AATSR and our Weather Forecast

Dr. Craig Donlon

European Space Agency

Noordwijk, the Netherlands

Overview

- Why is AATSR SST important for the weather forecast?
- How do we use AATSR data as part of the forecast?
- Examples of weather forecast outcomes
- Future perspectives

70% Earth's surface covered by water

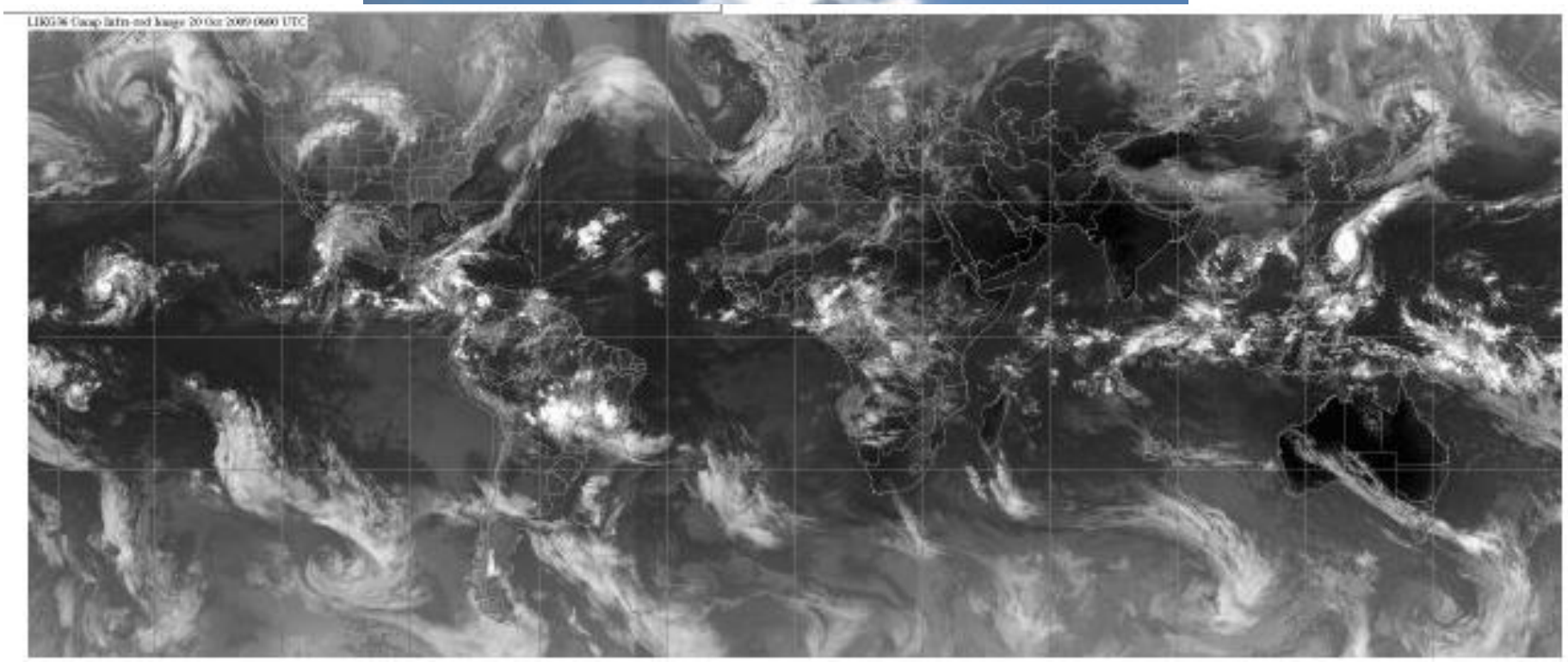
The final frontier…

"*If I were to choose a single phrase to characterize the first century of modern oceanography, it would be a century of under-sampling.*"

Walter Munk, Woods Hole Oceanographic Institute, 2000

SST and the weather

Microburst, Long Island, in The Bahamas. **© Dene Georgelin.**

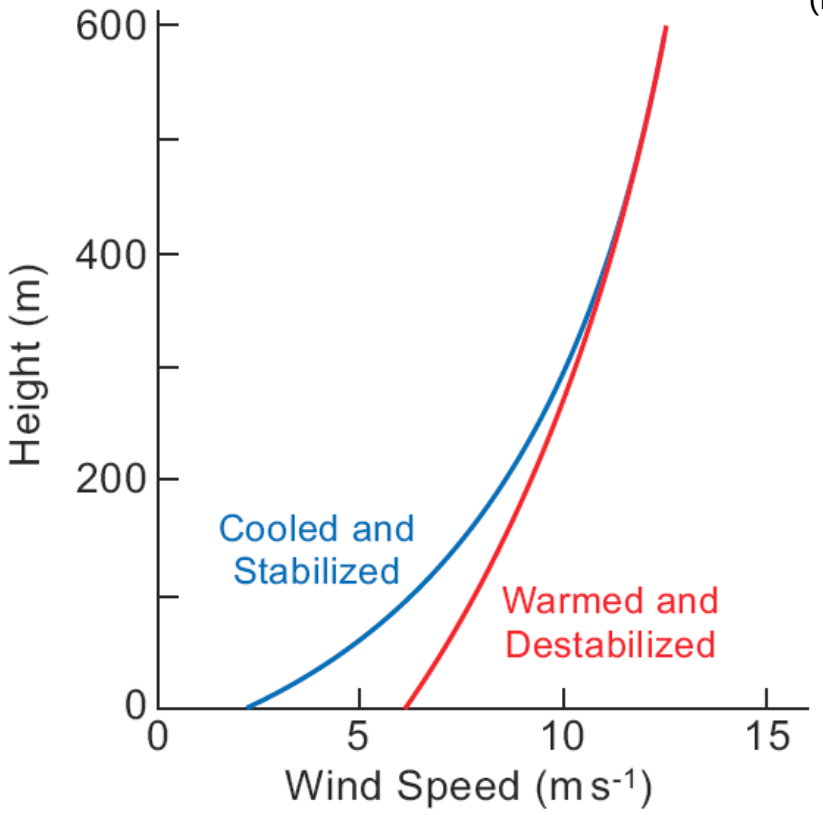


07:00 20th October 2009

SST influence on the marine atmospheric boundary layer

Schematic Summary of SST Influence on the Wind Speed Profile in the Marine Atmospheric Boundary Layer

(D. Chelton and Park et al, 2006)



This is similar to diurnal variation of the atmospheric boundary layer over land:

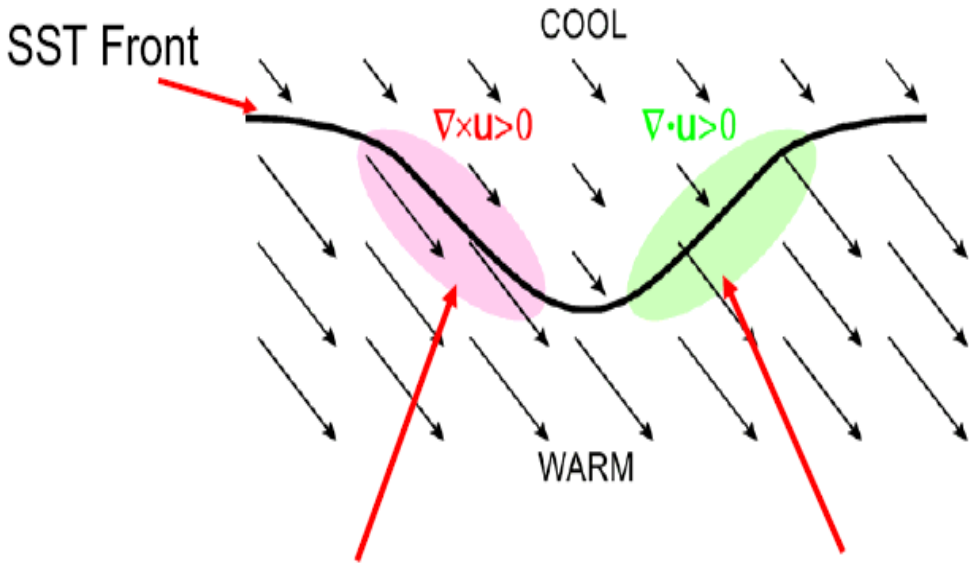
- *nocturnal stable boundary layer from radiative cooling*
- *daytime unstable boundary layer from solar heating of the land*

Note that vertical turbulent mixing is not the only term that is important in the momentum balance. The nonlinear advection and pressure gradient terms are also important, especially the latter.

- *see later discussion of wind direction changes across SST fronts*

SST influence on the marine atmospheric boundary layer

SST-Induced Perturbations of Vorticity and Divergence Near SST Fronts



Vorticity associated with crosswind SST gradient as winds blow along SST fronts

Divergence associated with downwind SST gradient as winds blow across SST fronts

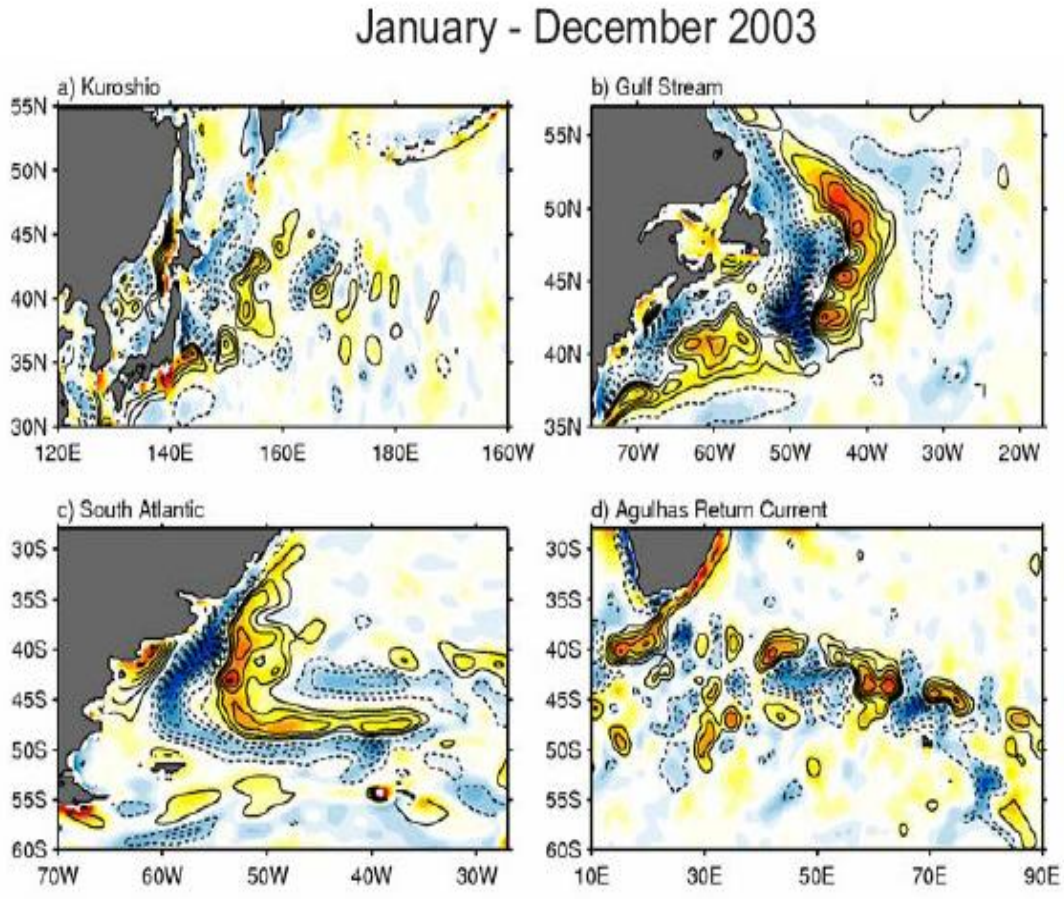
(D. Chelton)

SST influence on the marine atmospheric boundary layer

Photograph taken from the NOAA P-3 aircraft looking northeast across the North Wall of the Gulf Stream. The winds were blowing from the northeast at the time of the photograph. The seas were calm over the colder slope waters to the northwest of the Gulf Stream (the upper left area of the photo) and white caps covered the warmer water to the southeast. (Courtesy of Paul Chang, NOAA.)

(D. Chelton)

SST influence on the marine atmospheric boundary layer



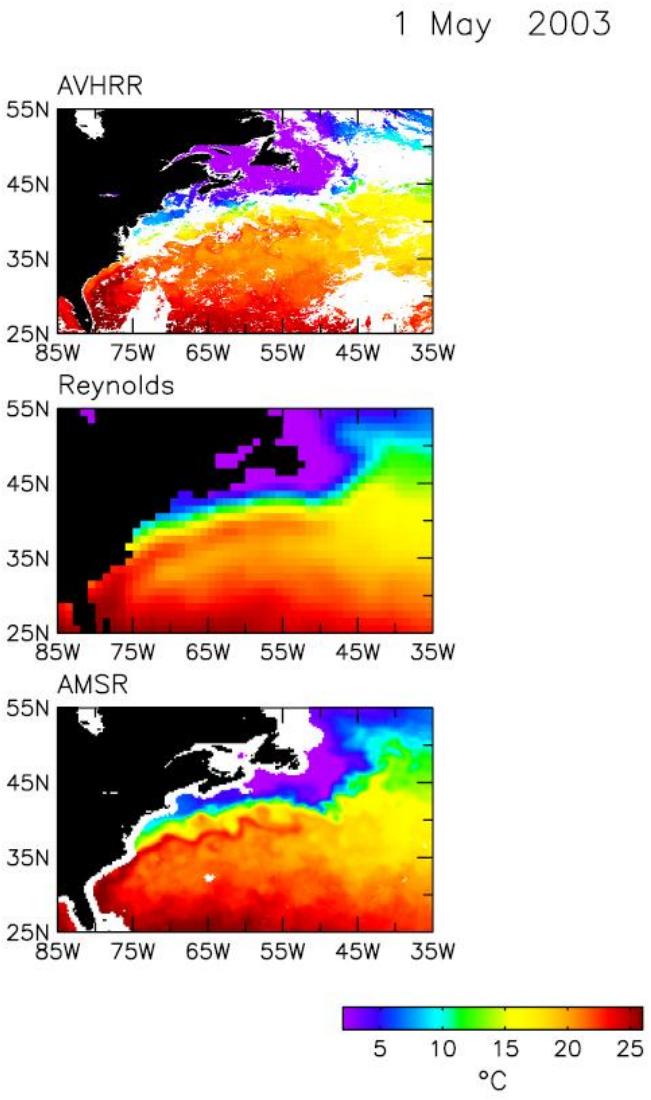
QuickScat winds (High pass filtered) and AMSRE Passive microwave SST

Differences between warm and cold regions are ~3-5ºC and ~2-3 m/s

Solid contours = warm SST perturbations
Dashed contours = cool SST perturbations

(D. Chelton)

Impact of high resolution SSTs on SST gradients in NWP

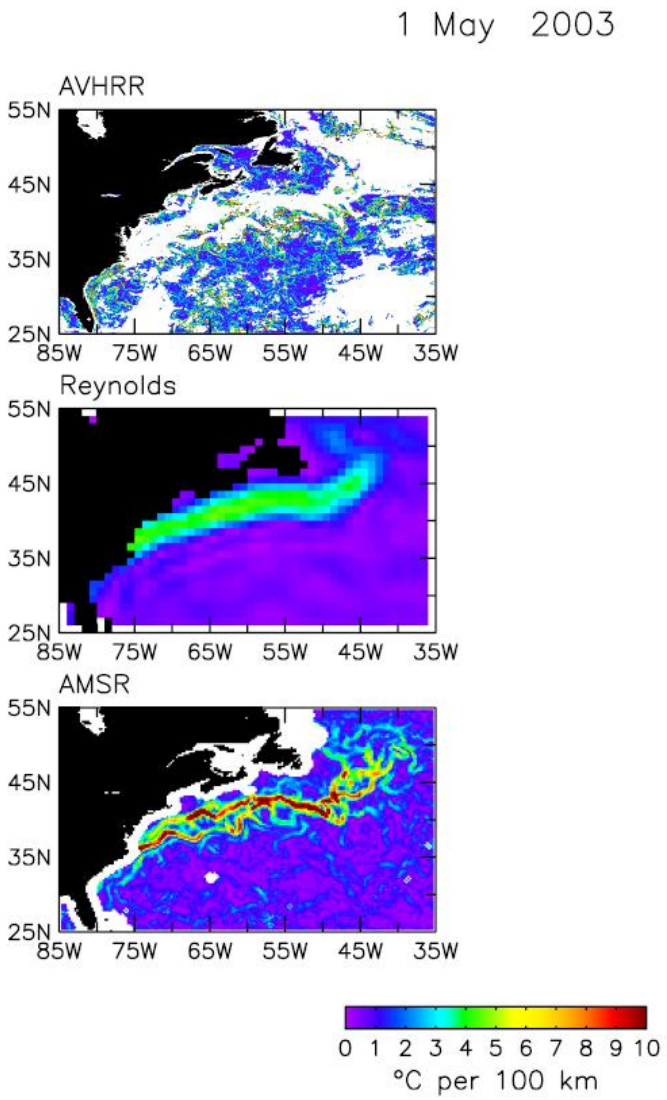


Impact of using combined infrared and microwave SSTs on resolving SST gradients

(D. Chelton)

(D Chelton)

Impact of high resolution SSTs on SST gradients in NWP



Impact of using combined infrared and microwave SSTs on resolving SST gradients

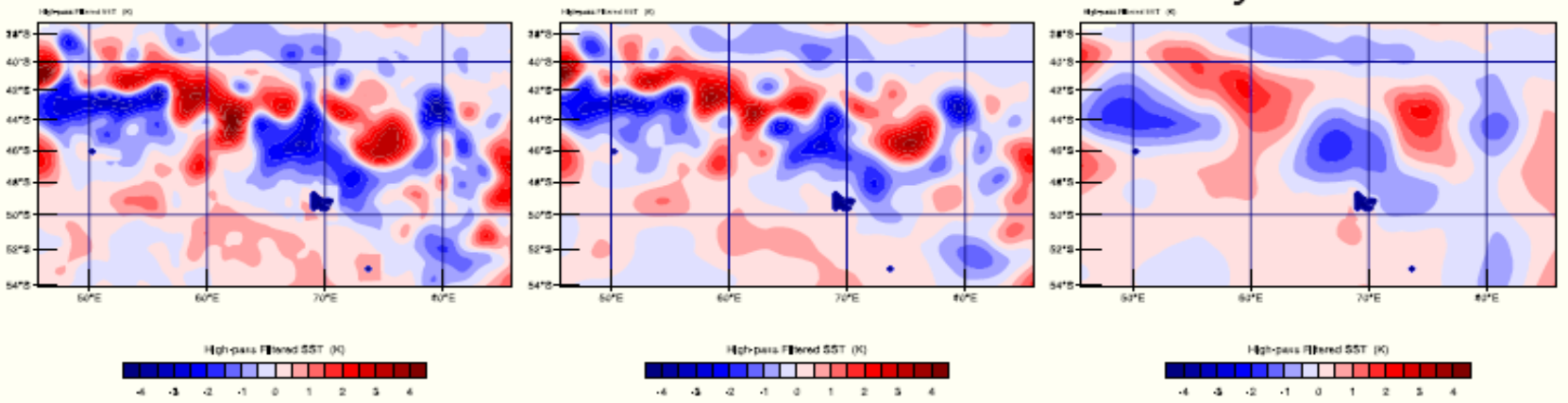
(D. Chelton)

