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AIMS: Australia's tropical marine research agency

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Revision History

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3. DATA SOURCES

Report cards are typically compiled and communicated annually. However, the time window that constitutes a year differs from report card to report card. Many environmental report cards communicate on data collected within a financial year. This schedule provides a reporting window that is consistent with other management and governmental considerations. Others use a time window that naturally aligns with the cycle of some major underlying environmental gradient - such as wet/dry season. For this project, we are adopting using the same water year (1st Oct – 31 Sept) definition as the AIMS inshore Water Quality Marine Monitoring Program (Lønborg et al., 2016).

The Great Barrier Reef Marine Park (GBR)spans nearly 14° of latitude and covers approximately 344,400km^2.

- spanning multiple jurisdictions/pressures as well as distance offshore - more useful to partition the GBR into smaller more homogeneous zones representing combinations of region and water body. - Six regions (Cape York, Wet Tropics, Dry Tropics, Mackay Whitsunday, Fitzroy and Burnett Mary) - Four water bodies (Enclosed Coastal, Open Coastal, Midshelf and Offshore) - define each...

Table 1: Great Barrier Reef spatial Zones and associated Regions and Water bodies.

GBRMPA Zone	Zone	Region	Water body
Enclosed_Coastal_Cape_York	Enclosed_Coastal_Cape York	Cape York	Enclosed Coastal
Enclosed_Coastal_Terrain_NRM	Enclosed_Coastal_Wet Tropics	Wet Tropics	Enclosed Coastal
Enclosed_Coastal_Burdekin_Dry_Tropics_NRM	Enclosed_Coastal_Dry Tropics	Dry Tropics	Enclosed Coastal
Enclosed_Coastal_Mackay_Whitsunday_NRM_Group	Enclosed_Coastal_Mackay Whitsunday	Mackay Whitsunday	Enclosed Coastal
Enclosed_Coastal_Fitzroy_Basin_Association	Enclosed_Coastal_Fitzroy	Fitzroy	Enclosed Coastal
Enclosed_Coastal_Burnett_Mary_Regional_Group_for_NRM	Enclosed_Coastal_Burnett Mary	Burnett Mary	Enclosed Coastal
Open_Coastal_Cape_York	Open_Coastal_Cape York	Cape York	Open Coastal
Open_Coastal_Terrain_NRM	Open_Coastal_Wet Tropics	Wet Tropics	Open Coastal
Open_Coastal_Burdekin_Dry_Tropics_NRM	Open_Coastal_Dry Tropics	Dry Tropics	Open Coastal
Open_Coastal_Mackay_Whitsunday_NRM_Group	Open_Coastal_Mackay Whitsunday	Mackay Whitsunday	Open Coastal
Open_Coastal_Fitzroy_Basin_Association	Open_Coastal_Fitzroy	Fitzroy	Open Coastal
Open_Coastal_Burnett_Mary_Regional_Group_for_NRM	Open_Coastal_Burnett Mary	Burnett Mary	Open Coastal
Midshelf_Cape_York	Midshelf_Cape York	Cape York	Midshelf
Midshelf_Terrain_NRM	Midshelf_Wet Tropics	Wet Tropics	Midshelf
Midshelf_Burdekin_Dry_Tropics_NRM	Midshelf_Dry Tropics	Dry Tropics	Midshelf
Midshelf_Mackay_Whitsunday_NRM_Group	Midshelf_Mackay Whitsunday	Mackay Whitsunday	Midshelf
Midshelf_Fitzroy_Basin_Association	Midshelf_Fitzroy	Fitzroy	Midshelf
Midshelf_Burnett_Mary_Regional_Group_for_NRM	Midshelf_Burnett Mary	Burnett Mary	Midshelf
Offshore_Cape_York	Offshore_Cape York	Cape York	Offshore
Offshore_Terrain_NRM	Offshore_Wet Tropics	Wet Tropics	Offshore
Offshore_Burdekin_Dry_Tropics_NRM	Offshore_Dry Tropics	Dry Tropics	Offshore
Offshore_Mackay_Whitsunday_NRM_Group	Offshore_Mackay Whitsunday	Mackay Whitsunday	Offshore
Offshore_Fitzroy_Basin_Association	Offshore_Fitzroy	Fitzroy	Offshore
Offshore_Burnett_Mary_Regional_Group_for_NRM	Offshore_Burnett Mary	Burnett Mary	Offshore

Table 2: Summary of used data sources.

Source	Custodian	Description
AIMS Insitu	AIMS	AIMS inshore monitoring program Niskin data
AIMS FLNTU	AIMS	AIMS inshore monitoring program FLNTU logger data
Satellite	BOM	BOM: Catalog http://ereeftds.bom.gov.au/ereefs/tds/catalog/ereef/mwq/P1D/2002/catalog.html
eReefs	eReefs	provide a description in ../parameters/sources.csv
eReefs926	eReefs	eReefs: http://dapds00.nci.org.au/thredds/catalog/fx3/gbr4_bgc_926/catalog.html

3.1 Indicators

One of the biggest challenges of report card development is the selection of appropriate indicators from amongst a potentially very large candidate pool. Since the outcomes, conclusions and implications are all dependent on the indicators selected, the selection process is one of the most influential steps and has justifiably received a great deal of attention.

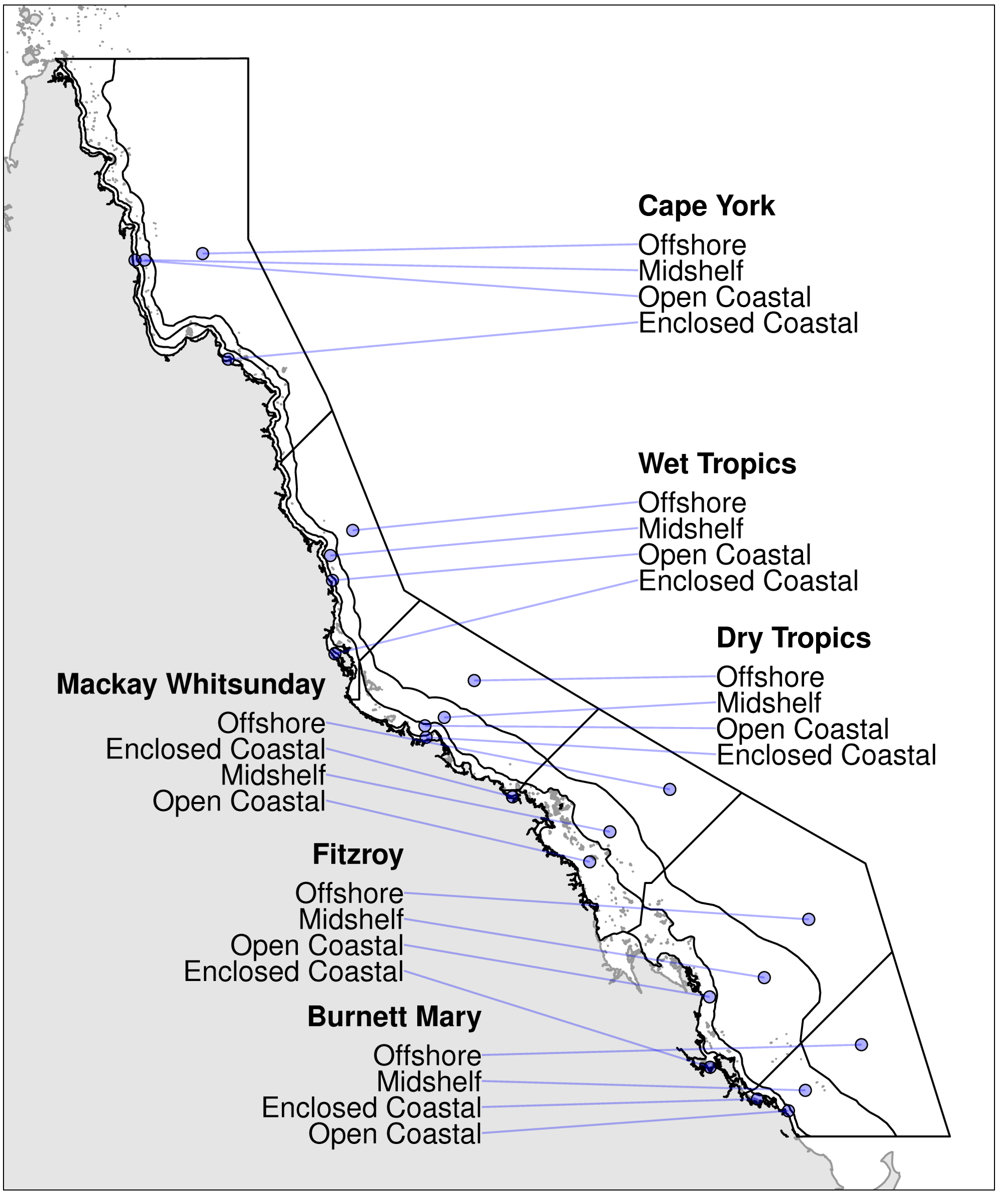


Figure 1: Great Barrier Reef Zones (Regions and Water Bodies).

As part of their ecosystem report card framework, Harwell et al. (1999) urged that the alignment of scientific information with societal goals and objectives should be the guiding principal of indicator selection. In their framework, clearly articulated societal goals and objectives (a combination of societal values and scientific knowledge, such as restored and sustainable wetland system) are translated into Essential Ecosystem Characteristics (EECs) that represent a set of generic attributes that further refine the broad goals (such as water quality, sediment quality, habitat quality, ecological processes). The EEC's are then further translated into a set of scientific informed indicators that are measured or monitored to indicate the status of trends or states associated with the EEC's.

There have since been numerous studies that have focused on providing more formal, objective criterion for indicator selection (Dauvin et al., 2008; Emerson et al., 2012; Flint et al., 2012; James et al., 2012). Whilst the specifics vary, most can be broadly encapsulated by a Dauvin et al. (2008)'s contextual implementation of the Doran (1981)'s SMART (Simple, Measurable, Achievable, Realistic, and Time limited) principle. A 'good' indicator should be representative, easily interpreted, broadly comparable, sensitive to change and have a reference or guideline value. To be 'useful', an indicator must be approved by international consensus, be well grounded and documented, have a reasonable cost/benefit ratio and have adequate historical and on-going spatial-temporal coverage. Flint et al. (2012) and James et al. (2012) further developed numerical scoring systems to help evaluate indicators objectively. Nevertheless, (Neary, 2012) warned against the potential to manipulate an index by saturating with inappropriate or biased indicators and whilst recommending that an index comprise of at least seven indicators, they did advocate that the type of indicator is more important than the number of indicators.

Since final outcomes are likely to be highly influenced by indicator choice, the robustness and sensitivity of both indicators and final outcomes to changes in ecosystem health should be understood if not formally investigated as part of the indicator selection process (Dobbie and Dail, 2013). Sensitivity analyses can involve:

- simulating changes in the underlying data of different magnitudes and estimating the resulting sensitivity (percentage or probability of change) expressed by the indicator
- estimating the effect of past perturbations on the indicator hindcasted from on historical data

As stressed above, indicators should align intimately with report card objectives. Yet in the more broad ecosystem report card frameworks, such indicators are often too general to be measurable. Therefore, in such cases, the indicators are further sub-divided into progressively more specific measures. For example, an indicator of water quality might comprise sub-indicators of nutrients, metals and physico-chemistry which in turn might be represented by more specific measures such as total nitrogen, mercury, dissolved oxygen, pH etc.

The resulting design is a hierarchical structure in which sub-indicators (etc) are nested within indicators and spatial scales are nested from entire regions, sub-regions or zones down to individual sites or sampling units. One of the strengths of such a hierarchical report card framework is that the inherent inbuilt redundancy allows for the addition, deletion or exchange of finer scale items (sites and actual measured variables) with minimum disruption to the actual report indicators. That is, the indicator is relatively robust to some degree of internal makeup. Furthermore, by abstracting away the fine details of an indicator, similar indicators from different report cards (each potentially comprising different sampling designs) are more directly comparably. For example, in different report cards that include water quality, a water quality indicator of 'water clarity' might comprise different Measures (e.g. suspended solids, NTU, Secchi depth etc) collected from different sources (e.g. satellite, in situ loggers or hand samples), yet provided each of these water clarity indicators are well calibrated, it should be possible to compare state and trend across the report cards.

Table 3: Water Quality Measure hierarchy specifying which Measures contribute to which Subindicators and which Subindicators contribute to which Indicators.

Indicator	Subindicator	Measure	Label	Units
Water Quality	Productivity	chl	Chlorophyll	μgL^{-1}
Water Quality	Water Clarity	nap	TSS	mgL^{-1}
Water Quality	Water Clarity	ntu	NTU	NTU
Water Quality	Water Clarity	sd	Secchi	m
Water Quality	Nutrients	NOx	NOx	μgL^{-1}

3.2 AIMS insitu samples

The AIMS component of MMP inshore water quality monitoring sampling program has been designed to quantify spatial and temporal patterns in inshore water quality, particularly in the context of catchment loads. Details of the sampling design are outlined in (Lønborg et al., 2016). From 2006–2014, AIMS visited 20 sites, three times per year (roughly corresponding to wet, early and late dry seasons), see Figures 2 and 3. The sites were largely selected along approximate north-south transects proximal to major rivers so as to provide samples along an expected water quality gradients (exposure to runoff). Following a review in 2014, the design was modified to intensify the spatial (32 sites) and temporal (typically between 5 and 10 samples per year) coverage of the sampling program. In particular, additional sampling effort was applied around three priority focal areas (Russell-Mulgrave, Tully and Burdekin).

