Creation of South Pacific's Cyclone Pam, March 2015.

Background:

Cyclones - or hurricanes in the northern hemisphere - are initiated by a sudden local temperature difference in ocean water. This causes a pressure difference which in turn produces winds; the larger the temperature difference, the larger the winds. The Coriolis force causes the quickly moving air to rotate clockwise, hence the name "cyclone" in the southern hemisphere, and anti-clockwise in the northern, where they are variously known as hurricanes or typhoons. The Coriolis force also prevents cyclones forming within 5° of the Equator. The cyclone centre has a very low atmospheric pressure caused by the initiating hot area. A Category 5 cyclone like Pam has a central pressure of less than 920 mb (cf "normal" sea level of 101 mb).

The dominating questions to be asked are therefore
"What causes the hot area? Where? When?"

Actually, the first two answers are rather simple for most cyclones I've looked at. (I'm not a professional in this field, and so I do not monitor them closely.) But for Cyclone Pam, those two answers are glaringly obvious. The third – timing - can also be answered in a general sort of way.

The short answer is: **the hot area results from undersea volcanic discharges**. Such discharges are almost always from tectonic plate boundaries, mostly from diverging, but also from converging. Globally, about 3 times as much is discharged from diverging as from converging[i]. There's also a relatively small proportion from the several dozen "Hot Spots" worldwide, the best known being Iceland and Hawaii.)

Magma oozes out at about 1400K, and for example, each cubic metre of lava can raise the temperature of 300 m^3 of water by 4°C. (Lava is erupted magma.) The most frequently occurring terrestrial eruptions are VEI = 2 ejecting 10^6 to 10^7 m^3. Pam may have resulted from a higher VEI, guessing by its large size.
[Volcanic Explosive Index: it goes up to 7, perhaps its sole representative in the past 10,000 years being Tambora 1815.]

[Plates beneath the Ocean are 5 to 10 km deep, 30 to 50 km beneath continents.]
Converging plate boundaries are where two plates are colliding, eg Himalayas, Andes, the site of the 2004 tsunami, etc. These collisions are violent, in geological terms, but are not necessarily associated with eruptions, eg Himalayas. They are sites of large Magnitude earthquakes.
Diverging are where two plates are separating from one another. Obviously a several kilometre deep vacuum cannot be created so that lava is always erupted. Not the cause of large quakes.
Transform plates are where two plates slide past each other. They can be the source of large earthquakes, but not usually of volcanic activity. The San Andreas Fault is an example.

Magma from the relatively fluid Crust - the Asthenosphere which lies beneath the rocky Lithosphere - is squeezed out and exudes over the ocean floor – heating the ocean directly. There have been some interesting, shall we say, arguments put forward which AGW has been forced to explain the recent puzzling warming.

Terrestrial volcanoes, which in addition to the obvious heat evolved, eject ash into the air, thereby shielding Earth from solar heating and causing net overall cooling.

Undersea volcanoes warm the oceans directly and as they have no ash, there is no ash-cooling. As opposed to terrestrial volcanoes, they add to global warming, but heating the oceans first. Whether they form at converging or diverging plates, they are rather quiet affairs, as seen from the surface; one can sail over a full-blown eruption without noticing it happening - as has been noted for a recent Samoan converging eruption. This is because the gases evolved by these volcanoes are compressed and/or dissolved beneath kilometres of water.

Undersea plate and volcanic activity does not appear in any climate or weather models of which I am aware. Perhaps this is because the majority of such models were created before the confirmation of the plates' existence in the 1970s by deep-sea research vessels such as ALVIN. Even Wegener's Continental Drift theory was largely ridiculed until that discovery. Perhaps climatology is still pre-70s!

Undersea diverging plate volcanic activity is particularly difficult to observe; I believe the first such observation occurred only in the past decade – if my memory serves me. Divergence is inherently less forceful than convergence or transform - typically Mag 5 or less – and so more difficult to positively detect by conventional seismometers. They can be detected by hydrophones such as used by Navies. Some detections have only come to light in very recent decades when the USN released some previously highly classified SOSUS data, but the data is still patchy.

