REGIONAL TIDAL ATLAS FOR COASTAL AND SHELF SEAS:

METHODOLOGY AND VALIDATION

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Methodology: regional modeling and data assimilation

- **Objectives :** provide high accuracy coastal and shelf seas tidal atlas

- **Tidal model :**
  - FE sequential model (T-UGOm)
  - Error estimates: spectral ensemble generation
    - Based on empirical hydrodynamics and energetic considerations

- **Tidal data :**
  - Tide gauges, altimeter data (X-TRACK data processing*) harmonic constants
  - Error estimates:
    - Harmonic analysis error estimate (white noise assumption)
    - Along-track variability (smoothness assumption)
    - Xovers misfits

- **Data assimilation (spectral space)**
  - Spectral Ensemble Optimal Interpolation (SpEnOI), mono-chromatic
  - Optimal tidal elevation AND currents

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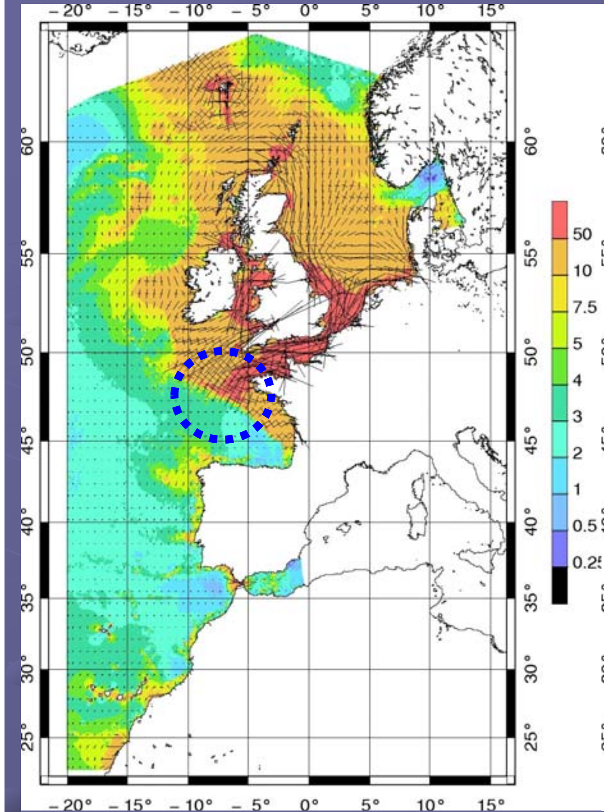
Project status

- **Project releases:**
  - North-East Atlantic and Mediterranean Sea atlases completed, validated, released
  - Persian Gulf atlas to be released soon
- **Present tasks:**
  - Complementary validation:
    - Internal tide impact
    - Minor amplitude constituents validation
  - Methodology improvement
    - Hydrodynamic model improvement
    - Data error assessment
    - Data processing
    - Polychromatic assimilation, energetic constraints addition
- **Target definition round:**
  - Identify highest priority for next atlases

Internal tide contamination

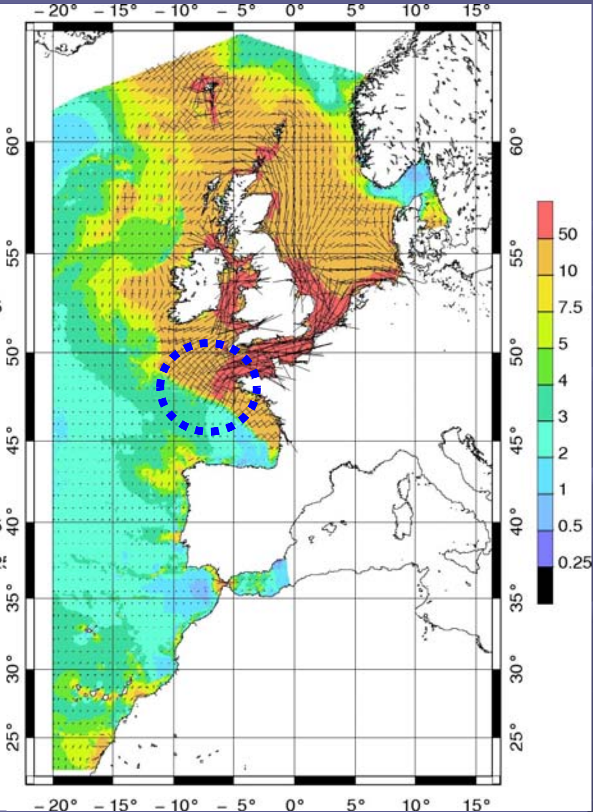
- **Initial approach**
  - No data pre-processing (after harmonic analysis)
  - Let data error estimates and model error covariance filter non-barotropic contributions
- Does it work ?

M_2 tidal currents



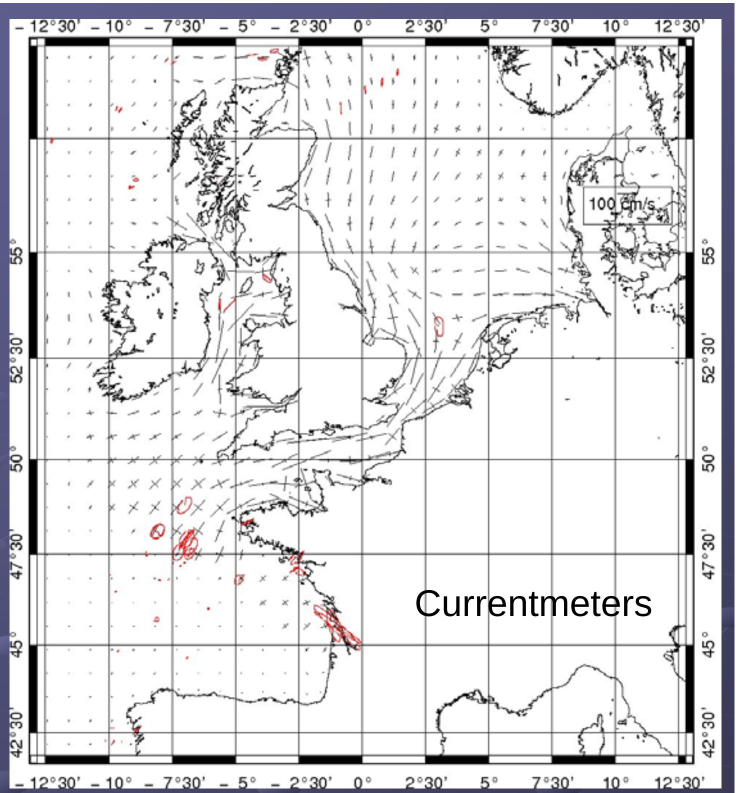
NEA-COMAPI (optimal)

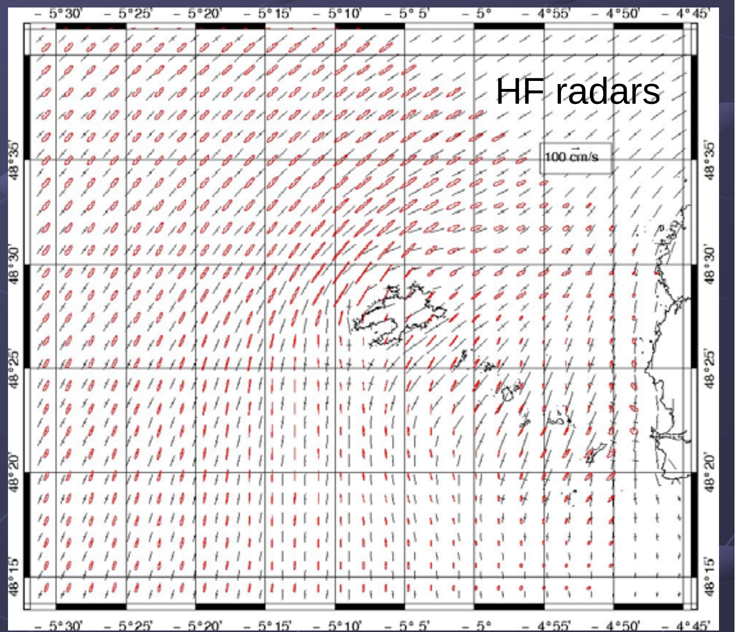
NEA-Bathymetry Version-2009



NEA-COMAPI (hydrodynamic)

NEA-Bathymetry Version-2009

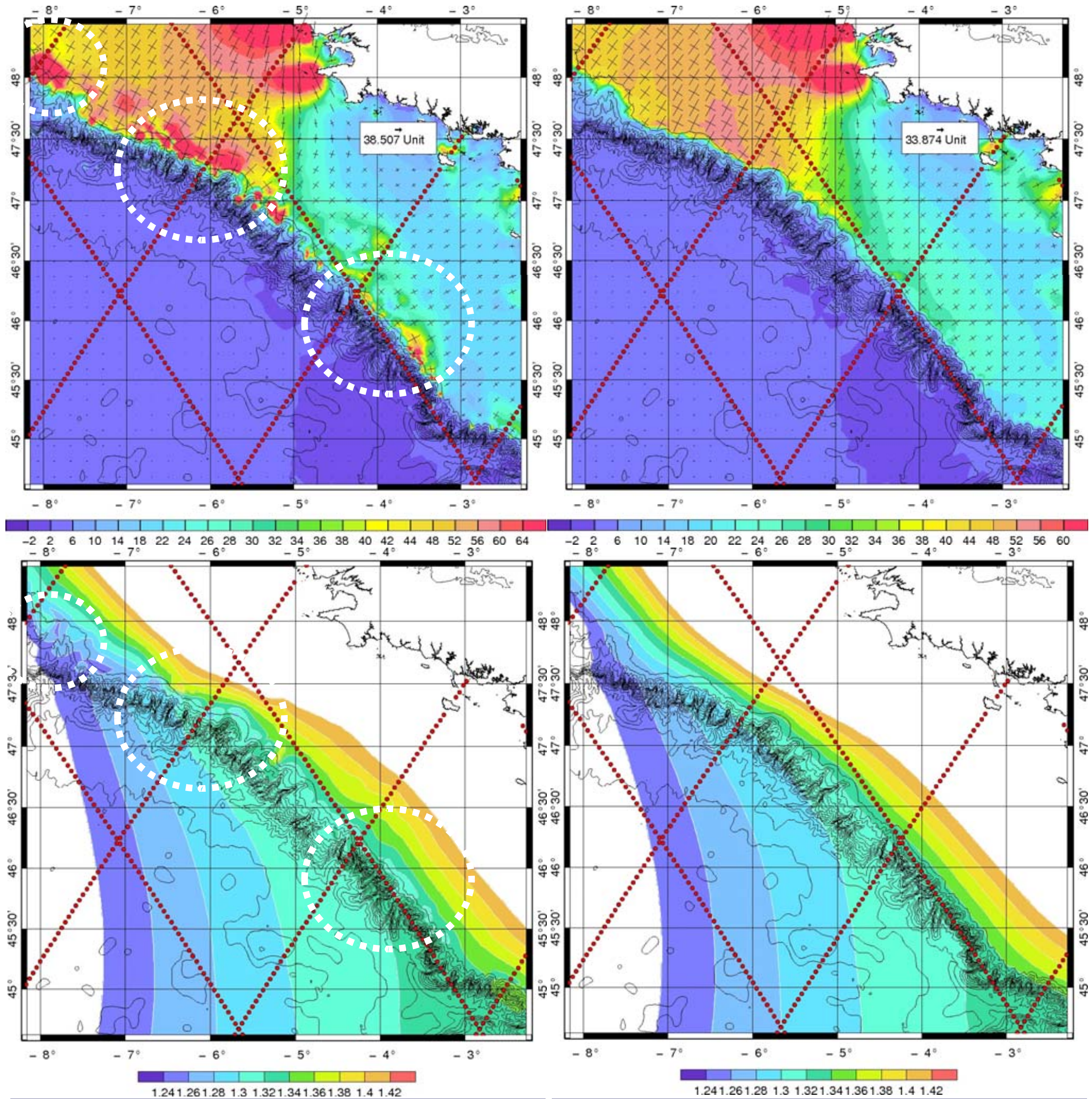




- Hydrodynamical and optimal currents consistent with observations
- Differences more or less in observation error bars, except at Biscay shelf's edge

