Universidade de São Paulo

Operational forecast system for storm surges in Brazil and Mozambique

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Towards an Operational forecast system for storm surges in ~~Brazil and~~ Mozambique

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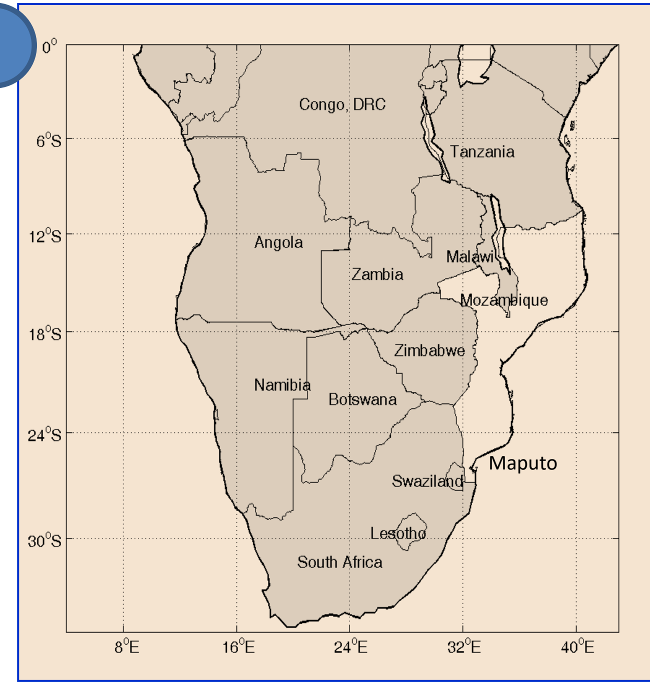
Cooperation project between IAG/USP, FC/UEM and INAM funded by CAPES