These investigations are further hindered by the various earthquake data collection agencies, eg Geosciences Australia, making the agency policy to NOT release data of less than Mag 5 for two years, although occasionally some slip through. They are recorded, just not released. I do not know why but it could be that as such data are inherently difficult to verify, requiring longer calculation, more recording stations' data and human thought to pin down. They do not want to release incorrect data. And of course, as these activities are so small, they are not so important…. Are they?

Cyclone Pam.

This very large, Category 5, tropical cyclone initiated on 06March2015 near the small south-west Pacific island nation, Vanuatu, causing calamitous damage, particularly as there was little warning. It seemed to spring from nowhere, just a few kilometres east of Vanuatu's Vanua Lava Island. However, its initiating heat source came from below the ocean at the western edge of the diverging Hazel-Holme Ridge.

The following seismic data are extracted from Geosciences Australia's site[ii]. It's bang on target for the Ridge and Pam! Fortunately – for science rather than the victims – these satisfied the Mag 5 criterion and so were published.

Magnitude	UTC Date	UTC Time	Latitude	Longitude	Approximate location	Depth (km)
5	2015-02-24	02:58:53	-13.458	166.998	Vanuatu Islands.	114
5.1	2015-03-03	04:36:45	-13.919	167.972	Vanuatu Islands.	8

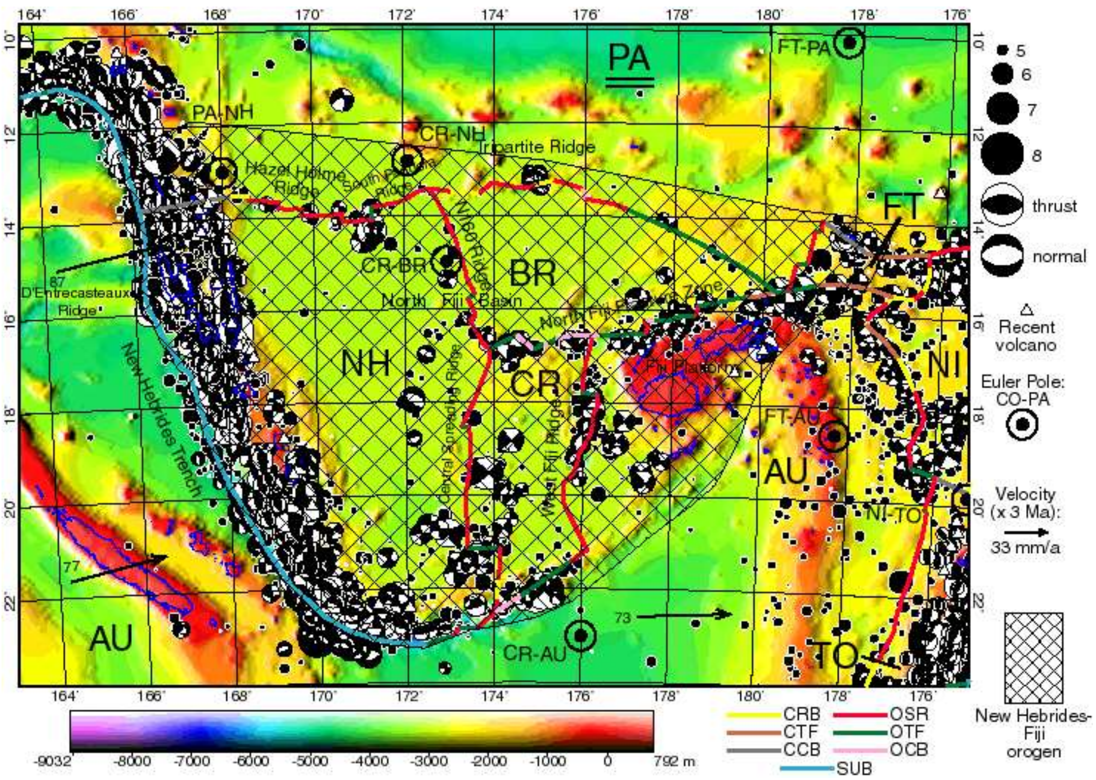

Figure 1[iii]**.** Boundaries (heavy colored lines) of the New Hebrides (NH), Balmoral Reef (BR), Conway Reef (CR), and Futuna (FT) plates. All are included in the New Hebrides-Fiji orogen because of evidence that they may be deforming rapidly. Surrounding plates are Australia (AU), Tonga (TO), Niuafo'ou (NI), and Pacific (PA). Conventions as in Figure 2, except coastlines are blue. Oblique Mercator projection on great circle passing E-W through (17° S, 174° E).

