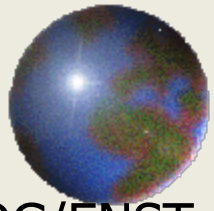
Hurricanes



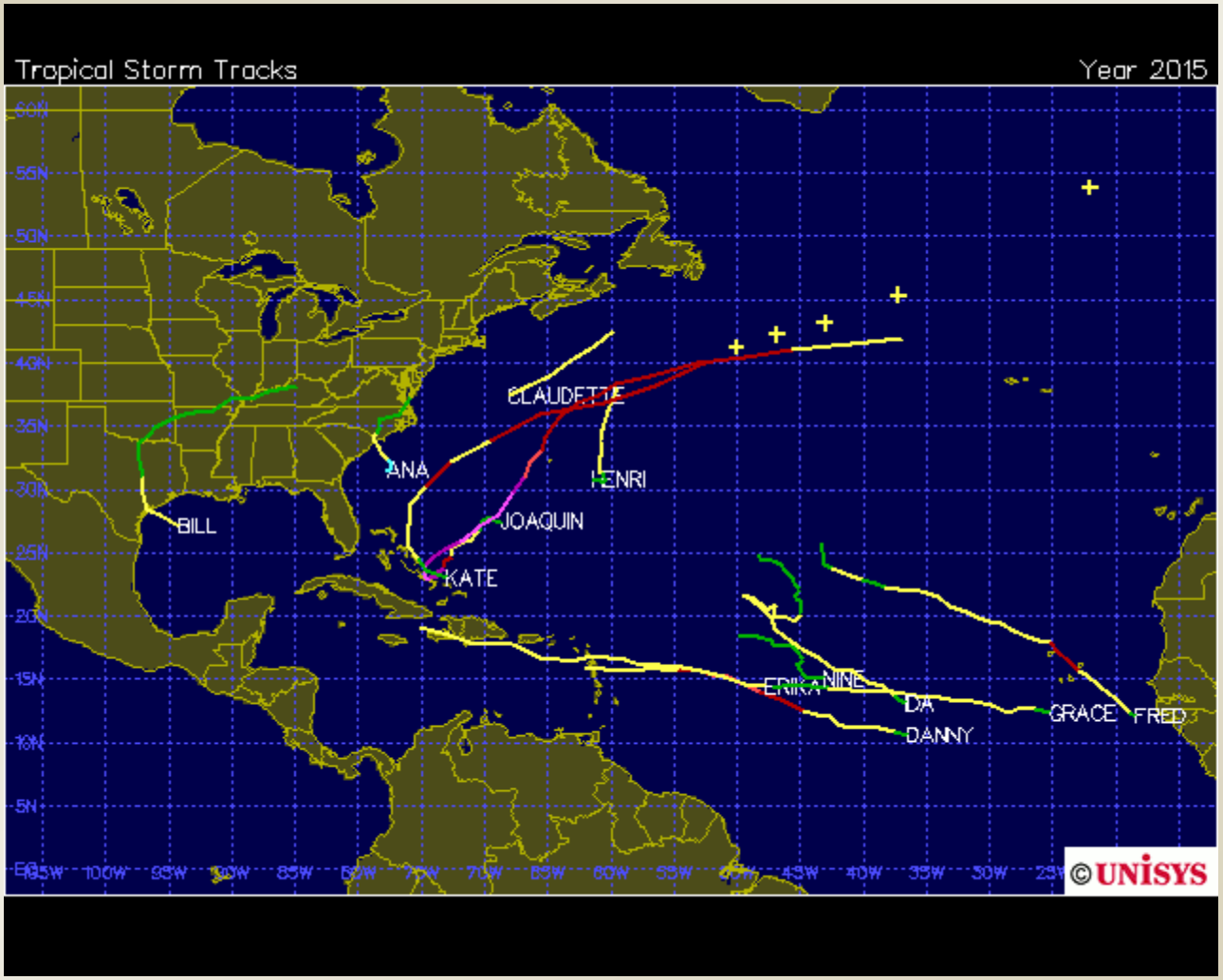
GEOG/ENST 2331

Lecture 19

Ahrens: Chapter 15

Figure to right

Atlantic Hurricanes: 2015 (to Nov. 20)



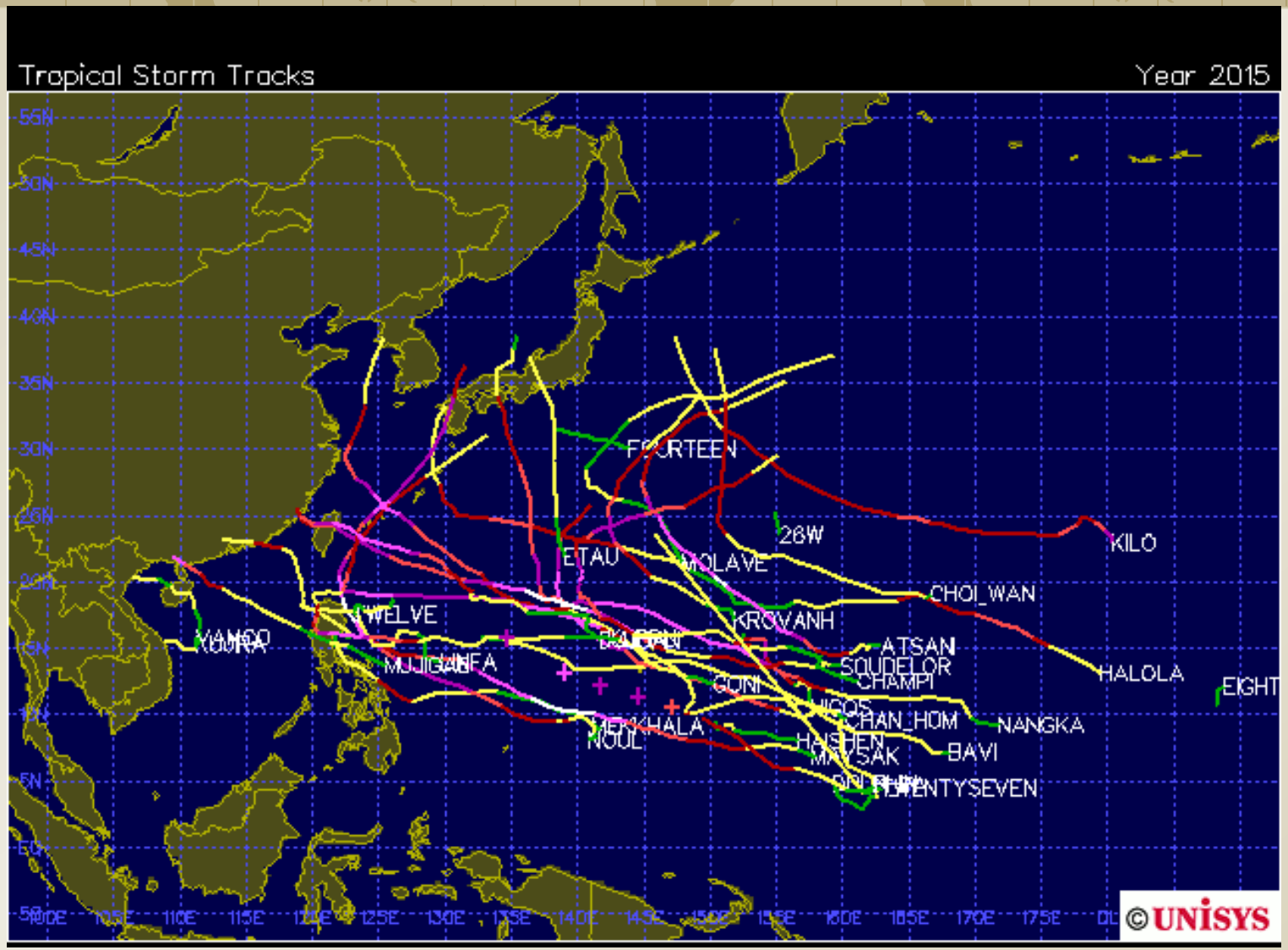
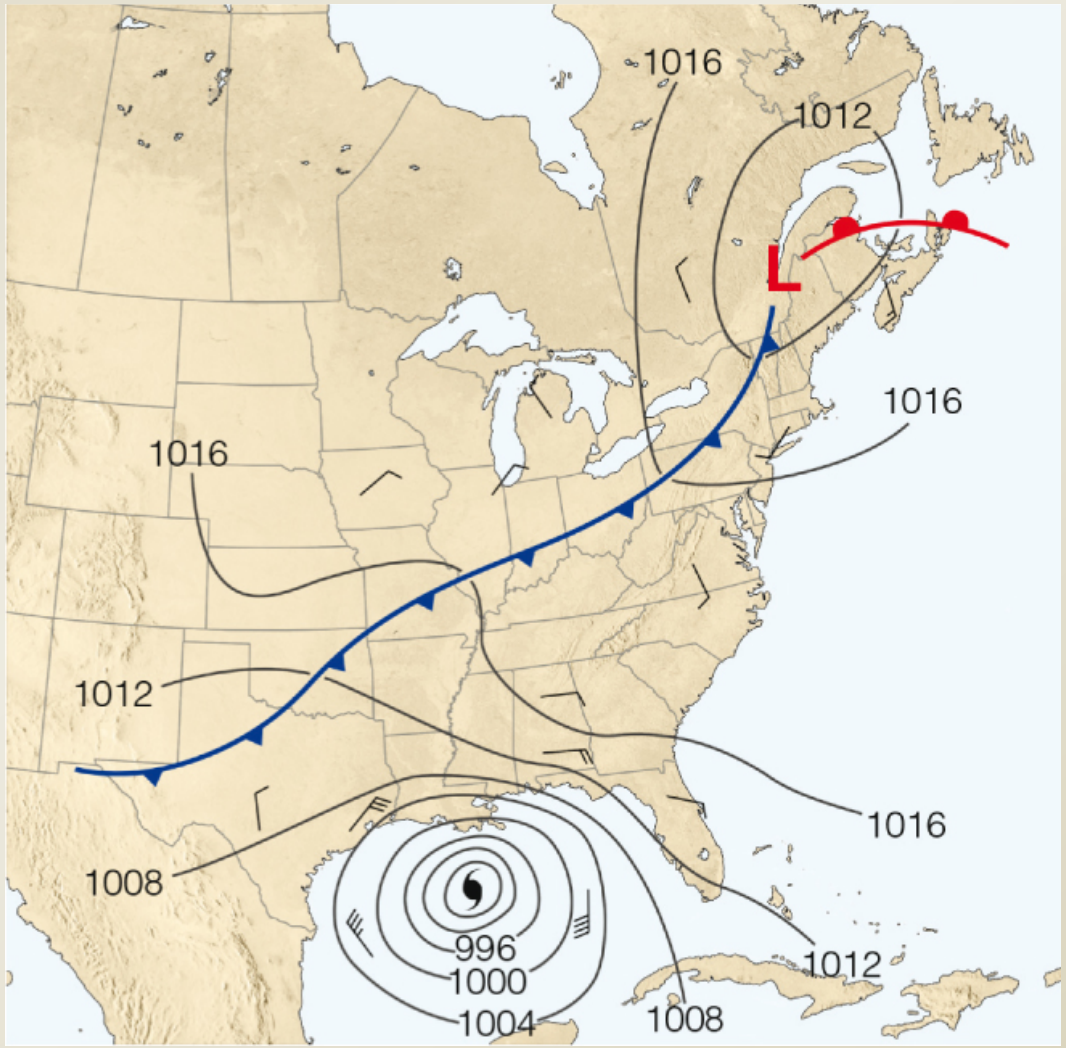


