Bermuda 1-2 Race Preparations
METOC Considerations

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Preparation is Everything !!!

Races are lost on the water

Anon…

What is Weather ?

Weather… n ……

: the state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness

……. Webster

or Alternatively ……. **A Collision of Air Masses**

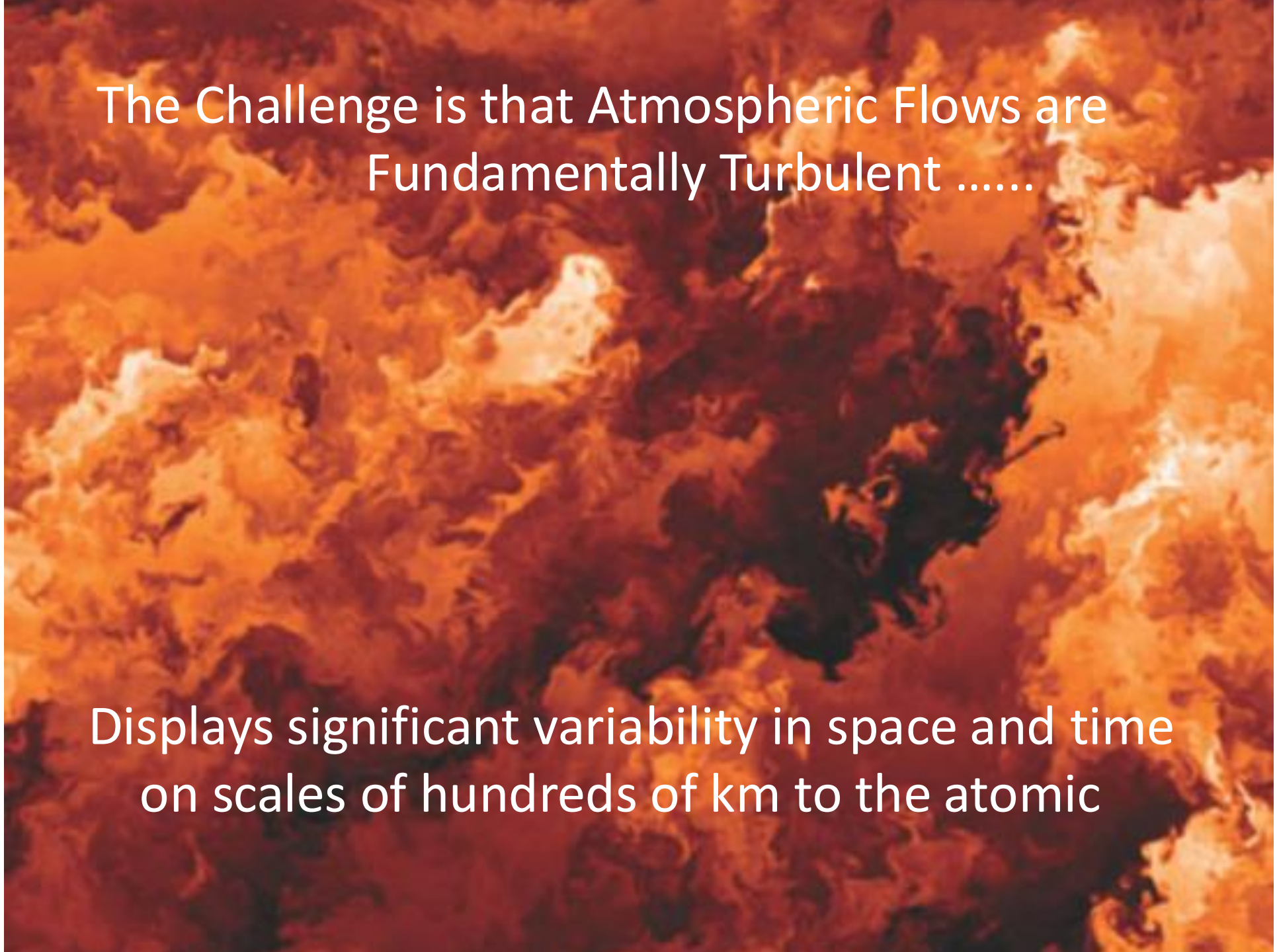
Air mass …. n ……

a body of air extending hundreds or thousands of miles horizontally and sometimes as high as the stratosphere and maintaining as it travels nearly uniform conditions of temperature and humidity at any given level

