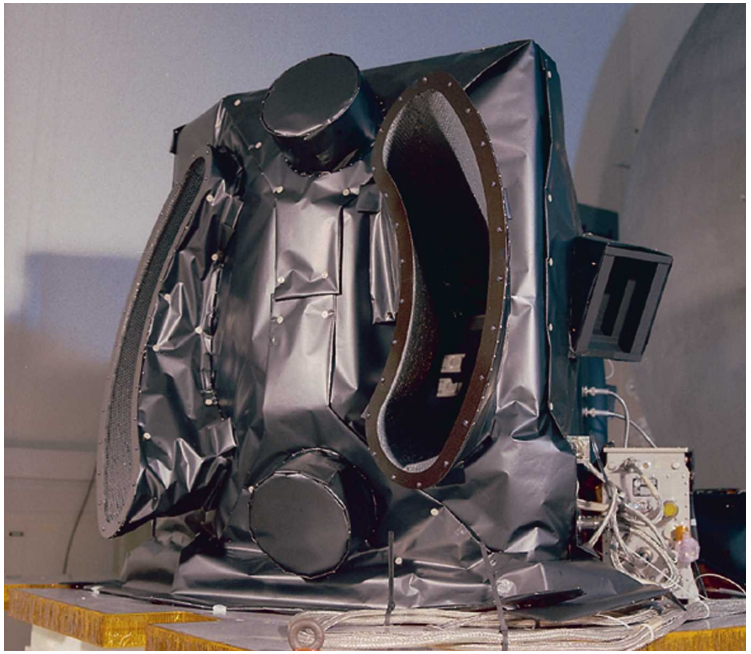
The ENVISAT (A)ATSR: the precision tool for global SST measurement

Dr. Craig Donlon *et al…*

European Space Agency, Noordwijk, the Netherlands

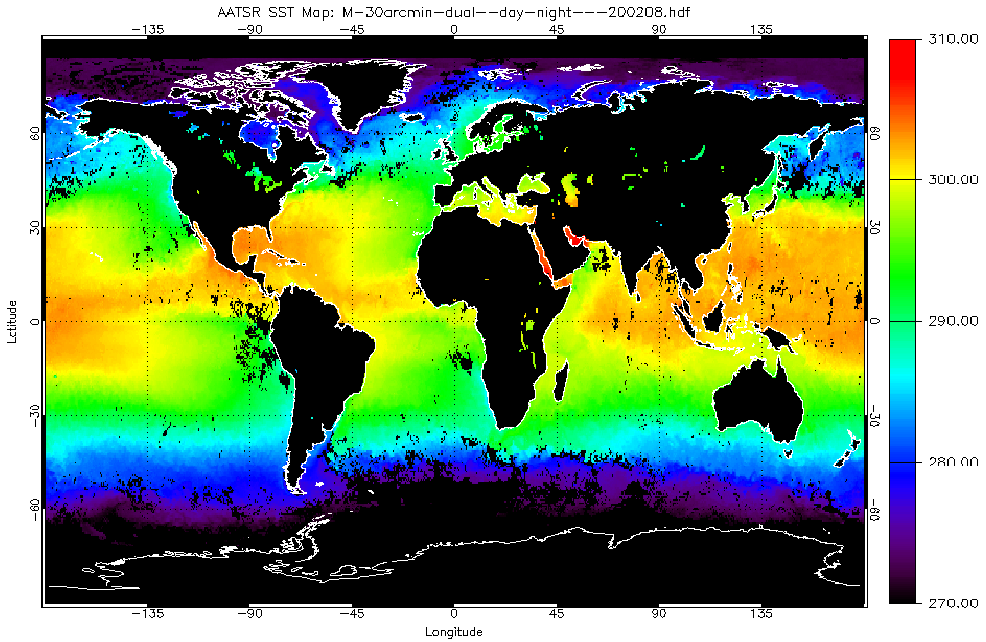


Acknowledgements – the *et al*

- David Llewellyn-Jones and Gary Corlett at University of Leicester
- Dave Smith, Tim Nightingale Chris Mutlow and Team at Rutherford Appleton Laboratory
- Matt Martin Emma Fiedler, Jonah Roberts-Jones, John Stark, John Kennedy, Nick Rayner, Adrian Hines, Roger Saunders at the Met Office
- Anne O'Caroll (Met Office – now at EUMETSAT)
- Ian Robinson, Fred Wimmer and Gary Fisher at NOC, Southampton
- Pierre LeBorgne and Team at CMS Lannion
- Chris Merchant at University of Edinburgh and ESA SST_cci Team
- Hugh Kelliher at Space Connexions
- Many, many others that make (A)ATSR happen…

Overview

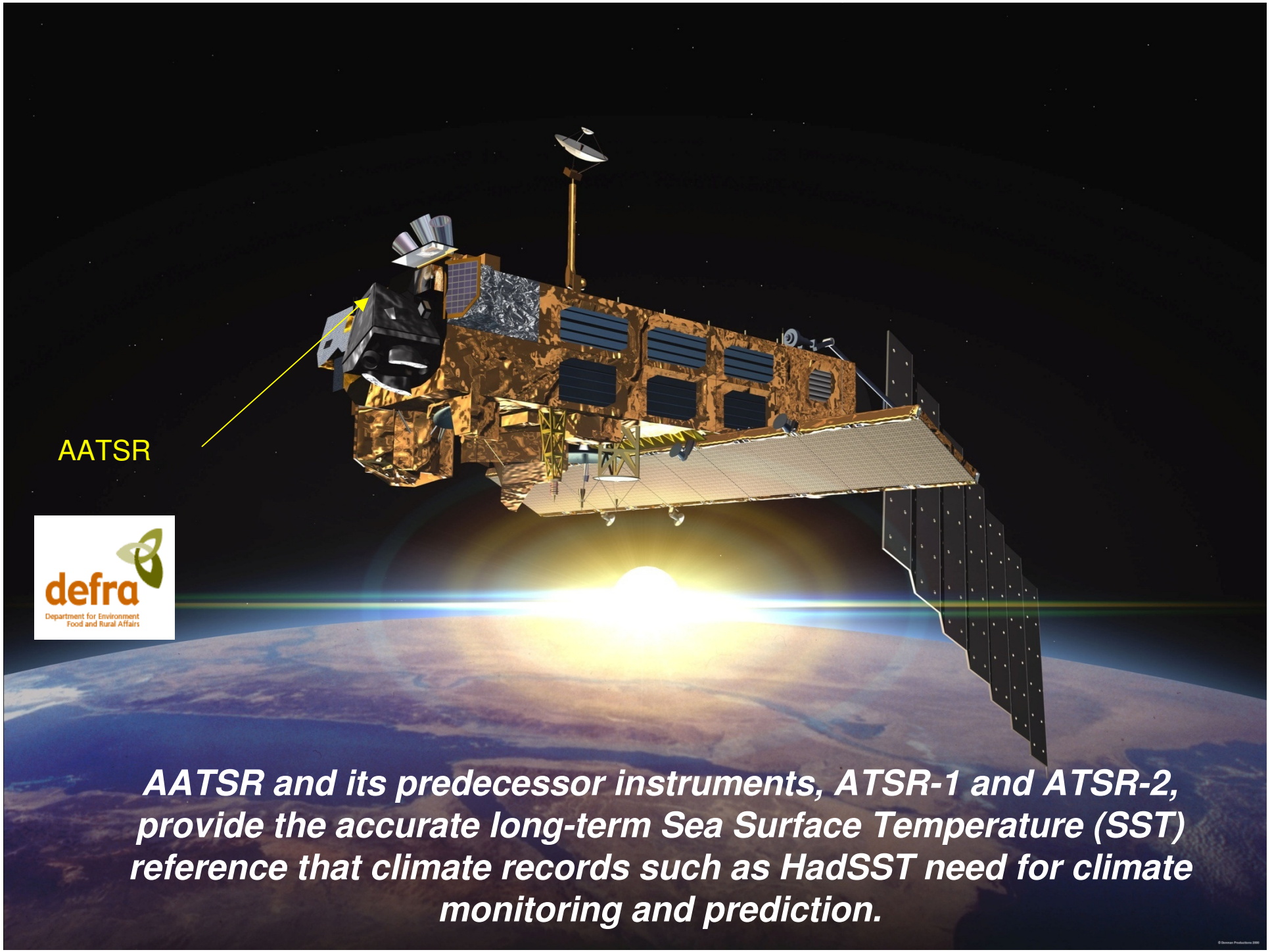
- Tour of (A)ATSR
- How good is it?
- Using AATSR as a reference Sensor
- Operational use of (A)ATSR
- Use in climate data records to support GCOS ECV
- Future perspectives



We have 10 years of global coverage, accurate, independent* SSTskin measurements from ENVISAT AATSR in hand

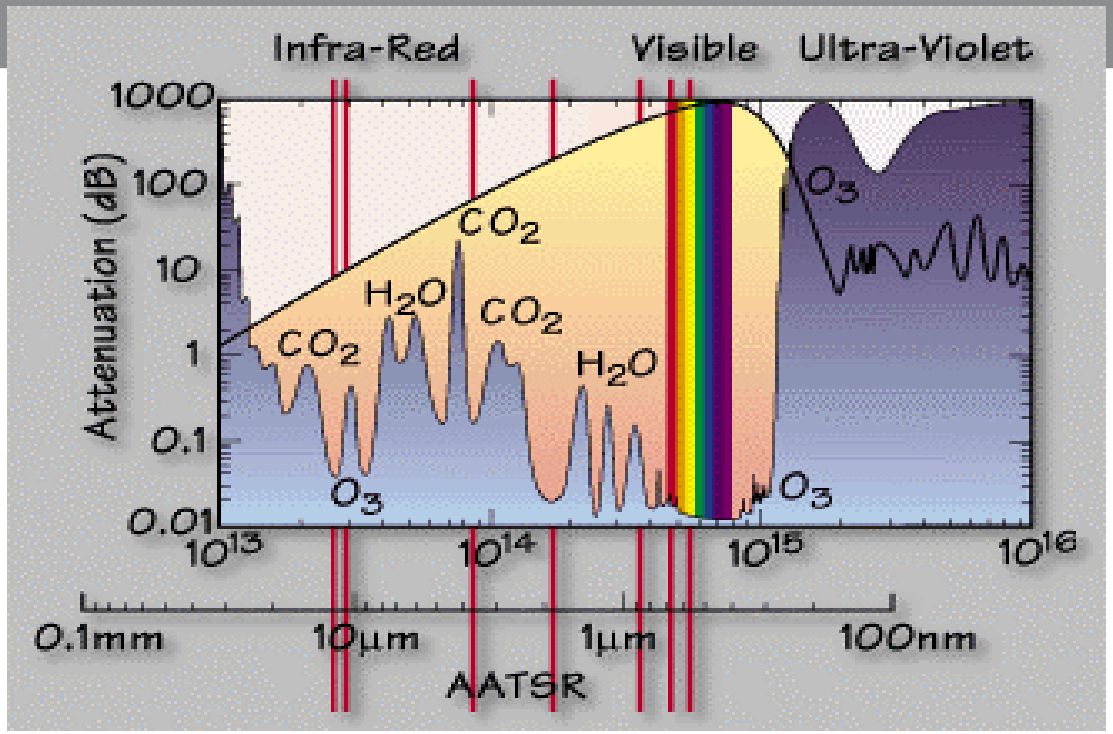
Why is SST important?

- Why is Sea Surface Temperature (SST) and (A)ATSR important?
  - SST is a **critical parameter in determining rates of ocean-atmosphere heat transfer**, which is one of the major drivers of weather and climatic behaviour
  - Numerical Ocean Prediction (NOP) and Numerical Weather Prediction (NWP) both need accurate SST
  - Also, precisely measured global SST, as a reasonably stable geophysical variable, is an important indicator of **global environmental change**
  - For this reason, SST is an **Essential Climate Variable (ECV)** of the Global Climate Observing System (GCOS) that has been adopted by GEOSS
  - Within the GCOS Implementation Plan**, the (A)ATSR SST record has been defined as a Fundamental Climate Data Record (FCDR)**
- The Design of (A)ATSR from conception was for accuracy…



AATSR and its predecessor instruments, ATSR-1 and ATSR-2, provide the accurate long-term Sea Surface Temperature (SST) reference that climate records such as HadSST need for climate monitoring and prediction.

(A)ATSR Instrument Features



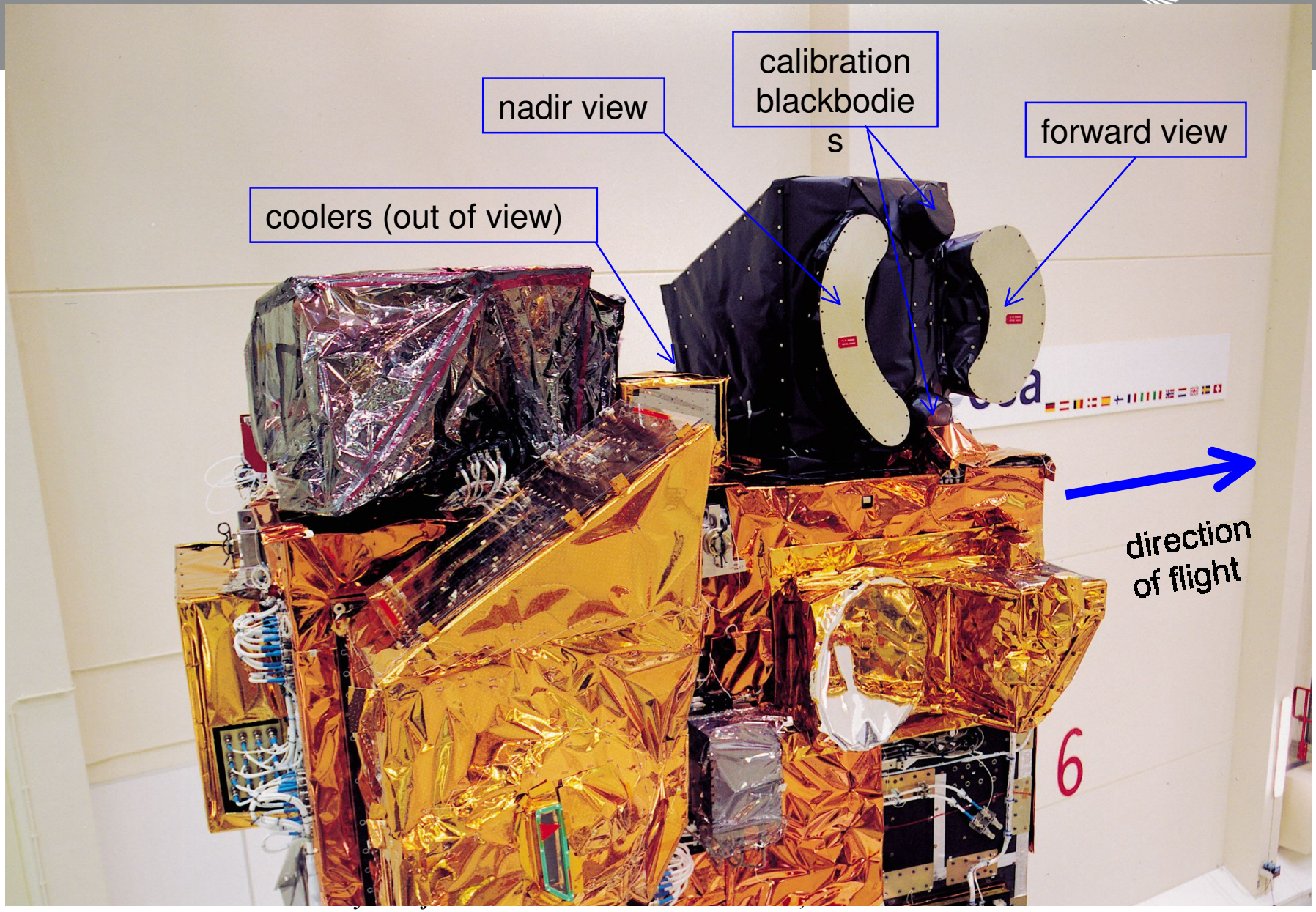
SST 3 channel retrieval
12, 11, 3.7 µm

Near Infrared and Visible
1.6, 0.87. 0.66, 0.55 µm

SST 2 channel retrieval
12, 11 µm

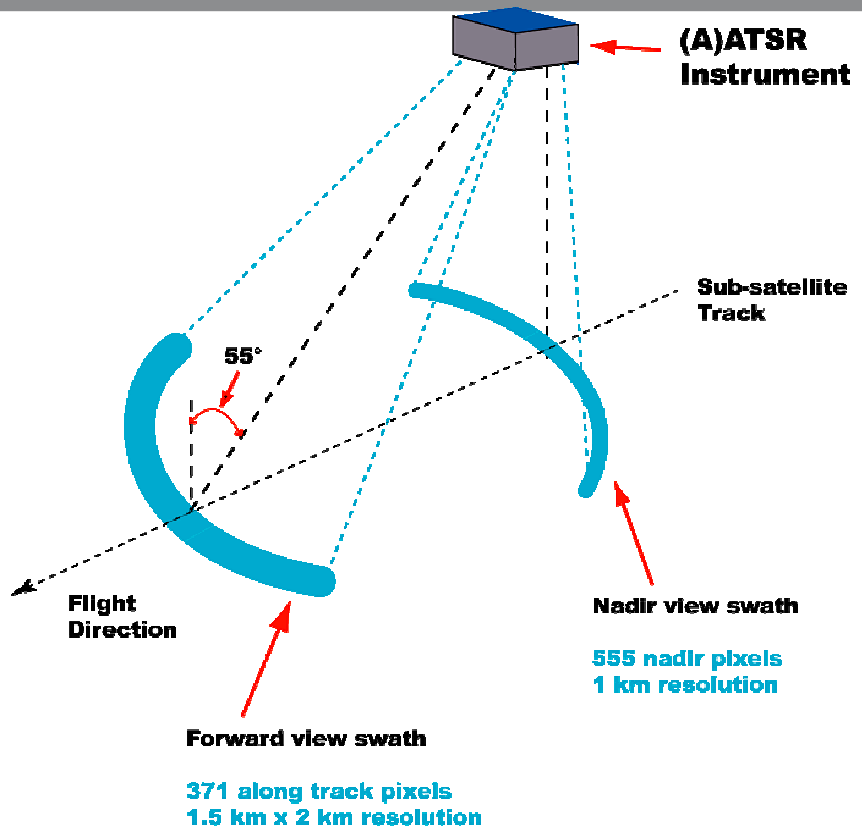
2 sets of products
Dual-view & Nadir-only

