Adjoint And Cloud Applications Of The ECCO V4 Framework

Gaël Forget

Caltech, Pasadena

2017/11/06

– The 2 km CS and LLC grids, as well as descending resolution grids
– The MITgcm estimation framework implementation charted in Fig. 5
– The model setup subjected to forward and adjoint daily regression tests
– The state estimate output, including model–data misfits
– The observational data input, including weights, to the state estimate
– The forward model input needed to re-compute the 1992–2011 solution
– The testreport_ecco.m tool to verify re-runs of the 1992–2011 solution
– The gcmfaces Matlab framework to analyze global, gridded solutions
– The MITprof Matlab framework to process and analyze in situ profiles
– The solution's standard analysis produced by gcmfaces and MITprof

Forget, Campin, Heimbach, Hill, Ponte, and Wunsch 2015, GMD, https://doi.org/10.5194/gmd-8-3071-2015

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Gaël Forget	Presentation Outline	2017/11/06

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Jochem Marotzke, Ralf Giering, Kate Q. Zhang, Detlef Stammer, Chris Hill, Tong Lee

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

G. Forget[1], J.-M. Campin[1], P. Heimbach[1,2,3], C. N. Hill[1], R. M. Ponte[4], and C. Wunsch[5]

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Cloud-based solutions for distributed climate modeling

Nadya Vinogradova[1], Mark Shiffer[1], Gael Forget[2], and Chris Hill[2]
[1]Cambridge Climate Institute, MA
[2]Massachusetts Institute of Technology, MA

http://hdl.handle.net/1721.1/111605

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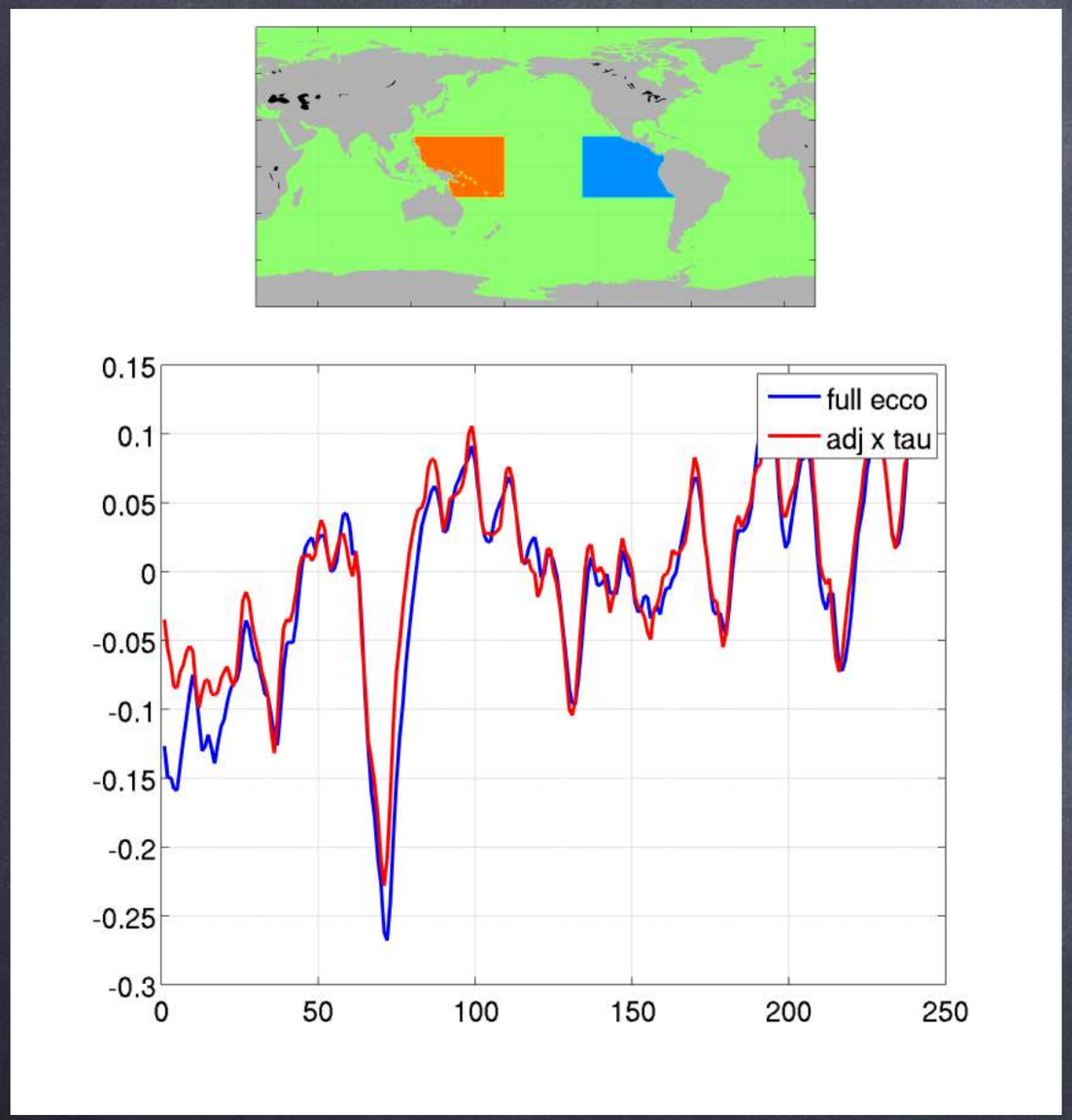
→ ∞

Gaël Forget

The Adjoint Method (A Prototypical Example)

2017/11/06

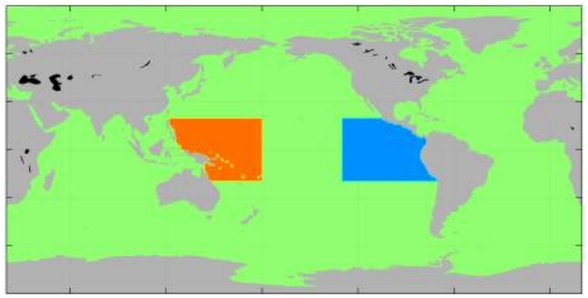


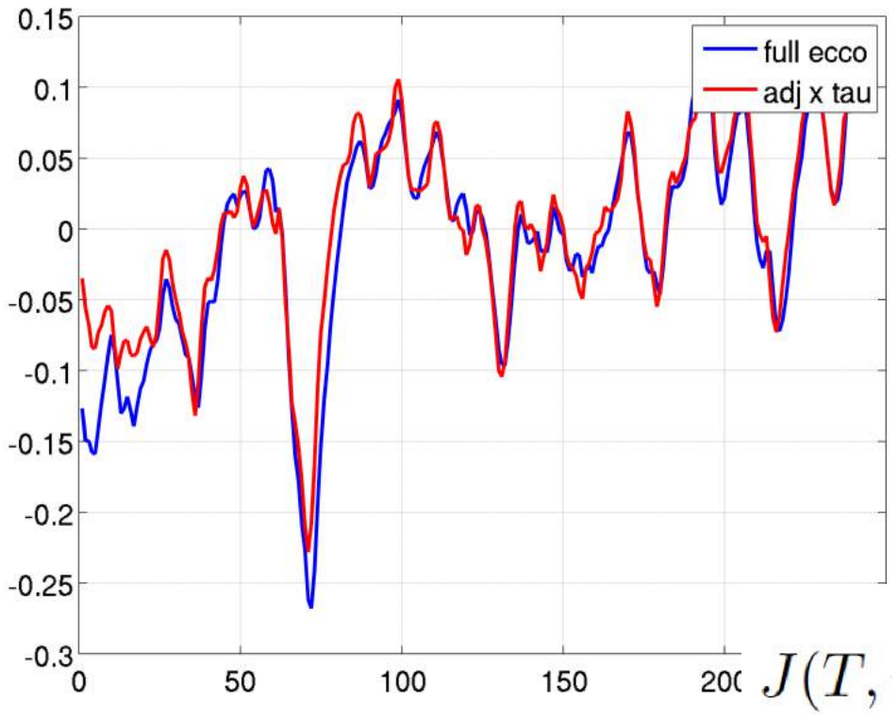
Tropical Pacific Sea Level Difference (blue curve) and its reconstruction (red curve) ...

