Optimizing Tides in Barotropic HYCOM

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Objectives

- Improve tidal water levels and currents in HYCOM with the best available internal wave drag scheme
- Better surface tides give better internal tides in HYCOM
- Improved tidal prediction skills allows HYCOM to be used for nesting (internal) tides in regional models

Barotropic Tide Model

- One layer momentum equation

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} + f\hat{k} \times \mathbf{u} = -g\nabla(\eta - \eta_{EQ} - \eta_{SAL}) - \frac{C_d|\mathbf{u}|\mathbf{u}}{H} - \frac{C\mathbf{u}}{\rho_o H} + \mathcal{F}$$

forcing | bottom drag | int. w. drag

- Global tripolar grid with 2/25° resolution
- M_2 equilibrium tide and spatially varying scalar Self Attraction and Loading $\eta_{SAL} = \beta(x, y) \cdot \eta$
- *First* find best RMS by varying linear internal wave drag, *then* iterate SAL
- Model is run for 33 days; last three days are analyzed

Internal Wave Drag Schemes

- Jayne and St Laurent (2001) scalar:

$$C_{JSL} = \frac{\pi}{L} \widetilde{H}^2 N_b$$

- Nycander (2005) tensor:

$$\mathbb{C} = \frac{N_b}{4\pi} \sqrt{1 - \frac{f^2}{\omega^2}} (\nabla h \nabla J + \nabla J \nabla h) = \begin{bmatrix} C_{xx} & C_{xy} \\ C_{yx} & C_{yy} \end{bmatrix}$$

- Nycander scalar

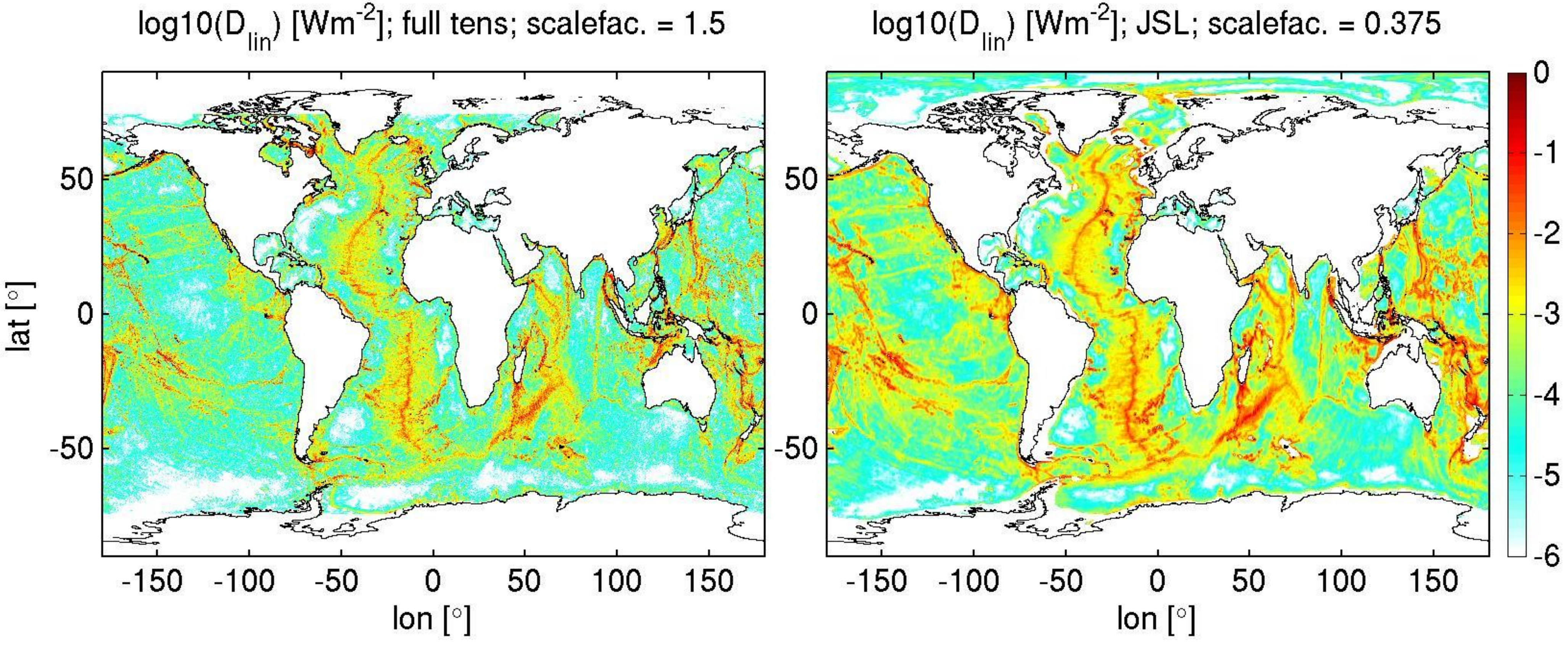
$$C_{NC} = \frac{\langle D_{\mathbb{C}} \rangle}{\rho_0 \langle |\mathbf{u}|^2 \rangle} = \frac{\langle \mathbf{u} \cdot \mathbb{C} \cdot \mathbf{u} \rangle}{\langle |\mathbf{u}|^2 \rangle}$$

- *N* from GDEM and *h* from 30” GEBCO.

Internal Wave Drag Schemes

study	type	Characteristics	Scale factor range	Name
Jayne and St Laurent (2001)	scalar	full	0.25 – 0.75	**JSL**
Nycander (2005)	tensor	full	0.5 – 4	**full tens**
Nycander (2005)	scalar	full	0.5 – 4	**full scalar**
Nycander (2005)	tensor	reduced at supercritical slopes	0.5 – 8	**tens no supercr**
Nycander (2005)	scalar	reduced at supercritical slopes	0.5 – 6	**scal no supercr**
Nycander (2005)	scalar	reduced above 2000 m	1 – 5	**lim scal 2km**

