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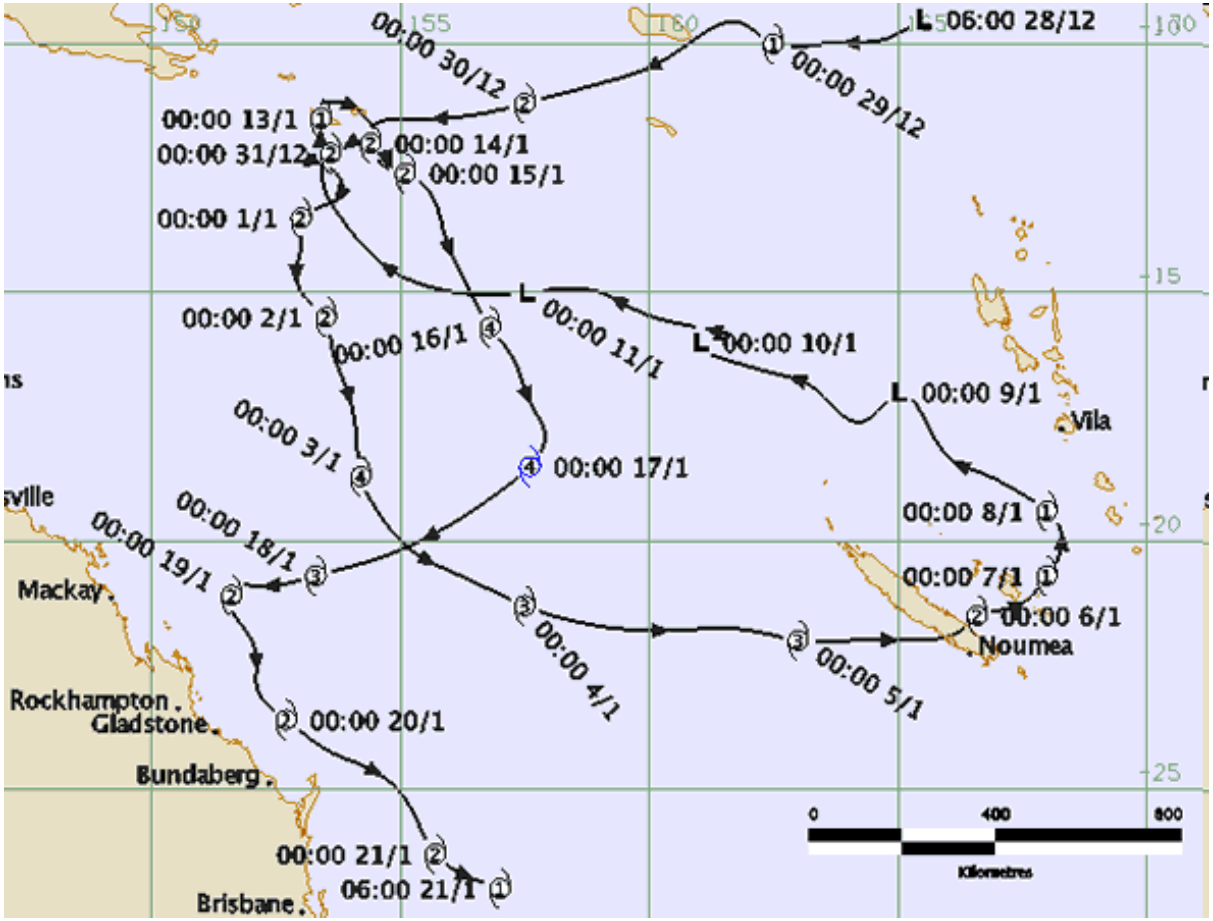
Track Forecasting
Are TCs ‘unpredictable'?

- Conceptual frameworks
- The process
- NWP
- Consensus processes
- Ensembles



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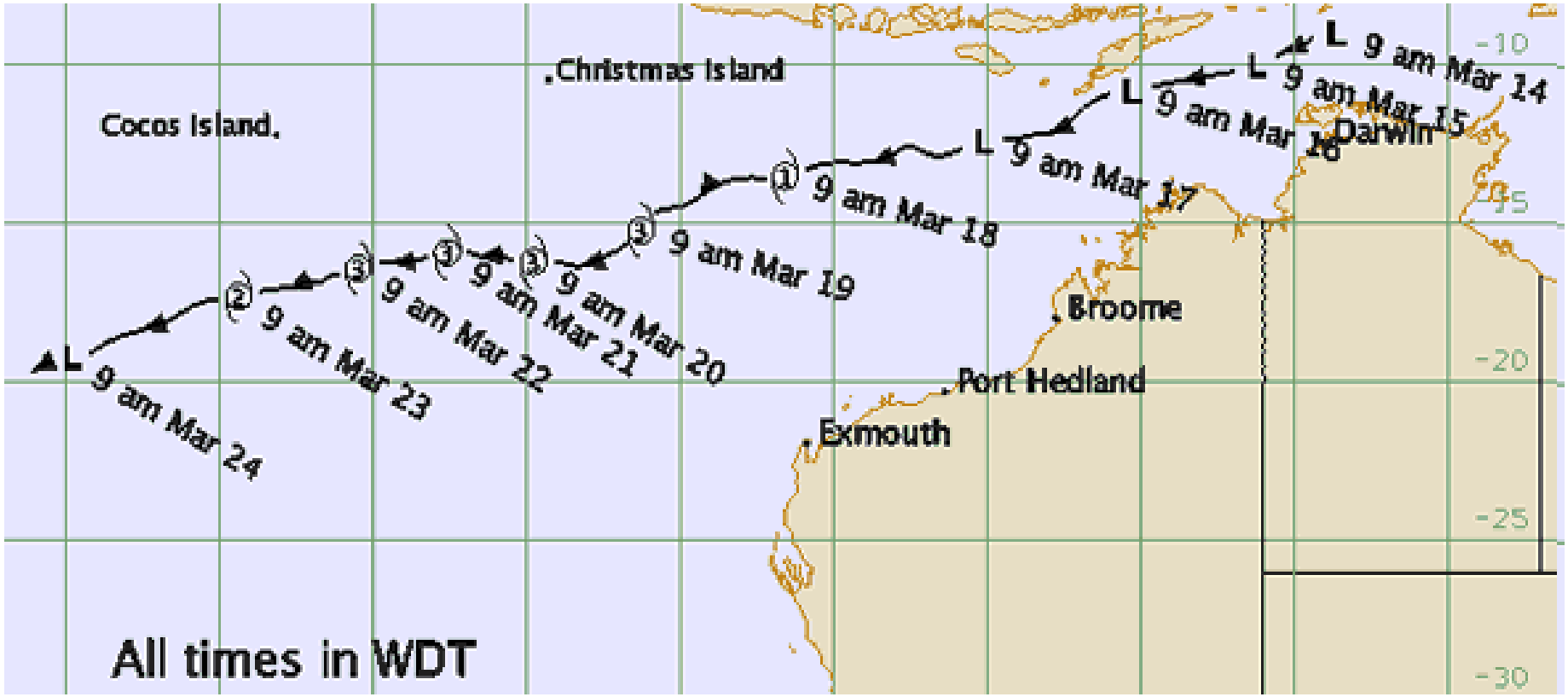
Does track depend upon the intensity?

Changes in inner core processes have little effect on track



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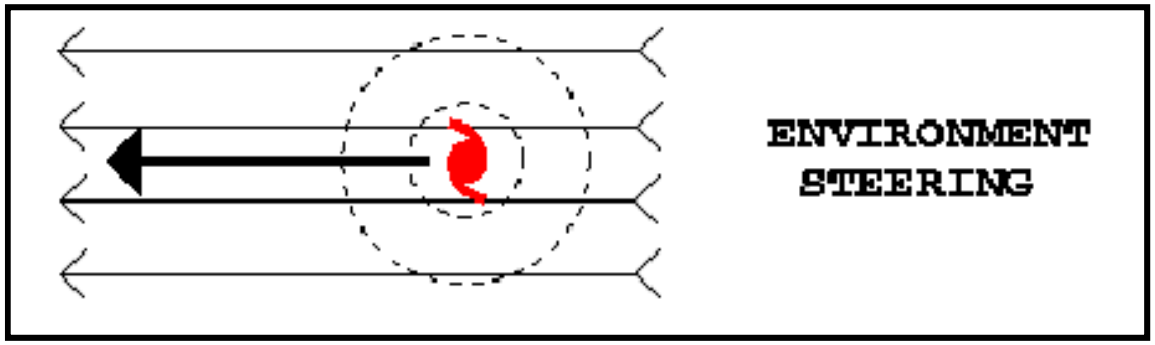
TC Motion
"Cork in a stream"

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**).



SCALE ANALYSIS OF THE VORTICITY EQUATION

Use scales for tropical cyclone outer wind:

$L \sim 500 \quad km$
$Rotational \quad wind \quad V \sim 10 \quad m/s$
$Divergent \quad wind \quad U \sim 1 \quad m/s$
$\Delta P \sim 10^5 \quad Pa$
$T \sim \frac{L}{V} \sim 5 \times 10^4 \quad sec$
$\zeta \sim \frac{V}{L} \sim 2 \times 10^{-5} sec^{-1}$
$\delta \sim \frac{U}{L} \sim 2 \times 10^{-6} sec^{-1}$
$\omega \sim \delta \Delta P \sim 0.2 \quad Pa/sec$

$$\frac{\partial \zeta}{\partial t} = -V \cdot \nabla \zeta - \omega \frac{\partial \zeta}{\partial P} - \beta v - (\zeta + f)\delta - k \cdot \nabla \omega \times \frac{\partial V}{\partial P}$$

(1) (1) (4) (2) (3) (4)

4×10^{-10} 4×10^{-10} 4×10^{-11} 2×10^{-10} 1×10^{-10} 4×10^{-11}

From NHC in 2011 WMO ppt

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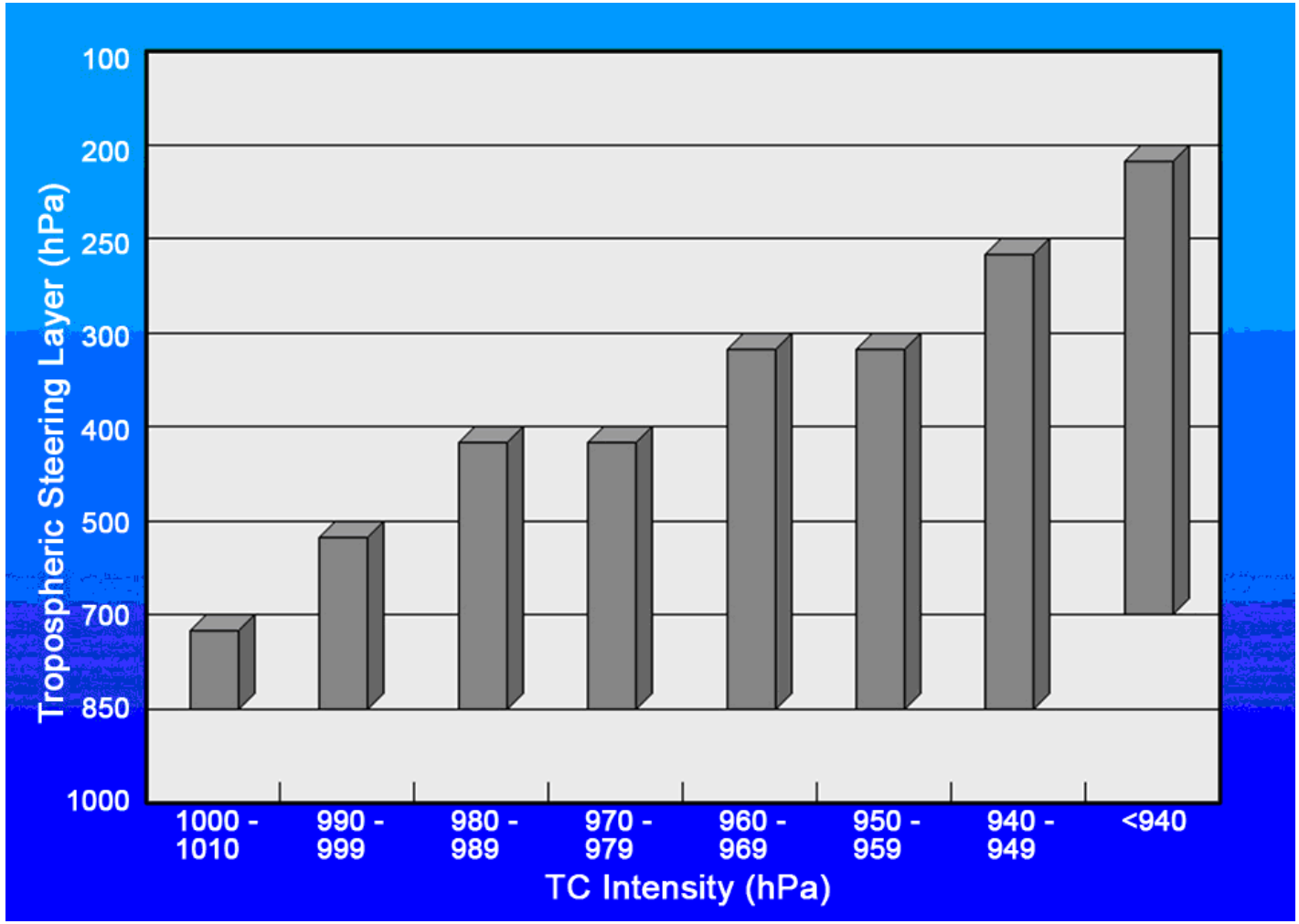
Depth of the steering flow