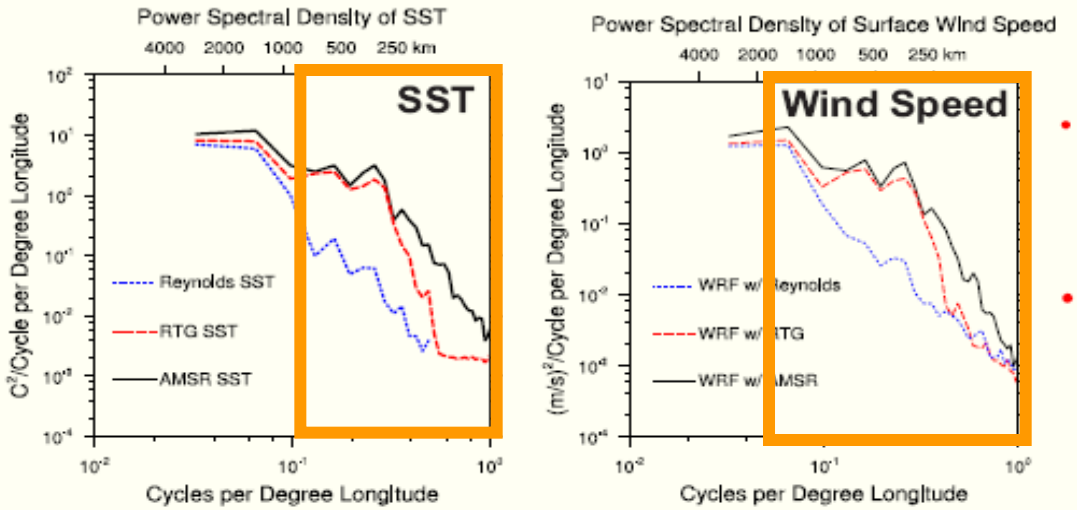
(D Chelton)

Impact of high resolution SSTs on SST gradients in NWP

Sensitivity to Specification of the SST Boundary Condition

AMSR SST | *RTG SST* | *Reynolds SST*





- *Forcing by Reynolds SST underestimates the energy on all scales shorter than ~1000 km.*
- ***Forcing by RTG SST underestimates the energy only on scales shorter than ~250 km***

Over prediction of East coast cyclones due to SST boundary condition in the US NWS Eta Model (30th Dec. 2000)

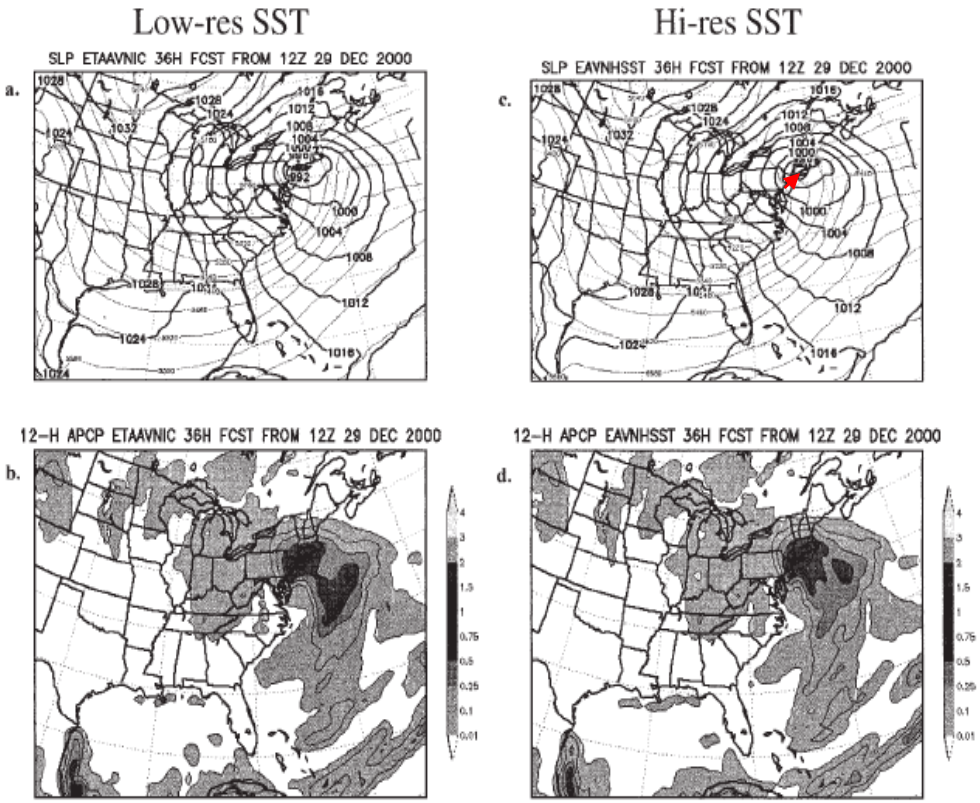


FIG. 3. (a) The 24-h operational Eta sea level pressure (mb) forecast valid at 1200 UTC 12 Dec 2000. (b) The 36-h forecast precipitation (in.) from the operational Eta valid at 0000 UTC 12 Dec 2000. (c) Comparable to (a) but with EtaX forecast using the RTG_SST analysis. (d) Comparable to (b) but with EtaX forecast using the RTG_SST analysis.

THIÉBAUX et al, BAMS, 2003

- Predicted 12–25 cm. of snow over the Baltimore–Washington metropolitan area with 2–3 days lead
- **Actual snowfall was zero…**
- Eta exhibited westward bias in predicted snowfall patterns.
- Concluded that errors in the mslp and precip. forecasts were either directly coupled to or indirectly dependent on the Atlantic coast SST distribution
- **High resolution SST matters to NWP**
- RTG_SST became operational 30 January 2001

Over prediction of East coast cyclones due to SST boundary condition in the US NWS Eta Model (30th Dec. 2000)

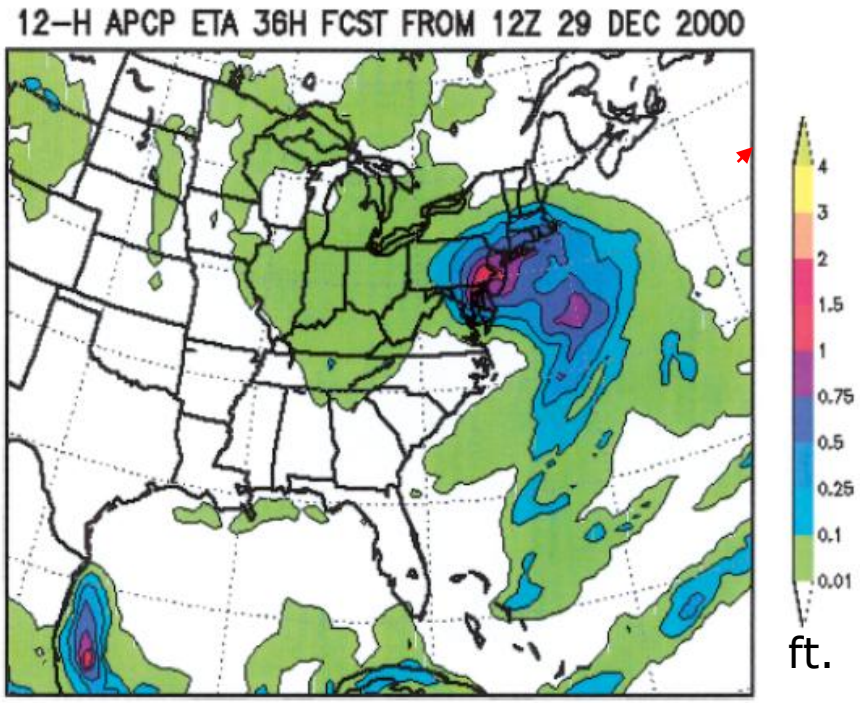


FIG. 1. Eta Model 36-h forecast of 12-h accumulated precipitation, from 1200 UTC 29 Dec 2000.

- Predicted 12–25 cm. of snow over the Baltimore–Washington metropolitan area with 2–3 days lead
- **Actual snowfall was zero…**
- Eta exhibited westward bias in predicted snowfall patterns.

THIÉBAUX et al, BAMS, 2003

Over prediction of East coast cyclones due to SST boundary condition in the US NWS Eta Model (30th Dec. 2000)

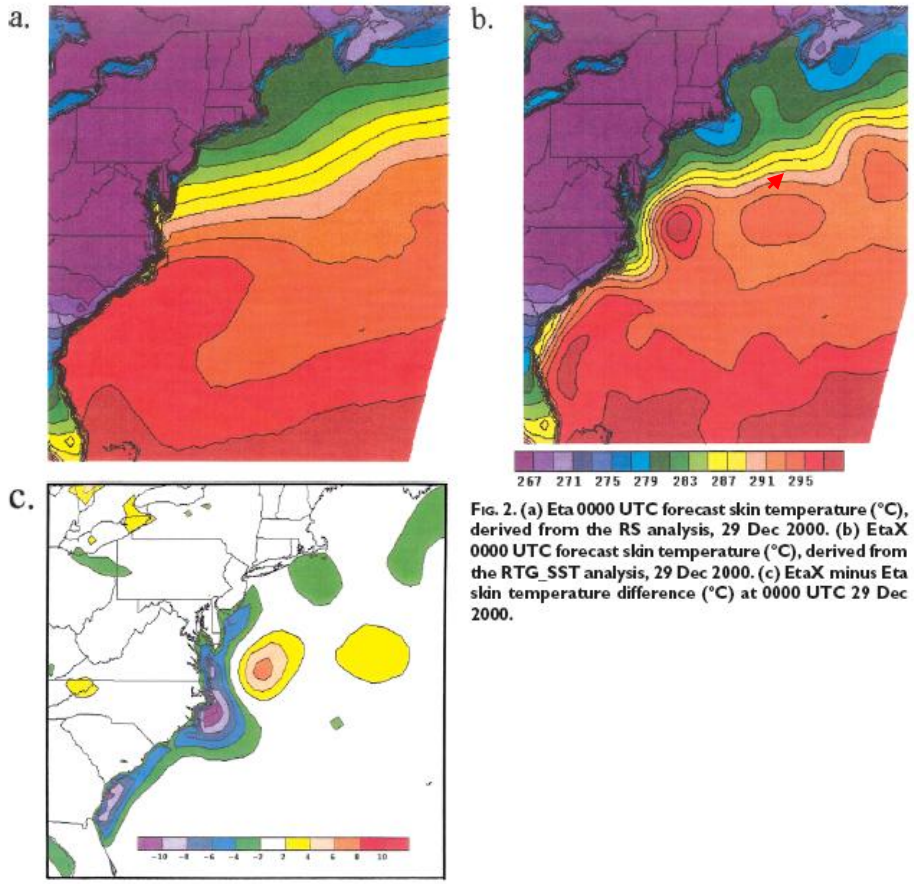


FIG. 2. (a) Eta 0000 UTC forecast skin temperature (°C), derived from the RS analysis, 29 Dec 2000. (b) EtaX 0000 UTC forecast skin temperature (°C), derived from the RTG_SST analysis, 29 Dec 2000. (c) EtaX minus Eta skin temperature difference (°C) at 0000 UTC 29 Dec 2000.

- Predicted 12–25 cm. of snow over the Baltimore–Washington metropolitan area with 2–3 days lead
- **Actual snowfall was zero…**
- Eta exhibited westward bias in predicted snowfall patterns.

THIÉBAUX et al, BAMS, 2003

Over prediction of East coast cyclones due to SST boundary condition in the US NWS Eta Model (30th Dec. 2000)

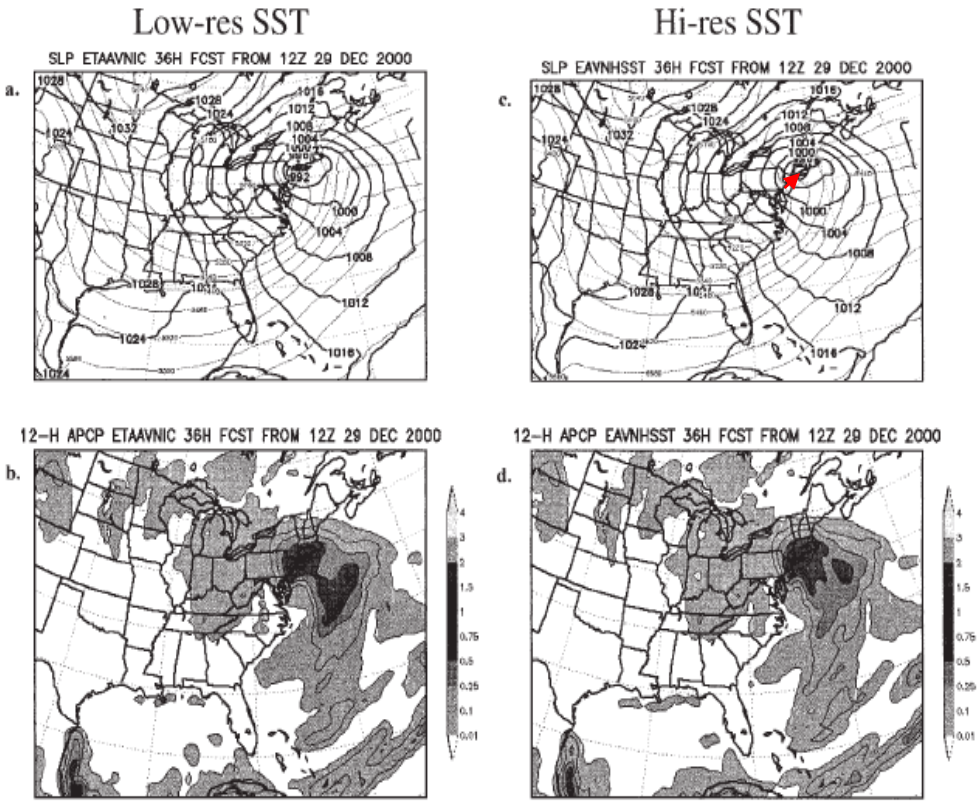
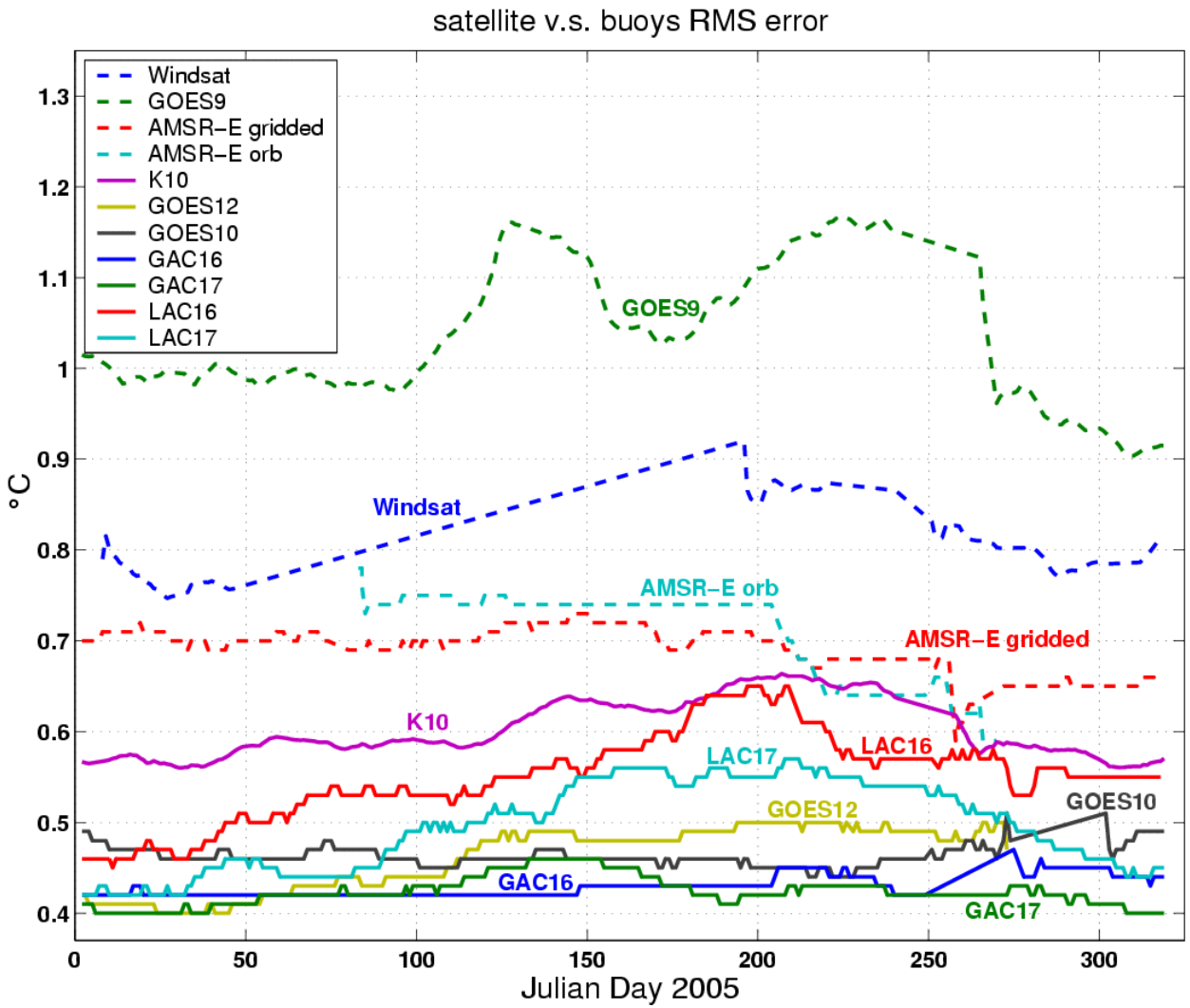


FIG. 3. (a) The 24-h operational Eta sea level pressure (mb) forecast valid at 1200 UTC 12 Dec 2000. (b) The 36-h forecast precipitation (in.) from the operational Eta valid at 0000 UTC 12 Dec 2000. (c) Comparable to (a) but with EtaX forecast using the RTG_SST analysis. (d) Comparable to (b) but with EtaX forecast using the RTG_SST analysis.

