Filtrácia dát na povrchu Zeme a na orbitách družicových misií

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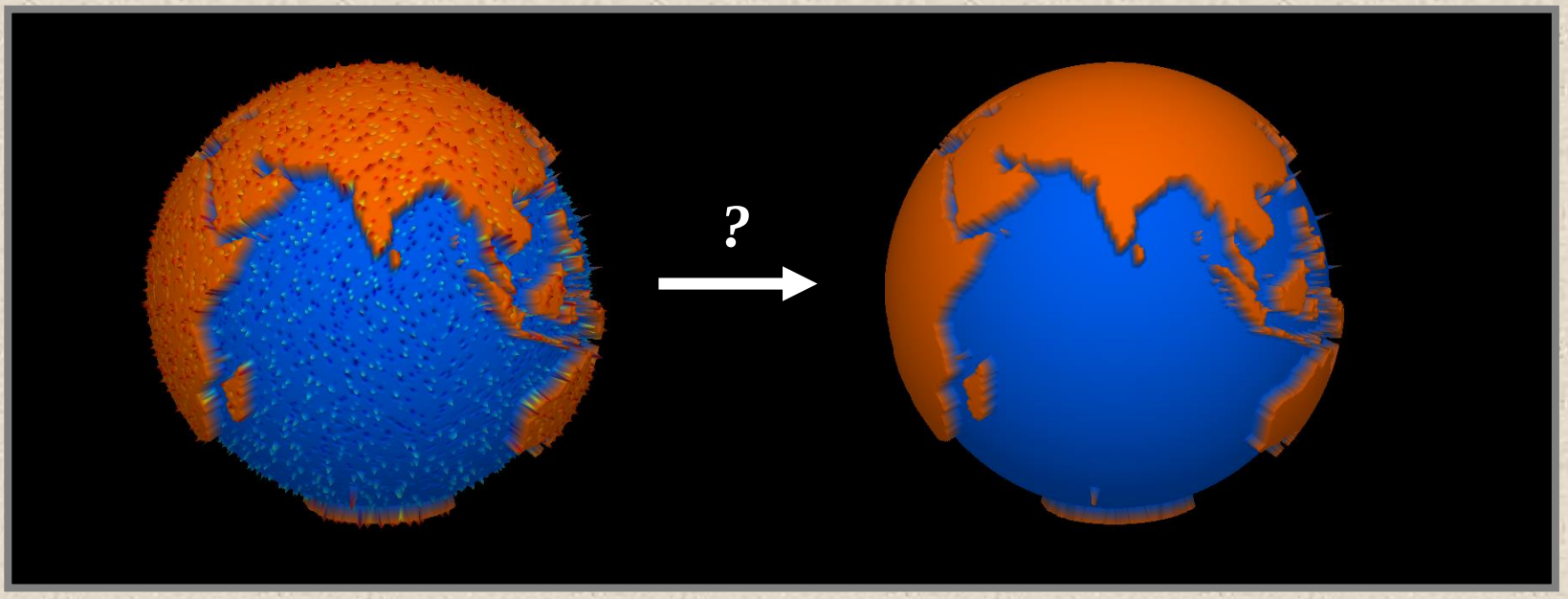


Obsah

- **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*

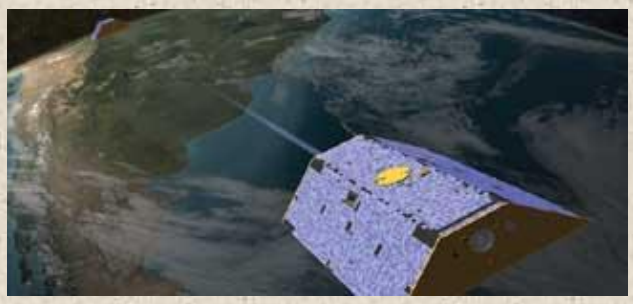
⇒ **merania sú ovplyvnené šumom**

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)**

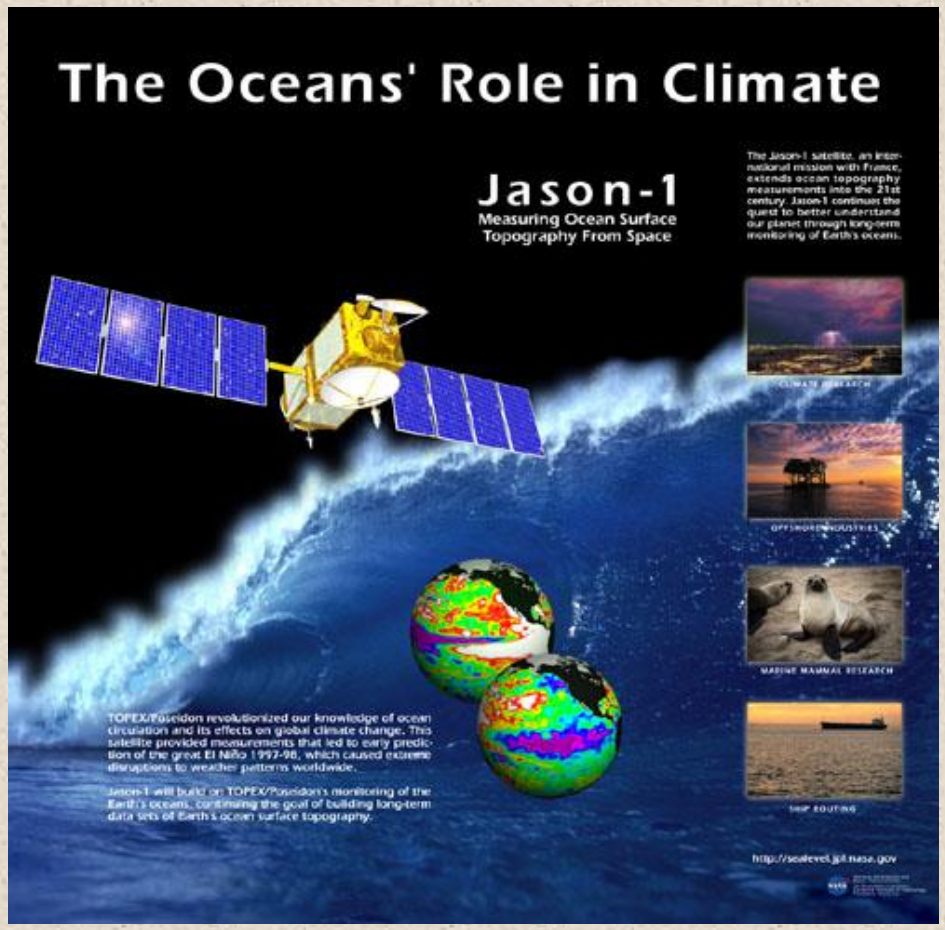
Družicová altimetria – variácia hladiny oceánov

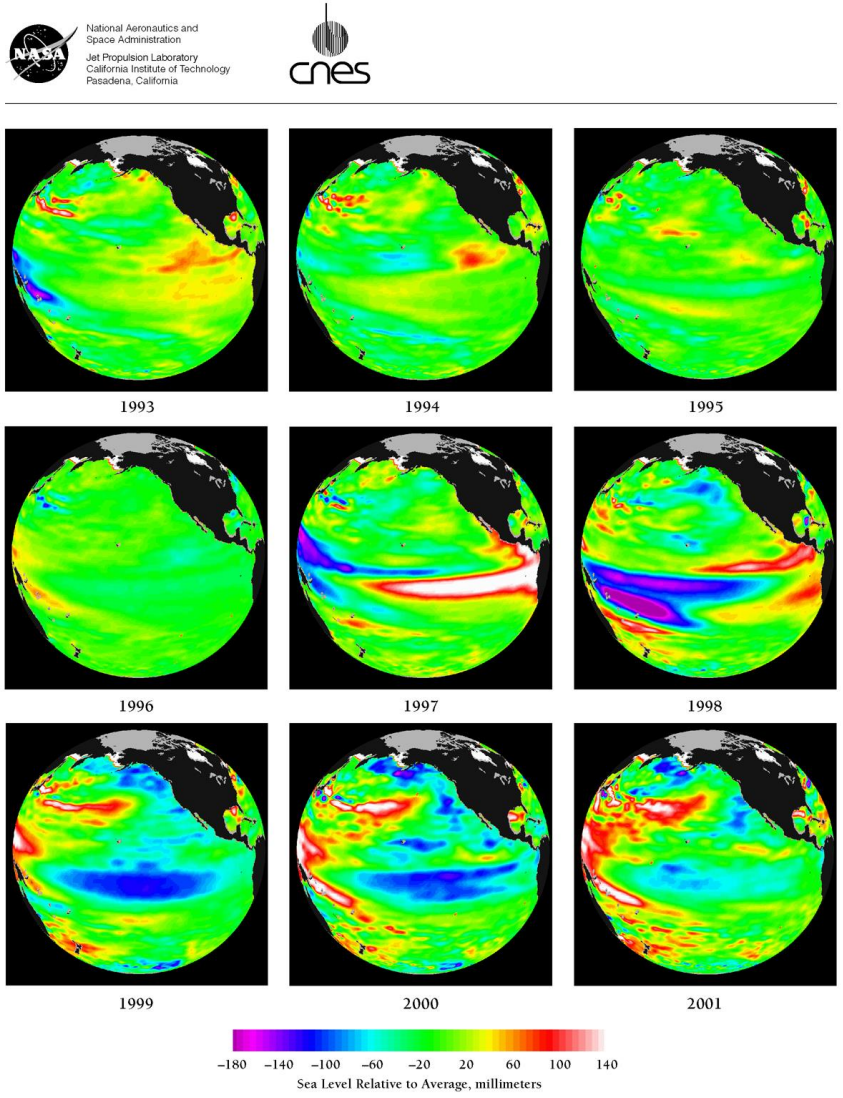
- **Seasat** (1978), **Geosat** (1985), **TOPEX-Poseidon** (1992-2006)
- **ERS-2, Jason-1, ENVISAT, Jason-2, ...**

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)**

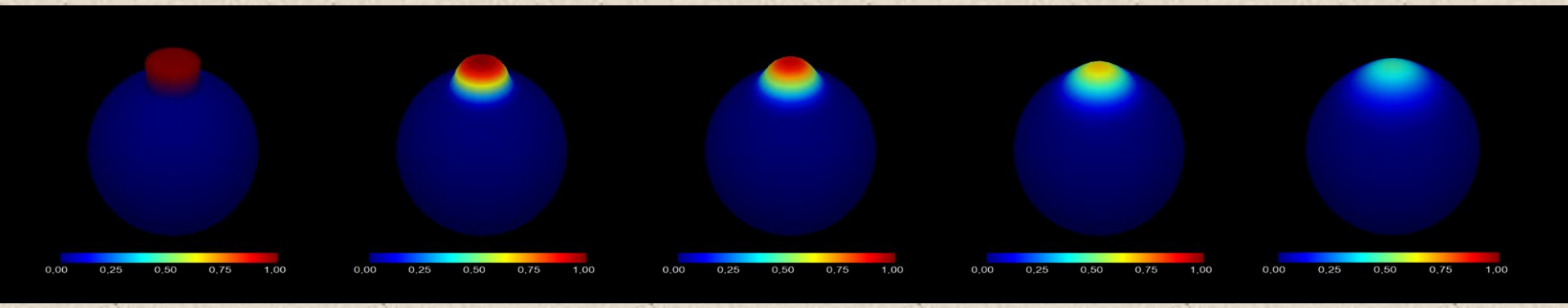
Rovnica vedenia tepla na ploche

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

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

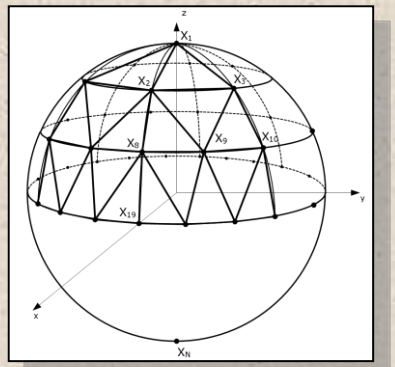
$u(x,t)$ ***– skalárna funkcia daná na ploche***

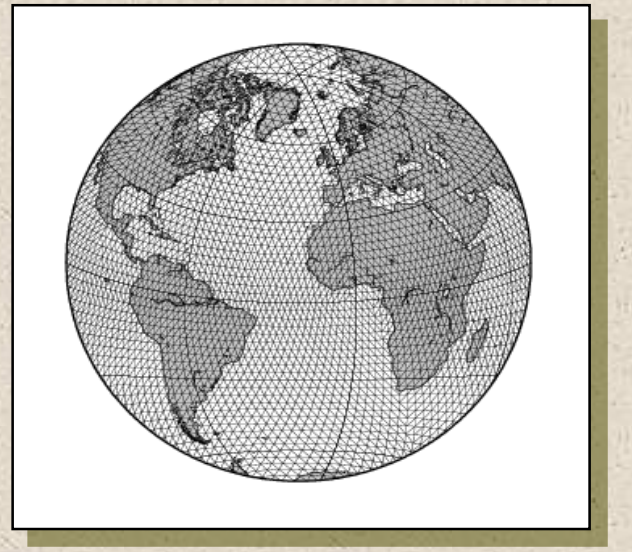
- ***vstupné zašumené dáta ako počiatočná podmienka:*** $u(x,0) = u_o(x)$



Numerické riešenie metódou konečných objemov

Triangulácia uzavretej plochy

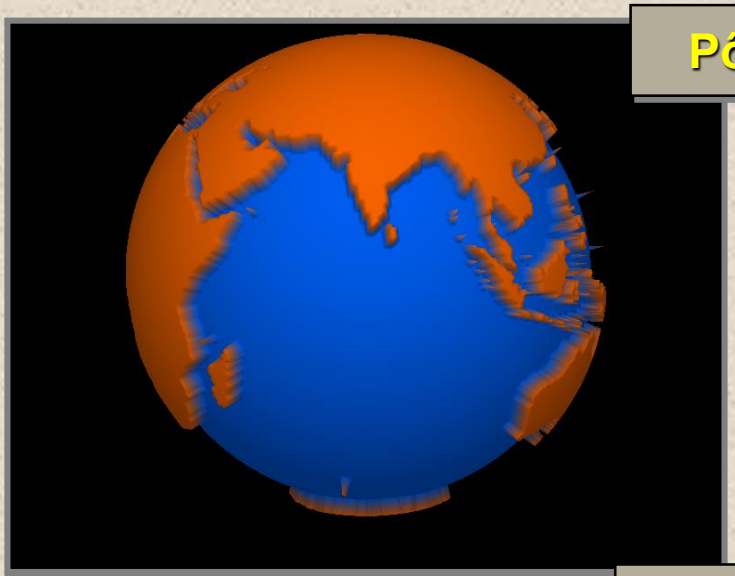




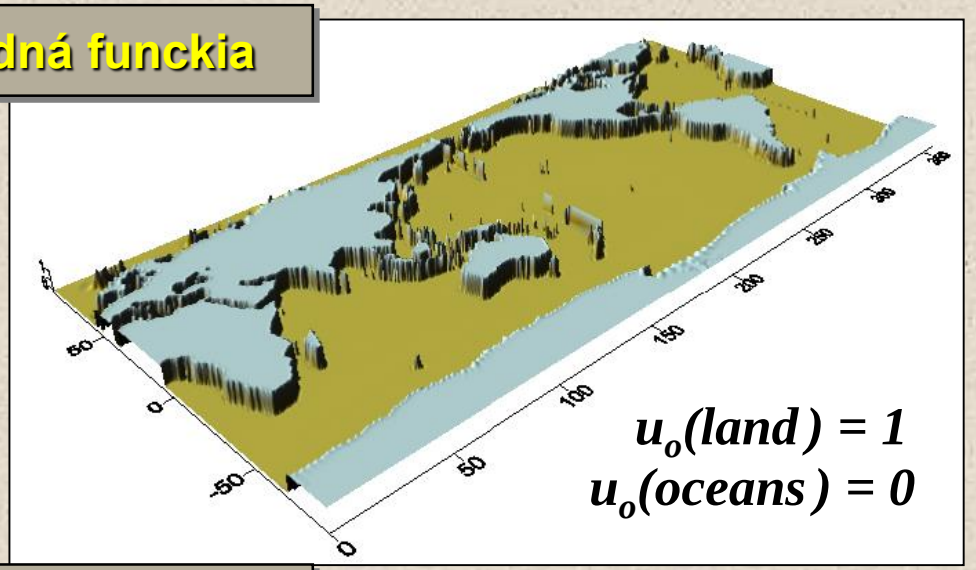
Riešenie systému lineárnych rovníc

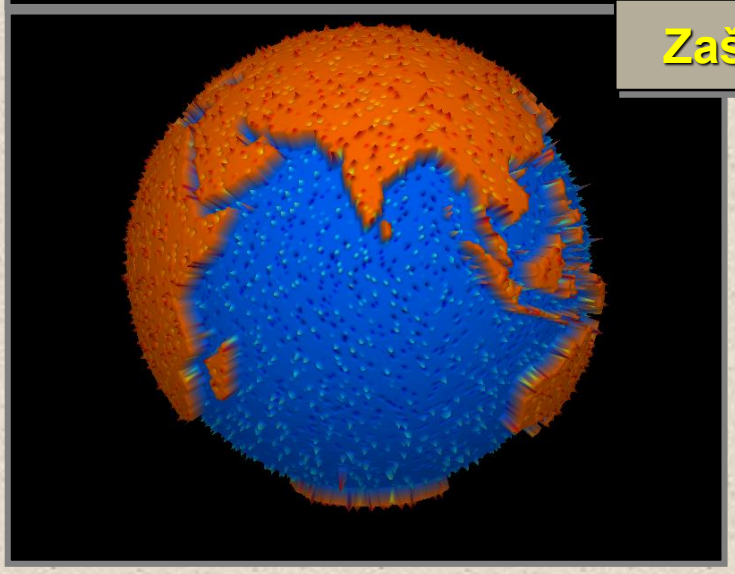
- ***lineárna difúzia*** ⇒ ***riešenia rovnice vedenia tepla (zhladzuje aj dôležité prvky)***
- ***nelineárna difúzia*** ⇒ ***riešenia modifikovanej rovnice vedenia tepla (umožňuje zachovávať dôležité prvky)***

