Brief sampling of TC-relevant products at moe.met.fsu.edu
TCLOGG
Well-calibrated genesis guidance for TWO

Experimental 0-120 h TC genesis probability
2019-09-19 12Z consensus guidance

Not a public product. Do NOT share with unauthorized users.

Available models in current guidance cycle (init time):
- CMC [C] (12Z)
- ECM [E] (00Z)
- GFS [G] (12Z)
- NAV [N] (12Z)
- UKM [U] (12Z)

Letters below the genesis probability indicate the models that predicted genesis

http://moe.met.fsu.edu/modelgenec  Uses data from GFS v15.1
TCPROB

Landfall probabilities given current TC location

Probability of a tropical cyclone eventually passing over USA @ any intensity based upon a given position. Using 1949/1886–2019 best-track.

http://moe.met.fsu.edu/tcprob

Updated: Mon Apr 26 13:37:35 UTC 2021
Unofficial Forecast Global TC ACE Based Upon Operational Models
Comparison starts with time: 2020091100

<table>
<thead>
<tr>
<th>Model</th>
<th>Initialization</th>
<th>&quot;TCs&quot;</th>
<th>ACE</th>
<th>Hours</th>
<th>ACE/24hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMC</td>
<td>2020091100</td>
<td>5</td>
<td>12.5</td>
<td>180</td>
<td>1.67</td>
</tr>
<tr>
<td>GFS</td>
<td>2020091100</td>
<td>5</td>
<td>34.1</td>
<td>180</td>
<td>4.55</td>
</tr>
<tr>
<td>HWRF**</td>
<td>2020091100</td>
<td>3</td>
<td>25.7</td>
<td>125</td>
<td>2.05</td>
</tr>
<tr>
<td>JMA</td>
<td>2020091100</td>
<td>1</td>
<td>1.4</td>
<td>132</td>
<td>0.025</td>
</tr>
<tr>
<td>NAVGEM</td>
<td>2020091100</td>
<td>3</td>
<td>14.7</td>
<td>180</td>
<td>1.98</td>
</tr>
<tr>
<td>UKM</td>
<td>2020091100</td>
<td>4</td>
<td>21.3</td>
<td>168</td>
<td>3.04</td>
</tr>
</tbody>
</table>

**ACE may increase as additional domains are received.
*: Instantaneous # of model "TCs"*

2020091100 GFS (0.50°)
Diagnosed TC Tracks and ACE Contribution through 180hr
5 Unofficial TCs Contributing
1 Global 180hr Forecast ACE = 34.1 [4.55 per 24hr]
CYCLONEPHASE
Analysis and forecast of cyclone structure

(One focus of the following presentation).
The Analysis and Prediction of Hybrid Cyclones and Structural Transition From One Perspective

Robert Hart, Florida State University
rhart@fsu.edu

“Subtropical Gustav”
9 Sep 2002

NHC 26 April 2021
Outline

• Part 1: The problem of gray-area cyclones
  – The textbook cyclone paradigm
  – Why the fuss?
  – Examples
  – A cyclone phase space as one approach
  – Example lifecycles and web page

• Part 2: What determines post-tropical evolution?
  – CPS Composite Structure
  – ET RI vs. RW
  – Posttropical warm-seclusion vs. cold-core
  – The role of the TC vs. the trough
We are taught in class about two mutually exclusive cyclone “worlds”

- **Extratropical cyclones**
  - Exist in the midlatitudes to polar latitudes
  - Form through the interaction of upper level disturbances with surface fronts
  - Intensity through baroclinic instability
  - Convert APE to EKE
  - Minimal role of diabatics

- **Tropical Cyclones**
  - Exist in the tropics to subtropics
  - Form through potential various methods of organizing convection
  - Intensify through flux induced latent and sensible heat
  - Convert diabatic heating to PE and KE
Quiz: Separate the 5 tropical cyclones from the 5 extratropical.
Quiz 2: The sometimes helpful, sometimes perilous reliance on time of year, geography, and SST for assuming structure
Example of misleading geography:

NHC Best Track from Beven (2001)
Hurricane Michelle (2001): GOES-8 Visible Imagery

1800 UTC 2 November

1800 UTC 3 November
Hurricane Michelle (2001): GOES-8 Visible Imagery

1800 UTC 4 November

1800 UTC 5 November
Hurricane Michelle (2001): GOES-8 Visible Imagery

1800 UTC 6 November

1800 UTC 7 November
Some relevant questions…

• What makes a cyclone warm or cold-core?

