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SPACEBORNE ACTIVE REMOTE SENSING:

- ALTIMETRY
- CLIMATE CHANGE ISSUES

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SUMMARY

- SATELLITE ALTIMETRY: PRINCIPLE OF MEASUREMENT, JASON SATELLITES, PHENOMENA OBSERVED
- CLIMATE CHANGE AND REMOTE SENSING
- OPERATIONAL OCEANOGRAPHY

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SATELLITE ALTIMETRY: INTRODUCTION

- **Seventy-one per cent of the planet's surface is covered by water** and a key dimension to understanding the forces behind changing weather patterns can only be found by mapping variations in ocean surface conditions all over the world and by using the collected data to develop and run powerful models of ocean behaviour.
- Combining oceanic and atmospheric models $\Rightarrow$ accurate forecasts on both a short- and long-term basis.
- Coupling of oceanic and atmospheric models needed to take the mesoscale (medium-distance) dynamics of the oceans $\Rightarrow$ **weather forecasting** beyond two weeks.
- The oceans are also an important part of the process of climate change and a **rise in sea levels** all over the world is widely recognized as potentially one of the most devastating consequences of global warming.

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SATELLITE ALTIMETRY

JASON 1, 2 SATELLITES: CNES, NASA, NOAA and EUMETSAT

Measurements:

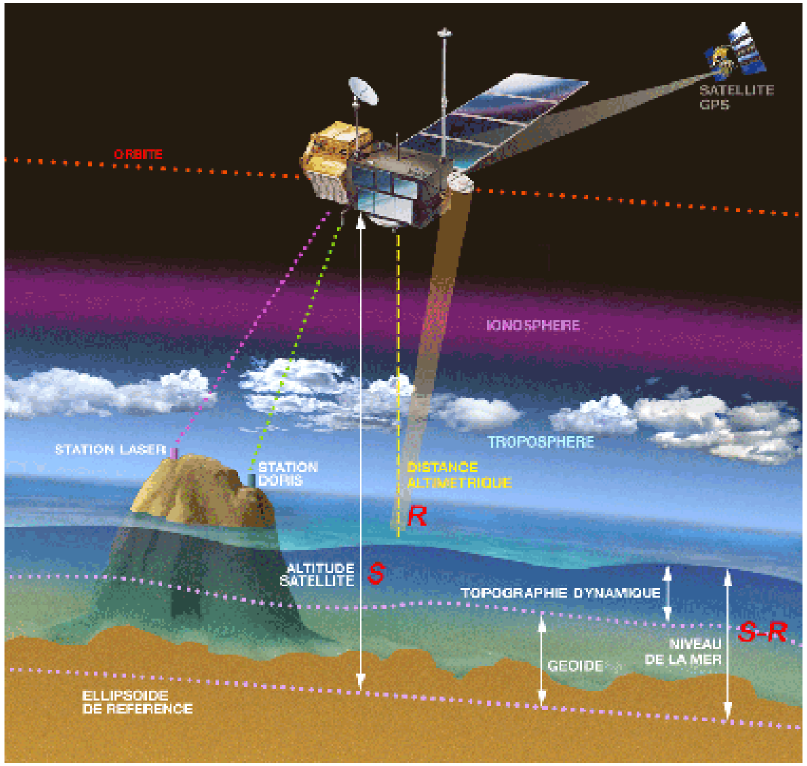
● Distance between the Satellite and the sea

● wave height

● wind speeds

Accuracy:

- Range to surface (cm, corrected) : 2.3
- Radial orbit height (cm) : 1.0
- Sea-surface height (cm) : 2.5
- Wind speed (m/s) : 1.5



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SATELLITE ALTIMETRY

- Altimetry is a technique for measuring height. Satellite altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Combined with precise satellite location data, altimetry measurements yield sea-surface heights.
- TOPEX-POSEIDON launched on August 10, 1992, decommissioned late 2005.
- Jason-1 satellite was launched on December 7, 2001.
- Jason-2 satellite was launched on June 20, 2008.
- Orbit :
  - Altitude 1336 km, circular, non-sun-synchronous
  - 66° inclination, global data coverage between 66°N and 66°S latitude
  - 10-day repeat of ground track (±1-km accuracy)
  - coverage of 95% of ice-free oceans every 10-days

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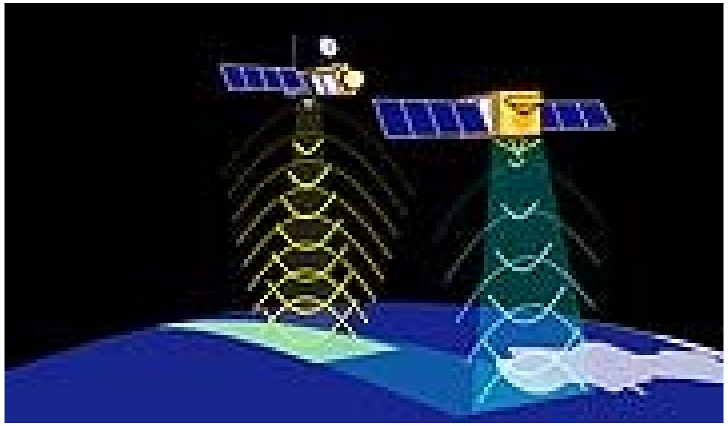
SATELLITE ALTIMETRY: tandem mission



- After launch of Jason-2 , the satellite moved into position along the same *ground track* and ahead of Jason-1, and the two spacecrafts make measurements in tandem.
- As with the TOPEX/Poseidon and Jason-1 Tandem Mission, which lasted more than four years, the near simultaneous measurements from the same altitude of the same sea surface locations by the Jason-1 and Jason-2 altimeters allow scientists to compare and correlate the two altimetry measurements. These careful comparisons ensure that Jason-2 continues adding seamlessly to the sixteen years of TOPEX/Poseidon and Jason-1 data. This long, continuous time series of data is critical for improving climate prediction capabilities.

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TECHNOLOGY: computation of sea level

- To calculate sea-surface height (or sea level): need to know the satellite's exact position.

- Three 3 positioning systems — DORIS, LRA and GPSP — are used. These systems complement each other to give the satellite's position with centimetre accuracy.

- Altimeter measurements are distorted by water in the atmosphere. To correct for this error, the Advanced Microwave Radiometer (AMR) collects 3 signals at different wavelengths from the ocean. The AMR is a passive sensor that collects certain signals from the ocean and deduces atmospheric parameters, for example, clouds and wind speed. Each signal is sensitive to a different parameter: the speed of the 1st signal is affected by water vapour, the 2nd by surface wind effects and the 3rd by non-precipitating clouds.

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TECHNOLOGY: computation of sea wind

Estimates of wind and waves from altimeter: analysis of the return from the sea surface: peak backscattered power and shape of the waveforms.