Figure above Typhoons: 2015 (to Nov. 20)

Hurricanes

- Tropical cyclones
- Dynamics
  - Formation
  - Structure
  - Movement
  - Dissipation

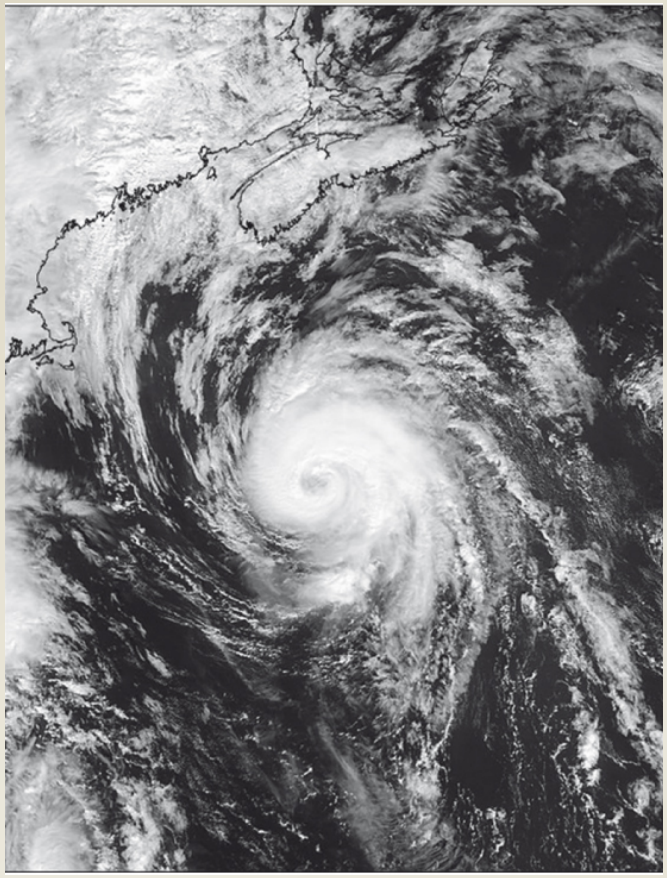


Ahrens: Fig. 1, p. 466
Hurricane Rita (Sept. 2005)

Tropical cyclones

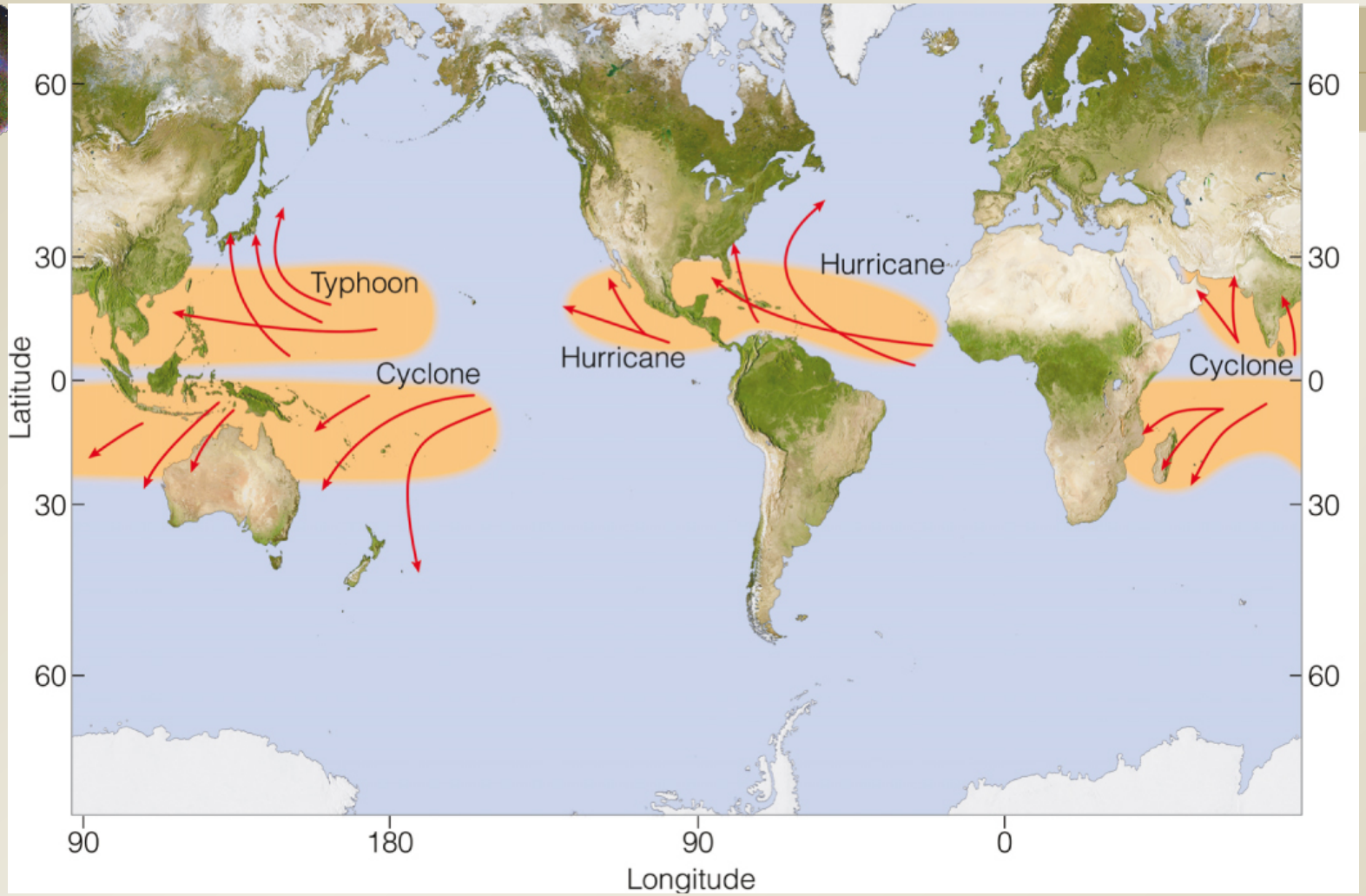
- The most powerful of all storms
- Lesser intensity than tornadoes but larger size and longer life span makes hurricanes much more devastating
- Average diameters are approximately 600 km and central pressures average about 950 hPa but may be as low as 870 hPa