Internal Wave Drag Schemes



Nycander tensor

JSL scalar

Validation

- Compare HYCOM and TPXO8 M_2 water levels

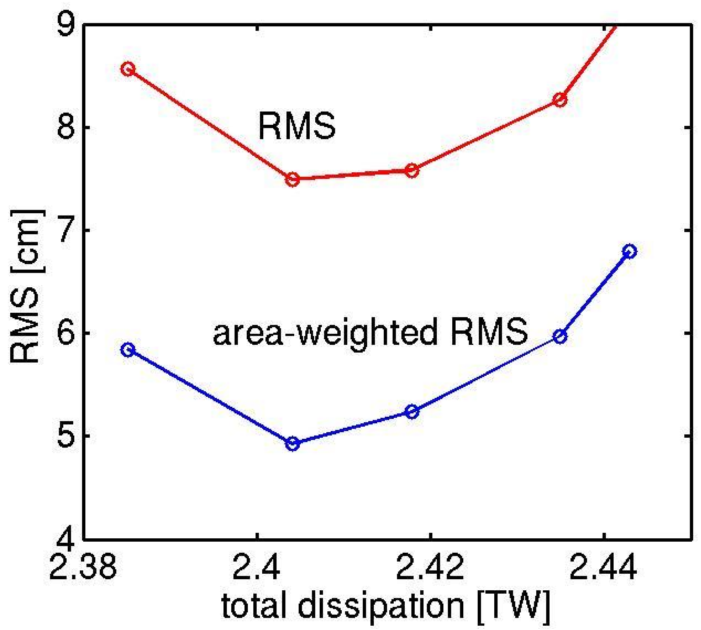
  - error in each grid point

$$RMS_t = \sqrt{\frac{1}{T}\int(\eta_m - \eta_o)^2 dt} = \sqrt{\langle(\eta_m - \eta_o)^2\rangle}$$

  - global mean

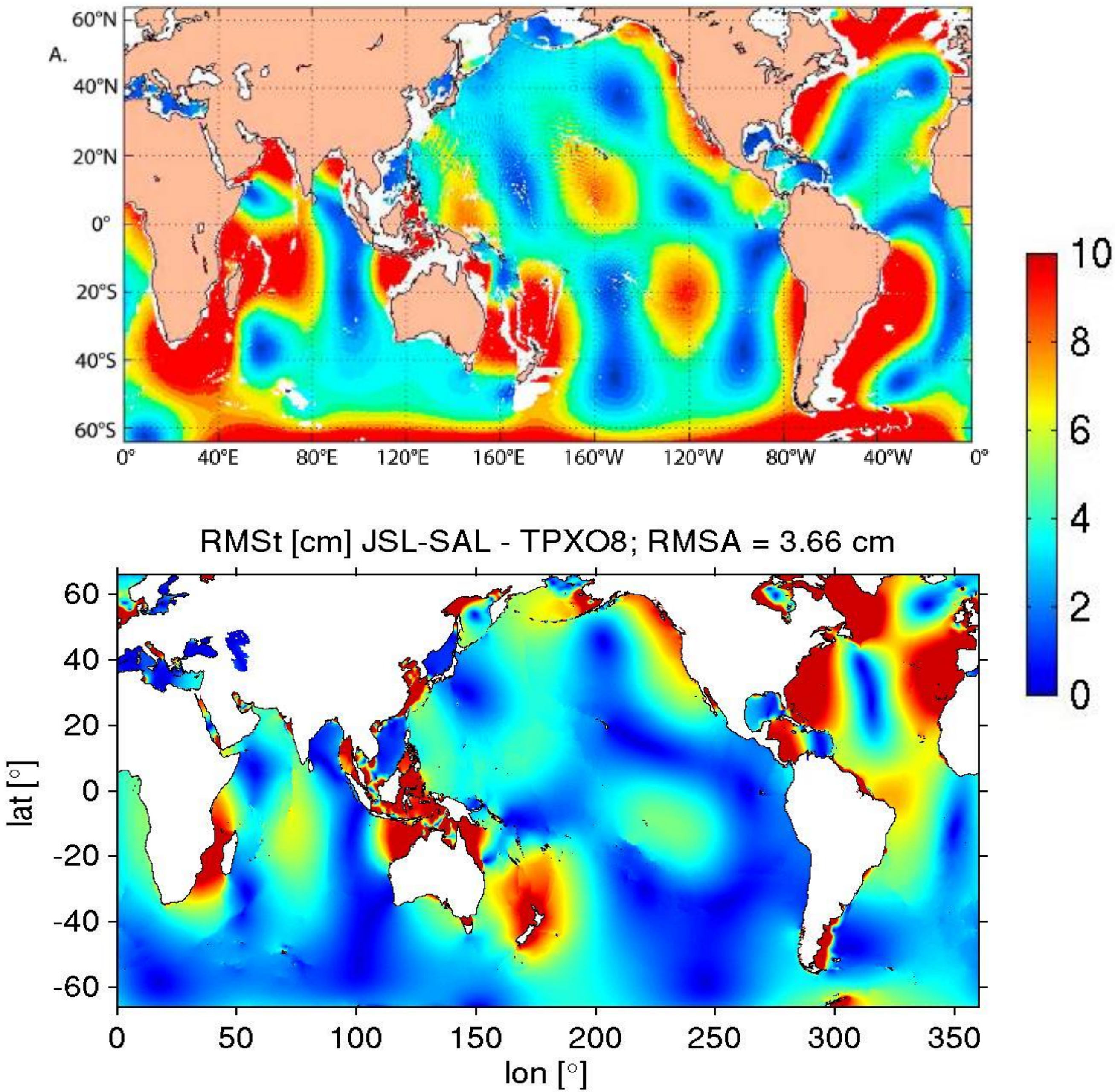
Method 1) $RMS = \sqrt{\frac{\int RMS_t{}^2 dA}{\int dA}}$

Method 2) $RMS_A = \frac{\int RMS_t \, dA}{\int dA}$



RMS_t

Previous 3D HYCOM (Shriver et al, 2012); RMS_A = 7.5 cm



Validation

- Compare HYCOM and TPXO M_2 mean energy dissipation rates
- TPXO:

$$\underbrace{W}_{\text{input}} + \underbrace{\nabla \cdot \mathbf{P}}_{\text{flux div.}} = D$$

Dissipation rates of TPXO4a, TPXO6.2*, TPXO7.2*, and TPXO8-ATLAS*

*provided by Mattias Green

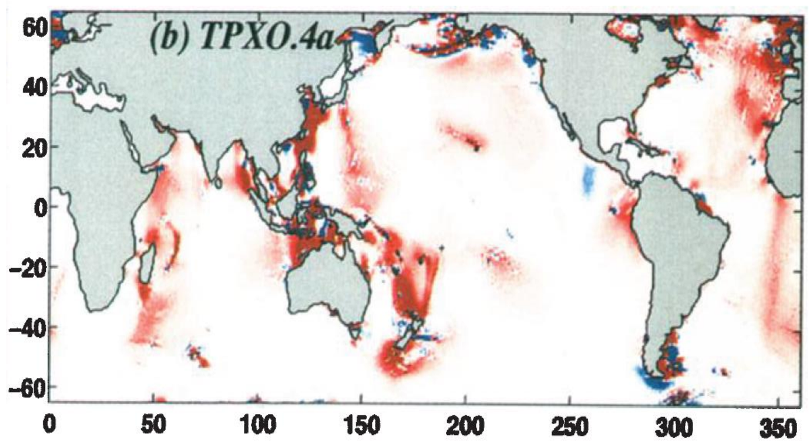
- HYCOM:

$$D = \underbrace{\rho_0 \langle \mathbf{u} \cdot \mathbb{C} \cdot \mathbf{u} \rangle}_{\text{internal w. drag}} + \underbrace{\rho_0 \langle C_\mathrm{D} |\mathbf{u}|^3 \rangle}_{\text{bottom drag}}$$