Testovací príklad

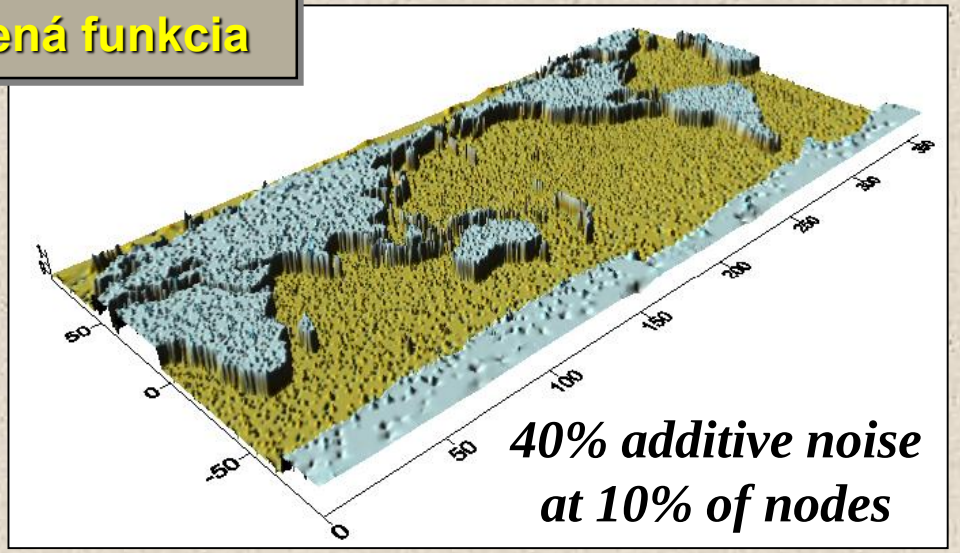


Pôvodná funckia



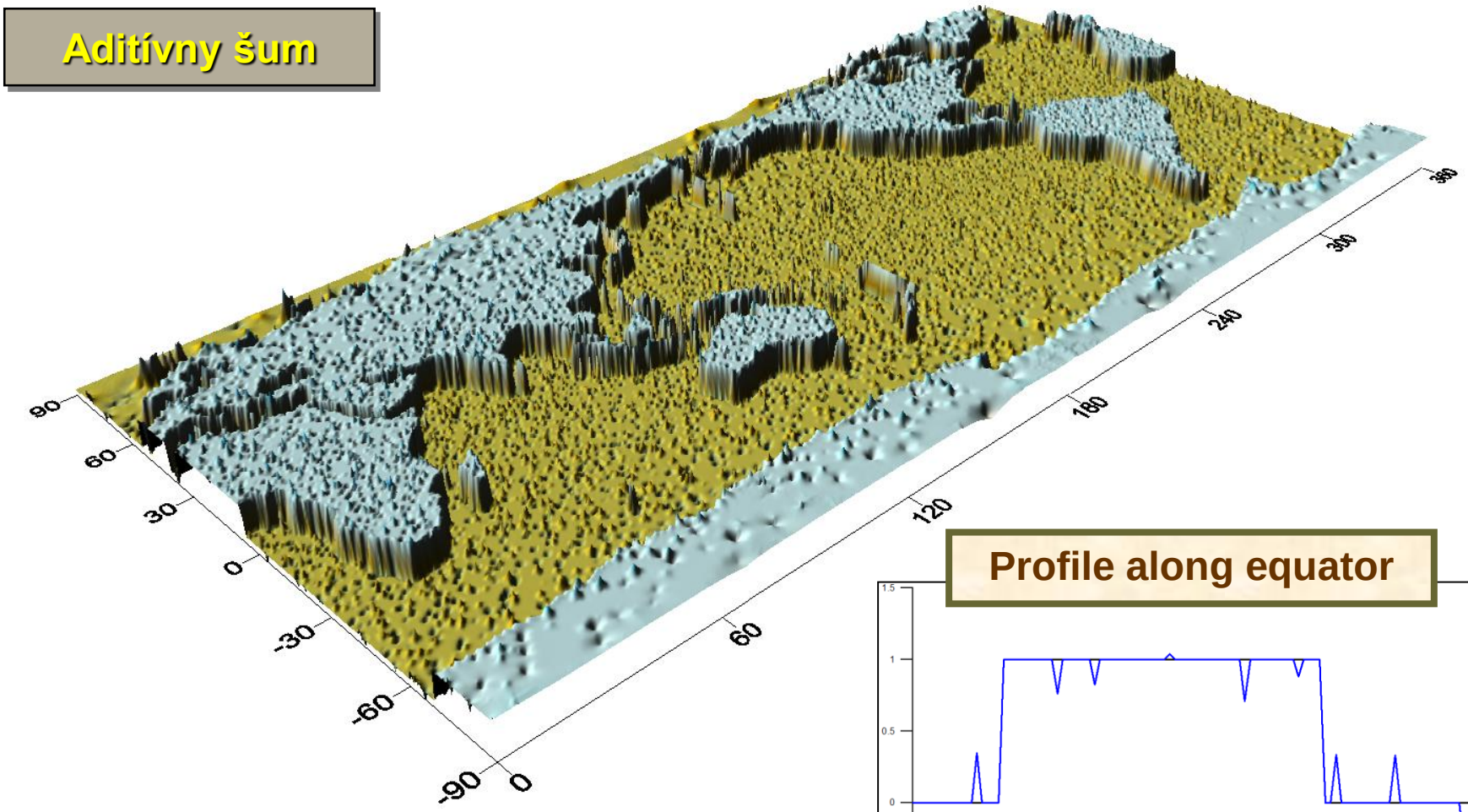


Zašumená funkcia

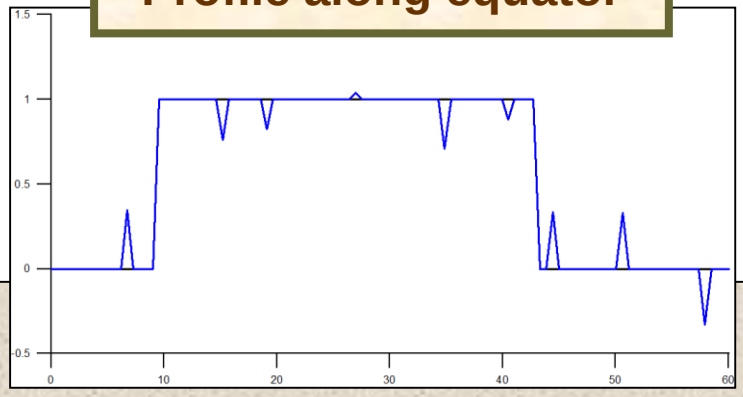


Lineárna difúzia – vstupné dáta

Aditívny šum

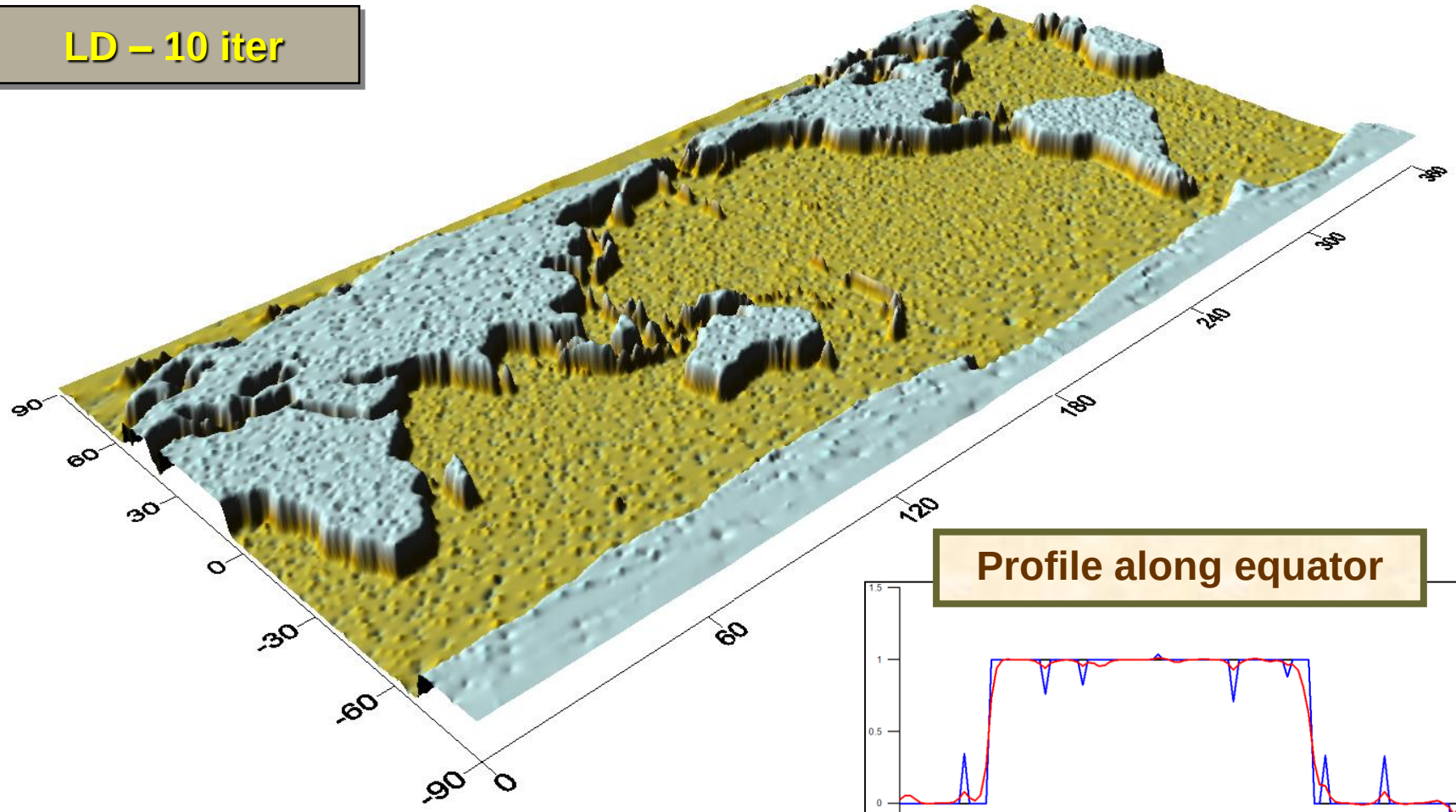


Profile along equator

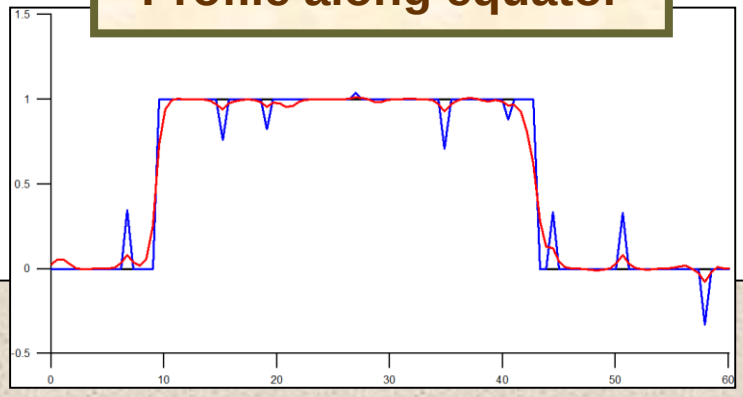


Linear diffusion – 10 iterations

LD – 10 iter

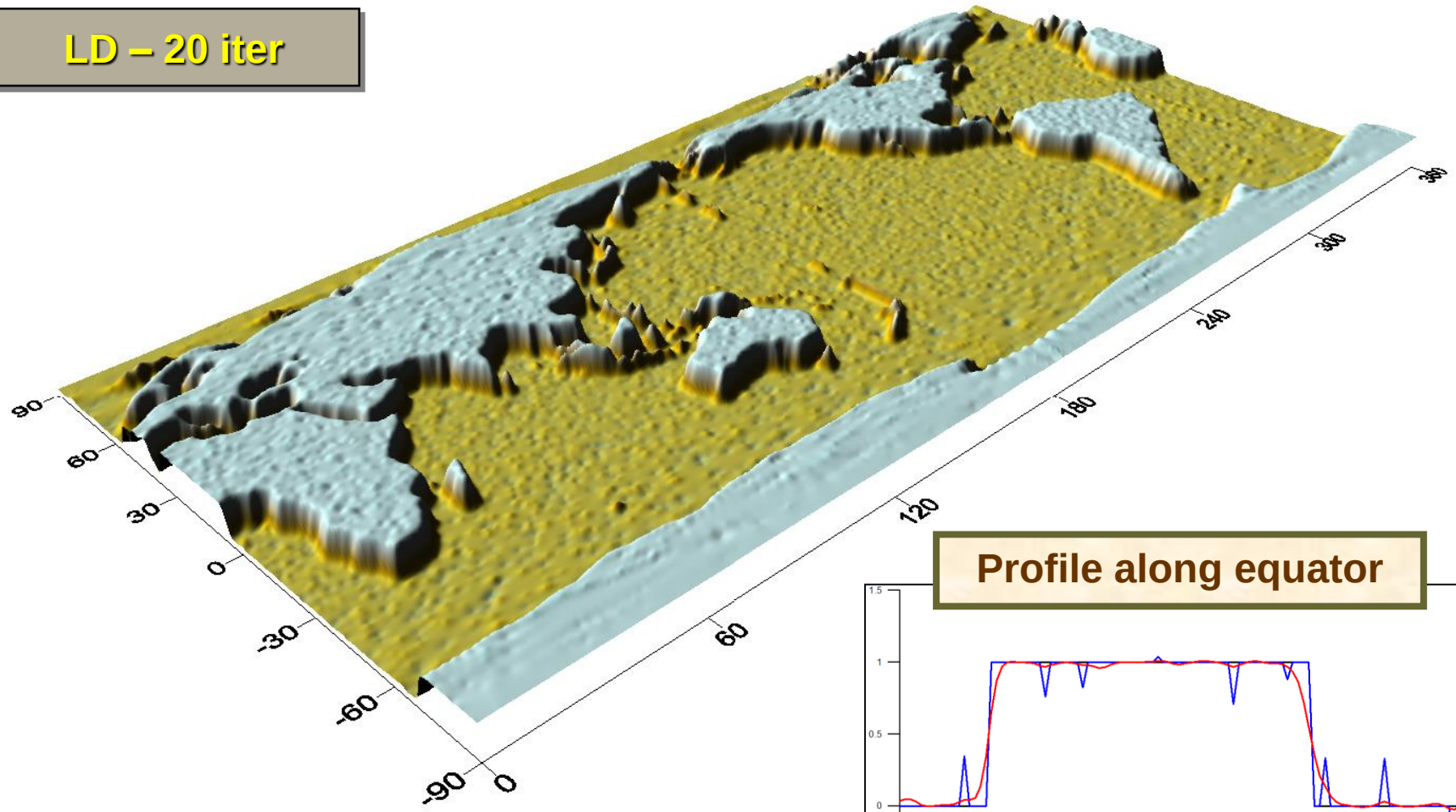


Profile along equator

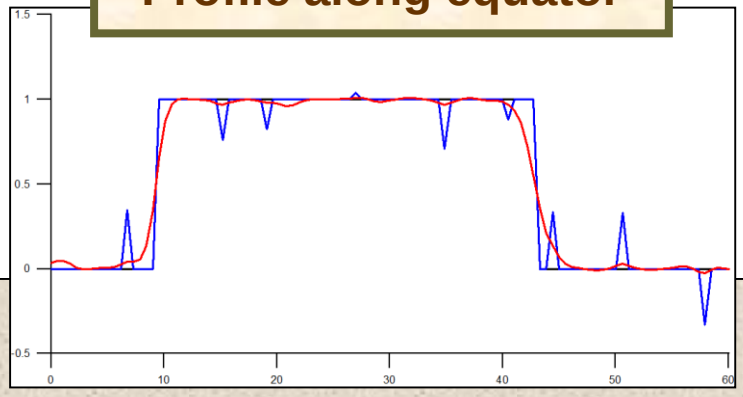


Linear diffusion – 20 iterations

LD – 20 iter

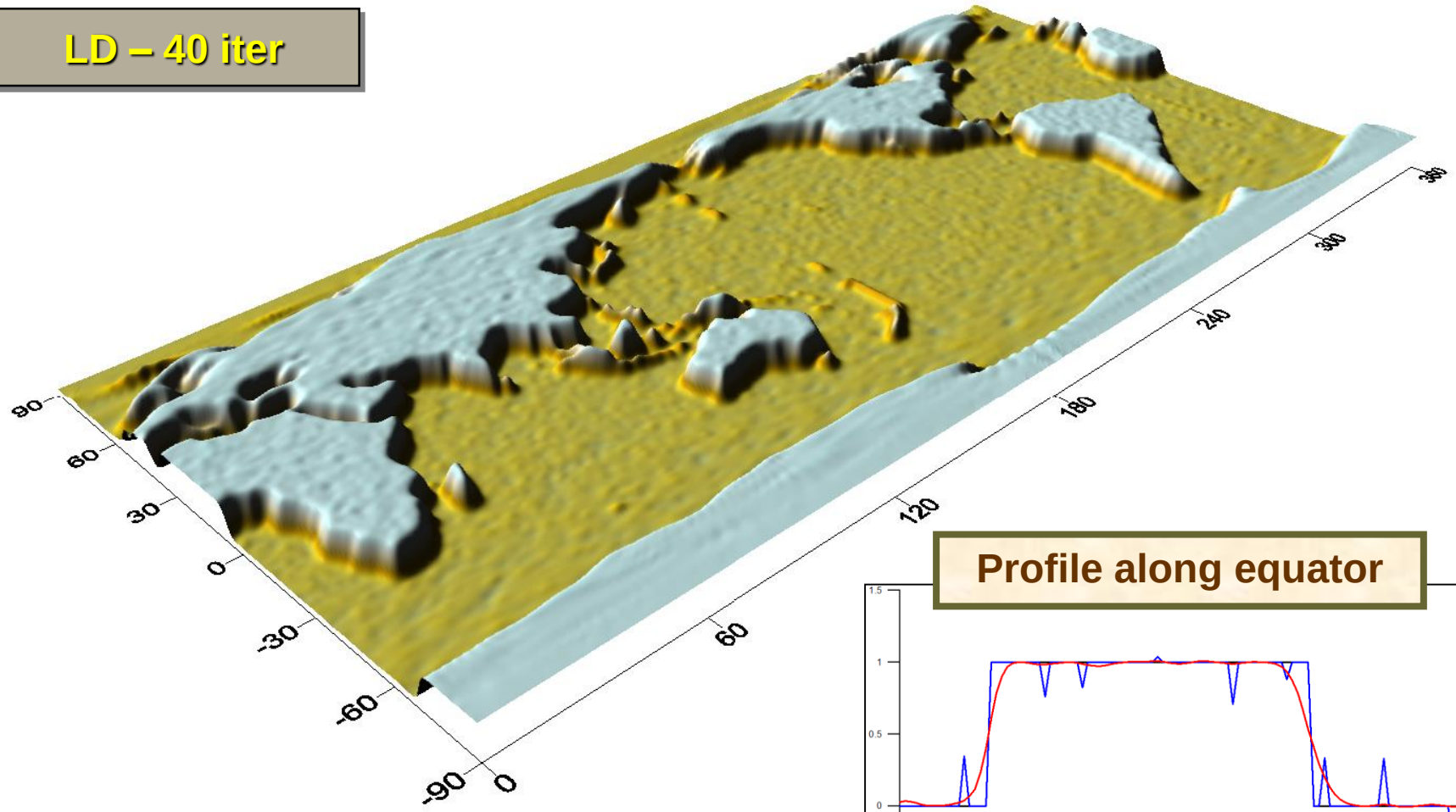


Profile along equator

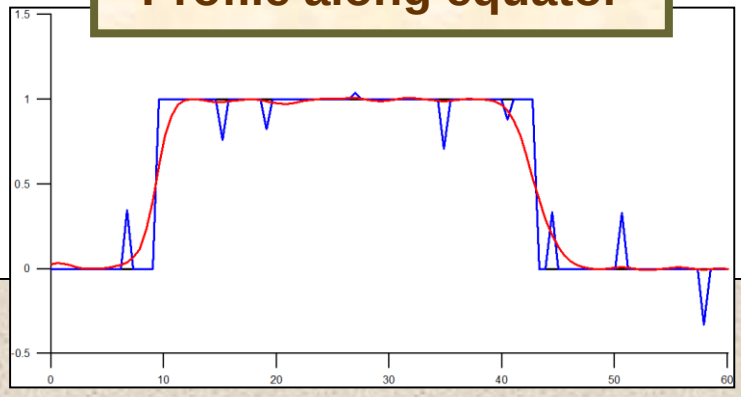


Linear diffusion – 40 iterations

LD – 40 iter

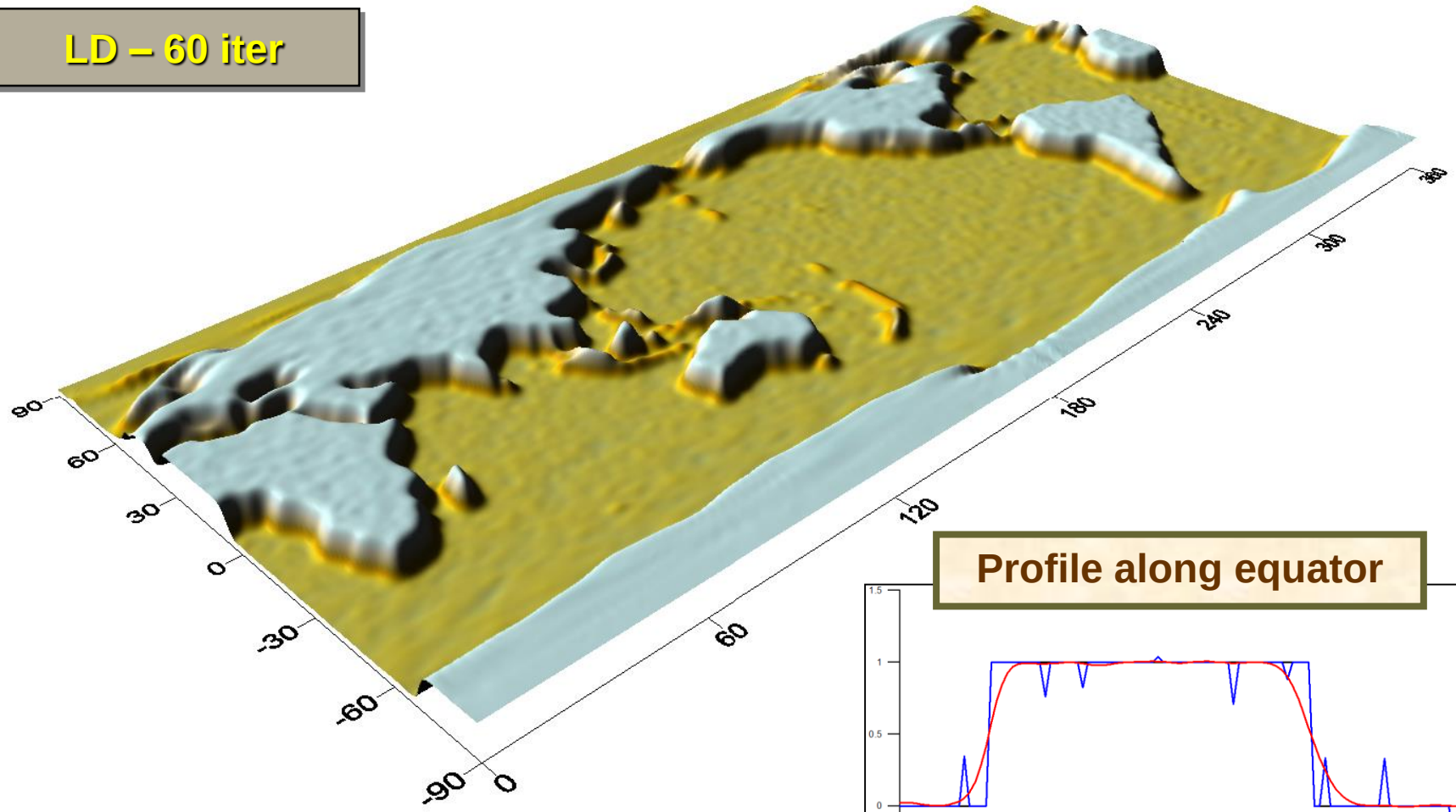


Profile along equator

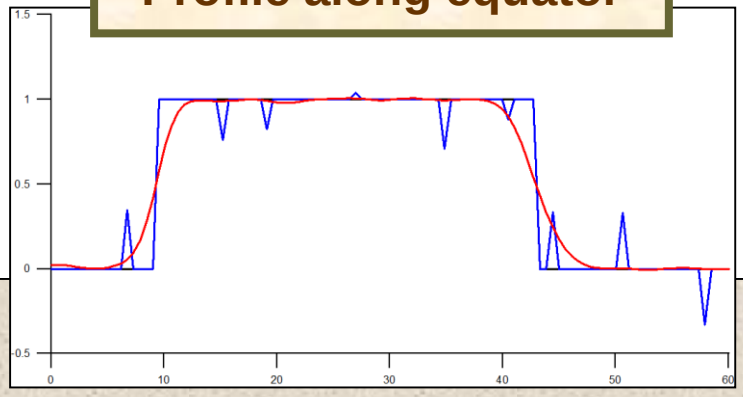


Linear diffusion – 60 iterations

LD – 60 iter

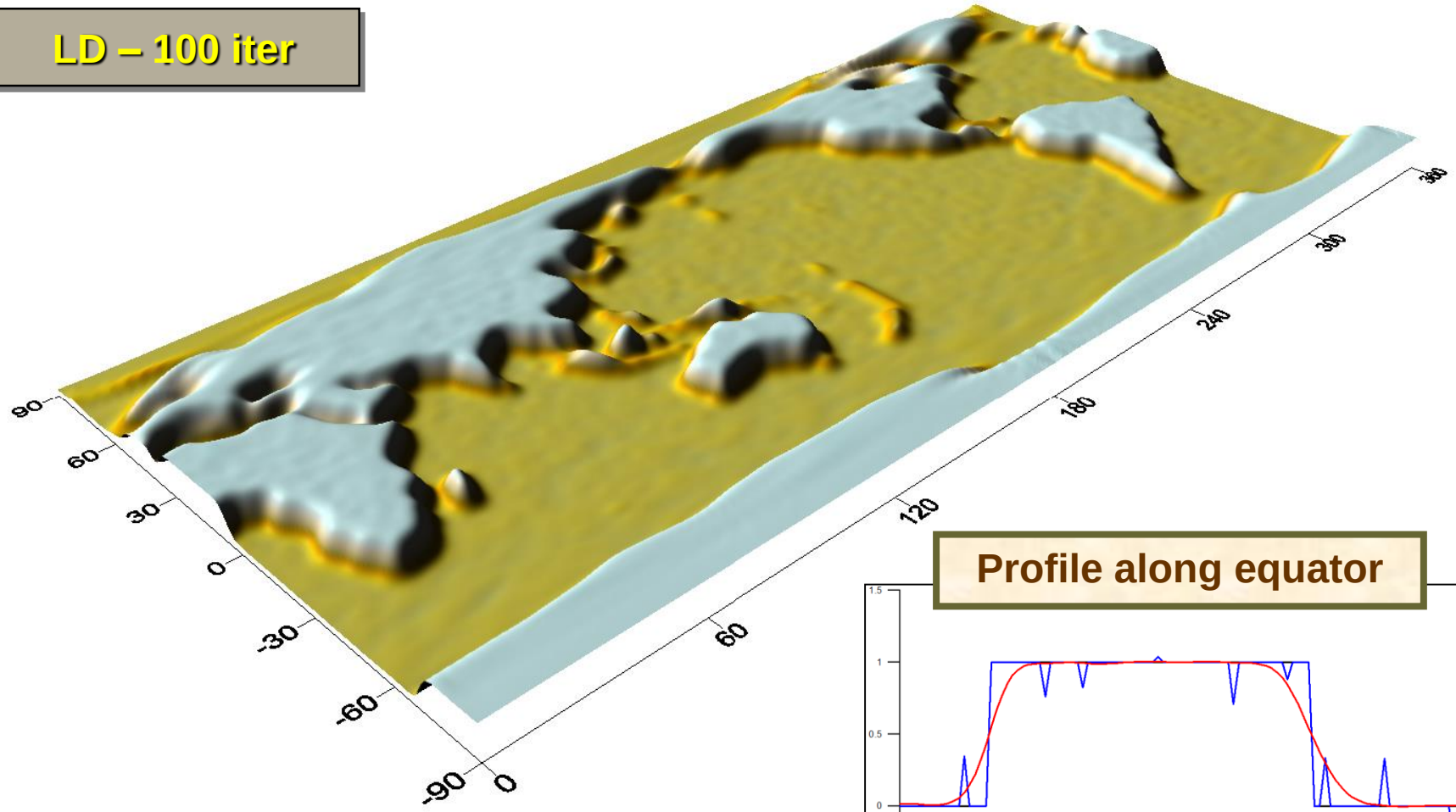


