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IMOS Integrated Marine Observing System

Ingesting SLSTR SST into IMOS Multi-sensor SST composites

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GHRSST-XXI Science Team Meeting, 1-4 June 2020

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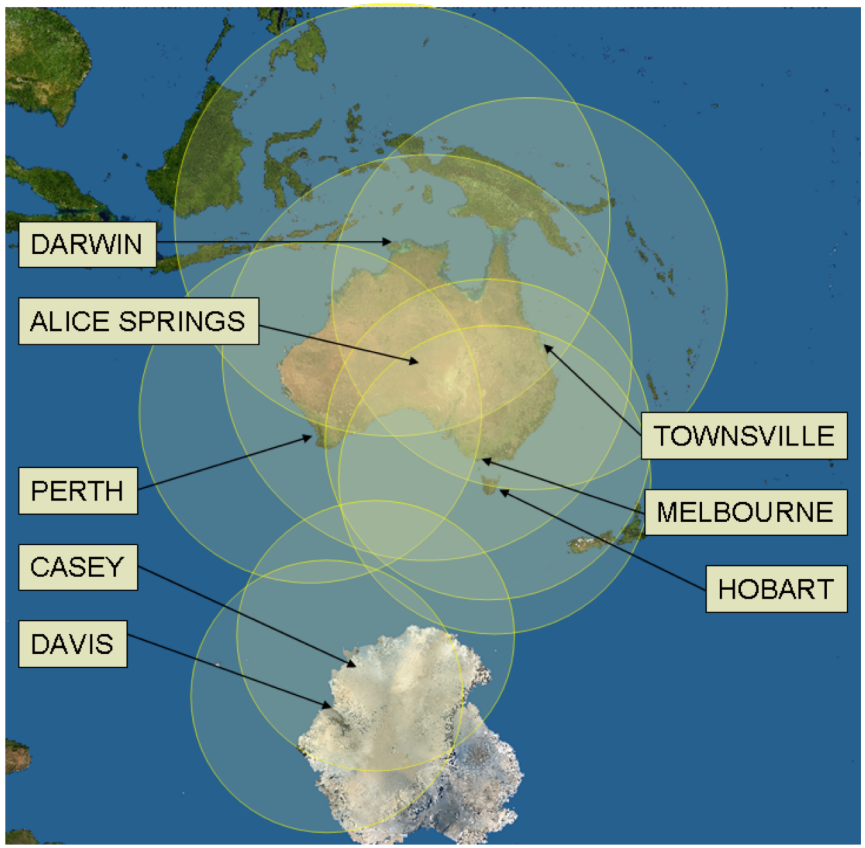
IMOS GHRSST products

- Prior to MODIS in 2002, the only wide swath, 1 km resolution, satellite SSTs available were direct-broadcast (“HRPT”) 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
- CSIRO has accurately navigated and stitched these raw ASDA from 1992 to present



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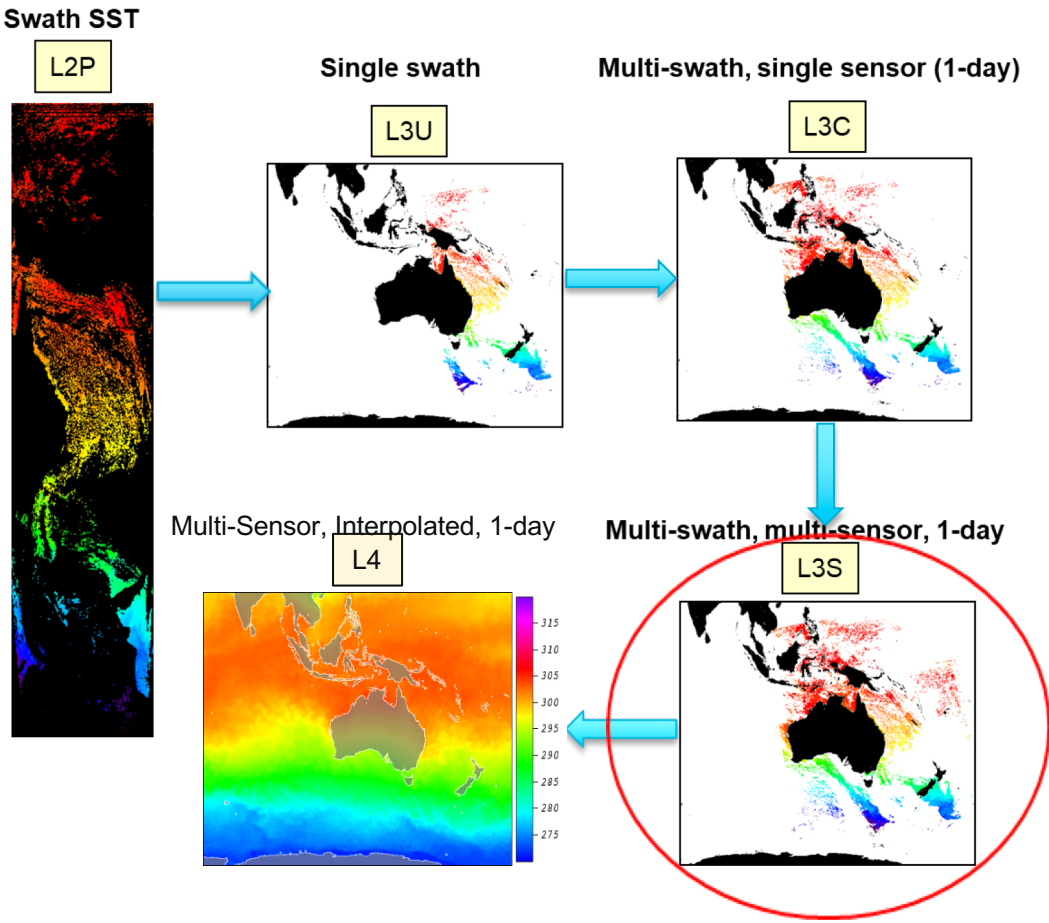
IMOS GHRSST products

As a contribution to the Integrated Marine Observing System (IMOS), we provide five types of GHRSST GDS2 format Level 2, level 3 and level 4 SST products:

- L2P (geolocated, native resolution of sensor)
- L3U (swath, gridded)
- L3C (multiple swath, gridded)
- L3S (multiple sensor, gridded)
- L4 (multiple sensor, statistically interpolated, gridded)