THIÉBAUX et al, BAMS, 2003

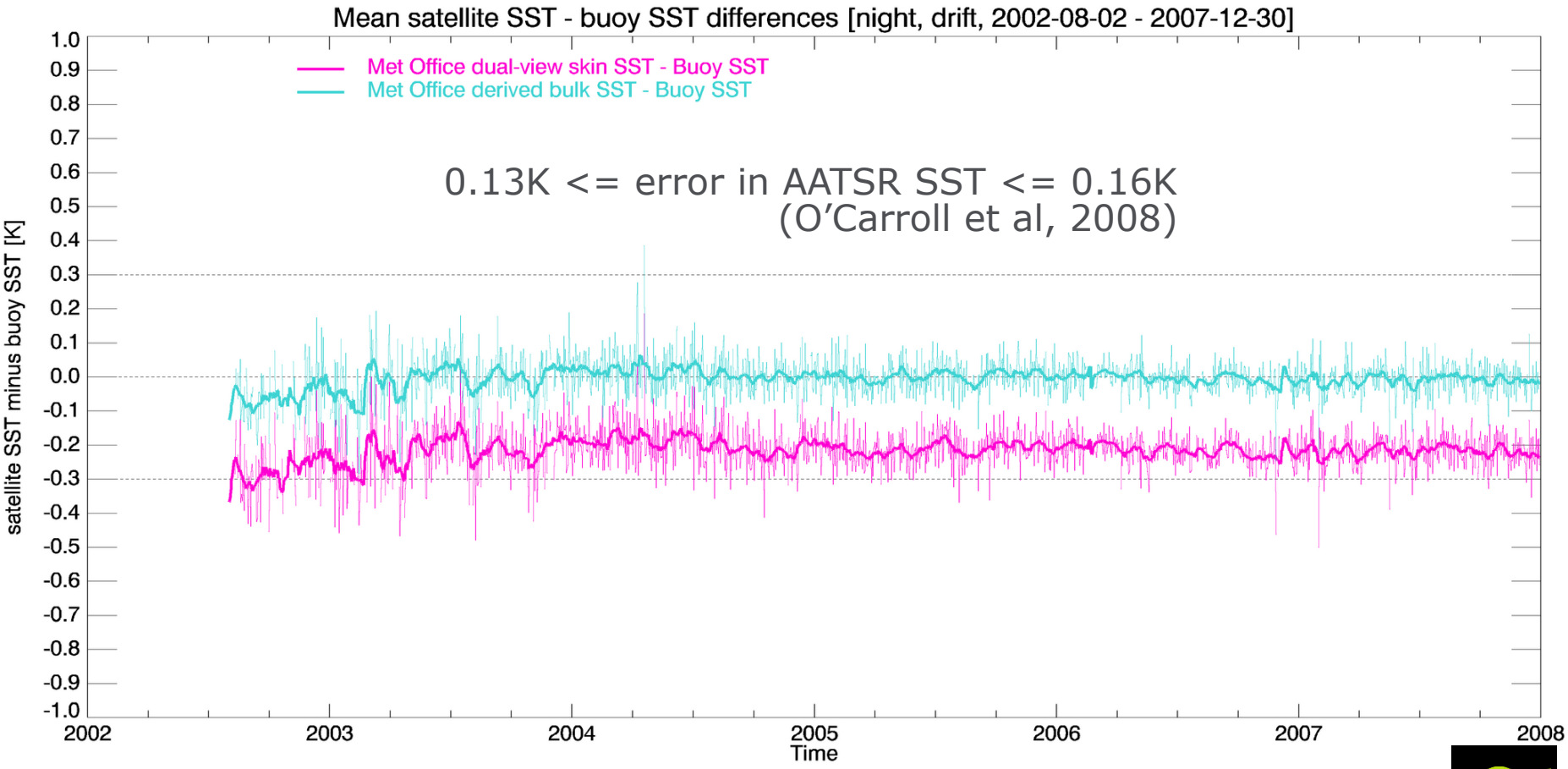
- Predicted 12–25 cm. of snow over the Baltimore–Washington metropolitan area with 2–3 days lead
- **Actual snowfall was zero…**
- Eta exhibited westward bias in predicted snowfall patterns.
- Concluded that errors in the mslp and precip. forecasts were either directly coupled to or indirectly dependent on the Atlantic coast SST distribution
- **High resolution SST matters to NWP**
- RTG_SST became operational 30 January 2001

Satellite SST biases



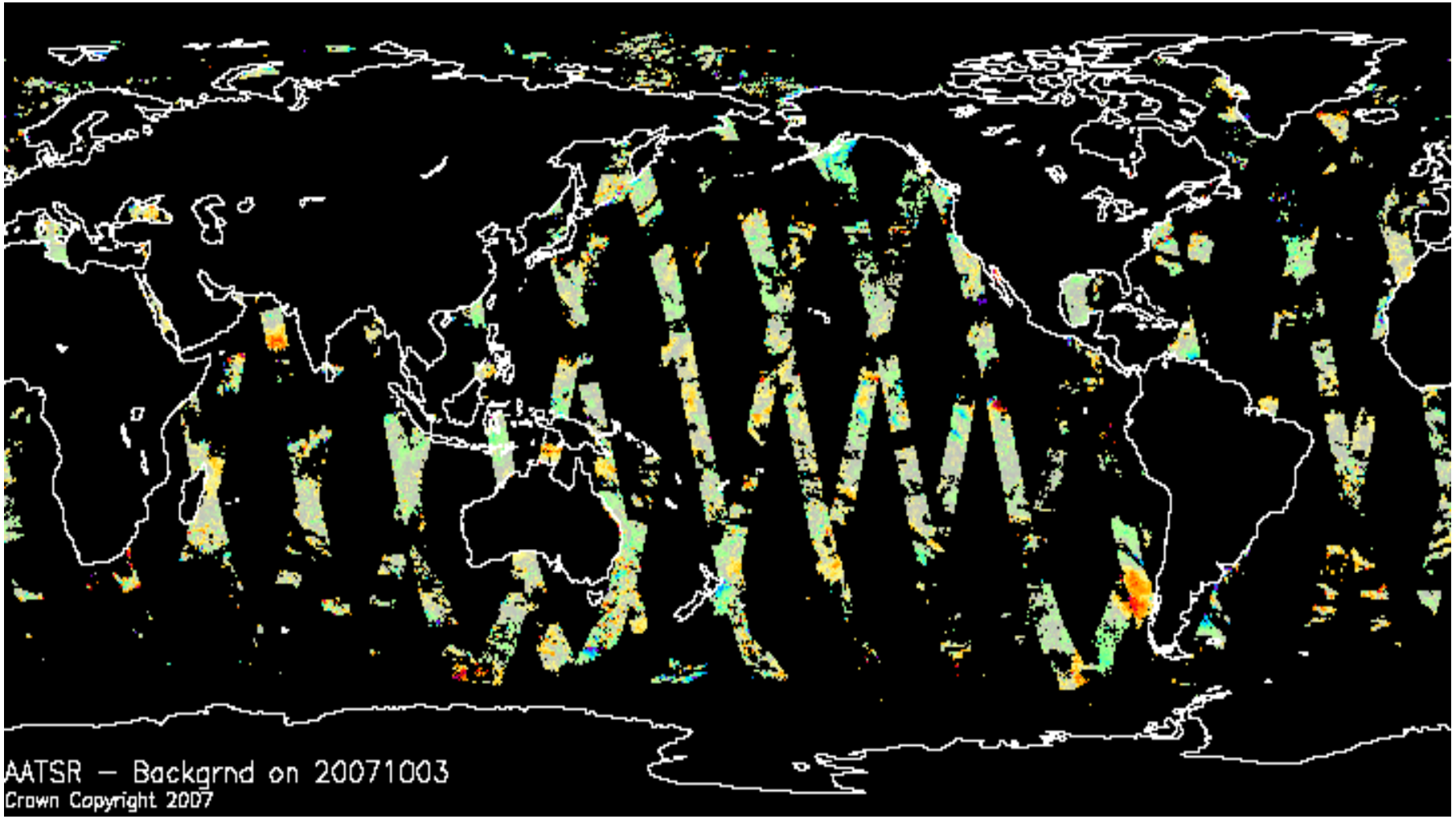
Doug May, NAVOCEANO)

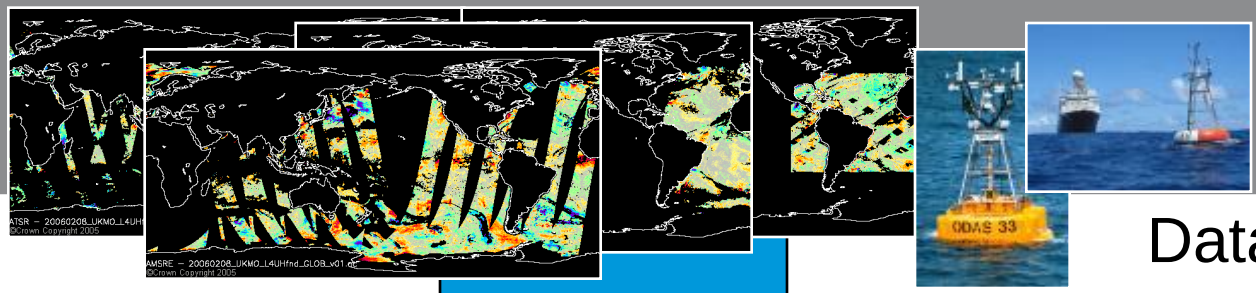
AATSR stability and accuracy (METEO product)



(R Saunders)

Typical NRT 24 hour coverage of AATSR





Data Sources

OSTIA Basic Architecture

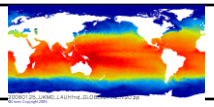
Database

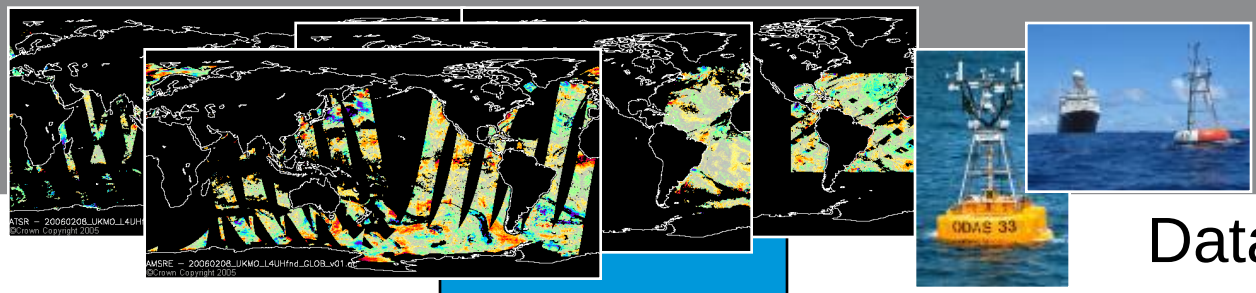
Quality Control
-Background check -Diurnal warming flagging

Satellite Bias Estimation
-Find match-ups -O.I. estimate.

Analysis
-Using 2 background error scales
-Spatially varying backgrd. errors

Anomaly Persistence Forecast
With weak relaxation to climatology

Daily SST 



Data Sources

OSTIA Basic Architecture

Database

Quality Control

-Background check -Diurnal warming flagging

Anomaly Persistence Forecast

With weak relaxation to climatology

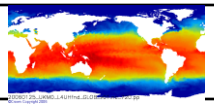
AATSR is a fundamental component of the OSTIA bias correction

Analysis

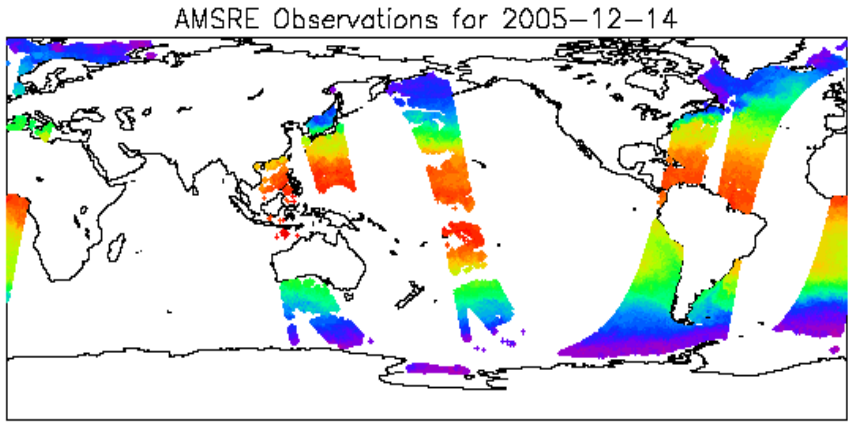
-Using 2 background error scales

-Spatially varying backgrd. errors

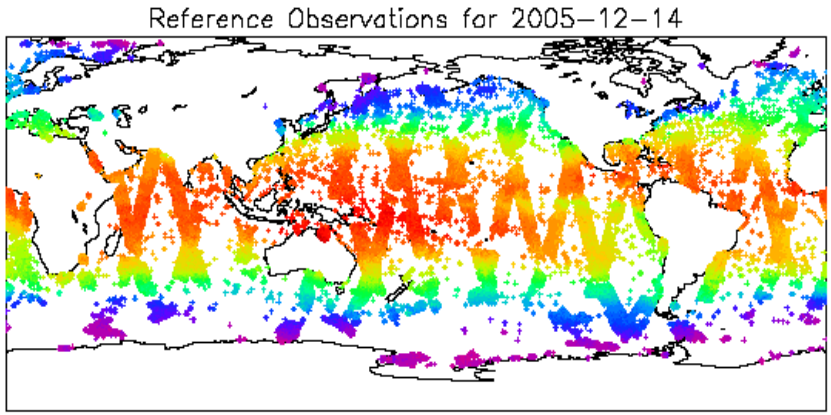
Daily SST



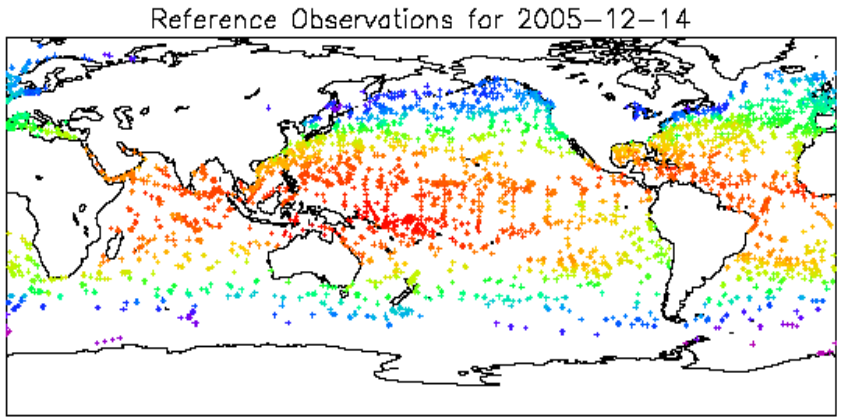
Bias correction : The Importance of AATSR (used ALL data every day)



AMSR-E Observations for 14 Dec. '05



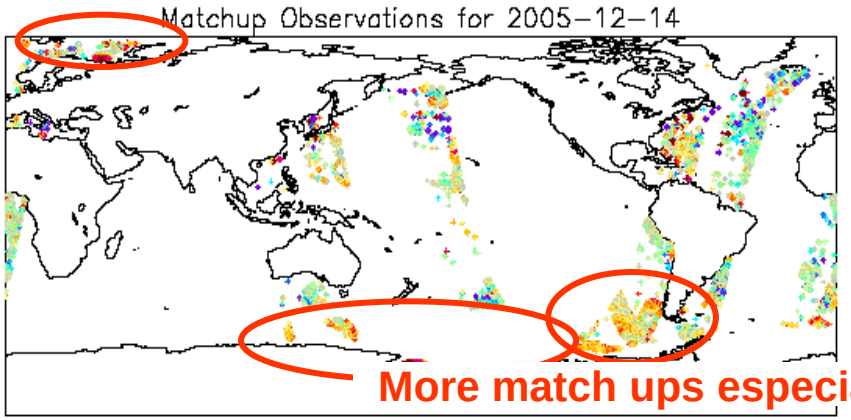
Reference observations (With AATSR)



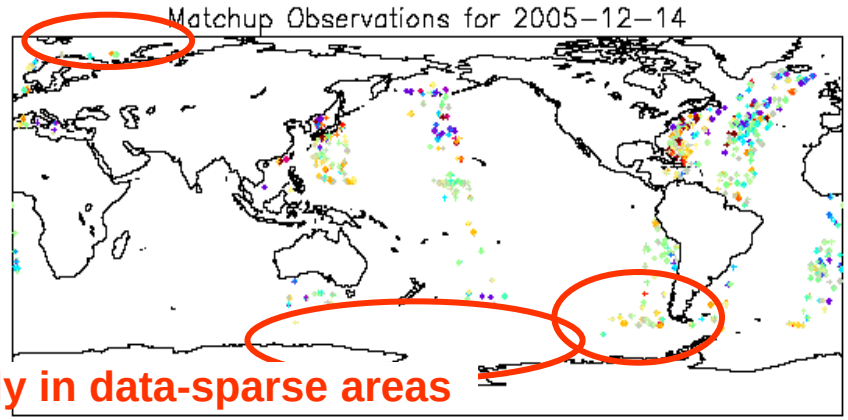
Reference observations (No AATSR)

