Evolution of Hurricane Science, 1980-2010

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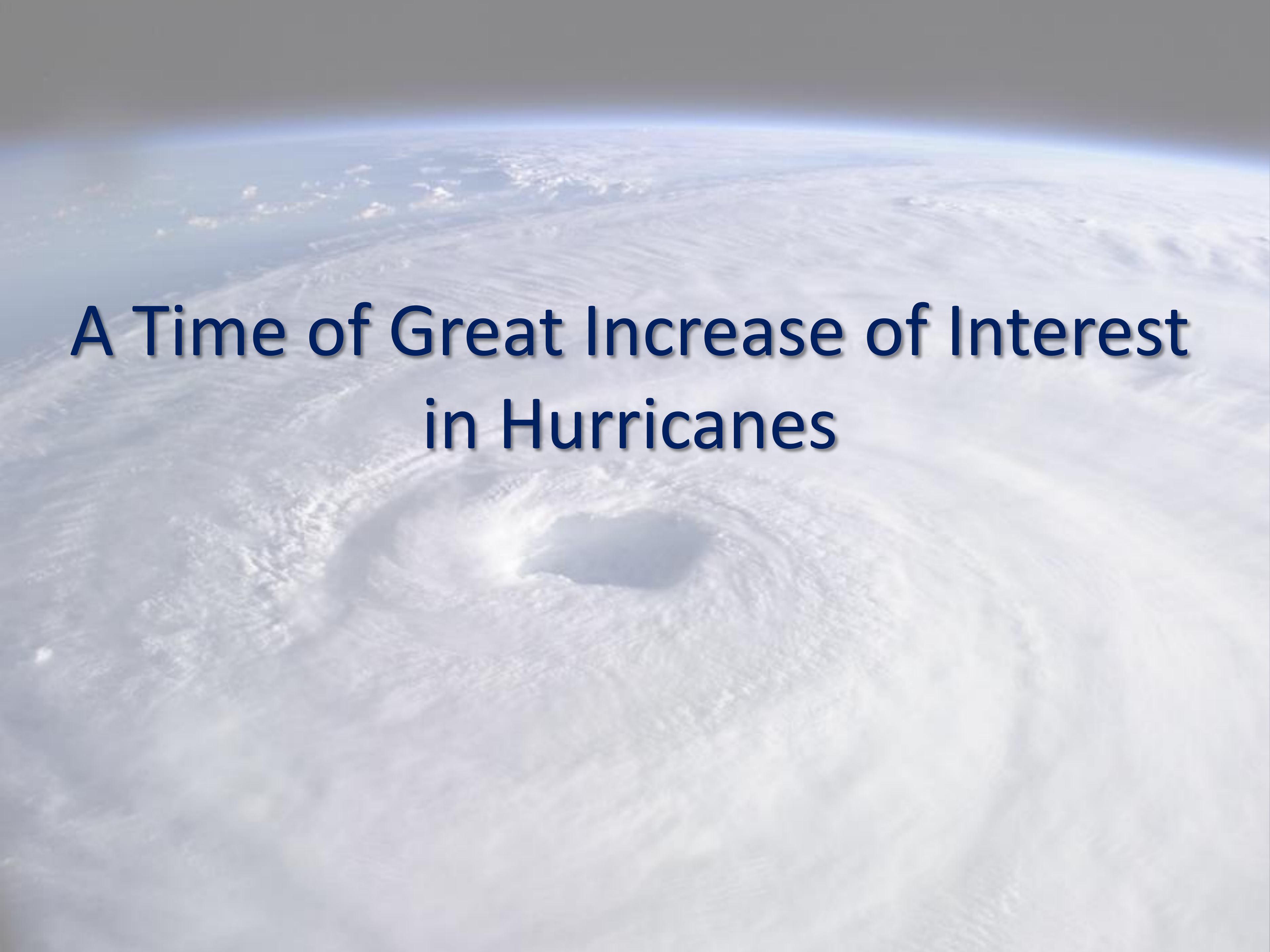
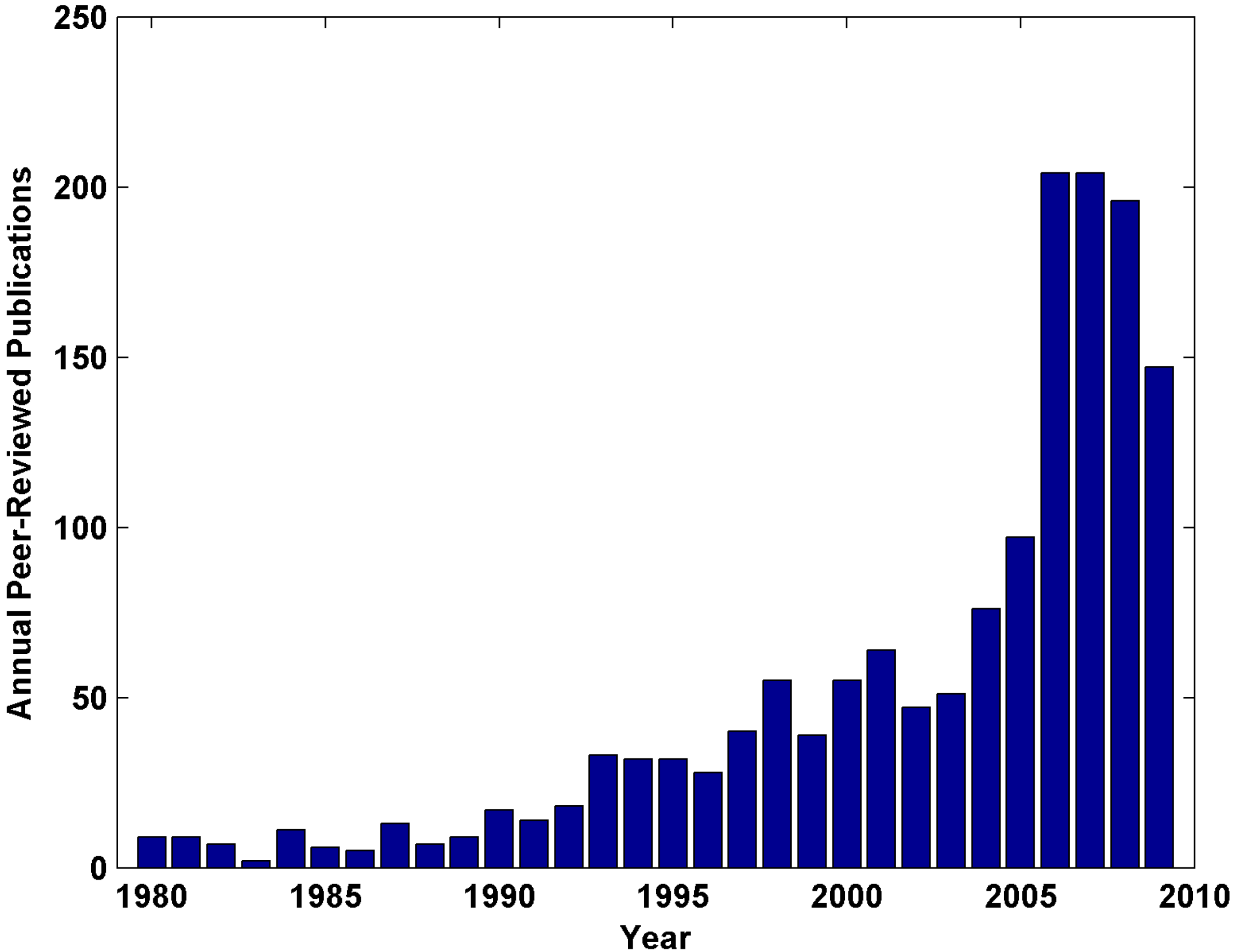
A Time of Great Increase of Interest in Hurricanes





Annual Number of Peer-Reviewed Articles with “Hurricane” or “Tropical Cyclone” in their Titles, according to *Meteorological and Geoastrophysical Abstracts*

Theory:

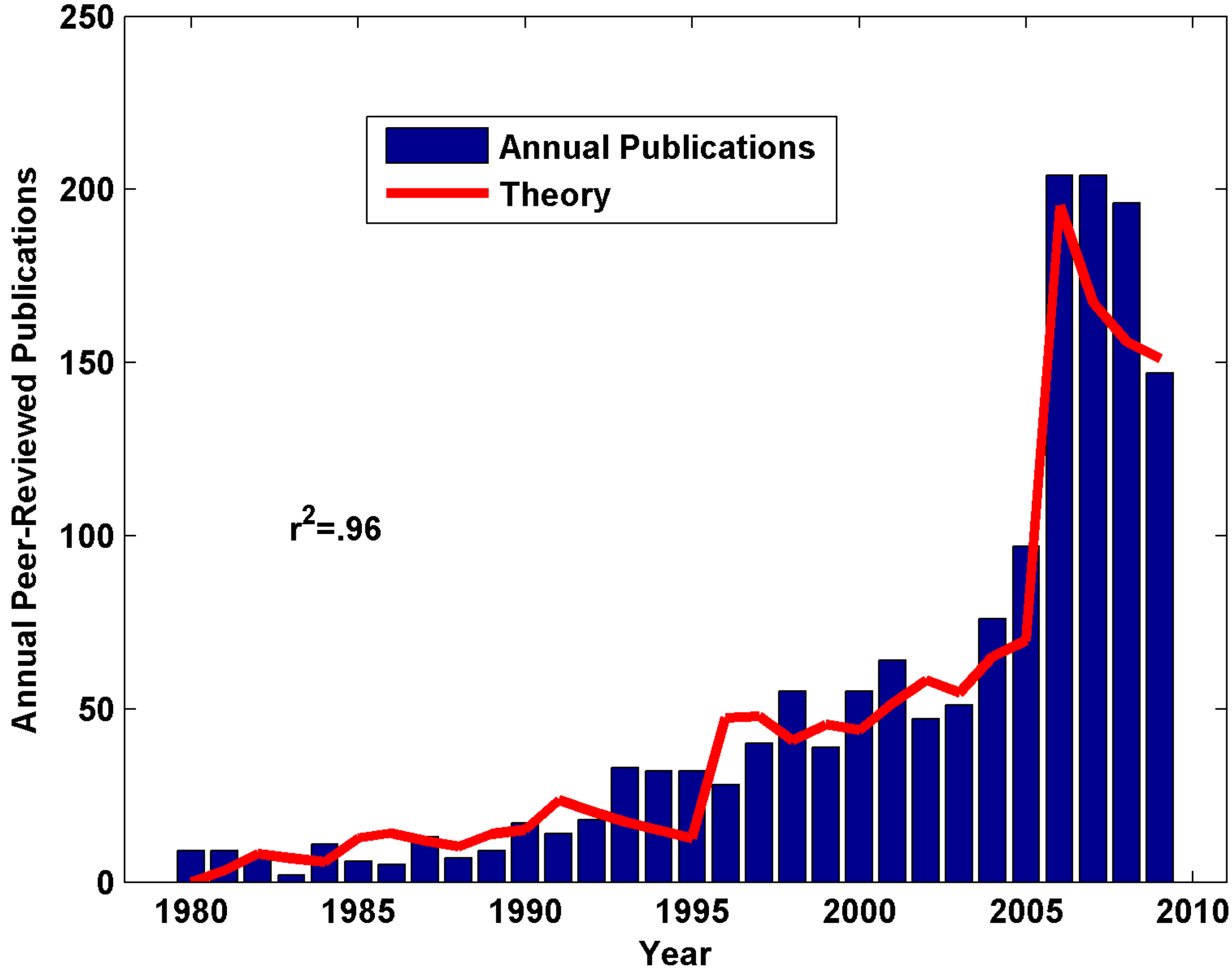
Interest Stimulation

$$\frac{\partial PRP}{\partial t} = 0.08\ N_{Atl} - 6^{\,5/2} - \frac{PRP}{6\ years}$$

