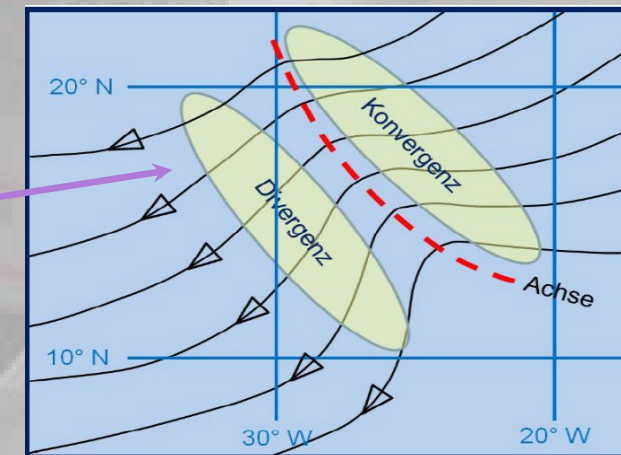
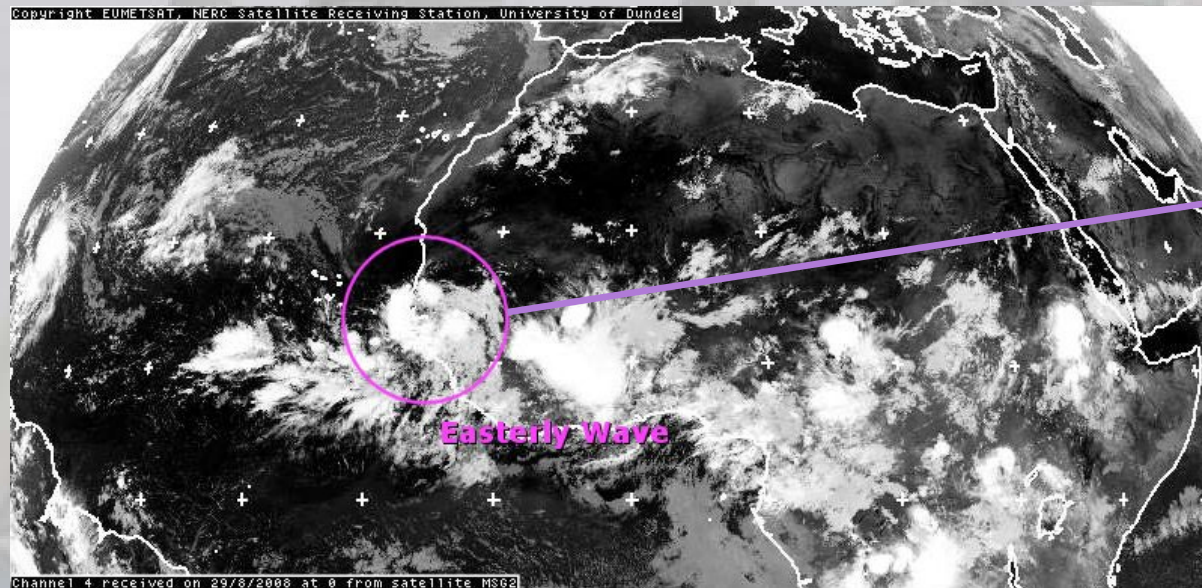


TROPICAL WIND SYSTEMS

Necessary Preconditions for the onset of Hurricane development

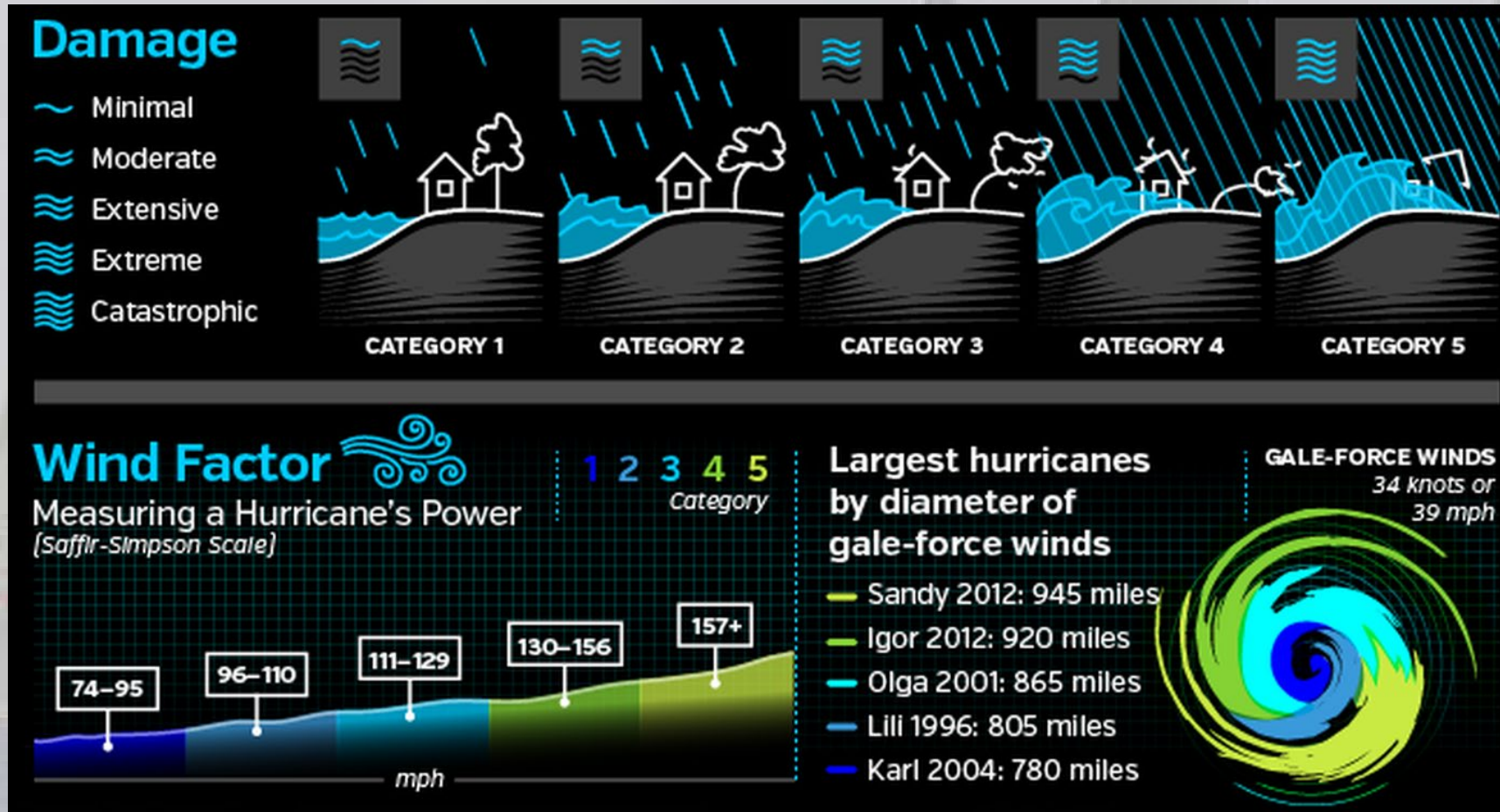
- Latitude $> 5^\circ$ N/S for Coriolis force, to initialize vortex motion
- Water temperature $> 27^\circ$ C for energy (evaporation, latent heat transfer)
- Upper air divergence, Easterly Wave for dynamic onset of lifting
- Moist-unstable stratification for conditions intensifying lift development
- Low vertical windshear for conservation of vertical circulation cells



TROPICAL WIND SYSTEMS

Tropical storm categories including Saffir-Simpson-Scale

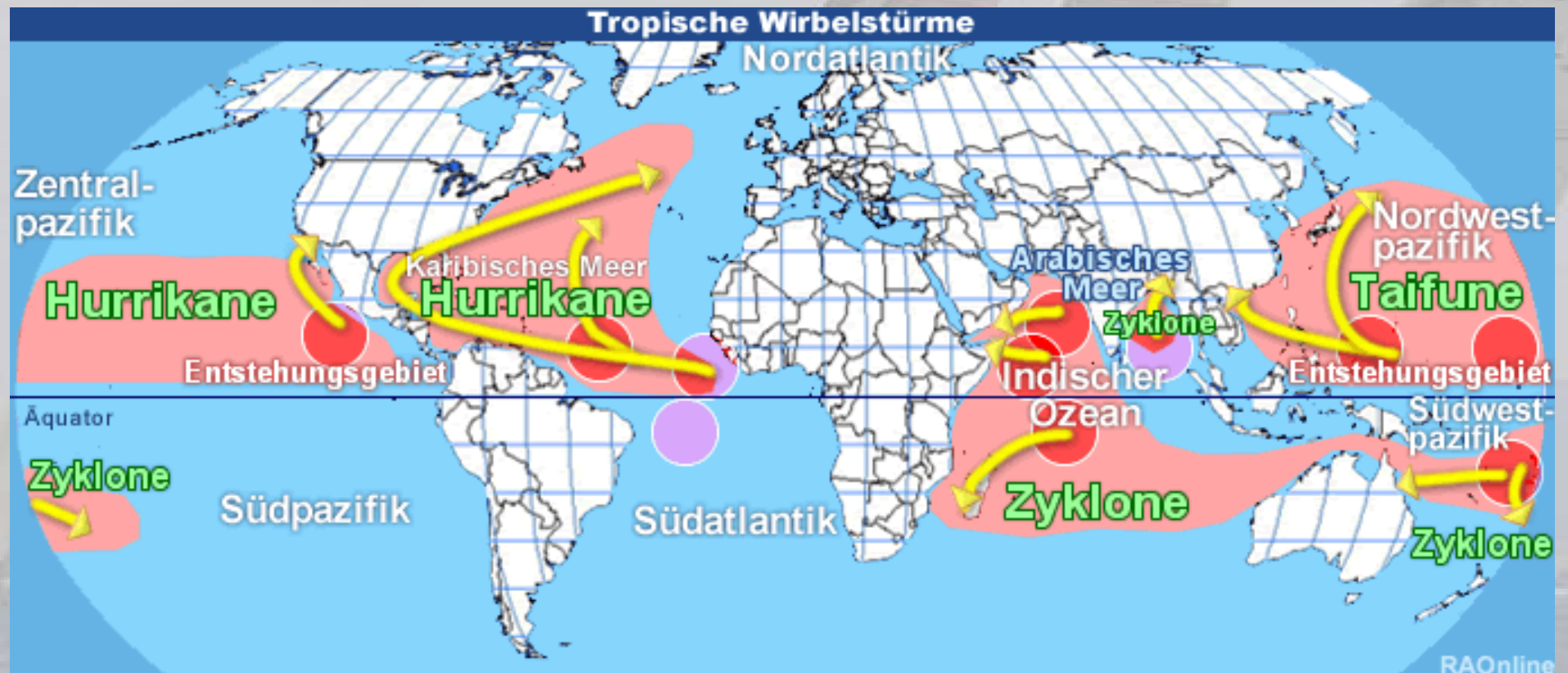
- Tropical Depression TD Bft.7 or less 33 kt or less
- Tropical Storm TS Bft.8 - Bft.11 34 kt – 63 kt
- Hurricane Category 1-5 Bft.12 64 kt or more



TROPICAL WIND SYSTEMS

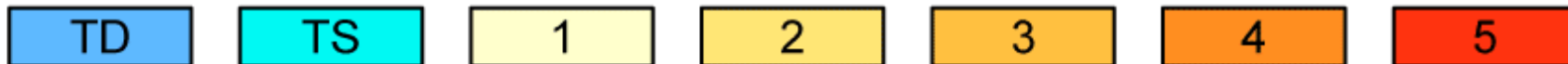
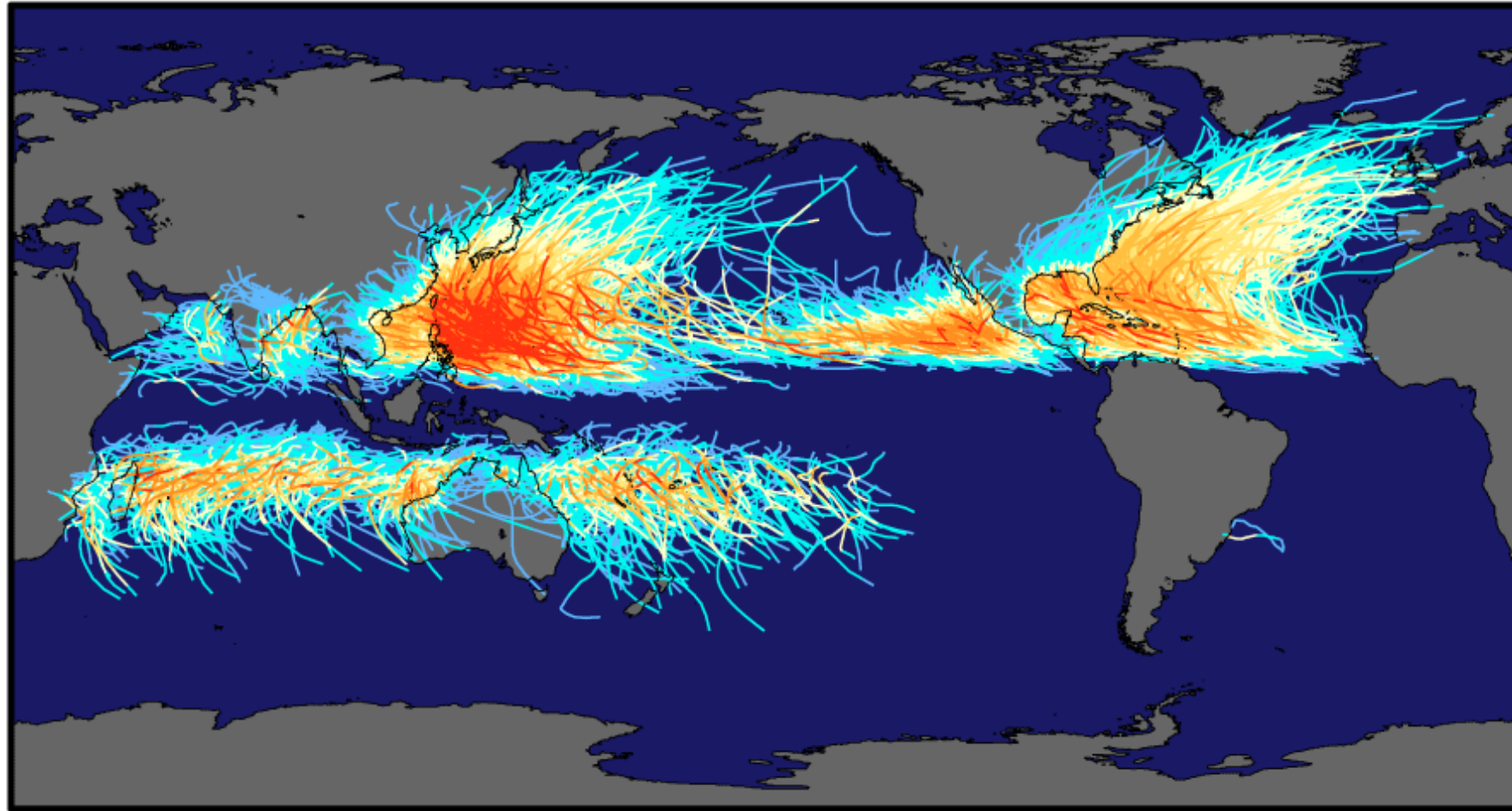
Occurrence und storm tracks

