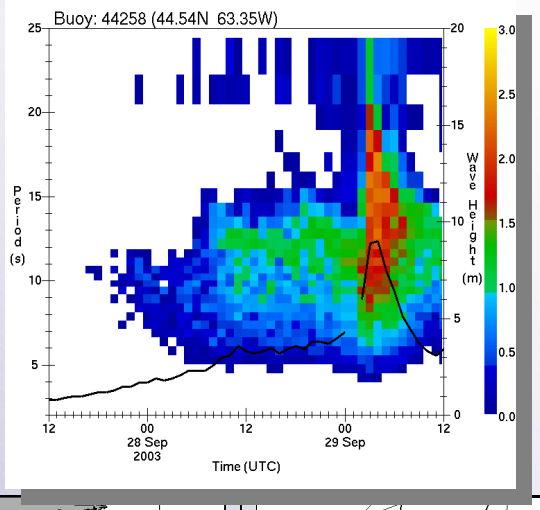
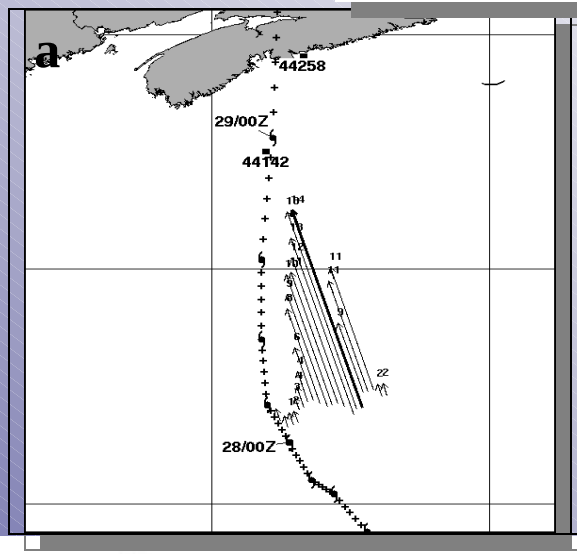
DESKTOP HURRICANE-WAVES RESONANCE MODELING

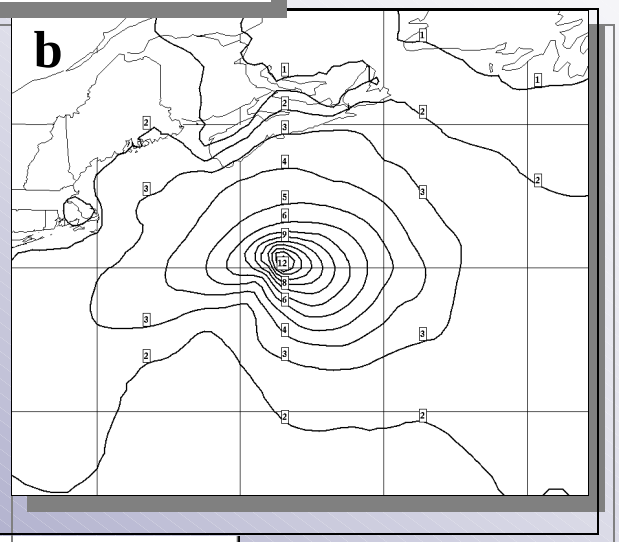
Zero to Waves in 60 Seconds

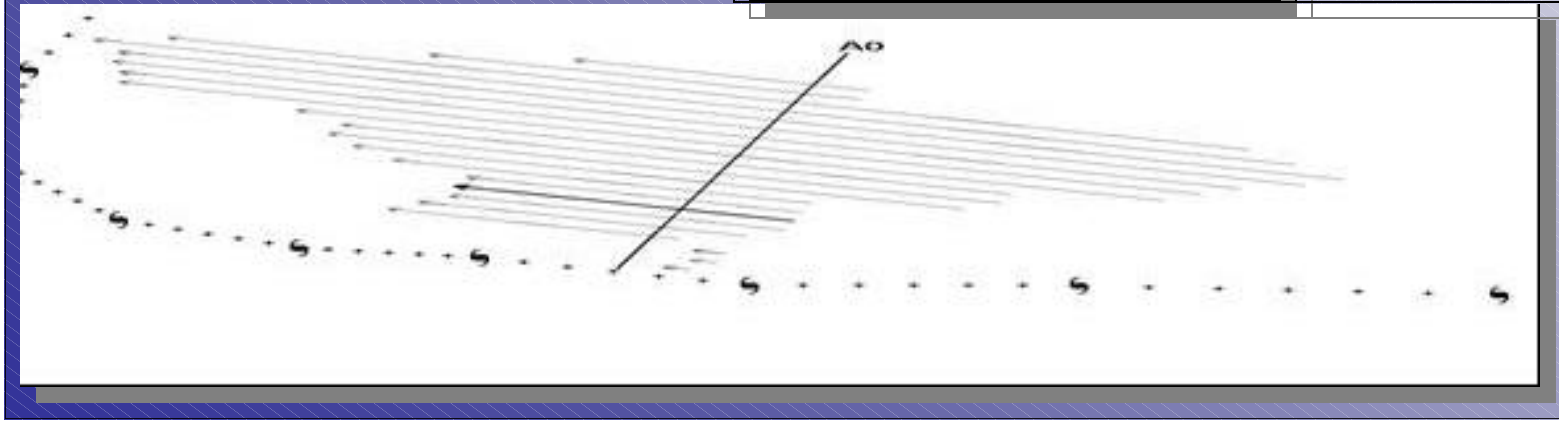
Allan W. MacAfee
Peter J. Bowyer



Canadian Hurricane Centre







OBJECTIVE

Canadian Hurricane Centre

To model the size and location of the largest significant waves with a tropical cyclone . . . past, present, or future . . . in an operationally-viable time (less than 1 minute).

Used in conjunction with full spectral wave models.

Dominant Factors

Canadian Hurricane Centre

Wind Waves - I.T.W.S. (Cardone)

“It’s the wind, stupid!”

Dominant Factors

Canadian Hurricane Centre

Wind Waves - I.T.W.S. (Cardone)

“It’s the wind, stupid!”

Shallow Water - I.T.B.S. (Smith)

“It’s the bathymetry, stupid!”

Dominant Factors

Canadian Hurricane Centre

Wind Waves - I.T.W.S. (Cardone)

“It’s the wind, stupid!”

Shallow Water - I.T.B.S. (Smith)

“It’s the bathymetry, stupid!”

Moving Systems - A.T.S.S.D. (MacAfee & Bowyer)

“And the storm speed, dummy!”

Trapped-Fetch Waves

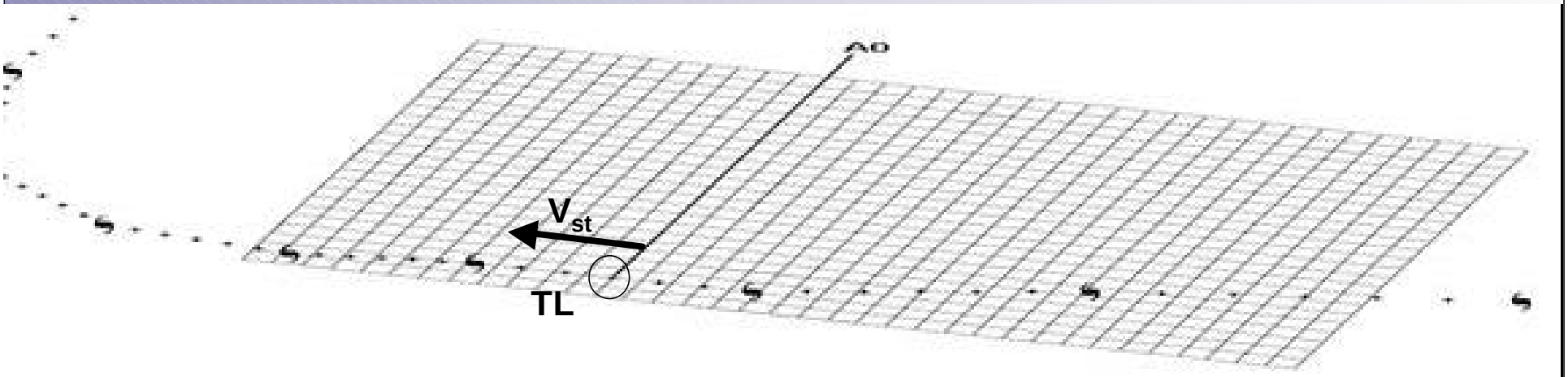
Canadian Hurricane Centre

The key to forecasting trapped-fetch waves is to remember to think in a Lagrangian reference frame since the waves may continue to build if they move in harmony with a translating weather system which supports them . . . even if the storm is weakening!!!

The complexities of tropical cyclone wind fields and the waves that they generate require a wave model which employs a parameterized wind field and a highly resolved wave calculation methodology.

MODEL GRID

Canadian Hurricane Centre

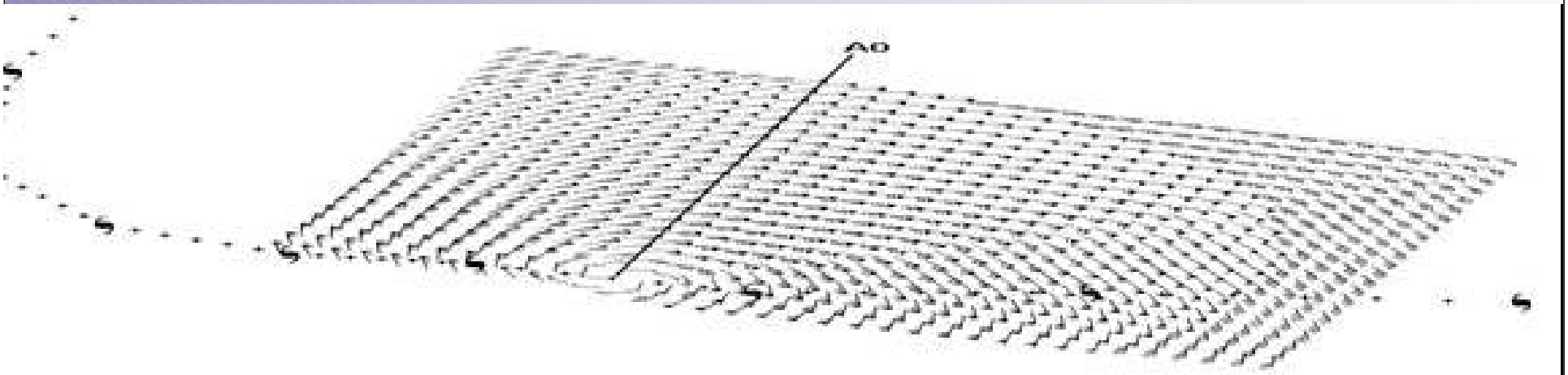


- 6-hrly HURDAT track converted to 1-hr track locations
- 37 X 25 modeling grid (6 n mi / 11 km resolution)
- Reference line A_0 is orthogonal to storm motion V_{st}
- Unique rectangular offset grid always captures the largest waves while also minimizing computational time

MODEL WINDS

Modified Rankine
Slosh
Modified Holland
DeMaria Vortex

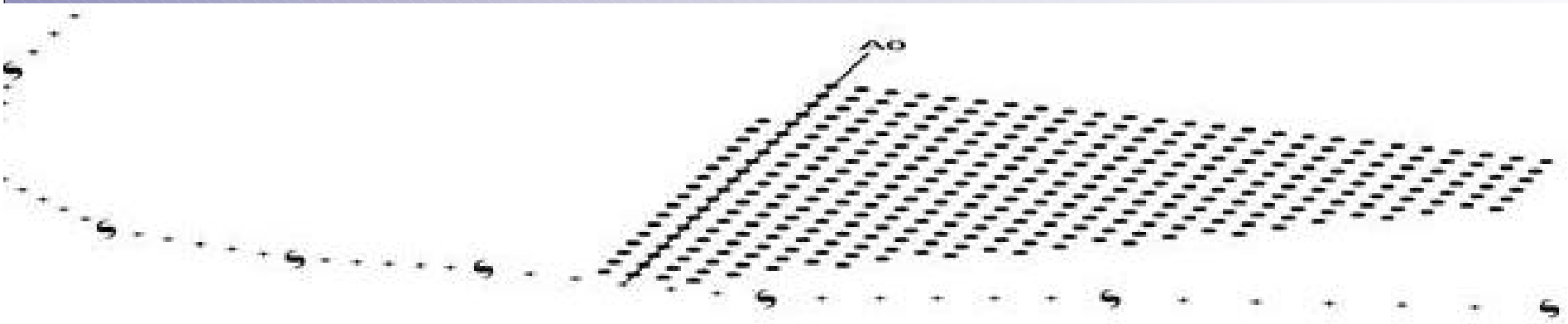
Canadian Hurricane Centre



- CHC parametric wind models (modified Holland shown)
- Wind displayed at every 2nd grid point
- Forecaster-specified or HURDAT. . . converted to 1-hr

WAVE MODEL "Seed Points"

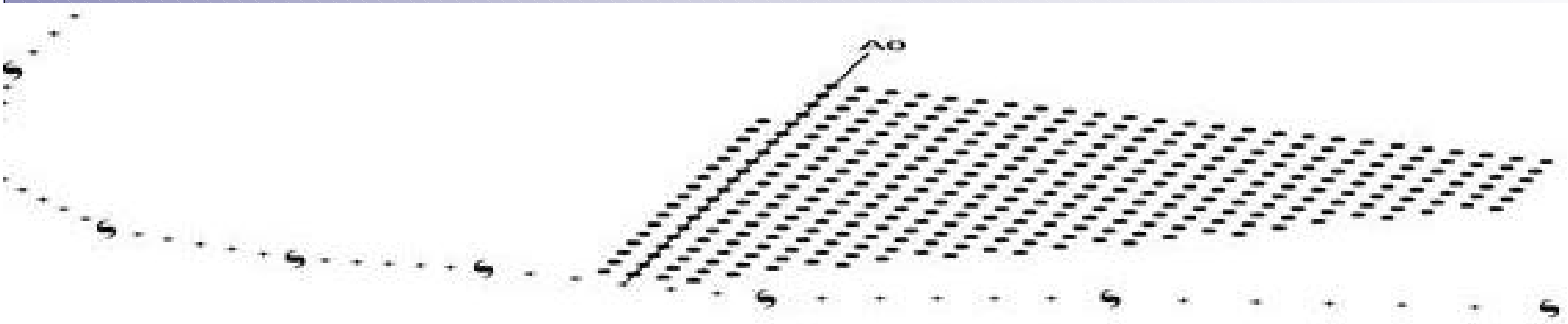
Canadian Hurricane Centre



To reduce computational time, originating wave-points are pre-selected only for waves that "have a future," based on criteria for both wind speed and direction. The reduced, non-interacting wave point calculation set is determined by:

WAVE MODEL "Seed Points"

Canadian Hurricane Centre

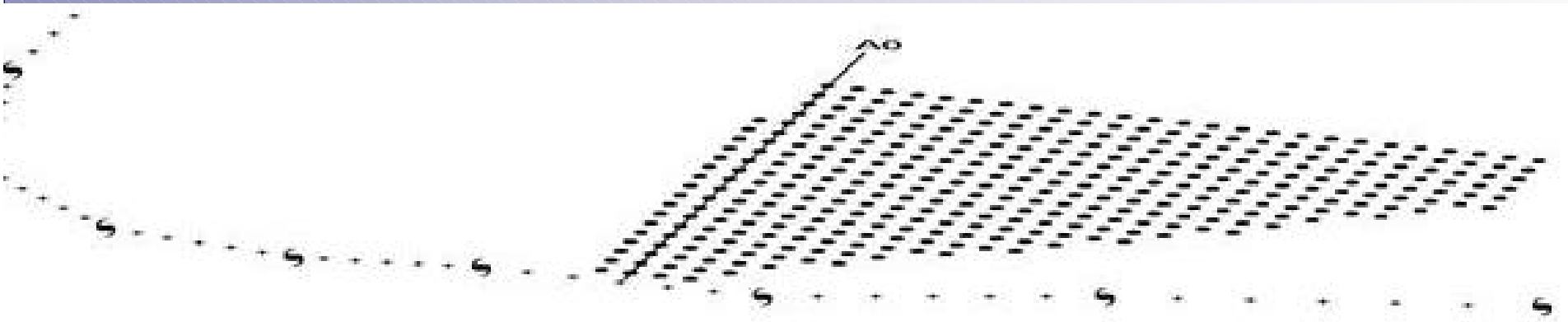


1. Wind direction criterion – within 30 degrees of V_{st} (Saville). Applied to points forward of A_0
2. Wind speed criterion – within 75% of winds along A0. (Determined through testing). Applied to points trailing A0.

