Filtrácia dát na povrchu Zeme a na orbitách družicových misií

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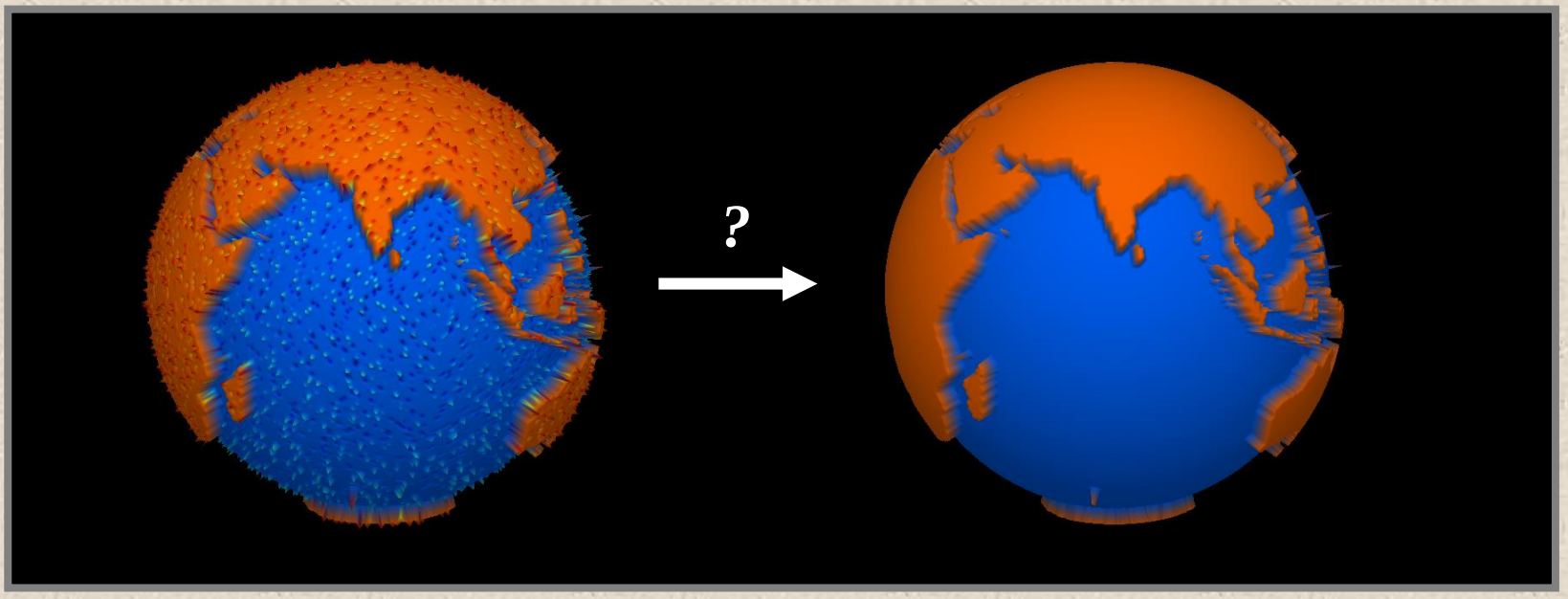


Obsah

- **Motivácia**
- **Difúzna filtrácia na uzavretých plochách**
  (napr. na guli, elipsoide alebo na zemskom povrchu)
- **Testovací príklad**
- **Filtrovanie priamych meraní družicovej misie GOCE**
- **Filtrovanie dynamickej topografie oceánov**

Motivácia

- *množstvo družicových misií monitorujúcich našu planétu*

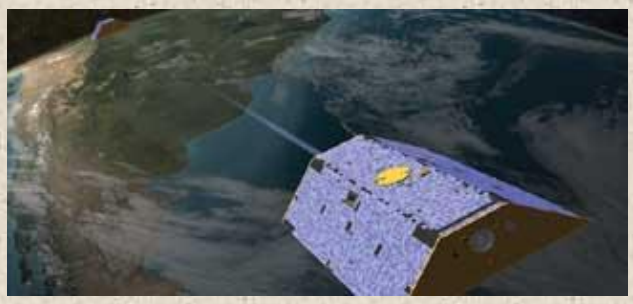
⇒ **merania sú ovplyvnené šumom**

Dôvody: - *prechod signálu atmosférou (troposférou a ionosférou)*
- *nepresnosť polohy a orientácie družicovej misie*
- *chyby samotného meracieho zariadenia*

Tiažové pole zeme a jeho časové variácie

CHAMP **(2000-2010)**

GRACE **(2002-now)**



GOCE **(2009-2013)**

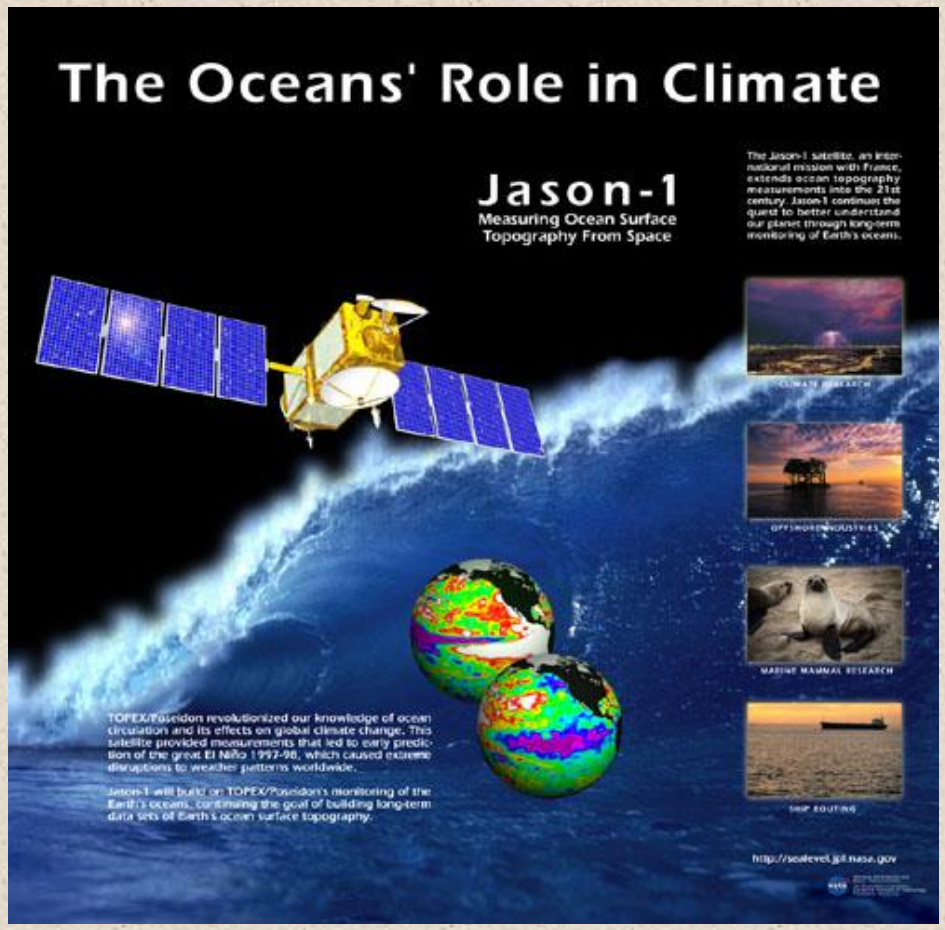
Družicová altimetria – variácia hladiny oceánov

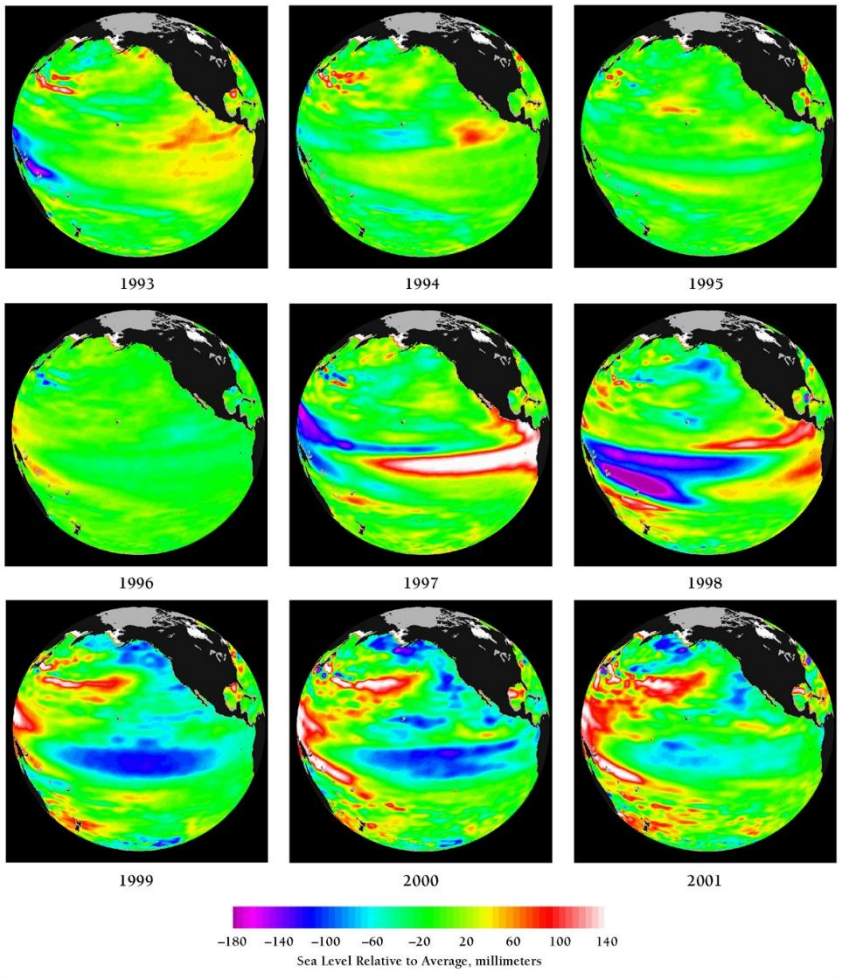
- **Seasat** (1978), **Geosat** (1985), **TOPEX-Poseidon** (1992-2006)
- **ERS-2, Jason-1, ENVISAT, Jason-2, ...**

Motivácia

Vplyv oceánov na klímu

Vplyv filtrácie dát na interpretáciu výsledkov





Difúzna filtrácia dát na uzavretých plochách

- ***filtrovanie šumu v dátach*** ***sa dá realizovať aj pomocou riešenia tzv. rovnice vedenia tepla***

⇒ často sa používa v spracovaní obrazu (image processing)

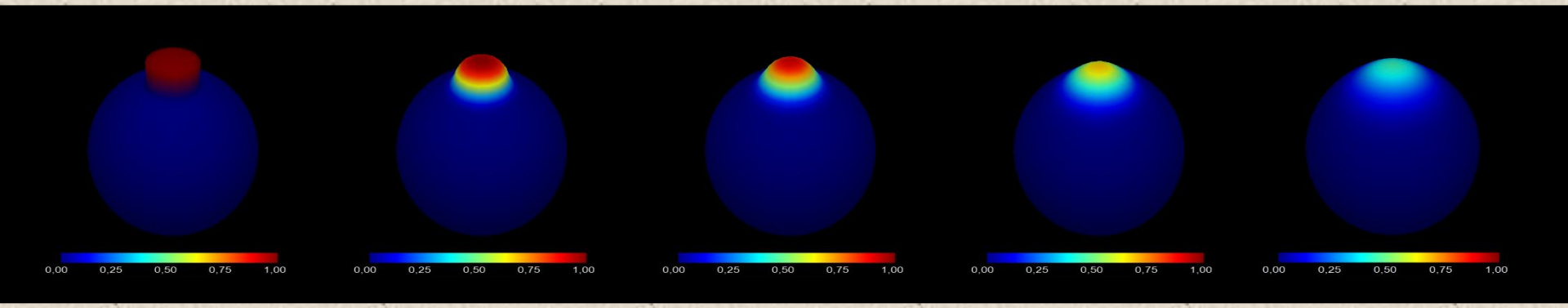
Rovnica vedenia tepla na ploche

$$\frac{\partial u(x,t)}{\partial t} - \Delta_S u(x,t) = 0$$

Δ_S ***- the Lapace–Beltrami operator (druhé derivácie)***

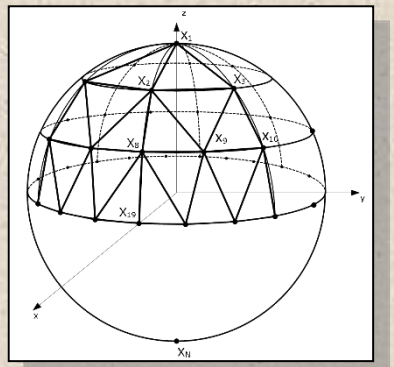
$u(x,t)$ ***– skalárna funkcia daná na ploche***

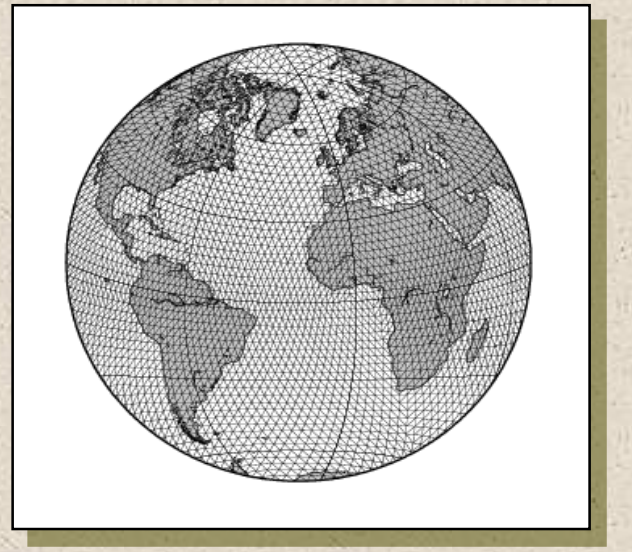
- ***vstupné zašumené dáta ako počiatočná podmienka:*** $u(x,0) = u_o(x)$



Numerické riešenie metódou konečných objemov

Triangulácia uzavretej plochy

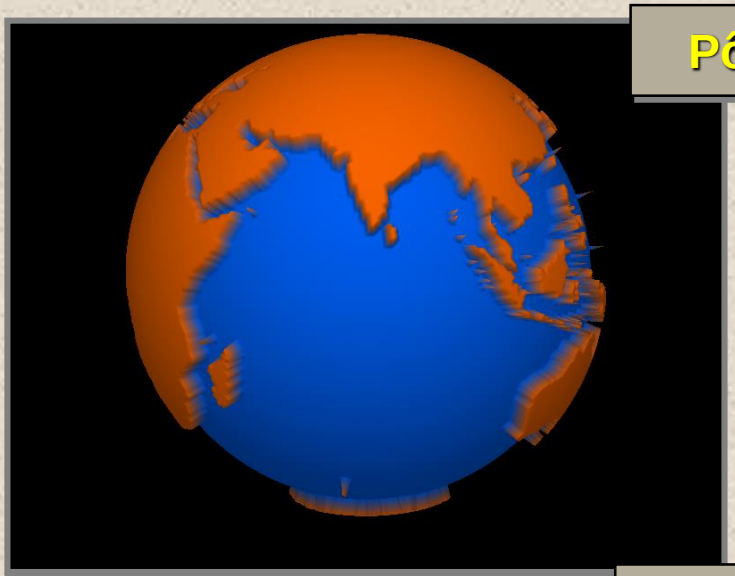




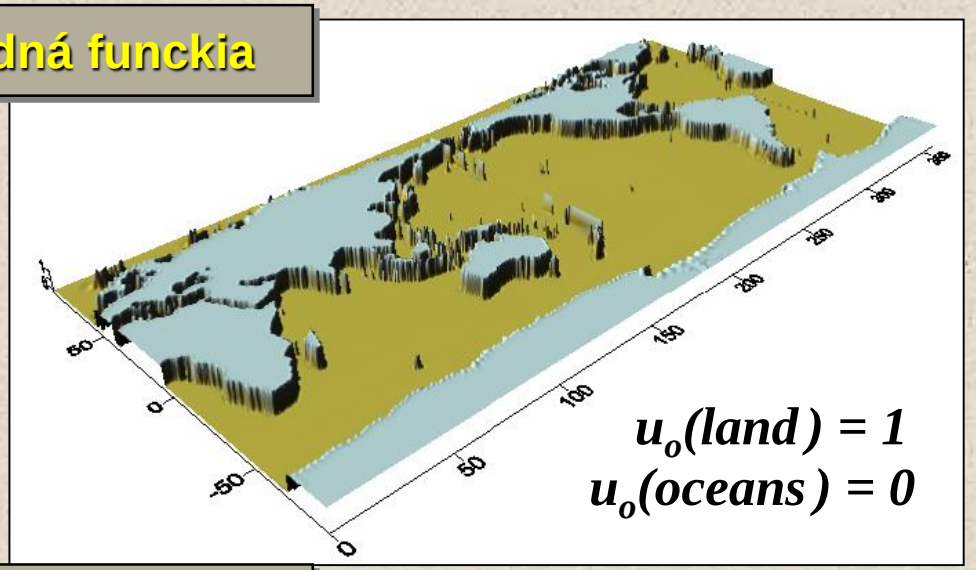
Riešenie systému lineárnych rovníc

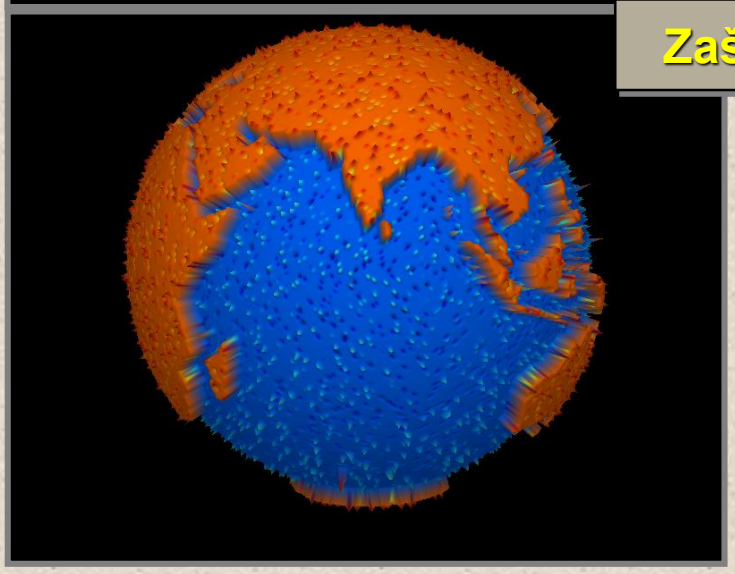
- *lineárna difúzia* ⇒ *riešenia rovnice vedenia tepla (zhladzuje aj dôležité prvky)*
- *nelineárna difúzia* ⇒ *riešenia modifikovanej rovnice vedenia tepla (umožňuje zachovávať dôležité prvky)*