Gaël Forget

The Adjoint Method (A Prototypical Example)

2017/11/06





Tropical Pacific Sea Level Difference (blue curve) and its reconstruction (red curve) ...

... obtained by convolving adjoint sensitivities with wind stress anomalies (Eqs. below).

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

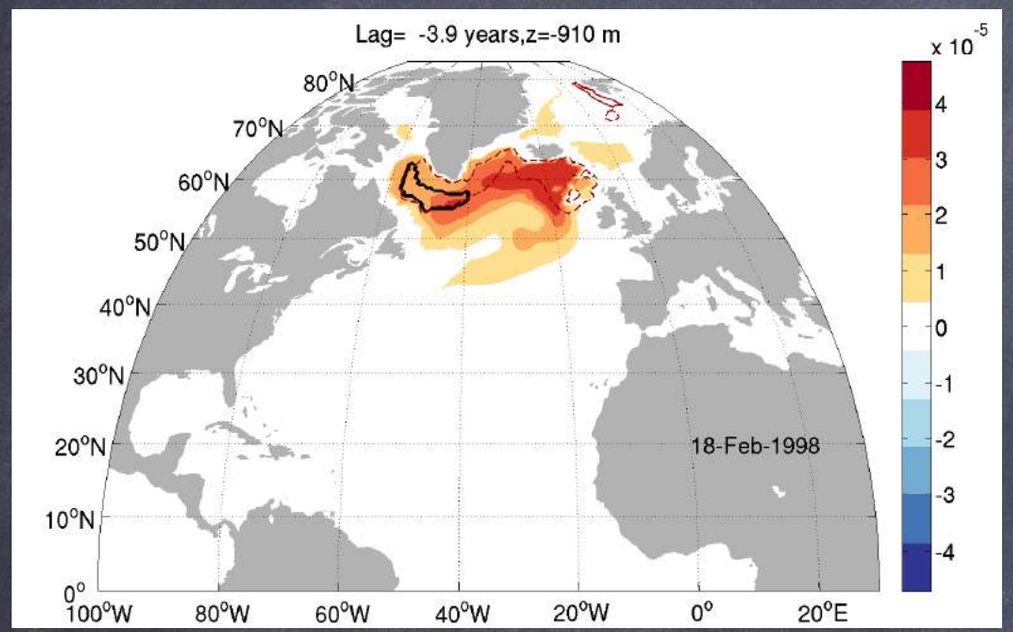
$$\mathcal{G}(x,y,t-T) = \frac{\partial J}{\partial \tau}(t-T) \text{ from the adjoint model}$$

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

Gaël Forget

Adjoint Sensitivity Analyses (Labrador Sea Heat Content)

2017/11/06



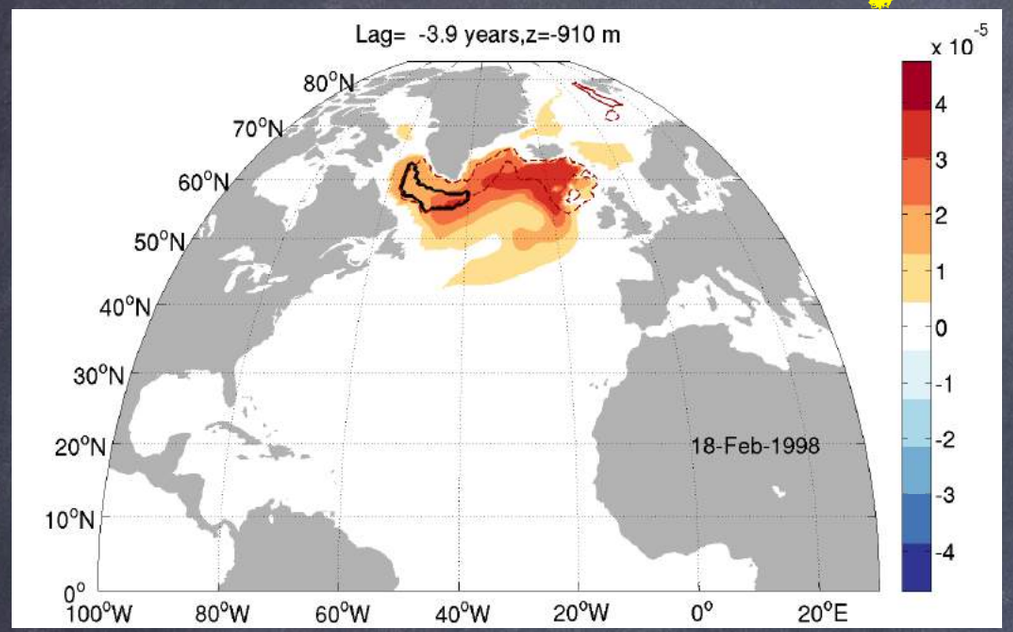
Daniel Jones, Gael Forget, Bablu Sinha, Simon Josey, Emma Boland, Andrew Meijers, Emily Shuckburgh (in prep.)

Gaël Forget

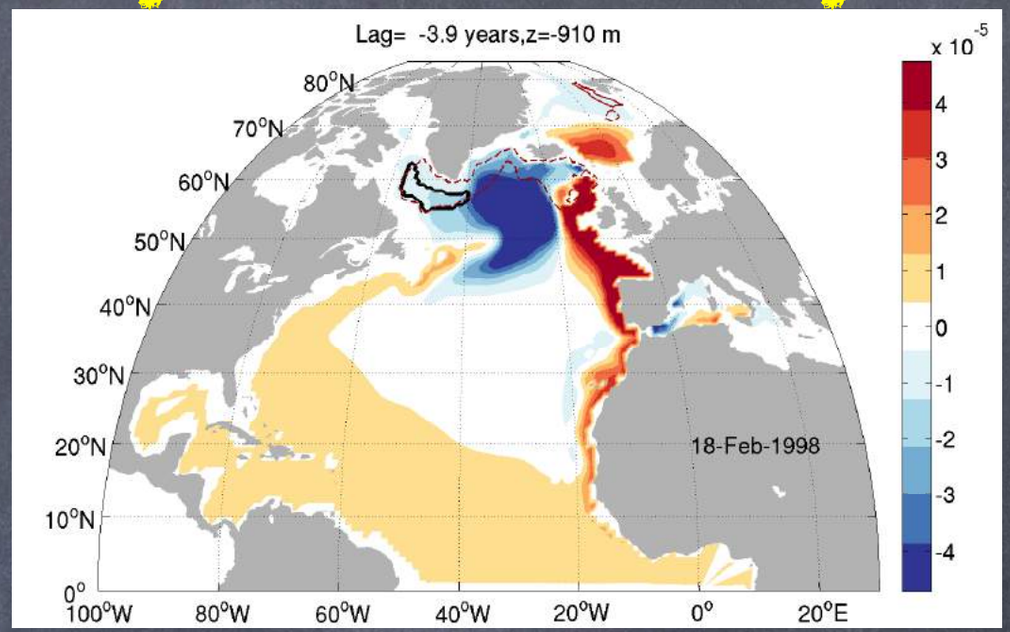
Adjoint Sensitivity Analyses (Labrador Sea Heat Content)

2017/11/06

Kinematic Sensitivity



dynamic Sensitivity



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Adjoint Sensitivity Analyses (Labrador Sea Heat Content)