AATSR on Envisat

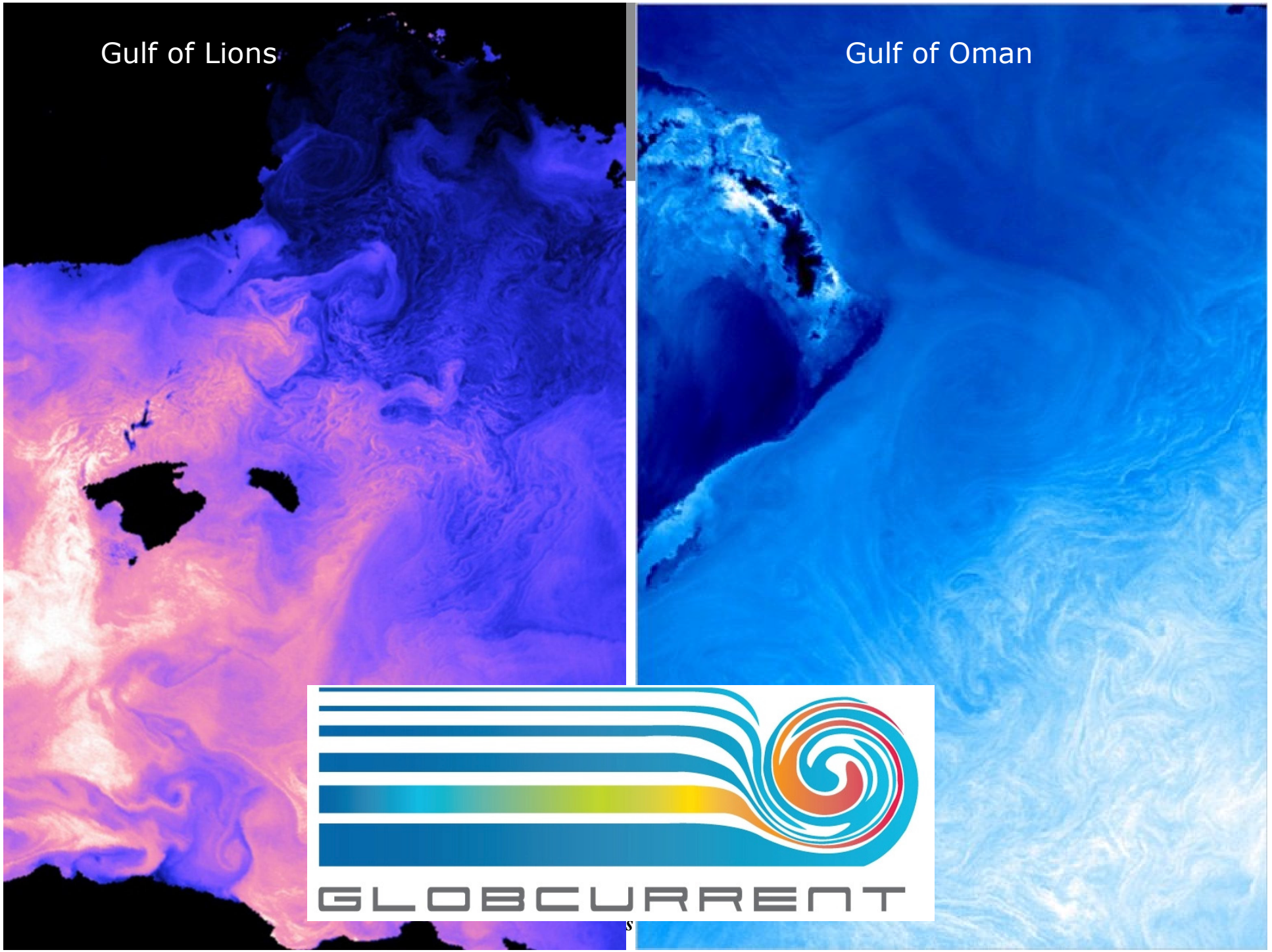


(A)ATSR Instrument Features

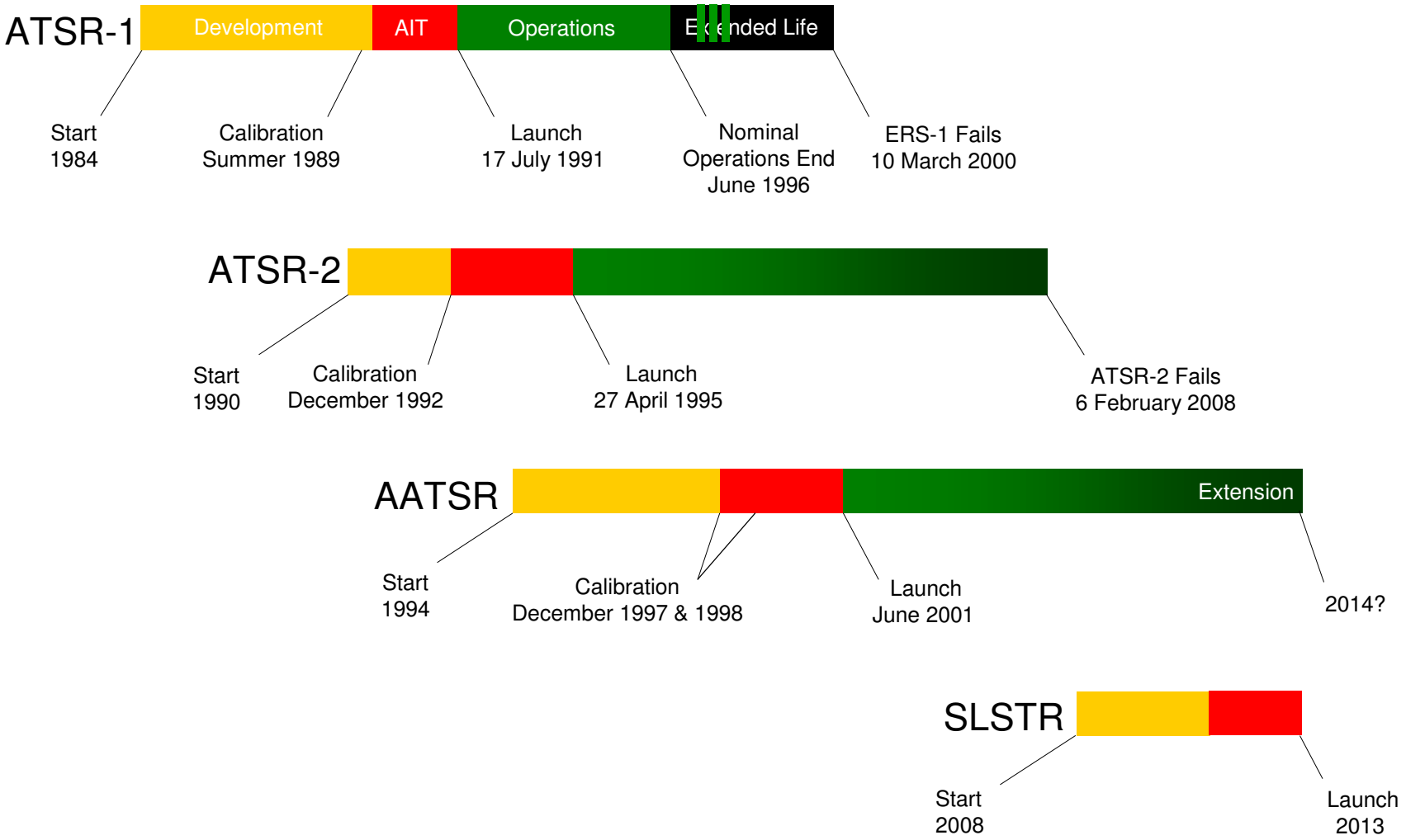
- AATSR is a thermal infrared and visible imaging radiometer
- Dual view (nadir and 55° to nadir)
  - Along-track scanning, giving two views of the same scene at different angles, to correct for atmospheric effects
- On-board calibration
  - 2 on-board black bodies for IR calibration
  - VISCAL unit for visible channel calibration

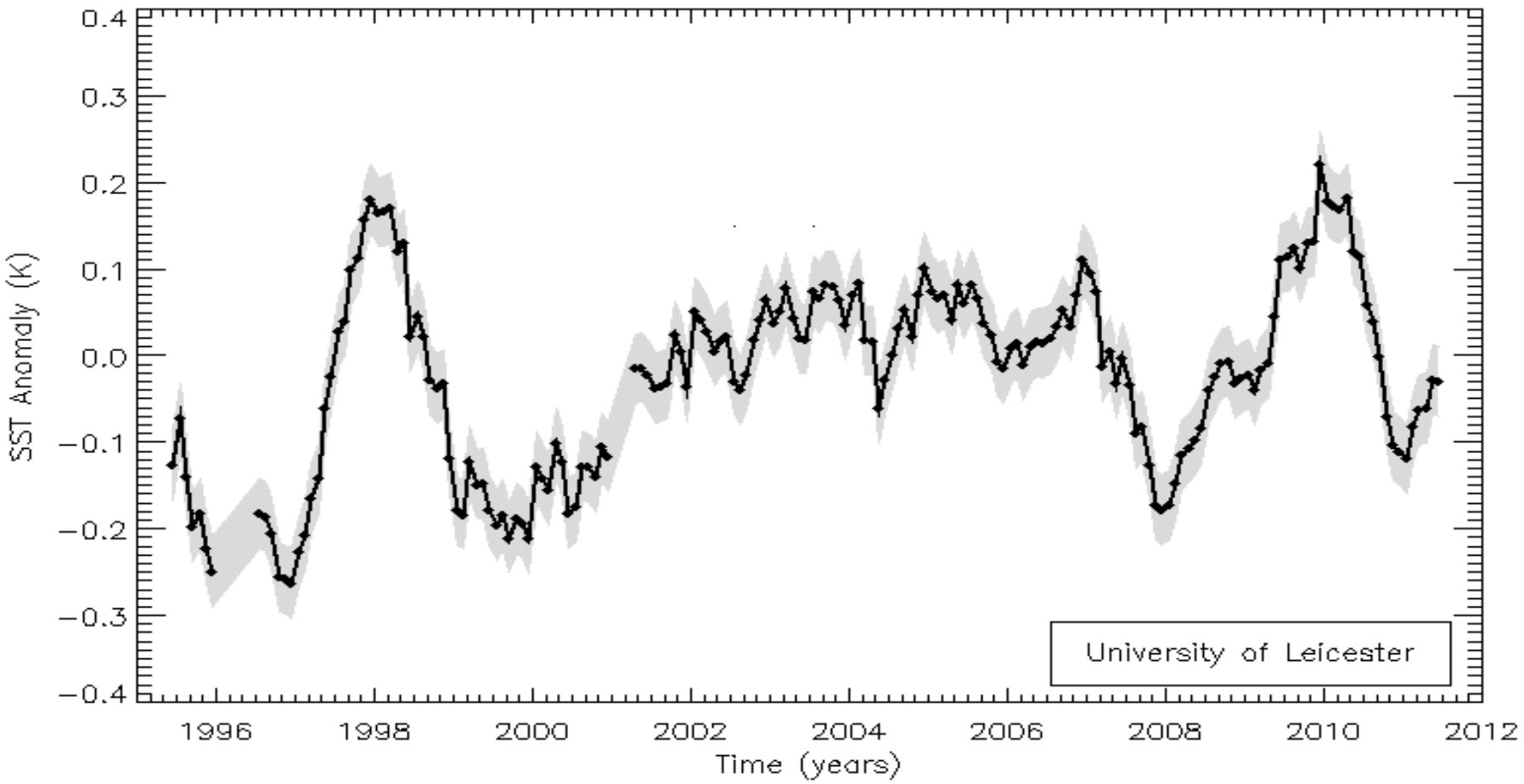


These features make (A)ATSR the most accurate spaceborne radiometer for measuring SST


Gulf of Lions
Gulf of Oman
GLOBCURRENT

(A)ATSR Flight Operations - Sensors Timeline

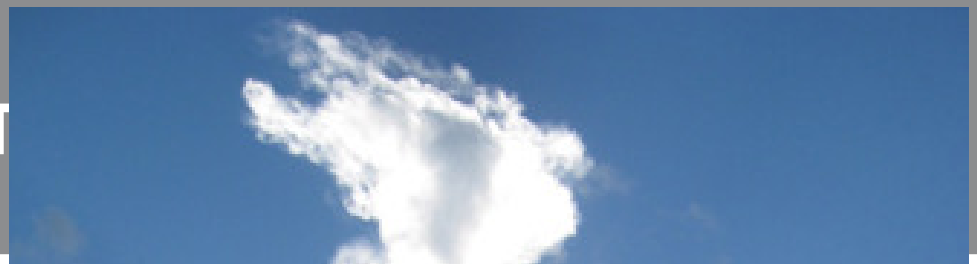




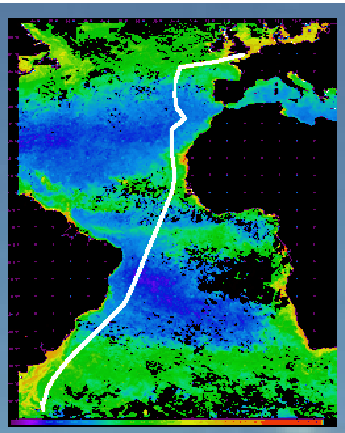
Monthly global averages of the dual-view 3-channel night-time SST anomaly are plotted over the time-period between the launch of ERS-2 in 1995 and the present.