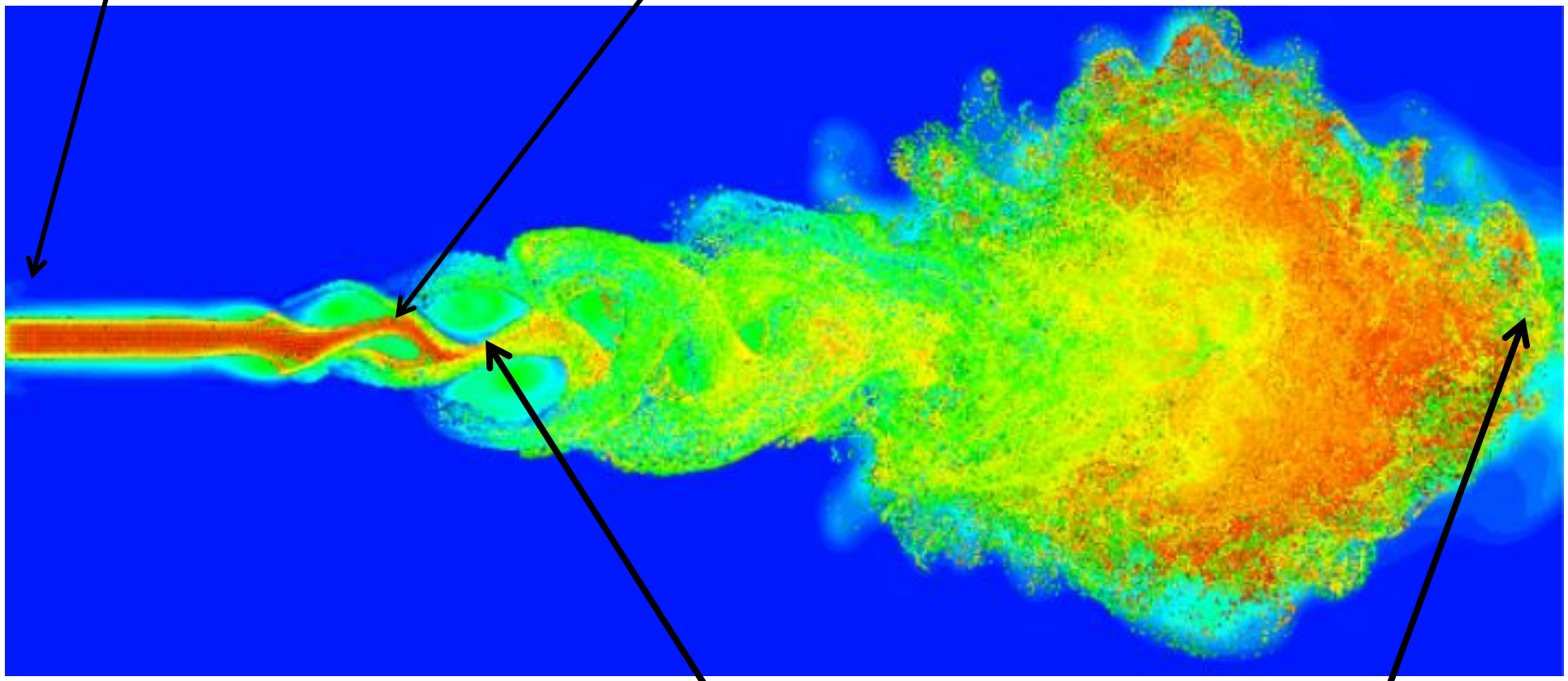
…….. Webster

"Except for man himself, the weather is probably the most variable, unreliable, and fluctuary phenomenon of which human intelligence has dared to attempt a science"