2017/11/06

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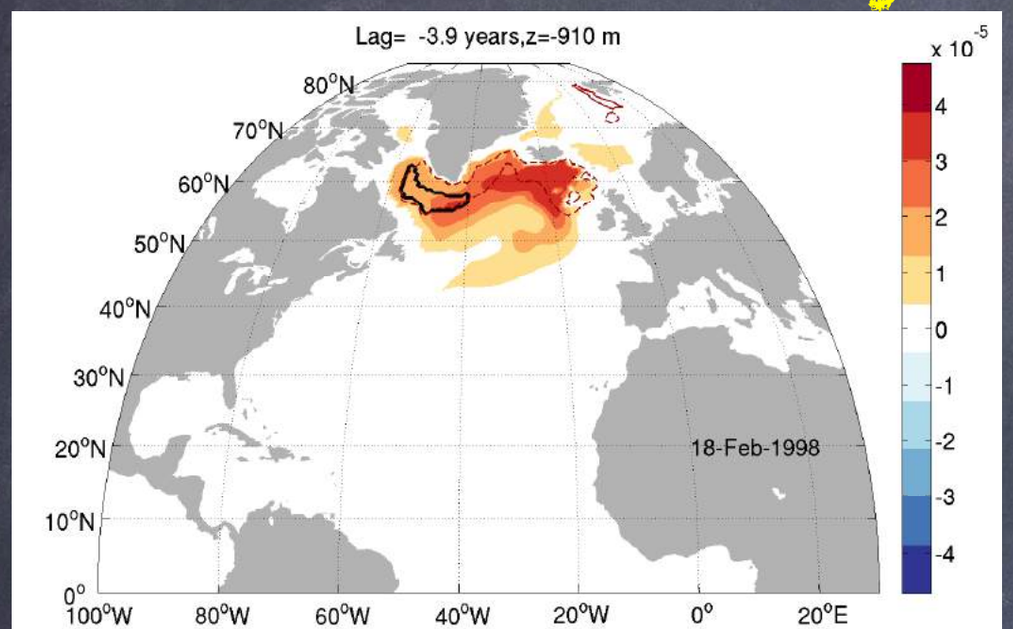
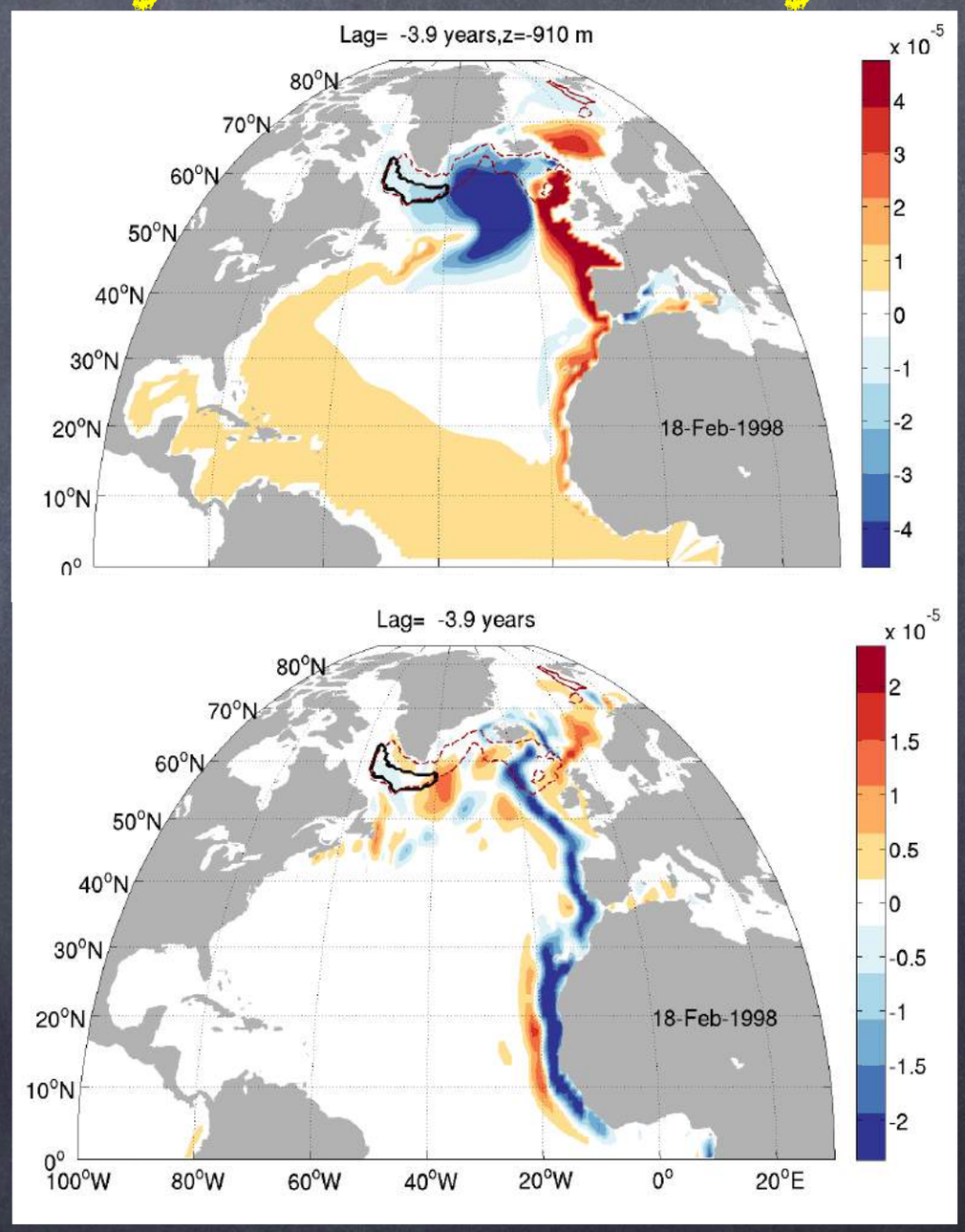


dynamic Sensitivity



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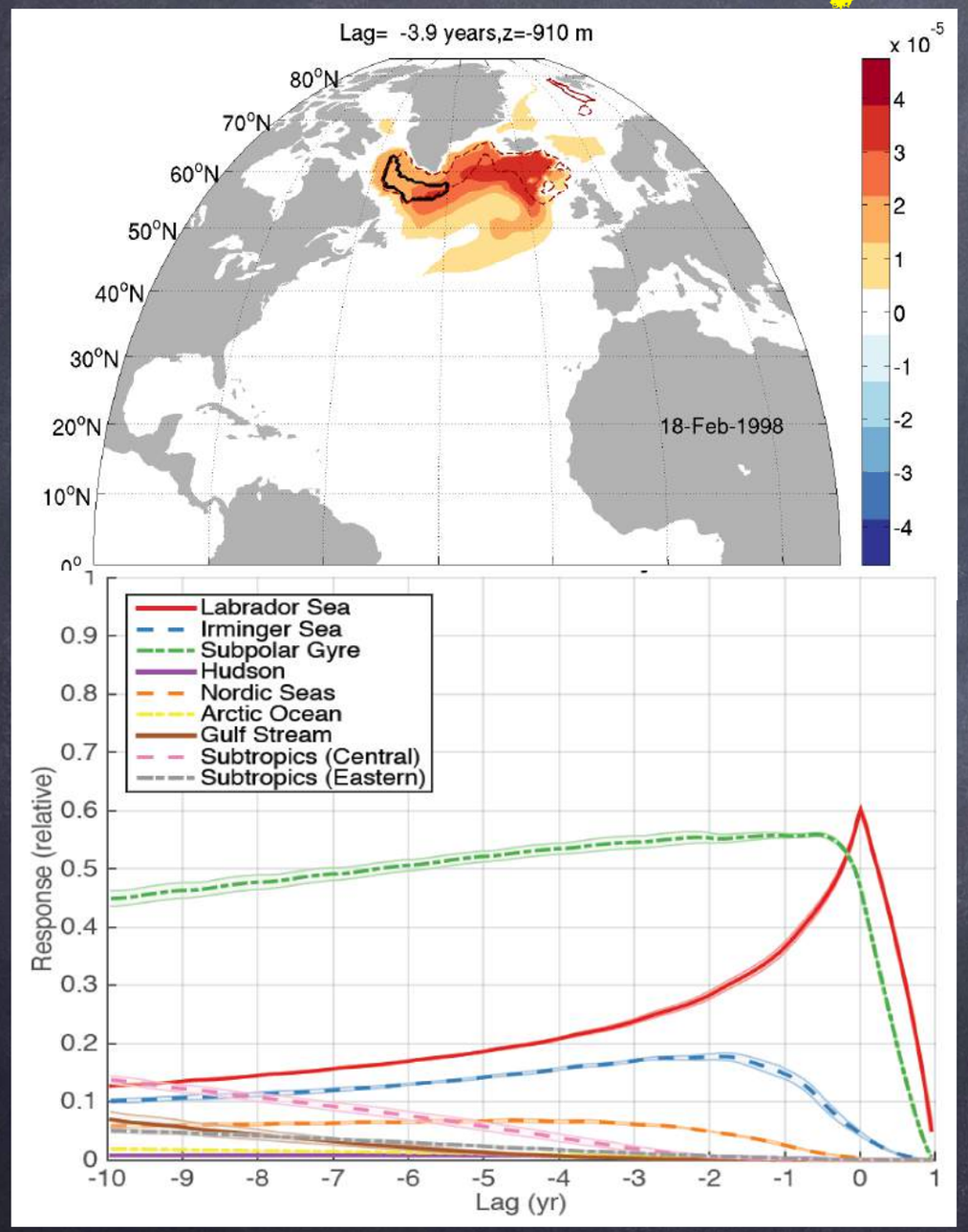
Gaël Forget

