Gael Forget
MIT, Jan. 16th 2015

Independent Activities Period

Introduction to ocean data-model analysis

course 4: the global ECCO v4 model setup and solution

1. general specifications
2. horizontal grid and vertical coordinate
3. structural and parametric model sensitivity
4. the state estimate model run

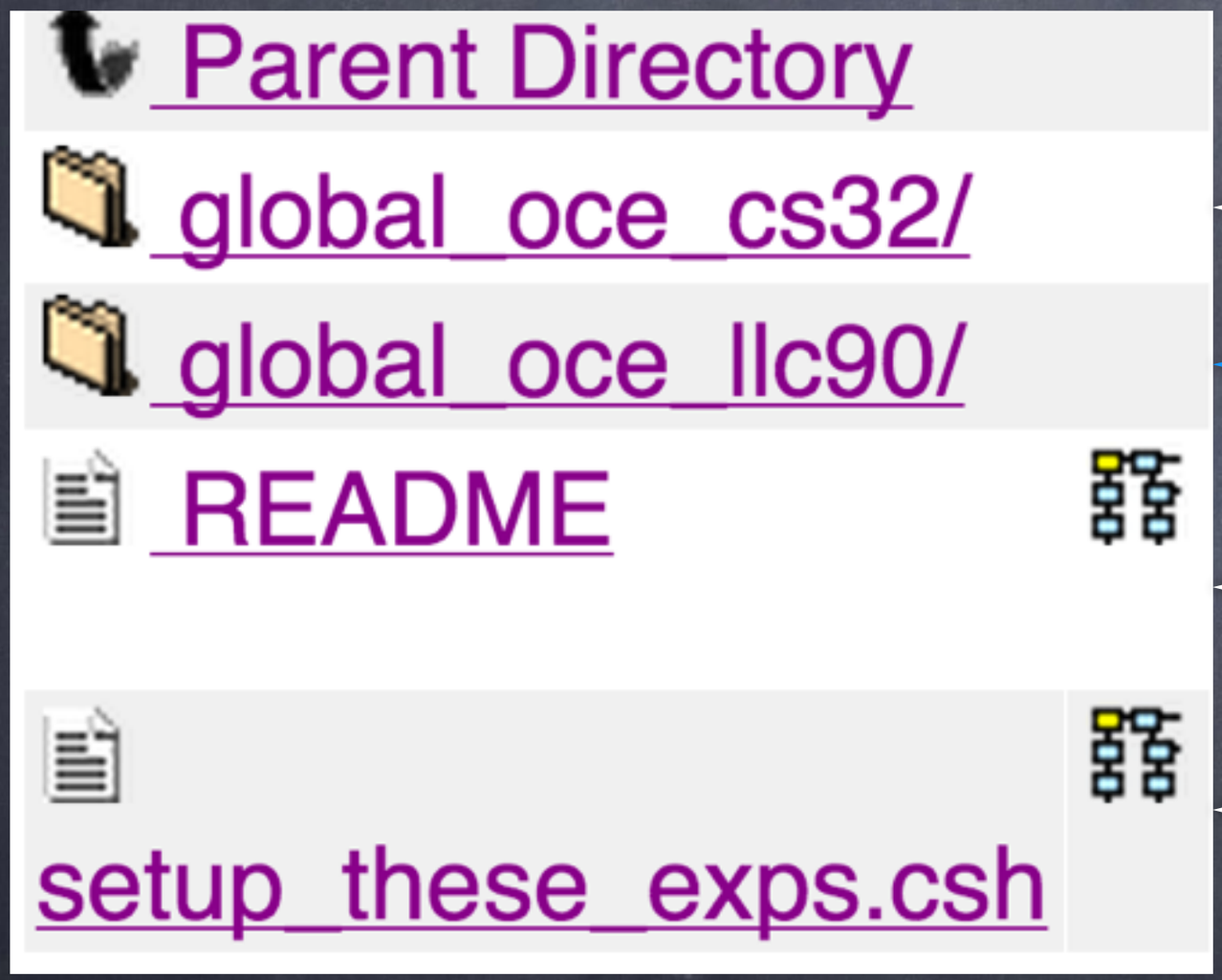
5. interactive session : self-guided exercises
6. resources, bibliography

... course 5 : usage of the MITgcm

(1) general specifications

- MITgcm, foward (and adjoint) model, 1992-2011
- fully global grid (including Arctic), doubled # grid points (still non-eddying) and vertical resol. (50 levels), largely updated numerics
- ERA-Interim forcing, real freshwater flux (with R* coordinate), interactive seaice model
- adjusted mixing parameters, forcing, 1992 IC
- improved fit to in situ profiles, SST, altim.
- monthly state estimate output, standard analysis @ ecco-group.org ...

