time series are shown as black curves in Fig. 15, with identically laid out panels.

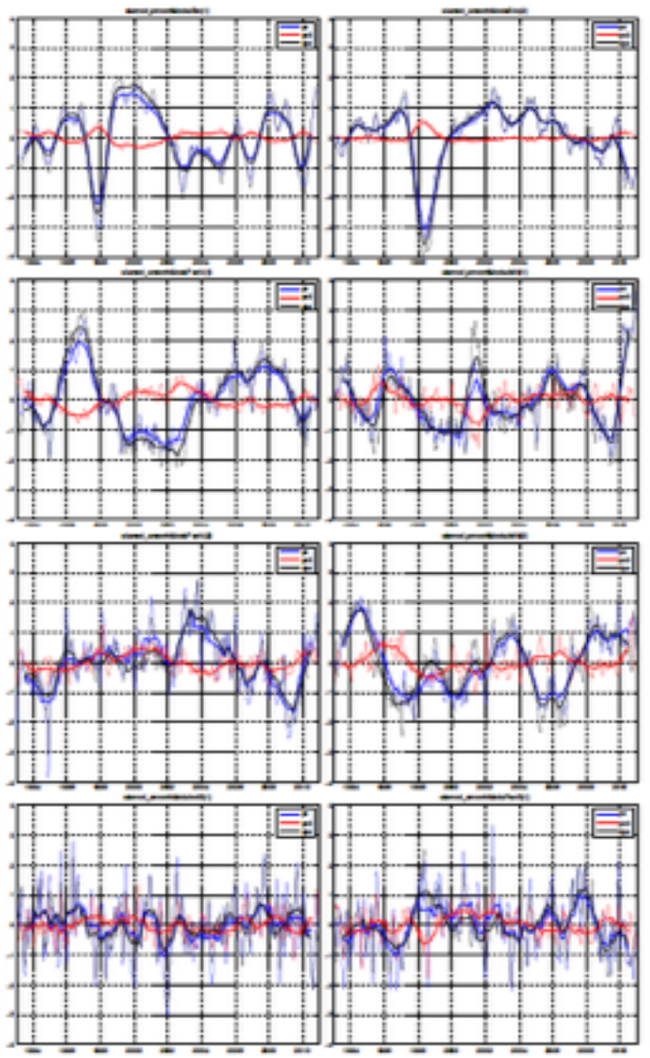
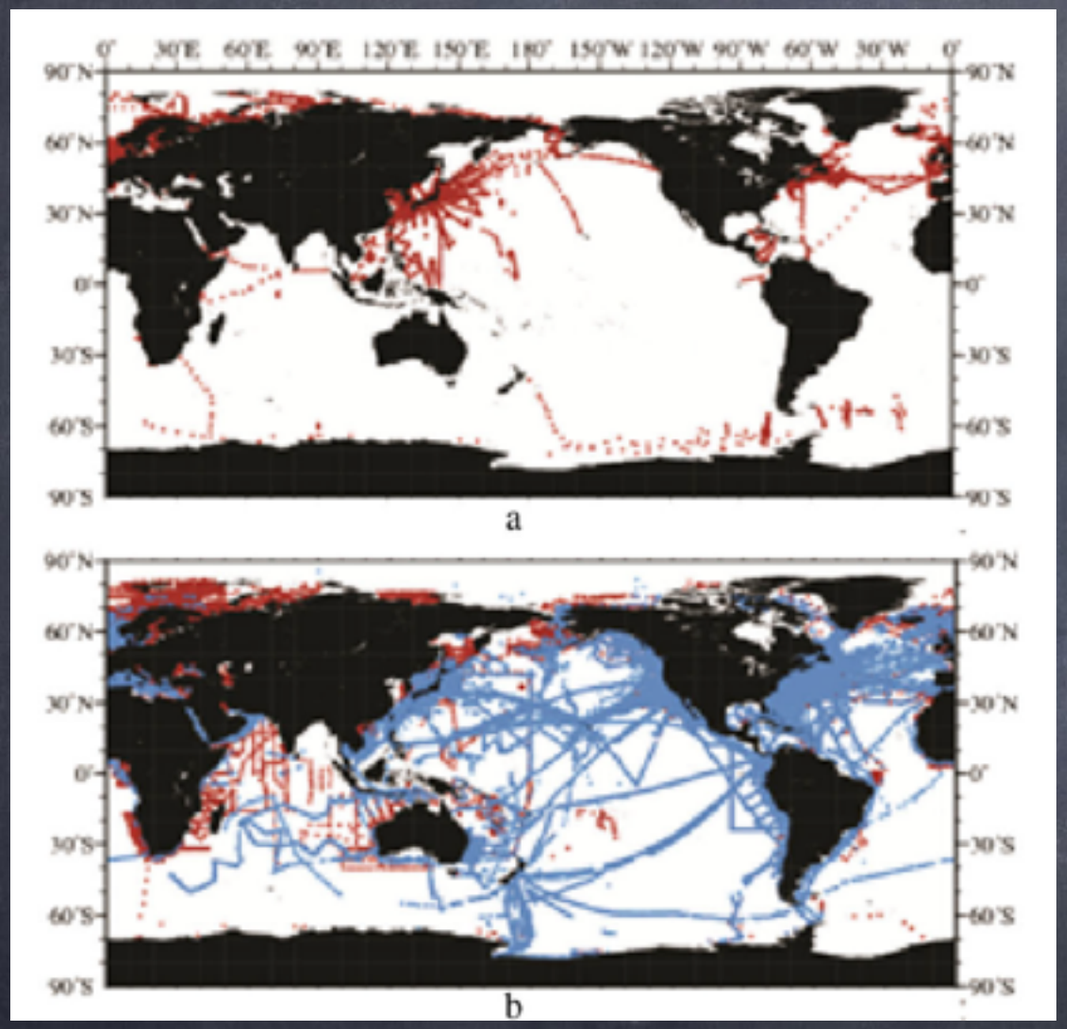
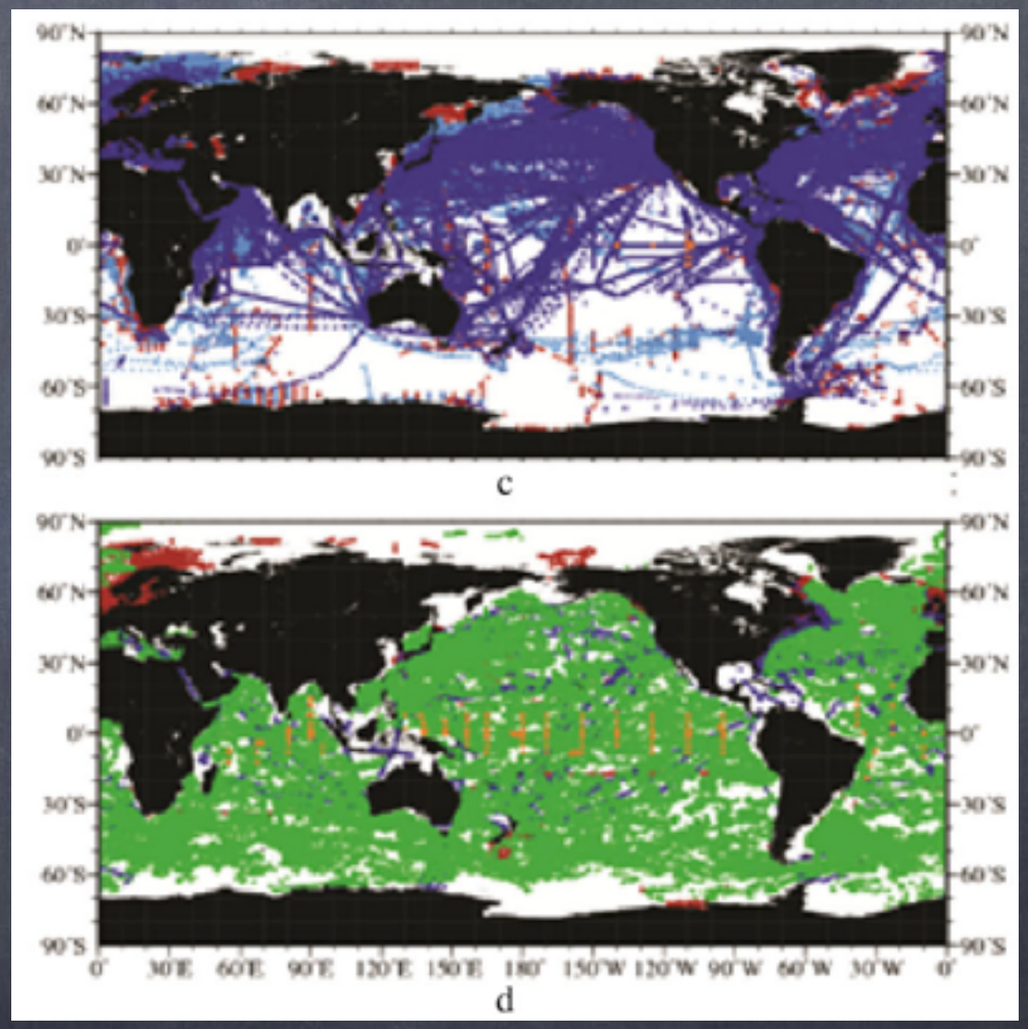


Figure 15: Principal component time series (black curves; unitless and of variance 1) associated with the spatial patterns in Fig. 14 (with identically laid out panels) for the state estimate.[39] Corresponding time series for altimetry and model-data misfits are also shown as blue and red curves, respectively (see Appendix B for algorithmic details). Thin curves are monthly means, while thick curves are annual means.