Area	Name	Season
Atlantic	Hurricane	August - October
Pazific	Taifun	April - December
Indic	Zyklon	December - March



TROPICAL WIND SYSTEMS

Tracks and Intensity of All Tropical Storms



Saffir-Simpson Hurricane Intensity Scale

TROPICAL WIND SYSTEMS - STRUCTURE

Outer Region

Inner Region

Cloud wall

Eye

wind increase towards center

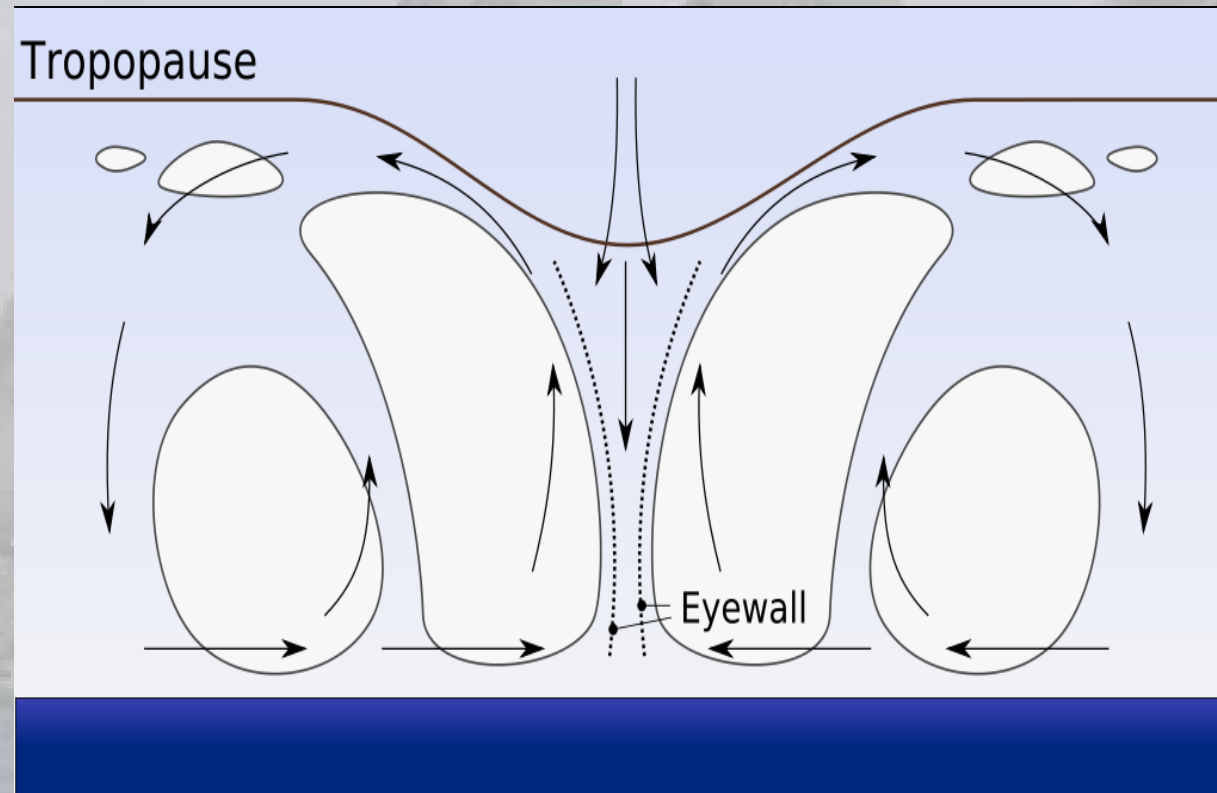
spiral cloud bands

$v_{\text{rad}} \sim 10\text{-}20 \text{ kt}$, $v_{\text{tan}} \sim 100\text{-}130 \text{ kt}$

width 30-40 nm, $v_{\text{vert}} \sim 10\text{-}20 \text{ mps}$

diameter 15 to 25 nm

Saffir-Simpson hurricane wind scale	
Category	Wind speeds
Five	$\geq 70 \text{ m/s}$, $\geq 137 \text{ knots}$ $\geq 157 \text{ mph}$, $\geq 252 \text{ km/h}$
Four	58–70 m/s, 113–136 knots 130–156 mph, 209–251 km/h
Three	50–58 m/s, 96–112 knots 111–129 mph, 178–208 km/h
Two	43–49 m/s, 83–95 knots 96–110 mph, 154–177 km/h
One	33–42 m/s, 64–82 knots 74–95 mph, 119–153 km/h
Additional classifications	
Tropical storm	18–32 m/s, 35–63 knots 39–73 mph, 63–118 km/h
Tropical depression	$< 17 \text{ m/s}$, $< 34 \text{ knots}$ $< 38 \text{ mph}$, $< 62 \text{ km/h}$



TROPICAL WIND SYSTEMS - STRUCTURE

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Inner Region

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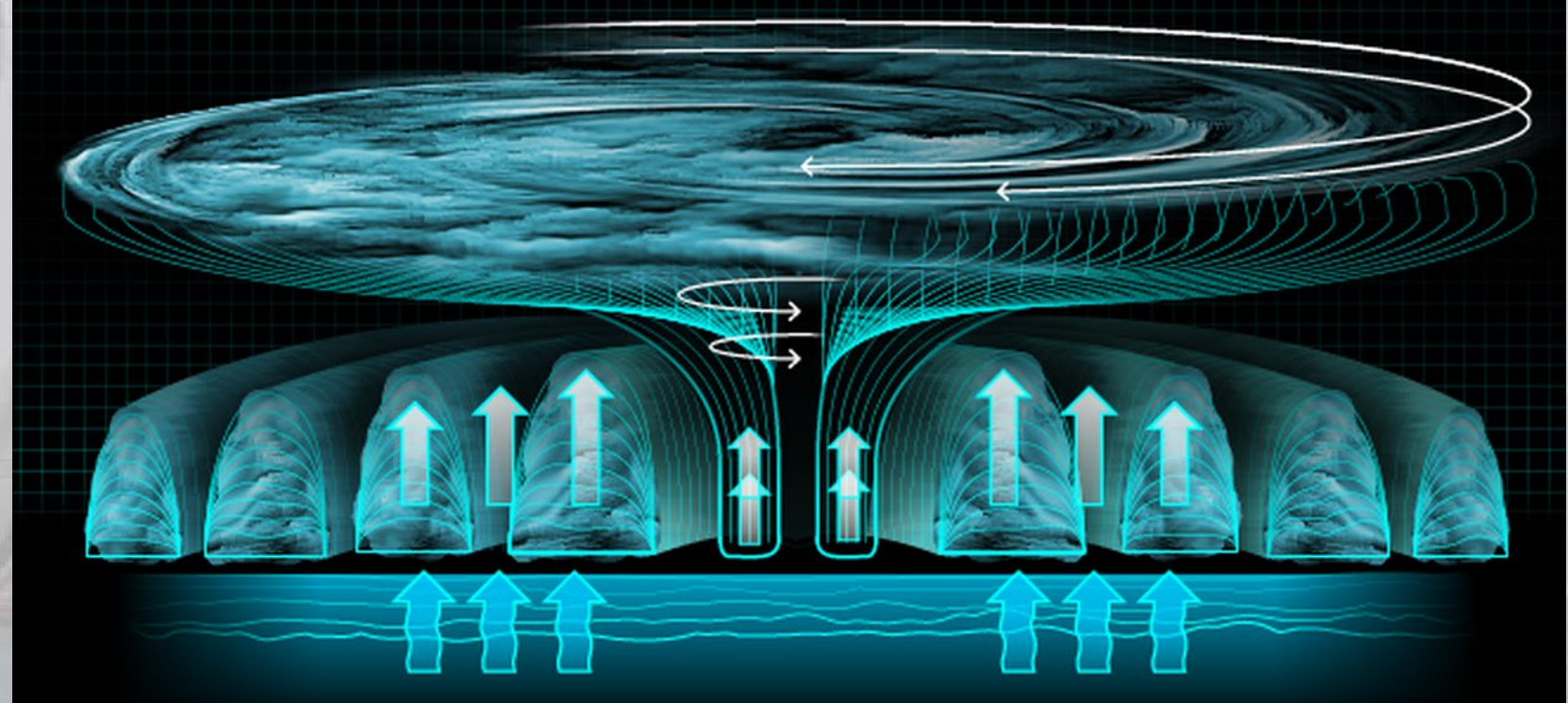
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North Atlantic



