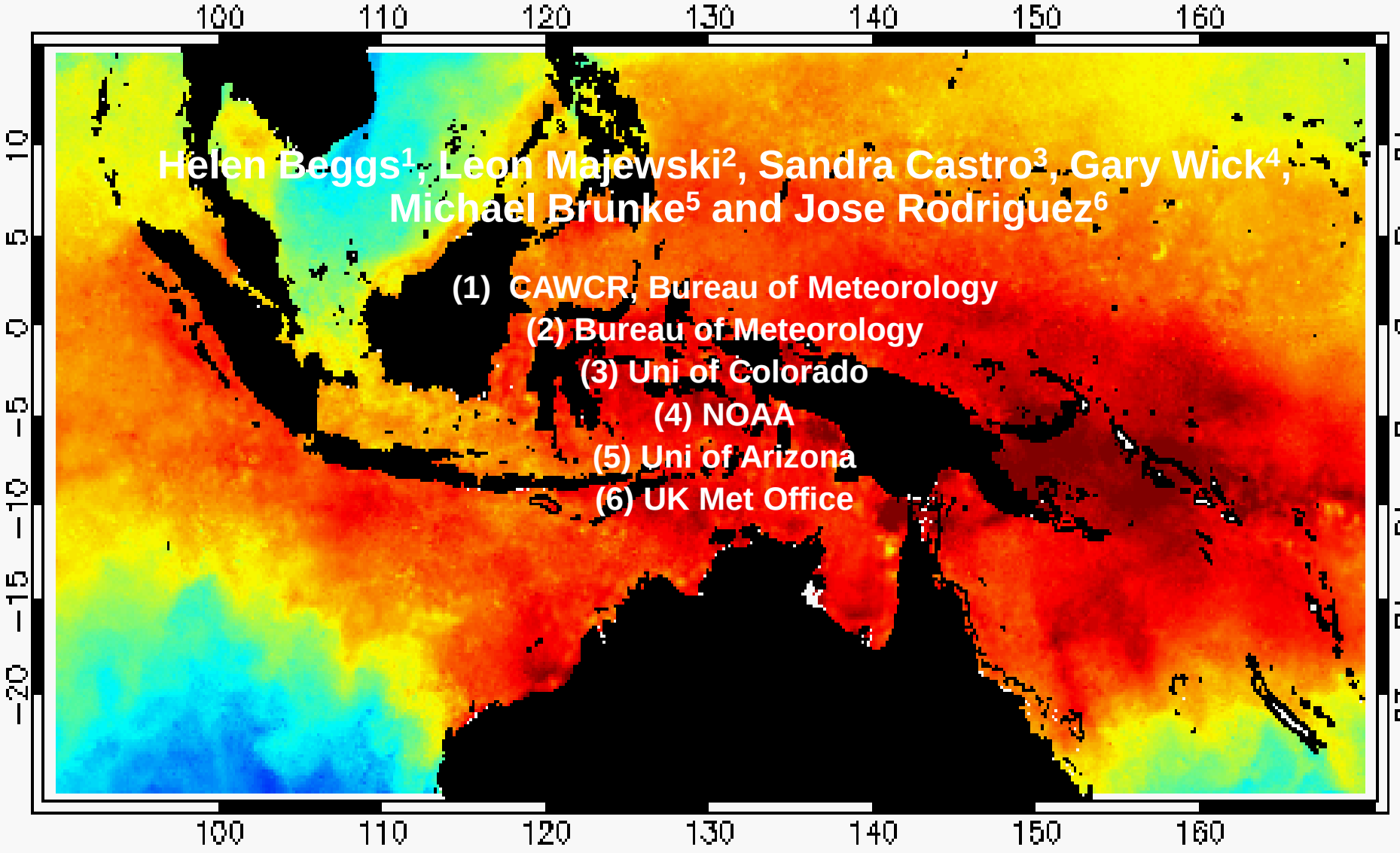
Update on the Tropical Warm Pool Diurnal Variability Project (TWP+)



Helen Beggs[1], Leon Majewski[2], Sandra Castro[3], Gary Wick[4], Michael Brunke[5] and Jose Rodriguez[6]

(1) CAWCR, Bureau of Meteorology
(2) Bureau of Meteorology
(3) Uni of Colorado
(4) NOAA
(5) Uni of Arizona
(6) UK Met Office

14th GHRSST Science Team Meeting, Woods Hole, 17-21 June 2013

GHRSST
Group for High Resolution Sea Surface Temperature

Tropical Warm Pool Diurnal Variability Project (TWP+)

Aims

- Assess multiple satellite SST products over TWP
- Quantify diurnal warm-layer events using satellite data
- Assess ≥ 8 diurnal warming models run using common inputs

Period

Jan–Apr 2010

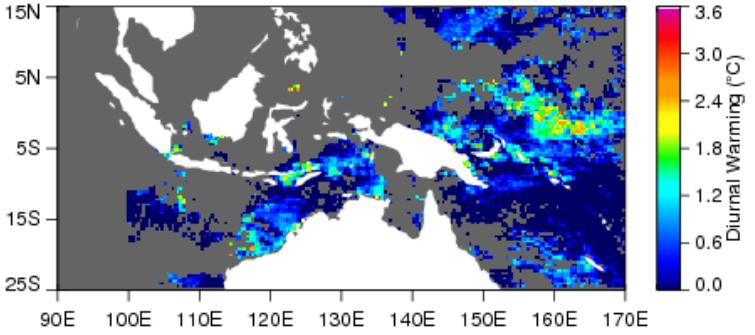
Location

25°S to 15°N, 90°E to 170°E

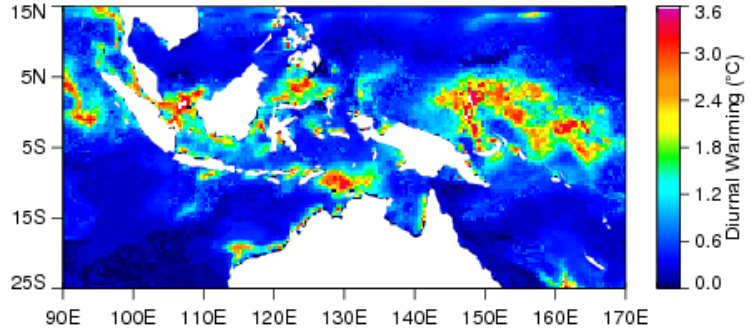
Collaborators

Bureau of Meteorology, NOAA, Meteo-France, Met Office, WHOI, Uni of Colorado, Uni of Edinburgh, Uni of Arizona, Uni of Miami, JMA

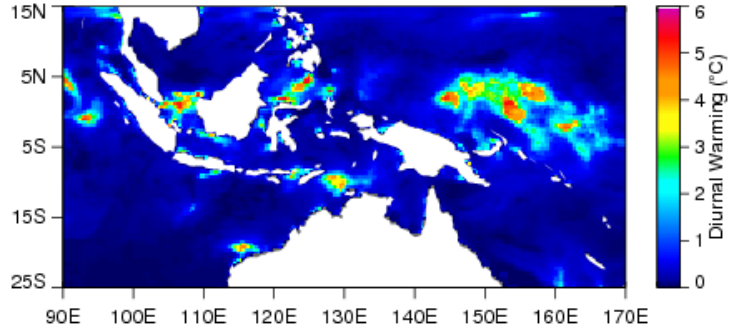
26 Apr 2010
MTSAT-1R Observed DW



Castro Look-Up Table DW



Wick Modified Kantha-Clayson DW



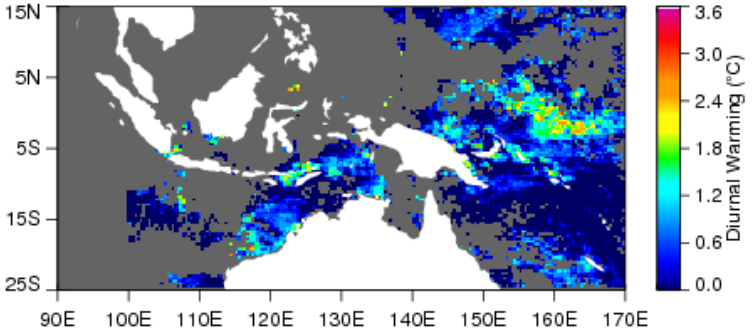
GHRSST
Group for High Resolution Sea Surface Temperature

Tropical Warm Pool Diurnal Variability Project (TWP+)

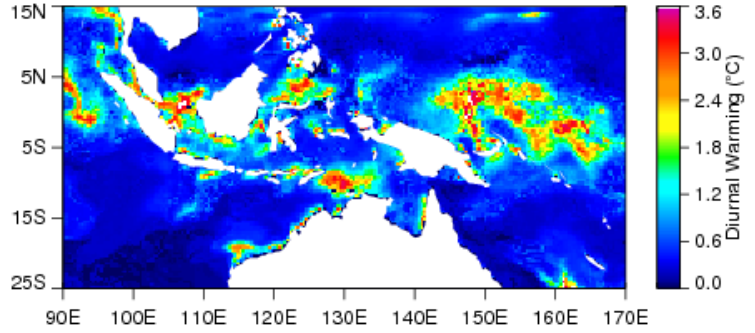
TWP+ Data Set

- Satellite SST
  - IR: AVHRR (METOP-A, NOAA-17,18 & 19)
  - IR dual-view: AATSR (Envisat)
  - MW: AMSR-E (AQUA)
  - MW: WindSat (Coriolis)
  - Geo: JAMI (MTSAT-1R)
- Bureau Regional foundation SST Analysis (RAMSSA)
- In Situ SST (buoys, ships)
- Bureau Numerical Weather Prediction surface flux fields (ACCESS-R)
- Bureau Sea State Forecasts (AUSWAM)
- 7 DV Model outputs

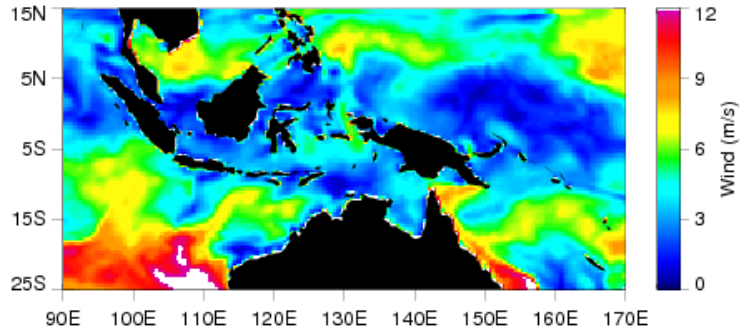
26 Apr 2010
MTSAT-1R Observed DW



Castro Look-Up Table DW



ACCESS-R 10m Wind

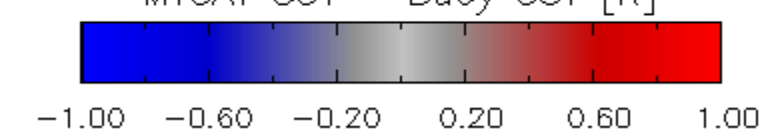


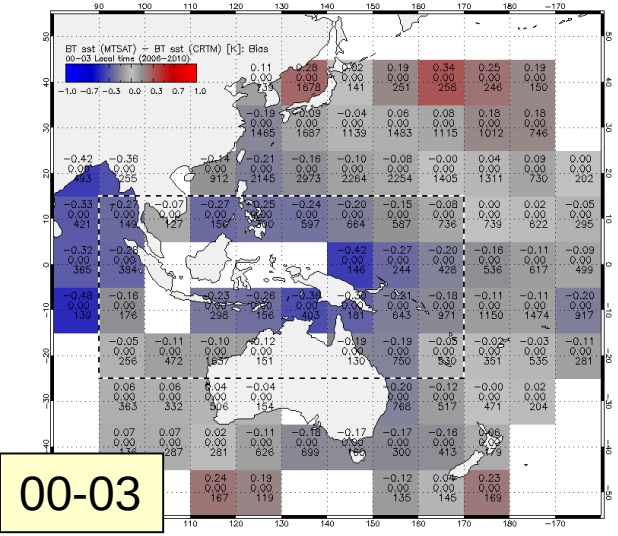
Mar 2012 TWP+ Workshop recommendations re satellite SSTs for DV

- Consistent algorithm for day and night
- Consistent bias and standard deviation
- Consistent spatial bias
- Expand land mask to eliminate coastal DV
- Only use best quality SSTs with similar quality neighbours

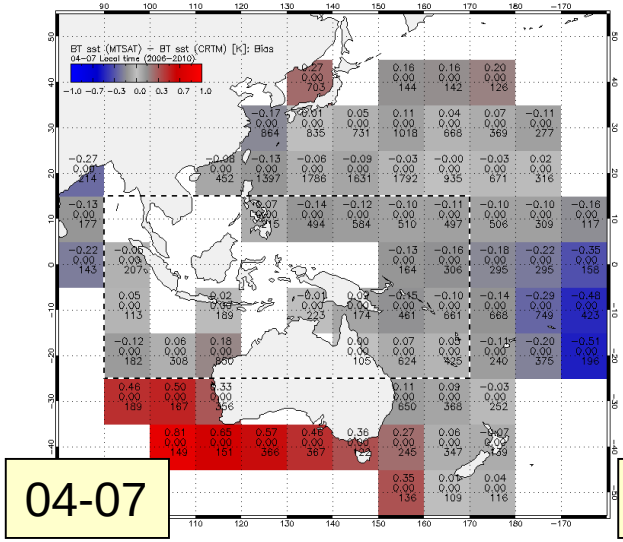
- Specific improvements to MTSAT-1R SSTs:
  - Include a distance from land variable
  - Expand longitude range to 90°E

Spatial Bias Patterns/Issues
MTSAT pre-correction

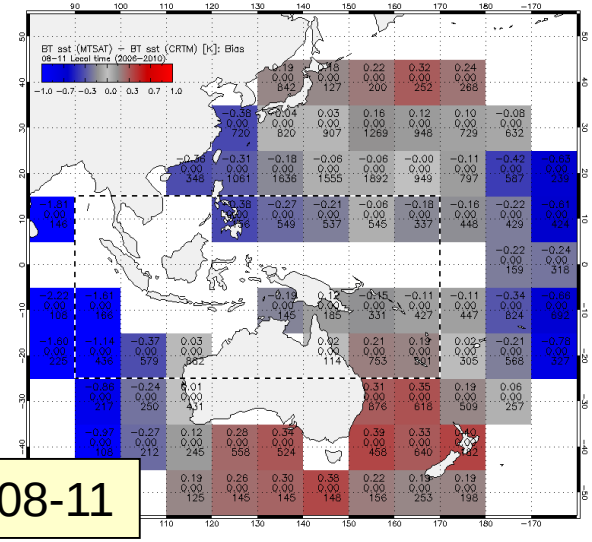




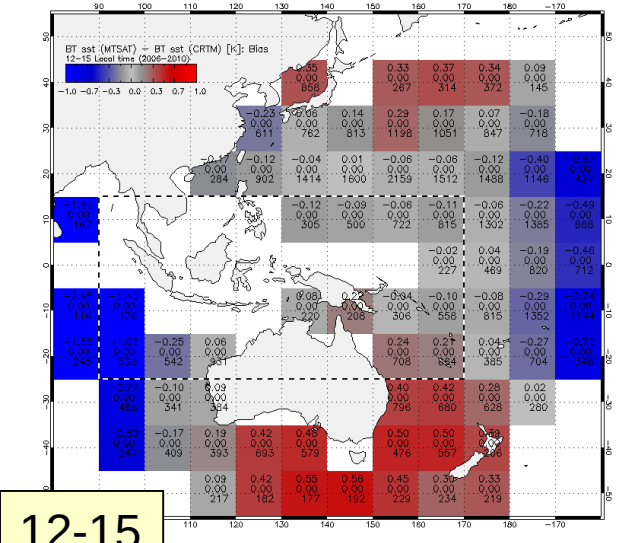
00-03



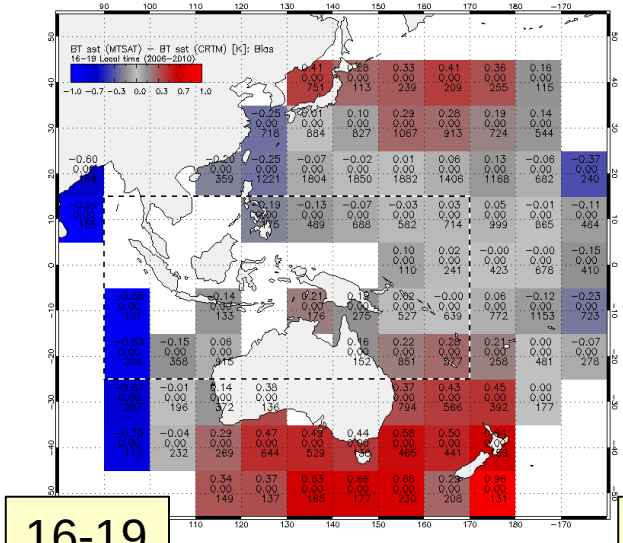
04-07



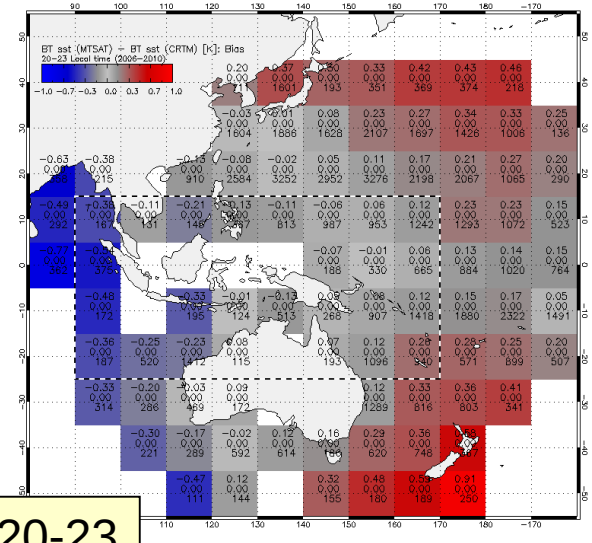
08-11



12-15

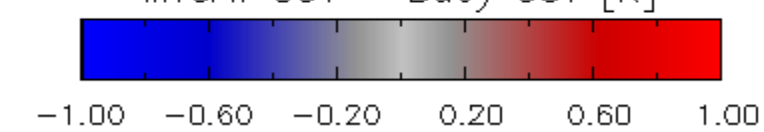


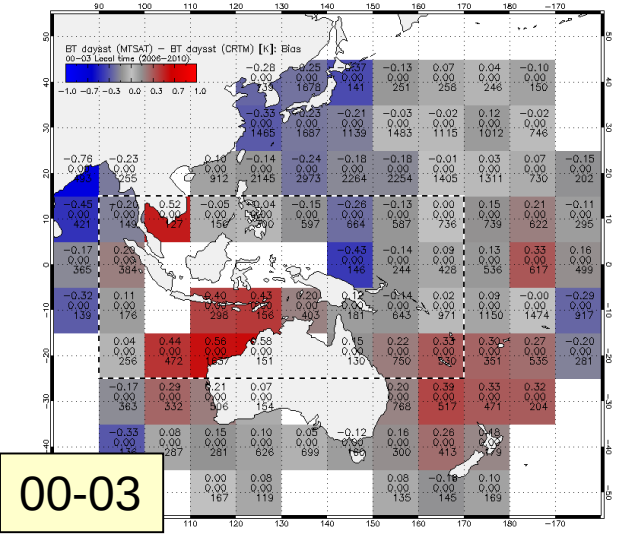
16-19



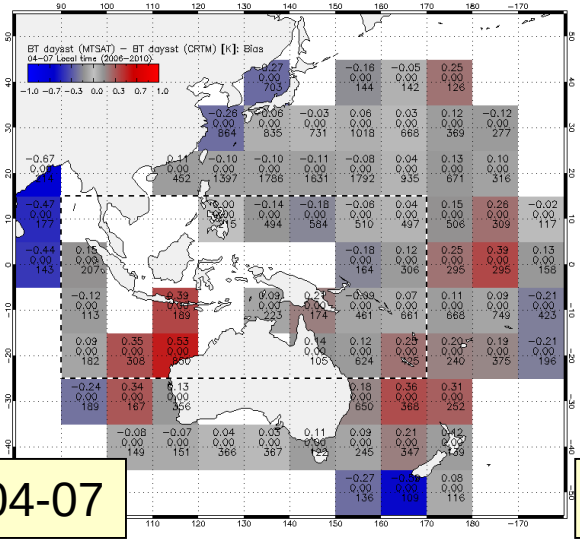
20-23

Spatial Bias Patterns/Issues
MTSAT post-correction

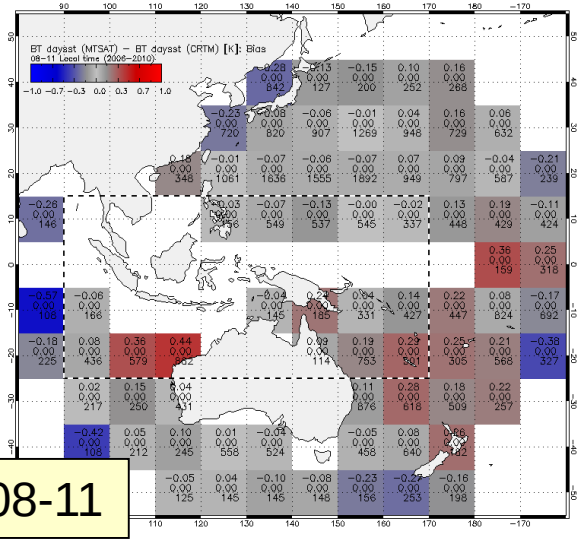




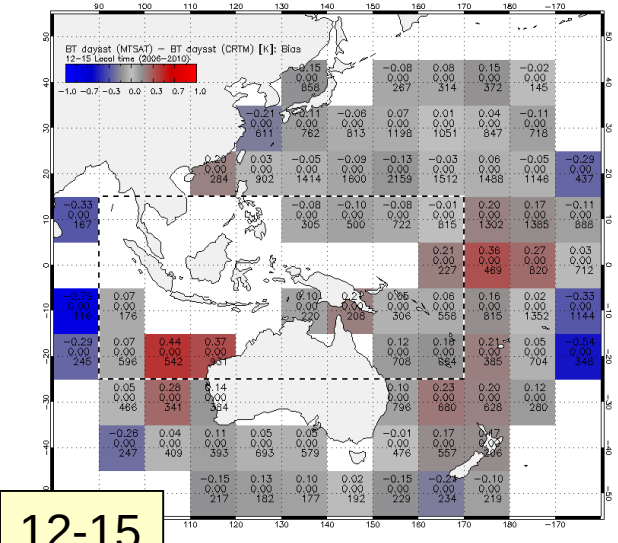
00-03



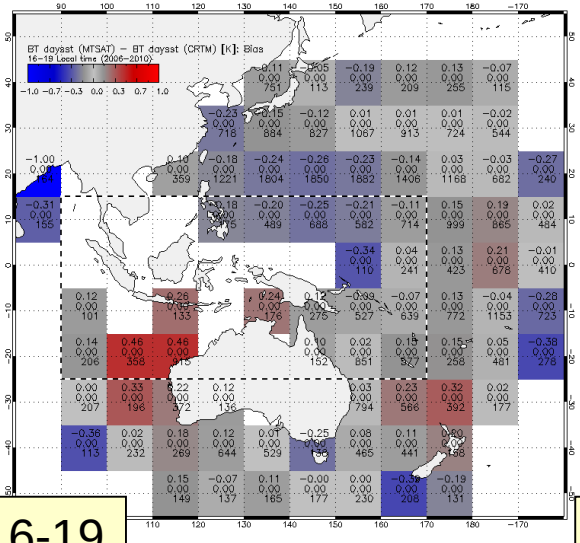
04-07



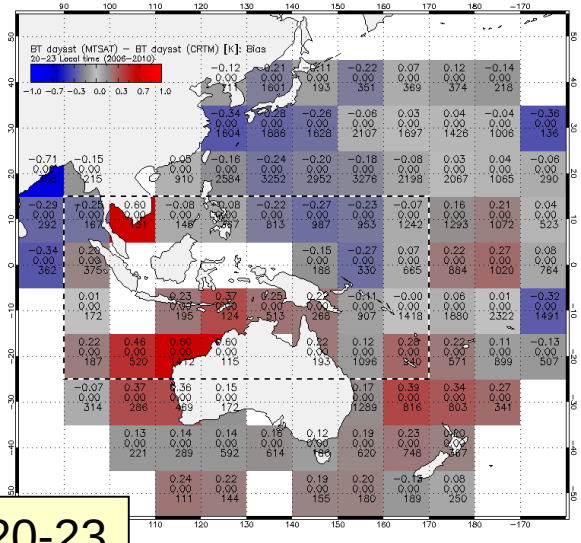
08-11



12-15



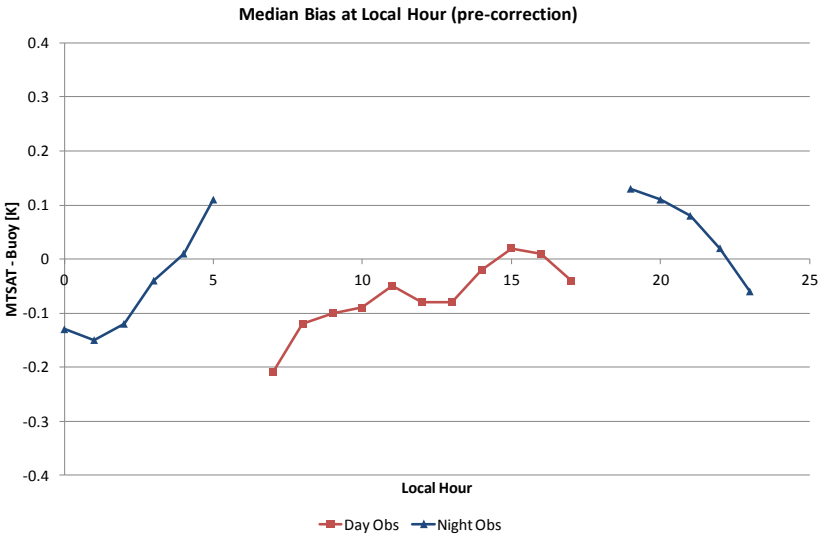
16-19



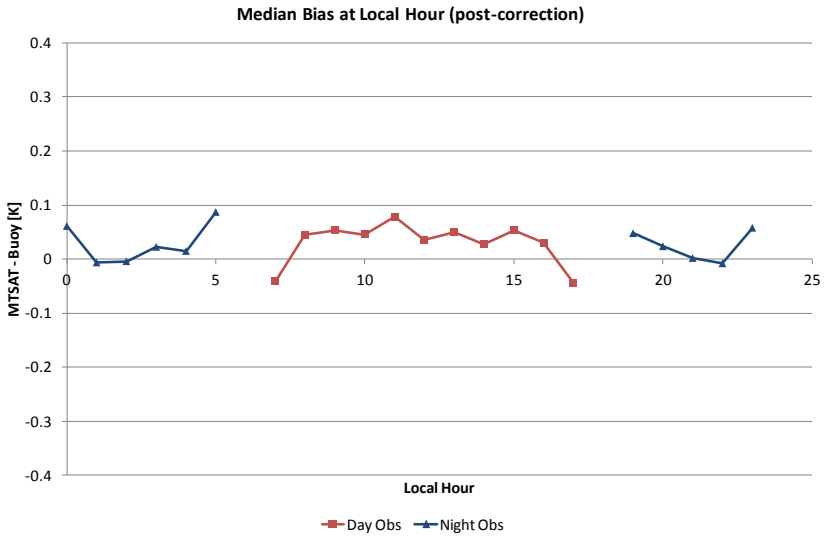
20-23

MTSAT-1R SSTskin Temporal Bias/Issues by local hour 2006 – 2010 over whole scene

Pre-correction

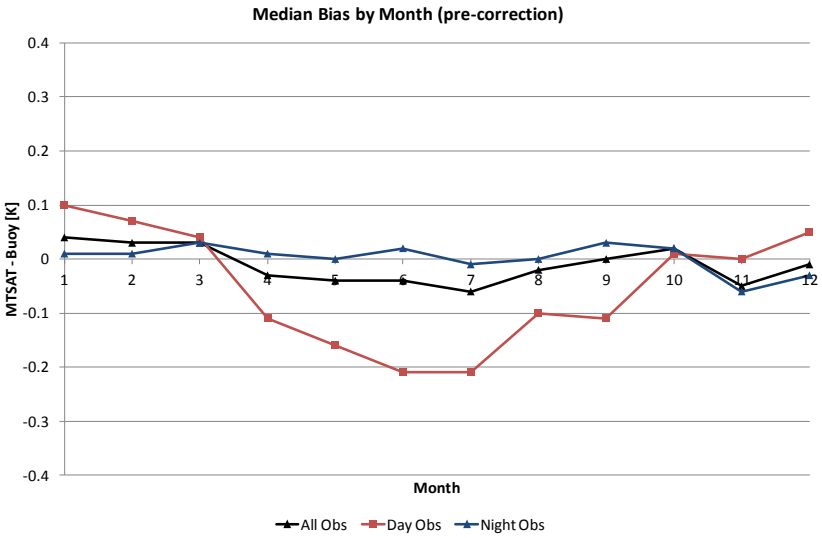


Post-correction

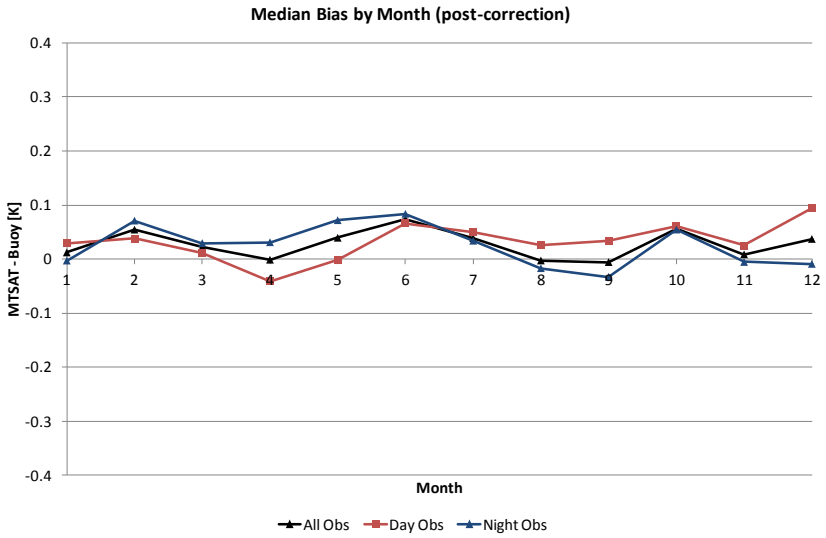


MTSAT-1R SSTskin Temporal Bias/Issues by month 2006 – 2010 over whole scene

Pre-correction



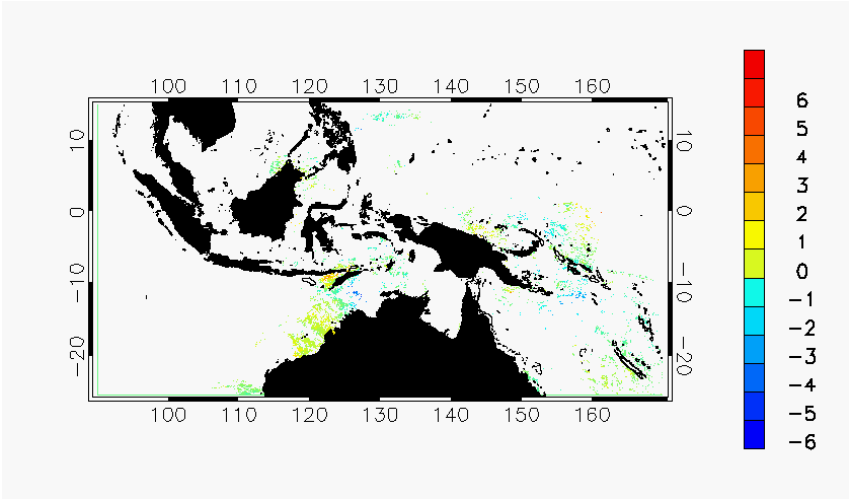
Post-correction



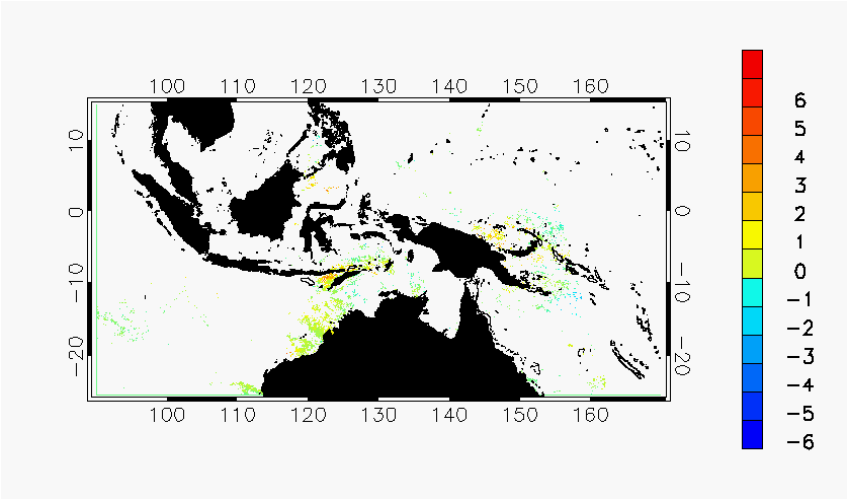
All obs, night obs, day obs

Satellite SST (day) – Satellite SST (night)
26 Apr 2010

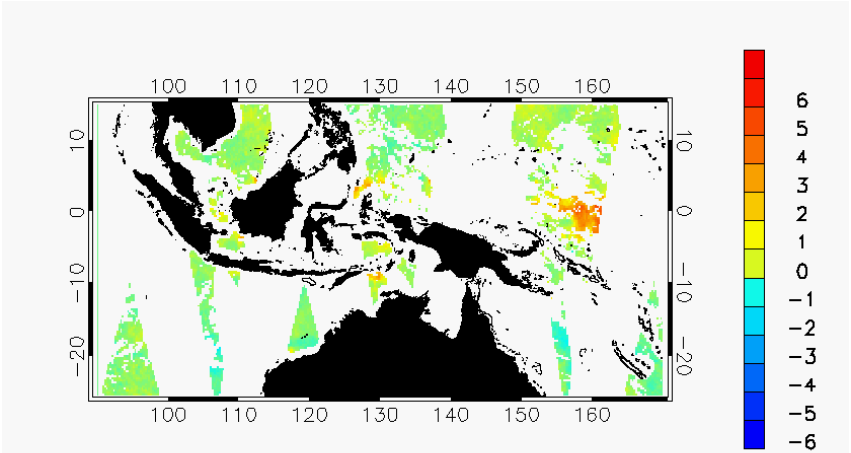
NOAA-18 (PC ≥ 4)



