Title: REVIEWING PAST EXTREME CLIMATIC EVENTS USING SATELLITE ANALYSED DAILY WIND AND SEA SURFACE TEMPERATURE DATA.

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Abstract

Climatic extremes and hazards such as Typhoons, Hurricanes and Cyclones can be verified by the use of daily climatic elements like sea surface temperature and wind direction and speed. Meteorological satellite data such as Sea Surface Temperatures (SST), Wind direction and speed are important parameters to determine the occurrence of Hydro meteorological hazards such as Storms, Tropical storms, Typhoons, Cyclones, Hurricanes, Winterstorms, Tornadoes, Droughts, floods and ENSO events. This paper demonstrates a useful technique that can be used to verify the past climatic extreme events. The technique involves the use of FERRET software to plot analysed Sea Surface Temperatures, wind direction and speed. Results show that there is a strong consistency with the wind pattern as well as the SSTs depicting the existence of the phenomenon. Ferret software plots are good in showing and proving the past occurrences of the Hydro meteorological phenomenon as well as verifying the ENSO events. Details are presented in the text.

Keywords: Sea Surface Temperature (SST), Wind, FERRET, Hydrometeorological hazards, ENSO
1. INTRODUCTION

Climatic extremes can be hazardous to the environment as well as to living things including human beings. These natural climatic disasters include cyclones, Hurricanes, Typhoons, Floods and droughts caused by ENSO phenomenon and the damage caused can be sometimes costly. According to estimates of the National Ocean and Atmospheric Administration’s (NOAA’s) National Weather Services, the damages due to Hurricanes Hugo (in 1989), Andrew (in 1992), and Iniki (in 1992) caused a cumulative loss in excess of $40 billion (EOS Science Plan - chapter 3 – Rothrock et al). The objective of this study is to demonstrate a technique that can be used to provide useful representative review of some past and resent hazards related to hydrometeorological hazards. This paper demonstrates a useful technique that can be used to verify the past natural events. The study will be based on daily analysed data sets collected historically using satellite analysed daily wind and sea surface temperature data.

2. Study Areas

These include the Indian ocean where cyclones normally occurs, the central America including the Caribbean in the central pacific where we have the hurricanes, the eastern pacific islands where we get the typhoons and the Nino region where we have ENSO events signals (Fig. 1 and 2).

3. Objective of the study

The objective of this study is to demonstrate the techniques that can be used to review as well as verifying the past occurrences of the natural disasters or hazards. The technique can also help to review ENSO events during El Nino or La Nina episodes. This is mainly achieved by plotting analyzed satellite daily data such as wind and sea surface temperatures (SST) using Ferret software.

Fig. 1. Hydrometeorological Hazards Areas
Fig. 2. SSTs for 21 November, 2010 Nino region (source Ferret software)
4. Research questions

- How can we detect the occurrence of natural phenomena
- How much is the damage caused by these natural hazards particularly over the coastlines.
- How much is the estimate cost to repair the damage caused by these disasters.
- Which coastlines are frequently hit by these natural disasters?

5. Materials and Methodology

Softwares used in this study include; Microsoft Word, PowerPoint and Ferret. Ferret software is the main tool used in this study. Ferret is an interactive computer visualization and analysis environment designed to meet the needs of oceanographers and meteorologists analyzing large and complex gridded data sets. “Gridded data sets” in the Ferret environment may be multi-dimensional model outputs, gridded data products (e.g., climatologies), singly dimensioned arrays such as time series and profiles, and for certain classes of analysis, scattered n-tuples (optionally, grid-able using Ferret’s objective analysis procedures). Ferret accepts data from ASCII and binary files, and from two standardized, self-describing formats. Ferret’s gridded variables can be one to four dimensions—usually (but not necessarily) longitude, latitude, depth, and time. The coordinates along each axis may be regularly or irregularly spaced. Ferret offers the ability to define new variables interactively as mathematical expressions involving data set variables and abstract coordinates. Calculations may be applied over arbitrarily shaped regions. Ferret’s “external functions” framework allows external code written in FORTRAN, C, or C++ to merge seamlessly into Ferret at runtime. Using external functions, users may easily add specialized model diagnostics, advanced mathematical capabilities, and custom output formats to Ferret. A collection of general utility external functions is included with Ferret. (Hankin and Denham, 1996).

