Climatology of Tropical Cyclones

This information has been summarised from the Introduction to Tropical Meteorology (2nd Edition) which can be accessed, free of charge, on the MetEd/ COMET website (requires free registration).

Tropical cyclones are a natural part of the climate system, forming in all tropical ocean basins with the possible exception of the South Atlantic, although rare storms with tropical characteristics are observed in the South Atlantic and the Gulf of Oman (see below).

Seasonality

Environmental conditions favourable for tropical cyclone formation vary geographically and by season. Broadly speaking, warm ocean temperatures and weak vertical wind shear (difference in wind velocity at right angles to wind direction) are two of the necessary, but not sufficient, conditions for tropical cyclogenesis.

The wind shear tends to be weaker early in the local summer, increasing as the tropical and subtropical oceans warm and the winter Hadley cell strengthens through the local summer and into autumn. Thus, the Southern Hemisphere (SH) seasonal cycle is out of phase with the Northern Hemisphere (NH) and generally follows the seasonal monsoon variations (Figure 1).

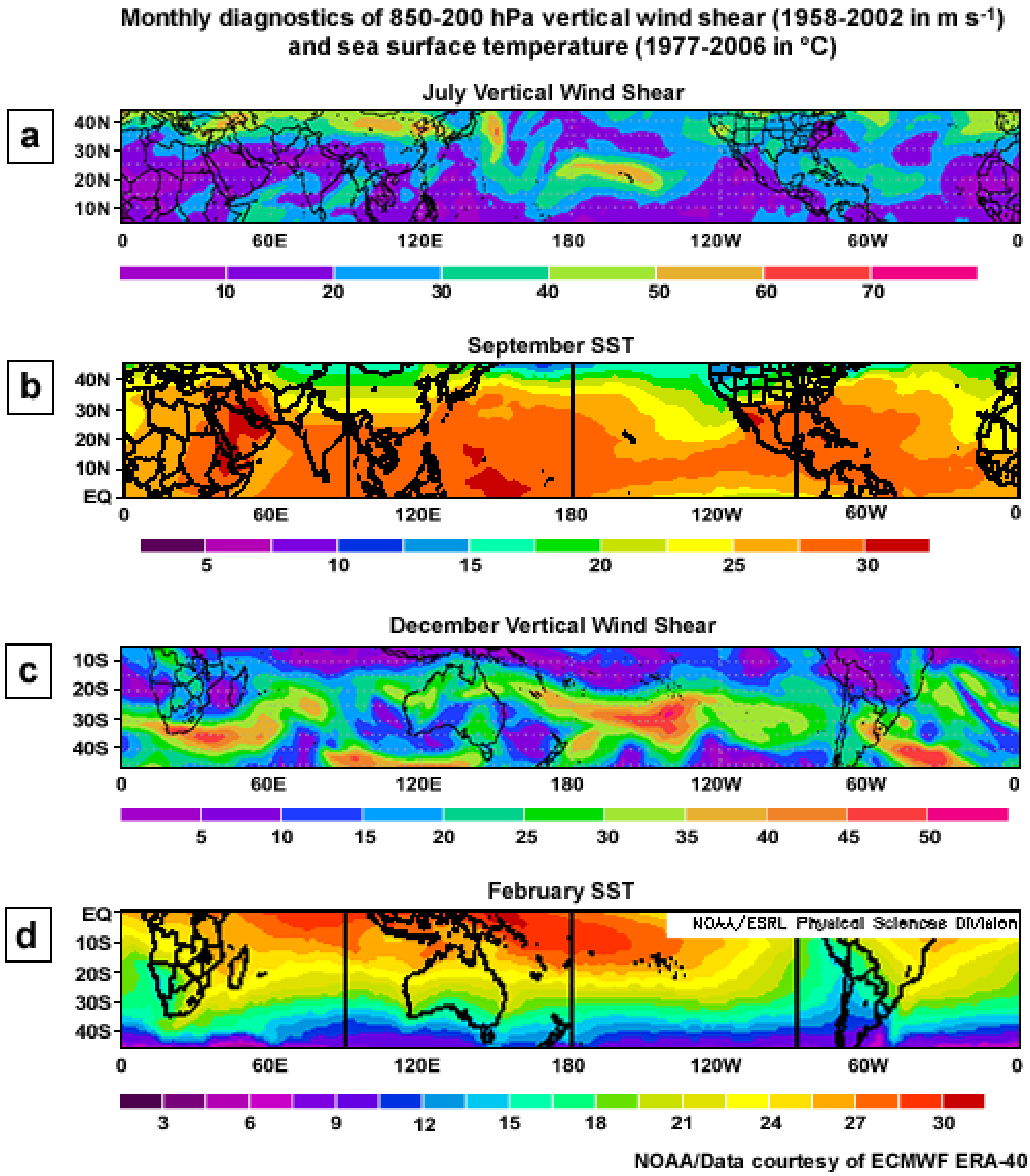

Figure 1 *Monthly diagnostics of 850–200 hPa vertical wind shear (1958 2002 in m s-1) and SST (1977 2006 in °C). (a) July shear and (b) September SST for the NH; (c) December shear and (d) February SST for the SH. Wind shear values are in 10 m s-1 bands from < 10 m s-1 in light purple then dark purple, blue, teal, green, orange, red, and >70 m s-1 in pink. The SST colour scheme follows the same order in 3°C increments from 3°C to 30°C. Shear and SST are from ERA–40 analyses.*

While tropical cyclones are common in most of the global tropics, the western North Pacific is the only basin in which they have been observed in every month of the year (Fig. 2 overleaf). The formation of Tropical Storm Ana in April 2003 and the 2005 Atlantic storms, concluding with Tropical Storm Zeta—for which warnings were issued until 6 January 2006, mean that tropical cyclones have been recorded in the North Atlantic in all months except February and March.

Based on long–term statistics of tropical cyclones in the North Atlantic; the "hurricane season" for that basin is defined from 1 June through 30 November.

The Eastern North Pacific hurricane season begins on 15 May and also extends to 30 November.

In the North Indian Ocean tropical cyclones tend to occur in the monsoon transition months of early (May-June) and late in the wet season (October–November), when the large–scale conditions for genesis are most favourable over that ocean.

In the Southern Hemisphere, the tropical cyclone seasons typically extend from November through April, although early and late season storms (October and May) have been observed.

