Oceanography from Space

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National Oceanography Centre

NATURAL ENVIRONMENT RESEARCH COUNCIL

*With invaluable help (and lots of material) from **Prof. Ian S. Robinson**, Univ. Southampton*

whose "Measuring the Oceans from Space" (2004) by Springer-Praxis is an excellent reference textbook.

A slightly expanded title….

Oceanography

Study of
a component of the Earth System which is vital to mankind and crucial for climate…

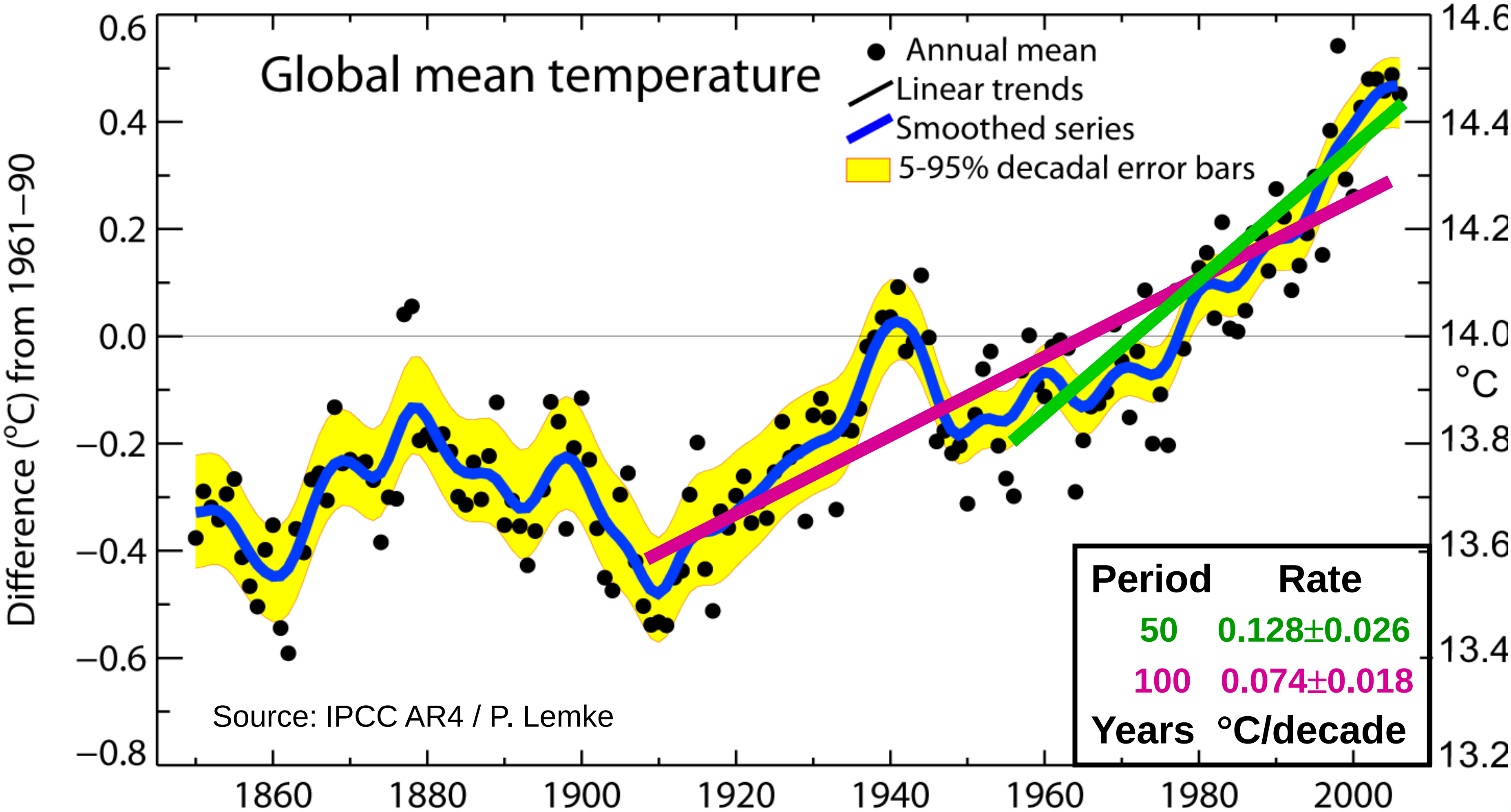
from space

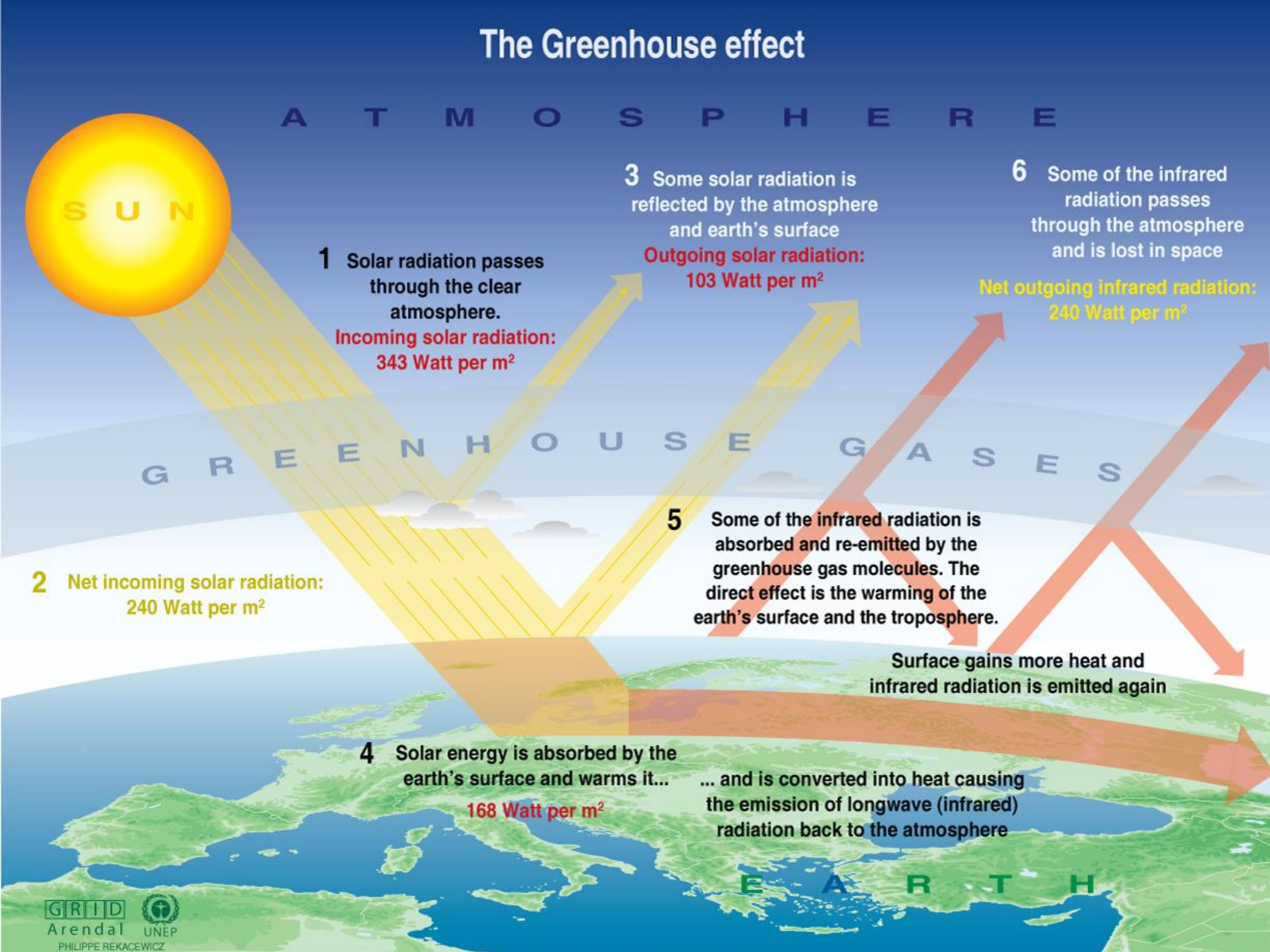
…from a **very privileged viewpoint !!**

Why study the ocean?

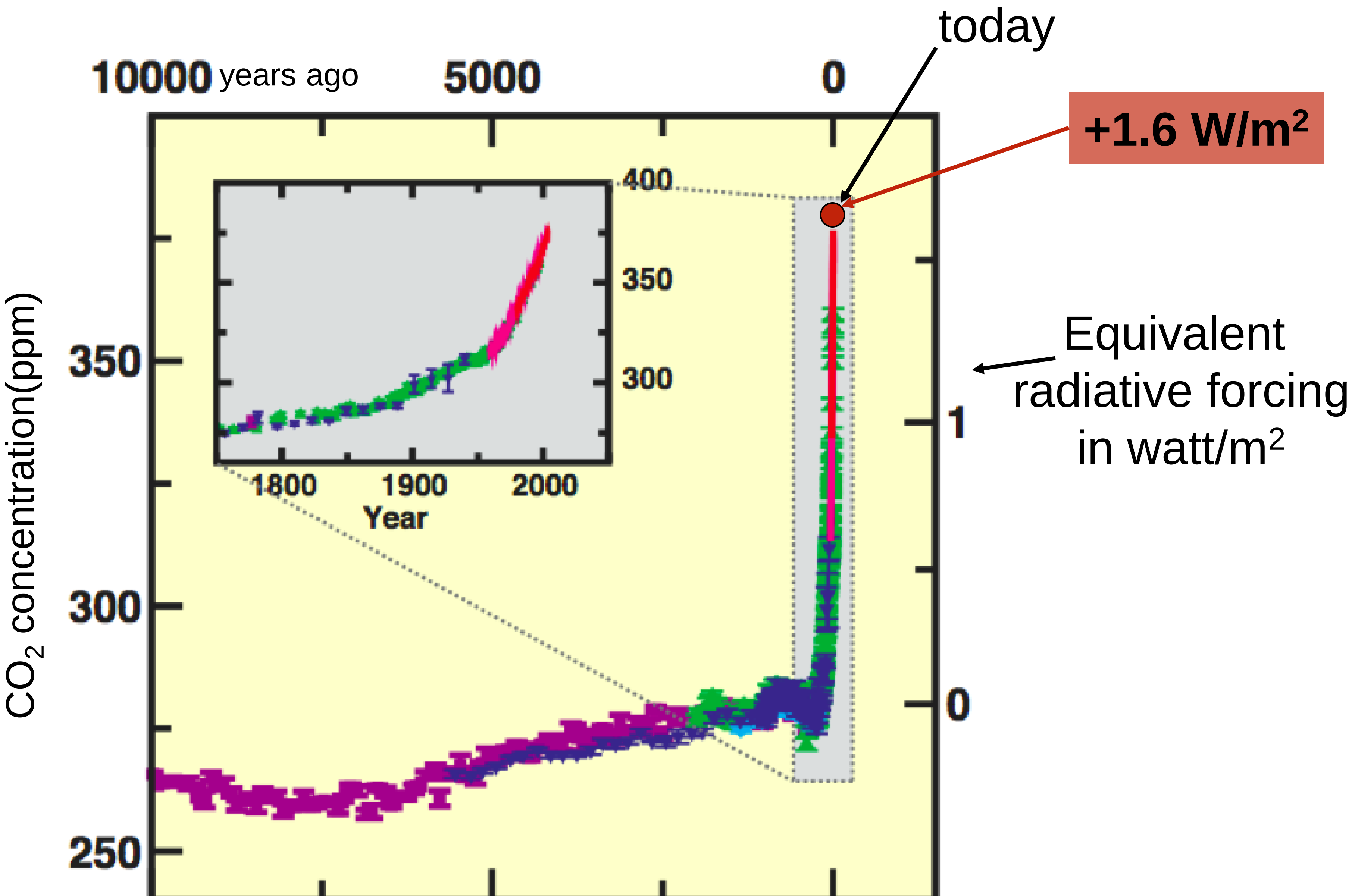
- **LOCAL** drivers: fisheries, shipping, transportation, coastal erosion, leisure…
- **GLOBAL** drivers: climate and climate change

Climate change – global warming



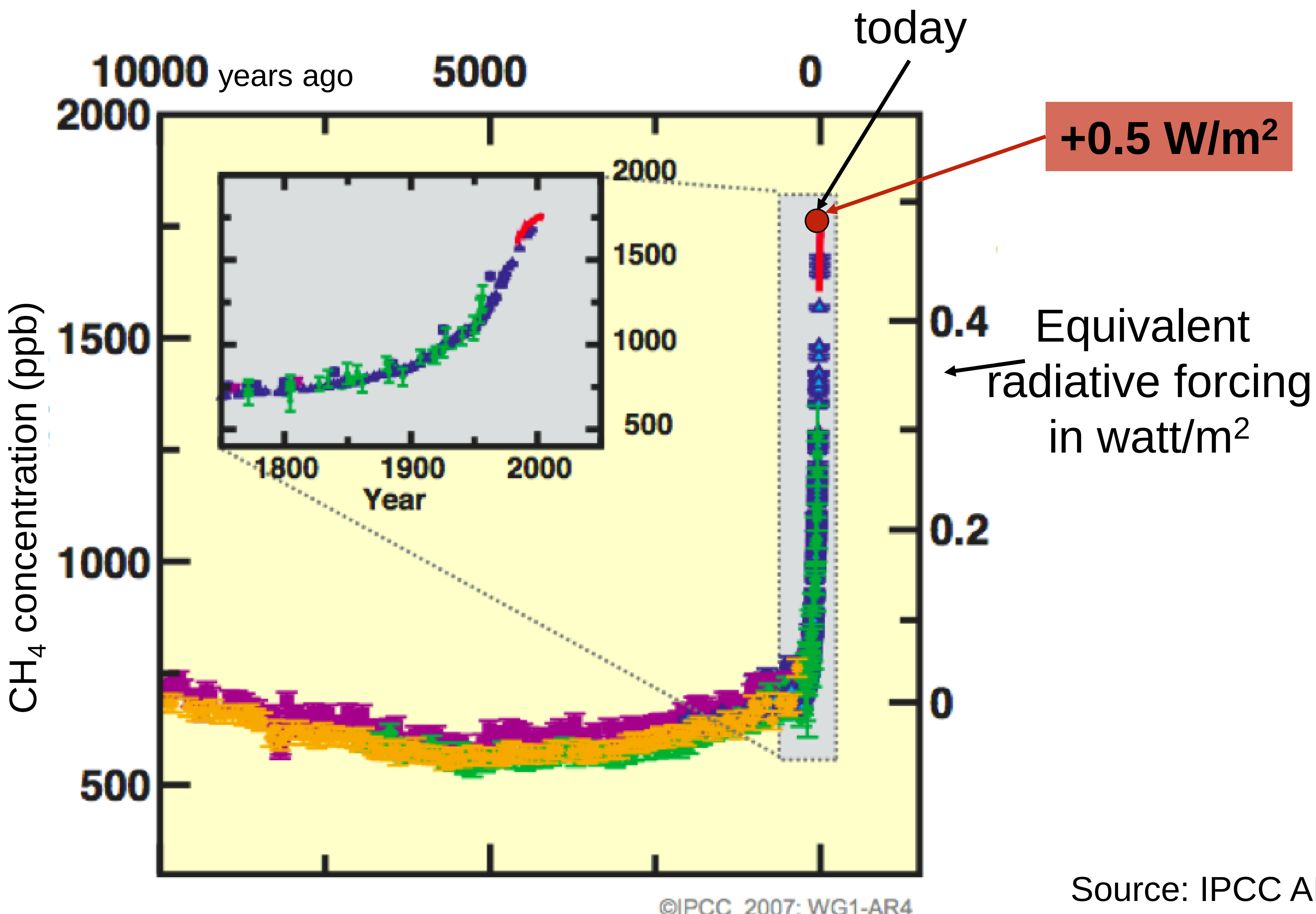

The Greenhouse effect
ATMOSPHERE
SUN
1 Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m2
2 Net incoming solar radiation: 240 Watt per m2
3 Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m2
6 Some of the infrared radiation passes through the atmosphere and is lost in space
Net outgoing infrared radiation: 240 Watt per m2
GREENHOUSE GASES
5 Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.
Surface gains more heat and infrared radiation is emitted again
4 Solar energy is absorbed by the earth's surface and warms it...
168 Watt per m2
... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
EARTH
GRID Arendal
UNEP
PHILIPPE REKACEWICZ

10000 years of CO_2 concentration



Source: IPCC AR4

10000 years of methane concentration



Source: IPCC AR4

CO_2 + methane → ~2 W/m^2 in excess

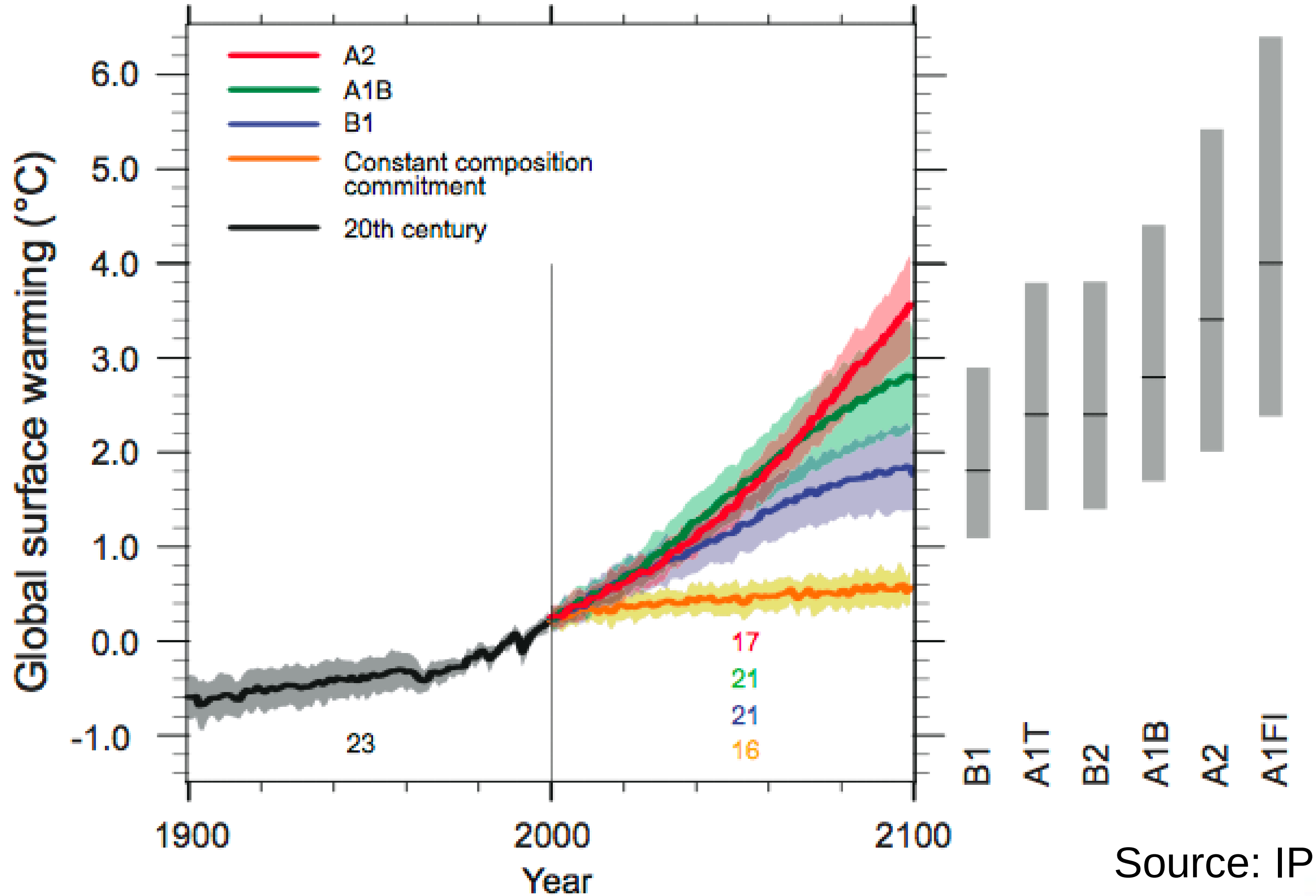
Average over entire globe and all seasons, i.e.

How much is it, in practice?

1 Electric heater = 1500 Watt


1 football pitch =
7500 sq. meters
= 15000 Watt

Climate change – the projections



Source: IPCC AR4

Some of the key questions

- Climate change is here upon us, mainly as an effect of GHG emissions resulting in excess radiative forcing
- … but the oceans are the **main heat storage** on Earth…
  - Top 3 m contain same heat as whole atmosphere…

  …and oceans' mean depth > 3000m
- How do they **affect climate change** (mitigate? Make worse?)
- How are they **changing** as an effect? Can we predict the future trends?
- How do these changes **impact on marine life**?
- How do these changes **impact on society**?

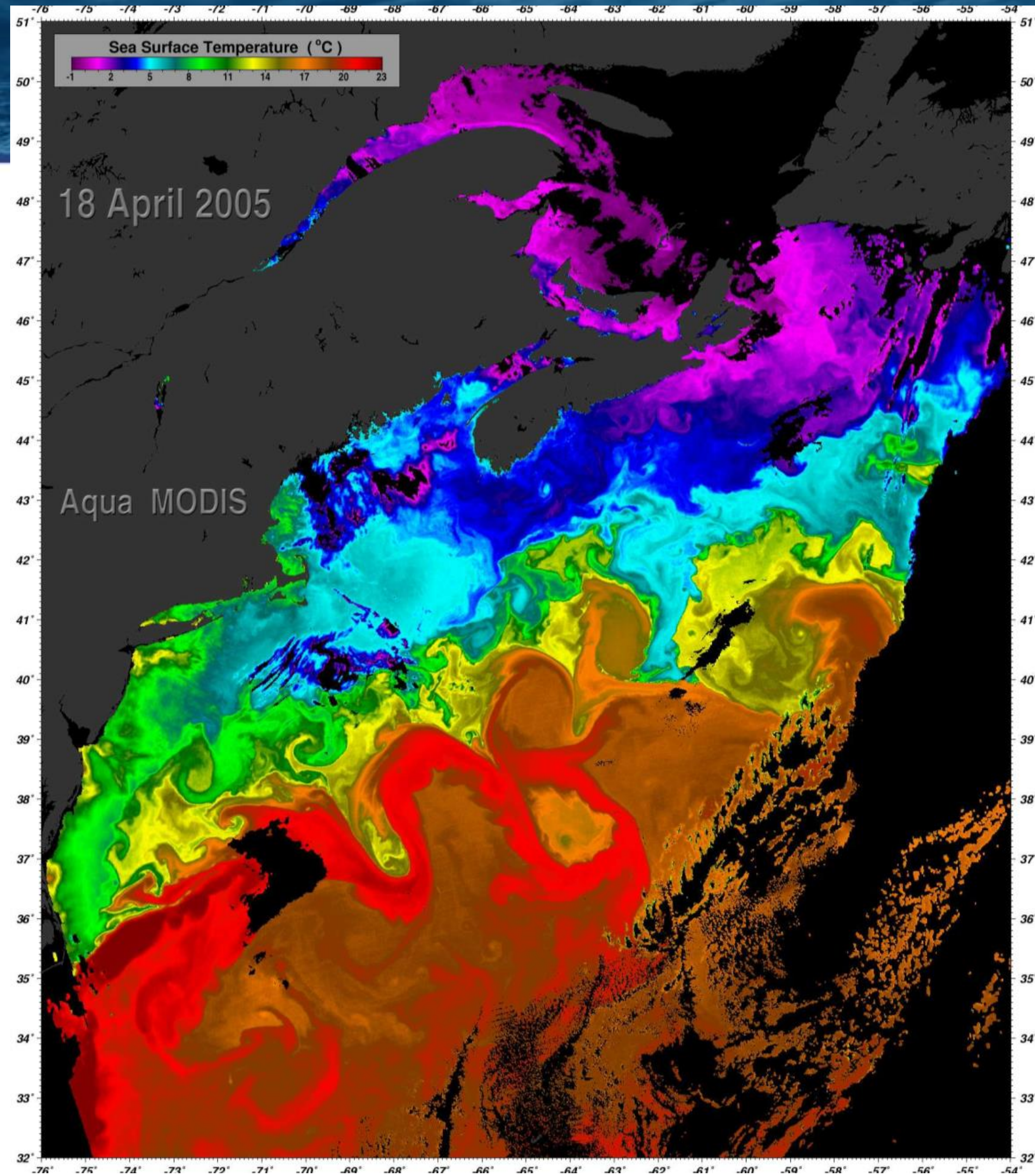
We need a **global, privileged viewpoint** to provide the observations needed to answer these global questions

