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IMOS Integrated Marine Observing System

Use of ACSPO VIIRS L3U SST in the Australian Bureau of Meteorology

Helen Beggs, Pallavi Govekar, Chris Griffin, Pavel Sakov and Leon Majewski

Bureau of Meteorology, Melbourne, Australia

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Background

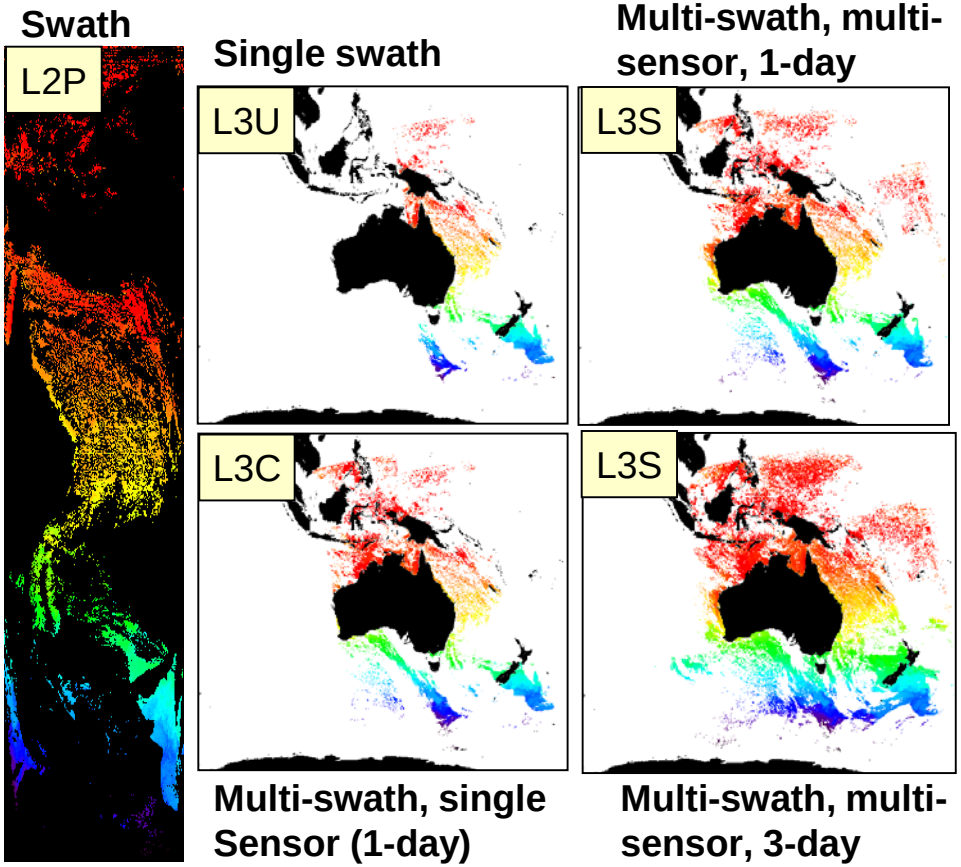
IMOS

- BoM currently uses NAVOCEANO's 9 km x 4 km global AVHRR SST data from NOAA-18/19 and METOP-A/B in operational SST analyses and ocean models
- BoM produces GHRSST L2P, L3U, L3C and L3S products from HRPT AVHRR SST data from NOAA satellites for IMOS Project and operational BoM systems
- Need Suomi-NPP and JPSS VIIRS SSTs for above systems as a follow-on to NOAA-19 AVHRR SST
- Unable to access VIIRS L2P SST via FTP in real-time due to high volumes so requested ACSPO produce lower resolution VIIRS L3U files
- NOAA/STAR produces ACSPO VIIRS 0.02º L3U SST (0.2m) product with rectangular grid aligned with IMOS 0.02º L3U product
- BoM currently testing these products for operational systems (IMOS L3U/L3C/L3S, SST analyses and ocean forecasts).

IMOS HRPT AVHRR GHRSST products

http://imos.org.au/sstproducts.html

- BoM and CSIRO have 1.1 km (at nadir) HRPT AVHRR data from NOAA-11 to NOAA-19 from reception stations in Australia and Antarctica back to mid-1980's
- For IMOS, BoM has produced GHRSST products (0.02º L3U, L3C, L3S) over two domains (Australia and Southern Ocean) from 1992 to present using the "stitched" HRPT AVHRR SST archive
- Can IMOS use ACSPO VIIRS SST data to continue the IMOS SST data set and improve spatial coverage?