(1) general specifications



Mini setup

Primary setup

Guidelines

Install script

http://mitgcm.org/viewvc/MITgcm/MITgcm_contrib/gael/verification/

(1) general specifications

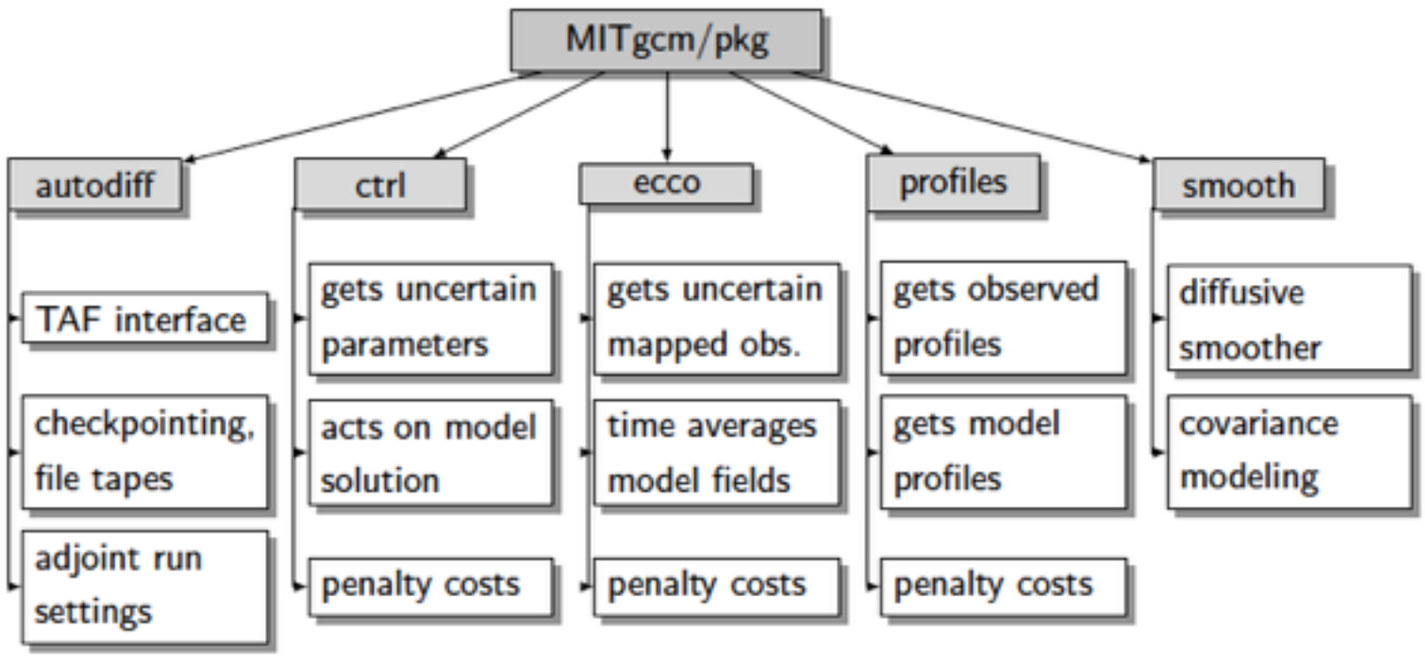


Figure 5: Organization and roles of MITgcm estimation modules. A more complete presentation can be found within the MITgcm manual.