WAVE MODEL

(Bretschneider formulations)

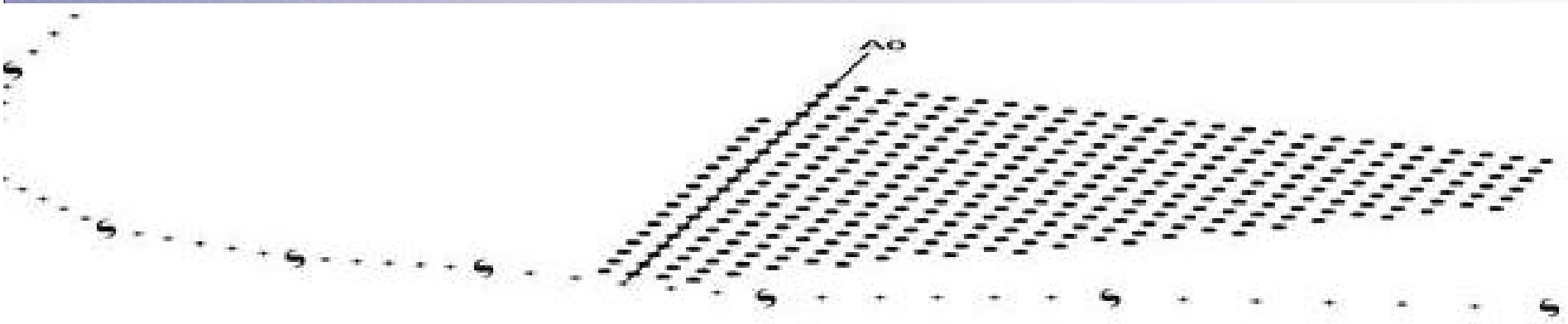
Canadian Hurricane Centre



- Waves are generated at each point with wave energy propagating only in the direction of storm motion (as a trajectory) . . . for a time-step of 1 hour
- Storm advances 1 hour and the new winds are applied to the new waves

WAVE MODEL

Canadian Hurricane Centre

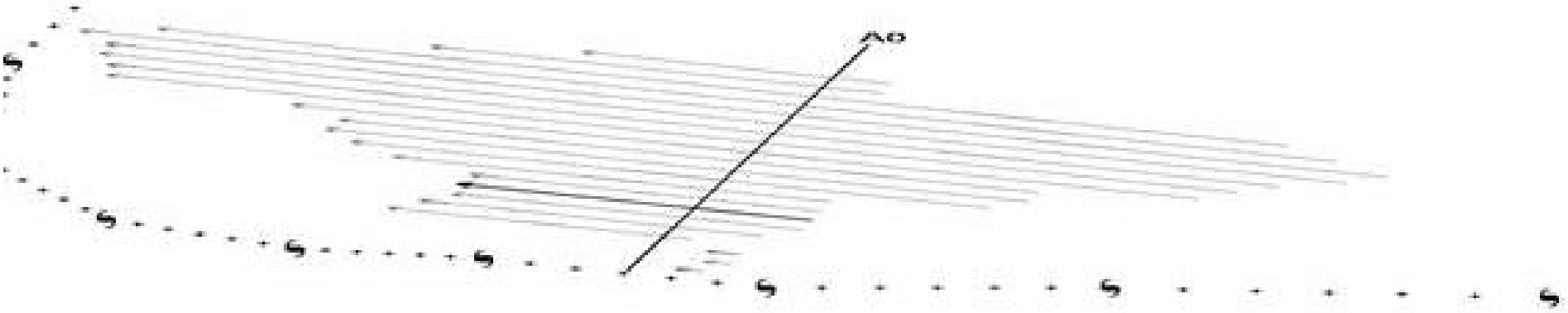


- Waves from each initial calculation point are generated through successive time-steps until they are no longer supported by the local wind . . . they are then terminated.
- The trajectory from each grid row (perpendicular to A_0) which generates the largest waves is retained.

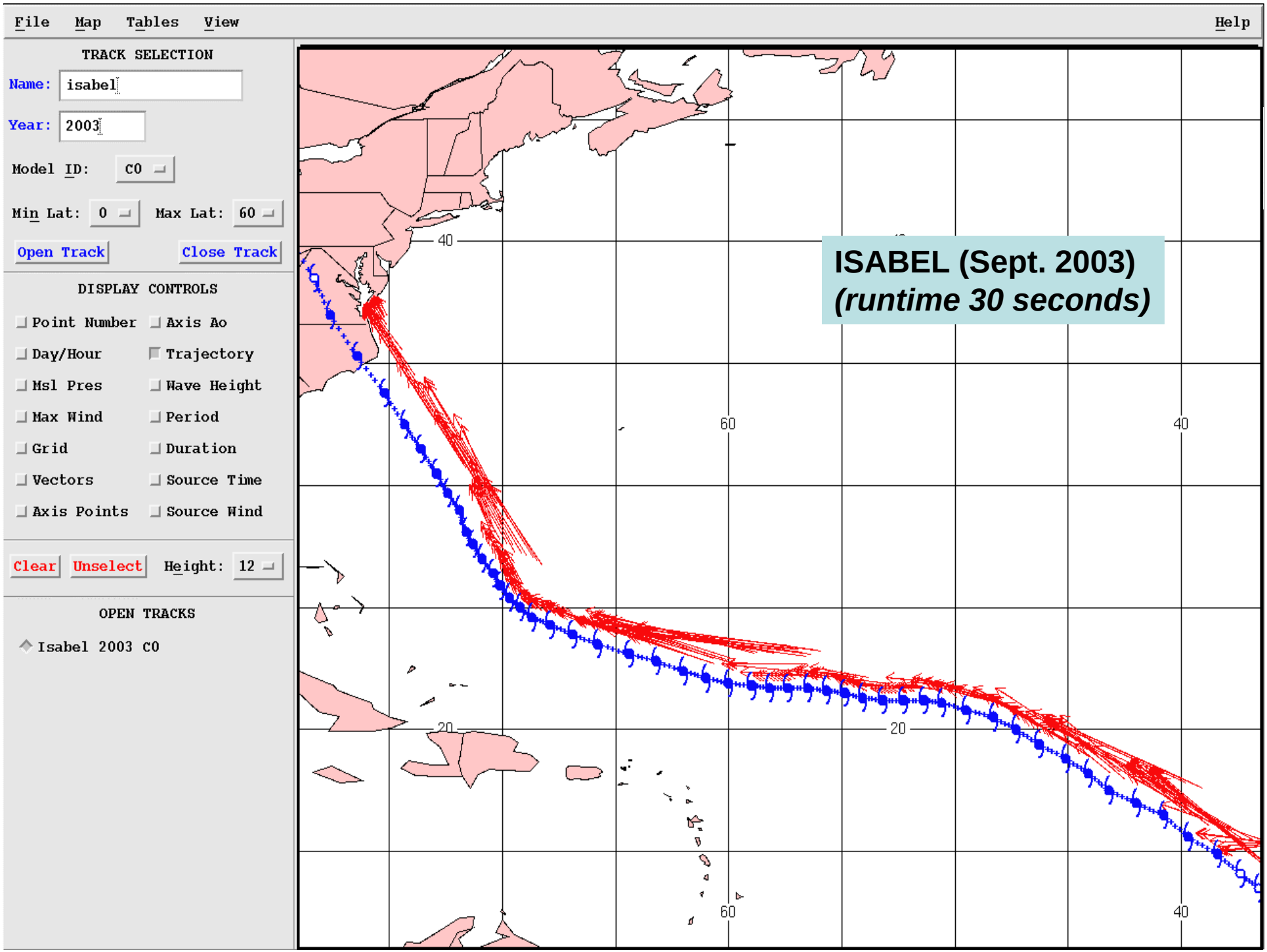
WAVE MODEL – Wave trajectories

(from a single initial track location)

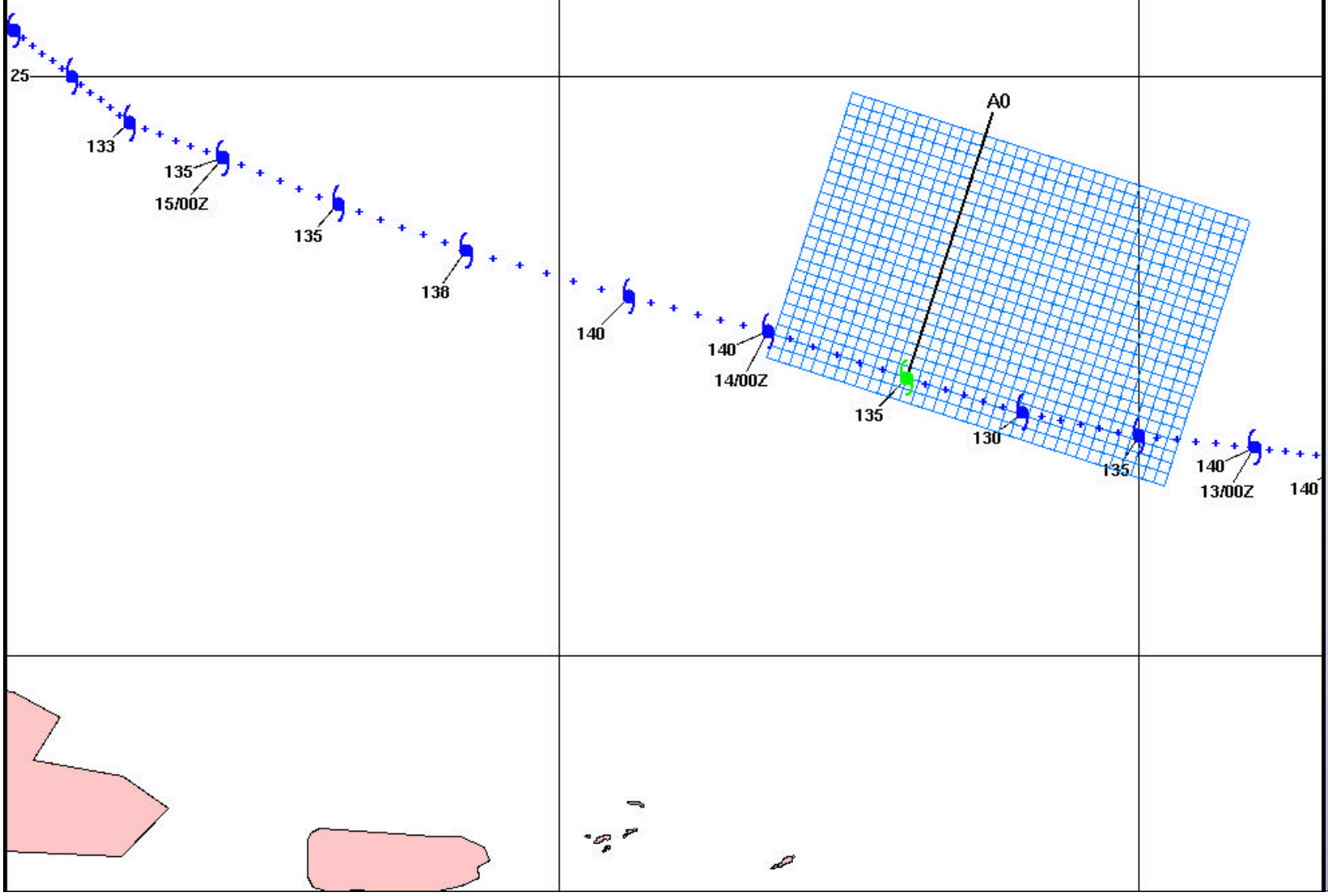
Canadian Hurricane Centre



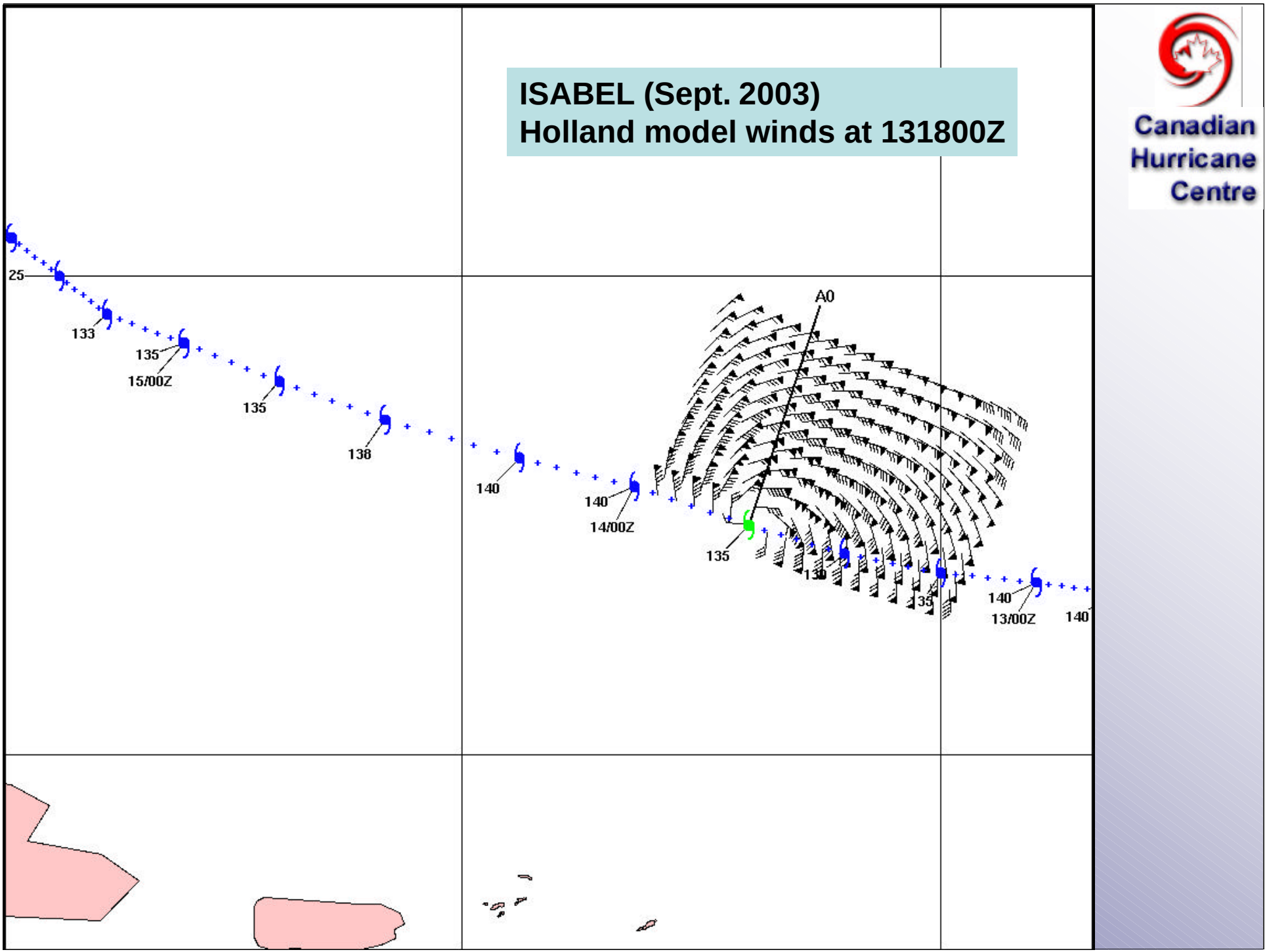
- The trajectory generating the largest waves from each grid row is plotted.
- The trajectory from all rows which generates the largest waves (the dominant trajectory) is highlighted in **bold**

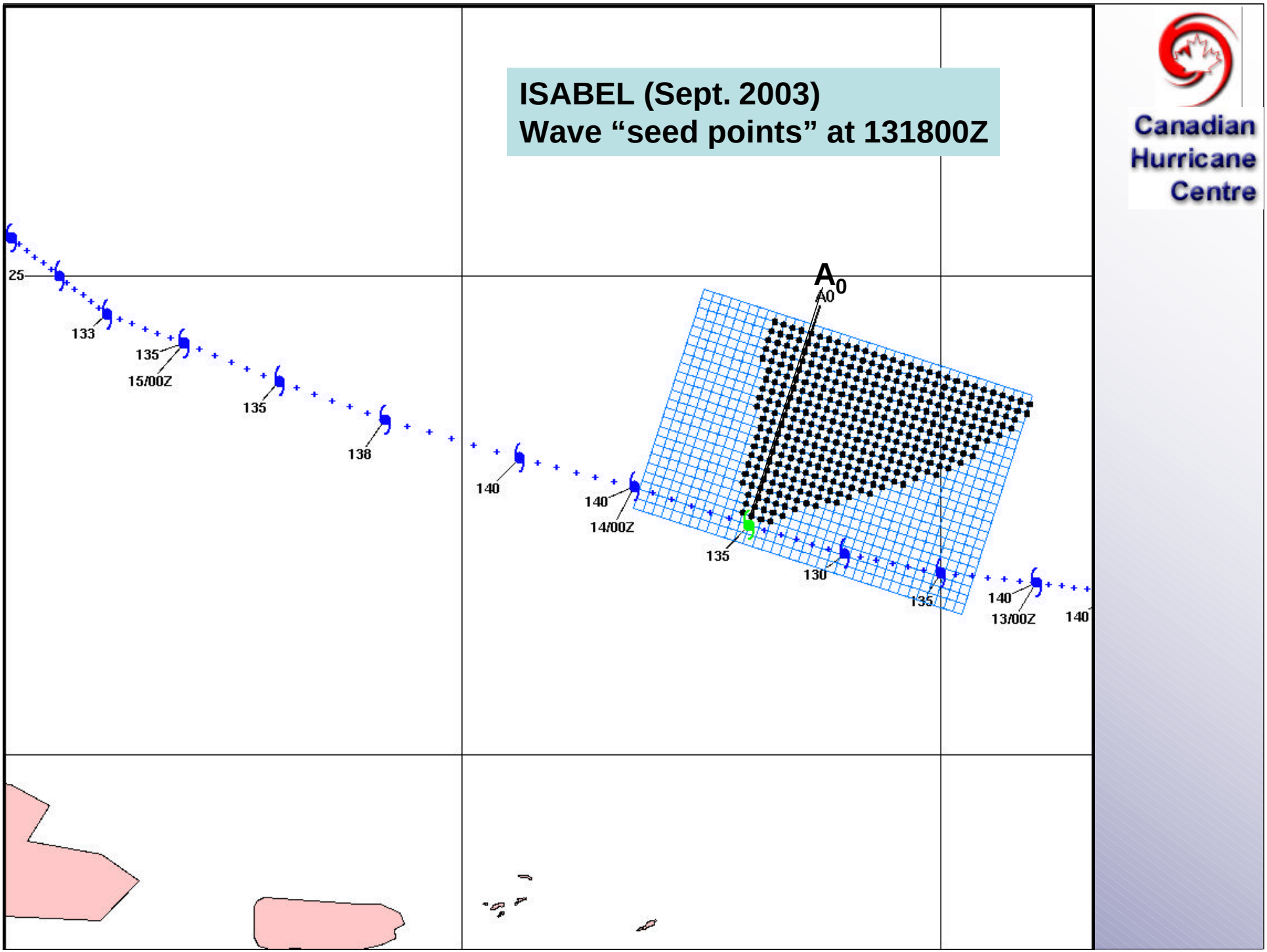

File
Map
Tables
View
Help
TRACK SELECTION
Name: isabel
Year: 2003
Model ID: CO
Min Lat: 0
Max Lat: 60
Open Track
Close Track
DISPLAY CONTROLS
Point Number
Axis Ao
Day/Hour
Trajectory
Msl Pres
Wave Height
Max Wind
Period
Grid
Duration
Vectors
Source Time
Axis Points
Source Wind
Clear
Unselect
Height: 12
OPEN TRACKS
Isabel 2003 CO
ISABEL (Sept. 2003)
(runtime 30 seconds)
40
60
40
20
20
60
40

