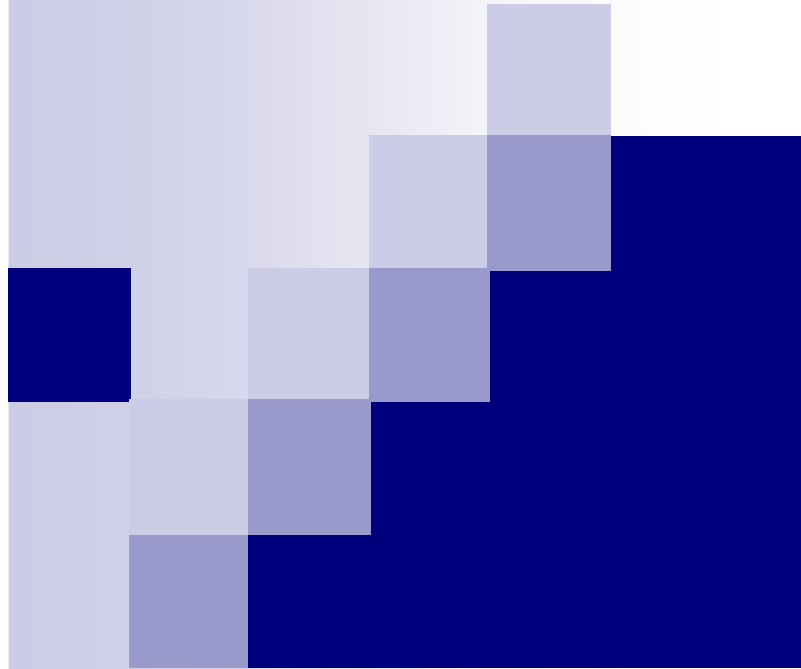
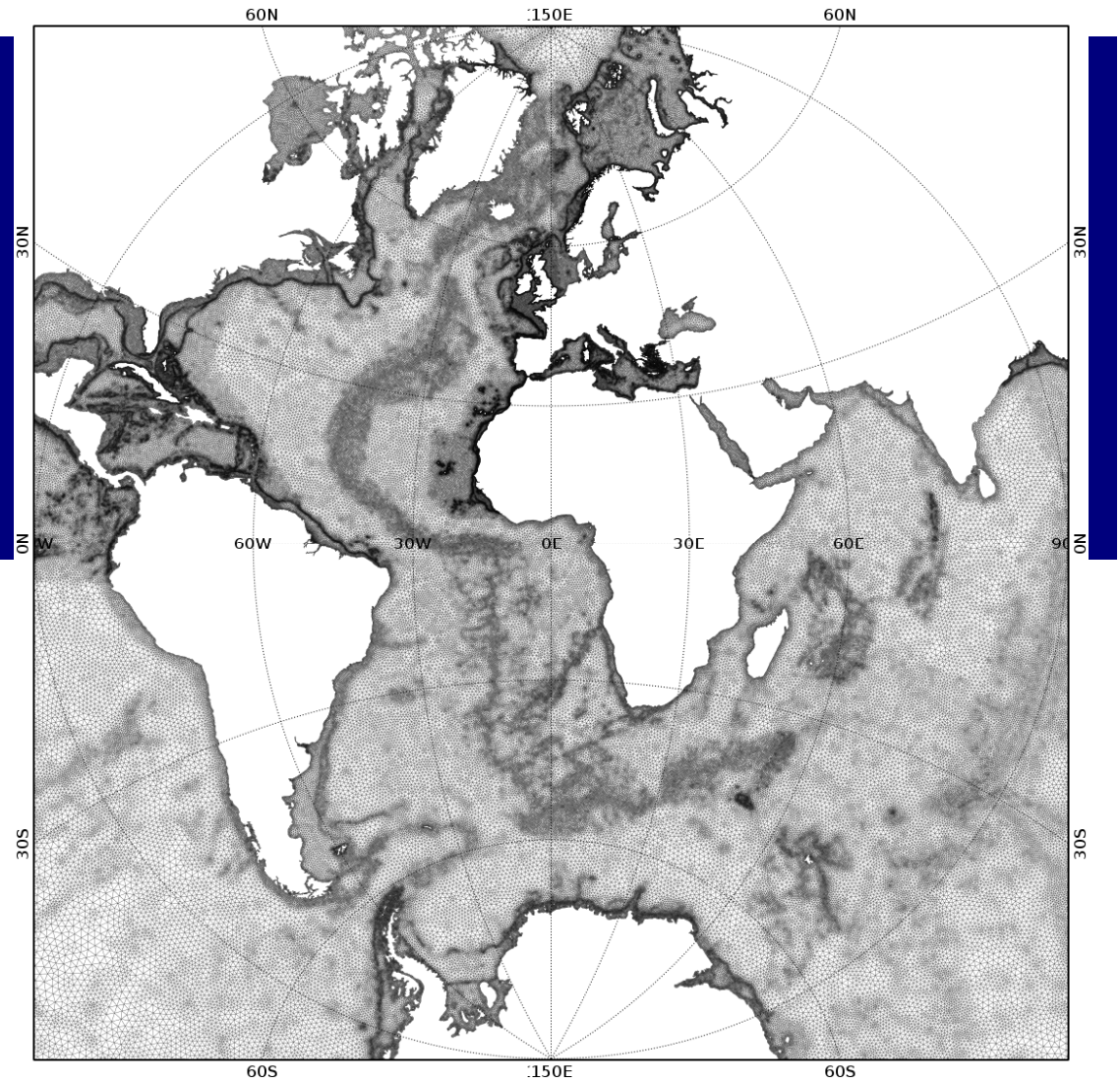


Precision des atlas de marée et impact sur les effets de charge/auto-attraction



Florent Lyard
Damien Allain
LEGOS/observatoire Midi-Pyrénées
Toulouse

Florent.lyard@legos.obs-mip.fr





Modélisation et impacts de la haute fréquence océanique

Marée, surcote

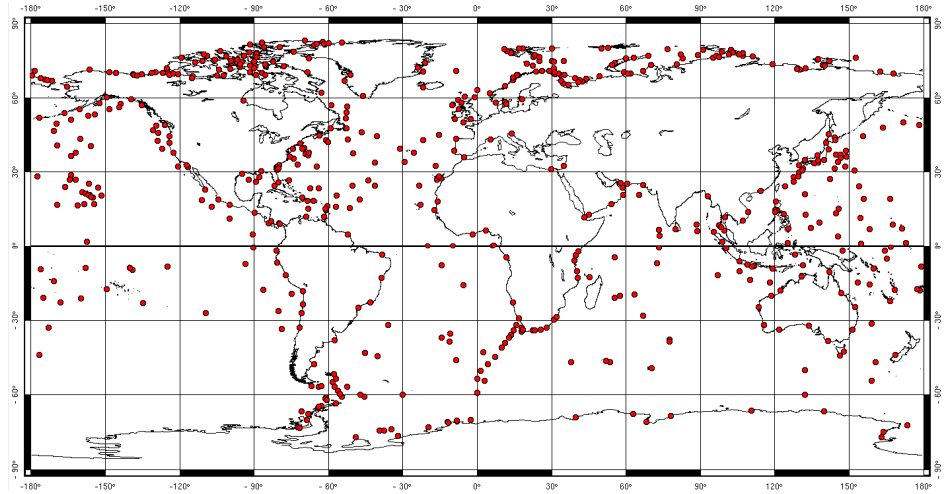
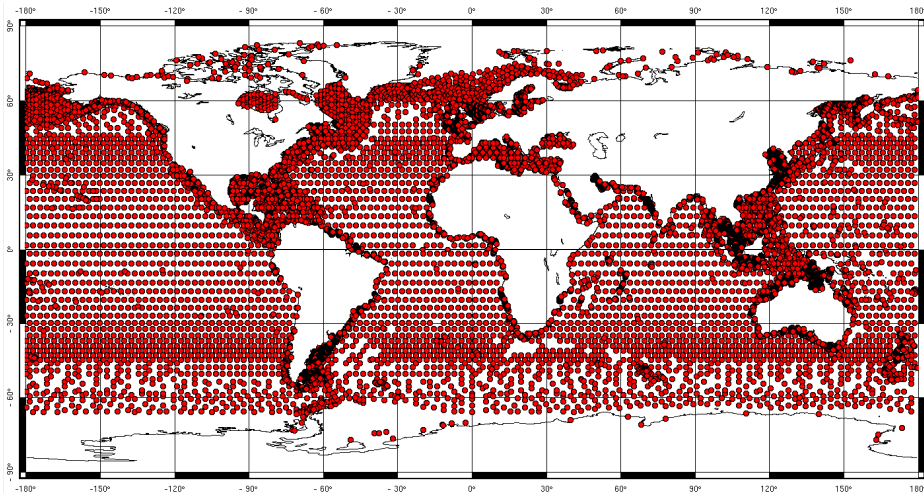
- **Traitement et corrections géophysiques des observations spatiales**
 - De-aliasing des observation altimétriques et gravimétriques spatiales
 - Corrections des signatures de surface libre/re-distribution de masse projetées dans les basses fréquences
 - Conversion surface libre géocentrique/océanique (déformation radiale)
 - Orbitographie
 - Amélioration de la POD

- **Approches**
 - Modélisation non-structurée (éléments finis) shallow-water océan global
 - Assimilation de données (marée)
 - Marégraphie
 - Altimétrie: TP/Jason, ERS/Envisat/Saral

- **Applications dérivées**
 - Détermination des effets de charges et auto-attractions
 - participent aux équations shallow-water de l'Océan
 - Down-scaling régional
 - Corrections des observations de campagne/in situ (dont GPS, gravimètres)

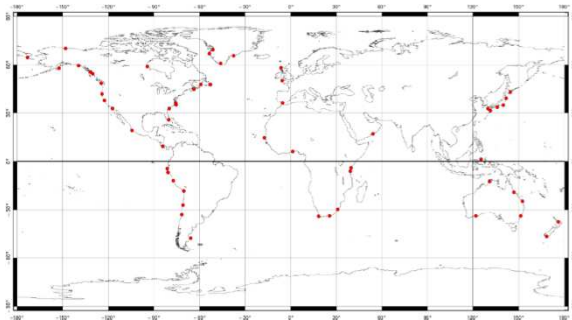
Data assimilation

- Spectral data assimilation code (SpEnOI)
 - Ensemble method within representers approach
 - perturbations on bathymetry, friction coefficient, wave drag coefficient, minimum bathymetry value, loading effects
 - ~900 members
- Altimetry and TG data
 - ~12 500 cross-overs/along track altimetry data assimilated
 - ~600 TG

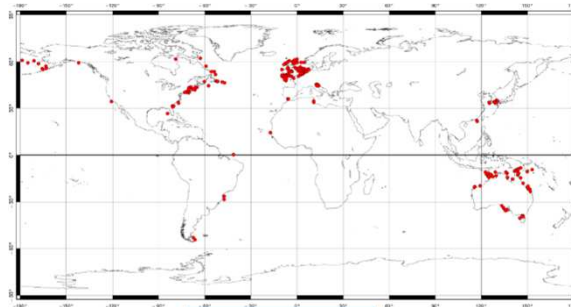


Tidal atlas validation

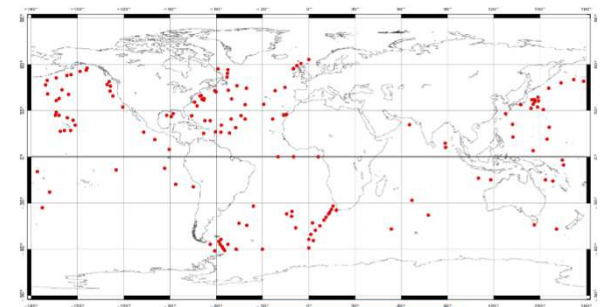
- Deep, Shallow, Coastal TG databases used in Stammer et al. paper (2014)