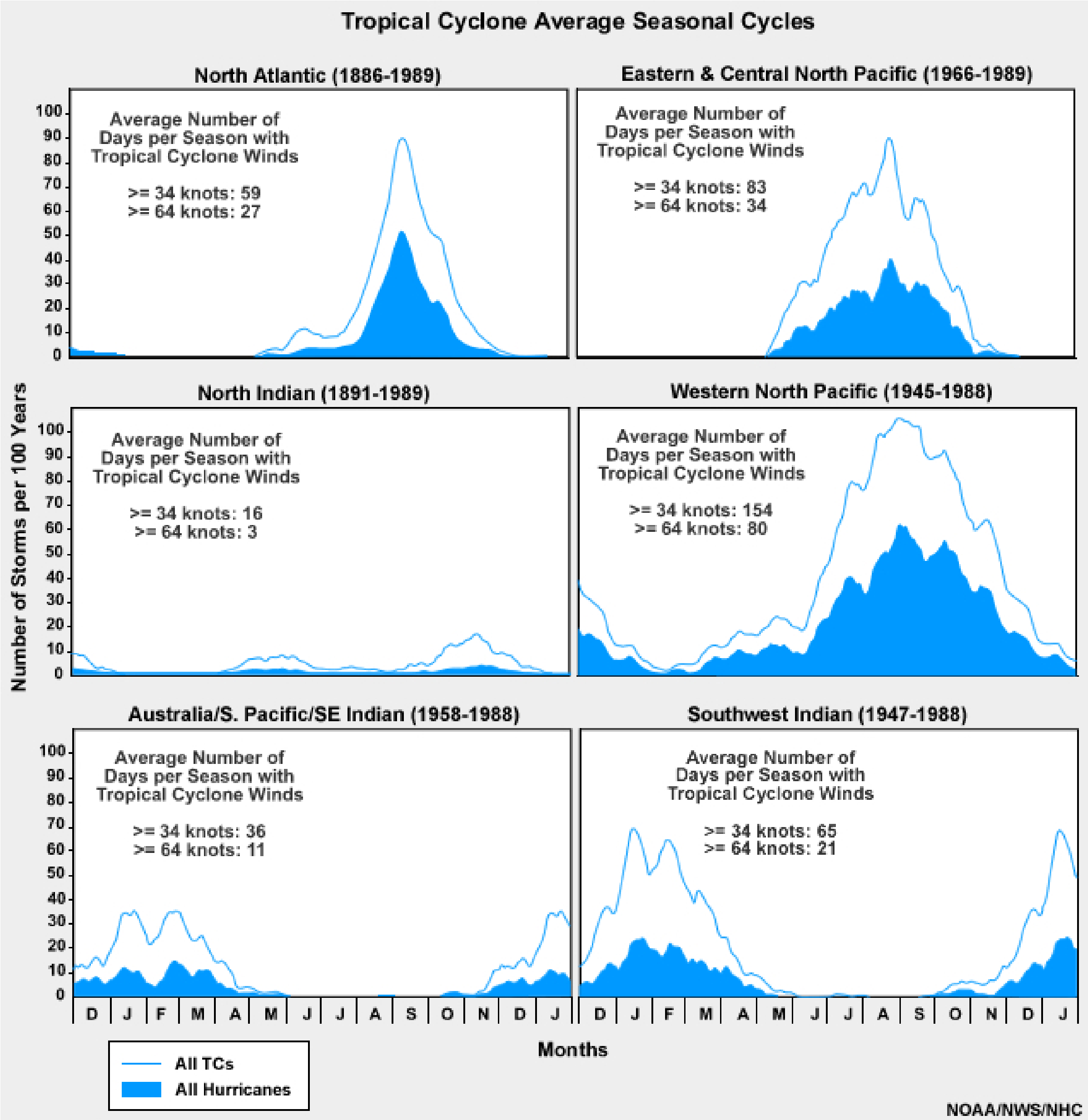

Fig. 8.54.

NHC

Figure 2 *Average annual cycle of tropical cyclone occurrence for each ocean basin. The abscissa spans the 13 months, December through January of the following year; the ordinate is the number of storms per hundred years. For each day, the graph shows the number of years that a cyclone was present (normalized per 100 years). The blue line represents all tropical cyclones (surface winds greater than 17 m s-1 or 34 knots); shading represents tropical cyclones of hurricane strength (surface winds greater than 33 m s-1 or 64 knots). The averaging time for the mean surface wind speeds varies across basins.*

Further information

- Summary of 2005 Atlantic Hurricane Season,
  http://www.nhc.noaa.gov/2005atlan.shtml
- NHC Archive of Hurricane Seasons
  http://www.nhc.noaa.gov/pastall.shtml
- Japan Meteorological Agency (JMA),
  http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/trackarchives.html
- NOAA NWS Climate Prediction Center, Expert Assessments (assessments, advisories, outlooks)
  http://www.cpc.ncep.noaa.gov/products/expert_assessment/
- NASA visualizations of 2005 hurricane season, IR clouds, SST, storm tracks, name labels
  http://svs.gsfc.nasa.gov/goto?3354 (list of all movies with and without audio)
- Video interview with Dr. Jenni Evans, Penn State University Weather World,
  https://www.youtube.com/watch?v=u5AJwvjMQP8&feature=youtu.be

South Atlantic Tropical Cyclone Catarina (2004)

No tropical cyclones have been observed in the South Atlantic since the beginning of the satellite era (over 40 years ago) until "Tropical Cyclone Catarina" made landfall in Brazil on 28 March 2004 (Fig 3). Because the South Atlantic was thought to be unfavourable for tropical cyclone formation, there was no list of WMO-sanctioned names for this basin. Catarina was named for the Brazilian state of Santa Catarina where it made landfall. This rarest of tropical cyclones left its mark: at least two people lost their lives, 11 were reported missing and 75 severely injured. Roughly 32,000 homes were damaged and almost 400 were destroyed, giving a total damage estimate of about US $350M.