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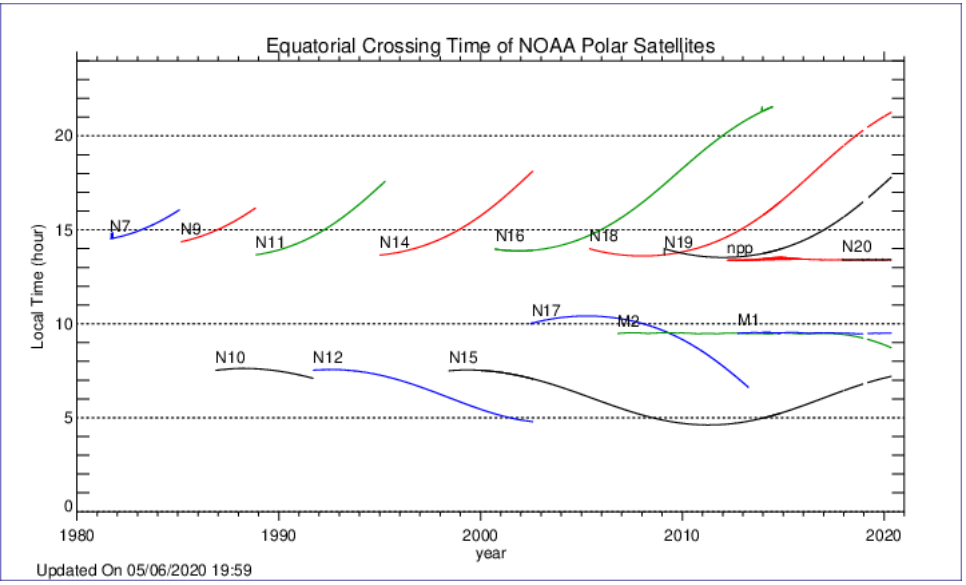
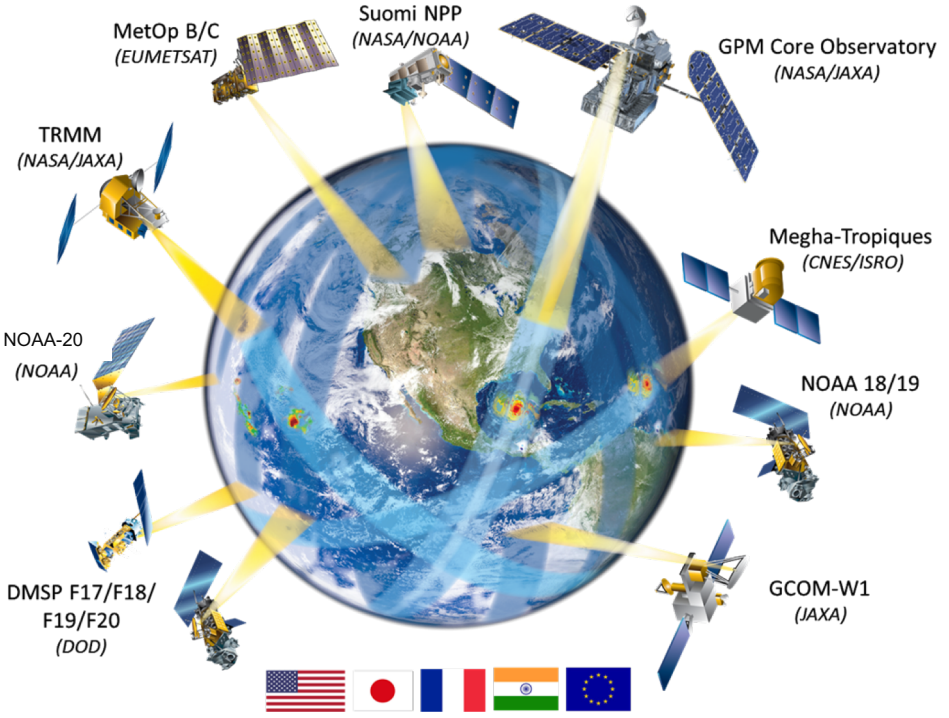
Multisensor L3S SST products

- Several satellites provide Sea Surface Temperature (SST) data
- Spatial coverage may be improved by merging data from satellite sensors that have different equatorial crossing times



Constellation of polar-orbiting satellites (image credit: NASA)



https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_avhrr_ect.php

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Multi-sensor L3S SST

At BoM, we produce operational Multi-sensor L3S SST products using infrared data from

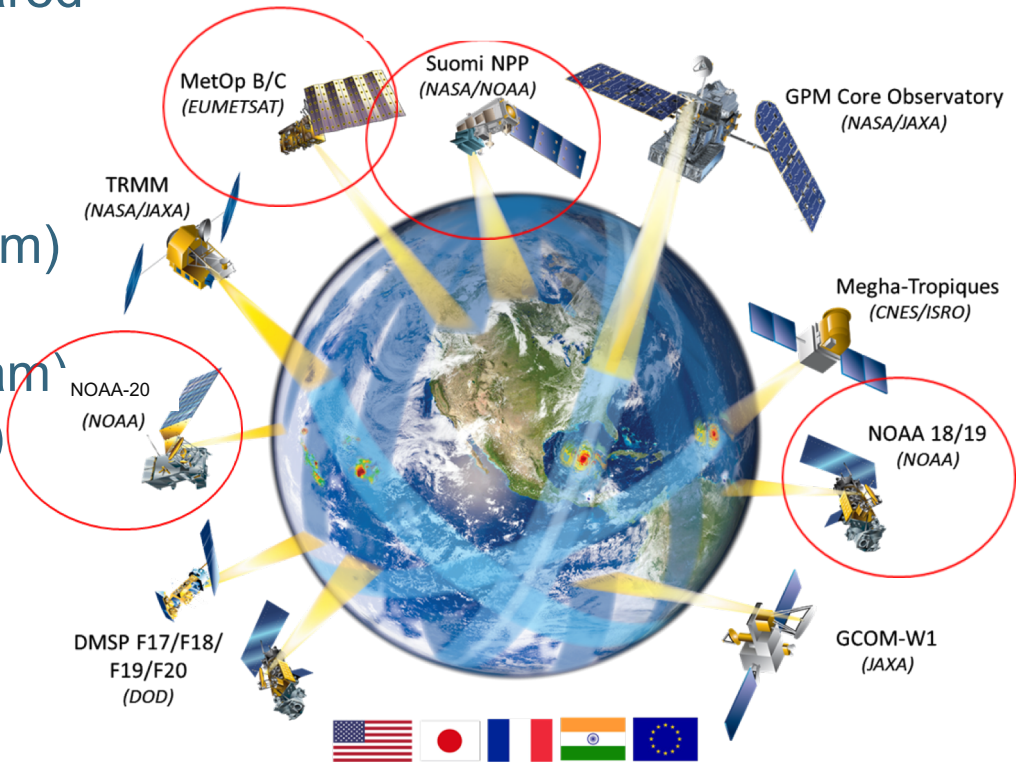
❑ Polar orbiters:

- NOAA-18 AVHRR (ECT 9:15 am/pm)
- MetOp-B (ECT 9:30 am/pm)
- Suomi-NPP VIIRS (ECT 1:30 pm/am`
- NOAA-20 VIIRS (ECT 1:30pm/am)

Now experimenting with addition of:

- Sentinel-3A (ECT 10 am/pm)
- Sentinel-3B (ECT 10 am/pm)

Constellation of polar-orbiting satellites (image credit: NASA)



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Multi-sensor L3S SST

- EUMETSAT produces SLSTR L2P product for both Sentinel-3A and Sentinel-3B satellites.
- BoM downloads these SLSTR L2P files using the Copernicus Hub on NCI
- Investigating effect of adding SLSTR to our current Multi-sensor L3S in terms of spatial coverage and overall accuracy.
- Only Dual view data with quality level 5 are used.