Profile along equator

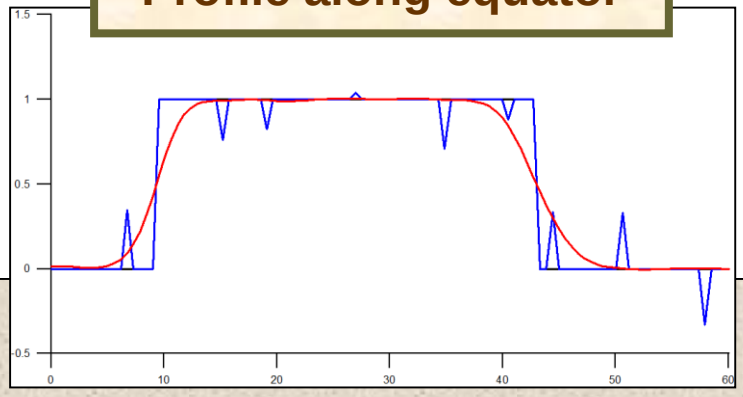


Linear diffusion – 100 iterations

LD – 100 iter



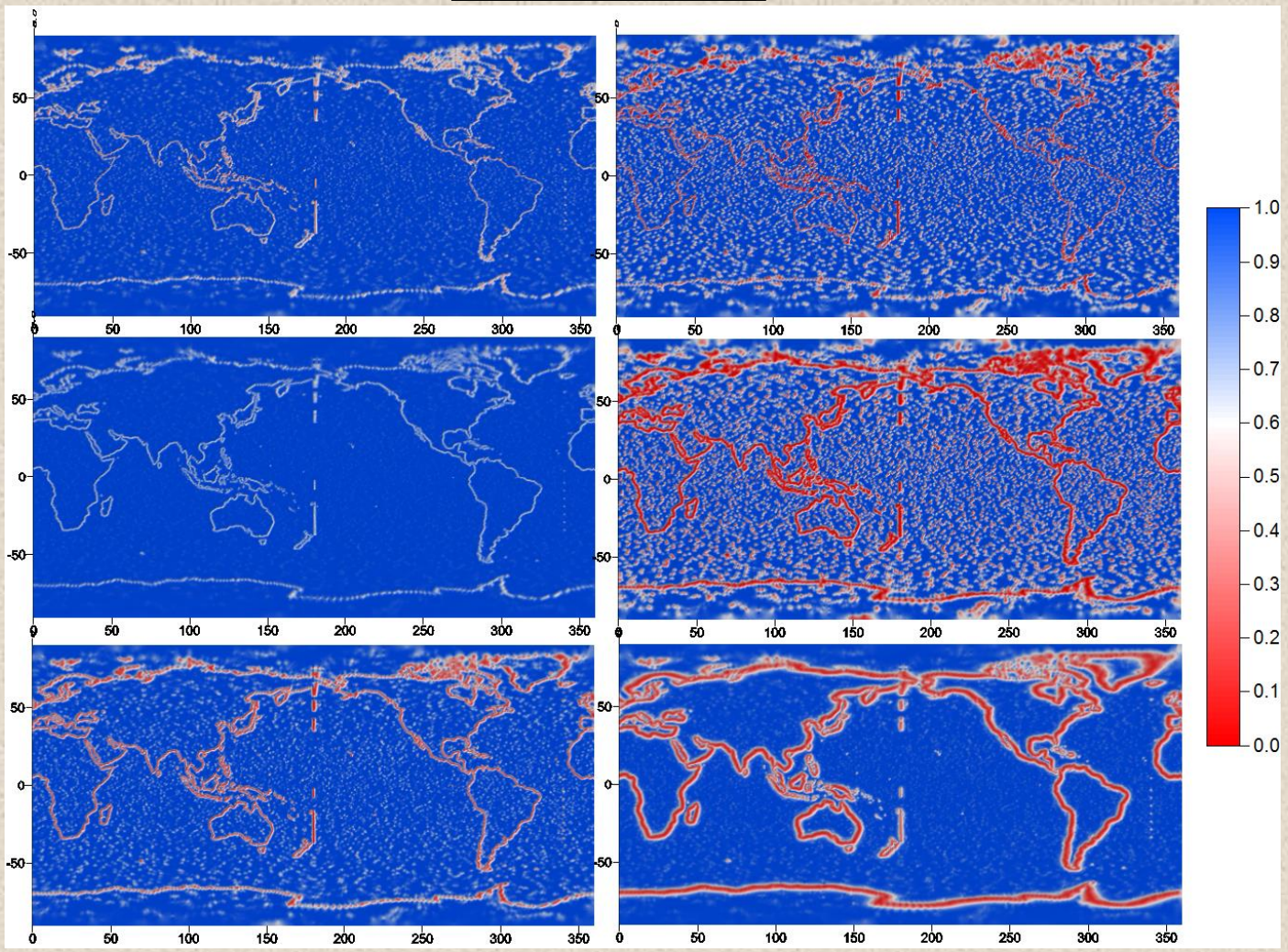
Profile along equator



Nelinárna difúzia – hranový detektor

Hranový detektor

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



$\sigma = \tau$

$H = 10^{10}$

$\sigma = \tau$

$H = 10^{11}$

$\sigma = 10\tau$

$H = 10^{10}$

$\sigma = 10\tau$

$H = 10^{12}$

$\sigma = 10\tau$

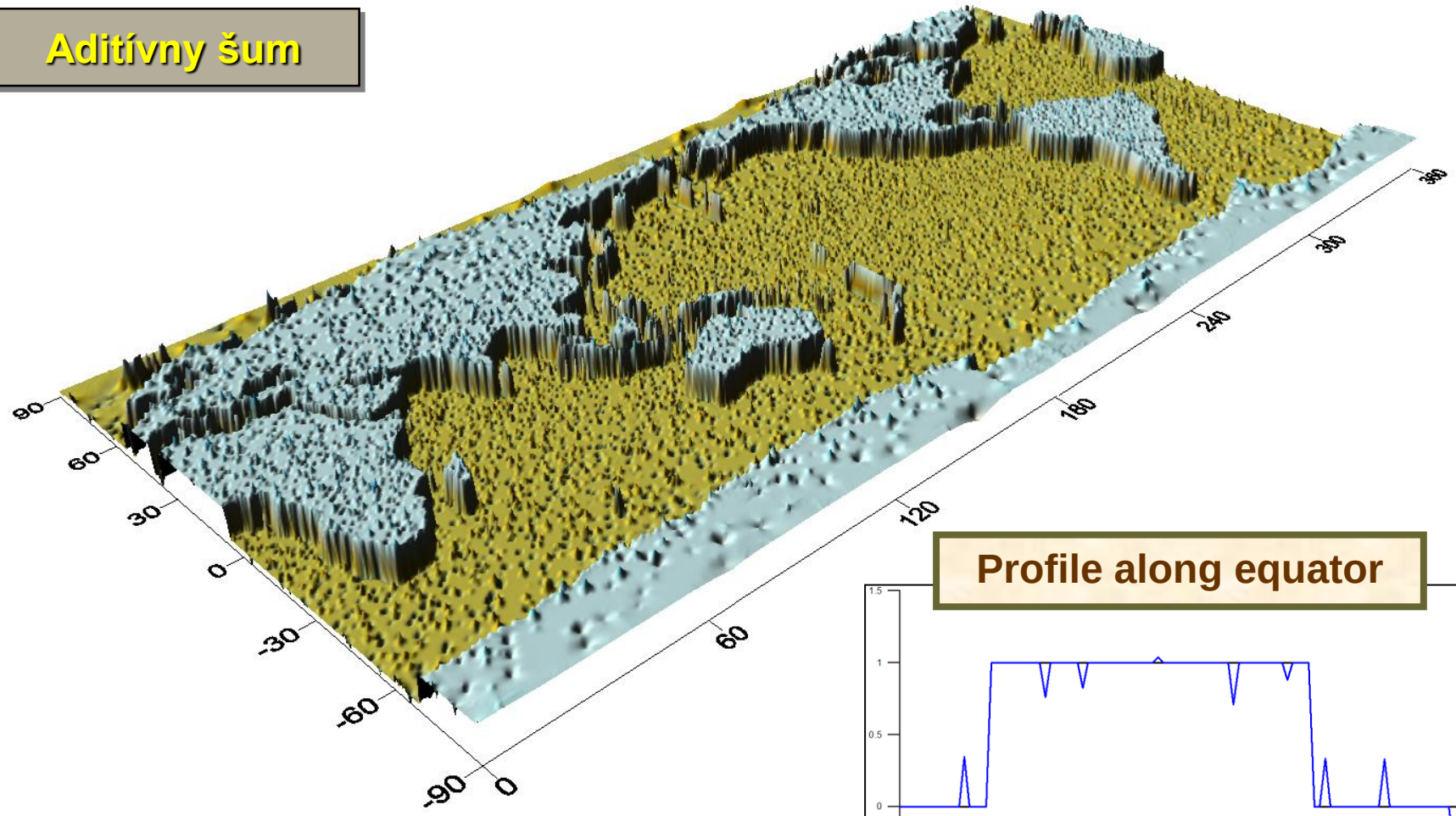
$H = 10^{11}$

$\sigma = 100\tau$

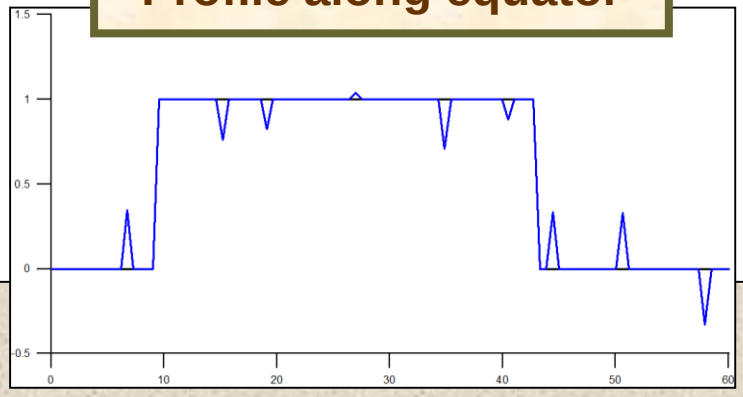
$H = 10^{12}$

Nelineárna difúzia – vstupné dáta

Aditívny šum

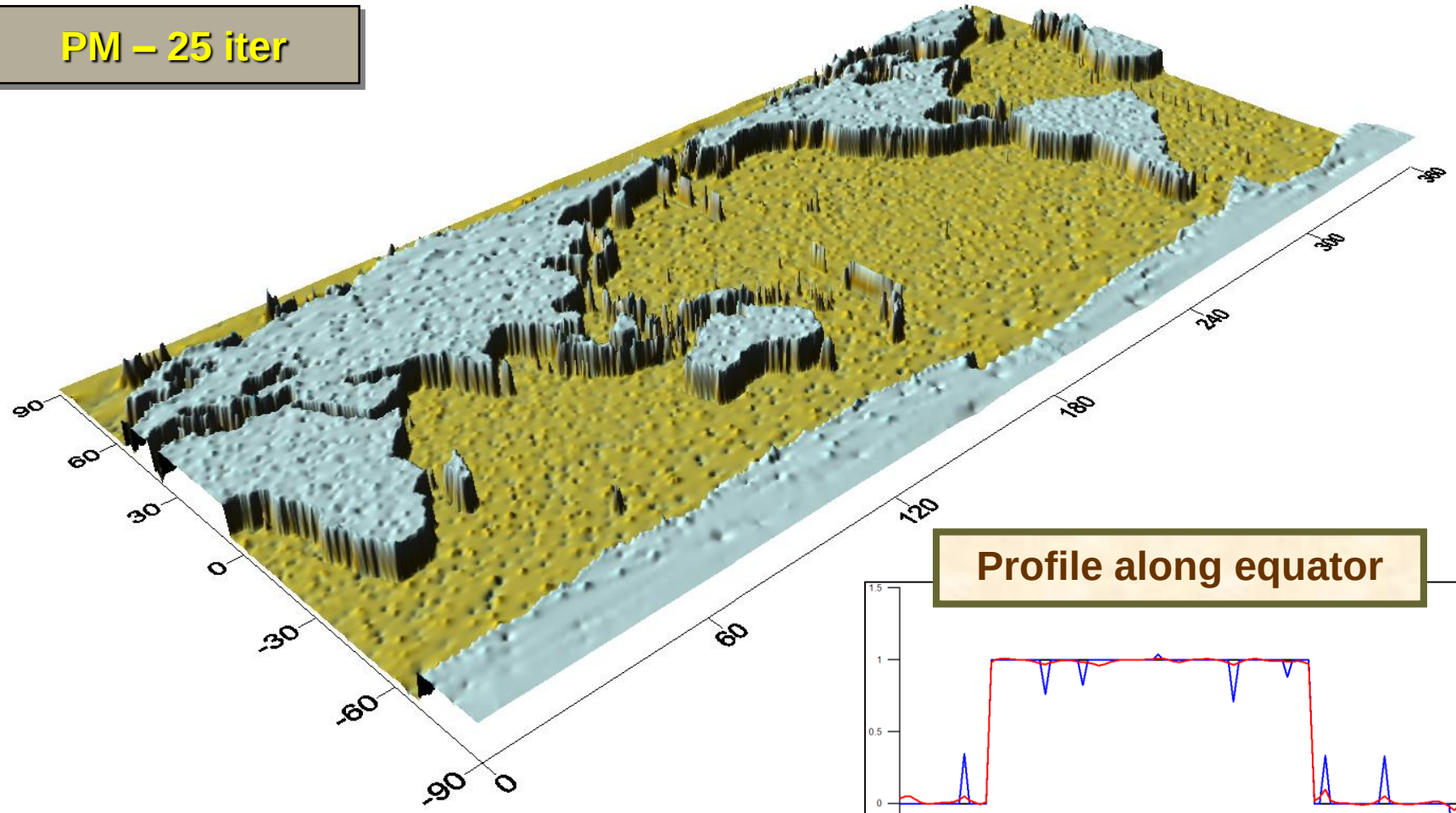


Profile along equator

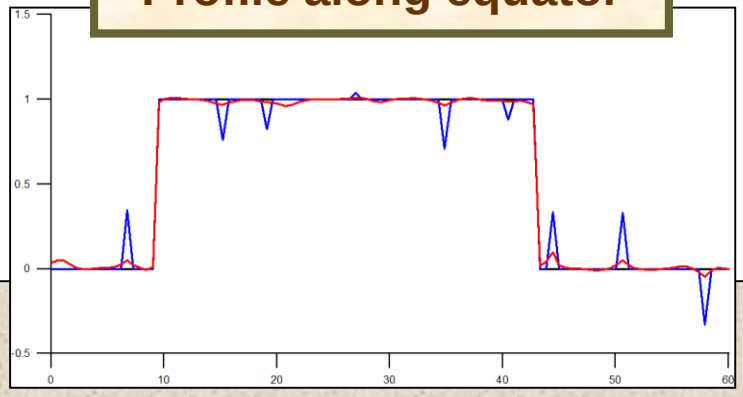


Nonlinear diffusion – 25 iterations

PM – 25 iter

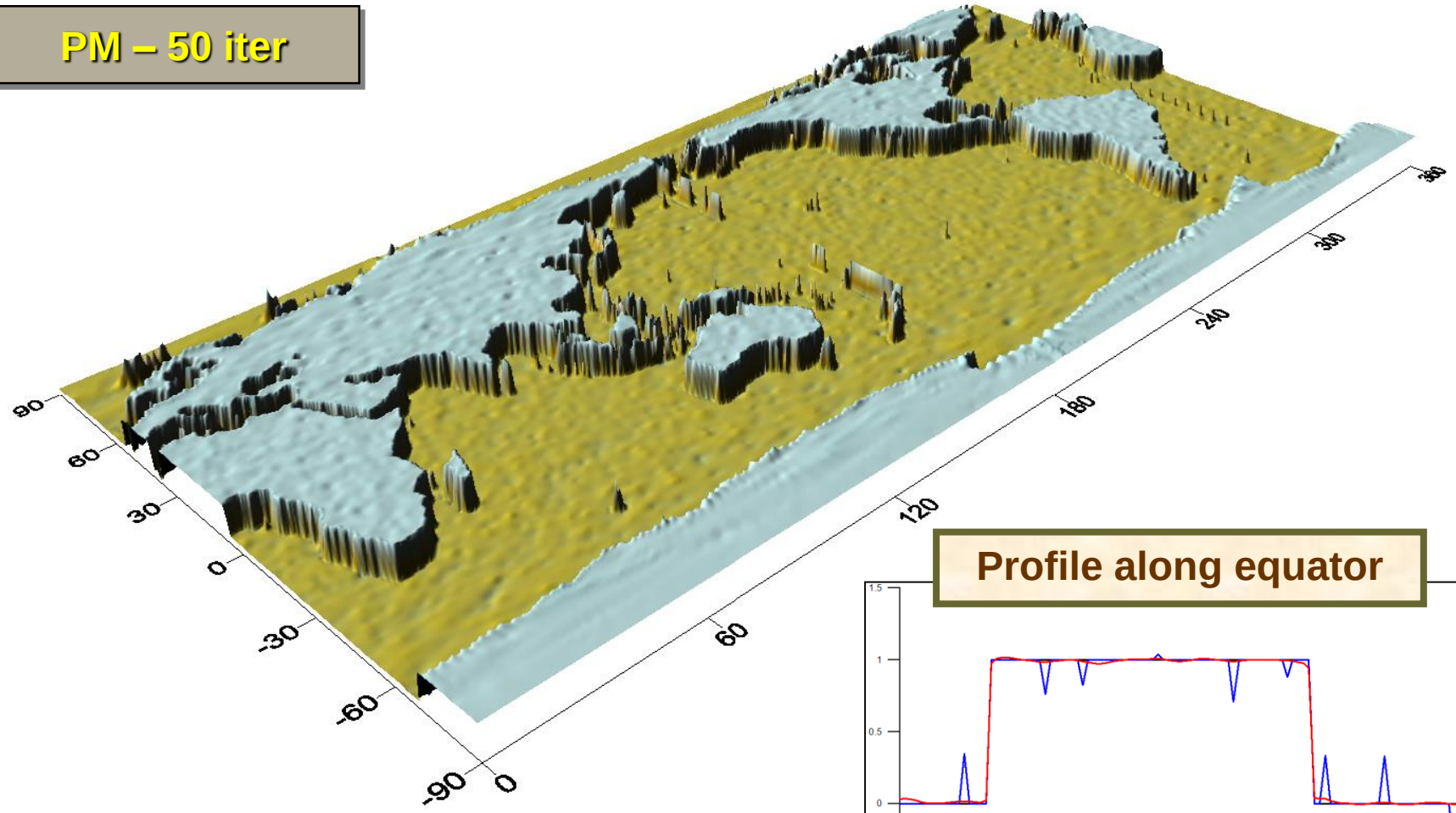


Profile along equator

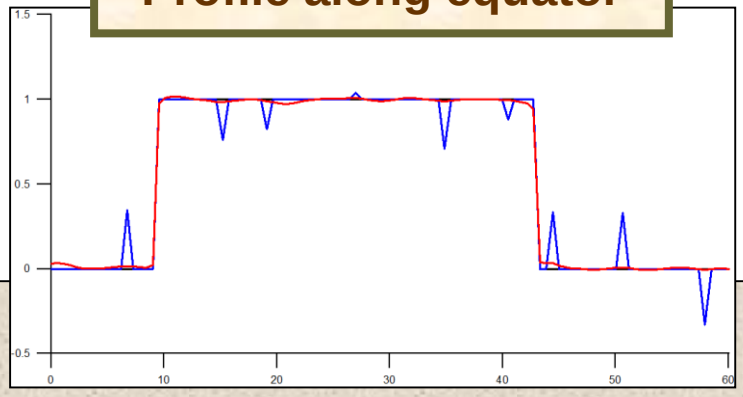