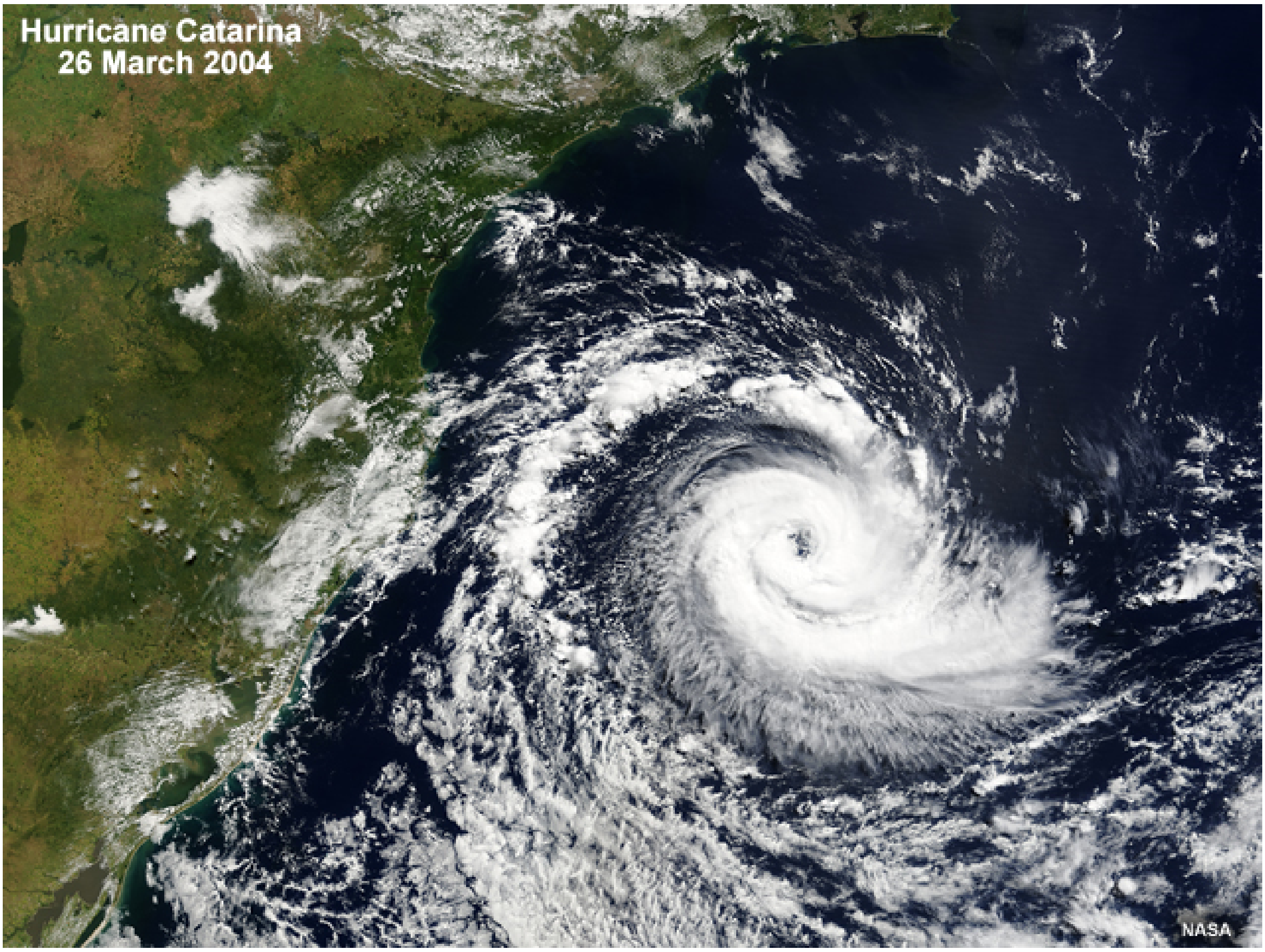

Figure 3 MODIS image of Tropical Cyclone Catarina on 26 Mar 2004. At this time, Catarina was estimated to have surface winds of 35 m s-1 (Saffir-Simpson Category 1).

Why was Catarina such a surprise?

Until Catarina, the cooler SST of the tropical South Atlantic and the strong vertical wind shear were thought to preclude tropical cyclone formation. The warmest waters in this region are usually near 26°C (thought to be the minimum SST needed for tropical cyclone formation in the present climate) but Catarina began life as a subtropical storm. In the North Atlantic, subtropical storms form over cooler water and are precursors to tropical cyclogenesis roughly once or twice per season.

So, we see that, storms forming under the right conditions farther from the equator can become tropical cyclones. Intensity theory provides another piece of the puzzle: if the tropopause and surface are cool, it is still possible to achieve hurricane intensity. So we see that the formation and intensification of Catarina can be explained by our current understanding of tropical cyclones.

How do we know that Catarina achieved hurricane status (at least 33 m/s)? The most comprehensive information on Catarina came from the TRMM139 TMI (a satellite instrument to measure rainfall using microwaves), which sensed the warm core of the system that is typical of a tropical cyclone and the spiral band structure (Fig. 4). QuikSCAT - a NASA instrument that used microwaves to measure winds by inferring their strength from the roughness of the sea that itself was on a Japanese Advanced Earth Observing Satellite called ADEOS-1 - recorded the surface winds (Fig. 5.)

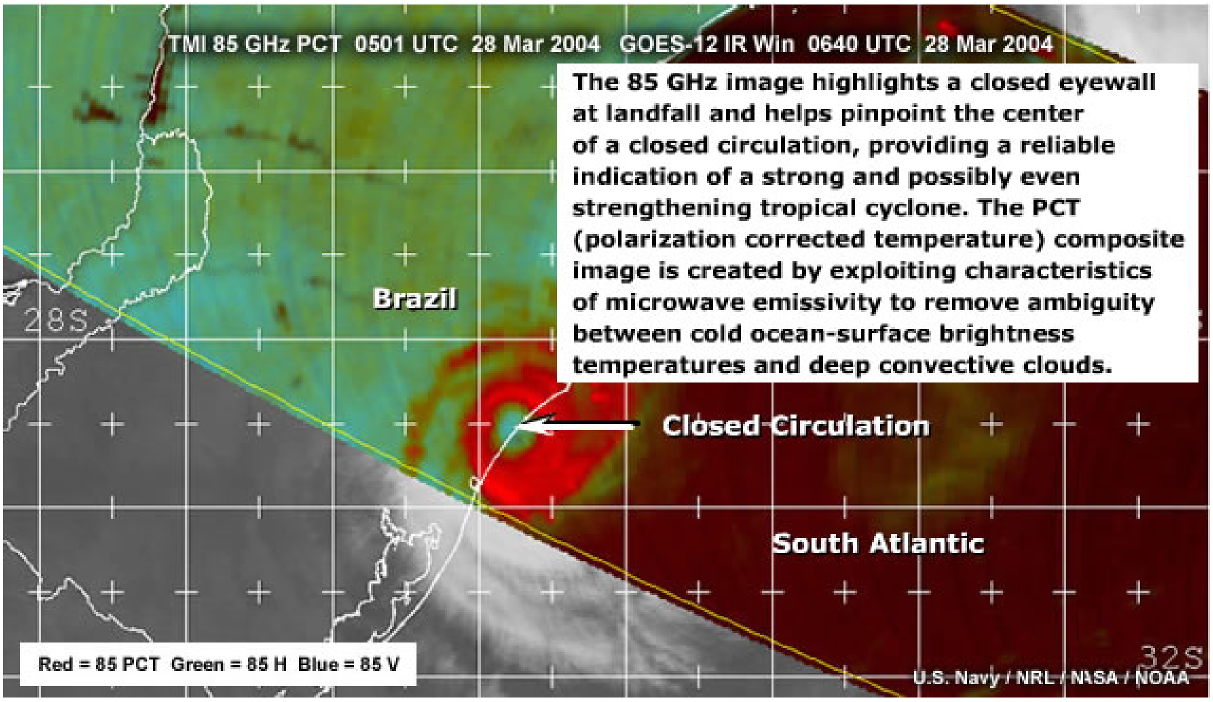

Figure 4 7.2. 85 GHz microwave image of Tropical Cyclone Catarina taken by the TMI at 0501 UTC 28 Mar 2004.

