GODAE Summer School, Toulon

22nd Sep, 2004

Measuring the Ocean from Space, 2

Opportunities and limitations of sampling from satellites

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Purpose of these Lectures

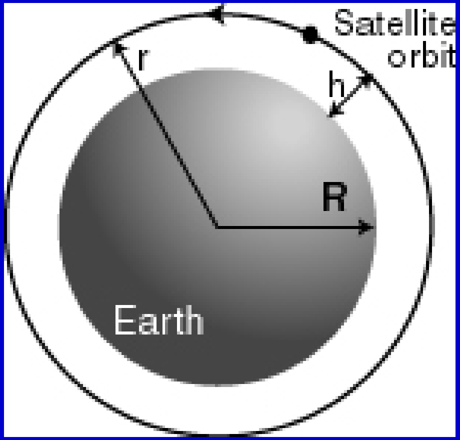
- The Aim: To learn enough about the basic methods of Space Oceanography to be able critically to appraise global ocean datasets from satellites and understand how to use them effectively.
- Objective of Lecture 1 (yesterday): To understand what sensors in Space actually measure, and how to derive useful ocean parameters from the primary measurements.
- Objective of Lecture 2 (today): To recognise the measurement and sampling limitations of satellite sensors, and learn how best to exploit the benefits of satellite data.

Outline of lecture

- The sampling limitations of satellite-derived data
- Measuring SST from satellites
  - Infra-red methods
- Which Sea surface temperature are we seeing from Space ?
- GHRSST: a case study on preparing SST data for assimilation into models

The sampling limitations of satellite-derived data

Satellite orbit limitations



- Period of orbit,

$$T = 2\pi\sqrt{\frac{a^3}{GM}}$$

  - where GM = 3.986 10^{14} m^3s^{s-1}

- Angular speed about the earth,

$$\frac{d\theta}{dt} = \frac{\sqrt{GMr}}{r^2}$$

- Linear speed of satellite,

$$V = \sqrt{\frac{GM}{a}} = R\sqrt{\frac{g}{r}} = R\sqrt{\frac{g}{R+h}}$$

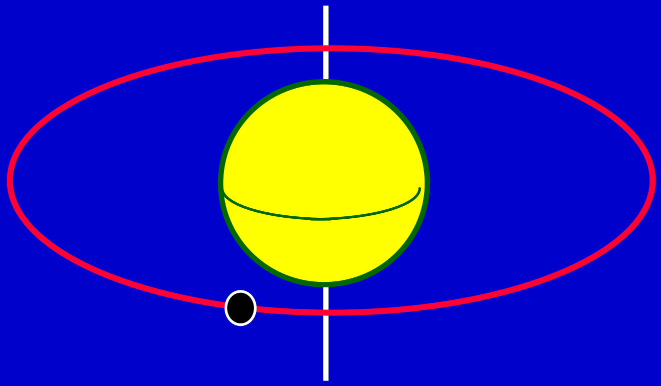
  - where g = 9.81 ms^{-2}, R = 6378km (Earth's mean radius)

- Speed of the satellite sub-point over the ground,

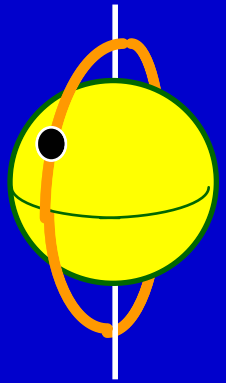
$$V_g = \frac{R^2}{R+h}\sqrt{\frac{g}{R+h}}$$

Two types of orbit for remote sensing

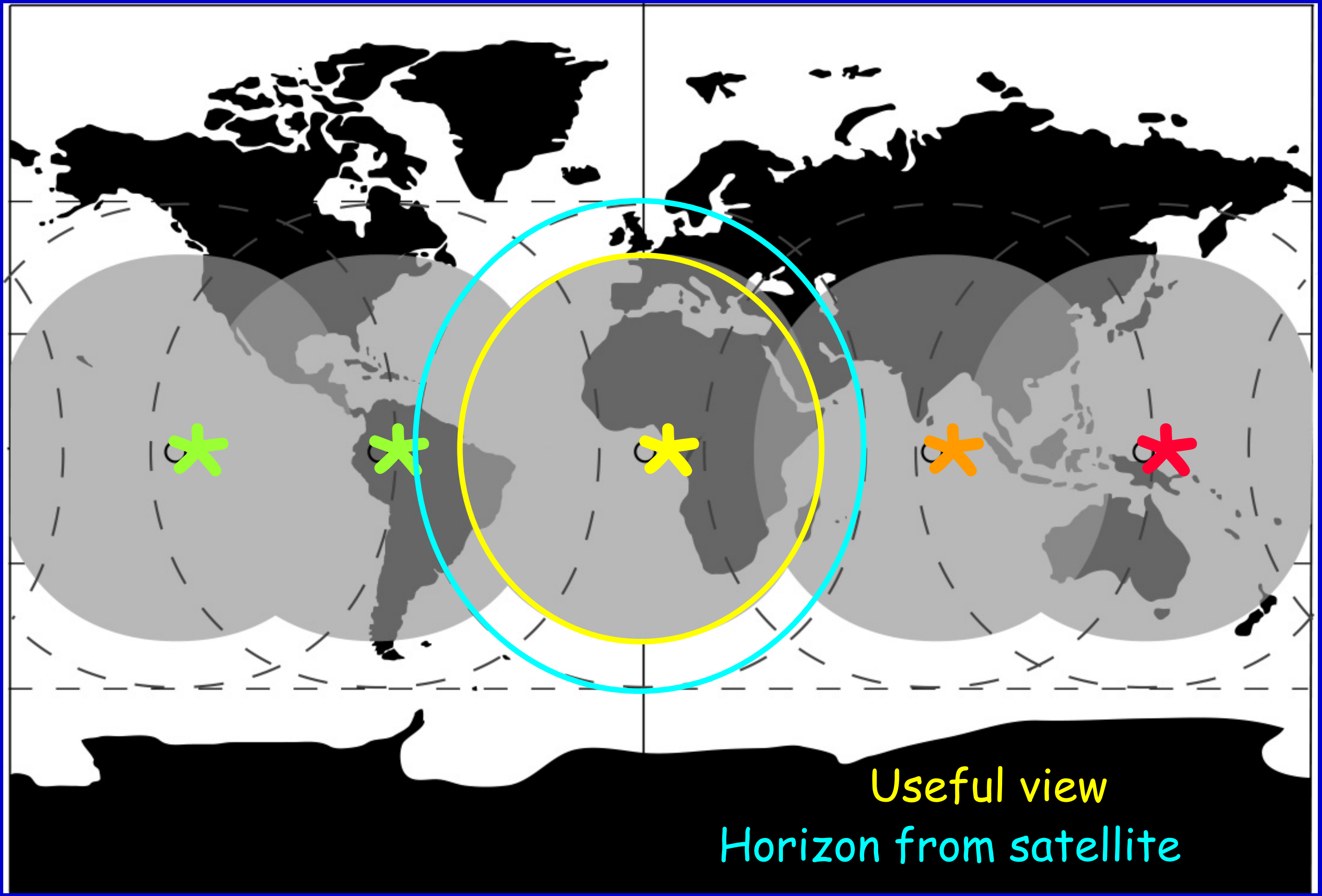
- Geostationary orbits
  - For an orbital period of one sidereal day (T = 23.93 hours), the satellite travels with the earth.
  - This requires r = 42290 km, h = 35910 km.
  - The satellite remains over the equator.



- Near-polar orbits
  - T is approximately 100 min.
  - h is 700 to 1000 km.



What a geostationary orbit sees



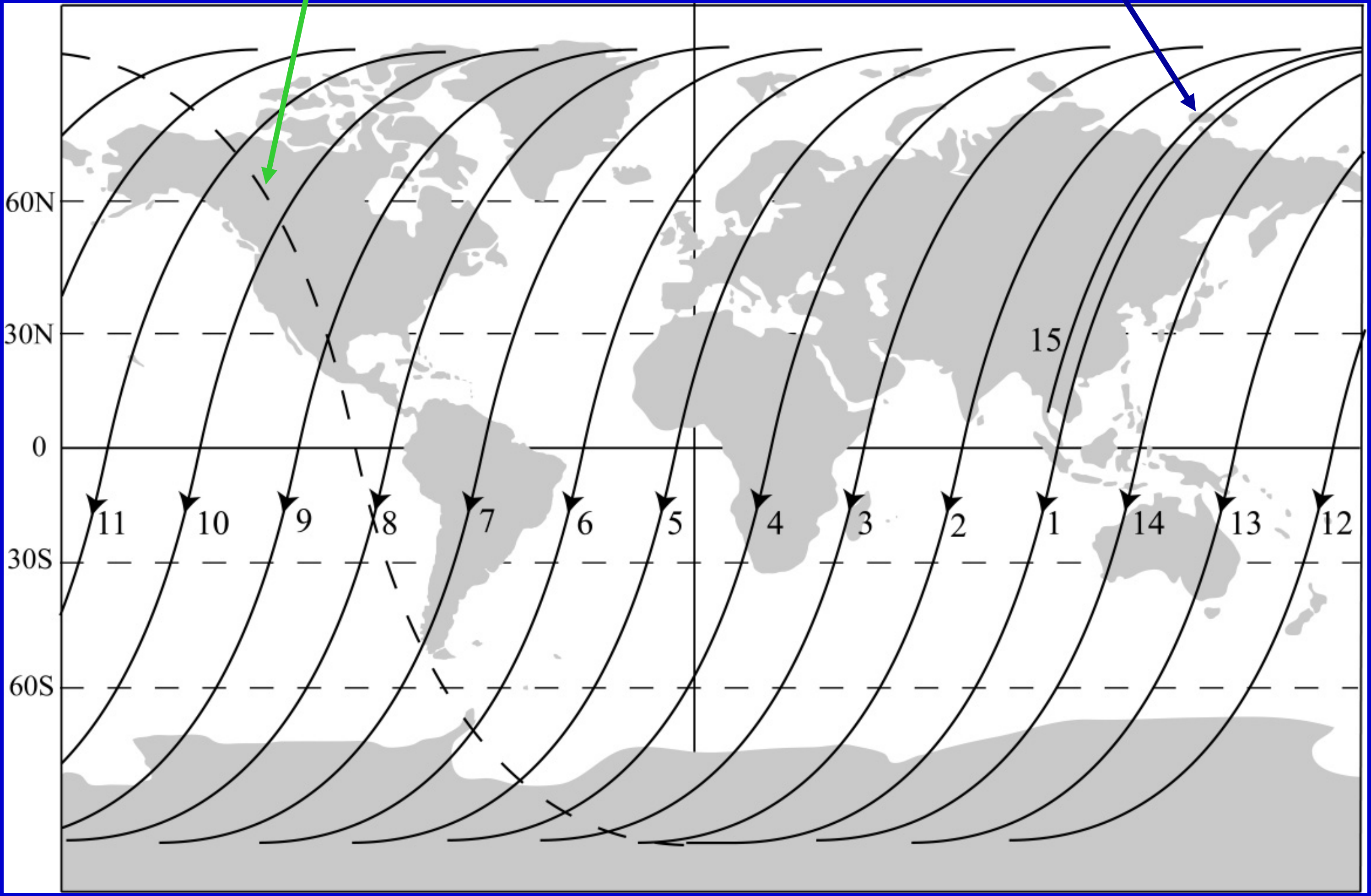
Useful view
Horizon from satellite

Earth coverage by a polar orbiter

One day's descending tracks

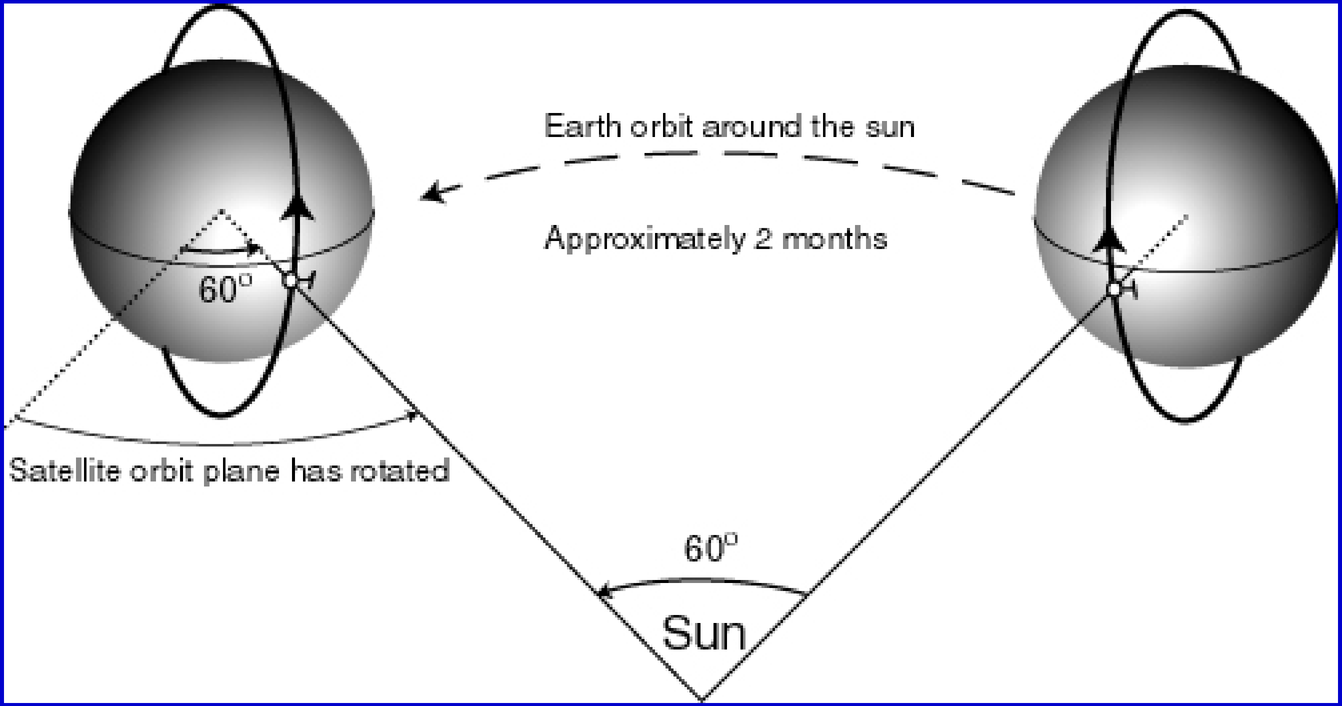
Ascending track between 1 and 2

First track of the next day



Sun-synchronous orbits

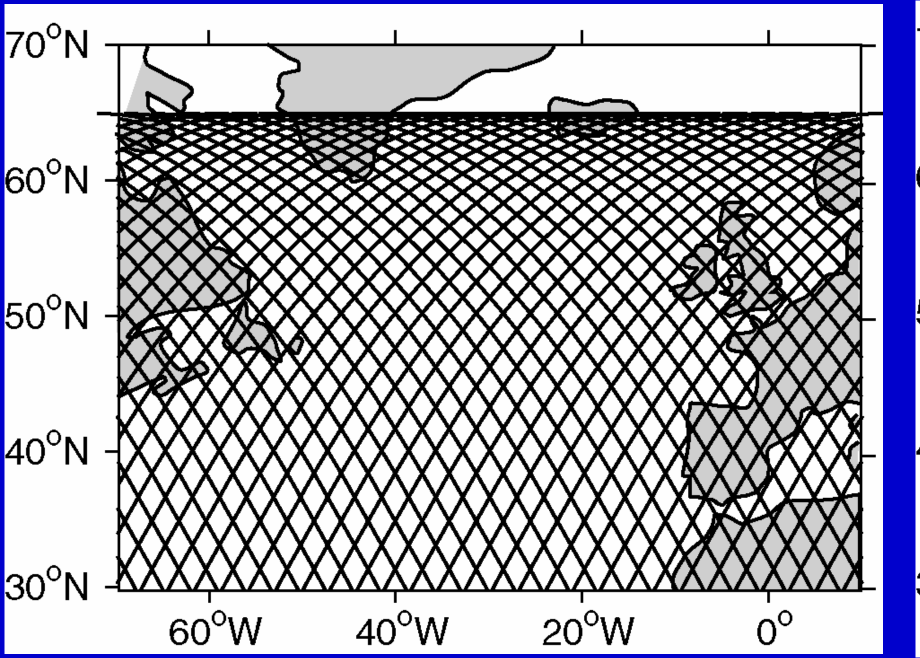
- A special class of polar orbit
- The orbit plane *precesses* in phase with the sun

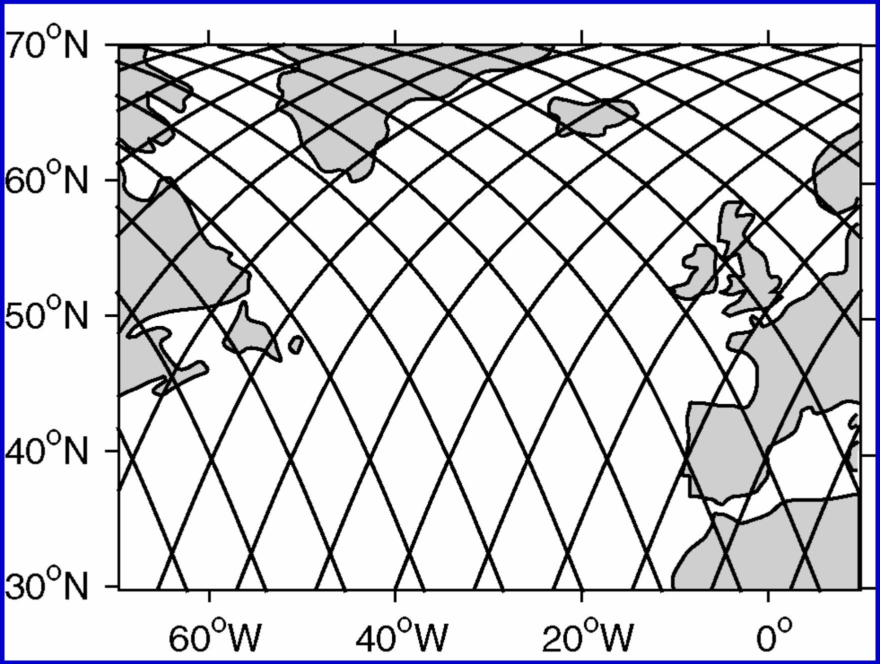


This requires dW/dt = 0.986 deg/day. Orbital mechanics requires *i* > 90 deg

Thus the satellite passes overhead at a given latitude at the same local (solar) time each day throughout the year.

