EL NIÑO and LA NIÑA observed with ERS

Introduction

One of the most interesting aspects of our climate is its variability. ENSO (El Niño and Southern Oscillation) cycles refer to the coherent, large-scale fluctuation in ocean surface and subsurface temperatures, sea level heights, atmospheric winds, air pressure and tropical rainfalls across the tropical Pacific. The terms El Niño and La Niña represent the opposite oceanographic component extremes of an ENSO cycle. El Niño or ‘warm’ episodes are characterized by an increase in the eastern equatorial Pacific sea surface temperatures of 2° to 5° C, while La Niña or ‘cold’ episodes correspond to a decrease of 1° to 4° C in the same area. Generally long-time scale phenomena are often associated with abnormal weather, temperature and rainfall patterns over vast and seemingly unrelated parts of the globe, far larger than a particular affected region. The set of climatic anomalies referred to as ENSO is the most energetic and best defined pattern of interannual variability.
The particular payload configuration of ERS with the Radar Altimeter (RA) and the Along-Track Scanning Radiometer (ATSR) on-board, provides very precise sea surface heights and sea surface temperatures. The quality of the acquired data and the repetitive ERS cycle, which allows frequent global coverage of the earth, made it possible to monitor in high detail the premise of the ENSO cycle that arose around June 1997.

ATSR instrument

The Along Track Scanning Radiometer (ATSR) developed by a consortium of laboratories led by the Rutherford Appleton Laboratory is flying on board the ERS satellites since 1991. ATSR-2 has three visible and near infrared channels centered at 0.55, 0.65, 0.86 µm and 4 Infra Red channels centered at 1.6, 3.7, 10.8, and 12 µm.
The ATSR is an instrument using conical scan system producing a double view of the same surface (55 degrees forward and nadir) with a 512 km swath allowing a full repetitive coverage in 4 days with a resolution of 1km.
The instrument is equipped with a very precise on board calibration system which provides a excellent accuracy of the measurement. Its high radiometric sensitivity -signal to noise better than 0.05 in all MIR and IR channels for temperature higher than 270 K- together with the 12 bits digitalization enable the detection of fine sea structures and sea temperature variation.
The same instrument, but enhanced will continue to fly on ENVISAT-1 to be launched end 1999. This would ensure the continuity of the measurements.

ATSR data

The sea surface temperature was monitored using the SADIST-2 products Averaged Sea Surface Temperature (ASST). Monthly composites were created for the observation of ENSO. Monthly sea surface temperature means were compared to data acquired in 1995 during the same month. This implies that no annual cycle is present anymore in the sea surface temperature anomalies, shown in the images.
The ASST products have been produced by Rutherford Appleton Laboratory (RAL) except for the months of May and June 1999. For the composites of these months ASST products were processed at the near-real time service of Trømsoe Groundstation, which is now operational. At Trømsoe 10 orbits out of 14 are daily being processed and made available on-line.

RA instrument

The ERS-2 Radar Altimeter is a Ku-band (13.8 GHz) nadir-pointing active microwave sensor designed to measure the time return echoes from ocean, ice and land surfaces. These measurements are repeated 1000 times per second and are averaged for noise reduction purposes to provide one measurement every 7 km along the track.

Satellite altimeters consist of a transmitter that sends out short chirped pulses, a receiver to record the pulses after they are reflected by the surface below (e.g., the ocean surface) and an ultra-stable and accurate clock to measure the time interval between emission and reception. The height of the sea surface can be determined by differentiating the orbital altitude of the satellite and the radar range measurement.

Furthermore, the slope of the echo leading edge is related to the height distribution of the reflecting facets and thus to the ocean wave height. Finally, the power level of the echoed signal depends on small-scale surface roughness and thus on wind speed.

The same type of instrument, but greatly improved will continue to fly on ENVISAT-1 to be launched end 1999. This will ensure the continuity of the measurements.

RA data

For the monitoring of the sea level height the OPR (Ocean Product) data are used and enhanced with precise orbits form the Delft University of Technology. The sequence has been kept up to date (until March 1999) with ERS-2 OPR data taken before it’s final stage. This allows to monitor the ENSO event with a delay of a few weeks only.

The OPR data have been corrected for bias jumps, oscillator drift, dry tropospheric, wet tropospheric and ionospheric path delays, solid earth and pole tides, ocean tides and loading, sea state bias, inverse barometer and Ohio State University MSS95 was taken as a reference mean sea surface height. The orbit correction from the OPR was not applied as such, but a data refinement was achieved by the performing a minimization of the sea level differences at crossovers of ascending and descending tracks with a maximum interval of 17.5 days.

