

APPENDIX A: eReefs biogeochemical configuration and model assessment - simulation gbr4-H2p0-B2p0-Chyd-Dcrt

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1 Outline

This report displays technical specifications of model parameterisation and initialisation for the eReef biogeochemical model (run gbr4-H2p0-B2p0-Chyd-Dcrt) and comparison of model simulation results with observations from individual sites and moorings in the Great Barrier Reef Marine Park (GBRMP) domain.

Results: observations are blue; model simulations are black

Specific details for model results

- The model (gbr4-H2p0-B2p0-Chyd-Dcrt) uses gauged flow and SOURCE catchment model loads for GBR rivers and uses gauged flows and linear loads for rivers outside the GBRMP domain.
- If the model grid shown in the figures is shallower than the observational depth then the model will take the deepest water column cell.
- The deepest observational depths at the sites varied throughout the 4 years of sampling but were generally within the same horizontal grid cell within the model.

2 Acknowledgments

The eReefs BGC model analysis would not be possible without the continuing observational analysis datasets which play a highly significant role in the successful interpretation of the biogeochemical cycles and management of this model.

Primary observational data sources: Integrated Marine Observing System (IMOS) - IMOS is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative IMOS moorings and includes the National Reference Stations (Yongala and Stradbroke used in this study). Other key observations were sourced from AIMS data center and include AIMS Water Quality monitoring sites, carbon chemistry projects and Reef Rescue Project moorings.

3 Skill metrics

The following shows the skill metrics used for model and observation comparison within this document.

- RMSE - Root Mean Square Error: $RMSE = \sqrt{\frac{1}{n} \sum_{j=1}^n (y_j - \hat{y}_j)^2}$
- r - correlation coefficient: $r = cov(y_j, \hat{y}_j) / \sqrt{cov(y_j, y_j) cov(\hat{y}_j, \hat{y}_j)}$
- bias - model bias: $bias = \frac{1}{n} \sum_{j=1}^n (y_j - \hat{y}_j)$
- normalised bias (given in bar graphs only) - bias is normalised to make it non-dimensionless and has an ideal value of 0
- MAE - mean absolute error: $MAE = \frac{1}{n} \sum_{j=1}^n |y_j - \hat{y}_j|$
- d2 - Willmot's skill metric, ratio of the MAE and the mean absolute deviation about the observed mean (Willmott et al., 1985).(ideal value - close to 1)
- MAPE - mean absolute percentage error

The metric values for each variable and site are calculated from the duration of the simulation and does not include periods where observations or model have no data.

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink KM, Legates DR, O'Donnell J, Rowe CM. 1985. Statistics for the evaluation of model performance. Journal of Geophysical Research 90: 8995-9005.

4 Observation sites

The observation sites that are used to compare with the model are shown in this section. They include AIMS water quality monitoring sites, Marine Monitoring Program (MMP) sites, IMOS/NRS moorings, Coral chemistry surveys. Satellite views showing the location of the sites and their proximity to Islands and Queensland coast are shown using Google maps

Table 1: Observational sources used for model comparison

Database type	Number of sites/voyages with WQM	Holdings	BGC Parameters
AIMS WQM standard sites	16-20 sites with many taken at 2 depths most at approx 3 month intervals	AIMS WQM	NH4 NOX DIP Chla (not HPLC) TSS DOC DON DOP
Marine Monitoring Program (MMP) sites	14 Sites that correspond with AIMS WQM sites above (2009-2014)	MMP/AIMS	Chl (fluorescence), turbidity
IMOS moorings chlorophyll and TSS	6 moorings with WQM instruments, generally 2 WQM depths per mooring (continuous fluorescence)	IMOS	Chl (fluorescence) and turbidity
IMOS/NRS Moorings chlorophyll	2 continuous Chl (fluorescence) and turbidity moorings at Yongala and Stradbroke	IMOS	Chl (fluorescence) and turbidity
NRS IMOS Moorings	WQM monthly samples and Chl monthly at two moorings at Yongala and Stradbroke,	Aims database and IMOS	NH4 NOX DIP Chla (HPLC) TSS Aragonite saturation state, DIC, pH, alkalinity
Coral chemistry sites	Sample set from mid 2011 to 2013 of 14 monthly sample sites (same as MMP sites)	Miles Furnas	Aragonite saturation state, DIC, pH, alkalinity
HPLC chlorophyll samples	assorted HPLC samples from moorings and voyages and one off transects in the barrier reef region and at model boundaries	AESOP and IMOS and Data Trawler	Chla (HPLC)
Flood plumes	4 regional areas where flood plume WQ samples are taken (15 per site over the flooding period(weekly): Burdekin, Burnett Mary, Fitzroy and wet tropics	James Cook University	Note some parameters not always taken: Kd, TSS, Chla (HPLC), turbidity, NH3, NOX DIP, DON NOX, DOP
Samples North of the Noosa River to Fitzroy	Received 4 WQ datasets 21 Nov 2014 that are predominantly very close to shore and up into estuaries from Noosa to Fitzroy mainly close inshore and estuary samples	Jonathon Hodge via CQAMP	Alkalinity, Chl-a, NH4, NOx, DON, DOC, Oxygen, DIP, TSS,
Sporadic Aims WQM sites throughout the 2010 to 2014 period, underway or special research	50 sites temporally sporadic or ad hoc most near the coast or very close to inner reef Islands	Aims WQM	NH4, NOX, DIP, CHL, TSS, DOC, DON, DOP, NOx
Voyage sites Coral Sea	Historic: 1920 until present (~100 sites) sporadic or ad hoc	marlin trawler and data	NH4 NOX DIP Chl TSS
Voyages near Fly river	Historic: 1920 until present (~20 sites) sporadic or ad hoc	marlin trawler and data	NH4 NOX DIP Chl TSS
Voyage sites Coral Sea near PNG gulf	Historic:1920 until present (~50 sites) sporadic or ad hoc	marlin trawler and data	NH4 NOX DIP Chl TSS
Voyage sites Torres strait	Historic:1920 until present (~30 sites) sporadic or ad hoc	marlin trawler and data	NH4 NOX DIP Chl TSS
Voyage sites or longitudinal surveys from new and Queensland border	Historic:1970 until present (~200 sites) sporadic or ad hoc	marlin trawler and data	NH4 NOX DIP Chl TSS

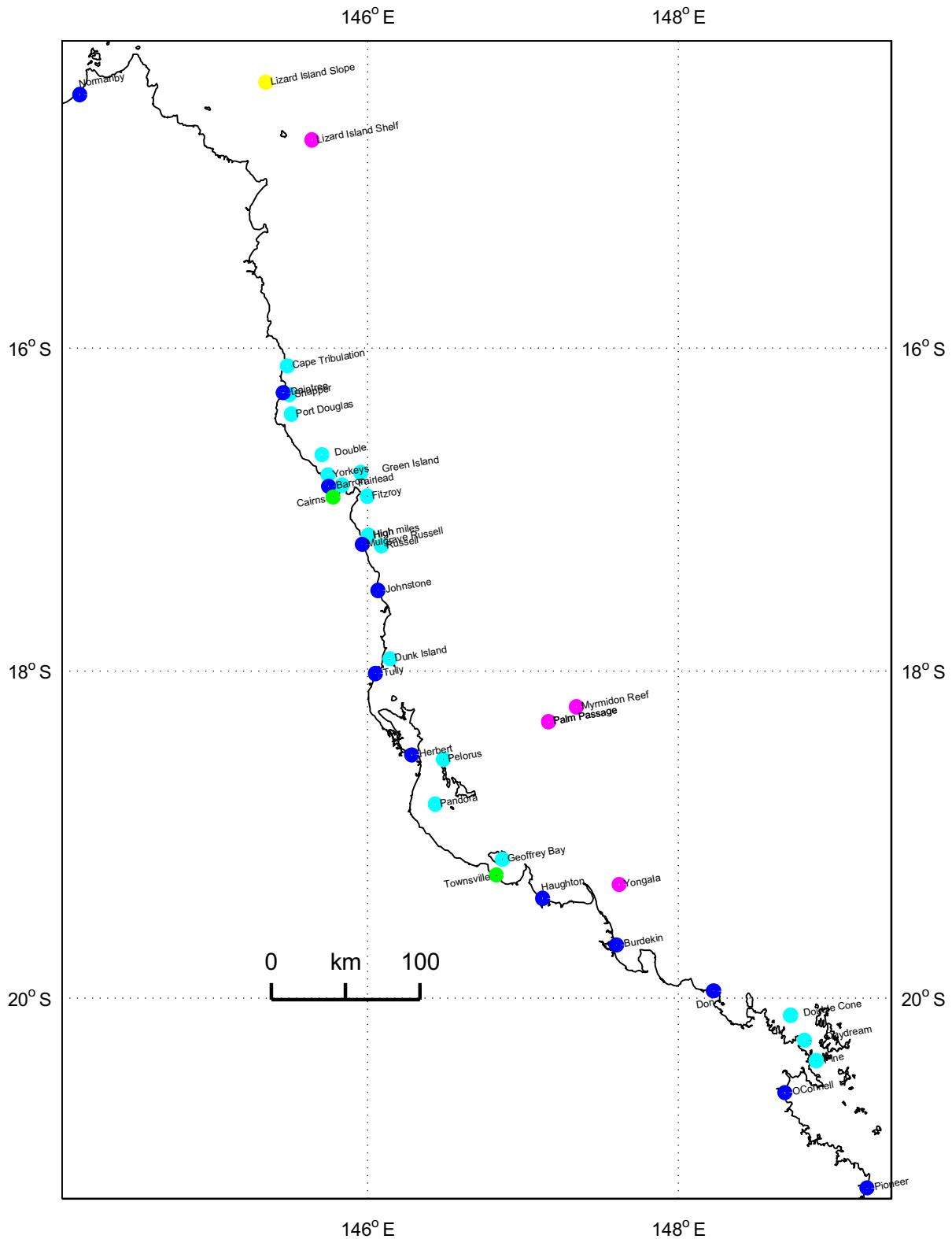


Figure 1: Map of northern GBR sites: Pink: IMOS/NRS sites and mooring locations. Aqua: AIMS WQM sites, Yellow: IMOS moorings that have only hydrological data. Green: Towns. Blue: Rivers included in the model domain.

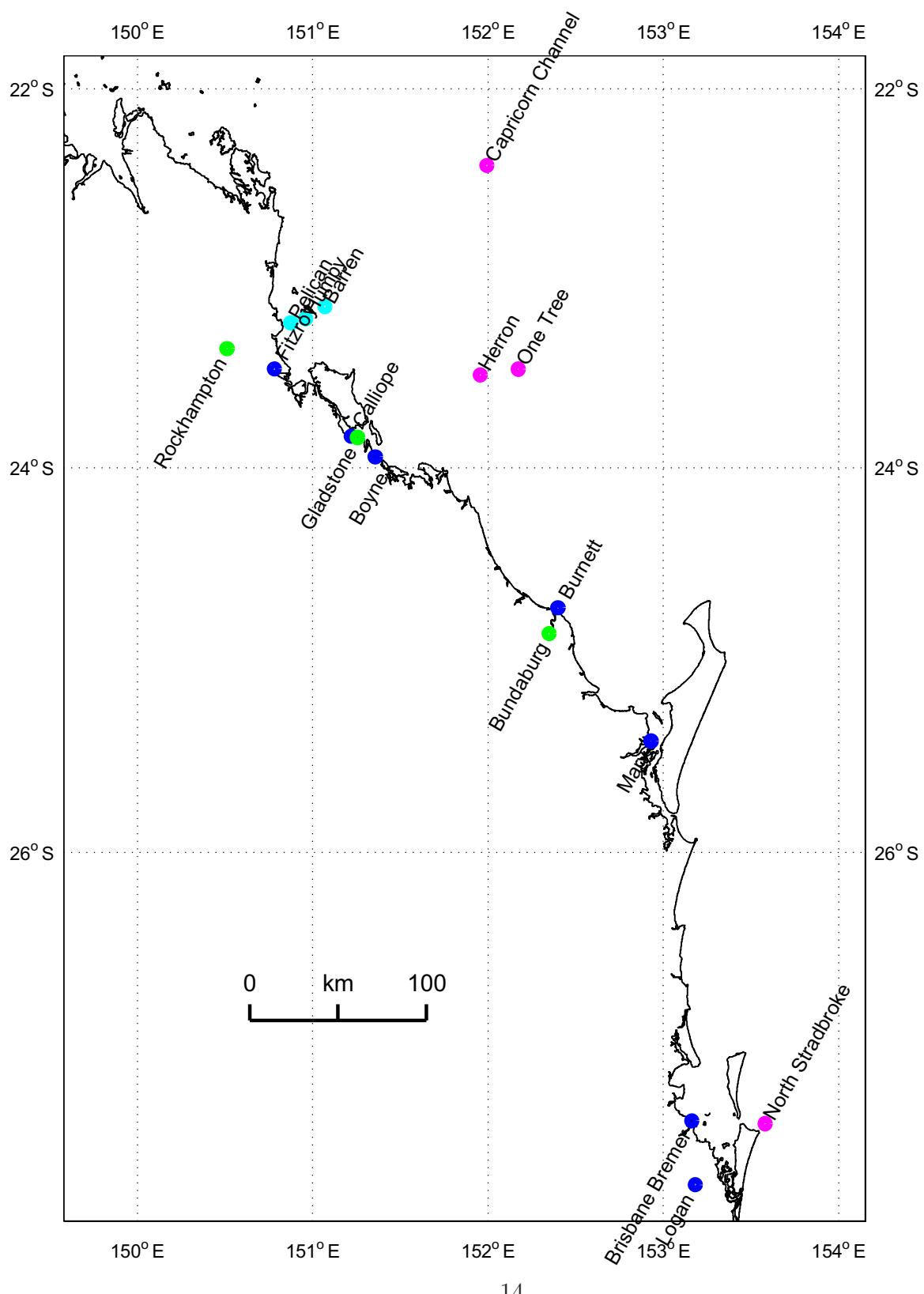


Figure 2: Map of southern GBR sites: Pink: IMOS/NRS sites and mooring locations. Aqua: AIMS WQM sites, Yellow: IMOS moorings that have only hydrological data. Green: Towns. Blue: Rivers included in the model domain.

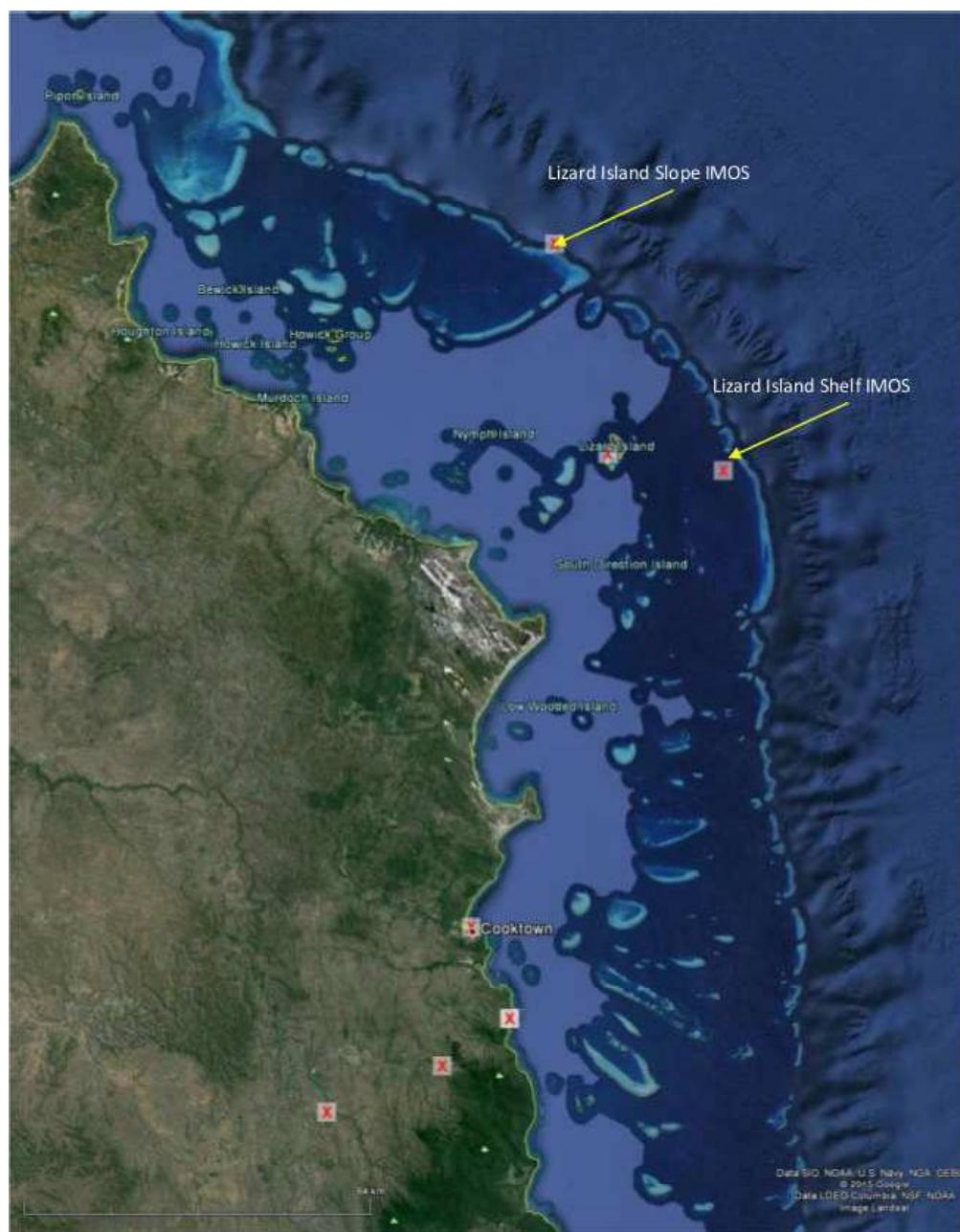


Figure 3: Google maps of sites: Lizard Island Slope and Lizard Island Shelf IMOS mooring sites

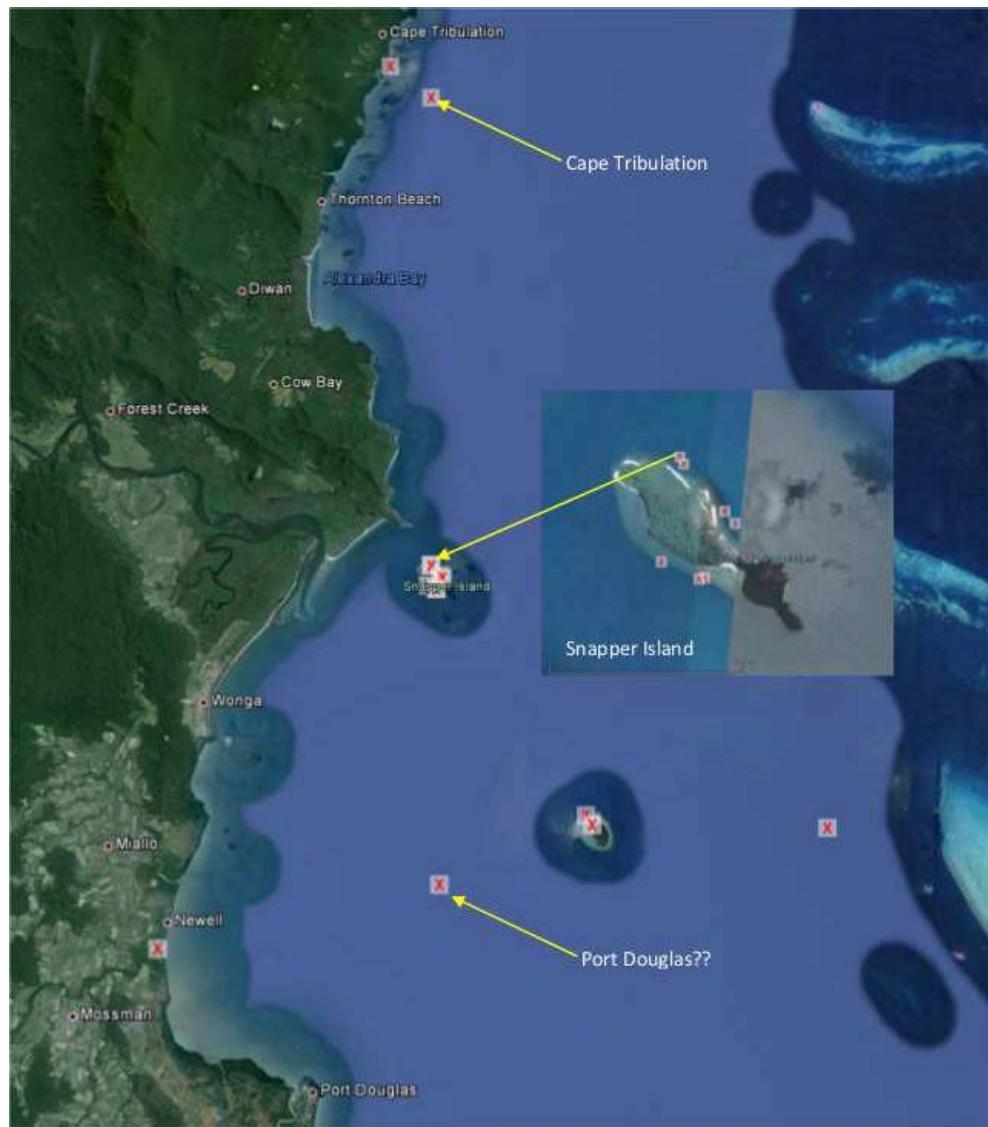


Figure 4: Google maps of sites: Cape Tribulation and Snapper and Port Douglas

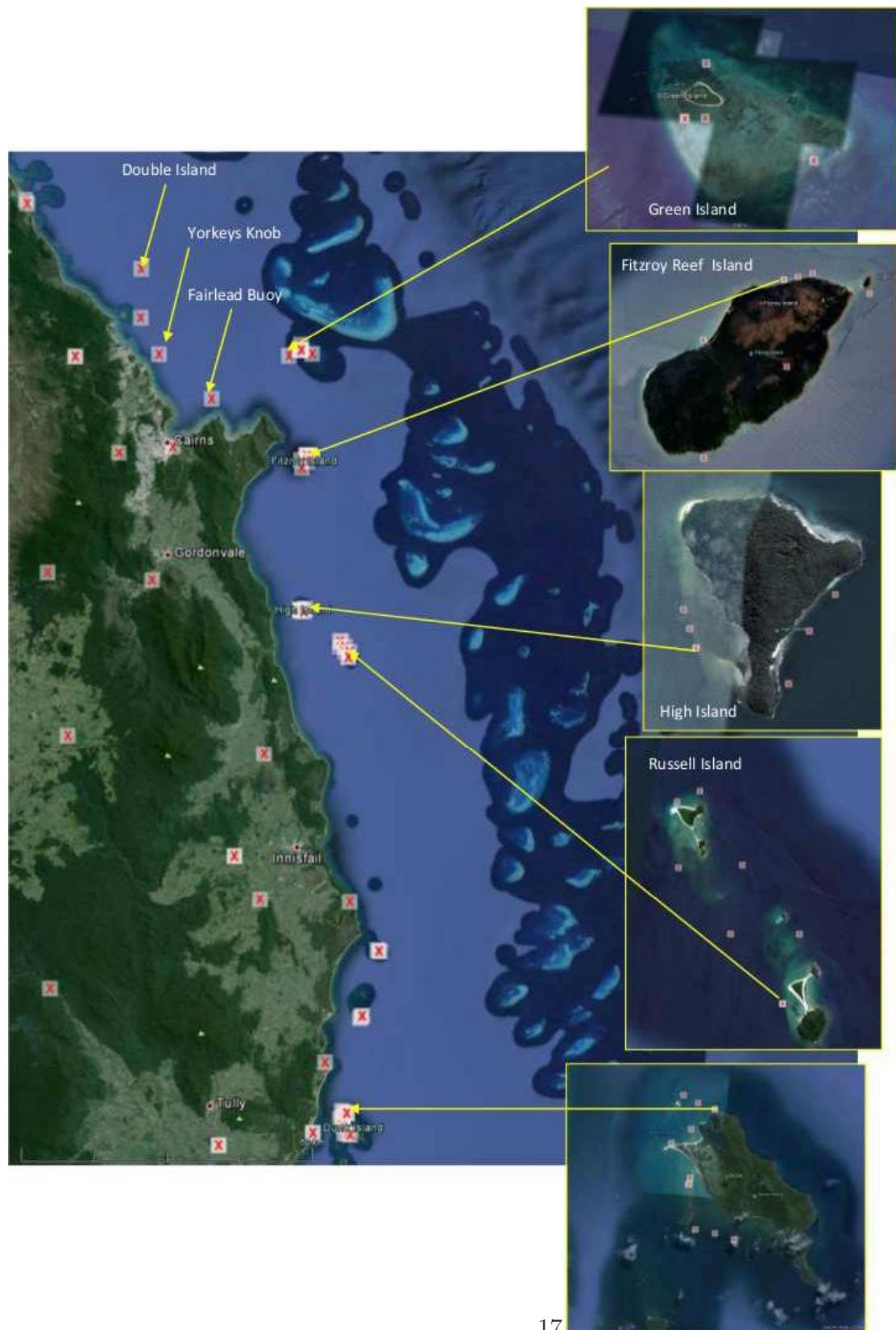


Figure 5: Google maps of sites:Double Island, Yorkeys Knob, Fairlead Buoy, Green Island, Fitzroy Reef Island, High Island, Russell Island and Dunk Island