Scientist Attention Span

$$PRP = Annual\ peer-reviewed\ publications$$

$$N_{Atl} = Number\ of\ Atlantic\ TCs\ per\ year$$



250
200
150
100
50
0
Annual Peer-Reviewed Publications
Annual Publications
Theory
r²=.96
1980
1985
1990
1995
2000
2005
2010
Year

Major Basic Research Developments

- Rejection of CISK
- Return to older view of Kleinschmidt and Riehl
- Development of physically consistent potential intensity theory
- Conclusive demonstration of ocean feedback on hurricane intensity
- Refinement of theory of tropical cyclone motion

- Quantification of structure of vertical motions
- Identification of eddy PV (angular momentum) fluxes in outflow layer as an influence on intensity change
- Further quantification of vertical shear effects on storm motion, structure, and intensity
- Further quantification of ENSO effects on NH TCs
- Modulation of TC activity by the Madden-Julian Oscillation

- Reemergence of interest in vortex Rossby waves
- Progress in understanding TC genesis through large-scale field experiments
- Accelerated research in extratropical transition
- Importance of surface effects: waves and spray
- Identification and understanding of superintensity

- Development of paleotempestology
- Emergence of research on long-term climate change effects on hurricanes
- Identification of physical and biological feedbacks of hurricanes upon climate

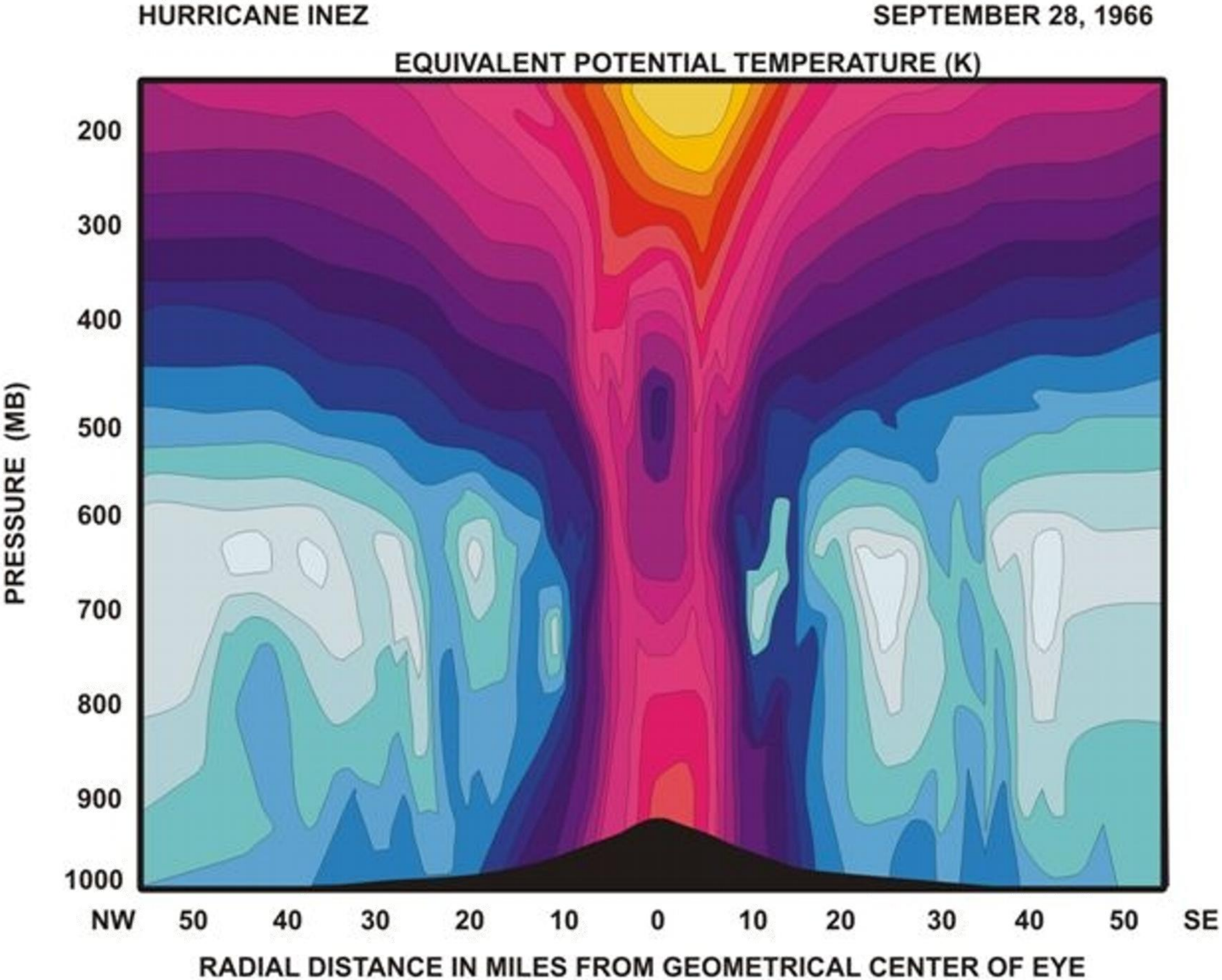
- "The heat removed from the sea by the storm is the basic energy source of the typhoon. In comparison to it, the latent heat of the water vapor, which the air carries with it from the outside, plays no more than a secondary role"

  -- *E. Kleinschmidt, 1951*

- "It is proposed that the cyclone develops by a kind of secondary instability in which existing cumulus convection is augmented in regions of low-level horizontal convergence and quenched in regions of low-level divergence"