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Constructing IMOS L3U SST

- BOM uses OSISAF produced FRAC AVHRR L2P SST products for MetOpA and MetOpB, and EUMETSAT produced SLSTR L2P SST for Sentinel 3A and Sentinel 3B and produces respective L3U SSTs on IMOS 0.02º grid over two Australian and Southern Ocean domains.
- NOAA/STAR produces "ACSPO" VIIRS_NPP and VIIRS_N20 0.02º single swath, composite "L3U" SST products (on IMOS grid)
- Only the files that have data on the IMOS grid (20˚N-70˚S, 60˚E-190˚E) are processed further.
- l2p_flags are redefined using ancillary fields (e.g. sea ice, winds, dt_analysis) that are used for standard IMOS L3U files.

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Constructing IMOS L3U SST

- In order to merge with IMOS AVHRR L3U SSTs, these L3U SSTs are modified such that the quality_level is redefined as the minimum of the original 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

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Why adjust the quality level in this way?

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 (Griffin et al., 2017 at http://imos.org.au/fileadmin/user_upload/shared/SRS/SST/GHRSST-DOC-basic-v1.0r1.pdf)

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

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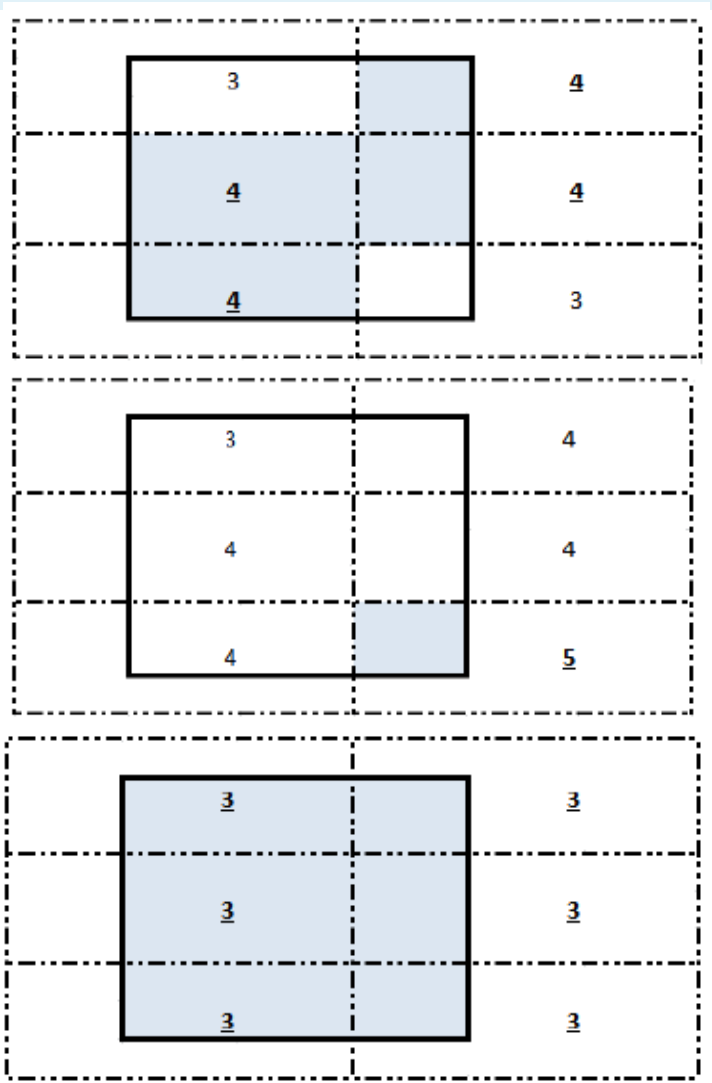
Composition of swaths

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

The four q=4 pixels would be used for average, the target would have quality=4

One q=5 pixel would be used, the target would have ql=5

All 6 ql=3 pixels would be used, the target would have ql=3



Sentinel-3A and 3B L3C products

- We composited SLSTR L3U data to construct our new SLSTR L3C product
- Merged L3C SST over a given time period and location is defined as weighted average of the best quality source L3U pixels on the IMOS 0.02 degree grid

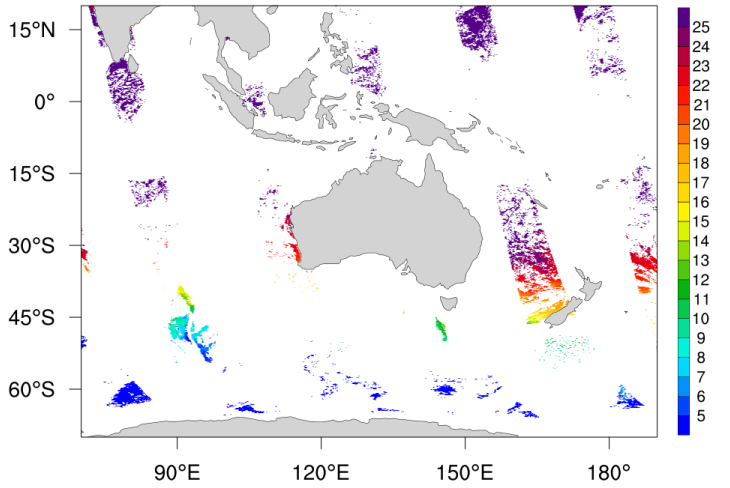
$$T_{\text{satellite},C,j} = \frac{\sum_{i \in j} \frac{n_{U,i}}{\sigma^2_{U,i}} T_{\text{satellite},U,i}}{\sum_{i \in j} \frac{n_{U,i}}{\sigma^2_{U,i}}}$$

n_U - degree of freedom

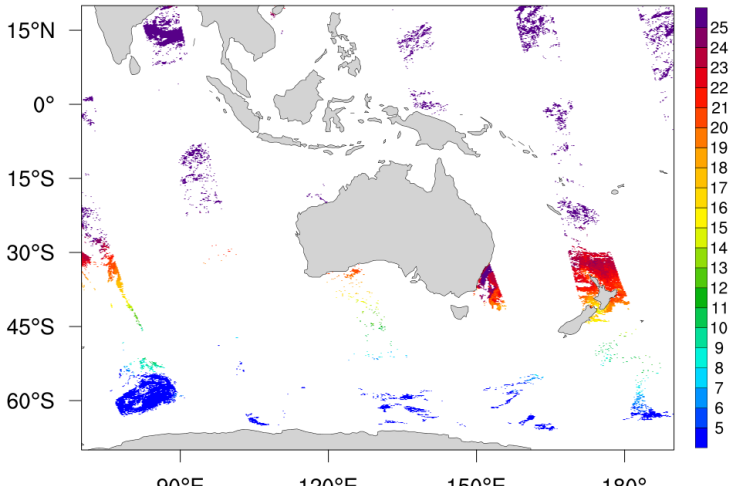
σ_U - estimate of the measurement error

Sea surface temperatures with quality level 4 and 5 For L3C-1day night file from (a) Sentinel-3A and (b)Sentinel-3B for 31st January 2020.