University of Leicester

Sea Surface T

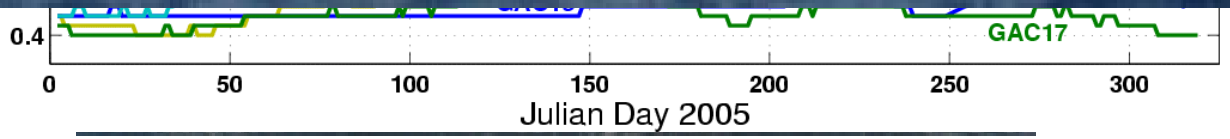


satellite v.s. buoys RMS error



C Donlon
circa 1992

See http://www.amt-uk.org/about_amt.aspx

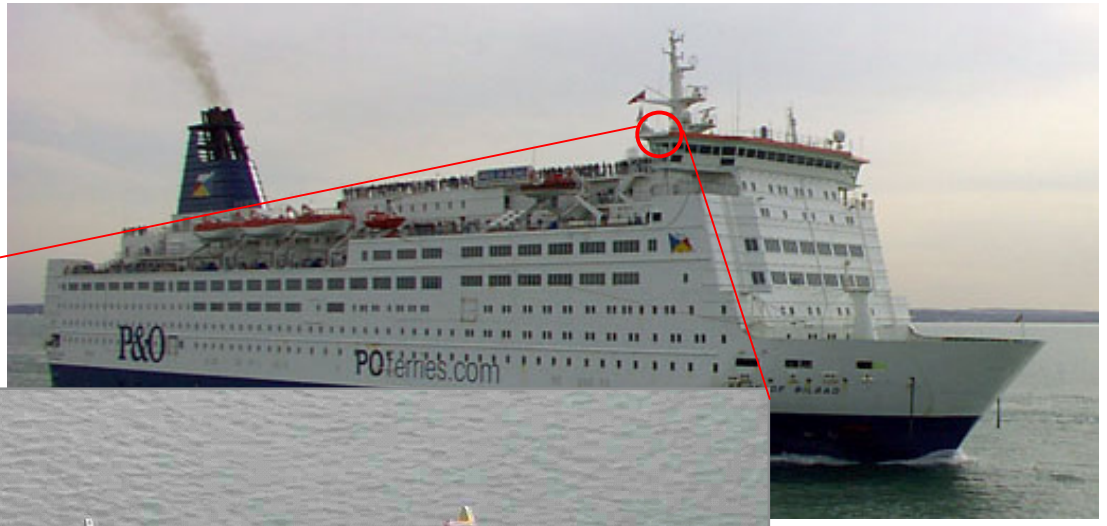


AATSR Validation – SST validation using ISAR

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

esa

Infrared SST Autonomous Radiometer (ISAR) views the sea surface from the starboard bridge wing at ~40° to vertical (outside the bow wake)



Long-term validation of AATSR SST data products using shipborne radiometry in the Bay of Biscay and English Channel

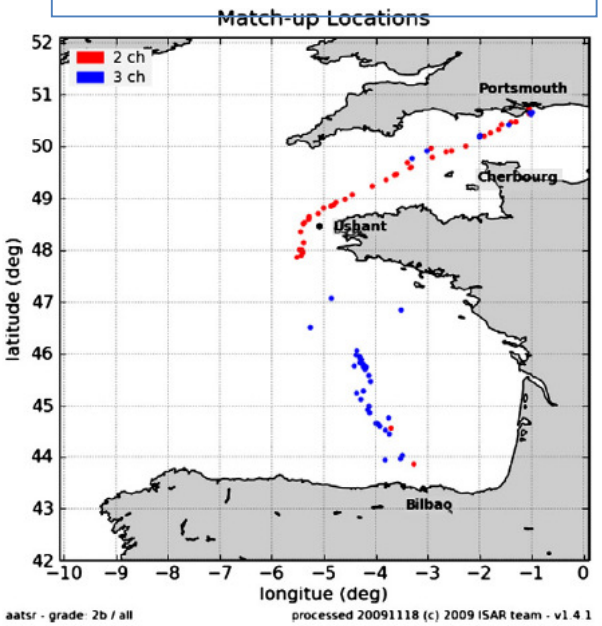
Werenfrid Wimmer [a], Ian S. Robinson [a,*], Craig J. Donlon [b]

[a] School of Ocean and Earth Science, National Oceanography Centre, University of Southampton Waterfront Campus, European Way, Southampton SO14 3ZH, United Kingdom
[b] European Space Agency ESTEC Facility, Keplerlaan 1, 2201 AZ Noordwijk, Netherlands

Statistics for match-ups from 7th December 2005 to April 2009 (AATSR dual-view SST-ISAR), filtered to remove AATSR data with lower confidence values. The table shows the bias and standard deviation, the number of matches, the number of overpasses from which they came, and the percentage reduction in the match-up population compared with the unfiltered data as in Table 3.

Grade of coincidence	Mean bias, AATSR–ISAR	Standard deviation	No. of matches	Overpass numbers	Population reduction by removing data with CV<5
2 Waveband algorithm (Dual-2)					
1	−0.03	0.30	136	36	5%
2A	−0.02	0.60	209	57	13%
2B	−0.04	0.39	549	58	3%
3	−0.05	0.54	784	68	7%
4	0.02	0.76	2372	131	7%
3 Waveband algorithm (Dual-3)					
1	0.00	0.23	326	48	8%
2A	0.00	0.32	411	68	13%
2B	−0.01	0.26	1137	62	7%
3	−0.03	0.32	1423	87	11%
4	−0.05	0.38	4299	140	13%

Near continuous ISAR data on this line between 2005 – 2012!



ATSR infrared radiometric calibration and in-orbit performance

Dave Smith [a,*], Chris Mutlow [a], John Delderfield [a], Bob Watkins [b], Graeme Mason [c]

[a] STFC, Rutherford Appleton Laboratory, Chilton, Didcot, OX11 0QX, United Kingdom
[b] Department of Atmospheric Oceanic and Planetary Physics, University of Oxford, Parks Road, Oxford, OX1 3PU, United Kingdom
[c] ESA, ESRIN, Via Galileo Galilei, Casella Postale 64, 00044 Frascati, Roma, Italy

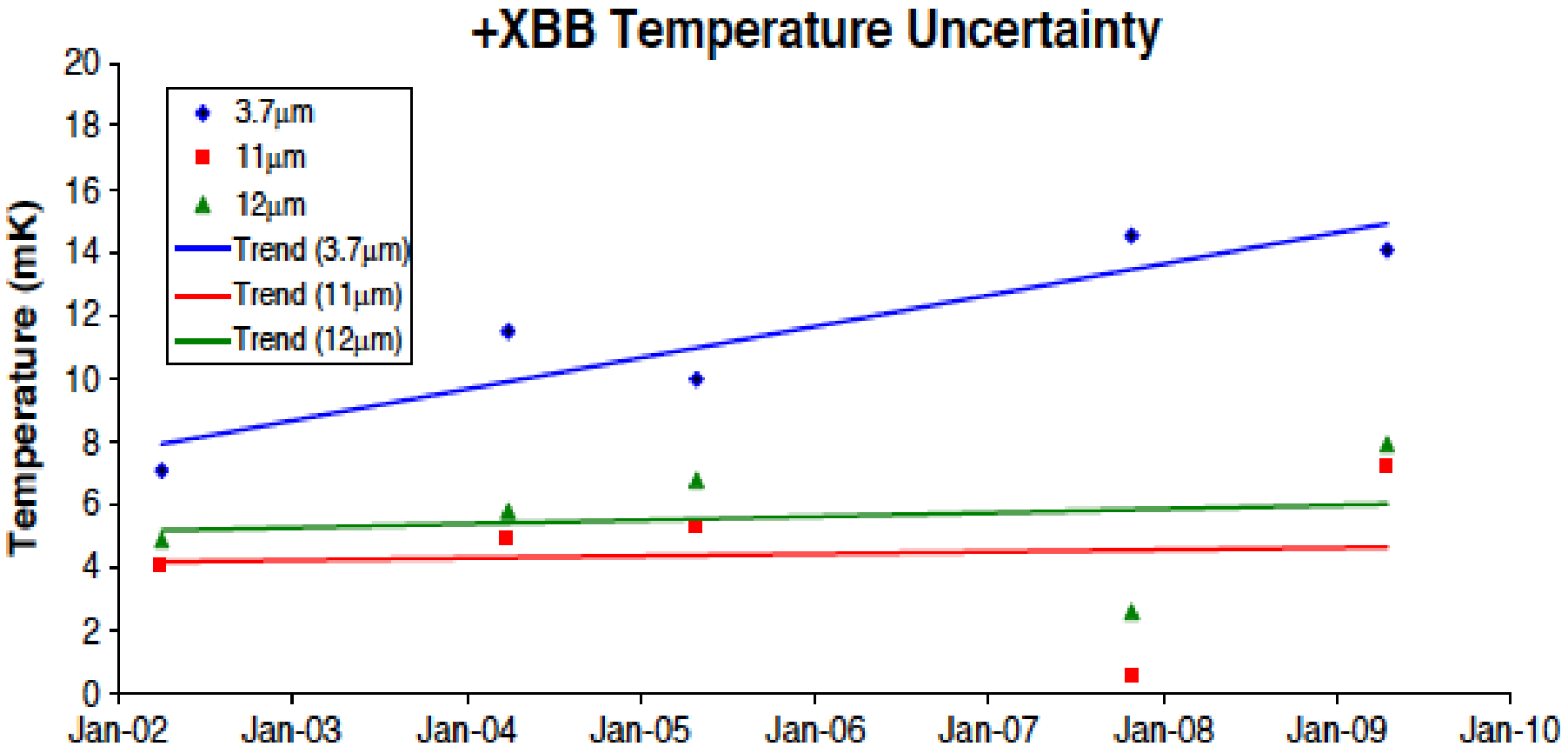
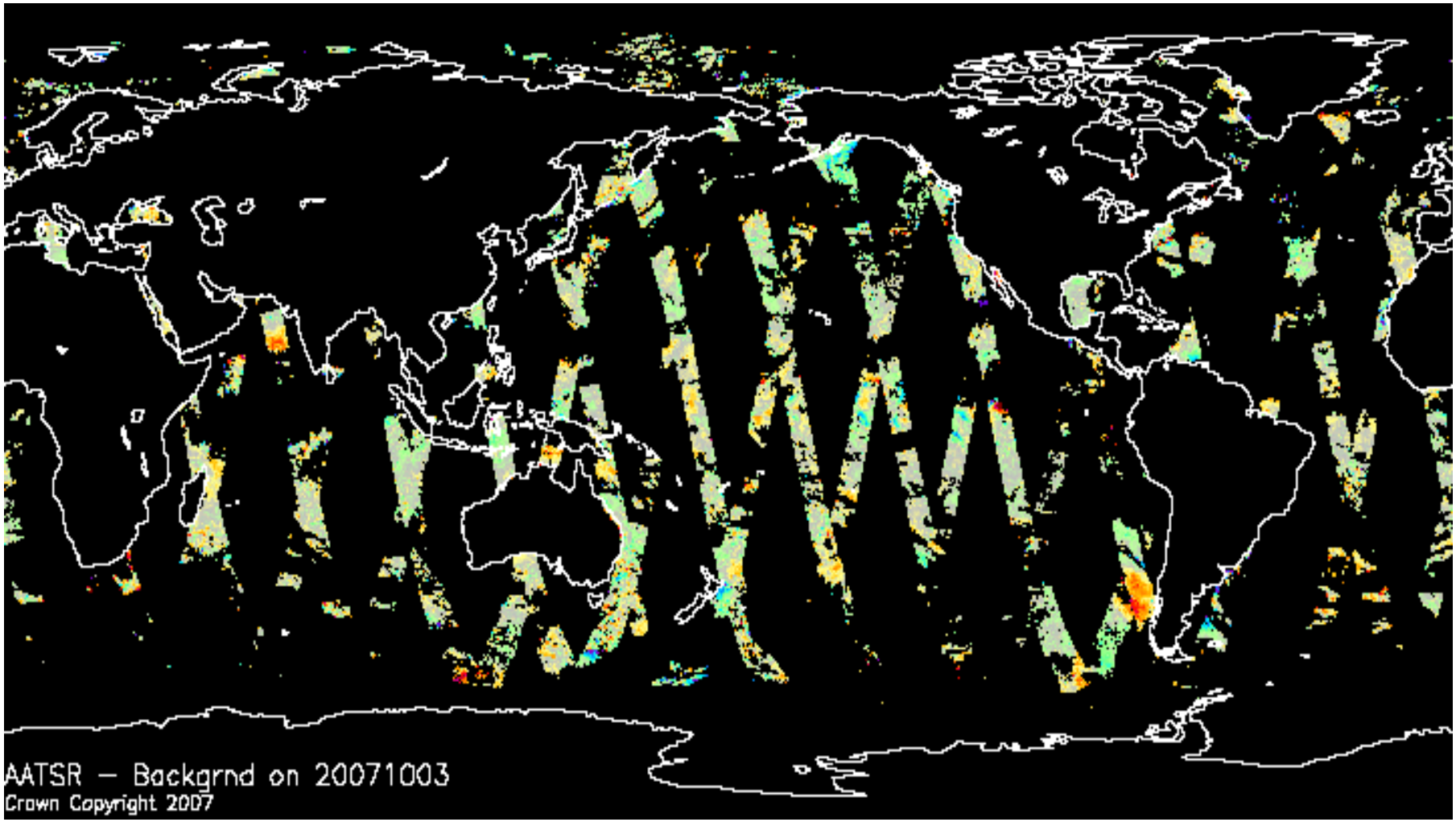


Fig. 10. Blackbody temperature uncertainties from the AATSR cross-over tests.

Typical NRT 24 hour coverage of AATSR



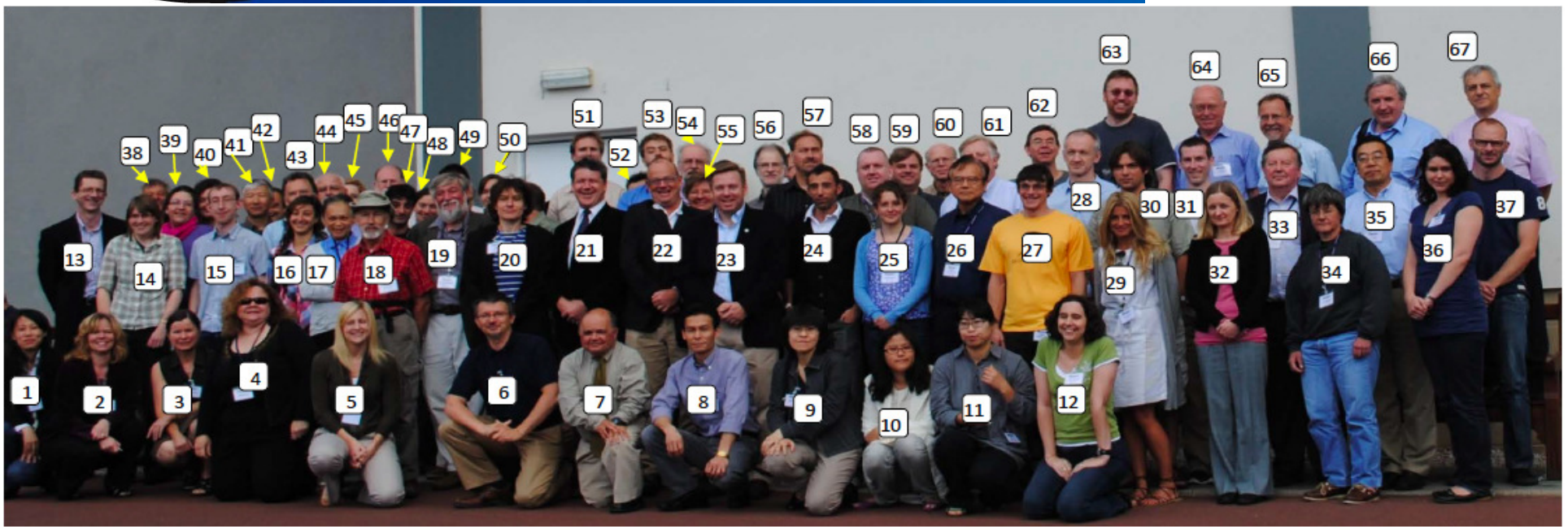
Synergistic Data-Merging of AATSR Data - In the words of the PI (DLJ)

- AATSR SSTs are very accurate
- BUT – coverage (essential for weather and climate) is very poor
- Other satellites sensors have excellent coverage but inadequate accuracy
- There are two successful schemes for synergistic data-merging, exploiting the complementary strengths of different data-sources, where AATSR provides the benchmark for accuracy:
  - OSTIA, from UK Met Office, is a daily analysis of global SST
  - Météo France generate a merged product from AATSR and SEVIRI, on the Eumetsat Meteorological Geostationary Satellite (MSG), which generates SST fields every 30 minutes. AATSR provides the accuracy and SEVIRI provides coverage and time resolution.
- The SST ECV to be produced under ESA's Climate Change Initiative will use the data-merging techniques developed by the (A)ATSR community.
  - This technique will be applied to the entire SST dataset

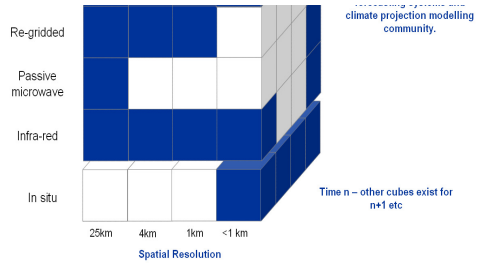
GHRSST-PP

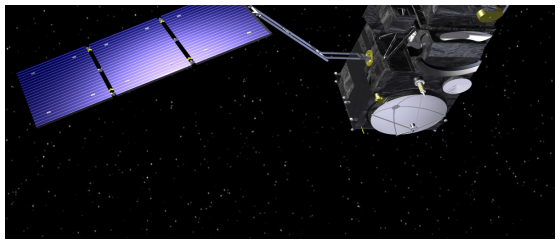
GODAE High Resolution Sea Surface Temperature Pilot Project

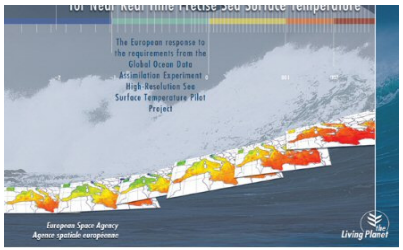
medspiration
EUROPEAN NODE FOR SEA SURFACE TEMPERATURE



Donlon, C., and Coauthors, 2007: The Global Ocean Data Assimilation Experiment High-resolution Sea Surface Temperature Pilot Project. *Bull. Amer. Meteor. Soc.*, **88**, 1197–1213.
doi: http://dx.doi.org/10.1175/BAMS-88-8-1197