Figure 6: Google maps of sites: Geoffrey Bay and Yongala

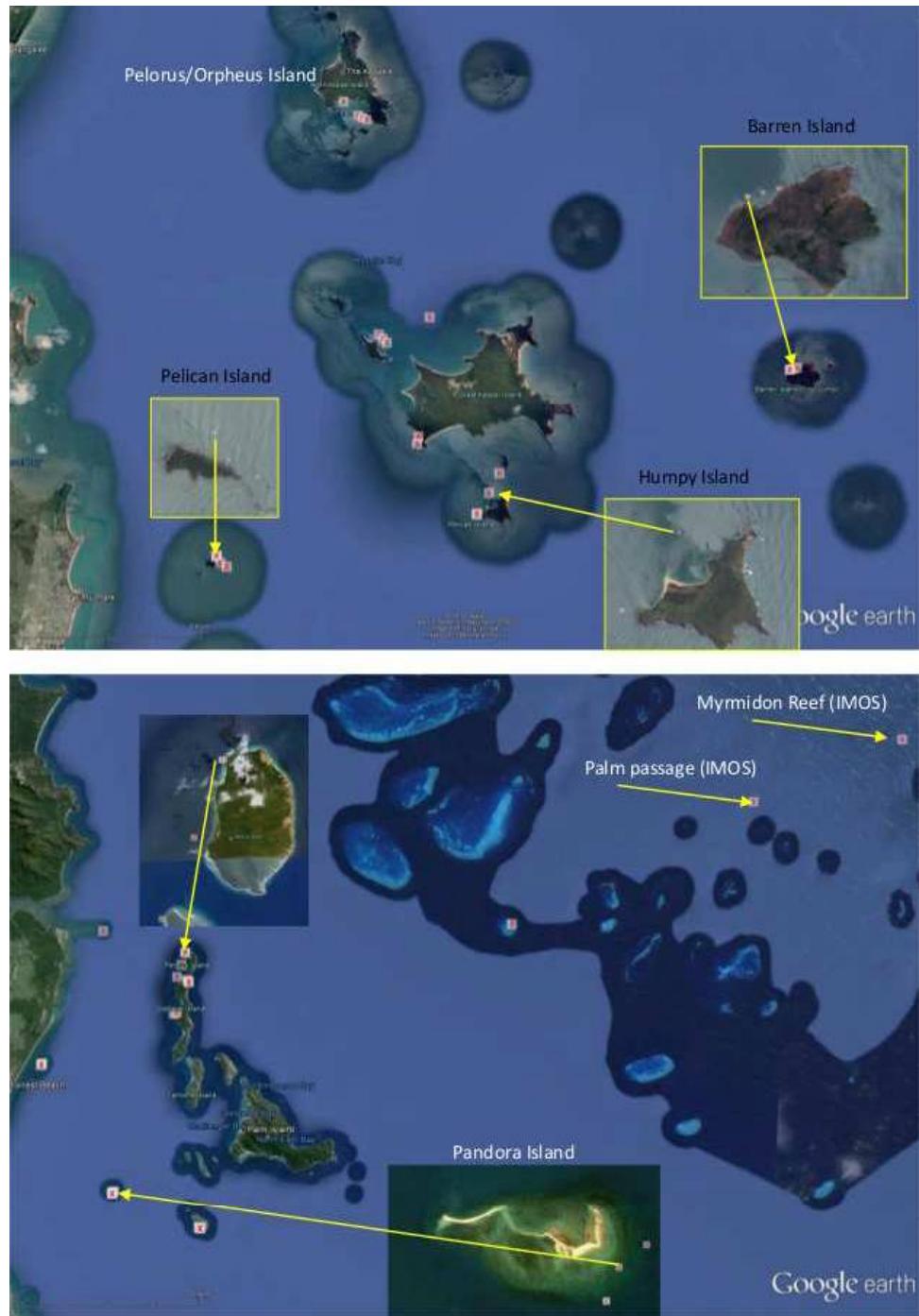


Figure 7: Google maps of sites: Top map Pelorus/Orpheus Island, Barren Island, Pelican Island, Humpy Island. Bottom map Myrmidon Reef and Palm Passage moorings (IMOS), Pelorus Island and Pandora Island



Figure 8: Google maps of sites: Top map Capricorn Channel, Heron Island and One Tree East. Bottom map Double Cone island, Daydream island and Pine Island.

5 Model configuration

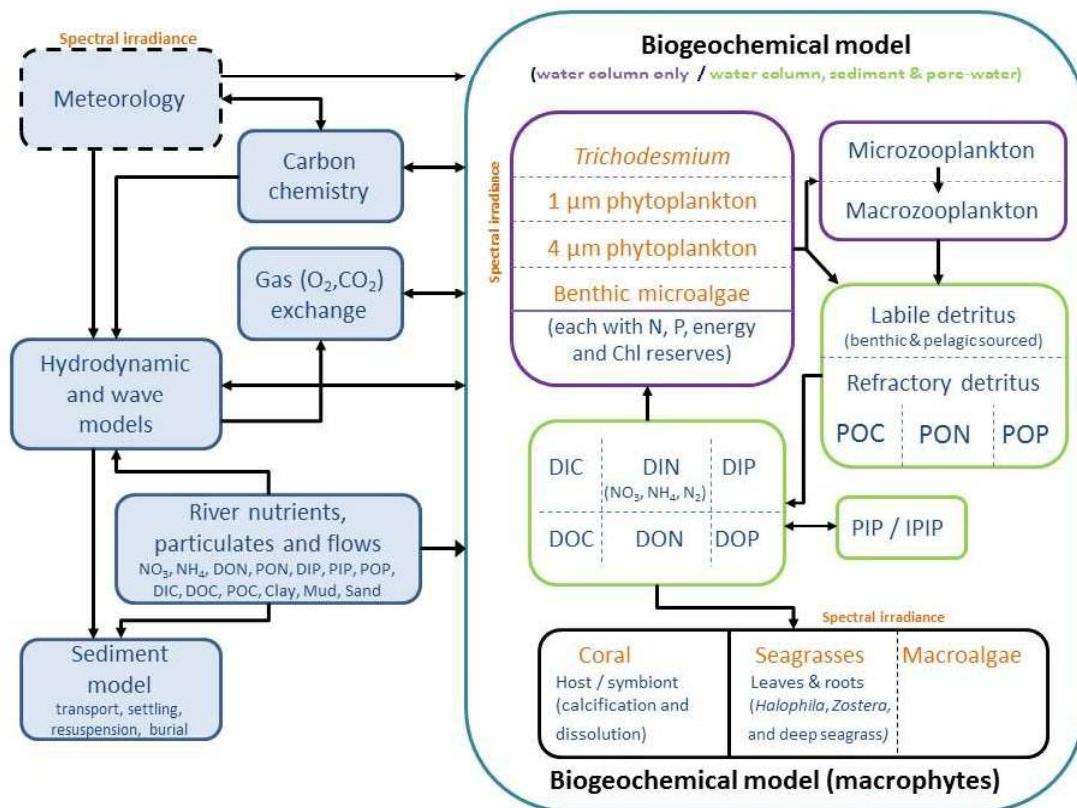


Figure 9: Schematic of EMS model with enhanced processes for eReefs shown in red.

6 Model assessment

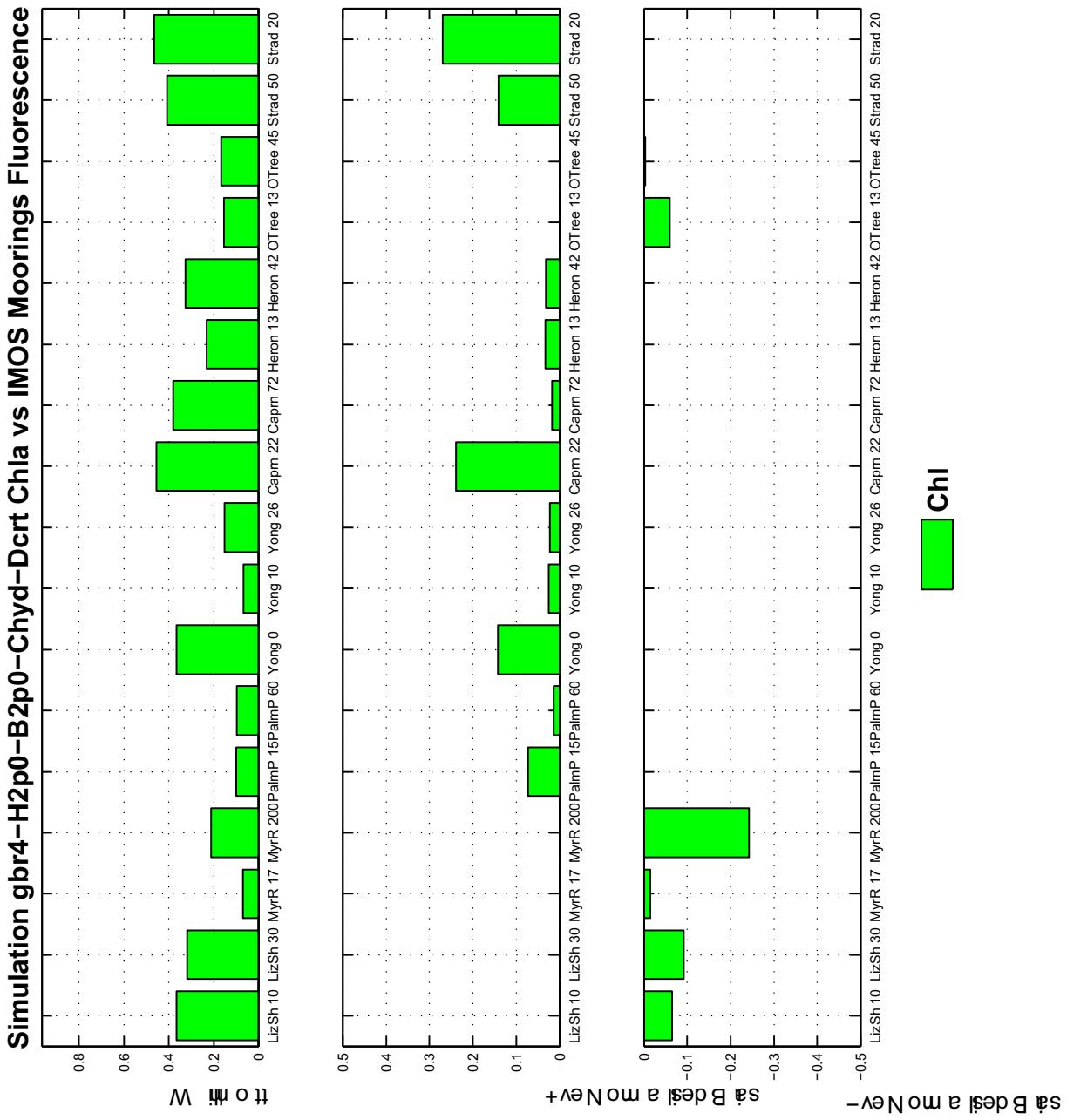


Figure 10: Statistical plots for the normalised bias and willmott index metrics for chlorophyll at the IMOS moorings.

Simulation gbr4–H2p0–B2p0–CChyd–Dcrt vs AIMS WQM

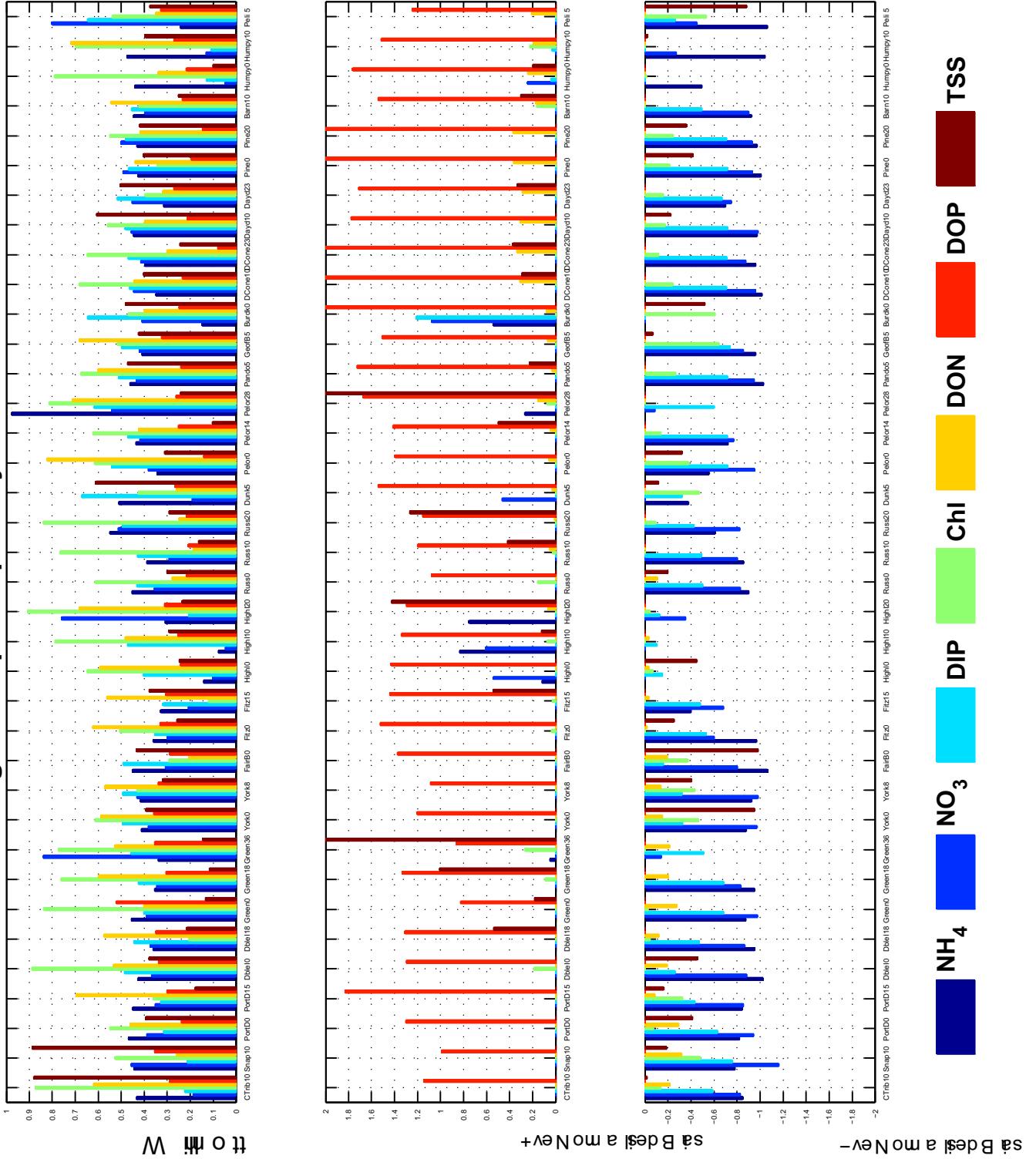


Figure 11: Statistical plots for the normalised metrics shown in the figures for the AIMS water quality monitoring sites. Numbers at end of site name indicate depth

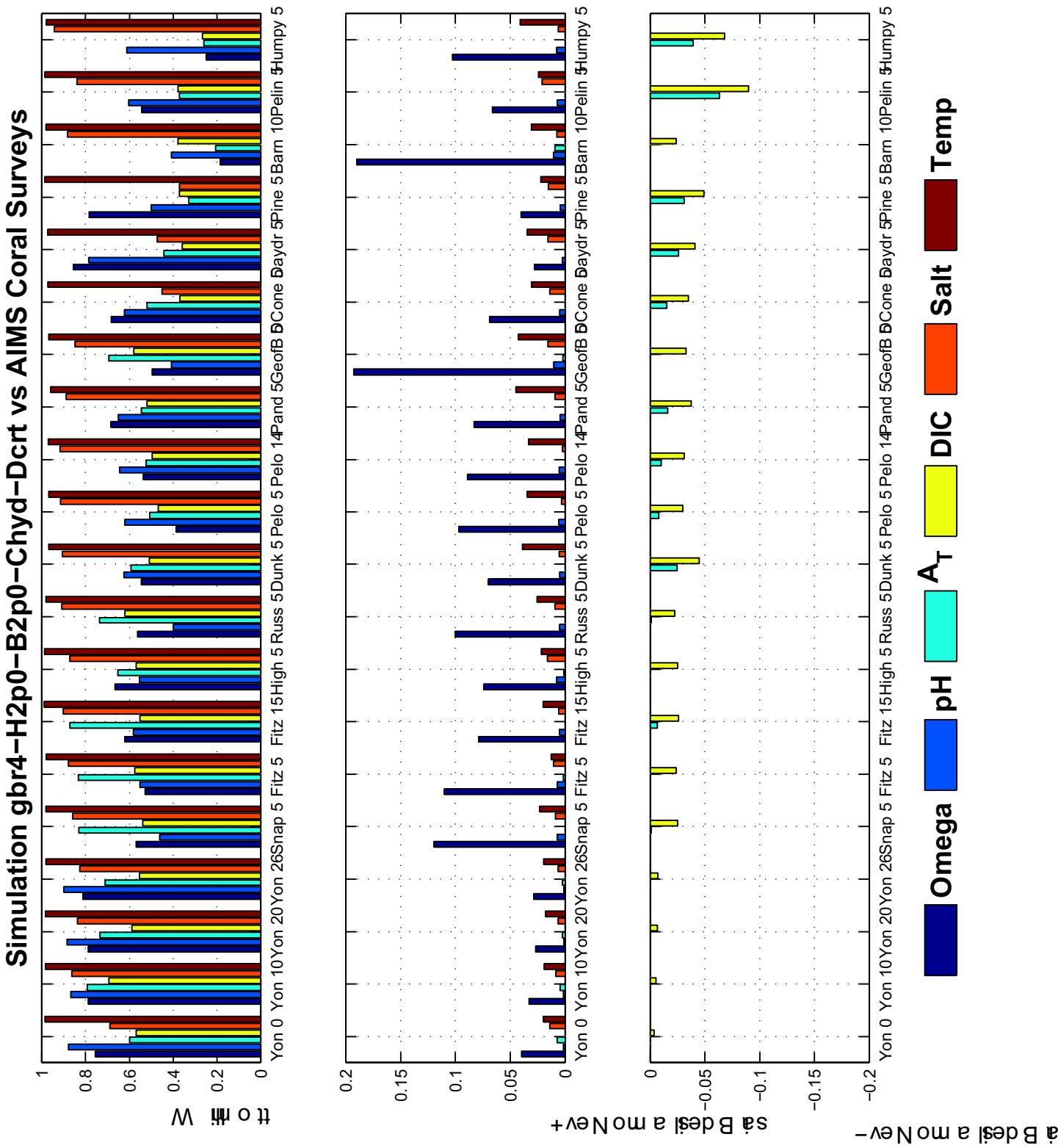


Figure 12: Statistical plots for the normalised metrics shown in the figures for the Coral Chemistry sites. Numbers at end of site name indicate depth

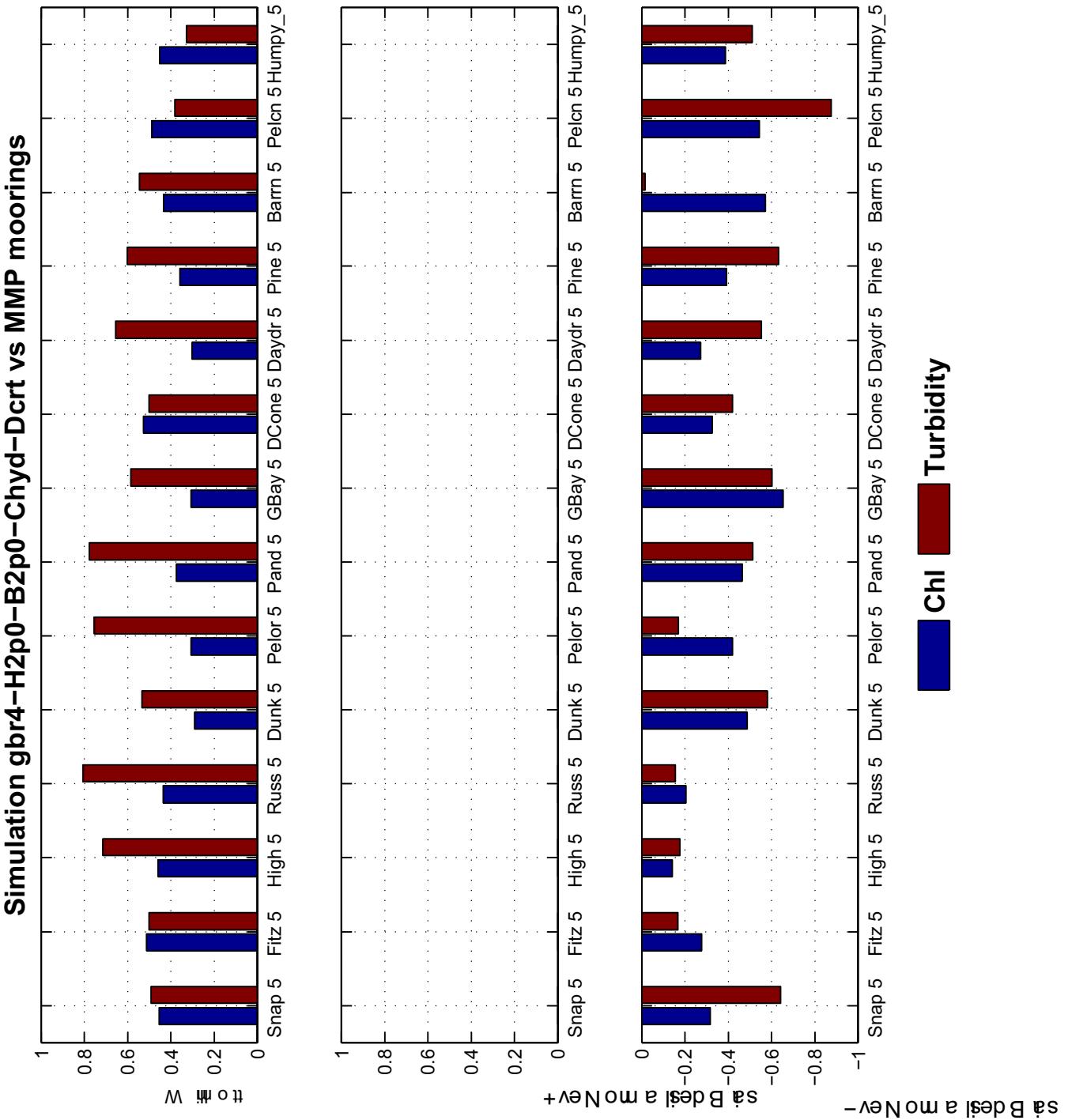


Figure 13: Statistical plots for the normalised metrics shown in the figures for the Marine Monitoring Program (MMP) sites for Chlorophyll a from model simulation with fluorescence from Mooring and simulated turbidity from model with turbidity from mooring. Numbers at end of site name indicate depth

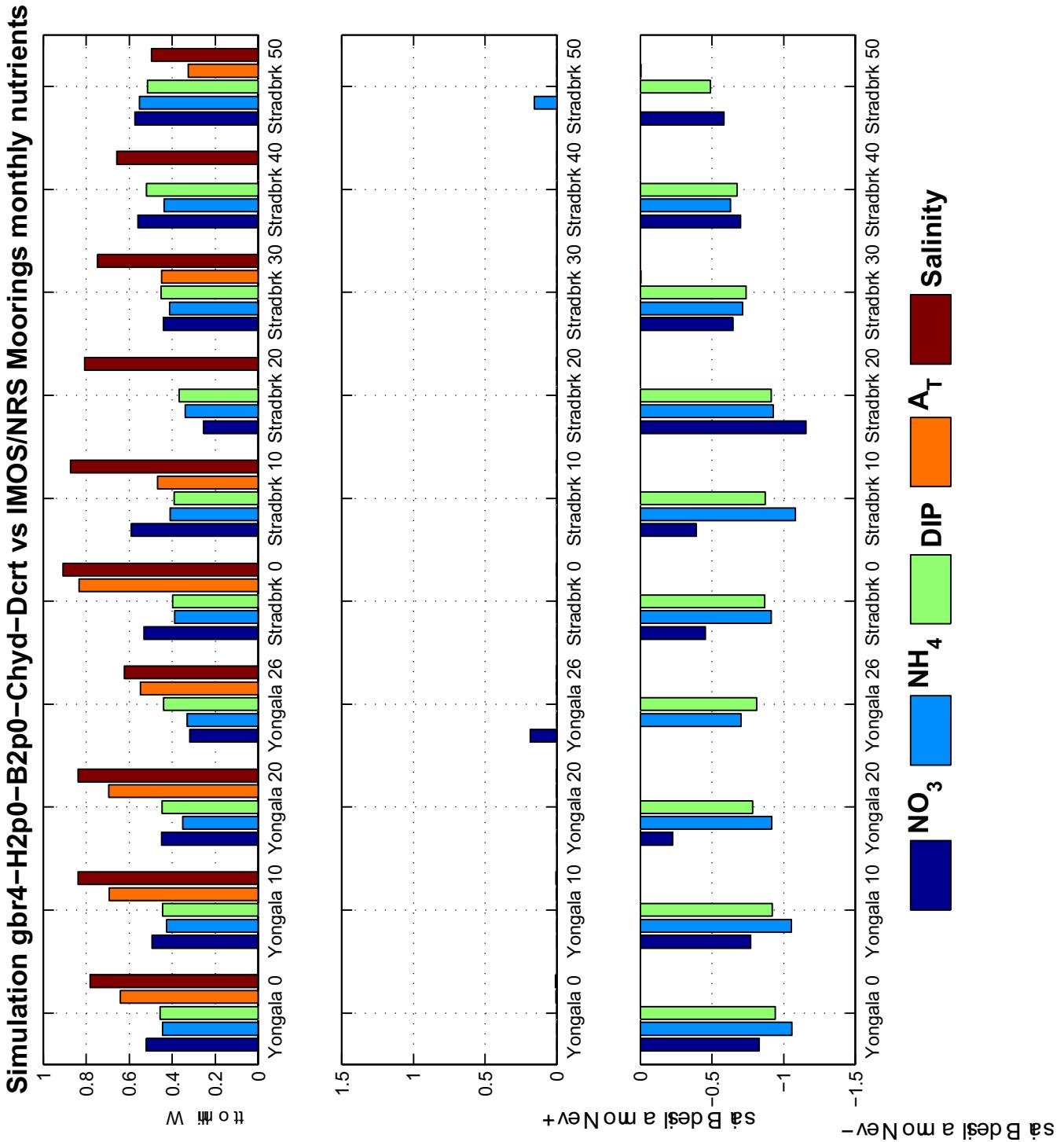


Figure 14: Statistical plots for the normalised metrics shown in the figures for the NRS moorings for chlorophyll and nutrients. Numbers at end of site name indicate depth

