Numerical modelling of fine sediment transport in the GBR region

www.csiro.au

CSIRO Marine & Atmospheric Research

Nugzar Margvelashvili, Mike Herzfeld, Emlyn Jones, Mathieu Mongin, Farhan Rizwi, Jenny Skerratt, Karen Wild-Allen, John Andrewartha, Mark Baird

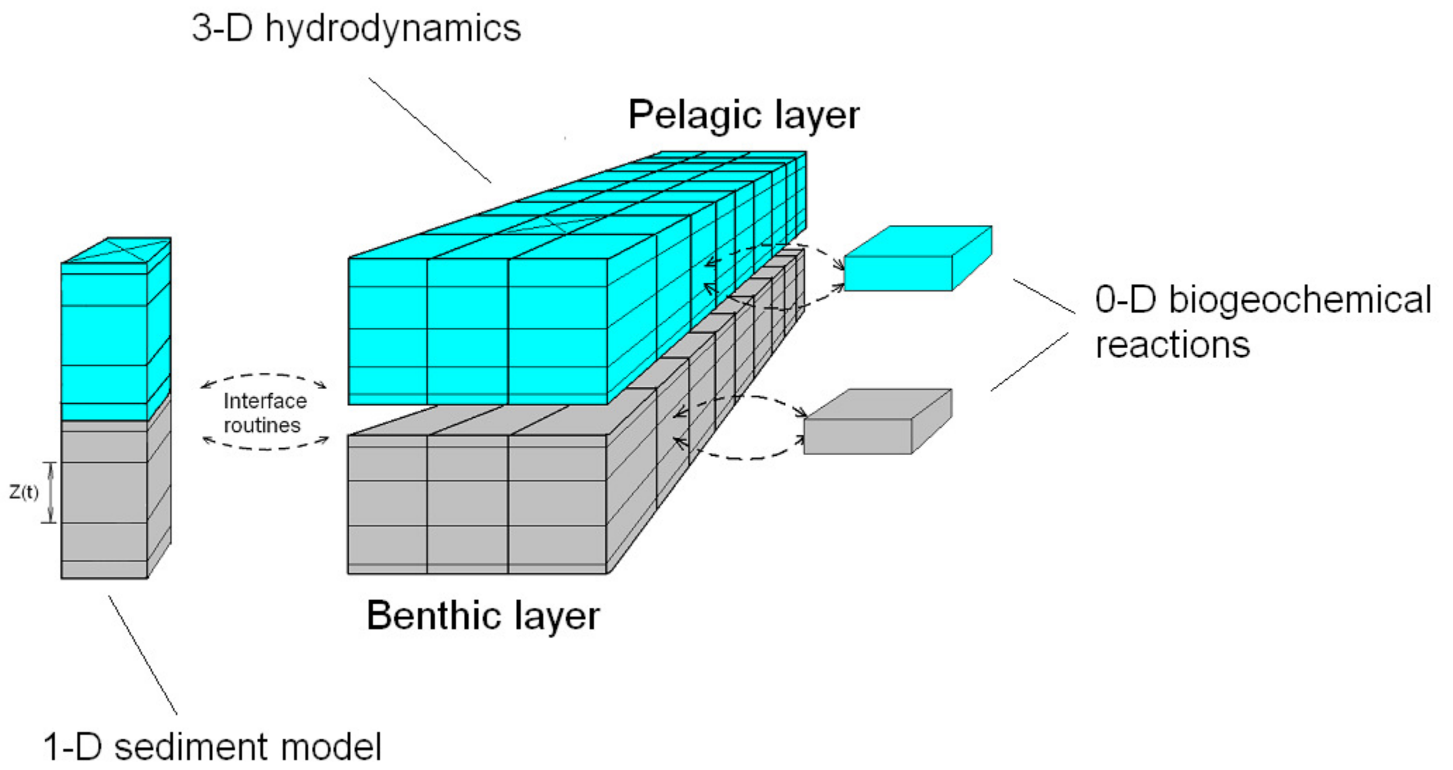
March 2016

Outline

- Overview of sediment transport model
- Calibration and validation study
- Baseline scenario
- Scenarios with altered loads from catchments
- Conclusions

Sediment transport model

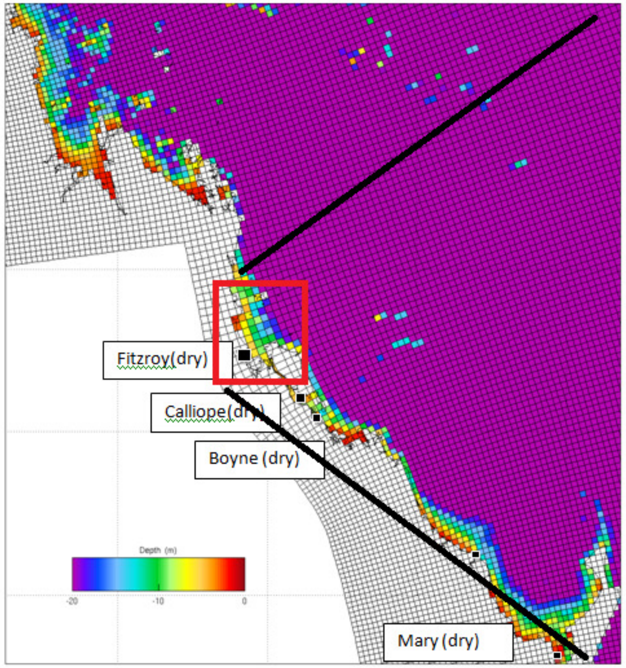
- Adds a multilayer sediment bed to the EMS grid
- Simulates sinking, deposition and resuspension of multiple size-classes of sediment
- Is driven by 3-D hydrodynamics and wave data
- Provides physical settings to simulate biogeochemical model

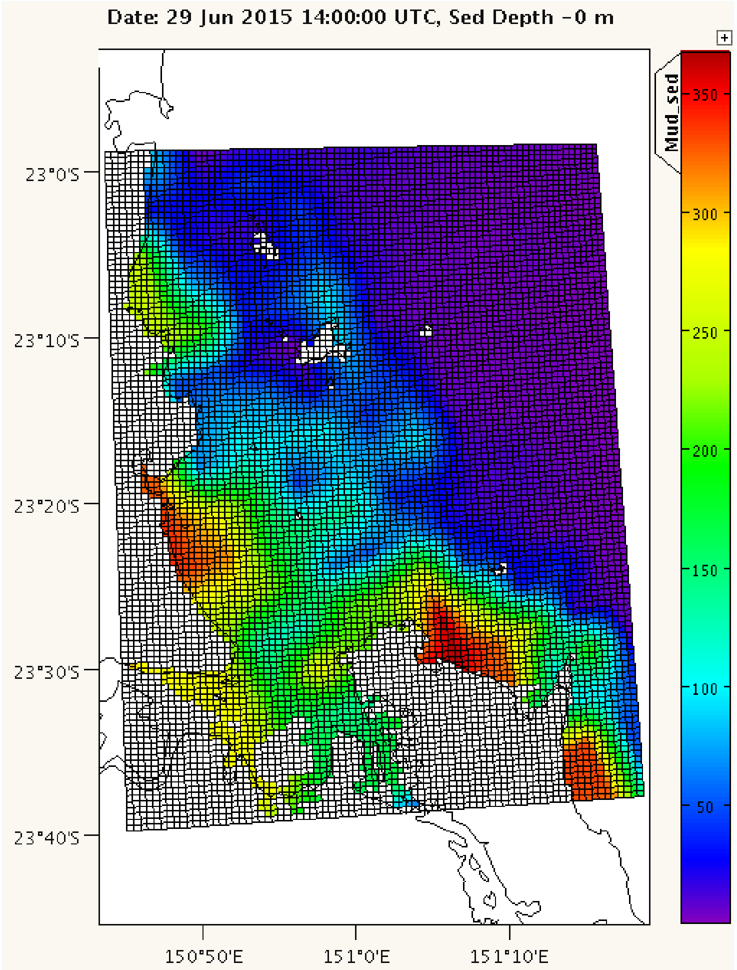


Sediment transport model

- Coupled to hydrodynamic and biogeochemical models
- Near-real-time simulation with 1 and 4 km models
  http://research.csiro.au/ereefs/
- Builds an archive of hind-cast simulations
- Nested approach to traverse scales

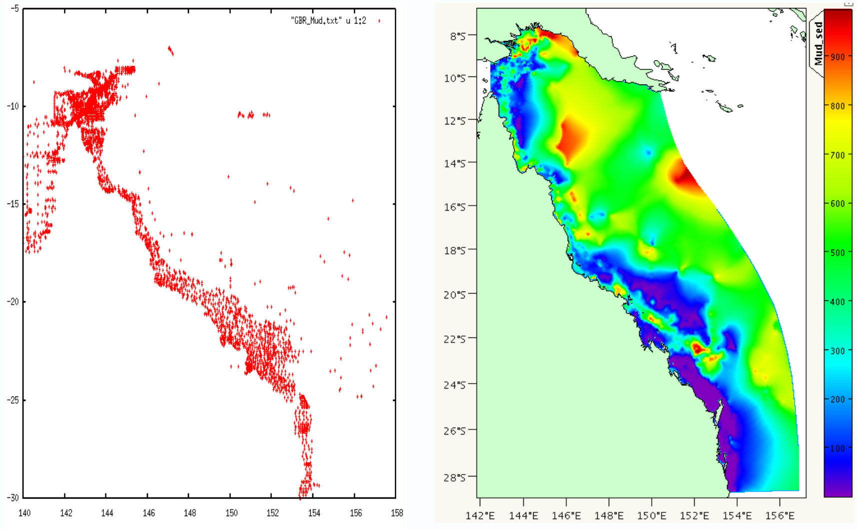
- Nested fine-resolution RECOM model



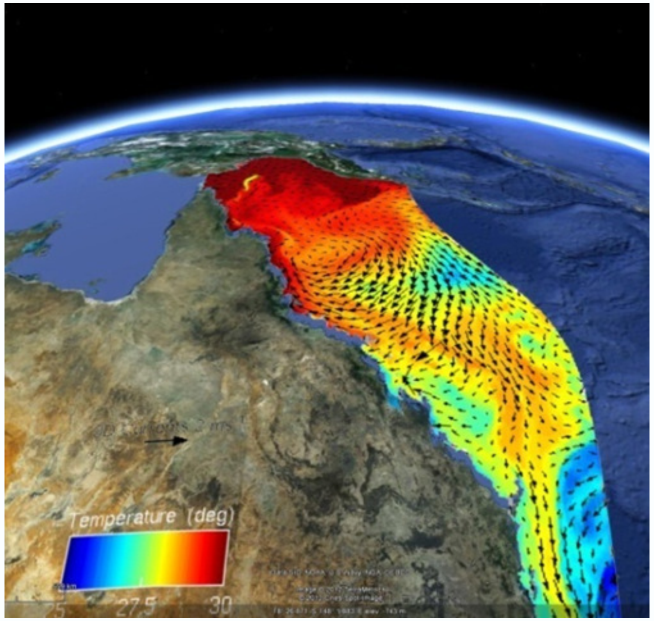


Sediment transport model

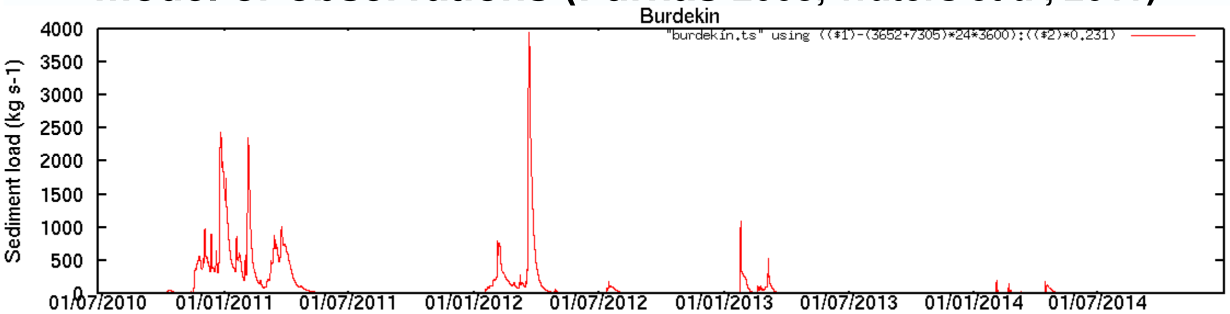
Sampling sites (left) and interpolated benthic mud (Geoscience Australia)

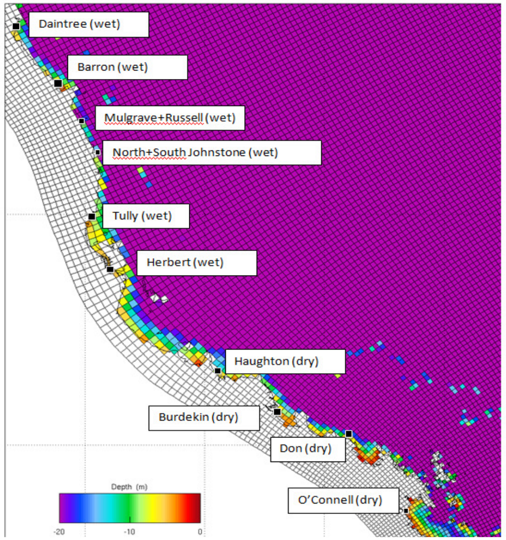


Driven by simulated waves and currents (SHOC and WaveWatch III)



Catchment loads estimated from either catchment model or observations (Furnas 2003, Waters et al, 2011).