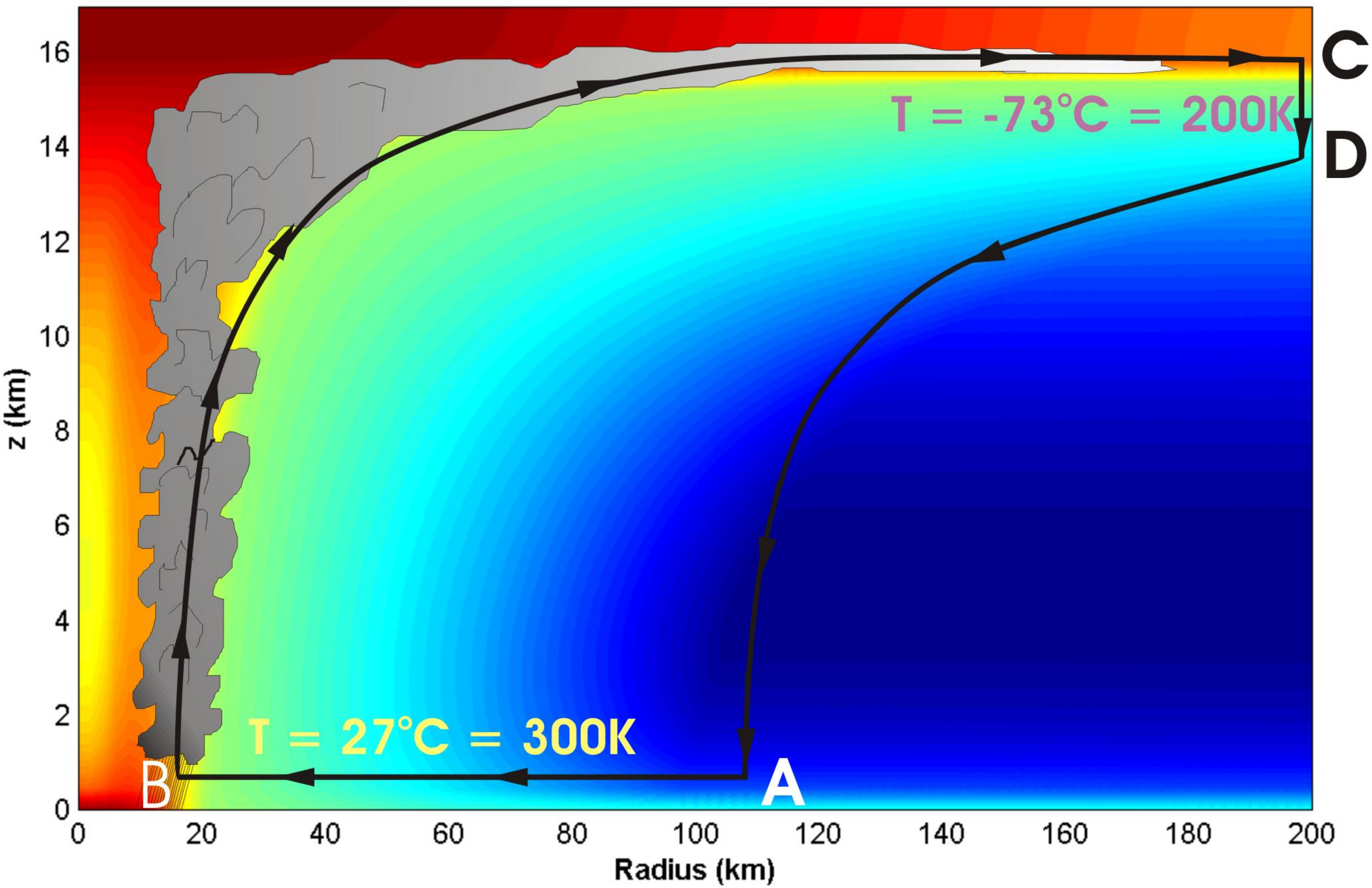
  -- *J. Charney and A. Eliassen, 1964*

Distribution of Entropy in Hurricane Inez, 1966

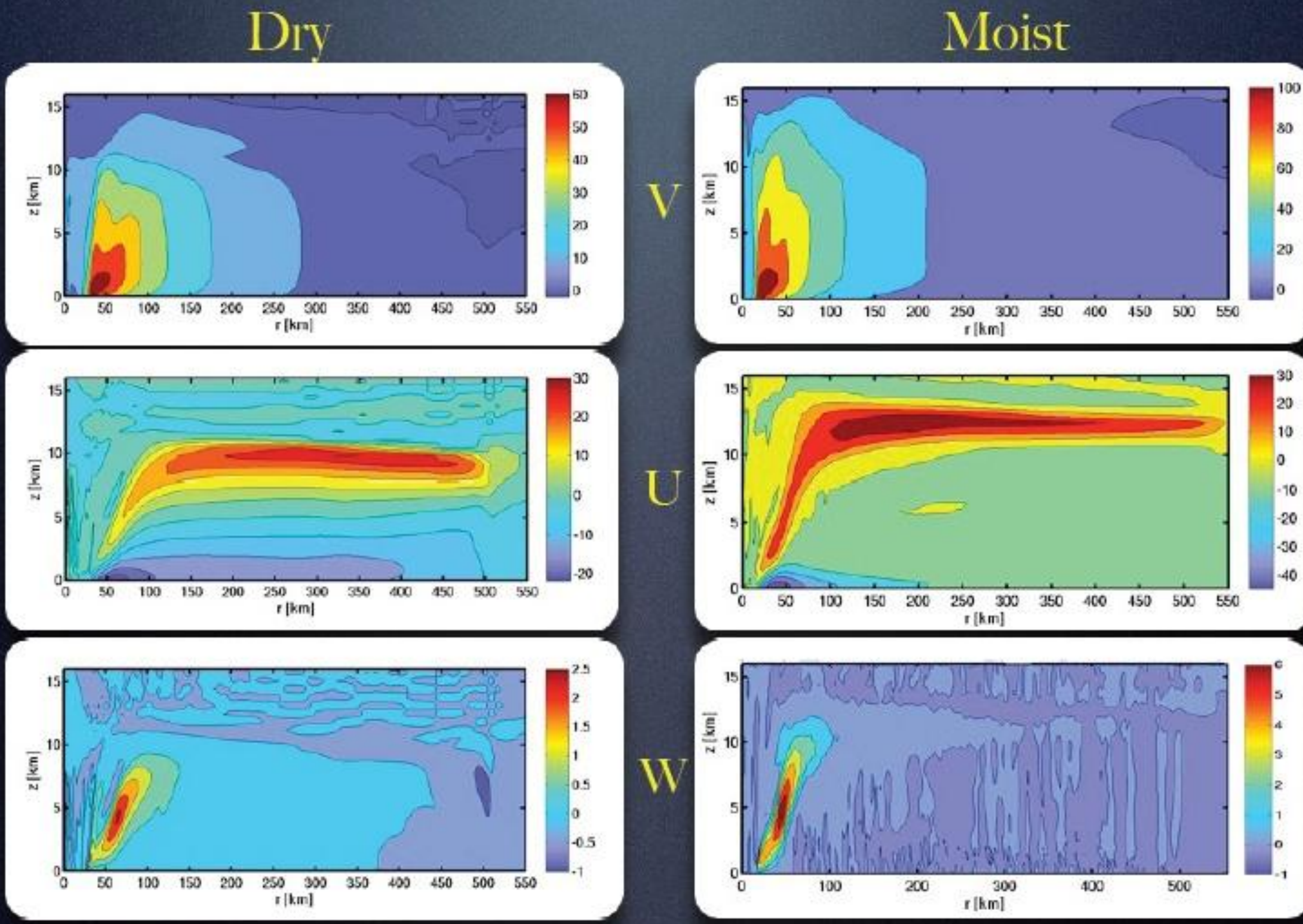


Source: Hawkins and Imbembo, 1976

Energy Production Cycle

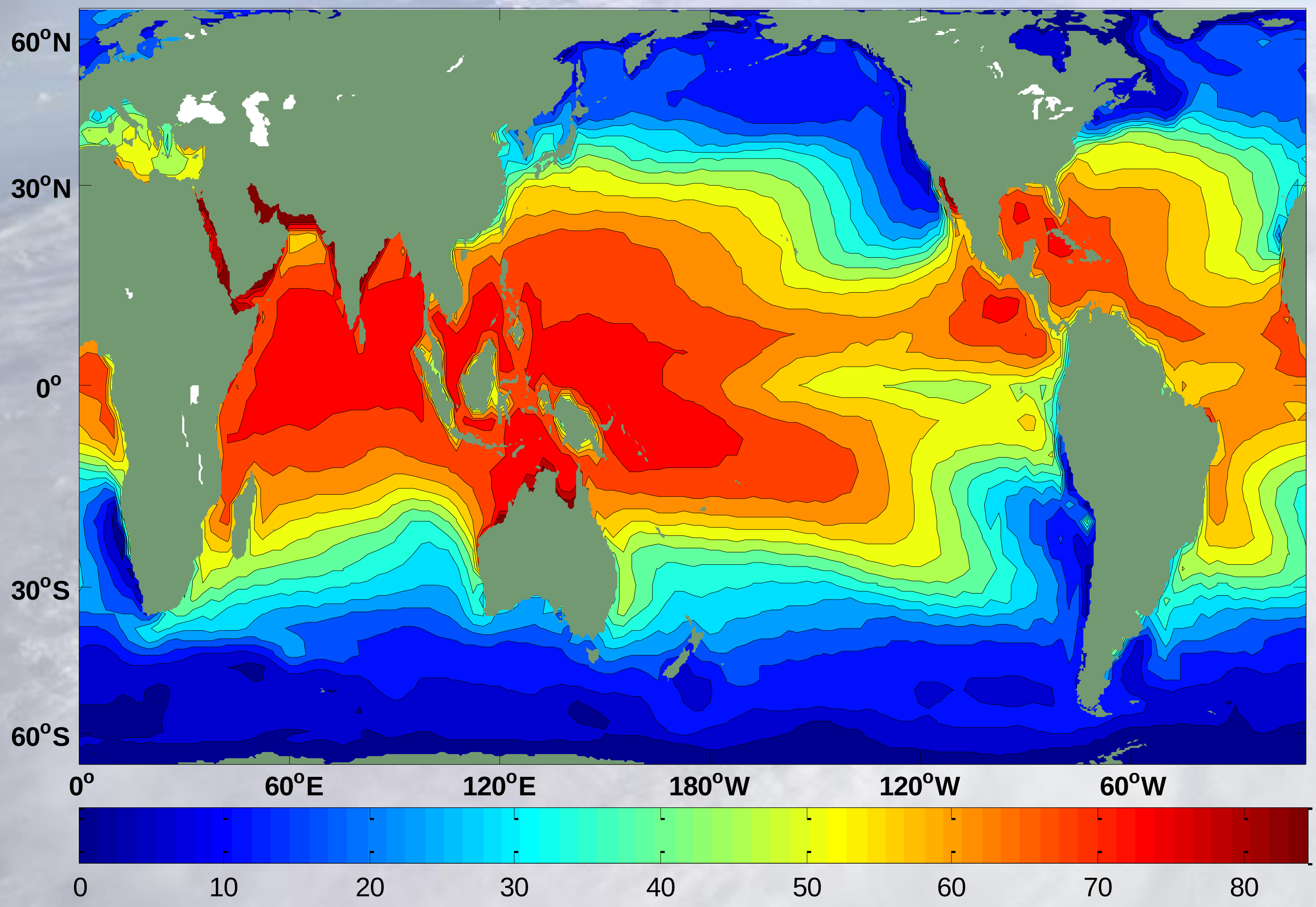


Dry Hurricane Simulations - Steady State

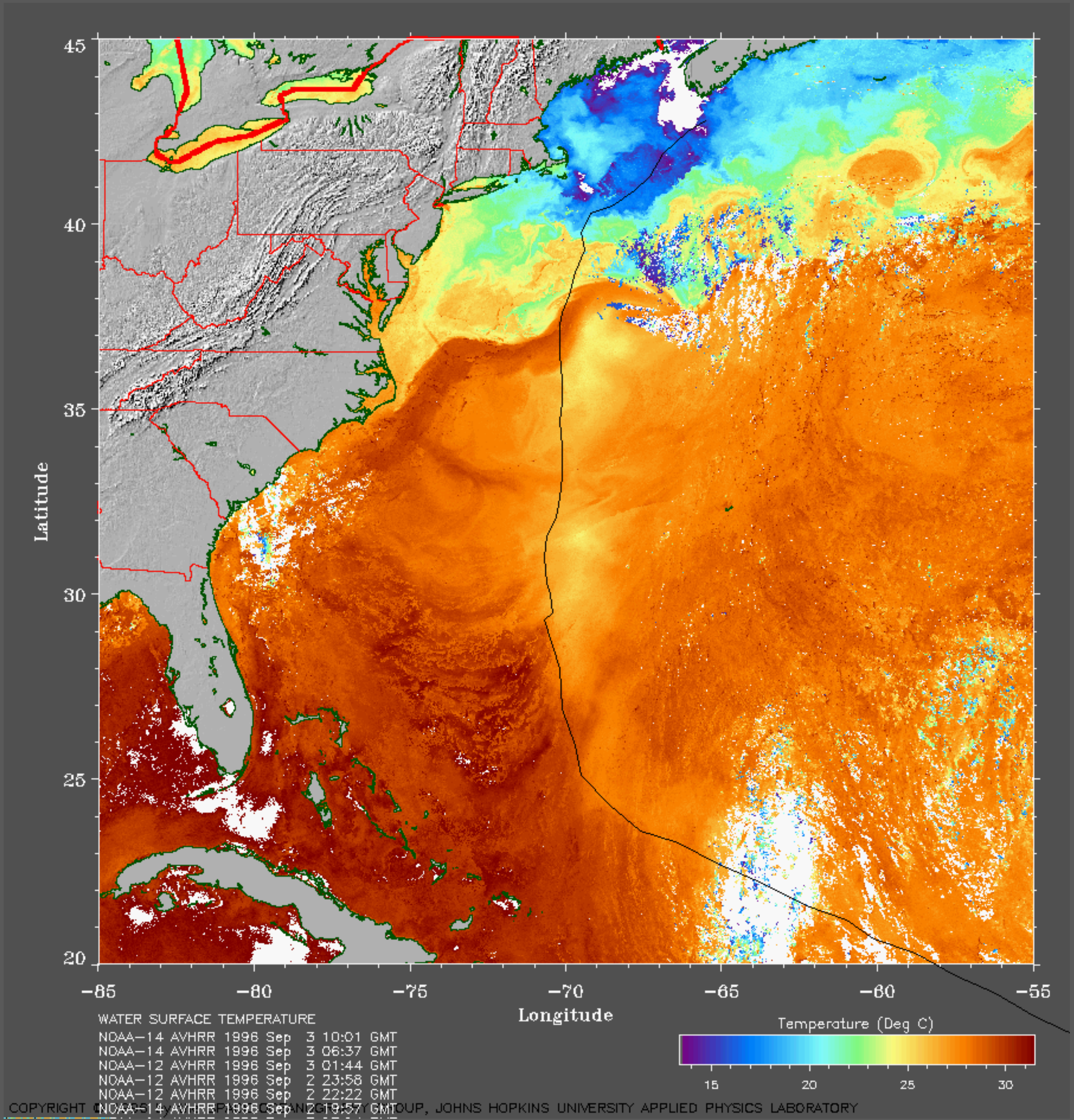


Simulations by Aga Smith-Mrowiec

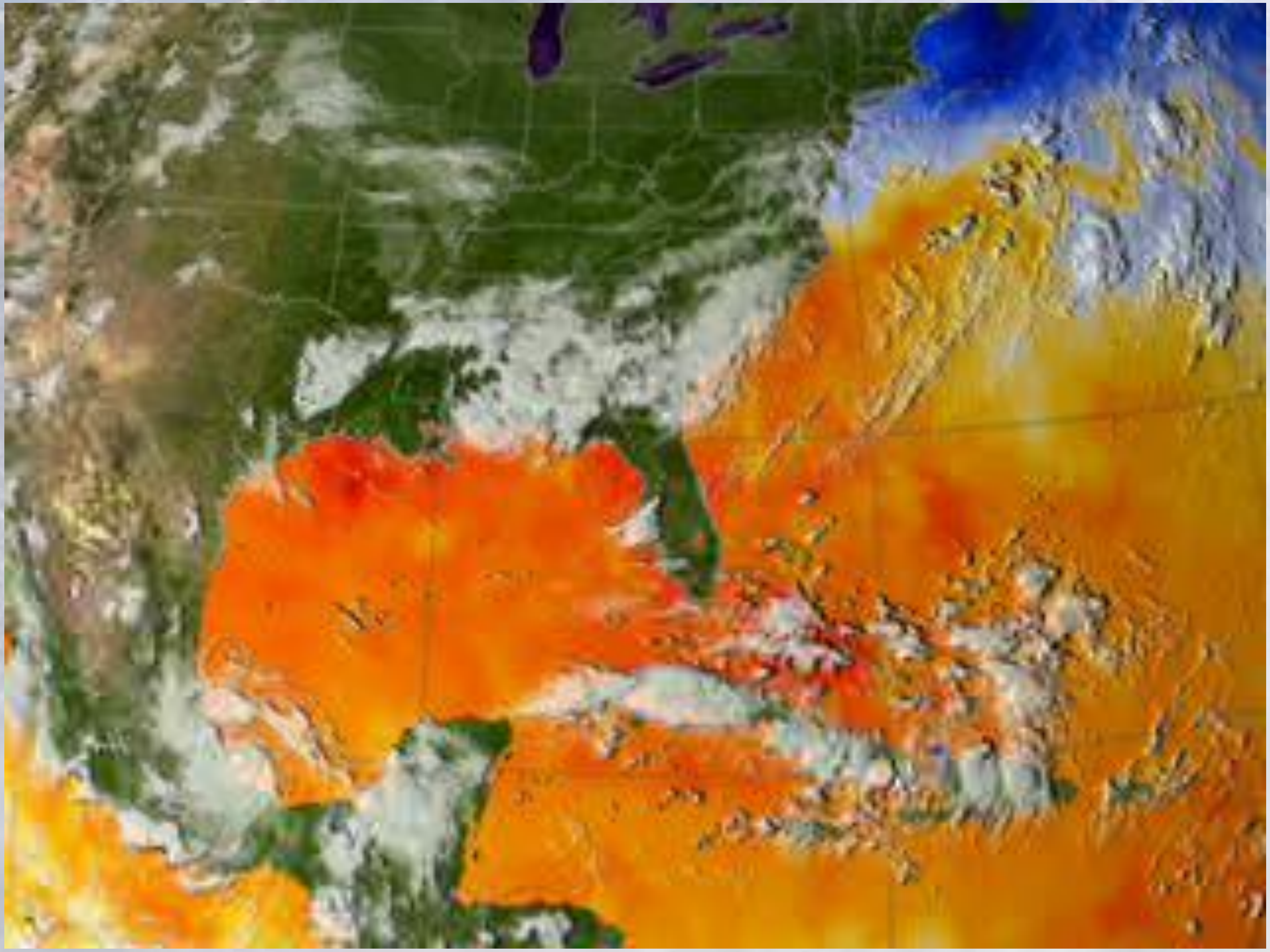
Annual Maximum Potential Intensity (m/s)