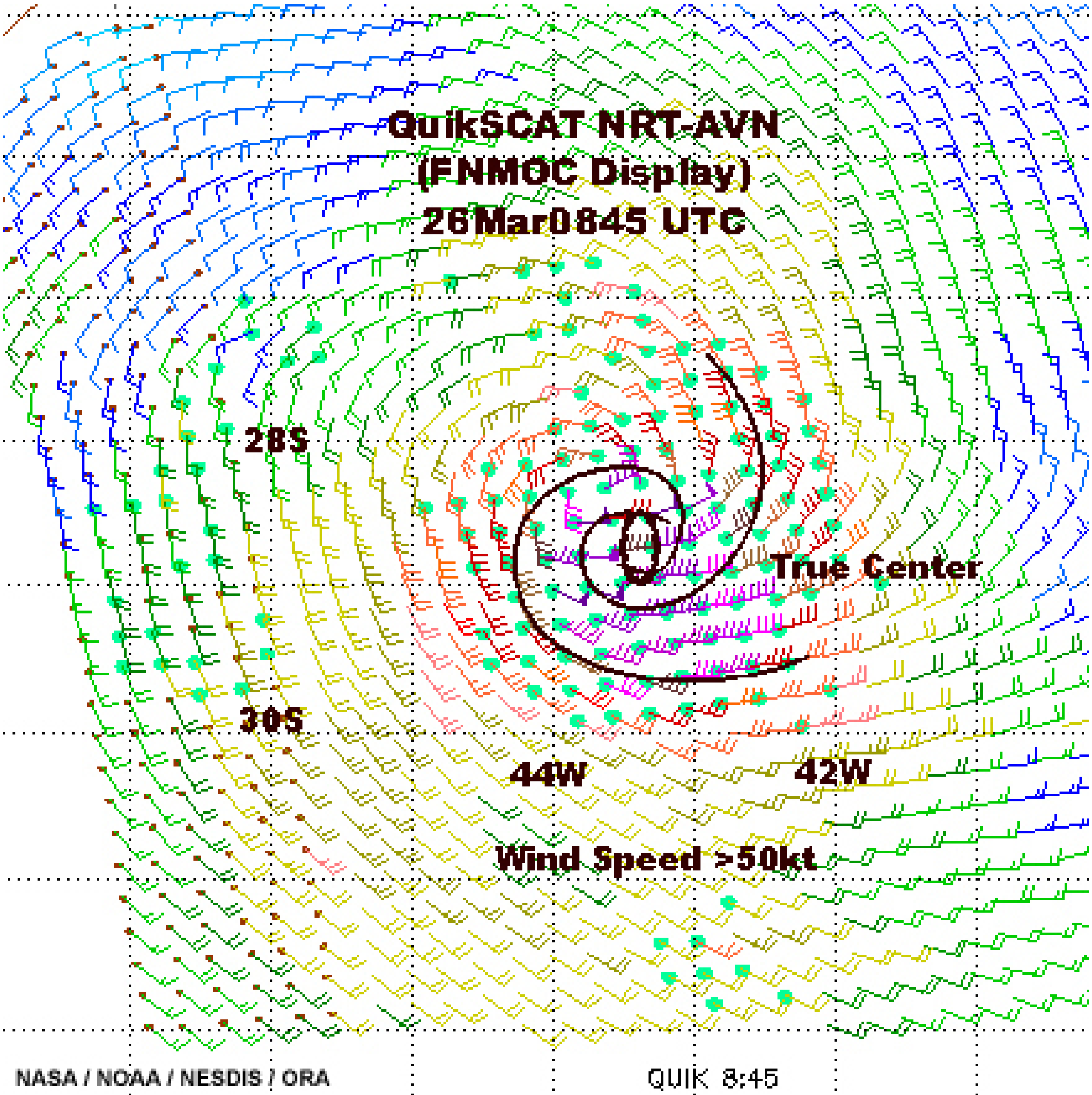

Figure 5 QuikSCAT scan of Tropical Cyclone Catarina at 0845 UTC 26 Mar 2004, when Catarina was still intensifying. Green dots indicate winds that may be inaccurate due to rain interfering with the measurement; Wind barbs are in knots (1 knot = 0.51 m s-1). (See https://www.wikihow.com/Read-Wind-Barbs)

Further information

NB These sites are archived from 2004 and make contain broken links and/or very dated interfaces.

- NASA Earth Observatory -Rare South Atlantic Tropical Cyclone
  https://earthobservatory.nasa.gov/images/12937/rare-south-atlantic-tropical-cyclone
- University of Wisconsin-Madison – Hurricane Caterina
  http://tropic.ssec.wisc.edu/storm_archive/brazil/brazil.html

Tropical Cyclone Gonu (2007)

Tropical Cyclone Gonuj entered the Gulf of Oman as a "Severe Cyclonic Storm" (Figure 6.) with 1–minute maximum sustained winds of 43 m/s (153 km h^{-1}, 95 mph). As the storm moved across the Gulf towards the Iranian coast, it weakened to a tropical storm with winds of around 23 m/ s (83 km/ h, 51 mph,) at landfall on 7 June 2007.

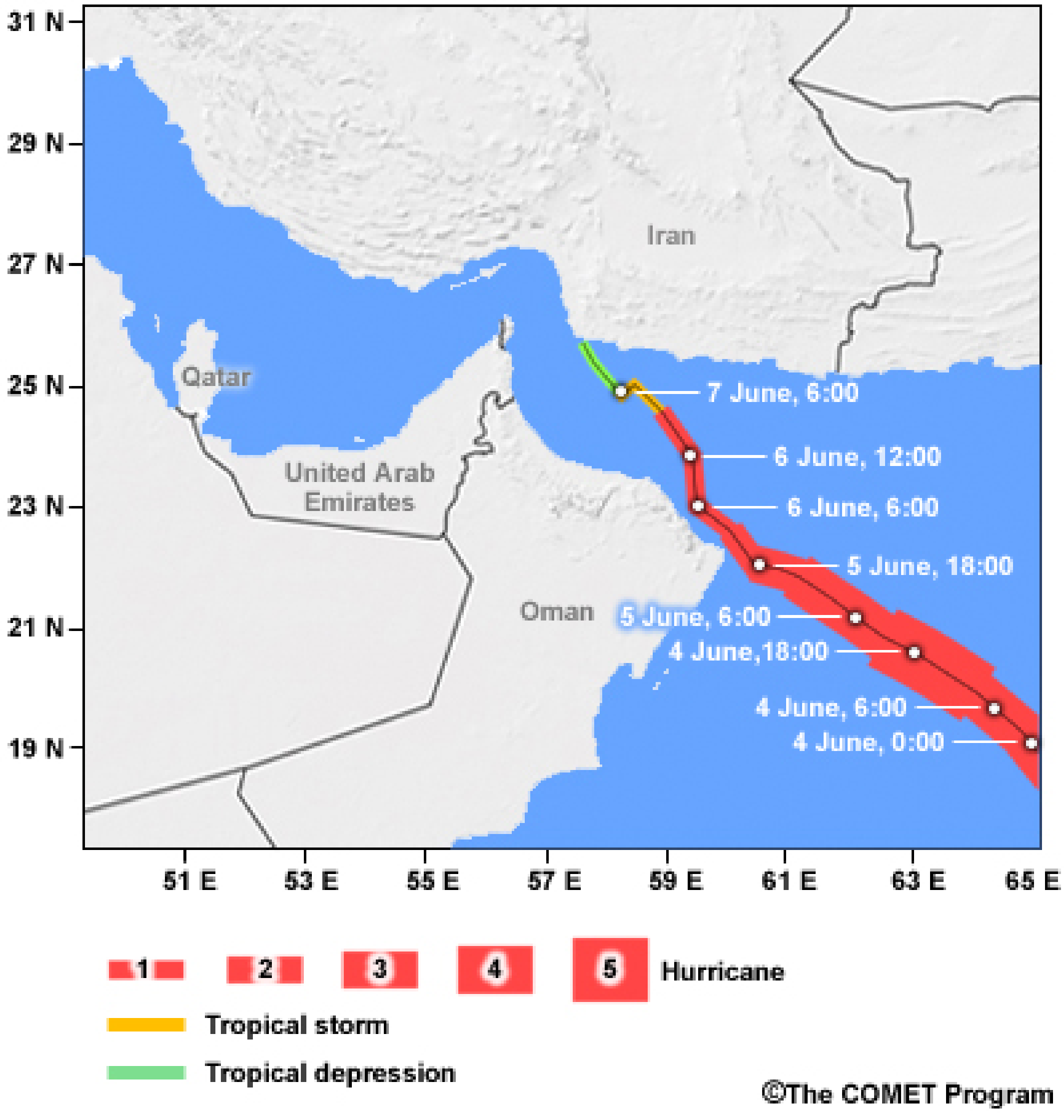

Figure 6 Track and windspeed of super cyclonic storm Gonu (2007).

Although Gonu made landfall in Iran, its major effects were in Oman. The Omani capital, Muscat, was impacted by severe winds and associated waves, as well as the torrential rain. Topographic enhancement of the storm rainfall compounded the flooding in Muscat. Gonu was blamed for only three fatalities in Iran; in contrast 25 fatalities were reported in Oman, with about the same number of people reported missing.

Intraseasonal Variability

Variation of the necessary conditions for tropical cyclogenesis can lead to clustering of formation events within a storm season. These intraseasonal variations in tropical cyclogenesis frequency are driven by a variety of factors; some, such as the 30–60 day oscillation of tropical rainfall, the MJO (Madden-Julien Oscillation), are tropics-wide phenomena, while others are regional modulators of genesis, such as the Saharan Air Layer (SAL) in the North Atlantic.

