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IMOS Integrated Marine Observing System

Australian GHRSST Products and Verification

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[#]Leader, IMOS Satellite Remote Sensing Facility

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Things to consider when choosing an SST product…

Depth

Horizontal Resolution

Temporal Resolution

Level 3 vs Level 4

Sensitivity

Stability

Accuracy

Non-gridded vs gridded

Specified Uncertainties

Date Span

Latency

Metadata

"Operational"?

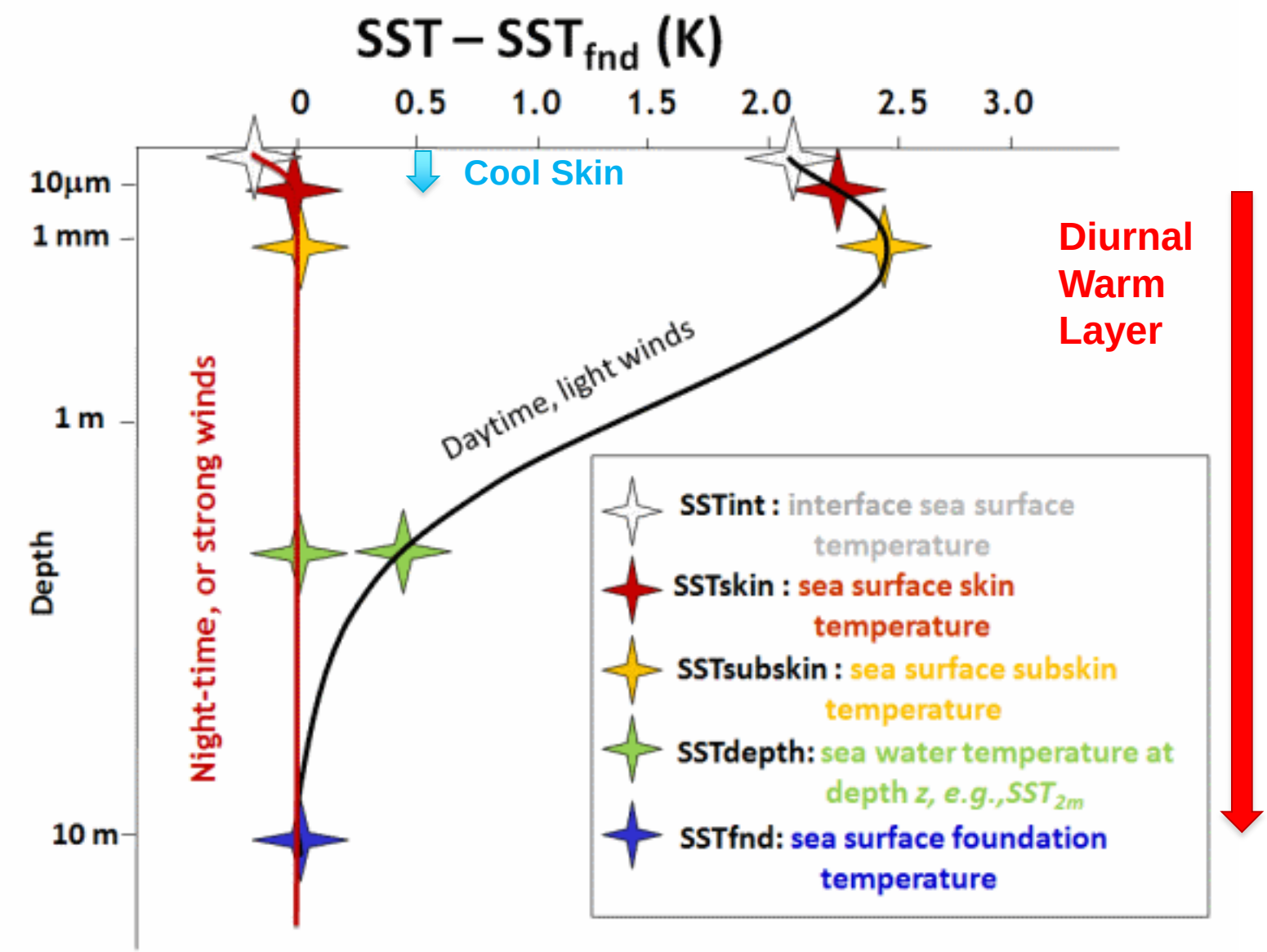
Format

Availability

One SST product cannot best suit every application!

Why SST depth is important

www.ghrsst.org



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Bureau of Meteorology GHRSST products

Designed for different applications…

- 1 km IMOS AVHRR L2P SSTskin *(SST Analyses – Tue)*
- 2 km IMOS AVHRR L3U SSTskin *(OceanCurrent – Tue)*
- 2 km 1/3-day IMOS AVHRR L3C SSTskin *(X. Zhu, H. Zhang – Tue)*
- 2 km 1/3/6/14-day and 1-month IMOS AVHRR L3S SSTskin/SSTfnd *(ReefTemp – Mon; OceanCurrent – Tue)*
- 2 km 10-min Himawari-8 L2P SSTskin *(Chris Griffin – Mon)*
- 5 km hourly IMOS MTSAT-1R L3U SSTskin *(Haifeng Zhang – Tue)*
- 9 km Daily Regional L4 SSTfnd *(Lixin Qi – Tue)*
- 25 km Daily Global L4 SSTfnd *(Lixin Qi – Tue)*
- 100 km Weekly/Monthly Global L4 SSTdepth *(Lixin Qi – Tue)*

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Weekly/Monthly Global SST analyses

Developer: Neville Smith, Contact: Lixin Qi

http://www.bom.gov.au/marine/sst.shtml

Format: GHRSST v1.6 L4 netCDF3

Depth: ~1 m

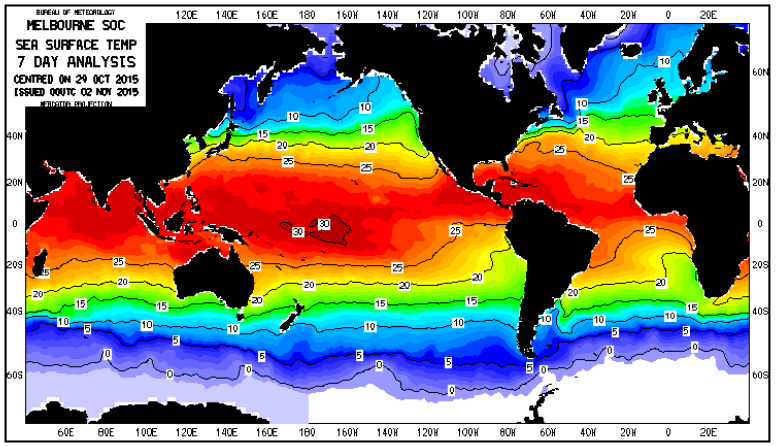
Resolution: 1º weekly/monthly

Available: 2001 to near real-time

Method: Optimal interpolation

Inputs:

- 9 km NAVOCEANO GAC AVHRR (NOAA-18, NOAA-19, METOP-A, METOP-B) GHRSST-L2P SST1m
- Buoy, ship, CTD, XBT in situ SSTdepth (GTS)
- Background: Weighted combination of previous week's analysis and Reynolds SSTdepth climatology



Uses: Bureau's NINO indices and Climate Outlooks (www.bom.gov.au/climate/enso).

Access: http://reg.bom.gov.au/climate/data-services/ocean-data.shtml

Daily Regional and Global Multi-Sensor SST analyses (RAMSSA and GAMSSA)

Australian Government
Bureau of Meteorology

Developer: Helen Beggs

http://www.bom.gov.au/marine/sst.shtml

Format: GHRSST v1.6 L4 netCDF3

Depth: Foundation SST estimate

Resolution: 0.083º regional, 0.25º global daily

Available: 2008 to real-time

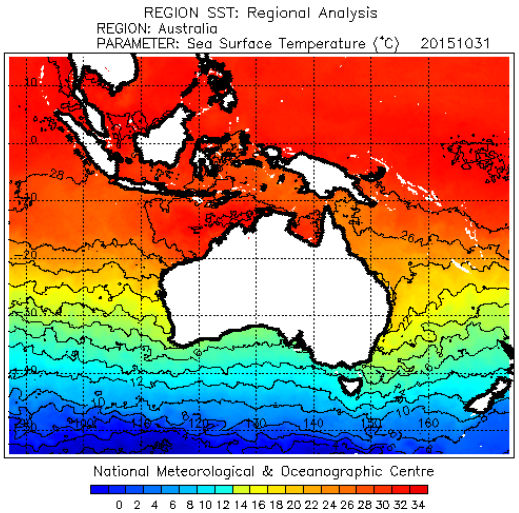
Method: Optimal interpolation

SST inputs:

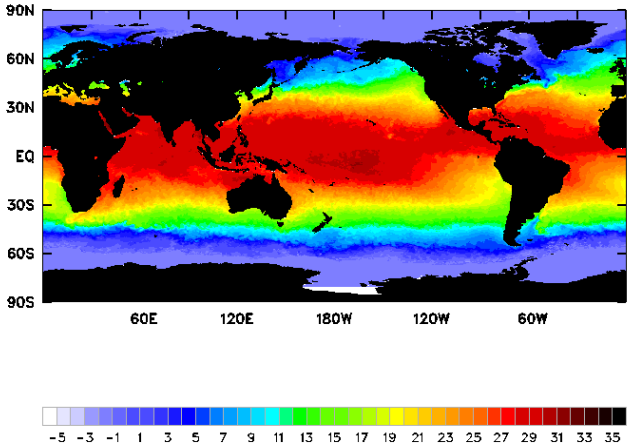
- 1 km IMOS HRPT AVHRR (NOAA-18,-19) L2P SSTskin
- 9 km NAVOCEANO GAC AVHRR GHRSST-L2P SST1m
- ~50 km AMSR-2 (Aqua) L2P SSTsubskin
- ~50 km WindSat L2P_gridded SSTsubskin
- Buoy and ship in situ SSTdepth

Uses: Boundary condition for NWP models, initialising Seasonal Prediction Model, validating ocean forecasts.

http://podaac.jpl.nasa.gov/dataset/ABOM-L4LRfnd-GLOB-GAMSSA_28km or ABOM-L4HRfnd-AUS-RAMSSA_09km



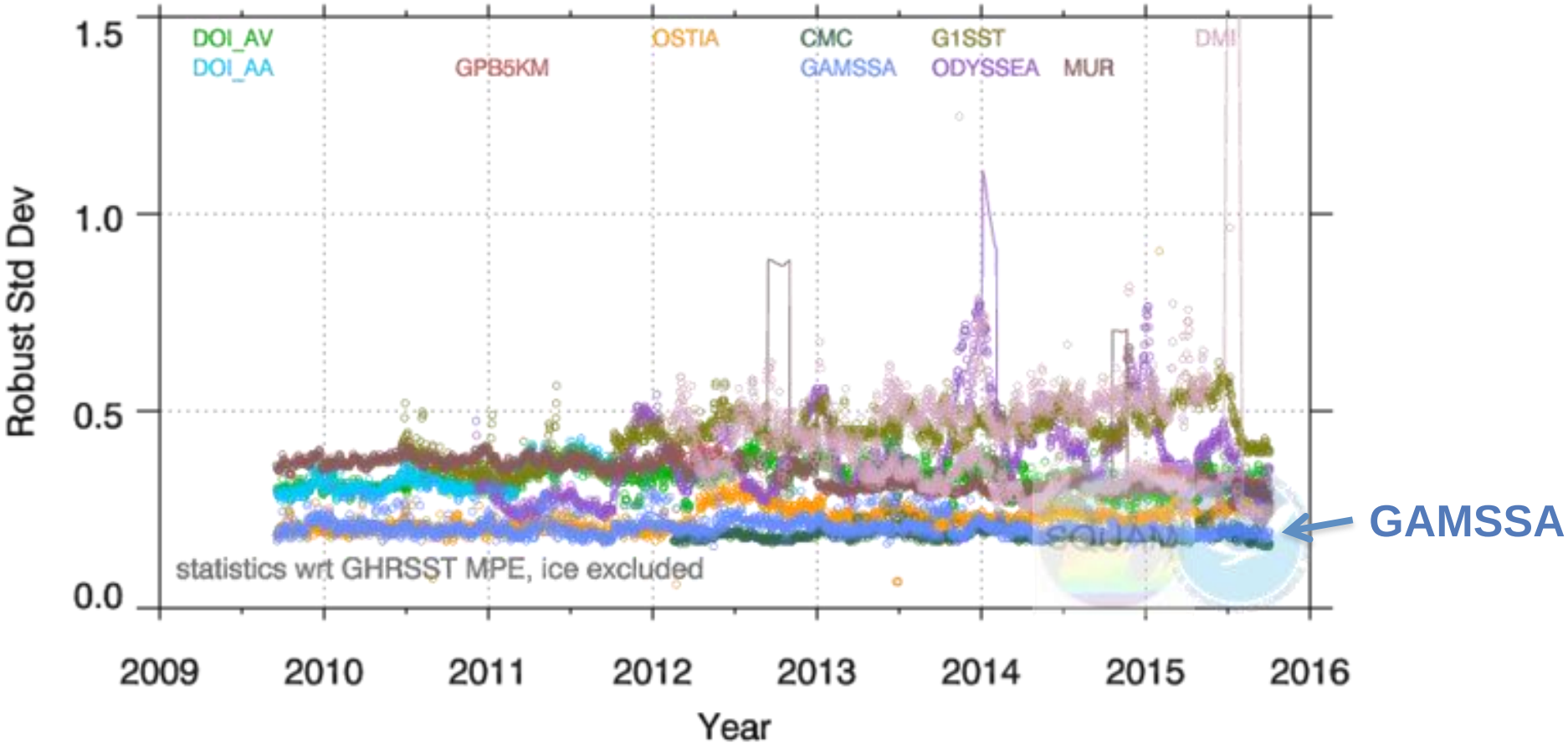
31 Oct 2015 Global Daily SST Analysis



Daily Global SST Analysis (GAMSSA) verification against GHRSST Multi-Product Ensemble

http://www.star.nesdis.noaa.gov/sod/sst/squam/L4/index.html#

Robust St Dev (SST analysis – GMPE)