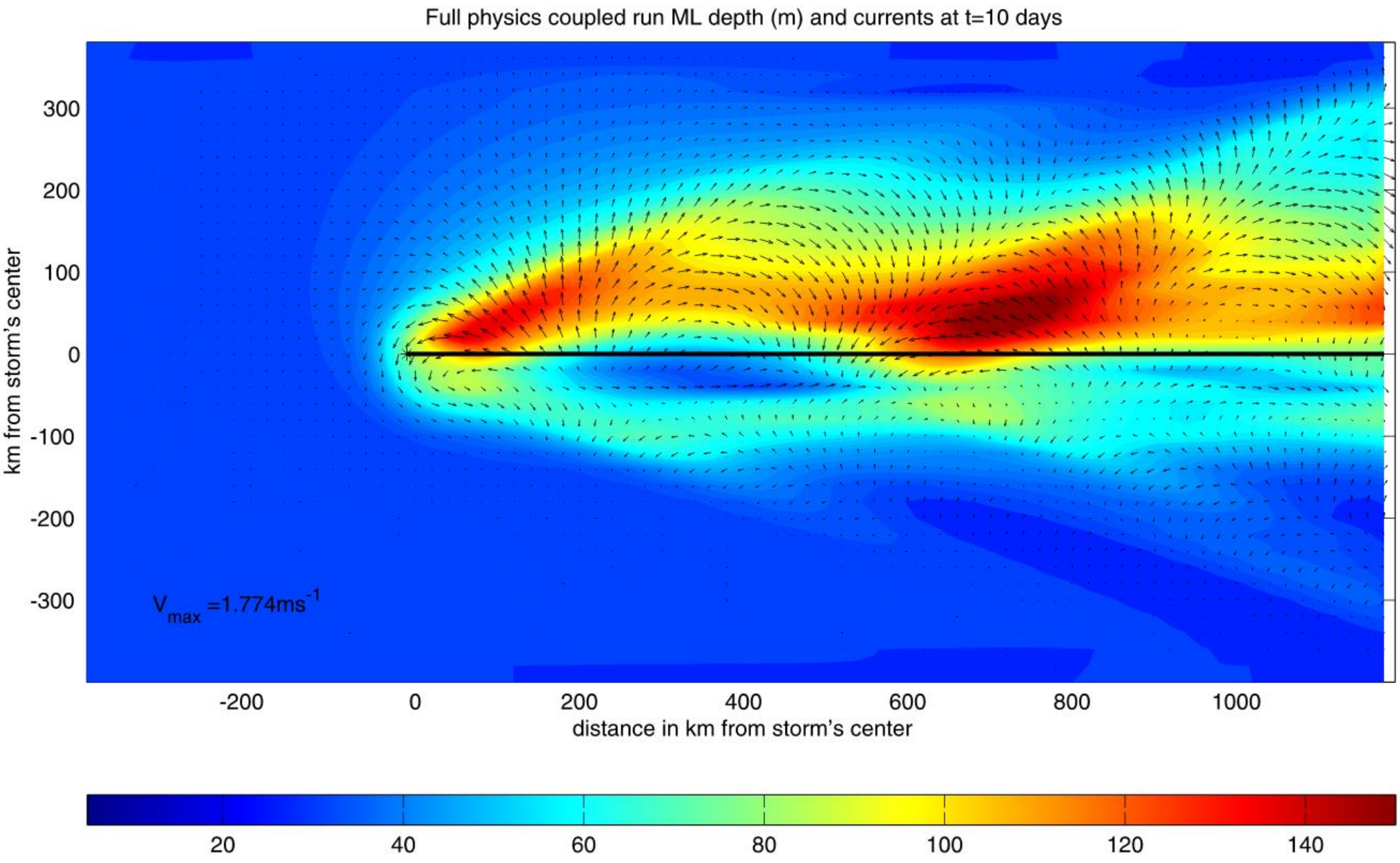
Hurricane-Ocean Interaction



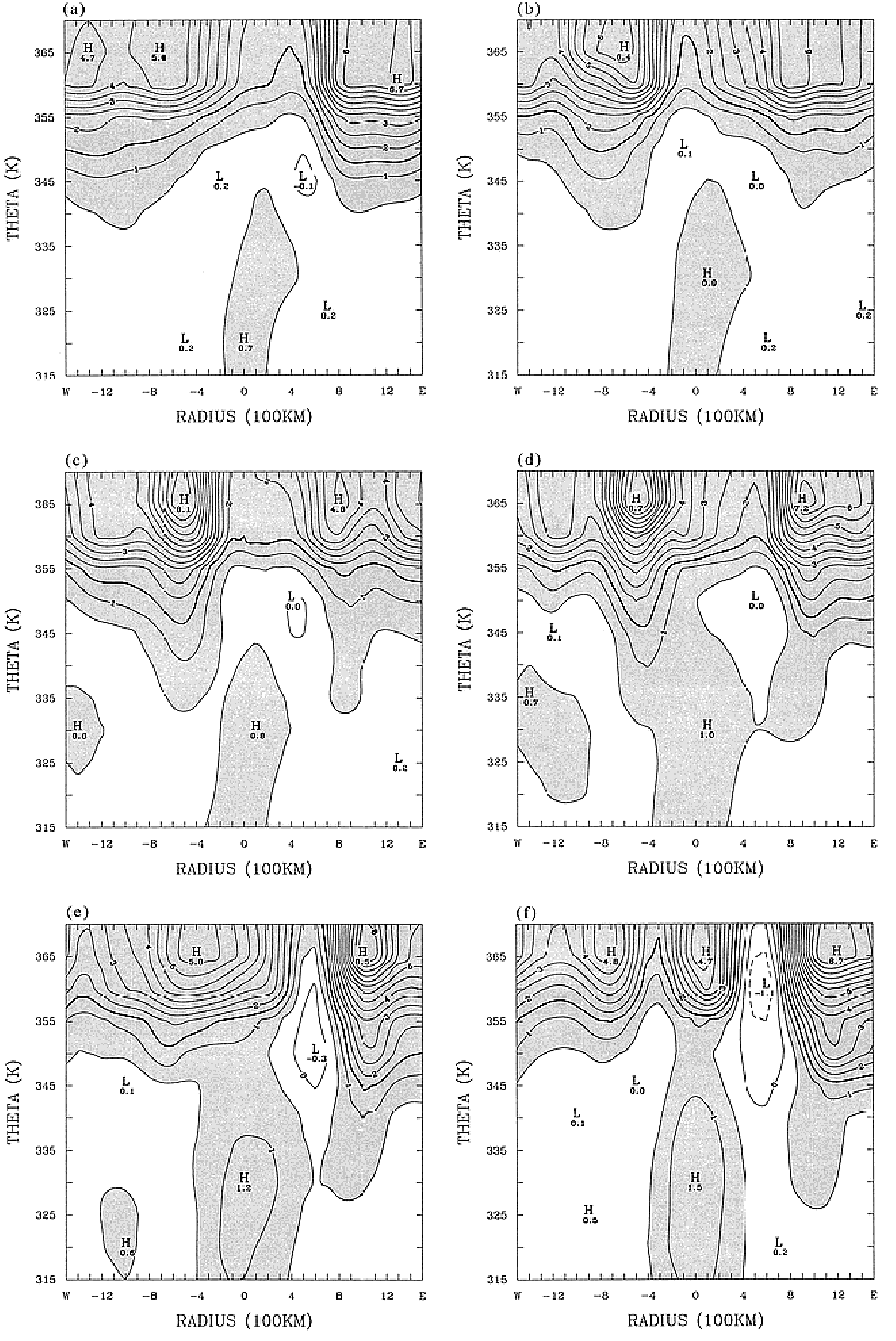
Hurricane Katrina, 2005



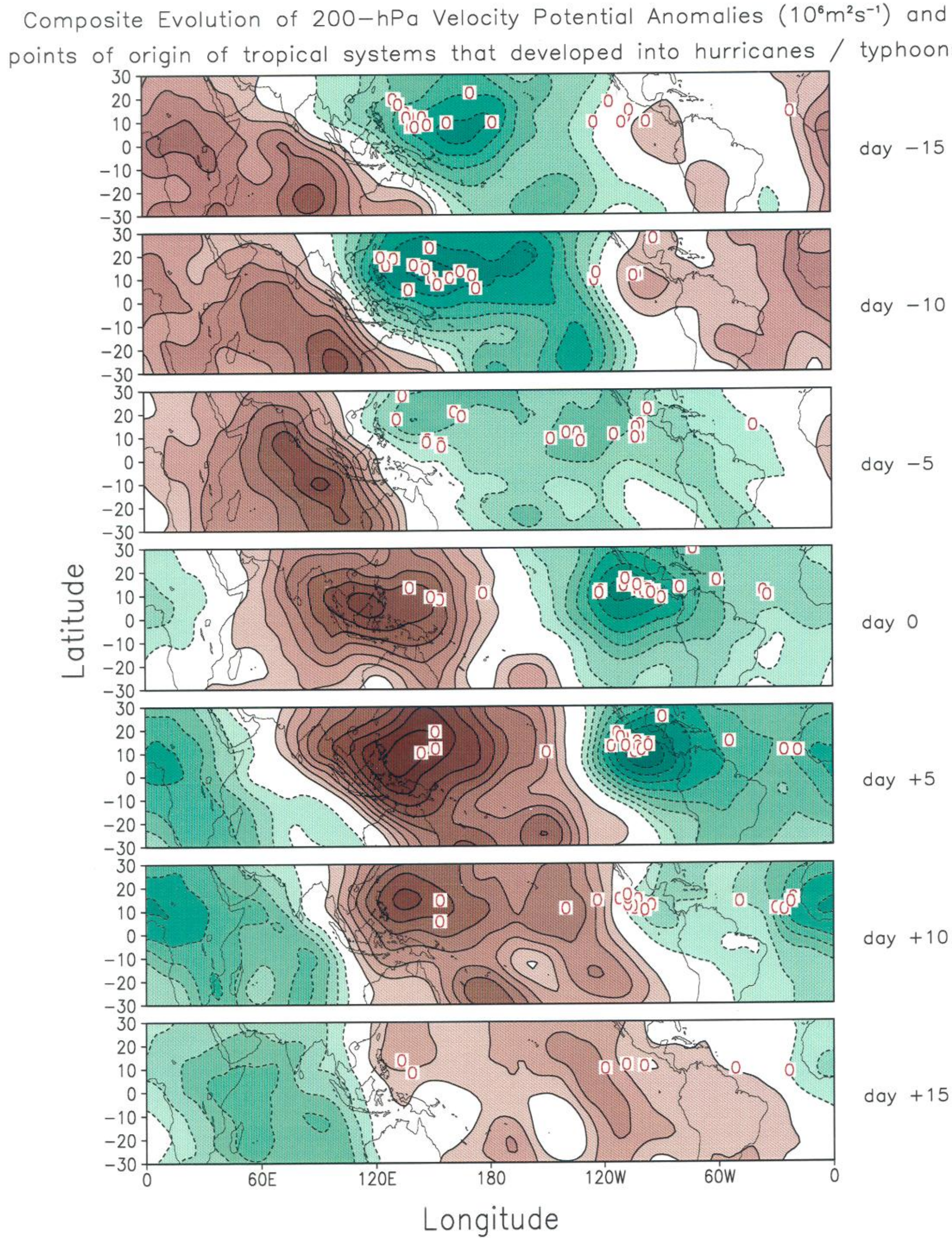
Mixed layer depth and currents



Cross-Sections of Ertel Potential Vorticity, through Tropical Storm Danny of 1985. From *Molinari et al., 1998*



Tropical cyclone activity and the MJO



Tropical Experiment in Mexico (TEXMEX), 1991

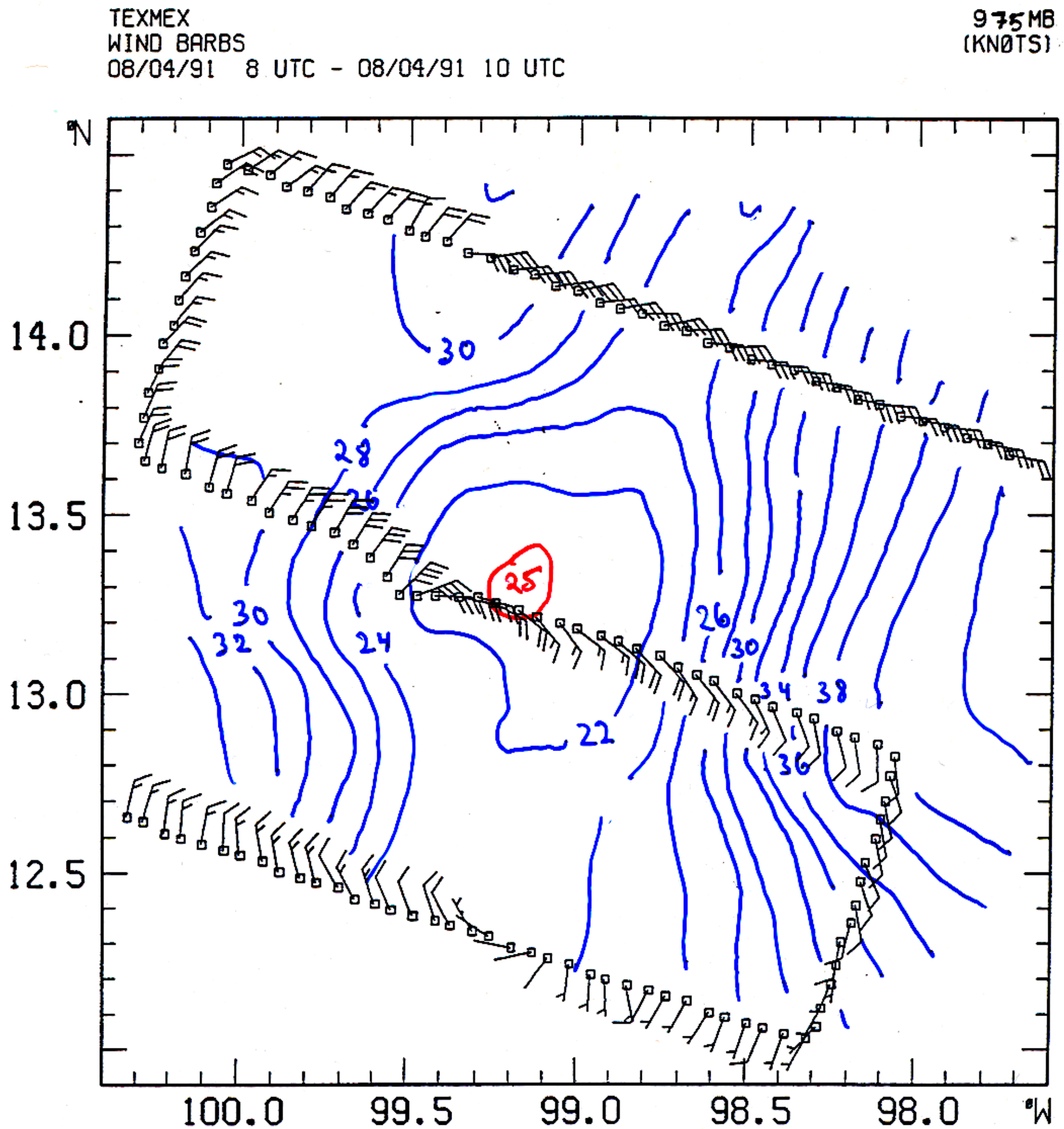
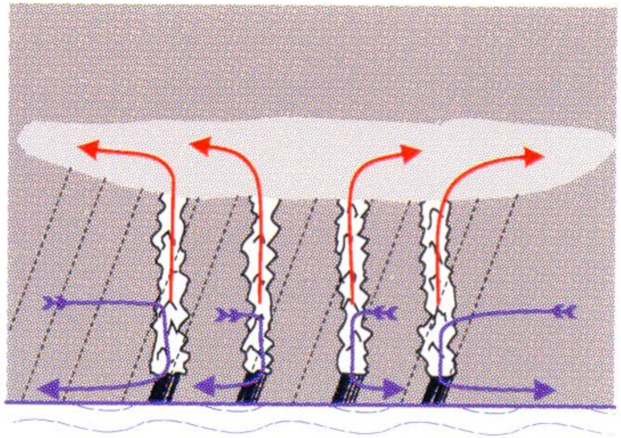


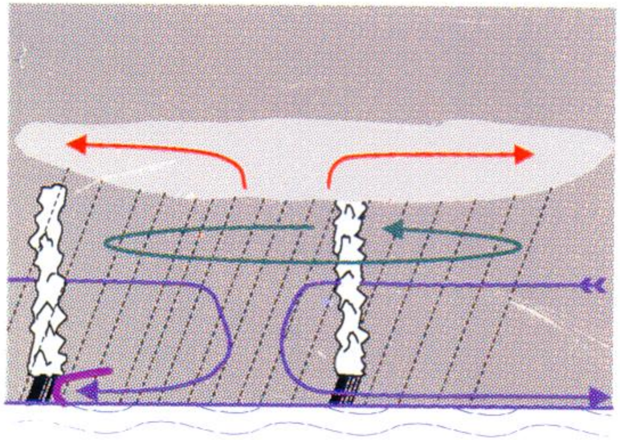
Figure 70: The ~~700~~ 975 hPa pattern for flight 910804H.