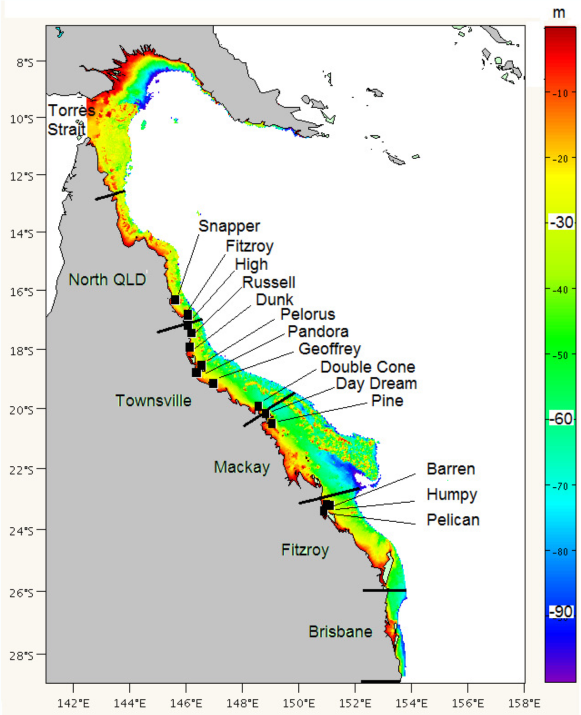


Sediment transport model

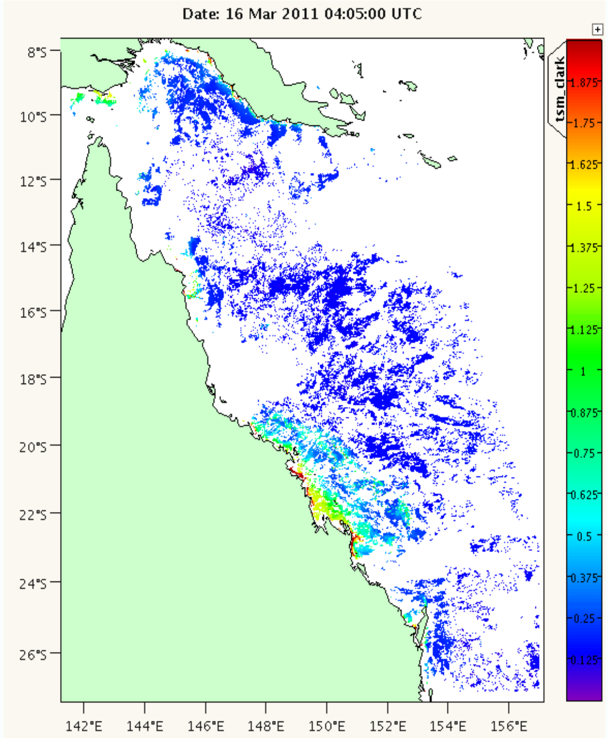
- Challenge to constrain semi-empirical model in a heterogeneous environment of the GBR region
- Calibration strategy
  - Initial concentrations and bottom roughness estimated via ensemble assimilation of the 6 months TSS inferred from remote-sensing
  - Ensemble of models, produced through the assimilation step, reduced to a single model
  - Improved sediment transport model validated against 4 years turbidity records from Reef Rescue and GBROOS moorings
- Scenarios
  - Altered loads from catchments

Data assimilation scenario

- eDICE data assimilation package
- Estimates of suspended sediment concentration inferred from remote sensing
- Assimilation scenario
  - Unknowns - initial concentration of benthic sediment and bottom roughness
  - 3 basis function
  - 32 members of the ensemble run on NCI
  - 2 days assimilation window
  - 12 subregions

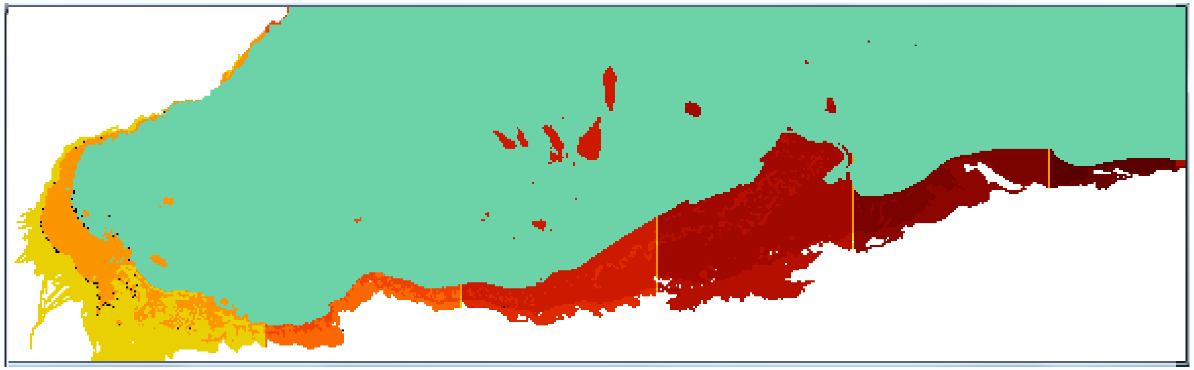


Reef Rescue observation sites and subregions map

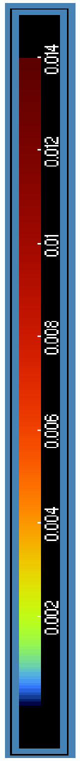


Suspended sediment (Brando, Schroeder, King)