Revisit interval – impact on spatial resolution





~10-day orbit repeat

Inclination 65°

Spacing at equator ~315 km

3-day orbit repeat

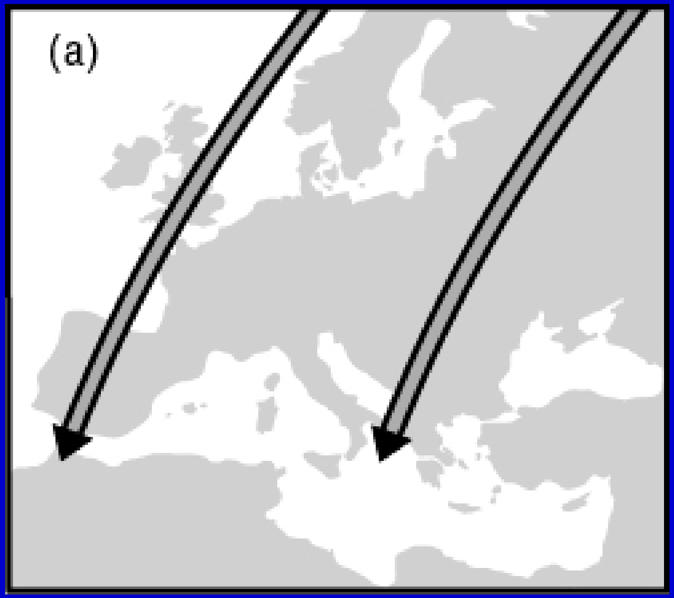
Inclination 72°

Spacing at equator ~800 km

Revisit interval dependence on swath

Same orbit

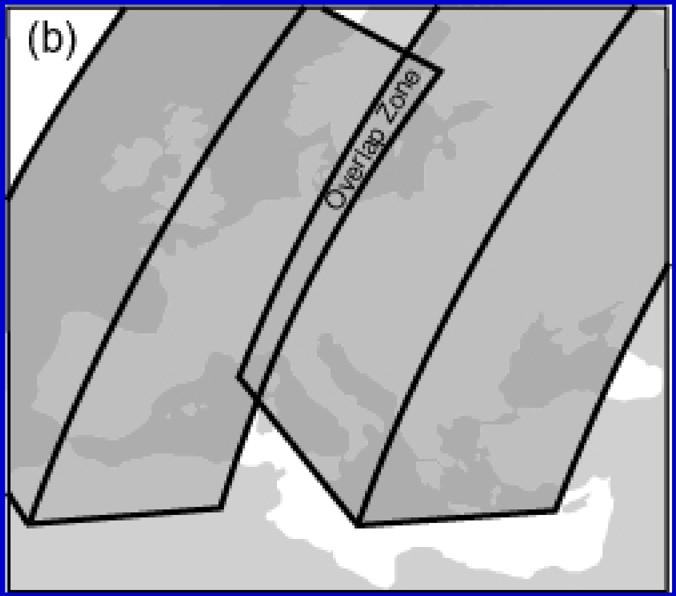
Narrow Swath



Swath just wide enough to fill the track spacing over a full cycle.

Revisit interval is the same as the orbit repeat cycle.

Wide Swath



Swath wide enough to fill the space between adjacent orbits.

Revisit interval is 24 hours.**

Intermediate swaths have intermediate revisit intervals, depending on orbit cycle

Measuring sea surface temperature from satellites

Infra-red radiometry

Thermal emission from the sea surface

Black body radiation, M_λ (measured in $Wm^{-2}m^{-1}$), at wavelength, λ , is emitted by an ideal surface according to the Plank equation:-

$$M_\lambda = \frac{C_1}{\lambda^5\left[\exp\left(\frac{C_2}{\lambda T}\right)-1\right]}$$

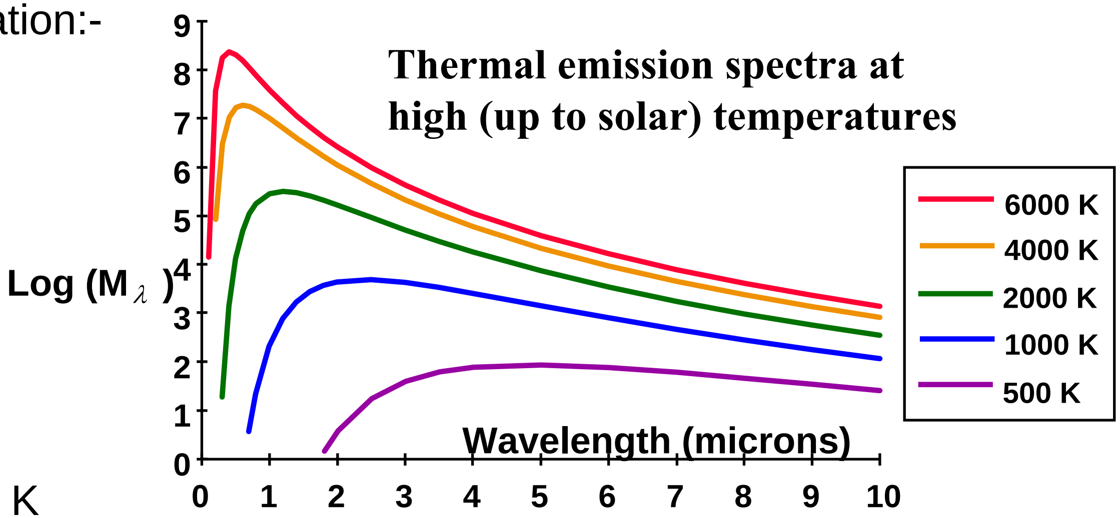
where

λ is the wavelength in m.

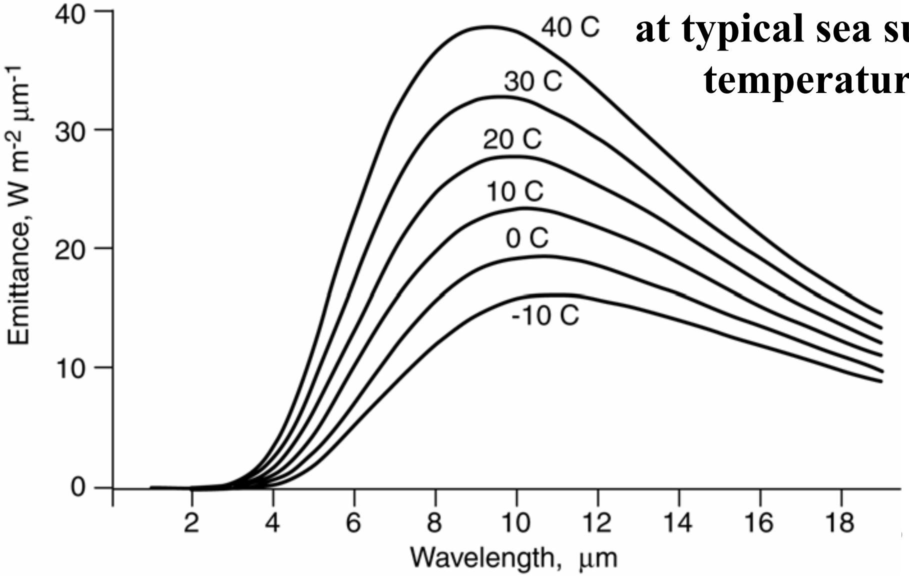
C_1 is a constant = 3.74 10^{-16} Wm^2

C_2 is a constant = 1,44 10^{-2} m deg K

T = temperature of the surface in K

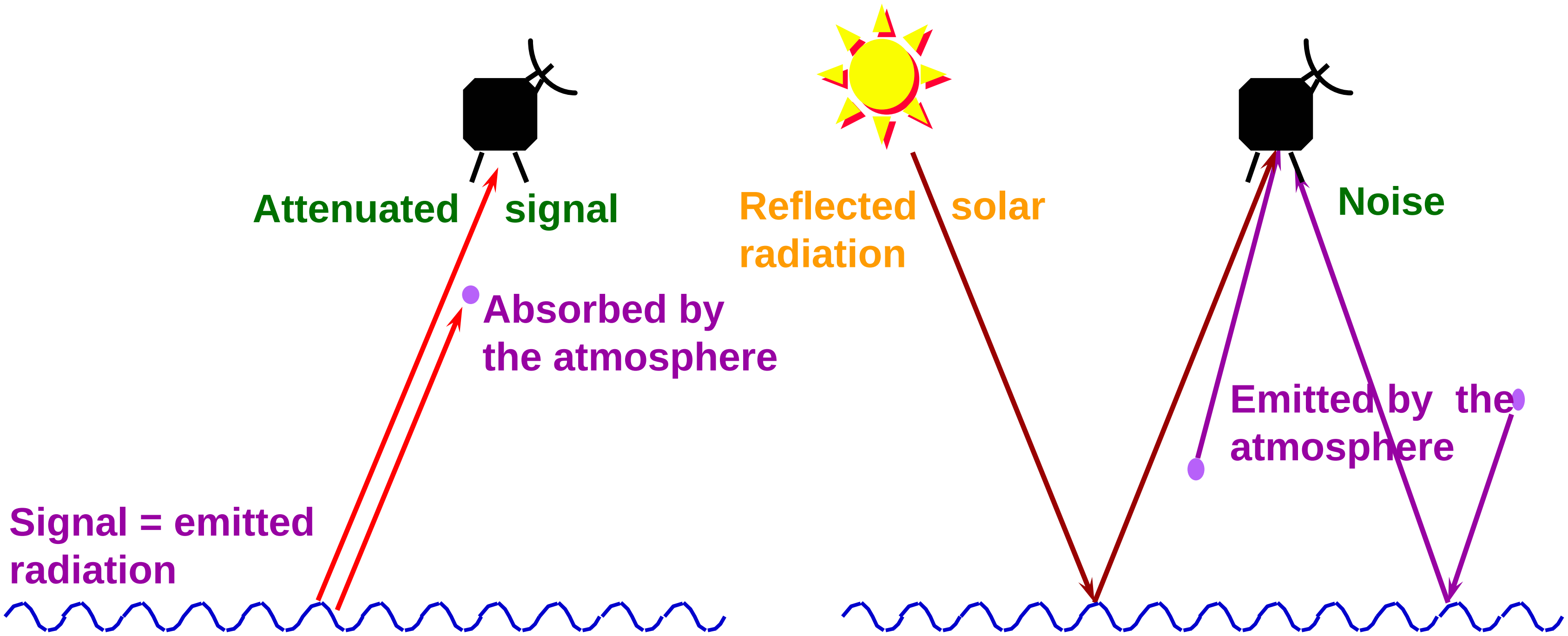

Thermal emission spectra at high (up to solar) temperatures

Black-body radiation at typical sea surface temperatures



The real surface emits less than the black-body radiation, by a factor ε called the **emissivity**

Atmospheric interactions with I-R radiation



Attenuated signal

Absorbed by the atmosphere

Signal = emitted radiation

Reflected solar radiation

Noise

Emitted by the atmosphere

ε for sea water is about 0.99 so the water-leaving signal is almost the black body radiation.

Reflectance is (1 -ε) which is very small, so solar reflection is negligible at 11 microns.

Thermal emission is approximately Lambertian, but it may be affected by surface foam and films.

Thermal emission by the atmosphere is the greatest source of atmospheric noise.

Atmospheric correction of infra-red data

- **The Problem to be corrected:**

  The “Brightness temperature”, T_b, is generally less than than the true sea surface temperature T_s.

  The difference, dT, is caused by atmospheric absorption of infrared.

- **Atmospheric correction:**

  Estimate T_s as accurately as possible

  Allow for variable absorption (dT not uniform)

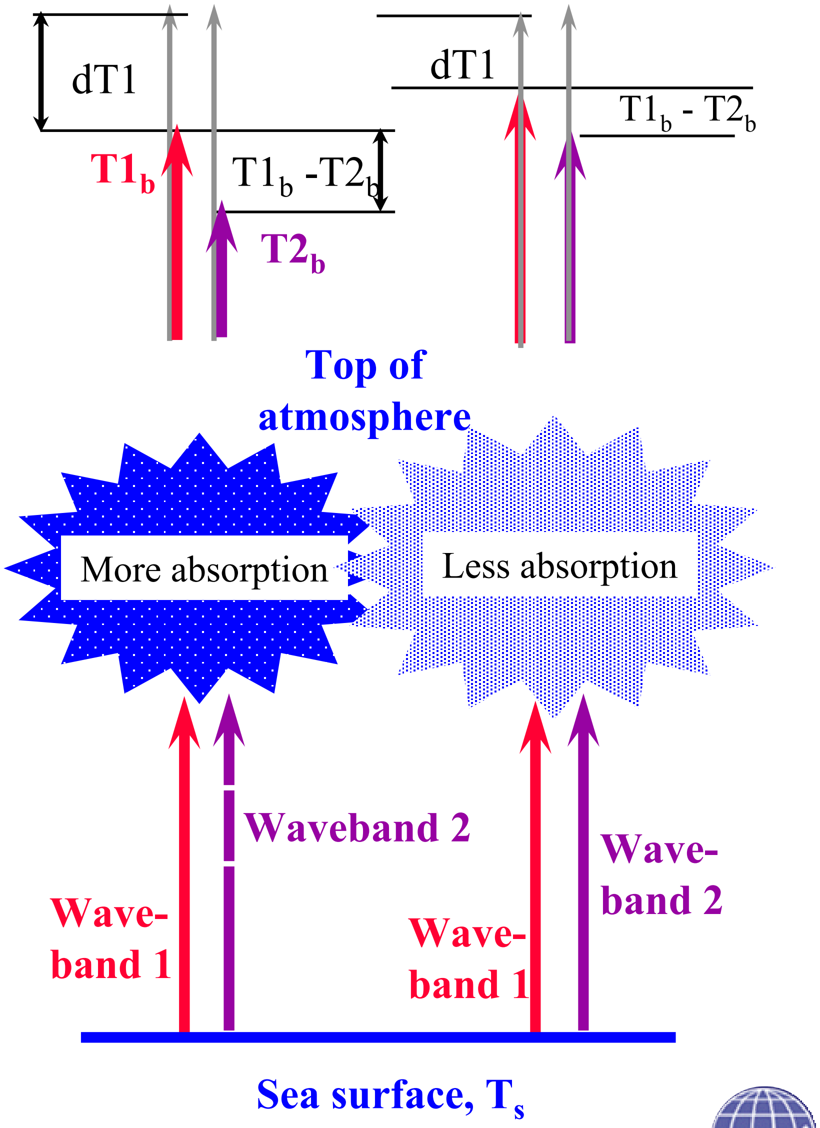
- **The approach**

  Measure T_b in different ways, for which dT differs even for the same pixel.

  e.g. Use different wavebands, $T1_b$,$T2_b$,

  ($T1_b$ - $T2_b$) gives a measure of the amount of atmospheric absorption at each pixel

  Therefore dT = function of ($T1_b$ - $T2_b$)



Atmospheric correction algorithms

- **Simple multichannel**

  Assume a linear relation between dT and $T1_b$ - $T2_b$

  $T_s = a\ T1_b + b\ (T1_b - T2_b) + c$

- **Non-linear**

  $T_s = a\ T1_b + b\ (T1_b - T2_b) + c\ (T1_b - T2_b)^2 + d$

  or $T_s\ = a\ T1_b + b\ (T1_b - T2_b) + c\ (T1_b - T2_b)\ (1 - \cos(q) + d)$

  where q is the viewing angle of incidence

- **Multi-channel**

  Use more than two wavebands

  Or use second viewing angle

- **Coefficients**

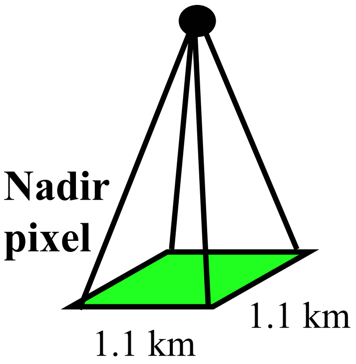
  The values of a, b, c, d, are determined empirically

  ***Either* to match in situ temperature measurements (drifting buoys)**

  ***or* to match model-simulated data**

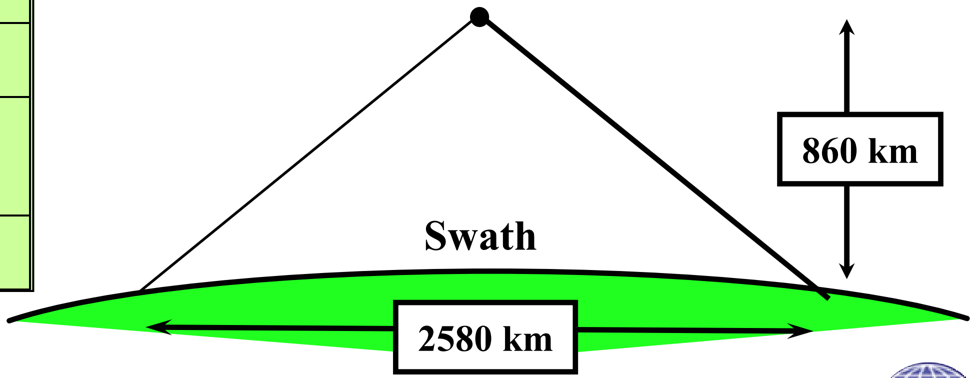
Infra-red sensors: AVHRR

- **Advanced Very-High Resolution Radiometer**
- **Since 1982 the AVHRR/2 has been deployed on NOAA-7, -9,-etc**
- **Specification**