Testovací príklad

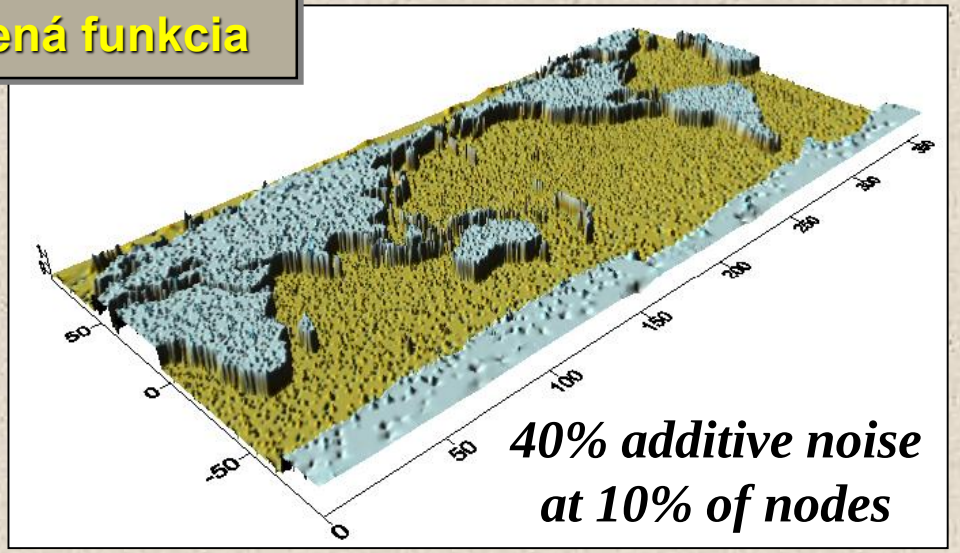


Pôvodná funckia



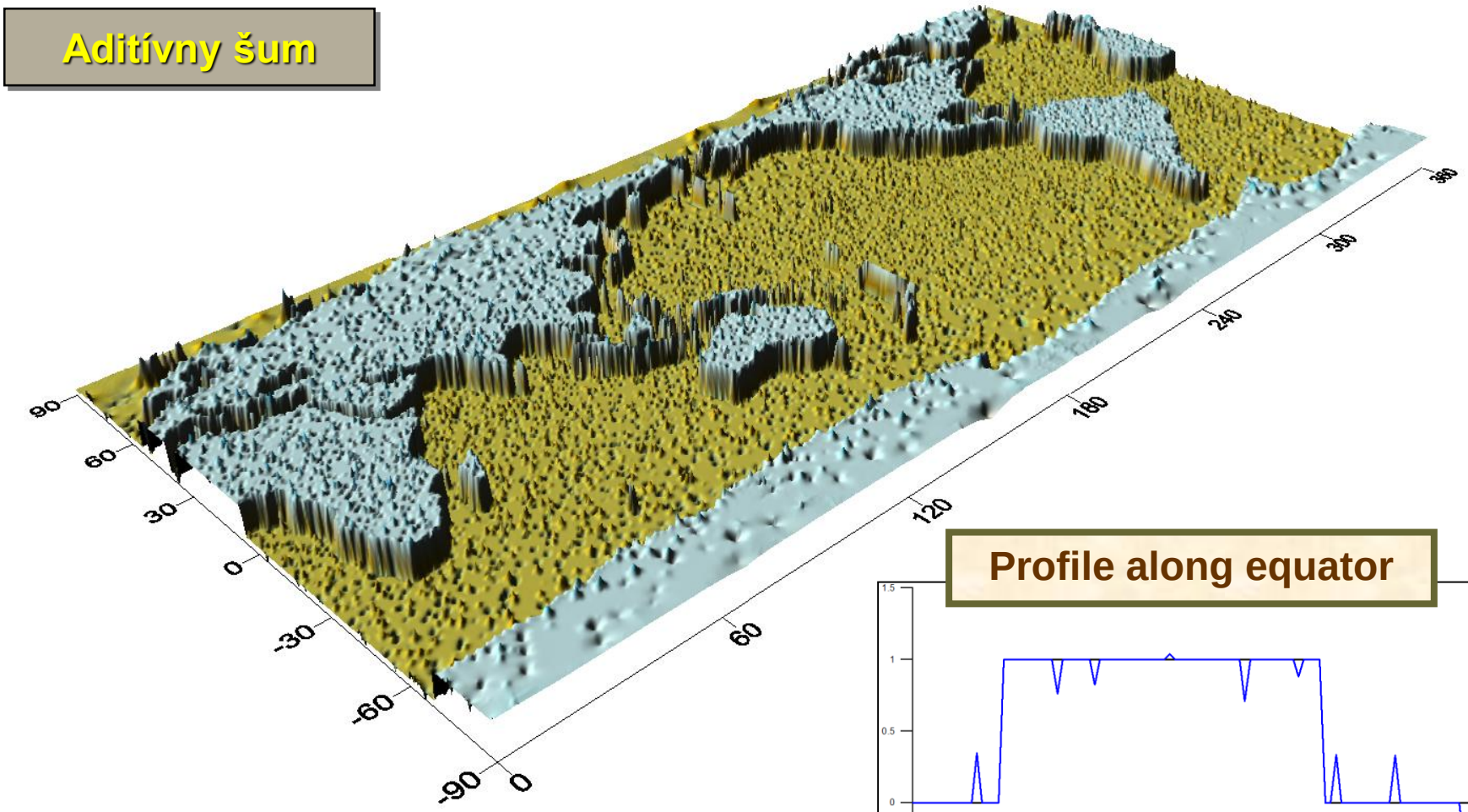


Zašumená funkcia

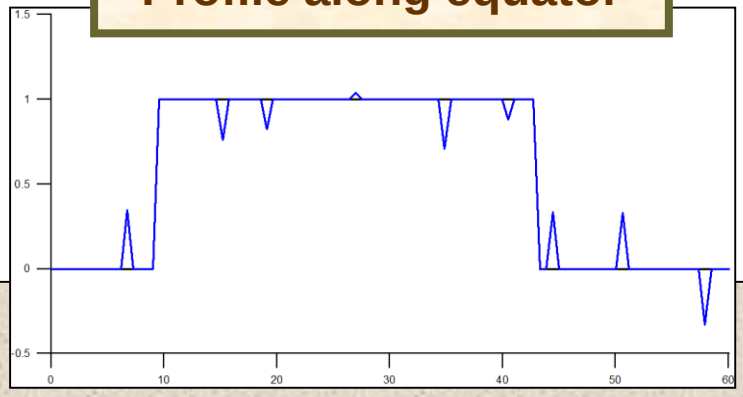


Lineárna difúzia – vstupné dáta

Aditívny šum

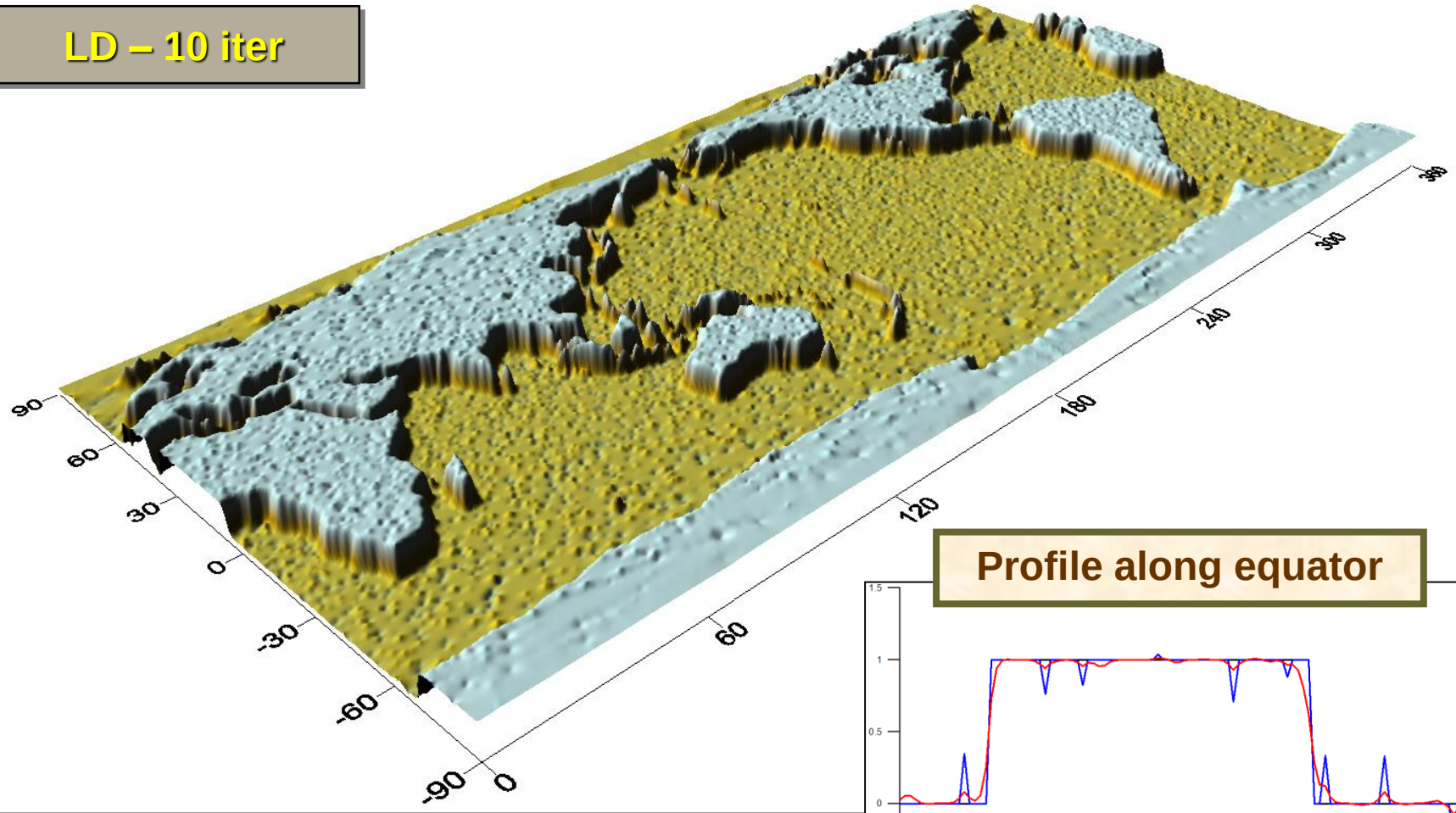


Profile along equator

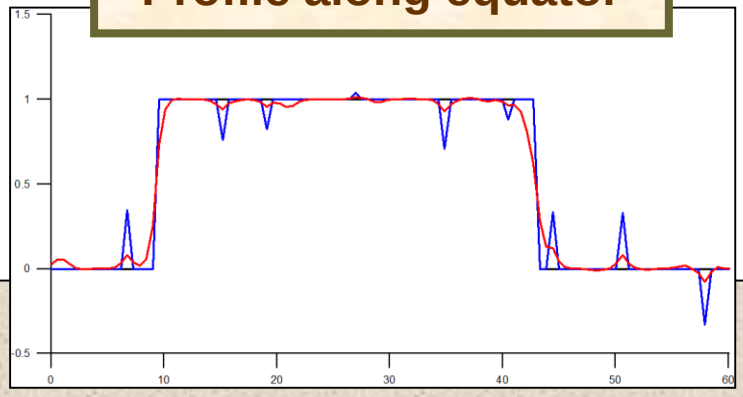


Linear diffusion – 10 iterations

LD – 10 iter

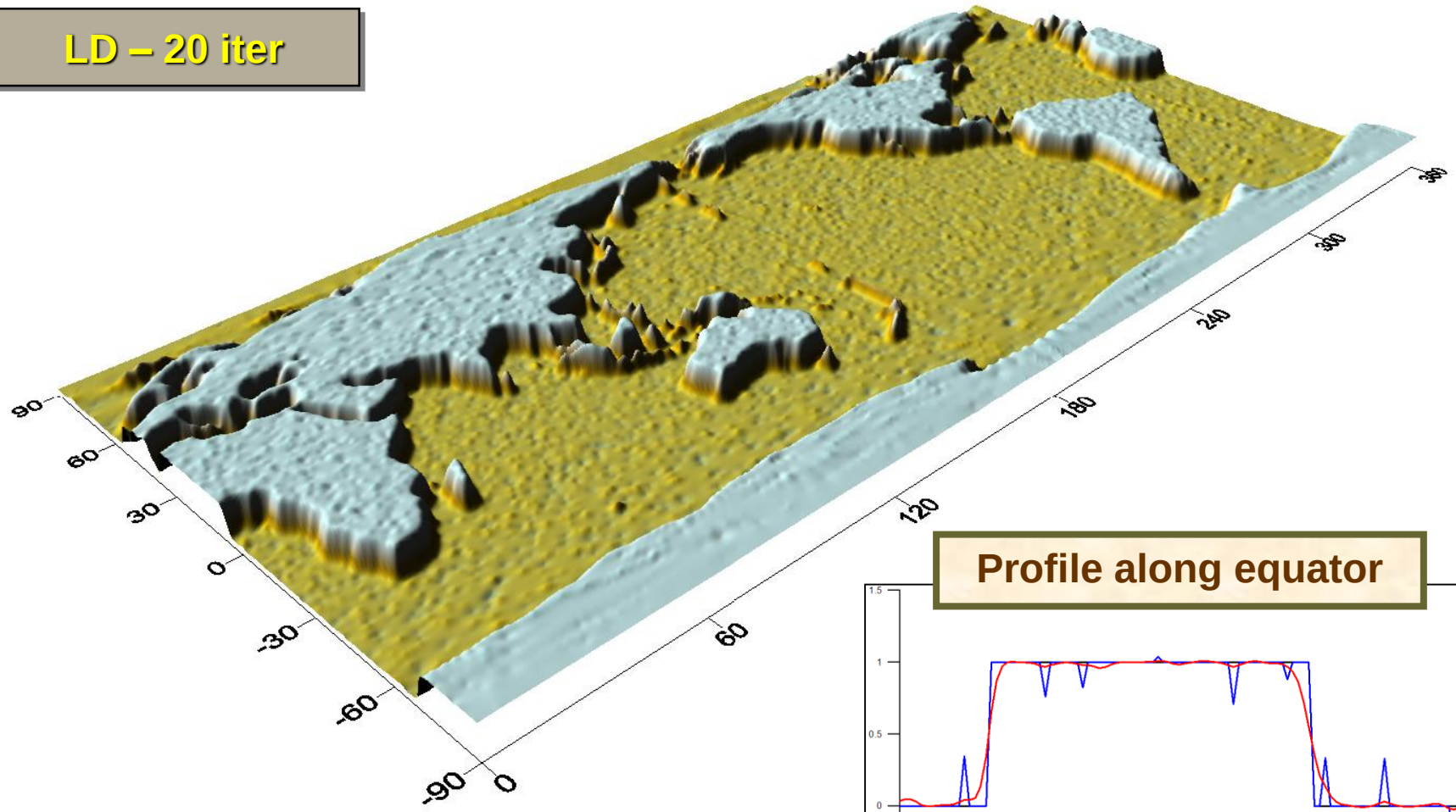


Profile along equator

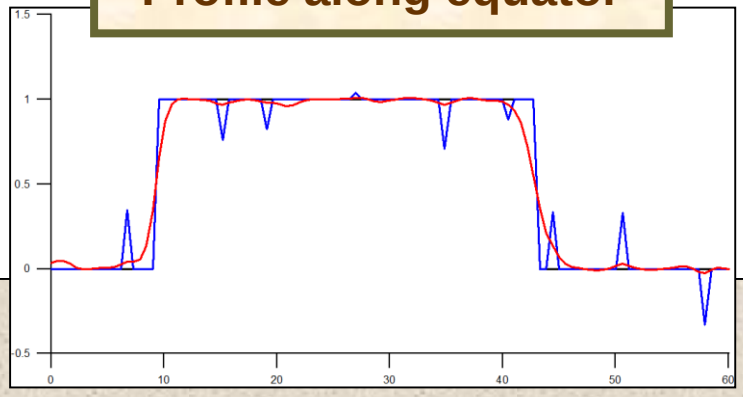


Linear diffusion – 20 iterations

LD – 20 iter

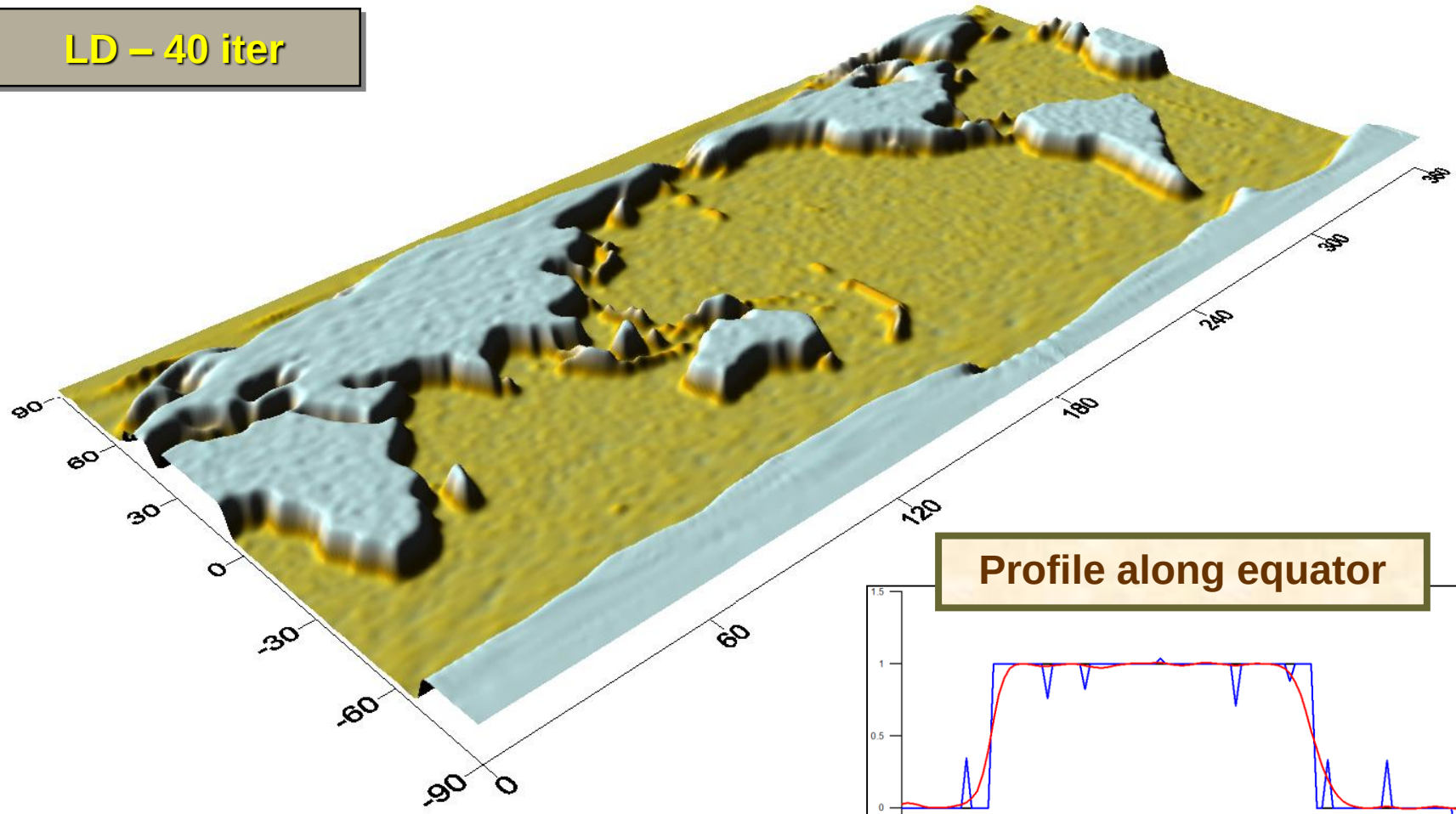


Profile along equator

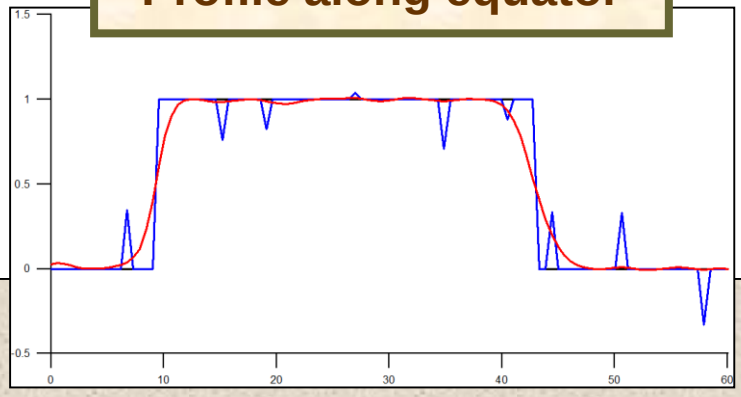


Linear diffusion – 40 iterations

LD – 40 iter

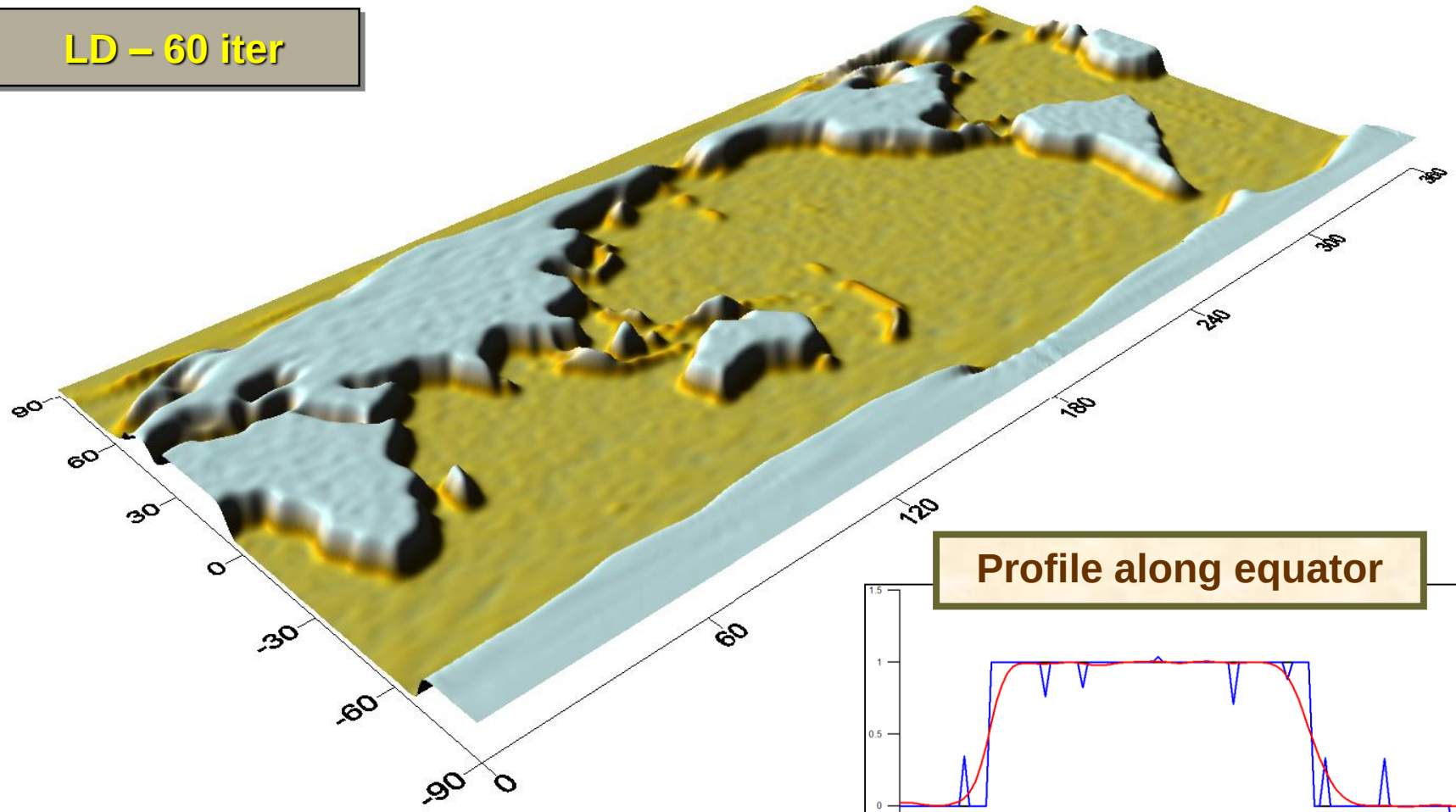


Profile along equator

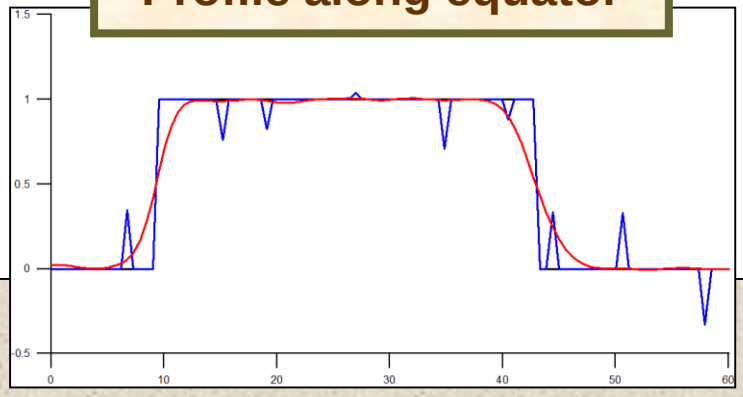


Linear diffusion – 60 iterations

LD – 60 iter

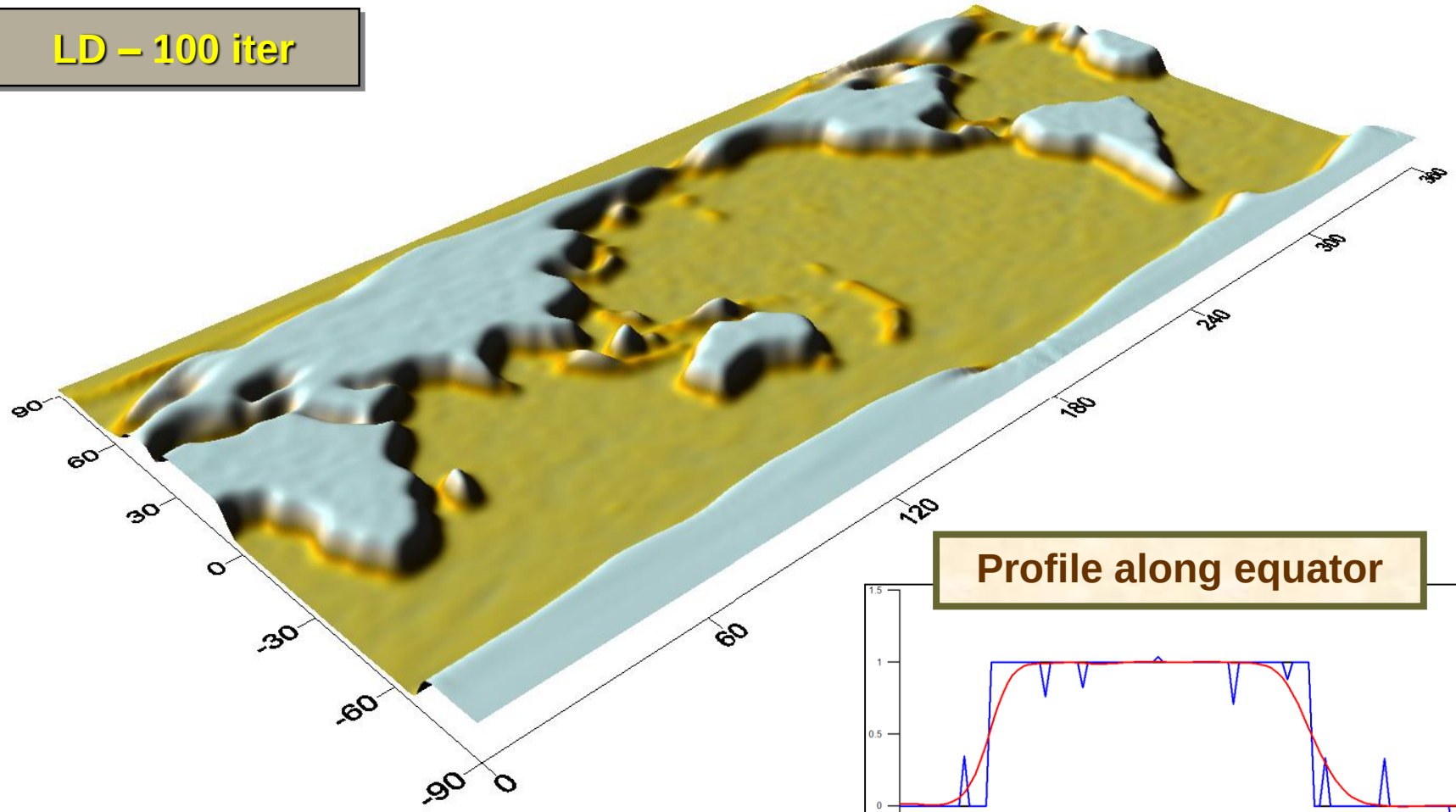


Profile along equator

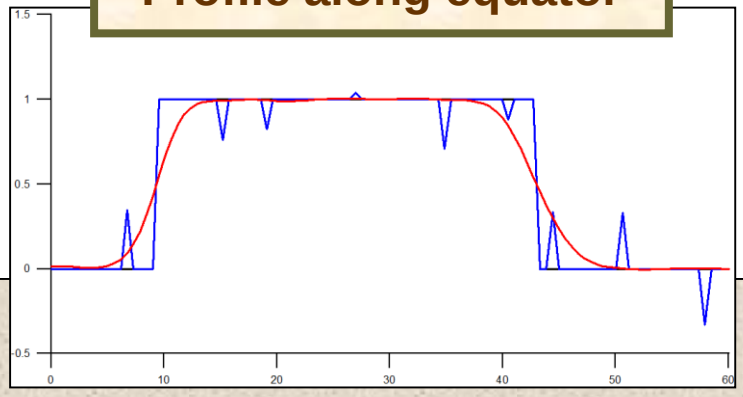


Linear diffusion – 100 iterations

LD – 100 iter



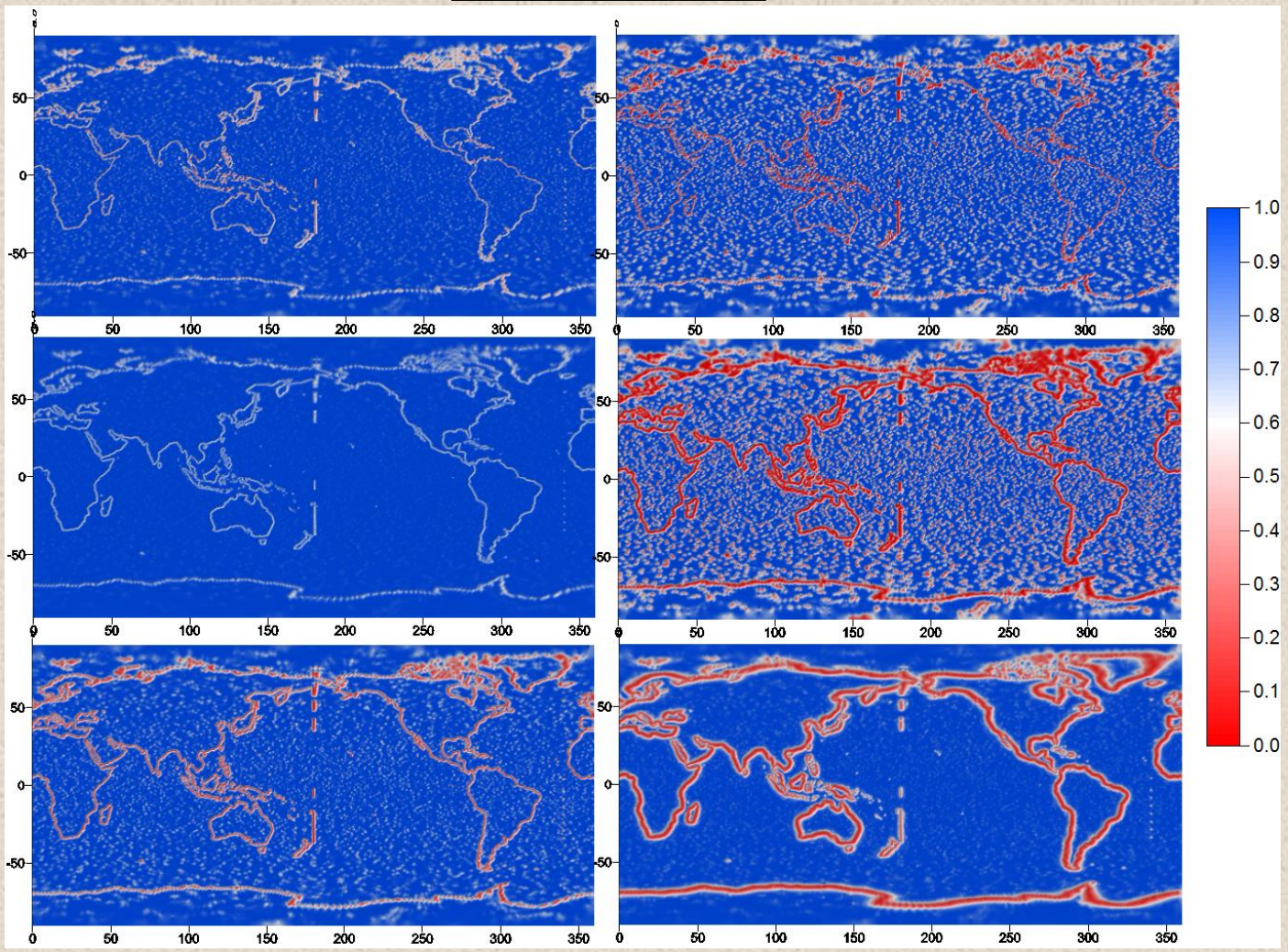
Profile along equator



Nelinárna difúzia – hranový detektor

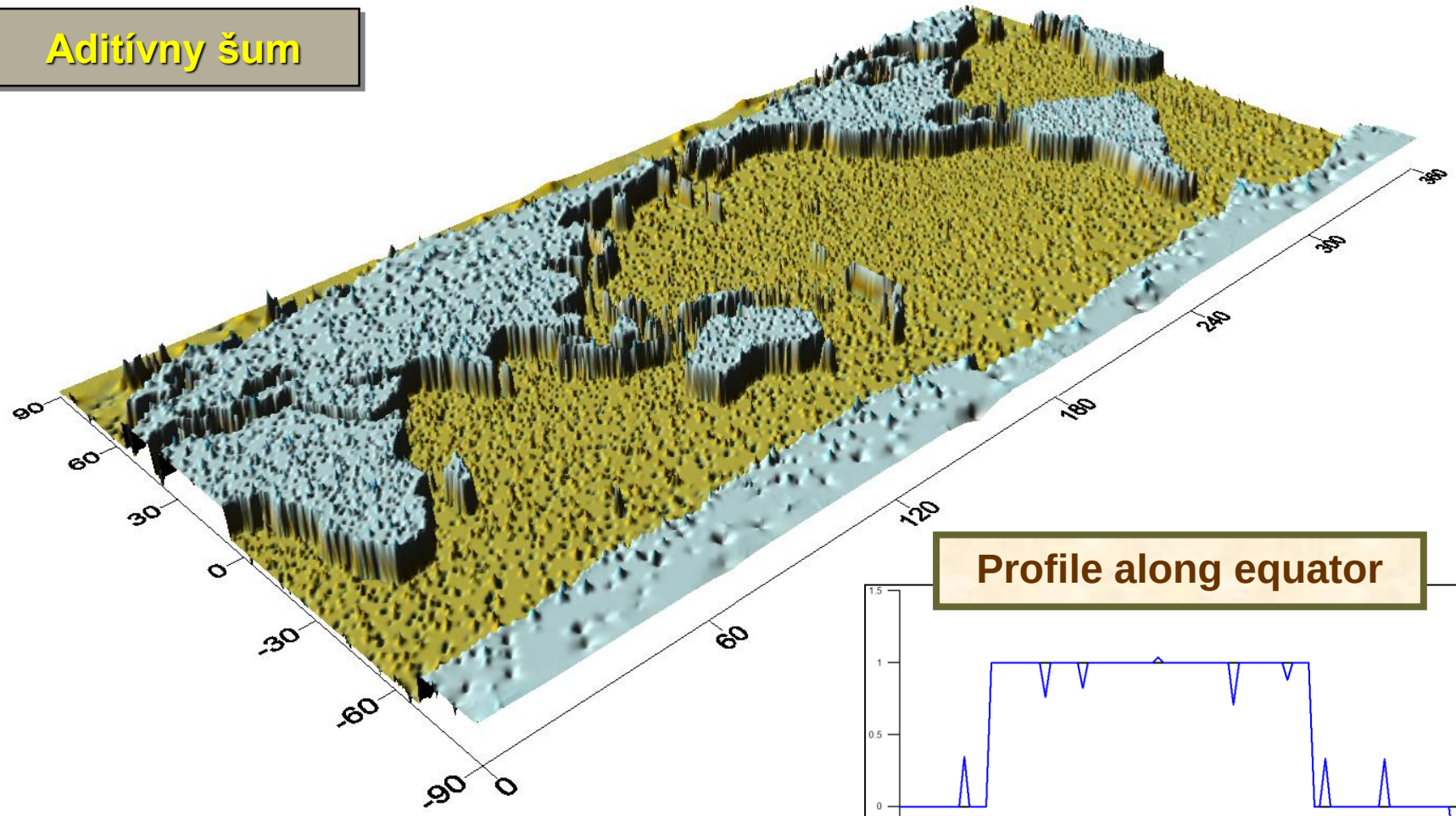
Hranový detektor

$$g(\nu) = \frac{1}{1 + H\left|\nabla_S u^{\sigma}\right|^2}$$

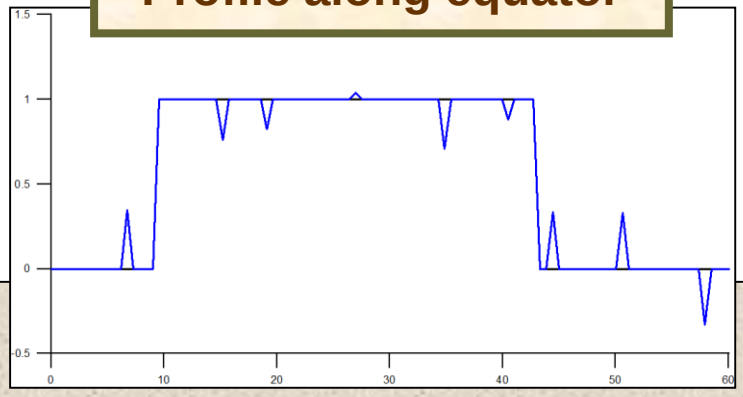


Nelineárna difúzia – vstupné dáta

Aditívny šum

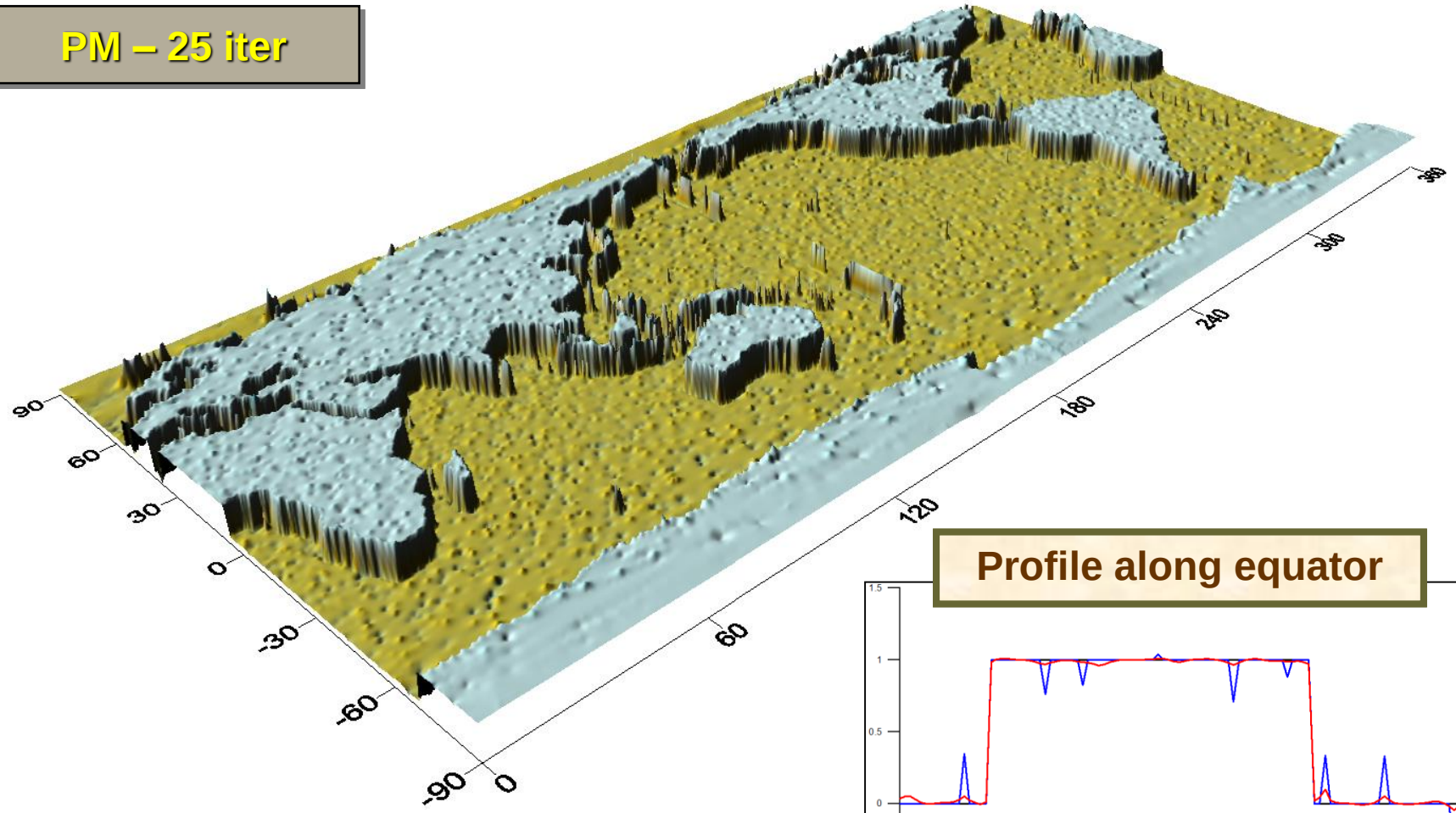


Profile along equator

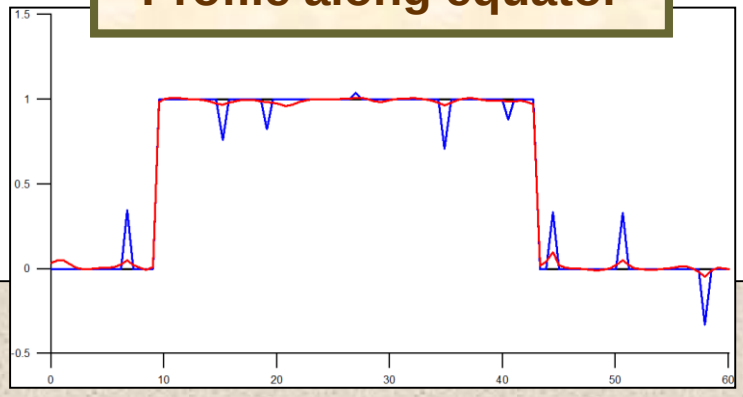


Nonlinear diffusion – 25 iterations

PM – 25 iter

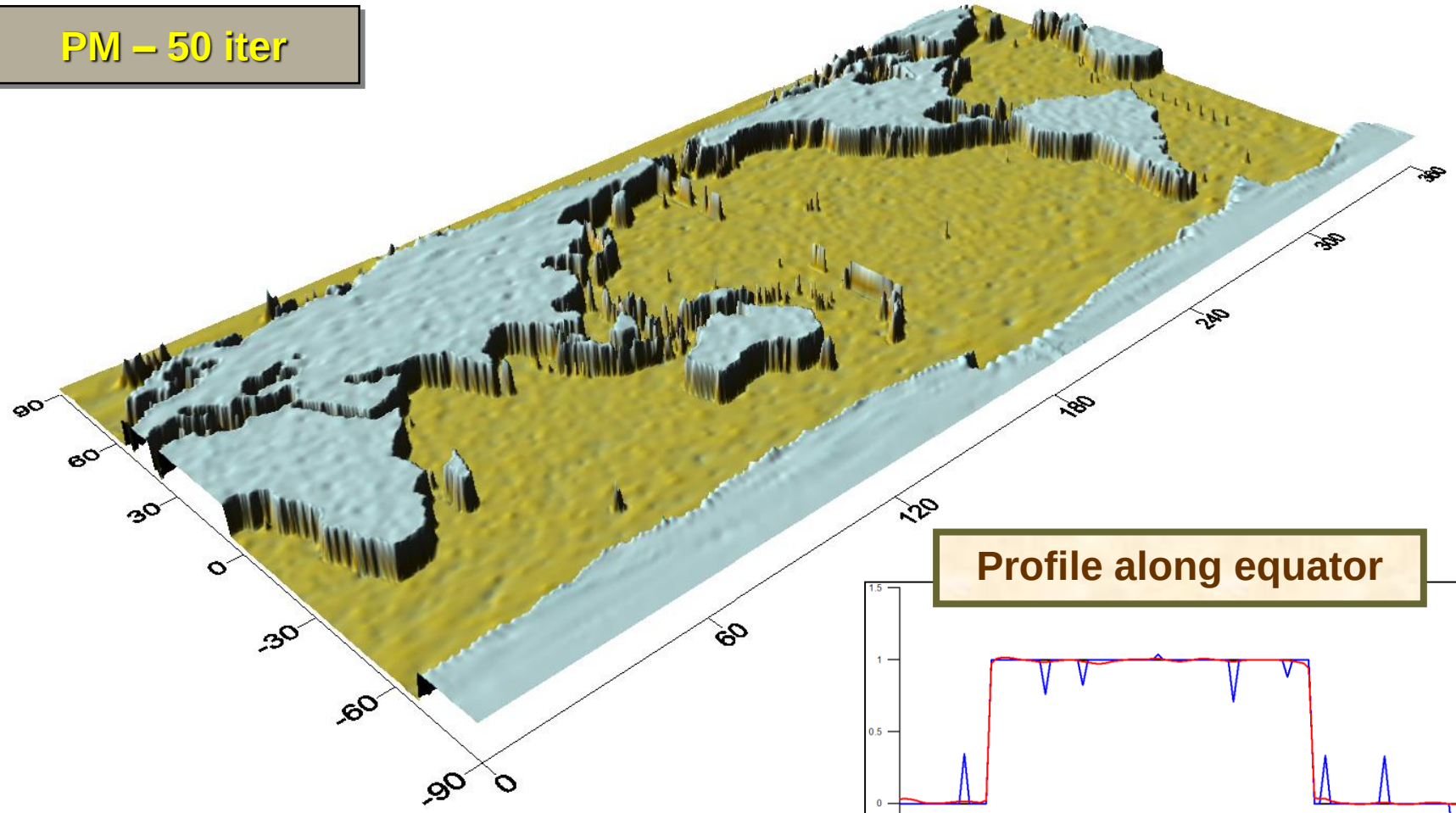


Profile along equator