M2 currents anomalies

- Located at shelf's edge
- Co-located with elevation anomalies



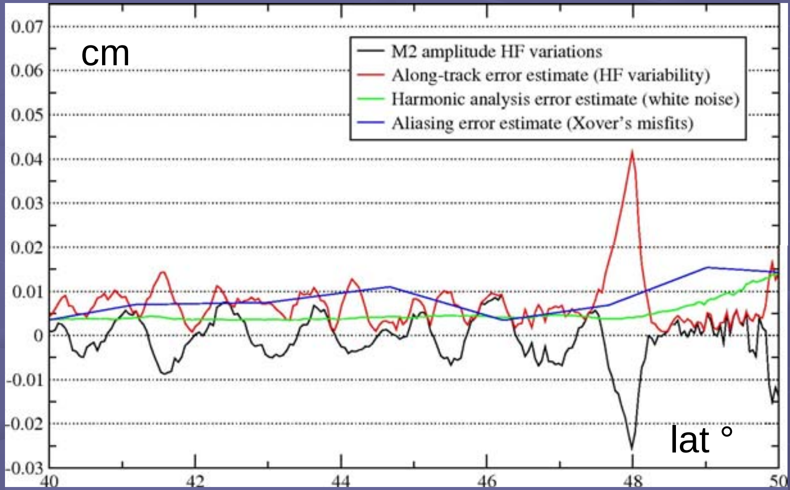
NEA-COMAPI (optimal)
NEA-Bathymetry Version-2009

NEA-COMAPI (hydrodynamic)
NEA-Bathymetry Version-2009

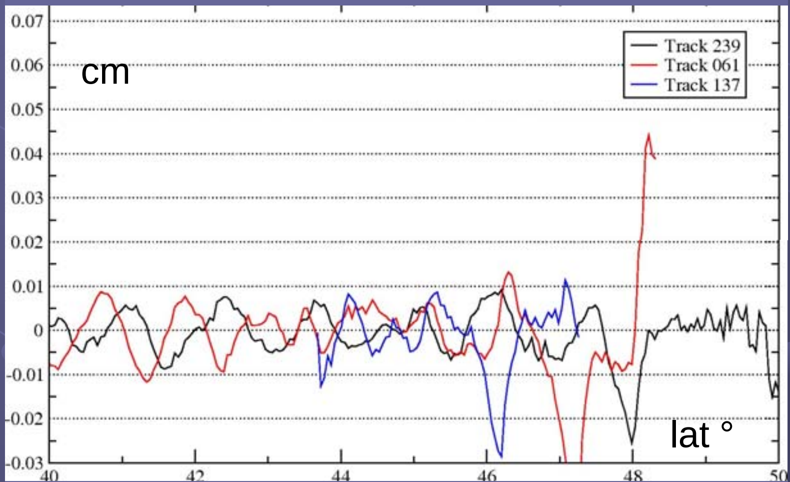
M_2 assimilation

- O(1) cm internal tide surface signature
- O(1cm) data error estimates

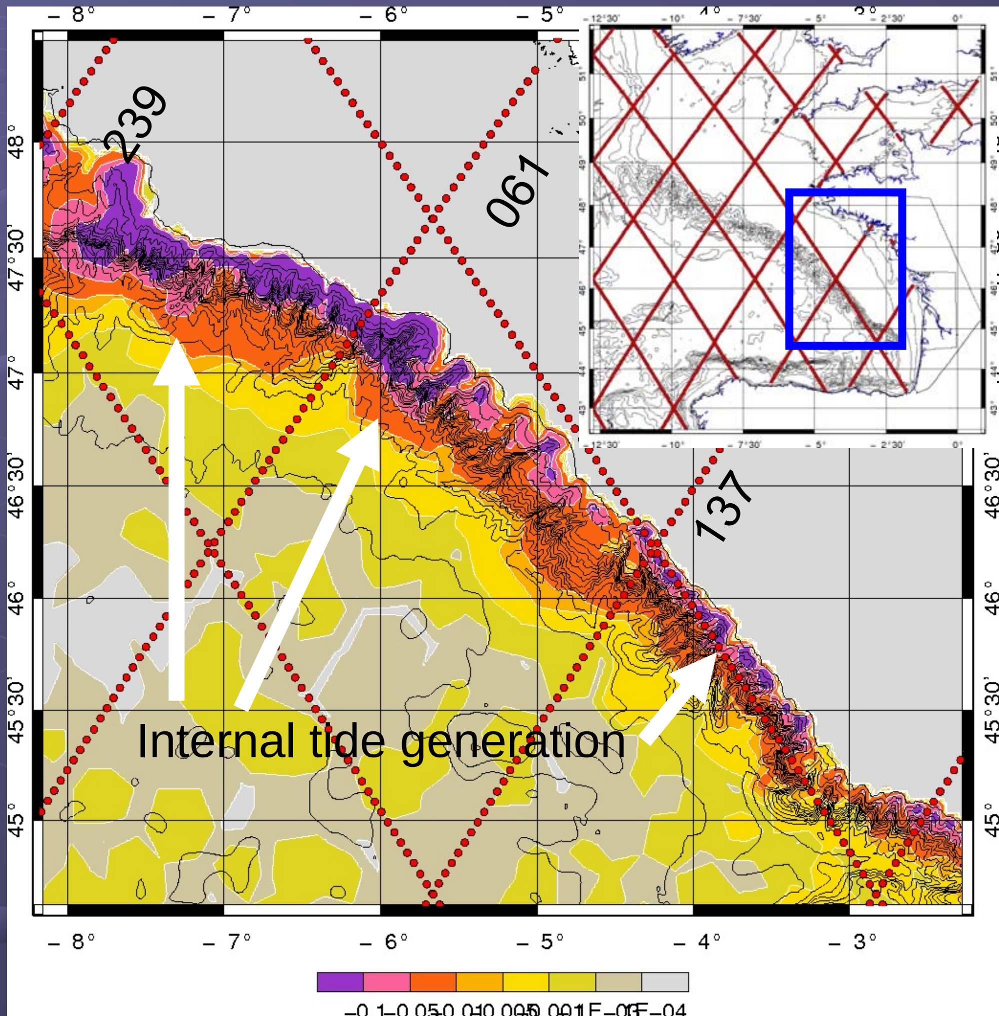
Not sufficient to avoid assimilation contamination



