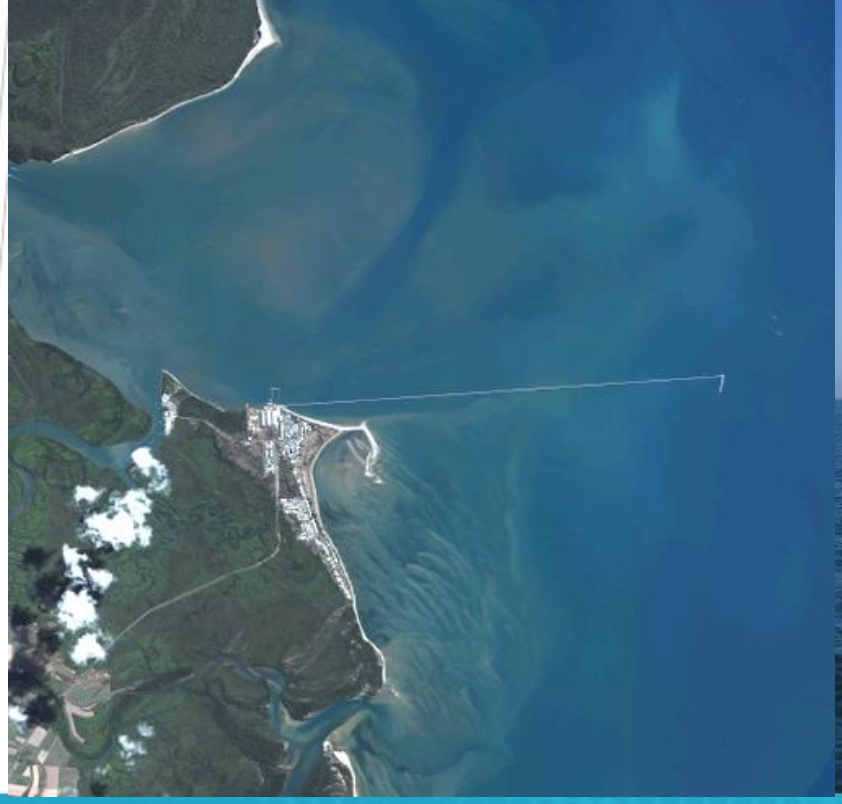

www.csiro.au

Overview coastal-ocean colour cal-val Australia

Vittorio Brando, Rex Keen, Paul Daniel, Adam Baumeister, Matt Nethery, Henry Baumeister, Aaron Hawdon, Garry Swan, Ross Mitchell, Susan Campbell, Thomas Schroeder, Young Je Park, Rebecca Edwards, Andy Steven, Simon Allen, Lesley Clementson, Arnold Dekker

IMOS Integrated Marine Observing System

Lucinda Jetty Coastal Observatory (LJCO)

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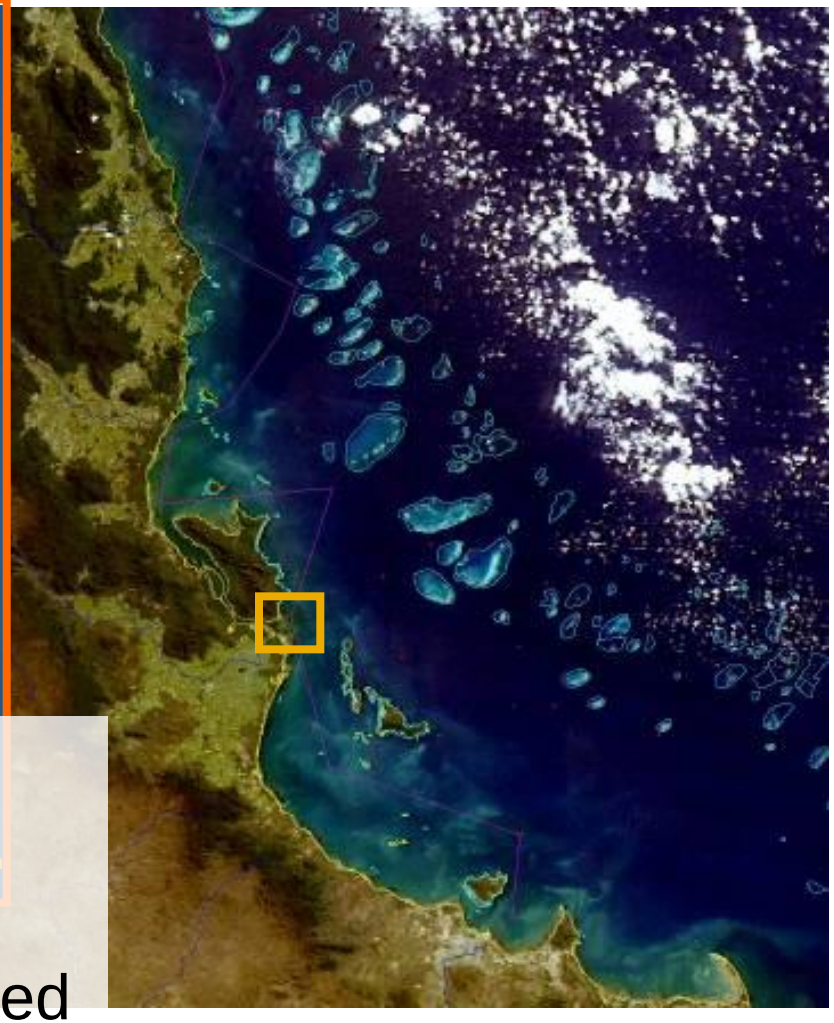
Contents

- The Lucinda Jetty Coastal Observatory (LJCO)- data on MERMAID ☺
- MERIS Products validation in Great Barrier Reef
- DALEC: Dynamic Above water radiance (L) and irradiance (E) Collector (DALEC) hyperspectral radiometer

Introduction

- The Lucinda Jetty Coastal Observatory (LJCO) was established as part of Australia's Integrated Marine Observing System (IMOS
- LJCO provides a continuous time series of above water radiometry and below water optical measurements in these complex coastal waters for improving and validating coastal and continental shelf remotely-sensed satellite ocean colour products.

The Lucinda Jetty Coastal Observatory



The location of the LJCO is ideal to monitor and characterize the optical properties in a coastal system where the sources of particulate and dissolved matter substantially vary during the tidal and seasonal cycles.

IMOS Integrated Marine Observing System

Lucinda Jetty Coastal Observatory (LJCO)

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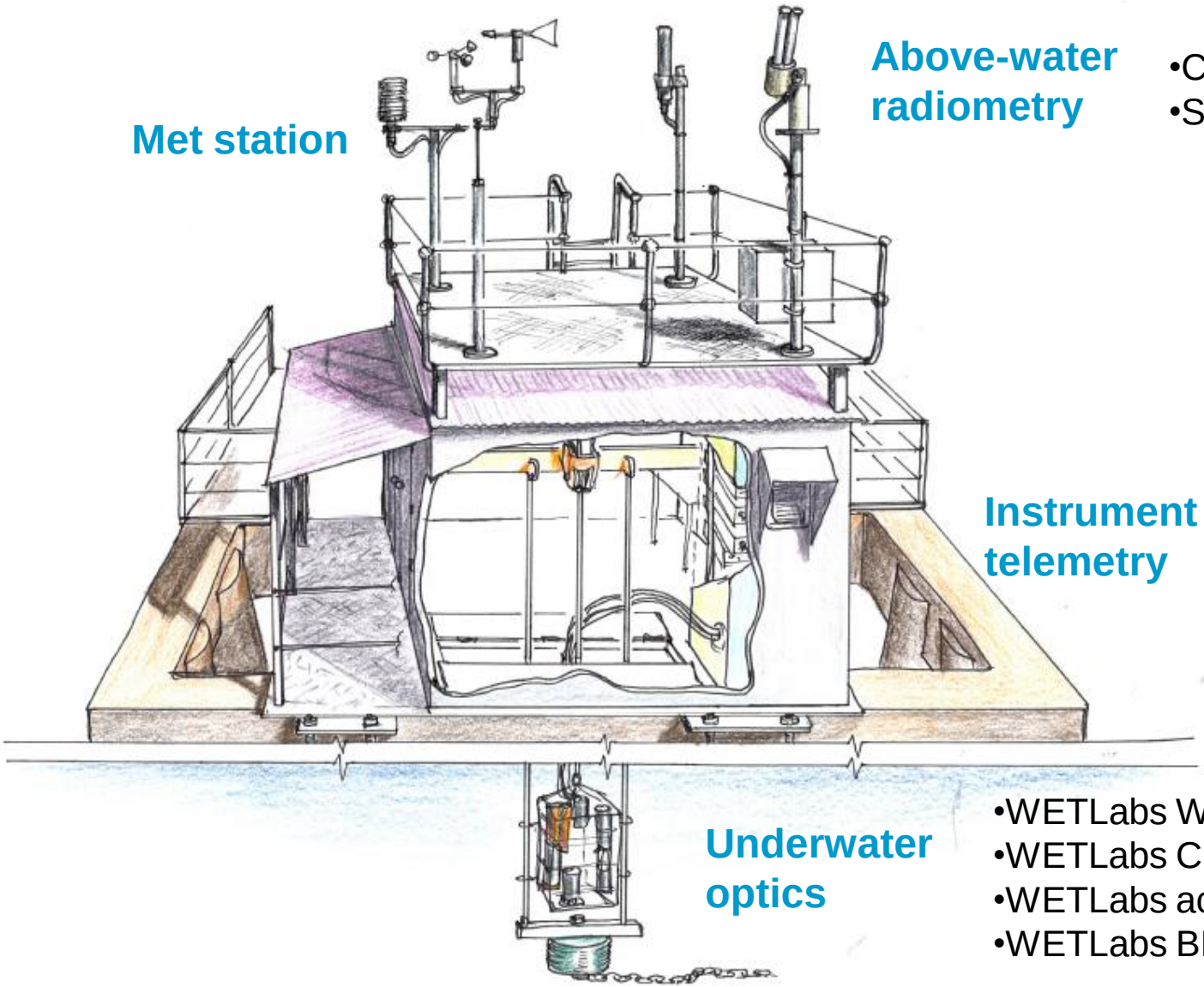
Lucinda Jetty from the water

Lucinda Jetty: Northern Dolphin

Lucinda Jetty: Northern Dolphin

Sketch of LJCO facility



Met station

Above-water radiometry

- CIMEL SeaPRISM
- Satlantic HyperOCR

Instrument telemetry

- Power supply
- UPS
- NextG Router
- Linux Server
- WETLabs DAPCS
- PC controller
- Automated winch

Underwater optics

- WETLabs WQM
- WETLabs CDOM fluorometer
- WETLabs ac-s
- WETLabs BB9

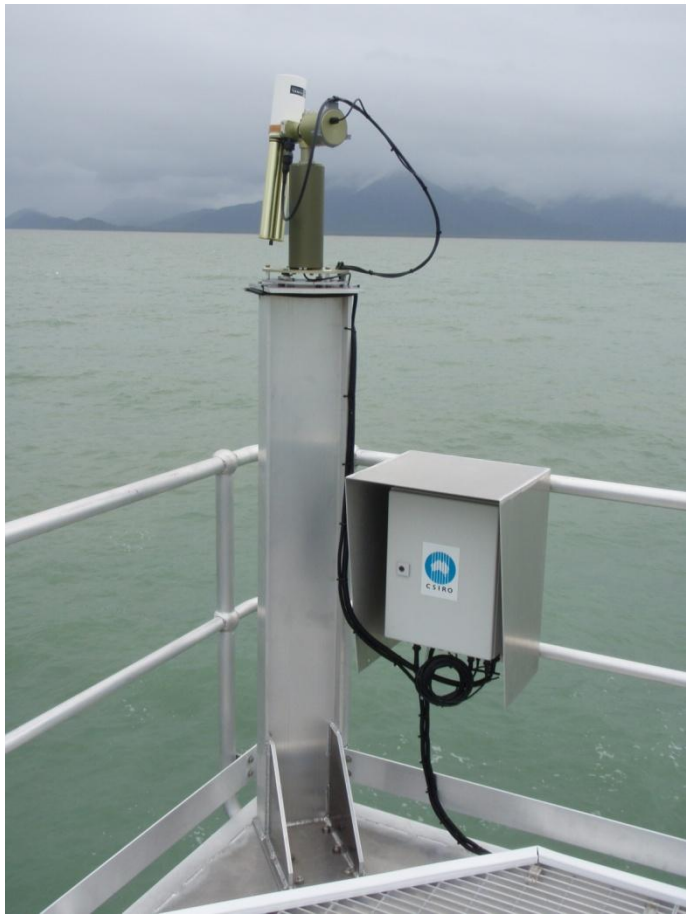
em CSIRO

LJCO facility

Instrumentation:
Above-water radiometry and aerosol characterization

CIMEL-SeaPRISM

- a CIMEL CE-318 automated sunphotometer modified to perform above-water radiometric measurements in addition to the regular atmospheric measurements defined for NASA's Aerosol Robotic Network (AERONET).
- autonomously perform multiple sky- and sea-radiance observations at programmable viewing and azimuth angles at nine centre wavelengths in the 412–1020 nm spectral range.
- SeaPRISM sea-viewing measurements are performed every 15 minutes with the objective of collecting data between 8 AM and 4 PM local time.