Ferret provides fully documented graphics, data listings, or extractions of data to files with a single command. Without leaving the Ferret environment, graphical output may be customized to produce publication-ready graphics. Graphic representations include line plots, scatter plots, line contours, filled contours, rasters, vector arrows, polygonal regions and 3D wire frames. Graphics may be presented on a wide variety of map projections. Interfaces to integrate with 3D and animation applications, such as Vis5D and XDataSlices are also provided. Ferret has an optional point-and-click graphical user interface (GUI). The GUI is fully integrated with Ferret’s command line interface. The user may freely mix text-based commands with mouse actions (push buttons, etc.). Ferret’s journal file will log all of the actions performed during a session such that the entire session, including GUI inputs, can be replayed and edited at a later time. Ferret was developed by the Thermal Modeling and Analysis Project (TMAP) at NOAA/PMEL in Seattle to analyze the outputs of its numerical ocean models and compare them with gridded, observational data. Model data sets are often multi-gigabyte in size with mixed 3- and 4-dimensional variables defined on staggered grids. (Hankin and Denham, 1996). Firstly, it is better to discuss how Ferret works in plotting historical Meteorological parameters such as sea surface temperature (SST), air temperature (AIRT), Specific humidity
(SPEH), Wind speed (WSPD), Zonal wind (UWND), Meridional wind (VWND) and Sea Level Pressure (SLP). This data is found in COADS climatologically data set using FERRET. COADS is the comprehensive ocean-atmosphere data set compiled from ship reports over the global ocean. The daily climatology introduced here represents a six hour reading in a day i.e. at 0000, 0600, 1200 and 1800 hrs. (Hankin and Denham, 1996). In the case of wind, UWND is u-wind at 10 meters and VWND is v-wind at 10 meters. In these data sets the index "I" refers to longitude, "J" to latitude, "K" to the vertical dimension, and "L" to time. In the listing the values under each qualifier present the points available along that axis. For example 1:180 indicates that locations 1 through 180 are represented in the data set. "L" refers to time in hours in a day i.e. L=1 means data observed and analyzed by satellite at midnight 00:00, L=2 is for 06:00, L=3 is at 12:00 and L=4 is at 18:00. It must be pointed out that time here is UTC or GMT. The study reviews cyclone Eline from 16th to 21st February 2000, cyclone Japheth of 25th Feb. – 4th Mar. 2003, Hurricane Hugo from 17th -24th September, 1989 and Typhoon Morakot 5th to 12th Aug. 2009. The vector winds were plotted for each day at midday in each case showing the strength and position of the phenomena. In the case of the ENSO phenomena, sea surface temperatures (SST) as well as the winds confirming the existence of the phenomena were plotted using the same ferret software as in the case of natural hazards. Selected times and days which fell during a La Nina or El Nino episode were plotted i.e. 24th July 1998, 26th Sept. 1998, 6th, 7th Nov. 2010, and 12th Dec. 2010.

6 Results and Discussion
Cyclone Eline actually was noticed on 8th Feb. 2000 at about 16S, 92E in the Indian Ocean, it moved westwards and on 9th it was at 18.5E, 84E, on 10th it was at 18S, 78E, on 11th it was at 17.5S, 72E, on 12th at 16S, 67E, on 13th at 15.5S, 62E. On 14th it was moving towards the Indian ocean islands of Mauritius and Reunion at 17S, 58E, and on 15th its effect were being felt by Mauritius and Reunion islands at 18S, 55E. On 16th Feb. 2000 Cyclone Eline hit the Madagascan coast (see Fig. 5 below and Fig 1 at the annex.)
Cyclone Eline hit the coast of Madagascar and eventually central Madagascar on 16\textsuperscript{th} and 17\textsuperscript{th} Feb.2000 (Fig.1&2 at the annex) ,as shown by the concentration of strong vector winds indicating clockwise flow. Eline moved towards the Mozambique Channel on 18\textsuperscript{th} and 19\textsuperscript{th} (Fig.3&4 respectively at the annex). Eline finally hit the Mozambican coast where caused destructive damage over Mozambique with the worst torrential rains to hit the region since 1966 (Cyclone_Elinetim.ppt,(2000). The resulting Flood in Mozambique destroyed thousands of homes and killed massive amounts of people whom had no shelter from the rising waters(Fig.6 below).