Velden & Leslie (1993)

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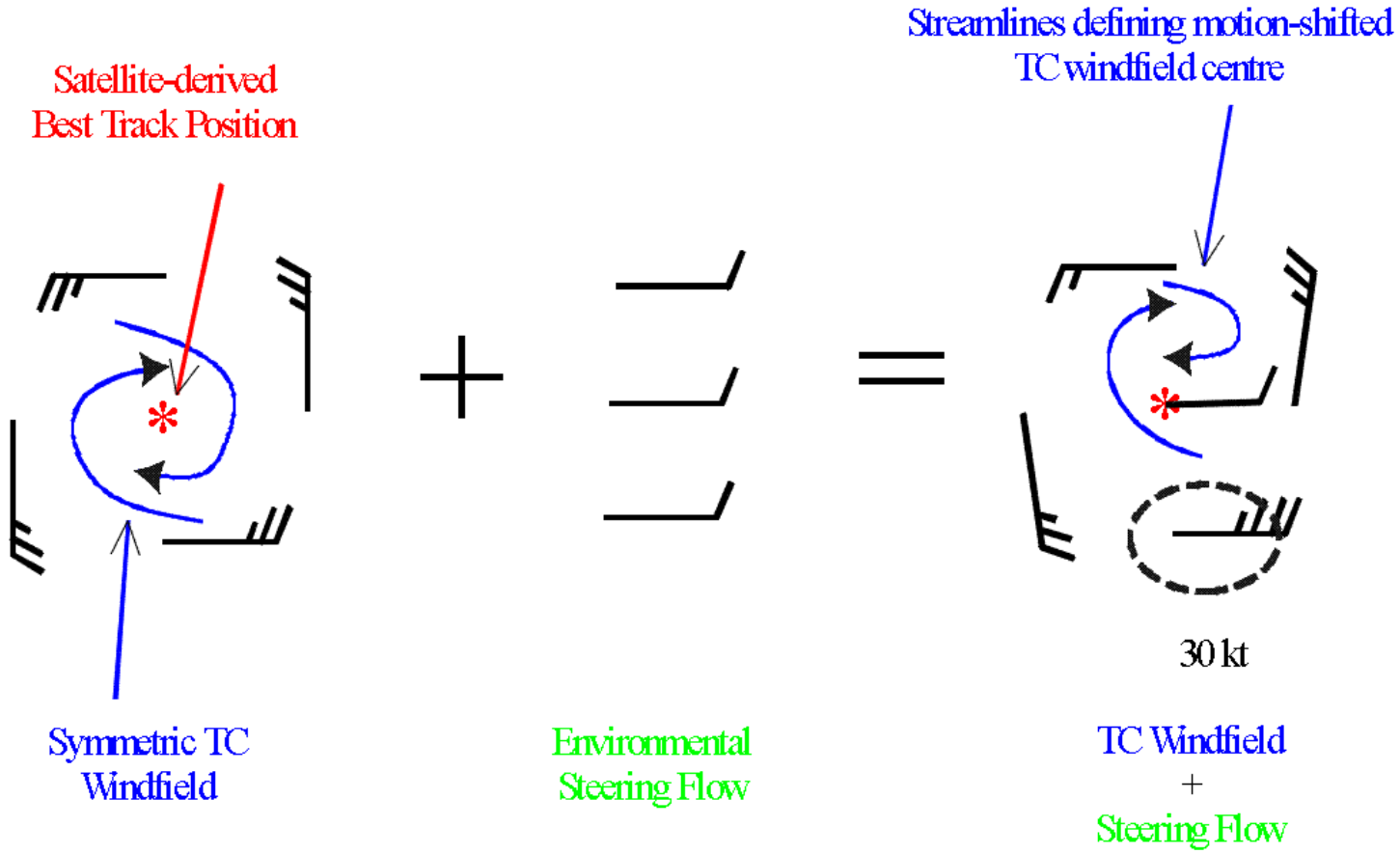
Moving TC Windfield Conceptual Model

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



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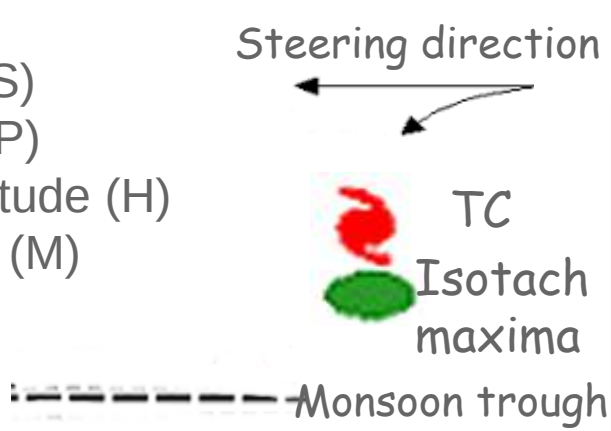
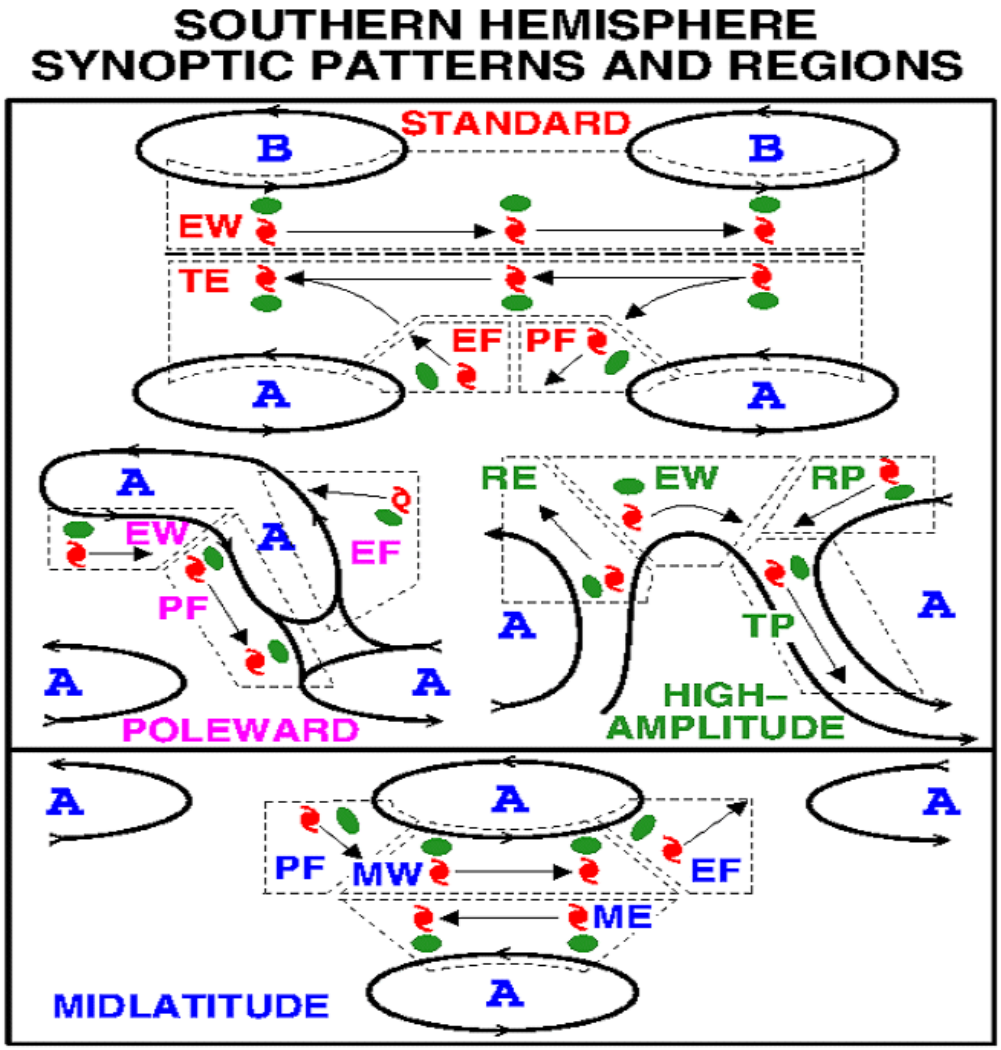
Synoptic Steering patterns

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)





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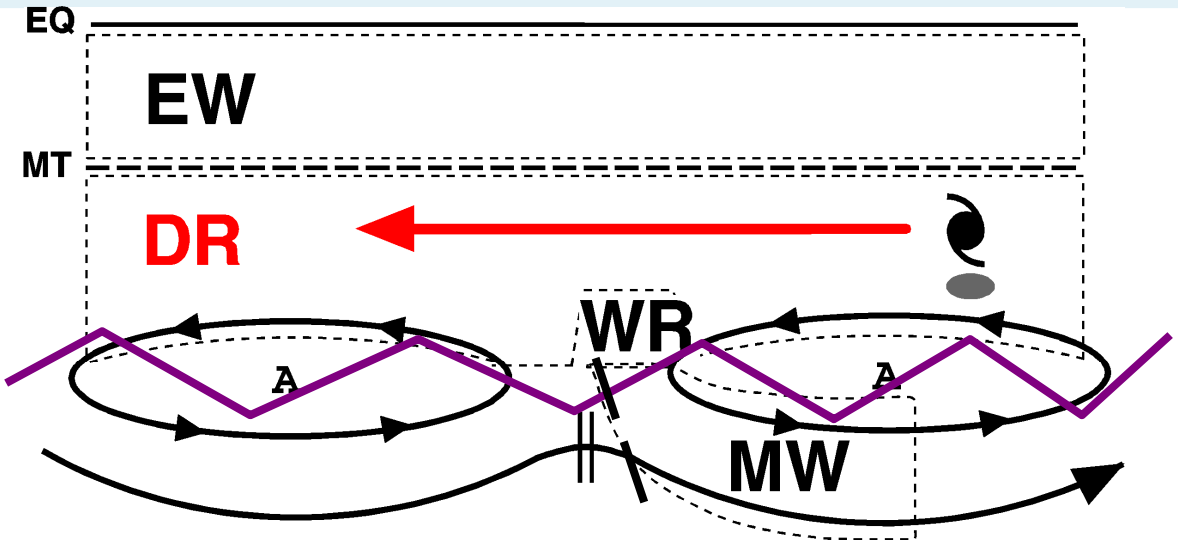
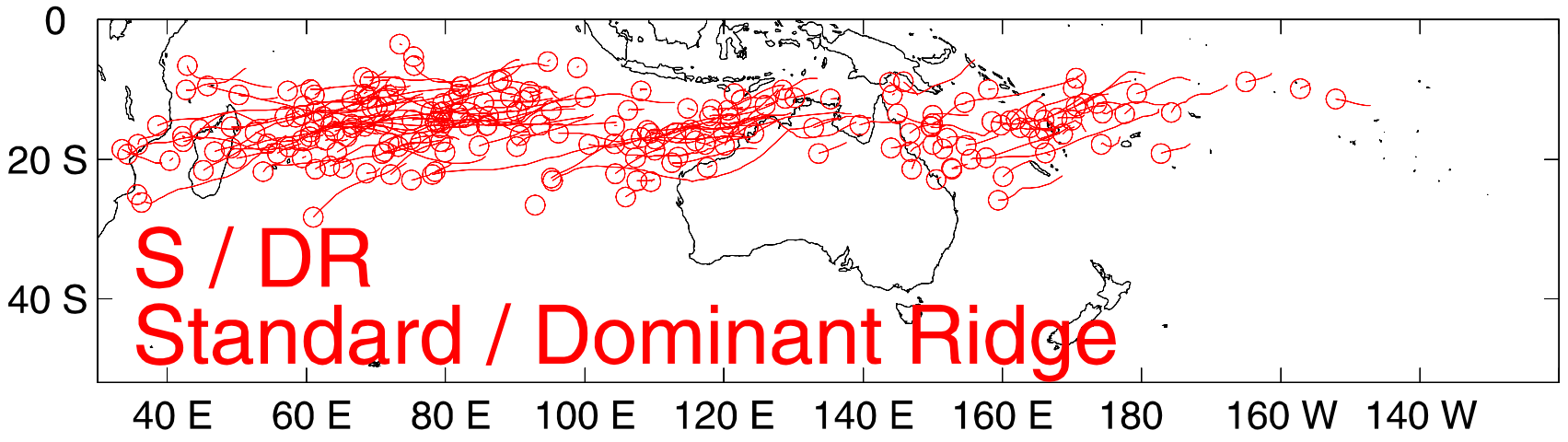
Standard / Dominant Ridge





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TC Motion
Secondary influences

- “Beta effect”
- Trochoidal oscillations
- Fujiwhara effects

Velden & Leslie (1993)