Nonlinear diffusion – 50 iterations

PM – 50 iter

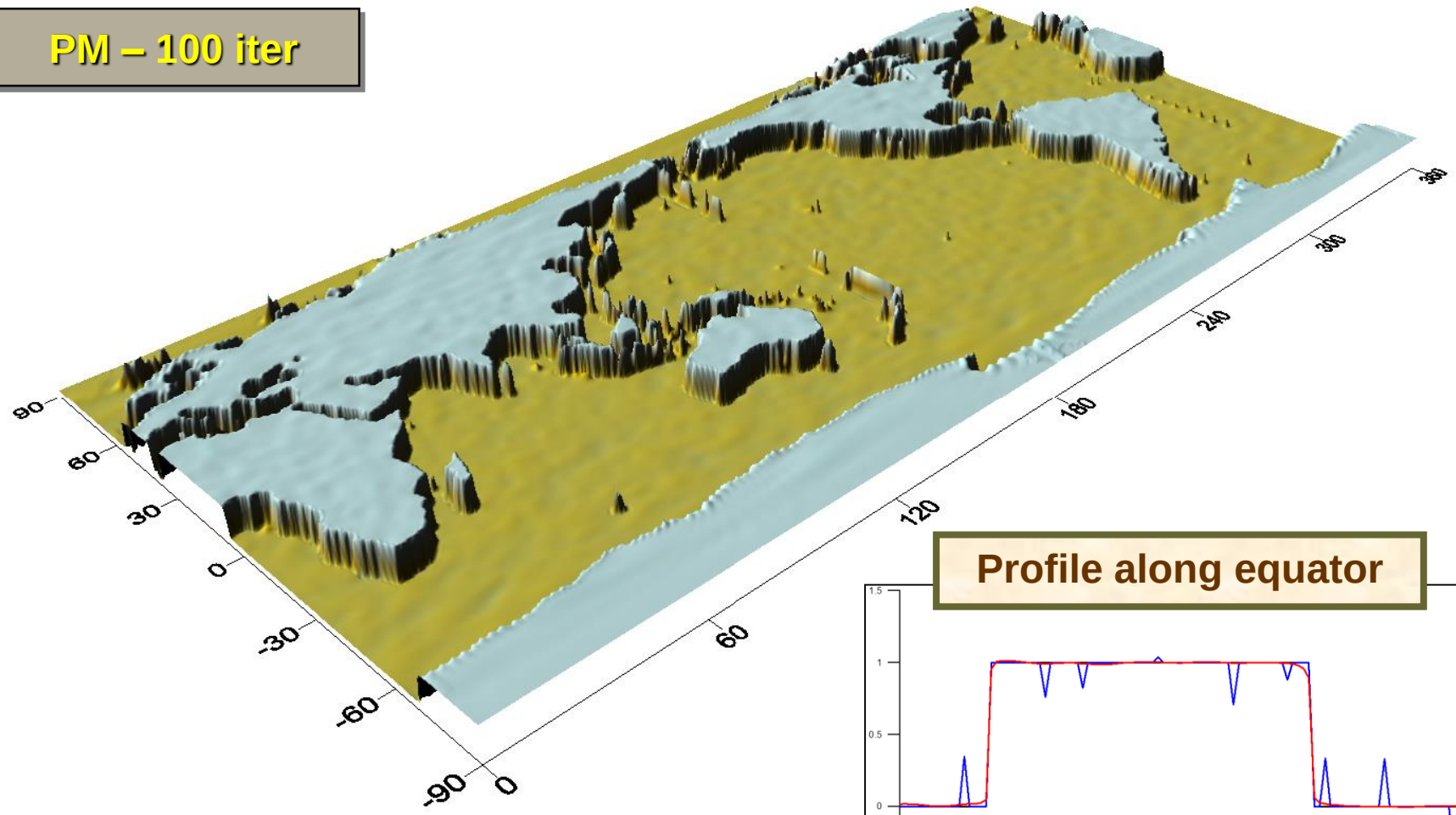


Profile along equator

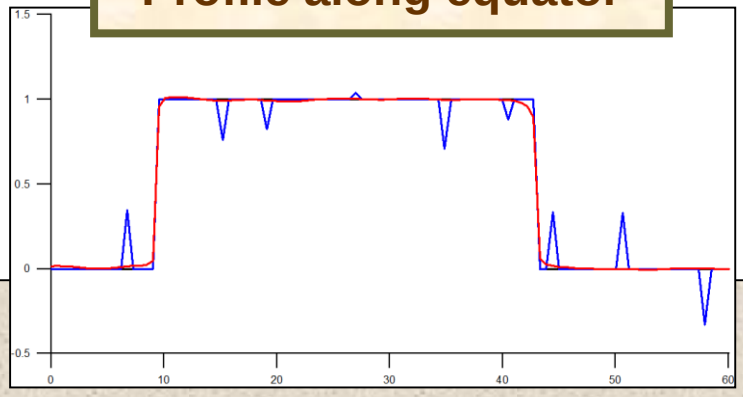


Nonlinear diffusion – 100 iterations

PM – 100 iter

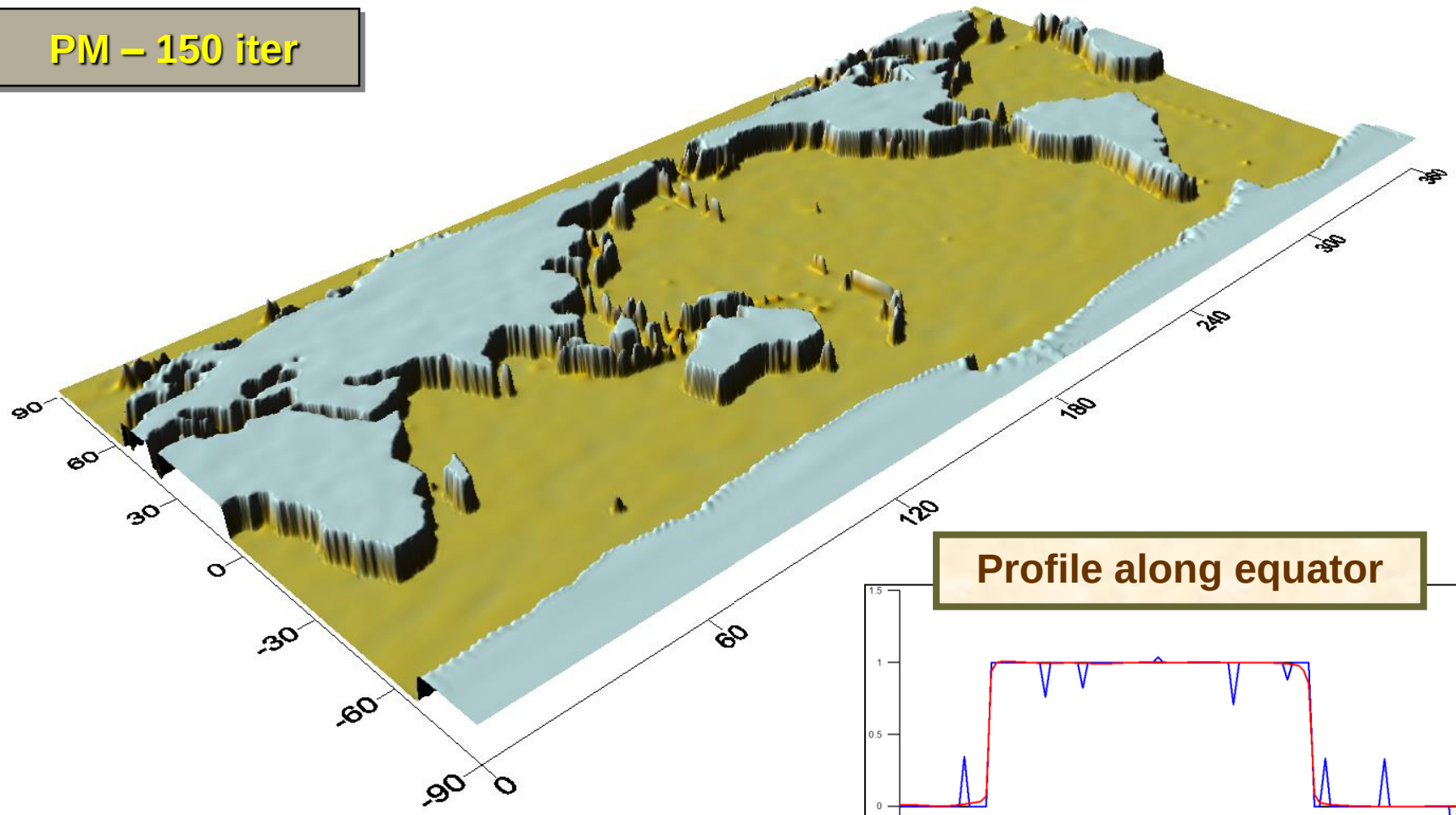


Profile along equator

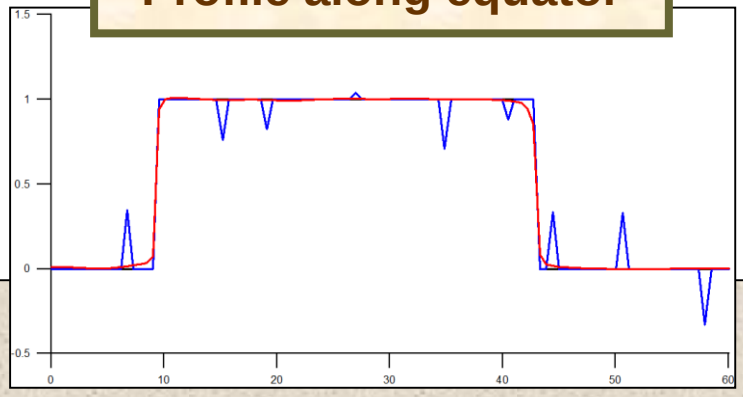


Nonlinear diffusion – 150 iterations

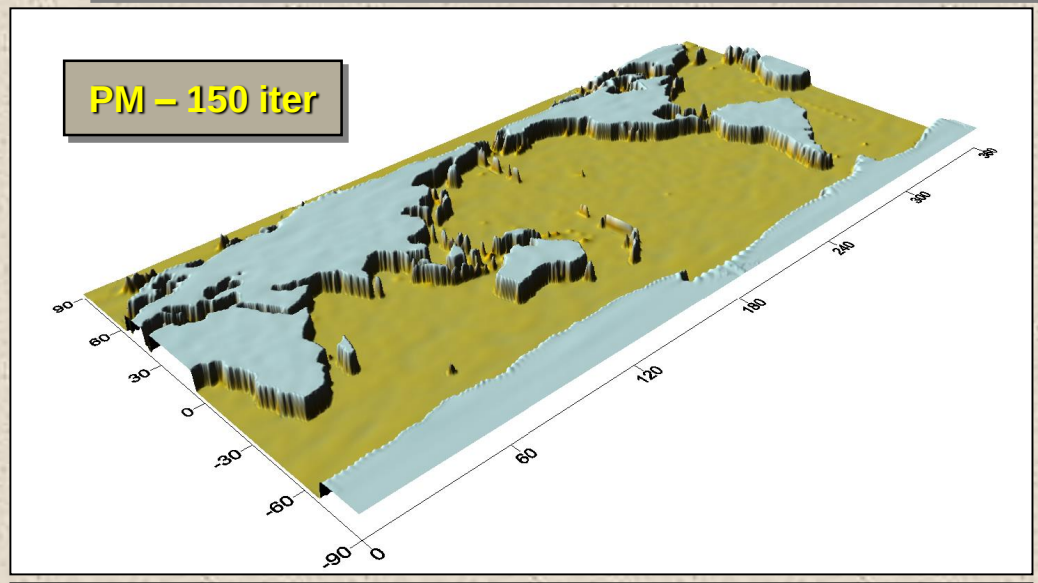
PM – 150 iter

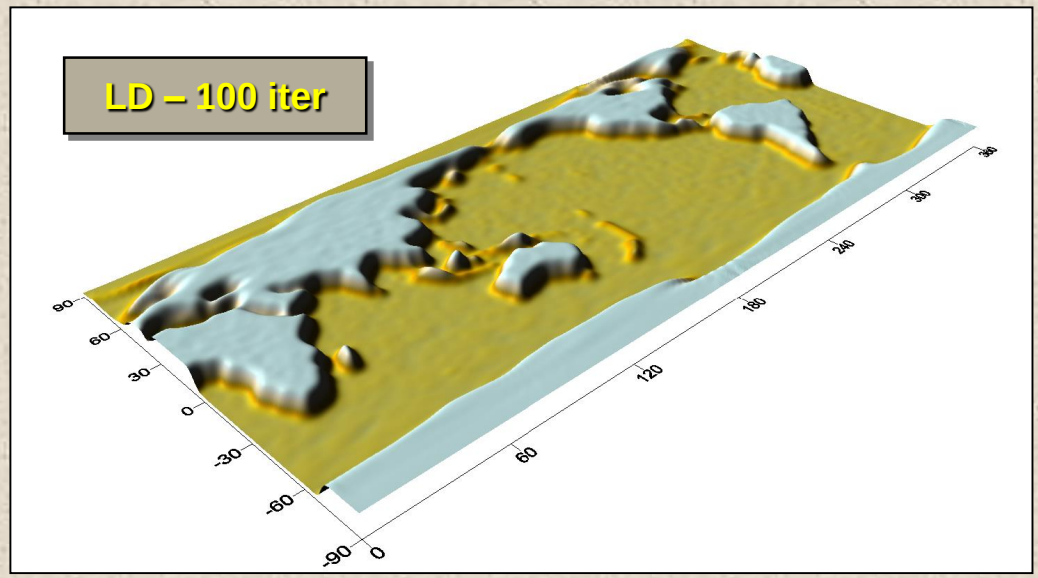


Profile along equator

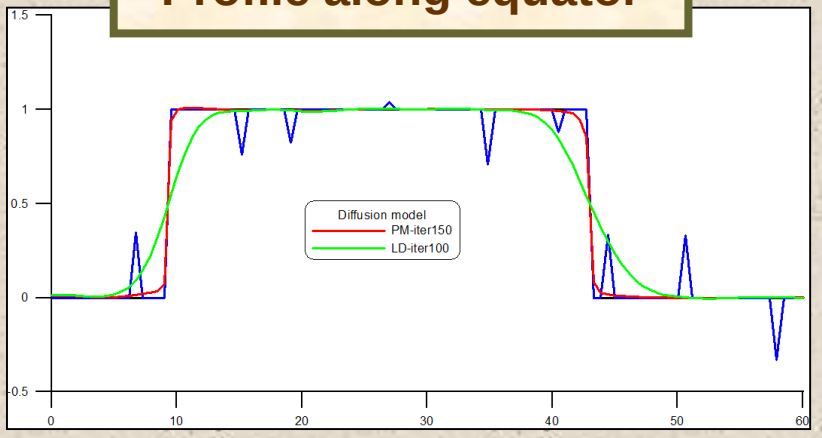


Porovnanie: lineárna ↔ nelineárna difúzia



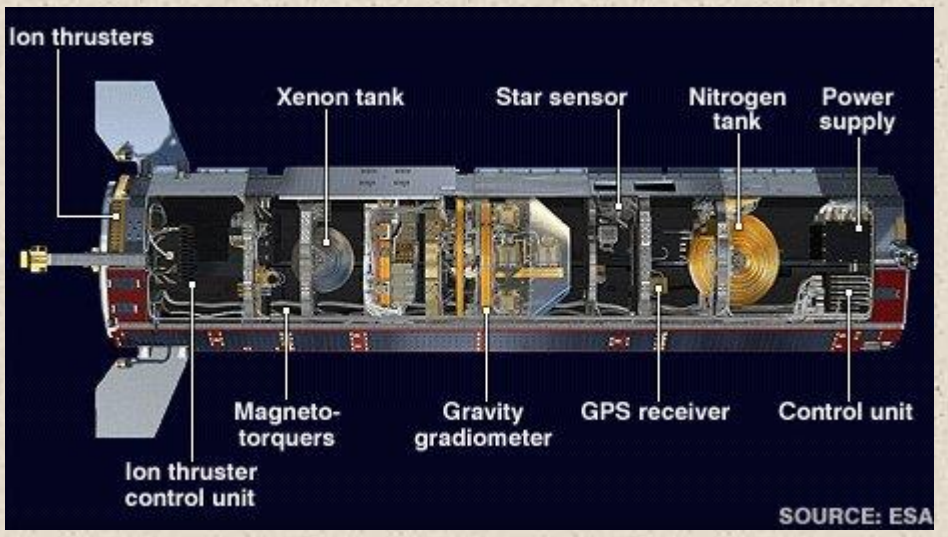


Profile along equator



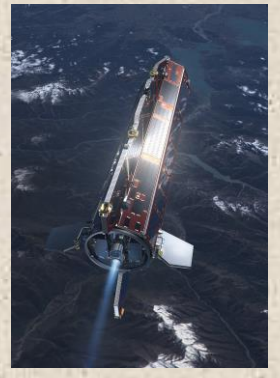
Družicová misia GOCE

Gravity Field and Stady-State Ocean Circulation Explorer



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

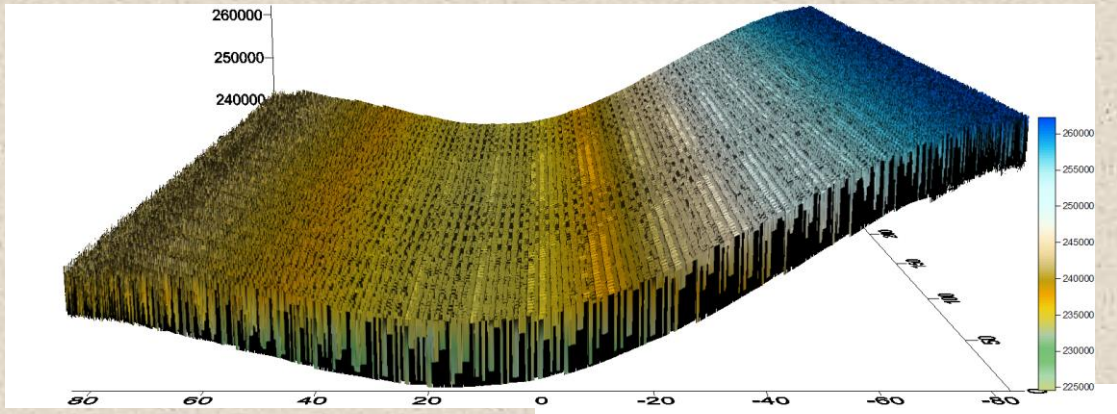
Vypustenie družice
(17 marec 2009)

