

Ten years after the first tropical cyclone ever recorded in the South Atlantic, we investigate the possibility and potential impact of another event like it.

## **The risk of tropical cyclones in Brazil**





In the insurance industry, to call a risk insignificant can be a dangerous claim to make. Nature has surprised the world time and time again with catastrophes that were beyond widely held beliefs. Such an event occurred in 2004 when we saw the first tropical cyclone ever confirmed off the coast of Brazil. Ten years on, a new scientific study explores the main atmospheric conditions that influence tropical cyclones in the South Atlantic. Its findings are featured in this publication. They point towards an important observation: while the generally low number of storms in this region can be explained convincingly, Brazil is not free from tropical cyclone risk.



For a long time, the South Atlantic was assumed to be an ocean basin in which tropical cyclones do not occur at all. This thinking had to be changed fundamentally when tropical cyclone Catarina struck in March 2004 (see Figure 1). In addition to a number of casualties, people living in the affected areas along the coast in the southern Brazil states of Santa Catarina and Rio Grande do Sul suffered considerable damage to property, infrastructure and agriculture. Prior to this event, such destruction had been deemed impossible from this type of natural hazard. The concern over potential future impacts to society as well as scientific curiosity in respect of these rare – but obviously possible – events triggered a range of research activities in the years following tropical cyclone Catarina.

### The insurance industry needs to know more

As one important stakeholder in the mitigation of catastrophe risks, the insurance and reinsurance communities have a natural interest in understanding better where, how often and at what intensity tropical cyclones in the South Atlantic can strike land. The protection of assets by means of insurance has grown at an astounding speed over the last decade, even outpacing the general economic development in Brazil. As in other regions of the world, coastal locations have been one focal point of this growth. Having been considered free of the danger of tropical cyclones, however, Brazil's coastal communities have not taken the type of damage prevention and mitigation measures needed to protect themselves against the kind of high winds and rough seas produced by such events. Thus, for a storm of a given intensity, far more severe damage must be



A resident starts to clean up a car yard in Torres on the day after the landfall of tropical cyclone Catarina.

expected in Brazil than in places that experience tropical cyclones more frequently (eg Florida).

To better understand the factors that determine tropical cyclone formation in the South Atlantic, Swiss Re collaborated in a study with the Institute for Atmospheric and Climate Science (IAC) at the ETH Zurich, Switzerland. The study examined the question why tropical cyclones are very rare in this ocean basin and how the atmospheric conditions deviated from the norm during tropical cyclone Catarina and a few smaller tropical storms that have occurred in the area so far.

**Tropical Cyclones in the South Atlantic – why are they so rare?**

If one looks at a global map of tropical cyclone tracks, it's striking that the South Atlantic is the only ocean basin worldwide with an almost complete absence of

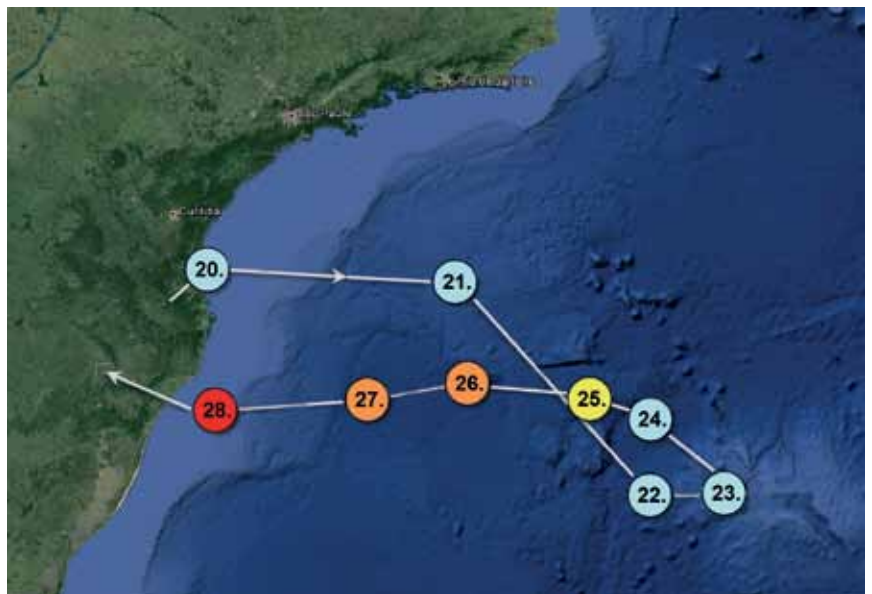
such tracks. So far, the absence of tropical cyclones in the South Atlantic had commonly been associated with excessive 'wind shear'. While investigating this important factor in detail, the recent ETH Zurich study analysed a number of additional factors that can equally limit or enhance the formation of tropical cyclones.

