Tropical Cyclone Forecasts

Technical content: low

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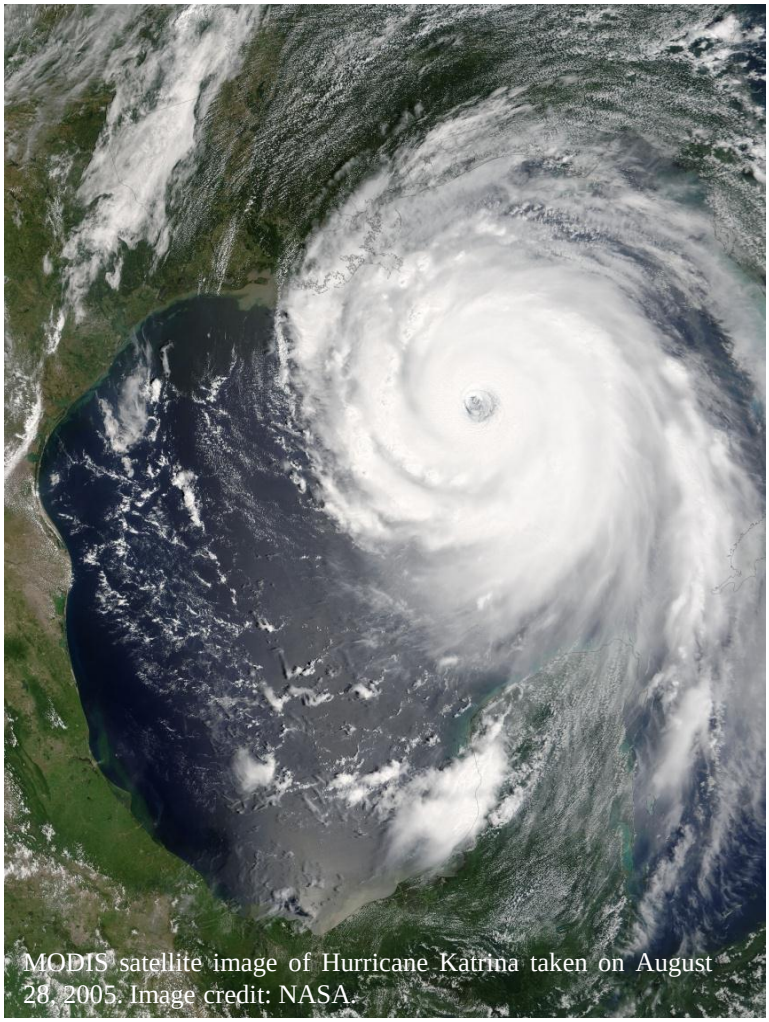
What is a tropical cyclone?

"Tropical cyclone" is the common name used to describe low-pressure air systems that show intense convective activity (thunderstorms) organised in the form of spiral bands, with surface winds exceeding 62 km/h. Katrina, Sandy, Nargis and Haiyan are notorious recent examples of tropical cyclones. Tropical cyclones rate as the primary natural disaster in terms of causing death, destruction and economic loss. Katrina resulted in ~1500 casualties, and caused damages in excess of $100 billion while Typhoon Haiyan killed over 6000 people when it made landfall in the Philippines in November 2013. Unlike tornadoes, the main threat from tropical cyclones comes not from the high winds, but rather from the rising waters or "storm surges" that cause coastal flooding or tsunami-like phenomenon. Low-lying areas, such as New Orleans and Bangladesh, are particularly vulnerable to this threat. Cyclone-related damage can also come about from the strong winds, torrential rains or the presence of hurricane-spawned tornadoes.



MODIS satellite image of Hurricane Katrina taken on August 28, 2005. Image credit: NASA.