Sao Paulo: IAG/USP

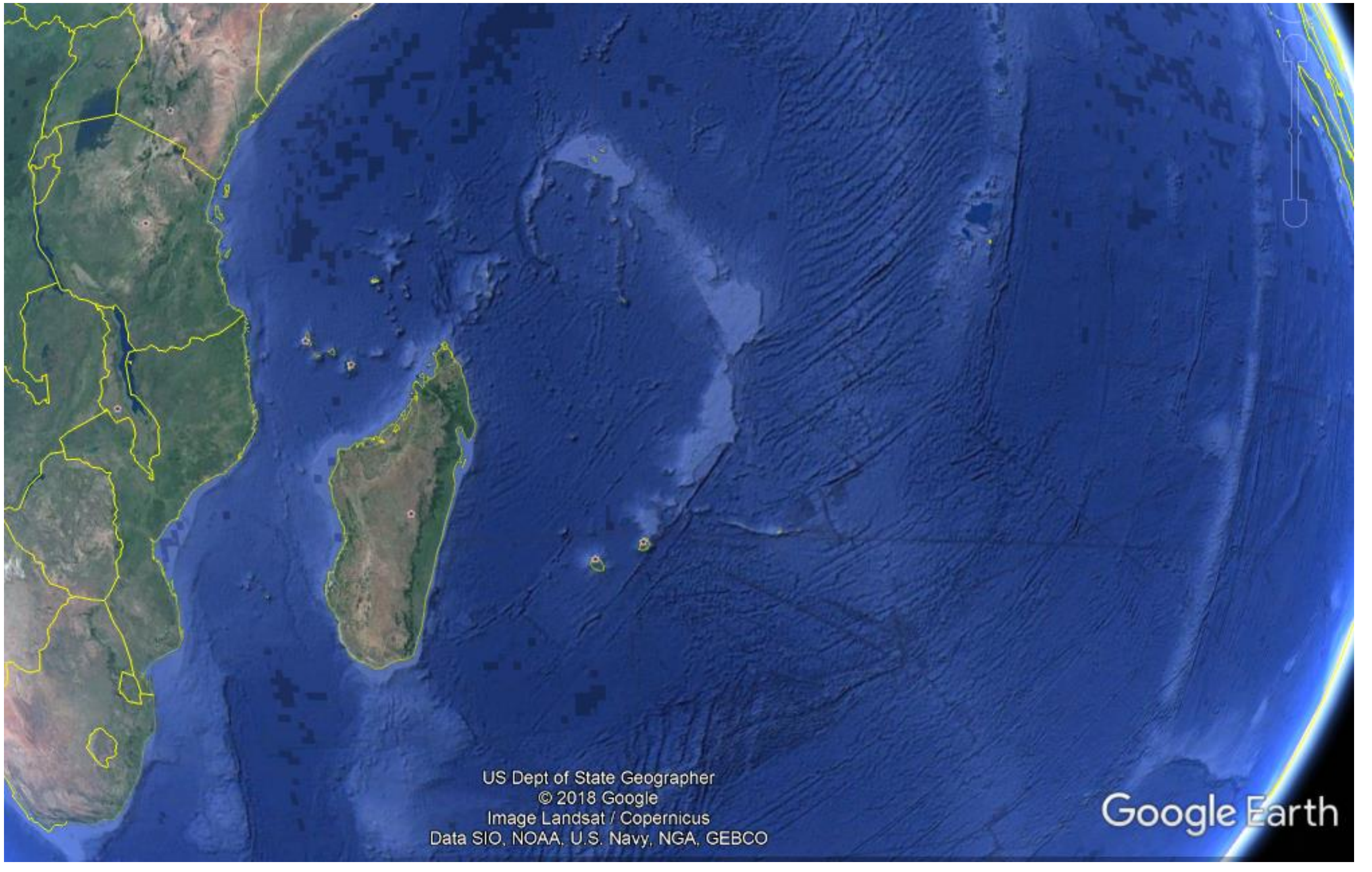
INSTITUTO DE ASTRONOMIA, GEOFÍSICA E CIÊNCIAS ATMOSFÉRICAS

CAPES

Maputo: FC/UEM, INAM

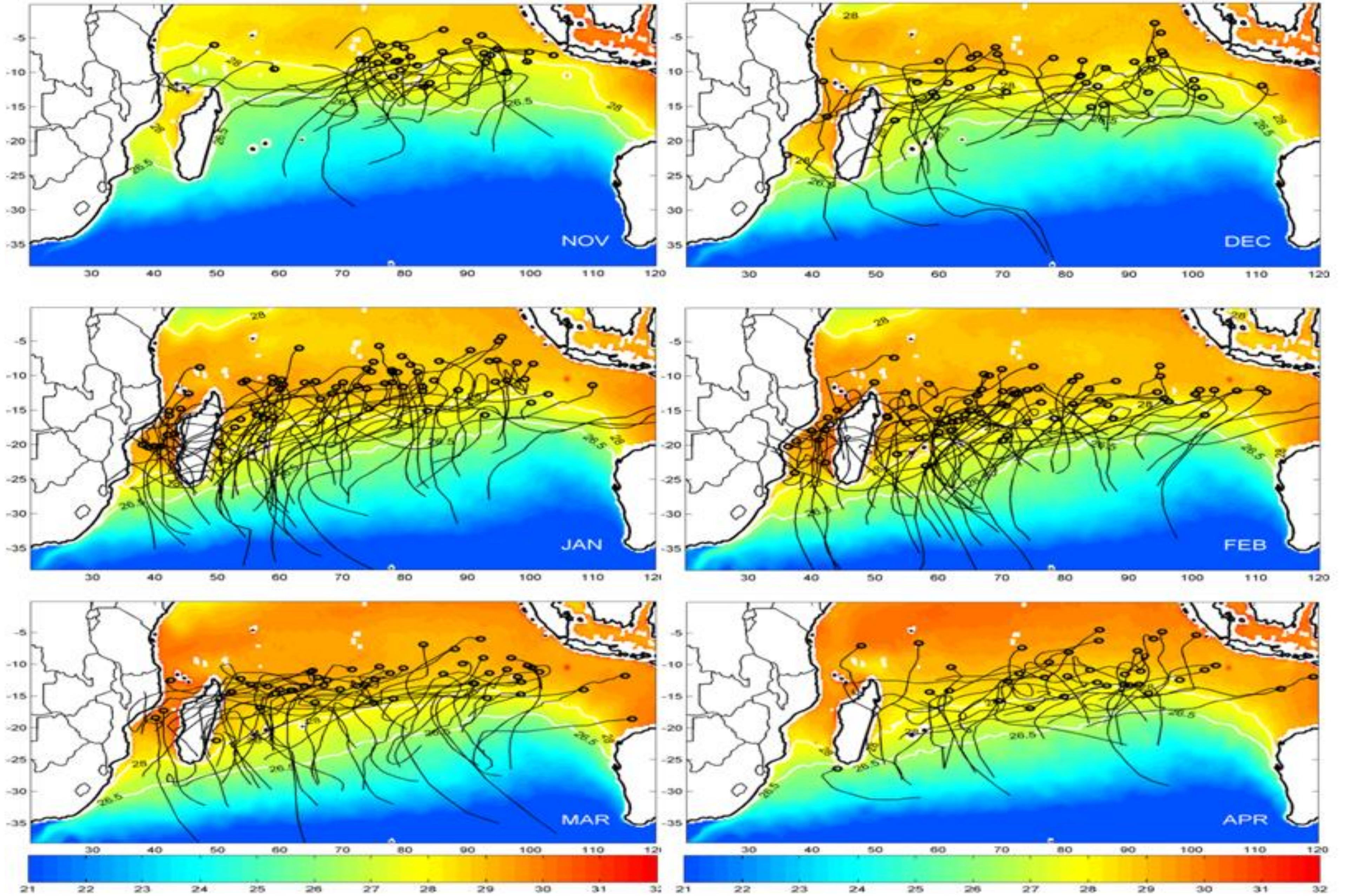
INAM

Southwest Indian Ocean



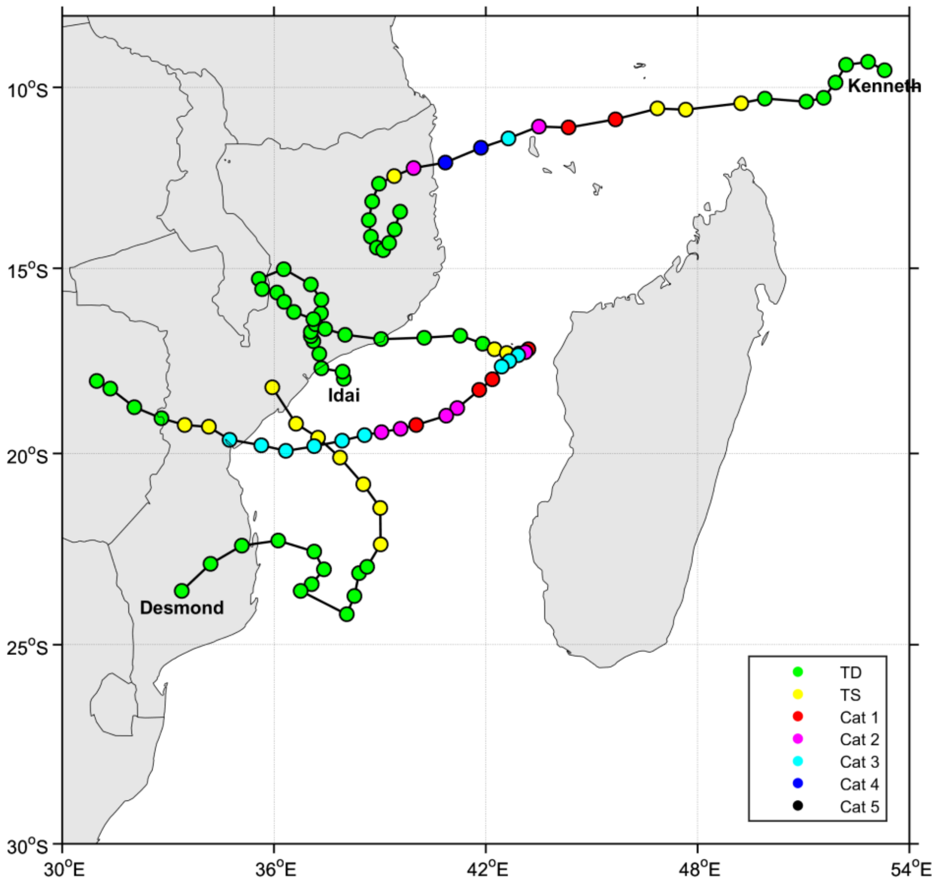
- Madagascar and Mozambique Channel
- wide and shallow continental shelf (central and south)
- large astronomical tidal range
- large rivers (central and south)
- immense low lying coastal plains
- high vulnerability to tropical cyclones

Tropical cyclones in Southwest Indian Ocean between 1980-2007 (November - April) and climatological SST (Mavume et al. 2009)



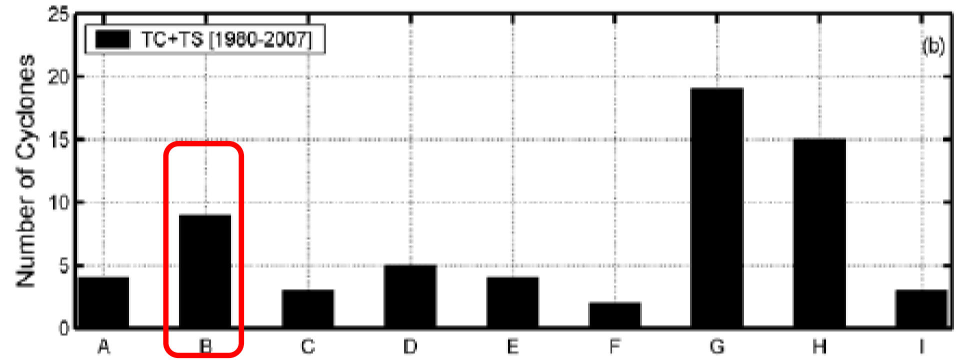
Why to model storm surges in the central coast of Mozambique?