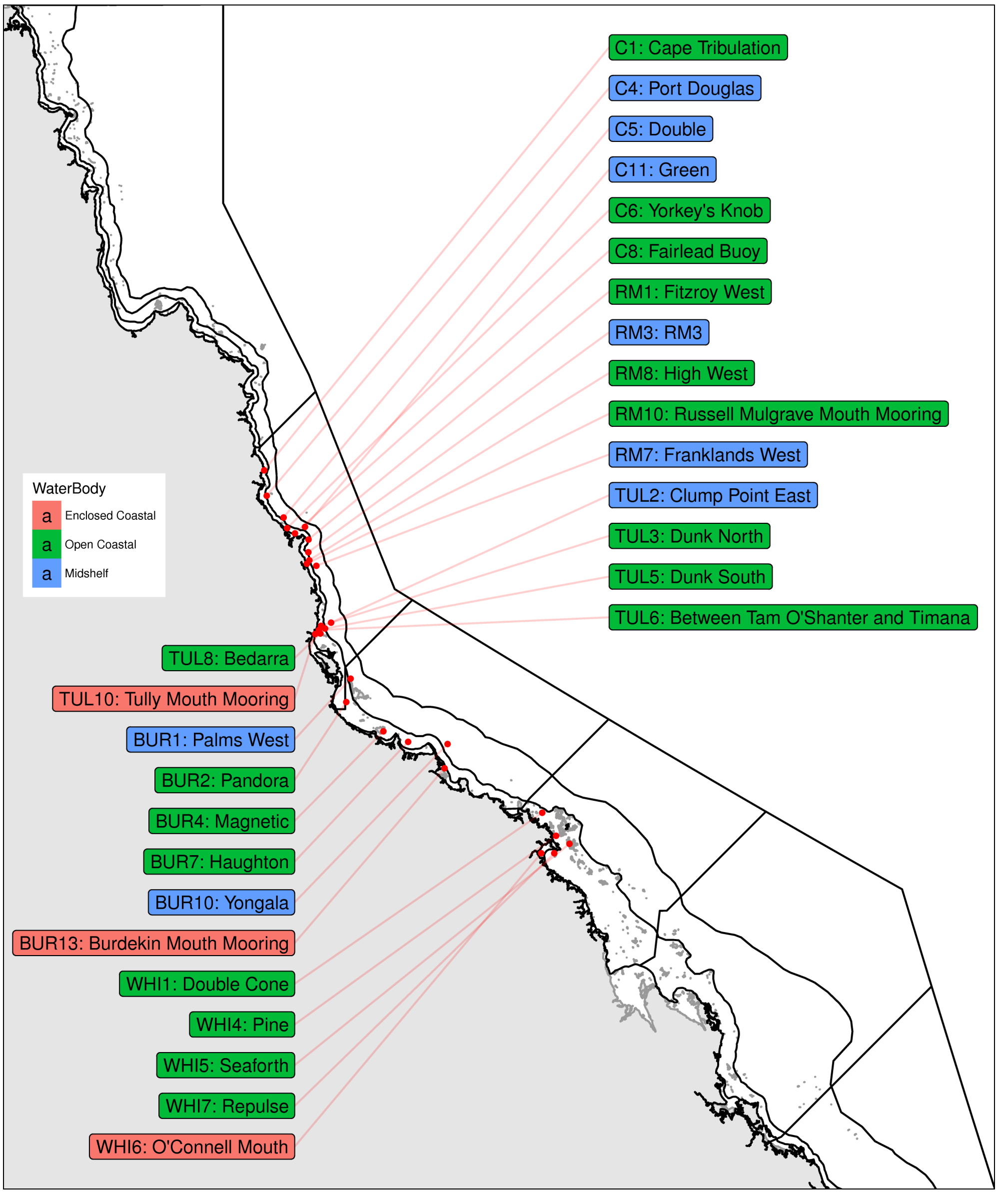


Figure 2: Map of AIMS in situ samples.

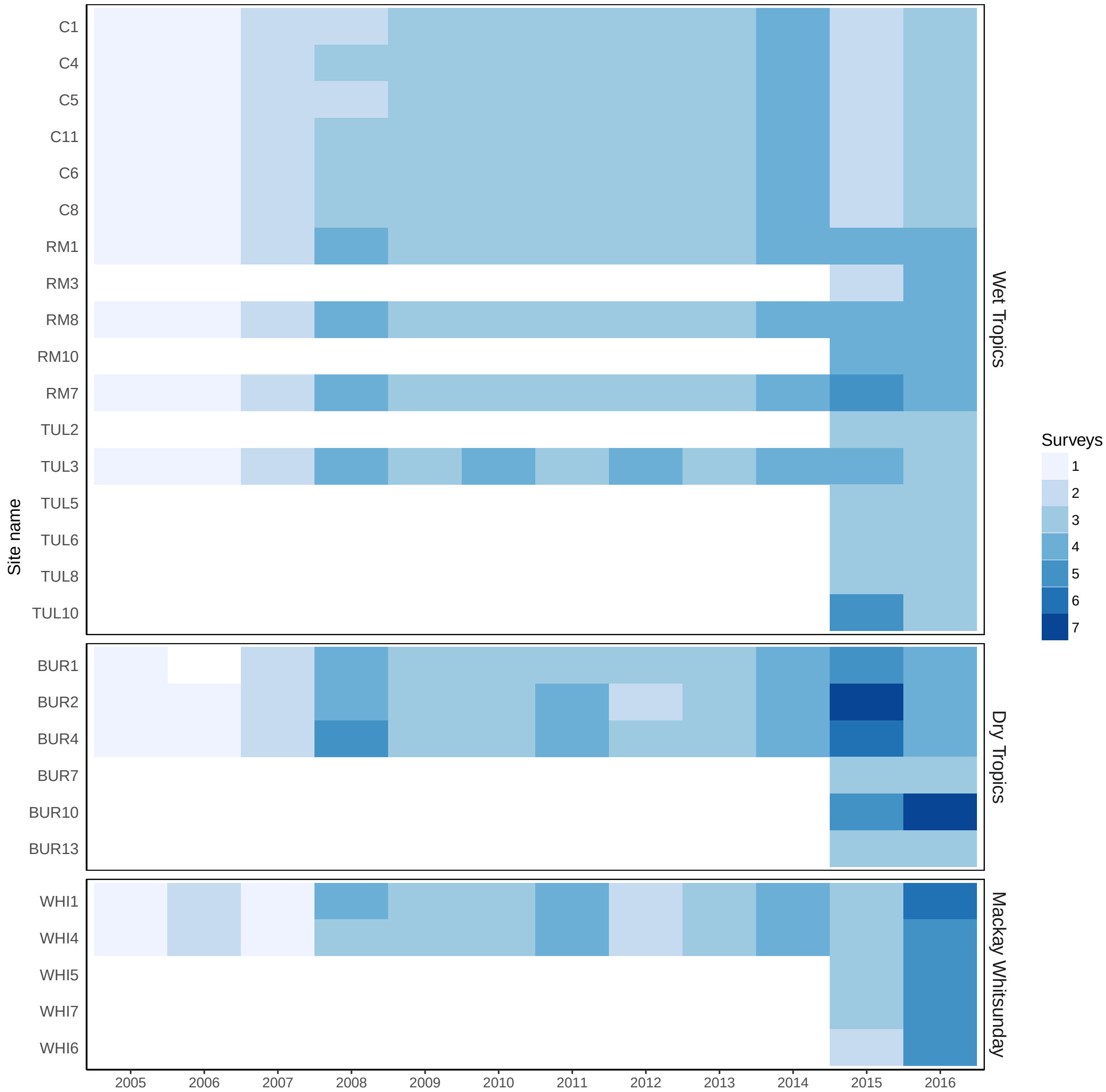


Figure 3: Spatial and temporal distribution of AIMS insitu samples. Sites names follow Great Barrier Reef Marine Park Authority (GBRMPA) and sites are arranged north to south into the focal Regions. Blue shading of tiles denotes the number of surveys conducted in the year at each site.

Table 4: Measures collected in AIMS MMP insitu inshore water quality monitoring program. NOx is the sum of NO_2 and NO_3. Data used are annual means of depth weighted averages per site.

Measure	Variable	Description	Abbreviation	Conversion	Units
Chlorophyll-a	DRIFTCHL_UGPERL.wm	Chlorophyll-a (µg/L)	chl	x1	μgL^{-1}
Total Suspended Solids	TSS_MGPERL.wm	Suspended solids (mg/L)	nap	x1	mgL^{-1}
Secchi Depth	SECCHI_DEPTH.wm	Secchi depth (m)	sd	x1	m
NOx	NOX.wm	Nitrite and Nitrate measured by microanalyser (µM/L)	NOx	x14	μgL^{-1}

3.3 AIMS FLNTU samples

Combination continuous Flourometer and Turbidity Sensors (hereafter FLNTU) loggers were deployed at 15 of the AIMS MMP inshore water quality monitoring sites.

Table 5: Measures collected in AIMS MMP flntu inshore water quality monitoring program. Data used are daily means per site.

Measure	Variable	Description	Abbreviation	Conversion	Units
Chlorophyll-a	CHL_QA_AVG	??	chl	CHL_QA_AVG x1	μgL^{-1}
NTU	NTU_QA_AVG	??	ntu	NTU_QA_AVG x1	NTU

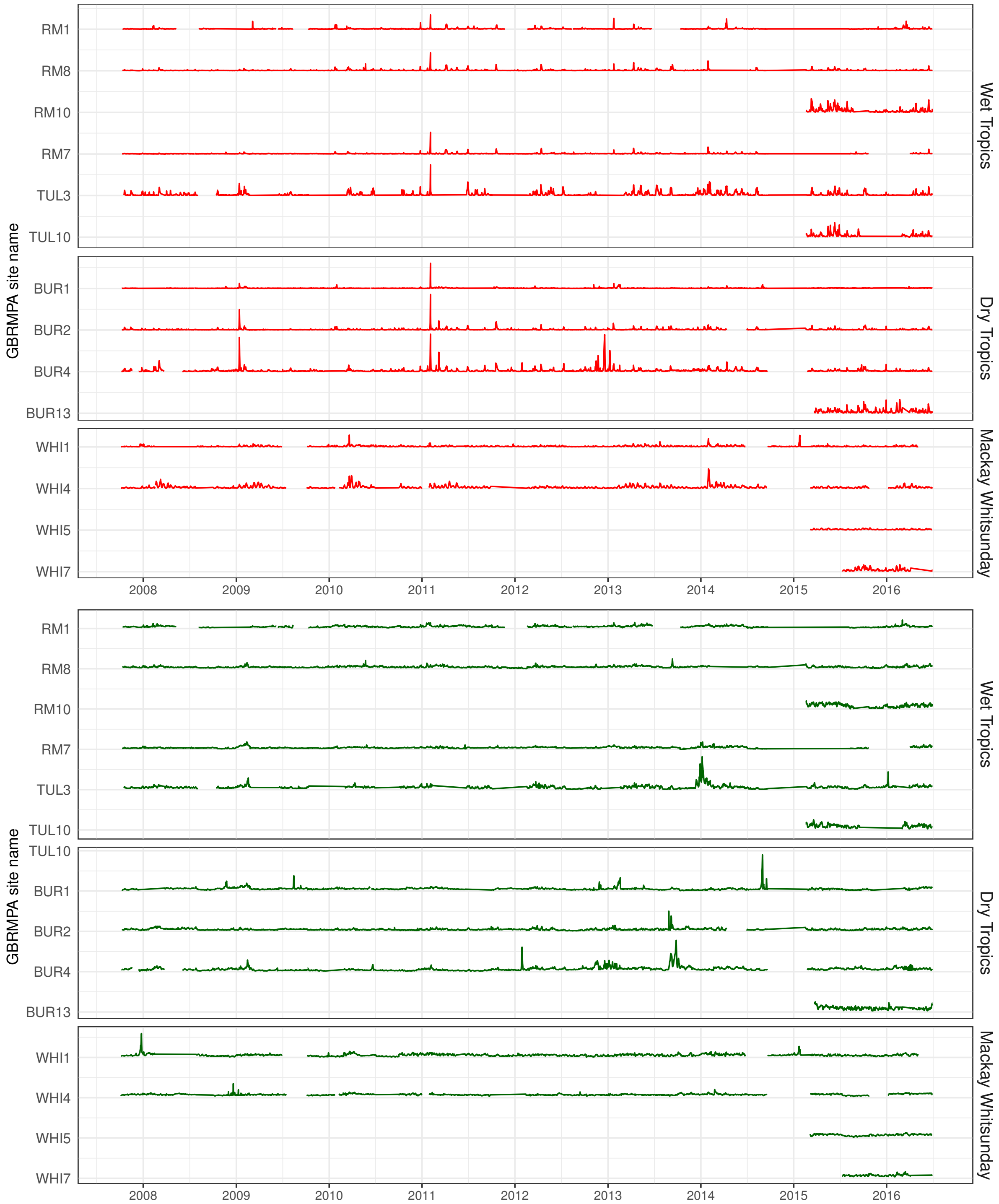


Figure 4: Spatial and temporal distribution of AIMS FLNTU samples (Red: NTU, Green: Chlorophyll-a). Sites names follow Great Barrier Reef Marine Park Authority (GBRMPA) and sites are arranged north to south into the focal Regions.

3.4 Remote sensing (BOM satellite)

Daily (July 2002–Dec 2016, $1 \times 1 km^2$ resolution) Moderate Resolution Imaging Spectroradiometer (MODIS satellite) imagery (hereafter referred to as Satellite) data were obtained by downloading NETCDF files from the thredds server.

Table 6: Measures collected from MODIS satellite imaging. Data used are daily means per pixel. Variable and Description pertain to the eReefs source. Conversion indicates the conversion applied on data to conform to threshold Units. Abbreviation provides a consistent key accross data.