Tracks 239: internal tide surface signature and error bars



Tracks 061,137,239: internal tide surface signature

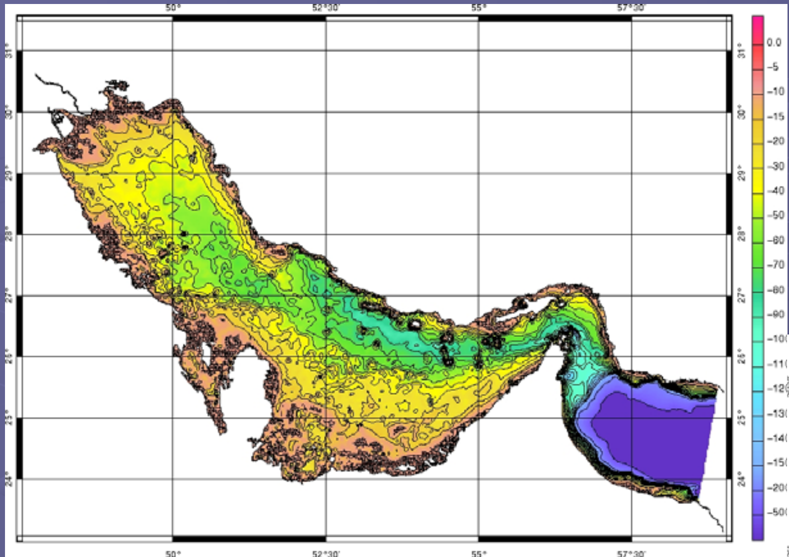


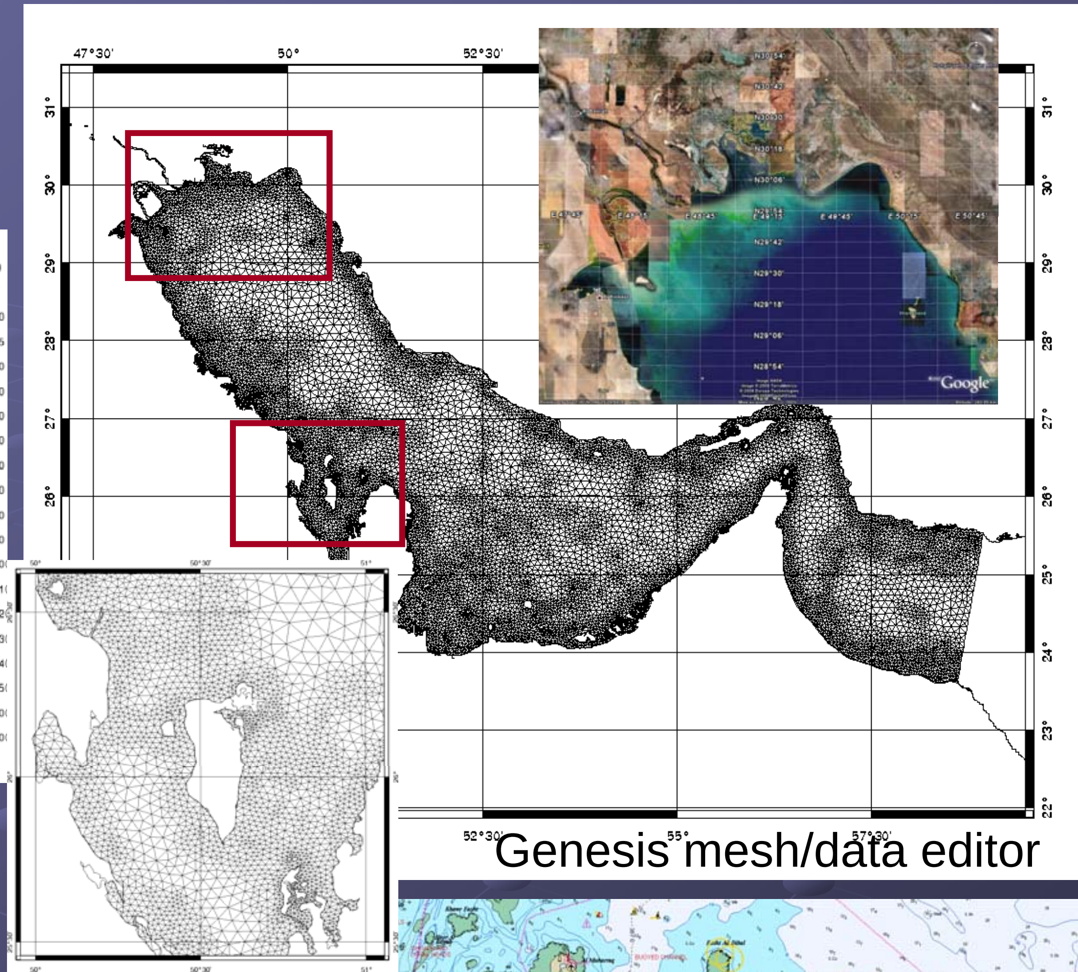
NEA-COMAPI (hydrodynamic)
Internal tide wave drag, rate of work (W/m²)

Small amplitude constituents

- **Coastal tidal spectrum**
  - Based on the major constituents
  - Include a large number of minor constituents, mostly below 1 cm amplitude except in some very locallized area
- **Does altimetry provide a tractable observation?**
  - Amplitude/noise ratio issue
  - Error estimate accuracy issue

Persian Gulf pilot model





Genesis mesh/data editor

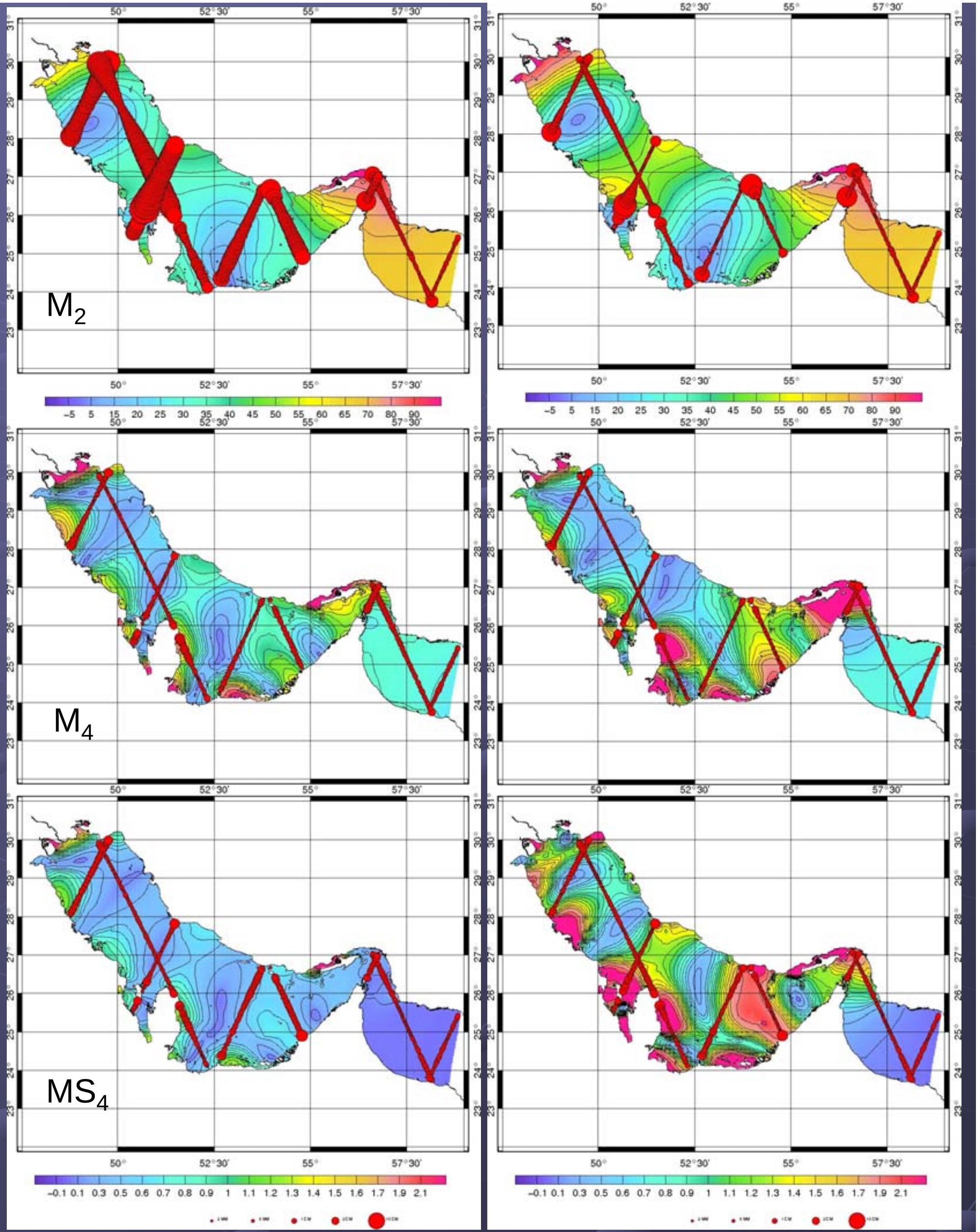
- **Geometry:**
  - NOAA shorelines
  - SHOM bathymetry
  - O(1) km resolution along the shorelines
- **Forcing :**
  - FES2004 OBCs
  - Astronomic forcing
  - FES2004 loading/self-attraction
- **Dissipation :**
  - Homogeneous bottom rugosity length
  - Internal wave drag
  - Smagorinsky horizontal diffusion

Data assimilation

comparison of prior and posterior misfits

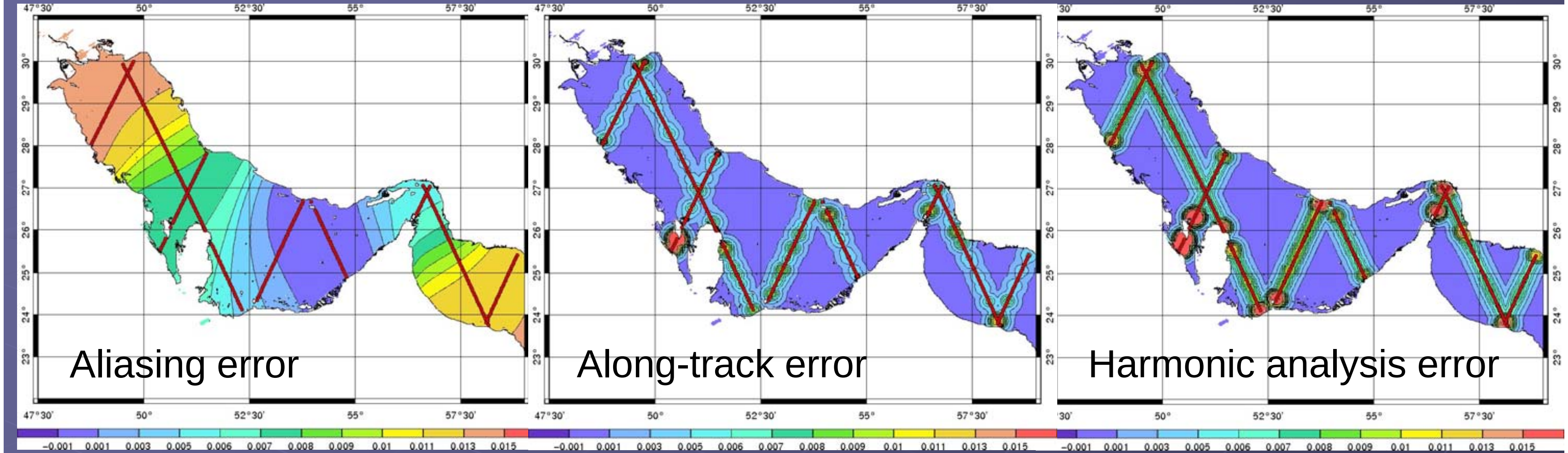
Altimetry

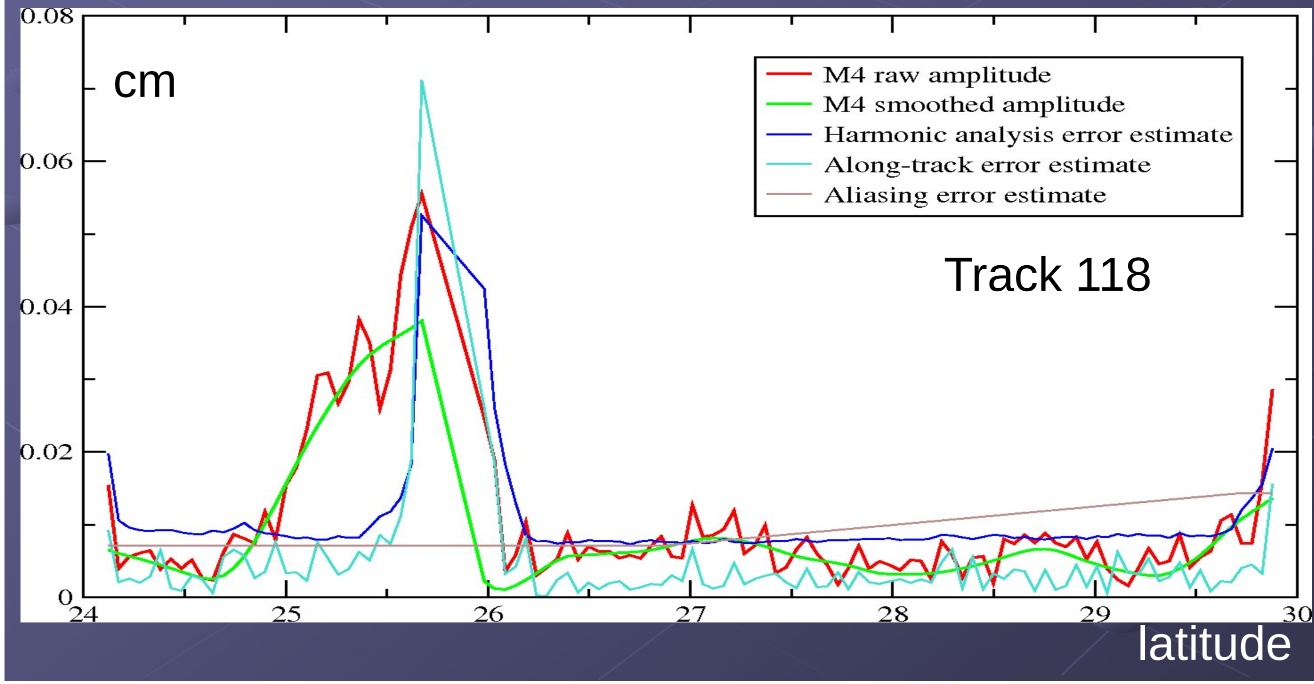
- **Large constituent (M_2):**
  - Large amplitude/noise ratio
  - Significant misfit reduction
  - Limited sensitivity to data error estimate
- **Minor constituents:**
  - O(1) amplitude/noise ratio
  - Limited misfit reduction
  - increased sensitivity to data error estimate