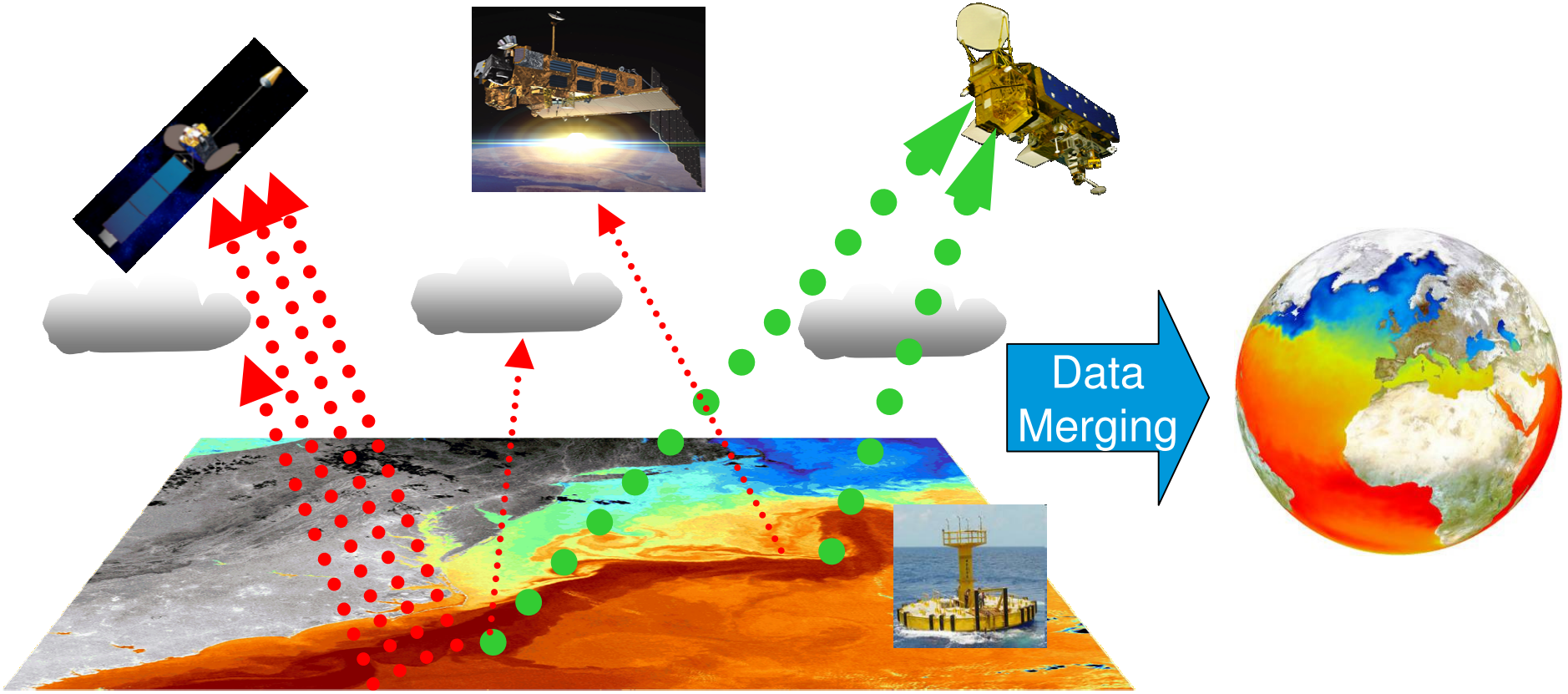




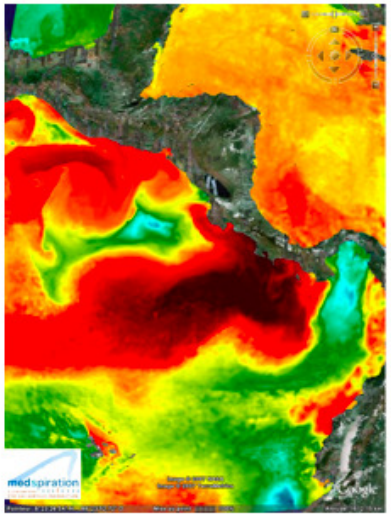


A Celebration: 10 years of Marine Observations with ENVISAT , IFREMER 8th March 2012

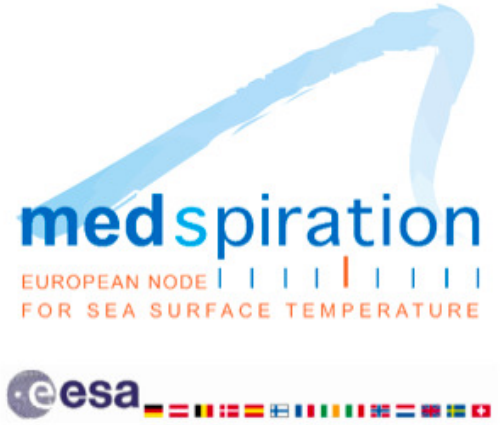
GHRSST Builds on EO complementarities



- 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***



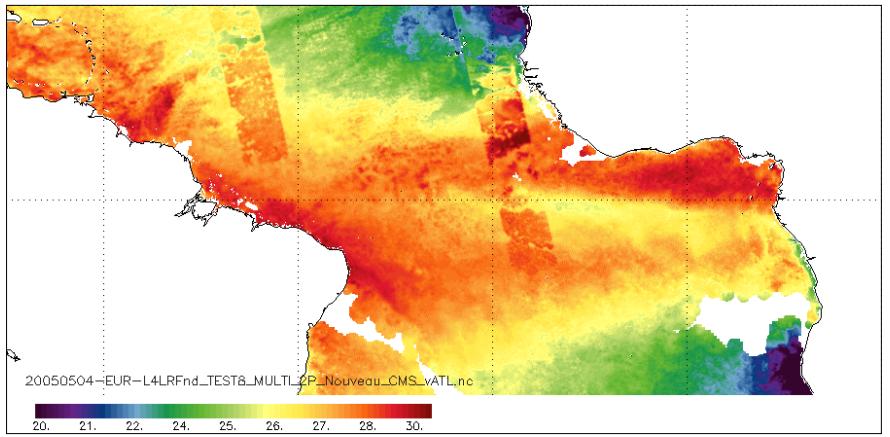
Jean-François Piollé (Ifremer/CERSAT)
Ian S.Robinson (NOCS)



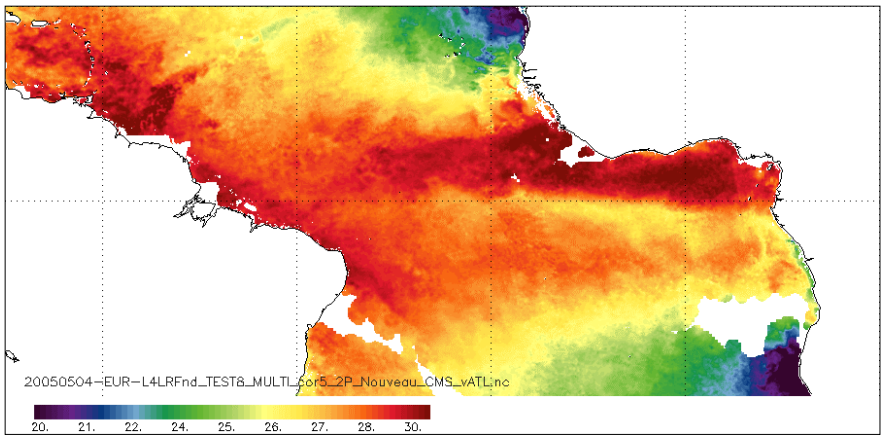
Observations with

Geostationary (SEVIRI) and AATSR Data: Aerosol Robust Data from AATSR.

‘Simple’ combination of SEVIRI data with AATSR data.
Differences are 1.5 - 2.0℃



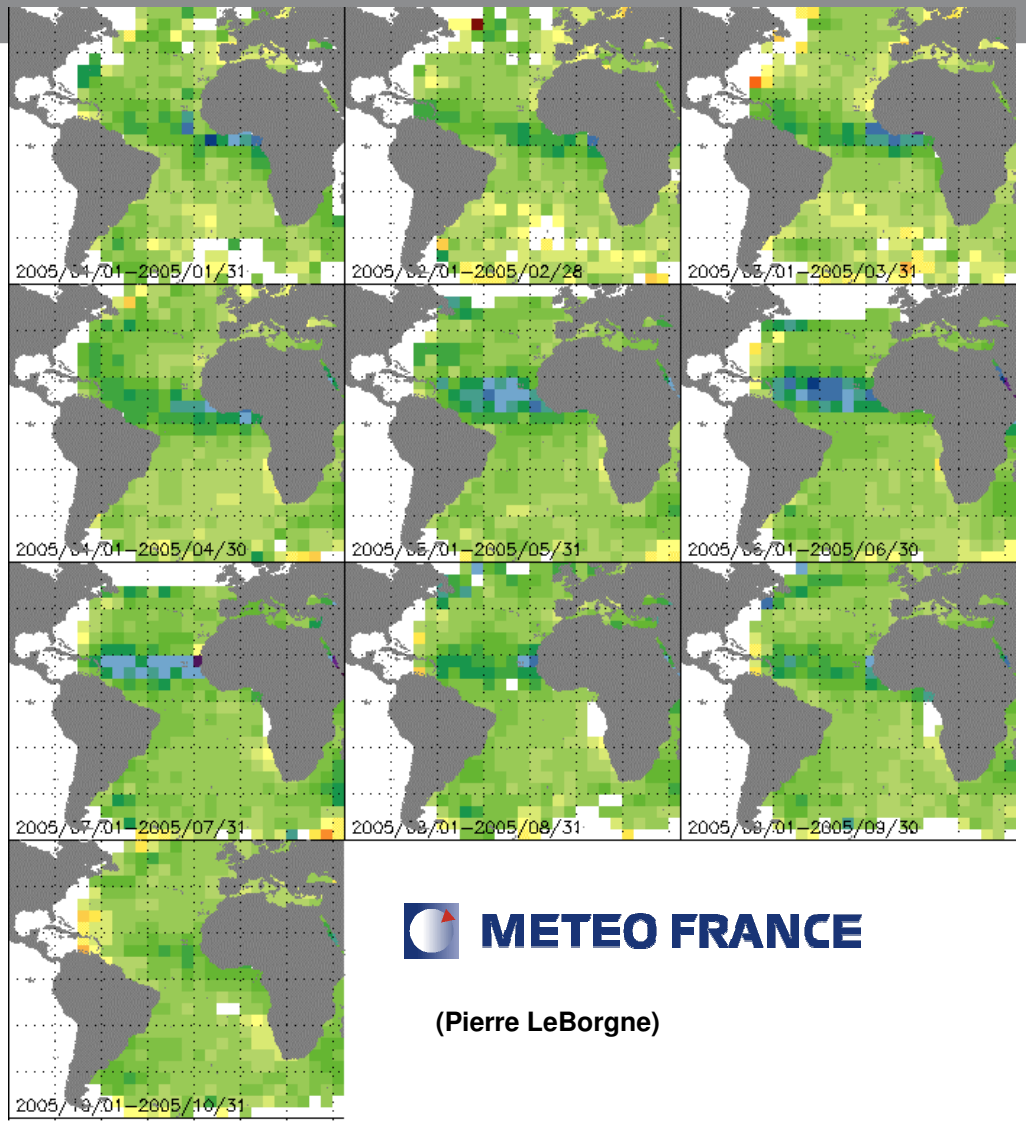
With bias correction, based on the difference between AATSR-SEVIRI SSTs, applied to SEVIRI data



Information provided by Pierre Le Borgne, Météo France, Lannion

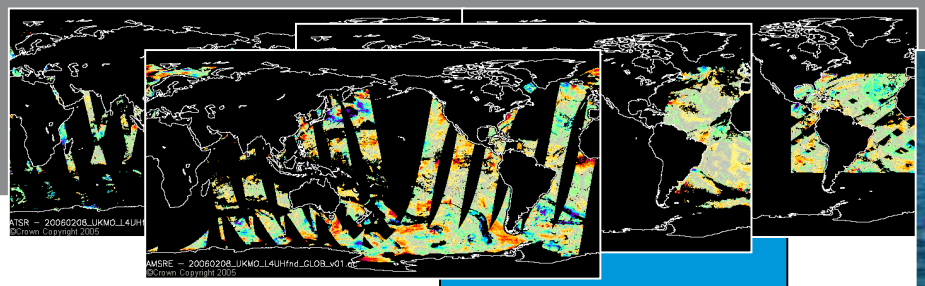
GHRSST-PP L2P Inter-comparison – SEVIRI-AATSR (Saharan mineral dust)

- 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
- Verification by AATSR



METEO FRANCE

(Pierre LeBorgne)



Data Sources

OSTIA Basic Architecture

Database

Quality Control

-Background check -Diurnal warming flagging

Anomaly Persistence Forecast

With weak relaxation to climatology

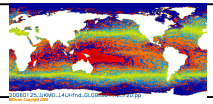
AATSR is a fundamental component of the OSTIA bias correction

Analysis

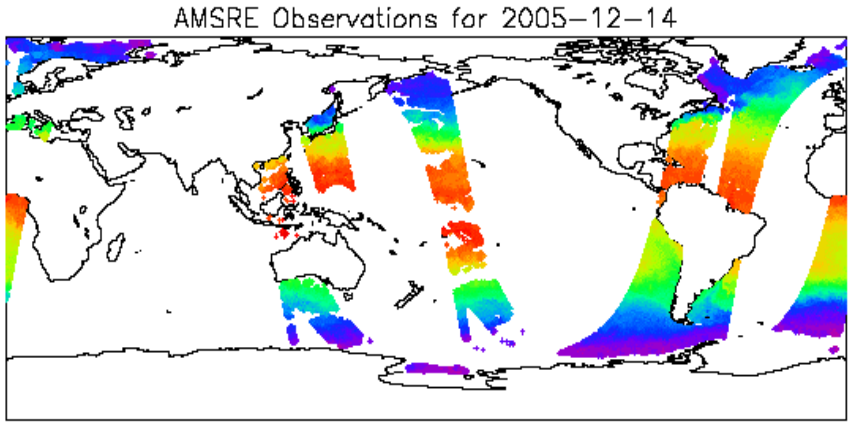
-Using 2 background error scales
-Spatially varying backgrd. errors

Met Office

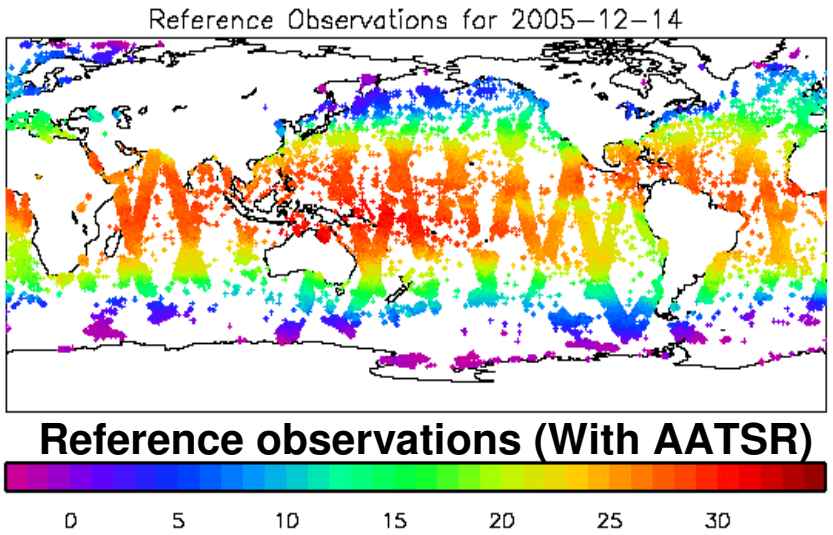
Daily SST



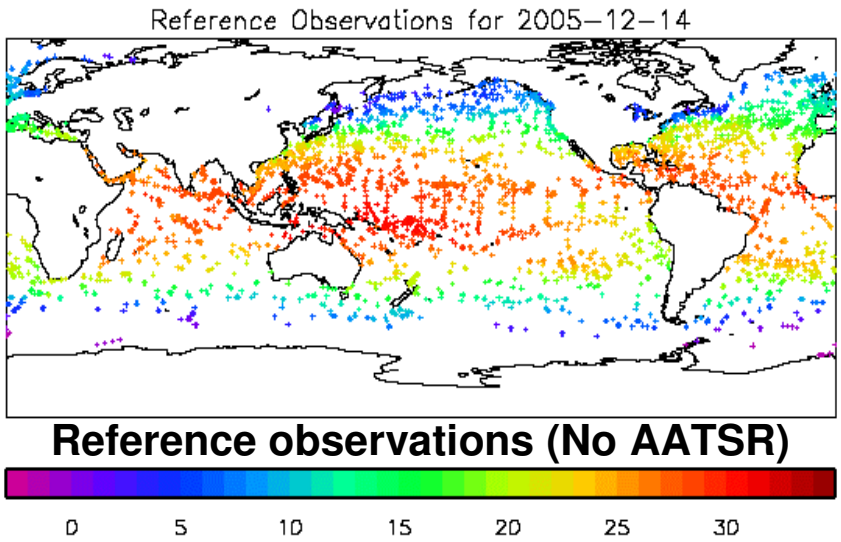
Bias correction : The Importance of AATSR (used ALL data every day)