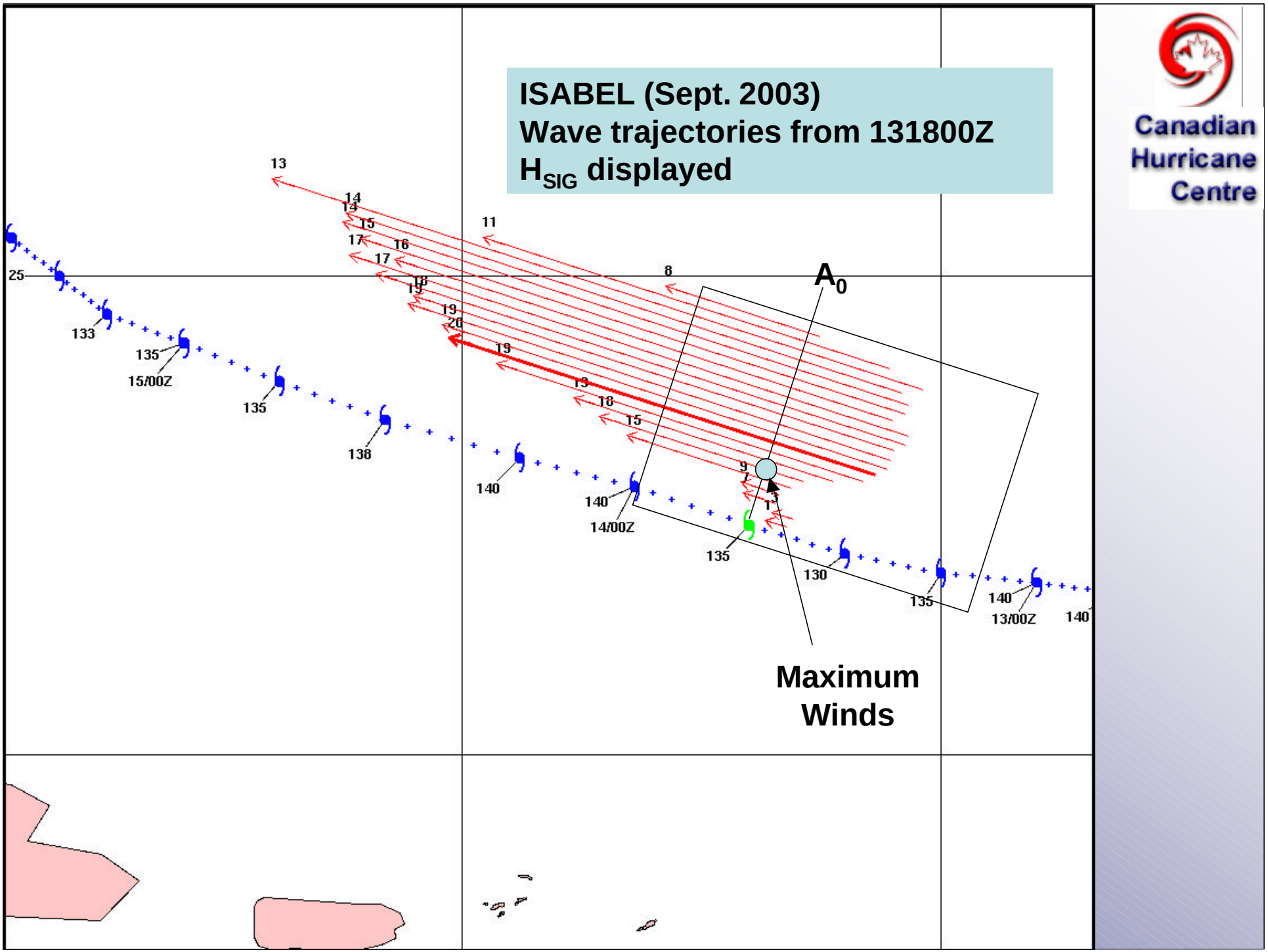
ISABEL (Sept. 2003)
Model grid at 131800Z

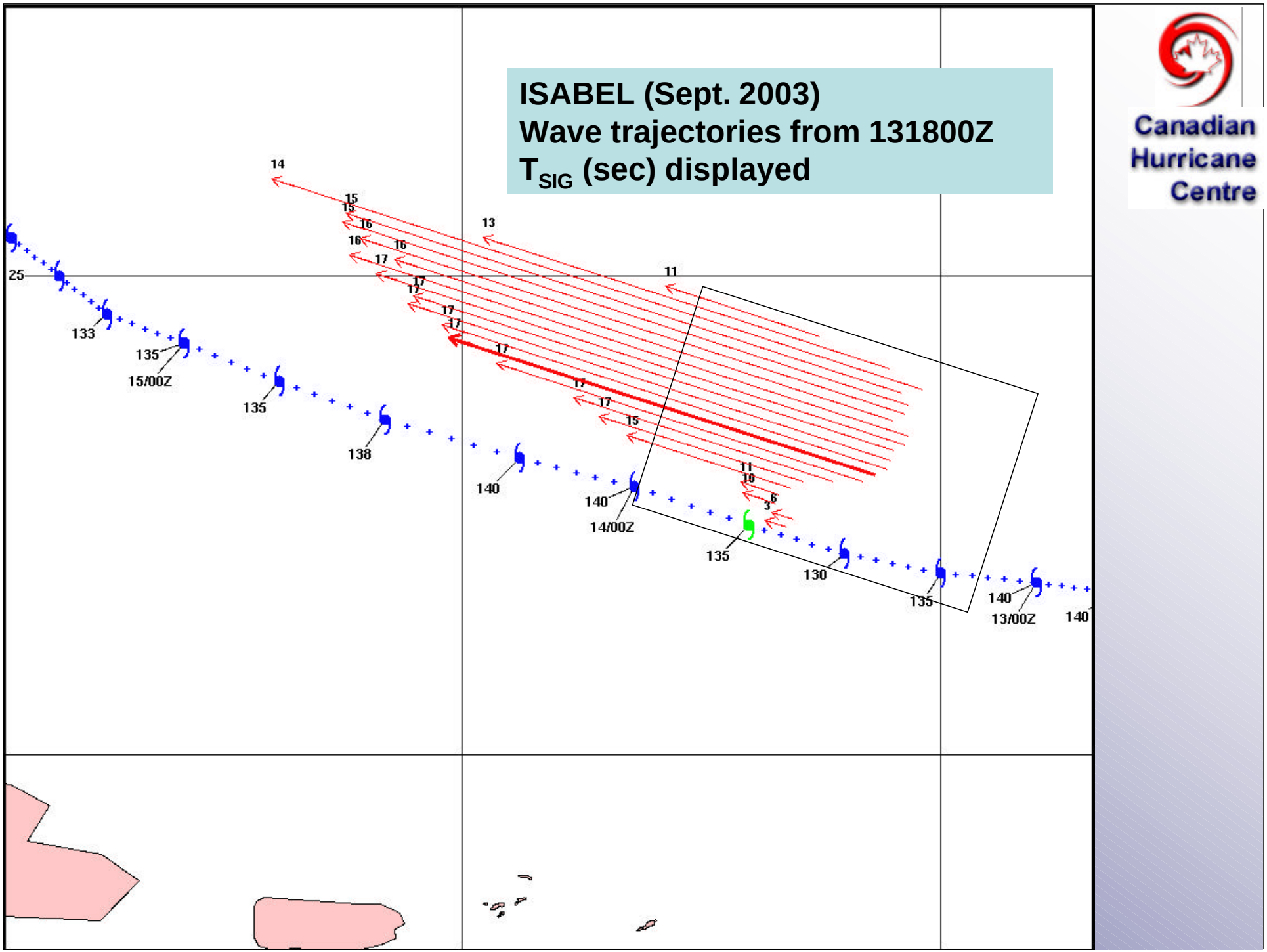


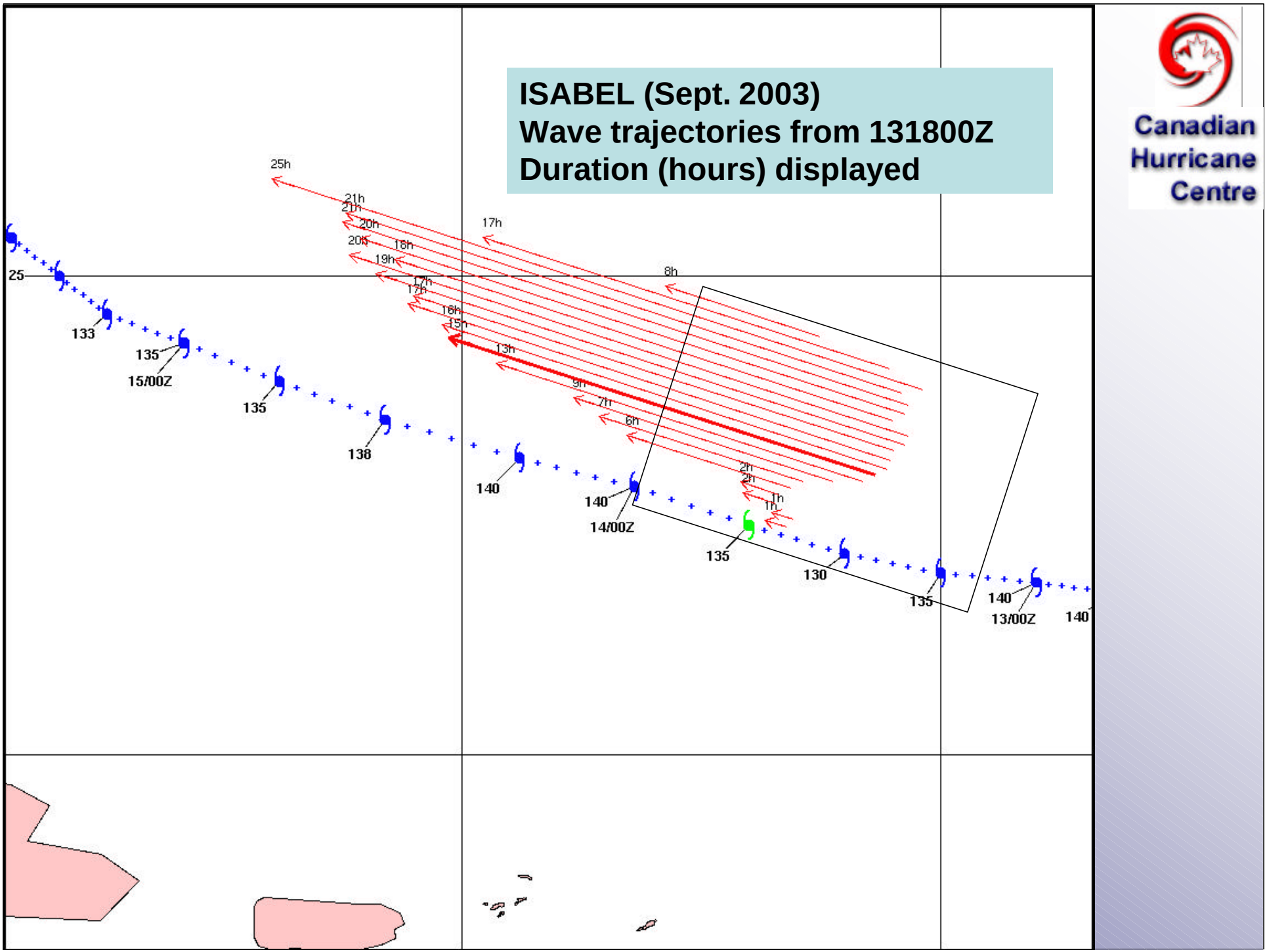
Canadian Hurricane Centre

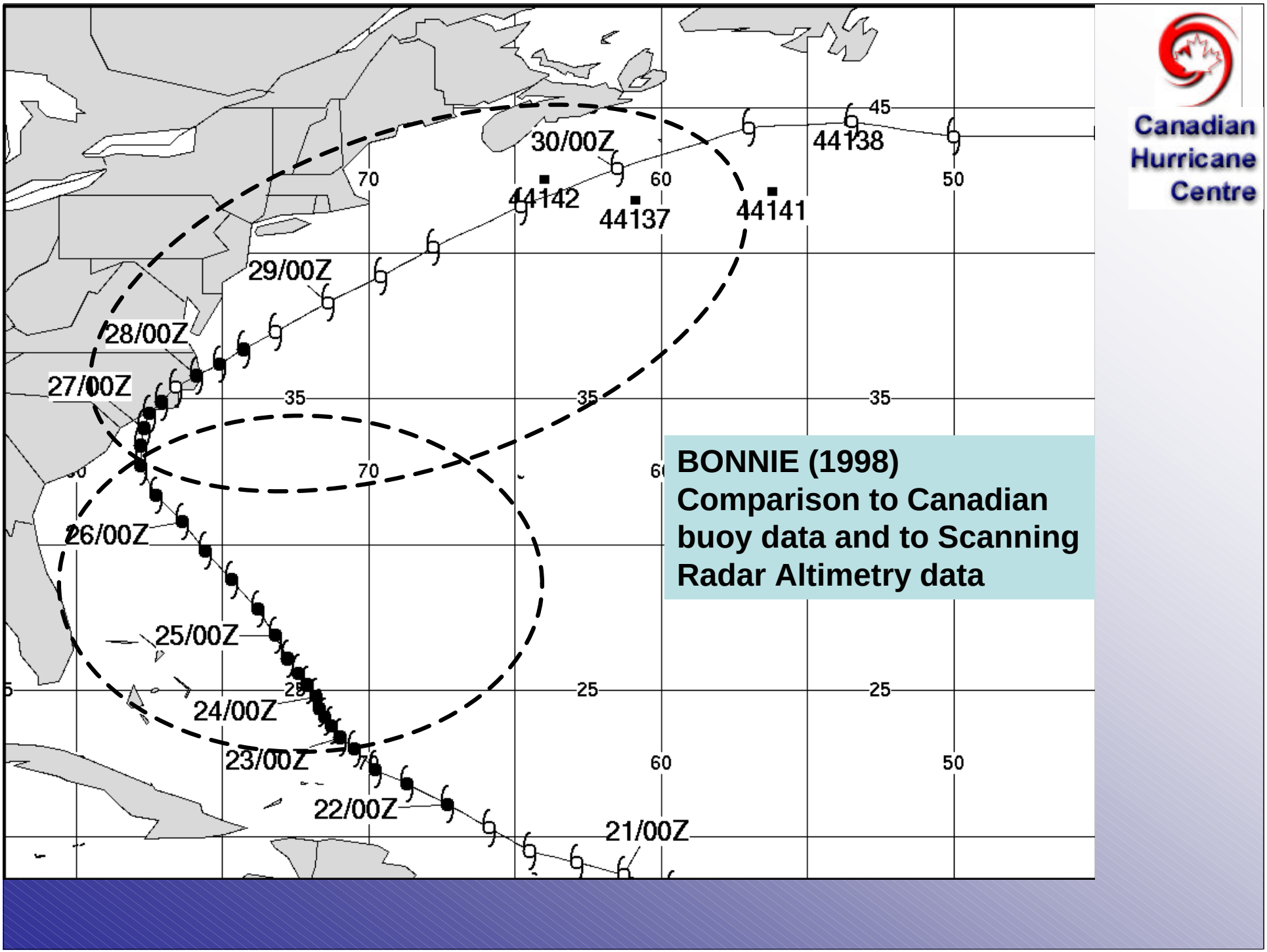

ISABEL (Sept. 2003)
Holland model winds at 131800Z
Canadian Hurricane Centre
25
133
135
15/00Z
135
138
140
140
14/00Z
A0
135
140
13/00Z
140


ISABEL (Sept. 2003)
Wave “seed points” at 131800Z
Canadian Hurricane Centre
25
133
135
15/00Z
135
138
140
140
14/00Z
135
130
135
140
13/00Z
140
A0
A0


ISABEL (Sept. 2003)
Wave trajectories from 131800Z
H_{SIG} displayed
Canadian Hurricane Centre
A_0
Maximum Winds
15/00Z
14/00Z
13/00Z


ISABEL (Sept. 2003)
Wave trajectories from 131800Z
T_{SIG} (sec) displayed
Canadian Hurricane Centre
14
15
15
16
16
16
17
17
17
17
17
17
17
15
13
11
11
10
6
3
25
133
135
15/00Z
135
138
140
140
14/00Z
135
130
135
140
13/00Z
140