Coastal

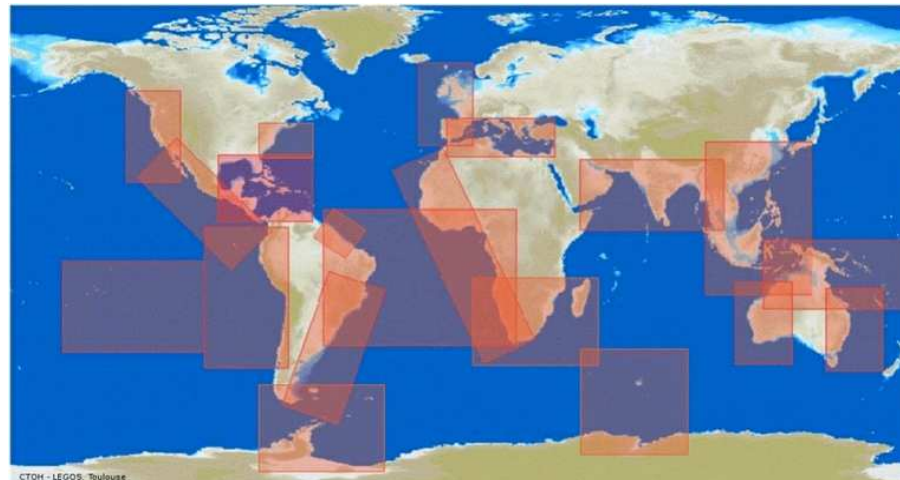


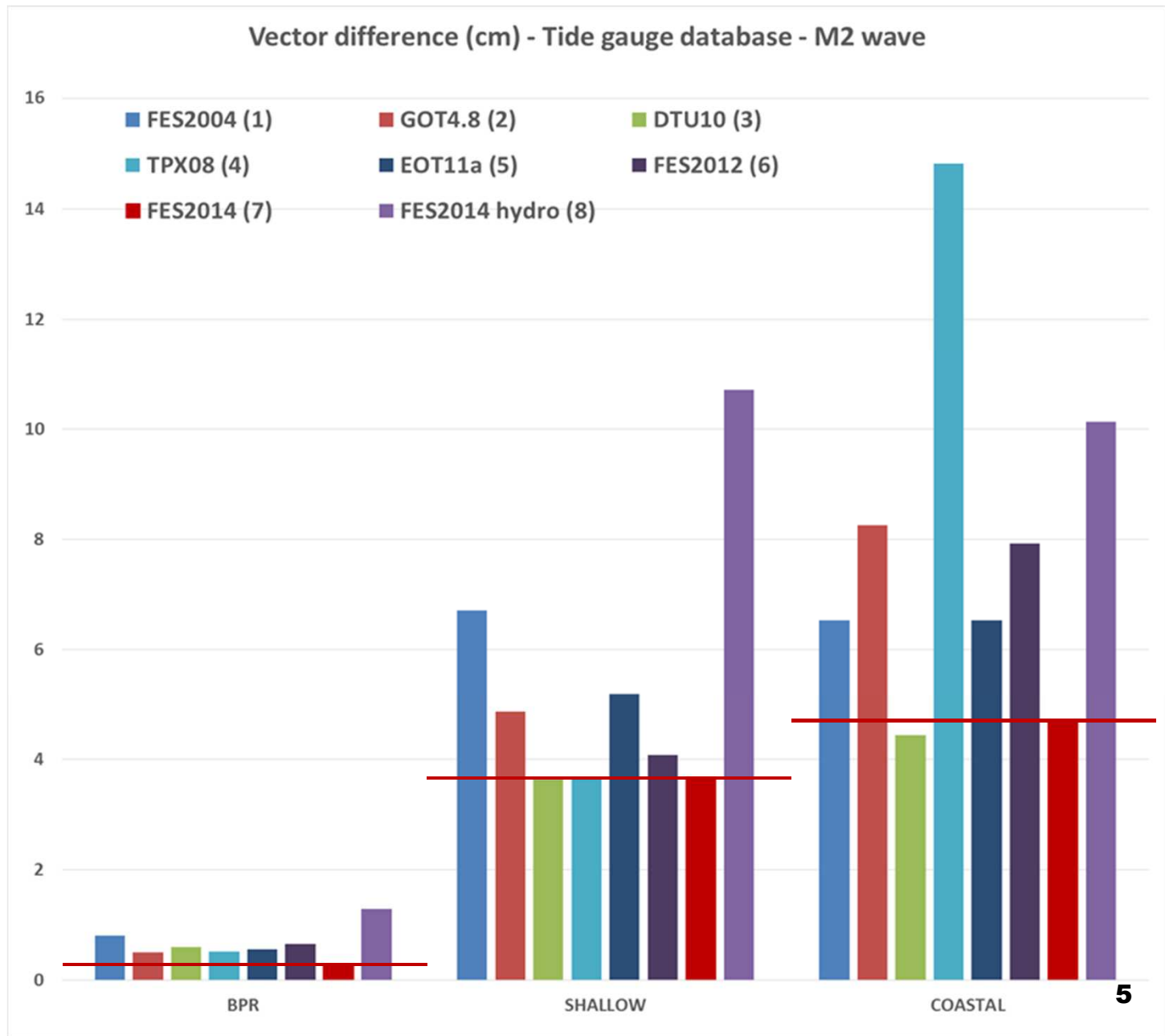
Shallow

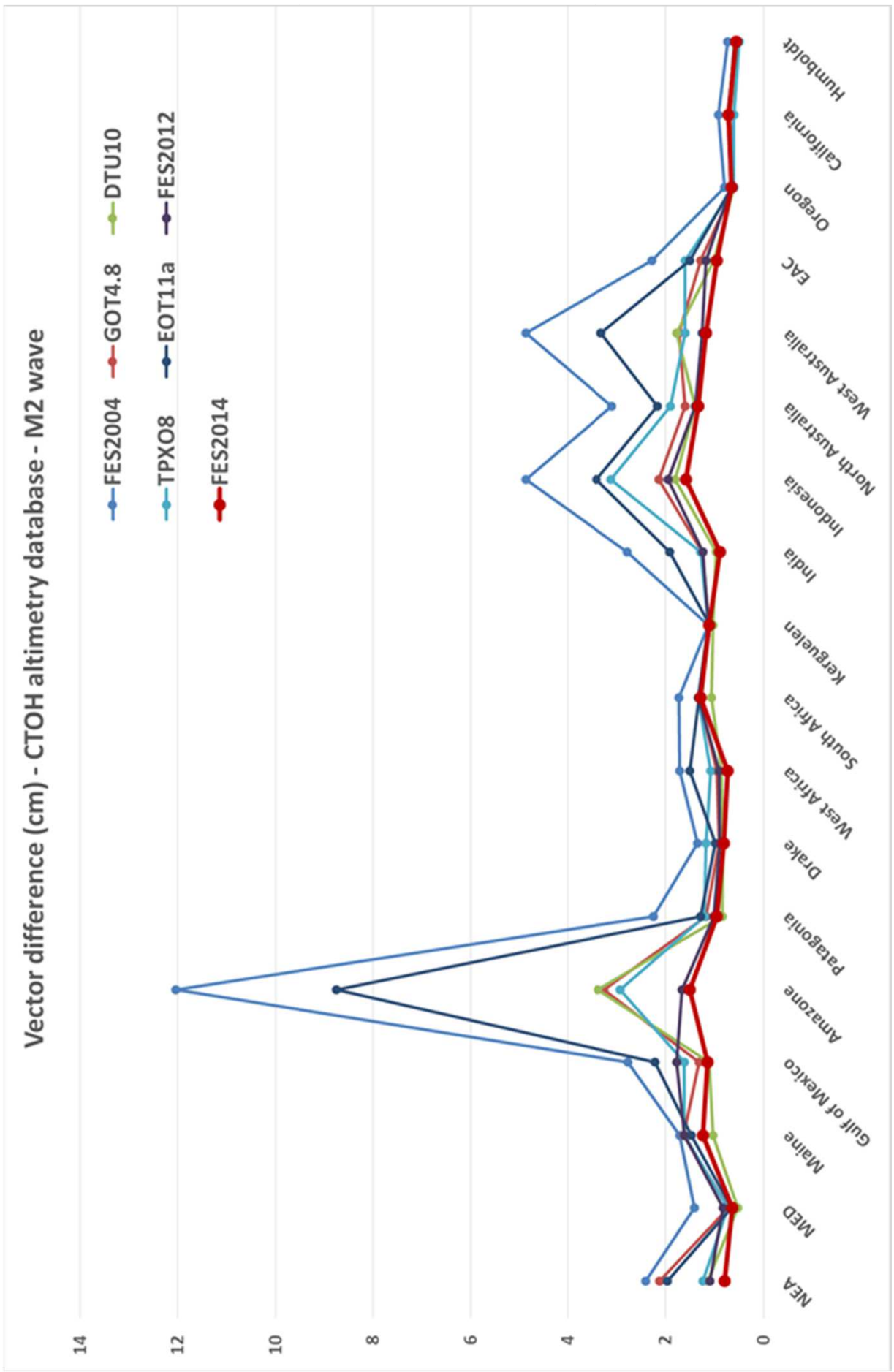
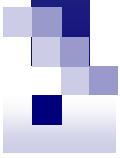


Deep BPR

- Altimeter tidal constituents (CTOH) : <http://ctoh.legos.obs-mip.fr/products/coastal-products/>

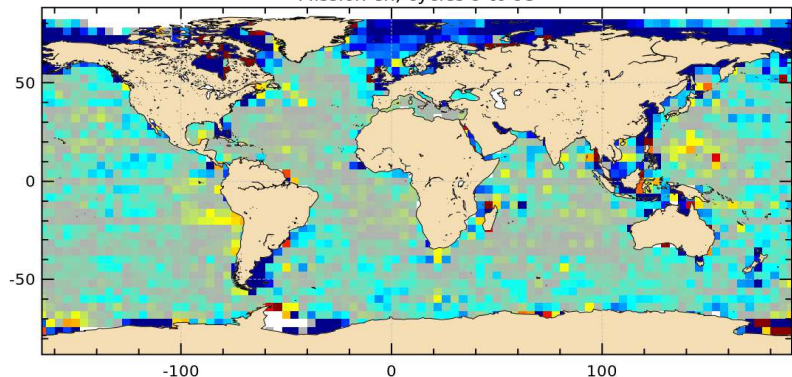




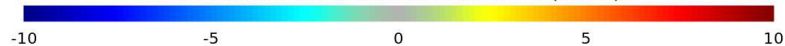


VAR(SSH with FES2014NEWComple) - VAR(SSH with GOT4V10)

Mission en, cycles 9 to 93



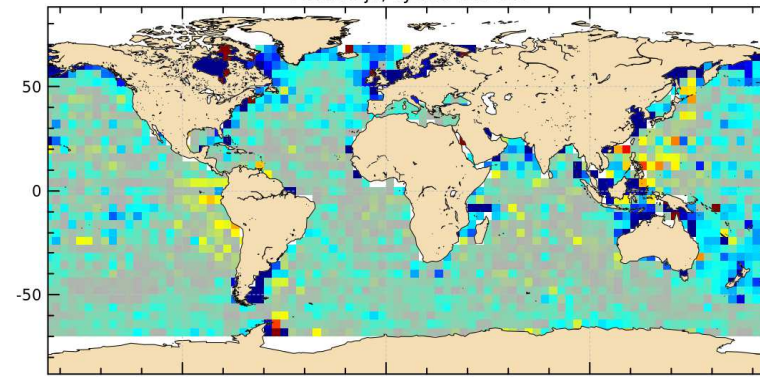
SSH crossovers : difference of variances (cm²)



Nbr :	2719	Std Dev :	204.54015	Min :	-7503.3205
Mean :	-11.503472	Median :	-0.95925503	Max :	2307.768

VAR(SSH with FES2014NEWComple) - VAR(SSH with GOT4V10)

Mission j1, cycles 1 to 248



SSH crossovers : difference of variances (cm²)

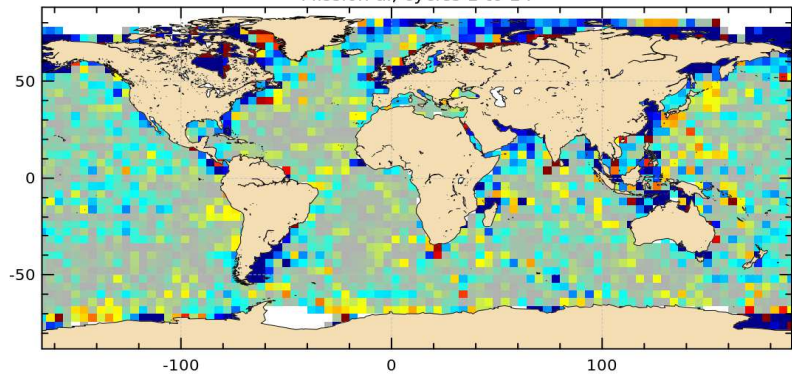


Nbr :	2338	Std Dev :	467.94683	Min :	-19884.601
Mean :	-16.296663	Median :	-0.9477227	Max :	890.24527

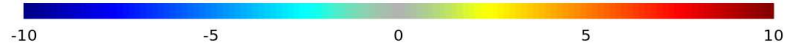
FES2014 vs GOT4V8-10 SSH

VAR(SSH with FES2014NEWComple) - VAR(SSH with GOT4V10)

Mission al, cycles 1 to 14



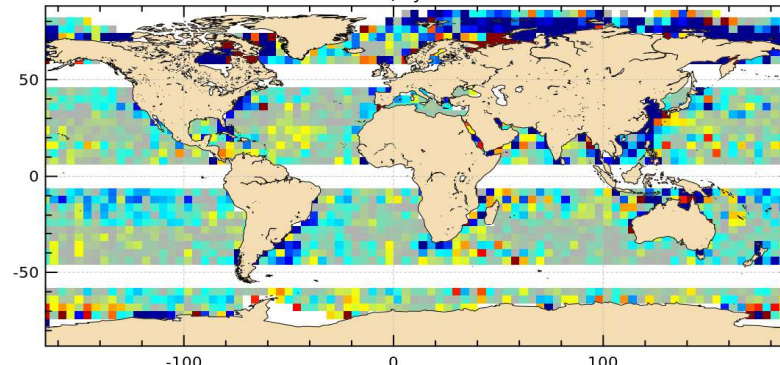
SSH crossovers : difference of variances (cm²)



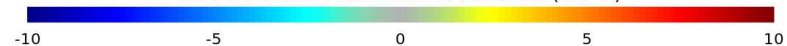
Nbr :	2676	Std Dev :	161.73211	Min :	-7793.5008
Mean :	-8.2575014	Median :	-0.47466308	Max :	1444.9718

VAR(SSH with FES2014) - VAR(SSH with GOT4V10)

Mission c2, cycles 14 to 64



SSH crossovers : difference of variances (cm²)



Nbr :	2007	Std Dev :	66.830582	Min :	-1502.6012
Mean :	-3.5739516	Median :	-0.59237606	Max :	2163.249



Marée (et surcôte) SWOT/OSTST

Mercator-Ocean, D. Allain, A. Koch-Larouy, F. Lyard, R. Benshila, L. Chevallier (Université de Rouen)

- Modélisation marée barotrope globale (OSTST)
 - FES20XX
 - 1km resolution along coastlines
 - Configurations régionales (CNES/ESA)

- Modélisation marée barocline régionale (TOSCA/COCTO, PhD CNES/CLS)
 - Bay of Biscay
 - Tropical Pacific (Tuamotu), Tropical Atlantic (Amazon shelf)

- Modélisation estuarienne (TOSCA/COCTO, SHOM)
 - Configurations
 - Seine and Gironde rivers
 - Red River (HILO)
 - Amazon River (POC/SWOT)
 - SWOT simulator
 - SWOT observation processing
 - Estuarine OBCs for coastal/regional ocean circulation models