The Beta effect

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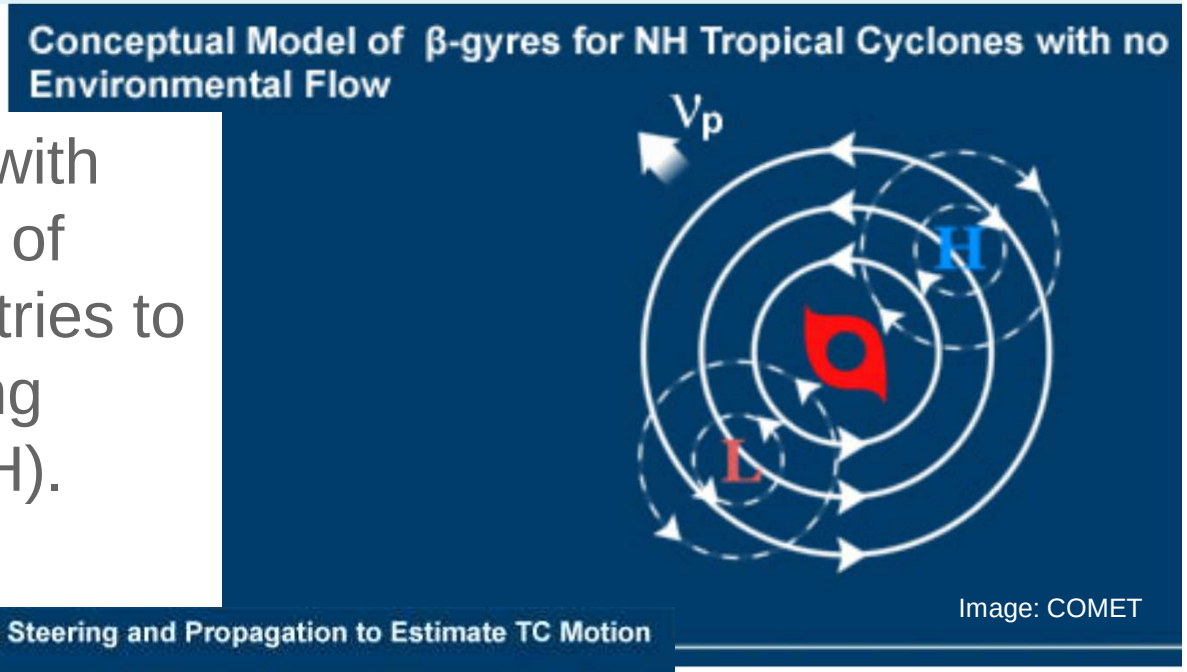
TC circulation combined with the South-North variation of Coriolis induces asymmetries to produce a net NW steering current at a few knots (NH).

Size dependent



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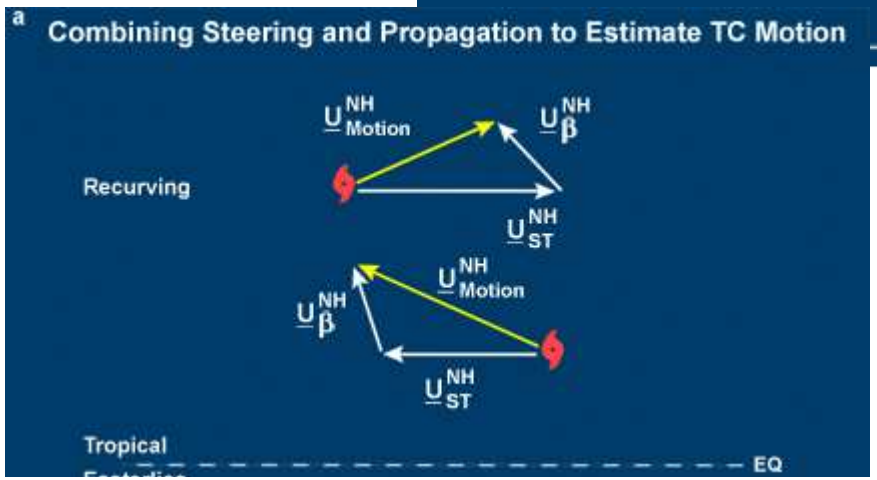

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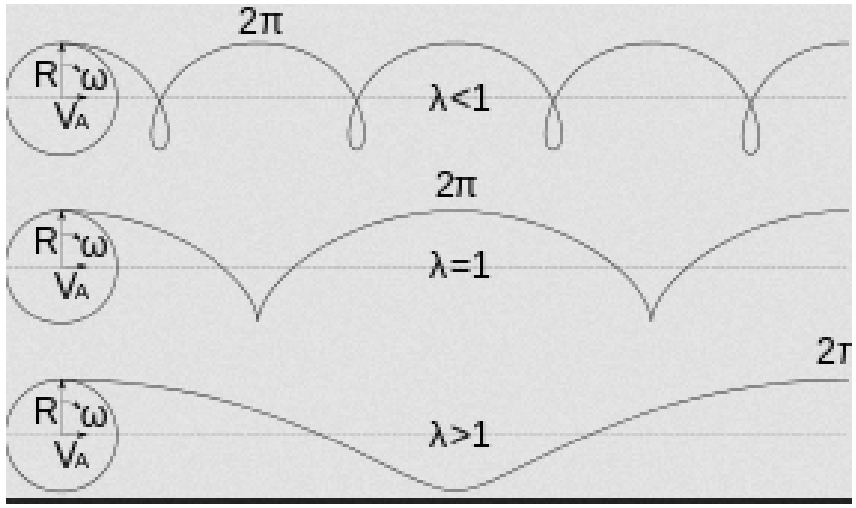
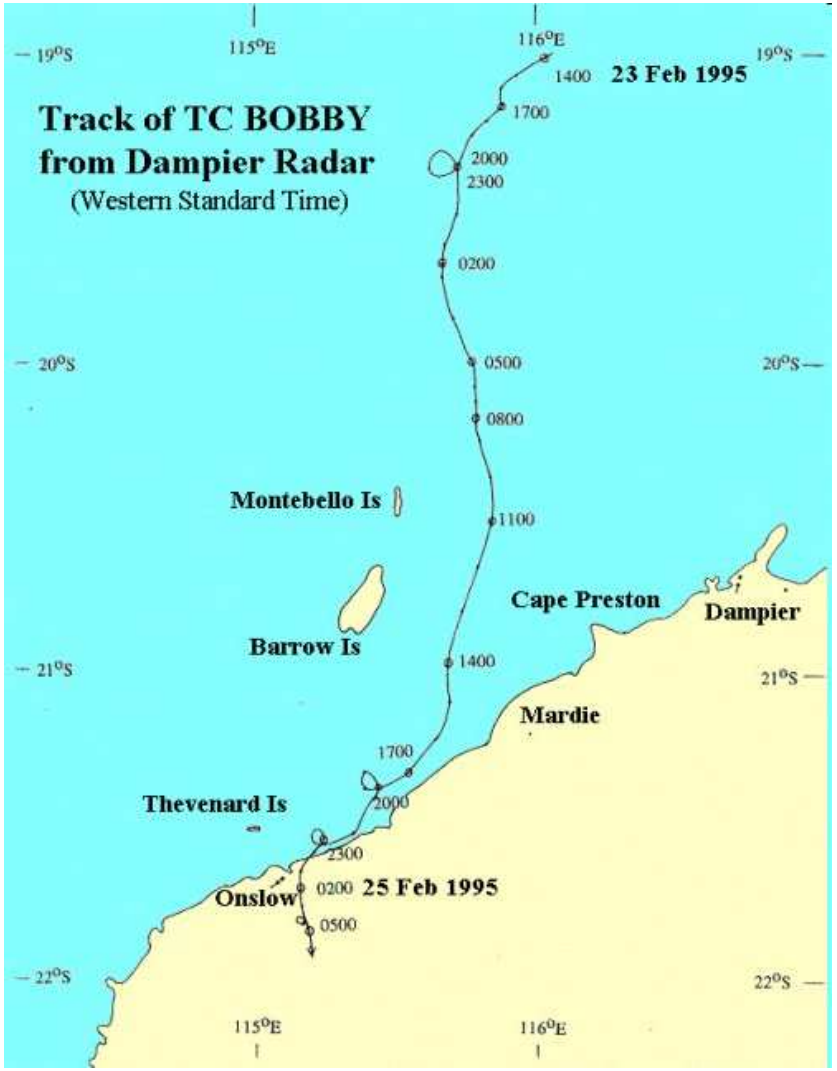
Trochoidal oscillations

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



Wikipedia:https://upload.wikimedia.org/wikipedia/commons/thumb/f/f0/Cycloids.svg/290px-Cycloids.svg.png



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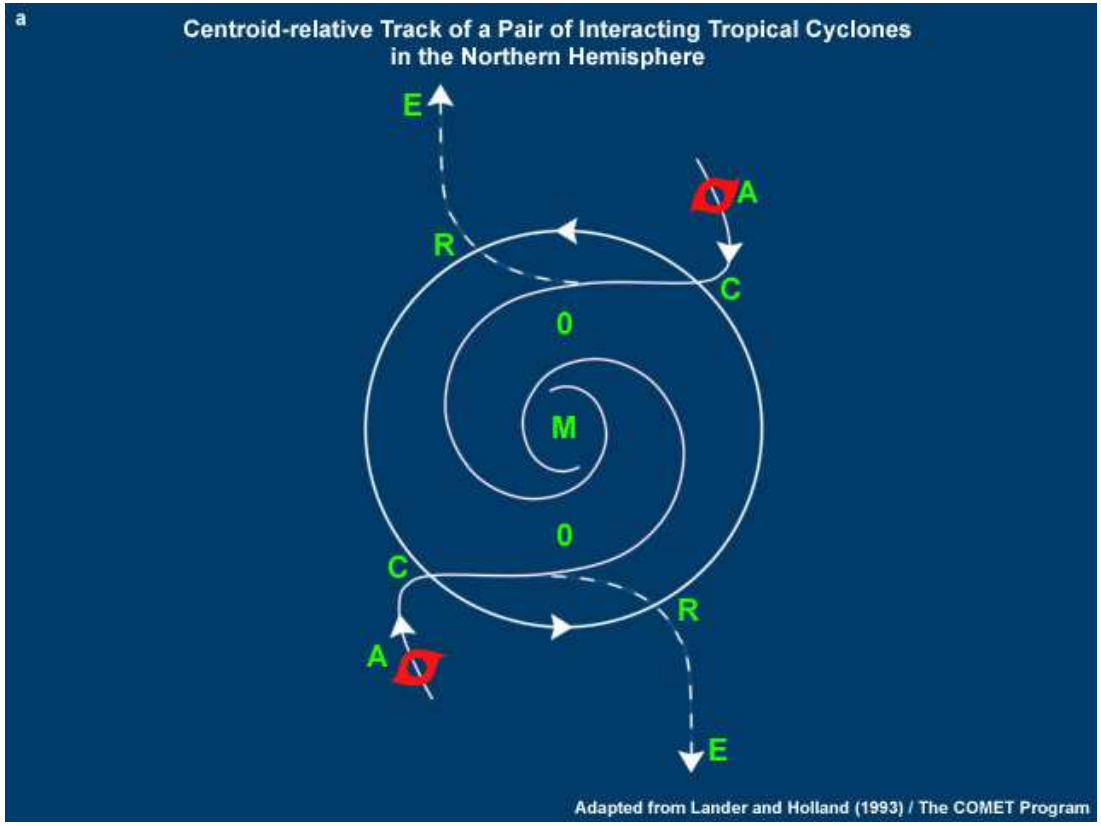
The Fujiwhara effect

Interaction between two TCs
→ dependent on size & separation distance

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



https://www.meted.ucar.edu/tropical/textbook_2nd_edition/media/flash/fujiwhara_zeb_alex_1998.swf
Merger example