- Back scatter, σo, from the sea surface: sensitive to small scale surface roughness (short ocean waves).
- σo is the primary variable used in estimating wind speed.
- σo sensitive to much larger waves that are only related weakly to the local wind ⇒ recent algorithms for wind speed also include the altimeter estimate of significant wave height.
- Significant wave height (SWH) can be estimated using the return pulse by large waves, since the radar signal can be reflected from both the troughs and peaks of waves. The sea surface height is usually estimated from the centre point of the leading edge.

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CLIMATE CHANGE ISSUES

- Climate change has now become a reality and the data accumulated since for years show that the climate is warming on a global scale
- Today, climatology relies increasingly on space technology. Earth observation delivers series of precise, global measurements matching the scale of planetary climate phenomena.
- Remote sensing is the acquisition of physical data without touch or contact. It is a form a vision but nothing new. ⇒ ***Focus on the usage of the electromagnetic spectrum and of Earth Observation satellites to monitor some aspects of climate change***.
- Importance of the ITU-R Radio Regulations to protect the Earth Exploration Satellite frequencies.

MEAN SEA LEVEL RISE

- **Global mean Sea Level rise is one of the consequences of global warming**. Monitoring this level is an application of altimetry, and one of the main issue in Environmental sciences of the 21st century.
- It is quite **difficult to separate the natural variability of the climate from the warming effects**. The *measurements of the mean sea levels are derived from a period of time of* ***15 years*** *of satellite earth observation*: **<u>such a period of time is short</u>**. In addition to that, it is necessary to indicate that human induced peturbation is added to the natural climate variability.
- Climate change signals can be detected only if they are greater than the background natural variability. Detecting global climate change is much more demanding than monitoring regional impacts.
- Need to have a stable environnment and time series must be stable and accurate.
- The rise of the sea level is mainly a consequence of past climatic events. The following figure shows that the rise is about **<u>3,4 mm per year, roughly 5 cm within 15 years.</u>**

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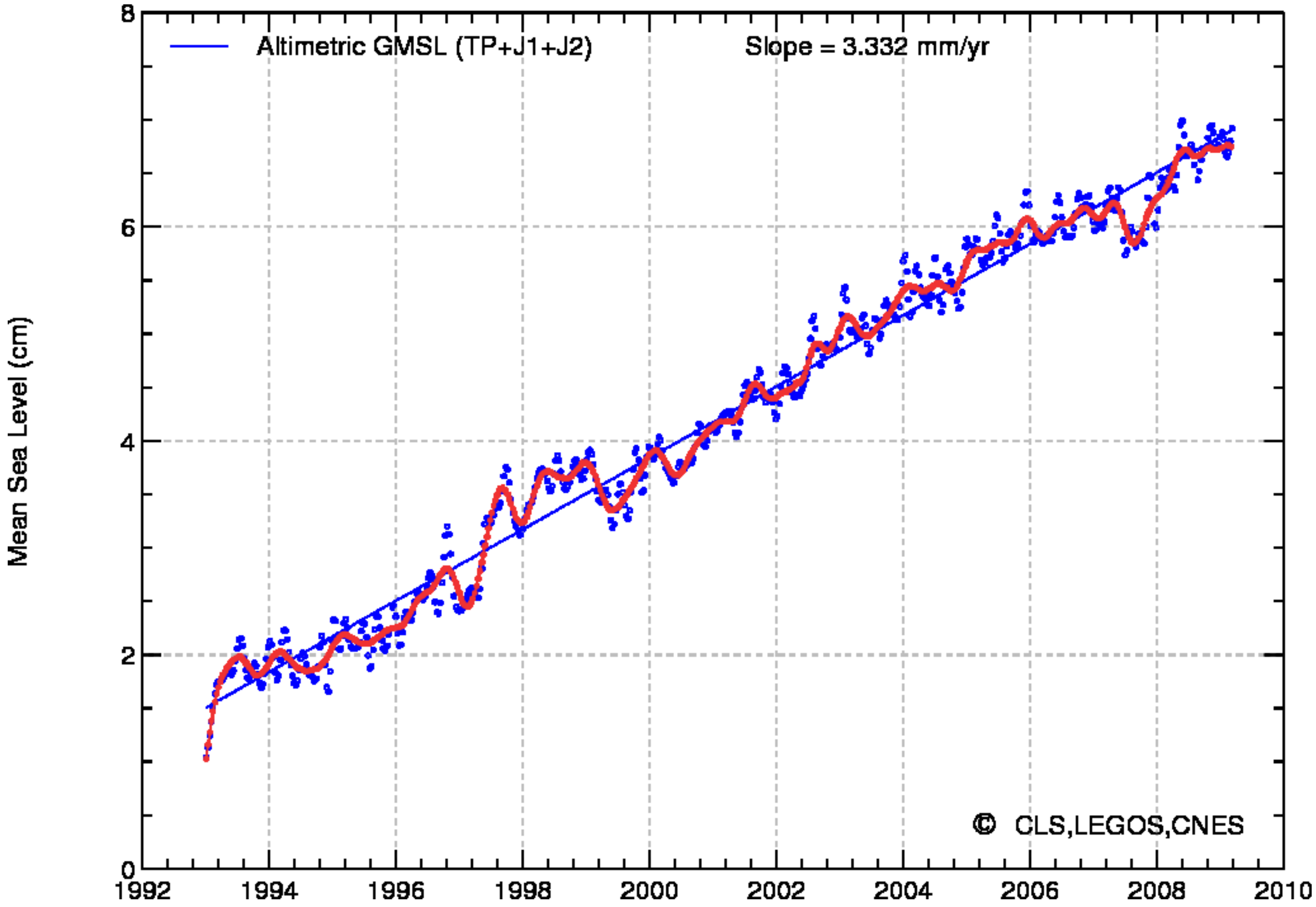
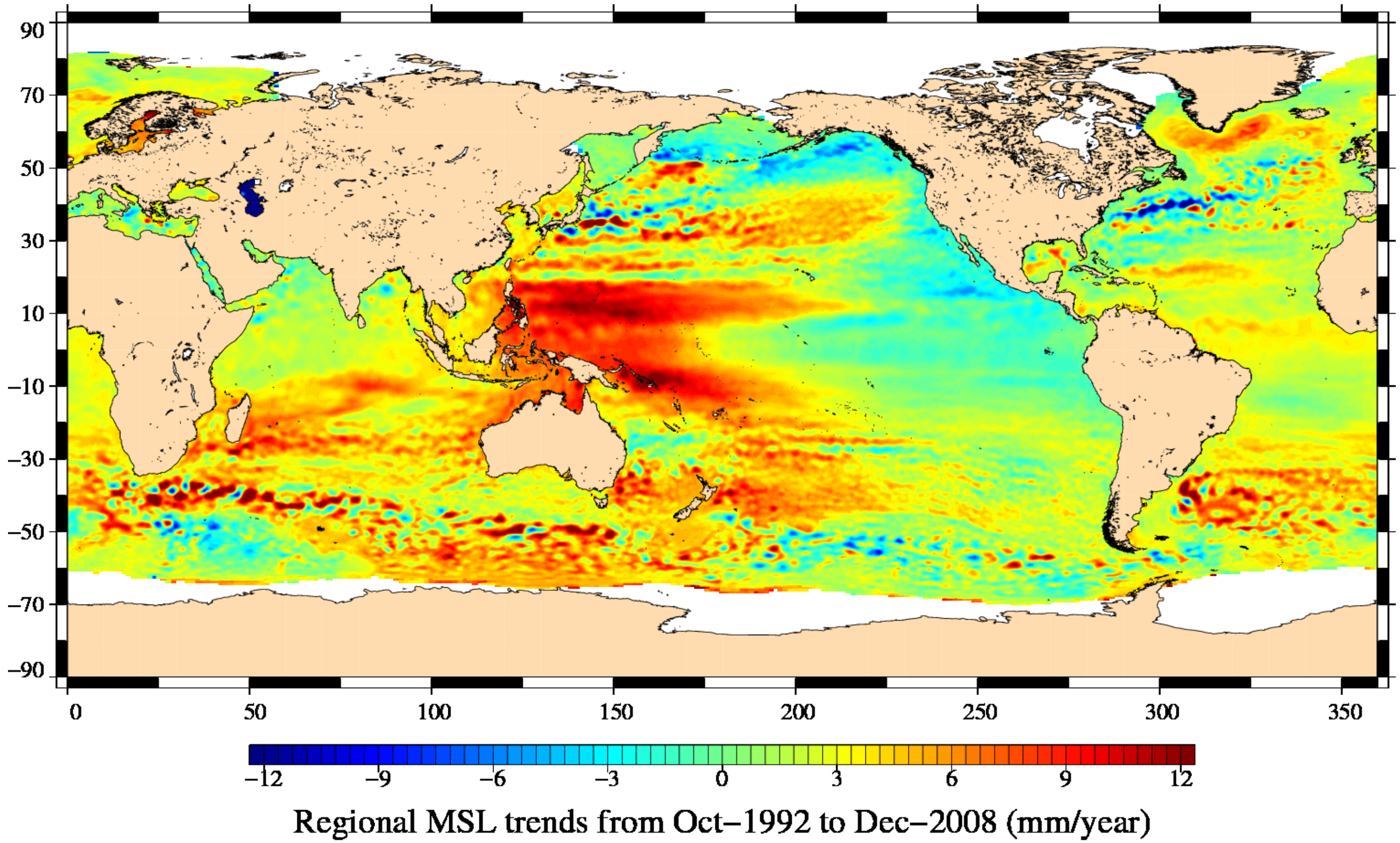
MEAN SEA LEVEL RISE