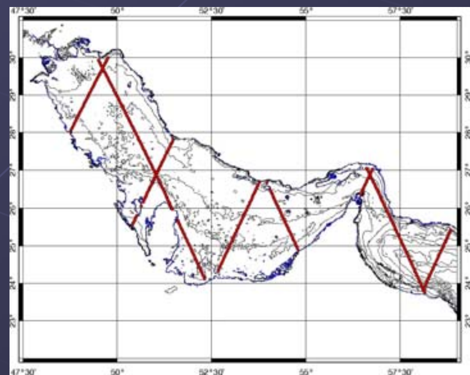


Reference Optimal

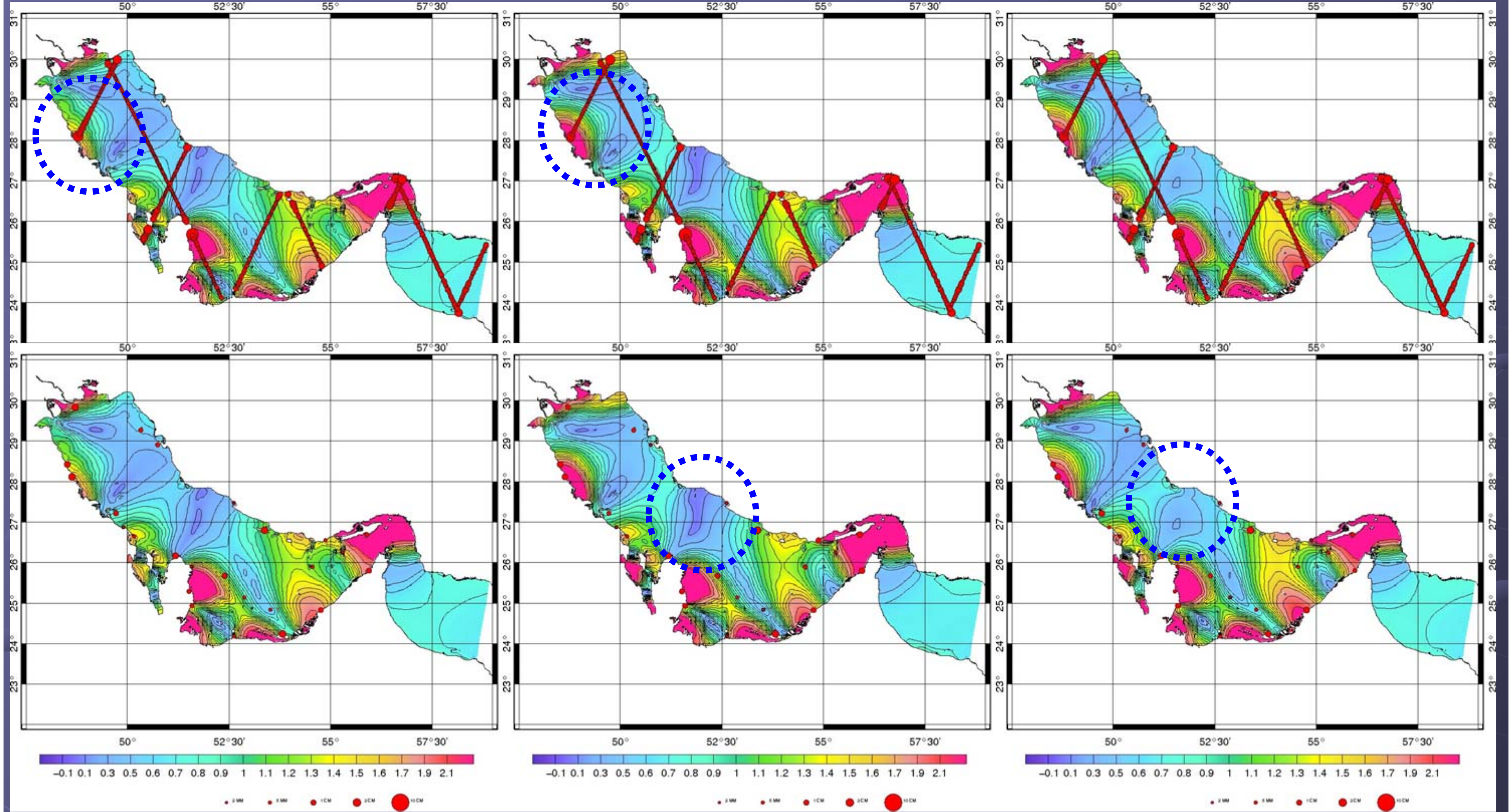
M_4 data error estimates







M_4 sensitivity to data error estimates



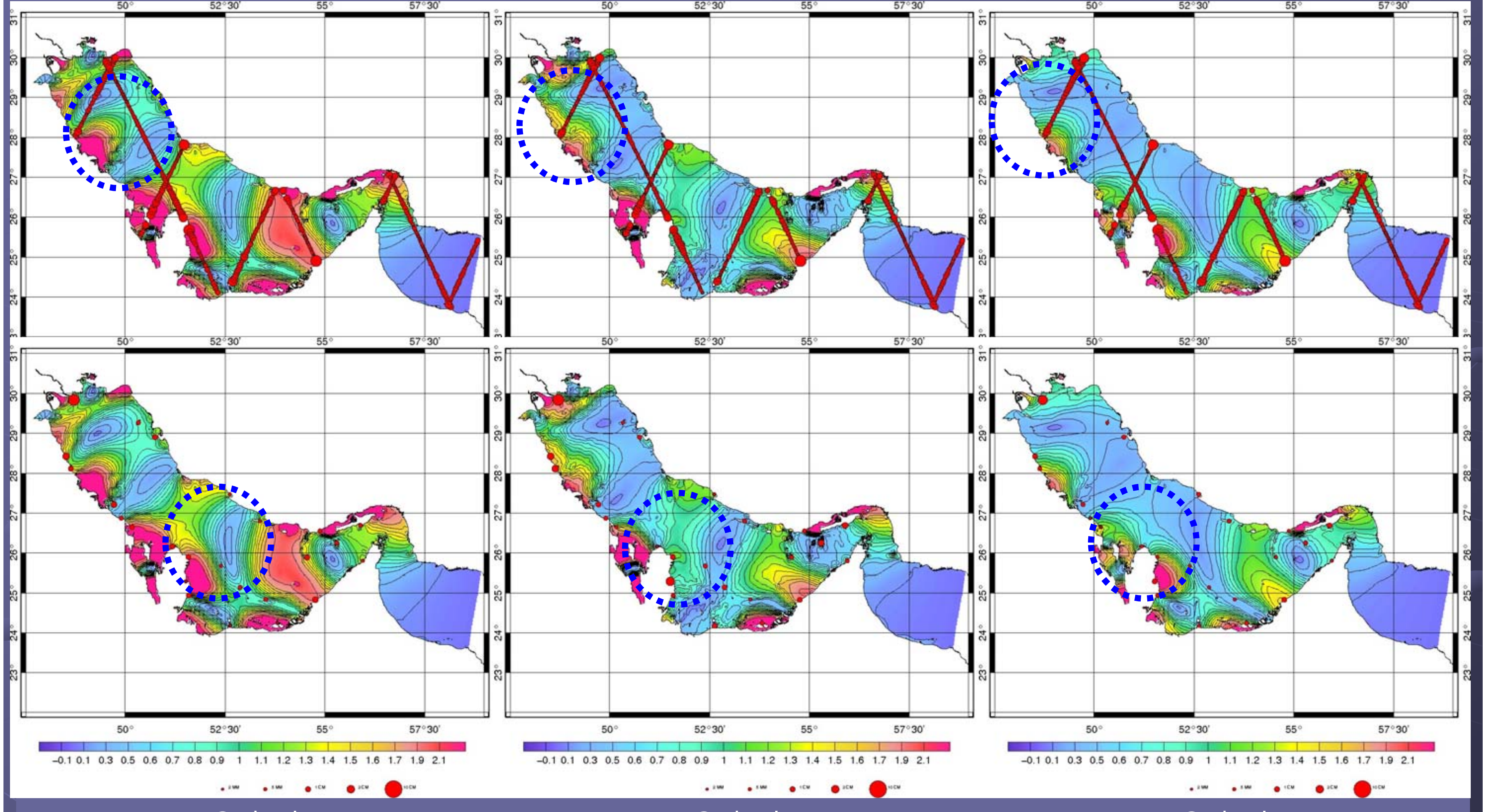
Optimal
(standard)
RMS = 9 mm

Optimal
(along-track error estimate)
RMS = 9

Optimal
(analysis error estimate)
RMS = 8

Reference RMS = 13 mm

MS_4 sensitivity to data error estimates



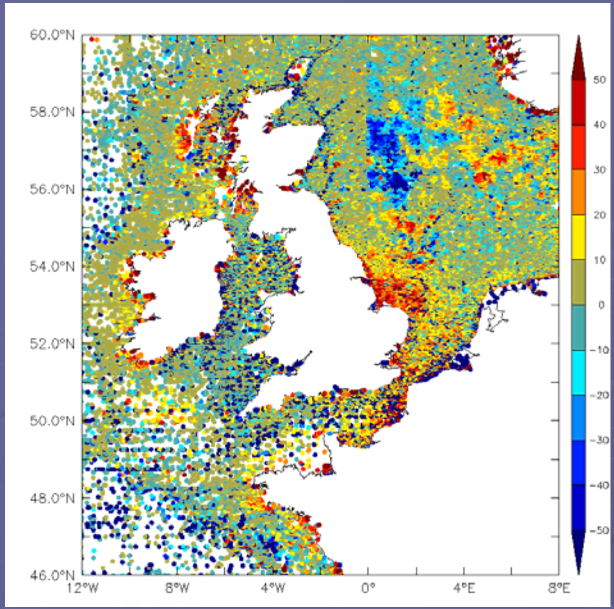
Optimal (standard) RMS = 11 mm	Optimal (along-track error estimate) RMS = 12	Optimal (analysis error estimate) RMS = 8