It is practical for numerical analysis

(2) what is interpolated data?





Interpolation ~ filling in the blanks

using statistical or dynamical model

(2) what is interpolated data?

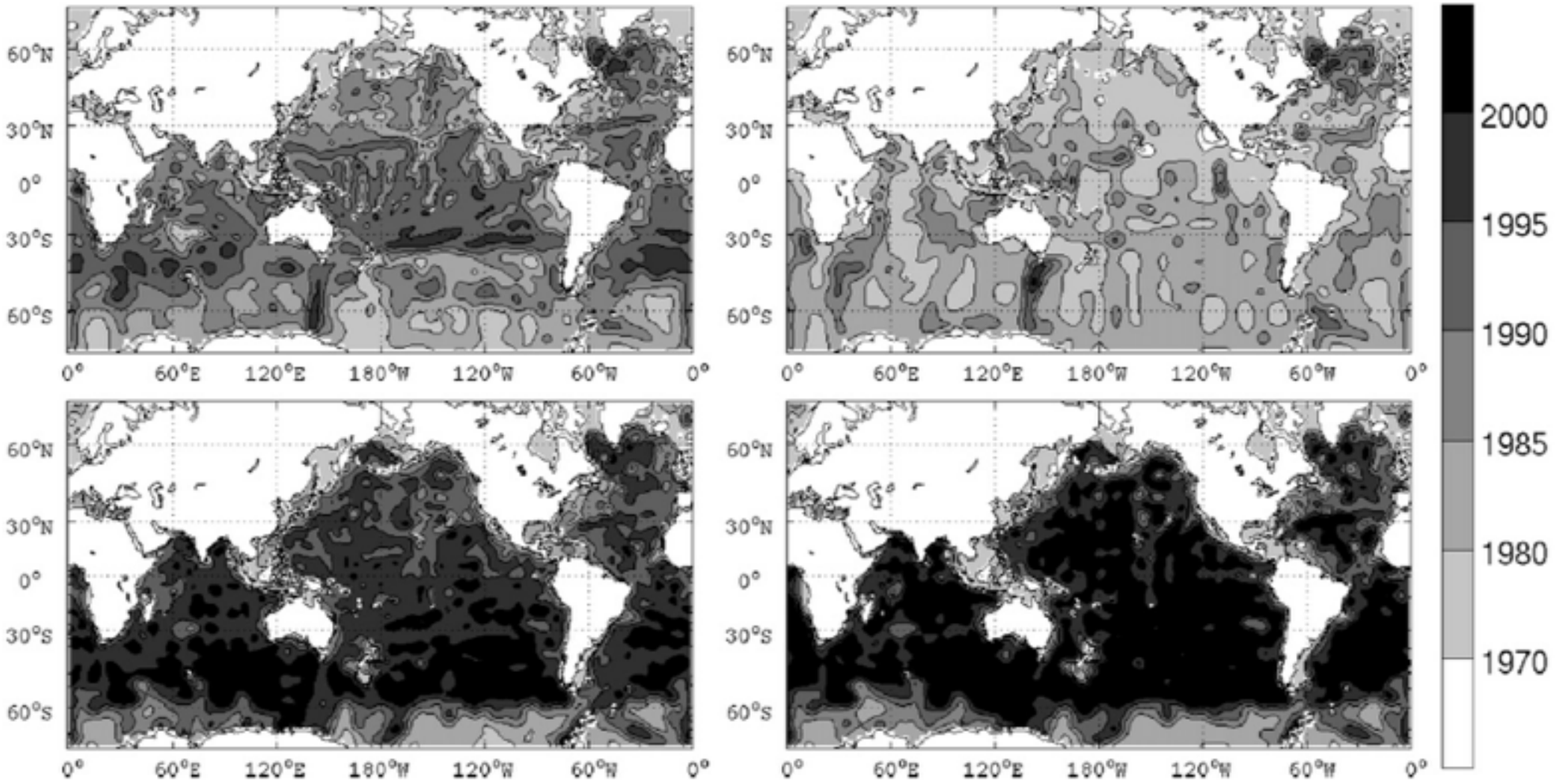
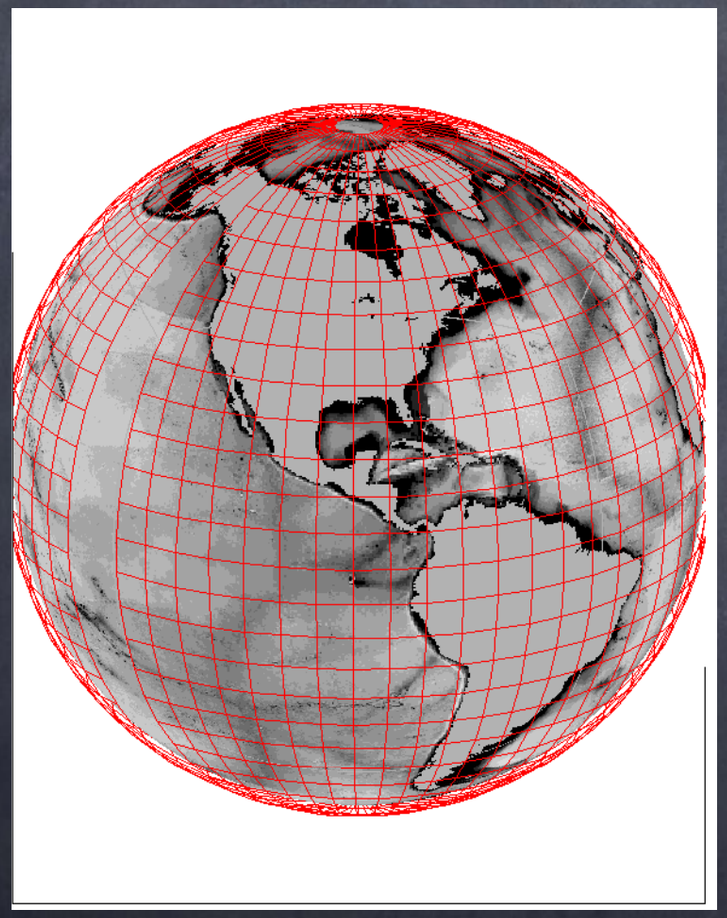
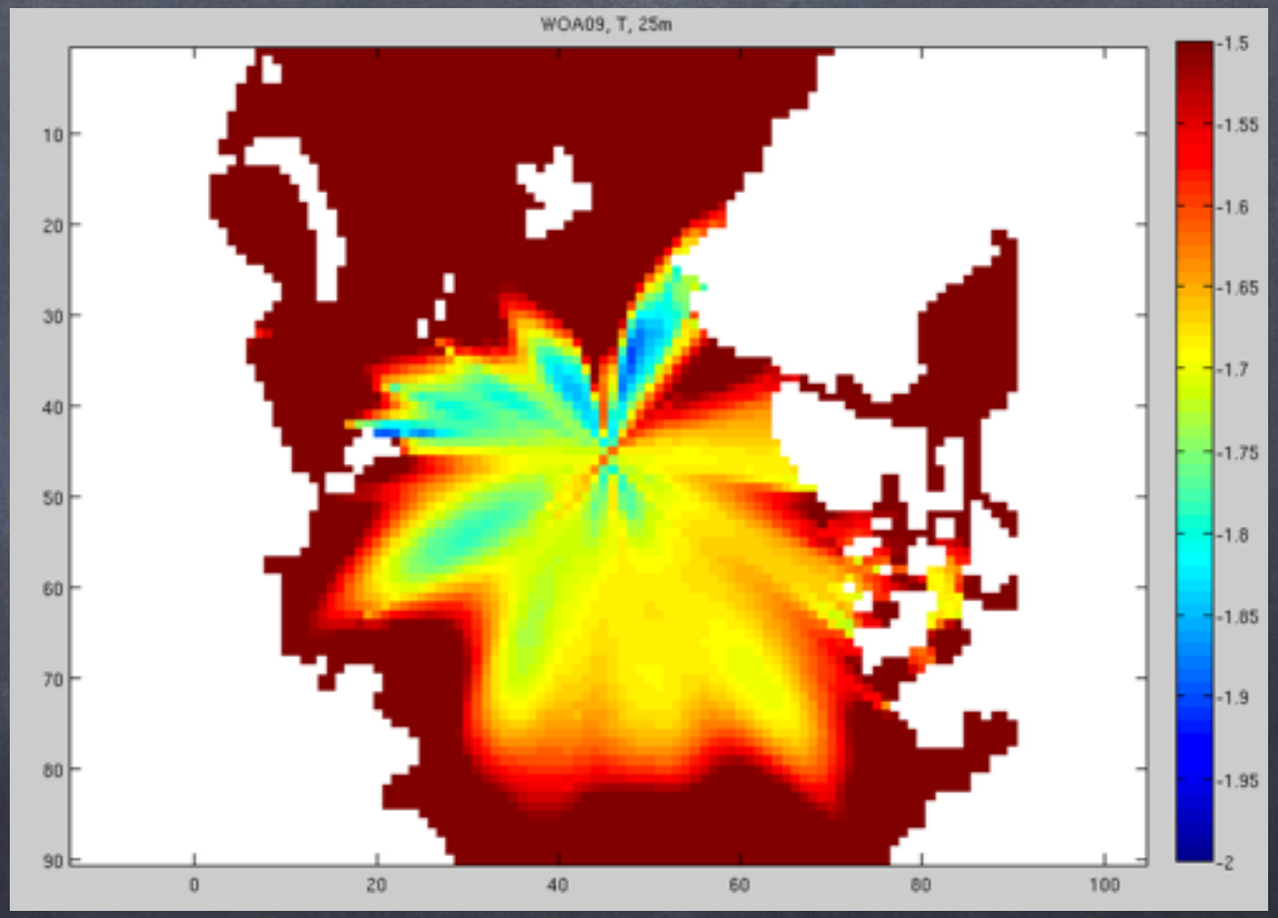