IMOS MTSAT-1R SST Products

Developer: Leon Majewski in collaboration with Eileen Maturi, Andy Harris and Jon Mittaz (NOAA/CICS)

Format: GHRSST v2.0 L3U netCDF4

Depth: skin

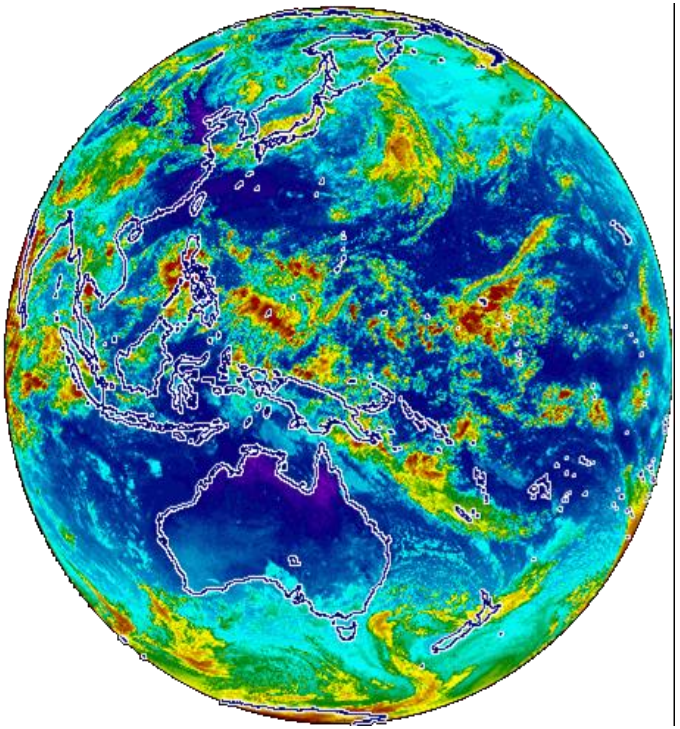
Resolution: 0.05º hourly

Available: v2: Jun 2006 – Jun 2010; v3: Jan – Apr 2010

Method: Regional SST algorithm based on regression with drifting buoy network. Bayesian cloud screening. Per pixel estimates of uncertainty (SD & Bias) calculated using ±30 days of matches, collocated, and ±1 hour

Inputs:

- ~4 km brightness temperatures from JAMI radiometer on JMA's geostationary MTSAT-1R satellite
- Drifting Buoy SSTdepth (from GTS)
- ACCESS-G 10 m winds



Uses: GHRSST Tropical Warm Pool SST Diurnal Variation (TWP+) Project *(Zhang and Zhu -Tue am)*

Access: http://rs-data1-mel.csiro.au/imos-srs/sst/ghrsst/L3U/mtsat1r

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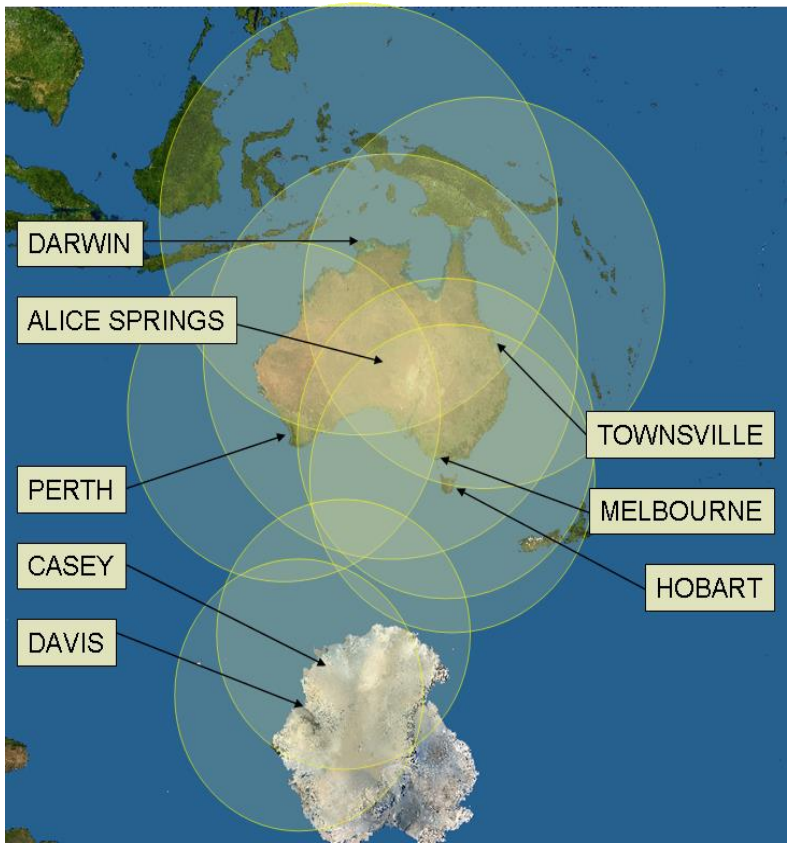
Why do we need 1 km resolution AVHRR SST Products?

- 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.
- Australia has direct broadcast ("HRPT") AVHRR data back to 1992 from reception stations in Australia and Antarctica.



IMOS HRPT AVHRR GHRSST products

Developer: Chris Griffin

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

Format: GHRSST v2.0 L2P/L3U/L3C/L3S netCDF4

Depth: skin (day-only/night-only), foundation (day+night)

Resolution: swath: 1-4 km, gridded: 0.02º 1/3/6/14-day and 1-month day-only, night-only, day+night

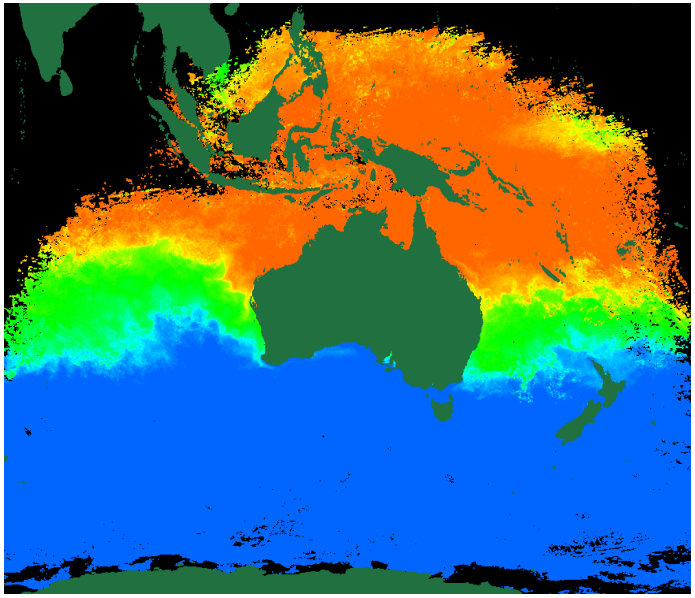
Available: fv01: Jan 2015 to real-time; fv02: 1992 – Dec 2014 (aim to be real-time in 2016)

Inputs: 1-4 km brightness temperatures from AVHRR radiometers on NOAA Polar Orbiting Environmental Satellites (NOAA-11 to NOAA-19)

Method: Skin SSTs derived by regressing brightness temperatures against collocated drifting buoy SSTs (~20 cm depth) followed by subtracting 0.17 K. Foundation SSTs derived from skin SSTs by rejecting observations for low NWP wind speeds and adding 0.17 K.

Fv02 uses running 1 year calibration window, adjusted monthly.

1 month day+night L3S SSTfnd



February 2008

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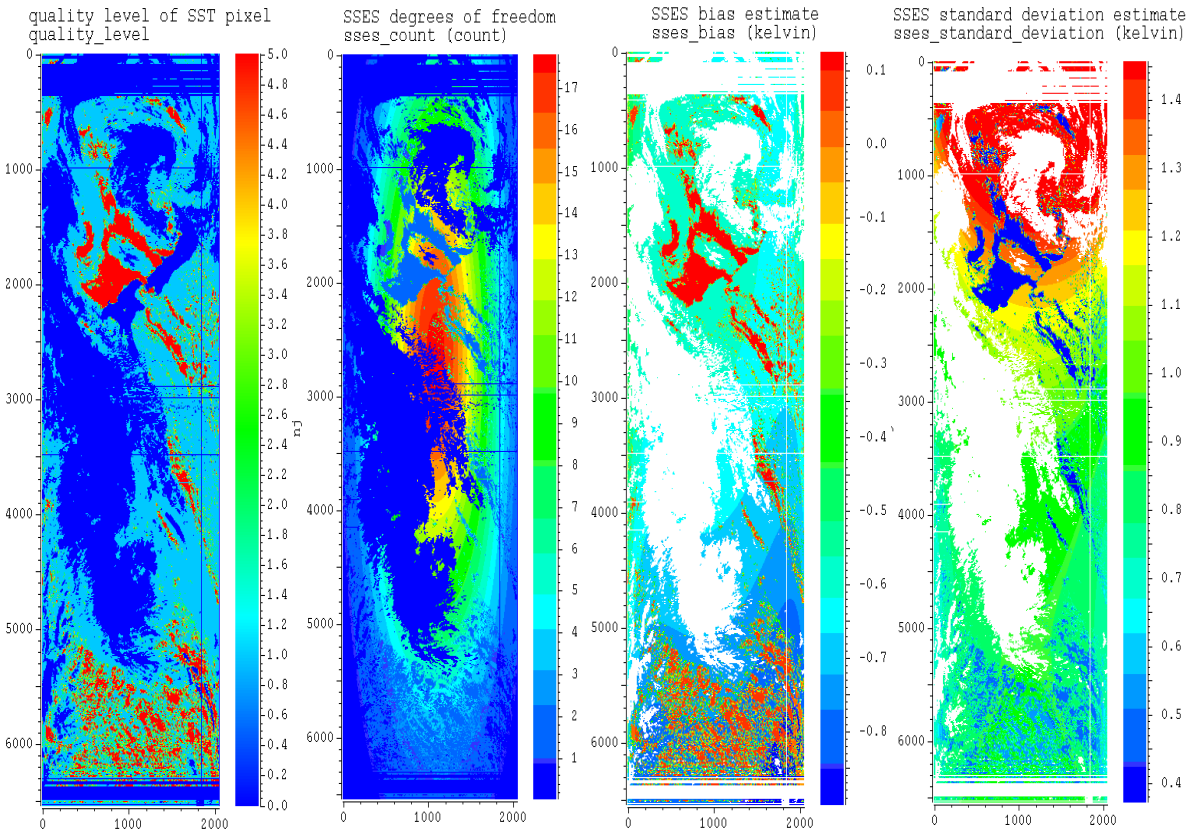
New SSES: "Adaptive Error Statistics"

- Rolling 1 year window adjusted every 5 days
- Measurements are weighted by time (120 day time constant)
- 6-d model based on time of day, satellite zenith angle, quality level, longitude, latitude and age
- Per pixel
- Continuously varying across FOV



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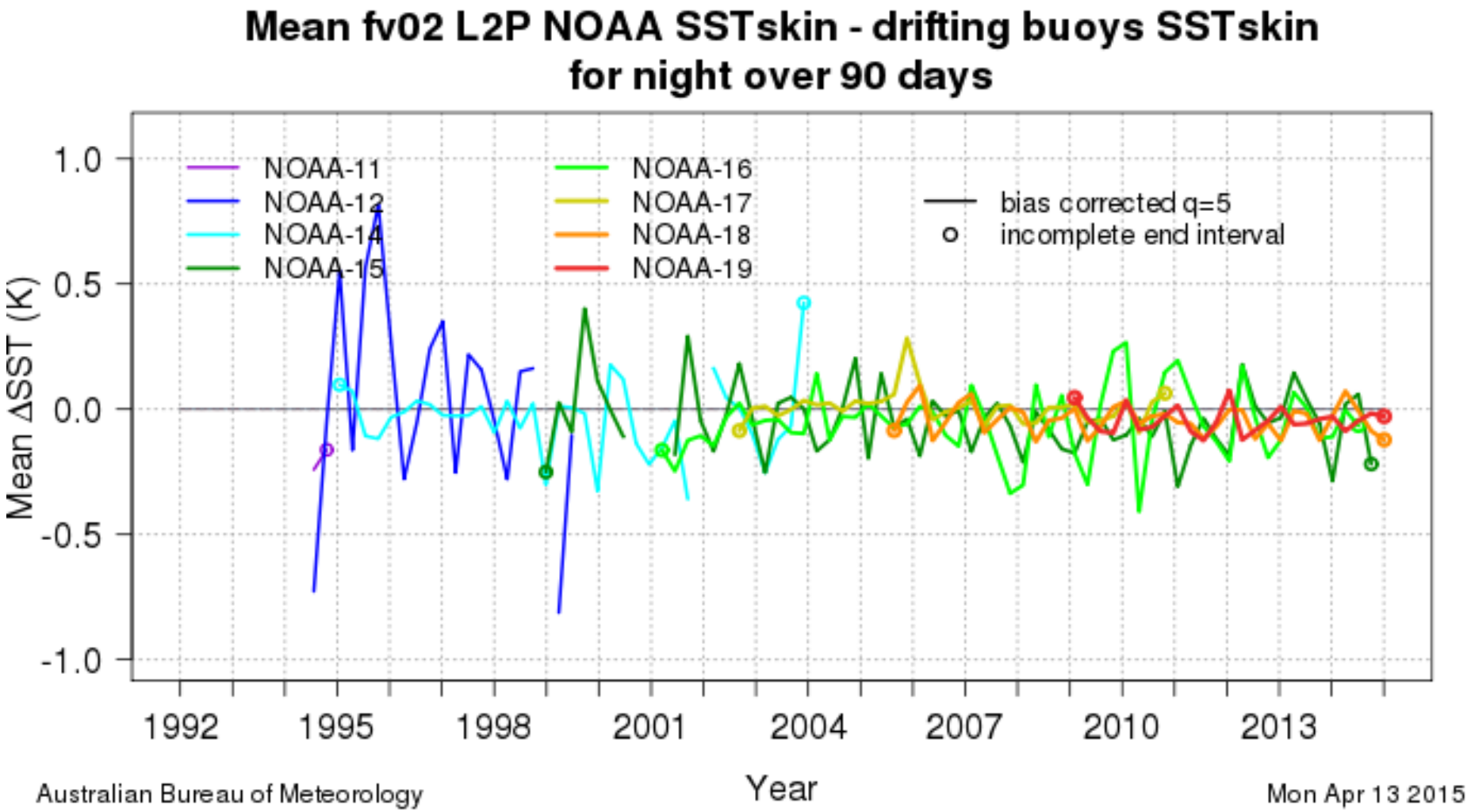
fv02 L2P SST on-line verification