DAS experiment with the twin model run

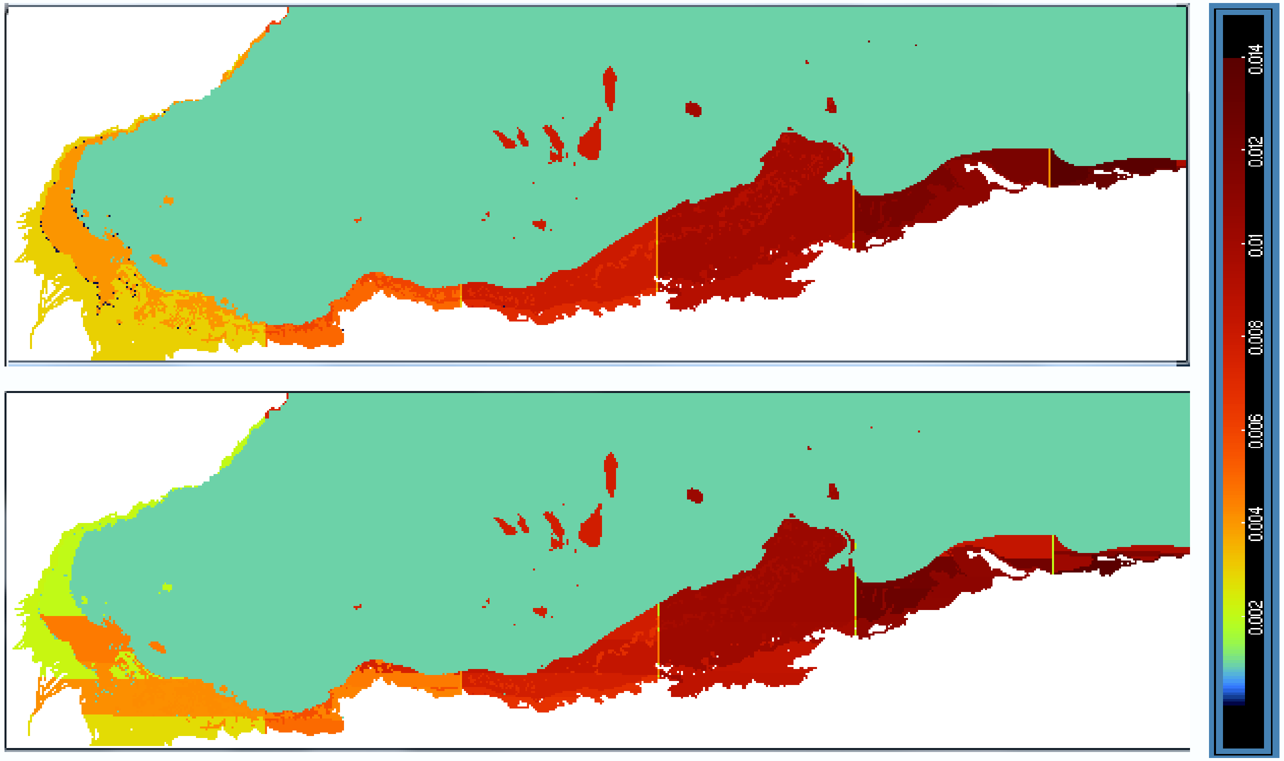


Bottom roughness underpinning twin model run

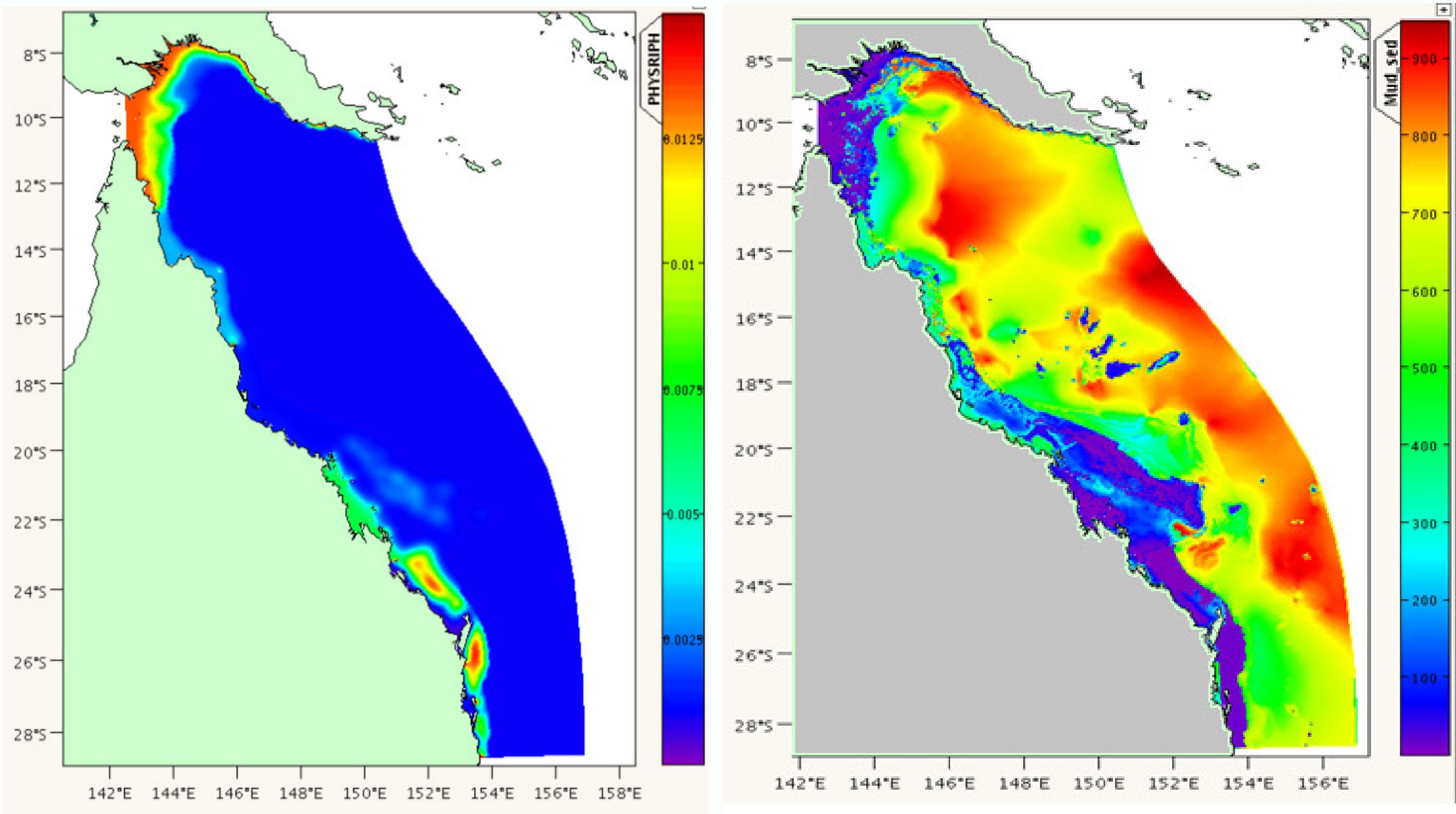


- The goal of the data assimilation experiment is to recover the distribution of the bottom roughness from synthetic observations produced by the twin model
- The twin model predicts surface TSS at locations coinciding with the locations of the remote sensing data.
- This predicted TSS is considered synthetic observations to be assimilated by the original model.

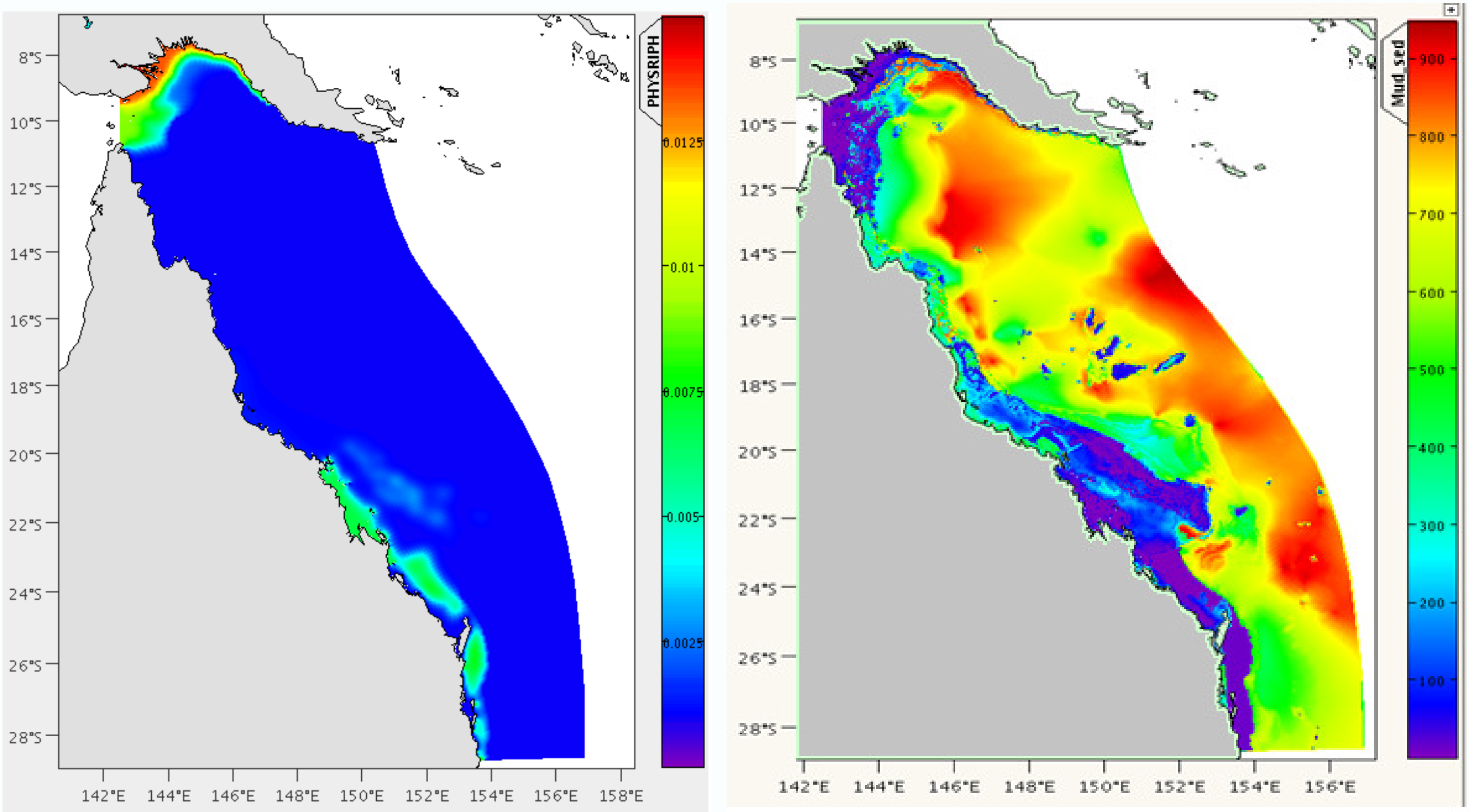
DAS experiment with the twin model run



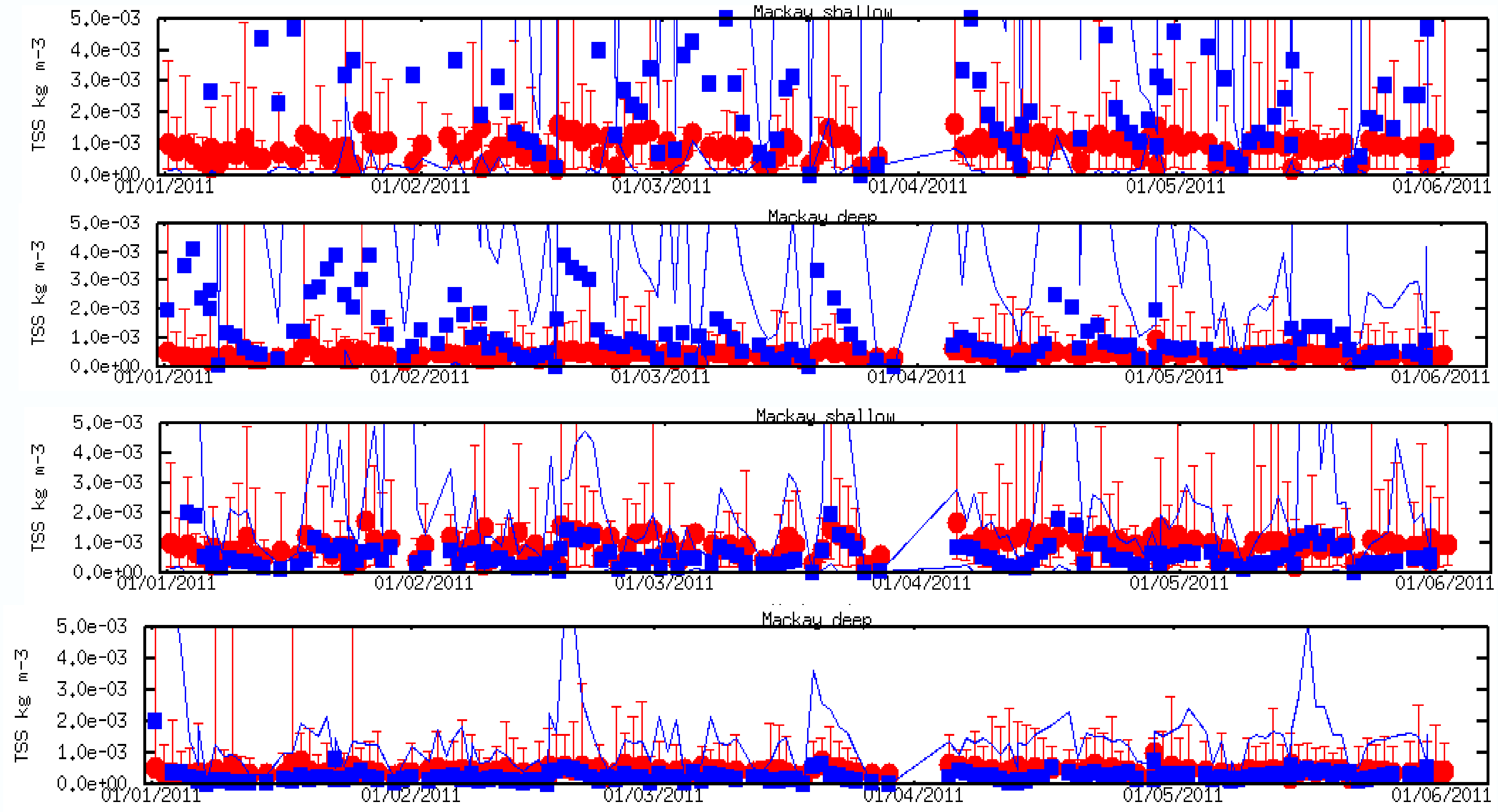
True (top plot) and estimated (bottom plot) bottom roughness. The estimated bottom roughness is based on the ensemble of 32 models integrated across members of the ensemble and over the last month of the assimilation period.



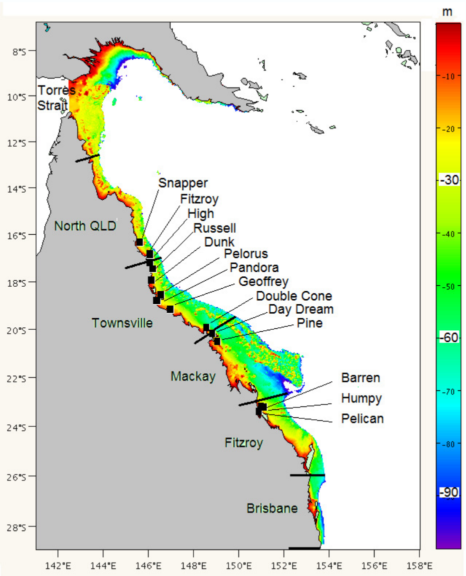
Bottom roughness (left) and concentration of benthic mud (right) estimated through the data assimilation and validation study