FIG. 1. Mean date of observation for two datasets, (left) T and (right) S, on average for the upper 1000 m. The mean date of observation is mapped using the OI procedure described in appendix A, taking 1980 as the first guess. The date of observation map shows the period that the associated T or S map (produced with OI) would best represent. It depends on the temporal distribution of observations. (bottom) The dataset consists of the Boyer et al. (2006) observations from 1950 to 2006, complemented with recent Argo observations (up to 2006). (top) The dataset is restricted to observations between 1950 and 2000.

Some sort of time average

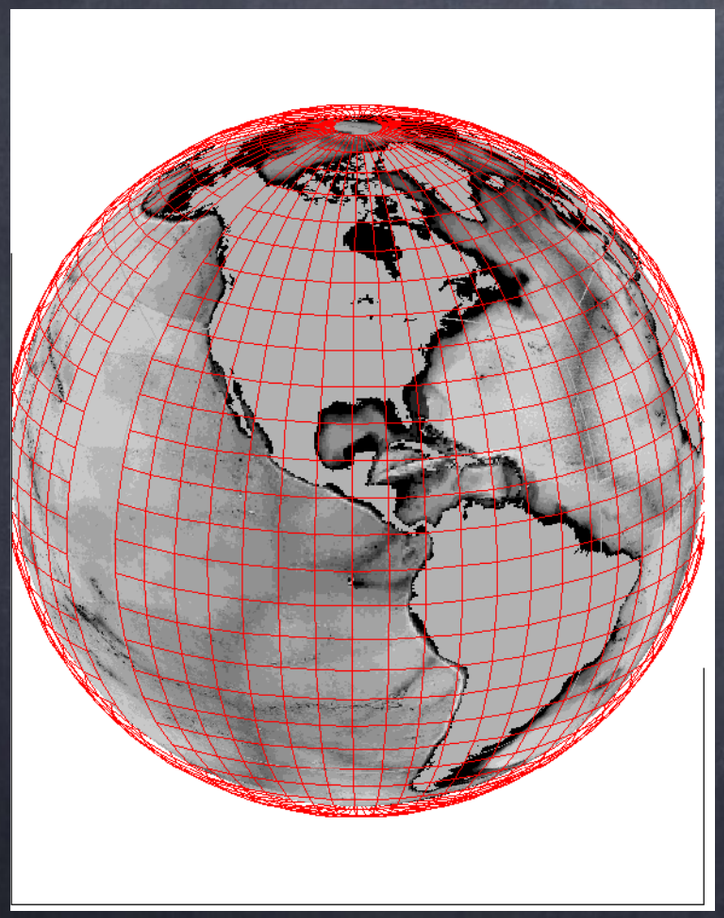
(2) what is interpolated data?

