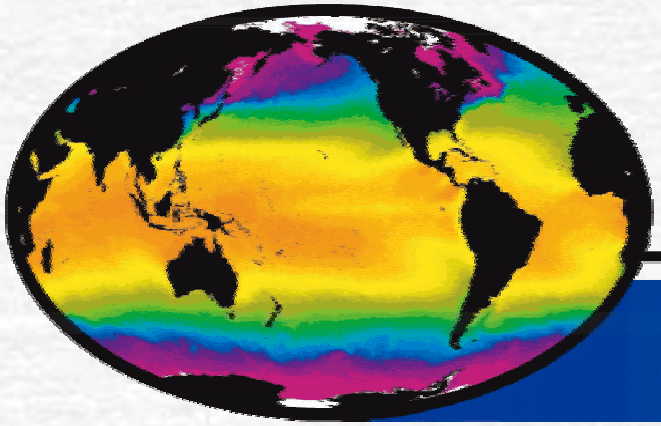


GHRSST-PP

GODAE High Resolution Sea Surface Temperature Pilot Project

Craig Donlon

Director of the GHRSST-PP International Project Office, Met Office, Exeter, UK. (craig.donlon@metoffice.com)

Presented at the Second JCOMM Workshop on Advances in Marine Climatology (CLIMAR-II), Brussels, Belgium 17-22 November 2003.

GHRSST-PP Home Page http://www.ghrsst-pp.org

Overview

- What is the GHRSST-PP?
- The GHRSST-PP Data Processing Model
- GHRSST-PP Data Products
- Applications
- Schedule for the Pilot Project
- Summary

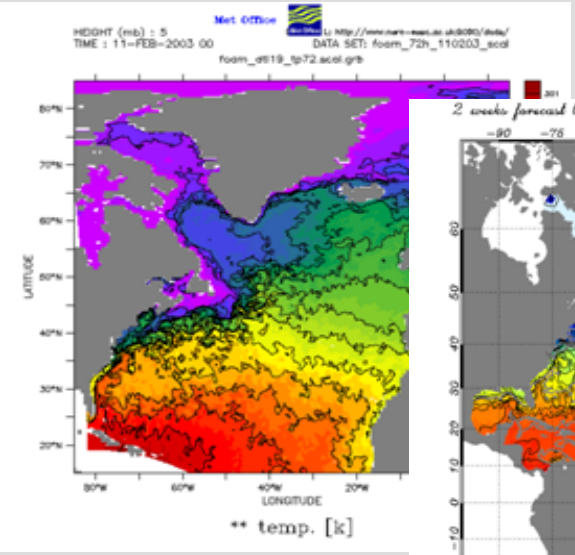
GODAE and the GHRSST-PP

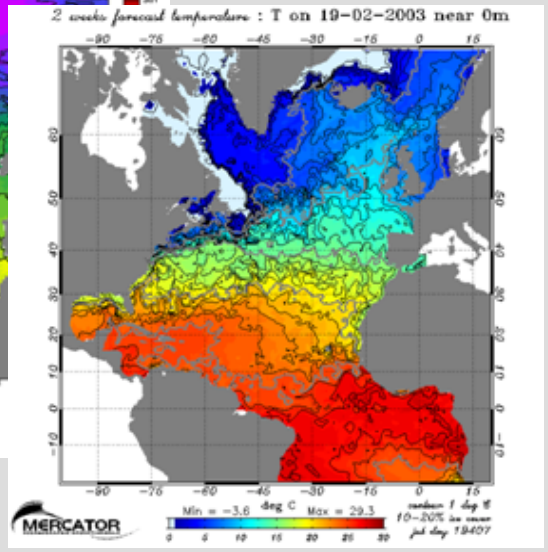
GHRSST-PP
GODAE High Resolution Sea Surface Temperature Pilot Project

FEEDBACK

ASSIMILATION
Init. cond./forcing/boundary Con.

Better **Weather** forecasts
Better **Ocean** Forecasts
Better **OUTCOMES**





FOAM 1/9deg 72hr forecast made on 11/02/2003

MERCATOR bi-weekly forecast made on 5/02/2002

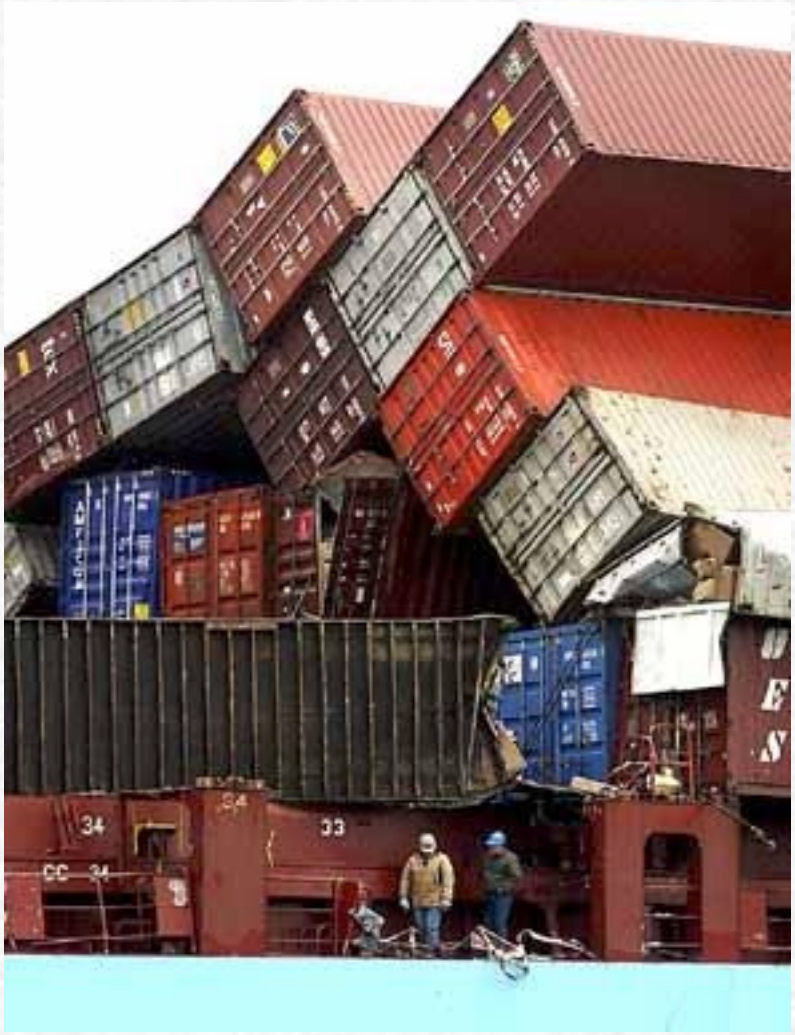
Tailored OUTPUTS

Applications

- **Alleviation of Poverty**
- **Safety/security of life and property**
- Monitoring of natural hazards/disasters
- Detection and predicting climate variability
- Management of natural resources
- Public health
- Safety of marine operations
- Preserving and restoring the health of ecosystems
- Water quality water quality indicators.
- Tourism and leisure

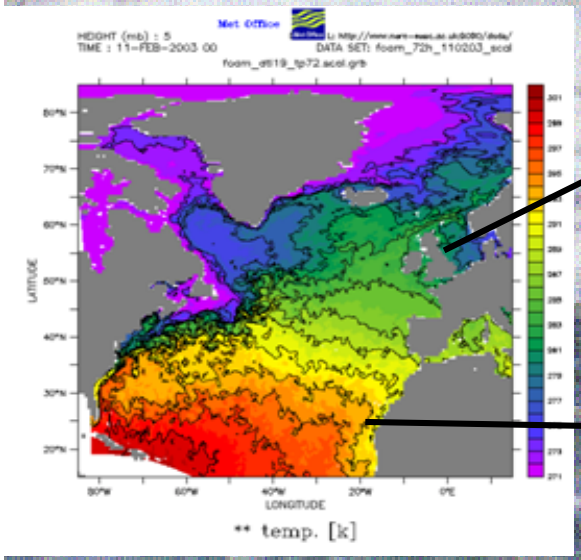
From the Gulf of Mexico
after hurricane Lilly, Sept. 2002

Karin Magnussen, Met.No.

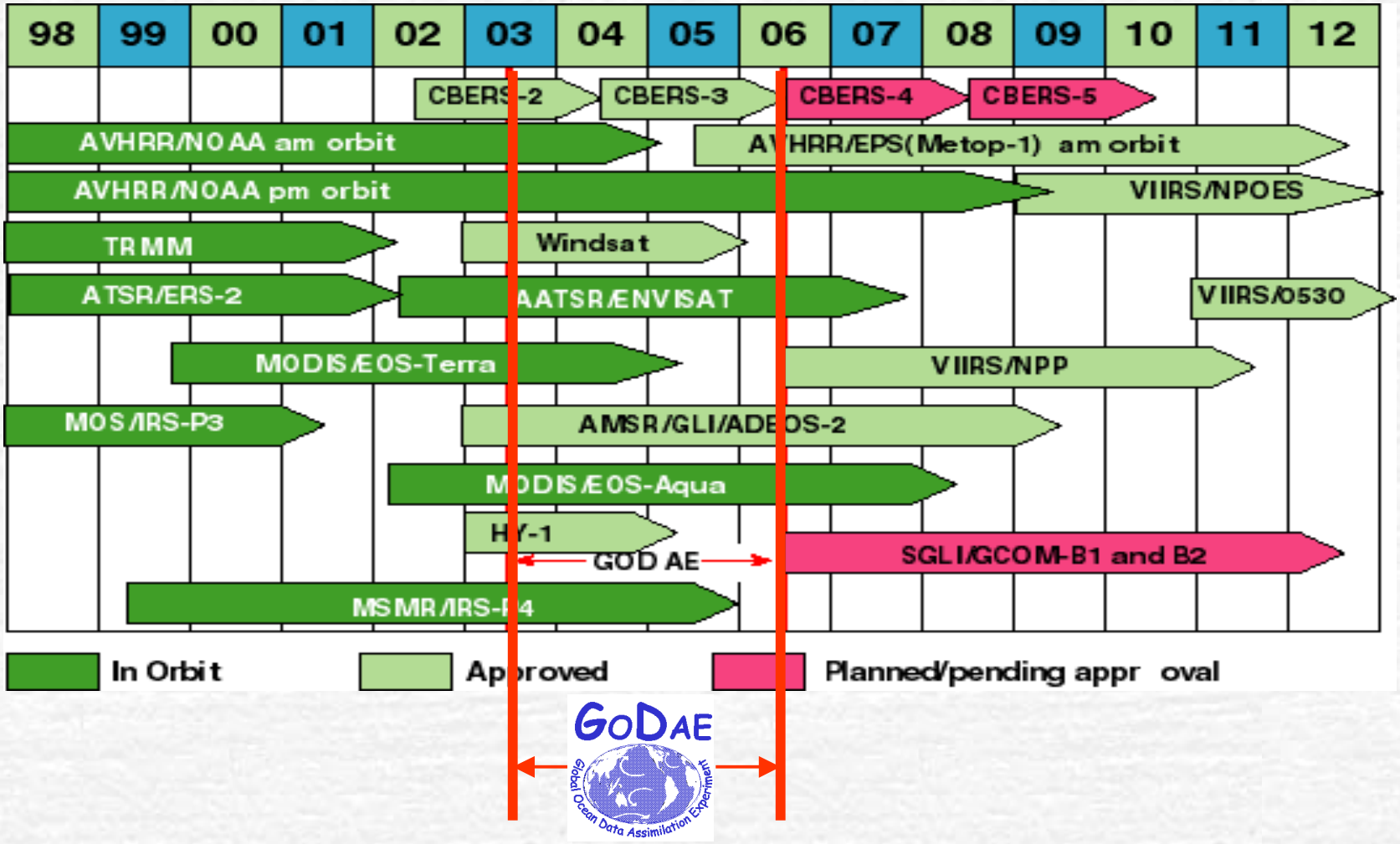


Maersk Carolina after "meeting a storm South of Grand Banks", 24. January 2003 - 130 containers fell into the sea **(Karin Magnussen, met.no)**

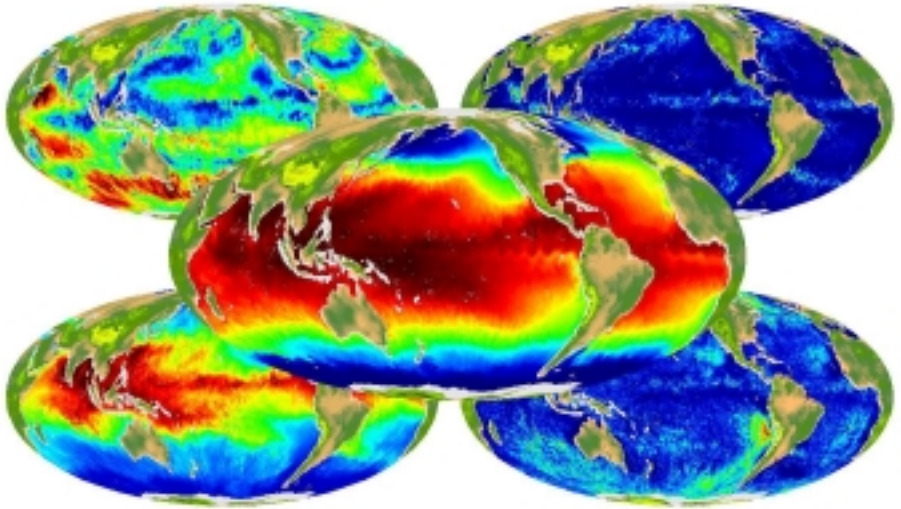
Fishing vessel in heavy seas

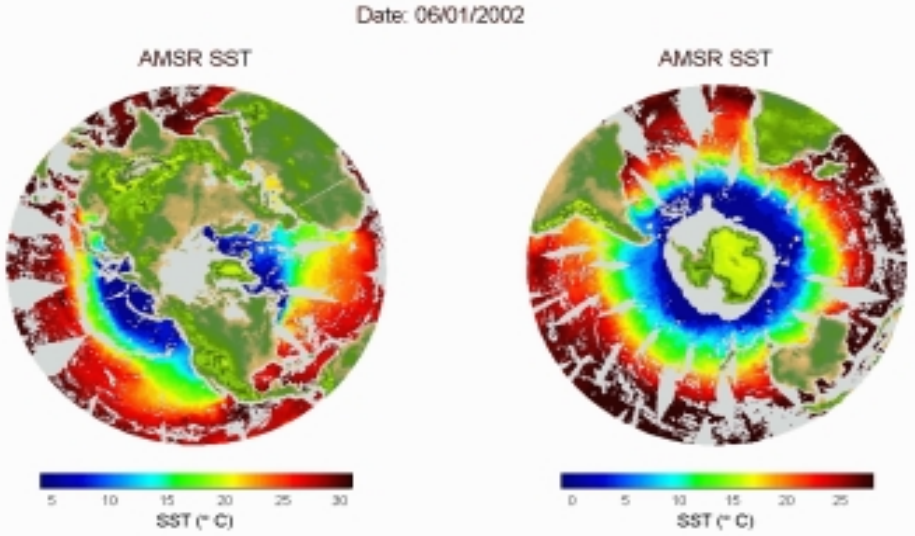


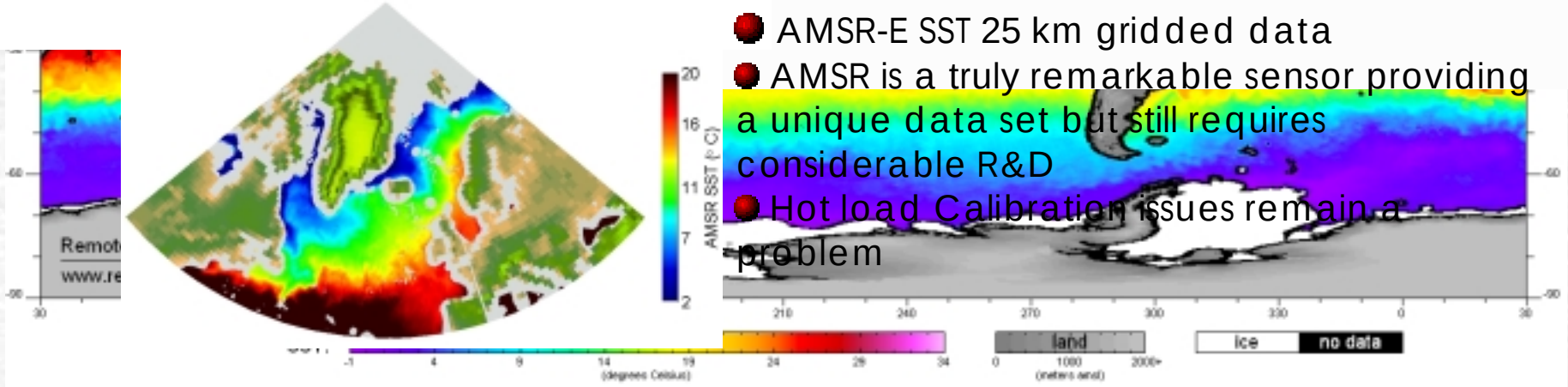
This IS the "Golden Age" for satellite SST