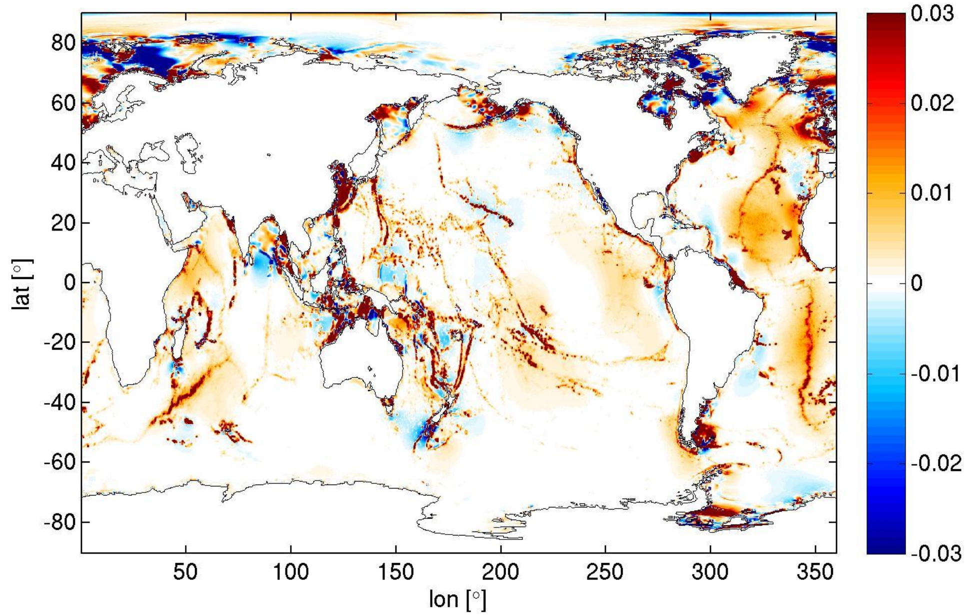
HYCOM rates are the average of the offline and online computations

TPXO Dissipation Maps

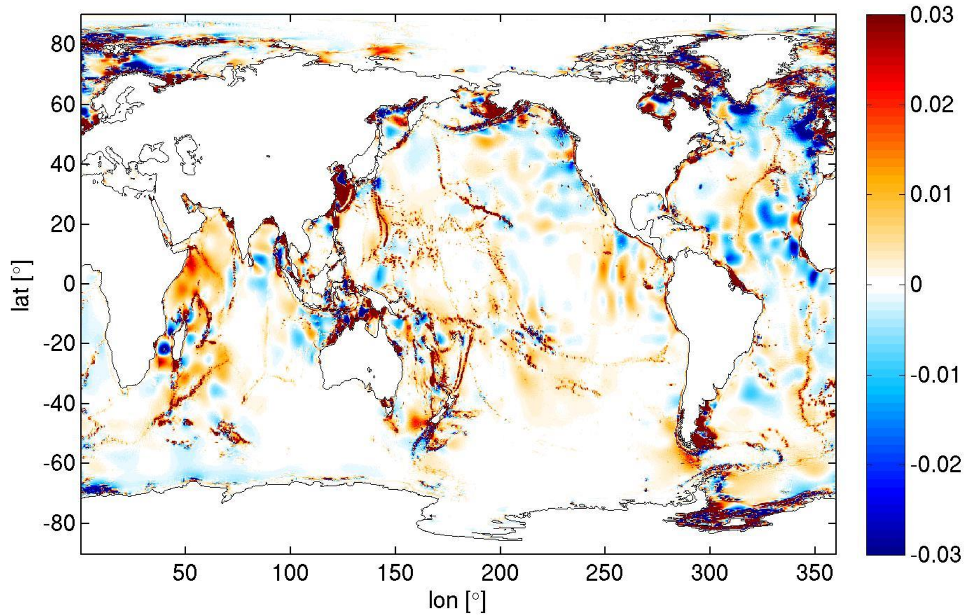
TPX04a



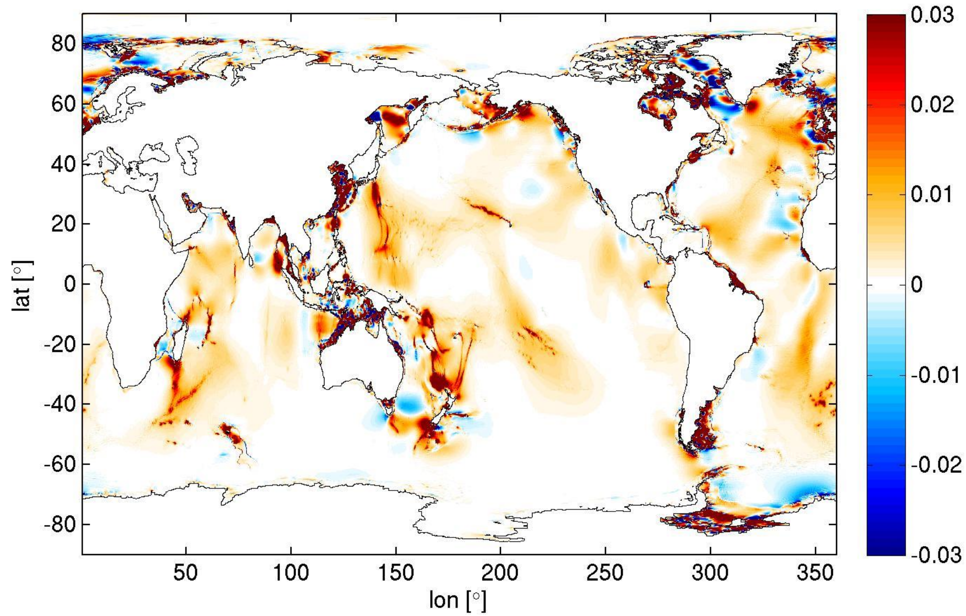
TPX06.2 [W/m²]



TPX07.2 [W/m²]