Map of sea level variation trends since 1992: regional trends



Sea level variation trends since 1992: regional trends

- The rise in the level of the oceans is far from uniform. In certain ocean regions the sea level has indeed risen (up to 20 mm/year), in others it has fallen an equivalent amount.
- One reason for the rise of the sea level is the thermal expansion (see next slide for the whole set of reasons). Such reason explains the regional differences. The rise of the Western Pacific Ocean has been about 3 times higher than the average rise level.
- These regional differences have to be better taken into account within the climate models. It is quite difficult when some islands within the pacific or indian oceans will disappear under the water.

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WHAT IS MAKING THE OCEANS RISE?

Mean sea level rise causes are better and better known. Comparison between measurements coming from different techniques enables to better specify the various contributions between water exchanges, thermal expansions, etc. Other measurements enable to estimate ice melting (glaciers and indlandsis), continental water storage variations, etc.

Changes in water temperature impact sea level variations. As water warms, it expands and its volume increases, causing levels to rise.

The quantity of salts in the water has also an influence on sea level, since it changes the water density. The more salty the water, the denser it is, and the lower the level. ⇒ See presentation on SMOS

Thermal expansion		**1.6 +/- 0.5 mm/yr**	
Glaciers and ice caps		**0.77 +/- 0.22 mm/yr**	
Greenland ice sheet		**0.21 +/- 0.07 mm/yr**	
Antarctic ice sheet		**0.21 +/- 0.35 mm/yr**	
Sum	**2.8 +/- 0.7 mm/yr**	**Observed**	**3.1 +/- 0.7 mm/yr**

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MEAN SEA LEVEL RISE: discussion

- The mean sea level rise was about 1.7 mm per year the last 50 years. However, since 1990, this rise began to be 3.4 mm per year. This sudden rise increase has been observed mainly through satellite observations.
- However, in the past, there were periods lasting between 10 and 20 years showing a sudden rise or a sudden decrease.
- Therefore, the current observed mean sea level rise for about 15 years does not reflect the acceleration of climate change. The reasons of the “slow” acceleration of the rise sea level are not yet clarified.
- However, the reasons for the sea level rise (see before) are generally approved and there is a general consensus that these phenomena are a consequence of the climate change.
- Moreover, GIEC experts say that the **phenomena of the rise of the sea level should not be reversed**. Higher dramatic figures are currently circulating.

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El *Niño* Southern Oscillation - *ENSO*

- **Better knowledge of ocean circulation is enabling us to better understand and predict climate, especially natural catastrophes such as El *Niño*. This phenomenon, caused by anomalous warm water arrivals on the coast of Peru, brings severe weather patterns, such as drought, flooding, and cyclones. It is now possible to predict El *Niño* from ocean data.**
- **Forecasting El *Niño***
  - **Since the 1990s, an in situ observation system has been set up in the Pacific and new satellites have continuously scanned the global ocean. Though we cannot avoid El *Niño*'s whims, we can predict and mitigate its impacts.**
- **Impacts around the world**
  - **Warm El Niños and cold La Niñas follow each other against the backdrop of the ocean seasons. These surface temperature and sea level anomalies in the intertropical Pacific affect climate worldwide.**