Tropical cyclone terminology



Ahrens: Fig. 3, p. 471
Hurricane Juan, 2003

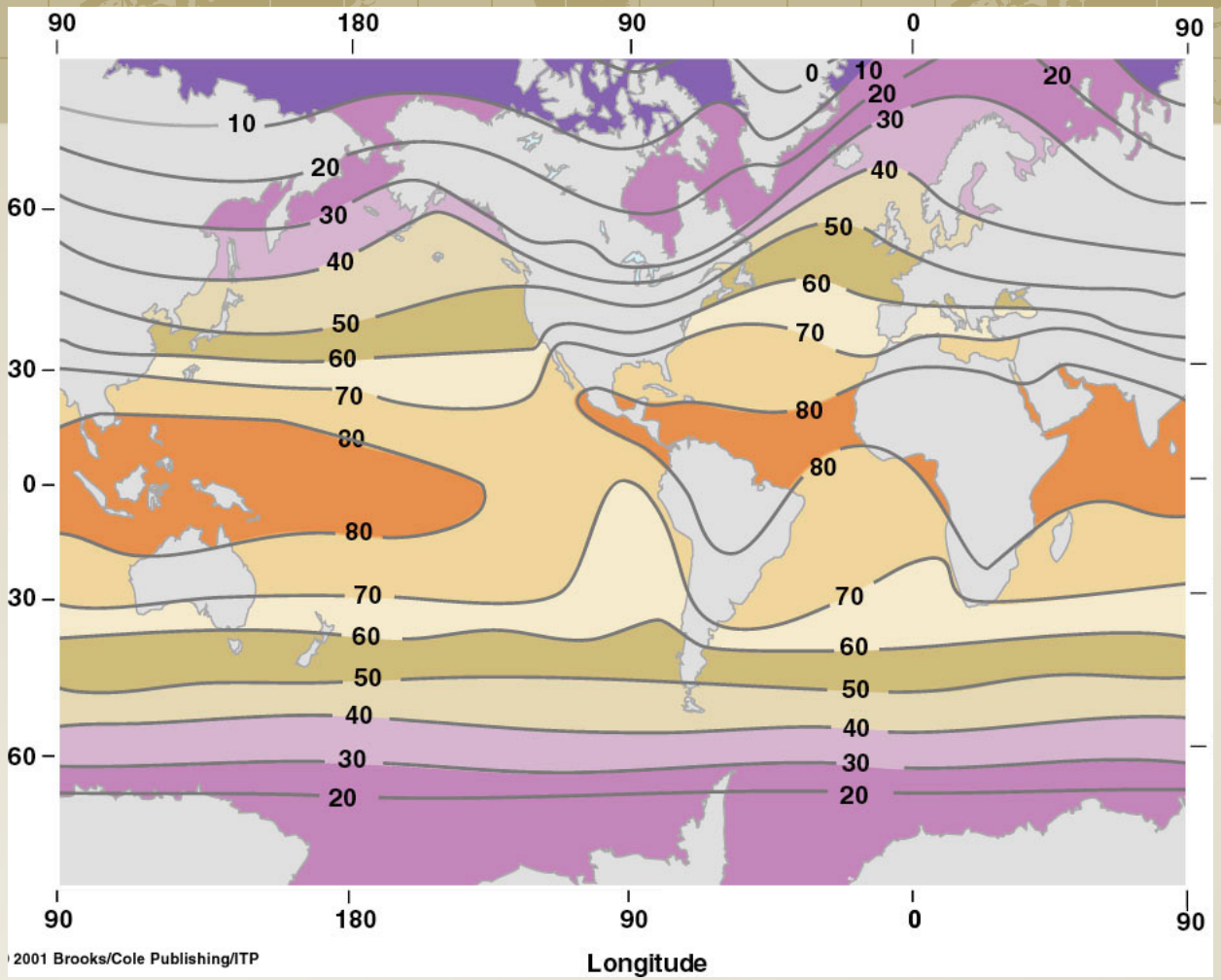
- Hurricane
  - North American term
  - Taino language
- Typhoon
  - Western Pacific term
  - "Tai fung" (Chinese)
  - "Tai-fu" (Japanese)
  - "Great wind"
- Severe Tropical Cyclone
  - Southern Hemisphere and Indian Ocean



Tropical Cyclones

Tropical cyclone genesis areas and related storm tracks

Ahrens: Fig. 15.11



SST Distribution

All regions of tropical cyclone development frequently exceed 27°C (80°F).

Definitions

- Tropical depression
  - Low pressure system in tropical ocean
- Tropical storm (*Named* storm)
  - Sustained winds of 60-120 km/h (18-33 m/s)
- Hurricane/Typhoon/Severe Tropical Cyclone
  - Sustained winds of 120-180 km/h (33-50 m/s)
  - Categories 1-2
- Major Hurricane/Typhoon/Cyclone
  - Sustained winds exceeding 180 km/h (50 m/s)
  - Categories 3-5

Saffir-Simpson Scale for Hurricane Strength

Herbert Saffir and Robert Simpson

Table 12–2 The Saffir-Simpson Scale

Category	Pressure mb	Wind Speed km/hr	Wind Speed mph	Storm Surge m	Storm Surge ft	Damage
1	≥ 980	119–154	74–95	1–2	4–5	Minimal
2	965–979	155–178	96–110	2–3	6–8	Moderate
3	945–964	179–210	111–130	3–4	9–12	Extensive
4	920–944	211–250	131–155	4–6	13–18	Extreme
5	< 920	> 250	> 155	> 6	> 18	Catastrophic

A&B: Table 12-2

Annual frequency of hurricane-strength storms

Basin	Maximum	Minimum	Average
Atlantic	12	2	5.9
NH East Pacific	16	4	9.0
NH West Pacific	24	9	16.9
NH Indian	5	0	2.2
SH West Indian	11	2	6.7
SH East Indian	8	0	3.6
SH West Pacific	12	0	4.8
Global	**64**	**36**	**48.3**

Source: A&B Table 12-1

Hurricane-strength storms: 2015 compared to average

Basin	1 an 2	3 to 5	Total	Average
Atlantic	2	2	4	5.9
NH East Pacific*	5	10	15	9.0
NH West Pacific*	4	18	22	16.9
NH Indian	0	2	2	2.2
SH Indian	3	2	5	10.3
SH West Pacific	3	2	5	4.8
* **Active Trop Storm Global**	**17**	**36**	**53**	**48.3**