• If all low pressure areas result from a column of air that is on average warmer than its environment, how can there be cold-core cyclones?

• What are the hydrostatic consequences of this thermodynamic structure & the resulting profile of cyclone “strength”?

• What about existence of mixed phase cyclones?

• Why the fuss? 60 knots is 60 knots!

• Let’s first take a step back and reexamine the textbook structures
Classic warm-core cyclone: TC

Hurricane Bonnie (1998) Temperature Anomaly

Low pressure results from column of air on average warmer than environment, with the anomalous warmth in the troposphere.

Source:
Advanced Microwave Sounder (AMSU)
Temperature Anomaly

Image courtesy Mark DeMaria, CIRA/CSU
www.cira.colostate.edu/ramm/tropic/amsustrm.asp
Classic warm-core cyclone: TC

TC Height Field (m) from hydrostatic balance

Warm: expansion of surfaces

Cold: contraction of height surface
Classic warm-core cyclone: TC

Height anomaly from zonal mean shaded

Height anomaly increases with altitude in troposphere
Classic warm-core cyclone: TC

- Intensifies through: sustained convection, surface fluxes.
- Cyclone strength greatest near the top of the PBL

⇒ Gradient wind balance in a convective environ.
Classic cold-core cyclone: Extratropical

Cleveland Superbomb Temperature Anomaly

Low pressure results from column of air on average warmer than environment, with the anomalous warmth in the stratosphere
Classic cold-core cyclone: Extratropical

Height anomaly from zonal mean shaded

Height anomaly decreases with altitude in troposphere
Classic cold-core cyclone: Extratropical

- Intensifies through: baroclinic development, tropopause lowering.
- Cyclone strength greatest near tropopause

⇒ QG theory in a minimally convective environ
Hybrid (non-conventional) cyclone

What if an occluded extratropical cyclone moves over warm water? Characteristics of tropical and extratropical cyclones.
<table>
<thead>
<tr>
<th>Year</th>
<th>Researcher/Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
<td>Tannehill (1938): 1938 New England Hurricane</td>
</tr>
<tr>
<td>1939</td>
<td>Pierce (1939): 1938 New England Hurricane</td>
</tr>
<tr>
<td>1955</td>
<td>Knox (1955): Hurricane Hazel</td>
</tr>
<tr>
<td>1958</td>
<td>Palmén (1958): Hurricane Hazel</td>
</tr>
<tr>
<td>1972</td>
<td>Simpson (1972): “Neutercanes”</td>
</tr>
<tr>
<td>1975</td>
<td>Hebert &amp; Poteat (1975): Subtropical cyclones</td>
</tr>
<tr>
<td>1981</td>
<td>Bosart (1981): President’s Day Snowstorm</td>
</tr>
<tr>
<td>1990</td>
<td>Shapiro &amp; Keyser (1990): Warm seclusion extratropical</td>
</tr>
<tr>
<td>1997</td>
<td>Beven (1997): Cyclone diagram, Hybrid cyclones, Mediterranean</td>
</tr>
<tr>
<td>2000</td>
<td>Miner et al. (2000): Hurricane “Huron”</td>
</tr>
</tbody>
</table>
Non-conventional cyclones: Examples

1938 New England Hurricane

- Began as intense tropical cyclone
- Rapid transformation into an intense hybrid cyclone over New England (left)
- Enormous damage ($3.5 billion adjusted to 1990). 10% of trees downed in New England. 600+ lives lost.
- Basic theories do not explain a frontal hurricane
Non-conventional cyclones: Examples

Christmas 1994
Hybrid New England Storm

Classic (prior to Sandy) example of how track, structure, intensity and eventual impacts are related.