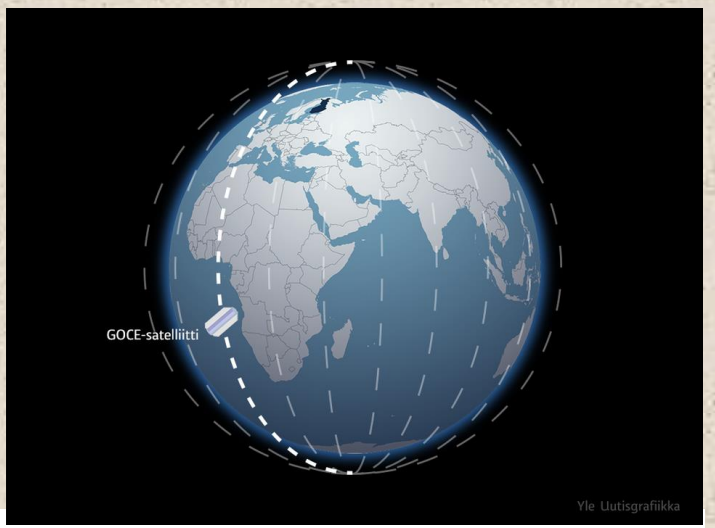


Koniec misie
(11 november 2013)

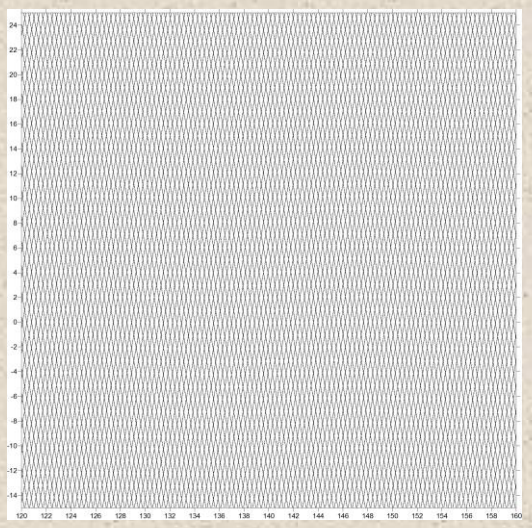
Orbity družicovej misie GOCE

Výška letu nad elipsoidom

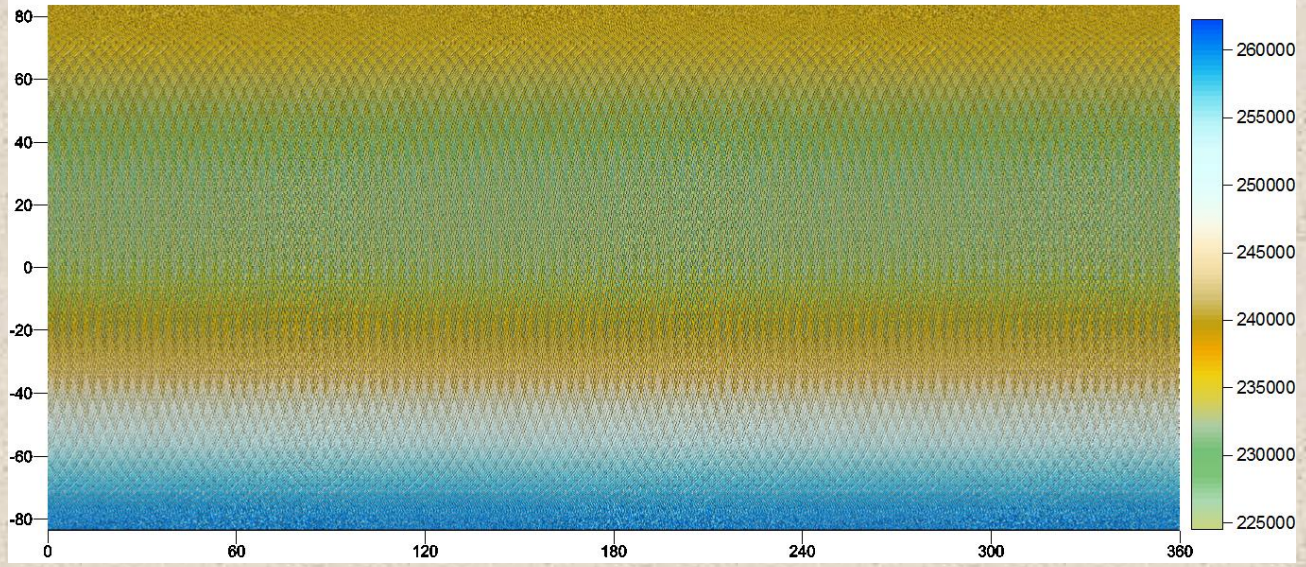




Hustota meraní
(61 dní)