AMSR-E Observations for 14 Dec. '05



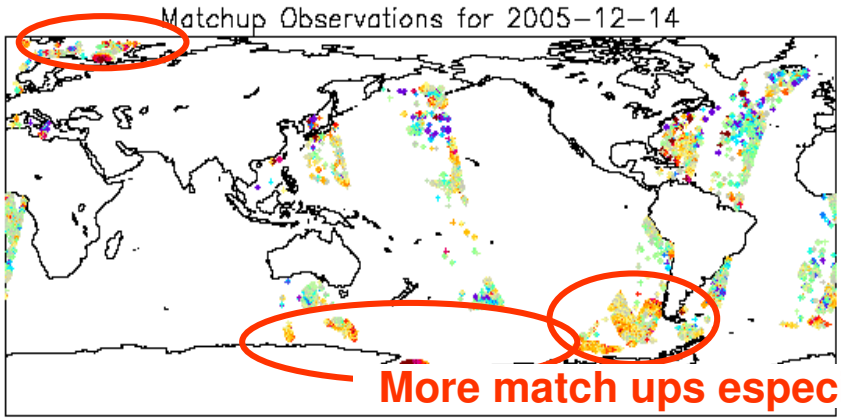
Reference observations (With AATSR)



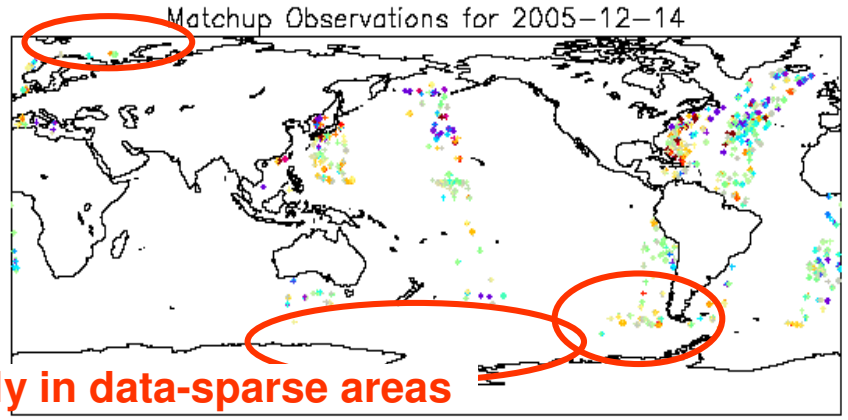
Reference observations (No AATSR)

Impact of AATSR on AMSRE bias correction for 14 Dec

In situ + AATSR

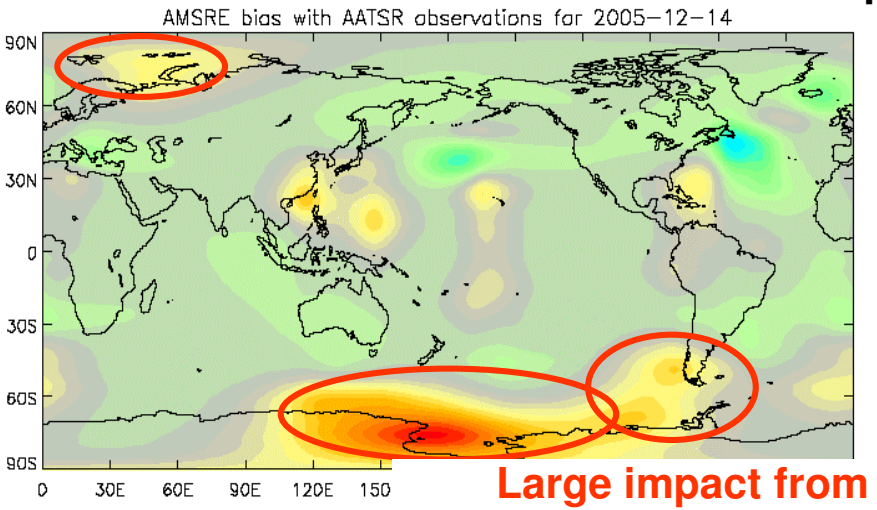


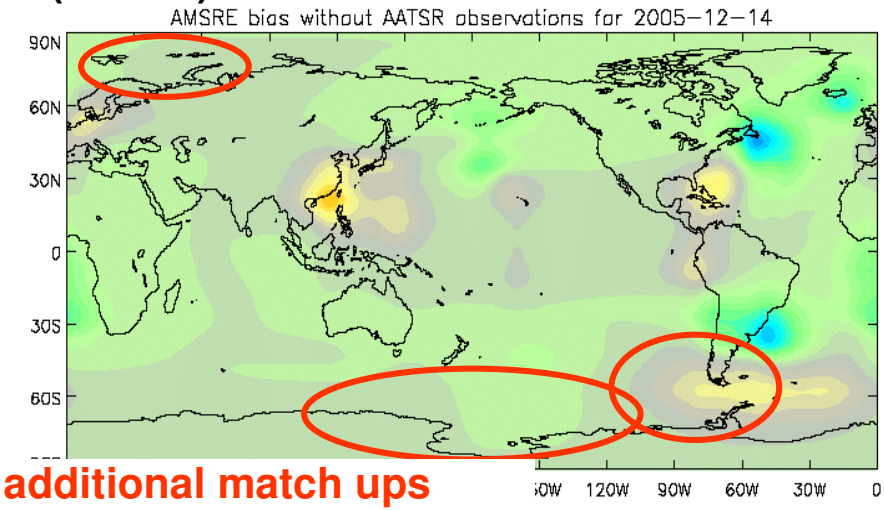
In situ only



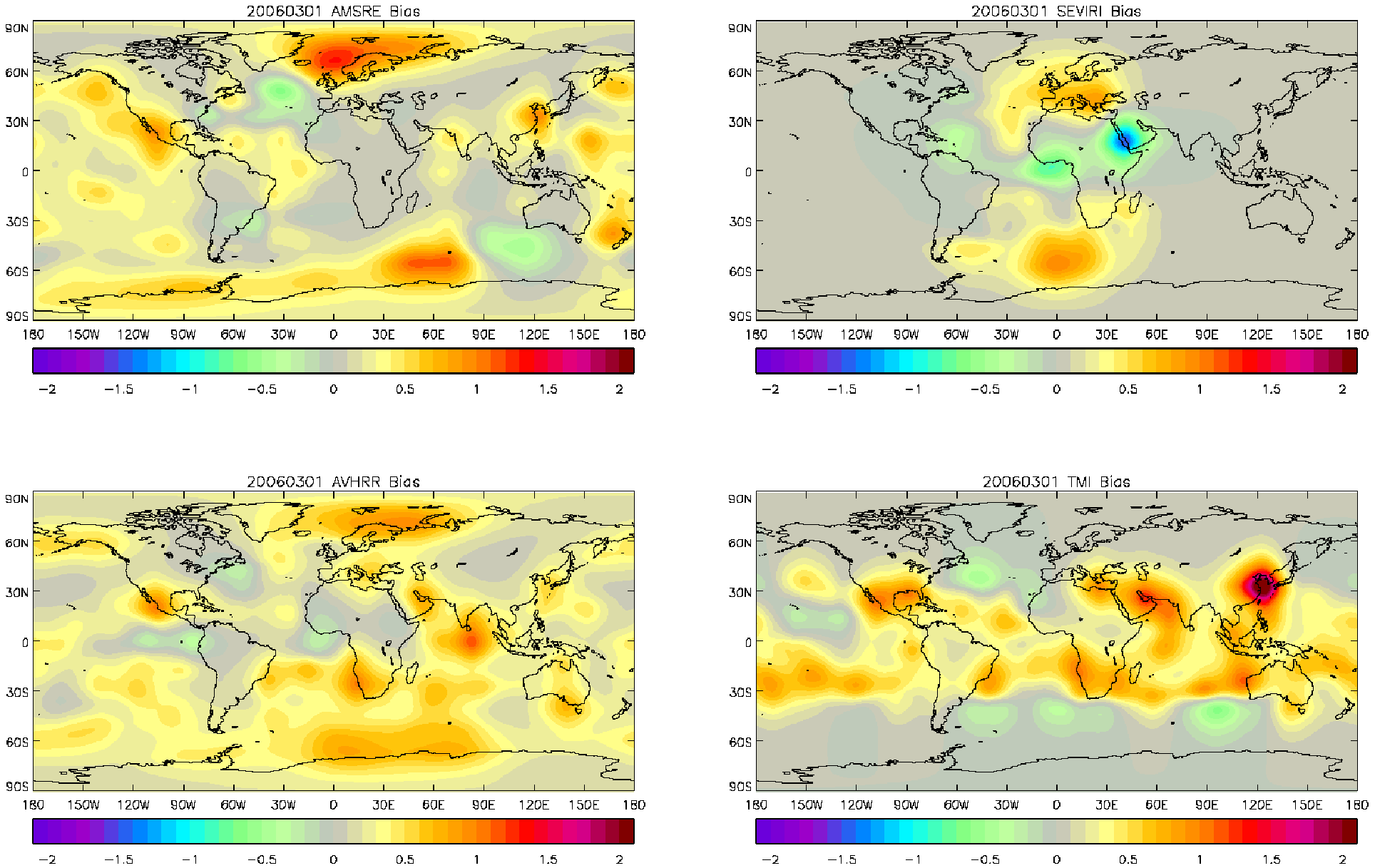
More match ups especially in data-sparse areas

Match ups (<25km)



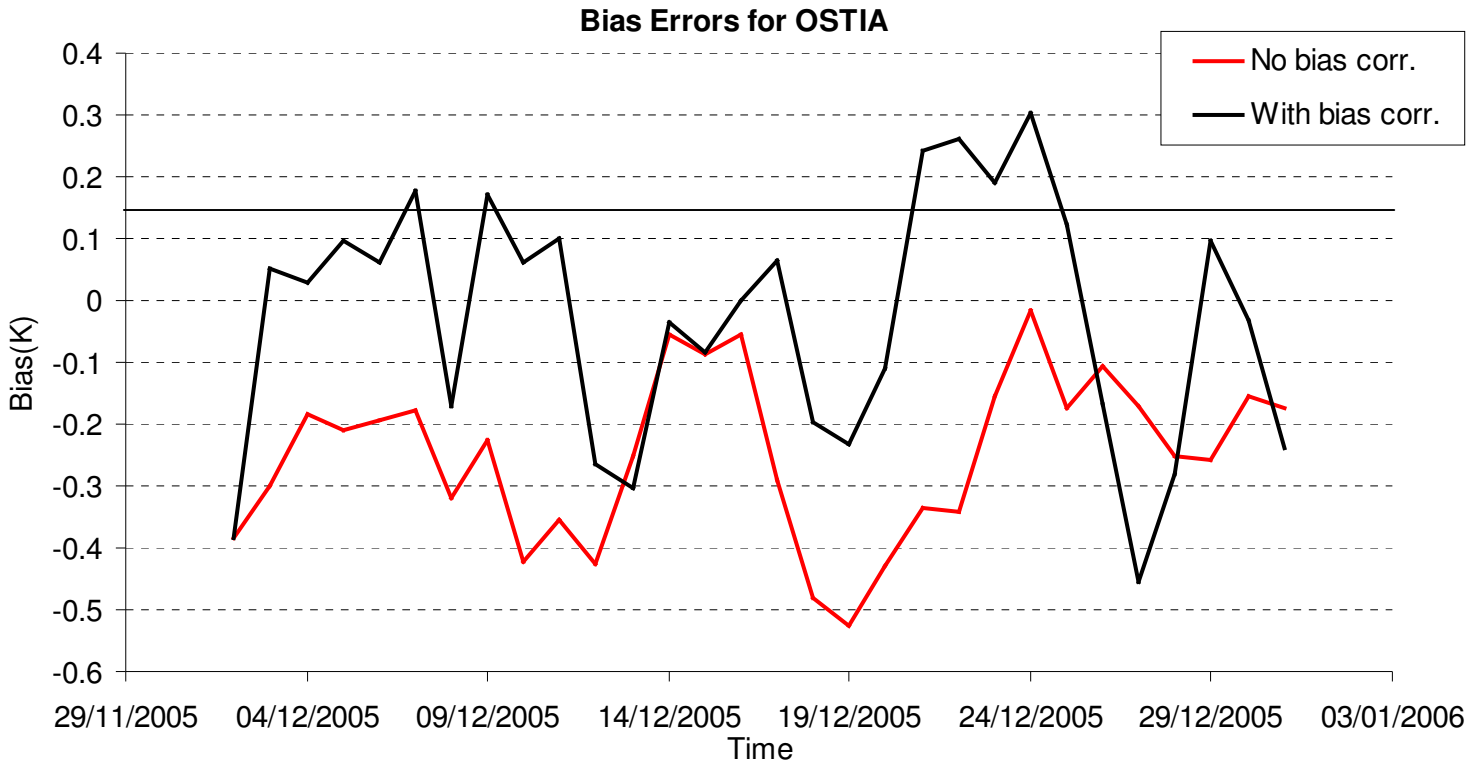


Large impact from additional match ups



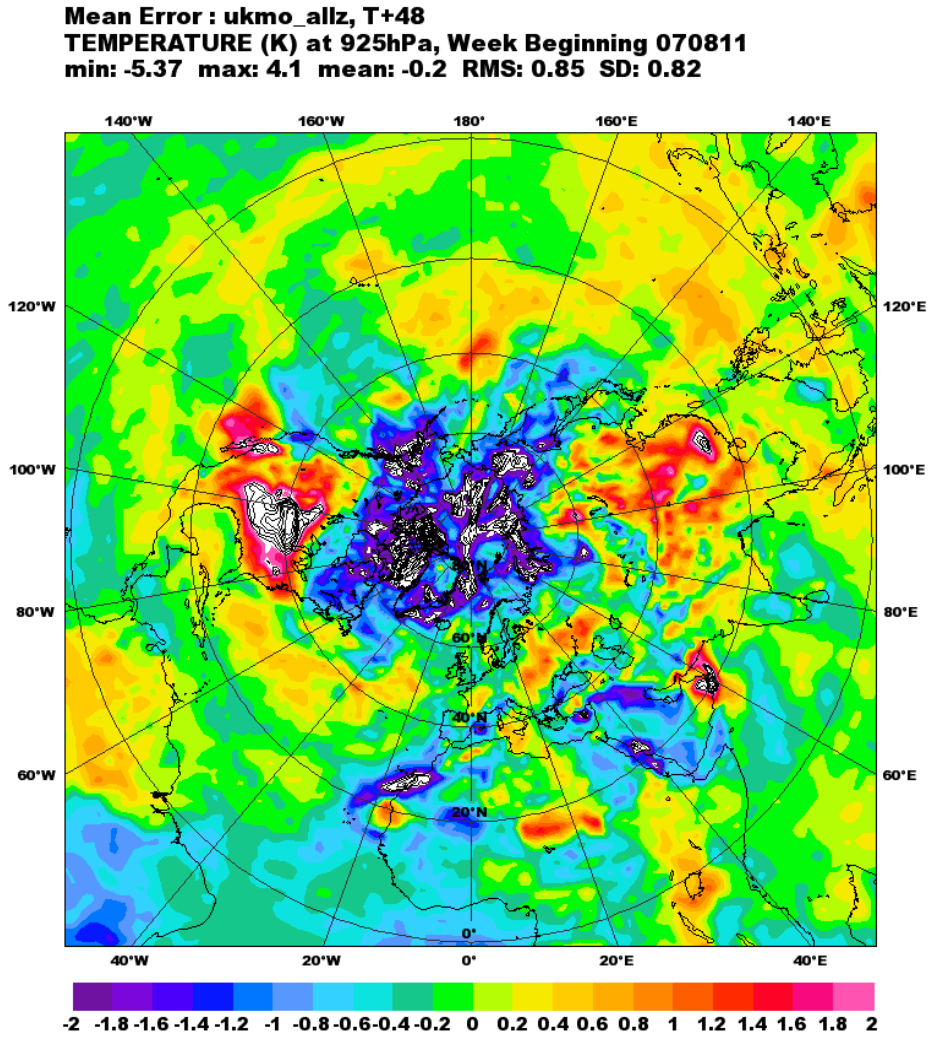
Bias correction (K)

Mean : -0.25 and -0.03



- Shows observation minus background (previous day).
- ~250 obs / day.