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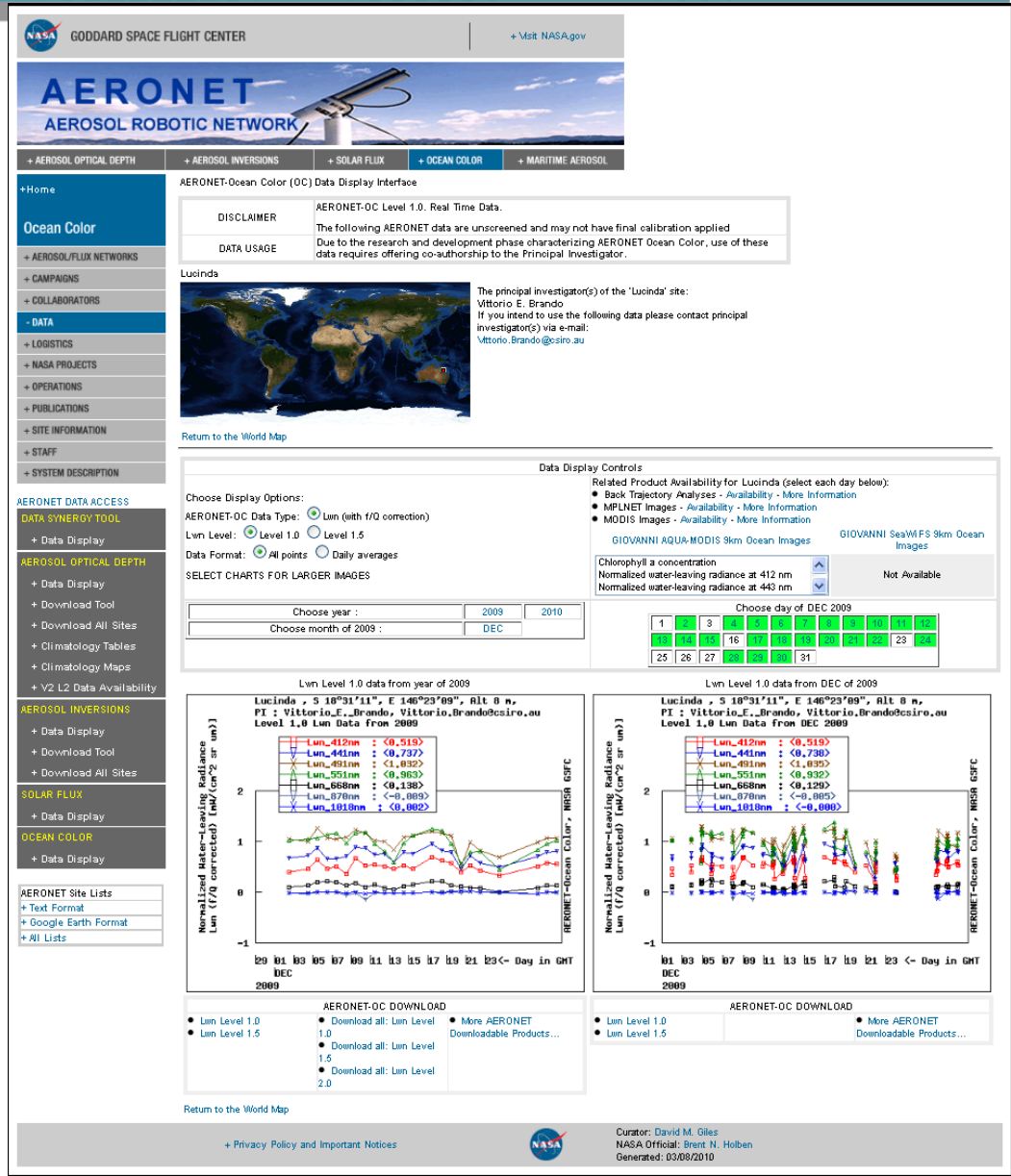
Instrumentation:
Above-water radiometry and aerosol characterization

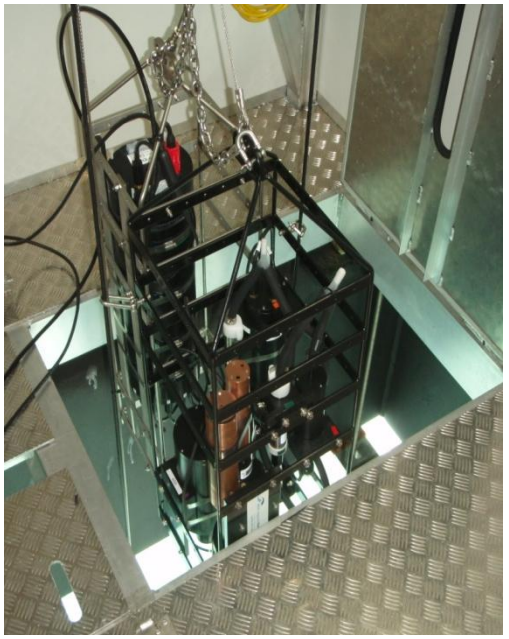
CIMEL-SeaPRISM

- SeaPRISM data is collected, processed following the AERONET-OC common protocols and archived at NASA.
- Derived products are accessible through a Web interface under a specified data policy.



Instrumentation:
inherent optical properties of the water column

- **Optical package is deployed at the Jetty to characterize the Inherent optical properties of these waters:**
  - WET Labs WQM (integrated sensors for conductivity, temperature, pressure, dissolved oxygen, chlorophyll fluorometer, and turbidity)
  - WET Labs Wetstar chromophoric dissolved organic matter (CDOM) fluorometer.
  - One WETLabs ac-s spectral absorption meter (10-cm path length) will used for the acquisition of in situ measures of the total and dissolved absorption and attenuation coefficients. A WETLabs BB9 will be provide measures of total backscattering coefficients.
- **Data is acquired in continuous mode at a nominal depth of ~1.5-2 m .**
- **We have two identical sets to be hot-swapped for maintenance and calibration**

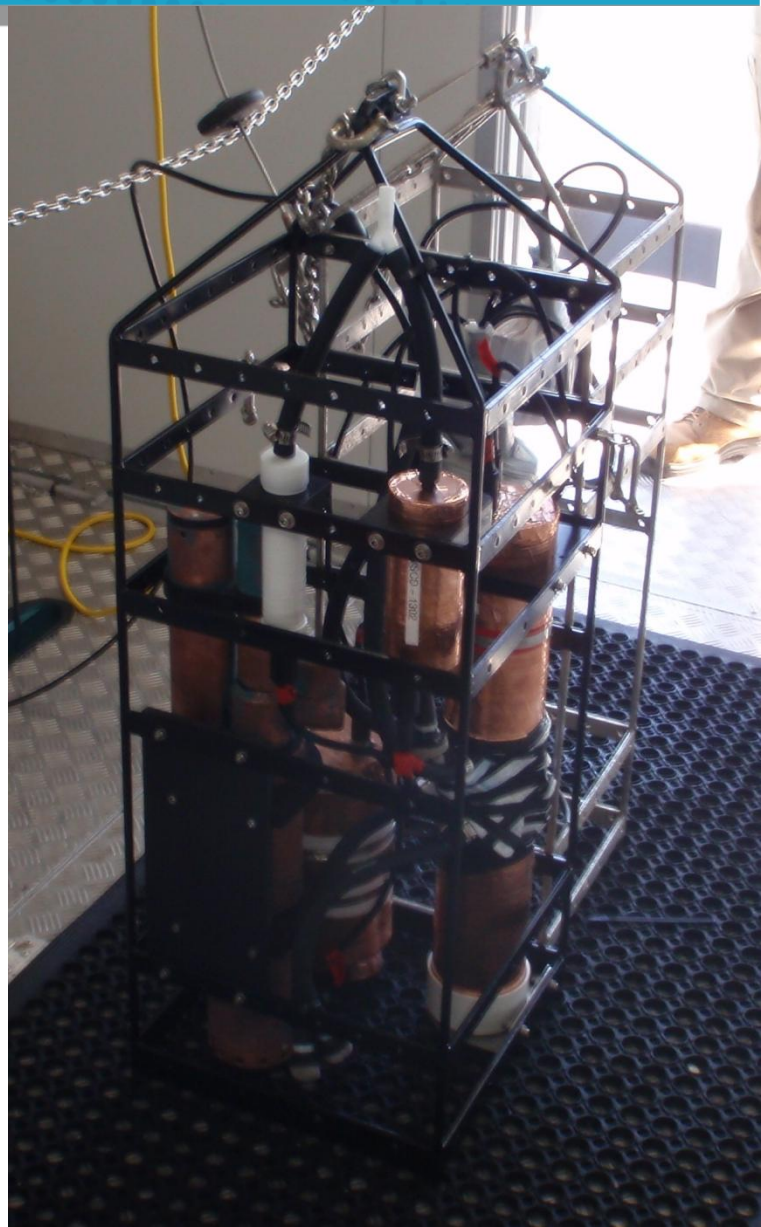


Instrumentation:
ancillary information on weather and sky and sea conditions

- **Weather conditions at the site are measured using a Vaisala WXT520 multi parameter instrument which measures barometric pressure, humidity, precipitation, air temperature, wind speed and direction.**
- **Two hemispherical cameras to capture a full sky view and a sea state information for use in post processing and interpretation of radiometric data**

Maintenance and calibration

- Antibiofouling system
  - Sensor systems are surrounded by copper either by copper shielding or adhesive backed copper tape
  - WETLabs WQM utilizes the bio-wiper™ active cleaning and protection system
- Servicing and calibration
  - The instruments are serviced on a fortnightly basis for cleaning of the SeaPRISM and in water optical packages.
  - The SeaPRISM is calibrated by NASA following the AERONET-OC protocols prior and following each 6-12 months deployment. Only after the post deployment calibration the data will be processed to L2 and released after QA/QC..
  - Following instrument changeover the *in situ* optical instruments are returned to the laboratory for cleaning, calibration and re-application of anti fouling copper coatings.
  - All instruments are tested and calibrated with MilliQ water prior to each deployment.



Discrete measurements of bio-optical and biogeochemical data (ideally) on 1 to 2 week basis

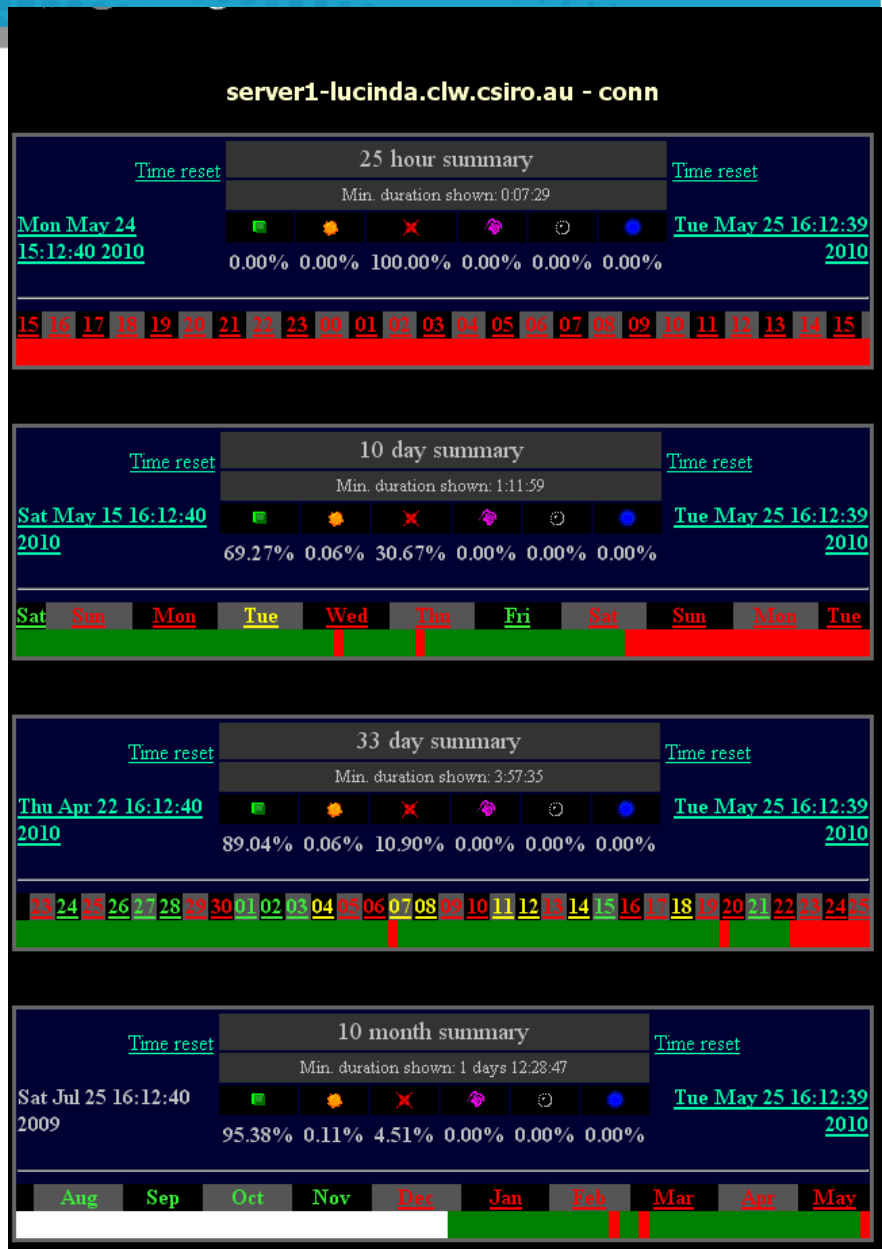
1. **near-water surface sampling**
    1. Biogeochemical data (to match instrument package - performed at CMAR laboratories in Hobart, as for all IMOS reference stations):
        1. phytoplankton pigments by HPLC
        2. total suspended solids (organic and mineral fractions)
        3. Nutrients
        4. TOC, DOC and POC (TBD)
    2. Spectrophotometric light absorption by :
        1. total particulate matter & phytoplankton pigments (providing non-algal particulate matter absorption)
        2. coloured dissolved organic matter.
2. **Underwater light measurements:**
    1. Up and downwelling radiance/irradiance measurements (incl profiles for k_d) with Satlantic Hyper OCS tethered profiling system
    2. LISST-100 particle sizing and refractive index