Constructing IMOS VIIRS L3U product

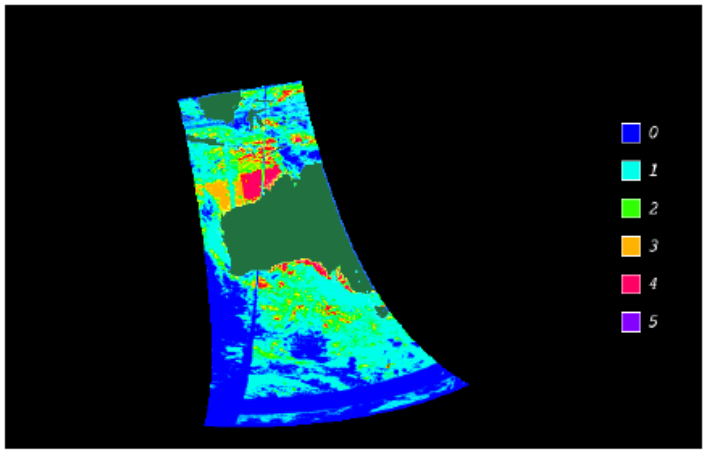
- NOAA/STAR produces "ACSPO" VIIRS_NPP 0.02º single swath, composite "L3U" SST product (on IMOS grid)
- In order to merge with IMOS AVHRR L3U SSTs, ACSPO VIIRS L3U files are modified such that the quality_level is redefined as the minimum of the original VIIRS_NPP ACSPO_v2.40 quality_level and quality level, q_s, calculated using Sensor Specific Error Statistics (SSES), using sses_bias (μ_{sses}) and sses_standard_deviation (σ_{sses}) estimates, thus:

$$q_{\text{sses}} = \frac{1}{\sqrt{2}}\sqrt{\max\left(\left(\frac{\sigma_{\text{sses}}}{\sigma_0}\right)^2 + \left(\frac{\mu_{\text{sses}} - \mu_0}{\sigma_{\text{sses}}}\right)^2 - 1, 0\right)}$$

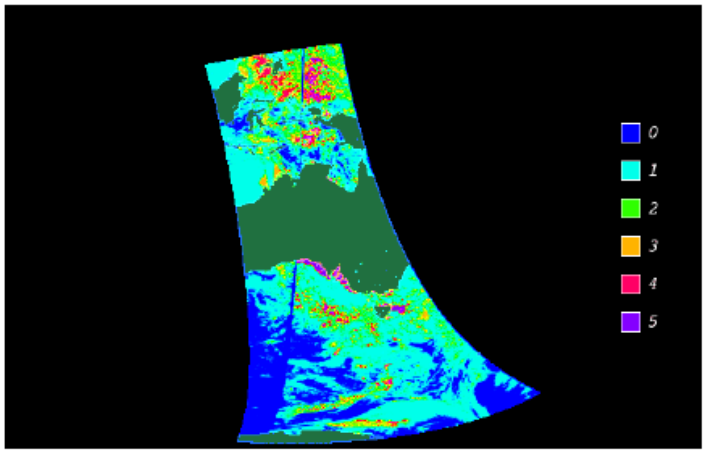
$$q_s = \lfloor 5 \exp^{\eta q_{\text{sses}}} \rceil$$

- Different data sources can then be combined using q_s, *provided that* η/σ_0 = constant

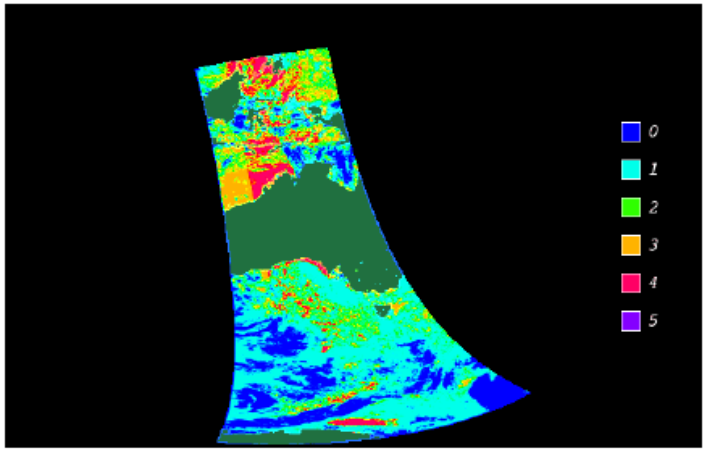
“Remapped Quality Level” min(quality_level, q_s)