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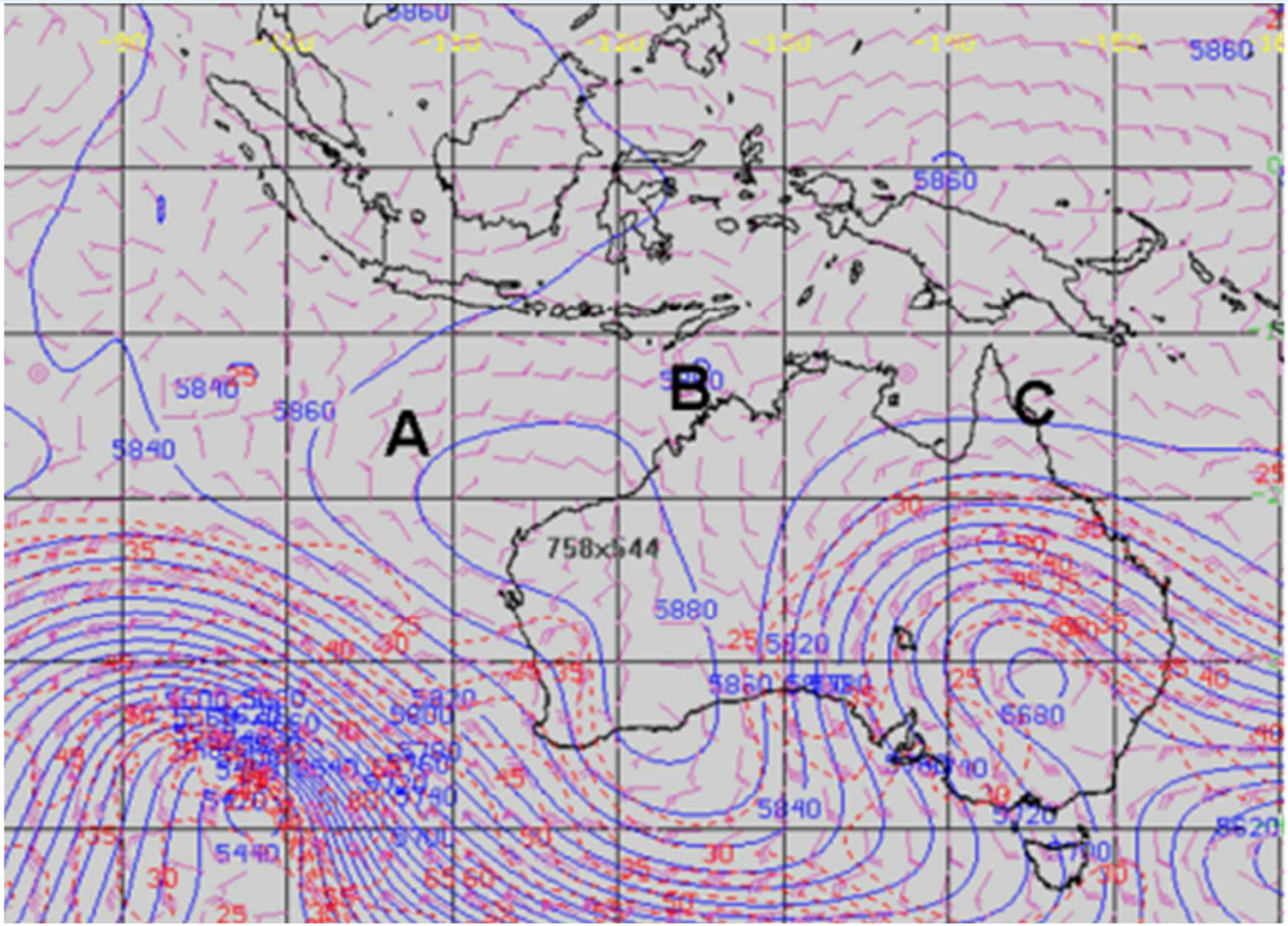
What direction would TCs be steered at A/B/C?



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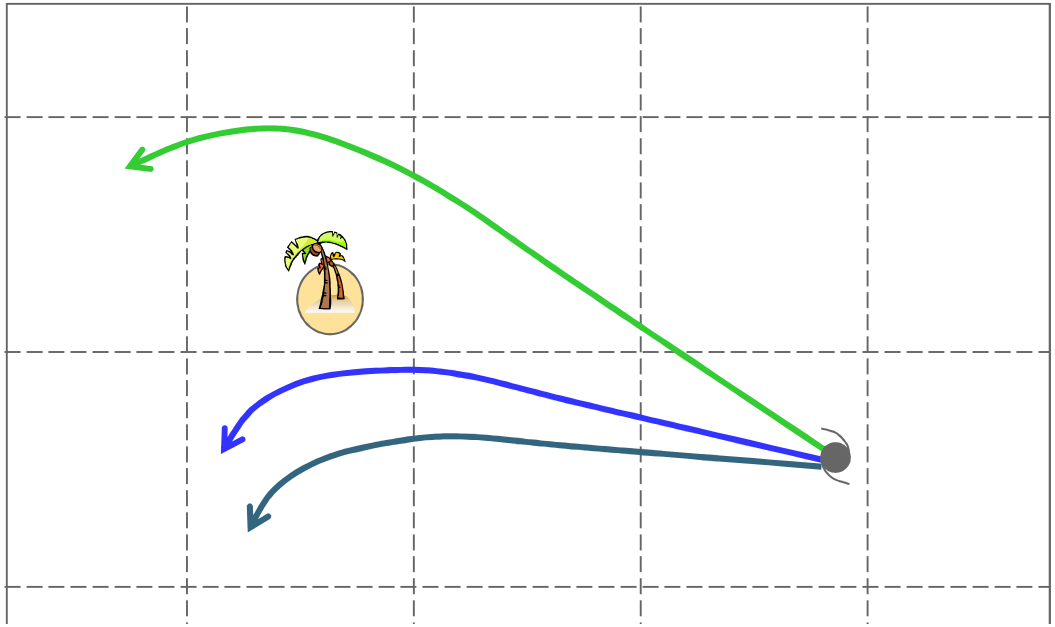
Consensus Forecasting

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



Forecast 1
Forecast 2
Forecast 3

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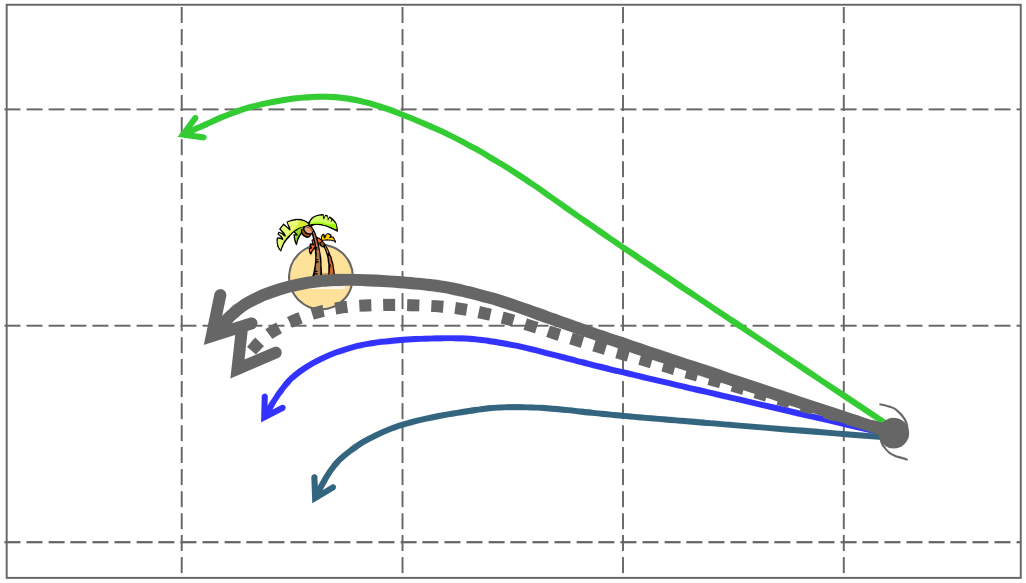
Suppose you have three forecasts for a tropical cyclone threatening an island...



Forecast 1
Forecast 2
Forecast 3

Simple average
Weighted average

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*

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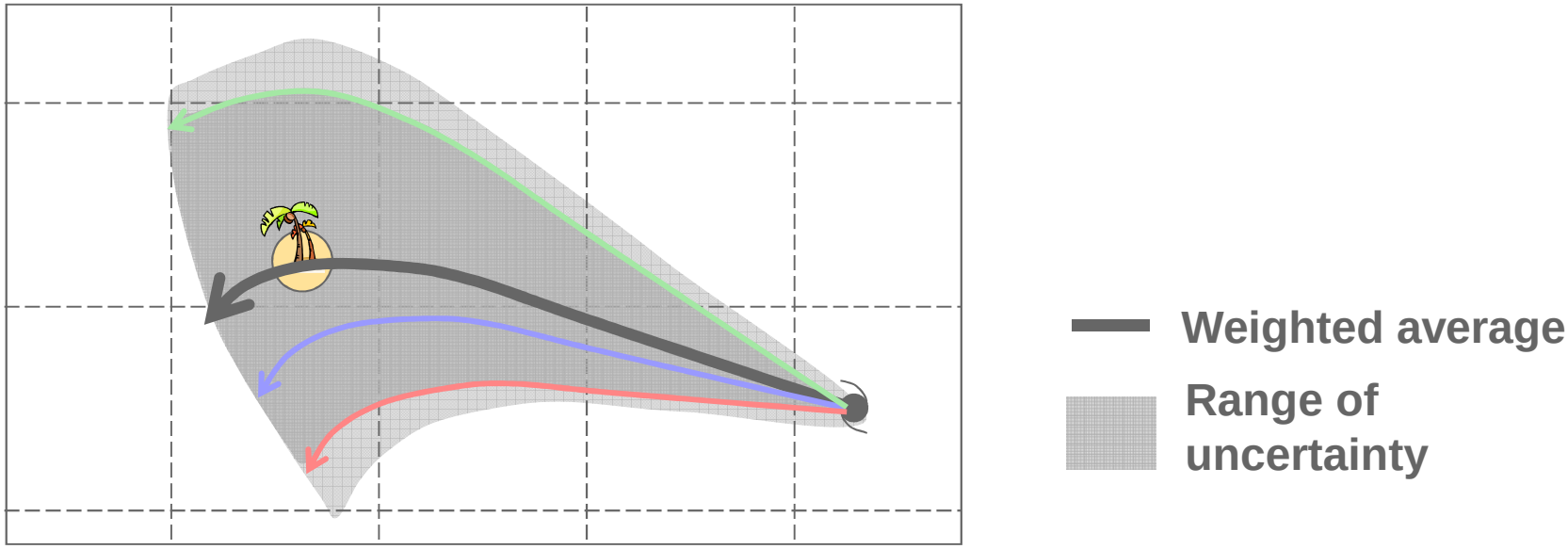
Suppose you have three forecasts for a tropical cyclone threatening an island...



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.

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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

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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

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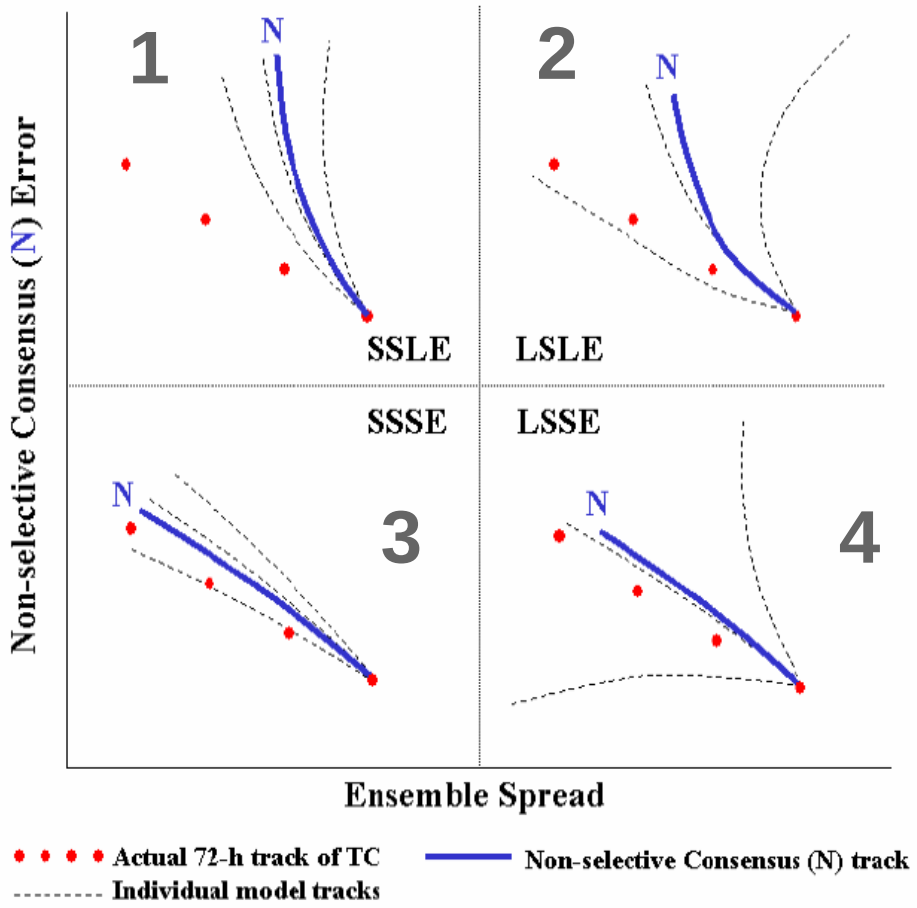
Error vs Spread