MITgcm components

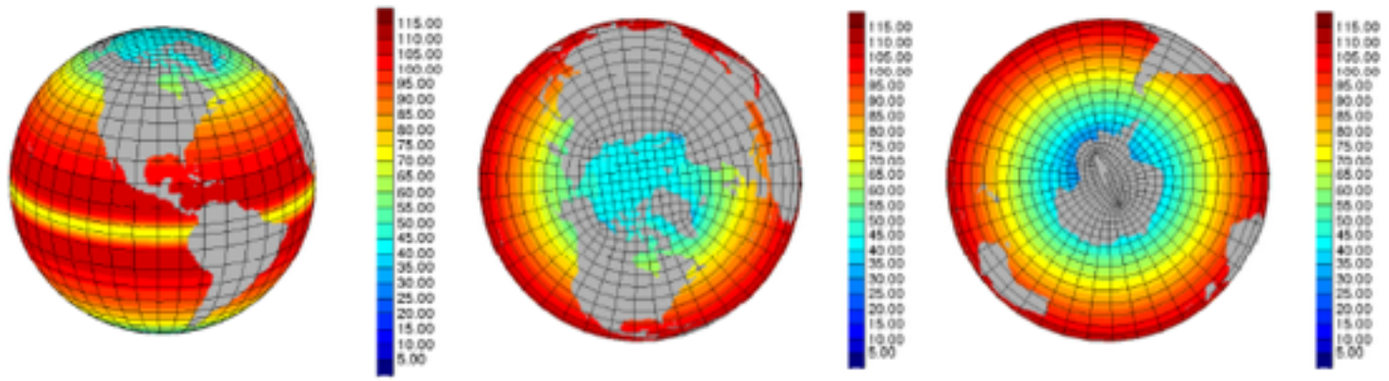
see code/packages.conf

and data.pkg

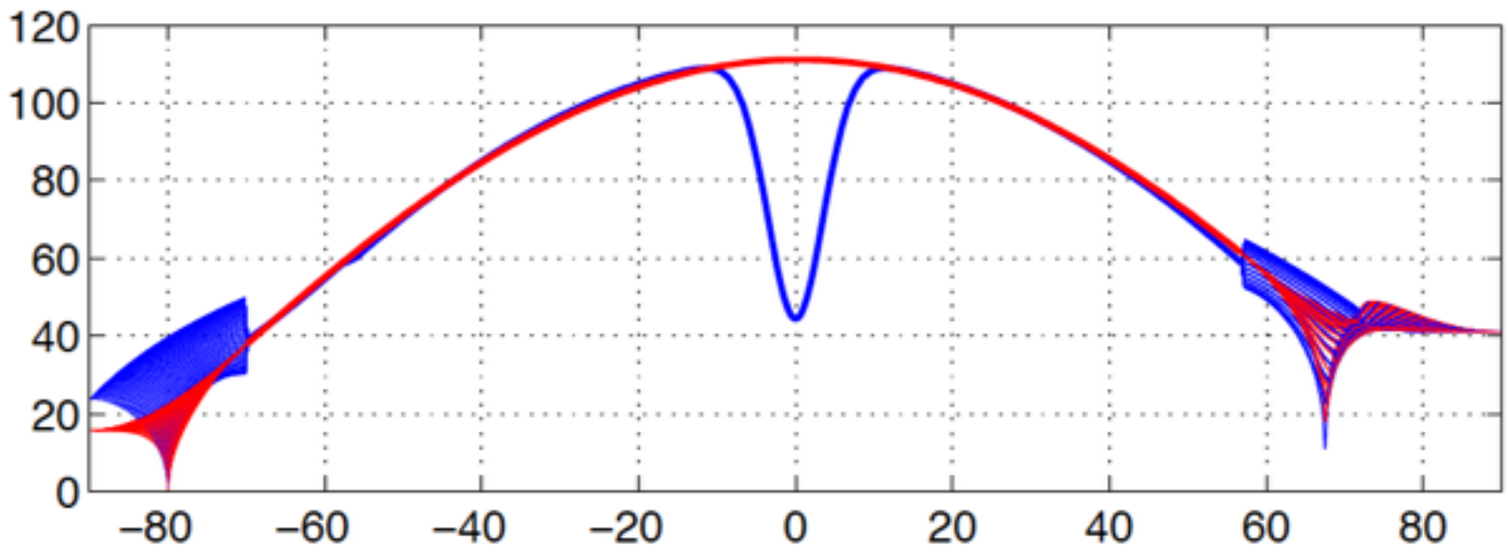
```
# Packages
 &PACKAGES
 useEXF    = .TRUE.,
#useRBCS   = .TRUE.,
 useGMRedi= .TRUE.,
# useKPP    = .TRUE.,
 useSBO    = .TRUE.,
#useMNC    = .TRUE.,
 useSeaice= .TRUE.,
#useThsice=.TRUE.,
 useGGL90=.TRUE.,
 useSALT_PlUME=.TRUE.,
# useDOWN_SLOPE=.TRUE.,
 useDiagnostics=.TRUE.,
 useECCO=.TRUE.,
 useCTRL=.TRUE.,
 useProfiles=.TRUE.,
 useSMOOTH=.FALSE.,
#useGrdchk=.TRUE.,
#useLayers=.TRUE.,
#
#usePtracers=.TRUE.,
#useBBL=.TRUE.,
 /
```

(2) horizontal grid and vertical coordinate

Figure 2: Average grid spacing for LLC90 (in km) computed as the square root of grid cell area. LLC90 denotes the LLC grid with 90 grid points as the common face dimension.



zonally asymmetric (see Fig.2), leading to the depicted grid spacing ranges.