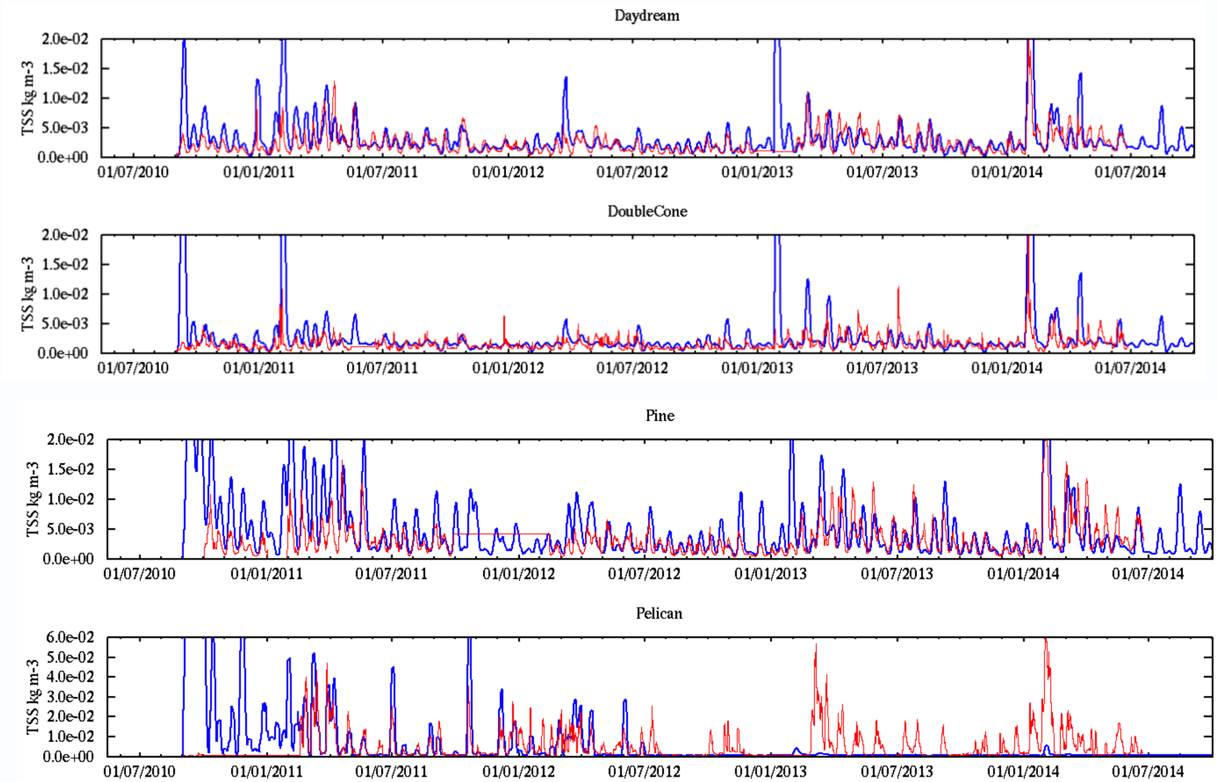


Bottom roughness (left) and concentration of benthic mud (right) estimated through the data assimilation and validation study

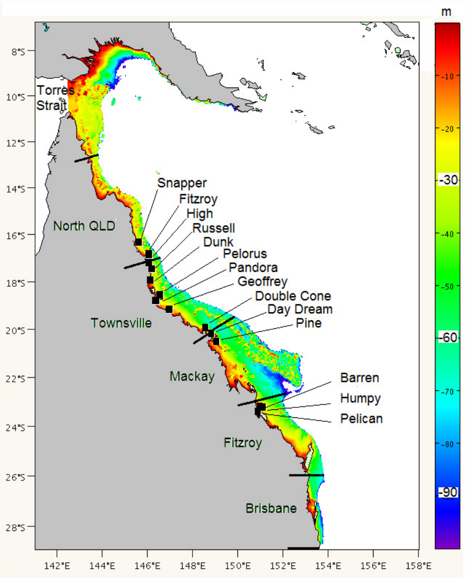


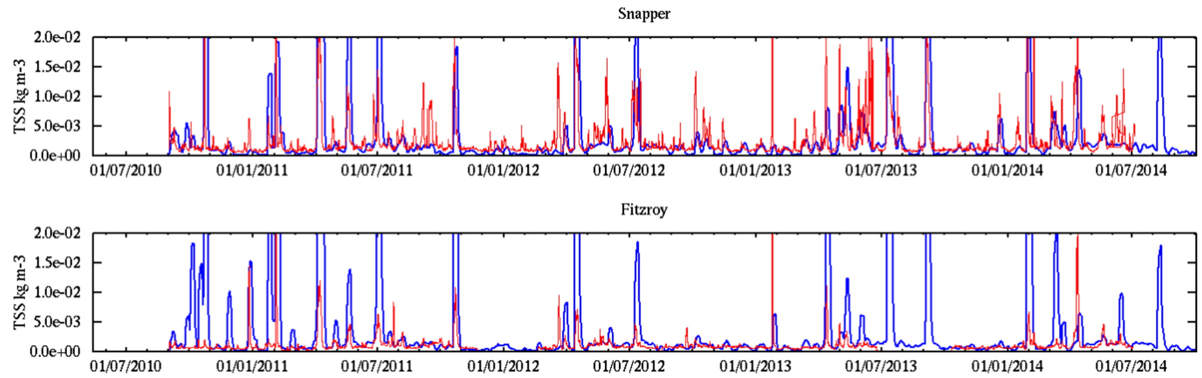
Control run of the ensemble of models vs observations (top plots). Data-assimilating run of the ensemble of models vs observations (bottom plots). Mackay coastal subregions. Red dots show observations integrated over the subregion. Blue dots show modelled data integrated over the subregion and over the ensemble members.

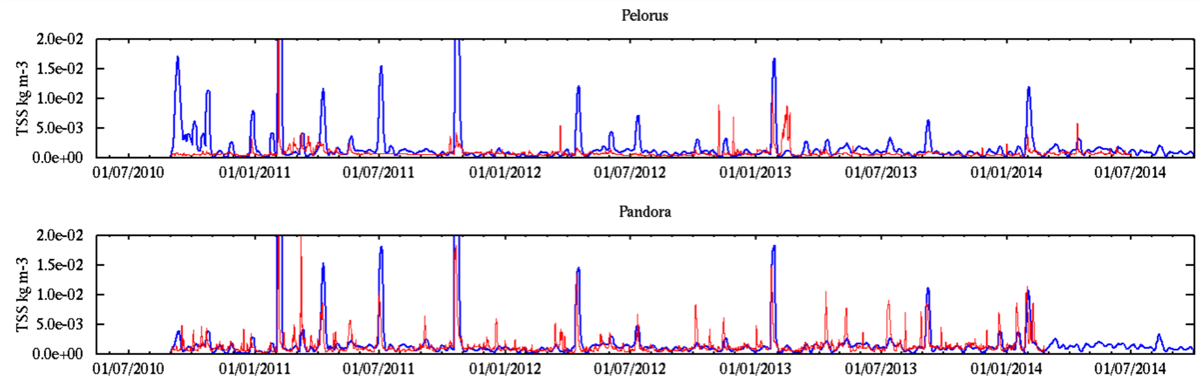




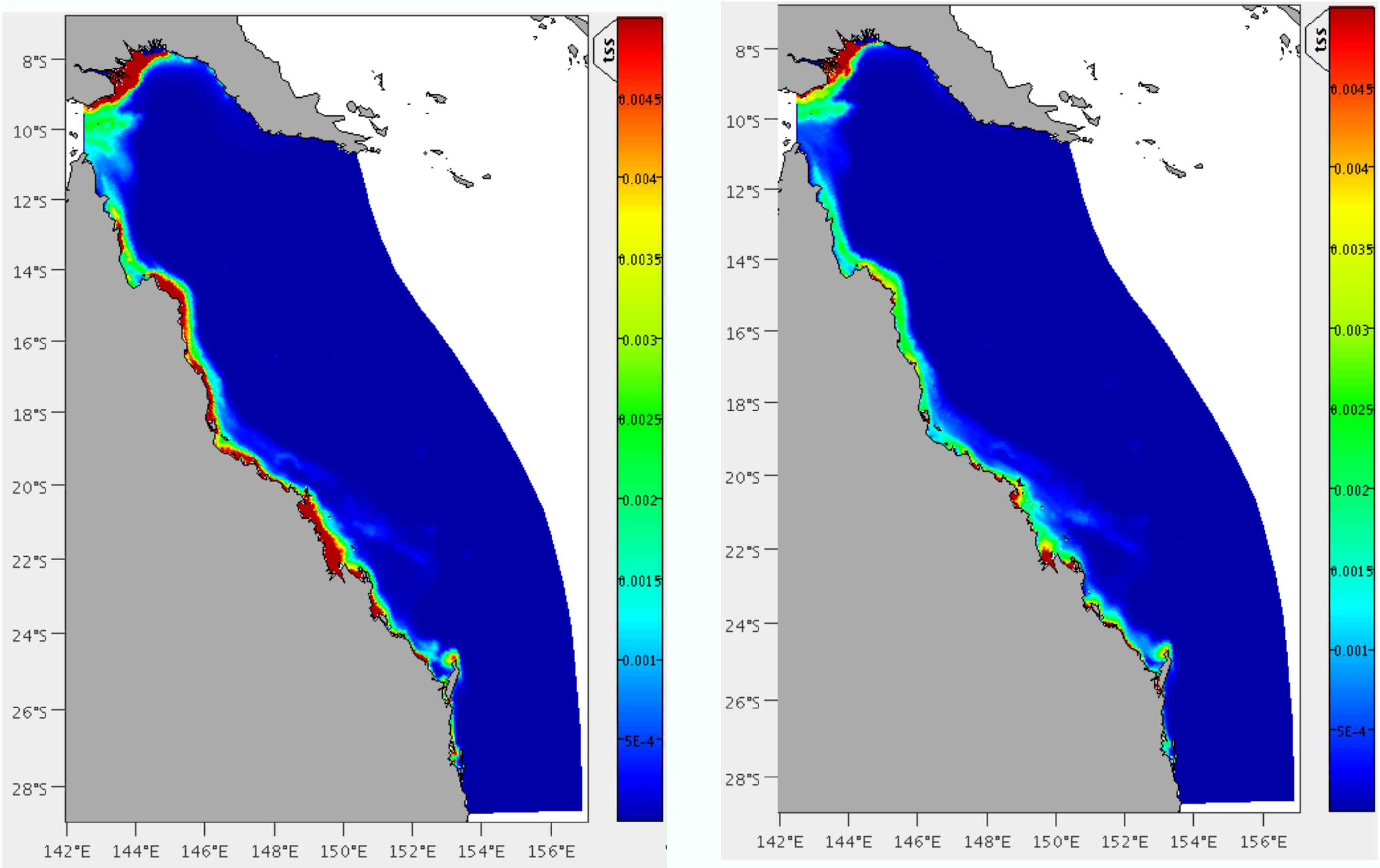
Simulated sediment concentration (blue) vs observations. Both model and observations are passed through the low-pass filter with a 1 day cutoff period.





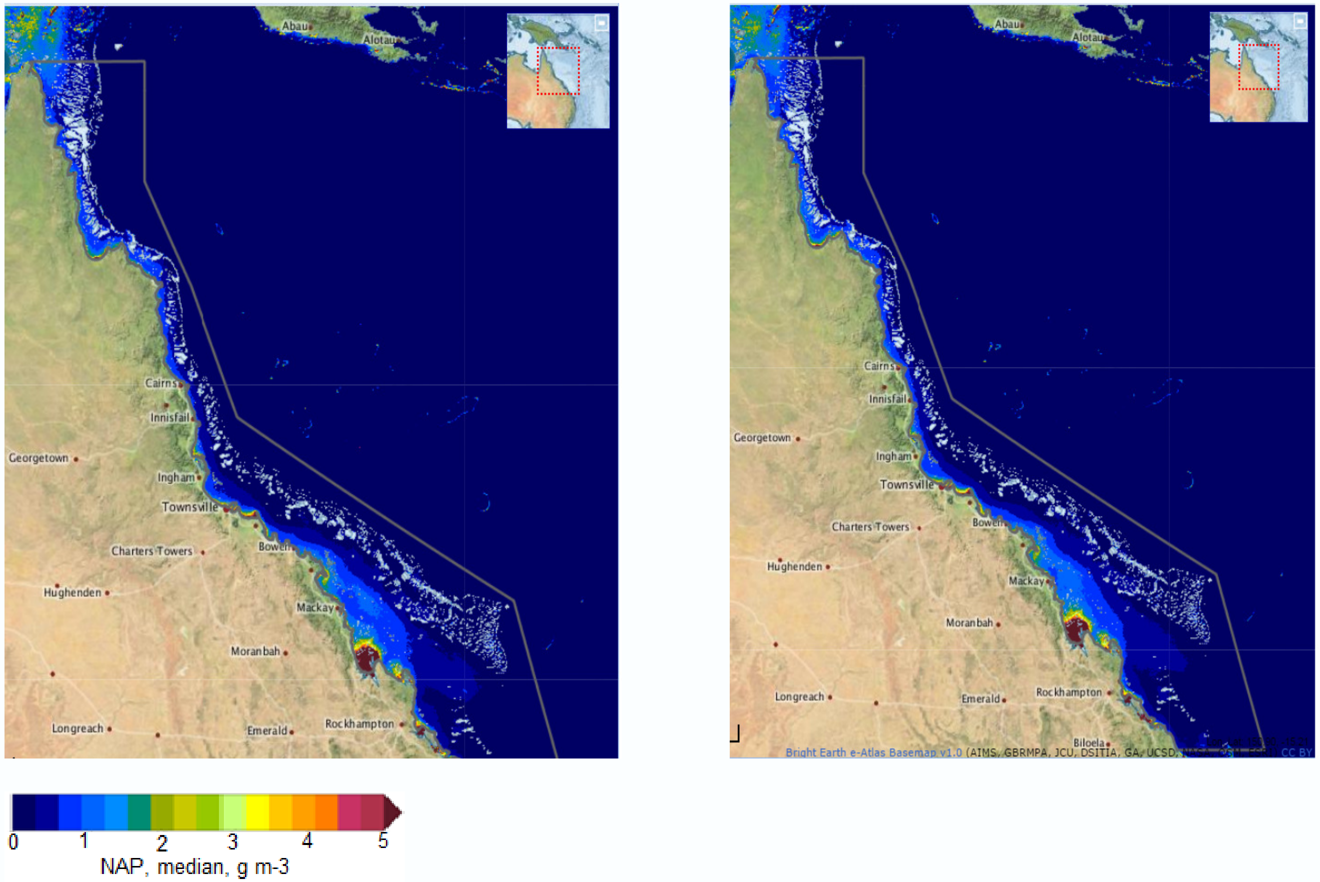


Simulated sediment concentration (blue) vs observations. Both model and observations are passed through the low-pass filter with a 1 day cutoff period.