http://opendap.bom.gov.au:8080/thredds/fileServer/abom_imos_ghrsst_archive/v02.0fv02/Validation/web/index.html



fv02 L2P SST on-line routine verification

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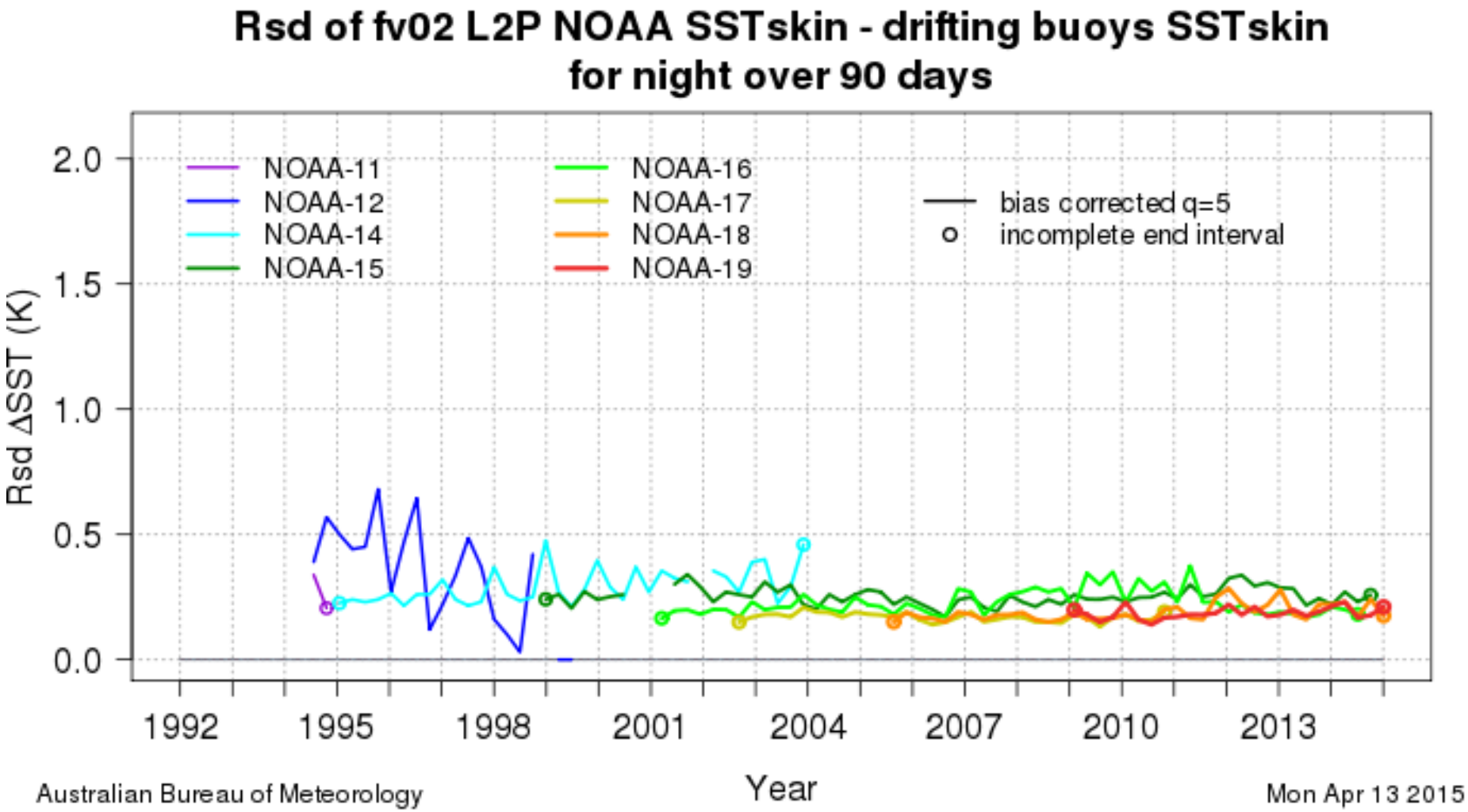
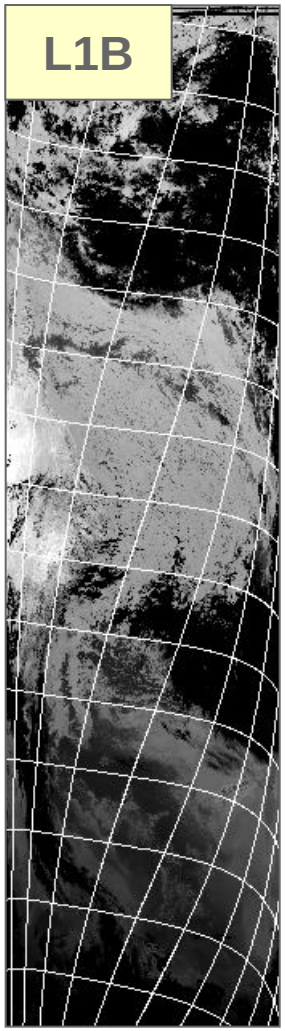
http://opendap.bom.gov.au:8080/thredds/fileServer/abom_imos_ghrsst_archive/v02.0fv02/Validation/web/index.html

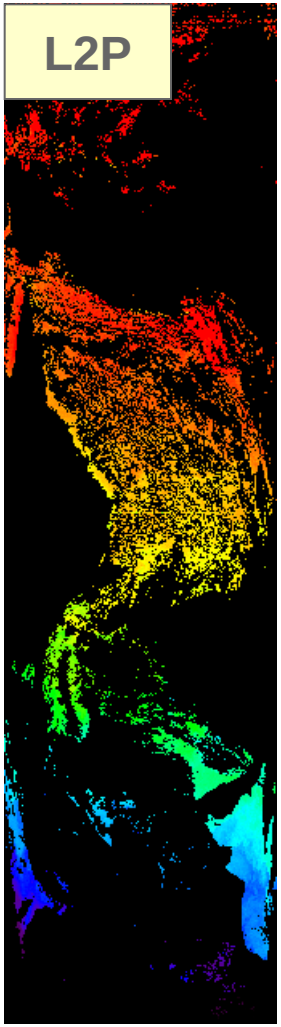


Range of IMOS-GHRSST products

Swath BT

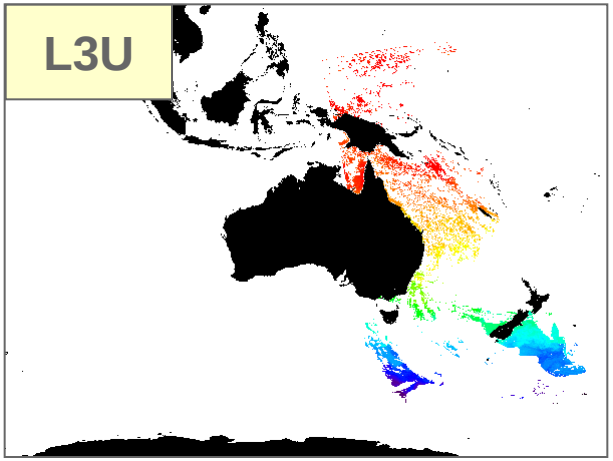


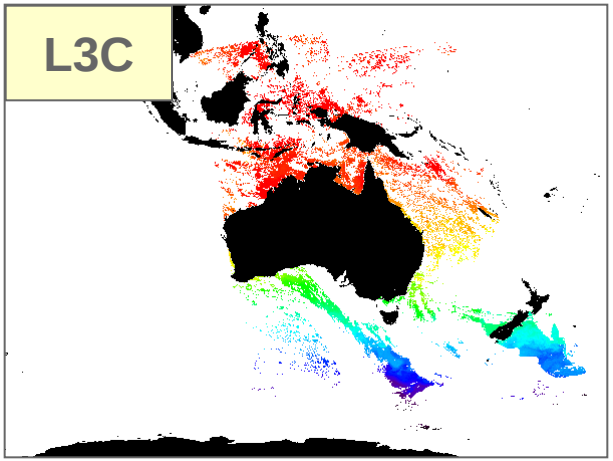
Swath SST



N18: 2011-04-30 04:01:33

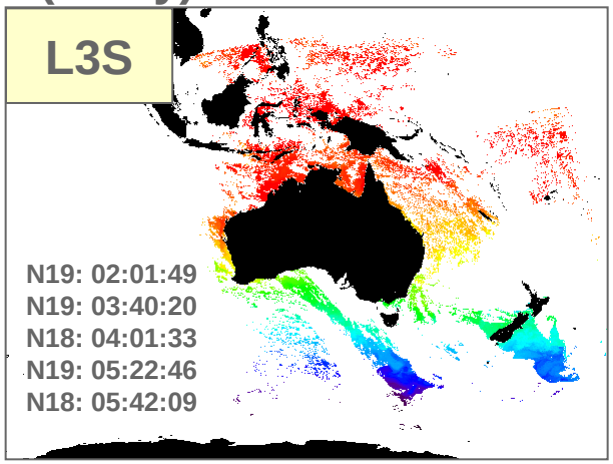
single swath

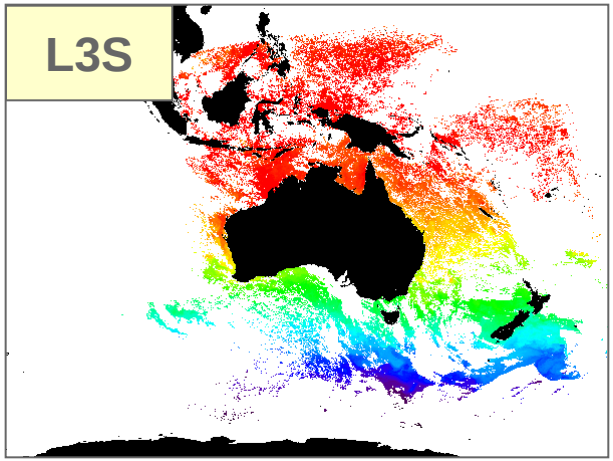




multi-swath, single sensor

multi-swath, multi-sensor, (1-day)





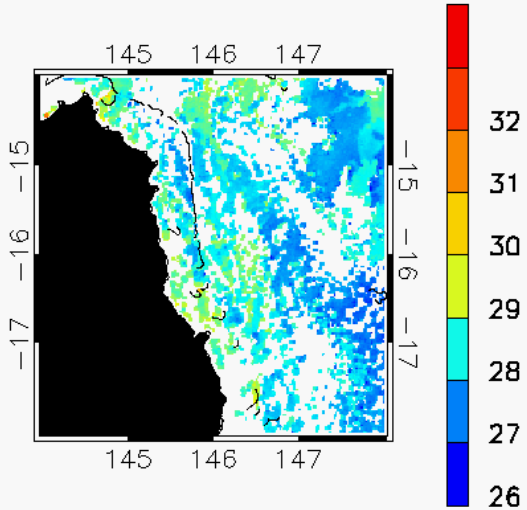
multi-swath, multi-sensor, multi-day (3-day)

+ 6-day, 14-day, 1-month L3S

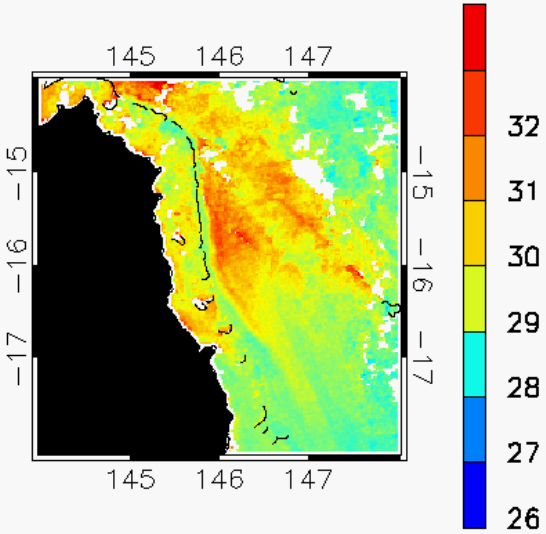
Why day-only, night-only and day+night L3S products?