Data Acquisition and processing Controllers and telemetry

- **Data from all the instruments is acquired in real time or in delayed mode using a mix of instrument controllers, loggers, a rack mounted Dell PowerEdge 2950 Linux Server and an Advantech ARK PC installed in an air-conditioned cabinet (25 C).**
- **Computers and communication devices are powered via a UPS.**
- **Remote control over circuit switching is obtained through the use of a power distribution unit allowing devices to be remotely powered on and off via an Ethernet interface.**

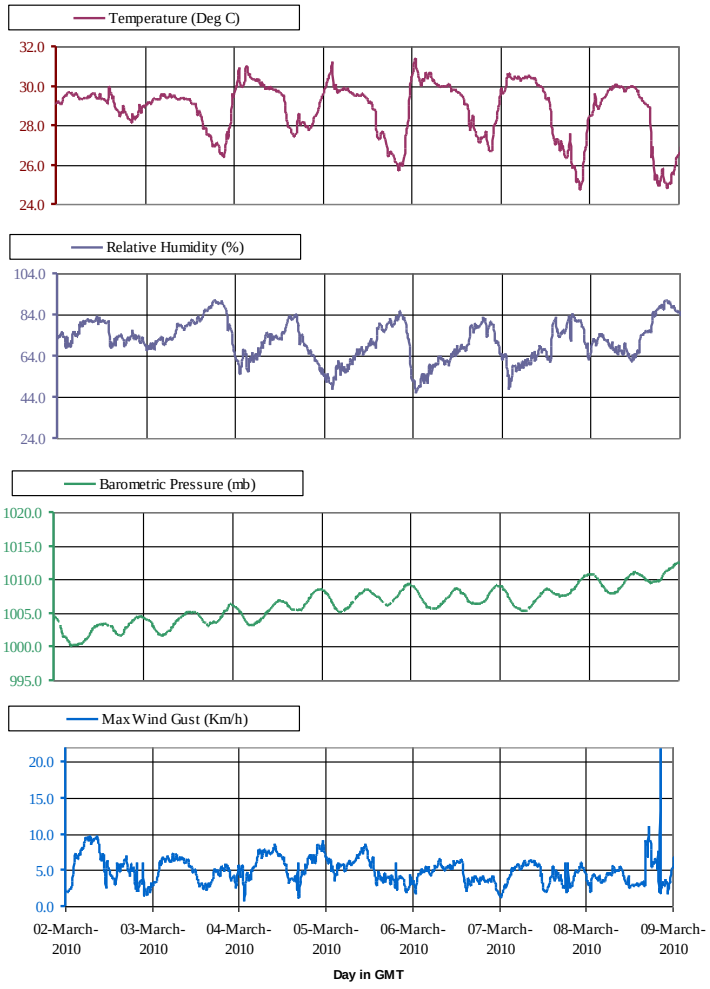
Data Acquisition and processing
Controllers and telemetry

- **Network connectivity is provided thorough a broadband connection on Telstra's NextG Mobile Network.**
- **Static IP addresses are provided to all the devices installed on site by a CISCO VPN gateway allowing direct connection to the CSIRO network for data transfer and acquisition.**
- **Connectivity of all the devices at LJCO to the network is monitored by Big Brother ® network monitoring software. In the event of failure e-mail and SMS alert messages are automatically generated.**



Data Acquisition and processing
Data processing and access

- **The raw data-streams for the *in situ* water optical package, the Satlantic HyperOCR and the weather data are uploaded via NextG broadband to CSIRO's data storage in Canberra.**
- **After pre-processing and QA/QC protocols are applied to each data stream, the near real time data will be packaged into IMOS compatible netCDF files and uploaded to eMII (the IMOS data and information facility) for archiving and distribution.**
- **When the provisioning phase of the data streams is completed all the data streams generated at LJCO will be made freely available according to the IMOS data policy.**
- **As all IMOS data, LJCO data will be accessible through the IMOS Ocean Portal [http://imos.aodn.org.au/webportal/].**
- **The SeaPRISM derived data products are accessible through the AERONET-OC web page at NASA Goddard Space Flight Center [http://aeronet.gsfc.nasa.gov/].**



IMOS Integrated Marine Observing System

Lucinda Jetty Coastal Observatory (LJCO)

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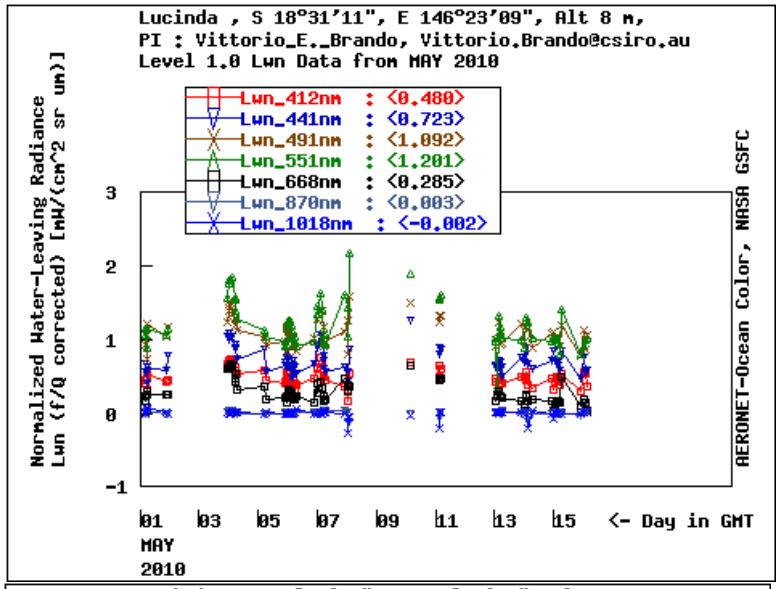
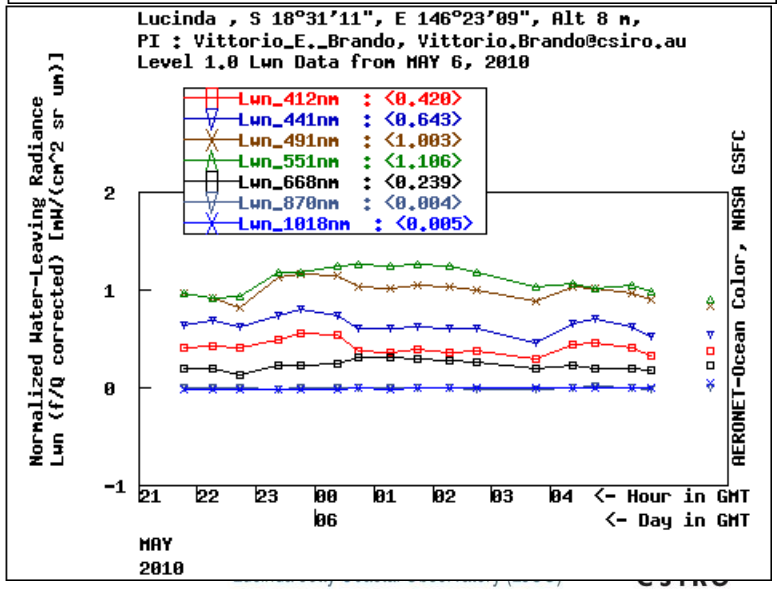
Applications of LJCO data
Validation of coastal-ocean colour products

- **LJCO delivers continuous *in situ* measurements for the validation of coastal-ocean colour products in the GBR.**
- **The match up analysis of satellite retrievals vs. *in situ* measurements will enable the assessment of accuracy for aerosol optical pro-perties, normalized water-leaving radiances, water inherent optical properties and biogeochemical concentrations.**
  - The accuracy of atmospheric correction algorithms will be evaluated using the SeaPRISM data stream i.e. water leaving radiance (or remote sensing reflectance) and atmospheric optical thickness, as well as ancillary weather and sky information.



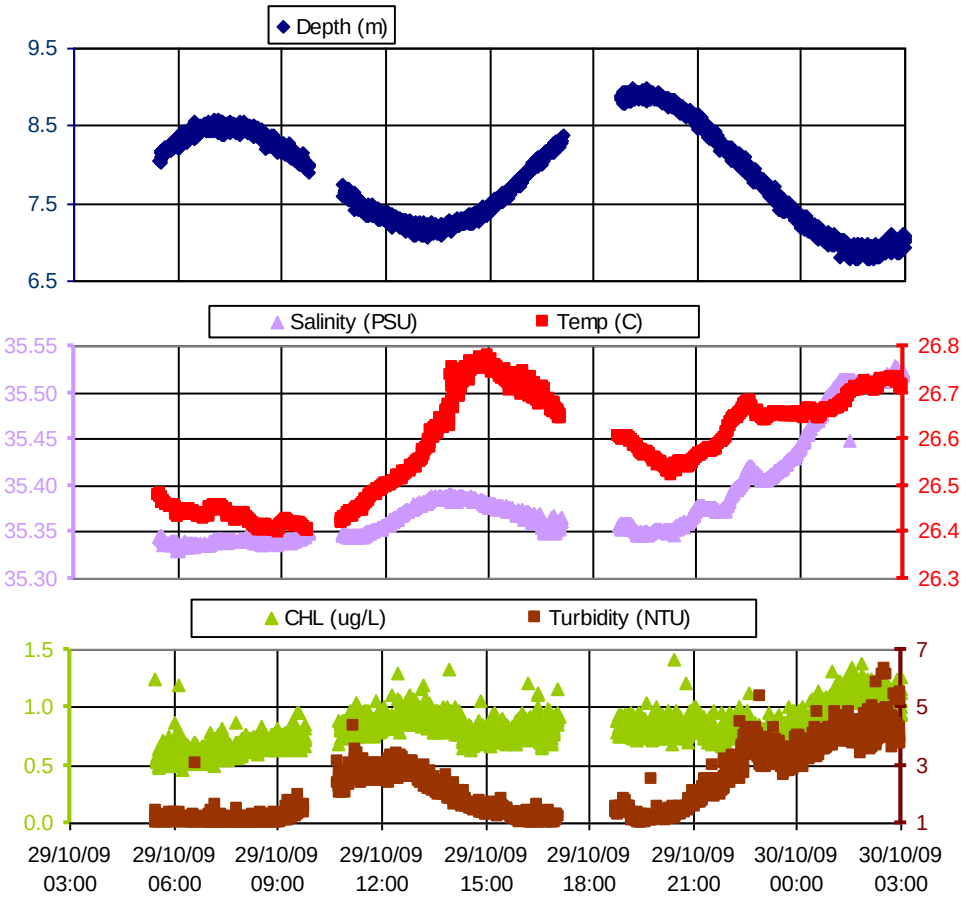


Applications of LJCO data
Validation of coastal-ocean colour products

- **LJCO delivers continuous *in situ* measurements for the validation of coastal-ocean colour products in the GBR.**
- **The match up analysis of satellite retrievals vs. *in situ* measurements will enable the assessment of accuracy for aerosol optical pro-perties, normalized water-leaving radiances, water inherent optical properties and biogeochemical concentrations.**
  - The accuracy of the algorithms for the retrieval of optical properties from ocean colour data (i.e. absorption and scattering, apportioned to phytoplankton, dissolved and non-algal particulate matter) will be quantified using the inherent optical properties estimated from the instruments data collected with ac-s and BB9.
  - The accuracy of ocean colour algorithms for the retrieval of biogeochemical quantities will be assessed using the laboratory-based measurements of concentrations of chlorophyll, coloured dissolved organic matter and particulate matter from direct sampling of the water column.

Applications of LJCO data
Process studies

- **In addition to the validation activities the combined bio-optical observations will be useful for a variety of process studies such as :**
  - particle and phytoplankton temporal dynamics (e.g. assessing diurnal to seasonal variability),
  - modeling of the underwater light climate for primary production,
  - identifying optical proxies linking optical observations to biogeochemical properties and
  - radiative transfer modeling studies to derive optical closure between inherent and apparent optical properties.
- **These studies will benefit from the broad range of conditions occurring at this site where the sources of particulate and dissolved matter substantially vary during the tidal and seasonal cycles due to the interaction of the Herbert River, the Hinchinbrook Channel and the costal waters of the GBR lagoon.**



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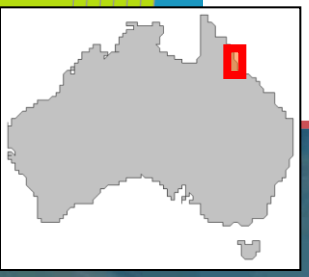
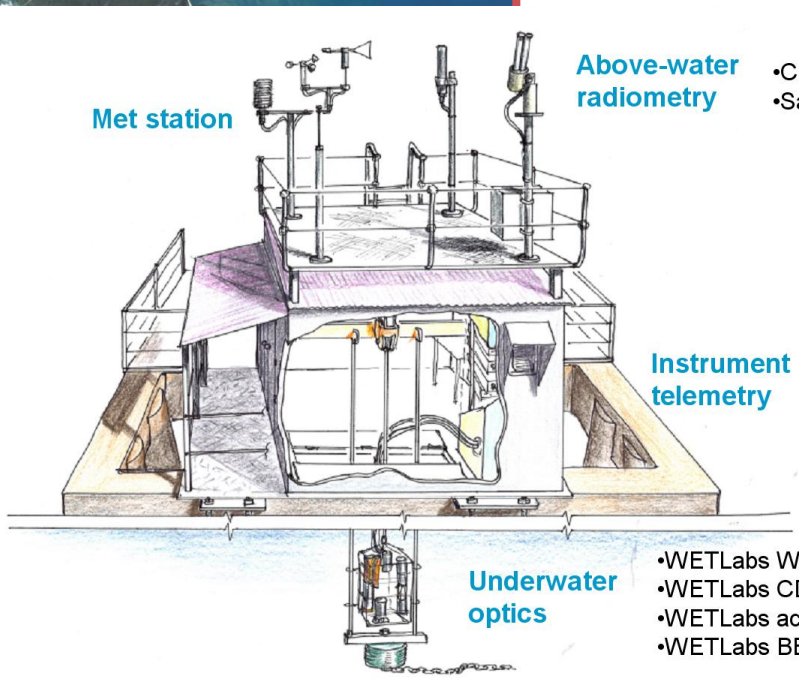
Lucinda Jetty Coastal Observatory (LJCO)
imos.org.au/ljco.html