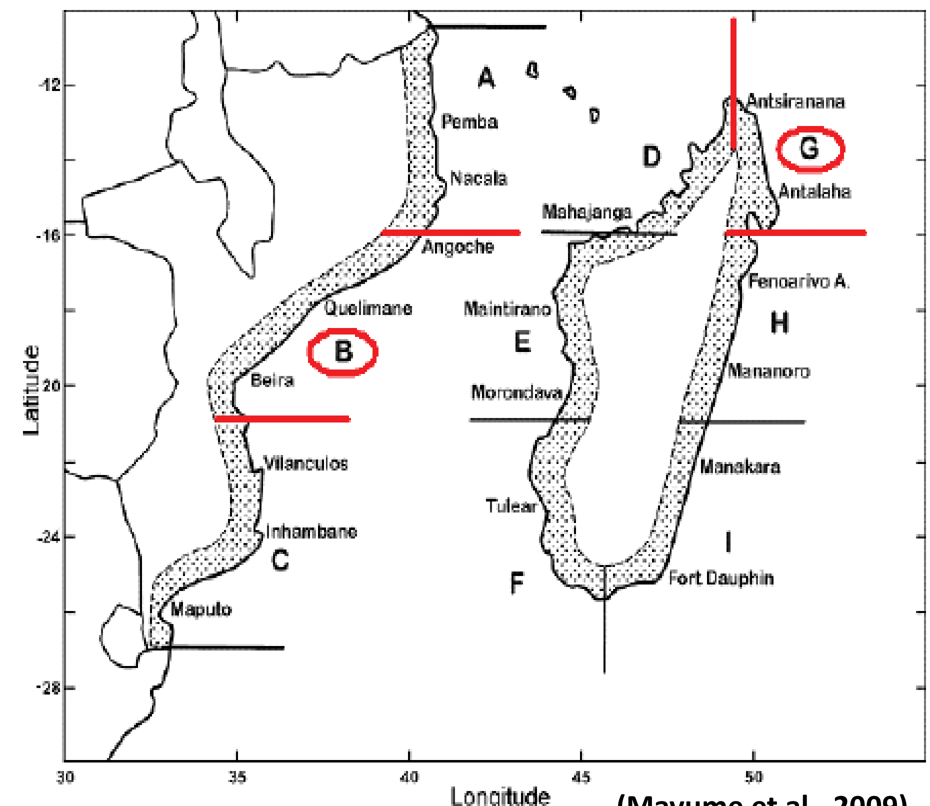
Cyclone season 2018/2019



Best-track data source: RSMC La Reunion

Landfalling Tropical cyclones in Mozambique and Madagascar





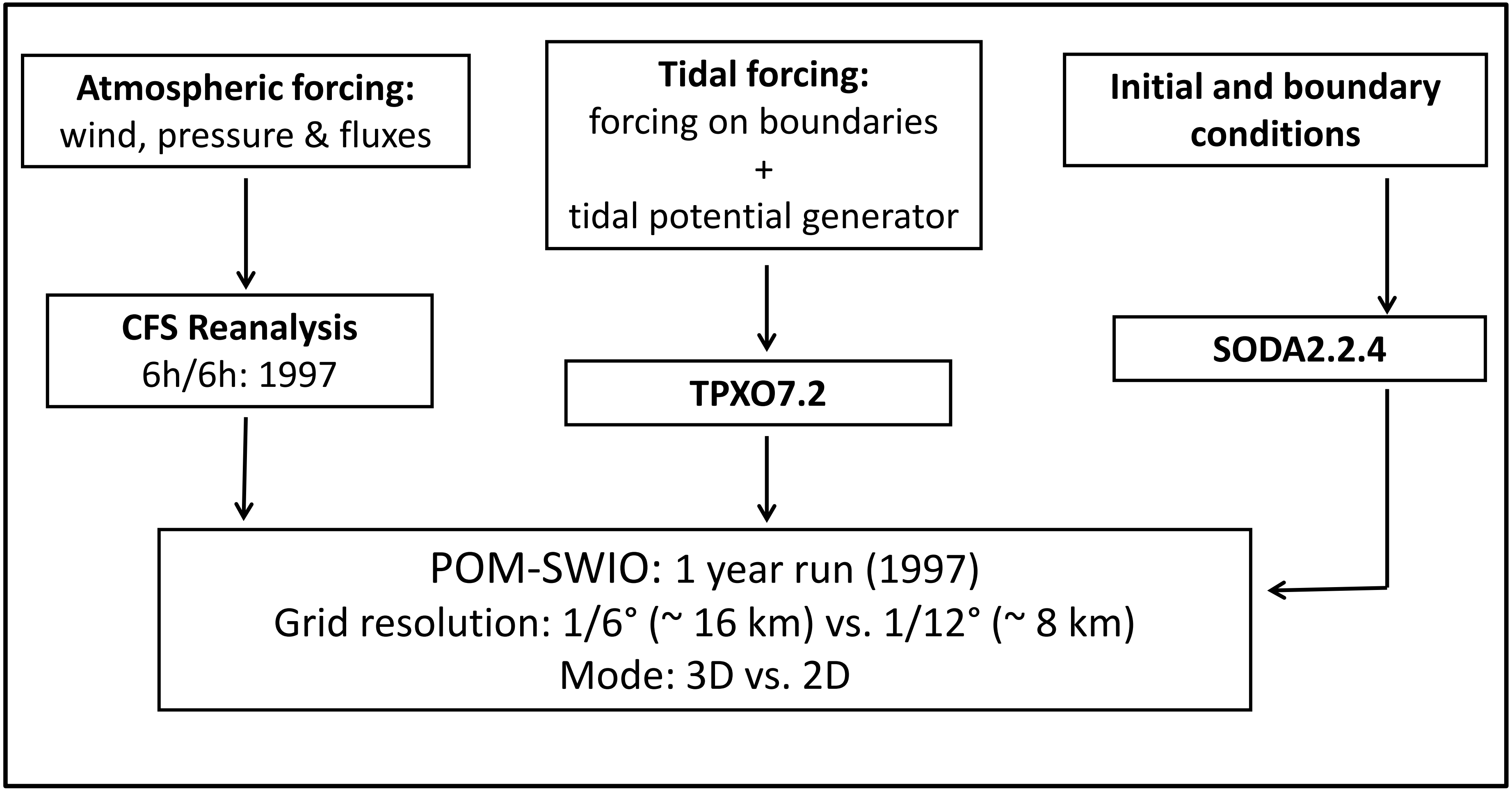
(Mavume et al., 2009)

Scientific questions to be explored:

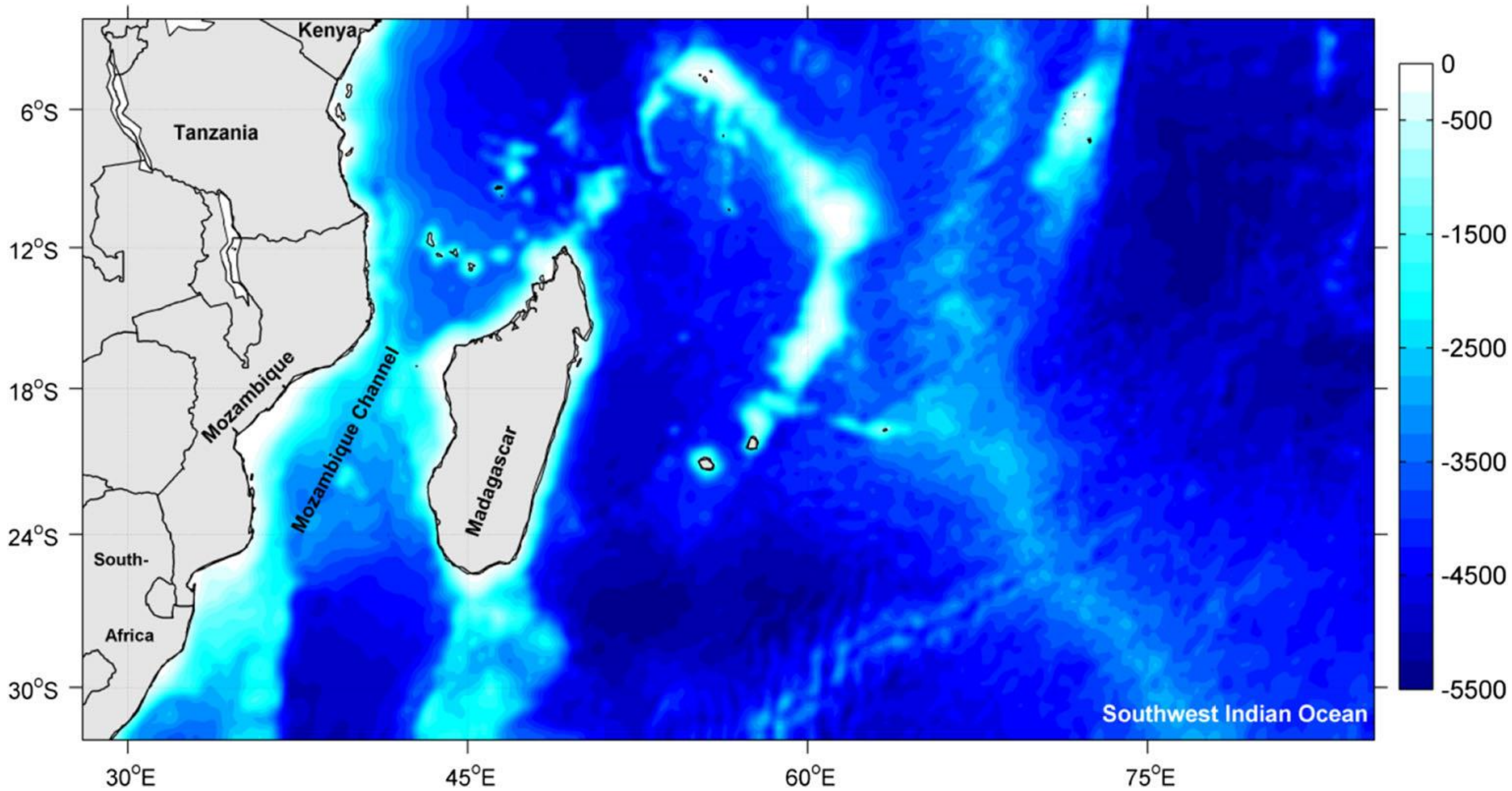
- Can increased model resolution improve tidal representation and thus total water levels?
- Are there differences in using 3D (baroclinic) or 2D (barotropic) versions of the model to simulate storm surges in this specific area?
- Are there combined effects of the forcings: tides, winds and sea level pressure?

Modelling Strategy

The Princeton Ocean Model on the SouthWest Indian Ocean (POM-SWIO)

