

Discussion on data/solution updates

ECCO Meeting, California Institute of Technology, Pasadena

November 6-8, 2017

- What vital data sets have we been using?**
- How to make sure we keep up with data sets for future estimates?**
- How to share data processing responsibilities?**
- Define plans for maintaining "central" estimates up-to-date**

Data sets used in v4r3

Variable	Observations
Sea level	TOPEX/Poseidon (1993-2005), Jason-1 (2002-2008), Jason-2 (2008-2015), Geosat-Follow-On (2001-2007), CryoSat-2 (2011-2015), ERS-1/2 (1992-2001), ENVISAT (2002-2012), SARAL/AltiKa (2013-2015)
Global mean sea level	Average of mean sea level curves from AVISO, CSIRO, NOAA
Temperature profiles	Argo floats (1995-2015), XBTs (1992-2008), CTDs (1992-2011), Southern Elephant seals as Oceanographic Samplers (SEaOS; 2004-2010), Ice-Tethered Profilers (ITP, 2004-2011)
Temperature (moorings)	Beaufort Gyre, Bering/Davis/Fram Straits (coverage?)
Salinity profiles	Argo floats (1997-2015), CTDs (1992-2011), SEaOS (2004-2010)
Salinity (moorings)	Beaufort Gyre, Bering/Davis/Fram Straits (coverage?)
Sea surface temperature	AVHRR (1992-2013)
Sea surface salinity	Aquarius (2011-2013)
Sea-ice concentration	SSM/I DMSP-F11 (1992-2000) and -F13 (1995-2009) and SSMIS DMSP-F17 (2006-2015)
Ocean bottom pressure	GRACE (2002-2014), including global mean ocean mass
TS climatology	World Ocean Atlas 2009
Mean dynamic topography	DTU13 (1992-2012)

Data sets used in v4r3

Data	Filename	Version	Source	Post-processed by
GRACE OBP	GRACE_jpl_rl05m_withland_YYYY	One	JPL (http://grace.jpl.nasa.gov/data/get-data/jpl_global_mascons/)	Katherine Quinn (1/7/2016)
Global mean OBP	GRACE_jpl_rl05m_SpatialMean.asc	One	JPL (http://grace.jpl.nasa.gov/data/get-data/jpl_global_mascons/)	Katherine Quinn (1/7/2016)
RADS TP/J1/J2 SSH	RADS_TJ_mar2016_YYYY		RADS	
RADS GFO/C2 SSH	RADS_GFO_C2_mar2016_YYYY		RADS	
RADS ERS/ENVISAT/SARAL/AltiKa SSH	RADS_ERS_ENV_SA_mar2016_YYYY		RADS	
MDT	mdt_dtu13.bin	DTU13	DTU	Katherine Quinn (12/10/2014)
Global mean SSH	ensemble_avg_gmsl.asc		AVISO, CSIRO, NOAA	Christopher Piecuch (03/07/2016)
NOAA NSIDC Sea-ice concentration	IAA_NSIDC_DAILY_MAPPED_TO_LL90_YYYY.bin		NOAA/NSIDC	Ian Fenty
Aquarius SSS	monthlyAQ_v3_092011-122013_YYYY		Aquarius	Nadya vinogradova (06/13/2014)
Reynolds SST	reynolds_oiv2_r1_YYYY		NOAA/NCDC	
WOA09 Climatology T	T_monthly_woa09	WOA09	NOAA/NODC	
WOA09 Climatology S	S_monthly_woa09	WOA09	NOAA/NODC	
Profile data				
Argo TS	go_YYYY_feb2016_llc90_step_09_20160308.nc		Argo	Ian Fenty
CTD TS	:td_Arctic_NordicSeas_GAMMA_20150915.nc		CTD	Ian Fenty
CTD TS	ctdhilat_nodupices_GAMMA_20150915.nc		CTD	Ian Fenty
CTD TS	ctdlowlat_GAMMA_20150915.nc		CTD	Ian Fenty
XBT T	xbt_GAMMA_20150915.nc		XBT	Ian Fenty
CLIMODE TS	climode_GAMMA_20150915.nc		CLIMODE	Ian Fenty
ICES TS	:s19922012hi_pot_theta_GAMMA_20150915.nc		ICES	Ian Fenty
ICES TS	:s19922012lo_pot_theta_GAMMA_20150915.nc		ICES	Ian Fenty
ITP TS	itp_GAMMA_20150915.nc		ITP	Ian Fenty
SEaOS TS	seals_GAMMA_20150915.nc		SEaOS	Ian Fenty
Beaufort Gyre mooring TS	beaufortgyremooring_GAMMA_20150915.nc			Ian Fenty
Bering Strait mooring TS	beringstraitmooring_GAMMA_20150915.nc			Ian Fenty
Davis Strait mooring TS	davisstraitmooring_GAMMA_20150915.nc			Ian Fenty
Fram Strait mooring TS	framstraitmooring_GAMMA_20150915.nc			Ian Fenty