1 Jan 2014

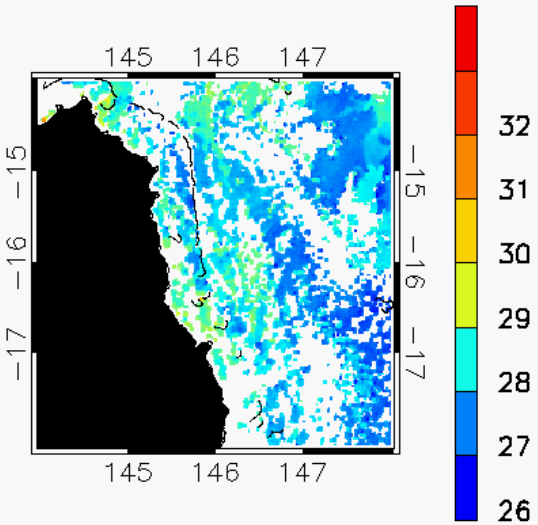
2 km IMOS day+night L3S



2 km IMOS day L3S

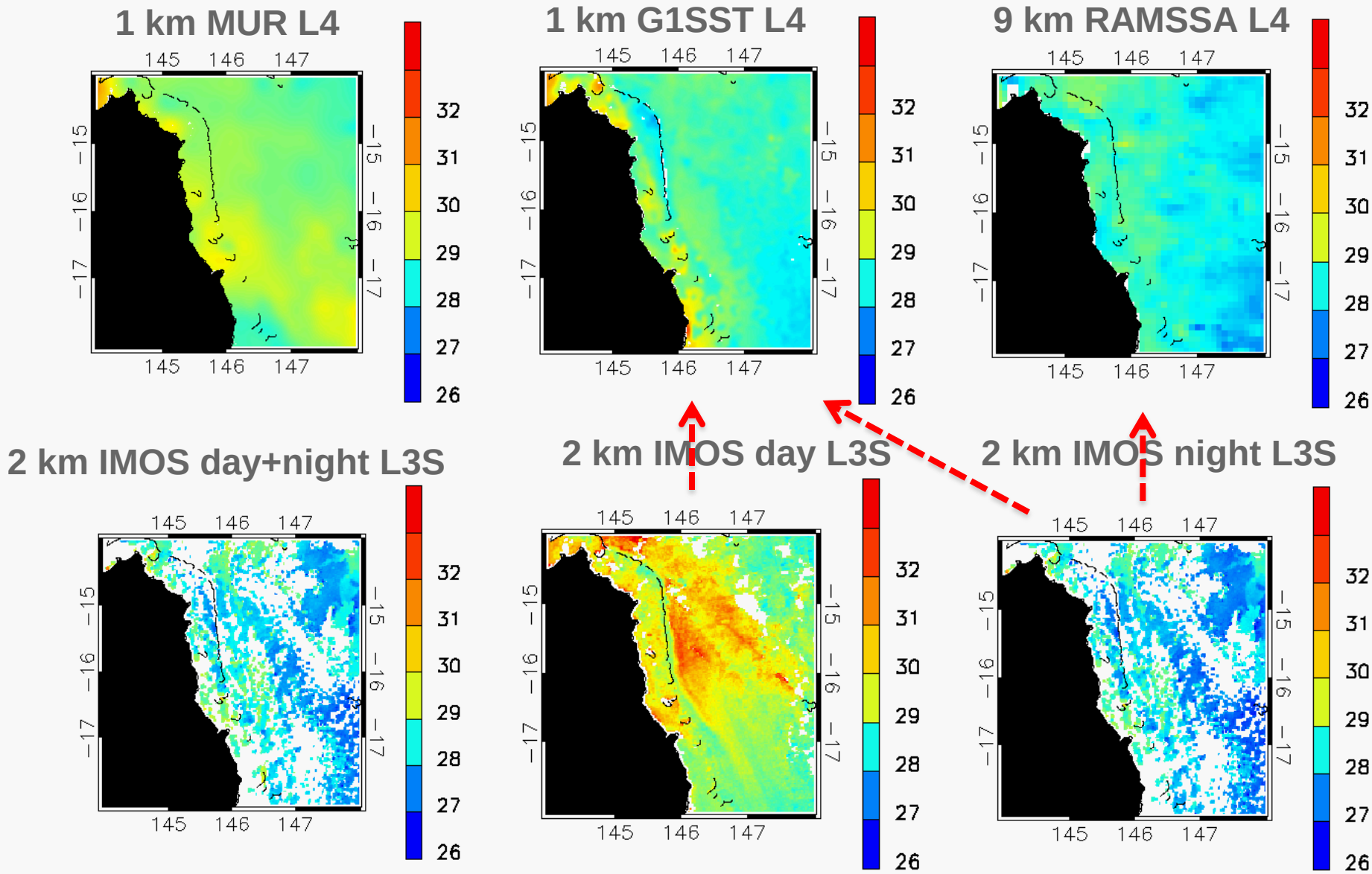


2 km IMOS night L3S



L4 interpolated SST vs L3S composite SST

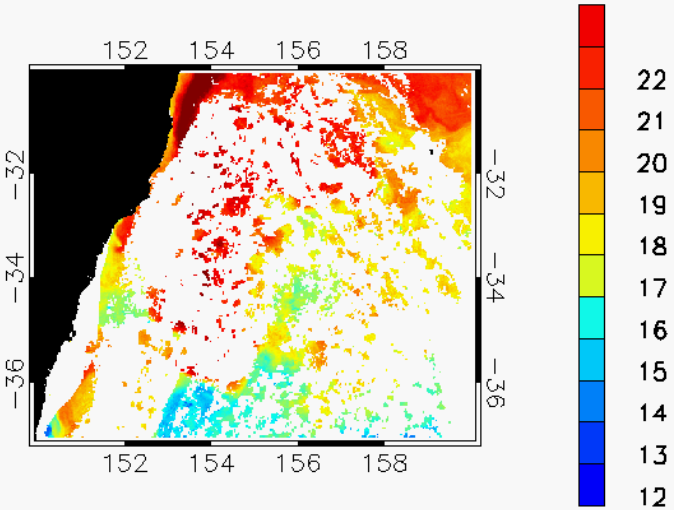
L4 grid resolution ≠ Feature resolution!



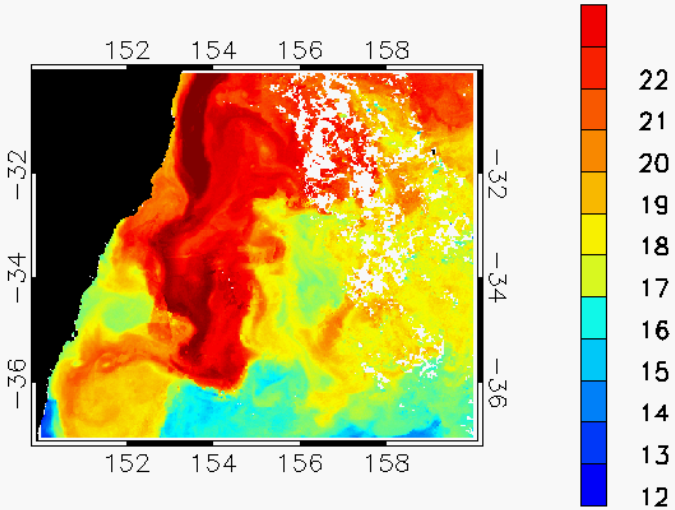
Temporal Averaging vs Spatial Interpolation

E.g. Multi-satellite day+night SSTfnd for 15 Aug 2013

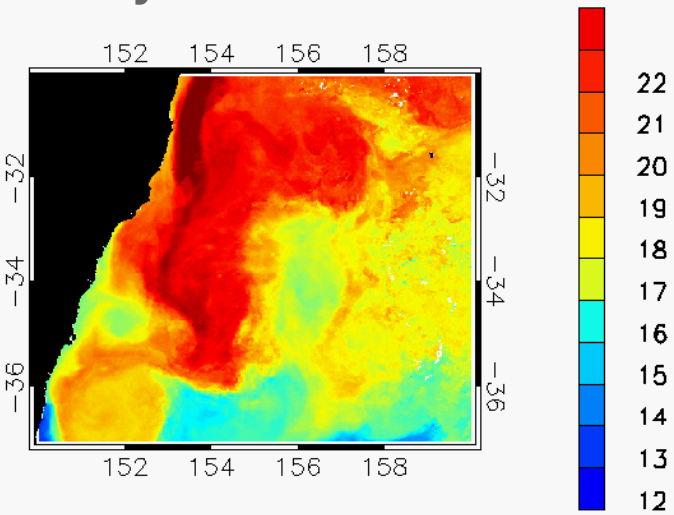
1-day 2 km L3S



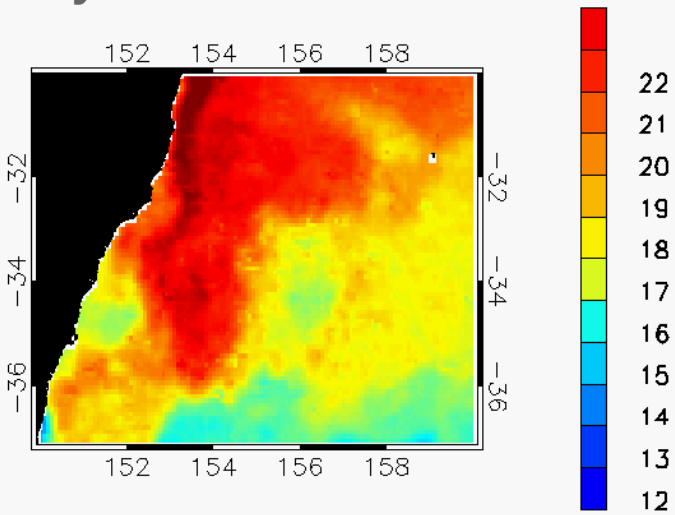
3-day 2 km L3S



6-day 2 km L3S



Daily 9 km RAMSSA L4



Future IMOS-GHRSST Products

- Operationalise fv01 and fv02 IMOS AVHRR SST
- Include Himawari-8 SSTs in IMOS-GHRSST suite
- Ingest 0.02º ACSPO VIIRS L3U into IMOS-GHRSST L3S
- Produce IMOS-GHRSST products from AVHRR on METOP-B
- More information:
  - http://imos.org.au/sstproducts.html
  - Contact h.beggs@bom.gov.au

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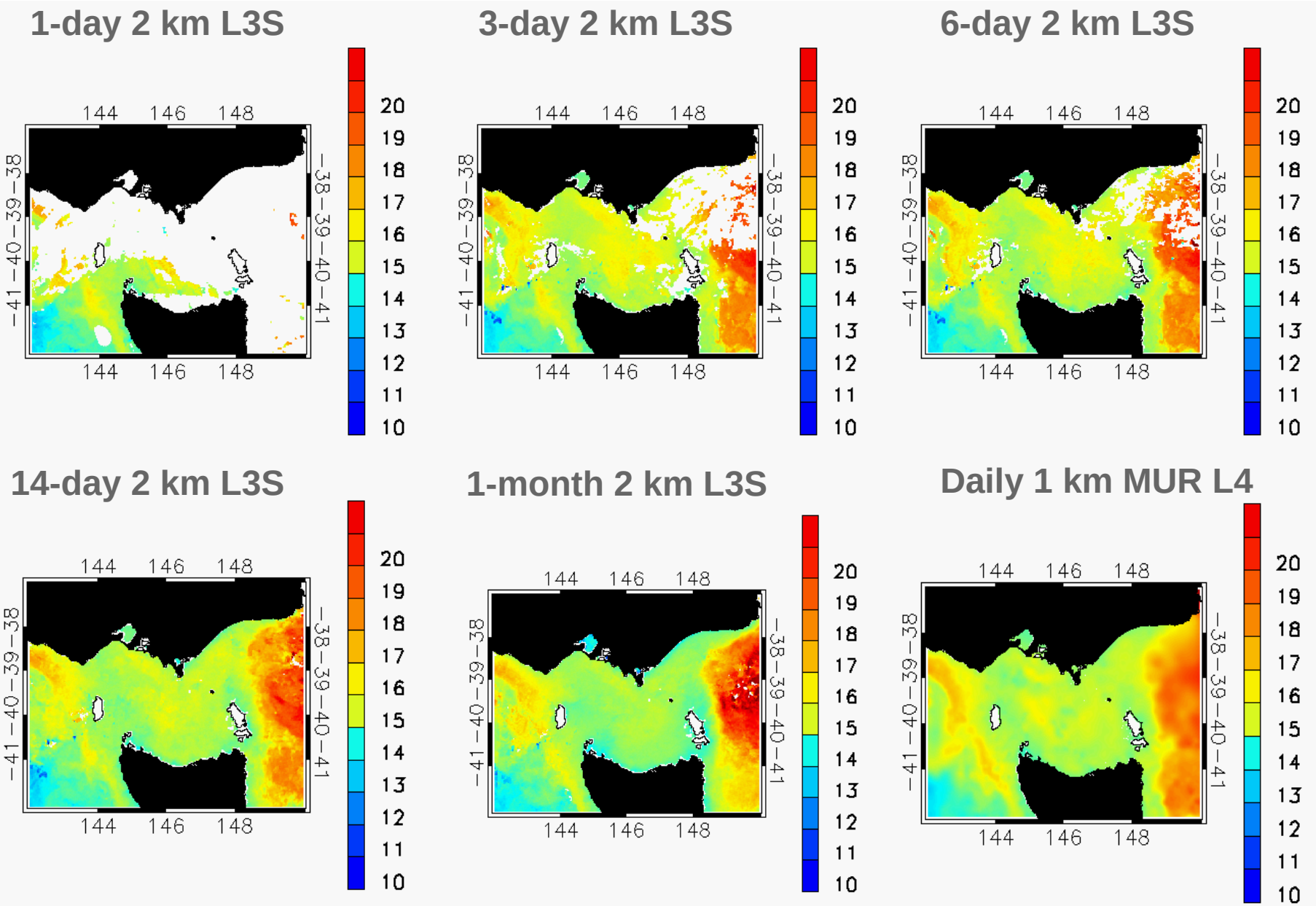
Summary

- Different SST products suit different applications…
- Be clear what SST depth you need
- Weigh up spatial coverage vs accuracy
- L4 grid resolution ≠ ocean feature resolution ("sensitivity")
  - L3 will be more sensitive than L4 but has gaps
- Match the product temporal resolution to the process resolution
  - E.g. day ↔ 1 km, week ↔ 7 km, month ↔ 25 km, year ↔ 2000 km, decade ↔ 4000 km …

Additional slides for discussion

Temporal Averaging vs Spatial Interpolation

E.g. Multi-satellite day+night SSTfnd for 2 Jun 2014

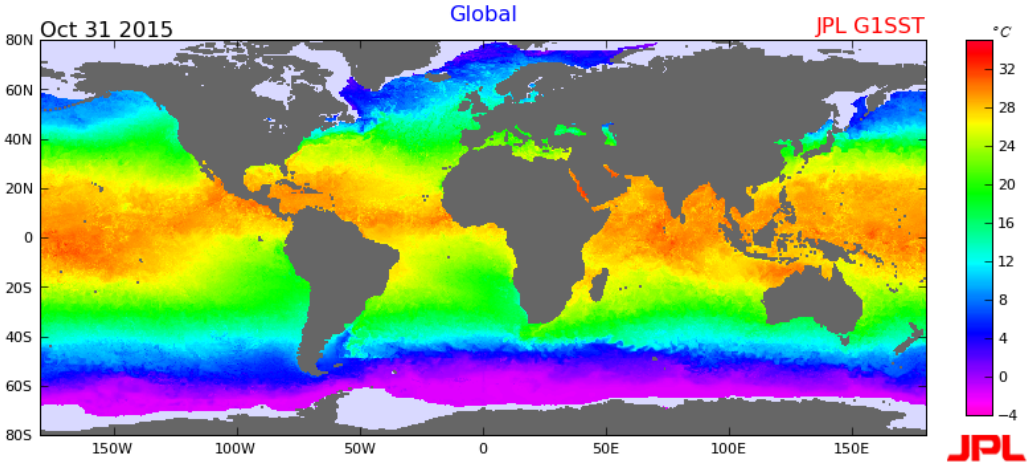


Different IMOS-GHRSST Products suit different applications

L2P (geolocated swath)