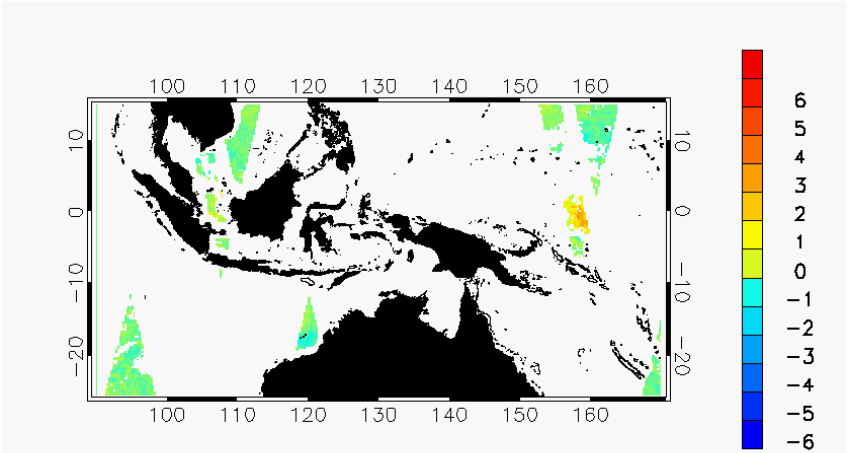
NOAA-19 (PC ≥ 4)



AMSR-E (PC ≥ 2)



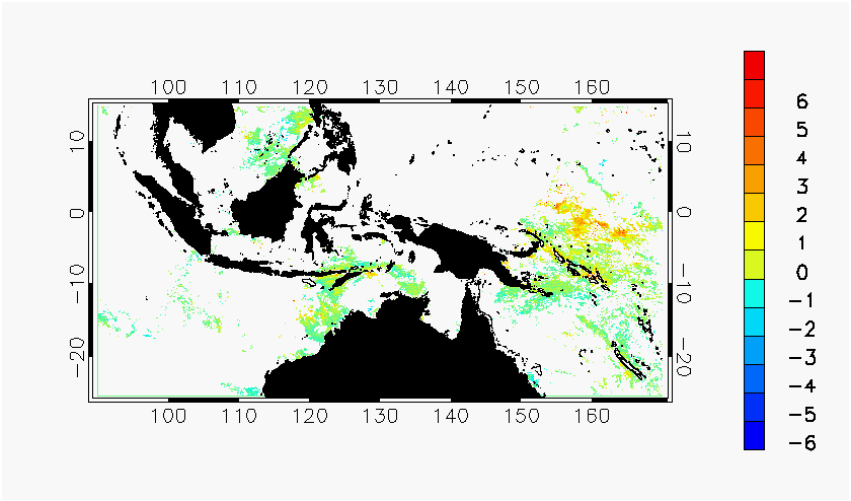
WindSat (PC ≥ 2)



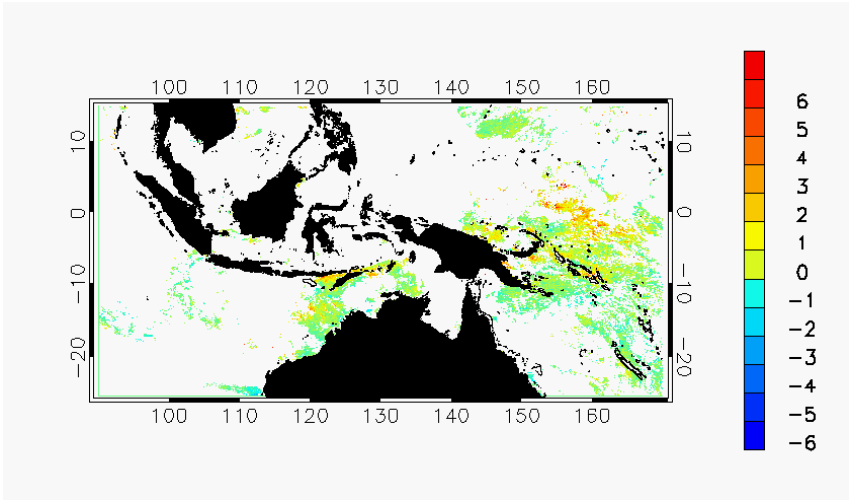
v3 MTSAT-1R SSTskin – new MTSAT-1R SSTfnd

26 Apr 2010 (PC = 5)

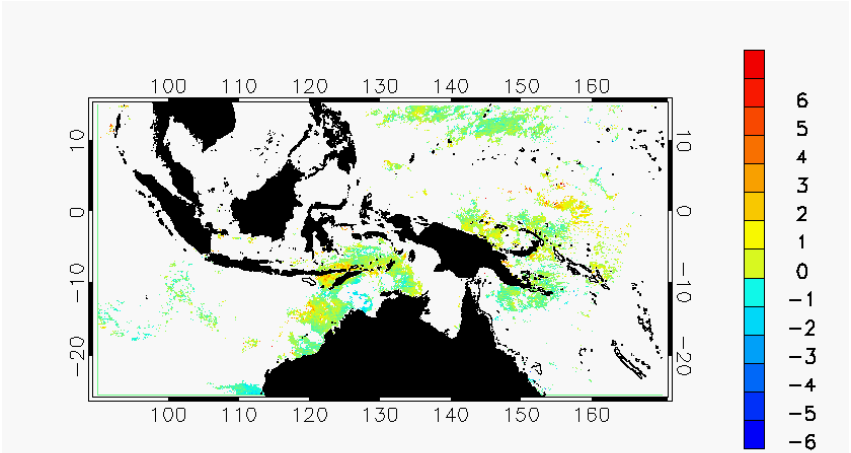
0200 UT



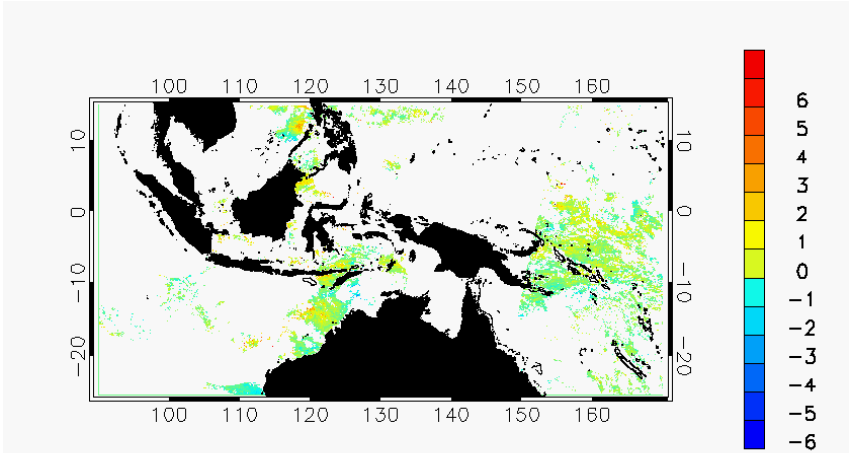
0400 UT



0600 UT



0800 UT



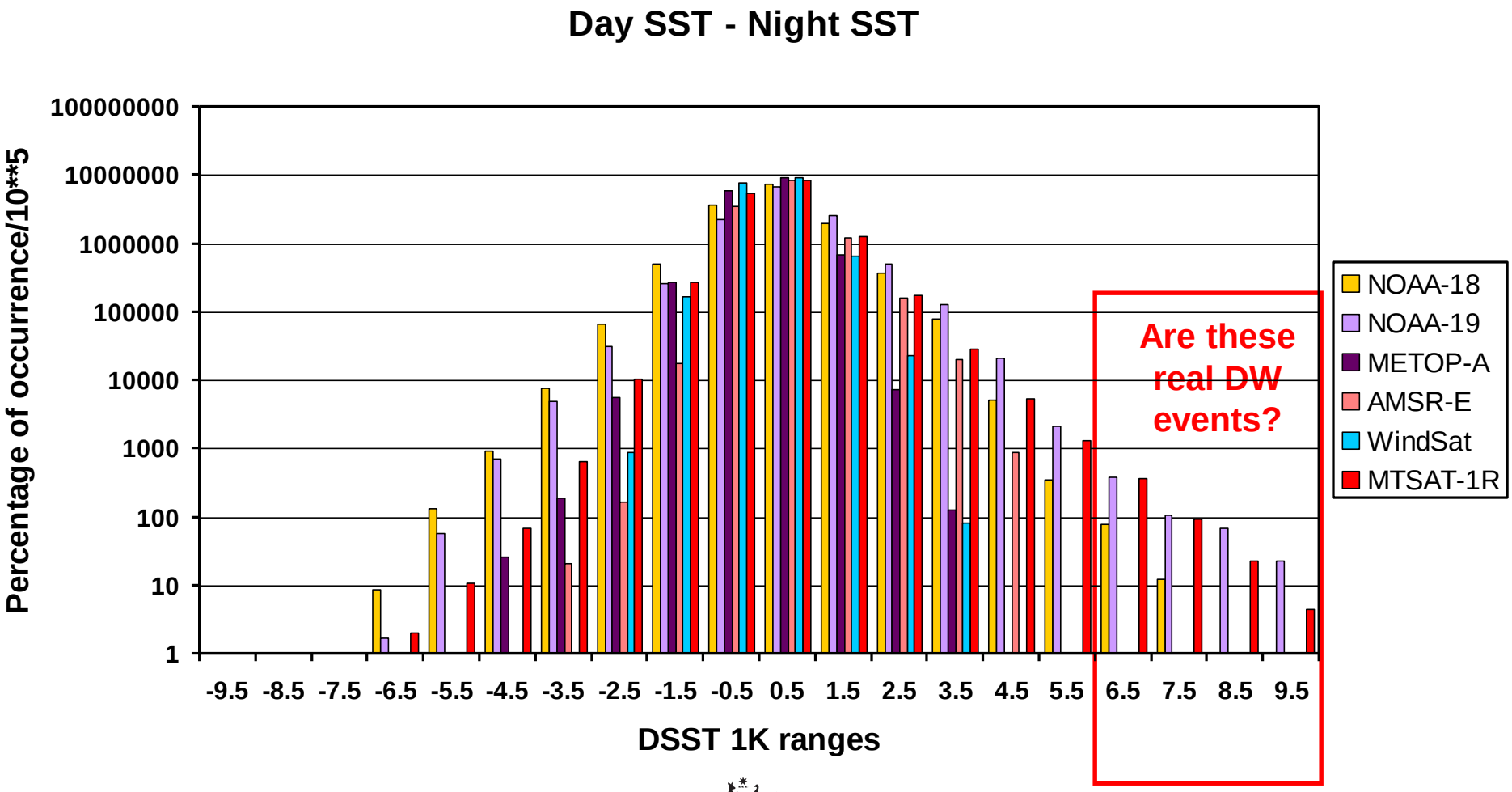
Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Percentage of occurrence of 1ºC ranges of Day SST – Night SST 1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

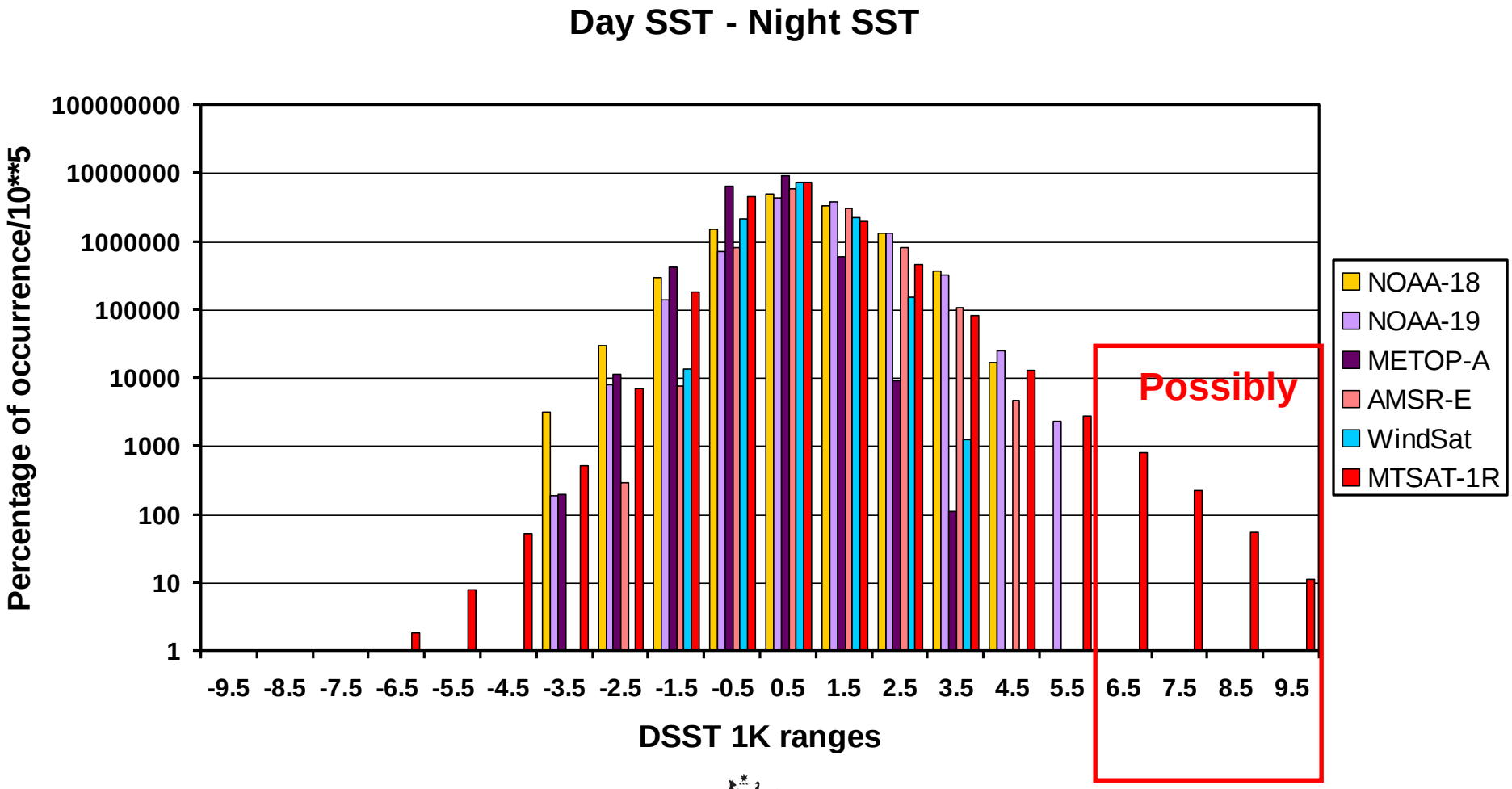
Expanding land mask by 0.5° x 0.5°



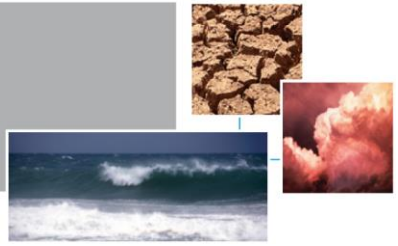
Percentage occurrence of 1ºC ranges of Day SST – Night SST
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)

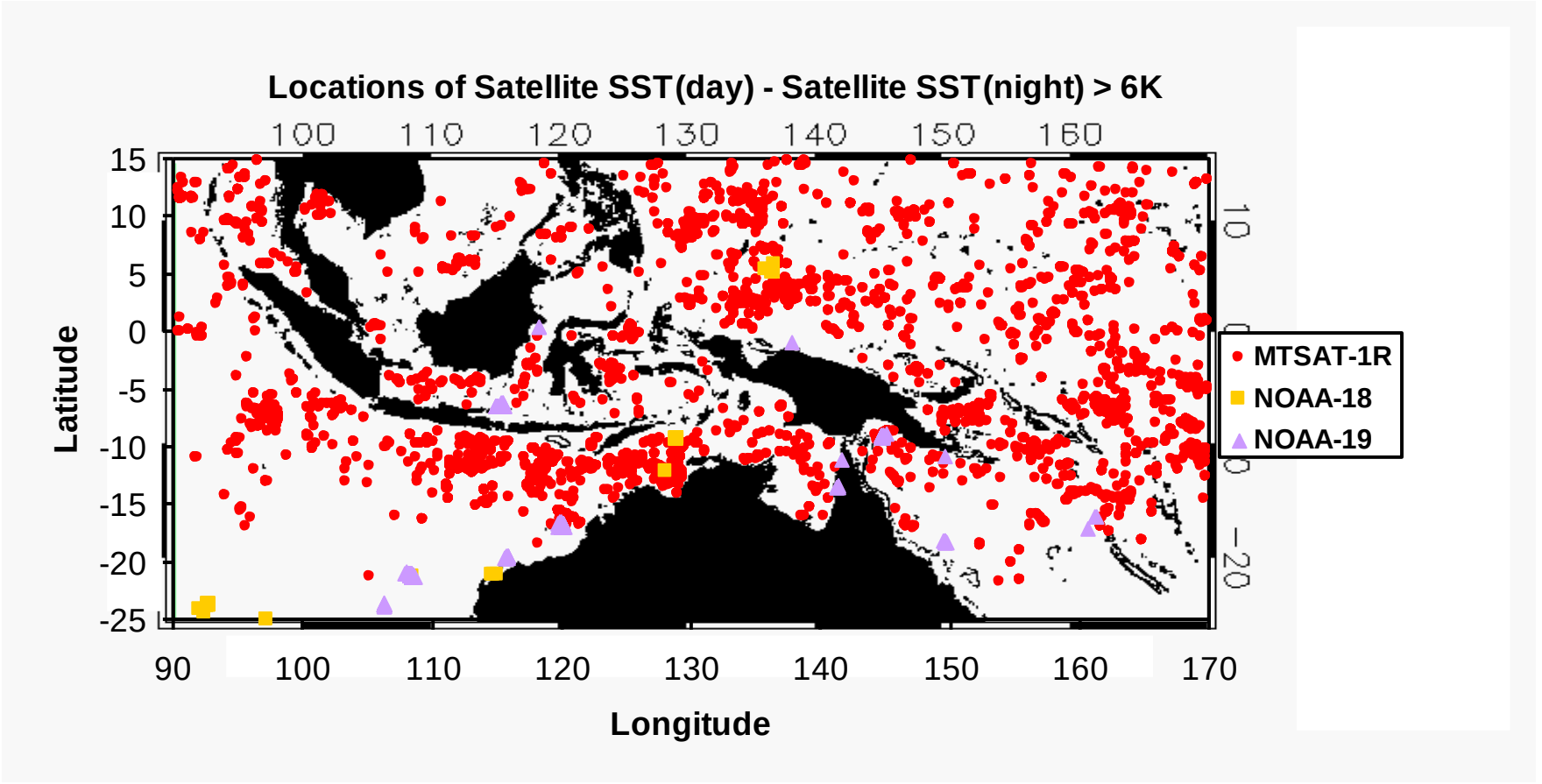
Only include matchups for Winds ≤ 3 m/s



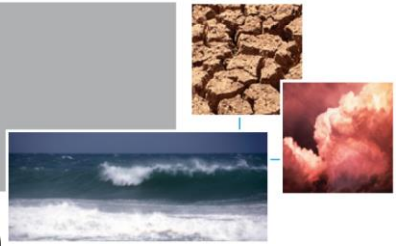
Locations of Day SST – Night SST > 6K
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5°

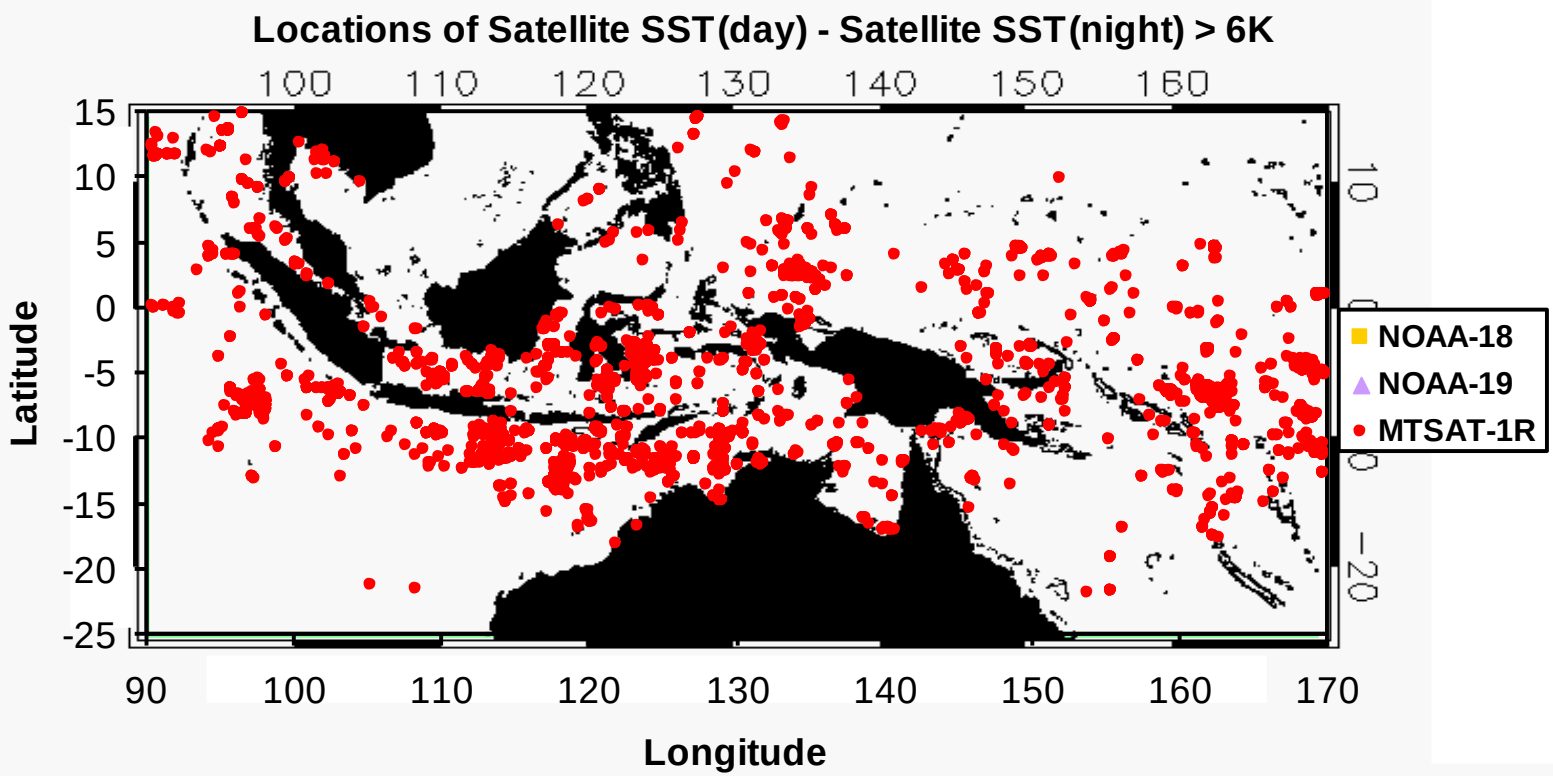


Locations of Day SST – Night SST > 6K
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)

Only include matchups for ACCESS-R Winds ≤ 3 m/s

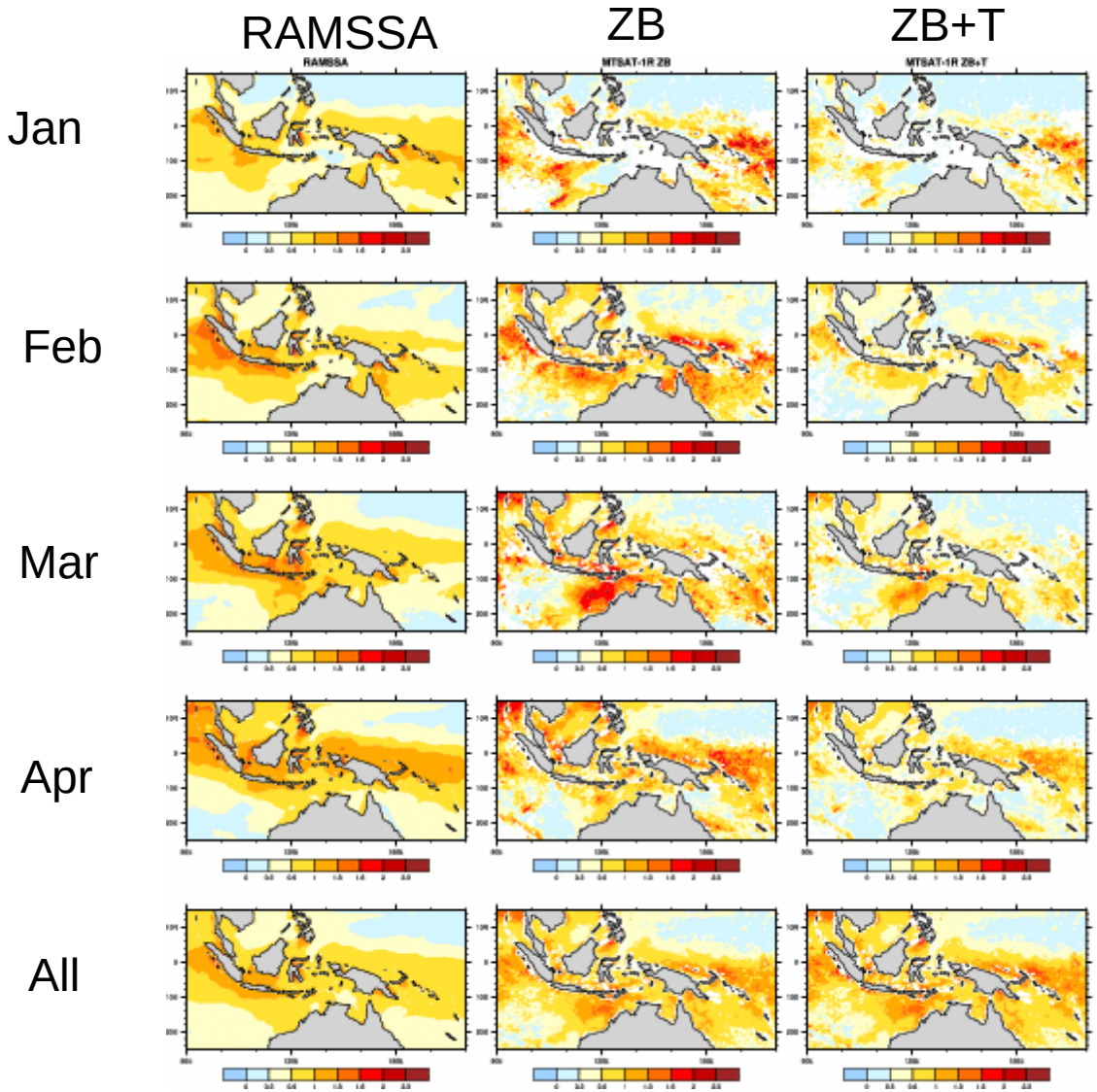


TWP+ Models

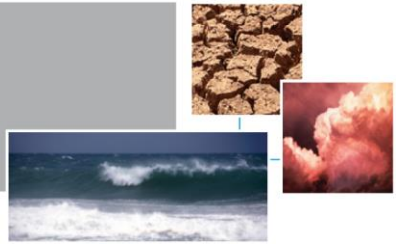
DV models that use TWP+ ACCESS-R fluxes as inputs:

a. **Gentemann et al (2003)** as used in **RAMSSA_skin** (winds) (Helen Beggs and Sandra Castro) **Done**
b. **Castro Look Up Tables** (winds, SW radiation) (Sandra Castro) **Done**
c. Bogdanoff-Clayson Parameterisation (winds, SW radiation, 24 hr accumulated precipitation) (Carol Anne Clayson)
d. **COARE** (Gary Wick) **Done**
e. POSH v2 (Chelle Gentemann)
f. GOTM (Gary Wick) **Started**
g. Wick's Modified Kantha-Clayson (Gary Wick) **Done**
h. Janssen's Modified Kantha-Clayson (Who?)
i. Kantha-Clayson DV model with sea state (Carol Anne Clayson) **Started**
j. **Zeng and Beljaars** (Michael Brunke) **Done**
k. **Z-B + T** (Michael Brunke) **Done**
l. Bluelink High Res **CLAM-R** Atmosphere-Ocean Coupled Model hourly 0.1° SST(0.25m) (Paul Sandery) **Done**
m. Met Office **HadGEM3_GA3** coupled ocean model hourly 0.25° SST(0.5m) **Done**

Michael Brunke's SSTskin - SSTfnd using v3 MTSAT-1R SSTfnd



Conclusions



- New v3 MTSAT-1R SSTskin and MTSAT-1R SSTfnd data sets look good
- DV model comparisons can proceed with revised MTSAT-1R data
- Day SST – Night SST up to 10°C were measured from NOAA-19 and MTSAT-1R for all winds but MTSAT-1R only for winds ≤ 3 m/s
- Need to study regions where more than one satellite measured high DW

- TWP+ Project web page: **https://www.ghrsst.org/ghrsst-science/science-team-groups/dv-wg/twp**