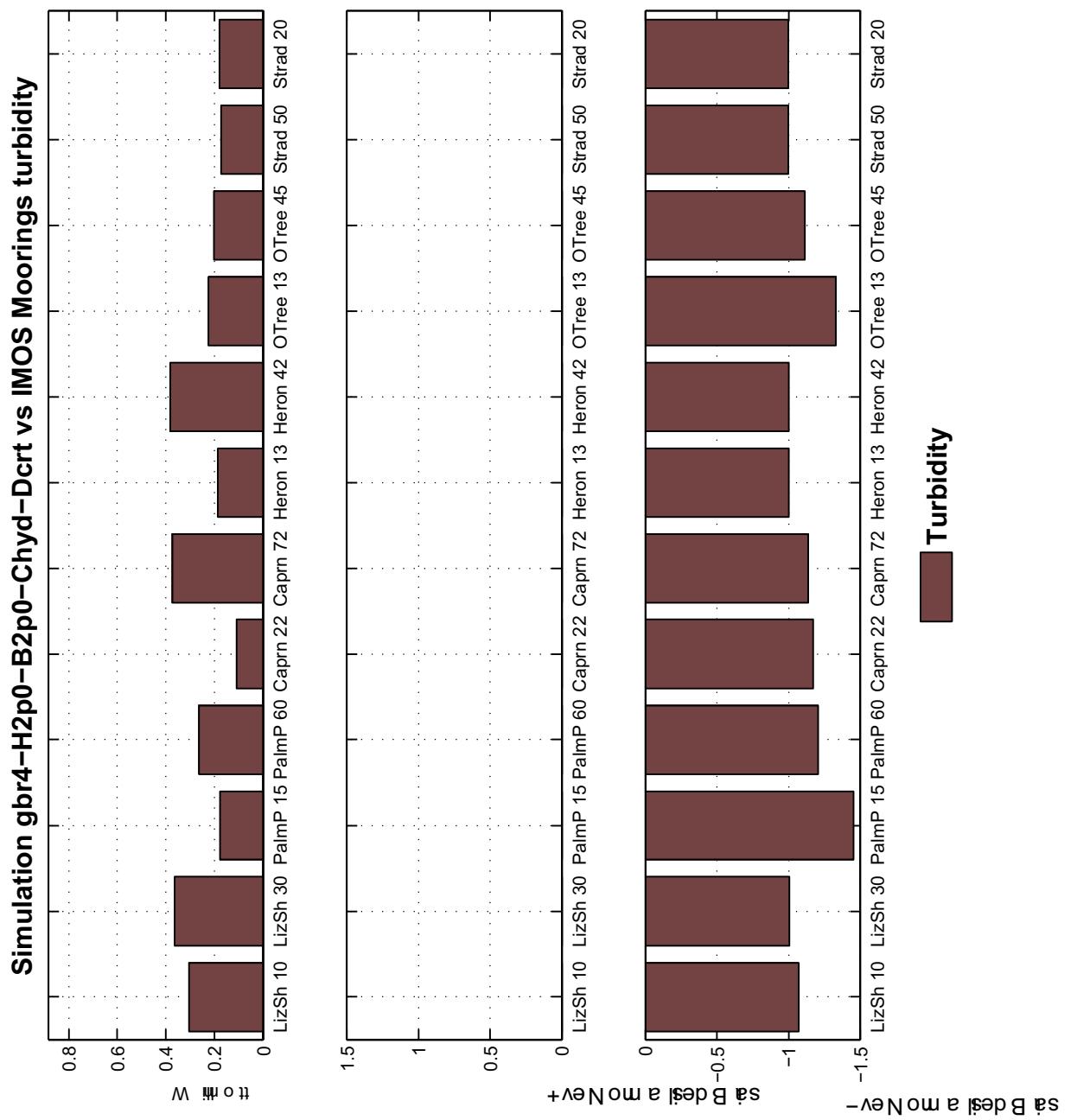


Figure 15: Statistical plots for the normalised metrics shown in the figures for the IMOS moorings turbidity. Numbers at end of site name indicate depth

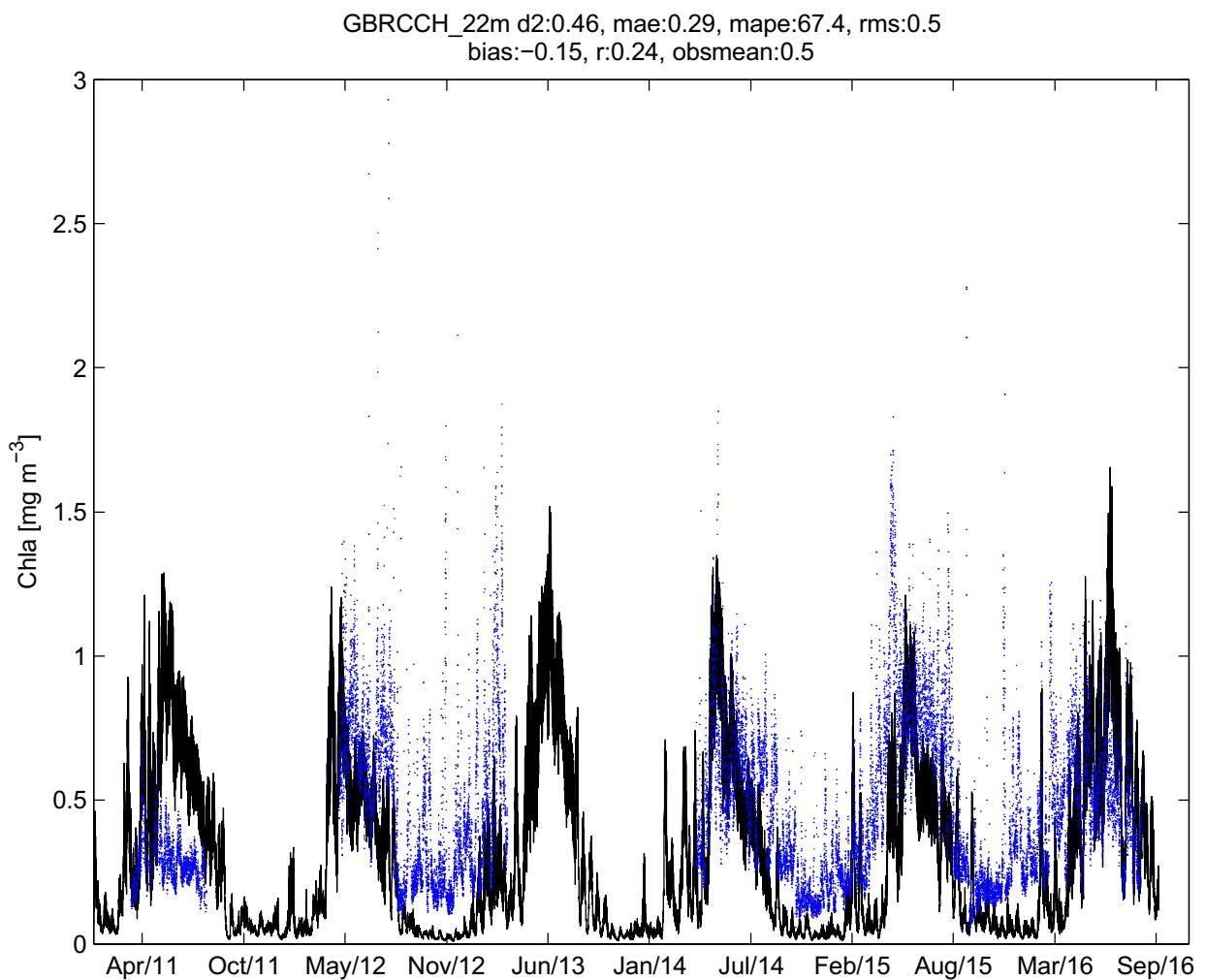


Figure 16: Capricorn Channel (GBRCCH) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 22 m. Model grid deepest point at this site 91.17 m. Observation deepest point at this site 92 m.

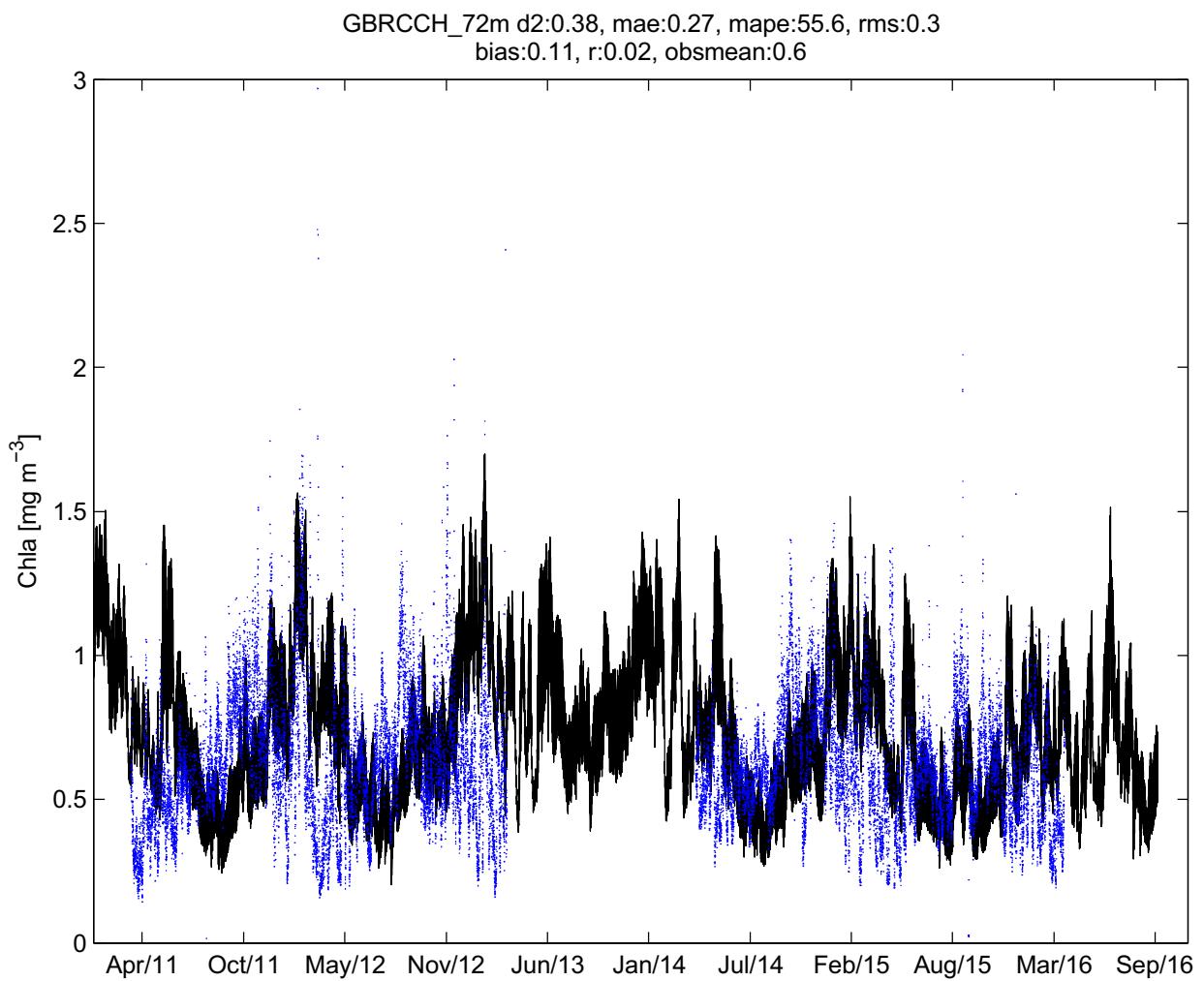


Figure 17: Capricorn Channel (GBRCCH) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 72 m. Model grid deepest point at this site 91.17 m. Observation deepest point at this site 92 m.

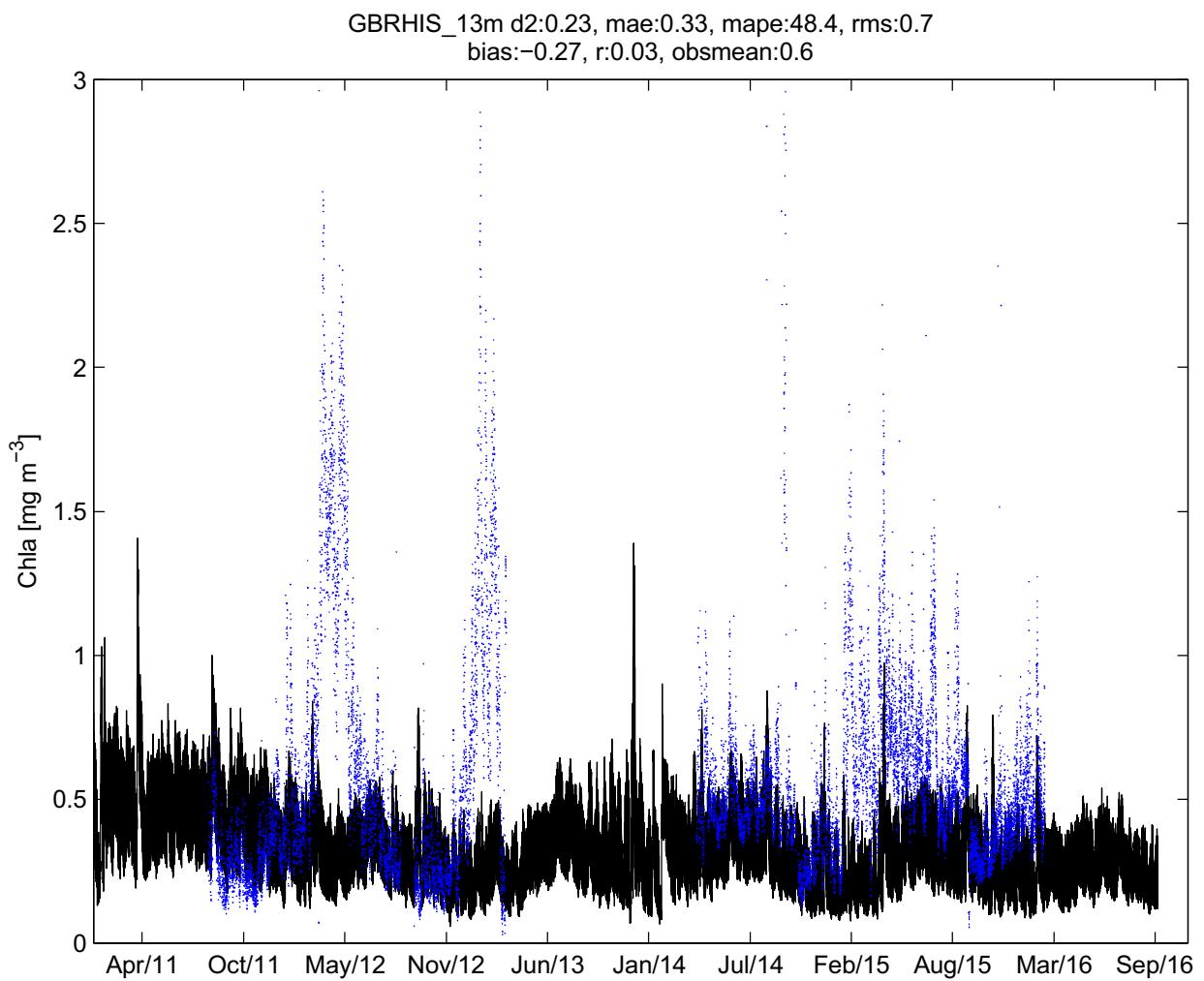


Figure 18: Heron Island South (GBRHIS) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 13 m. Model grid deepest point at this site -47.01 m. Observation deepest point at this site 46 m.

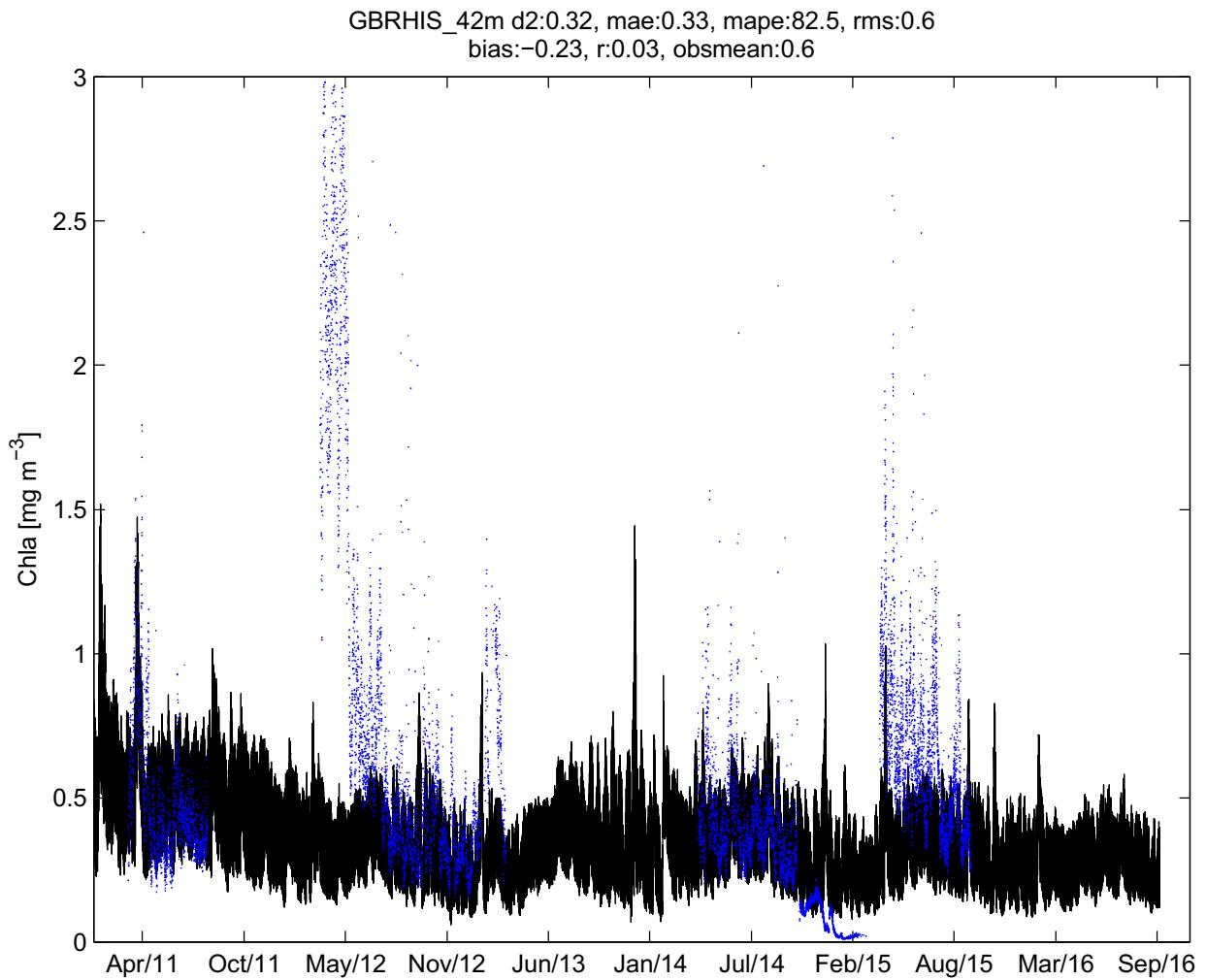


Figure 19: Heron Island South (GBRHIS) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 42 m. Model grid deepest point at this site -47.01 m. Observation deepest point at this site 46 m.

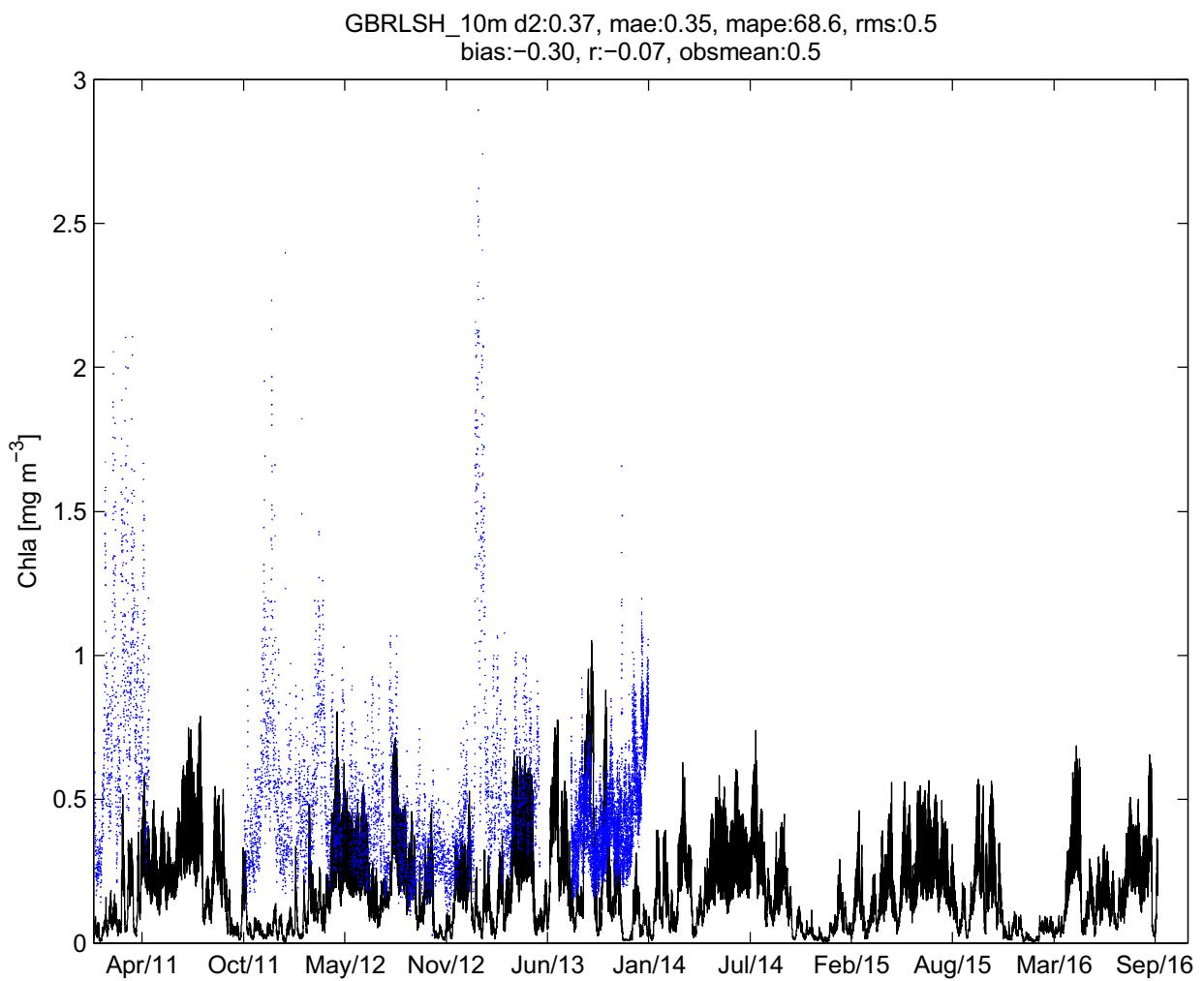


Figure 20: Lizard Shelf (GBRLSH) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Chlorophyll fluorescence . Field observation depth taken: 10 m. Model grid deepest point at this site -30.32 m. Observation deepest point at this site 31 m.