The most important prerequisites for tropical cyclone formation are:

- High sea surface temperatures: 26.5°C to a water depth of 50 meters is a commonly accepted minimum threshold, although low air temperatures may allow tropical cyclone formation at lower water temperatures.
- Low vertical wind shear: Winds blowing in different speeds or in different directions at various elevations in the atmosphere, so called 'wind shear', will inhibit tropical cyclone formation, if it is too strong.

Figure 1: The track of tropical cyclone Catarina. The numbers within the bullets specify the position of the storm at a respective day in March 2004.

- The colours mark Catarina's classification:
- subropical storm
  - tropical storm
  - tropical cyclone category 1
  - tropical cyclone category 2



- Sufficient vorticity: Tropical cyclone formation requires a pre-existing atmospheric disturbance (eg thunderstorms) with some initial rotational movement. In some areas of the world such disturbances occur regularly (eg the African easterly waves in the North Atlantic) while in others almost not at all (eg in the South Atlantic).
- High humidity: The existence of dry air masses in the atmosphere can inhibit thunderstorm activity required for tropical cyclone formation.

In the ETH Zurich study, these four prerequisites were investigated on a monthly basis utilising a global atmospheric re-analysis dataset spanning the years 1979 to 2011 (ERA-Interim). A comparison with other ocean basins like the North Atlantic or the Southwest Pacific

showed that in the South Atlantic the prerequisites align only very rarely and in small areas, thus limiting the chance for a tropical cyclone to occur.

Not surprisingly, the study shows that the Southern Hemisphere summer months of January, February and March are most conducive to tropical cyclone formation. In terms of geographical area, a section of the South Atlantic southeast of Rio de Janeiro and Sao Paulo, between 22 and 30 degrees south, is most favourable for tropical cyclone formation. The good news is that the prevailing summer winds tend to blow any storms eastwards into the open South Atlantic Ocean. The bad news is that the conditions which favour the formation of tropical cyclones may also reverse the wind direction. Such a switch of wind direction will then drive storms towards the Brazilian coast – just as it happened in the case of tropical cyclone Catarina (see text box ‘In focus: tropical cyclone Catarina’)

#### **In focus: tropical cyclone Catarina**

On March 28, 2004 tropical cyclone Catarina made landfall on the coast of the southern Brazilian state of Santa Catarina. Since it was the first tropical cyclone in the area, people, buildings and infrastructure were not well prepared for such a storm. According to Swiss Re’s sigma database, it caused economic damage of almost half a billion US dollars. Catarina exhibited a rather unusual life cycle. It formed initially as a “subtropical cyclone”, showing characteristics of both a tropical and an extratropical cyclone. From 19 March onwards, this subtropical cy-

clone moved away from the Brazilian coast in a southeasterly direction towards the open Atlantic ocean. Due to the onset of a special atmospheric pattern, the system made a sudden turn of 180 degrees on 23 March and transitioned into a tropical cyclone. From there on, the system intensified gradually as it approached the Brazilian coast and made landfall on 28 March. Sustained wind speeds were estimated at 160-180 km/h, which corresponds to category two on the Saffir Simpson tropical cyclone intensity scale (Source: Beerli et al. 2014).