Reference RMS = 9 mm

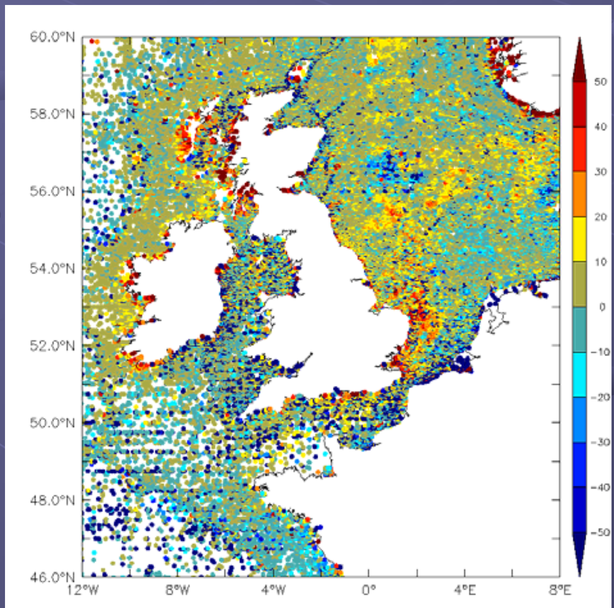
Hydrodynamic model accuracy

- **Only a limited number of constituents can be improved by assimilation from altimetry**
  - Major constituents: M_2,S_2,N_2,K_2,K_1,O_1,P_1,Q_1
  - Second rank astronomical constituents: $2N_2$,Mu_2,Nu_2,L_2,T_2+…
  - Major compound constituents: M_4,MS_4+…
- **Most of coastal spectrum directly derived from hydrodynamical modeling**
- **Accuracy of prior model remains a critical issue**
  - Bathymetry
  - Others…