Ocean remote sensing: a privileged view

- Spatially detailed
  - Spatial resolution from meters to kms
  - A synoptic picture that is 100 km - 10 000 km wide
- Regularly repeated
  - Revisit intervals between 30 min. and 35 days
  - Continuously repeated over years to decades
- Global coverage
  - Satellites see the parts where ships rarely go
  - Single-sensor consistency - no inter-calibration uncertainties
- Measures parameters that cannot be observed in situ
  - Surface roughness at short length scales (2-50 cm)
  - Surface slope (a few cm over 100s of kilometres)

Spatially detailed overview of mesoscale ocean processes

North Atlantic Sea Surface temperature showing the Gulf Stream meandering



A spatially detailed view of ocean colour

An image of Florida and Cuba captured by the MERIS sensor on ESA Envisat

The light green areas are shallow reef areas

A spatially detailed view of turbidity in coastal seas

2 February 2007
This Envisat image shows Bohai Bay in the People's Republic of China.

False colour composite from full resolution MERIS data
(Pixel size 300m)

ESA image

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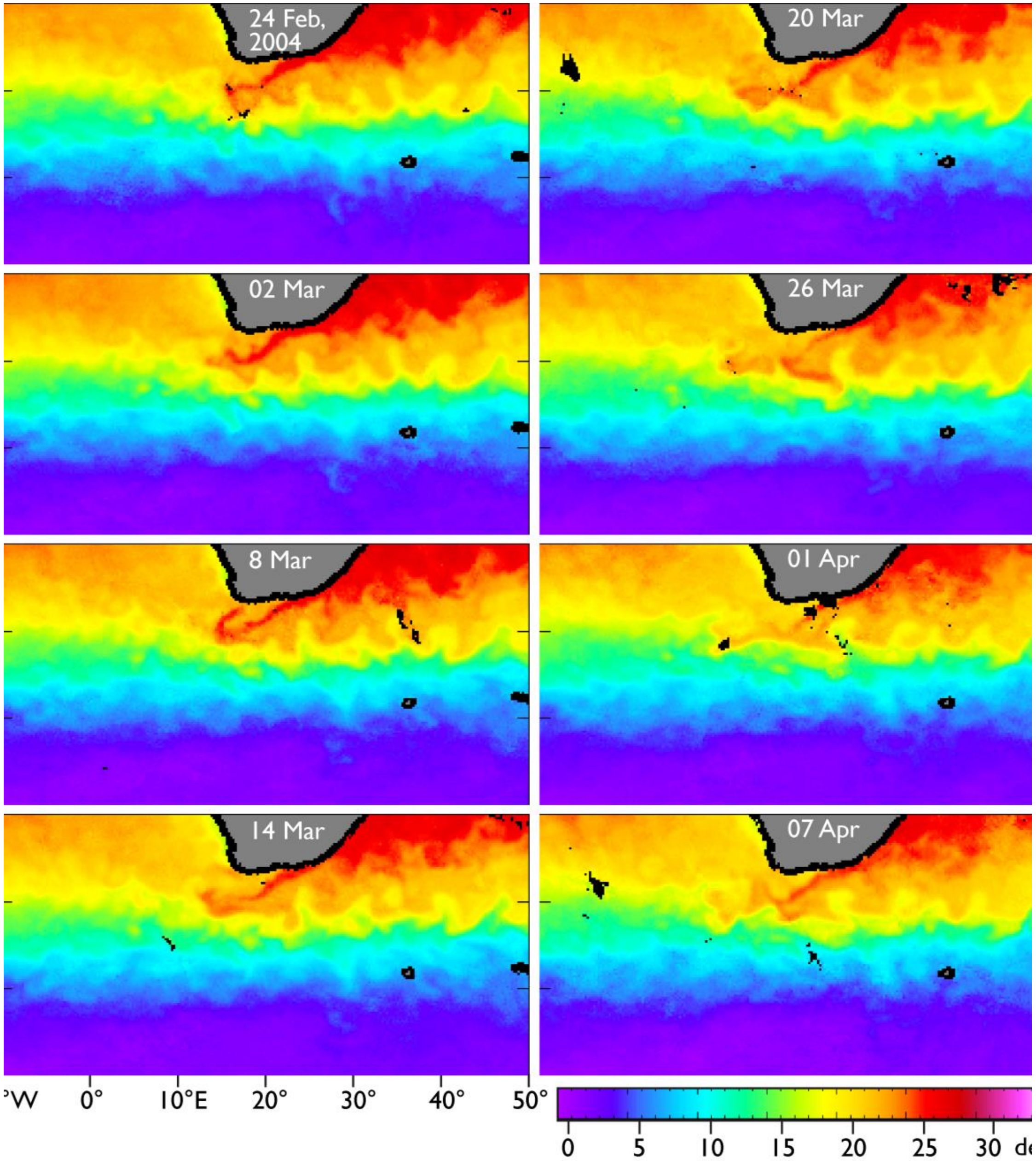
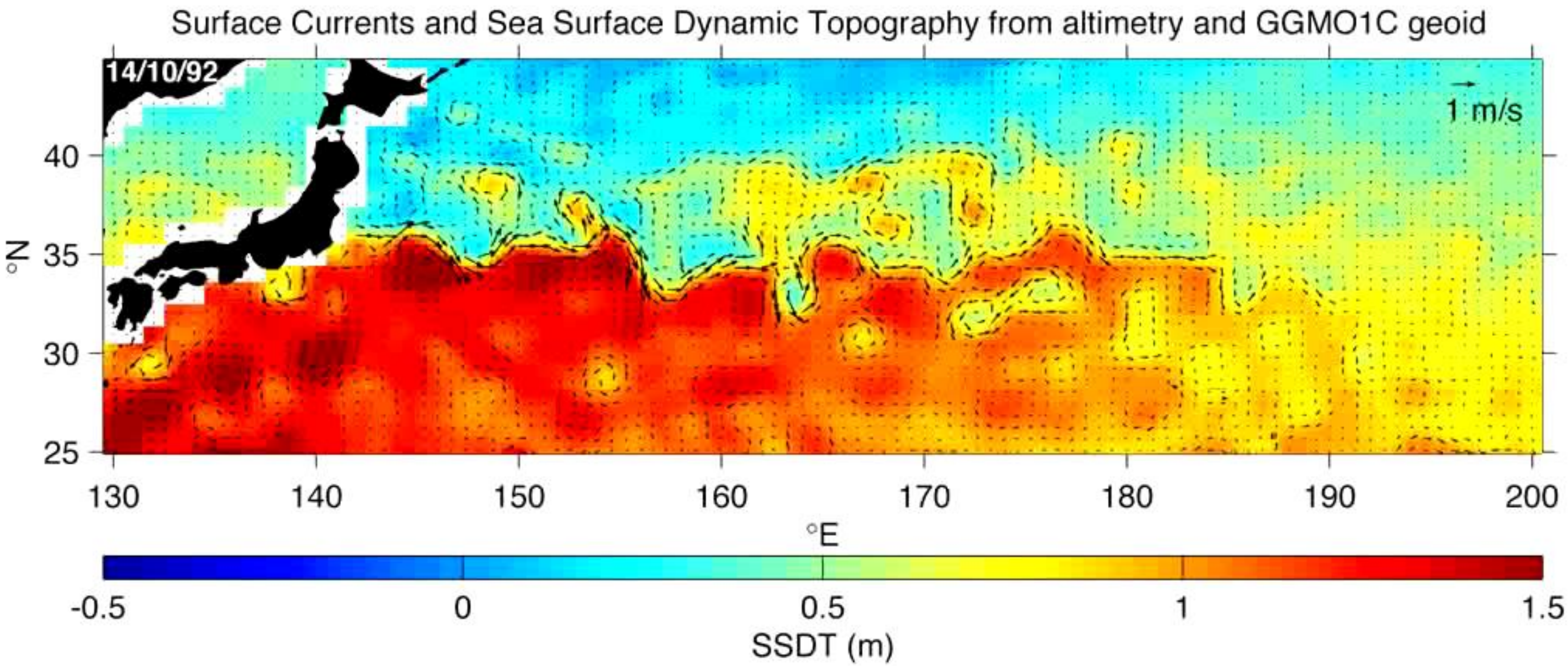
Regularly repeated views of the Agulhas retroflection

SST from the AMSR-E Microwave radiometer plotted at 6-day intervals

This is a “choke-point” for the surface flow of warm water from the Indian to the Atlantic ocean



Kuroshio current from Altimetry: a movie



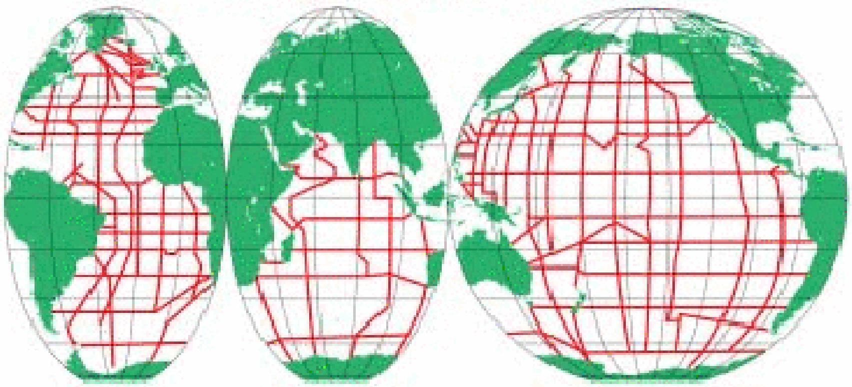
1 full map every 7 days, from a combination of all available satellite altimeters

Movie by Doug McNeall, NOC (now UK MetOffice)

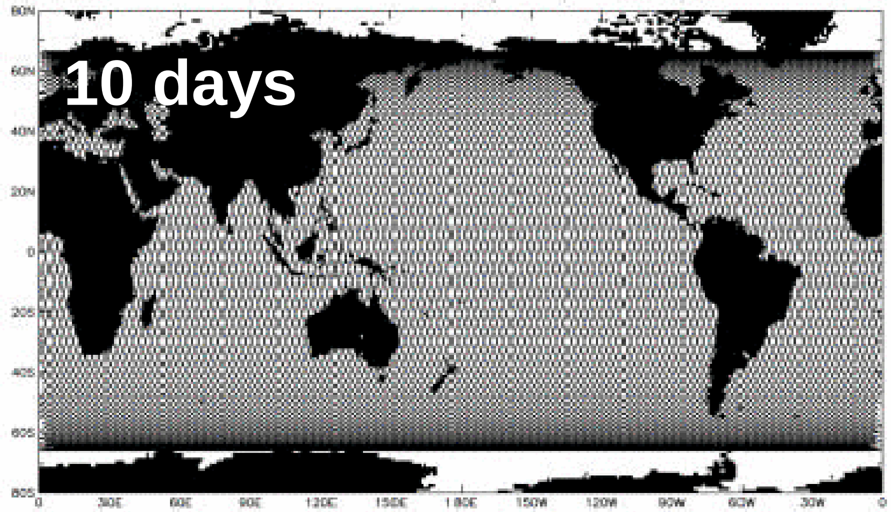
A quantum leap in sampling!

10 years

WOCE Hydrographic Survey Lines

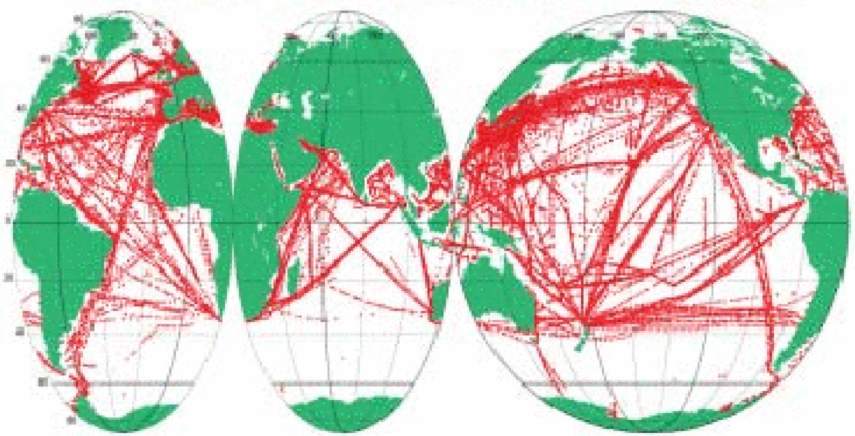


TOPEX/POSEIDON 10-Day Repeat Ground Track

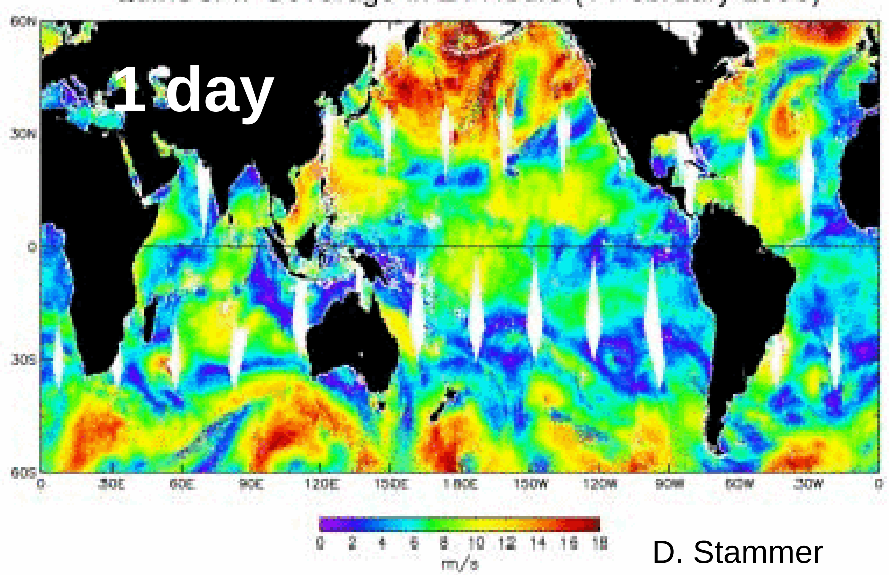


10 years

Observations from Volunteer Observing Ships



QuikSCAT Coverage in 24 Hours (1 February 2000)



D. Stammer

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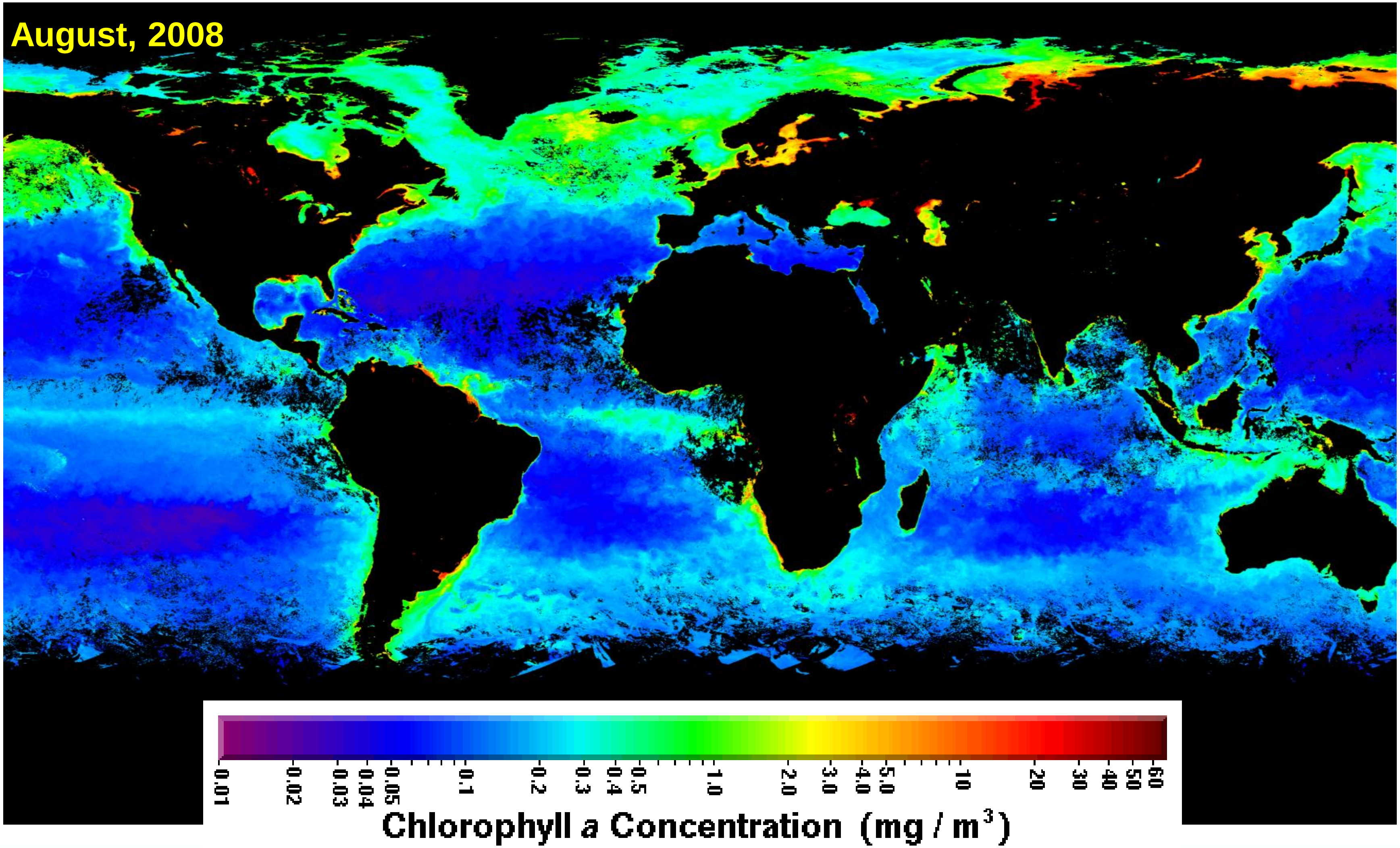
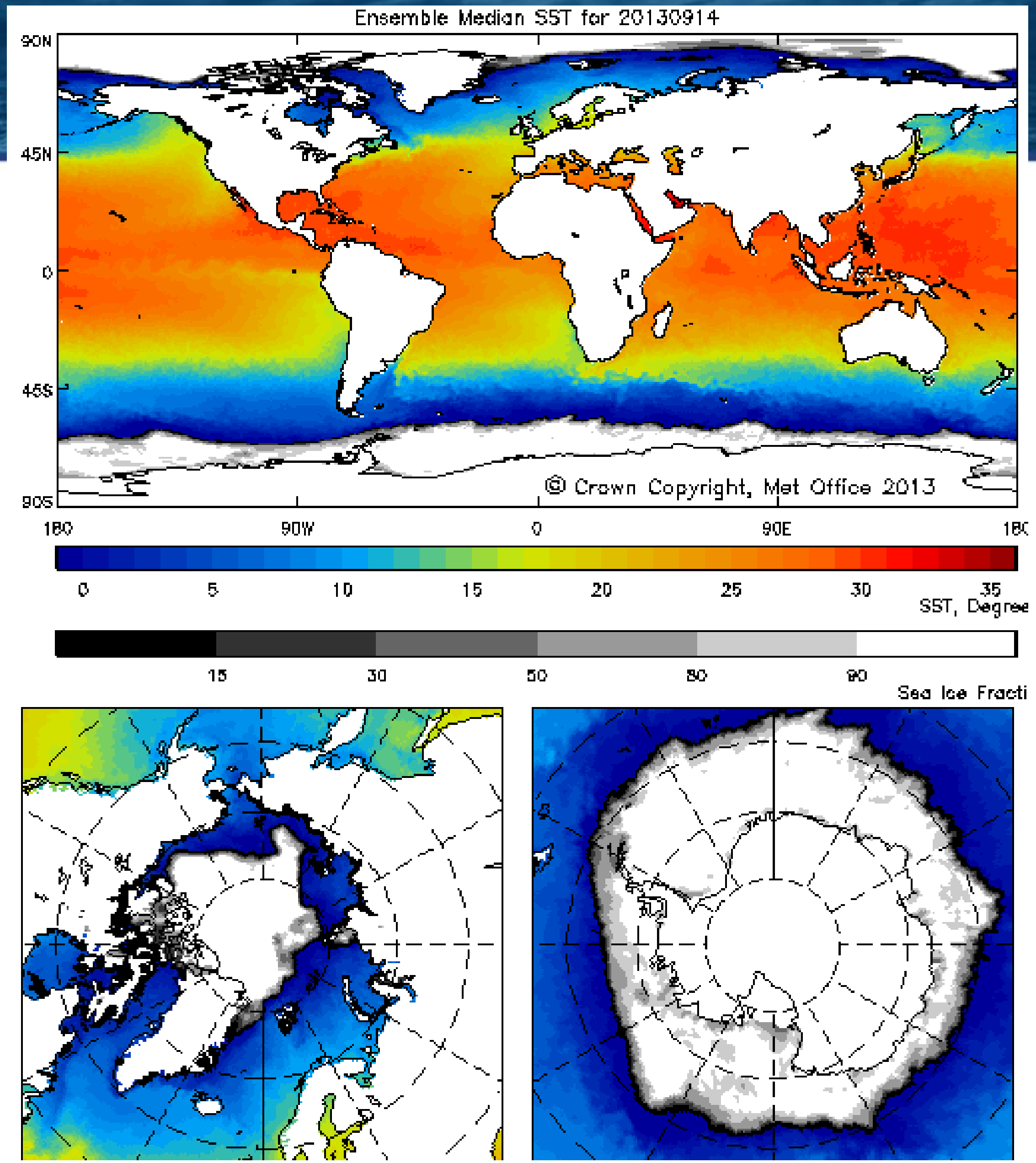
Global measurements for global science

The distribution of ocean chlorophyll measured from MODIS



Global sea surface temperature

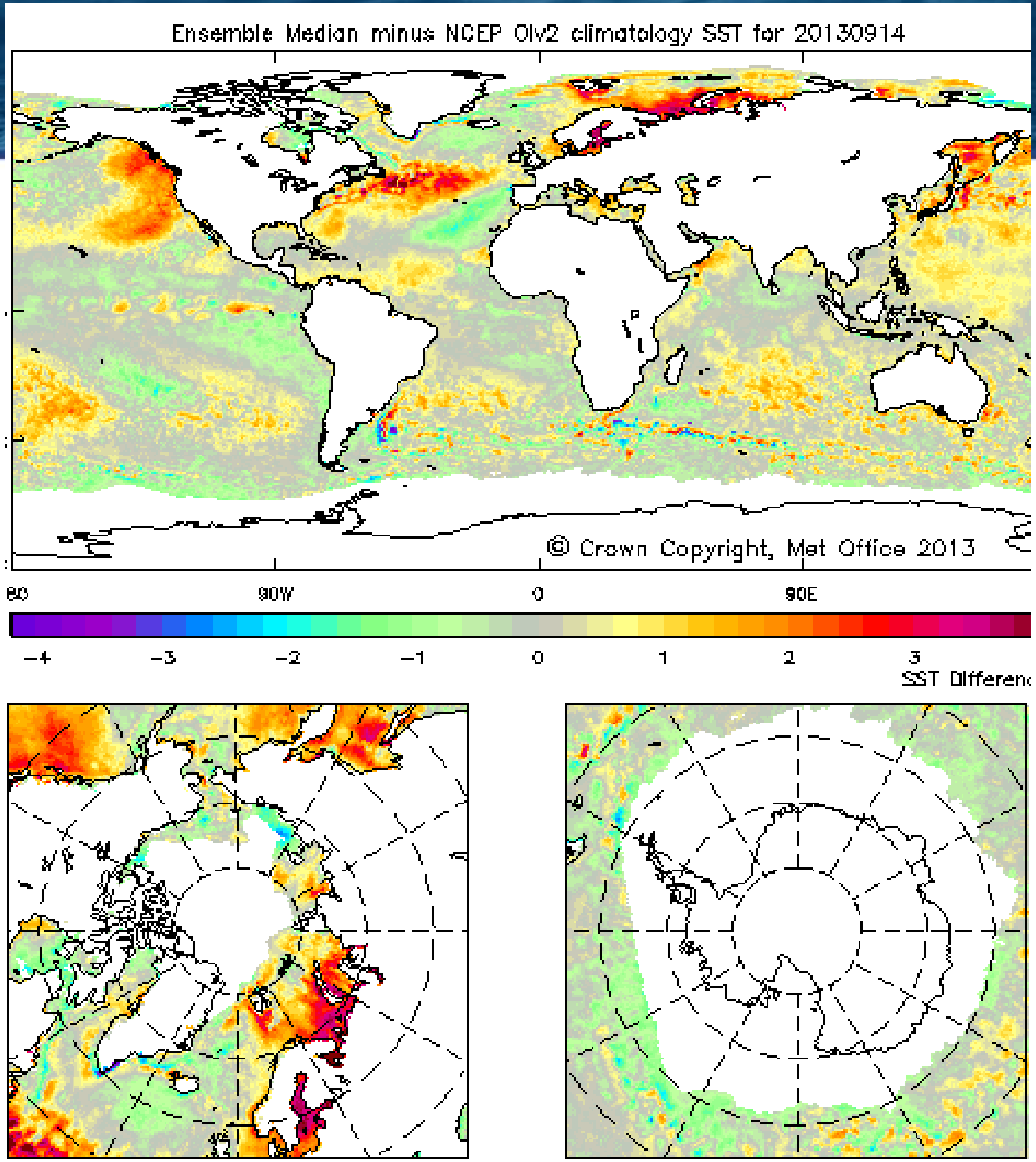
Ensemble of SST analyses derived from satellite data from several sensors,
for 14 Sept 2013