1-day night L3C (QL=4, 5) from Sentinel3A



1-day night L3C (QL=4, 5) from Sentinel3B



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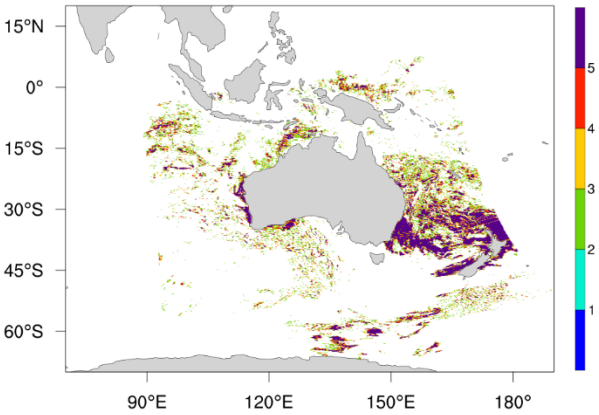
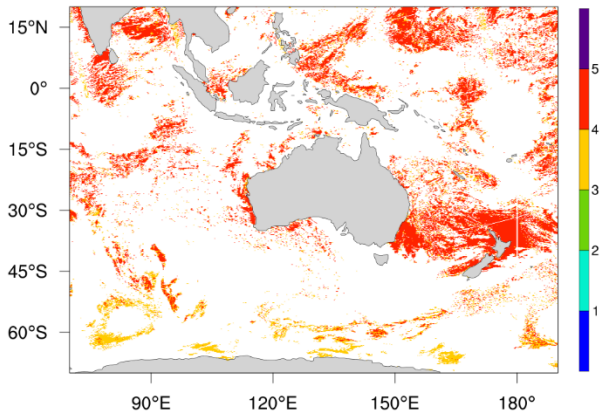
Remapped Quality Level

L3C-1day night file for 31 Jan 2020

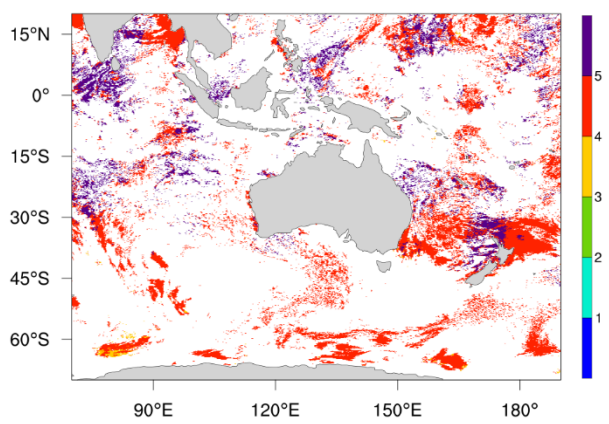
NOAA-18



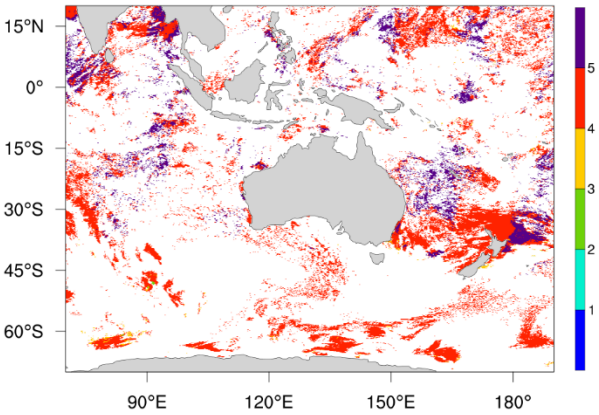
MetOpB



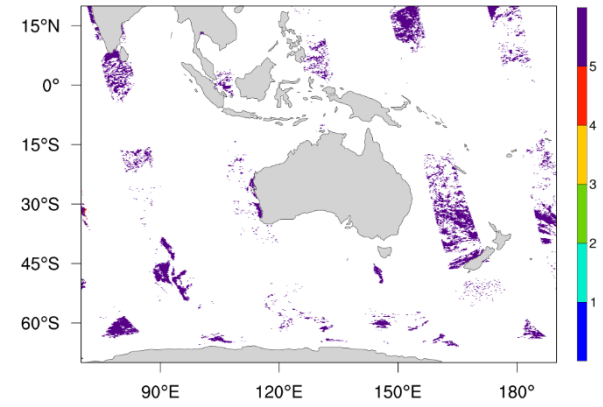
NPP



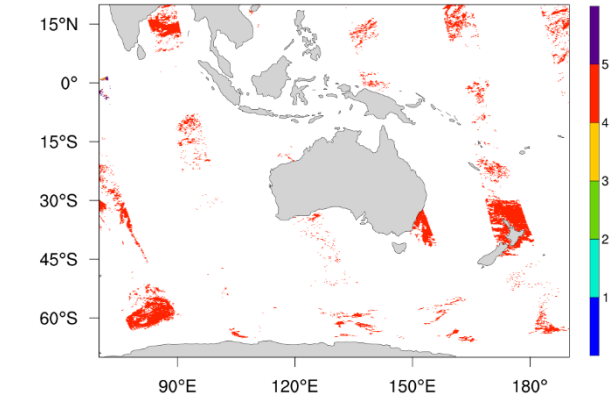
N20



Sentinel-3A



Sentinel-3B



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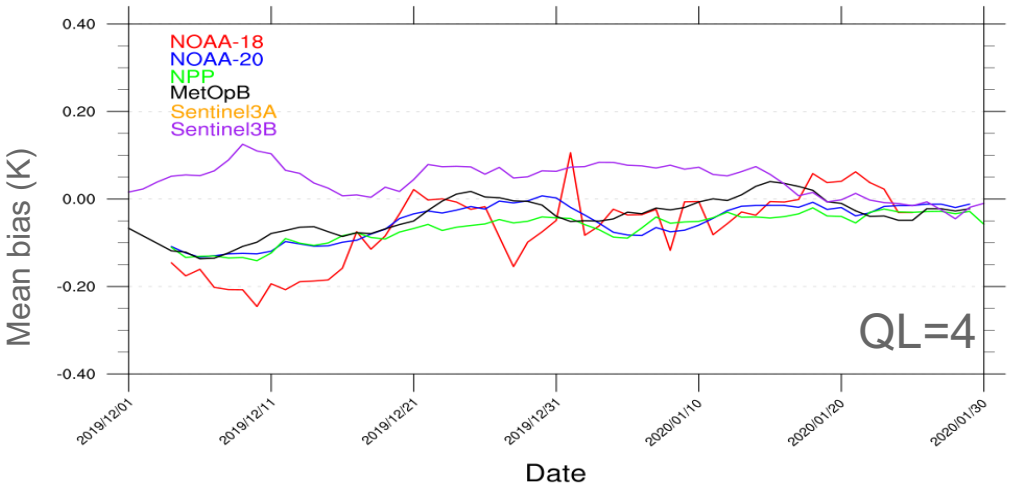
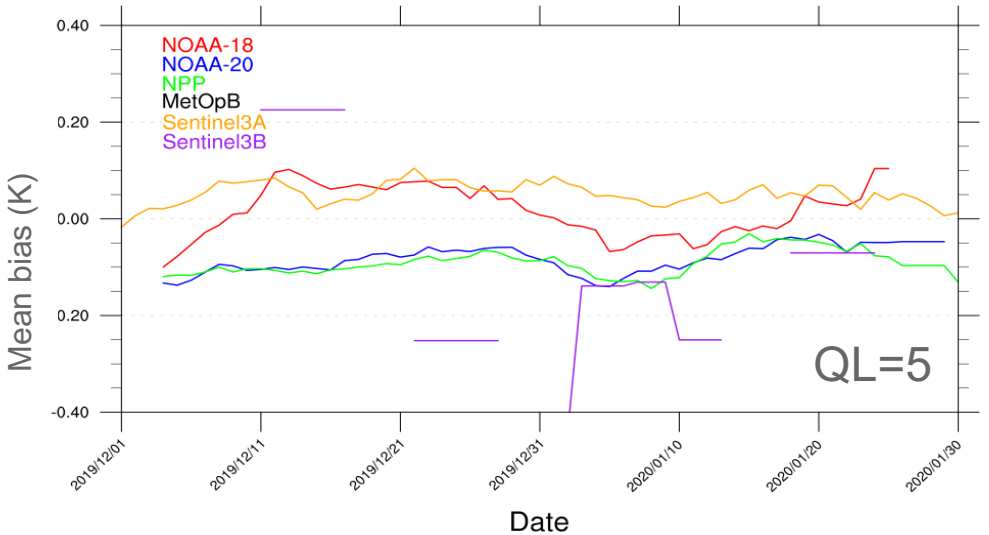
L3C Validation against Drifting and Tropical Moored Buoys