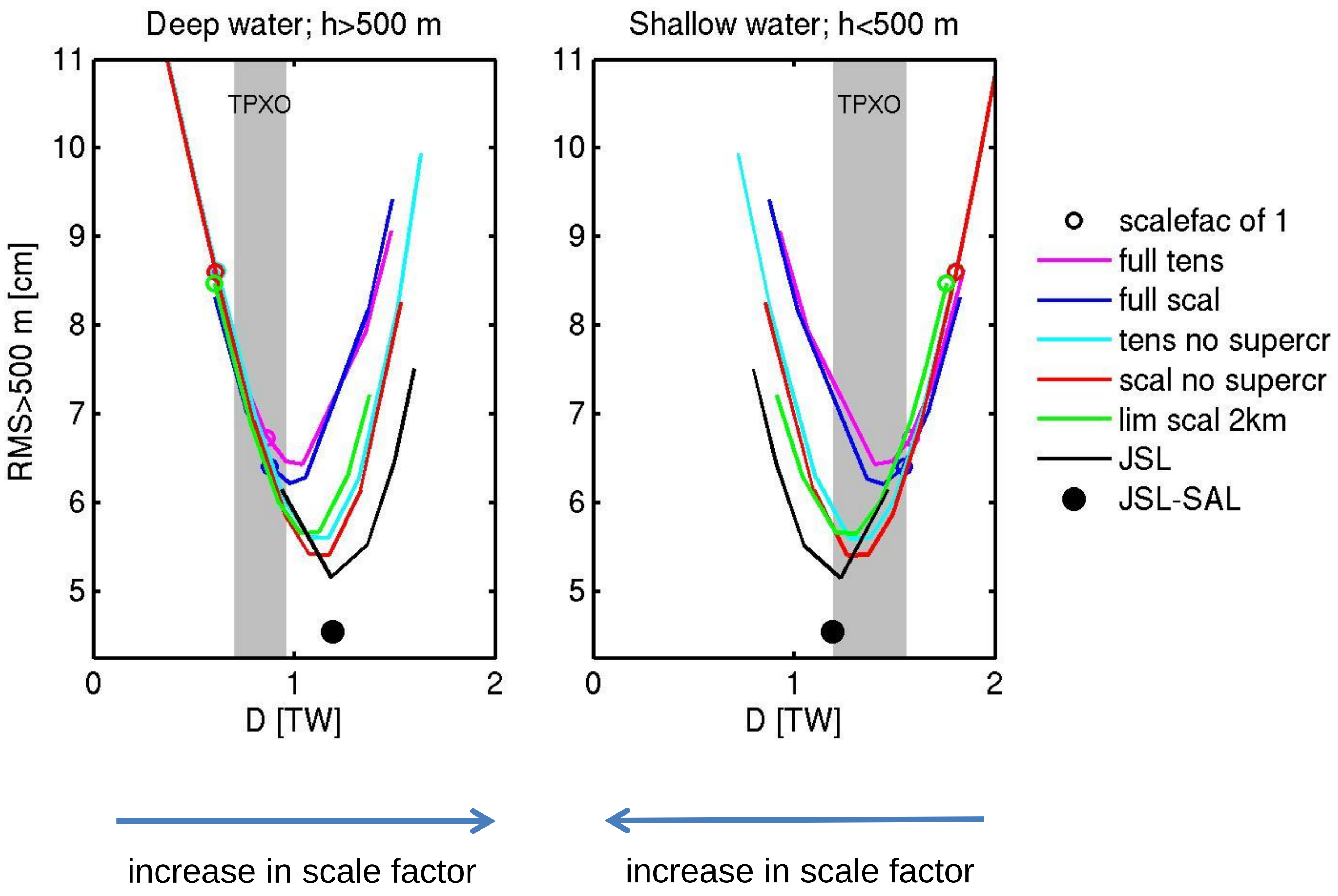


TPX08-ATLAS [W/m²]