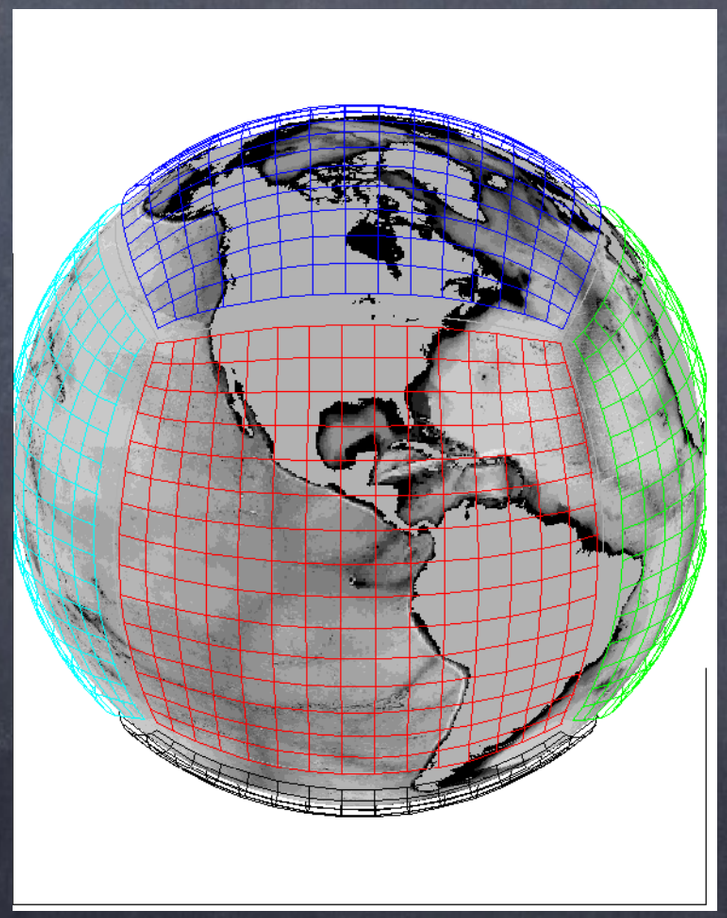


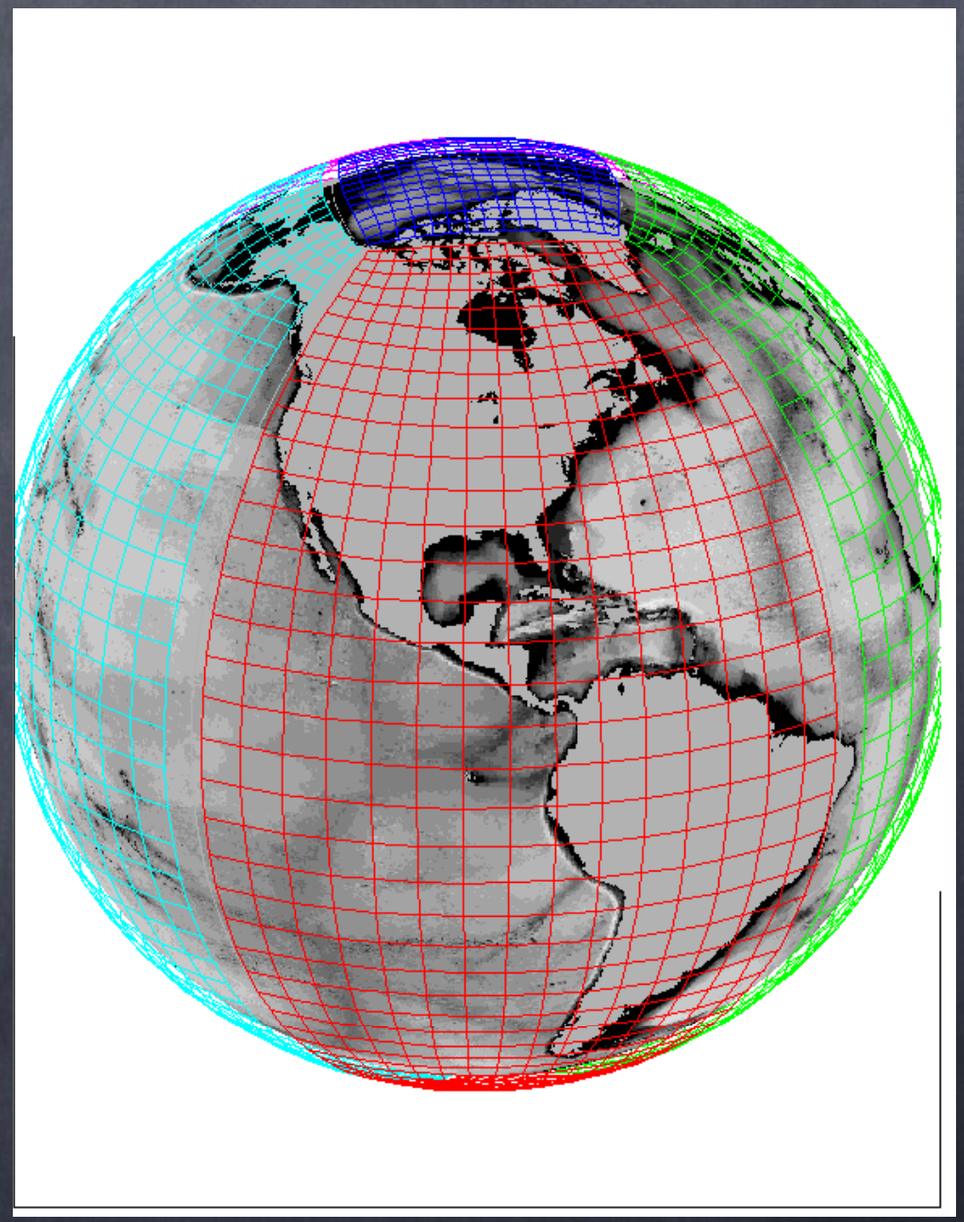


Some sort of geographic projection

(3) gridding the earth



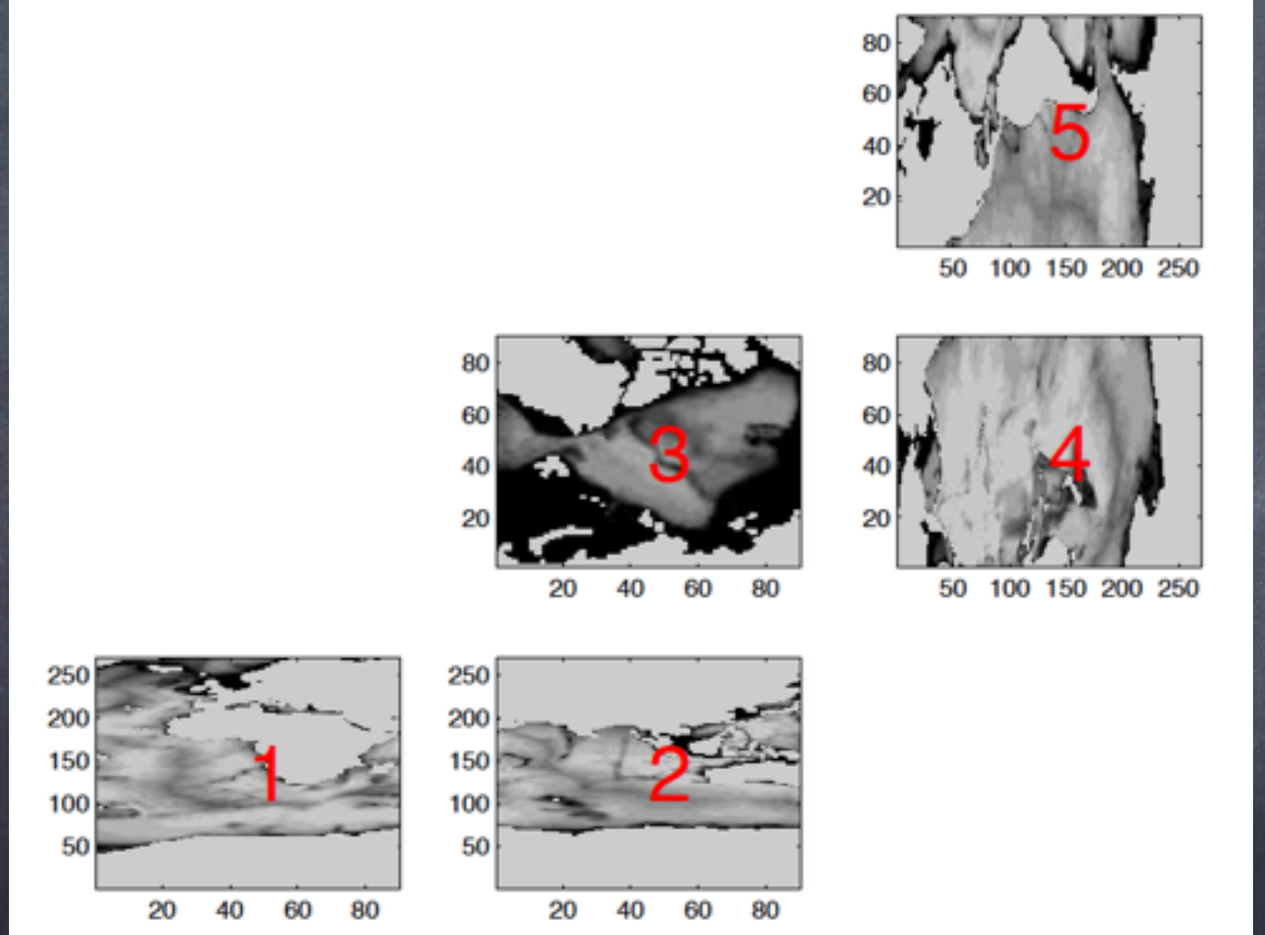




ECCO v4 grid

(3) gridding the earth

Figure 12: Example of a field (ocean bathymetry) mapped to the ECCO v4 grid and displayed in a way that reflects the grid topology. The five grid 'faces' number are indicated in red, and their dimensions are shown in black.



MITgcm and gcmfaces representation

(3) gridding the earth

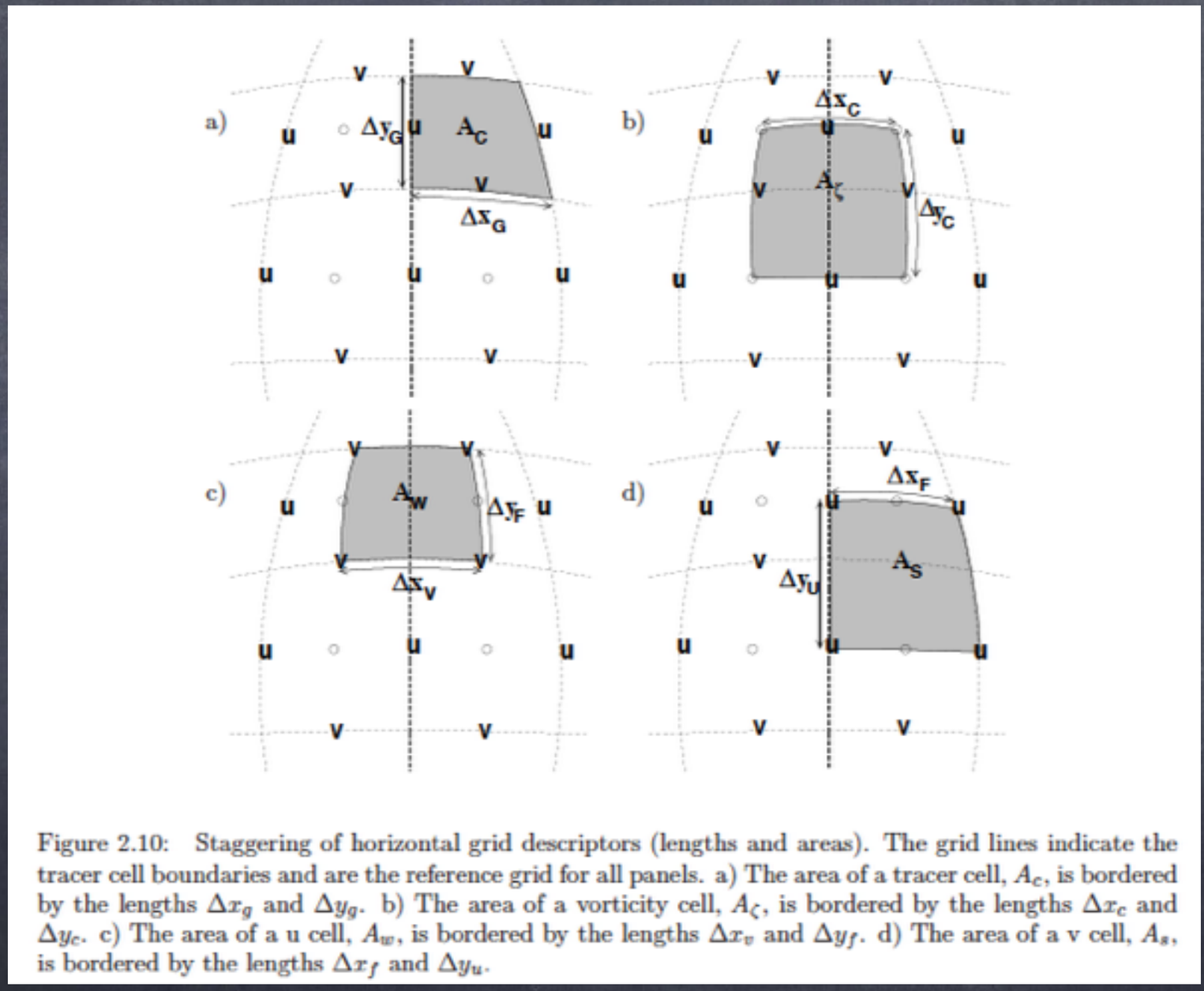


Figure 2.10: Staggering of horizontal grid descriptors (lengths and areas). The grid lines indicate the tracer cell boundaries and are the reference grid for all panels. a) The area of a tracer cell, A_c, is bordered by the lengths Δx_g and Δy_g. b) The area of a vorticity cell, A_ζ, is bordered by the lengths Δx_c and Δy_c. c) The area of a u cell, A_w, is bordered by the lengths Δx_v and Δy_f. d) The area of a v cell, A_s, is bordered by the lengths Δx_f and Δy_u.