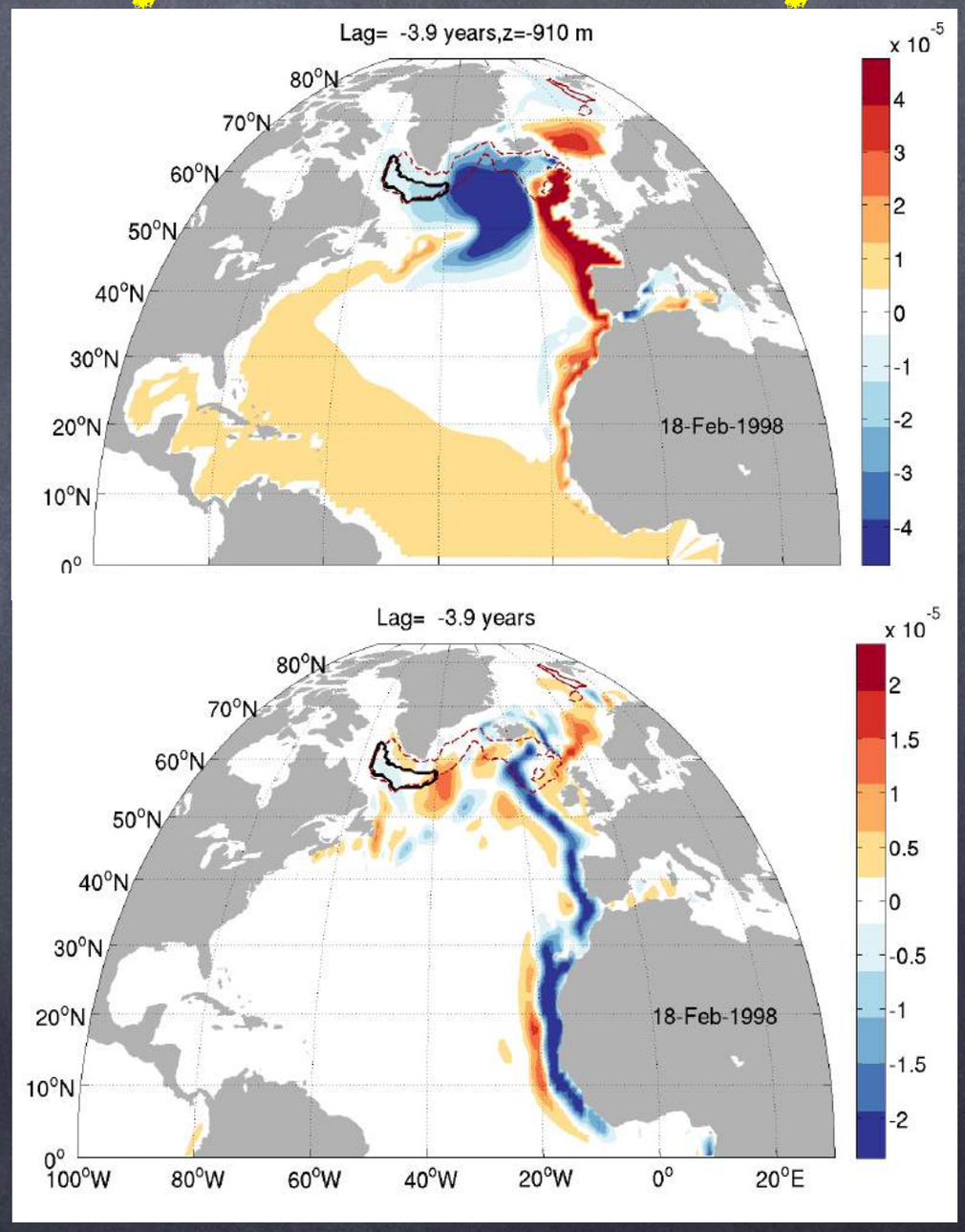
Adjoint Sensitivity Analyses (Labrador Sea Heat Content)

2017/11/06

Kinematic Sensitivity



dynamic Sensitivity

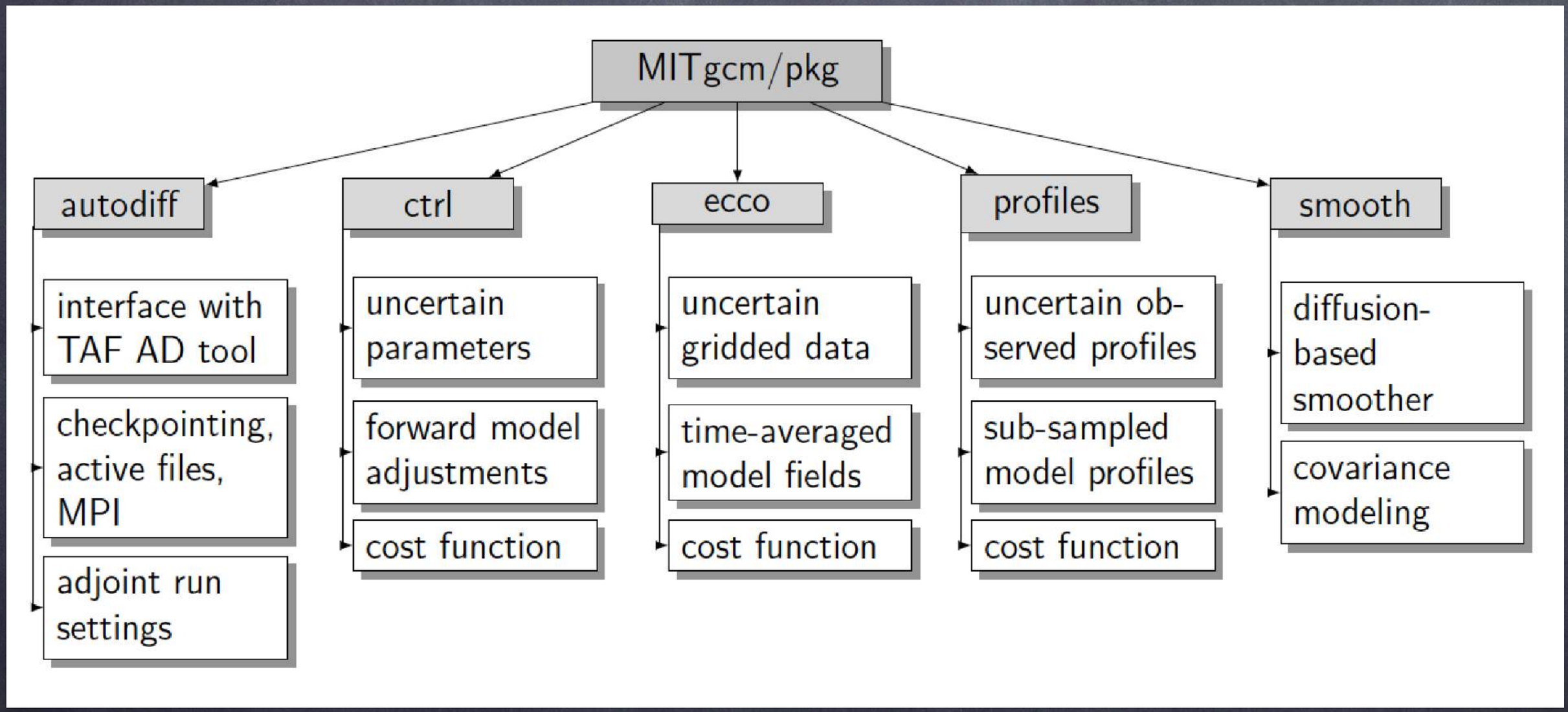


Daniel Jones, Gael Forget, Bablu Sinha, Simon Josey, Emma Boland, Andrew Meijers, Emily Shuckburgh (in prep.)