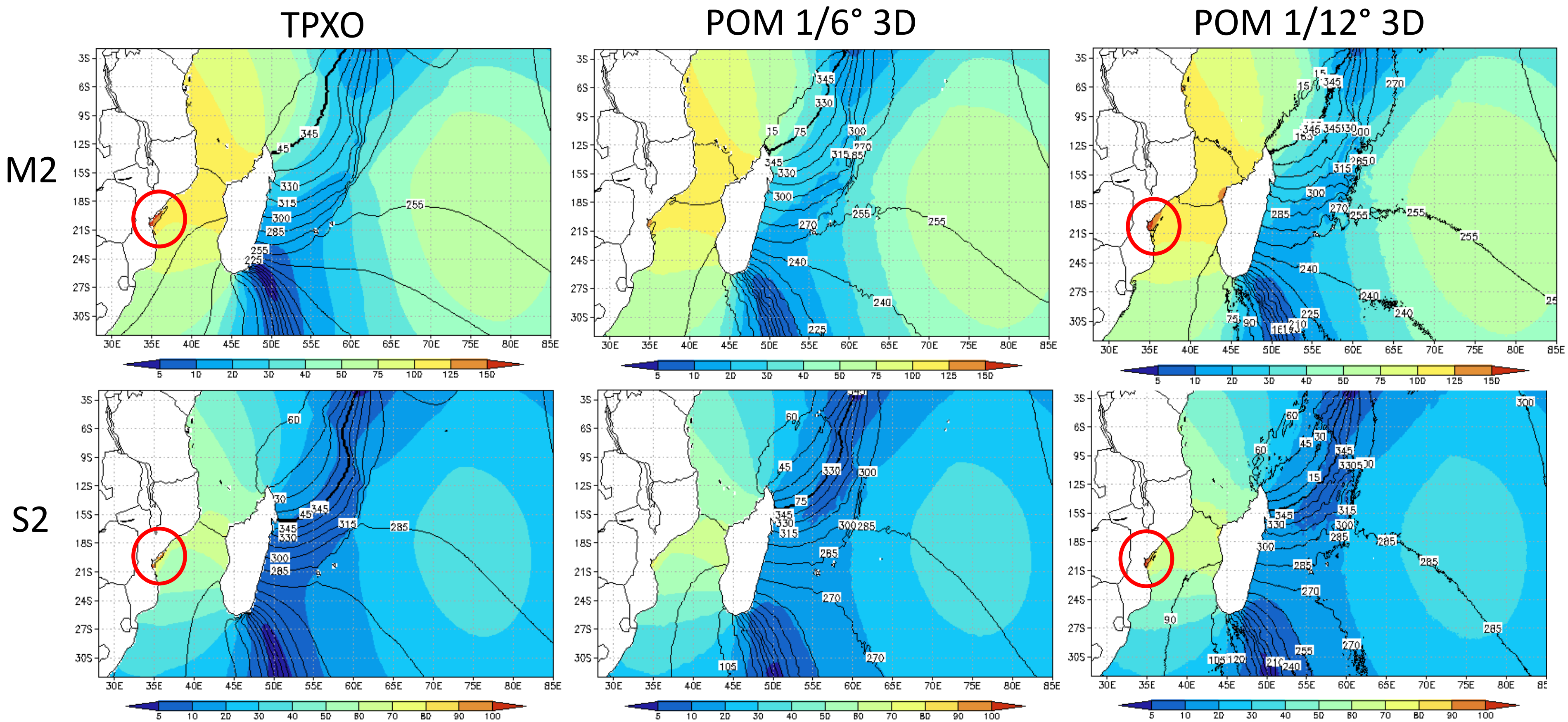


POM-SWIO grid



Validation – Tides

Amplitudes (cm) and phases (°GW) of the principal semidiurnal tidal constituents

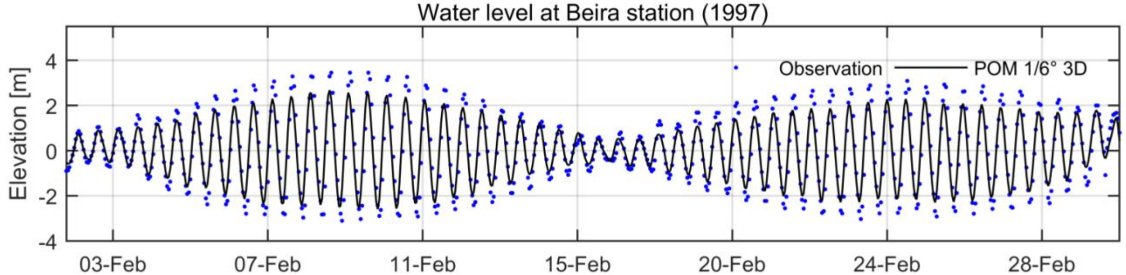


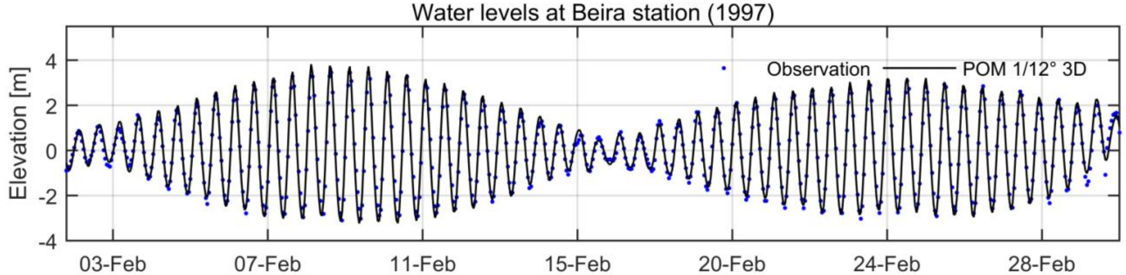
- Both model configurations are able to capture the basin-wide large-scale tidal patterns;
- But, only when the horizontal resolution is as high as 1/12° (~8 km) the model is able to capture tidal amplification in central part of Mozambique coast

Validation – Tides

Principal tidal constituents bias (model minus observation)

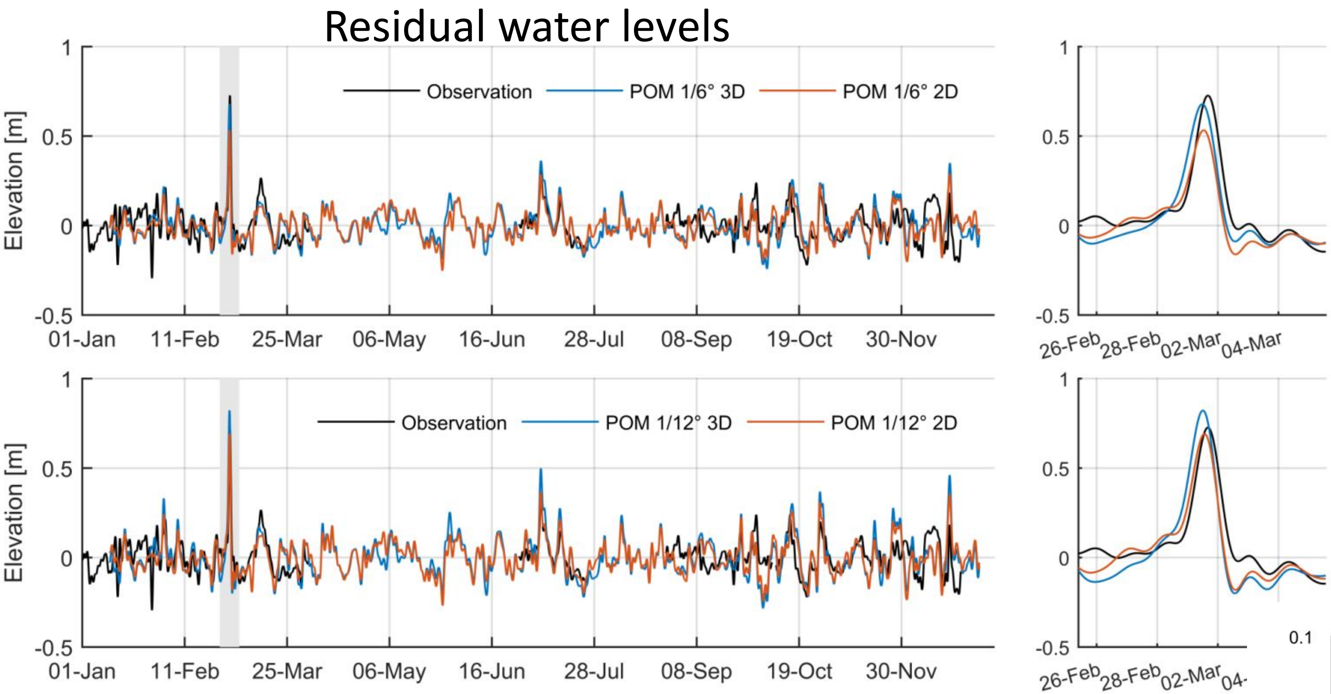
	M2		S2		O1		K1	
	Amplitude (m)	Phase (°)	Amplitude (m)	Phase (°)	Amplitude (m)	Phase (°)	Amplitude (m)	Phase (°)
	Observation							
	1.8184	28.55	1.0317	138.49	0.0223	287.38	0.0074	298.70
	Model bias							
3D 1/6°	-0.35 (19%)	-16.81	-0.18 (17%)	-19.88	0.01 (0.44%)	2.37	<-0.01 (57%)	-185.22
2D 1/6°	-0.33 (18%)	-16.05	-0.16 (16%)	-19.21	0.01 (0.46%)	1.44	<-0.01 (66%)	-178.13
3D 1/12°	0.13 (7%)	-4.73	0.14 (14%)	-6.19	0.01 (59%)	6.59	<-0.01 (64%)	-154.91
2D 1/12°	0.15 (9%)	-0.78	0.15 (14%)	-0.57	0.01 (55%)	9.40	<-0.01 (59%)	-149.71

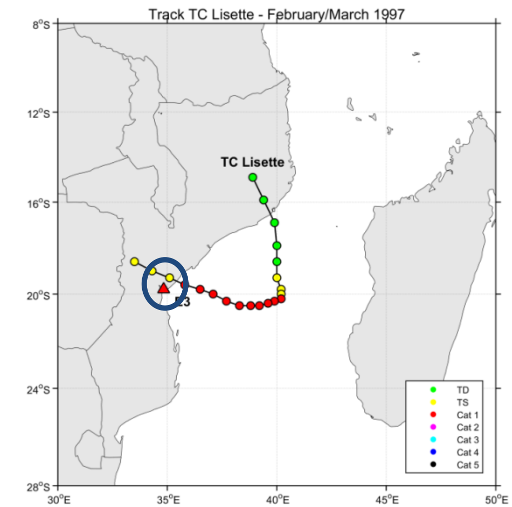




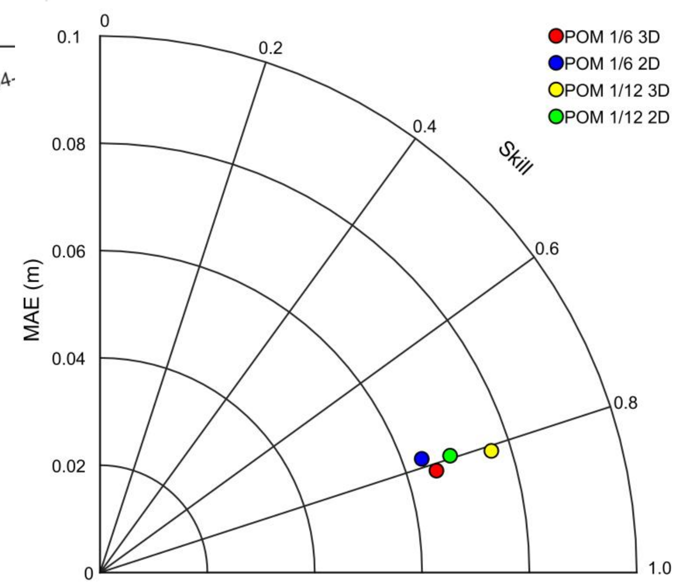
Validation – Surges

TC Lisette (February/March 1997)