- Contact **h.beggs@bom.gov.au** for access to TWP+ and IMOS SST data

Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Helen Beggs

Phone: 03 9669 4394
Email: h.beggs@bom.gov.au
Web: www.cawcr.gov.au

Thank you

www.cawcr.gov.au

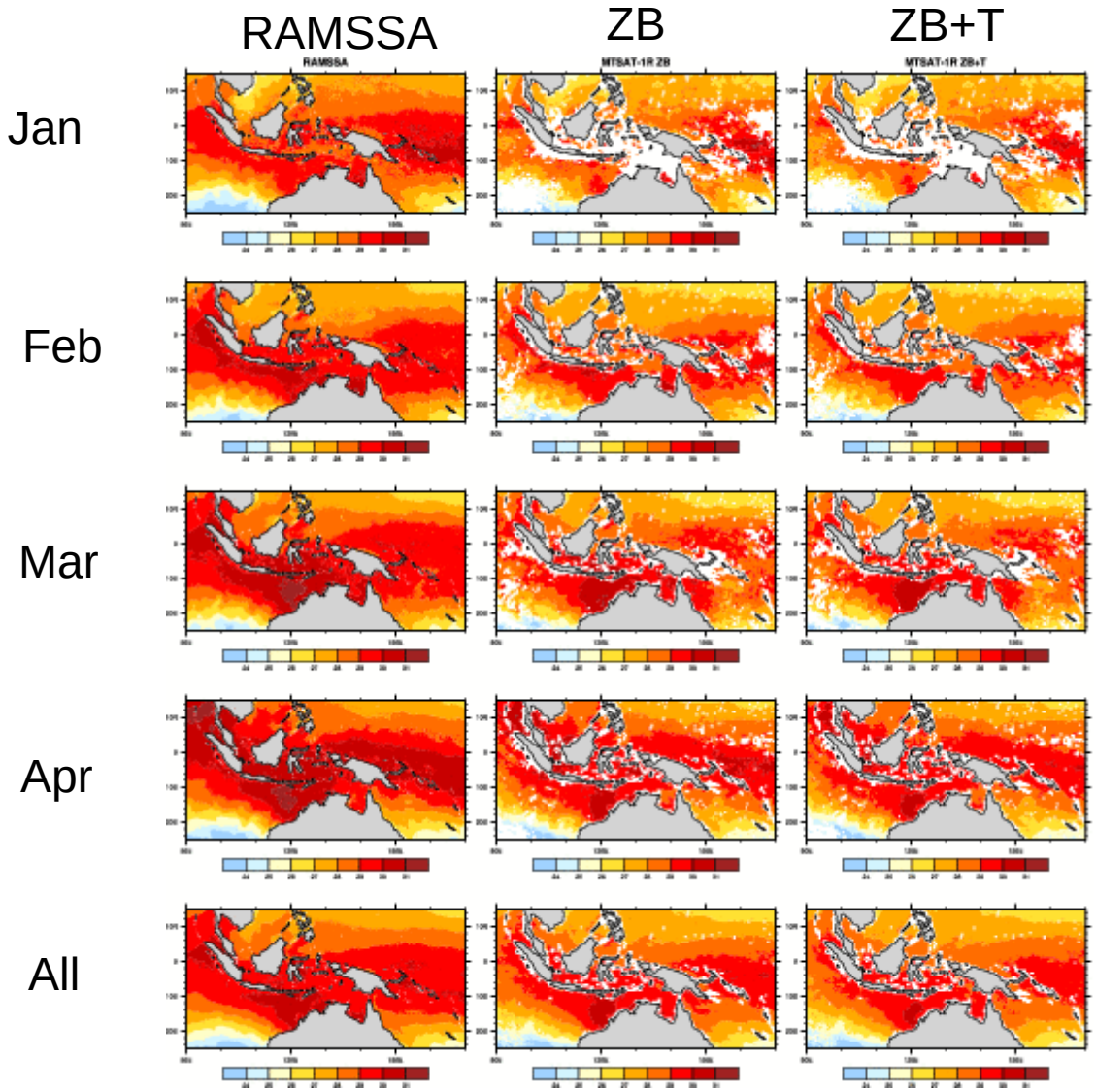
Extra Slides for discussion

Australian Government
Bureau of Meteorology

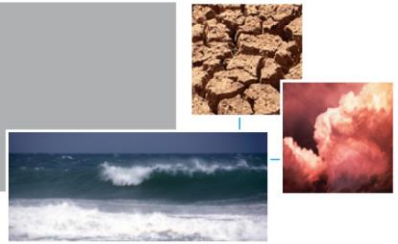
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

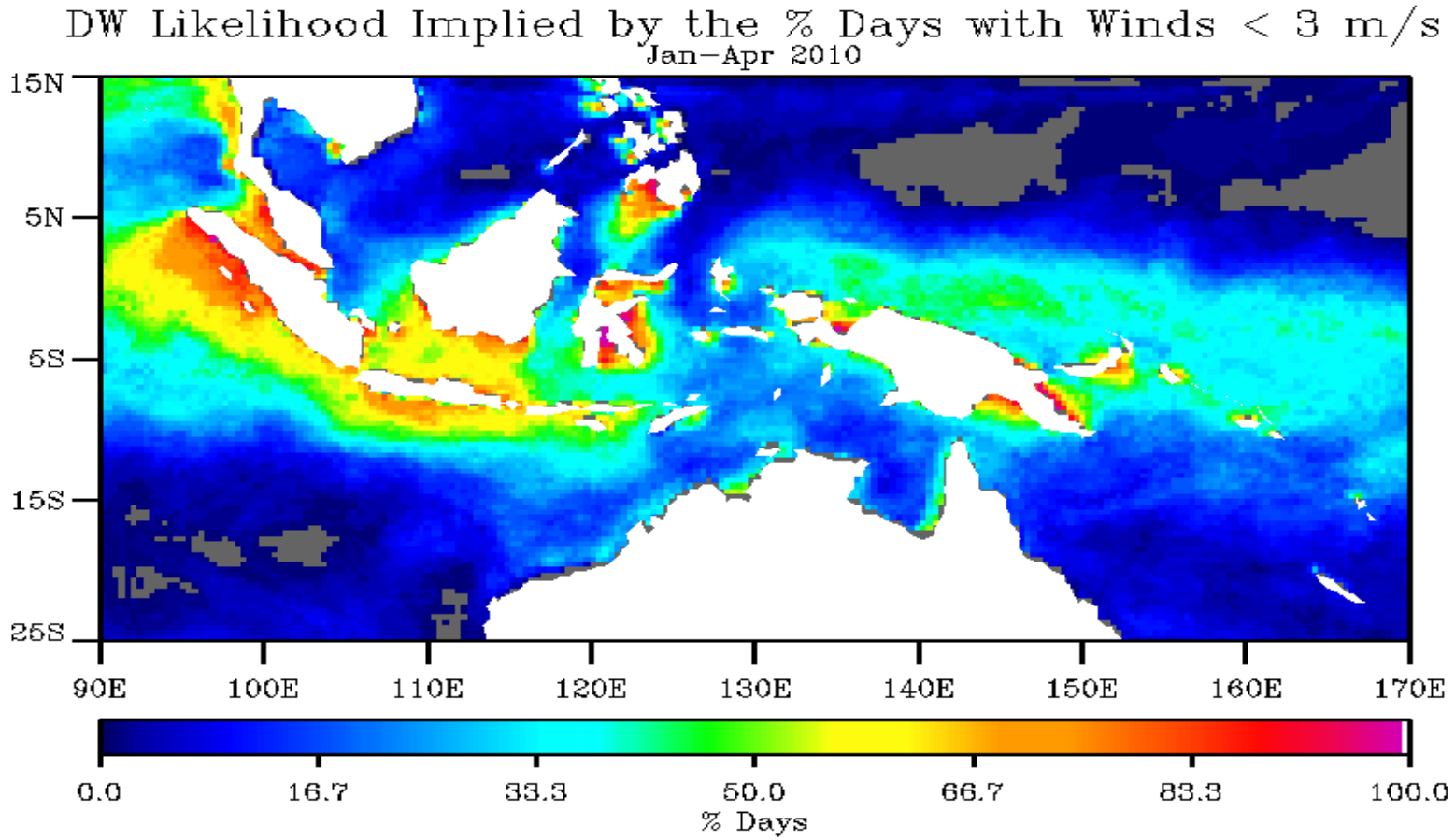
CSIRO

Michael Brunke's SSTskin using v3 MTSAT-1R SSTfnd



DW Likelihood Implied by the % Days with Winds < 3 m/s



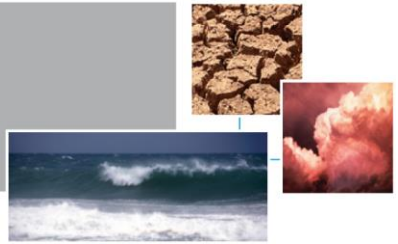


Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Consistent Day/Night 2-ch algorithm MTSAT



- **MODEL = SST + GFAC + DFAC + TFAC**
  - SST formulation:
    - SST = P[0]*BT11 + P[1]*(BT11-BT12) +P[2]*(BT11-BT12)*SECTHETA
  - Scan pattern:
    - GFAC = P[3]*(XIDX-P[4])^2.0 +P[5]*(YIDX^2.0)
  - Solar Declination/Earth Sun Distance:
    - DFAC = P[6]*(DECL) + P[7]*(ESDIST-1)
  - Time of day:
    - TFAC = P[8]*SIN(OBSHOUR/12.*!DPI) +P[9]*SIN(2*OBSHOUR/12.*!DPI)

TWP+ netCDF Data Sets

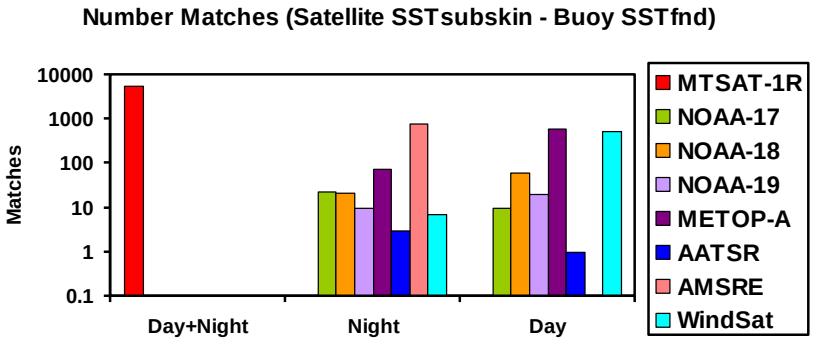
Email h.beggs@bom.gov.au for OPeNDAP URL

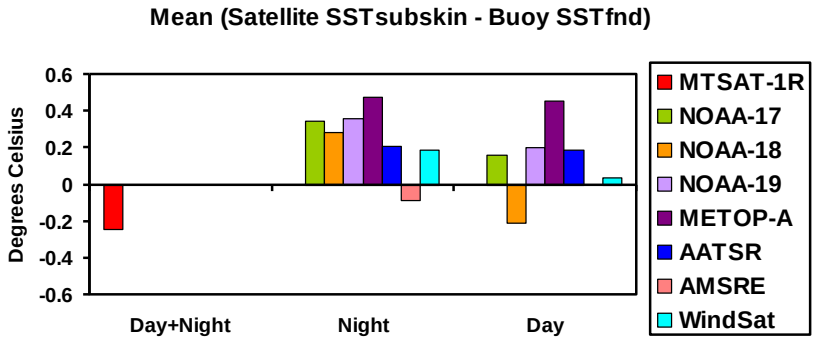
- BoM Regional NWP forecast fluxes (ACCESS-R) (hourly, 0.375º)
- BoM AUSWAM sea state forecasts (12-hrly, 0.5º)
- BoM RAMSSA Regional SSTfnd analyses (daily, 1/12º)
- BLUElink/BoM RAMSSA_skin Regional SSTskin analyses (hourly, 1/12º)
- IMOS/BoM v3 MTSAT-1R SSTskin L3 (hourly, 0.05º)
- IMOS/CU MTSAT-1R SSTfnd daily L3 (daily, 0.05°) – using v3 MTSAT-1R
- EUMETSAT METOP-A SSTsubskin L3 (day/night, 0.025º)
- IMOS/BoM NOAA-17/18/19 AVHRR SSTskin L3C (day/night, 0.02º) – still to be reprocessed to same 3 ch day/night algorithm
- UoE ARC v1.1 AATSR SSTskin L3 (day/night, 0.1º)
- RSS AMSR-E v7 SSTsubskin L2P-gridded (day/night, 0.25º)
- RSS WindSat v7 SSTsubskin composites (day/night, 0.25º)
- IMOS/BoM ship SST
- IMOS/BoM air-sea flux obs from ships and SO mooring
- GTS Buoy SST
- Plots
- IDL code to read data files
- DV Model Outputs

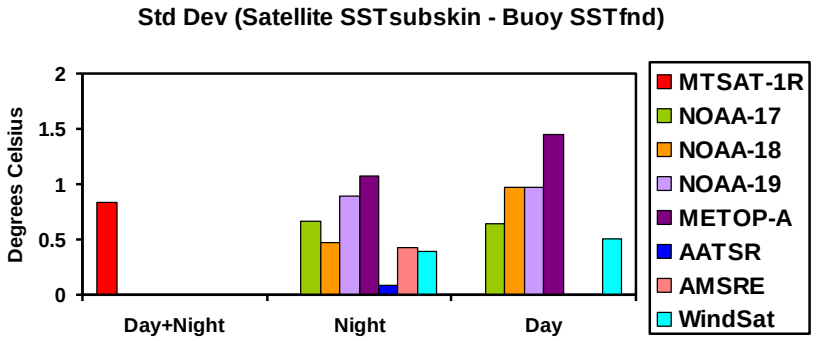
Satellite SSTsubskin – Buoy SSTfnd

Matches ±1 hr and same grid cell where W ≥ 2 m/s (night), W ≥ 6 m/s (day)

Jan – Apr 2010





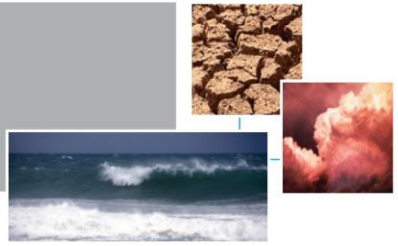


Australian Government
Bureau of Meteorology

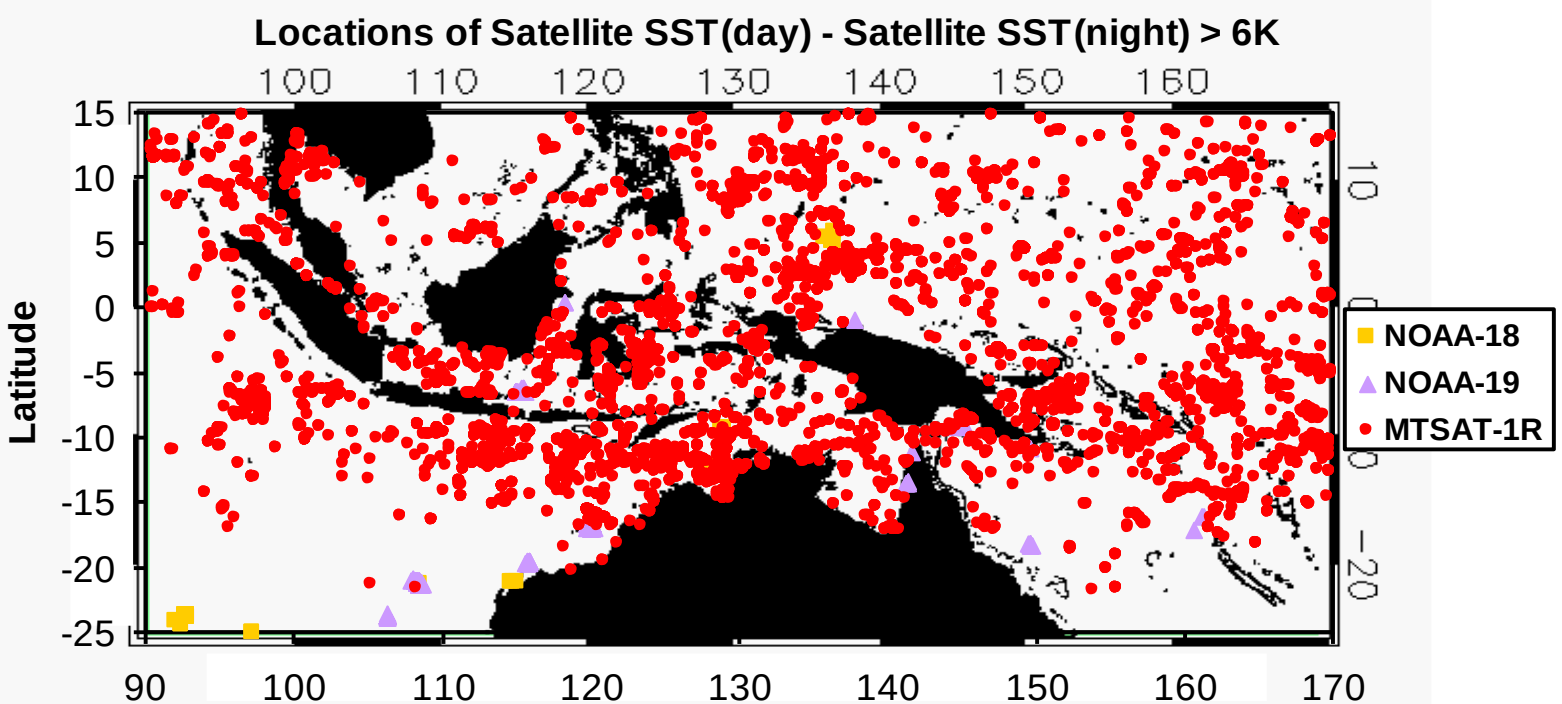
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Locations of Day SST – Night SST > 6K
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)



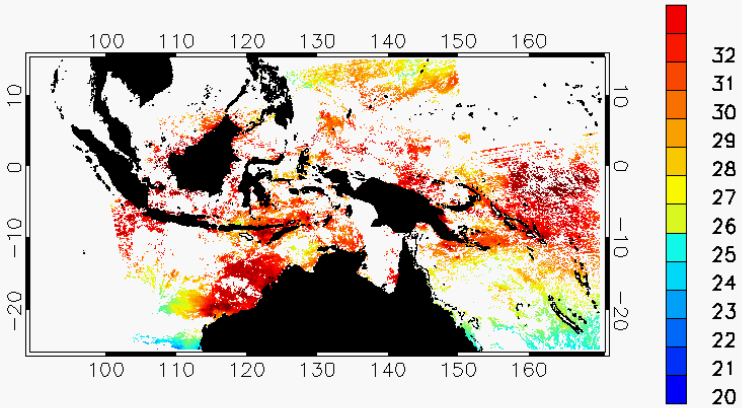
Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

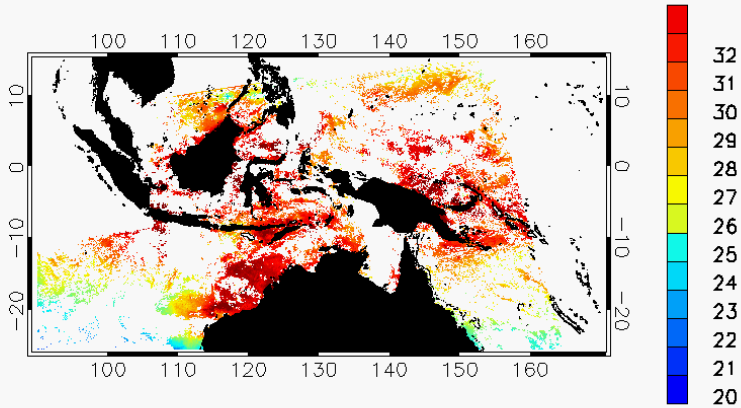
CSIRO

Afternoon Polar-orbiting Satellite SST
26 Apr 2010

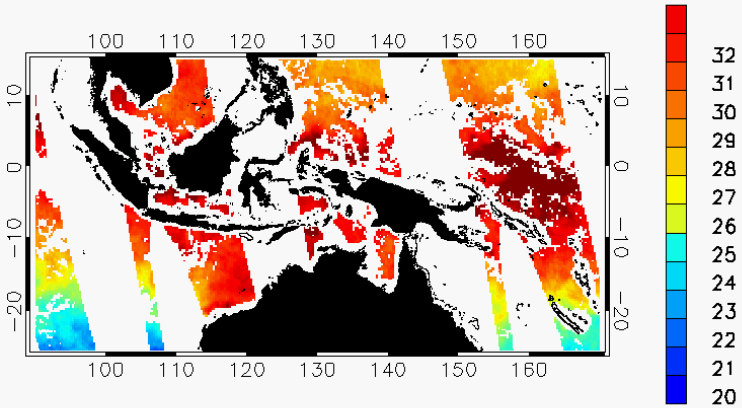
IMOS NOAA-18 (2 pm)



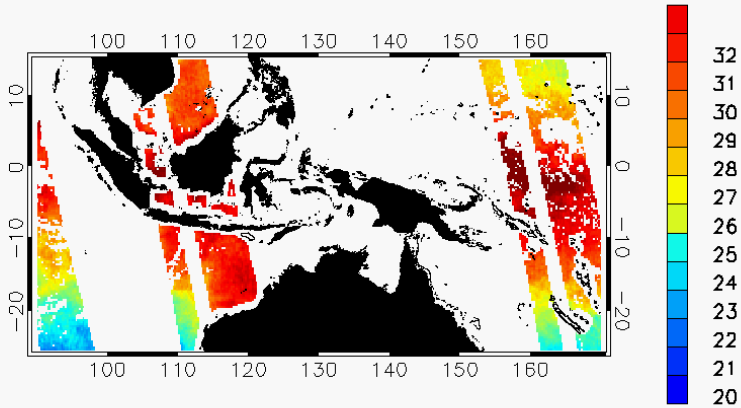
IMOS NOAA-19 (2 pm)



AMSR-E (2 pm)



WindSat (6 pm)



Australian Government
Bureau of Meteorology

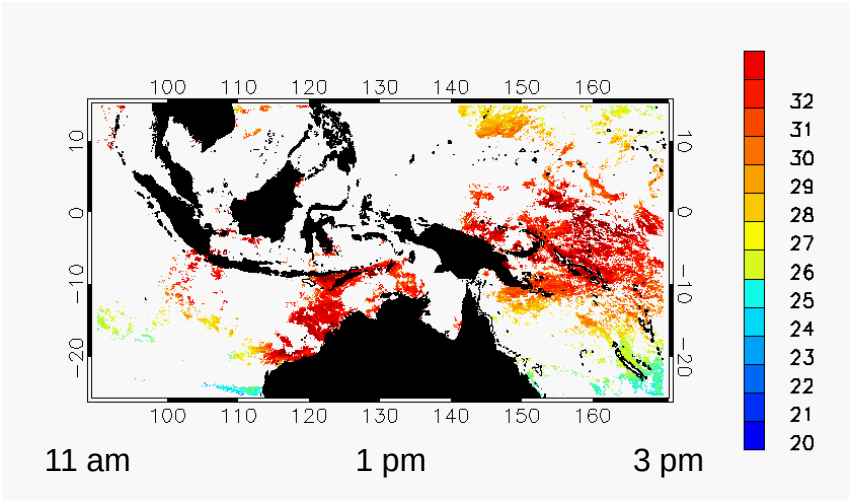
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

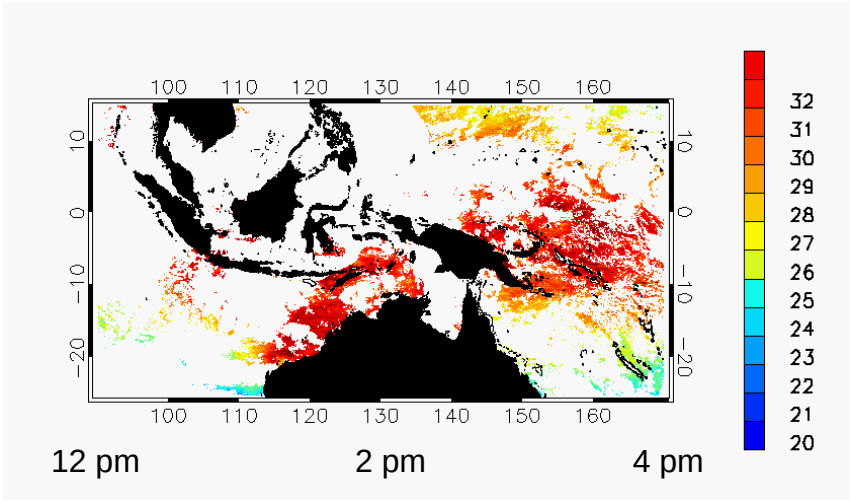
IMOS Geostationary v3 MTSAT-1R hourly SST

26 Apr 2010 (2 pm ± 2 hours)

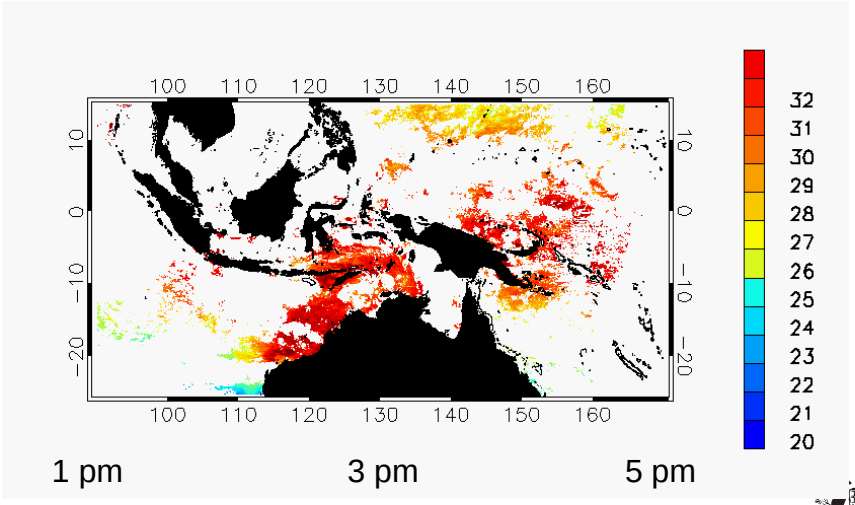
0400 UT



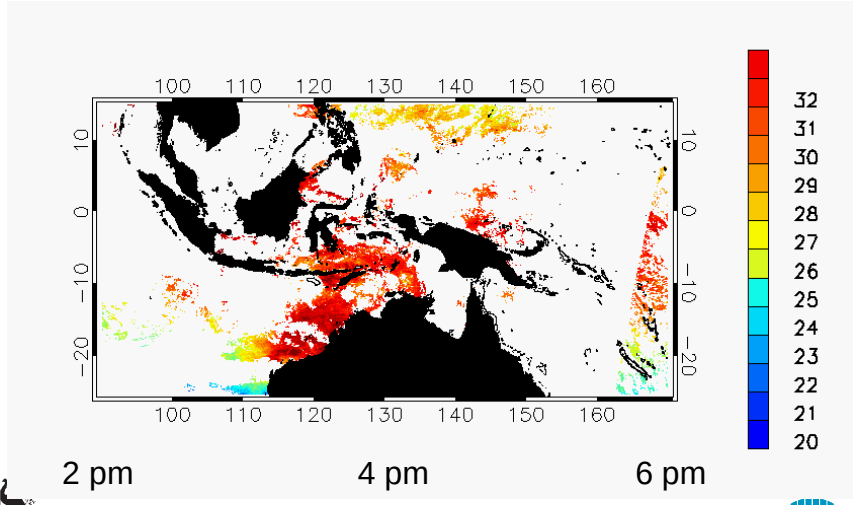
0500 UT



0600 UT



0700 UT

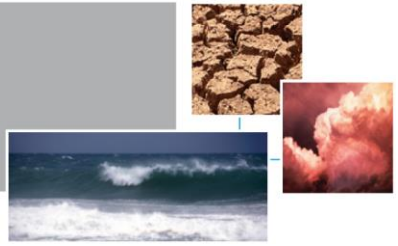


Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

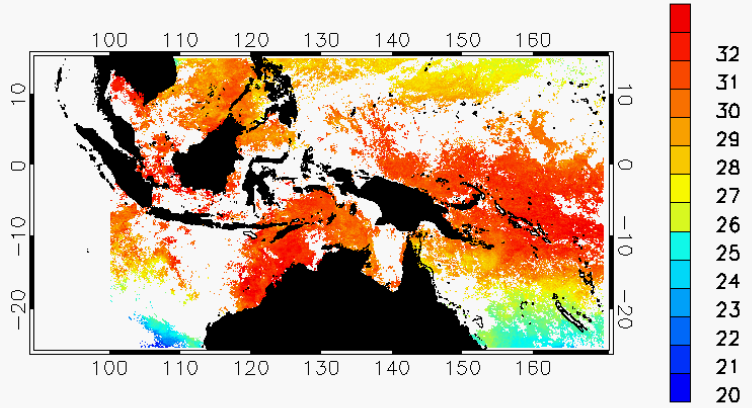
CSIRO

Daily “foundation” (pre-dawn) SST
26 Apr 2010

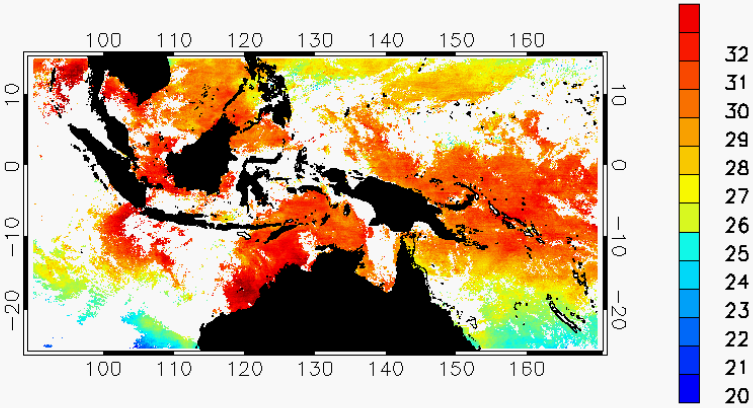


MTSAT-1R composite (10 pm – 5 am)

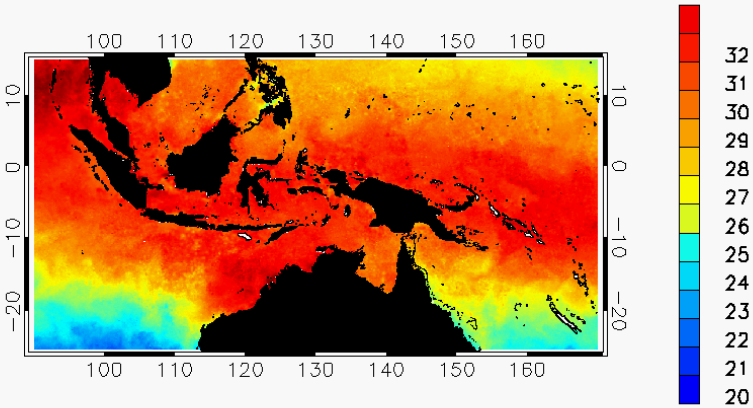
Old (pc = 5)



New (pc ≥ 3)

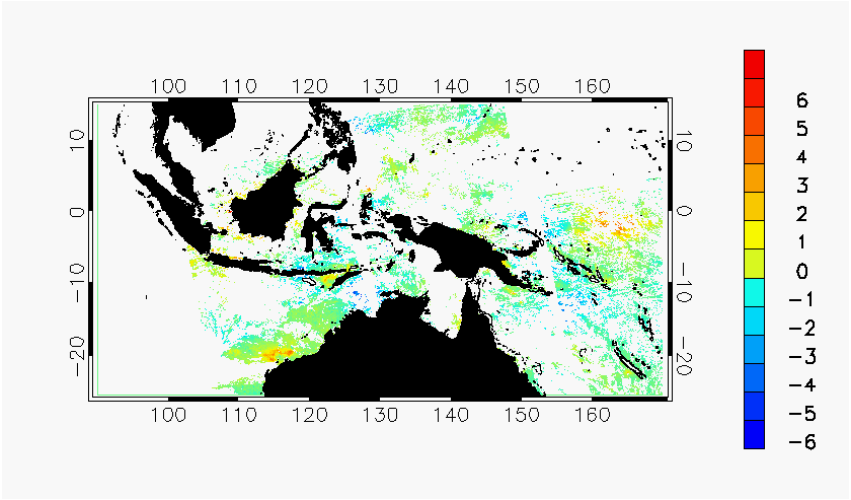


RAMSSA analysis

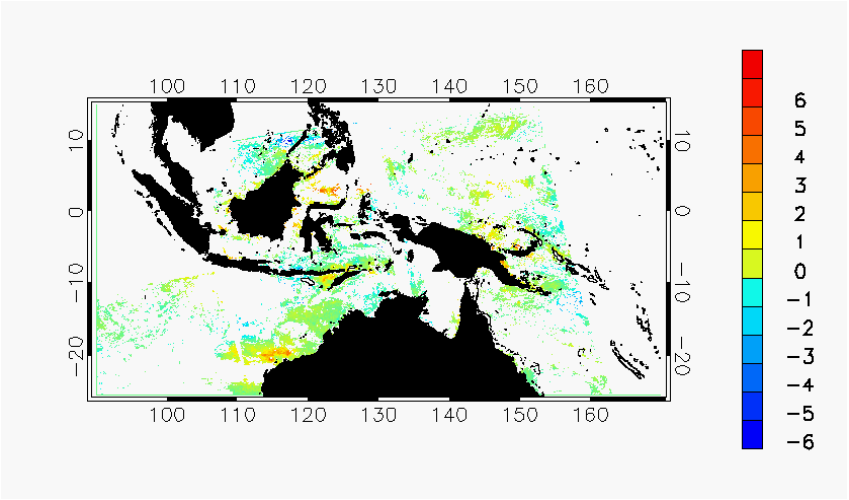


Satellite SST (day) – RAMSSA SSTfnd
26 Apr 2010

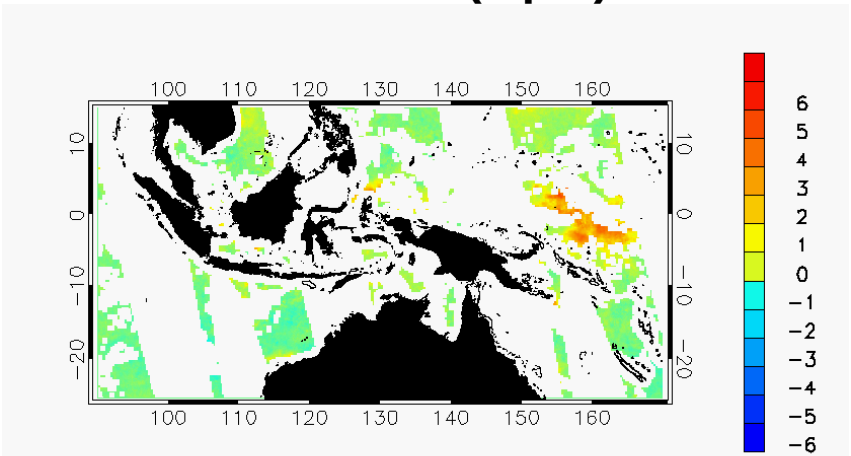
IMOS NOAA-18 (2 pm)