Lat-Lon-Cap grid … see session #2 and gcmfaces

(2) horizontal grid and vertical coordinate

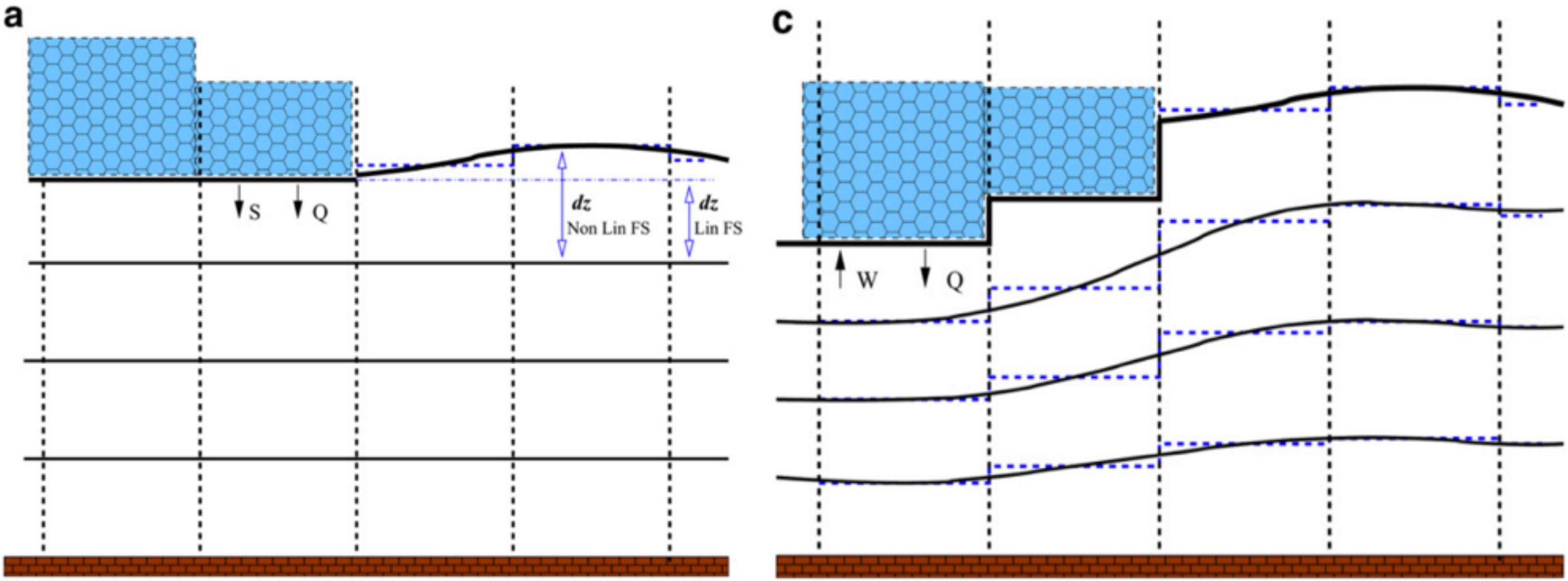


Fig. 1. Schematic view of three sea ice formulations: (a) no mass exchange (virtual salt flux); (b and c) real fresh water formulation (non-linear free-surface), in z-coordinates (b) and using z^*-coordinates (c). Heat flux (Q), and salt flux (S) in (a) or fresh-water flux (W) in (b and c), are represented by short arrows, corresponding to freezing conditions. Two open arrows in (a) represent the surface layer thickness dz which is used to compute oceanic advective fluxes, corresponding to the non-linear free-surface case $dz = \Delta z_1 + \eta$ and the approximated linear free-surface case $dz = \Delta z_1$. The sea-surface position is not affected by sea ice in (a) (so called "levitating" sea ice), but is depressed by the weight of sea ice in (b and c), with the first level empty in the left column of (b). The tilt of the coordinate in (c) avoids the problem of disappearing levels.