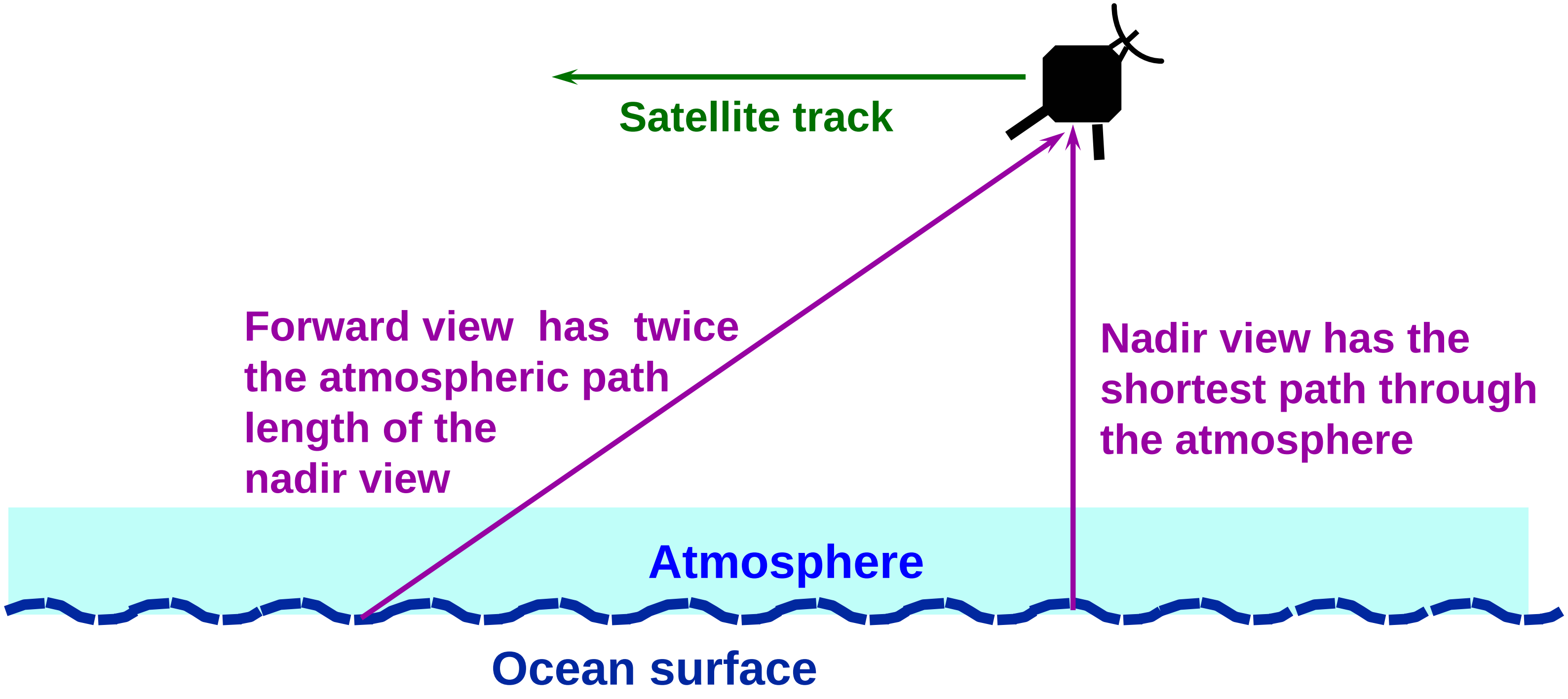


Channel	AVHRR/2 wave-bands (microns)	Description	Application
1	0.58 - 0.68	Visible	water turbidity
2	0.725 - 1.10	Near infra-red	coastline, clouds
3	3.55 - 3.93	Thermal I-R (night only)	SST
4	10.3 - 11.3	Thermal I-R	SST
5	11.5 - 12.5	Thermal I-R	SST

Sensitivity of thermal channels (NEΔT)	0.12 K at 300K
Number of digitisation levels	1024 (10-bit)
Ground field of view, Square Pixels	1.1 km at nadir
Swath width	2580 km



Multi-look atmospheric correction methods

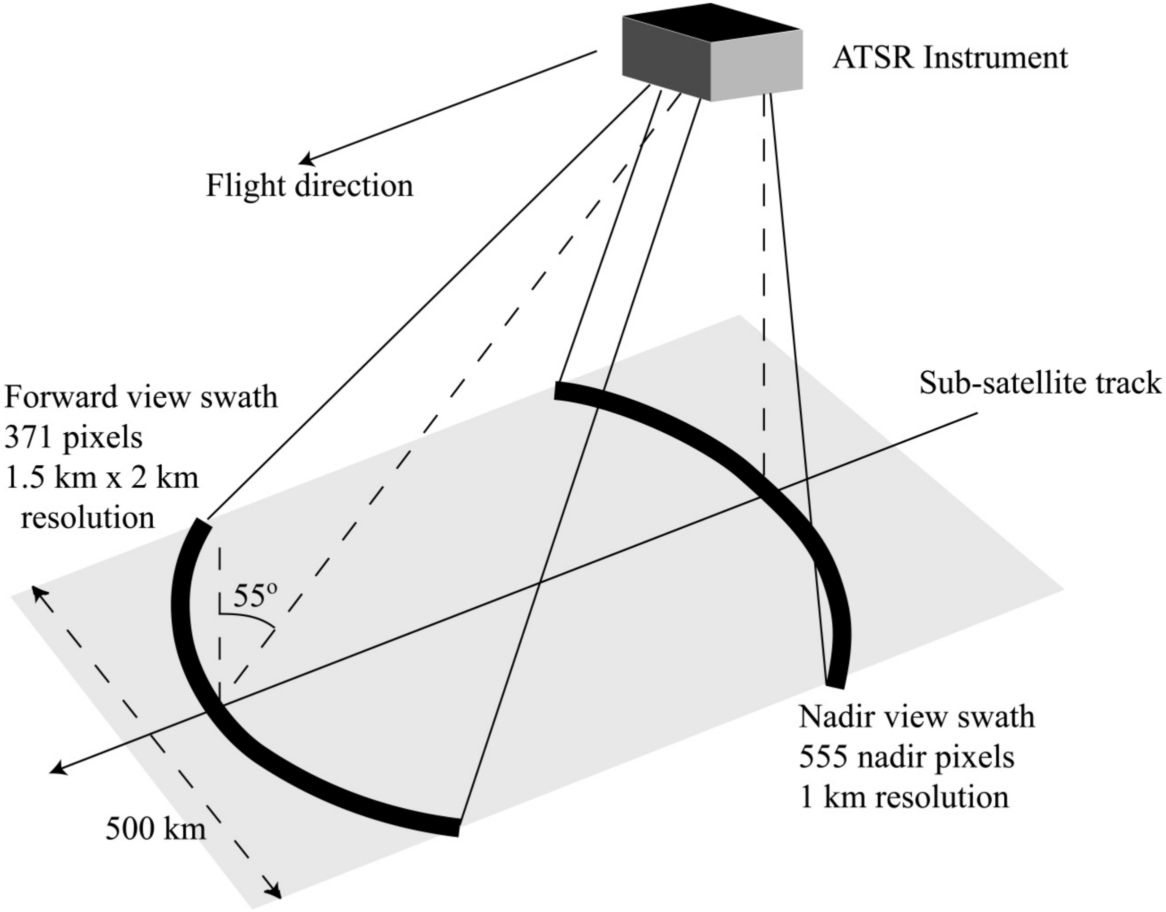


Different views of the same patch of sea (separated in time by ~3.5 min.) through different thicknesses of atmosphere will differ by an amount which depends upon the total effect of the atmosphere on the radiance reaching the satellite.

Improved atmospheric correction algorithms use two views (multi-angle) as well as multi-spectral information

The along-track scanning radiometer

- **Flown on ERS-1 and 2 and Envisat.**



I-R sensors: ATSR

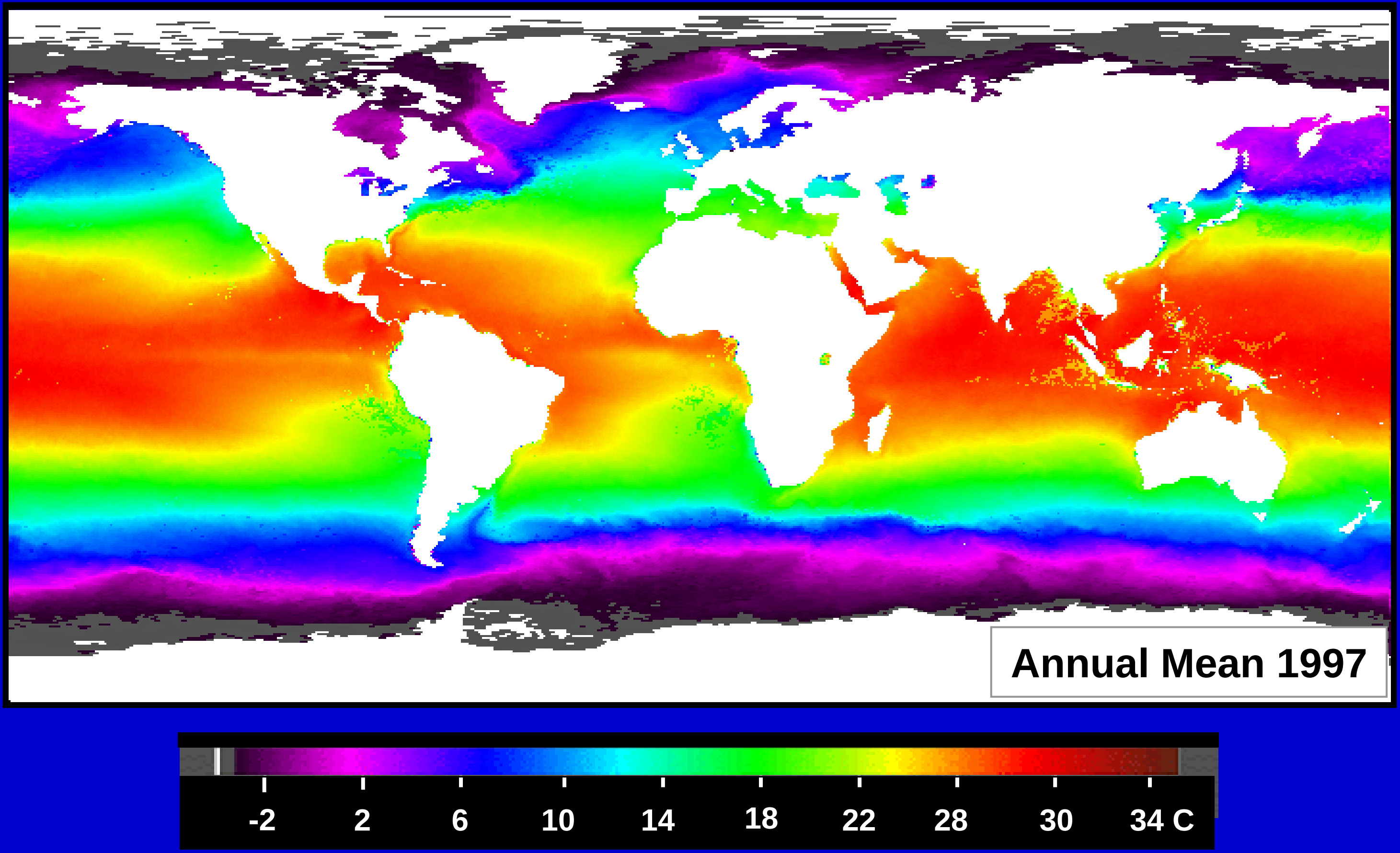
(Along-Track Scanning Radiometer)

- **Conical viewing geometry**
  - **Views the ground twice (at nadir and 60 deg. forward)**
  - **1 km pixels at nadir (curved scan lines)**
  - **Swath width only 500 km**
- **Improved accuracy**
  - **Cooled detector for higher sensitivity (0.1 degC)**
  - **On-board calibration: two temperature-controlled black body reference targets.**
  - **Data digitisation into 12 - bit integers**
- **Improved atmospheric correction**
  - **Wavebands at 3.7, 10.5 and 11.5 microns like AVHRR**
  - **Dual view gives extra atmospheric information (4- and 6-channel algorithms**
  - **Uses semi-physical T_{skin} algorithms independent of buoy calibration**
- **Monitors global sea-surface temperature**
  - **Accuracy better than 0.3 deg C**

Cloud - the implacable enemy of infra-red remote sensing

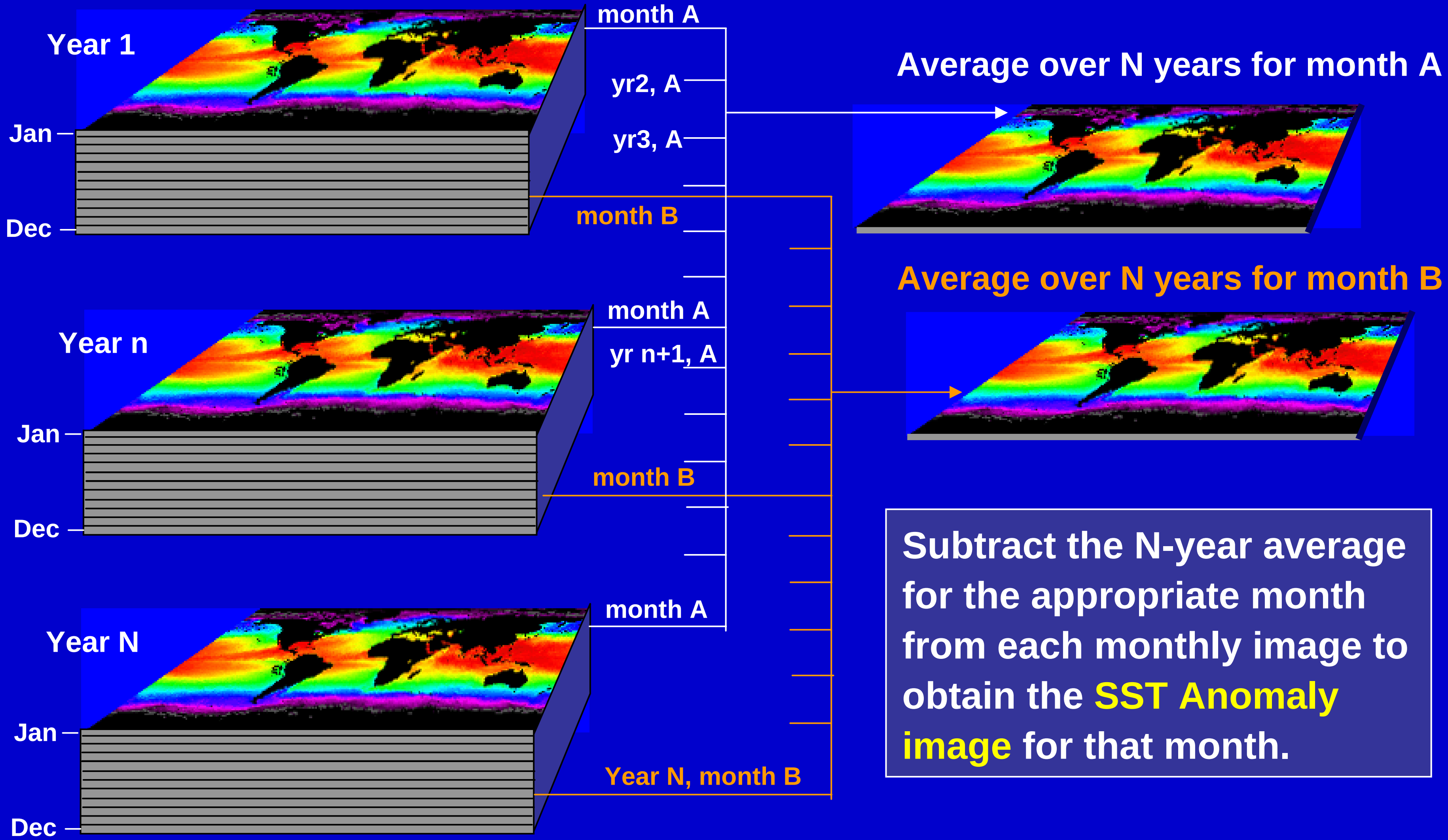
- There is no IR way of measuring SST below cloud
- First priority: detect cloud – a variety of methods
- Consequences of poor cloud detection
  - Biases the SST low in climatic averages
  - "False hits" of cloud can hide frontal and other dynamical structures
- Coping with cloud
  - Fill the gaps : optimal interpolation or modelling – invents data !
  - Assimilate and put up with gaps
  - Additional observations
    - microwave radiometry
    - geostationary I-R sensors can see whenever the cloud breaks
- Generate composites from several overpasses

Monthly mean Satellite SST: 1997



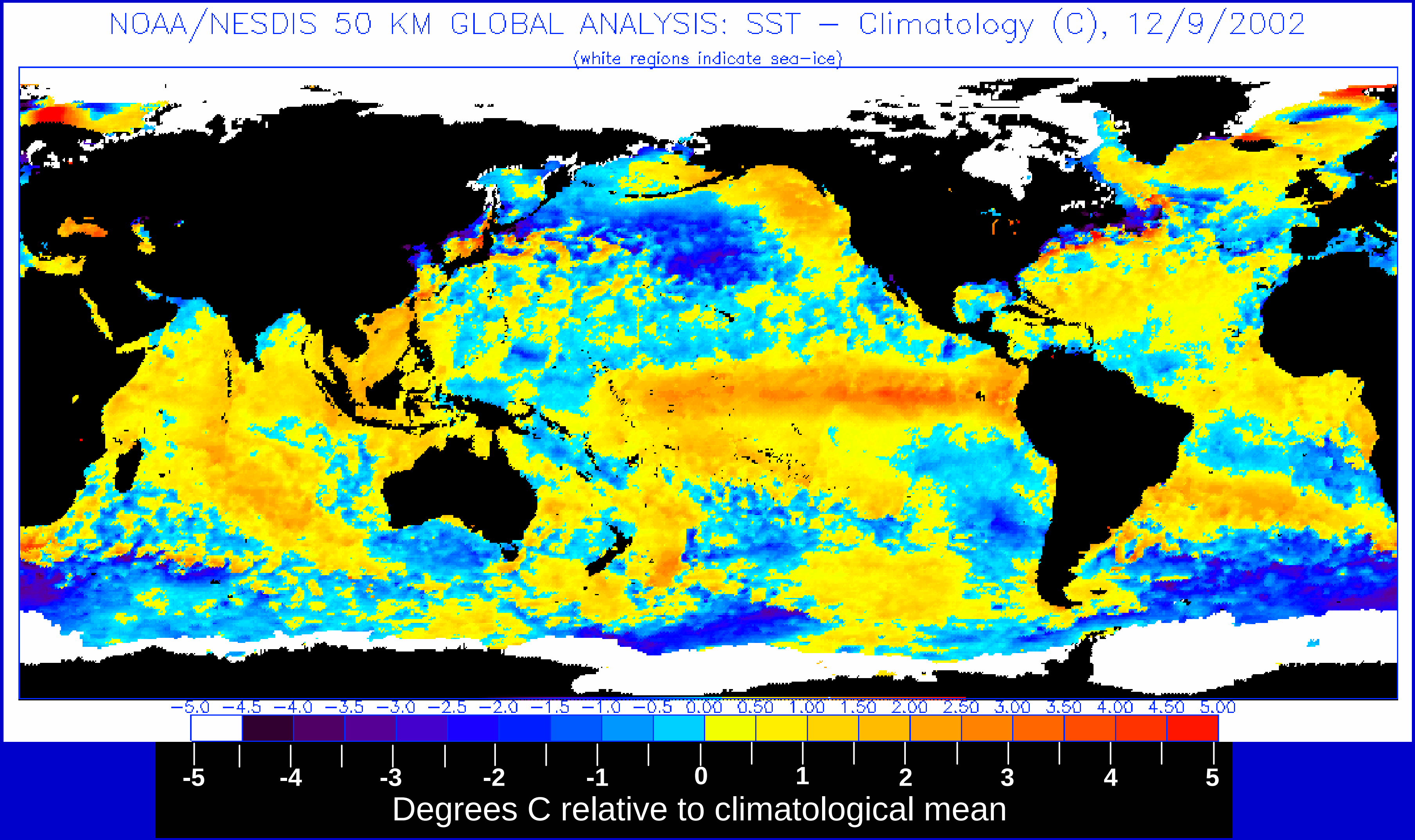
Monthly mean SST data from the NASA “Pathfinder” analysis for 1997. The spatial resolution is 9 km.