Evaporation from the ocean surface (latent heat) provides the primary energy source for tropical cyclones. Therefore, these storms generally form only in areas where the sea surface temperatures are sufficiently warm (>26.5ºC) over an extended period of time. This includes the three tropical oceans: Atlantic, Pacific and Indian. Depending on its location, if the storm is sufficiently strong, it will either be called a hurricane (Atlantic or East Pacific), a typhoon (Northwest Pacific), a severe tropical cyclone (around Australia), a very severe cyclonic storm (North Indian Ocean) or a tropical cyclone (Southwest Indian Ocean). In the Atlantic, tropical cyclones are alternatively given male and female names, starting with the letter A for the first storm, B for the second, and so forth. Cyclones in other ocean basins are also named, each using a different naming convention. For example, in the western Pacific, they are assigned a name from a list submitted by different nations within the basin.

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Tropical cyclone activity in each basin varies widely from one year to the next and sometimes even from one decade to the next, and because these storms are such a serious social and economic concern, there is a strong interest from emergency and financial planners in mitigating against possible losses by using long-term climate forecasts.

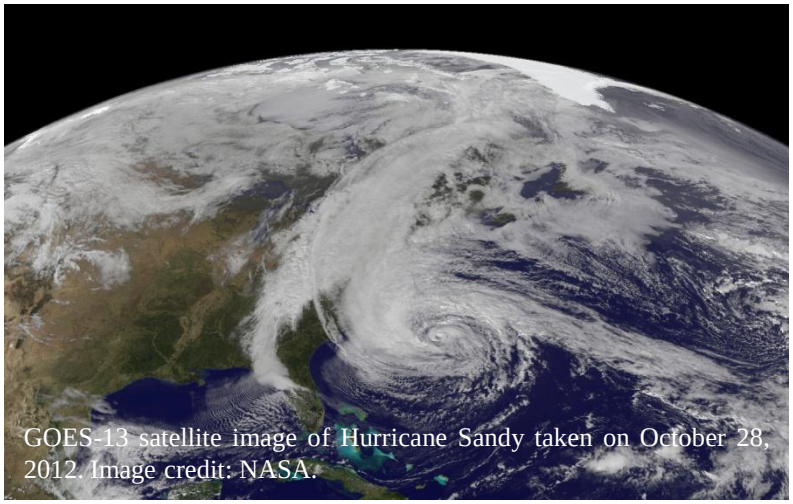
Seasonal predictions of tropical cyclones

Over seasonal timescales, from 3-10 months in advance, predictions are made for the level of cyclone activity to occur during a given season rather than for individual storms. Such predictions will indicate, for example, the expected number of cyclones that will form or the number of days that there will be cyclones during a season. Such predictions are typically issued in the months leading up to each tropical cyclone season by a by a range of national agencies and research centres such as the Met Office and the European Centre for Medium-Range Weather Forecasts (ECMWF), and also by some private firms.

For example, the forecast issued in May by the Met Office for the 2014 Atlantic hurricane season was:

	Forecast	Actual
Tropical Storms	10 ±3	8
Hurricanes	6 ±3	6
ACE ($10^4 kt^2$)	84 ±37	67

ACE, or Accumulated Cyclone Energy, is a measure of the collective intensity and duration of all tropical storms over a given hurricane season.



GOES-13 satellite image of Hurricane Sandy taken on October 28, 2012. Image credit: NASA.

Seasonal tropical cyclone predictions are possible since cyclone activity is known to be influenced by predictable climate factors, such as the El Niño Southern Oscillation (ENSO), which impact the atmospheric circulation in the regions where cyclones develop. Knowing the state of ENSO at the beginning of a tropical cyclone season as well as its likely evolution throughout a season provides information on whether the risk of cyclone activity is heightened or lowered. ENSO is known to influence cyclone activity in the Atlantic, western and eastern North Pacific and around Australia.