Description of ENSO

The whole oceanographic and atmospheric system of ocean currents and winds are constantly redistributing the sun energy absorbed by the water and the atmosphere. In the equatorial Pacific, Trade Winds are blowing fairly constantly from the east to the west. These Trade Winds transport water and cause the sea level to slope up from east to west. In west water piles up and in the east upwelling of waters from deeper colder layers to the surface occurs. The Trade Winds are maintained by the high pressure region above South America, where cool and dry air converges, and by the Indonesian low pressure region, where warm moist air rises, producing cumulonimbus clouds and heavy rainfall.

Throughout the year the ocean surface temperature is warmest in the west and coldest in the east of the equatorial Pacific (*fig. 1*). During the Northern Hemisphere winter (Southern Hemisphere summer), the pressure above South-America drops and the pressure above Indonesia rises. As a result Trade Winds become weaker and upwelling diminishes, such that less cold, fresh and nutritious water arises at the surface in the eastern part. The largest difference between the two regions is observed during September, October when the temperatures reach their annual minimum temperatures across the central and east -central Pacific. Normally in December the temperatures begin to increase and reach a peak in April in the central and central-east Pacific, while temperatures in the extreme eastern Pacific start increasing in November and peak in March. This annual

appearing of warmer ocean surface water along the South American coast around Christmas is what Peruvian fishermen used to call El Niño (Christmas Child). This period of two-three months was used to repair the boats, the nets, etc.... During the Northern Hemisphere summer the inverse happens. In contrast to the central and eastern part of the Pacific the sea surface temperatures across the western tropical Pacific and Indonesia remain warm and nearly constant all year.
However, sometimes the annual cycle gets triggered into an extreme state, the Trade Winds become extremely weak and may even become westerly in the western Pacific under the influence of the changing pressure distribution (what is nowadays called El Niño) or extremely strong (La Niña). Both extreme states can persist for a period of several months, and it can take a up to a whole year to come back to 'normal'.