Generating SST anomaly maps



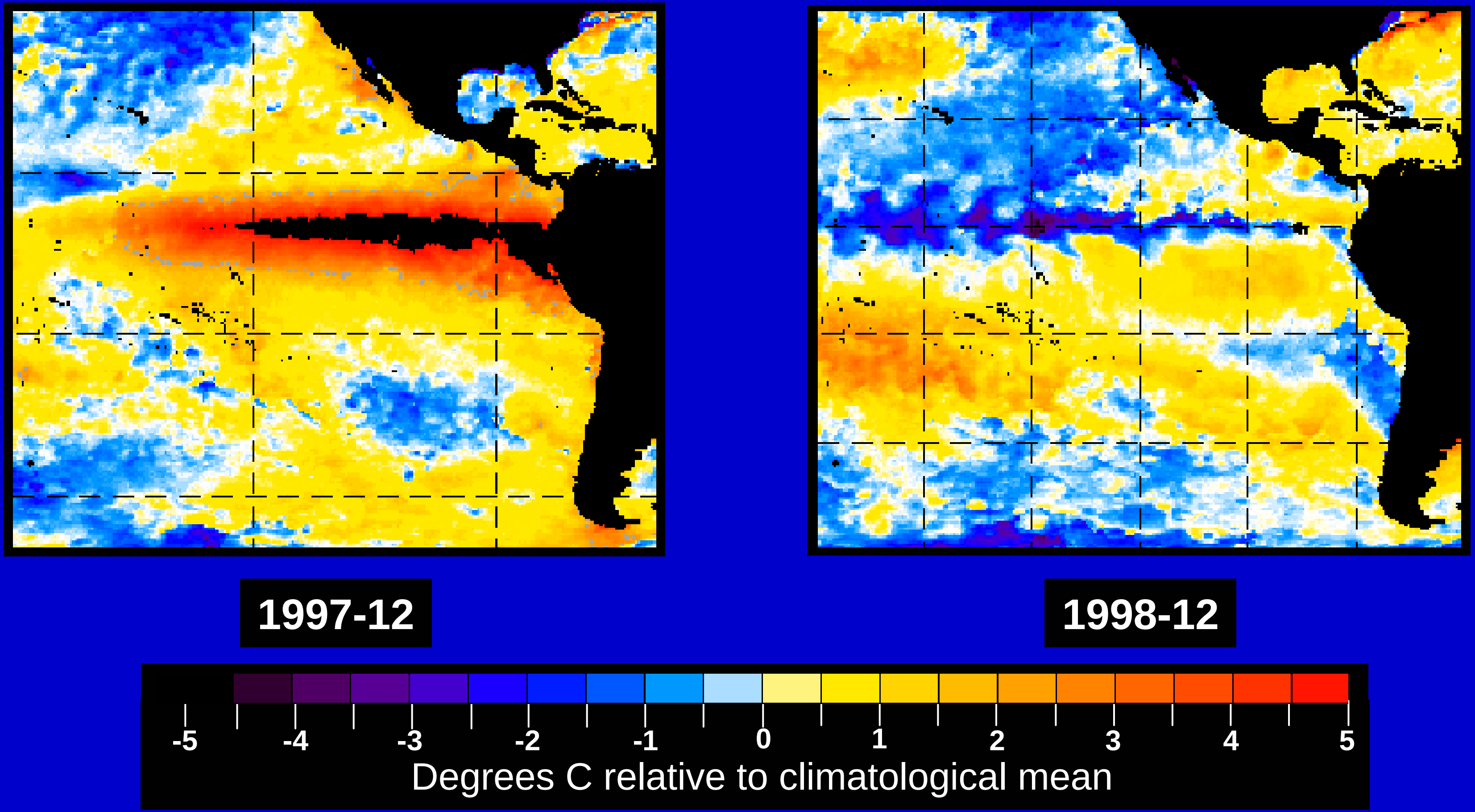
Subtract the N-year average for the appropriate month from each monthly image to obtain the SST Anomaly image for that month.

SST Anomaly map from AVHRR



Data processed by Al Strong and provided by the Products System Branch of NOAA/NESDIS

Evidence of El Niño in SST Anomalies

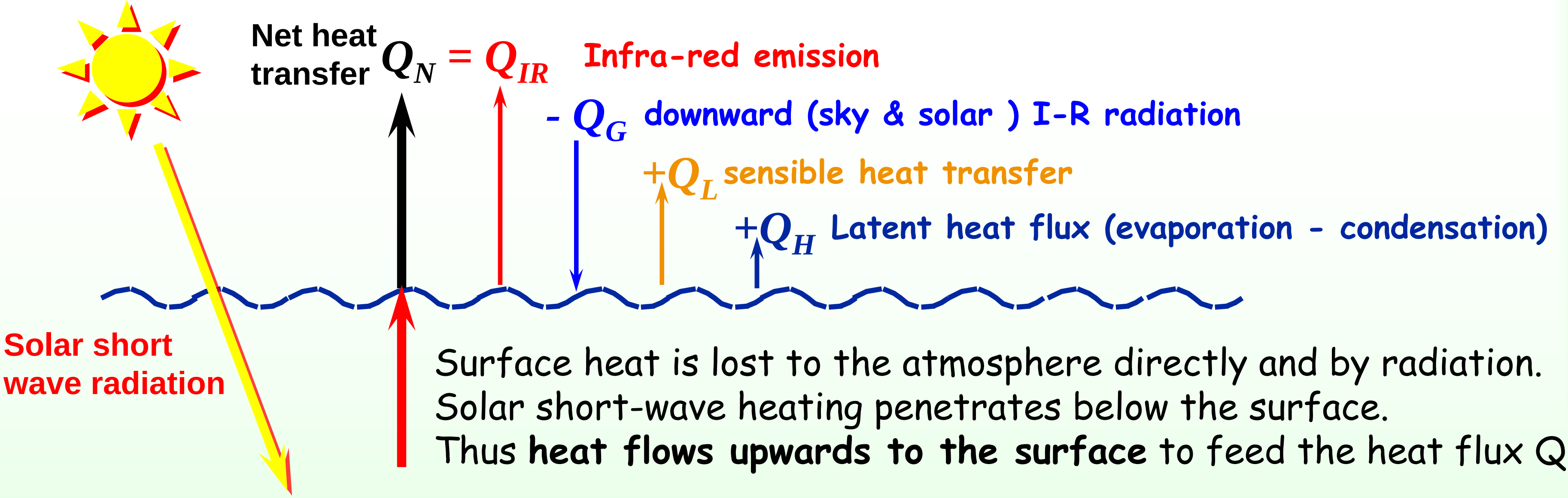


1997-12

1998-12

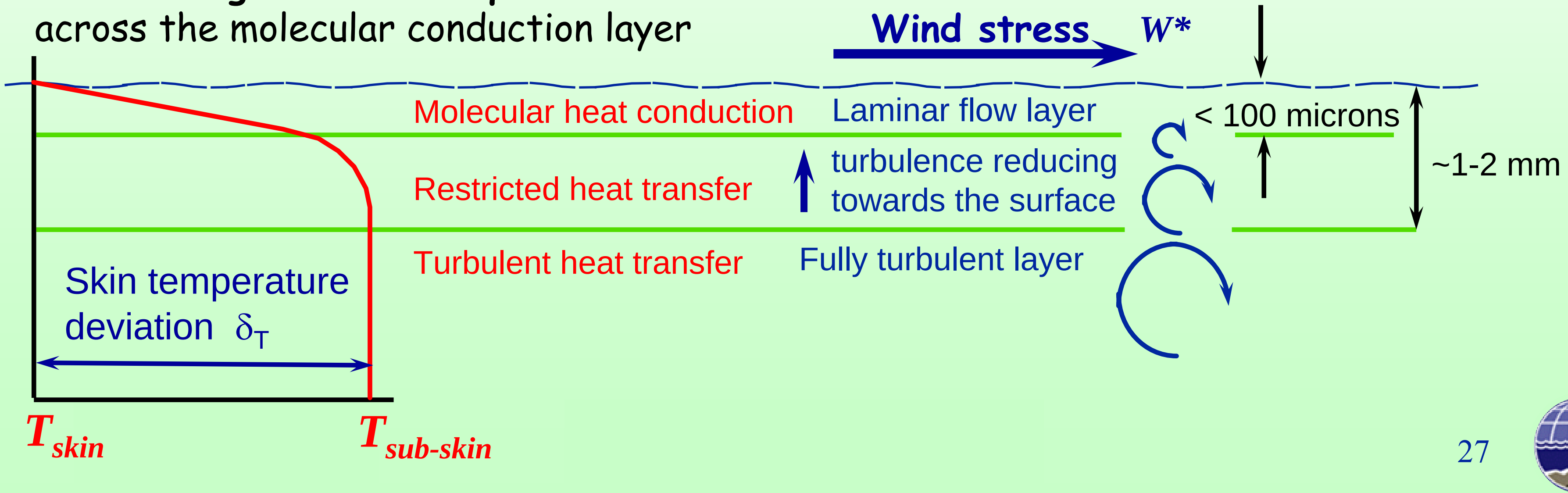
Which sea surface temperature do we see from Space ?

The skin - bulk temperature difference



Surface heat is lost to the atmosphere directly and by radiation.
Solar short-wave heating penetrates below the surface.
Thus **heat flows upwards to the surface** to feed the heat flux Q_N

A **thermal gradient is required** to drive heat across the molecular conduction layer

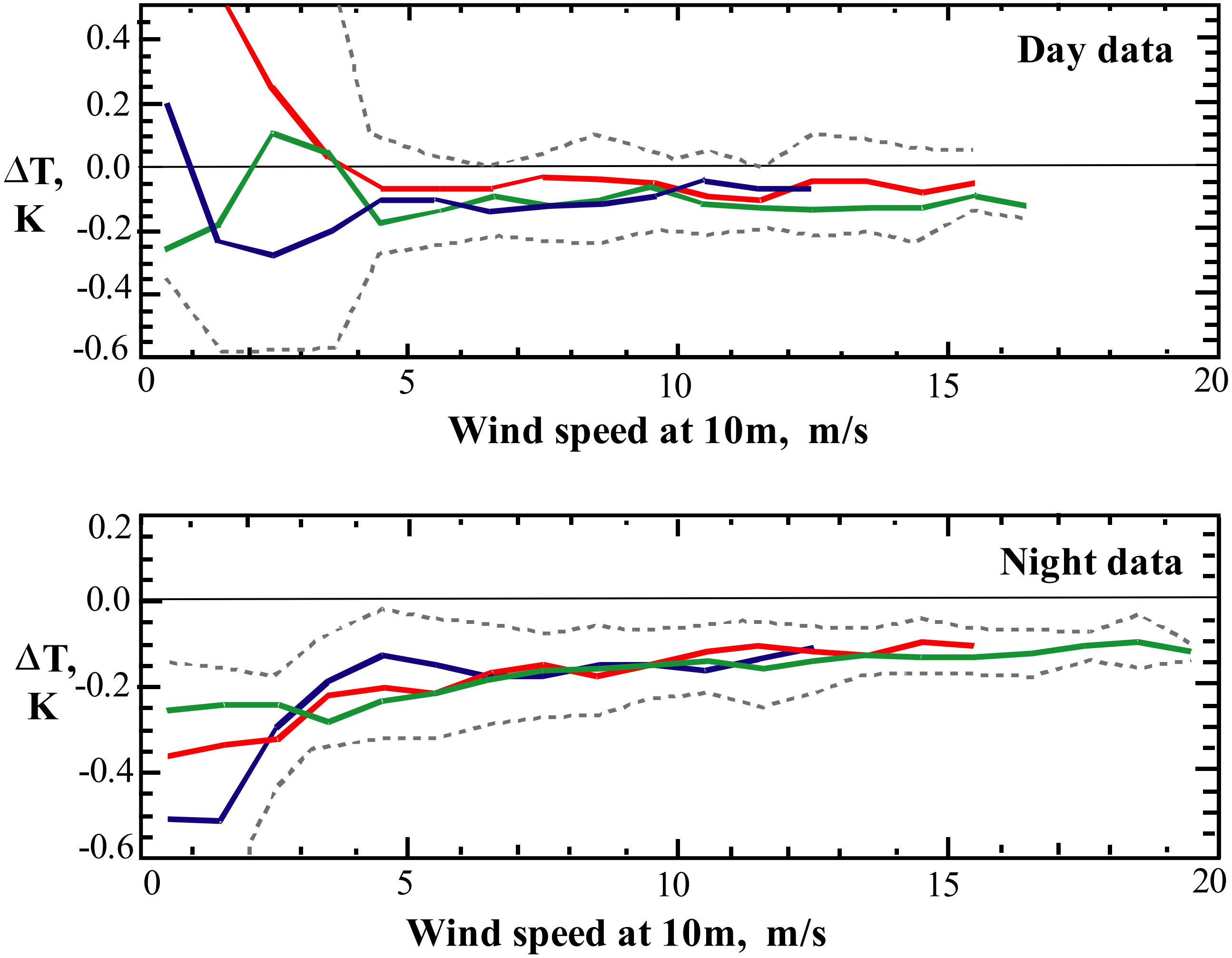


Direct measurements of $\delta T = T_{Skin} - T_{bulk}$

Measured by Donlon et al (1999), over the Atlantic Meridional Transect

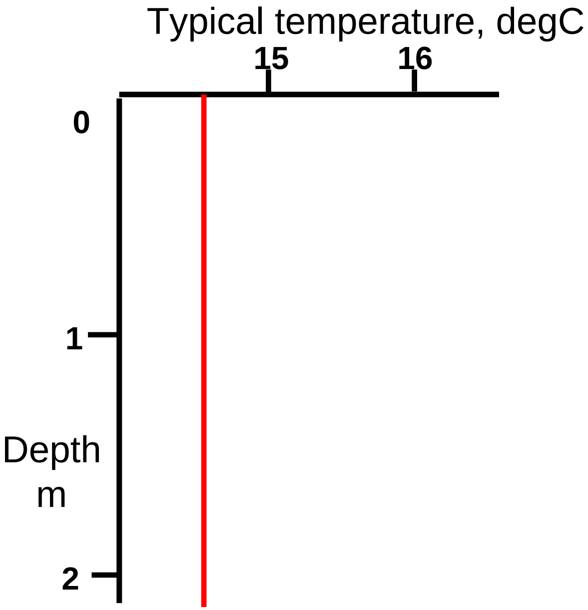
Geophys. Res. Let., **26,** pp 2505-2508**.**

🟥 **ROSSA, AMT-3, Sep-Oct 1996**
🟩 **ROSSA, AMT-7, Sep-Oct 1998**
🟦 **CHAOS, May-June 1998**



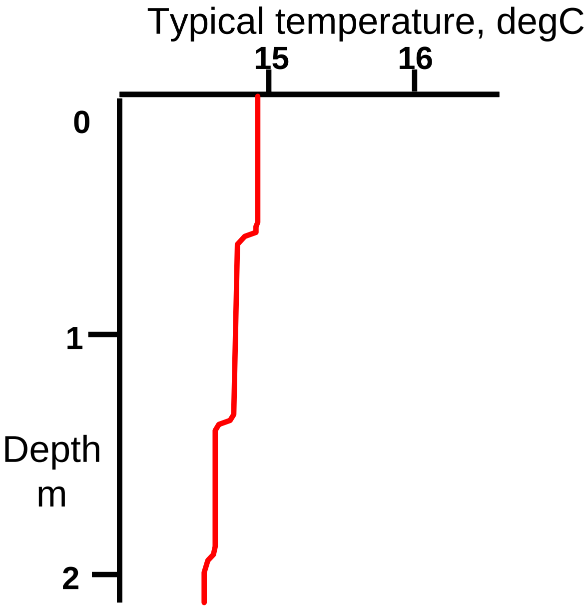
The diurnal thermocline

Night, or windy day



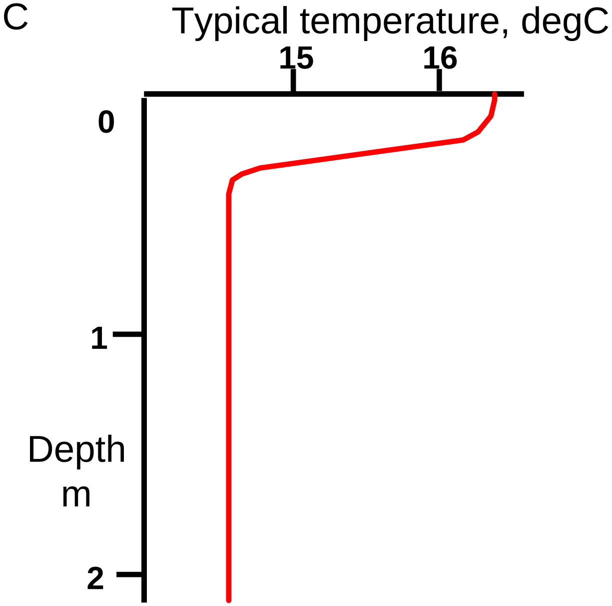
Weak insolation and strong wind mixing.
or Zero insolation and buoyancy instability.
Uniform temperature.