Gaël Forget

The ECCO V4 Framework (At The MITgcm Level)

2017/11/06

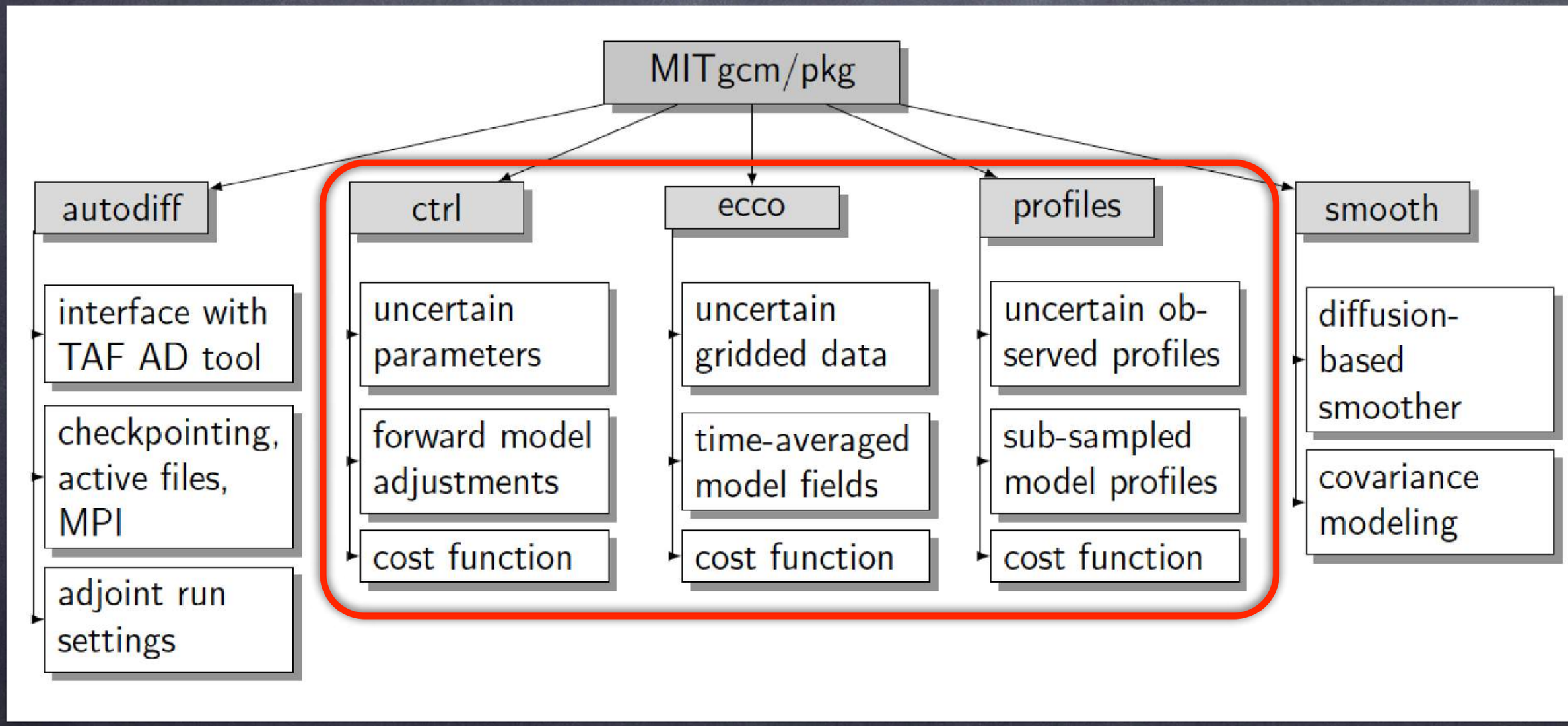


Forget, Campin, Heimbach, Hill, Ponte, and Wunsch 2015, GMD, https://doi.org/10.5194/gmd-8-3071-2015

Gaël Forget

The ECCO V4 Framework (At The MITgcm Level)

2017/11/06



Forget, Campin, Heimbach, Hill, Ponte, and Wunsch 2015, GMD, https://doi.org/10.5194/gmd-8-3071-2015

Gaël Forget

Streamlined Exp. Set Up
(At Run Time)

2017/11/06

Gaël Forget

Streamlined Exp. Set Up (At Run Time)

2017/11/06

```
1
2  gcmfaces_global;
3  grid_load('../run/',6,'compact');
4
5  if 0;
6      mskW=convert2gcmfaces(mygrid.LATS_MASKS(100).mskWedge);
7      mskS=convert2gcmfaces(mygrid.LATS_MASKS(100).mskSedge);
8      mskW(isnan(mskW))=0;
9      mskS(isnan(mskS))=0;
10     write2file('north10_maskW',mskW);
11     write2file('north10_maskS',mskS);
12 end;
13
14 if 0;
15     msk=mygrid.YC<-30;
16     msk=convert2gcmfaces(msk.*mygrid.mskC(:,:,1));
17     msk(isnan(msk))=0;
18     write2file('south30_maskC',msk);
19     %
20     msk=ones(1,50); msk(11:end)=0;
21     write2file('south30_maskK',msk);
22     msk=zeros(1,10); msk(5)=1;
23     write2file('south30_maskT',msk);
24 end;
```

Create mask of region or transect (e.g., using gcmfaces)

Gaël Forget

Streamlined Exp. Set Up (At Run Time)

2017/11/06

```
gcmfaces_global;
grid_load('../run/',6,'compact');

if 0;
    mskW=convert2gcmfaces(mygrid.LATS_MASKS(100).mskWedge);
    mskS=convert2gcmfaces(mygrid.LATS_MASKS(100).mskSedge);
    mskW(isnan(mskW))=0;
    mskS(isnan(mskS))=0;
    write2file('north10_maskW',mskW);
    write2file('north10_maskS',mskS);
end;

if 0;
    msk=mygrid.YC<-30;
    msk=convert2gcmfaces(msk.*mygrid.mskC(:,:,1));
    msk(isnan(msk))=0;
    write2file('south30_maskC',msk);
    %
    msk=ones(1,50); msk(11:end)=0;
    write2file('south30_maskK',msk);
    msk=zeros(1,10); msk(5)=1;
    write2file('south30_maskT',msk);
end;
```

Create mask of region or transect (e.g., using gcmfaces)

```
# ********************
# ECCO cost functions
# ********************
 &ECCO_COST_NML
 &
# ***************************
# ECCO generic cost functions
# ***************************
 &ECCO_GENCOST_NML
 gencost_avgperiod(1)  = 'step',
 gencost_barfile(1) = 'm_boxmean_theta',
 gencost_mask(1) = 'south30_mask',
 gencost_name(1) = 'south30_mean_theta',
 gencost_outputlevel(1)=1,
 mult_gencost(1) = 1.D+07,
#
 gencost_avgperiod(2)  = 'step',
 gencost_barfile(2) = 'm_horflux_vol',
 gencost_mask(2) = 'north10_mask',
 gencost_name(2) = 'north10_flux_vol',
 gencost_outputlevel(2)=1,
 mult_gencost(2) = 1.,
#
```

Set up pkg/ecco via data.ecco (boxmean, horflux, etc.)