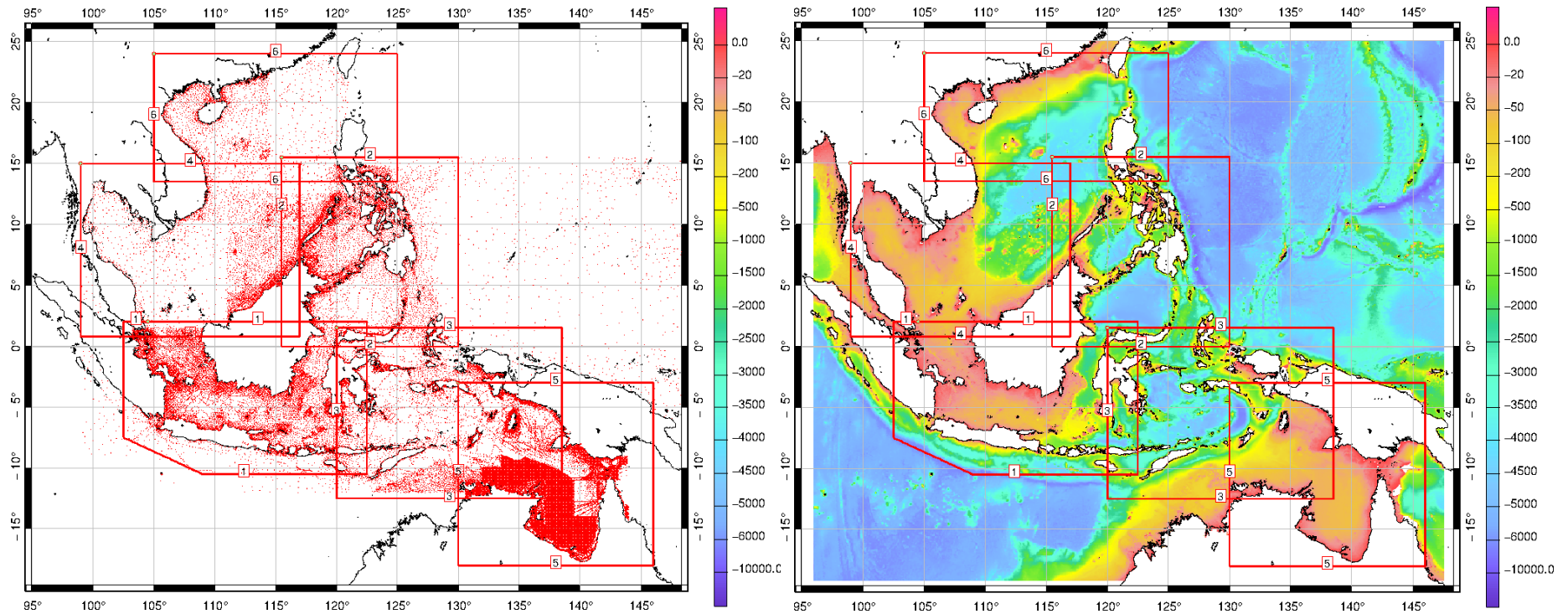


Evolutions

- Enjeux historiques pour la précision des modèles
 - Précision avant assimilation:
 - Bathymétrie
 - Paramétrisation transfert d'énergie barotrope/barocline
 - Précision de la donnée altimétrique
 - Durée des missions
 - Traitements

- Nouveaux enjeux
 - LSA
 - Amélioration des atlas existants de marée
 - Prise en compte pour la surcote
 - Impact du niveau moyen dans la propagations des ondes de gravité
 - Physique non-hydrostatiques
 - Couplage marée/surcote

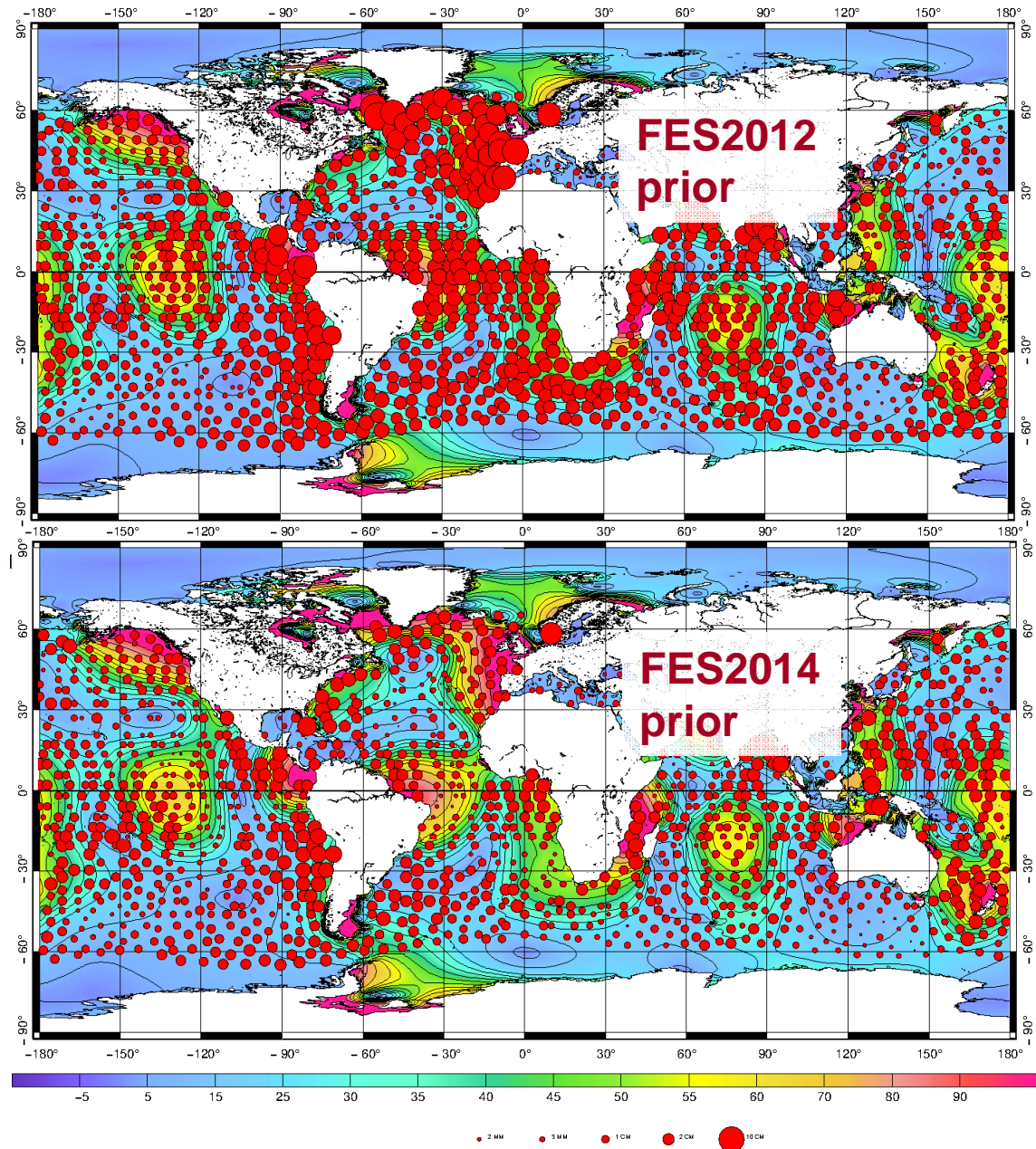
Bathymetry reconstruction



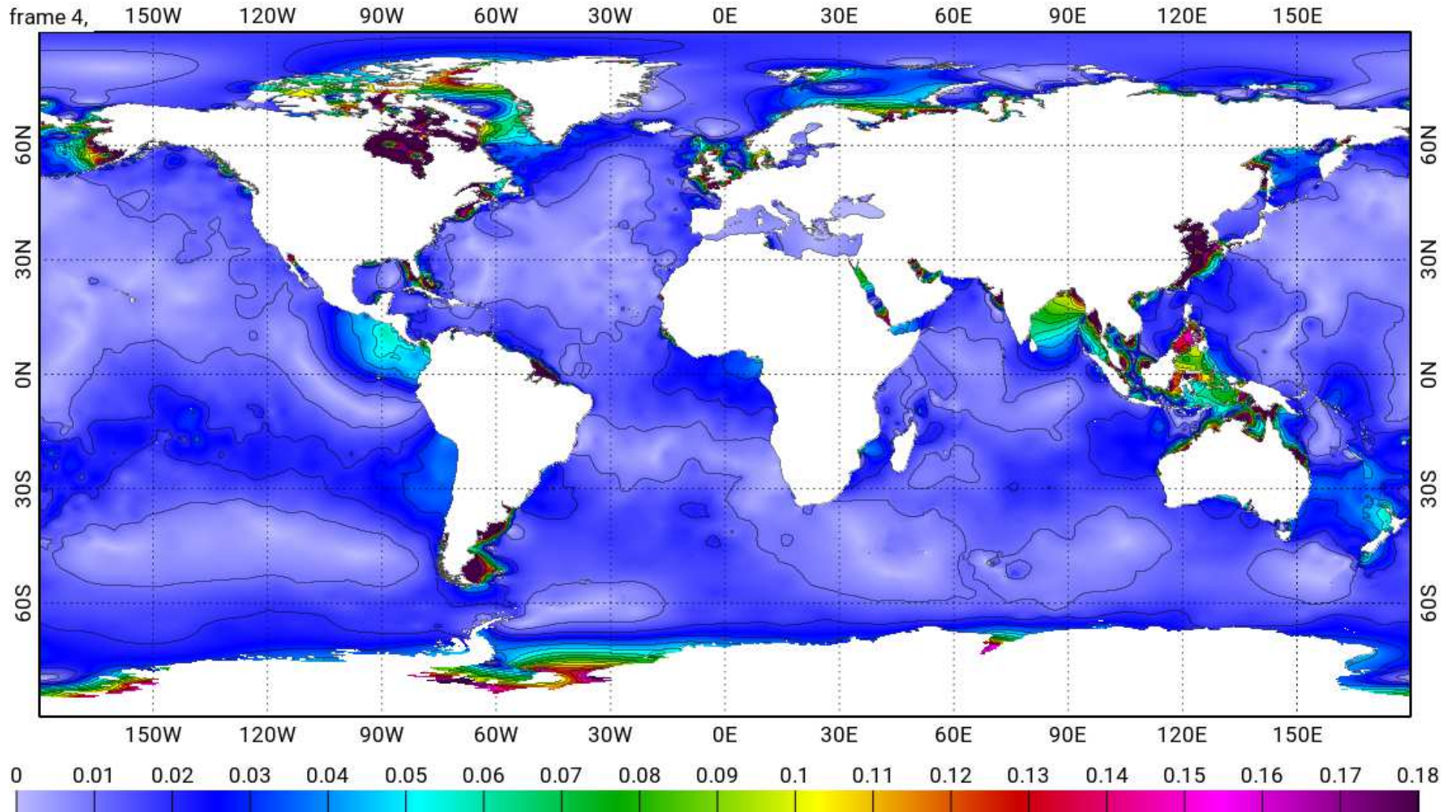
Hydrodynamical simulation accuracy improvement

M2 RMS (TP/J1/J2 covers)
Deep ocean 2.4 cm
Shelf seas 9.3 cm

M2 RMS (TP/J1/J2 covers)
Deep ocean 1.3 cm
Shelf seas 5.5 cm

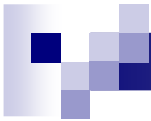


M₂ FES2014: hydrodynamic versus assimilated



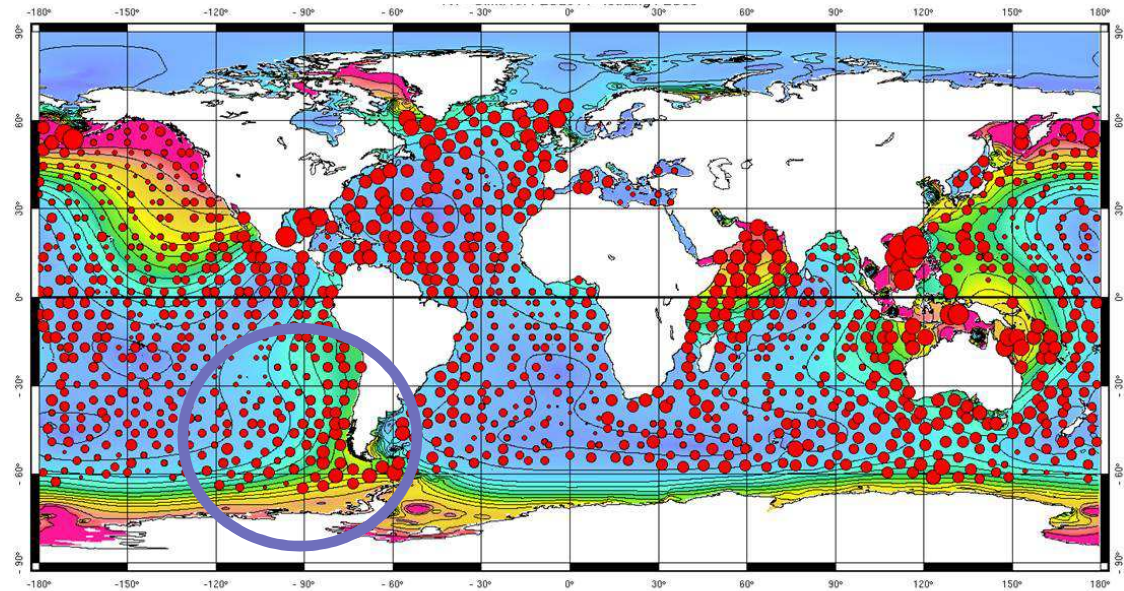


New investigations



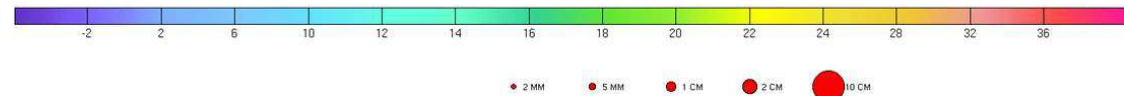
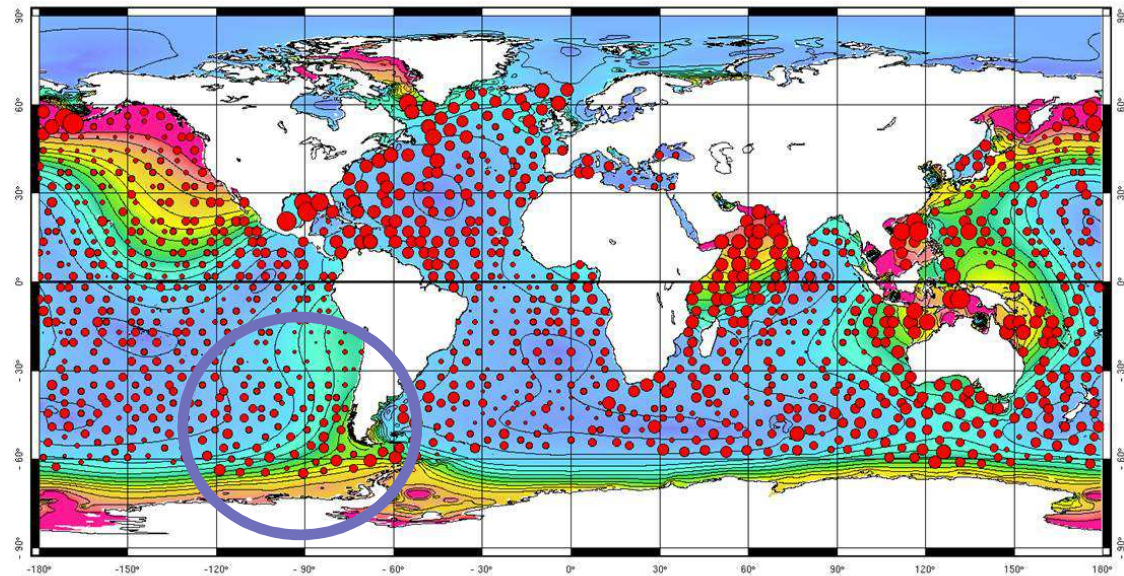
K1 forced with FES99 LSA