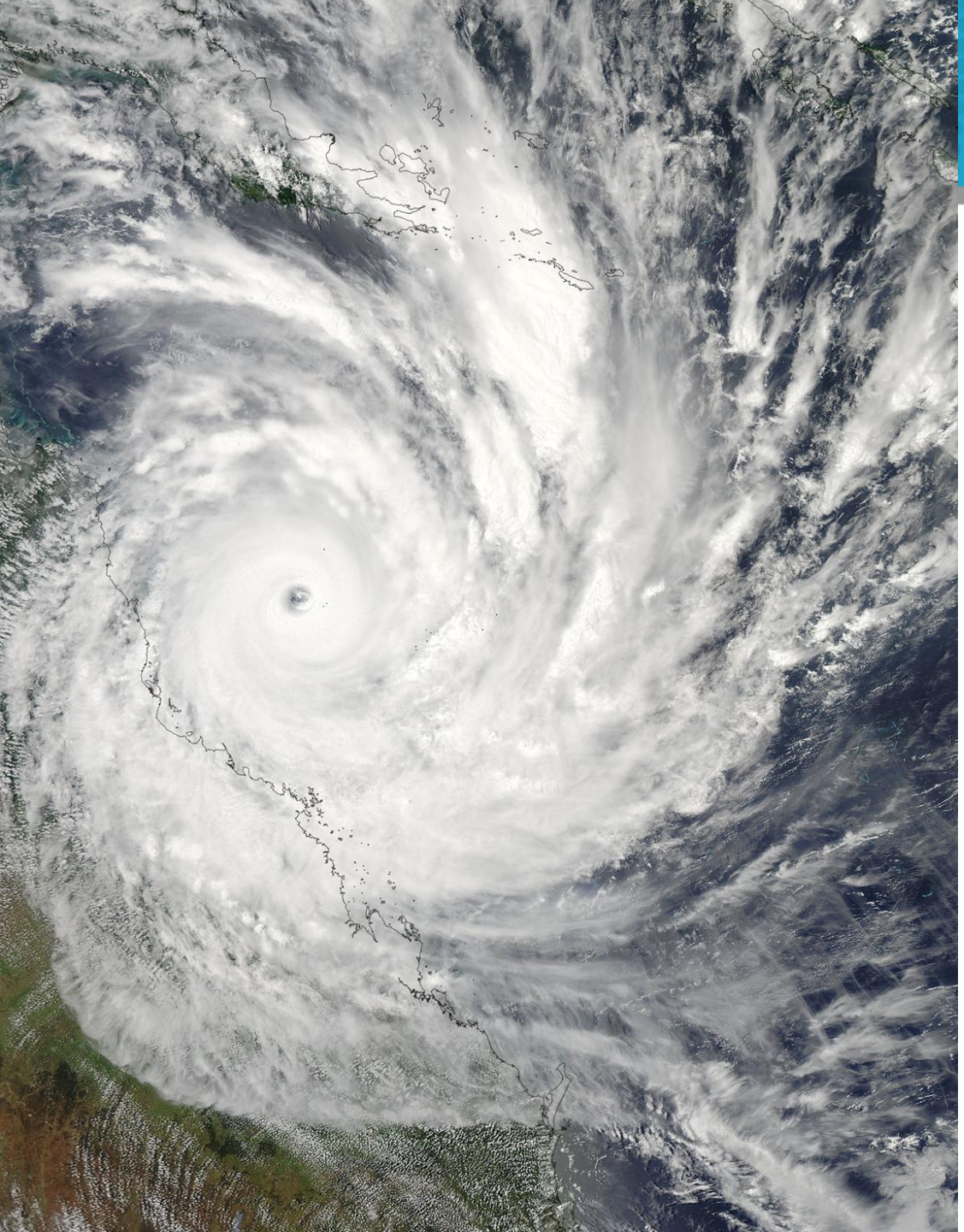


Met station

Above-water radiometry
- CIMEL SeaPRISM
- Satlantic HyperOCR

Instrument telemetry
- Power supply
- UPS
- NextG Router
- Linux Server
- WETLabs DAPCS
- PC controller
- Automated winch

Underwater optics
- WETLabs WQM
- WETLabs CDOM fluorometer.
- WETLabs ac-s
- WETLabs BB9



And then cyclone Yasi paid a visit Feb 2011

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After Cyclone Yasi: Jan 2011
Lucinda Jetty: Northern Dolphin

Match up results
MERIS Chlorophyll algorithms

- **Results from PhD research of David Blondeau-Patissier**

Algorithms tested in PhD research David B-P.

1. MERIS FUB- WeW 1-step procedure (implicit)
2. MERIS FUB- WeW 2-step procedure (explicit)
3. MERIS Case-2 regional
4. MERIS Standard Algal 2 (limited match-ups because less Level 2 data than Level 1 for CLW archive)
5. MERIS Standard Algal 1 (same as above)

(Note CSIRO's ANN Atcor + adaptive LMI algorithm is tested in Round Robin-presented on Friday)

Products tested

- **Chl**
- **TSS**
- **No CDOM for this match-up analysis**

Differences in algorithms

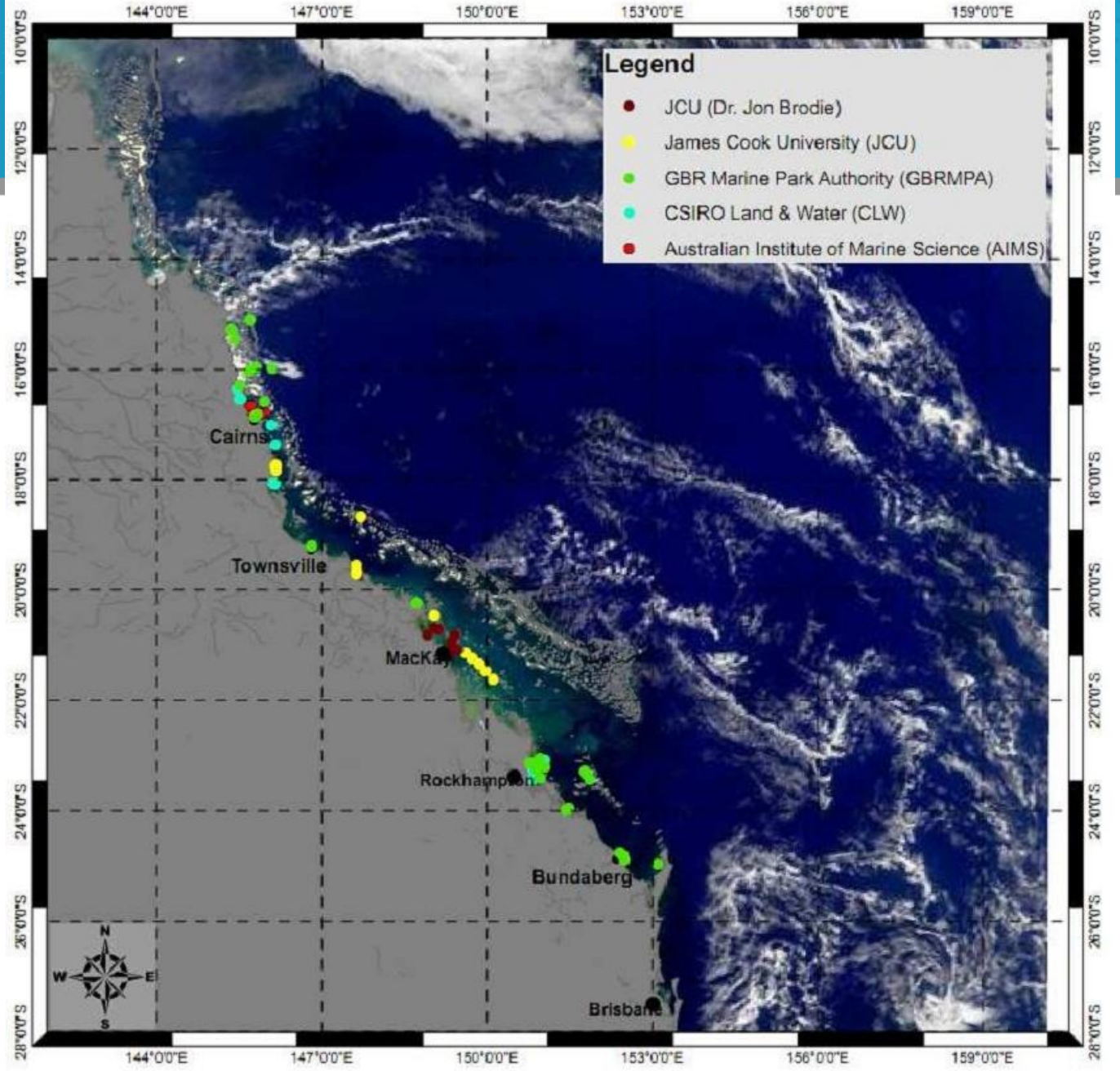
- **For both the MERIS standard L2 (standard) and Case-2 Regional, the water properties were retrieved following the atmospheric correction.**
- **In the FUB-WeW implicit (1-step), the concentrations are directly derived from the TOA radiances, without any separate atmospheric correction.**
- **In the FUB-WeW explicit (2-step), concentrations are derived from the bottom-of-atmosphere. There is an atmospheric correction of the signal in that case prior the derivation of the concentrations. This latter method should be more accurate but it seems to be more sensitive to error propagation following atmospheric correction**

Method

- In situ dataset limited to 2002-2009
- Total of 1804 stations from AIMS, CLW, GBRMPA, JCU etc (not all with CHL)
- 45% of this dataset sampled during wet season
- 30% of samples had TSS
- 15% of samples had CDOM

Method

- **The selected MERIS images were within 5 hours from the in situ sampling time, in UTC**
- **The MERIS images were not reprojected**
- **MERIS algorithms were computed using the BEAM® toolbox**
- **The validation was performed on the closest MERIS pixel to the recorded in situ location so this validation was performed on a single RR pixel.**
- **MERIS L2 quality and science flags were applied.**



Map of the **80** match-up locations that are within 5 hours of the MERIS overpasses from the CLW archive.