Gulf of Mexico extratropical cyclone that acquired partial tropical characteristics

A partial eye was observed when the cyclone was just east of Long Island

Wind gusts of 50-100mph observed across southern New England

Largest U.S. power outage (350,000) since Andrew in 1992

Forecast 6hr earlier: chance of light rain, winds of 5-15mph.
Model interpretation: What type of development?

For KAREN(2001): 12Z11OCT2001 MSLP (hPa)
- **P<sub>MIN</sub>=1009hPa**

For KAREN(2001): 12Z12OCT2001 MSLP (hPa)
- **P<sub>MIN</sub>=1001hPa**

For KAREN(2001): 12Z13OCT2001 MSLP (hPa)
- **P<sub>MIN</sub>=1003hPa**

For KAREN(2001): 00Z15OCT2001 MSLP (hPa)
- **P<sub>MIN</sub>=1005hPa**
Why is the structure of a cyclone important?

- Predictability is a function of structure
- Model interpretation/trust is a function of structure
- It is often not at first apparent what the model is forecasting, or the nature of cyclone development
- Potential intensity is a function of structure
Impact is a function of structural evolution and interaction.

Fran (1996): No transition

Floyd (1999):
Transition from pos. tilt trough

Hazel (1954):
Transition from a neg. tilt trough

Analysis courtesy
NOAA/NWS/NHC

Analysis courtesy
NCAR/NCEP
Reanalysis-2

Analysis courtesy
Jim Abraham, CHC
Significance:

- Classification
- Better understanding of the current state
- Applying conceptual models or designing new ones
- The type/extent of expected impact/damage
- Quantifying potential for intensity change and its uncertainty
  - Scales of motion dependence
  - Maximum intensity
- How can intensity change be forecast if there is great structural uncertainty?
- Amount of intrinsic (mis)trust of numerical model forecasts

⇒ Need a diagnosis of basic cyclone structure that is more flexible than only tropical or extratropical
Goal:
A more flexible approach to cyclone characterization

⇒To describe the basic structure of tropical, extratropical, and hybrid cyclones simultaneously using a cyclone phase space.
Cyclone Parameter 1: Vertical structure

- $V_T$: Thermal Wind [Warm vs. Cold Core]

Height anomaly

Warm core

Hybrid

Cold Core

300mb

600mb

900mb
Cyclone Parameter - $V_T$: Thermal Wind

Warm-core example: Hurricane Floyd 14 Sep 1999

Vertical profile of $Z_{MAX} - Z_{MIN}$ is proportional to thermal wind ($V_T$).

$$\frac{\partial (Z_{MAX} - Z_{MIN})}{\partial \ln p} = -|V_T|$$

Two layers of interest

$$\frac{\partial (Z_{MAX} - Z_{MIN})}{\partial \ln p} \bigg|_{300hPa} = -|V_T^U|$$

$$\frac{\partial (Z_{MAX} - Z_{MIN})}{\partial \ln p} \bigg|_{600hPa} = -|V_T^L|$$
Cyclone Parameter \(-V_T\): Thermal Wind

Cold-core example:
Cleveland Superbomb 26 Jan 1978

\[
\frac{\partial (Z_{MAX} - Z_{MIN})}{\partial \ln p} \bigg|_{300hPa} = -|V_T^U| \\
\frac{\partial (Z_{MAX} - Z_{MIN})}{\partial \ln p} \bigg|_{600hPa} = -|V_T^L|
\]
QG Height Tendency Eqn:

\[ \nabla^2 \frac{\partial \Phi}{\partial t} + \frac{\partial}{\partial p} \left[ \frac{f_0^2}{\sigma} \frac{\partial}{\partial p} \left( \frac{\partial \Phi}{\partial t} \right) \right] = -f_0 V_g \cdot \nabla (\xi_g + f) - \frac{\partial}{\partial p} \left[ \frac{f_0^2}{\sigma} V_g \cdot \nabla \left( -\frac{\partial \Phi}{\partial p} \right) \right] 
- f_0 K(p) \xi_g - \frac{\partial}{\partial p} \left[ \frac{f_0^2 R \dot{Q}}{\sigma \rho c_p} \right] \]

- **LHS:** Estimate of synoptic-scale height fall or height rise magnitude.