To Nov. 20, 2015

Sources: Unisys; A&B Table 12-1

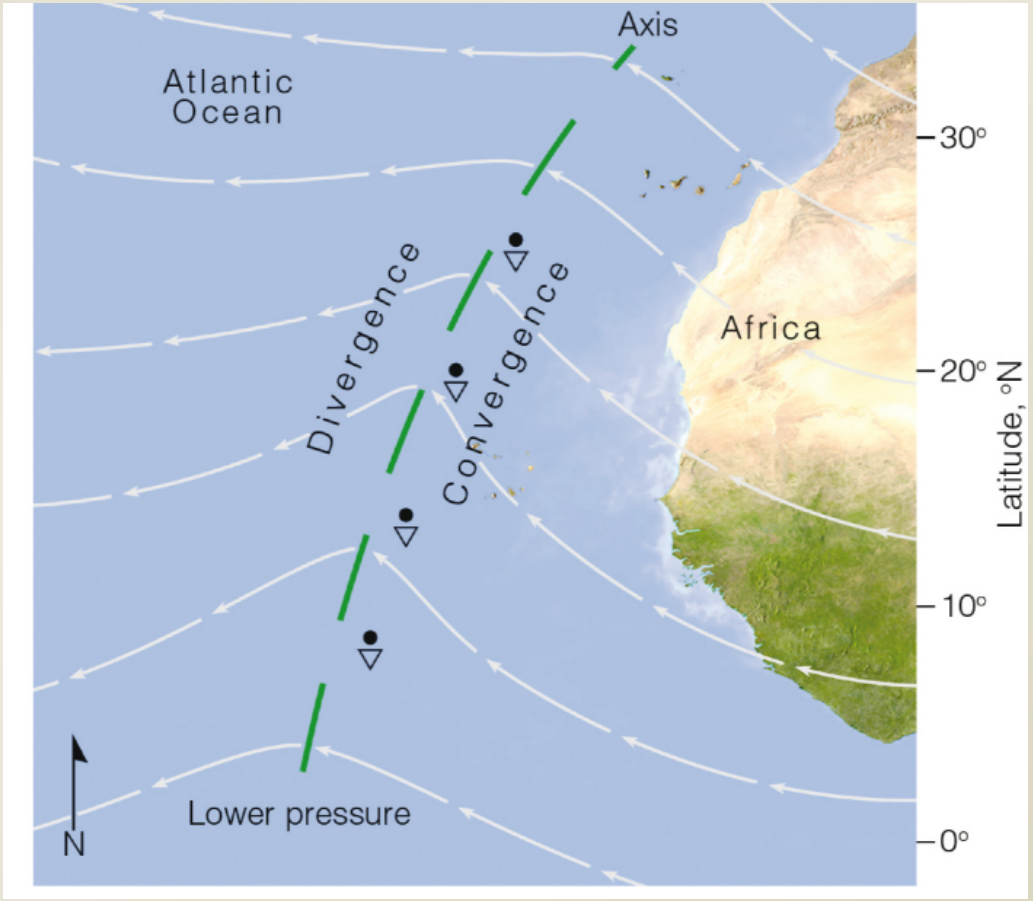
#	Name	Date	Wind (knots)	Cat
1	TS ANA	08-11 MAY	40	
2	TS BILL	16-20 JUN	50	
3	TS CLAUDETTE	13-14 JUL	45	
4	Hurr-3 DANNY	18-24 AUG	100	3
5	TS ERIKA	25-29 AUG	45	
6	Hurr-1 FRED	30 AUG-06 SEP	75	1
7	TS GRACE	05-09 SEP	45	
8	TS HENRI	09-11 SEP	35	
9	T D NINE	16-19 SEP	30	
10	TS IDA	18-27 SEP	45	
11	Hurr-4 JOAQUIN	28 SEP-08 OCT	135	4
12	Hurri-1 KATE	09-12 NOV	65	1

Cyclone ingredients

- Hurricanes form only over deep water layers with sea surface temperature (SST) in excess of 27°C
  - Poleward of about 20° (latitude), SSTs are usually too cold
- Coriolis force is an important contributor
  - Hurricanes do not form equatorward of 5°
- An unstable atmosphere is also necessary
- Strong vertical wind shear must be absent

Atlantic Basin Storm Development

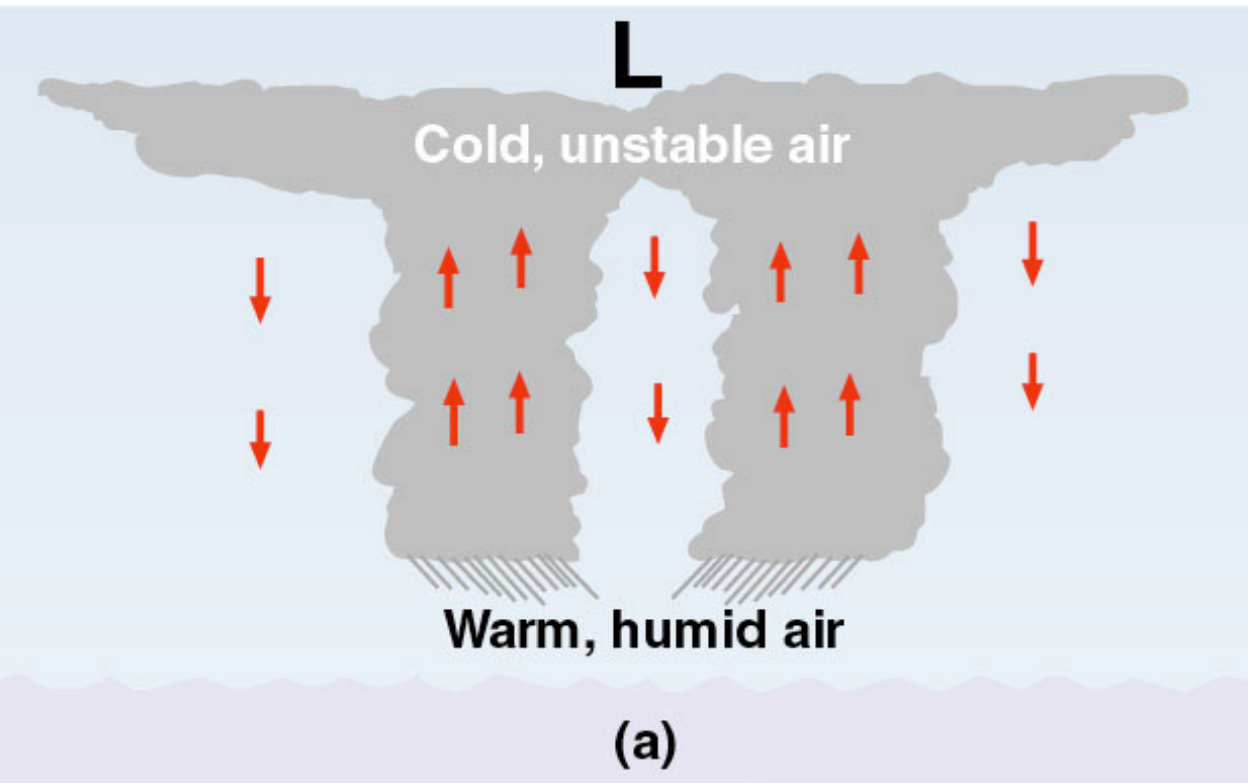
- June through November
- Begins as a tropical wave in the trade winds
  - Originates in East Africa
- One week to cross the Atlantic (15-35 km/h)



An easterly wave in surface winds
Ahrens: Figure 15.1

Hurricane structure

- 10% of 'seedlings' develop into **rotating storms**
- Growth fuelled by rising warm, saturated air
- Group of thunderstorms becomes organized and self-sustaining