A revolution: AMSR-E and ~~AMSR~~ SST

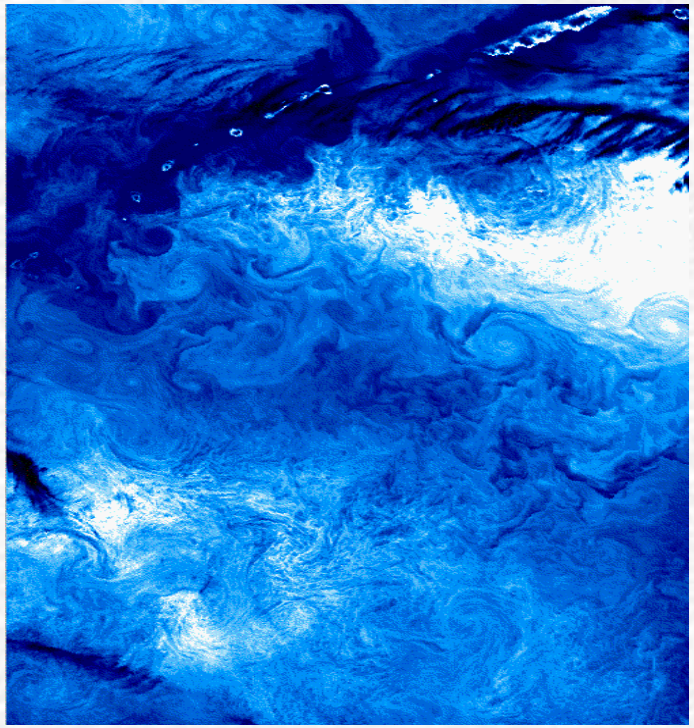




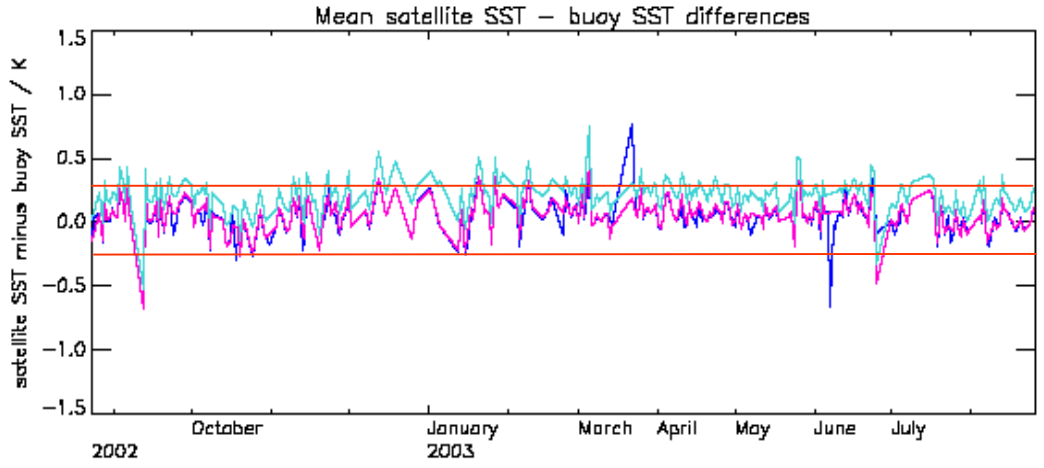


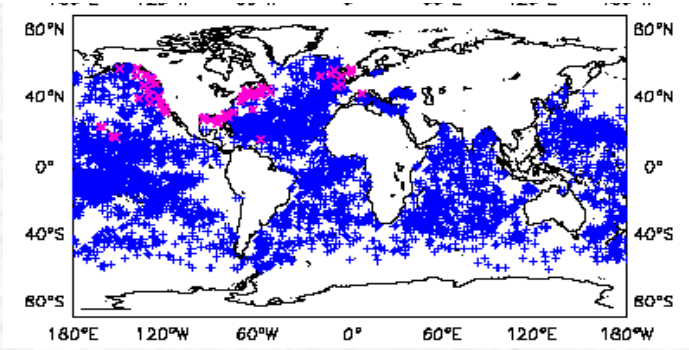
- AMSR-E SST 25 km gridded data
- AMSR is a truly remarkable sensor providing a unique data set but still requires considerable R&D
- Hot load Calibration issues remain a problem

IR sensors: High spatial and radiometric resolution (AATSR)



AATSR Eastern tip of Arabian peninsula © ESA





Means for period Aug 02 – Aug 03:

all: 0.05 K (σ 0.41 K)

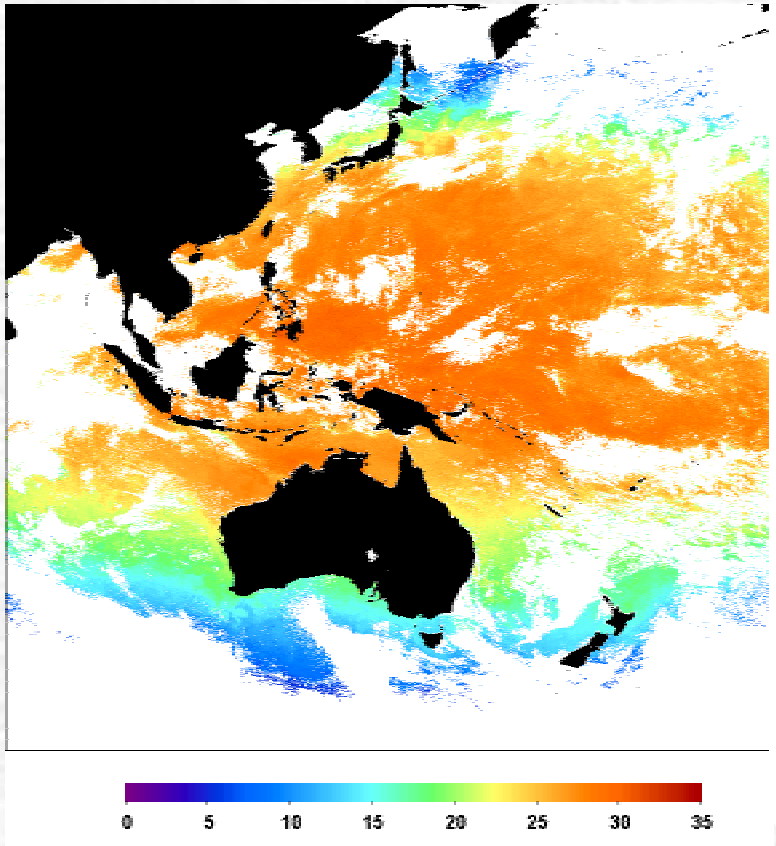
night: 0.07 K (σ 0.35 K)

day: 0.03 K (σ 0.46 K)

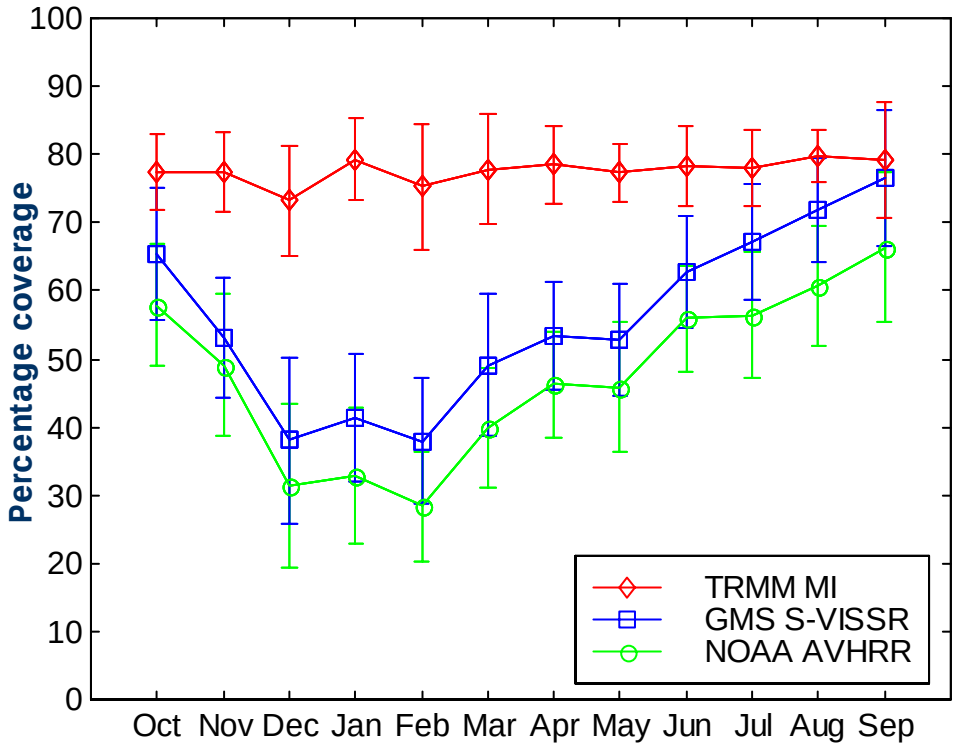
- High radiometric accuracy and fidelity (A. O'Carrol)
- Daily global coverage But a major problem with cloud
  - Persistent in particular regions and seasons
  - e.g., GMS footprint over Japan RDAC area

Met Office

Temporal sampling bias



GMS VISSR SST Japan (H. Kawamura)



(Figure: L. Guan)

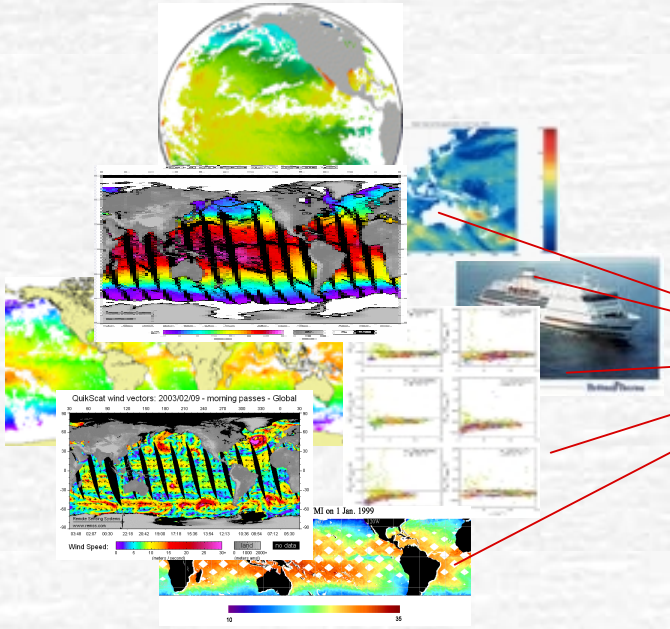
- **Only Microwave SST provides temporally unbiased sample as the IR data are obscured by seasonal clouds**

The GHRSST-PP

- GODAE requires global high-resolution sea surface temperature in near real-time for assimilation into ocean models.
- Satellite observations provide the only data stream that can satisfy this requirement
- The major challenge is to quantify the errors due to uncertainty in:
  - Atmospheric transmission models
    - not considered directly as we are dealing with L2 data sets
  - Cloud contamination in IR data sets
  - Rain/RF contamination in microwave SST
  - Atmospheric aerosol contamination
  - Sea Ice extent and SST in the marginal ice zone
  - Diurnal variability (including alias)
  - Satellite and in situ instrument stability and calibration
  - The interpretation of in situ SST relative to the skin and sub-skin measurements provided by satellites.

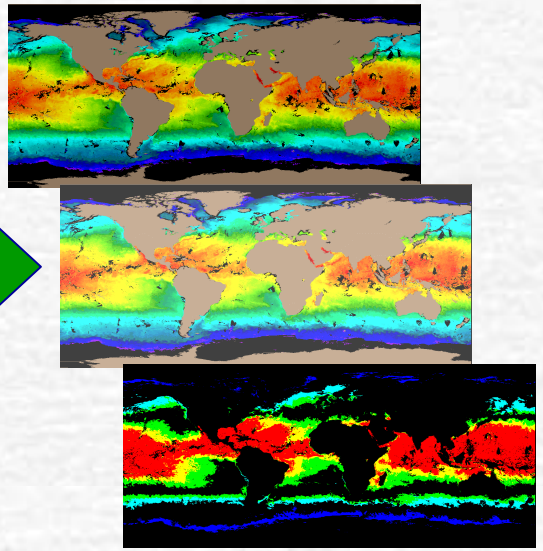
The GHRSST-PP Concept

- In principle, the merging and analysis of complementary satellite and in situ measurements can deliver SST products with enhanced accuracy, spatial and temporal coverage.
- Emphasis on synergy benefits



Quality Control

ANALYSIS

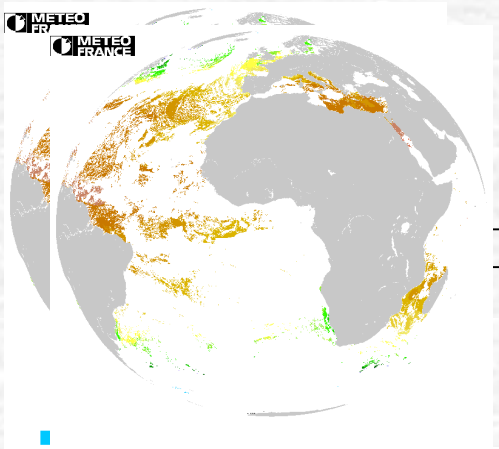


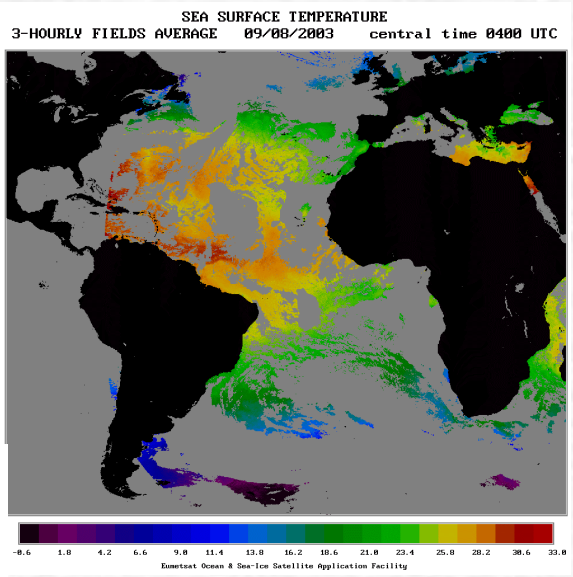
Move incomplete and inhomogeneous data

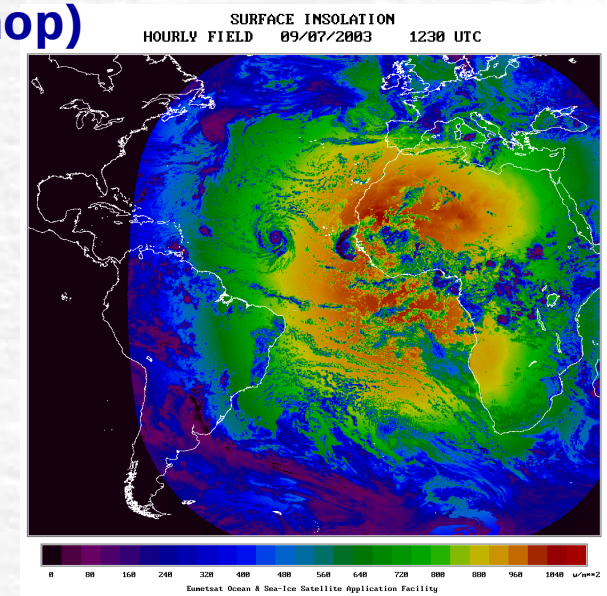
Complete, homogeneous QC data and applications

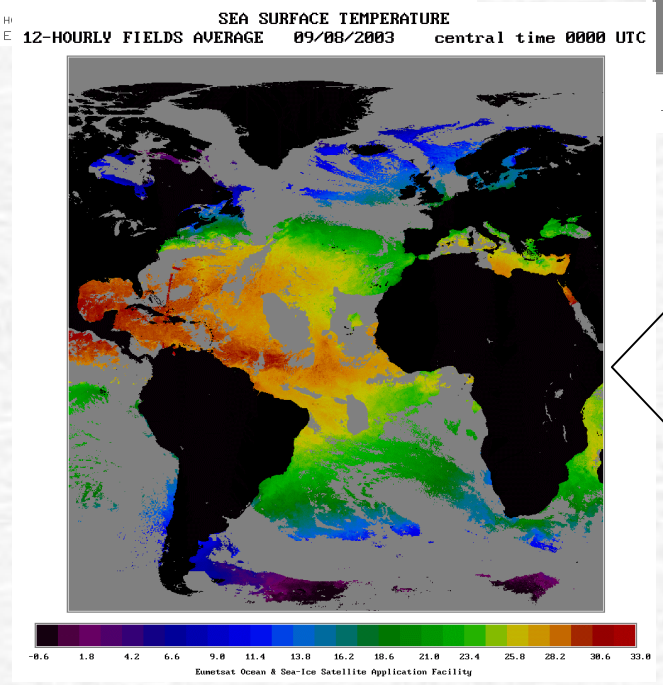
MSG SEVIRI: Operational SST, SSI and DLI

