WATERSPOUTS AND EARTH DYNAMICS.
A POSSIBLE RISK FOR AVIATION.

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Abstract:
It is suggested that fair weather waterspouts on sea can be feed with energy obtained from geothermal and volcanic undersea activity. This process can occasionally rise sand and stones from the ocean basin up to the sea surface, and from these, the waterspout dynamics can lift solid materials up to some kilometres height in the atmosphere. This implies a risk for aircraft navigation if the mechanism is not investigated further.

To my sister Maria Paz,
whose persistence has made possible this paper.
Santa Cruz de Tenerife, May 2011

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1. Preface: A privileged observer.

My sister Maria Paz was flying in a commercial flight to Tenerife (Canary Islands), where she was born. For this and other reasons she has fly over the island many times in her life. Hence she is customary with the flying and weather conditions during the approach to any of the two airports in the island. On November 16th of 2009 Maria Paz and her seven years old son were approaching Tenerife to Los Rodeos Airport when she observed the phenomenon that I want to tell you in her own words:

"It was around 18 hours Local Time when the voice of approximation was given and passengers required to fasten seatbelts. We where facing Tenerife island by the north. The normal route coming from Madrid towards Tenerife (Los Rodeos) was turn on the left in order to face Santa Cruz de Tenerife from South to North, towards La Laguna and finally taking land up in Los Rodeos. But that evening we turned abruptly on to the right and after a while, on the left again, so that I could see Las Canteras beach in Gran Canaria underneath me. I thought we where going to land at Gran Canaria airport. Suddenly we turned again on the left, towards Tenerife from South to North, flying next to the crater of El Teide, destination of Los Rodeos. Through the window of the left side of the plane, 20 or 30 Km far away from our position I saw that big chimney with a cloud on top of it. At the beginning I imagined it was an enormous torch of black rain coming out the small white and perfect cloud, but few minutes later the chimney was wider and grey and observed things inside it. They where stones of all different dimensions. Nobody inside the plane seemed to be aware of this phenomenon, so that I did not said anything to the flight attendants and stared at the nucleus of the storm searching for a big stone to observe its direction. The big stone was upwards in a slowly spinning movement. It was rounded and somewhat like a kidney. I don't think the flight cockpit crew member have had any opportunity to stare at the stones, because I suppose they where busy with the instrumental and I could not talk to them when we arrived the airport building because they had the door closed and the purser did not allow me to pass inside. Two years later, before writing to ICAO, I tried my best with the company to find out the captain, but until now, I have received no answer.
The grey cloud become wider and wider until a big grey curtain was formed. The sky was totally blue on the far end, and with apparently no wind at all, and really hot outside the terminal of Los Rodeos…."

The following draws of Fig. 1 are sketches in the attempt to explaining me what she saw.