Sunny day, light wind



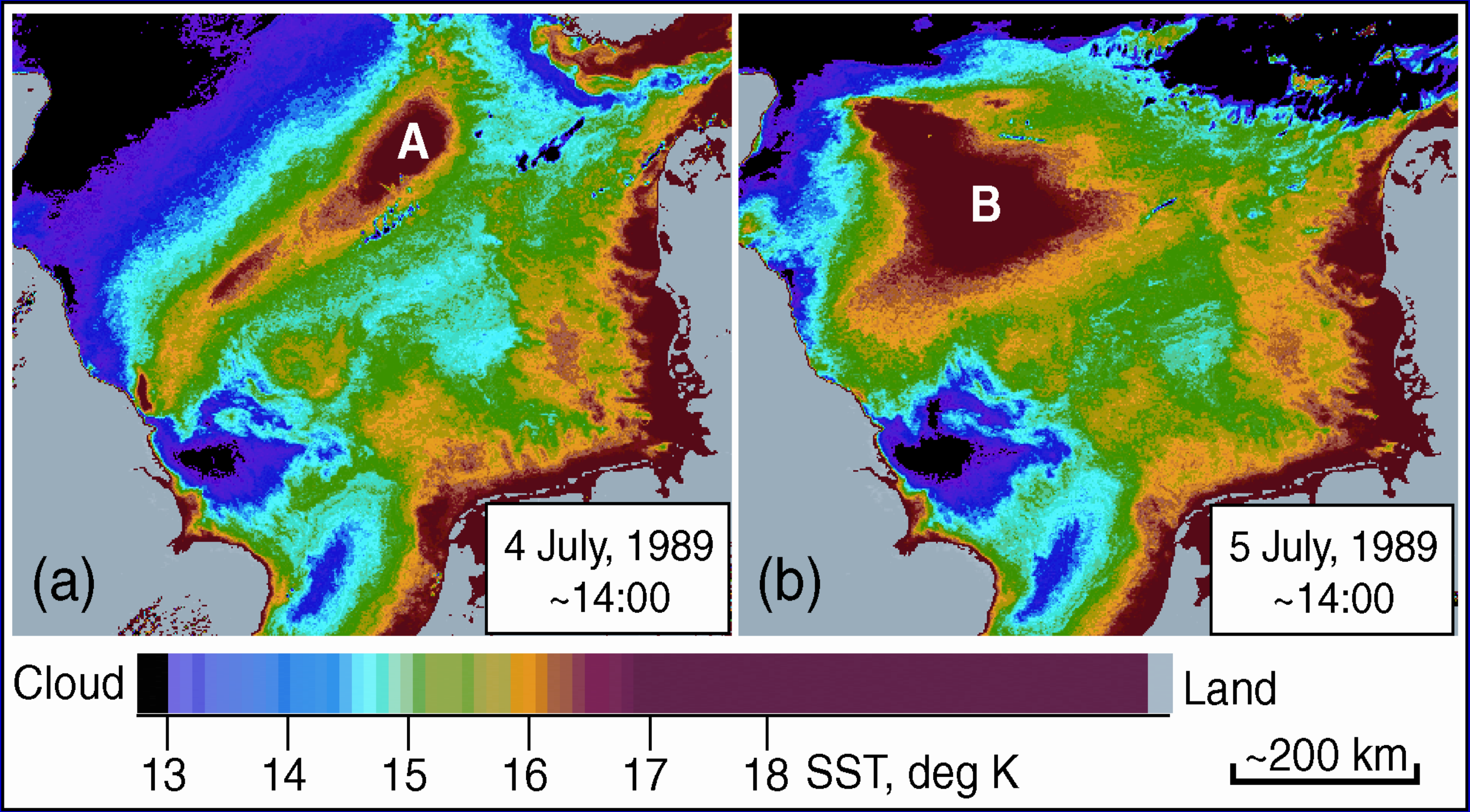
Strong insolation.
Weak to moderate wind mixing.
Weak temperature gradient.

Calm, sunny day



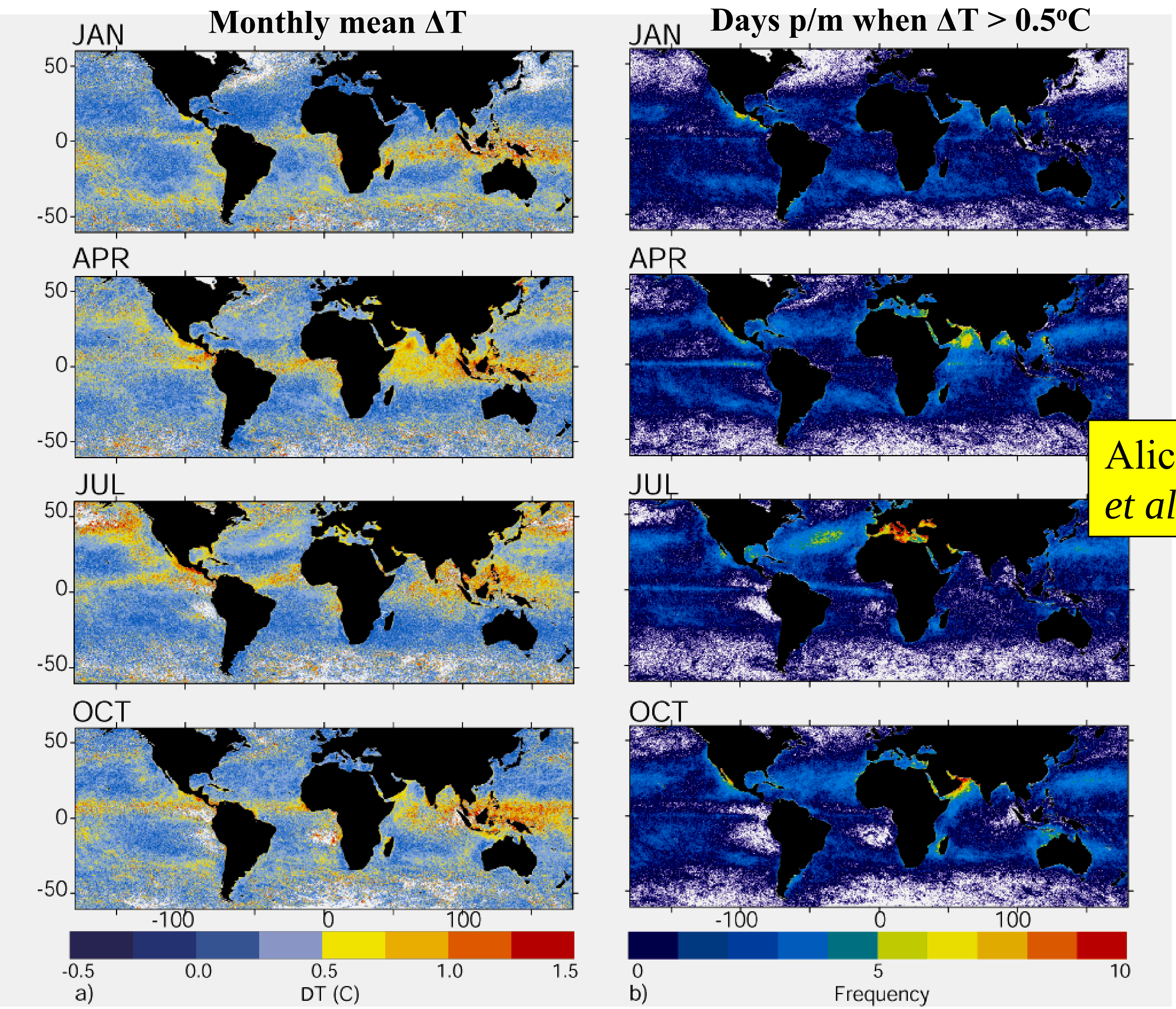
Strong insolation.
Zero to weak wind mixing.
Strong temperature gradient

Diurnal warming features in North Sea



A and B are examples of diurnal warming

Six Year Pathfinder Climatology of $\Delta T_{14:00\text{-}02:00}$ (18km)



Alice Stuart-Menteth *et al*., JGR (2003)

Importance of the diurnal thermocline for remote sensing of SST

- Develops during the day
  - Surface temperature 0.5 to 1 K warmer in the early afternoon than the previous or subsequent night. Max amplitude 5 K
- Varies with meteorological conditions
  - Strongest in summer (longer and more direct solar heating).
  - Strongest in calm conditions.
- Spatially variable within an image
  - Patchiness on daytime images - the so-called ‘afternoon effect’.
  - Masks underlying meso-scale mixed-layer temperature patterns.
- Introduces a warm bias to SST records
  - Eliminate by using only night-time images,
  - Or ignore daytime images under particular conditions,
  - Or predict and correct for the effect (difficult to do confidently).

Skin, bulk or both?

- **What do users require?**
  - T_{bulk} for thermal capacity, deep convection etc. and for existing flux parameterisation.
  - T_S for air-sea interaction processes, better for fluxes eventually?
  - Is $\Delta T_{diurnal}$ useful in itself?

- **In situ measurements**
  - T_{bulk} is conventionally observed.
  - But at what depth?
  - May be compromised by $\Delta T_{diurnal}$
  - Strictly we should record T_z and z.
  - Shipborne radiometry with sky correction can now measure T_{skin}

- **Satellite observations**
  - All satellites "see" <u>only</u> T_S.
  - T_S is precisely defined at the surface.
    - Must allow for ε and sky reflection.
    - N.B. m/w penetrates slightly deeper.
  - T_S atmospheric algorithms are fundamentally-based.
    - Independent of in situ calibration.
    - Require in situ T_S for validation only.
  - T_{bulk} algorithms have hybrid function.
    - ΔT represented as a globally applied bias correction.
    - Cannot eliminate noise from ΔT.
    - Require in situ calibration.
    - Sensitive to definition of T_{bulk}.
    - A well-developed in situ buoy network.

Preparing SST for assimilation into ocean models

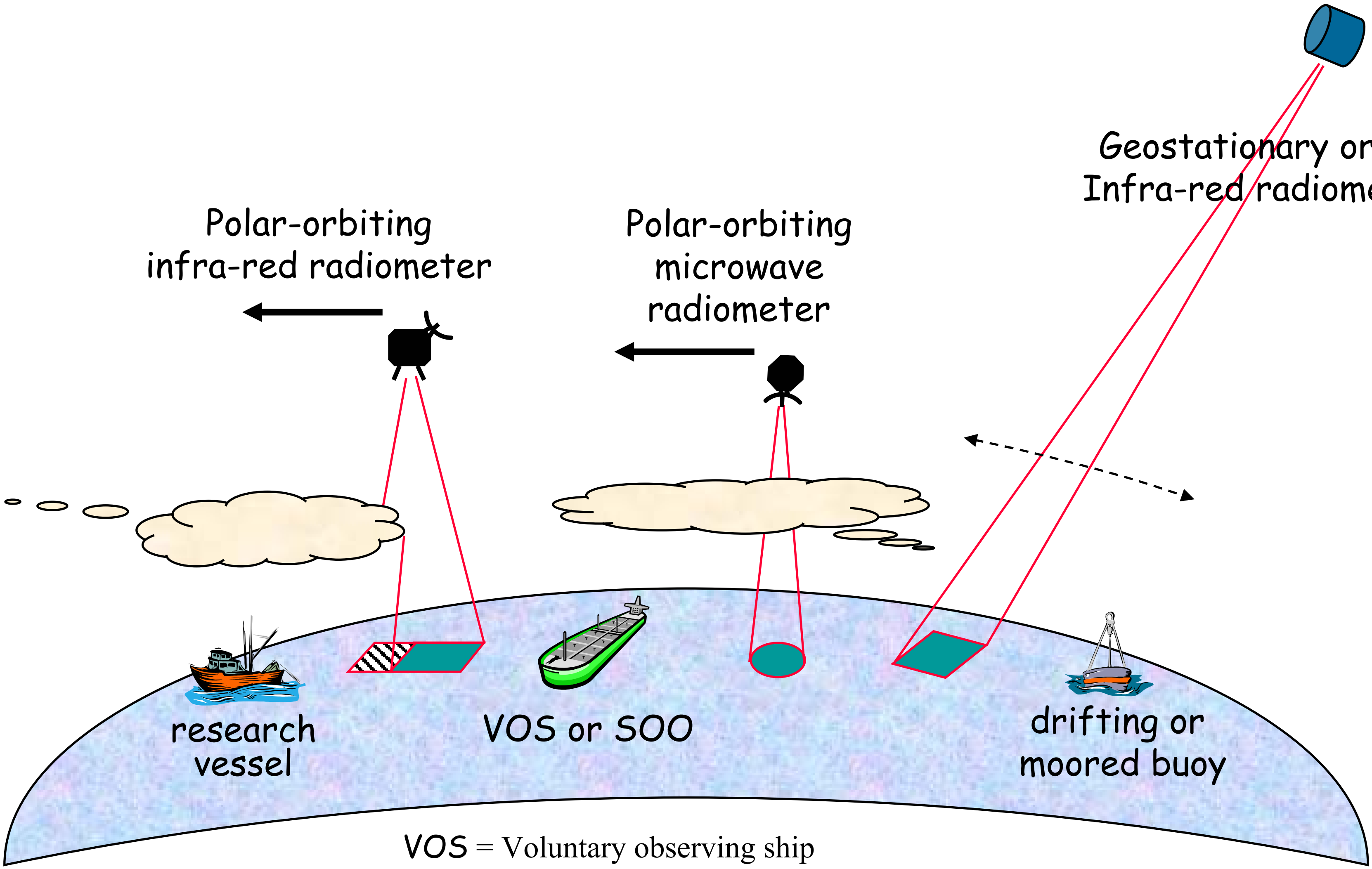
The GODAE Challenge

“Develop a global, high-resolution sea surface temperature analysis with proper consideration of the skin effect and sufficient temporal resolution to resolve the diurnal cycle, that is available in real-time for all environmental and climate applications.”

The Challenge of using SST from Space

- The importance of sea surface temperature (SST) as a variable for assimilation into ocean dynamical models
  - Characterises the mesoscale variability of the upper ocean
  - A key property influencing air-sea interaction processes
  - An important property in its own right –
    - Fluxes, CO_2 solubility, upwelling, climate change indicator, etc.
- Measured from Space from a variety of platforms using a variety of techniques
  - Limitations of sampling frequency, cloud cover, spatial resolution
- How to maximise the benefits of complementary data sources?
- How best to prepare the data from diverse sources for assimilation

Platforms for Measuring SST

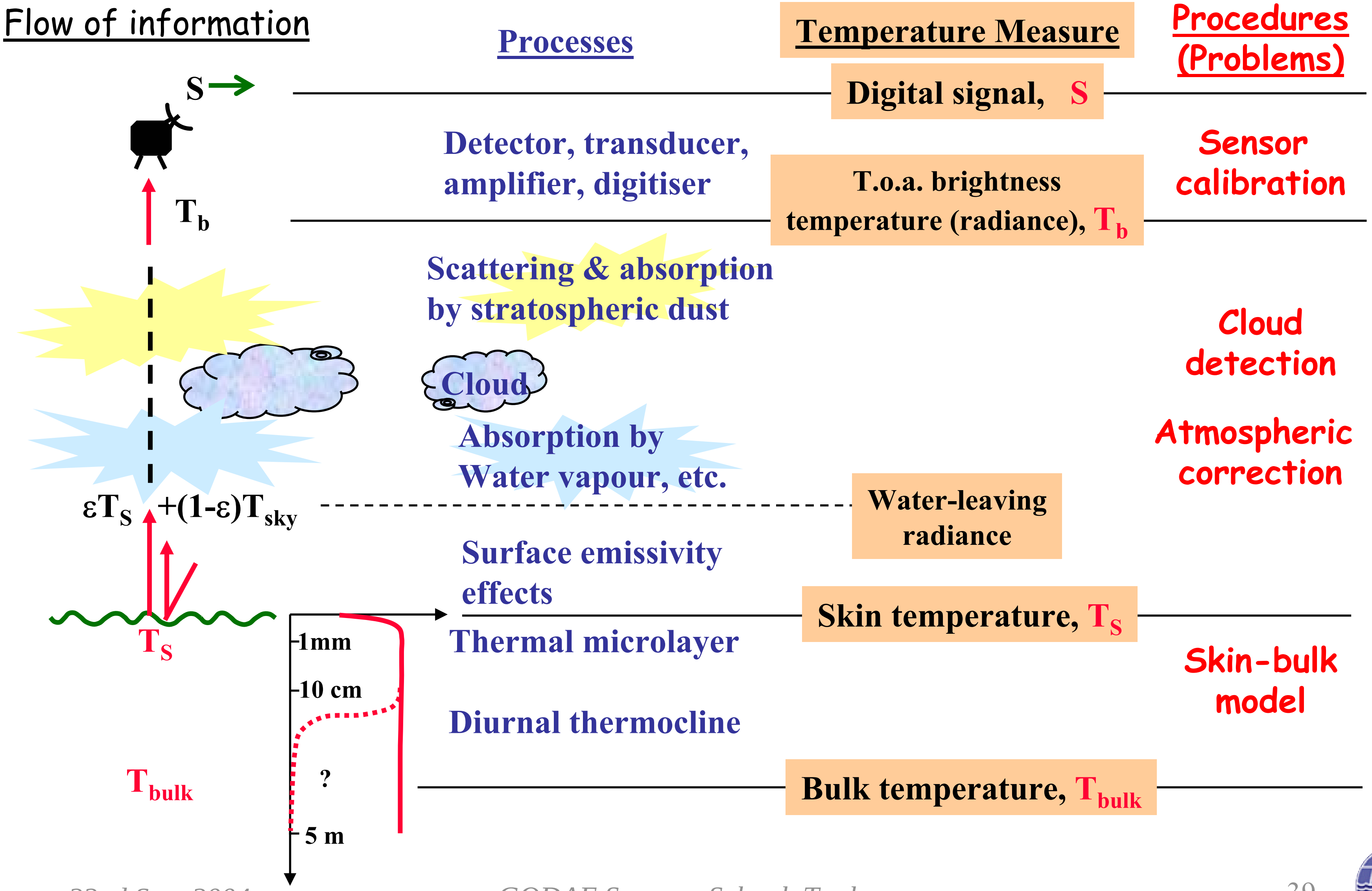


VOS = Voluntary observing ship
SOO = Ship-of-opportunity

Measuring SST: Sampling capability

Instrument	Spatial sampling	Time sampling	Depth sampling	Performance
In Situ				
Research vessel	Precise, very sparse	Continuous	T_{bulk} at all z T_{Skin}	<0.1 K 0.1 K
Buoy	Distributed, sparse	1 hr - 1 day	T_{bulk} at z = 0.3 - 1.5m (z is uncertain)	0.1 K
Voluntary observing ship reports	Track-limited, sparse	1 day	T_{bulk} at c.w. intake z = 1-7m	0.5 K
Ship-of-opportunity, autonomous sensors	Track-limited, sparse	1 hr	T_{bulk} at z = 1-7m T_{Skin}	0.1 K 0.1 K
Satellite				
Polar orbit infra-red radiometer	Global; 1 km, cloud-limit	12 hr	T_S ($z \sim 10$ μm)	0.1K - 0.5 K
Polar-orbit micro-wave radiometer	Global; 50 (20?) km	12 hr - 2 days	T_S ($z < 1$mm)	0.5K-1.0 K
Geostationary orbit I-R radiometer	45S - 45N; 2-6 km, cloud	30 min	T_S ($z \sim 10$ μm)	0.3-0.5 K

Processes affecting SST Measurement



Flow of information

Processes

Temperature Measure

Procedures (Problems)

Digital signal, S

Detector, transducer, amplifier, digitiser

T.o.a. brightness temperature (radiance), T_b

Sensor calibration

Scattering & absorption by stratospheric dust

Cloud detection

Cloud

Absorption by Water vapour, etc.