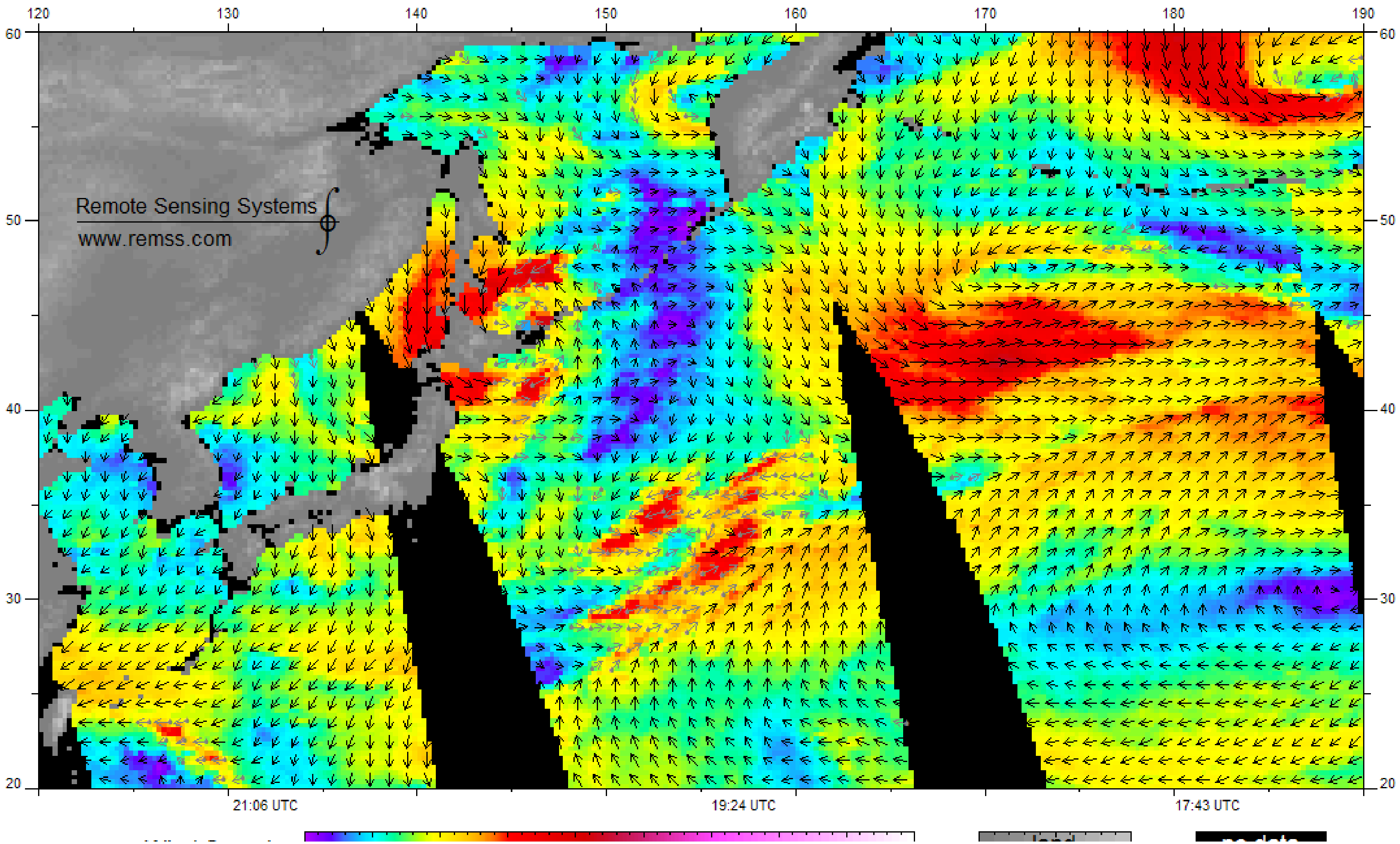
Source: http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html

SST anomaly compared to Climatology

Anomalies for 14 Sept 2013

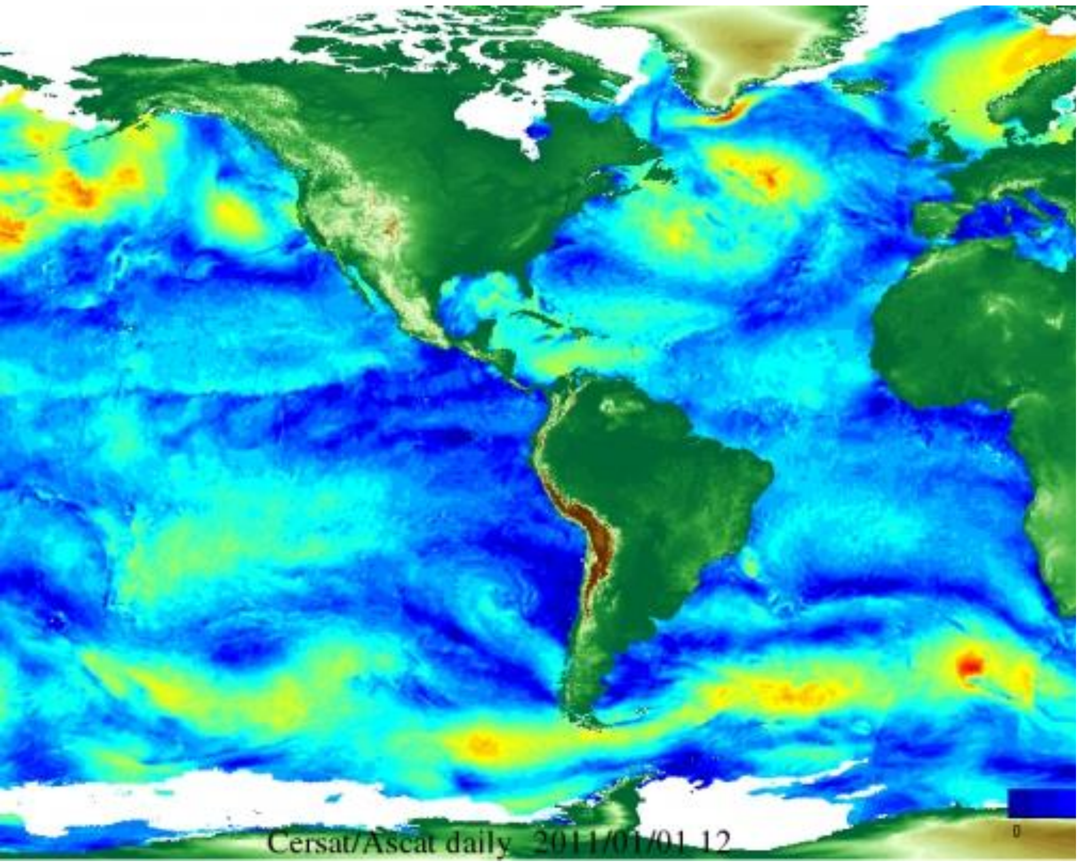


North Pacific winds from Quikscat

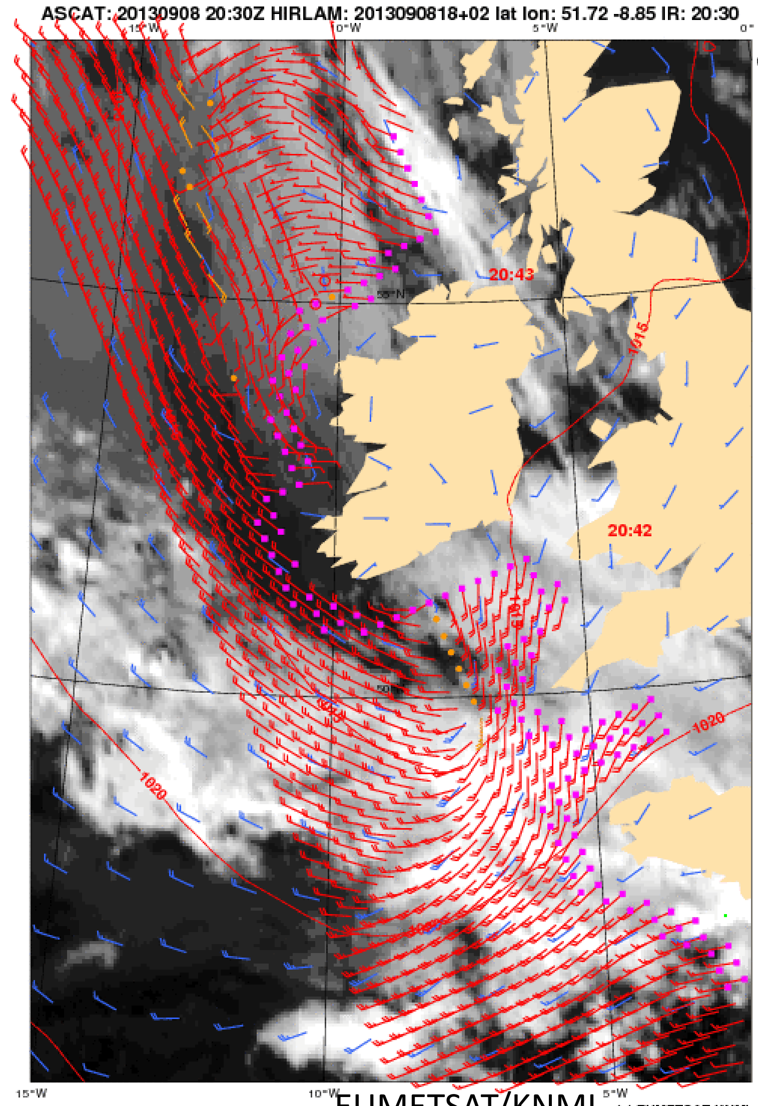


Source:- http://www.ssmi.com/qscat/qscat_browse.html

Scatterometers are fully operational



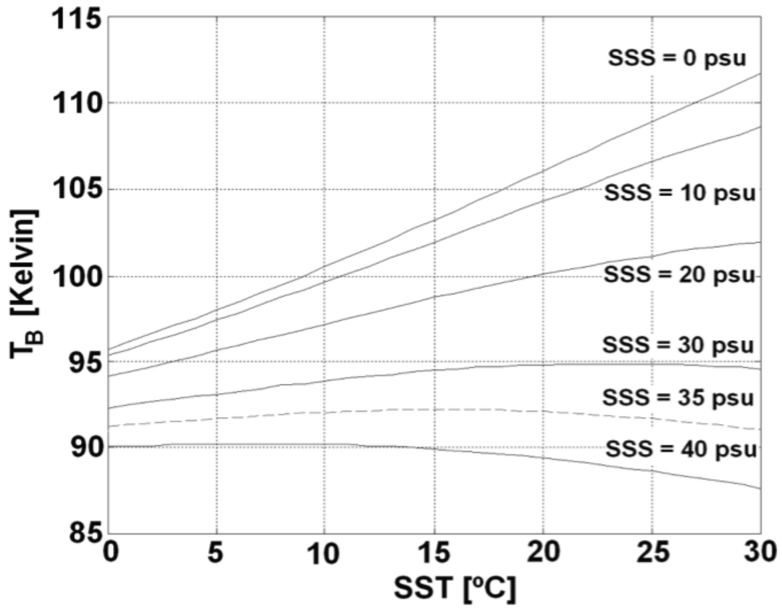
CERSAT



EUMETSAT/KNMI

Salinity from Space

- L-band (1.4GHz) has a small dependence on salinity
- Much stronger dependence on surface temperature
- Strongly influenced by surface roughness
- Also impacted by surface foam, external noise…

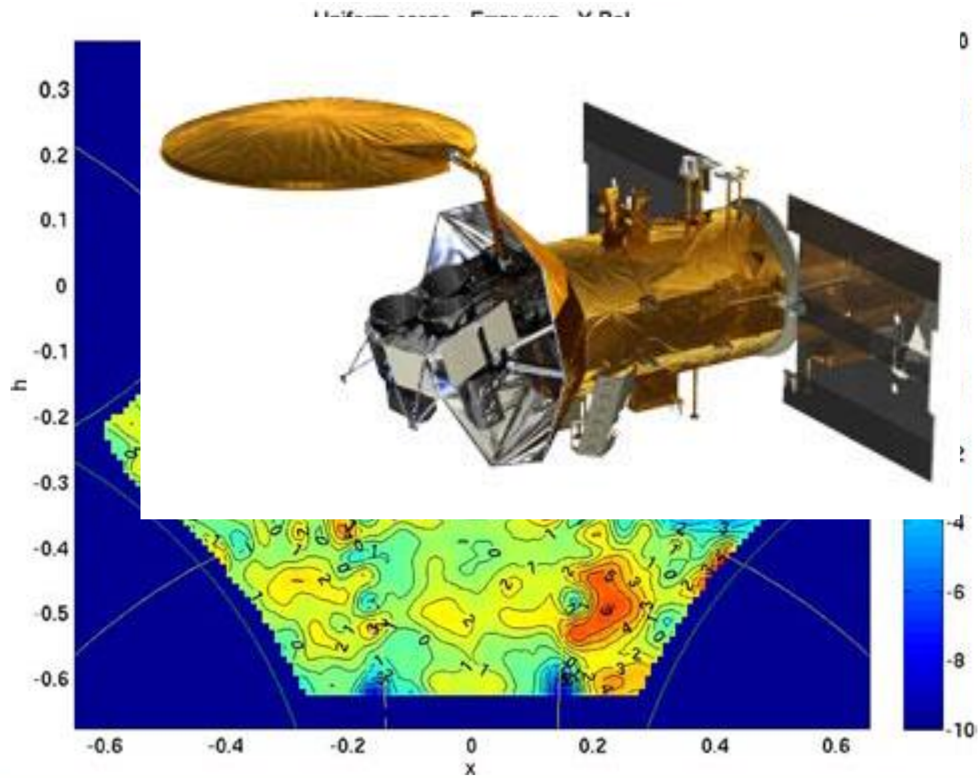


L-band TB against SST and SSS (Swift, 1980)

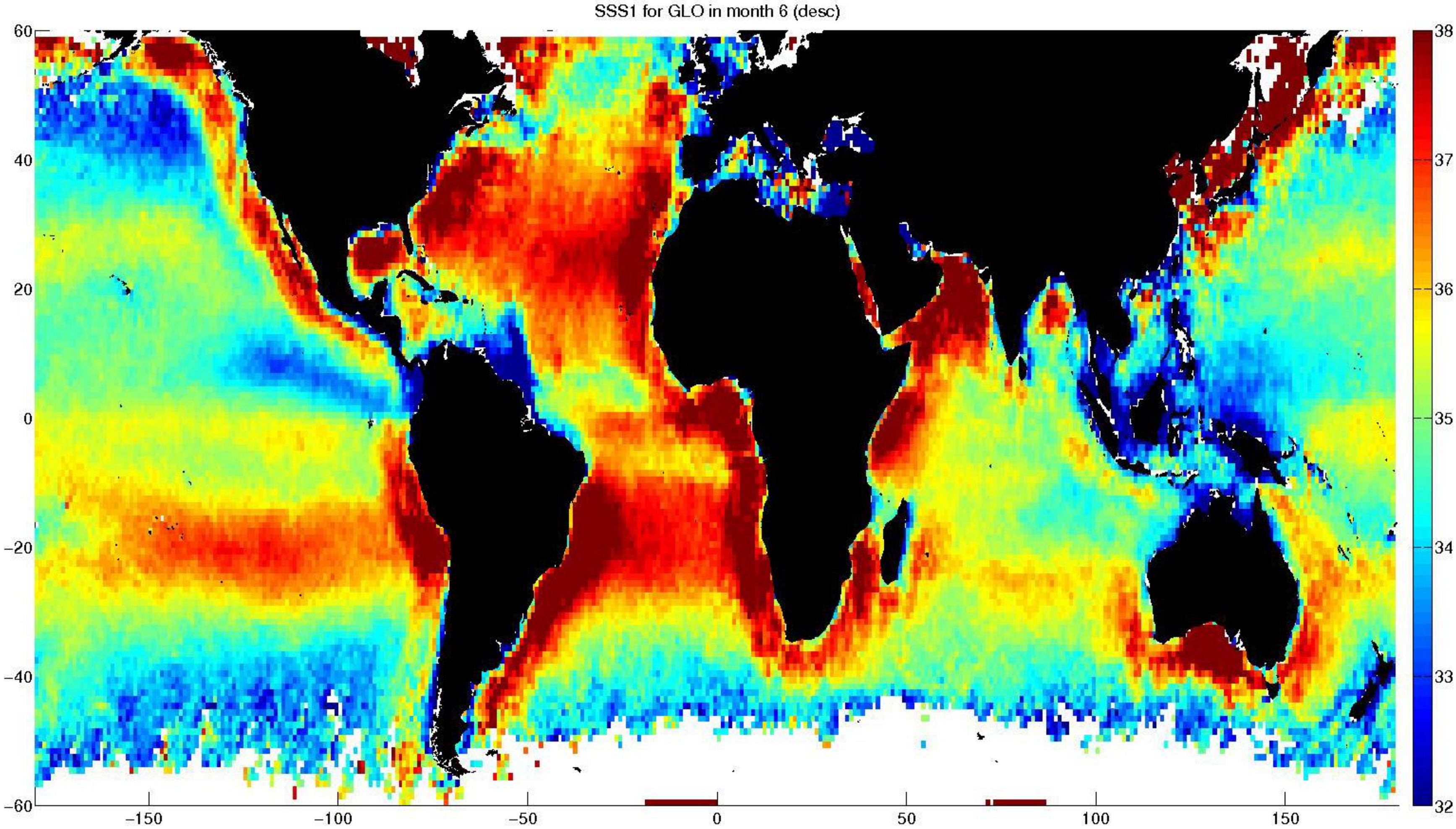
0.7 K/psu at 30° C
cf 0.2 K/psu at 0° C

Salinity from Space

- Soil Moisture and Ocean Salinity (SMOS)
  - synthetic aperture (interferometric radiometer)
  - 35km resolution
  - 3 day repeat
- Aquarius
  - Passive radiometer
  - 100km resolution
  - 7 day global coverage

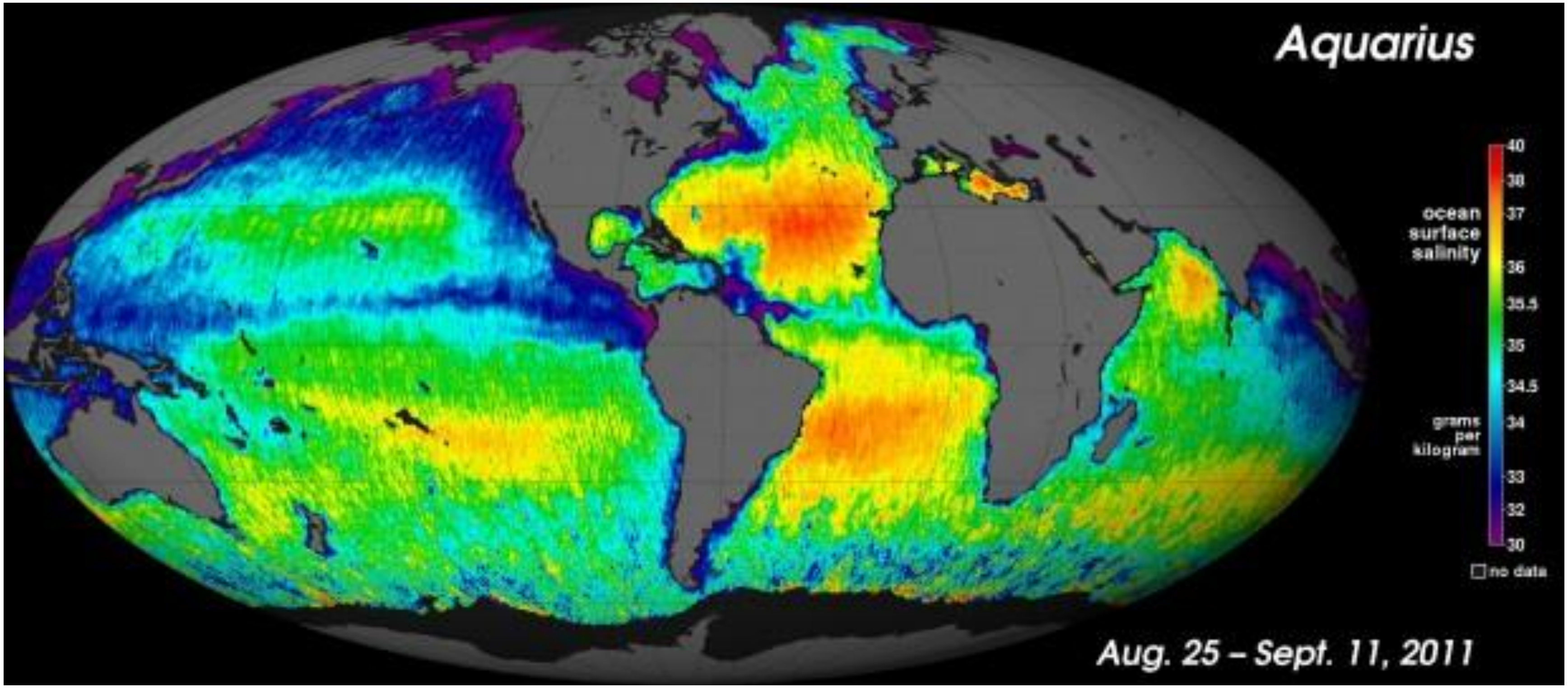


Salinity from Space : SMOS



ESA/NOC – C Banks

Salinity from Space: Aquarius



NASA/GSFC/JPL-Caltech

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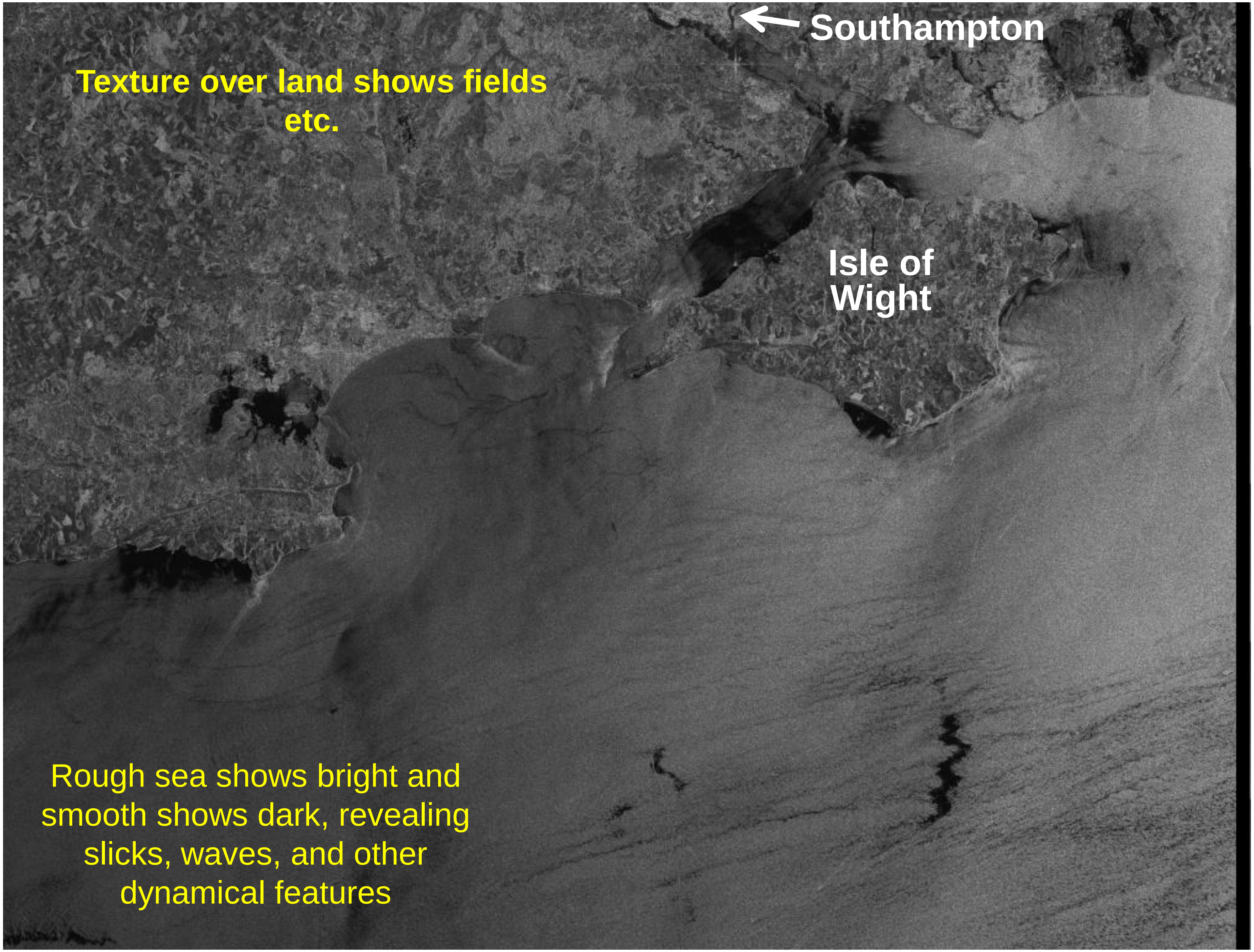
This SAR image over the Isle of Wight is from ESA's ERS-1 satellite