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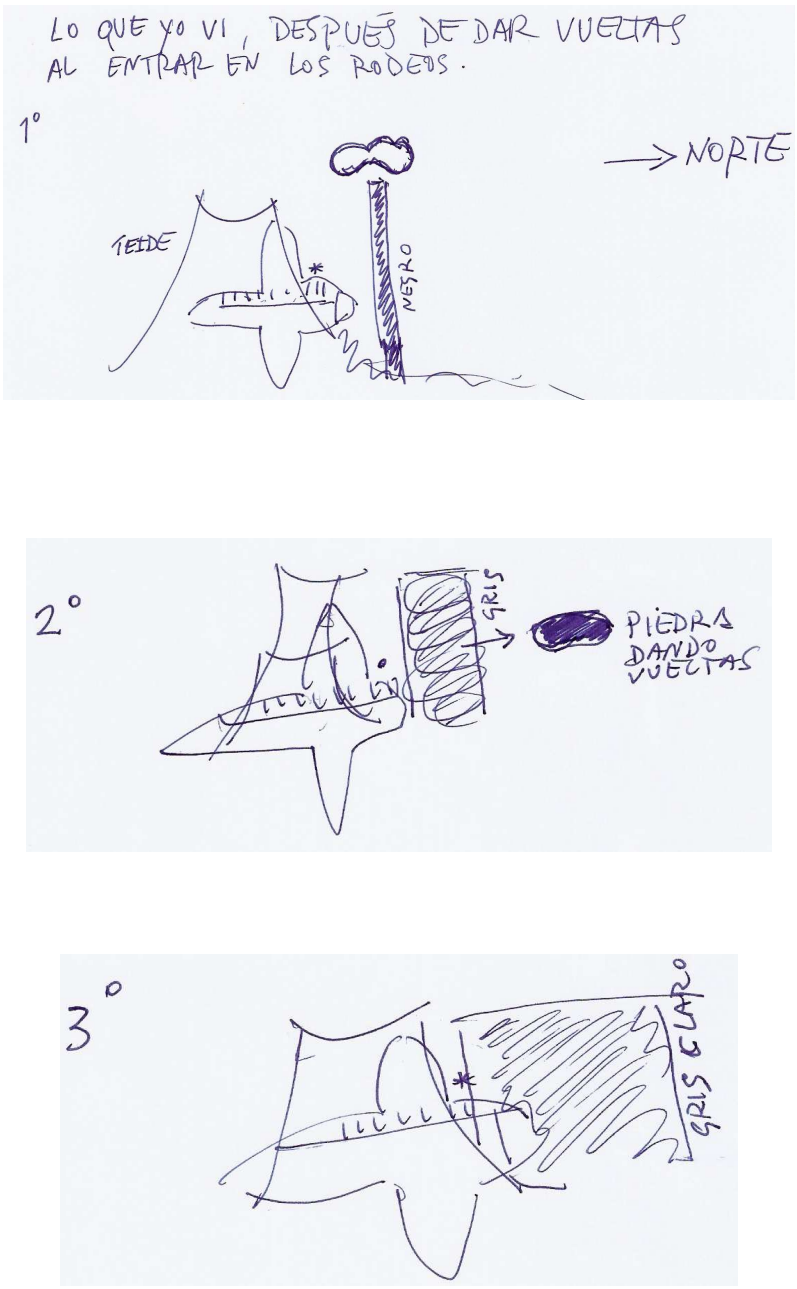

Fig. 1 Drawings done by Mª Paz in explaining the phenomenon she saw.

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2. Fair weather waterspouts: The state of the art.

The beautiful picture below (Fig. 2) shows that a waterspout is essentially a tornado on the sea.

Fig. 2. Image obtained from
www.google.es/search?q=waterspouts&hl=es&prmd=ivns&tbm=isch&tbo=u&source=univ&sa=X&ei=P9yxTZrwMJS2hAf7sanrCg&sqi=2&ved=0CEkQsAQ&biw=1920&bih=1069
taken by Joseph Golden, NOAA, from airplane in Florida Keys.

But there are important differences with a land tornado:

1. This last are always associated with the development of large convective cells with the production of great cumulonimbus previous to the formation of a tornado. On the other hand, fair weather waterspouts are often not linked to strong weather storms, hence their name.
2. The strength of the damage produced by waterspouts is usually thought to be much smaller than those of tornados (F0/F1) with wind velocities smaller than 100 Km/h.
3. Meanwhile tornados can have a life of some days and can move around thousands of Km, waterspouts like to stay on the site and their life time is not much larger than half an hour.
4. Tornados produced on the sea can enter land and preserve for many days, while waterspouts usually die as soon as they touch land.
5. Waterspouts occur all over the world, but there are some places where they are very often. One of them is Florida Keys.

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3. The Physics of the process.

The heating of the earth surface has its origin in two sources: The external solar irradiation and the geothermal contribution coming from inside the earth. Both can produce direct heating but also indirectly as for example through the Belt Conveyor or climate changes as ENSO and others.
When local heating is produced on the sea surface, the air current lines over sea try to converge to the heat focus to fill the vacuum produced by the ascending air mass previously heated (Fig. 3). This produces a convective cell with axial symmetry that transport wet air from the sea surface to the base of the clouds where condensation is produced because of the rapid cooling during the ascension.