TROPICAL WIND SYSTEMS - STRUCTURE

Outer Region

Inner Region

Cloud wall

Eye

wind increase towards center

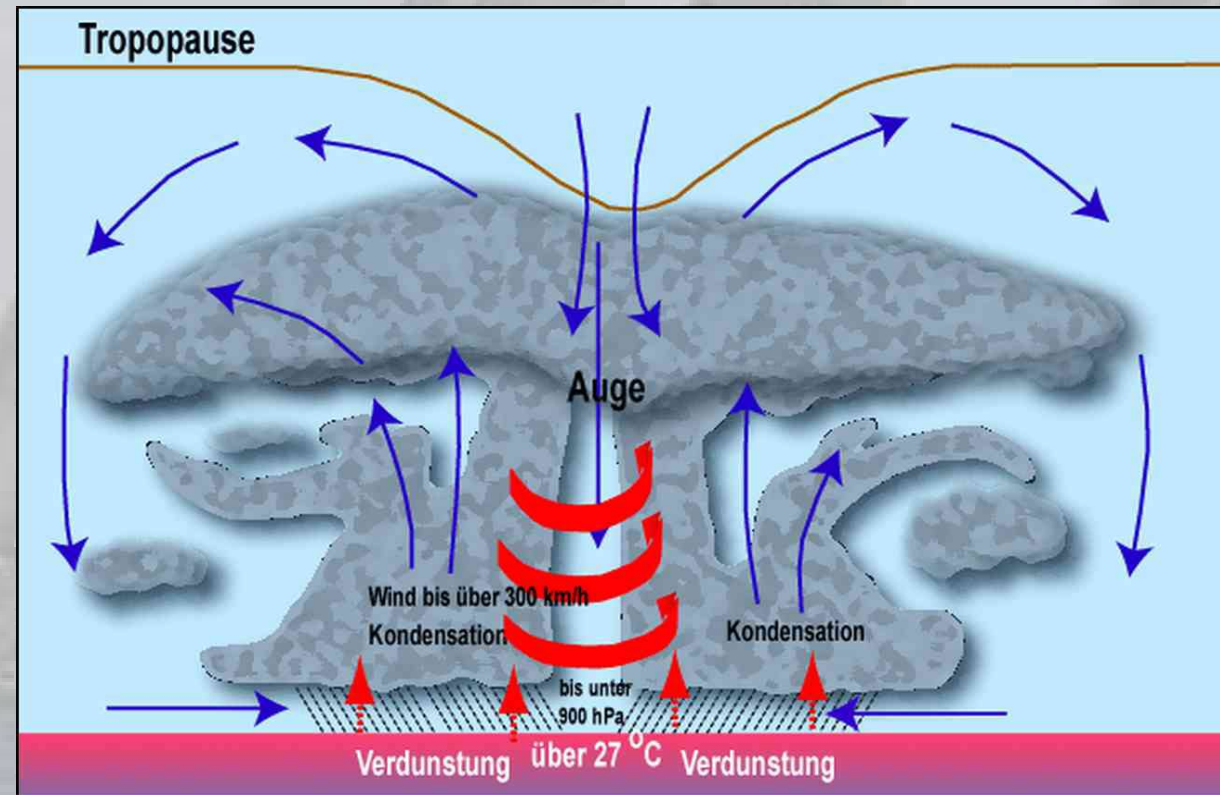
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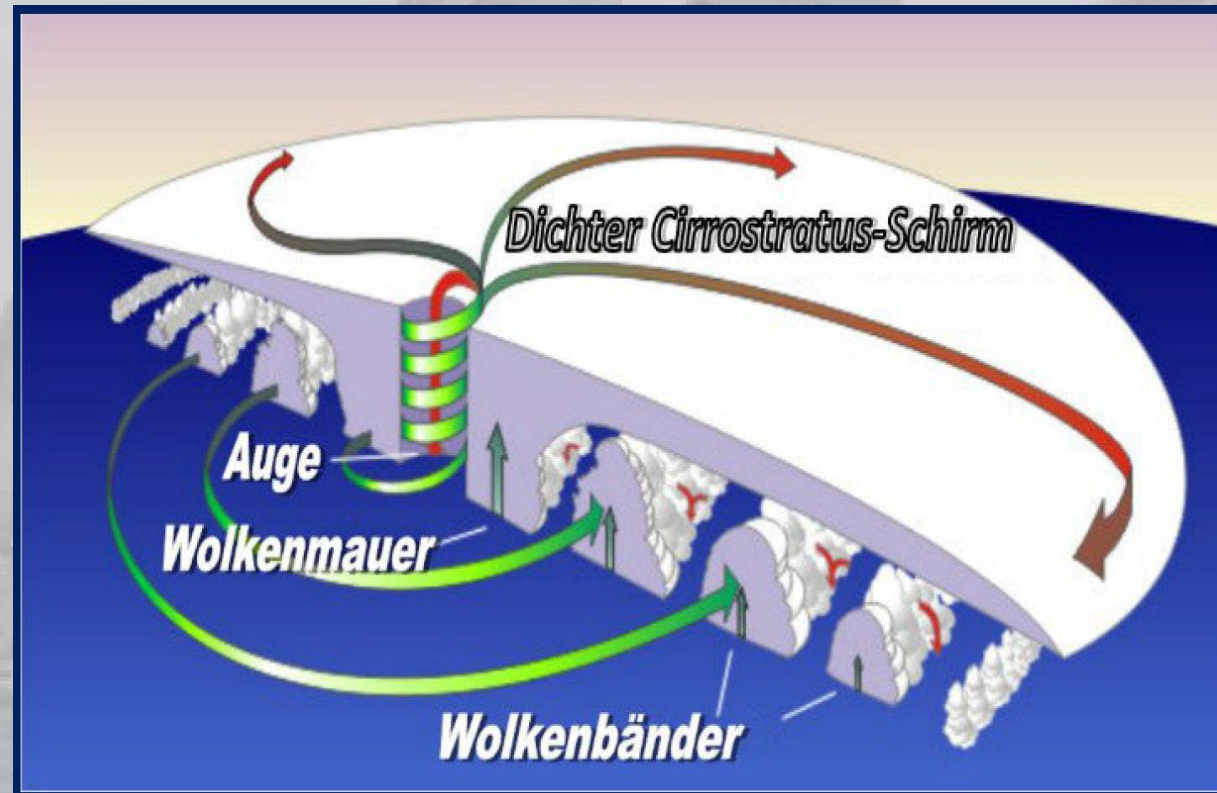
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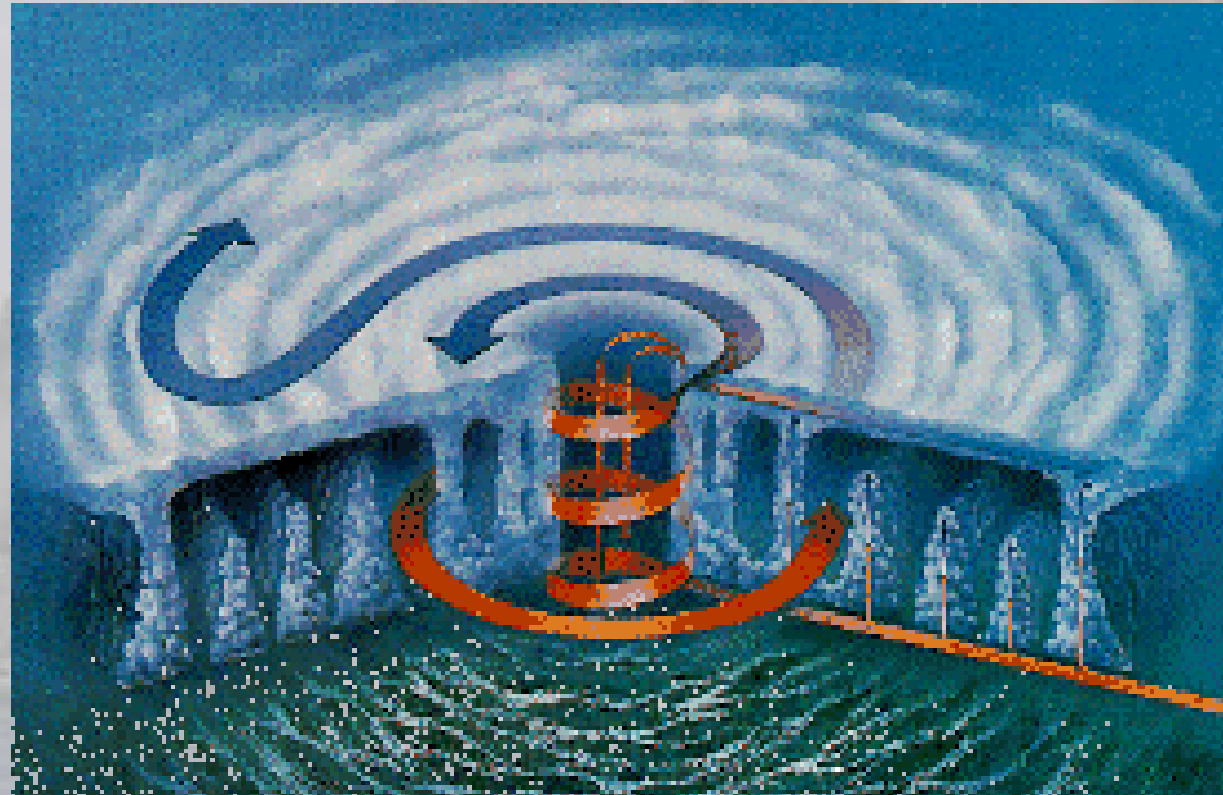
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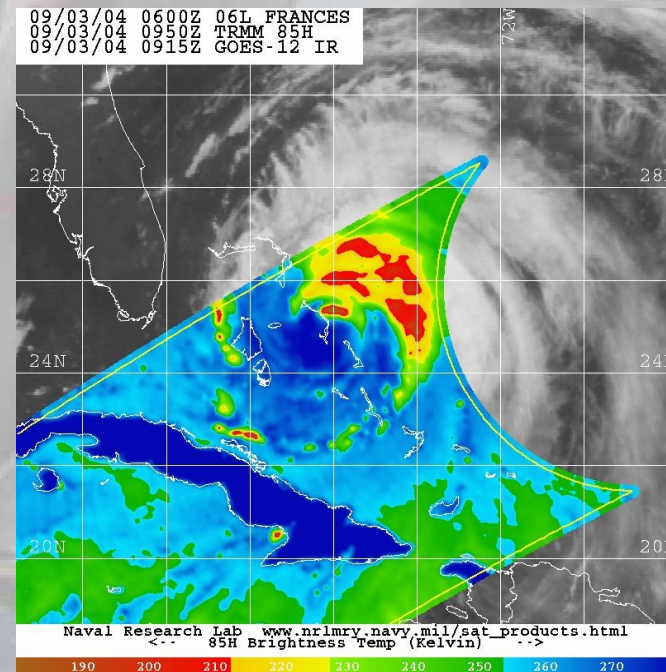
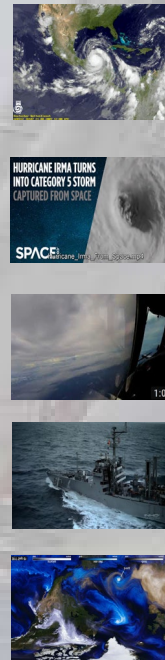
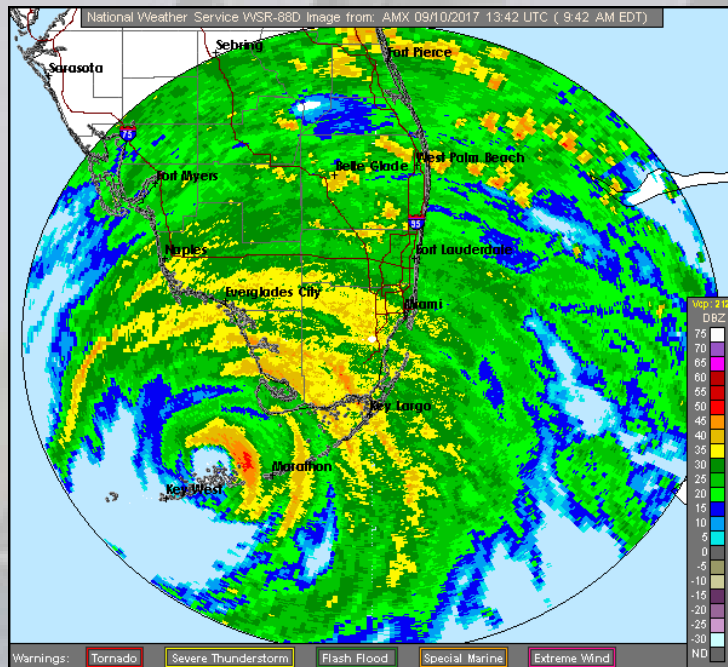
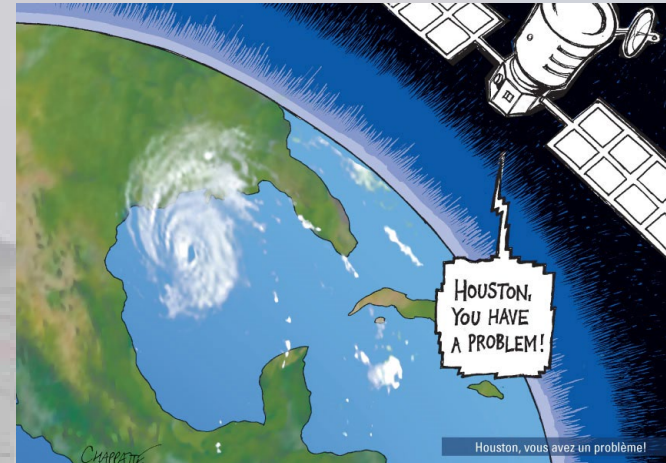
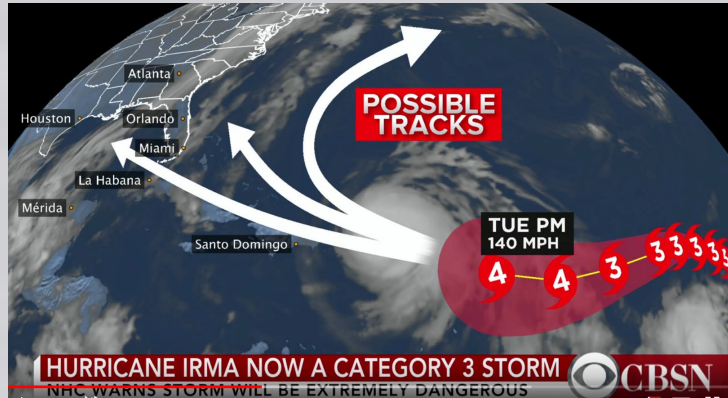
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MONITORING HURRICANE IRMA SEPTEMBER 2017