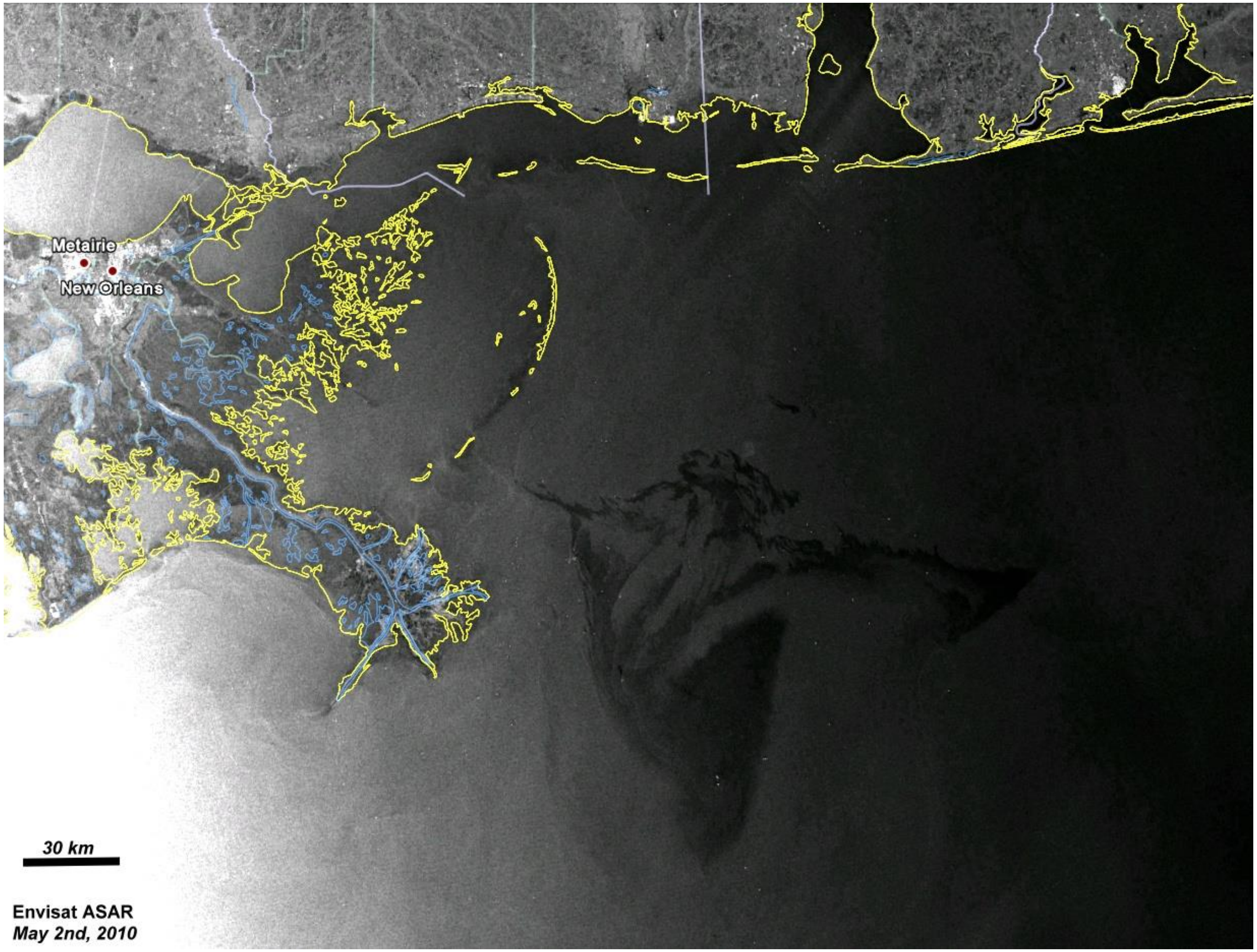


SAR images of sea surf. roughness

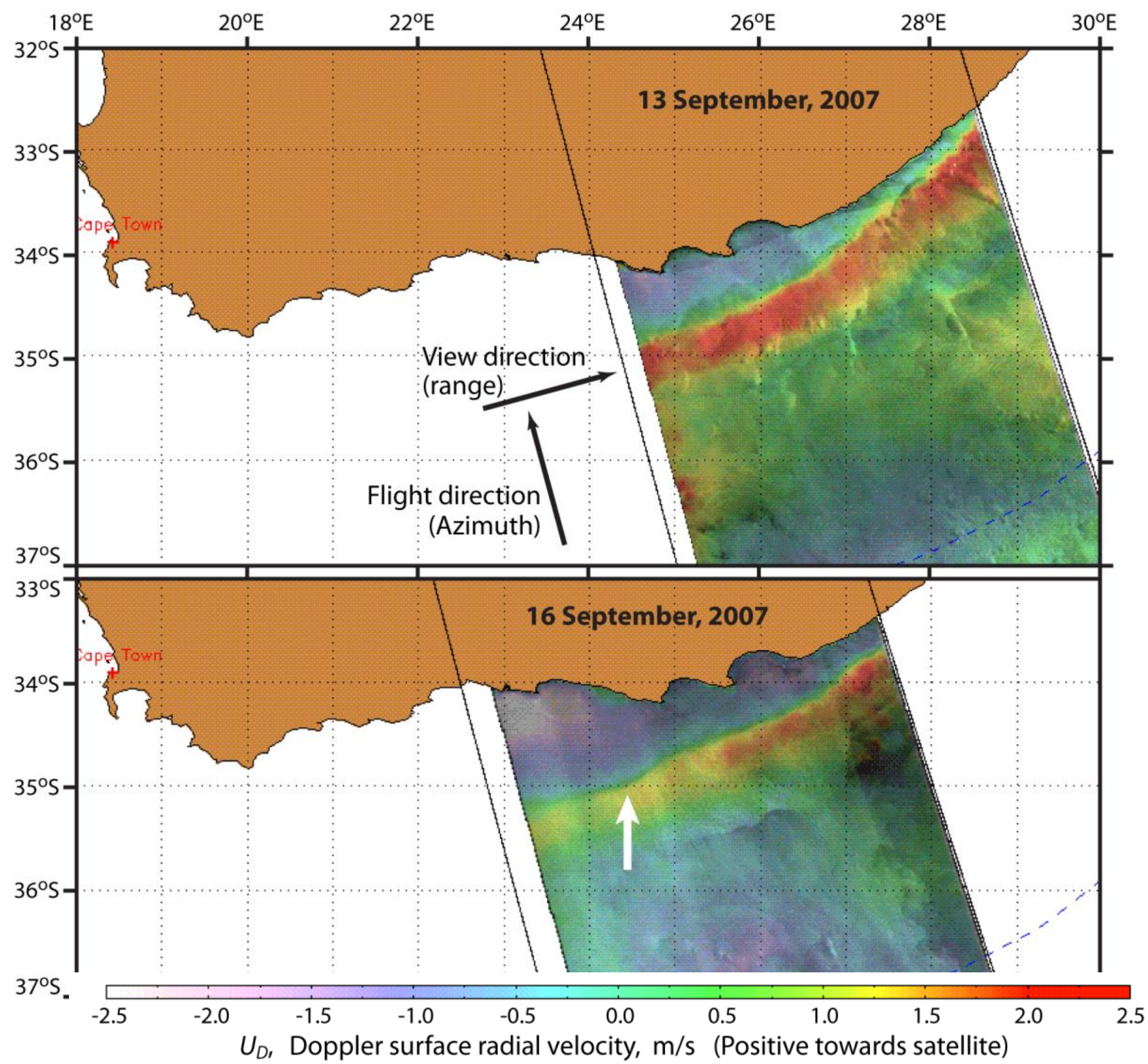
A possible oil seepage slick observed in ERS SAR imagery

Mediterranean ERS SAR image shows signatures of (a) katabatic winds, (b) convective atmospheric cells, (c) low winds, (d) ocean eddies and (e) internal waves.

Envisat ASAR monitors the GoM spill



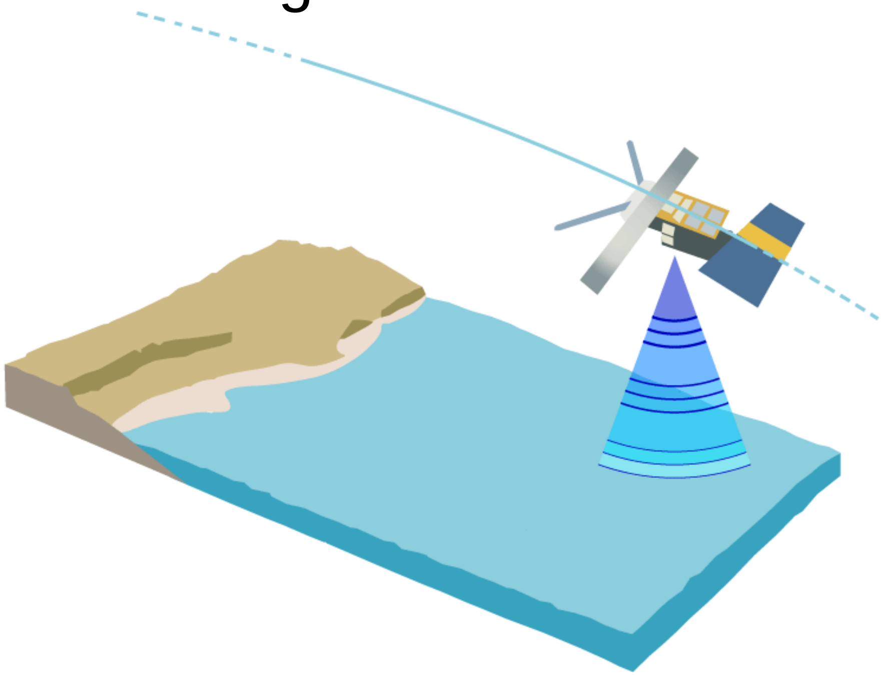
SAR currents



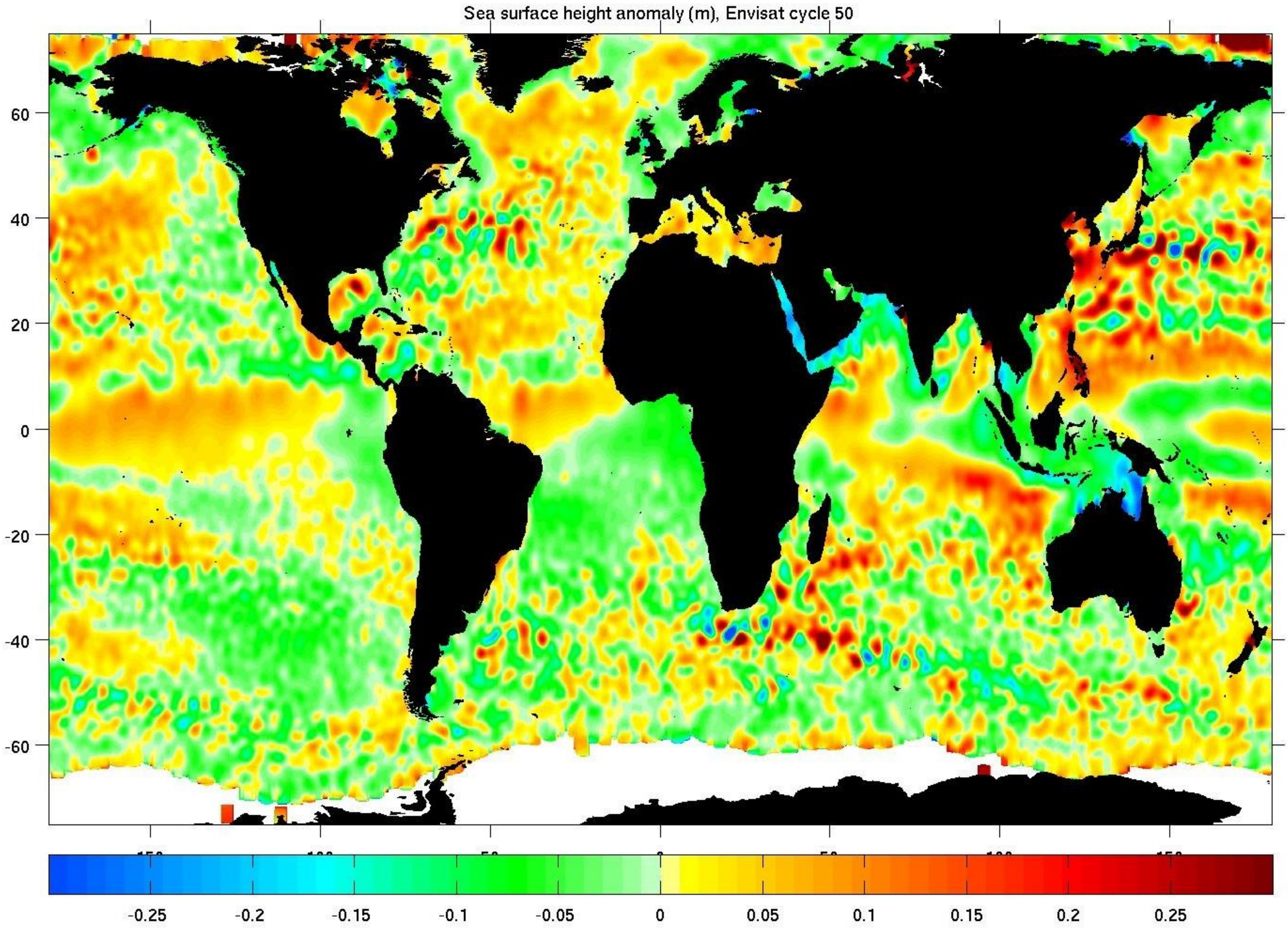
BoostTechnologies

Satellite Altimetry

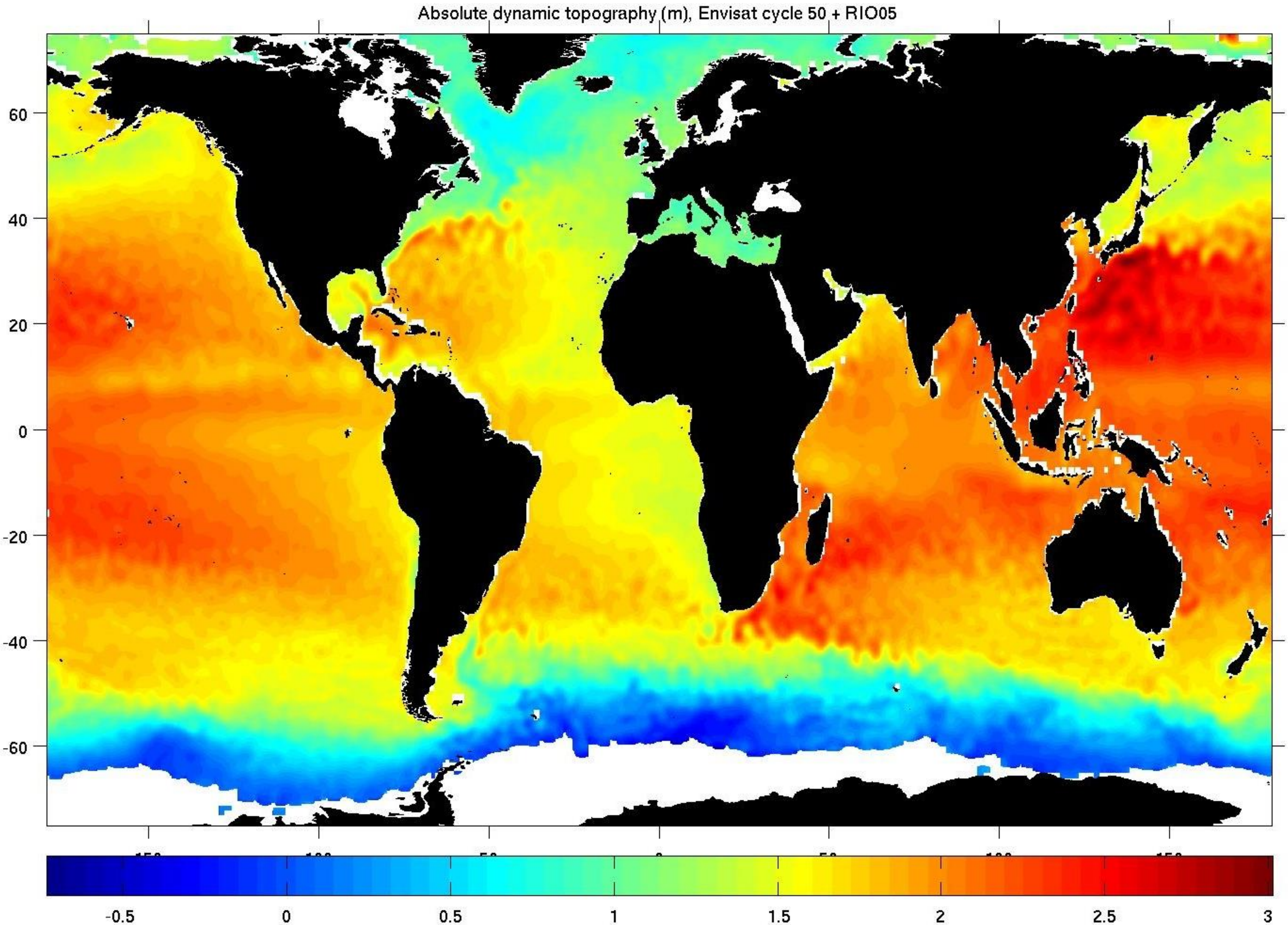
- one of the most successful EO techniques
  - synoptic, sustained view of surface ocean dynamics (currents, eddies, planetary waves)
  - accurate, long-term global and regional sea level monitoring



SEA LEVEL ANOMALY

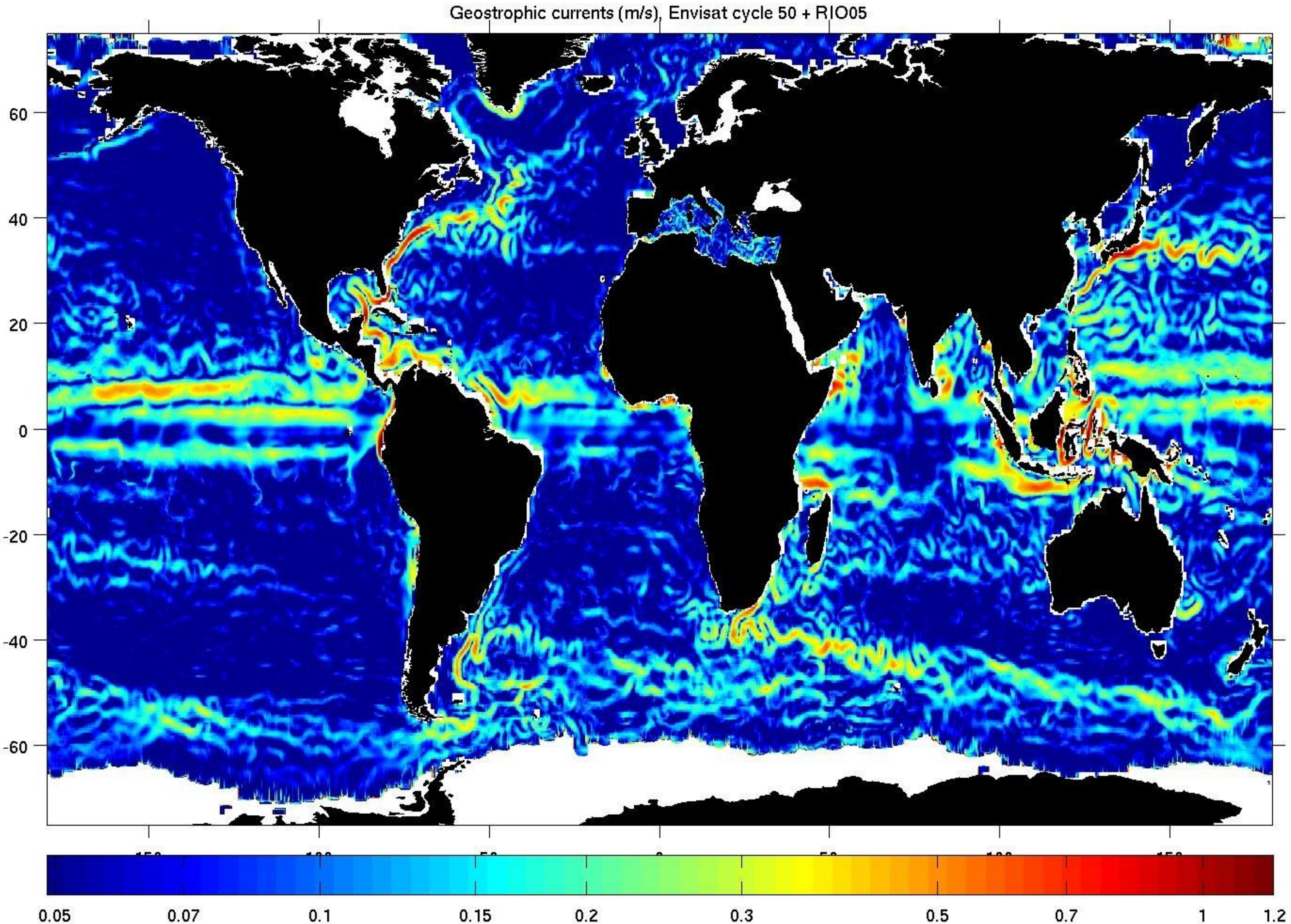


ABSOLUTE DYN TOPO



Computed from Envisat cycle 50 SSHA + Rio05 Mean Dynamic Topography

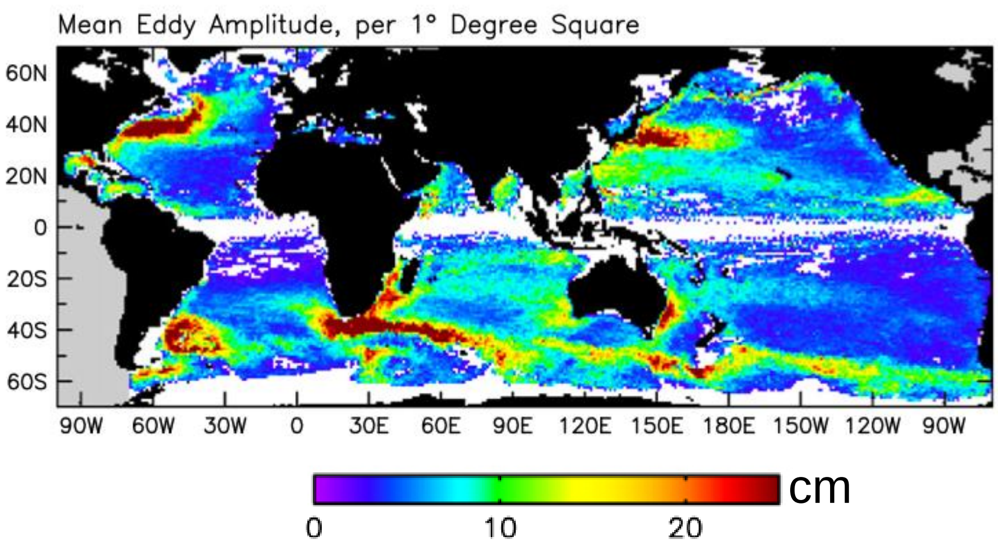
SURFACE CURRENTS

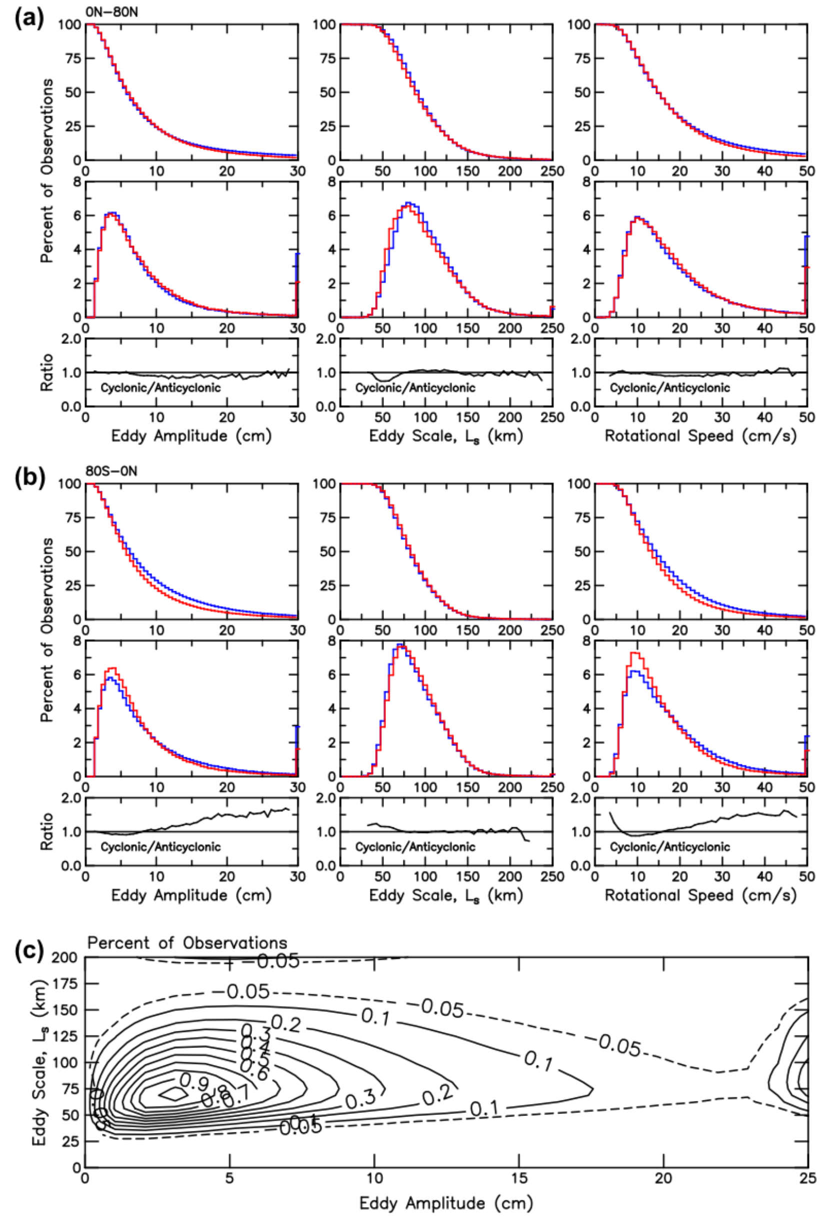


Computed from Envisat cycle 50 SSHA + Rio05 Mean Dynamic Topography

MESOSCALE FEATURES

- Chelton et al., 2011, have identified **35891 eddies** (with lifetimes >=16 wks) in 16 years of two-mission altimeter data
- averages:
  - lifetime 32 weeks
  - propagation distance 550 km
  - amplitude 8 cm
  - radius 90 km