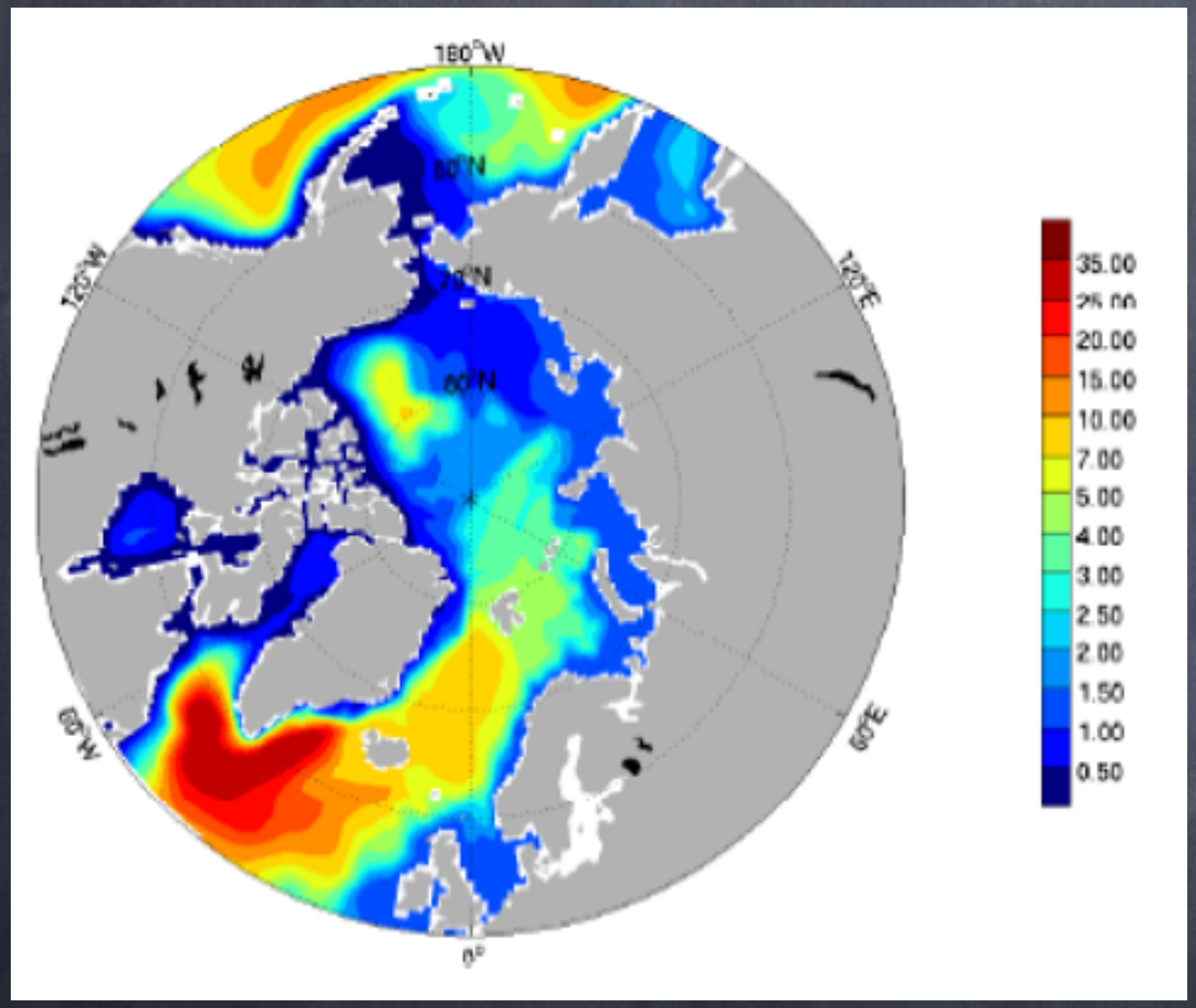
R* coordinate

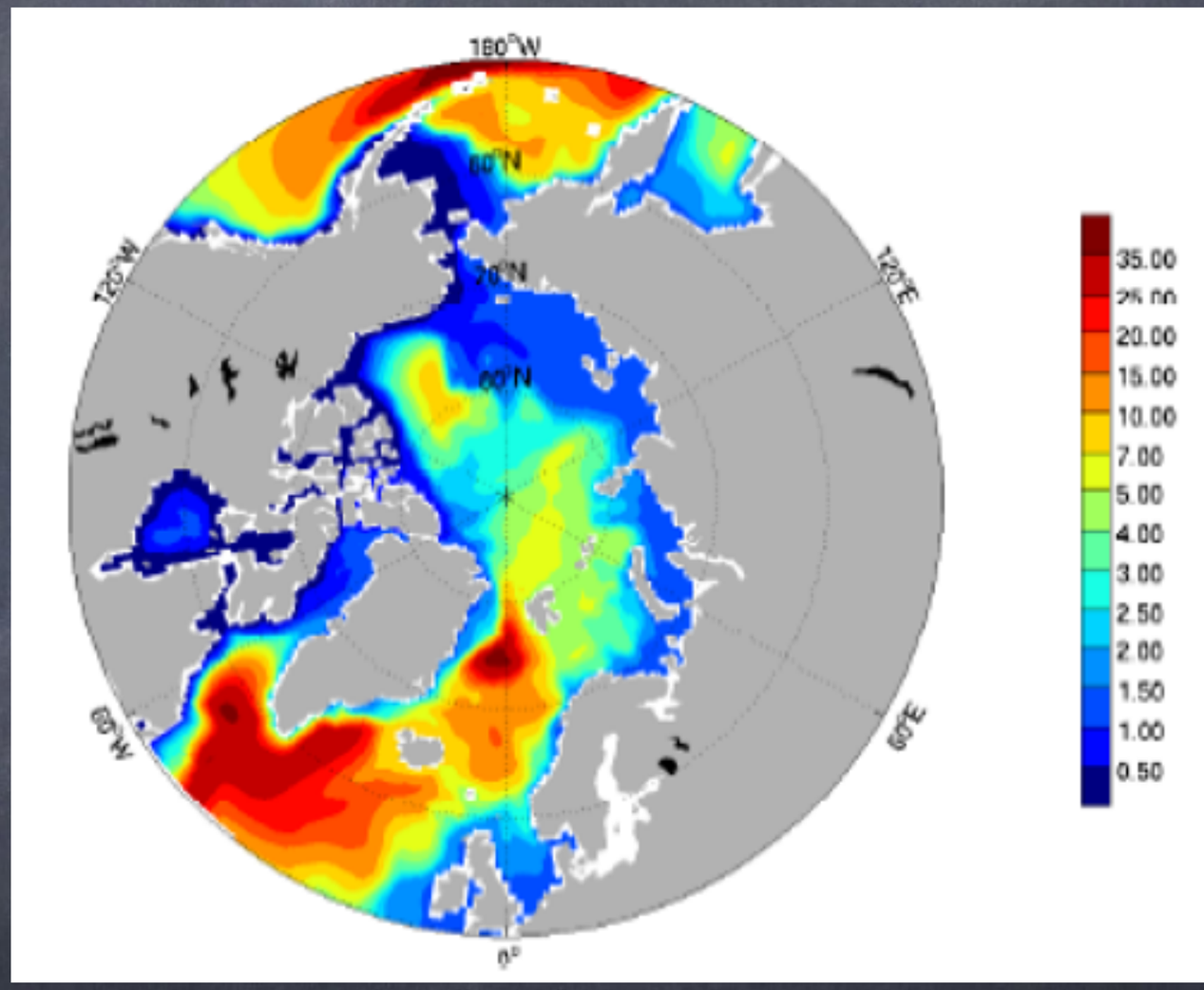
'hFacC' in MITgcm

Mass exchanges

'useRealFreshWaterFlux'