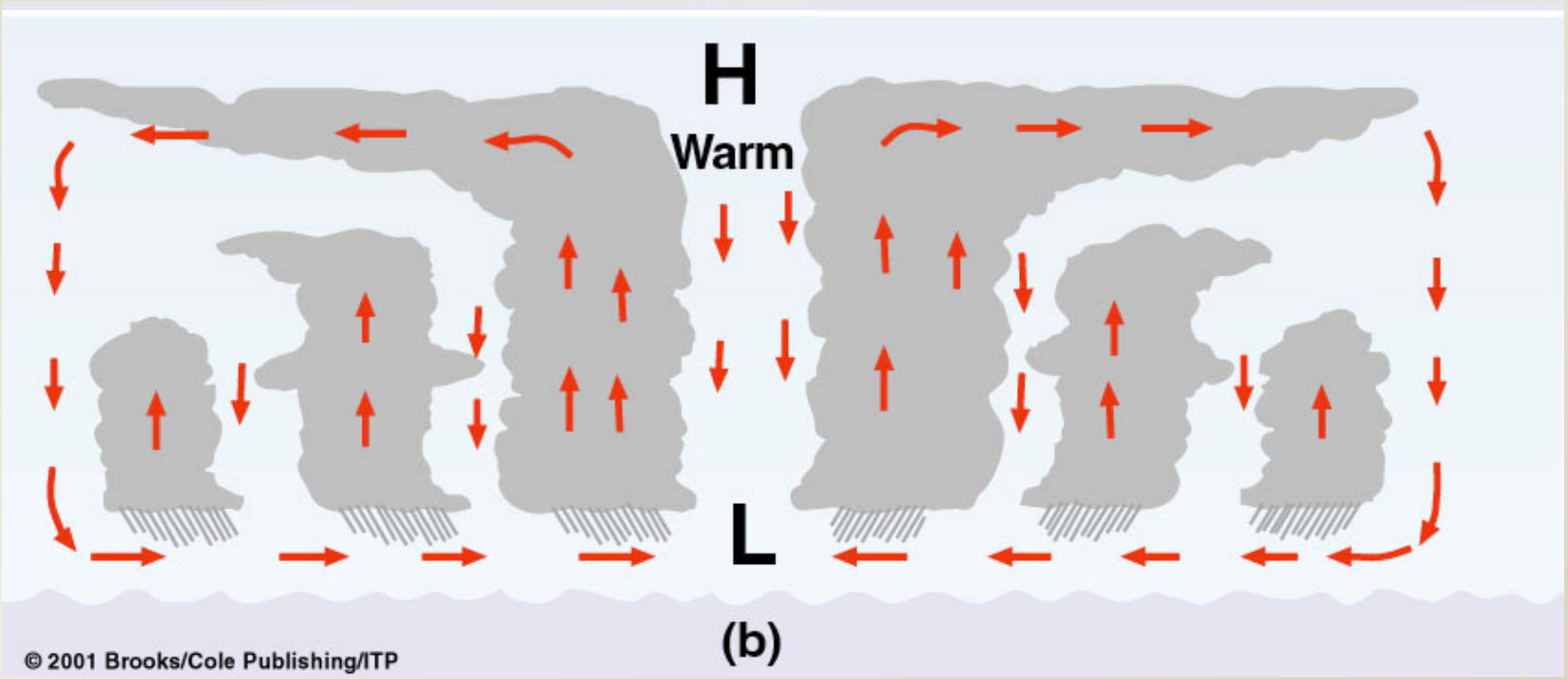


Hurricane dynamics

Rising air

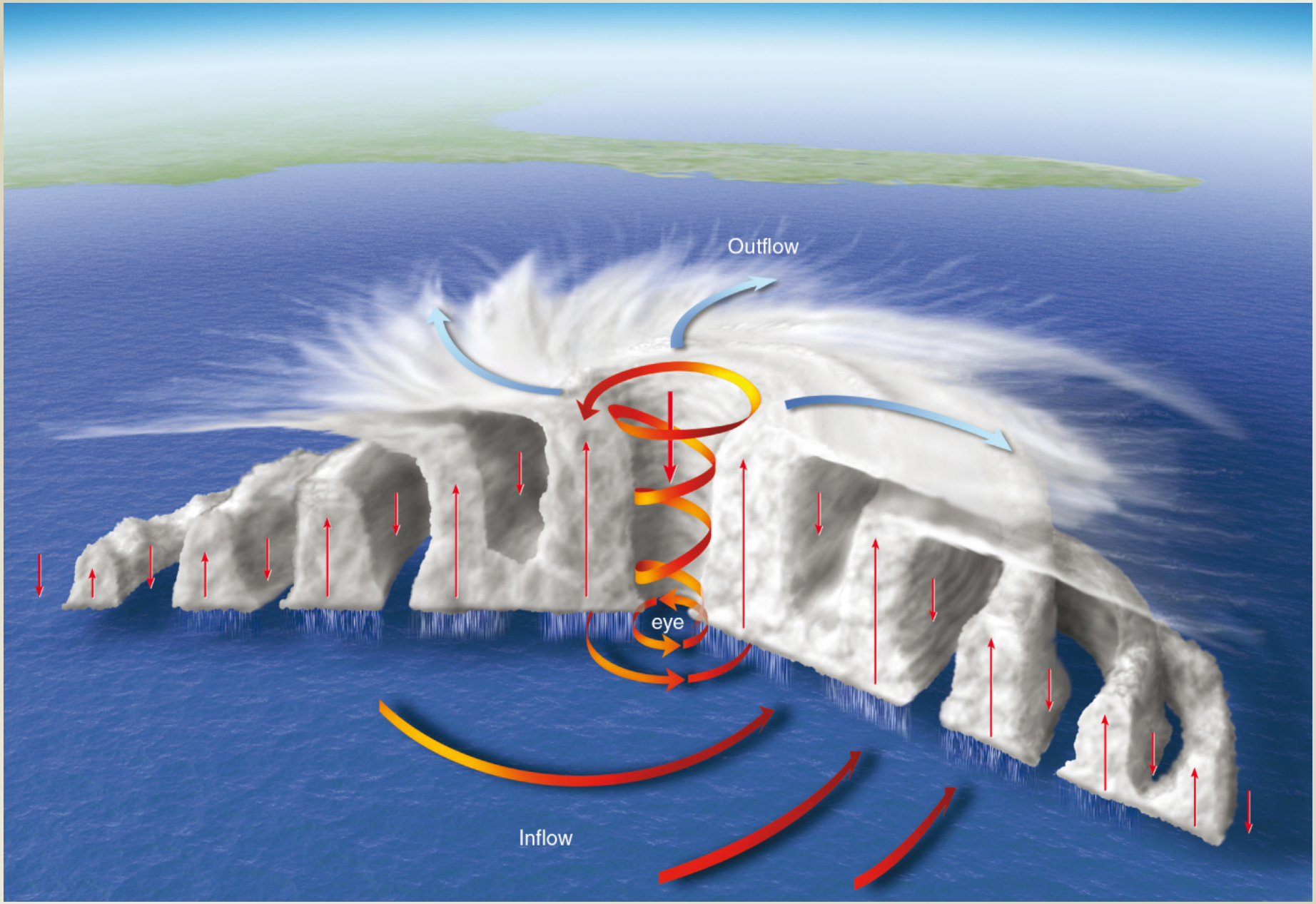
- Releases latent heat
- Warms upper atmosphere
- Causes upper air to diverge

Eye forms in the middle where air is sinking



Hurricane dynamics

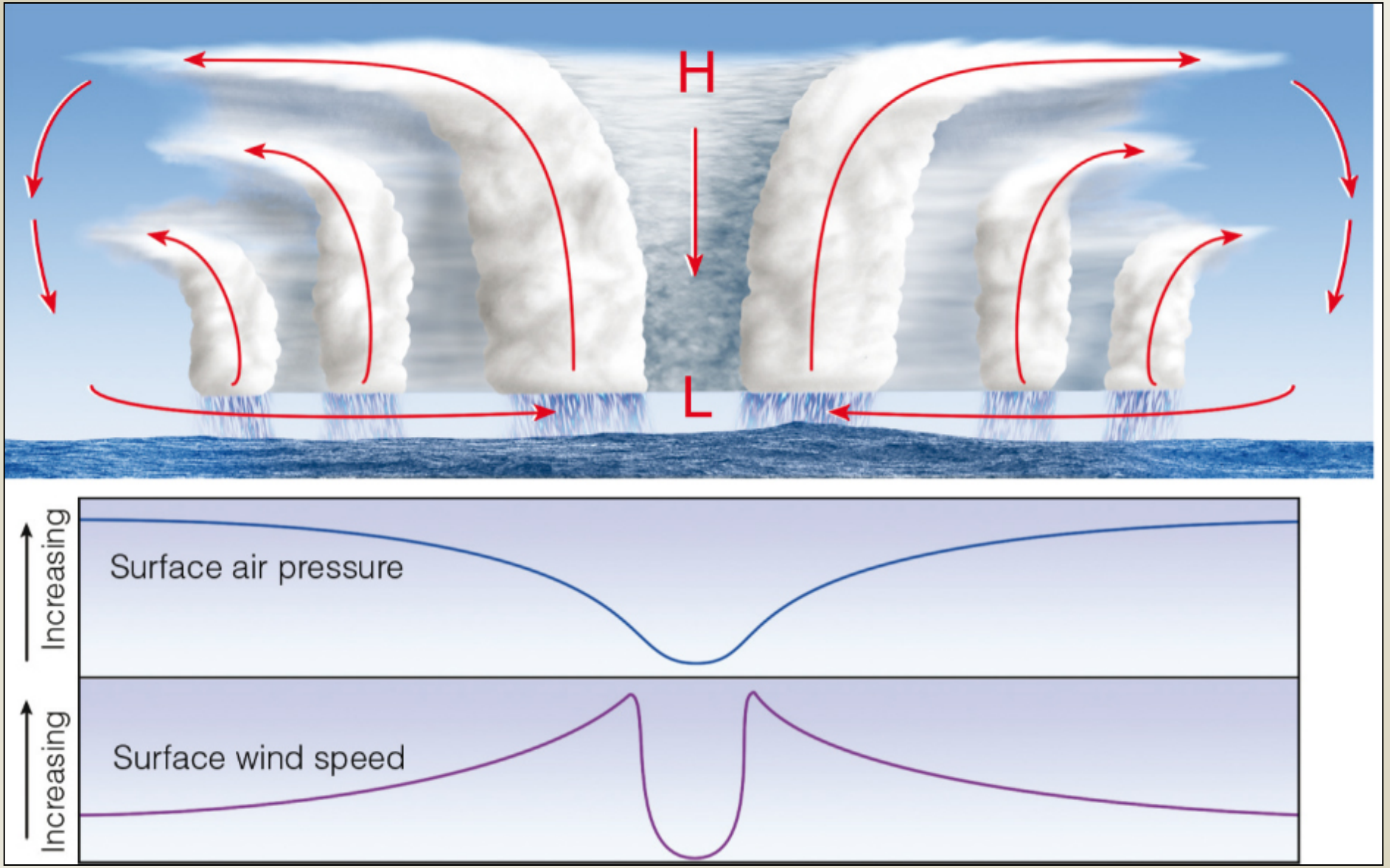
- The horizontal pressure gradient changes with altitude
  - At about 7.5 km, pressures are equal inside and outside
  - From 7.5 km to the tropopause, pressures within the storm *exceed* those outside the storm
- Lower portion of the storm rotates cyclonically
- Upper portion rotates anticyclonically