- **LHS:** How this varies in the vertical essentially drives whether a cyclone is becoming more or less cold or warm core, or evolving.

- **RHS:** Vorticity Advection, Differential Thermal Advection, Friction, and Differential Diabatics.
QG Height Tendency Eqn:

\[
\nabla^2 \frac{\partial \Phi}{\partial t} + \frac{\partial}{\partial p} \left[ \frac{f_0^2}{\sigma} \frac{\partial}{\partial p} \left( \frac{\partial \Phi}{\partial t} \right) \right] = -f_0 \mathbf{v}_g \cdot \nabla (\zeta_g + f) - \frac{\partial}{\partial p} \left[ \frac{f_0^2}{\sigma} \mathbf{v}_g \cdot \nabla \left( -\frac{\partial \Phi}{\partial p} \right) \right] - f_0 K(p) \zeta_g - \frac{\partial}{\partial p} \left[ \frac{f_0^2 R \dot{Q}}{\sigma p c_p} \right]
\]

- RHS: Vorticity Advection
  CVA ⇒ Height Falls, AVA ⇒ Height Rises

- RHS: Differential Thermal Advection, Diabatics
  WAA/Latent Heating increasing with height ⇒ Height Falls at low levels, height rises aloft

These determine how \(-V_T^L\) and \(-V_T^U\) change with time.
Cyclone Parameter 2: Horizontal structure

B: Thermal Asymmetry

Symmetric  Hybrid  Asymmetric
Cyclone Parameter B: Thermal Asymmetry

- Defined using storm-relative 900-600hPa mean thickness field (shaded) asymmetry within 500km radius:

\[
B = \frac{Z_{600\,hPa} - Z_{900\,hPa}}{R} - \frac{Z_{600\,hPa} - Z_{900\,hPa}}{L}
\]

- \( B \gg 0 \): Frontal
- \( B \approx 0 \): Nonfrontal
Cyclone Parameter B: Thermal Asymmetry

*Conventional Tropical cyclone:* $B \approx 0$

Forming → Mature → Decay

- Forming: $L$
- Mature: $L$
- Decay: $L$

*Conventional Extratropical cyclone:* $B$ varies

Developing → Mature → Occlusion

- Developing: $B \gg 0$
- Mature: $B > 0$
- Occlusion: $B \approx 0$
Cyclone Parameters Overview: B

(a) Hurricane Floyd: 12Z14SEP1999 1.0° NOGAPS Analysis

900–600hPa Thickness
B = 2 m

(b) Cleveland Superbomb: 06Z26JAN1978 2.5° NCAR Reanalysis

900–600hPa Thickness
B = 106 m
Constructing Phase Space
Constructing 3-D phase space from cyclone parameters: $B, -V_T^L, -V_T^U$

A trajectory within 3-D generally too complex to visualize in an operational setting

⇒ Take two cross sections (slices):
Phase Diagram 1
Thermal Asymmetry versus Lower-Tropospheric Thermal Wind

Symmetric warm core
• $B \leq 10$ and $-V_{TL} > 0$
  – Tropical cyclones, warm seclusions

Asymmetric warm core
• $B > 10$ and $-V_{TL} > 0$
  – Hybrid cyclones, warm seclusions
  – Most cyclones undergoing ET found here

Symmetric cold core
• $B \leq 10$ and $-V_{TL} < 0$
  – Occluded extratropical cyclones

Asymmetric cold core
• $B > 10$ and $-V_{TL} < 0$
  – Developing or mature extratropical cyclones

Slide courtesy of Dr. Mike Brennan, NHC
Phase Diagram 2
Upper vs. Lower tropospheric Thermal Wind