Measure	Variable	Description	Abbreviation	Conversion	Units
Chlorophyll-a	Chl_MIM	??	chl	Chl_MIM x1	µgL^{-1}
Non-Algal Particles	Nap_MIM	??	nap	Nap_MIM x1	mgL^{-1}
Secchi Depth	SD_MIM	??	sd	SD_MIM x1	m

3.5 eReefs assimilated model

Mark to provide a brief description. In this context, the eReefs model refers to the gbr4_bgc_?? model (see Table?? for the catalog and model descriptions).

This source of data only extends back to 2014. Whilst the eReefs GBR4_BGC_? model technically does contain 2013 calendar year data, the current project partitions time into water years in which the full 2013 water year starts in October 2012. Therefore as the 2013 is not a complete 12 months of data, it is excluded from analyses. Unfortunately, this means that any signals associated with the 2010-2011 floods are unavailable.

Table 7: Measures collected from eReefs assimilated model. Data used are daily means per pixel. Variable and Description pertain to the eReefs source. Conversion indicates the conversion applied on data to conform to threshold Units. Abbreviation provides a consistent key accross data.

Measure	Variable	Description	Abbreviation	Conversion	Units
Chlorophyll-a	Chl_a_um	Sum of Chlorophyll concentration of four microalgae types (mg/m^3)	chl	Chl_a_um x1	µgL^{-1}
Non-Algal Particles	EFI	??	nap	EFI x1000	mgL^{-1}
Secchi Depth	Kd_490	??	sd	1/Kd_490	m
NOx	NO3	Concentration of Nitrate. As Nitrite is not represented in the model, NO3 = $[NO_3^-] + [NO_2^-]$ (mg/m^3)	NOx	NO3 x1	µgL^{-1}

3.6 eReefs926

Mark to provide a brief description. In this context, the eReefs926 model refers to the gbr4_bgc_926 model (see Table?? This model provides alternative formulation and importantly does extend back to the full 2013 water year thereby providing some coverage closer to the 2010-2011 flood period.

Variables used as per Table 7

3.7 Thresholds

An environmental health metric represents the state or condition relative to some reference, threshold or expectation. Most of the current water quality indices compare values to a set of specifically selected guidelines. These guidelines are either formulated specifically from long-term historical data appropriate to the spatial and temporal domain of interest or else are based on ANZEC guidelines (Australian and New Zealand Environment and Conservation Council, 2000).

Typically there are strict guidelines on how these guidelines should be applied. In particular, the guidelines associated with various measures used in various report cards throughout the Great Barrier Reef should be applied to annually aggregated data - not individual observations. Since this project intends to generate indices on the scale of individual observations, we have decided to refer to the guidelines as thresholds so as to avoid contradicting the terms of use of guidelines..

The thresholds used for each Measure within each Region and Water body are indicated in Table ?? (page ??). Note, that whilst the application of seasonal thresholds could potentially remove some uncertainty, in the absence of clear consensus on how to define wet and dry seasons and what the associated set of thresholds would be, seasonal thresholds are not used in this project.

4. EXPLORATORY DATA ANALYSIS

Exploratory data analysis is vital for informing data processing and analysis as well as establishing assumptions and limitations. Of particular importance for the current project is the spatial and temporal distribution and variability of the various data Measures and Sources. As such, a series of exploratory plots have been generated (see Appendix ?? begging on page ??). In the interest of keeping the main text free of copious graphics, we have elected to present only a small fraction of the exploratory data analyses figures here. The figures presented will act as exemplars of general format and predominant features or patterns.

4.1 All data

Figures 5 – 8 display the temporal distribution of Chlorophyll-a, TSS, Secchi depth and NOx observations for the Wet Tropics Open Coastal Zone from AIMS insitu, AIMS FLNTU, Satellite, eReefs and eReefs926 sources. All combinations of Measure/Zone/Source can be found in Figures ??–??.

All of the figures are presented with log-transformed y-axes as the data are typically skewed to the right. This is expected for parameters that have a natural minimum (zero), yet no theoretical maximum. It does however mean that these distributional properties should be considered during the analyses. In particular, for mean based aggregations, outliers and skewed distributions can impart unrepresentative influence on outcomes.

Each of the data sources presents different variability characteristics. The scale of the range of AIMS insitu data is predominantly and approximately less than or equal to the scale of the half/twice the associated threshold value (Fig. 5a). The AIMS FLNTU logger data (Fig. 5b) have a larger range than the AIMS insitu data - presumably because the former data collection frequency captures most of the peaks and trophs whereas the later is unlikely to do so. Similarly, the scale of the range eReefs and eReefs926 data (Fig. 5d-e) is approximately equal to the scale of the range of the span from half/twice the threshold value. This reflects both a more complete time series and broader spatial extent represented in the data. In contrast to the AIMS insitu and to a lesser extent the AIMS FLNTU and eReefs data, the scale of the range of the Satellite is relatively large - typically a greater span than the range of half/twice threshold value (Fig. 5c).

The Satellite, eReefs and eReefs926 data series all start and end part of the way through a water year. For annually aggregated data, this is likely to result in unrepresentative estimates and thus only full water years will be analysed.

4.2 Annual data

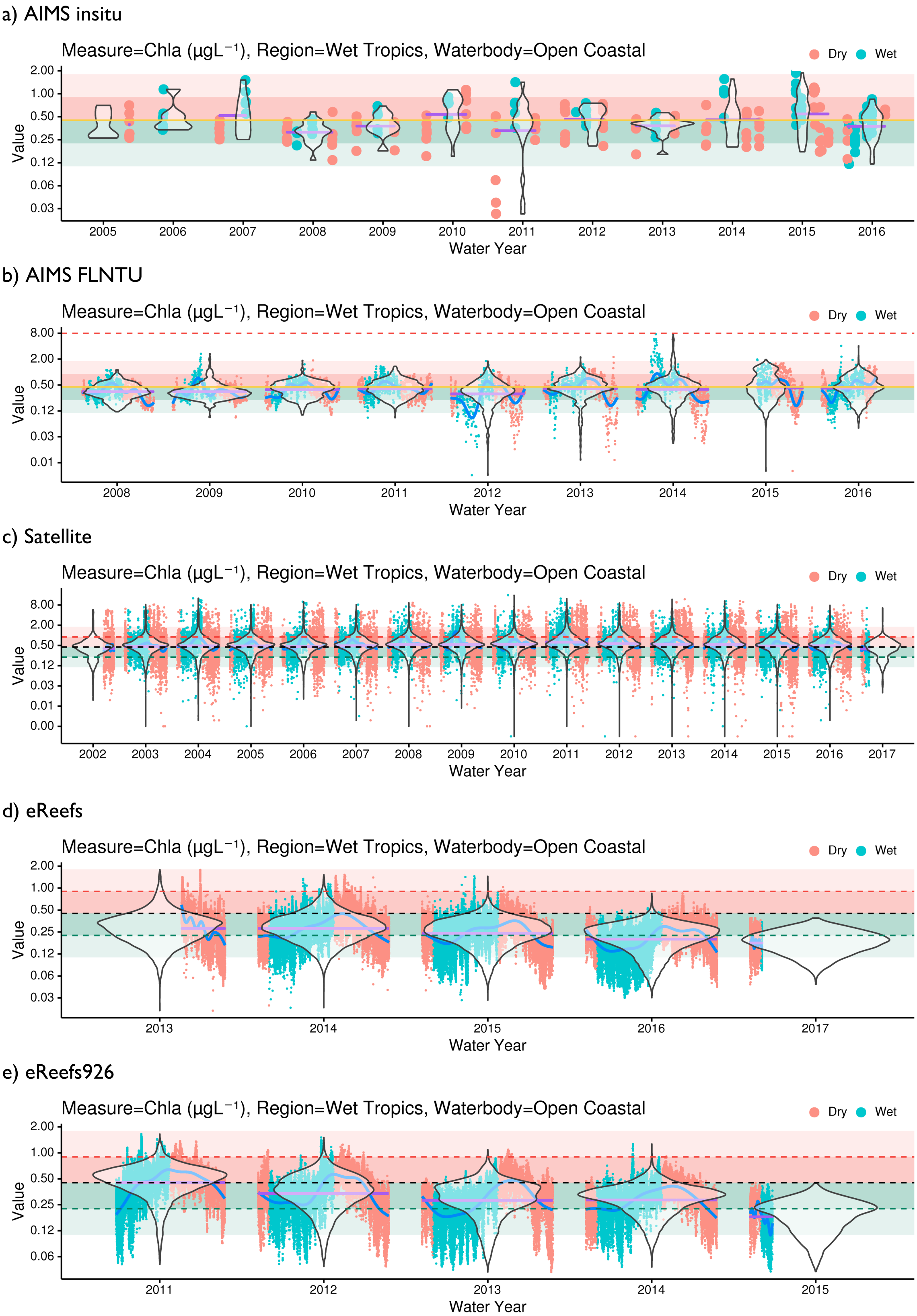


Figure 5: Observed (logarithmic axis with violin plot overlay) Chlorophyll-a data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) AIMS FLNTU, c) Satellite, d) eReefs and e) eReefs926. Observations are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Blue smoother represents Generalized Additive Mixed Model within a water year and purple line represents average within the water year. Horizontal red, black and green dashed lines denote the twice threshold, threshold and half threshold values respectively. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

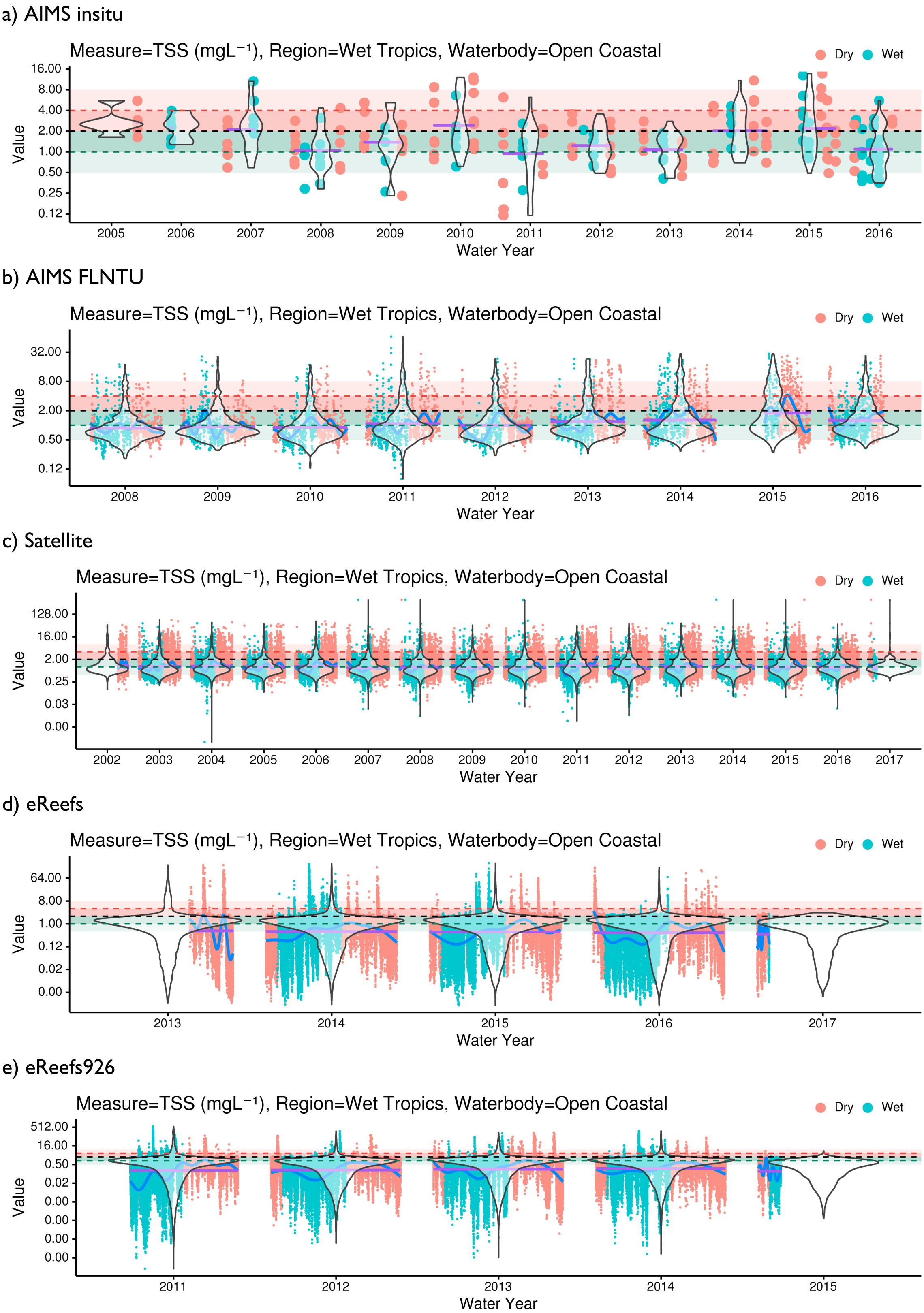


Figure 6: Observed (logarithmic axis with violin plot overlay) TSS data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) AIMS FLNTU, c) Satellite, d) eReefs and e) eReefs926. Observations are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Blue smoother represents Generalized Additive Mixed Model within a water year and purple line represents average within the water year. Horizontal red, black and green dashed lines denote the twice threshold, threshold and half threshold values respectively. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