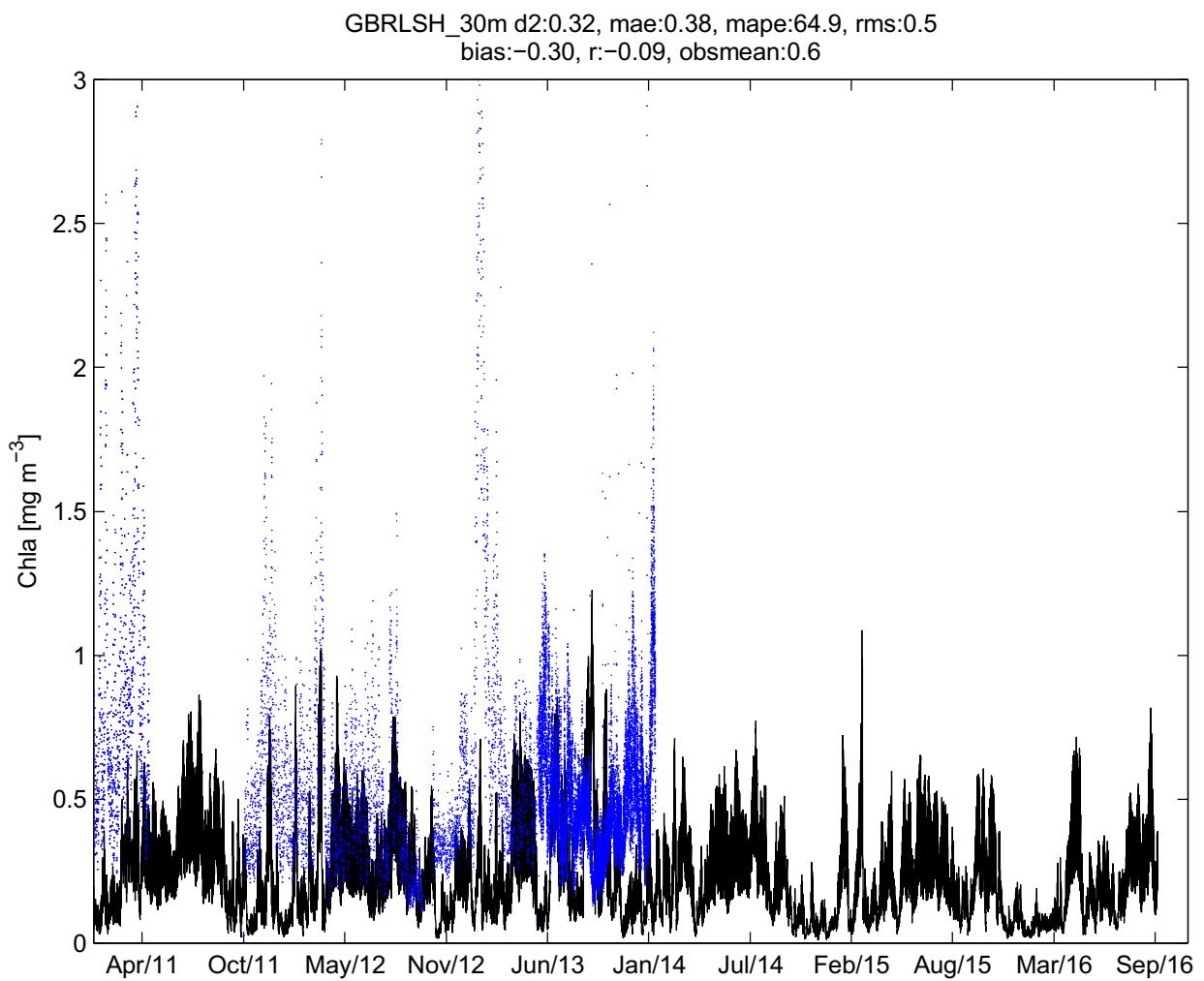


Figure 21: Lizard Shelf (GBRLSH) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 30 m. Model grid deepest point at this site -30.32 m. Observation deepest point at this site 31 m.

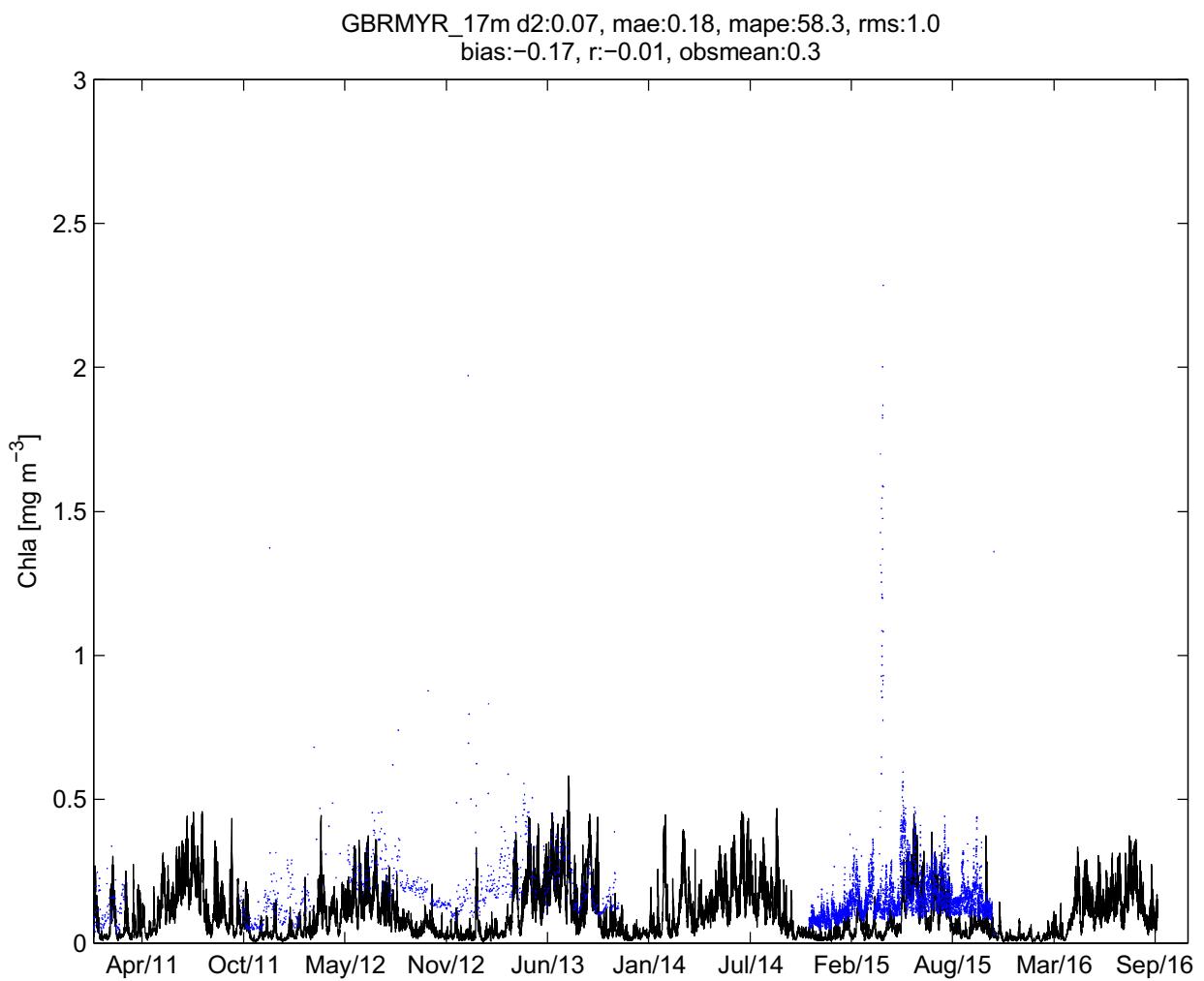


Figure 22: Myrmidon (GBRMYR) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 17 m. Model grid deepest point at this site -220 m. Observation deepest point at this site 203 m.

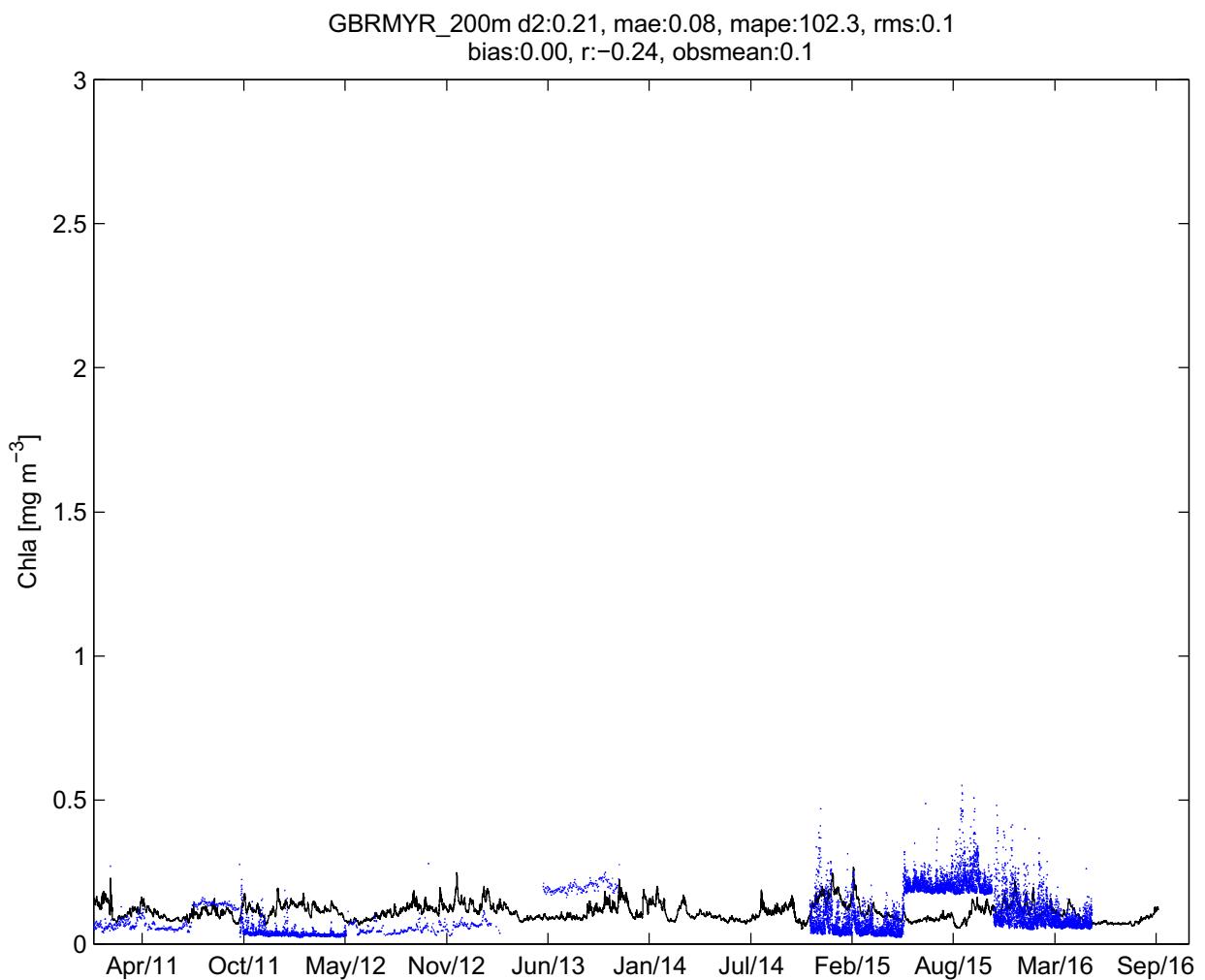


Figure 23: Myrmidon (GBRMYR) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 200 m. Model grid deepest point at this site -220 m. Observation deepest point at this site 203 m.

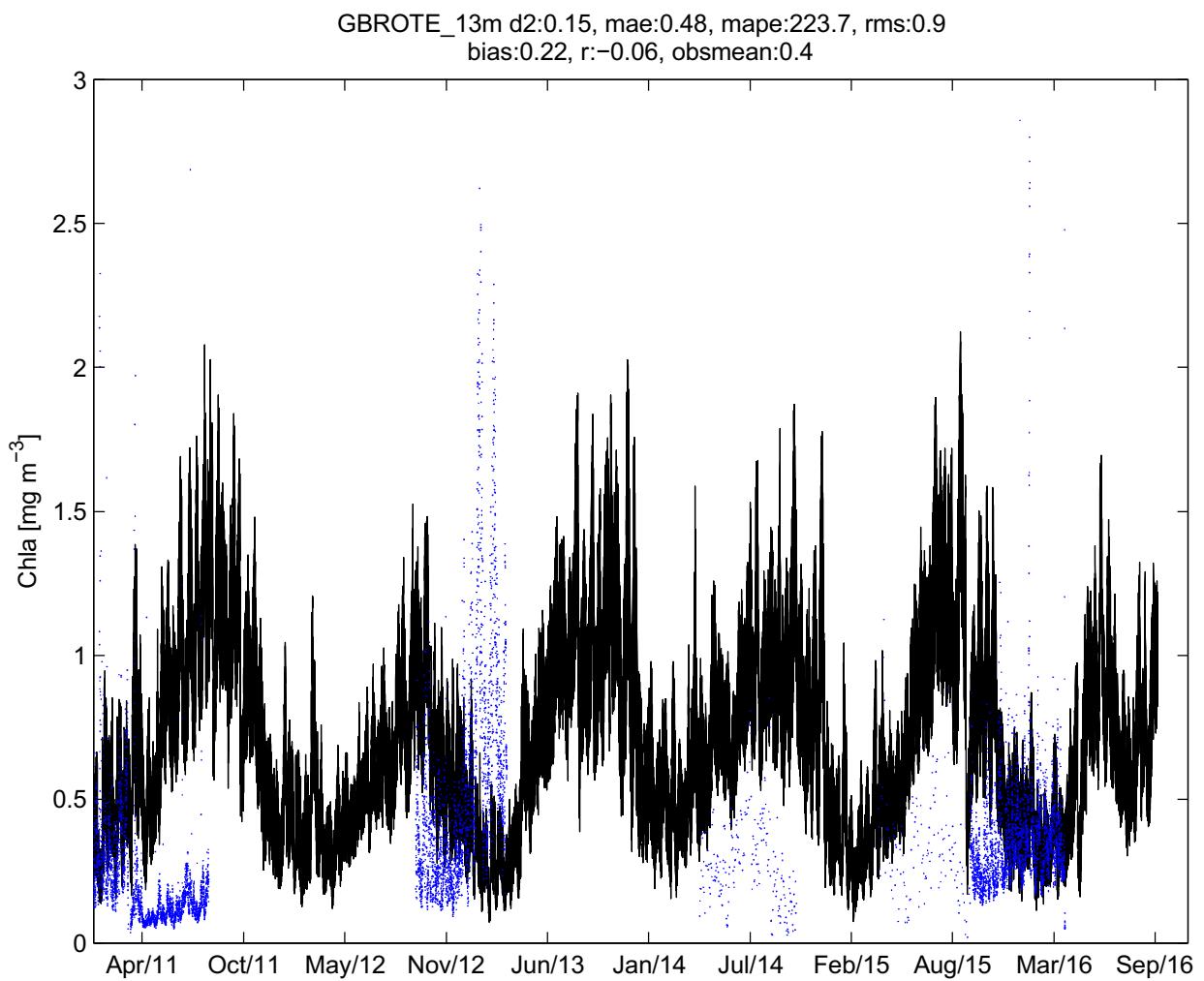


Figure 24: One Tree (GBROTE) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 13 m. Model grid deepest point at this site -62.61 m. Observation deepest point at this site 58 m.

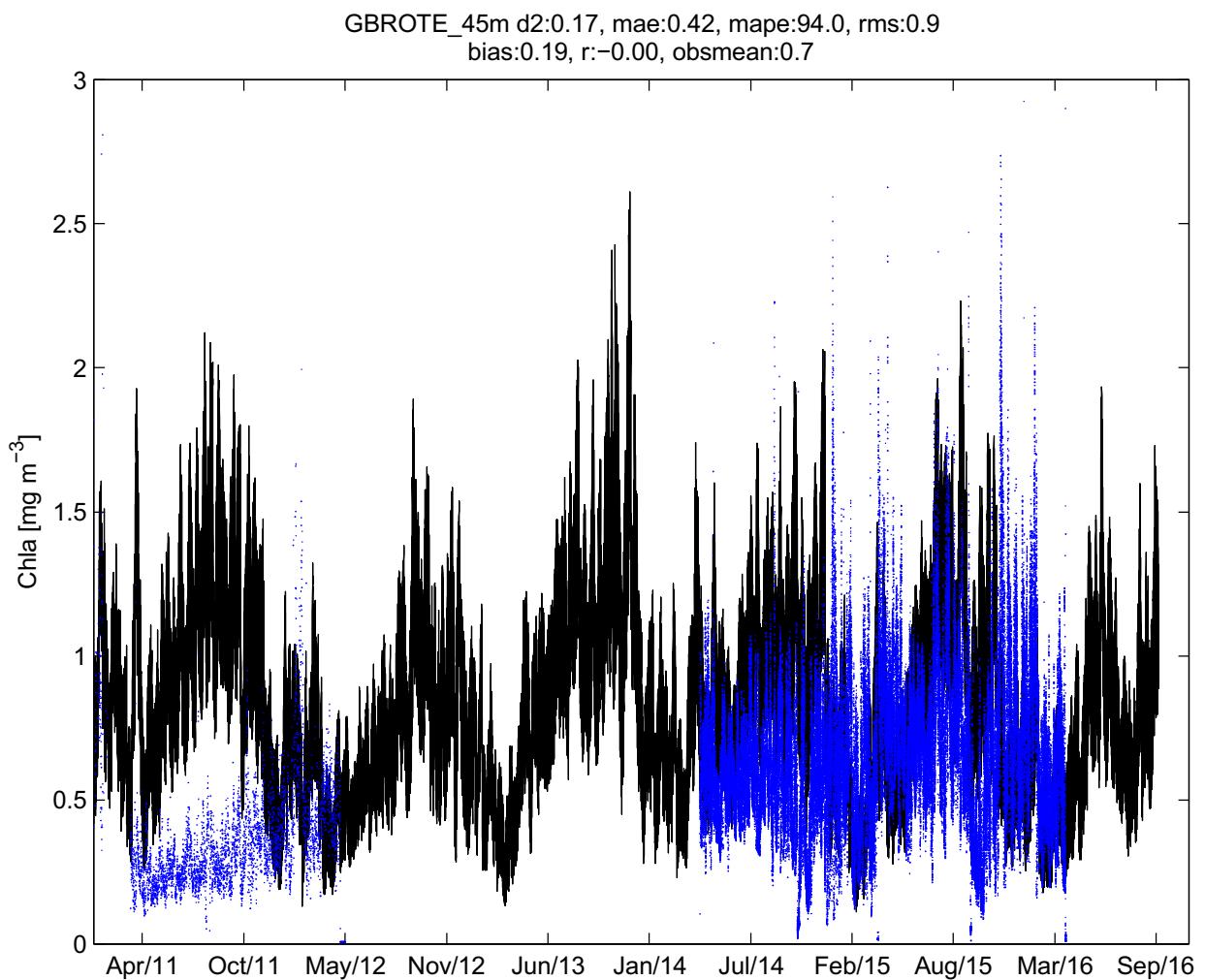


Figure 25: One Tree (GBROTE) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 45 m. Model grid deepest point at this site -62.61 m. Observation deepest point at this site 58 m.

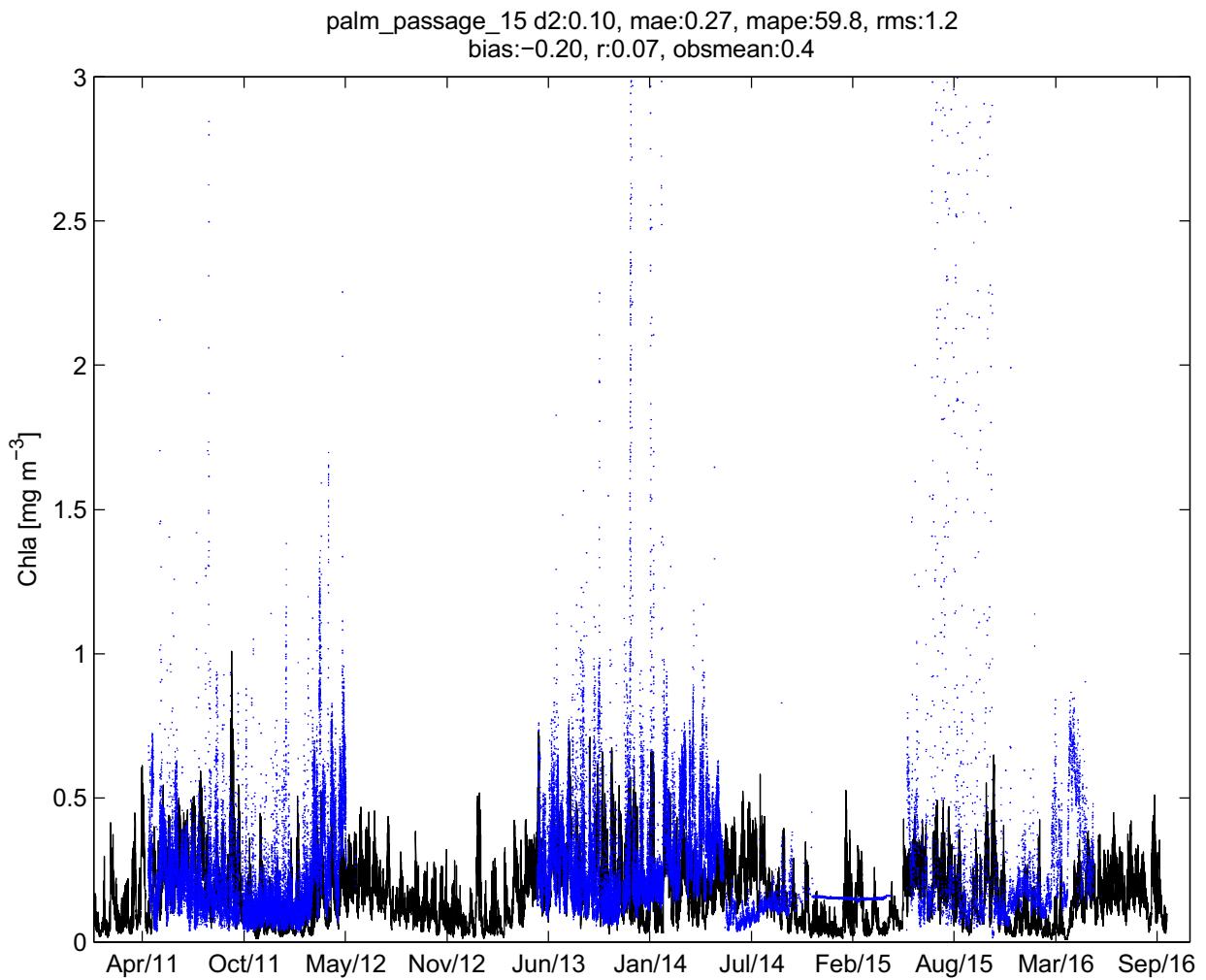


Figure 26: Palm Passage(GBRPPS) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 15 m. Model grid deepest point at this site 71.9 m. Observation deepest point at this site 70 m.

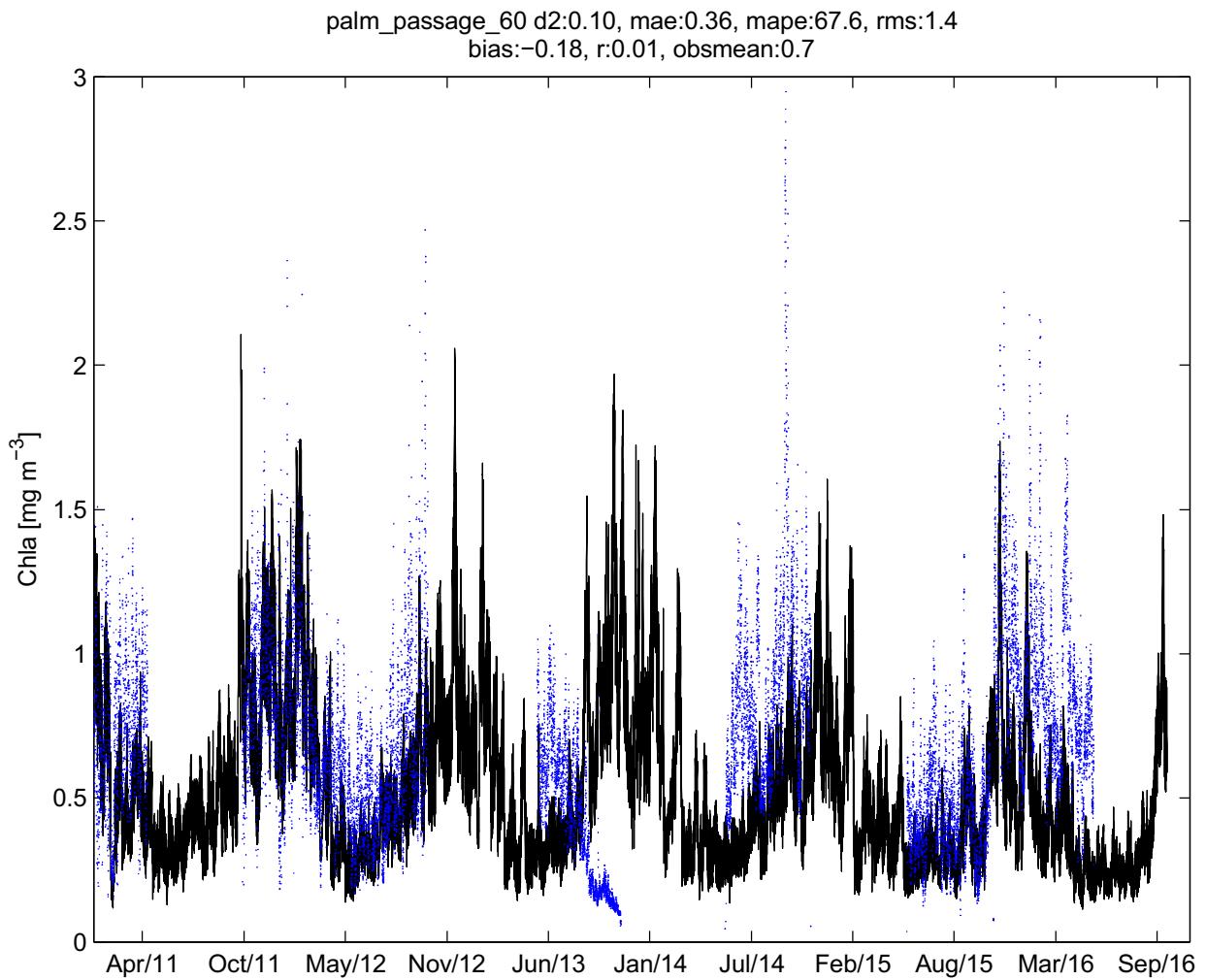


Figure 27: Palm Passage(GBRPPS) Chl IMOS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 60 m. Model grid deepest point at this site 71.9 m. Observation deepest point at this site 70 m.