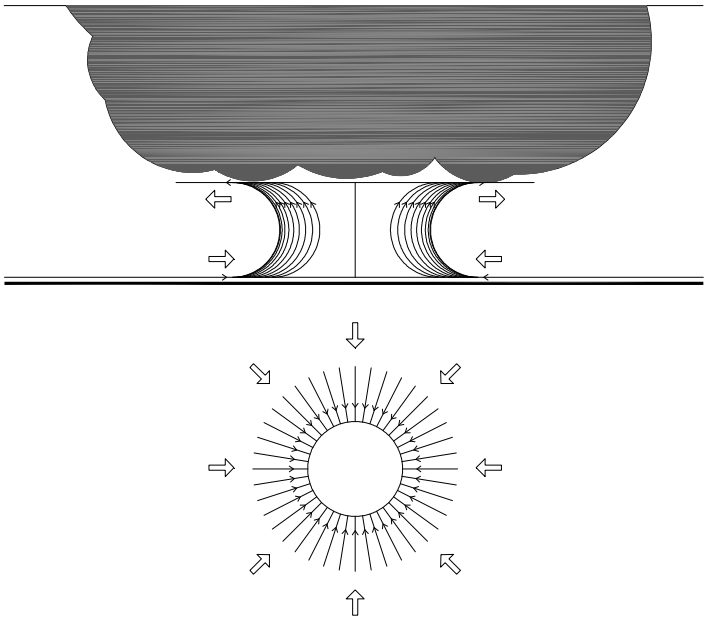

Fig. 3 When the earth or sea surface gets heated, convective fluxes are produced with ascending and descending current lines that transport in the oceans water vapor from sea up to the base of clouds.

The condensation of wet air delivers an important amount of heat (535 cal/g H2O) that helps rising water drops to a higher height. This gives rise to the formation of cumulonimbus. The question we want to emphasize here is that although air is very compressible, at the low pressure and velocities that are normal in the dynamic of the atmosphere, air usually behaves as if it where an incompressible fluid. This means Fig. 3, that much before the current lines converge significantly to the funnel they start rising up. Because of the air incompressible behaviour, the size of the funnel like in Fig. 3 would be enormous (maybe thousands of kilometres). For example, the intertropical convergence zone (ITCZ), which is the ascending part of convective Hadley cell can measure 1000 Km or more.

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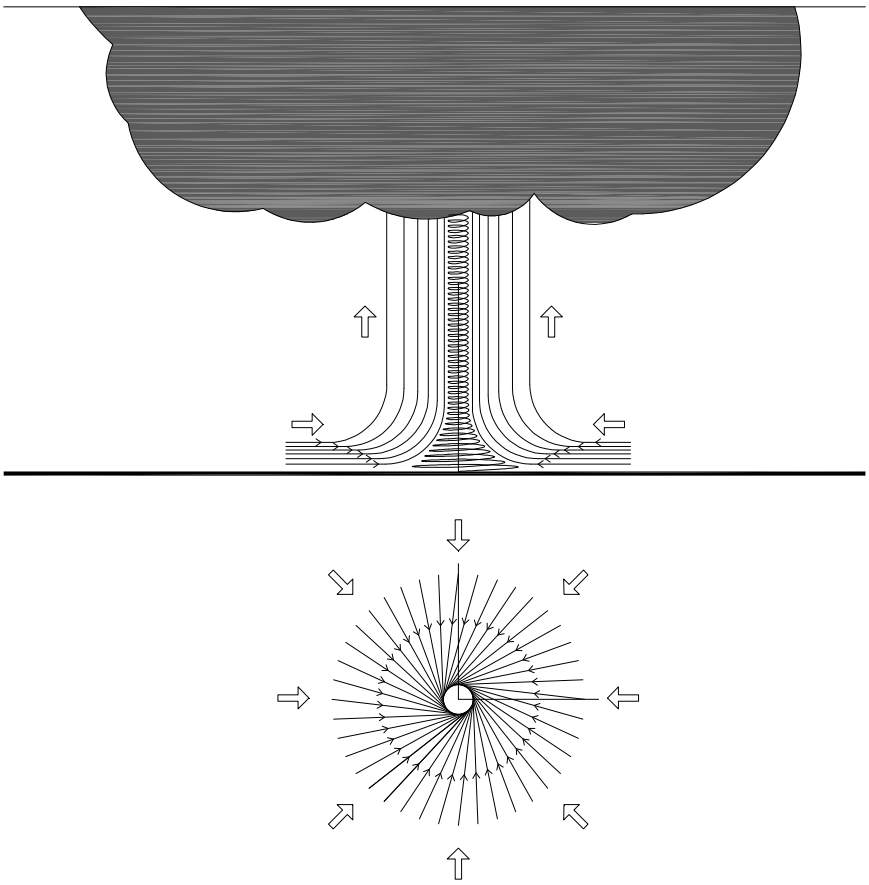

Fig. 4 Cyclone rotation induced by strong earth drag or high vertical velocity in funnel.