Error ~9mm RMS (deep ocean)

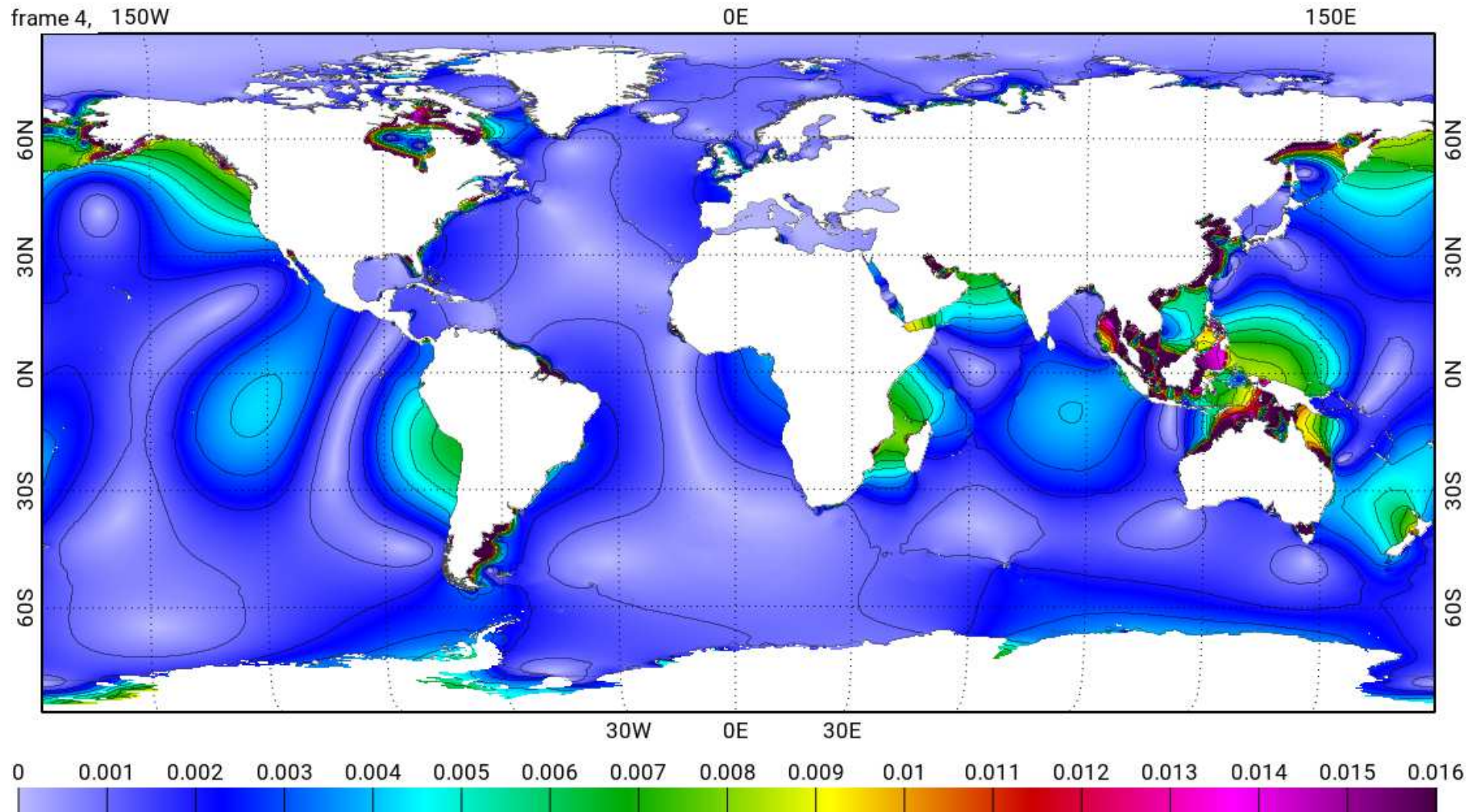


K1 forced with FES2014 LSA (courtesy of JP Boy)

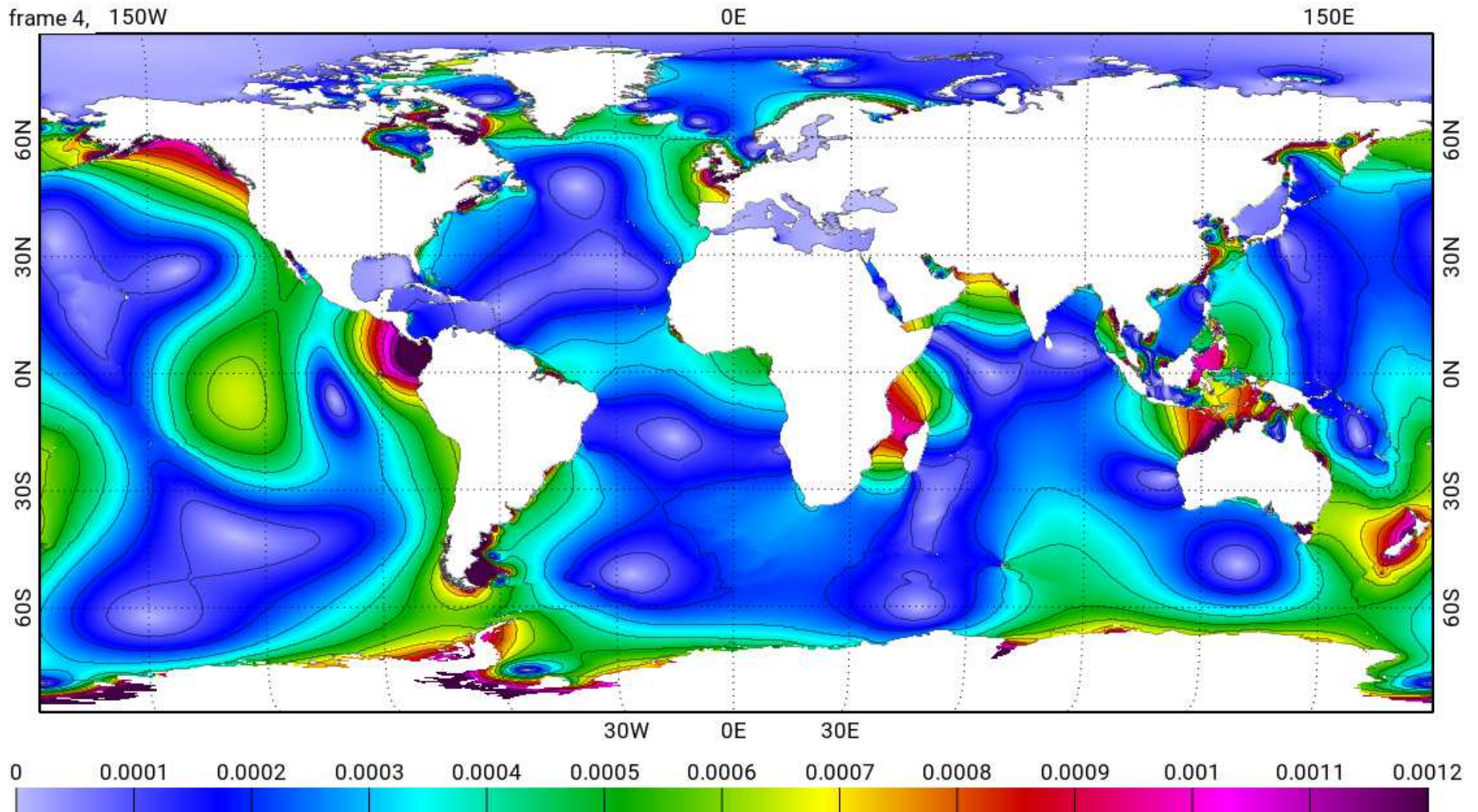
Error ~7mm RMS (deep ocean)



M₂ tide: impact of MDT pressure

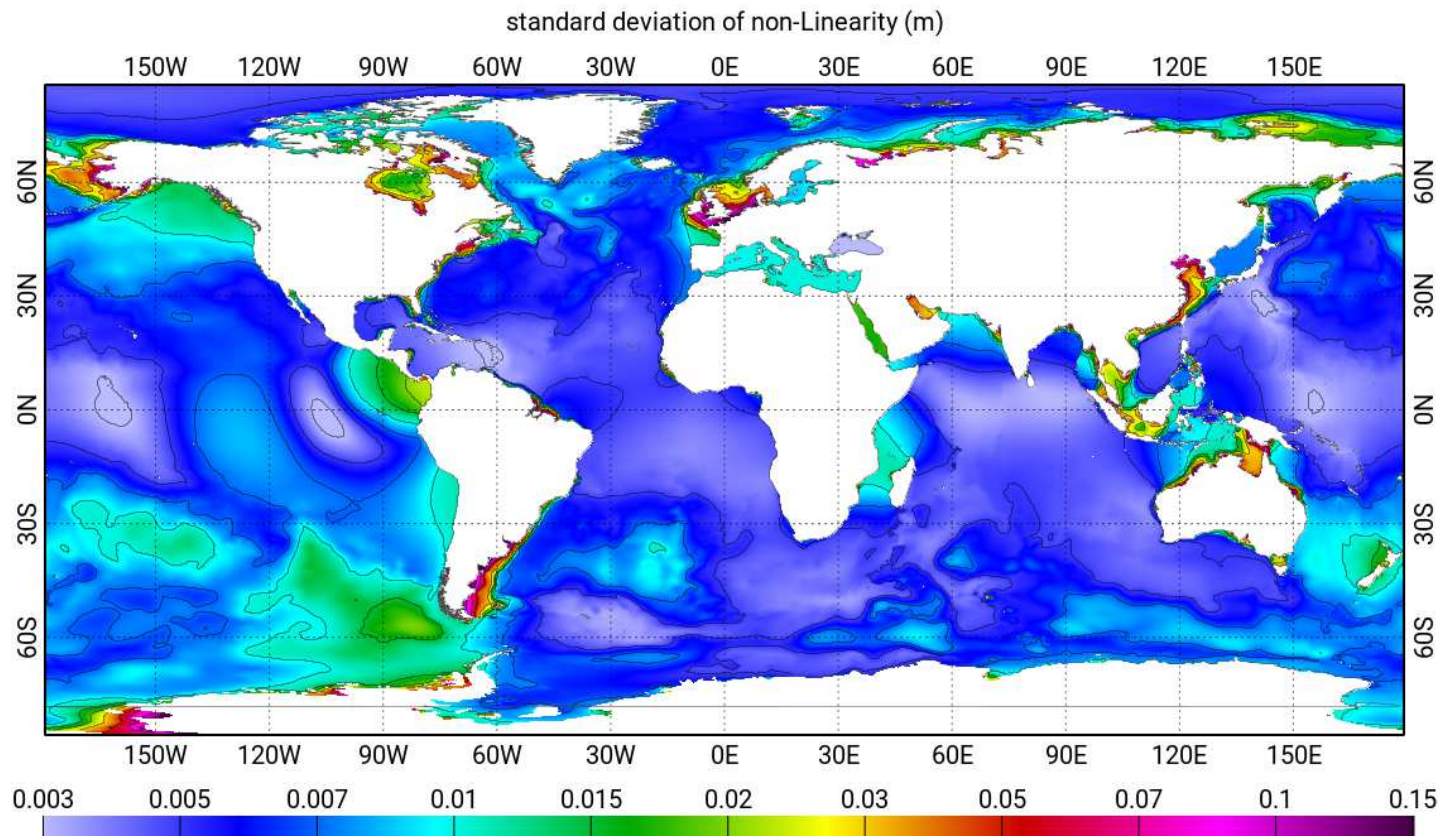


M₂ tide: impact of non-hydrostatic pressure



~0,5 mm improvement, all basins

Storm surge operational configuration upgrade (SALP, GRACE, etc...)



- Forcing
 - ERA, ECMWF OP, LWDA, etc..
 - Bulk, WW3 stress
- Grid configuration
 - Bathymetry
 - Resolution
 - MPI performances
- Dynamics
 - Tidal non-linearities
 - Loading/self-attraction
- Validation against
 - tide gauges
 - altimetry residuals



LSA investigations

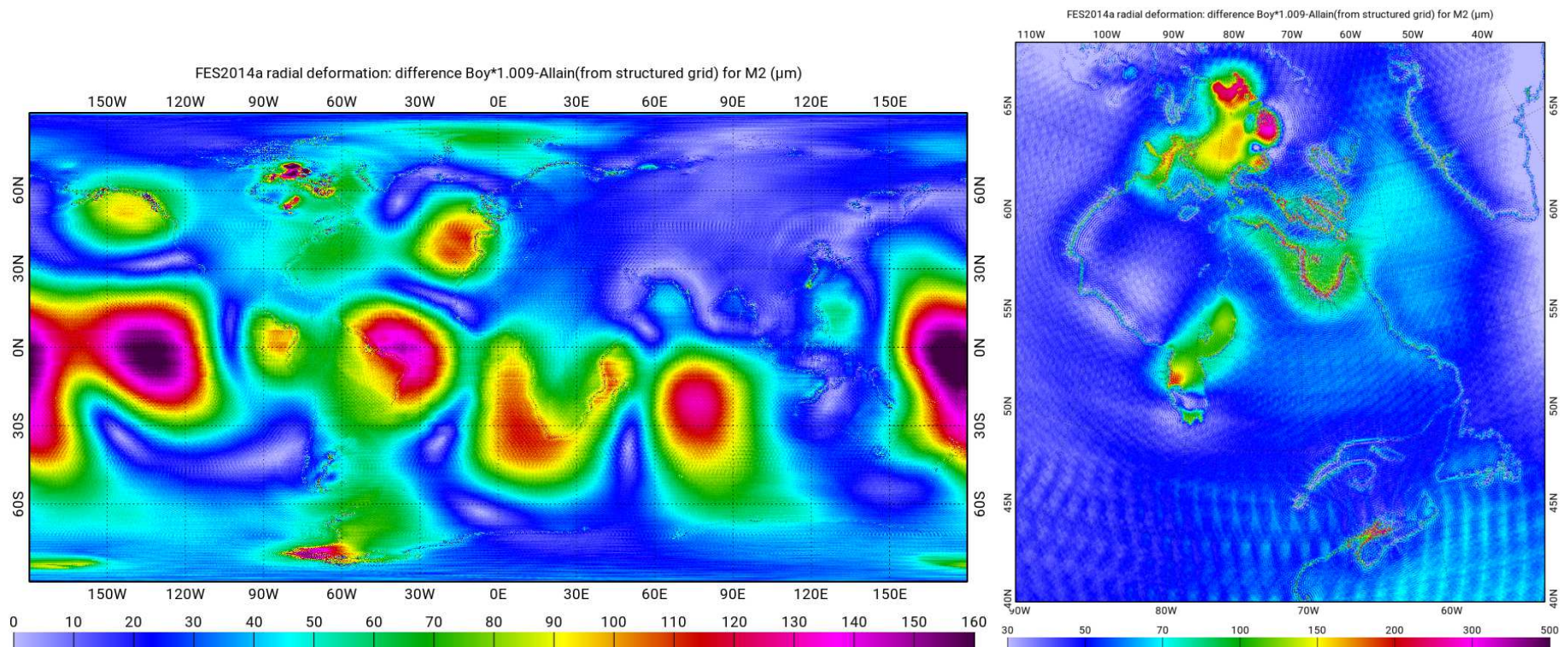
Deformation radial

Software :