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

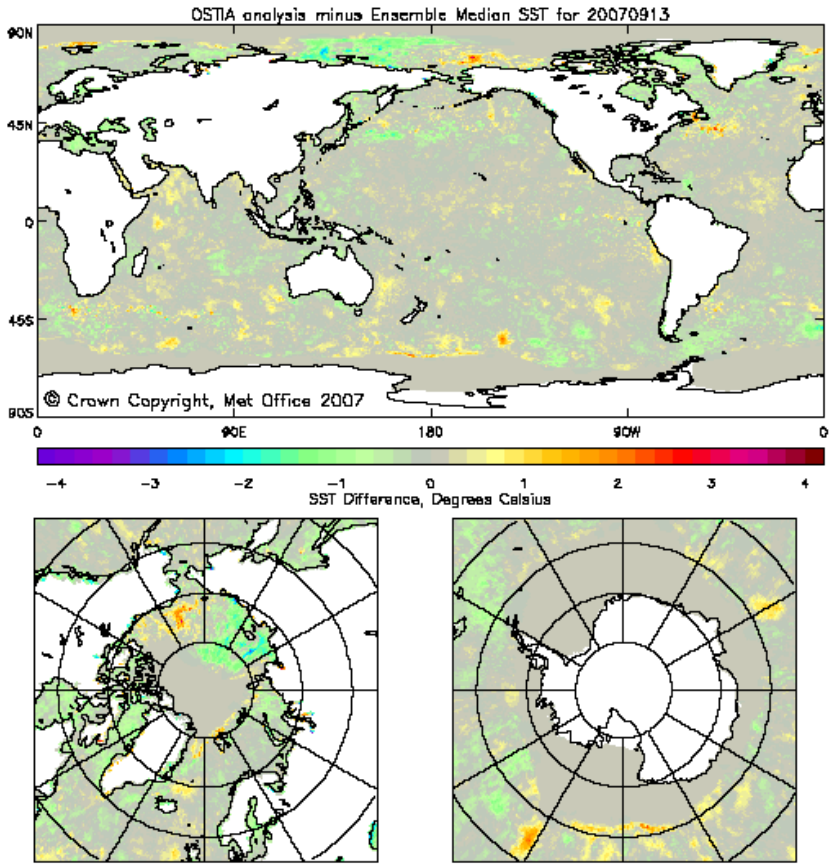


Temperature Bias at 925 hPa, 48hr forecasts

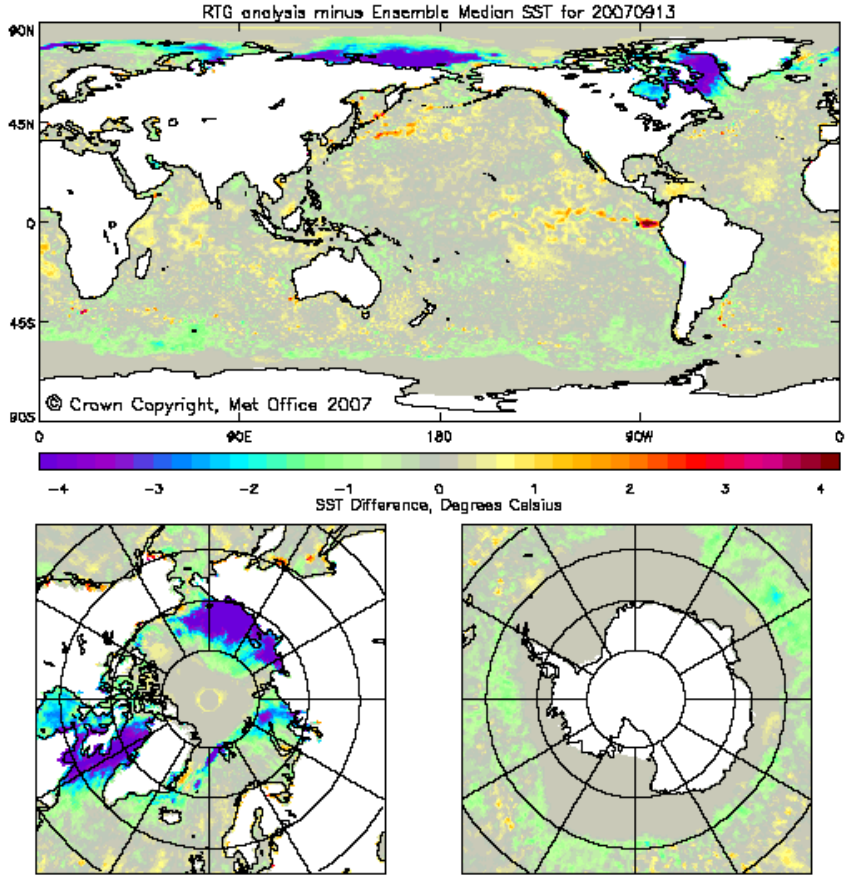
11th August 2007

Fixing the problems…

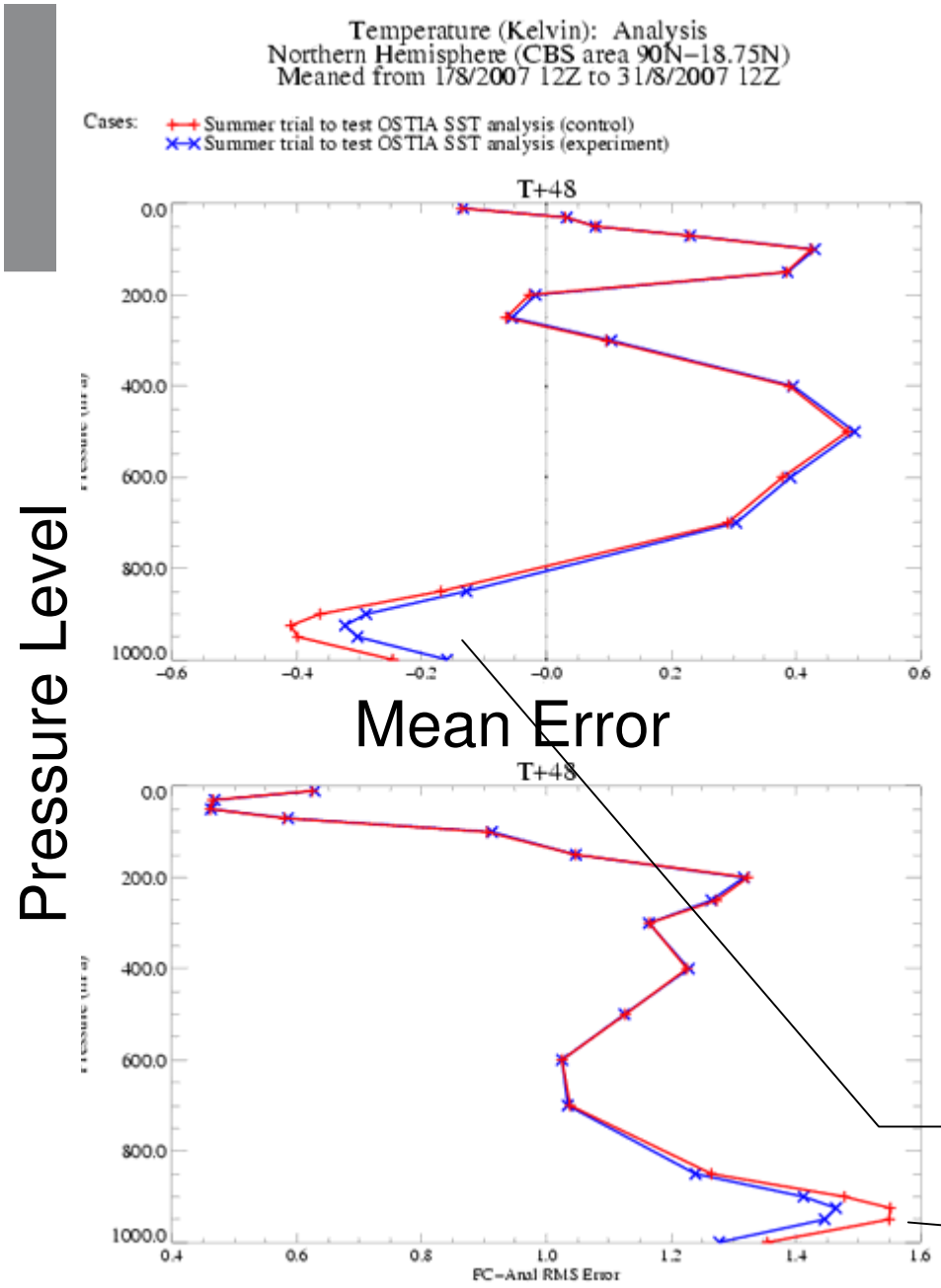
OSTIA - ensemble



RTG - ensemble



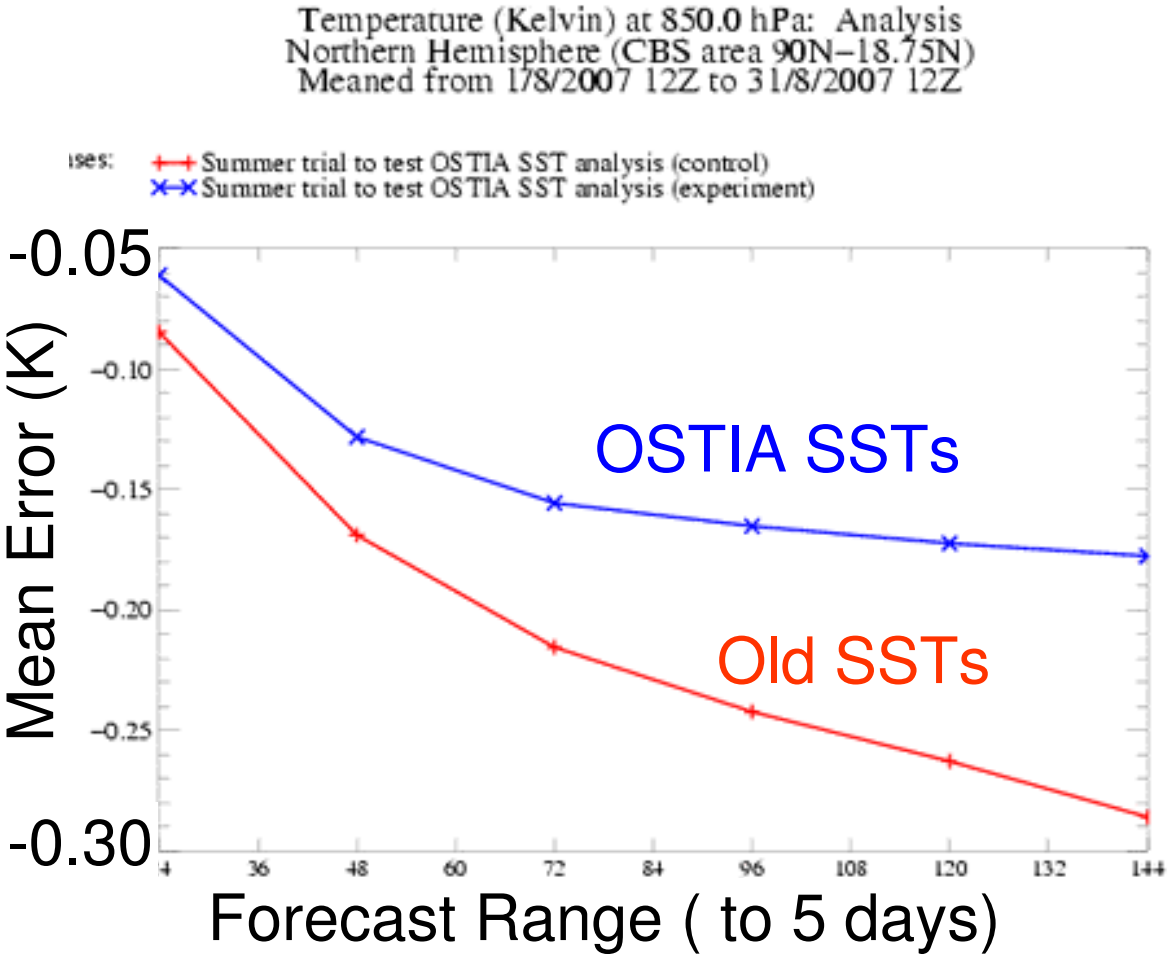
- RTG SST didn't capture the Arctic warming.



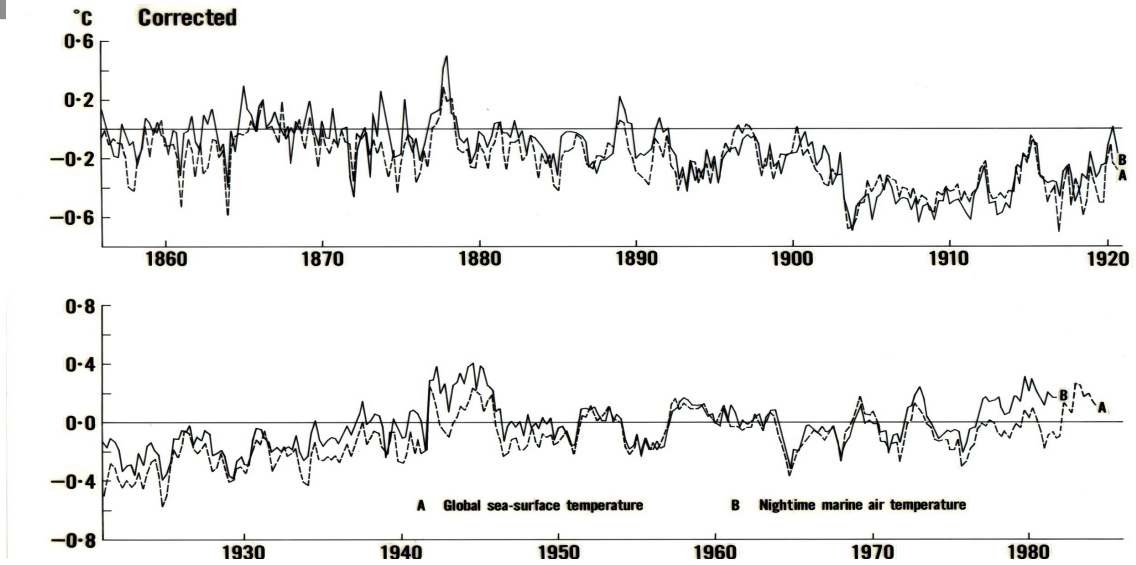
- N Hem. Temperature profiles @ T+48
- OSTIA improved the RMS and bias in the NWP forecasts during the trial period.
- AATSR underpins the OSTIA system

Reduced Bias at low levels

Met Office: August 2007 NWP Trial Results



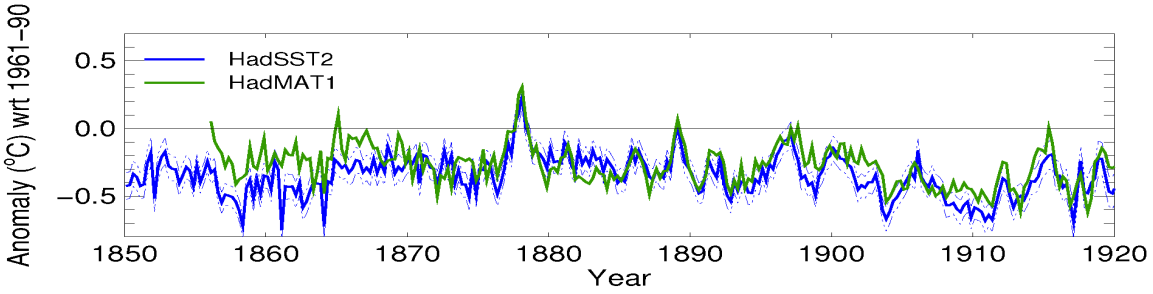
- OSTIA SSTs substantially reduced the negative bias seen with NWP SSTs at 850hPa.



Original SST and night marine air temperature data with bias adjustments

Folland, Parker and Kates, 1984, Nature.

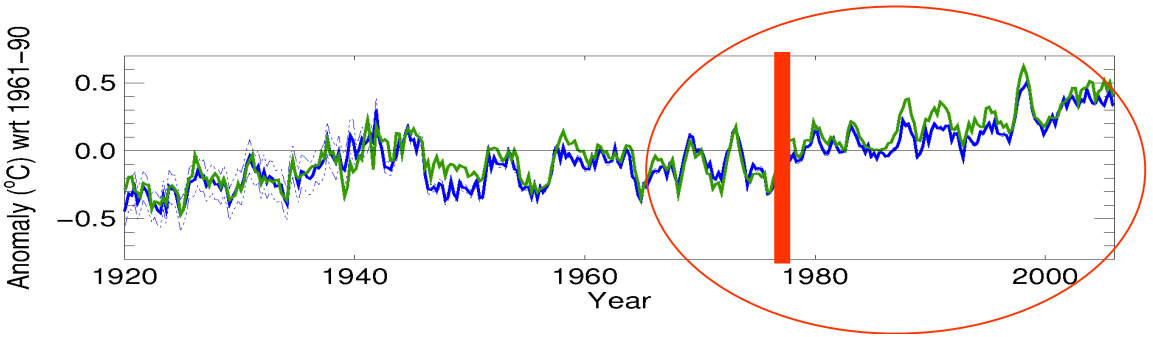
(anomalies from 1951-80)



HadSST2 data used in IPCC Fourth Assessment Report

Rayner et al, 2006, JGR (Atmos).