1. TRIGGERING



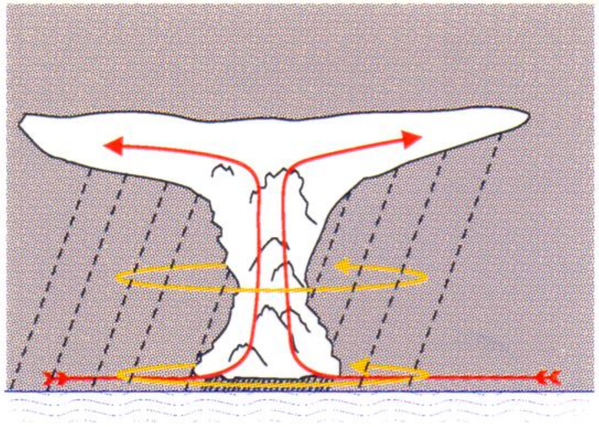
- Formation of long-lived mesoscale stratiform anvil
- Appears to require large-scale ascent in the upper troposphere
- Reduction of subcloud layer entropy by downdrafts

2. Gestation



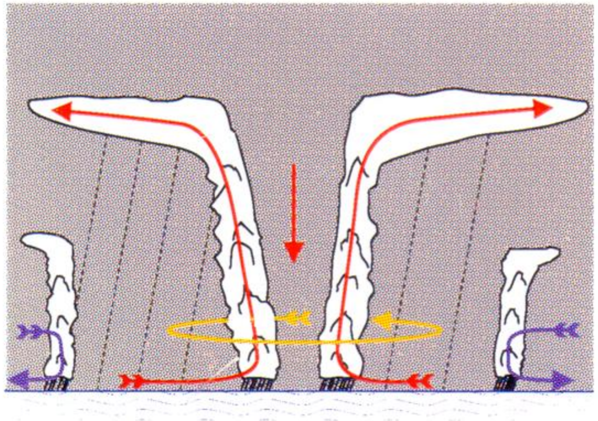
- Light to moderate stratiform rain; little deep convection, except at periphery
- Formation of middle tropospheric mesoscale cyclone cold core in the lower troposphere
- *High relative humidity* develops in core
- Subcloud layer entropy recovers

3. Ignition



- New episode of convection that is *free of downdraft* forms near core
- Strong surface *in*flow, strong surface heat fluxes
- Carnot engine switched on