Data updating (I)

- Sea level (JPL/MIT)**

- Global mean sea level (AER/JPL)**

- Ocean bottom pressure (AER/JPL)**
 - Grids**
 - Global mean**

- Mean dynamic topography...upcoming DTU17 (AER/UTA)**

Data updating (II)

- SST (JPL/MIT)**
- SSS...update Aquarius through end of mission, upcoming v5...(AER/JPL)**
- Sea-ice concentration...An using OSISAF/daily/until April 2015 (UTA/JPL)**

Data updating (III)

Temperature profiles

Argo (MIT/JPL)

XBT (JPL/MIT)

CTD (JPL/MIT)

SEaOS (??)

ICES (JPL)

ITP...updates through 2015 by An, used in ASTE, from J. Toole and R. Krischfield (UTA/JPL)

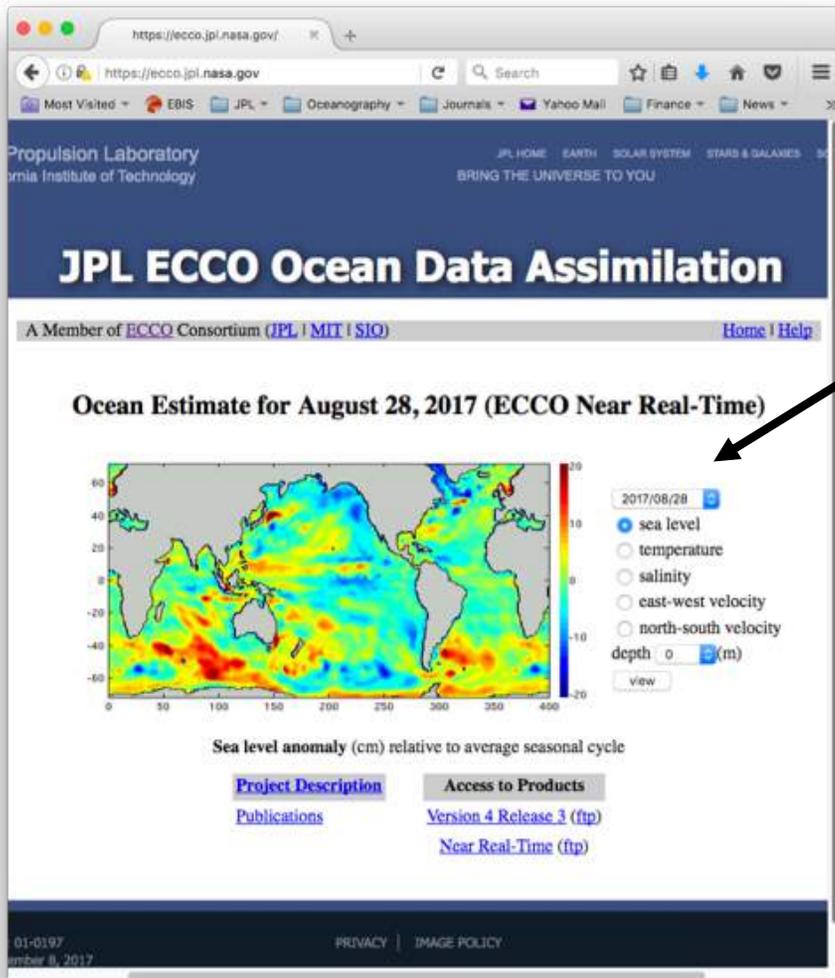
Salinity profiles (as for T profiles)