- L3C-01day, night only, weekly statistics, Mean Bias, 1 Dec 2019- 31 Jan 2020.
- *Mean bias = SST - in situ SST + 0.17 (in Kelvin)*
- Sentinel 3A and 3B have less bias than any other satellite sensor.





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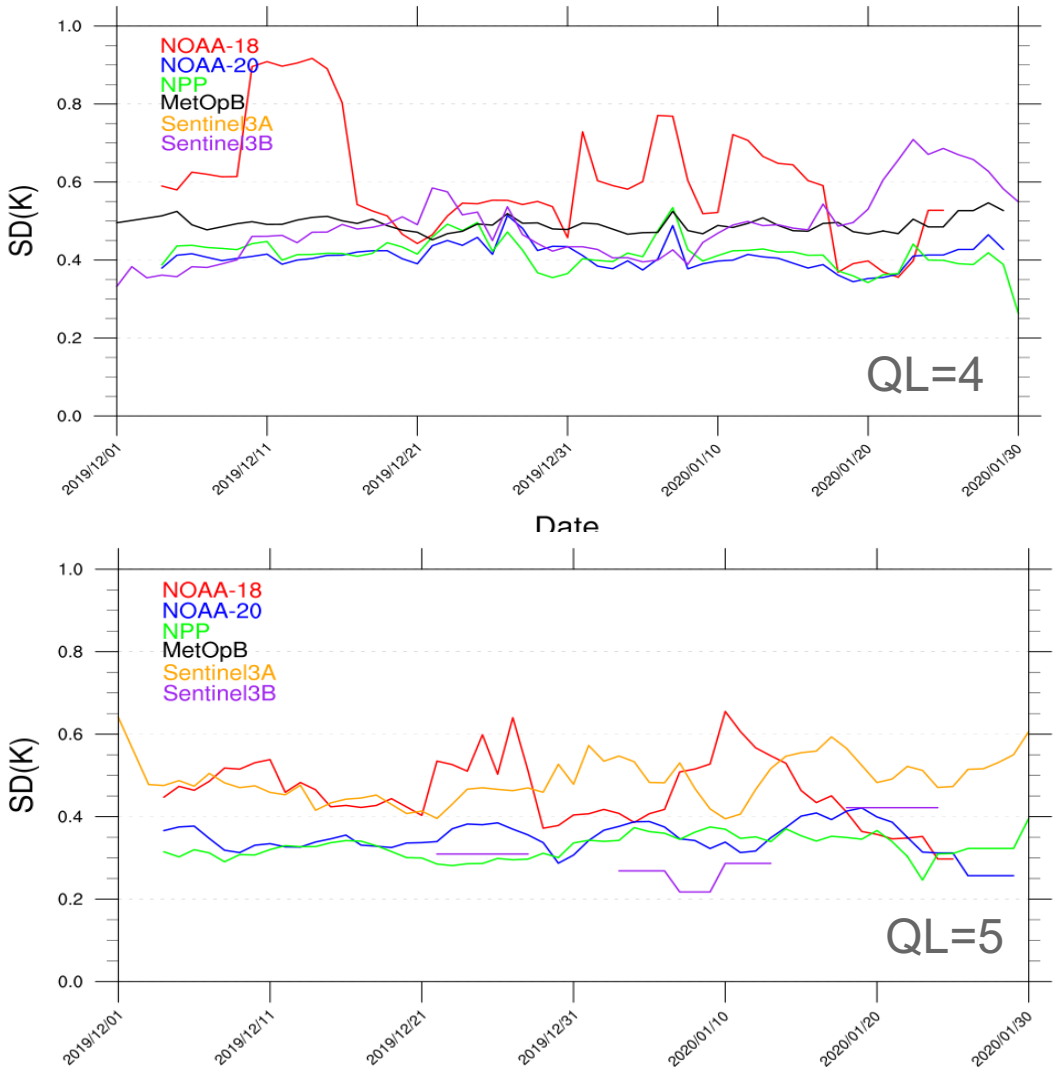
L3C Validation against Drifting and Tropical Moored Buoys

- L3C-01day, night only, weekly statistics, Standard Deviation, 1Dec 2019-31 Jan 2020.
- Sentinel 3A and 3B have similar SD like any other satellite sensor.



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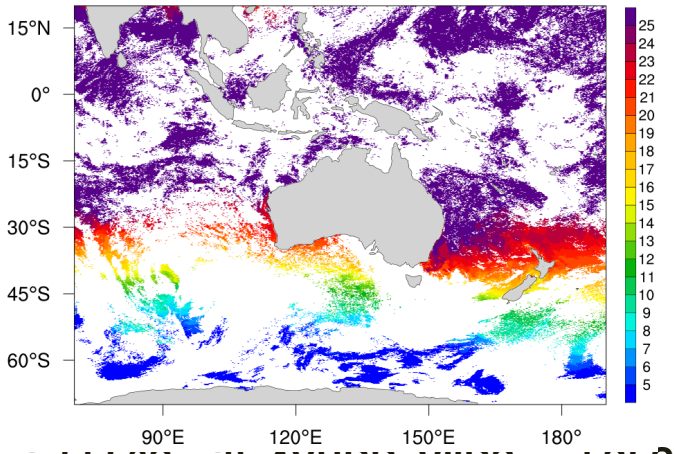
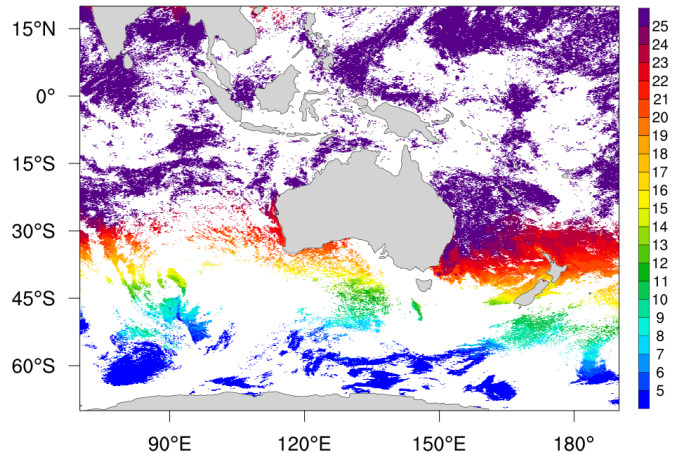
Multi-sensor L3S product

- We composited L3C data to construct our new "Multisensor" L3S product
- Remapped quality of all AVHRR, VIIRS and SLSTR data and then used those remapped quality and equal weighted average method for constructing Multi-sensor products.