Impact of AATSR on AMSRE bias correction for 14 Dec

In situ + AATSR

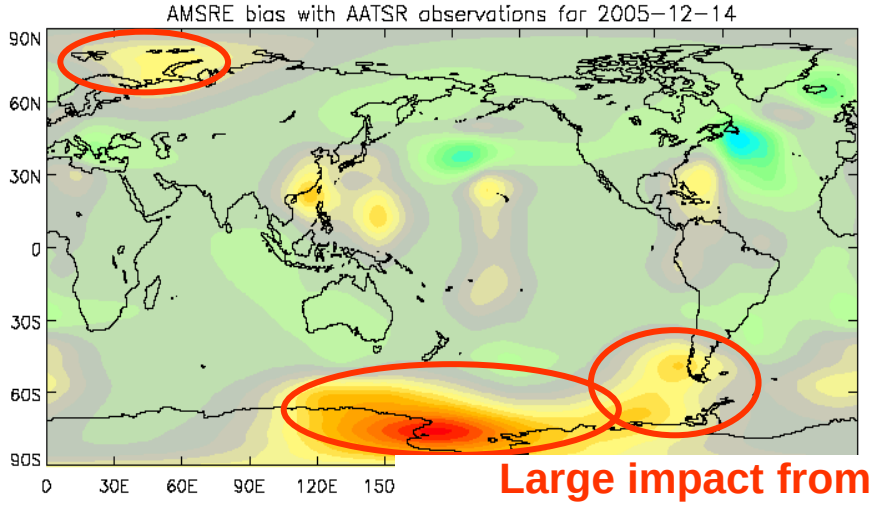


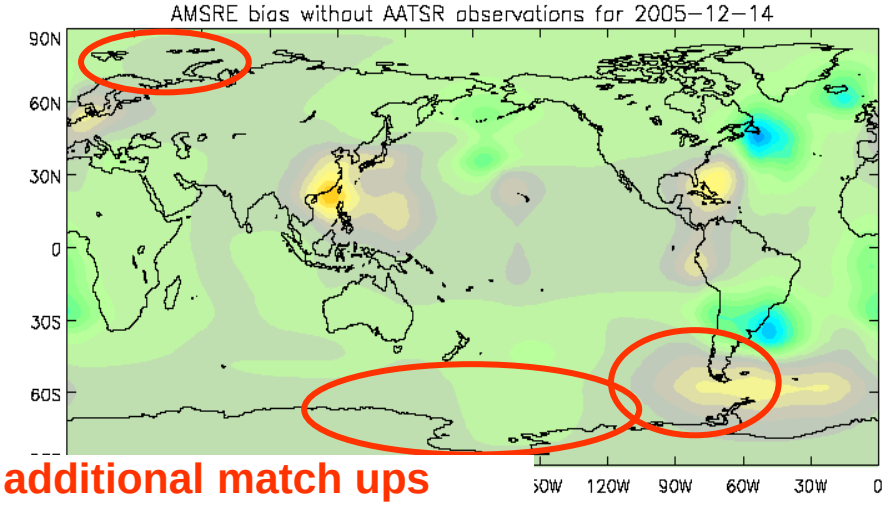
In situ only



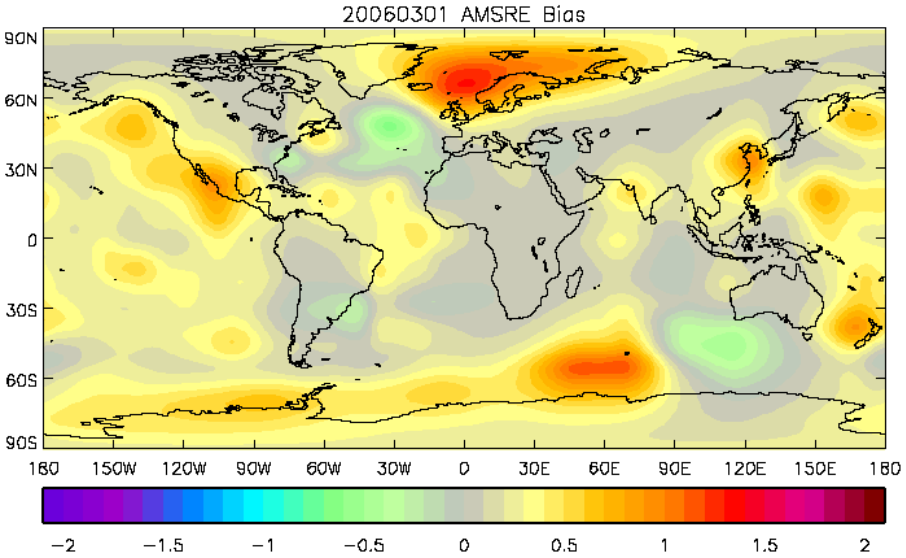
More match ups especially in data-sparse areas

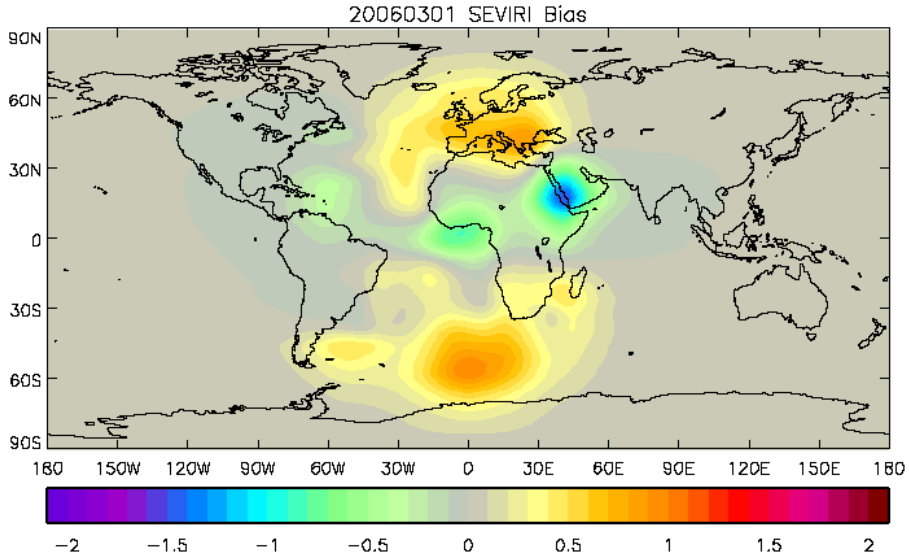
Match ups (<25km)

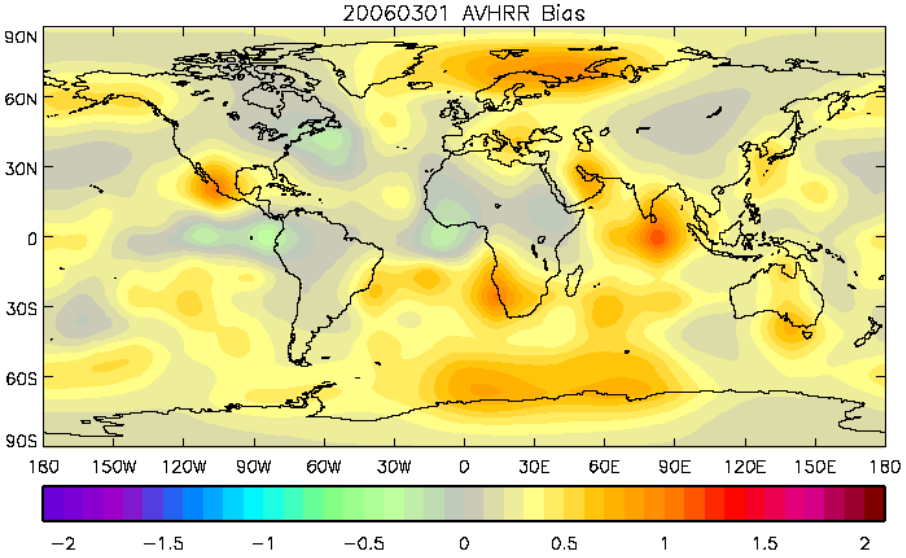


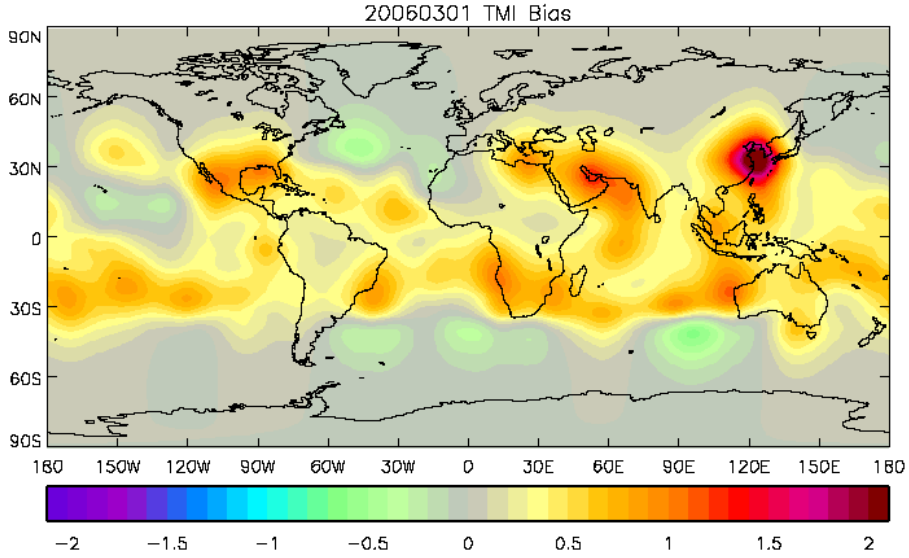


Large impact from additional match ups



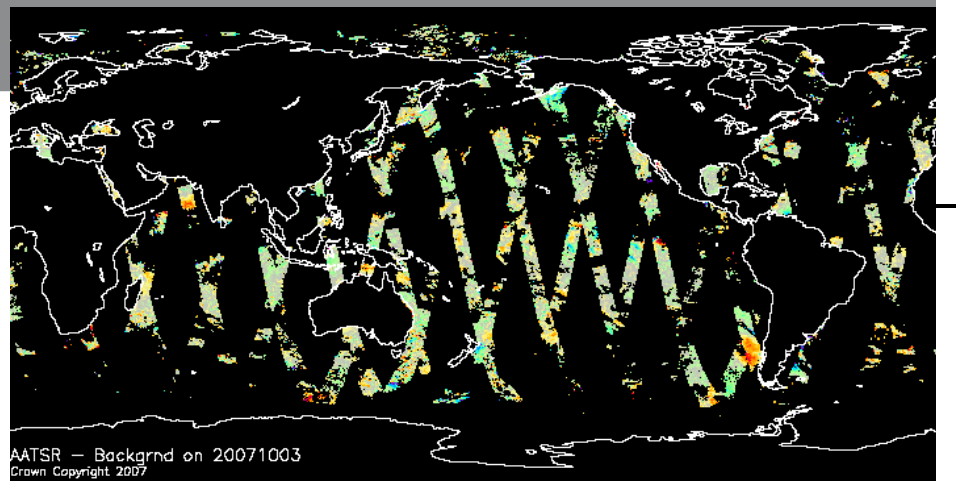


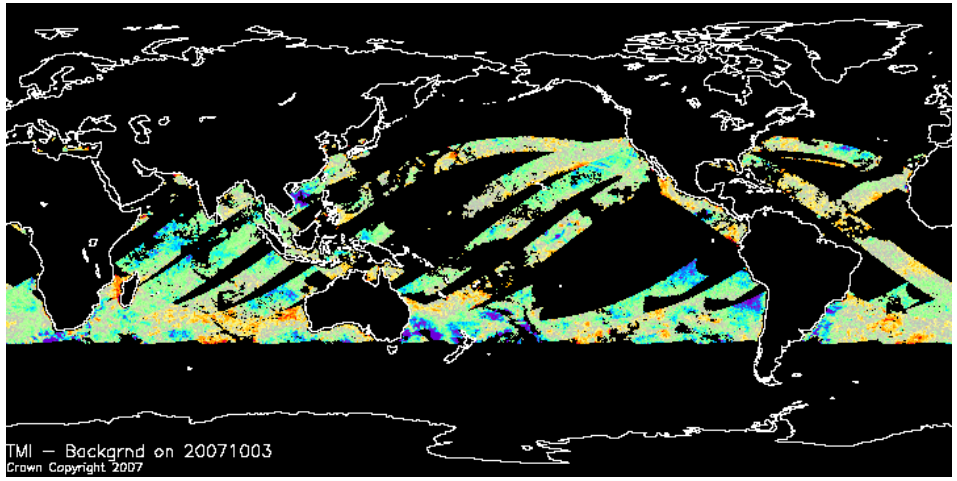


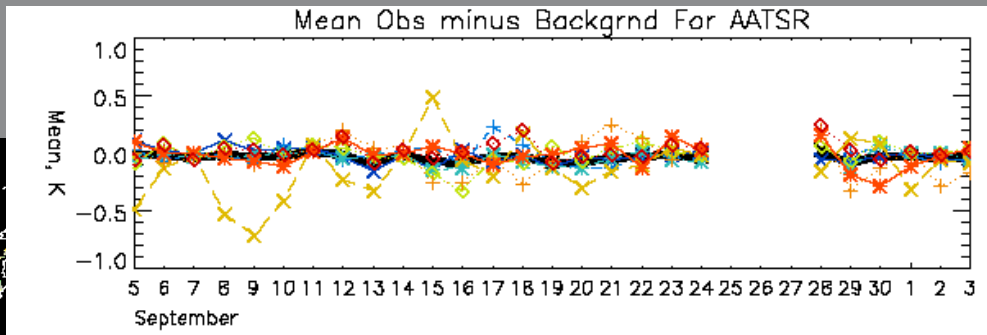


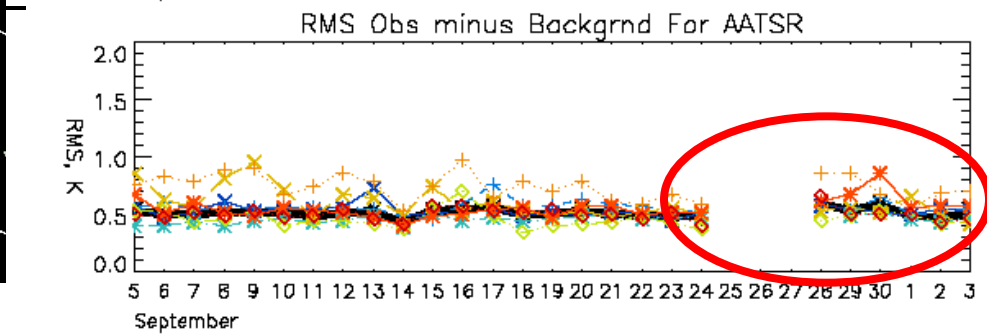
Bias correction (K)