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



Courtesy: R. Ellsberry

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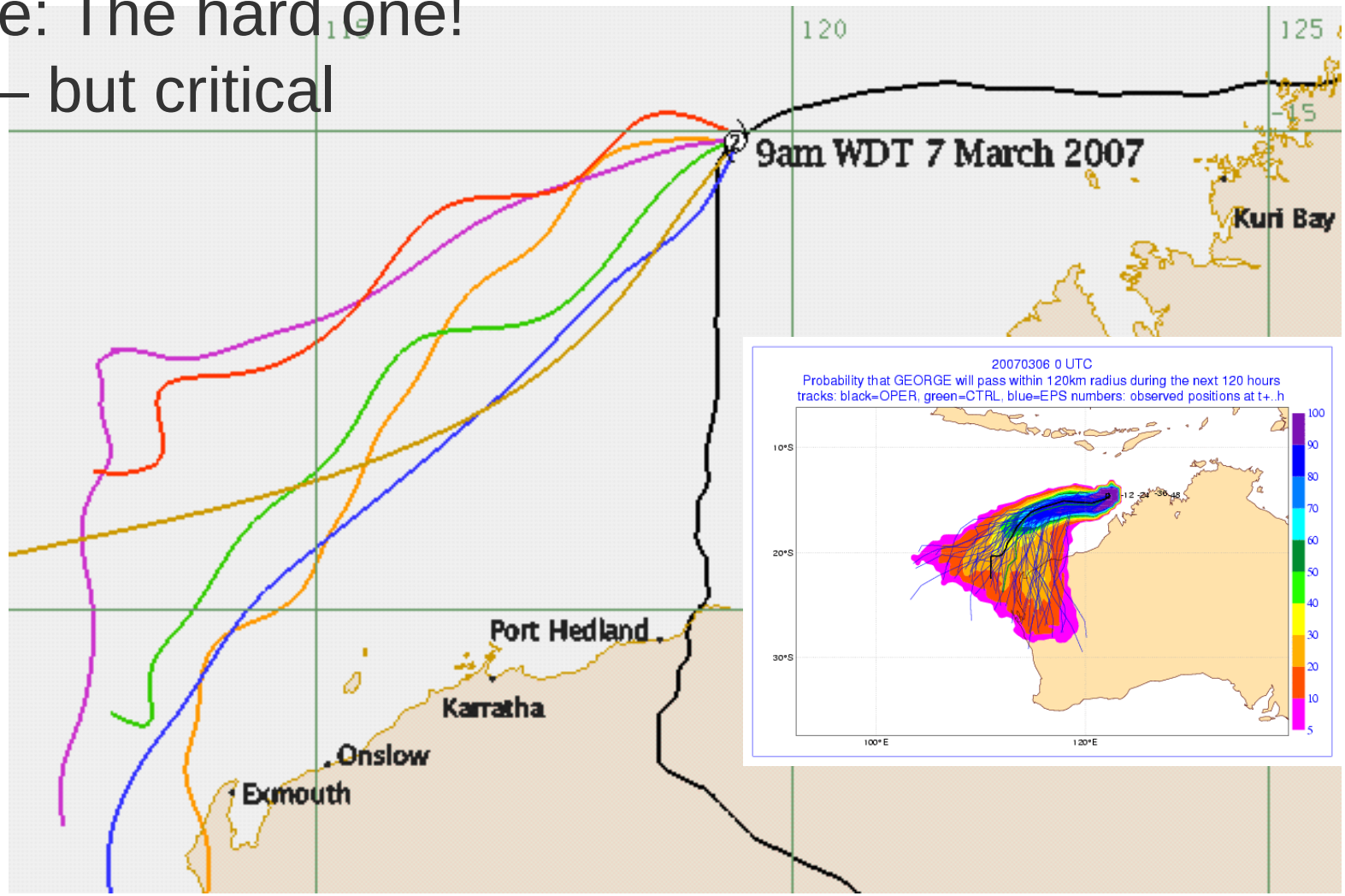
Low model spread- high error

TC George: The hard one!
Very rare – but critical



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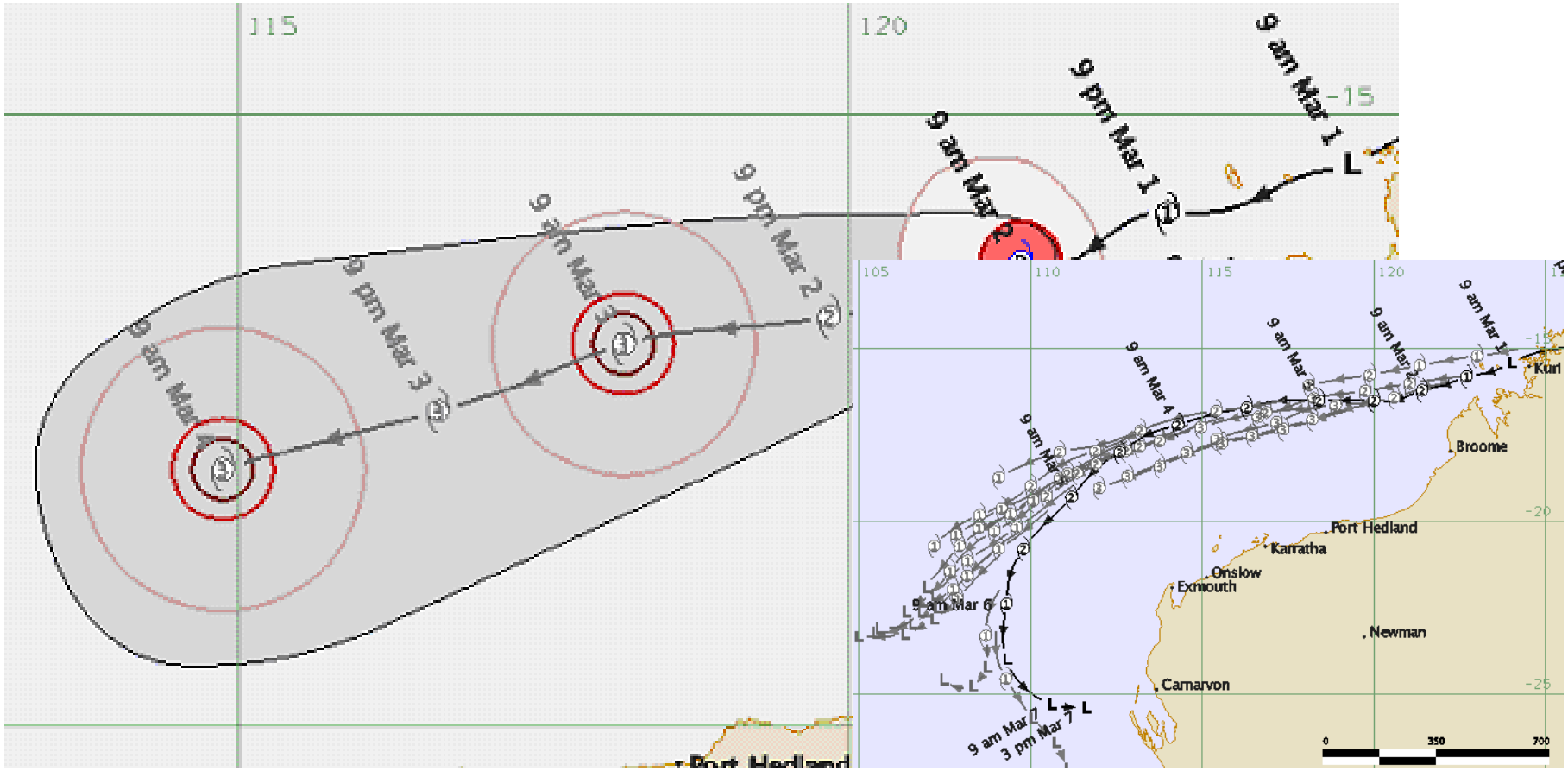
Low model spread - low error

Ophelia: High confidence



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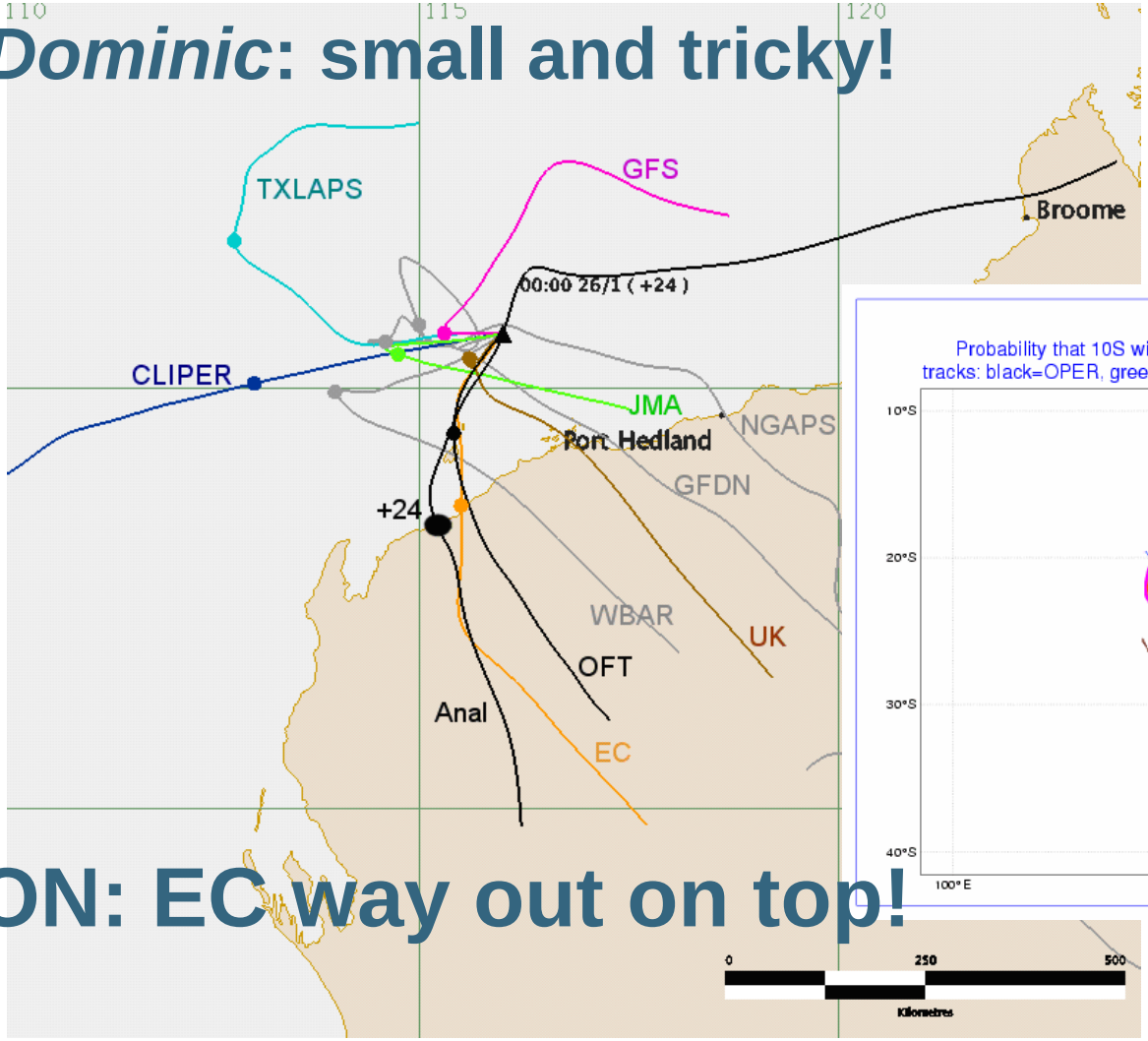
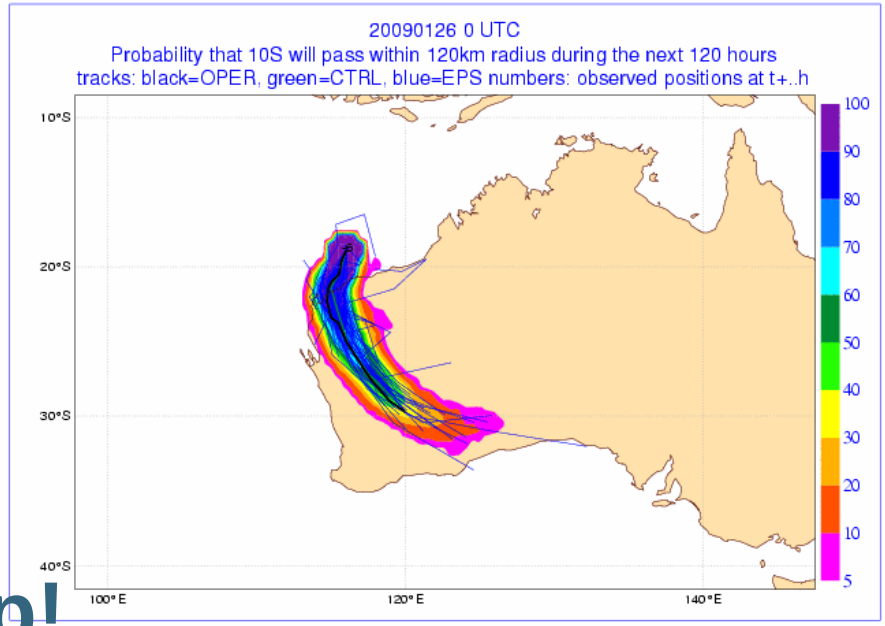
High model spread – challenge to be selective

Dominic: small and tricky!





SCON: EC way out on top!