ISABEL (Sept. 2003)
Wave trajectories from 131800Z
Duration (hours) displayed
Canadian Hurricane Centre
25h
21h
20h
19h
17h
16h
15h
13h
9h
7h
6h
8h
2h
1h
25
133
135
15/00Z
135
138
140
140
14/00Z
135
130
135
140
13/00Z
140

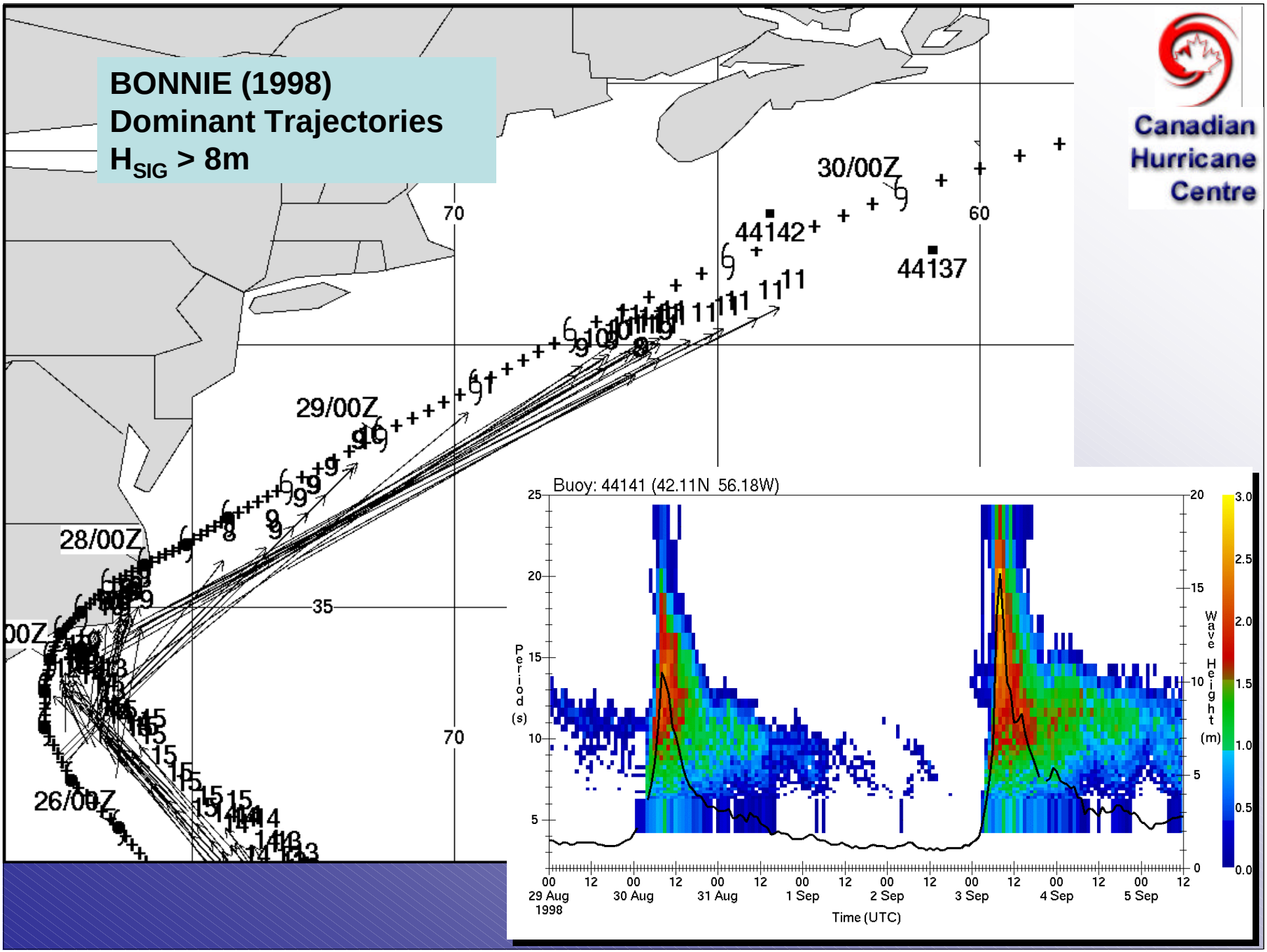


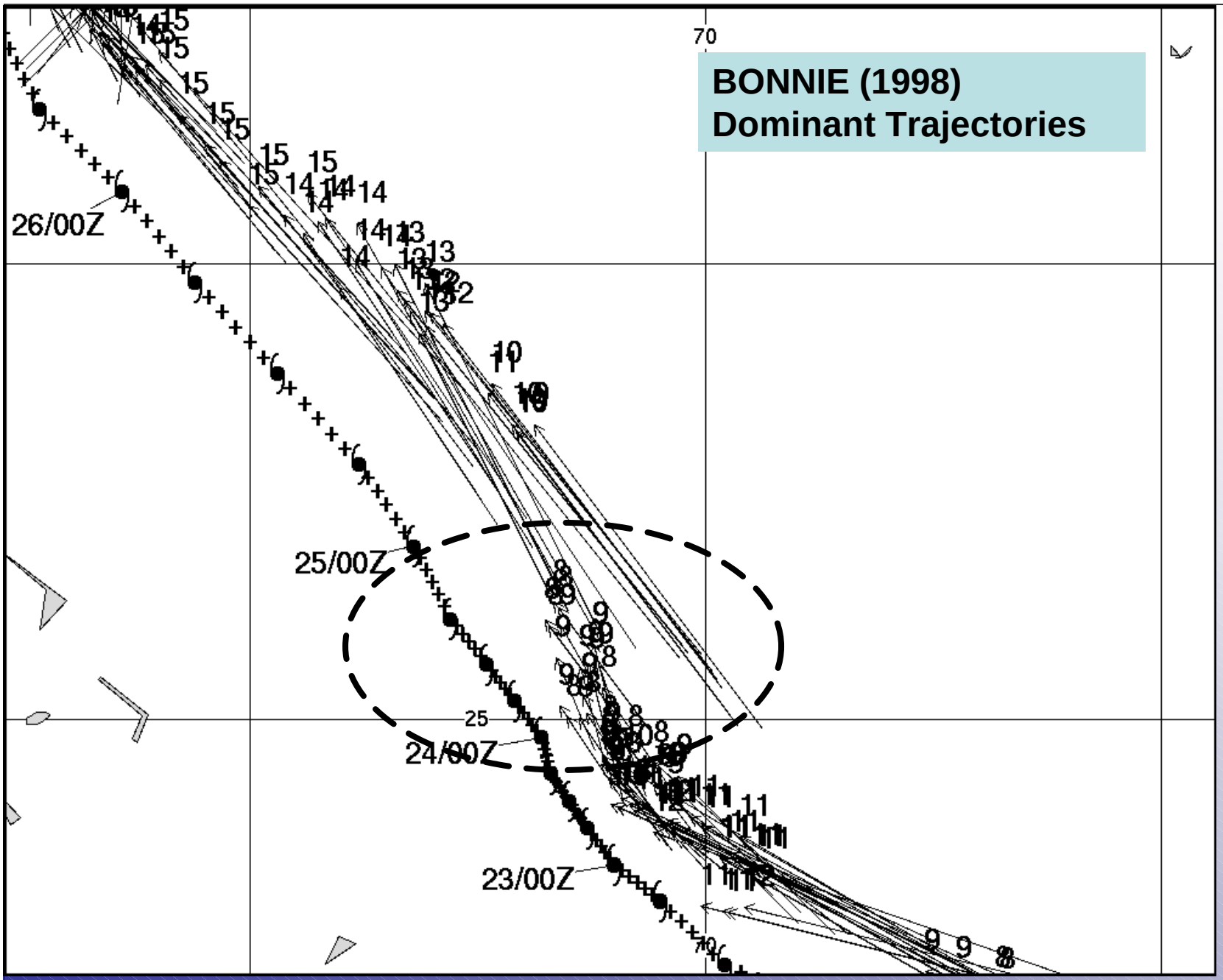
BONNIE (1998)
Comparison to Canadian buoy data and to Scanning Radar Altimetry data