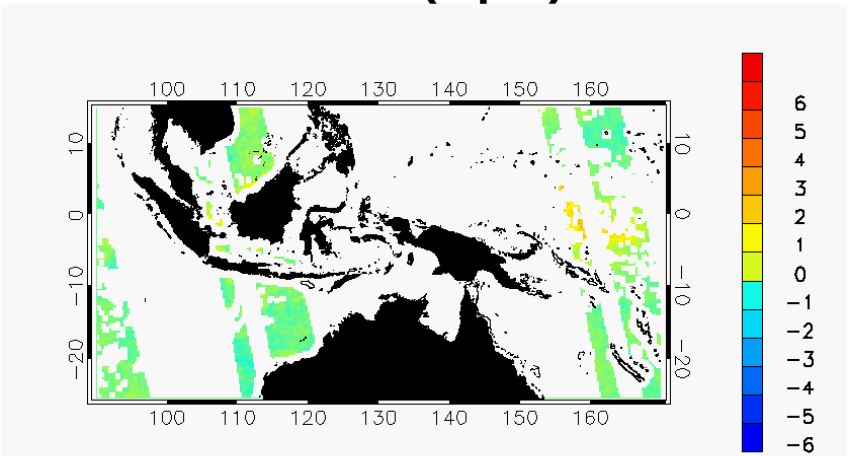
IMOS NOAA-19 (2 pm)



AMSR-E (2 pm)



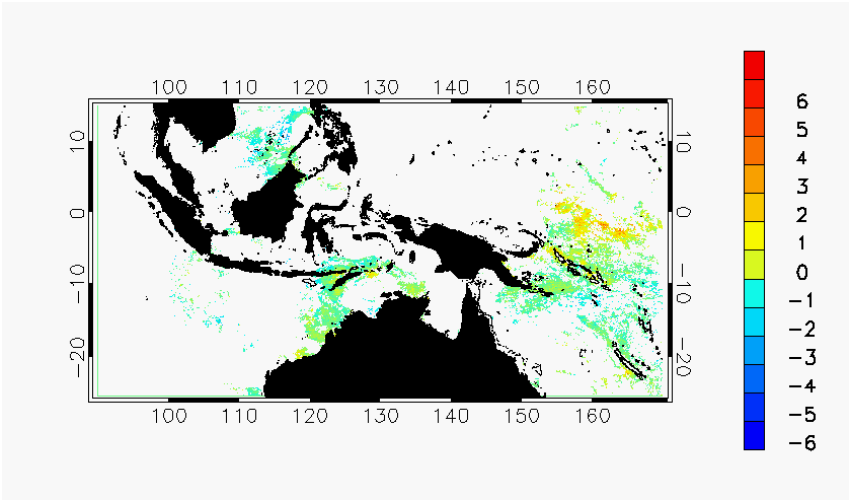
WindSat (6 pm)



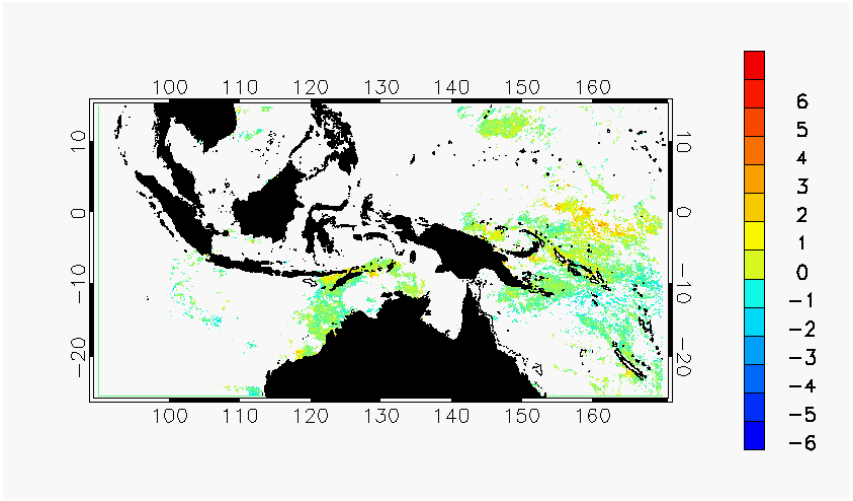
v2 MTSAT-1R SSTskin – old MTSAT-1R SSTfnd

26 Apr 2010 (PC = 5)

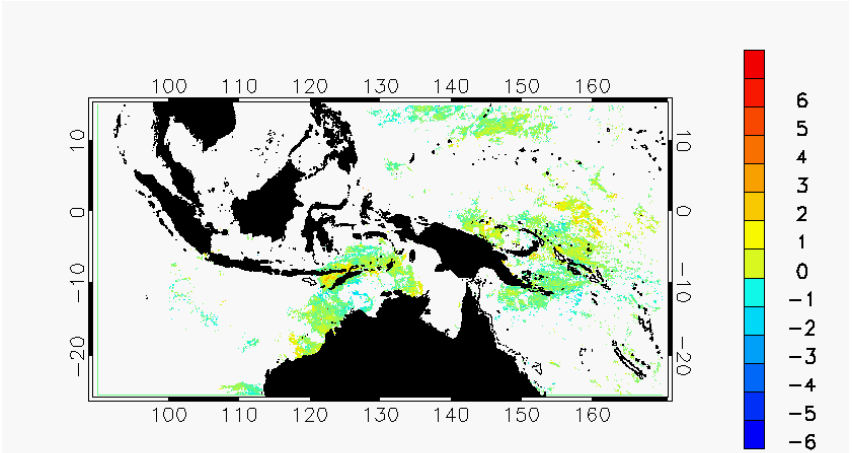
0200 UT



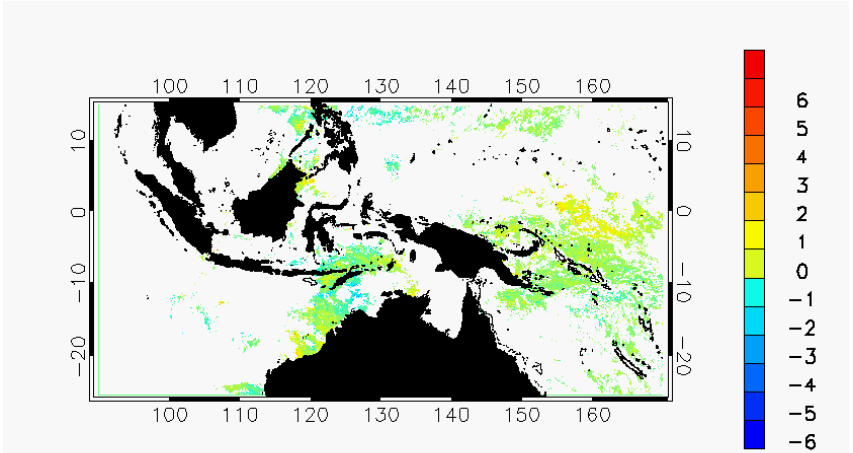
0400 UT



0600 UT



0800 UT



Australian Government
Bureau of Meteorology

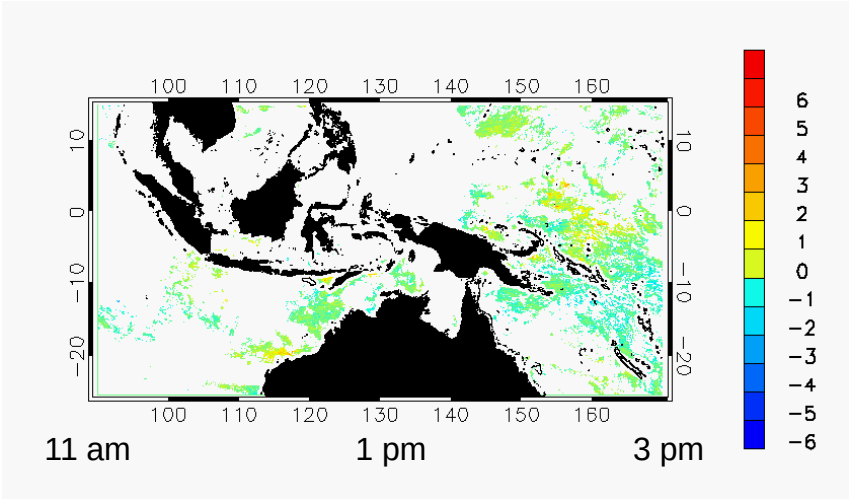
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

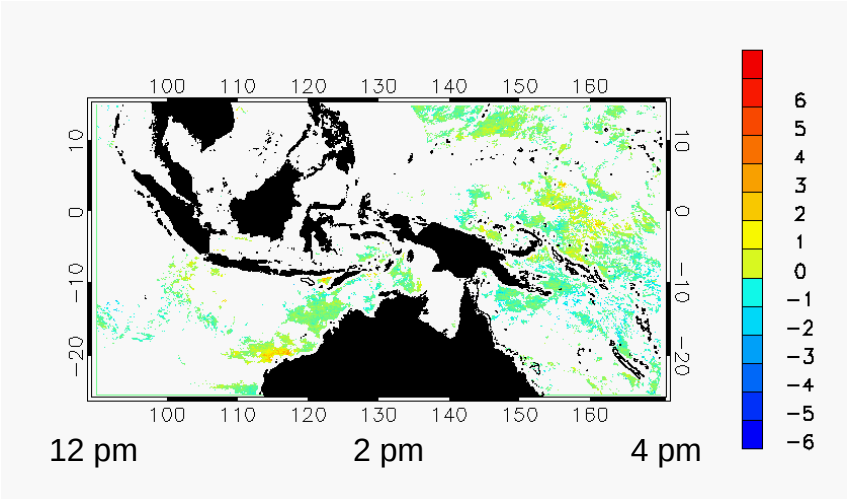
v3 MTSAT-1R SSTskin – RAMSSA SSTfnd

26 Apr 2010 (2 pm ± 2 hours)

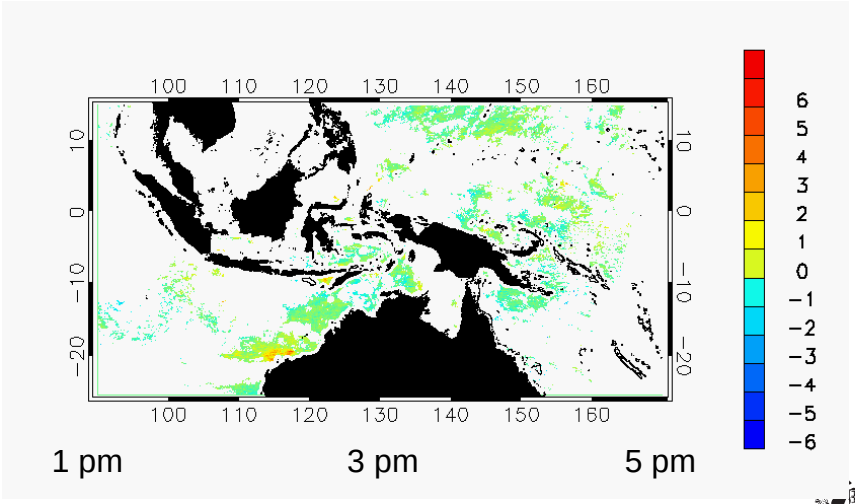
0400 UT



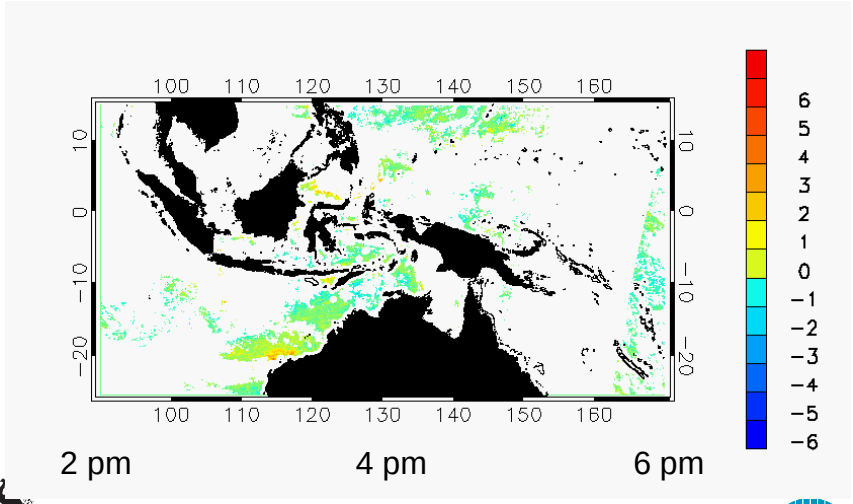
0500 UT



0600 UT



0700 UT



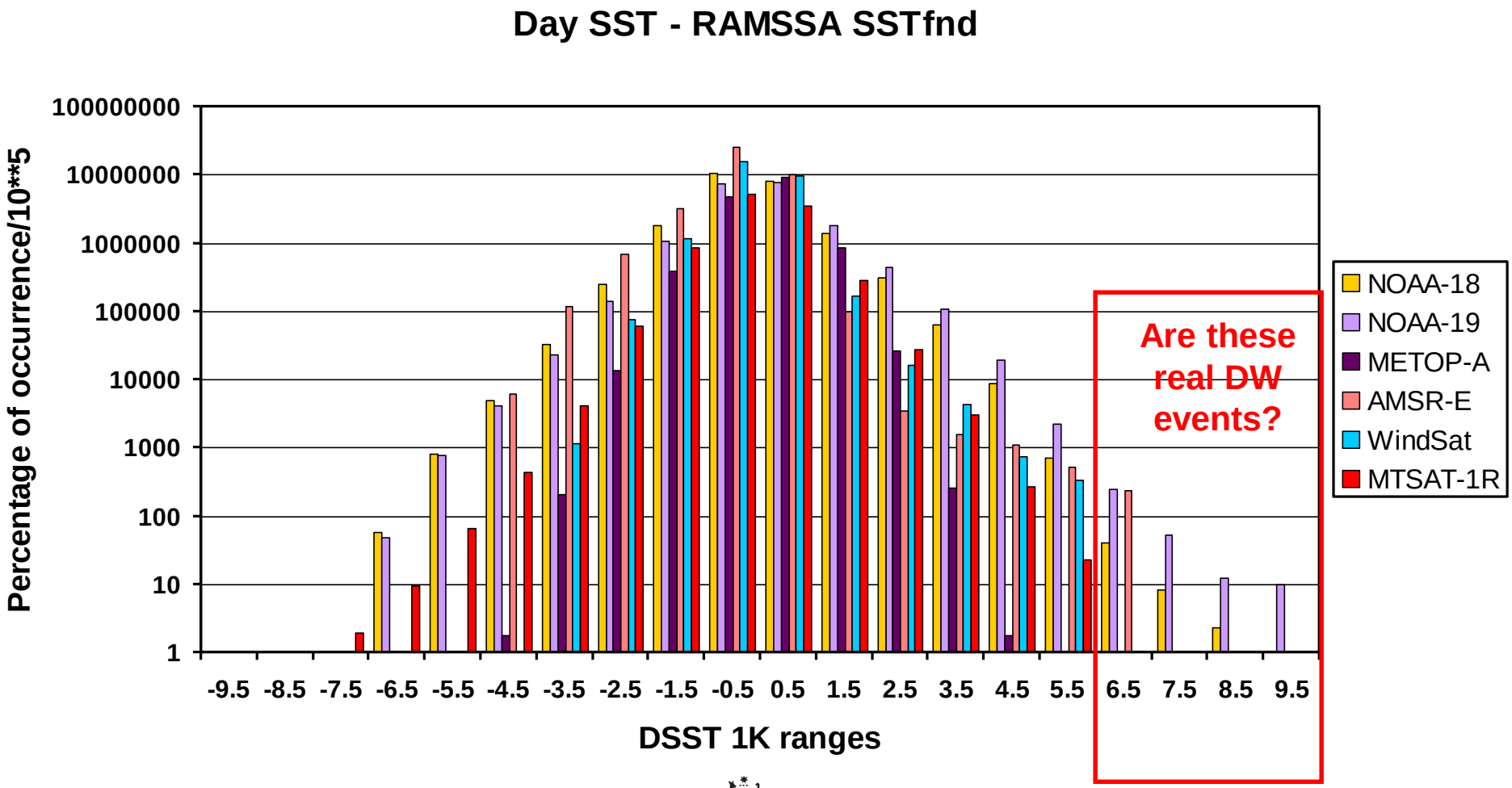
Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

Percentage occurrence of 1ºC ranges of Day SST – RAMSSA SSTfnd 1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

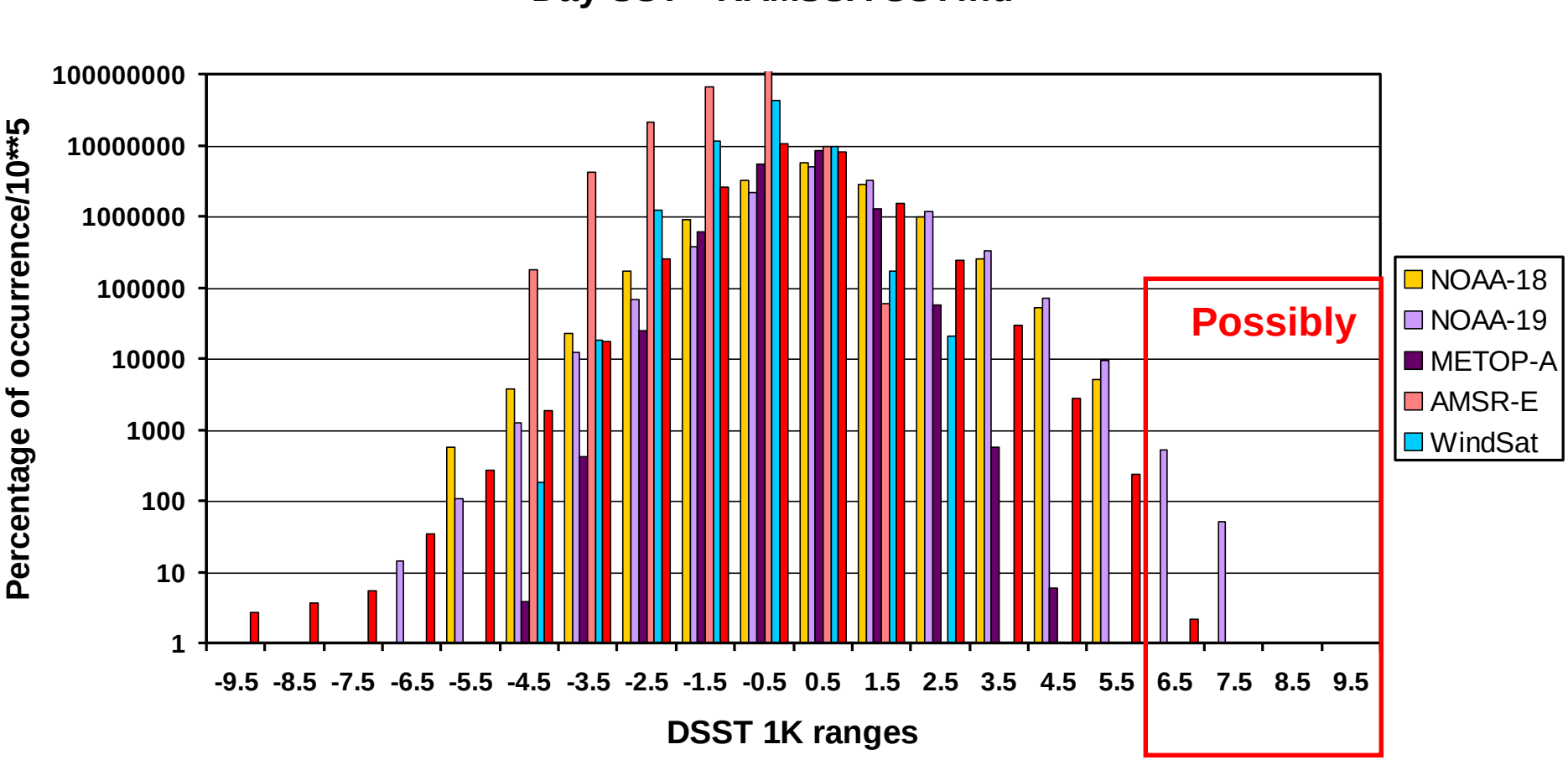
Expanding land mask by 0.5° x 0.5°



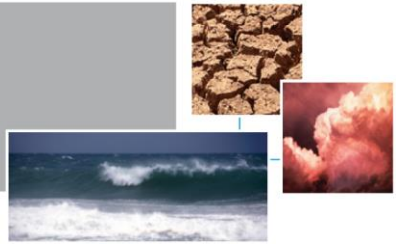
Percentage occurrence of 1ºC ranges of Day SST – RAMSSA SSTfnd 1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

Expanding land mask by 0.5° x 0.5°

Only include matchups for ACCESS-R Winds ≤ 3 m/s

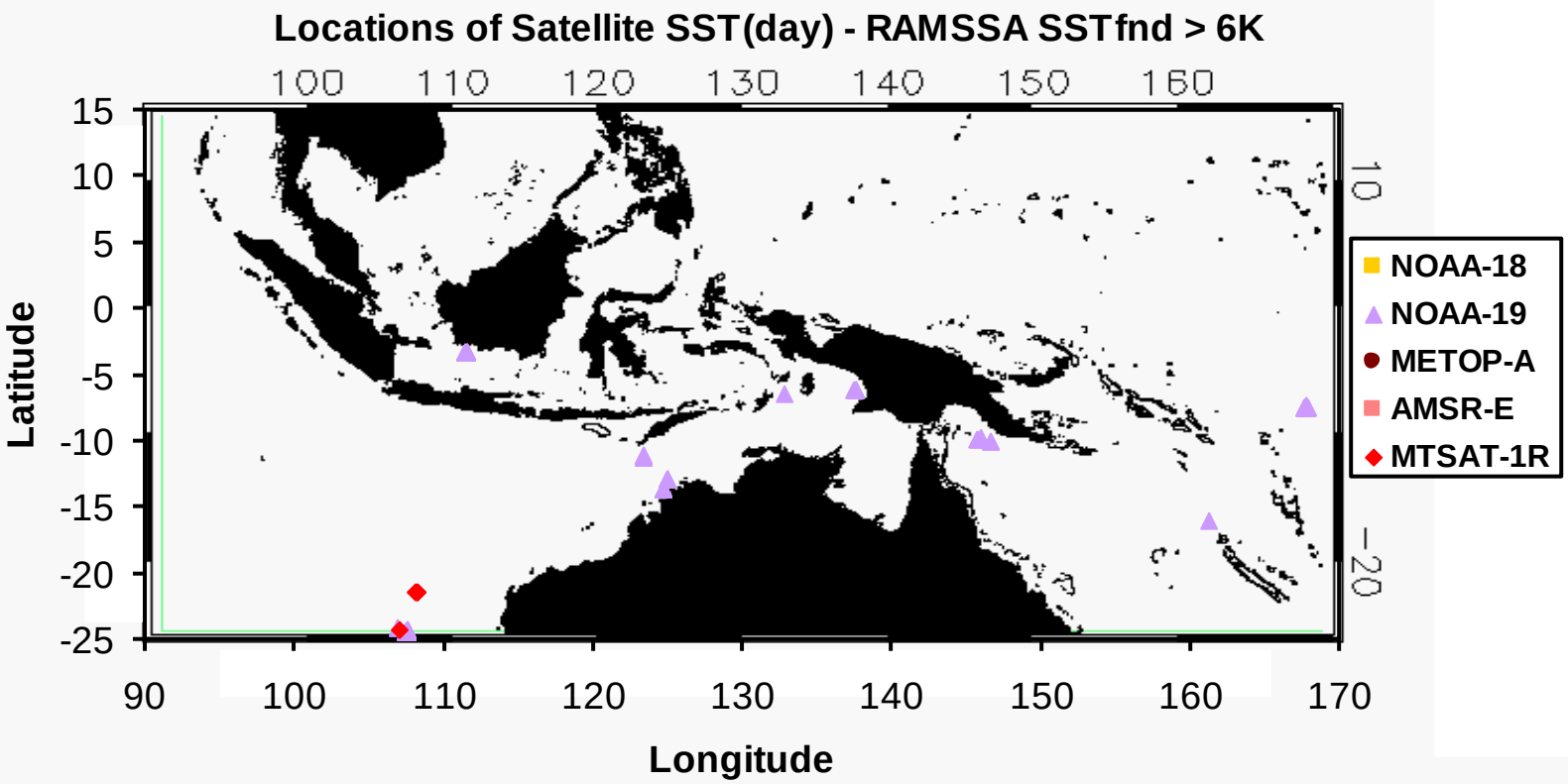


Locations of Day SST – RAMSSA SSTfnd > 6K
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



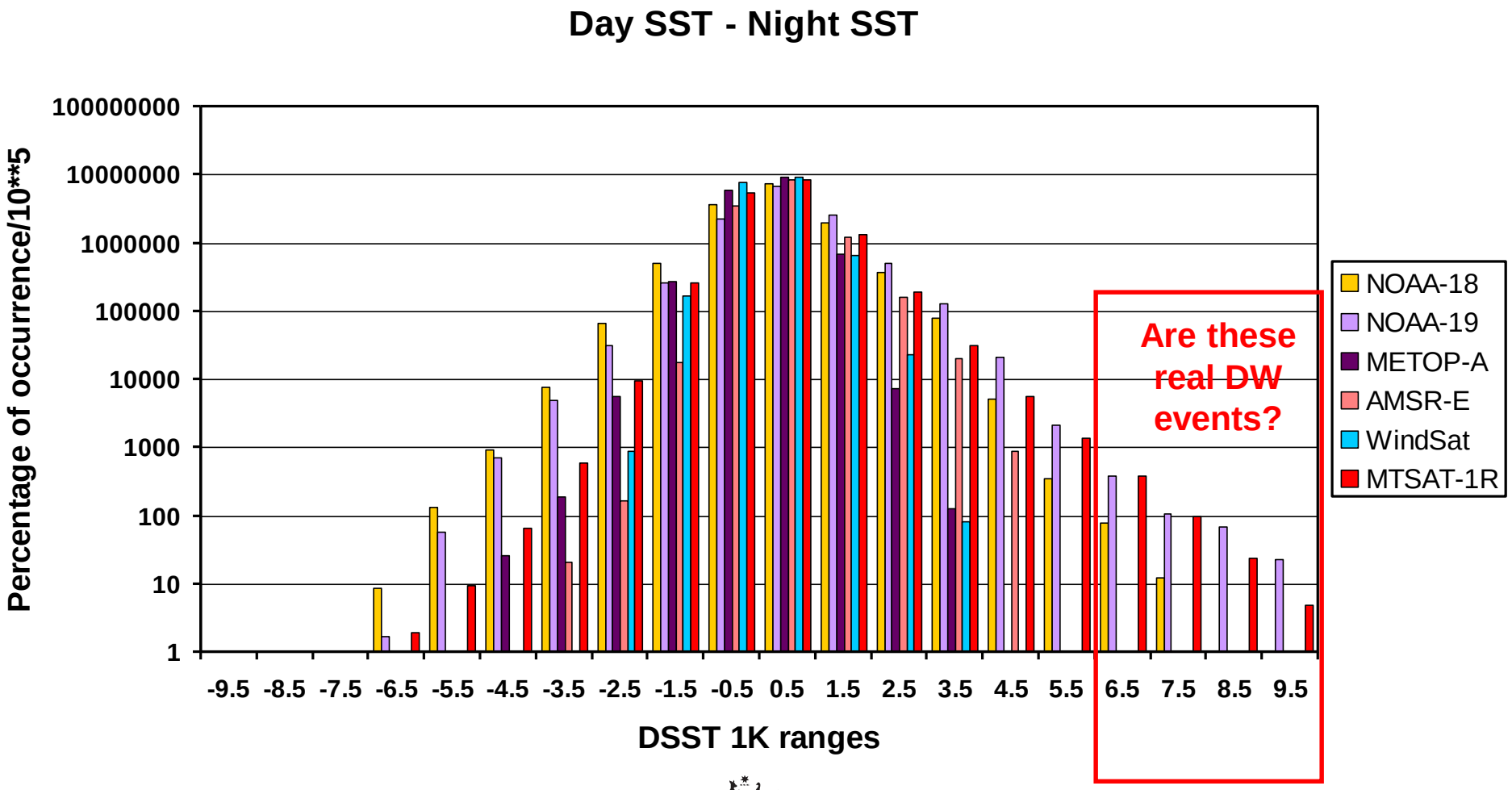
Expanding land mask by 0.5° x 0.5°

Only include matchups for ACCESS-R Winds ≤ 3 m/s



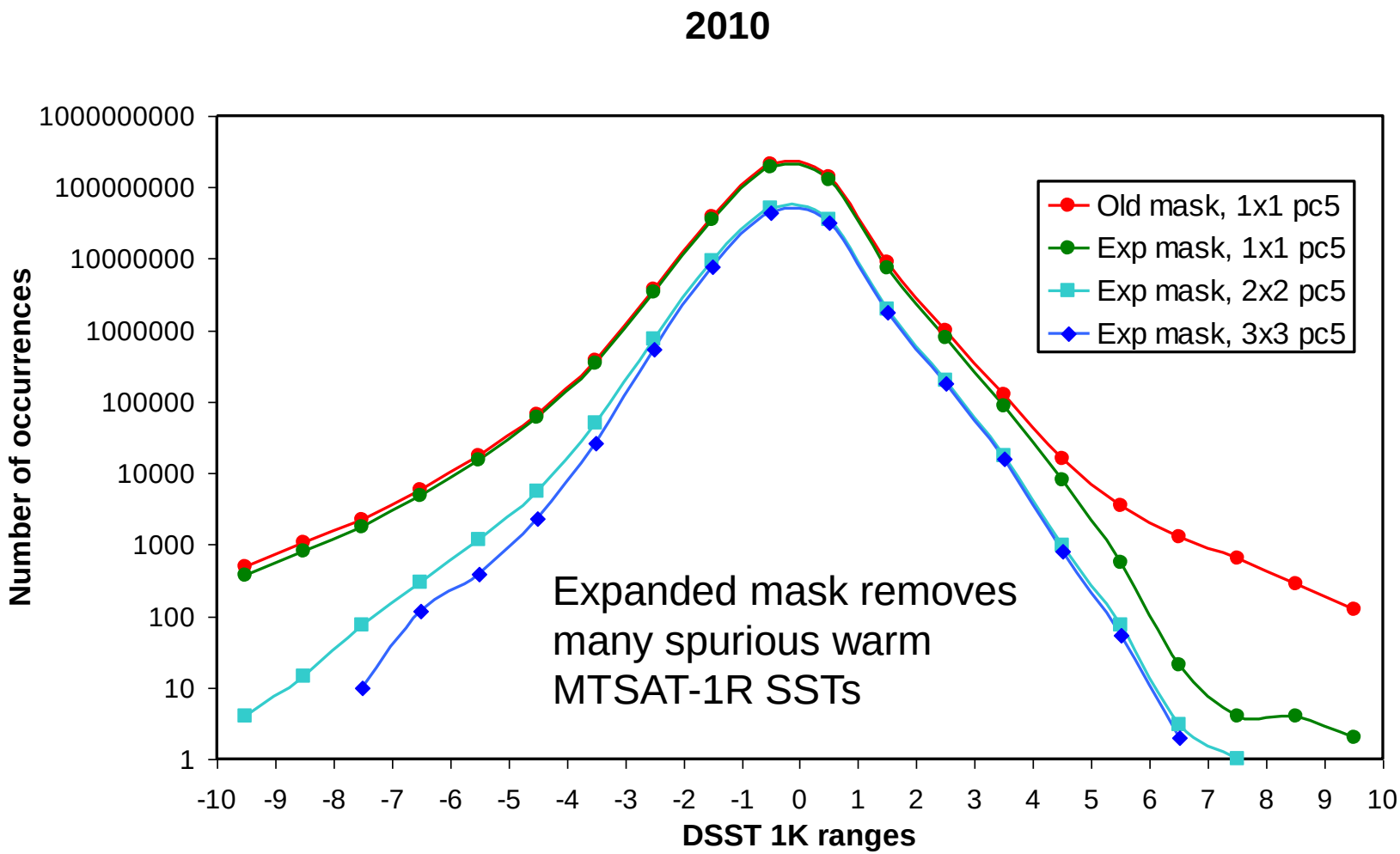
Percentage of occurrence of 1ºC ranges of Day SST – Night SST 1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)

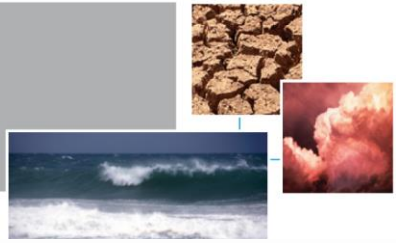


Number of 1ºC ranges of MTSAT-1R SSTskin – RAMSSA SSTfnd 1 Jan – 30 Apr 2010

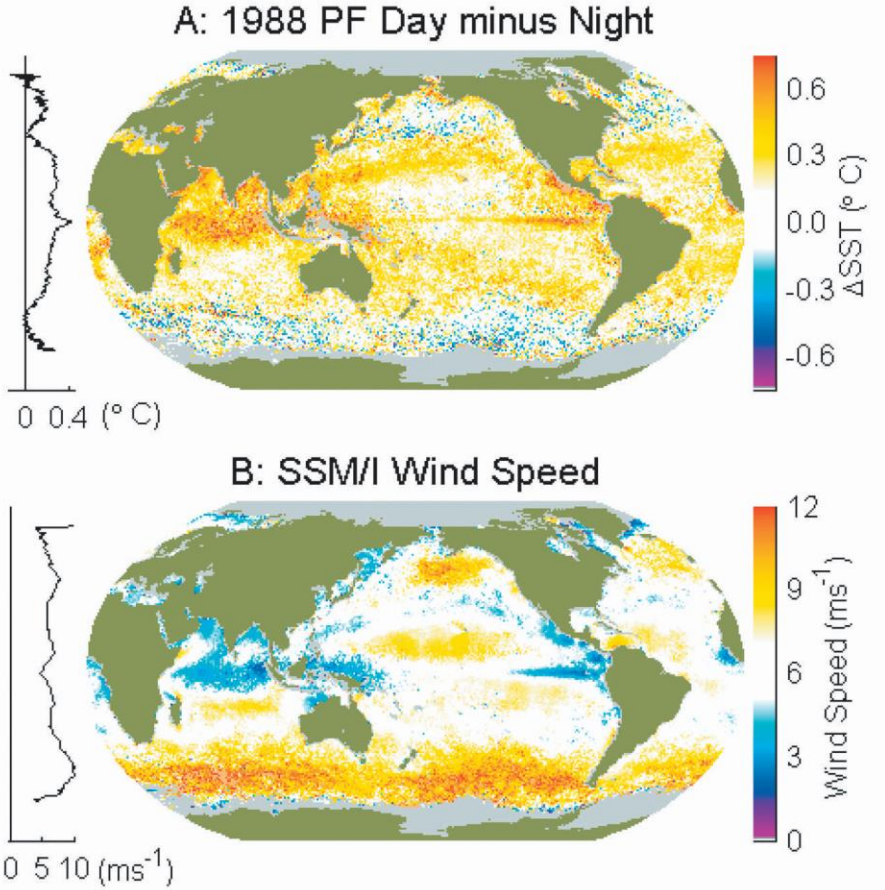
With and without expanded 9x9 land mask and 2x2 or 3x3 pixel filtering



Why study diurnal warming over Tropical Warm Pool?