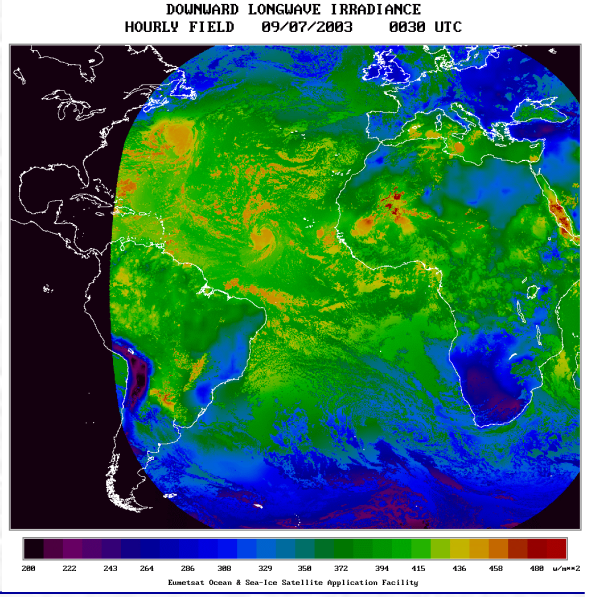
(P.LeBorgne, 4th GHRSST-PP Workshop)







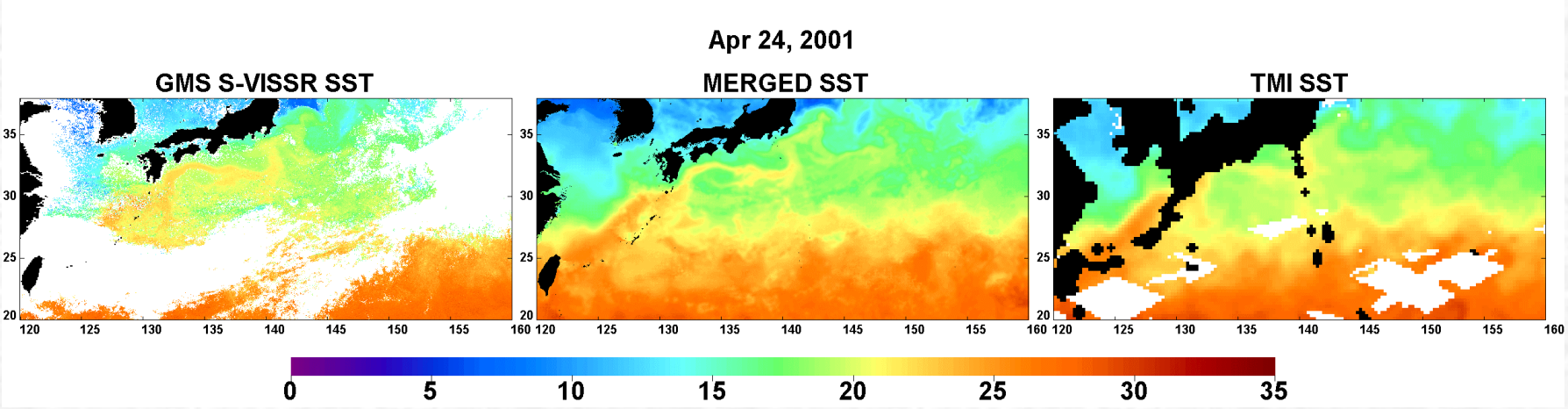




http://www.ghrsst-pp.org

GHRSST-PP

New Generation Sea Surface Temperature v1.0: example



(H. Kawamura)

High-resolution Cloud-free Daily SST Products

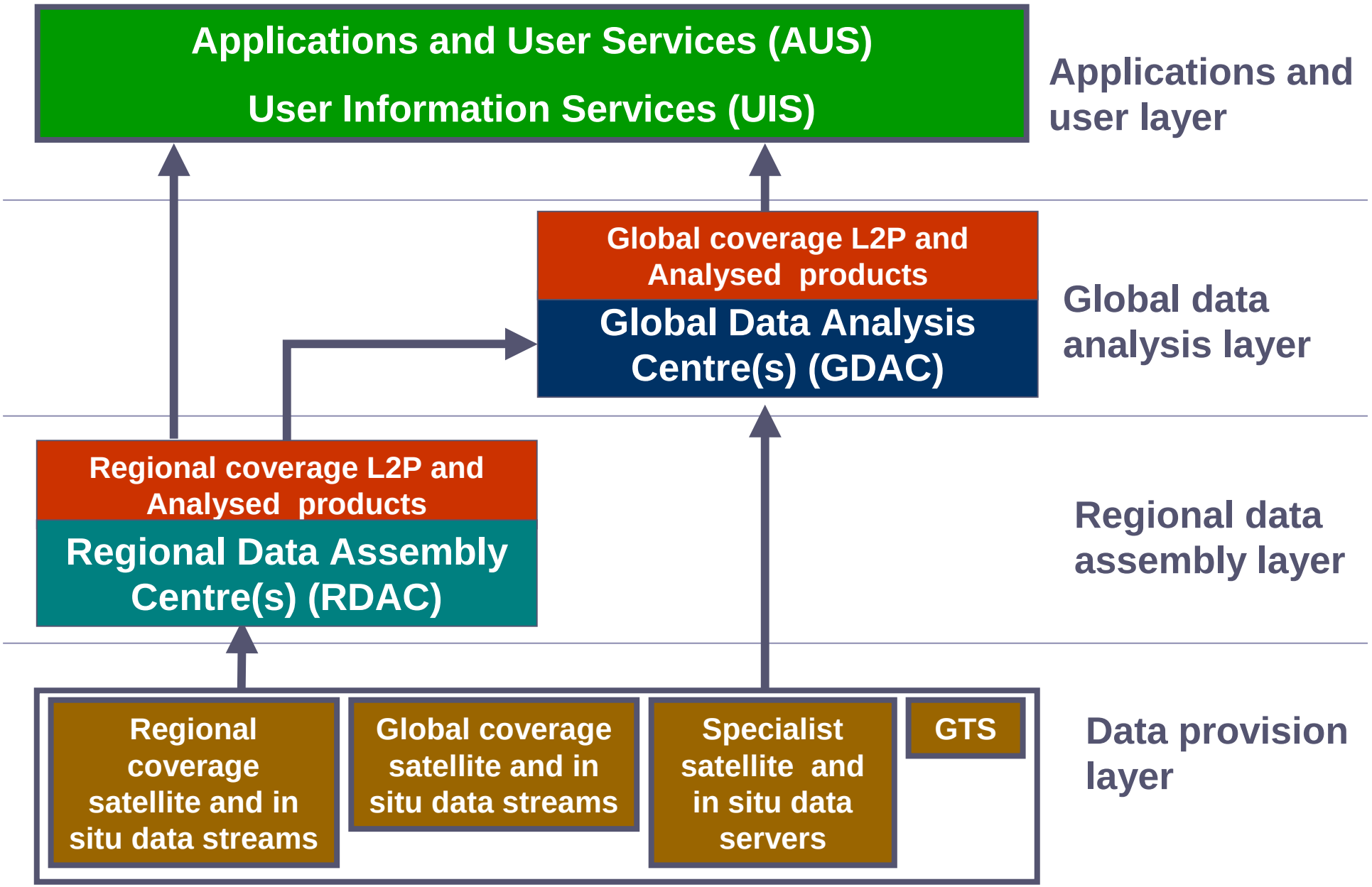
5-km spatial and 24-hour temporal resolution

http://www.ocean.caos.tohoku.ac.jp

The GHRSST-PP Development and Implementation Framework

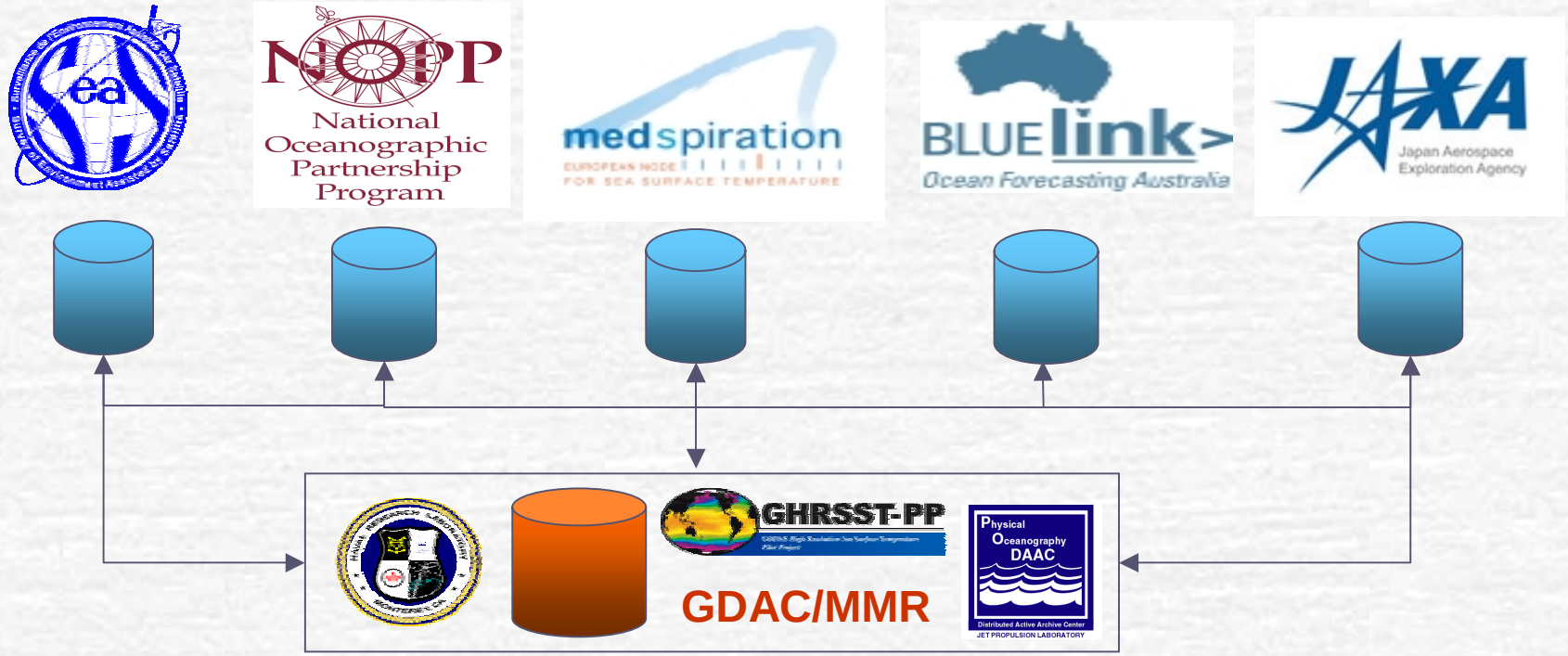
Implementation strategy

- Implementation needs a framework for success
  - Follow a pragmatic approach
  - Use what is already available
  - Build on existing capacity
- Preserve and enhance regional autonomy and identity
  - Provide a platform for regional actions
  - Preserve regional infrastructure and R&D investments
  - Leverage regional funding
- Provide a global project focus
  - For global data and products, agencies and scientists
  - Active outreach, promotion,and capacity building
  - Maintain the GODAE identity by working closely with GODAE applications
  - Metadata – the unifying project "matrix"
- Implementation Plan is built on a layered approach


Applications and User Services (AUS)
User Information Services (UIS)
Applications and user layer
Global coverage L2P and Analysed products
Global Data Analysis Centre(s) (GDAC)
Global data analysis layer
Regional coverage L2P and Analysed products
Regional Data Assembly Centre(s) (RDAC)
Regional data assembly layer
Regional coverage satellite and in situ data streams
Global coverage satellite and in situ data streams
Specialist satellite and in situ data servers
GTS
Data provision layer

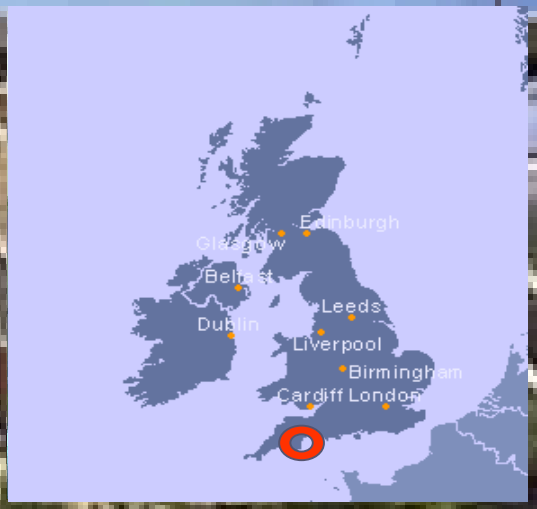
Global/Regional task sharing and connectivity: Regional leverage

- Implementation via **Regional Data assembly Centres (RDAC)** and **Global Data analysis Centres (GDAC)** interacting together to provide global coverage data products based on regional coverage inputs.
- Concept of **Global/Regional task sharing**



The GHRSST-PP Project Office

- Following endorsement by the ST at the 3rd workshop, a GHRSST-PP Project Office has now opened
- Joint sponsorship from ESA and the Met Office for a 3 year period (2003-2006)



- Remit:
  - *"To manage the international coordination and execution of the GHRSST-PP as described in the GHRSST-PP Development and Implementation Plan (GDIP) including all of its sub-components and deliverables."*

GHRSST-PP Organisation

GCOS International GODAE Steering Team (IGST)

International GHRSST-PP Project Office

International Science Team

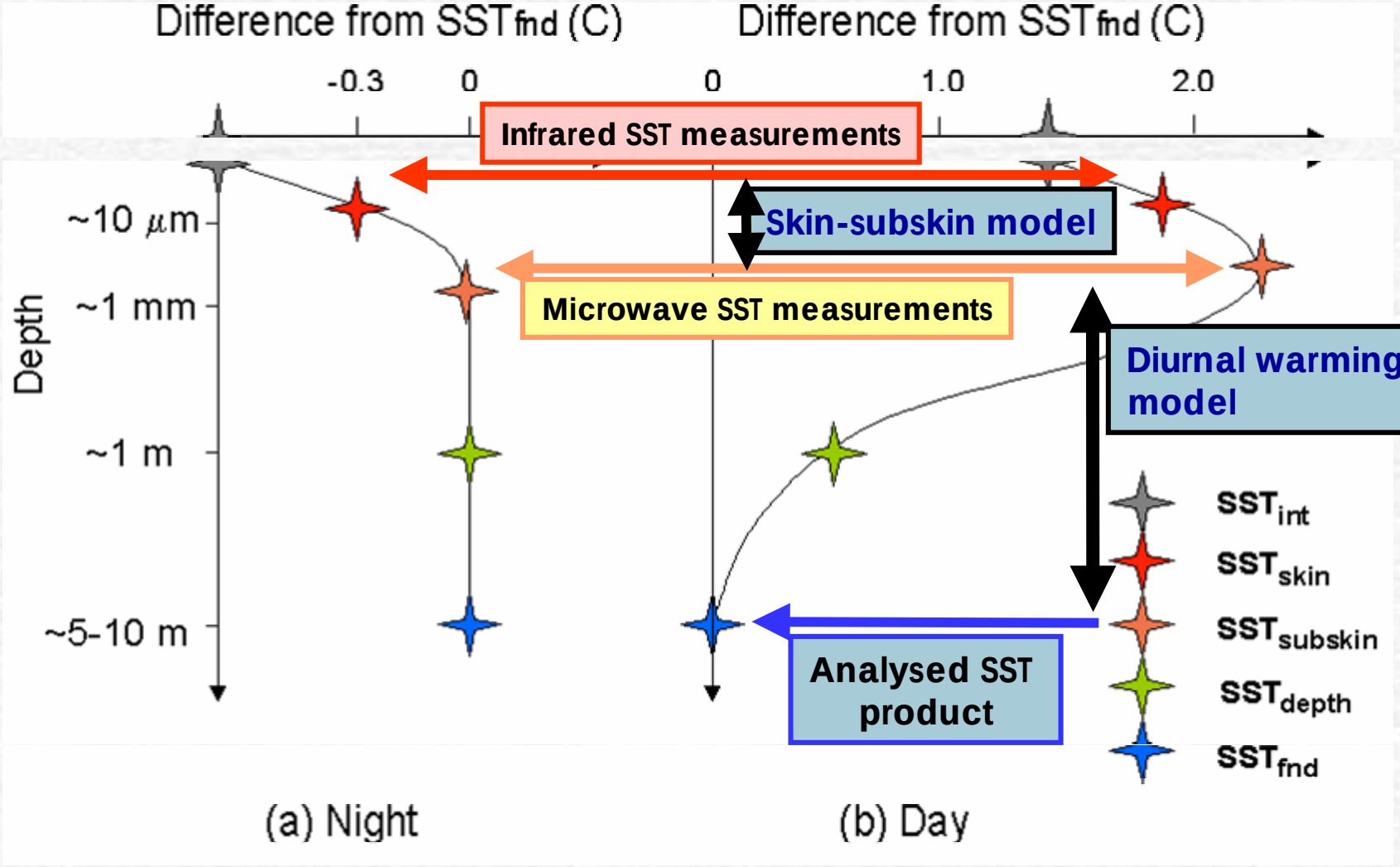
GHRSST-PP Reanalysis Project coordinating group (RAN-CG)	In Situ and Satellite Data Integration Technical Advisory Group (ISDI-TAG)	GHRSST-PP Data management coordinating group (DM-CG)	Diurnal variation Working group