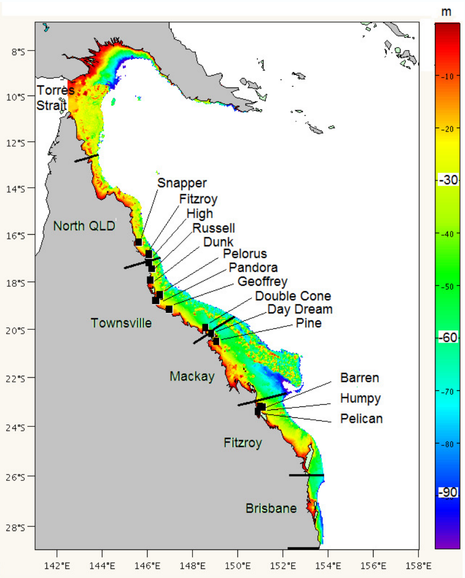
Simulated annual mean TSS. October 2010-September 2011 (left),

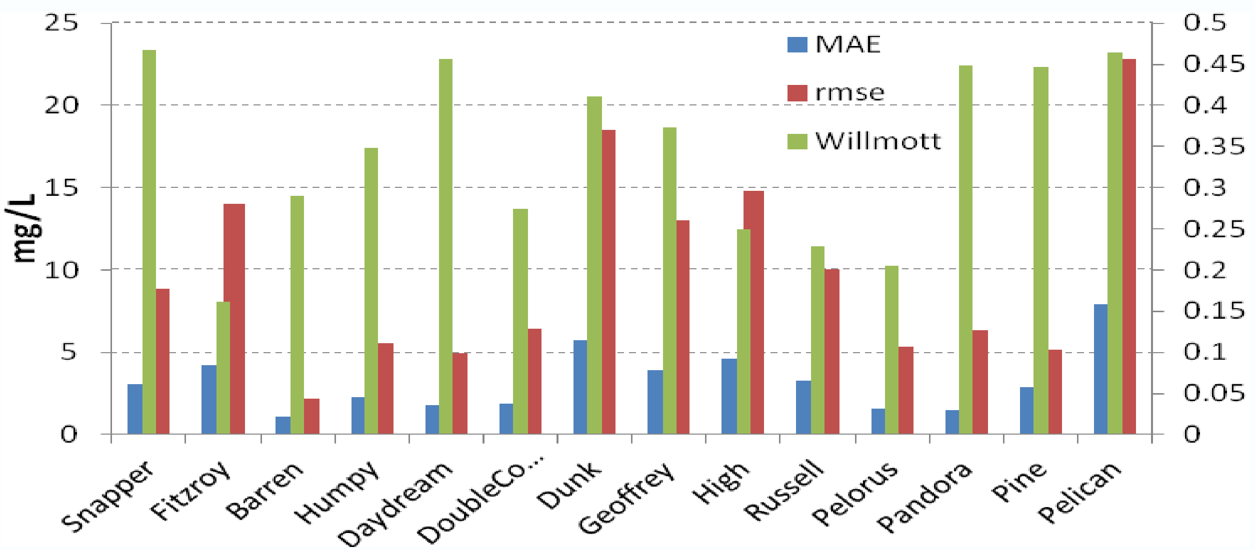
October 2013-September 2014 (right).



Annual median of TSS inferred from the remote sensing data for 2010 (left), and 2013 (right)

(http://www.bom.gov.au/marinewaterquality/)

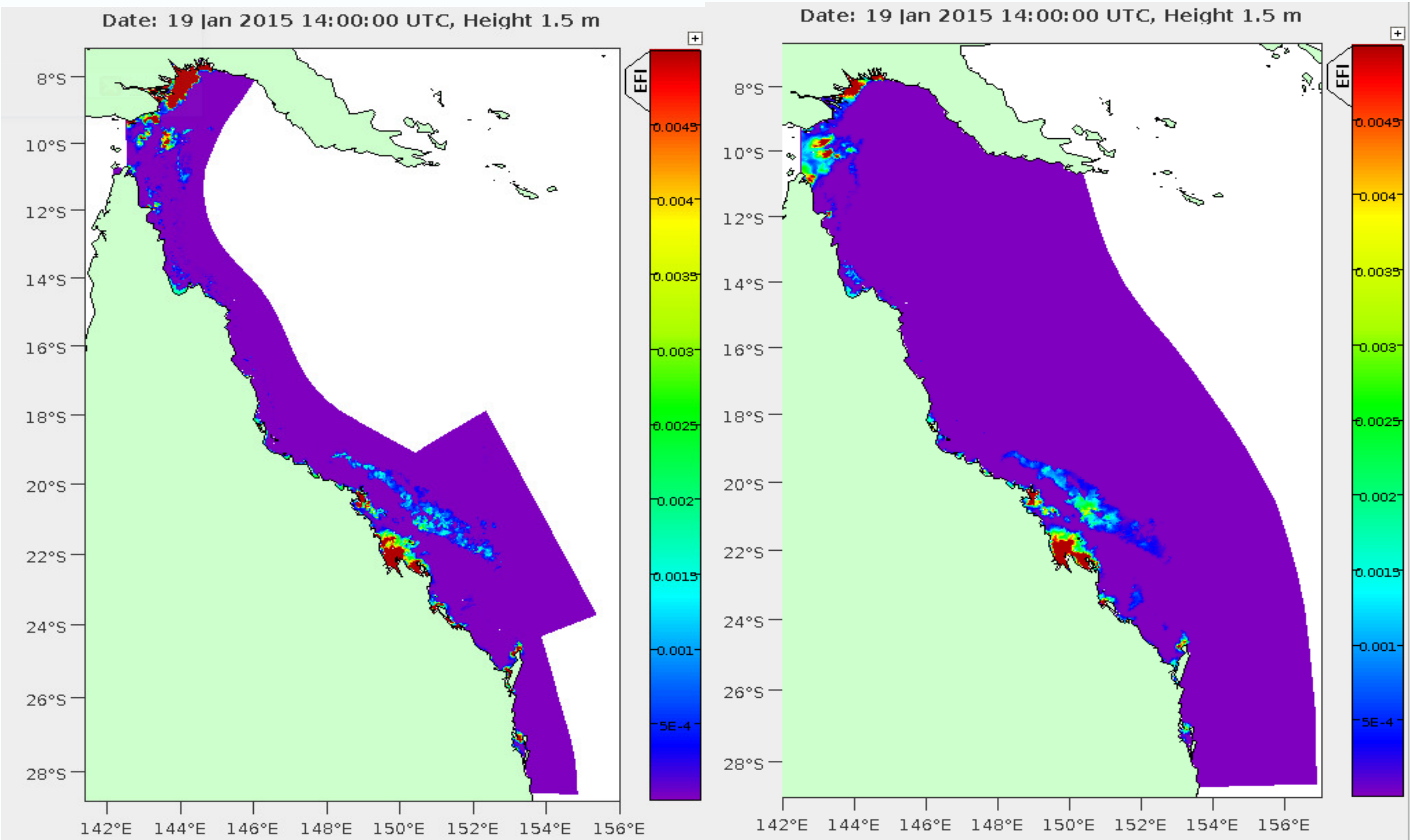




Mean Absolute Error (MAE), RMSE and Willmott-index of the simulated TSS records at observation sites

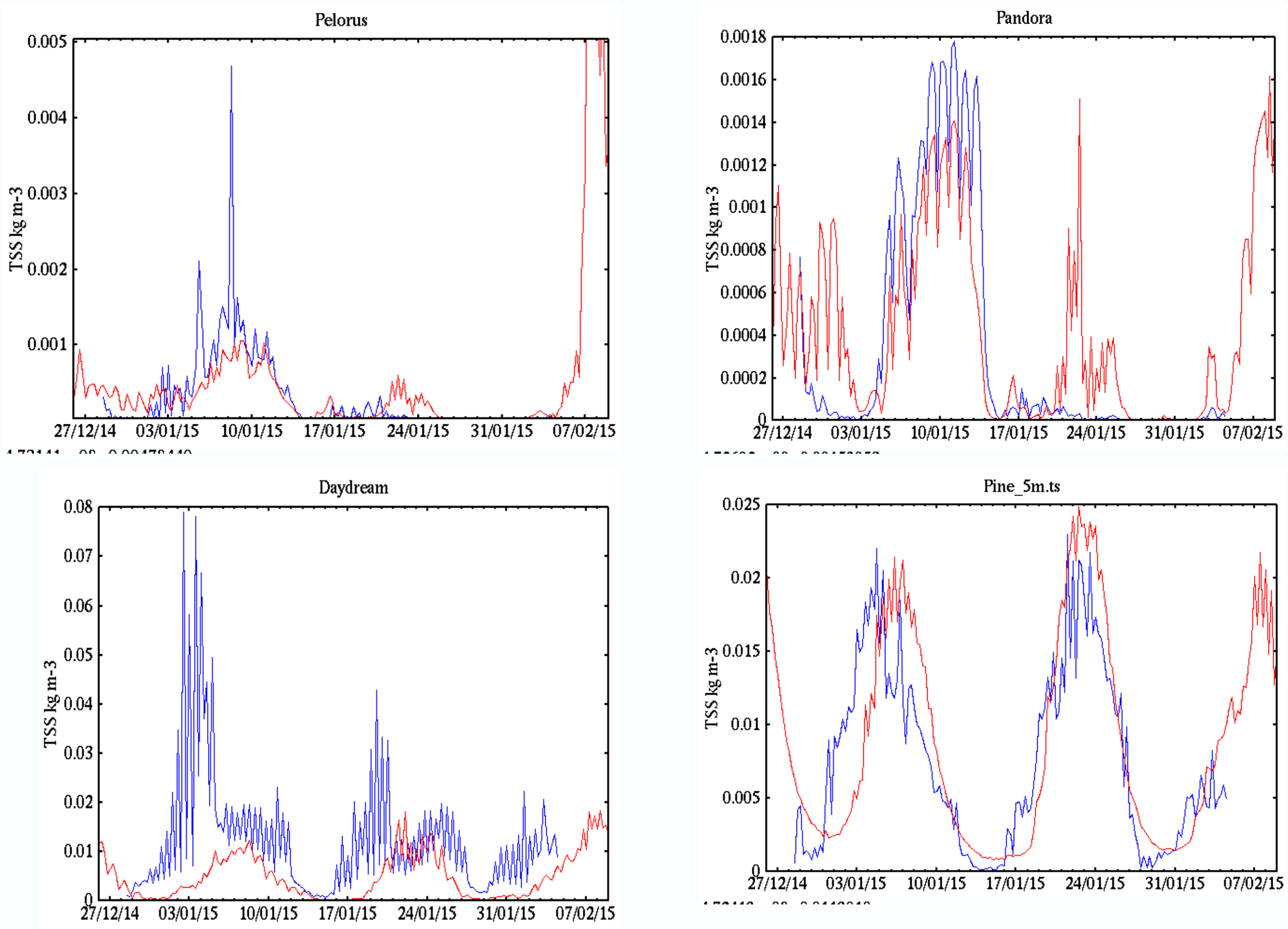
- The quality of the calibrated model varies across the GBR region and with time.
- The distribution of the simulated suspended sediment on GBR, in general, is consistent with observations.
- Uncertainty of the predictions attributed to both an inherently stochastic nature of the sediment processes on the shelf and uncertainty of the model itself.