Atmospheric correction

Water-leaving radiance

Surface emissivity effects

Skin temperature, T_S

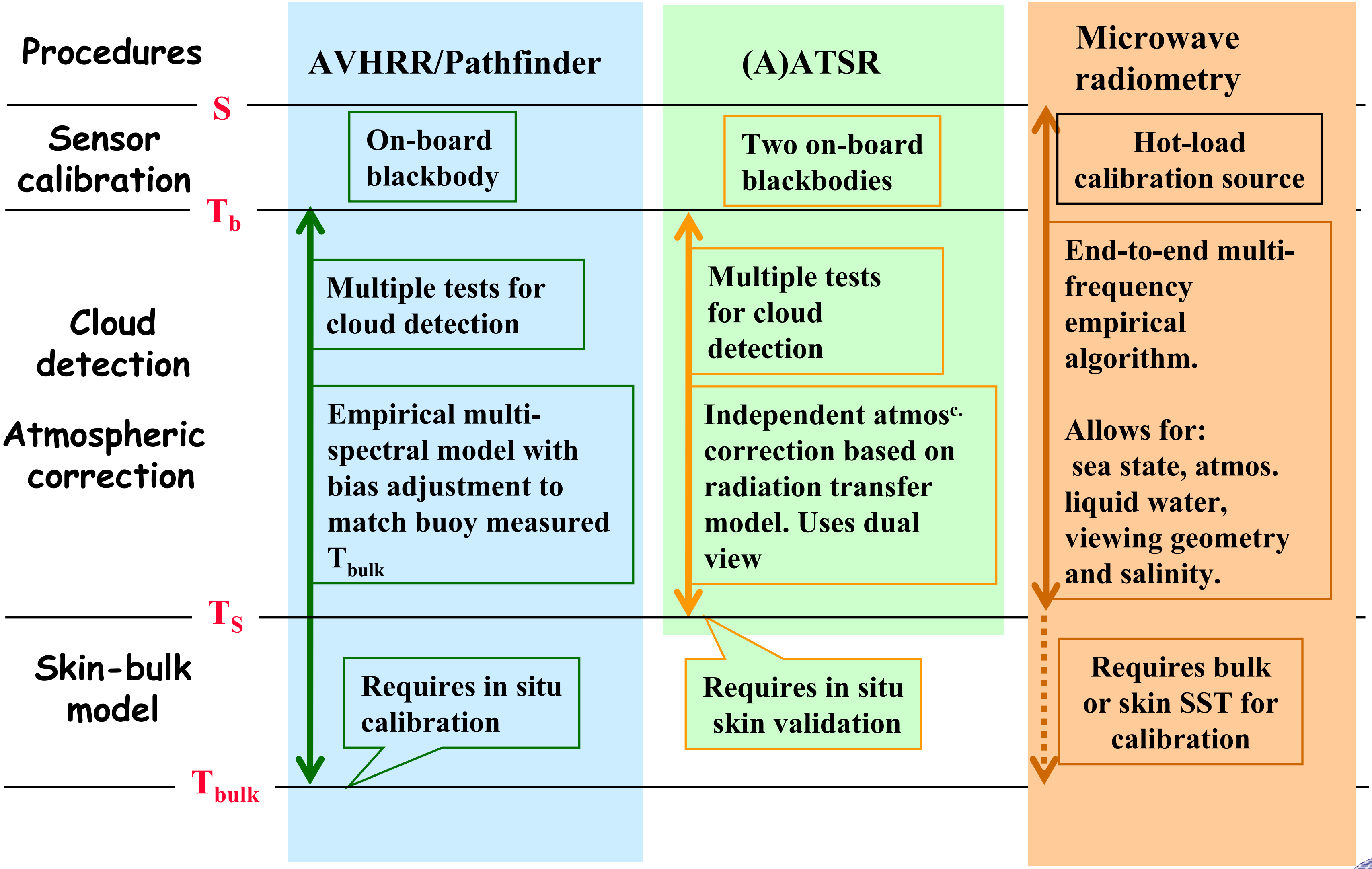
Thermal microlayer

Skin-bulk model

Diurnal thermocline

Bulk temperature, T_{bulk}

Approaches to SST recovery from space



Procedures

S

Sensor calibration

T_b

Cloud detection

Atmospheric correction

T_S

Skin-bulk model

T_{bulk}

AVHRR/Pathfinder

On-board blackbody

Multiple tests for cloud detection

Empirical multi-spectral model with bias adjustment to match buoy measured T_{bulk}

Requires in situ calibration

(A)ATSR

Two on-board blackbodies

Multiple tests for cloud detection

Independent atmos$^{c.}$ correction based on radiation transfer model. Uses dual view

Requires in situ skin validation

Microwave radiometry

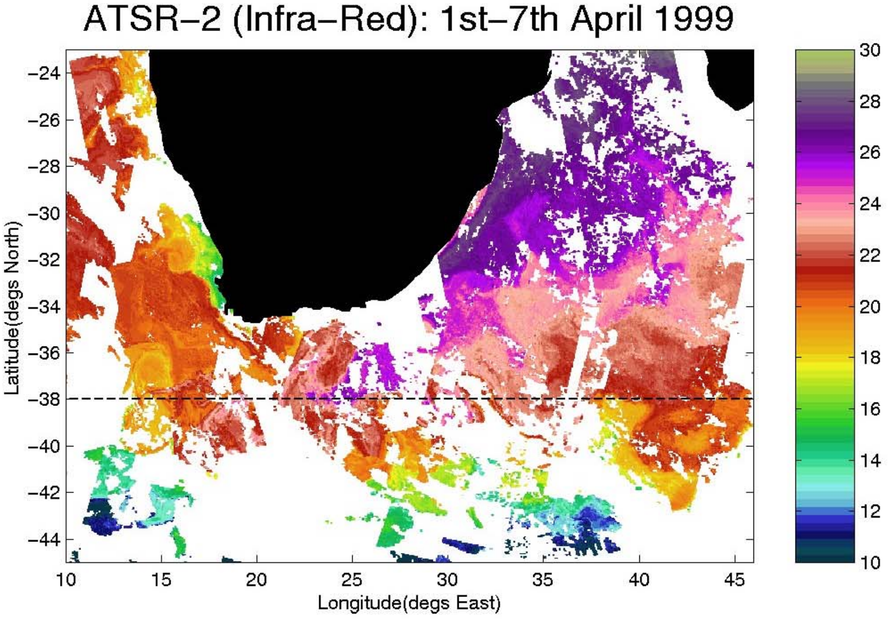
Hot-load calibration source

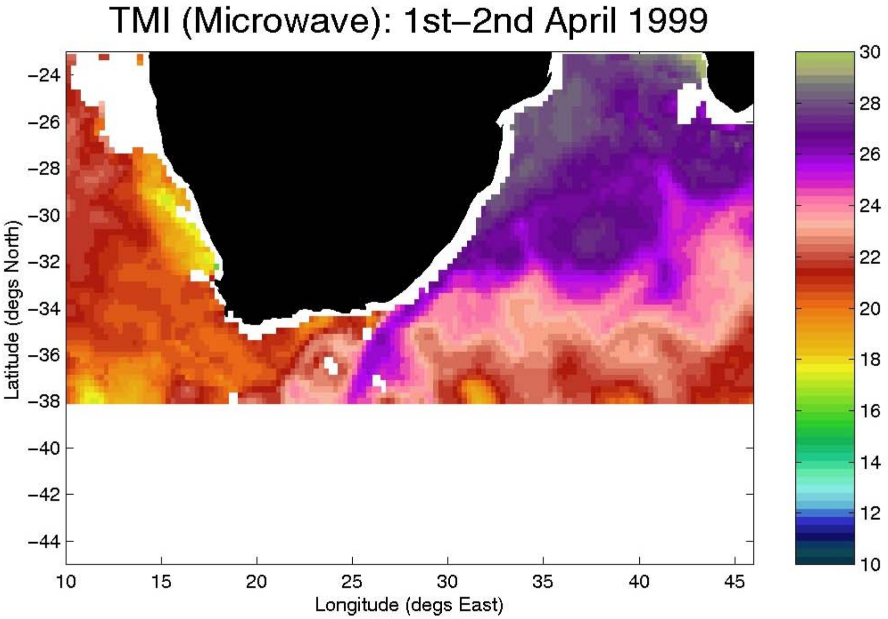
End-to-end multi-frequency empirical algorithm.

Allows for:
sea state, atmos. liquid water, viewing geometry and salinity.

Requires bulk or skin SST for calibration

Complementarity of infra-red and micro-wave radiometry


ATSR–2 (Infra–Red): 1st–7th April 1999


TMI (Microwave): 1st–2nd April 1999

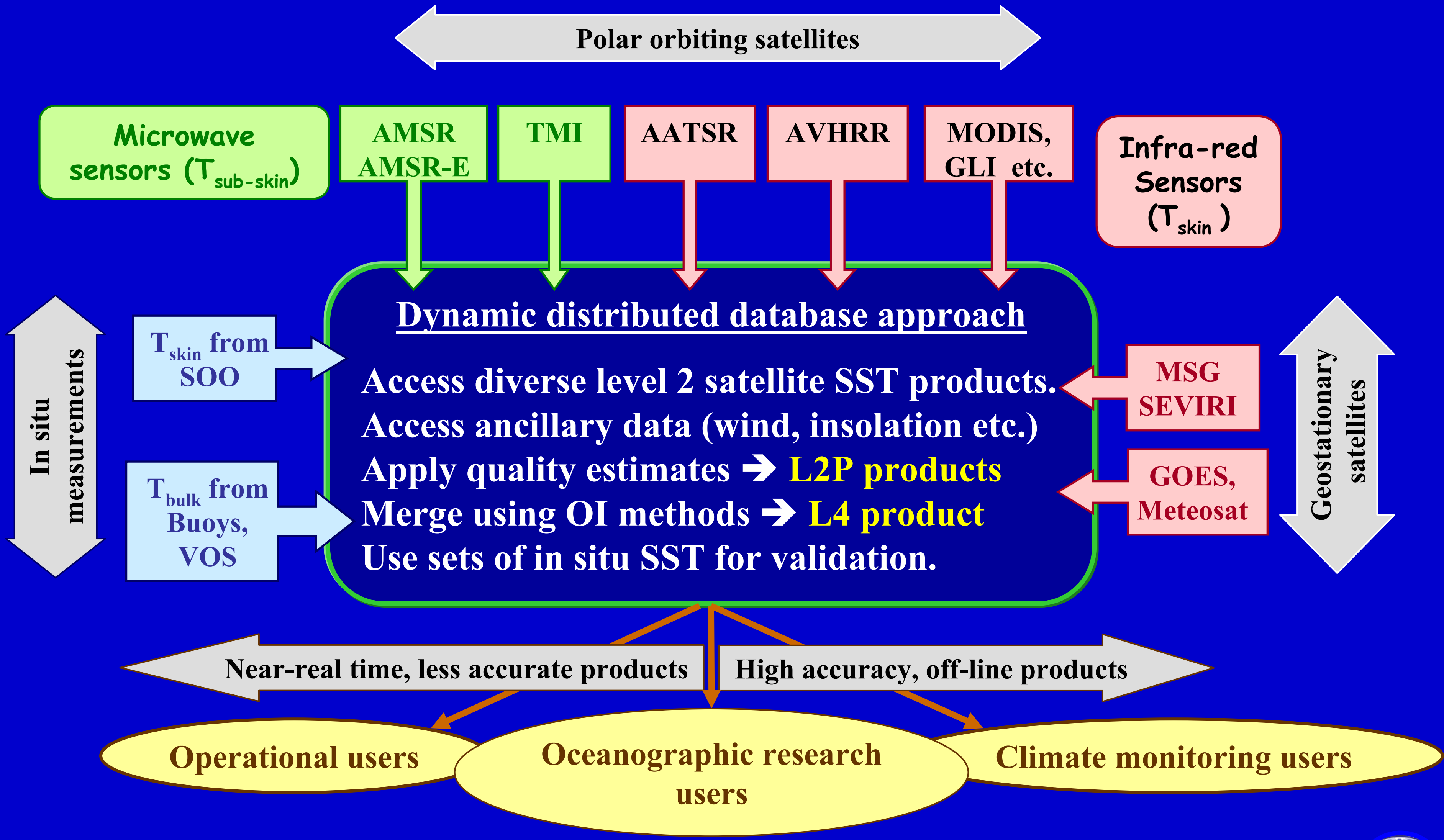
- **Compare ATSR**
  - 1km spatial resolution
  - 0.1 K resolution
  - Cloud dependent
- **with TRIMM Microwave Imager (TMI)**
  - 0.5º spatial resolution
  - 0.25º spatial sampling
  - 0.5 K resolution
  - Independent of cloud

Data courtesy of G C Quartly, SOC-LSO

Meeting the GODAE requirements

- Accuracy – 0.1K (0.2K for climate)
    - Achievable (almost) with specialist polar-orbiting infra-red sensors (AATSR),
    - This requirement exceeds the expectation of standard SST IR sensors on meteorological satellites (polar and geostationary)
    - The new SEVIRI on MSG may approach this requirement
    - Microwave sensors not yet able to meet this
    - Which SST do we mean??
- Spatial resolution -10 km (2-5 km in coastal seas)
    - Achievable with polar-orbiting and Geostationary IR sensors
    - Microwave radiometers resolve to 50 km (sampling every 25km)
- Temporal resolution – 6hr – able to resolve (avoid aliasing) the diurnal cycle
    - Achievable only with geostationary platforms
    - Cloud is the major drawback for IR sensors
    - Microwaves unaffected by cloud

The GODAE High-Resolution SST Pilot Project (GHRSST-PP) : Conceptual basis



Polar orbiting satellites

Microwave sensors ($T_{sub-skin}$)

AMSR AMSR-E

TMI

AATSR

AVHRR

MODIS, GLI etc.

Infra-red Sensors (T_{skin})

In situ measurements

T_{skin} from SOO

T_{bulk} from Buoys, VOS

Dynamic distributed database approach

Access diverse level 2 satellite SST products.
Access ancillary data (wind, insolation etc.)
Apply quality estimates ➔ L2P products
Merge using OI methods ➔ L4 product
Use sets of in situ SST for validation.

MSG SEVIRI

GOES, Meteosat

Geostationary satellites

Near-real time, less accurate products

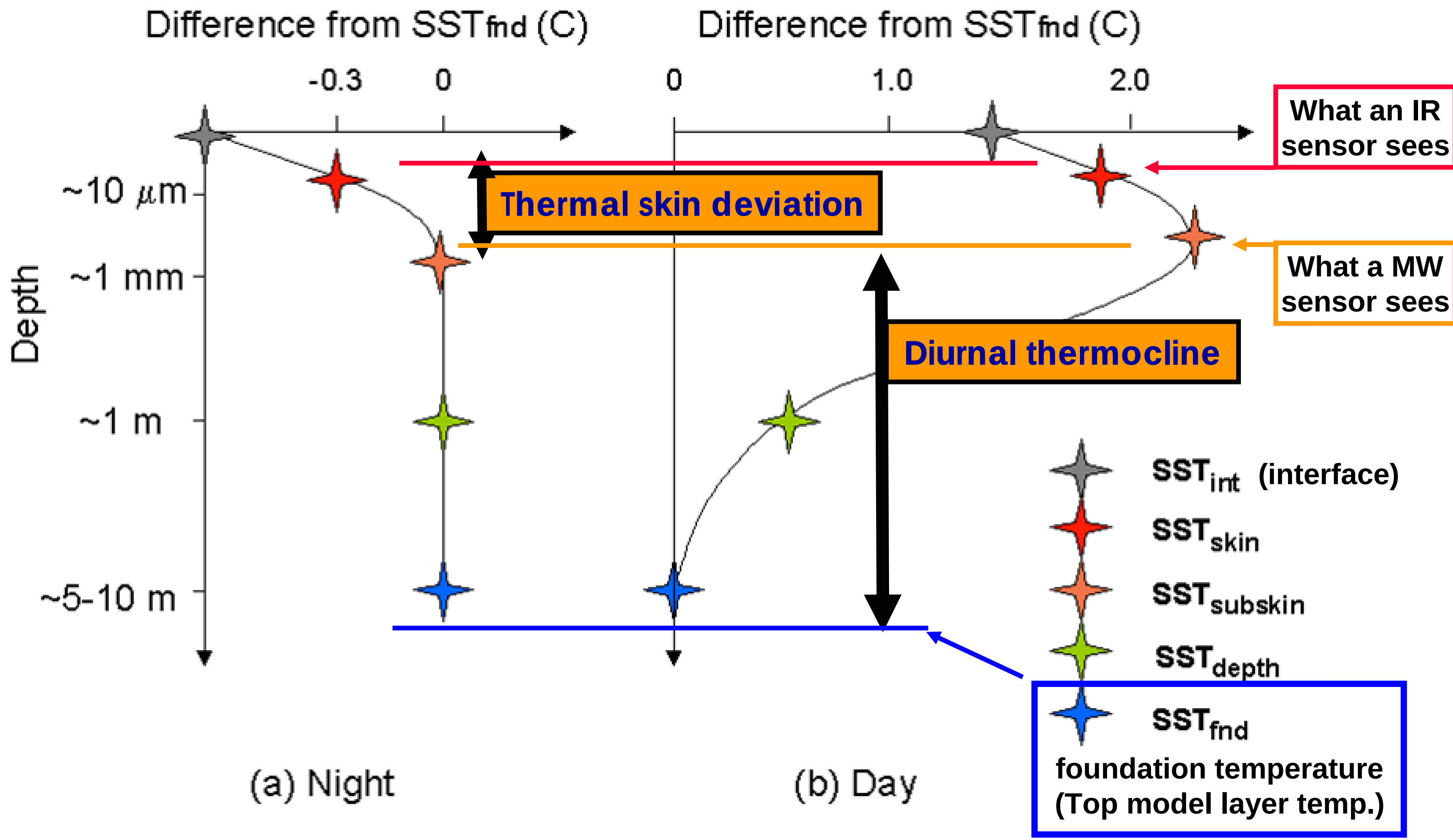
High accuracy, off-line products

Operational users

Oceanographic research users

Climate monitoring users

SST definitions within the GHRSST-PP



Thermal skin deviation

Diurnal thermocline

What an IR sensor sees

What a MW sensor sees

SST_{int} (interface)