Temperature/salinity (moorings)...updates for western Arctic/Fram Strait by An, used in ASTE (UTA/JPL)

JPL Updating ECCO Central Product



- Update the adjoint Central Estimate on an annual basis;
 - Redo the 25+ year optimization starting from existing solution,
 - Just redo the last ~5-years annually (re-)adjusting time-variable controls.
- Extend the adjoint Central Estimate in “near real-time” with Kalman filter/RTS smoother



- Updated quarterly
- Presently available for 01/1993-08/2017
- Kalman filter & RTS smoother
- Highlights @ <http://ecco.jpl.nasa.gov/>
- data: SSH, temperature profiles
- controls: winds

Pros:

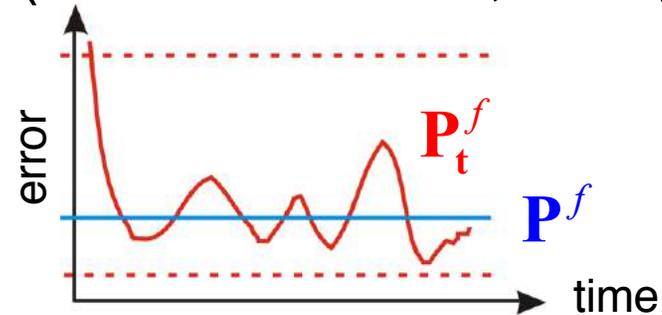
- Computationally inexpensive,
- Stable & robust,
- Formal uncertainty estimates,

Cons:

- Less comprehensive an estimate than the adjoint,

1) **Time-asymptotic** approximation (Fukumori et al., *JPO*, 1993);

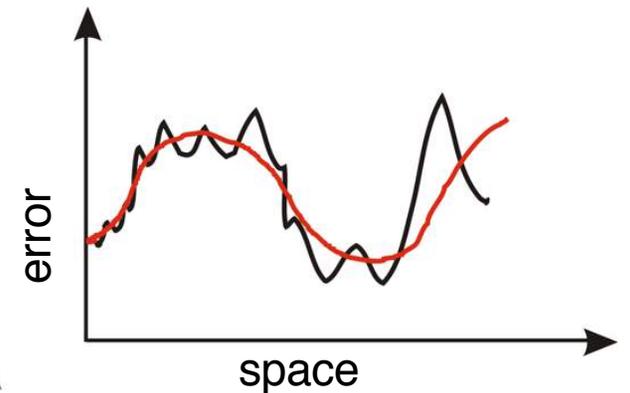
$$\mathbf{P}_t^f \approx \mathbf{P}^f$$



2) **State reduction** (Fukumori and Rizzoli, *JGR*, 1995).

$$\delta \mathbf{x} \approx \mathbf{B} \delta \mathbf{x}', \quad \dim(\delta \mathbf{x}) \quad \dim(\delta \mathbf{x}')$$