Deep warm core
- $-V_T^L > 0$, $-V_T^U > 0$
- Tropical cyclones

Deep cold core
- $-V_T^L < 0$, $-V_T^U < 0$
- Extratropical cyclones

Shallow warm core
- $-V_T^L > 0$, $-V_T^U < 0$
- Subtropical cyclones, warm seclusions

Slide courtesy of Dr. Mike Brennan, NHC
Hurricane Mitch (1998)

Case of symmetric, warm-core development and decay

Classic tropical cyclone

Slice 1:  B Vs. -V_T^L

M itch (1998) [1st NOGAPS Analysis]
Start (A): 12Z 21 OCT 1998 (Wed)
End (Z): 00Z 09 NOV 1998 (Mon)

Intensity (hPa):
1015  980
1010  975
1005  970
1000  965
995   960
990   955
985   950

Mean radius of 925hPa gale
force wind (km):
<100
200
300
500
750
Slice 1: B Vs. \(-V_T^L\)

Slice 2: $-V_T^L$ Vs. $-V_T^U$

Upward warm core development maturity, and decay.

With landfall, warm-core weakens more rapidly in lower troposphere than upper.
Slice 2: $-V_T^L$ Vs. $-V_T^U$

Upward warm core development maturity, and decay.

With landfall, warm-core weakens more rapidly in lower troposphere than upper.
December 1987 Extratropical Cyclone

Case of asymmetric, cold-core development and decay

Classic occlusion of an extratropical cyclone
Asymmetric cold-core evolution: Extratropical Cyclone

Slice 1: $B$ Vs. $-V_T^L$
Asymmetric cold-core evolution: Extratropical Cyclone Slice 1: $B$ Vs. $-V_T^L$
Asymmetric cold-core evolution: Extratropical Cyclone
Slice 2: $-V_T^L$ Vs. $-V_T^U$
Asymmetric cold-core evolution: Extratropical Cyclone
Slice 2: $-V_T^L$ Vs. $-V_T^U$
Hurricane Floyd (1999)

Multiple phase evolution:

Case of extratropical transition of a tropical cyclone
Warm-to-cold core transition: Extratropical Transition of Hurricane Floyd (1999): B Vs. $-V_T^L$
Warm-to-cold core transition: Extratropical Transition of Hurricane Floyd (1999) B Vs. $-V_T^L$

- Extratropical transition begins when $B=10m$
- Extratropical transition ends when $-V_T^L < 0$

⇒ Provides for objective indicators of extratropical transition lifecycle.
ET Phase Trajectory Example: NWATL

BONNIE(1998) [1.0° NOGAPS Analysis]
Start (A): 00Z19AUG1998 (Wed)
End (Z): 12Z03SEP1998 (Thu)

Symmetrical (Cyclonic)
Asymmetrical Cold-Core
Asymmetrical Warm-Core
Symmetrical Cold-Core

\[ -V_t^{[900-800\text{hPa} \text{ Thermal Wind}]} \]

\[ -V_t^{[800\text{hPa}]} \]

\[ -V_t^{[900\text{hPa}-600\text{hPa} \text{ Thermal Wind}]} \]

Intensity (hPa):
1015 990
1010 975
1005 970
1000 965
995 960
990 955
985 950
980 945
975 940

Mean radius of 925hPa gale

force wind (knot)
\[ <100 \]
\[ 200 \]
\[ 300 \]
\[ 500 \]
\[ 750 \]
ET Phase Trajectory Example: NEATL
ET Phase Trajectory Example: WPAC
ET Phase Trajectory Example: Aust

YANCE (1999) [1st NOGAPS Analysis]

Start (A): 12216MAR1999 [Tue]
End (Z): 12224MAR1999 [Wed]

- $V_t$ [900-600hPa Thermal Wind]