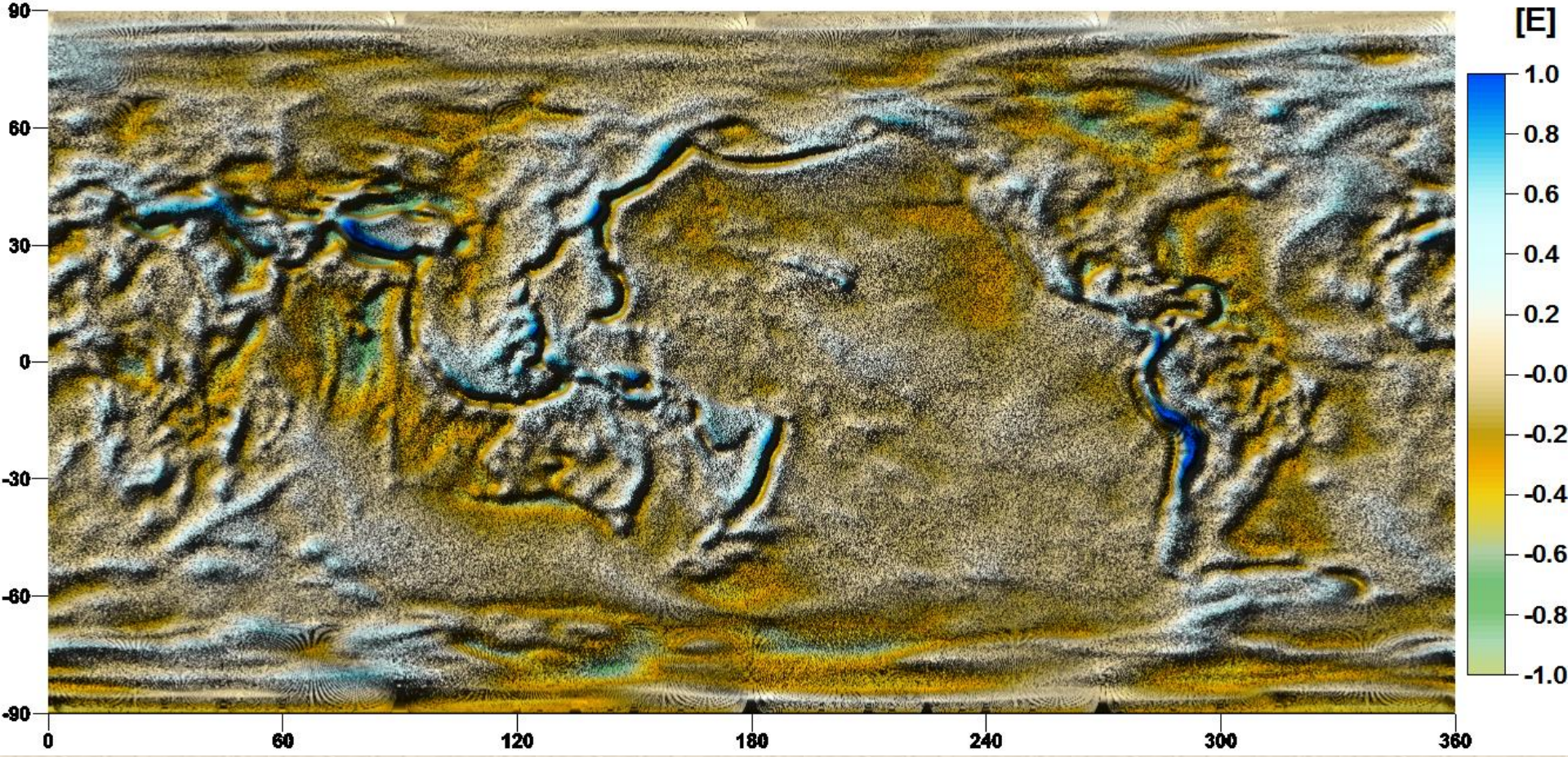
06 -07-2013



Priame merania GOCE

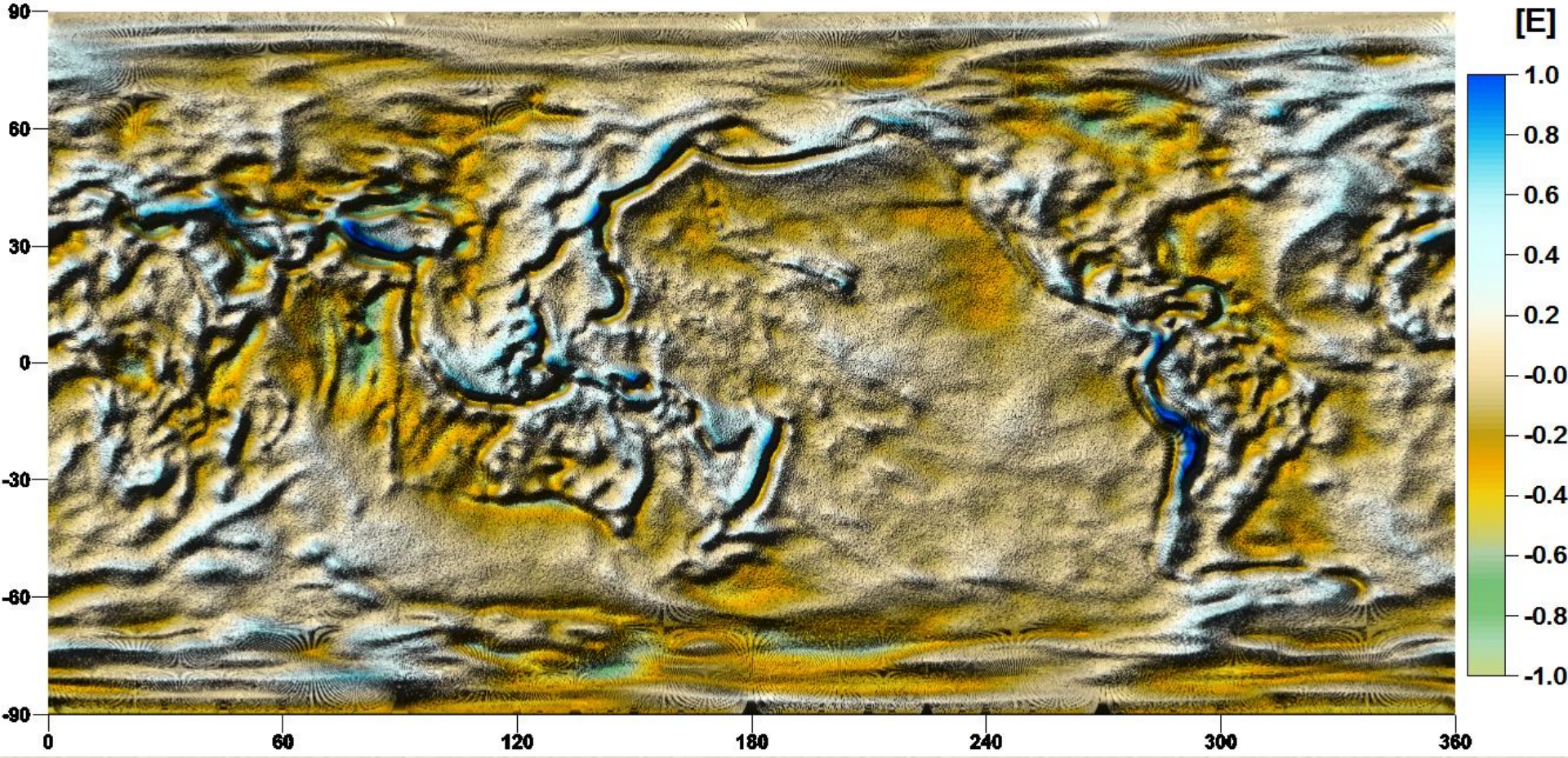
T_{zz} komponent tiažového tenzora

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



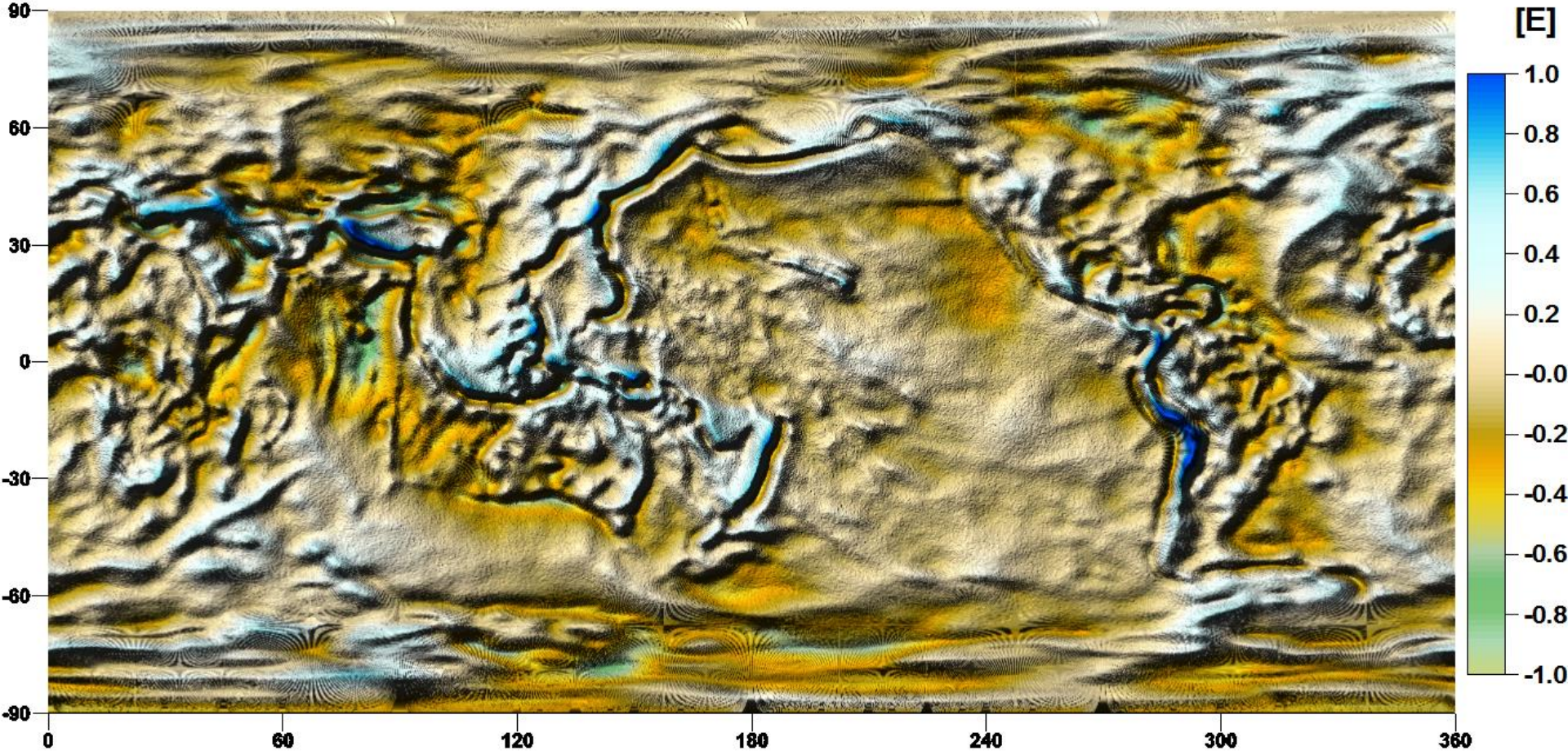
Nonlinear diffusion

10 iterations



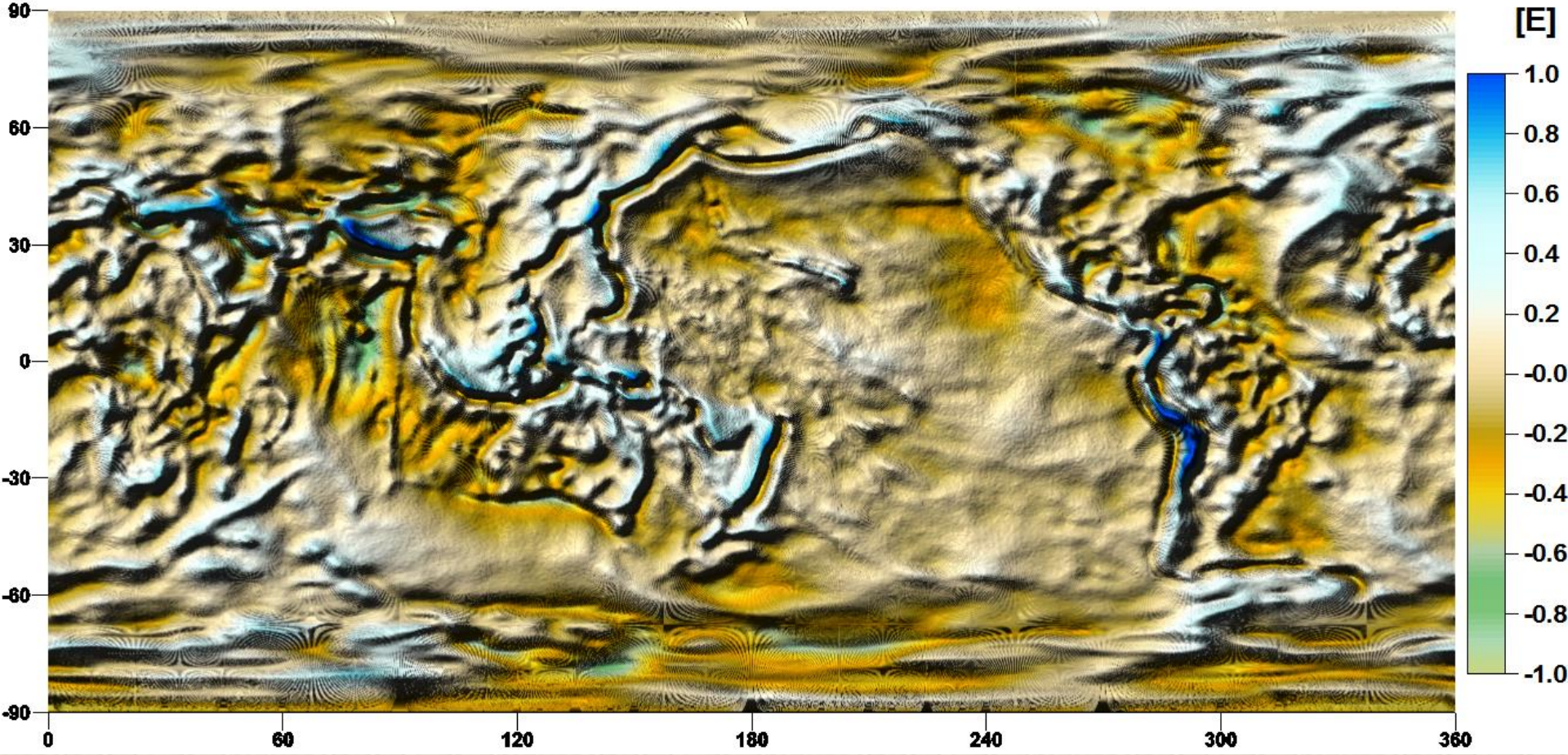
Nonlinear diffusion

20 iterations



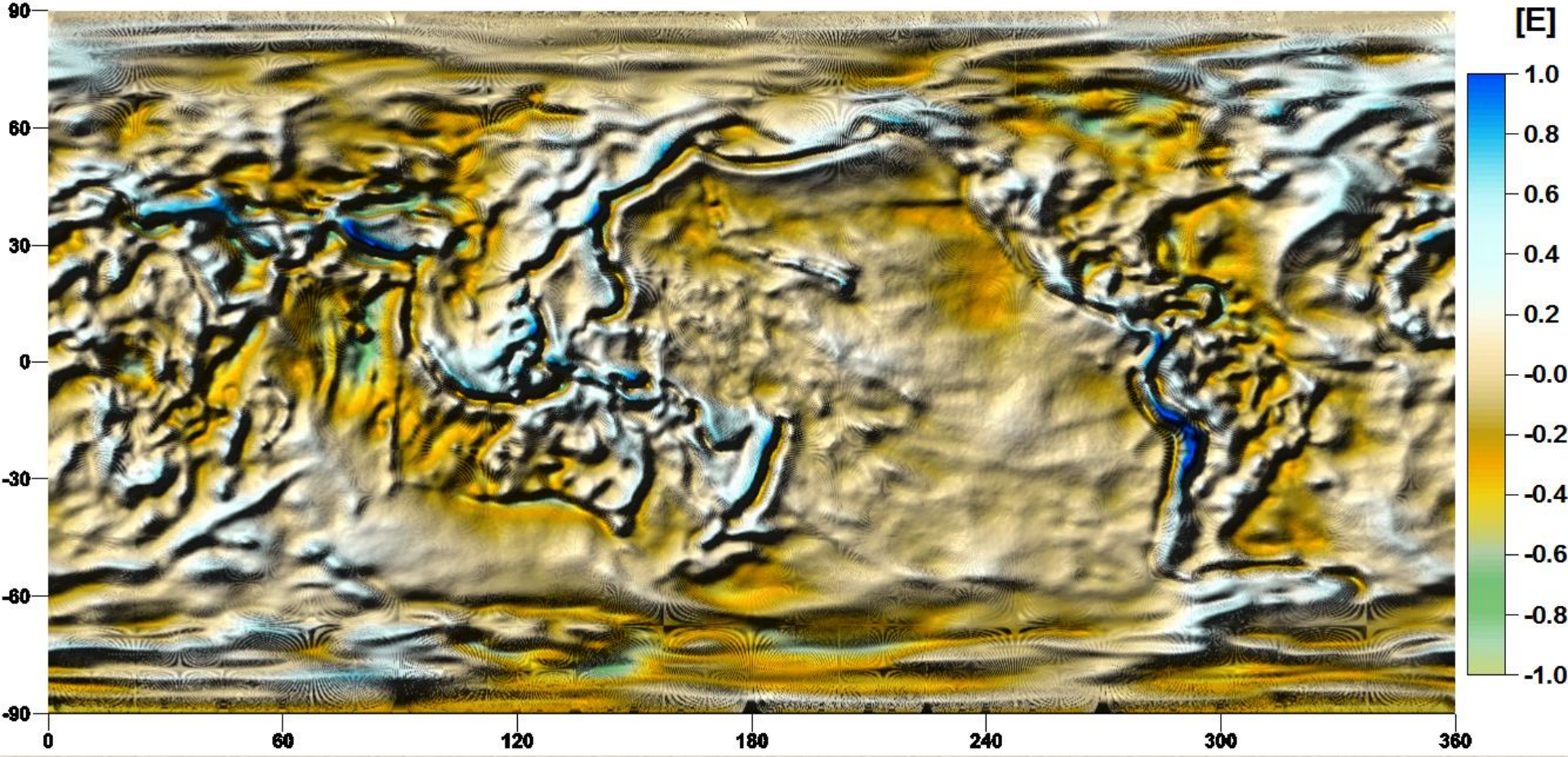
Nonlinear diffusion

50 iterations



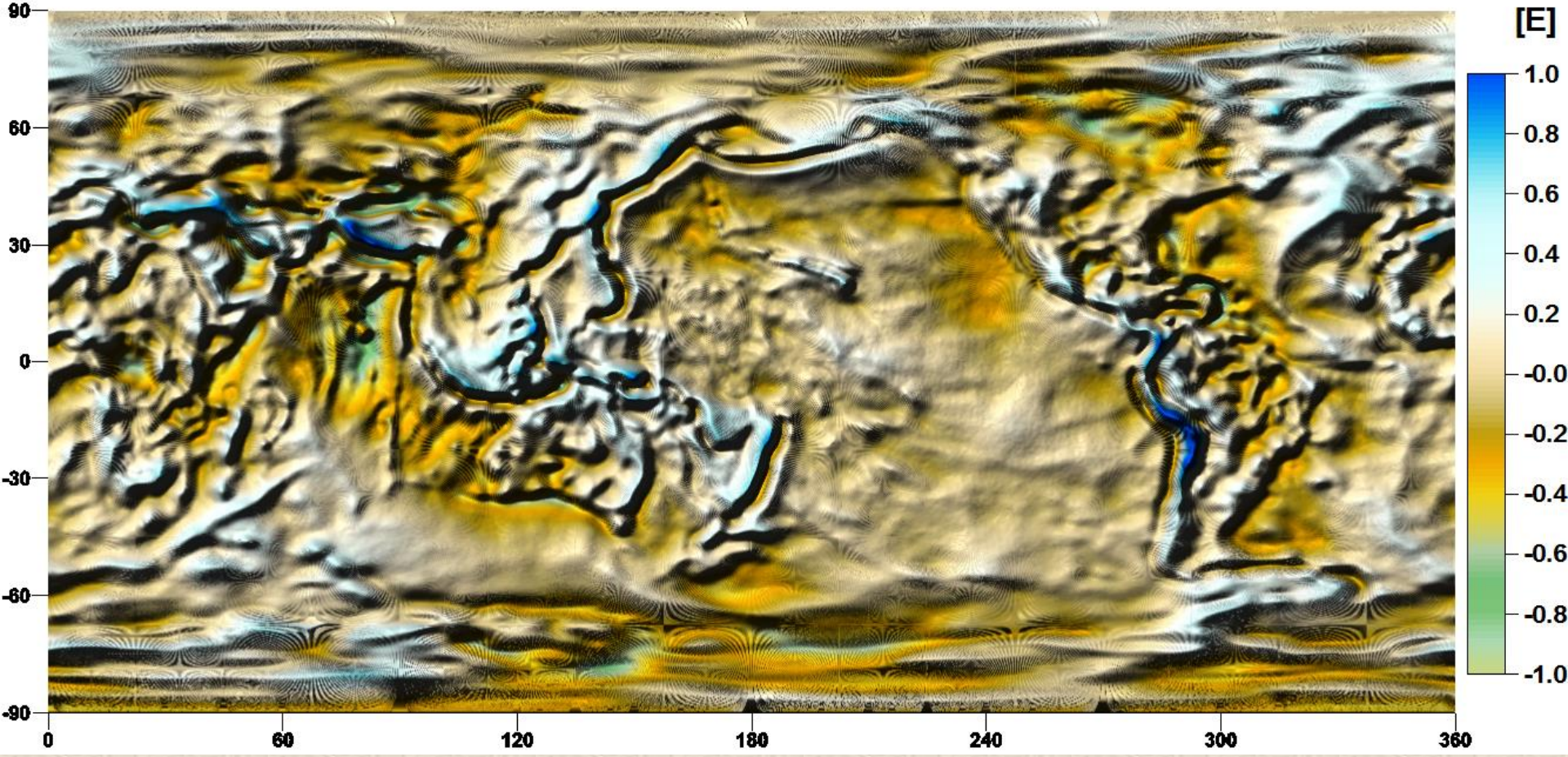
Nonlinear diffusion

100 iterations



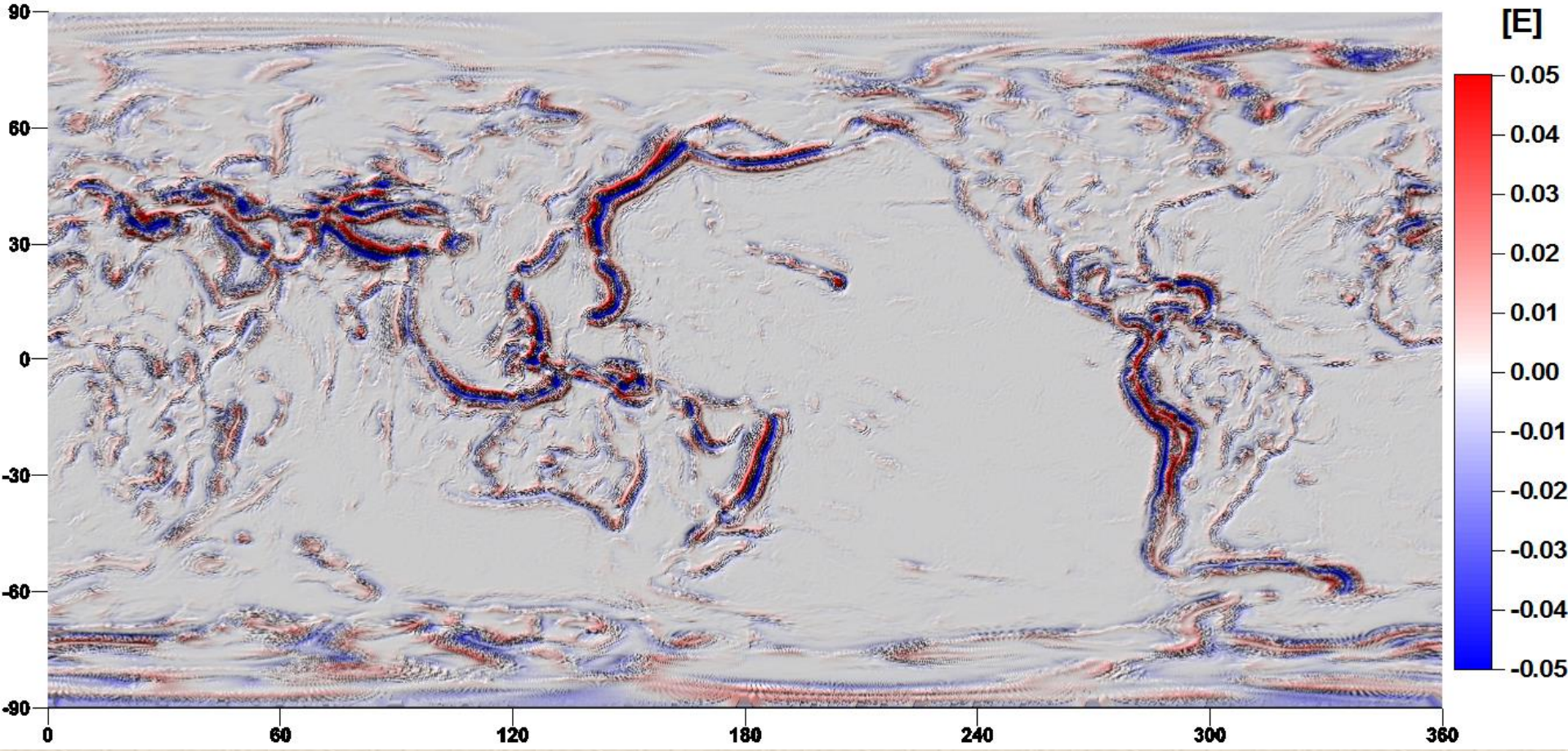
Linear diffusion

100 iterations



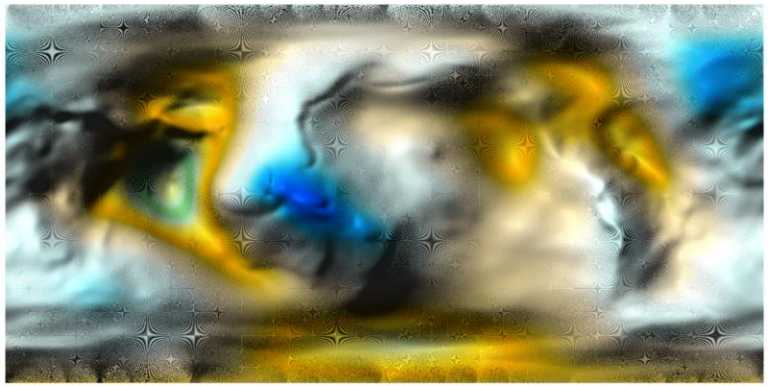
Nelineárna – lineárna difúzia

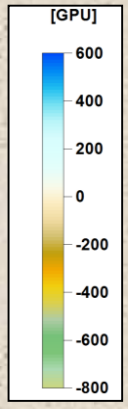
100 iterations



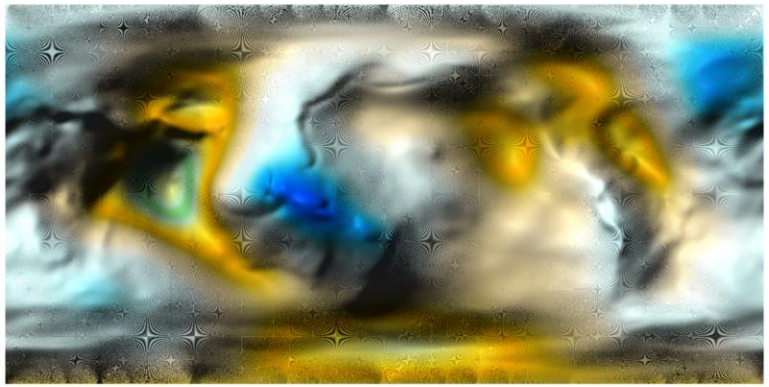
Model tiažového poľa z filtrovaných dát

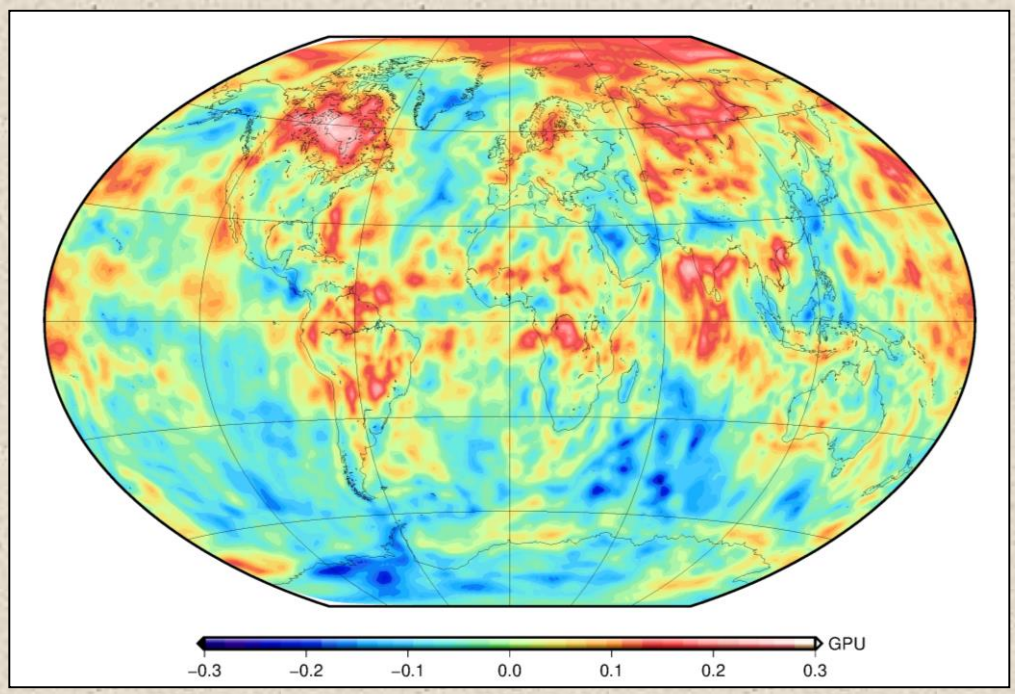
MFS





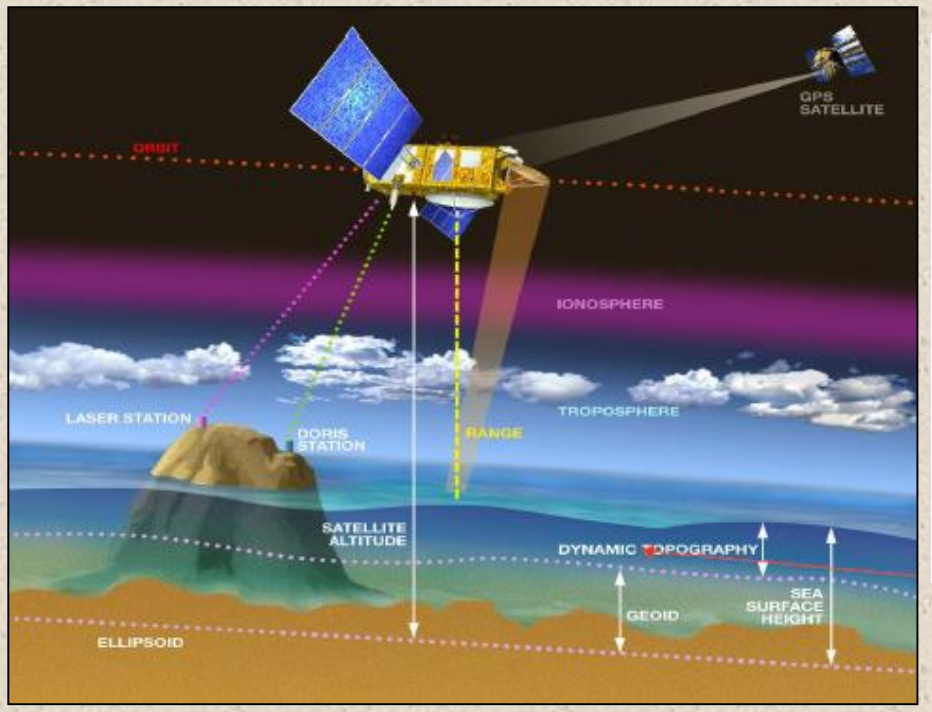
GOCO03S

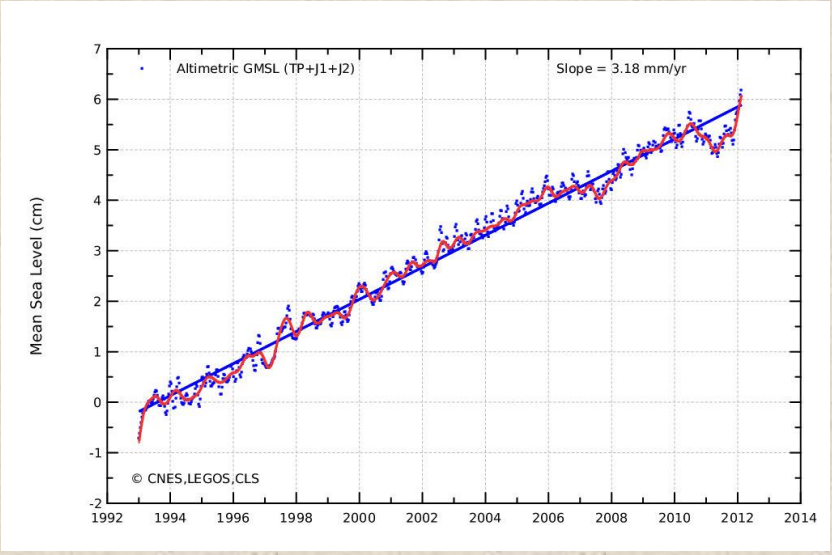


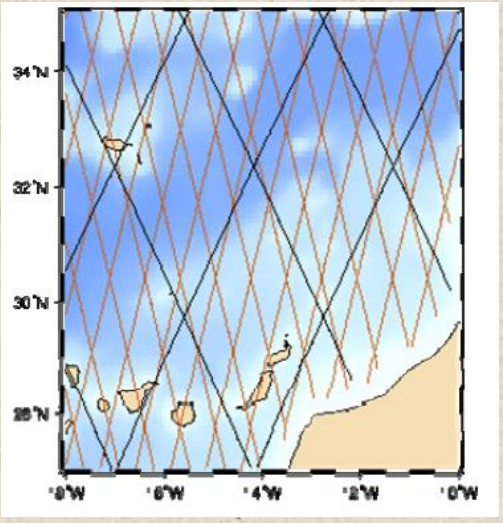


STATISTICS	
Nodes	5 760 002
Mean	-0.004 m^2s^{-2}
Max	0.268 m^2s^{-2}
MIN	-0.231 m^2s^{-2}
St. Dev.	0.069 m^2s^{-2}