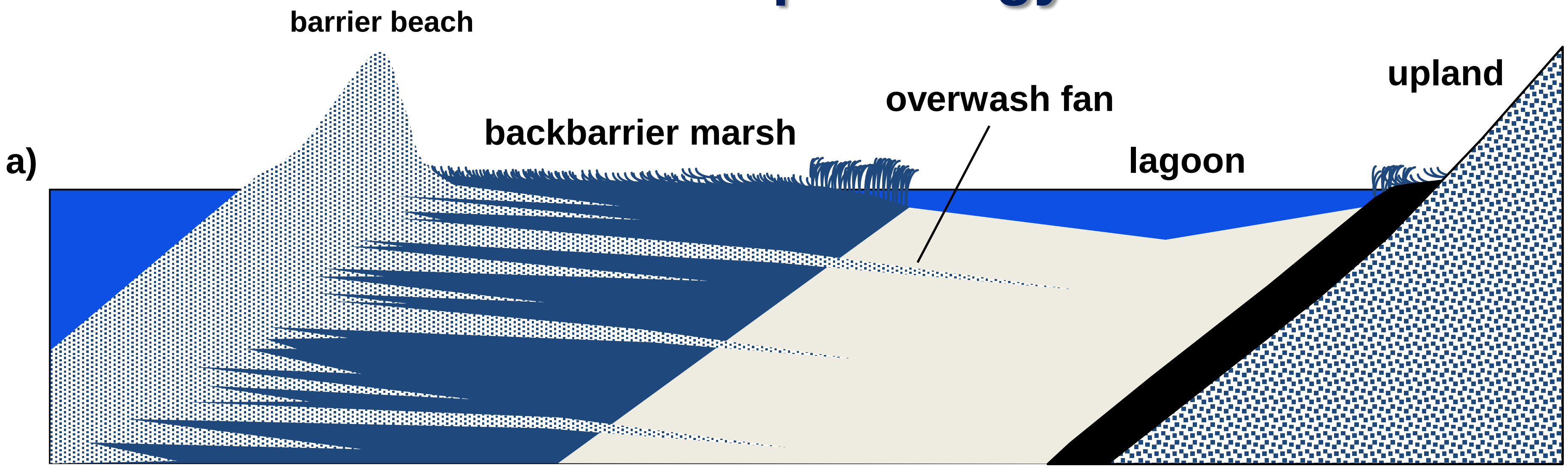
4. Intensification

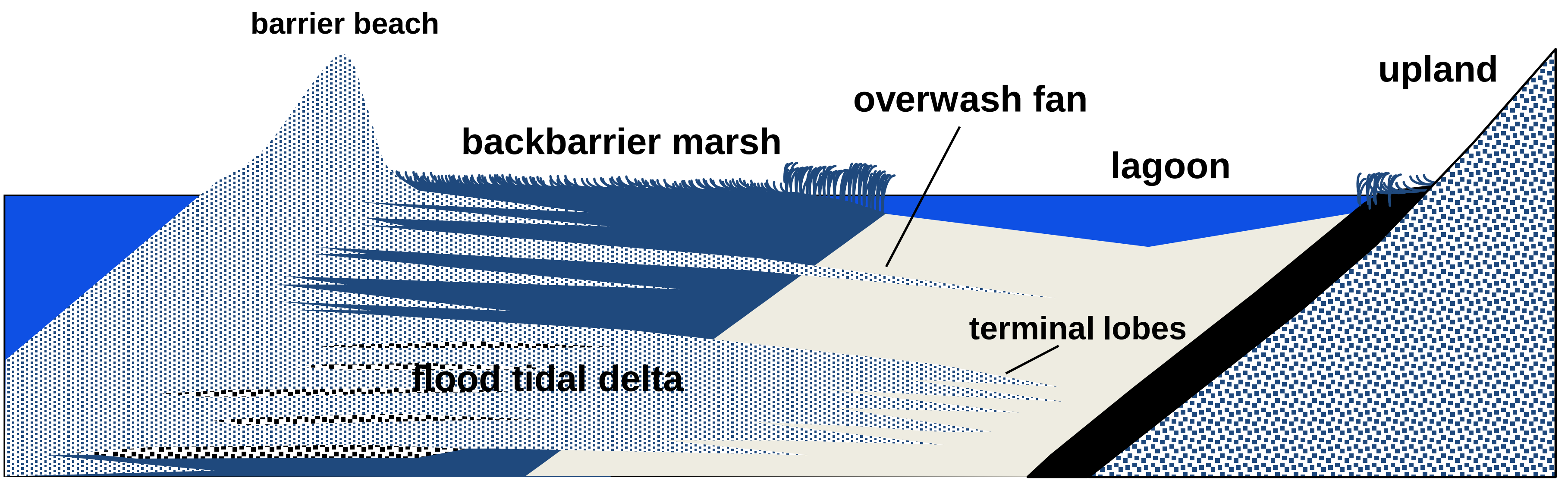


5. Maturity

6. Dissipation

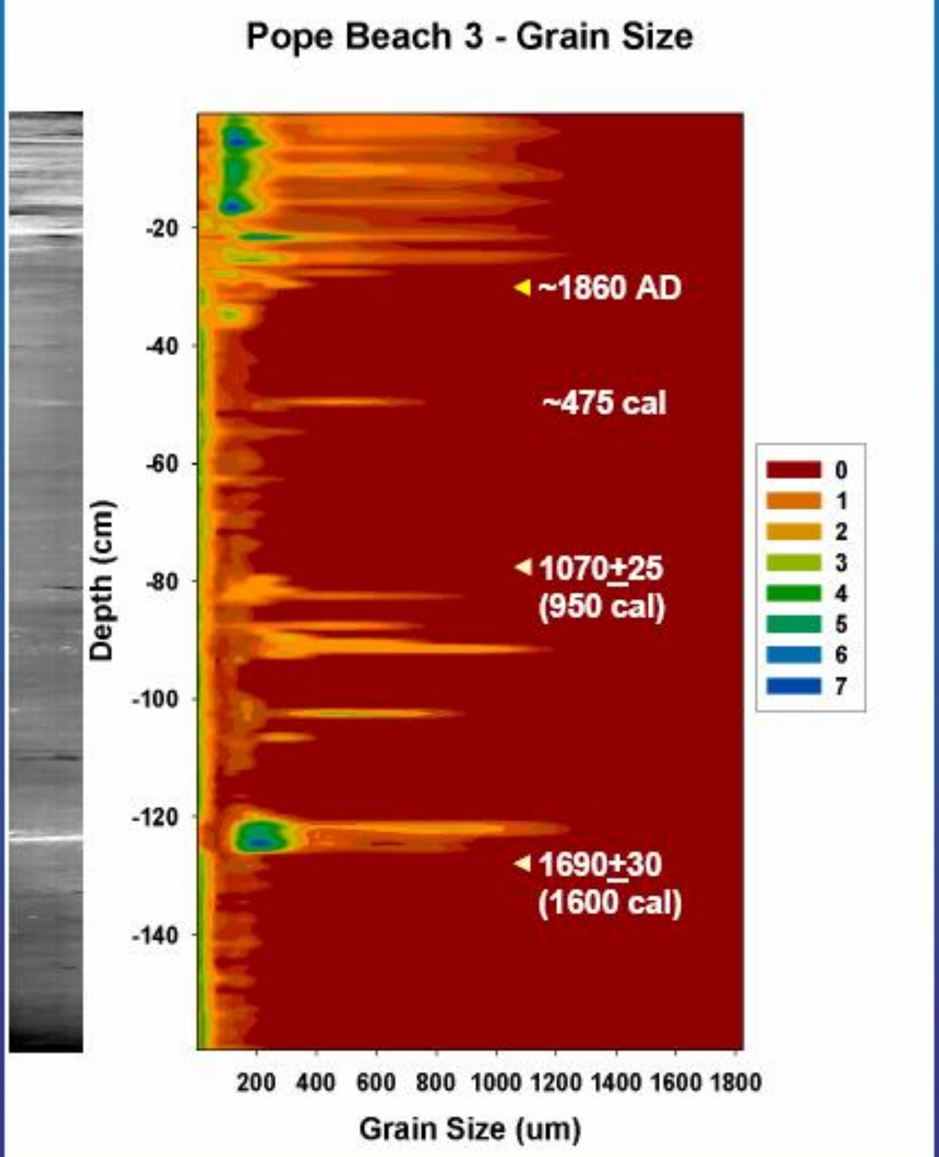
Paleotempestology





Source: Jeff Donnelly, WHOI

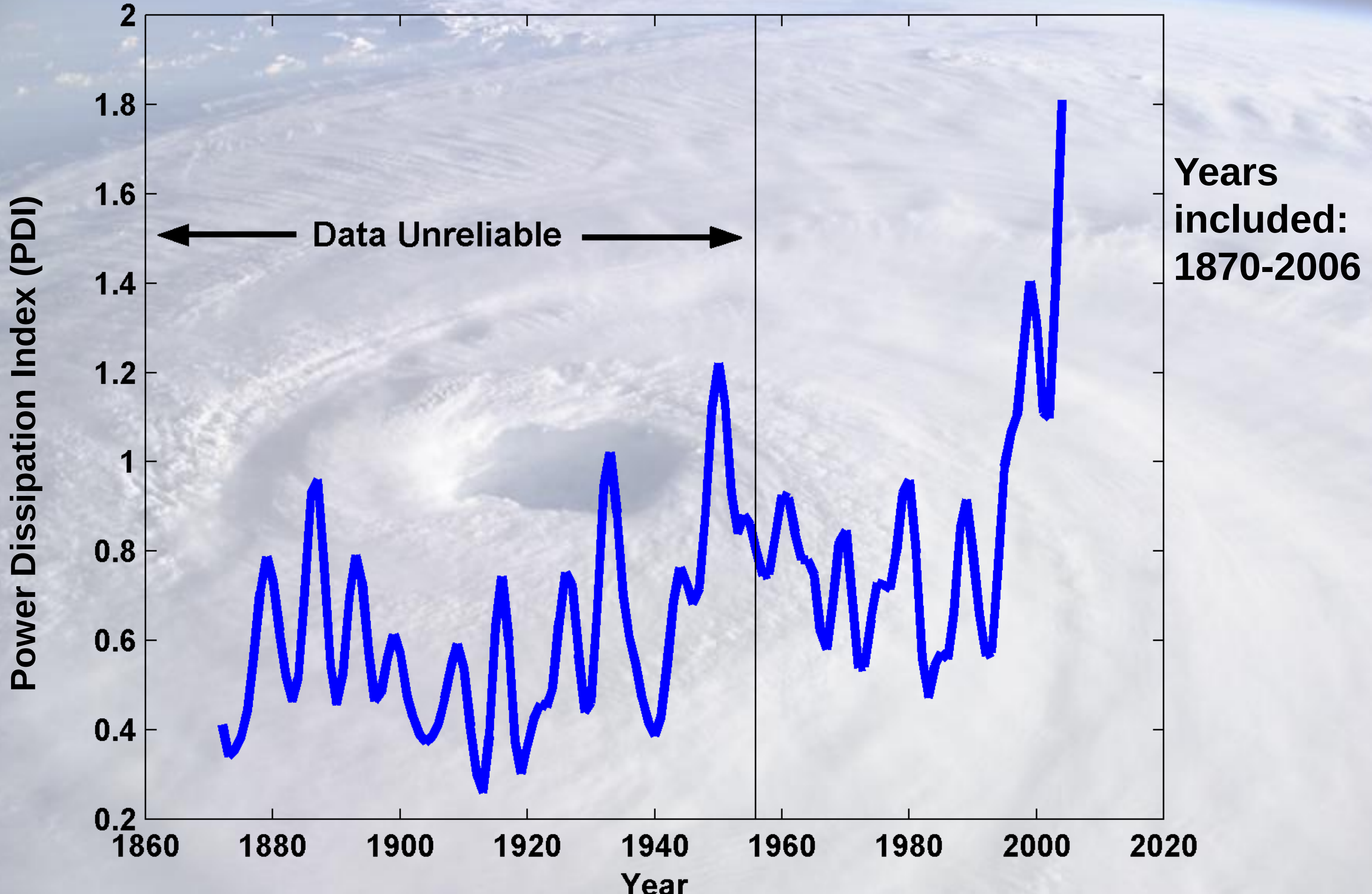
Pope Beach Marsh, Fairhaven, MA