- "Tropical Warm Pool" has highest SST over largest expanse of Earth's surface
- Important for Australian weather and climate
  - Heavy rain
  - Strong atmospheric heating
  - Weak mean winds
- Suspected high diurnal warming over TWP from satellite and in situ observations and models but not fully quantified

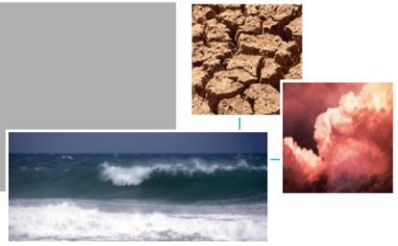


Gentemann et al. (2003) Geophy Res Let, Fig 4

Top: 1998 Pathfinder Day – Night SST

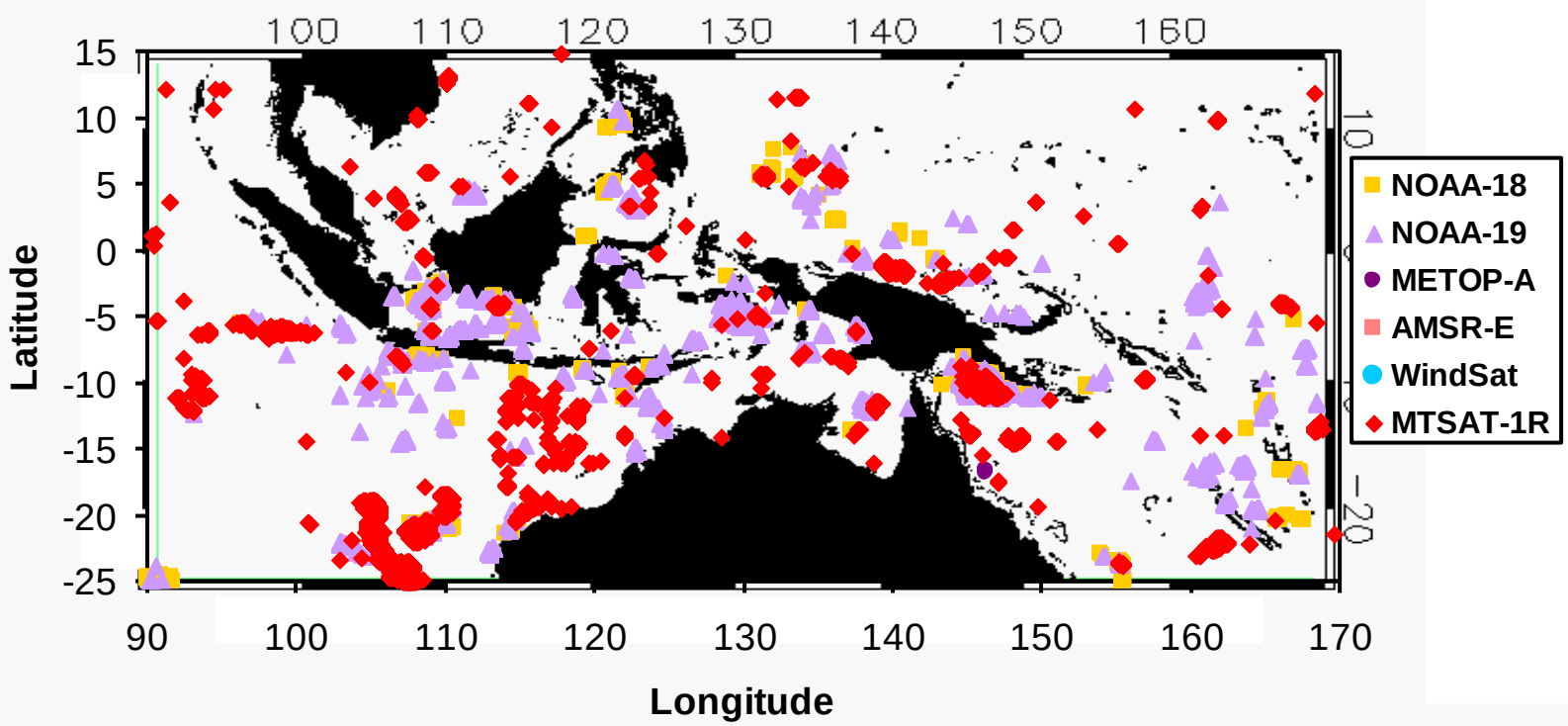
Bottom: SSM/I Wind Speed

Locations of Day SST – RAMSSA SSTfnd > 4K and < 6K
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

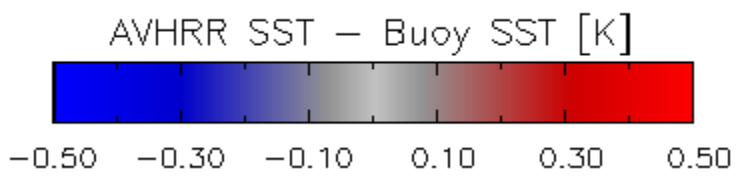


Expanding land mask by 0.5° x 0.5°

Only include matchups for Winds ≤ 3 m/s



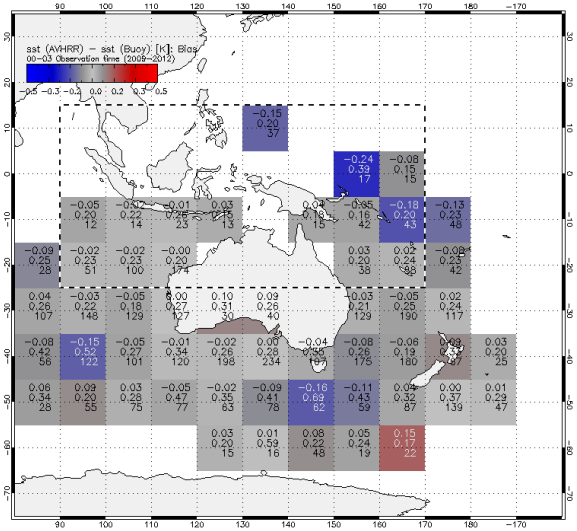
Spatial Bias Patterns/Issues AVHRR (BoM2011 algorithms)

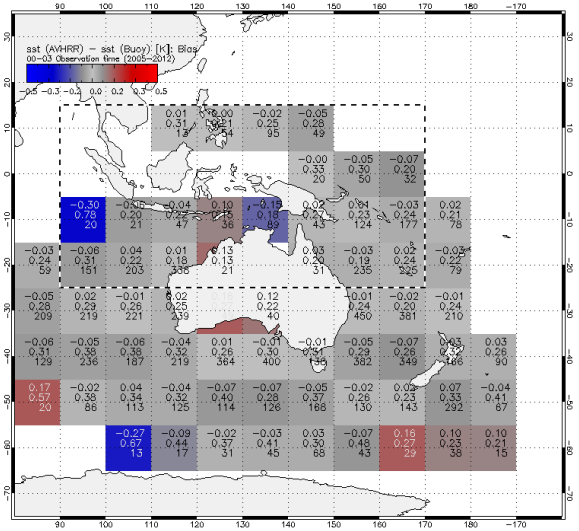


Night

← N19

N18 →

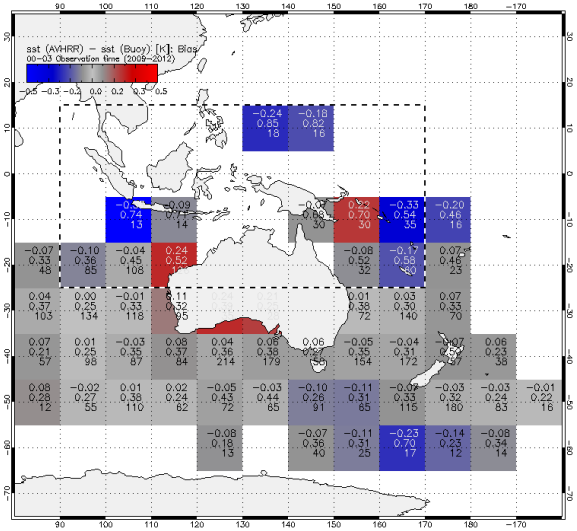


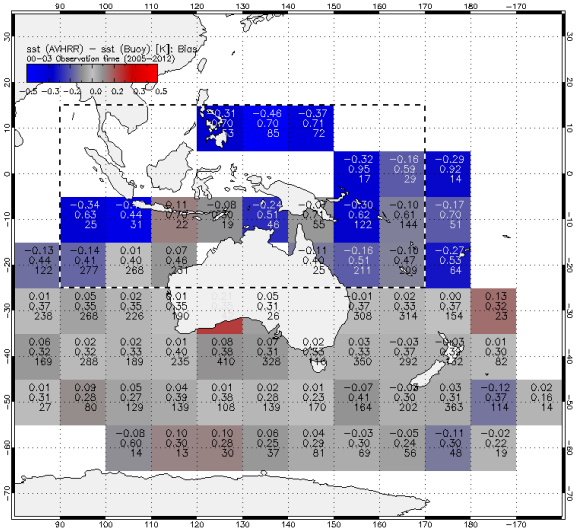


Day

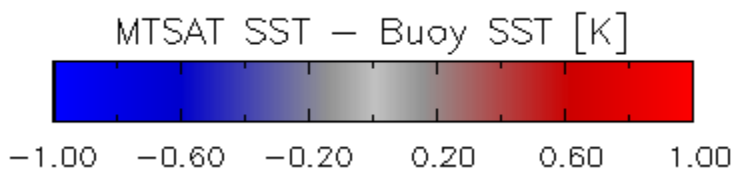
← N19

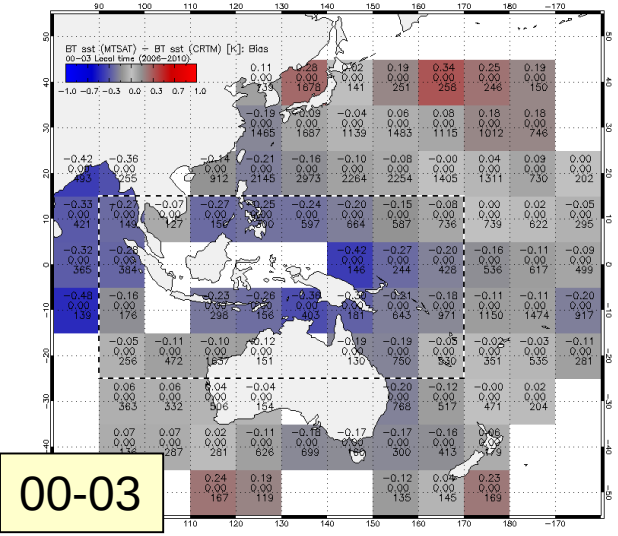
N18 →



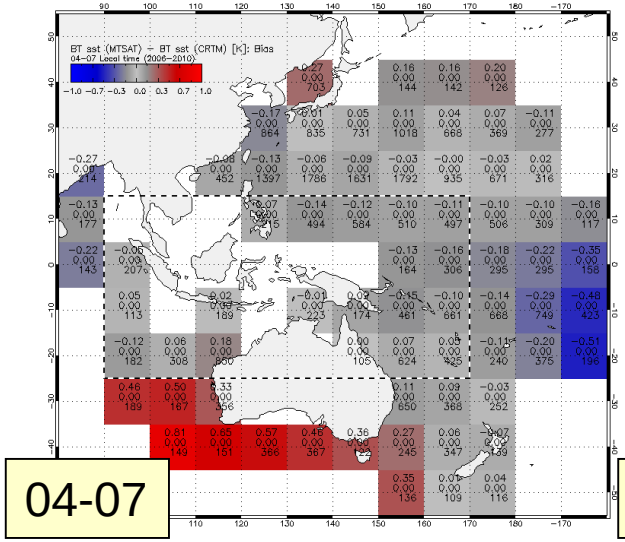


Spatial Bias Patterns/Issues
MTSAT

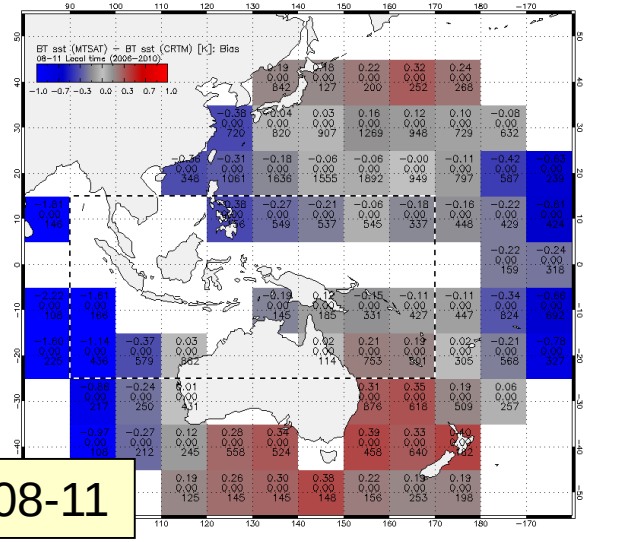




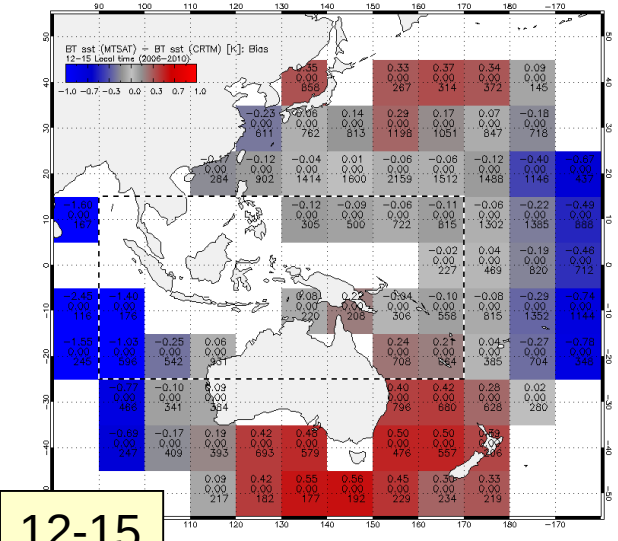
00-03



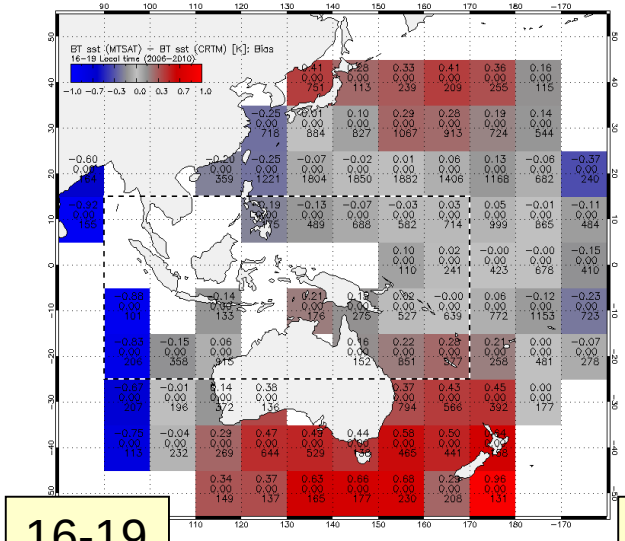
04-07



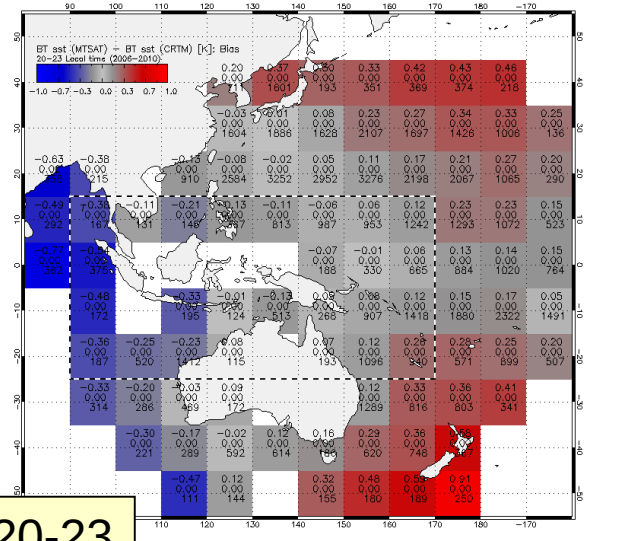
08-11



12-15

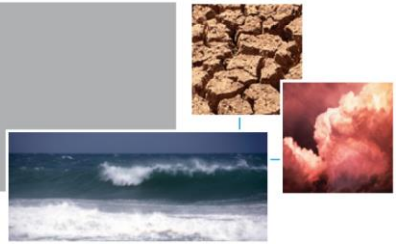


16-19

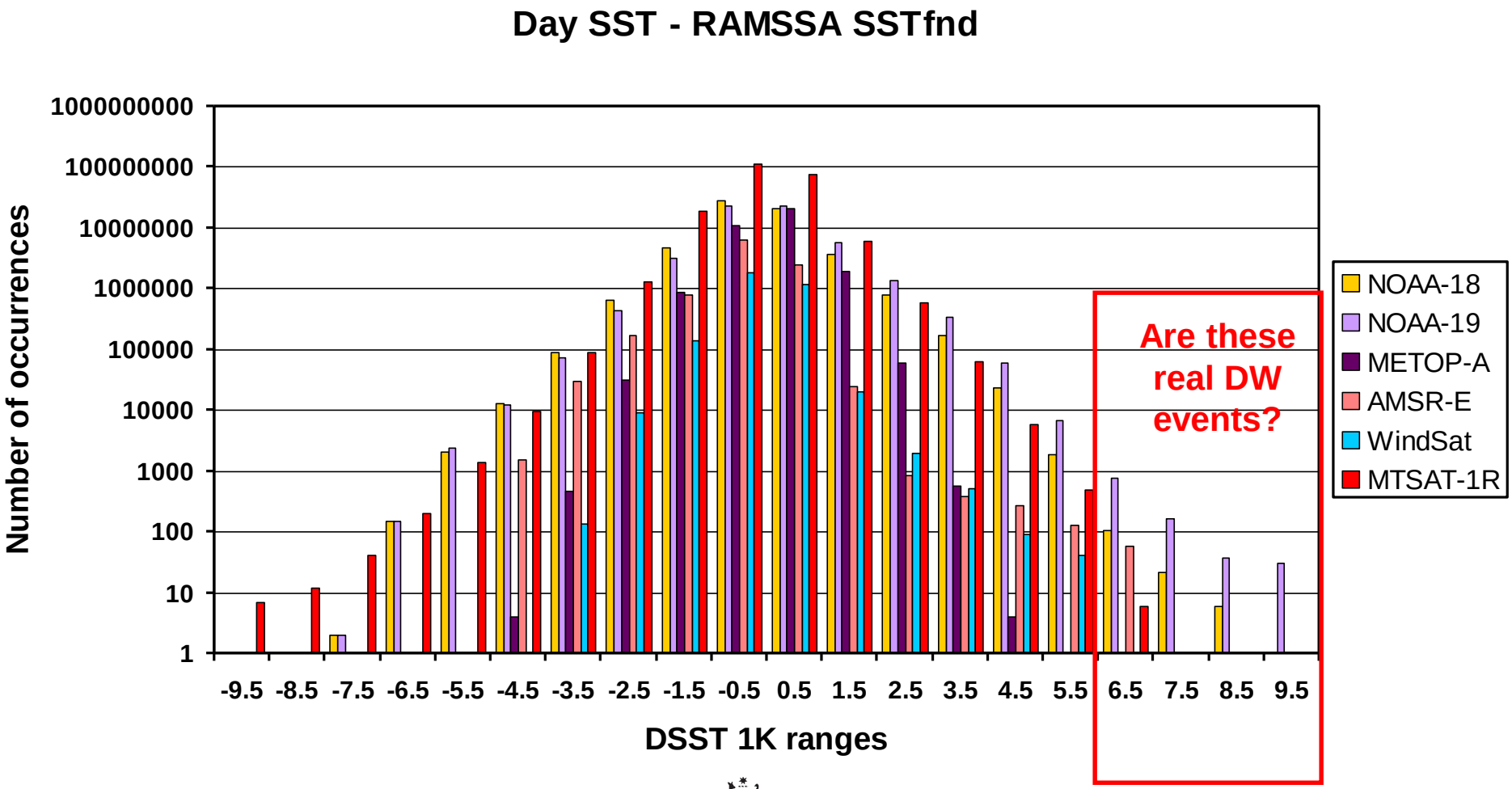


20-23

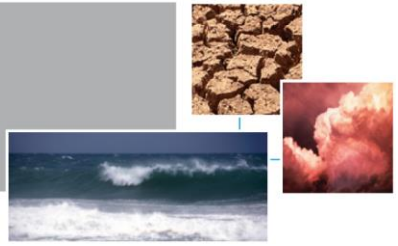
Number of 1ºC ranges of Day SST – RAMSSA SSTfnd
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



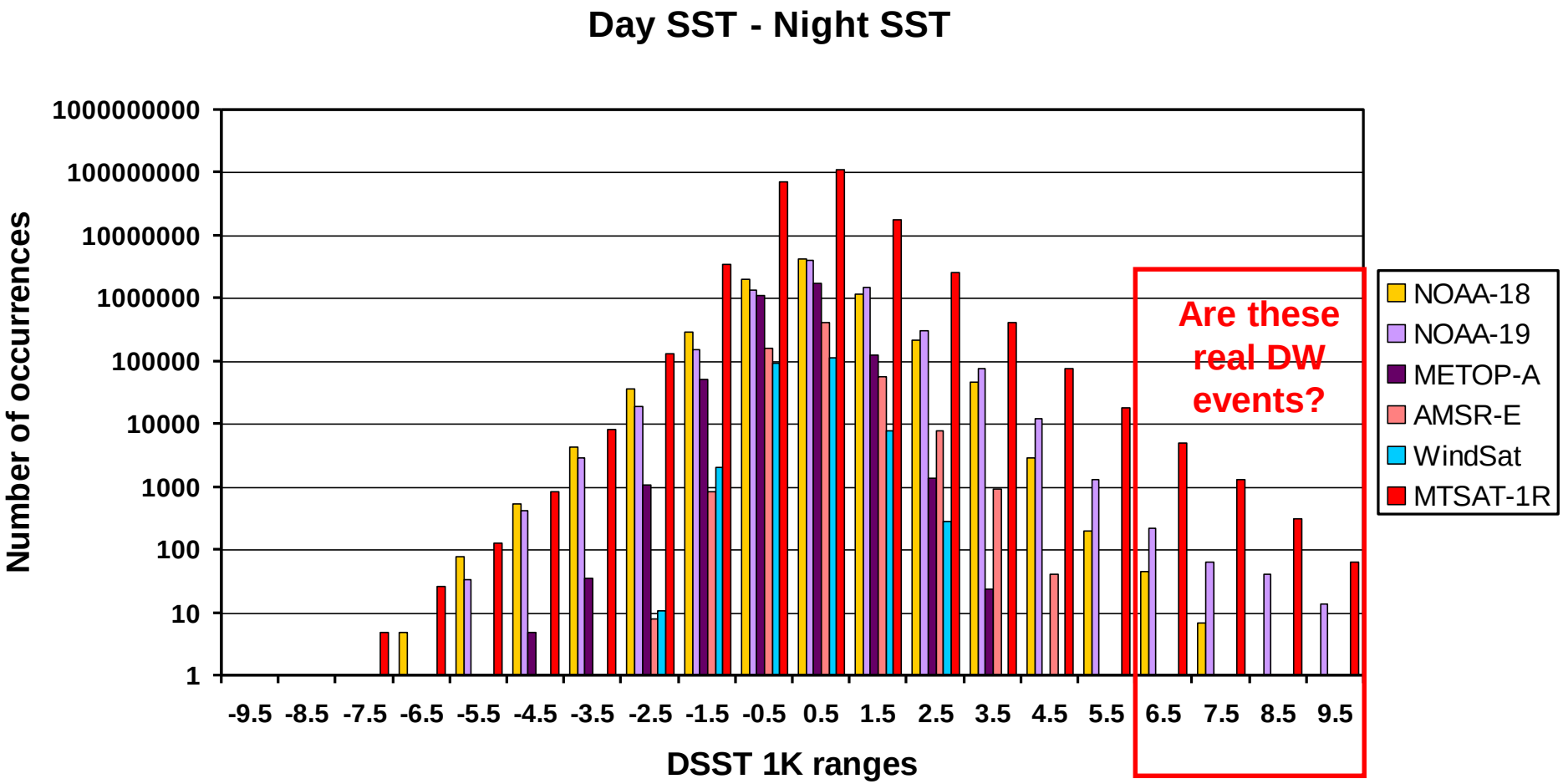
Expanding land mask by 0.5° x 0.5°



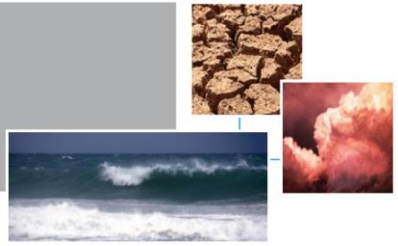
Number of 1ºC ranges of Day SST – Night SST
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



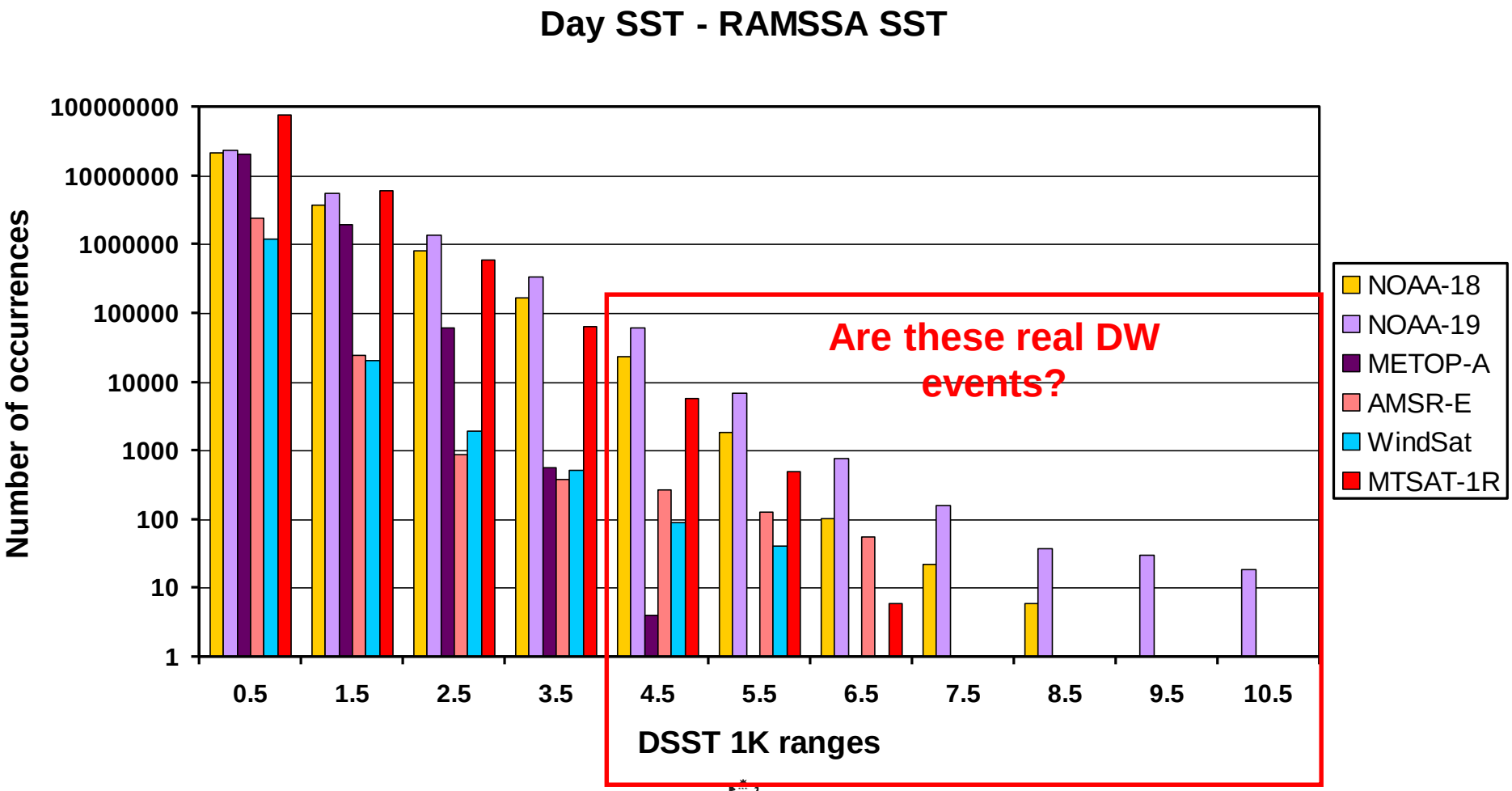
Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)