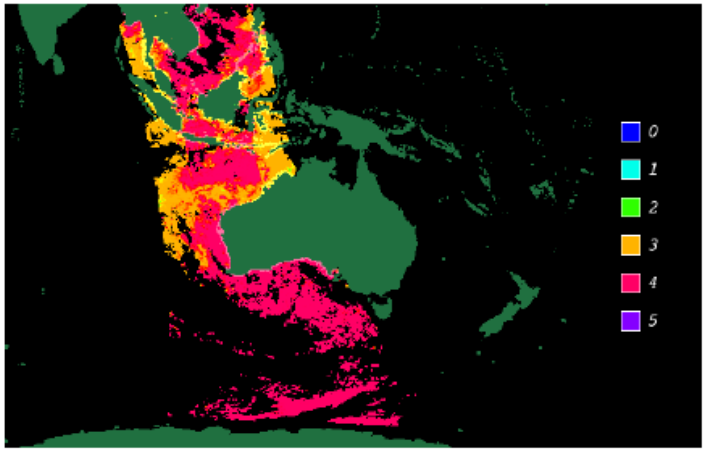
NOAA-15 fv01 L3U



NOAA-18 fv01 L3U



NOAA-19 fv01 L3U



L3U NPP VIIRS

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Why adjust the quality level in this way?

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Bureau compositing algorithms use sses_bias, sses_standard_deviation and degrees of freedom as parametric quality assessments, and quality_level as a non-parametric measure. Only highest non-parametric quality data are combined parametrically. Thus we need a good way to compare in absolute terms the quality of data streams from a non-parametric standpoint.

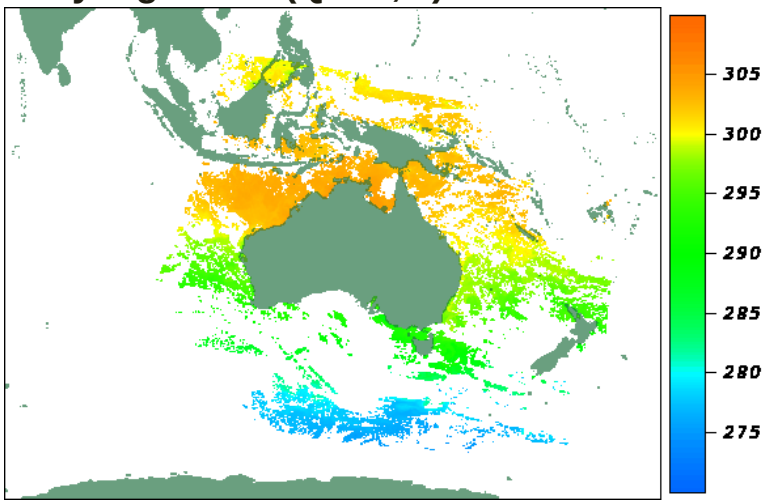
Remapping the quality level allows us to:

- track degradation in quality over each platform life
- combine "**old**" platforms with "**new**" platforms with appropriate quality assessment
- reflect the greater uncertainty of measurement and degraded quality as the uncertainty and deviation from in situ measurement increases
- provide supplier quality assessment based on other metrics