the C-Grid discretization

(3) gridding the earth

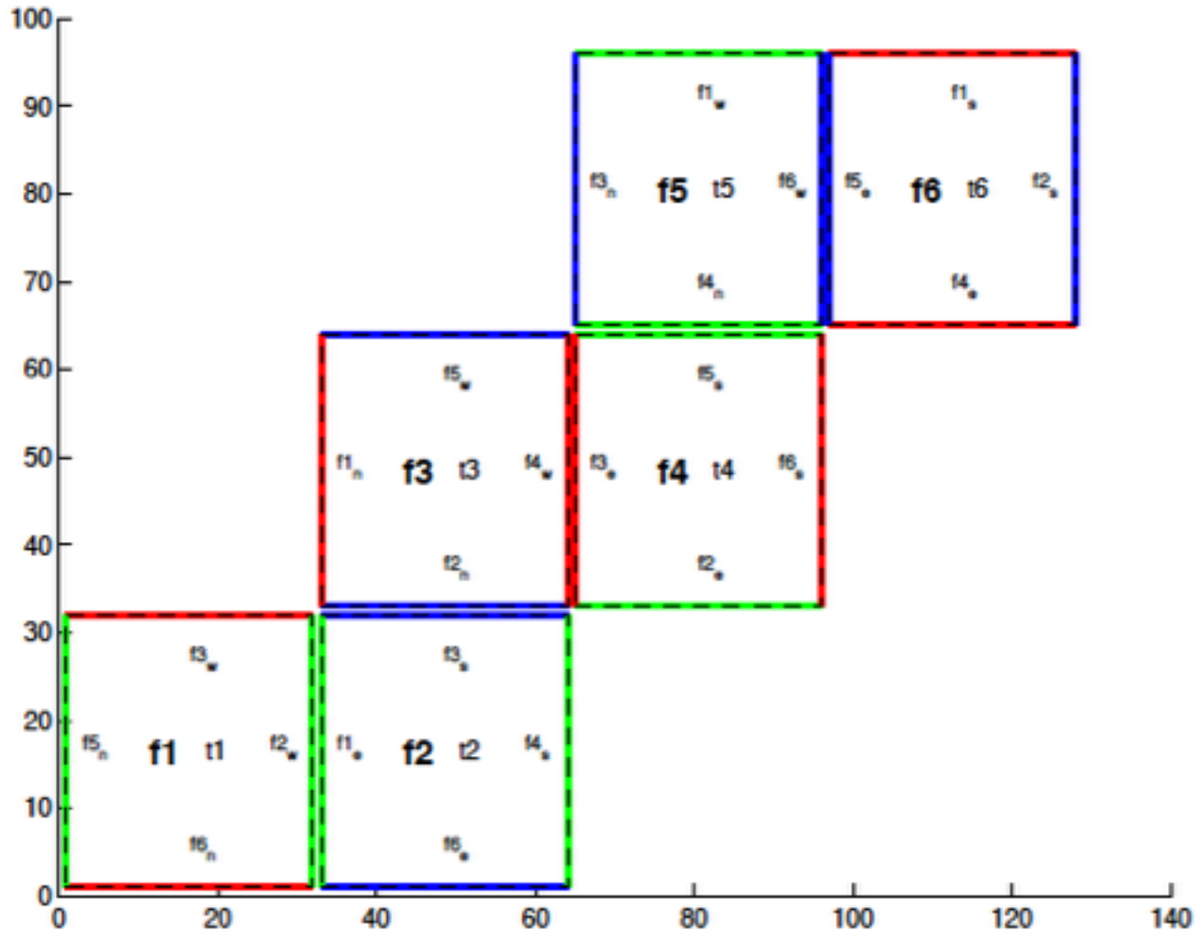
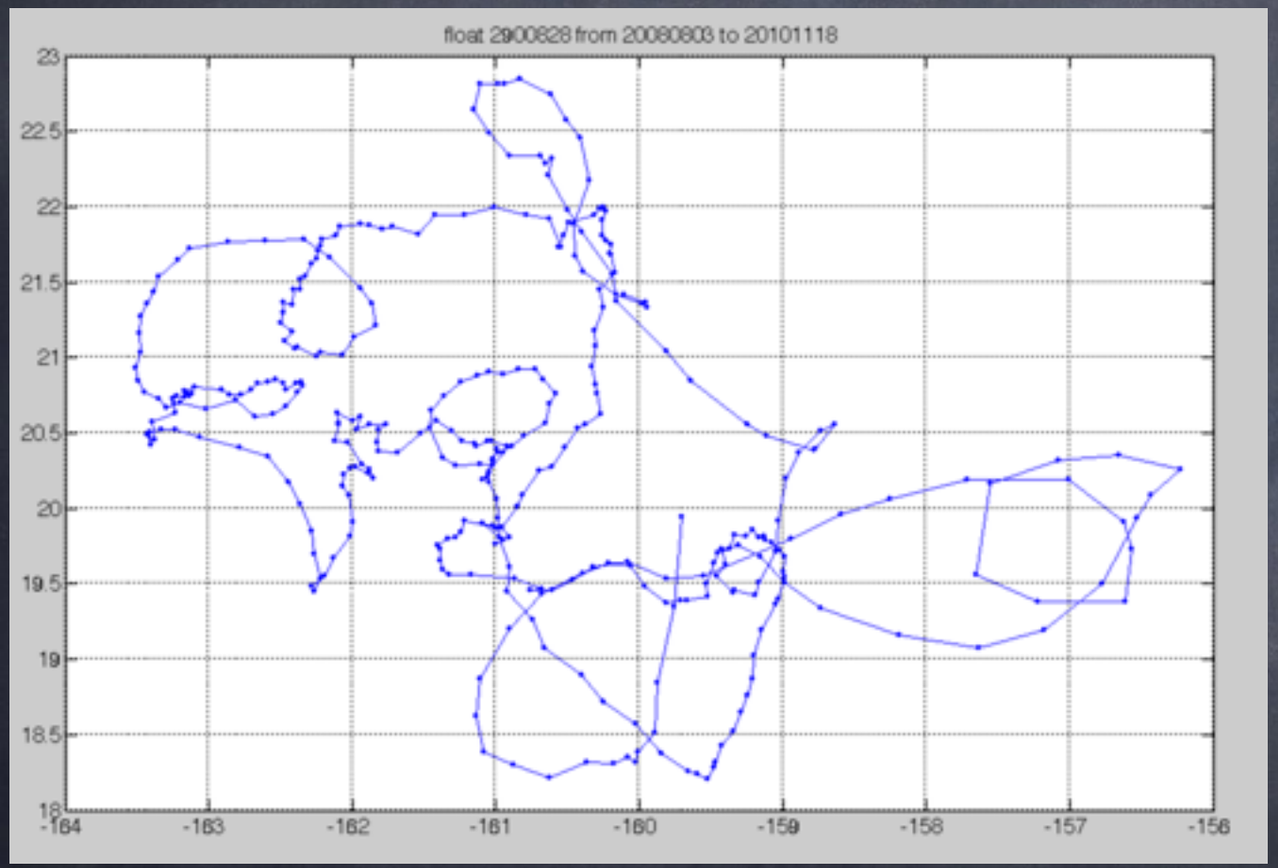


Figure 6.4: Plot of a cubed sphere topology with a 32×192 domain divided into six 32×32 subdomains with one tile each (`tnx=32, tny=32`). This is the default configuration.

connections and ‘exchanges’

(4) related considerations



velocity, displacement
(available from obs.)