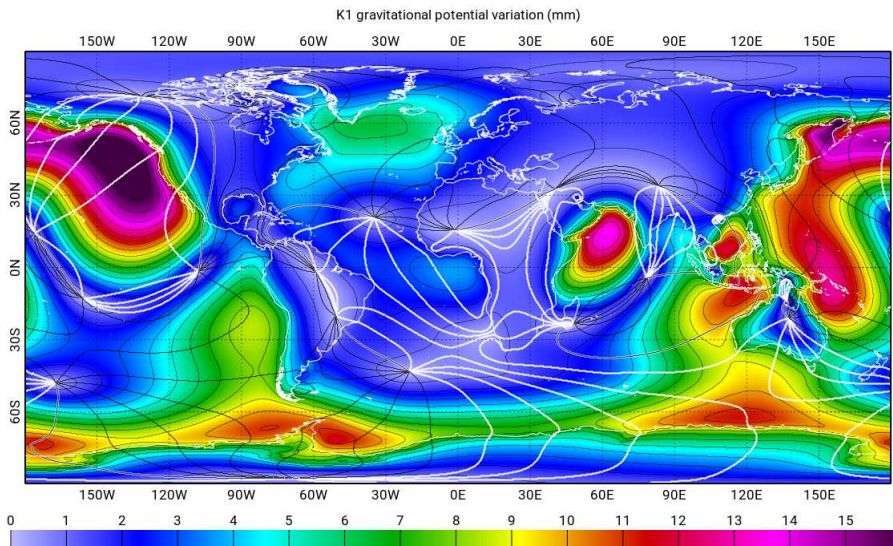
- handle structured and unstructured grid
- handle harmonic and real fields
- based on Green functions
- clustering optimisation

Validation

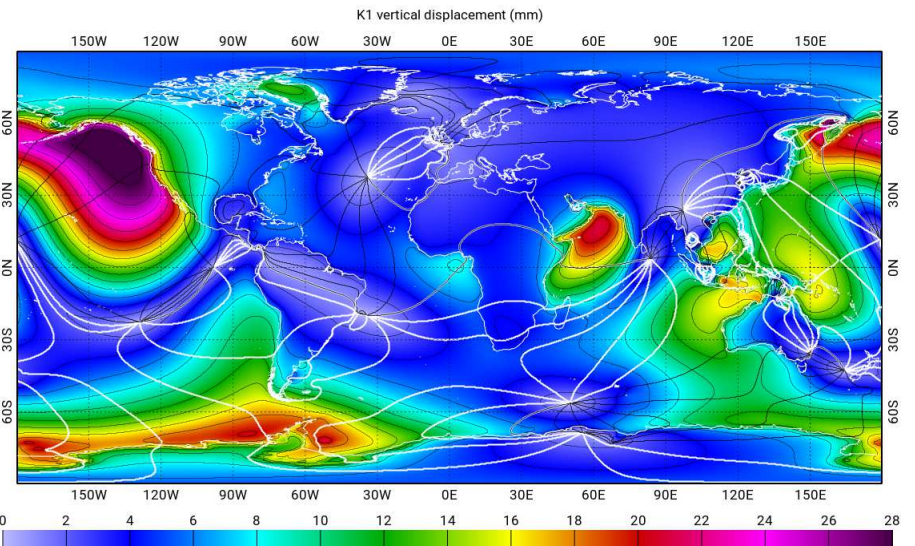
- J.P. Boy versus LEGOS



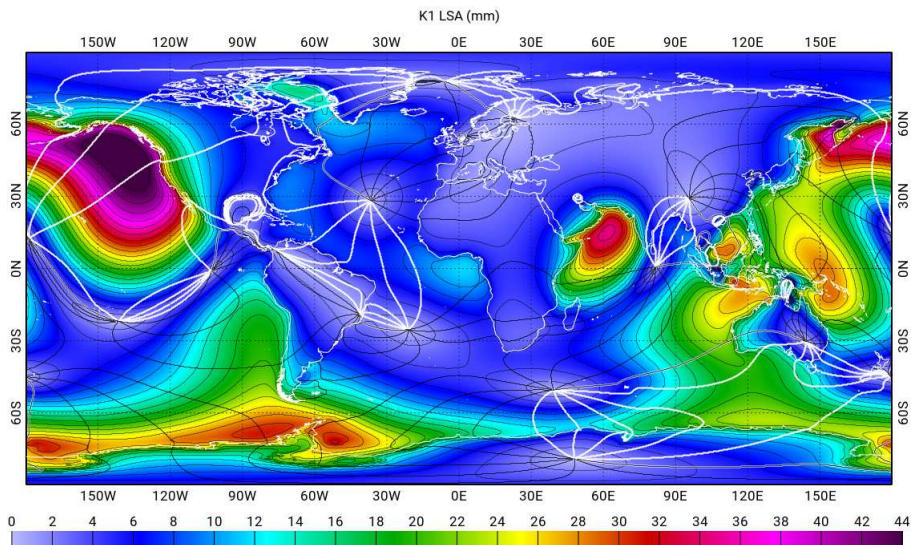
K1 tide



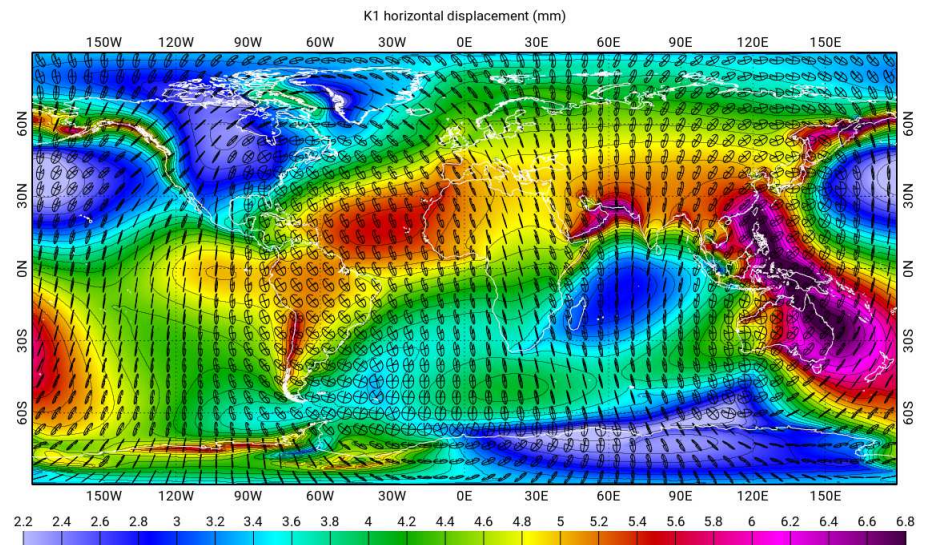
K_1 potential (mm)



K_1 radial displacement(mm)

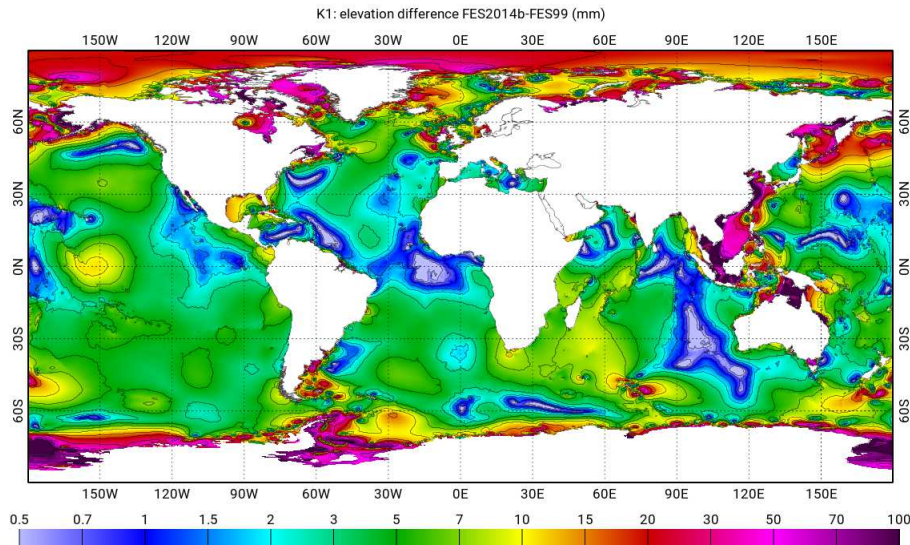


K_1 LSA (mm)

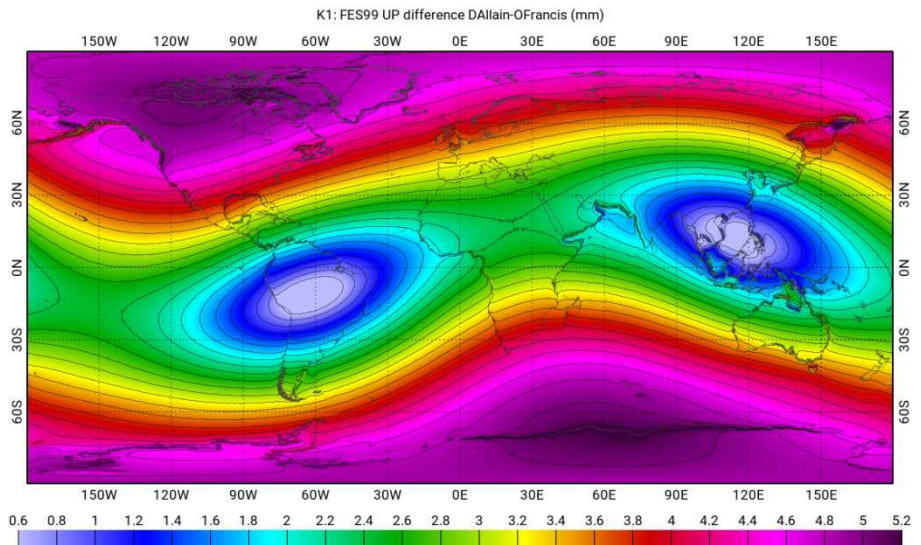


K_1 horizontal displacement(mm)

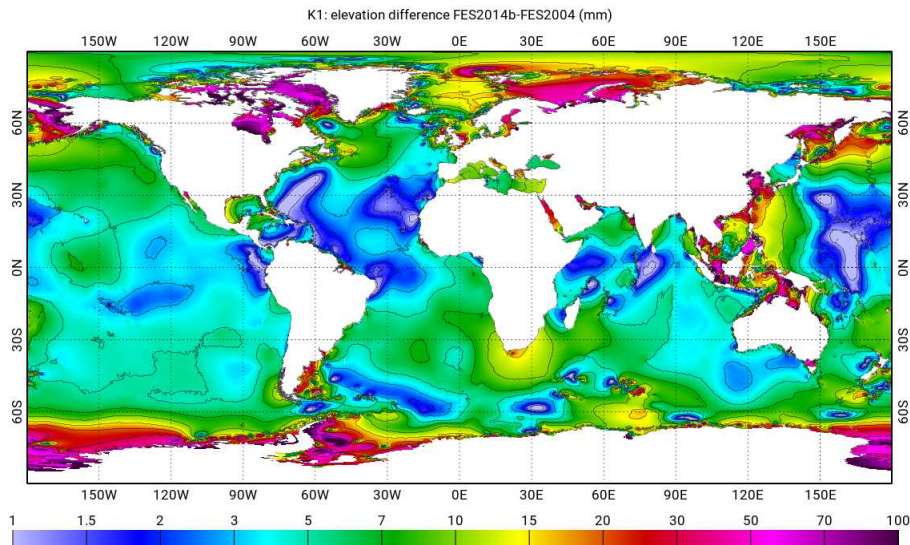
K1 vertical displacement, comparisons with previous releases



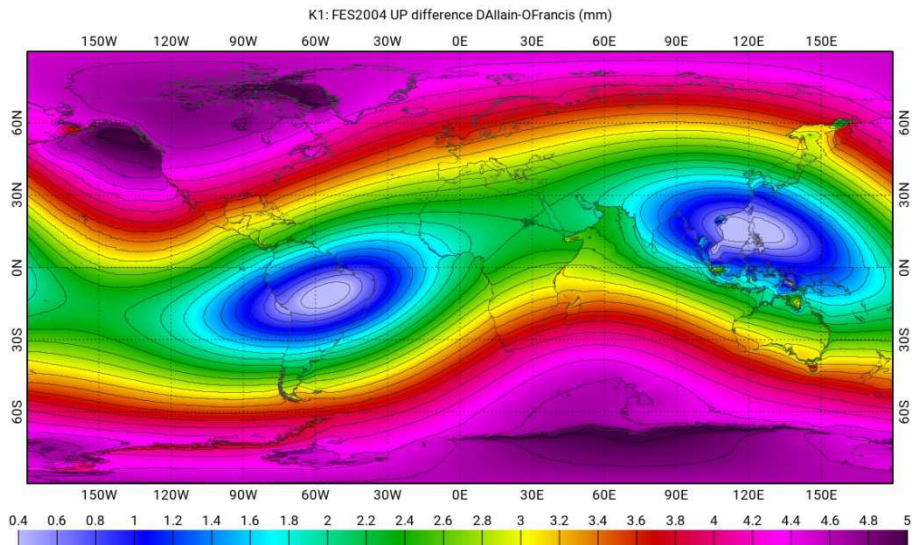
surface elevation : FES2014 versus FES99