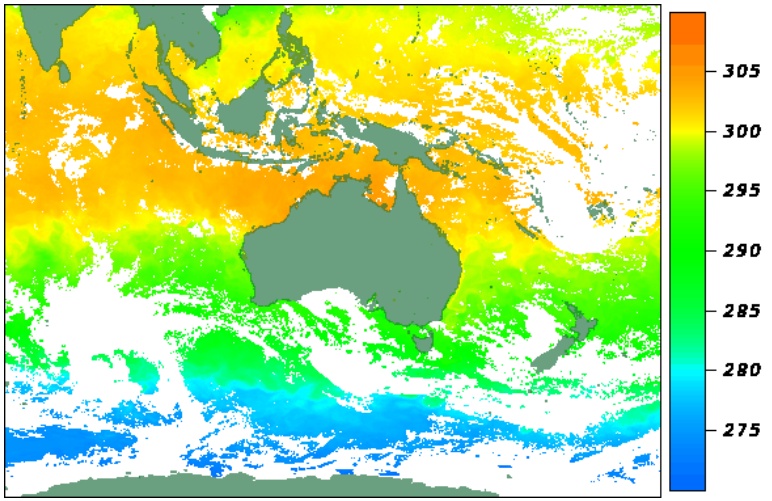
IMOS VIIRS L3C product

- We composited VIIRS_NPP L3U data to construct our new VIIRS L3C product

1-day night L3C (QL=4, 5) from NOAA-19



1-day night L3C (QL=4, 5) from VIIRS

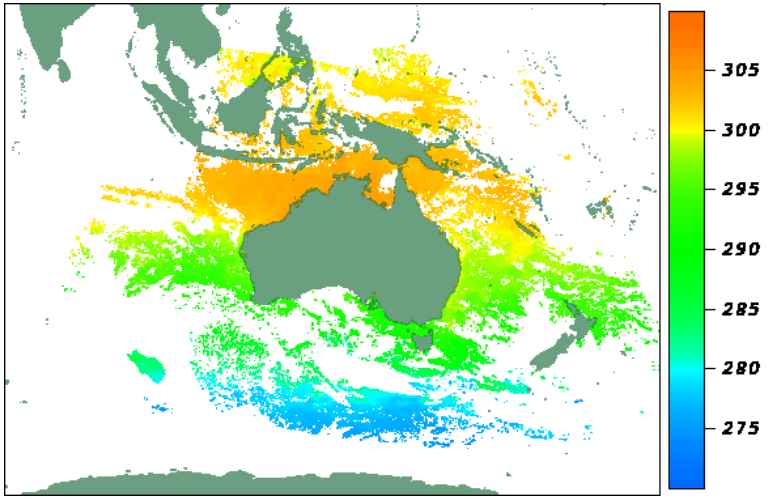


Sea surface temperatures with quality level 4 and 5 For L3C-1day night file from (a) NOAA-19 and (b)VIIRS_NPP for 22nd February 2016.

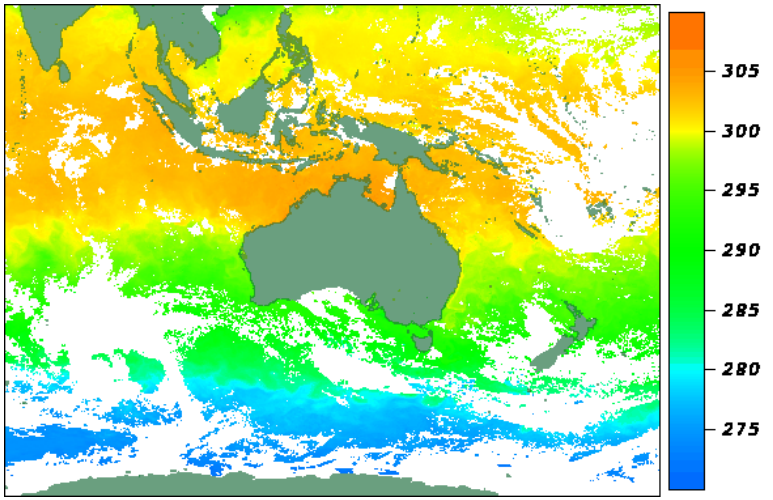
IMOS "Multi-sensor" L3S product

- We composited NOAA-15, NOAA-18, NOAA-19 and VIIRS_NPP data to construct our new "Multi-sensor" L3S product
- Note that in this example Multi-sensor L3S has greater spatial coverage than VIIRS L3C alone, for remapped quality level ≥ 4

1-day night L3S (QL=4, 5) from NOAA-18/19



1-day night L3S (QL=4, 5) from N-15/18/19 and VIIRS



Sea surface temperatures with quality level 4 and 5 For L3S-1day night file from (a) NOAA-18/19 and (b) Multi-sensors (NOAA-15/18/19 and VIIRS_NPP) for 22nd February 2016.

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VIIRS L3C/L3S Validation

IMOS

Compared QL ≥ 4 SST(0.2 m) from IMOS AVHRR and VIIRS L3C/L3S files with drifting and tropical moored buoy foundation SSTs for 1 Mar – 30 Jun 2017 over Australian domain (70ºE – 190ºE, 70ºS – 20ºN). Data collocated if within 6 hours and same 0.02º grid cell, and winds > 6 m/s (day), > 2 m/s (night).

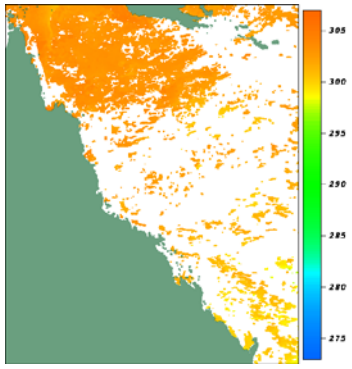
L3C/L3S Product	Day Matchups	Day Bias (K)	Day SD (K)	Night Matchups	Night Bias (K)	Night SD (K)
N-15 L3C	107	-0.10	1.14	2298	-0.03	0.69
N-18 L3C	846	0.04	0.66	4769	-0.01	0.65
N-19 L3C	2741	0.06	0.65	3835	0.02	0.44
VIIRS L3C	15355	0.21	0.36	20092	0.04	0.35
N-18/19 L3S	3958	-0.01	0.69	7123	0.00	0.57
Multi L3S	20901	0.23	0.45	24447	0.03	0.44

Use of VIIRS SSTs - Level 3 SST

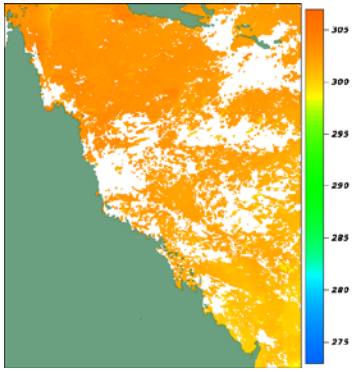
Due to enhanced spatial coverage and agreement with buoys, the IMOS multi-sensor L3S SST products are expected to provide better input for applications such as BoM's ReefTemp NextGen Coral Bleaching Nowcasting system and IMOS OceanCurrent.