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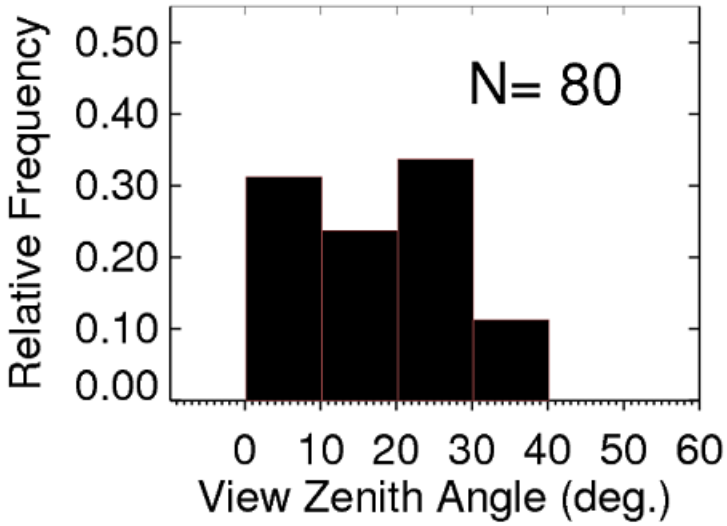
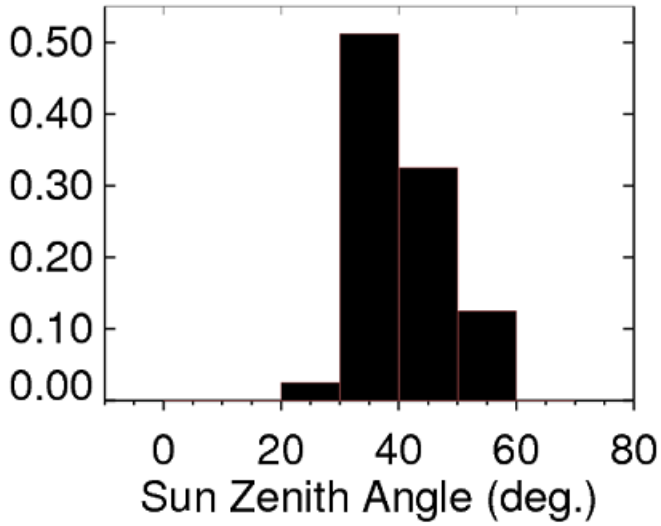
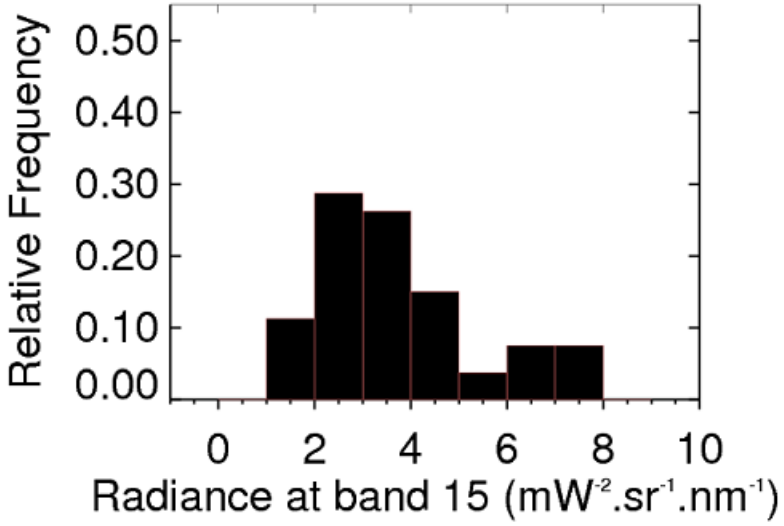
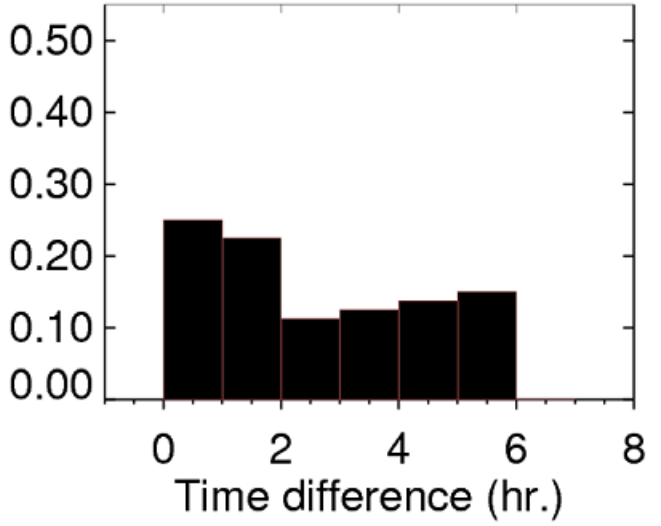
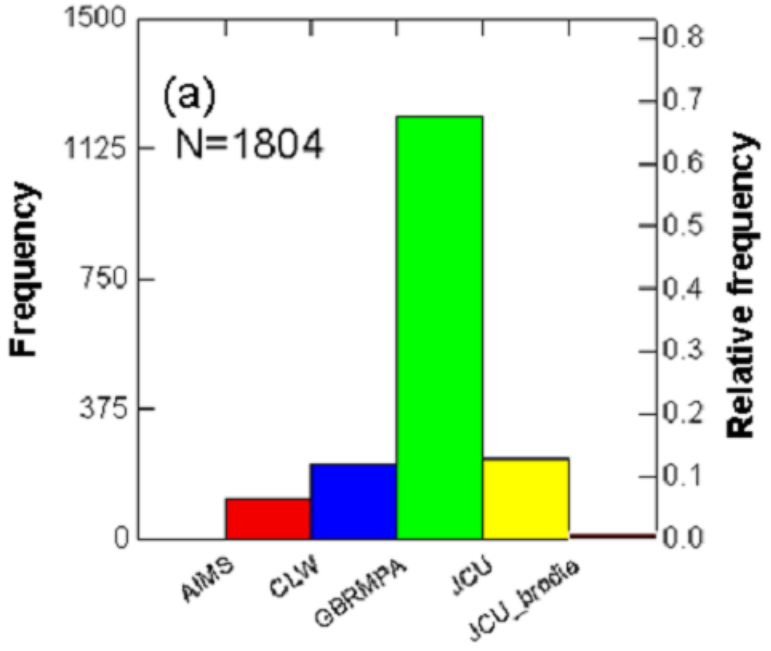
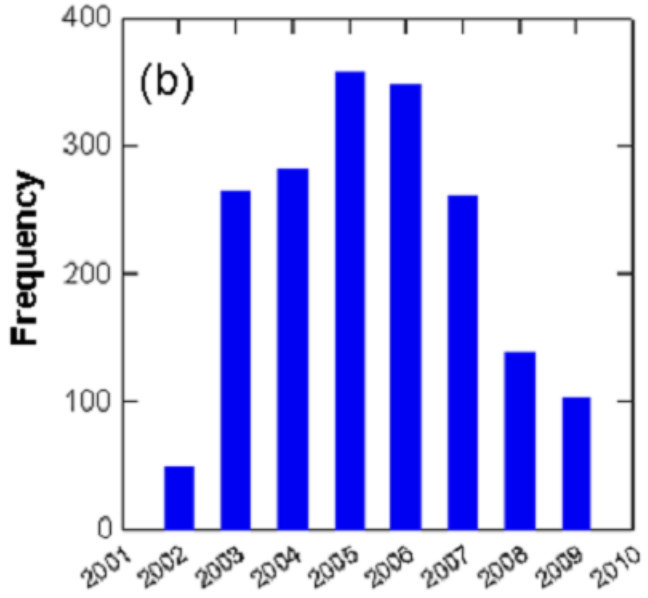

N= 80
Relative Frequency
0.50
0.40
0.30
0.20
0.10
0.00
0 10 20 30 40 50 60
View Zenith Angle (deg.)

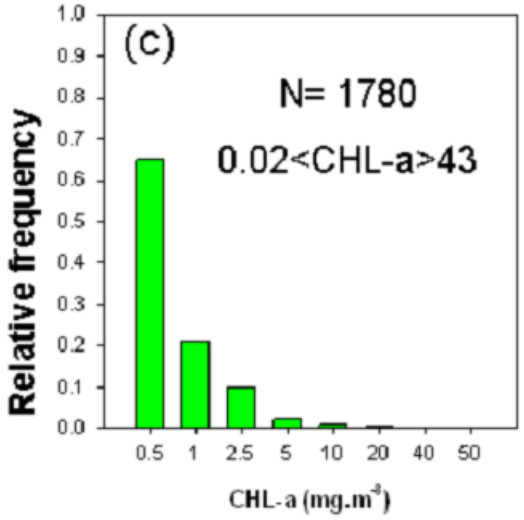

0.50
0.40
0.30
0.20
0.10
0.00
0 20 40 60 80
Sun Zenith Angle (deg.)

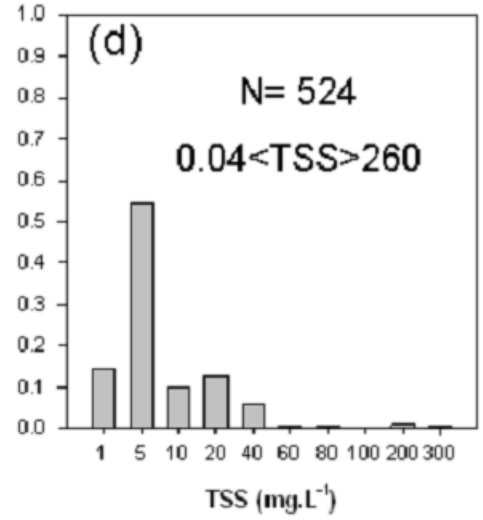

Relative Frequency
0.50
0.40
0.30
0.20
0.10
0.00
0 2 4 6 8 10
Radiance at band 15 (mW-2.sr-1.nm-1)


0.50
0.40
0.30
0.20
0.10
0.00
0 2 4 6 8
Time difference (hr.)


(a)
N=1804
Frequency
Relative frequency
1500
1125
750
375
0
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
AIMS
CLW
GBRMPA
JCU
JCU_brodie


(b)
Frequency
400
300
200
100
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


(c)
N= 1780
0.02<CHL-a>43
Relative frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.5
1
2.5
5
10
20
40
50
CHL-a (mg.m-3)


(d)
N= 524
0.04<TSS>260
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
5
10
20
40
60
80
100
200
300
TSS (mg.L-1)

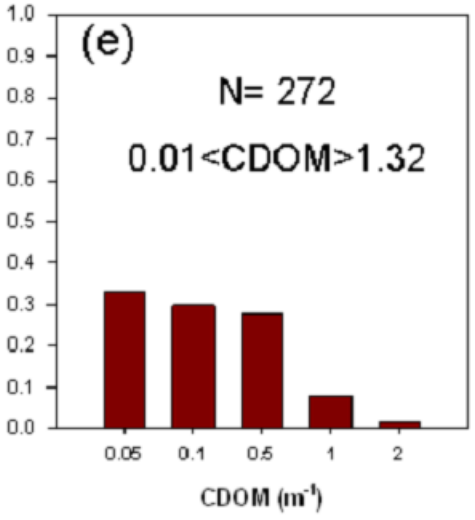

(e)
N= 272
0.01<CDOM>1.32
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.05
0.1
0.5
1
2
CDOM (m-1)

Table 12 Summary statistics for match-up results within 1 hour of *in situ* sampling, Chl (Annex B)

ALGORITHM	N	R^2 (%)	Slope (intercept)	MAPE(%)	RMSE (log)
FUB-WeW (1-step)	20	36	1.97 (0.17)	86	0.45
FUB-WeW (1-step) corrected	20	36	1.34 (-0.19)	53	0.42
FUB-WeW (2-step)	9*	8	1.35 (-0.18)	44	0.39
FUB-WeW (2-step) corrected	9*	8	0.91 (-0.43)	56	0.47
C2R	20	22	1.57 (0.30)	120	0.39
C2R corrected	20	22	1.63 (0.17)	87	0.39
L2 standard Algal 1	5*	48	1.90 (0.87)	330	0.61
L2 standard Algal 2	5*	28	1.08 (0.20)	71	0.25
L2 standard Algal 2 corrected	5*	28	1.21 (-0.03)	36	0.21

Table 13 Summary statistics for match-up results within 2 hours of *in situ* sampling, Chl (Annex B)

ALGORITHM	N	R^2 (%)	Slope (intercept)	MAPE(%)	RMSE (log)
FUB-WeW (1-step)	38	14	1.77 (-0.06)	110	0.62
FUB-WeW (1-step) corrected	38	14	1.20 (-0.35)	62	0.57
FUB-WeW (2-step)	13	8	-0.84 (-0.71)	58	0.61
FUB-WeW (2-step) corrected	13	8	-0.57 (-0.79)	62	0.66
C2R	38	14	1.55 (0.18)	120	0.48
C2R corrected	38	14	1.61 (0.04)	92	0.52
L2 standard Algal 1	11	0.2	1.19 (0.36)	250	0.59
L2 standard Algal 2	11	0.3	-0.81 (-0.56)	89	0.44
L2 standard Algal 2 corrected	11	0.3	-0.91 (-0.88)	60	0.57

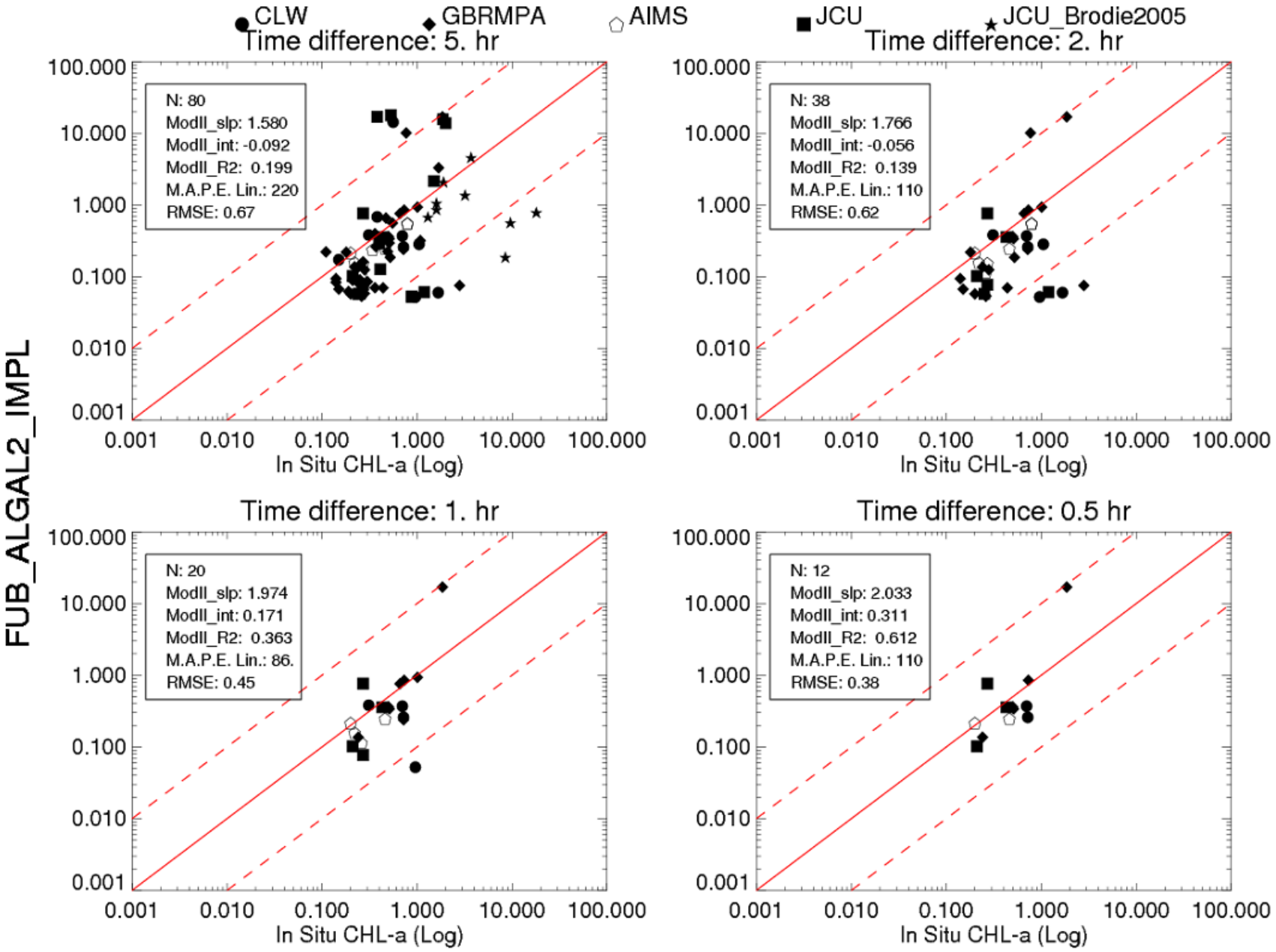
IRO

Table 14 Summary statistics for match-up results within 1 hour of *in situ* sampling, TSS (Annex B)

