Gael Forget
MIT, Jan. 22nd 2016

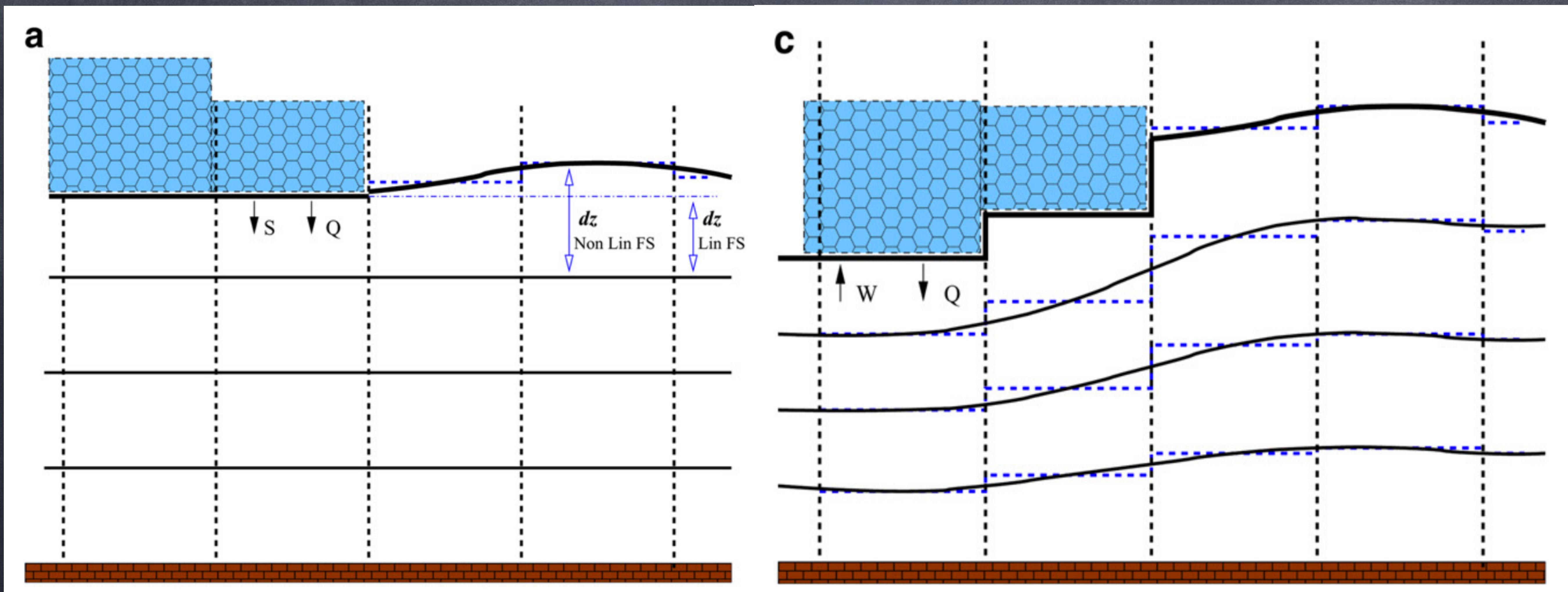
Independent Activities Period

Introduction to ocean data-model analysis

Class overview

I. observations
II. gridded products
III. numerical models
IV. completion of activities

(1) ocean modeling



The old ways

with levitating ice

R* coordinate

'hFacC' in MITgcm

(Campin et al 2008)

Mass exchanges

'useRealFreshWaterFlux'

(1) ocean modeling

$$\frac{\partial \eta}{\partial t} + \nabla \cdot \int_{-H}^{\eta} \boldsymbol{v}\, \mathrm{d}z = \frac{\mathrm{PmE}}{\rho_{\mathrm{c}}}, \tag{7}$$