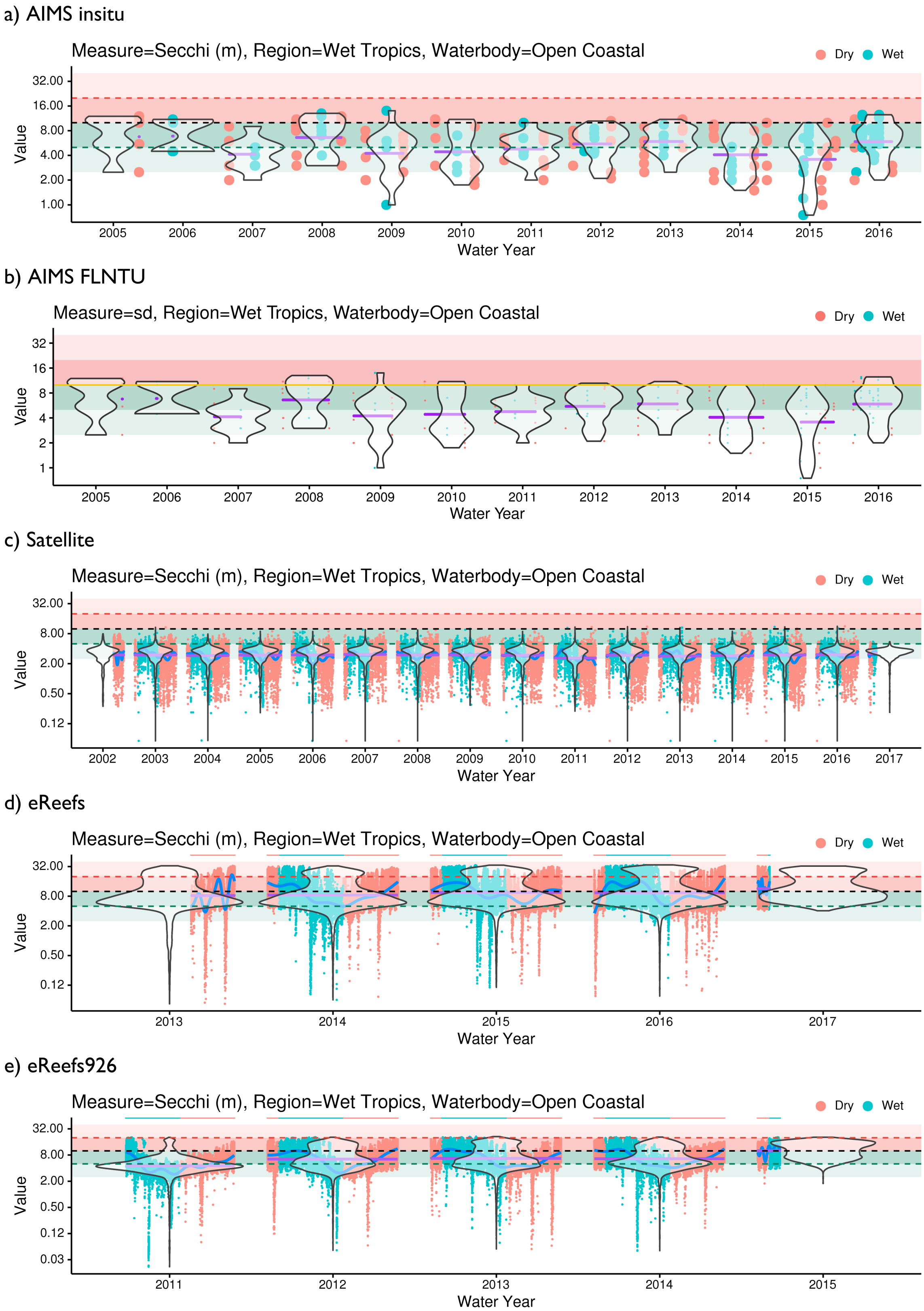
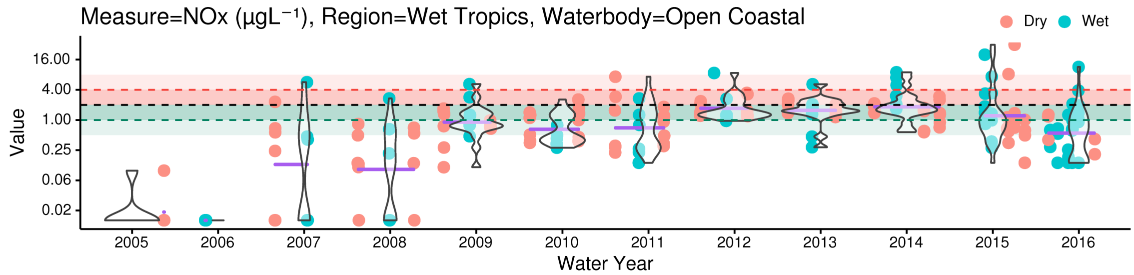
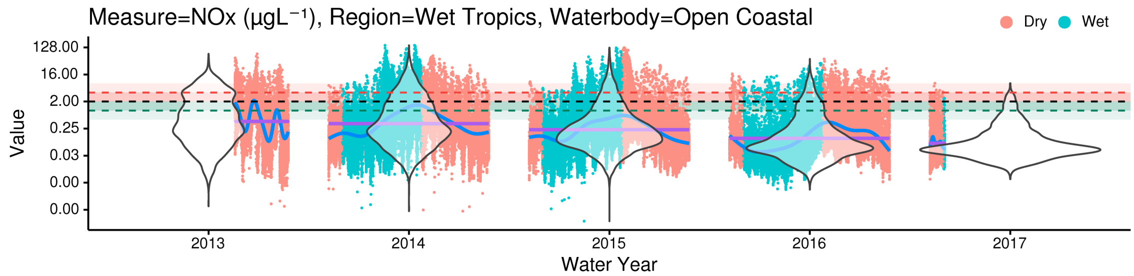


Figure 7: Observed (logarithmic axis with violin plot overlay) Secchi depth data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) AIMS FLNTU, c) Satellite, d) eReefs and e) eReefs926. Observations are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Blue smoother represents Generalized Additive Mixed Model within a water year and purple line represents average within the water year. Horizontal red, black and green dashed lines denote the twice threshold, threshold and half threshold values respectively. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

a) AIMS insitu



b) eReefs



c) eReefs926

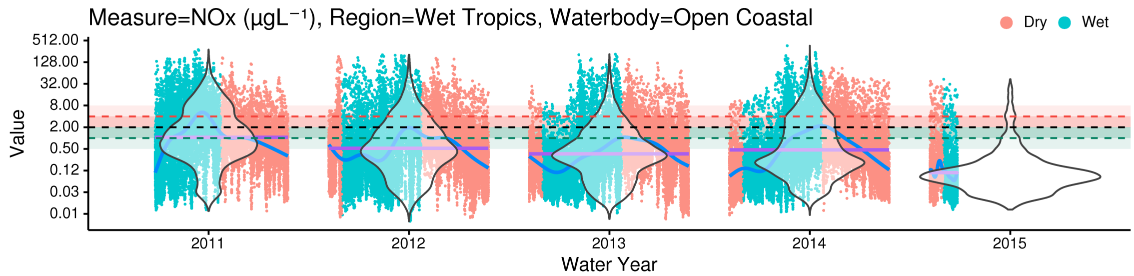


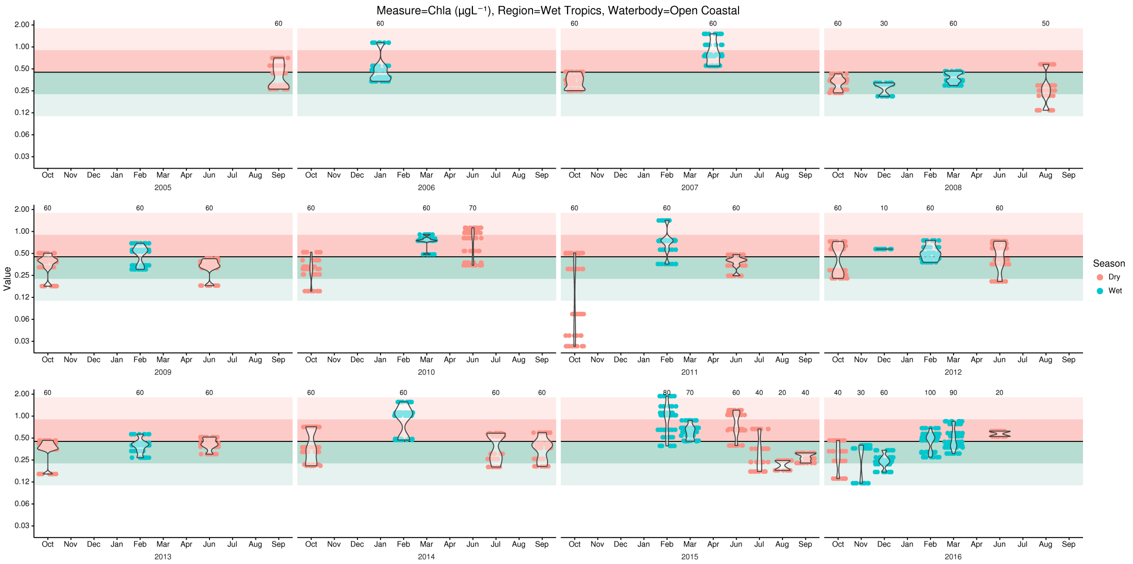
Figure 8: Observed (logarithmic axis with violin plot overlay) NOx data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) eReefs and c) eReefs926. Observations are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Blue smoother represents Generalized Additive Mixed Model within a water year and purple line represents average within the water year. Horizontal red, black and green dashed lines denote the twice threshold, threshold and half threshold values respectively. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

4.3 Monthly data

Figures 9 – 14 provide finer temporal resolution by displaying the temporal distribution of Chlorophyll-a, TSS, Secchi depth and NOx observations for the each month within Wet Tropics Open Coastal Zone from AIMS insitu, AIMS FLNTU, Satellite, eReefs and eReefs926 sources. Additional combinations of Measure/Zone/Source can be found in Figures ??–??.

The monthly violin plots do not add any additional insights with respect to understanding the characteristics of the underlying data to help guide the selection of appropriate indexation formulation or perhaps even Measure/Source selection. Rather, they provide a less compacted view of the underlying data from which patterns highlighted in Section ?? might be more easily appreciated.

a) AIMS insitu



b) AIMS FLNTU

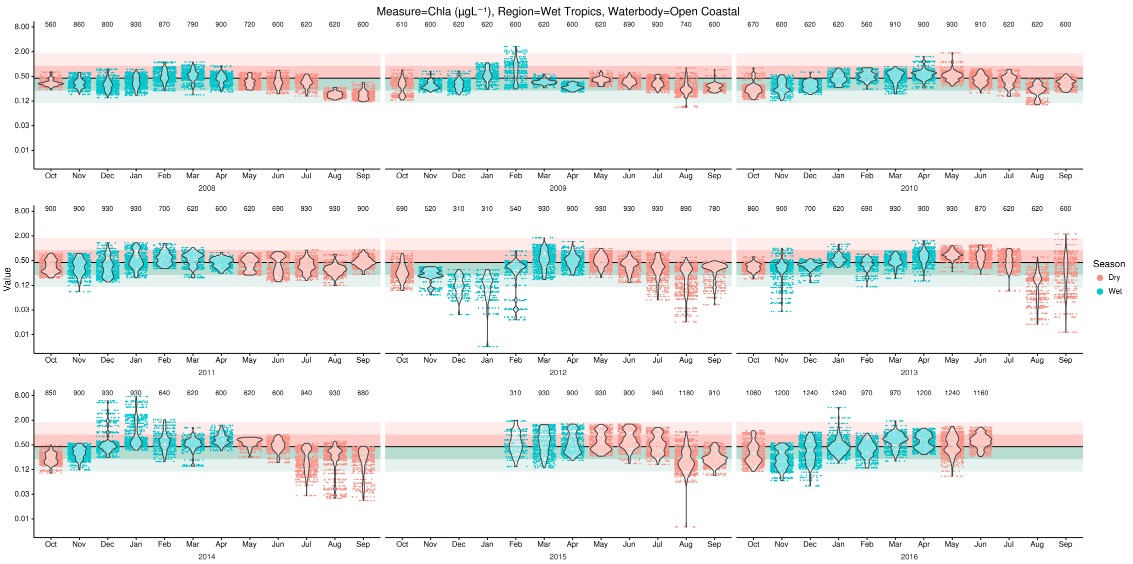
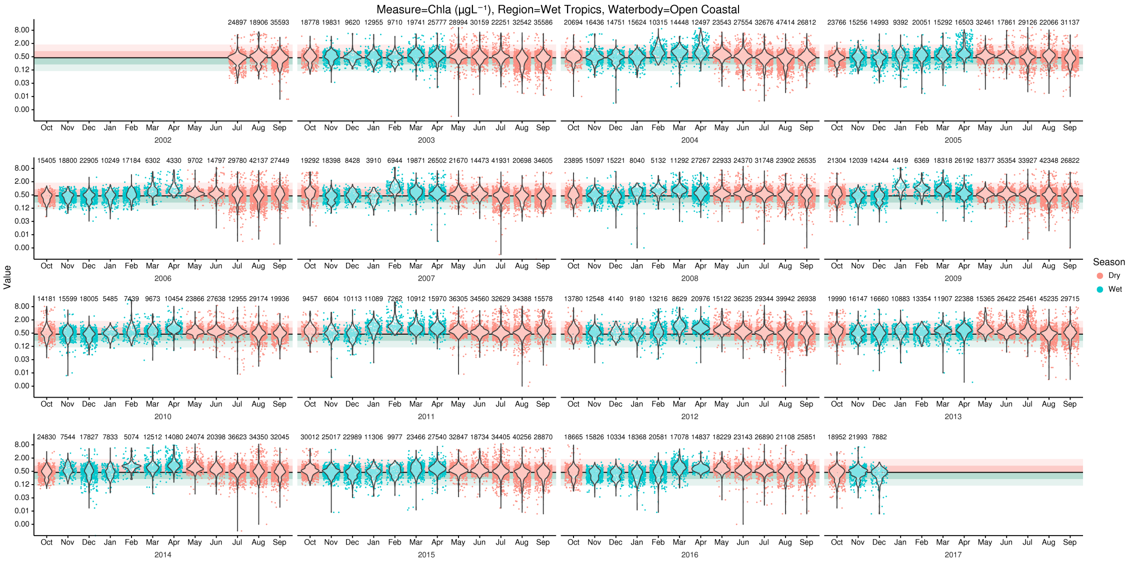