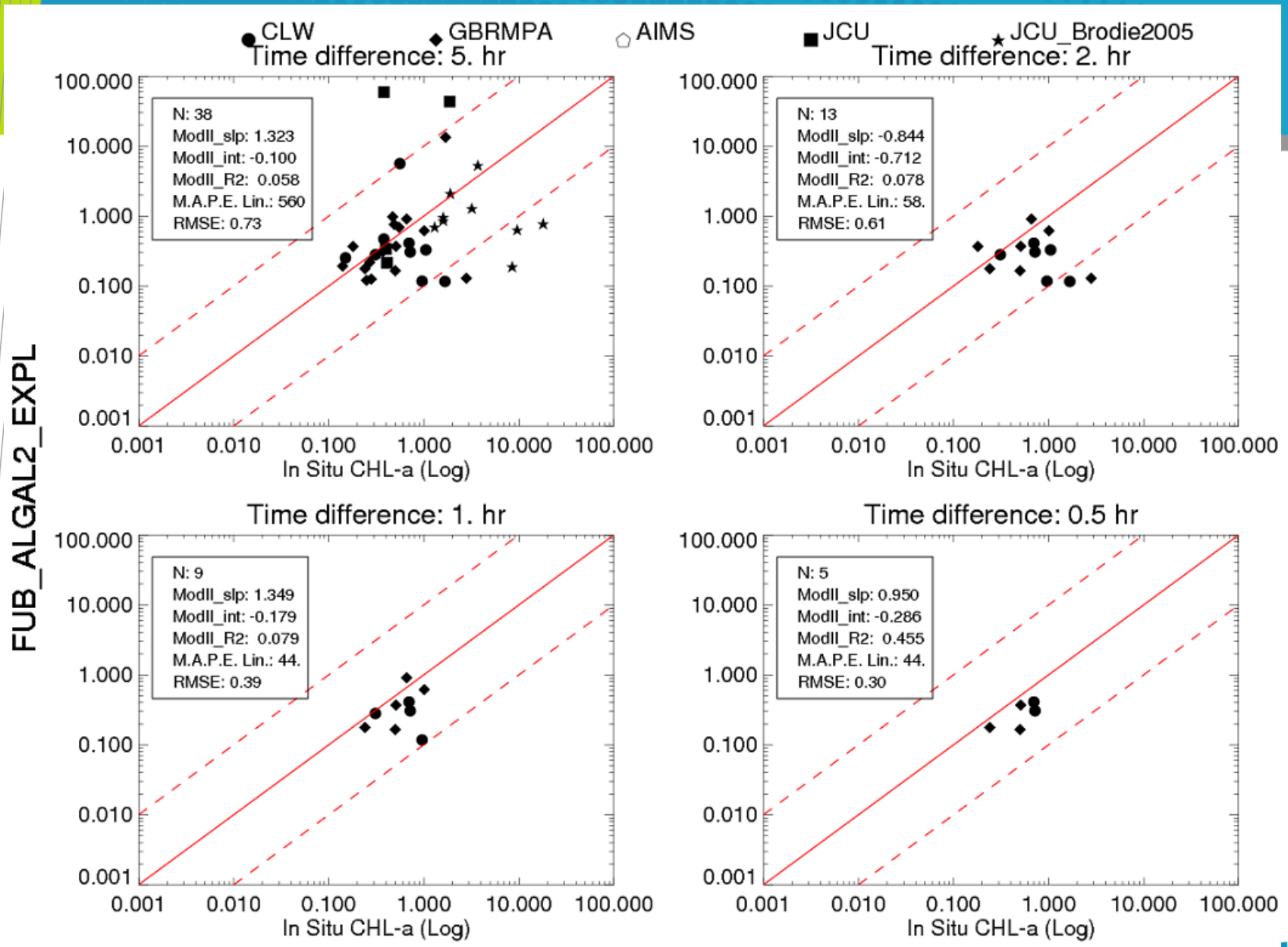
ALGORITHM	N	R^2 (%)	Slope (intercept)	MAPE(%)	RMSE (log)
FUB-WeW (1-step)	13	0.1	0.44 (-0.54)	65	1.10
FUB-WeW (2-step)	13	0.8	0.26 (-0.27)	55	0.90
C2R	13	0.8	0.30 (-0.14)	52	0.80
L2 standard TSS	4*	91	0.51 (-0.02)	33	0.20

Table 15 Summary statistics for match-up results within 2 hours of *in situ* sampling, TSS (Annex B)

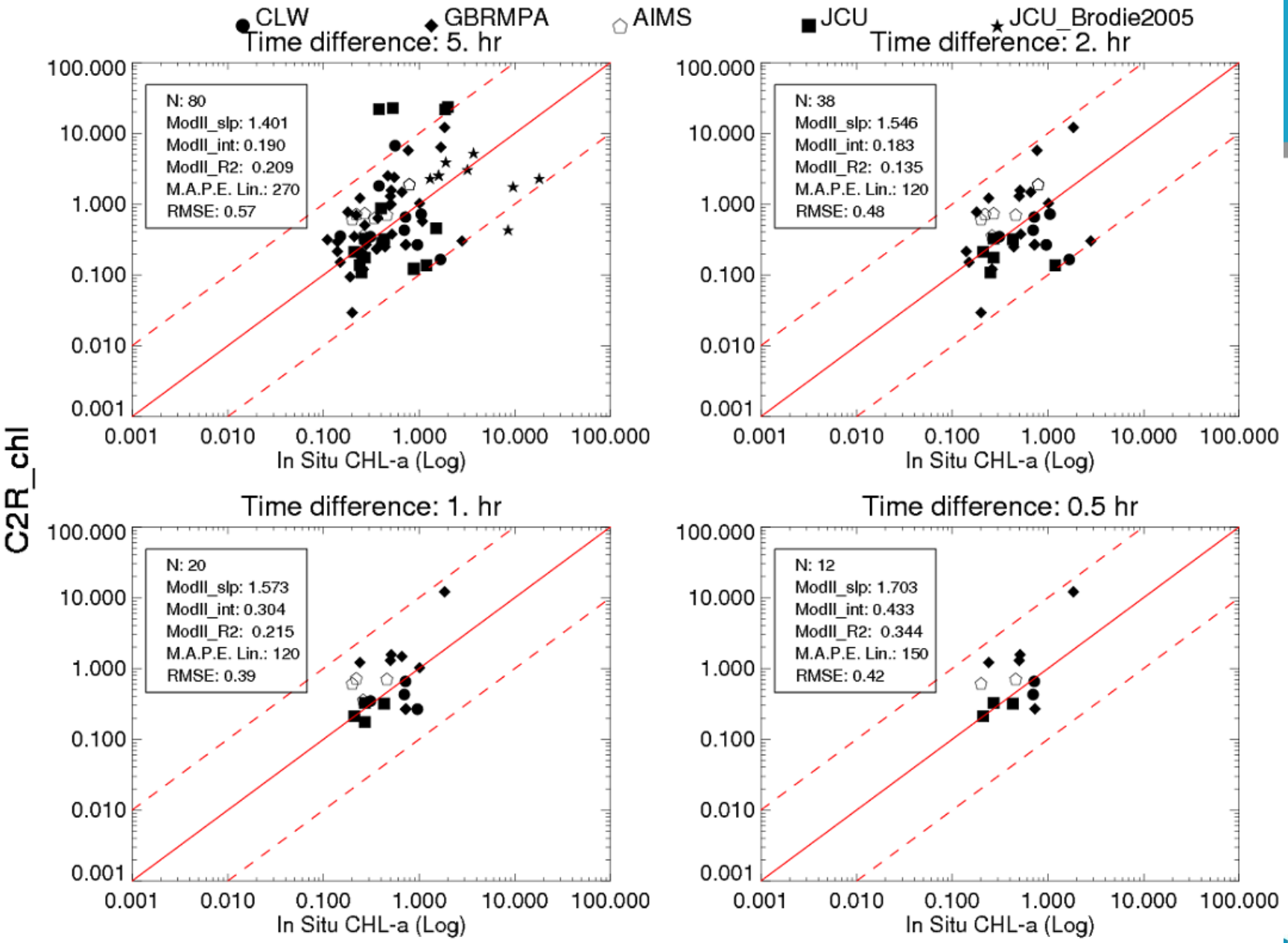
ALGORITHM	N	R^2 (%)	Slope (intercept)	MAPE(%)	RMSE (log)
FUB-WeW (1-step)	19	17	0.55 (-0.50)	59	0.92
FUB-WeW (2-step)	19	24	0.40 (-0.24)	60	0.76
C2R	19	25	0.46 (-0.12)	60	0.68
L2 standard TSS	7*	92	0.57 (0.002)	50	0.25



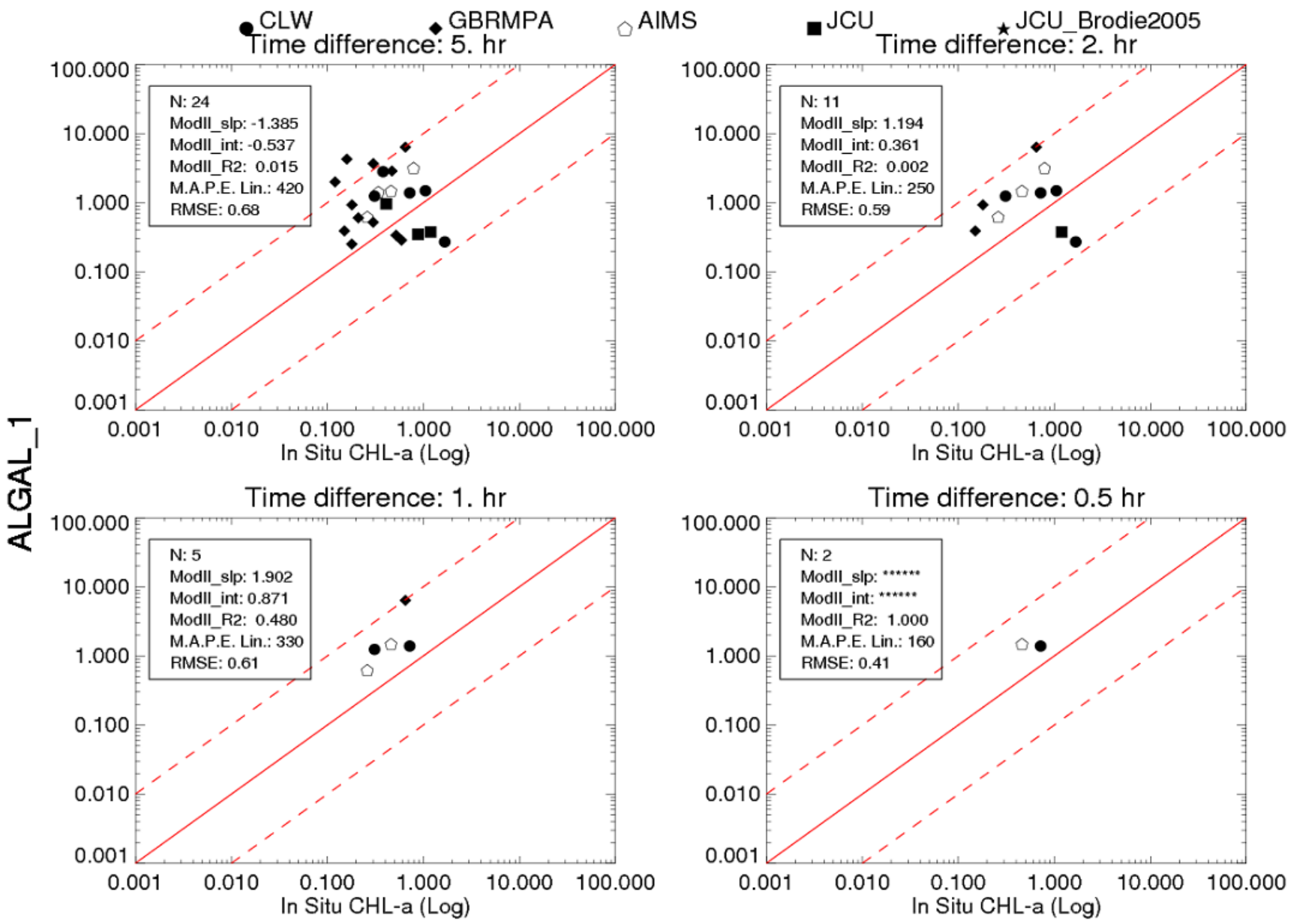
Annex B - Figure 1 Match-up results for FUB (implicit, 1-step) Chl retrievals (in mg.m^{-3})