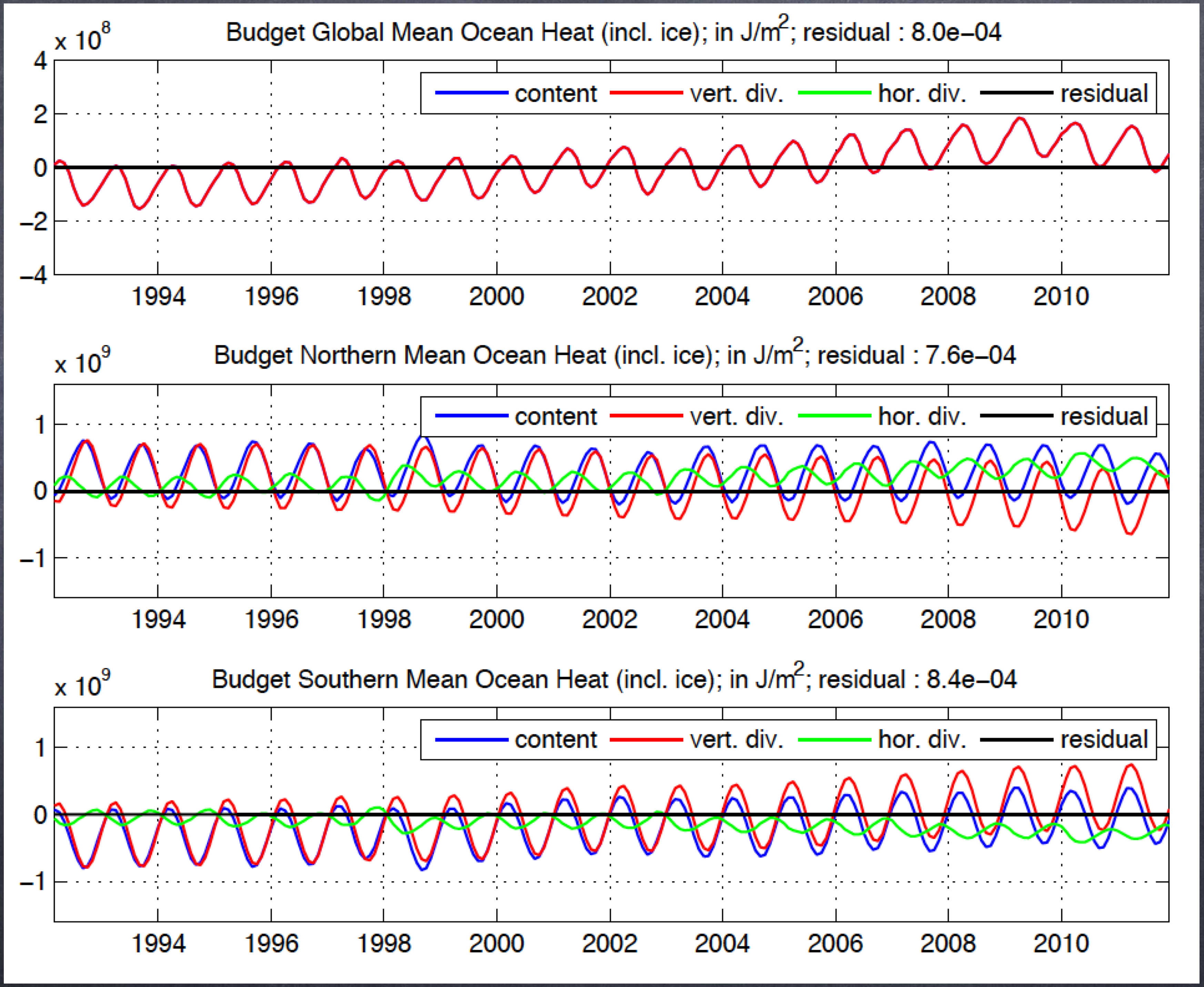
$$\frac{\partial}{\partial t}((\eta + H)\overline{\theta}) + \nabla \cdot \int_{-H}^{\eta} \theta\, \boldsymbol{v}_{\mathrm{res}}\, \mathrm{d}z = \frac{Q_{\mathrm{net}}}{\rho_{\mathrm{c}} C_p} + \int_{-H}^{\eta} D_{\sigma,\theta}\, \mathrm{d}z, \tag{8}$$

$$\frac{\partial}{\partial t}((\eta + H)\overline{S}) + \nabla \cdot \int_{-H}^{\eta} S\, \boldsymbol{v}_{\mathrm{res}}\, \mathrm{d}z = \frac{S_{\mathrm{flux}}}{\rho_{\mathrm{c}}} + \int_{-H}^{\eta} D_{\sigma,S}\, \mathrm{d}z, \tag{9}$$

where the overbar denotes vertical averaging according to $\overline{\varphi} = \frac{1}{(\eta+H)} \int_{-H}^{\eta} \varphi\, \mathrm{d}z$.