Intraseasonal Modulation by the Madden-Julian Oscillation (MJO)

The MJO is a travelling pattern that moves Eastward and is caused by a coupling of deep tropical convection and global atmospheric circulation. It typically manifests as unusual levels of rainfall. The passage of the "active" phase of the MJO through a region enhances the convective activity locally; conversely, the "inactive" phase of the MJO suppresses convective activity. Tropical cyclogenesis is likely near the peak of the MJO; Figure 7 (overleaf) shows phases of the MJO and the origins of disturbances that developed into tropical cyclones.

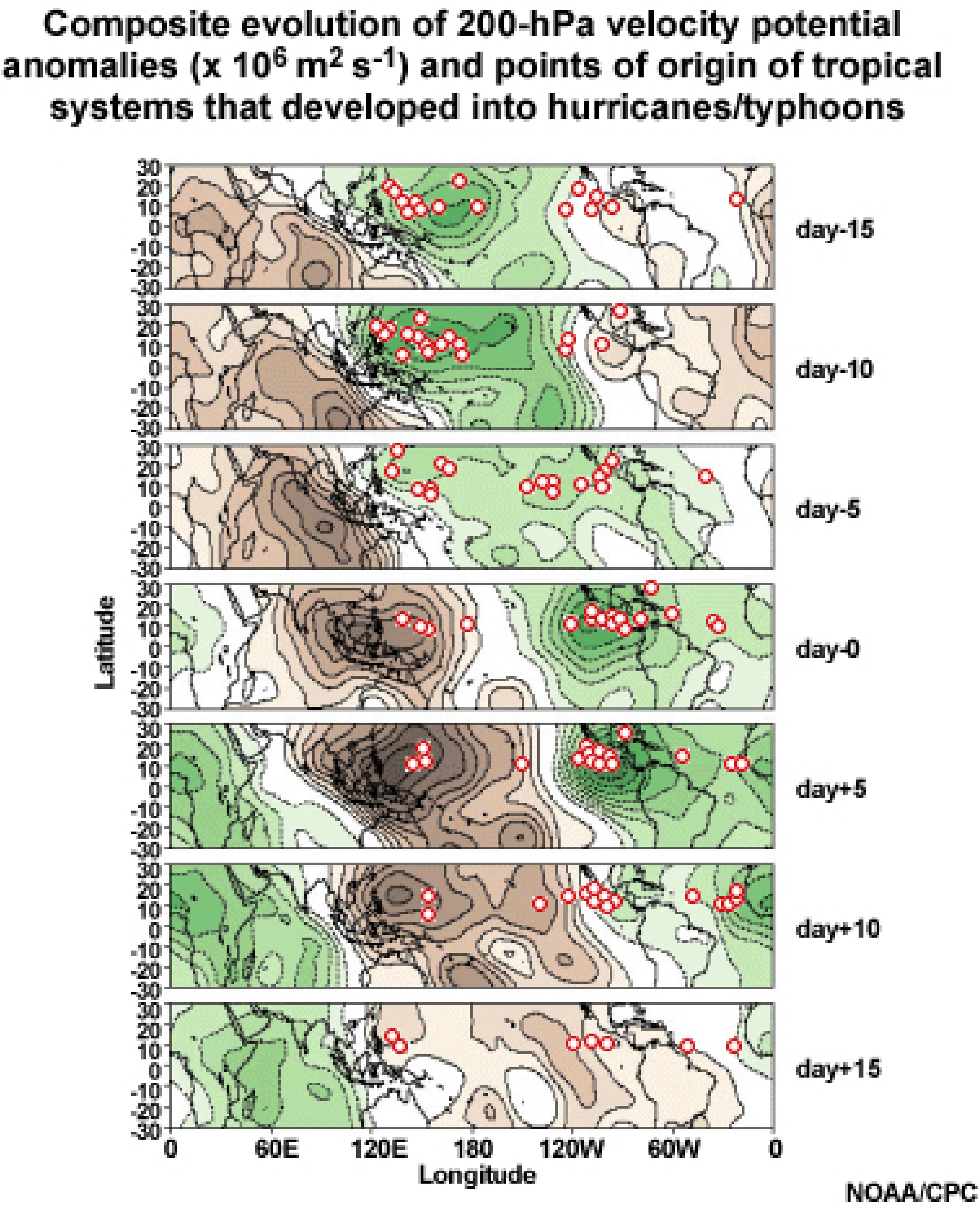

Figure 7 Points of origin of tropical systems that developed into tropical cyclones (red circles) relative to phases of the MJO. The MJO cycle is identified here by the 200 hPa velocity potential anomalies (10^5 x m^2/s); green is the peak and dark brown is the lull. Modulation of tropical cyclogenesis potential by the MJO agrees with the three-week active/ three week inactive periods of tropical cyclogenesis proposed much earlier.

Different hypotheses have been presented for why and how the MJO modulates tropical cyclogenesis. One perspective is that the increasing convective organization moistens the free troposphere through detrainment of moisture from the clouds. The moisture above the boundary layer provides a favourable environment for sustaining deep convection and for forming larger convective complexes.

An alternative perspective is that genesis is more likely for western Pacific storms not because the MJO acts an inherent control on genesis, but rather that the general increase in convective activity in the enhanced phase of the MJO produces many more seed systems from which a tropical storm could develop. However, that hypothesis was contradicted by another study that found that the fraction of systems developing from convective cluster to tropical storm is unchanged between "favourable" [convection active] and "unfavourable" [convection suppressed] phases of the MJO.

Since the vast majority of tropical cyclones in the Australian region form near the axis of the Australian summer monsoon, modulation of this feature by the MJO has been linked to tropical cyclone activity in that region.

Intraseasonal Modulation by the Saharan Air Layer (SAL)

Another large-scale modulator of tropical cyclone development in the eastern Atlantic is the Saharan Air Layer (or SAL), first identified in the 1970s. From late spring to early autumn the enhanced warm season solar radiation causes deep mixing over the Saharan Desert that results in a dry, well-mixed boundary layer that can extend up to 500 hPa (5,500m, 18,000 ft).

At its southern end, this Saharan boundary layer air is bounded by the African Easterly Jet, which has peak amplitude of 10–25 m s^{-1} near 700 hPa (3,000m, 10,000ft) (Fig. 8). Sand storms created in this dry environment result in suspended particles throughout the layer. Advection of this desert boundary layer over the Atlantic Ocean (often in association with an African easterly wave progression) results in its being undercut by a moist marine layer and creates the SAL. **The SAL is therefore an elevated layer of very dry, well-mixed air embedded in the Atlantic marine environment.**