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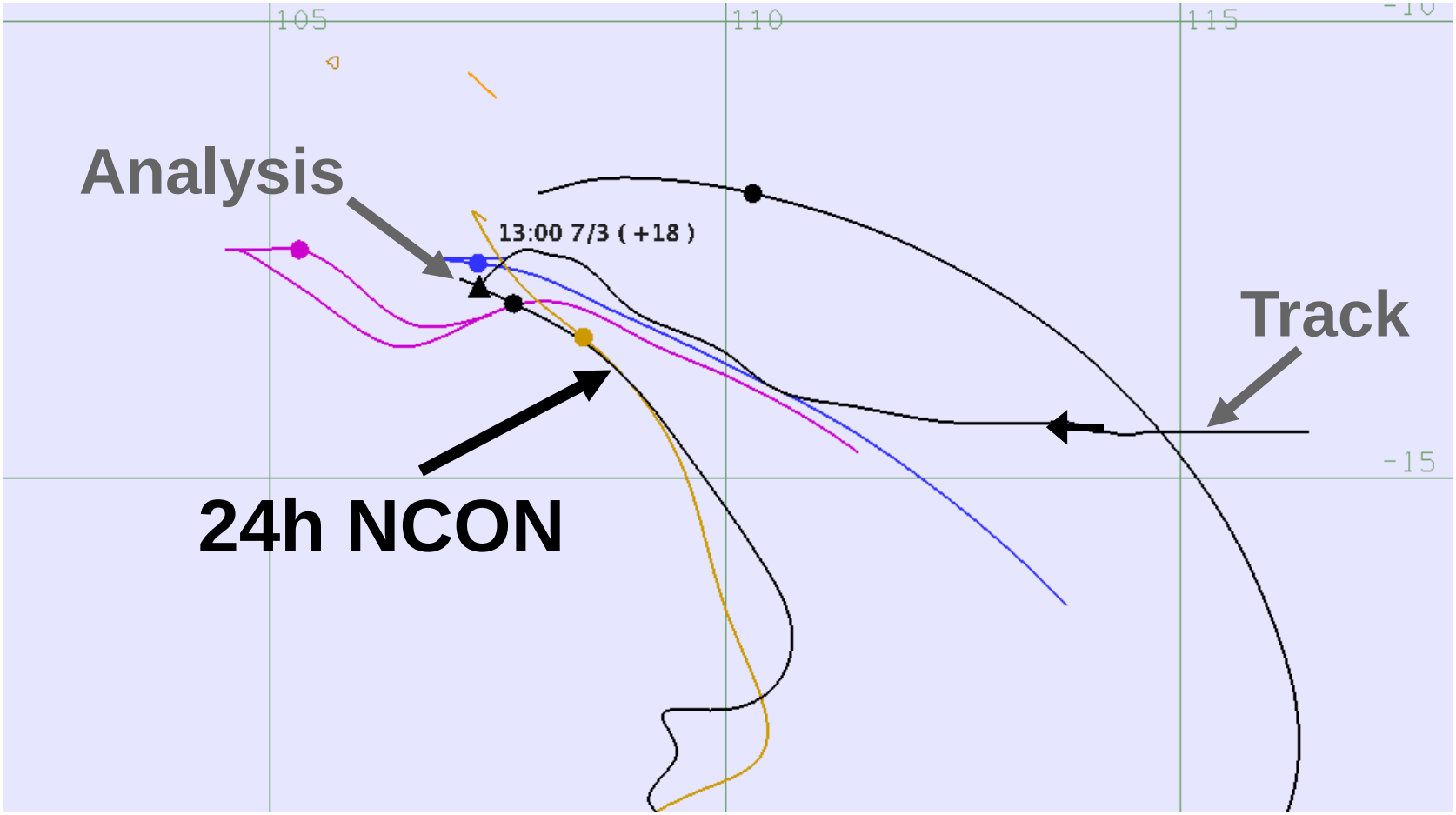
High model spread

Jacob: High uncertainty!



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High model spread

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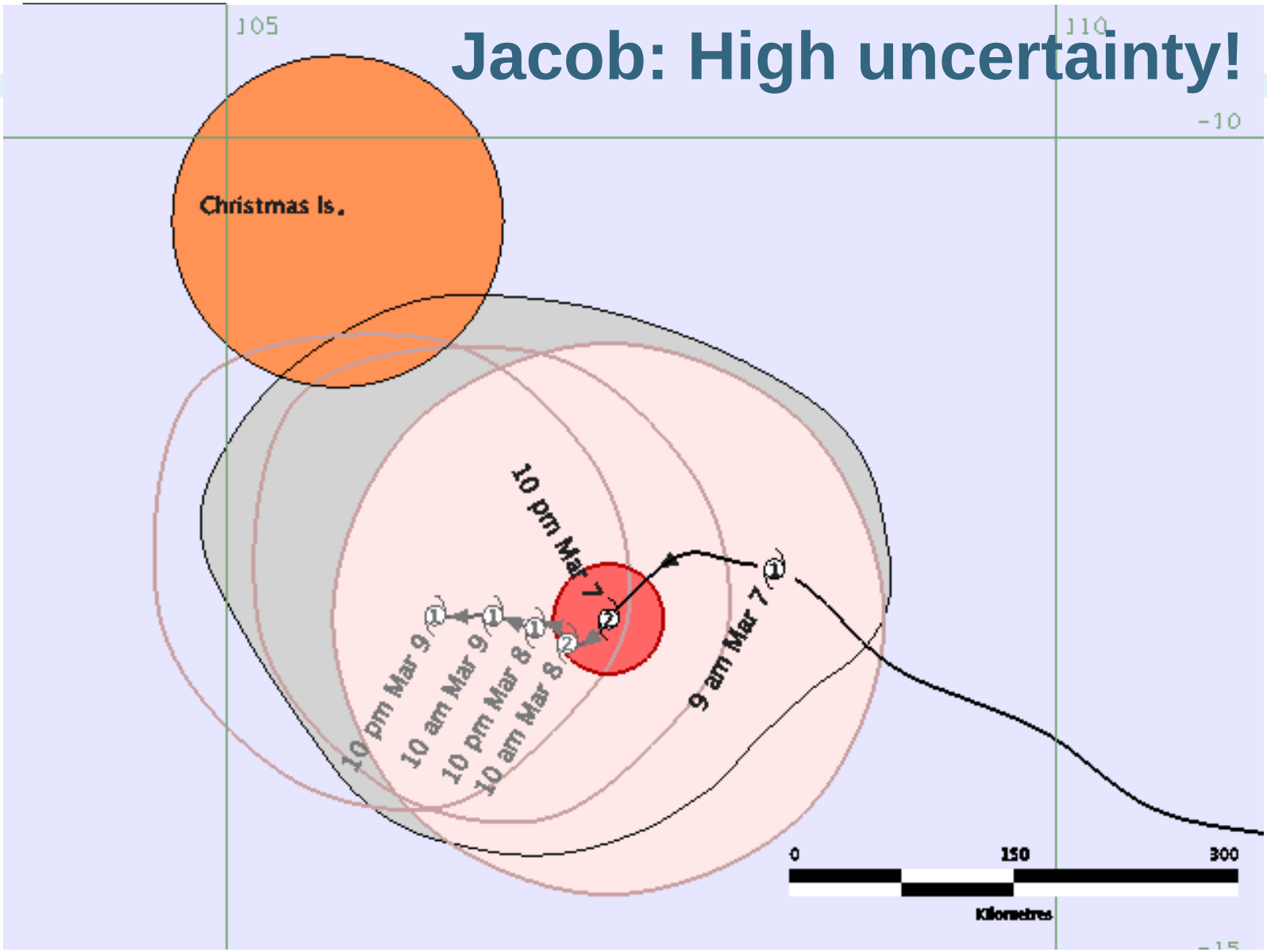

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Summary

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…

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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?

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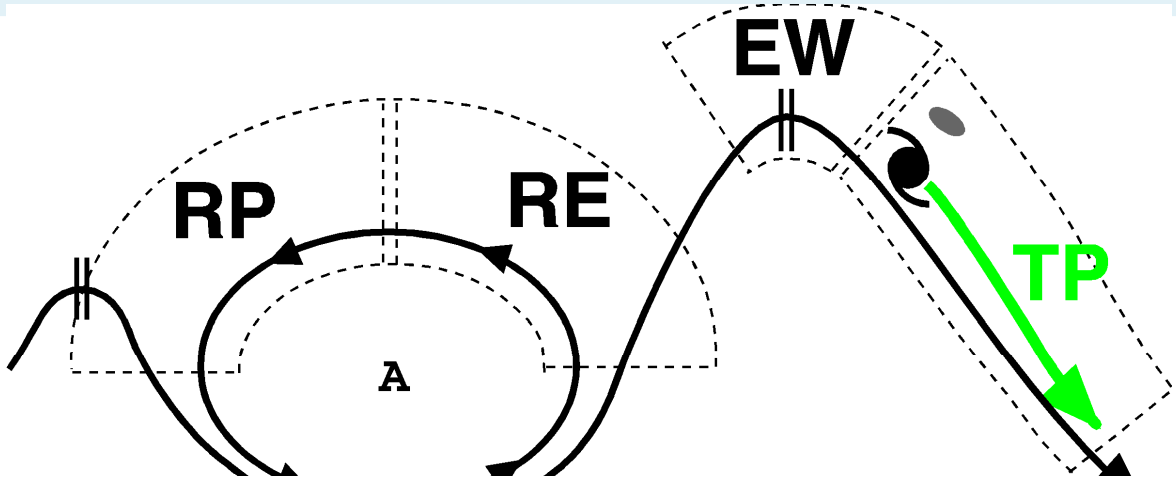
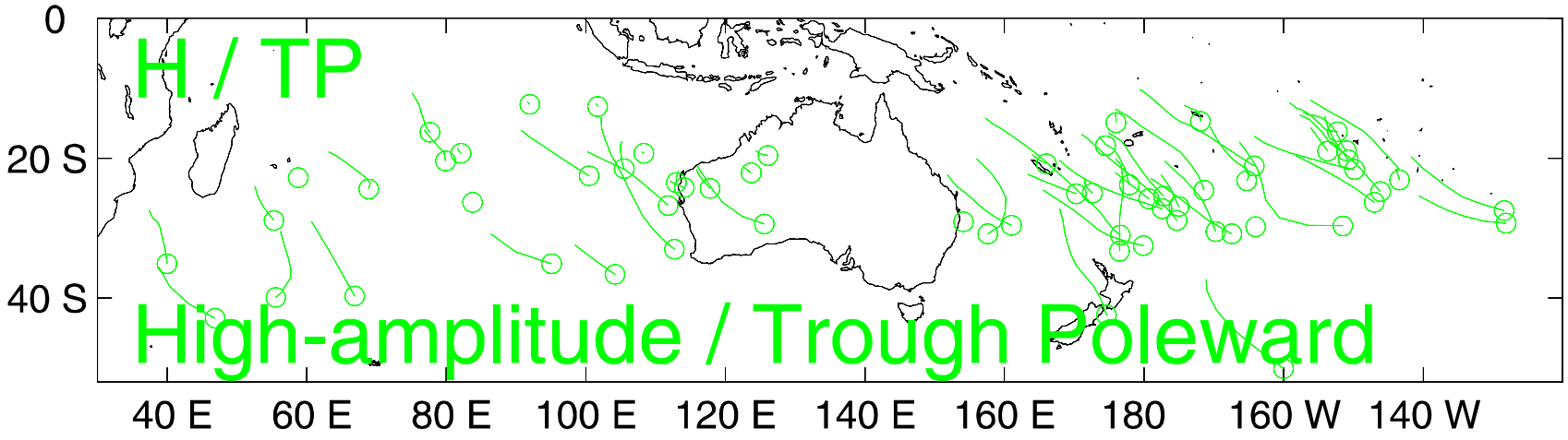
High-amplitude / Trough Poleward





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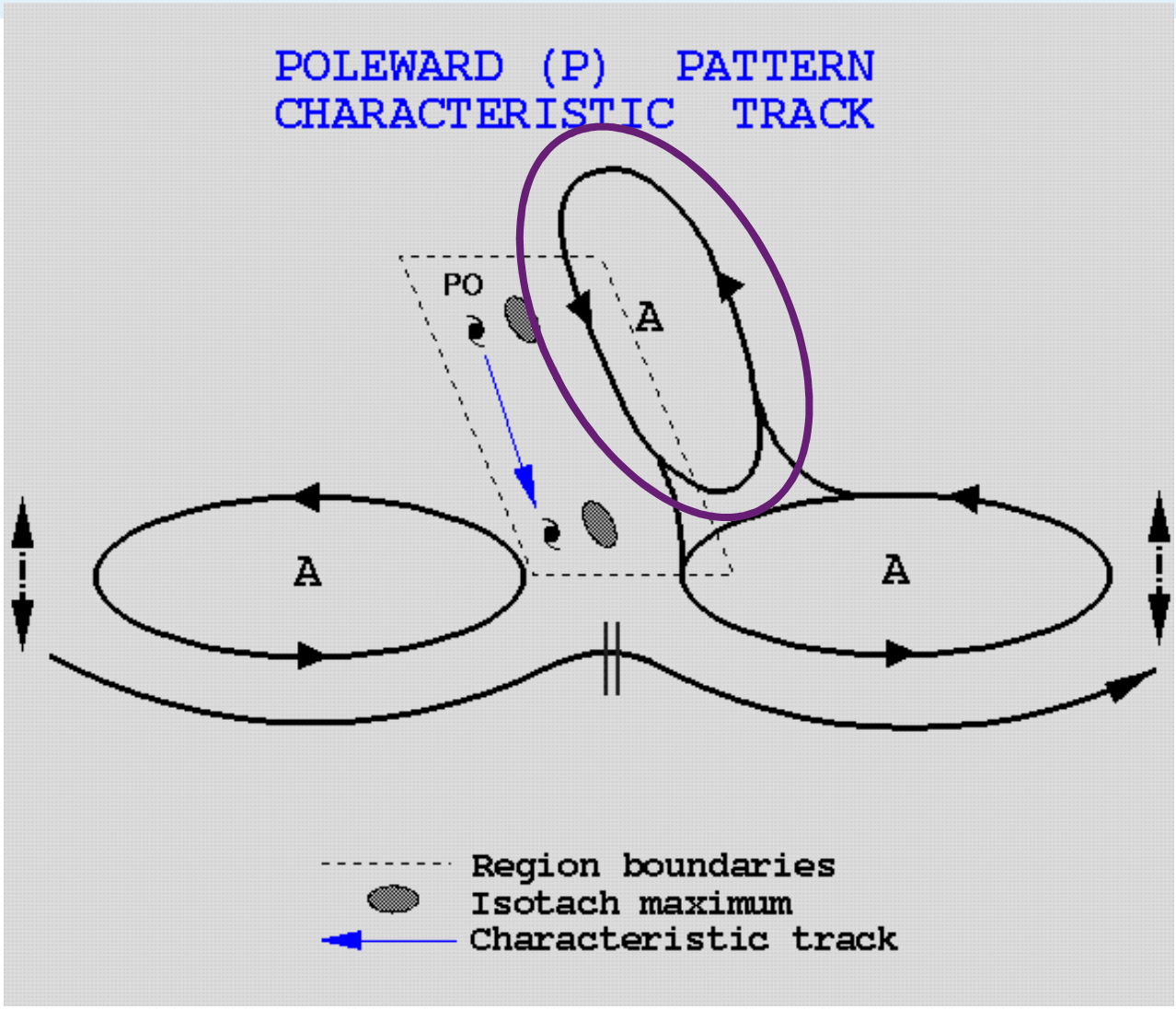
Poleward – peripheral ridge