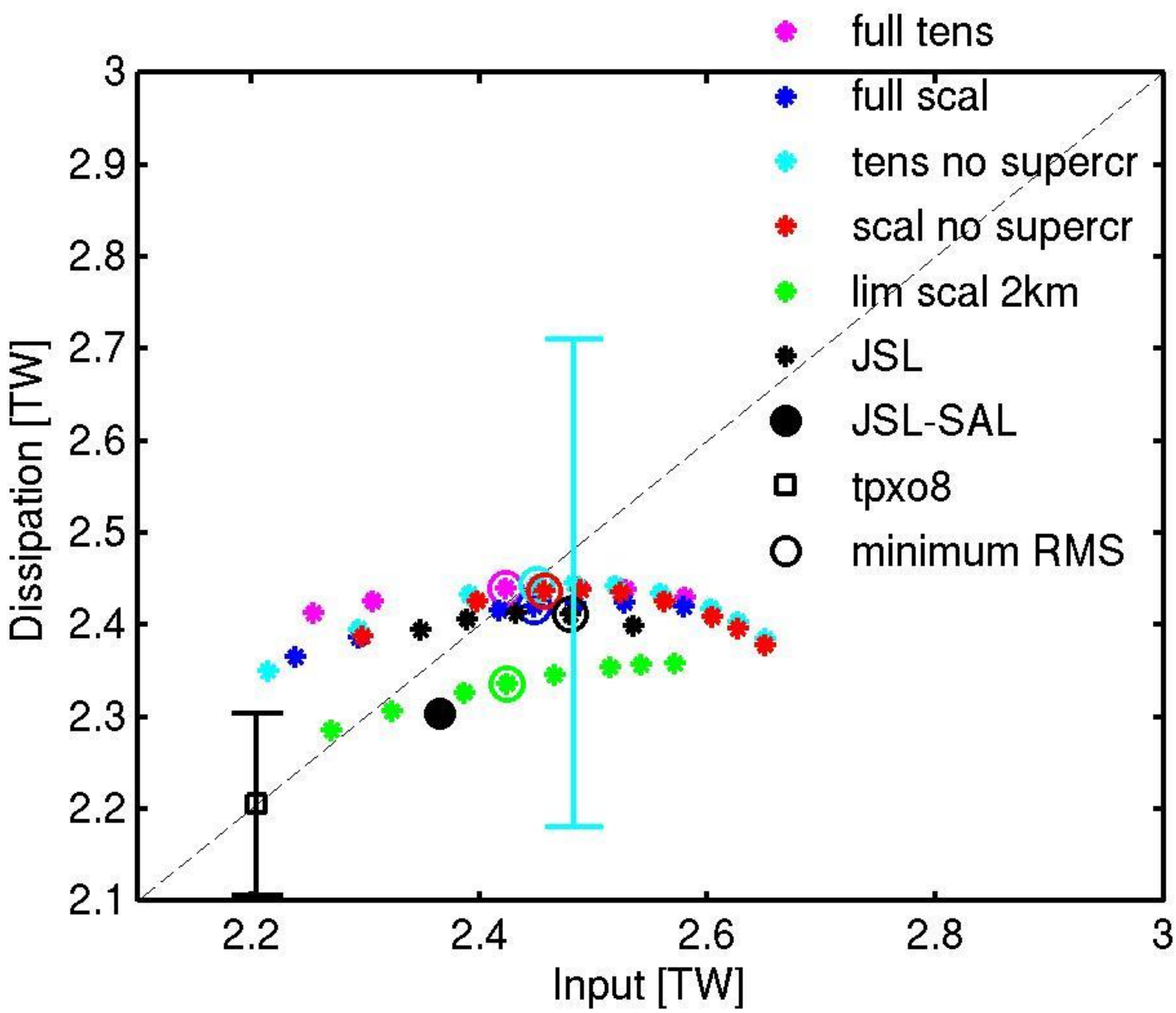


provided by Mattias Green

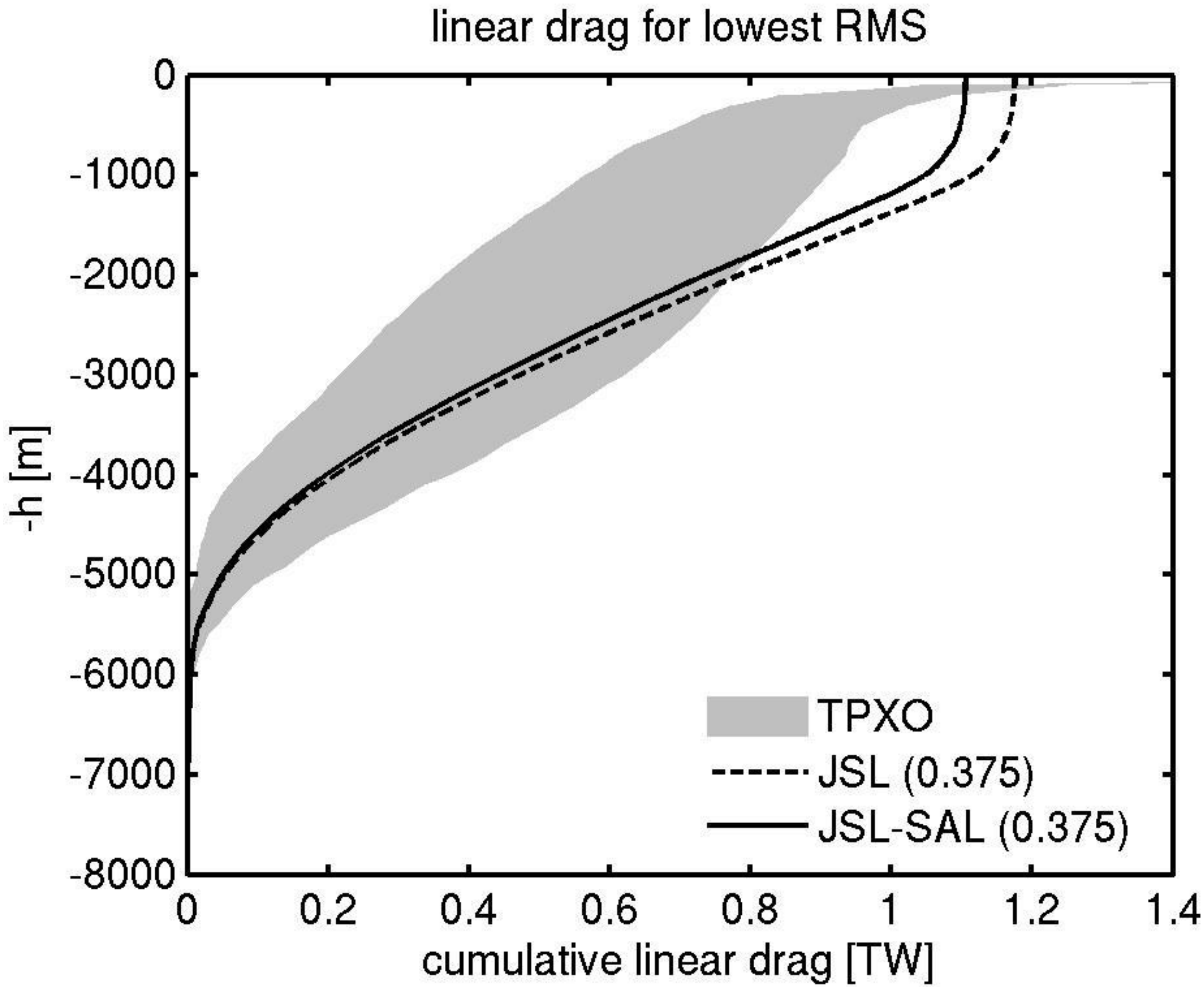
Global Validation



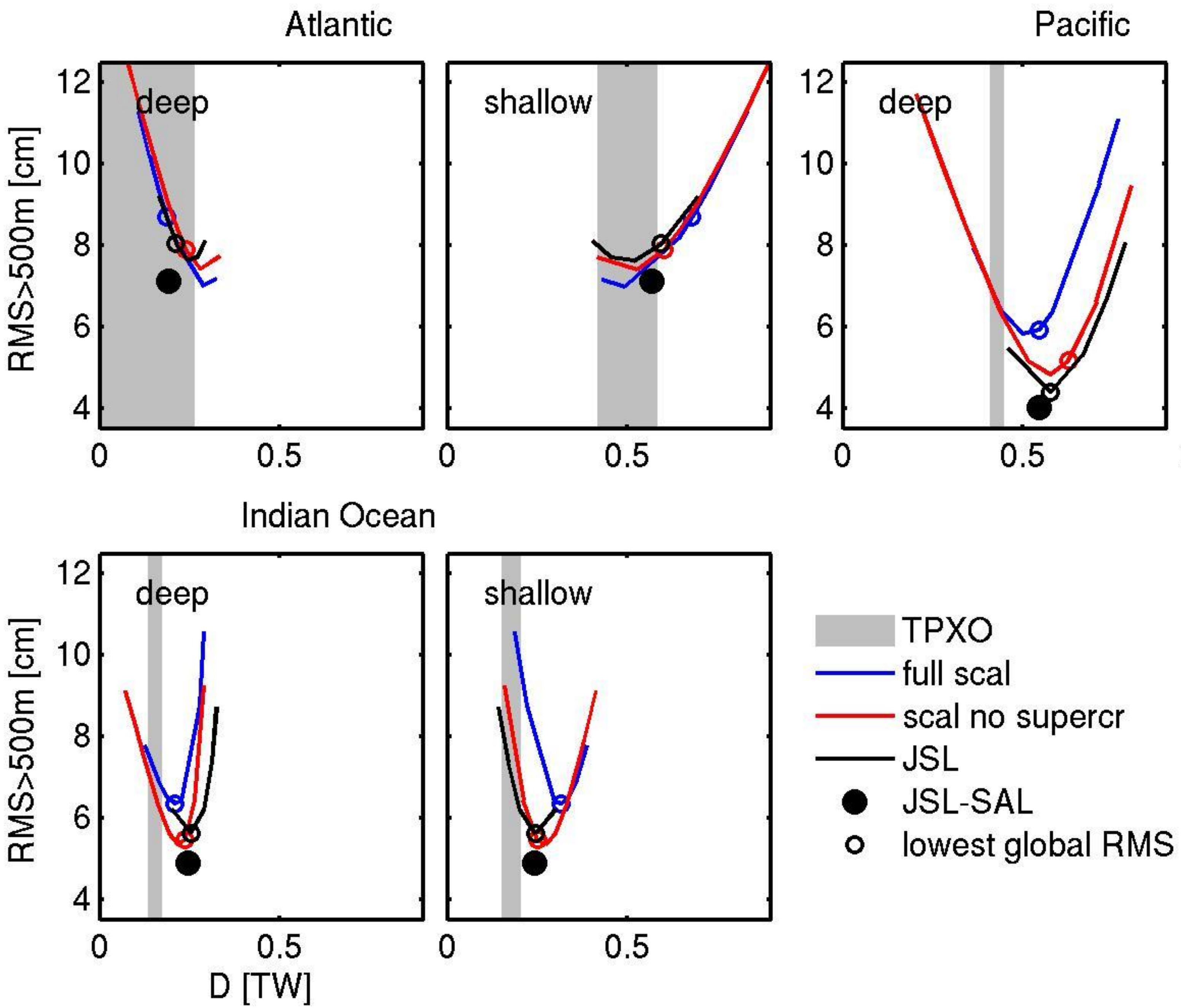
Global Validation



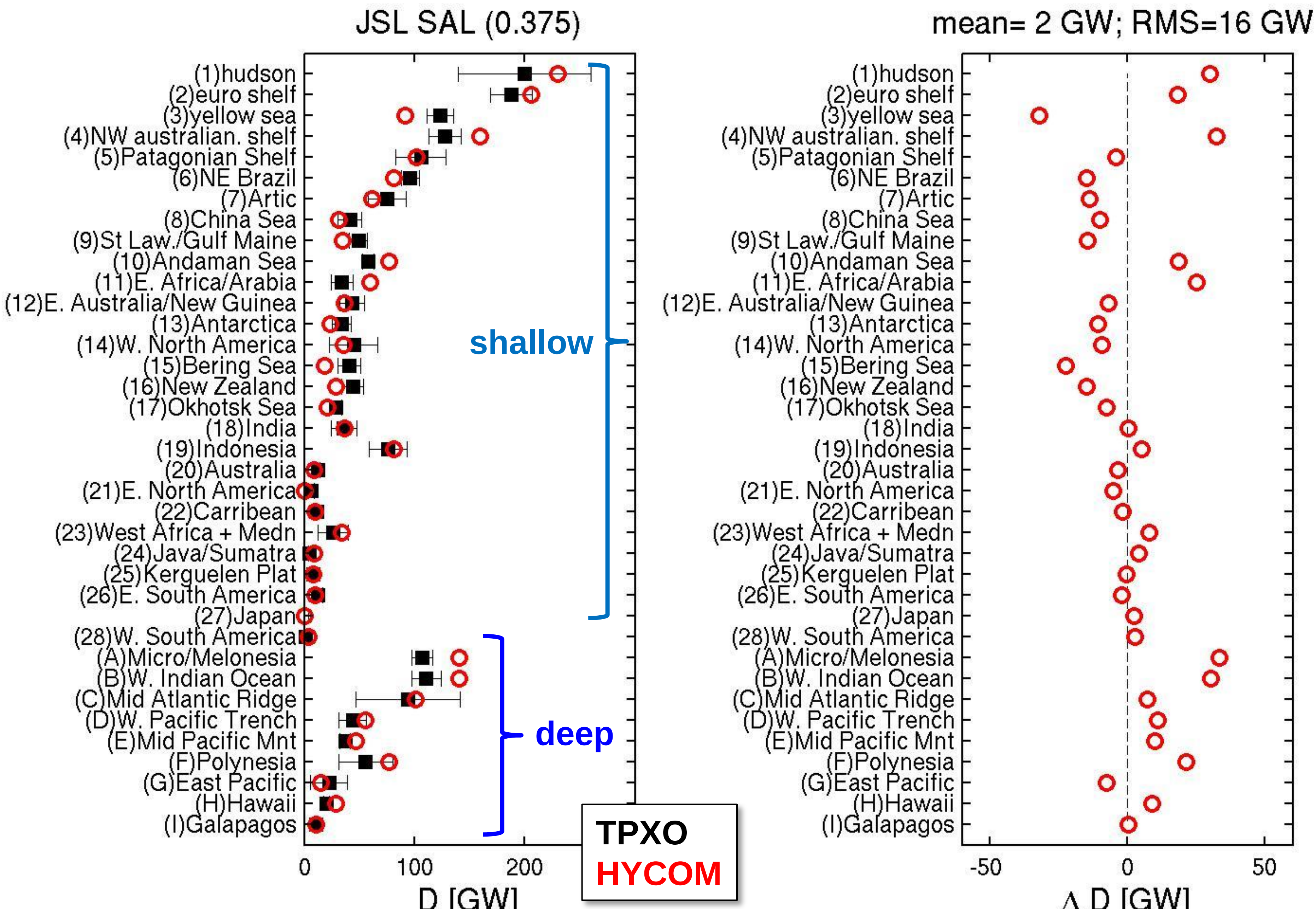
Global Validation



Basin Validation



Regional Validation



Compare with Past Results

Model Study	Linear drag	Model (Layers)	Res [º]	Data source	RMS (> 1km) [cm]	Tot. RMS [cm]
Jayne and St Laurent (2001)	JSL	JSL (1)	1/2	UT-CSR	**6.7**	
Arbic et al (2004)	Garner	HIM (2)	1/4	GOT99	**7.3***	
Arbic et al (2004)	-	HIM (2)	1/4	GOT99	**17.1***	
Simmons et al (2004)	-	HIM (2)	1/8	GOT99	**23.4***	
Egbert et al (2004)	Bell	OTIS (1)	1/12	TPXO5	**~5***	**~9***
Arbic et al (2010)	Garner	HYCOM (32)	2/25	tide gages	**8.3**	
Shriver et al (2010)	Garner	HYCOM (32)	2/25	TPXO7.2	**7.5***	
Muller et al (2012)	-	MPI-OM (40)	1/10	tide gages	**8.2**	
Green & Nycander (2012)	Nycndr	OTIS (1)	1/8	TPXO7.2	**7.0#**	
Buijsman et al (2013)	JSL	HYCOM (1)	2/25	TPXO8	**4.5***	**6.8**
Buijsman et al (2013)	JSL	HYCOM (1)	2/25	TPXO8	**3.6***	**4.3**