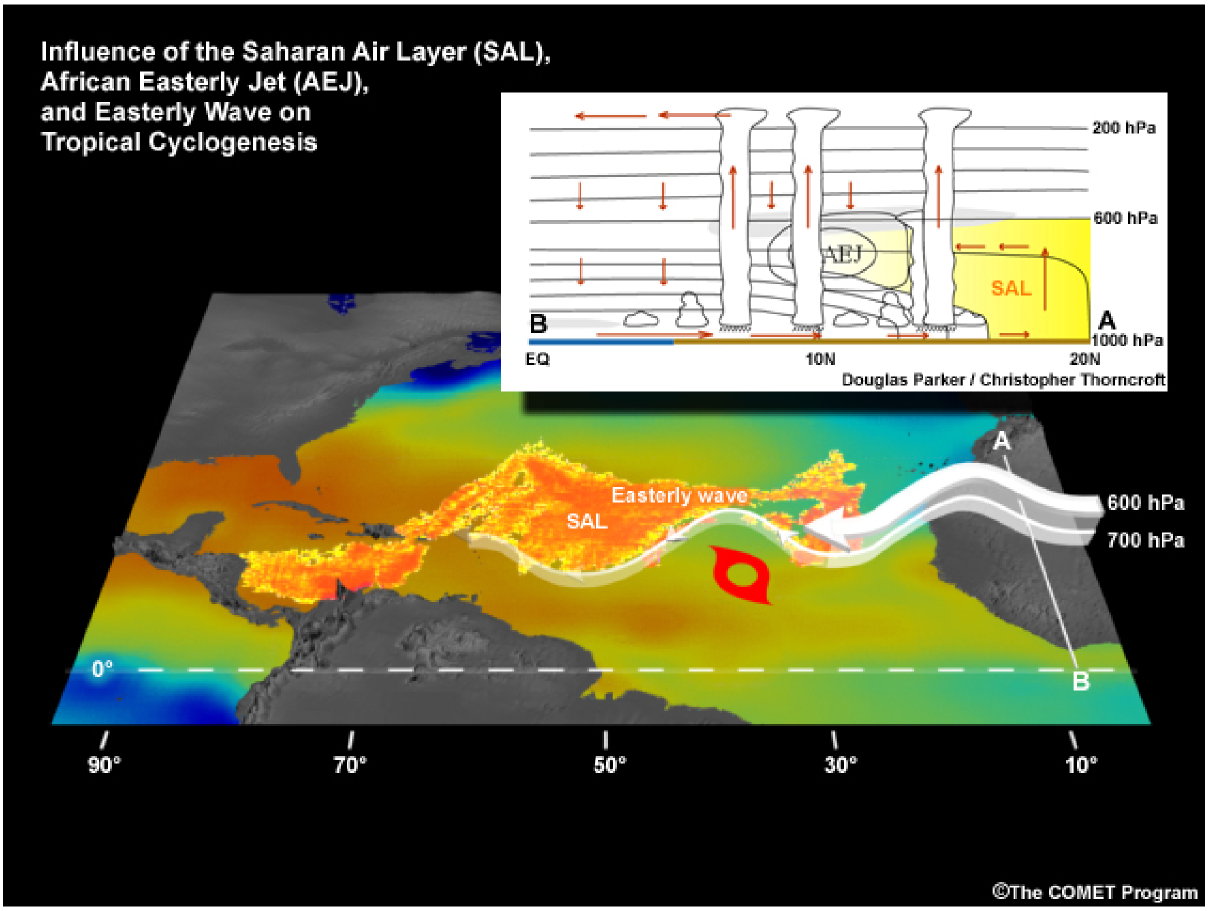

Figure 8 Schematic of the Saharan Air Layer, and influences on genesis, as described by Dunion and Velden152 and Karyampudi and Pierce.153 The African easterly jet (AEJ) at the southern bound of the SAL and an African easterly wave are shown. The cross–section is a conceptual model of the SAL, AEJ, and convective weather systems based on the JET 2000 field program.

A relationship between the SAL and tropical cyclogenesis is not surprising as the SAL is most prevalent off the West African coast in the Main Development Region (MDR) for Atlantic tropical cyclogenesis. It is the interaction between the SAL and tropical air to the south that creates cyclonic shear vorticity. Eventual coupling of low– and mid–level disturbances can then lead to tropical depression formation.

This positive relationship between the SAL and tropical cyclone formation is not ubiquitous however, as large SAL outbreaks can also weaken any mid–level disturbances and/or limit intensification.

One consequence of this uncertainty is that North Atlantic forecasting models may be less accurate if they inadequately characterise the SAL elevated dry layer and accompanying jet, though increased satellite data in recent years, and model improvements have both addressed this issue.

Further information

- NOAA Hurricane Research Division SAL project, http://www.aoml.noaa.gov/hrd/project2007/sal.html
- Real-time diagnostics of the SAL, http://tropic.ssec.wisc.edu/real-time/salmain.php?&prod=splitEW&time=

Interannual Variability

Before discussing interannual variability, it is important to understand the difference between annual cyclone activity (frequency and intensity) and the severity of cyclone impacts (landfall frequency, fatalities, and damage).

For example, the 2004 western North Pacific and Atlantic tropical storm seasons were not exceptionally active seasons. Yet, Japan suffered a total of ten landfalls and the US state of Florida had three landfalls and suffered the effects of a fourth storm that made landfall in the adjacent state of Alabama.

Commonly–used activity parameters are *not necessarily* good indicators of impacts, which can be influenced by other, less well-defined, modulators of tropical cyclogenesis and track.

For instance, one potential explanation for the impact of the 2004 North Atlantic season is that the large-scale steering flow and equatorial trough allowed storms to develop at low latitudes in the eastern Atlantic and to track westward, while remaining unusually close to the equator, before curving poleward as they approached or entered the Gulf of Mexico.

On interannual timescales, tropical cyclone variability can stem from global patterns of atmosphere or atmosphere–ocean variation, such as the El Niño Southern Oscillation (ENSO) or the Quasi-Biennial Oscillation (QBO) of the lower stratospheric wind. Rainfall in the western Sahel has also been associated with variations in the seasonal frequency and intensity of Atlantic tropical cyclones.

The active 2005 season in the North Atlantic was attributed to extraordinarily warm ocean temperatures in that basin, however the Atlantic and Gulf of Mexico were similarly warm in 2006 (Fig. 9c), which was an average year for tropical cyclone activity. Further, the patterns of Atlantic SST in 2004 and 2006 were very similar (Fig. 9a, c), yet 2004 was a relatively active year with 15 named storms (9 hurricanes).

Increased understanding of interannual modulators of tropical cyclone activity has inspired seasonal forecasts of likely season severity. While these forecasts have skill they have largely failed to identify shifts in activity that may be associated with multidecadal variability or, possibly, with global climate change.

To provide context for such shifts in tropical cyclone activity, longer term records of these storms and variations in environmental factors modulating genesis are necessary. Conventional observational methods cannot provide such records. Thus, proxy records are the mechanism that provide a window on tropical cyclone activity in the distant past.