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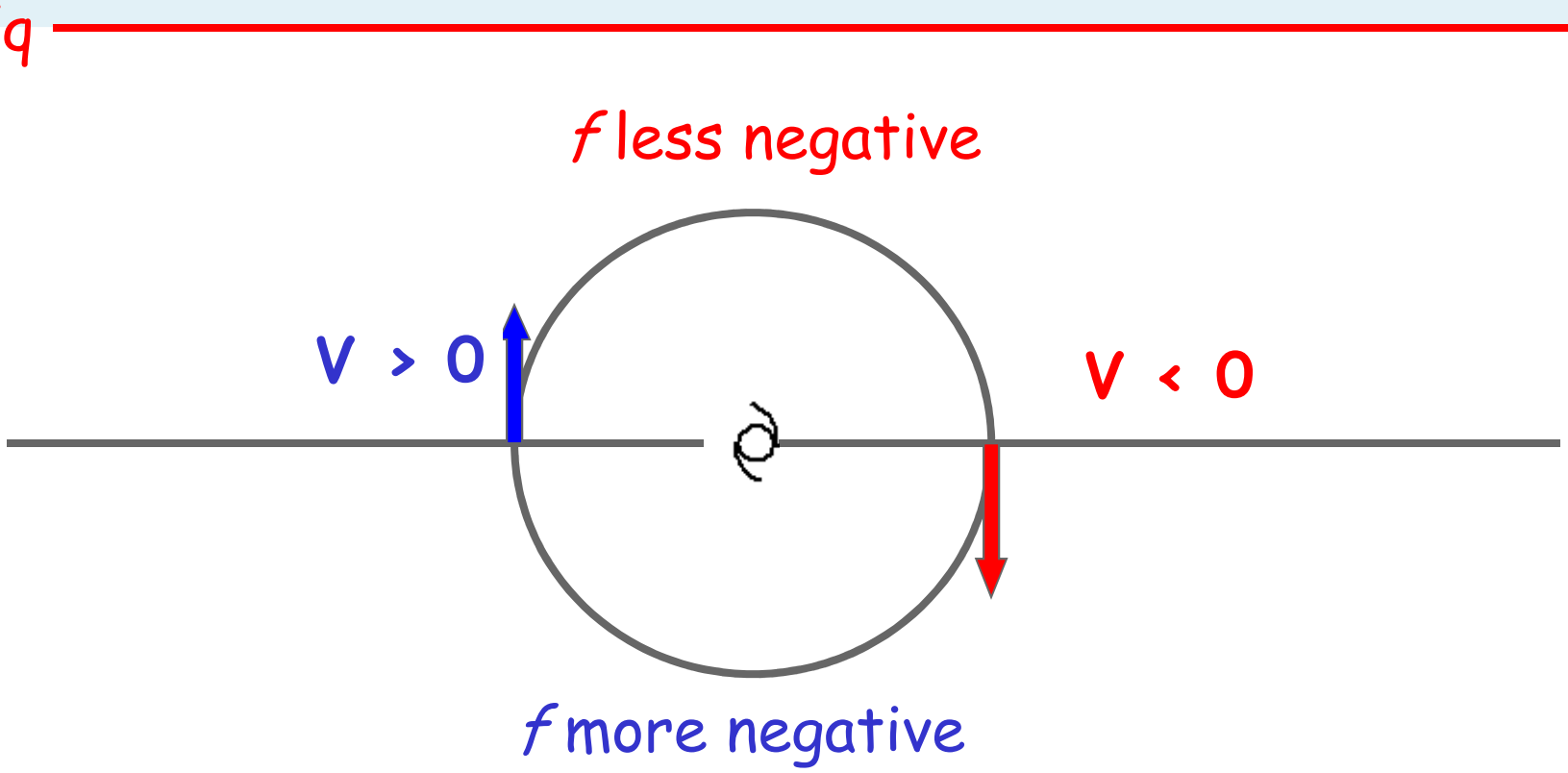
Planetary Vorticity Advection



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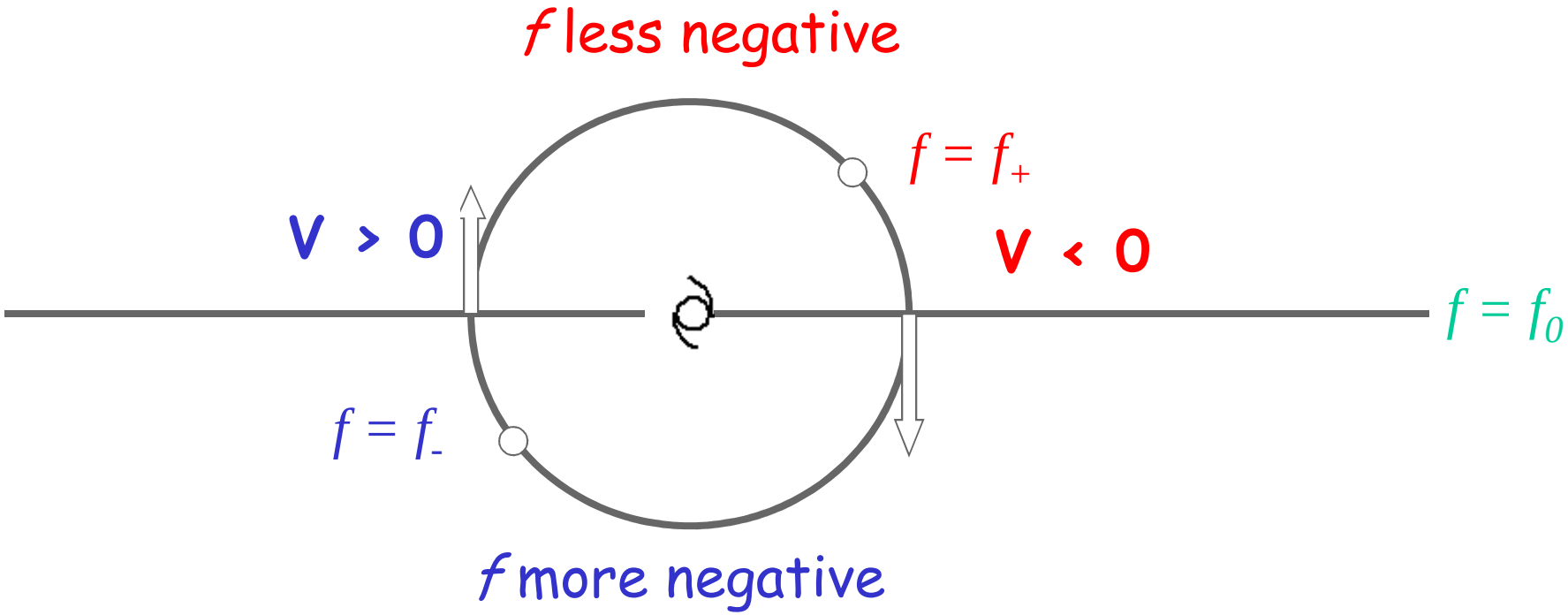
Planetary Vorticity Advection

Eq



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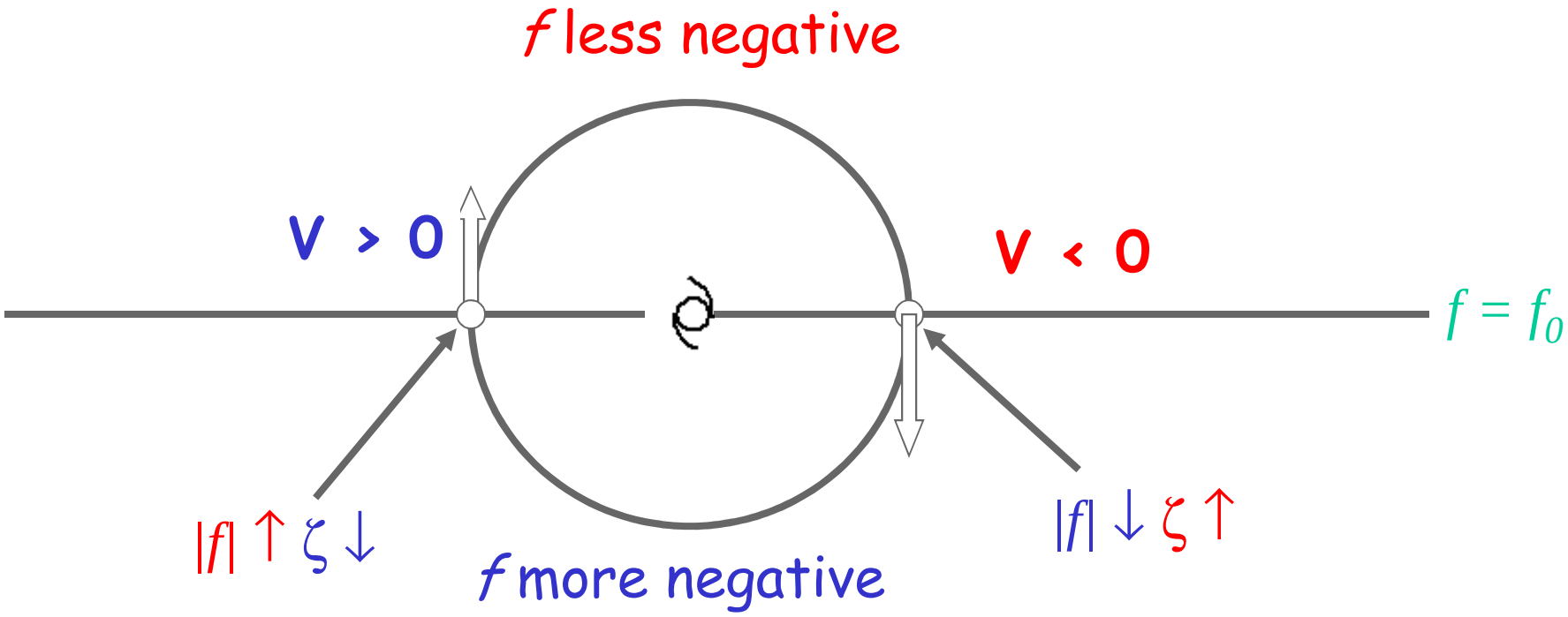