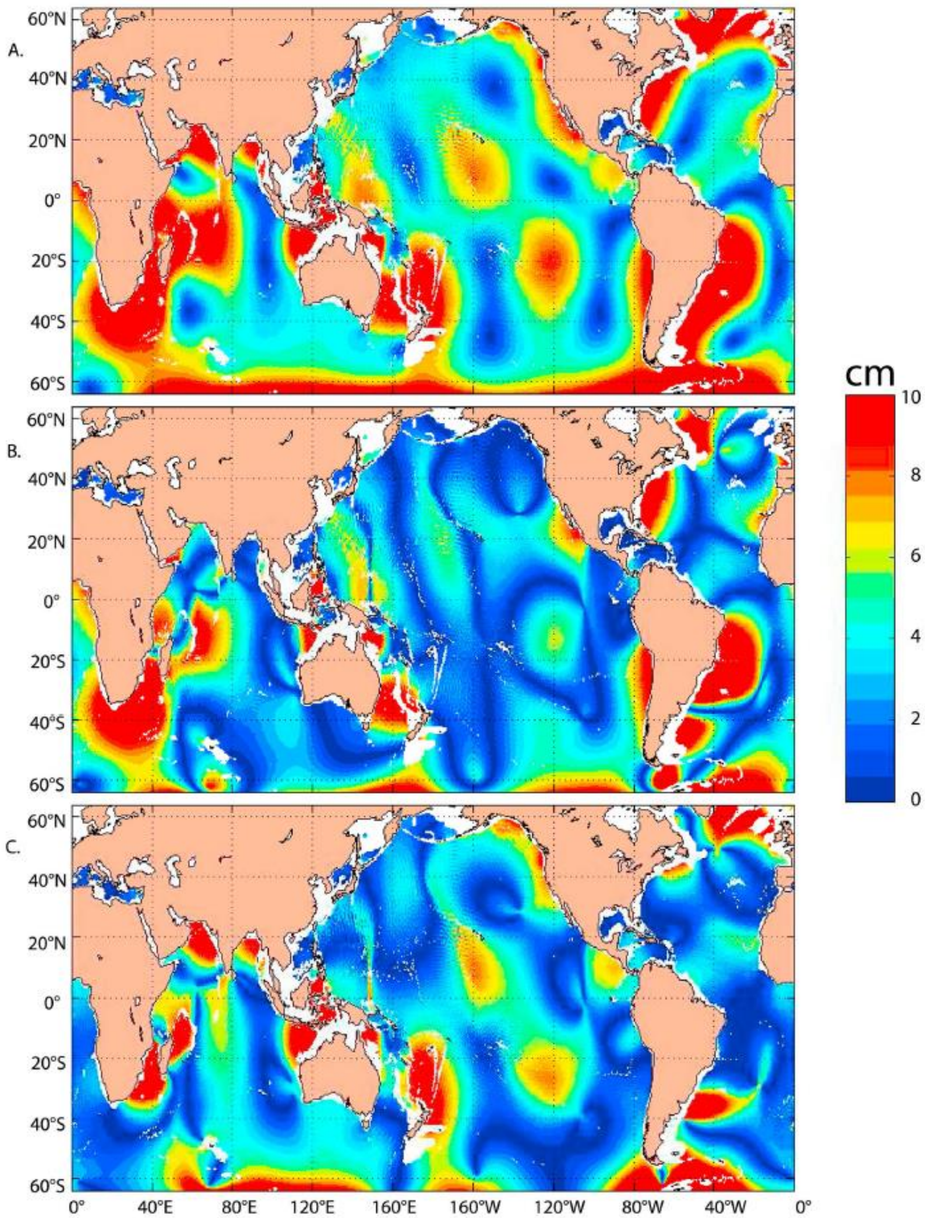
* equatorward of 66º area-weighted RMS value # >500 m