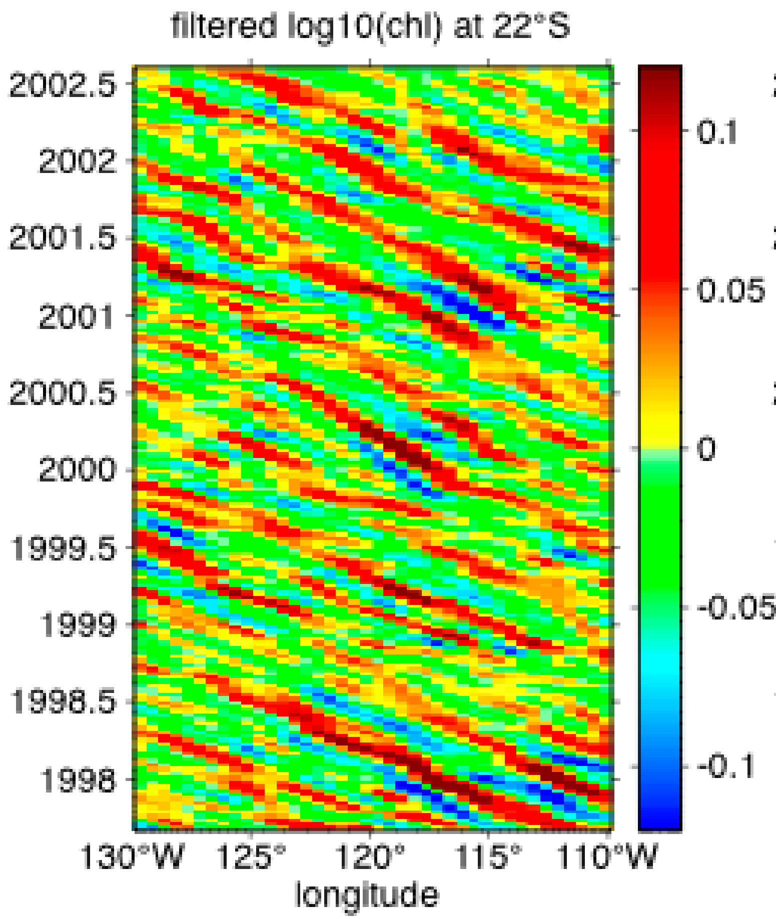


D. Chelton et al., 2011

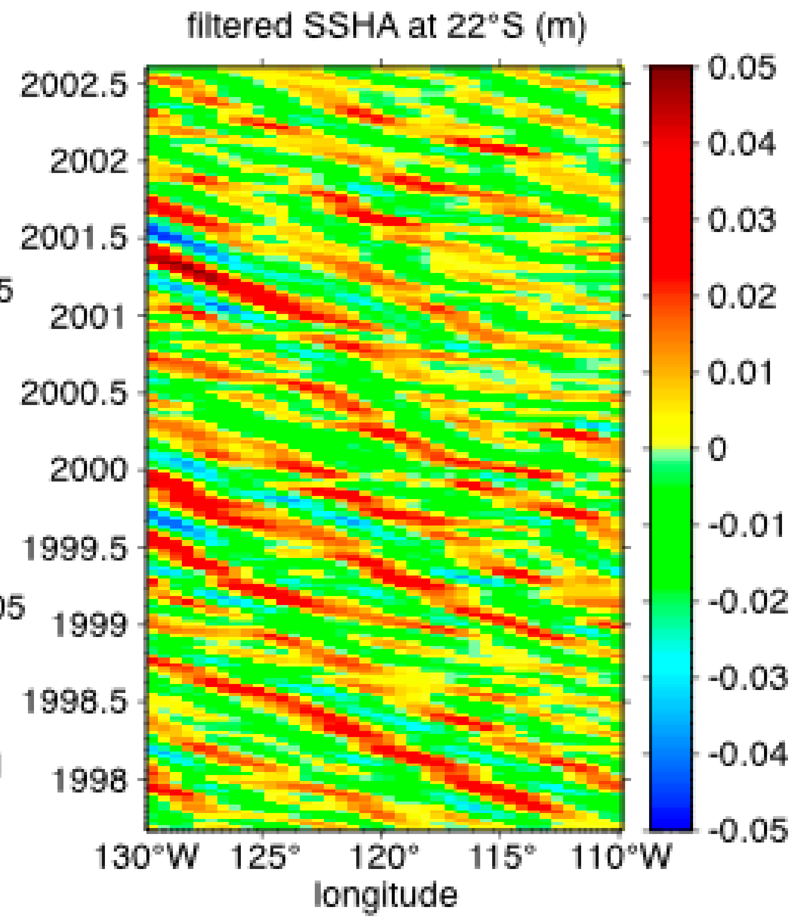
ROSSBY WAVES AND EDDIES

Cipollini et al, 2001; Uz et al, 2001; Siegel, 2001; Charria et al., 2003; Killworth et al, 2004; Dandonneau et al., 2004; Charria et al, 2006, various papers by Chelton and co-authors

Chlorophyll

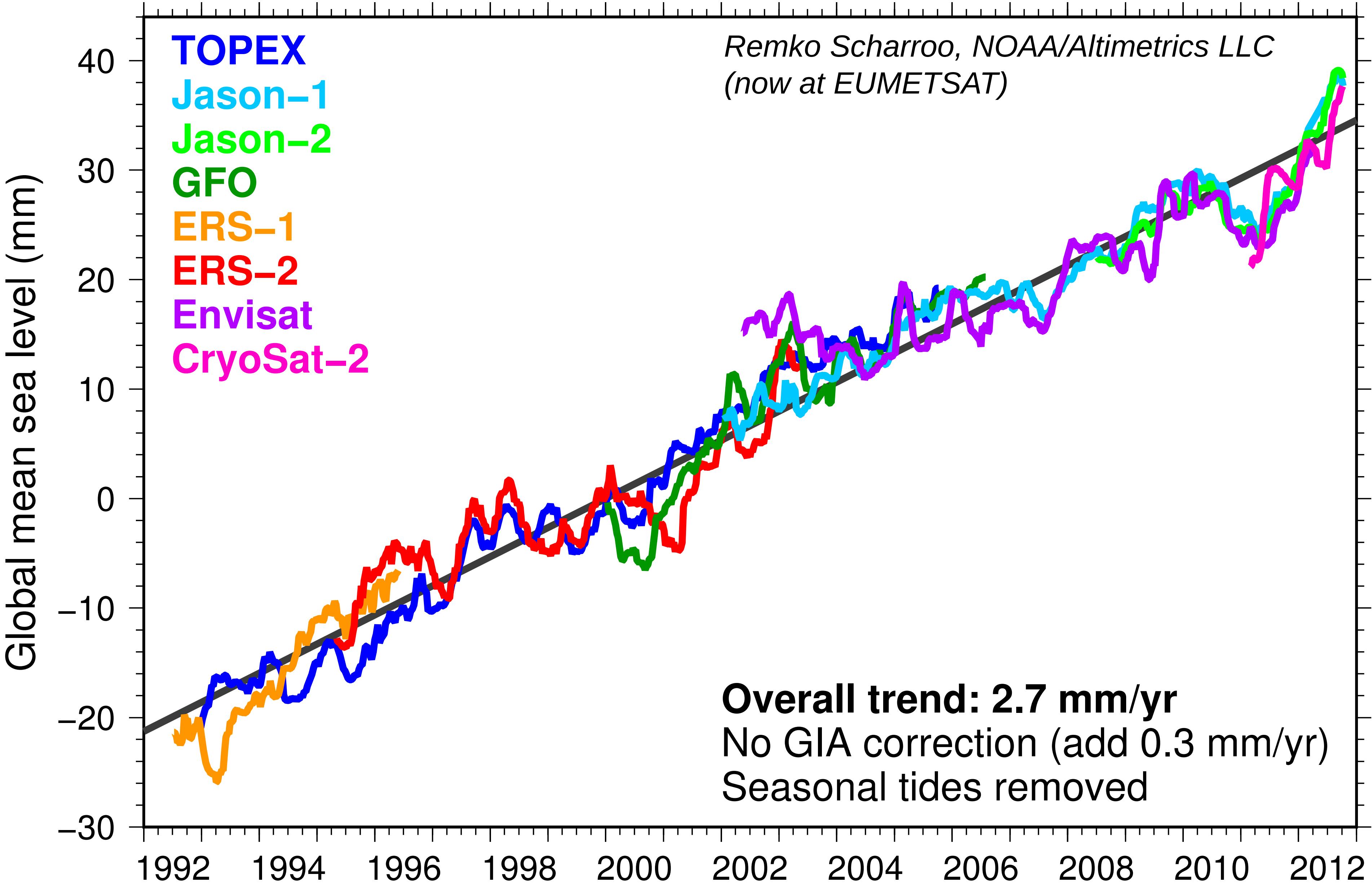


Sea Surface Height



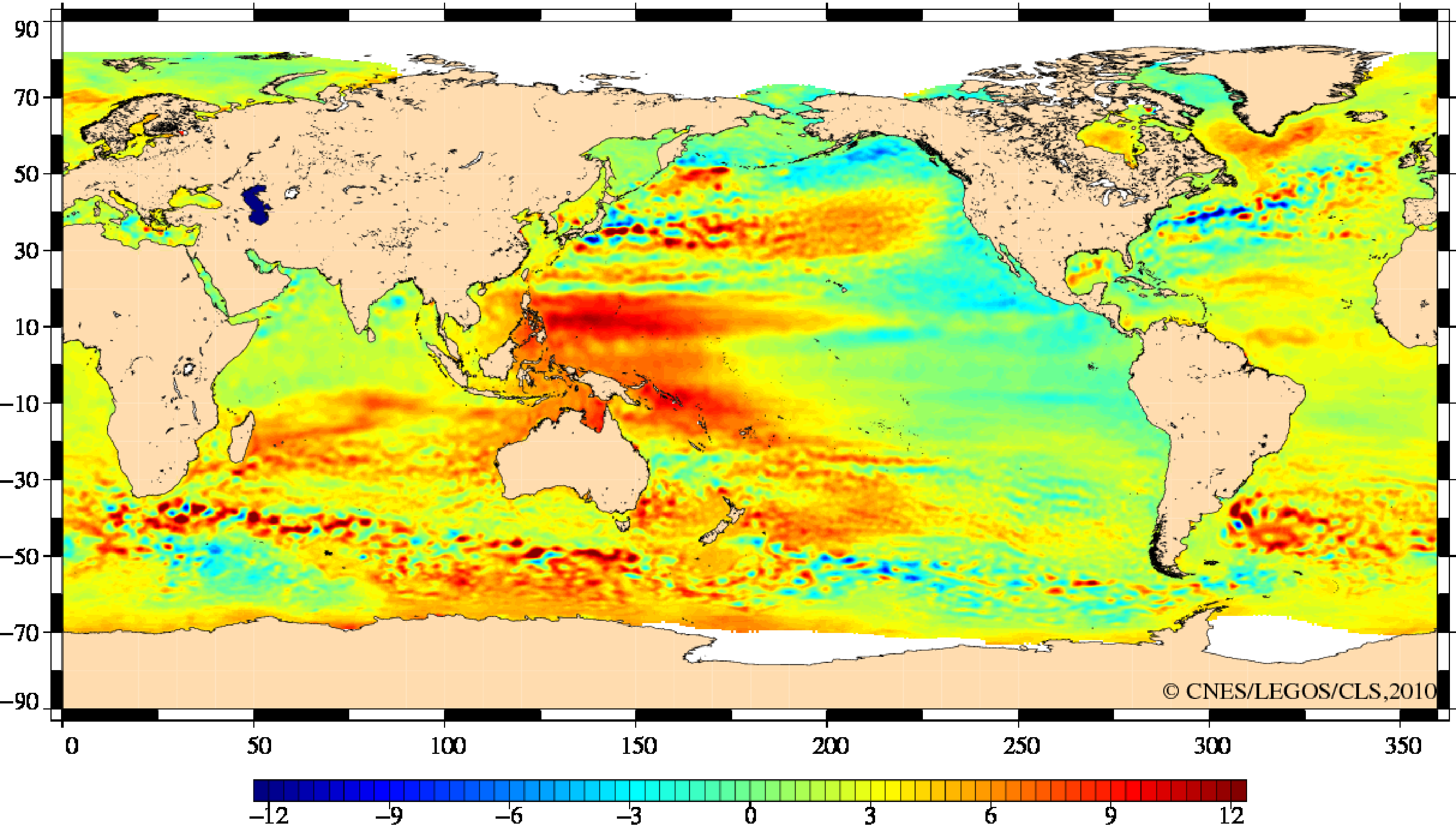
Great synergy possible in all studies of bio-phys interactions when altimetry is combined with SST, ocean colour

SEA LEVEL RISE - global



SEA LEVEL TRENDS - regional

→ Sea Level component on dedicated ESA programme, the "Climate Change Initiative"



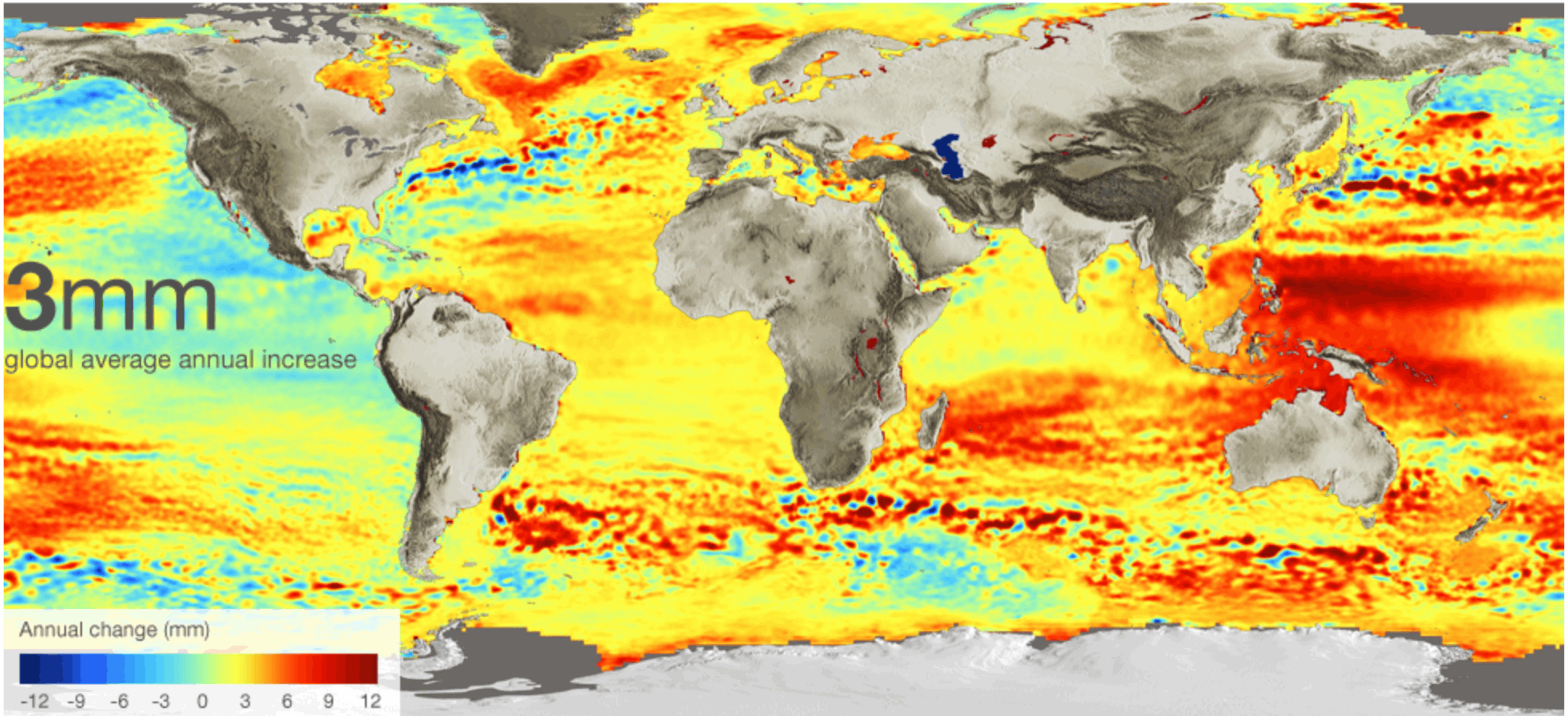
Regional MSL trends from Oct−1992 to Mar−2010 (mm/year)

24 September 2012 Last updated at 17:19

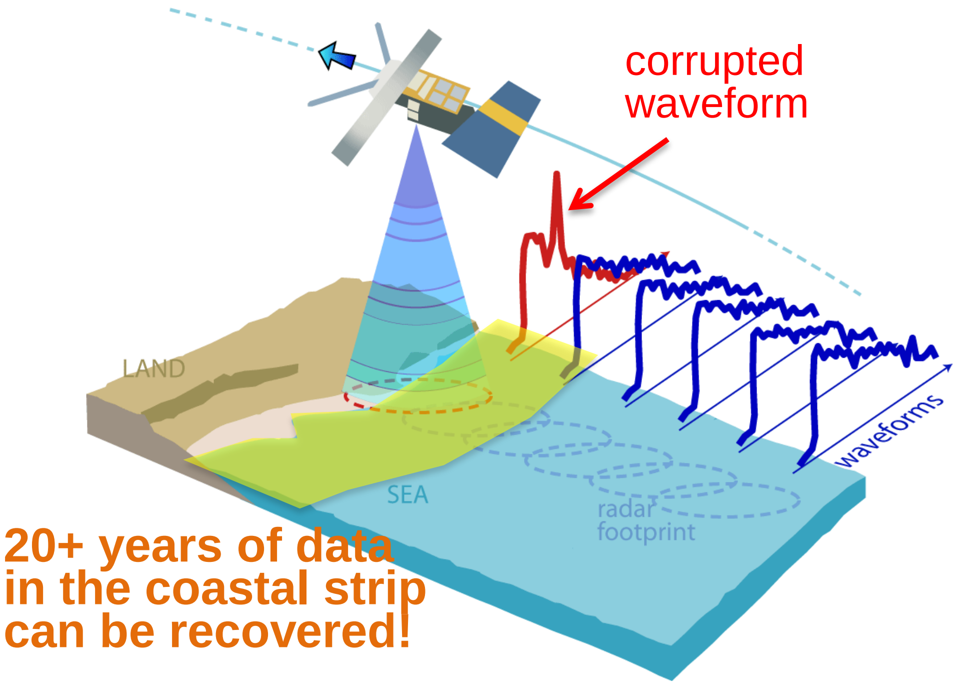
Satellites trace sea level change

Scientists have reviewed almost two decades of satellite data to build a new map showing the trend in sea levels. Globally, the oceans are rising, but there have been major regional differences over the period.

Annual average sea-level rise, 1993-2010



Coastal Altimetry



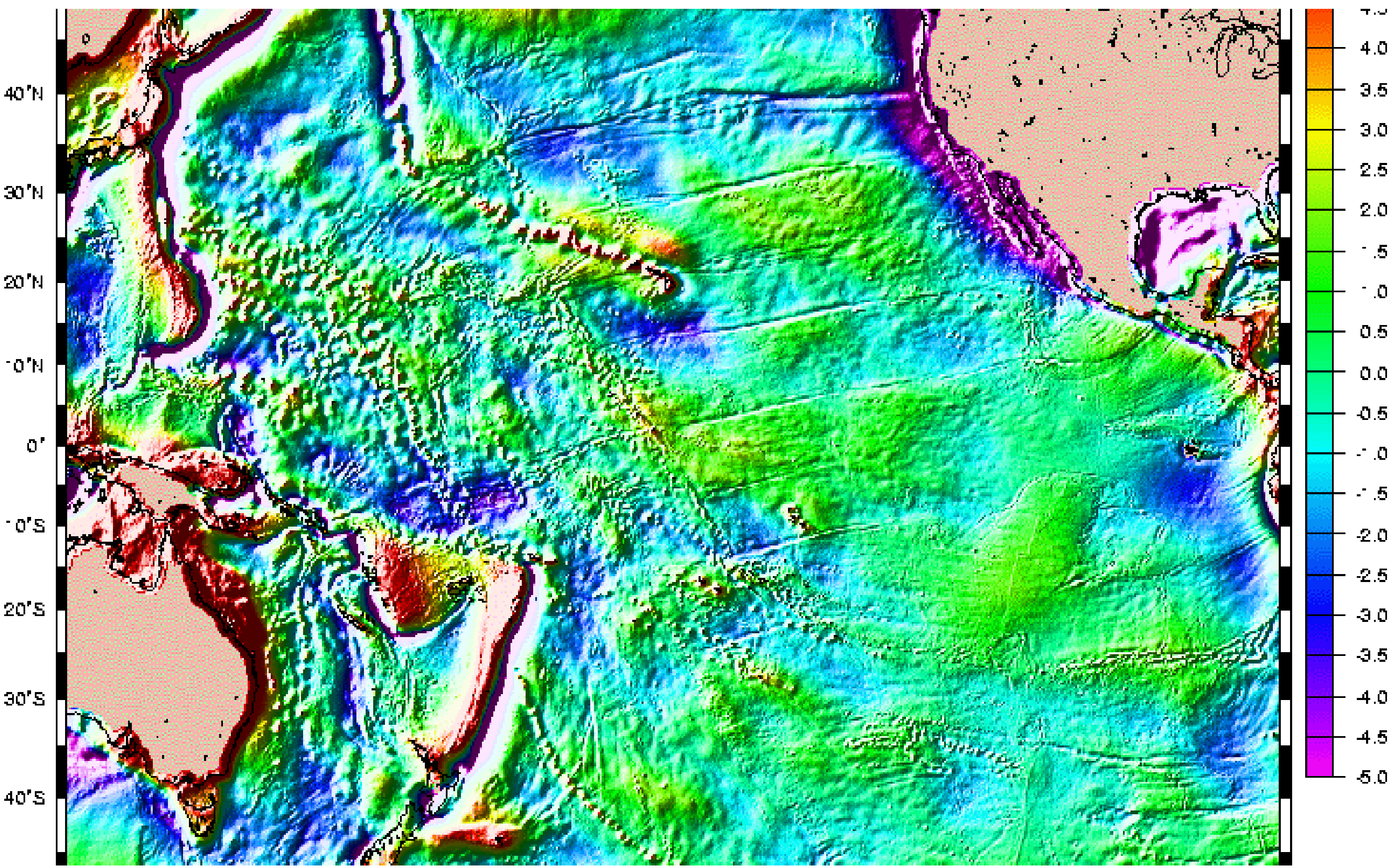
Standard altimetry does not quite go all the way to the coast!