GHRSST-PP Partners

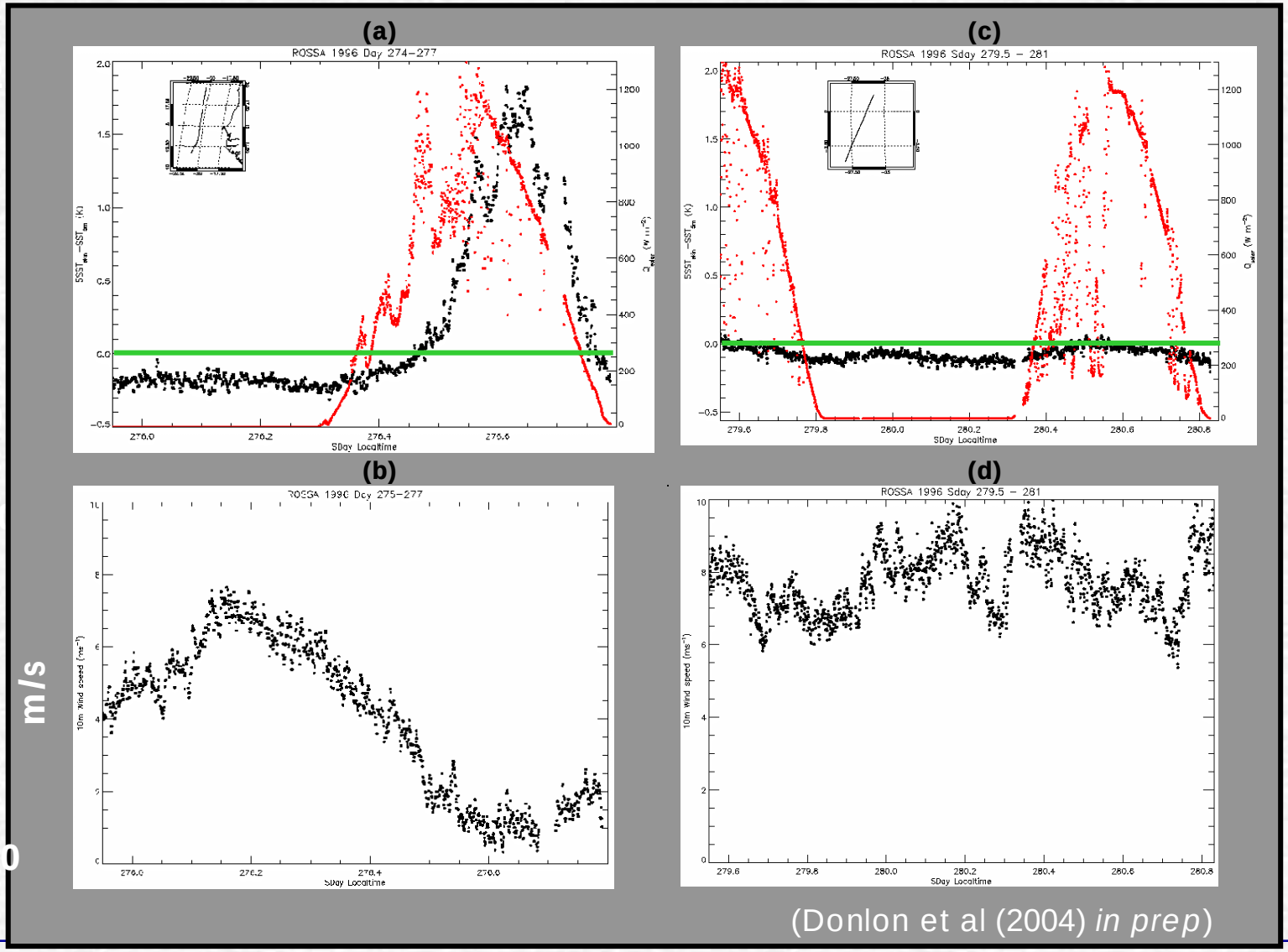
GHRSST-PP

The GHRSST-PP Data Processing Specification: GDSv1.0

SST definitions and data products within the GHRSST-PP

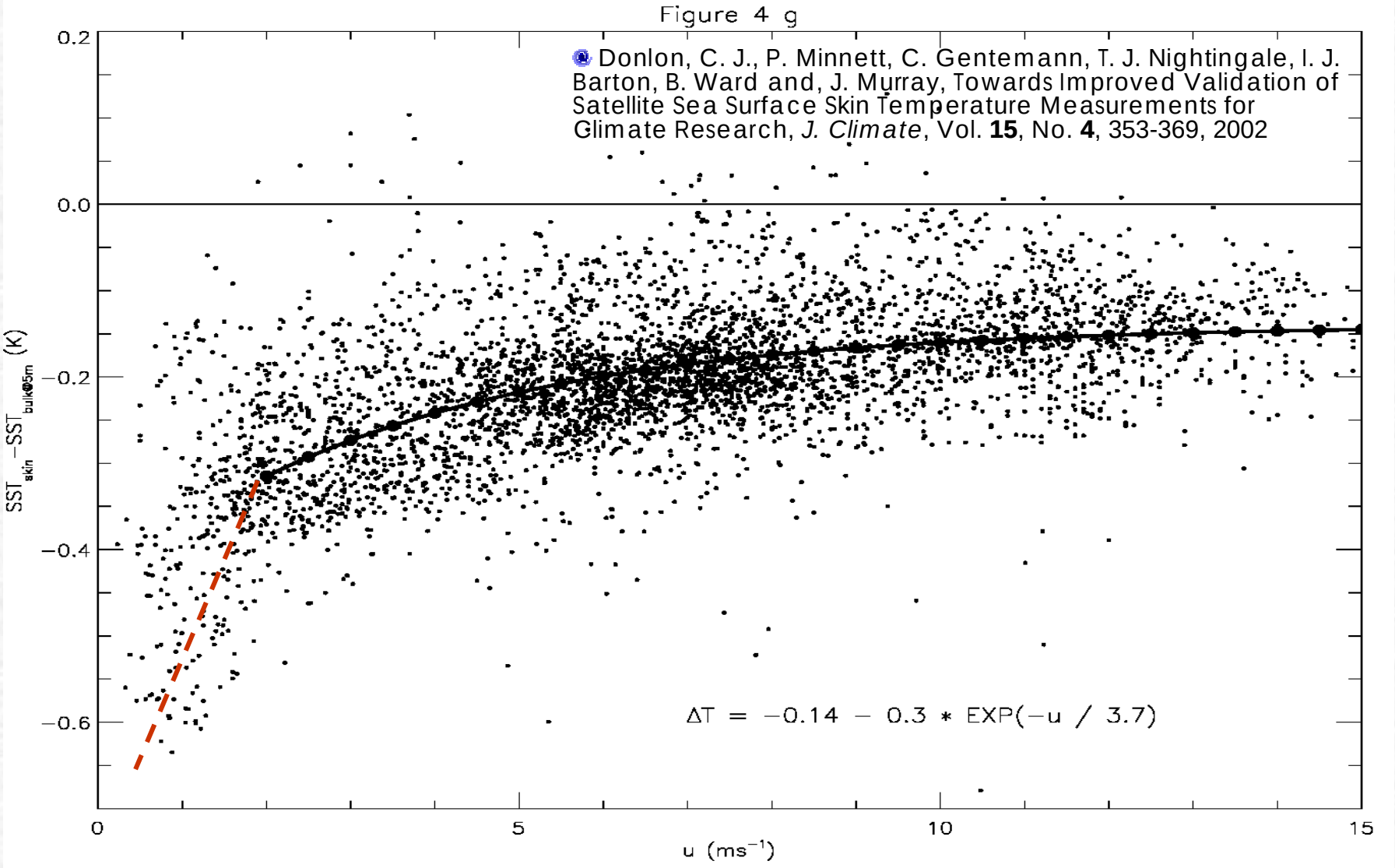


The ‘end to end’ Diurnal Cycle

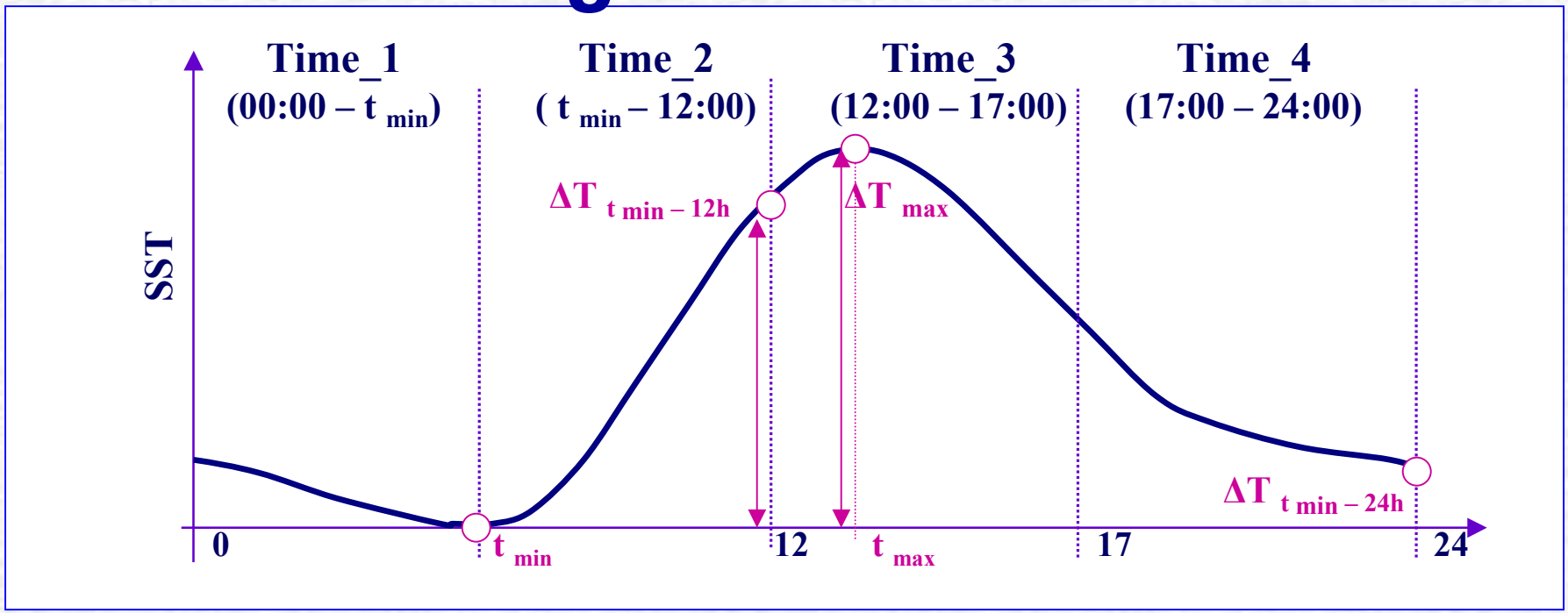


(Donlon et al (2004) *in prep*)

Resolving SST_{skin} & SST_{depth} Differences

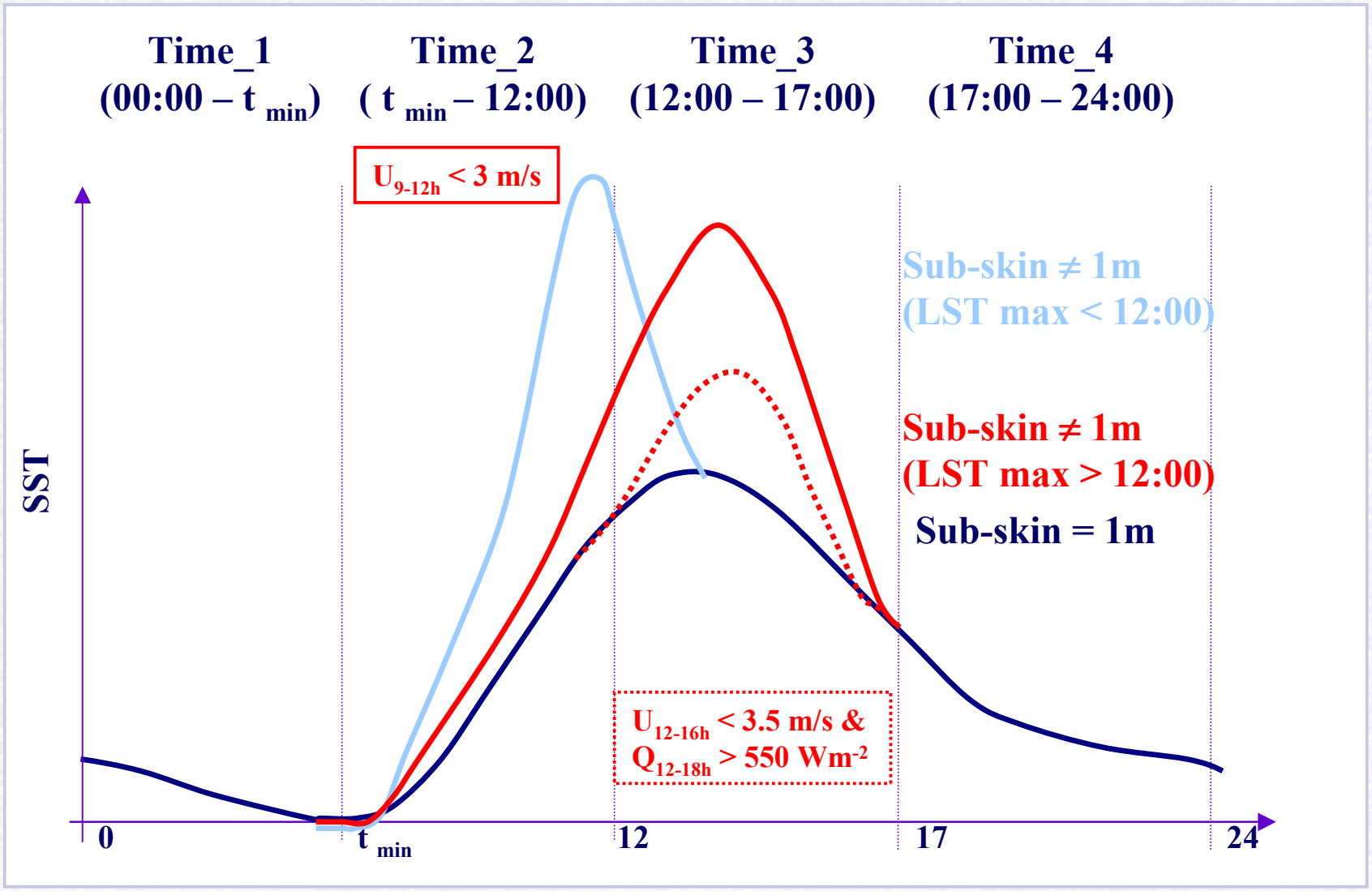


Resolving Diurnal variations



(A. Stuart-Menteth)