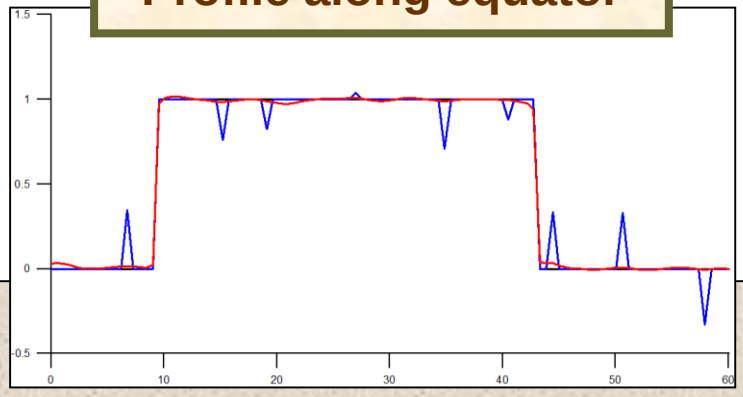


Nonlinear diffusion – 50 iterations

PM – 50 iter

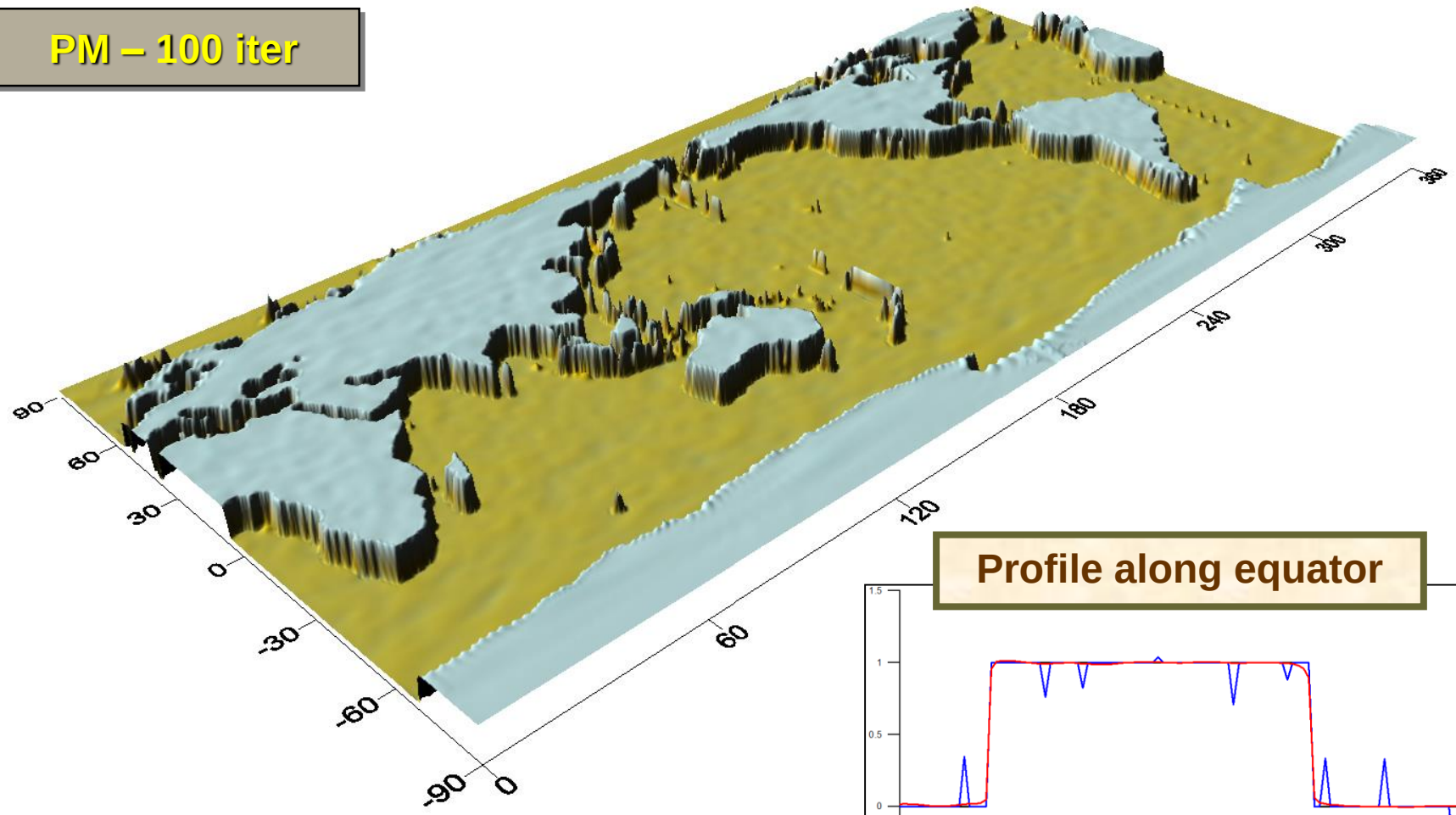


Profile along equator

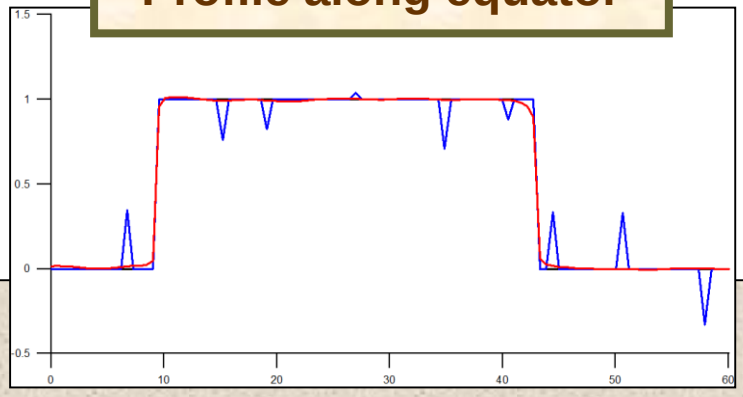


Nonlinear diffusion – 100 iterations

PM – 100 iter

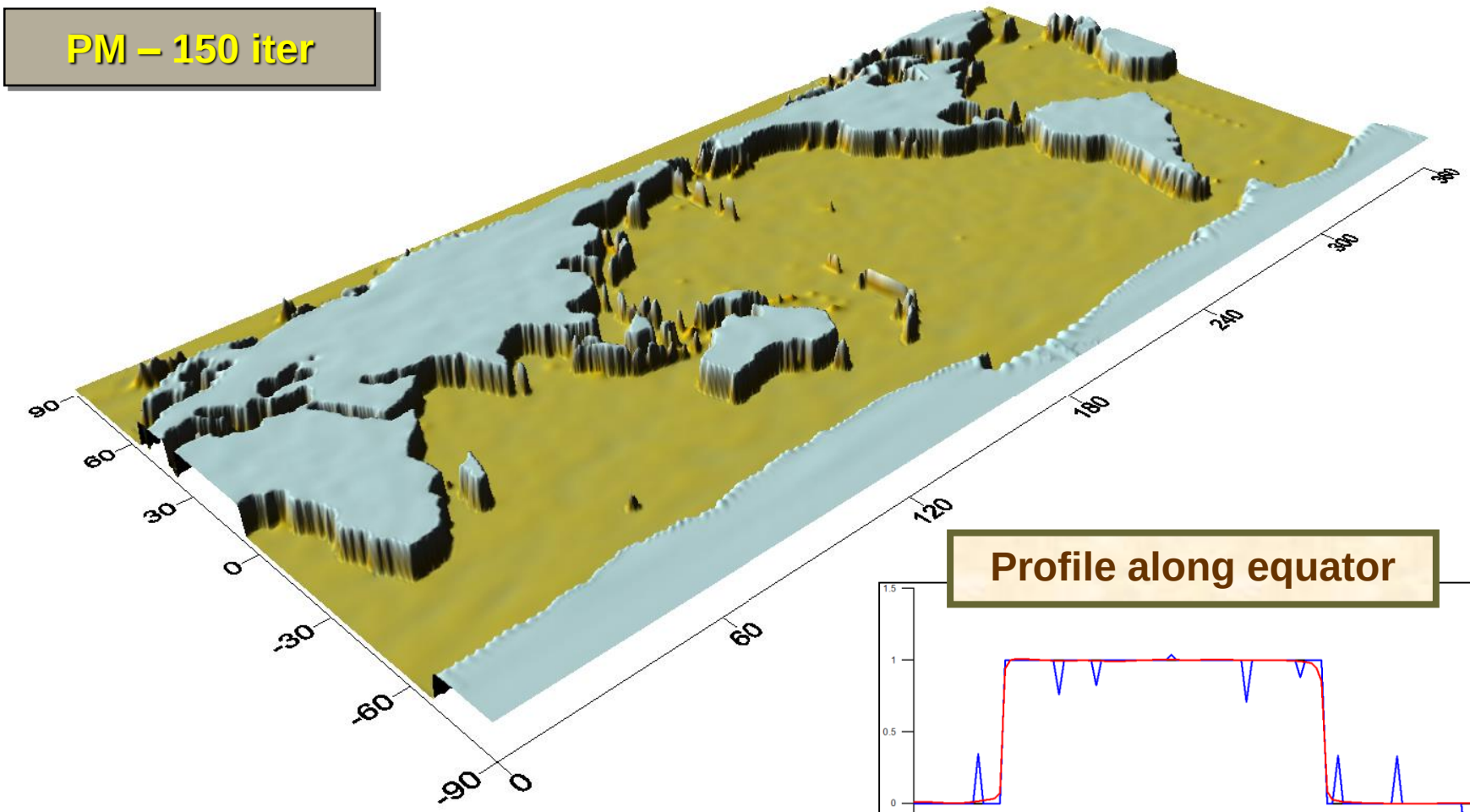


Profile along equator

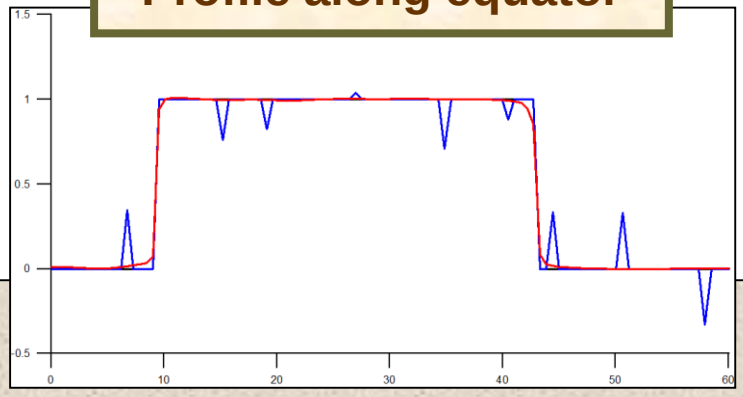


Nonlinear diffusion – 150 iterations

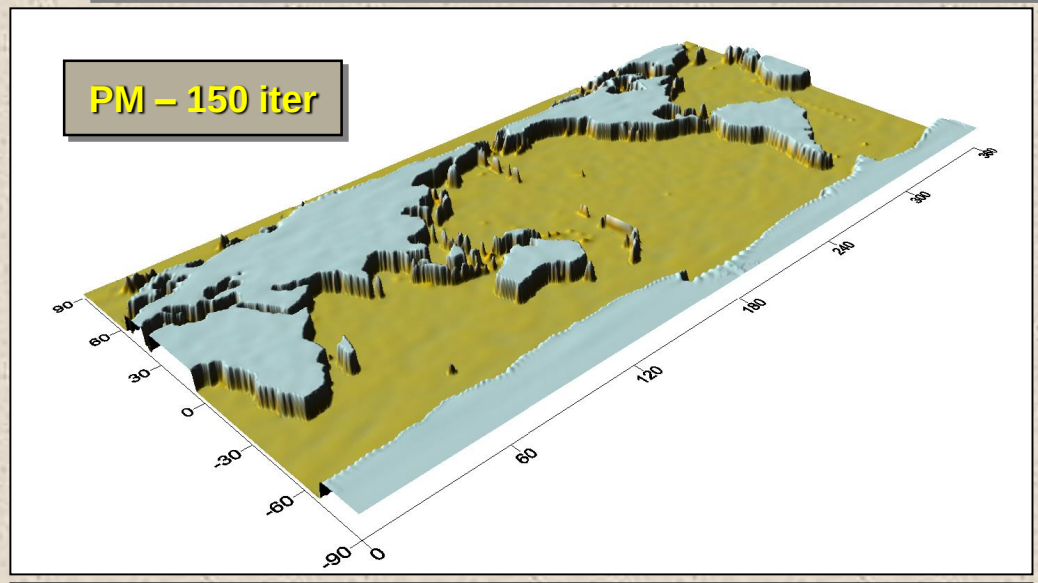
PM – 150 iter

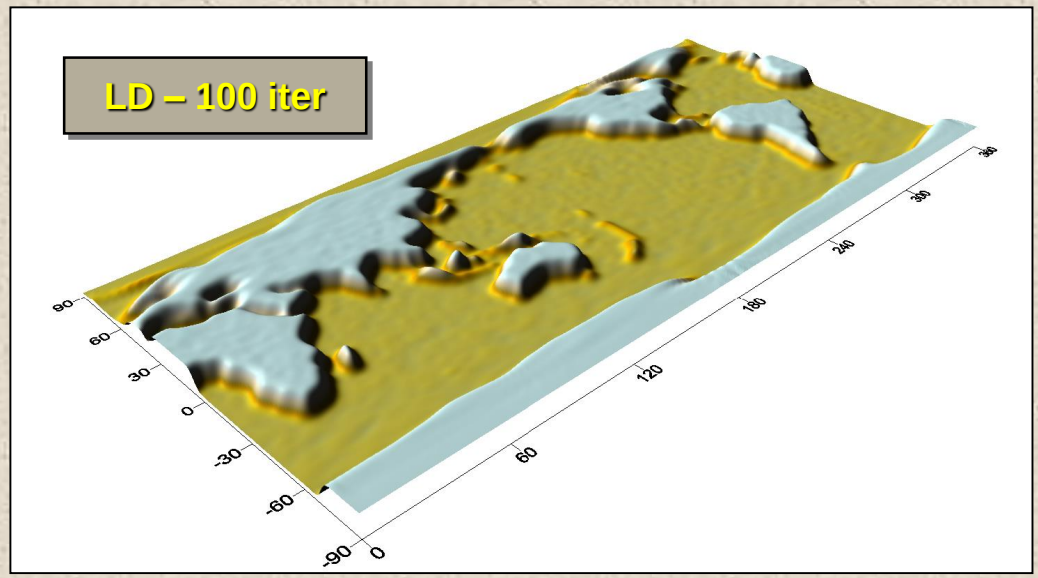


Profile along equator



Porovnanie: lineárna ↔ nelineárna difúzia





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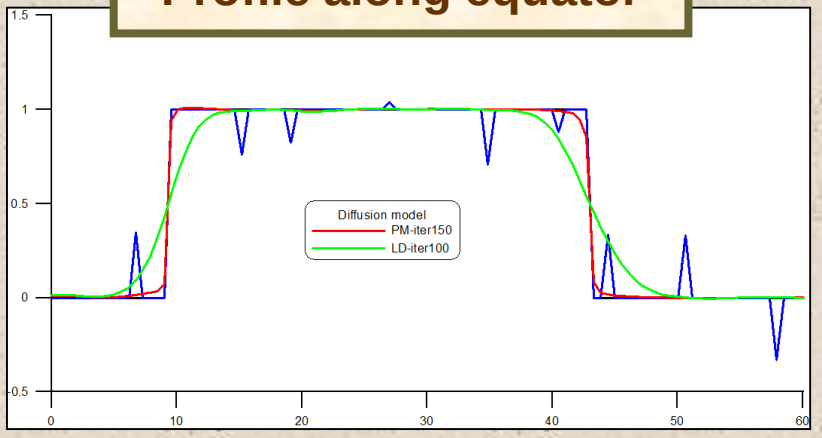
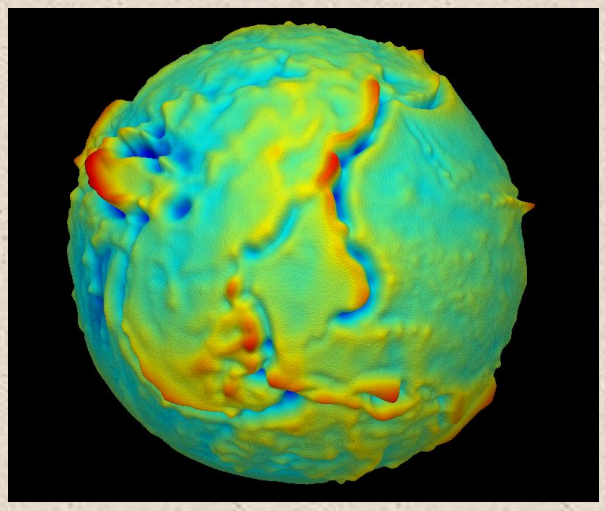
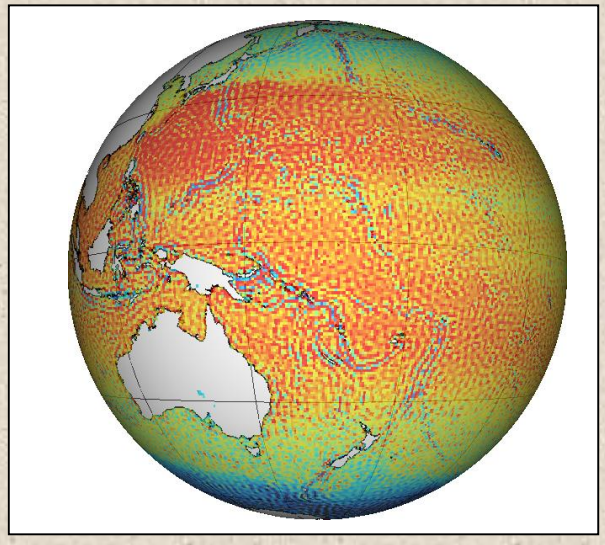


Filtrácia geodetických veličín

- **Filtrovanie priamych meraní družicovej misie GOCE**

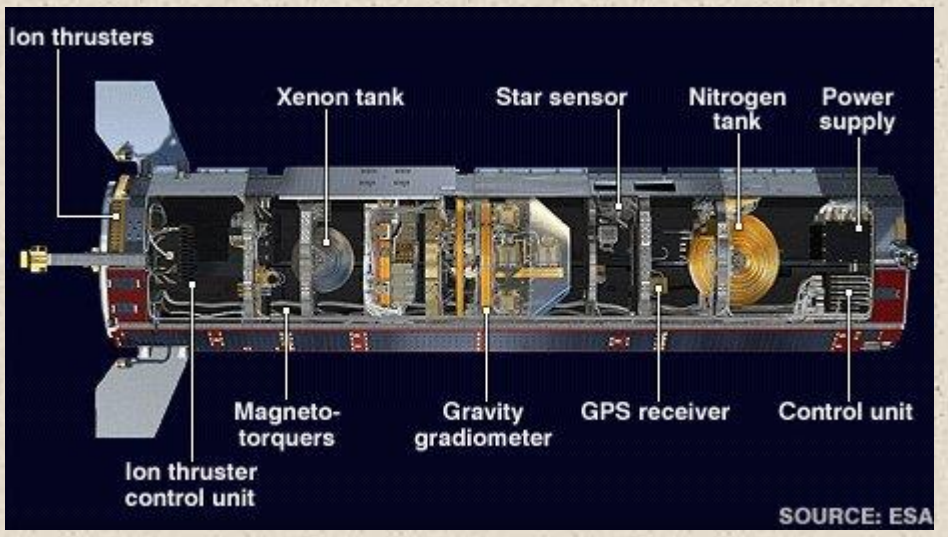


- **Filtrovanie strednej hladiny mora a dynamickej topografie oceánov**



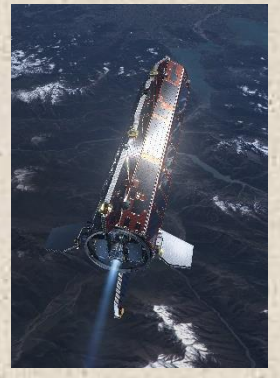
Družicová misia GOCE

Gravity Field and Stady-State Ocean Circulation Explorer



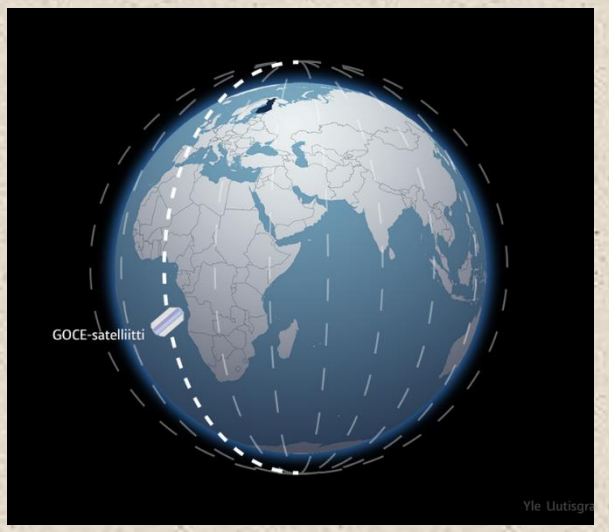
$$grad\left(gradV\right) = grad\left(\vec{g}\right) = \begin{bmatrix} V_{xx} & V_{xy} & V_{xz} \\ & V_{yy} & V_{yz} \\ & & V_{zz} \end{bmatrix}$$

Vypustenie družice
(17 marec 2009)

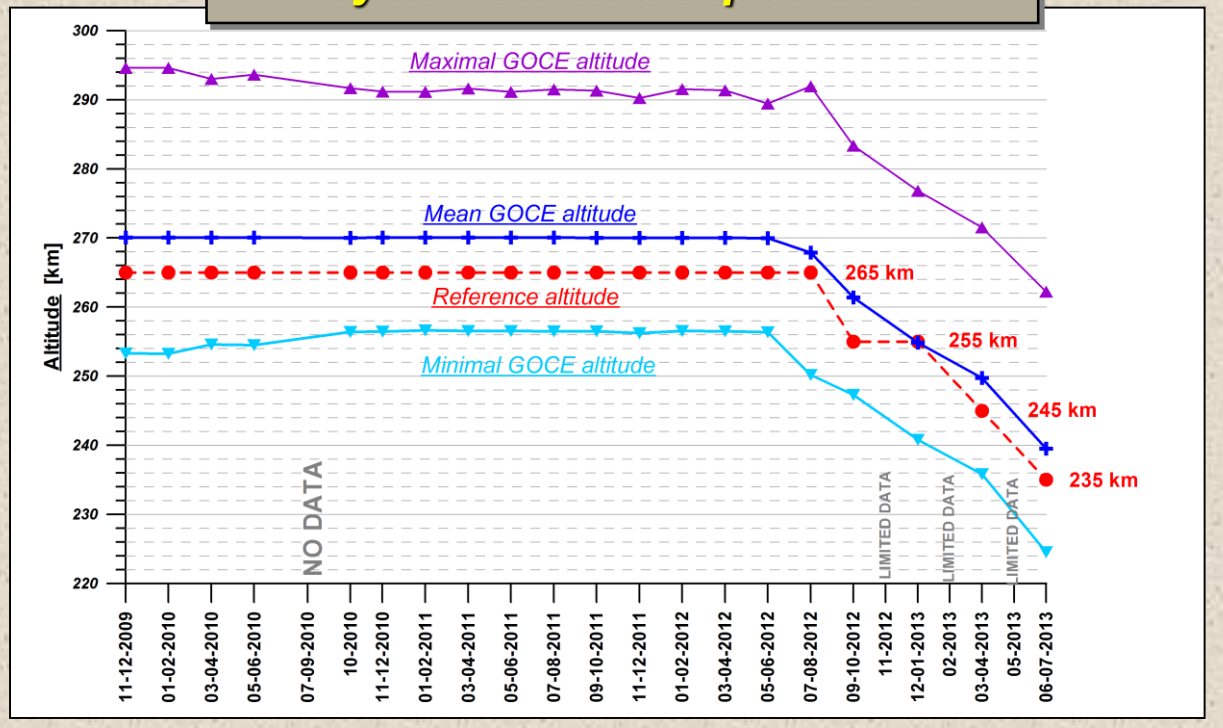


Koniec misie
(11 november 2013)

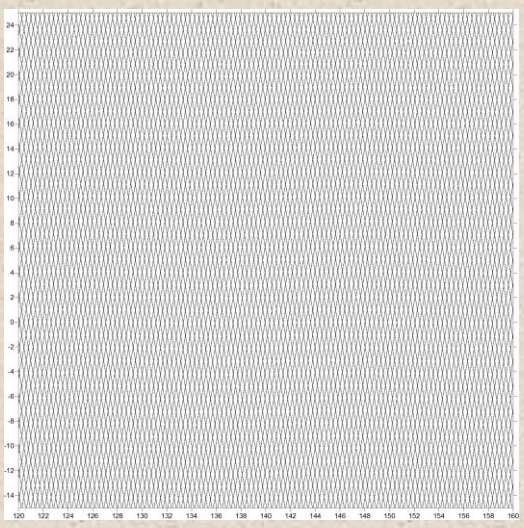
Orbity družicovej misie GOCE

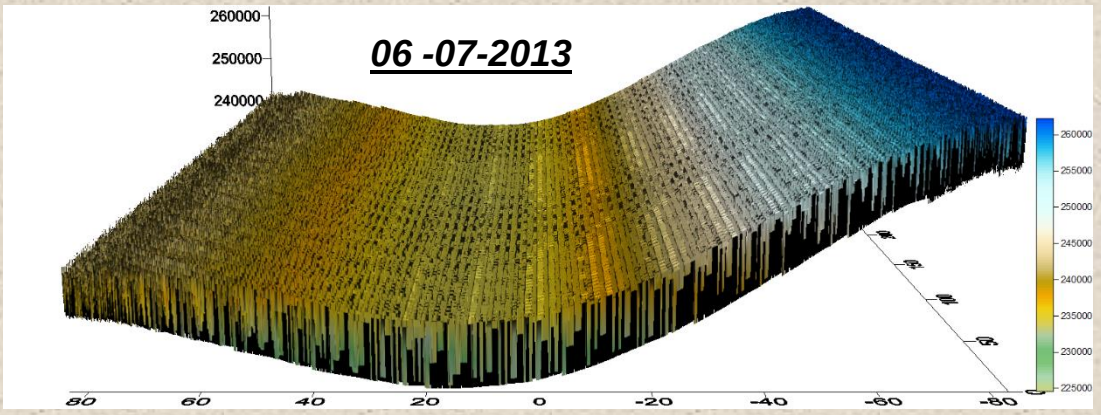


Výška letu nad elipsoidom



Hustota meraní
(61 dní)