- Overall skill shows minimal differences within the configurations.
- The 3D configuration has a tendency to represent slightly higher amplitudes during peak surges;



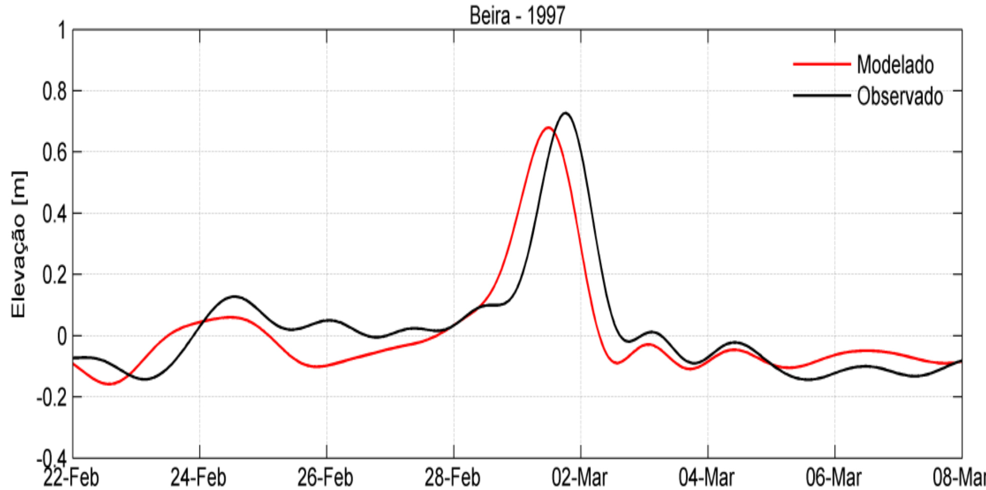
$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|M_i - O_i\right|$$

$$Skill = 1 - \frac{\sum_{i=1}^{n}(M_i - O_i)^2}{\sum_{i=1}^{n}\left(\left|M_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)^2}$$

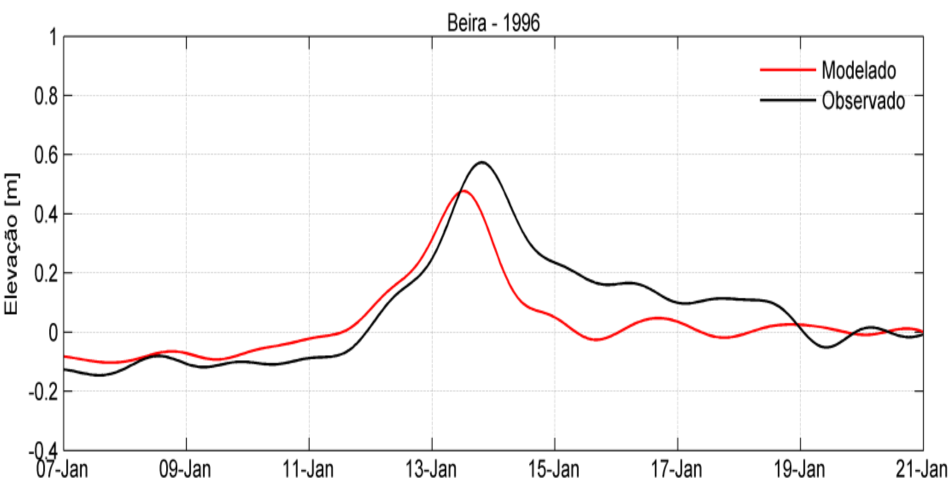
Model performance for previous TC cases within the SWIO domain

(when data exists for comparisons)

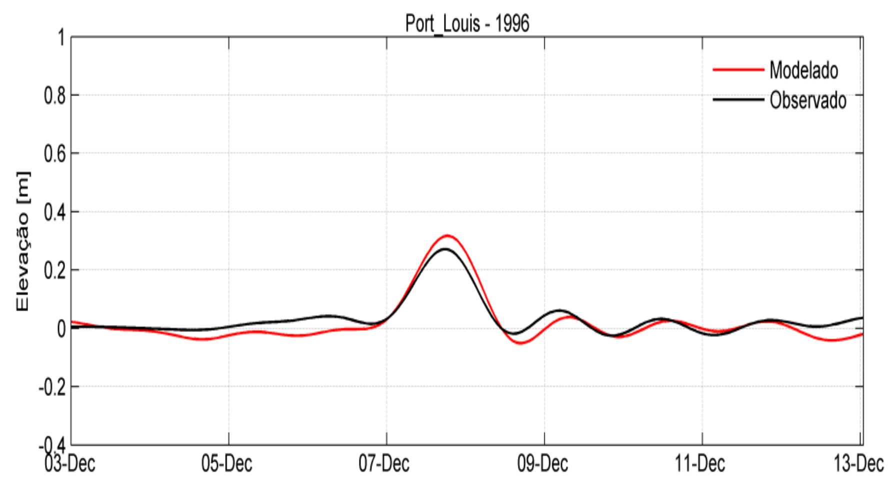
Tropical cyclone Lisette (1997)



Tropical cyclone Bonita (1996)



Tropical Cyclone Daniella (1996)



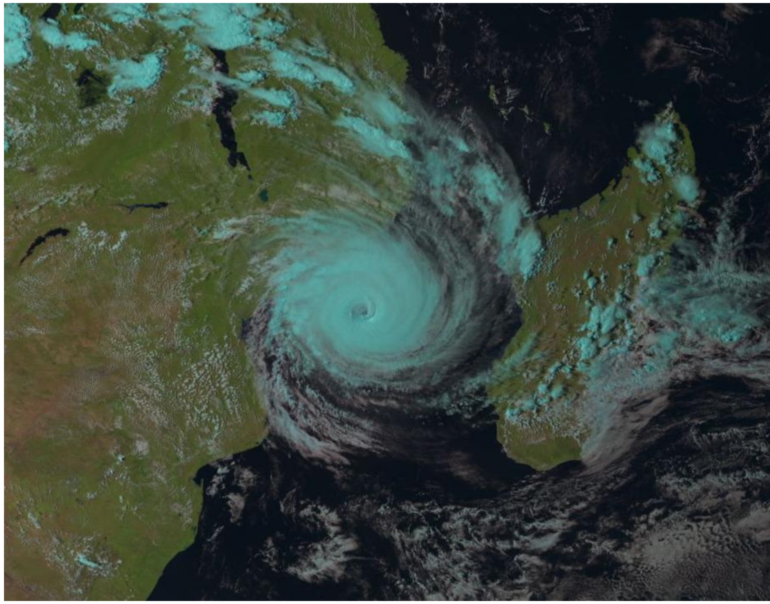
A recent storm surge case:

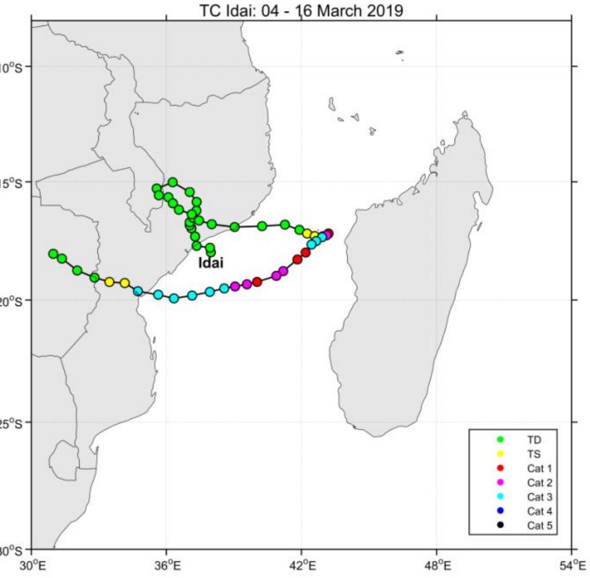
The catastrophic tropical cyclone Idai: 04 - 16 March 2019