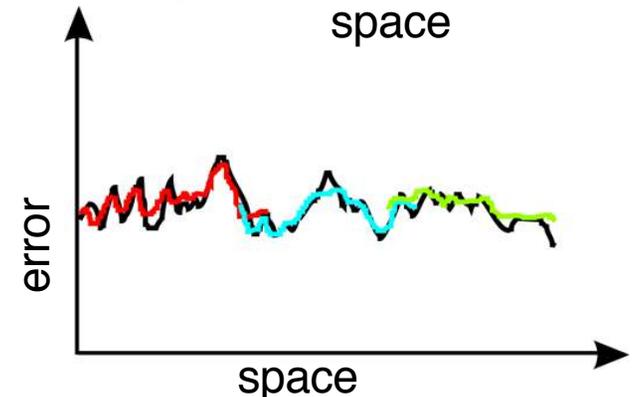
$$\mathbf{P} \equiv \langle \delta \mathbf{x} \delta \mathbf{x}^T \rangle \approx \mathbf{B} \langle \delta \mathbf{x}' \delta \mathbf{x}'^T \rangle \mathbf{B}^T \approx \mathbf{B} \mathbf{P}' \mathbf{B}^T$$

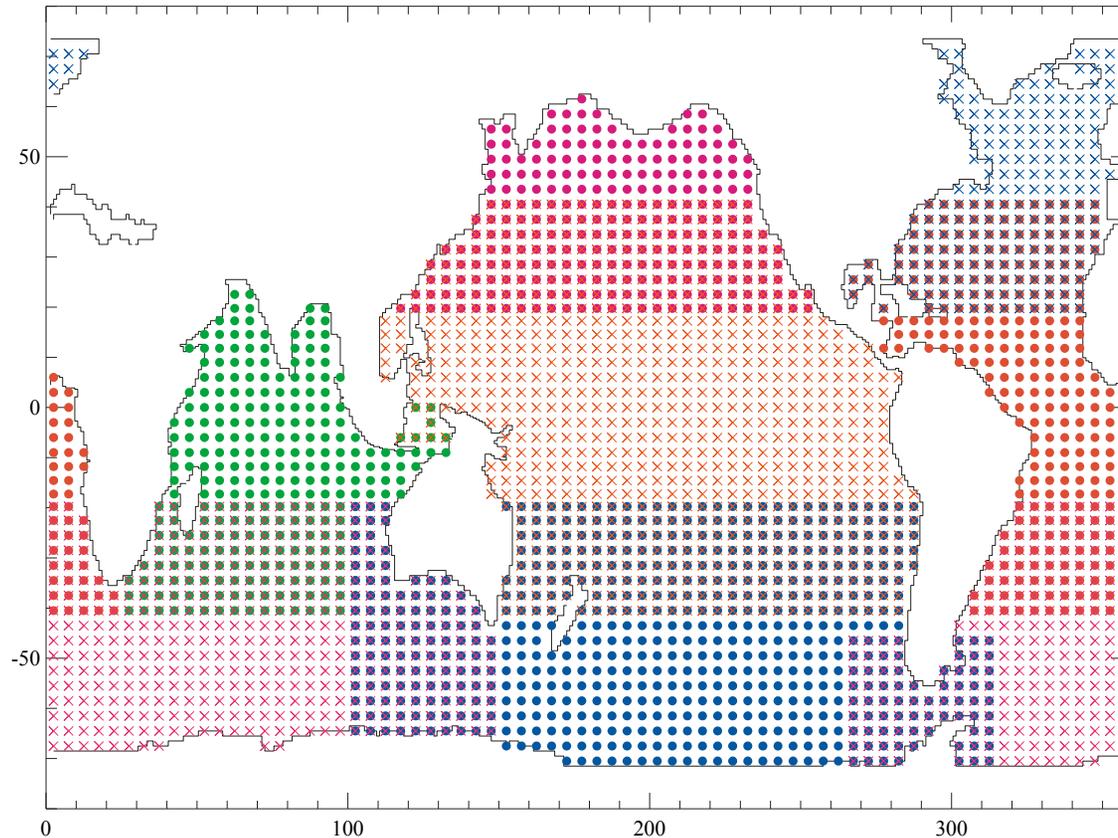


3) **Partitioning** (Fukumori, *MWR*, 2002).