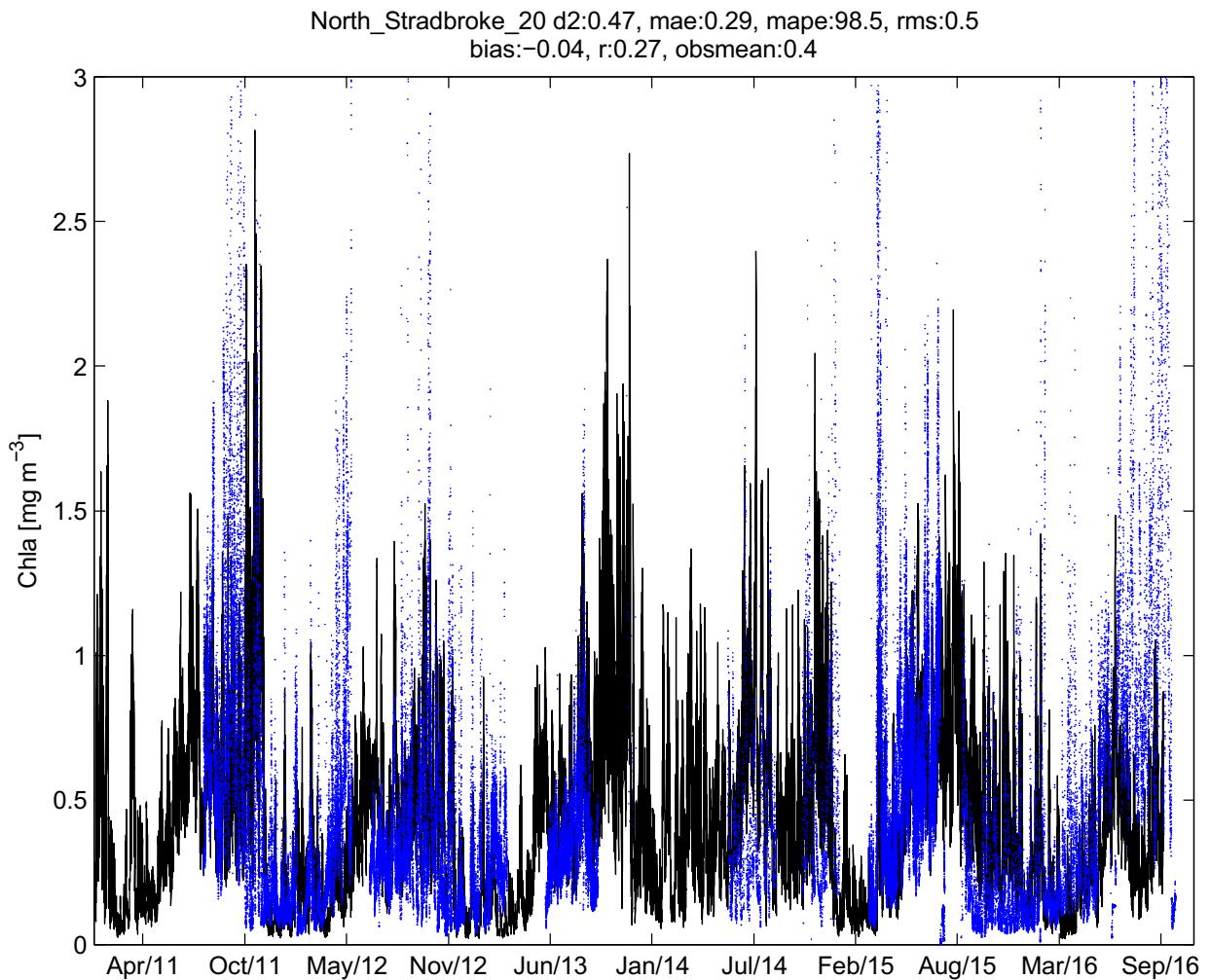


Figure 28: North Stradbroke (GBRNSI) Chl IMOS/NRS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 20 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

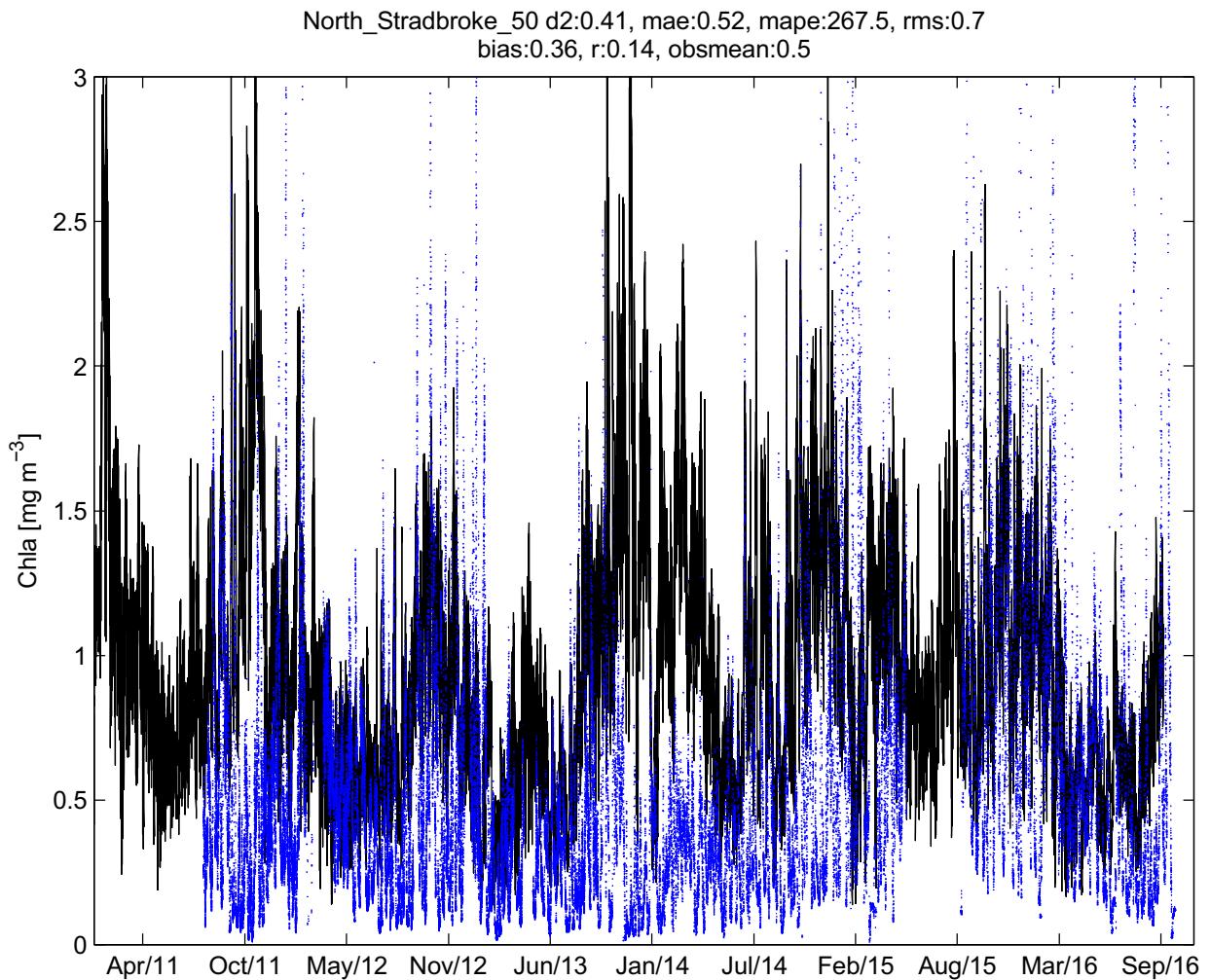


Figure 29: North Stradbroke (GBRNSI) Chl IMOS/NRS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 50 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

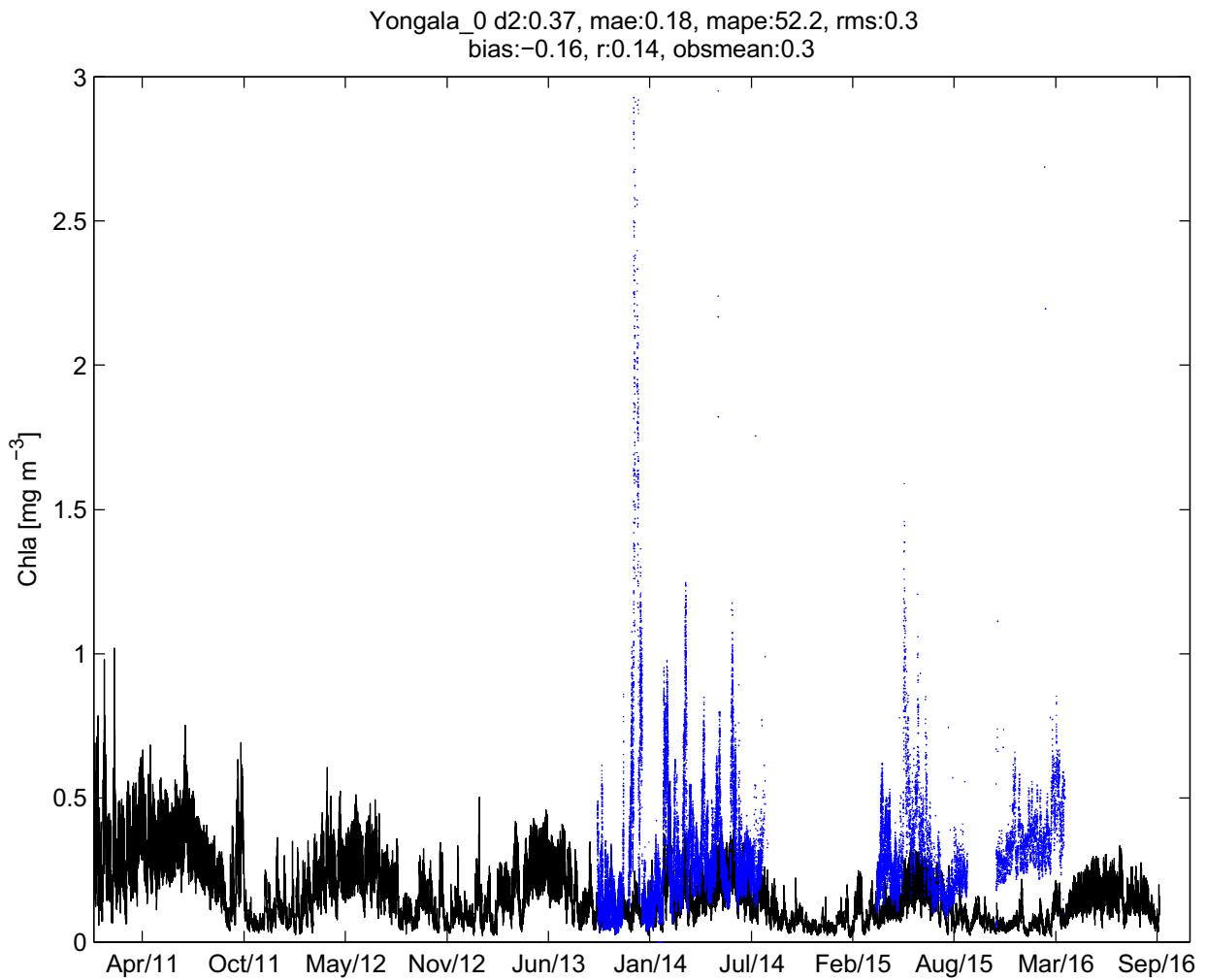


Figure 30: Yongala (NRSYON) Chl IMOS/NRS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 0 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

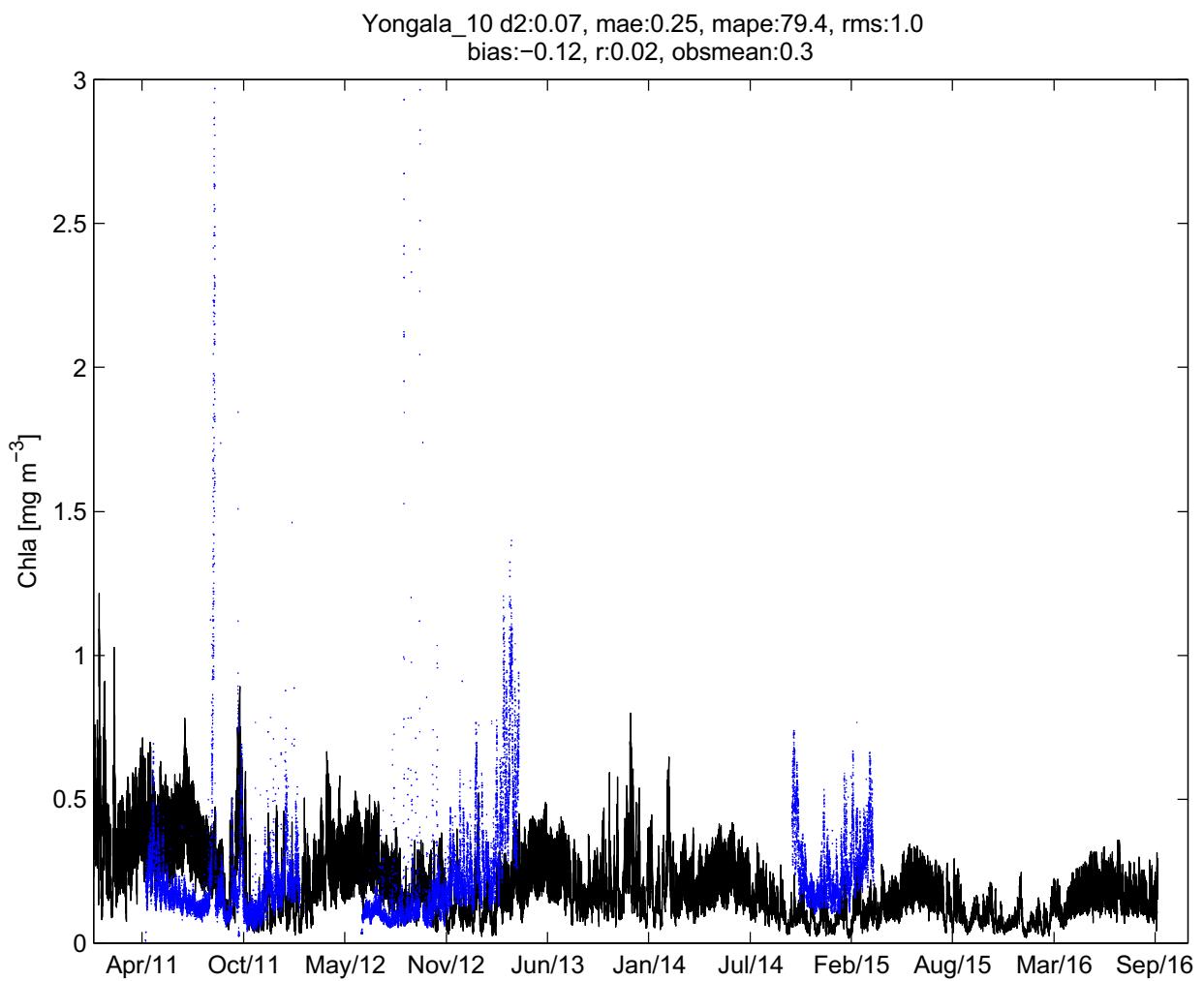


Figure 31: Yongala (NRSYON) Chl IMOS/NRS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 10 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

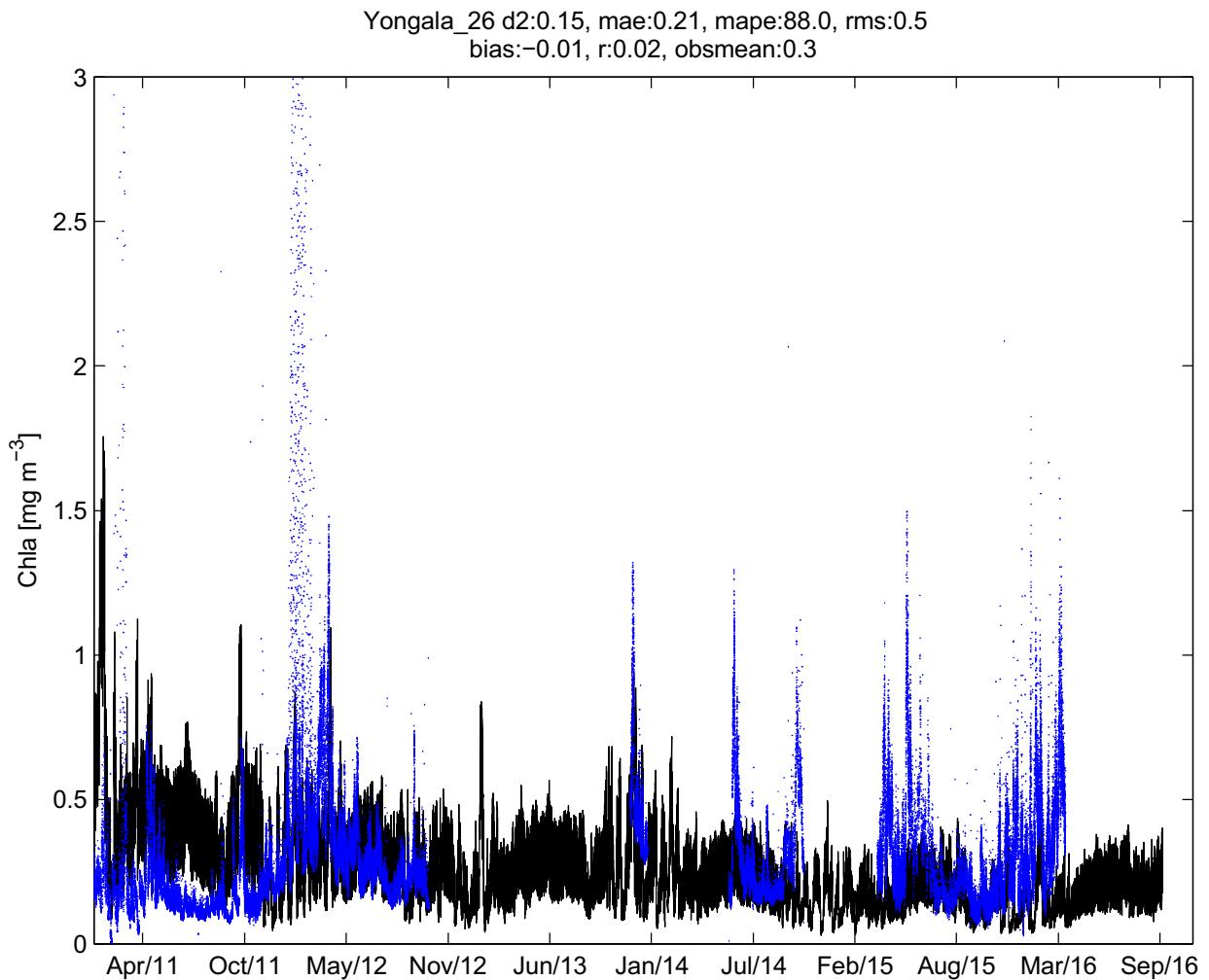


Figure 32: Yongala (NRSYON) Chl IMOS/NRS Mooring observations against GBR4 model: Observation (blue), model (black): Parameter/s = Chlorophyll fluorescence . Field observation depth taken: 26 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

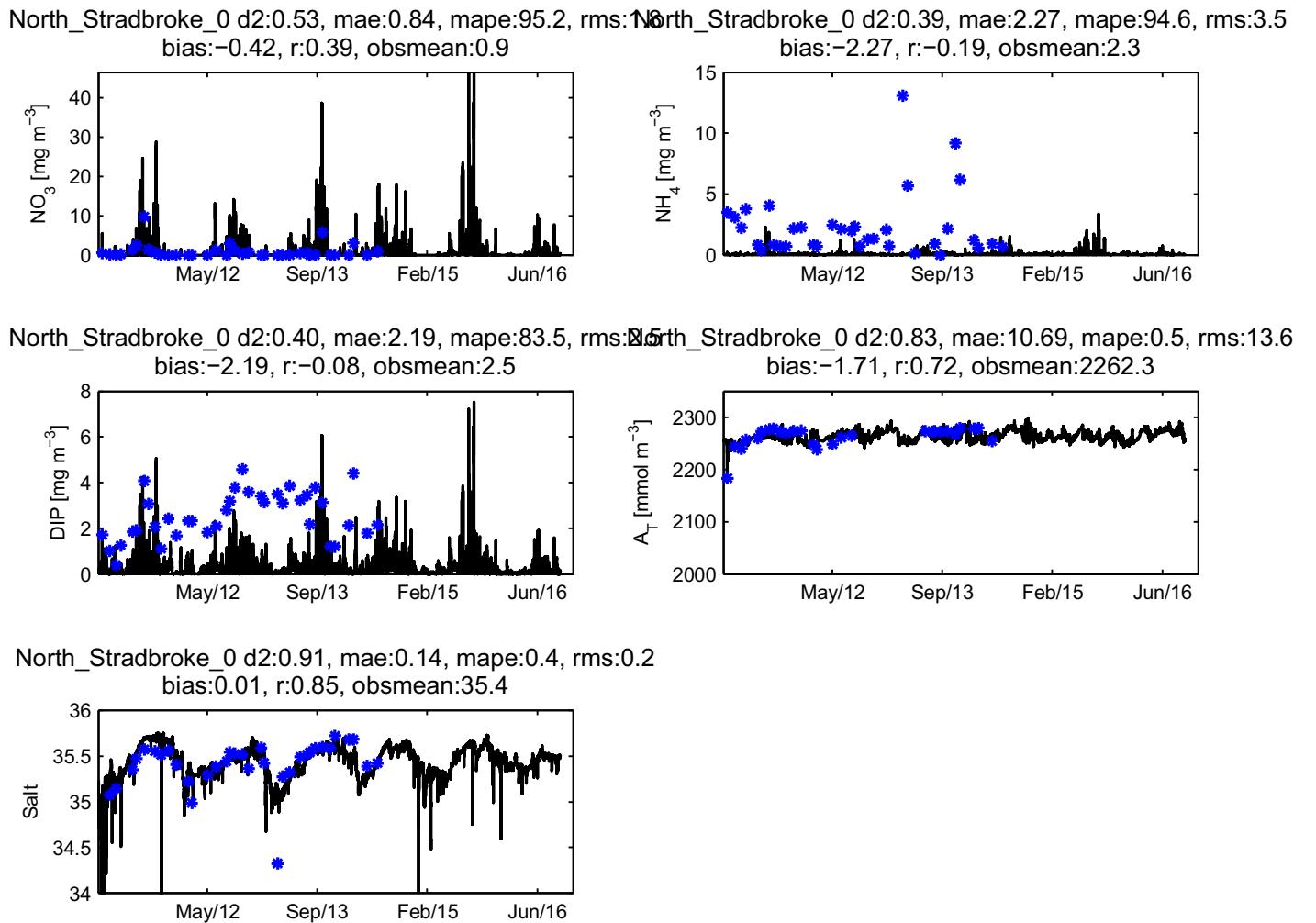


Figure 33: North Stradbroke (GBRNSI) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = (NO_3 , NH_4 , DIP , A_T). Field observation depth taken: 0 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