SST_{skin}

$SST_{subskin}$

SST_{depth}

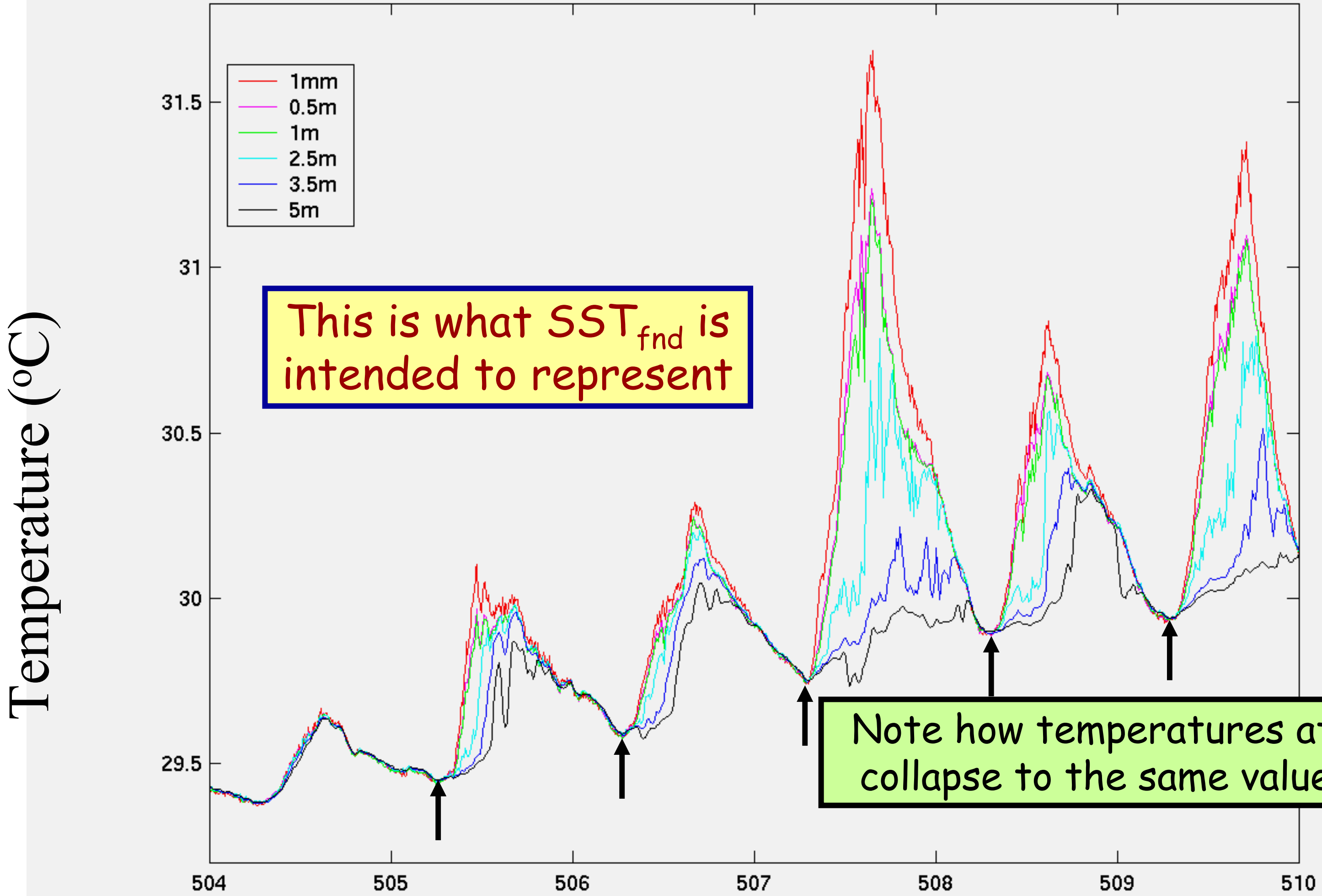
SST_{fnd}

foundation temperature (Top model layer temp.)

Outline of GHRSST analysis procedure

- L2P data consist only of satellite measurements
    - At the native resolution of each sensor’s SST product
    - skin SST (from infra-red radiometers) or
    - sub-skin SST (from microwave radiometers)
- For each L2P value, apply a diurnal warming (and skin-subskin) correction to estimate the corresponding SST_{fnd}
- L4 data generated by O-I using estimated SST_{fnd} as input
    - This has the variability characteristics of the upper mixed layer
    - Avoids undue influence of ephemeral near-surface thermal events
- SST_{fnd} has meaning only as a daily updated product
- Given SST_{fnd}, the skin and sub-skin SST can be estimated for any time of day
    - Apply parametric models for diurnal warming & skin-subskin

Thermal structure of top 5m (from sub-skin to 5m)



This is what SST_{fnd} is intended to represent

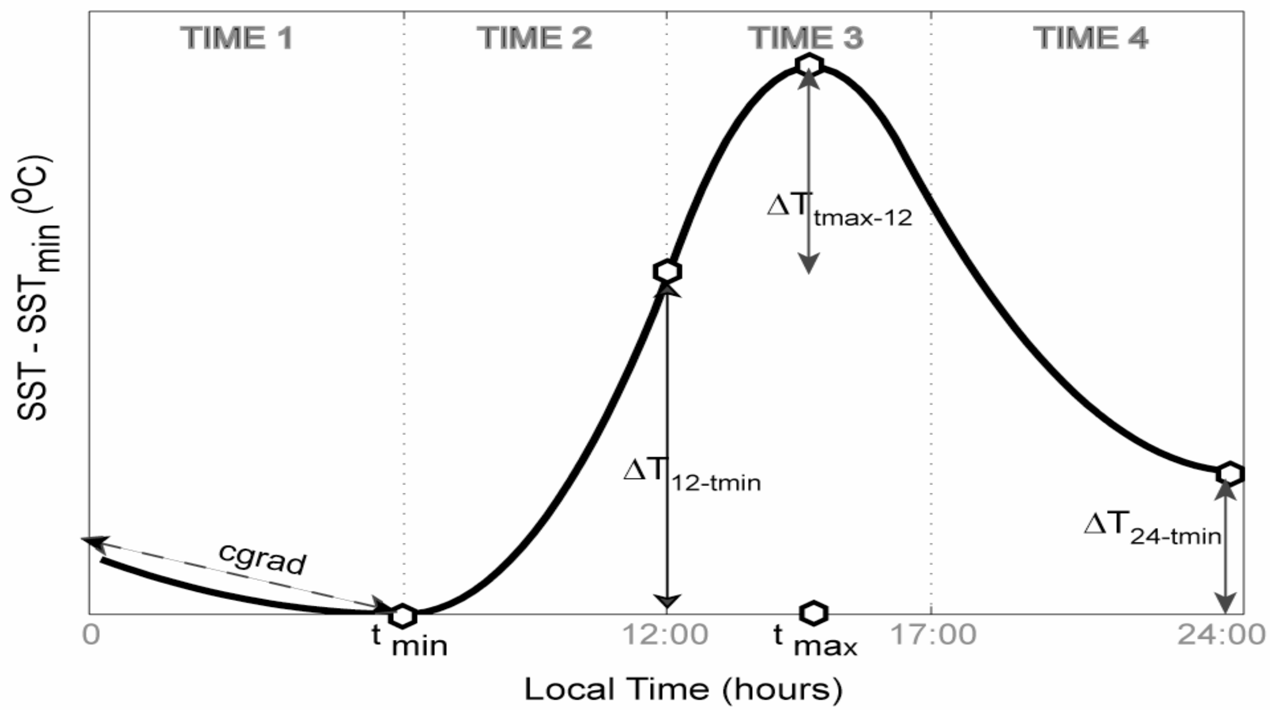
Note how temperatures at all depths collapse to the same value overnight

Arabian Sea WHOI Mooring Data - Spring 1995

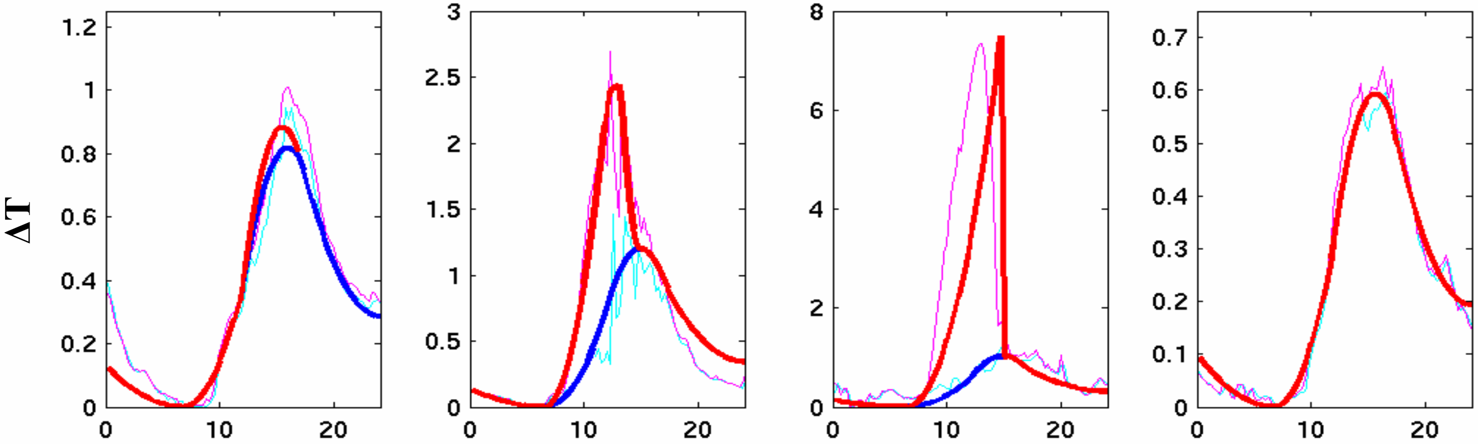
(1mm data estimated using *Fairall et al*. (1996))

(From the work of A. Stuart-Menteth)

New Diurnal Warming Parameterisation (*Stuart-Menteth et al.*)



Model	Required input
cgrad	U_{0-6h}
$\mathbf{t_{min}}$	U_{8-12h}, Q_{6-12h}
$\mathbf{\Delta T_{12-tmin}}$	U_{8-12h}, Q_{6-12h}
$\mathbf{t_{max}}$	U_{12-15h}, Q_{12-18h}
$\mathbf{\Delta T_{tmax-12}}$	U_{12-15h}, Q_{12-18h}
$\mathbf{\Delta T_{24-tmin}}$	U_{16-24h}, ΔT_{max}



Model v Obs.

1m (obs.)

Sub-skin (obs + Fairall)

1m (par. model)

Subskin (p.mod.)

The GHRSST-PP SST products: L2P

- Level 2 pre-processed
- Start with the basic SST level 2 products in sensor co-ordinates
- Add a quality flag and error statistics for each pixel
- Add ancillary data for quality reference (wind, insolation, ice etc)
- Time dependent error statistics from *in situ* match-up database
- Represents skin or sub-skin depending on sources
- Supplied in near real time for direct assimilation into op. models

The GHRSST-PP SST products: L4

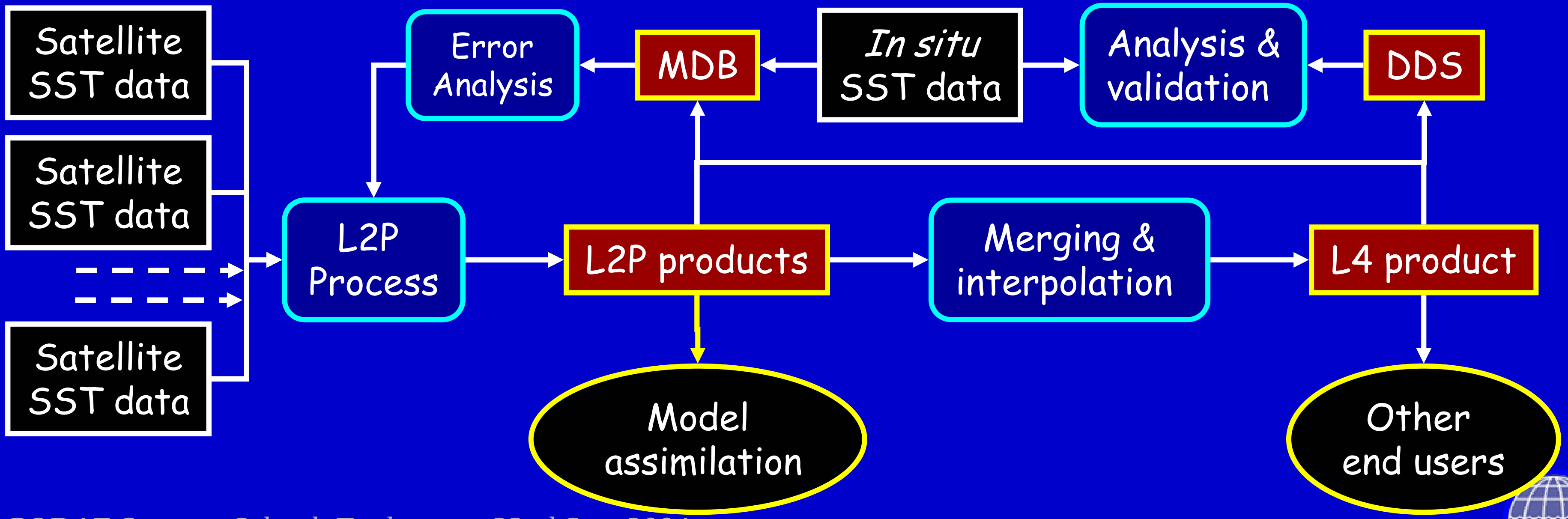
- Level 4
- Reduces all the available existing SST to SST$_{foundation}$ and merges them somehow to deliver a “best” product
- Use optimal interpolation (O-I) methods to blend data from sources of variable qualities and to fill sampling gaps
- Use different O-I criteria for different applications
  - Near-real time operational forecasts; or high accuracy climate record
- The L4 product represents a precisely defined form of “bulk” SST
- Includes estimate of the SST$_{skin}$ – SSTf$_{oundation}$ difference so skin SST can be retrieved

Preparing SST data for model assimilation
The GHRSST-PP approach

GHRSST-PP
GODAE High Resolution Sea Surface Temperature Pilot Project

- Uses all existing stable satellite SST data products
- Uses available in situ data
- Generates four types of output:

- L2P - The input SST data plus quality flags and error analysis
- L4 – Harmonises inputs, then merges by optimal interpolation
- MDB – Match-up database with in situ data
- DDS – Diagnostic data set