$$\delta \mathbf{x} \approx \mathbf{B}_1 \delta \mathbf{x}'_1 + \dots + \mathbf{B}_L \delta \mathbf{x}'_L \approx \sum_i^L \mathbf{B}_i \delta \mathbf{x}'_i$$

$$\mathbf{P} \approx \sum_i^L \mathbf{B}_i \mathbf{P}'_i \mathbf{B}_i^T, \quad \mathbf{P}'_i \equiv \langle \delta \mathbf{x}'_i \delta \mathbf{x}'_i^T \rangle$$





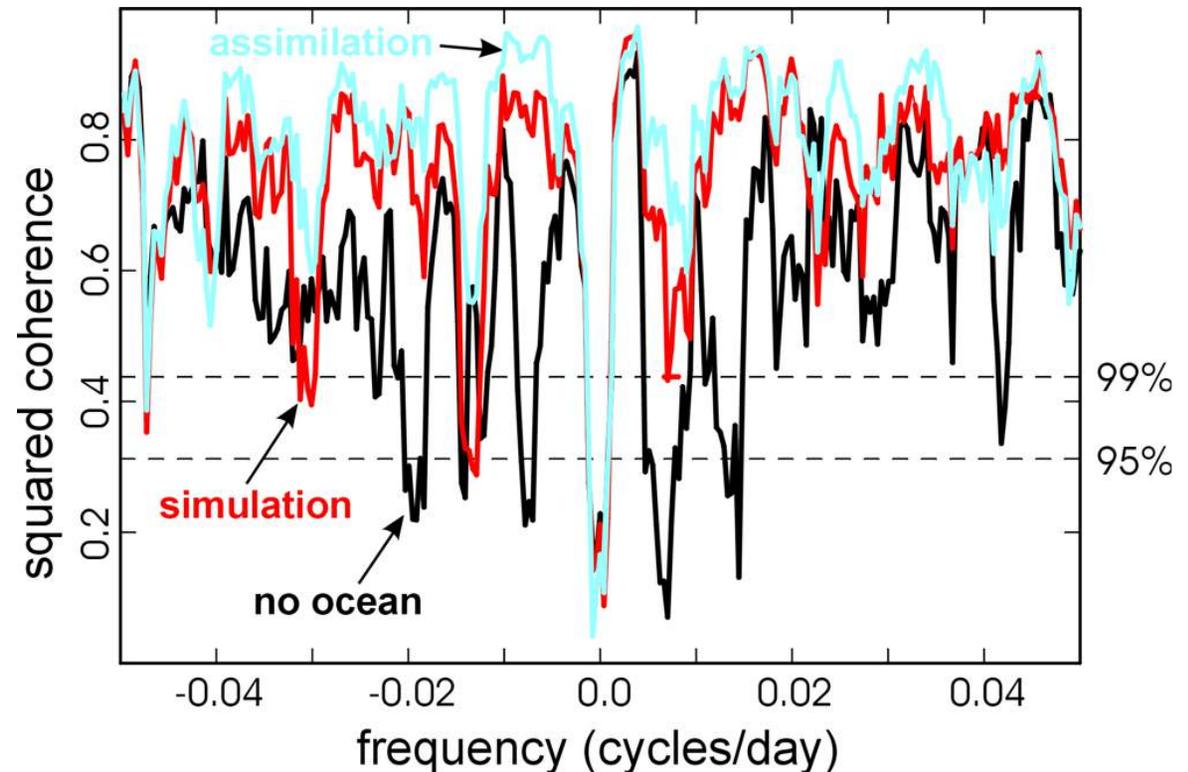
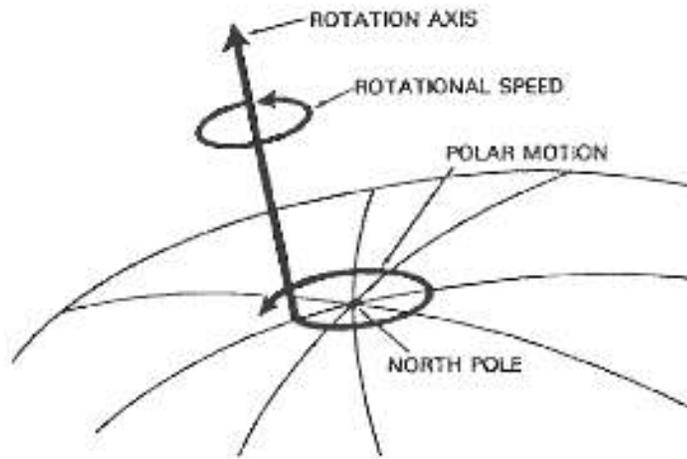
- **Global barotropic cell:** global $6^\circ \times 6^\circ$ grid, barotropic UVH
- **7 regional baroclinic cells:** regional $5^\circ \times 3^\circ$ grid, baroclinic UVD
(5 gravest modes)