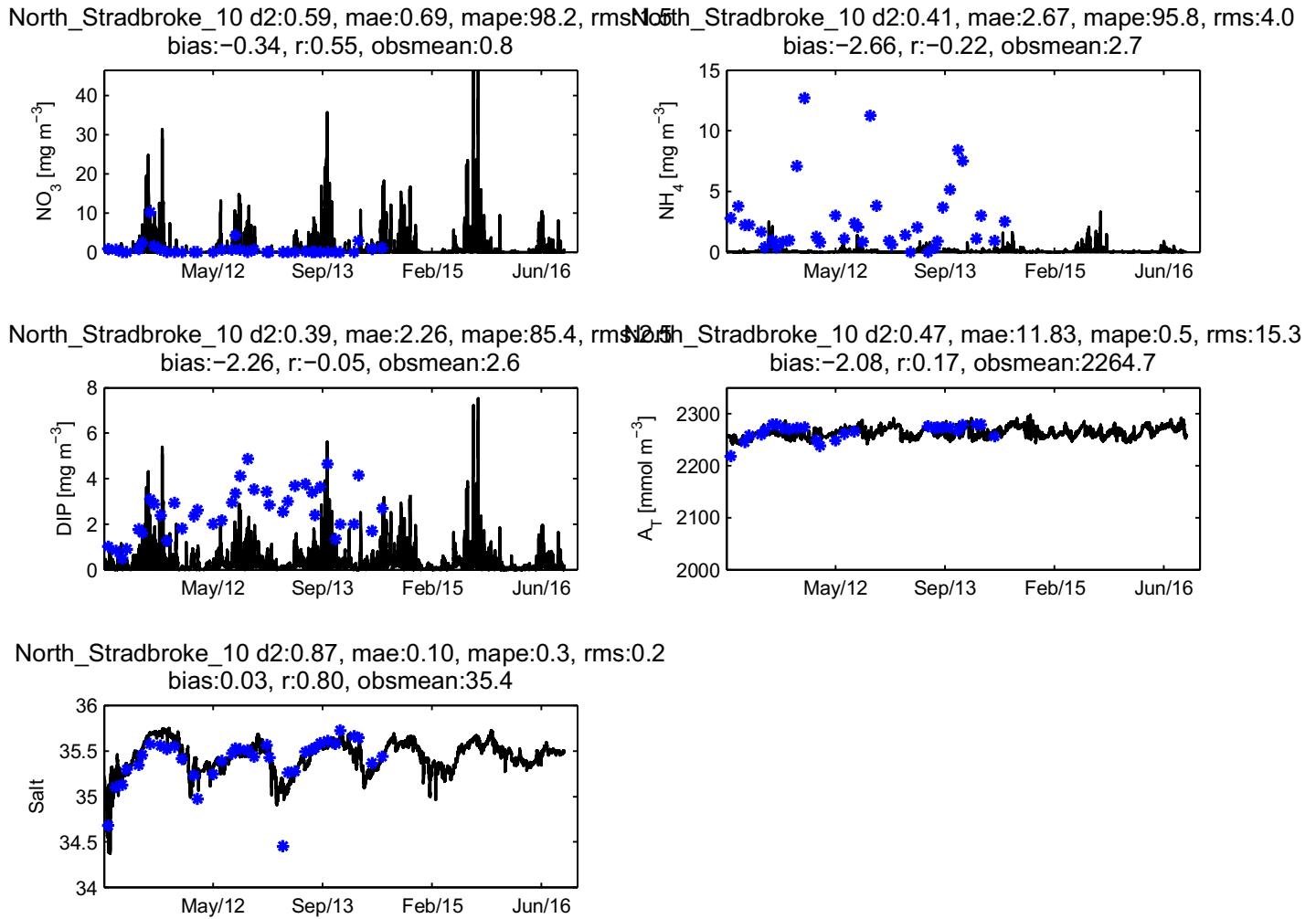


Figure 34: North Stradbroke (GBRNSI) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = NO_3 , NH_4 , DIP, A_T . Field observation depth taken: 10 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

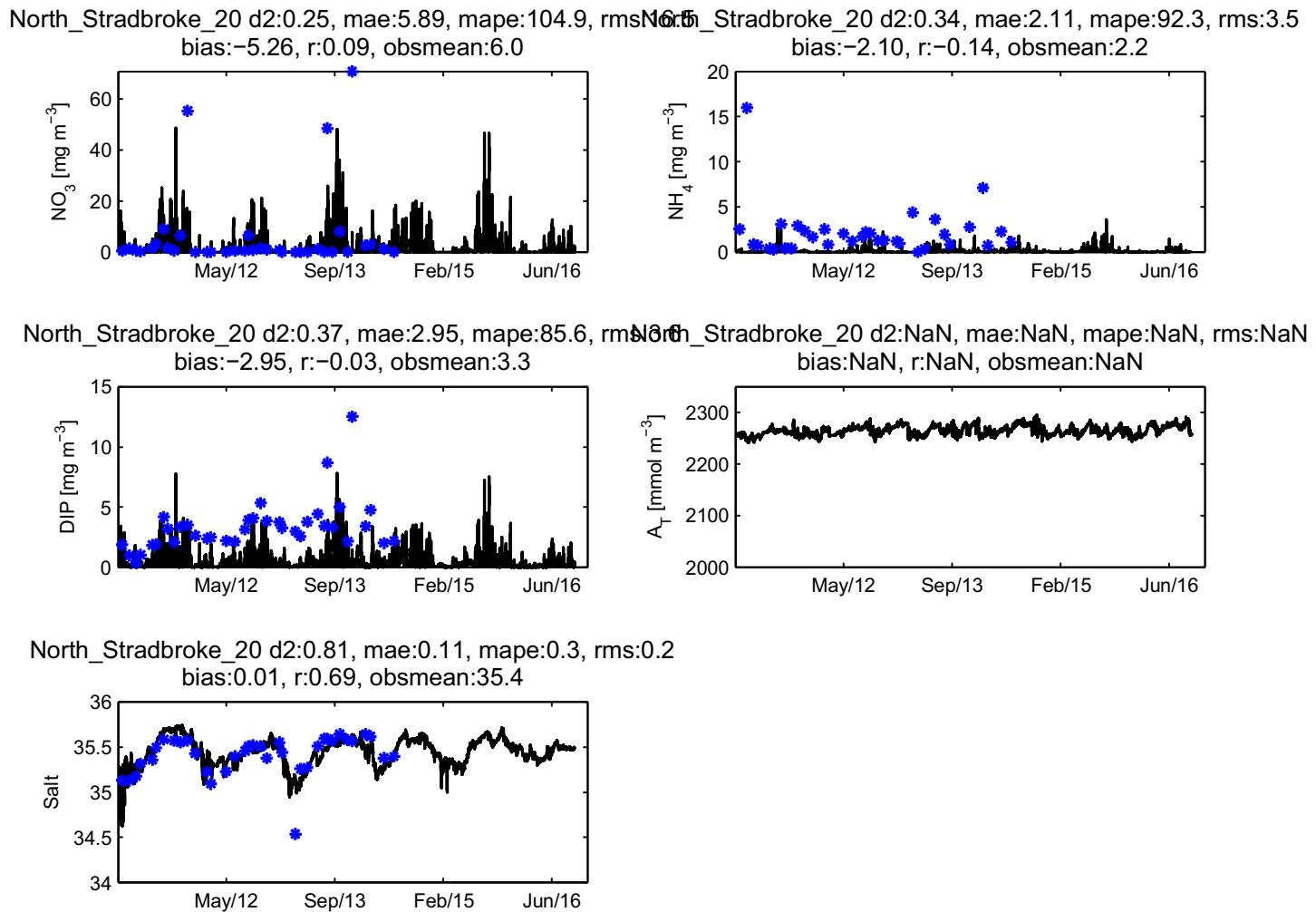


Figure 35: North Stradbroke (GBRNSI) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = NO_3 , NH_4 , DIP , A_T . Field observation depth taken: 20 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

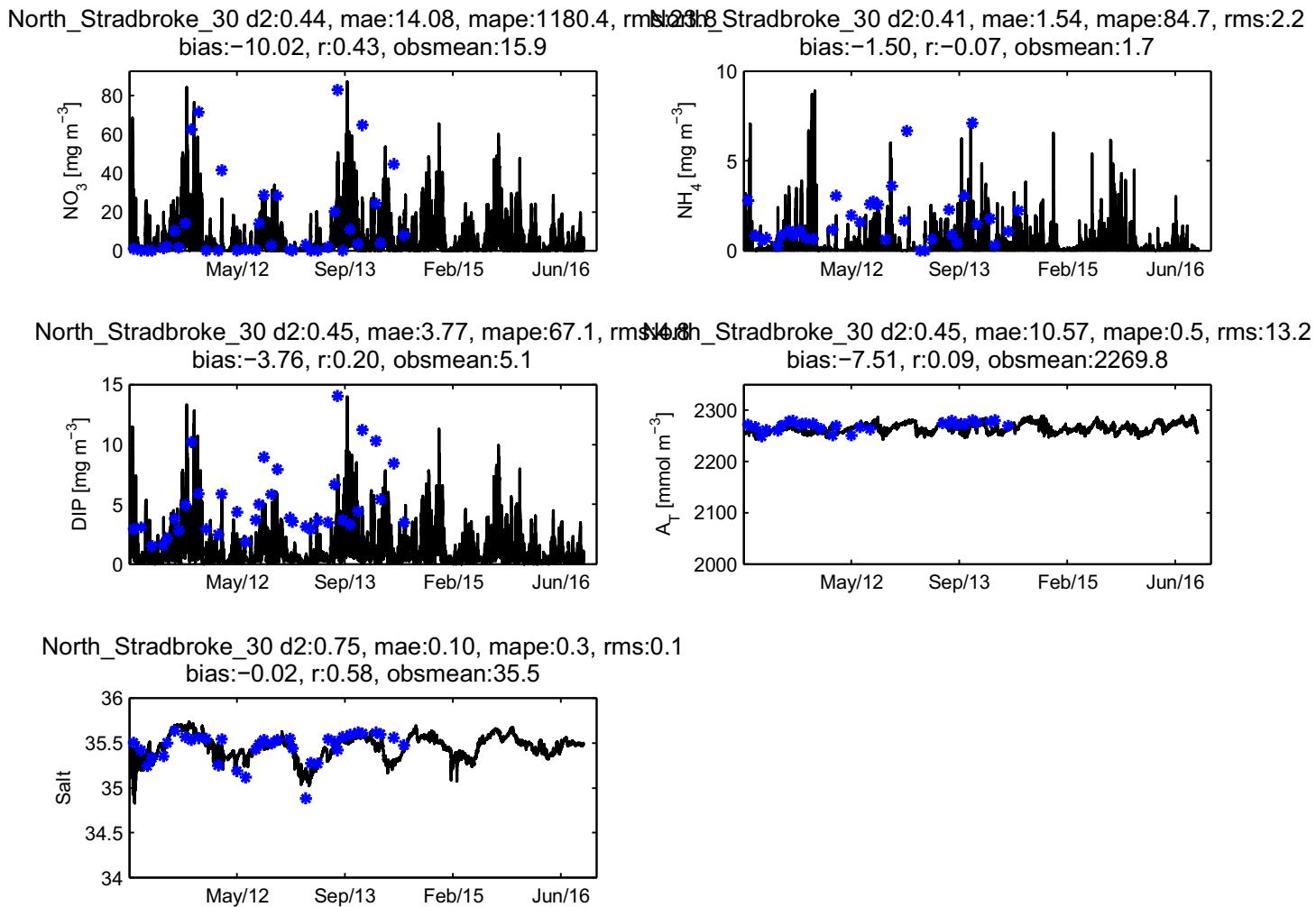


Figure 36: North Stradbroke (GBRNSI) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = NO_3 , NH_4 , DIP, A_T . Field observation depth taken: 30 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

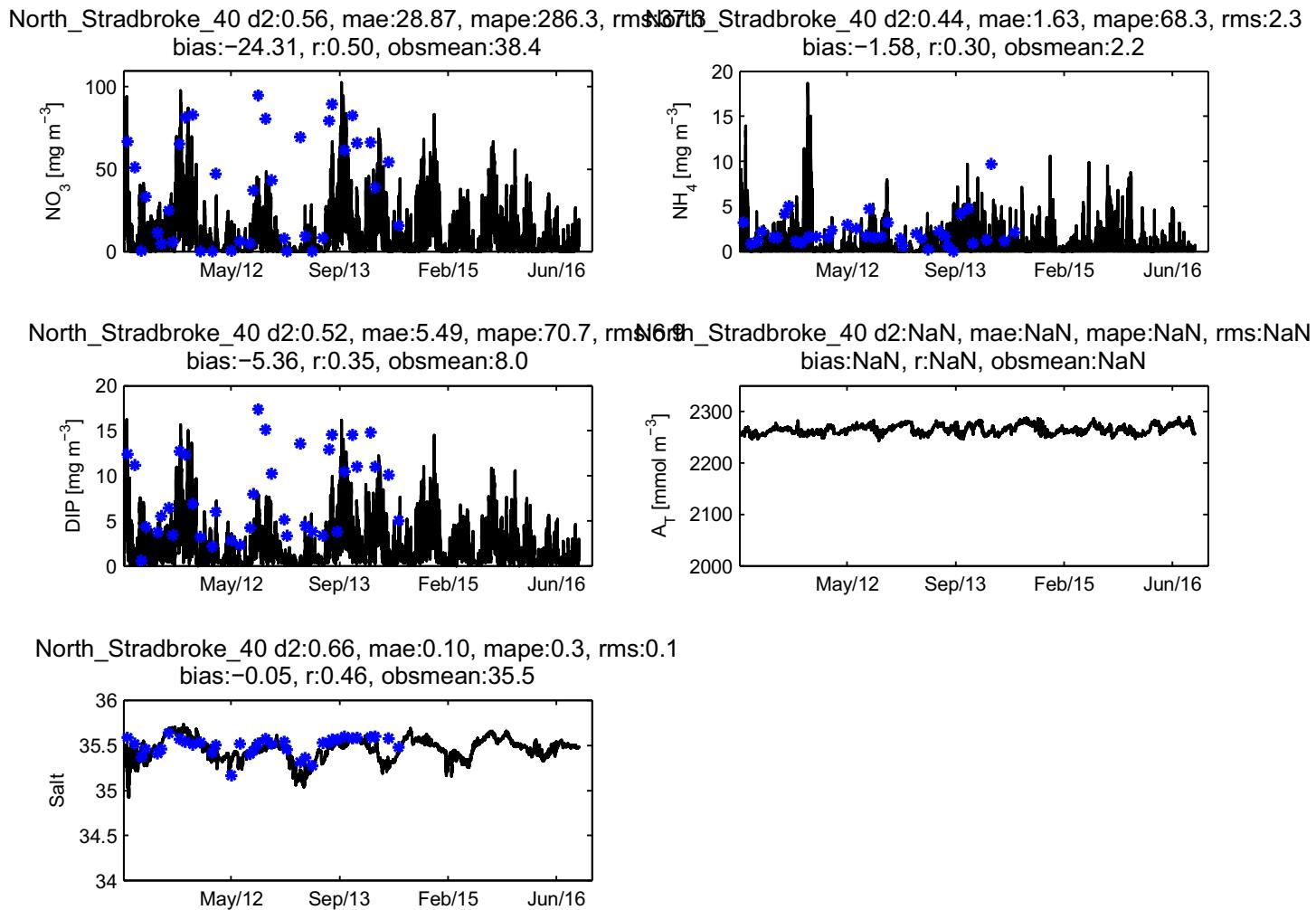


Figure 37: North Stradbroke (GBRNSI) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = NO_3 , NH_4 , DIP, A_T . Field observation depth taken: 40 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

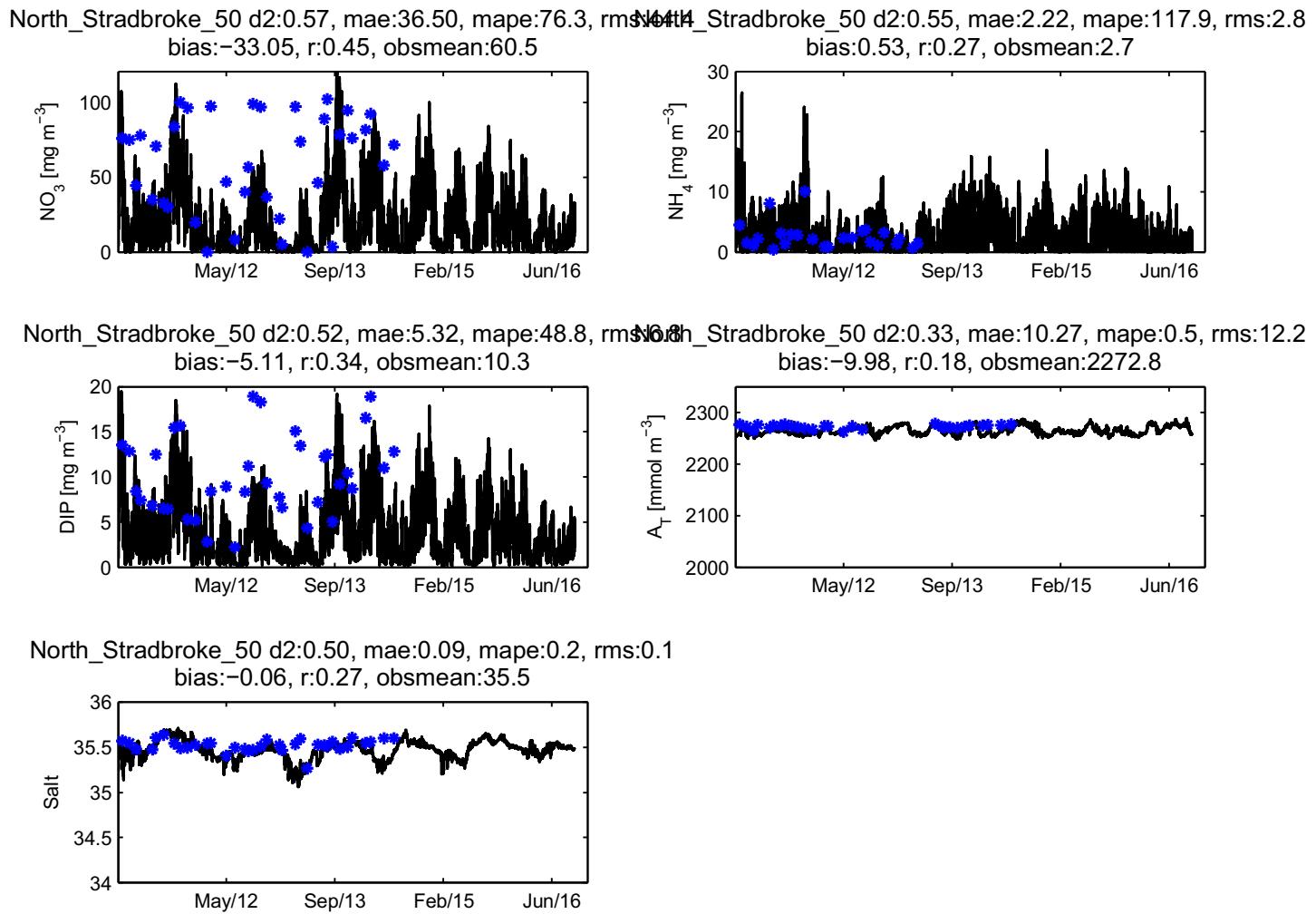


Figure 38: North Stradbroke (GBRNSI) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = NO₃, NH₄, DIP, A_T. Field observation depth taken: 50 m. Model grid deepest point at this site -66 m. Observation deepest point at this site 67 m.

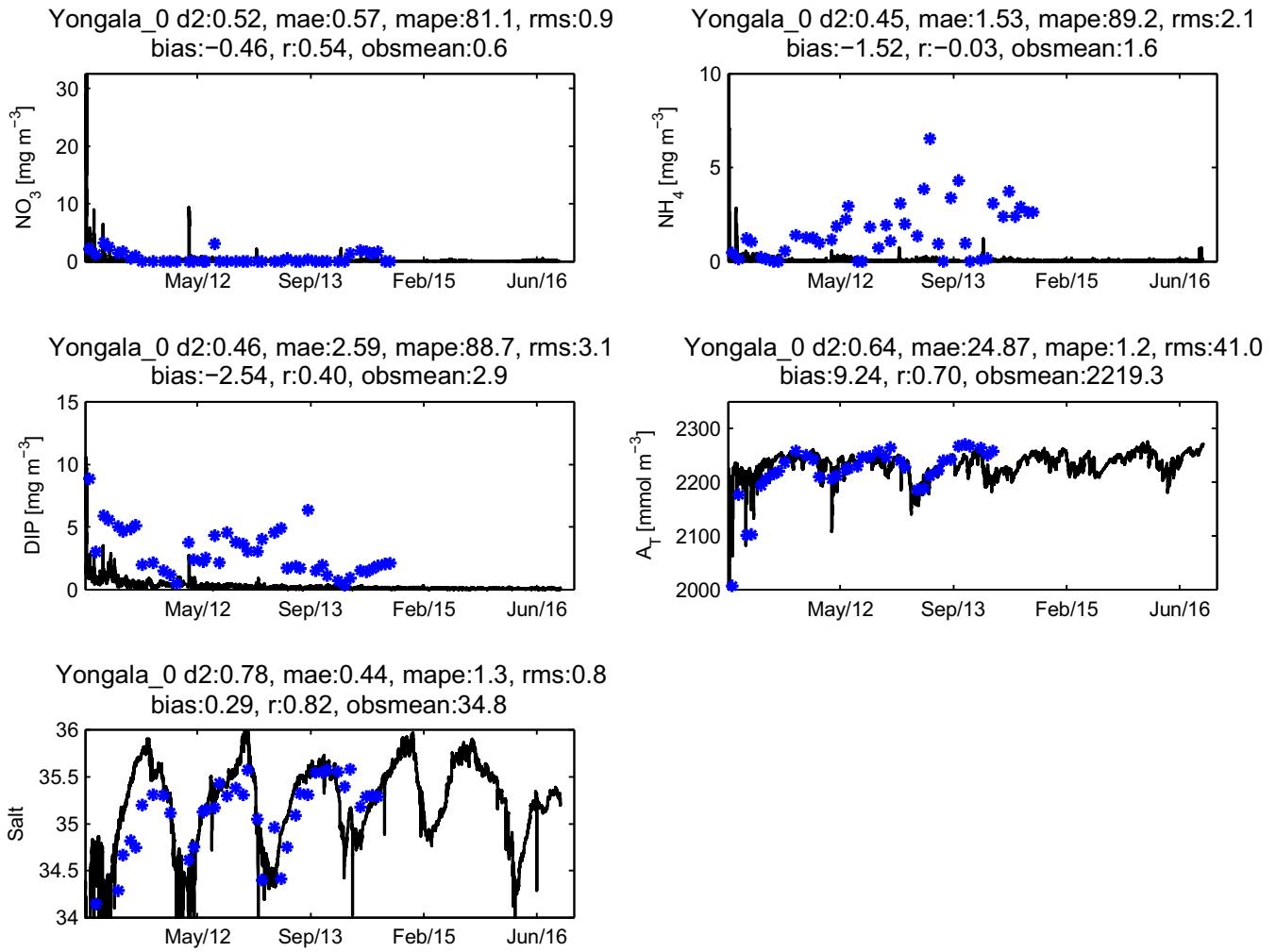


Figure 39: Yongala (NRSYON) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = (NO_3^- , NH_4^+ , DIP, A_T). Field observation depth taken: 0 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

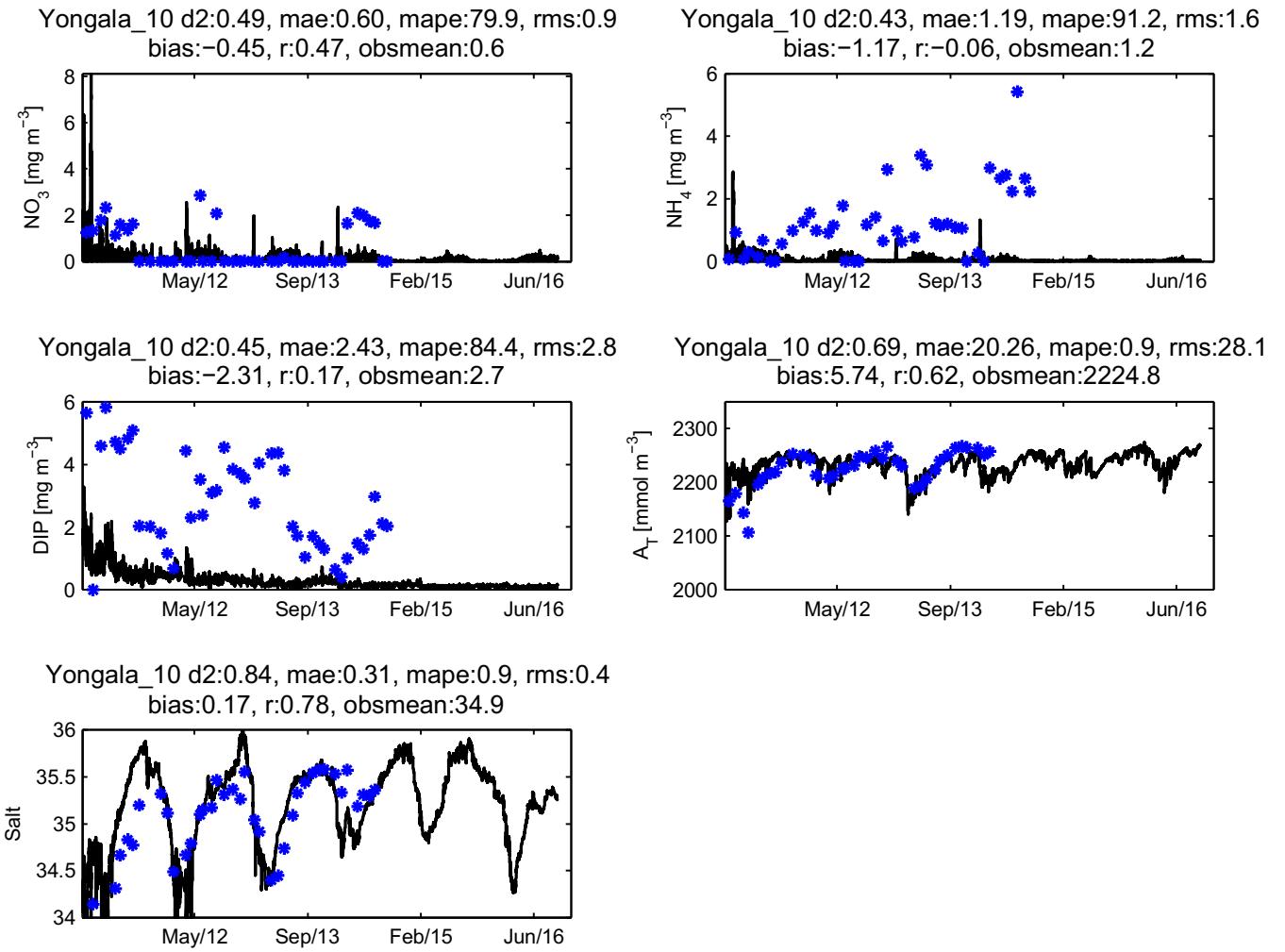


Figure 40: Yongala (NRSYON) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = (NO_3^- , NH_4^+ , DIP, A_T). Field observation depth taken: 10 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