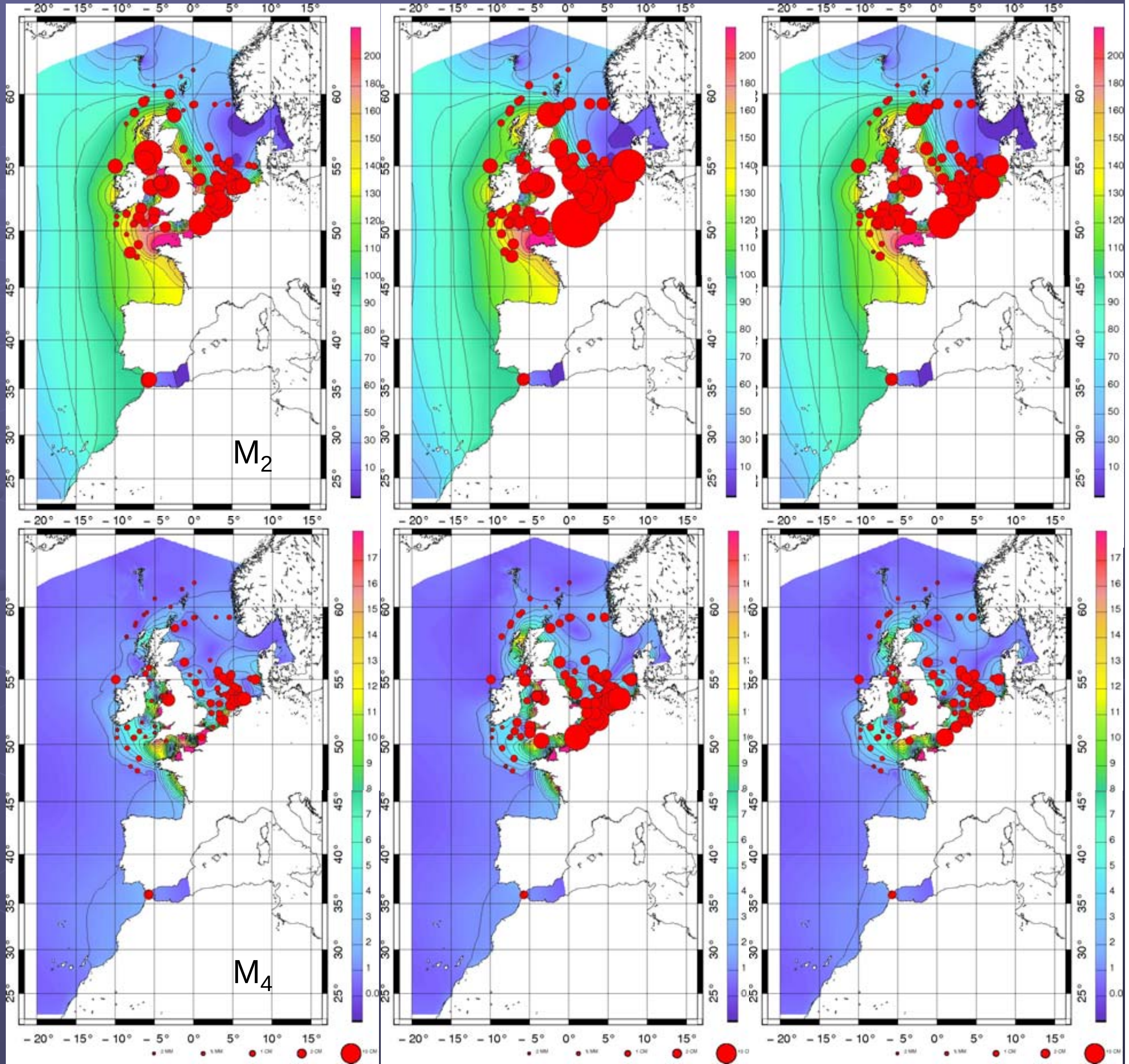
Bathymetry accuracy issue



Bathymetry Version-2009 versus XBTs depth

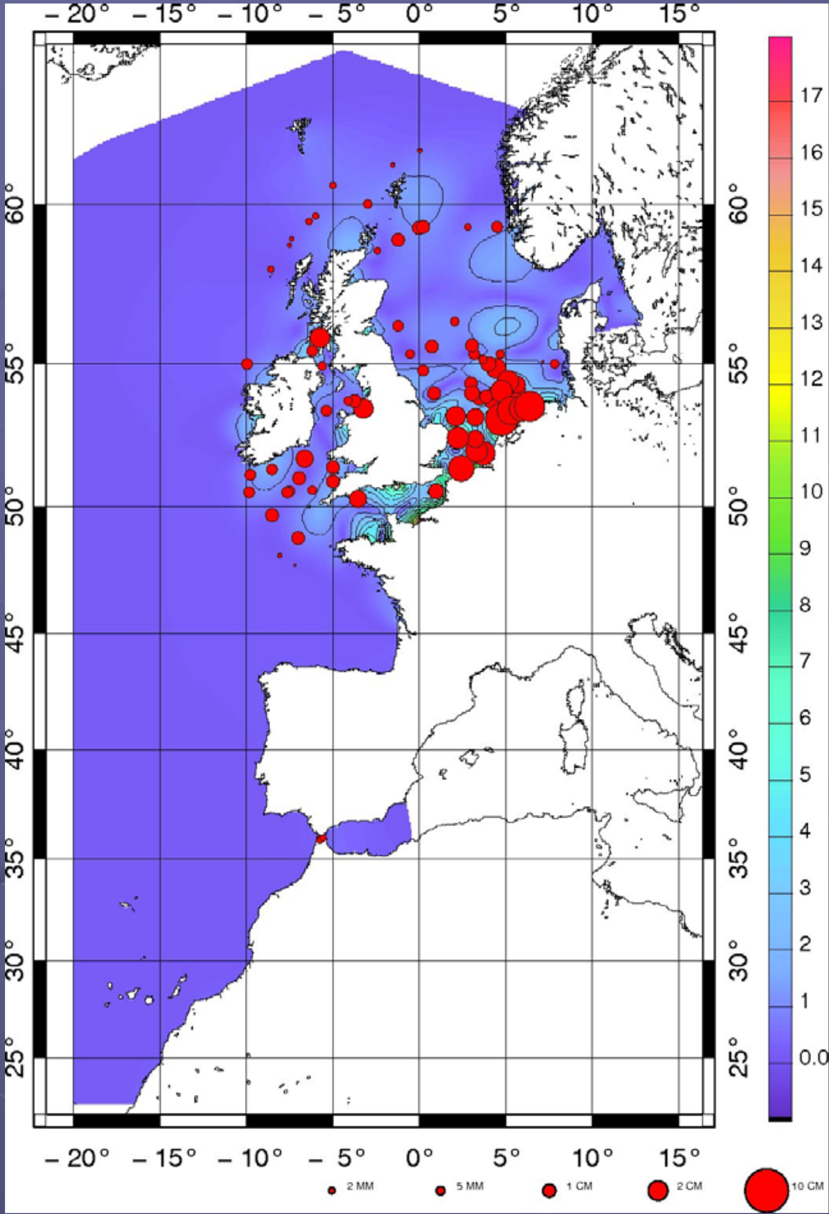


Bathymetry Version-2010 versus XBTs depth

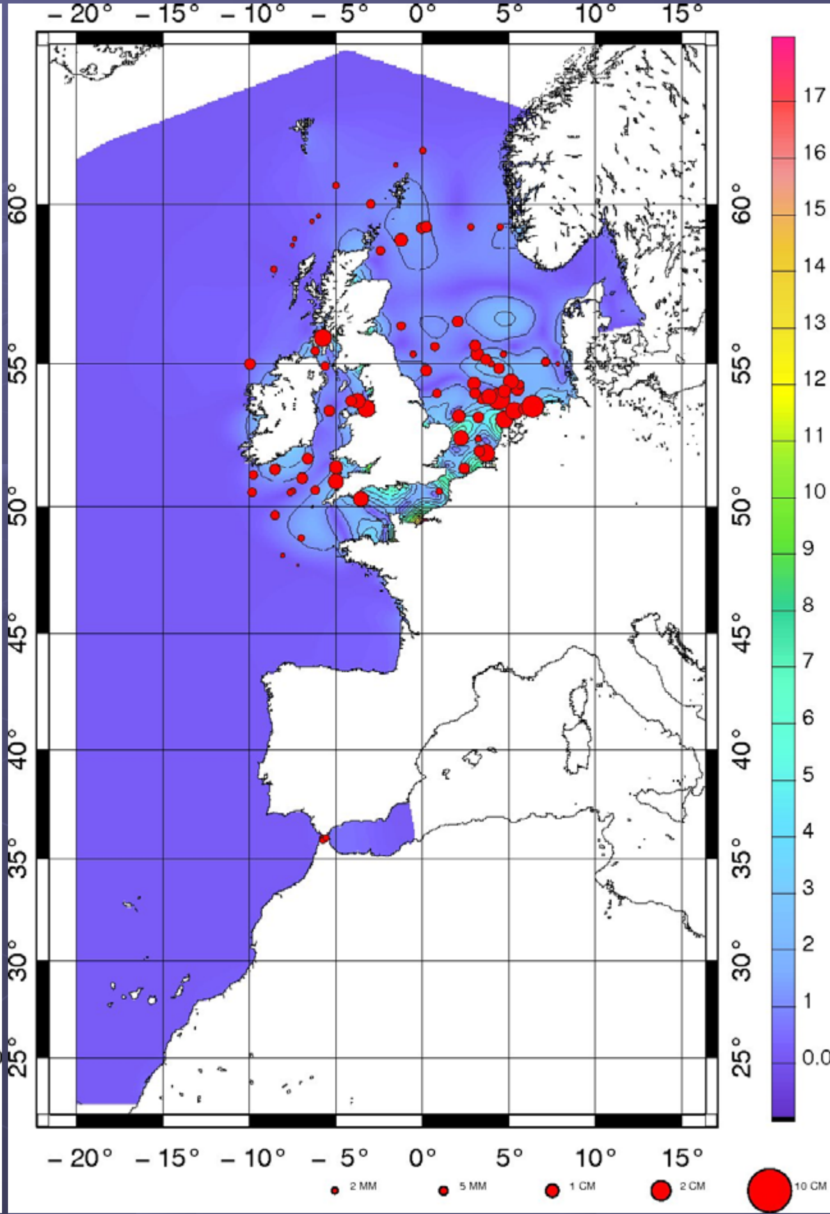


NEA-COMAPI (optimal)	NEA-COMAPI (hydrodynamic)	NEA-COMAPI (hydrodynamic)
Bathymetry Version-2009	*Bathymetry Version-2009*	*Bathymetry Version-2010*

M_6 hydrodynamic solution



NEA-Bathymetry Version-2009



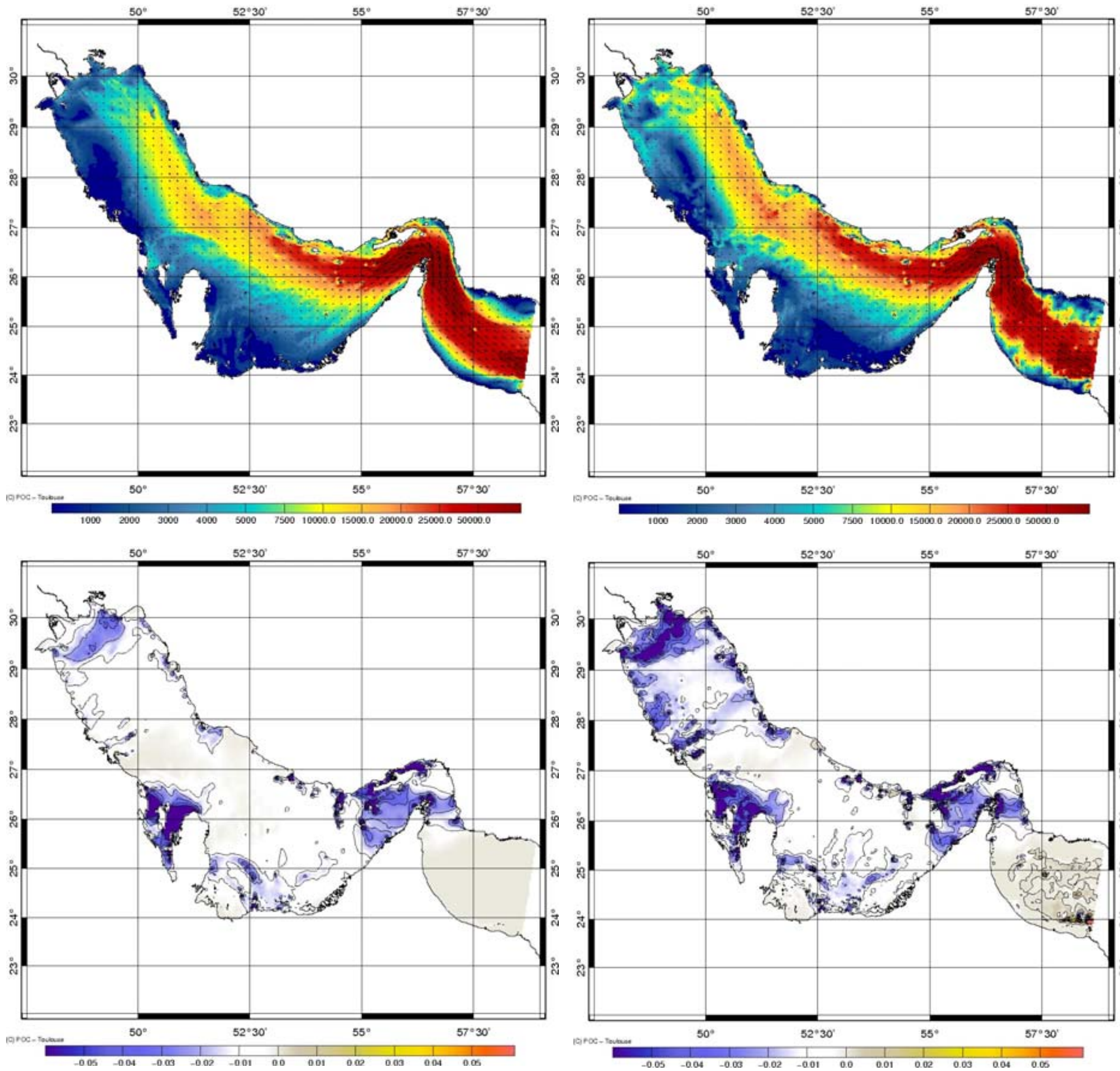
NEA-Bathymetry Version-2010

M_2 energy budget

Depth's error neglected

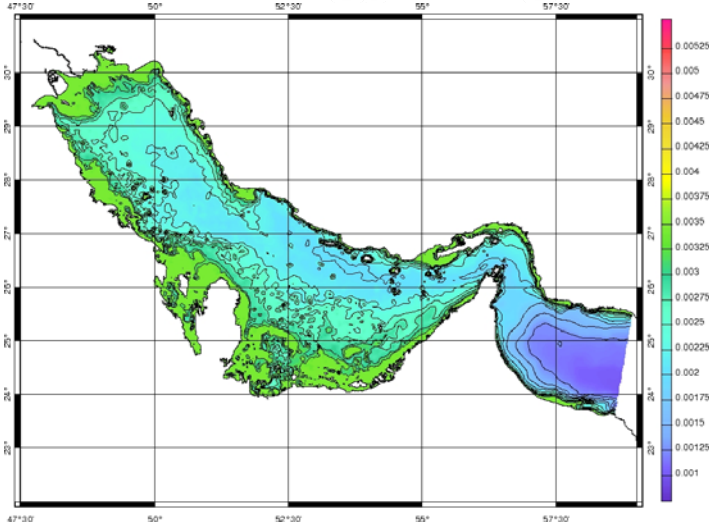
- **Energy fluxes ➔**
  w/m
- **Bottom friction RoW ➔**
  w/m²