Vertical displacement: FES2014 versus FES99

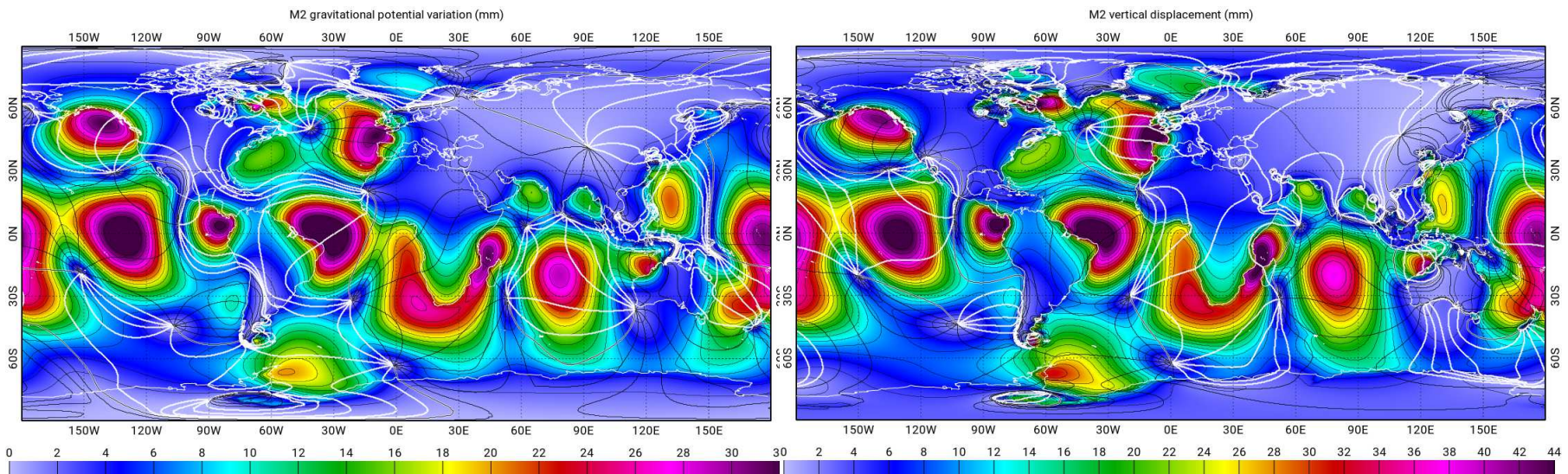


surface elevation : FES2014 versus FES2004



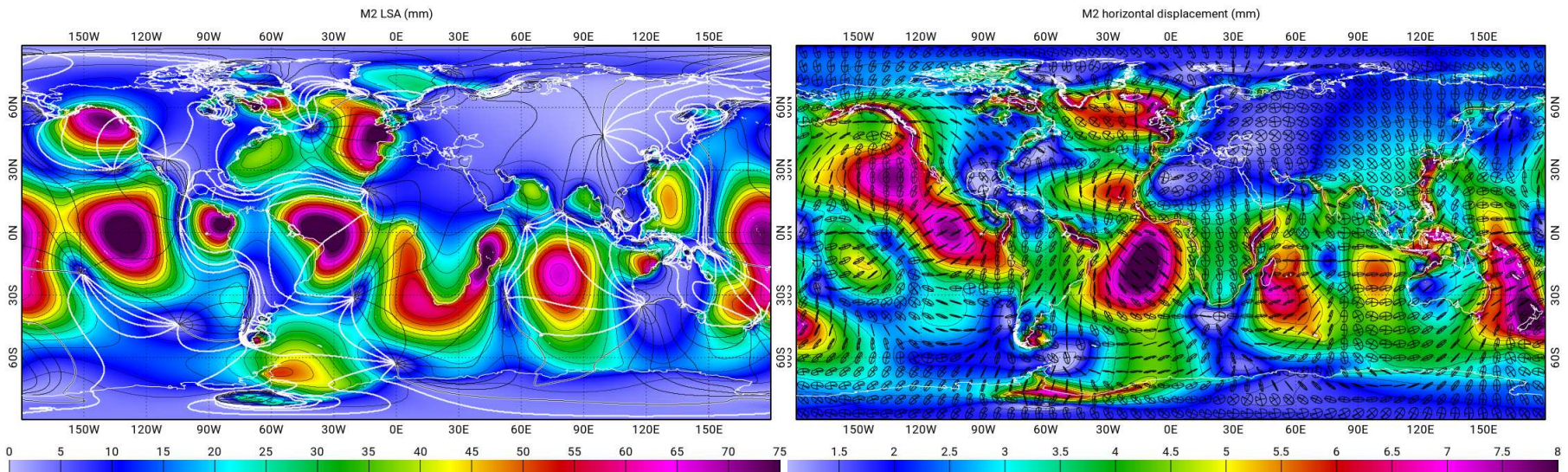
Vertical displacement: FES2014 versus FES2004

M2 tide



M₂ potential (mm)

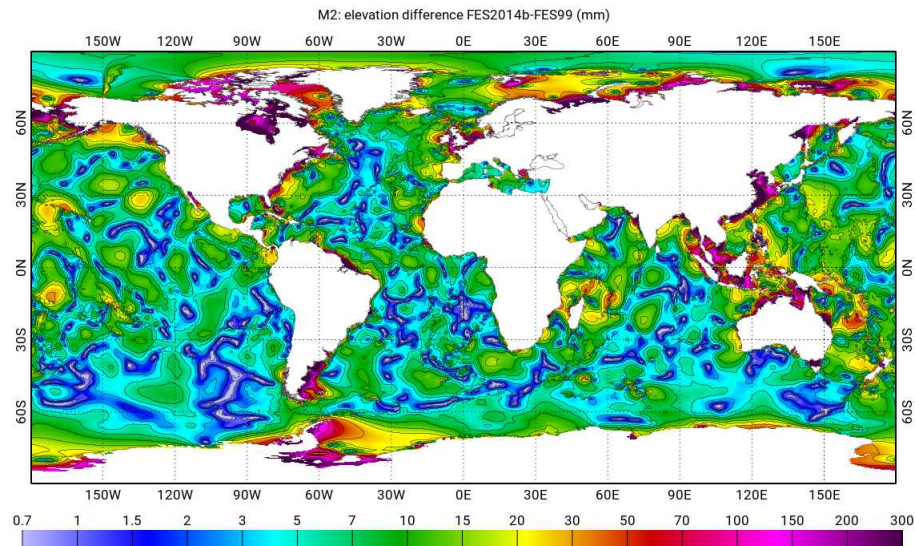
M₂ radial displacement(mm)



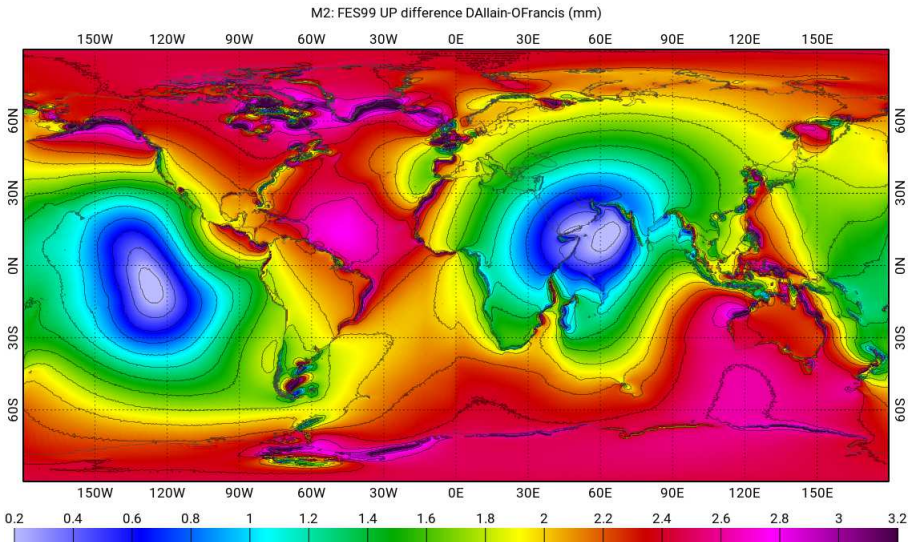
M₂ LSA (mm)

M₂ horizontal displacement(mm)

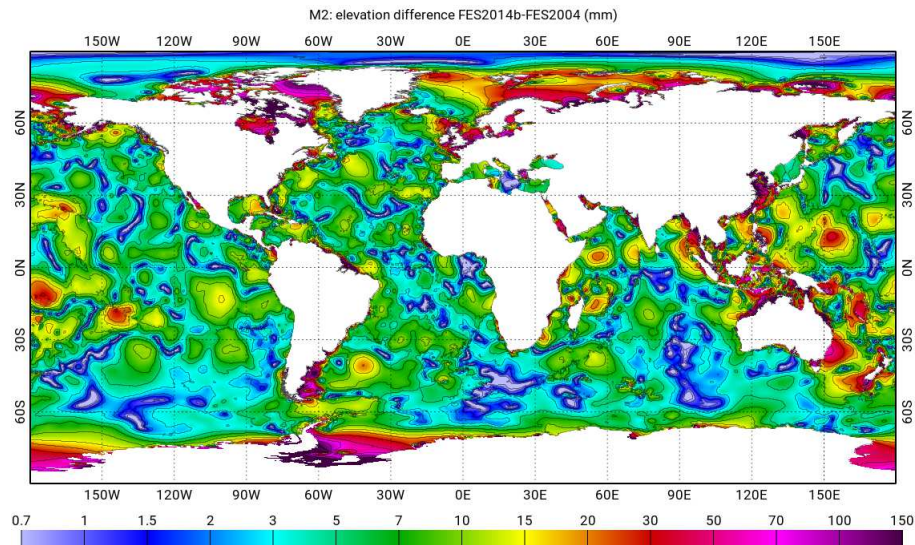
M2 vertical displacement, comparisons with previous releases



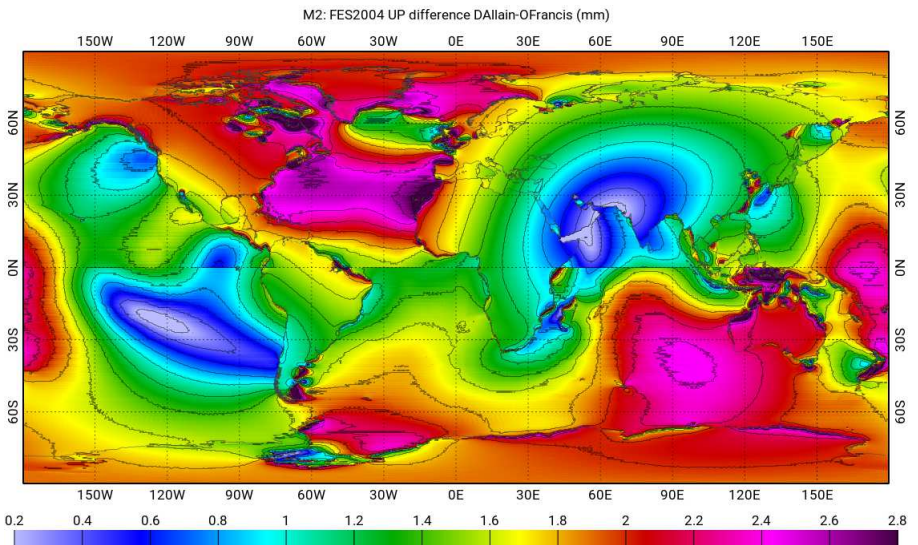
surface elevation : FES2014 versus FES99