Traditionally, data in the **coastal zone** are flagged as bad and left unused

(coastal zone: as a rule of thumb 0-50 km from coastline, but in practice, **any place where standard altimetry gets into trouble** as radar waveforms are non-standard and/or corrections become inaccurate)

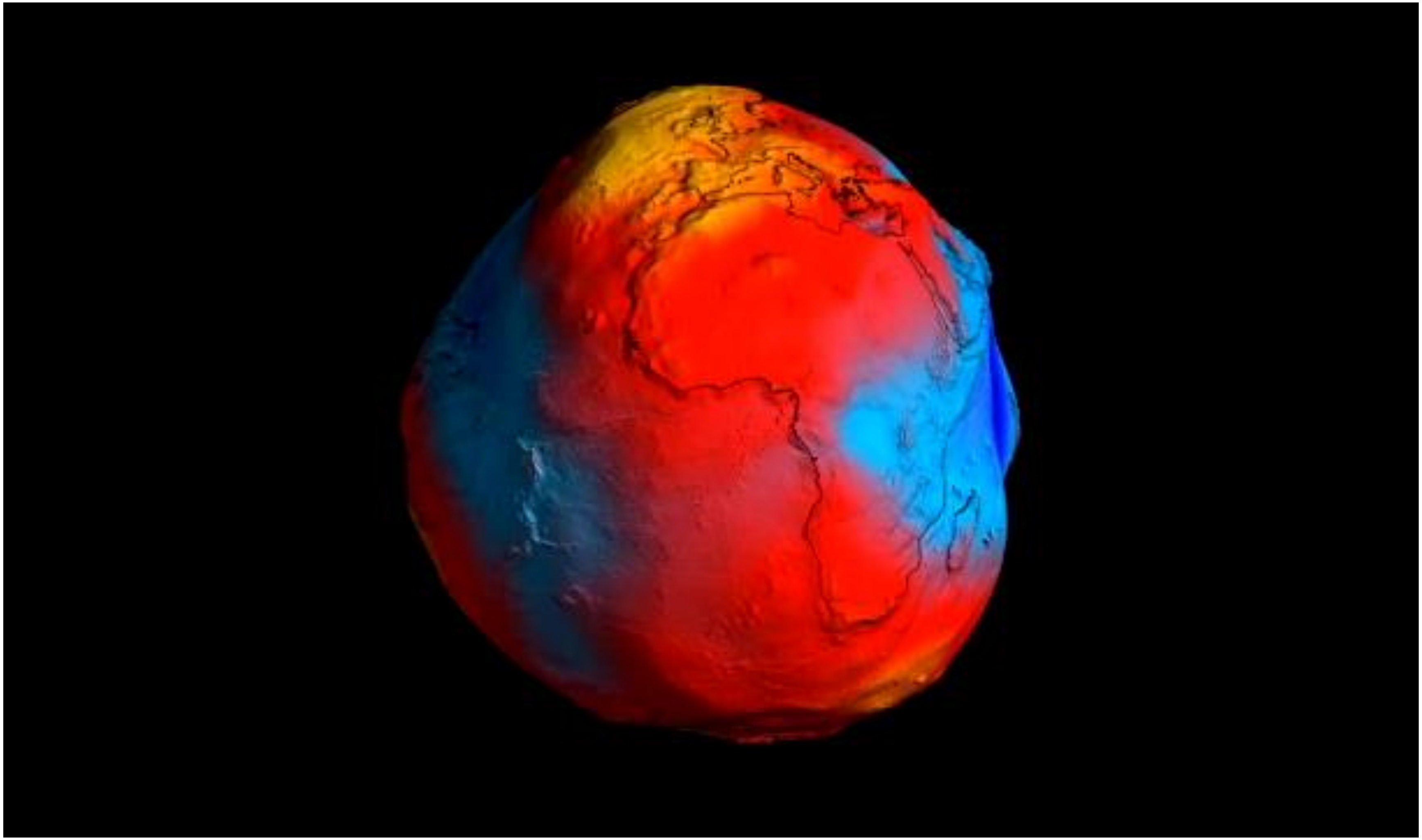
In recent years a vibrant community of researchers has started to believe that **most of those coastal data can be recovered** and that coastal altimetry can be **a legitimate component of coastal observing systems!**

Bottom topography – from space

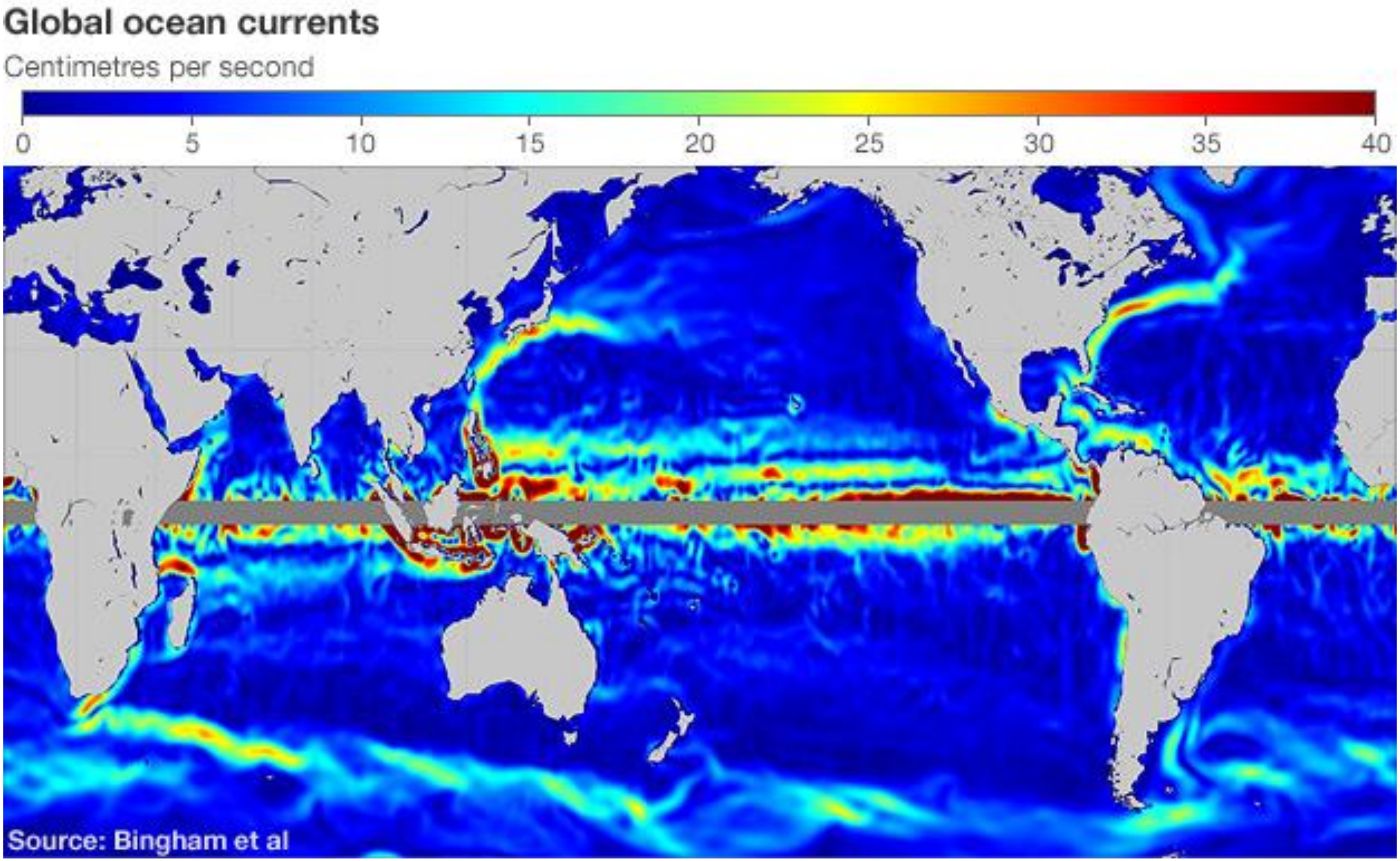


Based on TOPEX altimeter. High-pass filtered to emphasise the sea floor topography influence

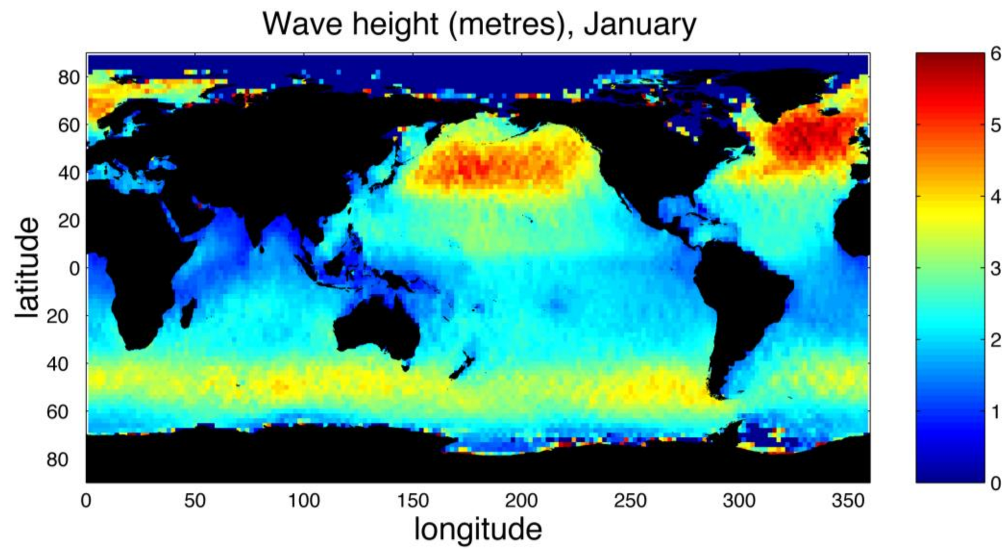
Geoid from GOCE

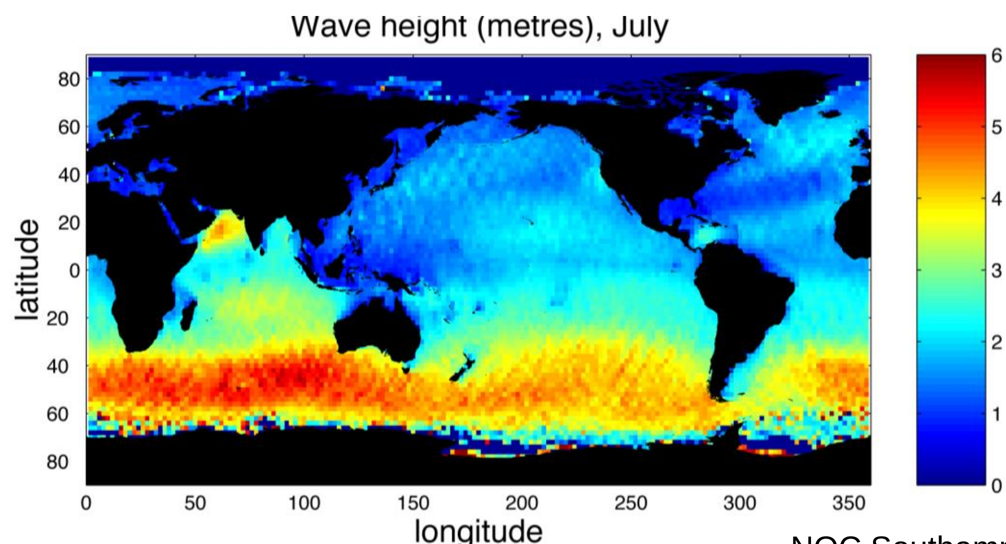


Global Currents from GOCE and altimetry

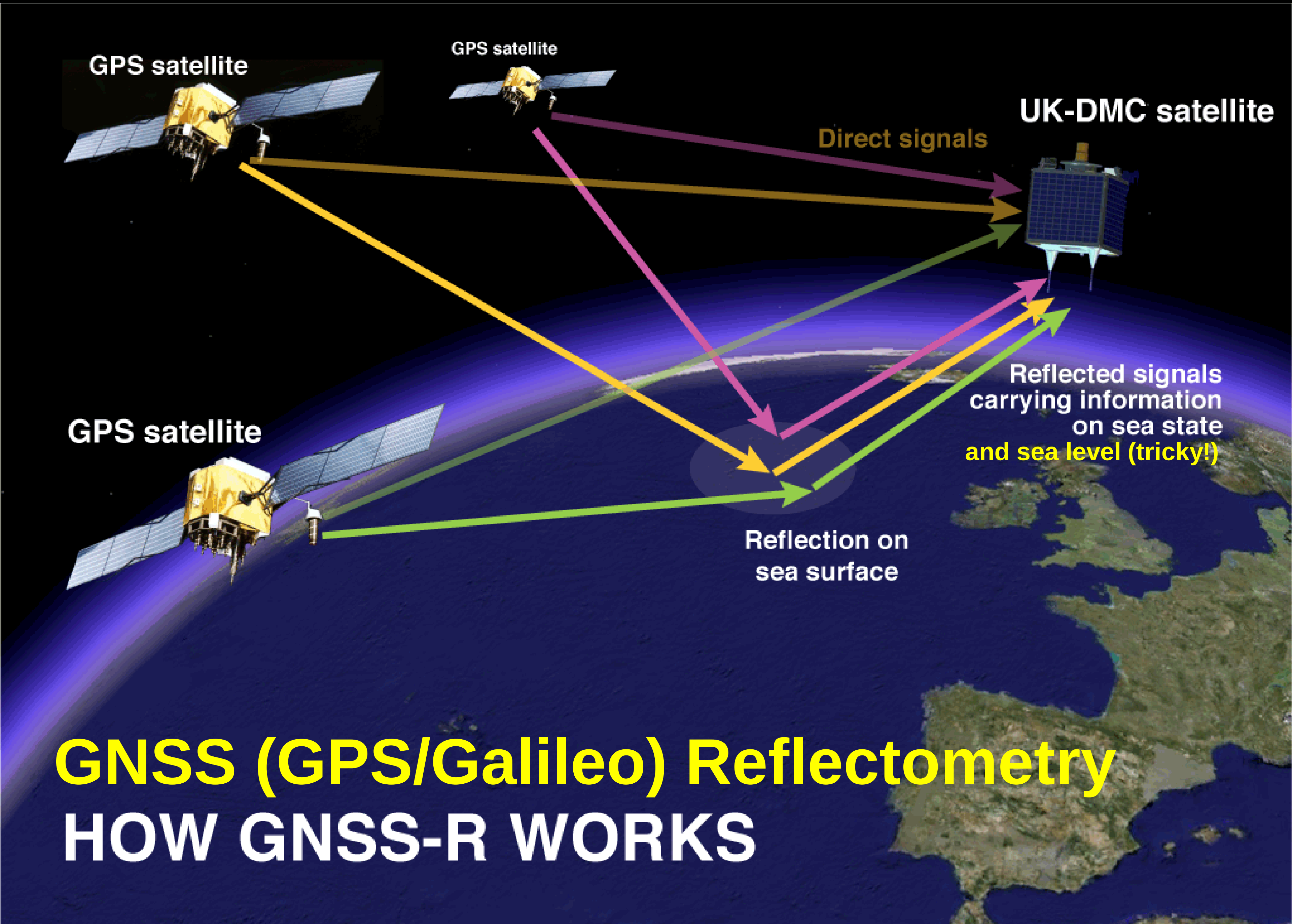


Wave Climate from Space





NOC Southampton



GNSS (GPS/Galileo) Reflectometry

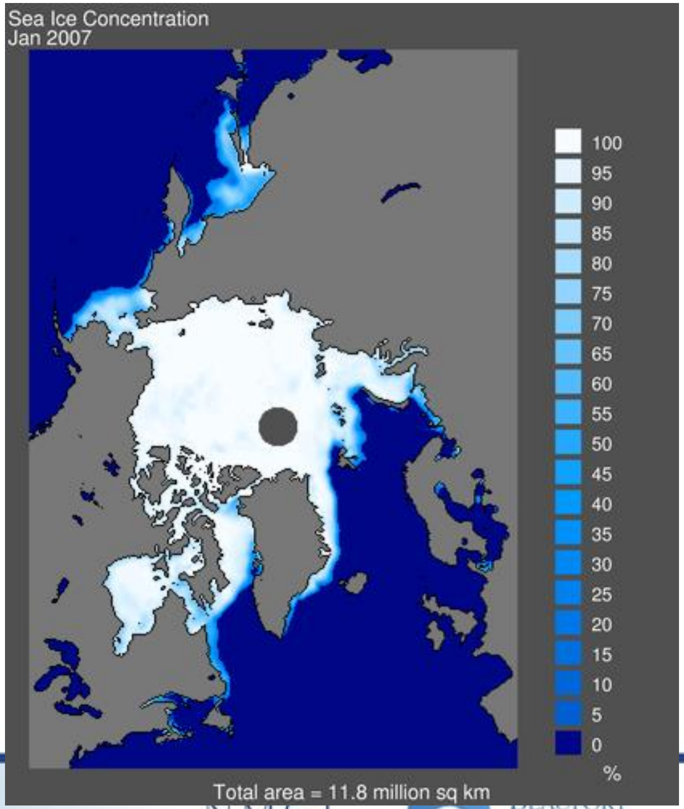
HOW GNSS-R WORKS

Sea Ice cover and extension

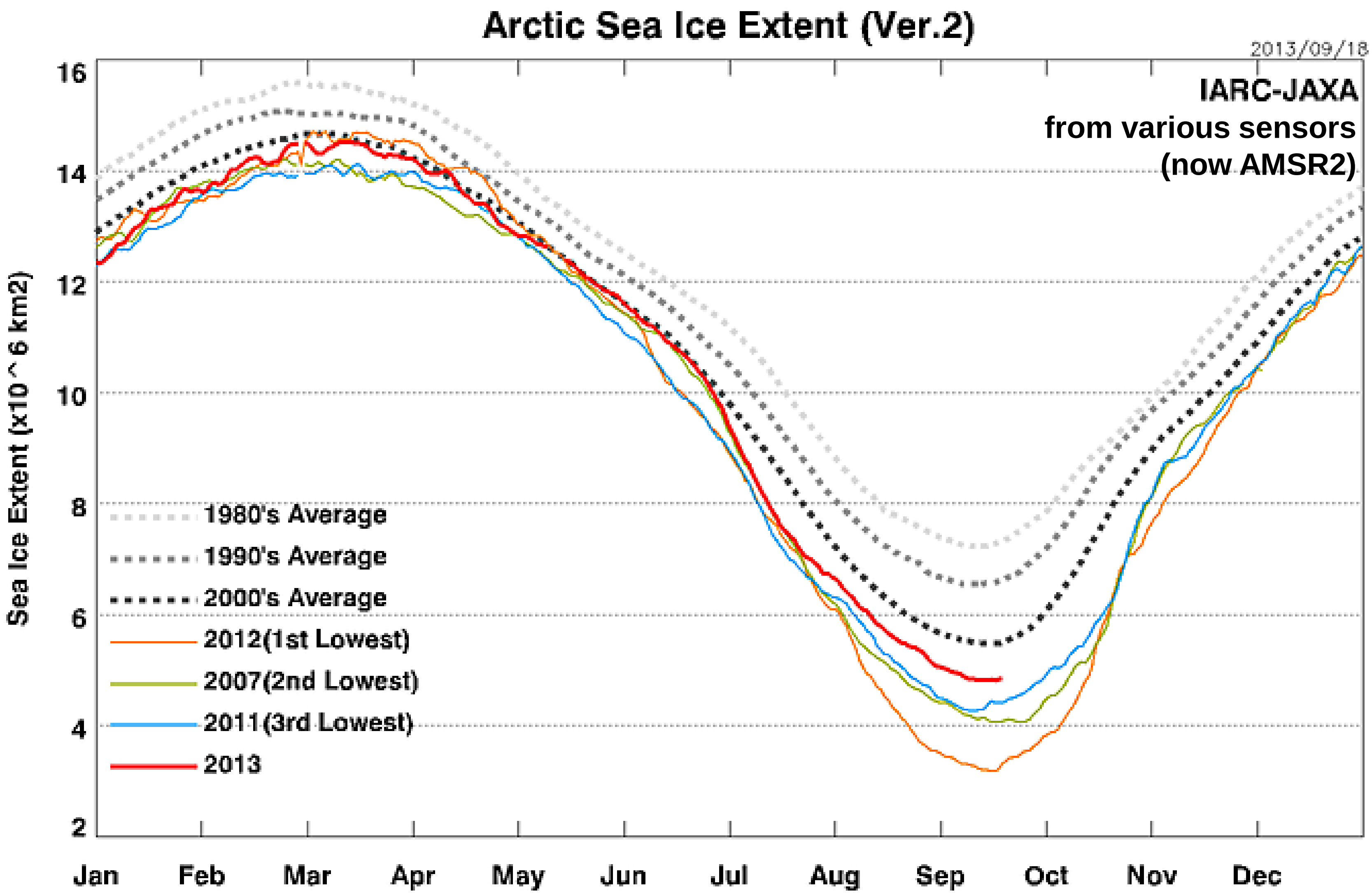
Source http://earth.esa.int/earthimages/

Envisat ASAR image A large iceberg, C-16, rammed into the well-known Drygalski Ice Tongue, a large sheet of glacial ice and snow in the Central Ross Sea in Antarctica, on 30 March 2006, breaking off the tongue's easternmost tip and forming a new iceberg. (Image is ~200 km square)

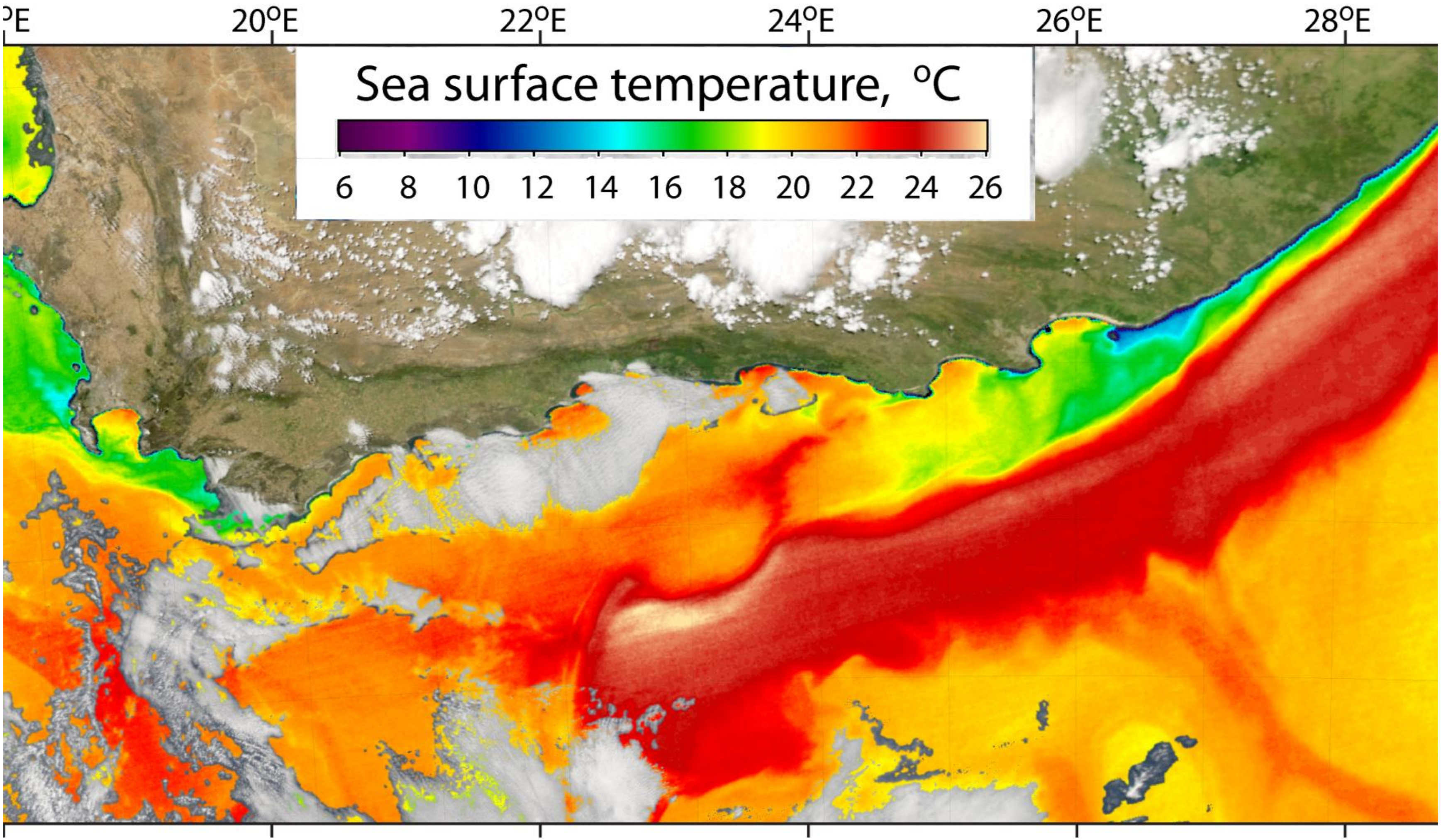
Sea-ice concentration based on microwave radiometry (from NSIDC)