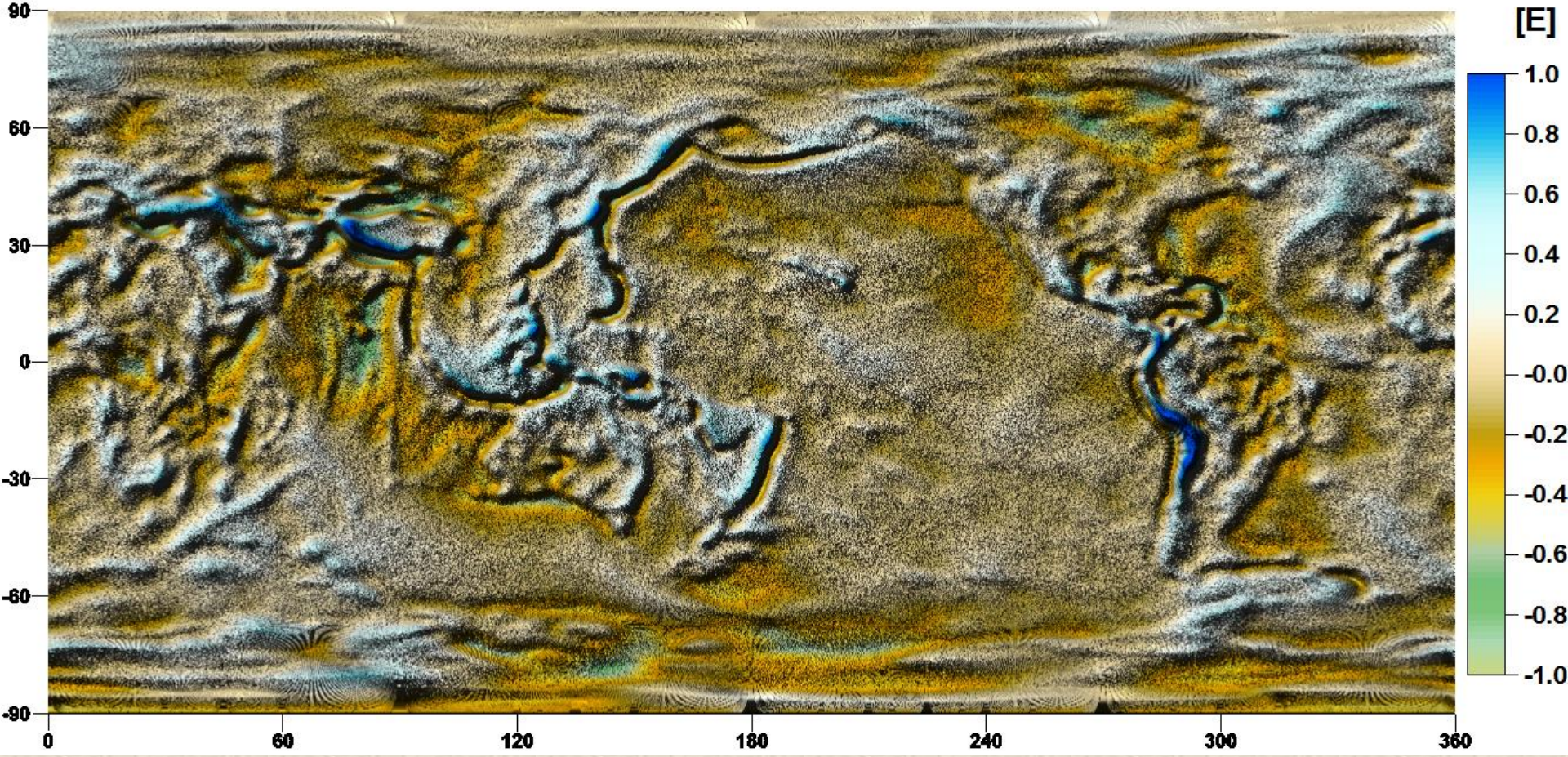




Priame merania GOCE

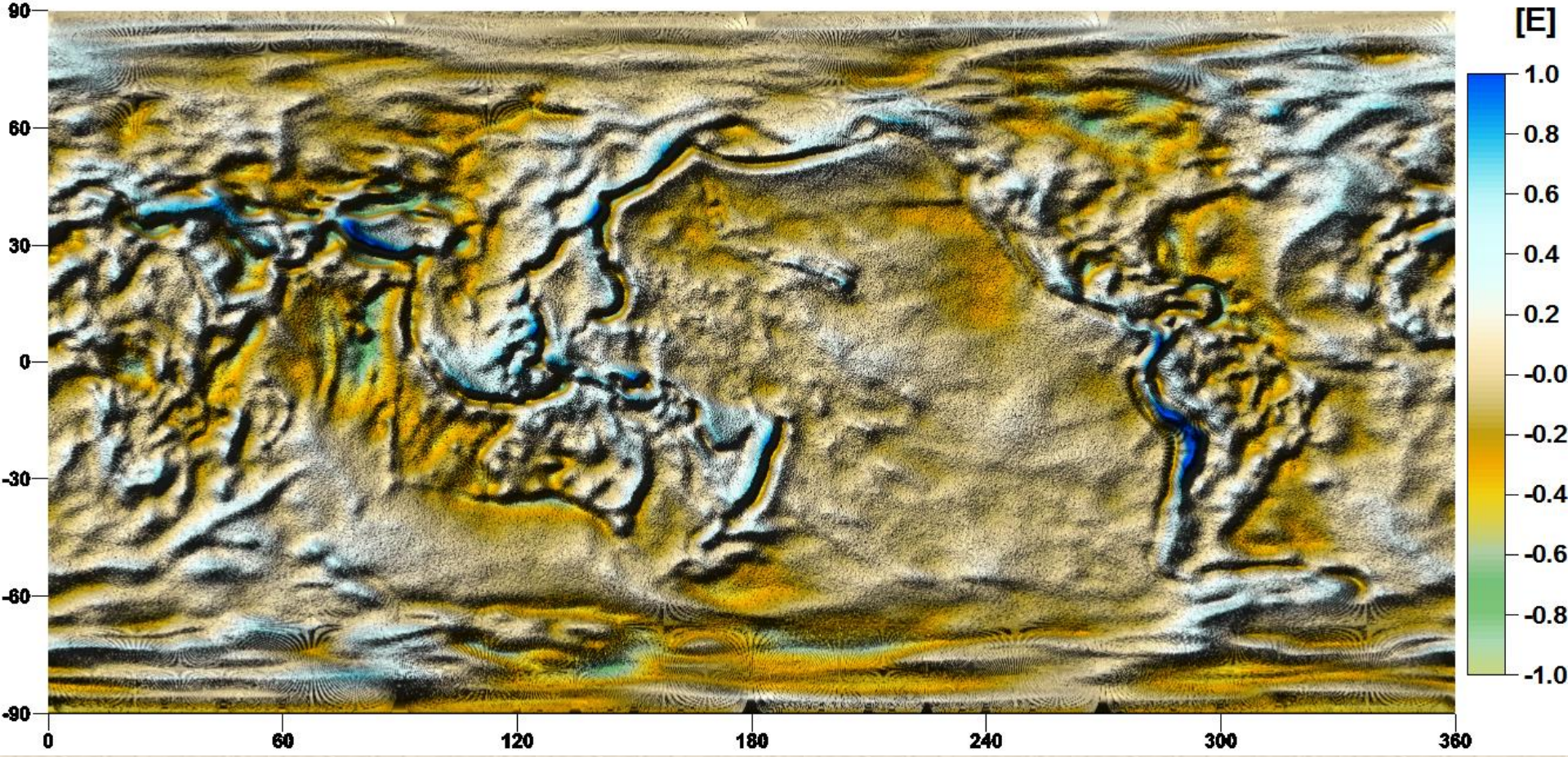
T_{zz} komponent tiažového tenzora

$$T_{zz} = V_{zz} - U_{zz}$$



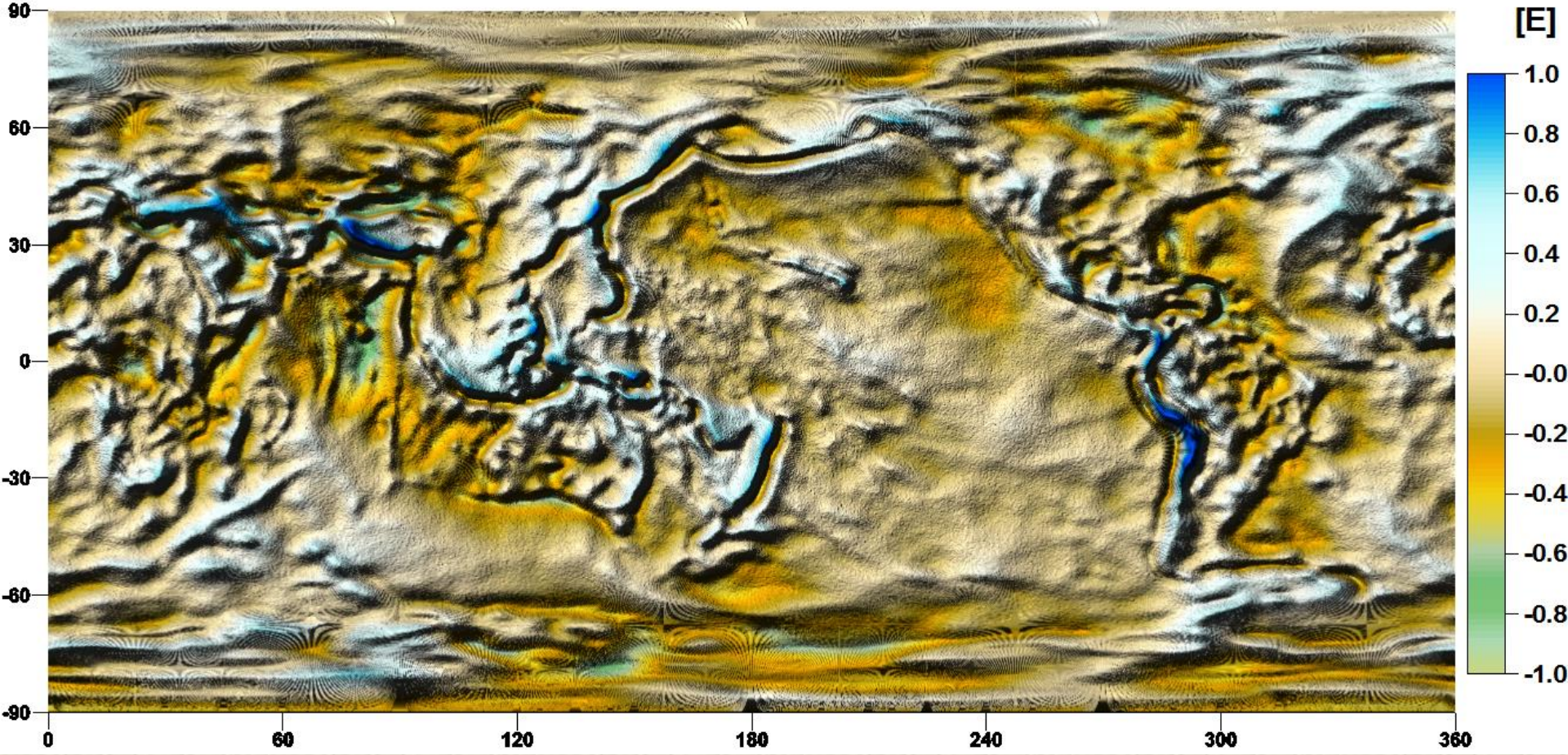
Nonlinear diffusion

10 iterations



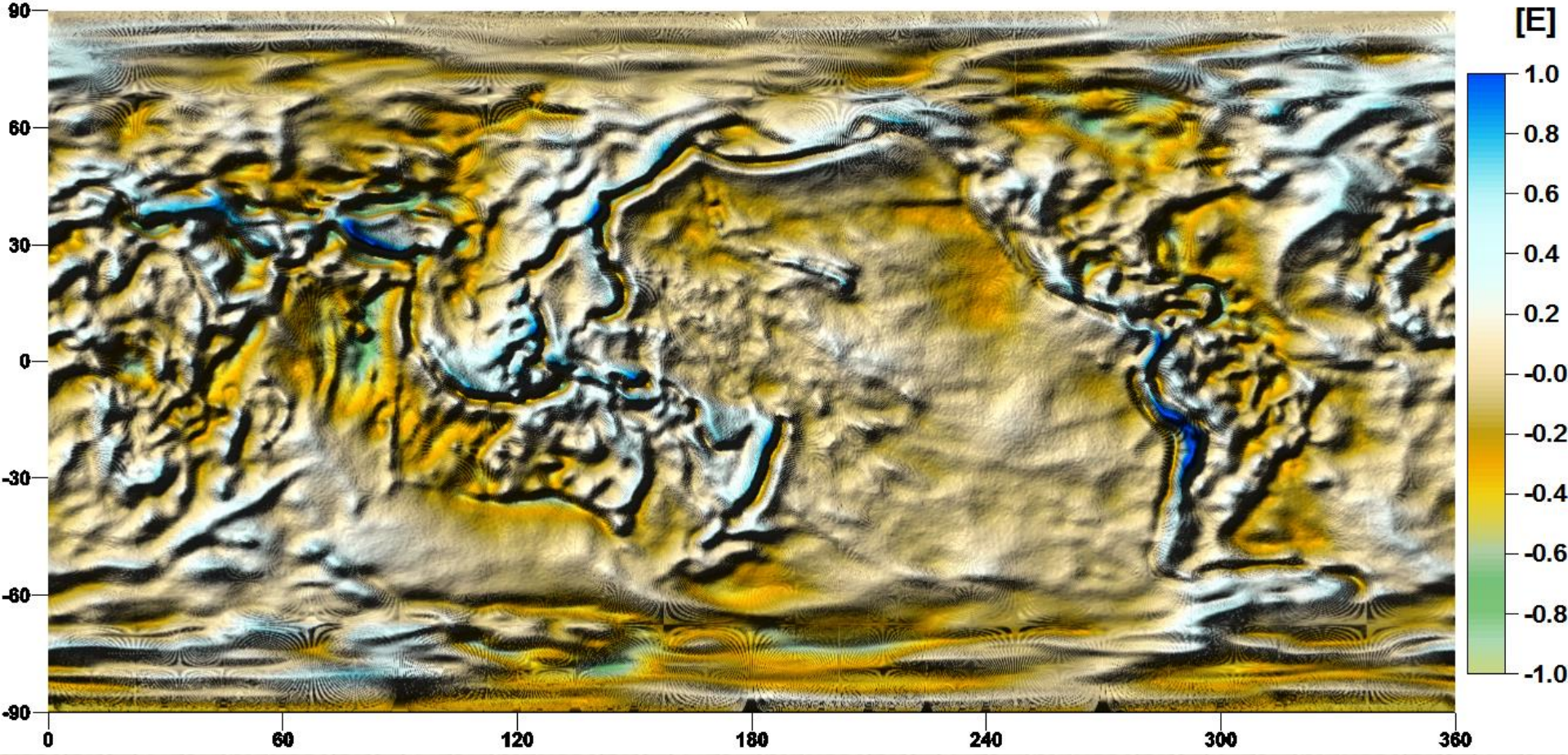
Nonlinear diffusion

20 iterations



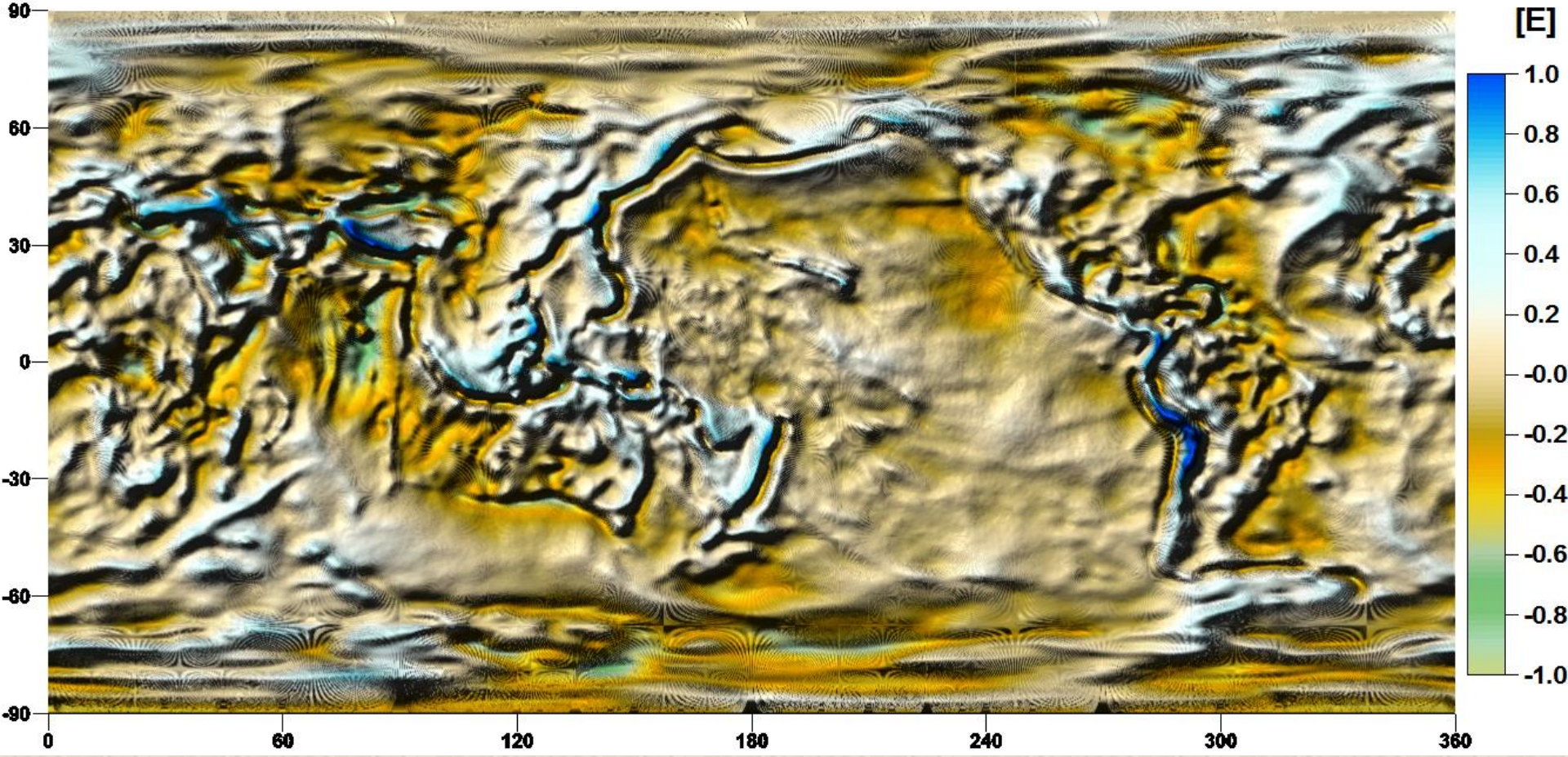
Nonlinear diffusion

50 iterations



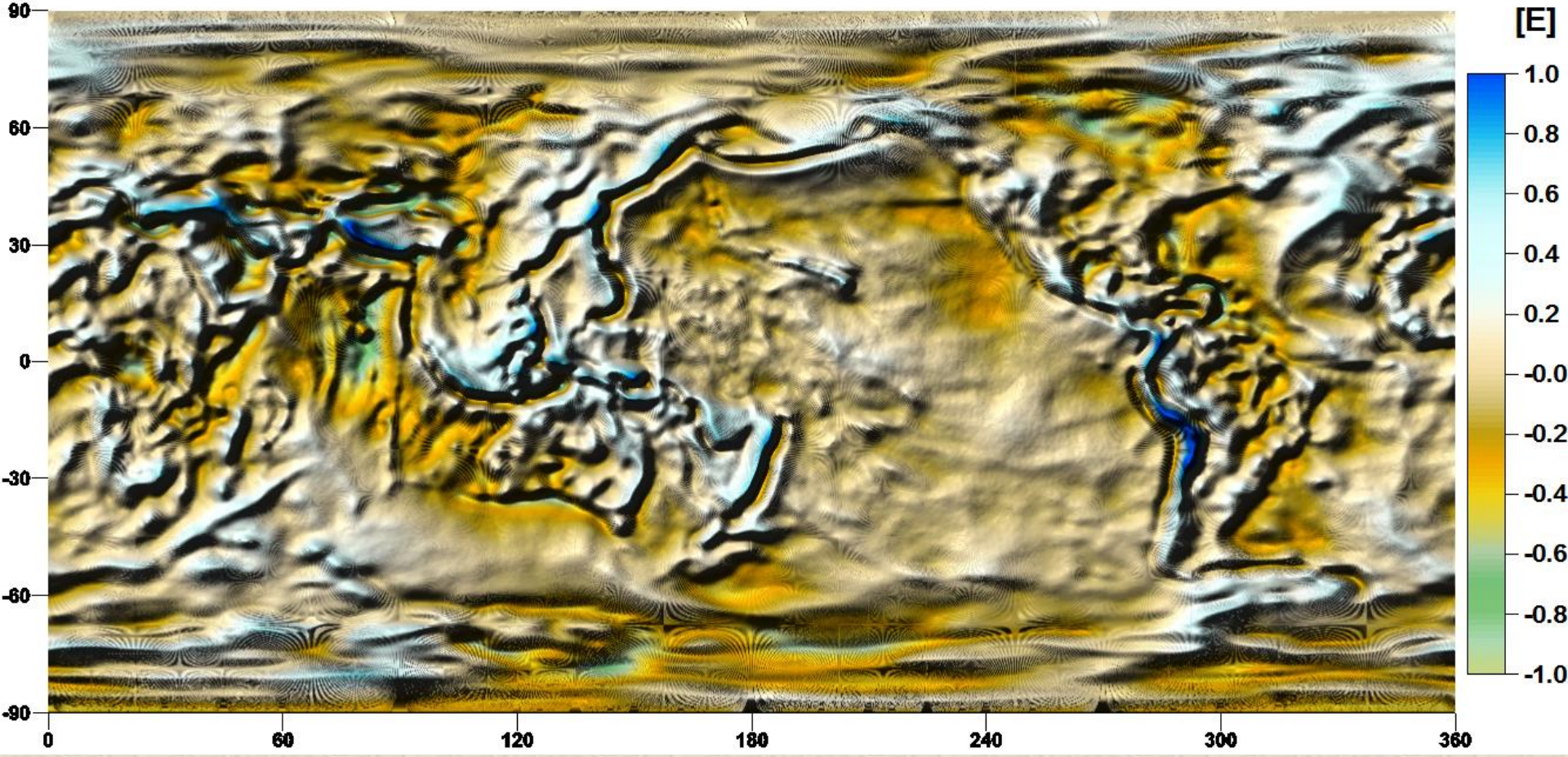
Nonlinear diffusion

100 iterations



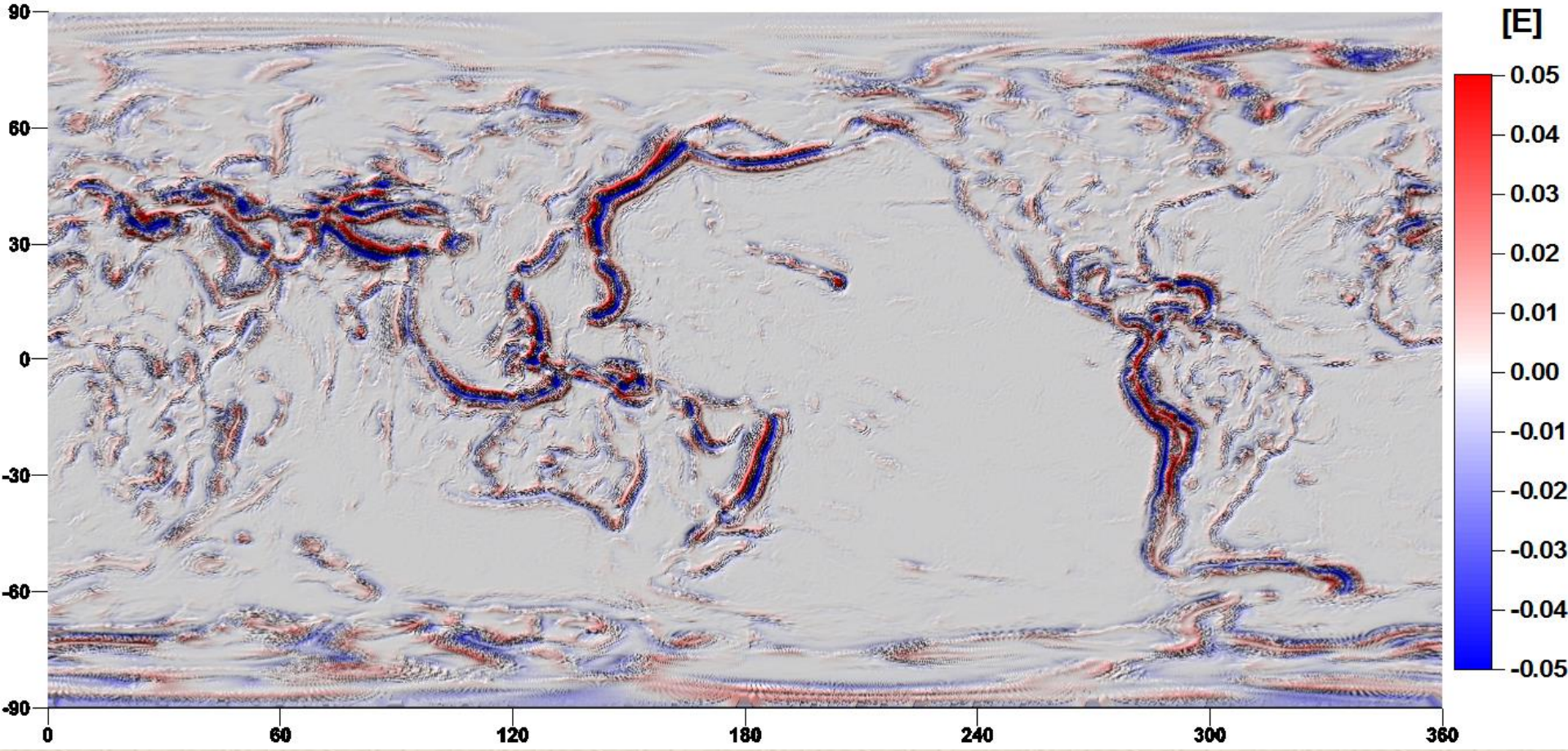
Linear diffusion

100 iterations



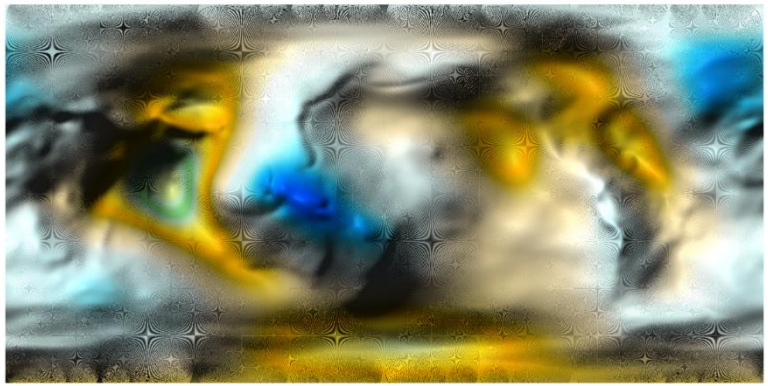
Nelineárna – lineárna difúzia

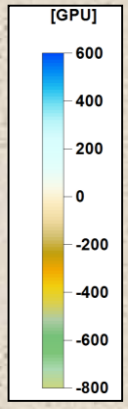
100 iterations



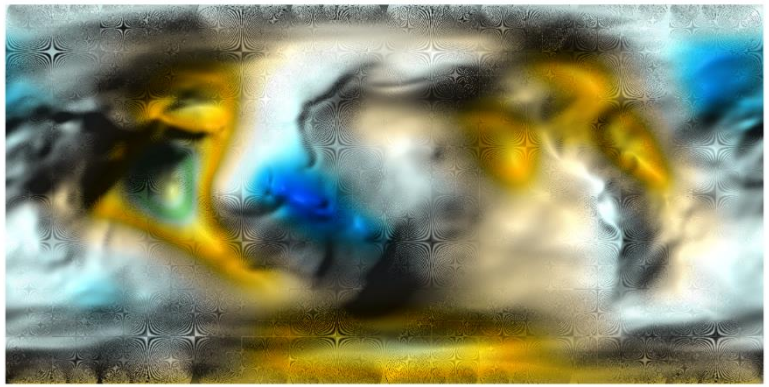
Model tiažového poľa z filtrovaných dát

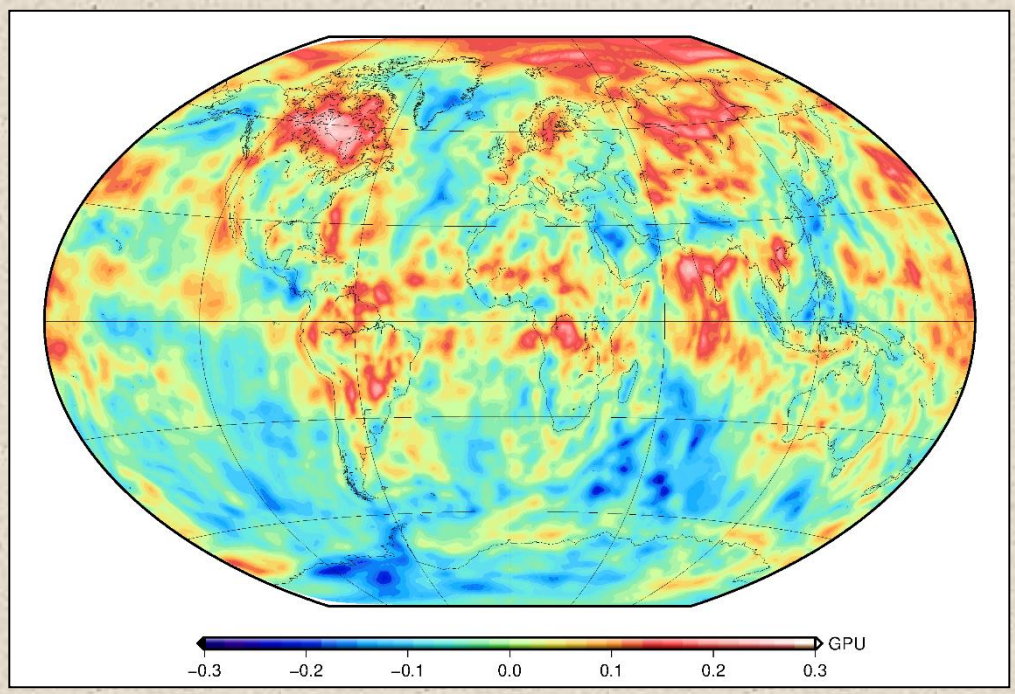
MFS





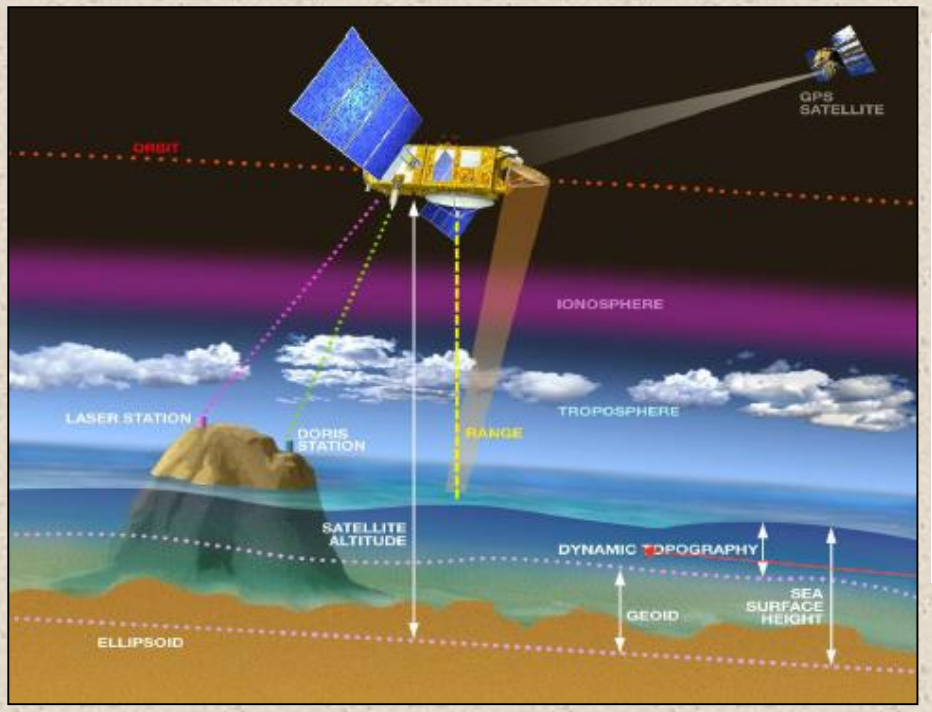
GOCO03S

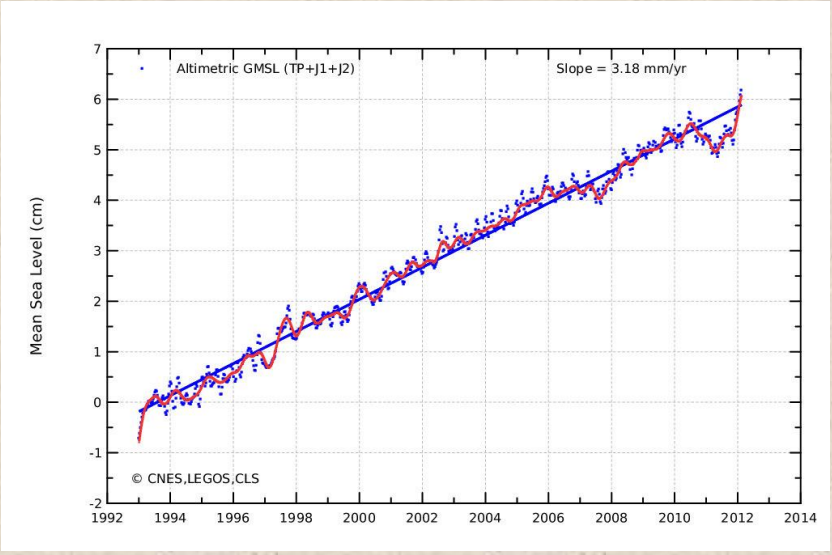


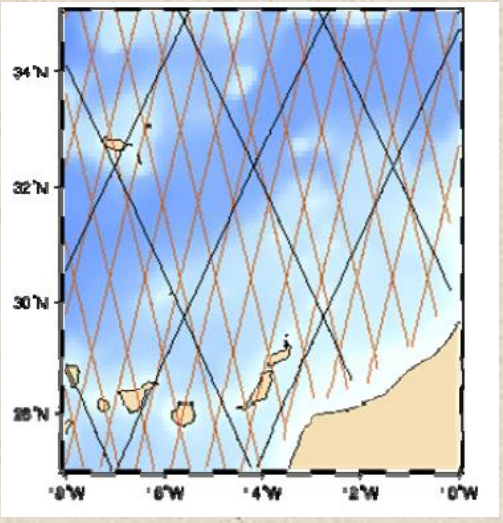


STATISTICS	
Nodes	5 760 002
Mean	-0.004 m^2s^{-2}
Max	0.268 m^2s^{-2}
MIN	-0.231 m^2s^{-2}
St. Dev.	0.069 m^2s^{-2}