Vertical displacement: FES2014 versus FES99

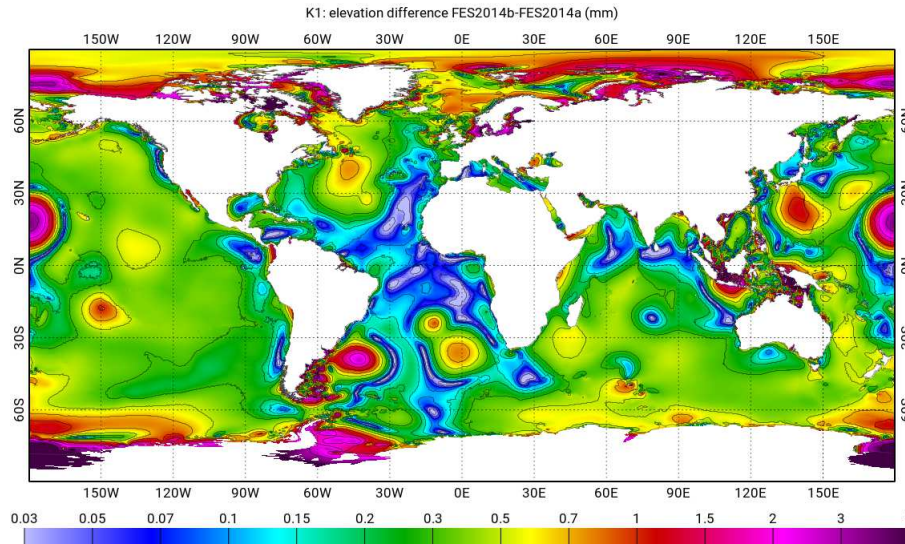


surface elevation : FES2014 versus FES2004

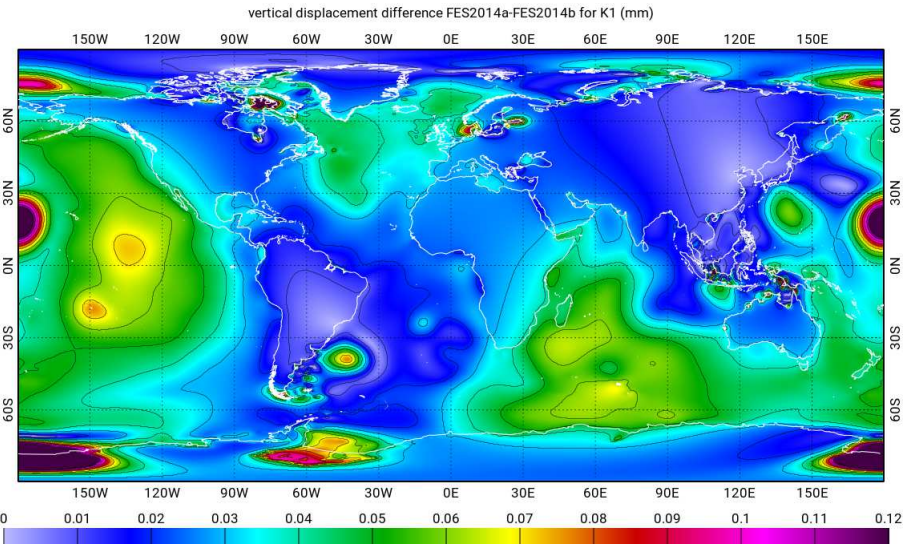


Vertical displacement: FES2014 versus FES2004

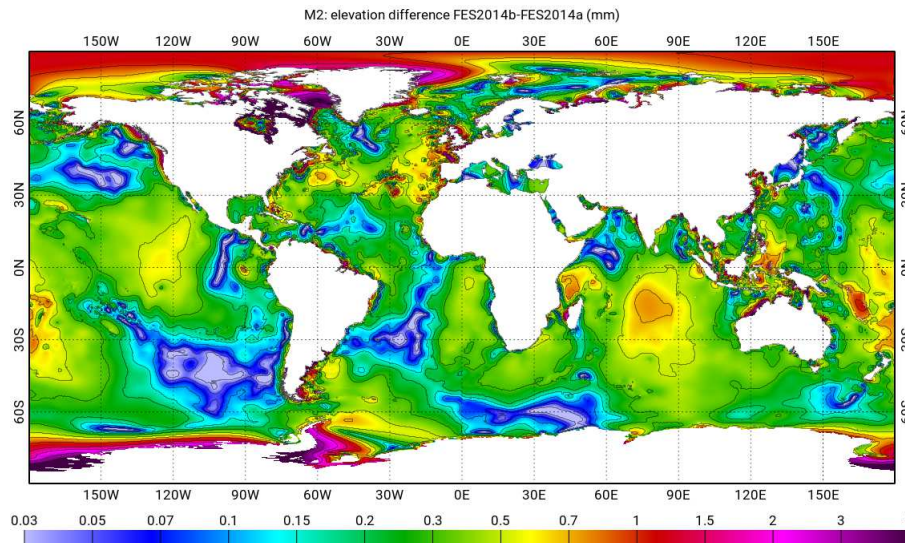
FES2014-b versus FES2014-a



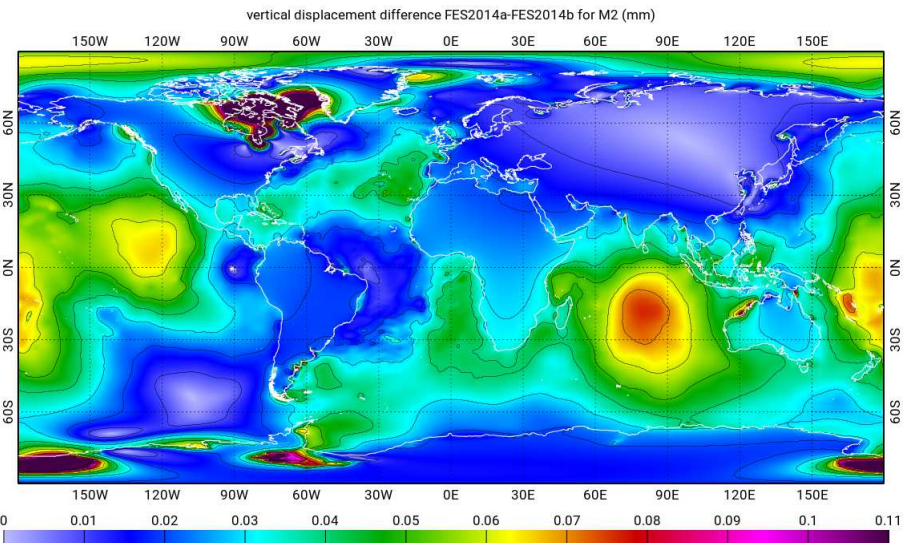
K1 surface elevation : FES2014 versus FES99



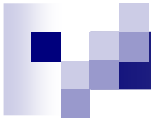
K1 vertical displacement: FES2014 versus FES99



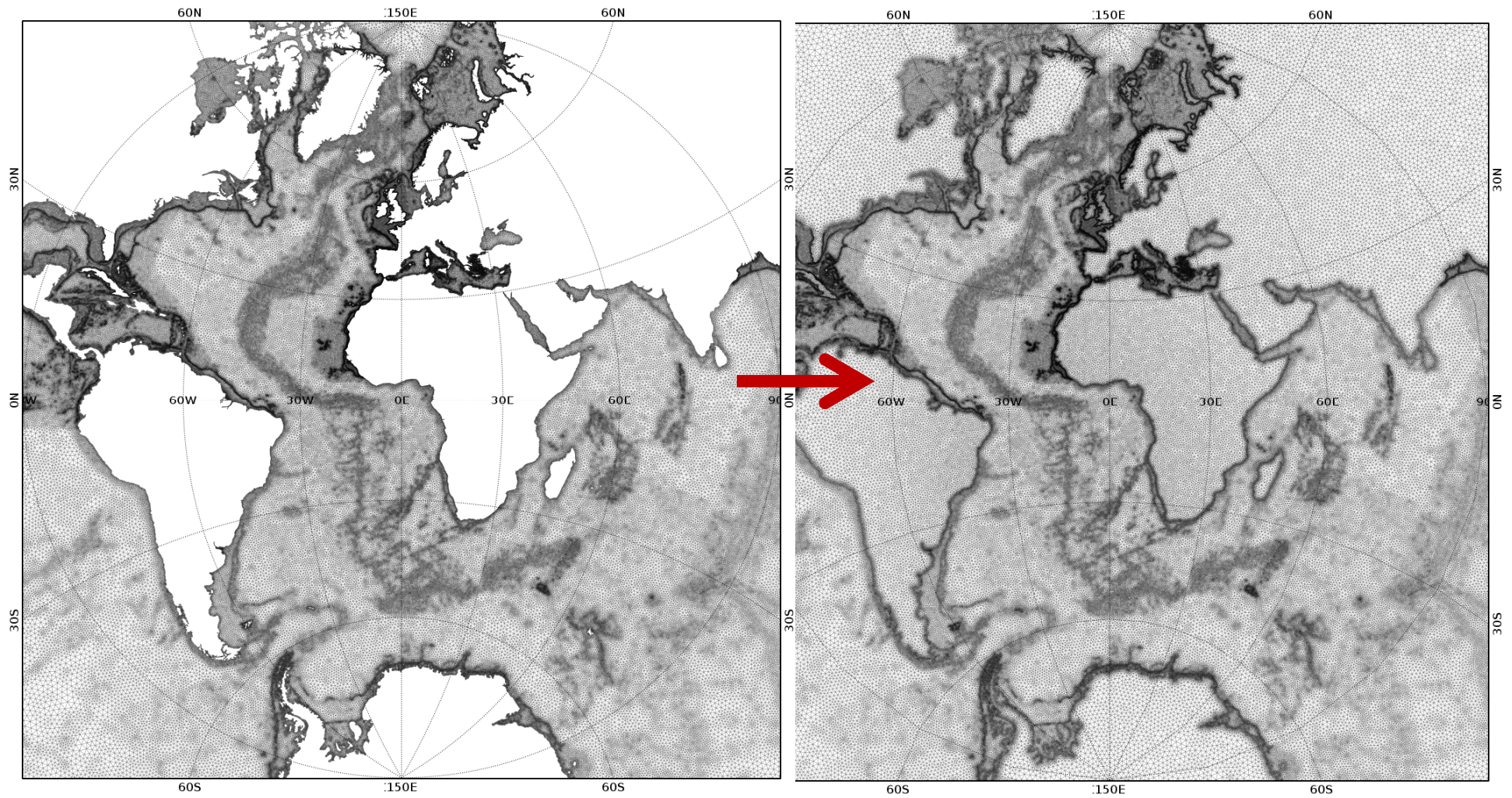
M2 surface elevation : FES2014 versus FES2004



M2 vertical displacement: FES2014 versus FES2004



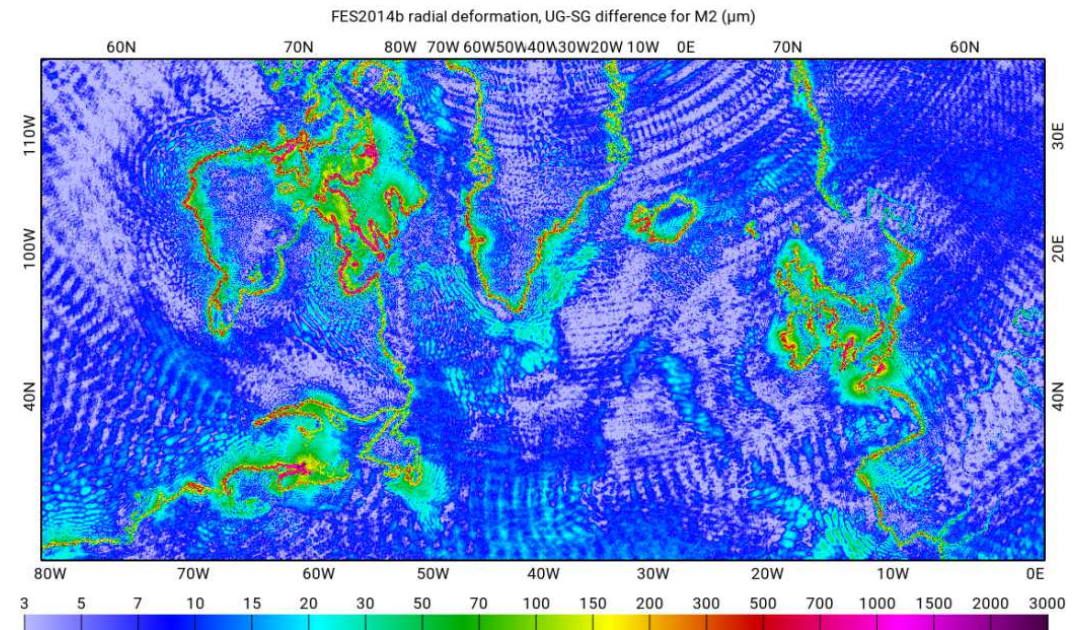
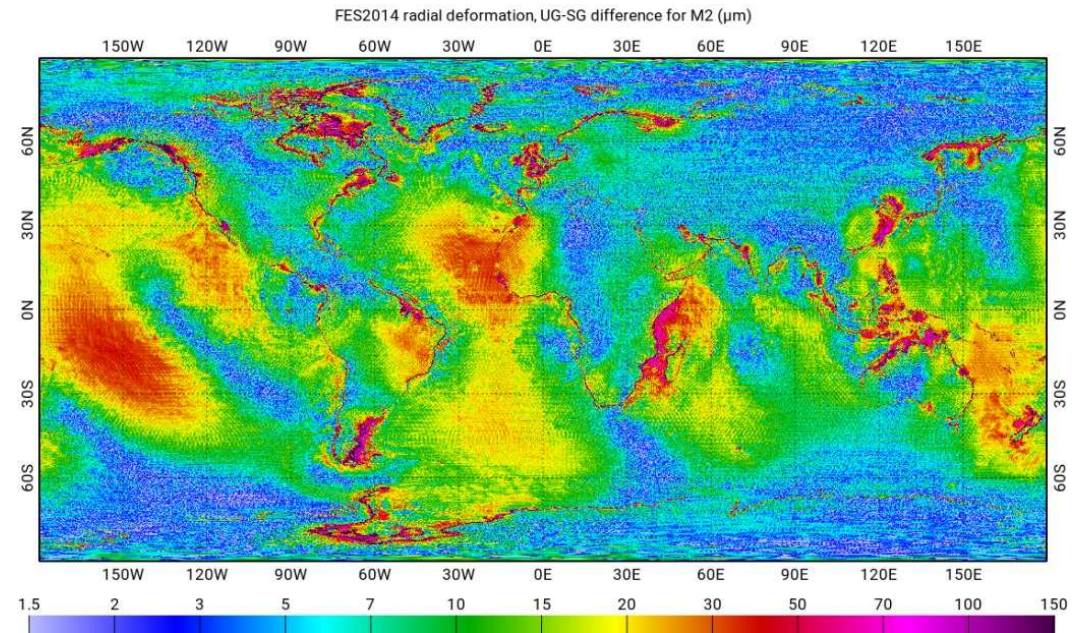
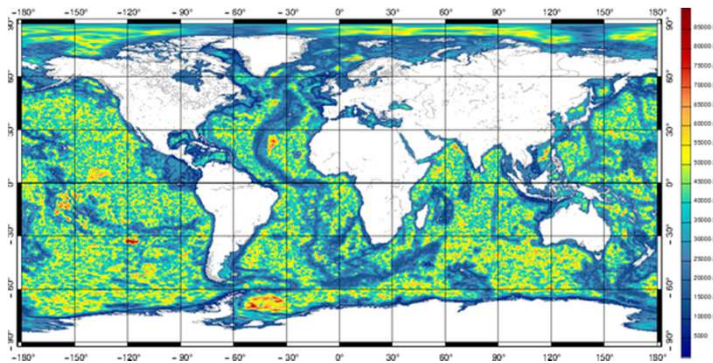
FES2014 mesh extension to islands and continents



Deformation radiale (FES2014-b)

structured versus unstructured

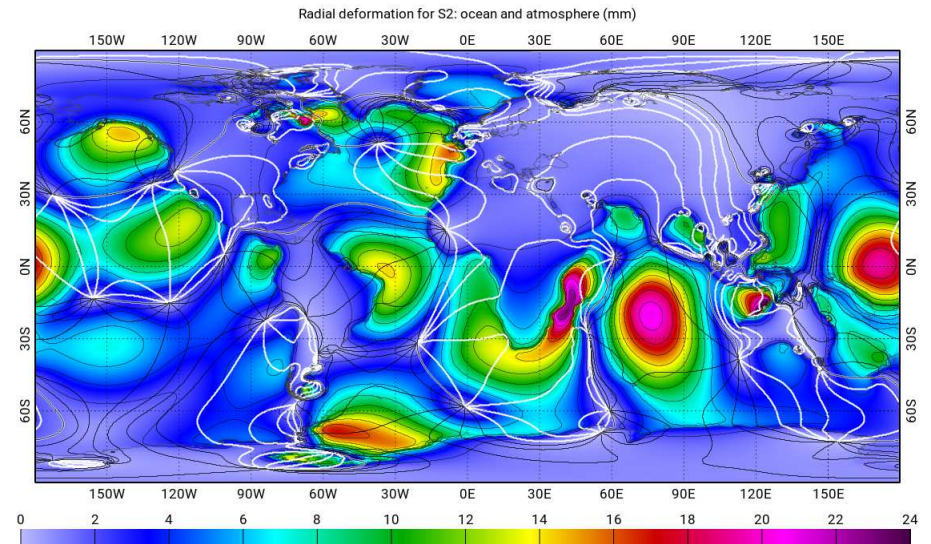
- structured:
 - 1/16° resolution atlas
 - loading on identical structured grid
- unstructured:
 - loading on identical unstructured grid