#### **What if Tropical Cyclone Catarina had struck somewhere else?**

Drawing on our long-standing expertise in modelling natural catastrophes on a global scale, we were in the position to take the findings of the ETH Zurich study one step further: we estimated insured losses for a range of possible tropical cyclone landfalls along the coast of Brazil and compiled a tropical cyclone hazard map for Brazil.

Our tropical cyclone risk assessment models consist of tens of thousands of so-called “probabilistic scenario events”: storms that have historically not happened, but are nevertheless physically realistic events that could happen in the future. In simple terms, such scenario events are generated by randomly perturbing environmental conditions that steer the development of a tropical cyclone over time (eg its direction, forward speed, intensity, etc.). We used this methodology to study the potential impact of storm events along the coast of Brazil.

The low number of observed tropical cyclone events makes it difficult to define the full scope of “climatologically reasonable” variations in the South Atlantic. We thus chose to define our scenario events in such a way that they fairly closely resemble the main characteristics of tropical cyclone Catarina’s life cycle.

The original loss figure recorded in the Swiss Re sigma database implies that if tropical cyclone Catarina happened today, economic damage of the order of USD 0.5 billion would result. We used this loss figure, as well as building construction considerations to derive the vulnerability (ie the damage to be expected for a given wind speed) of rural and urban assets.

Combining our scenario events with these vulnerabilities, we find that the financial impact of a tropical cyclone striking Brazil could add up to an economic loss of around USD 20 billion. Figure 2 shows the wind footprint (the maximum wind speeds over the entire lifetime) of a scenario triggering this loss amount. After heading in a northwesterly direction from its genesis location, the scenario event makes landfall close to the major port of Santos and the seaside resort of

Praia Grande, also affecting Sao Paulo while decaying inland. Supported by our in-house natural catastrophe model, we judge such a scenario as physically possible under current climate conditions.

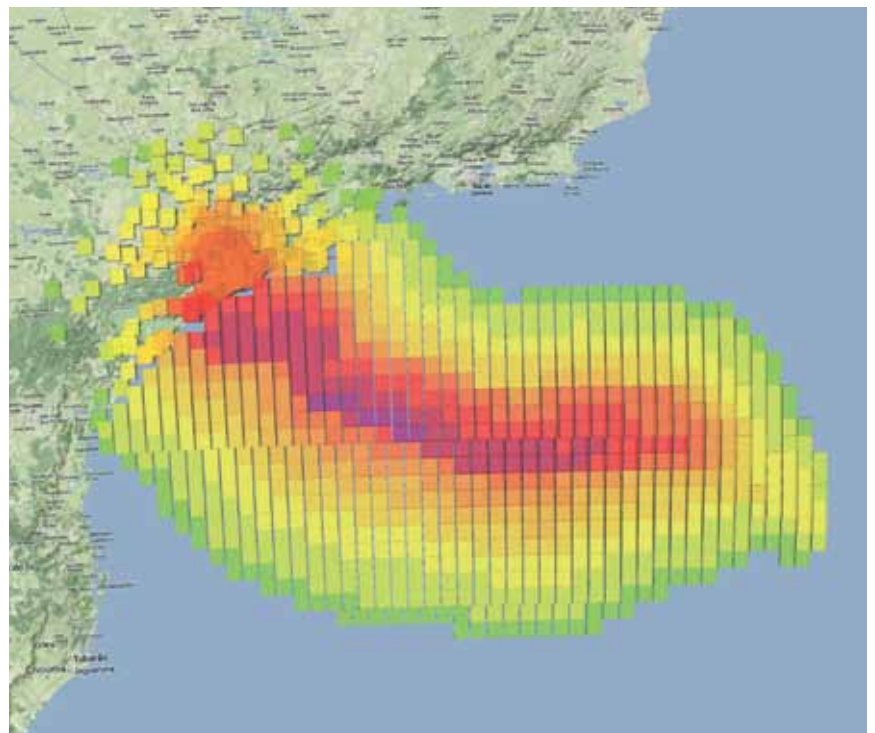
Most of our top ten largest scenario events for southern Brazil directly affect the main cities plus nearby coastal communities like the Sao Paulo metropolitan area, Curitiba or Porto Alegre. The average economic loss of the top ten scenario events is around USD 5.3 billion.