Monitoring Tropical Storms

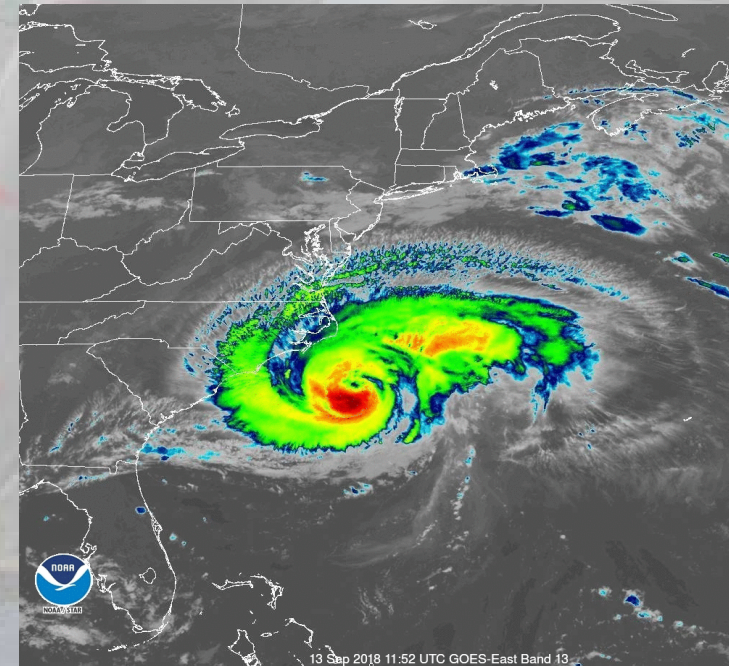
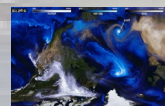
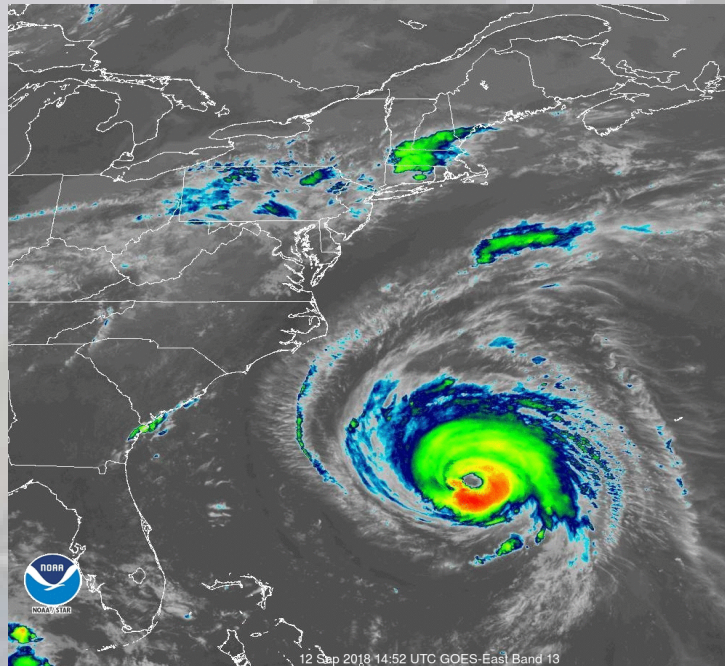
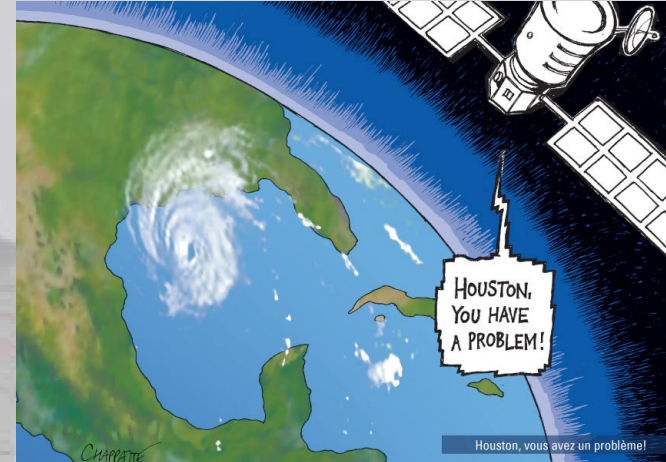
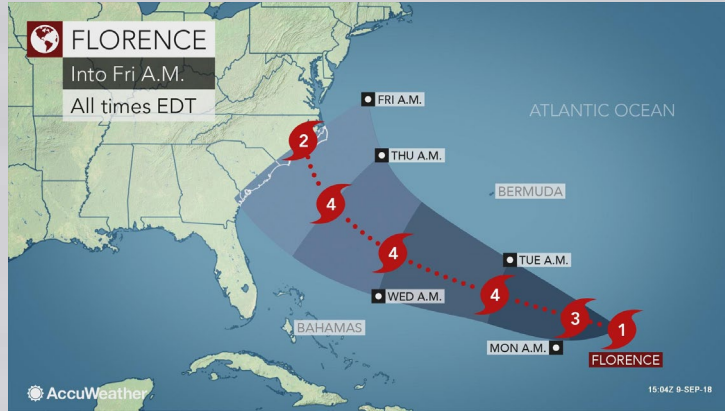
- ~~Ships~~, buoys
- Aircraft
- Drop sondes
- NWP-models
- Satellite
- Radar



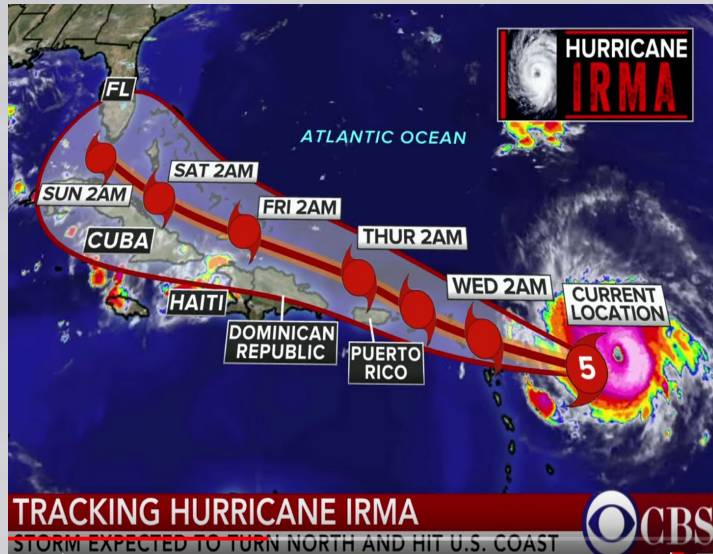
MONITORING HURRICANE FLORENCE SEPTEMBER 2017

Monitoring Tropical Storms

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- Aircraft
- Drop sondes
- NWP-models
- Satellite
- Radar



TROPICAL STORMS 1-2-3 RULE



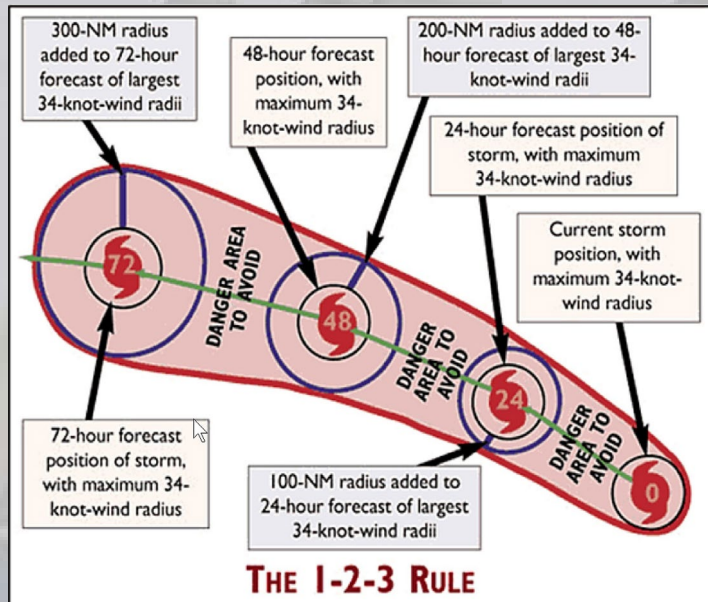
Due to increasing forecast error with time, a 'sector' is defined within which the hurricane will most likely move.

Monitoring enables this corridor to be quite narrow. Following the long-time statistics of the National Hurricane Center in Miami FL, the estimated error is

H+24	H+48	H+72
100 nm	200 nm	300 nm

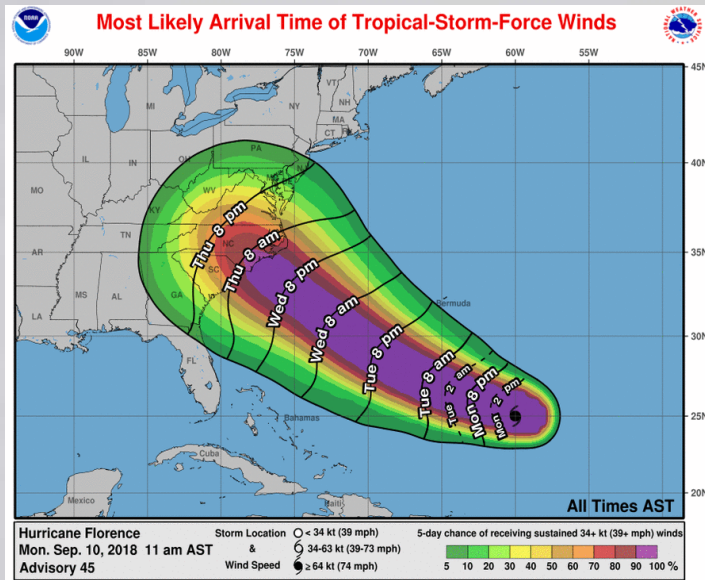
THE AREA OF DANGER TO BE AVOIDED

is defined by the envelope of the estimated forecast positions with the following margins of error