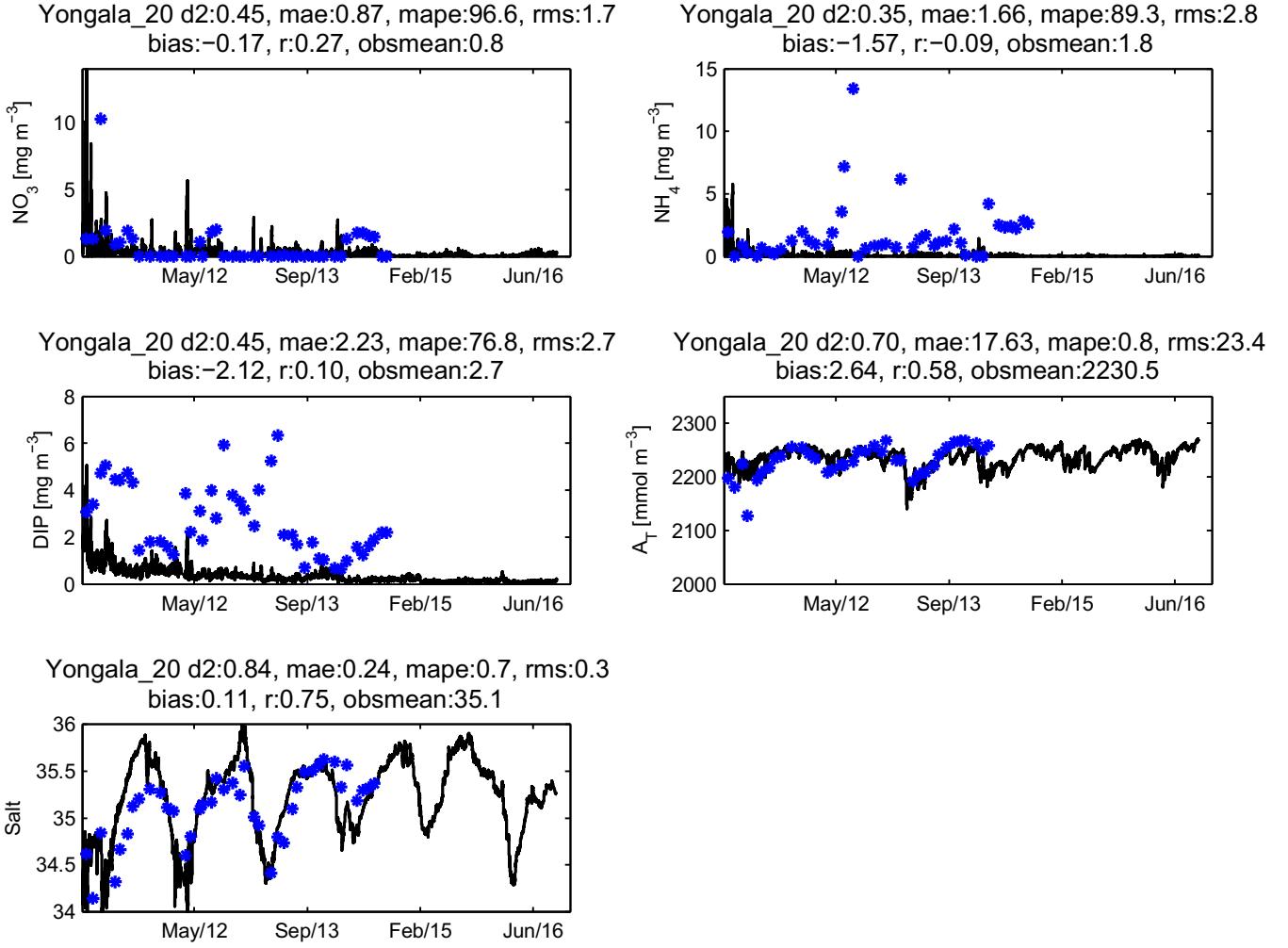


Figure 41: Yongala (NRSYON) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = (NO_3 , NH_4 , DIP, A_T). Field observation depth taken: 20 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

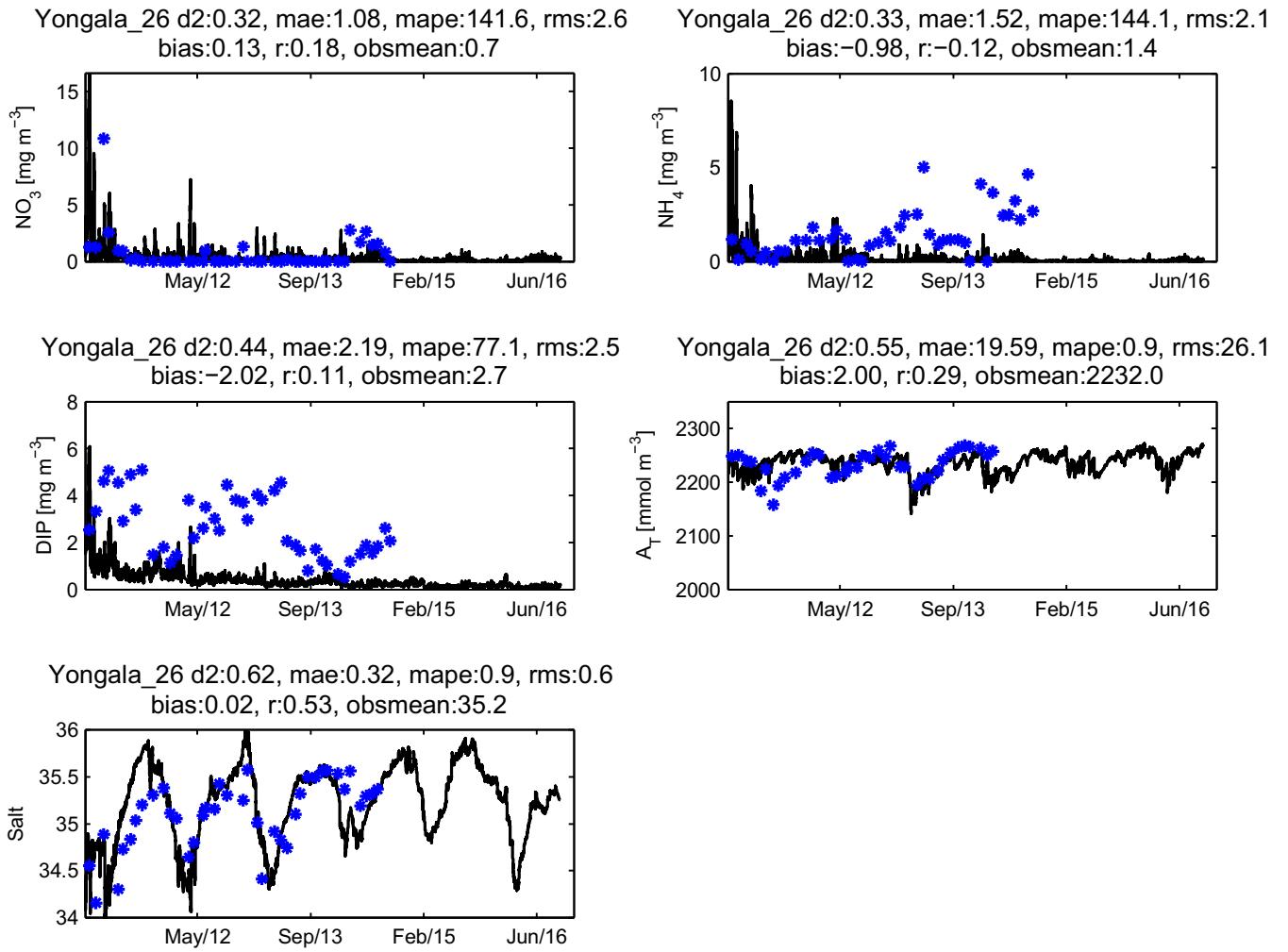


Figure 42: Yongala (NRSYON) Nutrients IMOS/NRS Monthly sample observations against GBR4 model: Observation (blue), model (black): Parameter/s = (NO_3 , NH_4 , DIP, A_T). Field observation depth taken: 26 m. Model grid deepest point at this site -28.62 m. Observation deepest point at this site 27 m.

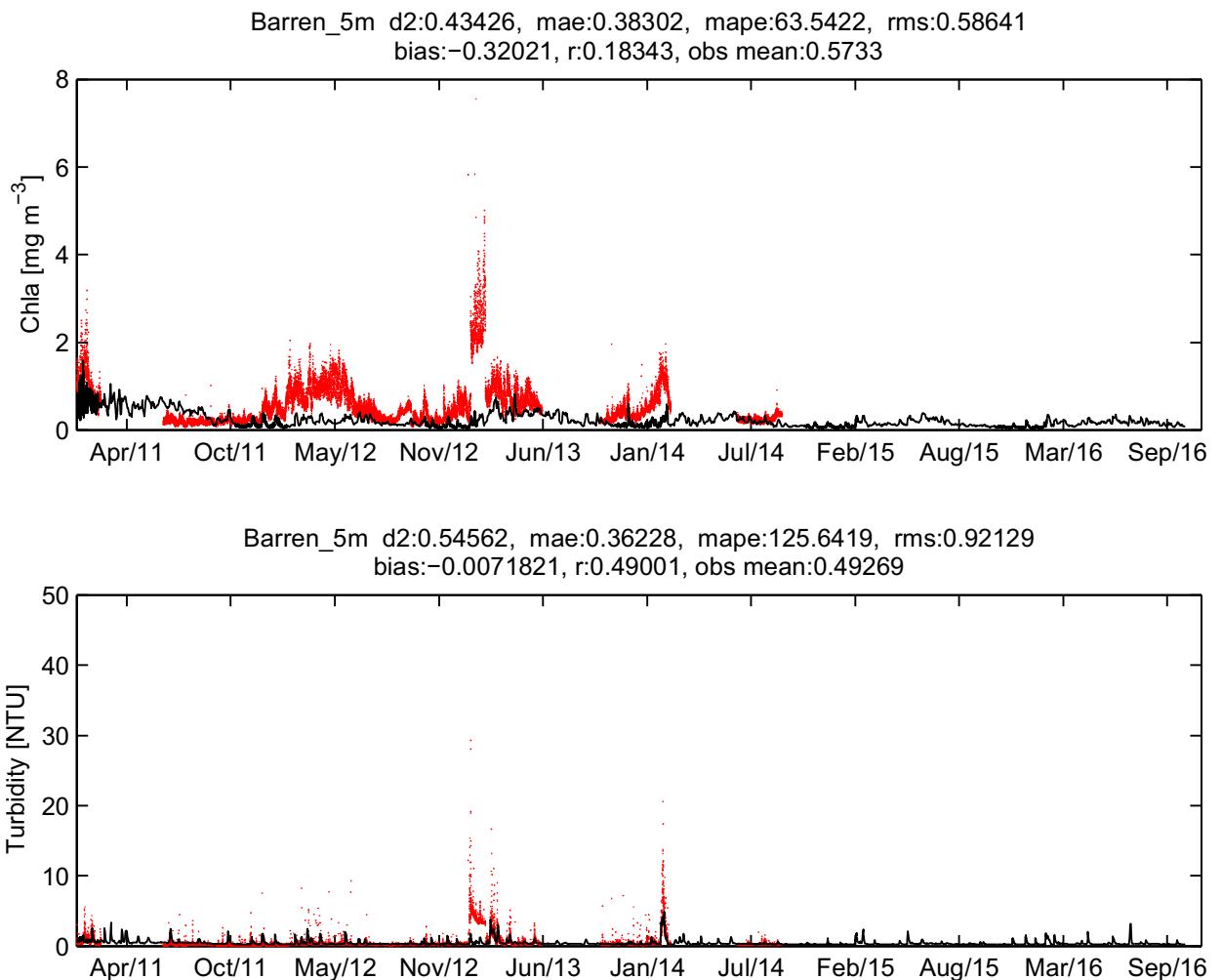


Figure 43: Barren Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence). Field observation depth taken: 5 m. Model grid deepest point at this site 24.26 m. Observation deepest point at this site 15.2 to 18.9 m.

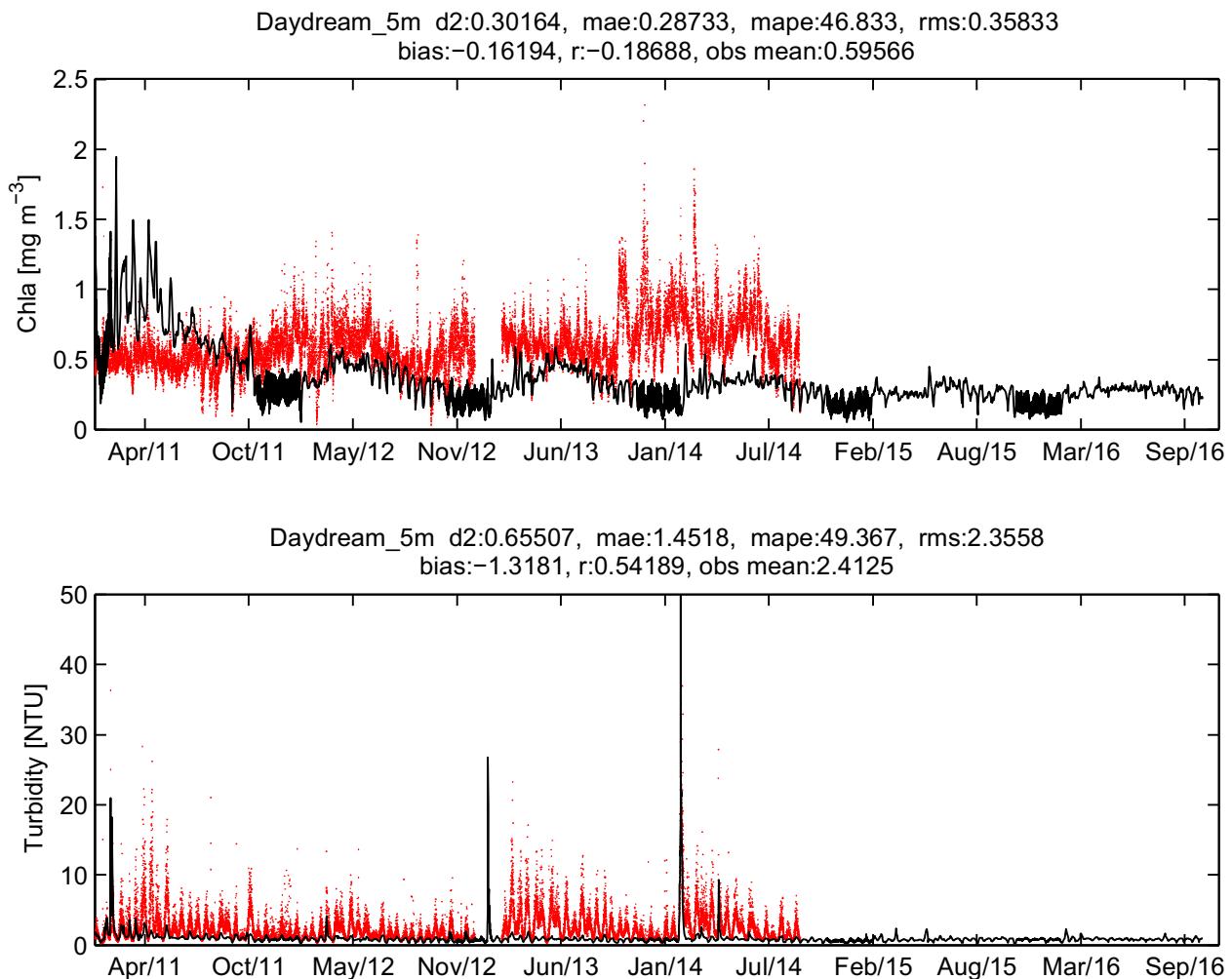


Figure 44: Daydream Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence) . Field observation depth taken: 5 m. Model grid deepest point at this site 16.76 m. Observation deepest point at this site 23.6 to 25.9 m.

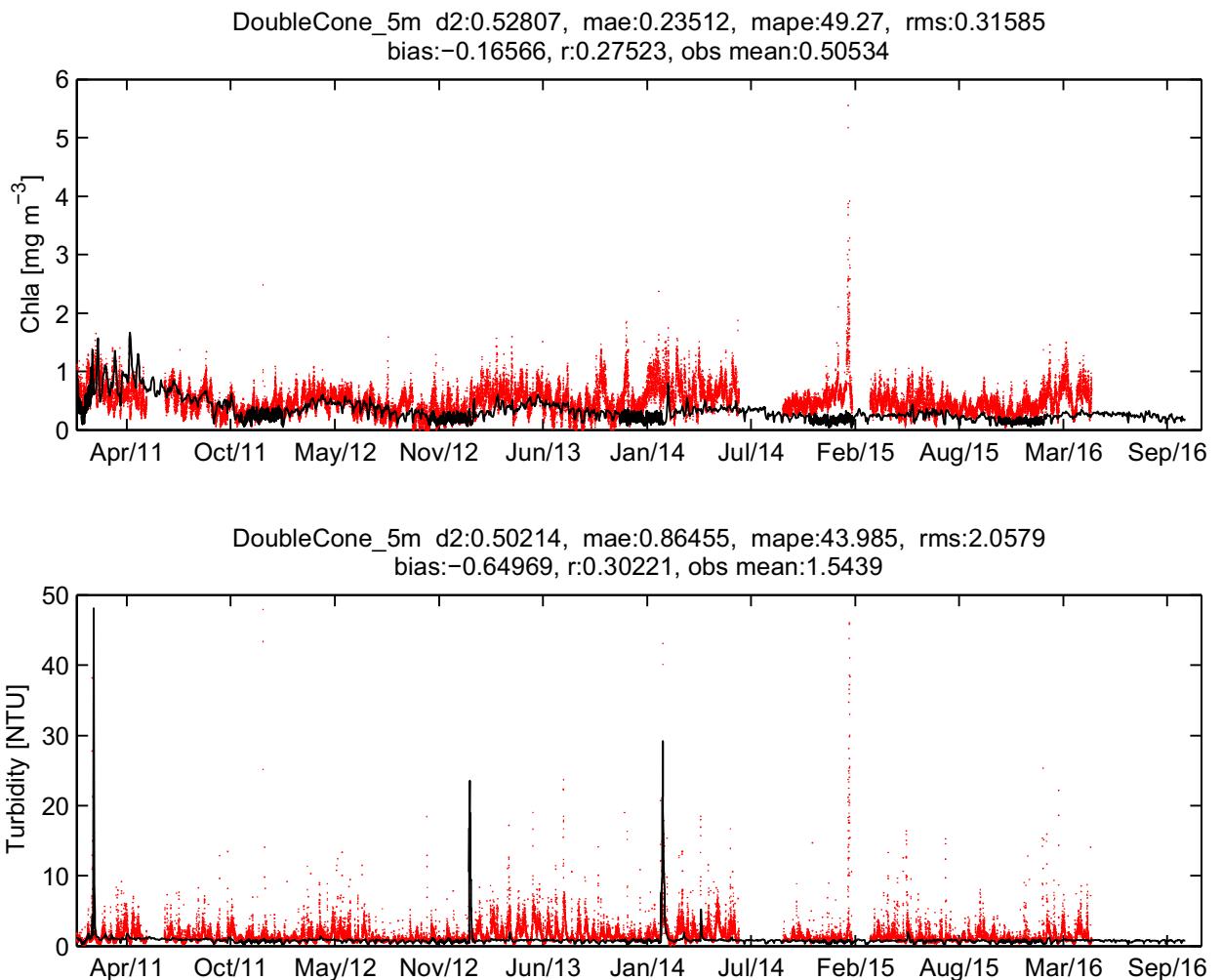


Figure 45: Double Cone Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence) . Field observation depth taken: 5 m. Model grid deepest point at this site 17.03 m. Observation deepest point at this site 23.0 to 31.0 m.

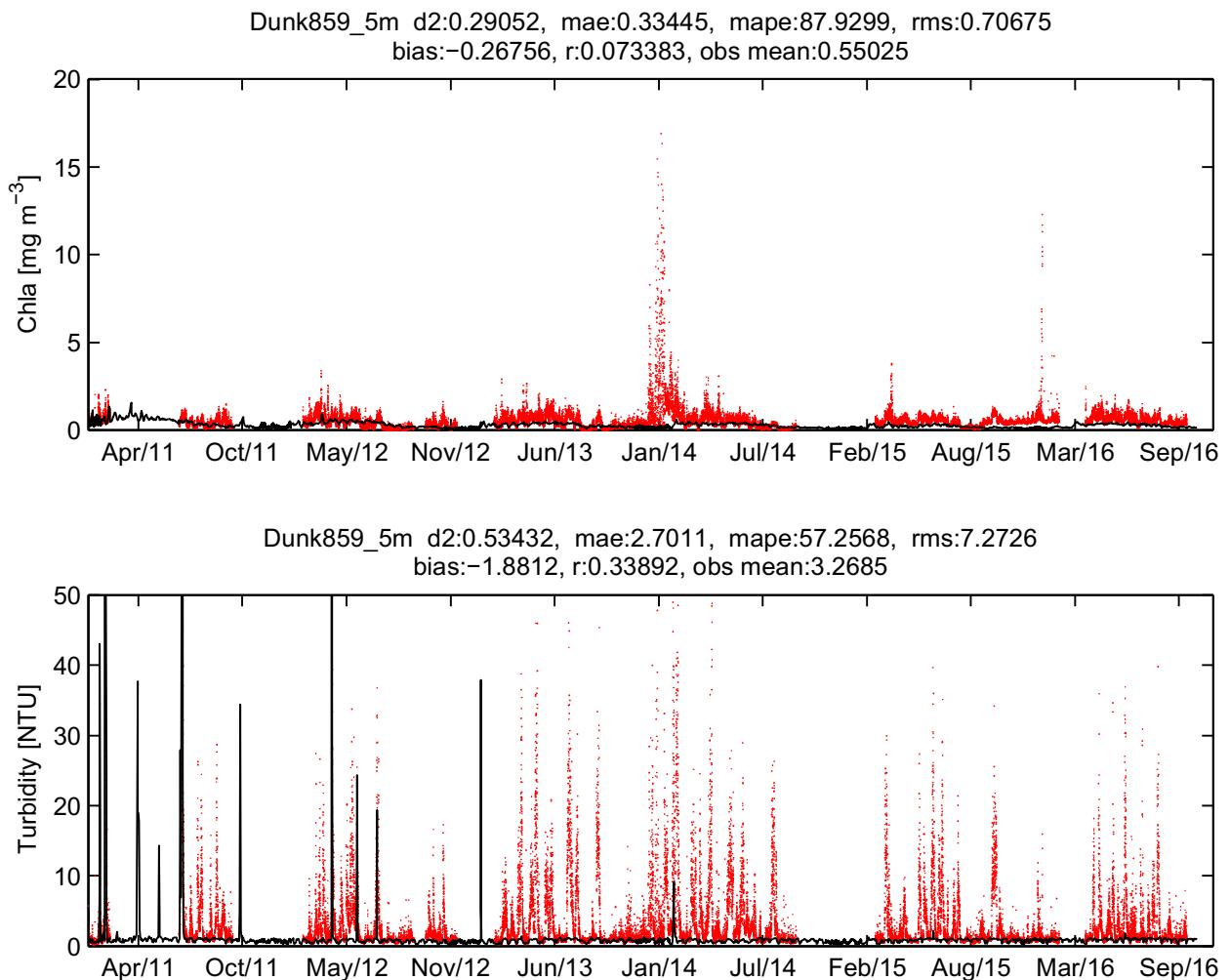


Figure 46: Dunk Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence) . Field observation depth taken: 5 m. Model grid deepest point at this site 9.15 m. Observation deepest point at this site 9.0 to 10.4 m.