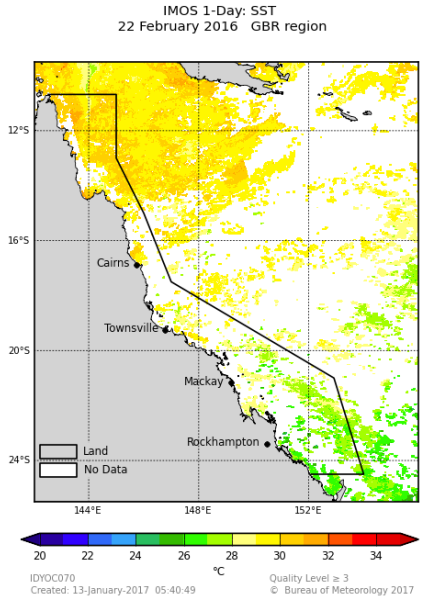
L3S-1night quality>=4 for 22 Feb 2016

AVHRR

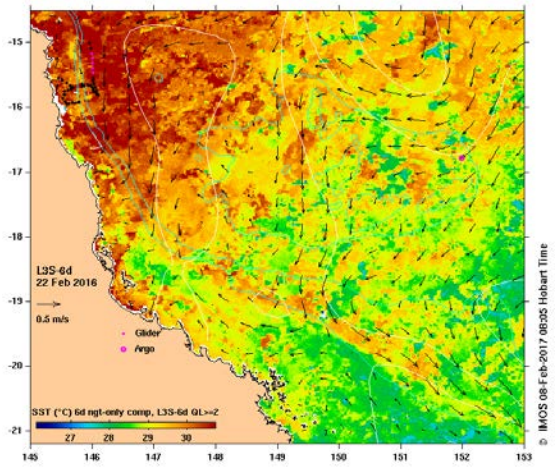


Multisensor





BoM ReefTemp NextGen map of the 2 km SST for 22 Feb 2016, generated using IMOS night-only 1-day L3S SSTs.
Image source:
http://www.bom.gov.au/environment/activities/reeftemp/reeftemp.shtml



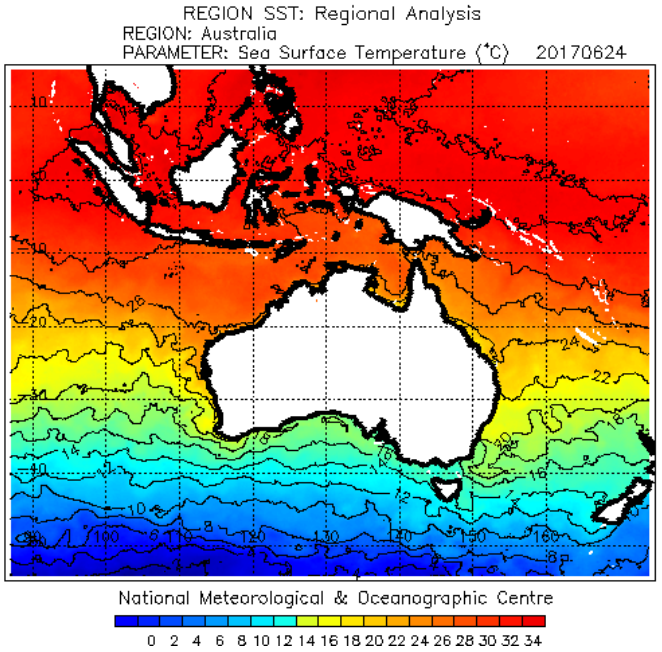
IMOS *OceanCurrent* map of the 2 km SST and surface ocean current vectors for 22 Feb 2016, generated using IMOS night-only 6-day L3S SSTs.
Image source:
http://oceancurrent.imos.org.au/sst.php

Use of VIIRS SSTs - Level 4 SST

- ACSPO VIIRS L3U SST data is being tested for ingestion into the Bureau's operational daily SST analyses (1/12º RAMSSA and 1/4º GAMSSA)

- Pre-processing system converts ACSPO VIIRS L3U data to IMOS VIIRS L3U format (QL changed) then collates to daily 1/12º and 1/4º L3C SSTfnd data
  - Using only SSTs for daytime ACCESS-G NWP analysis winds ≥ 6 m/s, nighttime winds ≥ 2 m/s
  - Will be optimally interpolated along with HRPT AVHRR, GAC AVHRR, AMSR-2 and in situ SSTfnd data into SST analyses