H+24	ff > 34kt	100 nm around estimated position
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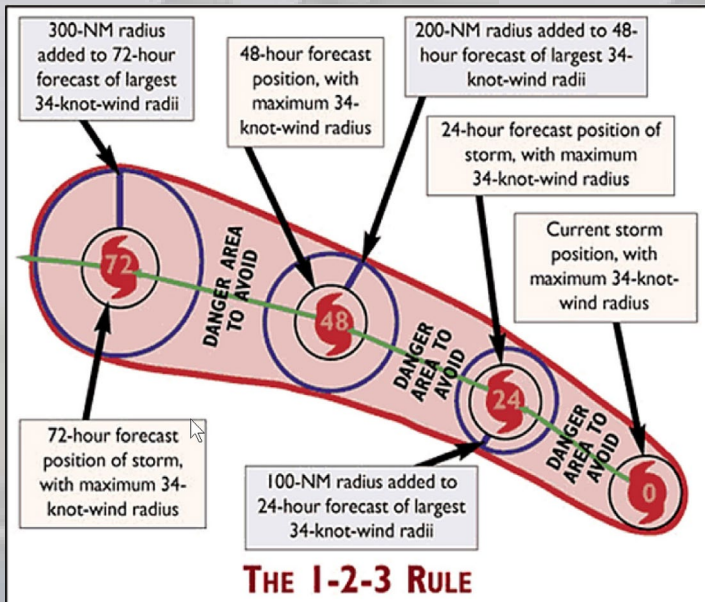
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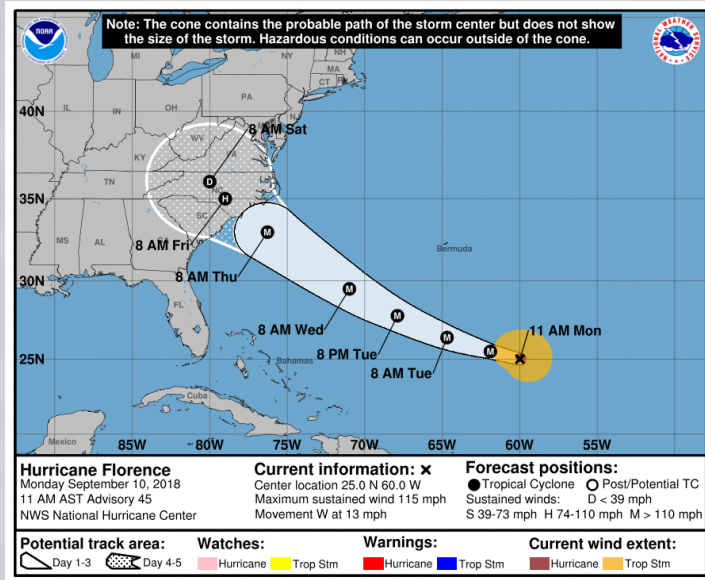
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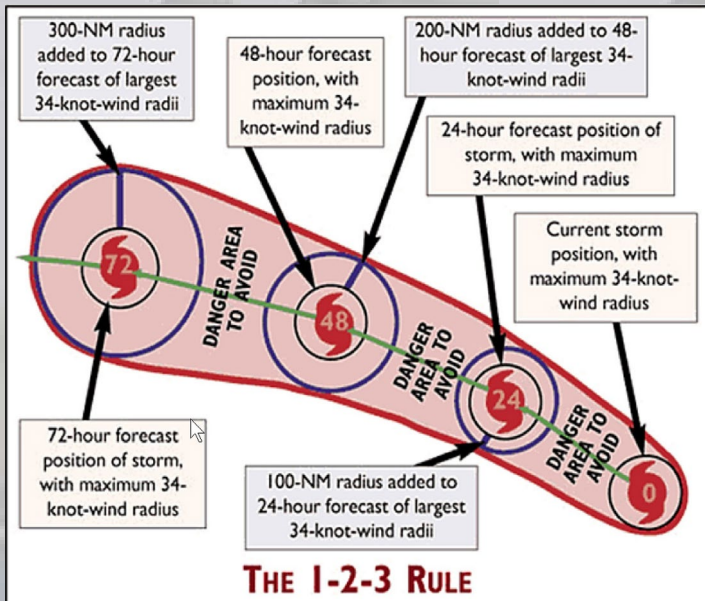
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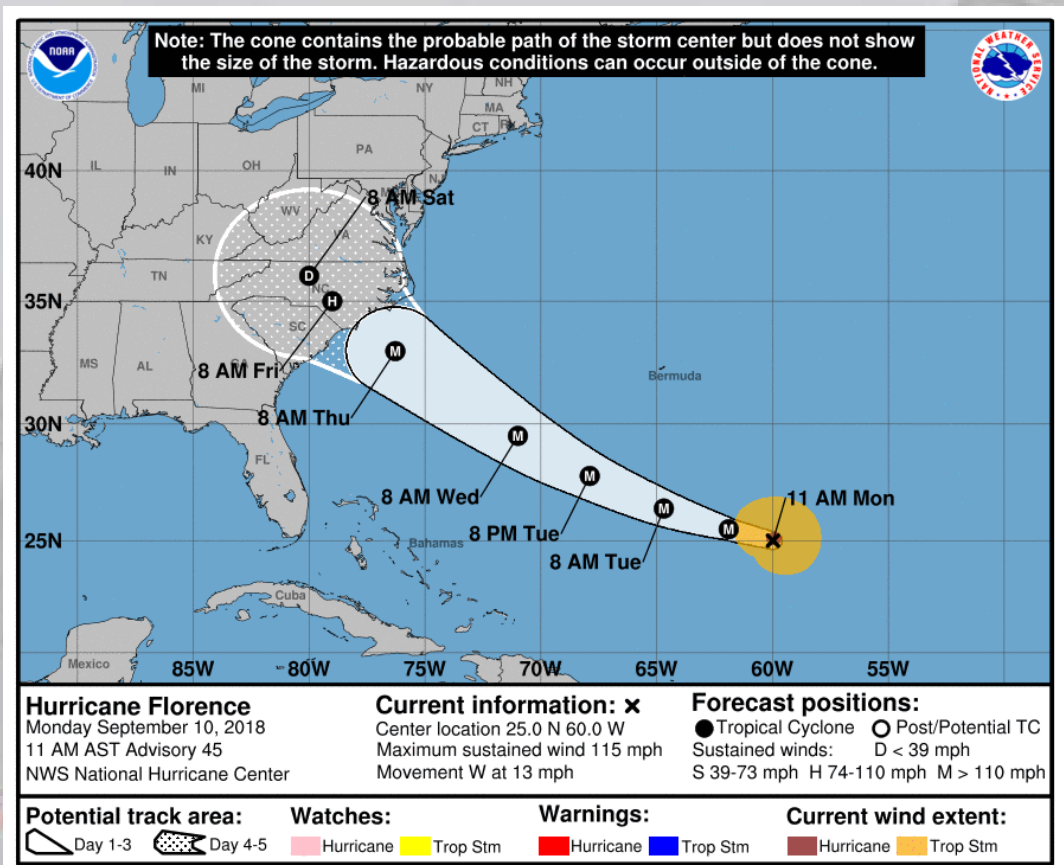
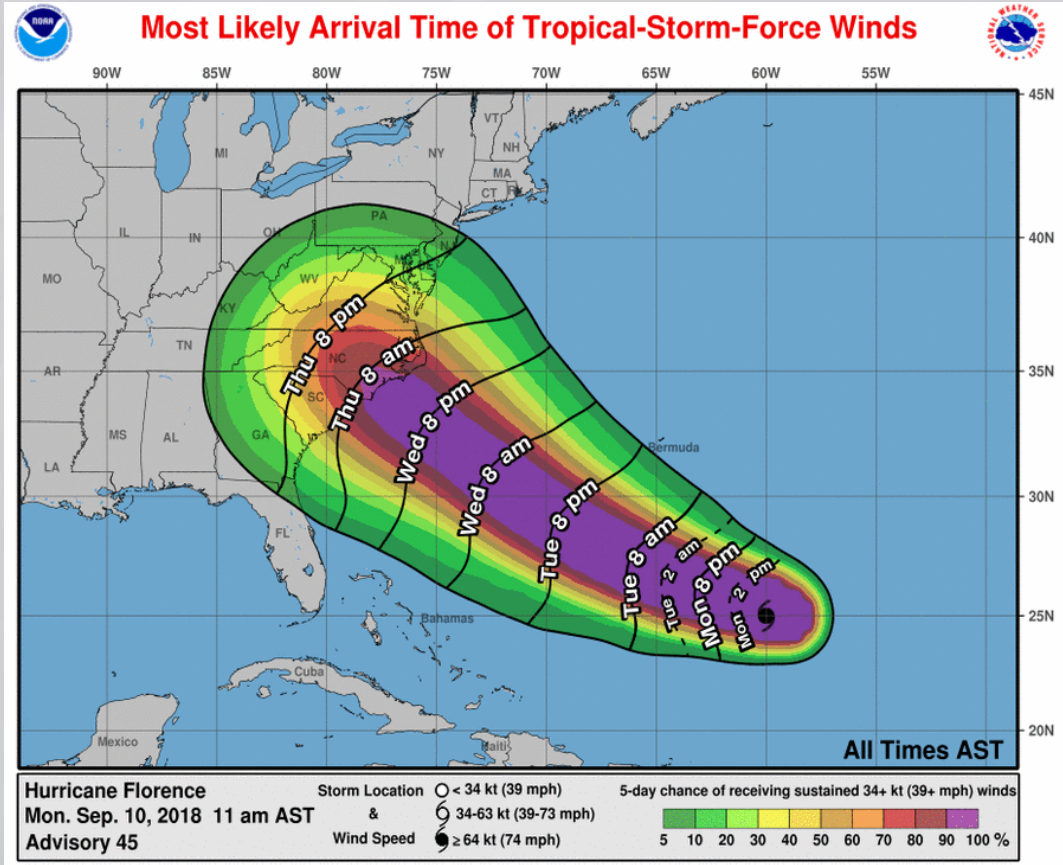
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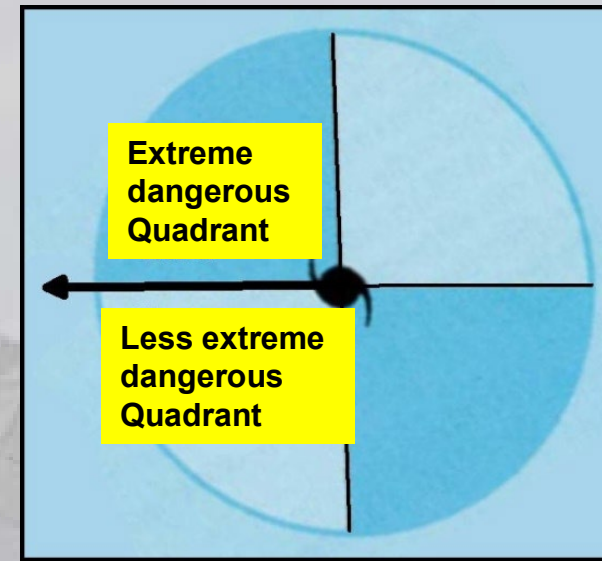
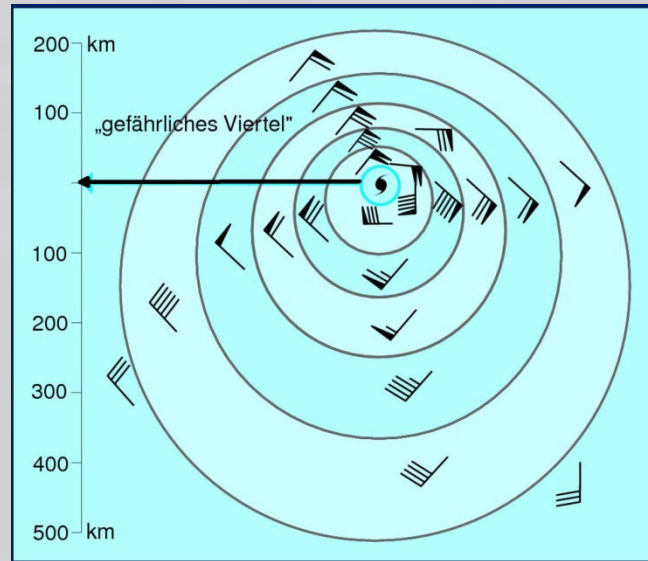
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TROPICAL STORMS AND NAVIGATION



Extreme / slightly less dangerous quarter due to addition / subtraction of wind vector and displacement vector

Today: Satellite, excellent Hurricane monitoring and warning system

Basic rule: **AVOID !**

Last known problem associated with a hurricane: 1957 Sailship SS Pamir

TROPICAL STORMS AND NAVIGATION

Lesson learnt: Do not try to cheat Hurricanes with navigational tricks !
AVOID ! AVOID ! AVOID !

PAMIR

Mit vollen Segeln in den Tod



Wo immer die „Pamir“ anlegte, feierten sich die Mädchen auf den Landstraßen der Speakeasies. Die 16- und 17-jährigen waren der Stolz der deutschen Handelshäuser. Im September 1927 kenterte der Segler im Wirbelsturm.

Die „Pamir“ war ein deutsches Segelschiff, das am 2. September 1927 im Atlantik von einem Hurrikan zerstört wurde. Die Besatzung wurde in vier Rettungsboote getrennt, von denen nur eines gerettet wurde. Die anderen drei Boote mit 52 Personen gingen verloren.



The Sydney Morning Herald

FRIDAY, SEPTEMBER 24, 1927

Pamir Survivors Now Total Six: Mass Rescue Story Denied

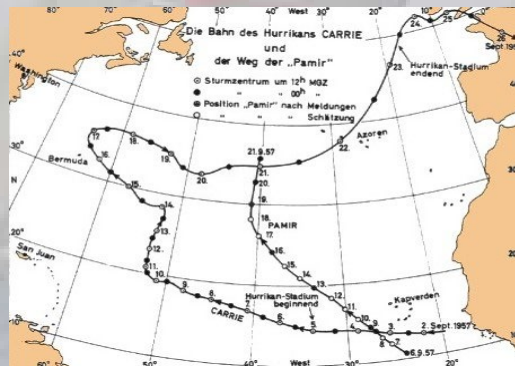
From Our Staff Correspondent And A.A.P.-Reuter

LONDON, Sept. 25.—A sixth survivor from the German barque Pamir has been rescued, but incorrect reports yesterday of 65 more survivors were caused by poor radio conditions and a mutilated radio conversation.

An inquiry at the Santa Maria airport, Azores, reported signing two more survivors. The survivors say the other boats were picked up by the U.S. Navy and taken to the States. The rescue was a relief to the survivors, who had been in the sea for 12 days. The ship was last sighted on Sept. 12, and the survivors were seen on Sept. 24. The rescue was a relief to the survivors, who had been in the sea for 12 days. The ship was last sighted on Sept. 12, and the survivors were seen on Sept. 24.



Capt. Karl-Helm Kraus, a survivor from the Pamir.



LAST OF THE GREAT WINDJAMMERS FOUNDERS IN AN ATLANTIC HURRICANE AND 13 TOWNS MOURN THEIR DEAD

PAMIR: ALL HOPE GONE

Storm-battered boats empty 52 SEA CADETS LOST

Express Staff Reporters
IN LONDON, BONN, AND NEW YORK

THE sailing ship Pamir, last of the great windjammers of the grain-race days, the elegant lady of the sea who defied steam and oil, lies at the bottom of the ocean, shattered by a raging hurricane in mid-Atlantic loneliness.

The people of Winden (Germany), who all day watched by radio and TV sets for the distant sea information, felt the loss of the Pamir as a personal one. It must be presumed, the TV stations, that the Pamir had broken up, although official confirmation was still awaited.

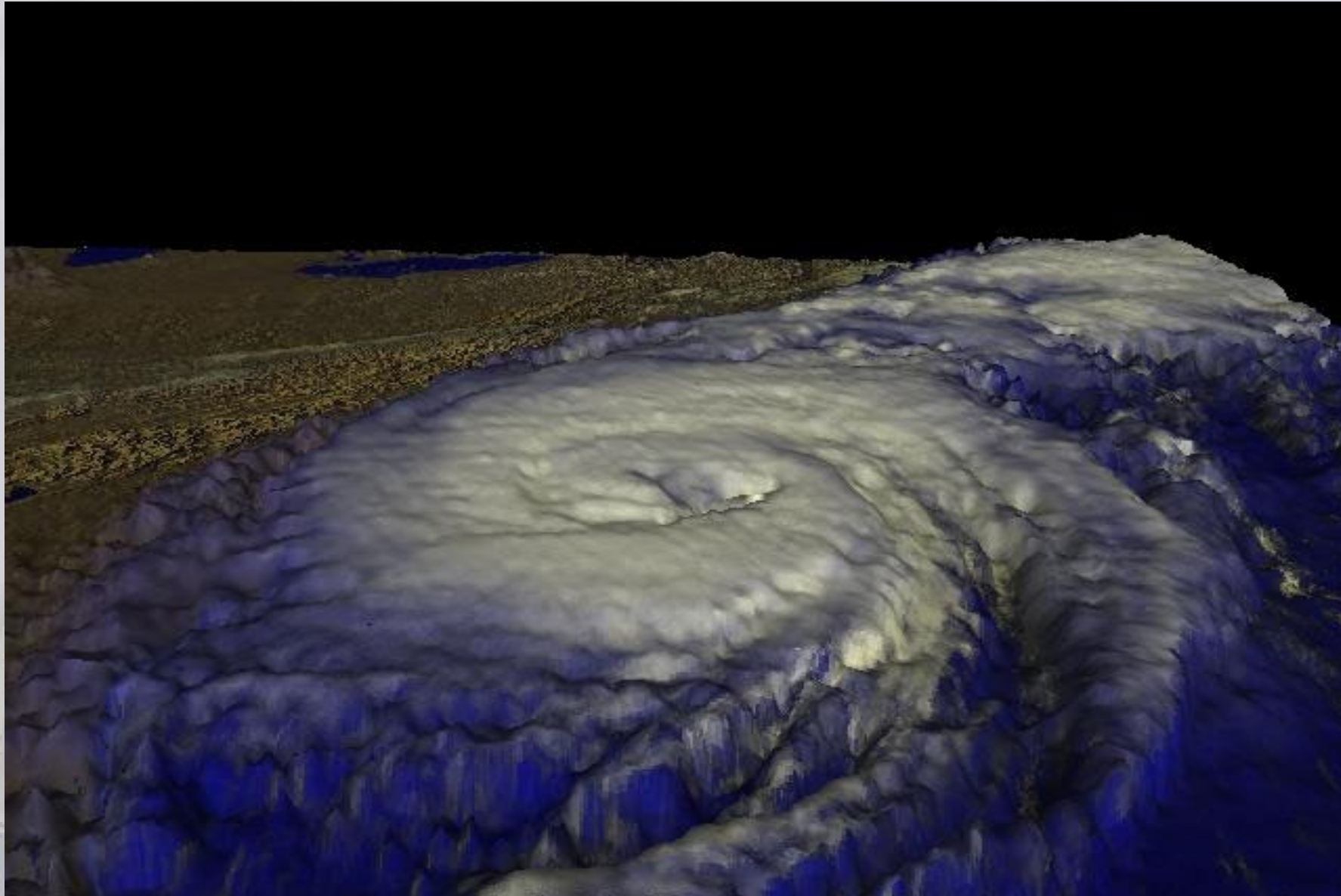
The broadcast signal programme was cancelled, and the broadcast which had been about the Pamir was also cancelled.