Gaël Forget

Streamlined Exp. Set Up (At Run Time)

2017/11/06

```
gcmfaces_global;
grid_load('../run/',6,'compact');

if 0;
    mskW=convert2gcmfaces(mygrid.LATS_MASKS(100).mskWedge);
    mskS=convert2gcmfaces(mygrid.LATS_MASKS(100).mskSedge);
    mskW(isnan(mskW))=0;
    mskS(isnan(mskS))=0;
    write2file('north10_maskW',mskW);
    write2file('north10_maskS',mskS);
end;

if 0;
    msk=mygrid.YC<-30;
    msk=convert2gcmfaces(msk.*mygrid.mskC(:,:,1));
    msk(isnan(msk))=0;
    write2file('south30_maskC',msk);
    %
    msk=ones(1,50); msk(11:end)=0;
    write2file('south30_maskK',msk);
    msk=zeros(1,10); msk(5)=1;
    write2file('south30_maskT',msk);
end;
```

Create mask of region or transect (e.g., using gcmfaces)

```
# ********************
# ECCO cost functions
# ********************
 &ECCO_COST_NML
 &
# ***************************
# ECCO generic cost functions
# ***************************
 &ECCO_GENCOST_NML
 gencost_avgperiod(1)  = 'step',
 gencost_barfile(1) = 'm_boxmean_theta',
 gencost_mask(1) = 'south30_mask',
 gencost_name(1) = 'south30_mean_theta',
 gencost_outputlevel(1)=1,
 mult_gencost(1) = 1.D+07,
#
 gencost_avgperiod(2)  = 'step',
 gencost_barfile(2) = 'm_horflux_vol',
 gencost_mask(2) = 'north10_mask',
 gencost_name(2) = 'north10_flux_vol',
 gencost_outputlevel(2)=1,
 mult_gencost(2) = 1.,
#
```

Set up pkg/ecco via data.ecco (boxmean, horflux, etc.)

Streamlined Exp. Set Up (At Run Time)

Gaël Forget

2017/11/06

```
gcmfaces_global;
grid_load('../run/',6,'compact');

if 0;
    mskW=convert2gcmfaces(mygrid.LATS_MASKS(100).mskWedge);
    mskS=convert2gcmfaces(mygrid.LATS_MASKS(100).mskSedge);
    mskW(isnan(mskW))=0;
    mskS(isnan(mskS))=0;
    write2file('north10_maskW',mskW);
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end;

if 0;
    msk=mygrid.YC<-30;
    msk=convert2gcmfaces(msk.*mygrid.mskC(:,:,1));
    msk(isnan(msk))=0;
    write2file('south30_maskC',msk);
    %
    msk=ones(1,50); msk(11:end)=0;
    write2file('south30_maskK',msk);
    msk=zeros(1,10); msk(5)=1;
    write2file('south30_maskT',msk);
end;
```

Create mask of region or transect (e.g., using gcmfaces)

```
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 &
# ***************************
# ECCO generic cost functions
# ***************************
 &ECCO_GENCOST_NML
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 gencost_barfile(1) = 'm_boxmean_theta',
 gencost_mask(1) = 'south30_mask',
 gencost_name(1) = 'south30_mean_theta',
 gencost_outputlevel(1)=1,
 mult_gencost(1) = 1.D+07,
#
 gencost_avgperiod(2)  = 'step',
 gencost_barfile(2) = 'm_horflux_vol',
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 gencost_outputlevel(2)=1,
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#
```

Set up pkg/ecco via data.ecco (boxmean, horflux, etc.)

Gaël Forget

Growing List Of Variables
(List Is Out Of Date …)

2017/11/06

Gaël Forget

Growing List Of Variables
(List Is Out Of Date ...)

2017/11/06

name	description
genarr2d	
xx_etan	initial sea surface height
xx_bottomdrag	bottom drag
xx_geothermal	geothermal heat flux
genarr3d	
xx_theta	initial potential temperature
xx_salt	initial salinity
xx_kapgm	GM coefficient
xx_kapredi	isopycnal diffusivity
xx_diffkr	diapycnal diffusivity
gentim2D	
xx_atemp	atmospheric temperature
xx_aqh	atmospheric specific humidity
xx_swdown	downward shortwave
xx_lwdown	downward longwave
xx_precip	precipitation
xx_uwind	zonal wind
xx_vwind	meridional wind
xx_tauu	zonal wind stress
xx_tauv	meridional wind stress

MITgcm/pkg/ctrl
(data.ctrl)

Gaël Forget

Growing List Of Variables
(List Is Out Of Date ...)

2017/11/06

name	description
genarr2d	
xx_etan	initial sea surface height
xx_bottomdrag	bottom drag
xx_geothermal	geothermal heat flux
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xx_diffkr	diapycnal diffusivity
gentim2D	
xx_atemp	atmospheric temperature
xx_aqh	atmospheric specific humidity
xx_swdown	downward shortwave
xx_lwdown	downward longwave
xx_precip	precipitation
xx_uwind	zonal wind
xx_vwind	meridional wind
xx_tauu	zonal wind stress
xx_tauv	meridional wind stress

MITgcm/pkg/ctrl
(data.ctrl)

variable name	description
m_eta	sea surface height
m_sst	sea surface temperature
m_sss	sea surface salinity
m_bp	bottom pressure
m_siarea	sea-ice area
m_siheff	sea-ice effective thickness
m_sihsnow	snow effective thickness
m_theta	potential temperature
m_salt	salinity
m_UE	zonal velocity
m_VN	meridional velocity
m_ustress	zonal wind stress
m_vstress	meridional wind stress
m_uwind	zonal wind
m_vwind	meridional wind
m_atemp	atmospheric temperature
m_aqh	atmospheric specific humidity
m_precip	precipitation
m_swdown	downward shortwave
m_lwdown	downward longwave
m_wspeed	wind speed
m_diffkr	vertical/diapycnal diffusivity
m_kapgm	GM diffusivity
m_kapredi	isopycnal diffusivity
m_geothermalflux	geothermal heat flux
m_bottomdrag	bottom drag

MITgcm/pkg/ecco
(data.ecco)

Gaël Forget

Growing List Of Variables (List Is Out Of Date ...)

2017/11/06

name	description
genarr2d	
xx_etan	initial sea surface height
xx_bottomdrag	bottom drag
xx_geothermal	geothermal heat flux
genarr3d	
xx_theta	initial potential temperature
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xx_kapgm	GM coefficient
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xx_diffkr	diapycnal diffusivity
gentim2D	
xx_atemp	atmospheric temperature
xx_aqh	atmospheric specific humidity
xx_swdown	downward shortwave
xx_lwdown	downward longwave
xx_precip	precipitation
xx_uwind	zonal wind
xx_vwind	meridional wind
xx_tauu	zonal wind stress
xx_tauv	meridional wind stress

MITgcm/pkg/ctrl
(data.ctrl)