Canadian Hurricane Centre

BONNIE (1998)
Dominant Trajectories
H_{SIG} > 8m

Canadian Hurricane Centre

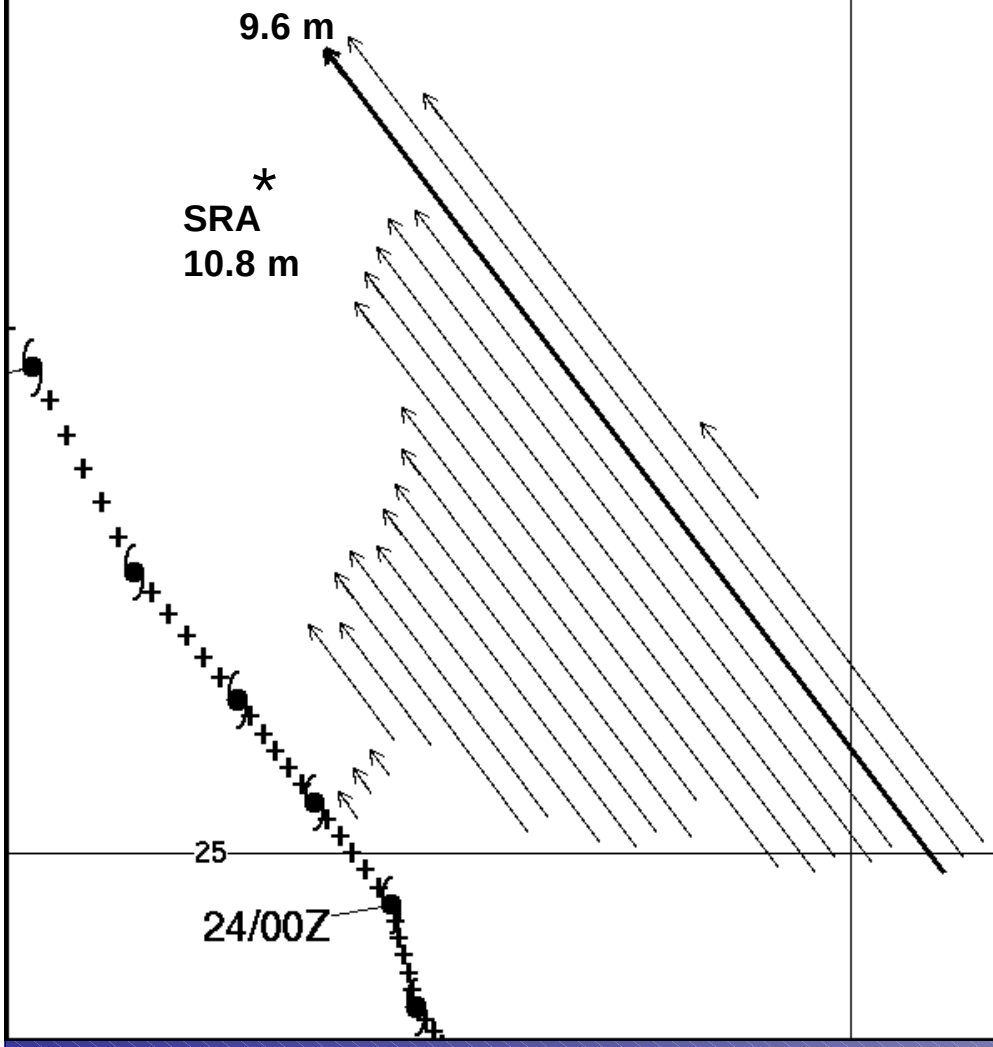




Canadian Hurricane Centre

BONNIE (1998)
Dominant Trajectories

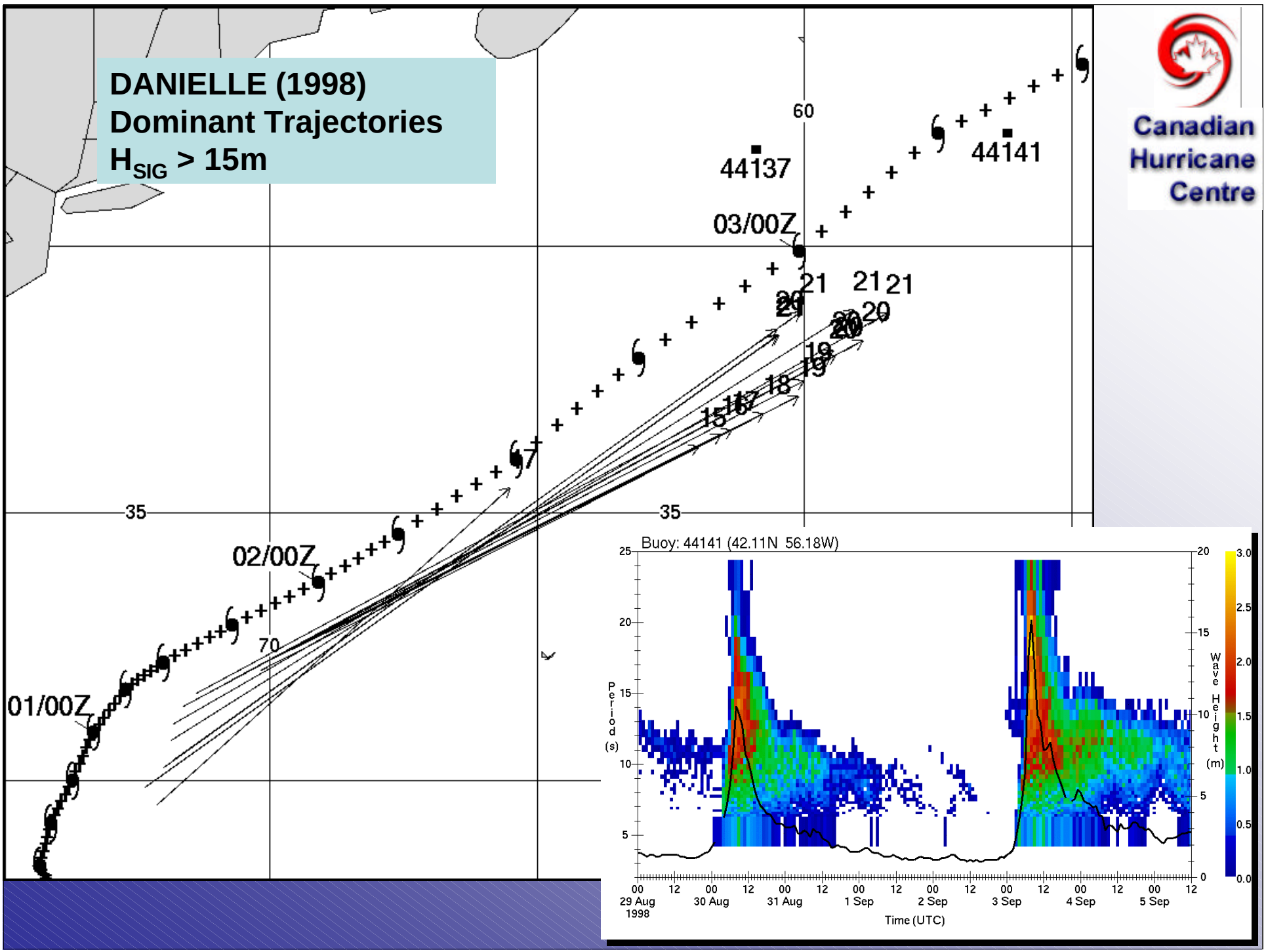
Canadian Hurricane Centre

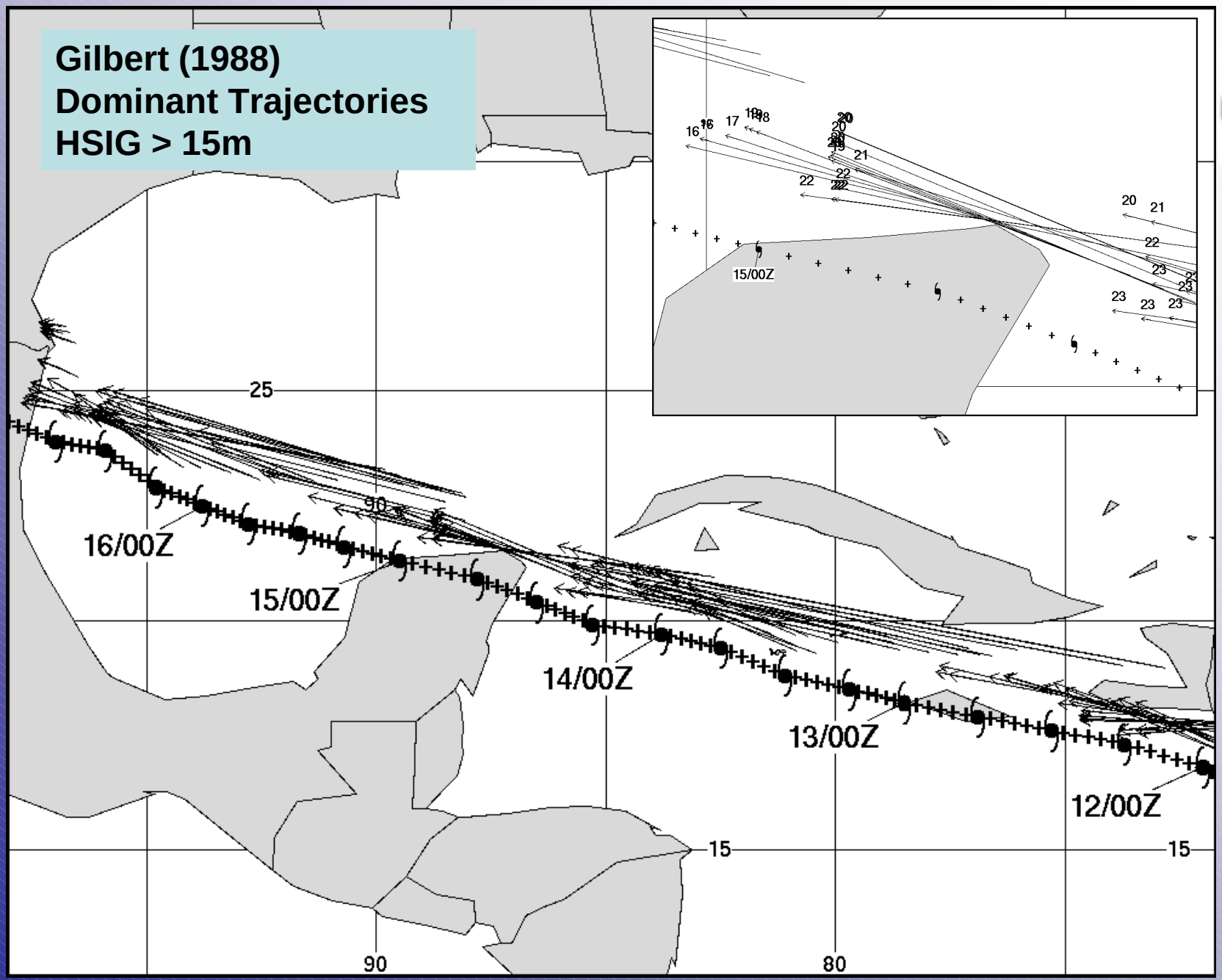


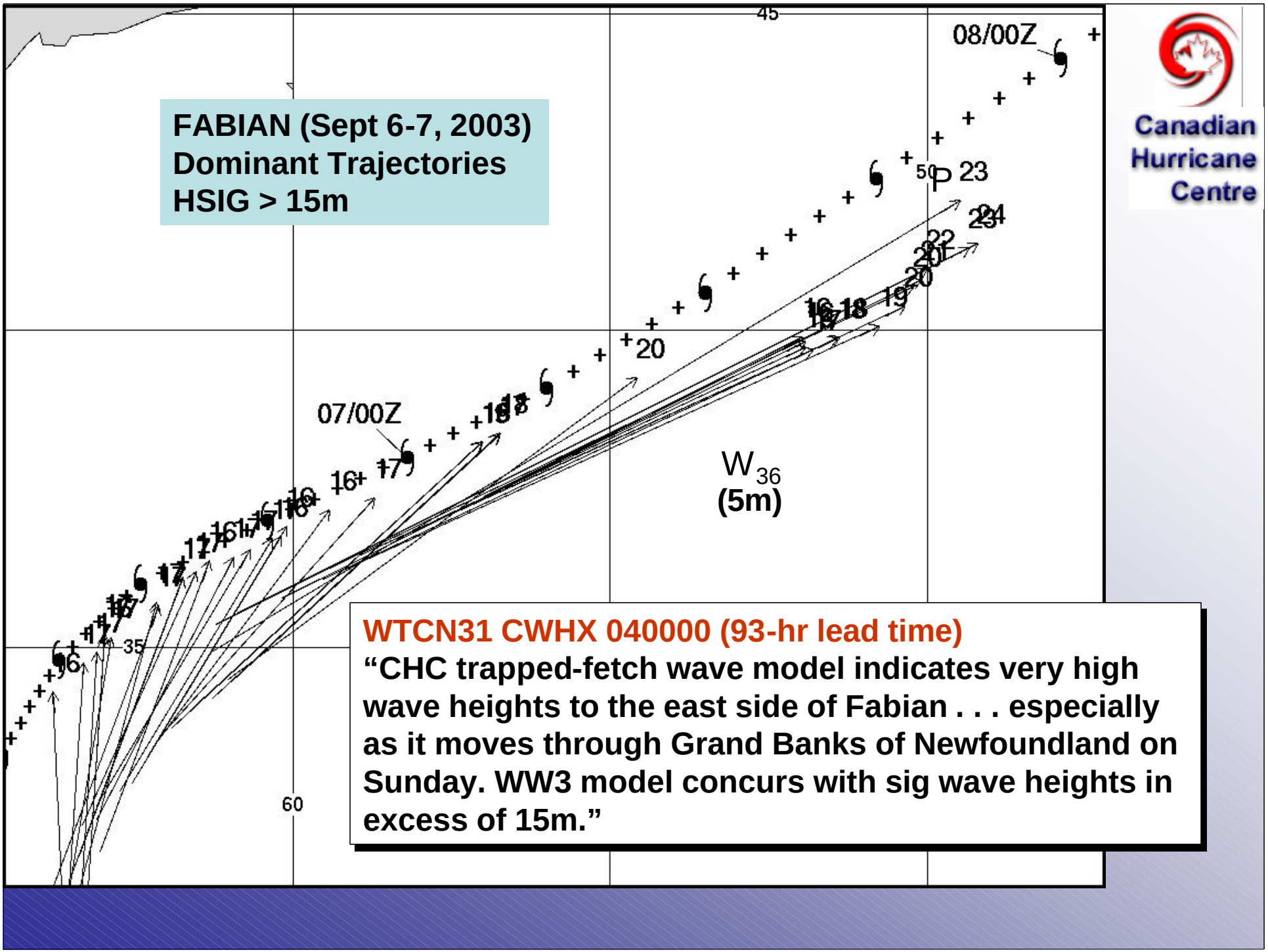
Asterisk denotes the location of the 10.8m maximum in the wave height field as measured by scanning radar altimetry (Wright et al, 2001). The model waves are still growing at this point but don't reach 11m until slightly farther downstream.

DANIELLE (1998)
Dominant Trajectories
H_{SIG} > 15m

Canadian Hurricane Centre



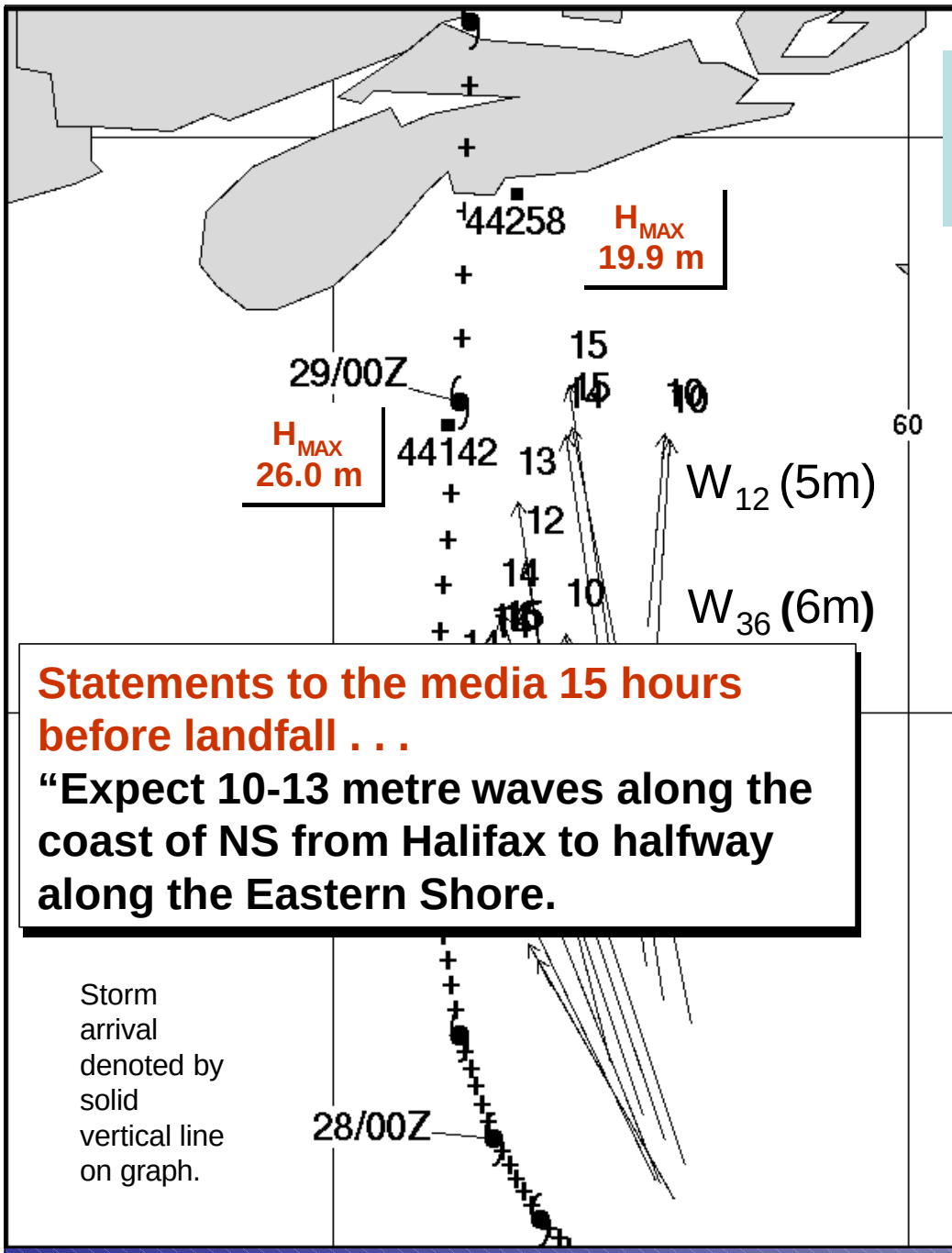

Gilbert (1988)
Dominant Trajectories
HSIG > 15m
Canadian Hurricane Centre
16/00Z
15/00Z
14/00Z
13/00Z
12/00Z
15/00Z
25
15
15
90
90
80


FABIAN (Sept 6-7, 2003)
Dominant Trajectories
HSIG > 15m
45
08/00Z
07/00Z
50
23
20
35
60
W36
(5m)
Canadian
Hurricane
Centre
WTCN31 CWHX 040000 (93-hr lead time)
"CHC trapped-fetch wave model indicates very high wave heights to the east side of Fabian . . . especially as it moves through Grand Banks of Newfoundland on Sunday. WW3 model concurs with sig wave heights in excess of 15m."

JUAN (2003)
Dominant Trajectories
H_{SIG} > 10m

Canadian Hurricane Centre

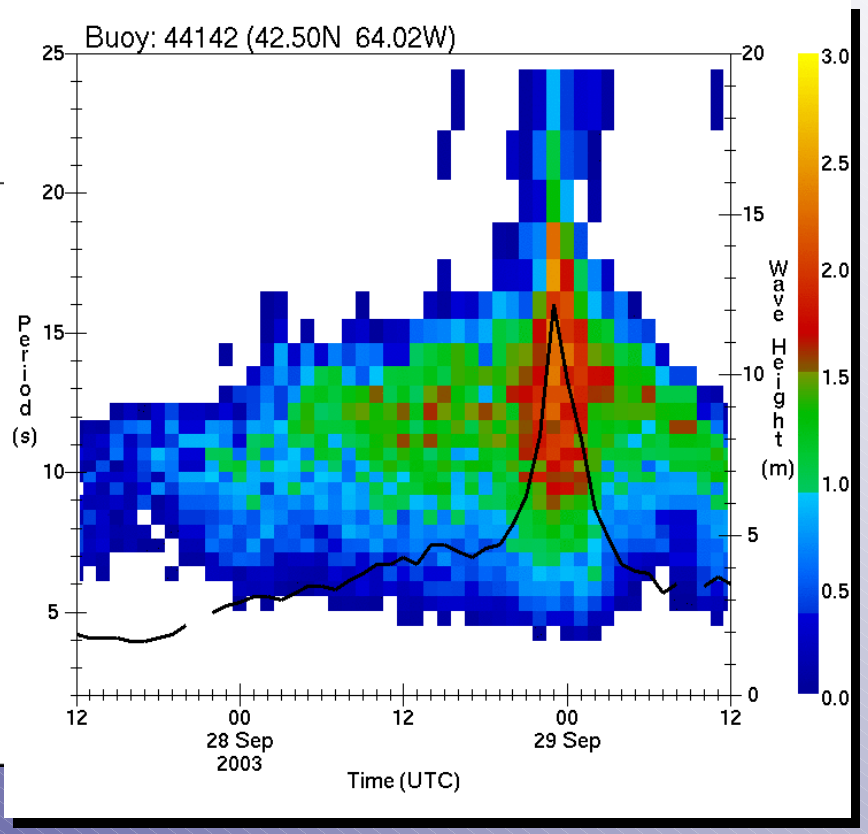
W_{12} – 12 hr Canadian WAM
W_{36} – 36 hr Canadian WAM



Statements to the media 15 hours before landfall . . .

"Expect 10-13 metre waves along the coast of NS from Halifax to halfway along the Eastern Shore.

Storm arrival denoted by solid vertical line on graph.



SUMMARY

Canadian Hurricane Centre

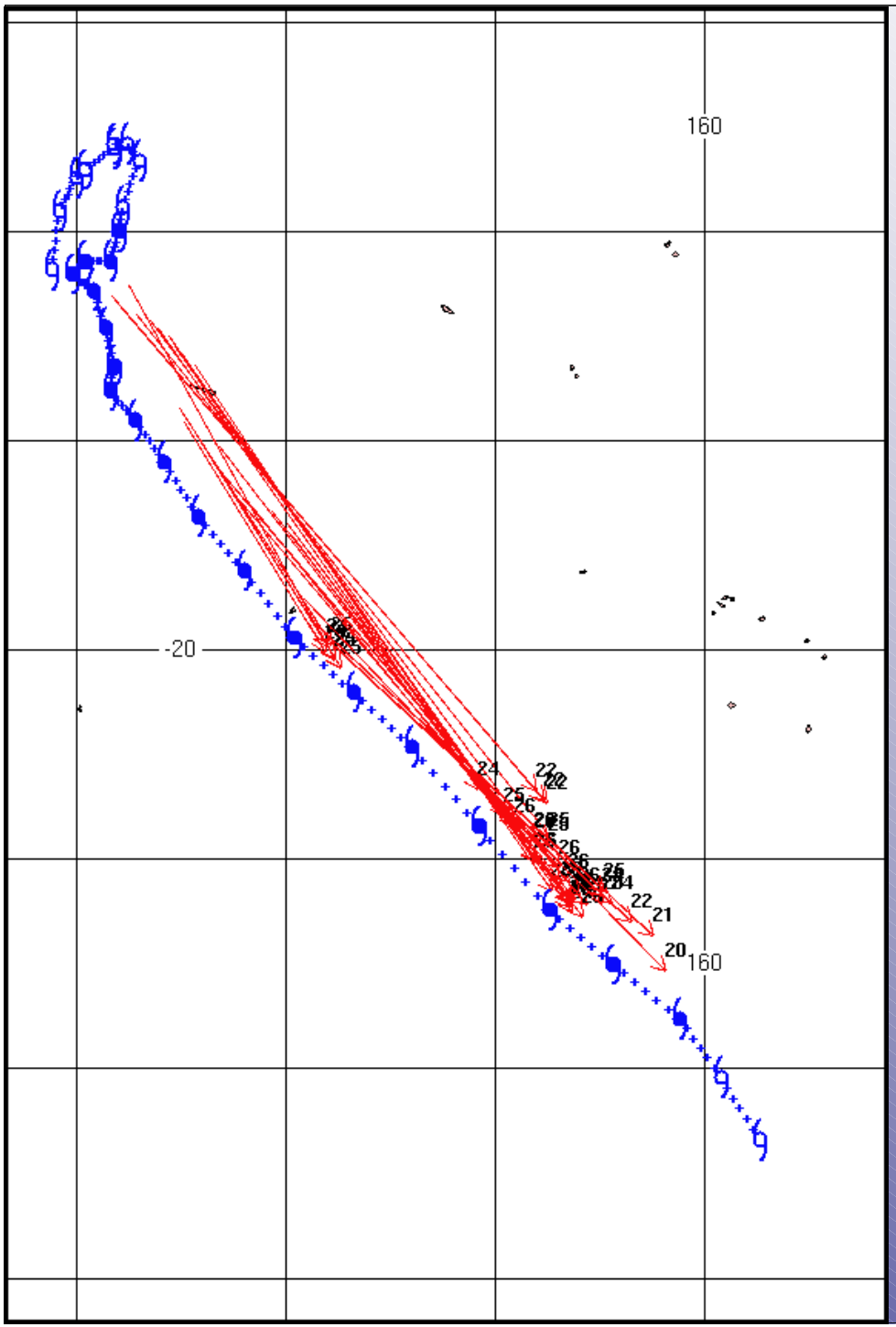
The CHC trapped-fetch wave model skillfully models wave-storm resonance with tropical cyclones and provides detailed wave trajectory information to forecasters **within seconds** of adjustments to the storm track or intensity (note: Ginger 1971 required 40-60 seconds to model the winds and waves for its 703 hours of existence . . . depending on machine activity).

The patterns and arrival times of wave trajectories are very good…wave heights >18m are cause for some consternation.