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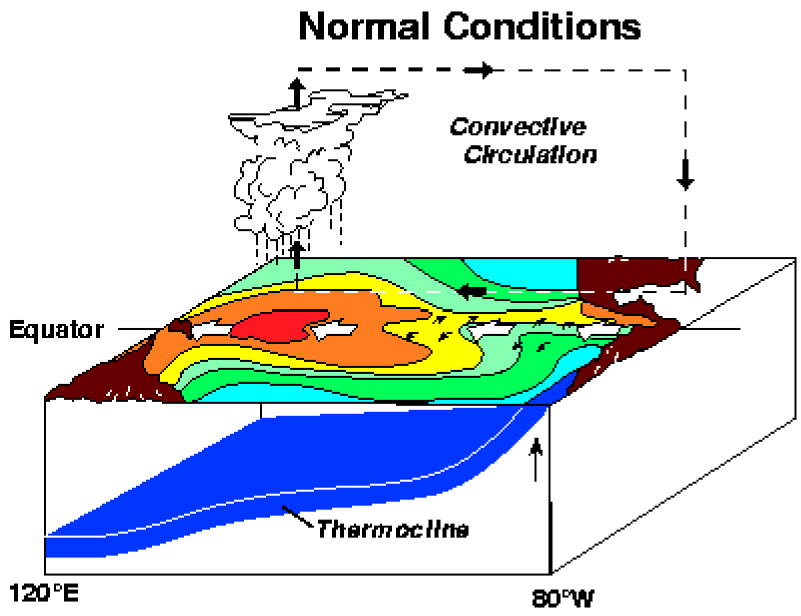
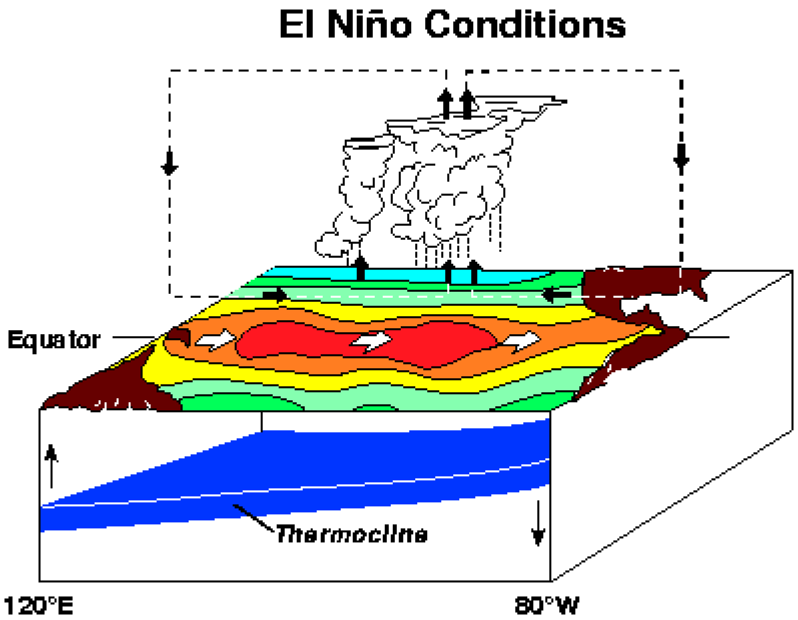
El Niňo