Fig.6.(Source Time Magazine (Mozambique floods).

On 25\textsuperscript{th} Feb. to 4\textsuperscript{th} Mar.2003 ,Cyclone Japhet occurred( Fig.7 to 14 at the annex).Latest satellite pictures and rainfall models indicated that Tropical Cyclone Japhet was ravaging southern Mozambique, and approached eastern Zimbabwe. The cyclone was very strong, and was characterized by strong maximum winds of 110km/hr, with gusts up of up to 140 km/hr. Such strong winds were accompanied by widespread damage (Ref. Beaufort Scale). Heavy rainfall was also accompanying the cyclone, and this resulted in flooding. News reports indicated that people in Mozambique had been affected, particularly in Inhumane, and Gaza provinces. Informal reports also indicate d impacts, particularly strong winds, as far as eastern Zimbabwe.(SADC Regional Remote Sensing Unit,2003).
The small purple circles were the forecast tracks of the cyclone, from left to right, at 1200GMT-03/03/2003; 000GMT-04/03/2003; and 1200GMT-04/03/2003. The cyclone center was currently over southern Mozambique, and was to enter Zimbabwe at 000GMT on 04/03/2003. However the effects were being felt far and wide (Figure 7b). In 1989, Hurricane Hugo, classic Cape Verde hurricane was first detected as a tropical wave emerging from the coast of Africa on September 9. Moving steadily westward, the system became a tropical depression the next day, a tropical storm on the 11th, and a hurricane on the 13th. Hugo turned west-northwest on September 15 as it became a Category 5 hurricane. It was still a Category 4 hurricane when the center moved through the Leeward Islands and St. Croix, USVI, and the 18th. Turning northwestward, the center passed across the eastern end of Puerto Rico on September 19. This general motion would continue with some acceleration until Hugo made landfall just north of Charleston, South Carolina on 22 September. Strengthening in the last twelve hours before landfall made Hugo a Category 4 hurricane at the coast. After landfall, the storm gradually recurved northeastward, becoming extratropical over southeastern Canada on September 23. (Hurricane History) Fig. 8 is showing the path of this hurricane.

The Ferret analysis of this hurricane is shown in Fig. 15 to 22 at the annex.
Typhoon Morakot formed early on August 2, 2009 as an unnamed tropical depression. During that day the depression gradually developed before being upgraded to a tropical storm and assigned the name Morakot, by the Japan Meteorological Agency late on August 3. The large system gradually intensified as it tracked westward towards Taiwan. By August 5, the JMA and JTWC upgraded Morakot to a typhoon. Due to the size of the typhoon, the barometric pressure steadily decreased; however, maximum winds only increased slightly. Early on August 7, the storm attained its peak intensity with winds of 140 km/h (85 mph 10-minute sustained) according to the JMA. The JTWC reported the storm to be slightly stronger, with winds peaking at 150 km/h (90 mph 1-minute sustained), the equivalent of a Category 1 hurricane on the Saffir–Simpson Hurricane Scale. Morakot weakened slightly before making landfall in central Taiwan later that day. Roughly 24 hours later, the storm emerged back over water into the Taiwan Strait and weakened to a severe tropical storm before making landfall in China on August 9. The storm gradually weakened as it continued to slowly track inland. The remnants of the typhoon eventually dissipated on August 11.