A large part of these economic losses would remain uninsured. However, rapid economic growth has led to a strong increase in commercial and industrial (‘named risk’ or ‘all risk’) insurance coverage, which would cover losses caused by a tropical cyclone. Business Interruption and Contingent Business Interruption covers could substantially add to the loss burden in case a major commercial/industrial zone would be affected. Also, losses from the agricultural sector could be picked up by insurers to some degree. Given the scenario event shown in Figure 2, and assuming that 5% of the economic losses are currently insured, the insurance industry would face claims of USD 1 bn - for natural catastrophes in Brazil, an unprecedented amount.

Figure 2: The modelled wind footprint of the simulated scenario event that causes the highest economic loss. The city of Sao Paulo is strongly affected by this scenario event.

The colour range represents 1-min sustained wind speeds:

- up to 25.5 m/s
- up to 32.5 m/s
- up to 39.5 m/s
- up to 46.5 m/s
- > 46.5 m/s





Storm over the city of Porto Alegre, Brazil in the southern state of Rio Grande do Sul.





### The role of climate change

The occurrence of tropical cyclone Catarina raises the question if there is any link to climate change. The answer to this is not conclusive. What we can say with certainty is that climate change itself is a fact. Our atmosphere and oceans have warmed markedly, the amounts of snow and ice have diminished, sea levels have risen, and the concentration of greenhouse gases has gone up strongly, says the UN Intergovernmental Panel on Climate Change (IPCC). What this means for us and how we can adapt to climate change is discussed in Swiss Re's latest sigma report on natural catastrophes.

With regard to the South Atlantic, it is true that the number of detected storms which show some characteristics of tropical cyclones but have not fully developed into such has increased over the last decade. While this increase could be a sign of climate change, it may simply be that weather forecasters have become more aware of such events. However, extremes like tropical cyclone Catarina are rare by definition, and it is impossible to blame climate change for any single event. There are not enough scientific facts to conclude if and how climate change is having an effect on weather events like Catarina in the South Atlantic Ocean.

The geographic distribution of environmental factors that support or inhibit tropical cyclone formation, as well as modelled and observed tropical storms, allow us to conclude that the coastal area between Paranaguá (Curitiba) and Florianópolis is at highest risk from winds triggered by tropical cyclones (Figure 3). Areas to the south and north as well as inland are at progressively lower risk.

We see this hazard map as a contribution to the continued investigation of natural hazard risk in Brazil. Given the current status of research, uncertainties around frequency and severity of events like tropical cyclone Catarina remain large. Due to the sparse population and the thin shipping traffic on the coast of southern Brazil in the past, it is possible that past landfalls of tropical cyclones might have gone unnoticed completely before the advent of satellite observation.

### A tropical cyclone hazard map for Brazil

Combining the insights from the external study carried out at the ETH Zurich and the internal investigations based on Swiss Re's global tropical cyclone modelling methodology, we compiled a 'Tropical Cyclone Hazard Map for Brazil' – to our knowledge, the first ever published.