1-day night L3S with AVHRR and VIIRS



1-day night L3S with AVHRR, VIIRS and SLSTR



Sea surface temperatures with quality level 4 and 5 for L3S-1day night file from (a) NOAA-18, MetOpB, NPP and N20 and (b) NOAA-18, MetOpB, NPP, N20,Sentinel-3A and Sentinel-3B for 31st January 2020.

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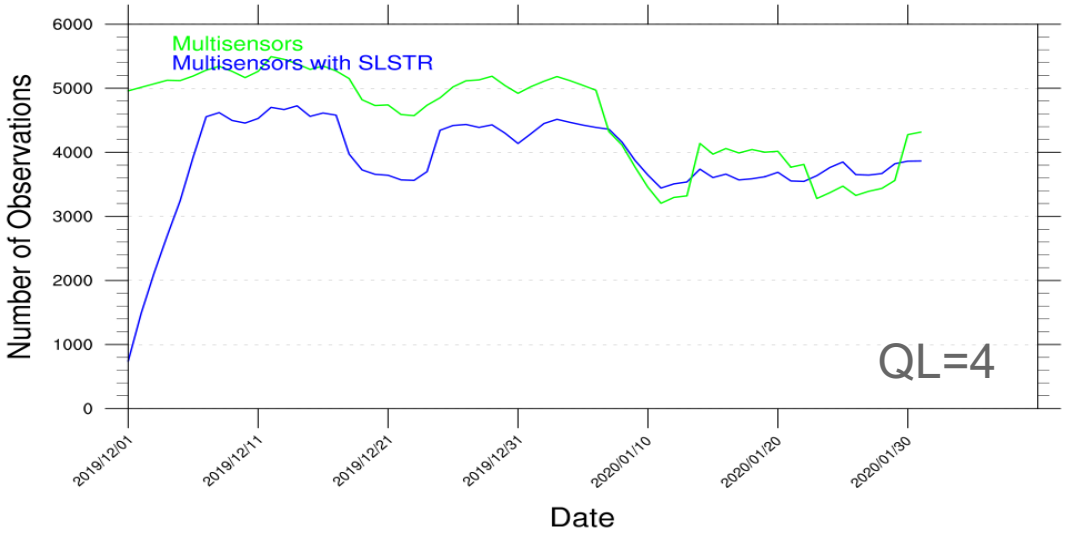
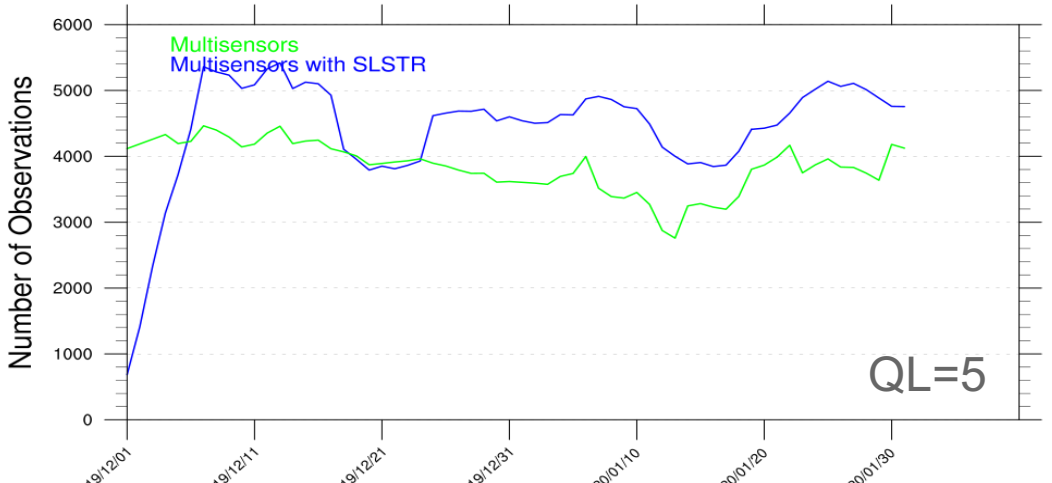
L3S Validation against Drifting and Tropical Moored Buoys

- L3S-1day Vs in-situ, night only, weekly statistics, Number of matchups,1 Dec 2019-31 Jan 2020
- Ingesting SLSTR improves spatial coverage of QL = 5 Multi-sensor L3S-01day SST





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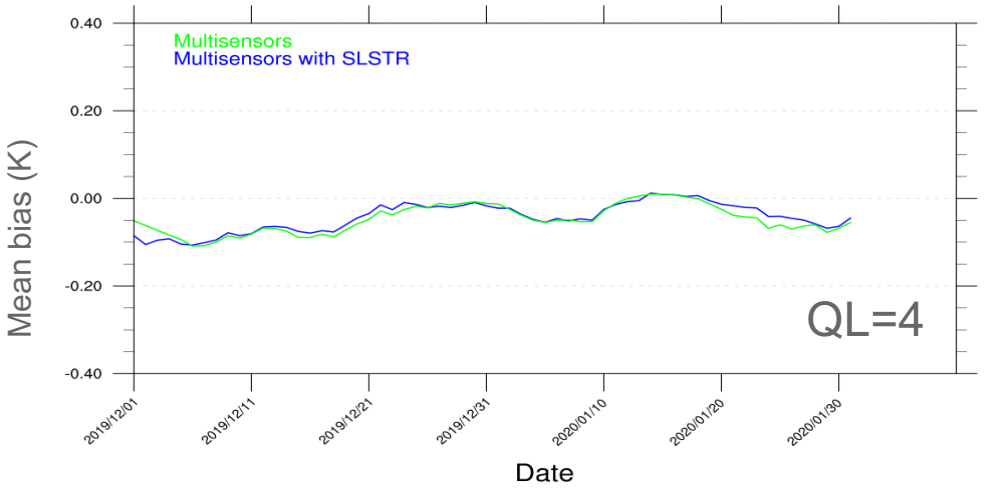
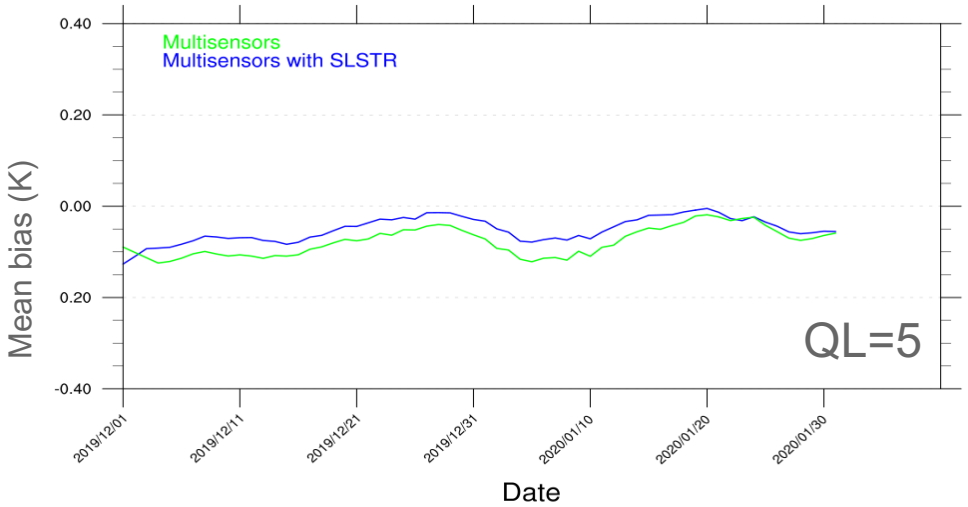
L3S Validation against Drifting and Tropical Moored Buoys