Arctic sea ice is shrinking

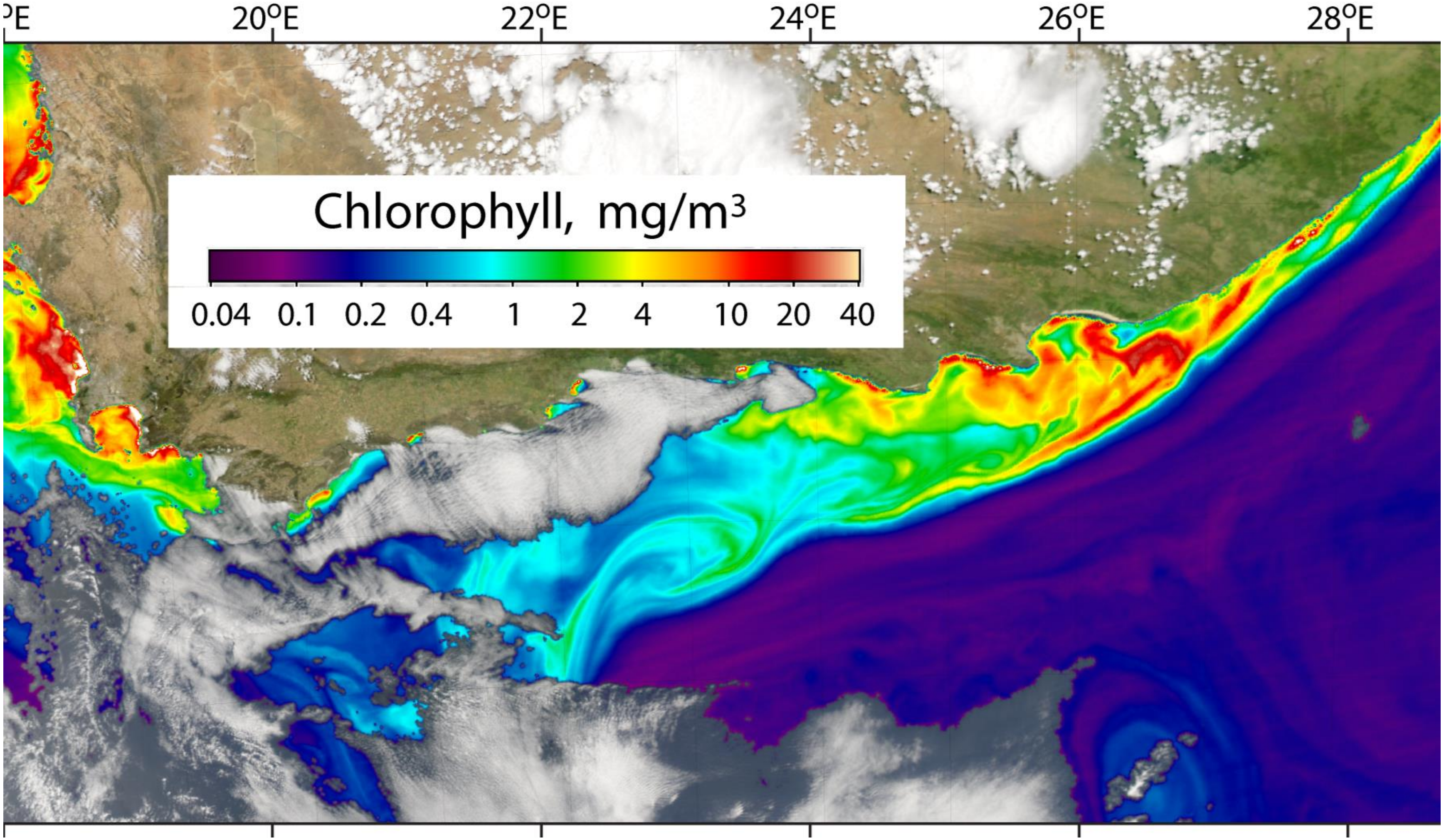


Synergy



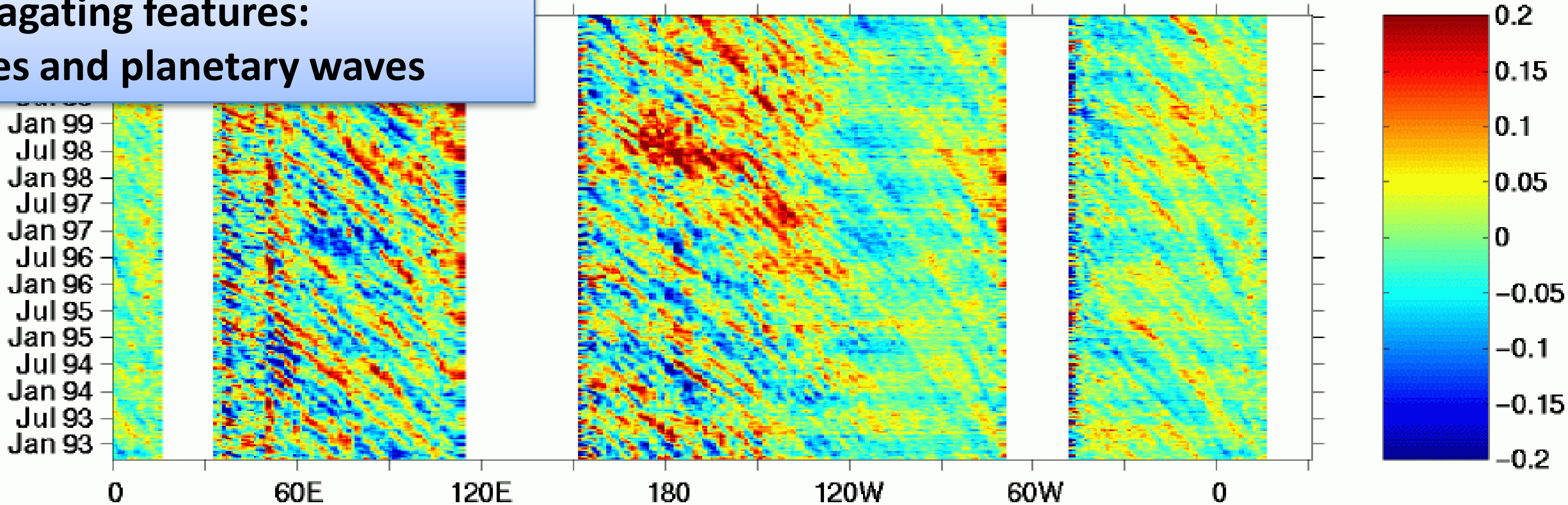
Sea surface temperature, °C
6
8
10
12
14
16
18
20
22
24
26
20°E
22°E
24°E
26°E
28°E

Synergy

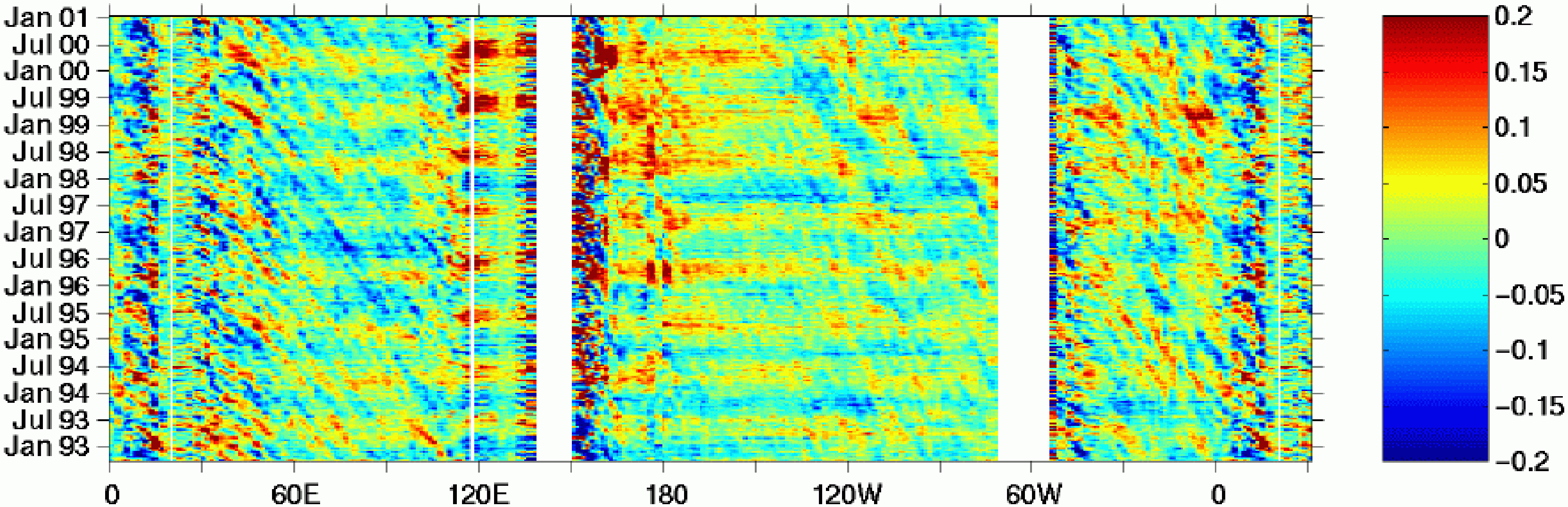


Propagating features:
Eddies and planetary waves

25 South



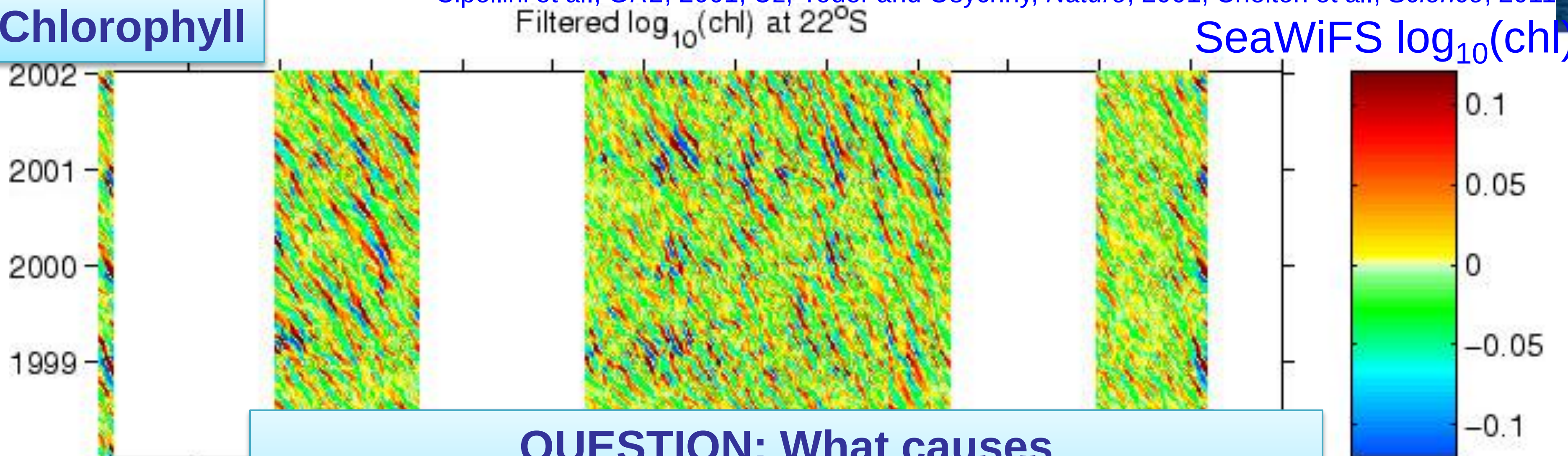
34 South



FACT: We see planetary waves and eddies in chlorophyll data

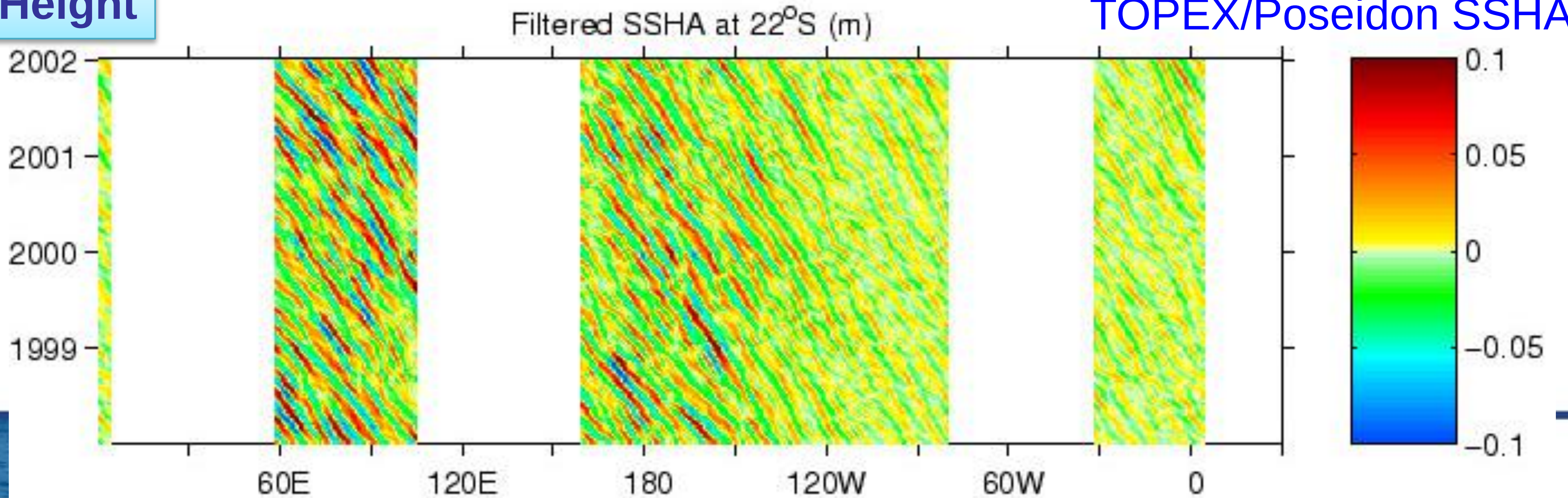
Cipollini et al., *GRL*, 2001; Uz, Yoder and Osychny, *Nature*, 2001, Chelton et al., *Science*, 2011

Chlorophyll



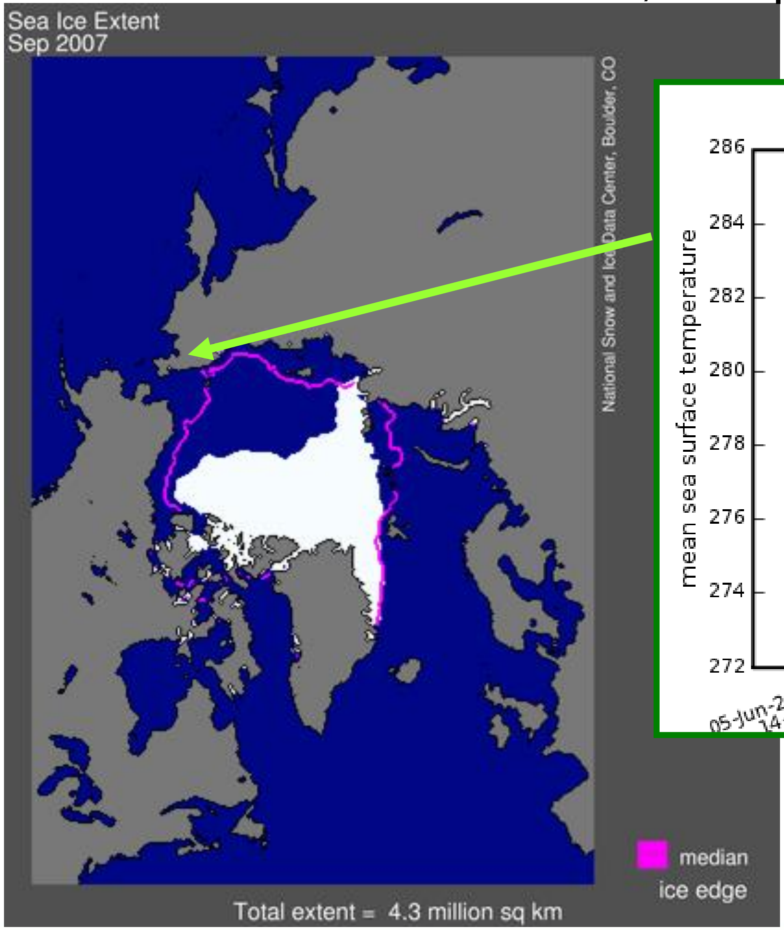
QUESTION: What causes the observed signature in the chlorophyll field?

Height

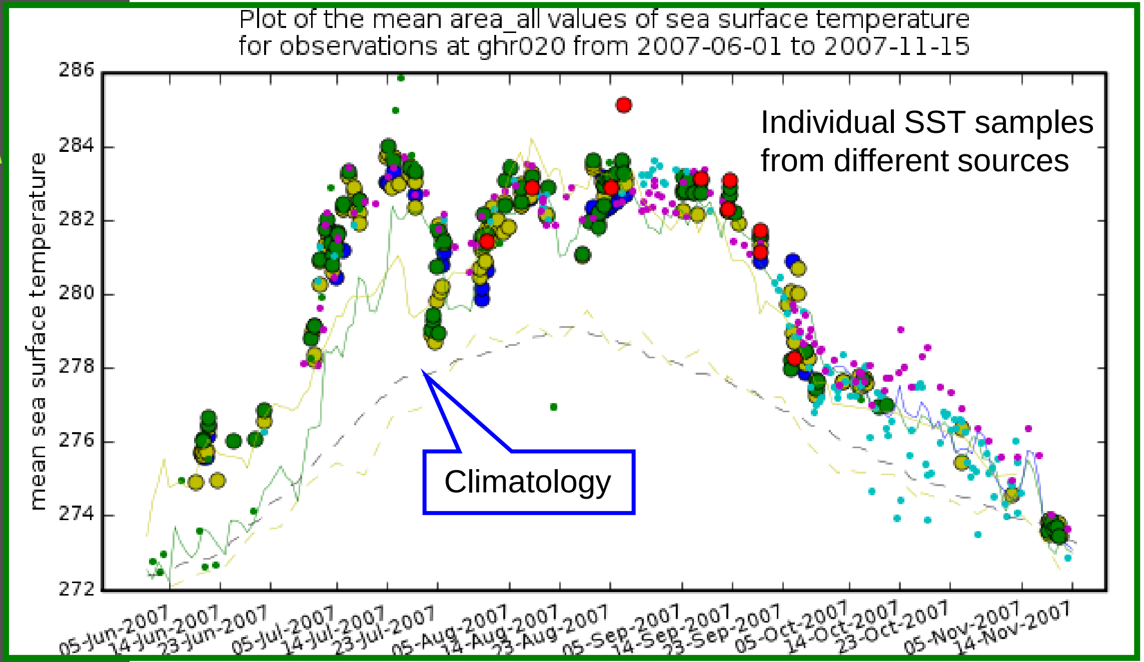


Synergy between different data types

In 2007 Satellites showed that the sea ice retreated in summer far further than ever before - almost to the N. Pole,

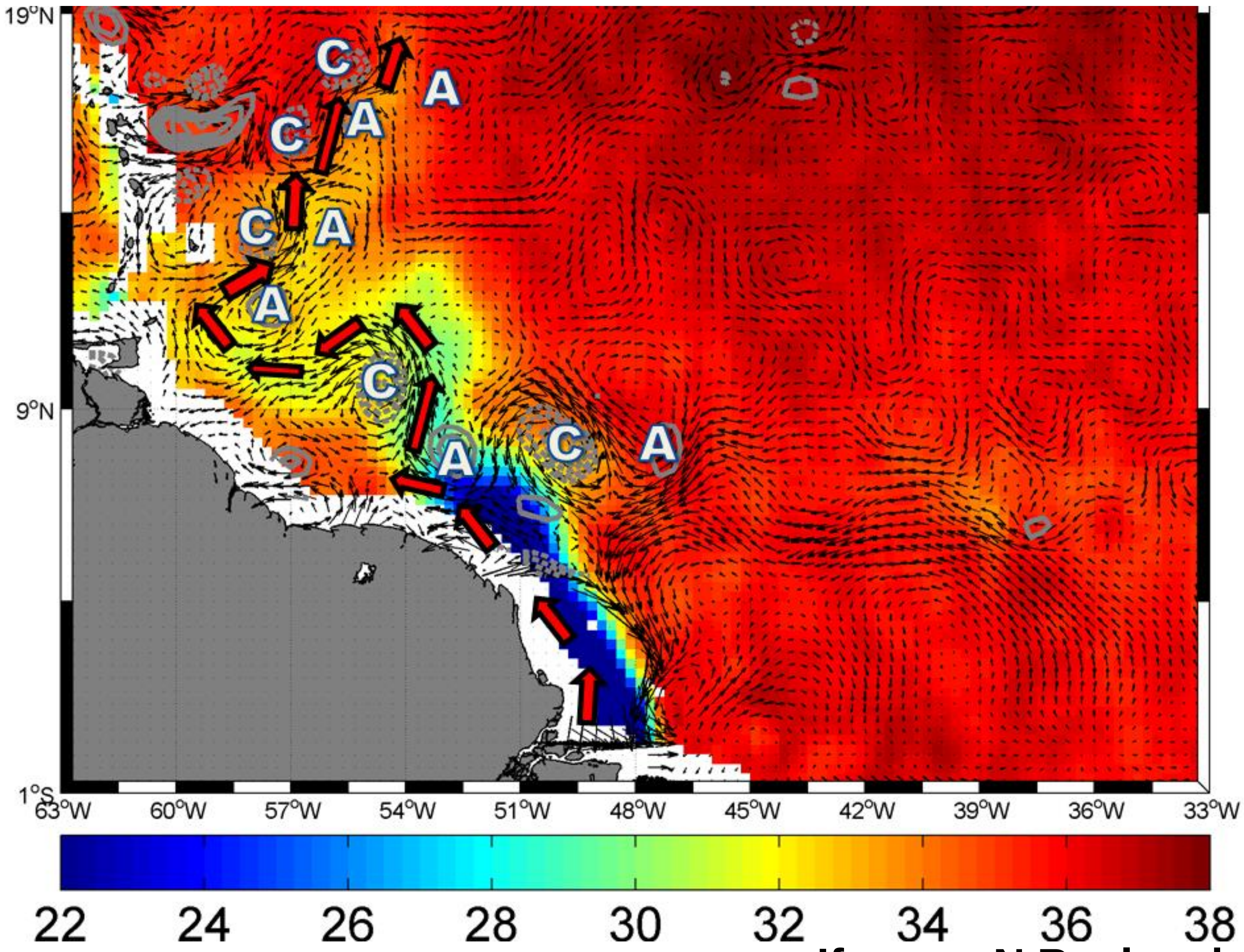


Interesting link with satellite data records of the temperature north of Bering Strait.