Ahrens: Figure 15.3

The Eye and Eye Wall

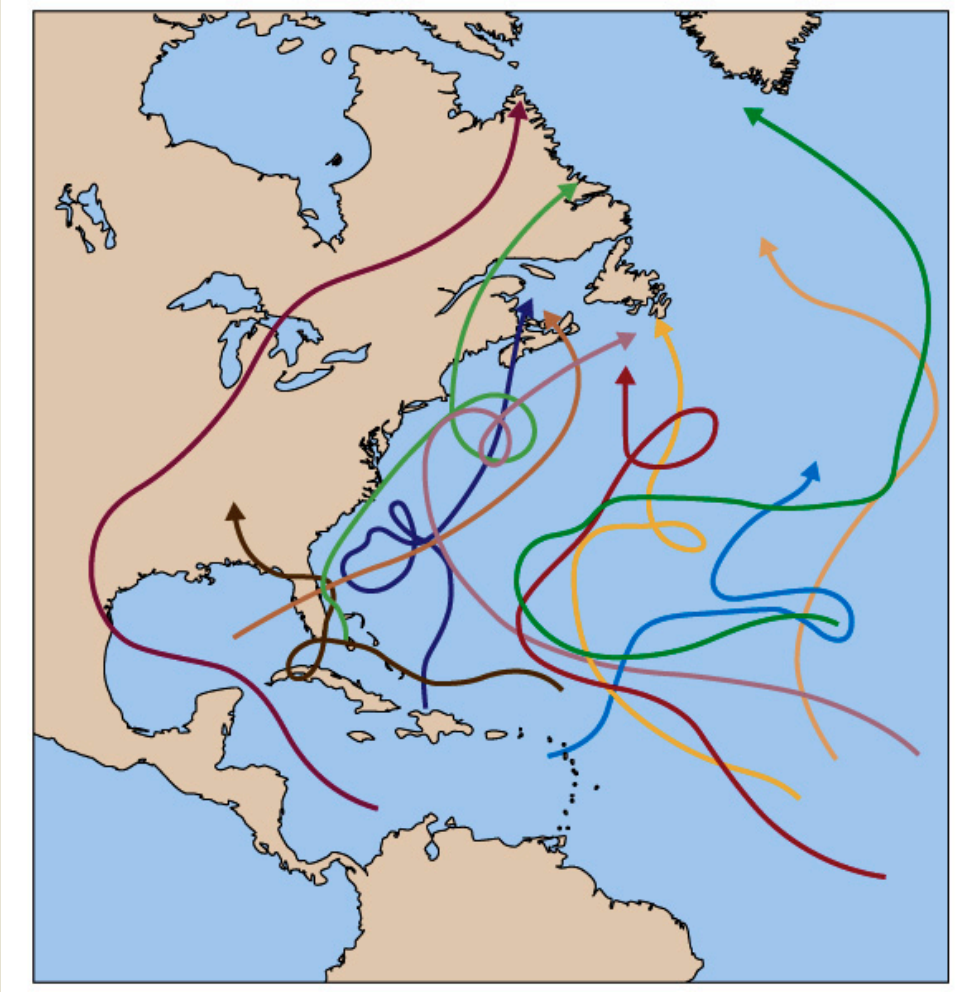
- The **eye** is an area of descending air and light winds
  - Average 25 km in diameter
  - A shrinking eye indicates storm intensification
- The **eye wall** is comprised of the strongest winds, the largest clouds, and the heaviest precipitation
  - Rainfall rates as high as 2500 mm/day



Ahrens: Fig. 15.9

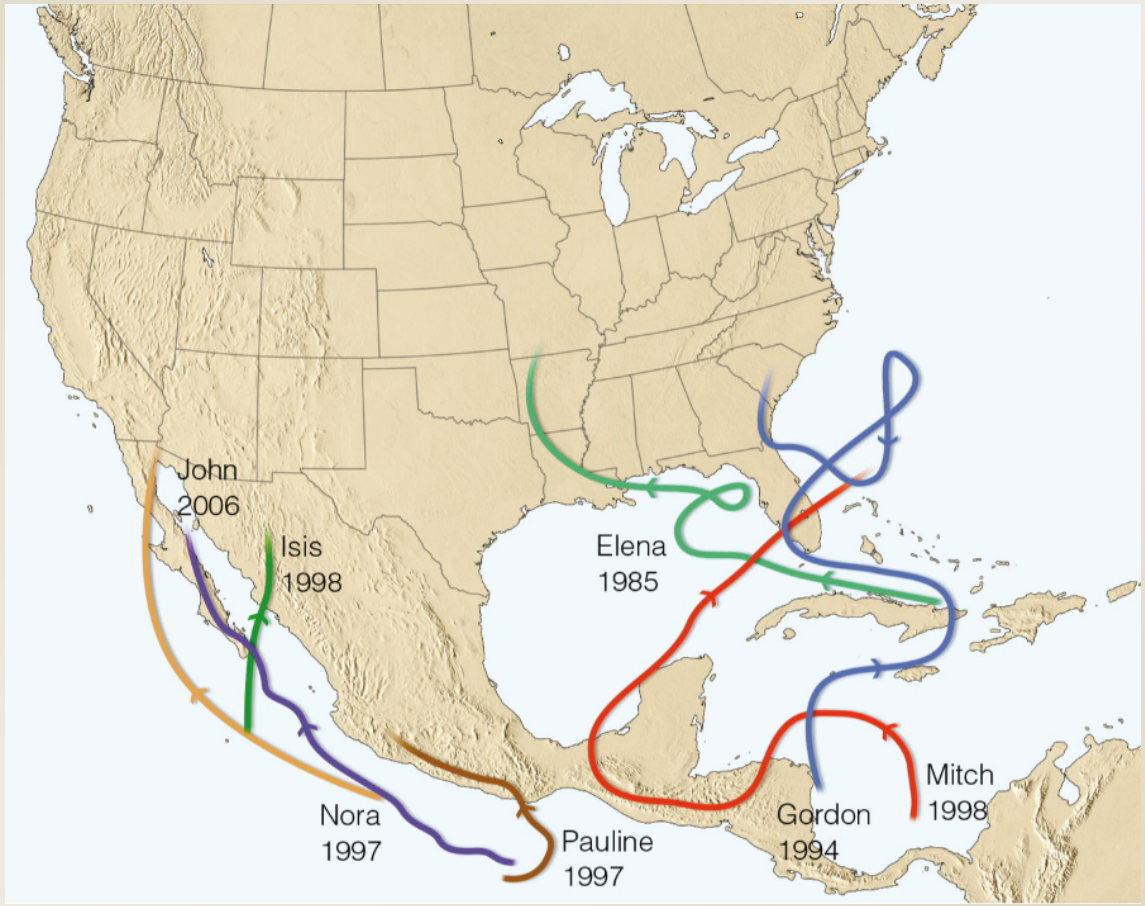
Atlantic Hurricane Movement

- Movement is dependent upon the stage of development
- In the Atlantic, storms that gain latitude ***curve back*** toward the northeast due to the influence of surface and upper-level westerlies