(Forget et al., GMD, 2015)

(1) ocean modeling



(in supplement of Forget et al., GMD, 2015)

(1) ocean modeling

regression tests (re-runs)

(for mH, . . . , tS). Positive numbers denote percentages (for differences above 1 %), whereas parenthesized negative numbers are powers of 10 (for differences below 1 %).

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 (65 g)	(−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)

structural model uncertainty

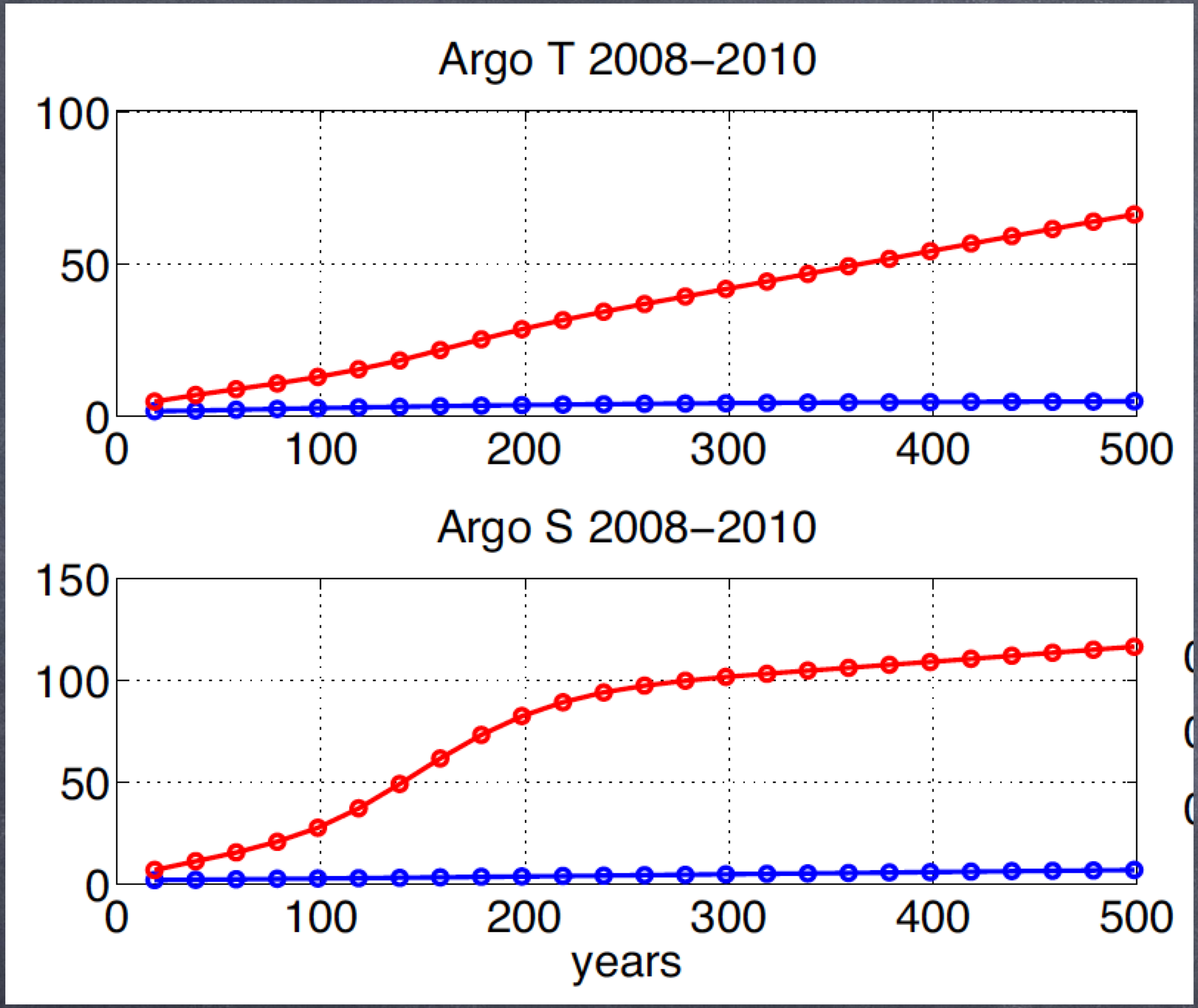
Explicit vert. DST-3	(−3)	(−2)	(−3)	(−2)	(−3)	(−3)	(−2)	60	50	37	(−3)	(−2)	4
Third-order upwind	(−4)	(−3)	(−3)	(−3)	(−4)	(−4)	(−3)	(−2)	(−2)	(−2)	(−4)	(−3)	(−3)
Flux-limited DST-3	3	6	1	(−2)	(−3)	(−2)	13	98	93	62	1	3	22
C-D scheme	40	52	17	7	2	25	64	69	13	56	2	5	53
Added viscosity	6	7	2	6	(−2)	3	6	40	28	31	(−2)	1	22
Added bottom visc.	4	5	1	6	(−2)	2	3	18	11	16	(−2)	1	17