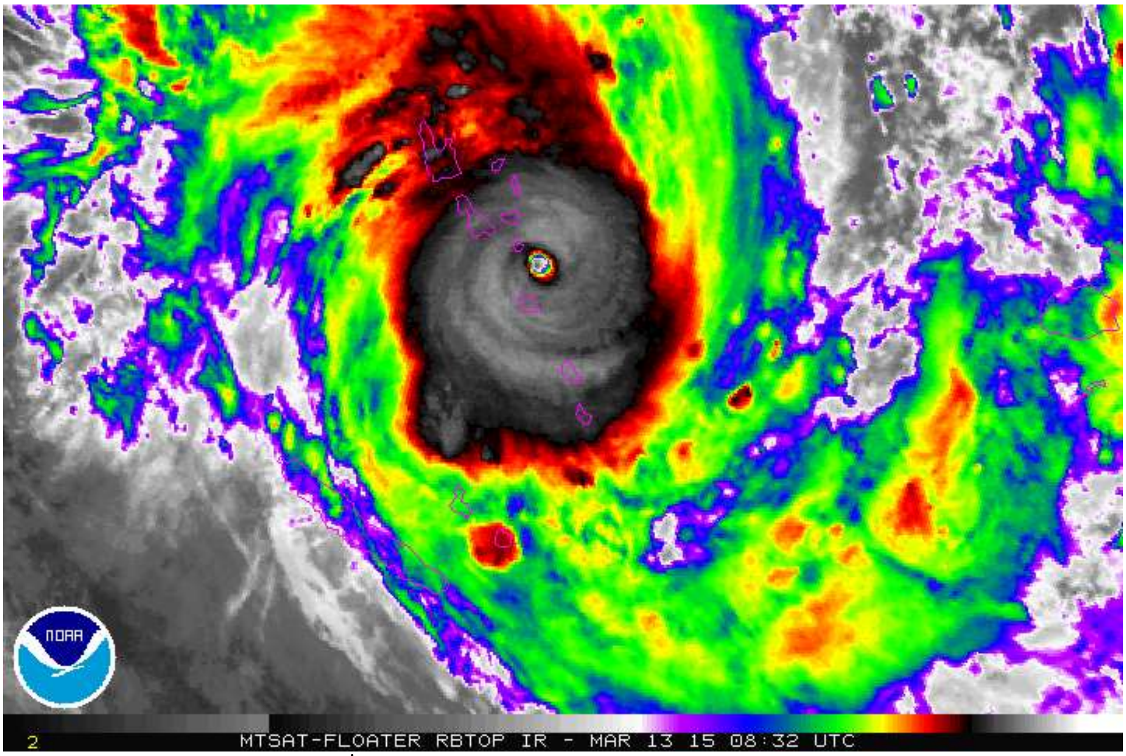

Figure 2[iv]: Pam’s origin southeast of Vanua Lava

There is a lot of significant seismic activity around the Vanuatu area; it's surrounded on both sides by The Ring of Fire! However, these 2 data points show the rising of activity at the Ridge, up to 8 km below the surface three days before Pam debuted. *There's the possibility of giving some warning of the danger here.* Presumably the magma blob eventually erupted at the ocean bottom very soon before this date, but as quakes less than 5 are not usually published in a timely fashion, one has to speculate – a little. Mag 5 is large for a diverging plate quake.

Other examples of tropical storms …. and El Nino.

Queensland 3 flooding events, January & February 2011

First. Mag 7·6 (-19·8°, 167·9° depth 31 km) undersea quake - plus large after-tremors occurred on 25Dec10 (UTC) 15 days before Toowoomba was hit with flooding. This is about the time needed for the anticlockwise ocean current from Vanuatu to arrive to dump its rain on Toowoomba, etc.