JPL Skill (Geodetic Applications)



Comparison to **independent data**: ECCO assimilation explains observed **polar motion** better than ocean simulation does.

Coherence of observed & modeled excitation



(Gross et al., 2003, JGR)

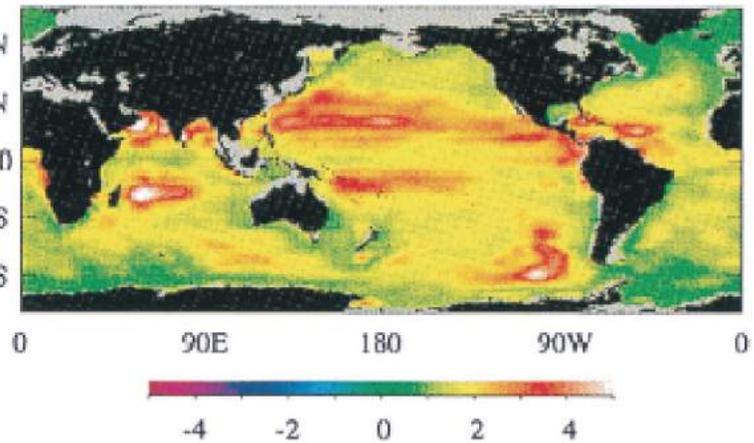
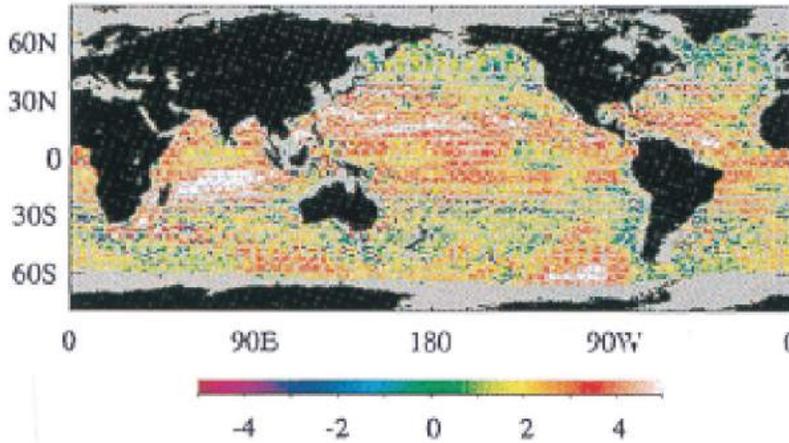
Error Estimate



Model-data residuals should be comparable to expectation
1st order

simulation - forecast residual

$$HP_{sim} H^T - HP^f H^T$$



forecast - analysis residual

$$HP^f H^T - HP^a H^T$$