Družicová altimetria

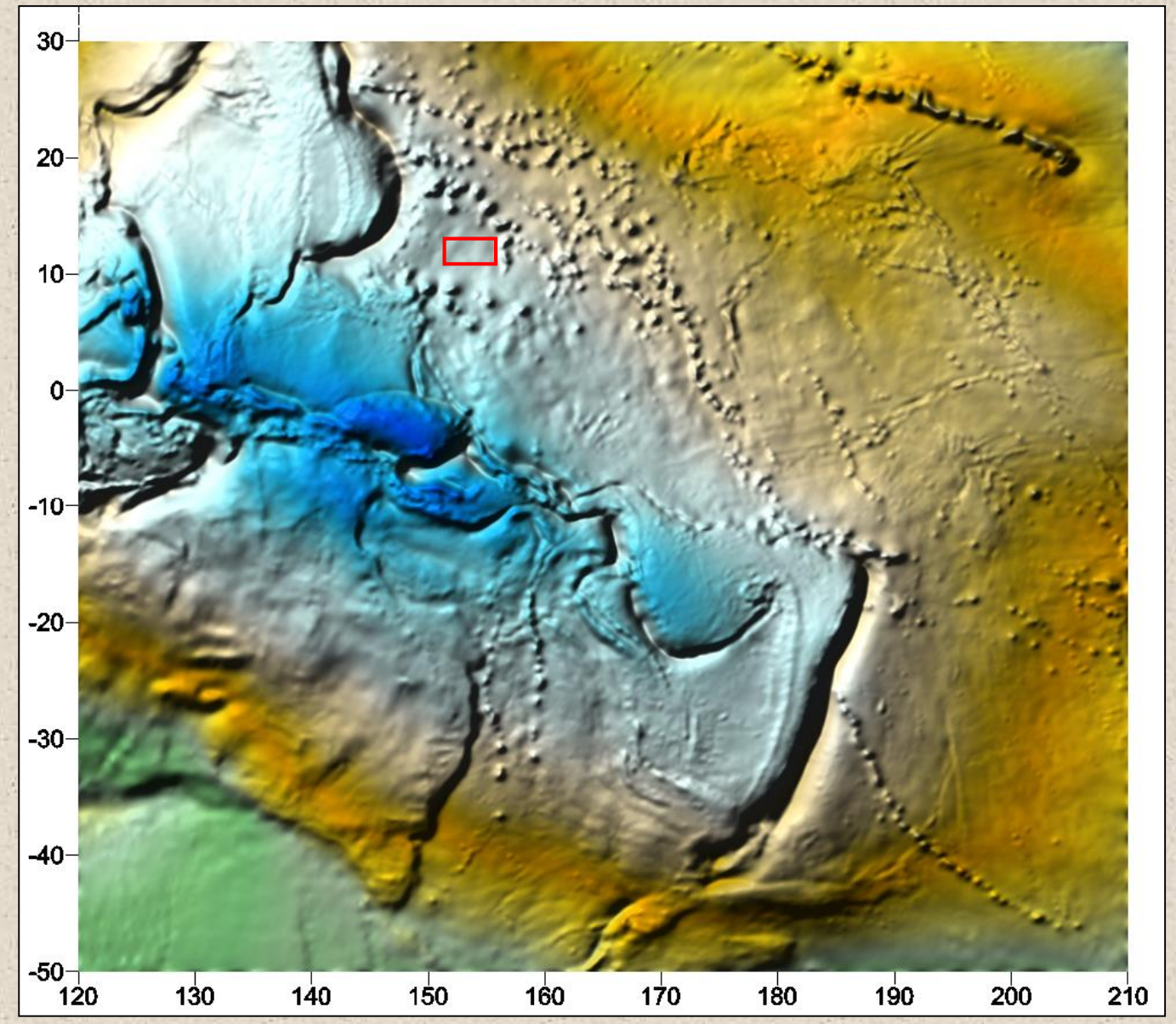






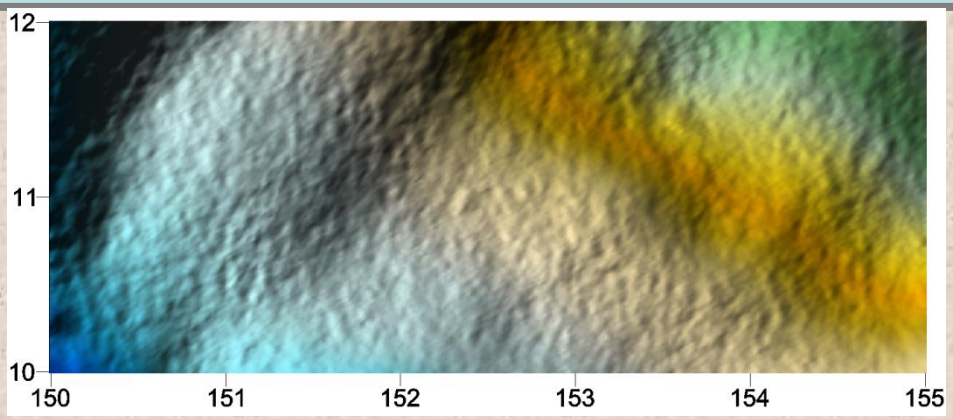
Družicová altimetria

Stredná hladina mora

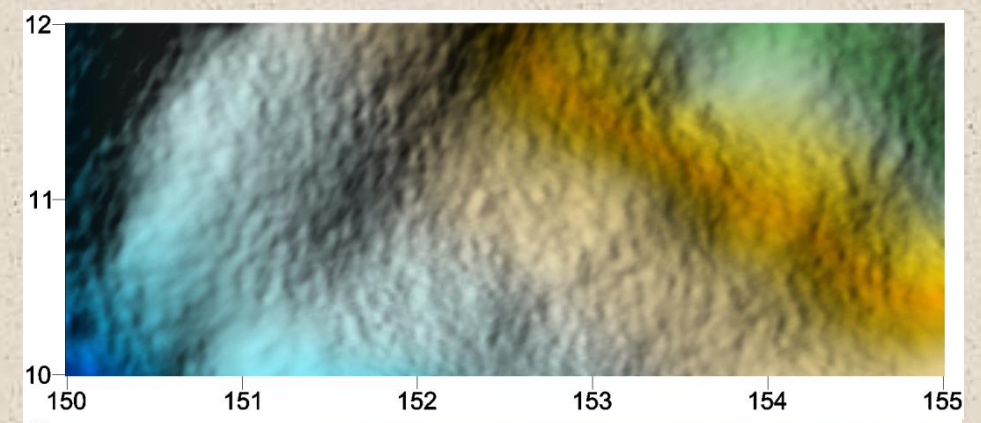


Filtrácia strednej hladiny mora

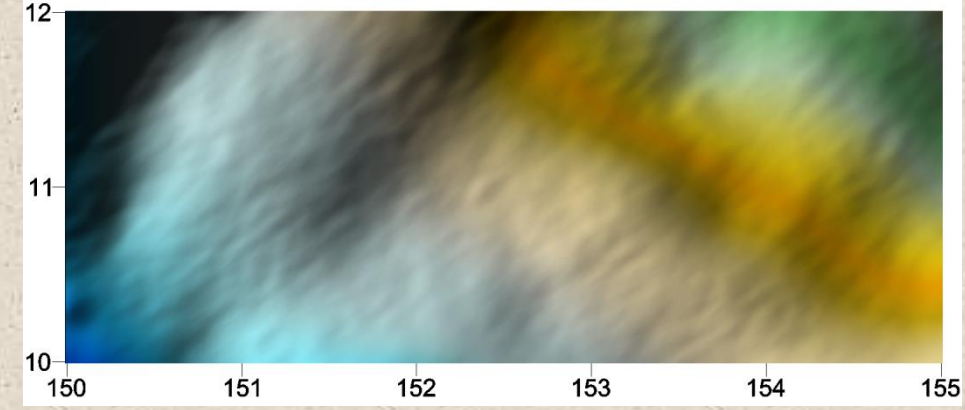
Model strednej hladiny mora DTU13 (1”x 1”)



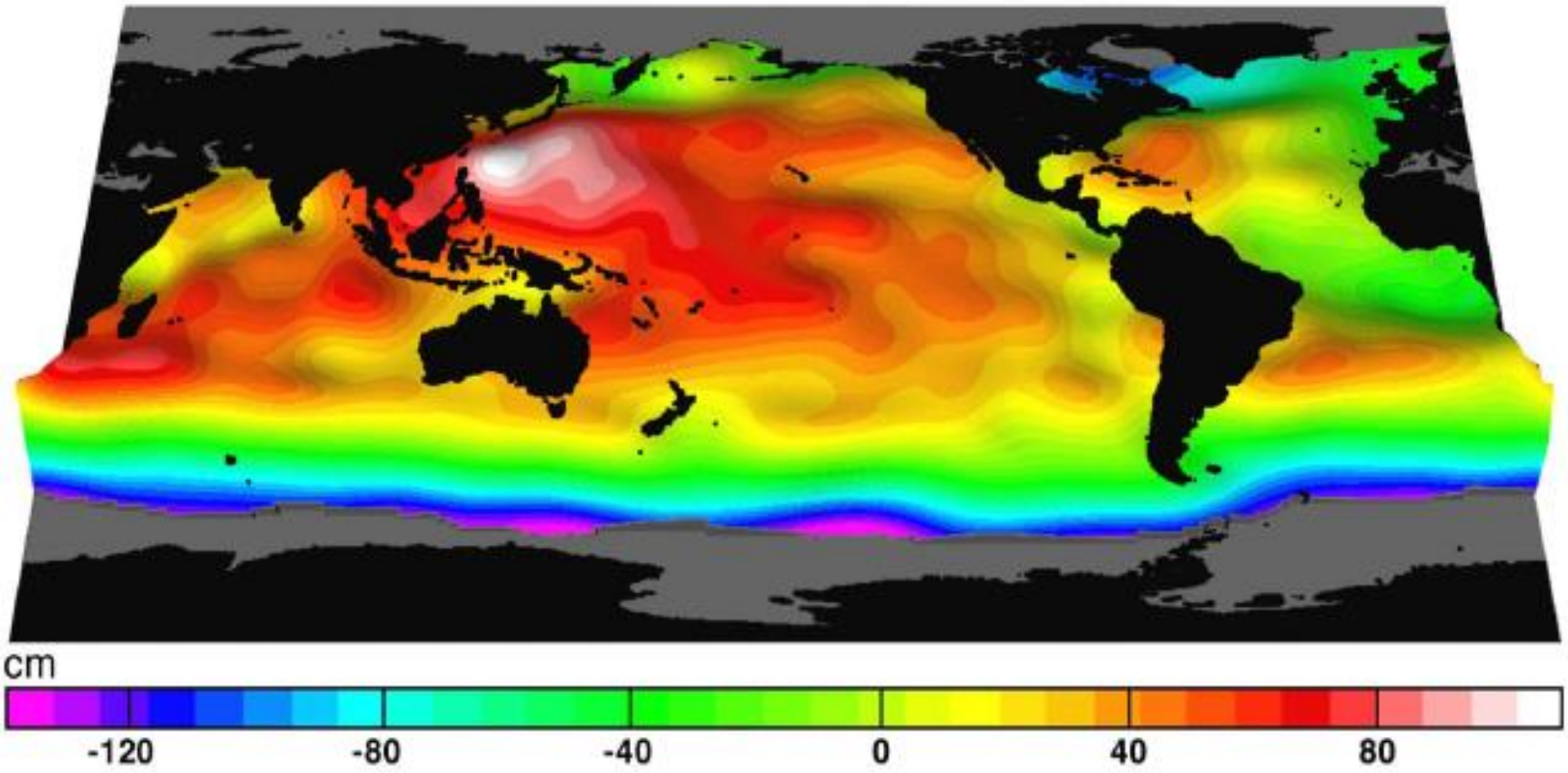
2 kroky nelineárnej filtrácie



2 kroky lineárnej filtrácie



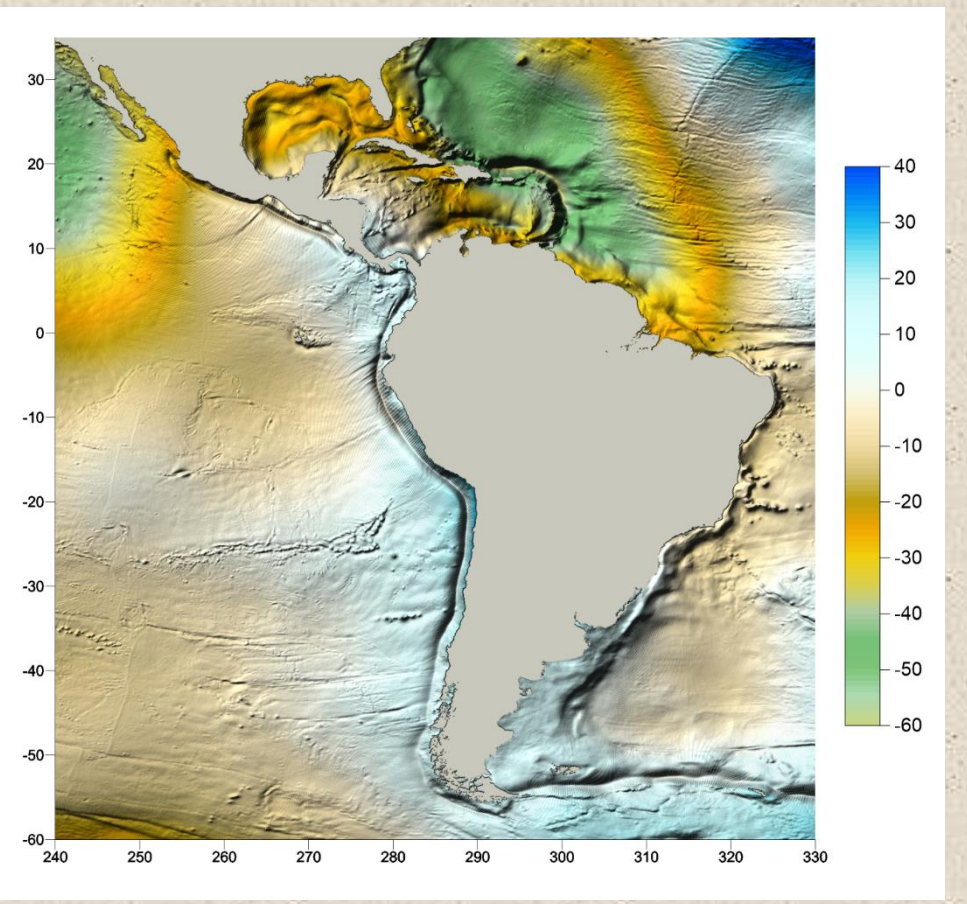
Dynamická topografia oceánov



Dynamická topografia oceánov

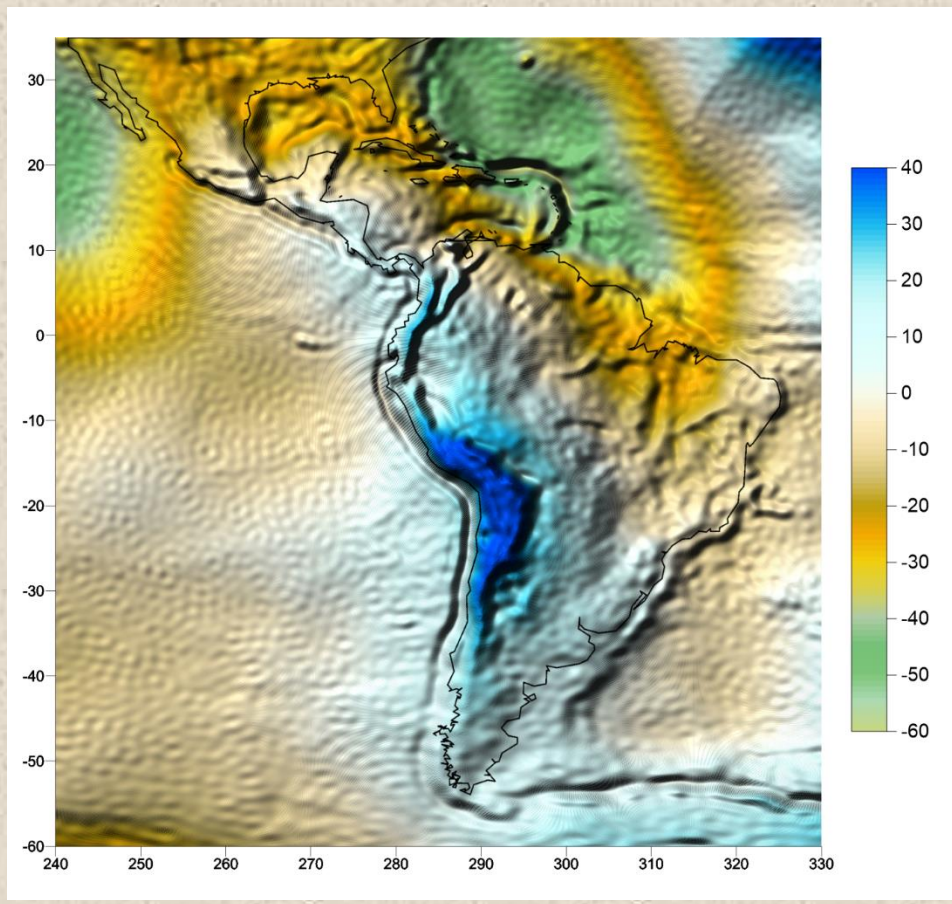
Družicová altimetry:

DTU13_MSS



Globálny geopotenciálny model:

GO_CONS_GCF_2_DIR_R5 *(SH do rádu 300)*



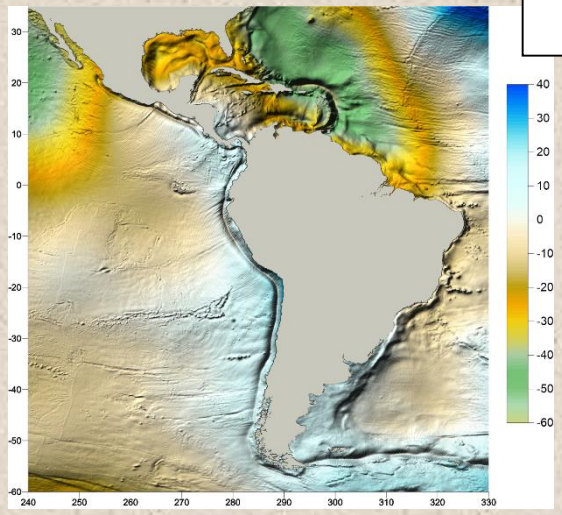
Dynamická topografia oceánov

"geodetický prístup"

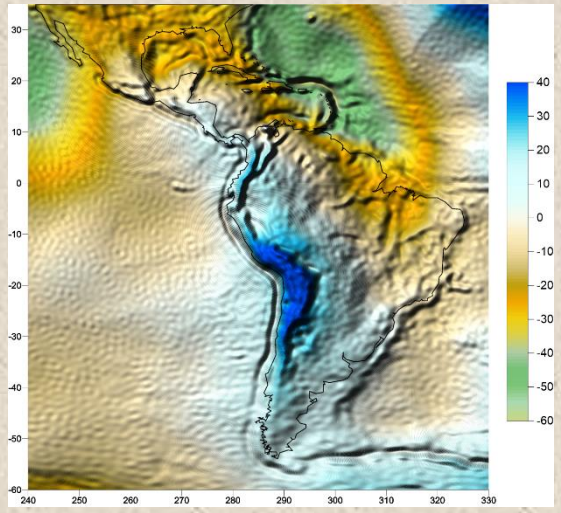
SDTO = SHM - geoid

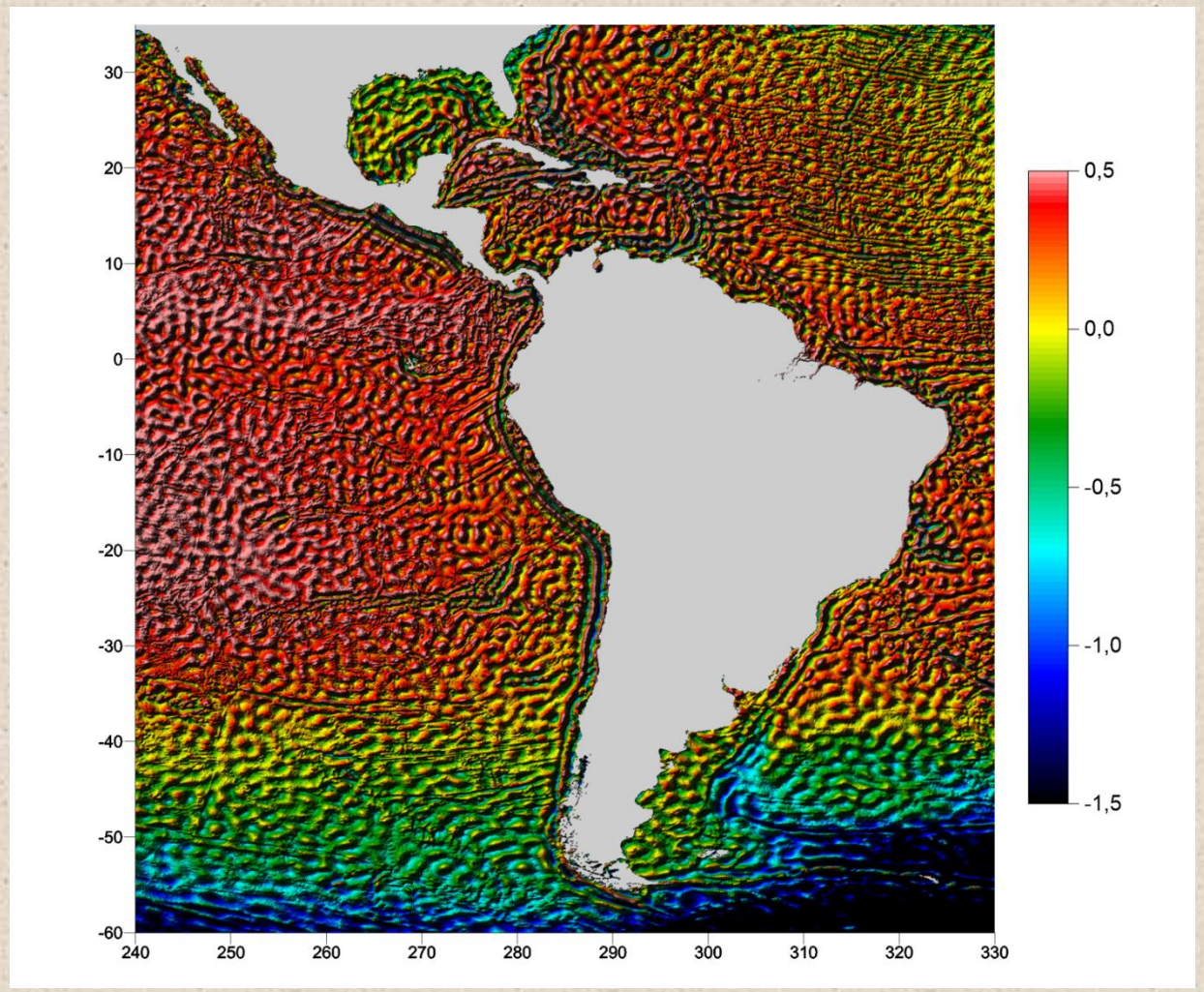
SDTO – stredná dynamická topografia oceánov
SHM – stredná hladina morí

DTU13_MSS

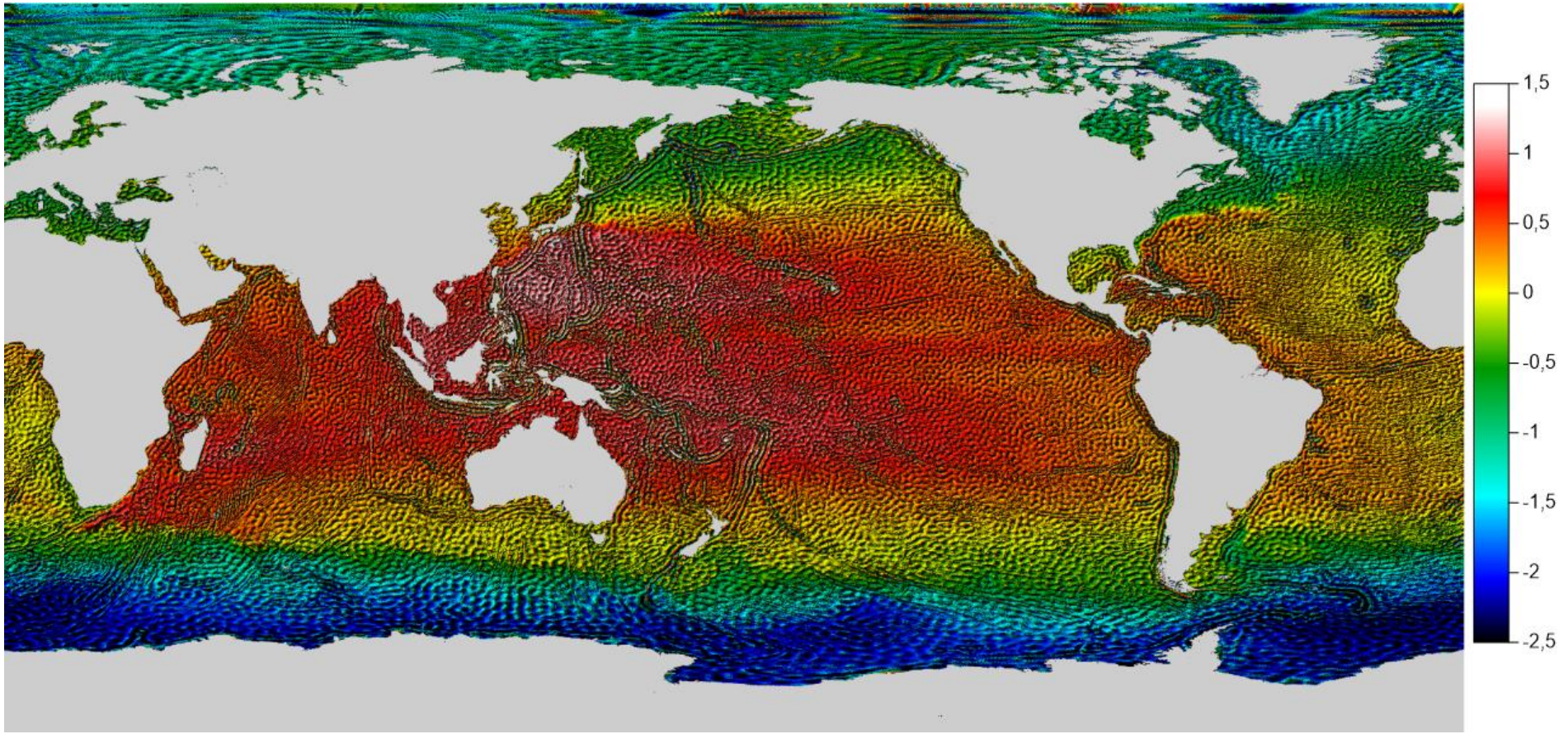


GO_CONS_GCF_2_DIR_R5





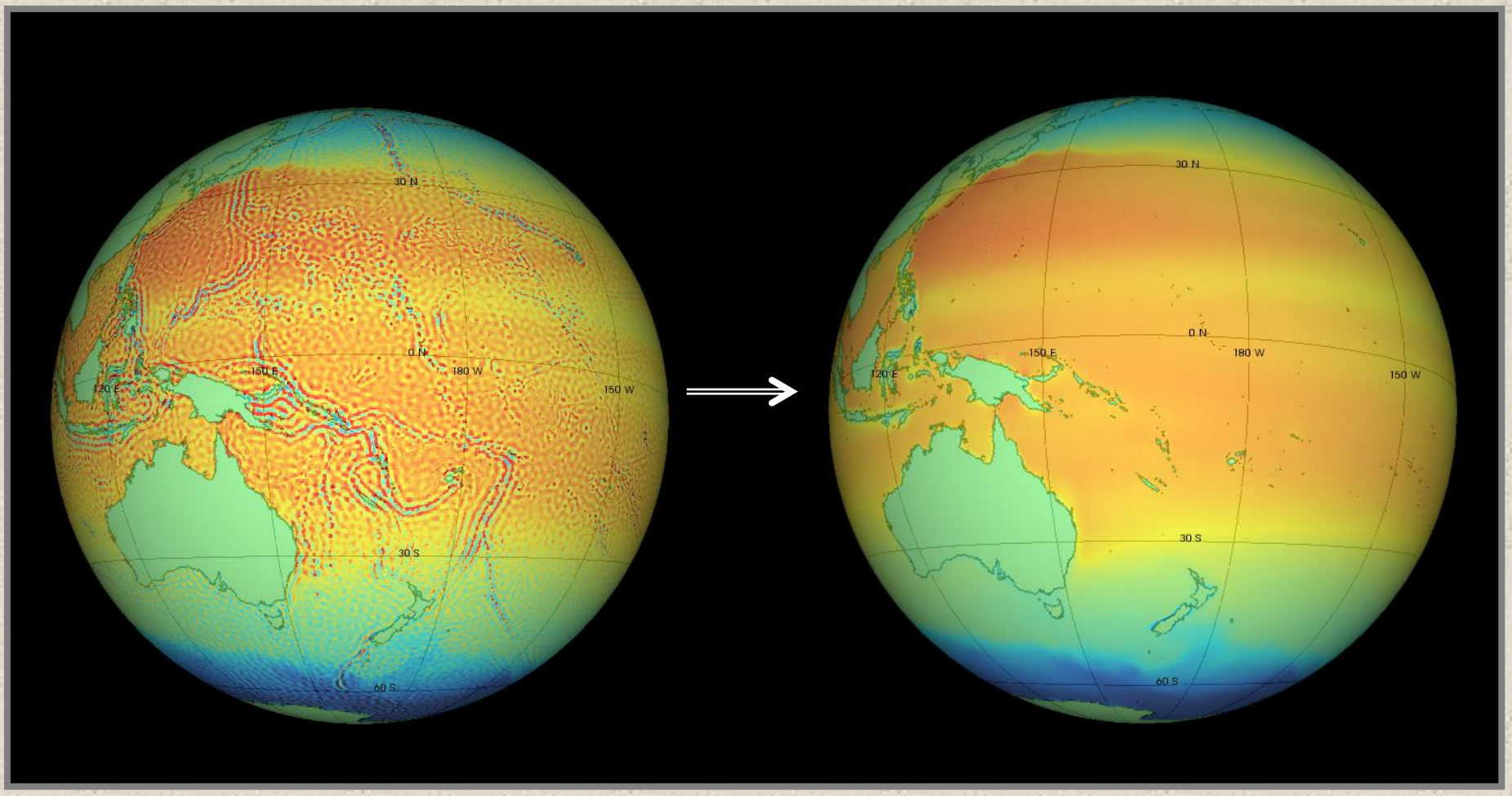
Dynamická topografia oceánov



Dynamická topografia oceánov

Družicová altimetry + GOCE

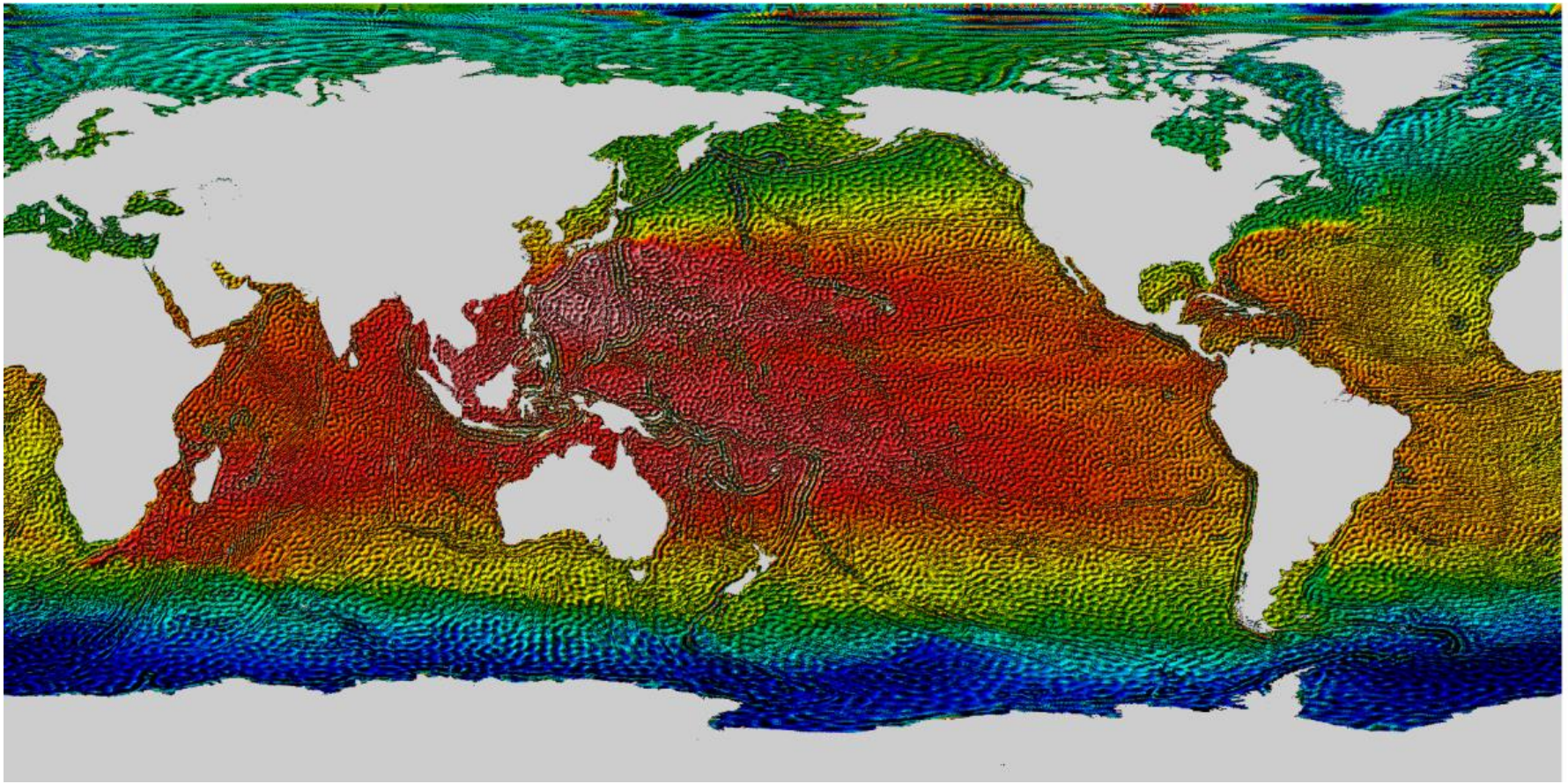
Po filtrovaní



Dynamická topografia oceánov

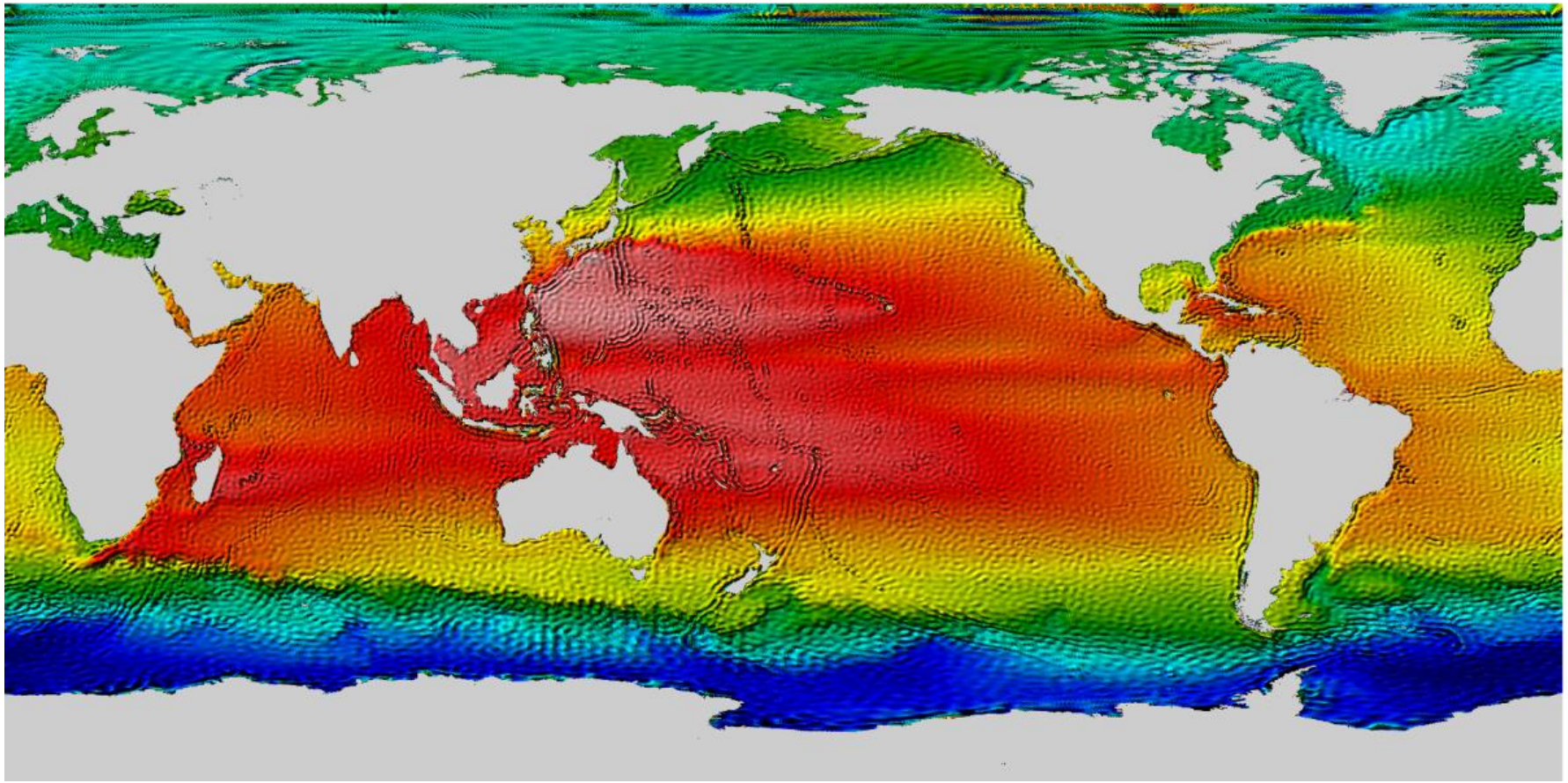
DTU13_MSS - GOCE_DIR5
(SH up to 300)