Figure 9: Observed (logarithmic axis with violin plot overlay) Chlorophyll-a data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) AIMS FLNTU. Observations grouped into months are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Sample sizes represented as numbers above violins and horizontal black dashed line denotes threshold value. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

a) Satellite



b) eReefs

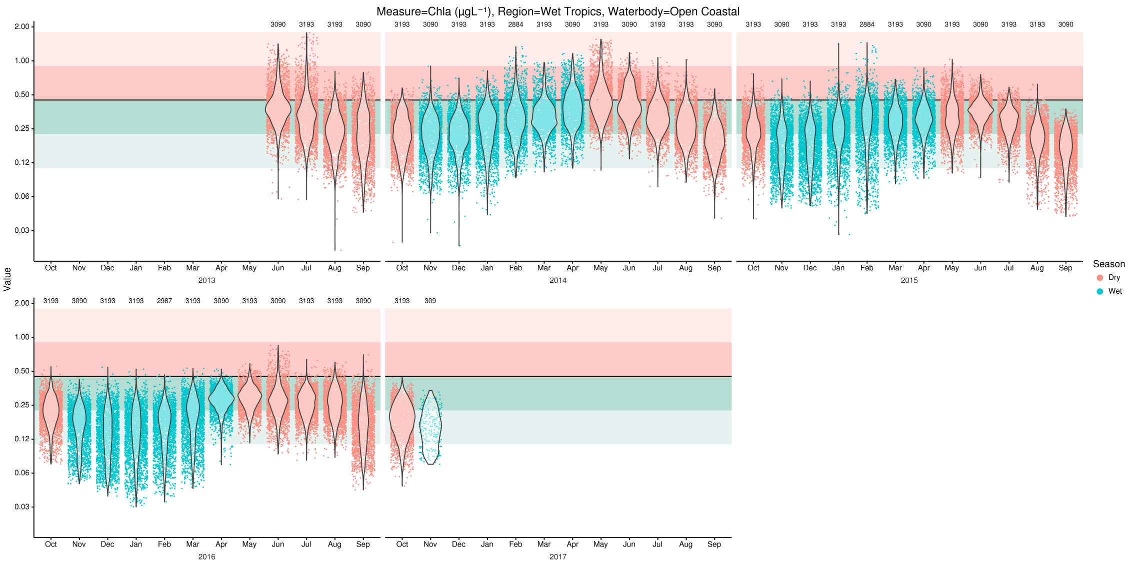
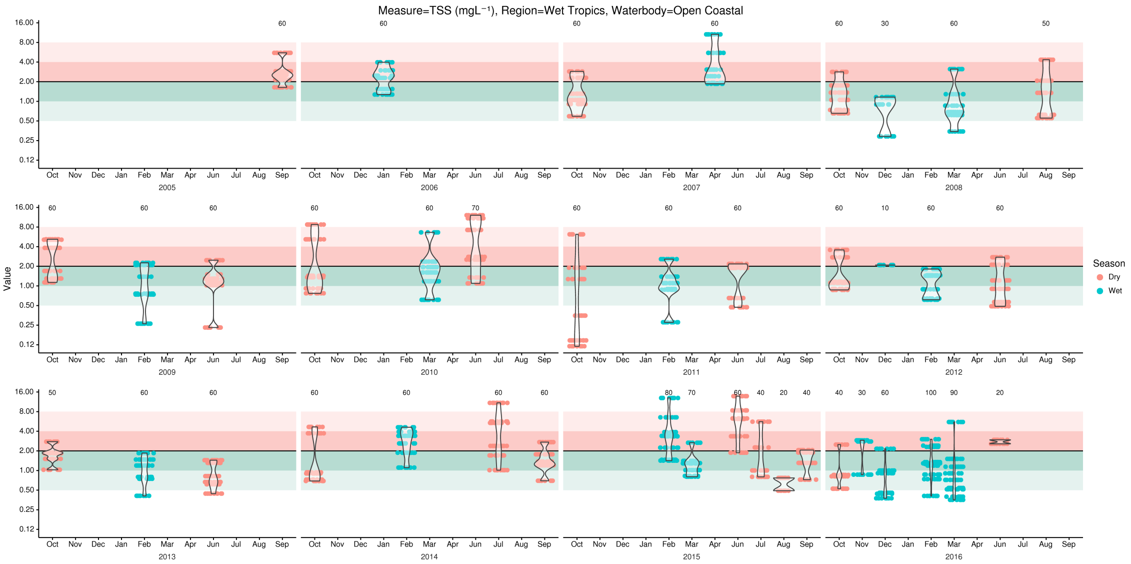


Figure 10: Observed (logarithmic axis with violin plot overlay) Chlorophyll-a data for the Wet Tropics Open Coastal Zone from a) Satellite, b) eReefs. Observations grouped into months are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Sample sizes represented as numbers above violins and horizontal black dashed line denotes threshold value. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

a) AIMS insitu



b) AIMS FLNTU

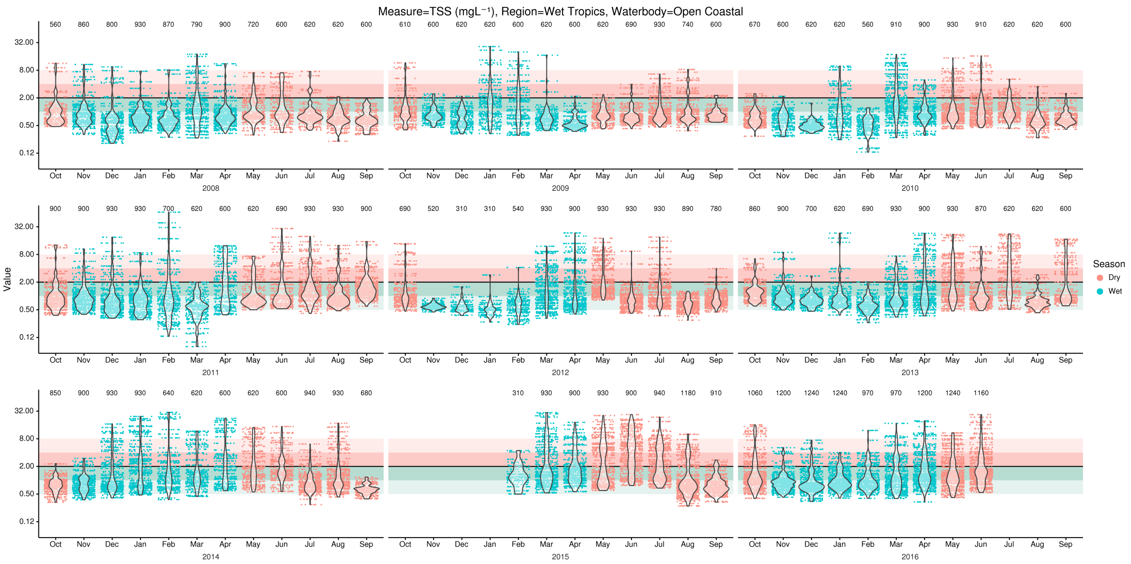
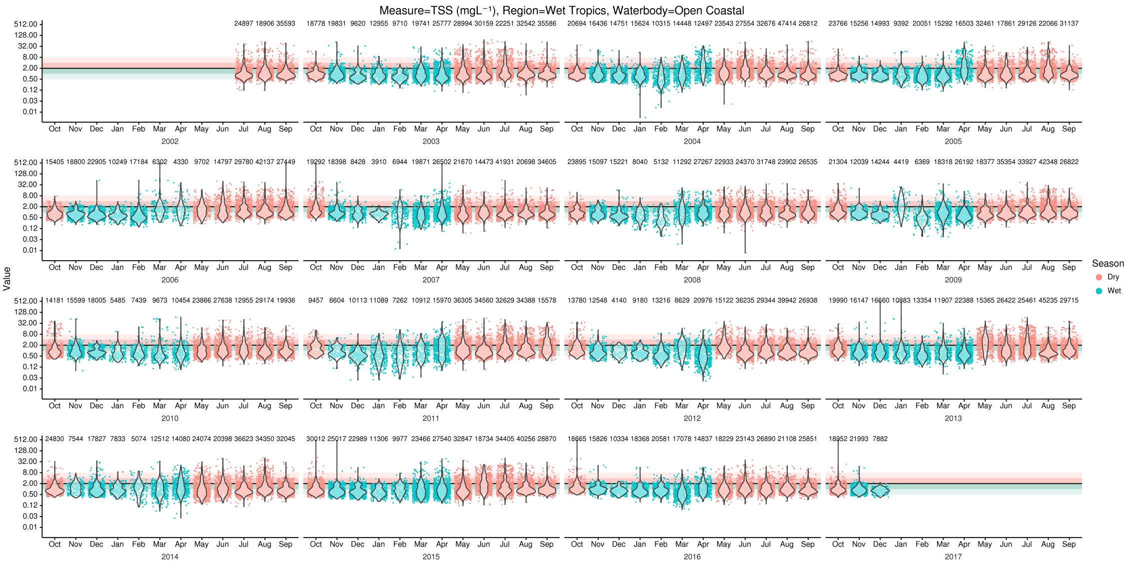


Figure 11: Observed (logarithmic axis with violin plot overlay) TSS data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) AIMS FLNTU. Observations grouped into months are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Sample sizes represented as numbers above violins and horizontal black dashed line denotes threshold value. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

a) Satellite



b) eReefs

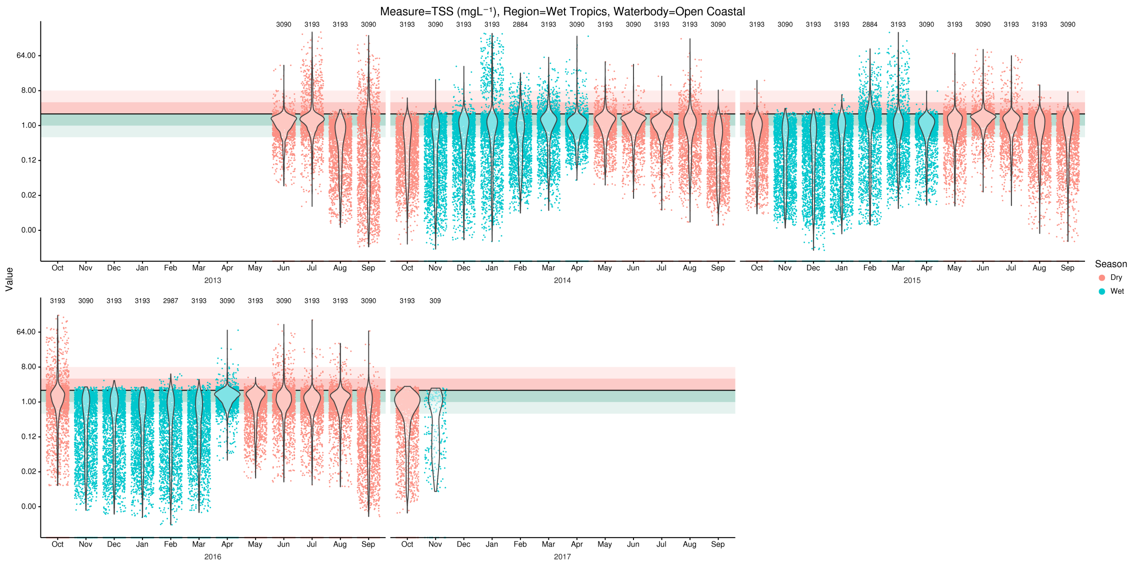
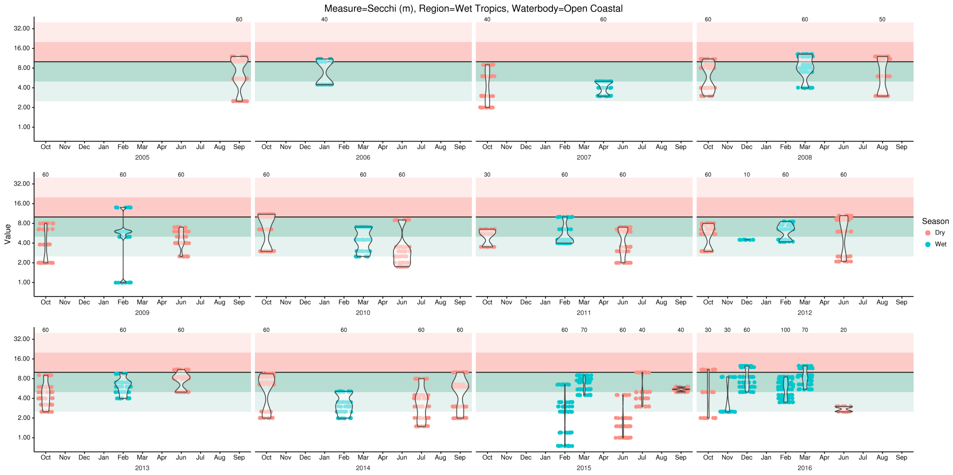
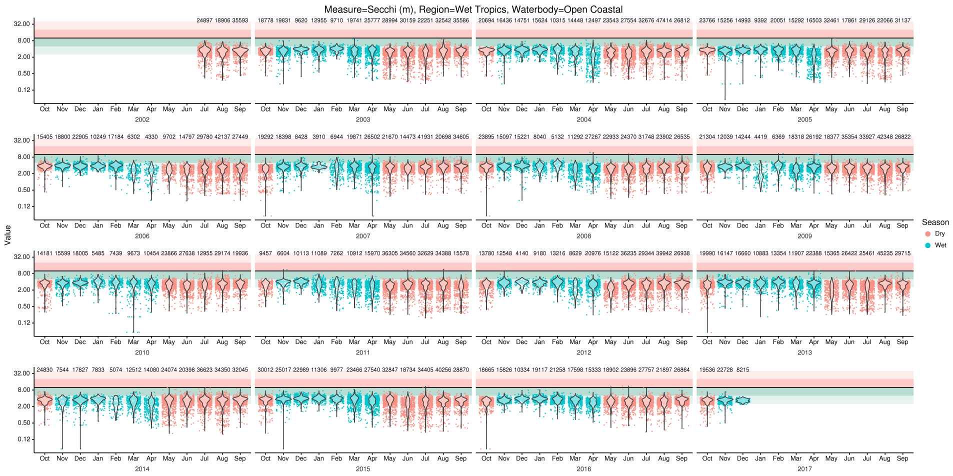