Uncalibrated GBR1 vs calibrated GBR4 model

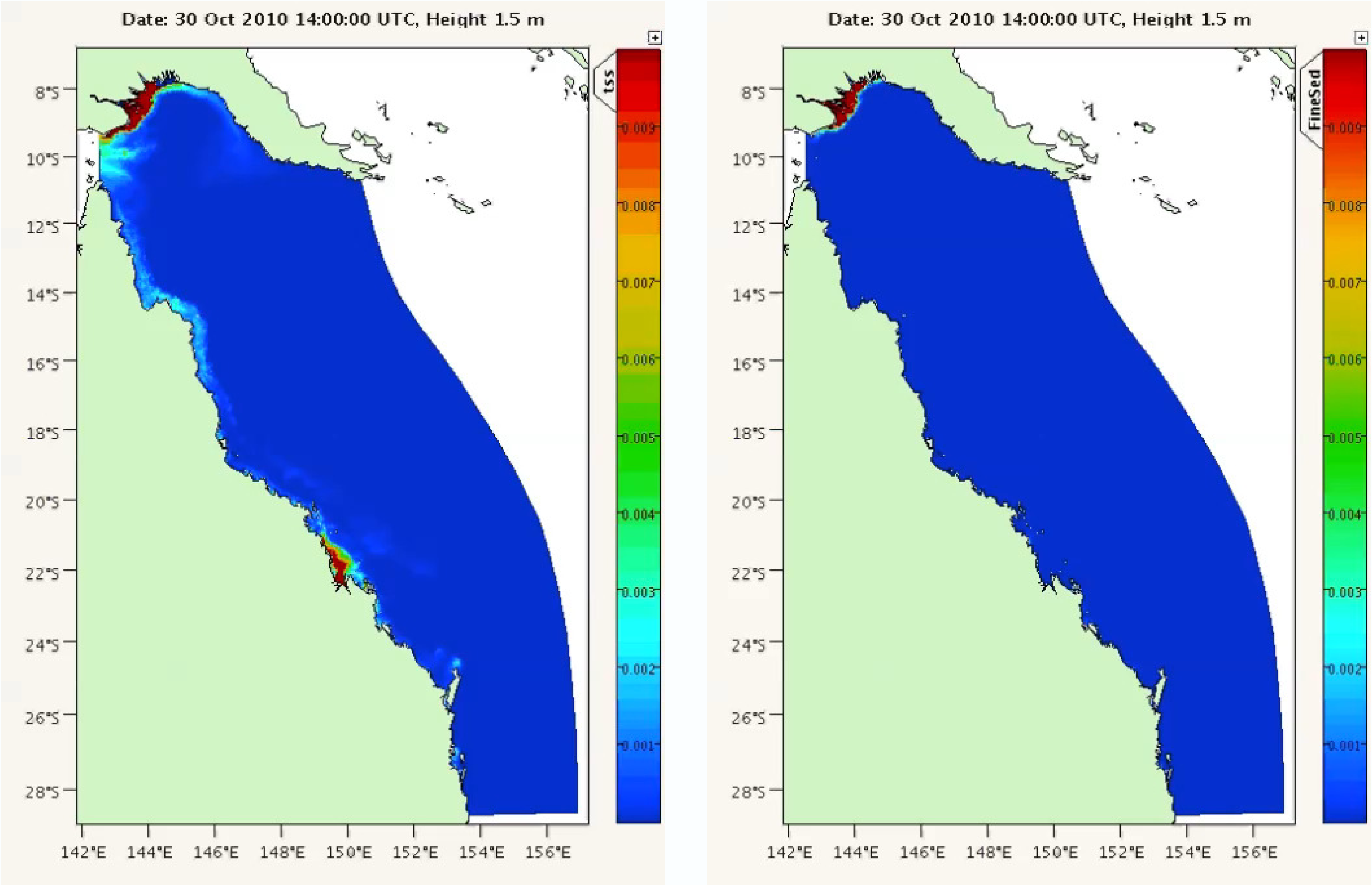


Snapshots of surface TSS (kg m-3) produced by GBR1 model (left) and GBR4 model (right).

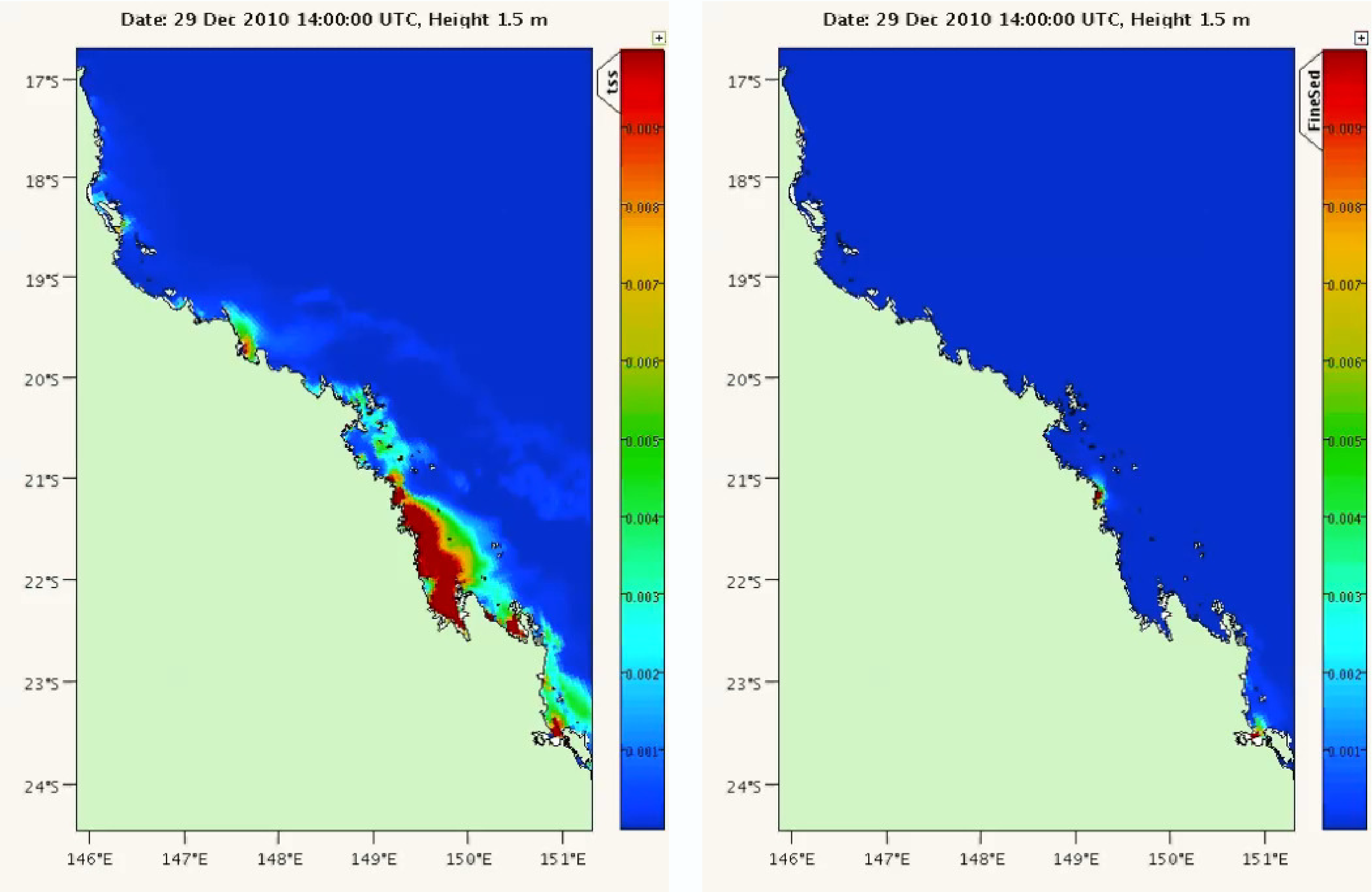
Uncalibrated GBR1 vs calibrated GBR4 model



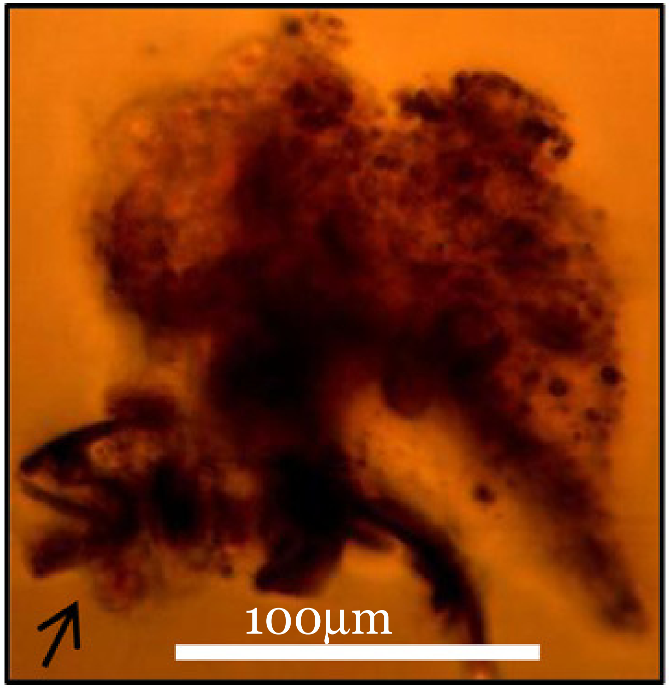
Time series of TSS simulated with GBR1 (blue) and GBR4 (red) models.



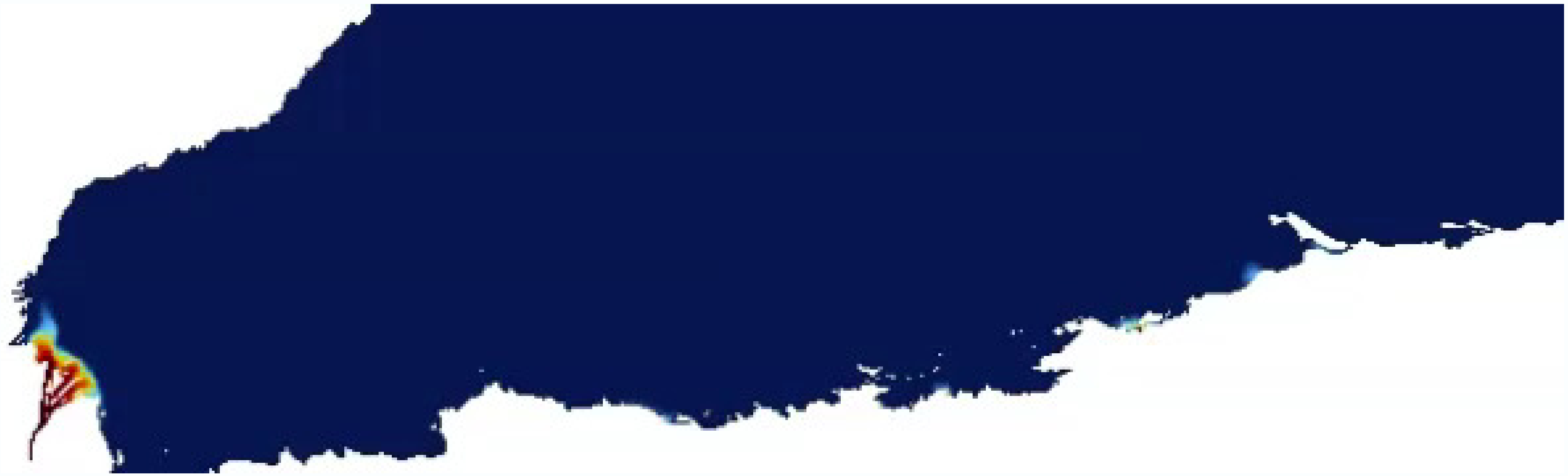
Simulated surface TSS (left) and catchment-sediment (right). Wet year.