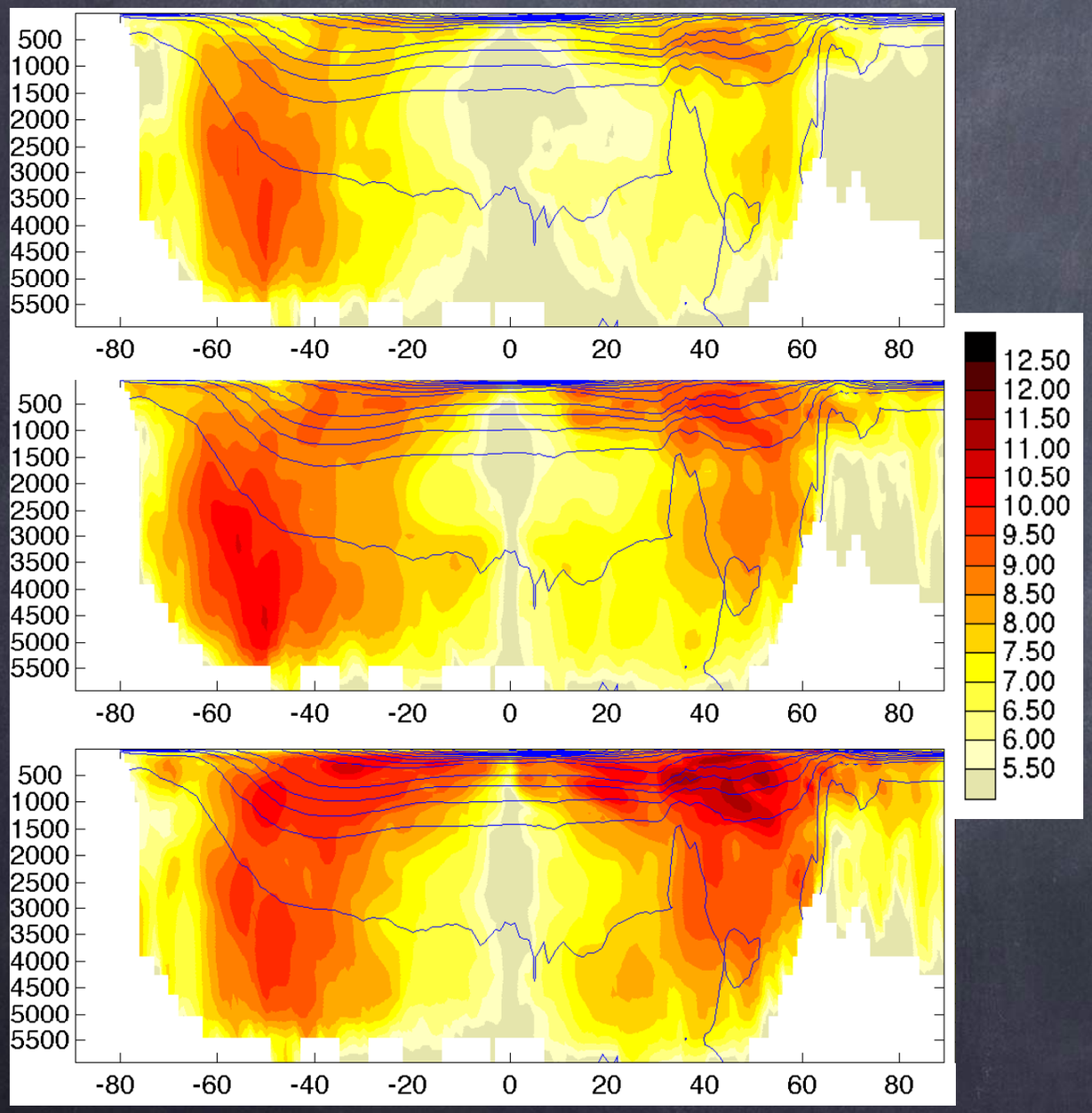
variable name	description
m_eta	sea surface height
m_sst	sea surface temperature
m_sss	sea surface salinity
m_bp	bottom pressure
m_siarea	sea-ice area
m_siheff	sea-ice effective thickness
m_sihsnow	snow effective thickness
m_theta	potential temperature
m_salt	salinity
m_UE	zonal velocity
m_VN	meridional velocity
m_ustress	zonal wind stress
m_vstress	meridional wind stress
m_uwind	zonal wind
m_vwind	meridional wind
m_atemp	atmospheric temperature
m_aqh	atmospheric specific humidity
m_precip	precipitation
m_swdown	downward shortwave
m_lwdown	downward longwave
m_wspeed	wind speed
m_diffkr	vertical/diapycnal diffusivity
m_kapgm	GM diffusivity
m_kapredi	isopycnal diffusivity
m_geothermalflux	geothermal heat flux
m_bottomdrag	bottom drag

MITgcm/pkg/ecco
(data.ecco)

Gaël Forget

Adjoint Sensitivity Analyses (Kgm vs. ECCO constraints)

2017/11/06



Forget, Ferreira, and Liang 2015, DOI: 10.5194/os-11-839-2015

Forget And Ponte 2015, DOI: 10.1016/j.pocean.2015.06.002

Forget et al. 2015, DOI: 10.5194/gmd-8-3071-2015

Gaël Forget

Running ECCO Via Cloud (AWS Prototype Recipe)

2017/11/06

//github.com/gaelforget/ECCO_v4_r2/tree/master/example_scripts

README.md

#Using cfncluster to run ECCO v4 r2

This file provides a recipe to run ECCO v4 r2 (Forget et al. 2015, 2016) using MITgcm and cfncluster. It relies on an AWS EBS volume snapshot for providing model intputs (snap-03a927d31811042e1 at the time of writing) and the ECCO v4 r2 github repository for providing model setup and installation scripts (see eccov4.pdf for additional documentation). For user support, if needed, contact ecco-support@mit.edu or mitgcm-support@mit.edu. As of 2017/01/25 the latest release of this repository is: DOI 10.5281/zenodo.260042

- **Recipe Location:** https://github.com/gaelforget/ECCO_v4_r2/example_scrips (few simple steps)
- **Estimated Cost:** O(40 US$) using spot instances
- **Rationale And Proof Of Concept:** Vinogradova, Shiffer, Forget, and Hill 2017 (hdl.handle.net/1721.1/111605)

Gaël Forget

Running ECCO Via Cloud (AWS Prototype Recipe)

2017/11/06

//github.com/gaelforget/ECCO_v4_r2/tree/master/example_scripts

README.md

#Using cfncluster to run ECCO v4 r2

This file provides a recipe to run ECCO v4 r2 (Forget et al. 2015, 2016) using MITgcm and cfncluster. It relies on an AWS EBS volume snapshot for providing model intputs (snap-03a927d31811042e1 at the time of writing) and the ECCO v4 r2 github repository for providing model setup and installation scripts (see eccov4.pdf for additional documentation). For user support, if needed, contact ecco-support@mit.edu or mitgcm-support@mit.edu. As of 2017/01/25 the latest release of this repository is: DOI 10.5281/zenodo.260042

- **Recipe Location:** https://github.com/gaelforget/ECCO_v4_r2/example_scrips (few simple steps)
- **Estimated Cost:** O(40 US$) using spot instances
- **Rationale And Proof Of Concept:** Vinogradova, Shiffer, Forget, and Hill 2017 (hdl.handle.net/1721.1/111605)

Gaël Forget

Running ECCO Via Cloud (AWS Prototype Recipe)

2017/11/06

//github.com/gaelforget/ECCO_v4_r2/tree/master/example_scripts

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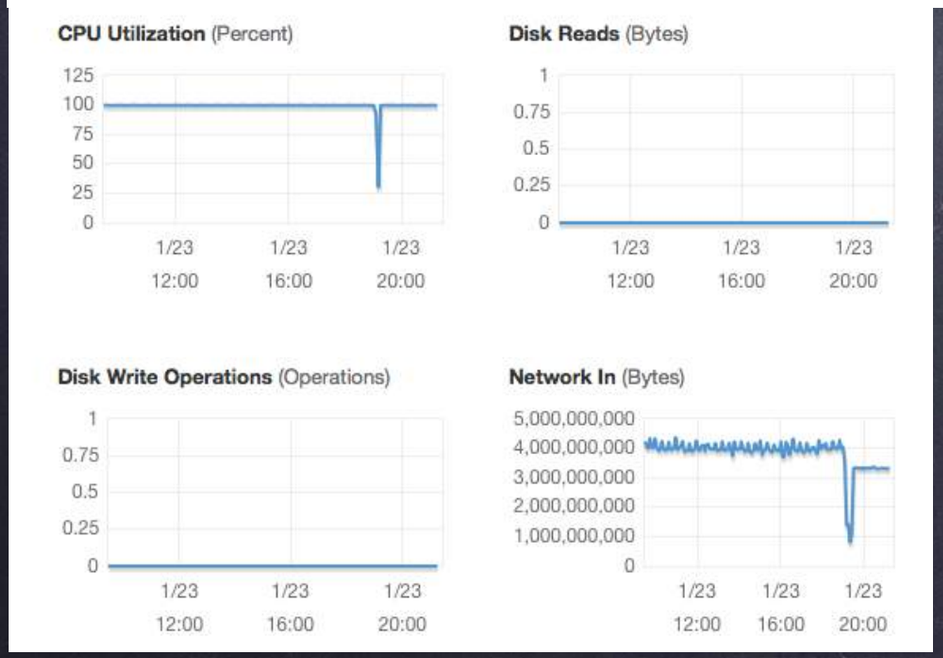
Running ECCO Via Cloud (AWS Look And Feel)