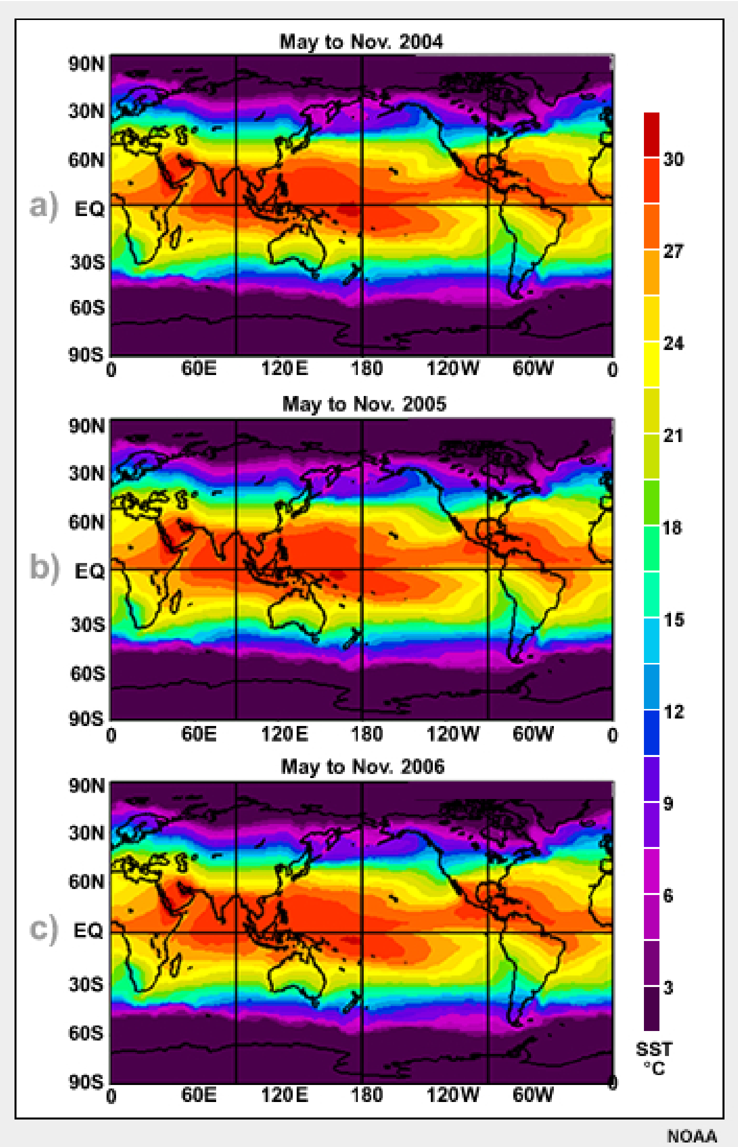

Figure 9 *Global NOAA optimum interpolation SST maps May through November inclusive for (a) 2004, (b) 2005, and (c) 2006.*

Further information

- **Seasonal summaries**
  Japan Meteorological Agency (JMA)
  http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/trackarchives.html
- Joint Typhoon Warning Center (JTWC)
  http://www.usno.navy.mil/JTWC/annual-tropical-cyclone-reports
- NHC Archive of Hurricane Seasons
  http://www.nhc.noaa.gov/pastall.shtml
- NHC 2004 Atlantic Tropical Cyclone Reports
  http://www.nhc.noaa.gov/2004atlan.shtml
- ENSO monitoring: Real-time data
  http://www.pmel.noaa.gov/tao/jsdisplay/
- Geophysical Fluid Dynamics Laboratory (NOAA). Global Warming and Hurricanes - An Overview of Current Research Results
  https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

Interannual Modulation Due to the El Niño Southern Oscillation (ENSO)

Variation in basin-scale annual tropical cyclone activity can derive from a range of spatial and temporal forcings (imposed disturbances). ENSO is one of the dominant, multi-year influences on tropical cyclone activity.

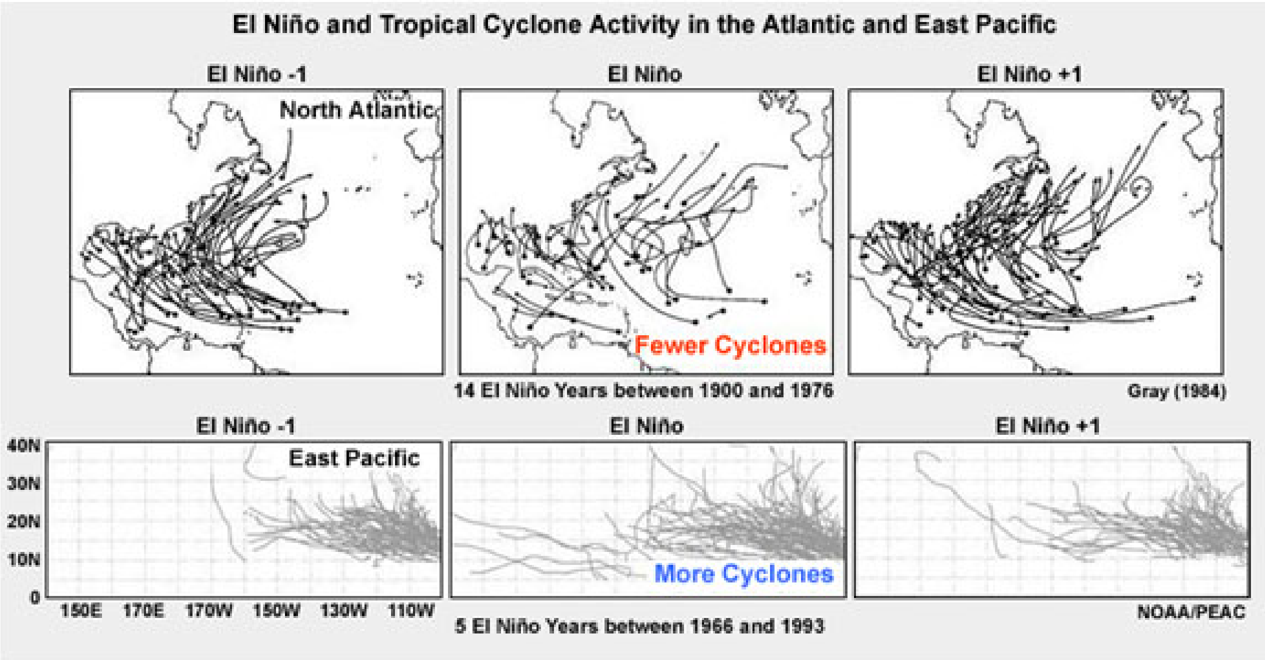

Figure 10 Tropical cyclone activity in the Atlantic (upper) and East Pacific (lower) the year before, during, and after El Niño.

The large-scale atmospheric and oceanic changes accompanying a warm event (El Niño) or a cold event (La Niña) result in shifts in the tropical regions most favourable to tropical cyclogenesis (e.g., Fig. 10).

For example, the suppression of convection in the Maritime Continent, and extension of the deep convective zone into the central Pacific and Indian Ocean basins during a warm event, is accompanied by changes to the vertical wind shear and SST patterns across the tropics. The result is cooler SST and stronger vertical wind shear in the tropical western Pacific and Atlantic basins as well as warmer SST and weakened vertical wind shear in the central Pacific, eastern North Pacific and the central Indian Oceans. **Consequently, tropical cyclone activity in the central Pacific, eastern North Pacific and the central Indian Oceans is generally enhanced during a warm event and tropical cyclones are less prevalent in the central ocean basins in neutral or cold event years.**

The inverse is true for the western Pacific and North Atlantic Oceans: cold events are more favourable for tropical cyclogenesis and so are typically accompanied by more active tropical cyclone seasons than neutral or warm event years.

Caution should be used when considering interannual variability and ENSO. Although 1992 was a warm event year (part of a multi–year sustained warm event), it was the year that a Category 5 hurricane made landfall in Miami, Florida. Hurricane Andrew was the first storm—and a very late start—of a relatively quiet season, yet it was the most devastating storm to hit the US mainland in almost twenty years. This demonstrates that links between seasonal activity and landfall frequency, storm intensity, or storm impacts are tenuous.

- Further information
  NHC report for Hurricane Andrew (1992)
  http://www.nhc.noaa.gov/1992andrew.html (Last updated 25/12/98)

Decadal Cycles and Long-term Climate Influences

While very long-time (multi–century) changes in the tropical climate have been investigated for decades, tropical cyclone variability on timescales longer than a few years has only recently been recognized.

Variations in the ENSO phenomenon on decadal timescales have been analysed from surface pressure and SST records extending back to the mid-19th century or even earlier. These data have been recovered from observation archives such as ship logs or from proxy records (of varying length, quality and detail). These ENSO variations have been proposed to impact typhoon and tropical cyclone activity in the Pacific, and possibly Indian Ocean basins. Long–term records of tropical cyclone activity - such as the six-century landfall record for China - may be used to test this link.