- $V^c$ [600hPa-300hPa Thermal Wind]
Cyclone Parameters Overview: B

Prior to peak tropical intensity

NHC Best-Track Cyclone Phase/Intensity

Evans & Hart 2003
North Atlantic ET Climatology

Number and percentage of North Atlantic TCs undergoing ET by month 1899–1996

Hart and Evans (2001) *Journal of Climate*

Slide courtesy of Dr. Mike Brennan, NHC
North Atlantic ET Climatology

Latitudinal distribution of ET in North Atlantic varies widely:
July through Sept: 40–50°N
Earlier and later in the season: 35–40°N

Hart and Evans (2001) *Journal of Climate*

Slide courtesy of Dr. Mike Brennan, NHC
Hurricane Olga (2001)

Multiple phase evolution:

Case of tropical transition of a cold-core cyclone
Cold-to-warm core transition: Tropical Transition of Hurricane Olga (2001)

\(-V_T^U\) Vs. \(-V_T^L\)

Tropical transition begins when \(-V_T^L > 0\)
(subtropical status)

Tropical transition completes when \(-V_T^U > 0\)
(tropical status)
Summary of cyclone types within the phase space

General locations of cyclones within phase space

- Developing/mature extratropical cyclones
- Hybrid cyclones, warm-seclusion cyclones
- Occluded extratropical cyclones
- Tropical cyclones, warm-seclusion cyclones

Axis labels:
- Asymmetric/Frontal
- Symmetric/Nonfrontal
- \(-V_T^L\)
- Cold Core
- Warm Core

Points:
- A
- Z
Summary of cyclone types within the phase space

General locations of cyclones within phase space

- Developing/mature extratropical cyclones
- Occluded extratropical cyclones
- Tropical Cyclones
- Subtropical cyclones
- Warm-seclusions
- ?Polar lows?
Real-time web page

http://moe.met.fsu.edu/cyclonephase
Real-time Cyclone Phase Analysis & Forecasting

• Phase diagrams produced in real-time for various operational and research models.

• Provides insight into cyclone evolution that may not be apparent from conventional analyses

• Web site: http://moe.met.fsu.edu/cyclonephase

• Also available a historical archive of CPS diagrams for nearly 200 cyclones
Cyclone phase evolution: Analyses & Forecasts

This page presents historical, analyzed (current), and model-forecast cyclone phase diagrams for northwestern hemisphere cyclones with the goals of improved structural forecasting, structural transition (subtropical/tropical/extratropical), cyclogenesis, and providing measures of structural predictability.

Please note that these products are experimental and not official forecasts. For official forecasts in the U.S., please refer to the National Weather Service and National Hurricane Center.

To the right are the most recently picked interesting diagrams. In this case, the UKMET analysis of extratropical transition of Ignacio and "landfall" near the Alaskan border as a weakening extratropical storm.

Latest deterministic model output:
CMC: 2015111712  GFS: 2015111712
NAVGEM: 2015111612  UKM: 2015111712

Current/recent GFDL model output:
invest90e: 2015111712  invest99e: 2015111612

Current/recent NCEP HWRF model output:
invest90e: 2015111712  invest93p: 2015111712
invest95w: 2015111618  invest97b: 2015111712
invest99e: 2015111612  twenty-se27w: 2015111712

Current/recent CIRA/NESDIS AMSU based diagrams:
ep92015: 2015111712  io972015: 2015111712
sh932016: 2015111712  wp272015: 2015111712
wp952015: 2015111700

Ensemble output:
Latest deterministic intercomparison: [2015111706 | 2015111700]

Latest CMC Ensemble: [2015111700 | 2015111612]
Latest GFS Ensemble: [2015111600 | 2015111512]
Latest NGP Ensemble: [2015111700 | 2015111612]
Latest CMC+GFS+NGP Ensemble: [2015111600 | 2015111512]

Example phase diagrams from past events: [View]
Example real-time cyclone availability for GFS

2015111712 GFS analysis and forecast cyclone phase evolution

Jump to: [NCEP GFS Ensemble Comparison | Deterministic Comparison | Historic Diagrams | Documentation/Help | Main Page]

0.25° NCEP GFS (12Z17NOV2015 run) Cyclones
SLP analysis and tracks [solid=history,dotted=forecast]
Forecasts through 180hr examined
Click on cyclone to view phase
Black = Existing Low; Red = Future Low (## = Cyclone Number)