Past tropical cyclones might also have been confused with "normal" thunderstorms. It will be interesting to follow – and possibly support – scientific endeavours that try to shed more light onto the risk of tropical cyclones in the South Atlantic. A review of century-old records

Figure 3: The tropical cyclone hazard map shows estimated 1/500 year return period peak gusts over open terrain at a height of 10m above ground. The return period provided is based on the assumption that a Catarina-like event will affect Brazil around once every 50-100 years. It is important to note that only winds triggered by tropical cyclones are considered in the map, while winds triggered by winter storms or severe convective storms/tornados are not considered.

- >50 m/s
- >45 m/s
- >40 m/s
- >35 m/s



### Natural hazards in Brazil

When it comes to natural catastrophes in Brazil the two most important issues are floods and droughts. In terms of number of events, floods rank as the most frequent natural catastrophes. However, in northeastern Brazil the infamous “Nordeste-droughts” are the main concern for the local population. The other exception is southern Brazil (the states Rio Grande do Sul, Santa Catarina and Paraná) where the atmospheric perils, such as windstorms, tornadoes and hail, play an equally important role as droughts and floods. These are triggered by severe thunderstorms which develop preferably in southern Brazil and northern Ar-

gentina, a situation similar to the “Tornado alley” in North America. While damages related to severe thunderstorms may be significant, they are strongly localised at the point of occurrence of a given storm. Thus, they present generally a high frequency but low severity risk. This is the main difference to tropical cyclones which may affect areas of several hundreds of kilometers, depending on the size of the respective cyclone. Therefore tropical cyclone Catarina, being the only documented tropical cyclone which made landfall at the Brazilian coast, added a previously unknown type of hazard to the spectrum of possible natural catastrophes in Brazil.

As the population and economy along the coast keep growing, the question of how to manage this risk will gain importance. An effective way to improve the resilience against the impact of tropical cyclones around the world has been the introduction of building codes with specific, hazard-based wind load provisions. Sea walls protecting key infrastructure (eg power supply, transportation, communication) strongly improve the capability to react in the aftermath of a natural disaster, as do available emergency plans. An appropriate land-use strategy, on the other hand, can help to minimise losses in the first place.

Financial protection via insurance will strongly facilitate recovery after an event by providing necessary funds to quickly rebuild after a catastrophe. Clearly, such measures need to stand in an adequate relation to the risk under consideration – for example in terms of costs, disruption to movement, visual impairment, cultural preferences etc.

As such, each country or region will need to find its particular mix of measures that improve its resilience in the face of natural catastrophe risks. We at Swiss Re look forward to continue to be part of this process – concerning tropical cyclones in Brazil, as well as any other natural hazard worldwide.

### Literature:

- Beerli et al. (2014) “Reinvestigation of environmental factors inhibiting tropical cyclogenesis in the South Atlantic”, publication in preparation please refer to <http://www.iac.ethz.ch/groups/wernli/publications>.
- Swiss Re *sigma* nat cat series

from Portuguese ships or Catholic missions, or the search for specific sediment deposits along the coast of Brazil could possibly deliver evidence for tropical cyclones that occurred long before tropical cyclone Catarina. Ever more sophisticated climate models may provide additional insights, including the impact climate change could have on the occurrence of tropical cyclones in the South Atlantic.

### The big picture: adequately managing risks

By writing this paper, we wanted to serve two main purposes: firstly, we aimed to raise awareness in respect of a poorly understood and widely ignored risk. While tropical cyclones will remain a rare occurrence, and present but one part of the ‘windstorm risks’ in Brazil (see text box ‘Natural hazards in Brazil’) their potential for loss accumulation over wide areas should not be ignored. Secondly, we wanted to provide a basis to discuss potential measures to avoid, contain or mitigate the risks posed by tropical cyclones in Brazil.

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Cover: Residents start to clean up their home in Torres, March 29, 2004, after a rare tropical cyclone known as Catarina formed in the South Atlantic and came ashore in southern Brazil a day before. Catarina killed at least two people, injured about 80 and forcing some 30,000 people to leave their homes. REUTERS/Paulo Whitaker PW/JDP

Maps on pg 3, 5, 7: © Google

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