external and parametric uncertainty

All controls	369	1027	160	56	17	242	313	7925	99	5295	46	29	396
Internal parameters	212	317	56	15	12	72	163	329	272	233	4	15	96
External forcing fields	63	437	87	27	17	117	112	7665	252	5114	44	12	234

(Forget et al., GMD, 2015)

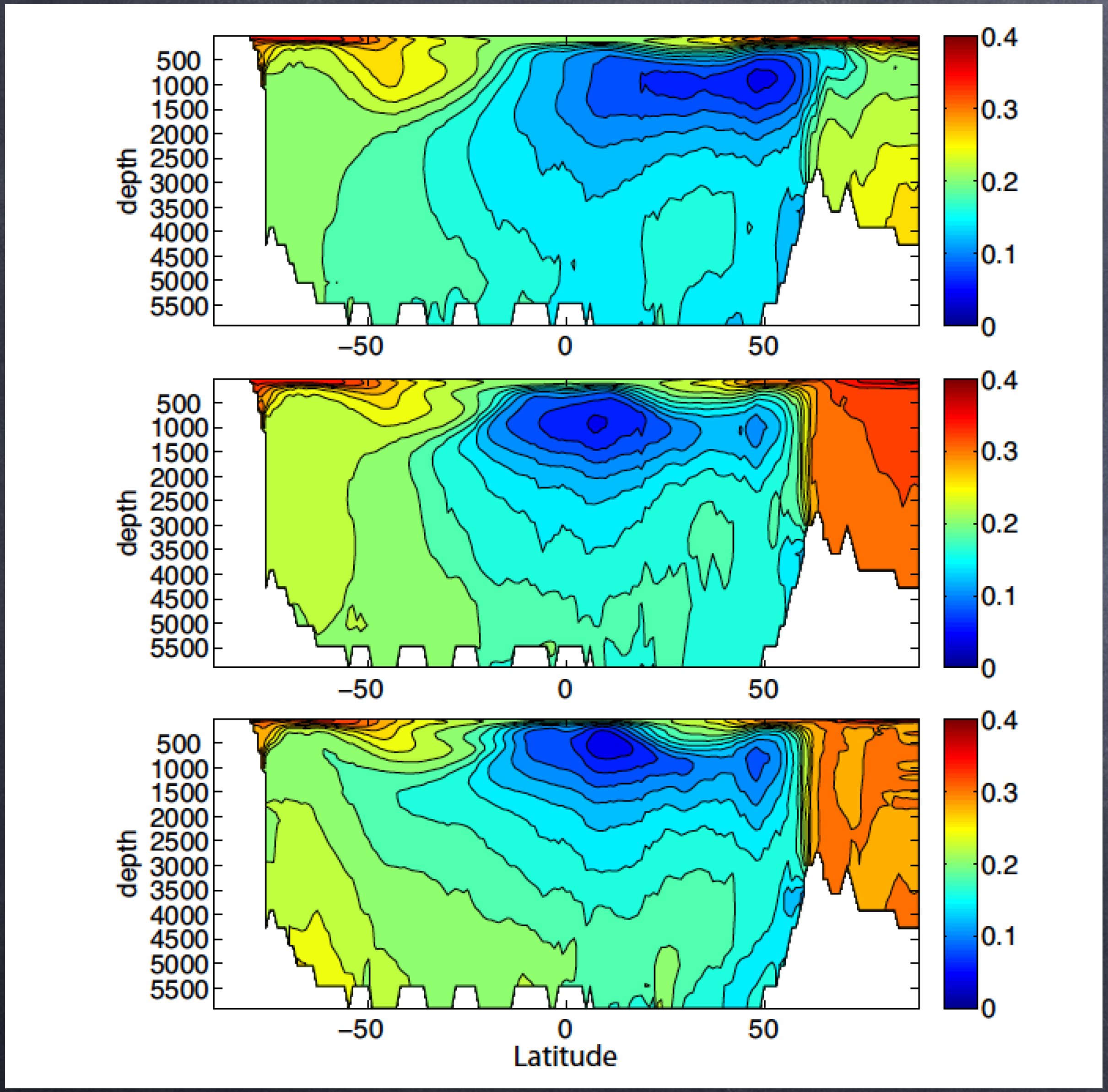
(1) ocean modeling



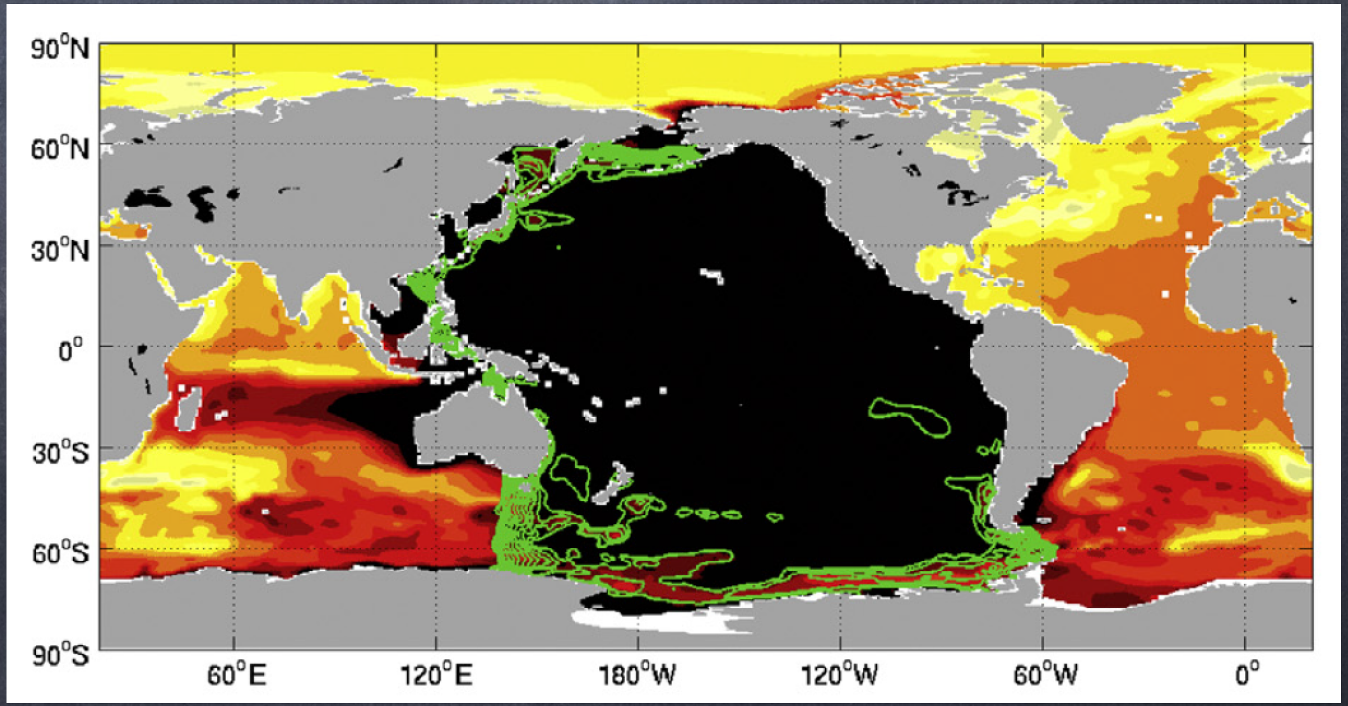
model drift reduction using model parameter inversions

(Forget et al., OS, 2015)

(2) example applications (forward)