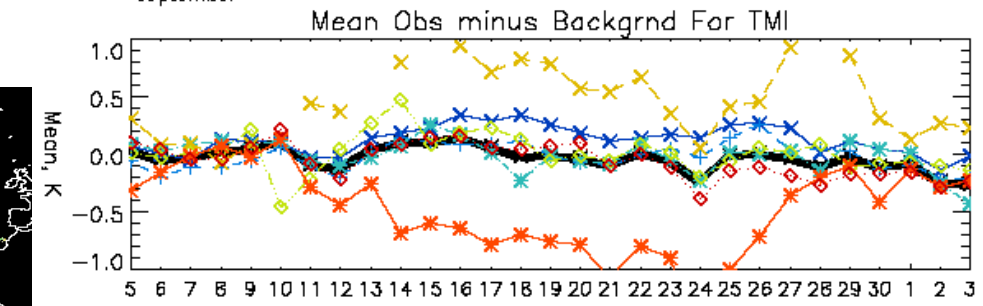
Operational monitoring

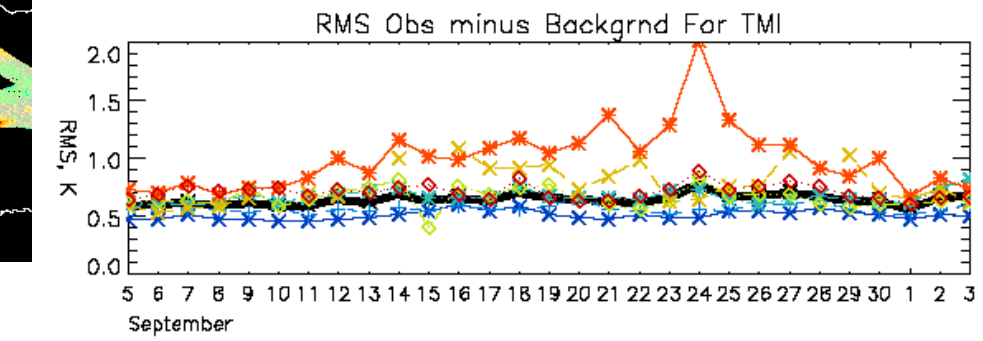




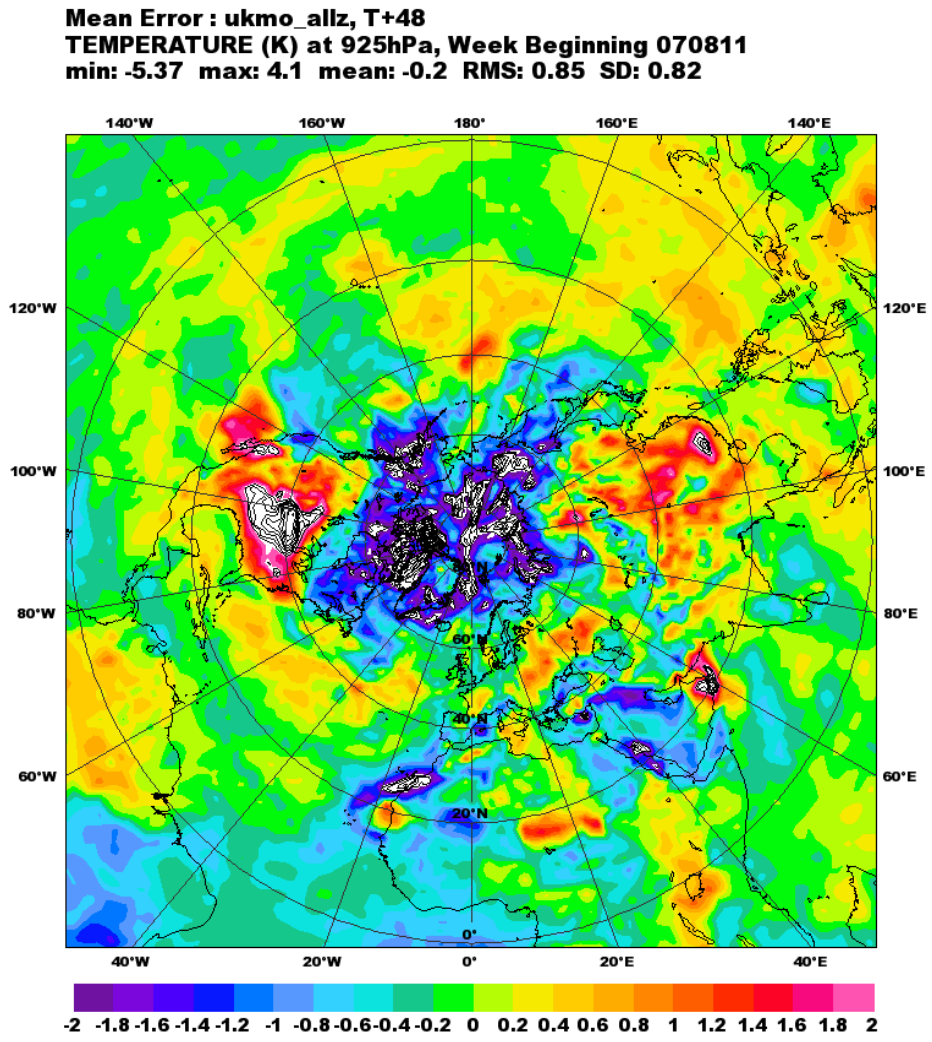








Anomaly differences over 7 days September 2007 – Minimum ice coverage in Arctic

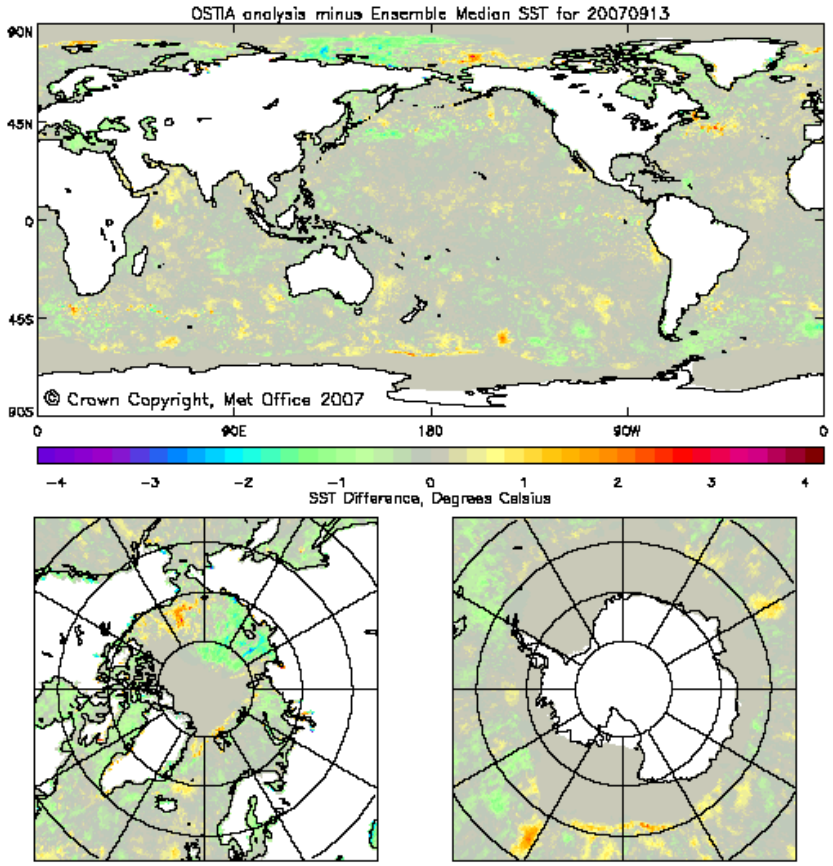


Temperature Bias at 925 hPa, 48hr forecasts

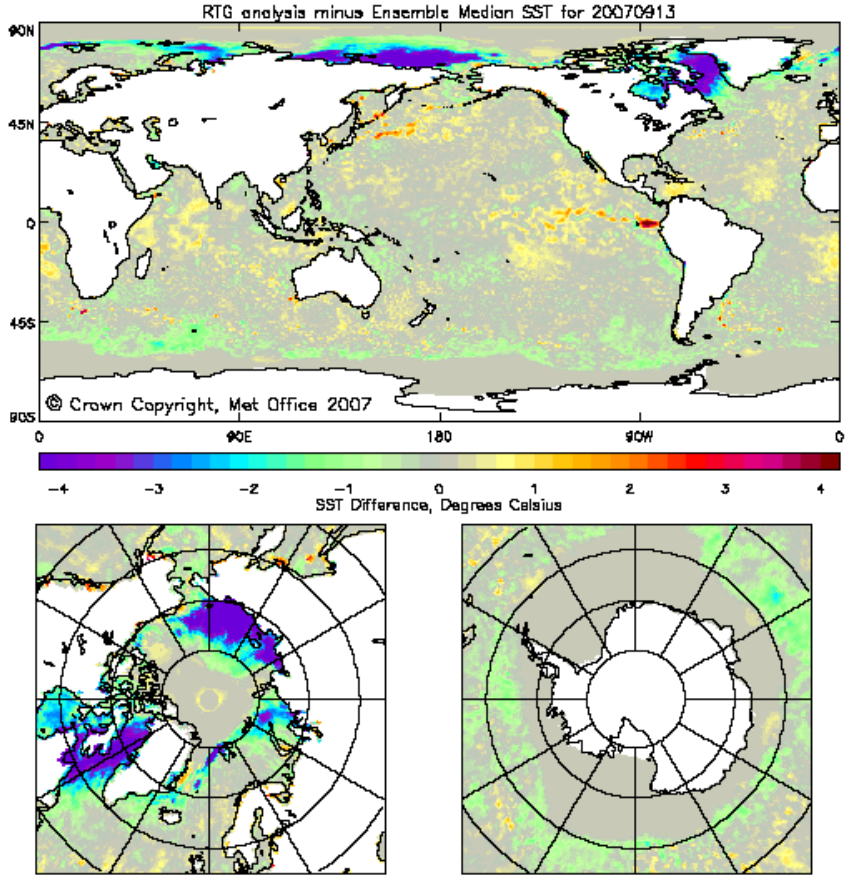
11th August 2007

Fixing the problems…

OSTIA - ensemble

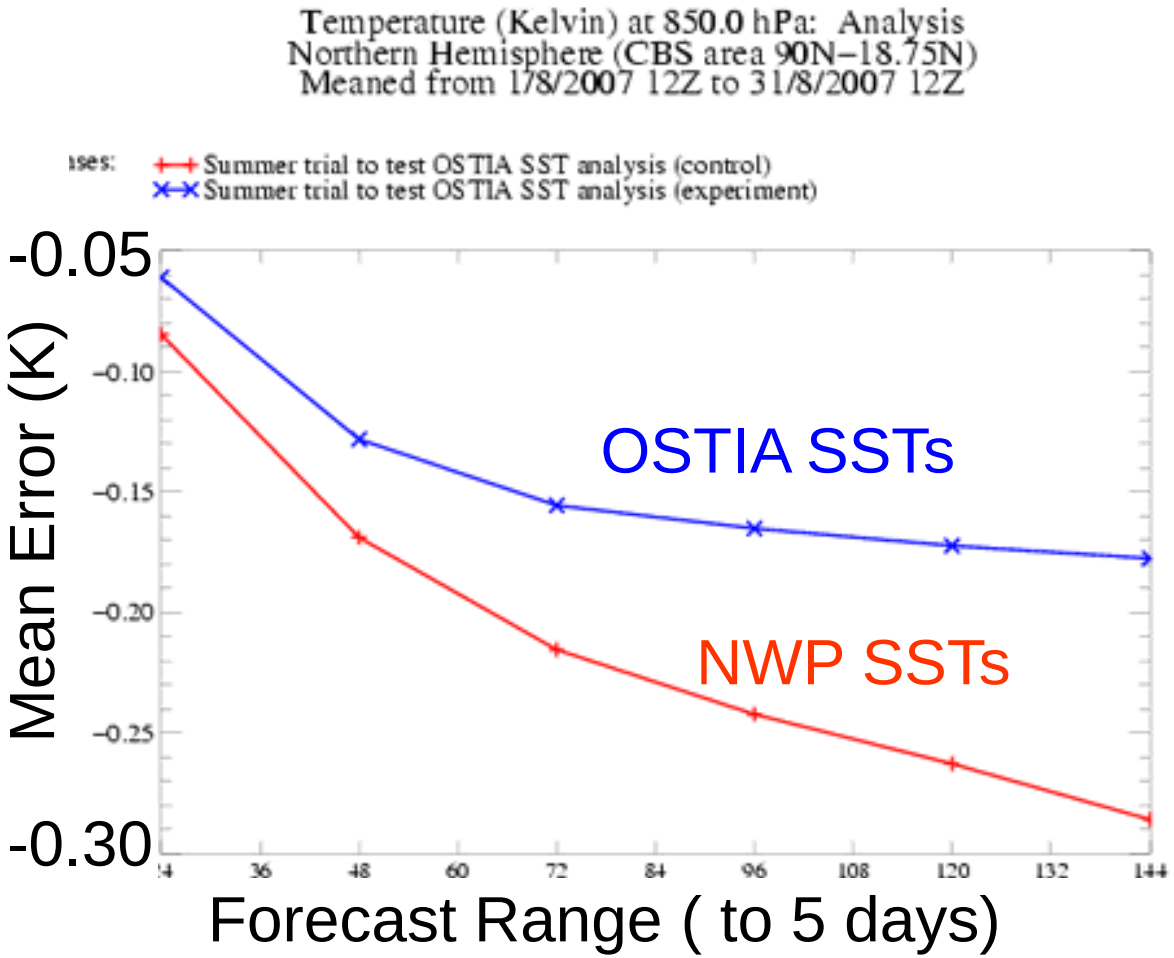


RTG - ensemble

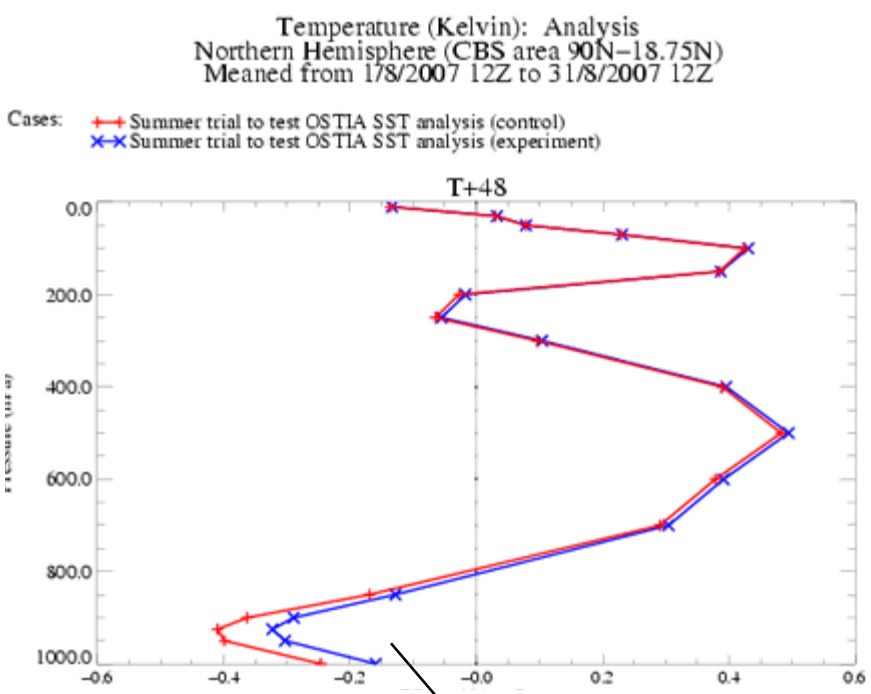


- RTG SST didn't capture the Arctic warming.

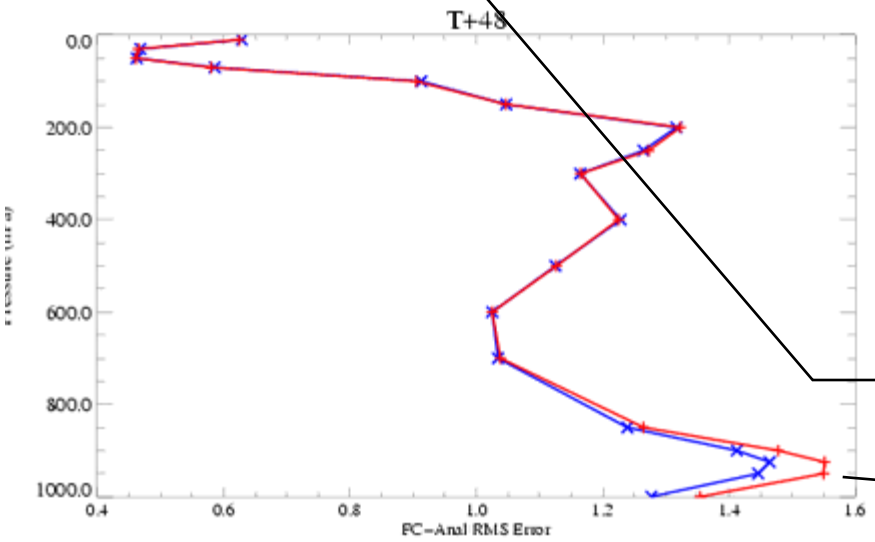
Met Office: August 2007 NWP Trial Results



- OSTIA SSTs substantially reduced the negative bias seen with NWP SSTs at 850hPa.



Mean Error



RMS Error

- N Hem. Temperature profiles @ T+48
- OSTIA improved the RMS and bias in the NWP forecasts during the trial period.
- AATSR underpins the OSTIA system

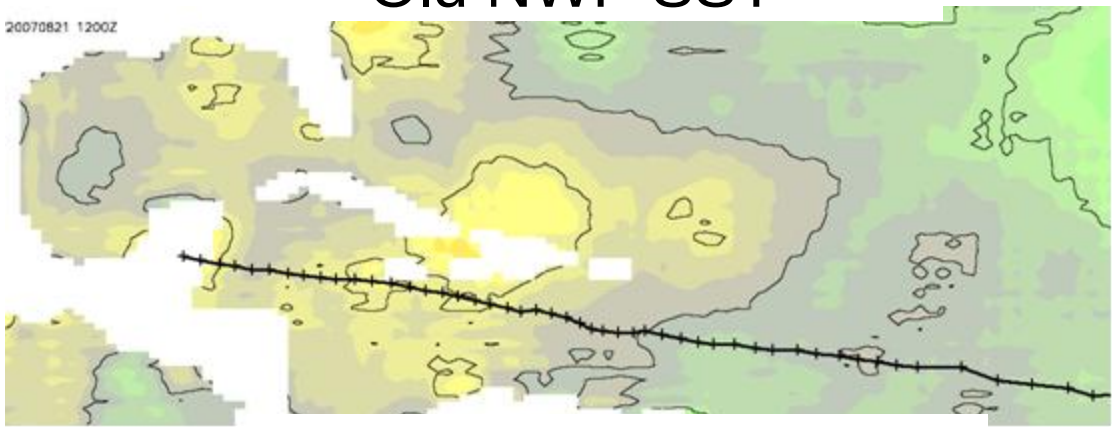
Reduced Bias at low levels

Hurricane Dean - 21st August 2007

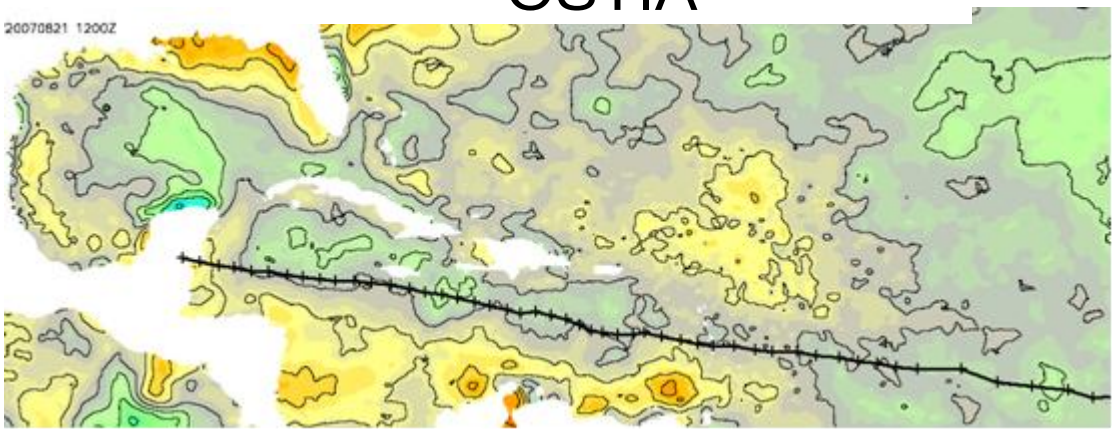
- Cold water upwelling in the wake of Hurricane Dean
- Significant improvement in NWP SST boundary conditions

Hurricane Dean - 21st August 2007

Old NWP SST



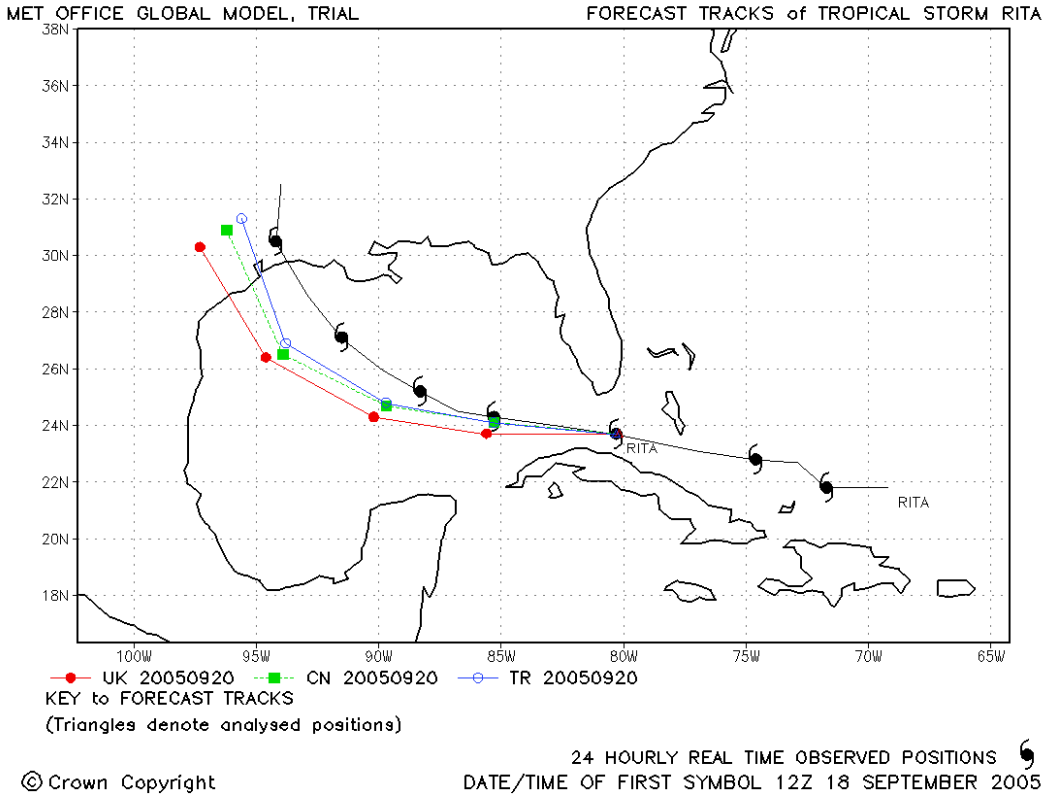
OSTIA

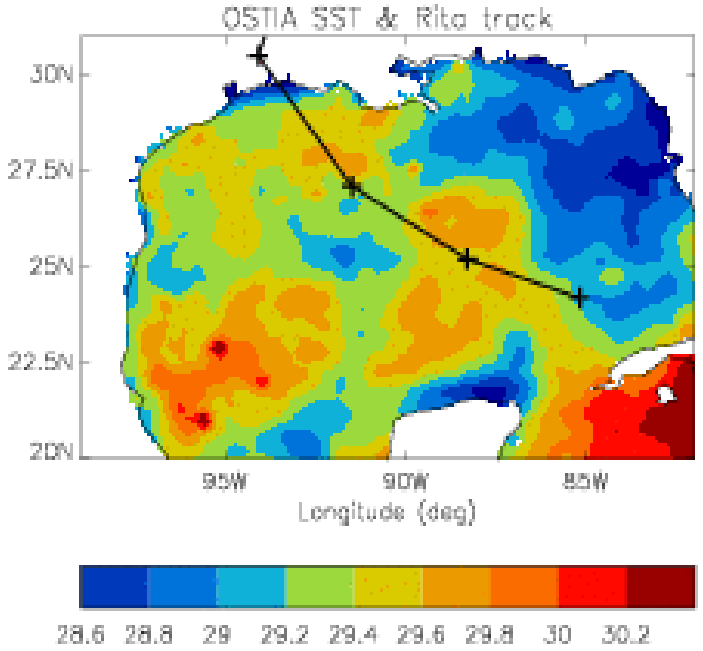


- Cold water upwelling in the wake of Hurricane Dean
- Significant improvement in NWP SST boundary conditions

SST minus Climatology :
Contours at 0.5° intervals.