RAMSSA SST Analysis for 24th June 2017



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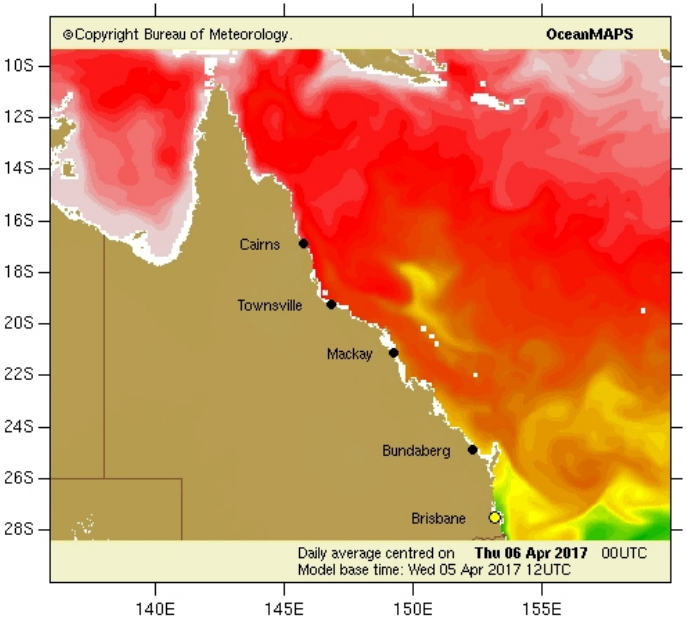
Use of VIIRS SSTs - Ocean Forecast SST

- By end of 2017 ACSPO VIIRS L3U SST data will be ingested into the Bureau's operational 10 km global ocean model, OceanMAPS v3.2, and 4 km Great Barrier Reef ocean model, eReefs
- Pre-processing system collates VIIRS L3U data to 6-hourly 0.04º L3C data
- Collated obs: (quality level = 5) AND (nighttime OR winds ≥ 6 m/s)
- Assimilating VIIRS L3C SST into eReefs resulted in marginal improvement in SST forecast error, with no major effect on other state variables
- Assimilating VIIRS significantly increased IR SST data coverage cf NAVO GAC AVHRR L2P

OceanMAPS forecast SST(2.5m)



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Summary

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- The high spatial resolution (0.75 km) of VIIRS SST data results in significant improvement in spatial coverage of IMOS multi-sensor L3S SST products and infrared SST inputs into ocean models and SST analyses at BoM
- Initial validation (March-June 2017) indicates that QL ≥ 4 multi-sensor L3S SSTs have significantly lower standard deviation than AVHRR-only L3S SSTs, when compared with buoy SSTs
- The improved L3S SST products are likely to provide better input for applications such as ReefTemp NextGen Coral Bleaching Nowcasting and IMOS OceanCurrent.
- Maps of pre-operational IMOS 1-day Multi-sensor L3S SST available in test ACSPO Regional Monitoring System (ARMS: https://www.star.nesdis.noaa.gov/sod/sst/arms_dev/arms_test2)

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Future work

IMOS

Over the coming 12 months, we aim to:

- Implement download of ACSPO VIIRS L3U files from operational NOAA FTP server rather than PO.DAAC
- More extensively validate VIIRS L3C/L3S files
- Provide operational, real-time IMOS fv01 VIIRS 2 km L3U, L3C and multi-sensor L3S files via the IMOS OPeNDAP server
- Reprocess IMOS fv02 AVHRR L3U/L3C/L3S and fv02 VIIRS L3C and multi-sensor L3S files for the period 1 Jan 2015 to 31 Dec 2016 using reprocessed ACSPO v2.4 VIIRS L3U files
- Test ingesting VIIRS L3C SSTfnd into RAMSSA/GAMSSA SST analyses
- Include ACSPO VIIRS L3U SST in operational general circulation ocean models – OceanMAPS v3.2 and eReefs

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Thank You!

Contact: helen.beggs@bom.gov.au

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Supplementary Slides

Constructing IMOS VIIRS L3U product

- Only the ACSPO VIIRS L3U files that have data on IMOS grid are processed further.
- ACSPO VIIRS L3U files are modified by adding ancillary fields to match up with standard IMOS L3U files (e.g. sea ice, winds, dt_analysis)
- l2p_flags are redefined using modified ancillary fields.
- The variable 'or_number_of _pixels' in the NOAA's VIIRS_NPP ACSPO_v2.40 L3U file indicates the original number of pixels from the L2Ps contributing to the SST value. VIIRS spatial resolution is 742m while AVHRR spatial resolution is 1.1km, almost double.
- To ensure that the pixel density is consistent between VIIRS with AVHRR at NADIR, we divided 'or_number_of_pixels' in OSPO VIIRS L3U file by two to get 'sses_count' in our new VIIRS L3U file.