Figure 12: Observed (logarithmic axis with violin plot overlay) TSS data for the Wet Tropics Open Coastal Zone from a) Satellite, b) eReefs. Observations grouped into months are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Sample sizes represented as numbers above violins and horizontal black dashed line denotes threshold value. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

a) AIMS insitu



b) Satellite



c) eReefs

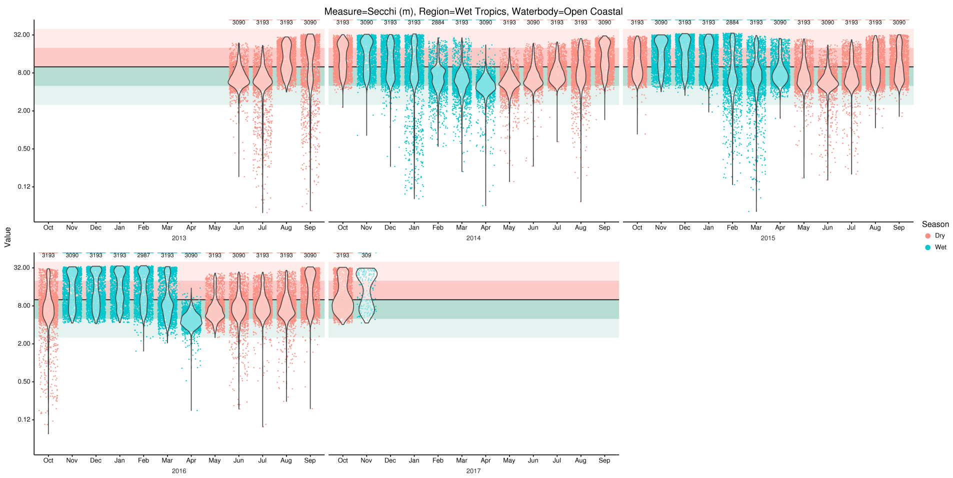
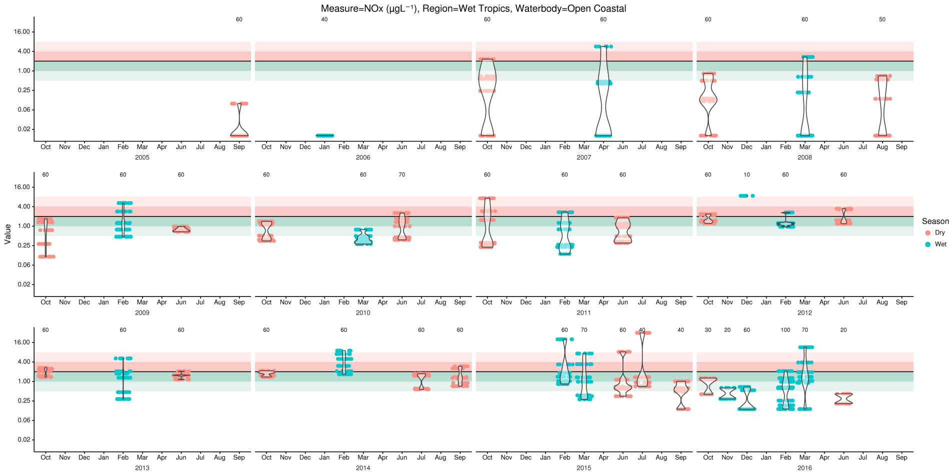
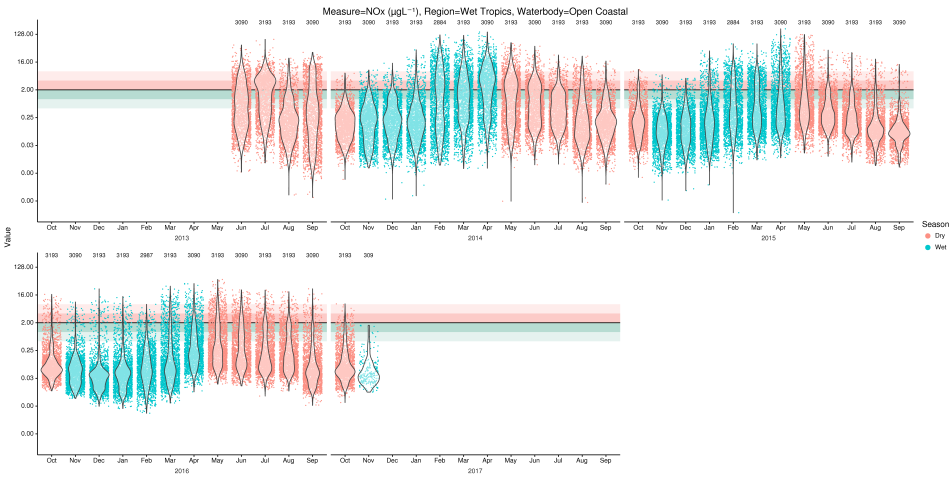


Figure 13: Observed (logarithmic axis with violin plot overlay) Secchi depth data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) Satellite and c) eReefs. Observations grouped into months are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Sample sizes represented as numbers above violins and horizontal black dashed line denotes threshold value. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

a) AIMS insitu



b) eReefs



c) eReefs926

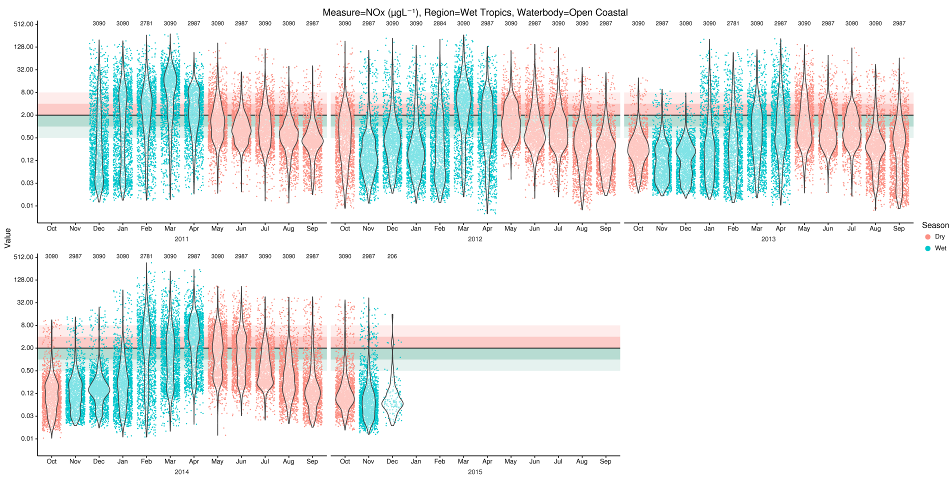


Figure 14: Observed (logarithmic axis with violin plot overlay) Secchi depth data for the Wet Tropics Open Coastal Zone from a) AIMS insitu, b) eReefs c) eReefs926. Observations grouped into months are ordered over time and colored conditional on season as Wet (blue symbols) and Dry (red symbols). Sample sizes represented as numbers above violins and horizontal black dashed line denotes threshold value. Red and green background shading indicates the range (10% shade: $\times 4, /4$, 30% shade: $\times 2, /2$) above and below threshold respectively.

4.4 Spatial data

Figures 15 – 22 explore the spatio-temporal patterns in observed data from a finer spatial perspective (focussing on just the Wet Tropics Open Coastal and Dry Tropics Midshelf Zones). These figures highlight the disparity in resolution between the different data sources. The AIMS insitu data is spatially very sparse [1]. The Satellite data has the most extensive spatial resolution and notwithstanding the many gaps due to various optical interferences (such as cloud cover), also has the greatest temporal coverage.

For the selected Zones and span of water years, there is little evidence of a major latitudinal gradient in Satellite Chlorophyll-a with most of any change (if any) occurring across the shelf. Indeed, Satellite parameters are relatively constant over space and time for the Dry Tropics Midshelf Zone (see Figs. 19–21b). Moreover, the spatial patterns of Satellite derived Chlorophyll-a and TSS appear relatively invariant between years (see Figs.15–21b).

The eReefs and eReefs926 do show some variability in spatial and temporal Chlorophyll-a and Secchi depth (see Figs. 15c-d,17c-d,19c-d and 21c-d), yet relatively little for TSS and NOx (at least for Dry Tropics Midshelf).

[1] the AIMS FLNTU logger data is even more sparse and thus is not shown.

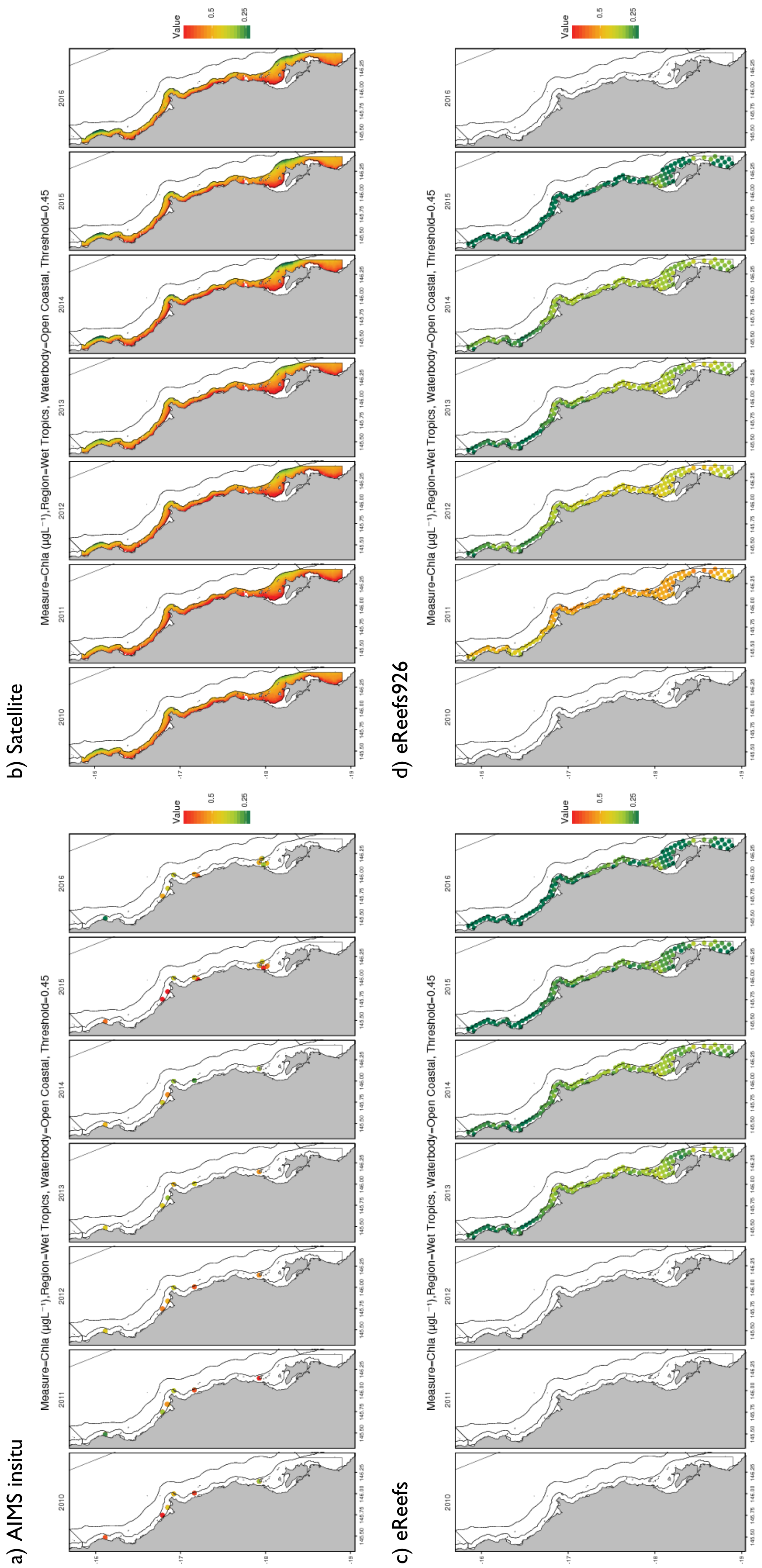


Figure 15: Spatial distribution of observed a) AIMS insitu, b) Satellite, c) eReefs and d) eReefs926 Chlorophyll-a (2009–2016) for the Wet Tropics Open Coastal Zone.