High Resolution SST improves Hurricane Rita trajectory track error





(M. McCulloch& J Hemming)

Track error: OSTIA=1.85, NWP=2.17. Better with OSTIA.

Future perspectives…

- Today, ***all AATSR data are used*** whenever they are available in every weather forecast
- AATSR satellite observations for bias adjustment are a pre-requisite for success in this strategy – now being used in USA, Australia and in France…
- As the NWP forecast is pushed out beyond 7 days SST becomes extremely important
  - especially in the coupled ocean-atmosphere case where ocean SST's will be at the atmospheric model grid-resolution
  - NWP grid resolutions of 4 - 10km are planned within a limited area NWP multi-model ensemble prediction systems (local scale may be 1-2km)
  - A flexible observation network targeting data sparse areas

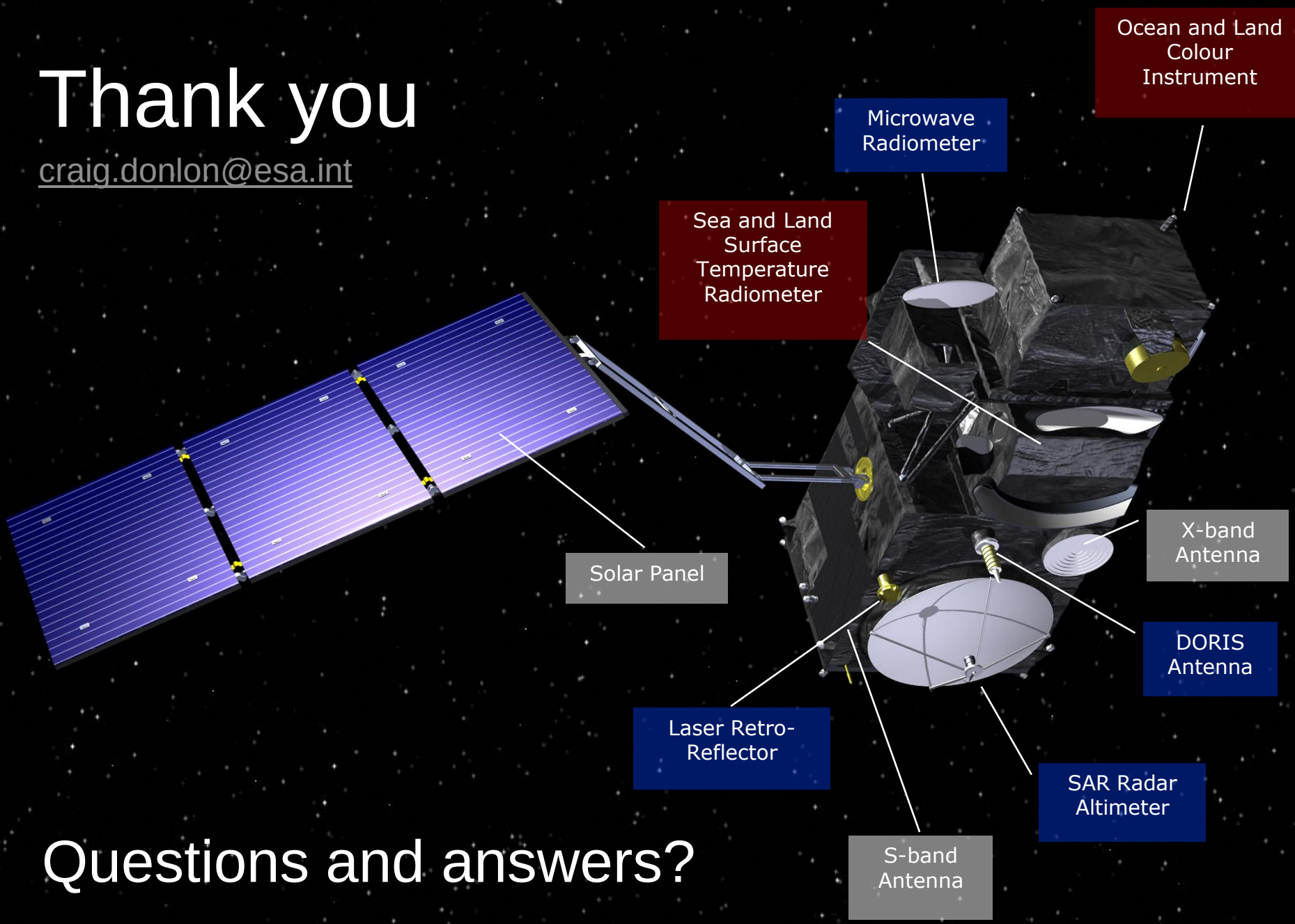
Take Home Message

- AATSR continues to provide the SST reference measurements for NWP SST analyses – every day – around the world!

- The dream has come true…

Thank you

craig.donlon@esa.int



Questions and answers?

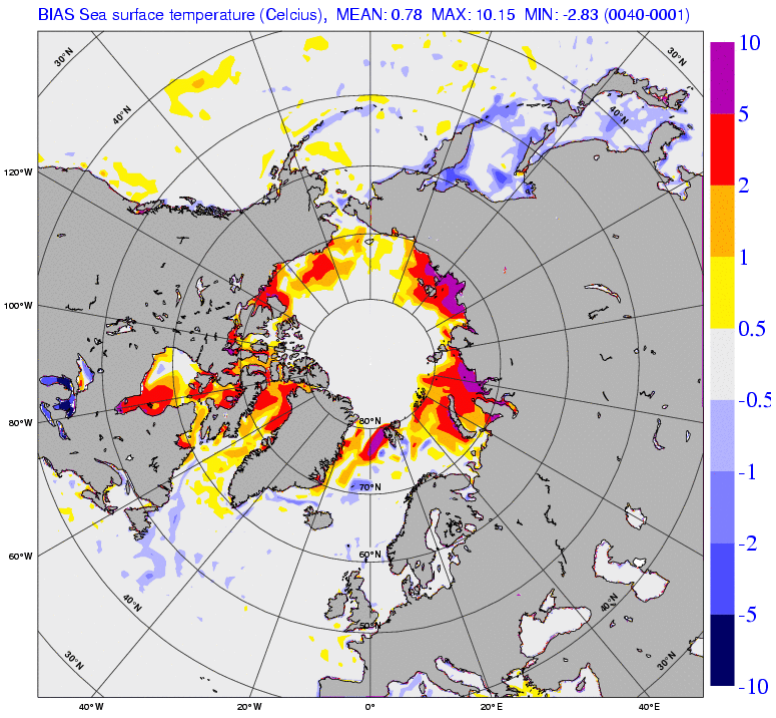
Use of OSTIA at ECMWF

(M Drusch)

OPER / NCEP SST
- **RTG SST**
- **0.5 x 0.5 degrees**

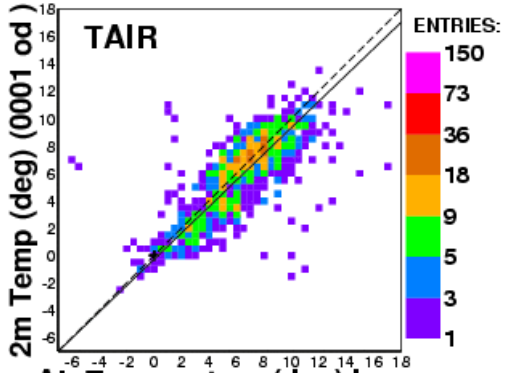
Validation against buoy data (North of 70 N, August 2008)

OSTIA / GHRSST – OPER / NCEP

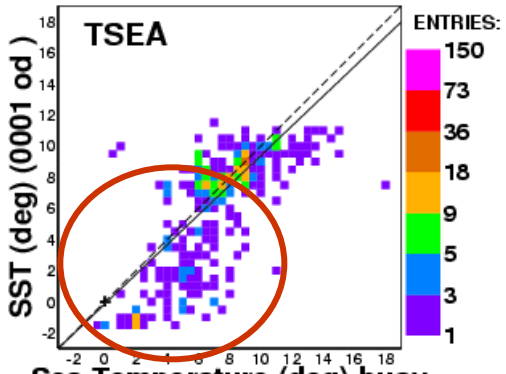


August 2008

OPER / NCEP

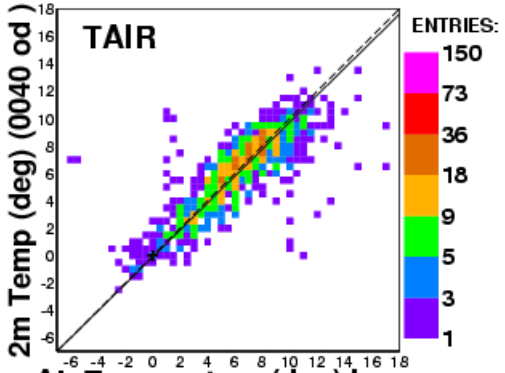


Comparison of analysed ECMWF air temperature with averaged buoy data.

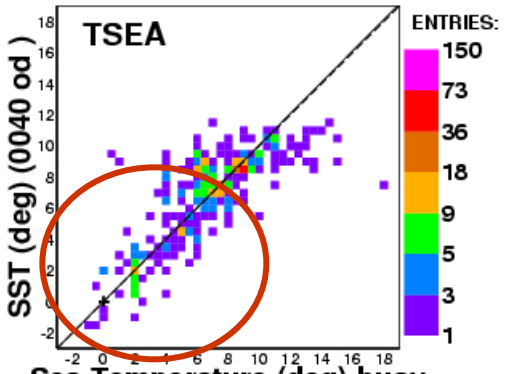


Comparison of analysed ECMWF sea temperature with averaged buoy data.

GHRSST / OSTIA



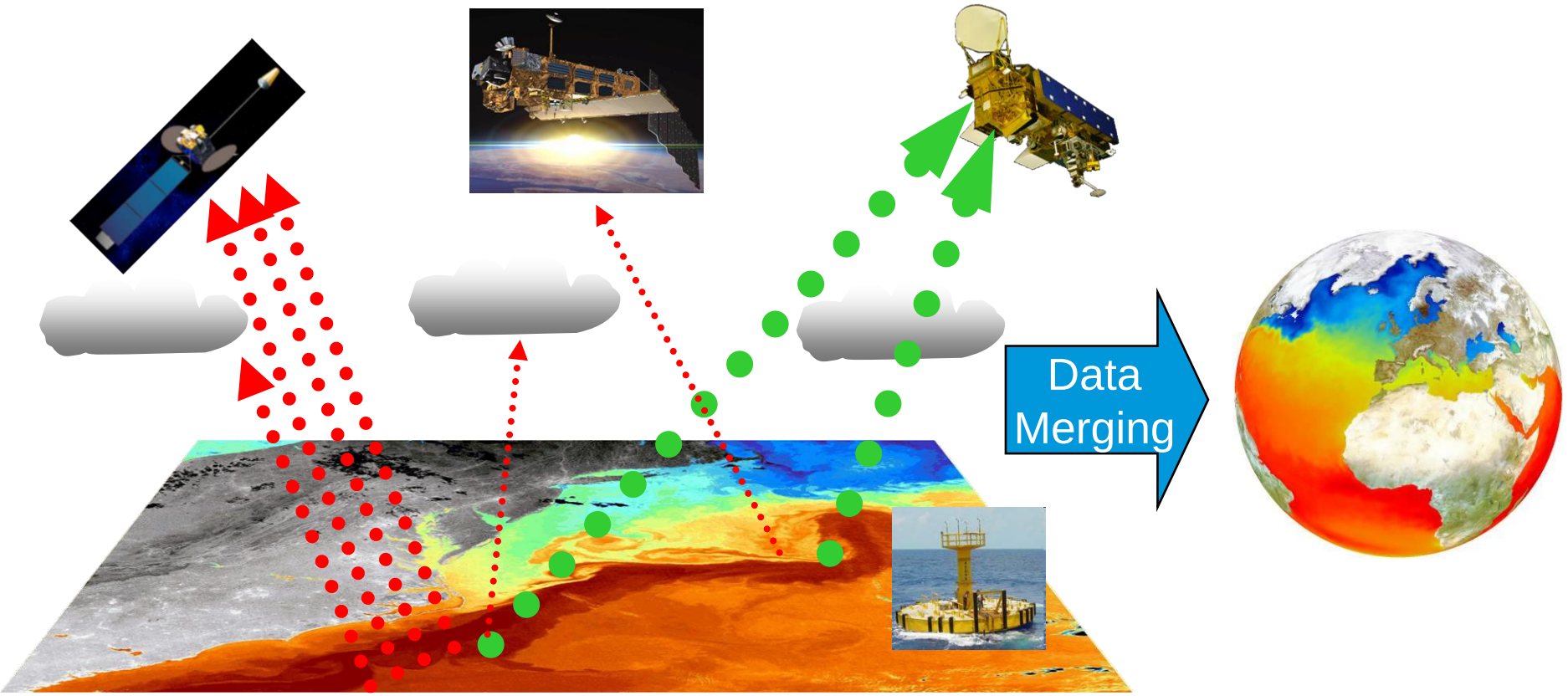
Comparison of analysed ECMWF air temperature with averaged buoy data.



Comparison of analysed ECMWF sea temperature with averaged buoy data.

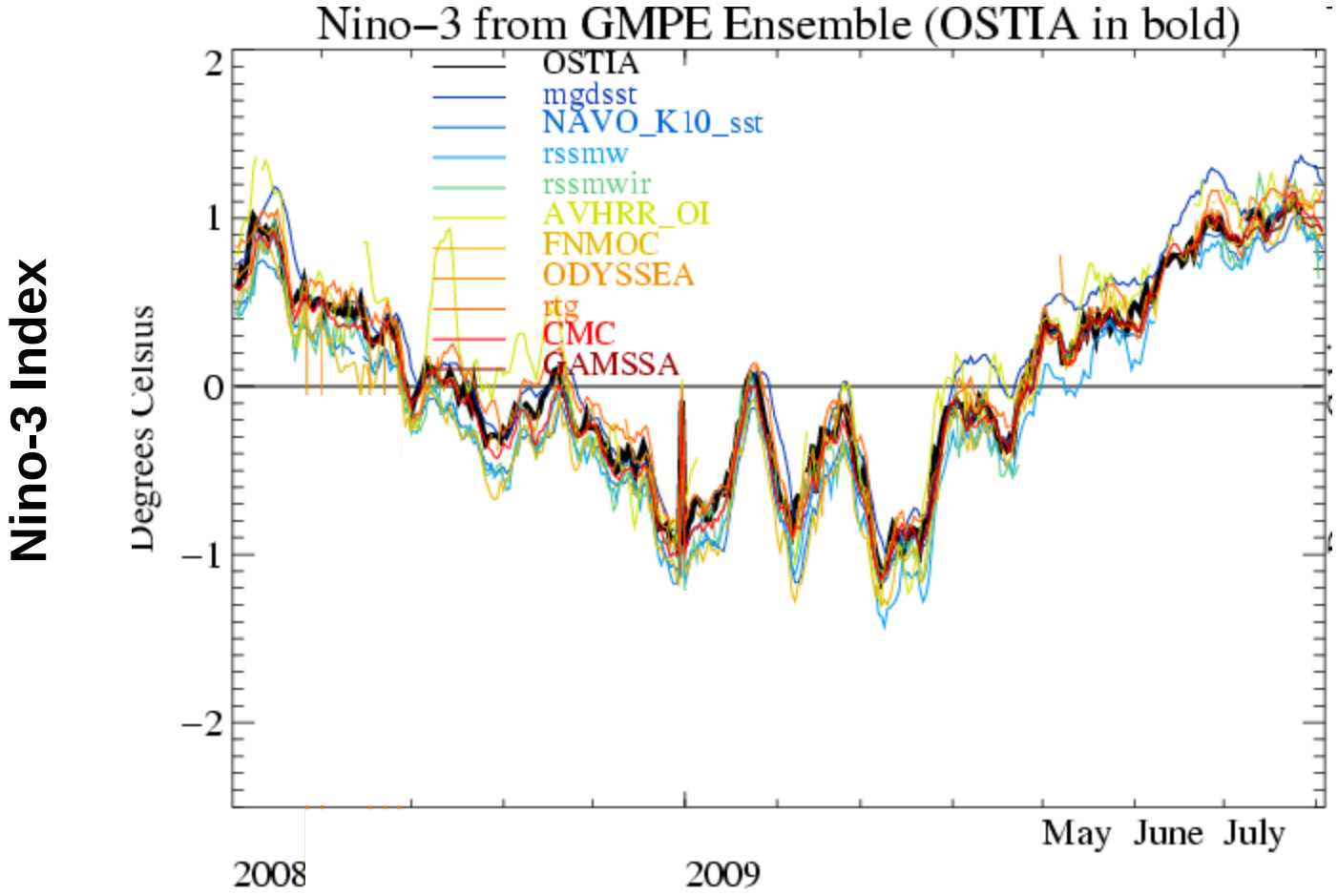
- Backups for Q&A

GHRSST Builds on EO complementarities

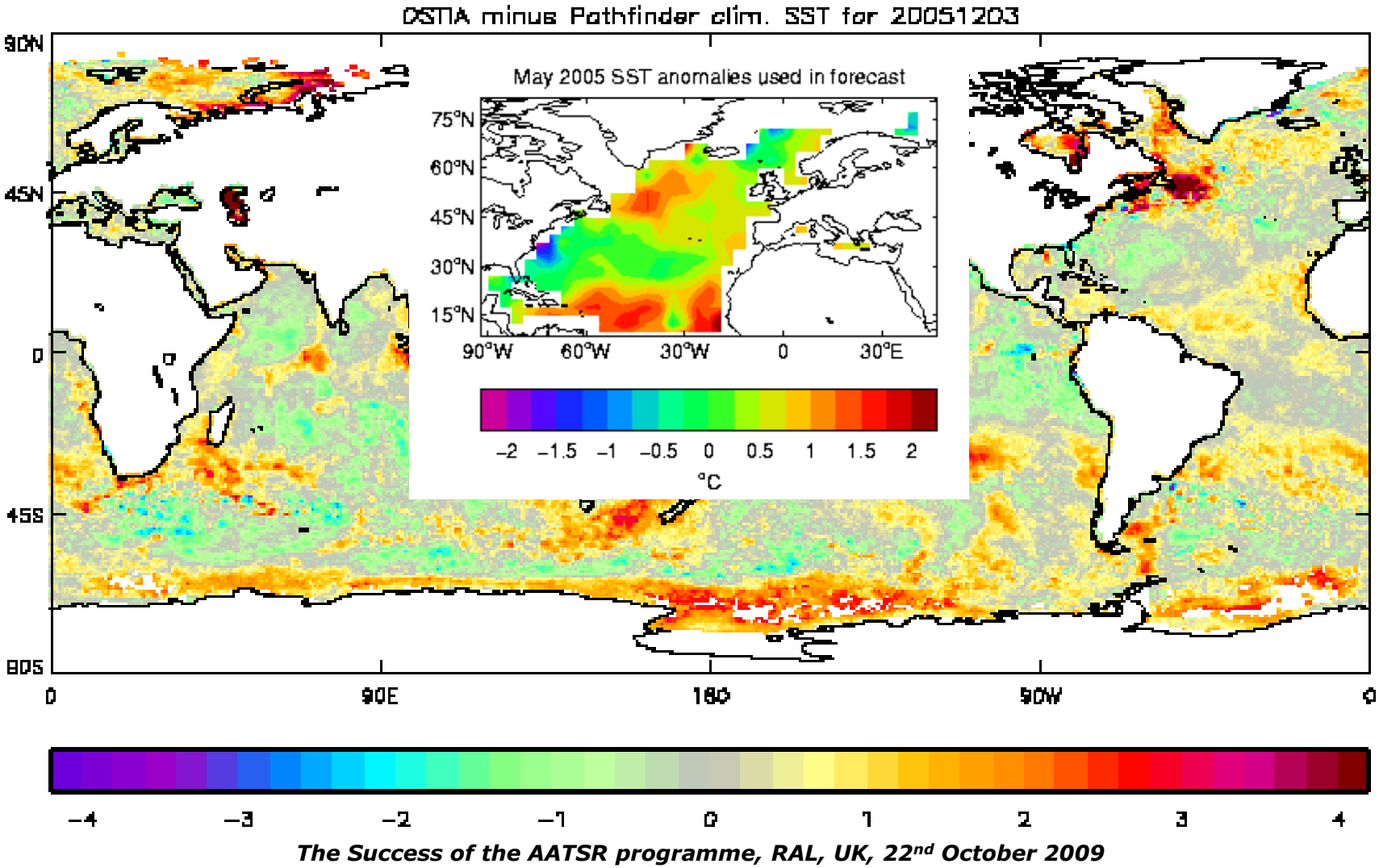


- Polar infrared has ***high accuracy & spatial resolution***
- Geostationary infrared has ***high temporal resolution***
- Microwave Polar orbiting has ***all-weather capability***
- In situ data provide ***reality in all weather conditions***