The great distance that air must displace over the sea attracted to a funnel like the one of Fig. 3 make current lines to be dragged by the earth rotation and this makes a vortex or cyclone like is shown in Fig. 4. Hence, current line do not converge to a point but to a ring with the gain of a vertical velocity in order to conserve equal the outgoing flux through the funnel with the horizontal incoming flux. Also the angular momentum along the current lines must be conserved. Hence, as the area of the funnel section is much smaller than the area of the normal section to the incoming flux, the vertical component of the velocity can be very large allowing the dragging of materials and animals as is usually seen in land tornados.

The fact that normally cyclones are produced by the effect of the earth rotation which drags the air in contact with the surface, means that the rotation sense has to be counterclockwise in the north hemisphere and the opposite in south hemisphe Fig. 4 This is true almost always, but a percentage of about 10 to 20% is estimated to spin opposite to what is expected. This can be explained by the collision of different weather fronts producing shear winds capable to overcome the earth rotation and give rise to clockwise rotation in north hemisphere, but also clockwise circulation is produced when the vertical ascension of air in the funnel is small enough. This makes the horizontal

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surface wind radial velocity to be small, hence the vertical gradient of the radial velocity is also small, and the surface – air friction is small. This makes the drag velocity of air to be small: The surface air moves quite independently of the rotating earth, and therefore the circulation is clockwise, the opposite to earth rotation. This is why large circulations in north atlantic ocean are clockwise (Alisios anticyclon, Gulf Stream).
The effect of cyclonic motion of the air is due to the earth drag and has nothing to do with the Coriolis force. This last are fictitious forces that produce the appearance of a rotation of the current lines of air to an observer sited on the earth that rotates with it. For example: An observer on the equator that observes a wind in north-south direction will have the impression that the current lines deviates strongly to west, although really it is the observer who is moving to East with the earth.
All circulations in north hemisphere that are not affected by the earth drag will be clockwise because of the Coriolis effect. On the other hand, when the earth drag is important, or it is the vertical gradient of the horizontal velocity, or the vertical velocity in the funnel, the circulation is counterclockwise. That is how rotate hurricanes, storms, cyclones and waterspouts in the north hemisphere. The opposite is true for the south hemisphere.
The size of the funnel is smaller the larger the matter flux is in the convection cell and this flux depends essentially on the amount of heat available for convection.
Waterspouts are usually tornados developed on water. Fig. 2 shows a waterspout in Florida Keys where it can be appreciated the wind direction, hence the counterclockwise direction of the giro.
In order to see many waterspouts, it is suggested the web page
www.google.es/search?q=waterspouts&hl=es&prmd=ivns&tbm=isch&tbo=u&source=univ&sa=X&ei=P9yxTZrwMJS2hAf7sanrCg&sqi=2&ved=0CEkQsAQ&biw=1920&bih=1069

that show many characteristics of these phenomena as the following:
Apparently, all waterspout are associated to clouds of vertical development that rotate counterclockwise with the cyclone.
Funnels show a velocity structure similar to that of cyclones, with a ring of highest velocity that decays rapidly to the interior, and slowly to the exterior.
The pressure is minimum where the velocity is maximum, that is on the ring and that produces the evaporation of water drops giving rise to a translucent halo around the funnel. This halo is more visible in the lower part of the waterspout, where the velocity is smaller and rises up to the base of the cloud injecting in it, at high ratio, large amounts of water vapor that condenses and produces a rapid evolution of the cumulus. The funnel interior, when the vortex has reached its maturity, shows a black aspect. This happens because near the interior, the rotation velocity is low and this increases the dynamic pressure allowing water vapor condensation by adiabatic cooling with vapor rising.
The force with which sea water is sucked in the funnel of the cyclone is determined by the depression that originates the high air velocity in this region. This is why it has been observed in occasions fishes and turtles thrown away kilometres inland by a waterspout.