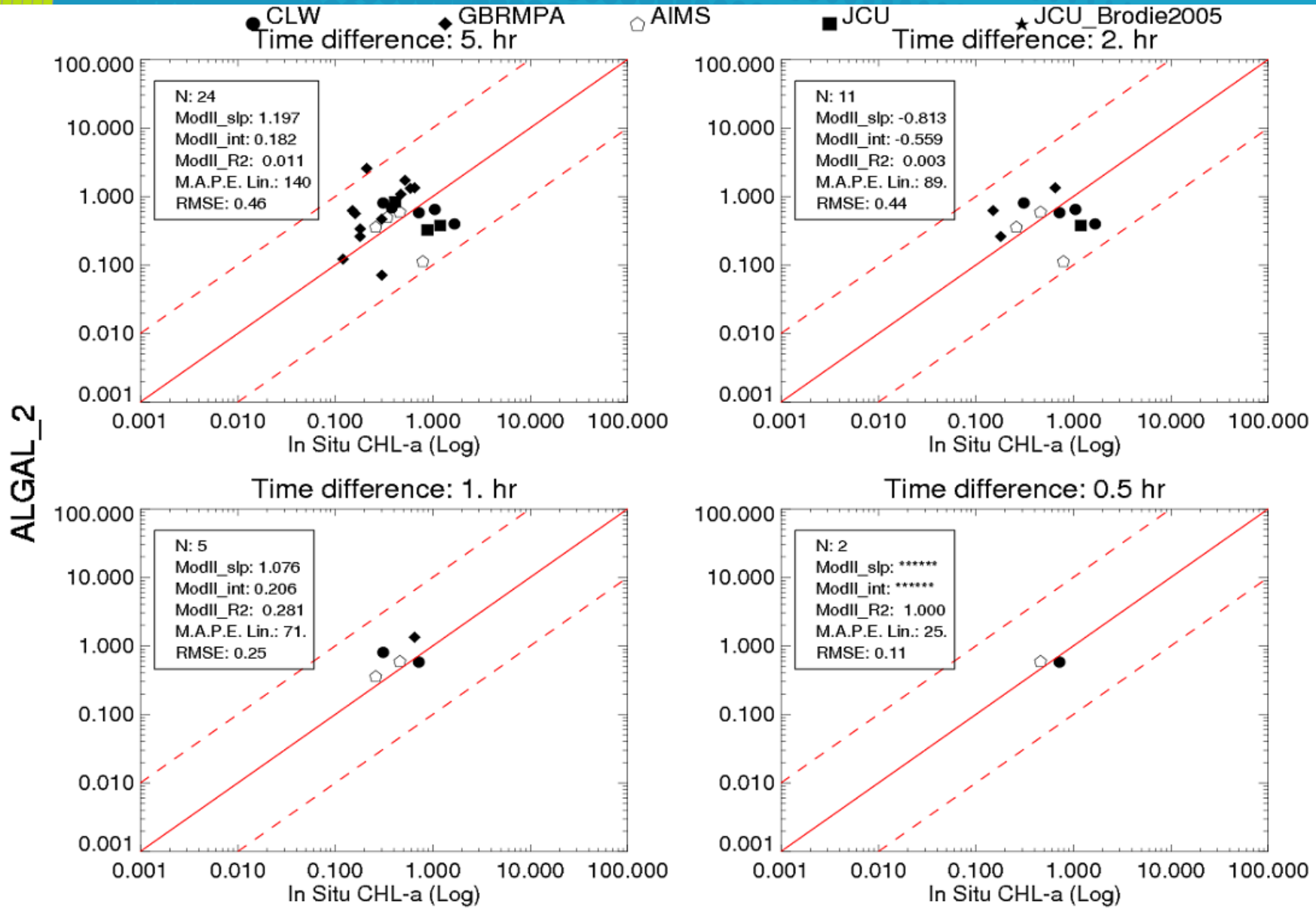
Annex B - Figure 3 Match-up results for FUB (explicit, 2-steps) Chl retrievals (in mg.m^{-3})



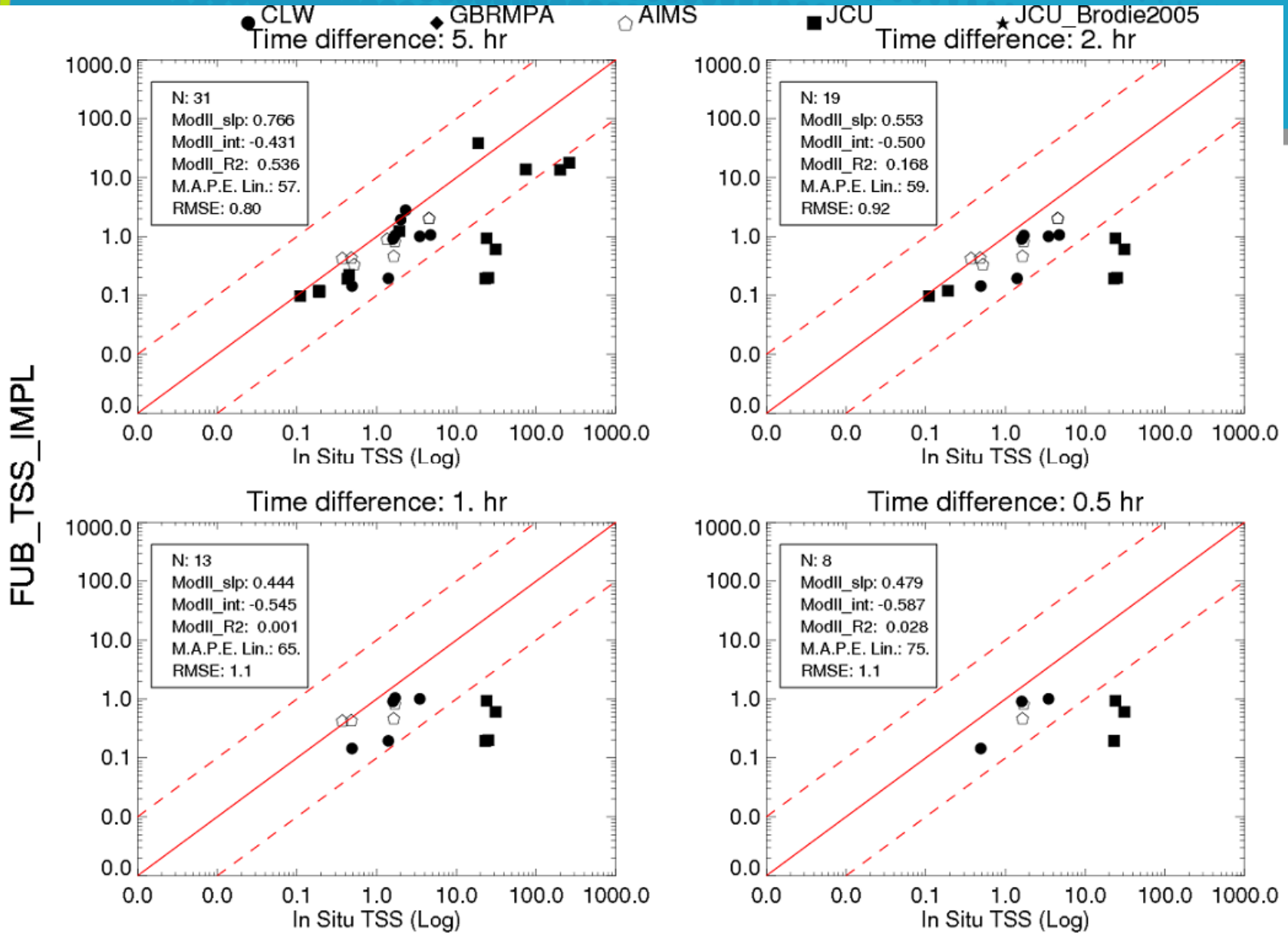
Annex B - Figure 5 Match-up results for Case 2 Regional Chl retrievals (in mg.m^{-3})



Annex B - Figure 7 Match-up results for MERIS standard L2 Algal 1 retrievals (in mg.m^{-3})

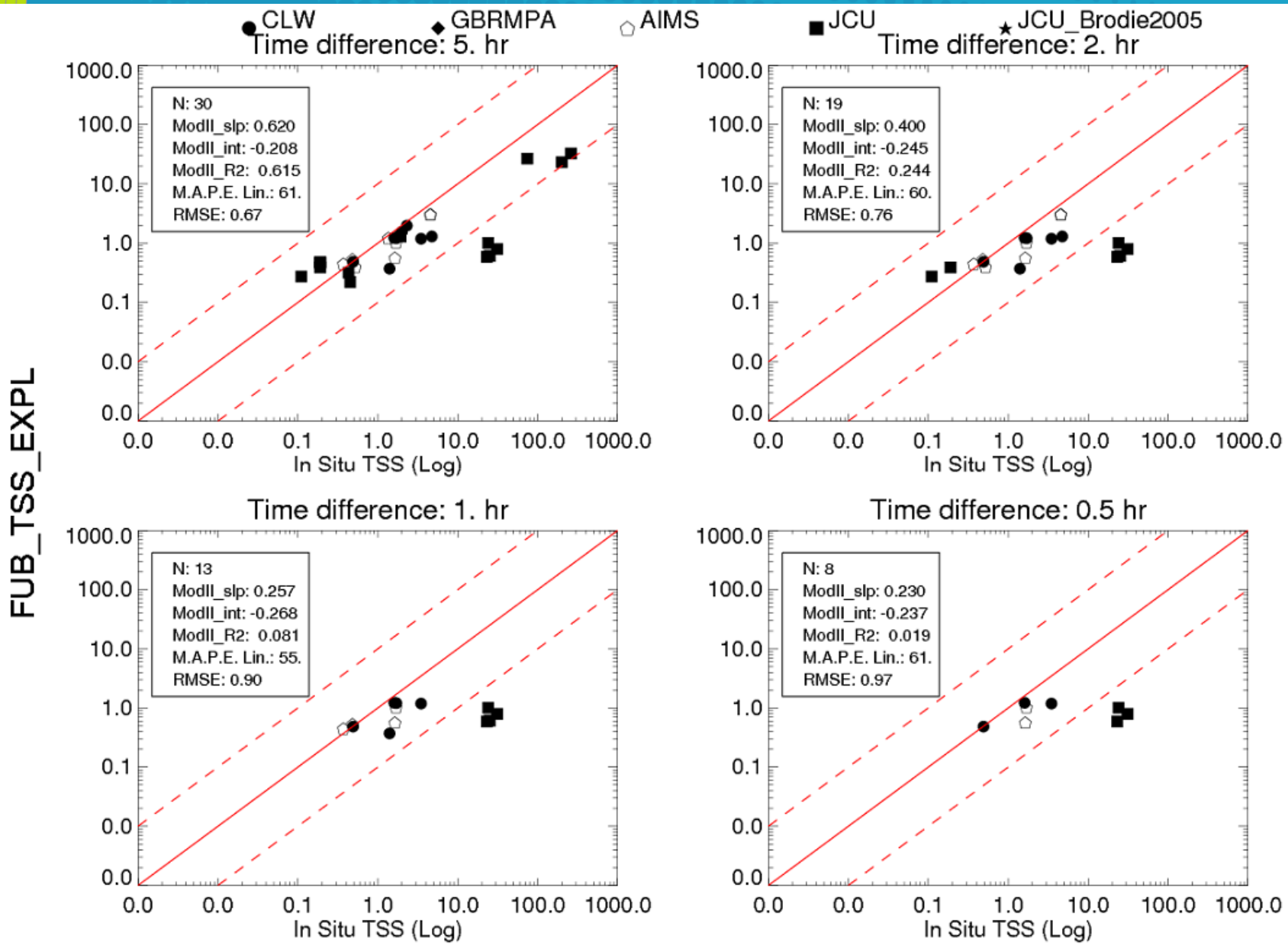


Annex B - Figure 8 Match-up results for MERIS standard L2 Algal 2 retrievals (in mg.m^{-3})

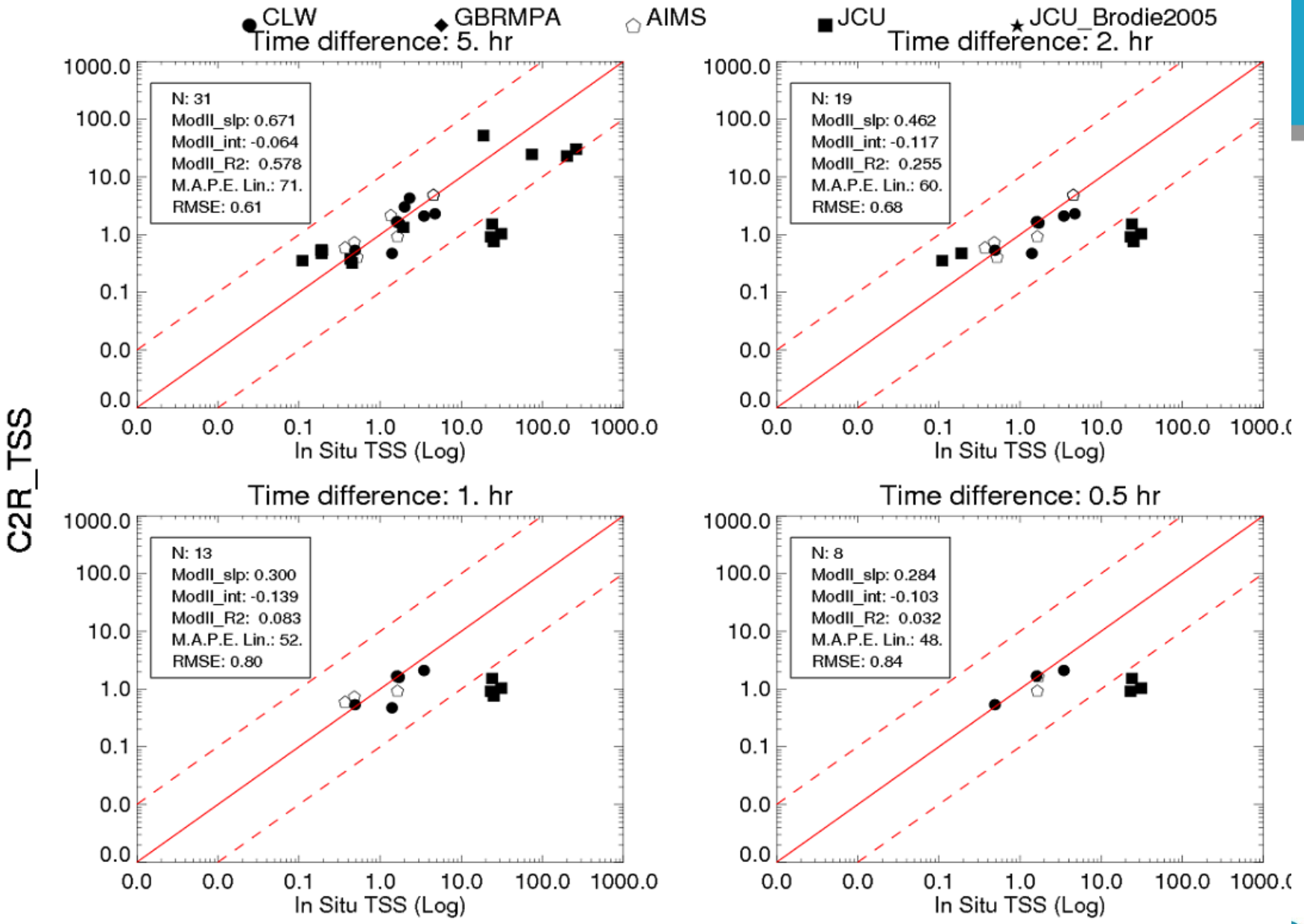


Annex B - Figure 10 Match-up results for FUB-WeW (1-step) TSS retrievals (in mg.L^{-1})