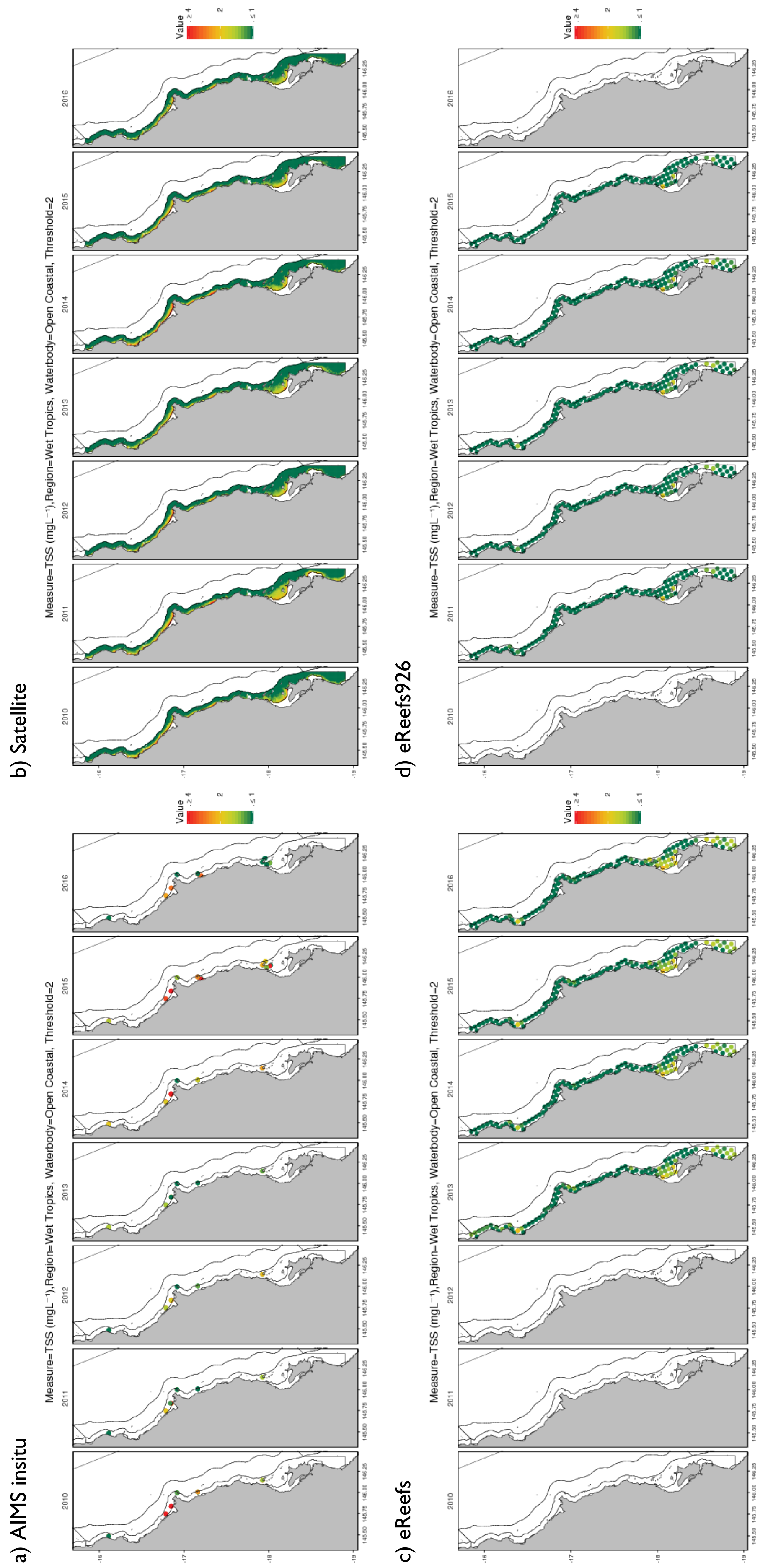


Figure 16: Spatial distribution of observed a) AIMS insitu, b) Satellite, c) eReefs and d) eReefs926 TSS (2009–2016) for the Wet Tropics Open Coastal Zone.

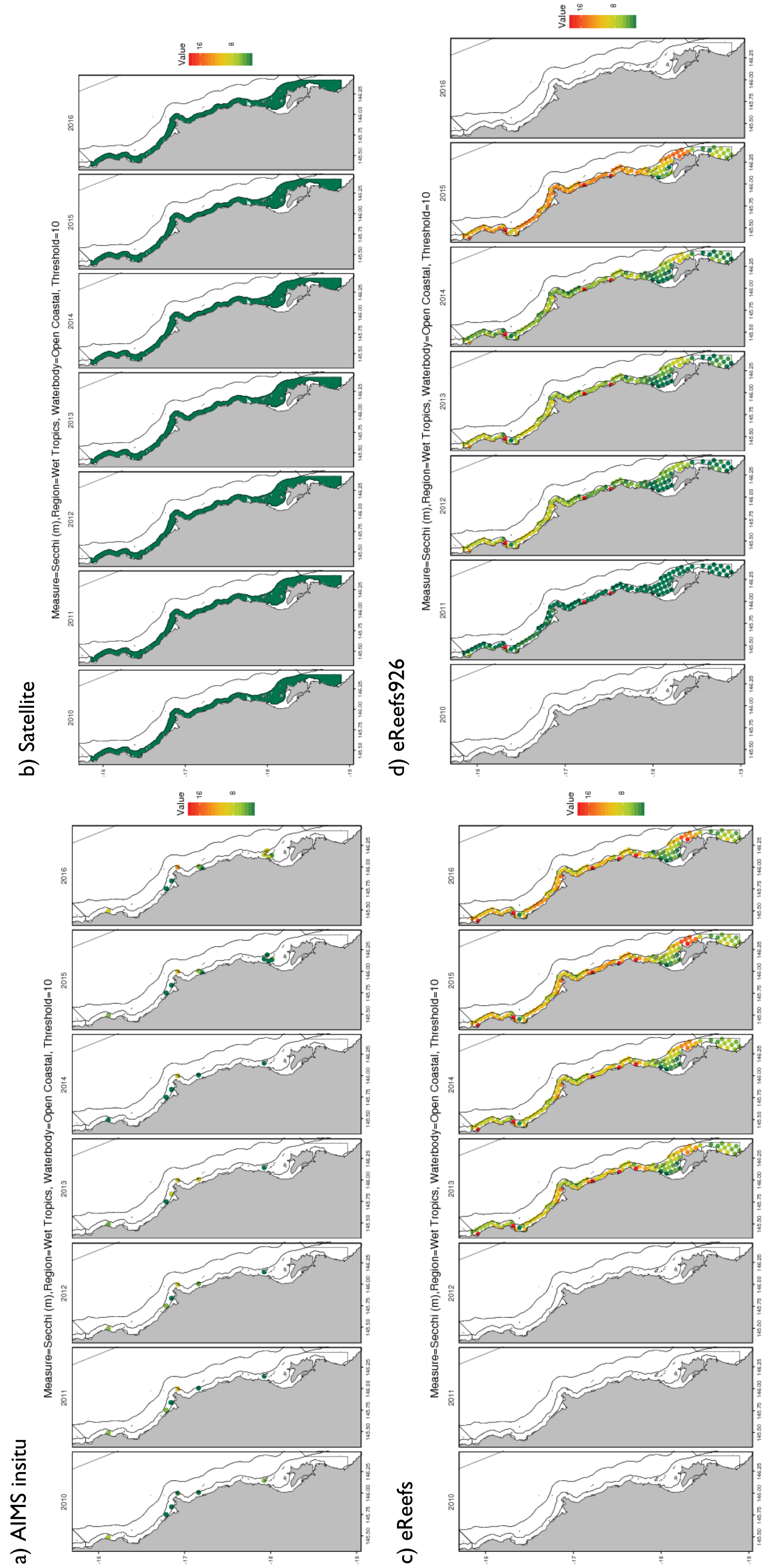


Figure 17: Spatial distribution of observed a) AIMS insitu, b) Satellite, c) eReefs and d) eReefs926 Secchi depth (2009–2016) for the Wet Tropics Open Coastal Zone.

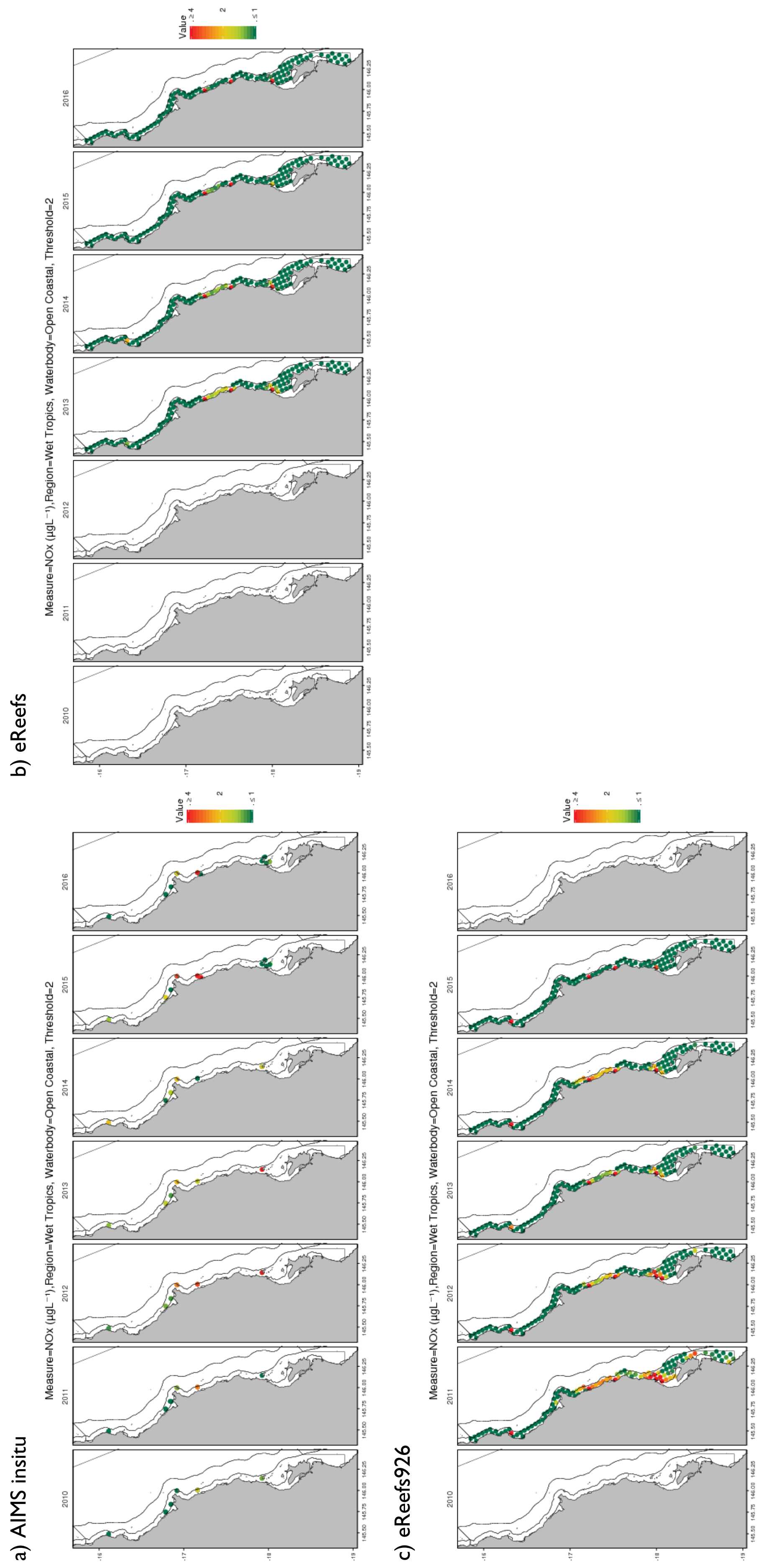


Figure 18: Spatial distribution of observed a) AIMS insitu, b) eReefs and c) eReefs926 NOx (2009–2016) for the Wet Tropics Open Coastal Zone.

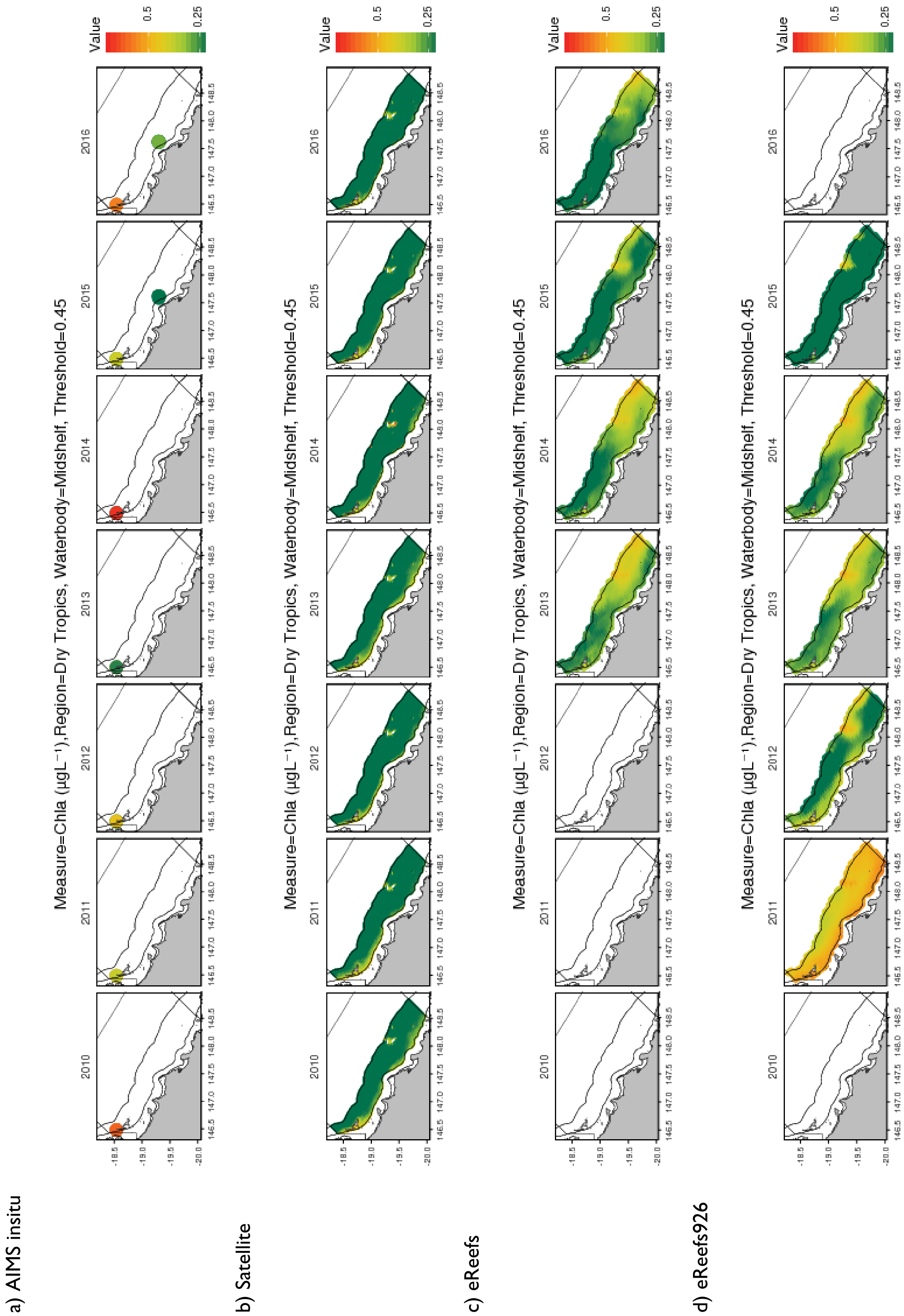


Figure 19: Spatial distribution of observed a) AIMS insitu, b) Satellite, c) eReefs and d) eReefs926 Chlorophyll-a (2009–2016) for the Dry Tropics Midshelf Zone.