An important aspect in relation to the rotation velocity of the earth is that the magnitude of the normal component to the earth surface changes with the sine of the latitude angle, hence there is no rotation at all on the equator, and at a latitude of 30º the rotation velocity is half the value on the poles. A consequence of this is that there is no Coriolis acceleration on the equator and this could be interpreted thinking that it is not possible

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to have cyclonic storms on equator, but this is not true because the evaporation in the intertropical convergenge zone (ITCZ) is high, and so are the surface winds and the earth drag effect. This makes very often a belt of storms near the equator that can go all around the earth. When the hot and wet air masses are transported to the north by the Hadley cell is frequent to form a line of storms named squall line. In occasions this storms produce waterspouts near equator.

Up to here, what we have said about waterspouts does not imply a special risk for navigation as all is reduced to winds, water or hail, to which navigation is prepared.
A more serious problem can be originated when offshore or inland volcanism throws clouds of ashes, which are often of puzolanic nature, that is light and abrasive which enlarges the permanence in air. This was the case of Eyjafjallajokull eruption in June 2010. Fortunately happens that most of aerial and submerged volcanic eruptions are detected in the day by people allowing to give international alarms to prevent navigation.
A data we want to emphasize is that it has been observed reciently a waterspout produced by a volcanic eruption at Kilauea in Hawai as it is shown in Fig. 5. This proves that a waterspout can take the energy to develop from the thermal heat delivered by the volcano. The heated water in the sea surface starts up the thermal convection of air and the cyclone mechanism as we have explained.
Nevertheless, the strong local character that usually have the waterspouts, the damage that can produce might be important.

Fig. 5 A waterspout forms offshore from an erupting Kilauea volcano vent in Kilauea, Hawaii. The picture shows that the waterspout takes the energy to develop from the heat delivered by the submerged volcano. Photograph by Steve and Donna O'Meara.
http://www.google.es/search?hl=es&biw=1920&bih=1069&tbm=isch&sa=1&q=waterspouts+kilauea&aq=f&aqi=&aql=&oq=

In the web page above it can be seen another view of the same phenomenon at Kilauea.

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Volcanic eruptions are very often in oceans. In fact, most of the eruptions in the world occur in oceans, specially on or near the Atlantic ridge, in the plate borders, subduction zones and in general in the most active zones of the earth crust, particularly in the active volcanic islands.

¿Is it possible for submarine volcanic activity to drag solid materials and ashes up to the sea surface? We refer to basaltic sands and stones of larger size. If we assume that the cyclone mechanism also works undersea, which is most reasonable if the geothermal characteristics of the source is sufficiently intense, wide and of long duration as to make the convective cell to work the time necessary to rise materials from the ocean basin to the sea surface. The accumulation of heat in the sea surface can again originate an atmospheric cyclone or waterspout capable to rise the solid materials described up to a height of various Km. But if the volcanic phenomenon is coincident with a squall line or an atmospheric storm, then the strength of the cyclone might be much greater and maybe materials can rise up to the flying height of an aircraft.

Basaltic sands have an average size of about 0.5 mm with a real density of about 3 g/cm3 and with a high content in magnetite Fe2O3, Mohs hardness about 5 and characteristic compressive strength about 200 Mpa. The dielectric constant and conductivity are relatively high as well as the magnetic susceptibility. For this reason, electromagnetic waves are probably strongly absorbed, even if the matter density is low, as should occur in the atmosphere.