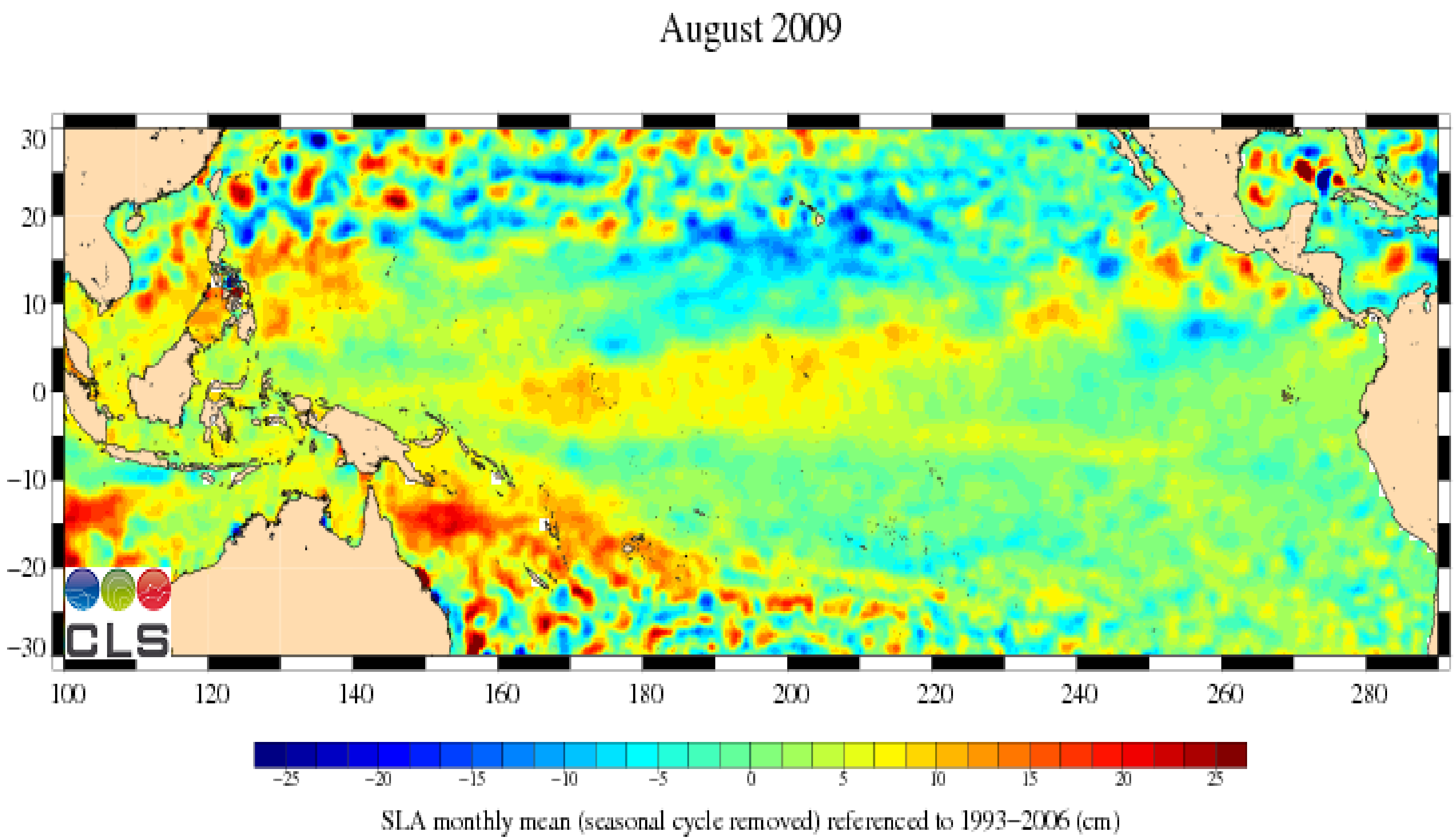


El *Niño* is behind rise in sea level

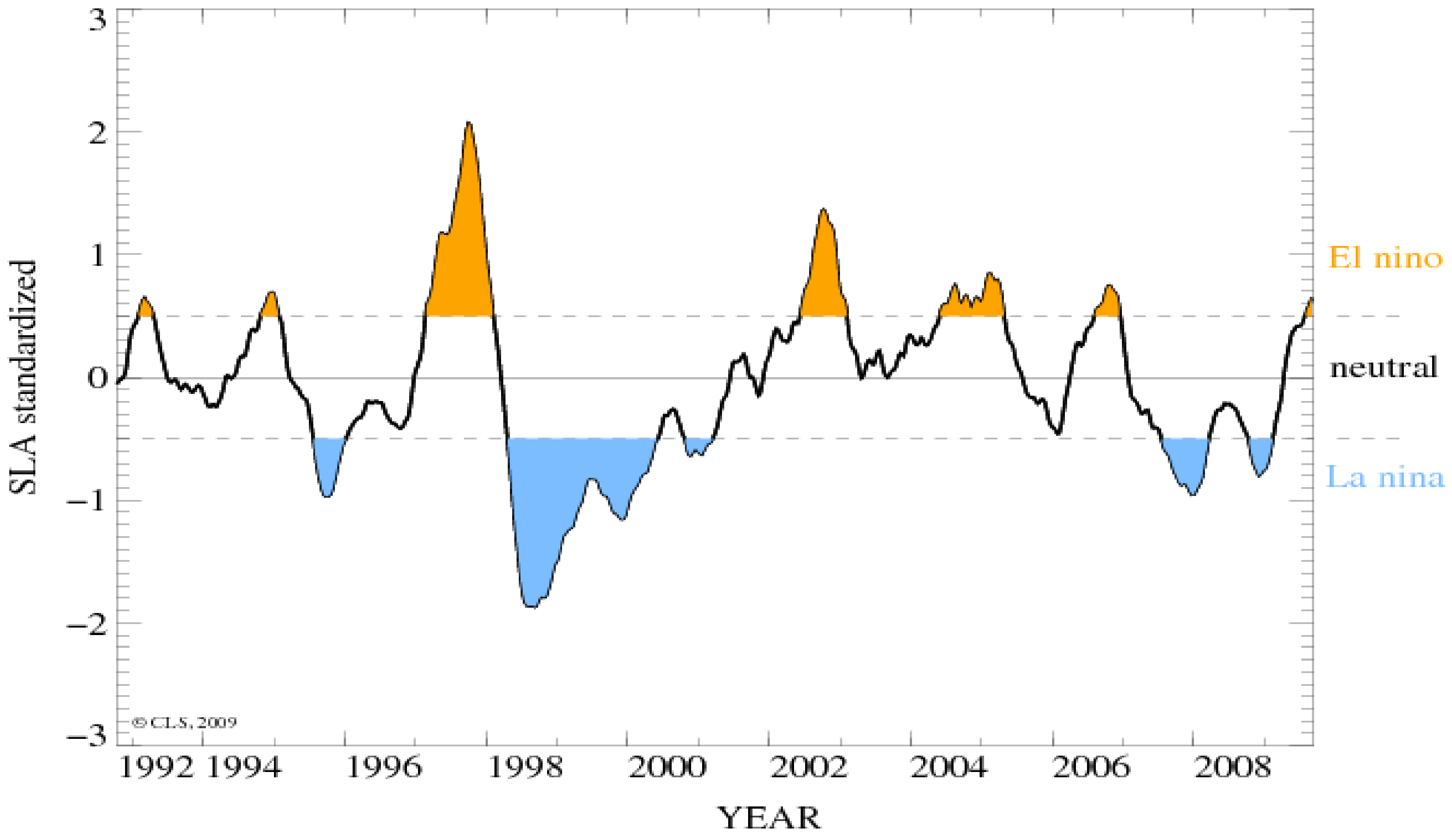
● The meteorological effects of El *Niño* 1997-1998 were felt worldwide, but it also contributed to variations in mean sea level. Indeed, sea level anomalies measured by *Topex*/*Poseidon* were over 20 centimeters in the equatorial Pacific when the phenomenon was at its height (and as much as 30 centimeters off the coast of Peru). These anomalies obviously had an effect on the global mean of sea levels.

● El *Niño* not a consequence of the climate change since it already exists, but could be amplified by the warming climate effect.

El *Niño* bulletin, latest news



Sea Level anomalies over the Pacific basin



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APPLICATION OF ALTIMETRY: SEA CURRENTS, ROUTING THE SHIPS

- Estimates of wind and waves data from altimeter measurements originate in analysis of the return from the sea surface.
- **Accuracy of wind speed (m/s) : 1.5**
- Satellite altimetry useful for ships: the knowledge of the sea currents (derived from observed sea level variations) will allow the ships to optimize their trip.
- Main practical applications of wind and wave data derived from altimeter measurements: **production of reliable atlases of wind and wave climate**. Commercial applications include evaluation of wind and wave energy resource, and evaluation of risks to shipping, marine structures and coastal defences. The usage of the products from the **project Ocean & Weather Routing alows to save fuel for the ships and therefore and has a positive impact on the environnment**.

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MyOcean – Ocean weather bulletins made in Europe

- **Mercator Ocean** has established ties with all the major national and international operational oceanography projects. Many specialists from other organisations are also contributing their experience, work methods, knowledge and specialised skills to enrich the Mercator project.
- **MyOcean**: project granted by the European Commission within the GMES Program: to define and to set up a concerted and integrated pan-European capacity for ocean monitoring and forecasting.

  Areas of benefit are: Maritime Security, Oil Spill combat, Marine Resources management, Climate Change, Seasonal Forecast, Coastal Activities, Ice Survey and Water Quality and Pollution.
- **GMES**: joint initiative of the European Commission and of European Space Agency designed to establish a European capacity for the provision and use of operational information for Global Monitoring of Environment and Security. GMES aims to develop Europe's capability to supply independent and permanent access to reliable and timely information on the status of Earth's environment at all scales, from global to regional and local, in support of EU policy and sustainable development.

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FORECASTING OUT TO 2 WEEKS

- The field of applications is huge: research, professional, civil or military and global or local uses
- There's only one ocean, and users need reliable data on sea state.
- MyOcean's 29 partner nations have formed a network of 12 oceanography data centres.
- Like Mercator Ocean now, the system will depend on data collected directly in situ and from satellites.
- These data will be fed into numerical prediction models to generate real-time analyses and 2-week ocean forecast bulletins.