- Input into “L4” SST analyses (e.g. Bureau's daily SST analyses – RAMSSA and GAMSSA, JPL Ourocean G1SST 1 km Global analysis)
- Future input into coastal ocean models (e.g. 4 km eReefs)

JPL G1SST daily SSTdepth



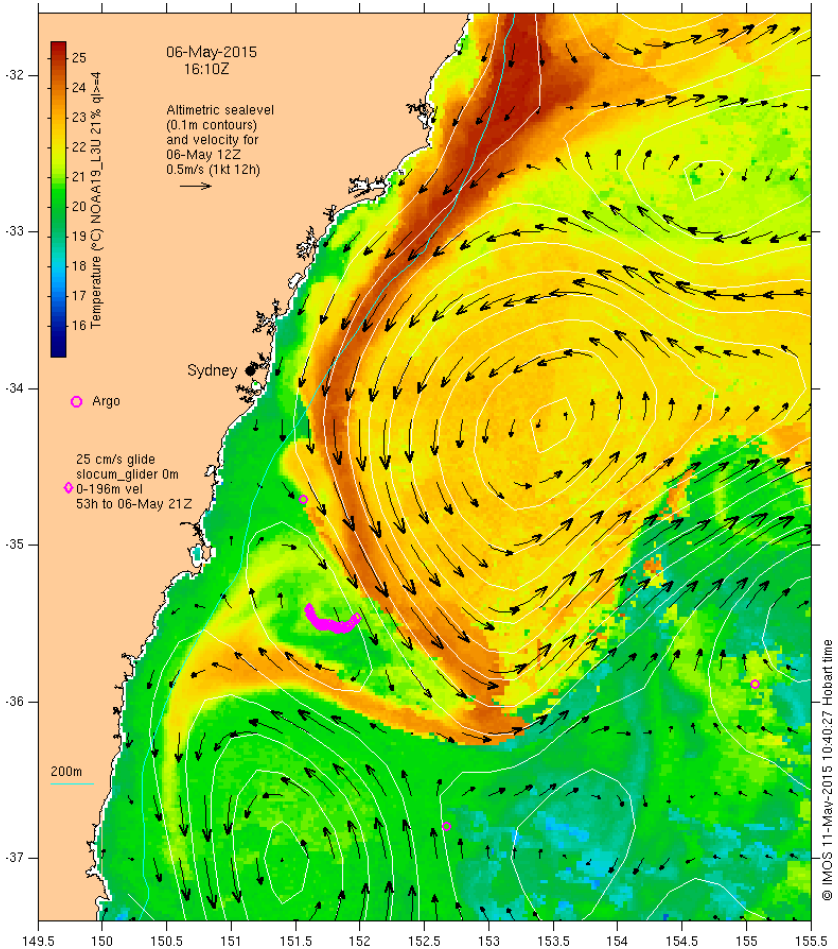
Different IMOS-GHRSST Products suit different applications

L3U (2 km gridded, single swath)

Real-time SST maps

- www.fishtrack.com
- IMOS OceanCurrent (http://oceancurrent.imos.org.au/sst.php) – Tue pm

OceanCurrent SST Map 6 May 2015



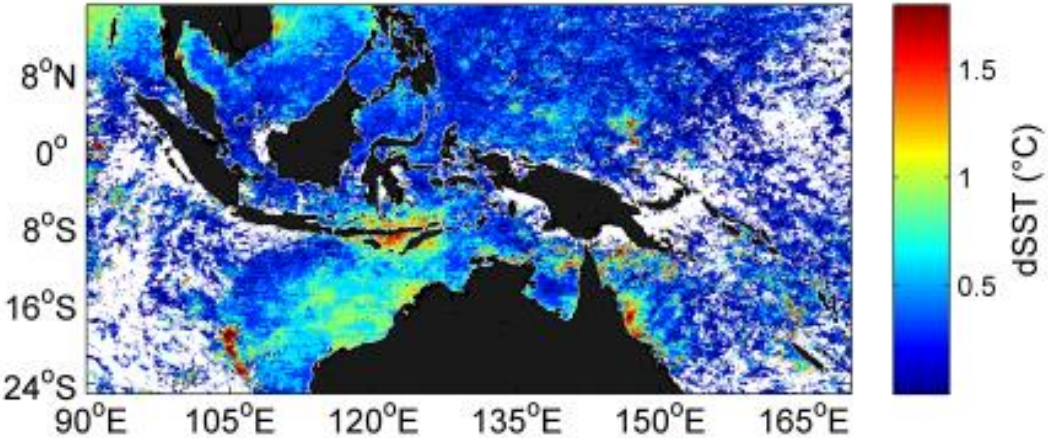
Different IMOS-GHRSST Products suit different applications

MTSAT-1R L3U (Hourly, 5 km gridded, single scene)

Research into diurnal warming

- Evaluation of dSST (0.5m) in GC2 coupled NWP experiments (José Rodriguez, UK Met Office)
- Great Barrier Reef (Xiaofang Zhu, PhD Uni of Miami) – Tue am
- Tropical Warm Pool (Haifeng Zhang, PhD UNSW@ADFA) – Tue am

Mean Mar 2010 MTSAT-1R ΔSST



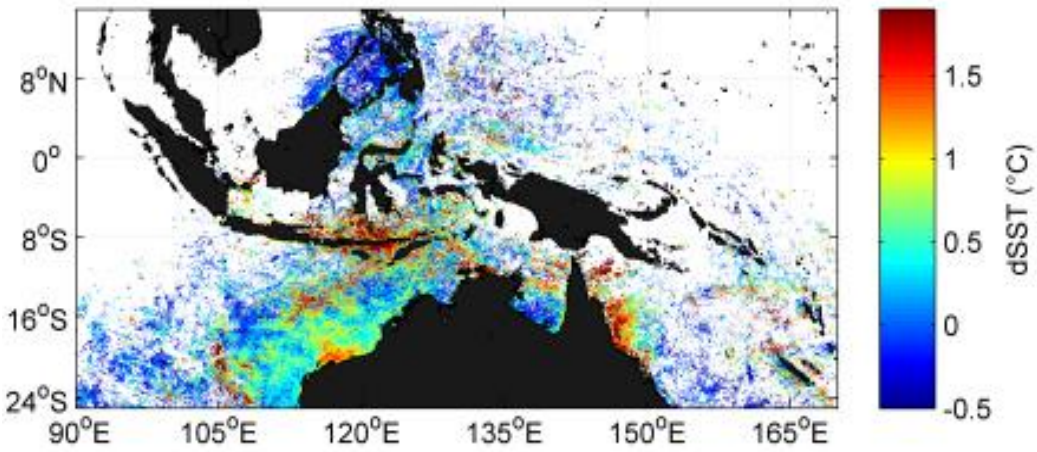
Different IMOS-GHRSST Products suit different applications

L3C (2 km gridded, multiple swath, night-only, day-only)

Research into diurnal warming

- Great Barrier Reef (Xiaofang Zhu, PhD Uni of Miami) – Tue am
- Tropical Warm Pool (Haifeng Zhang, PhD UNSW@ADFA) – Tue am

Mean Mar 2010 fv02 NOAA-19 ΔSST



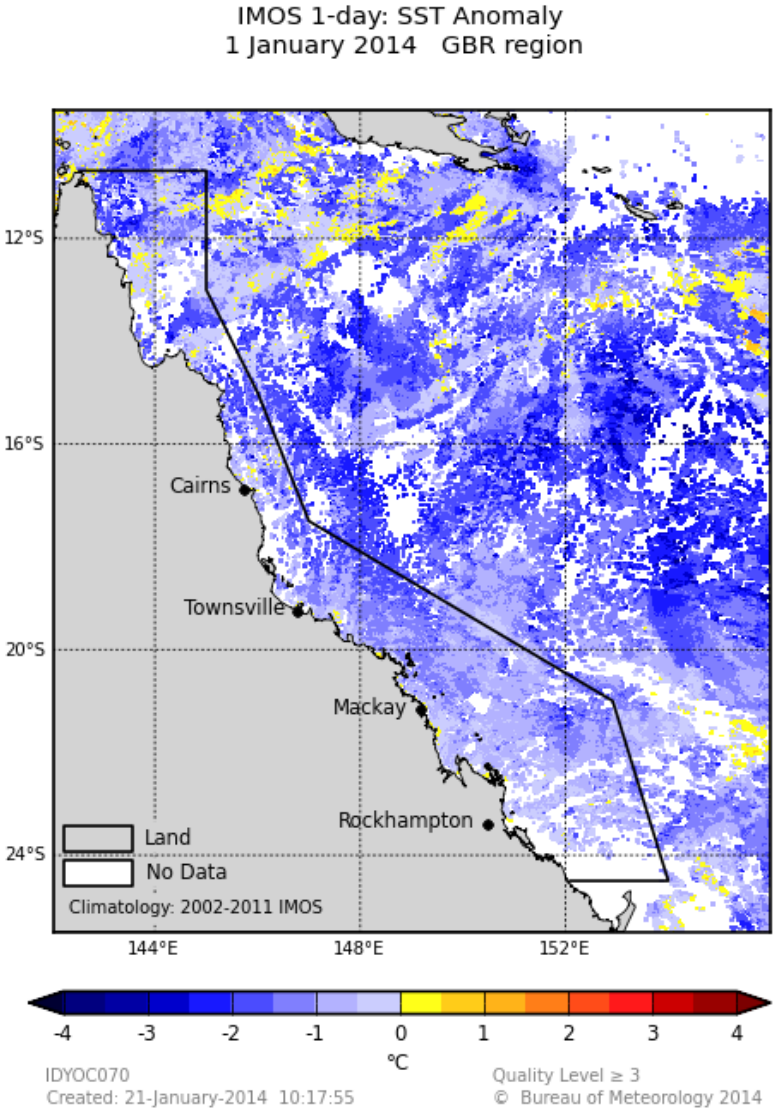
Different IMOS-GHRSST Products suit different applications

L3S (gridded, multiple sensor)

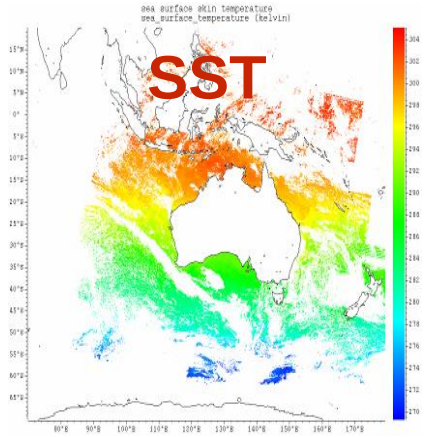
- Nowcasting of coral bleaching
  - ReefTemp NextGen uses night-only 1-day L3S http://www.bom.gov.au/marinewaterquality

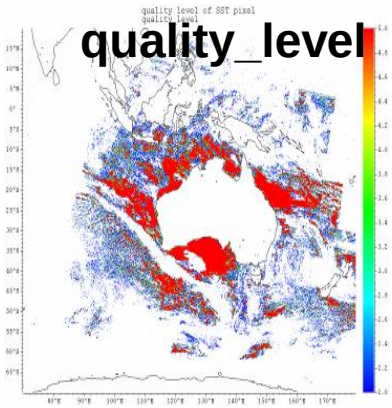
- Near RT maps of SST
- IMOS *OceanCurrent* uses day-only, night-only 3-day/6-day L3S and night-only 1-month L3S – Tue pm

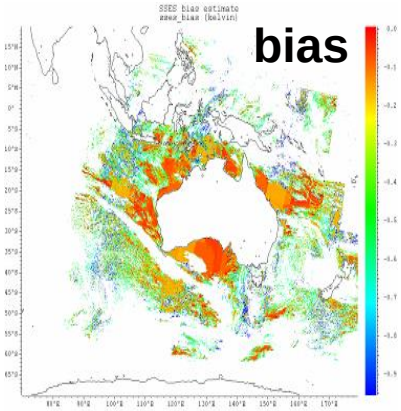
- Validation of high res ocean models

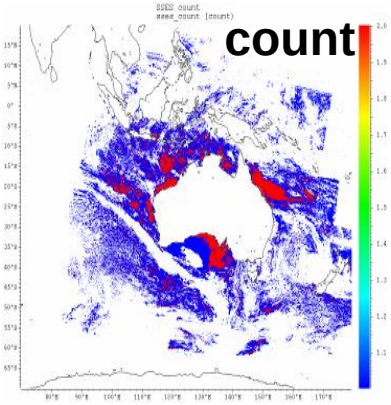


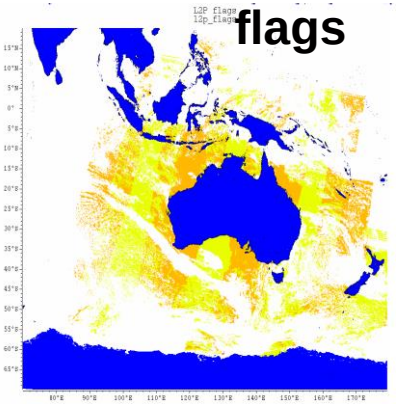
Useful pixel-by-pixel information (following GHRSST 2.0 format)