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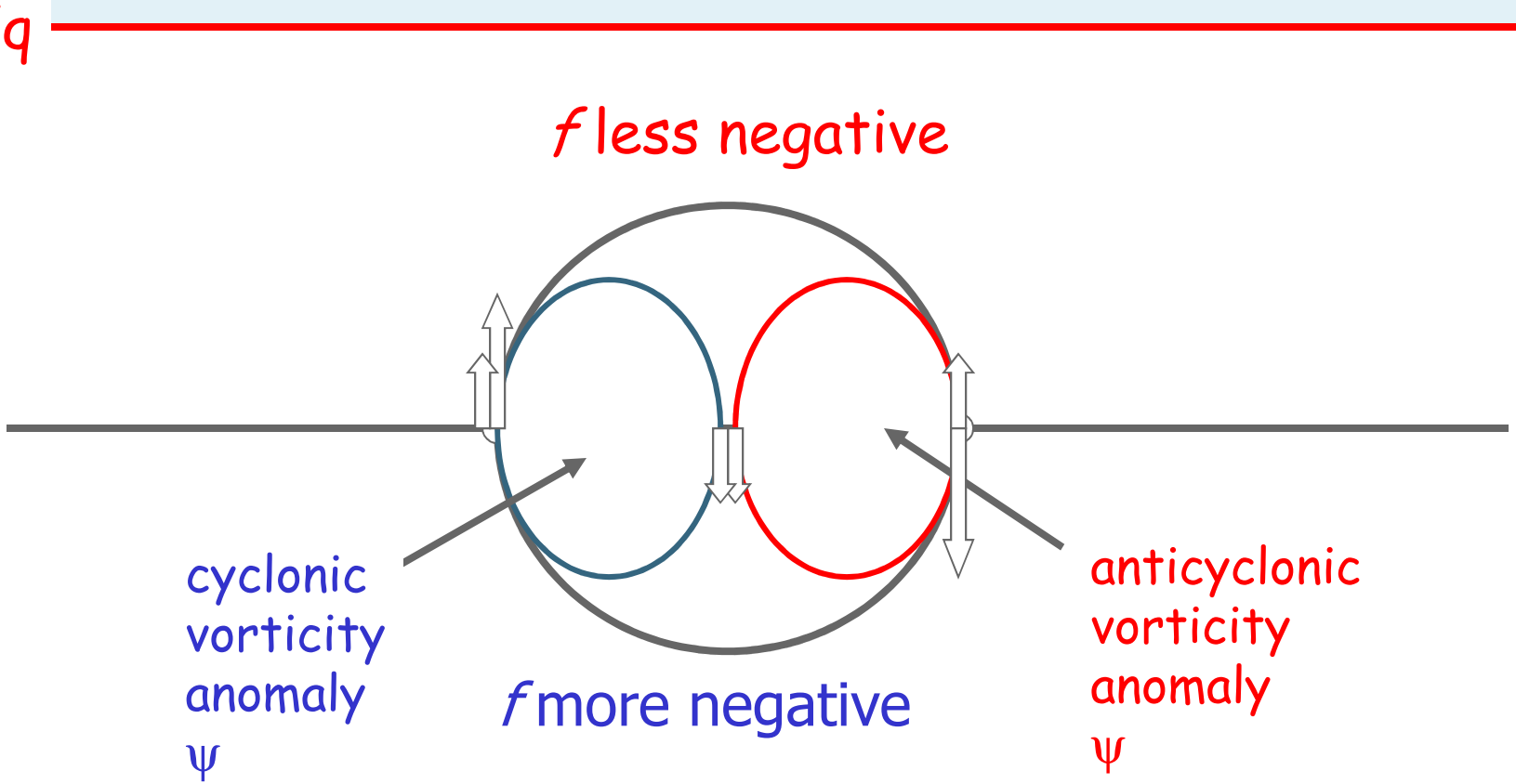

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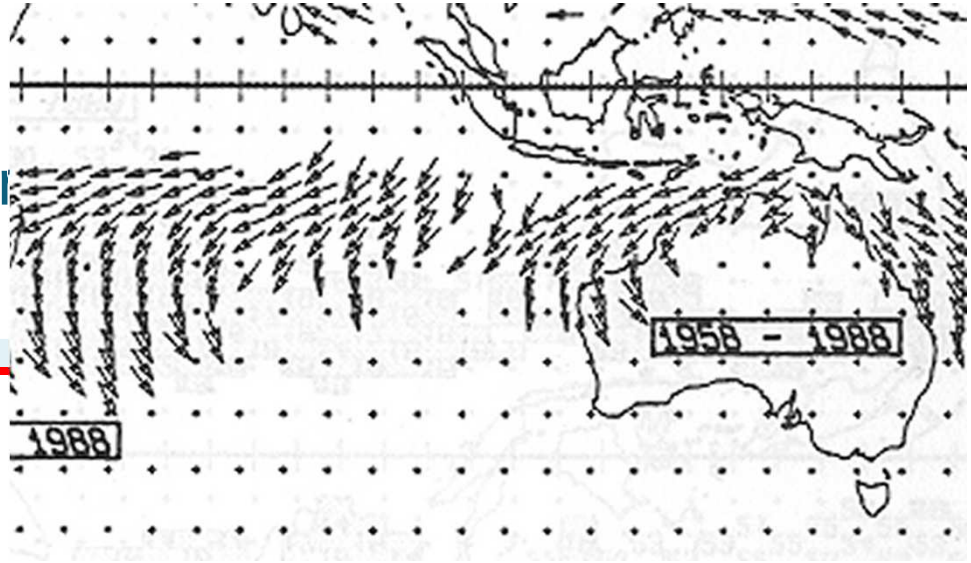
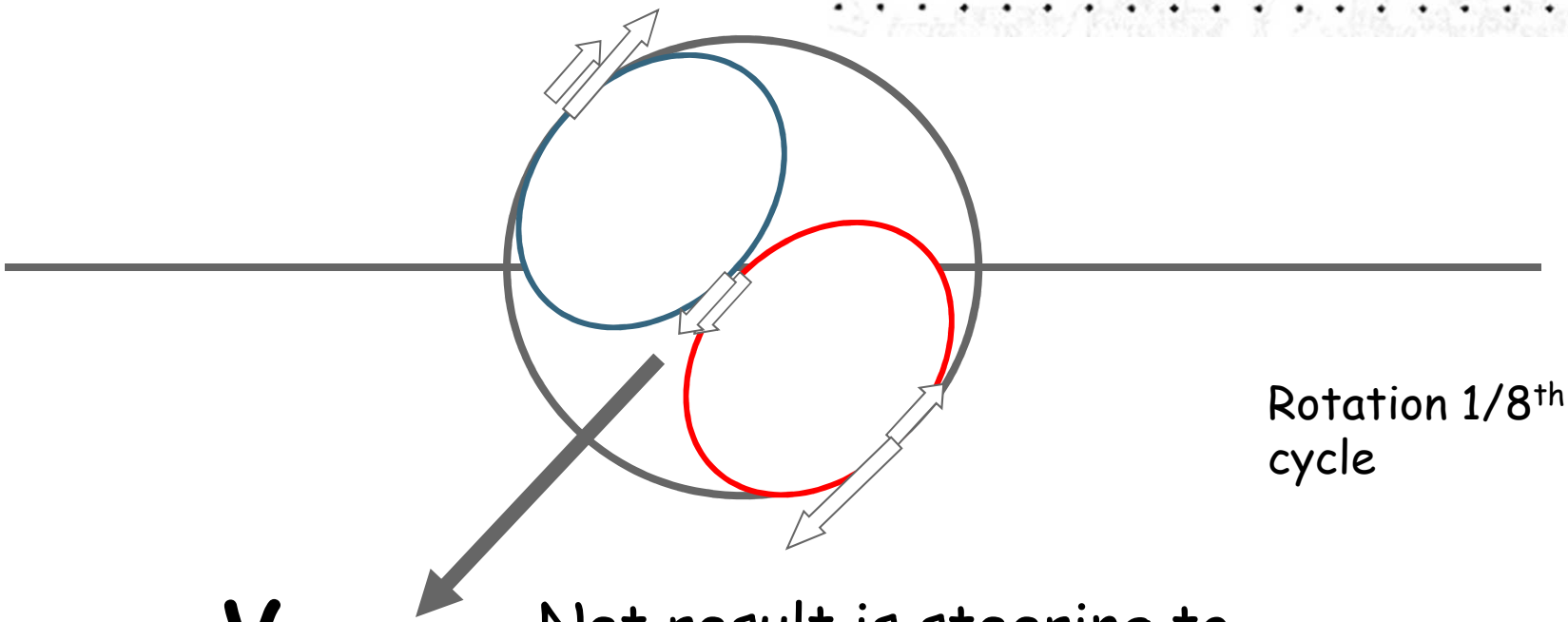
Planetar

Eq





Rotation 1/8th of a cycle

V_p

Net result is steering to **southwest** in **SH**

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Vorticity Equation

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).

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4×10^{-10} 4×10^{-10} 4×10^{-11} 2×10^{-10} 1×10^{-10} 4×10^{-11}

From NHC in 2011 WMO ppt

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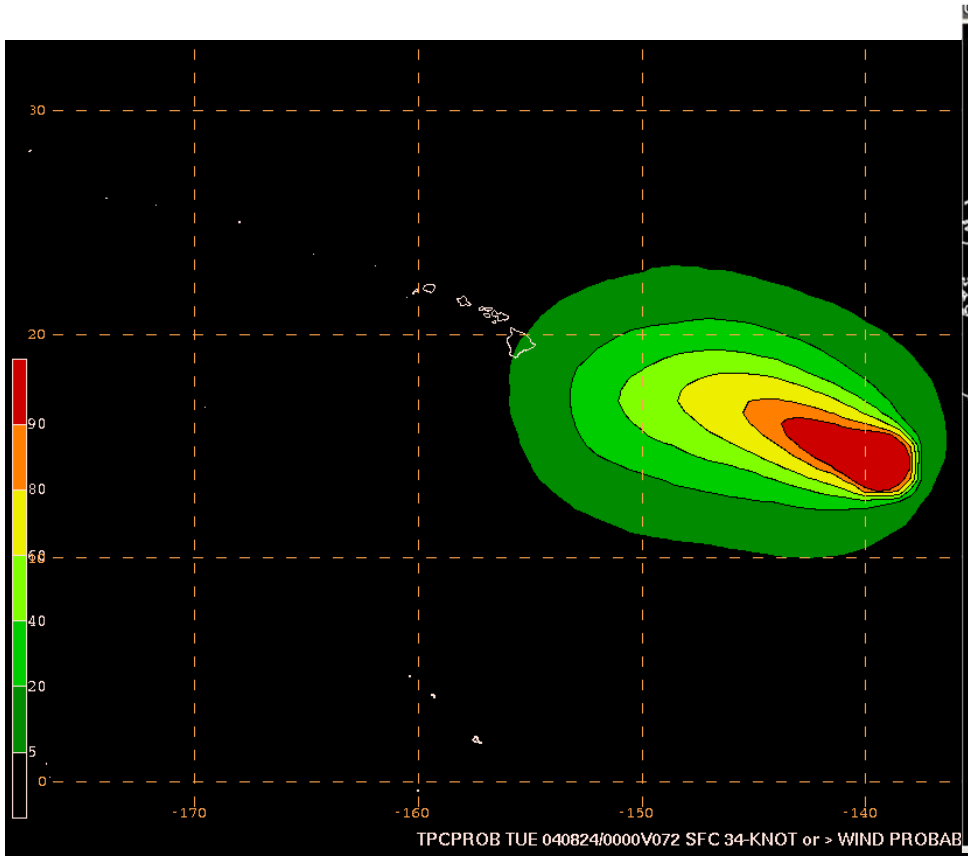
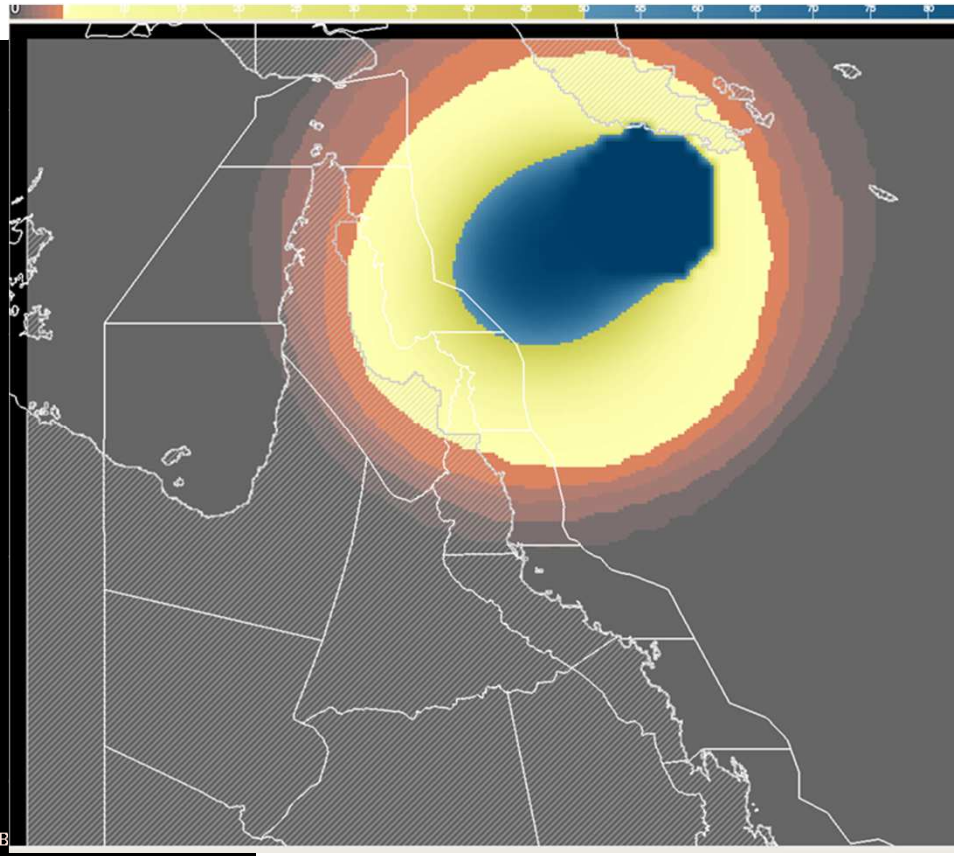
Moving to probability of impact – more info than probability of centre location

34 kt Cumulative



GFE probability of 34 kn winds



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TC Motion
"Cork in a stream"

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