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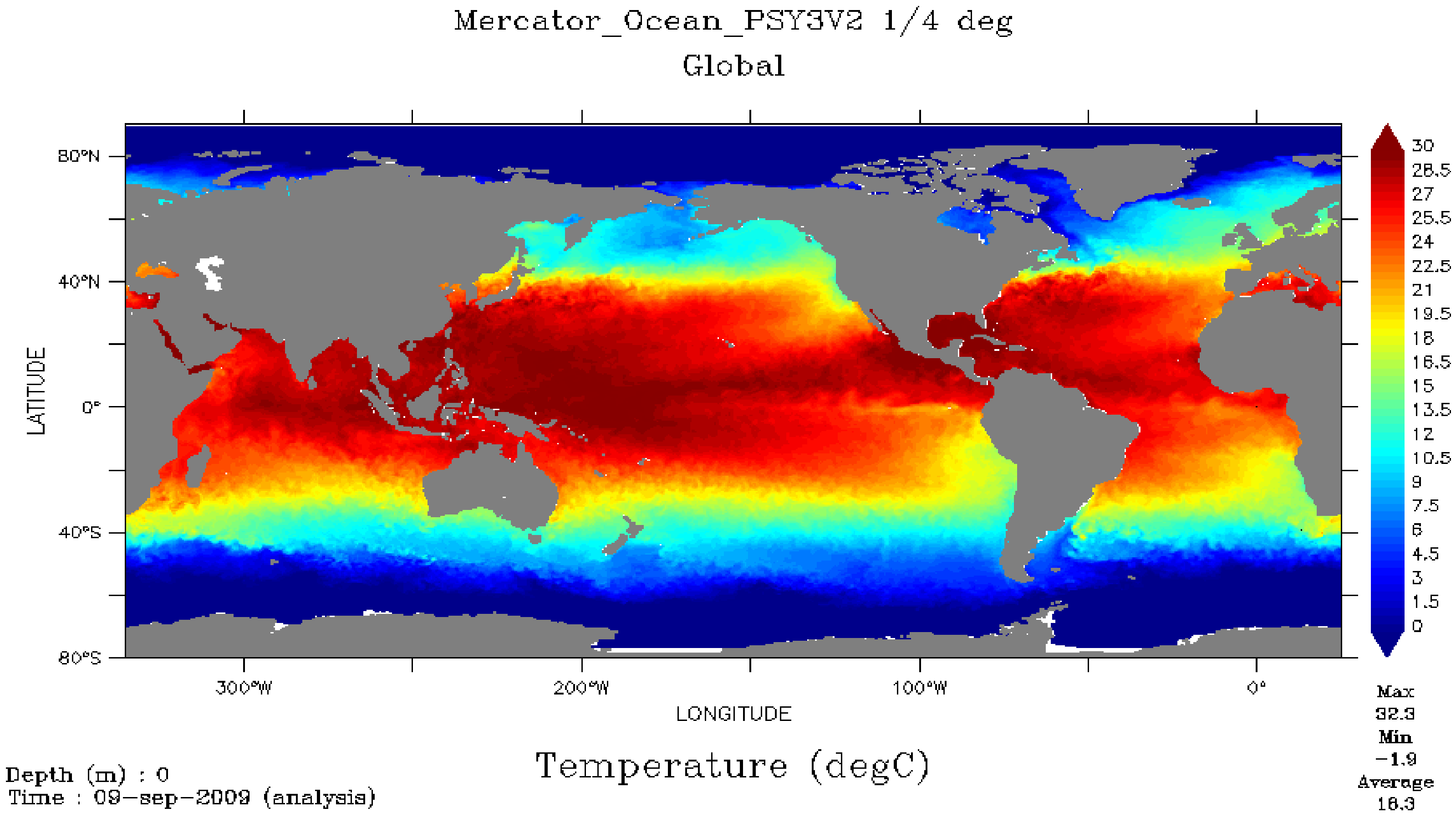
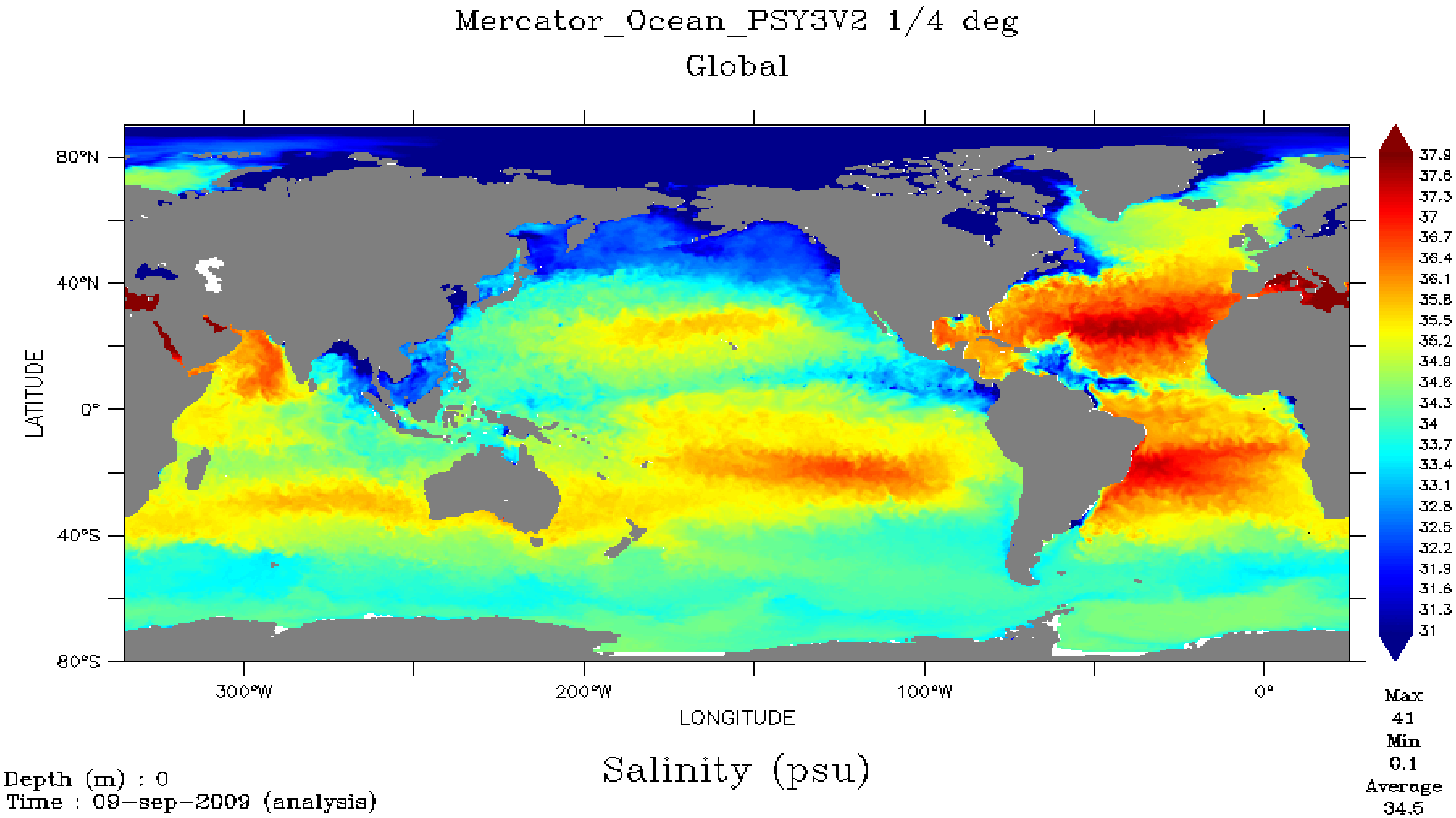
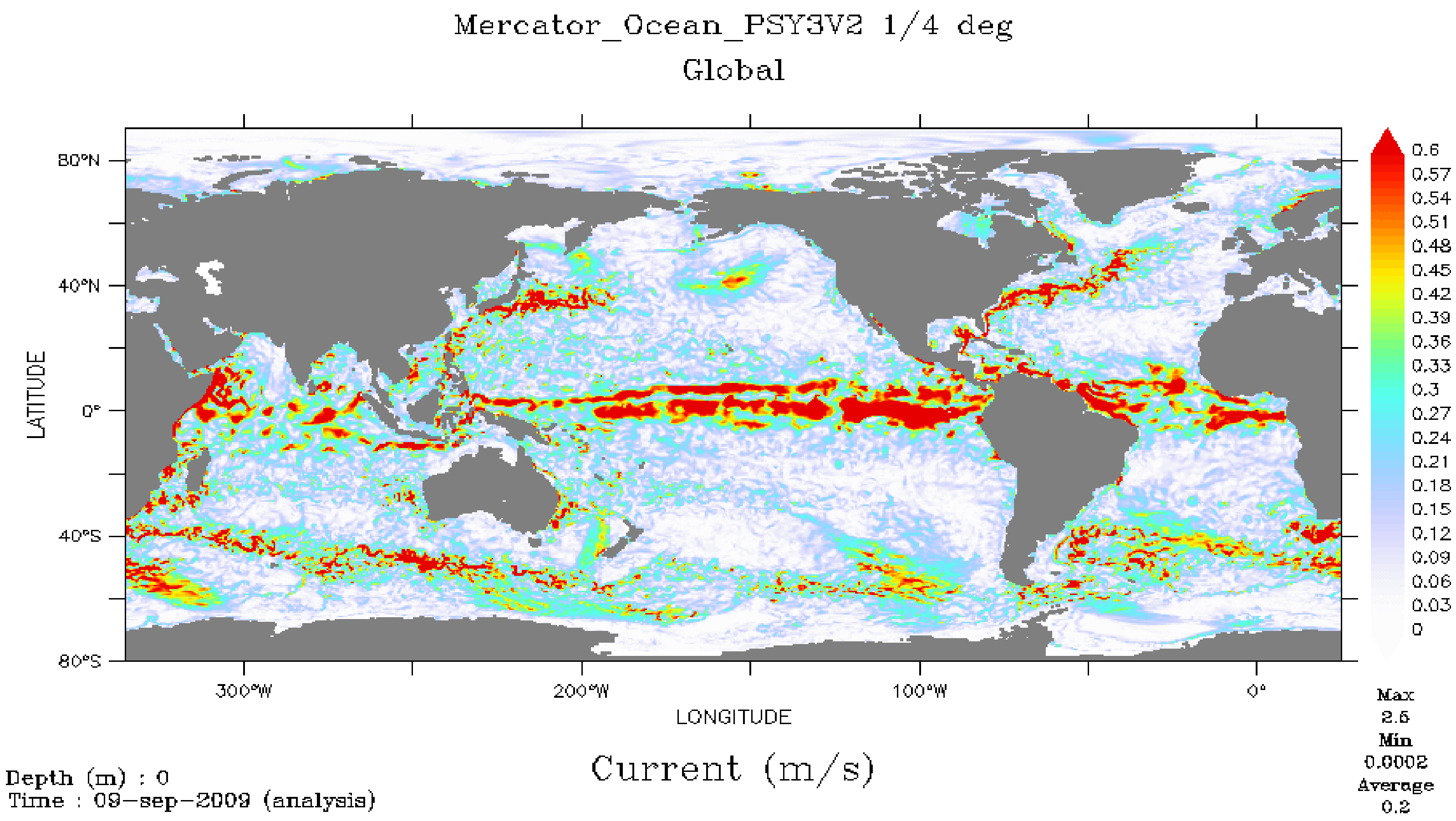
Real-time analysis of the ocean supplied by Mercator Ocean: temperature surface-water