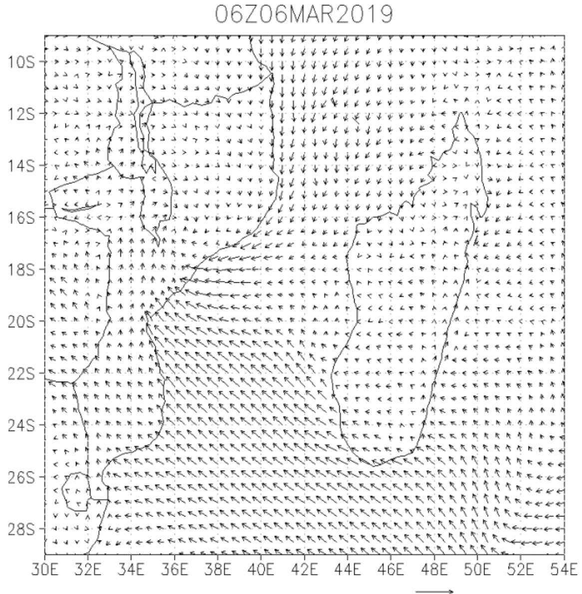
TC Idai (March 2019)

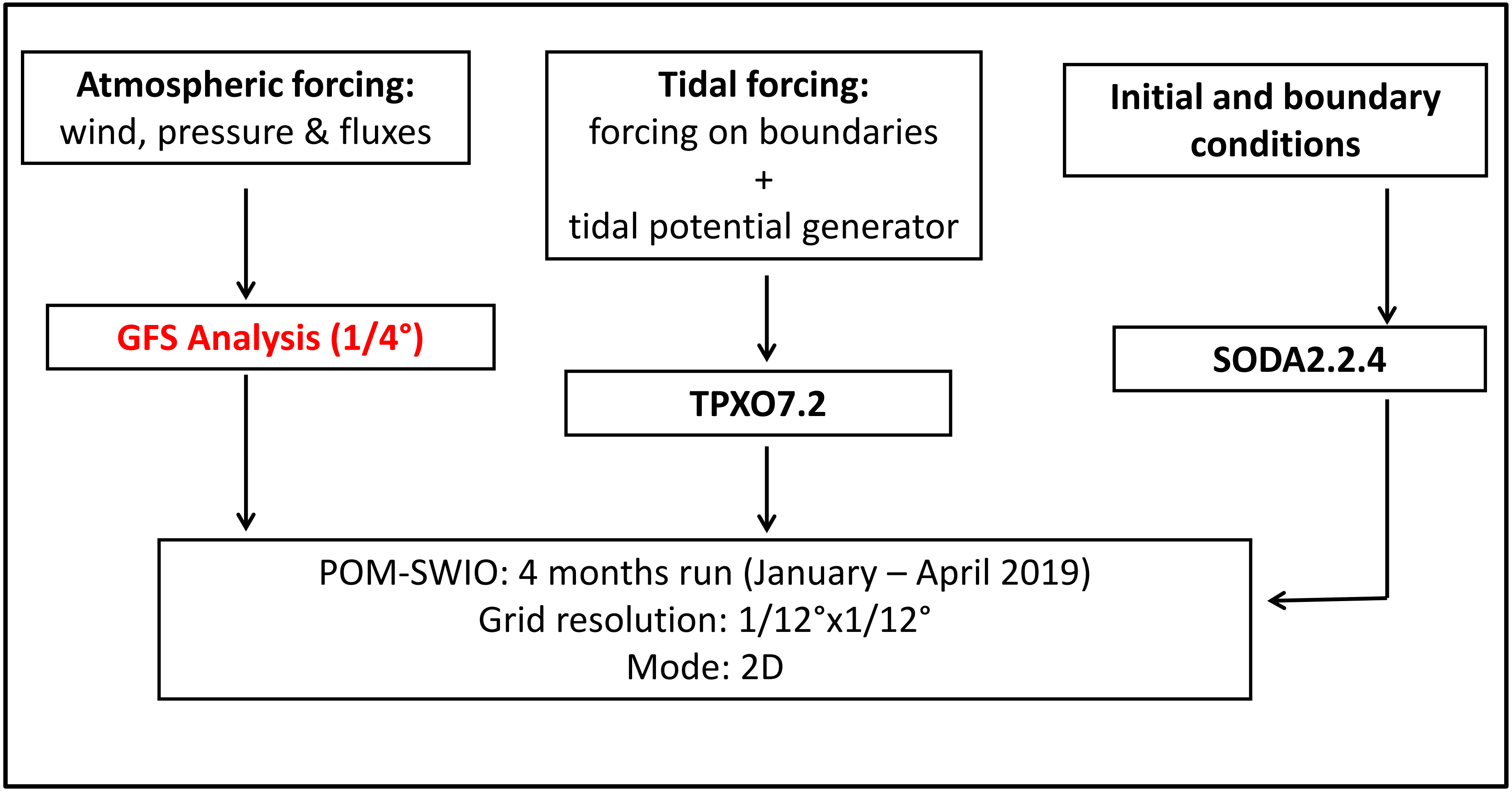
Most disastrous event in Mozambique's recent past:

- Intense TC (63 m/s; cat 3 on Saffir-Simpson hurricane scale);
- Destroyed over 80% of the second major city of Mozambique (Beira);
- More than 1 million people affected;
- Over 600 deaths reported;
- Widespread flood lasted for more than a week.



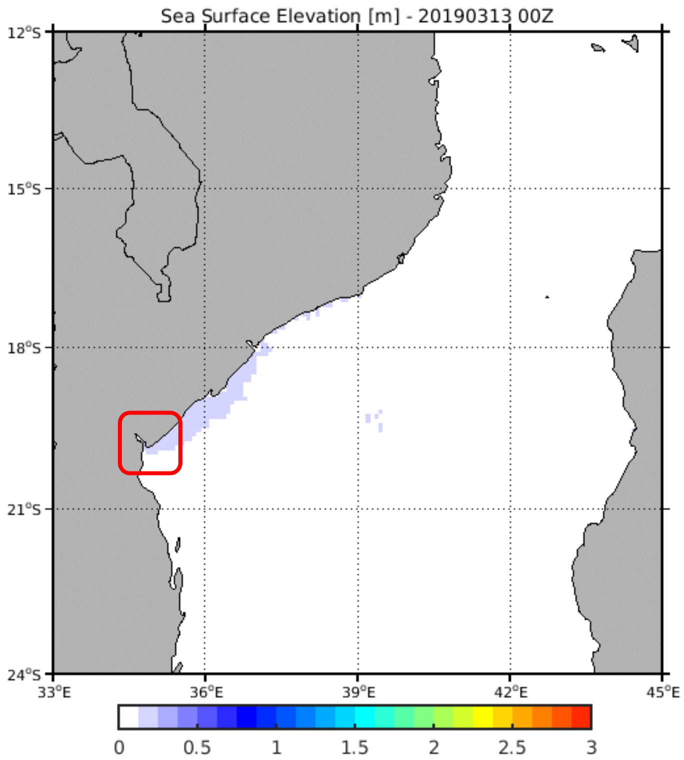


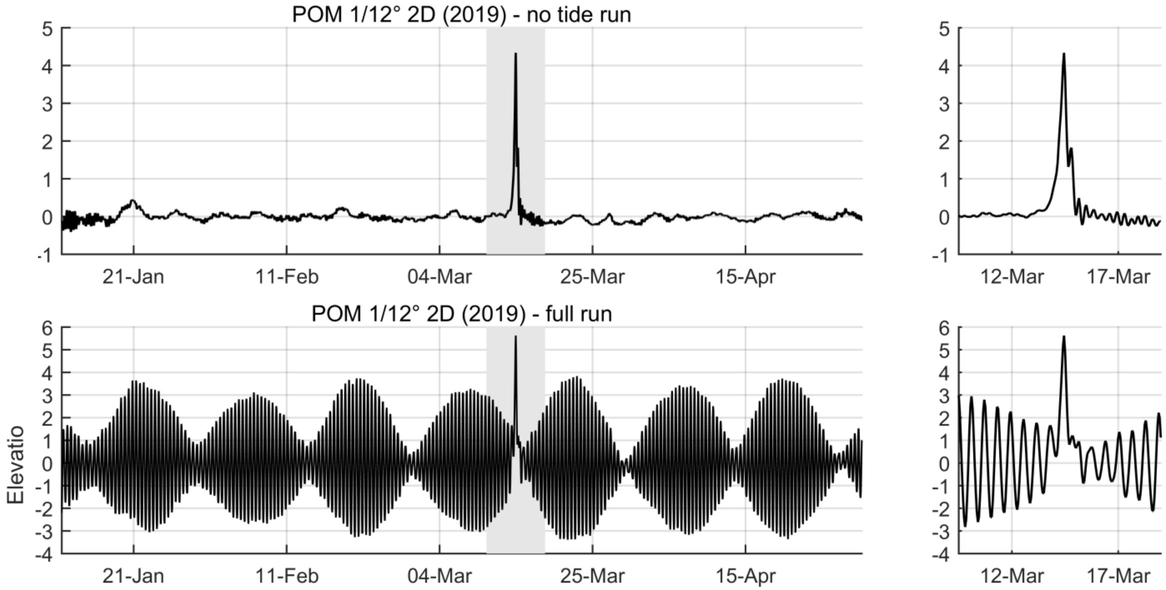




Atmospheric forcing:
wind, pressure & fluxes
Tidal forcing:
forcing on boundaries
+
tidal potential generator
Initial and boundary conditions
GFS Analysis (1/4°)
TPXO7.2
SODA2.2.4
POM-SWIO: 4 months run (January – April 2019)
Grid resolution: 1/12°x1/12°
Mode: 2D