Initial data



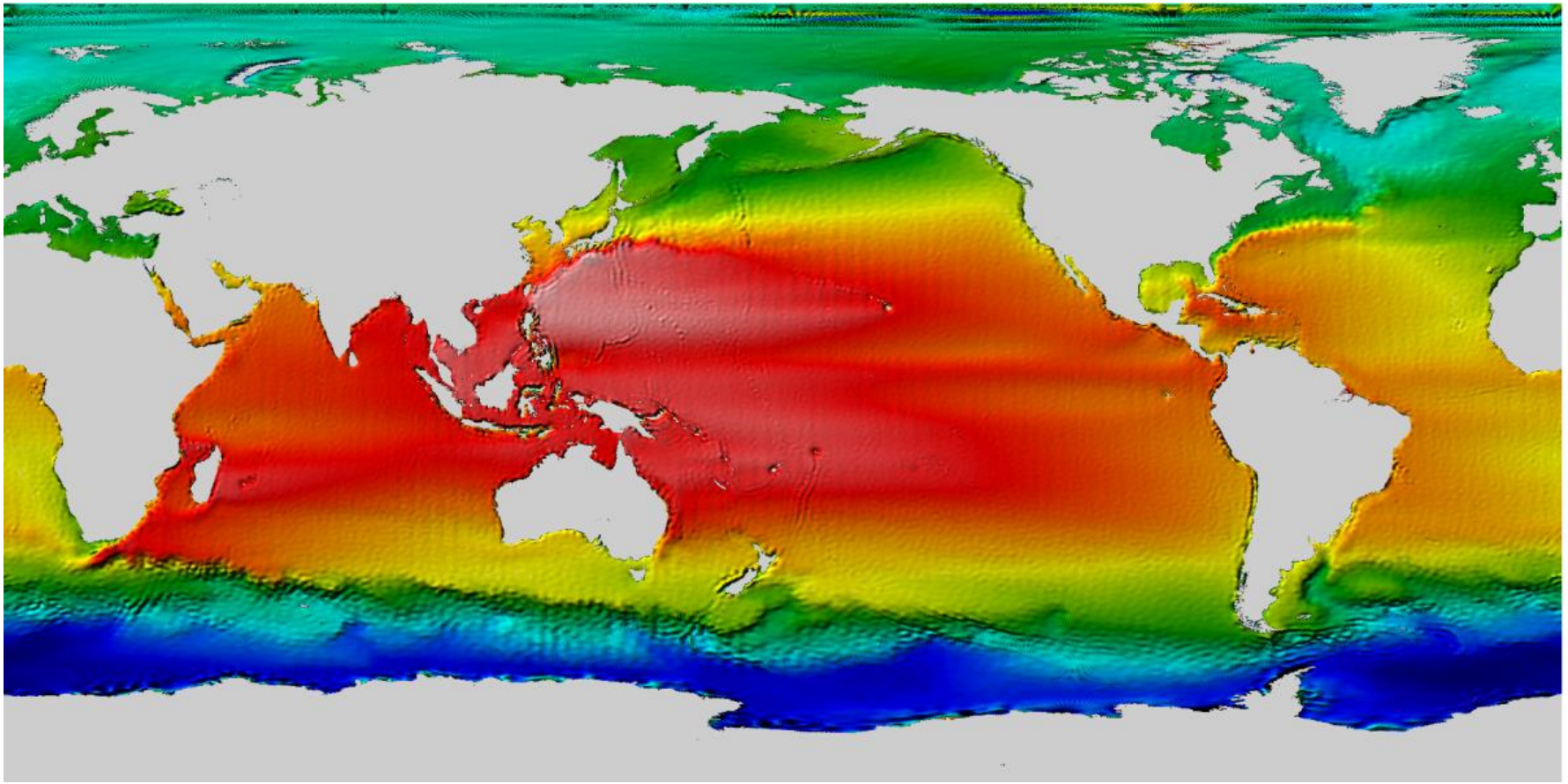
Nelineárna filtrácia

2 iterations



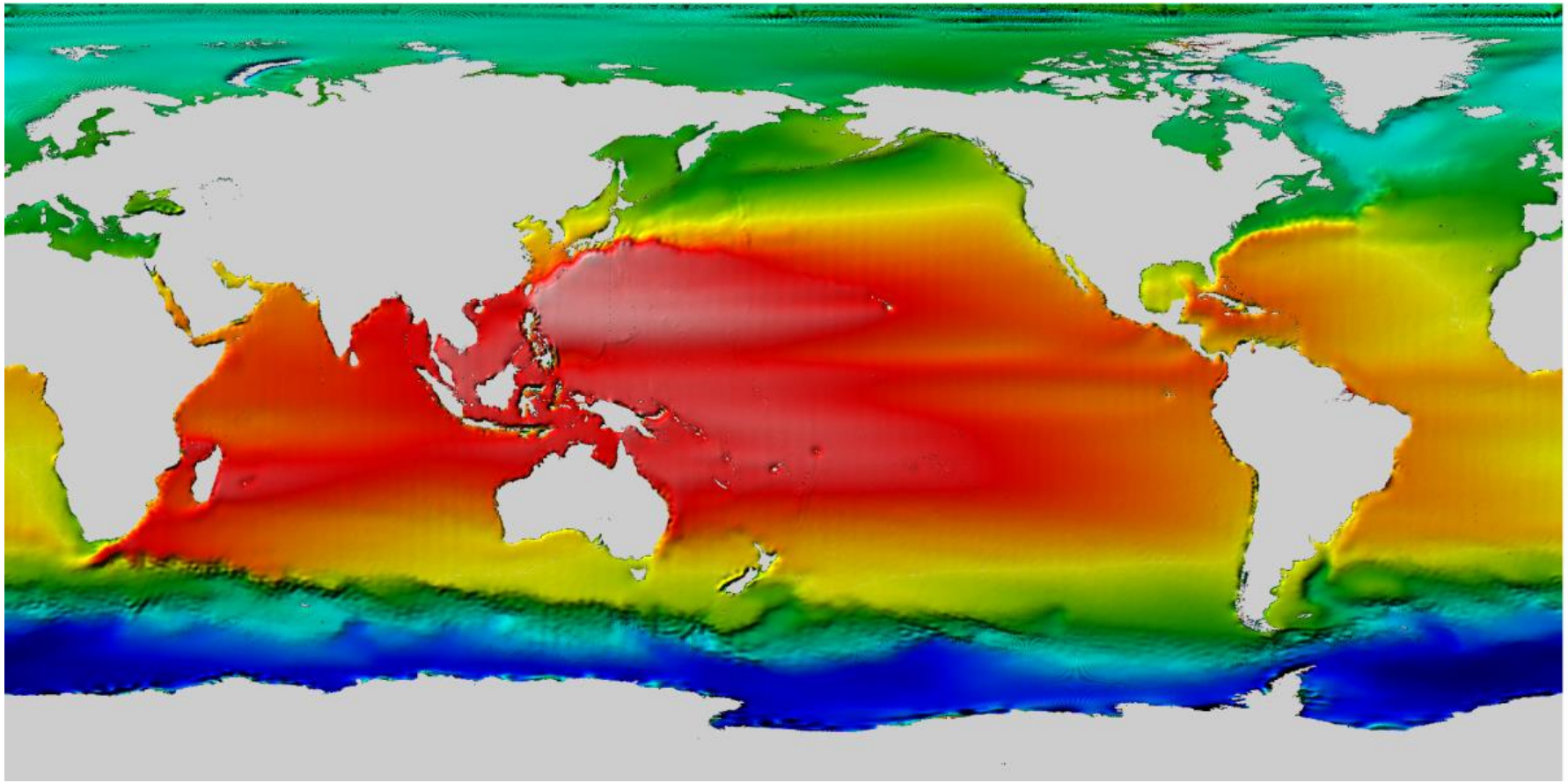
Nelineárna filtrácia

4 iterations



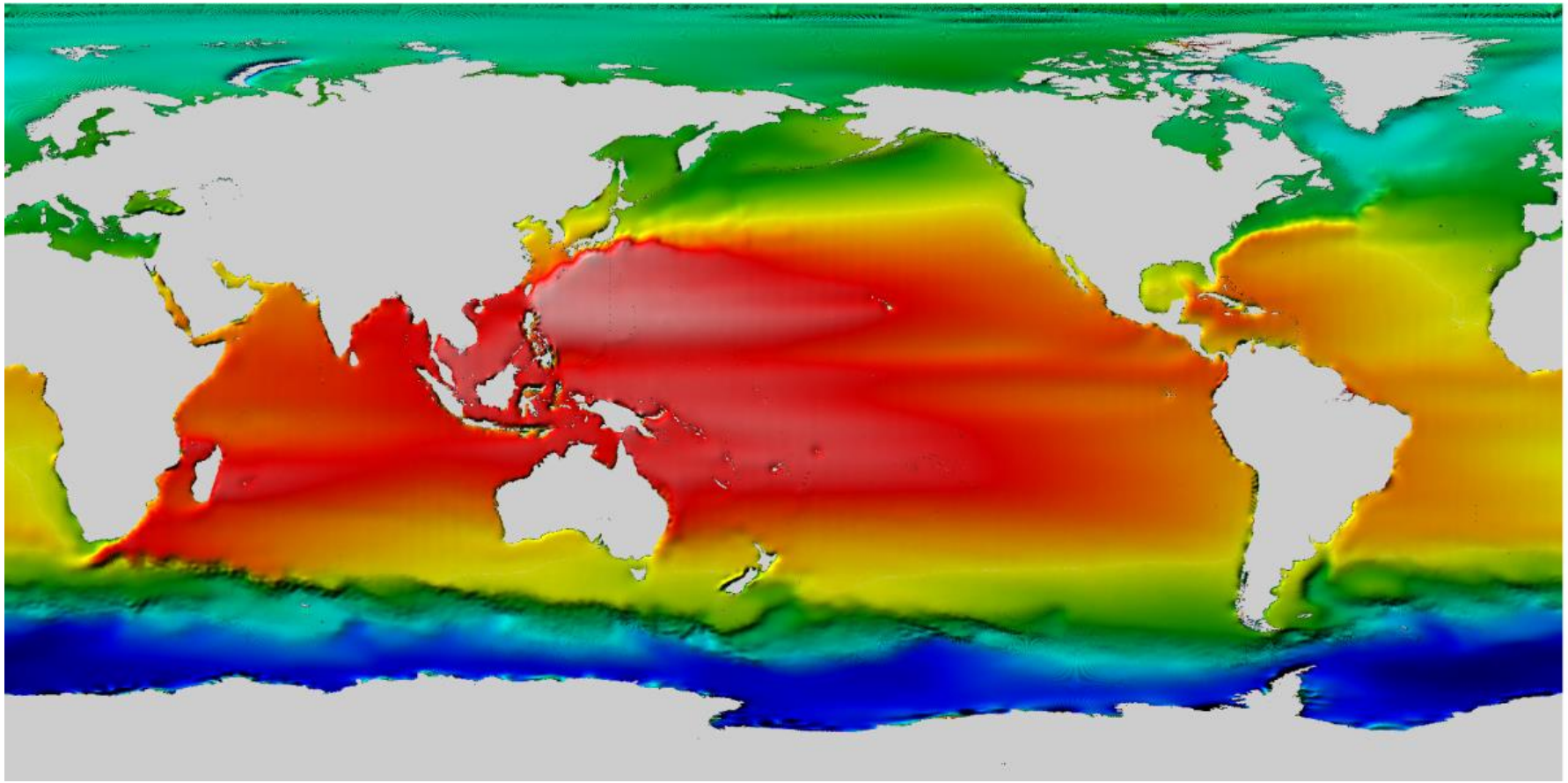
Nelineárna filtrácia

6 iterations



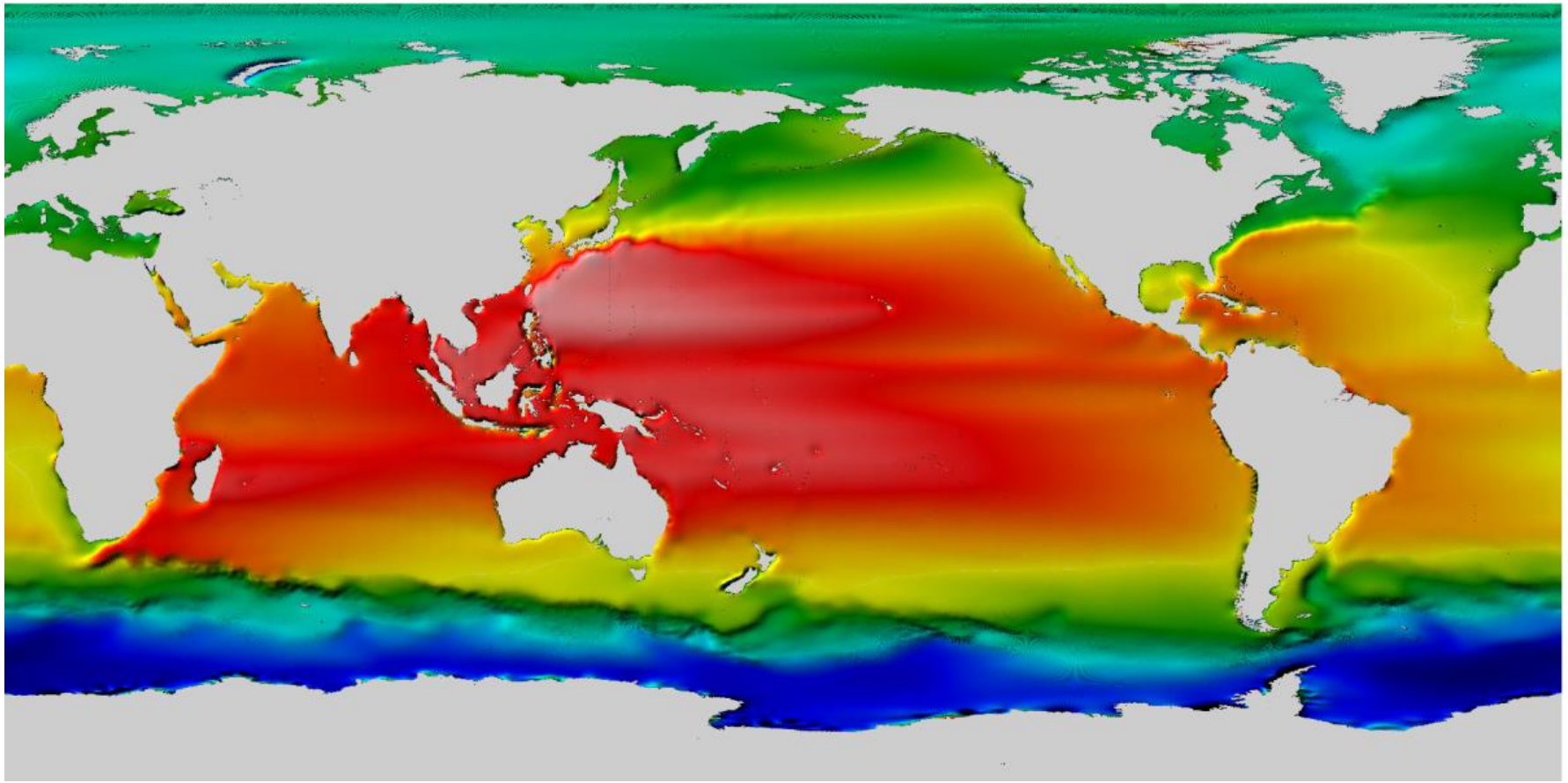
Nelineárna filtrácia

8 iterations



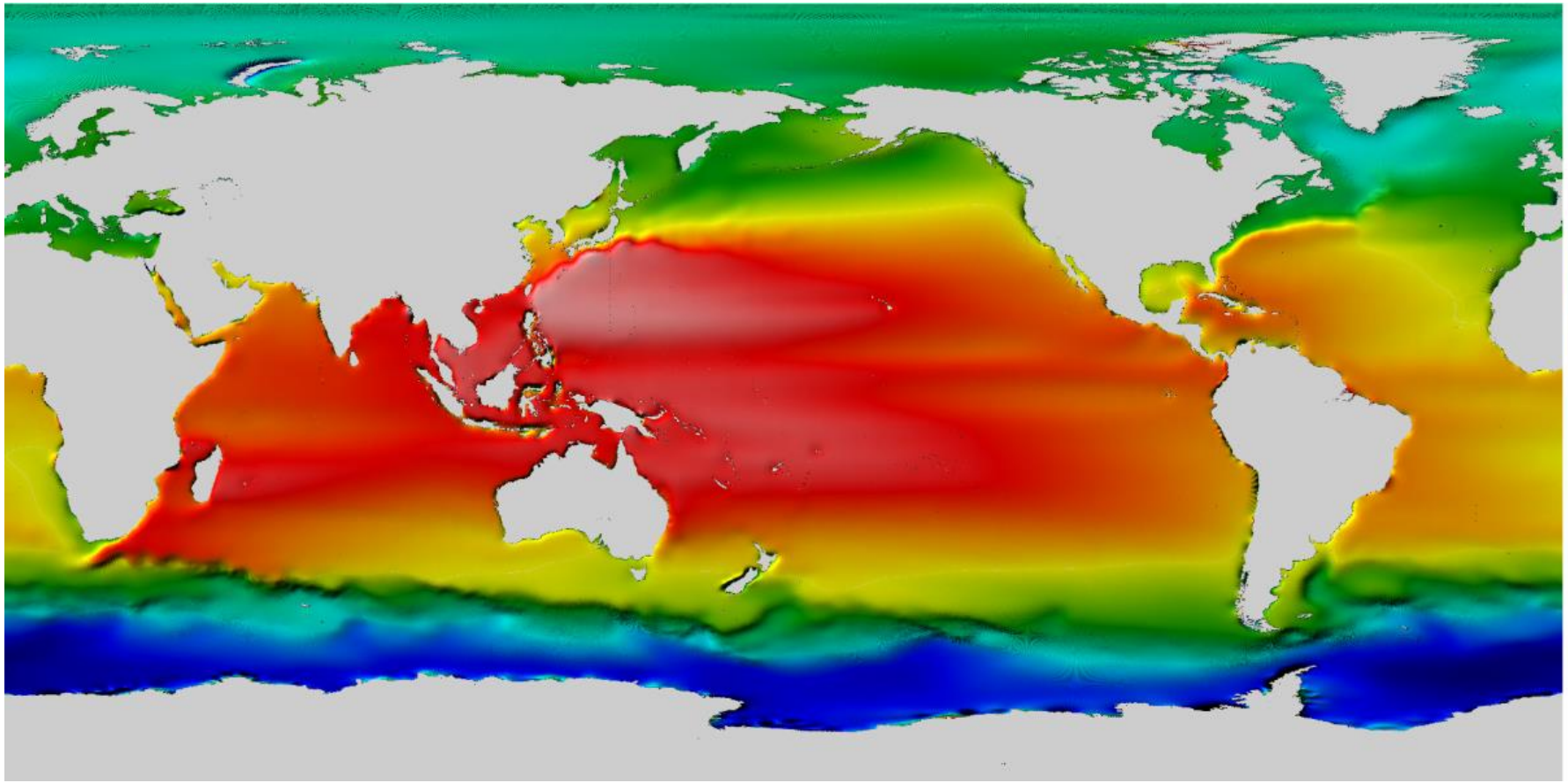
Nelineárna filtrácia

10 iterations



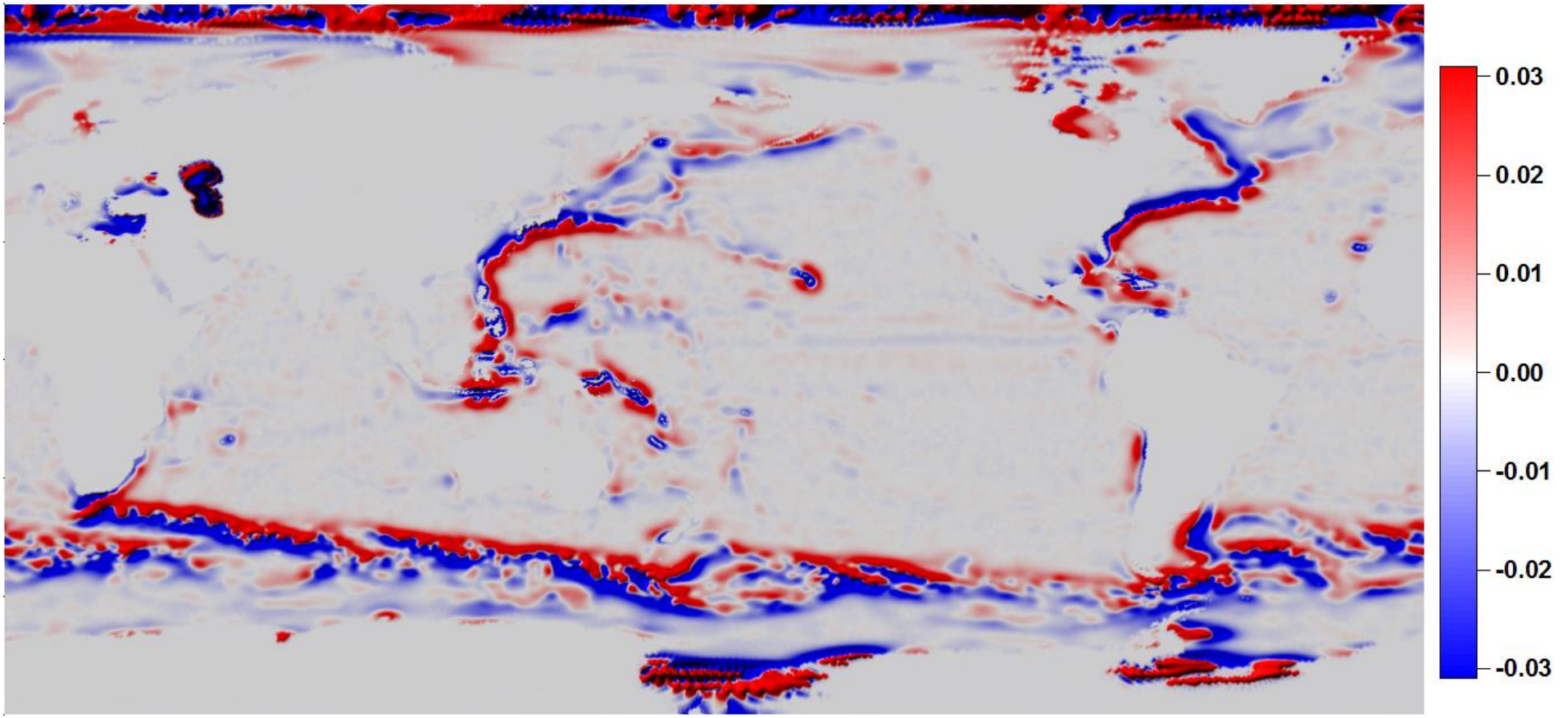
Nelineárna filtrácia

12 iterations

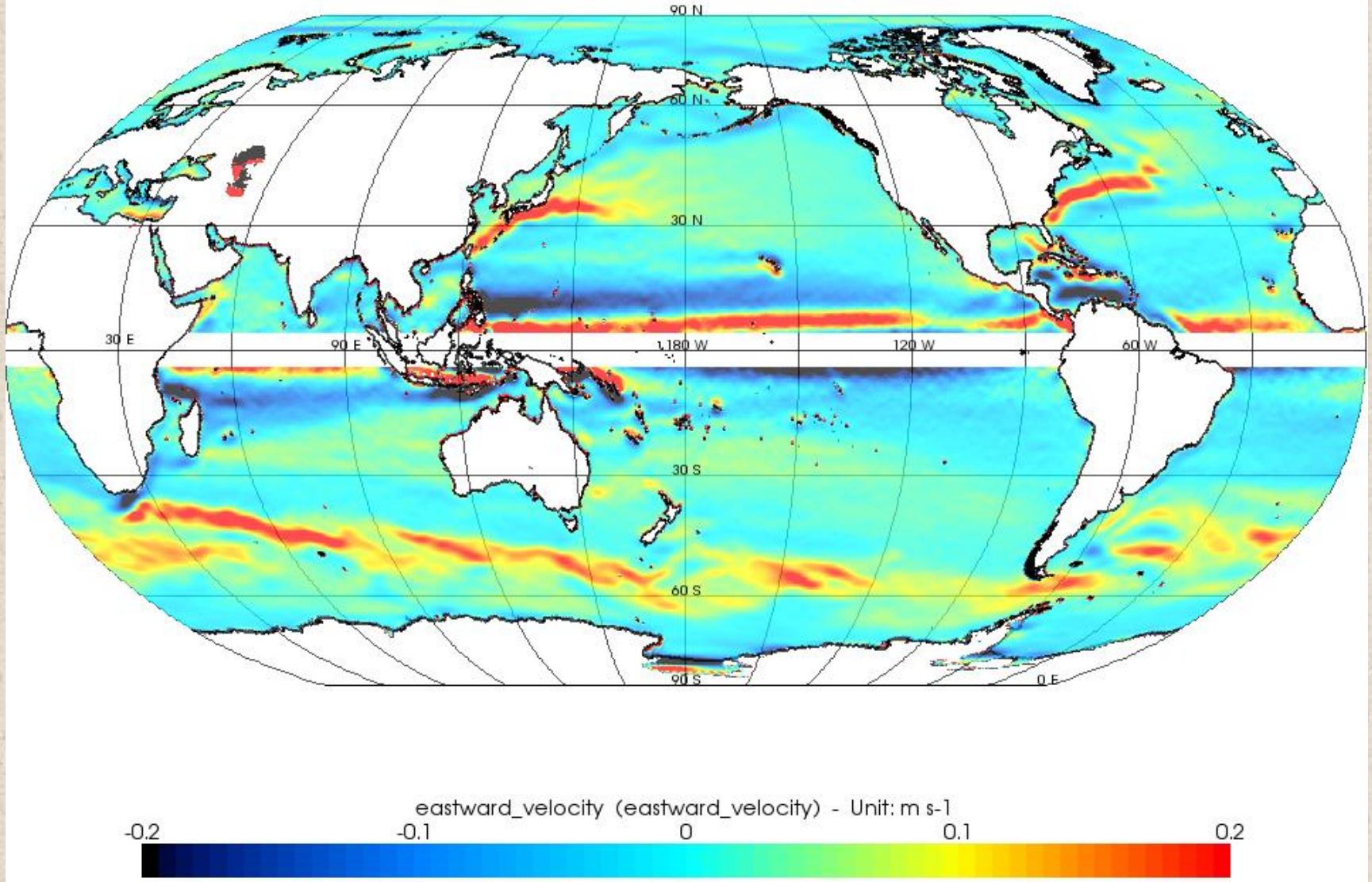


Nelineárna - lineárna difúzia

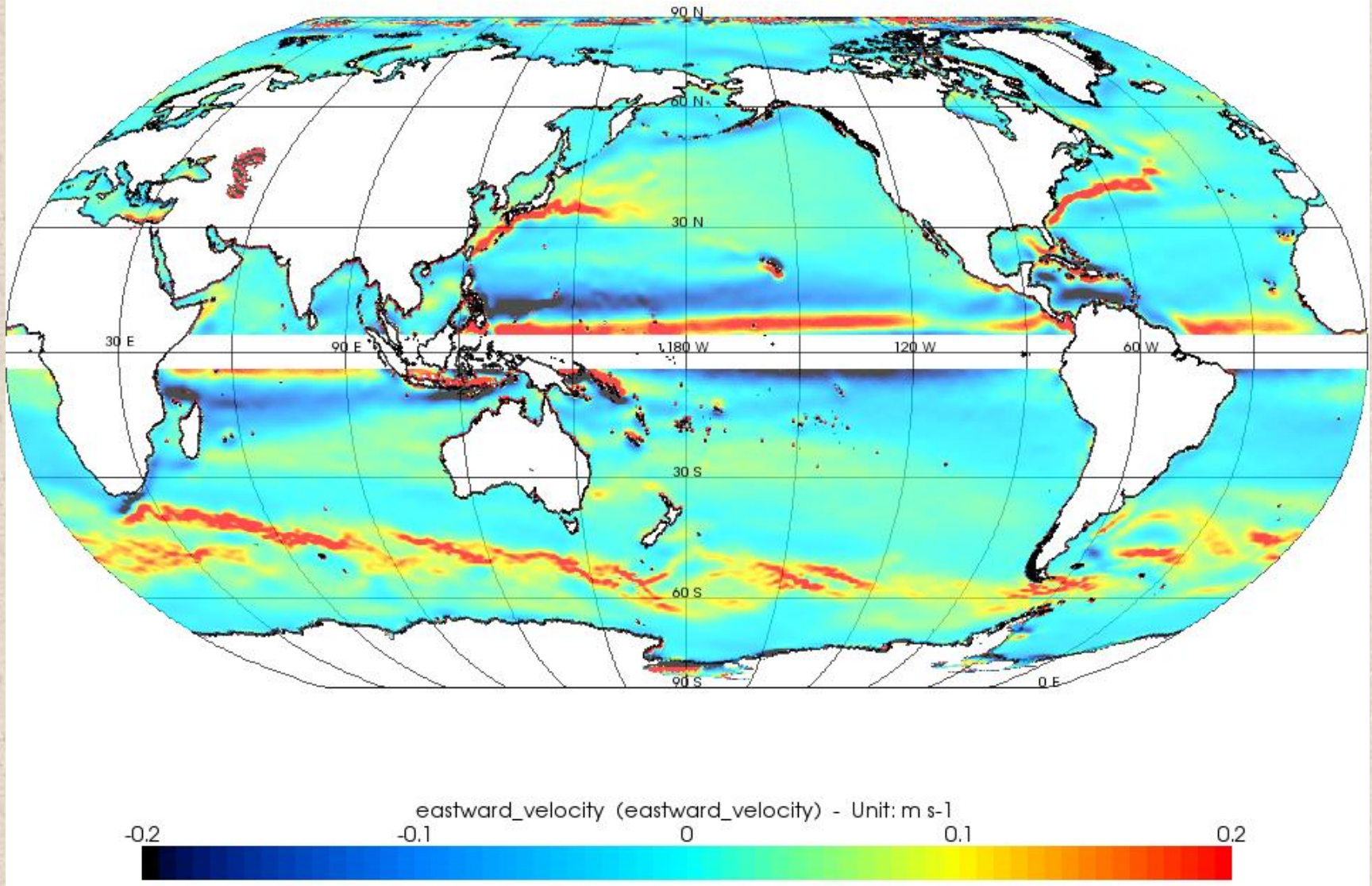
8 iterations



Geostrofické rýchlosti – lineárna difúzia

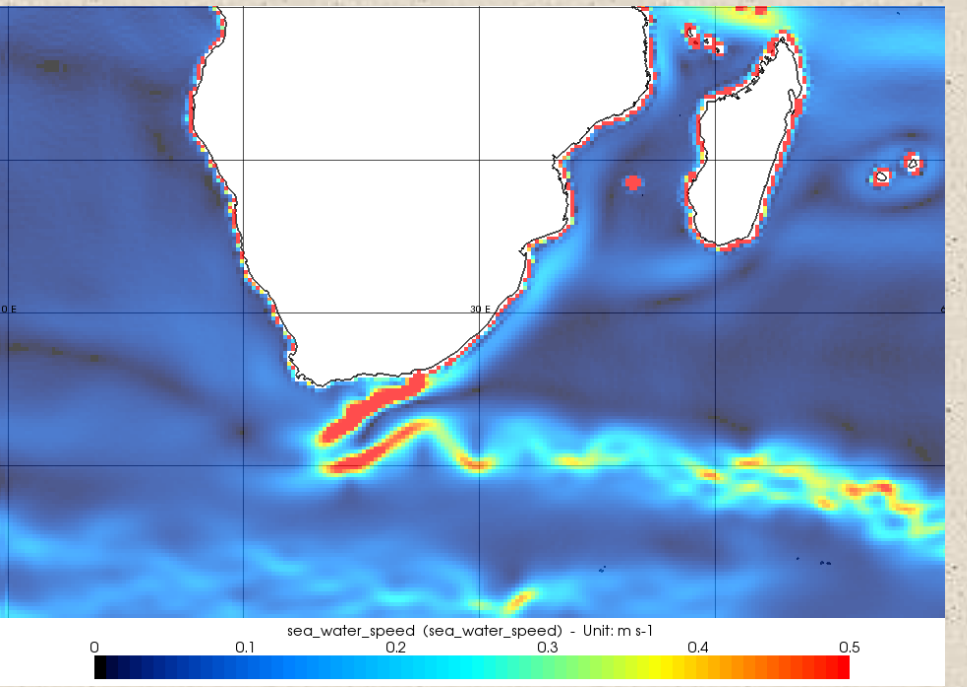


Geostrofické rýchlosti – nelineárna difúzia

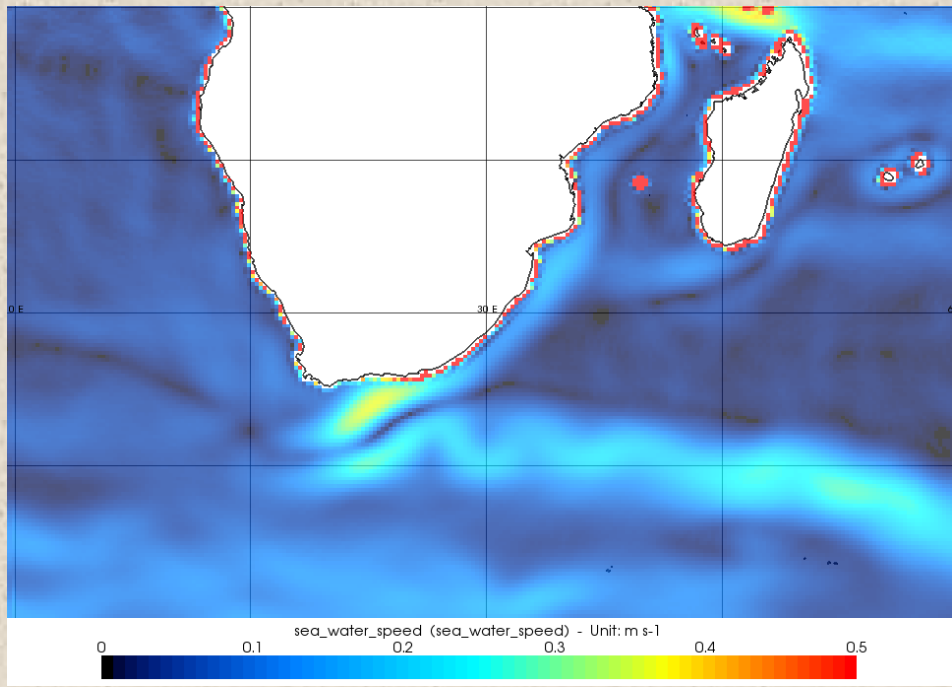


Geostrofické rýchlosti prúdov