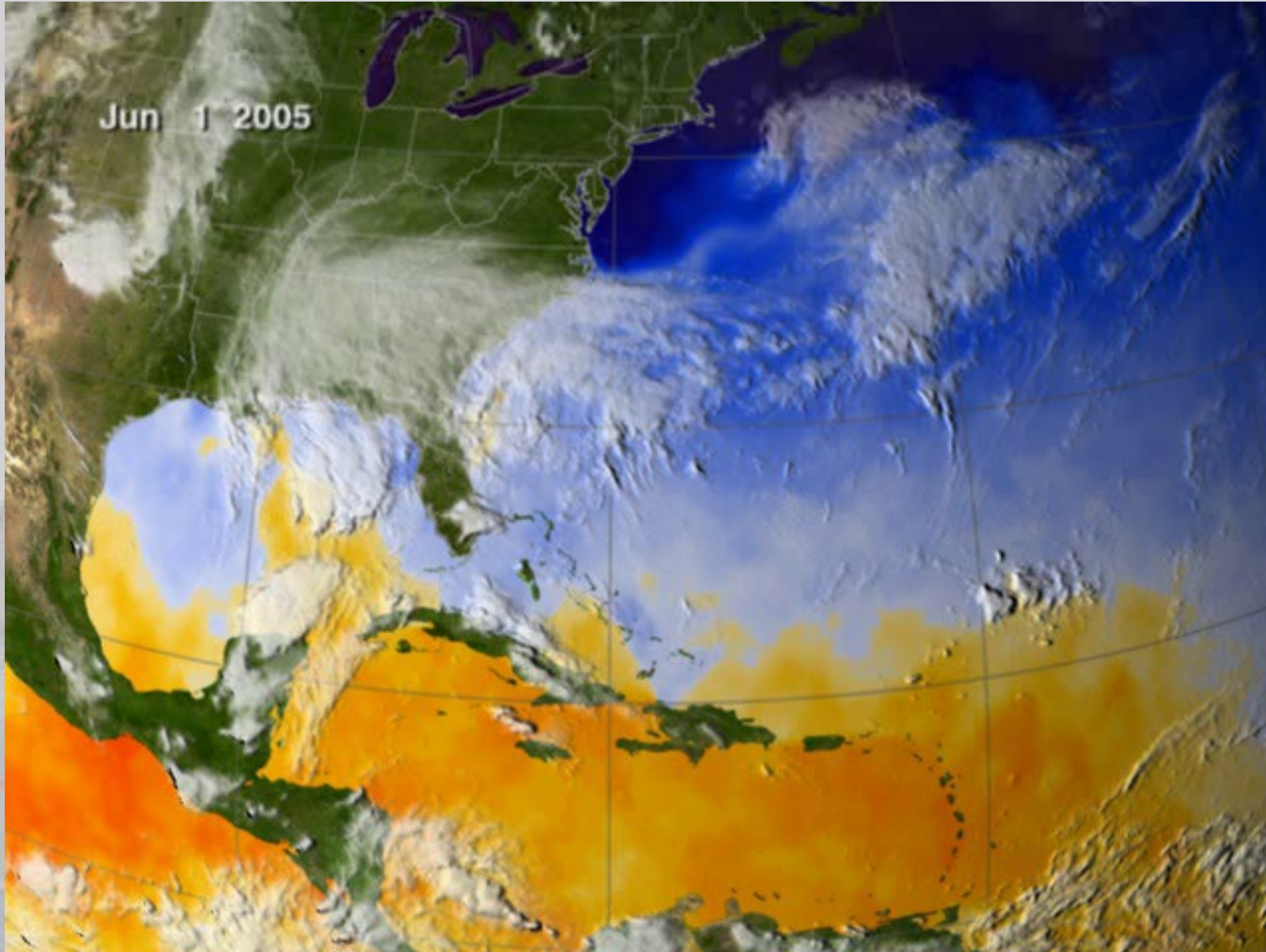
FREDERICK ELLIS
City Editor



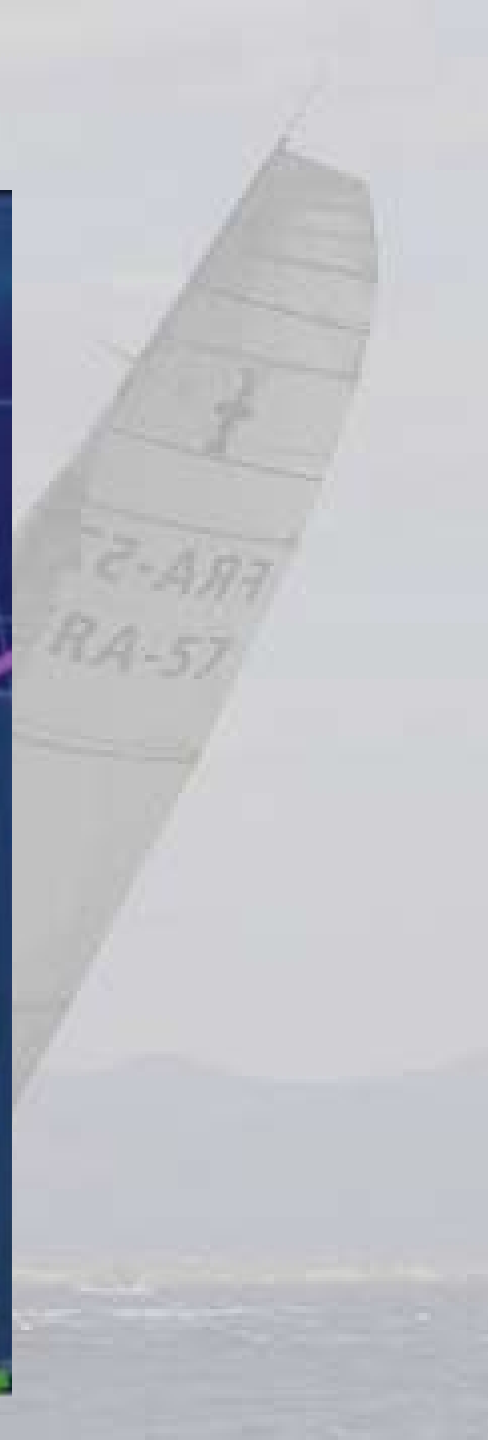
TROPICAL STORMS HURRICANE BONNIE 1998



HURRICANE TRACKS 2005



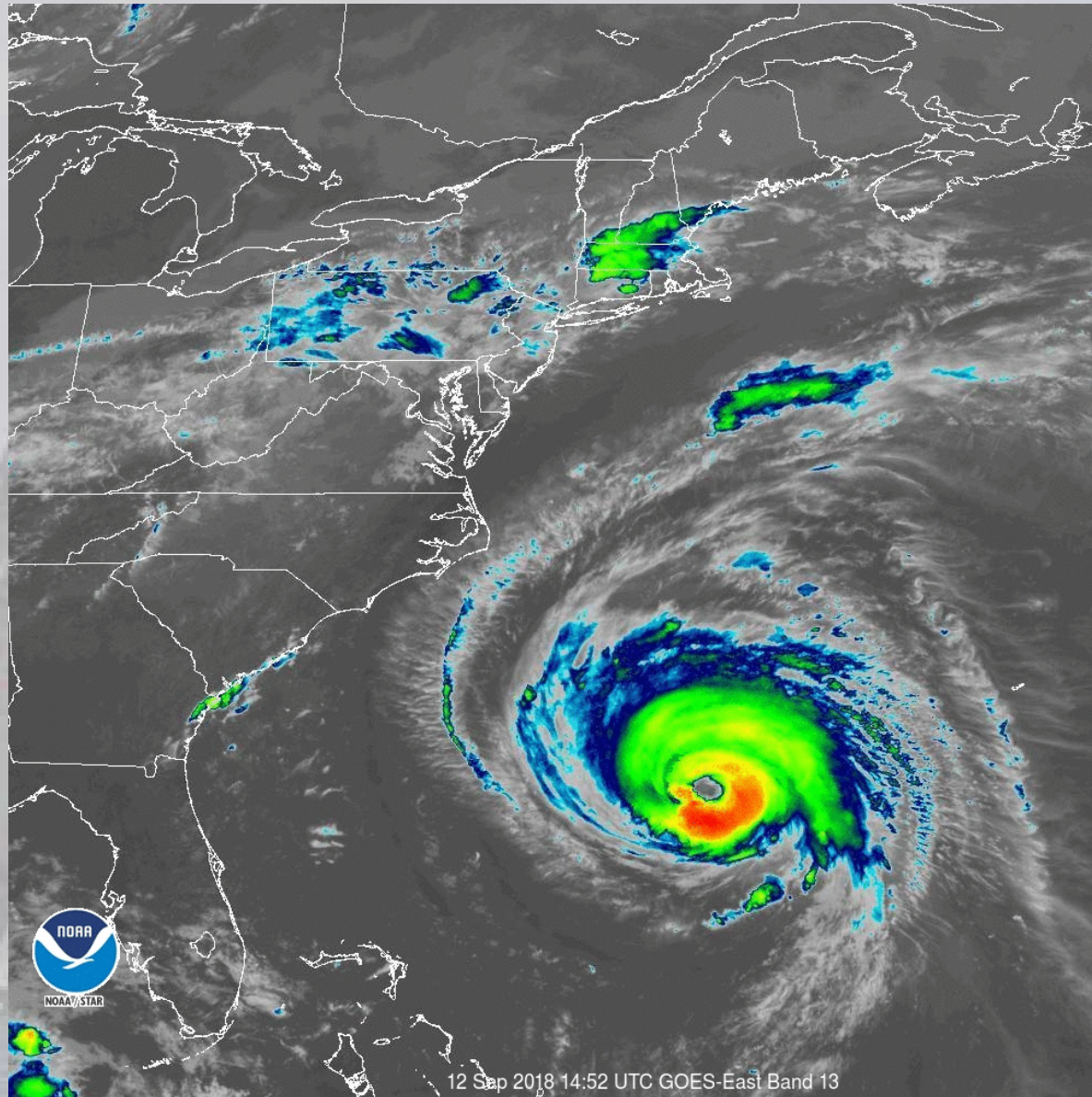
HURRICANE TRACKS 2017



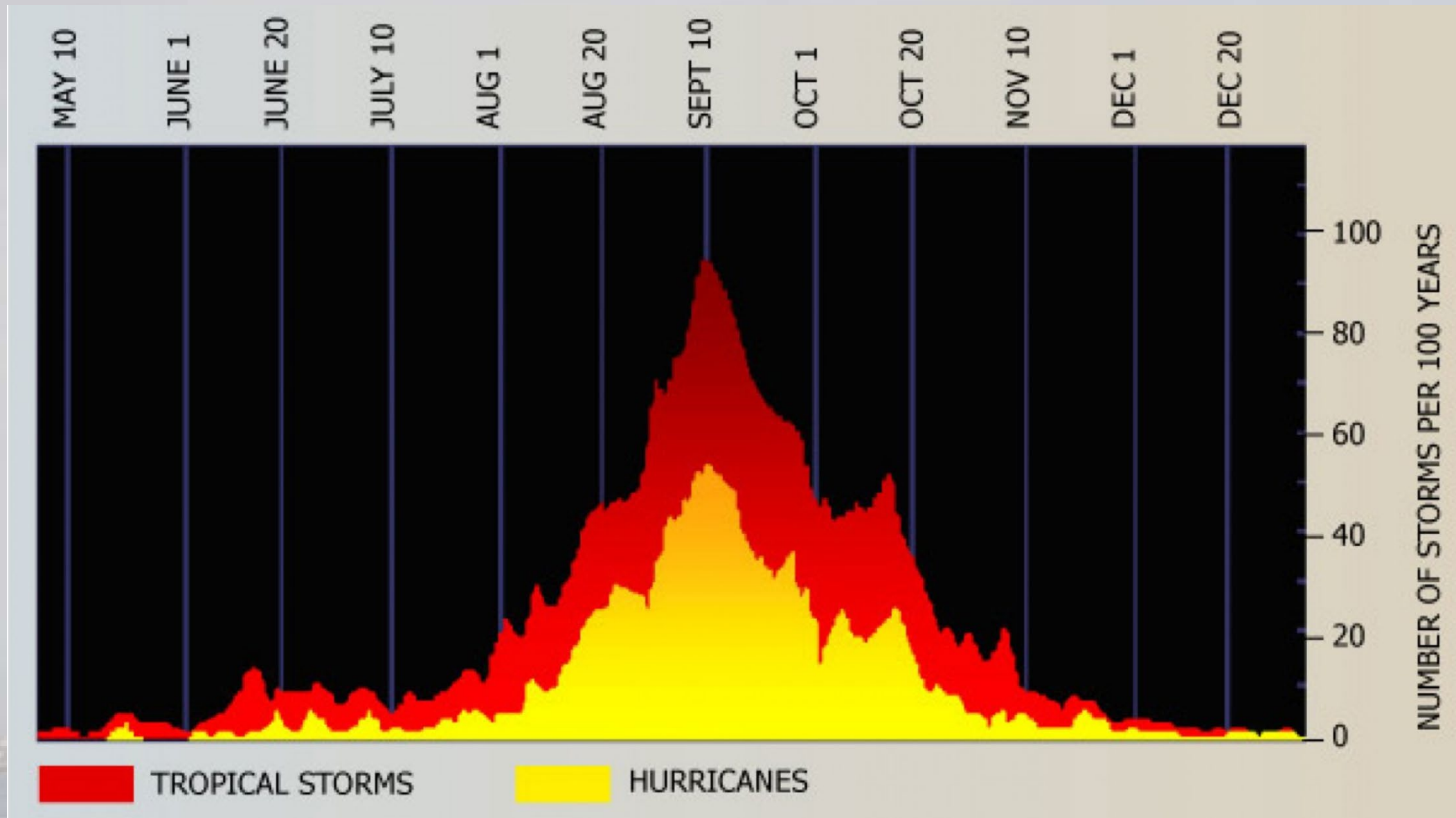
HURRICANE FLORENCE 2018



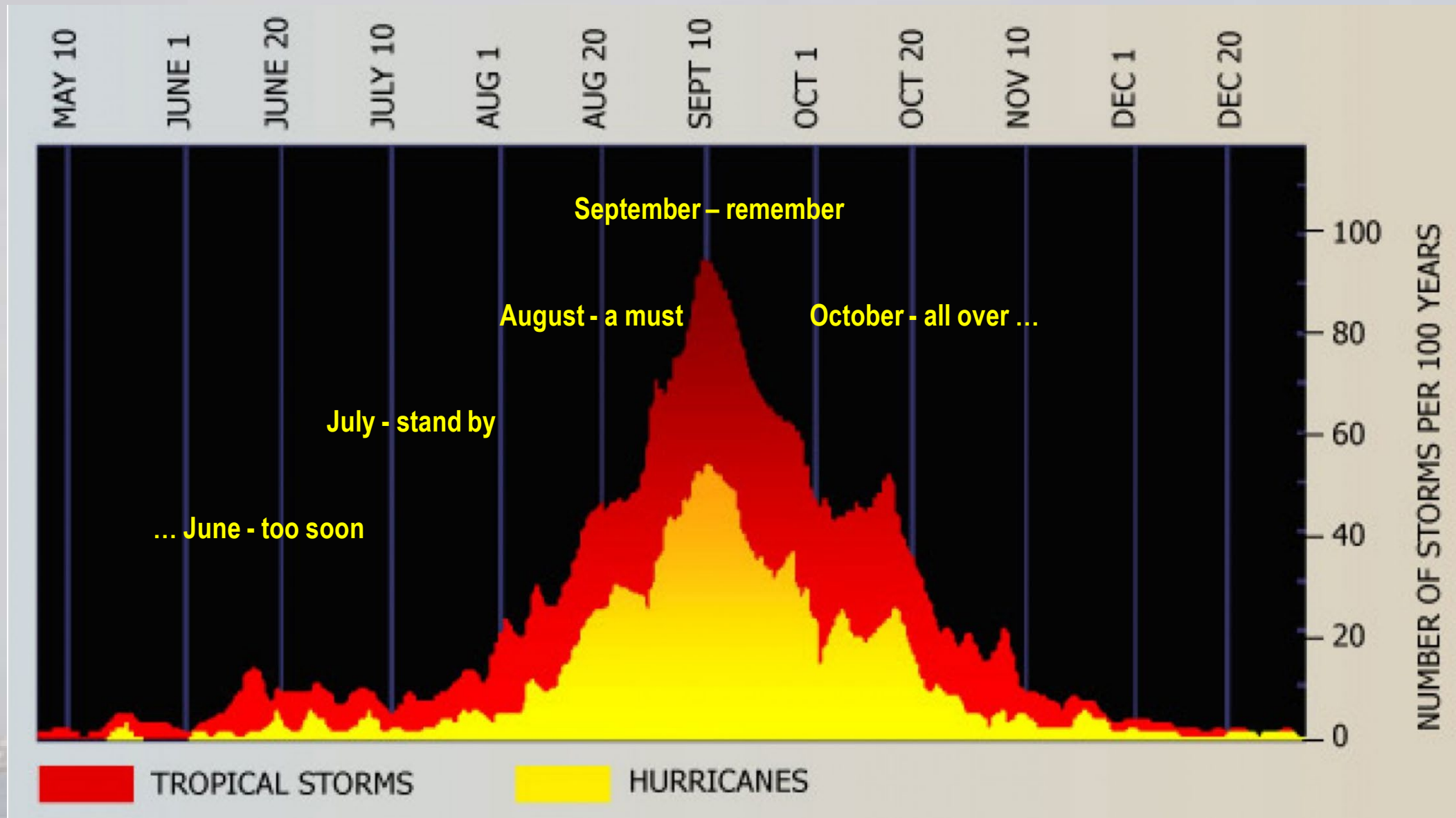
HURRICANE FLORENCE 2018



TROPICAL STORMS ANNUAL VARIATION



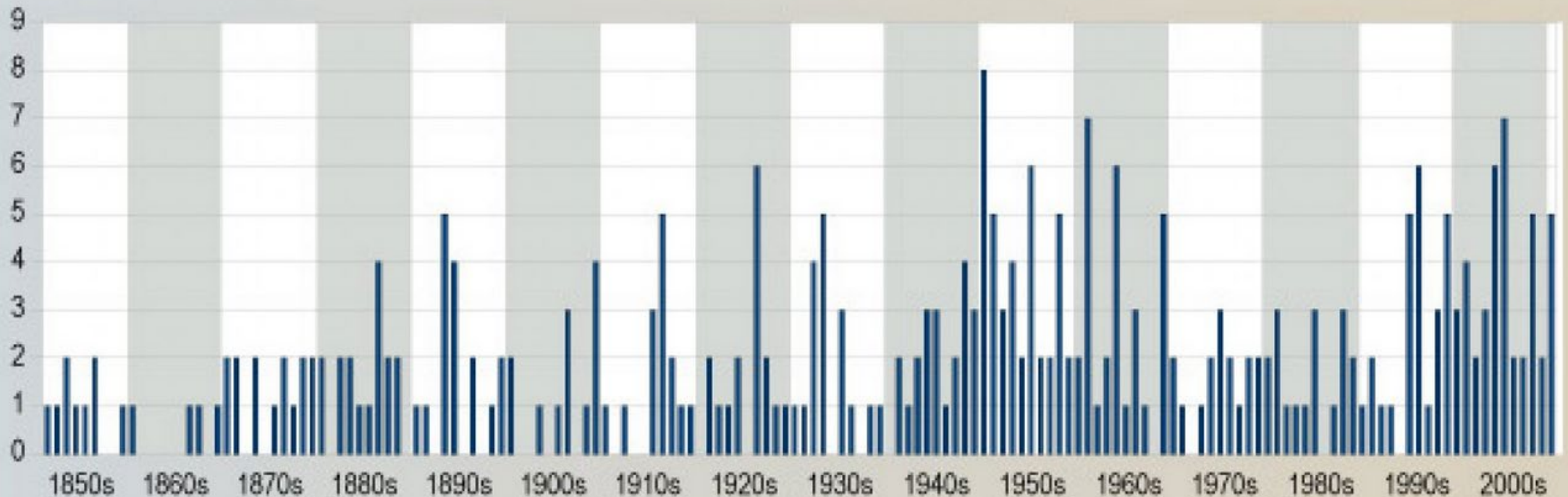
TROPICAL STORMS ANNUAL VARIATION



TROPICAL STORMS STATISTICS