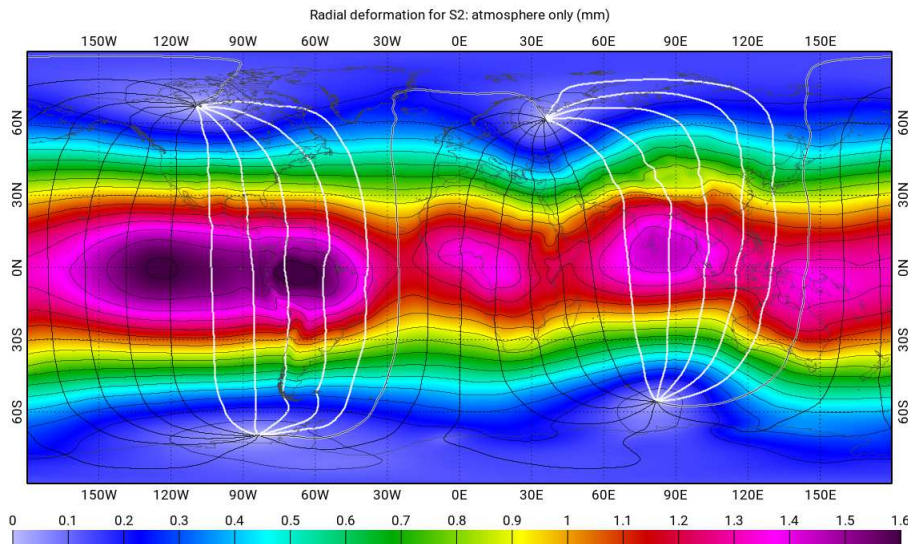
Deformation radiale

Atmospheric contribution to tides, S_2

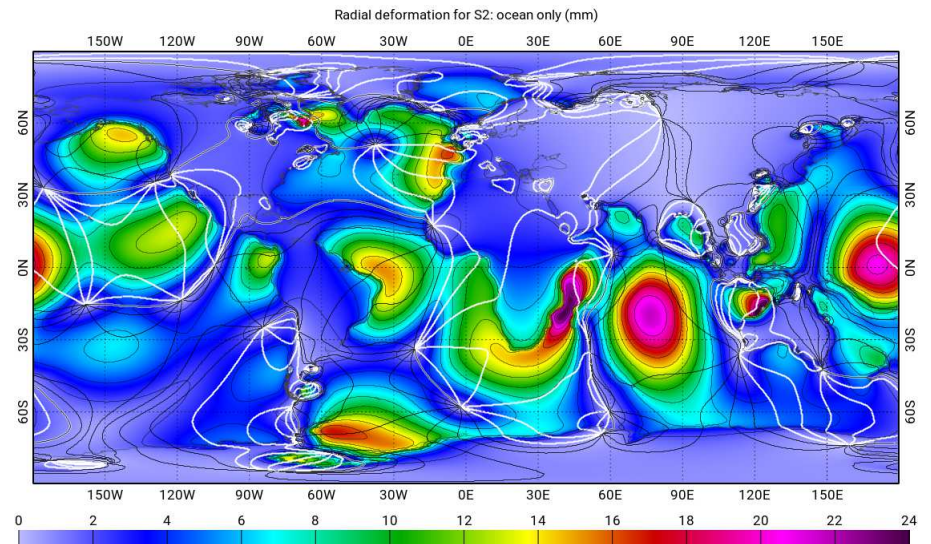
- S_2 atmospheric pressure forcing already in tidal forcing
- Not yet in loading/self-attraction terms
~10% of oceanic LSA



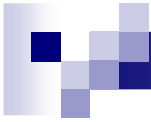
S_2 ocean sea level contribution (mm)



S_2 atmospheric pressure contribution (mm)

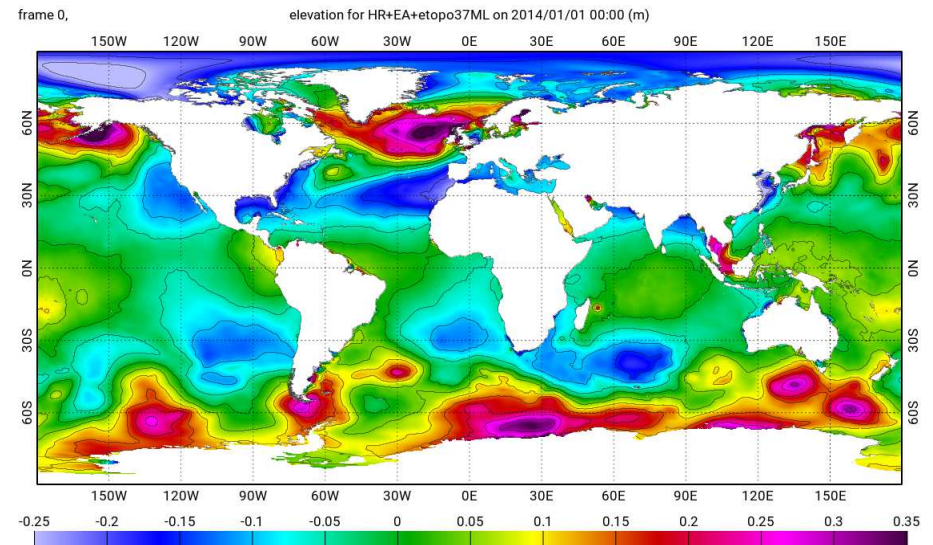
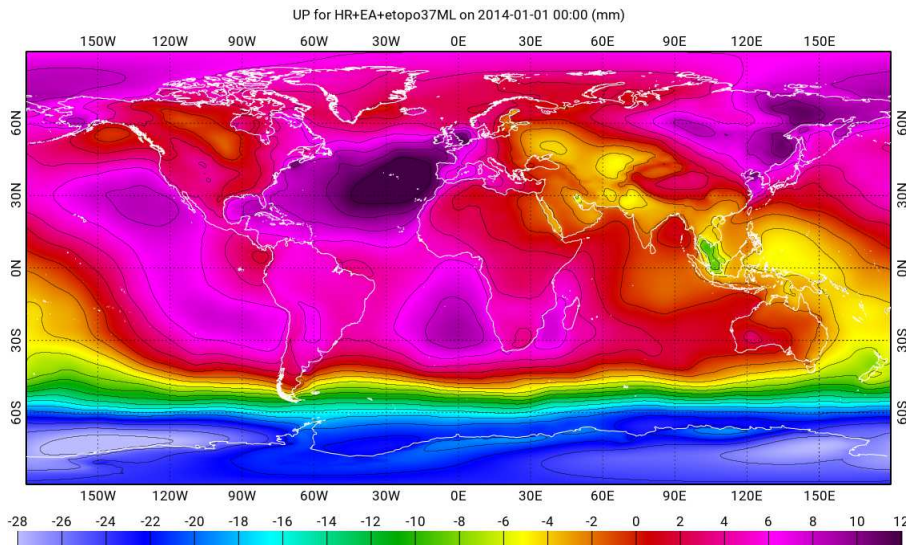
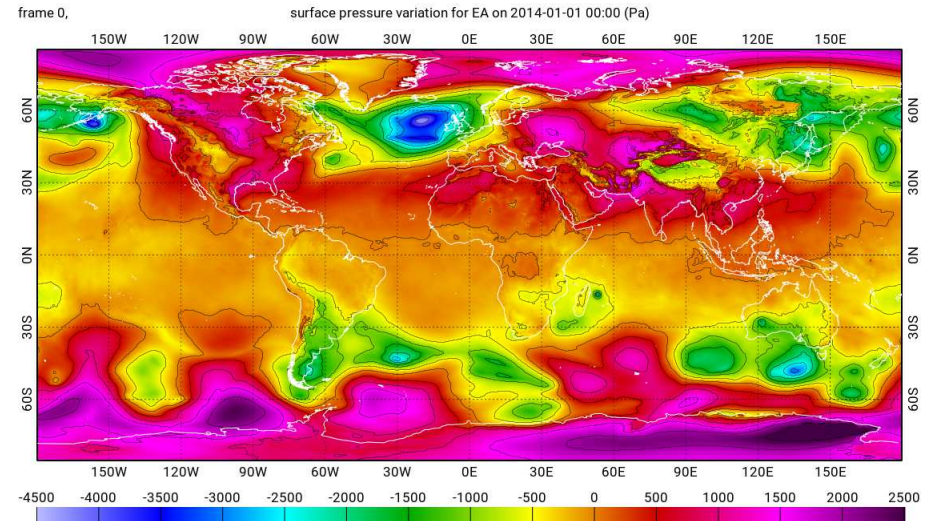


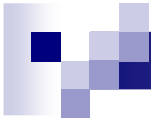
S_2 combined deformation (mm)



Atmospheric contribution to storm surges

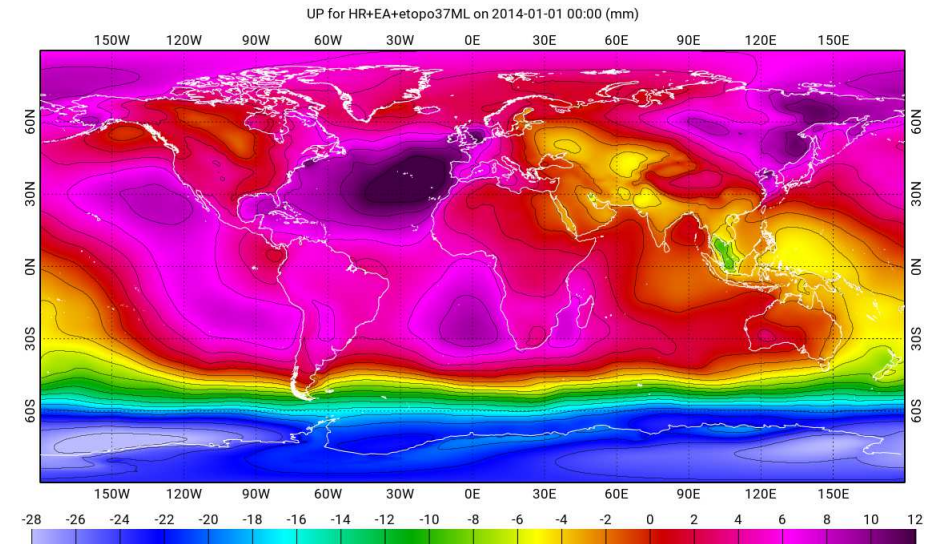
- atmospheric pressure forcing already in storm surges forcing
- Not yet in loading/self-attraction terms
~10% ?



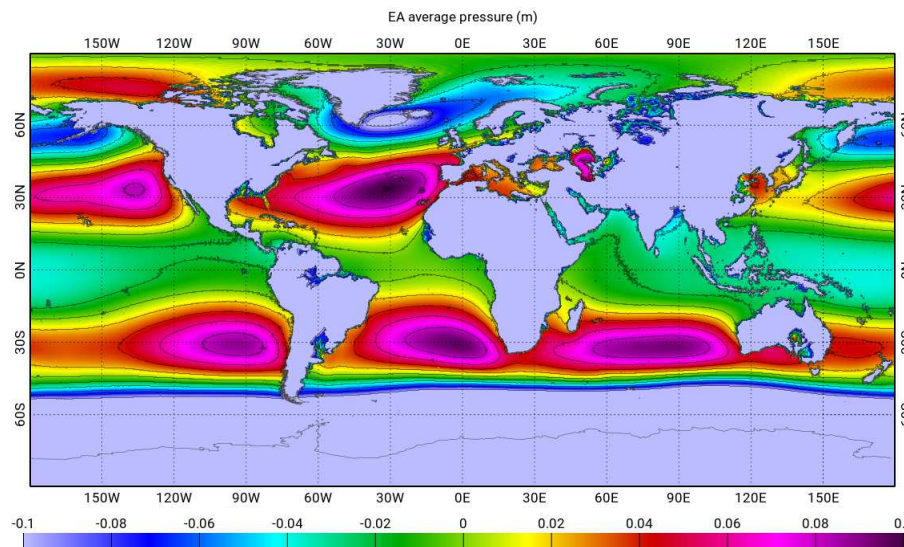


Atmospheric mean contribution

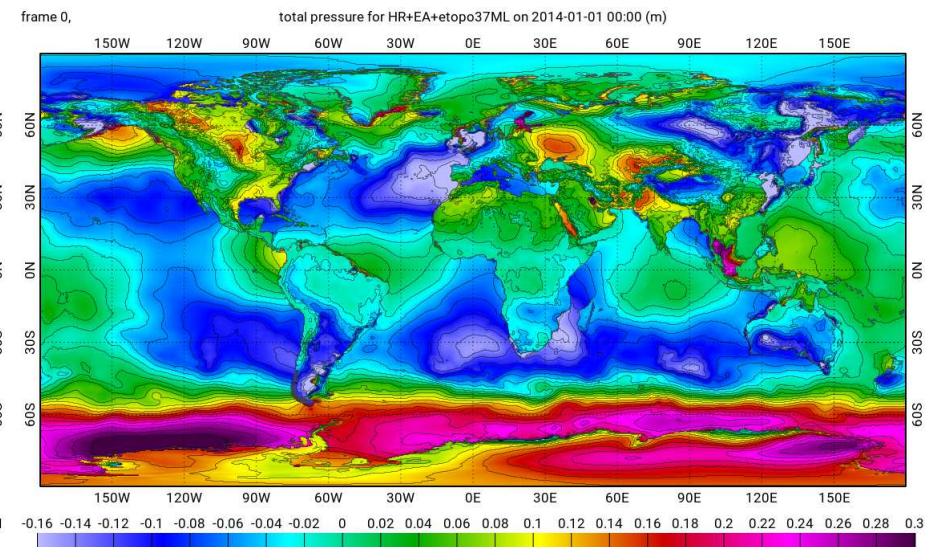
- How much already in mean level?



Radial displacement (mm)



Mean atmospheric surface pressure(m)



Instantaneous pressure (ocean+atmosphere) (m)



Conclusions/perspectives

- LSA impact on tides and storm surges to be investigated
 - Easy about tides
 - Still some numerical performances improvements needed for storm surges
 - More validations needed: GPS? gravimeters?
 - Non-homogeneous earth?

- Vertical reference systems
 - We know some mean levels
 - We would like to know some absolute levels (state of rest of ocean)
 - What about temporal evolution of « mean » and « absolute »
 - Consistent geoids

- Long term measurements/modelling are needed
 - Tides gauges + GPS
 - Altimetry + precise orbit
 - Ocean circulation simulations
 - Links in-between all those