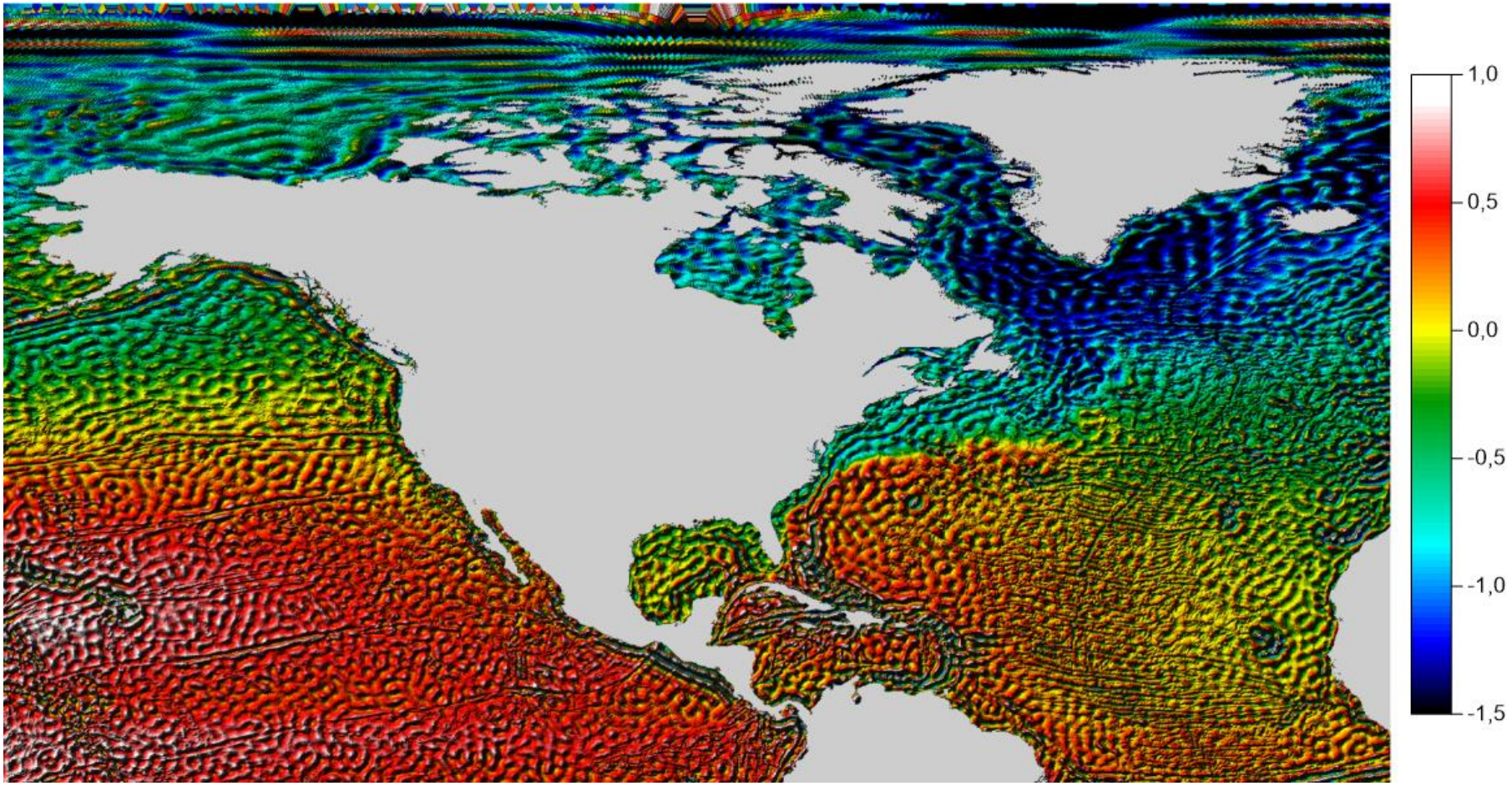
Nelineárna difúzia



Lineárna difúzia



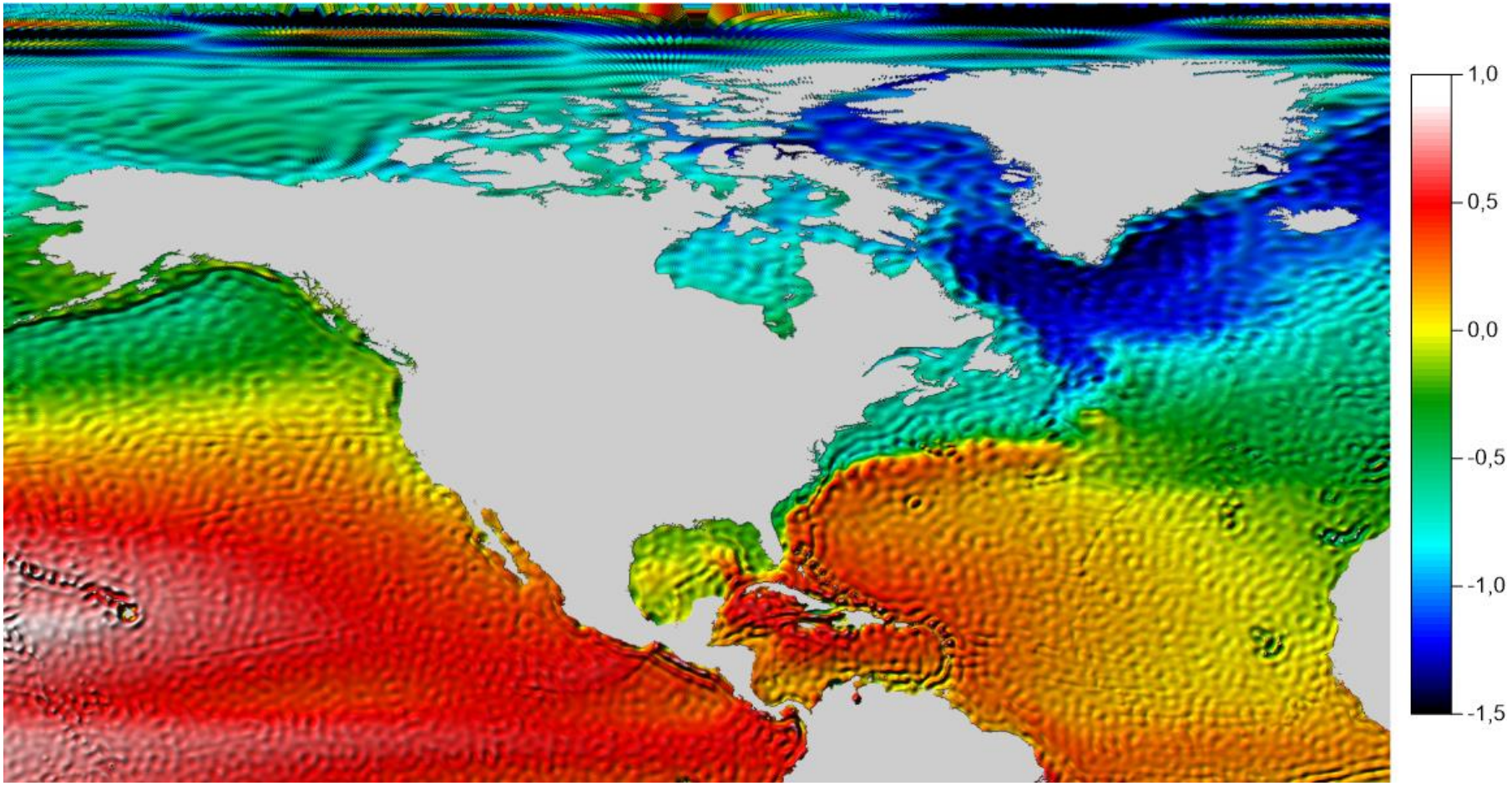
Filtrácia dynamickej topografie oceánov



GO_CONS_GCF_2_DIR_R5

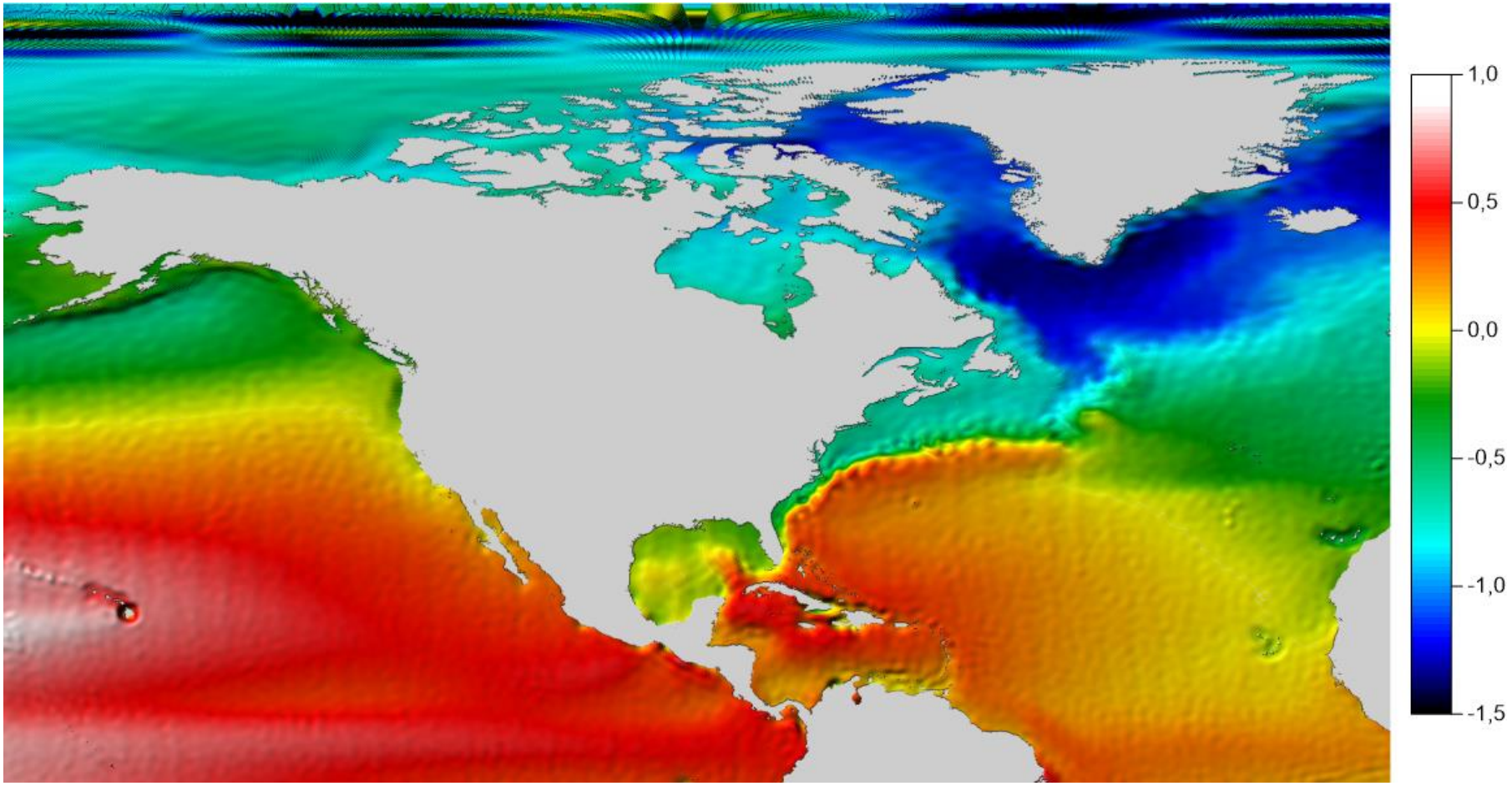
(SH up to d/o 300)

Filtrácia dynamickej topografie oceánov



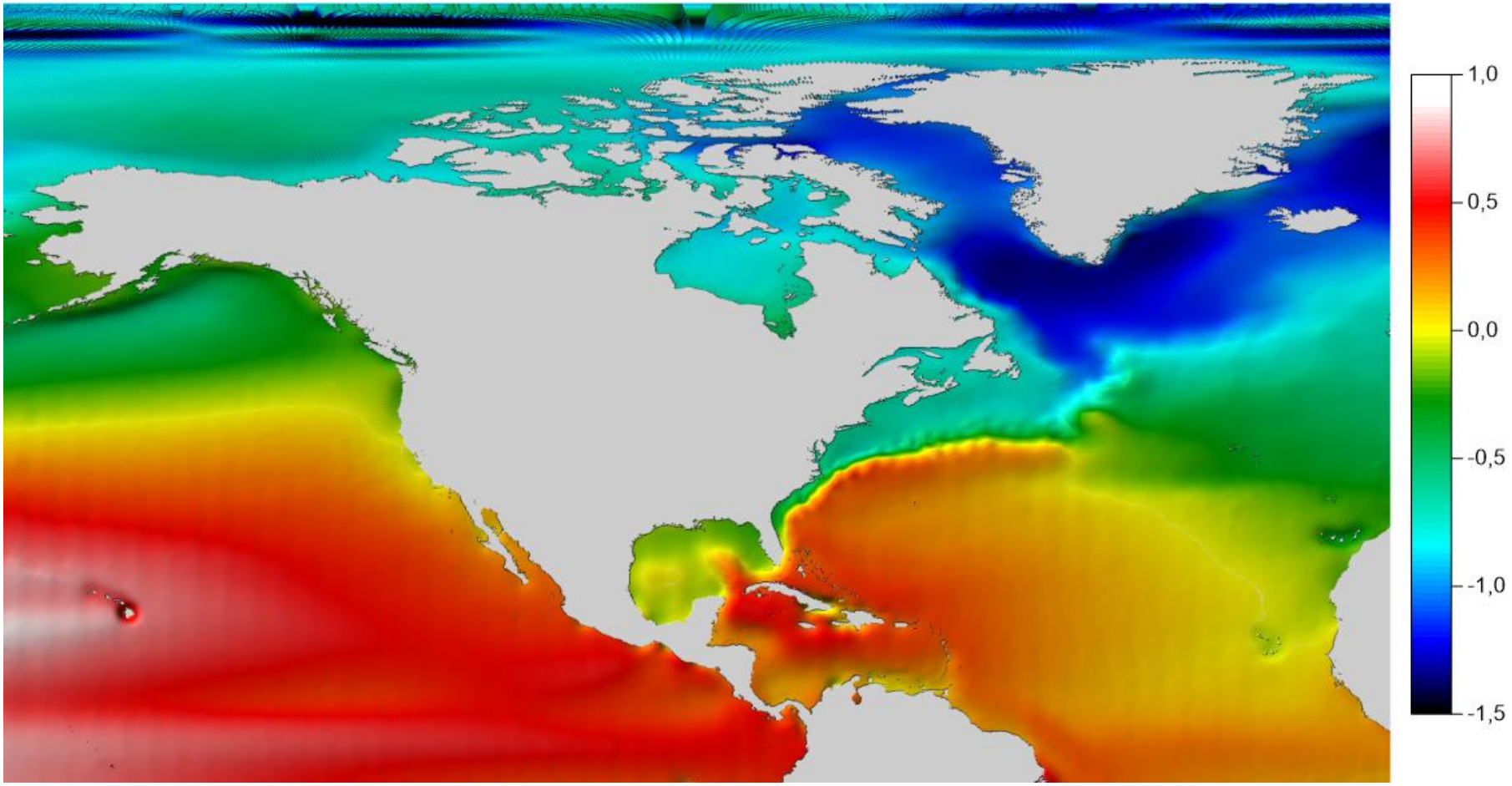
2 iterations

Filtrácia dynamickej topografie oceánov



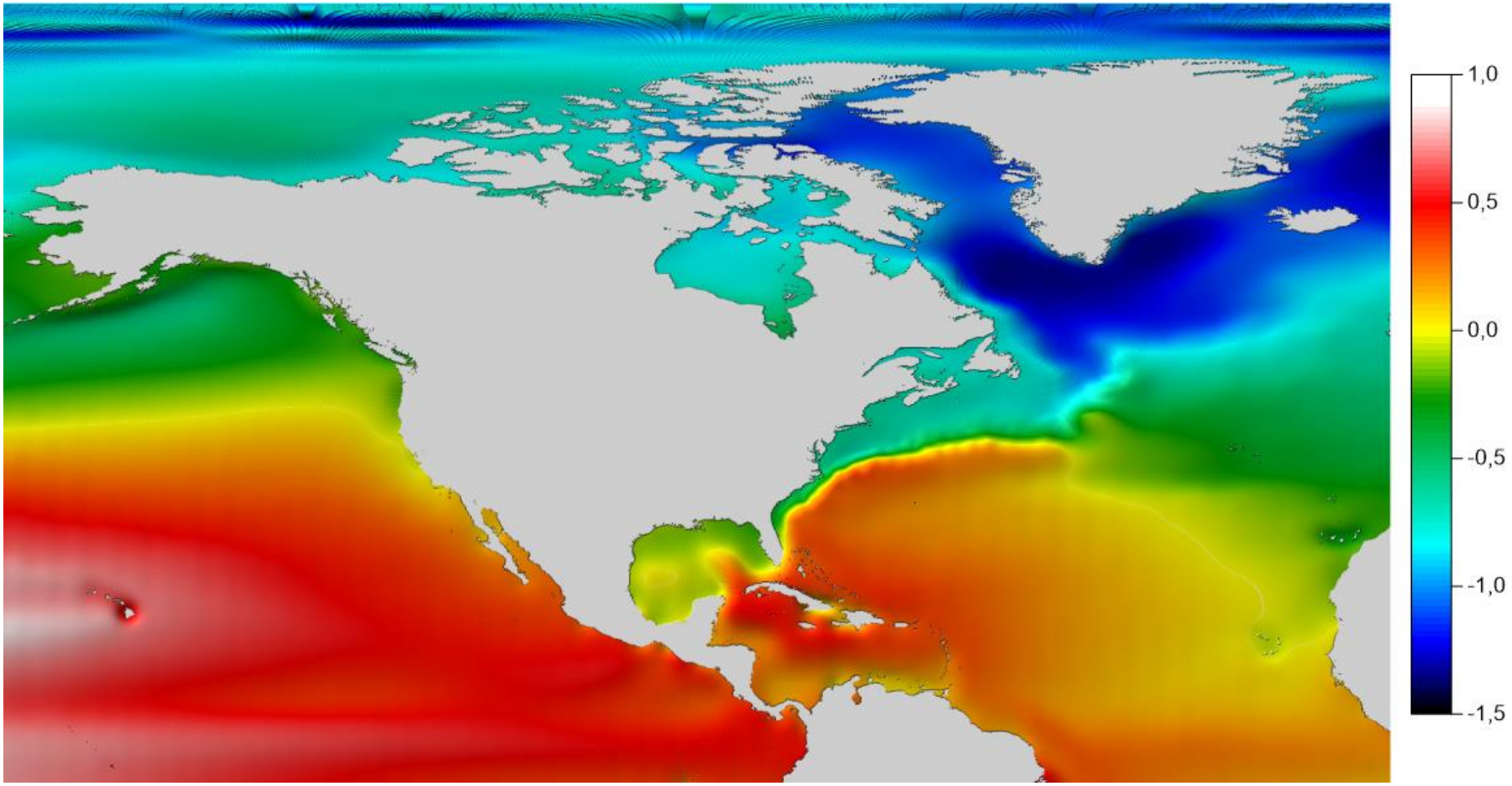
4 iterations

Filtrácia dynamickej topografie oceánov



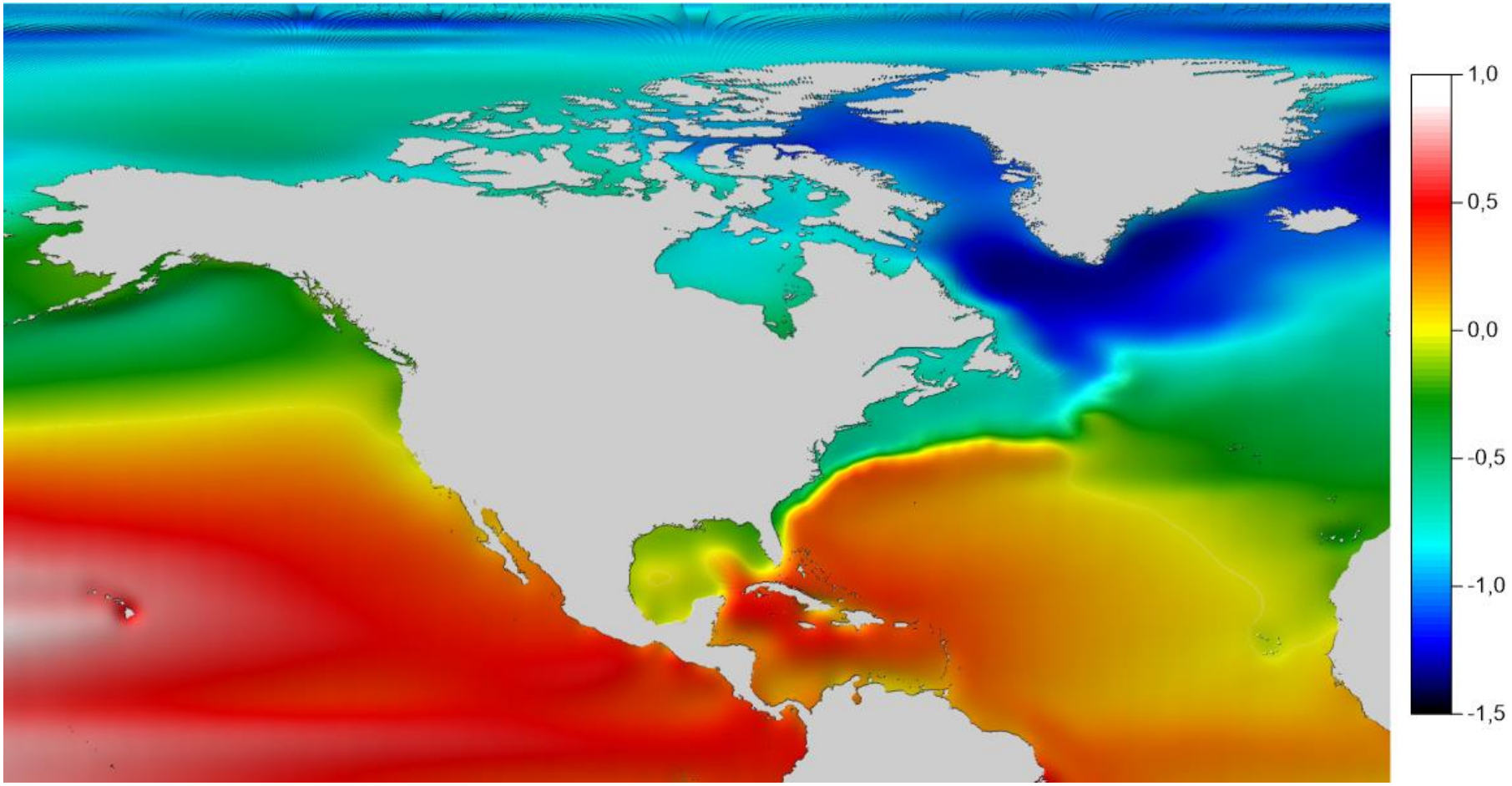
6 iterations

Filtrácia dynamickej topografie oceánov



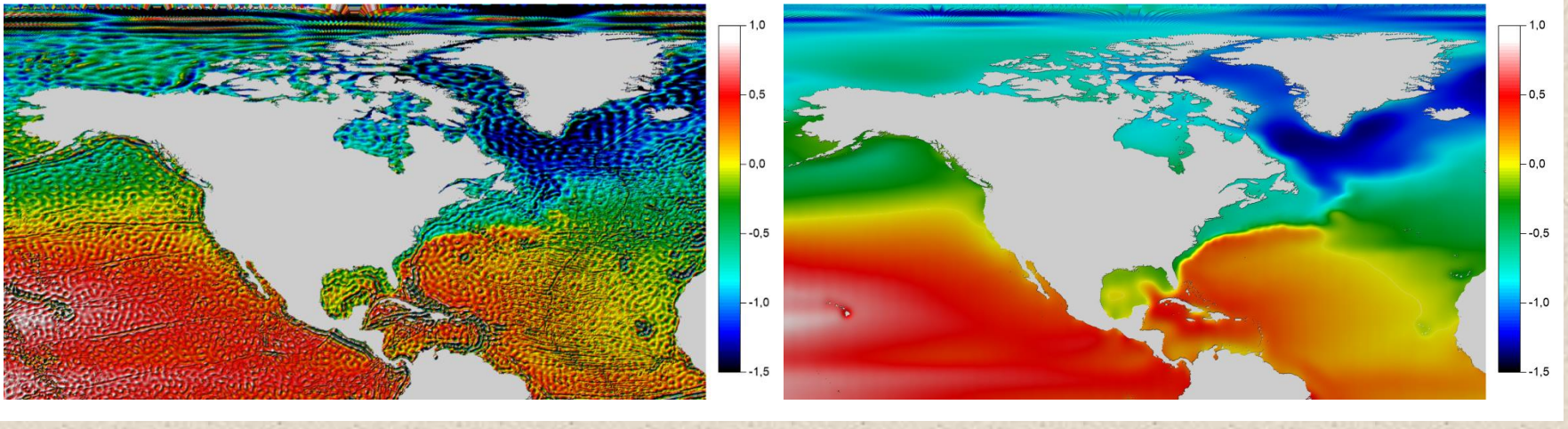
8 iterations

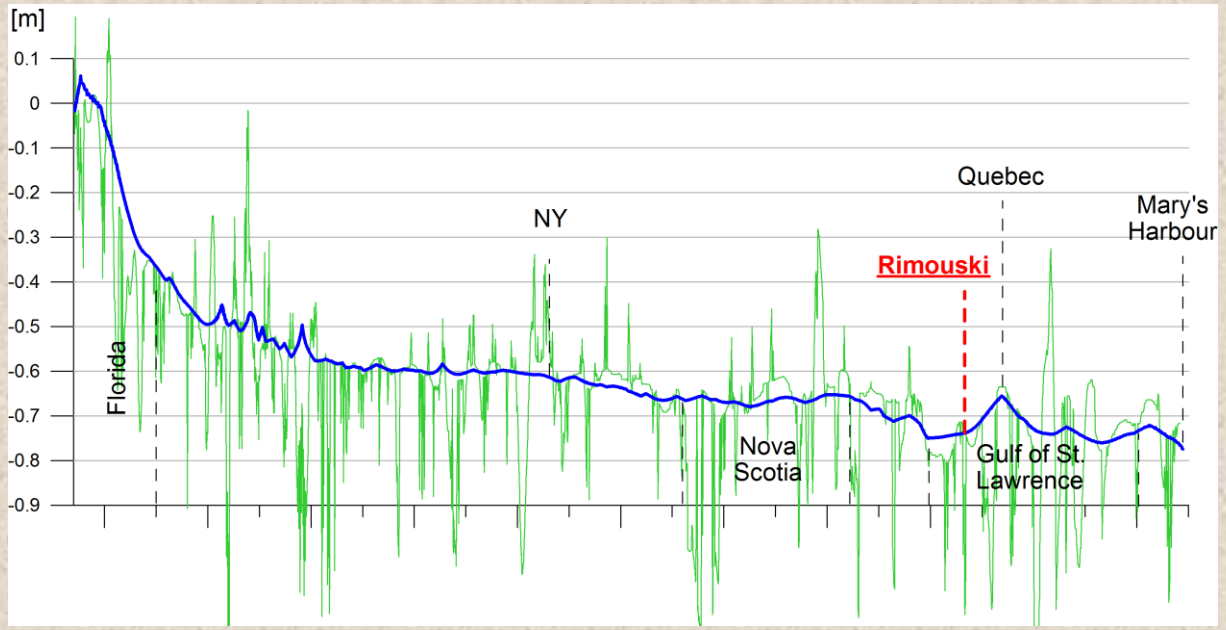
Filtrácia dynamickej topografie oceánov



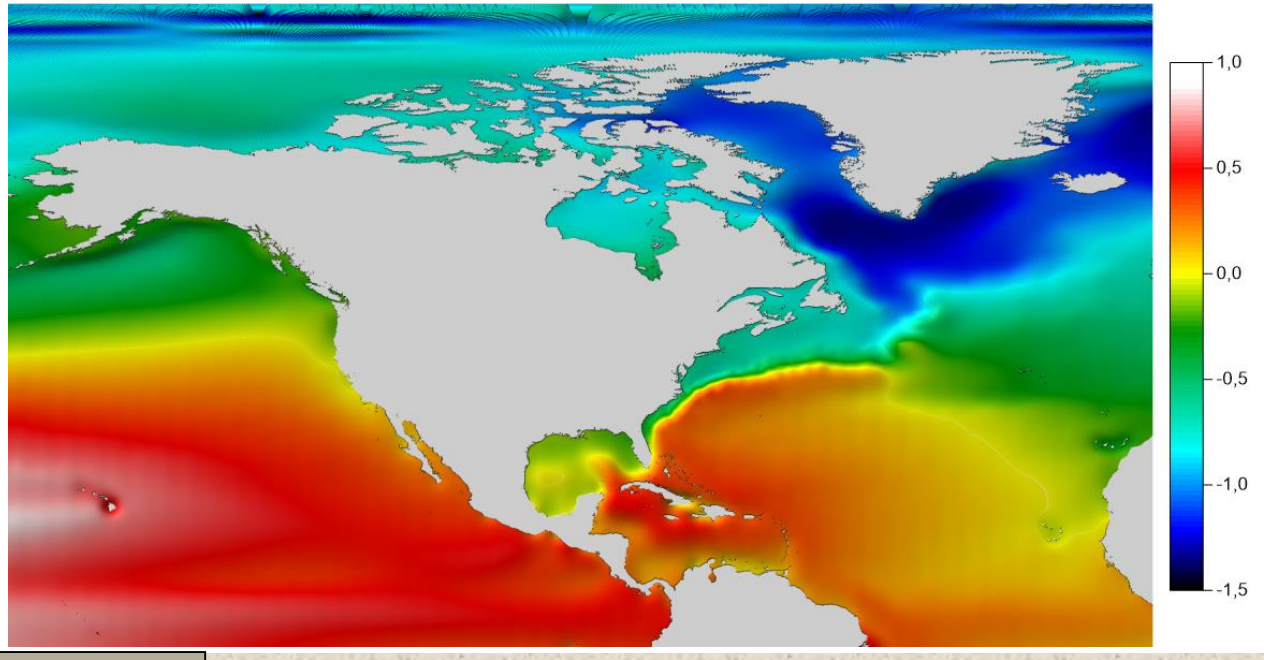
10 iterations

Interpolované hodnoty pozdĺž pobreží (Sev.Am.)