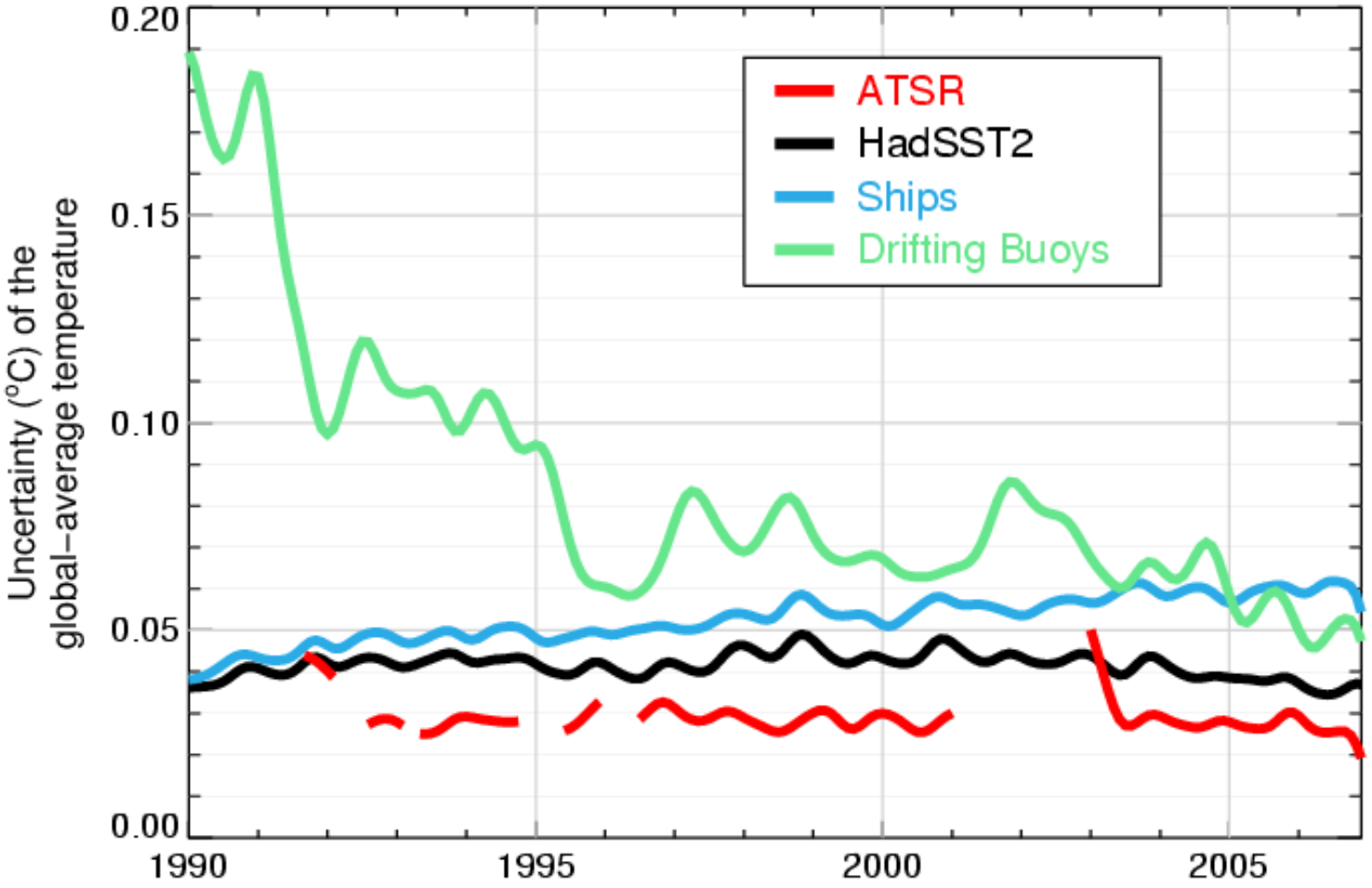
(anomalies from 1961-90)



Analysis methods have changed greatly; SST error estimates now available on all analysed space/time scales. No interpolation.

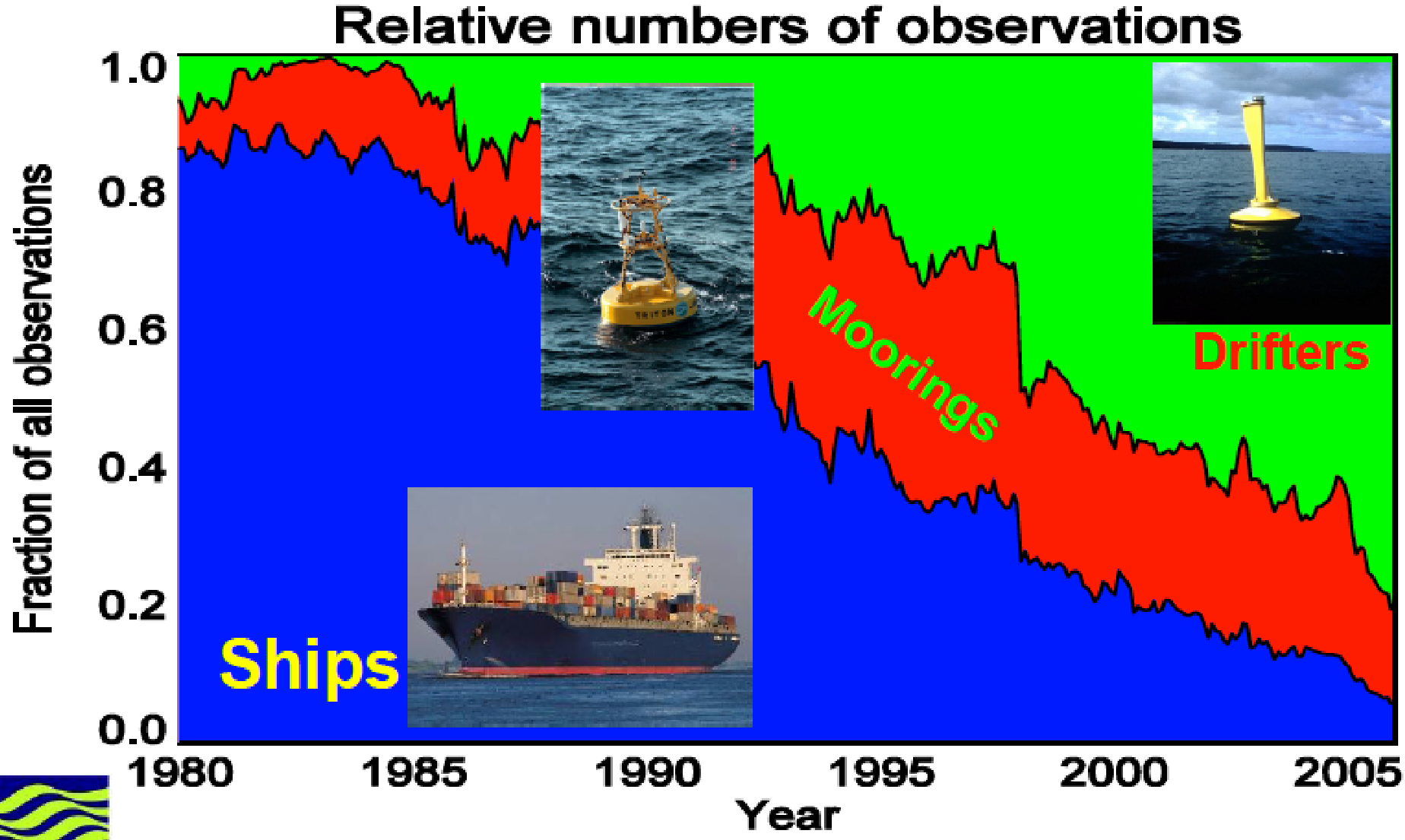
John Kennedy, Hadley Centre, UK.

ATSR provides a more accurate estimate of global average SST



© Crown

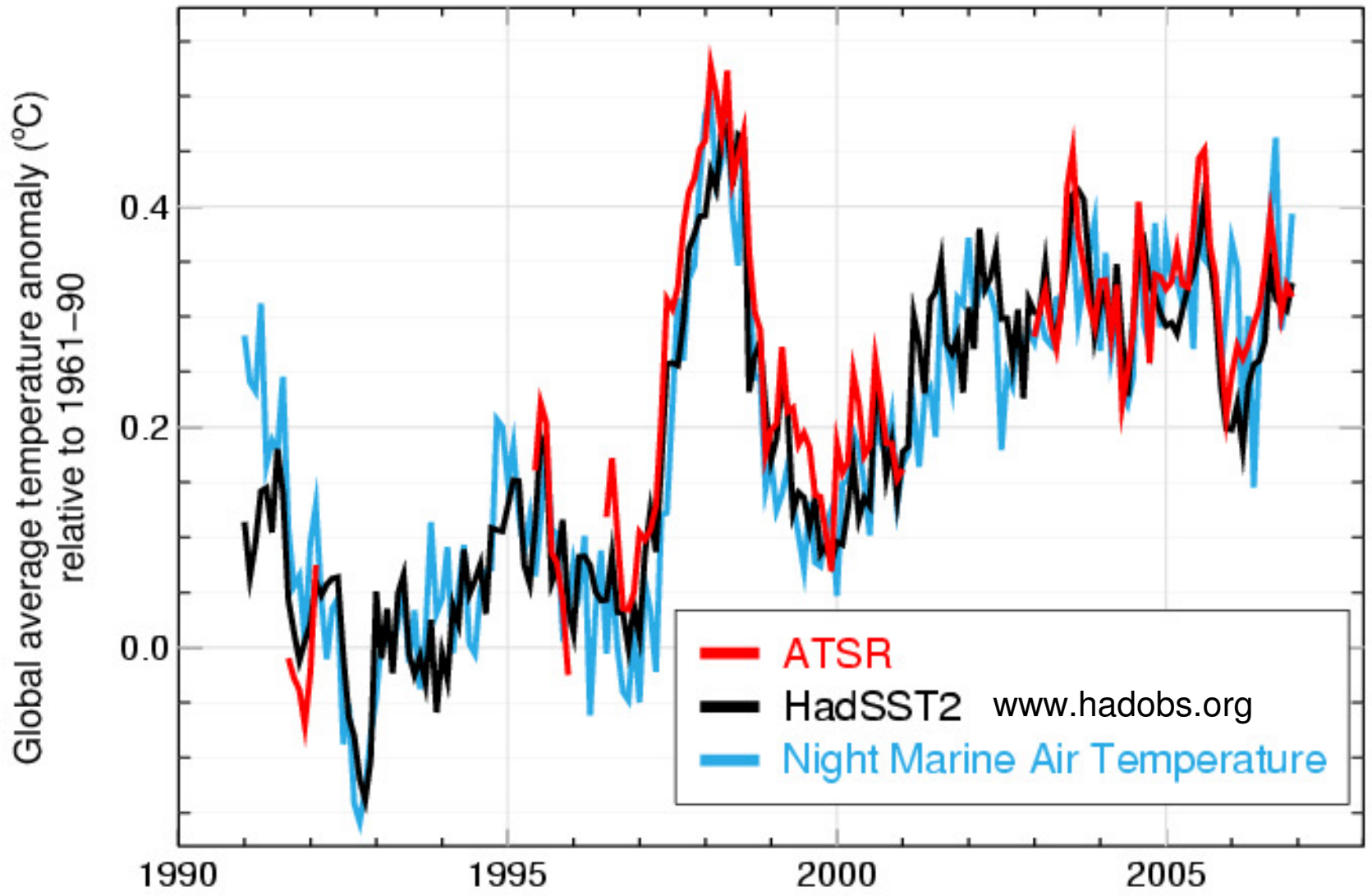
Numbers of observations



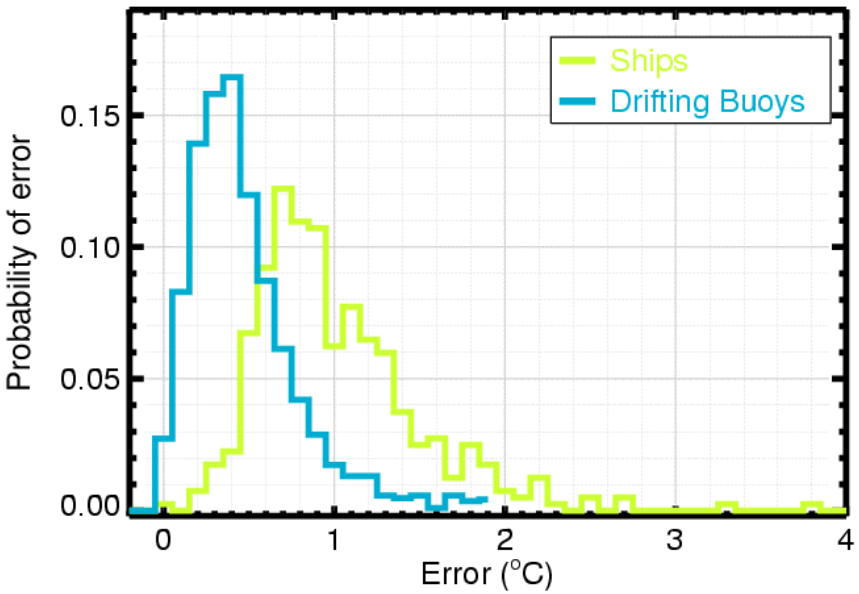
Met Office

Graph provided by John Kennedy

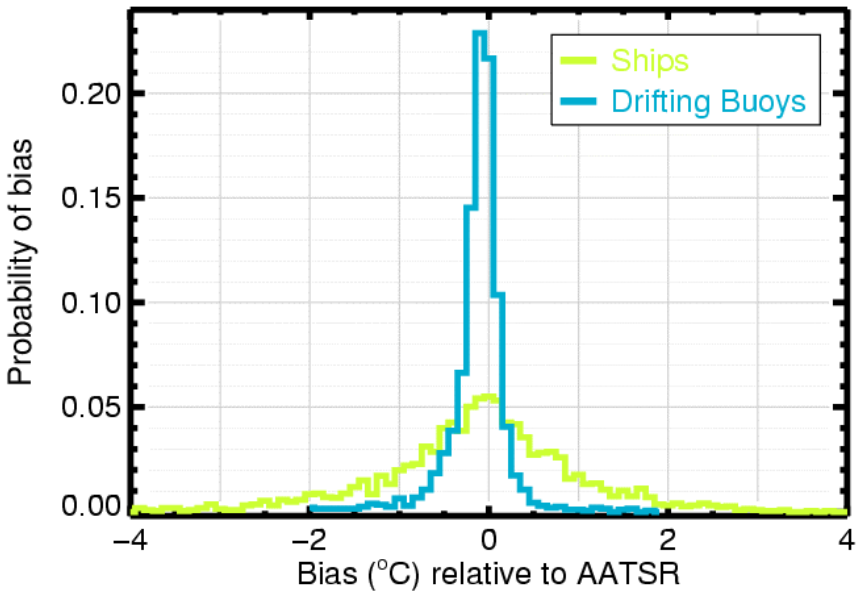
ATSR provides independent verification of *in situ* trends



ATSR is used to characterise in situ measurement biases



Distribution of measurement errors for ships and drifting buoys estimated from match-ups with ATSR data