(3) structural and parametric sensitivity





an example of structural sensitivity:
on/off switch of the C-D scheme

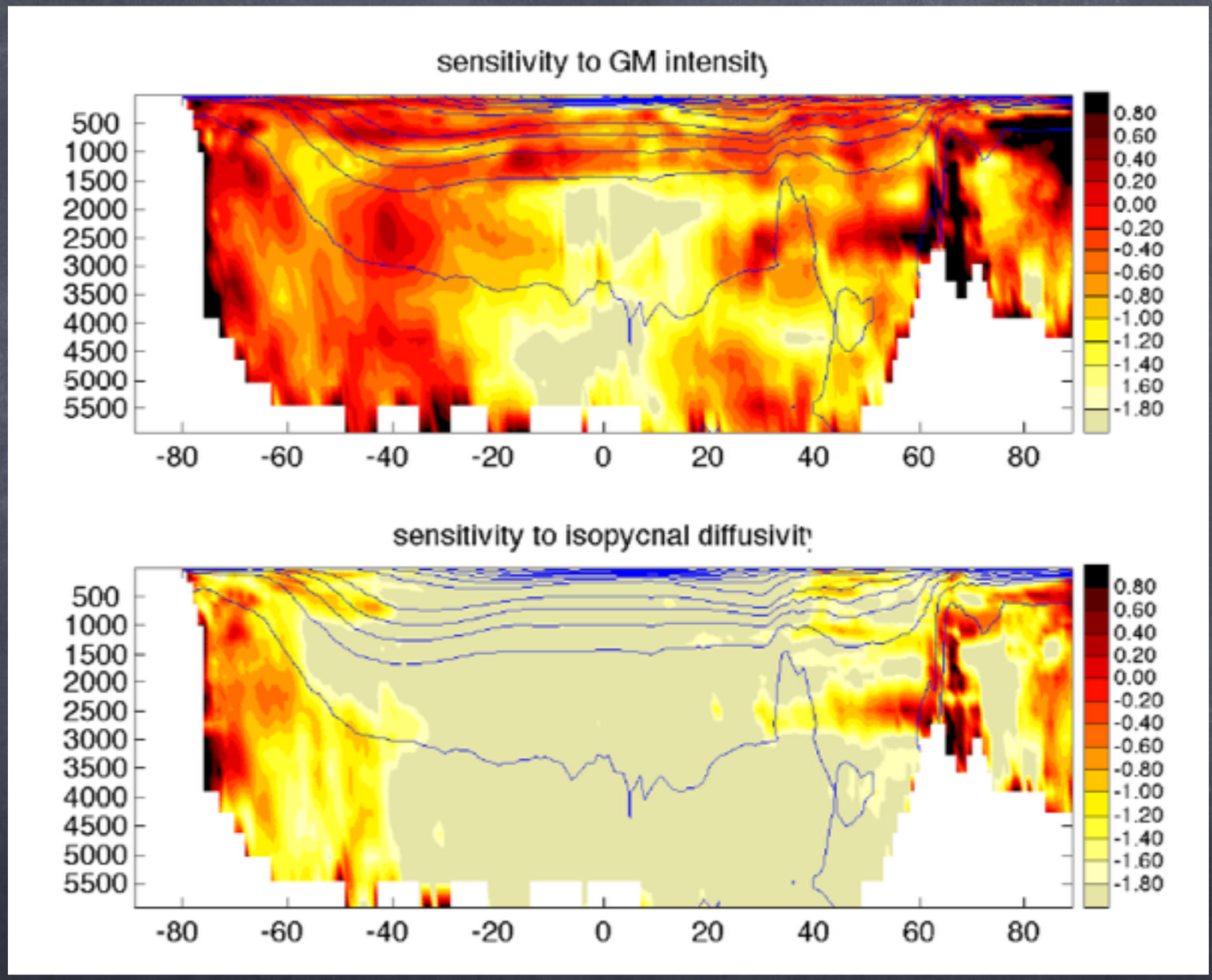
(3) structural and parametric sensitivity

experiment	jT	jS	jTs	jSs	jIs	jHa	jHm	mH	mT	mS	tV	tT	tS
computer update	(-6)	(-6)	(-7)	(-6)	(-5)	(-6)	(-7)	(-5)	(-5)	(-5)	(-6)	(-6)	(-5)
model update (65g)	(-7)	(-6)	(-6)	(-5)	(-6)	(-4)	(-4)	(-5)	(-5)	(-5)	(-6)	(-6)	(-5)
24 proc. clusters	(-6)	(-8)	(-6)	(-5)	(-5)	(-4)	(-4)	(-4)	(-5)	(-5)	(-6)	(-6)	(-5)
explicit vert. dst3	(-3)	(-2)	(-3)	(-2)	(-3)	(-3)	(-2)	60	50	37	(-3)	(-2)	4
3^{rd} order upwind	(-4)	(-3)	(-3)	(-3)	(-4)	(-4)	(-3)	(-2)	(-2)	(-2)	(-4)	(-3)	(-3)
flux limited dst3	3	6	1	(-2)	(-3)	(-2)	13	98	93	62	1	3	22
C-D scheme	40	52	17	7	2	25	64	69	13	56	2	5	53
added viscosity	6	7	2	6	(-2)	3	6	40	28	31	(-2)	1	22
added bottom visc.	4	5	1	6	(-2)	2	3	18	11	16	(-2)	1	17
KPP instead of GGL	4	11	7	10	11	4	3	148	149	95	(-2)	(-2)	22
added geo. heating	(-3)	(-3)	(-3)	(-3)	(-4)	(-3)	(-3)	(-2)	47	(-2)	(-3)	(-2)	1

Table 3: Benchmarking of (first three rows) and sensitivity experiments with (subsequent rows) the model configuration that produces the state estimate (section 5) being used here as the baseline 20 year solution. The sensitivity experiments pertain to tracer advection schemes, momentum equation settings, and boundary layers. Ocean characteristics that are used to gauged the sensitivity of ocean simulations are listed in Tab.2. Departures are computed relative to the state estimate, and normalized by the standard deviation of the state estimate result (for mH, ... , tS) or the state estimate-data distance (for jT, ... , jHm). Positive numbers denote percentages (for differences above 1%) whereas parenthesized negative numbers are powers of ten (for differences below 1%).

gauging sensitivity to model settings

(3) structural and parametric sensitivity



an example of parametric sensitivity:

turbulent transport parameters adjustement

(3) structural and parametric sensitivity

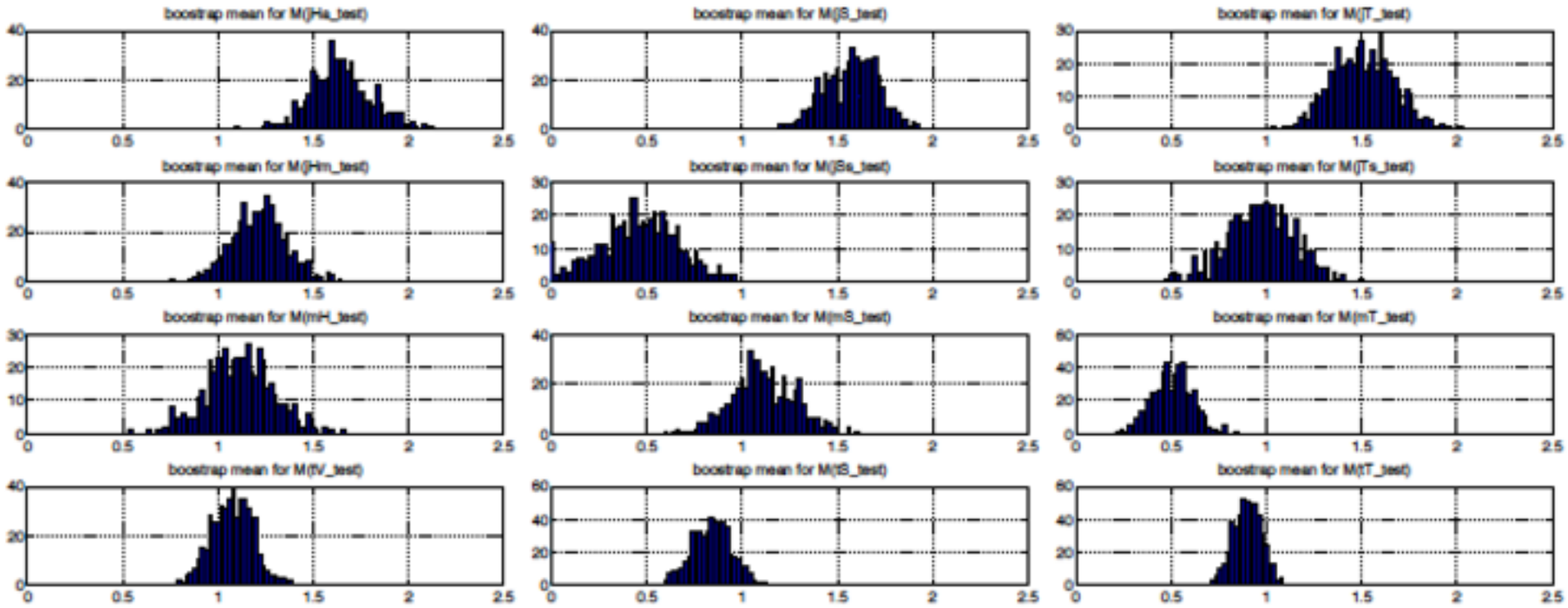


Figure 11: Bootstrap distribution for the controllability index (defined as $\mathcal{C}$ hereafter) of 1992-2011 ocean state characteristics. For a characteristics b, the quantity $\mathcal{C} = log_{10}(b_i/b_j)$ is computed for a set of 54 experiment pairs formed from the last 9 rows of Tab.3 values (b_j) and the last 6 rows of Tab.9 values (b_i). Values reported in Tab.3 as positive integers and parenthesized negative integers are examples of b_j and $log_{10}(b_j)$, respectively. Bootstrap resampling (500 members) gives the displayed distributions.

gauging parametric versus structural sensitivity

(4) the state estimate model run

- Model setup (8 time steps) benchmarked nightly
- Semi-automated process to install it (script)

...

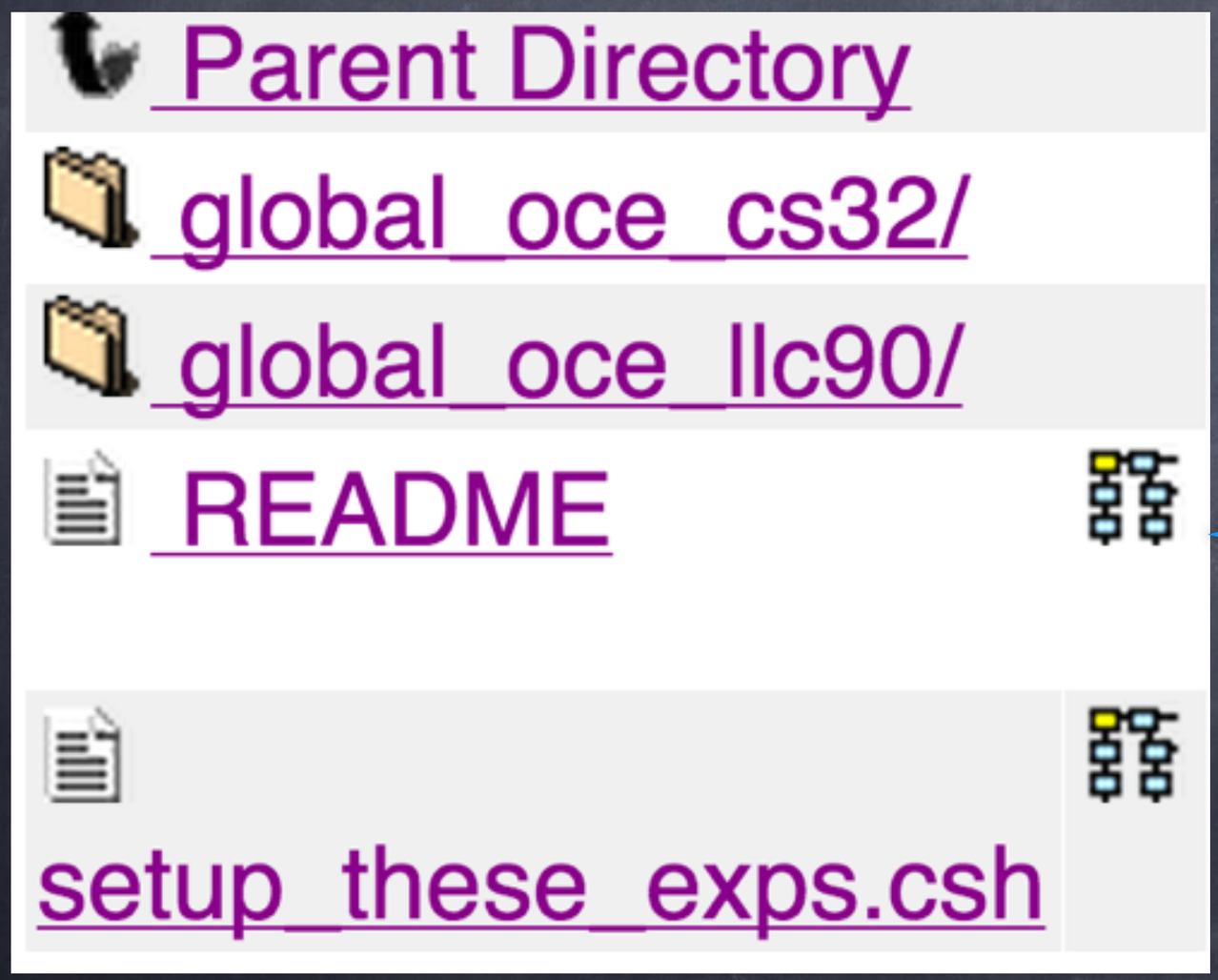
- State estimate (1992-2011) benchmarked monthly
- Requires additional binary input and Computation of e.g. O(8 hours) on 96 cores