Three possible physical mechanisms have been proposed to explain decadal modulation of ENSO:

- a coupled internal oscillator in the equatorial Pacific
- tropical forcing from midlatitude variability (i.e. cyclogenesis is stimulated by the midlatitude variations caused by ENSO)
- slowing of the global thermohaline circulation leading to decadal SST fluctuations in the Pacific.

It is not yet clear whether one of these mechanisms or a different mechanism not yet considered will explain this phenomenon.

The third proposed mechanism for interdecadal variability of ENSO builds upon the concept of the Ocean Conveyor Belt or global thermohaline circulation which links the global ocean currents. The surface ocean currents are driven by formation of "deep water" which sinks deep into the ocean in the northern Atlantic and in the Southern Ocean.

The correspondence between monsoonal rains (drought) over the Sahel region of West Africa, circulation changes in the tropical Atlantic, and enhanced (reduced) incidence of intense Atlantic hurricanes provides evidence of the link between African easterly wave activity and intense hurricane activity in the basin on multidecadal timescales.

Variations in the number of easterly waves are only weakly related to the total number of North Atlantic tropical cyclones in a season. Rather, fluctuations in easterly wave activity contribute to variations in the frequency of **intense** hurricanes (peak winds in excess of 50 m s^{-1}, corresponding to Saffir–Simpson Cat 3–5). This reflects the longer passage over warm ocean waters typical of storms reaching such intensities.

Multidecadal variations in Atlantic hurricane activity have been associated with long-term changes in the ocean temperatures and vertical shear of the horizontal winds in that ocean basin. These coupled variations have been termed the **Atlantic Multidecadal Oscillation** (AMO), which has also been linked to decadal-scale variations in the Ocean Conveyor Belt. If the Ocean Conveyor Belt is accelerated, the tropical Atlantic is warmer than climatology and hurricane activity increases. By this theory, warm (cool) phases of the tropical Atlantic correspond to transport of waters through the global ocean currents that is faster (slower) than climatology.

Since ocean temperatures and vertical wind shear have been strongly tied to the likelihood of tropical cyclogenesis, the link between these environmental fields and hurricane variability should be unsurprising. The periodic cycling of the ocean conveyor belt has been tied to long-term variations in Atlantic Ocean temperatures and extended West African droughts, apparently making a good case for multidecadal fluctuations in the ocean currents as the source of ocean surface temperature changes, the resultant variations in West African monsoon rainfall and, by implication, easterly wave frequency.

However, recent work has cast doubt on the multidecadal modulating influence of the oceans on Atlantic hurricanes, opting for an alternative explanation for the 20th Century ocean warming. In this scenario, global climate change combined with the cooling then warming due to the temporal variation in sulphate aerosols through the course of the 20th Century governed the evolution of Atlantic Ocean temperatures.

This global change (non–AMO) interpretation of Atlantic SST variations raises fundamental questions including "What are the mechanisms through which variations in the base state of the climate affect tropical cyclones?" and "Could changes in tropical cyclone characteristics feedback and influence the evolution of the base state of the climate?"

Current assessments of the association between the number and intensity of tropical cyclones, and climate change, are linked below.

- Vox – How climate change makes hurricanes worse
  https://www.youtube.com/watch?v=_0TCrGtTEQM
- Geophysical Fluid Dynamics Laboratory (NOAA). Global Warming and Hurricanes - An Overview of Current Research Results
  https://www.gfdl.noaa.gov/global-warming-and-hurricanes/
- Is climate change making hurricanes worse?
  https://www.theguardian.com/weather/ng-interactive/2018/sep/11/atlantic-hurricanes-are-storms-getting-worse
- Cyclones and climate change: connecting the dots
  https://phys.org/news/2017-08-cyclones-climate-dots.html

Seasonal Forecasting of Tropical Cyclone Activity

The first systematic, statistically-based seasonal forecasting methodology for tropical cyclone activity dates back to the late 1970s and focused on the Australian region. It was not until 1984 that scientists from Colorado State University began publishing regular forecasts of annual tropical cyclone activity for the North Atlantic basin.

The table below lists currently issuing seasonal forecasts of tropical cyclone activity. The group, their basin(s) of interest, the modelling approach used and the website location of their forecast products are provided. (NB Many of these groups have limited public-facing outputs).

Group	Basins	Type	Website
City University of Hong Kong, China (City U)	Western North Pacific	Statistical	http://www.cityu.edu.hk/

Colorado State University, USA (CSU)	Atlantic	Statistical	http://hurricane.atmos.colostate.edu/
Cuban Meteorological Institute (INSMET)	Atlantic	Statistical	http://www.insmet.cu/
European Centre for Medium-Range Weather Forecasts (ECMWF)	All basins	Dynamical	http://www.ecmwf.int/ (collaborating agencies only)
International Research Institute for Climate and Society (IRI)	All except Indian Ocean	Dynamical	http://iri.columbia.edu/forecast/tc_fcst/
Macquarie University, Australia	Australia/ Southwest Pacific	Statistical	http://www.iges.org/ellfb/past.html
National Meteorological Service, México (SMN)	Eastern North Pacific	Statistical	http://smn.cna.gob.mx/
National Climate Centre, China	Western North Pacific	Statistical	http://bcc.cma.gov.cn/
NOAA Hurricane Outlooks	Atlantic Eastern North Pacific Central North Pacific	Statistical	http://www.cpc.noaa.gov/index.php http://www.cpc.noaa.gov/index.php http://www.prh.noaa.gov/hnl/cphc/
Tropical Storm Risk (TSR)	Atlantic Western North Pacific Australian region	Statistical	http://www.tropicalstormrisk.com/

Early statistical predictions of North Atlantic seasonal hurricane activity relied predominantly on the phases of ENSO (either prior to the season or predicted for the peak of the season) and the quasi-biennial oscillation (QBO – a quasi-period oscillation of equatorial zonal winds), as well as Caribbean sea-level pressures.

For example, more tropical cyclones are predicted for cool events (anti–ENSO), west phase of the QBO or below-normal Caribbean basin sea level pressures - and especially if all three coincide. These relationships with seasonal tropical cyclone activity (defined by any of total number of named storms, named storm days, hurricanes or hurricane days) were explained in terms of changes in the tropical Atlantic atmosphere and ocean circulations that modified the necessary conditions for tropical cyclogenesis.

A variety of statistical models to predict basin–scale tropical cyclone activity around the globe are now available. Interestingly, even groups forecasting for the same basin use different predictors. For example, while QBO is used as a predictor in the Cuban Meteorological Institute forecasts for North Atlantic hurricane activity, it is not included in either the CSU or NOAA models.

A relatively recent innovation in seasonal tropical cyclone forecasting is dynamically-based forecasts. In this approach, global forecast models are run out for the season and the number of tropical cyclone-like vortices predicted in these models is counted. Various storm characteristics can be recorded for these modeled storms and predictions can also be issued on these quantities. One example is the accumulated cyclone energy (ACE), a measure of wind energy that is defined as the sum of the squares of the maximum sustained surface wind speed (knots) measured every six hours for all named systems while they are at least tropical storm strength.

A seasonal forecast model must demonstrate skill against a "no skill" baseline prediction to be useful. The most common no skill forecast used for operational weather forecast models is a combination of climatology and persistence (known as CLIPER). Evaluations of a number of available statistical seasonal forecast models demonstrated that these had skill against this CLIPER benchmark. This means that these models have (at least some) useful information on the likelihood of more or less activity in the upcoming season.