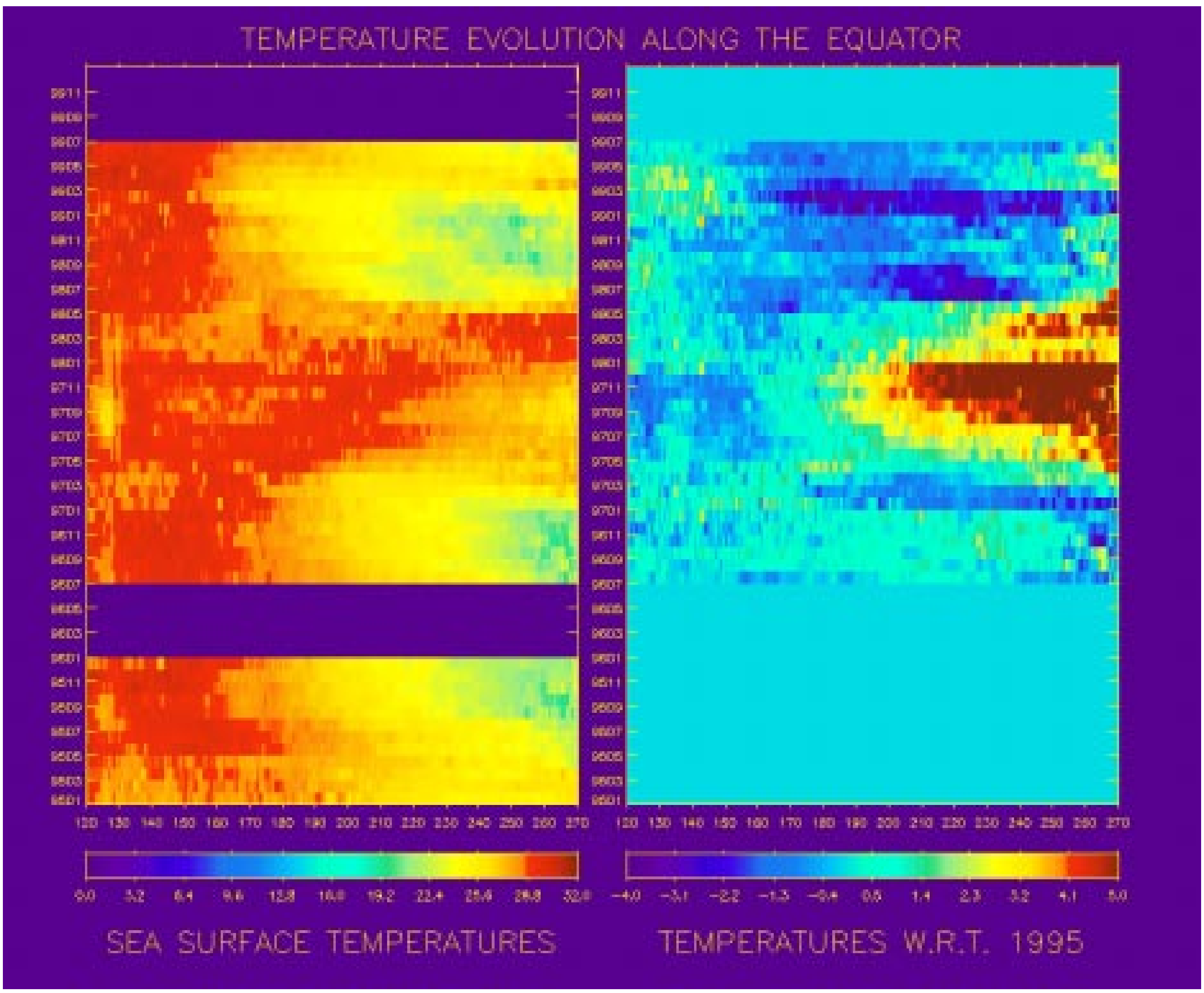

fig . 1, Evolution of the temperature along the equator from 120° to 270°

Effects of El Niño (*fig. 2*)
El Niño episodes are usually associated with increased rainfall across the east-central and eastern Pacific and with drier than normal conditions over northern Australia, Indonesia and The Philippines.

Wetter than normal conditions tend to be observed during December - February along coastal Ecuador, north-western Peru, southern Brazil, central Argentina and equatorial eastern Africa, during June-August in the intermountain regions of the US and central Chile.
Drier than normal conditions are observed during December - February northern South America, Central America and southern Africa, during June - August over eastern Australia.
Warmer than normal conditions can be expected during December - February across southeastern Asia, southeastern Africa, Japan, southern Alaska, western-central Canada, southeastern Brazil and southeastern Australia, during June - August along the westcoast of South America and across southeastern Brazil.
Cooler than normal conditions are usually found during December - February along the Gulf Coast of the US.

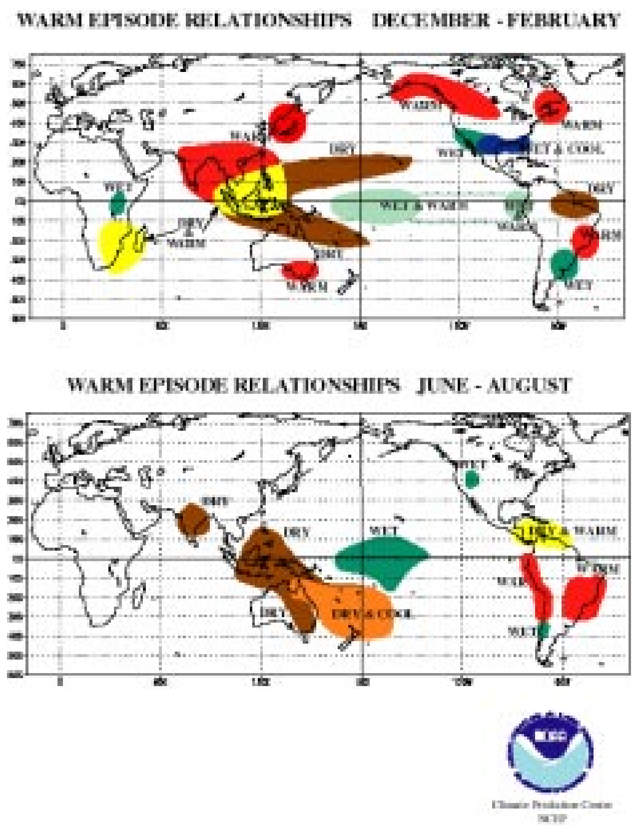

fig. 2

Effects of La Niña (*fig. 3*)
During La Niña, rainfall and thunderstorm activity diminishes over the central equatorial Pacific and becomes confined to Indonesia and the western Pacific. The area experiencing a reduction in rainfall generally coincides with the area of abnormally cold ocean surface temperatures.
Wetter than normal conditions can be observed during December - February over northern South America and southern Africa, during June - August over southern Australia.
Drier than normal conditions may be seen during December - February along coastal Ecuador, northwestern Peru and equatorial eastern Africa, during June - August southern Brazil and central Argentina.