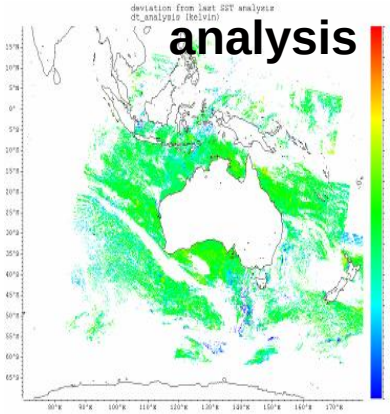


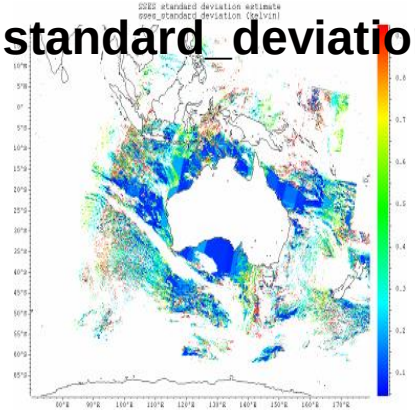












+ wind speed

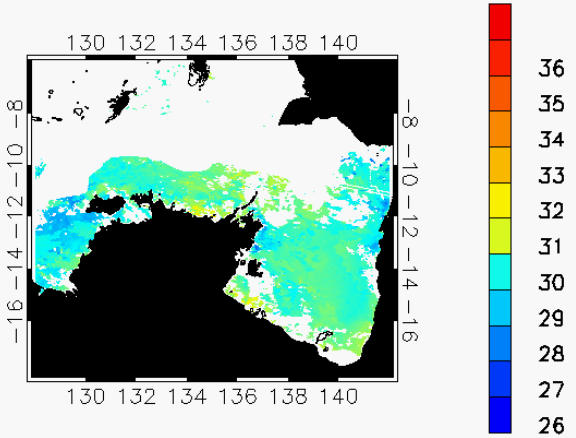
+ aerosol

+ sea ice fraction

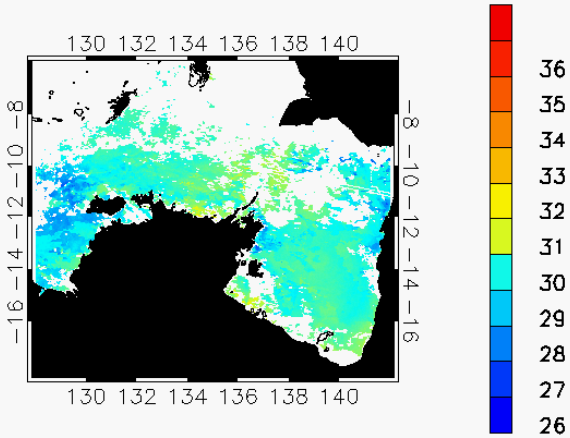
20131007 night composite from multiple satellites "L3S"

Why have day-only, night-only and day+night L3S SST products?

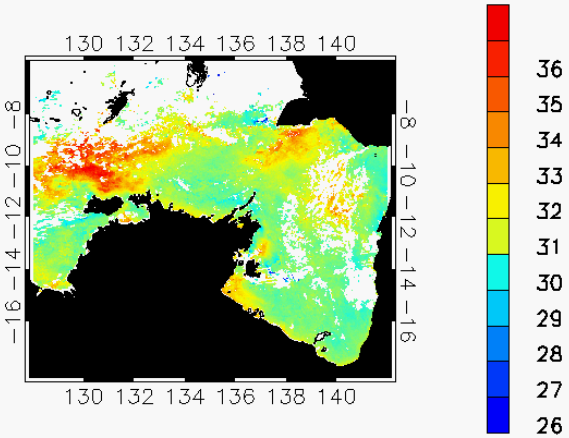
IMOS 1-day L3S day+night SSTfnd



IMOS 1-day L3S night-time SSTskin



IMOS 1-day L3S daytime SSTskin



2 Jan 2014

How does IMOS fv02 AVHRR L3C differ from Pathfinder AVHRR L3C SST?

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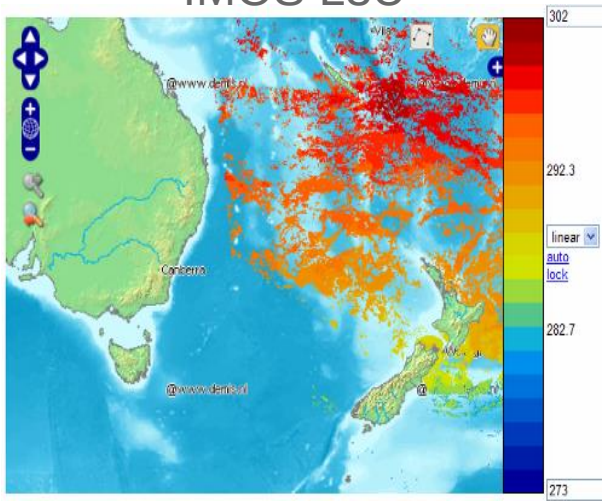
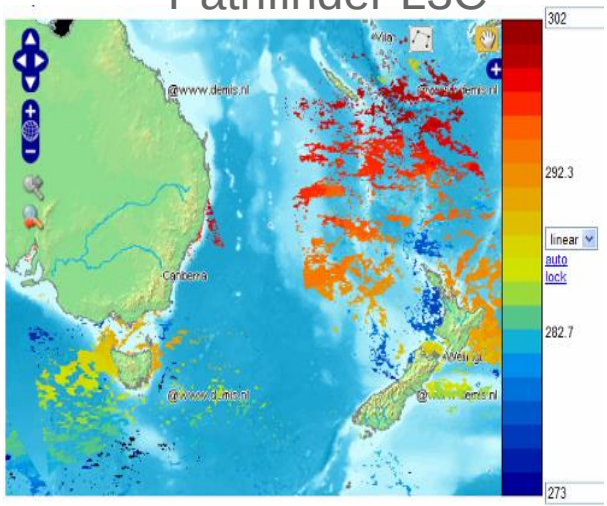
- **Wider swath width**
- **Higher spatial resolution** - 1.1 km x 1.1 km cf 4.4 km x 1.1 km resolution at nadir
- **More ancillary fields** - IMOS product has error estimates per pixel to comply with GHRSST spec
- **More satellites** - IMOS uses all available NOAA satellites, Pathfinder only one at a time
- IMOS back to 1992, Pathfinder back to 1981
- **IMOS real-time**, Pathfinder > 1 year behind
- IMOS uses "adaptive calibration" and "adaptive error statistics" to "tune" AVHRR SSTs using regional in situ data to minimise error

IMOS L3U

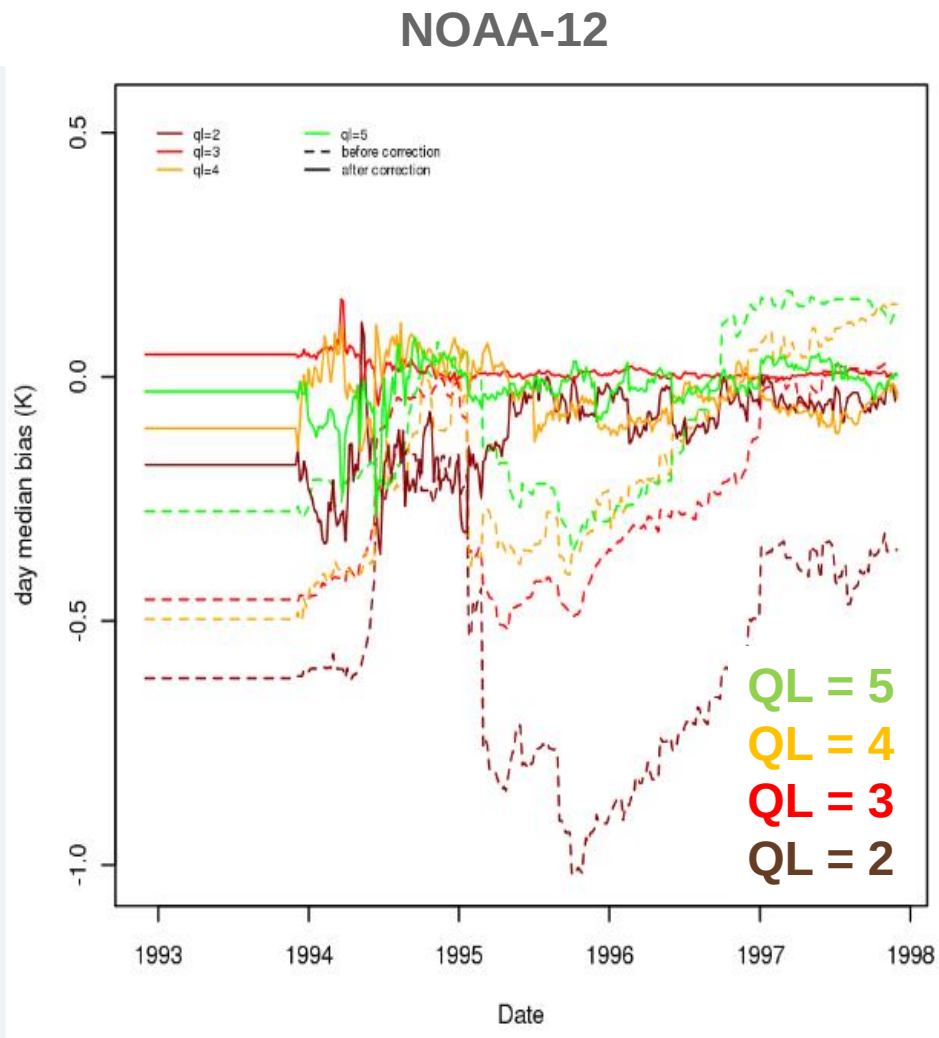


Pathfinder L3C



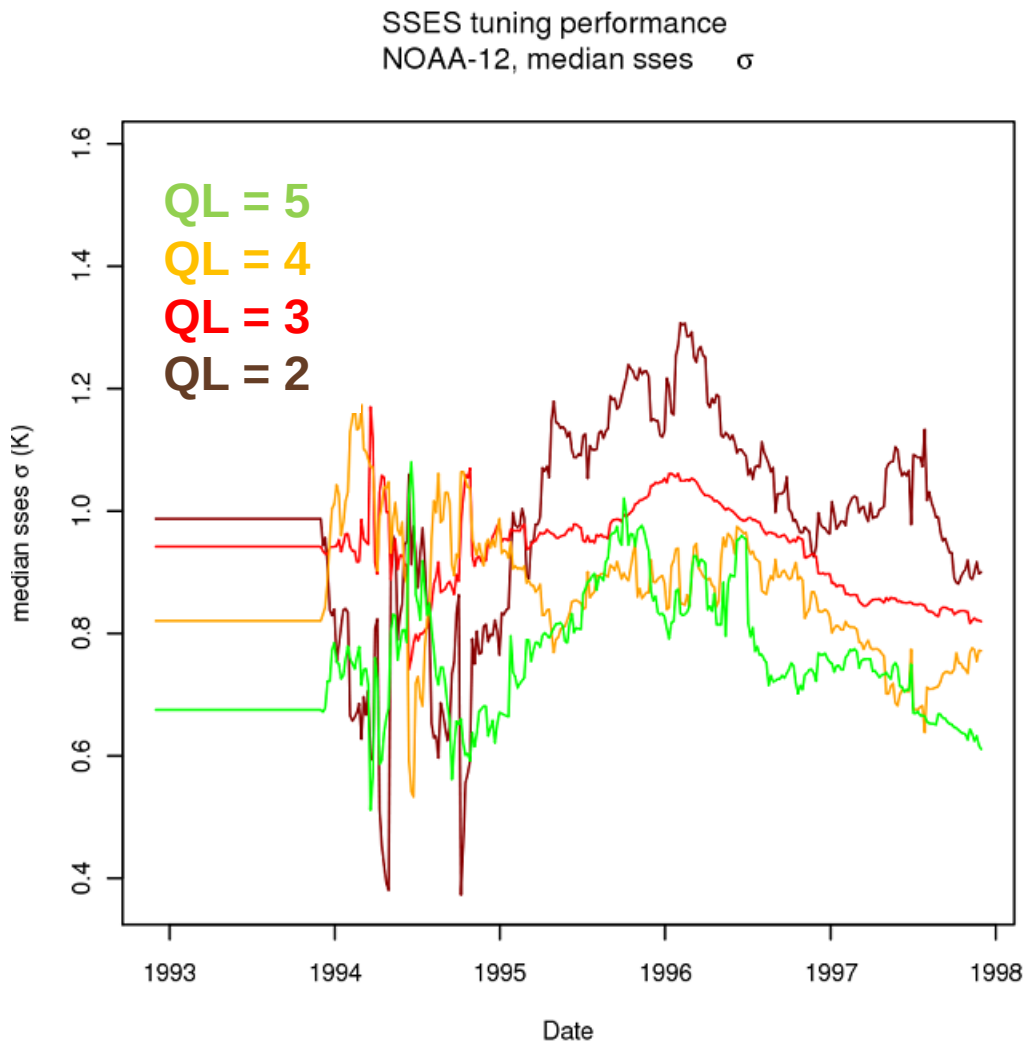
SSES Bias estimate performance

- Applying the bias correction improves the bias compared with *in situ* SST at all quality levels
- Dashed lines show before bias correction