FUTURE WORK

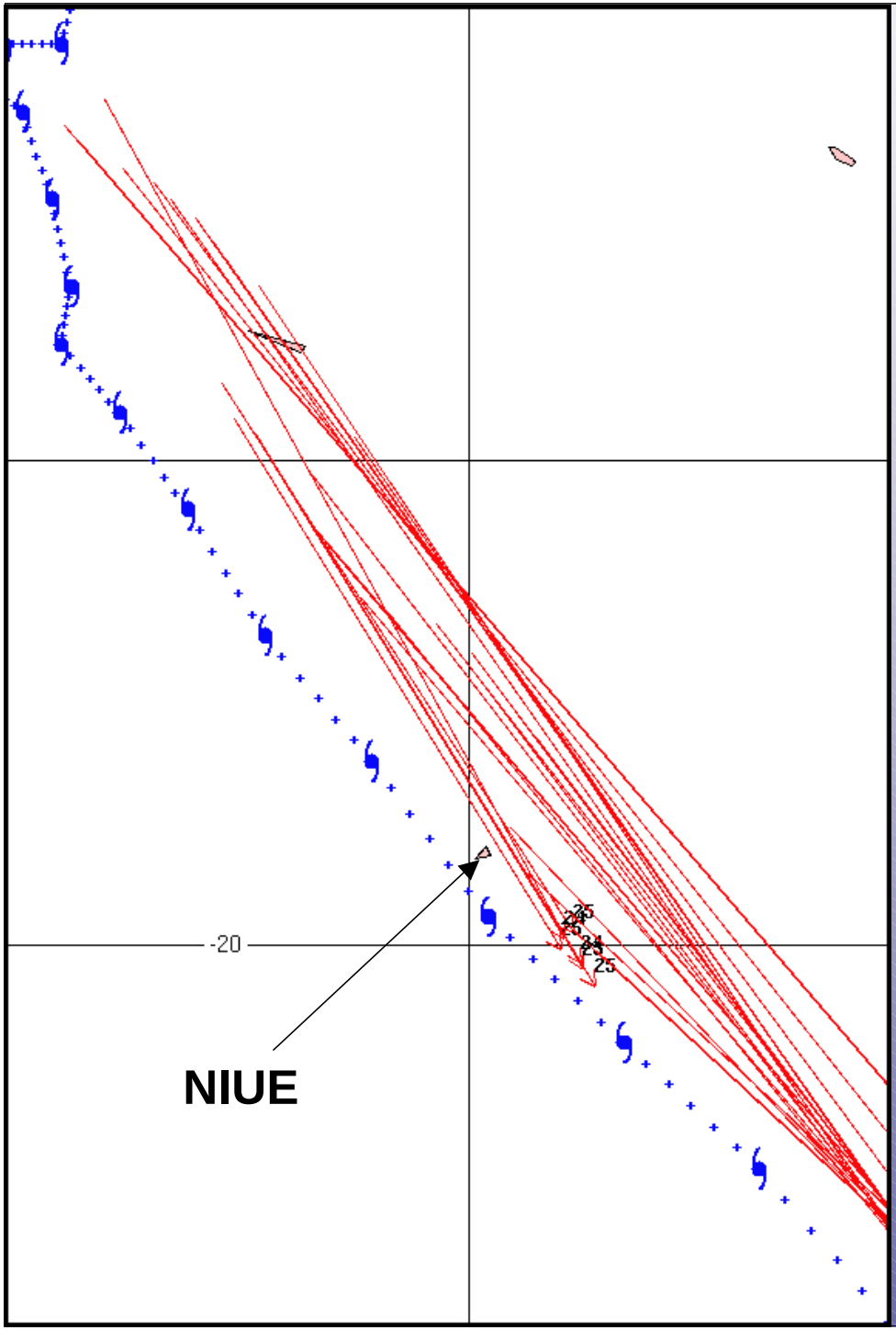
Canadian Hurricane Centre

1. Update wave formulations
2. Address issue of upper-limits on wave heights
3. Develop a climatology of maximum significant wave heights with TCs