Satellite SST data

Satellite SST data

Satellite SST data

Error Analysis

MDB

In situ SST data

Analysis & validation

DDS

L2P Process

L2P products

Merging & interpolation

L4 product

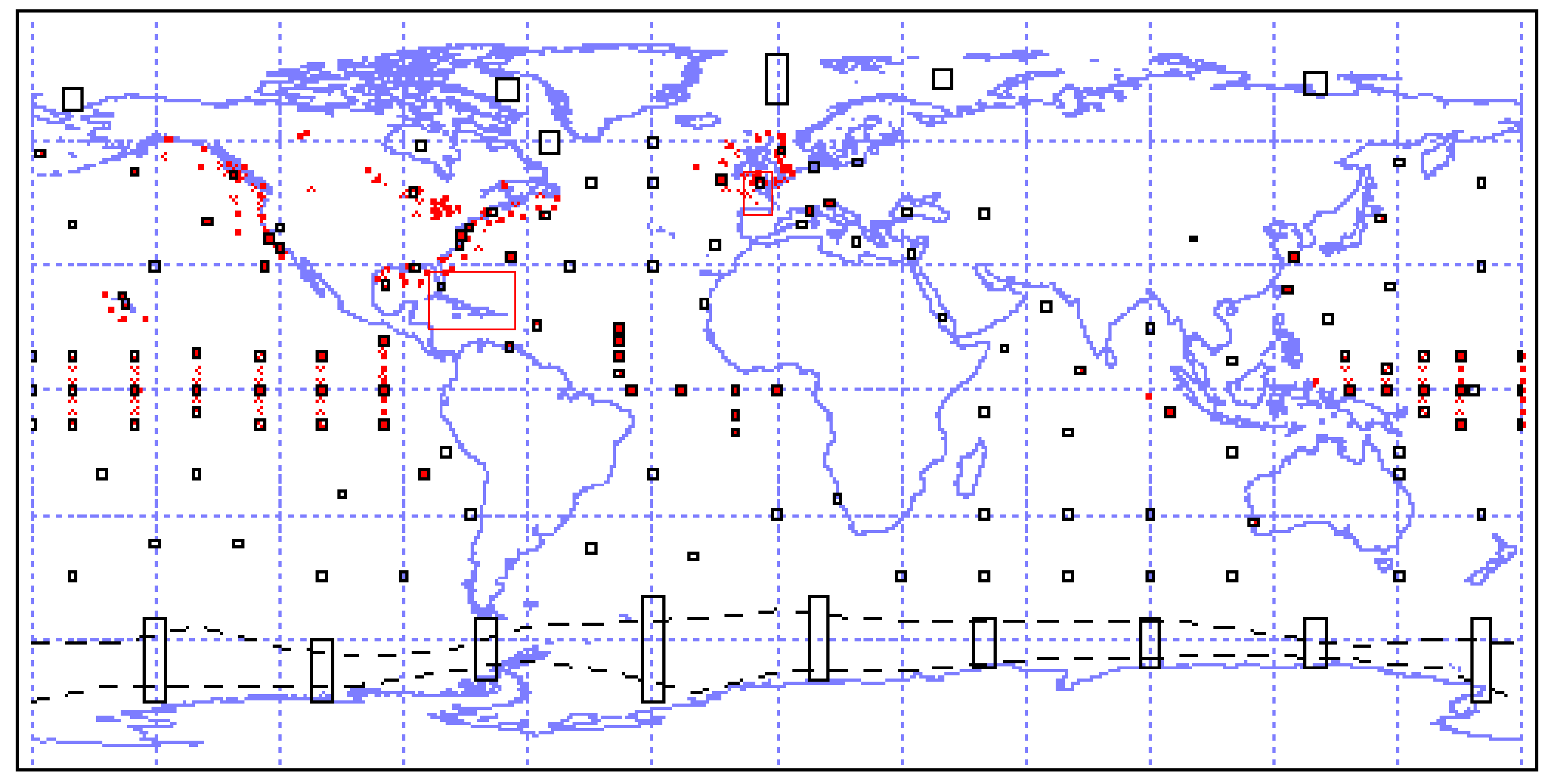
Model assimilation

Other end users

Maintaining the quality of SST products

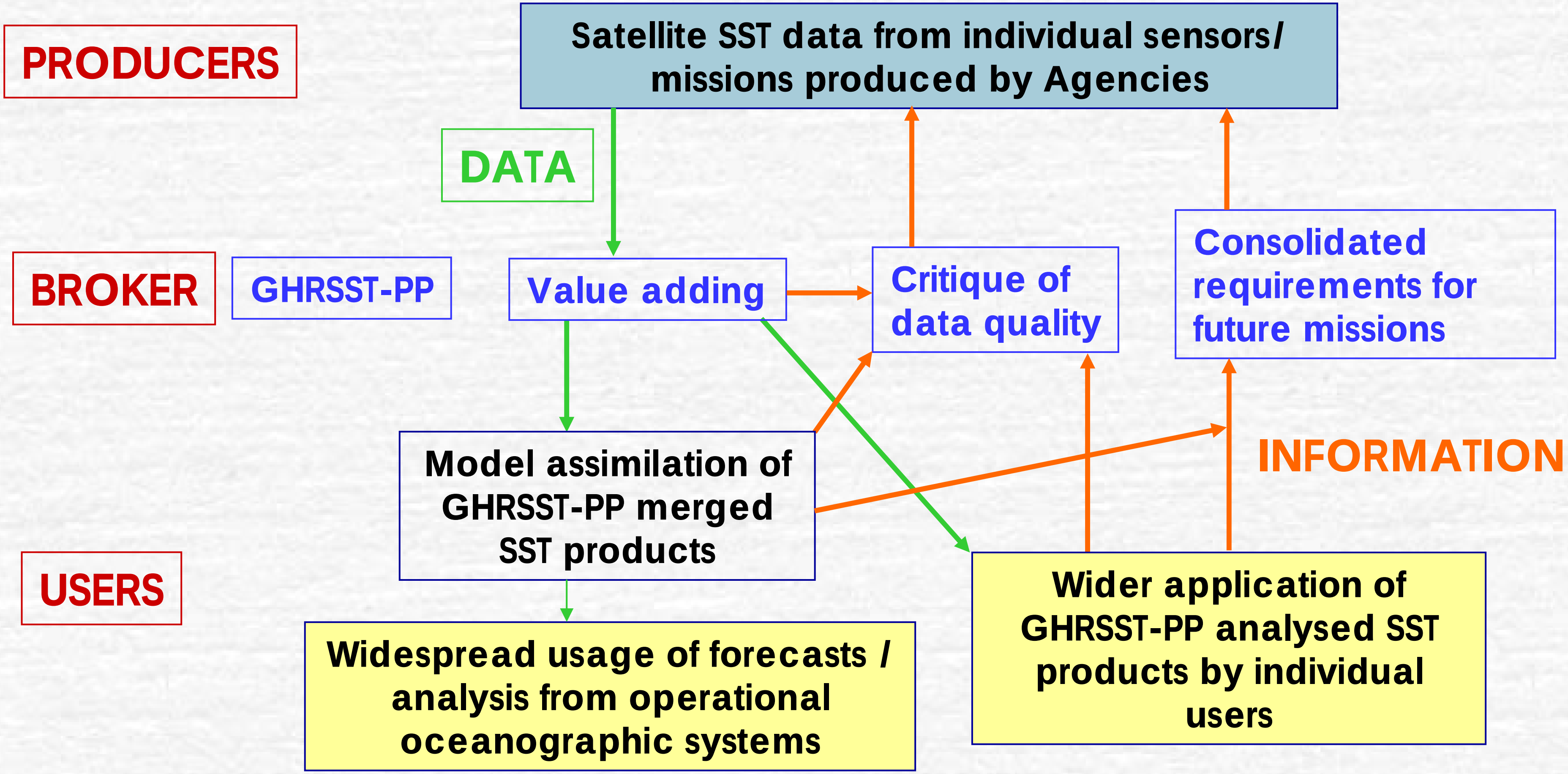
- Quality flagging of L2P products is the key
  - Depends on things such as proximity to cloud (IR) or proximity to land or rain (MW), and on the probability of diurnal warming
- Absolute accuracy is based on the match-up database (MDB) with in situ data
  - Different error statistics (bias and standard deviation) are derived from the MDB for different quality flags
  - Thus error statistics can be assigned to new data coming into the system once their quality flag has been determined
- Inter sensor biases detected using the Diagnostic data set (DDS)
- The primary challenge is to deliver a SST product whose accuracy is known

HR-DDS - locations v2.3



- Based on output of the 2nd, 3rd & 4th GHRSST-PP Science Team workshop feedback. Fully documented in the HR-DDS Implementation Plan (GHRSST/14)

A view of the role of the GHRSST -PP



PRODUCERS

Satellite SST data from individual sensors/ missions produced by Agencies

DATA

BROKER

GHRSST-PP

Value adding

Critique of data quality

Consolidated requirements for future missions

INFORMATION

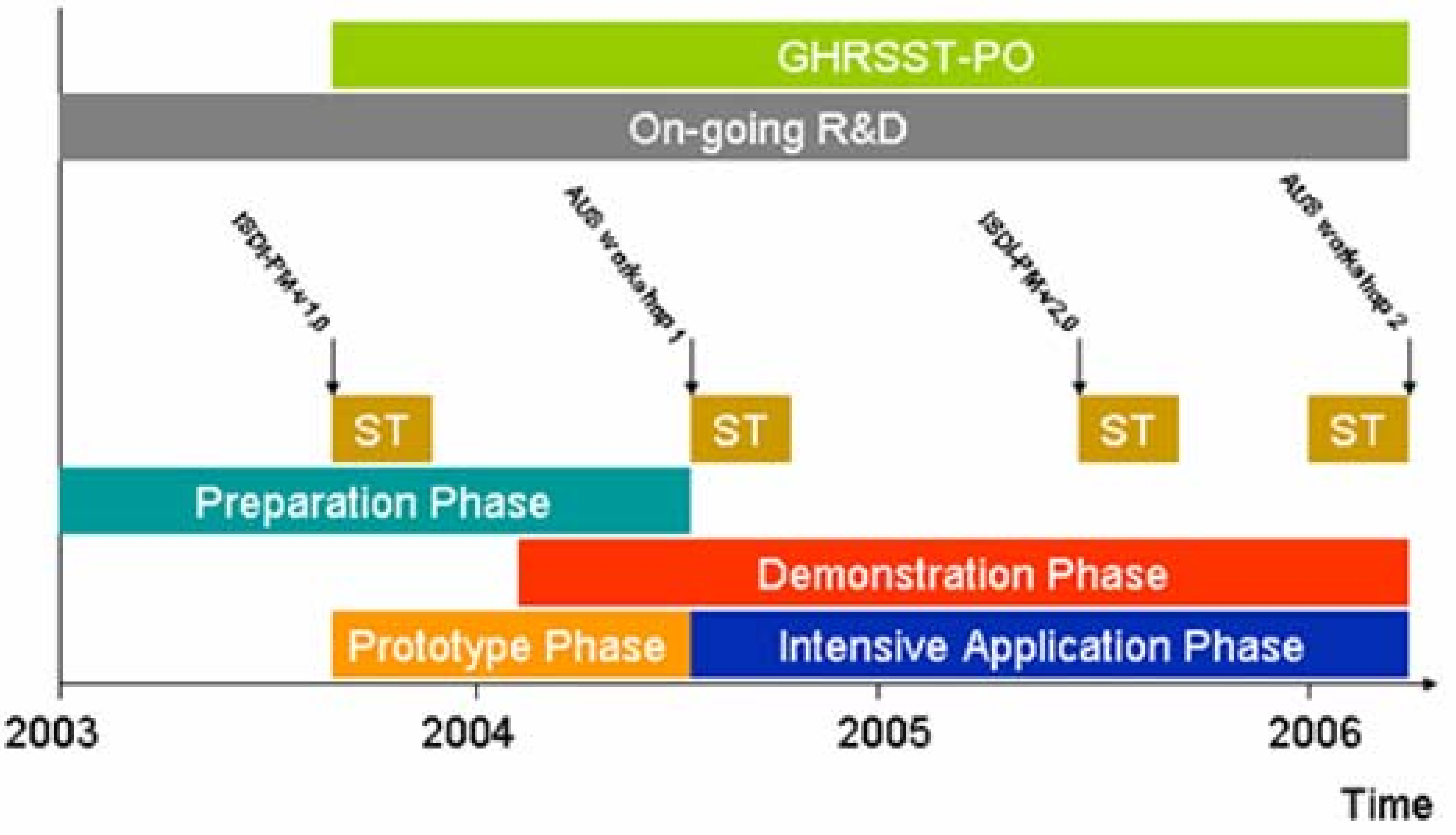
Model assimilation of GHRSST-PP merged SST products

USERS

Widespread usage of forecasts / analysis from operational oceanographic systems

Wider application of GHRSST-PP analysed SST products by individual users

GHRSST-PP Implementation Schedule



Medspiration

- An ESA Contract for €1M to serve as the European Regional Data Assembly Centre for GHRSST-PP.
- A European consortium led by SOC-LSO
  - Ifremer (Fr)
  - Meteo-France
  - CLS (Fr)
  - CNR (I)
  - Met.no (N)
  - Vega (UK)
- Most operational data processing performed in France
- SOC will host the Diagnostic Data Set (DDS)
  - Provides a valuable scientific analysis resource tool

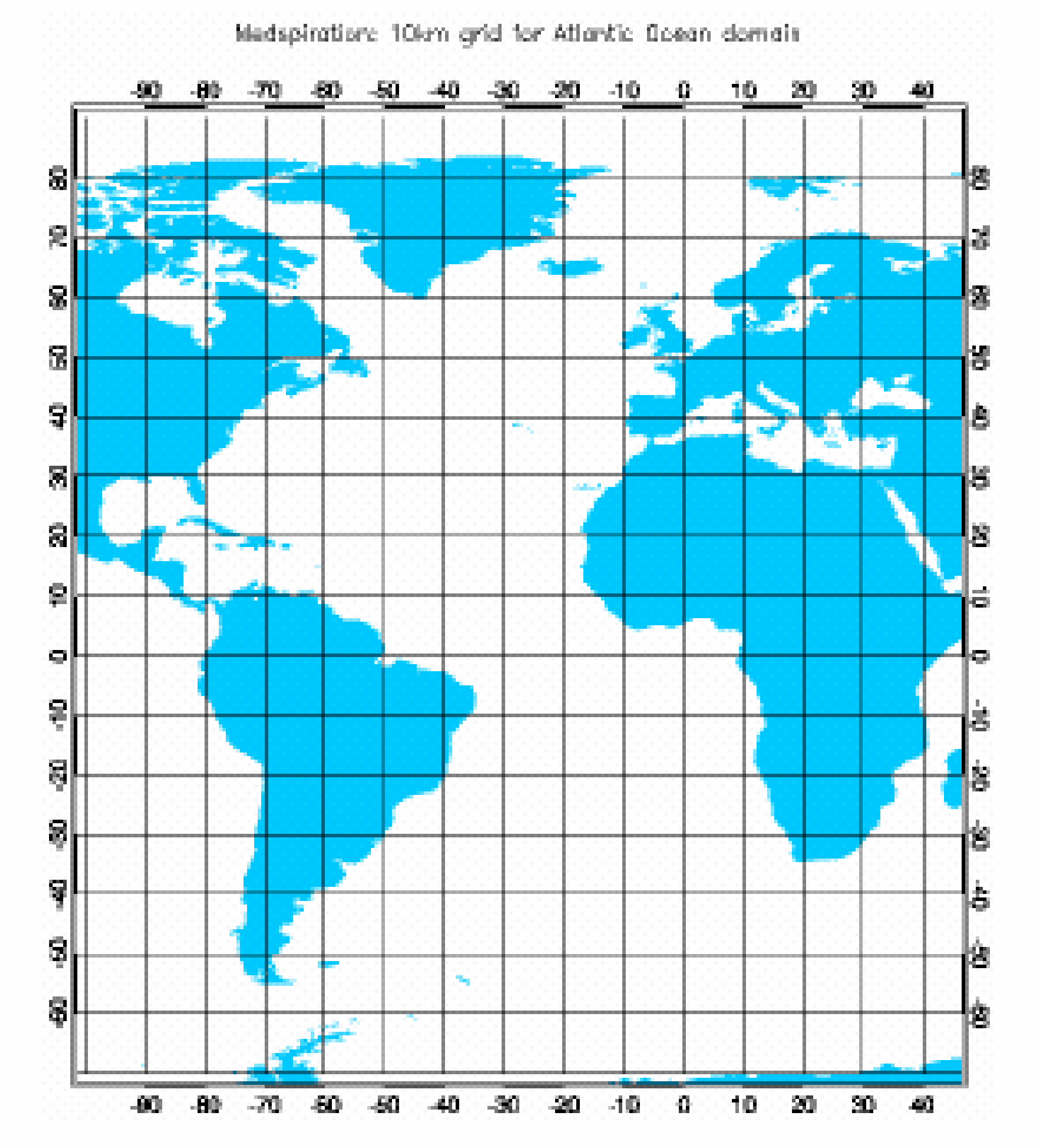
Medspiration Atlantic coverage

10 km grid

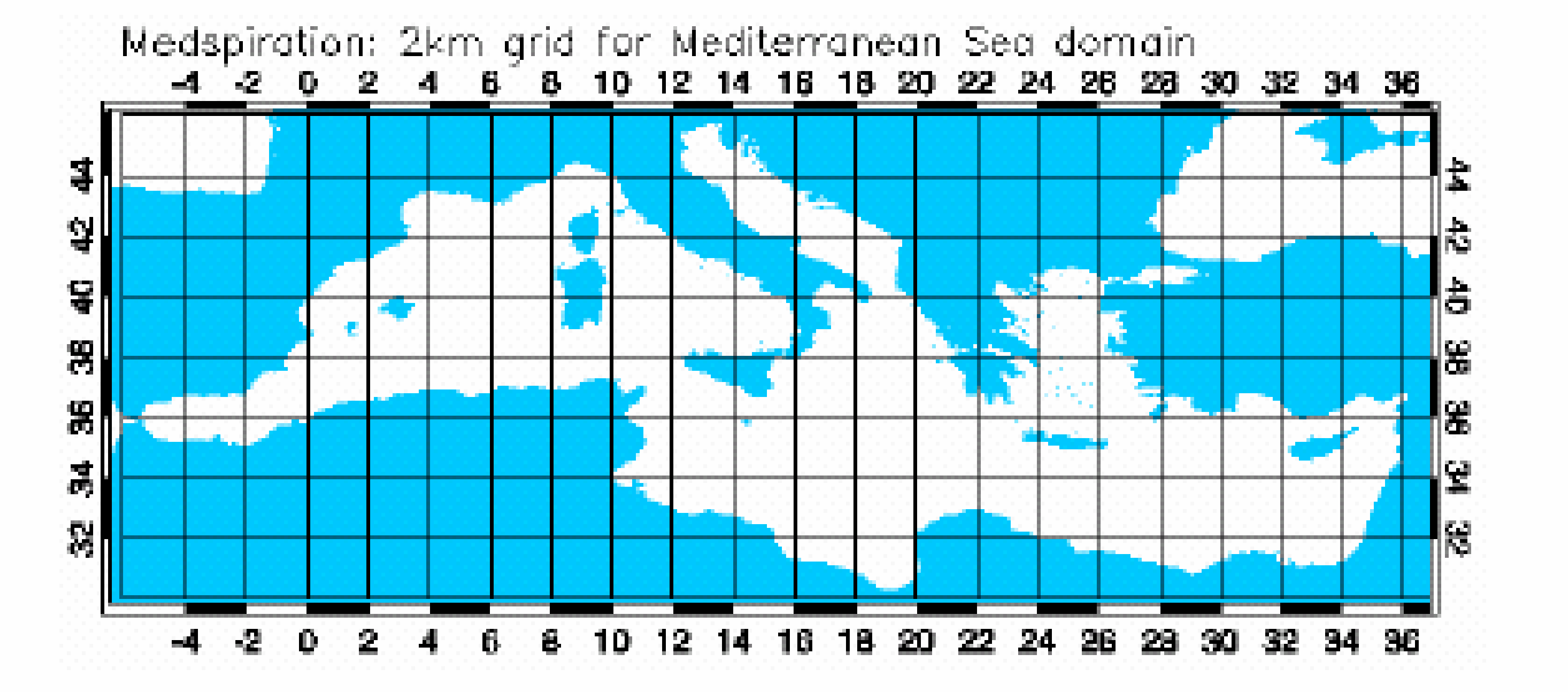
L2P, DDS and MDB

70°S to 90°N (to the ice limit)

100°W to 45°E (to include the adjacent seas but excluding any part of Pacific Ocean)



Mediterranean coverage



Ultra-high resolution (UHR) 2 km grid

All products including L4 analysed field

Current Status

- Medspiration has started 1st Jan 2004
- Qualification Review Nov 2004
- First operational demonstration March 2005
- Potential users welcomed into partnership
  - Assimilation into operational models
    - For example Mercator, FOAM, MFS etc.
  - New SST datasets for climate monitoring
- International developments in GHRSST-PP
  - Japan already has its RDAC operating
  - USA also spinning up a new RDAC activity
- Time to start interacting with modellers who can benefit from assimilating the new SST products

Medspiration Products

- GHRSST-PP L2P data products
  - Over the Atlantic Ocean
- SST_{fnd} UHR data (L4) for Mediterranean
  - Includes the analysed SST
- GHRSST diagnostic data set (HR-DDS) granules
  - Over the N Atlantic coverage area
- GHRSST match up database records (MDR)
  - Over the N Atlantic coverage area

What do modellers want to assimilate?

- L2P provides basic SST products from each individual source
  - Skin or subskin depending on sensor type
  - In native format
  - Delivered In near-real time
  - Adjustment needed to match to the model top layer temperature
- L4 analysed SST product
  - A best “merging” of all the different sources
  - At least 1 day delay
  - Additional errors from analysis
- Which is preferred?