Malkus, 1962


The Challenge is that Atmospheric Flows are Fundamentally Turbulent ……
Displays significant variability in space and time on scales of hundreds of km to the atomic

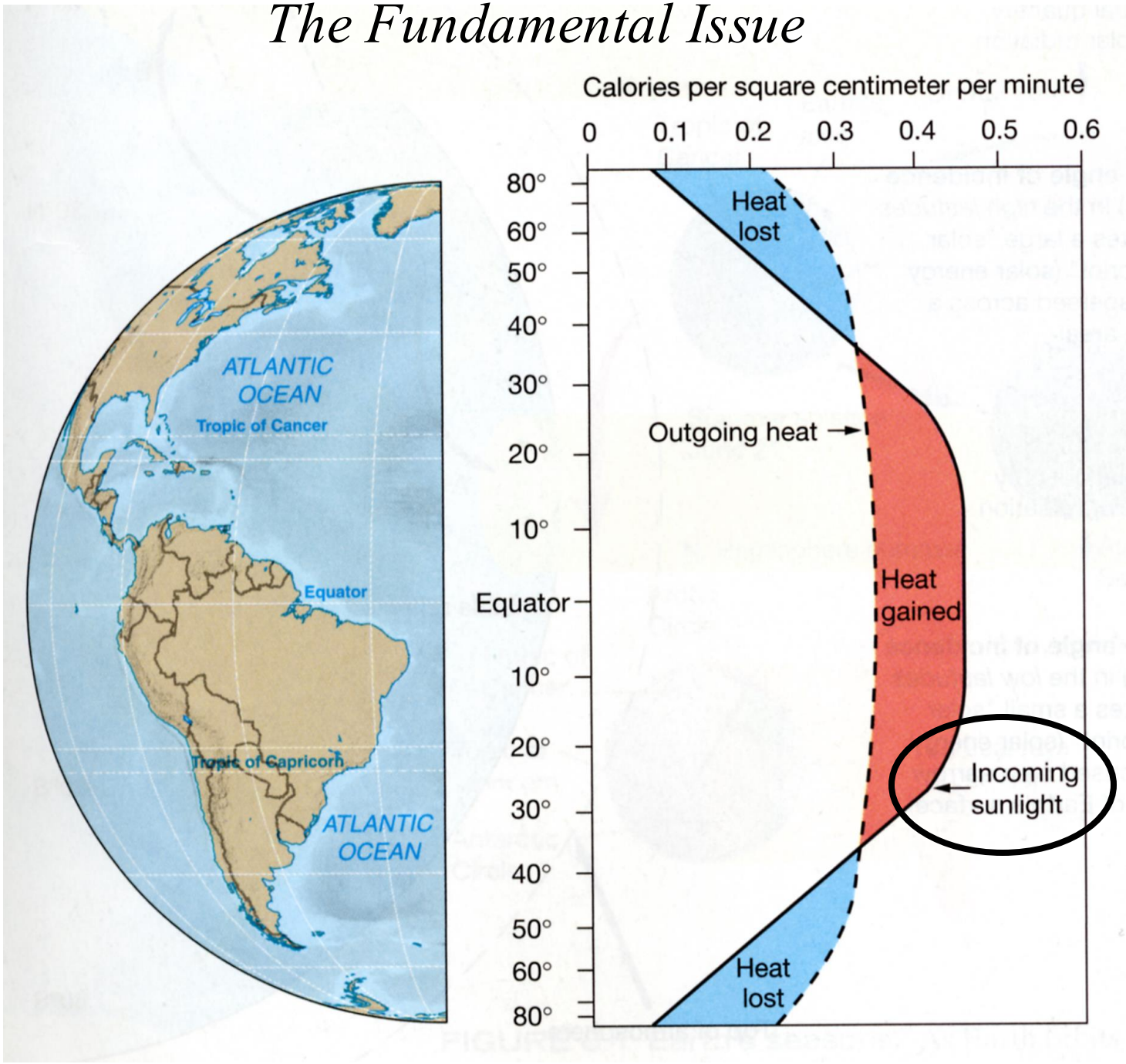
Laminar region (Deterministic)