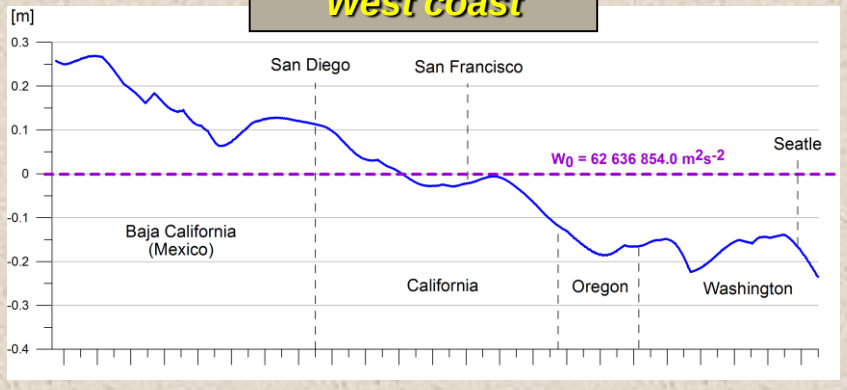




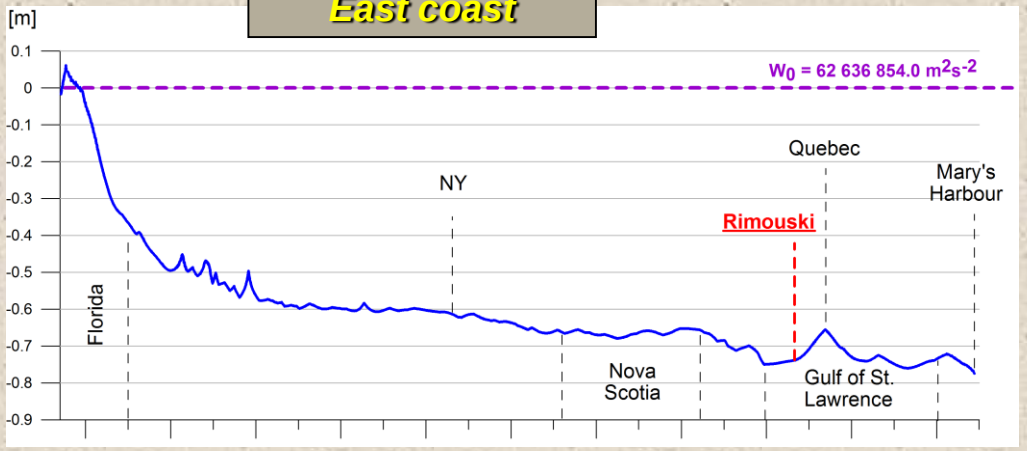
Interpolované hodnoty pozdĺž pobreží (Sev.Am.)



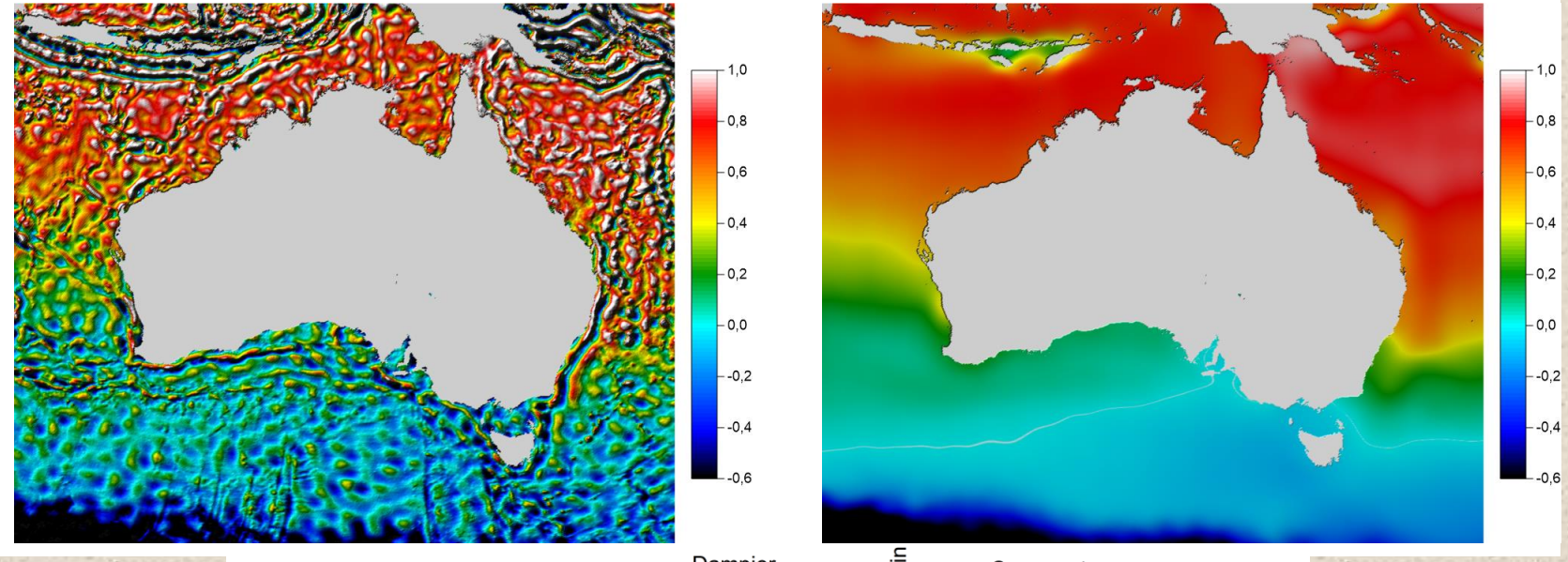
West coast

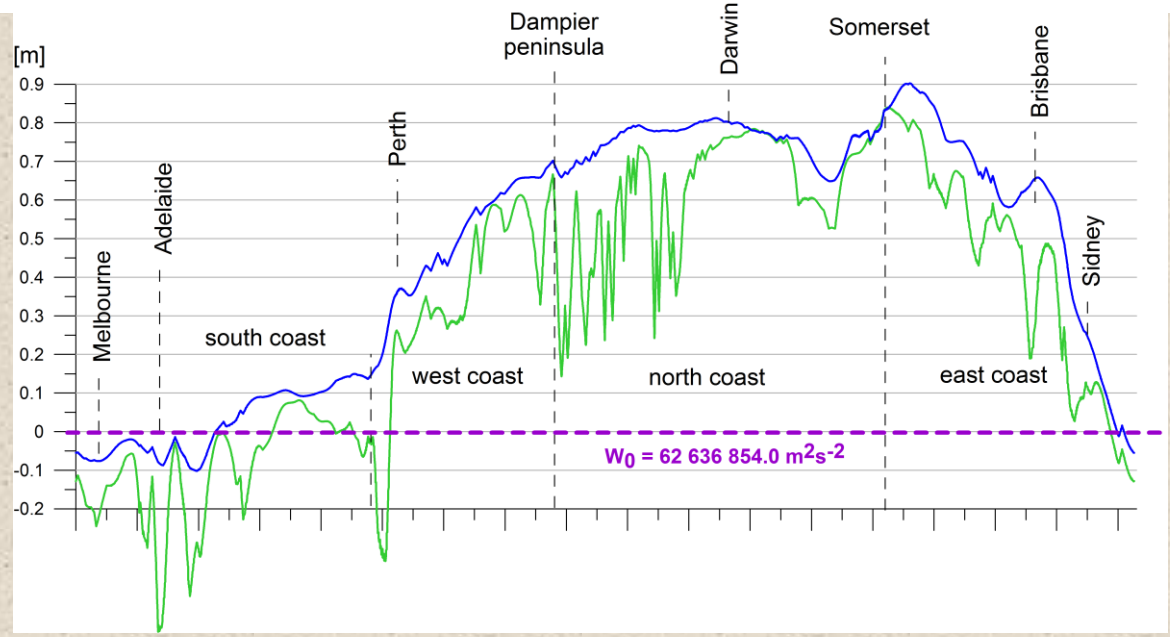


East coast

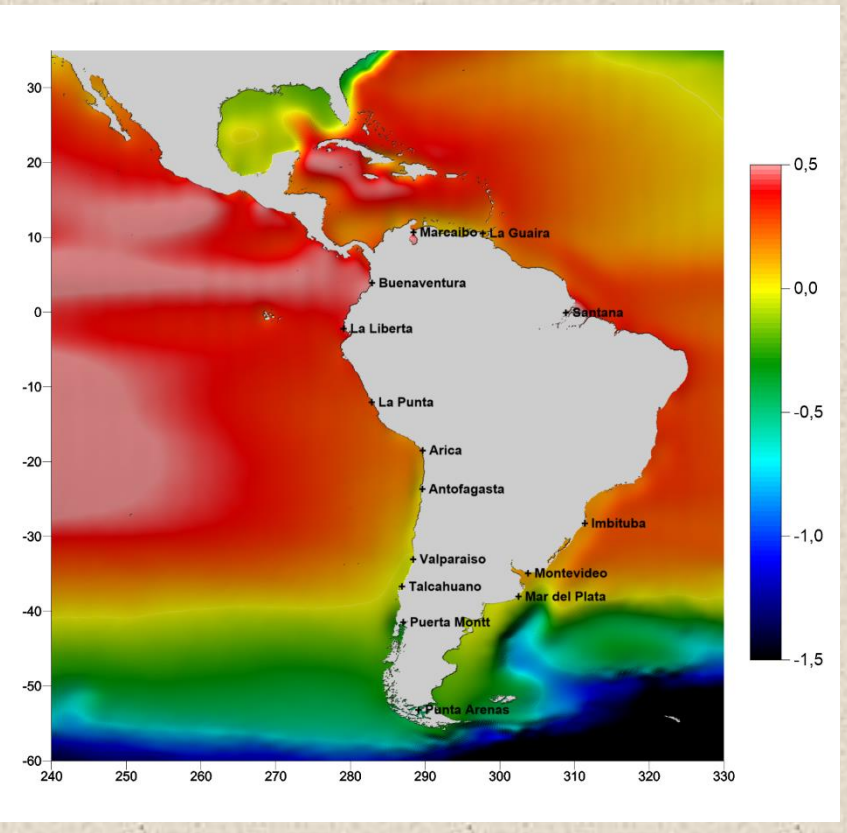


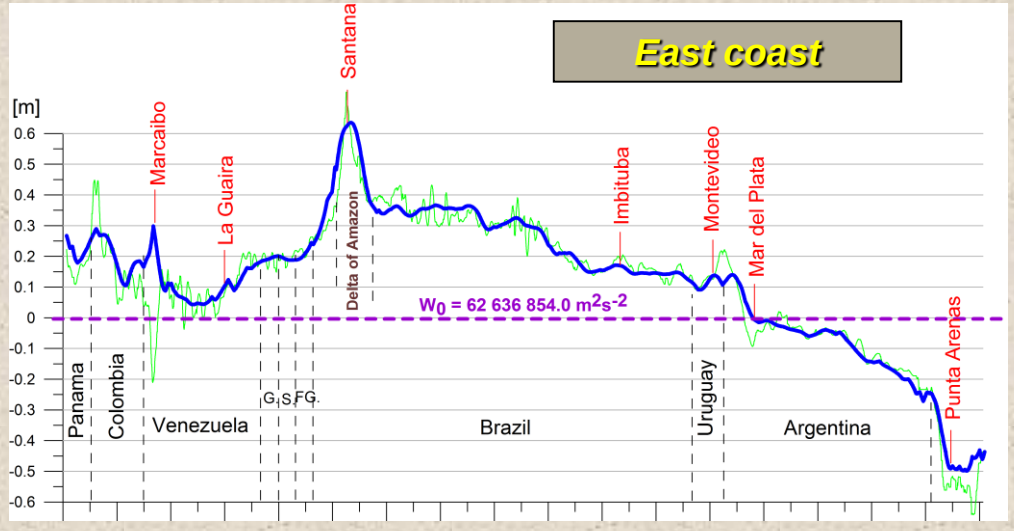
Interpolované hodnoty pozdĺž pobreží (Austrália)

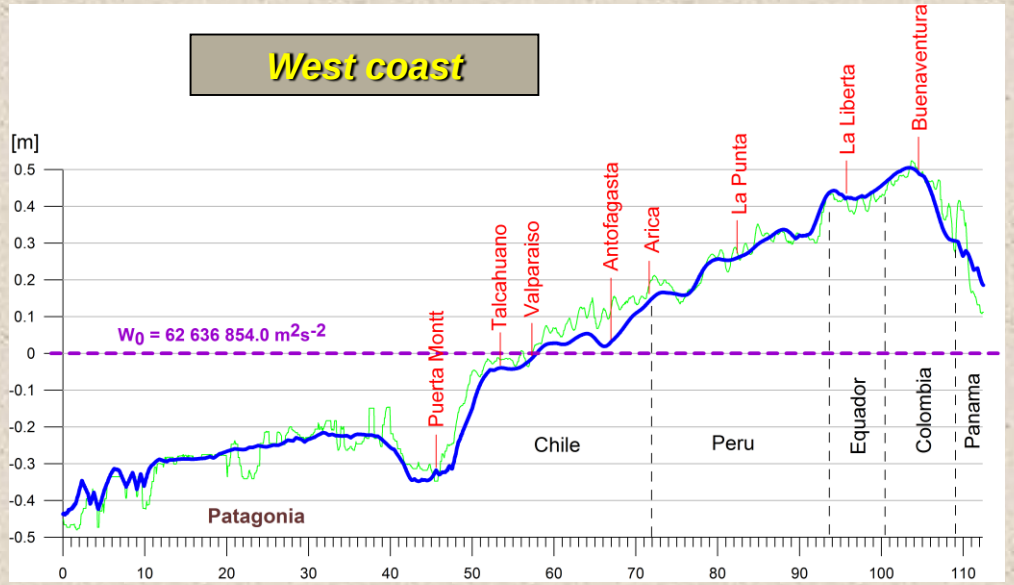




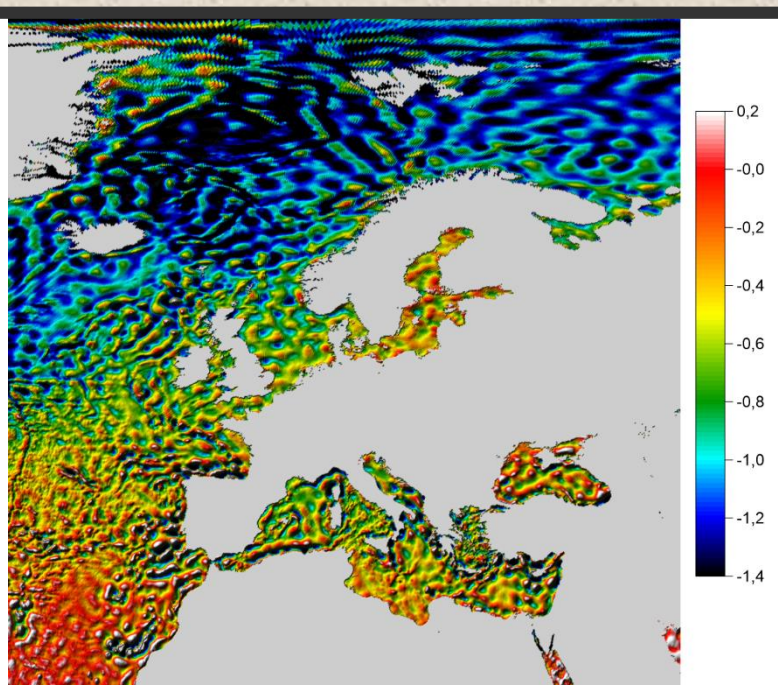
Interpolované hodnoty pozdĺž pobreží (Už.Am.)

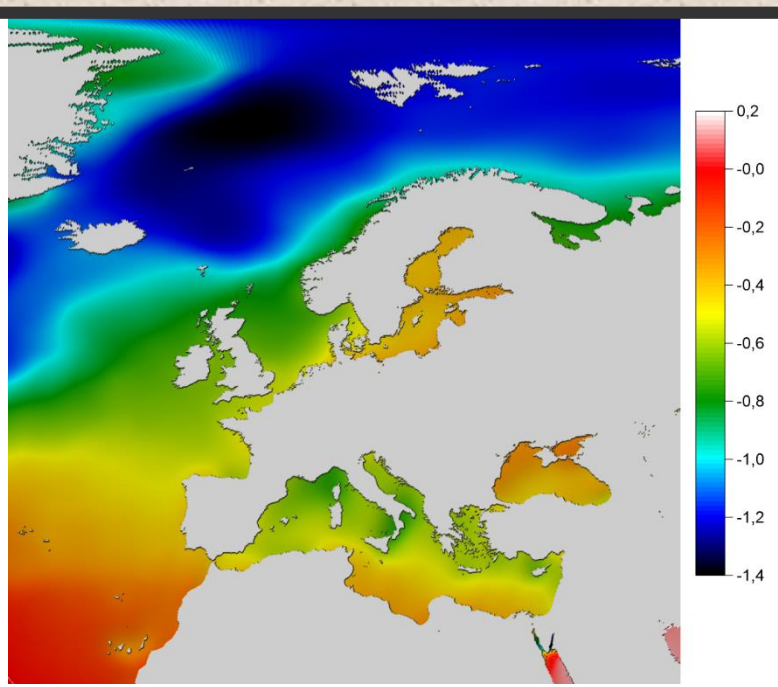


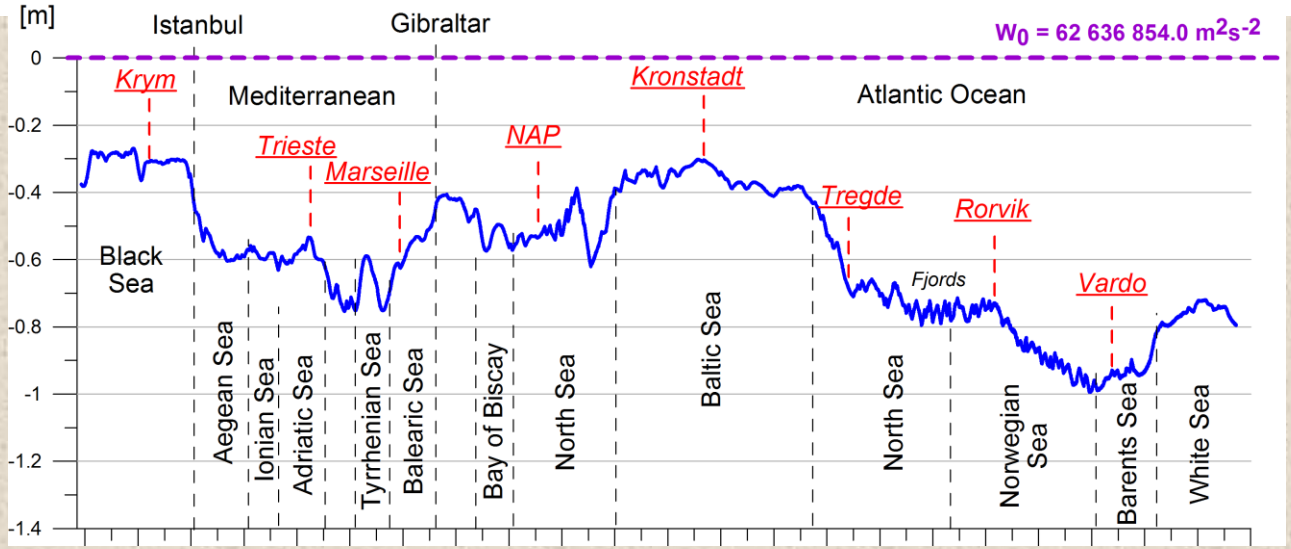




Interpolované hodnoty pozdĺž pobreží (Európa)

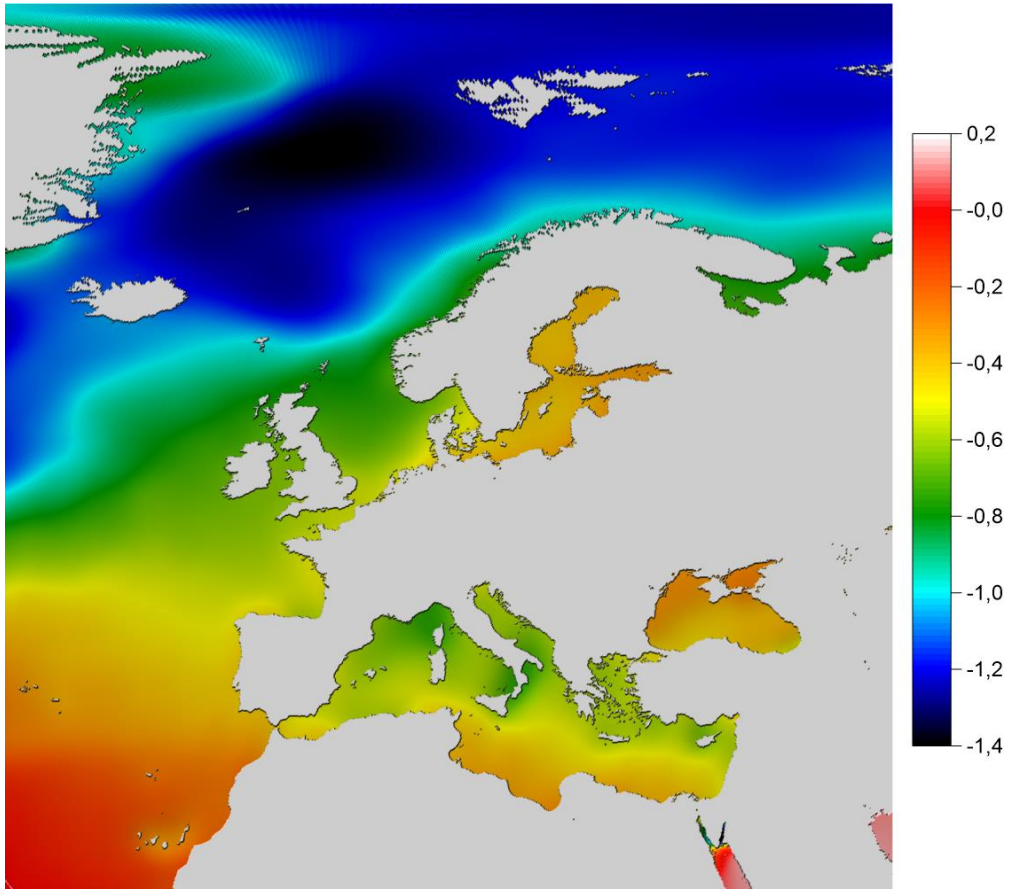






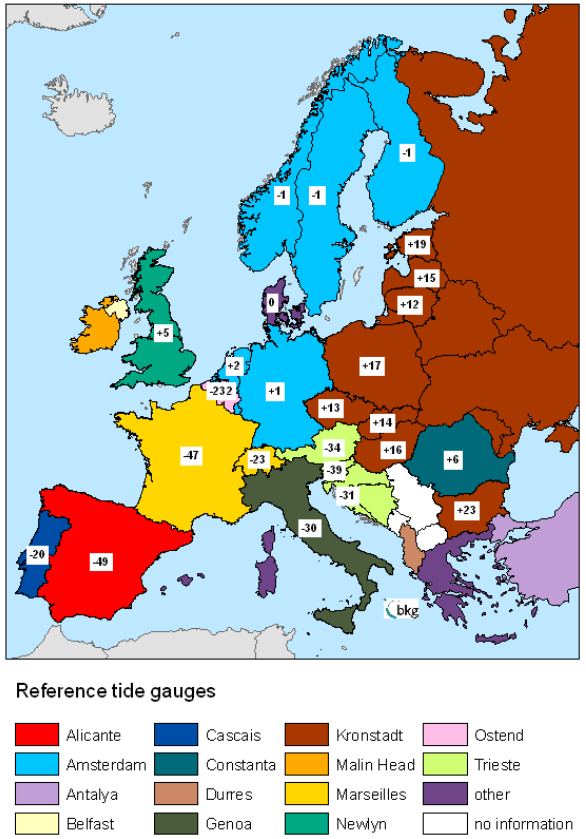
Porovnanie s výškovými systémami v Európe

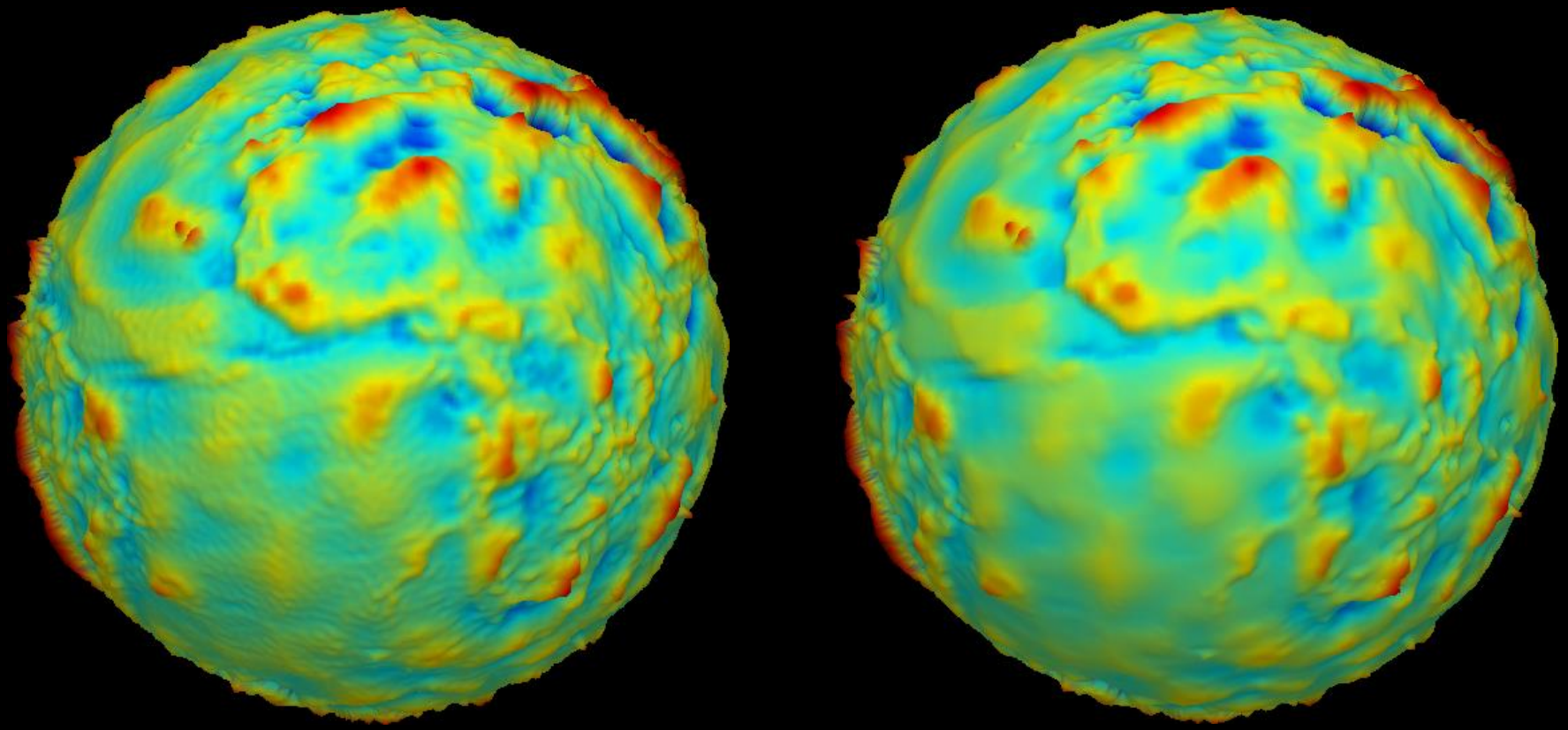
Satellite-only MDT



Relations between European national height reference systems and EVRF2007

(source: http://www.bkg.bund.de)





Vďaka za pozornosť