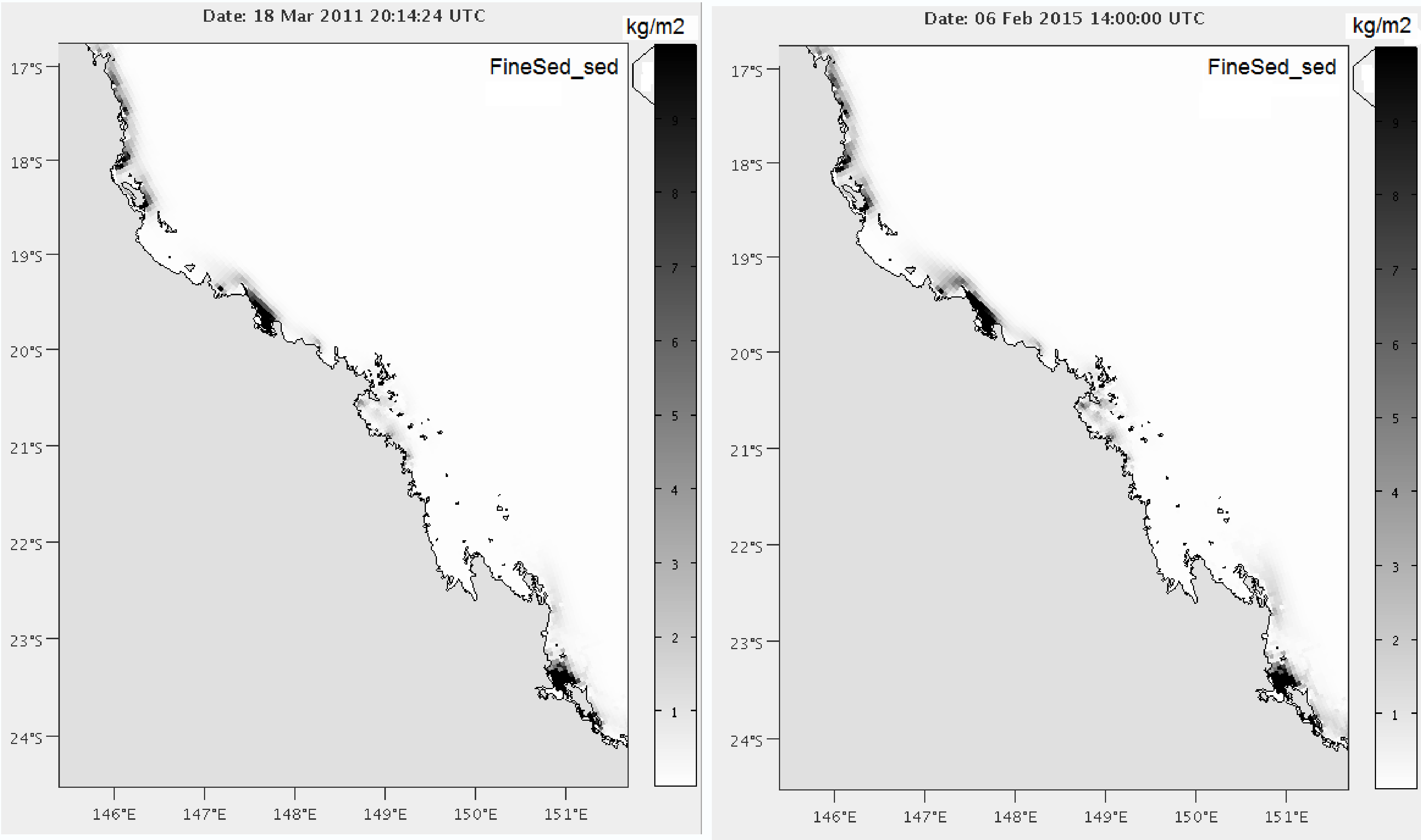
Simulated surface TSS (left) and catchment-sediment (right). Wet year.



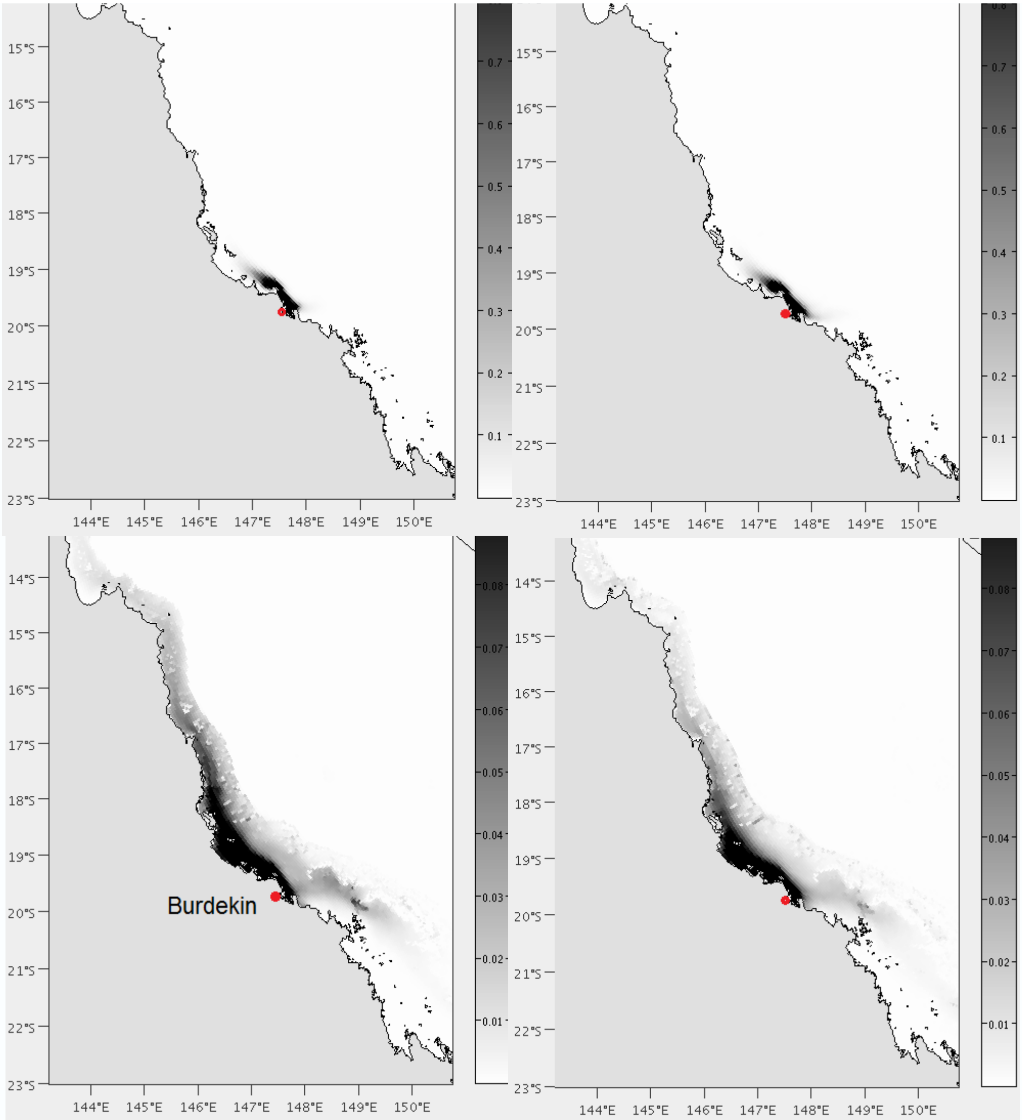
Organic-reach sediment flocs in the Burdekin River flood plume reaching Cleveland Bay (from Bainbridge et al., 2012).

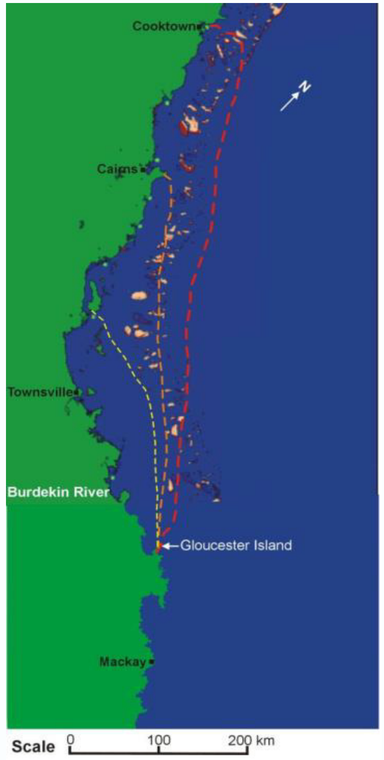


Surface concentration of very light fraction of sediment released from catchments



Benthic deposits of sediments from catchment in 2011 (left) and 2015



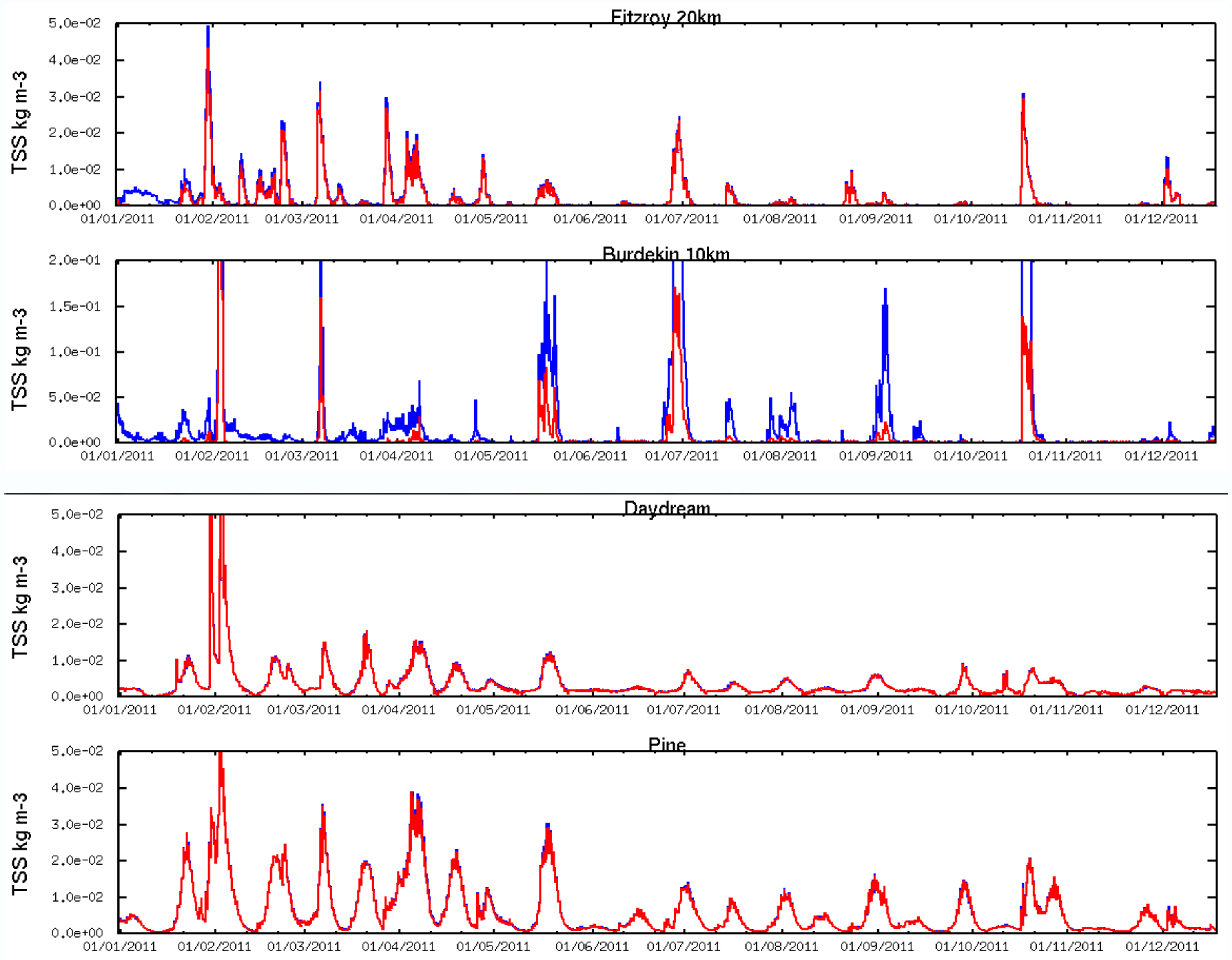


Benthic concentration of sediments delivered from the Burdekin catchment (kg/m3).