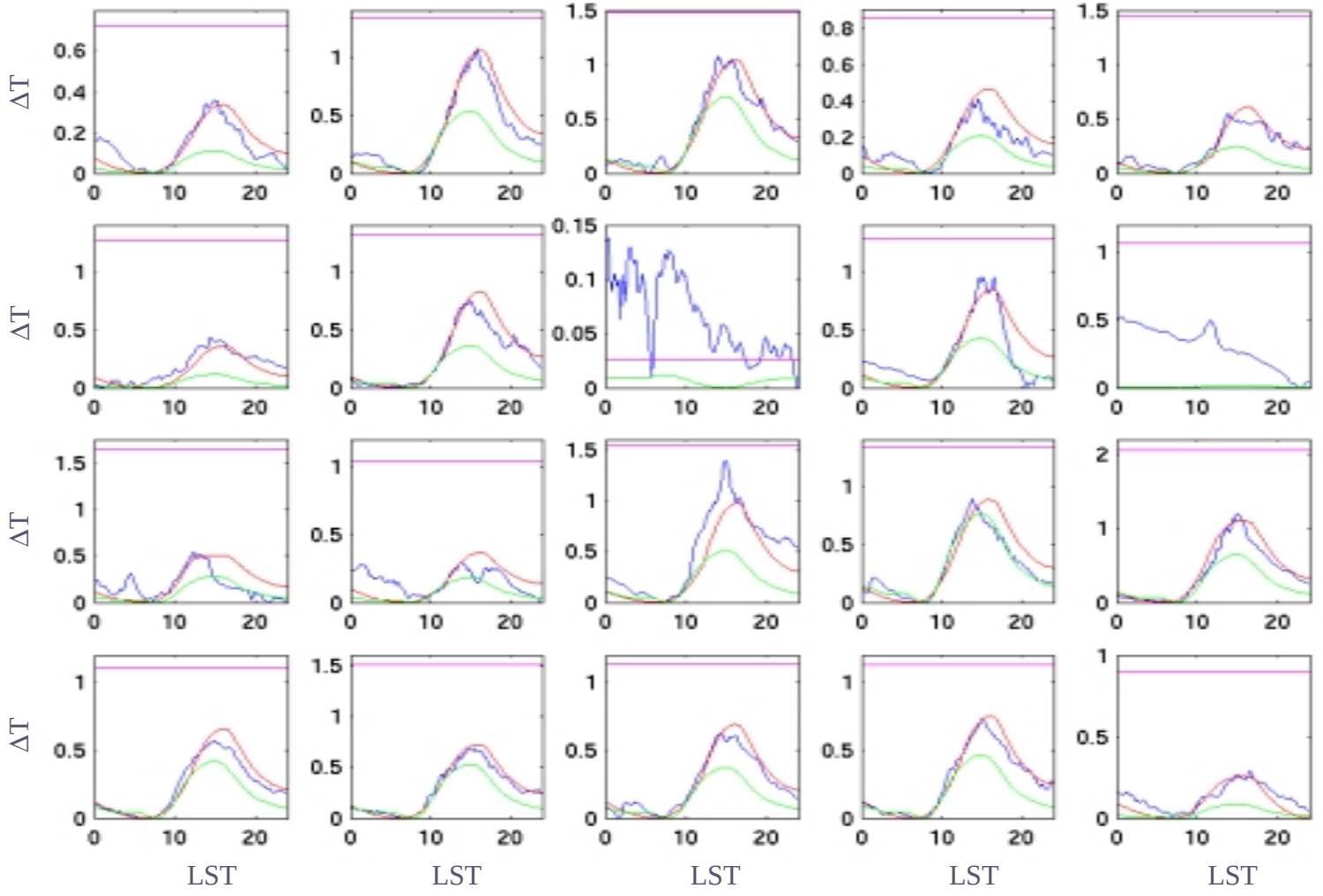
Variables required	$U_{0\text{-}6h}$	$U_{9\text{-}12h}$ $Q_{6\text{-}12h}$	$U_{12\text{-}16h}$ $Q_{12\text{-}18h}$	$U_{16\text{-}24h}$
Models	t_{min} Cooling grad.	$\Delta T_{t\,min\,-\,12h}$	ΔT_{max} t_{max}	$\Delta T_{t\,min\,-\,24h}$



Subskin = 1m parameterisation except when: **(A. Stuart-Menteth)**

$U_{9\text{-}12h} < 3$ m/s and $U_{12\text{-}16h} < 3.5$ m/s & $Q_{12\text{-}18h} > 550$ Wm^{-2}

1m: 0n, 10W – Eastern Equ. Atlantic (20 consecutive days)



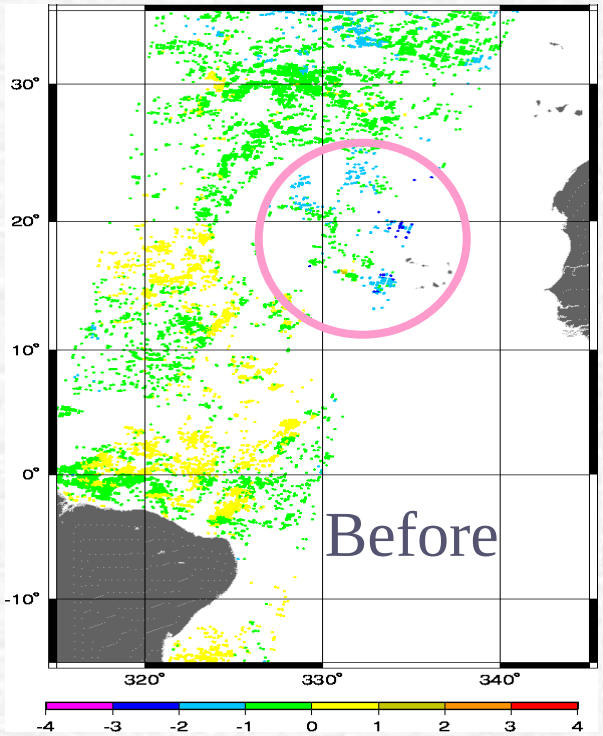
Buoy 1m Pirata Array

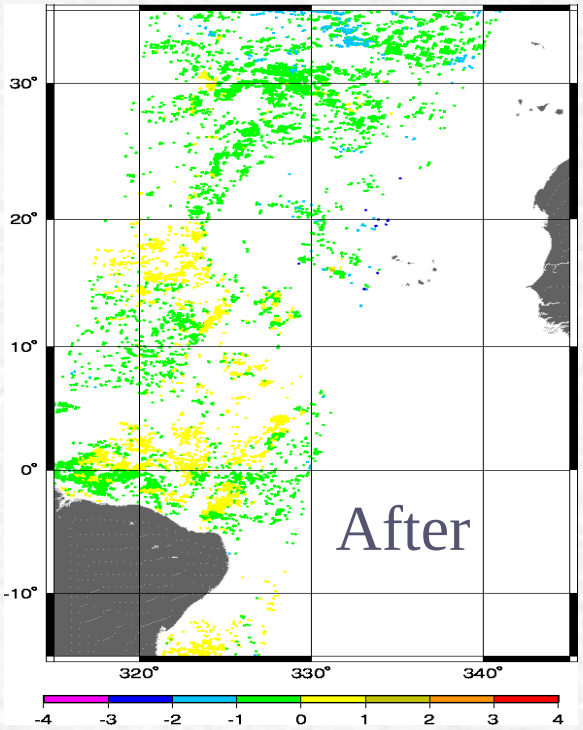
S-M 1m (Stuart-Menteth)

K&K 1m (Kawai & Kawamura, 2002)

CG TMI (Gentemann et al., 2003)

Flagging Aerosol Contamination





SST retrieval anomaly before and after dust screening (AVHRR)

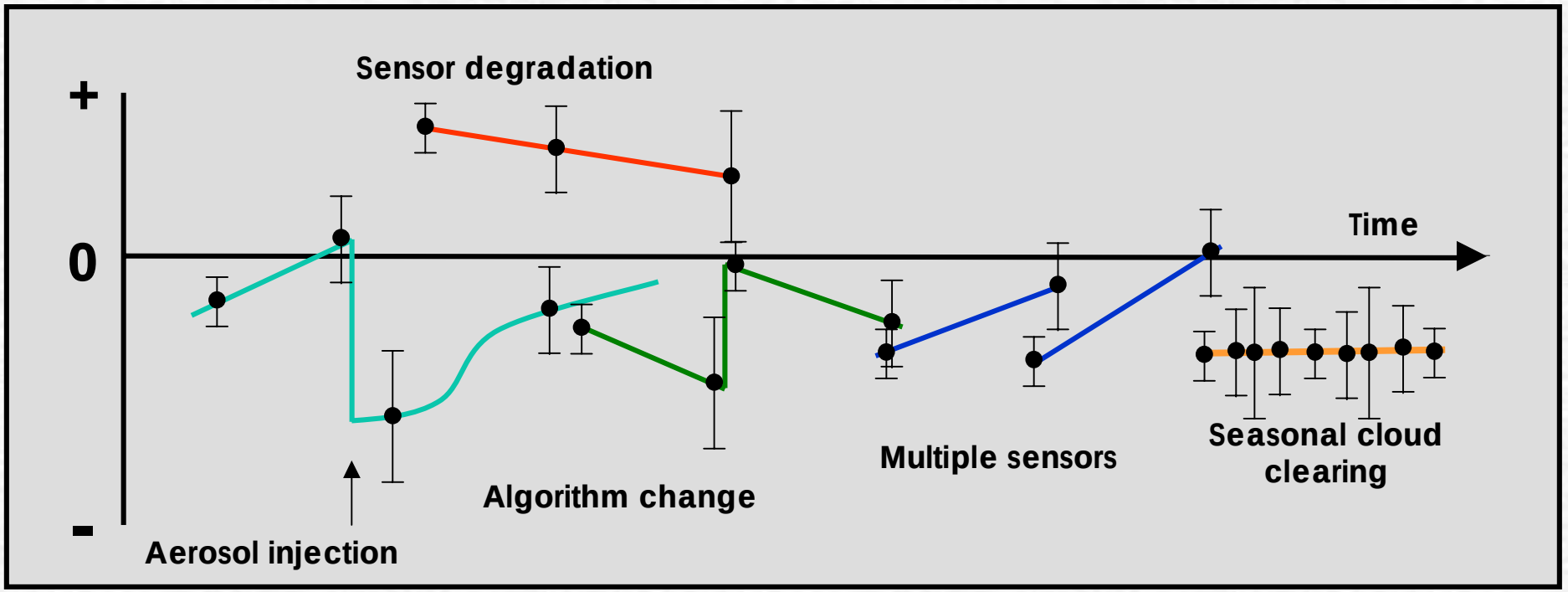
Simple technique is based on:

1) difference between dual window and split window and
2) difference between triple window and analyzed SST field.

Largest anomalies have been removed.

(J Cummings)

Satellite SST bias characteristics



- Satellite SST **bias error vary temporally** for many reasons sometimes changing sign
- What is the **reference 'truth'** to which these bias errors should be derived from?
- **In situ buoy data** is the most 'robust' in terms of accuracy and operational availability – necessary for satellite SST entry into the climate record

Measuring the SST_{1m}

Practically zero coverage in many areas – need to advise key areas for buoys

Optimal use of in situ resources

- We need to make optimal use of the limited in situ SST data to derive a bias and standard deviation for each satellite SST measurement
- Not enough buoys to do this!
- Concept of Single Sensor Error Statistics (SSES)
  - Assign a confidence level to each measurement based on objective criteria
    - For IR data these are proximity to cloudy data and deviation from a 'coldest SST climatology'
    - For MW data these are proximity to rainfall, land (side lobe contamination), sea ice and the wind speed.
- Error estimates (mean bias and standard deviation) are then derived by analysis of a large match up database (MDB) of contemporaneous satellite and in situ observations for each sensor and confidence level
- Based on operational schemes developed and currently used at EUMETSAT O&SI SAF and US Navy

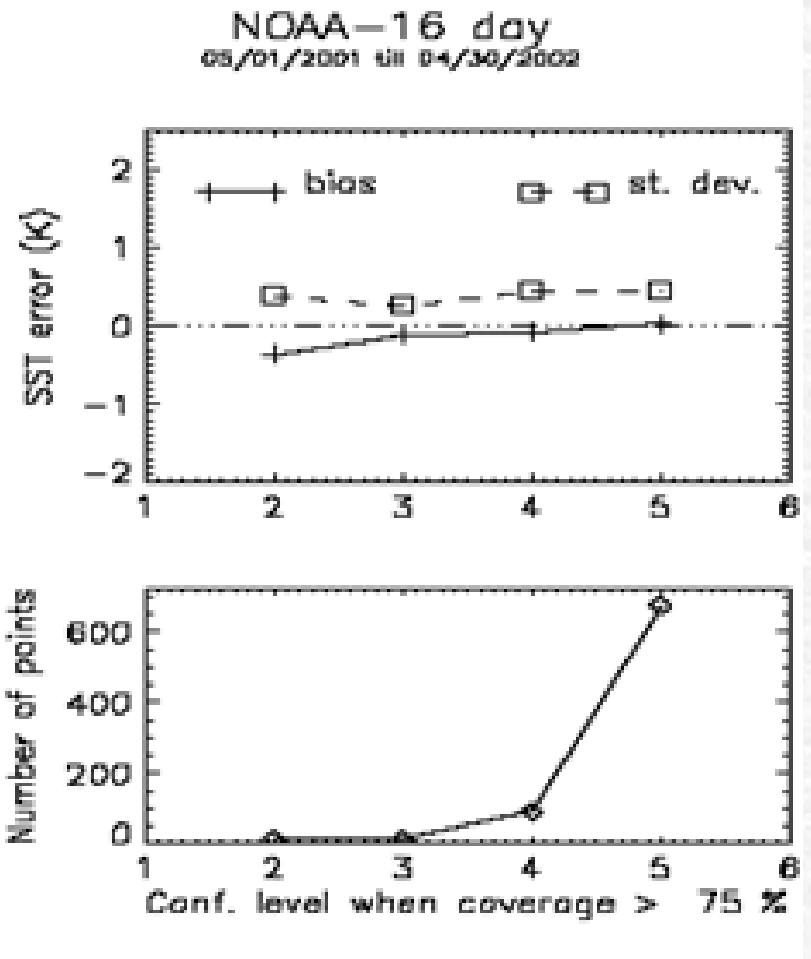
SSES Error statistics for NOAA 16

Confidence level determination

Temp. Threshold	acceptable		excellent
Tqual		bad	
Tnear			good
Tfar		cloudy	
	d1	d2	Distance from cloud

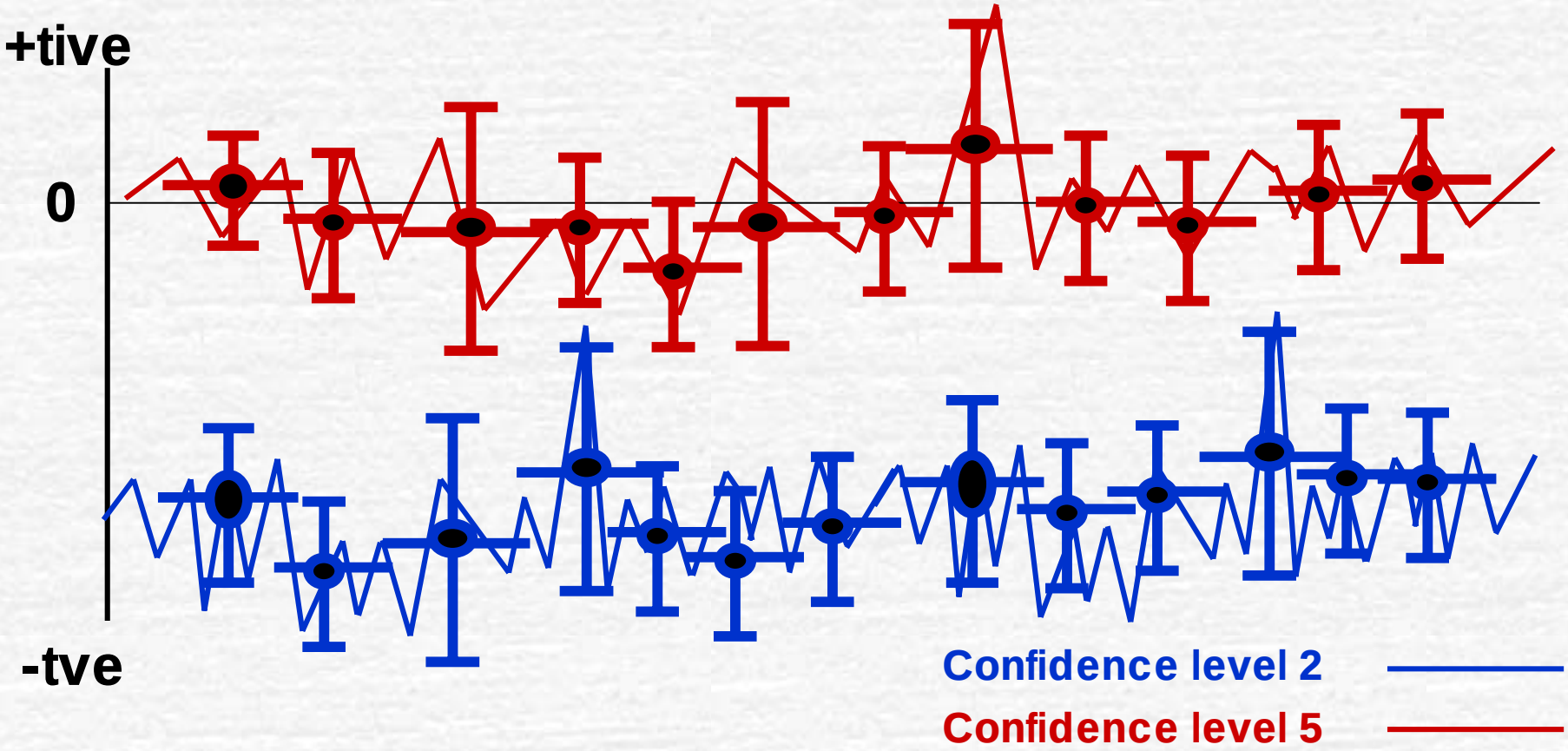
Confidence level as a function of temperature and distance from cloud