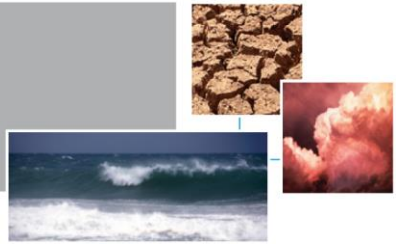
Number of 1ºC ranges of Day SST – RAMSSA SSTfnd
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5°

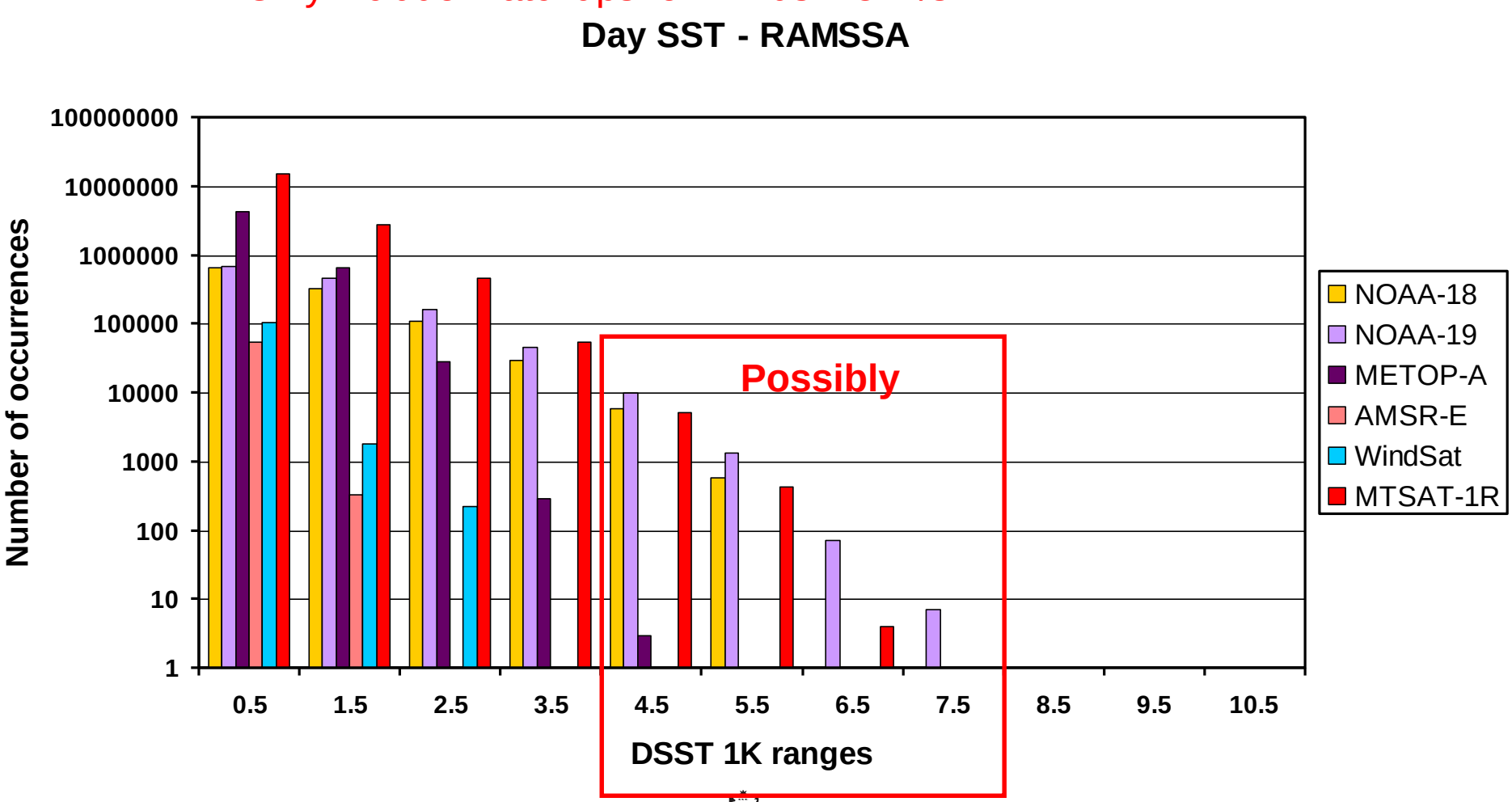


Number of 1ºC ranges of Day SST – RAMSSA SSTfnd
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)

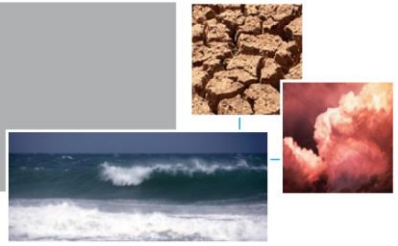


Expanding land mask by 0.5° x 0.5°

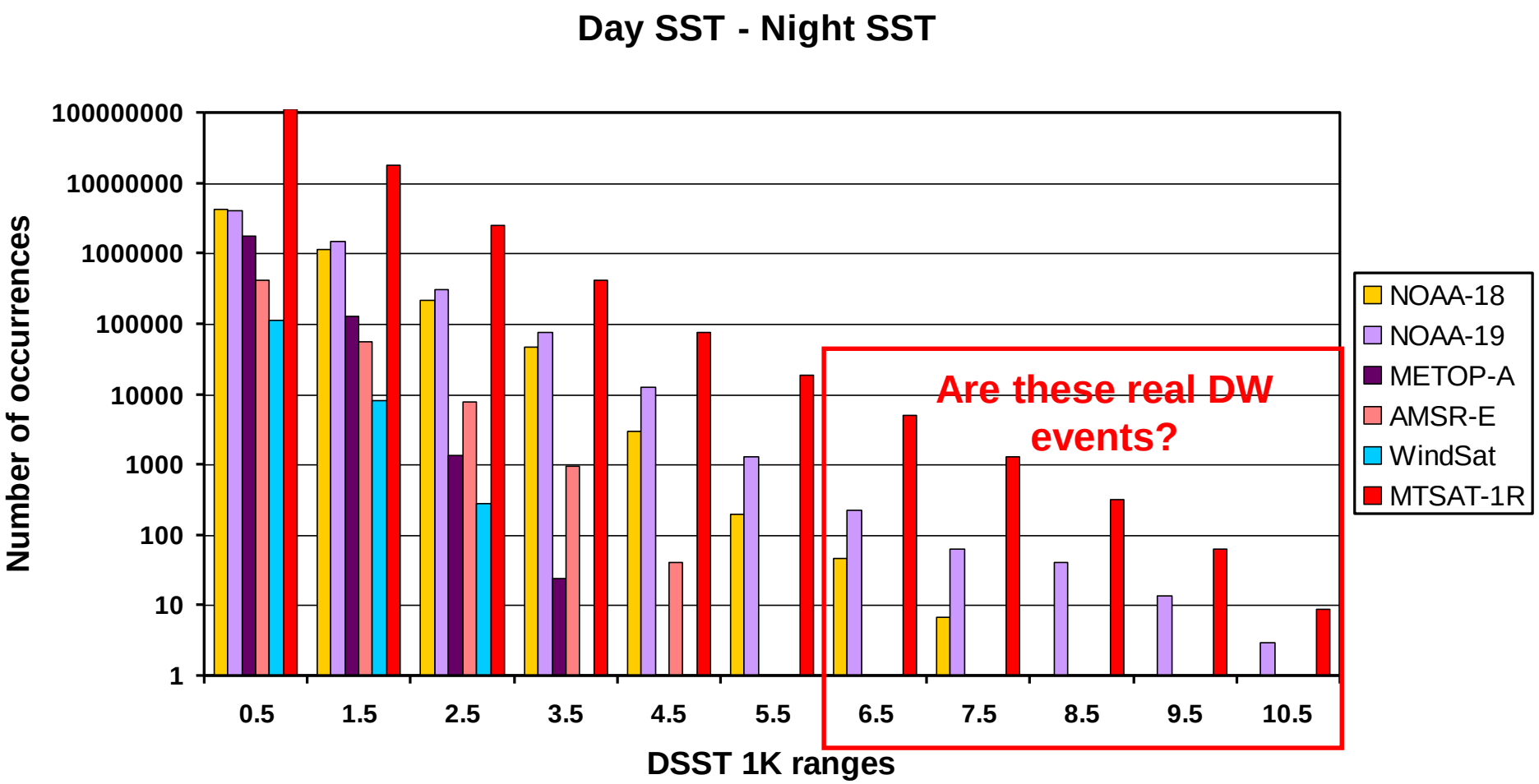
Only include matchups for Winds ≤ 3 m/s



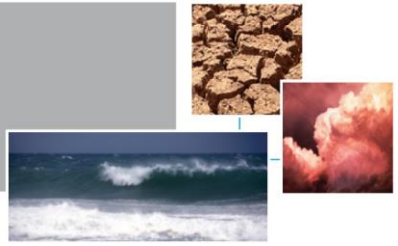
Number of 1ºC ranges of Day SST – Night SST
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)



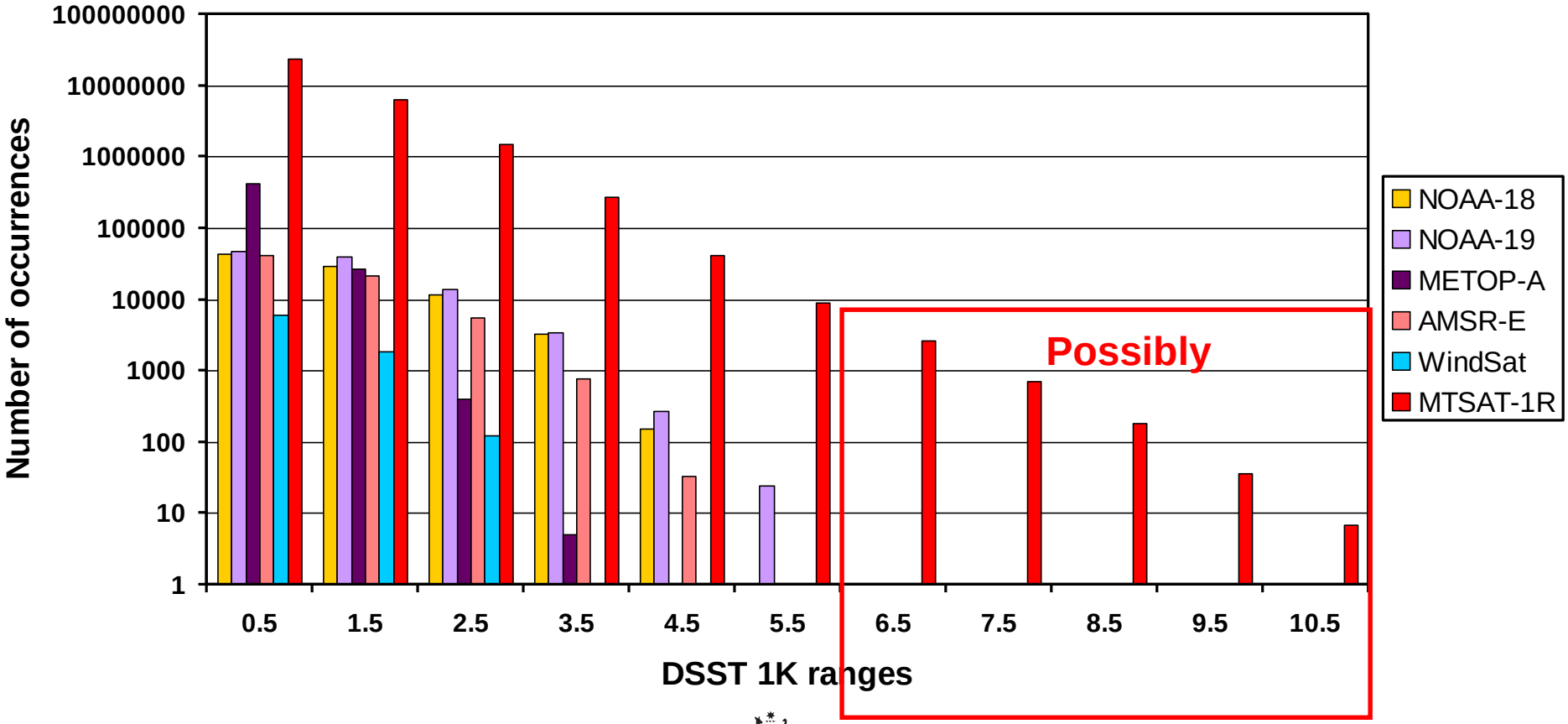
Number of 1ºC ranges of Day SST – Night SST
1 Jan – 30 Apr 2010 (Filtered for 2 x 2 good SSTs)



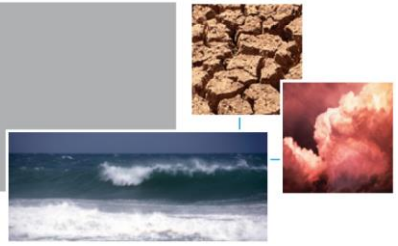
Expanding land mask by 0.5° x 0.5° (10 km for MTSAT)

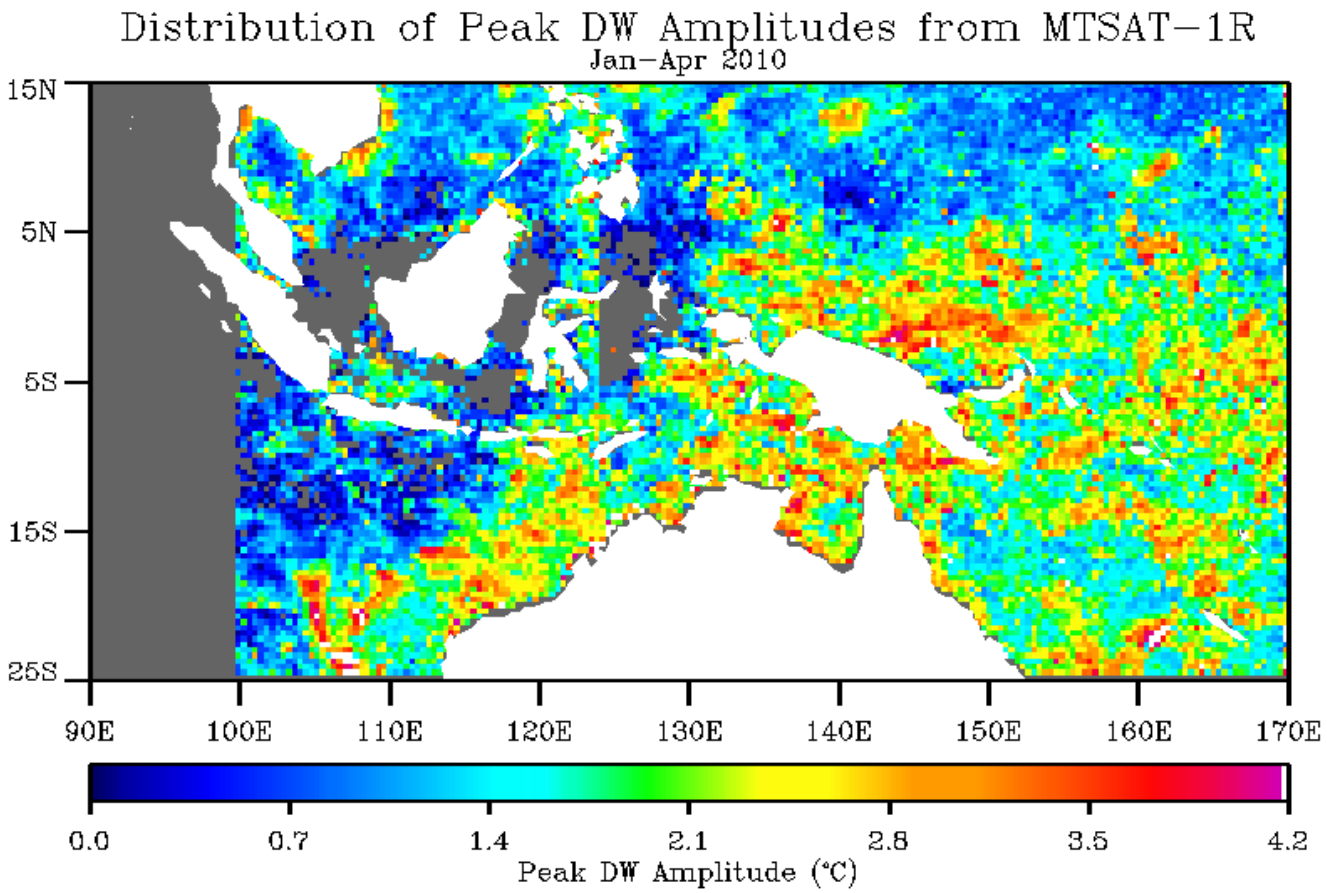
Only include matchups for Winds ≤ 3 m/s

Day SST - Night SST



Peak DW Amplitudes from MTSAT-1R
Jan-Apr 2010



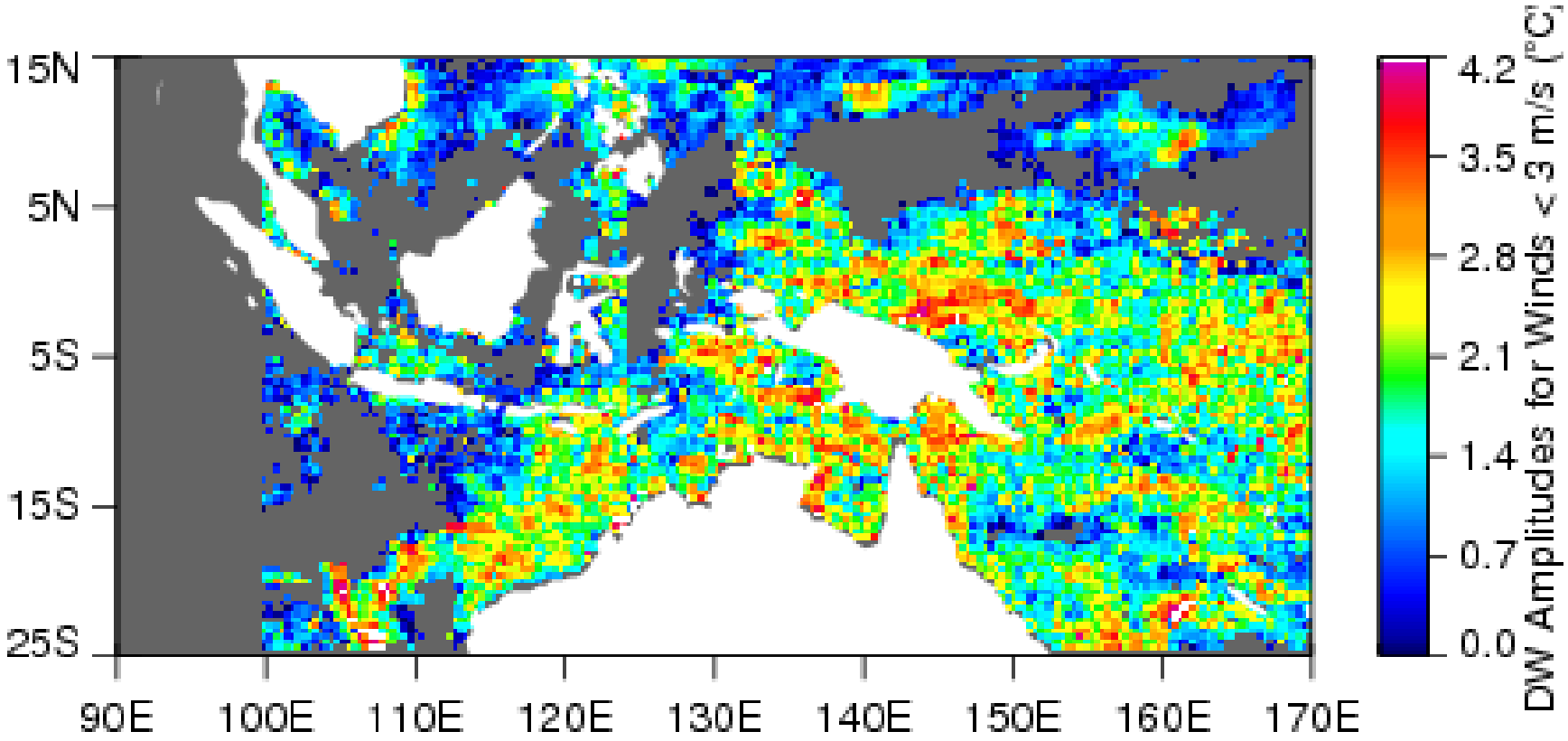


Peak (MTSAT-1R SSTskin – MTSAT-1R SSTfnd) up to ~4°C

Castro et al. (2012) Poster presented at 2012 Ocean Sciences Meeting

IMOS MTSAT-1R Peak Diurnal Warming Amplitudes Jan – Apr 2010

Regridded to 0.375° x 0.375°

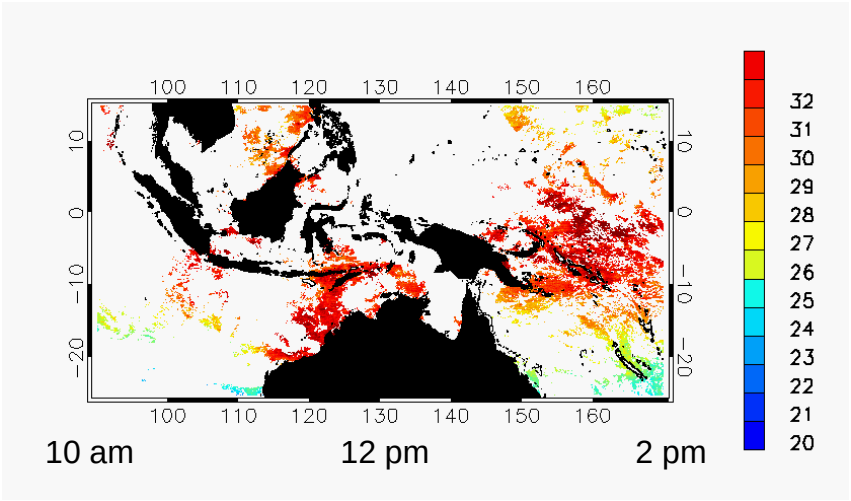


- Observed MTSAT-1R amplitudes of ~4ºC not uncommon from Jan-Apr 2010
- Homogeneously distributed across TWP+ domain

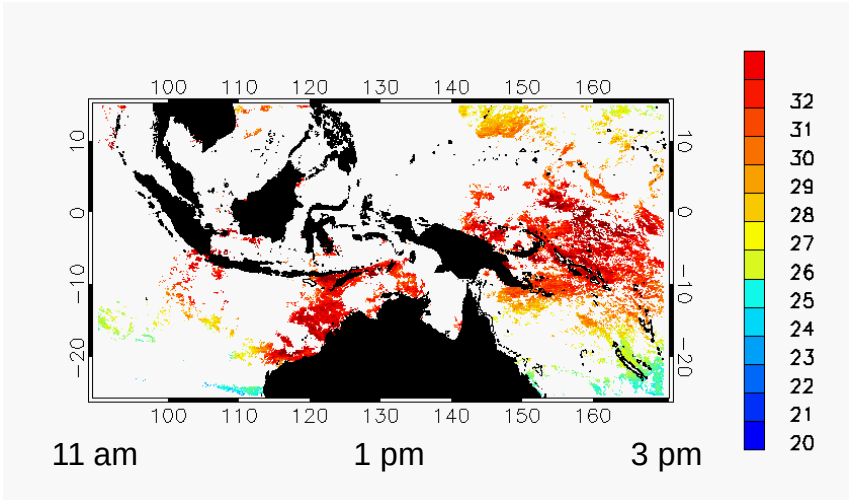
Geostationary MTSAT-1R hourly SST

26 Apr 2010 (2 pm ± 2 hours)

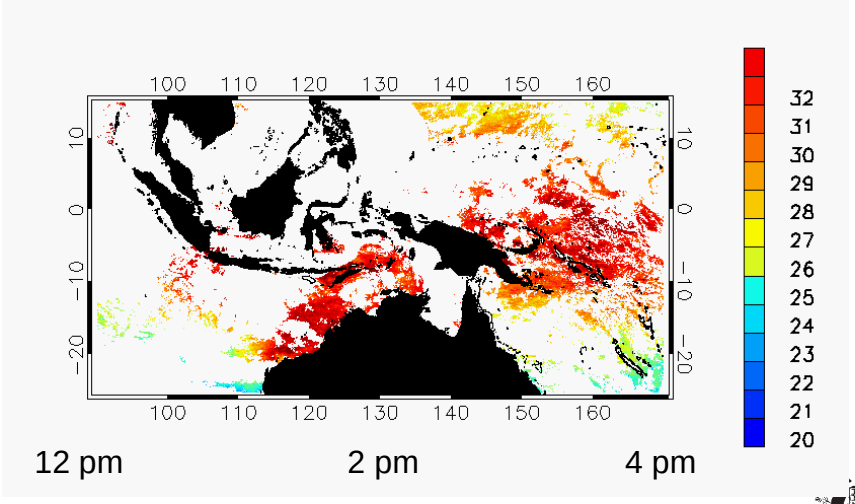
0300 UT



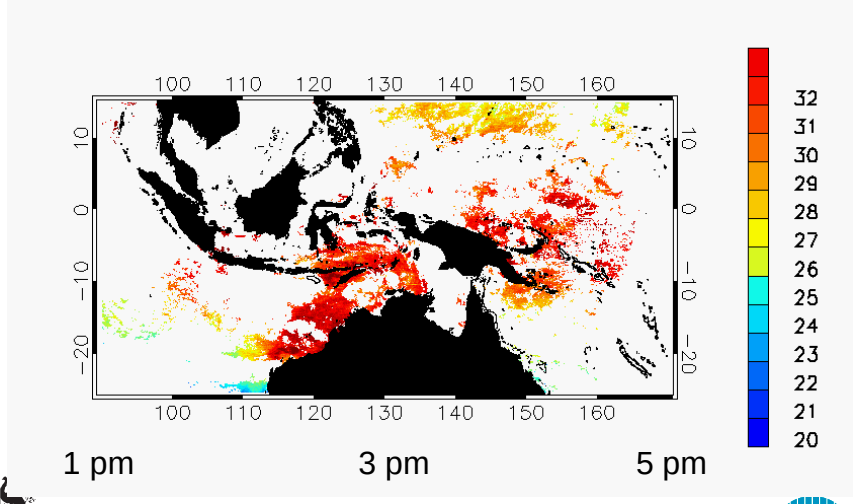
0400 UT



0500 UT



0600 UT



Australian Government
Bureau of Meteorology

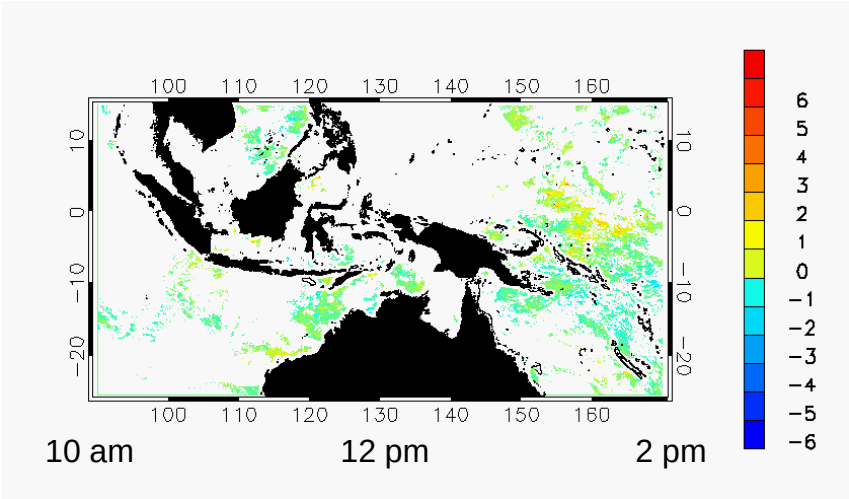
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

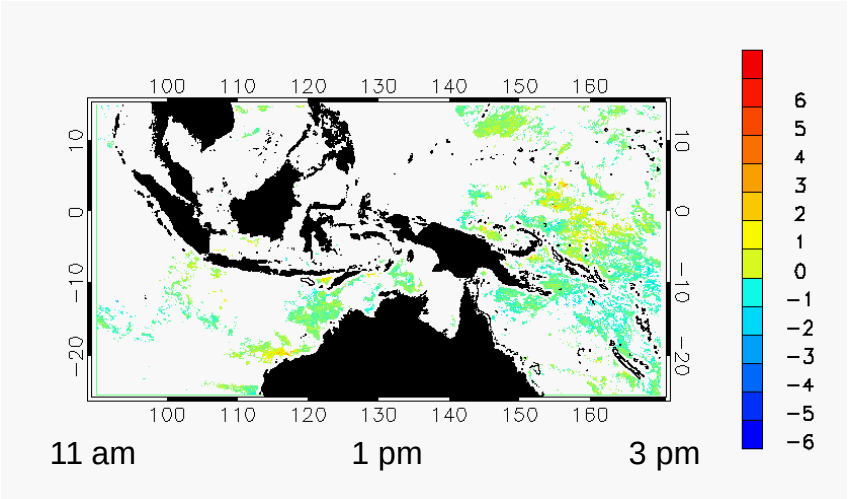
MTSAT-1R SSTskin – RAMSSA SSTfnd

26 Apr 2010 (2 pm ± 2 hours)

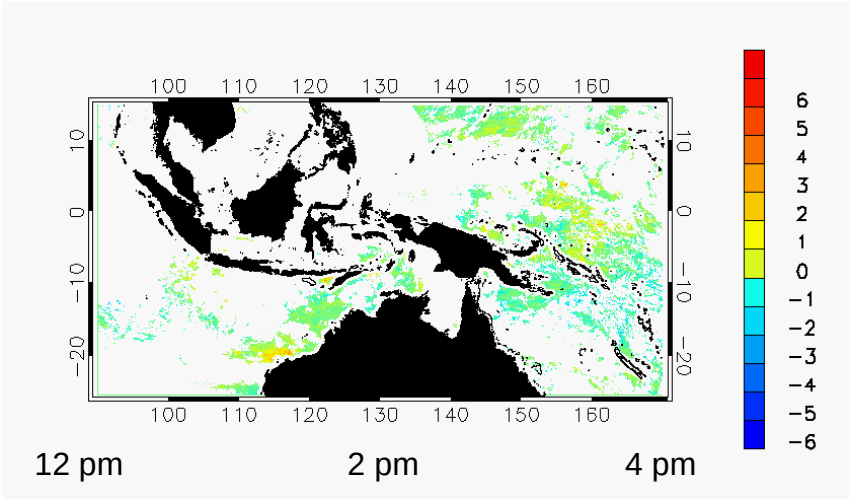
0300 UT



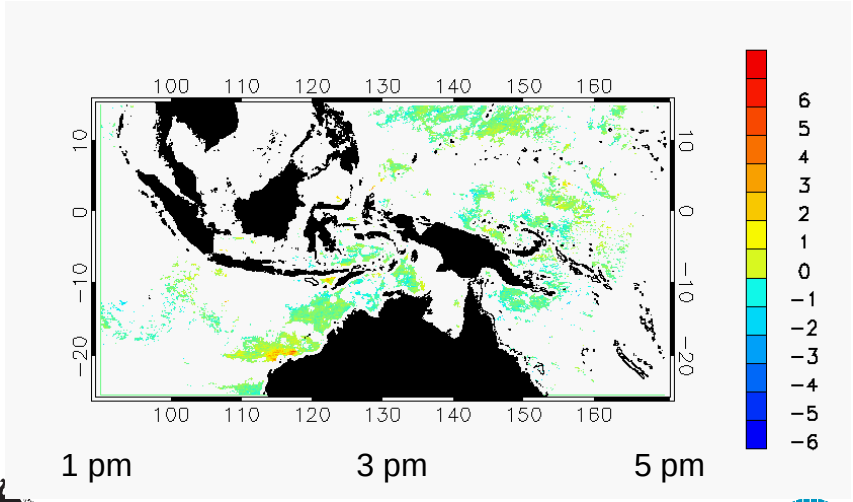
0400 UT



0500 UT



0600 UT

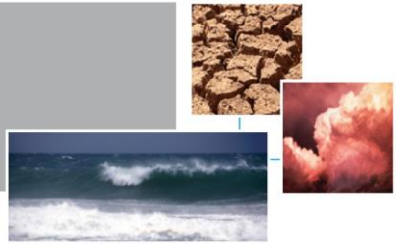


Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

MTSAT-1R Validation



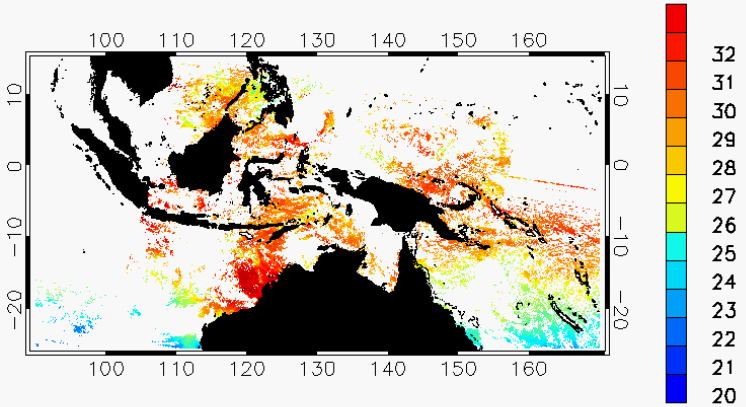
- **Product validation using drifting buoys (2006-2010)**
  - Period: 15 July 2006 – June 2010
  - Region: 60°S – 60°N, 100°E-160°W
  - Night: Bias: -0.068°C, St. Dev: 0.49°C (N=96572)
  - Day: Bias: -0.21°C, St. Dev: 0.85°C (N=56981)