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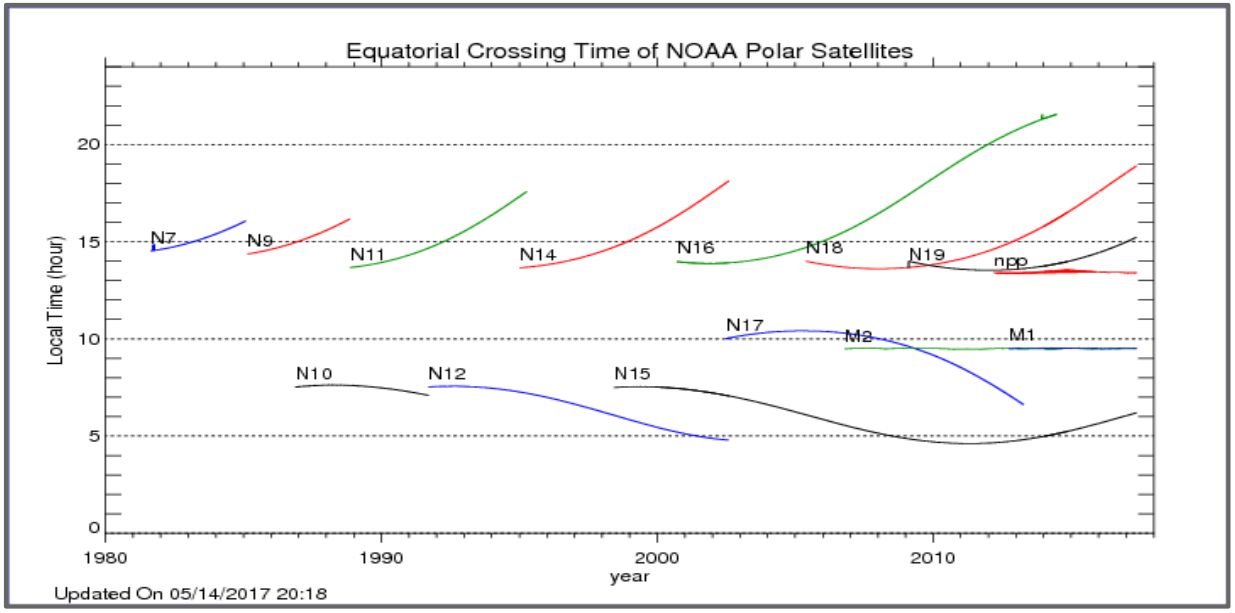
Equatorial Crossing Times for NOAA Polar Satellites

IMOS

The satellites NOAA-15, NOAA-18, NOAA-19 and Suomi-NPP have different equatorial crossing times. Currently, the daytime equatorial crossing time for

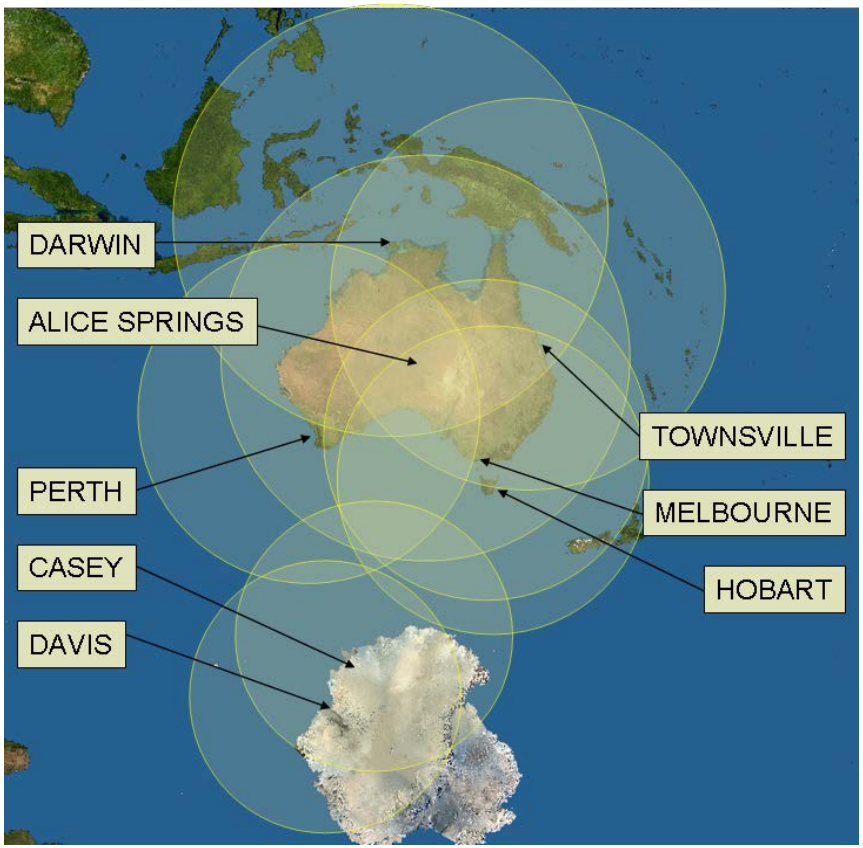
- NOAA-15 is ~ 18:00 LST (around sunset)
- NOAA-18 is ~ 19:00 LST (around sunset)
- NOAA-19 is ~ 15:00 LST (close to peak diurnal cycle)
- Suomi-NPP is ~13:30 LST (early afternoon)