Cooler than normal conditions during December - February noticeable over southeastern Africa, Japan, southern Alaska, western-central Canada and southeastern Brazil, during June - August across India and southeastern Asia, along the westcoast of South America, across the Gulf of Guinea and across northern South America and portions of Central America. Warmer than normal conditions during December - February can occur along the Gulf coast and the US.

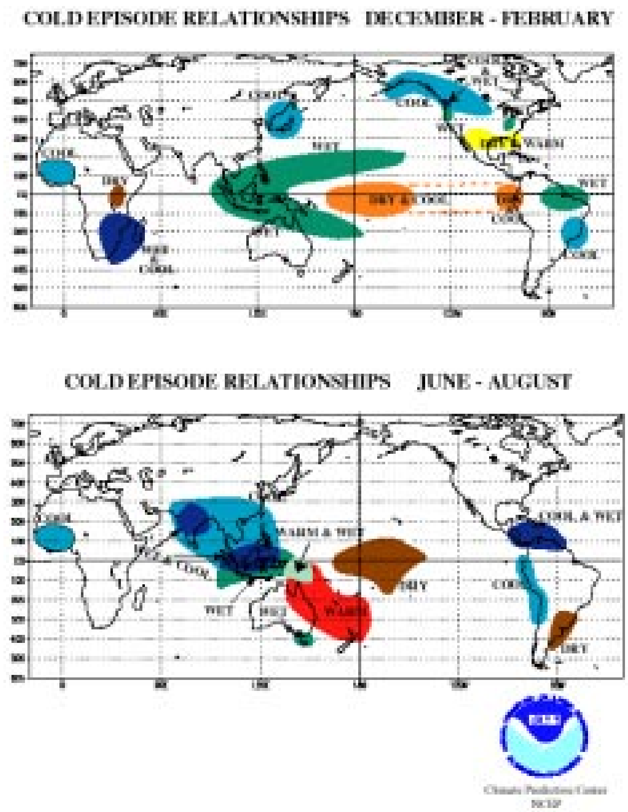

fig. 3

Importance of Earth Observation data

As El Niño or La Niña develops, it perturbs marine life in the Pacific and influences weather patterns throughout the world. Scientists are now taking their understanding of the ENSO phenomenon further by incorporating observations into prediction models.The atmosphere-ocean models are enhanced by the use of regular observed data fields such as ocean temperature, sea level height, wind speed, etc... The ability to anticipate how climate will change from one year to the next will lead to better management of agriculture, water supplies, fisheries and other resources. By including climate predictions into management decisions, humankind is becoming better adapted to the irregular rhythms of climate.

Countries that have taken similar initiatives include Peru, Australia, Brazil, Ethiopia and India. Although tropical countries have the most gain of successful predictions, many other countries outside the tropics such as Japan and US benefit from more accurate ENSO predictions.

Time sequence

Each time step (1 month) of this sequence consists a summary of what was written on climate anomalies in the press and thought to be related to either El Niño or La Niña.

May 1997
Forecast of El Niño warming of the ocean during the next six months, which could shift patterns of drought and flooding to other parts of the world next year.

June 1997
Ocean warming started, peak is expected in September or October 1997. Fish patterns have already been shifted.

July 1997
Predictions of sever flooding and crop damage in Ecuador through October 1997. SST have reached several degrees above normal off the coast of South America. Heat from the Pacific is becoming absorbed into the atmosphere. Crop losses due to drought in Indonesia. Record high temperatures in China and Alaska caused casualties. Fish migration from Colombia.

August 1997
Ocean warming equalled the previous record set in 1982. Droughts in the Philippines and south-east Asia. Severe storms and cold waves in South America. United Nations conference in Genova bout how the ocean warming may soon cause some of the worst weather extremes the world has ever seen. Quiet hurricane season in the Atlantic

September 1997
Severe droughts and bizarre frosts in Papua New Guinea. Food chain collapse on the Galapagos Islands. Wildfires and loss of hydroelectric power due to drought in Papua New Guinea. Java (Indonesia) is still waiting for the rain season to start.

October 1997
Java suffers from drought related diseases. Drought has destroyed crops in the mountains of Viet-nam. Fires in the Amazon have spread into virgin forest. Tropical storms in desert areas such as Baja California and Arizona.

November 1997
Heavy rains unleashed widespread inundations from Somalia, Ethiopia to Kenya. Swollen rivers in Ethiopia wiped out villages. An 840-miles-long plume of smoke drifted from Indonesia and Papua New Guinea. Somalia has the worst flooding ever, which caused to main rivers to merge. Monsoons across Indonesia and Malaysia cleared nearly all smoke that covered the region since three months. Heavy flooding in Ecuador. Uganda suffers from severe storms. Sever inundations in Tanzania

December 1997
Early summer heat wave in southern Australia. Thick smoke from forest fires hamper airborne relief in Java. Devastating storms in Peru.