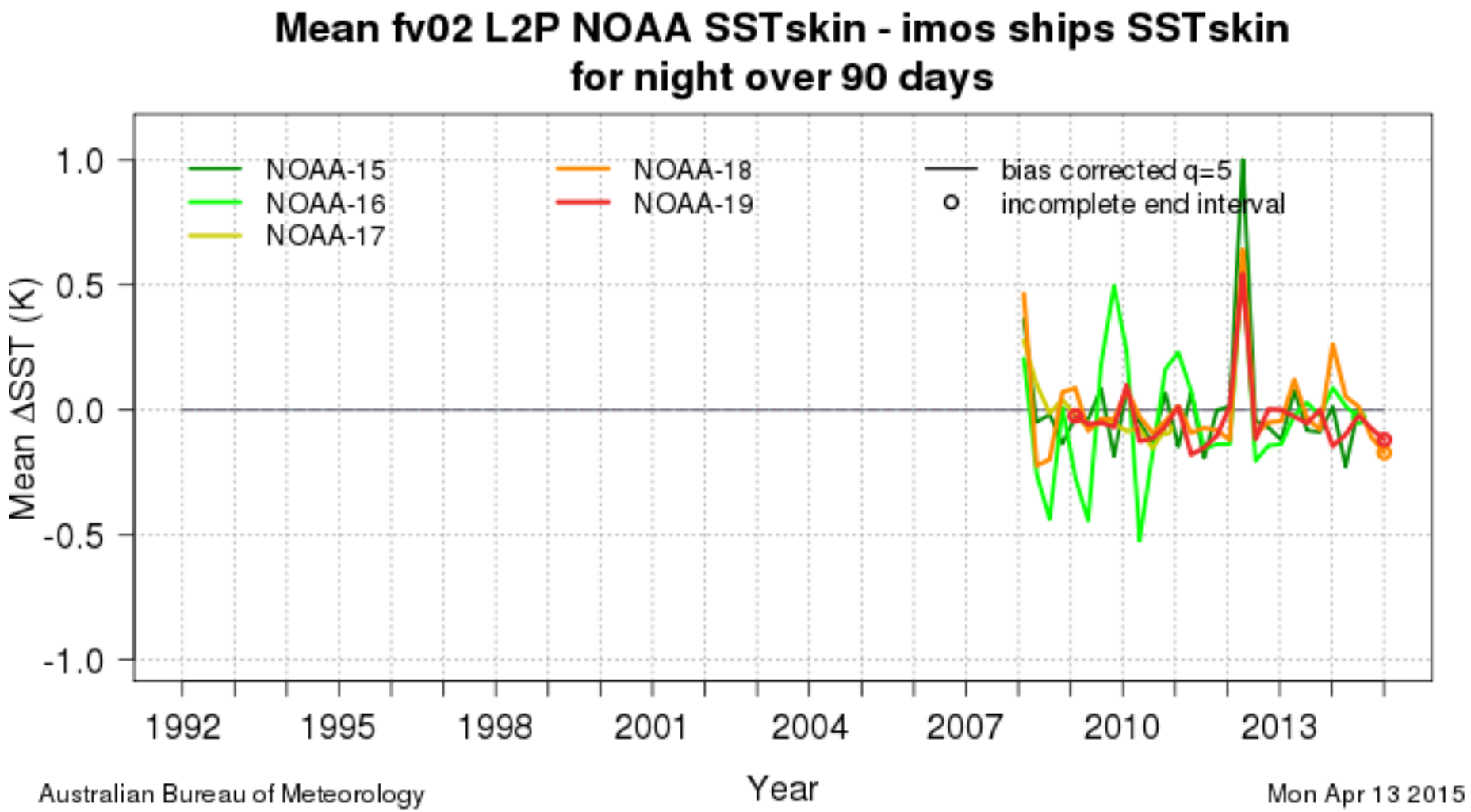
SSES Standard Deviation

- Standard deviation of AVHRR SSTs cf in situ SSTs at different quality levels are given in all IMOS SST files
- Variation over time (median standard deviation over the in situ matchups) is shown at the right for NOAA-12



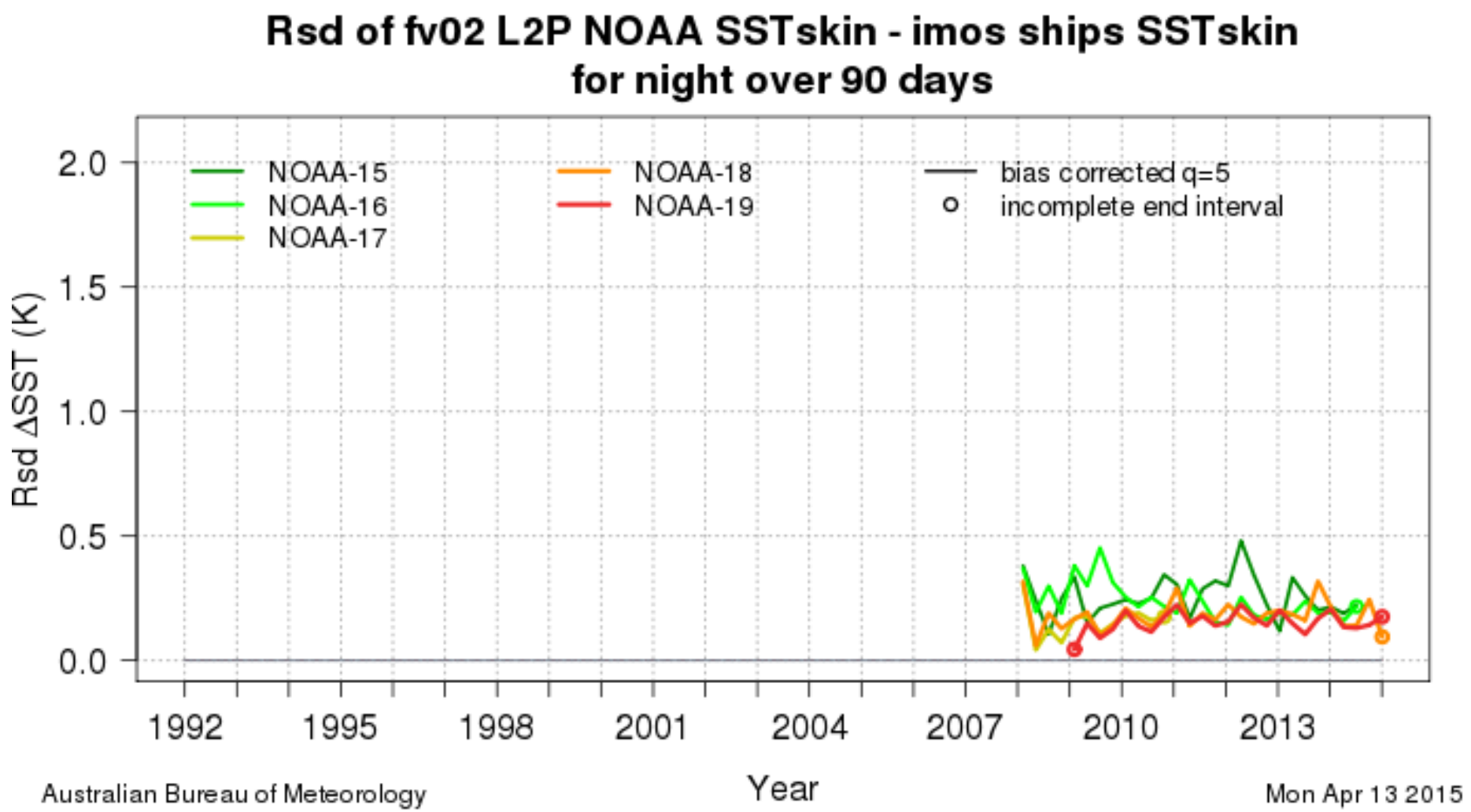
fv02 L2P SST on-line verification

http://opendap.bom.gov.au:8080/thredds/fileServer/abom_imos_ghrsst_archive/v02.0fv02/Validation/web/index.html



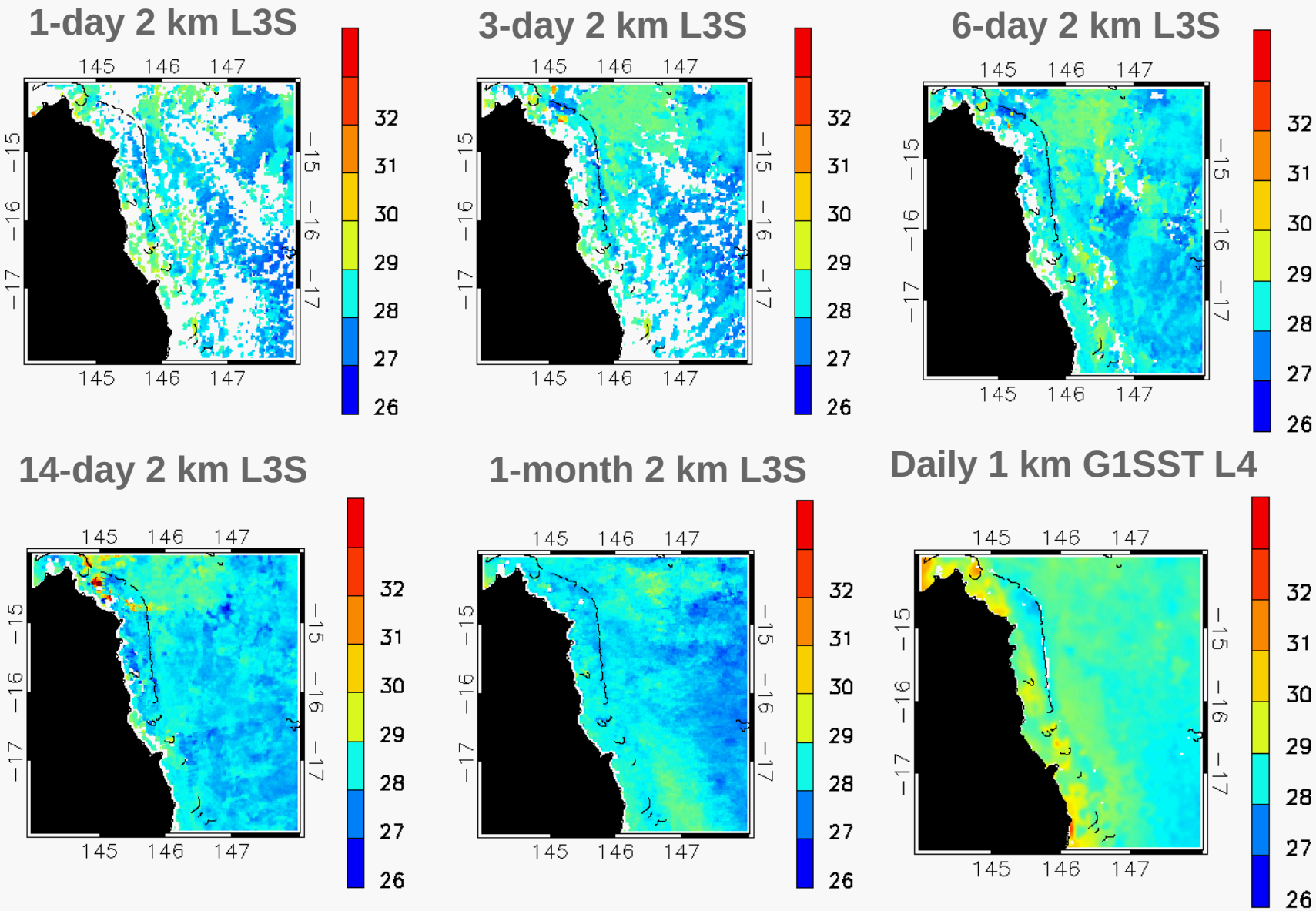
fv02 L2P SST on-line verification

http://opendap.bom.gov.au:8080/thredds/fileServer/abom_imos_ghrsst_archive/v02.0fv02/Validation/web/index.html



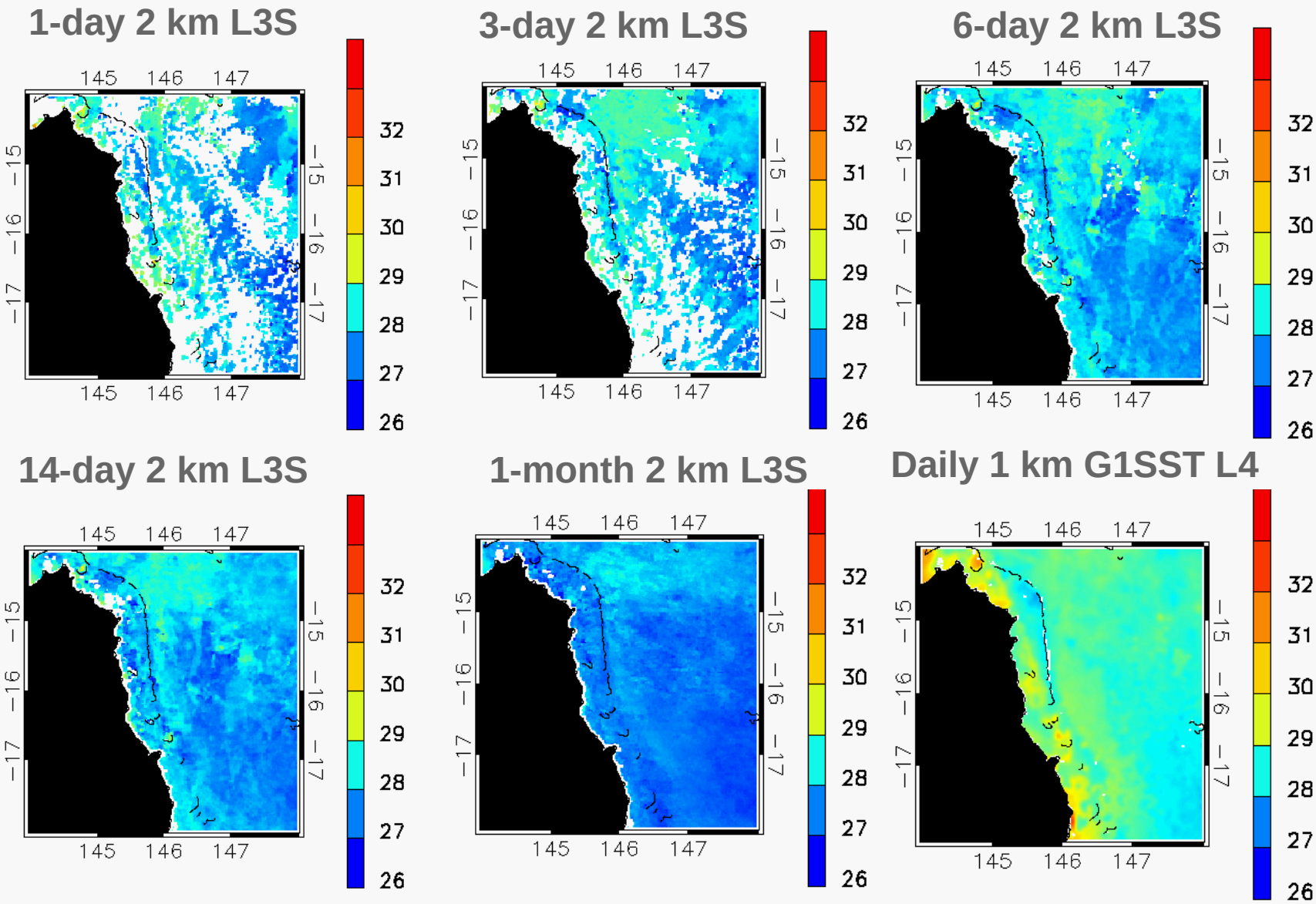
Temporal Averaging vs Spatial Interpolation