Source: Jeff Donnelly, Jon Woodruff, Phil Lane; WHOI

Atlantic Storm Maximum Power Dissipation

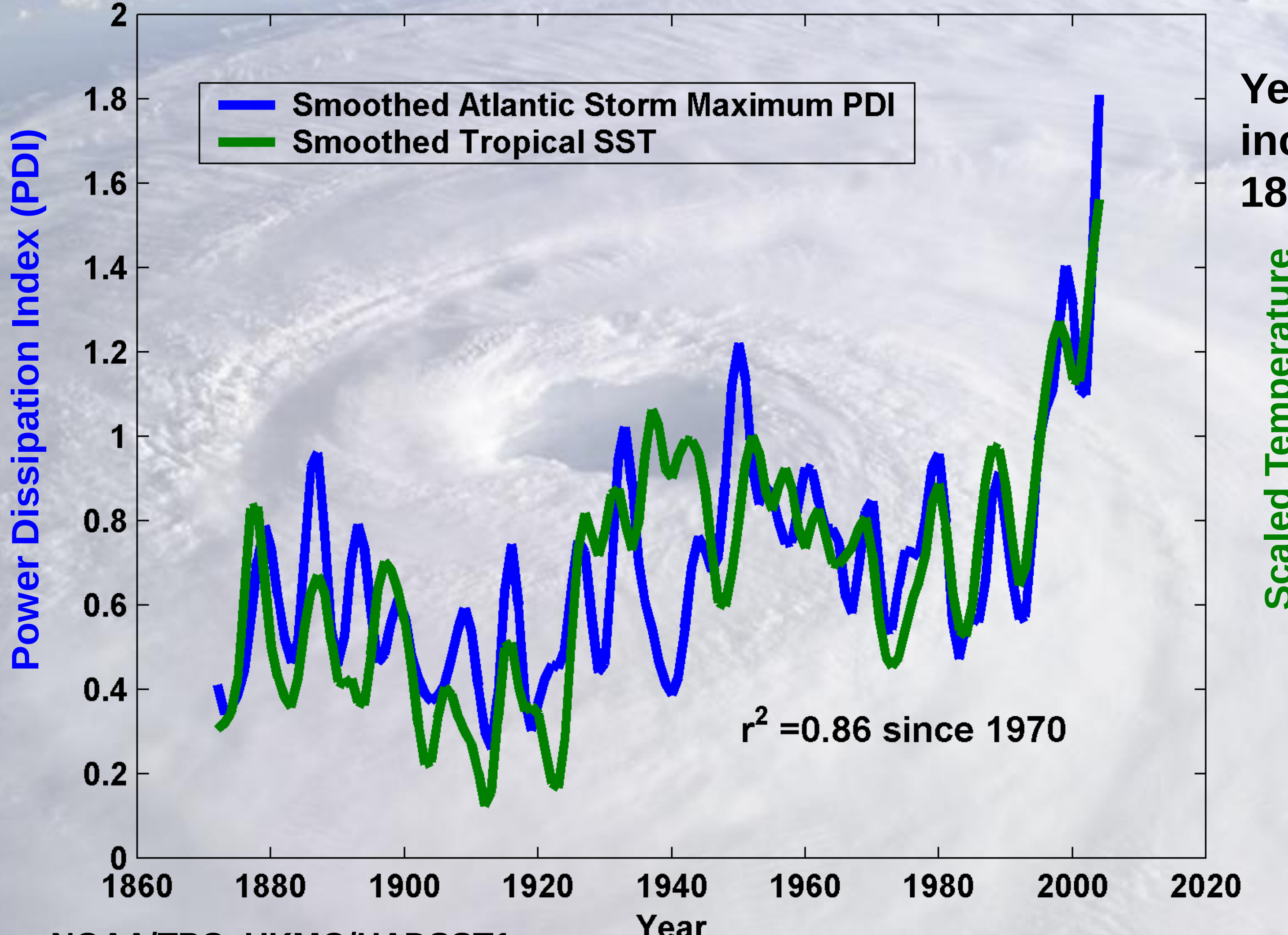
(Smoothed with a 1-3-4-3-1 filter)



Data Source: NOAA/TPC

Atlantic Sea Surface Temperatures and Storm Max Power Dissipation

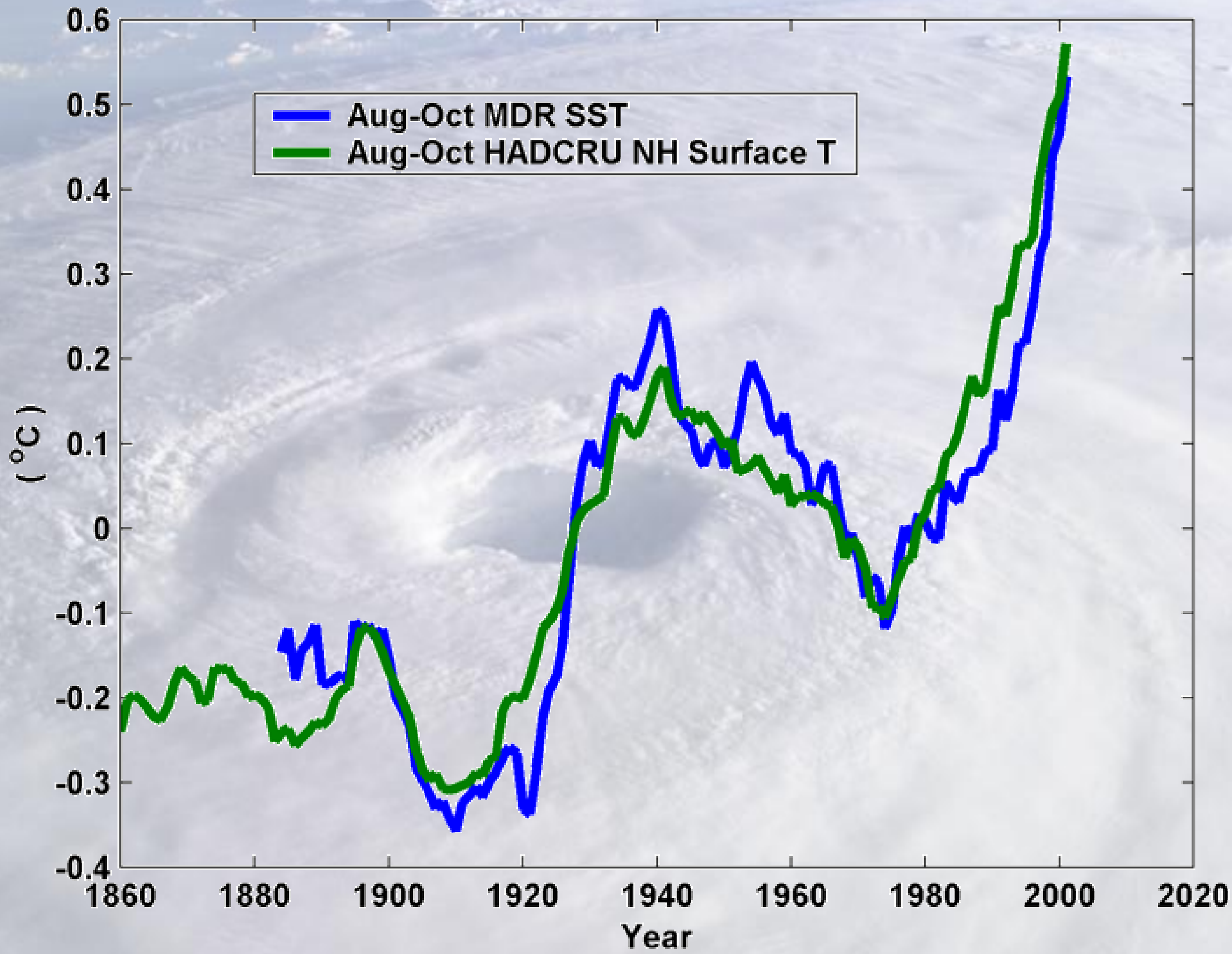
(Smoothed with a 1-3-4-3-1 filter)