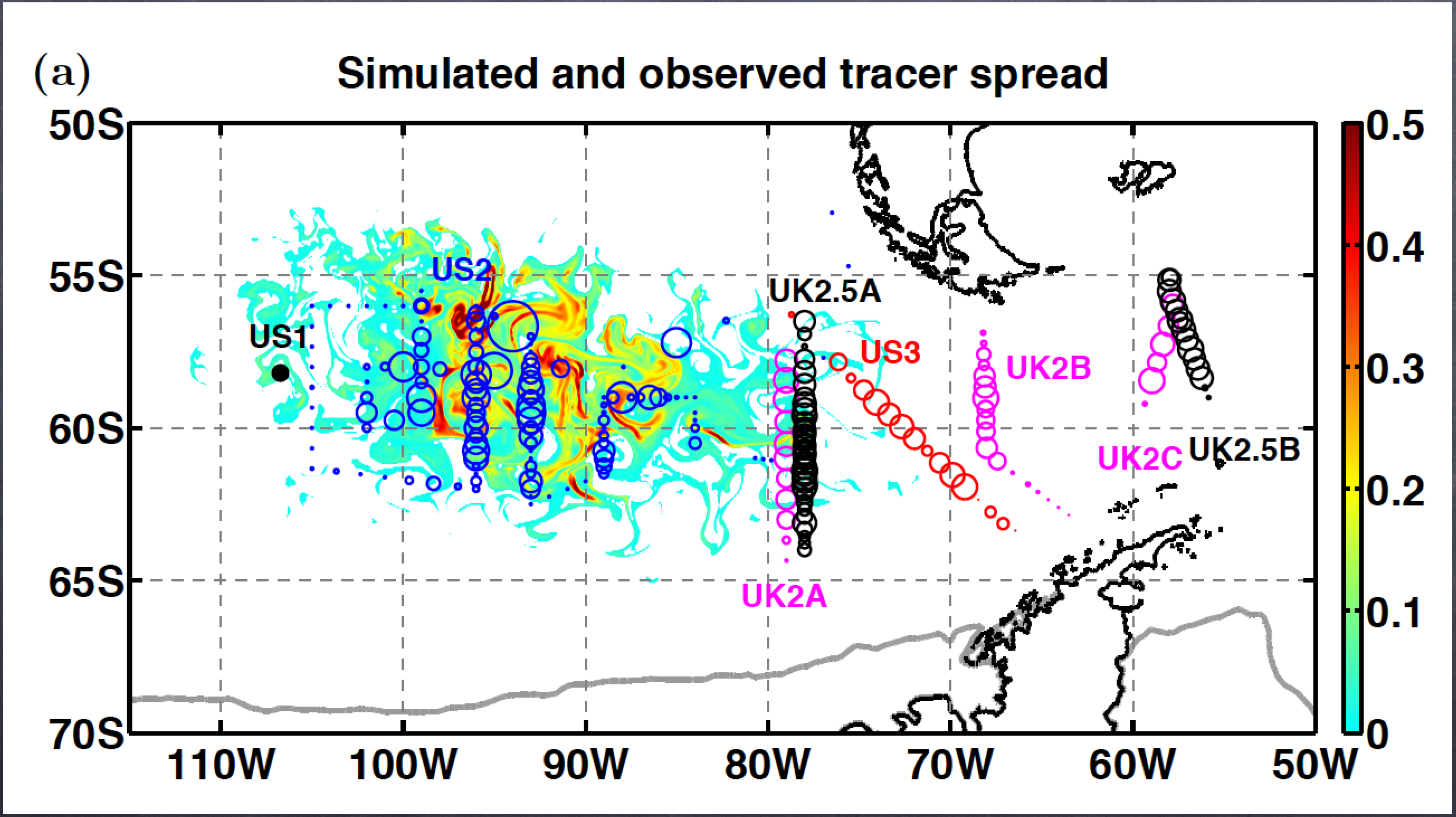
tracer simulations, perturbation experiments, etc.



(Forget et al., OS, 2015)

(Forget and Ponte, 2015)