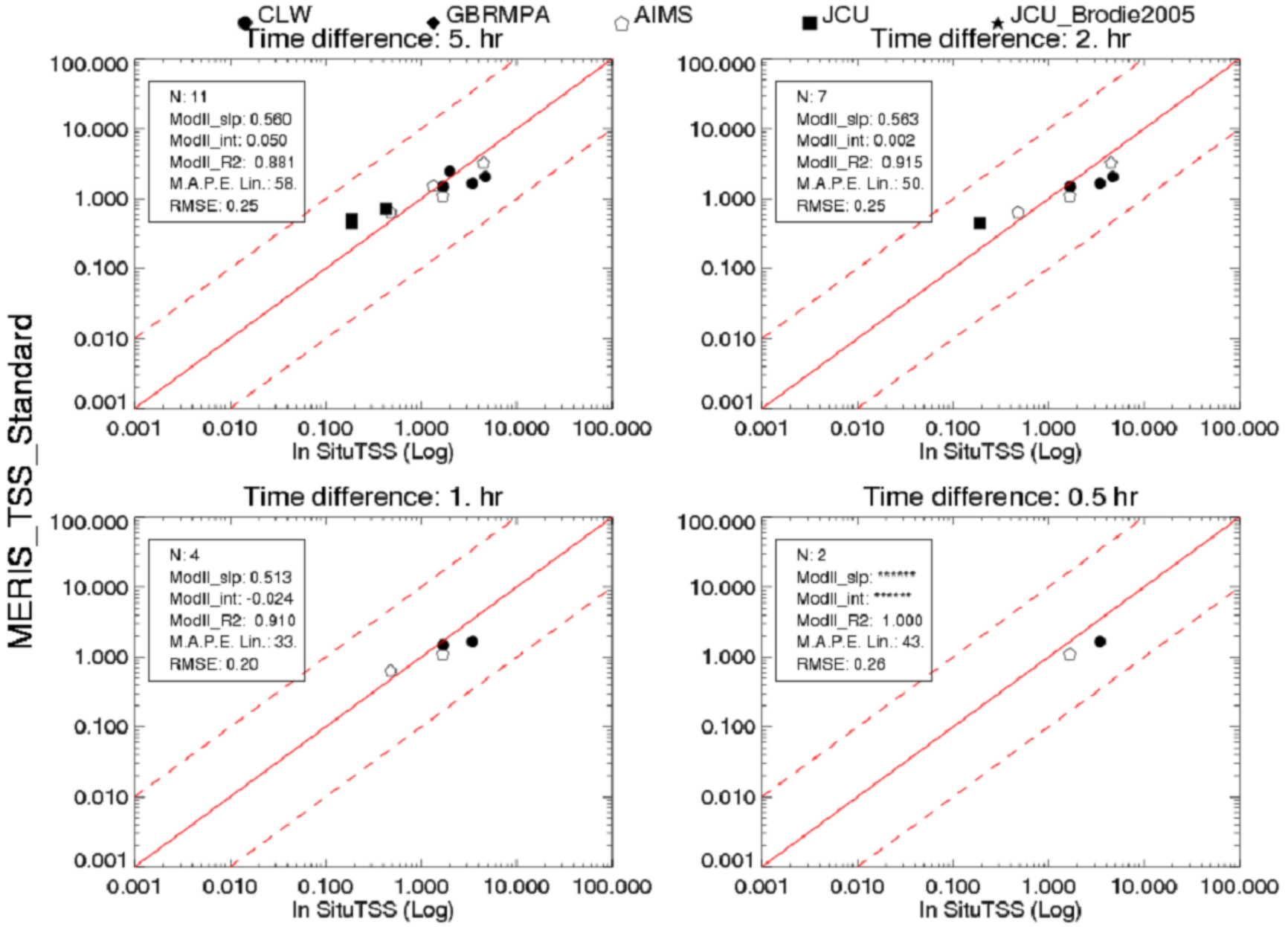
CSIRO



Annex B - Figure 11 Match-up results for FUB-WeW (2-step) TSS retrievals (in mg.L-1)

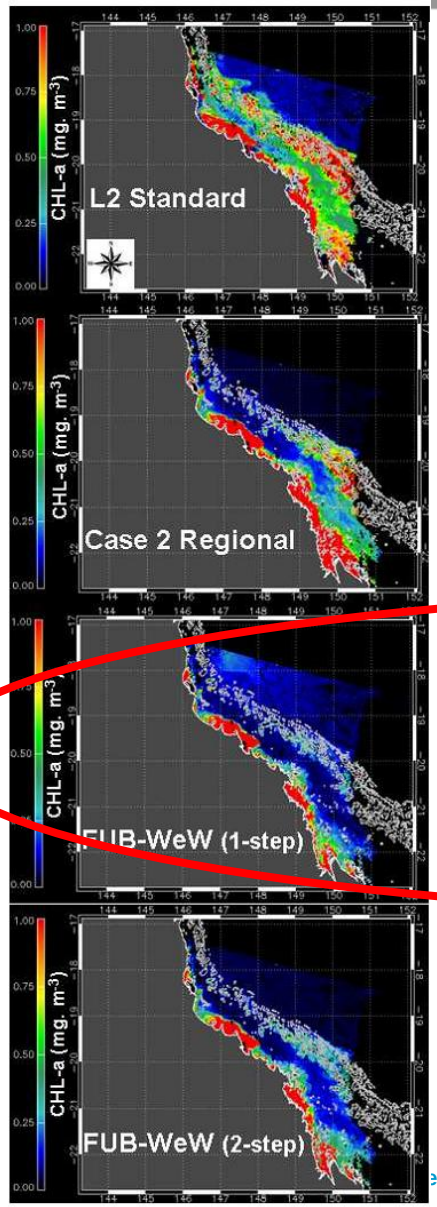


Annex B - Figure 12 Match-up results for C2R TSS retrievals (in mg.L-1)



Annex B - Figure 13 Match-up results for MERIS standard L2 TSS retrievals (in mg.L-1)

MERIS Coastal water algorithms and the GBR

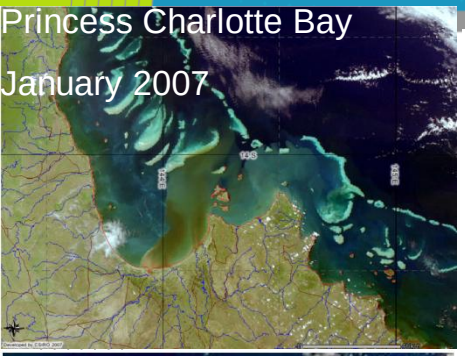


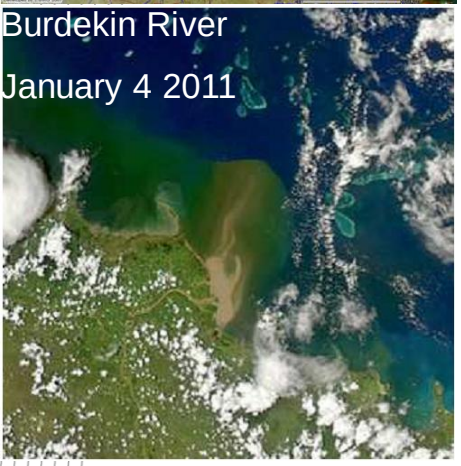
The same MERIS scene processing with 4 different algorithms provides different estimates of Chlorophyll-a concentrations

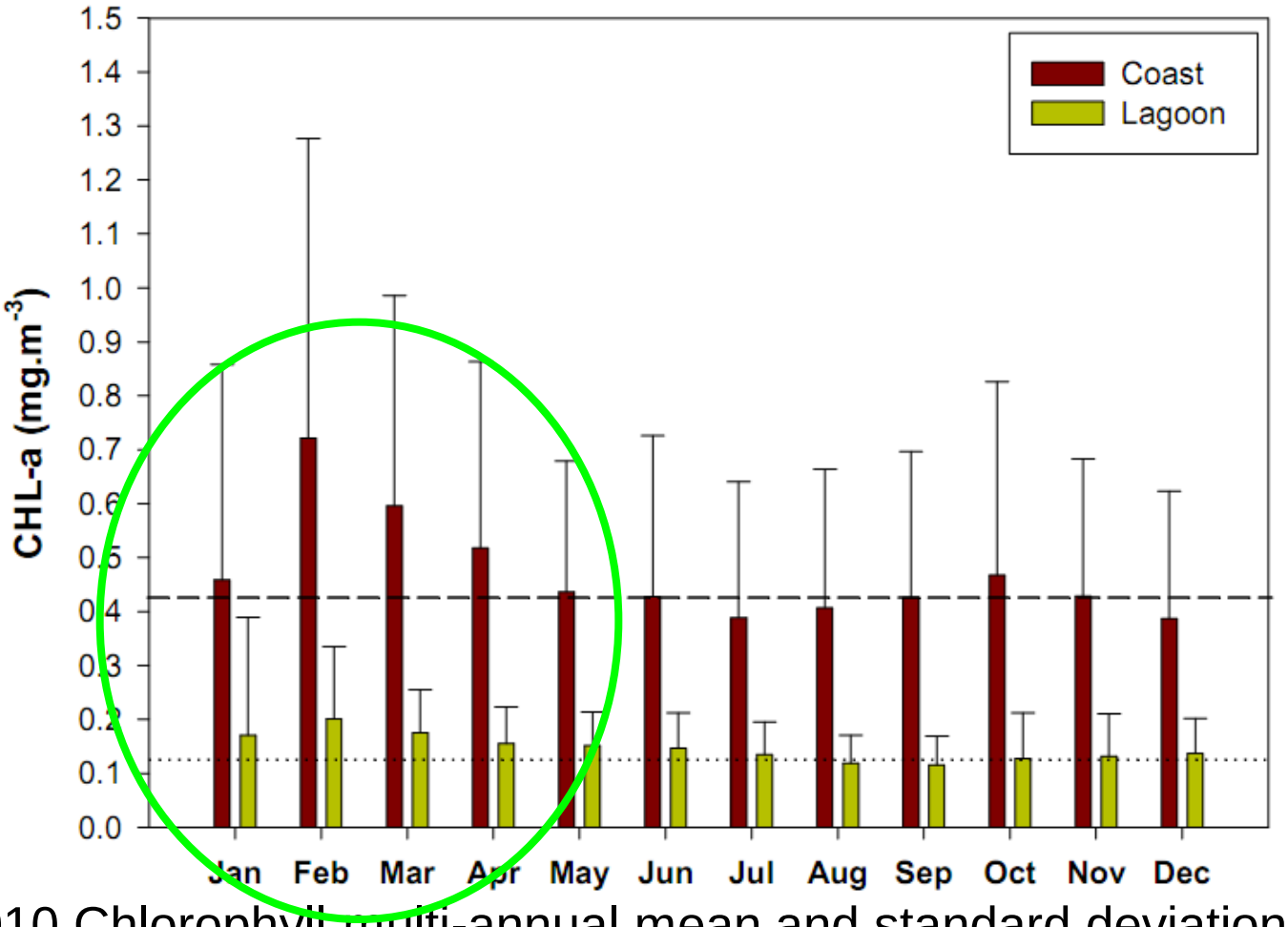
MERIS FUB-1 step: best performing algorithm for the retrieval of CHL

IMOS Integrated Marine Observing System
Lucinda Jetty Coastal Observatory (LJCO)
CSIRO

Multi-annual monthly Chlorophyll (MERIS)







2003-2010 Chlorophyll multi-annual mean and standard deviation

(for the Great Barrier Reef coastal and oligotrophic lagoonal waters)

The DALEC for Cal-Va

Burdekin River plume
February 2008

- To acquire spatial coverage for ship-based deployment, the Dynamic Above water radiance (L) and irradiance (E) Collector (DALEC) hyperspectral radiometer was developed by IMO in Perth (WA).
- This 3-channel spectroradiometer measures reflected light from in the water column across 256 different wavelength bins, from approximately 380 to 900 nm (UV/
- VIS/NIR). The DALEC is radiometrically calibrated
- Full attitudional RT sensor alignment

- Mounted on Australian Ocean research vessel:"Southern Surveyor" for circum Australia and Southern Ocean transects.

DALEC fully automated positioning spectroradiometer (Ed, Lw sky,Luw)

Summary Situation Australia CSIRO+IMOS MERIS, MODIS, OCM-2 –VIIRS, OLCI etc……..

- **LJCO for systematic coastal observations**
- **DALEC for systematic radiance and R around Australia and to Antarctica**
- **Cruises around Australia**
- **IMOS Bio-Optical Working Group equipping buoys Wetlabs WQM + fluoroprobes etc….**
- **SeaWiFS, MODIS and MERIS processed using ANN based atcor Adaptive SIOP LMI algorithms (=sensor agnostic) + standard products through supercomputing facility**
- **All data made available through IMOS AODN portal:**
- **[http://imos.aodn.org.au/webportal/].**