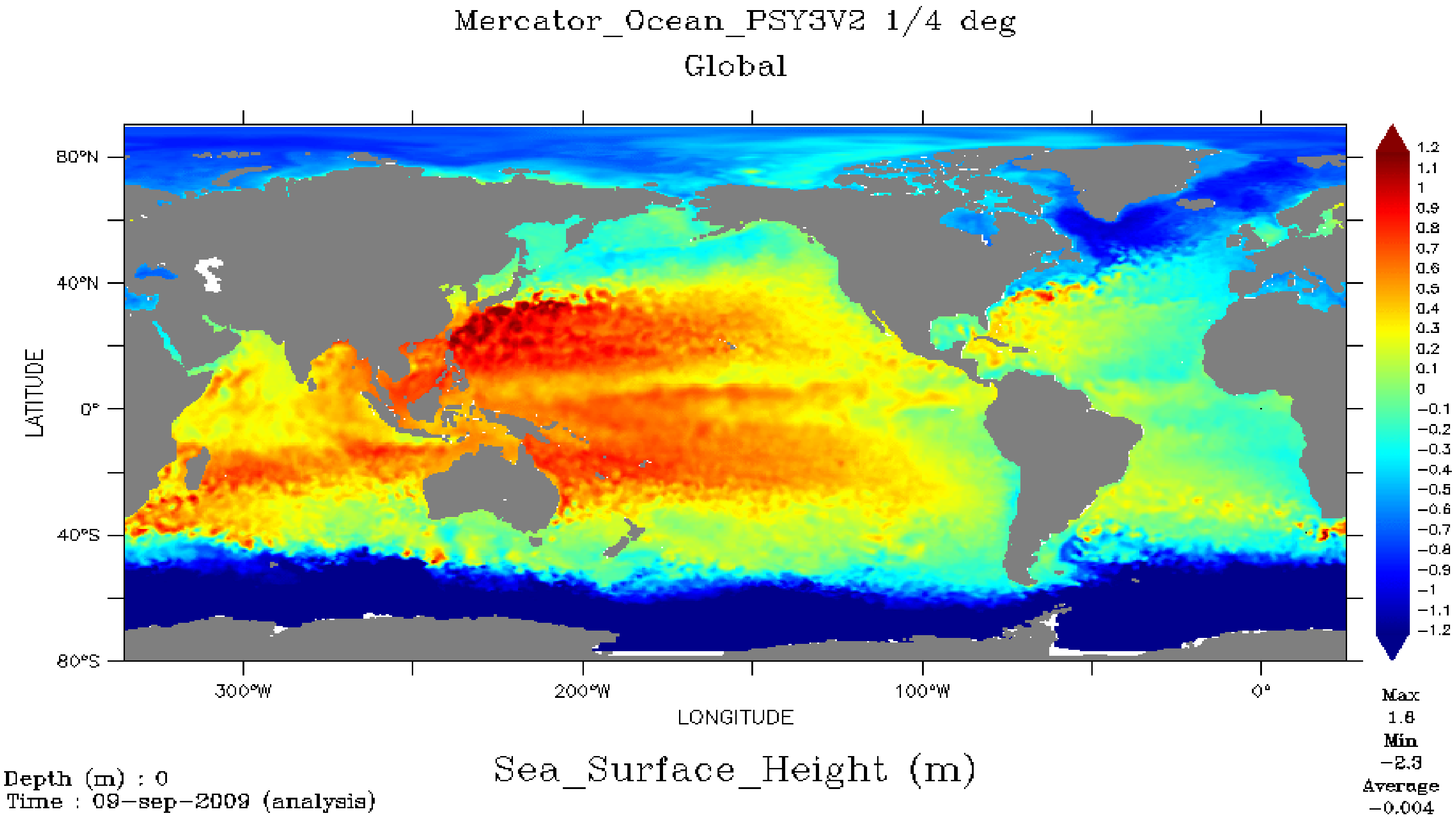
Real-time analysis of the ocean supplied by Mercator Ocean: salinity surface-water