Canadian Hurricane Centre

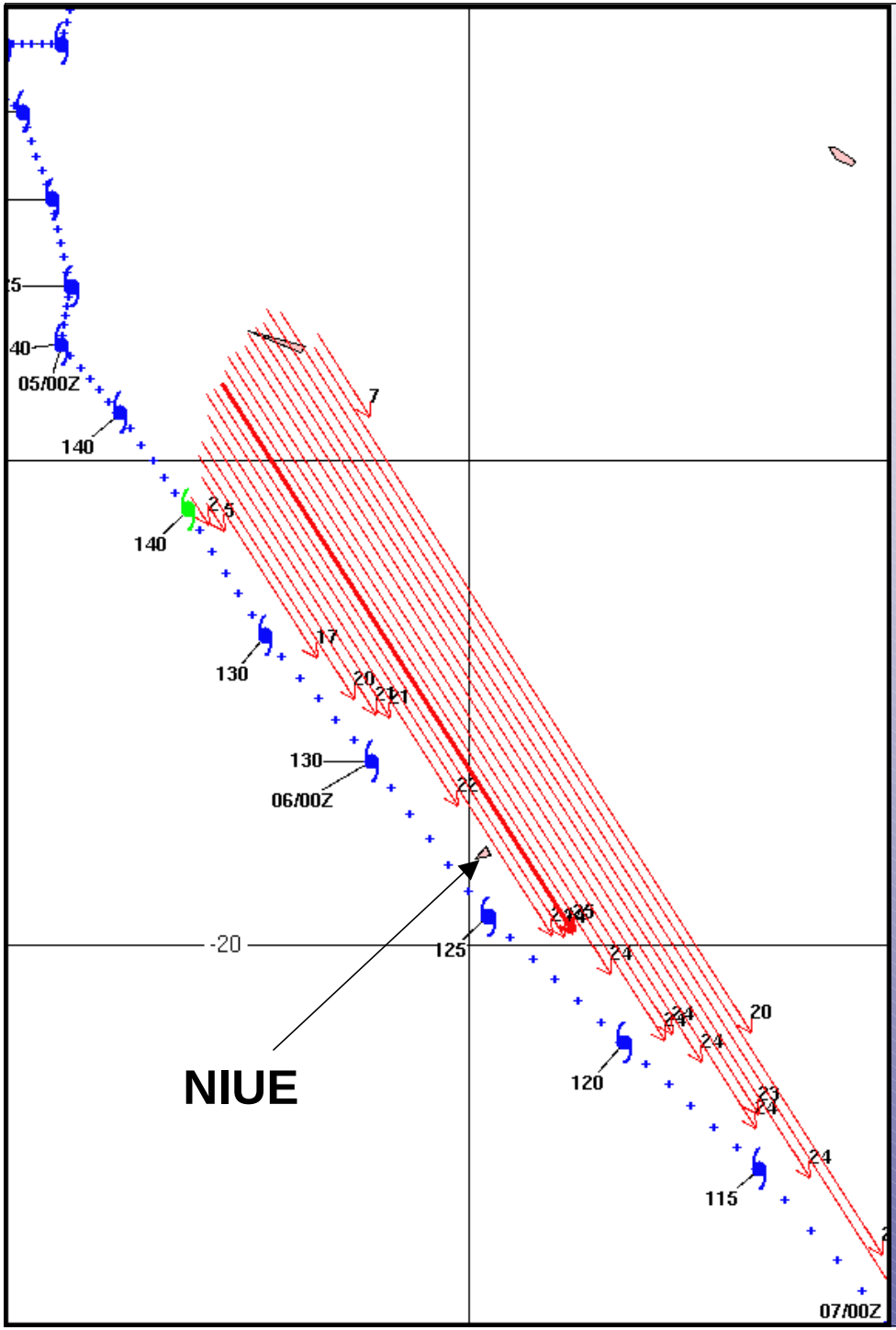
SE PAC Cyclone Heta
January 2004



Canadian Hurricane Centre

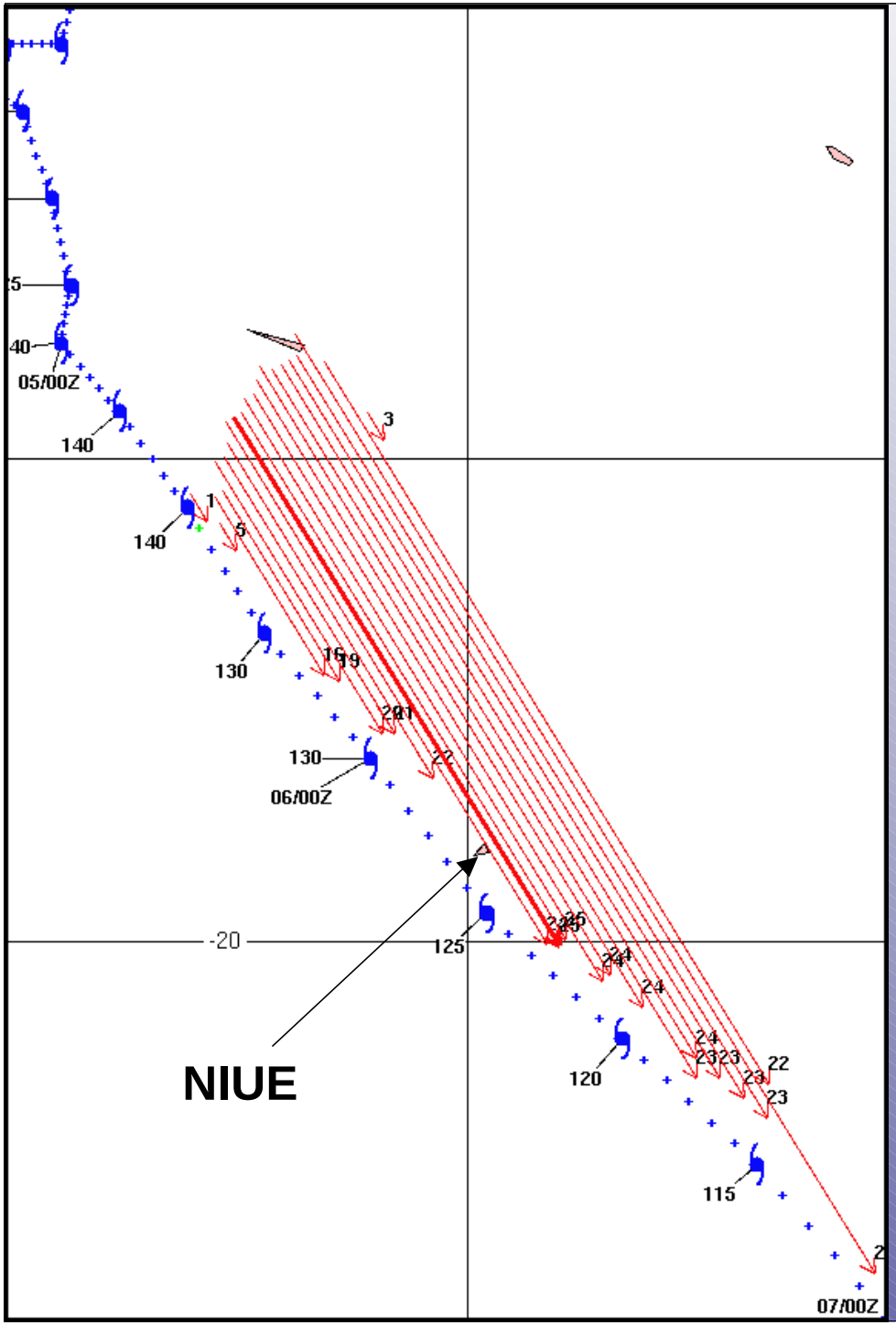
Heta
January 2004

NIUE experienced extreme wave damage over the island



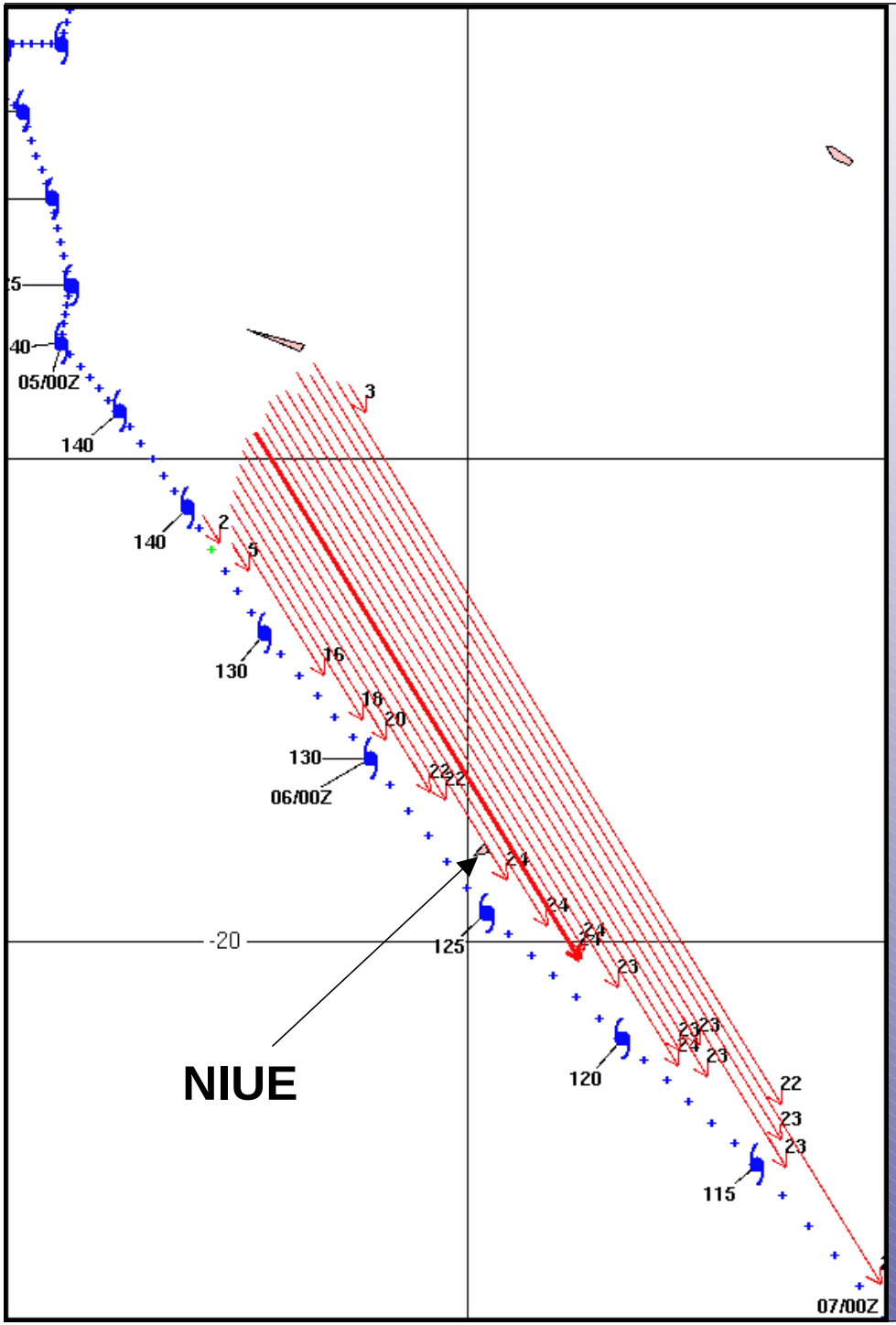
Canadian Hurricane Centre

Waves originating at 051200Z



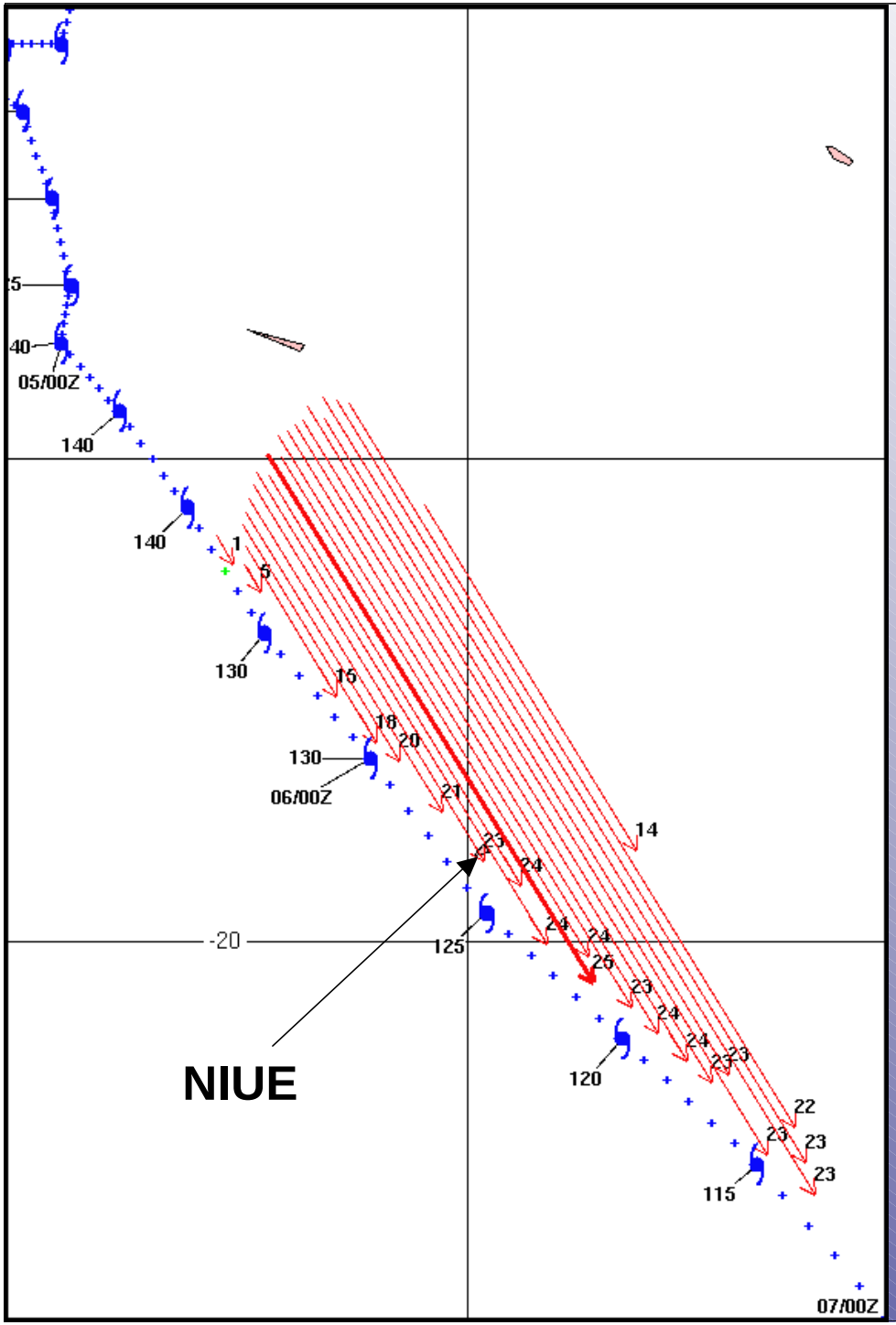
Canadian Hurricane Centre

Waves originating at 051300Z



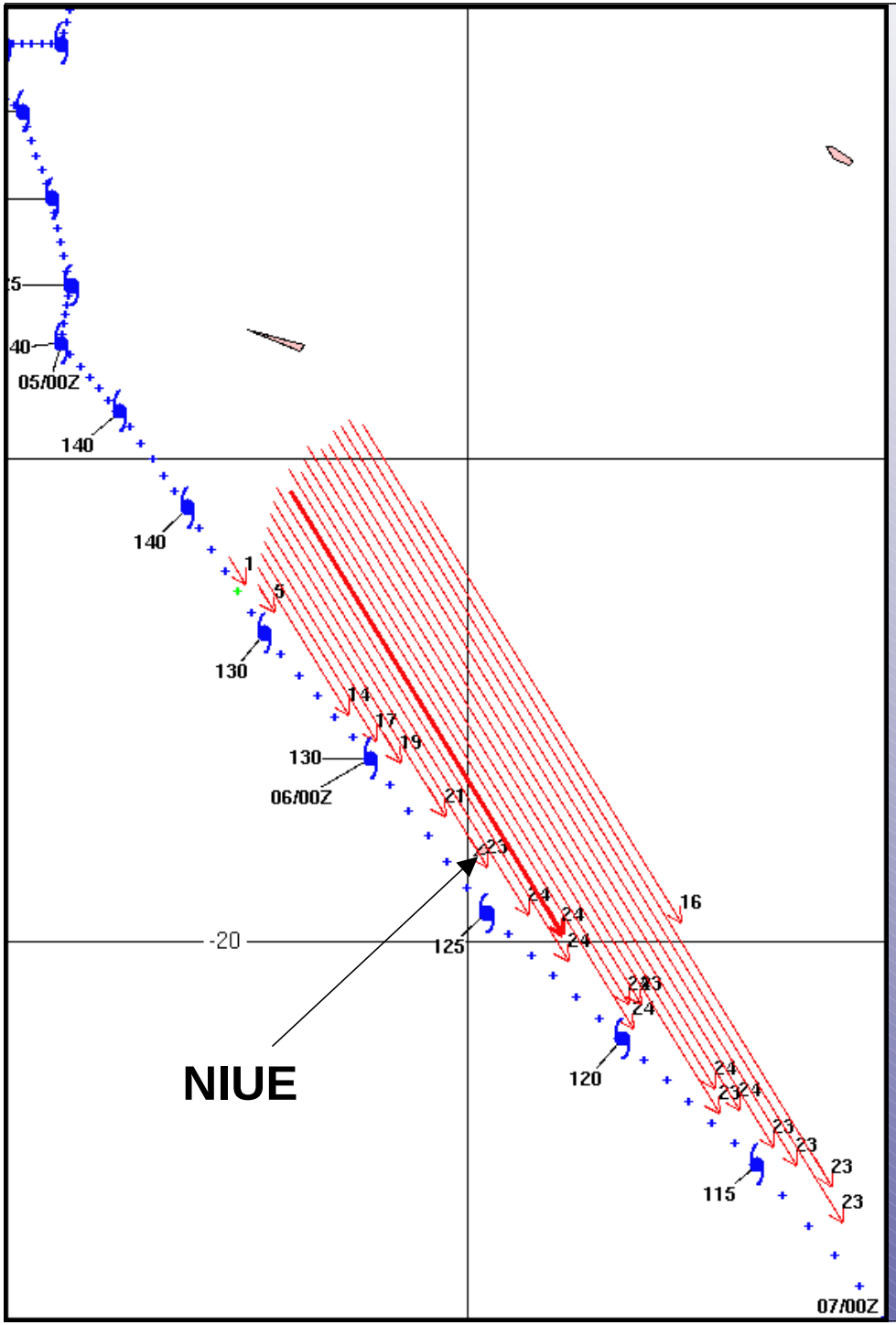
Canadian Hurricane Centre

Waves originating at 051400Z



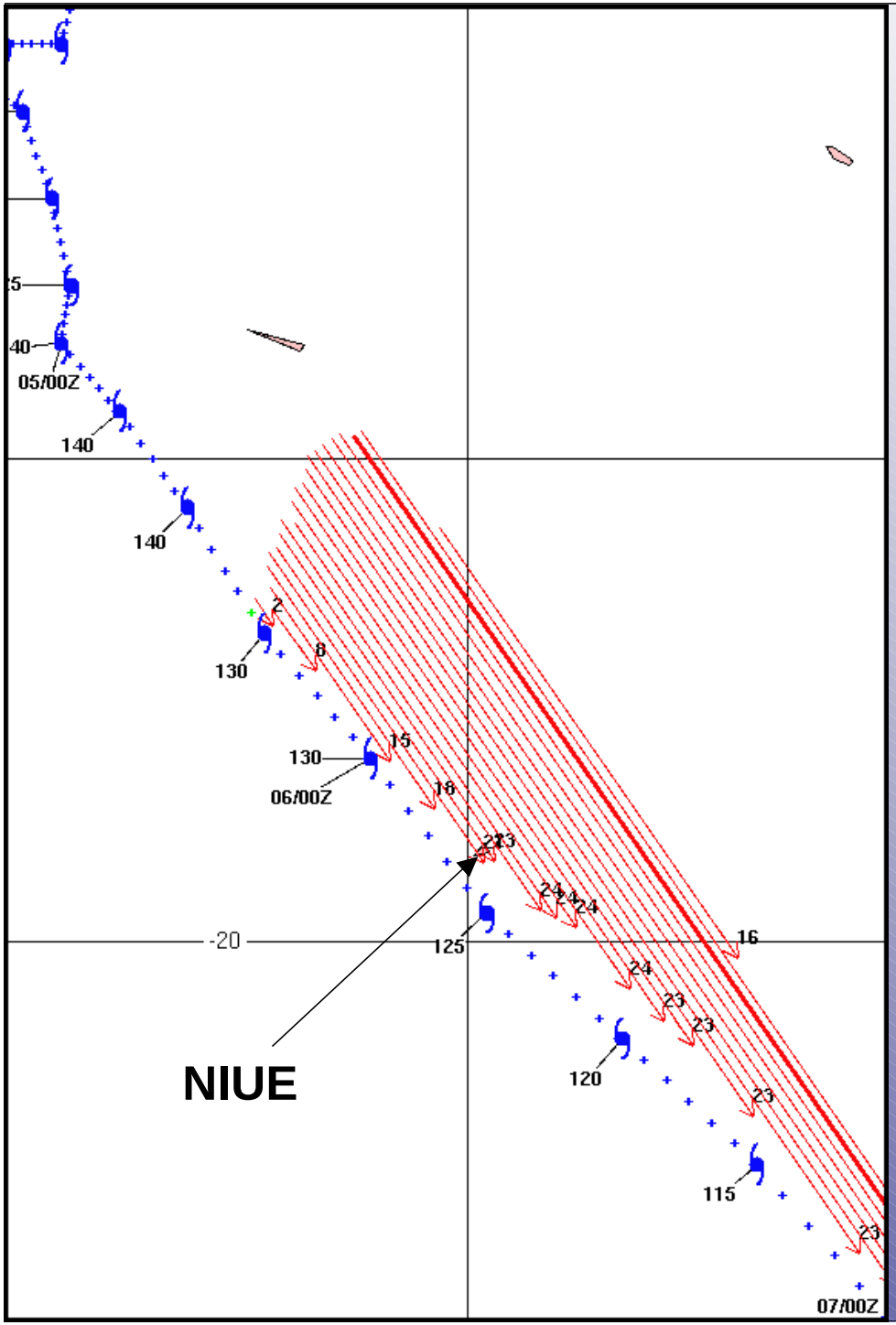
Canadian Hurricane Centre

Waves originating at 051500Z



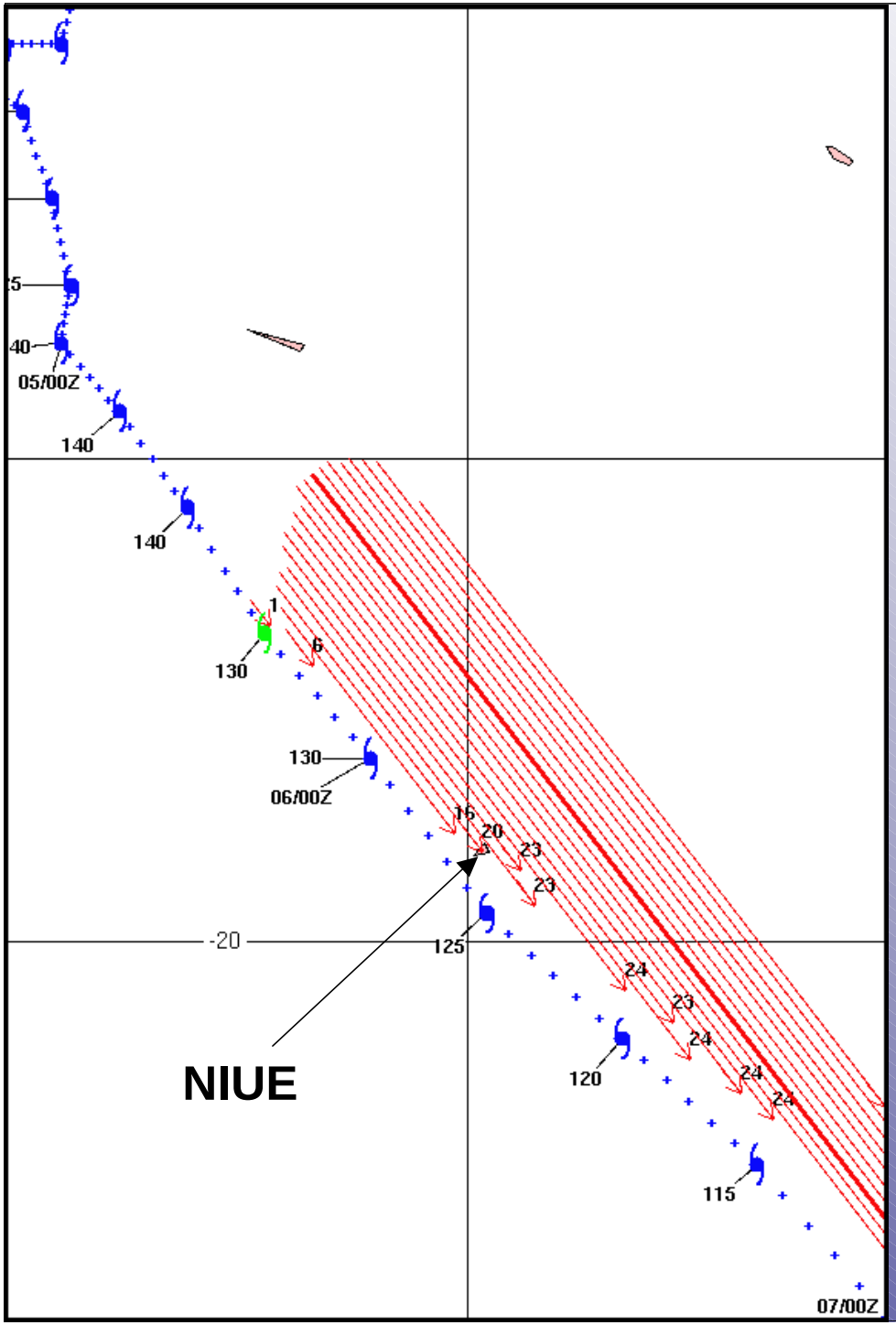
Canadian Hurricane Centre