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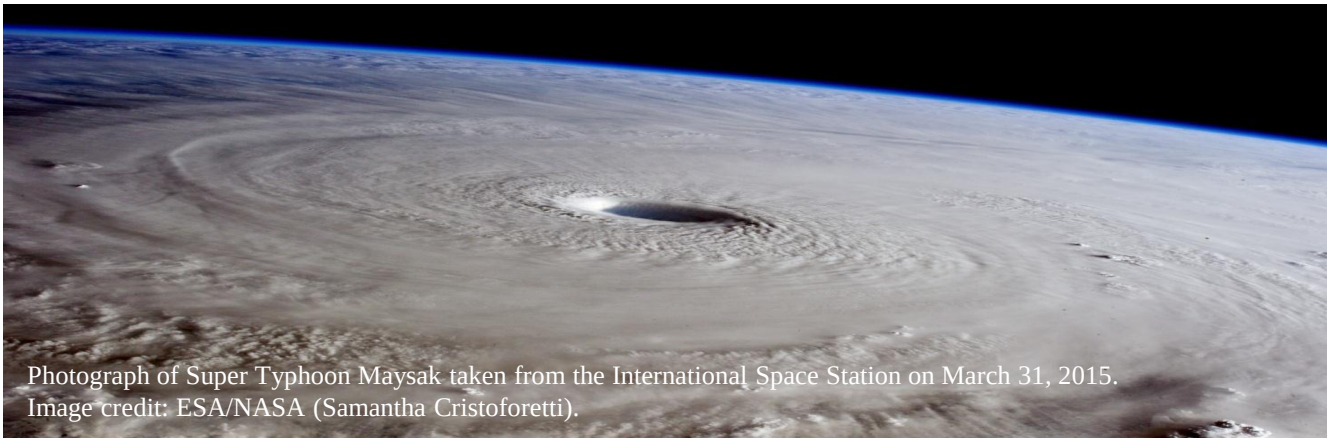
Two techniques are typically used to produce these forecasts. First, statistical predictions are performed by comparing the current season with previous seasons which share similar relevant features (such as sea surface temperatures and/or the state of ENSO). The frequency of cyclone activity from those past seasons is then used to make an estimate of the activity for the upcoming cyclone season. Dynamical predictions are made using comprehensive models of the atmosphere and ocean. These models are provided with the initial state of the Earth system, as observed ahead of the cyclone season, and are run many times for a period covering the entire upcoming season. Each simulation uses slightly different initial conditions to reflect possible variations in reality due to the chaotic nature of the climate and our incomplete knowledge of the system. This creates a range of potential outcomes known as an "ensemble". The tropical cyclone statistics of the entire ensemble are then used to make a prediction. Dynamical predictions have been demonstrated to improve upon the statistical approach over some geographical regions and timescales, but also require a large amount of computational power currently only available at a few institutions. There also exist statistical-dynamical hybrid forecasts where the large-scale fields are predicted by the climate models and cyclone activity is subsequently inferred from those forecasted fields.



Photograph of Super Typhoon Maysak taken from the International Space Station on March 31, 2015. Image credit: ESA/NASA (Samantha Cristoforetti).

The skill of these seasonal forecasts is strongly dependent on lead time and varies with ocean basin. In the Atlantic, there is little skill in the forecasts issued in April, but the skill climbs steadily for June (the beginning of the hurricane season) and August forecasts, with moderate to good skill levels being achieved for the latter. As examples, the correlation between forecast and observed numbers of storms achieved by the Met Office system at one month lead time suggests moderate skill for its May forecasts in the North Atlantic (correlation coefficient = 0.51) and western Pacific (0.57), but greater skill for November forecasts in the Australian region (0.69) (for retrospective forecasts 1996-2009).

Multi-annual predictions of tropical cyclones

Some studies have recently suggested that it is also possible to predict cyclone activity over multiple years in the Atlantic. This ability has been linked to slow changes in the Northern North Atlantic ocean circulation, which in turn impact the atmospheric circulation over the tropical Atlantic and, consequently, tropical cyclone formation. This type of forecast is still in the experimental stage and, so far, have only been attempted in the Atlantic and the western North Pacific basins.

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