Major Hurricanes, 1851-2010

Number of annual hurricanes ranked 3, 4 or 5 on the Saffir-Simpson Hurricane Scale. Scientists know that hurricane activity waxes and wanes on decades-long cycles related to global climate patterns.

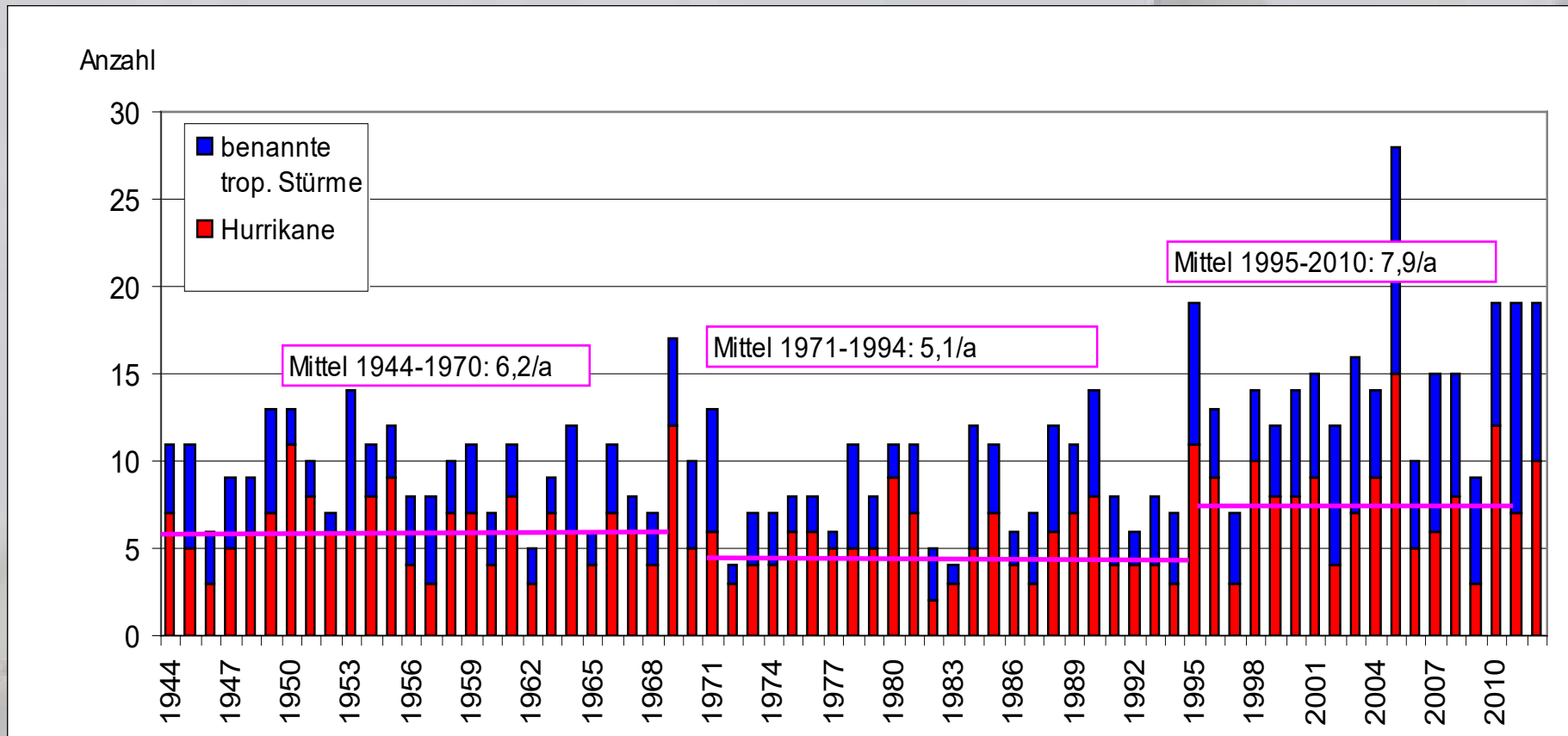


SOURCES: NOAA, NATIONAL HURRICANE CENTER, NATIONAL WEATHER SERVICE

KARL TATE / OurAmazingPlanet.com

TROPICAL STORMS STATISTICS

Annual numbers of tropical storms and hurricanes to which a name was given
Annual means of frequency of hurricanes