Real-time analysis of the ocean supplied by Mercator Ocean: sea current surface-water



Real-time analysis of the ocean supplied by Mercator Ocean: sea level surface-water



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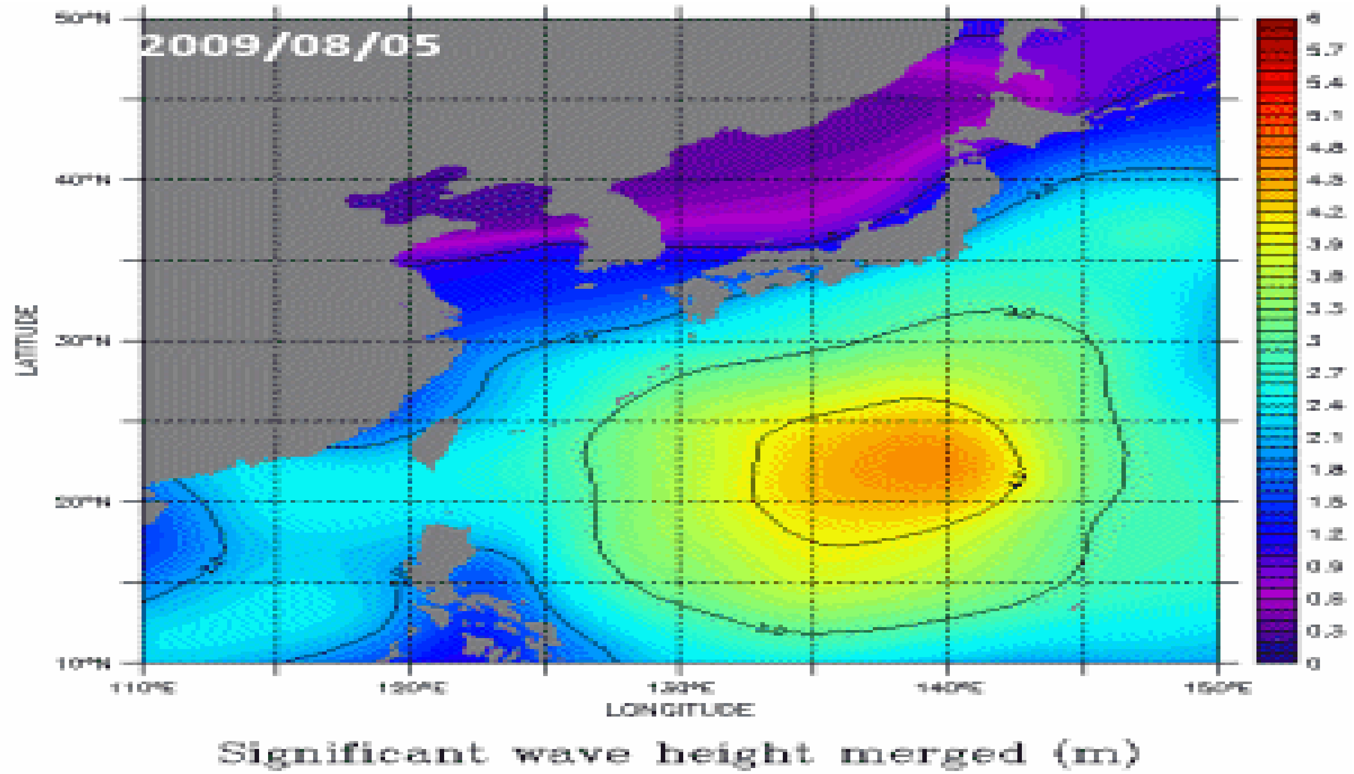
APPLICATION OF ALTIMETRY: CYCLONE MONITORING THROUGH AVISO

A severe typhoon slammed the island of Taiwan (China) early in August 2009. Although it was not classified beyond the Category 2, heavy rains (from 600 to 1000 mm) that caused huge flooding, devastating mudslides and leading to massive losses. Beginning with tropical depression in the Pacific Ocean on August 4, Morakot became a tropical storm and then a typhoon as it neared the eastern side of Taiwan (China) on the August 7. Wind and wave near-real time data deduced from altimetry.



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Frequencies for satellite active remote sensing

- **For most of the EESS (active) sensors, the operating frequency range is linked to the geophysical parameters to be observed. For instance, to enable measurement of clouds and precipitation, the wavelength needs to be small enough to reach the required sensitivity.**
- **For radar altimeters, the main frequencies used are at 5.3 GHz, 13.65 GHz and also at 35.4-36 GHz.**
- **In addition to active remote sensing frequencies, passive frequencies are needed for an accurate estimate of all the output products.**

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CONCLUSION (½): CLIMATE CHANGE

- Changes in weather, climate and the environment pose serious challenges to mankind. Meeting these challenges requires further improvements in weather forecasting, especially for mid- to long-term predictions. If there is a clearer picture of what is going to happen in the next 10 days, the next months - or even in the coming season - people and industries can prepare themselves much better for unstable weather patterns. Meeting these challenges also implies a better understanding of global climatic factors that cause such phenomena as for example El Niño and La Niña in the Pacific Ocean, dangerous hurricanes and typhoons, and especially the potential impact rising sea levels can have on coastlines worldwide.
- The oceans are also an important part of the process of climate change and a rise in sea levels all over the world is widely recognized as potentially one of the most devastating consequences of global warming.

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CONCLUSION (2/2): DATA ASSIMILATION

IT'S ALREADY TOMORROW WITH OPERATIONAL OCEANOGRAPHY

- More and more faster processing systems allowed altimetry data in near real-time.Their assimilation into models, in combination with other data (*in-situ*, water temperature, salinity, etc.) has helped operational altimetry. Mercator Ocean has issued its first ocean bulletin for the North Atlantic on January 17, 2001.
- After more than 15 years of progress in altimetry, it is necessary to continue and to confirm all efforts to ensure a sufficient spatial resolution for mesoscale observation and operational application
- The existence of at least two altimetry satellites in working order is needed for meseoscale observation. For operational applications, three, or even better, four, operational satellites are required.
- Maintaining the avaibility of the active frequency bands is also a fondamental issue.

The story continues …