- L3S-1day Vs in-situ, night only, weekly statistics, Mean Bias, 1 Dec 2019-31 Jan 2020
- Mean bias = SST - in situ SST + 0.17 (in Kelvin).
- Ingesting SLSTR slightly improves bias





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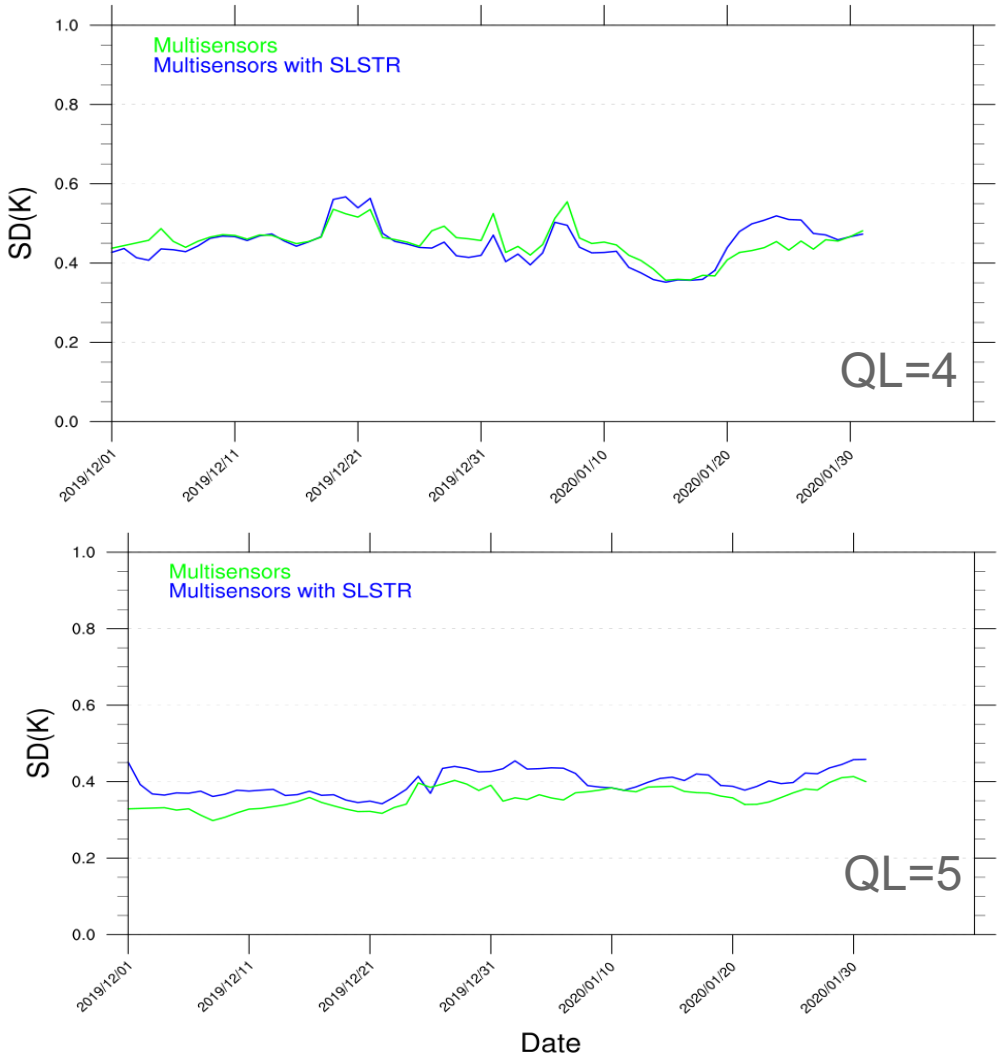
L3S Validation against Drifting and Tropical Moored Buoys

- L3S-1day Vs in-situ, night only, monthly statistics, Standard Deviation, 1 Dec 2019-31Jan 2020
- Ingesting SLSTR makes little impact to Standard Deviation