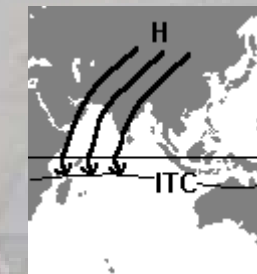
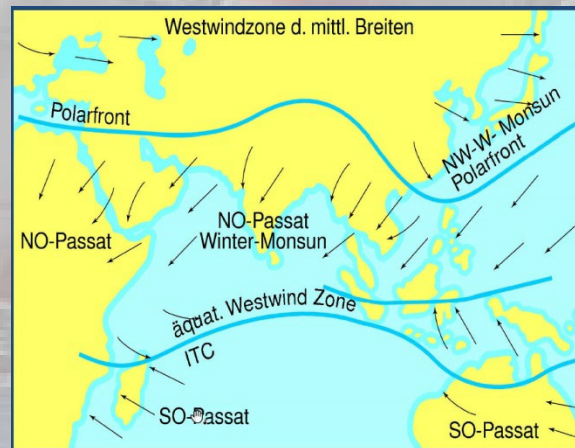
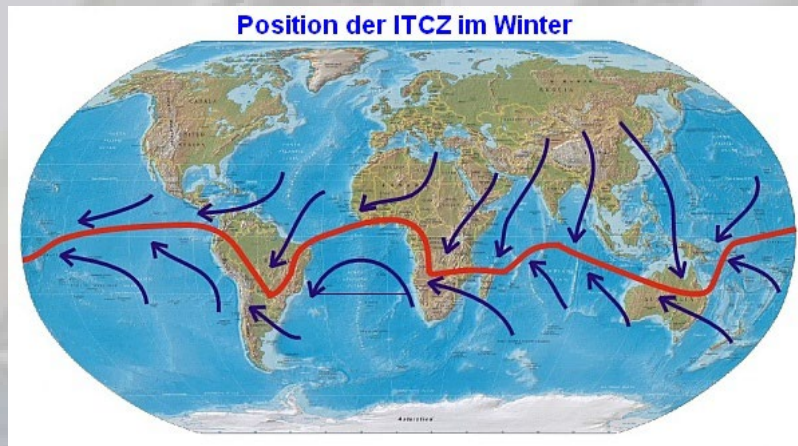
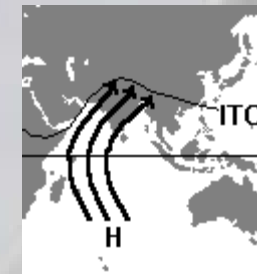
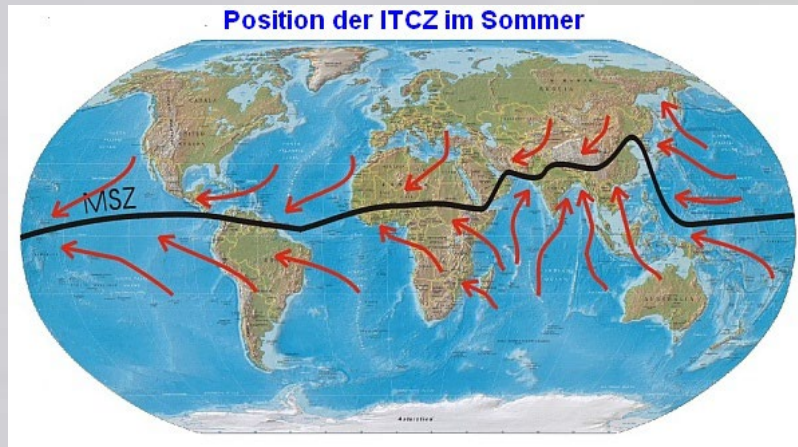
TROPICAL WIND SYSTEMS INDIA MONSOON

ITCZ position given by season, monsoon is like a 'large-scale sea-breeze'

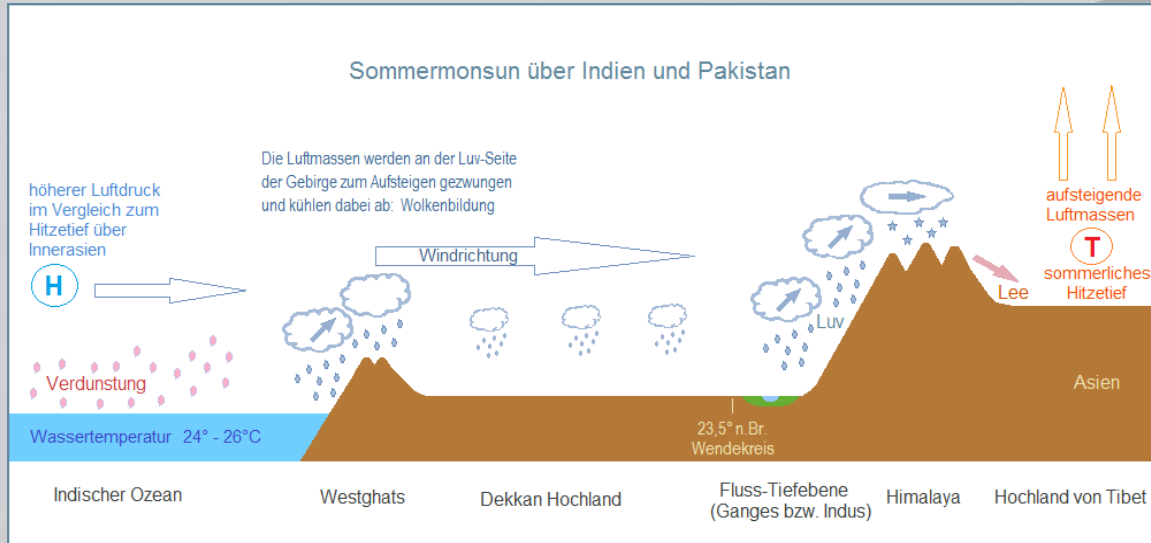
Summer: Heat Low Tibet
 Winter: Cold High Sibiria

SW Monsoon
 NE Trade wind winter monsoon

Jun-Sep rainy season
 Okt-Mai dry season

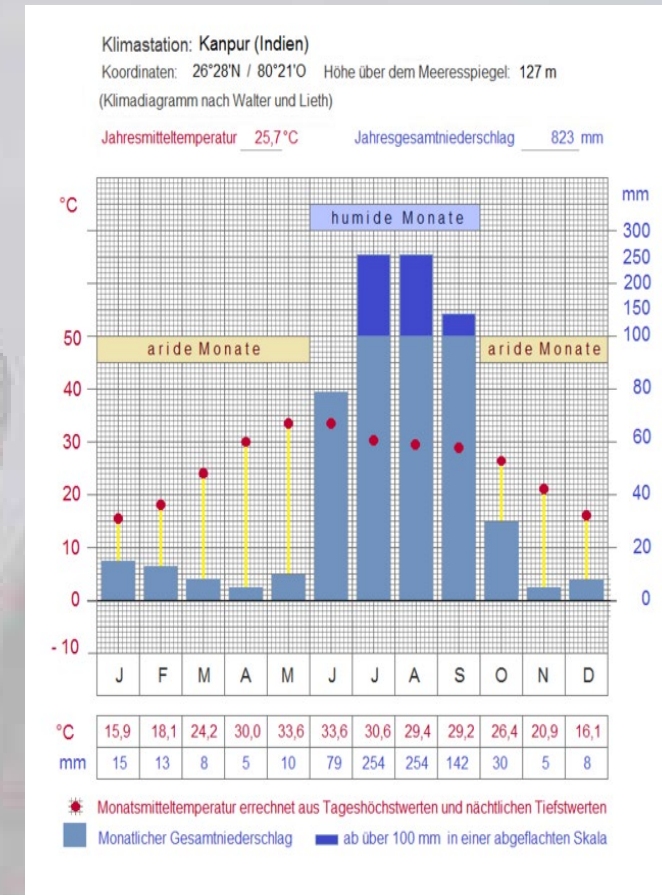
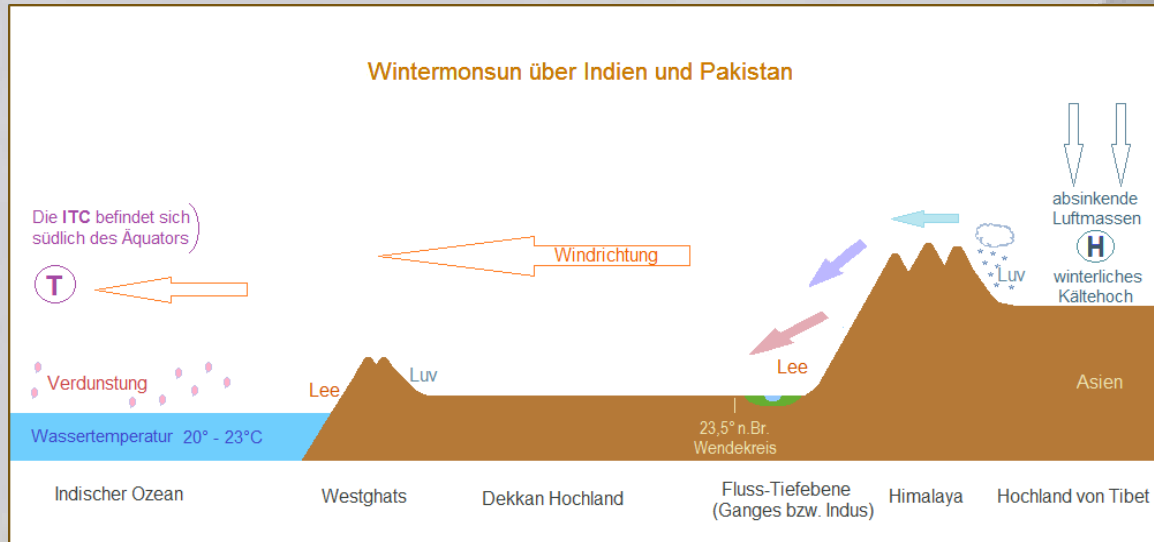


TROPICAL WIND SYSTEMS INDIA MONSOON



Summer monsoon, rainy season May-Aug annual rainfall ~ 12000 mm / year

TROPICAL WIND SYSTEMS – INDIA MONSOON



Winter monsoon, dry season Mar-May

Kampur annual variation of rainfall

QUESTIONS YOU SHOULD BE ABLE TO ANSWER

Tropical Storms TS

- ✓ What is the typical beginning of a TS over the North Atlantic?
 - ✓ Easterly Wave moving from W-Africa eastward

- ✓ Which are necessary preconditions for TS development?
 - ✓ 1. Water Temperature T_w or Sea Surface Temperature $SST > 27^\circ\text{C}$ to bring sufficient latent energy by evaporation into the atmosphere
 - ✓ 2. Geographical latitude $\text{Lat} > 5^\circ\text{N}$ to allow development of circulation
 - ✓ ... Unstable vertical stratification to allow vertical development
 - ✓ ... Low vertical windshear VWS to allow vertical development of circulation

- ✓ When is the 'Hurricane Season' in general and for the North Atlantic in particular
 - ✓ Late summer in general, July for North Atlantic
 - ✓ June – too soon; July – stand by; August – a must; September – remember; Oct – all over

QUESTIONS YOU SHOULD BE ABLE TO ANSWER

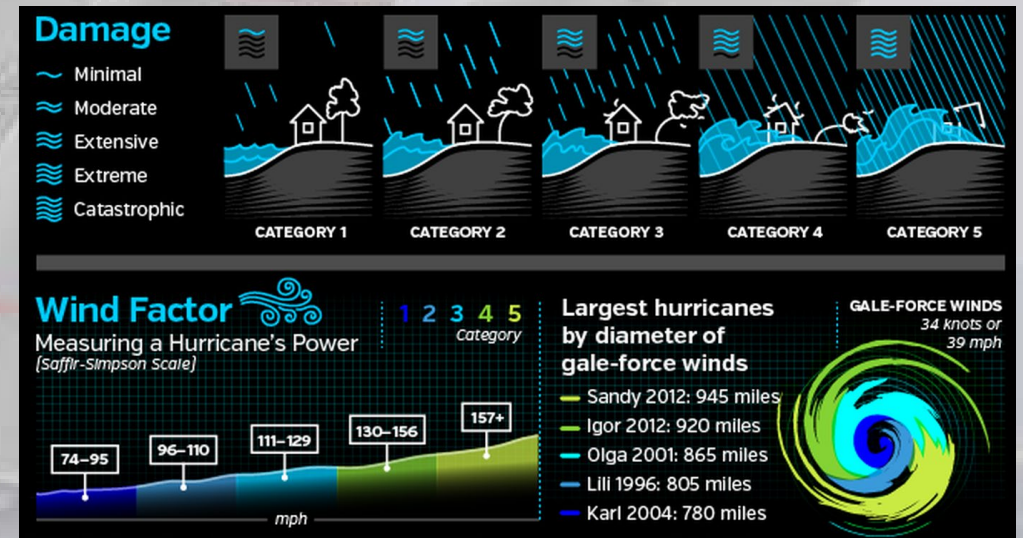
Tropical Storms

✓ How are tropical Storms categorized?

- ✓ Encountered / Estimated winds
- ✓ Encountered / Estimated winds

- Tropical Depression TD Bft.7 or less 33 kt or less
- Tropical Storm TS Bft.8 - Bft.11 34 kt – 63 kt
- Hurricane Bft.12 64 kt or more

- Hurricanes Categories
- Saffir-Simpson 1 Minimal
- Saffir-Simpson 2 Moderate
- Saffir-Simpson 3 Extensive
- Saffir-Simpson 4 Extreme
- Saffir-Simpson 5 Catastrophic, Devastating



QUESTIONS YOU SHOULD BE ABLE TO ANSWER

Tropical Circulation

- ✓ What is the Monsoon ?
 - ✓ Monsoon is a Land – Seabreeze – Circulation with the following scales
 - ✓ Time scale: Months, Seasons (typical Land/Sea Breeze: one day)
 - ✓ Length scale: 1000s of kilometers (typical Land/Sea Breeze: 10s of km)
- ✓ Seasonal Summer May-Aug Warm, moist, Heavy Rain over India (> 12.000mm/yr)
- ✓ Seasonal Winter Mar-May Cold, dry air,

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