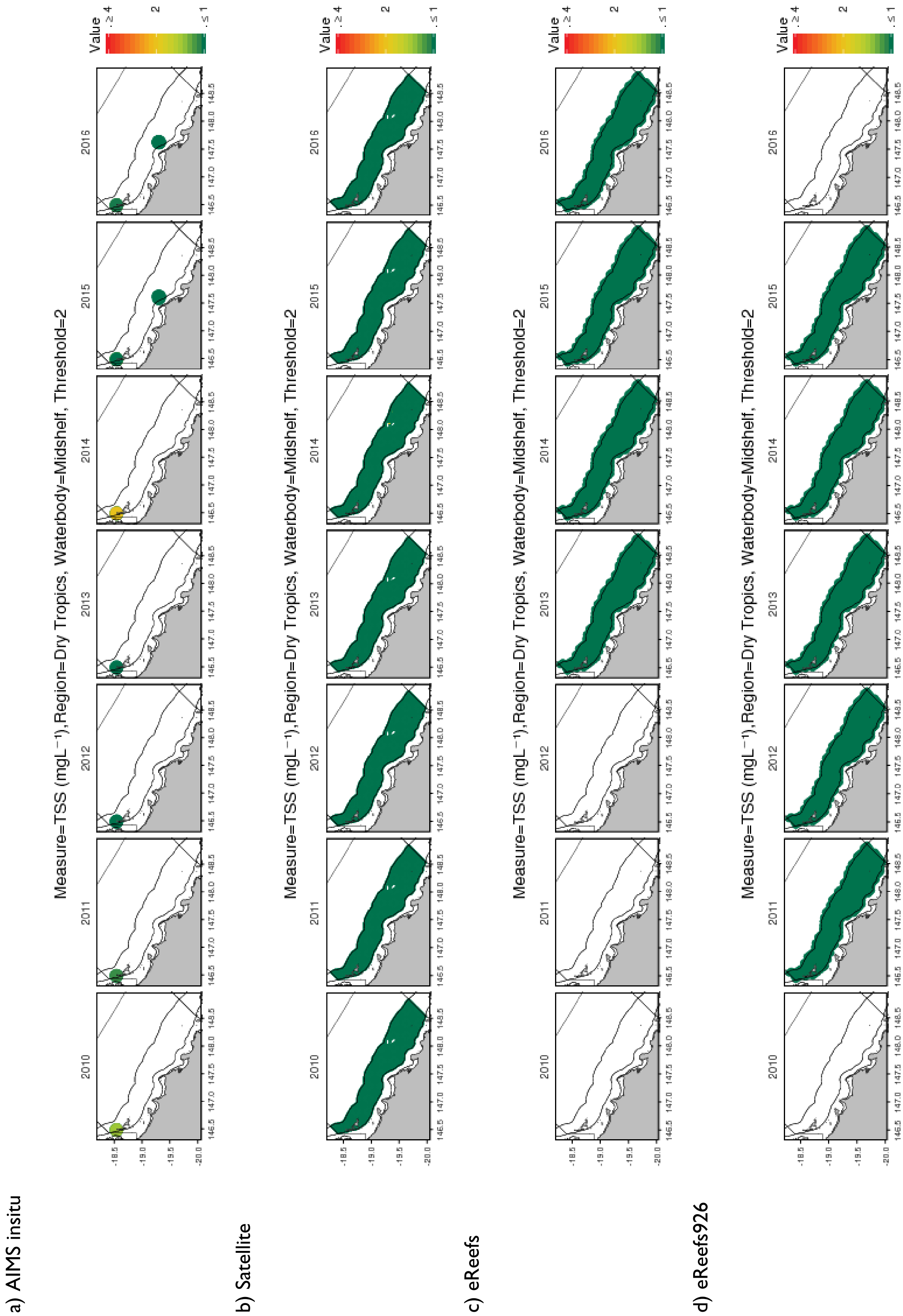


Figure 20: Spatial distribution of observed a) AIMS insitu, b) Satellite, c) eReefs and d) eReefs926 TSS (2009–2016) for the Dry Tropics Midshelf Zone.

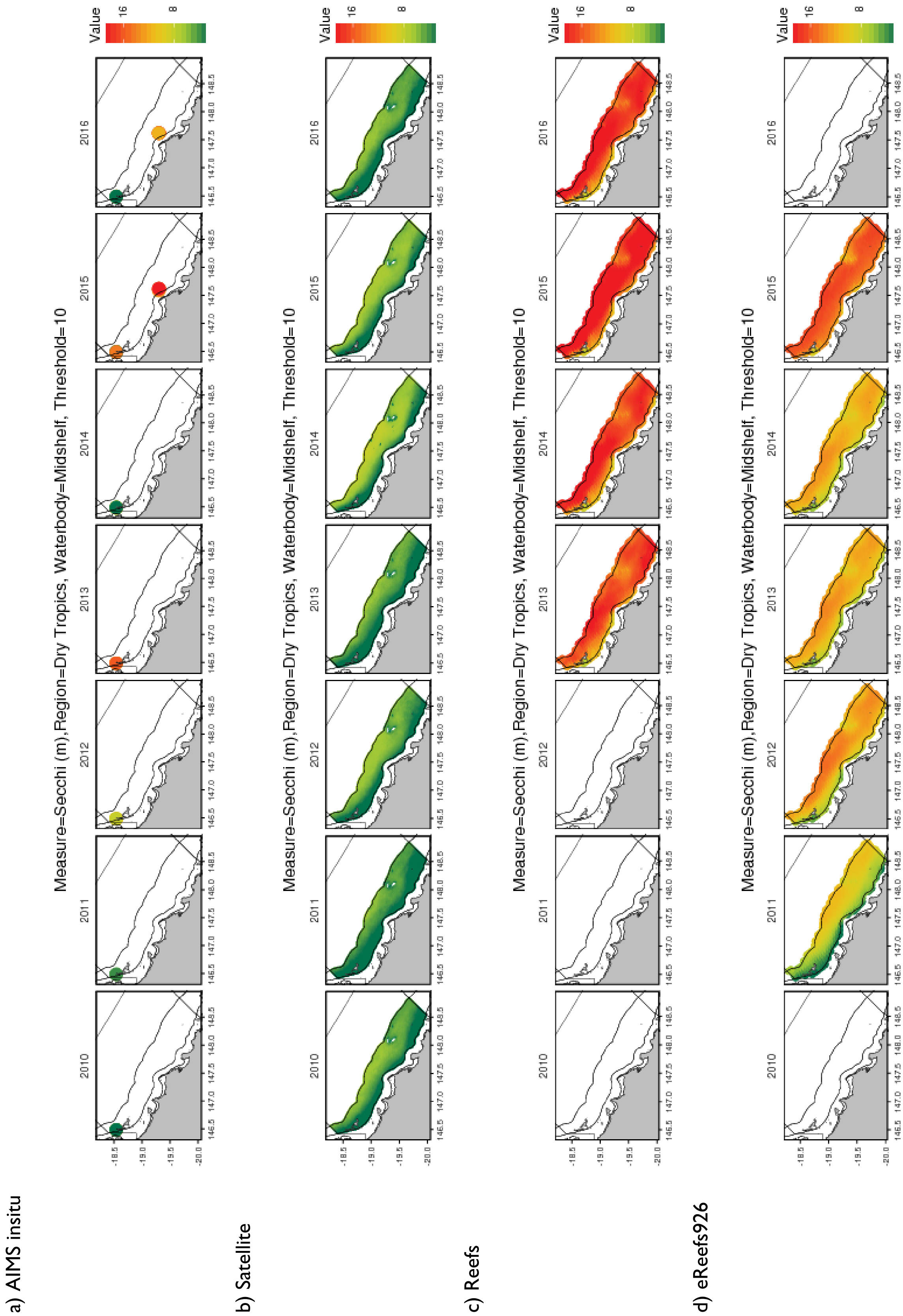
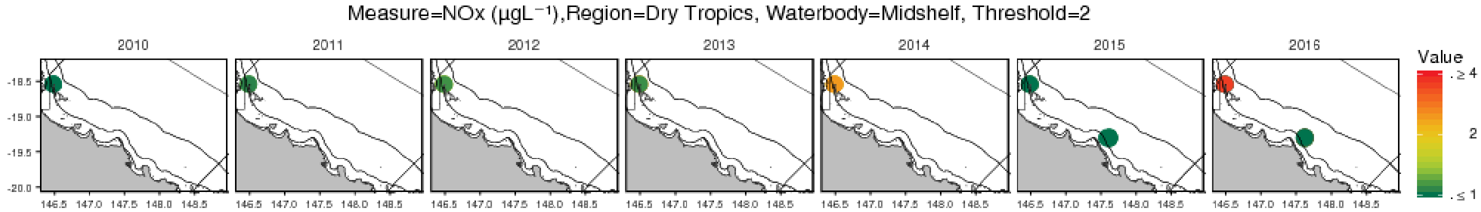
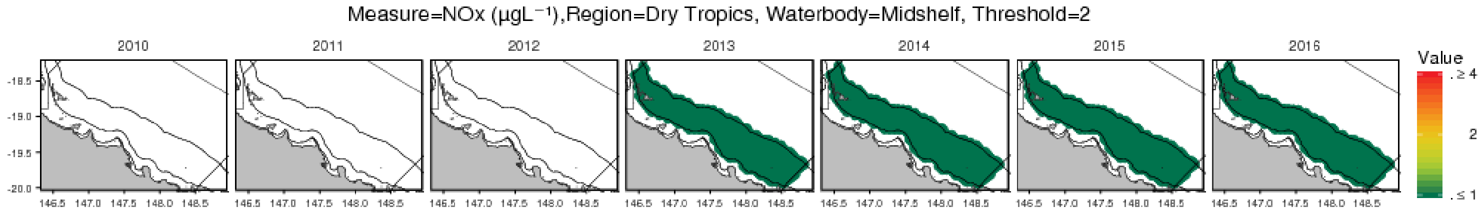


Figure 21: Spatial distribution of observed a) AIMS insitu, b) Satellite, c) eReefs and d) eReefs926 Secchi depth (2009–2016) for the Dry Tropics Midshelf Zone.

a) AIMS insitu



b) Reefs



c) eReefs926

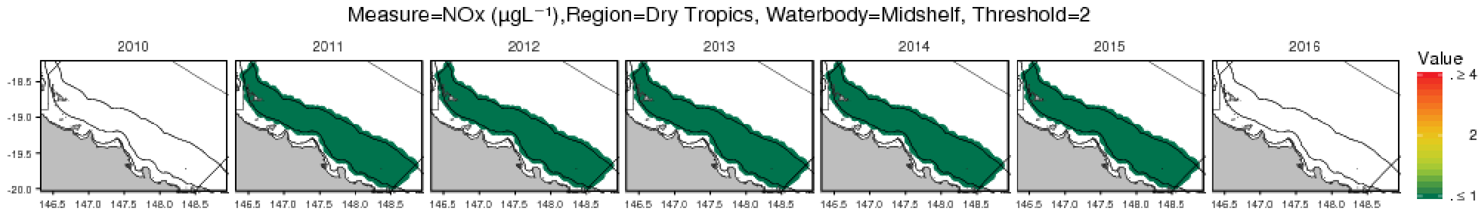


Figure 22: Spatial distribution of observed a) AIMS insitu, b) eReefs and c) eReefs926 NOx (2009–2016) for the Dry Tropics Midshelf Zone.

4.5 Comparison of data sources

5. INDEX METRICS

5.1 Theoretical framework

5.2 Multivariate health indicators

5.3 Thresholds

5.4 Unifying indices

5.5 Hierarchical indices

5.6 Summary of adopted methodologies

5.7 Index sensitivity

5.8 Index explorations

5.9 Indices

5.10 Sources

5.11 Exploration of Measures

5.12 Measure/Site

5.13 Summary of recommendations

6. HIERARCHICAL AGGREGATIONS

6.1 Theoretical framework

6.2 Bootstrap aggregation

6.3 Beta approximation

6.4 Weights

6.5 Expert interventions

6.6 Scores and Grades

6.7 Certainty rating

6.8 Confidence intervals

6.9 Summary of adopted methodologies

6.10 Aggregation summaries

6.10.1 Measure/Zone

6.10.2 Indicator/Site

6.10.3 Indicator/Zone

6.11 Summary of recommendations

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