January 1998
African floods in what should be the dry season. Hundreds of new fires broke out in parts of Indo-nesia due to continuous droughts.

February 1998

California swamped and fish floods and mudslides in Los Angeles. Mudslides and flooding in Peru and Ecuador. Venezuela and Colombia suffer from droughts and coffee crops are ruined. Borneo suffers from drought fir the seventh month.

March 1998

Thunderstorms lashed Florida. Hottest February since 1855 in New Zealand. Fierce storms triggered landslides in Ecuador. Deadly mudslides and flooding in Peru. Borneo produces a new cloud of smoke. Torrential storms swamp Alabama. Fishing industry in Peru is expected to recover in May 1998. Drought in Honduras. Six months drought and wildfires in Brazil is causing environmental catastrophe. Drought in Indonesia set stage for blazes. Peru suffers from yellow fever outbreak due to the constant storms. 70% crop losses in Namibia due to constant drought.

April 1998

NASA says that El Niño affected the Earth’s rotation, making days.4 milliseconds longer than usual. Downpour in Brazil brings hope to control the fires. A shift in the monsoon pattern seems to be ending the severe drought in Indonesia. Ocean temperatures off the coast of Peru are nearing normal levels. Although El Niño seems to be fading away, there is still danger for dramatic shifts in the weather due to heat absorption in the atmosphere. Worst drought ever in the Philippines is expected to last for at least another month. High water temperatures have resulted in extensive coral damage in Australia’s Great Barrier Reef. Ongoing El Niño rains have caused heavy inundations in Argentina. Brazil’s record drought worsens.

May 1998

Unsettled conditions and isolated thunderstorms due to dwindling El Niño ocean warming affect northern California, the heavy rains have produced more vegetation and caused an invasion of rats. Fires survive rainfall in Sumatra (Indonesia). Wildfires in northern and central Mexico due to drought. Heavy flooding in Paraguay. Uganda suffers from an epidemic sleeping disease, due to the incessant rains grass grew tall and increased the number of tsetse flies. Dengue fever outbreak in Jakarta. Cholera outbreak during flooding in Uganda. Continuous drought in Vietnam. Pre-monsoon rains brought unseasonably low temperatures, high winds, deadly blizzards and avalanches to the Himalaya. Intense heatwave in Pakistan and western India.

June 1998

Extensive crop losses in California. Drenching rains have eased drought in Vietnam. What was once the core of El Niño has actually cooled to below normal levels and may set stage for La Niña. It may still take months for all effects of El Niño to be filtered out of the system, due to the immense amount of heat transferred from the ocean into the atmosphere. The weakening El Niño ocean warmth appears to have suppressed tropical storm development until now. 60% of the sugar cane crop in Fiji has been destroyed due to continuous drought.

July 1998

El Niño seems to be responsible for torrential rains and massive economic losses in central and southern parts of China. Only half of the normal spring rainfall has fallen in Cuba, and has caused food shortage. Bird population has exploded during constant rains that have created a bumper grass crop, the destructive birds are attacking the wheat crops in Kenya. Tiger mosquitoes breeding continued during the unusual warm winter in Cambodia, and is causing a dengue fever outbreak.

August 1998
As the drought becomes more severe in Vietnam and rivers dry up. leaving standing water, waterborne diseases are increasing.

September 1998
El Niño is being blamed for dumping heavy winter rain in California, that caused more vegetation and a burgeoning pest population.

October 1998
Cuban drought is replaced by flood ruin.

November 1998
Annual monsoon rains have been heavier than usual in many parts of Malaysia due to La Niña.

December 1998
The last stages of El Niño phenomenon, were blamed for weeks of hazy choking fires in Indonesia, drought in Guayana and Papua New Guinea and extensive flooding in Ecuador, Peru and Kenya.

January 1999
Heavy rains blamed on La Niña caused downpours and unusual cold weather to southeastern Brazil. Absence of rain seems to be an effect of La Niña in east Africa.

No major events that seem to be related to ENSO were reported after January 1999

Conclusion

The El Niño episode started quite early during the year and this shift has persisted. La Niña conditions have weakened throughout the tropical Pacific during the past few months. The latest forecast models are fairly consistent in predicting cold episode conditions to continue into early 2000. The ATSR data processed at Trømsoe provide an excellent mean to observe the state of the ocean in near-real time.
The on-line ASST data are available at ***http://19.111.33.173/ATSRNRT***

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