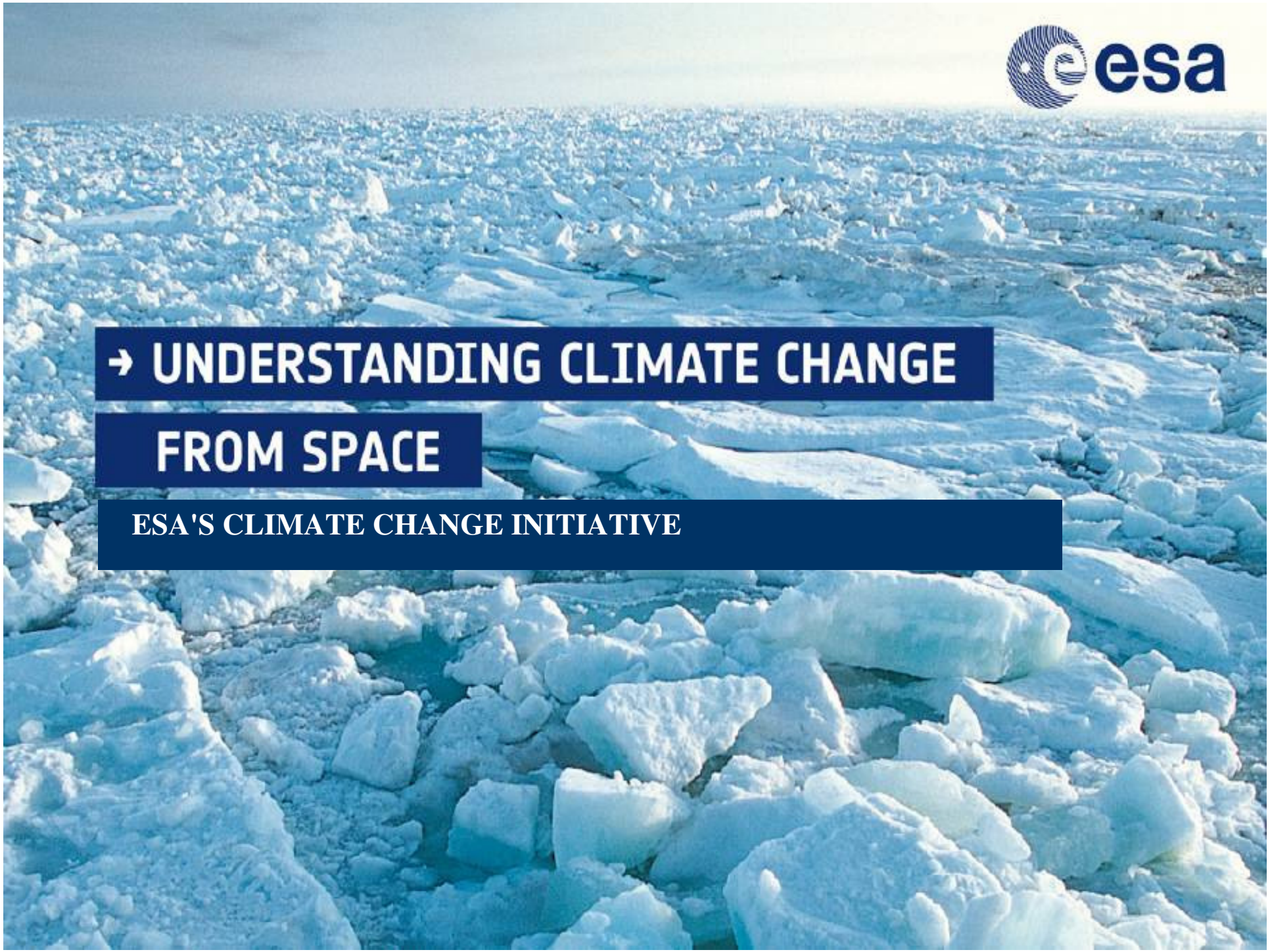


Distribution of the biases of ships and drifting buoys estimated from match-ups with ATSR data

Using AATSR data to assess the quality of in situ sea-surface temperature observations for climate studies

J.J. Kennedy *, R.O. Smith, N.A. Rayner

Met Office, Exeter, UK


esa
→ UNDERSTANDING CLIMATE CHANGE
FROM SPACE
ESA'S CLIMATE CHANGE INITIATIVE

SST_cci

A Celebration: 10 years of Marine Observations with ENVISAT , IFREMER 8th March 2012

Two Key (A)ATSR Projects

ATSR Reprocessing for Climate (ARC)

- Completed June 2011
- ATSR series SSTs
- 1991 to mid 2011

For data:

- www.neodc.rl.ac.uk/browse/neodc/arc

Climate Change Initiative(SST CCI)

- Ongoing (in year 2 of 3)
- SST CDR user requirements
- New SST CDR in 2012/3
  - ATSRs and AVHRRs

- For report:
- www.esa-sst-cci.org

NATURAL ENVIRONMENT RESEARCH COUNCIL

DEPARTMENT OF ENERGY & CLIMATE CHANGE

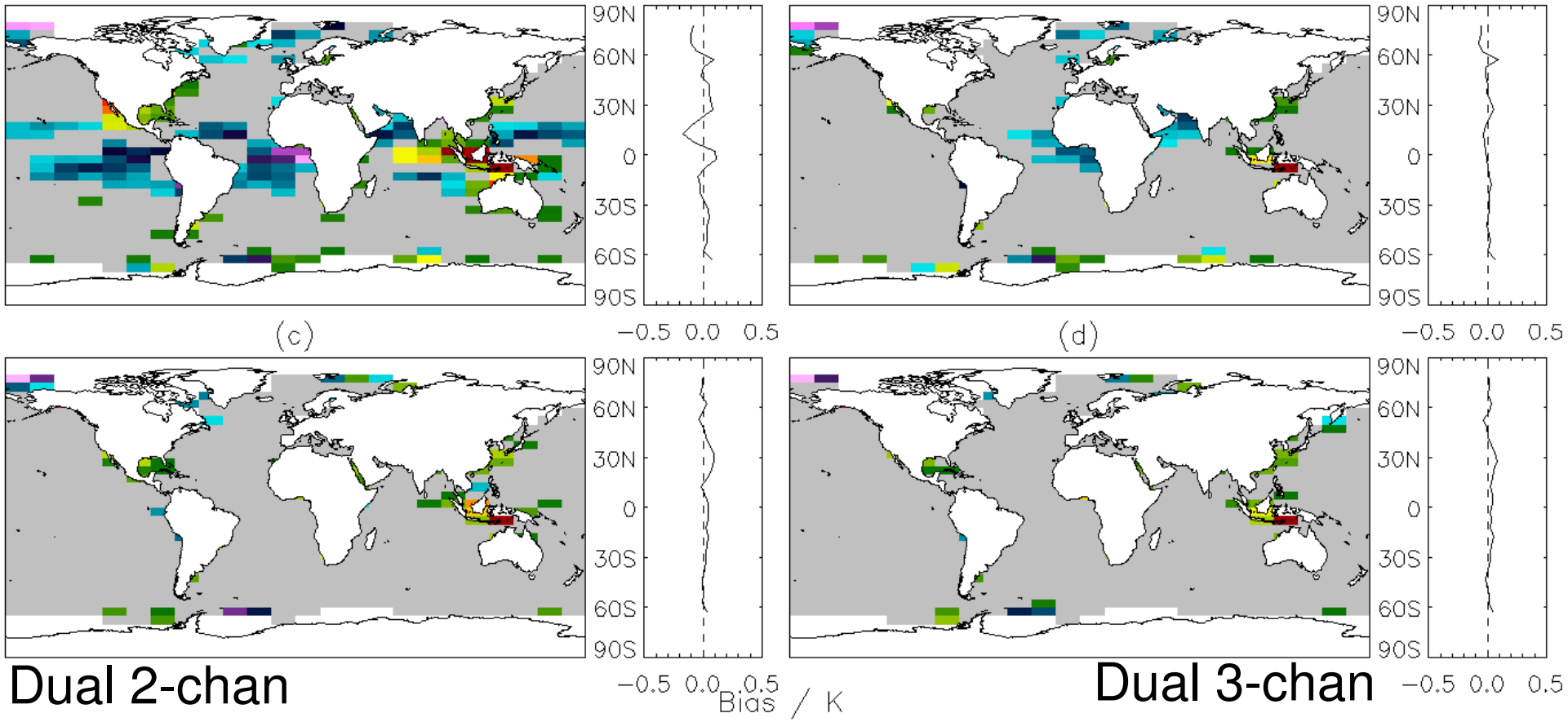
Major scientific and technical challenges

	PATHFINDER	ARC	CCI SST
Sensors	AVHRR	ATSR	AVHRR + ATSR
Tied to	Drifting buoys	Independent	Independent
Homogenized	No	Yes	Yes
Accounting for diurnal effects	No	Yes	Yes
Meets GCOS accuracy (0.25 K)	No	Yes	Yes
Meets ARC target accuracy (0.1 K)	No	Mostly	Yes/mostly
Retrieval method (TBC)	Coefficients	Coefficients	Optimal
Meets GCOS stability	No	Likely	Likely
Stability quantified	No	Yes	Yes
Clearly defined SST	No	SST-skin, depth	SST-skin, sub-skin, depth
Quantified uncertainties	No	Yes	Yes
Spatial resolution	4 km	0.1°	4 km / 0.05°
GHRSST & netCDF compliant	No	No	Yes
Period	1984 onwards	1991 - 2009	1991 - 2010

ARC $SST_{0.2m}$ minus drifting buoys

Nadir 2-chan

Nadir 3-chan



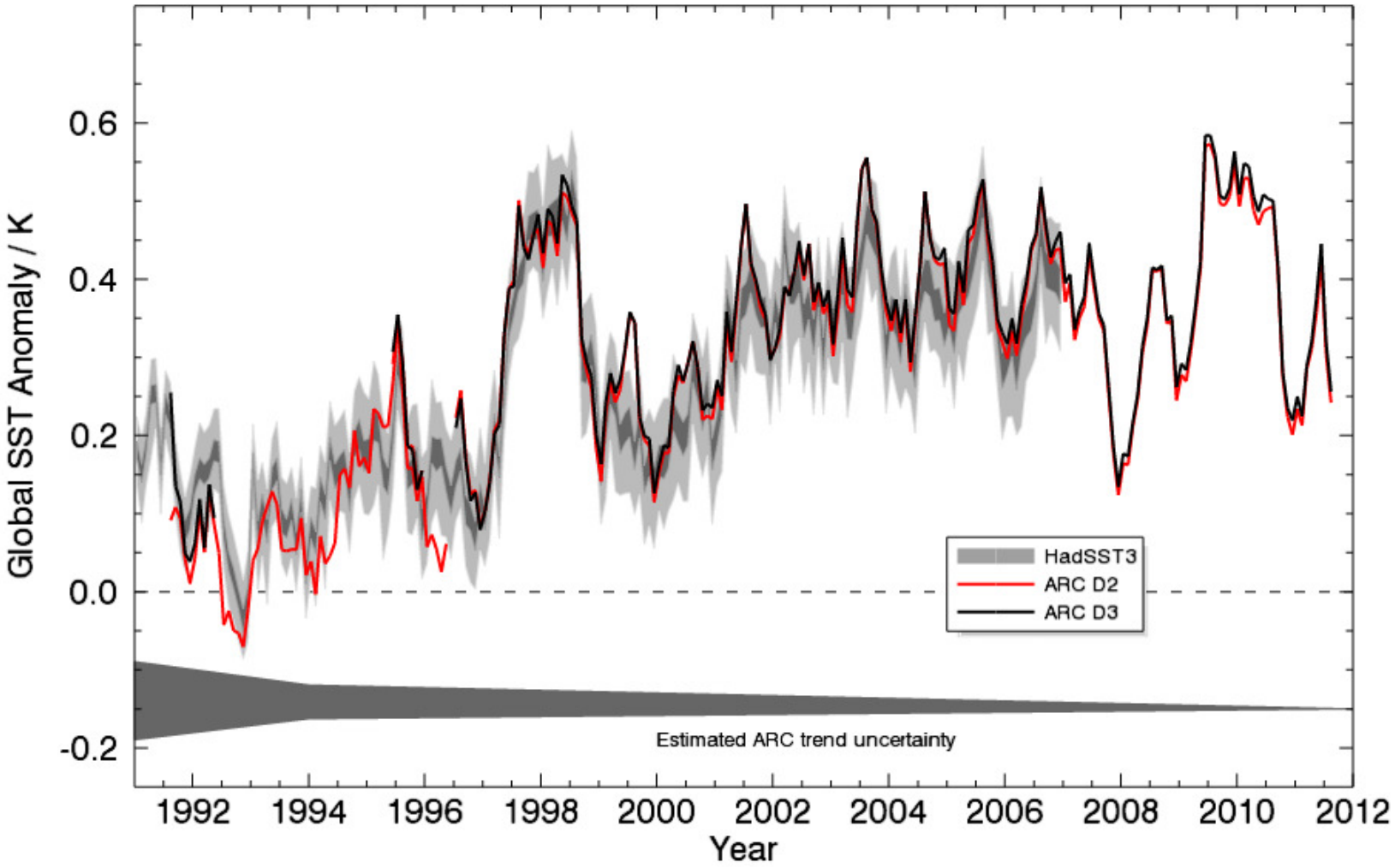
Dual 2-chan

Dual 3-chan

0.5 K

0.5 K

Independent time series



ESA SST_cci: Addressing Climate requirements

- Climate users require lower SST biases (0.1 K or better) than are found in traditional meteorological SST products
- Stability is a key parameter. Excellent stability (mK/yr) is possible for (A)ATSRs with careful exploitation of overlaps
- Sensitivity (or, equivalently, the amount of prior SST information embedded in CDR) should be quantified
- Uncertainty estimates should be part of the SST CDR and can be validated in their own right
- (A)ATSR SSTs are essentially independent of in situ observations, yet confirm the evolution of global SSTA in HadSST3

Future perspectives…

- Today, ***all AATSR data are used*** whenever they are available in every weather & ocean forecast at the Met Office
- 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 in development within a limited area NWP multi-model ensemble prediction systems (local scale may be 1-2km)
  - A flexible observation network targeting data sparse areas

Key Achievements of the AATSR Programme

- Rigorous development and refinement of the (A)ATSR Processing System
- Establishment of a comprehensive Validation Programme
- Establishment of productive dialogues with ESA, with user communities (e.g. GHRSST forum) and with validation data providers
- General promotional activities culminating in Science Museum Exhibition, opening in December 2010 and Special Issue of the Remote Sensing of Environment (RSE) Journal, planned for early 2011
- Pro-active monitoring of data quality, leading to identification and resolution of many data product issues
- The scientific analysis resulting in publication of the first global trend paper in 2004 and current definitive work on a global temperature time-series from the 19 year SST dataset
- Has allowed GMES to proceed with confidence in the development of Sentinel-3 SLSTR

Happy 10th Birthday AATSR!!

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

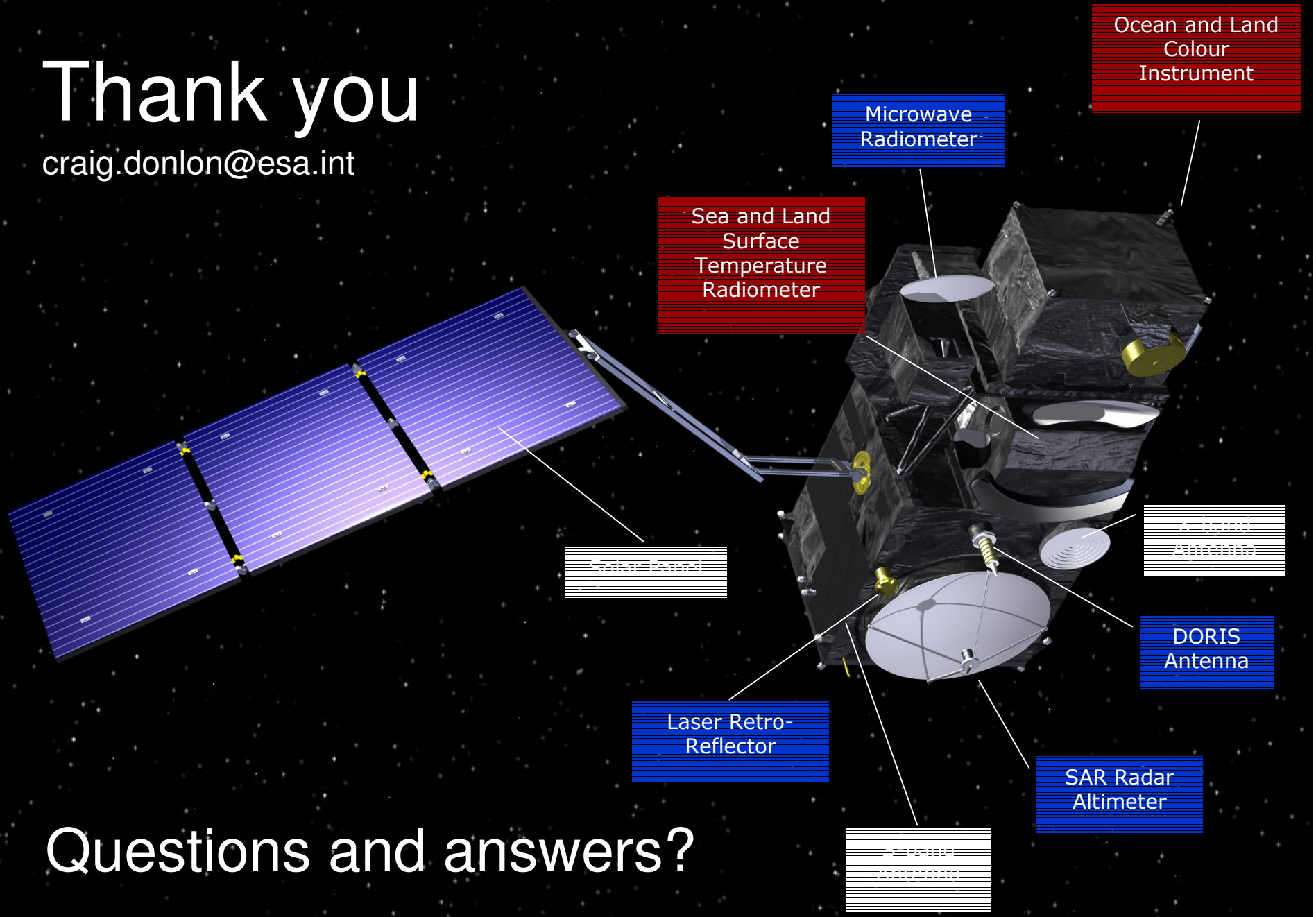
Prof. David Llewellyn-Jones,

PI for (A)ATSR

- The dream and vision of DLJ has come true…

Thank you

craig.donlon@esa.int



Questions and answers?