- **Three-way Comparison (AVHRR, Buoy, MTSAT-1R)**

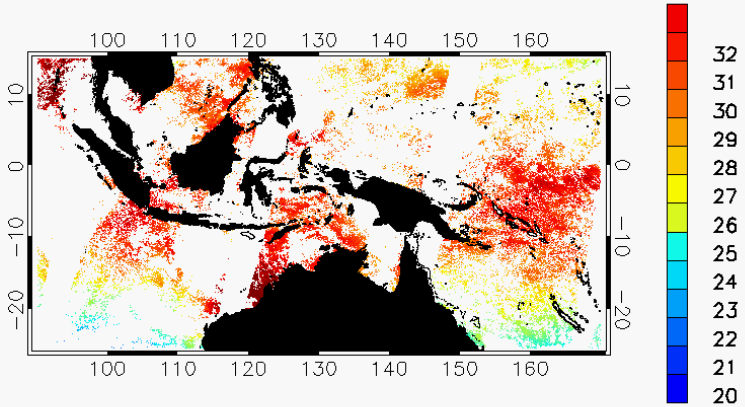
	Standard Deviation [C]			
	9am	2pm	11 pm	1 am
No. Samples	832	1139	814	799
AVHRR	0.363	0.332	0.165	0.172
Buoy	0.269	0.334	0.213	0.210
MTSAT	0.543	0.474	0.363	0.325

Morning Polar-orbiting Satellite SST
26 Apr 2010

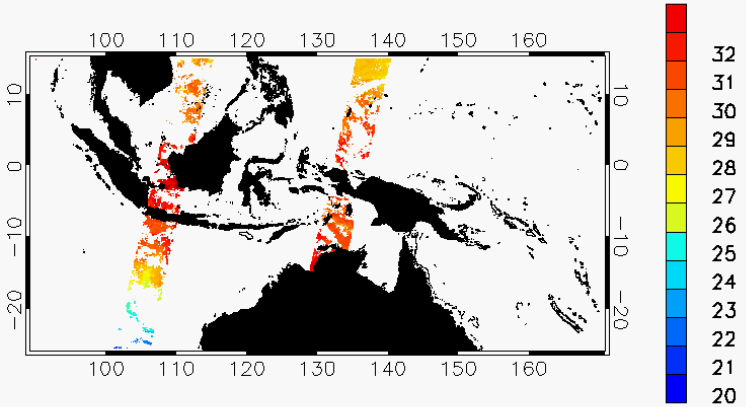
NOAA-17 (10 am)



METOP-A (9:30 am)



AATSR (10 am)



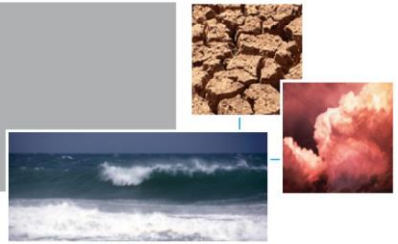
Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

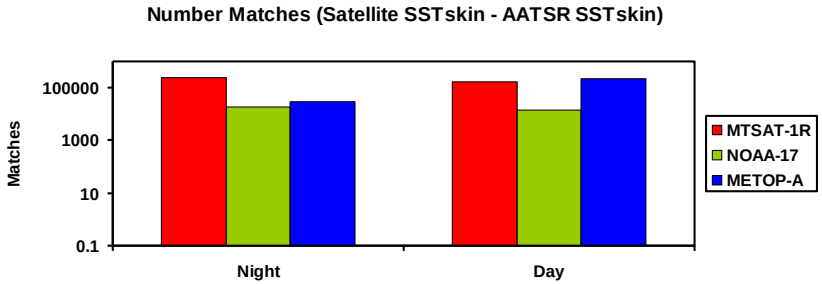
CSIRO

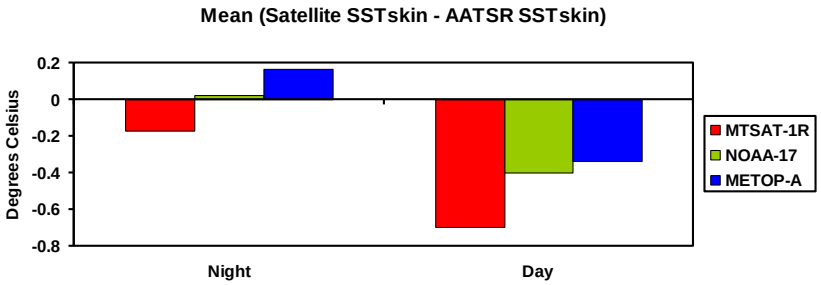
Satellite SSTskin – ARC v1.1 AATSR SSTskin

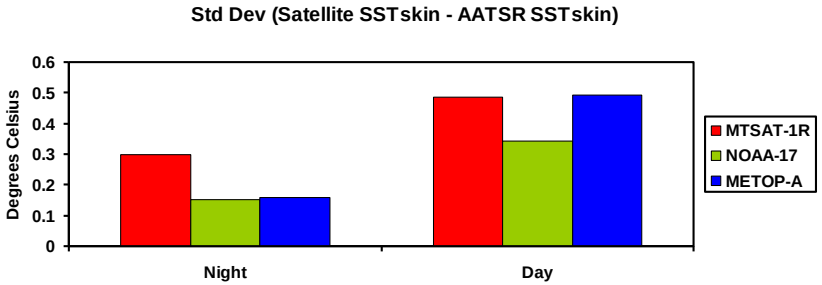
Matches ±2 hr (MTSAT ±1 hr) and same grid cell



Jan – Apr 2010





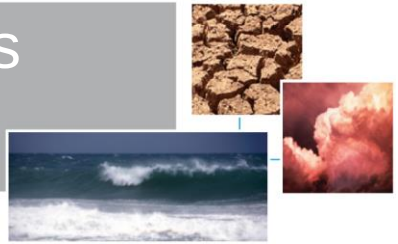


Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

BoM Regional Australian Multi-Sensor SST Analysis System



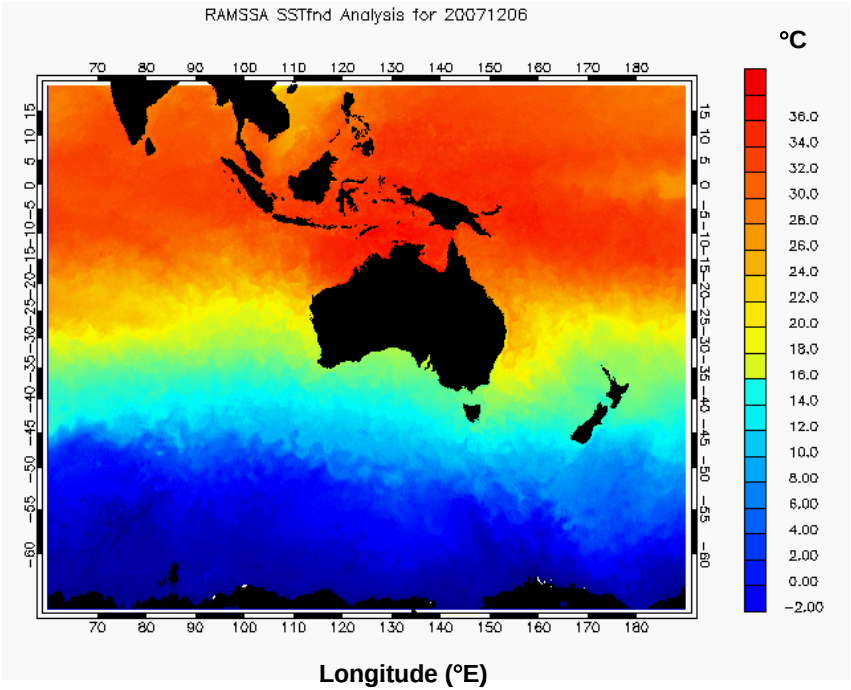
Depth: Foundation (pre-dawn SST)

Resolution: Daily, 1/12°

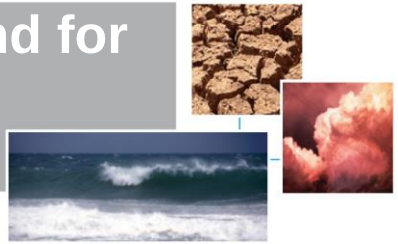
Domain: 60°E - 170°W , 20°N - 70°S

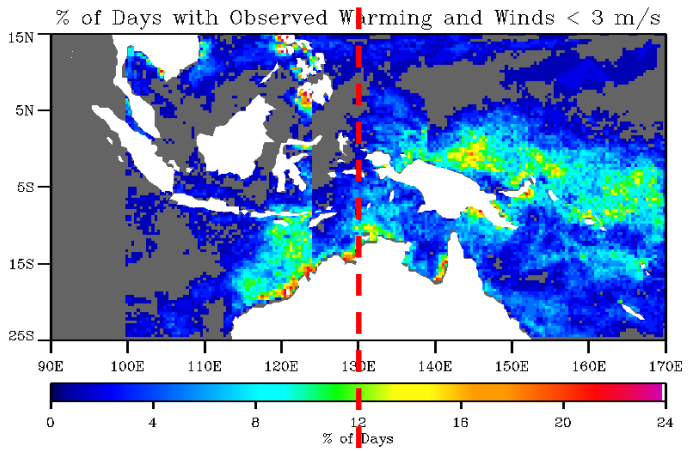
Data Inputs:

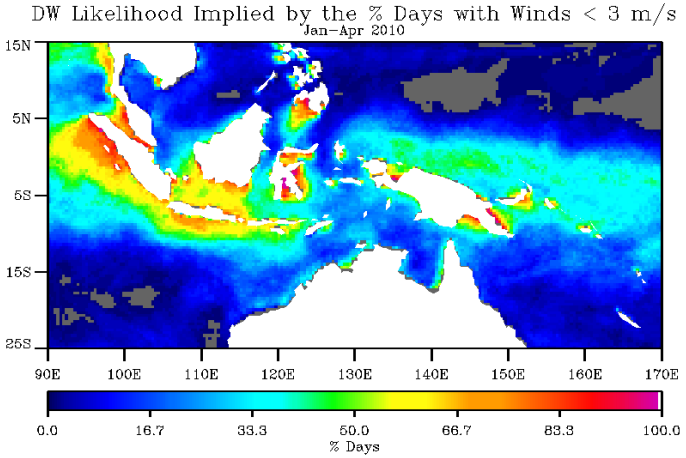
- NAVOCEANO GAC AVHRR (NOAA-17, NOAA-18, METOP-A)
- AMSR-E (Aqua)
- AATSR (EnviSat)
- Buoy and ship obs (GTS)
- 1/12° NCEP ice edge analyses



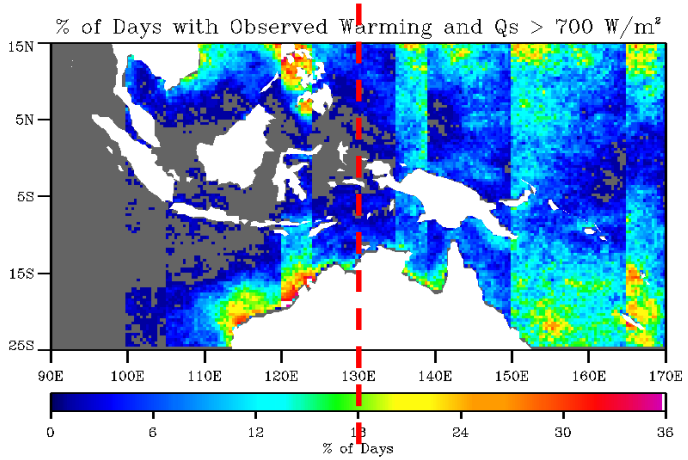
Observed DW from MTSAT SSTskin – MTSAT-1R SSTfnd for low winds and high insolation
Jan – Apr 2010

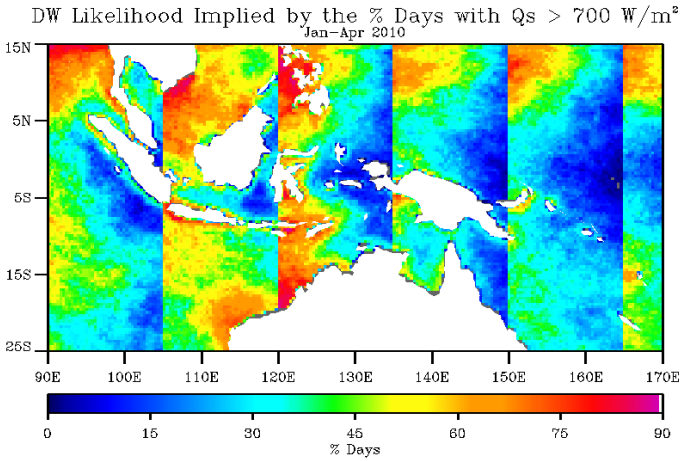






Low W AND High Qs | **Low W OR High Qs**





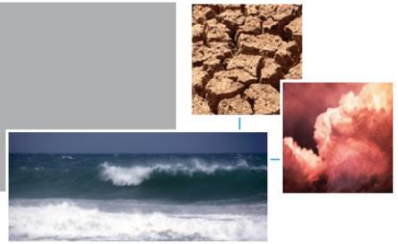
Australian Government
Bureau of Meteorology

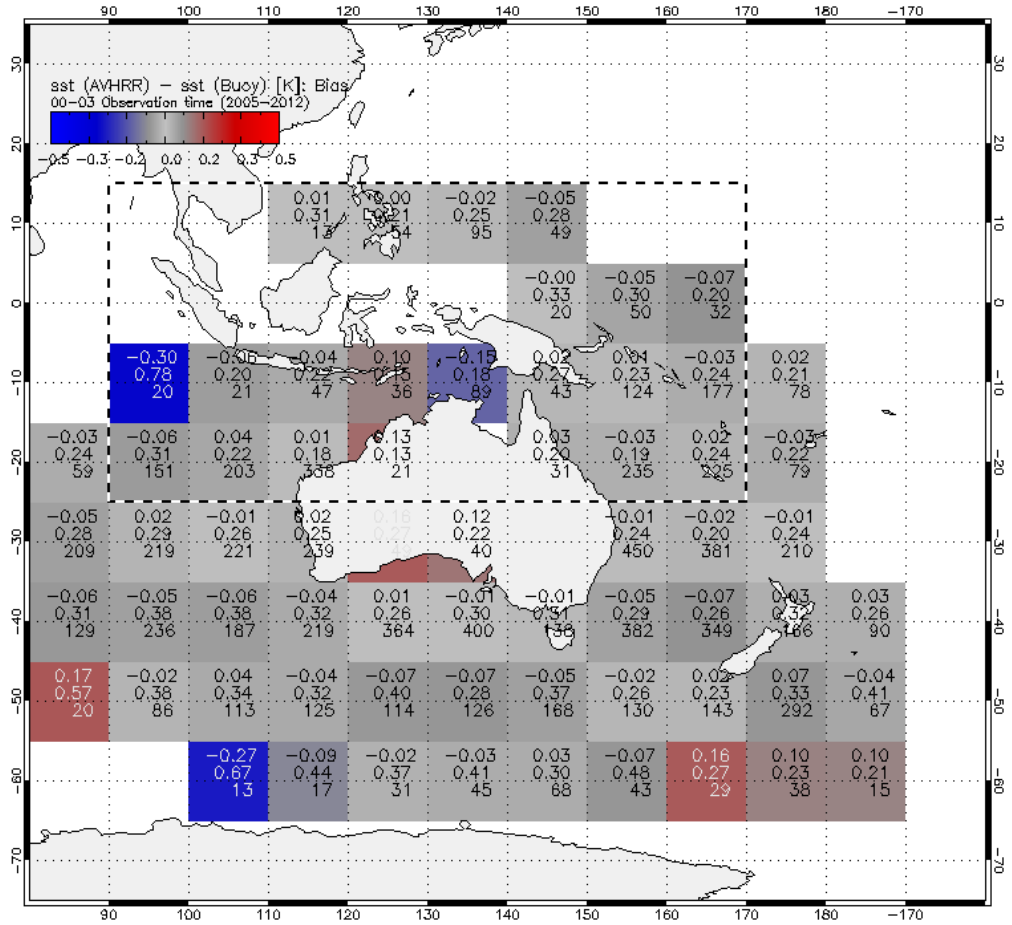
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

IMOS NOAA-18 L2P Spatial Bias – Night

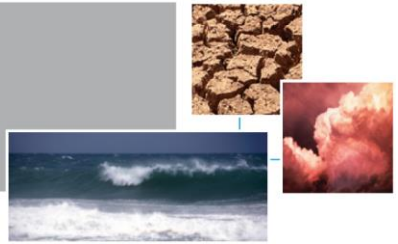
Matchups ±6 hrs, W ≥ 6 m/s (day), W ≥ 3 m/s (night)

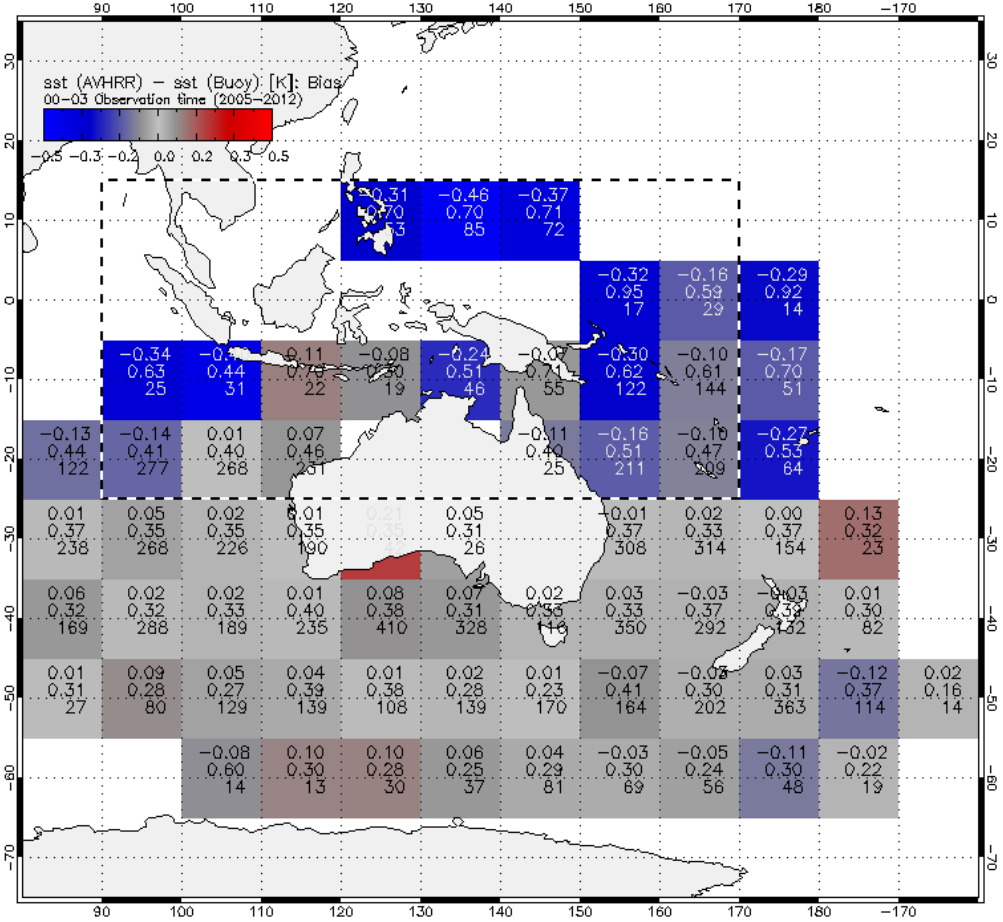




IMOS NOAA-18 L2P Spatial Bias – Day

Matchups ±6 hrs, W ≥ 6 m/s (day), W ≥ 3 m/s (night)





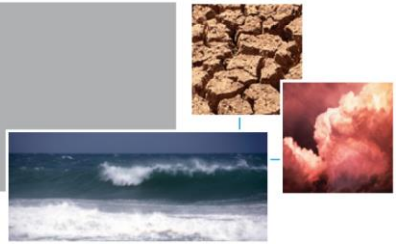
Australian Government
Bureau of Meteorology

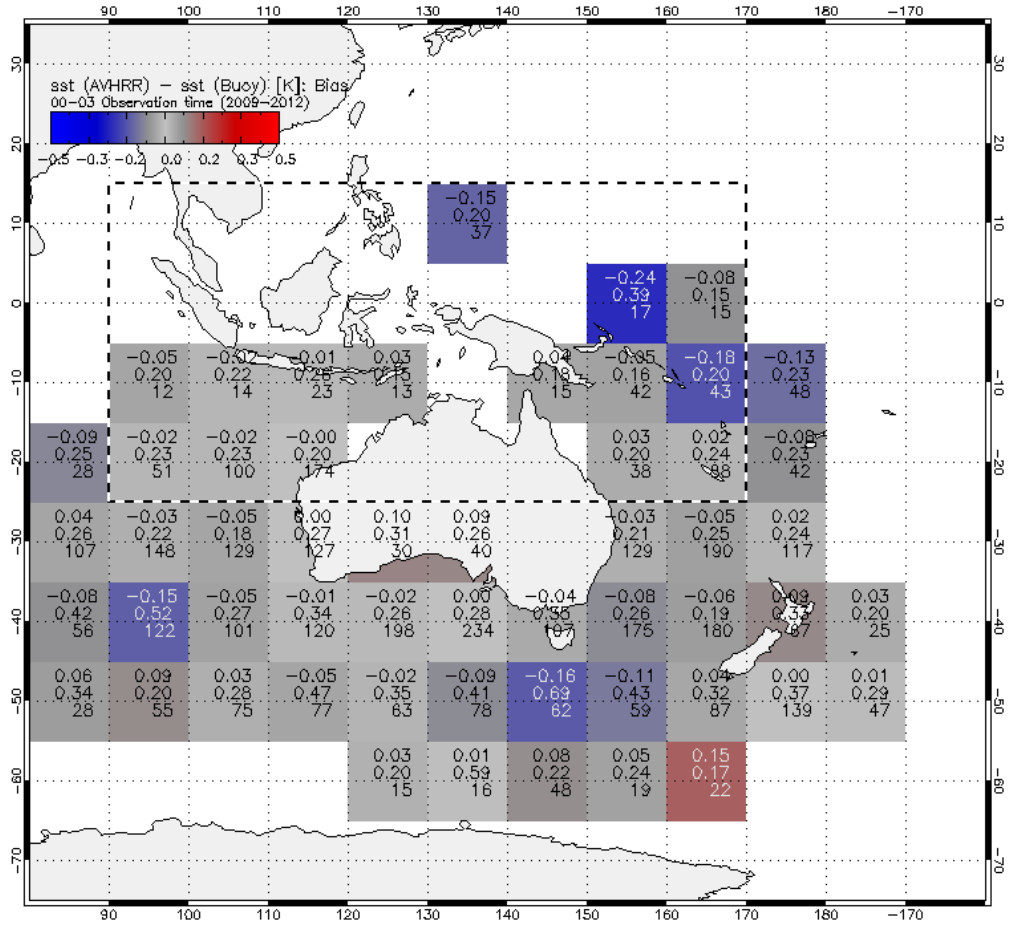
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

IMOS NOAA-19 L2P Spatial Bias – Night

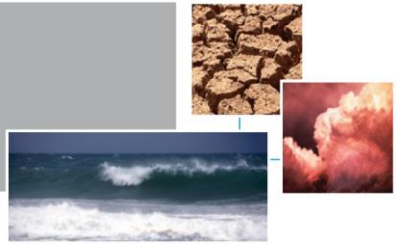
Matchups ±6 hrs, W ≥ 6 m/s (day), W ≥ 3 m/s (night)

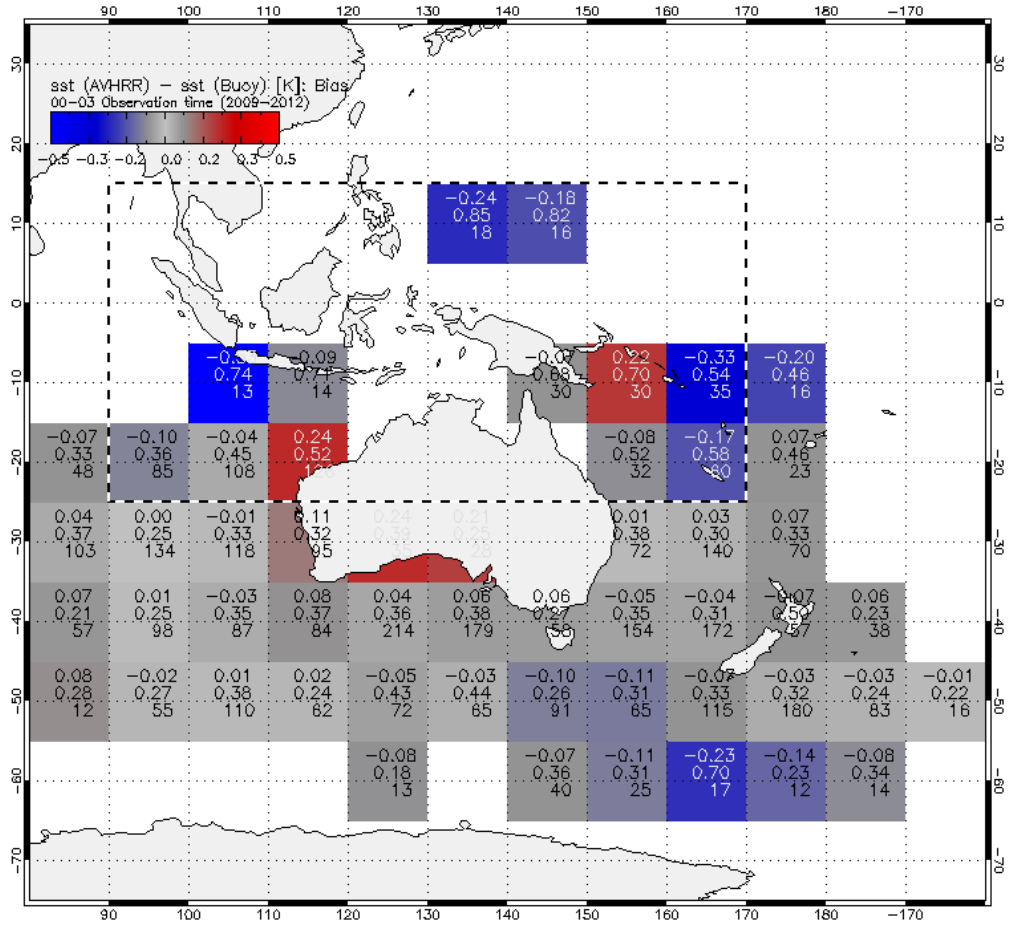




IMOS NOAA-19 L2P Spatial Bias – Day

Matchups ±6 hrs, W ≥ 6 m/s (day), W ≥ 3 m/s (night)



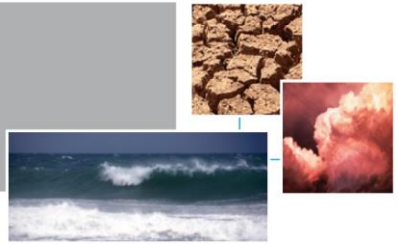


Australian Government
Bureau of Meteorology

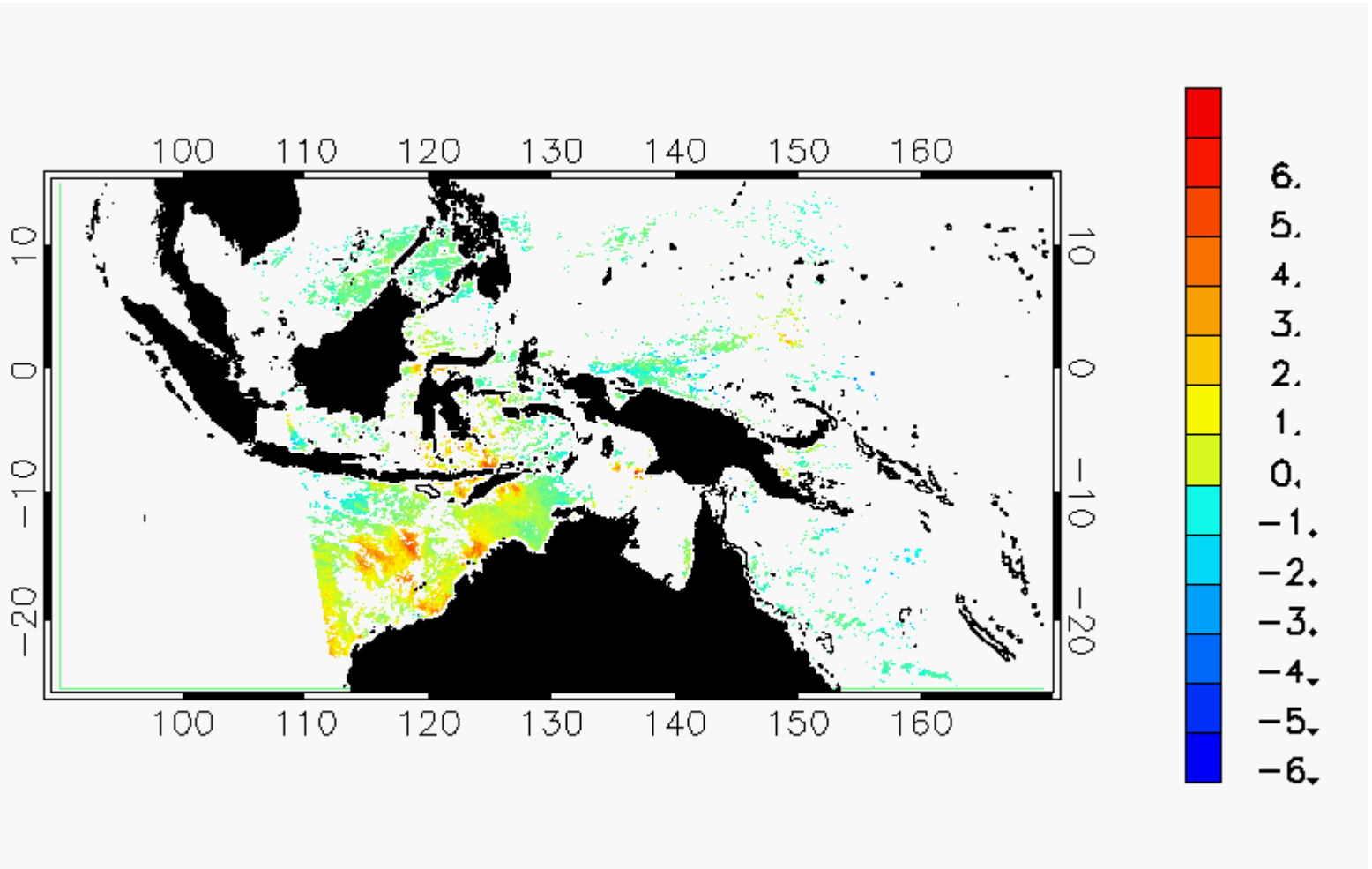
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