...

- Adjoint capability requires TAF ($ software)

(4) the state estimate model run

http://mitgcm.org/viewvc/MITgcm/MITgcm_contrib/gael/verification/



Start Here
(coming soon:
eccov4.pdf)

… interactive session

(4) the state estimate model run

experiment	jT	jS	jTs	jSs	jIs	jHa	jHm	mH	mT	mS	tV	tT	tS
computer update	(-6)	(-6)	(-7)	(-6)	(-5)	(-6)	(-7)	(-5)	(-5)	(-5)	(-6)	(-6)	(-5)
model update (65g)	(-7)	(-6)	(-6)	(-5)	(-6)	(-4)	(-4)	(-5)	(-5)	(-5)	(-6)	(-6)	(-5)
24 proc. clusters	(-6)	(-8)	(-6)	(-5)	(-5)	(-4)	(-4)	(-4)	(-5)	(-5)	(-6)	(-6)	(-5)
explicit vert. dst3	(-3)	(-2)	(-3)	(-2)	(-3)	(-3)	(-2)	60	50	37	(-3)	(-2)	4
3^{rd} order upwind	(-4)	(-3)	(-3)	(-3)	(-4)	(-4)	(-3)	(-2)	(-2)	(-2)	(-4)	(-3)	(-3)
flux limited dst3	3	6	1	(-2)	(-3)	(-2)	13	98	93	62	1	3	22
C-D scheme	40	52	17	7	2	25	64	69	13	56	2	5	53
added viscosity	6	7	2	6	(-2)	3	6	40	28	31	(-2)	1	22
added bottom visc.	4	5	1	6	(-2)	2	3	18	11	16	(-2)	1	17
KPP instead of GGL	4	11	7	10	11	4	3	148	149	95	(-2)	(-2)	22
added geo. heating	(-3)	(-3)	(-3)	(-3)	(-4)	(-3)	(-3)	(-2)	47	(-2)	(-3)	(-2)	1

Table 3: Benchmarking of (first three rows) and sensitivity experiments with (subsequent rows) the model configuration that produces the state estimate (section 5) being used here as the baseline 20 year solution. The sensitivity experiments pertain to tracer advection schemes, momentum equation settings, and boundary layers. Ocean characteristics that are used to gauged the sensitivity of ocean simulations are listed in Tab.2. Departures are computed relative to the state estimate, and normalized by the standard deviation of the state estimate result (for mH, ... , tS) or the state estimate-data distance (for jT, ... , jHm). Positive numbers denote percentages (for differences above 1%) whereas parenthesized negative numbers are powers of ten (for differences below 1%).

full run benchmarking : testreport_ecco.m

(coming soon: eccov4.pdf)

(5) interactive session : self-guided exercises

Below is a list of proposed, self guided exercises. I generally tried to order
the exercises by increasing complexity. While none of them is really challenging,
the various exercises aim to give you with first hand experience with the data sets
and tools discussed over the course of the IAP activity.

tips : - look for answers/examples in the programs we ran together in class #1 and #2
- type 'help read_nctiles' in matlab and similarly for all other functions
- use the matlab debugger to go through computations step by step

The actual listing is at
http://mitgcm.org/viewvc/*checkout*/MITgcm/MITgcm_contrib/gael/comm/course-idma2015/computing/iap-idma-exercises

or run the ECCO v4 mini benchmark

Directions were added in
http://mitgcm.org/viewvc/*checkout*/MITgcm/MITgcm_contrib/gael/comm/course-idma2015/computing/iap-idma-readme

(6) resources, bibliography

- Adcroft et al, 1999, A new treatment of the Coriolis terms in C-grid models at both high and low resolutions.
- Adcroft et al, 2004, Rescaled height coordinates for accurate representation of free-surface flows in ocean circulation models.
- Campin et al, 2008, Sea ice--ocean coupling using a rescaled vertical coordinate.
- Forget et al, to be subm., ECCO version 4: an integrated framework for non-linear inverse modeling and global ocean state estimation.
- Forget, to be subm., On the observability of turbulent transport rates by Argo: evidence from an inversion experiment.