0="unprocessed", 1="erroneous (cloudy)",
2="bad", 3="acceptable", 4="good", 5="excellent"

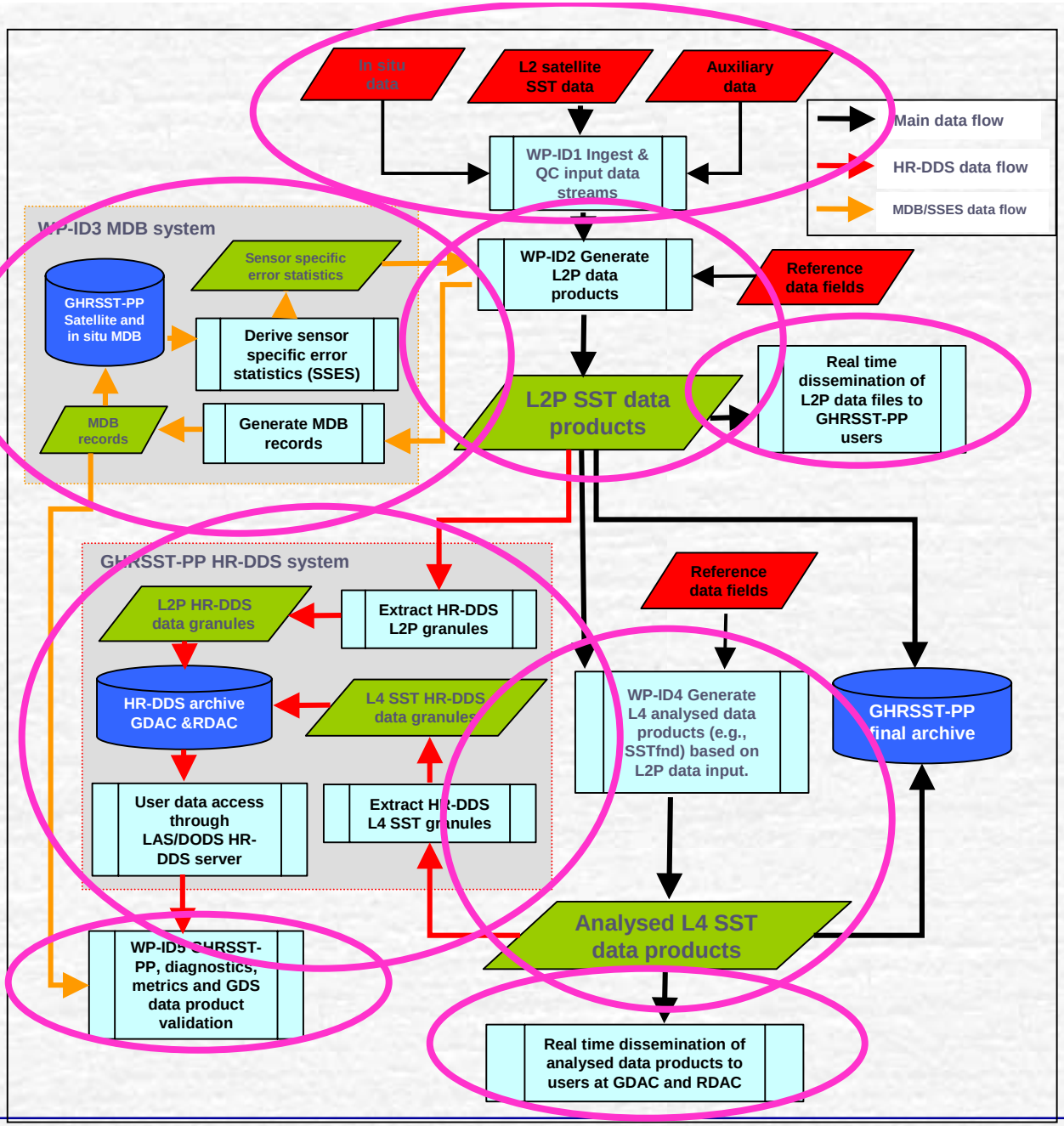


(Figures: P. LeBorgne)

SSES vary by sensor, confidence level and in time



- SSES must be regularly computed at intervals for each confidence level and each sensor from match up data



The GHRSST-PP GDS

Data Ingestion and QC

L2P data product production

GHRSST-PP Match-up database system & SSES generation

Analyzed SST data product production

GHRSST-PP HR-DDS

Data dissemination

Product validation

Data archive

Outputs from the GDSv1.0

(Agreed at GHRSST-PP IV)

Product identifier	Descriptive name	Description	Timeliness
L2P-<filename>	L2 pre-processed data	**Native L2 SST** and auxiliary data that have been quality controlled and re-formatted to **include confidence and error statistic data**.	**Within 6 hours of acquisition**
L4SSTfnd	GDAC L4 SSTfnd analysed data	**Global coverage** SSTfnd analyzed data products for each day **with diurnal variation information**	**24 hours**
SSES	Sensor specific error statistics	Mean bias and rms. Error statistical relationships to sensor specific confidence values.	**Weekly/biweekly (depends on buoy availability)**
MDB	Match up data base record	Near contemporaneous satellite and in situ data match up record.	**Real time**
L2P HR-DDS granules	L2P HR-DDS data granules	A high resolution diagnostic data set (HR-DDS) granule (2º x 2º latitude x longitude area) extracted from a L2P data product	**Delayed mode (1-3 days)**
L4SSTfnd-HRDDS	L4SSTfnd high resolution DDS data granule	A high resolution diagnostic data set (HR-DDS) granule (2º x 2º latitude x longitude area) extracted from a L4SSTfnd data product	**Delayed mode (1-3 days)**

L2P data products

(Agreed at GHRSST-PP IV)

- Available in real time by each sensor for assimilation
- netCDF 'CF' convention format
- Based on extensive discussions at GHRSST-IV

Global attributes	Mandatory
[n x m] array of SST data (e.g., TMI, AATSR, MODIS, AMSR etc)	Mandatory
geolocation data (specific to data set)	Mandatory
[n x m] array of confidence flags (specific to variable data set)	Mandatory

Name
Time
L2P_Version
L2_native_bias
L2_native_sd
Bias
s.d
DT_min
SSI_value
SSI_Dtime_from_SST
SSI_source
Wspd
Wspd_Dtime_from_SST
Wspd_source
Land_mask
Proximity_Confidence
DV_confidence
SST_alg_definition
FractionalSeaIce
FractionalSeaIce_source
AOD
Source_of_AOD
SatZA
Cloud
SunGlint
SatZA_bad
CosmeticFill
MW_SST_flag
Spare

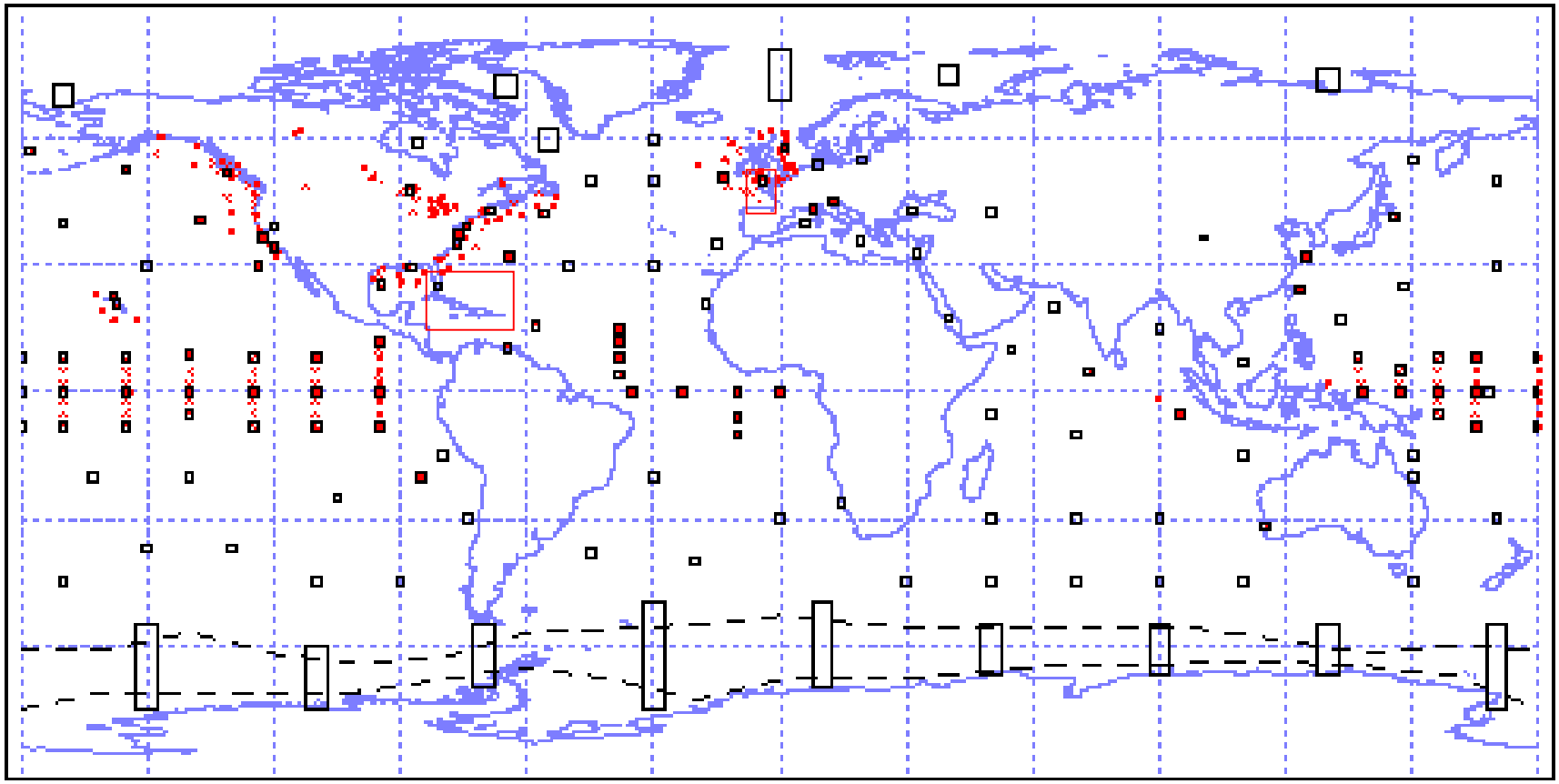
L4 data products
(Agreed at GHRSST-PP IV)

- Available each day
- netCDF as for L2P
- No 'optimal' analysis method has been agreed
- Instead, a strength of diversity is acknowledged
- At the next GHRSST-PP workshop, this will be a priority issue

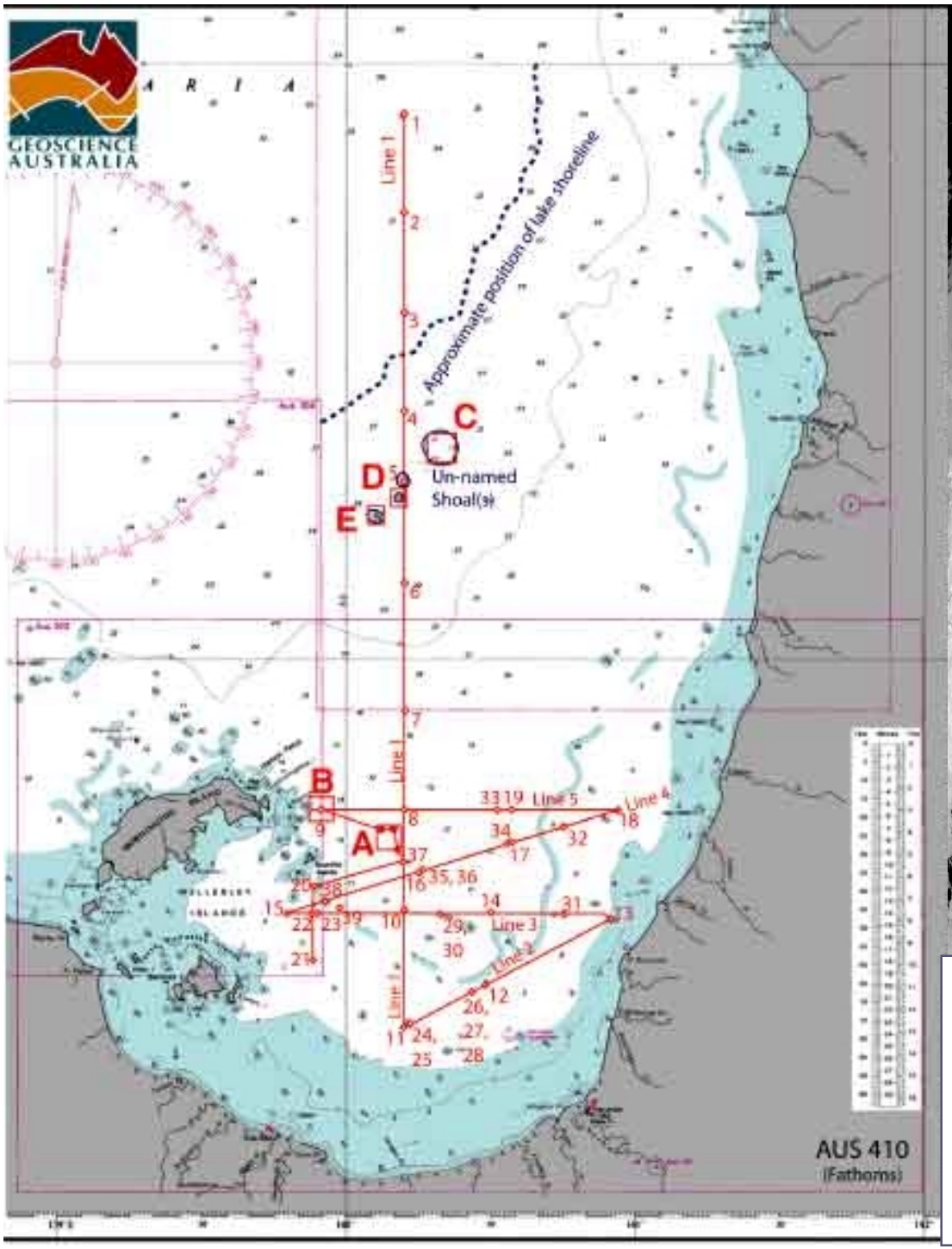
Name	Description
Land_sea_flag provided by data provider	Grid cell type classification sea or land
FractionalSealce	Ice contamination flag 0=no sea ice, 1=sea ice flag from native L2 data stream, 3=sea ice from reference field
Normalised_OI_error	
Bias	Analysis error bias
Skin_parameterisation	Coefficients for SSTfnd - SSTskin conversion model
Skin_parameterisation_scheme	
Spare	Reserved fro GDSv2

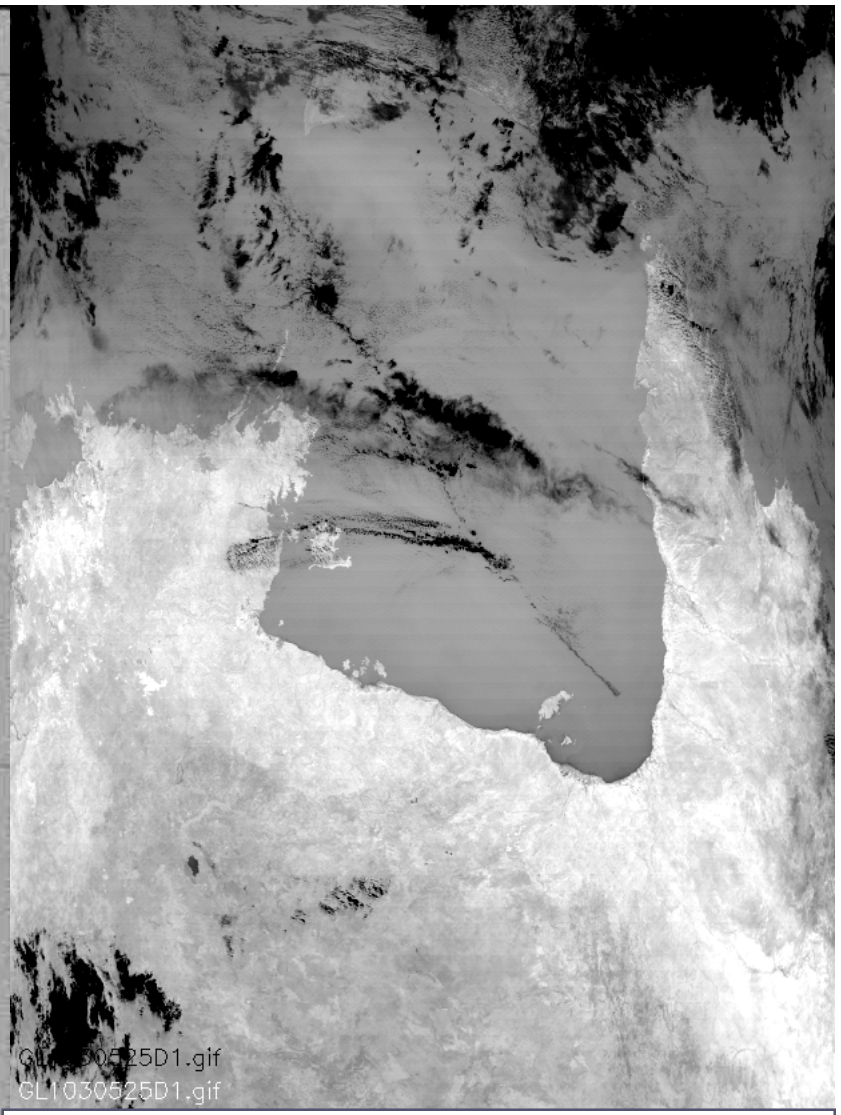
The High Resolution diagnostic Data Set: HR-DDS