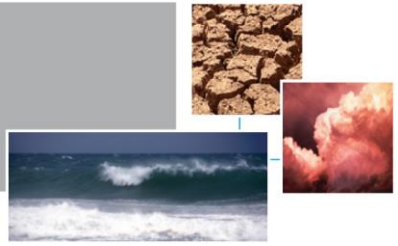
NOAA-19 Day SST – RAMSSA SSTfnd
12 Mar 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5°

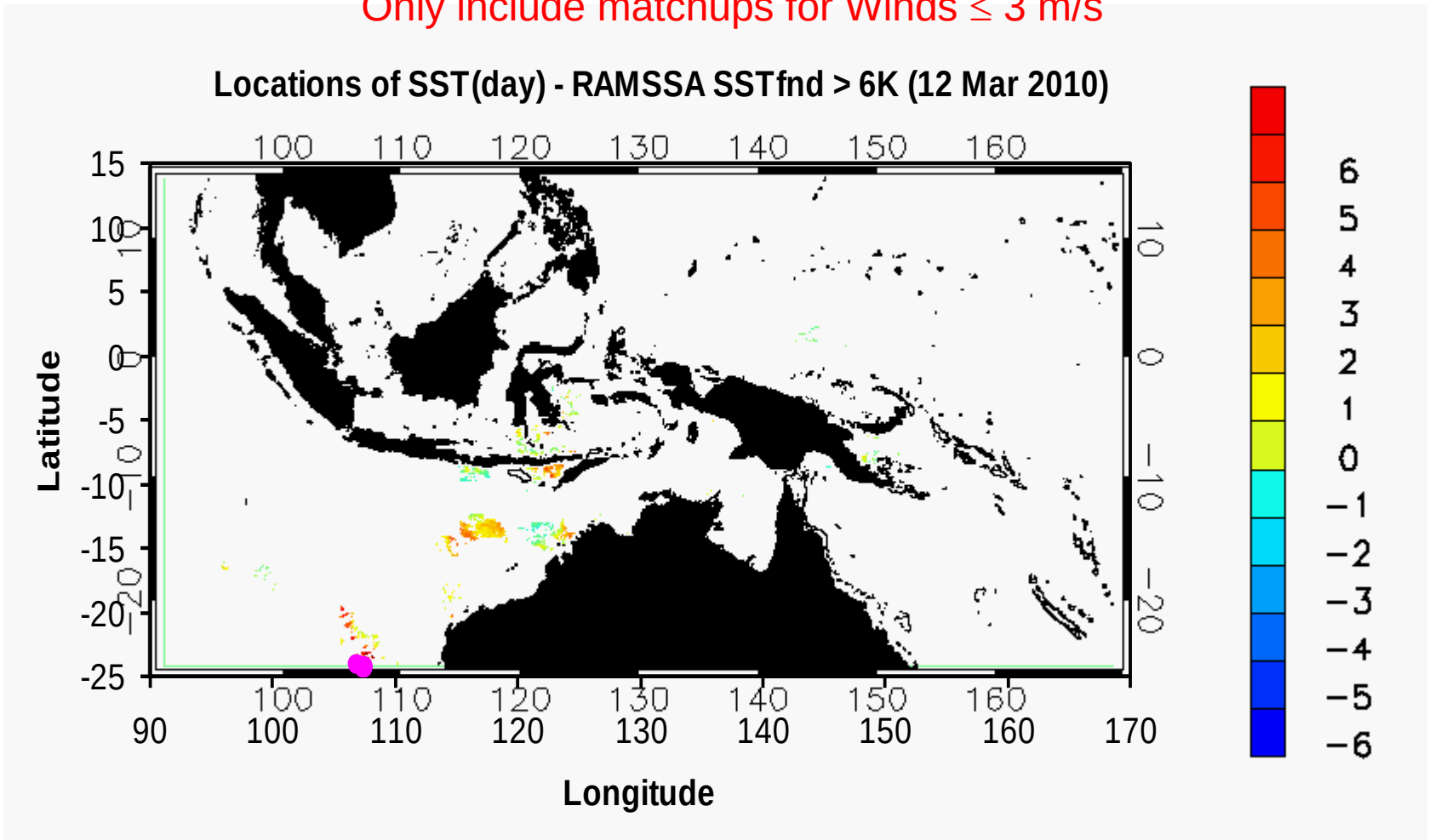


NOAA-19 Day SST – RAMSSA SSTfnd
12 Mar 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5°

Only include matchups for Winds ≤ 3 m/s

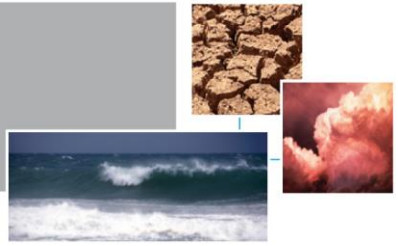


Australian Government
Bureau of Meteorology

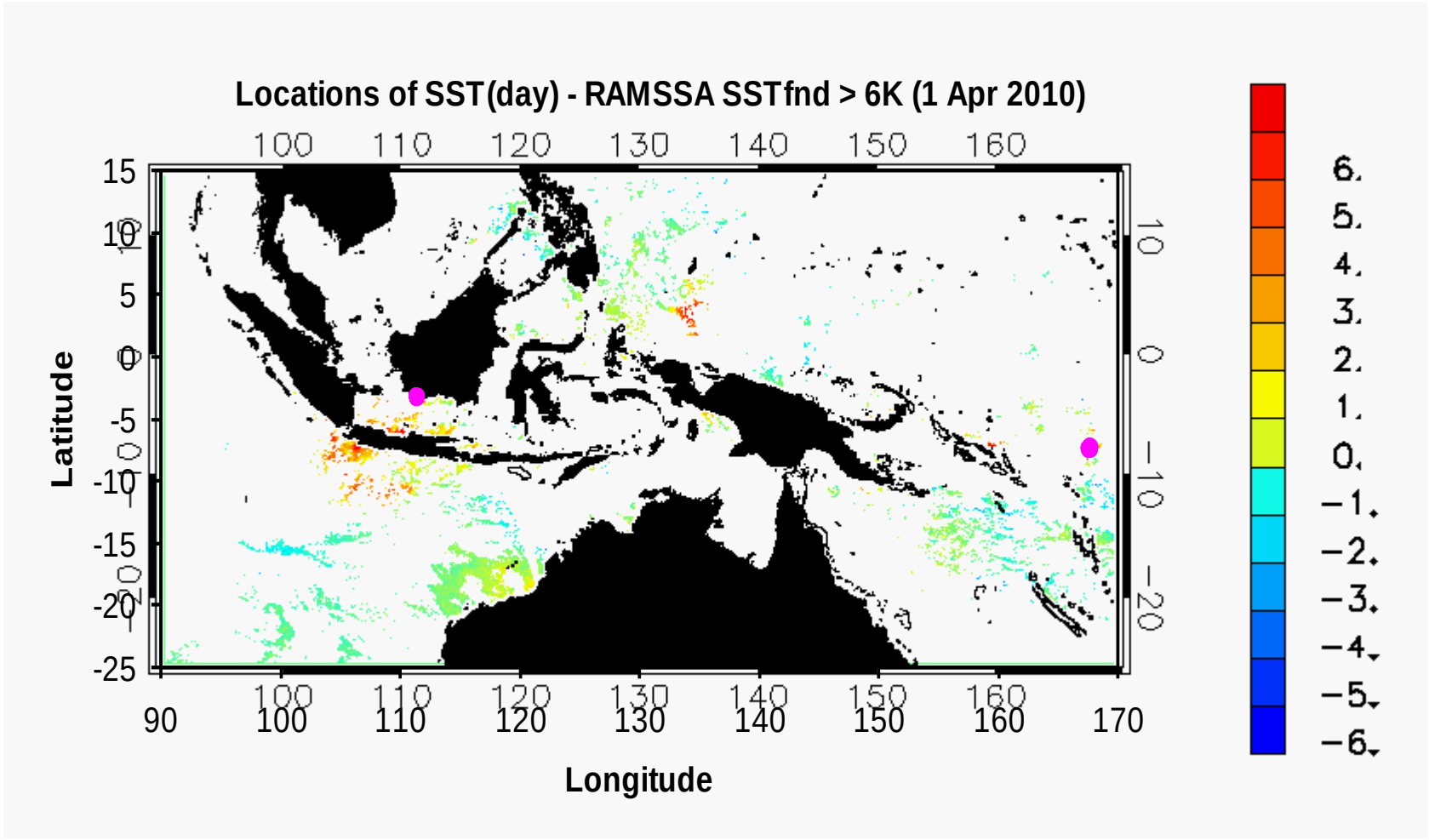
The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

CSIRO

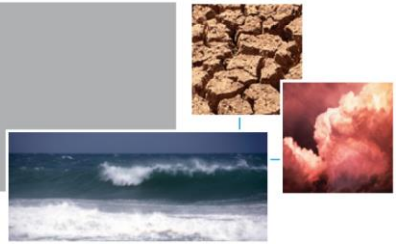
NOAA-19 Day SST – RAMSSA SSTfnd
1 Apr 2010 (Filtered for 2 x 2 good SSTs)



Expanding land mask by 0.5° x 0.5°

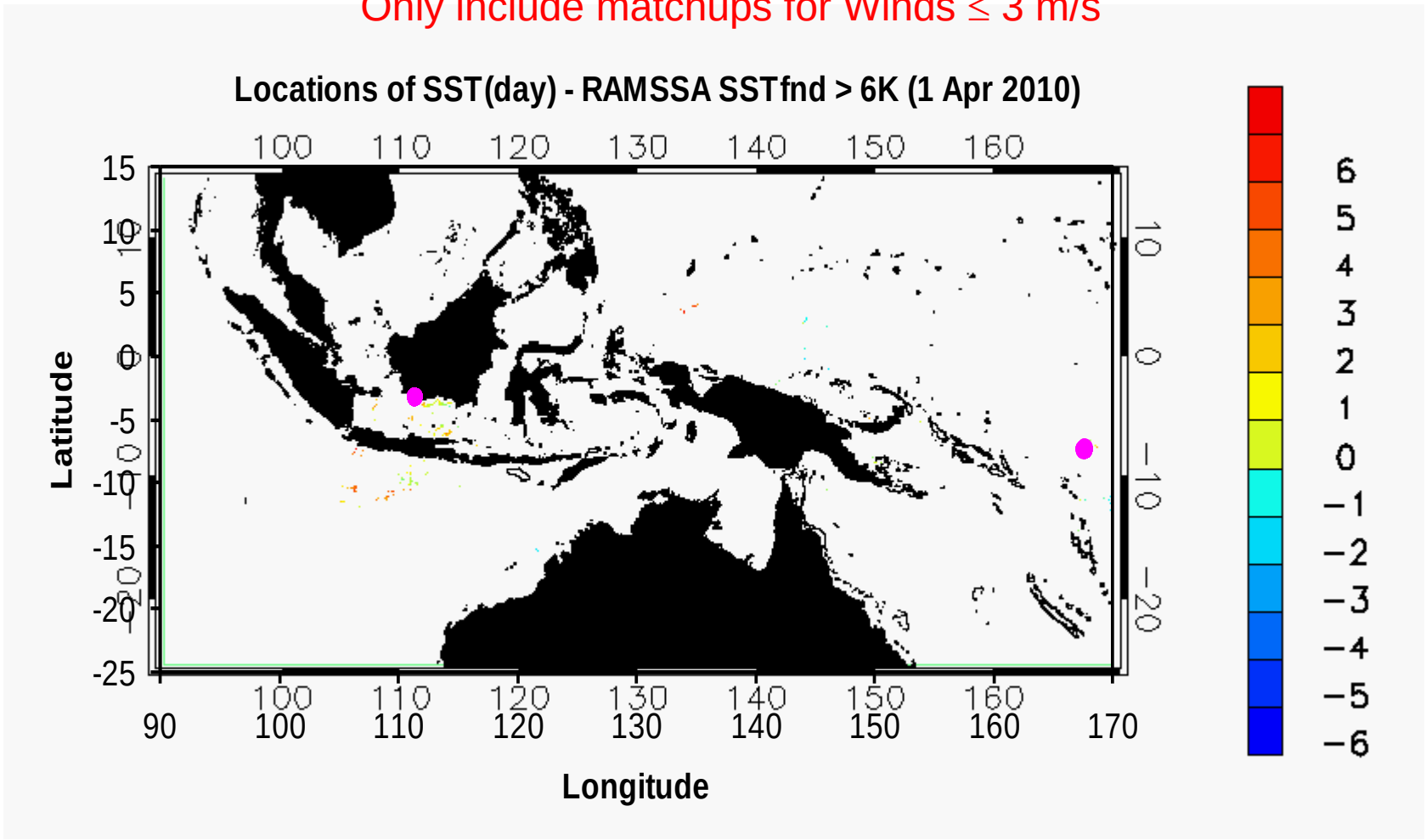


NOAA-19 Day SST – RAMSSA SSTfnd
1 Apr 2010 (Filtered for 2 x 2 good SSTs)

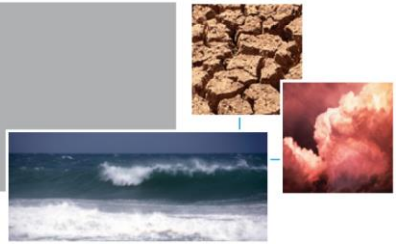


Expanding land mask by 0.5° x 0.5°

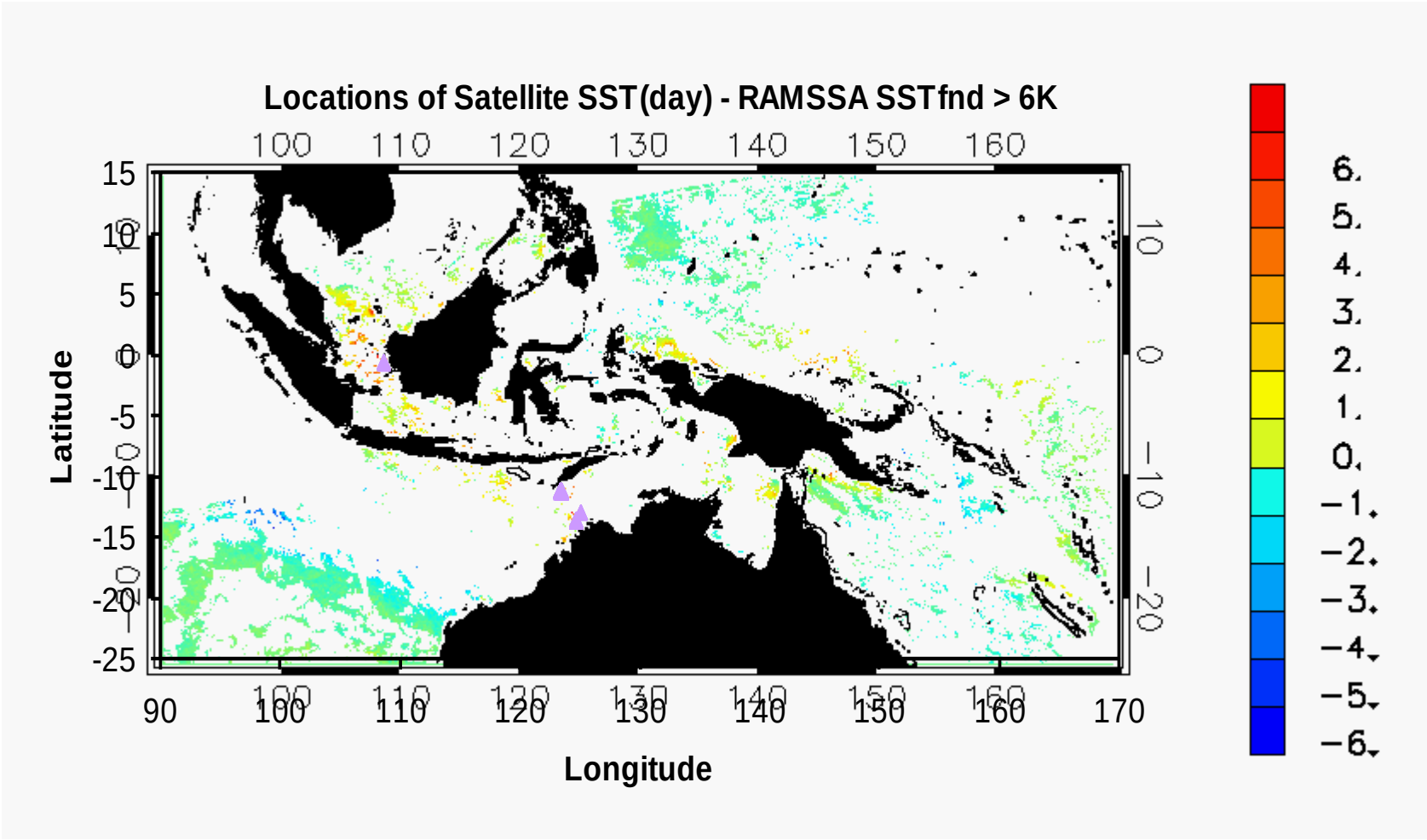
Only include matchups for Winds ≤ 3 m/s



NOAA-19 Day SST – RAMSSA SSTfnd
15 Apr 2010 (Filtered for 2 x 2 good SSTs)



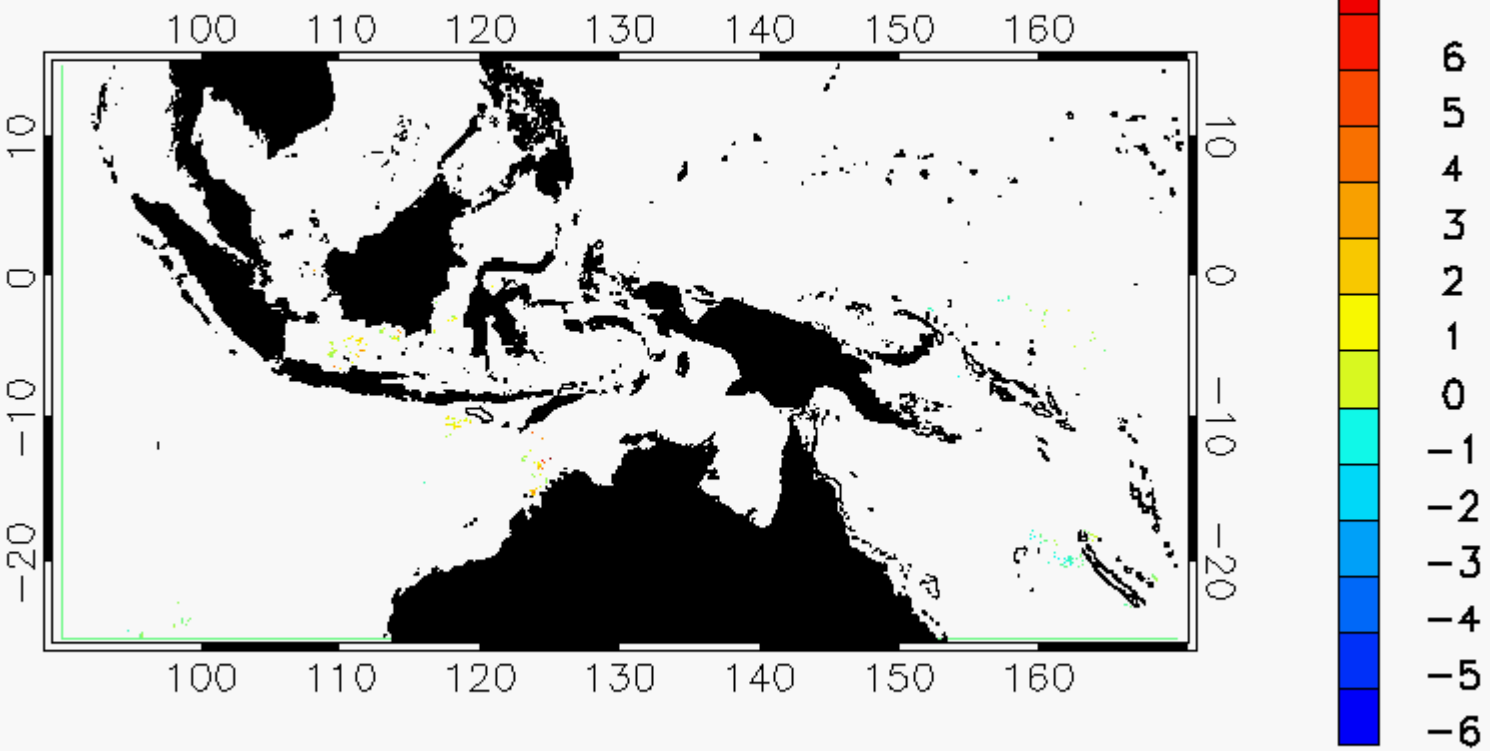
Expanding land mask by 0.5° x 0.5°



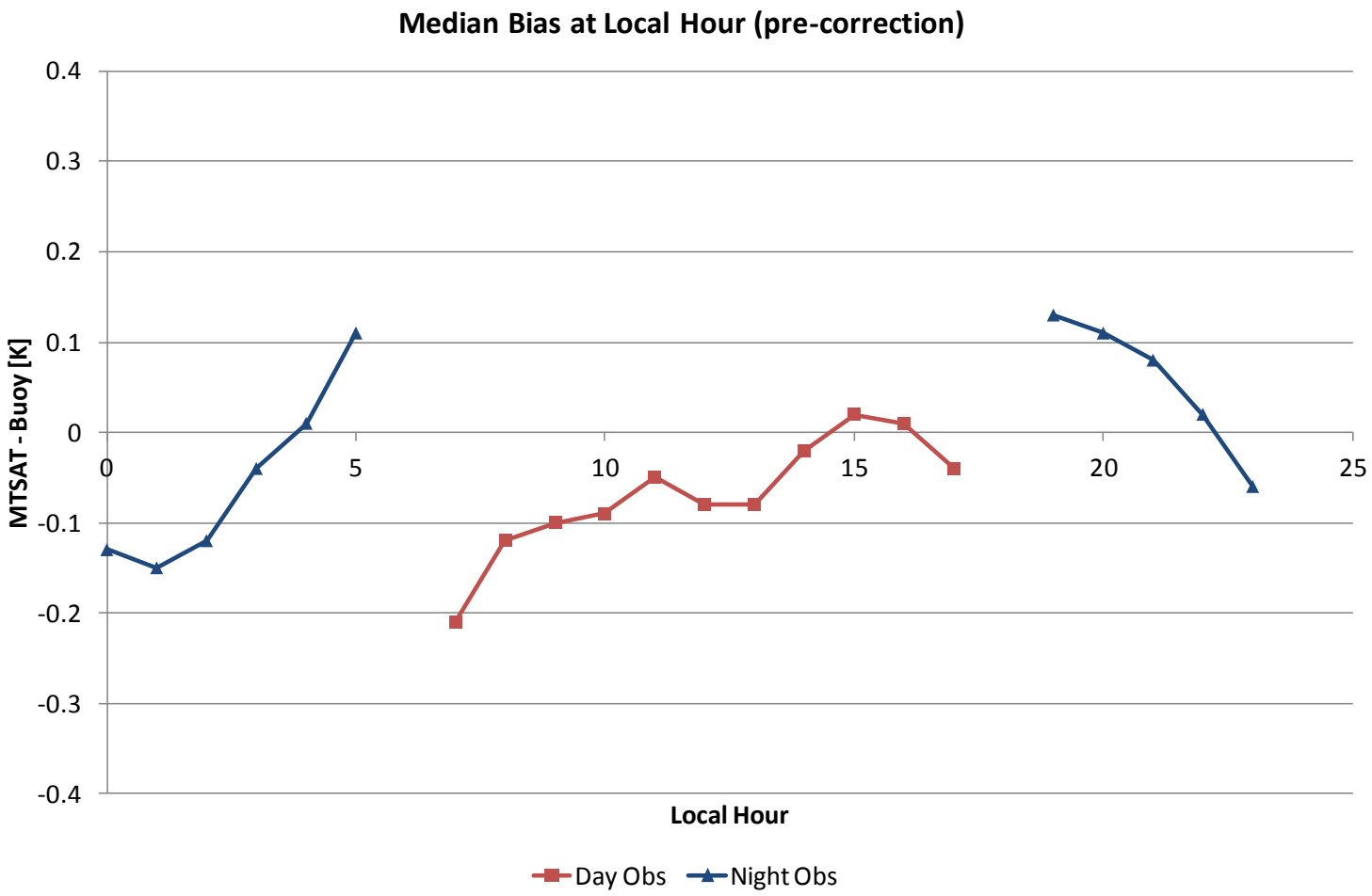
NOAA-19 Day SST – RAMSSA SSTfnd
15 Apr 2010 (Filtered for 2 x 2 good SSTs)

Expanding land mask by 0.5° x 0.5°

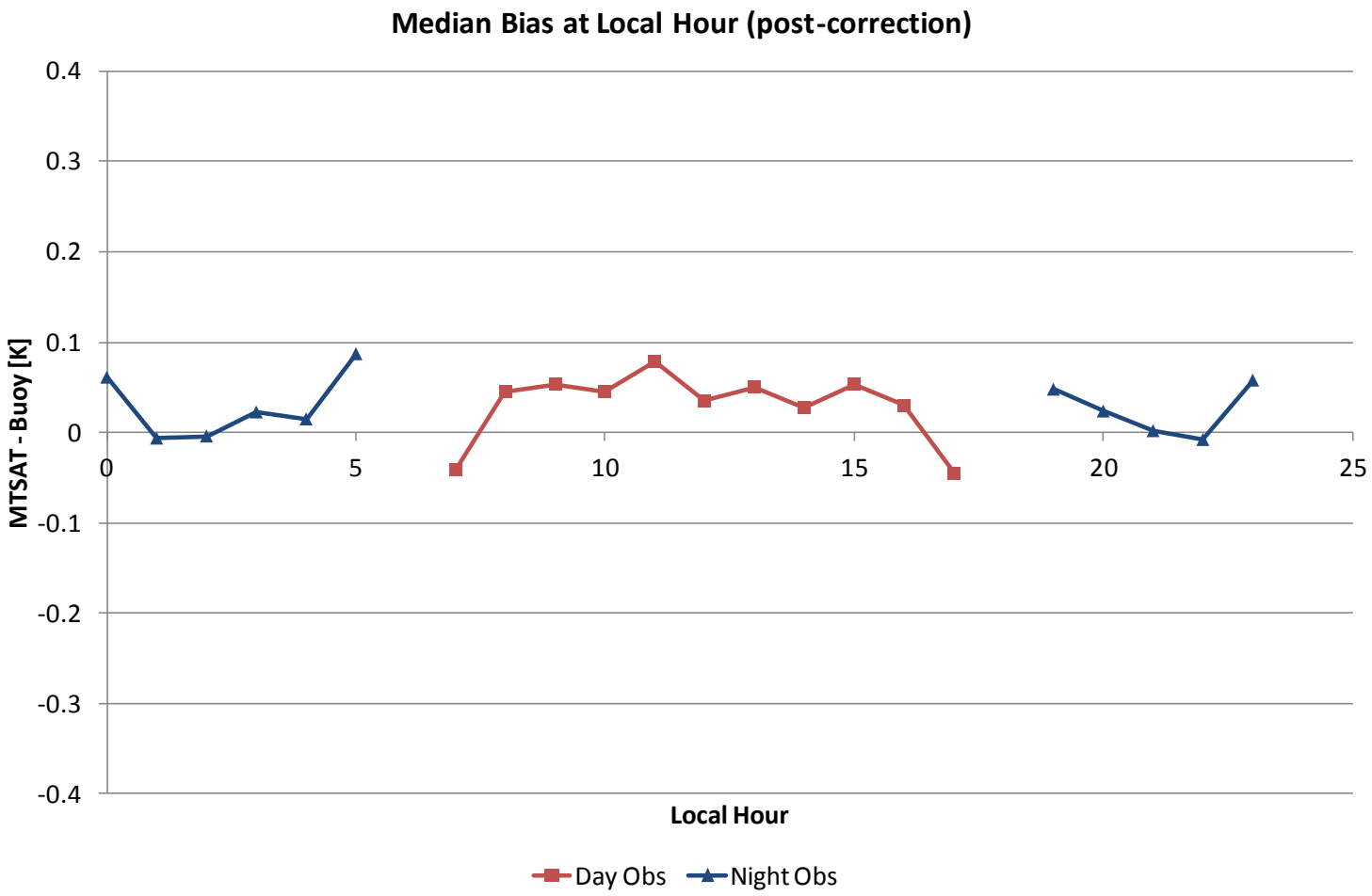
Only include matchups for Winds ≤ 3 m/s



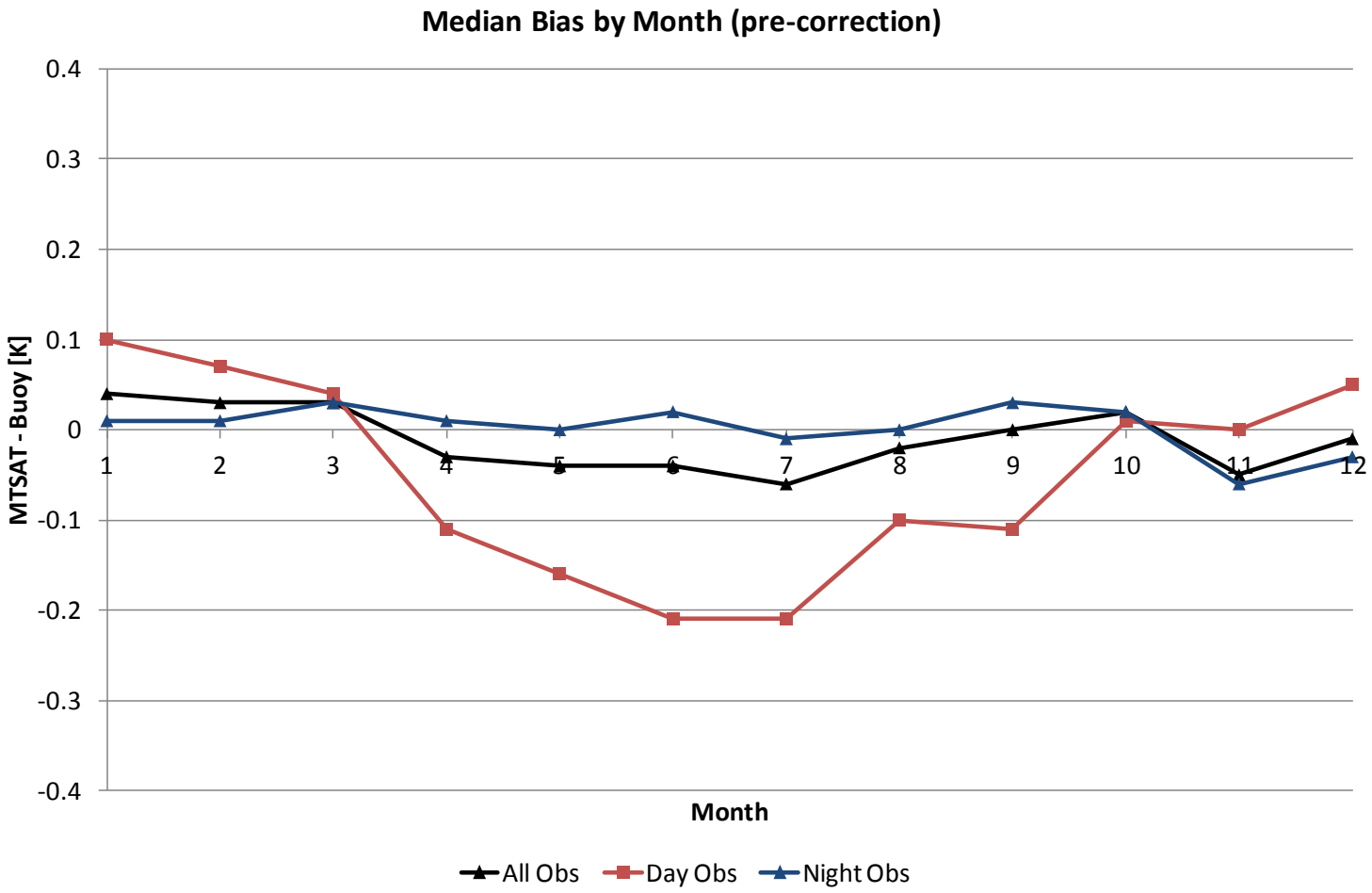
Temporal Bias/Issues
MTSAT pre-correction
2006 – 2010 over whole scene



Temporal Bias/Issues
MTSAT post-correction
2006 – 2010 over whole scene



Temporal Bias/Issues
MTSAT pre-correction
2006 – 2010 over whole scene



Temporal Bias/Issues
MTSAT post-correction
2006 – 2010 over whole scene