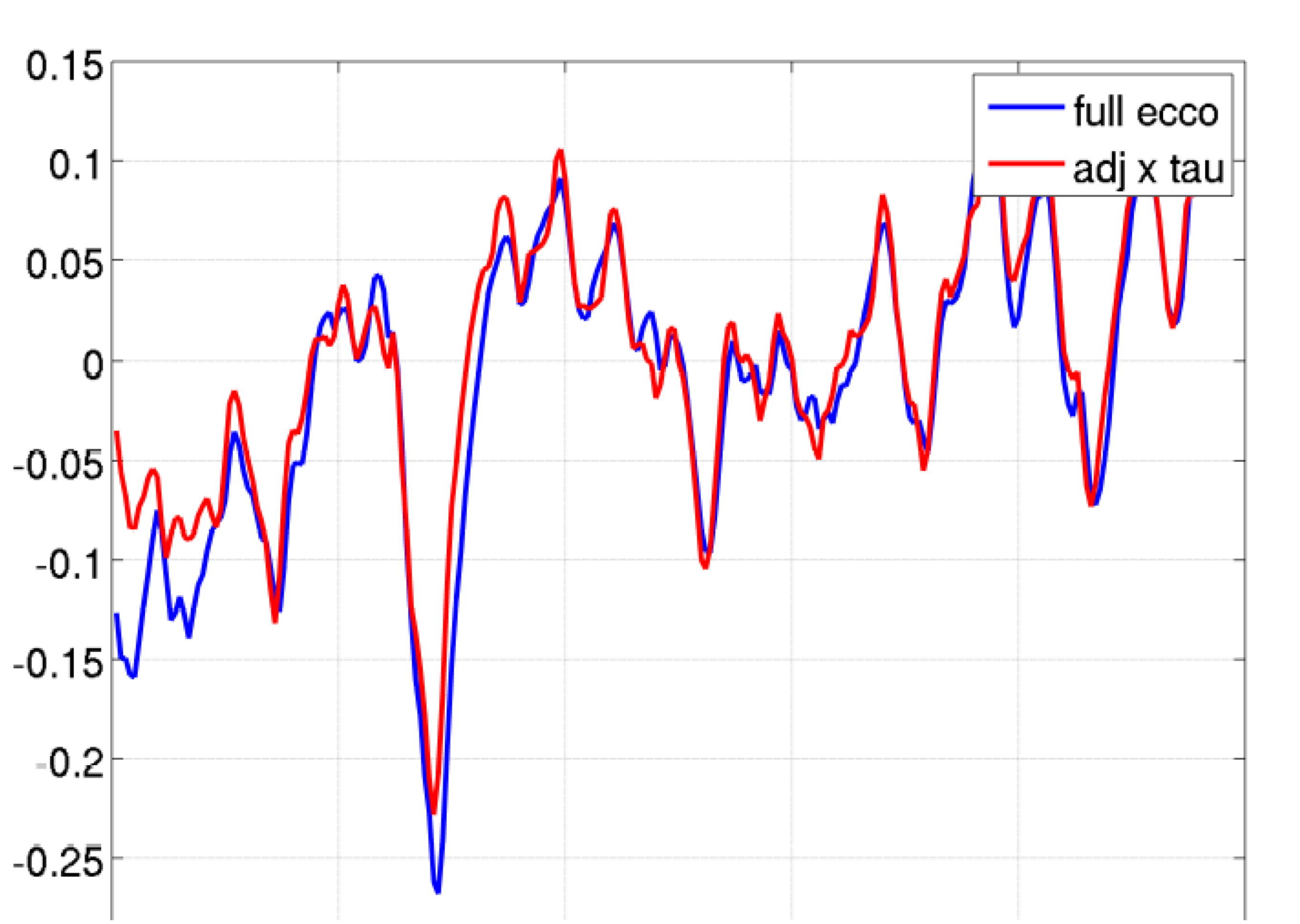
(2) example applications (forward)



high-resolution (~5km) nested models

(Tulloch et al., 2013)

(2) example applications (adjoint)



$$J(T,\tau) = \int_{wtp} H(x,y,T,\tau)\ dxdy - \int_{etp} H(x,y,T,\tau)\ dxdy$$

$$\mathcal{G}(x,y,t-T) = \frac{\partial J}{\partial \tau}(t-T) \ \text{ from the adjoint model}$$

$$K(T,\tau) = \int_{-\infty}^{T} \int_{glo} \mathcal{G}(x,y,t-T) \cdot \tau'(x,y,t)\ dxdy\ dt$$