Eg. North Queensland, 1 Jan 2014 mean SSTfnd products



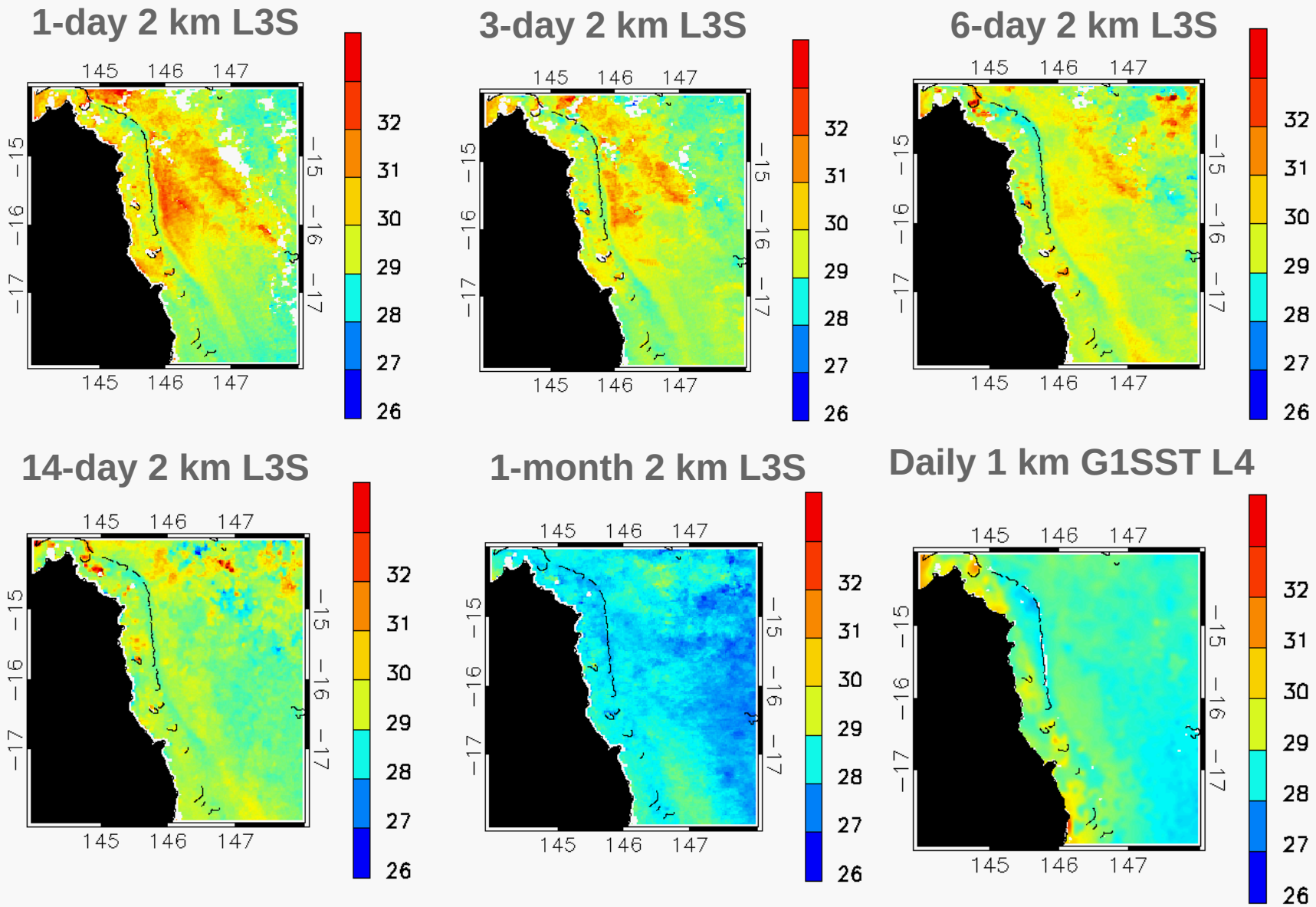
Temporal Averaging vs Spatial Interpolation

Eg. North Queensland, 1 Jan 2014 night-only L3S products



Temporal Averaging vs Spatial Interpolation

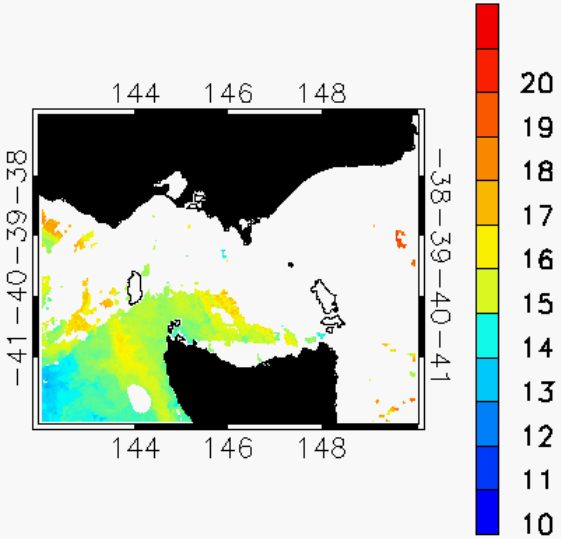
Eg. North Queensland, 1 Jan 2014 day-only L3S products



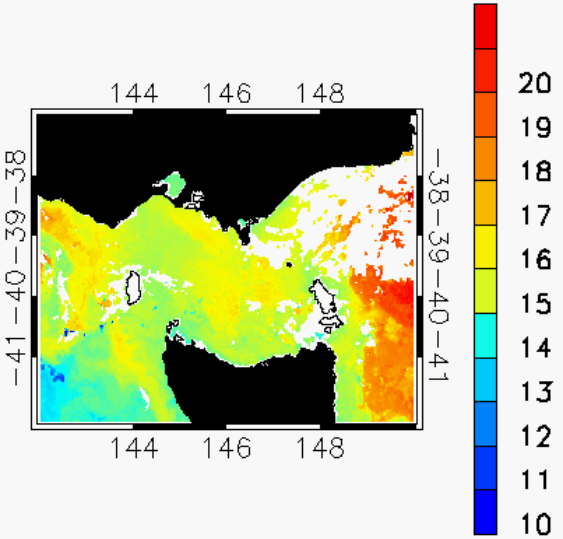
Temporal Averaging vs Spatial Interpolation

E.g. Multi-satellite day+night SSTfnd for 2 Jun 2014

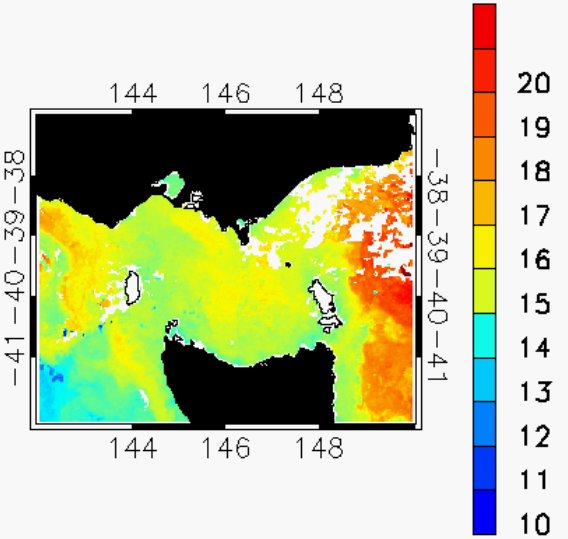
1-day 2 km L3S



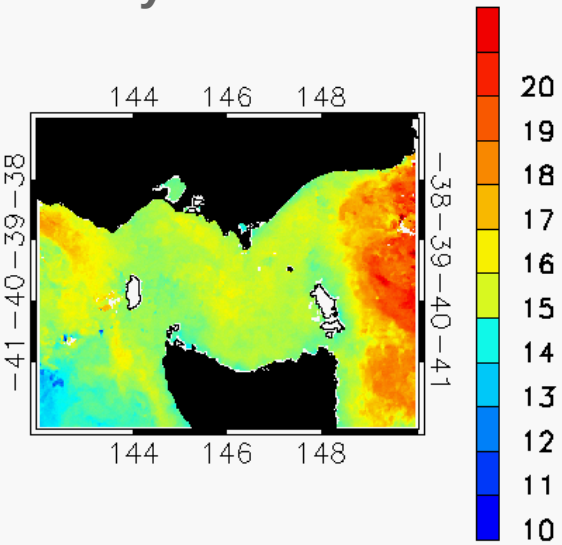
3-day 2 km L3S



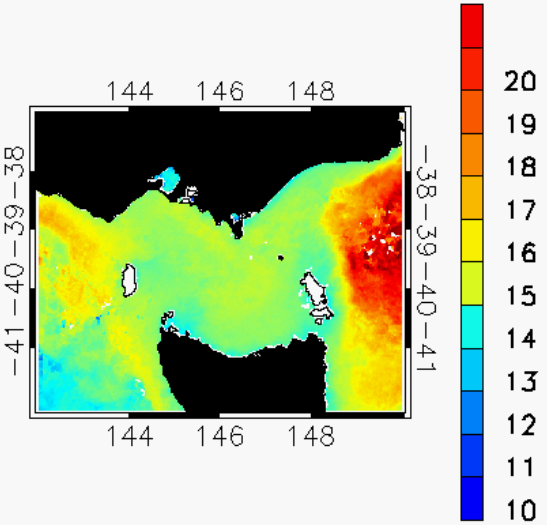
6-day 2 km L3S



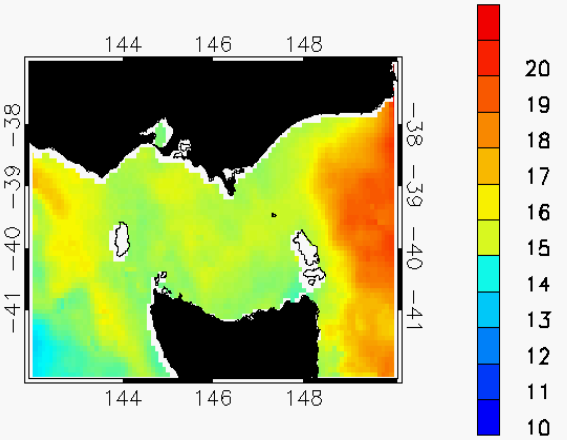
14-day 2 km L3S



1-month 2 km L3S



Daily 9 km RAMSSA L4



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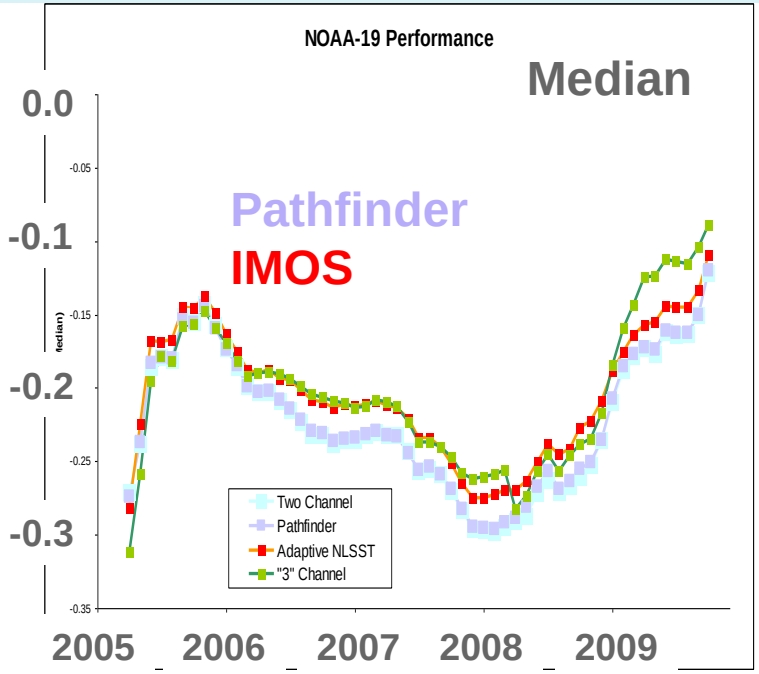
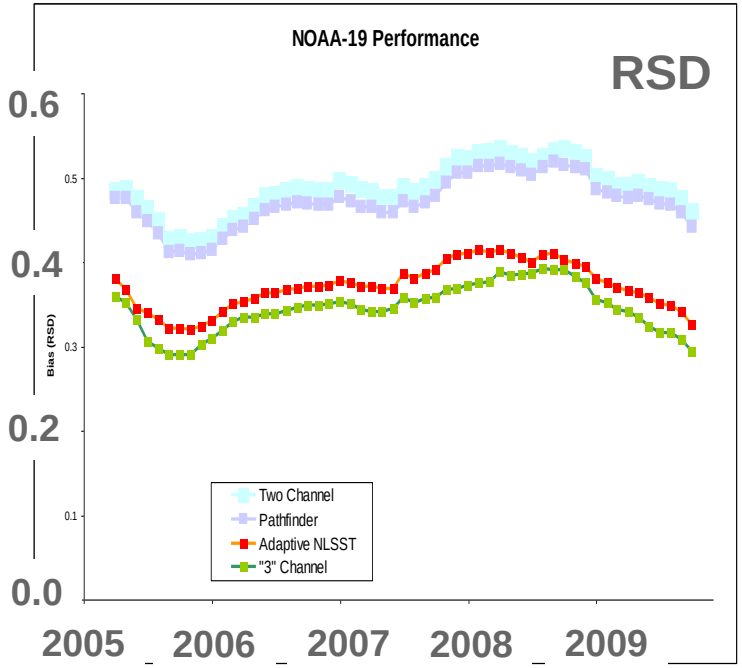
New to fv02 IMOS AVHRR SST: "Adaptive Calibration"!





- Running 1 year calibration window, adjusted monthly
- Tuned on best matchups with in situ SST
- Performance measured on an expanded matchup data set