Typhoon Morakot wrought catastrophic damage in Taiwan, leaving 461 people dead and 192 others missing, most of whom are feared dead and roughly NT$110 billion ($3.3 billion USD) in damages. The storm produced copious amounts of rainfall, peaking at 2,777 mm (109.3 in), surpassing the previous record of 1,736 mm (68.35 in) set by Typhoon Herb in 1996. Fig. 23 to 30 at the annex is showing the path of the dates from 5th to 12Typhooone.El Nino and La Nina are very distractive phenomena in terms of causing droughts in some parts of the world as well as floods in the other parts. These natural phenomena are usually detected in the Nino region which is equatorial Pacific Ocean. Fig. 9 to 12 showing how the past events can be reviewed using Ferret on daily basis. The colder temperatures indicates La Nina events while the warmer ones depicts El Nino.
7. Conclusions:
There is no doubt that Ferret is a very useful tool in carrying out some verification or review of the past natural hazards associated with water. Future occurrences can be estimated by following or comparing the similarities with the past ones. Through these plots, the cost that might be caused by an occurrence of the hazard can be estimated and budgeted for by decision makers.

8. References:
Fig. 1 Cyclone Eline 16th Feb. 2000 (source Ferret Analysis N.Aikayo, 2010) Fig. 2. Cyclone Eline 17th Feb. 2000 (source Ferret Analysis N. Aikayo, 2010)
Fig. 3 Cyclone Eline 18th Feb. 2000 (source Ferret Analysis N. Aikayo, 2010)

Fig. 4 Cyclone Eline 19th Feb. 2000 (source Ferret Analysis N. Aikayo, 2010)
Fig. 5 Cyclone Eline 20th Feb. 2000 (source Ferret Analysis N. Aikayo, 2010)

Fig. 6 Cyclone Eline 21st Feb. 2000 (source Ferret Analysis N. Aikayo, 2010)
Fig. 7. Cyclone Japhet 25th Feb. 2003 (source Ferret Analysis N. Aikayo, 2010)

Fig. 8. Cyclone Japhet 26th Feb. 2000 (source Ferret Analysis N. Aikayo, 2010)
Fig. 9. Cyclone Japhet 27th Feb. 2003 (source Ferret Analysis N. Aikayo, 2010)

Fig. 10. Cyclone Japhet 28th Feb. 2003 (source Ferret Analysis N. Aikayo, 2010)
Fig. 11. Cyclone Japhet 1st Mar. 2003 (source Ferret Analysis N. Aikayo, 2010)

Fig. 12. Cyclone Japhet 2nd Mar. 2003 (source Ferret Analysis N. Aikayo, 2010)
Fig. 13. Cyclone Japhet 3rd Mar. 2003 (source Ferret Analysis N. Aikayo, 2010)

Fig. 14. Cyclone Japhet 4th Mar. 2003 (source Ferret Analysis N. Aikayo, 2010)
Fig. 15. Hurricane Hugo 17th Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)

Fig. 16. Hurricane Hugo 18th Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)
Fig. 17. Hurricane Hugo 19th Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)

Fig. 18. Hurricane Hugo 20th Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)
Fig. 19. Hurricane Hugo 21st Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)  
Fig. 20. Hurricane Hugo 22nd Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)
Fig. 21. Hurricane Hugo 23rd Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)  

Fig. 22. Hurricane Hugo 24th Sept. 1989 (source Ferret Analysis N. Aikayo, 2010)
Fig. 23. Typhoon Morakot 5th Aug. 2009 (source Ferret Analysis N. Aikayo, 2010)  

Fig. 24. Typhoon Morakot 6th Aug. 2009 (source Ferret Analysis N. Aikayo, 2010)
Fig. 25. Typhoon Morakot 7th Aug. 2009 (source Ferret Analysis N. Aikayo, 2010)

Fig. 26. Typhoon Morakot 8th Aug. 2009 (source Ferret Analysis N. Aikayo, 2010)
Fig. 27. Typhoon Morakot 9th Aug. 2009 (source Ferret Analysis N.Aikayo, 2010)  
Fig. 28. Typhoon Morakot 10th Aug. 2009 (source Ferret Analysis N.Aikayo, 2010)
Fig. 29. Typhoon Morakot 11th Aug. 2009 (source Ferret Analysis N. Aikayo, 2010)

Fig. 30. Typhoon Morakot 12th Aug. 2009 (source Ferret Analysis N. Aikayo, 2010)