Družicová altimetria

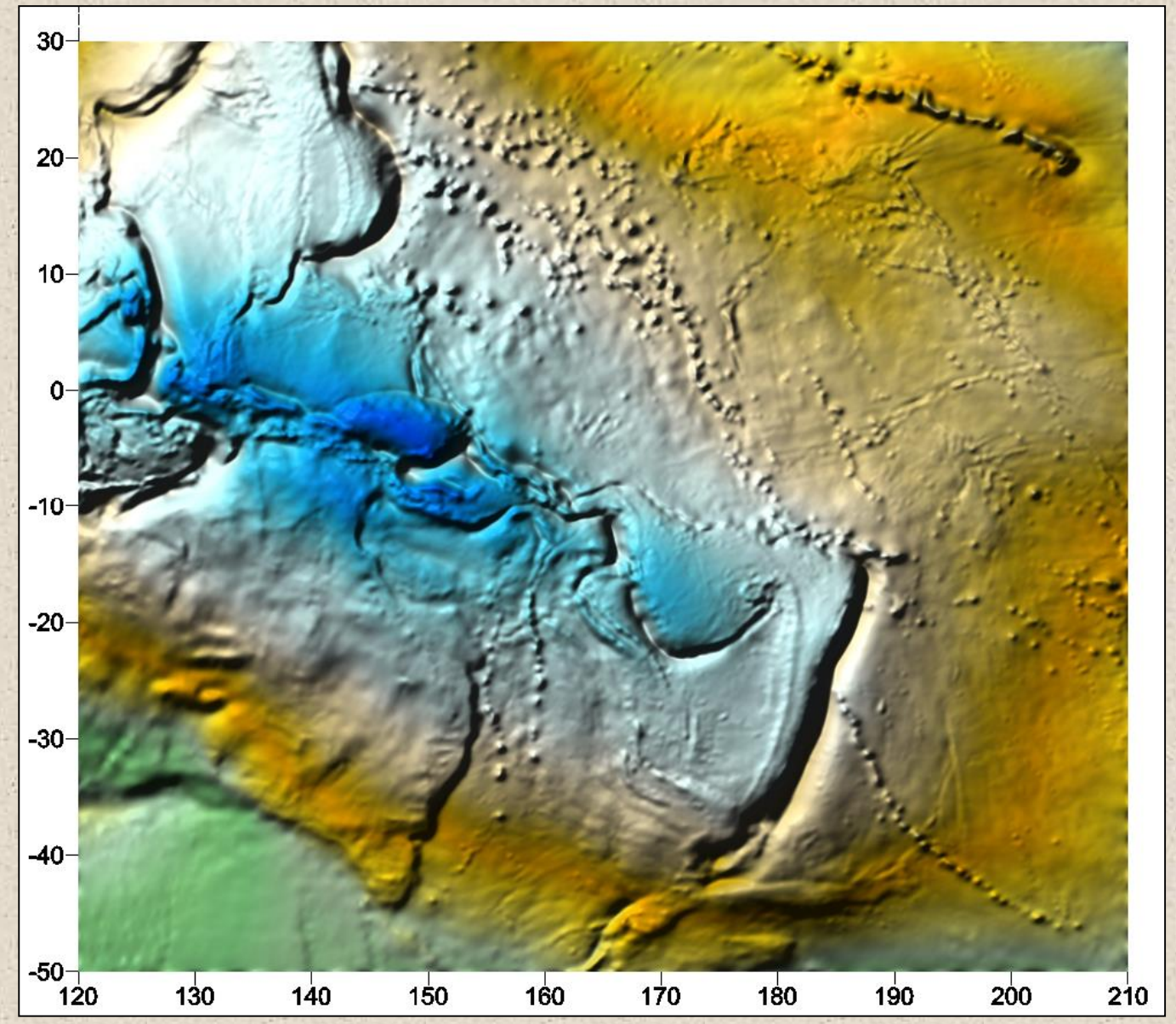




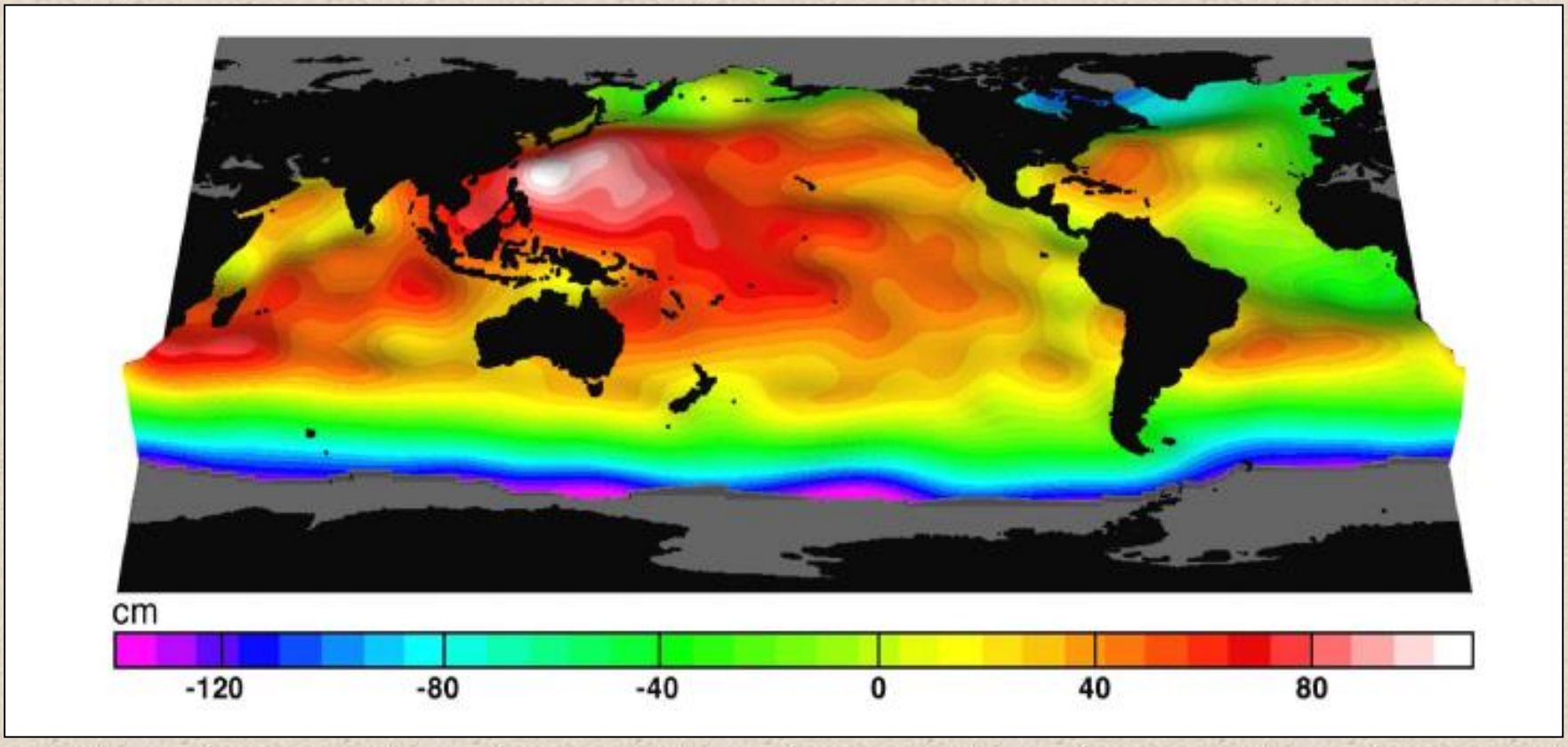


Družicová altimetria

Stredná hladina mora



Dynamická topografia oceánov



"geodetický prístup"

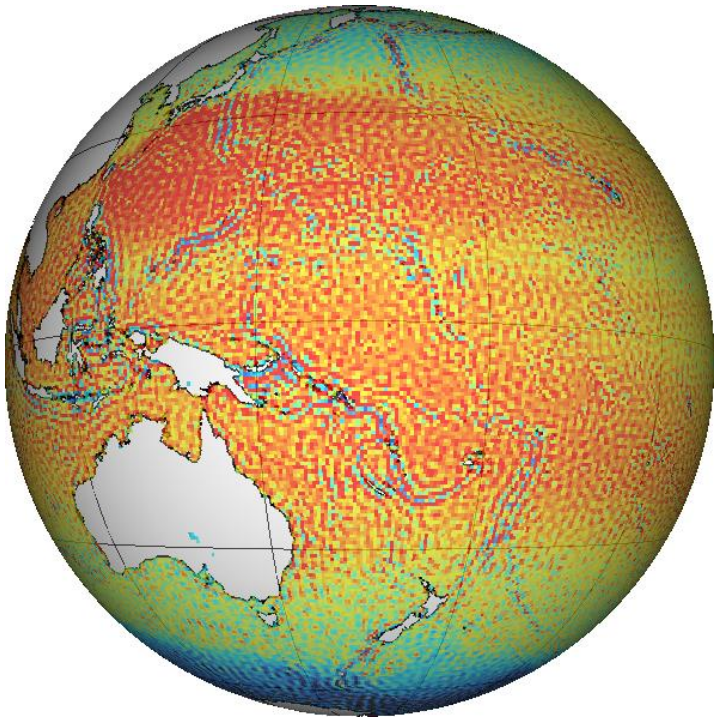
SDTO = SHM - geoid

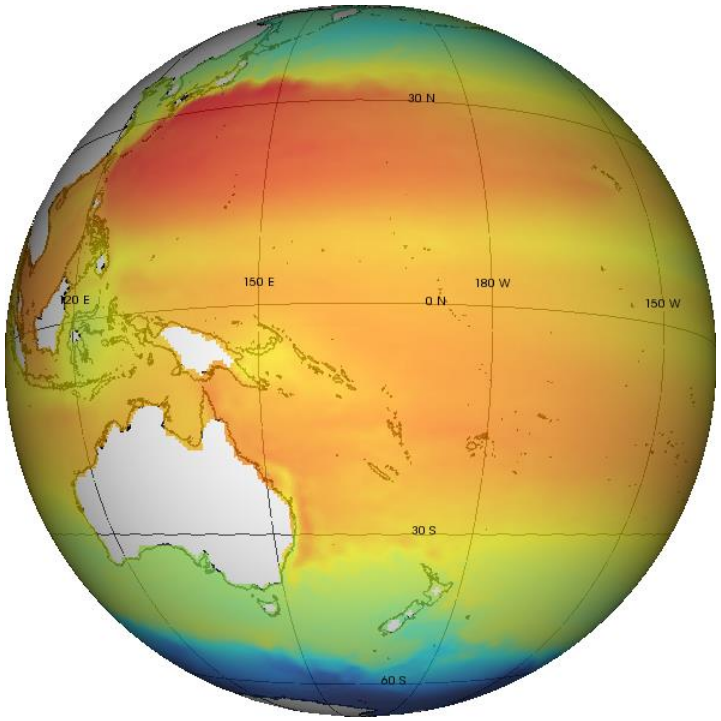
SDTO – stredná dynamická topografia oceánov
SHM – stredná hladina morí