A&B: Figure 12-12

Hurricane Movement

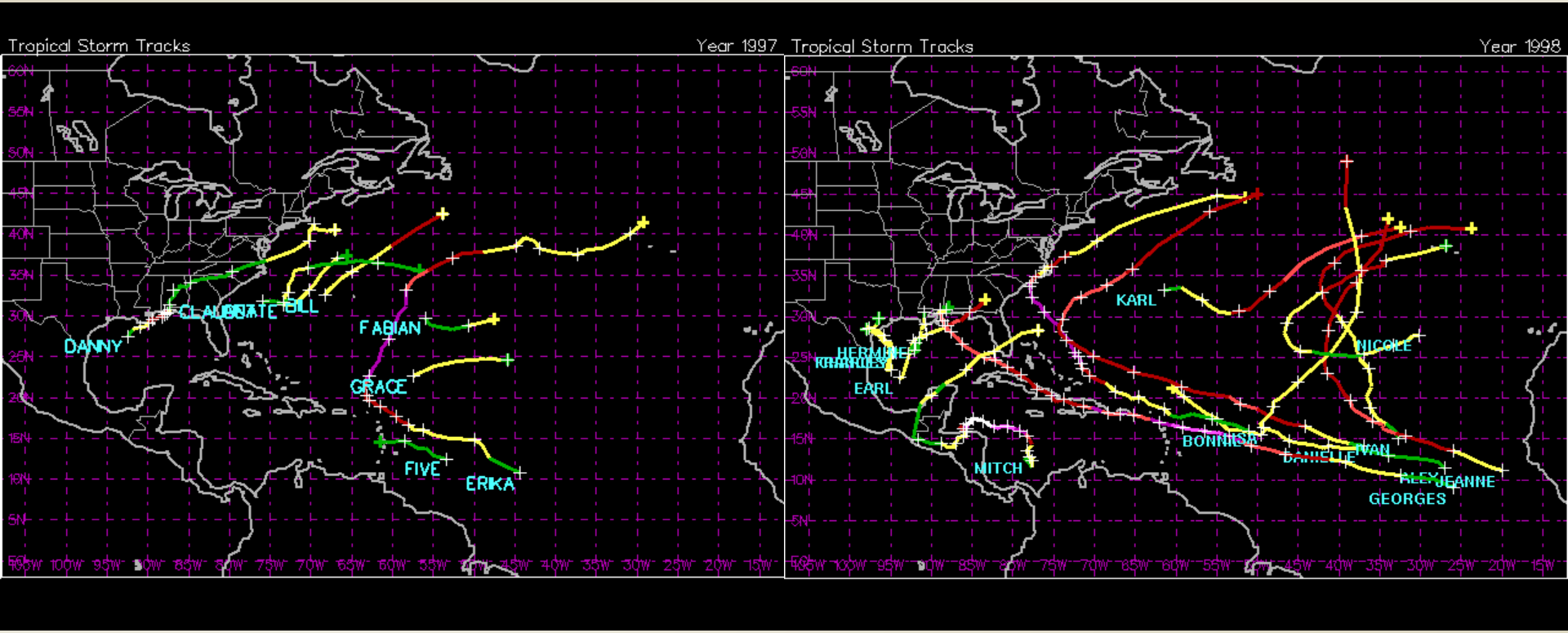


Ahrens: Fig. 15.12

Lifespan of a tropical cyclone

- SST – warmer water means more energy
- Upper wind structure – strong upper level winds inhibit tropical cyclone longevity
  - El Niño – more Pacific hurricanes, fewer Atlantic hurricanes
  - QBO – quasi-biennial oscillation of the winds in the tropical stratosphere
- Landfall

Atlantic Hurricanes and ENSO



1997 – El Niño year

1998 – Non-El Niño year

Cyclone dissipation

- Requires continuous supply of warm, moist air
  - Weakens over colder water
  - Weakens rapidly after landfall
- Slides back to tropical storm
  - Still carries a lot of rain

Hurricane hazards

- High winds
- Storm surge
- Flooding

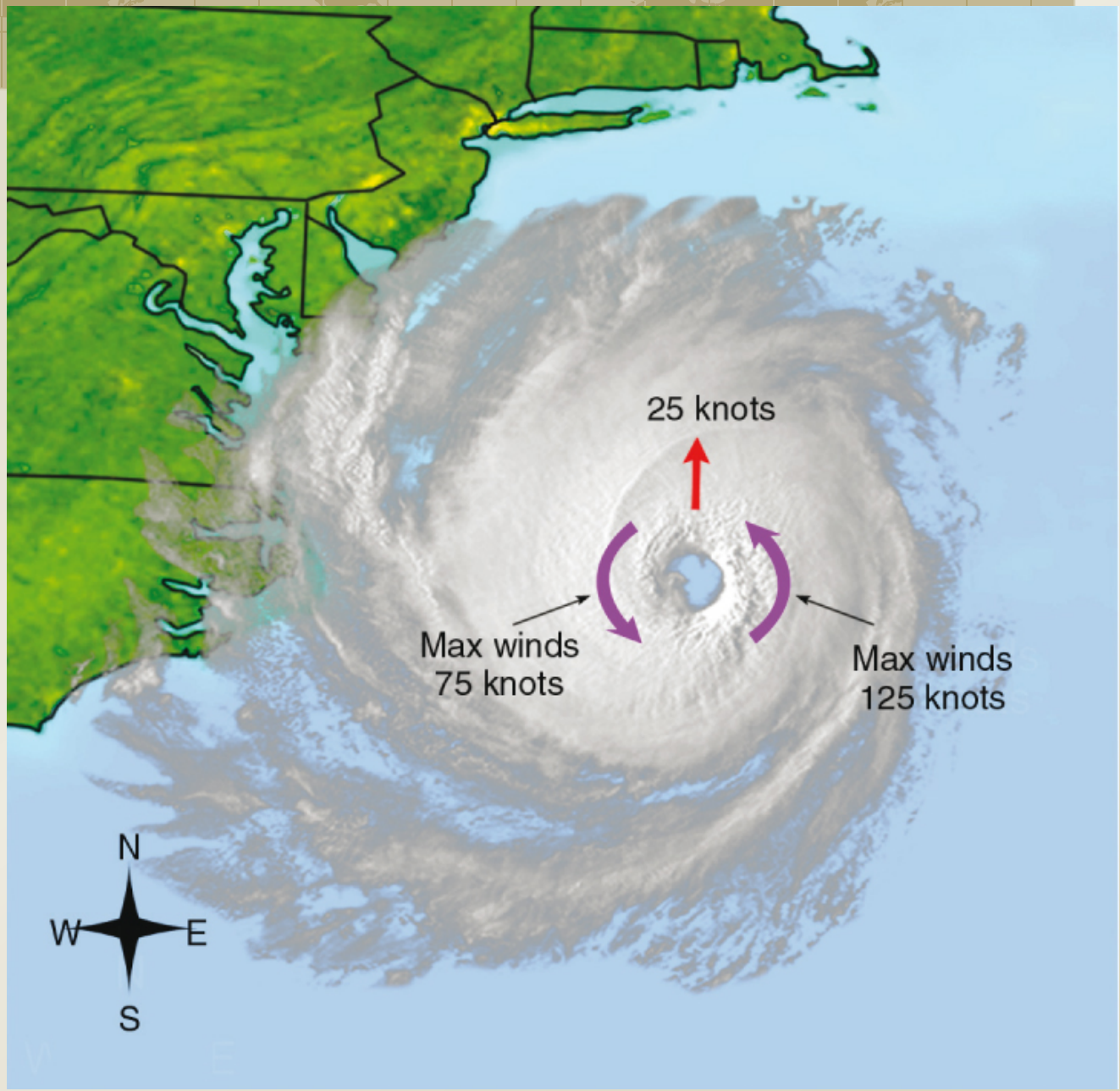
High winds

Excess of 120 km/h

Category 4
(>210 km/h)
- can blow the roofs off of houses

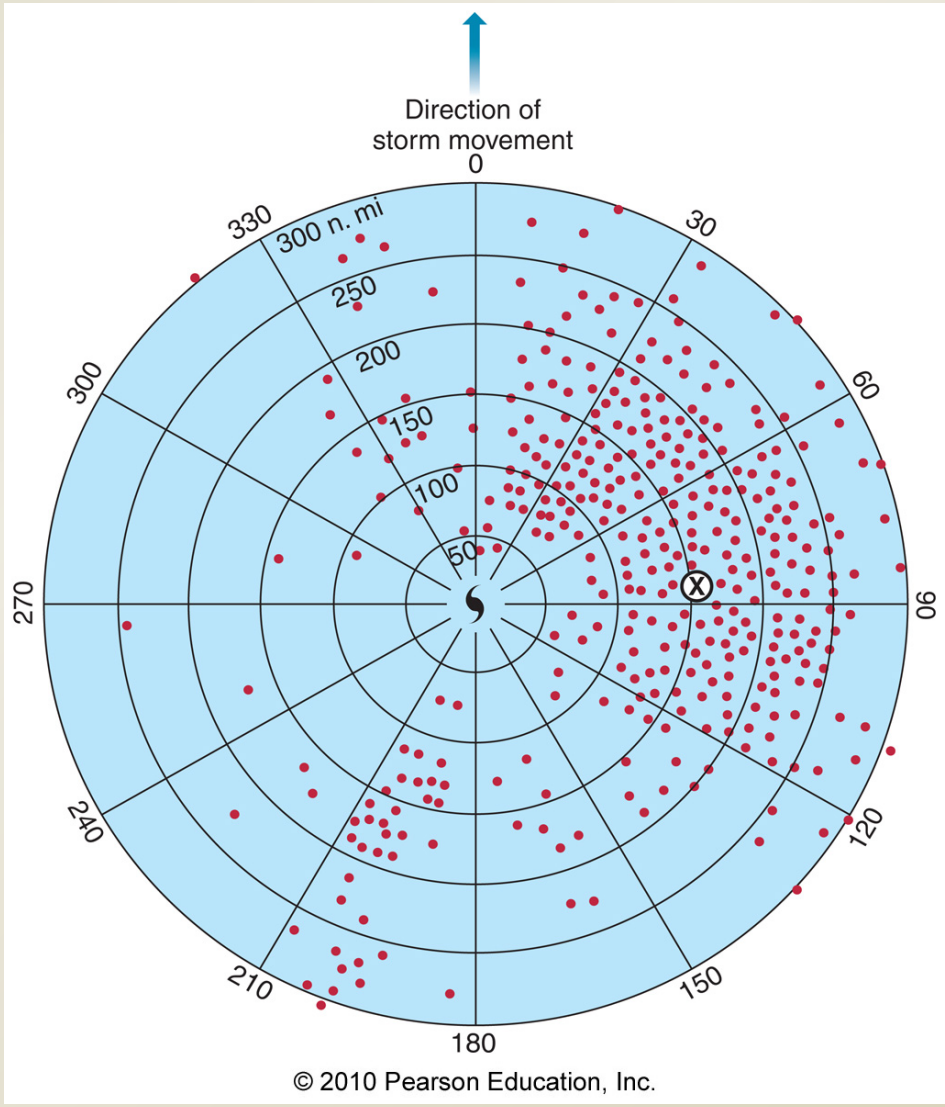
Category 5
(>250 km/h)
- can destroy houses