HR-DDS-v2.2 locations



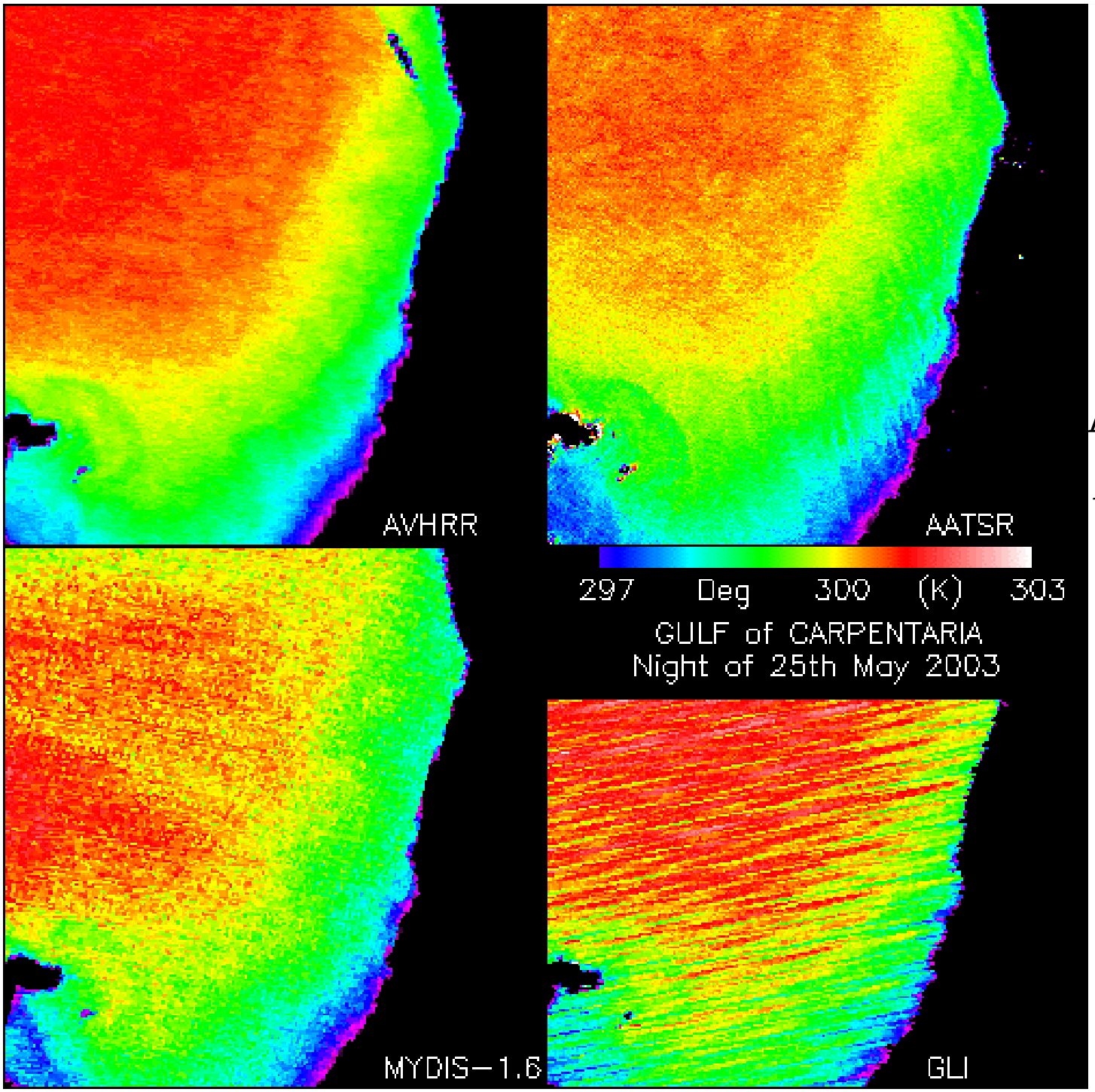
- **Based on output of the 2nd & 3rd GHRSST-PP workshop Science Team feedback. Fully documented in the HR-DDS Implementation Plan (GHRSST/14)**





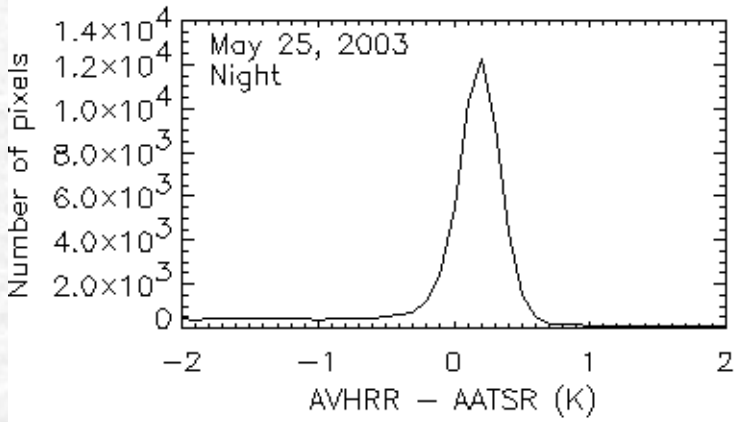
Gulf of Carpentaria

GLI 25 May 2003

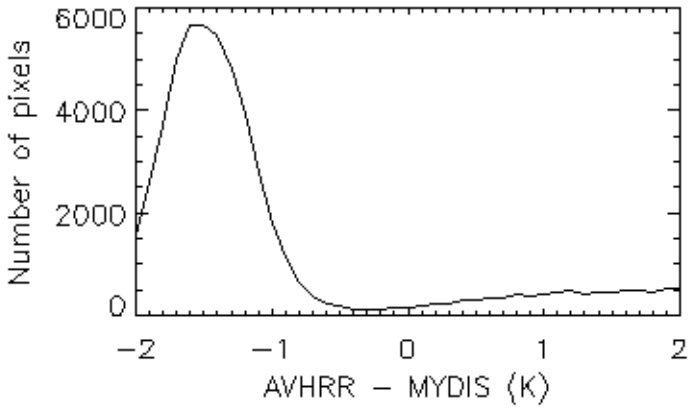


25 May 2003
Night - EST
AVHRR – 0330
AATSR – 2200
MYDIS – 0200
GLI – 2230

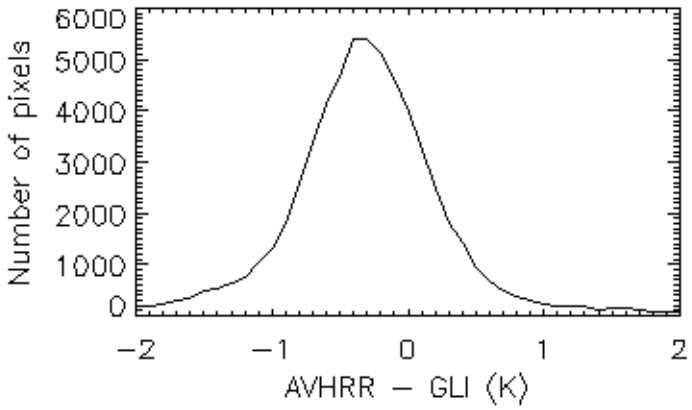
15.5–17.0 ^{O}S
139.5–142.0 ^{O}E



AVHRR – AATSR = 0.2 ^{O}C



AVHRR – MYDIS = -1.5 ^{O}C



AVHRR – GLI = -0.3 ^{O}C

The GHRSST-PP Reanalysis Project (RAN)

GHRSST-PP Reanalysis project

- Considered as an integral component *a priori*
- Overall Goals of Reanalysis:
  - Utilise SST data unavailable in real time (higher QC)
  - Create delayed mode, higher accuracy and consistency products
  - Link to longer term climate records
  - Enable reprocessing capability
  - Experiment with different OI schemes (Reynolds, Kaplan, Feigurth, France, Australia...)
- Daily SSTfnd product will be output
  - Accuracy: 0.3K absolute, 0.1K relative, temporally stable to 0.01K/decade (targets)
- Will allow a better error estimates and diurnal variability
- Delivery Timescale: ~ 1 year delay
- Provide a 'platinum' data set from a 'golden age'!

Application Experiments

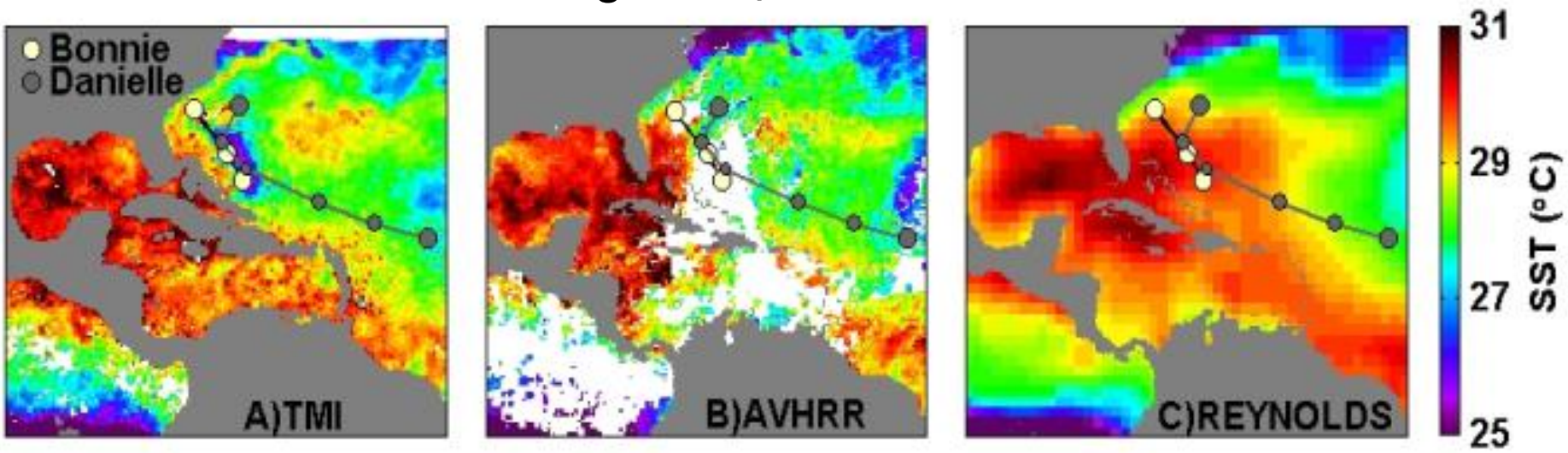
Regional Applications

- GHRSST-PP must engage diverse applications e.g.:
  - Ecosystem management
  - Pollution mitigation
  - Protection of Life and property
  - Power companies: the sea breeze and seasonal trends
    - Wind farm power generation
    - Real-time rapid cold front passage and available capacity
  - Building management: Air conditioning/building location
  - Oil industry: model initialisation and assimilation
  - Financial industry: better forecasting and climate change
  - Tourist industry!
- What happens on the land is determined by the "forgotten" distant ocean
- Metrics are key to application impact assessments (outcomes) and the success of the application this is a priority for the next 12 months
  - Forces an identification the key issues – makes people think!

New Possibilities

SST during Hurricane Danielle

August 25, 1998

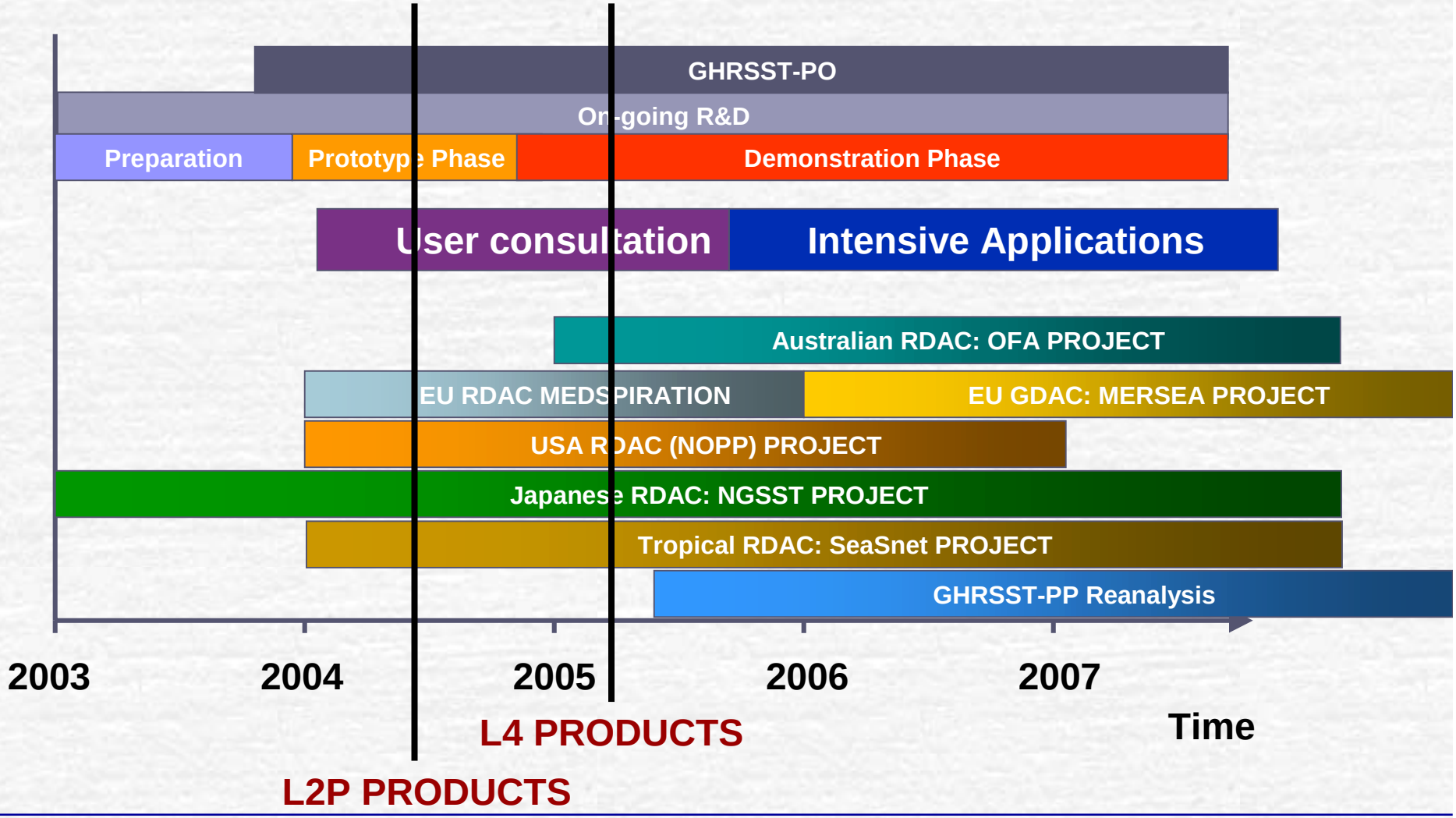


(C Gentemann, Remote Sensing Systems)

- **Bonnie caused significant cold upwelling not evident in AVHRR SST because of the clouds surrounding the storm.**
- **When Danielle passed over the cold wake of Bonnie the intensity decreased sharply and the storm veered to the NE.**