(3) running MITgcm and ECCO v4

7. **tutorial_global_oce_biogeo** - Ocean model coupled to the dissolved inorganic carbon biogeochemistry model. This experiment is described in detail in section 3.17.
8. **tutorial_global_oce_in_p** - Global ocean simulation in pressure coordinate (non-Boussinesq ocean model). Described in detail in section 3.13.
9. **tutorial_global_oce_latlon** - 4x4 degree global ocean simulation with steady climatological forcing. This experiment is described in detail in section 3.12.
10. **tutorial_global_oce_optim** - Global ocean state estimation at 4° resolution. This experiment is described in detail in section 3.18.
11. **tutorial_held_suarez_cs** - 3D atmosphere dynamics using Held and Suarez (1994) forcing on cubed sphere grid. This experiment is described in detail in section 3.14.
12. **tutorial_offline** - Offline form of the MITgcm to study advection of a passive tracer. This experiment is described in detail in section 3.20.
13. **tutorial_plume_on_slope** - Gravity Plume on a continental slope. This experiment is described in detail in section 3.16.

MITgcm and its 'verification experiments'

(manual.pdf available from mitgcm.org)

(3) running MITgcm and ECCO v4

MITgcm daily regression tests

baudelaire	linux_amd64_g77	adjoint-taf	20150128	summary.txt	26:27
baudelaire	linux_amd64_g77	forward	20150128	summary.txt	89:95
baudelaire	linux_amd64_gfortran.dvlp	adjoint-taf	20150128	summary.txt	27:27
baudelaire	linux_amd64_gfortran.dvlp	tanglin-taf	20150125	summary.txt	19:19
baudelaire	linux_amd64_gfortran.dvlp	adjoint-oad	20150128	summary.txt	8:8
baudelaire	linux_amd64_gfortran.dvlp	forward	20150128	summary.txt	95:95
baudelaire	linux_amd64_gfortran.dvlp	restart	20150128	summary.txt	93:95
baudelaire	linux_amd64_gfortran+mpi.dvlp	adjoint-taf	20150128	summary.txt	21:23
baudelaire	linux_amd64_gfortran+mpi.dvlp	forward	20150128	summary.txt	84:88
baudelaire	linux_amd64_gfortran+mpi+mth.dvlp	forward	20150128	summary.txt	77:81
baudelaire	linux_amd64_gfortran+mpi+mth.dvlp	restart	20150128	summary.txt	80:81
baudelaire	linux_amd64_gfortran+mth.dvlp	forward	20150128	summary.txt	83:83
baudelaire	linux_amd64_ifort11.dvlp	forward	20150128	summary.txt	91:95

ECCO v4 setup daily regression tests

glacier3	linux_amd64_gfortran+mpi	forward	20150128	summary.txt	5:5

(http://mitgcm.org/public/testing.html)

(3) running MITgcm and ECCO v4

genmake2

4.1. Build Tools

Many Open Source projects use the "GNU Autotools" to help streamline the build process for various Unix and Unix-like architectures. For a user, the result is the common "configure" (that is, "`./configure && make && make install`") commands. For MITgcm, the process is similar. Typical commands are:

```
$ genmake2 -mods=../code
$ make depend
$ make
```

testreport

4.2. The Verification Suite

The MITgcm CVS tree (within the `$ROOTDIR/verification/` directory) includes many (> 90) examples intended for regression testing. Each one of these test-experiment directories contains "known-good" output files along with all the input (including both code and data files) required for their re-calculation. Also included in `$ROOTDIR/verification/` is the shell script `testreport` to perform regression tests.

(devel_HOWTO.pdf from mitgcm.org)

(3) running MITgcm and ECCO v4

abstract

These notes pertain to the ECCO v4 state estimate, model setup, and associated codes (Forget et al., 2015). Section 1 summarizes download procedures and links to additional documentation[1]. Section 2 explains how ECCO v4 solutions, or corresponding short regression tests, can be re-run.

Contents

computational cost: 20 year run takes ~8h on 96 cores

(eccov4.pdf available from gaelforget.net)

(4) activity period

- **option 1:** explore relationships between variables (e.g. SST, qnet and MLD) and data sets (e.g. Reynolds SST, ECCO, and Argo) over a region of your choosing.

- Using Matlab from sessions #1 and #2 +

    - sea surface temperature and related variables
    - heat and FW fluxes into the ocean (and ice pack)
    - sea surface height and bottom pressure
    - near surface velocity and related vector variables

(see idma_load_fields.m)

(4) activity period

- **option 2:** download MITgcm and run some of its short `verification experiments' on one of the classroom linux computers. Visualize results with Matlab.
- Login as guest then open a terminal window and proceed as explained in idma2016-instructions.pdf (see instruction for session #4 activity).