4. Tenerife storm on 2011/11/16 and volcano Teide activity.

The weather predictions for November 16th 2009 few days before it, did not considered any possibility of instabilities or storm conditions on the North of Tenerife. On the contrary, the Canary Islands where under anticyclonic conditions with stable weather.
That day, after dawn and along the first hours in the morning, people made observations to the press as follows: "*It was a warmth and suffocating day*" or someone when getting out the bed: *"I found the floor flooded and the water hot …"*
Such signs suggested some kind of relation with a geothermal phenomenon, and so it was investigated in the database of the Instituto Geográfico Nacional (IGN) for seismic events finding as the nearest to November 16th the event 957703 M=1.6 of Noviembre 14th. We looked also for spectograms before the date of interest, but there are no data available until 45 days before November 16th in the IGN database. Also other Geophysical data have not been available for the author, with the exception of the seismic event mentioned, which is consistent with a fragile deformation of the crust at the East of Tenerife and a plastic deformation to the West two days after.
On occasion of the 6th congress "Cities on Volcanoes" Jun 2010, the author suggested a dismantle mechanism for volcanic islands that is based in the enlarging of the oceanic crust that produces the spread out of the magmatic flux to the offshore edifice. There, the smaller thickness of the crust allows its fracture and the freato-magmatic interaction.
Fig. 6 shows a sketch of the idea proposed in the poster presented.

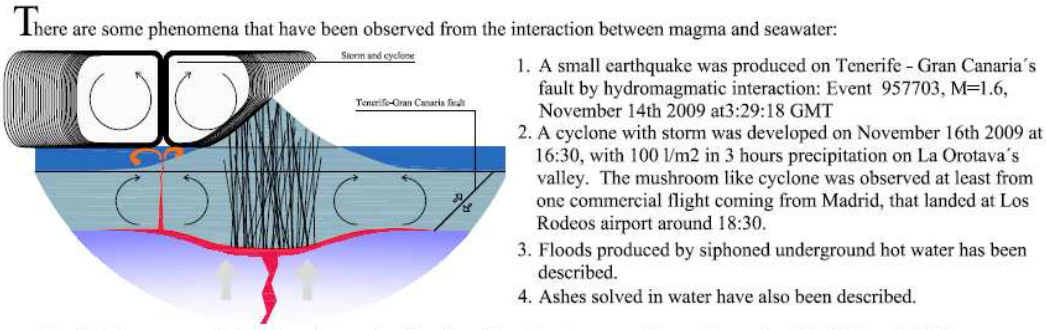

Fig. 8 Waterspout, whirlwind and storm developed on Tenerife, Orotava valley on November 16th 2009 at 16:30 hours. No meteorological explication is found as the event is incompatible with the evolution of whether prediction maps.

Fig. 6 Sketch of part of a poster presented in Congress "Cities on Volcanoes, Tenerife 2010- Suggested Mechanism for Growth and Dismantle of Volcanic Islands."

Poster available in http://www.luisblascabrera.com

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In Fig. 7 it is shown a sketch of the evolution of CO2 lowest concentration corresponding to 2009 in the period between Agust 1th and December 31th. The gape in Fig. 7 corresponds to the storm on Tenerife North the November 16th.

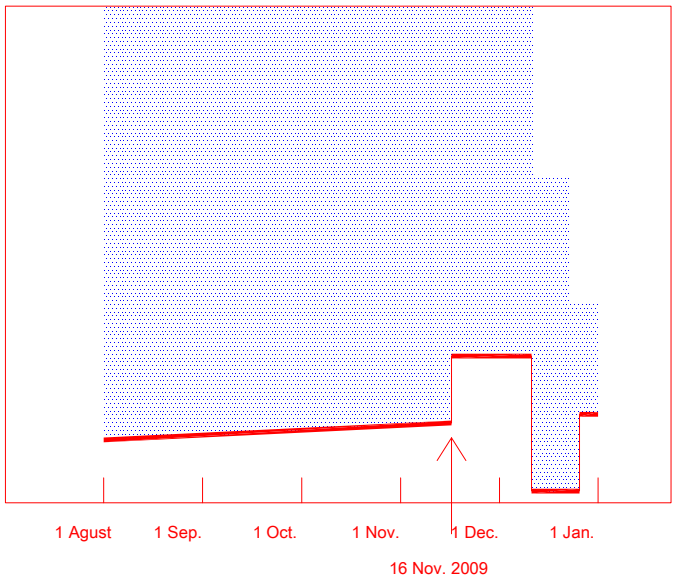

Fig. 7 Sketch of CO2 concentration at Teide peak from August 1th. (Source author)

The changes in CO2 emissions from Teide volcano can be correlated with the storm evolution along the day. In particular, peaks are observed around 9, 15 and 18 hours UTM.