Equatorial Crossing Time for NOAA Polar onboarding Satellites.
Image Source: https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_avhrr_ect.php

Introduction

- Passive infra-red sensors on polar-orbiting satellites provide the highest resolution SST observations from space (~1 km) but cannot sense SST under cloud.
- Pre-2002 (MODIS) the only wide swath, 1 km resolution, satellite SSTs available were direct-broadcast AVHRR SST from NOAA polar-orbiters.
- BoM and CSIRO have 1.1 km (at nadir) "HRPT" AVHRR data from NOAA-11 to NOAA-19 from reception stations in Australia and Antarctica back to mid-1980's



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OceanMAPS v3.1 SST Analyses and Forecasts

Lead: Gary Brassington; Contact: Xinmei Huang

http://www.bom.gov.au/oceanography/forecasts

Depth: Top cell depth 5 m so SST(2.5 m)

Resolution: Daily, 0.1º Global

Available: 9 Jun 2016 to real-time

Method: sequential, multi-variate, data assimilation based ensemble optimal interpolation

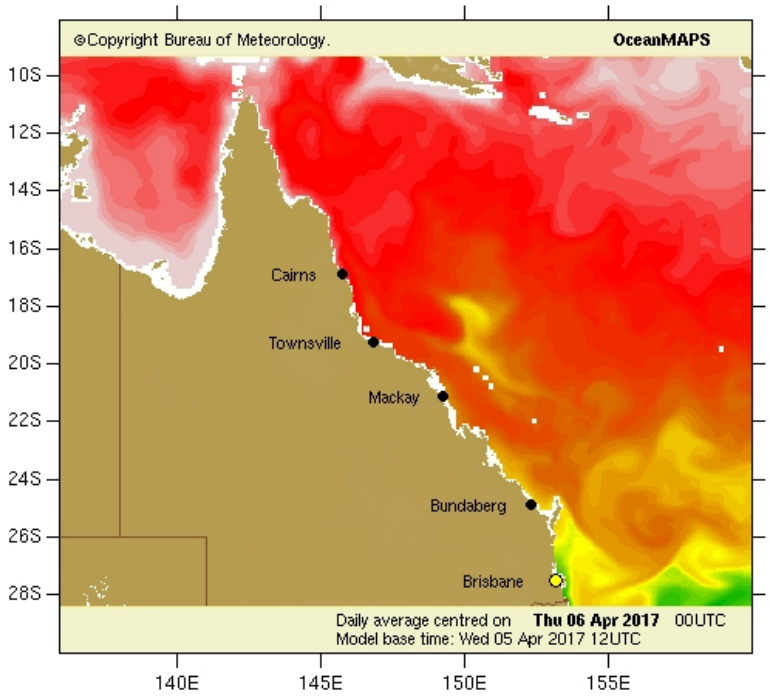
- Multivariate assimilation includes - altimetry, sat-SST, in situ T/S and XBT's

SST inputs:

- 9 km NAVOCEANO GAC AVHRR (NOAA-18/19, METOP-A/B) **L2P** SST1m
- ~50 km JAXA AMSR-2 (GCOM-W) **L2P** SSTsubskin
- Argo, XBT, CTD, mooring in situ SSTdepth (GTS, Coriolis, US-GODAE)

Uses: Defence, Search & Rescue, Oil Spills, shipping, etc

OceanMAPS forecast SST(2.5m)



Data availability

IMOS AVHRR-only 2 km L3U, L3C and L3S files are available by Thredds server from 1992 to present at http://rs-data1-mel.csiro.au/thredds/catalog/imos-srs/sst/ghrsst/catalog.html

The online operational validation of IMOS AVHRR L2P products is available at http://imos.org.au/sstdata_validation.html

The pre-operational real-time IMOS VIIRS L3U/L3C and multi-sensor L3S files from 1 March 2017 to present are available by request (contact: helen.beggs@bom.gov.au)