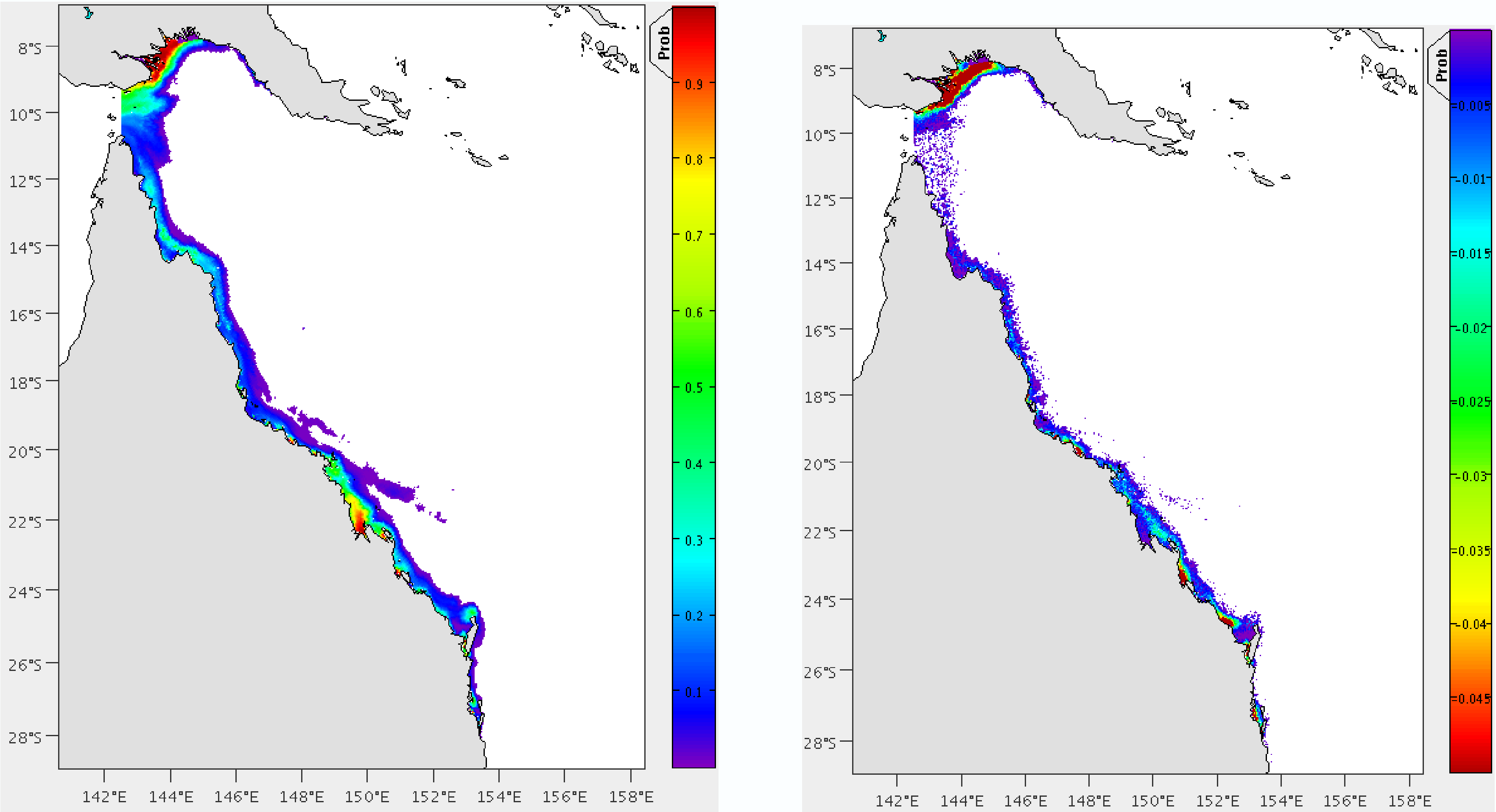
Fine sediment (top plot), dust sediment (bottom plot)

- Bulk of catchment sediment deposits in the close vicinity to river mouth (a few tens of km)
    - The closer to the river mouth, the higher the concentration of the deposition.
    - Benthic footprint of catchment sediment does not change substantially after 2011 and over the subsequent 3 years of the simulation period (i.e. no significant propagation of sediment along the coast after the flood event).

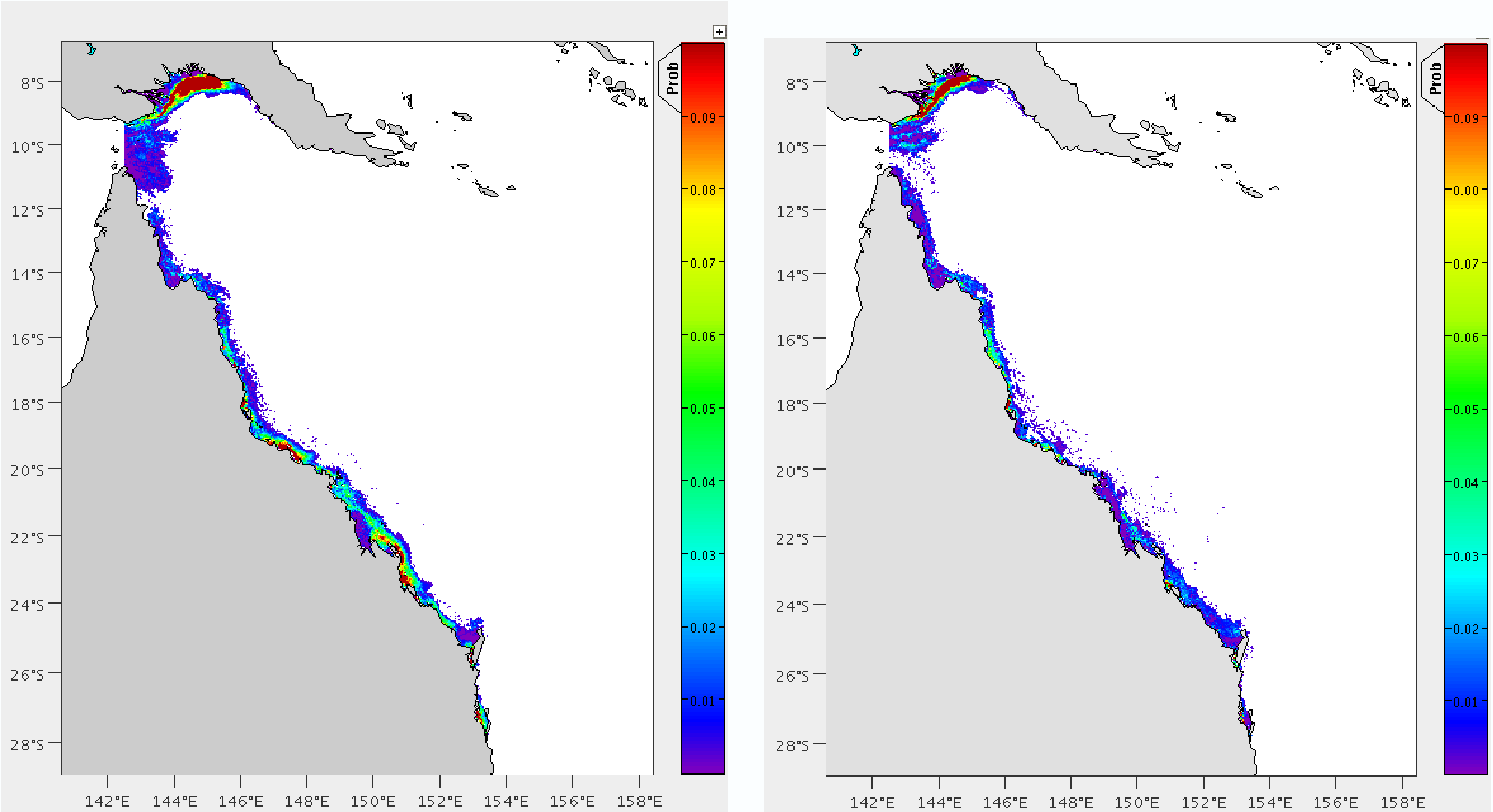
- Very fine fraction of catchment sediment can be carried by flood currents over longer distances and then dispersed through water column, and partly buried in sediments and washed offshore.
    - The model suggests limited (and slow) accumulation of these particles on the shelf over the 4 year simulation period.
    - Limited knowledge of properties of these particles.



Time series of TSS according to baseline scenario (blue) and scenario with no sediment loads from catchments

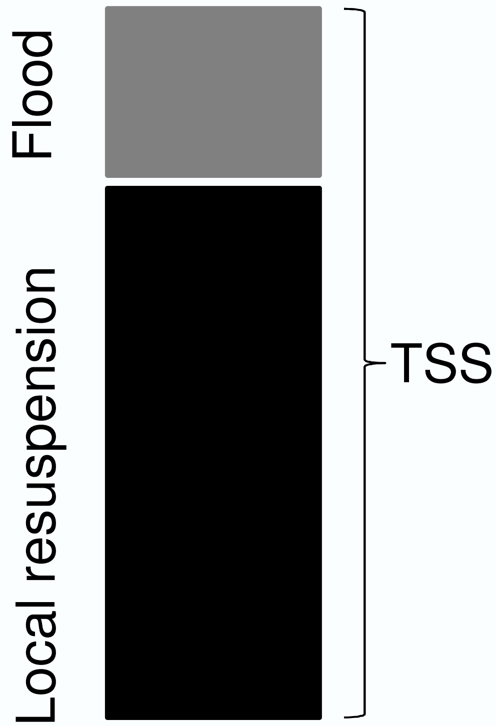


Four-year mean probability for TSS to exceed 2 mg/L according to baseline scenario (left) and the perturbation of this probability for the scenario with no river loads (right).



Perturbation of the annual mean probability for TSS to exceed 2 mg/L for the scenario with moderate dust load against baseline scenario. October 2010-September 2011 (left), October 2013-September 2014 (right).

- TSS = Local resuspension + Flood plume
- Altering sediment loads from catchments translates into altered TSS during and after flood events
  - These changes (particularly noticeable during wet years) persist until catchment particles are diffused, diluted and buried in deep sediments, so that TSS is again dominated by the resuspension of historical deposits
  - The area influenced by these changes will roughly correspond to the area covered by flood plumes - the closer to the river mouth, the larger the impact of the altered loads on TSS
- To have reduced levels of TSS sustained throughout the year (including dry season), benthic deposits must adjust to the altered boundary conditions
  - For example, by resuspension and winnowing of excessive amount of mud from benthic sediment
  - This adjustment could take much longer than simulated 4 years.



Conclusions

- Numerical model of the fine sediment transport on the GBR shelf has been developed. The model, in general, is consistent with observations and can be used to underpin various “what if” scenarios.

- The sediment transport model (coupled to hydrodynamic and biogeochemistry models) runs in near-real time and builds an archive of the simulated fields (http://research.csiro.au/ereefs/). This archive can have value by itself. It also provides sediment data required for a nested fine-resolution relocatable RECOM model.

Acknowledgements

- eReefs project
- CSIRO CSS TCP