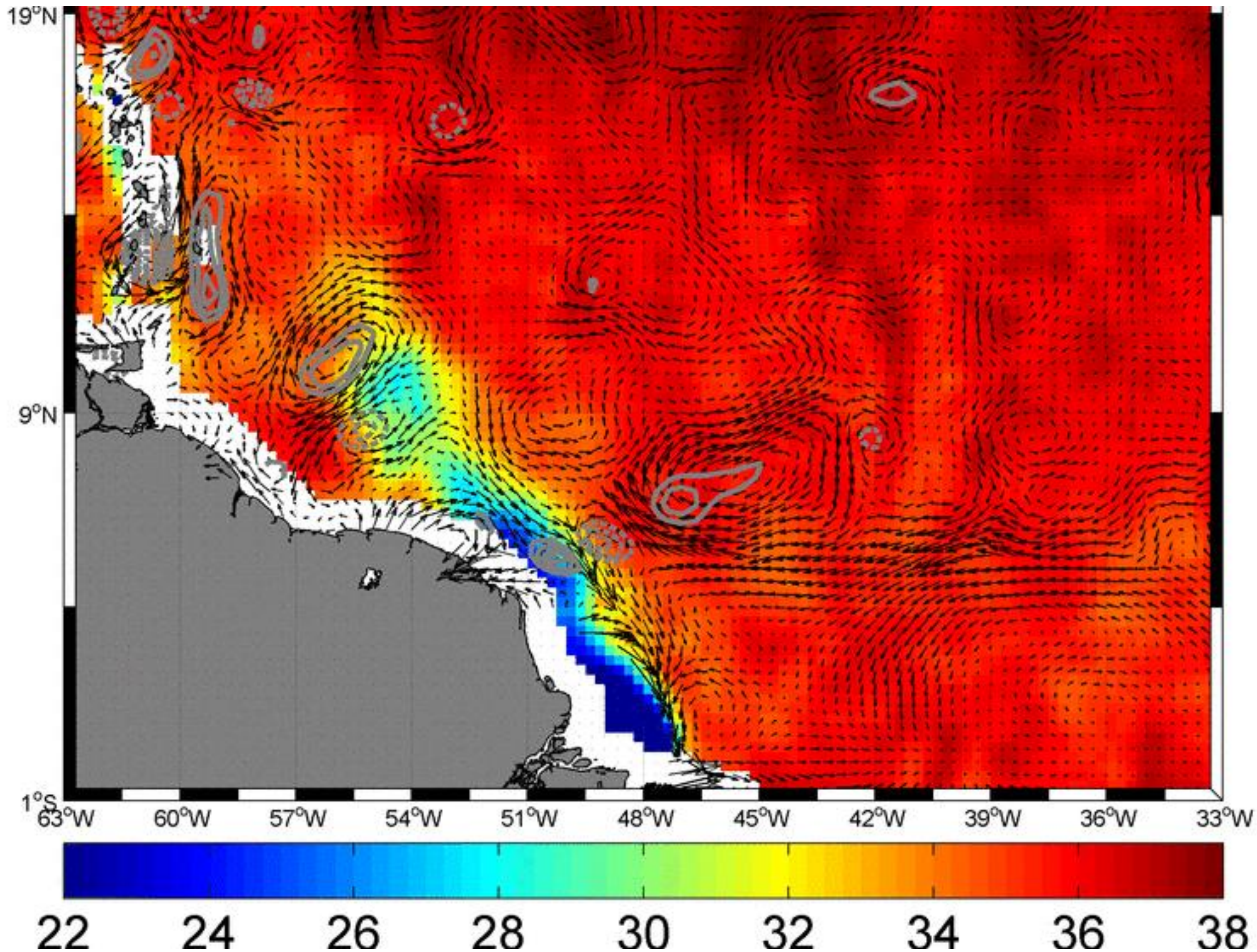
The temperatures were up to 8 K warmer than climatology.

SSS and altimeter currents

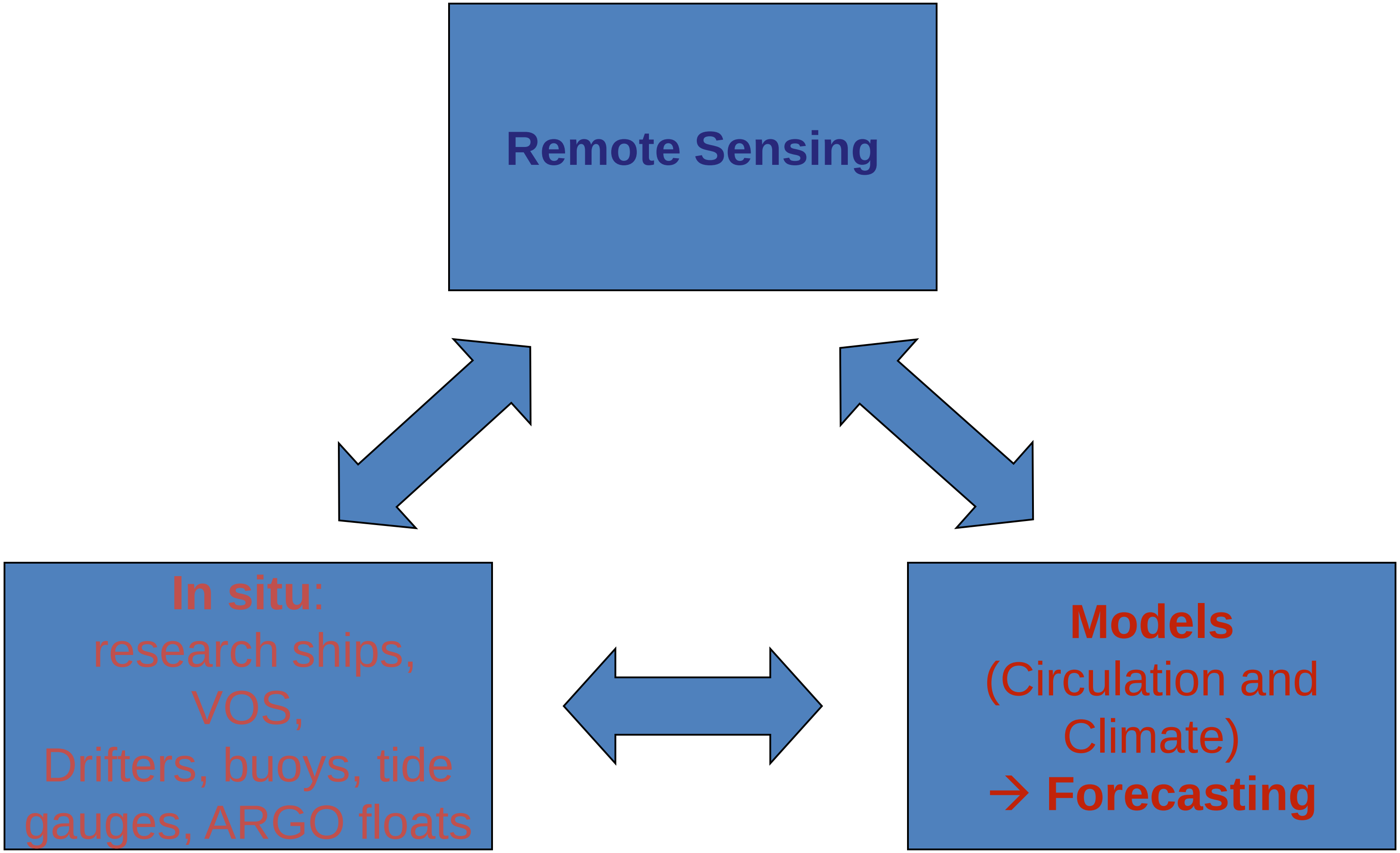


Ifremer: N Reul and J Tenerelli

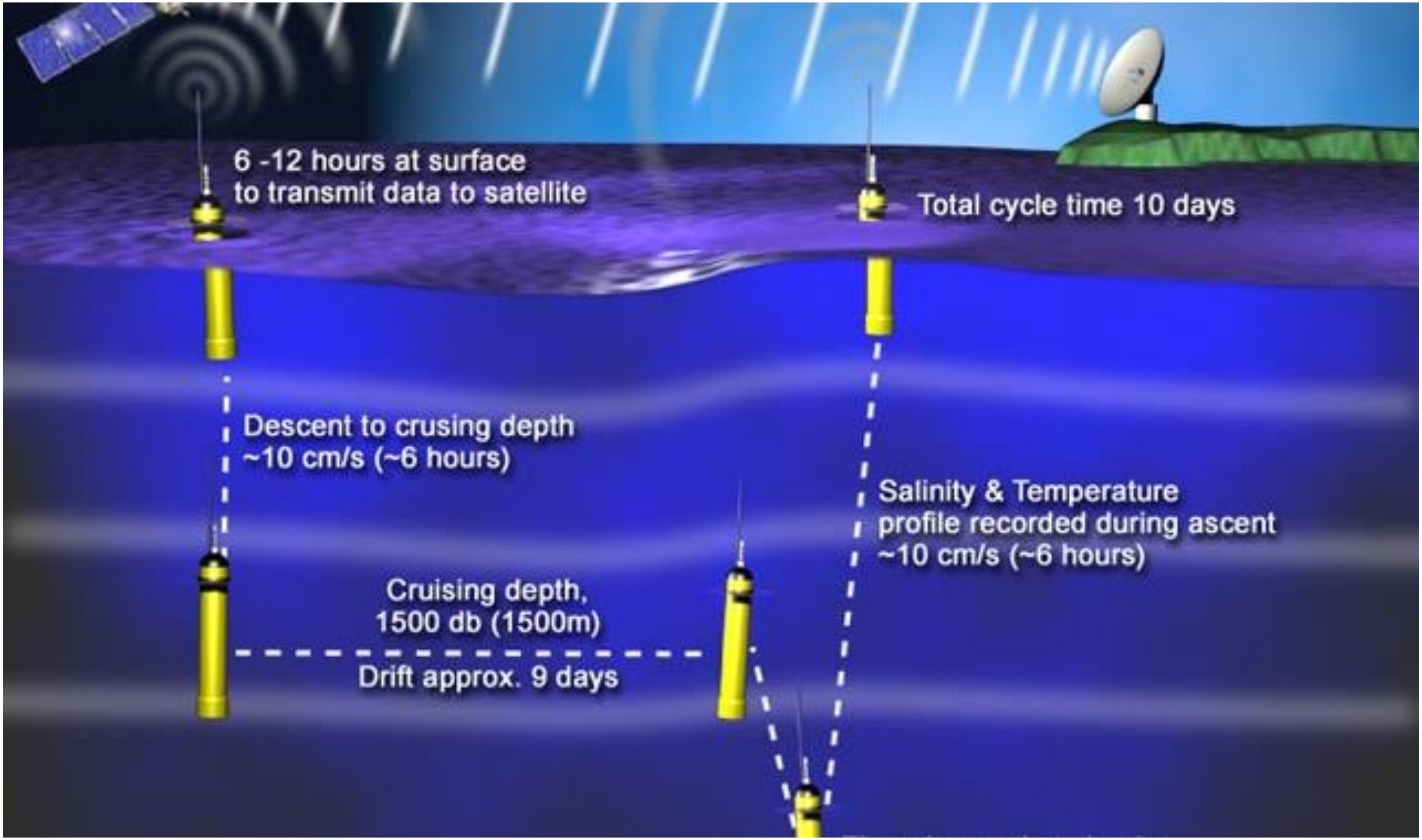
SSS and altimeter currents

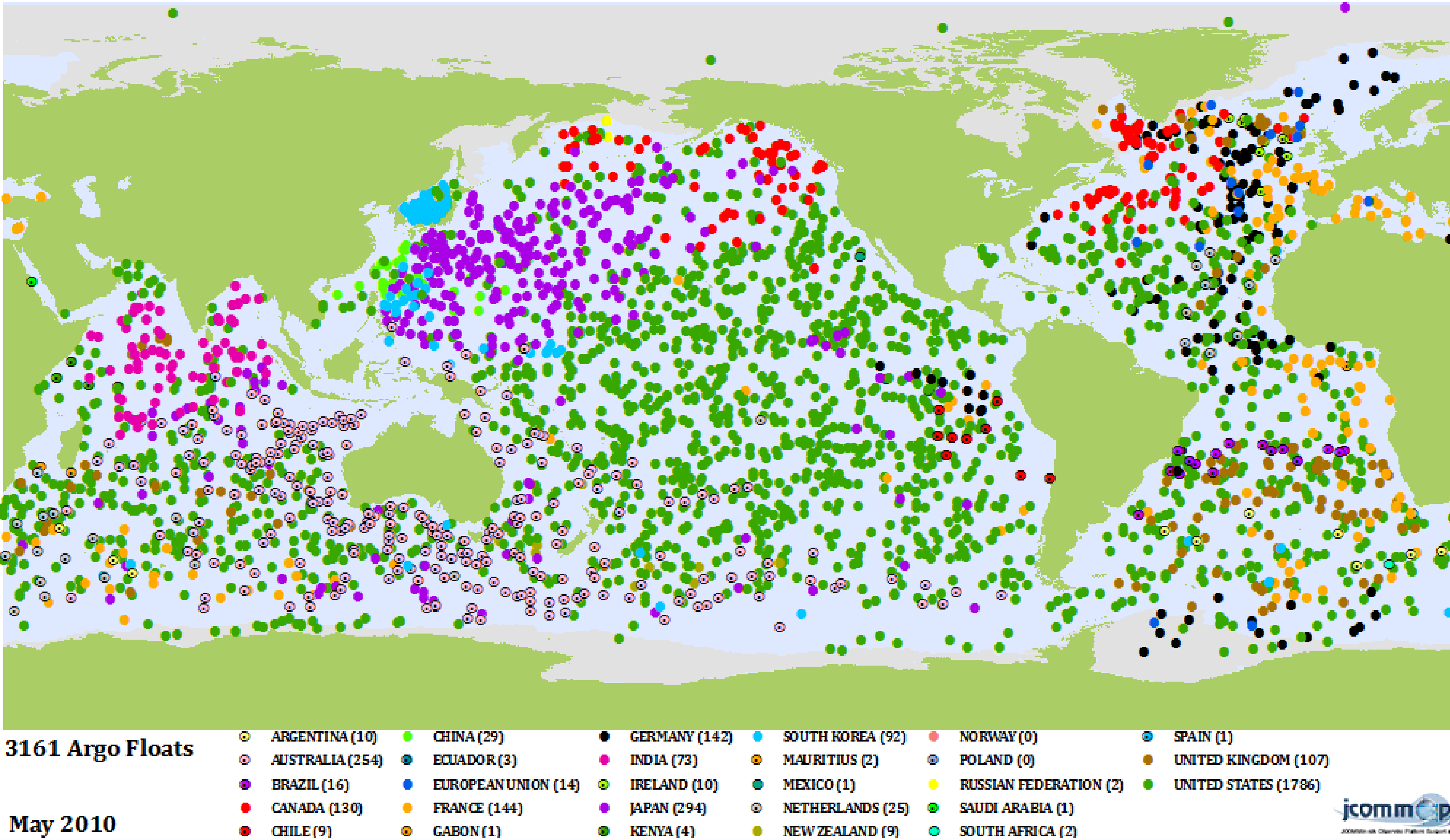


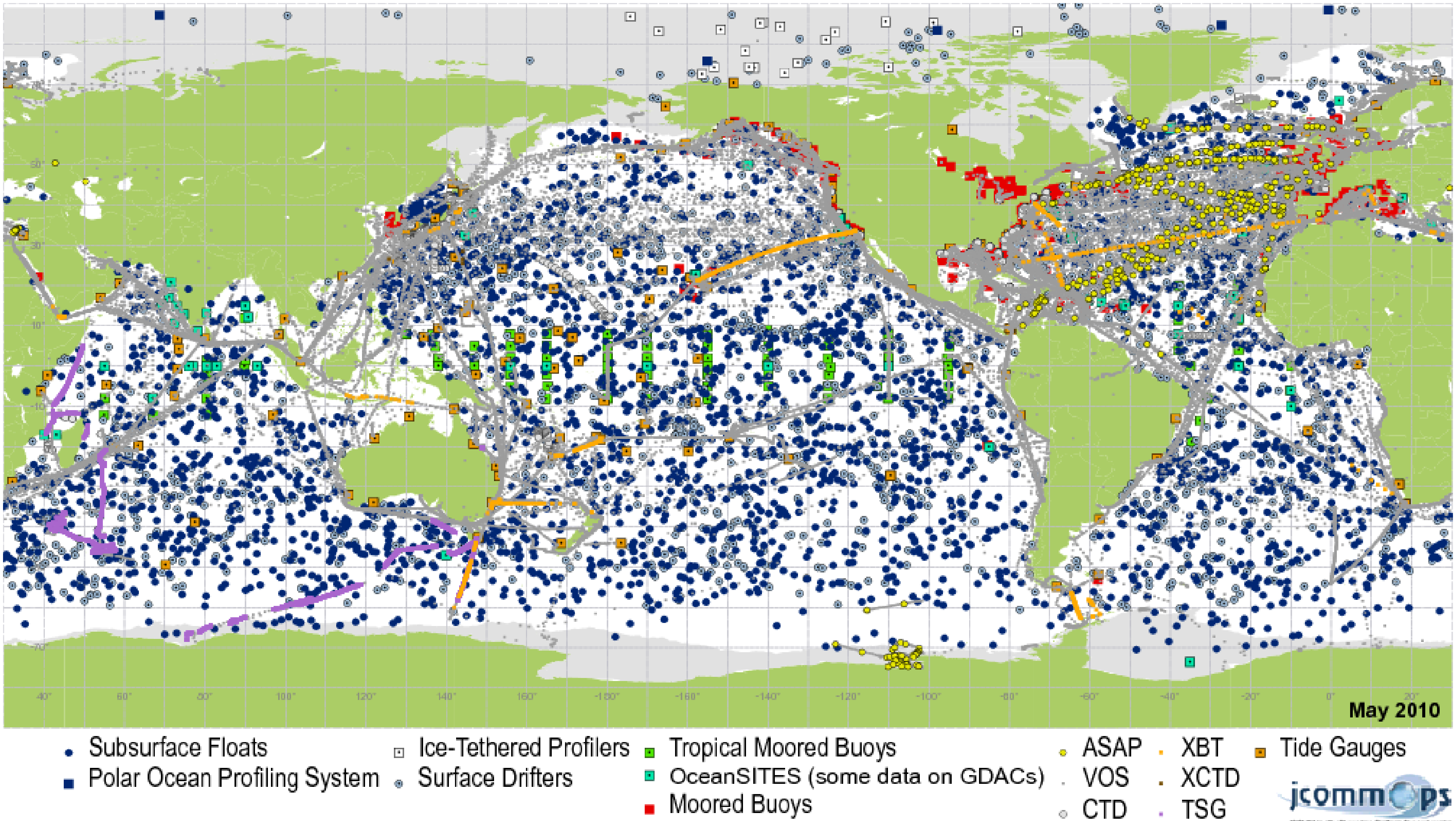
The Observing and Forecasting System



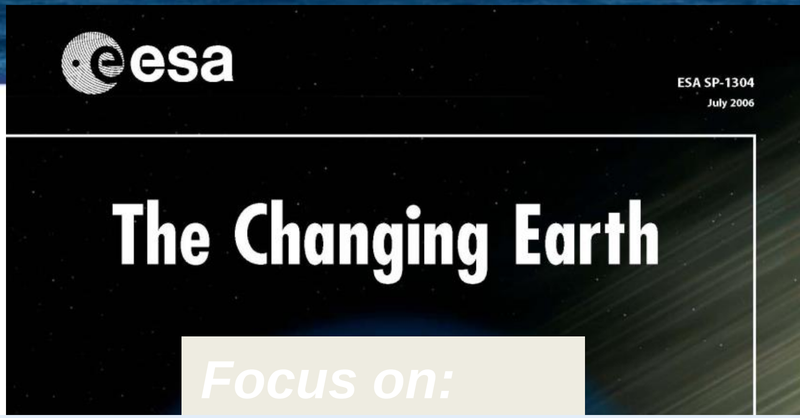
Synergy with Argo




3161 Argo Floats
May 2010
ARGENTINA (10)
AUSTRALIA (254)
BRAZIL (16)
CANADA (130)
CHILE (9)
CHINA (29)
ECUADOR (3)
EUROPEAN UNION (14)
FRANCE (144)
GABON (1)
GERMANY (142)
INDIA (73)
IRELAND (10)
JAPAN (294)
KENYA (4)
SOUTH KOREA (92)
MAURITIUS (2)
MEXICO (1)
NETHERLANDS (25)
NEW ZEALAND (9)
NORWAY (0)
POLAND (0)
RUSSIAN FEDERATION (2)
SAUDI ARABIA (1)
SOUTH AFRICA (2)
SPAIN (1)
UNITED KINGDOM (107)
UNITED STATES (1786)



Note: Last Locations for platforms. For Ships all locations during the month are presented.



- SP-1304 Science Strategy for ESA's Living Planet Programme, issued in 2006 after broad user consultation

The Challenges of the Oceans

Challenge 1: Quantify the interaction between variability in ocean dynamics, thermohaline circulation, sea level, and climate. ✔

Challenge 2: Understand physical and bio-chemical air/sea interaction processes. ✔

Challenge 3: Understand internal waves and the mesoscale in the ocean, its relevance for heat and energy transport and its influence on primary productivity. ✔

Challenge 4: C ... cal, biological a ...

Challenge 5: U ... ng. ✔

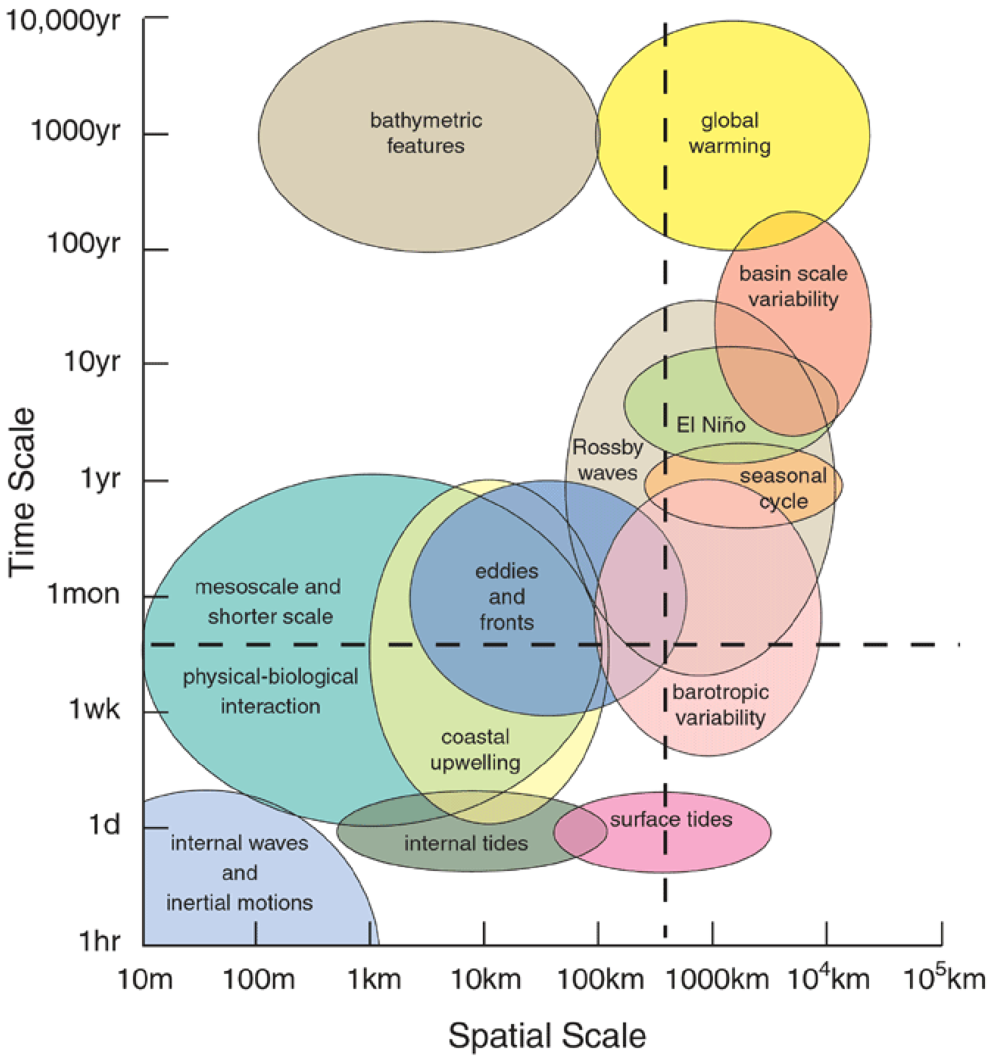
Challenge 6: Provide reliable model- and data-based assessments and predictions of the past, present and future state of the ocean. ✔

Being reviewed and updated, following in-depth discussion at Living Planet Symposium 2013

Available from http://esamultimedia.esa.int/docs/SP-1304.pdf

So many scales in the ocean….

With remote sensing we measure all these!



In summary….

- **Oceans are crucial** – to man & the climate system
- Remote sensing allows us to measure a range of oceanic parameters in a **synoptic** and **repeated** way like no other technique does; and the remotely-sensed parameters are useful in countless applications from the coastal/local/regional scale to the large/global scale (and to monitor climatic trends)
- The complexity of the techniques for remote sensing of the ocean call for a **new breed of scientists**, **specially trained to exploit the richness of information** in ocean remotely sensed data and the many **synergies** with in situ data and numerical models, using oceanographic knowledge and signal processing and statistics skills
- Those scientists are **you!**

Comments? Ideas? Get in touch: cipo@noc.ac.uk