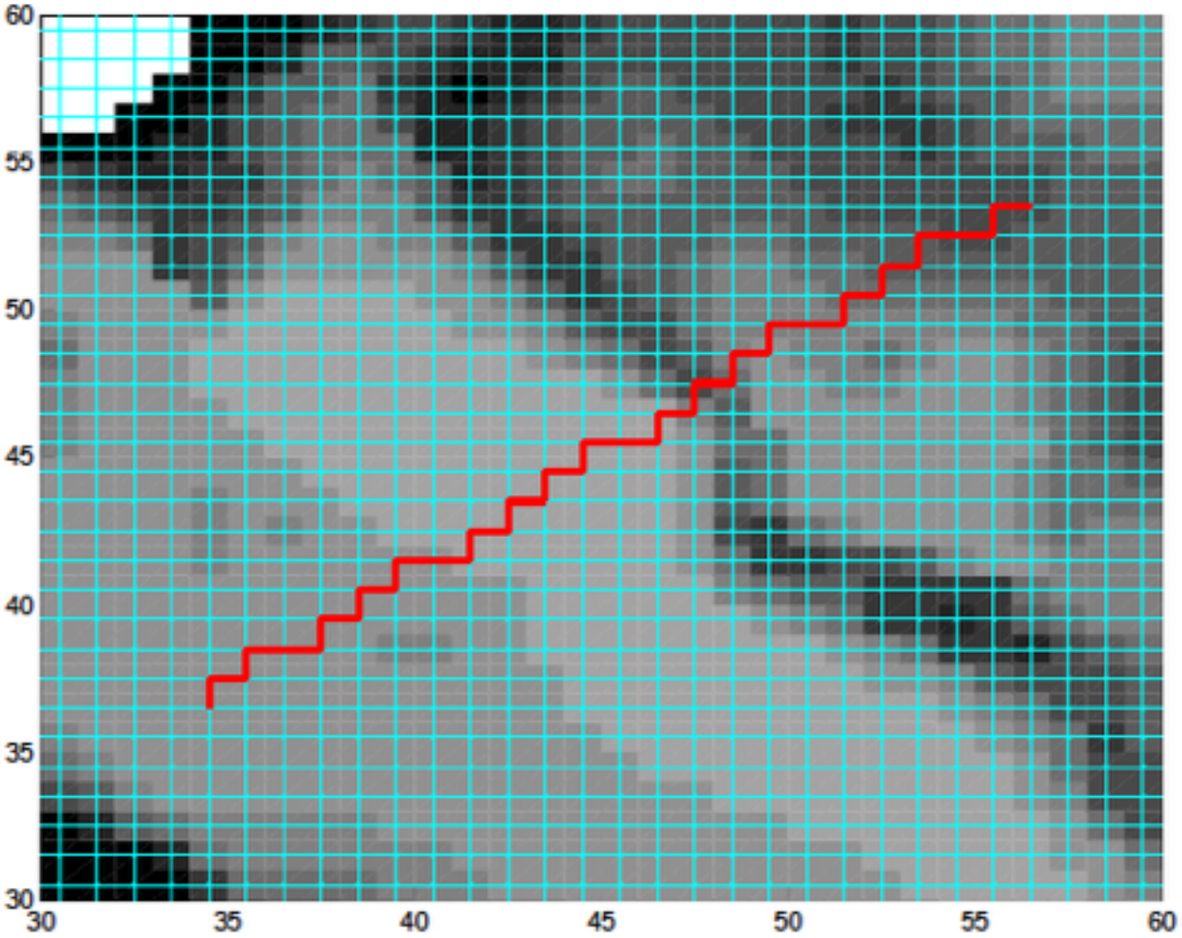
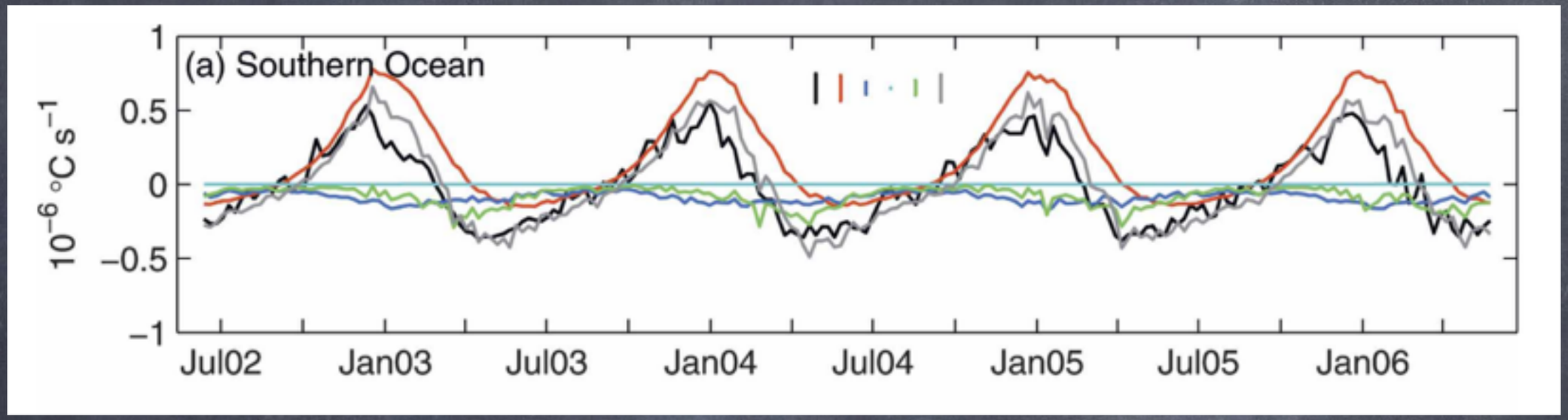


Figure 13: Example of a grid line path (in red) that approximates a transect between 45E-85N and 135W-85N. Location : central part of face 3 from Fig.12. Shading : ocean bottom depth. Blue lines : grid cell edges.

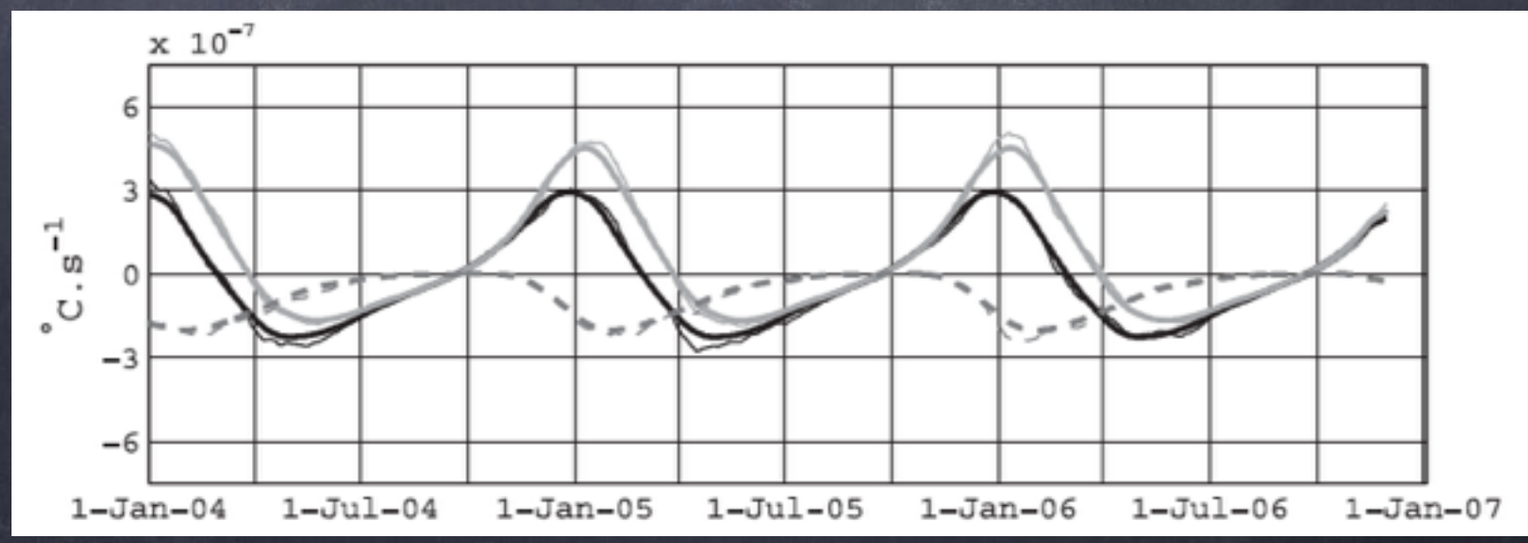
integrated transport
(requires stat. or dyn. model)

(4) related considerations

observational budgets can be estimated:



1) by assembling data sets with simple model



2) through ocean state estimation

(4) related considerations

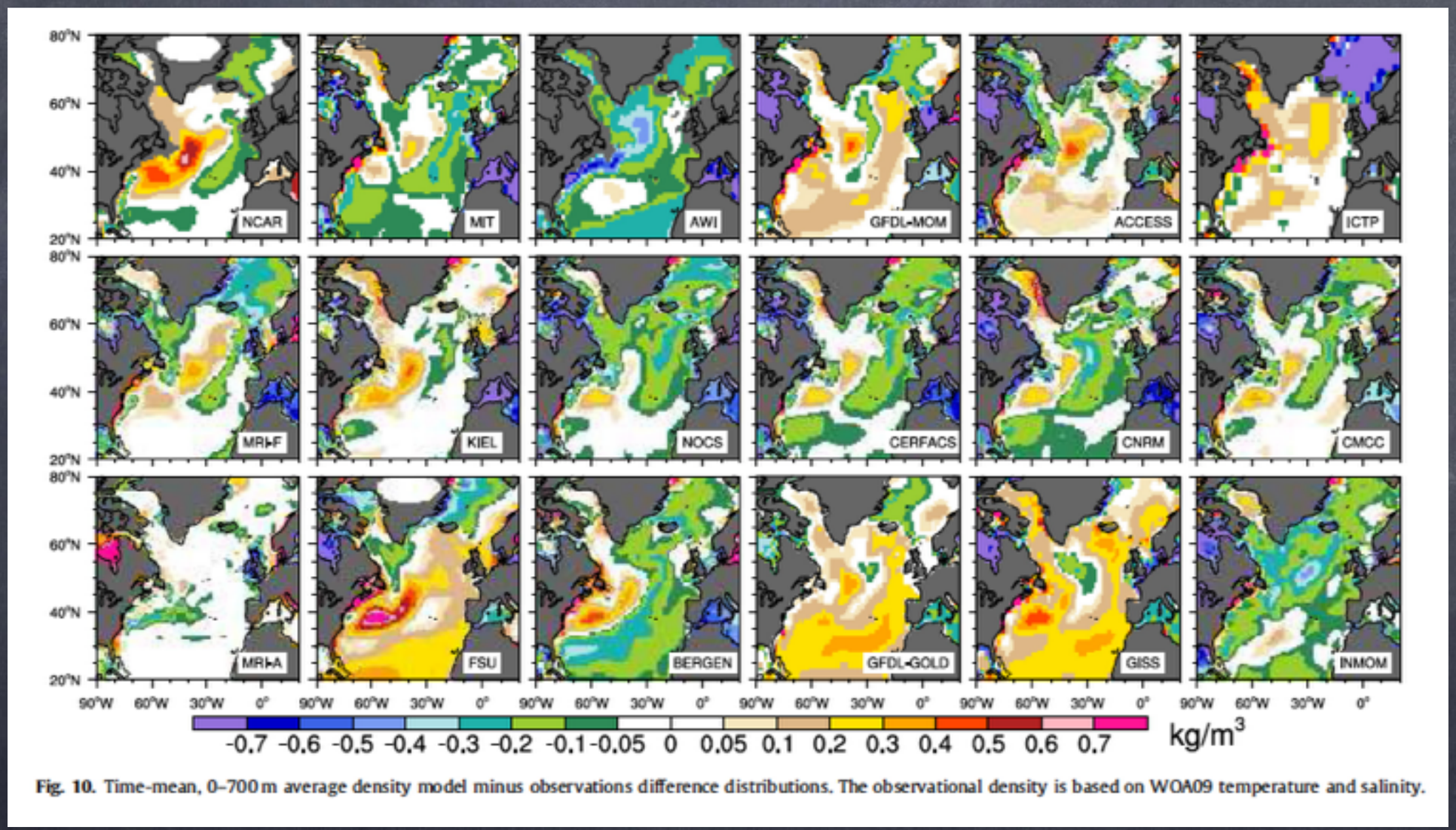
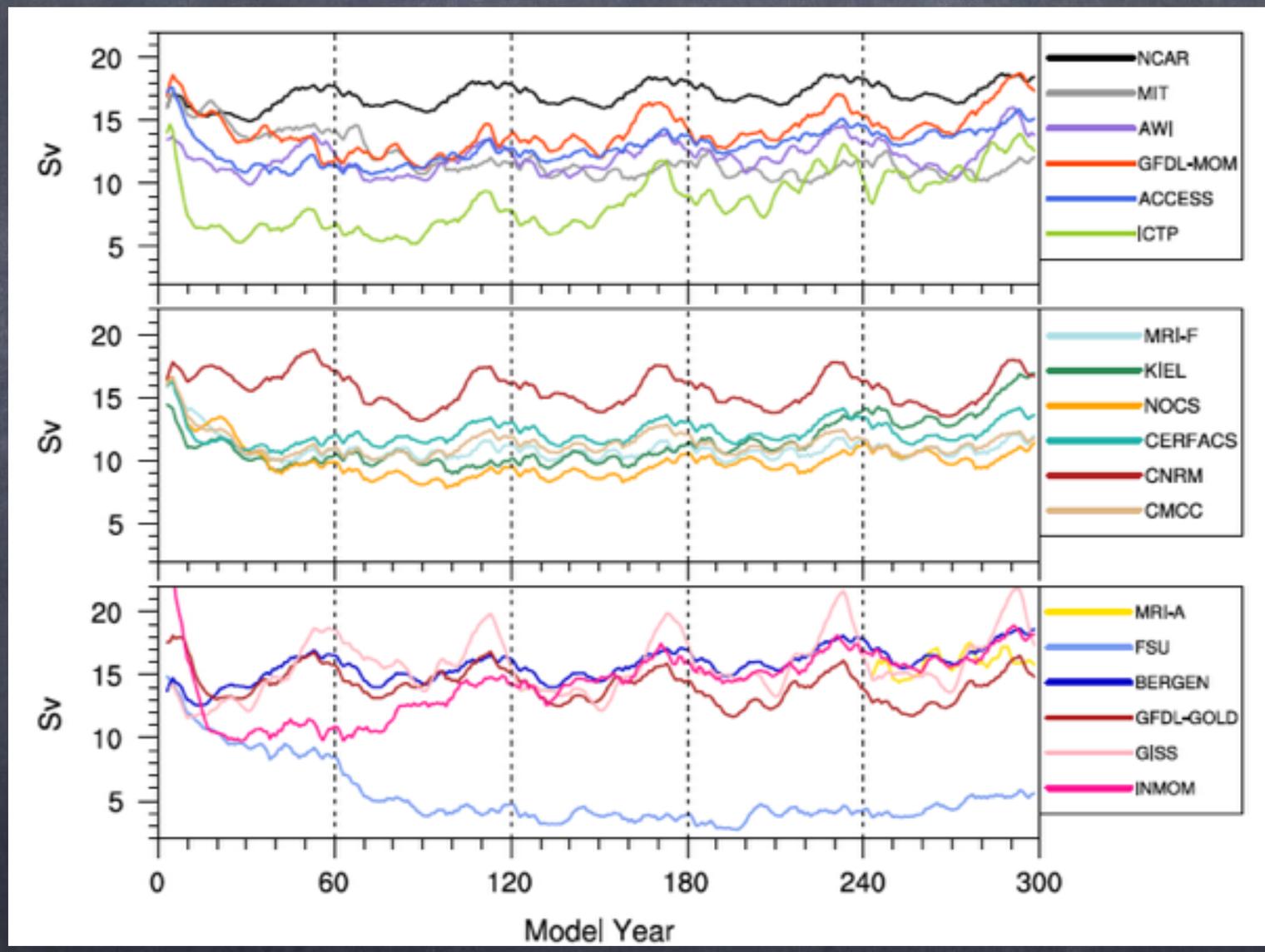


Fig. 10. Time-mean, 0–700 m average density model minus observations difference distributions. The observational density is based on WOA09 temperature and salinity.

Interpolating models can facilitate regional comparisons…

(4) related considerations



… but should be avoided for transports, budgets, etc.

(5) interactive session : ECCO

all ECCO v4 @ http://ecco-group.org/
follow the link seen below

IN THE NEWS

February 2014: Announcing a new-generation, global, bi-decadal state estimate: ECCO version 4

Following the ECCO meeting in January at MIT, the JPL/MIT/AER ECCO-Production team is happy to announce the release of a new-generation, global, bi-decadal state estimate (ECCO-Production, release 1). The product covers the period 1992 to 2011.

Several aspects of this new product have been highlighted already during the ECCO meeting. To re-iterate, some of the features include a fully global grid (LLC90) with the inclusion of the Arctic Ocean, telescoping from 1 to 1/3 deg. in the tropics, a doubling in vertical resolution (from 23 to 50 levels), forcing with the ERA-Interim atmospheric reanalysis, and improved treatment of data sets in terms of resolved vs. unresolved scales. The state estimate is being made available on its native grid on the DODS/OPeNDAP server

http://mit.ecco-group.org/opendap/ecco_for_las/version_4/release1/contents.html

The sub-directory ancillary_data/ has some extra information, including our standard analysis (standardAnalysis.pdf) that documents model-data misfits and physical variables of general interest. A copy of the matlab codes used to generate the standard analysis is also provided (gcmfaces_MITprof_r1.tar). As with releases of previous estimates, we think that many aspects of this release are mature (and improvements from previous versions), but with further improvements of some aspects to be expected in subsequent releases.