Nino-3 Index for Seasonal Forecasting

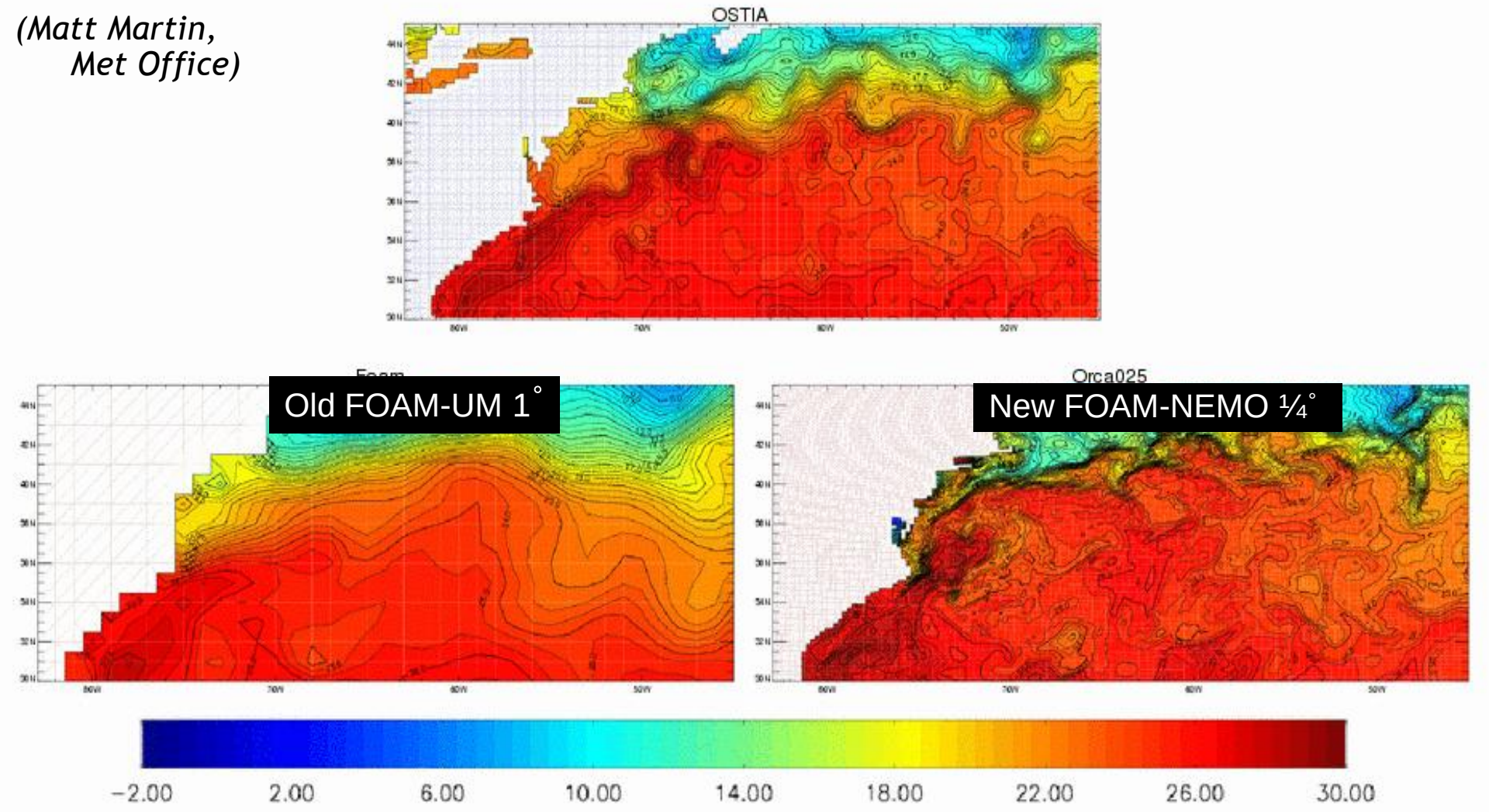


Seasonal Forecasting: Winter 2005/6



Met Office

(Matt Martin, Met Office)



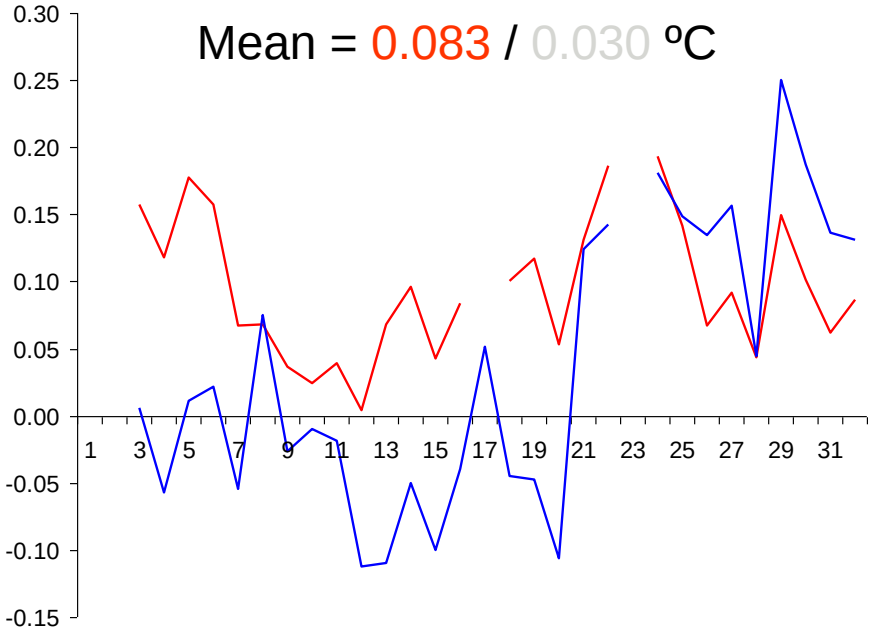
L2P data assimilation @ Met Office

North Atlantic 1/9º FOAM: validation against surface in situ observations

(Adrian Hines, Met Office)

24 hour forecast mean errors

Mean = 0.083 / 0.030 ºC

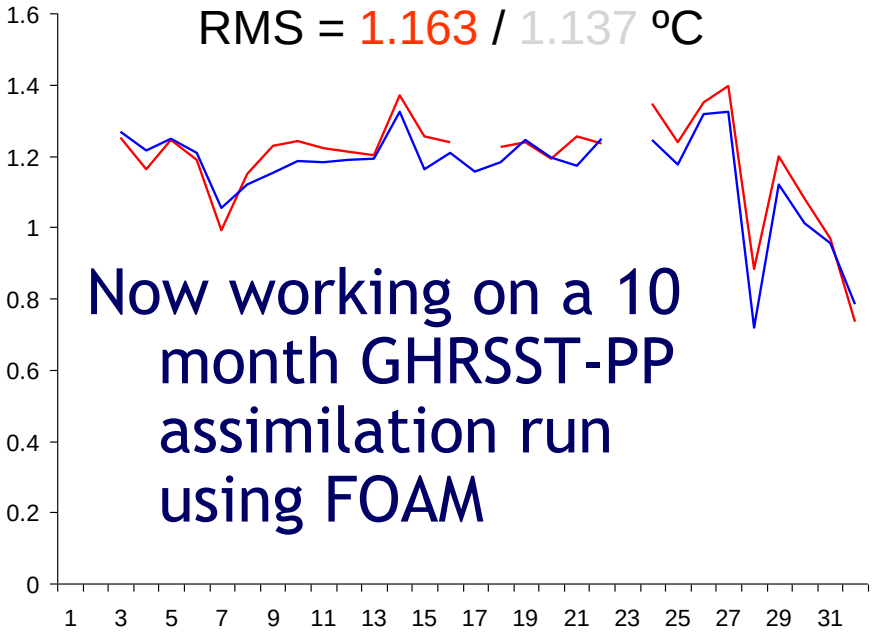


No Medspiration

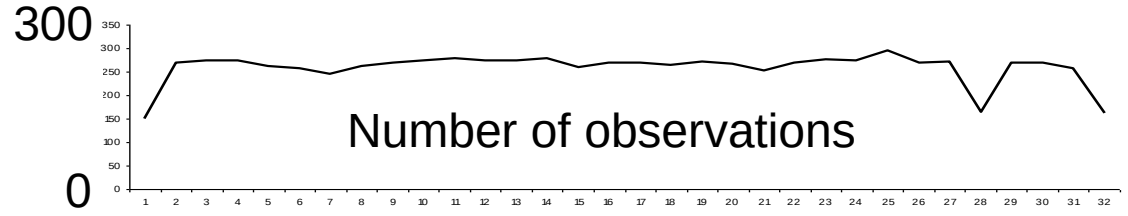
With Medspiration

24 hour forecast RMS errors

RMS = 1.163 / 1.137 ºC



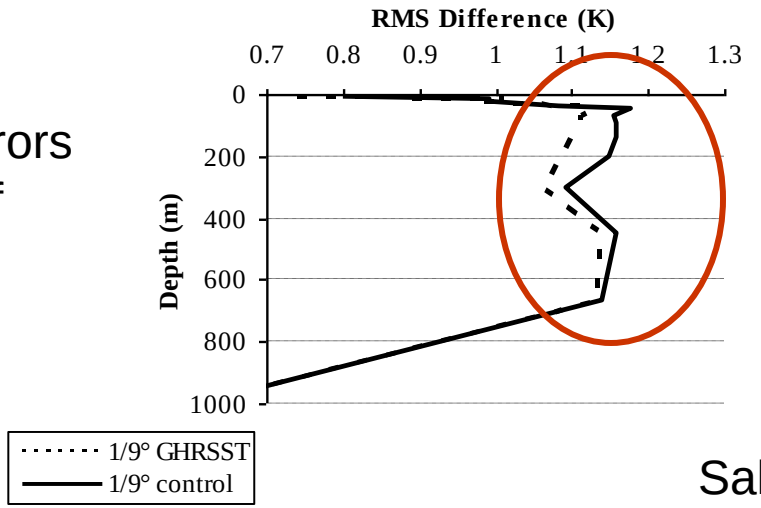
Now working on a 10 month GHRSST-PP assimilation run using FOAM

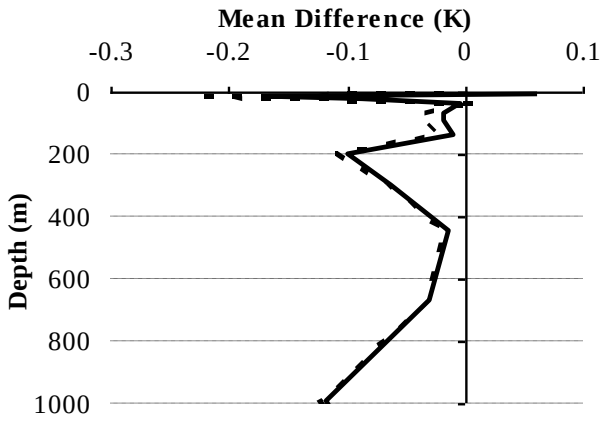


Impact of GHRSST in FOAM 1/9˚ ocean model - comparison with profile data

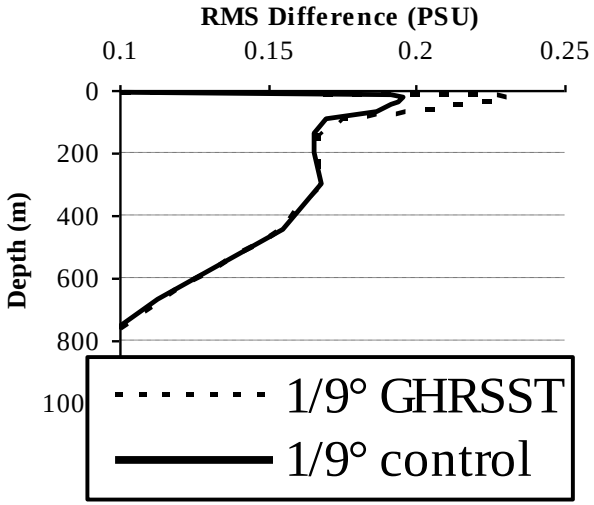
- GHRSST data reduces the RMS errors over the top 600m of ocean, with little change in the bias
- Near-surface salinity errors increased, particularly in NW Atlantic
- Reason for this is unclear at present – impact on stability?

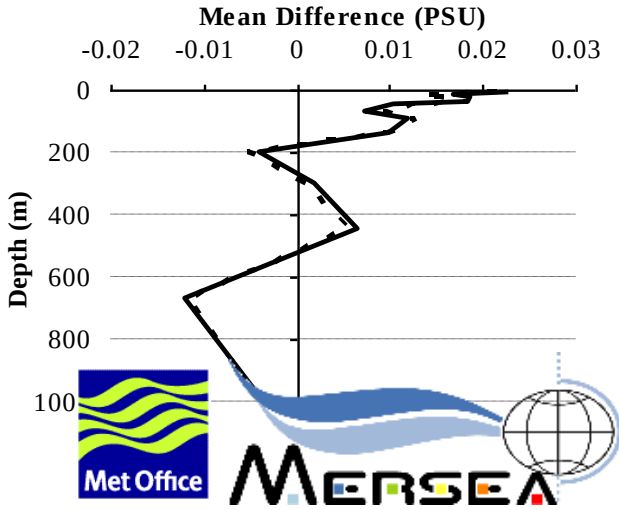
Temperature





Salinity

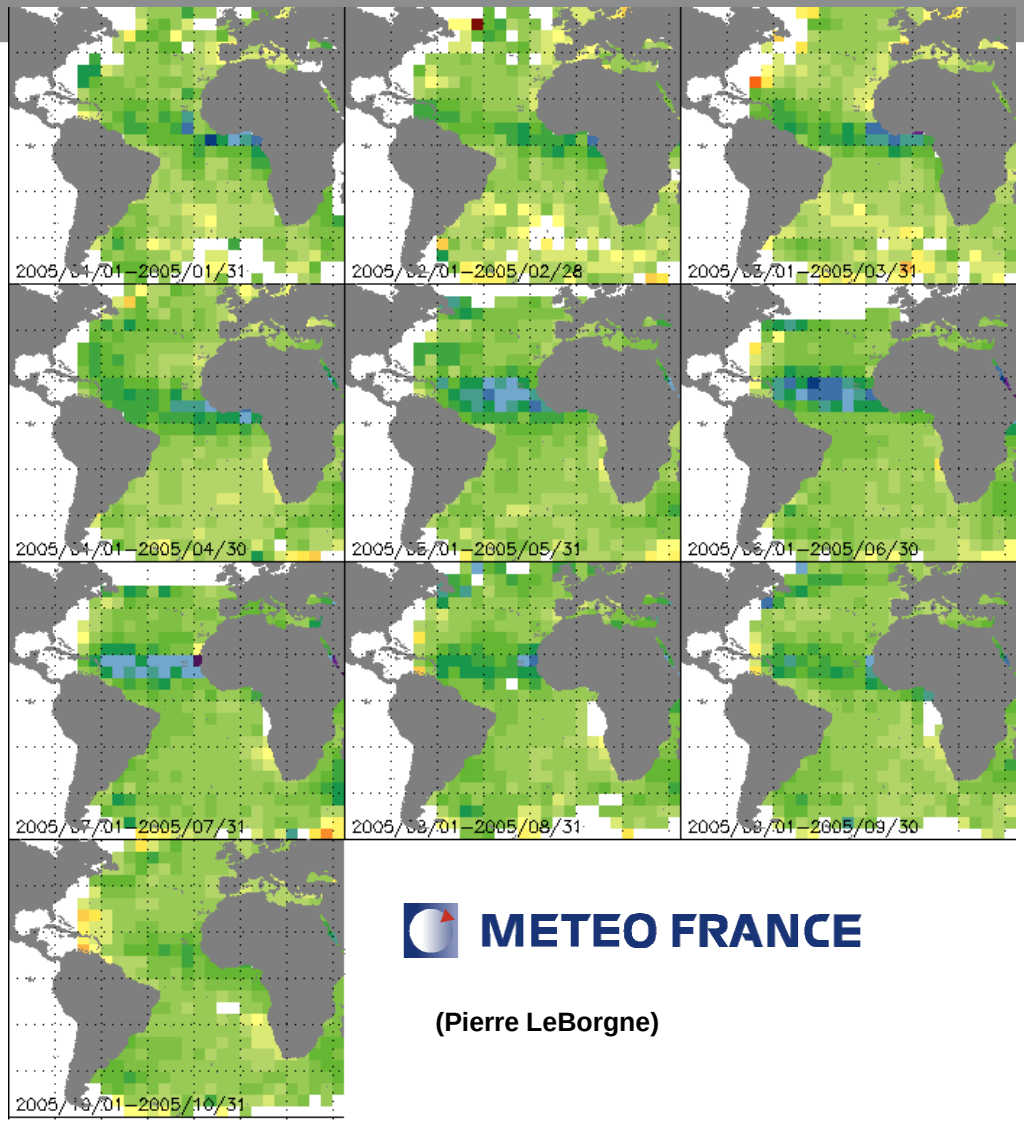




Validation against assimilated temperature profile data for April 2005.