2017/11/06

Name	Instance ID	Instance Type	Availability Zone	Instance State	Status Checks	Alarm Status
	i-05b62ae636de0e06c	t2.micro	us-east-1c	running	2/2 checks …	None
Master	i-04a656ec612e91ef3	m4.large	us-east-1b	running	2/2 checks …	None
Compute	i-01576100158 44f947	c4.4xlarge	us-east-1b	running	2/2 checks …	None
Compute	i-068dfcf291edf86d6	c4.4xlarge	us-east-1b	running	2/2 checks …	None
Compute	i-0abdaa2ab7fde3970	c4.4xlarge	us-east-1b	running	2/2 checks …	None
Compute	i-0acbfce1fc97f4dde	c4.4xlarge	us-east-1b	running	2/2 checks …	None
Compute	i-0cdf1656a88a0eb27	c4.4xlarge	us-east-1b	running	2/2 checks …	None
Compute	i-0ea878c8d152a2780	c4.4xlarge	us-east-1b	running	2/2 checks …	None



AWS console

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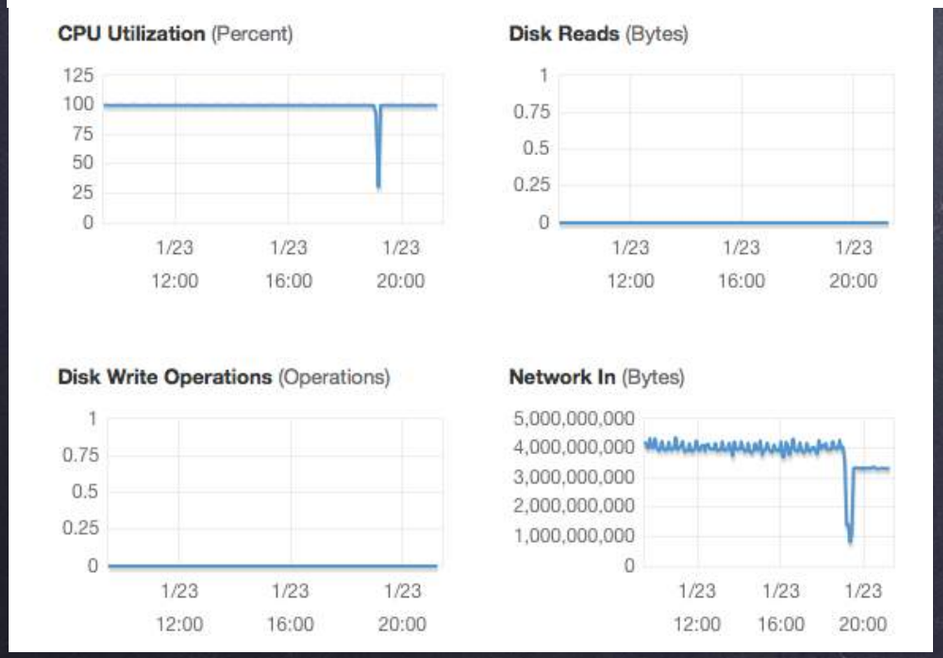

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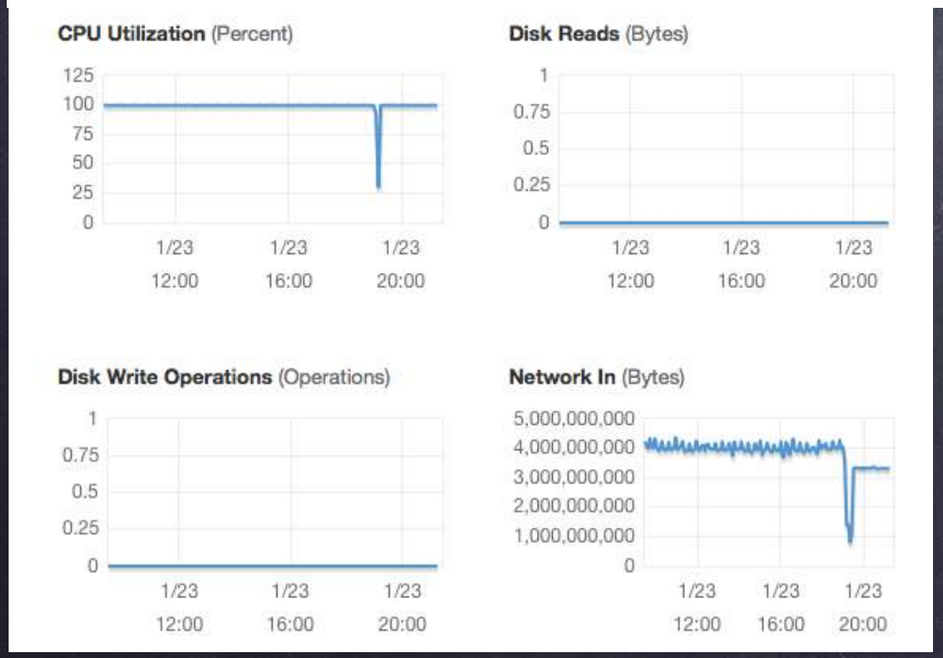

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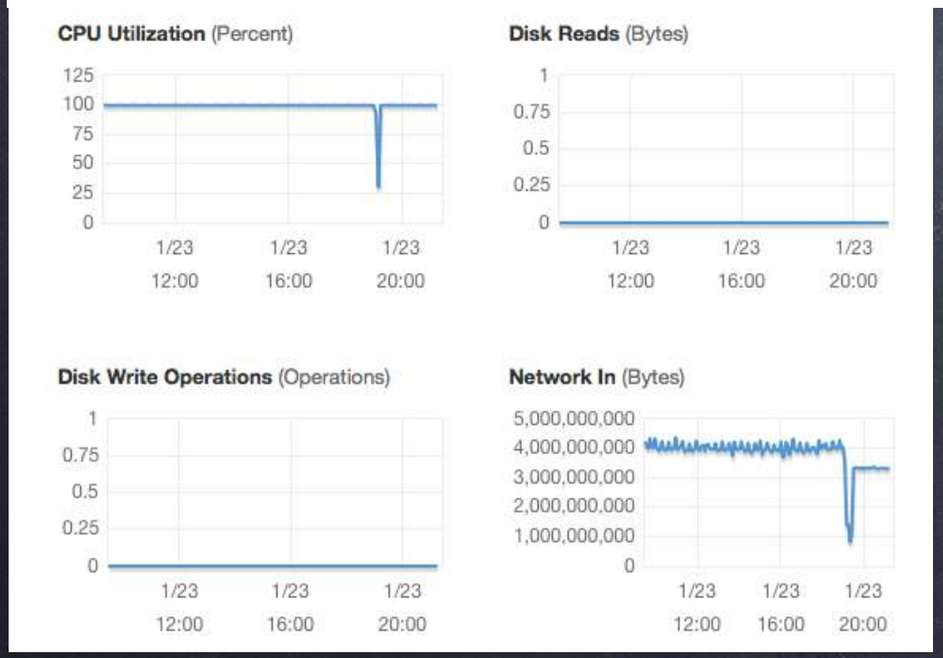

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AWS console

```
[ec2-user@ip-172-31-6-79 shared]$ ls -ltr run |tail
-rw-rw-r-- 1 ec2-user ec2-user     421200 Jan 23 19:33 mdtdiff_raw.data
-rw-rw-r-- 1 ec2-user ec2-user        158 Jan 23 19:33 mdtdiff_raw.meta
-rw-rw-r-- 1 ec2-user ec2-user     421200 Jan 23 19:33 mdtdiff_smooth.data
-rw-rw-r-- 1 ec2-user ec2-user        158 Jan 23 19:33 mdtdiff_smooth.meta
-rw-rw-r-- 1 ec2-user ec2-user     421200 Jan 23 19:33 sla2model_raw.data
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-rw-rw-r-- 1 ec2-user ec2-user     421200 Jan 23 19:33 misfits_mdt.data
-rw-rw-r-- 1 ec2-user ec2-user        158 Jan 23 19:33 misfits_mdt.meta
```

One Of The Compute Nodes

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