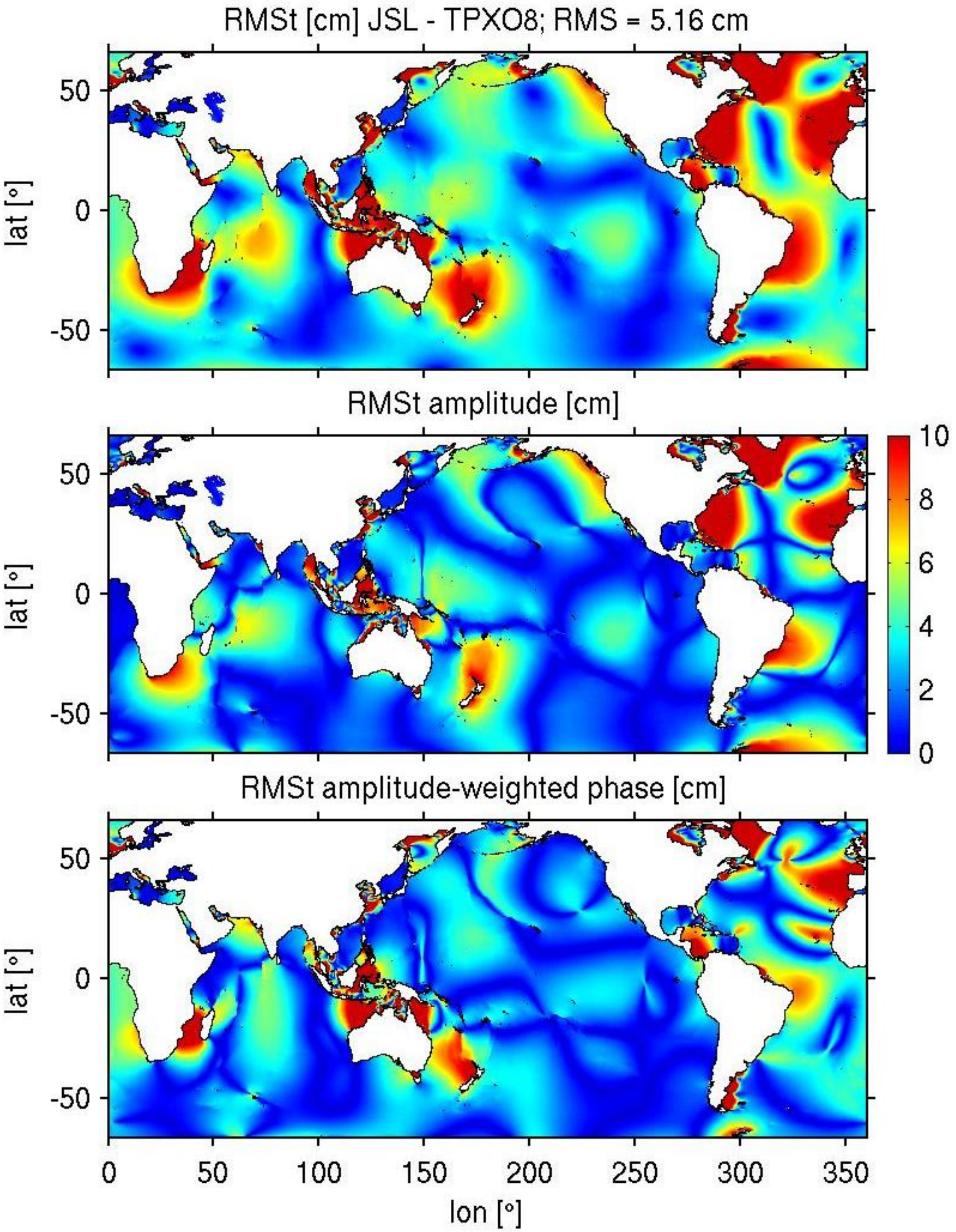
Conclusions

1. To get the best RMS the linear drag needs to be tuned
2. The full Nycander tensor has dissipation rates close to TPXO, but not the best RMS values
3. The Nycander scalar is slightly better than the tensor
4. Increasing the linear drag in deep relative to shallow water improves the water levels, but increases the discrepancy with the TPXO dissipation rates
5. The Atlantic is an outlier: the optimum RMS in the Atlantic is not the optimum RMS in the other basins
6. Iterating the SAL brings the model closer to TPXO

Lowest RMS_t for JSL

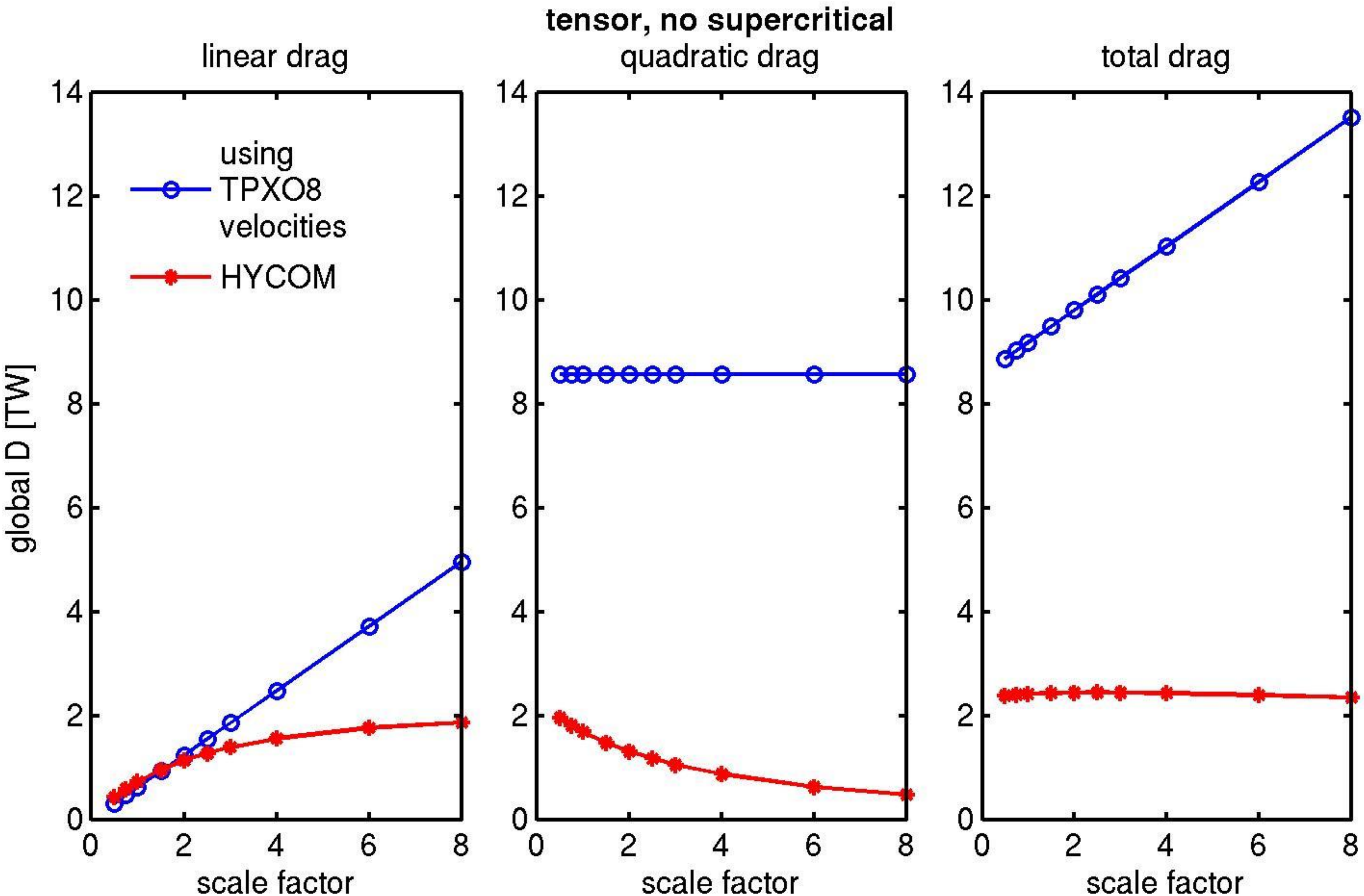
Previous 3D HYCOM; RMS_A = 7.5 cm





Shriver et al (2012)

Response to Scale Factor



Internal Wave Drag Schemes