GHRSST-PP L2P Inter-comparison – SEVIRI-AATSR (Saharan mineral dust)

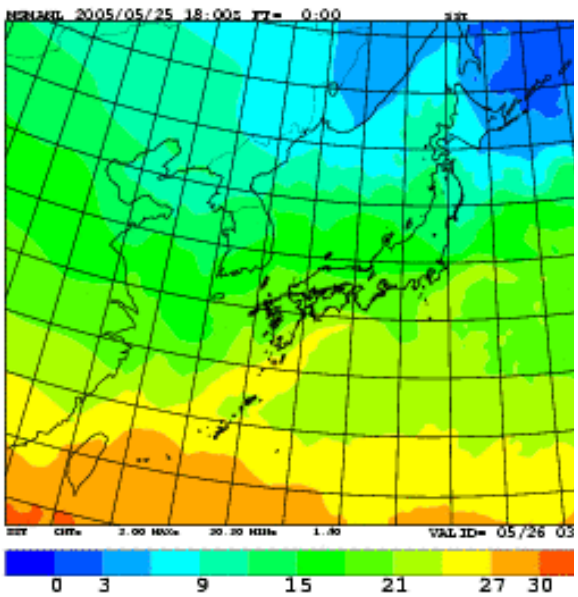
- Jan –Oct 2005 SEVIRI-AATSR (ATS_NR_2P)
- SEVIRI SST's corrupt due to Saharan Aerosol dust
- New correction strategy based on R/T modelling in prep. – Verification by AATSR

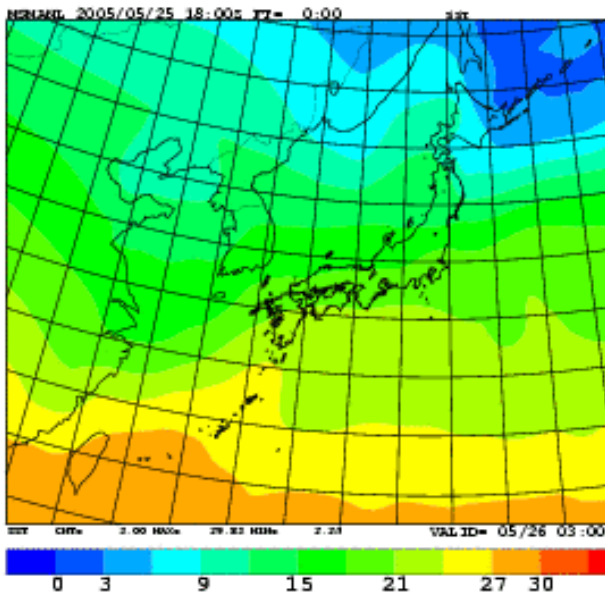


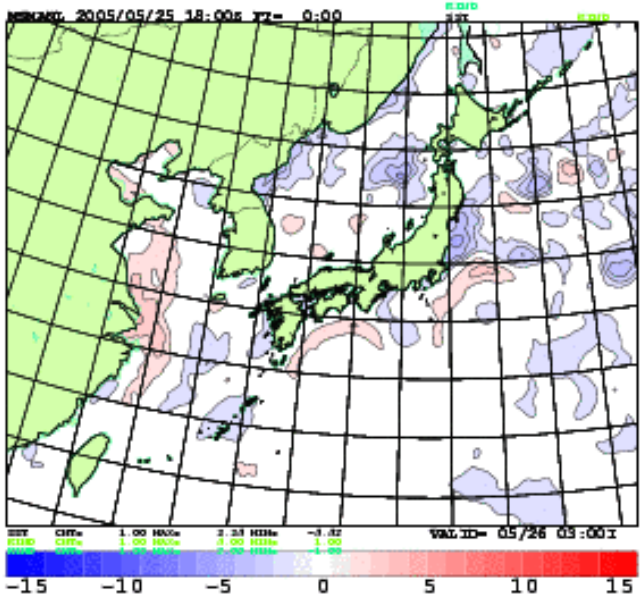
METEO FRANCE

(Pierre LeBorgne)

MGDSST and NPDSST (former SST analysis) on 24 May 2005 (T. Kuragano, JMA, Japan)







MGDSST
Spatial res.=0.25deg

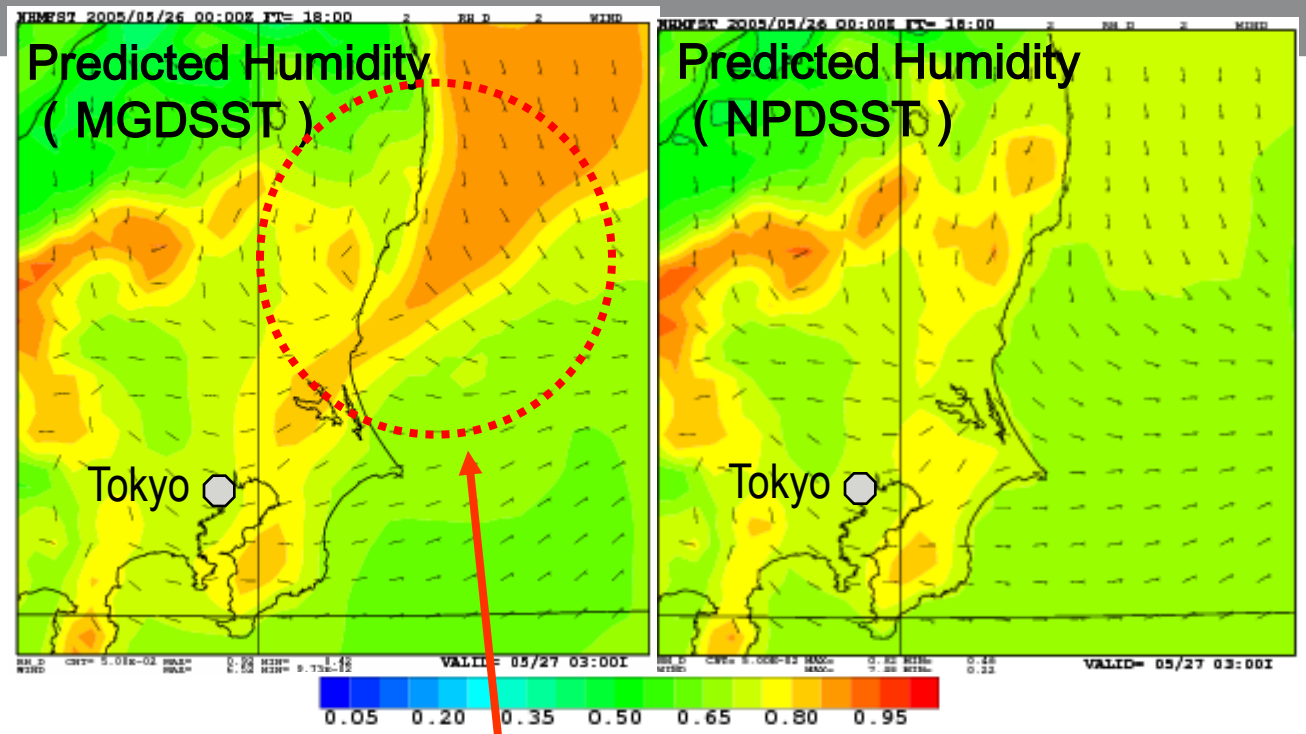
NPDSST
Spatial Res.=1deg

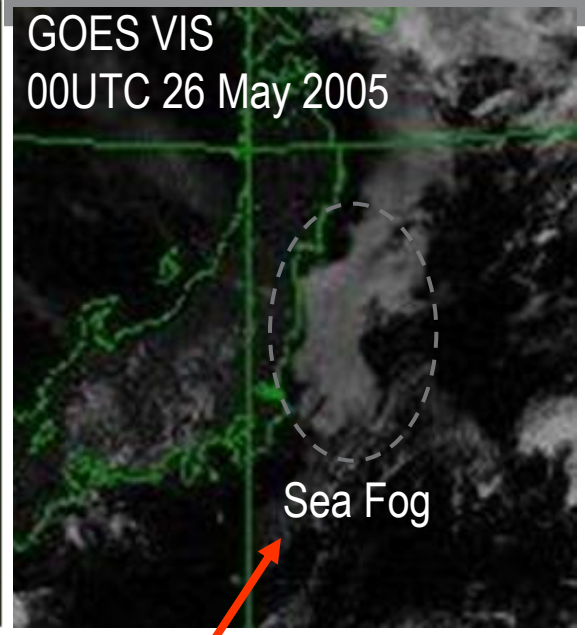
SST deviation
MGDSST-NPDSST

Large differences are found in the east of Japan, along Kuroshio and in the east of China.

Impact of the SSTs were tested in JMA MSM as its boundary condition.

Example of MSM Prediction: Surface humidity (18UTC 25 May, T. Kuragano, JMA, Japan)



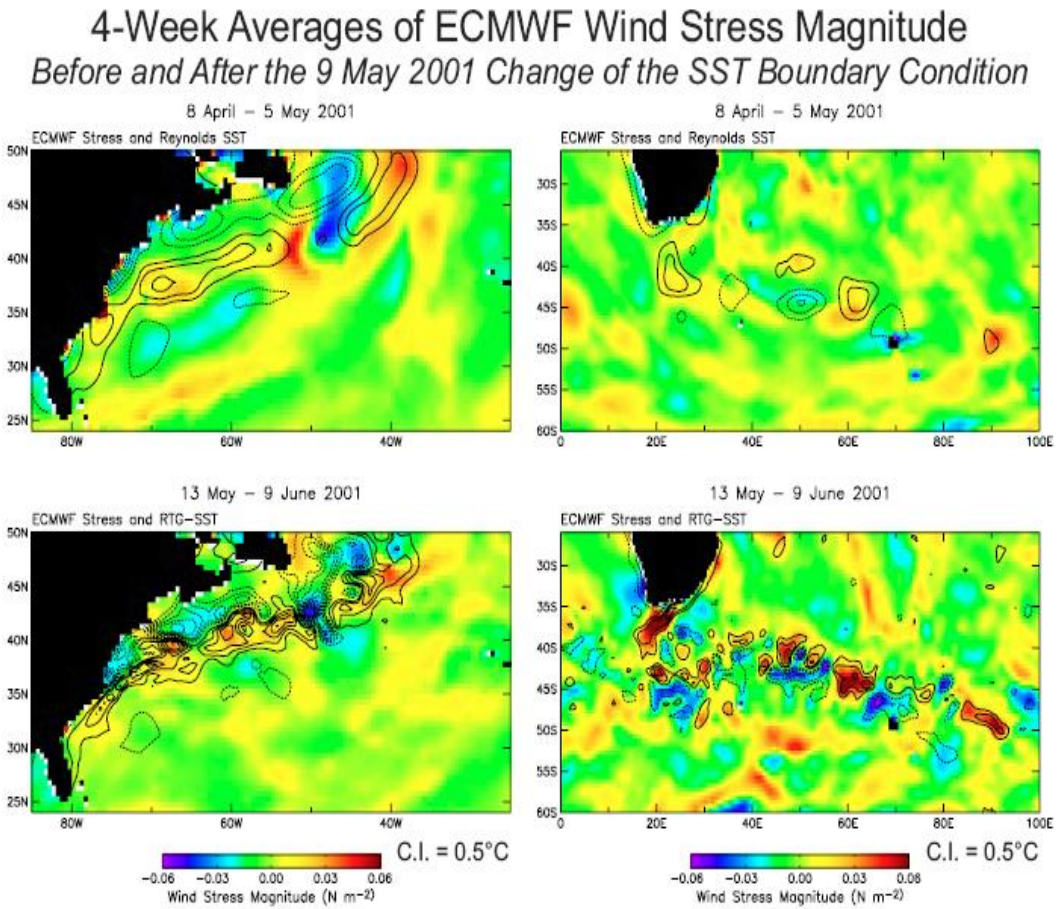


High humidity was successfully predicted by using MGDSST

Predictions of precipitation and air temperature on land are also improved by using MGDSST.

Operational use of MGDSST in JMA MSM and RSM, regional model, began in March, 2006.

Surface winds and SST…



Small-scale variability in the surface wind field increased abruptly after the 9 May 2001 change to a higher resolution SST boundary condition.

(D. Chelton)

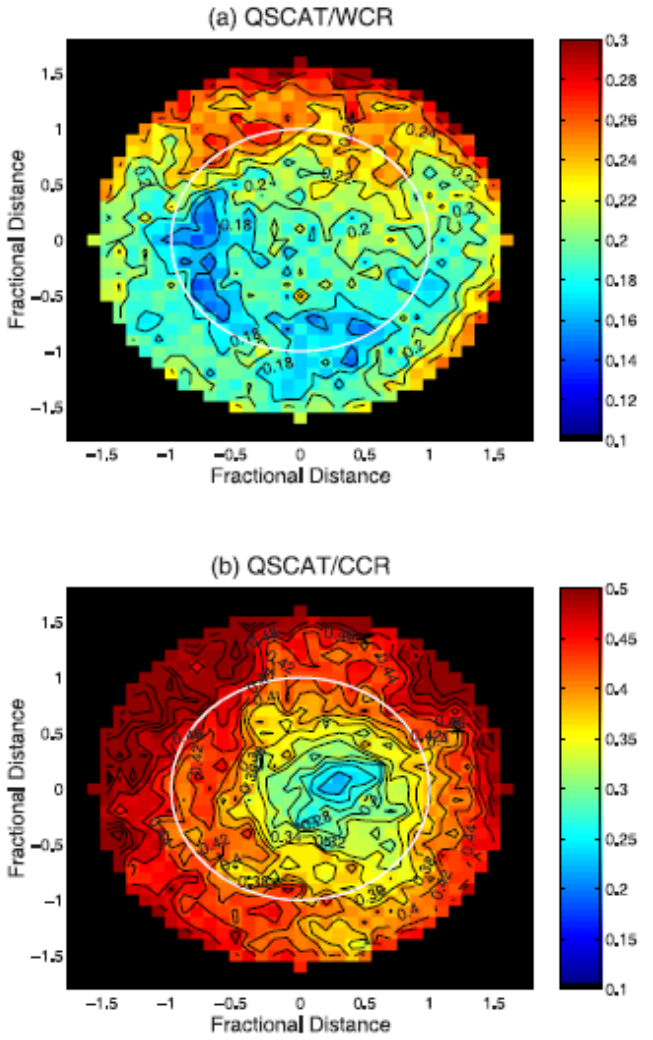


Figure 17. Cloudiness over (top) warm-core and (bottom) cold-core rings during the QuikSCAT period.

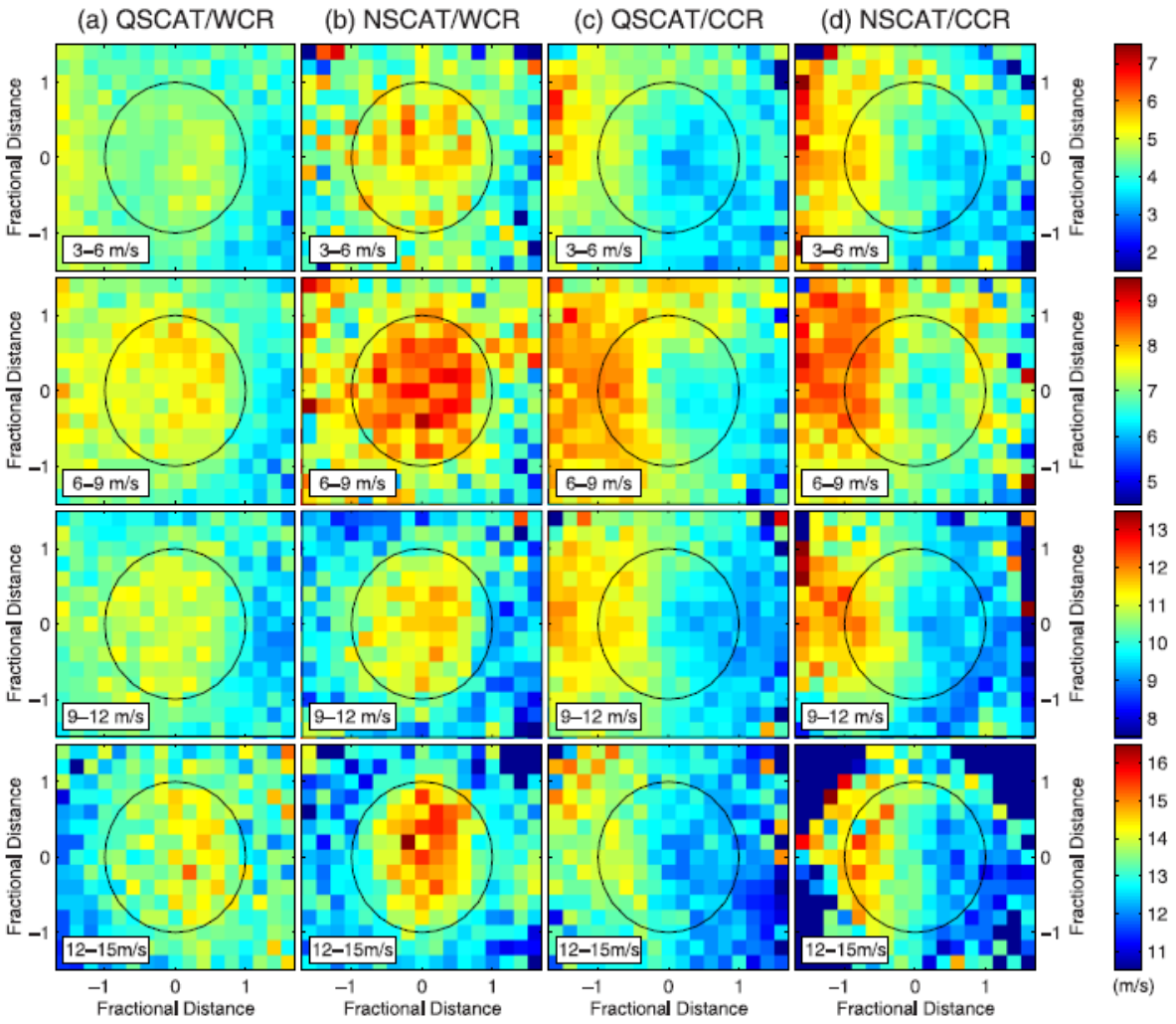


Figure 7. Component of scatterometer winds along the mean wind direction, in ring-centric coordinates rotated such that mean wind is upward in the figure. Data are binned by mean wind speed, data set, and type of ring, and averaged across all rings.