Waves originating at 051600Z



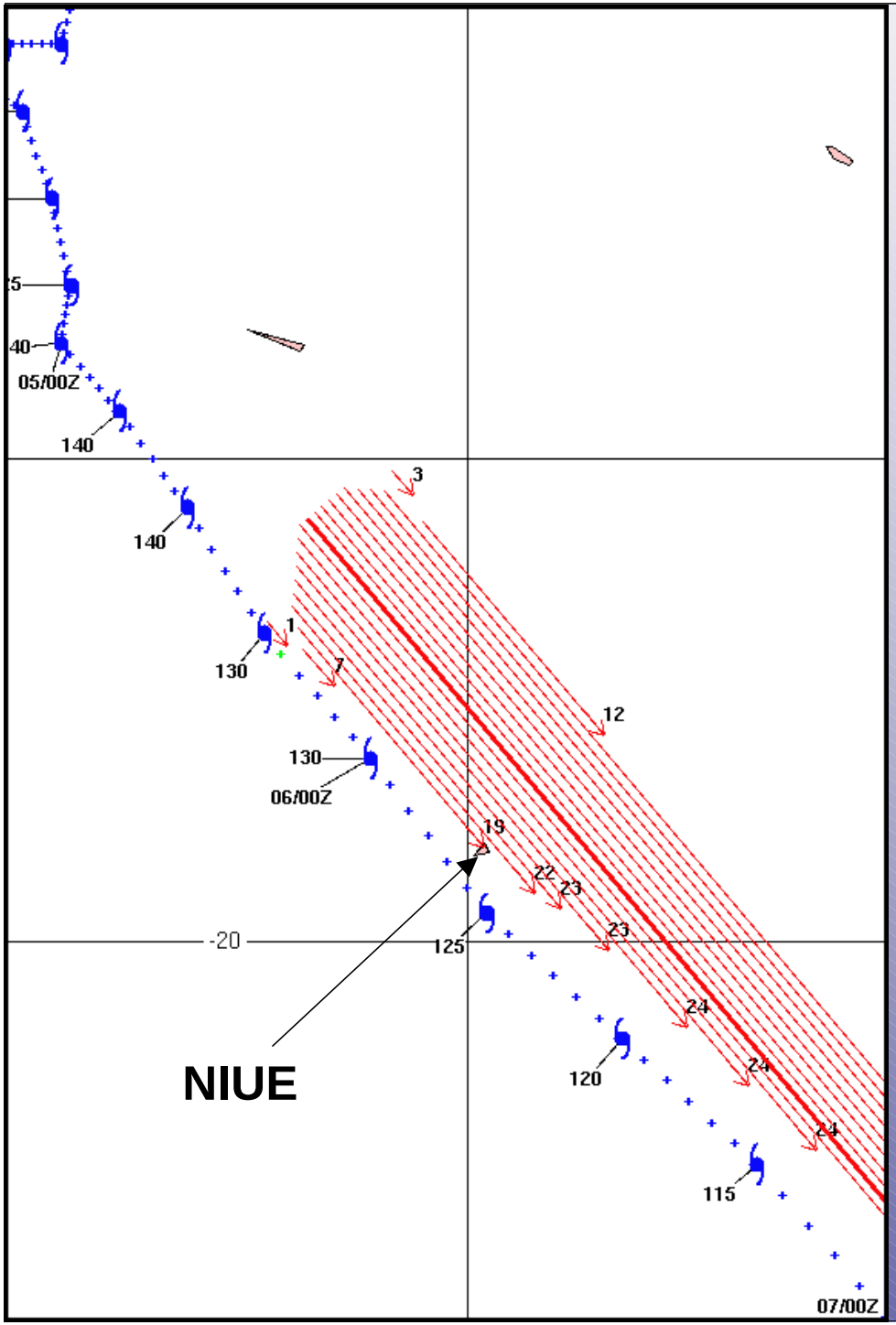
Canadian Hurricane Centre

Waves originating at 051700Z



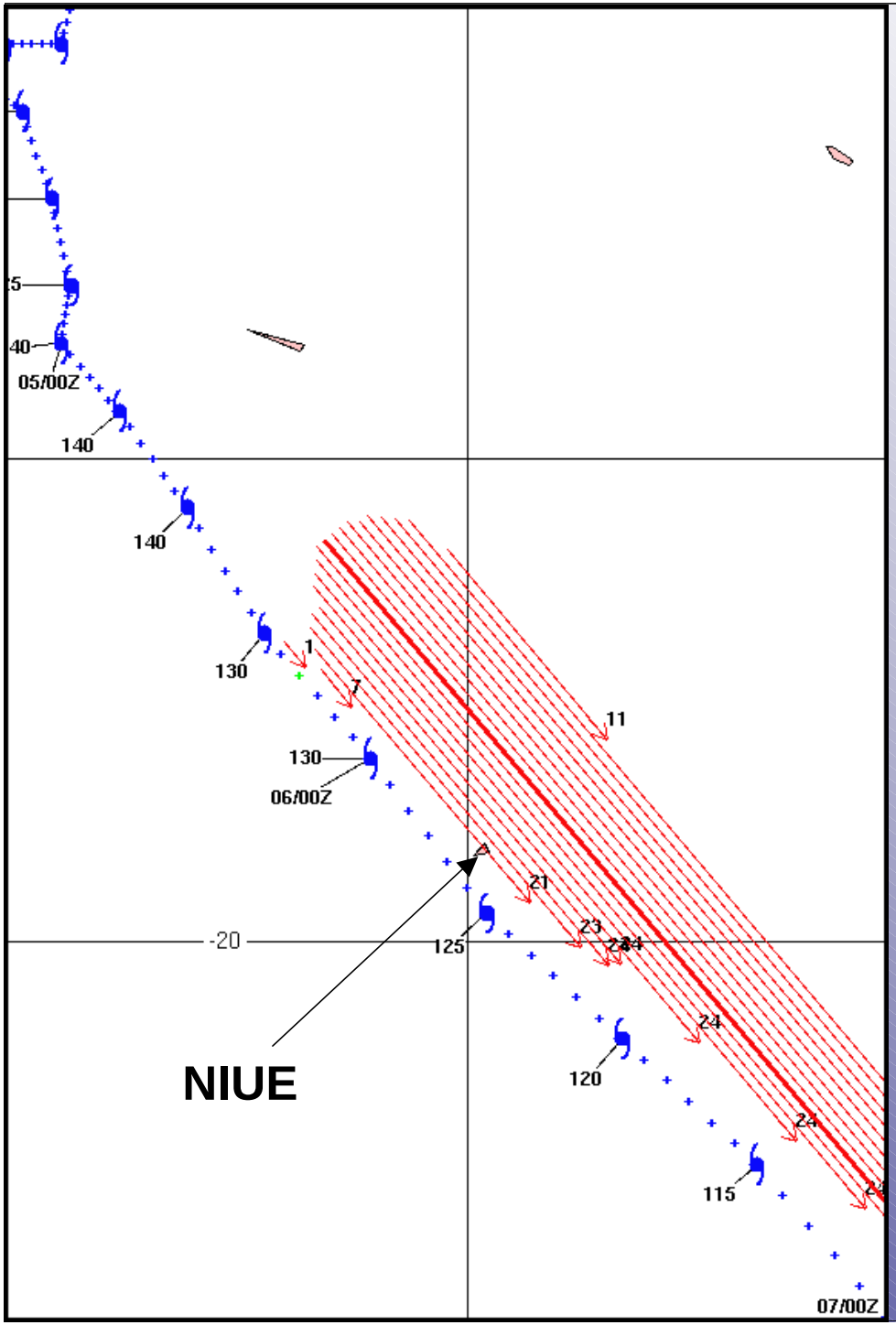
Canadian Hurricane Centre

Waves originating at 051800Z



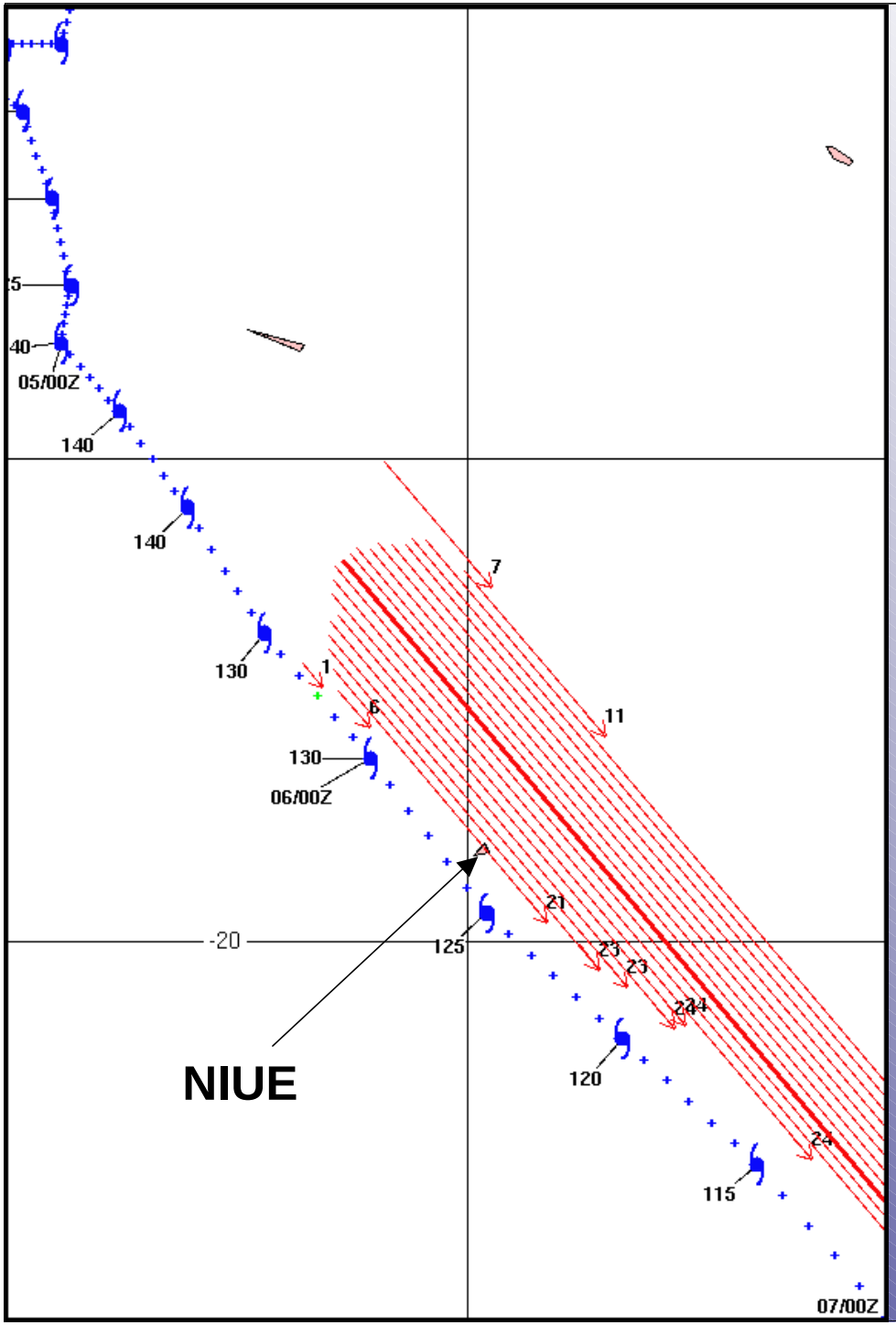
Canadian Hurricane Centre

Waves originating at 051900Z



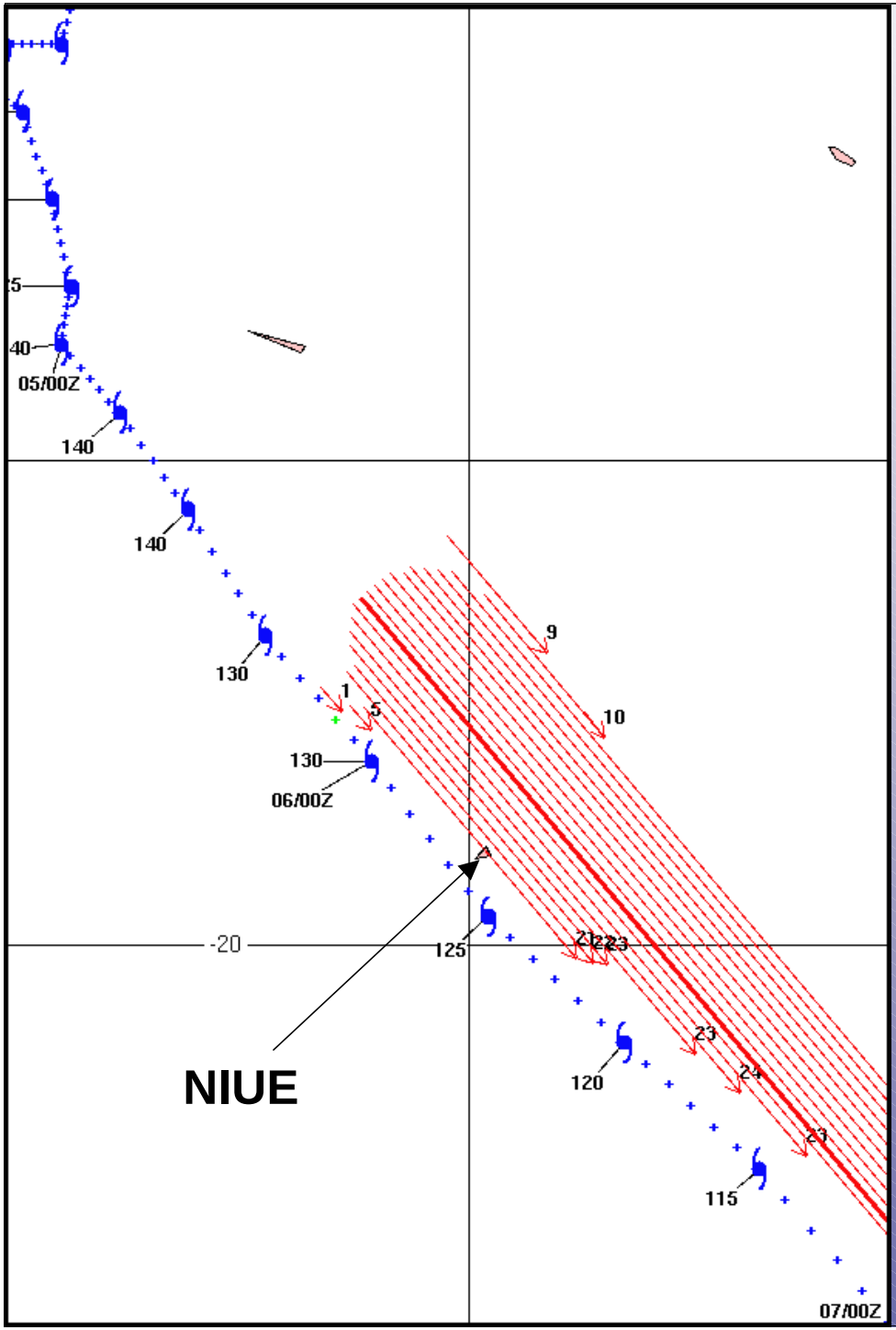
Canadian Hurricane Centre

Waves originating at 052000Z



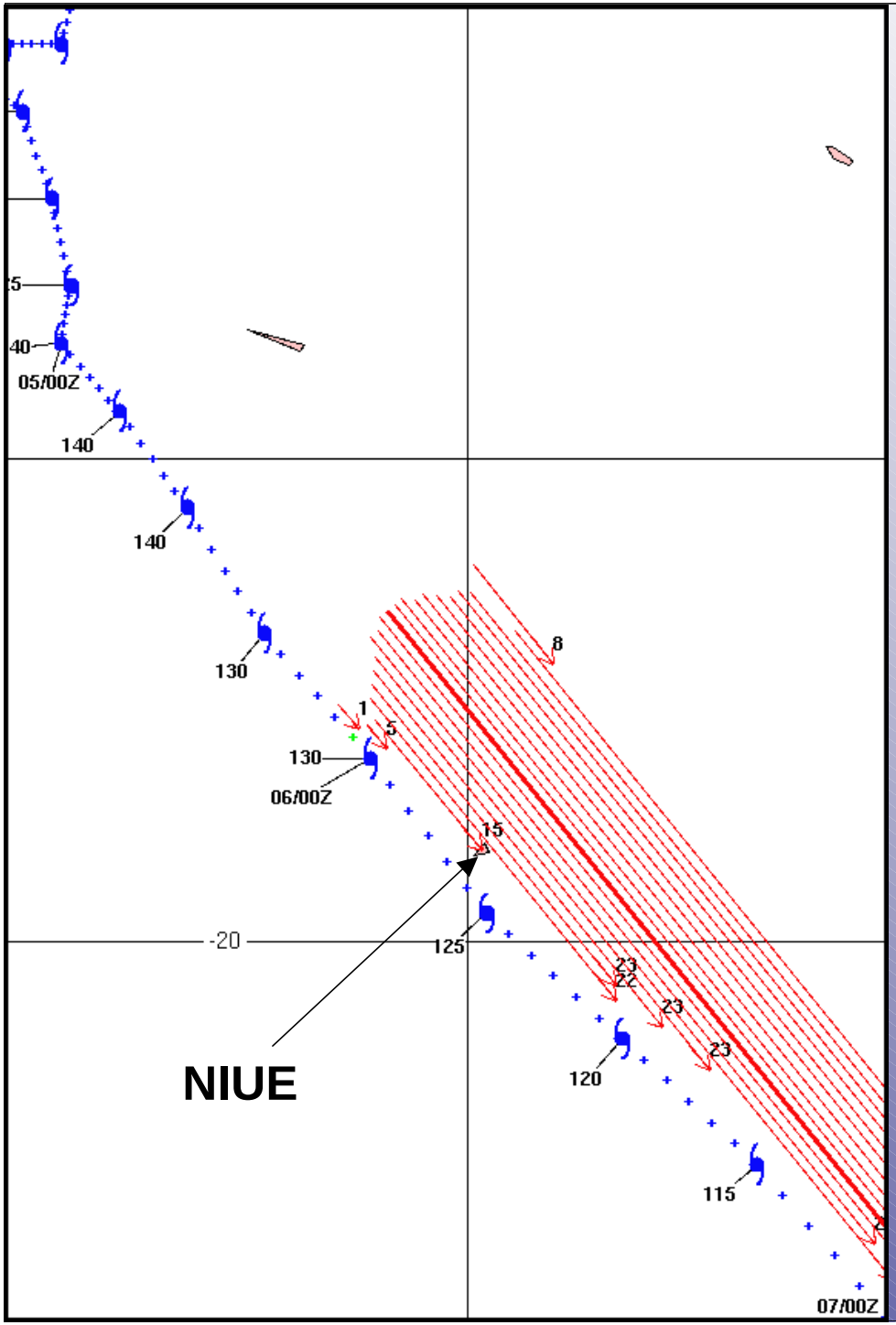
Canadian Hurricane Centre

Waves originating at 052100Z



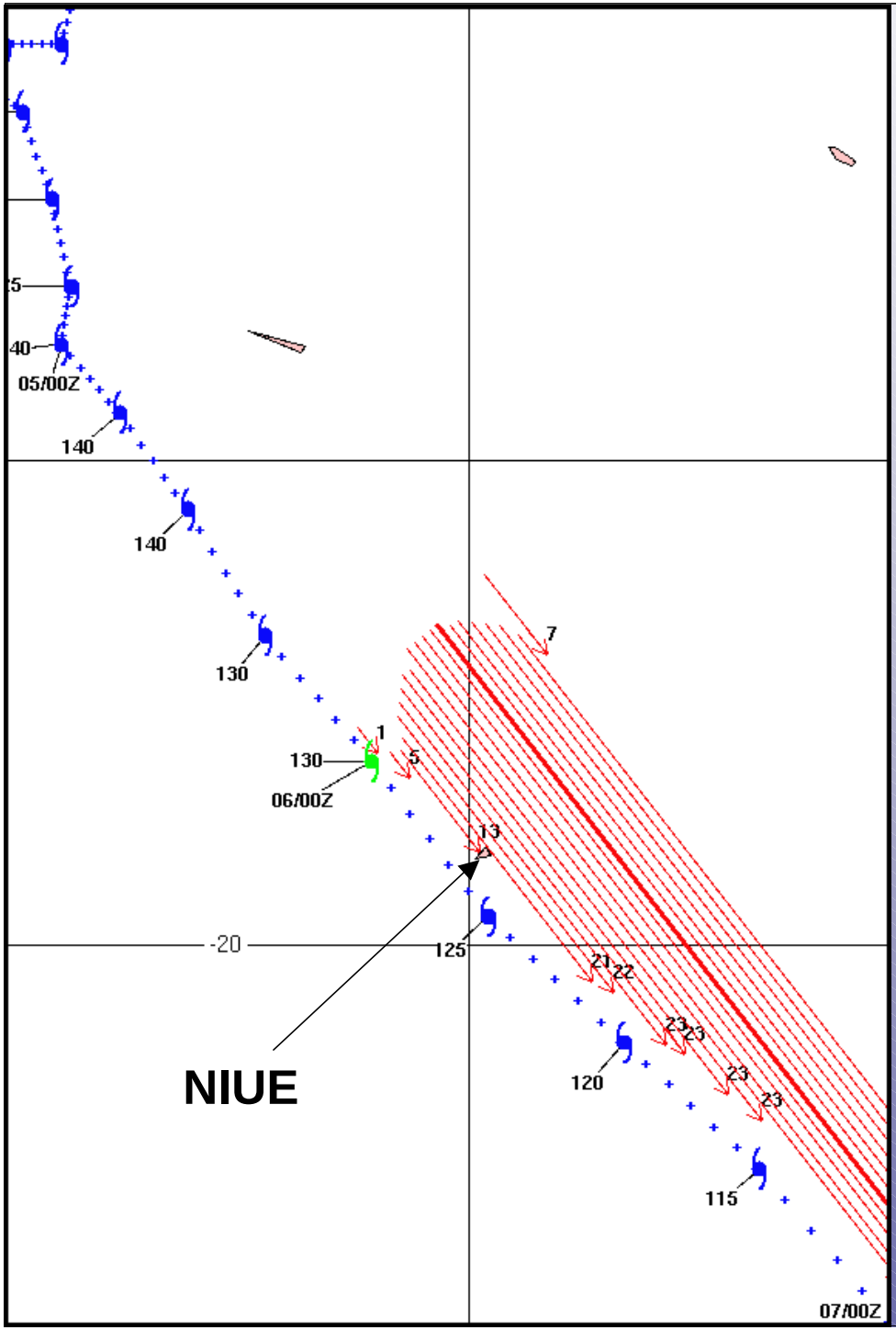
Canadian Hurricane Centre

Waves originating at 052200Z



Canadian Hurricane Centre

Waves originating at 052300Z



Canadian Hurricane Centre

Waves originating at 060000Z