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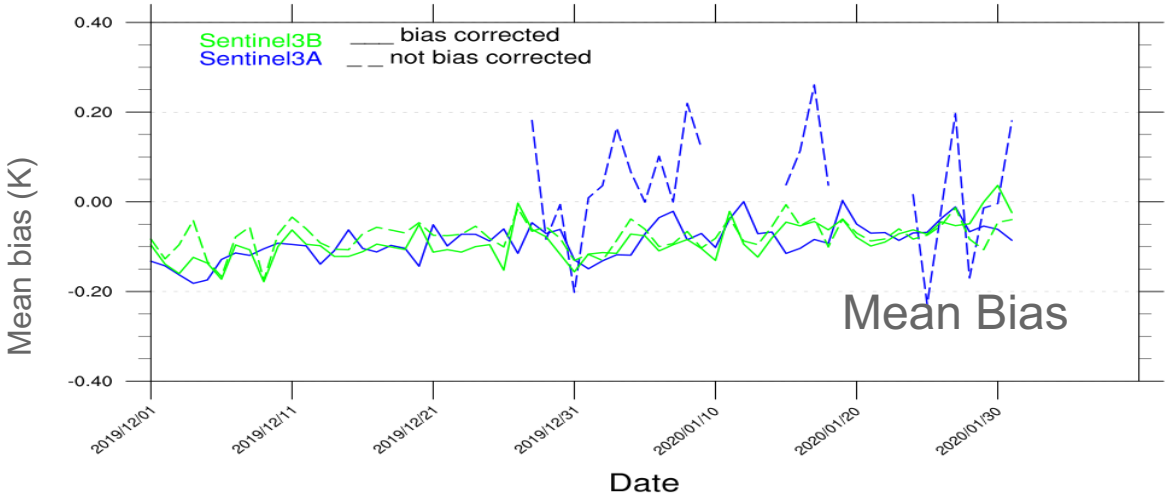
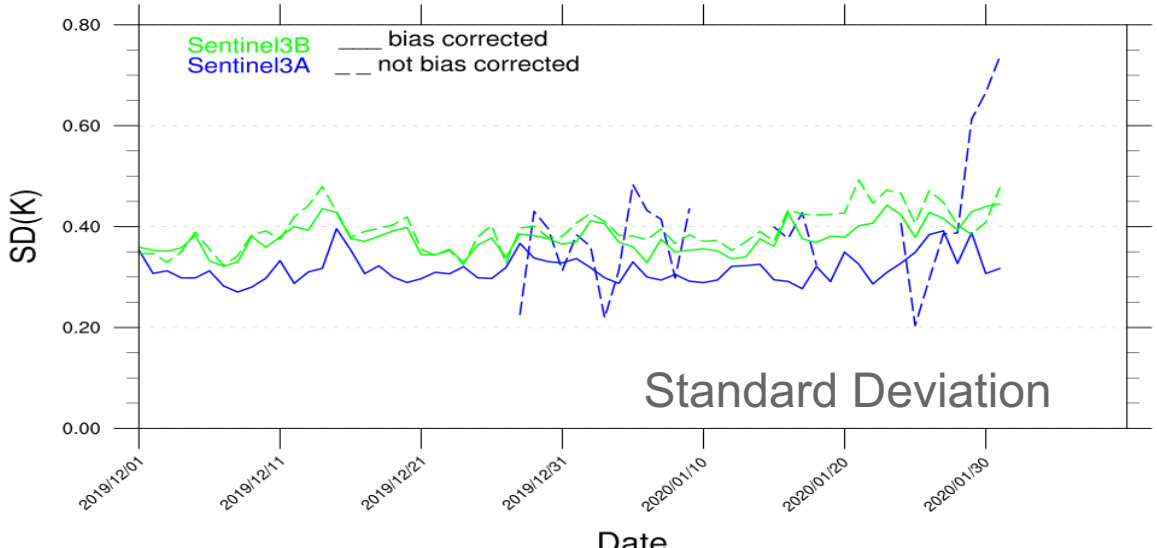
L3S Validation against SLSTR L3C

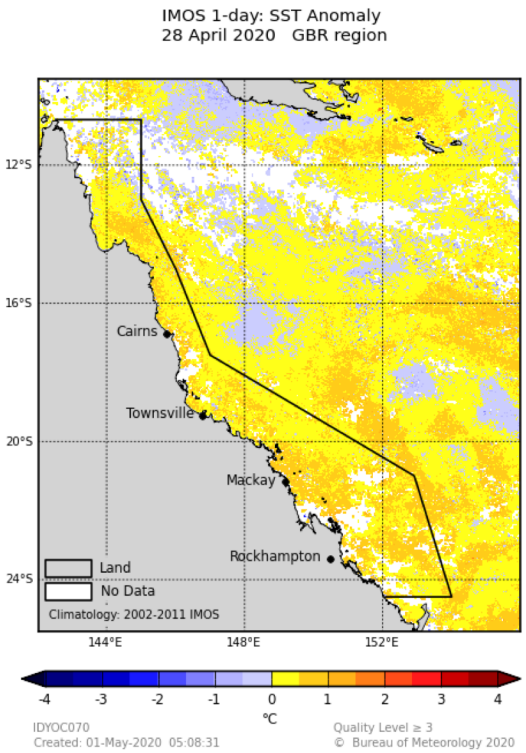
- Operational Multisensors L3S-1day Vs SLSTR L3C-1day, night only, daily statistics, QL≥4,1 Dec 2019-31Jan 2020
- Mean bias = SST – L3C SLSTR SST (in Kelvin).
- Very good agreement with SLSTR



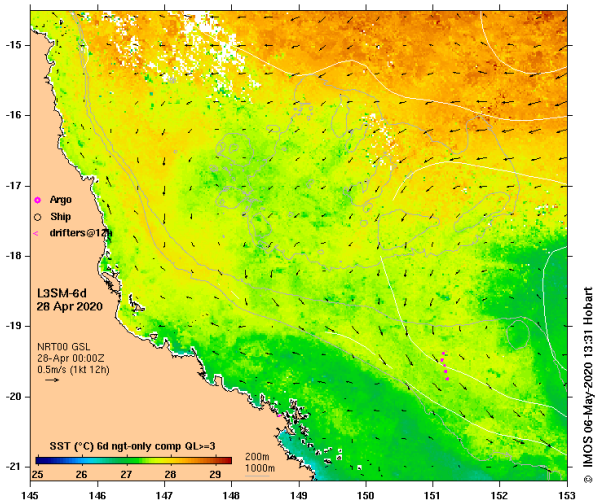


Use of Multi-sensor SST

The IMOS multi-sensor L3S SST products are providing better input for applications such as BoM's ReefTemp NextGen Coral Bleaching Nowcasting system and IMOS OceanCurrent.



BoM ReefTemp NextGen map of the 2 km SST anomaly for 28 Apr 2020, 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 28 Apr 2020, generated using IMOS night-only 6-day L3S SSTs.
Image source:
http://oceancurrent.imos.org.au/sst.php

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Summary

- Addition of SLSTR data slightly improves spatial coverage of highest quality (QL=5) data from the IMOS Multi-sensor L3S SST products.
- Initial validation (Dec 2019-Jan 2020) indicates that addition of SLSTR data to Multi-sensor L3S provides marginally better statistical parameters than operational Multi-sensors L3S, when compared with buoy SSTs.
- Narrower swaths of Sentinel 3A and 3B limit their use to provide specialised products, however, they can be used as reference sensors for validation of most of the SST products.

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Future work

Over the coming 6 months, we aim to:

- More extensively validate Sentinel L3C/L3S
- Experiment with adding Himawari-8 SST data to IMOS Multi-sensor L3S composites
- Develop SSES model that could be applied to all sensors contributing to the Multi-sensor L3S SSTs so that quality can be remapped more uniformly.

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Thank You!

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Supplementary Slides

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Useful sites for information on IMOS GHRSST products

GHRSST products: https://www.ghrsst.org/quick-start/

IMOS HRPT AVHRR GHRSST Products: http://imos.org.au/facilities/srs/sstproducts/sstdata0/

IMOS Multi-sensor GHRSST Products: http://imos.org.au/fileadmin/user_upload/shared/SRS/SST/Beggs_2019_IMOS_Multi-sensor_L3S_article_21Feb2018.pdf

IMOS GHRSST SST Validation: http://imos.org.au/facilities/srs/sstproducts/sstdata0/sstdata-validation/

Access to IMOS GHRSST Products: http://portal.aodn.org.au and http://thredds.aodn.org.au/thredds/catalog/IMOS/SRS/SST/ghrsst/catalog.html

IMOS OceanCurrent maps of IMOS L3U and L3S products: http://oceancurrent.imos.org.au

GHRSST L4 (inc GAMSSA) Validation/Inter-comparison: http://www.star.nesdis.noaa.gov/sod/sst/squam

Regional SST Maps (inc RAMSSA L4, IMOS L3S and other GHRSST L2P, L3U, L4 products): https://www.star.nesdis.noaa.gov/sod/sst/arms/