Previous GFS runs:
2015111712 2015111706
2015111709 2015111618
2015111612 2015111606
2015111609 2015111518
2015111512 2015111506
2015111509 2015111418
2015111512 2015111406

Other 2015111712 models:
CMC
NAYGEM
UKMET
Example GFS forecast TC

Forecast phase analysis

Zoomed
Example GFS forecast TC

Forecast phase analysis

Zoomed
Cyclone Phase Web Page Overview

- Trajectory through phase space describes structural evolution
  - A = When cyclone was first detected
  - C = Current analysis time
  - Z = Cyclone dissipation time or end of model forecast data
  - A→C = cyclone structural history
  - C→Z = cyclone structural forecast
  - Date is labeled at 00Z along phase trajectory

- Color of trajectory gives cyclone intensity in MSLP

- Size of marker gives average radius of 925hPa gale-force wind

- Cyclone track & underlying SST provided in inset

- Phase diagram quadrants are shaded to give more rapid interpretation
Ensemble cyclone phase

• Four sets of ensembles are produced:
  – All available deterministic models initialized within 6hr of each other
  – 20 GFS Ensembles
  – 20 CMC Ensembles
  – 20 NOGAPS Ensembles
  – 60-member combination

• All aim to provide forecast guidance for structural uncertainty
Multiple model solutions: Measure of structural forecast uncertainty
Multiple model solutions: Measure of structural forecast uncertainty
Hurricane Michelle (2001): Calibration from AMSU-based Phase Diagnostics

AMSU-derived 900–600 hPa Thickness (m) & MSLP (hPa)

Extratropically Transitioning Michelle

1200 UTC 6 Nov 2001

B = 29
Moderately asymmetric

AMSU-derived Thermal Wind Cyclone Phase Parameters

Extratropically Transitioning Michelle

1200 UTC 6 Nov 2001

$V_T^u = -135$ (cold-core)

$V_T^f = +88$ (warm-core)
Hurricane Michelle (2001): Calibration from AMSU-based Phase Diagnostics
The human element

• CPS diagrams:
  – Most helpful in the context of a firm understanding of cyclone development theory
  – Most helpful with an understanding of the strengths & limitations of NWP models
  – Most helpful with an understanding of individual model biases
  – Most helpful with a synthesis with all other tools available
  – Do not describe the finer (mesoscale) detail of storm evolution
  – While the diagrams are objective, their interpretation can still be subjective and dependent on forecaster model experience and conceptual models learned
Other Past/Current CPS Uses

- Tropical cyclone genesis diagnosis/forecasting
- Subtropical cyclone genesis diagnosis/forecasting
- Timing of extratropical transition
- Timing of tropical transition
- Diagnosis of structural predictability
- Diagnosis of when to switch NEXRAD radars to tropical mode
Phase space limitations

- Cyclone phase diagrams are dependent on the quality of the analyses upon which they are based.

- Three dimensions \((B, -V_T^L, -V_T^U)\) are not expected to explain all aspects of cyclone development.

- Other potential dimensions: static stability, long-wave pattern, jet streak configuration, binary cyclone interaction, tropopause height/folds, surface moisture availability, surface roughness...

- However, the chosen three parameters represent a large percentage of the variance & explain the crucial structural changes.
Often model analysis representation is poor
Often model analysis representation is poor

Jack Beven, NHC:  
“Garbage in, garbage out!”
“Instant” Warm-Seclusion Dilemma: Hurricane Sandy (2012)

NOTE: A 24hr running mean smoother is applied to the CPS trajectory.
Quiz: Separate the 5 tropical cyclones from the 5 extratropical.
Separate the 5 tropical cyclones from the 5 extratropical.

Images courtesy NCDC

Noel (2001)

Unnamed TC (1991)

“Perfect” Storm (1991)

President’s Day Blizzard (1979)

Floyd (1999)

Gloria (1985)

Superstorm of 1993

Michael (2000)

Extratropical Low