Dynamická topografia oceánov

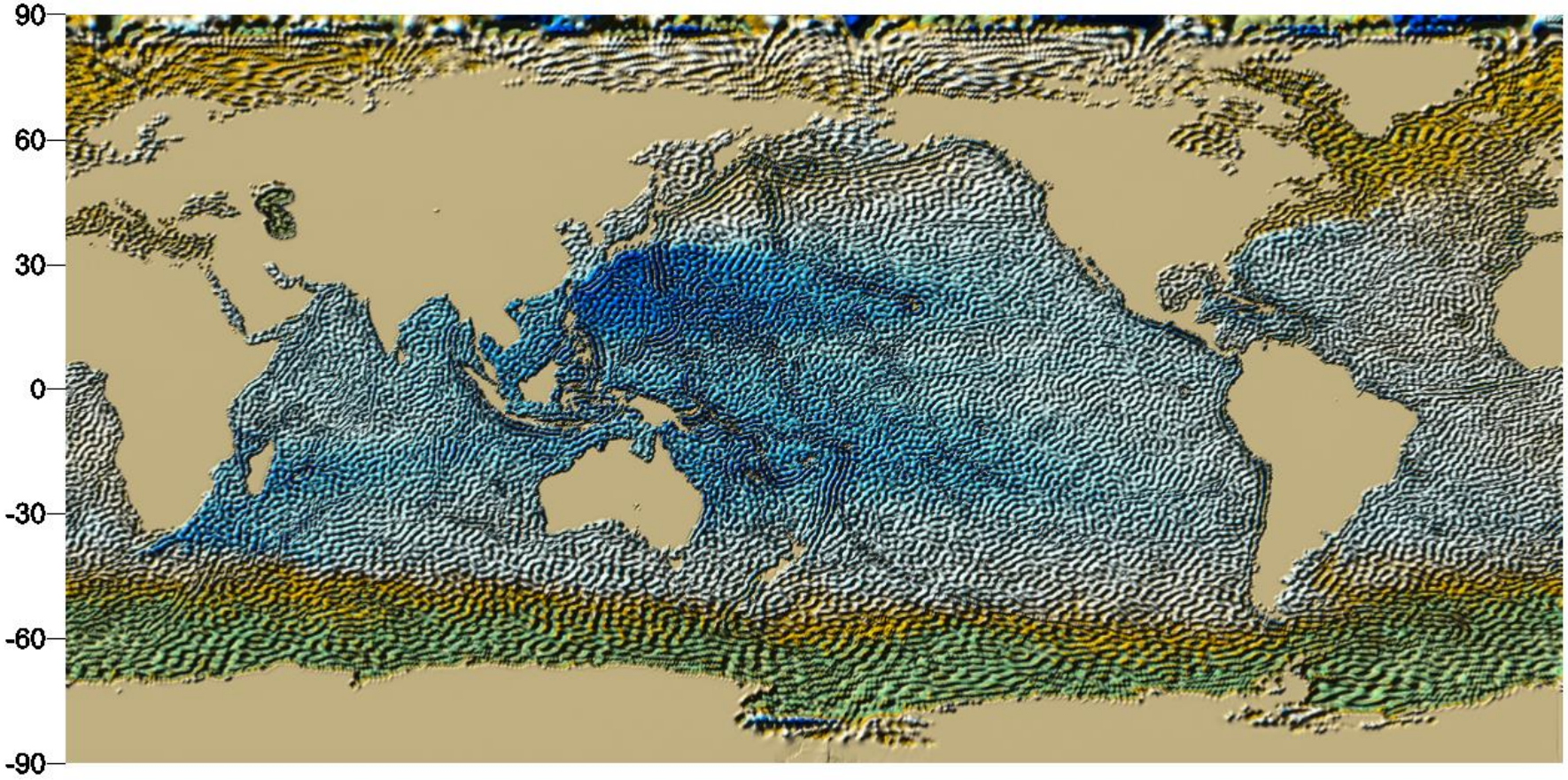
Satellite altimetry + GOCE

After filtering



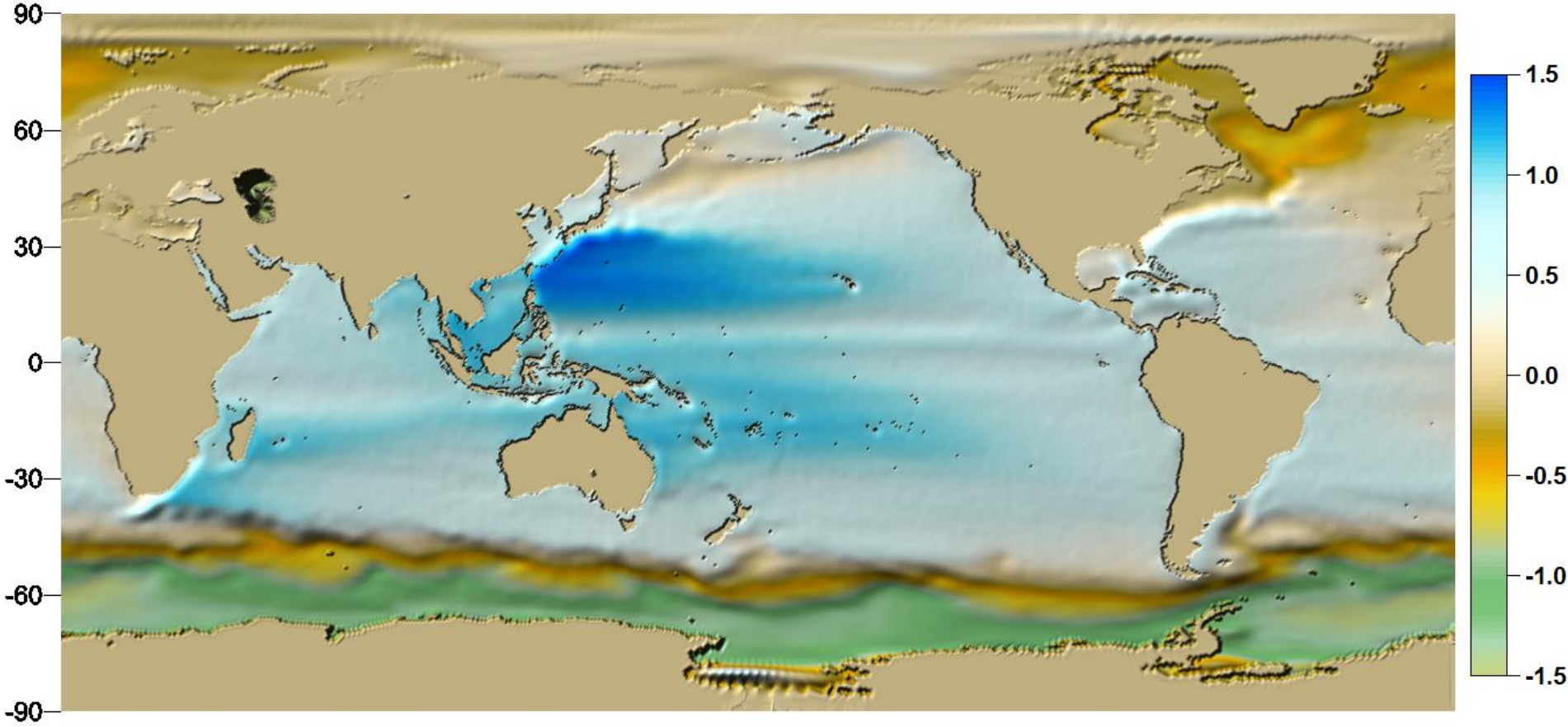


SDTO určená iba z družicových dát



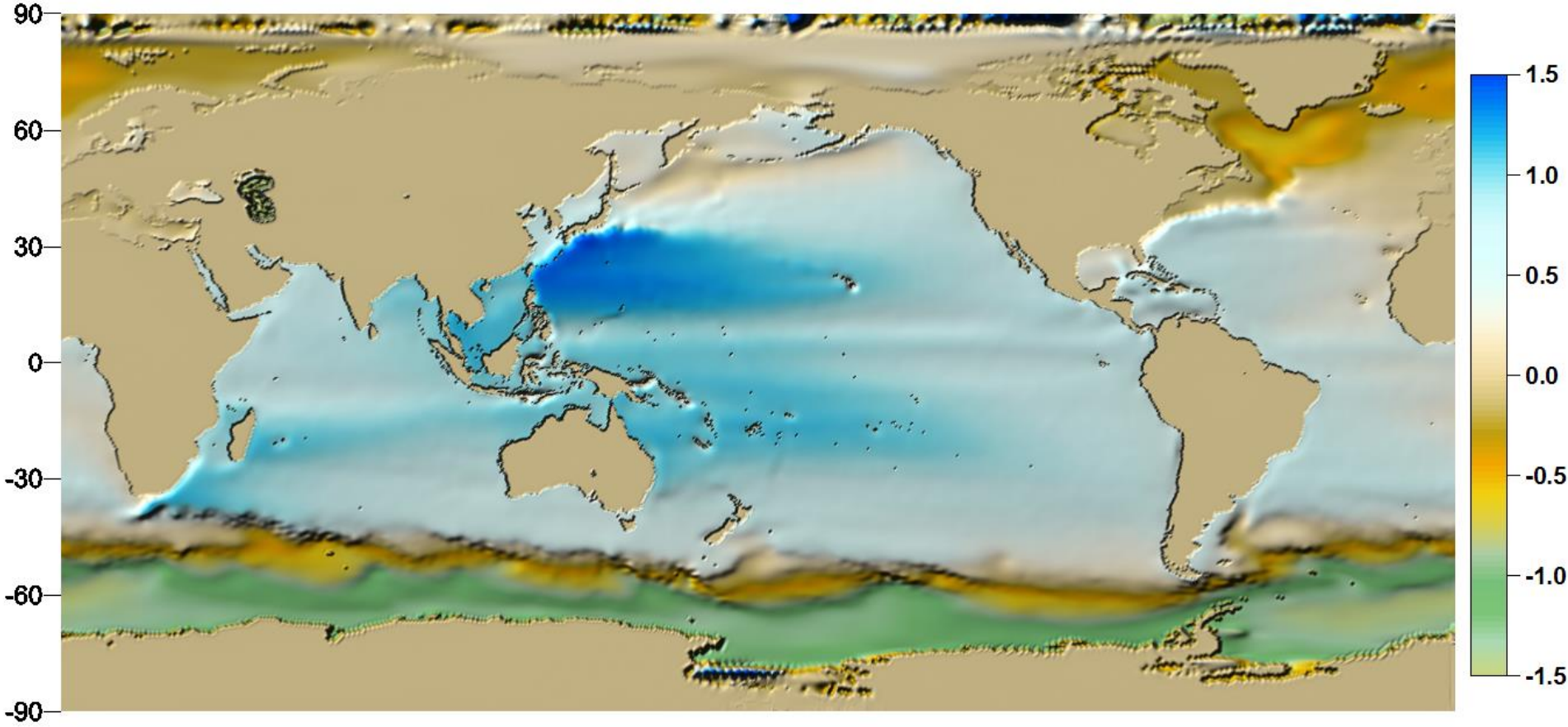
Initial data

Lineárna difúzia



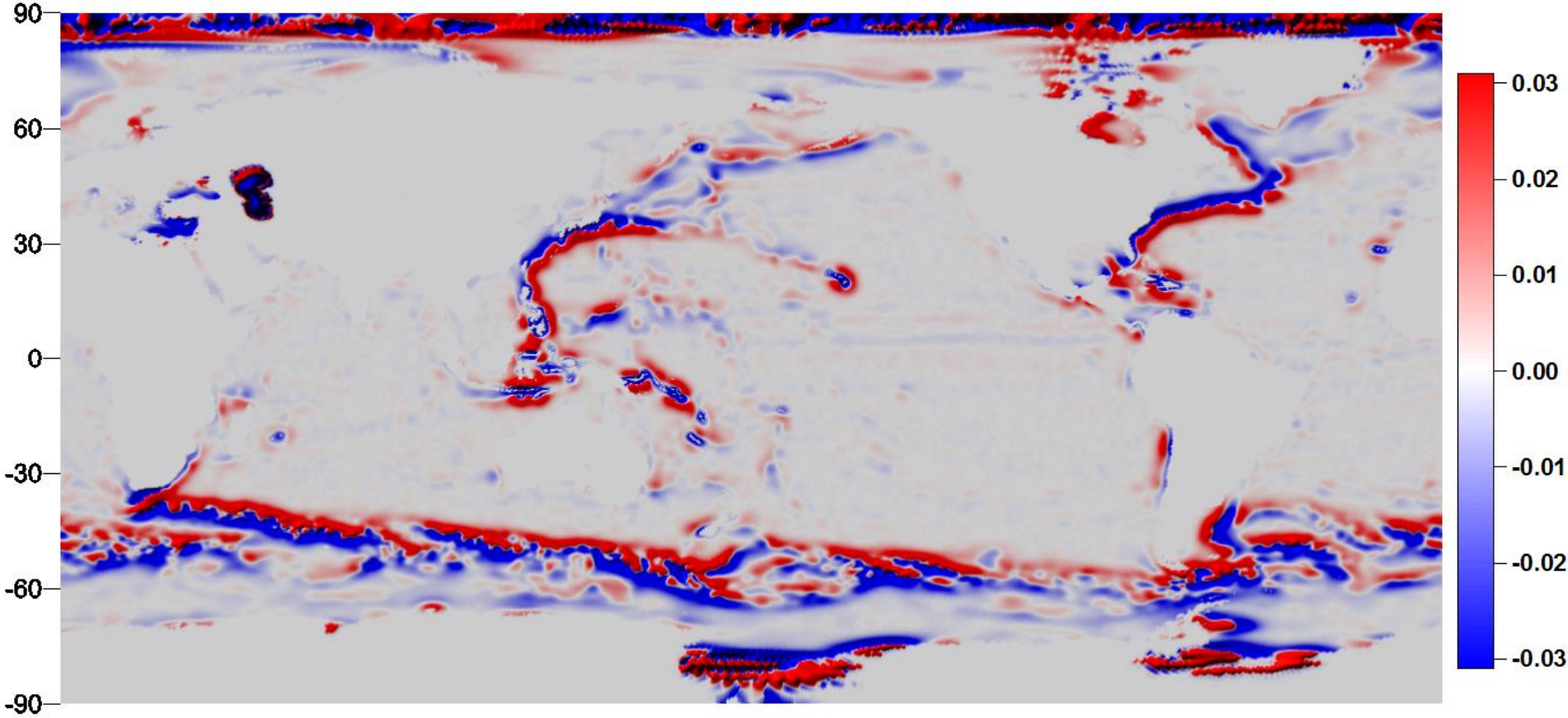
25 iterations

Nelineárna difúzia



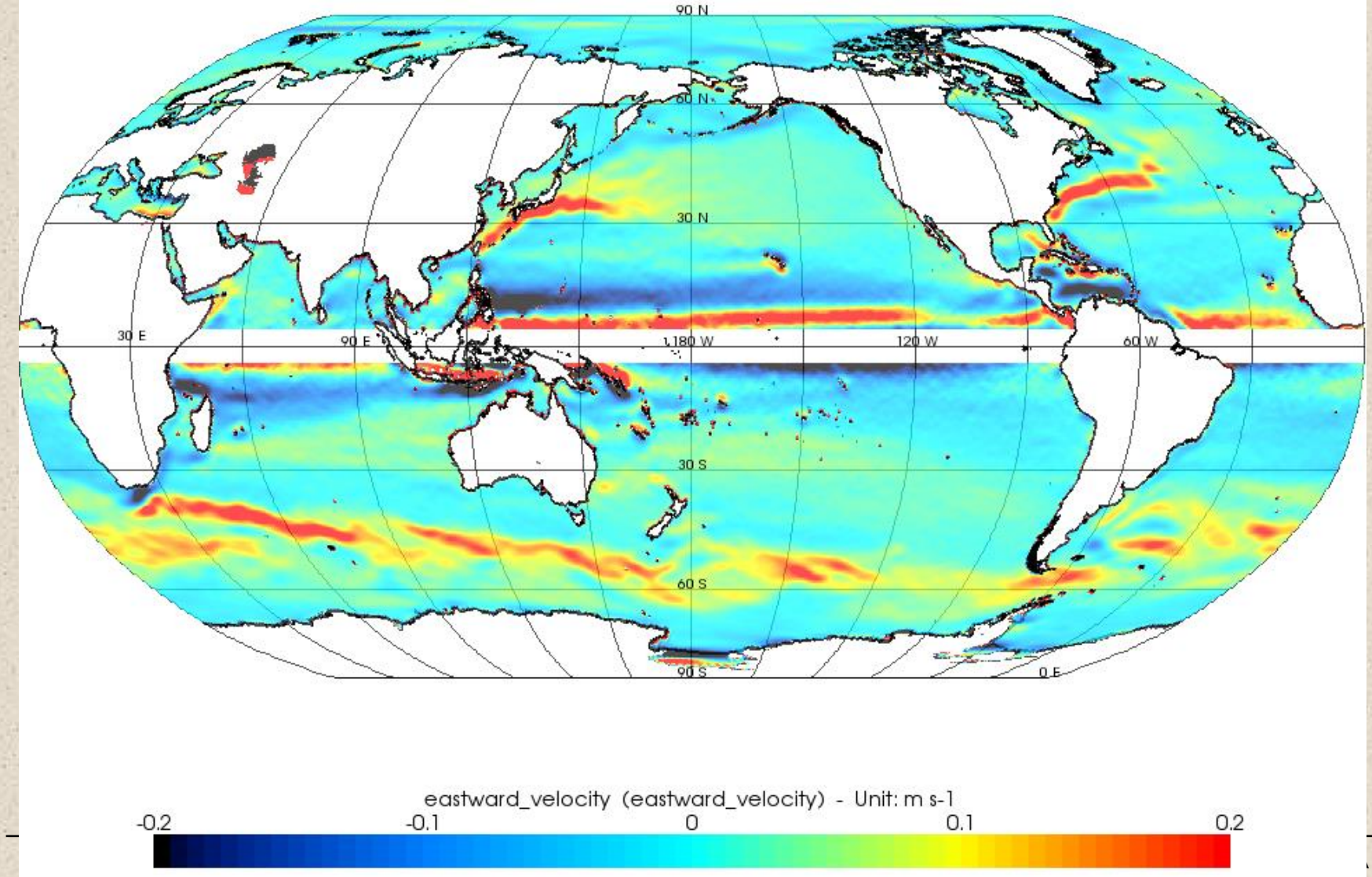
25 iterations

Nelineárna - lineárna difúzia

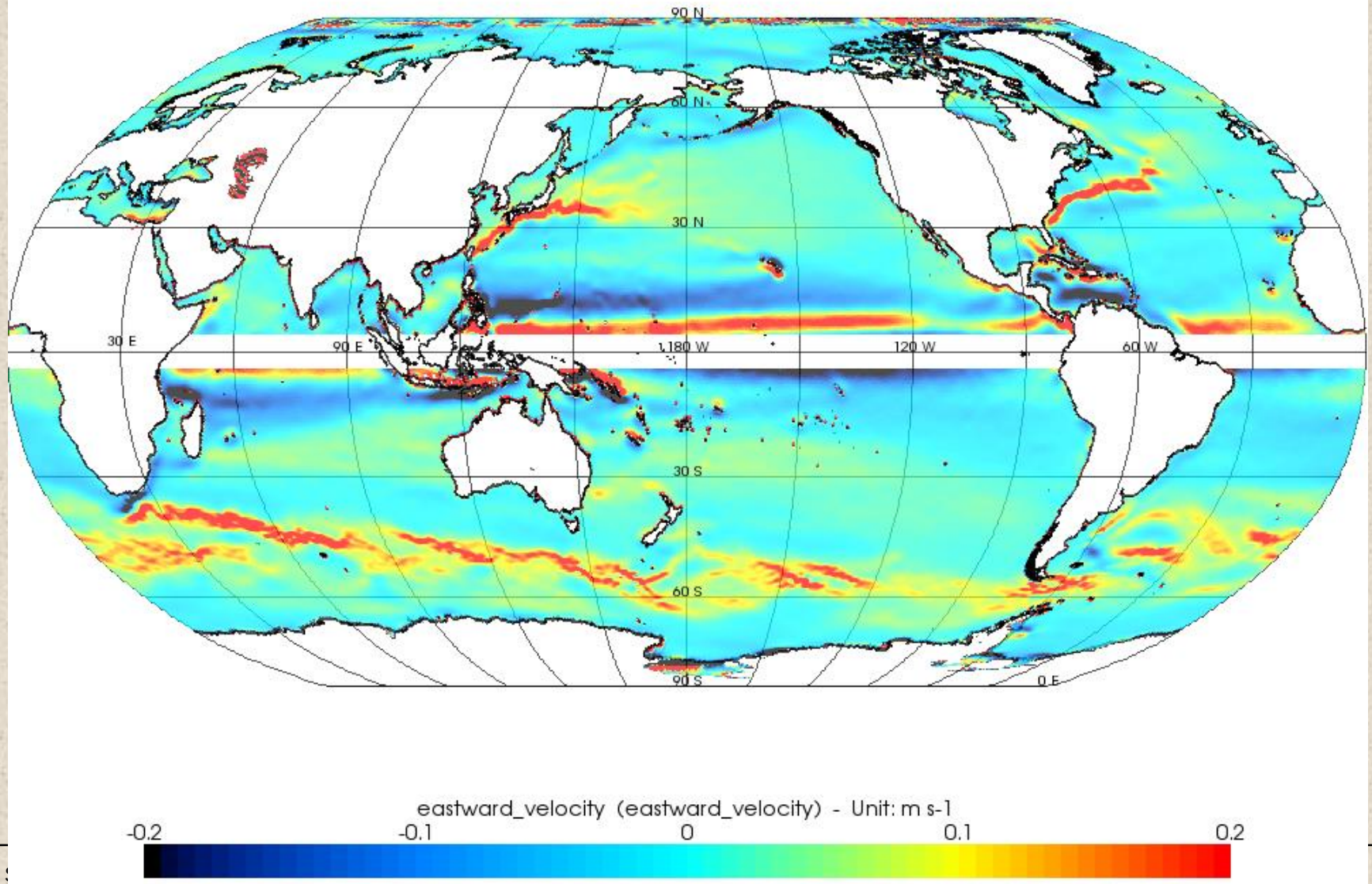


25 iterations

Geostrofické rýchlosti – lineárna difúzia

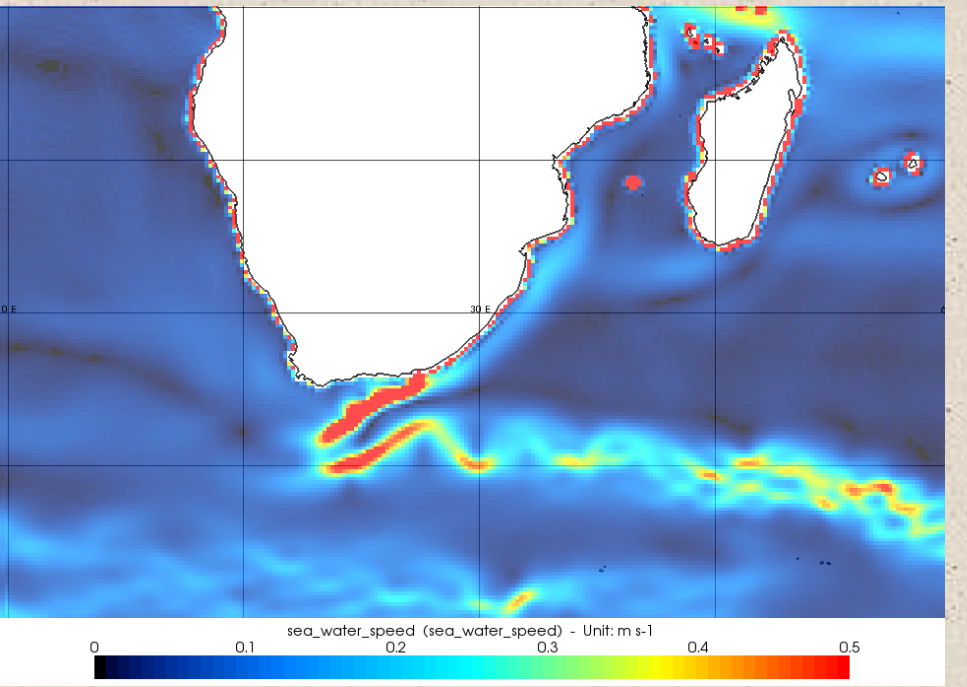


Geostrofické rýchlosti – nelineárna difúzia

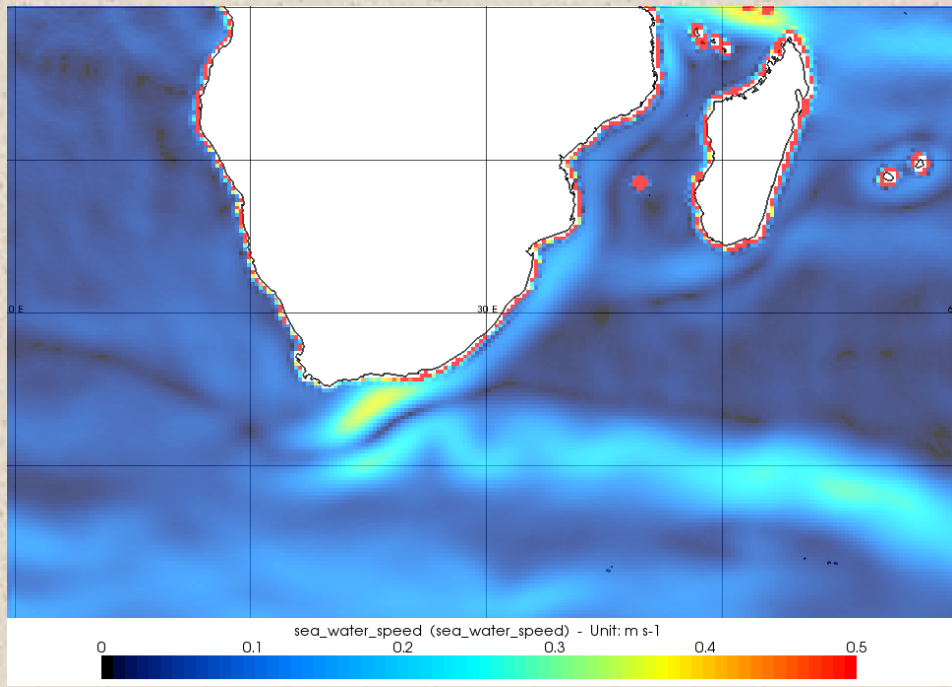


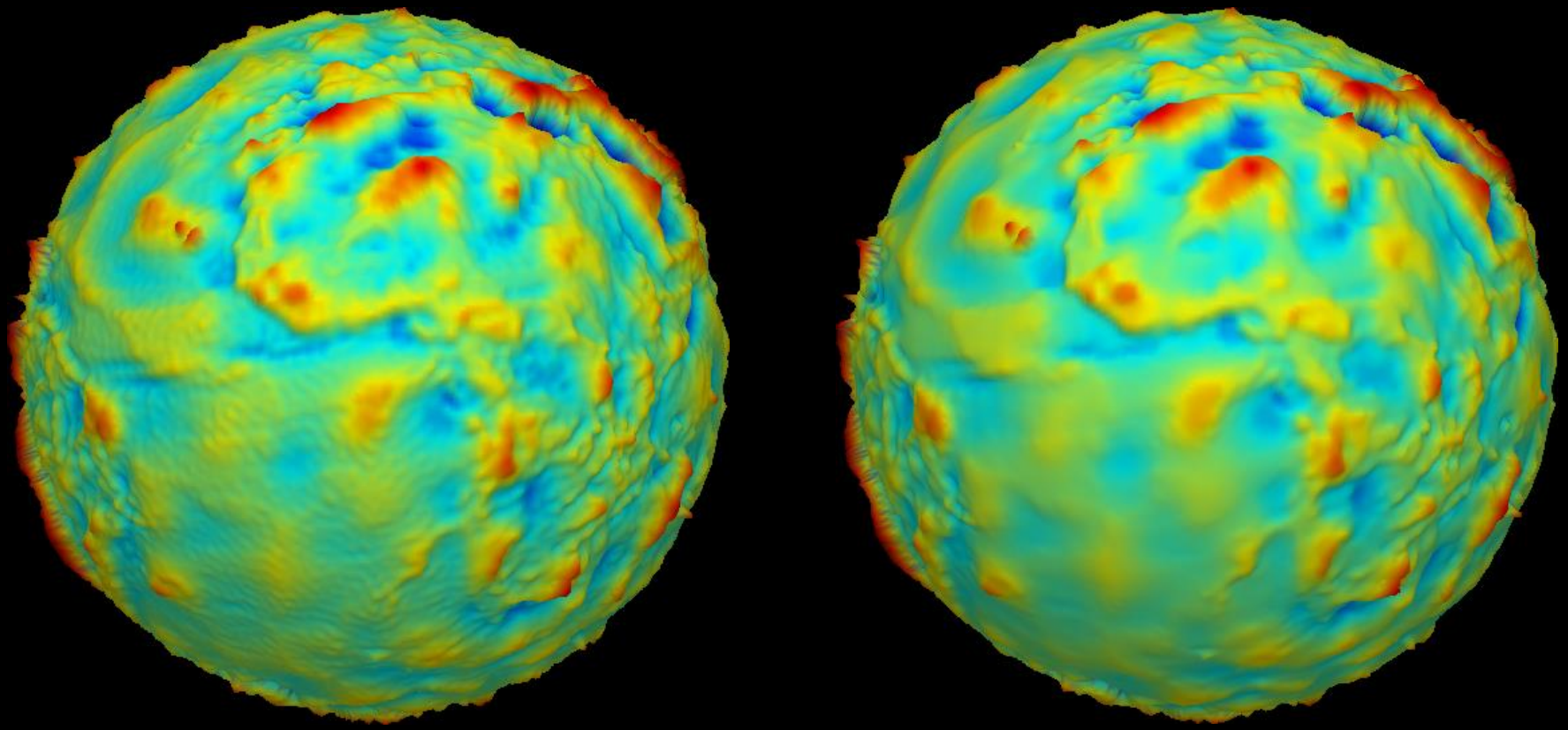
Geostrofické rýchlosti prúdov

Nelineárna difúzia



Lineárna difúzia





Vďaka za pozornosť