TC Idai (March 2019)





The influence of tides and SLP on surges

Factor separation [Stein and Alpert (1993) methodology]

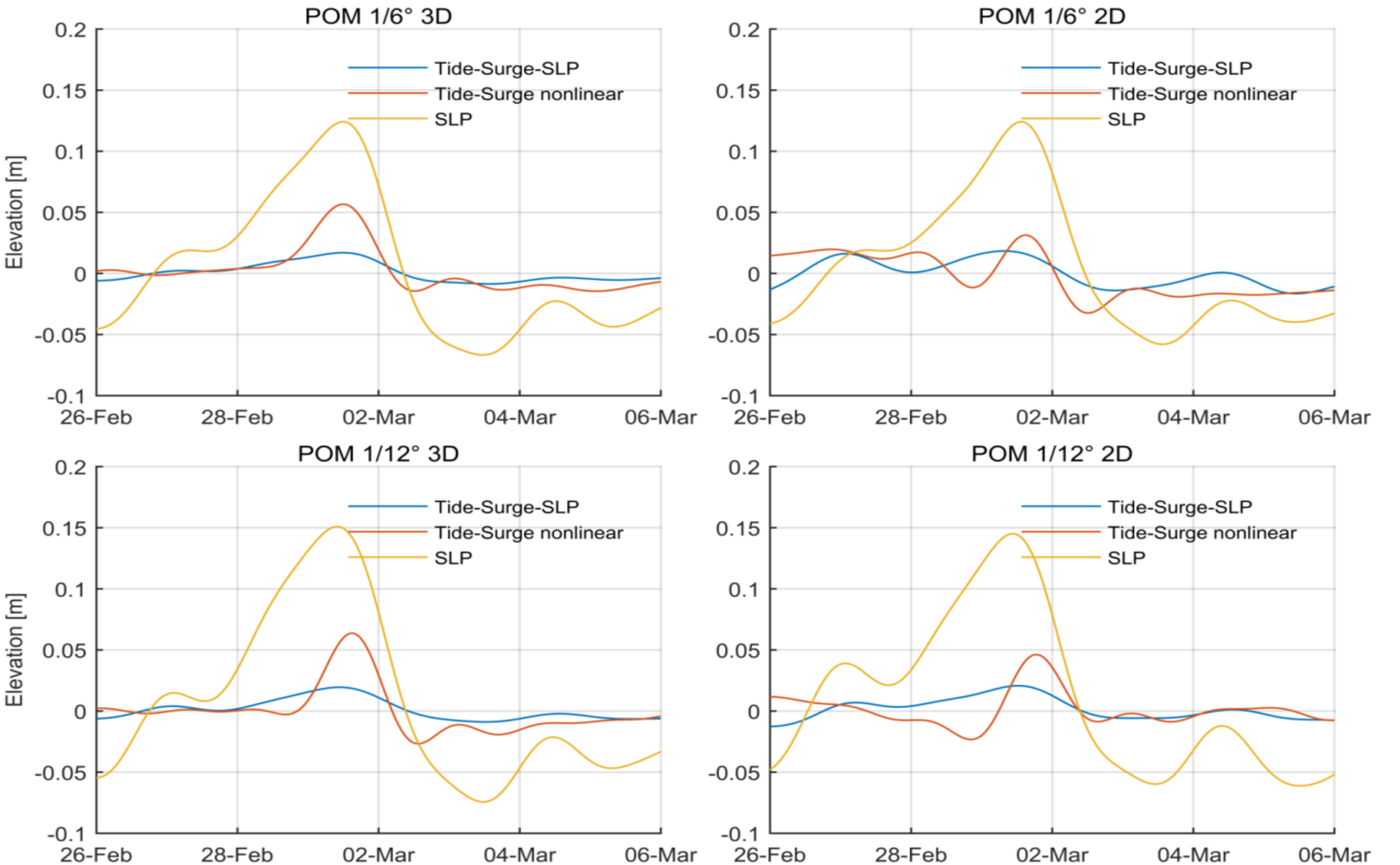
Experiment	Forcing
expA (control)	wind + tides + SLP
expB (no SLP)	wind+ tides
expC (no Tide)	wind+ SLP
expD	wind

r1 = expB - expD residual tidal due to tide-surge interaction

r2 = expC - expD residual due to SLP

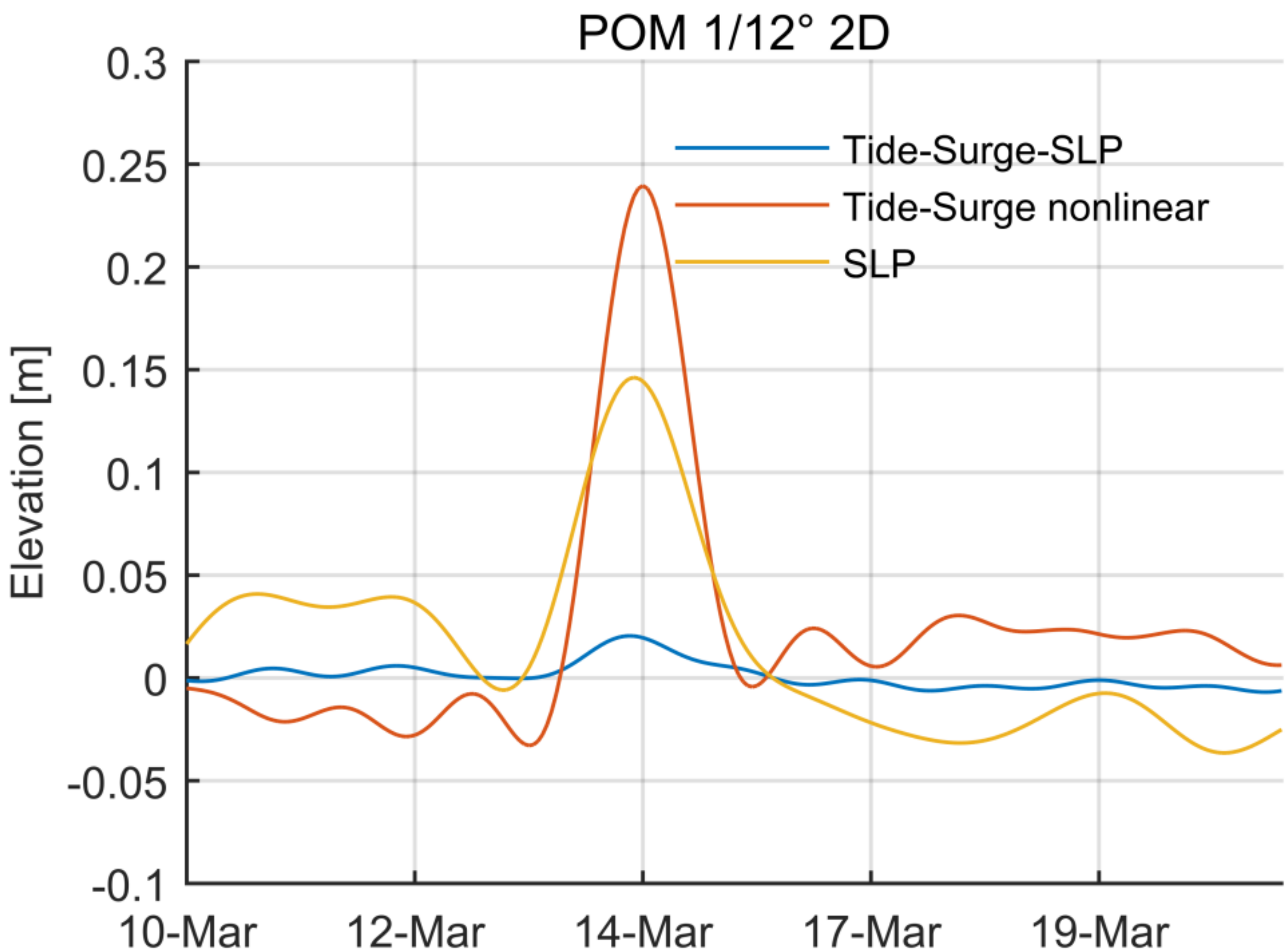
r12 = expA - (expB+expC) + expD residual due to tide-surge-SLP interaction

The influence of tides and SLP on surges peak – Lisette (1997)



- All the terms acted to increase the surge height during the peak;
- SLP term seems to dominate within all the experiments, but it is slight higher in the higher resolution configuration;

The influence of tides and SLP on surges peak – Idai (2019)