Ahrens: Fig. 15.14



Tornadoes

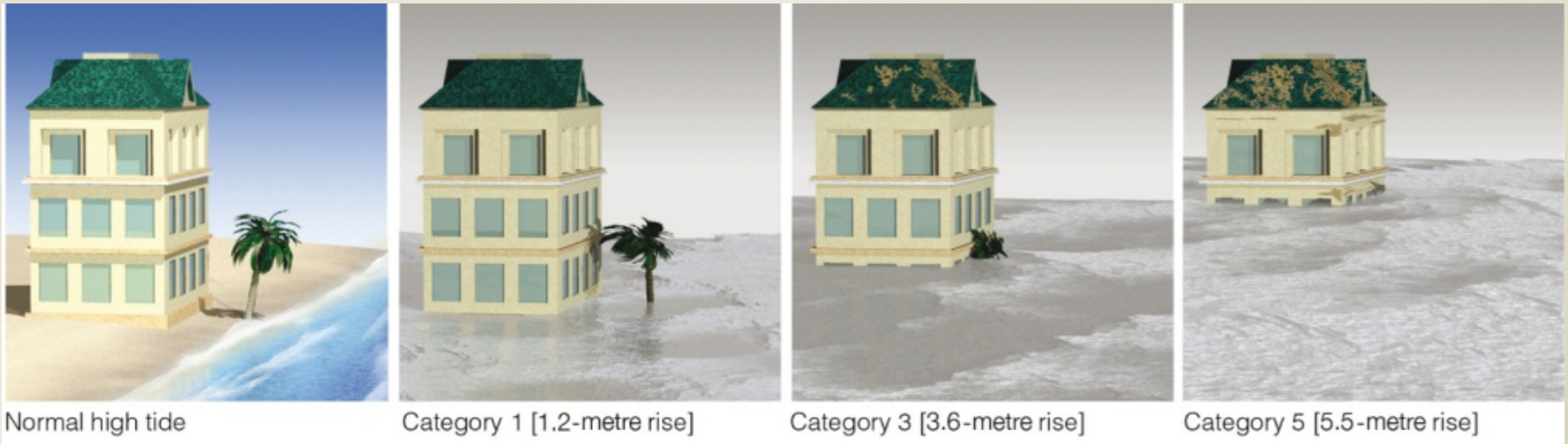
- Frequent feature of hurricanes
- Short duration
- May be triggered by landfall



A&B: Figure 12-15

Storm surge

- Rise in sea level
  - Piled up by heavy winds
  - Low pressure also produces a bulge
- Greatest potential for damage



Ahrens: Figure 15.15

Heavy rain

- 25 cm/day under a passing storm
- Floods, landslides
  - Freshwater flooding is the deadliest aspect of hurricanes
- Hurricane Mitch (1998):
  - 85 cm over a few days in Honduras and Nicaragua
  - Over 19 000 deaths
  - Deadliest hurricane in at least 200 years

Canadian Weather Service

1873

- "Great Nova Scotia Cyclone"
- Category 2 hurricane off the Nova Scotia coast
- Over 500 people killed

1876

- Telegraph lines set up to every major city in Eastern Canada.

Canadian Hurricanes

- Eastern provinces occasionally are hit by tropical storms – as far west as the Great Lakes
  - Great Lakes – 1 in 5 years
- Not an issue in the Western provinces
- Canadian Hurricane Centre
  - Halifax
  - Founded in 1986

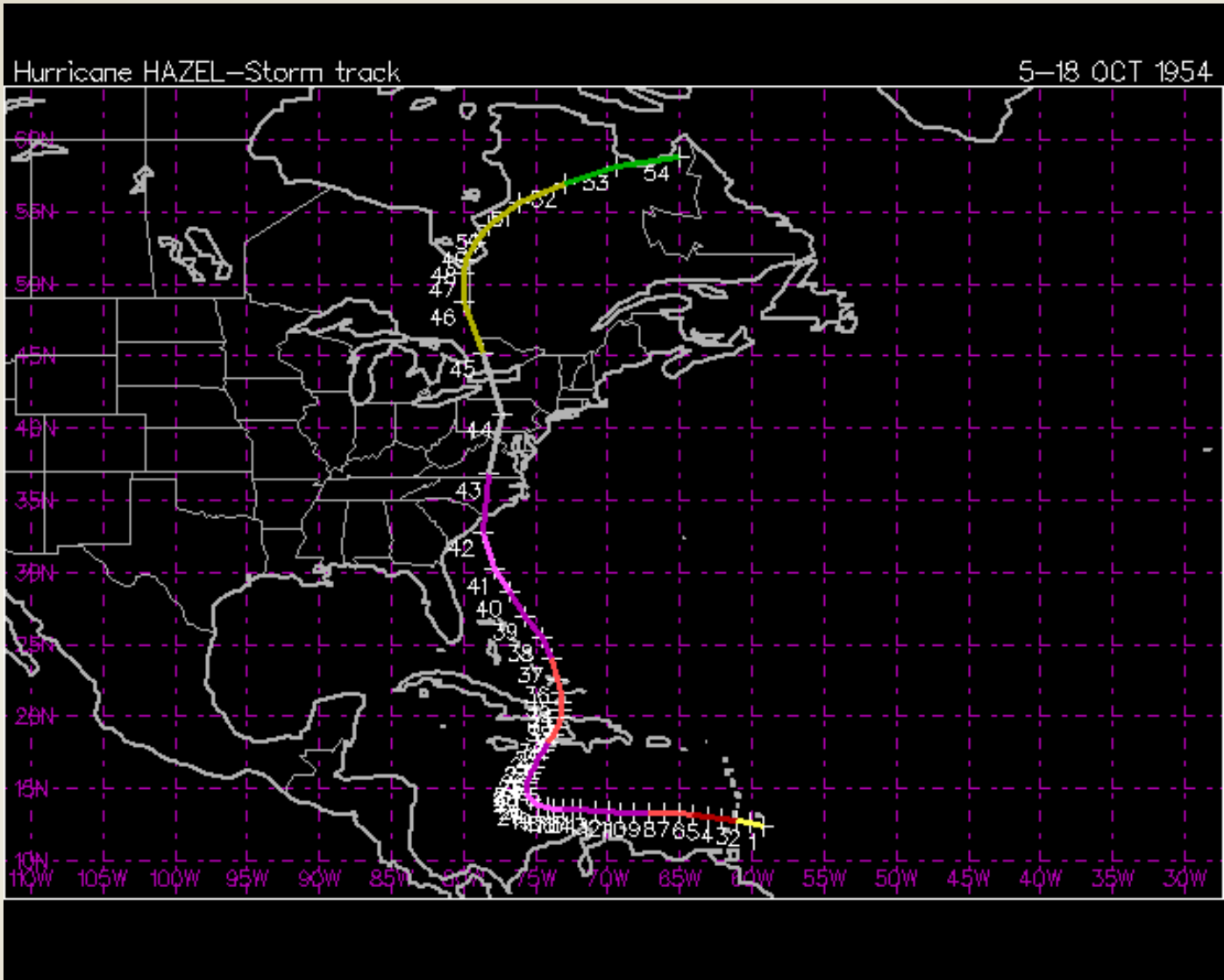
Igor floods Newfoundland
Source: CTV

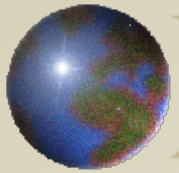
Hurricane Hazel (1954)

October 15, 1954

121.4 mm at Toronto International Airport

Transitioned storm





Coming up

- Course evaluations!

- Hurricane forecasting
  - More from Ahrens: Chapter 15
- Polar lows
  - From Ahrens: Chapter 12