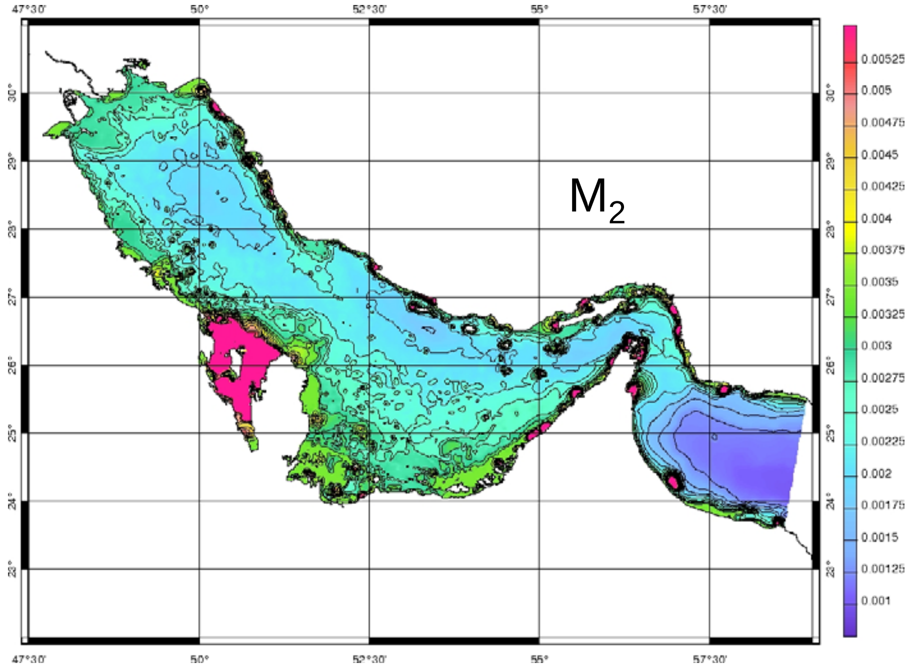
Hydrodynamic | Optimal

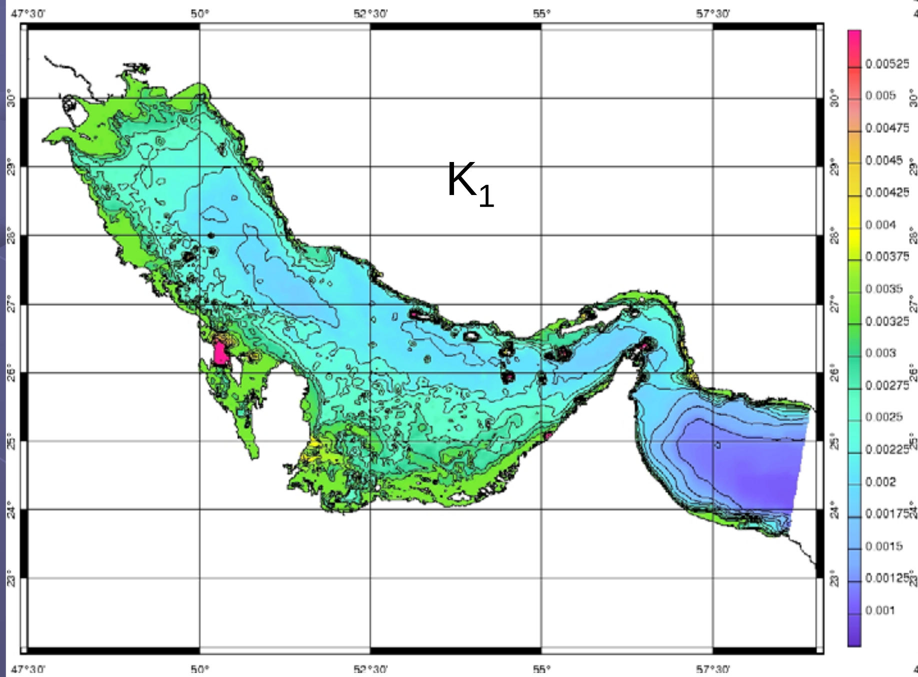


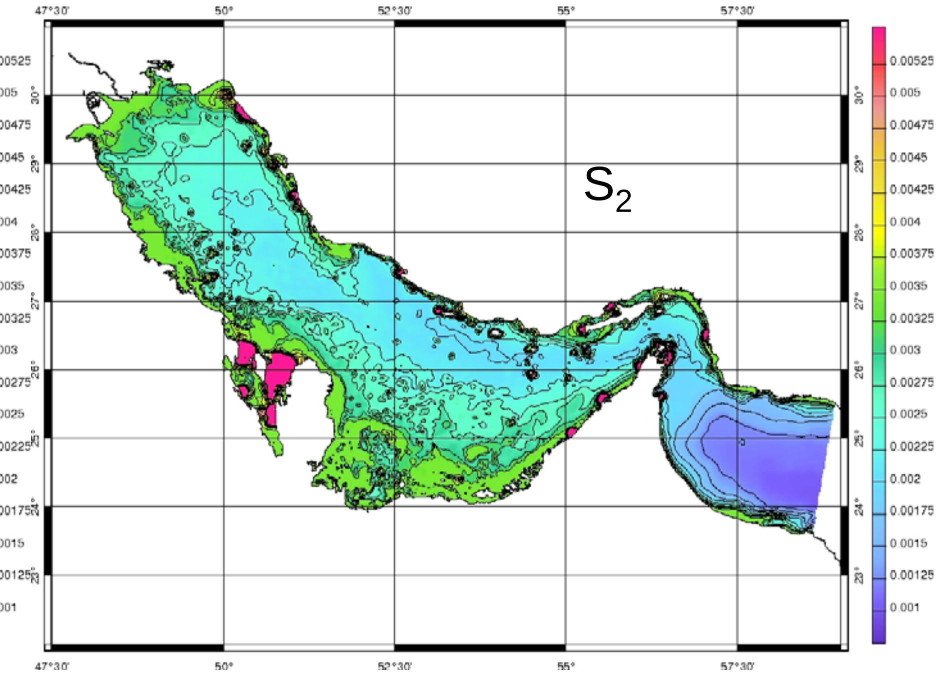
4.25 gW | 4.5 gW

Cd reconstruction from energy budget









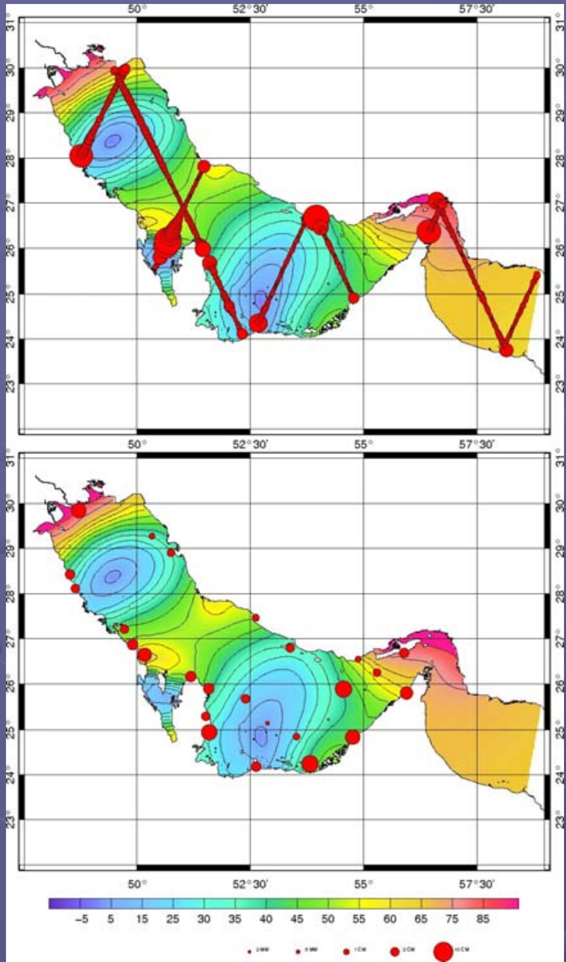
Conclusions

- Comprehensive coastal atlas validation is hard work
  - Numerous, small amplitude constituents, short wavelength
  - variance reduction in Envisat and GFO SLA would be useful
- Some efforts needed to more accurately derive data error estimates
  - Improve non-tidal signal contamination estimate (harmonic analysis, xovers misfits)
- Data pre-processing might be necessary
  - Internal tide signature filtering
  - Noise reduction
- Some Envisat and GFO data might be useful (MS_4)
- Assimilation:
  - Polychromatic assimilation seems necessary
  - Parameter identification would help for hydrodynamics model improvements
  - Iterative approach necessary to tune first guess model error description

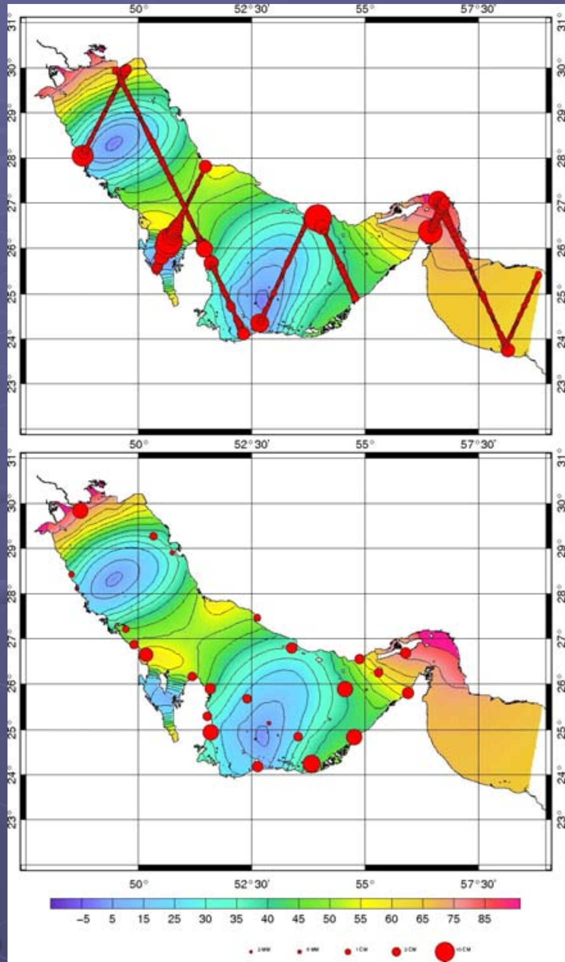
Regional modeling/assimilation platforms must be kept alive…

- Intermediate release can be produced at minor cost:
  - Data processing and error estimate improvements
  - Assimilation code evolution
- Ensemble reprocessing is a more heavy task:
  - Significant bathymetry improvements (full reprocessing)
  - Minor bathymetry improvements (membre's addition)
  - Tidal loading (membre's addition)
- Sequential (bi-annual?) atlas upgrade for coastal data processing

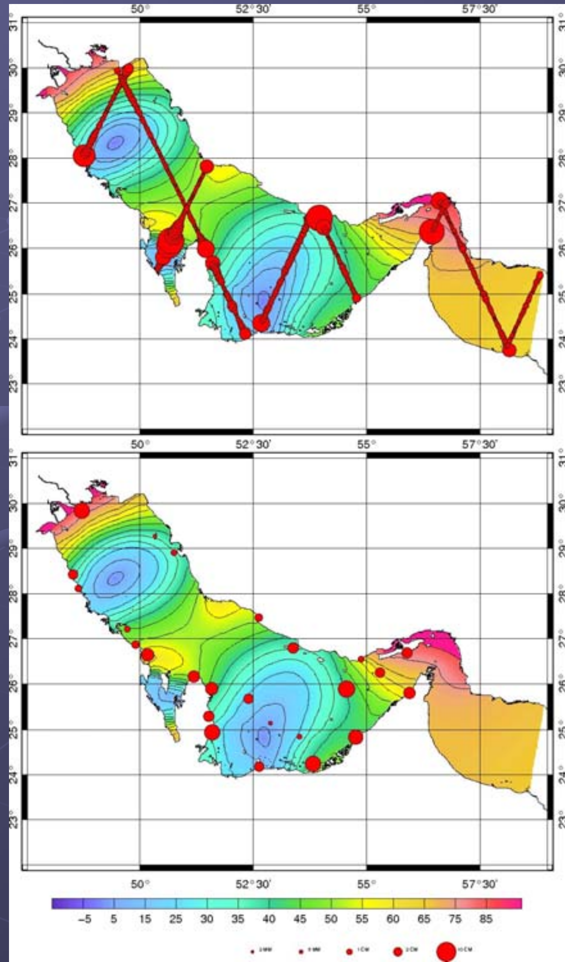
M_2 sensitivity to data error estimates



Optimal
(standard)
RMS = 36 mm



Optimal
(along-track error estimate)
RMS = 37



Optimal
(analysis error estimate)
RMS = 36

Reference RMS = 134 mm

Ensemble generation

- **Bathymetry :**
  - Collect various bathymetry database
  - Create/select a "most trusted" bathymetry
  - Generate perturbed bathymetry:

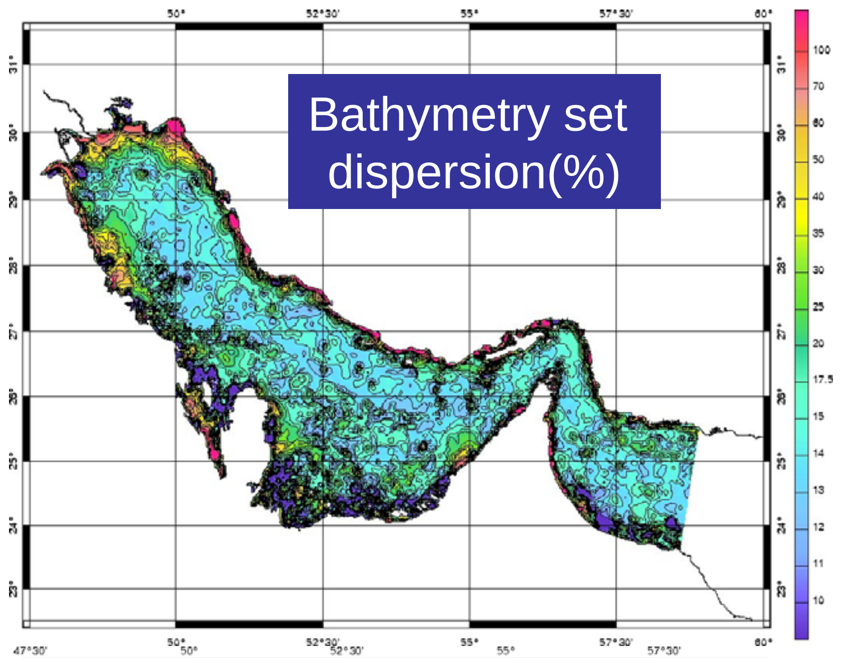
$$h_k = h_o + \sum_i \alpha_{i,k} h_i \quad \text{with} \quad \sum_i \alpha_{i,k} = 0$$

