Track Forecasting
Are TCs ‘unpredictable’?

- Conceptual frameworks
- The process
- NWP
- Consensus processes
- Ensembles
Does track depend upon the intensity?

Changes in inner core processes have little effect on track.
The dominant steering is on the scale of the outer circulation.

• To a first approximation, motion is governed by conservation of relative vorticity (vortex moves with the large-scale steering flow).
Depth of the steering flow

Velden & Leslie (1993)
Moving TC Windfield Conceptual Model

- Look for wind max wind
- Compare winds on opposite sides of TC
Synoptic Steering patterns

Pattern
- Standard (S)
- Poleward (P)
- High-Amplitude (H)
- Midlatitude (M)

Region
- Equatorial westerlies (EW)
- Tropical easterlies (TE)
- Poleward flow (PF)
- Equatorial flow (EF)
- Ridge poleward (RP)
- Ridge equatorward (RE)
- Trough poleward (TP)
- Midlatitude westerlies (MW)
- Midlatitude easterlies (ME)
Standard / Dominant Ridge
TC Motion
Secondary influences

- “Beta effect”
- Trochoidal oscillations
- Fujiwhara effects
The Beta effect

TC circulation combined with the South-North variation of Coriolis induces asymmetries to produce a net NW steering current at a few knots (NH).

Size dependent
Trochoidal oscillations

Convective asymmetries induce a wobble short term
Noticeable for slow moving TCs
Official track usually smoothed
Impacts landfall timing – storm tide

The Fujiwhara effect

Interaction between two TCs
→ dependent on size & separation distance

A – Approach
C – Capture
0 – Orbit
M – Merger
R – Recurve
E - Escape

Merger example
What direction would TCs be steered at A/B/C?
Consensus Forecasting

Suppose you have three forecasts for a tropical cyclone threatening an island...

- No problem... None of the forecasts go over my island
- Choose the forecast that is usually most accurate (ex: Forecast 1)
- Choose the forecast that was the most accurate yesterday
- Go with some kind of consensus
Suppose you have three forecasts for a tropical cyclone threatening an island...

Suppose you take the simple average of the three forecasts
• This is a reasonable consensus forecast
What if we give Forecast 1 more weight because we know it is usually more accurate?
• This is an even better consensus forecast most of the time
Suppose you have three forecasts for a tropical cyclone threatening an island...

The range of uncertainty can be represented by the spread (range) of the forecasts
...or maybe even a bit wider since the individual forecasts contain error.
Consensus Track Forecasting

Consensus methods now widespread, because:

- Clear evidence of improvement (seasonal timescales) over individual guidance
- It’s what forecasters naturally do
- Improved objectivity in track forecasting
- Removes the windscreen wiper effect
Consensus Theory

Why does it work?

The skill of a consensus depends on:
- The skill of the individual members
- Independence of error between members
- The number of members
1. Small Spread/Large Error: Nightmare
2. Large Spread/Large Error: Largest opportunity for improvement
3. Small Spread/Small Error: Ideal Case
4. Large Spread/Small Error: Opposing errors cancel each other out

Ensemble Spread

- Actual 72-h track of TC
- Non-selective Consensus (N) track
- Individual model tracks

Courtesy: R. Ellsberry
Low model spread - high error

TC George: The hard one!
Very rare – but critical
Low model spread - low error

Ophelia: High confidence
High model spread – challenge to be selective

Dominic: small and tricky!

SCON: EC way out on top!
High model spread

Jacob: High uncertainty!

Analysis

24h NCON

Track
High model spread

Jacob: High uncertainty!
Summary

Ingredients of good track forecasting
- Good Analysis and environment assessment
- Persistence (esp. for first 6-12h)
- Changes in the environment - conceptual models
- NWP consensus
  - => Selective (SCON) vs Non-selective (NCON)

To be continued with NWP…
Questions

1. A developing low (~30kn) is steered by winds
   a. 850-500hPa    b. 850-300hPa    c. 700-300hPa

2. YES or NO
   You have five different models available that show TC forecasting skill. Should you still use the least skillful of these models?
High-amplitude / Trough Poleward
Poleward – peripheral ridge
Planetary Vorticity Advection

\[ f \text{ less negative} \]

\[ V > 0 \]

\[ f \text{ more negative} \]

\[ V < 0 \]
Planetary Vorticity Advection

Eq

$f$ less negative

$V > 0$

$f = f_+$

$f = f_-$

$f$ more negative

$V < 0$

$f = f_0$
Planetary Vorticity Advection

\[ f \text{ less negative} \]

\[ V > 0 \]

\[ |A| \uparrow \zeta \downarrow \]

\[ f \text{ more negative} \]

\[ V < 0 \]

\[ |A| \downarrow \zeta \uparrow \]

Tropical Meteorology
Planetary Vorticity Advection

$\psi$ less negative

$\psi$ more negative

cyclonic vorticity anomaly

anticyclonic vorticity anomaly

Tropical Meteorology
Net result is steering to southwest in SH

Rotation 1/8\textsuperscript{th} of a cycle

Tropical Meteorology
The dominant steering is on the scale of the outer circulation.

• To a first approximation, motion governed by conservation of relative vorticity (vortex moves with the large-scale steering flow).

• Second order includes the Beta term (conservation of absolute vorticity).
Moving to probability of impact – more info than probability of centre location

34 kt Cumulative

GFE probability of 34 kn winds
TC Motion
“Cork in a stream”

– Depth of steering flow?
– Define environment?
– 50-80% of variance over 12-24 h