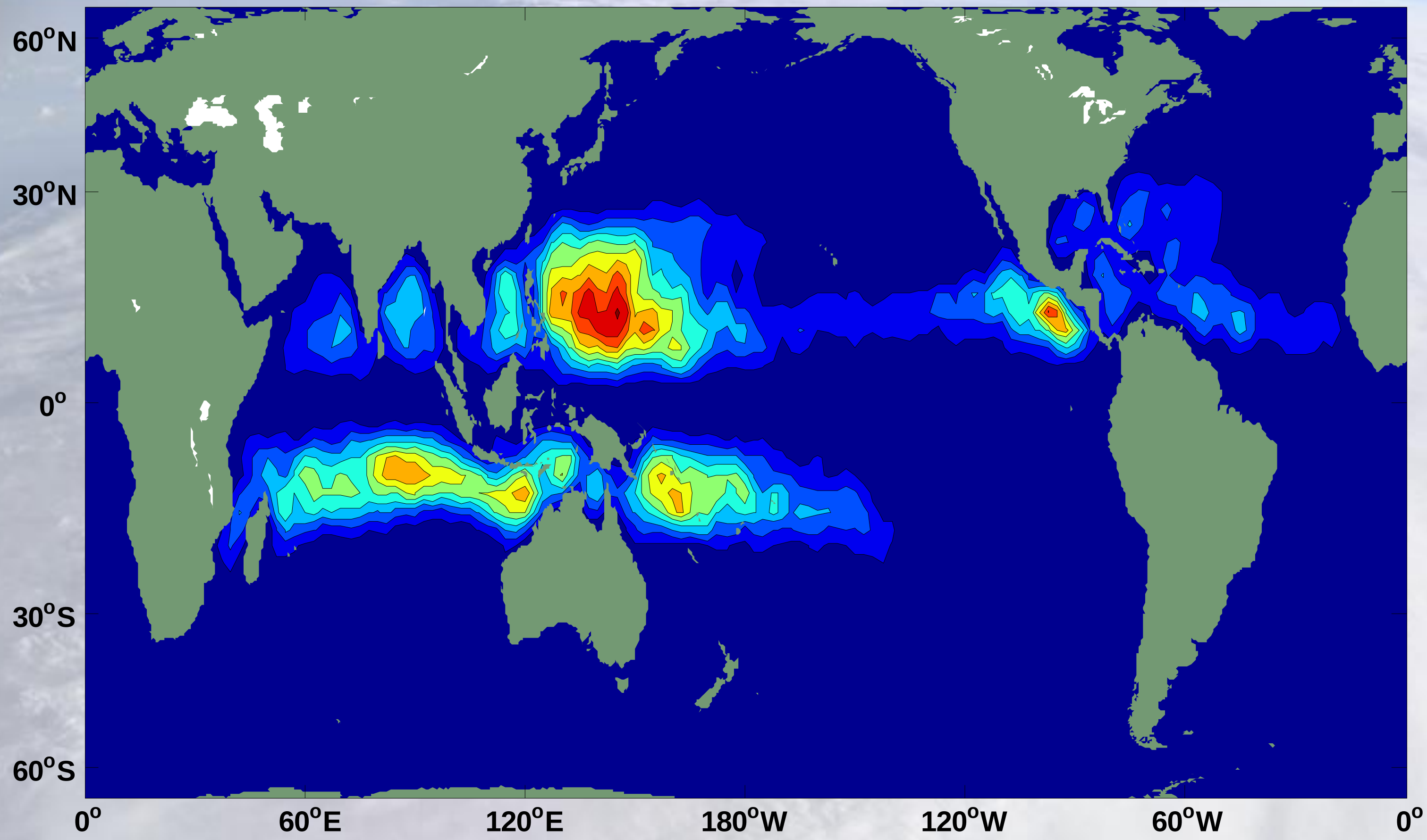


Years included: 1870-2006

Data Sources: NOAA/TPC, UKMO/HADSST1

10-year Running Average of Aug-Oct Northern Hemisphere Surface Temp and Hurricane Region Ocean Temp

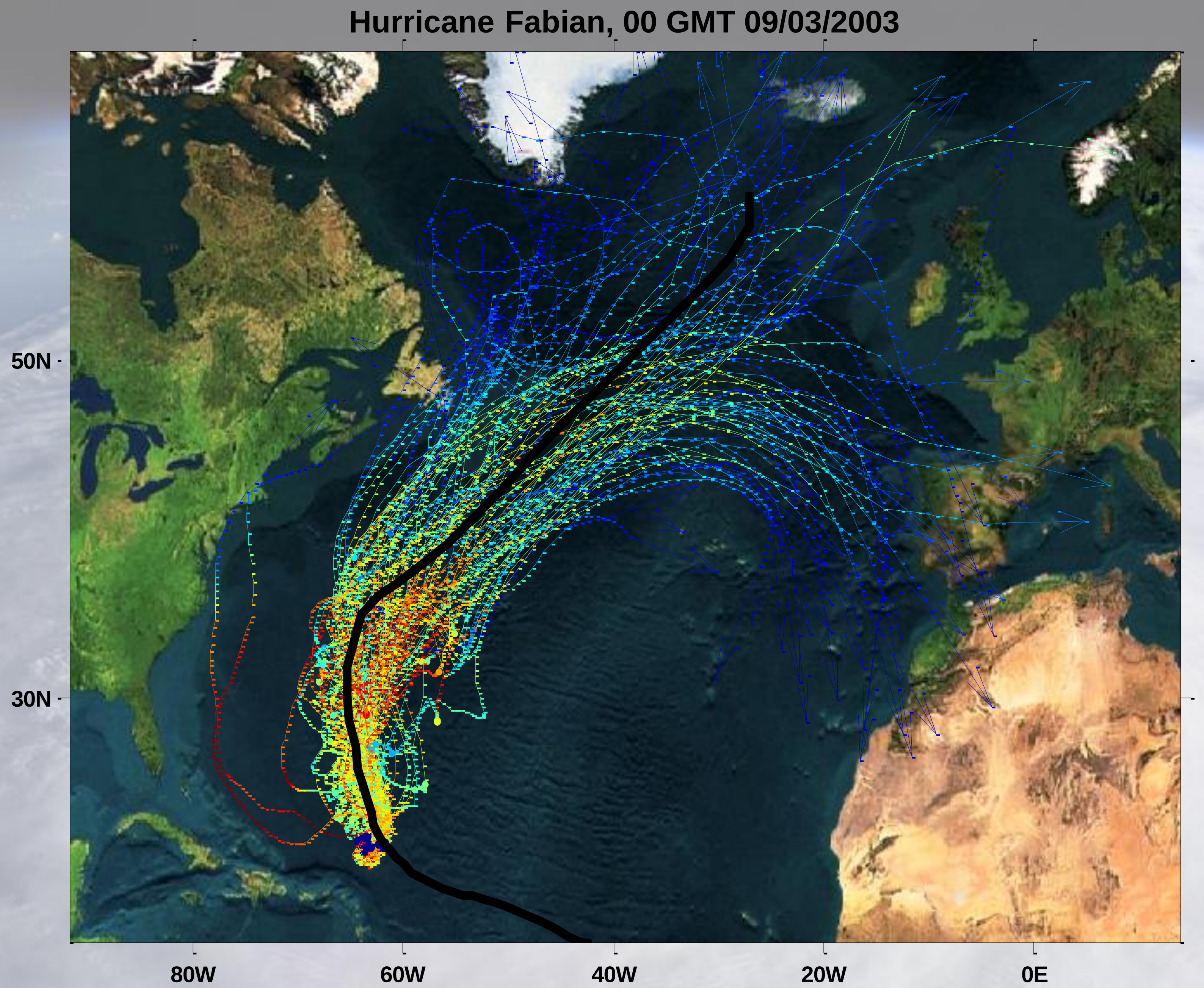


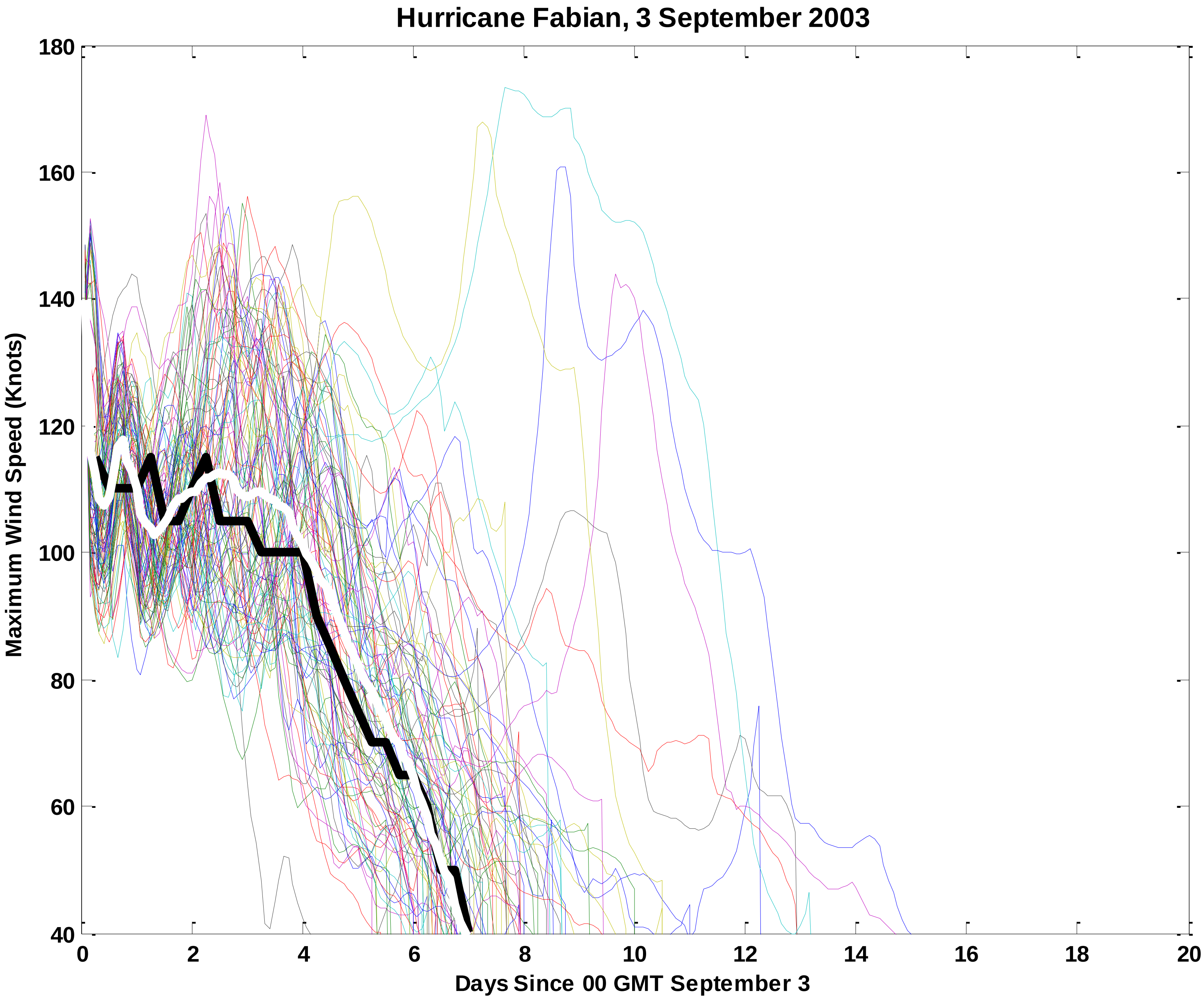


Annual Genesis Density by Random Seeing and Natural Selection applied to ERA 40 Reanalysis

A Look to the Future: Some Outstanding Problems

- Tropical cyclogenesis
- Basic predictability of tropical cyclone intensity
- Shear effects on TCs
- Superintensity and radial turbulent diffusion effects
- Climate control of TC tracks, intensity, and frequency
- Feedbacks of TCs on climate


Hurricane Fabian, 00 GMT 09/03/2003
50N
30N
80W
60W
40W
20W
0E


Hurricane Fabian, 3 September 2003
Maximum Wind Speed (Knots)
Days Since 00 GMT September 3
180
160
140
120
100
80
60
40
0
2
4
6
8
10
12
14
16
18
20