Second. There was another series of large quakes Mag 7 (-19·2°, 168·3° depth 39 km) starting 09Jan11 (UTC). There was another dump in SE Qld 19Jan11 - 10 days later. (There's an inexact match of timing as the rain can arrive via ocean currents or by wind-driven clouds.) Both of these quake series occurred at the convergent boundary on Vanuatu's west.

Lava is the major source of heat, rather than friction[v]. (There are equations for calculating friction heat, but is minimal, certainly with respect to lava eruption. For example, the devastating 1906 San Francisco slip-strike quake, Mag 7·8, produced no noticeable heating – although there were fires due to ruptured gas pipes, etc.) Therefore, the deduction is there are undersea volcanoes at this converging boundary location; a sudden large patch of warm ocean was tracked after each of these quakes, which could only have come from erupted lava.

These quakes generated storms rather than cyclones probably because they were at a converging boundary, where heat and magma are pushed and extruded between two plates being forced together, whereas for divergent they simply flow through an otherwise open crack – a faster process. The converging extrusion process is probably too slow relative to the local ocean current - which then simply disperses the heat over a larger area - to build up a warm enough ocean area sufficient for cyclone-generating fast winds.

Both of these quakes added large amounts of heat energy to the already tropically heated ocean, producing large amounts of rain. In each case, a large pool of heated water was tracked from here southwards along Australia's east coast.

Third. Severe Tropical Cyclone Yasi[vi] January-February 2011.

Yasi crossed the Australian coast near Innisfail, Qld late 02Feb11 as a devastating Category 5. Yasi began from a *preceding* typical tropical disturbance (26Jan11, -13·5°, 171·5°) but intensifying greatly 30Jan2011 to Category 3 near this location. The recorded seismic activity. (Eruptions can occur only *after* these times):

Mag	UTC Date	UTC	Latitude	Longitude	Location	Depth km
5	2011-01-28	20:03:11	-17.579	173.413	Fiji Islands Region.	77
5.5	2011-01-27	04:00:37	-11.676	166.317	Santa Cruz Islands.	72

5.3 2011-01-26 12:05:55 -18.932 168.2 Vanuatu Islands. 94

Only the 28Jan2011 west of Fiji (-17·6°, 173·4°) was on a diverging boundary. The difference in locations between the tropical low and the seismic activity gave the impetus for the spinning winds of a cyclone that formed on the 30th. The huge size of Yasi resulted from it being the sum of separate storm events, the pre-existing tropical low *plus* the cyclone-inducing submarine Fiji volcanic eruption.

El Nino. (This topic will be a separate article on this site.)
The real El Nino lies in an area close to the equator, running west from the ca Galapagos. This is also the location of perhaps the most seismically active area on Earth. EN occurs near the T-junction (ca 3°N, 103°W) of ocean ridges, the East Pacific Rise – by itself the fastest-spreading mid-ocean ridge in the world – the Cocos and the Galapagos Rift (or Rise). Lots of lava - lots of heat. Each of these boundaries is divergent.

[By "real El Nino", I mean the location as above. Many have used the term "El Nino" rather loosely to apply to similar extreme weather phenomena around the globe. El Nino itself applies to the very wet weather occurring in that area, whereas, perversely, in eastern Australia, it's applied to very dry conditions that *often* occur at the same time as the real EN.]

The **Take Home message** is that tropical (particularly) storms and cyclones initiate, not randomly, but at particular locations and times, determined by sub-sea tectonic plate boundary activity. This idea puts storms and severe tectonic events together, two previously regarded as random phenomena become one, raising the distinct possibility of being able to predict one or the other, or both!

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[i] (Prof Richard Arculus, public lecture at Uni of Adel 07Aug14.)

[ii] http://www.ga.gov.au/earthquakes/

[iii] http://peterbird.name/publications/2003_PB2002/2003_PB2002.htm

[iv] http://en.wikipedia.org/wiki/Cyclone_Pam

[v] D. L. Goldsby, T. E. Tullis. **Flash Heating Leads to Low Frictional Strength of Crustal Rocks at Earthquake Slip Rates**. *Science*, 2011; 334 (6053): 216 DOI: 10.1126/science.1207902

[vi] http://en.wikipedia.org/wiki/Cyclone_Yasi