Implementation Schedule

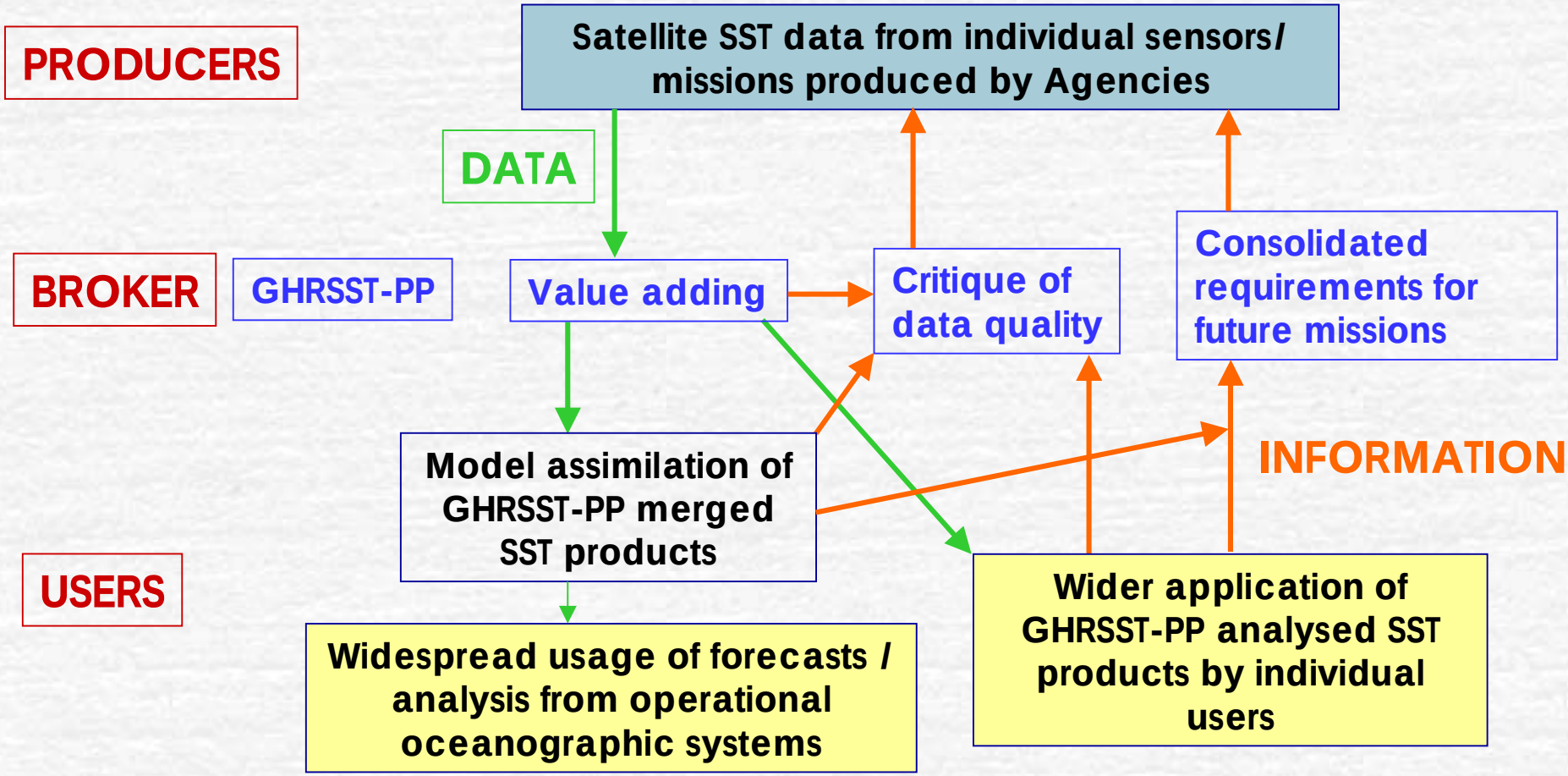
GHRSST-PP Schedule



Expected GHRSST-PP Outcomes

- Provide a new generation of operational SST products
  - Address the needs of national and international projects (GODAE, GOOS, CLIVAR, MERCATOR etc.)
- Ensure that duplication of SST activities are minimized
  - Synchronization of data merging/processing procedures, techniques, algorithms and data formats,
- An operationally efficient methodology for real time fusion of SST data
  - Increased efficiency and cost-effectiveness of SST product generation and delivery
- Develop and foster considerable scientific and operational knowledge during the lifecycle of the GHRSST-PP
  - Increase the network capacity within international and national projects of differing scope and budget

A view of the role of the GHRSST-PP



International GHRSST-PP Project Office

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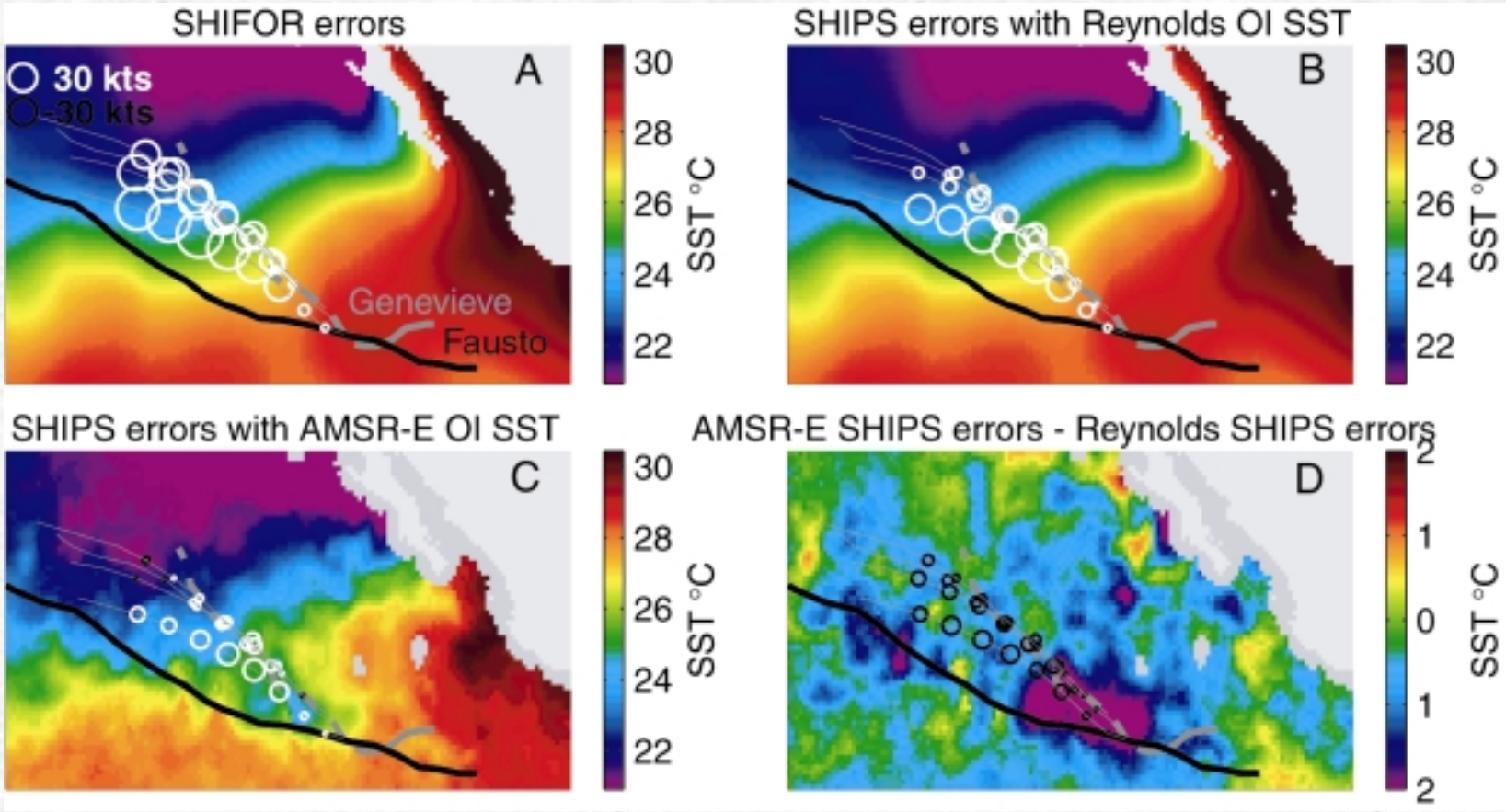
EX1 3PB
United Kingdom
Web: http://www.ghrsst-pp.org
E-mail: craig.donlon@metoffice.com

Hurricane Genevieve (2002)

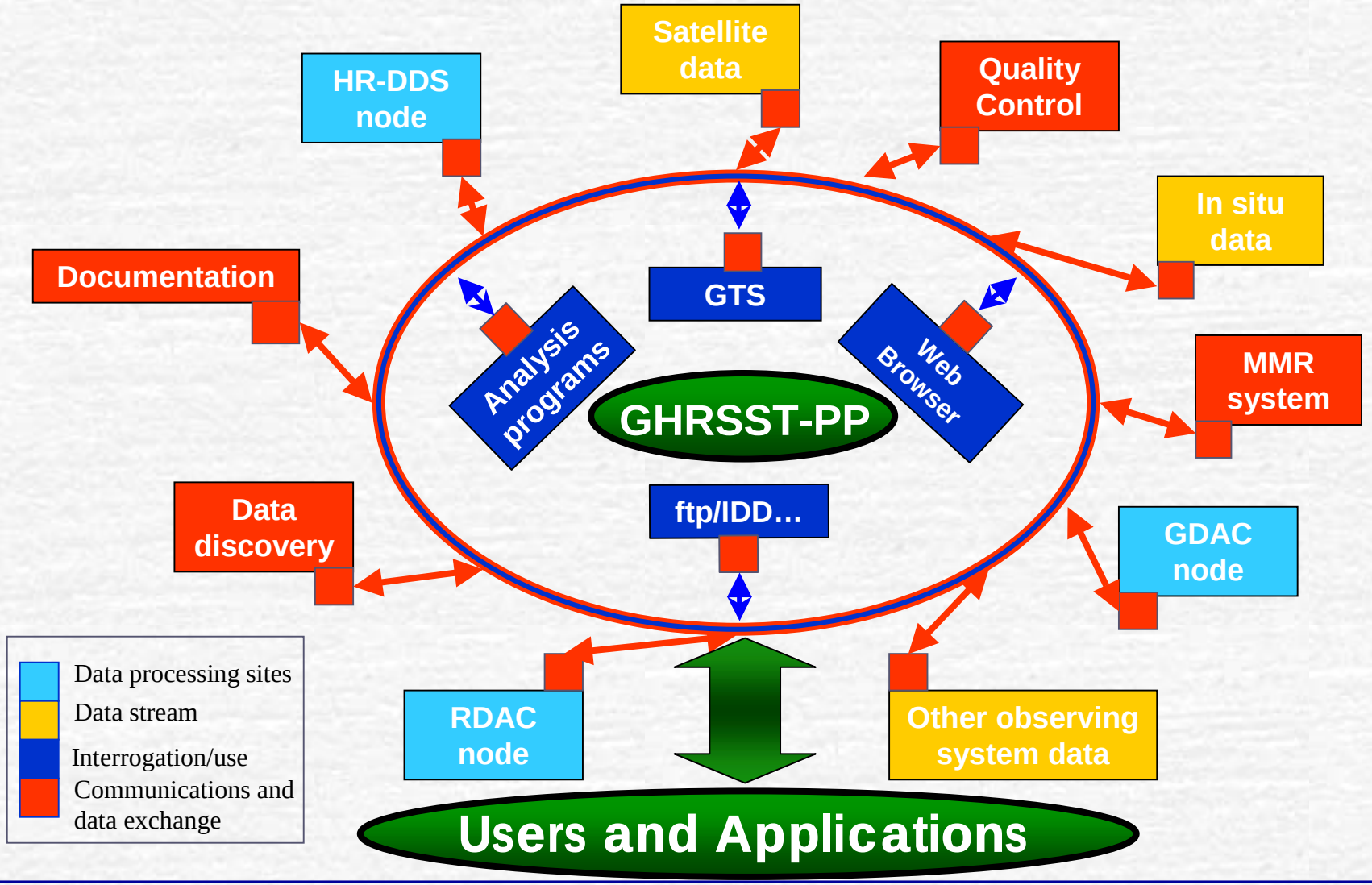
(Gentemann et al, 2003)

National Hurricane Centre (NHC) operational models

- Statistical Hurricane Intensity Prediction System (SHIPS)
- Statistical Hurricane Intensity Forecast (SHIFOR)

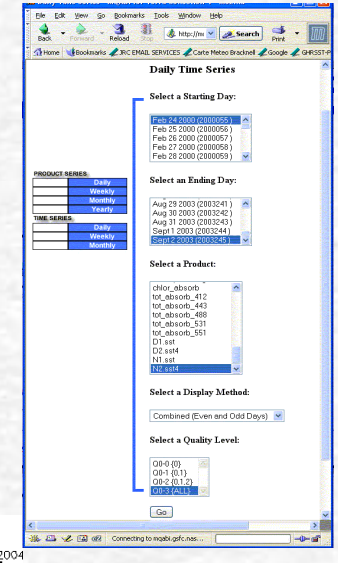


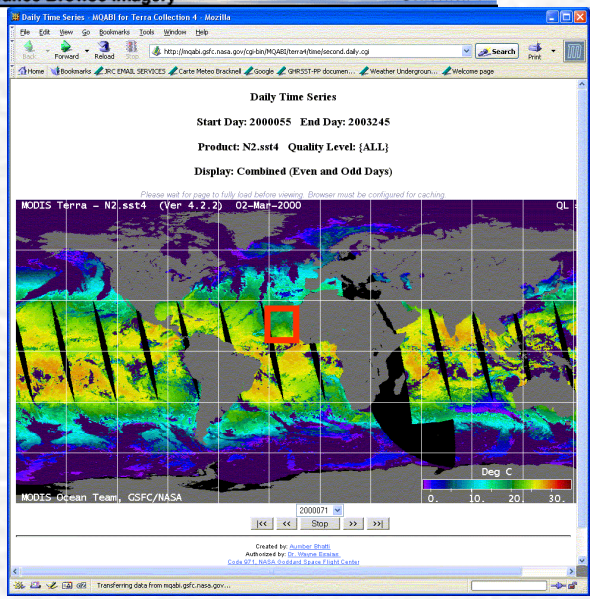
The GHRSST-PP Development and Implementation Plan

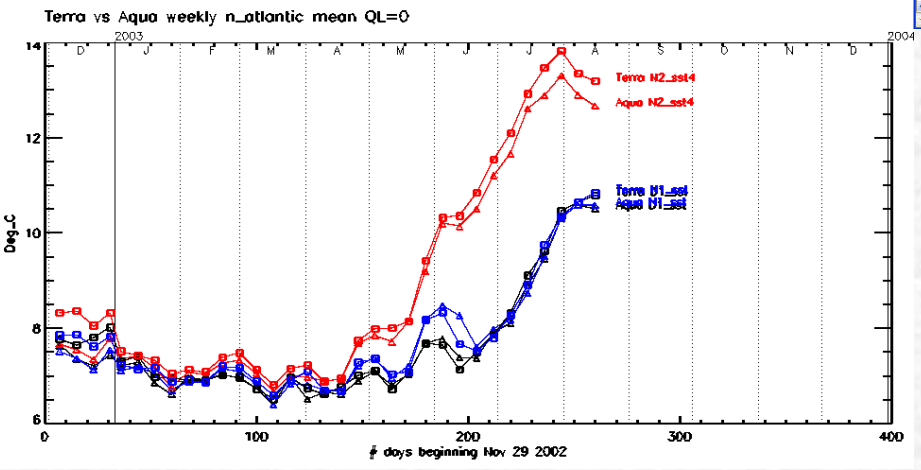


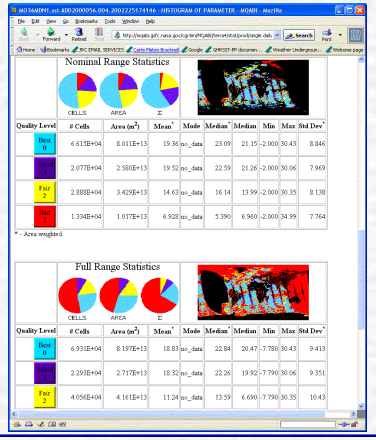
HR-DDS: Science and Applications

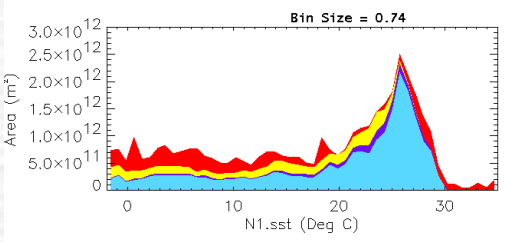
- Provides Time series plots of data values
- Provides browse imagery
- Move making is possible
- Dynamic statistics
- Browse imagery
- Very interactive and dynamic (see WWW example)











http://www.ghrsst-pp.org

GHRSST-PP

Users and Applications

- The User Information Service (UIS) provides low volume data access and information on GHRSST-PP logistics and operations
  - General low volume access to data products
- The Applications and User Services (AUS) links the GHRSST-PP to specific applications (GHRSST-PP "Power users") closely monitored by GHRSST-PP science team
  - E.g., MERCATOR, FOAM, JMA, Satellite Flux development etc.
  - Interactive Workshops and targeted outreach initiatives
  - Develop a deep relationship with specific applications to ensure appropriate feedback

Distributed HR-DDS concept

- Design is based on the GODAE data sharing Project The HR-DDS should contribute to the GODAE data sharing project