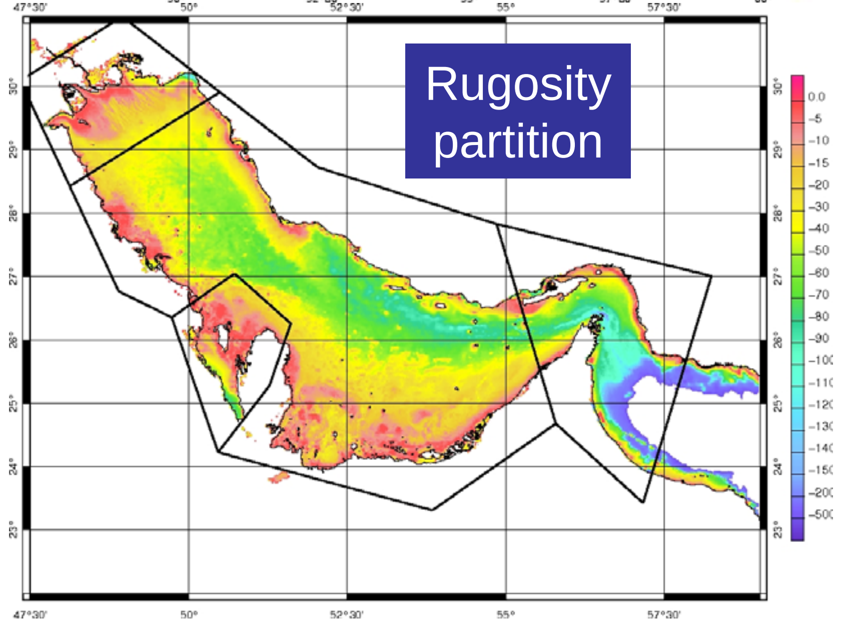
- **Open boundary conditions :**
  - Collect various tidal atlases
  - Create/select a "most trusted" atlas
  - Generate perturbed OBCs:

$$\tilde{\eta}_k = \eta_o + \sum_i \beta_{i,k} \eta_i \quad \text{with} \quad \sum_i \beta_{i,k} = 0$$

- **Bottom rugosity**
  - Identify significant bottom friction regions
  - Create a partition (using polygons)
  - Generate perturbed rugosity by varying rugosity value in each region

- **Internal tide drag**
  - Identify significant internal drag regions
  - Create a partition (using polygons)
  - Generate perturbed rugosityby varying rugosity value in each region





K_1 energy budget

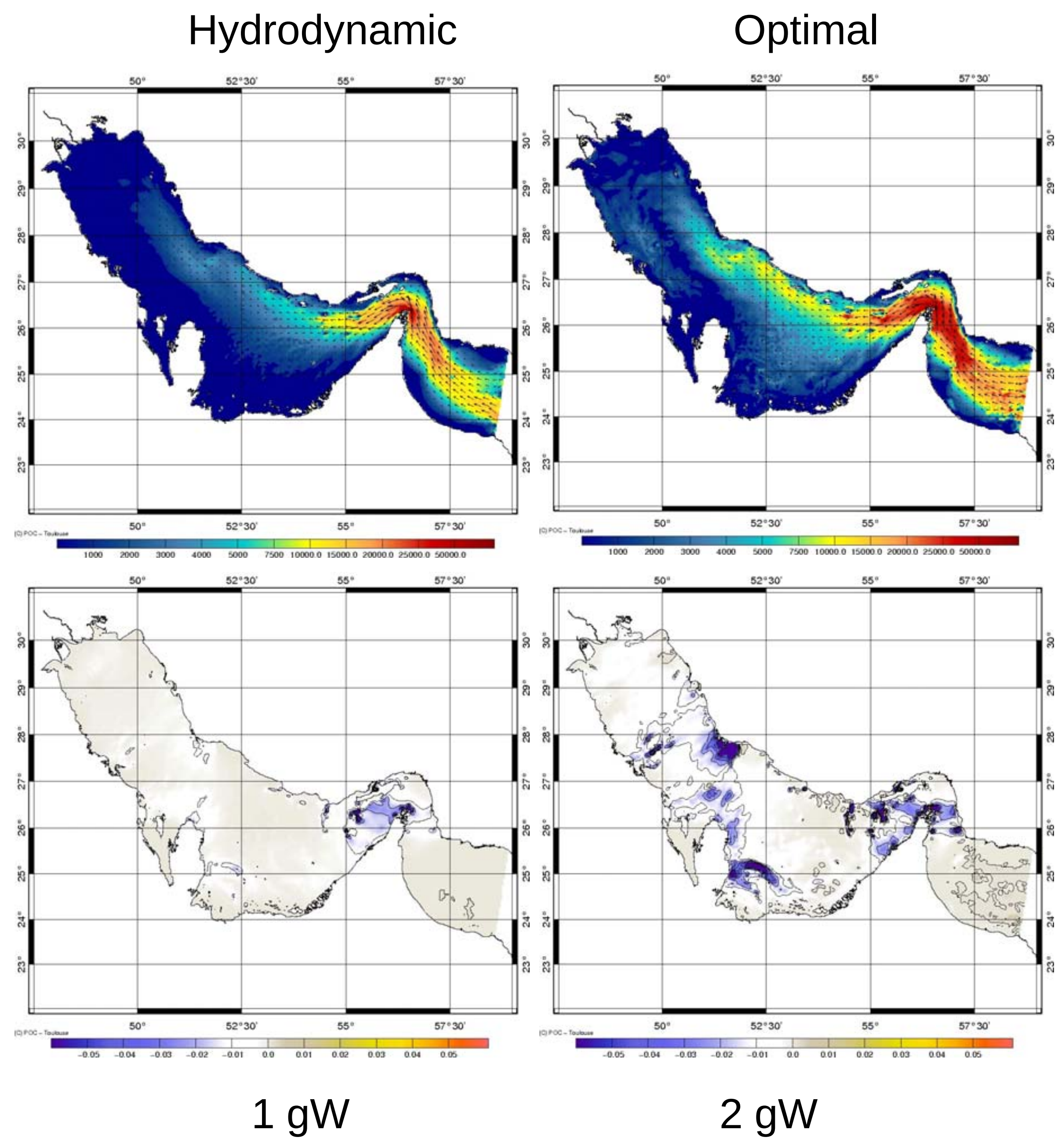
Depth's error neglected

- **Energy fluxes ➔**

  w/m

- **Bottom friction RoW ➔**

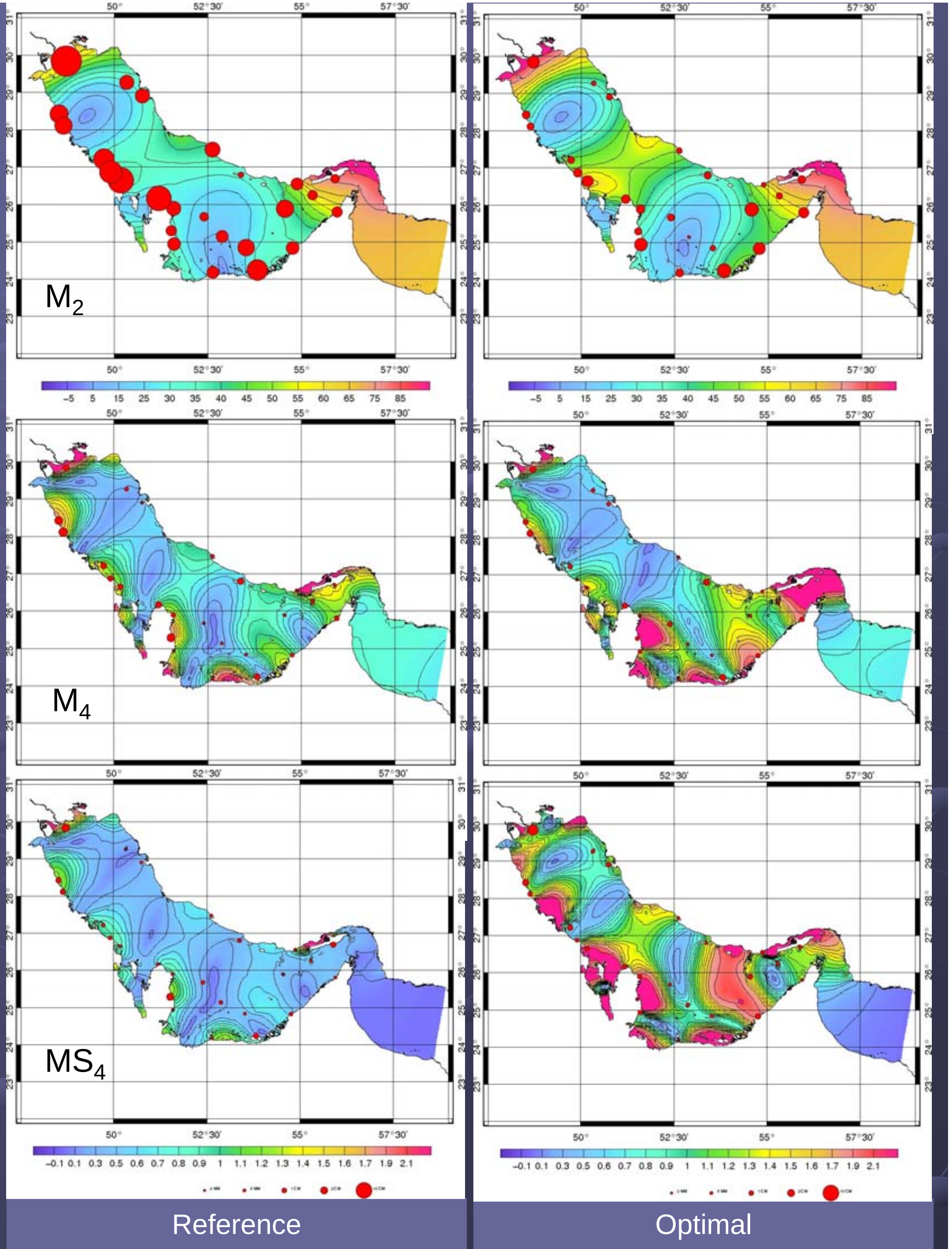
  w/m²



Data assimilation

comparison of prior and posterior misfits

Tide gauges



M_2 altimetry data assimilation