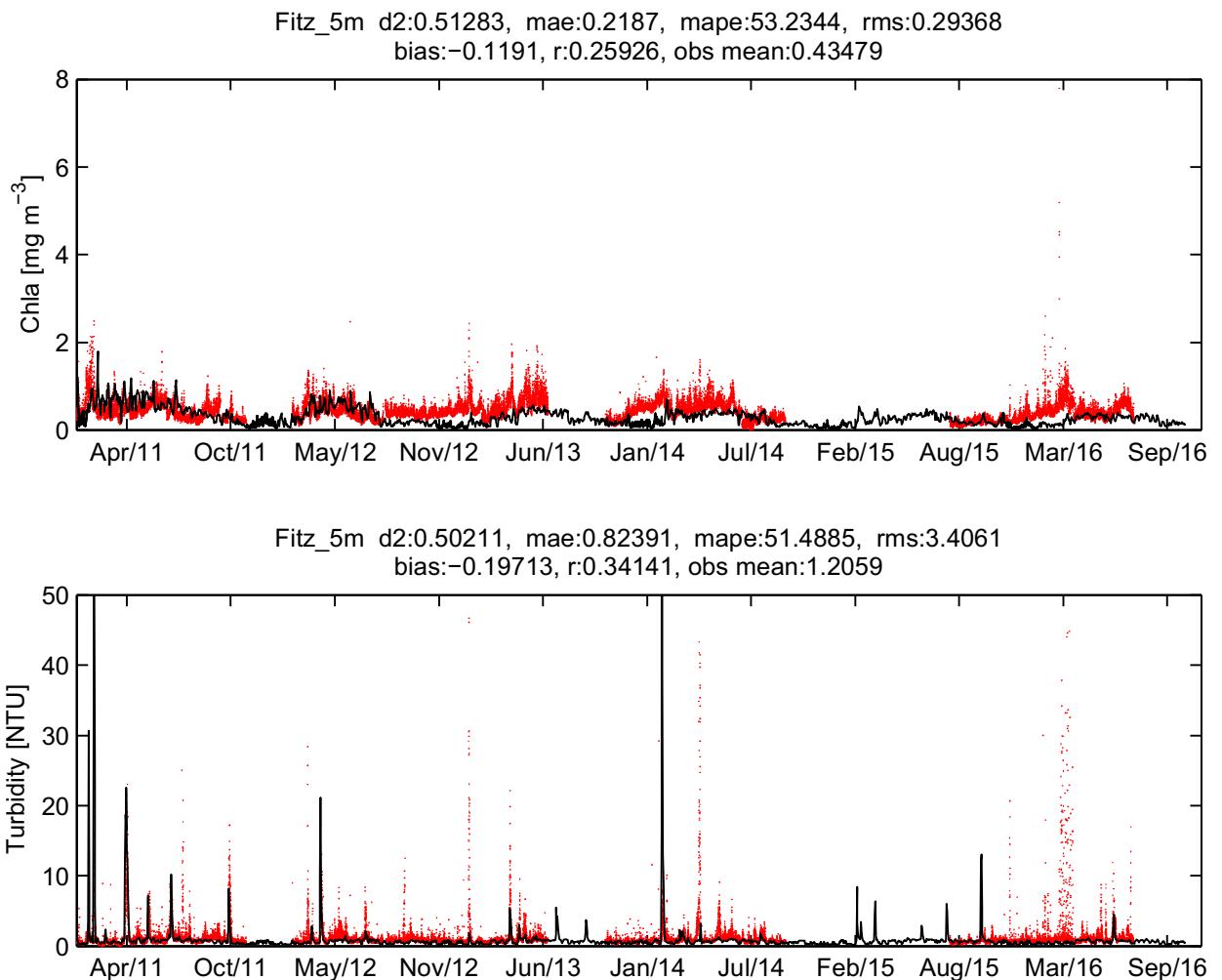


Figure 47: Fitzroy Reef Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence). Field observation depth taken: 5 m. Model grid deepest point at this site 27 m. Observation deepest point at this site 15.5 to 17.2 m.

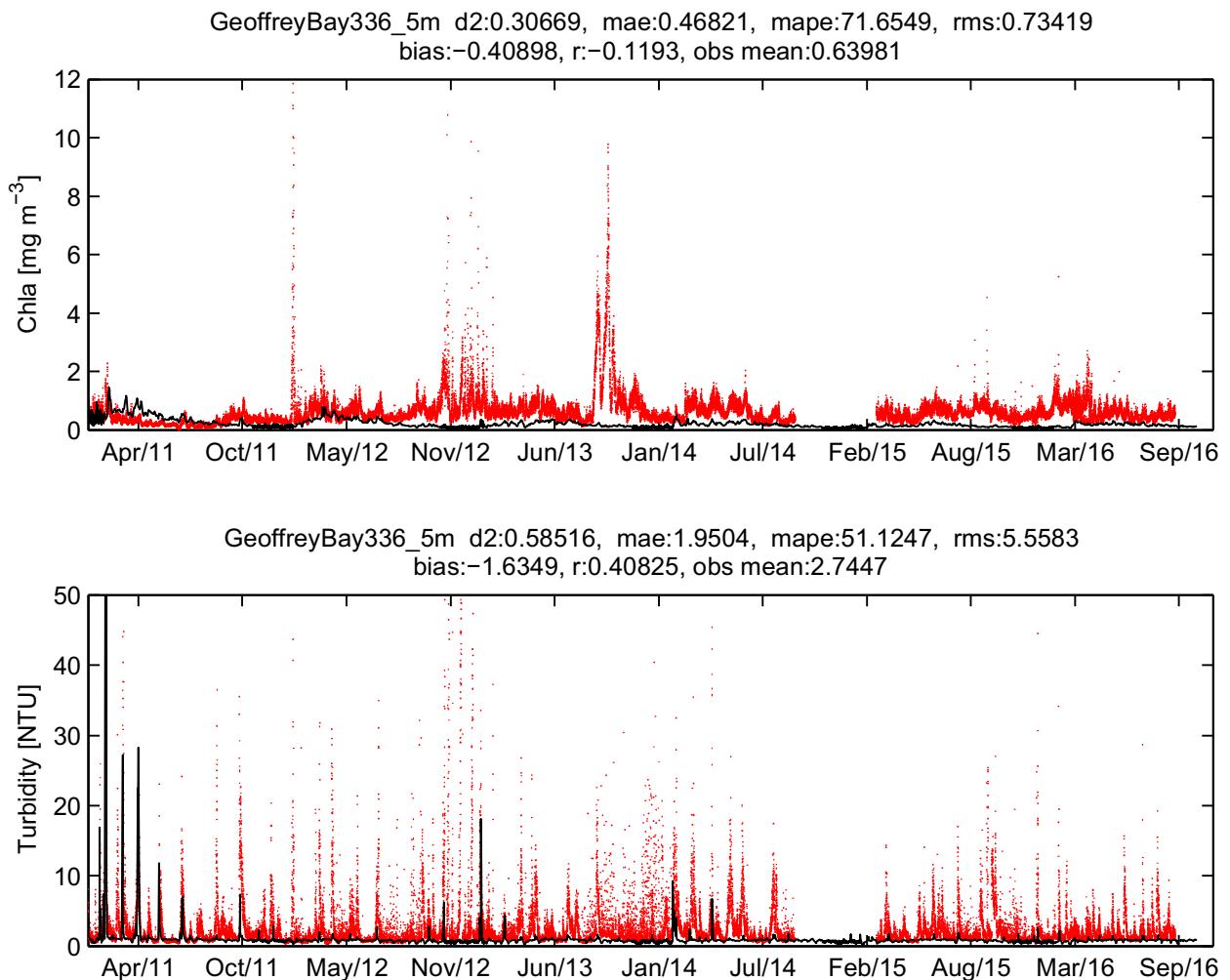


Figure 48: Geoffrey Bay Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence) . Field observation depth taken: 5 m. Model grid deepest point at this site -10.42 m. Observation deepest point at this site 9.9 to 12 m.

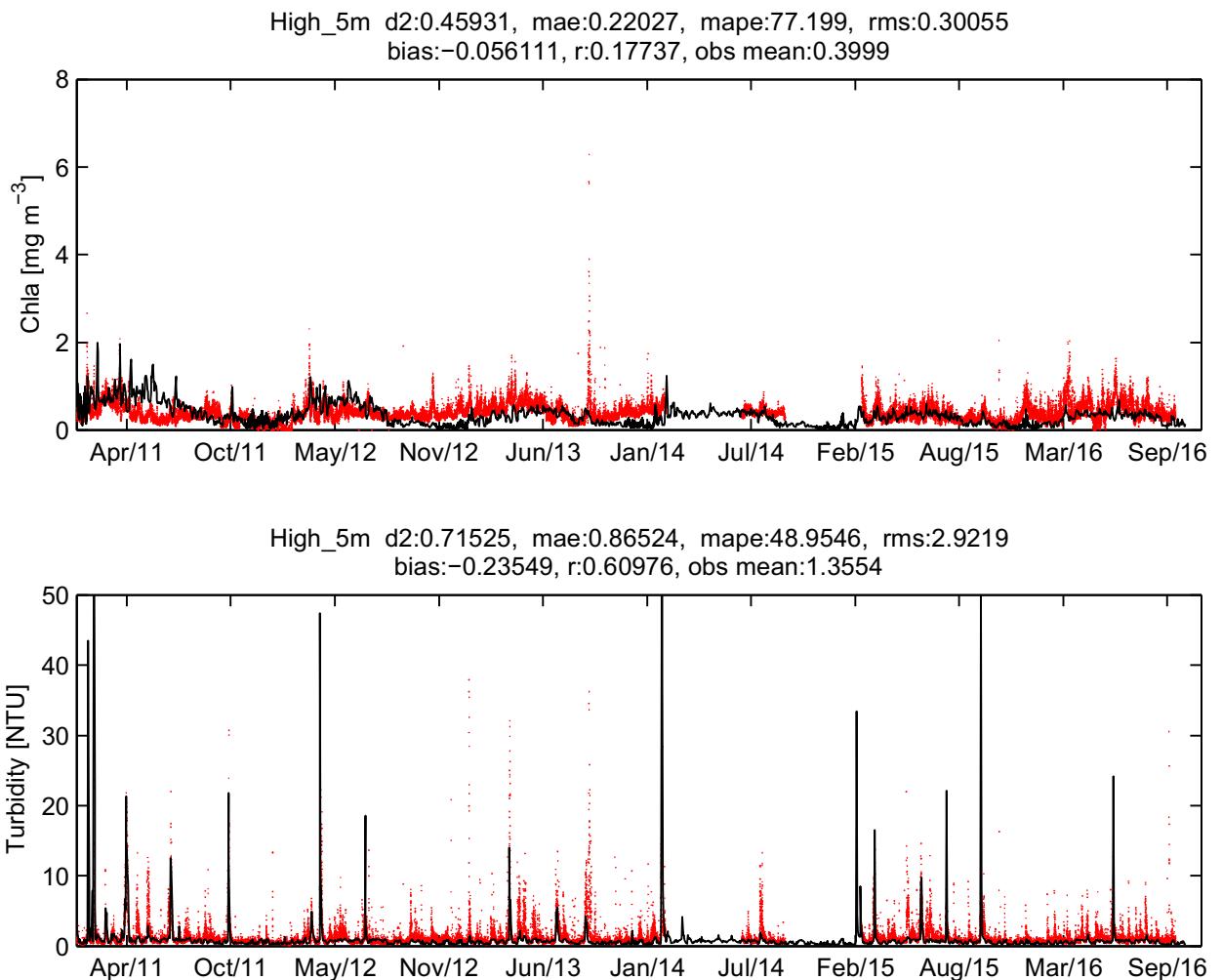


Figure 49: High Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence). Field observation depth taken: 5 m. Model grid deepest point at this site -17.64 m. Observation deepest point at this site 22.0 to 25.3 m.

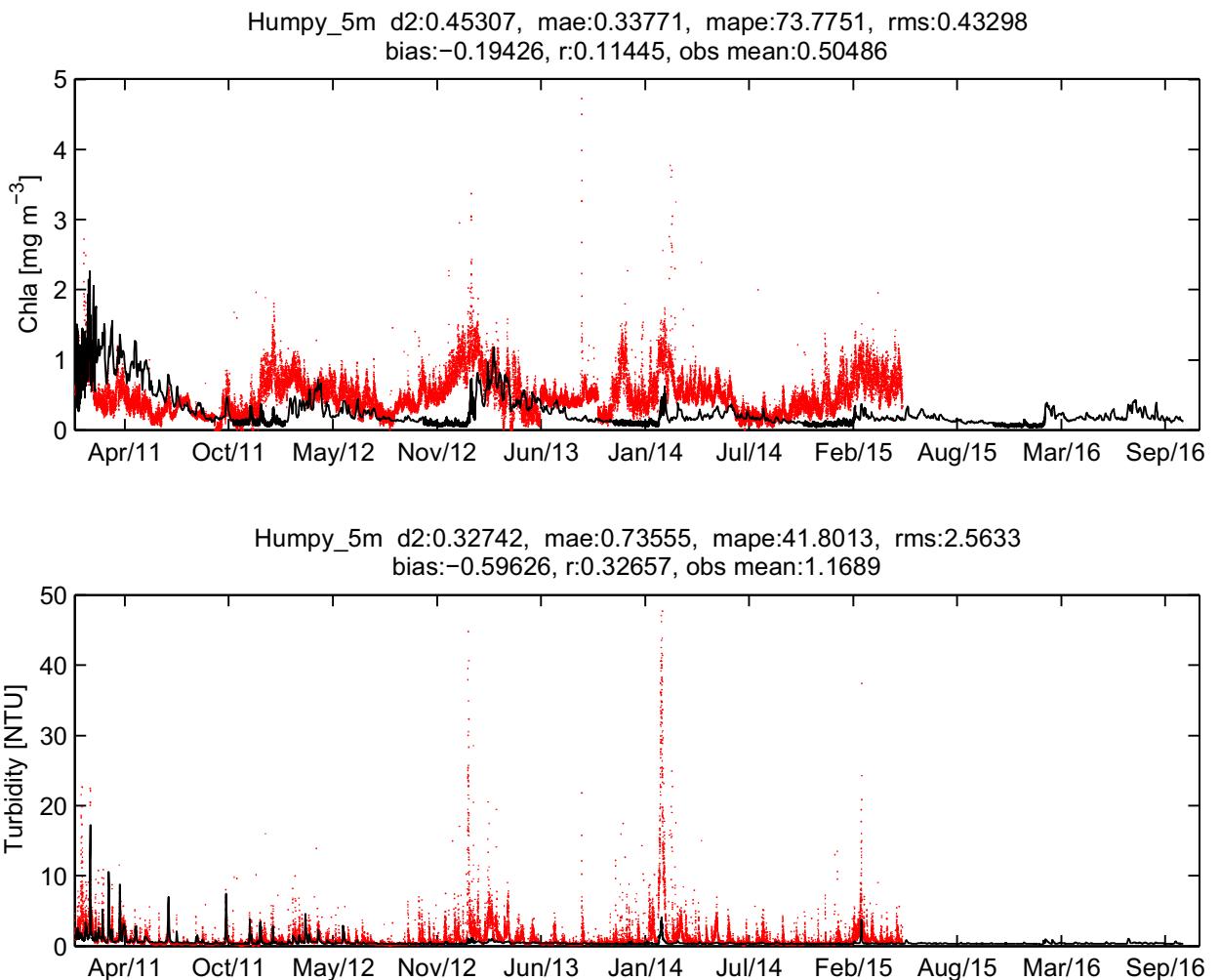


Figure 50: Humpy Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence). Field observation depth taken: 5 m. Model grid deepest point at this site -12.86 m. Observation deepest point at this site 12.6 to 19.5 m.

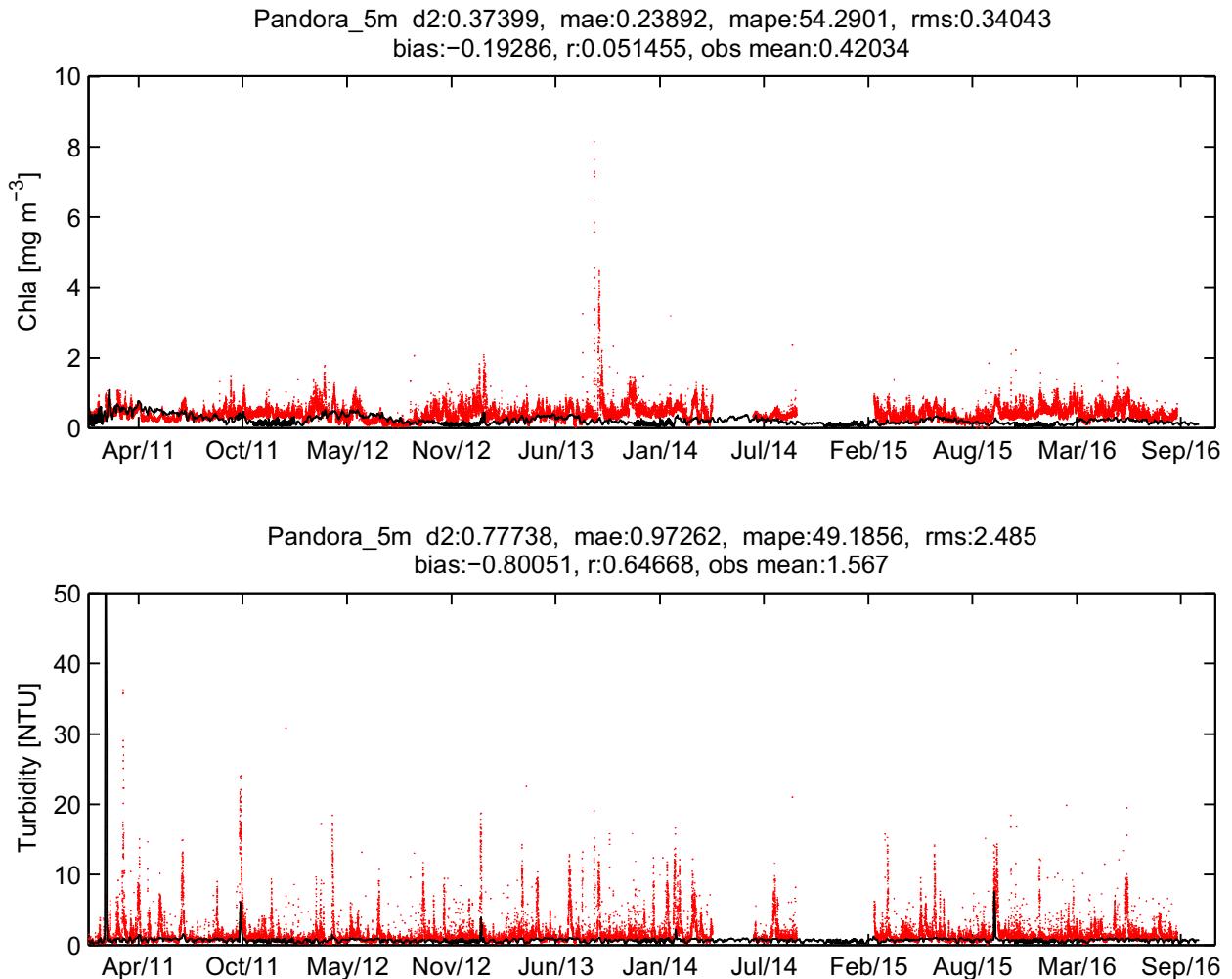


Figure 51: Pandora Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence). Field observation depth taken: 5 m. Model grid deepest point at this site -16.98 m. Observation deepest point at this site 12.9 to 13.9 m.

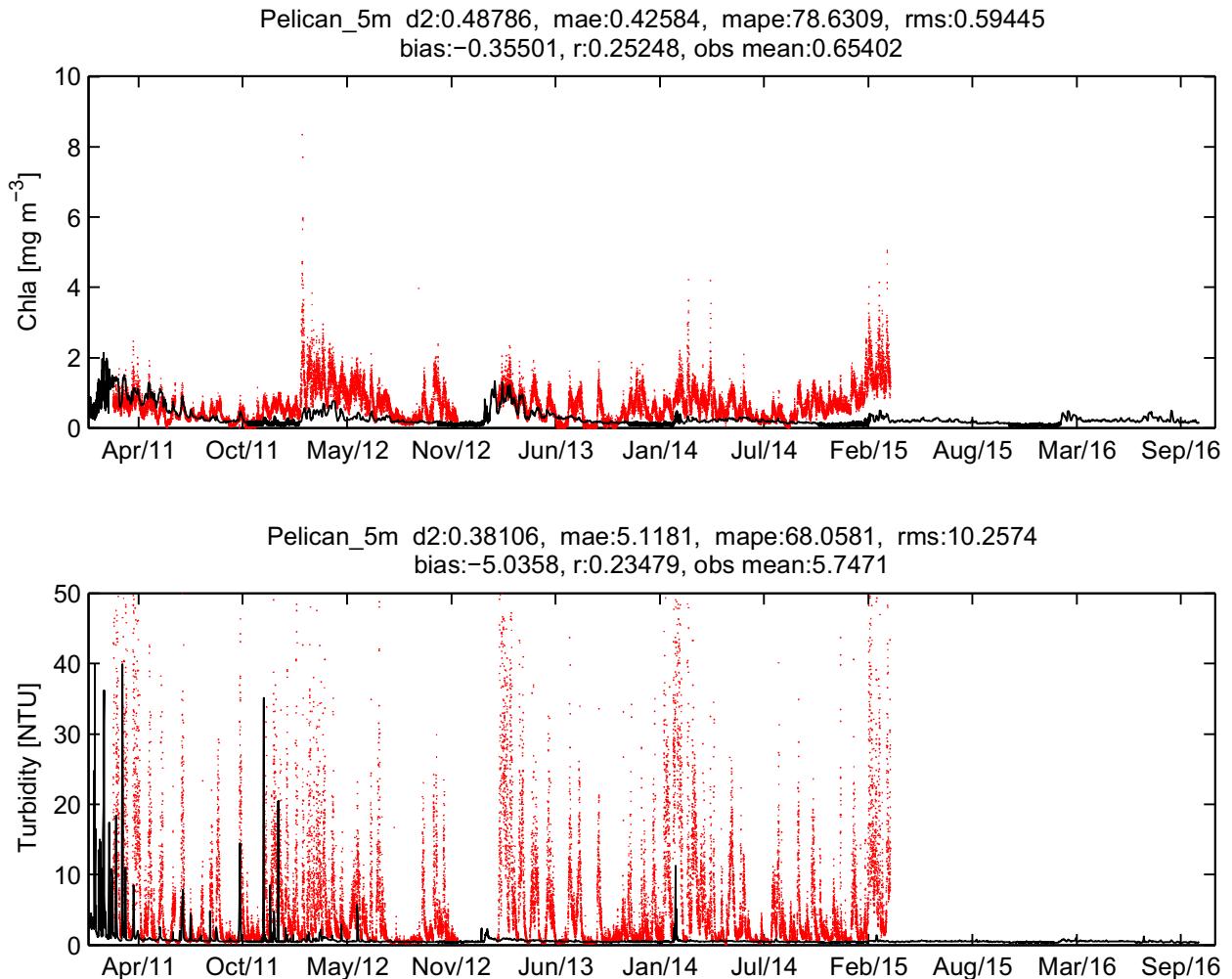


Figure 52: Pelican Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence) . Field observation depth taken: 5 m. Model grid deepest point at this site -4.47 m. Observation deepest point at this site 8.8 to 9.7 m.

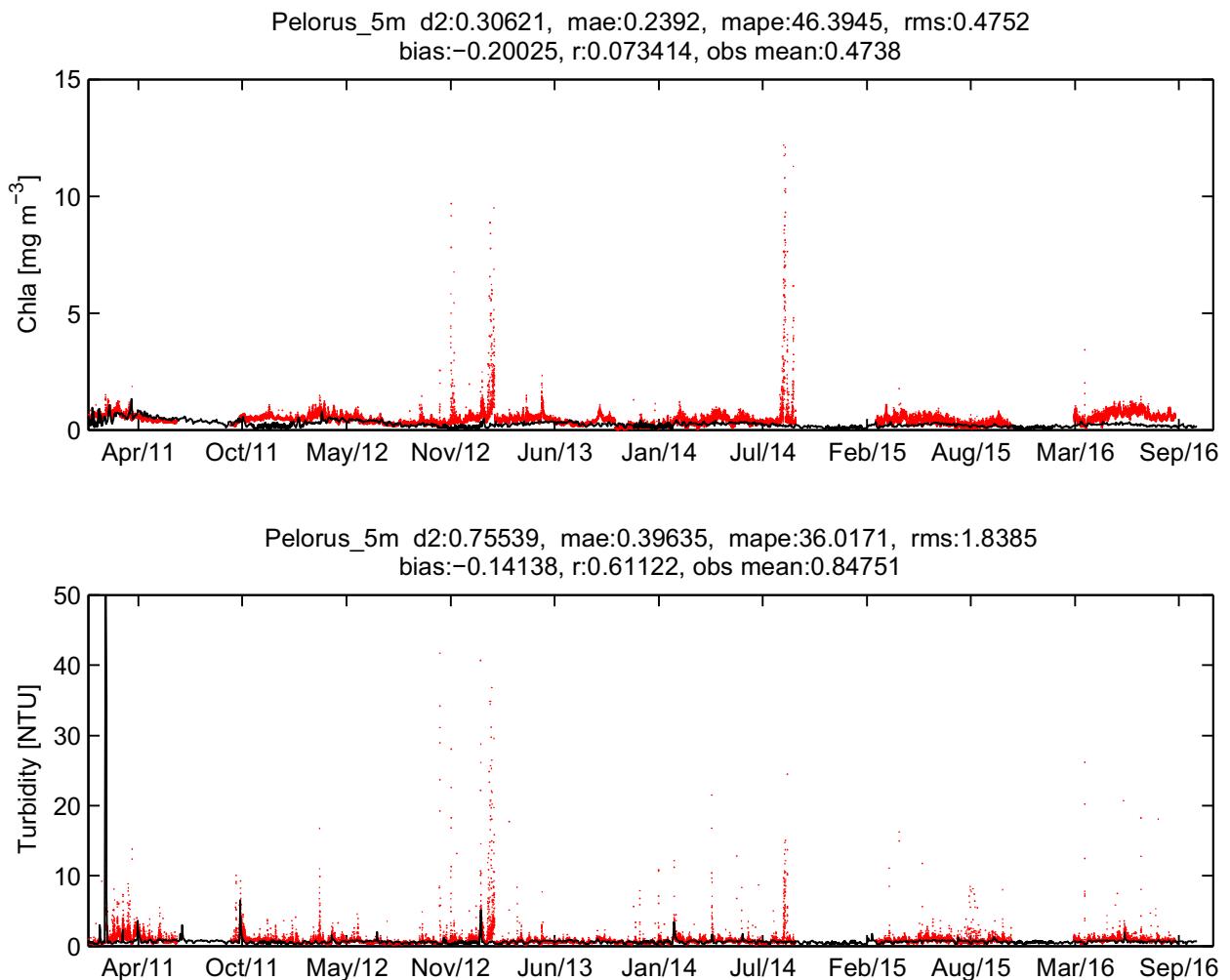


Figure 53: Pelorous/Orpheus Island Mooring Marine Monitoring Program (MMP) observations against GBR4 model: Observation (blue), model (black): Parameter/s = Turbidity and Chlorophyll (fluorescence) . Field observation depth taken: 5 m. Model grid deepest point at this site -24.64 m. Observation deepest point at this site 25.3 to 31.4 m.