The pictures we show below Fig. 8 and Fig. 9, do not prove anything because they where taken under not controlled conditions, but show curious effects that might have relation with the phenomenon: Fig. 8 seems to be taken from somewhere near El Sauzal in Tenerife north and about 9 am UTC, as inferred from the sun position. The yellow redish flamed cloud seems to arise from the north dorsal of Tenerife island, approximately over Orotava valley. The author suggests that the scattered light of yellow redish colour comes from CO2 hydrated molecules emitted from the corresponding 9 am event. The theoretical calculations for the scattering of light from a complex CO2 hydrate is left for a different paper.

Fig. 9 shows an obscure redish colour that the author thinks might be due to the sunset in a wet and dirty atmosphere due to the volcanic ashes. The picture has been taken in Puerto de la Cruz shore.

No contact has been possible to establish with the authors of the pictures.

Fig. 8 Image published by Maria del Mar Skatt Padron (Before Storm).
http://www.eltiempo.es/fotos/tenerife/fuego-en-el-cielo.html

Fig. 9 Unusual light in picture taken by Sergio while storm at Puerto de la Cruz in Tenerife on November 16/ 2009. **http://www.eltiempo.es/fotos/tenerife/tormenta-16-noviembre-2009.html**

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5. Risk for aviation: why, where and when.

The risk for aviation comes from the following characteristics of the undersea volcanic phenomenon:

5.1 Impossible prediction of submerged volcano activity, hence the navigation planes cannot include such phenomena, at least during the firs hours or days. Also, if the event happens in the night it will be invisible for the crew.

5.2 It is possible for planes meteorological radars to be able to detect the eco signals coming from air accumulations of basaltic sands, but probably the crew will not be able to identify nor suspect the nature of the risk.

5.3 The impact of a plane at a speed of 0.8 Mach against an accumulation of basaltic sand can produce a brake acceleration greater than 1 g and damages incompatible with the flight condition.

5.4 In the case of very low matter density in air, it is likely that sand grains produce scratch and impacts on the fuselage that should be apparent on the fronts of attack.

5.5 It is usual that aircraft crews describe what is known as Saint Elmos fires, an electrical phenomenon which is known for long time. It is more likely to see in bad weather or storm conditions, but I want to remember that in the decade of 80´s it was described on the wings of a plane a similar phenomenon to the Saint Elmos fire, although it was identify as the abrasion with sparkles produced by sand grains on the wing fronts.

5.6 The metallic composition (Fe) of the basaltic sands can avoid or difficult the communication with earth stations as the signal might have to fly across a large horizontal extension. On the other hand, the communications via satellite that use shorter wavelength might operate.

5.7 Although in principle, a submarine eruption cannot be excluded in any part of oceans, it is clear that the highest risk zones are sited on largest activity places of plate tectonics, and so we can enumerate the following:

a. Atlantic mid-ocean ridge.
b. Subduction zones in Pacific Ocean.
c. Active volcanic Islands and island arcs.
d. Earth Hot points.
e. Mega Hot points, specially: Area of Indonesia and Area of Caribean sea, Gulf of Mexico and Bahamas, that determine the ENSO oscillation [1].

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6. Suggested actions for prevention.

6.1 Further investigation of the problem from geophysical and navigation points of view.
6.2 Collection of data of unexplained accidents might be important.
6.3 Earth mapping of risk zones.
6.4 Radar detection of basaltic sand storms.
6.5 Approaching to volcanic islands and areas of risk seems to be important.
6.6 Flying autonomy should allow to go around unknown risk areas.
6.7 Security protocols should be reviewed at the light of this possible events.

Final Note: Although the author has no other information than what has been published in the press and in the web, and has no contrasted data to prove anything, wants to suggest the convenience of studying the accident of the flight AF 447 on 2009/6/1 at the light of the ideas exposed in order to improve our knowledge of the world, as well as for human benefit.

Santa Cruz de Tenerife, 2011 April 30

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[1] "Yield and Strength Theory of Materials. Part I" Luis Blas Cabrera. http://www.luisblascabrera.com

[2] http://www.aviaciondigitalglobal.com/newsFiles/20090702022842-4.pdf

Fig. 10 Interpretation of Fig. 1 by the author.