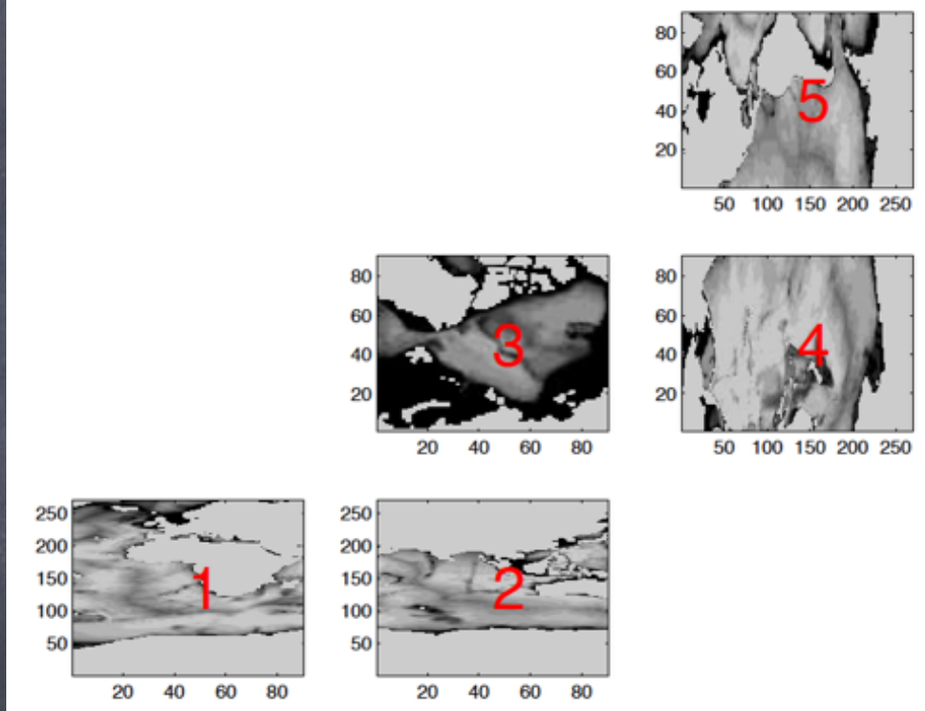
(5) interactive session : ECCO

```
ETAN.0001.nc
ETAN.0002.nc
ETAN.0003.nc
ETAN.0004.nc
ETAN.0005.nc
ETAN.0006.nc
ETAN.0007.nc
ETAN.0008.nc
ETAN.0009.nc
ETAN.0010.nc
ETAN.0011.nc
ETAN.0012.nc
ETAN.0013.nc
```

What is the file format ?

netcdf, tiles

Figure 12: Example of a field (ocean bathymetry) mapped to the ECCO v4 grid and displayed in a way that reflects the grid topology. The five grid 'faces' number are indicated in red, and their dimensions are shown in black.



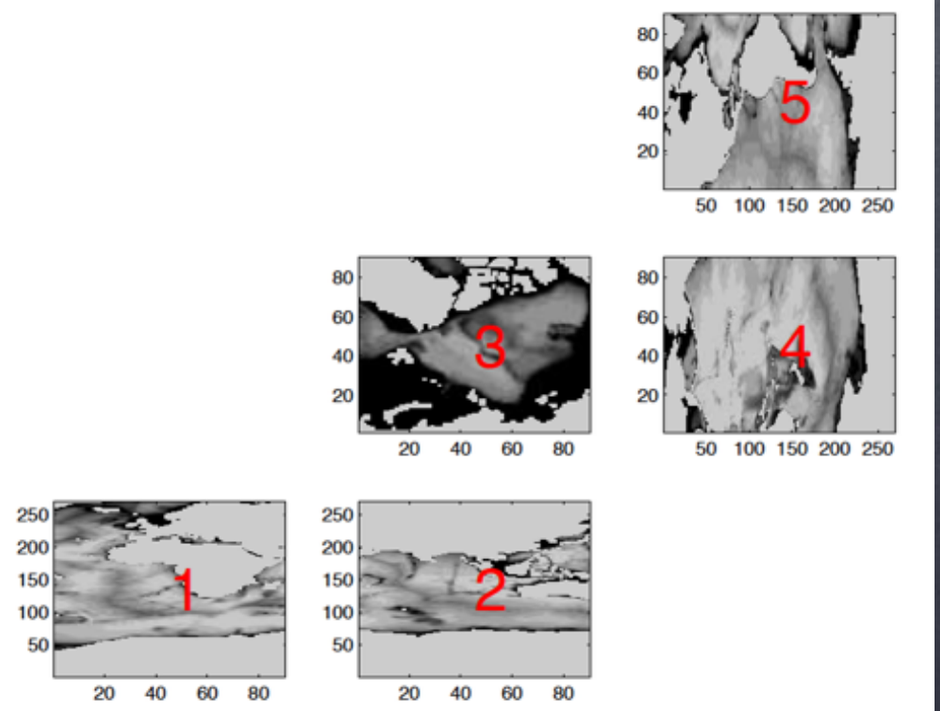
what is a tile ?

1 subdivision of the above faces

(5) interactive session : ECCO

```
fld =
        nFaces:    5
            f1:    [90x270 double]
            f2:    [90x270 double]
            f3:    [90x90 double]
            f4:    [270x90 double]
            f5:    [270x90 double]
```

Figure 12: Example of a field (ocean bathymetry) mapped to the ECCO v4 grid and displayed in a way that reflects the grid topology. The five grid 'faces' number are indicated in red, and their dimensions are shown in black.



within matlab, gcmfaces ...

mimics MITgcm...

(5) interactive session : ECCO

README
- fit to data
  - fit to in situ data
  - fit
  - fit
  - fit
  - fit
- volume, heat and salt transports
  - barotropic streamfunction
  - meridional streamfunction
  - meridional streamfunction (time series)
  - meridional heat transport
  - meridional freshwater transport
  - meridional salt transport
  - meridional transports (time series)
  - transects transport
- mean and variance maps
  - sea surface height
  - 3D state variables
  - air-sea heat flux
  - air-sea freshwater flux
  - surface wind stress
- global, zonal, regional averages
  - zonal mean tendencies
  - equatorial sections
  - global mean properties
  - zonal mean properties
  - zonal mean properties (surface)
  - seaice time series
- budgets
- budgets
- mixed layer depth fields

inputs for this are not online yet

inputs for this are not online yet

inputs for this are not online yet

… general & extensive diagnostic implementation
… ‘immediately’ diagnose the standard analysis for ECCO or any other MITgcm solution

(5) interactive session : ECCO

files used for interactive session (ECCO monthly climatology)

```
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/THETA
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/SALT
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/UVELMASS
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/VVELMASS
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/'ADVx_*'
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/'ADVy_*'
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/'DFxE_*'
wget --recursive ftp://mit.ecco-group.org/gforget/nctiles_climatology/'DFyE_*'
mv mit.ecco-group.org/gforget/nctiles_climatology release1/.
```

(6) resources, bibliography

- mitgcm documentation: http://mitgcm.org/public/r2_manual/latest/online_documents/manual.pdf

- gcmfaces documentation: http://mitgcm.org/viewvc/MITgcm/MITgcm_contrib/gael/matlab_class/gcmfaces.pdf

- ECCO v4 monthly output: http://mit.ecco-group.org/opendap/ecco_for_las/version_4/release1/nctiles/contents.html

- ECCO v4 monthly climatology: http://mit.ecco-group.org/opendap/ecco_for_las/version_4/release1/nctiles_climatology/contents.html

- ECCO v4 'standard analysis': http://mit.ecco-group.org/opendap/ecco_for_las/version_4/release1/ancillary_data/standardAnalysis.pdf

(6) resources, bibliography

- Iselin, 1939, The influence of vertical and lateral turbulence on the characteristics of the waters at mid-depths
- Forget et al, 2011, Estimated seasonal cycle of North Atlantic eighteen degree water volume
- Abraham et al, 2013, A review of global ocean temperature observations: Implications for ocean heat content estimates and climate change
- Forget and Ponte, under review, the Partition of Regional Sea Level Variability
- Dong et al, 2007, An Assessment of the Southern Ocean Mixed Layer Heat Budget
- Forget, 2010, Mapping ocean observations in a dynamical framework: A 2004-06 ocean atlas
- Danabasoglu et al, 2014, North Atlantic simulations in Coordinated Ocean-ice Reference Experiments phase II (CORE-II). Part I: Mean states
- Forget et al, to be subm., ECCO version 4: an integrated framework for non-linear inverse modeling and global ocean state estimation