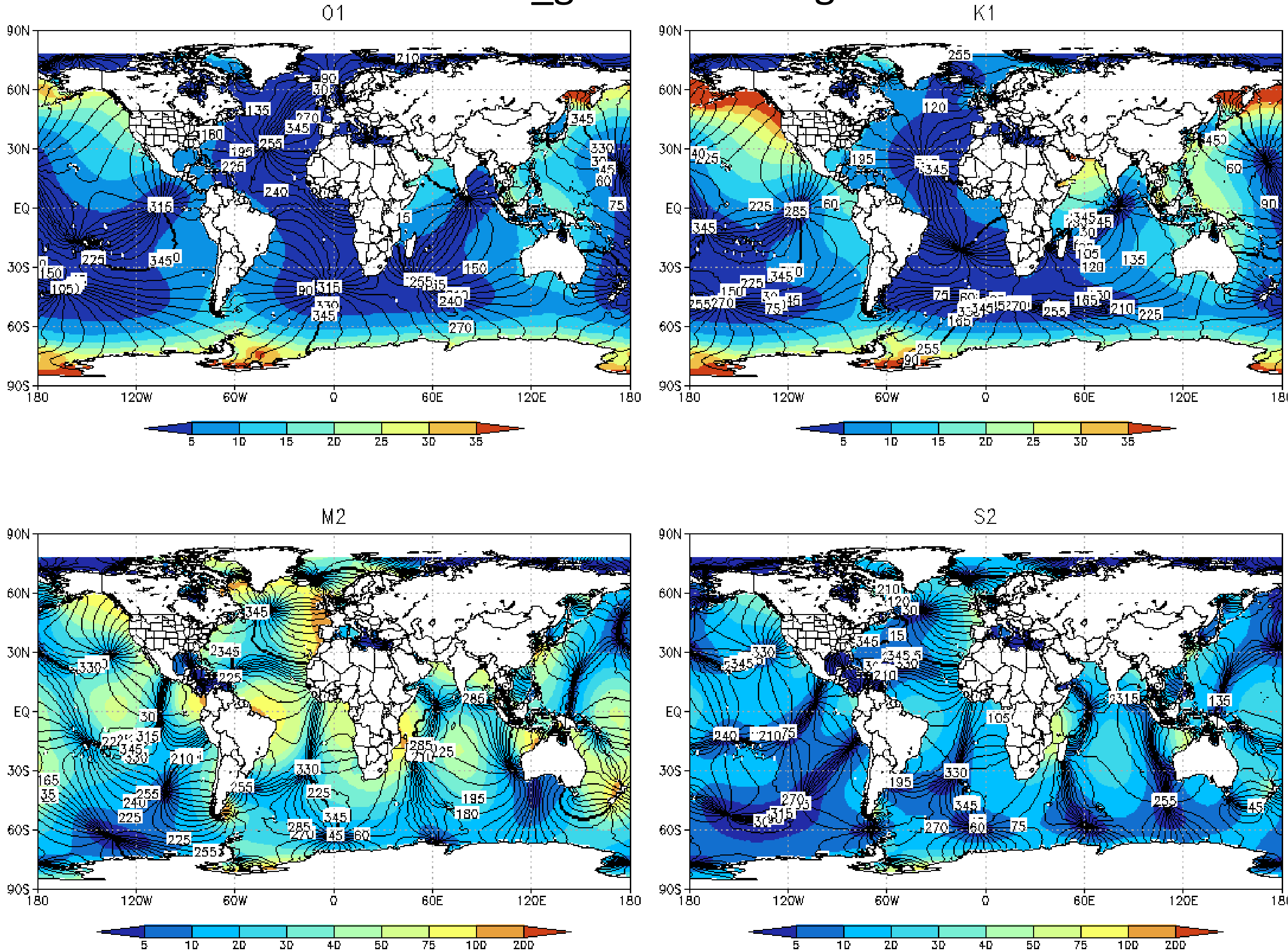
Issues to complete the setup for an operational stage

Final adjustment of tidal constituents

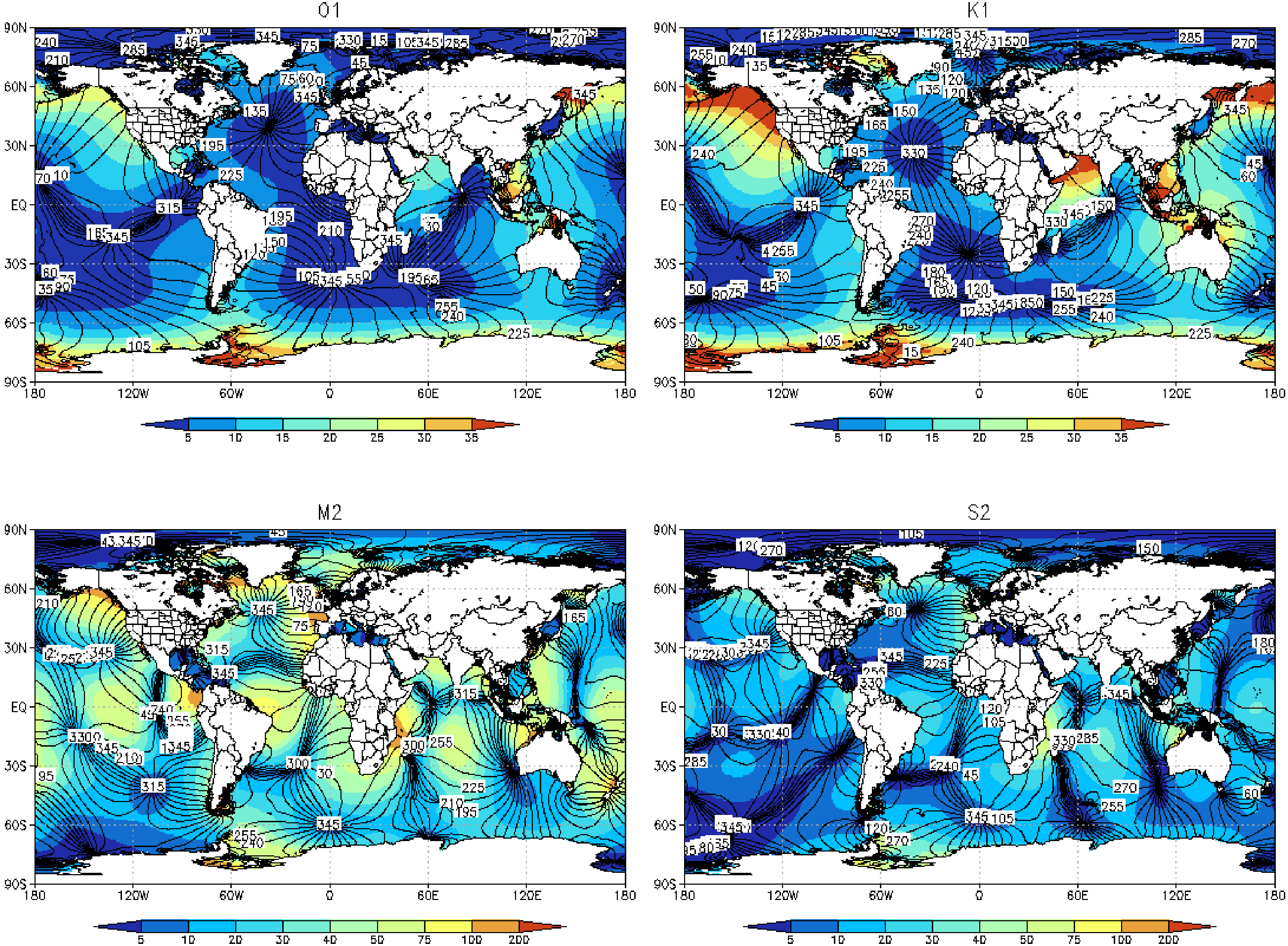
Innitial and boundary fields (for external and internal modes) from global analysis and forecasts

Use of ensemble forecast to evaluate uncertainties in the atmospheric forcing fields

POM_global 1 x 1 degree



TPXO 7.2


O1
K1
M2
S2
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
5 10 15 20 25 30 35
5 10 20 30 40 50 75 100 200

Preliminar Conclusions

- Modeled (1/12°) distributions of the semidiurnal tidal amplitudes and phases are in very good agreement with the observations as well as with the reference given by TPXO for both 2D and 3D particularly for 1/12° grid application
- The 3D configuration tends to reproduce higher storm surges heights than 2D during storm surge peaks, in part due to tide-surge nonlinear interactions

Preliminar Conclusions

- After the wind, SLP residual term appeared to dominate in the TC Lisette (1997) storm surge case whereas tide-surge nonlinear interactions surpassed SLP residual term in the TC Idai (2019) case. However it is necessary to reinforce that minimum SLP was largely misrepresented by the atmospheric forcing
- Dependence on global forecasts for initial and boundary conditions from Copernicus or others; solution for external mode could come from own global system, but still there is dependence on internal modes (T,S and currents)

Thanks for your attention!

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