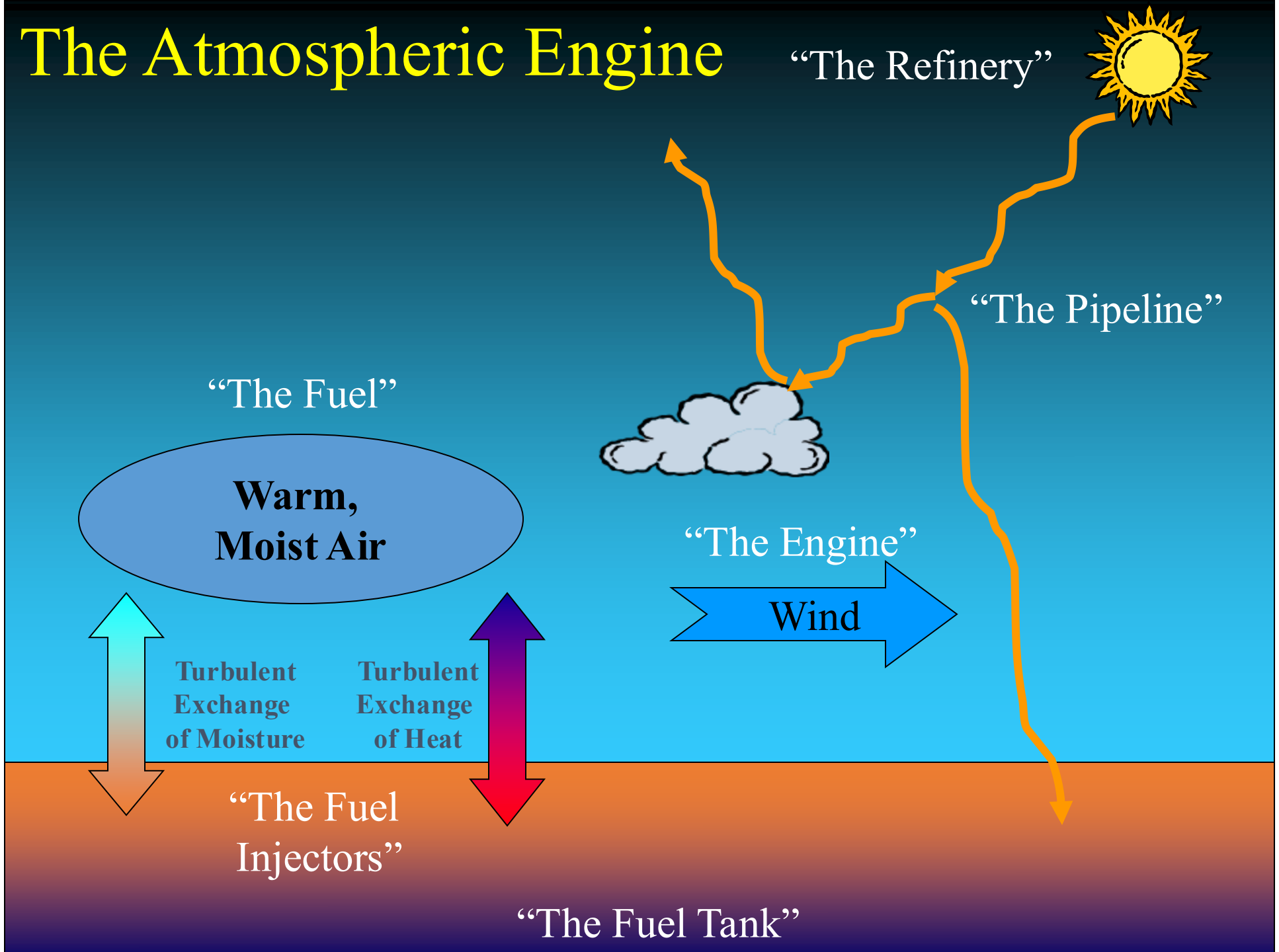


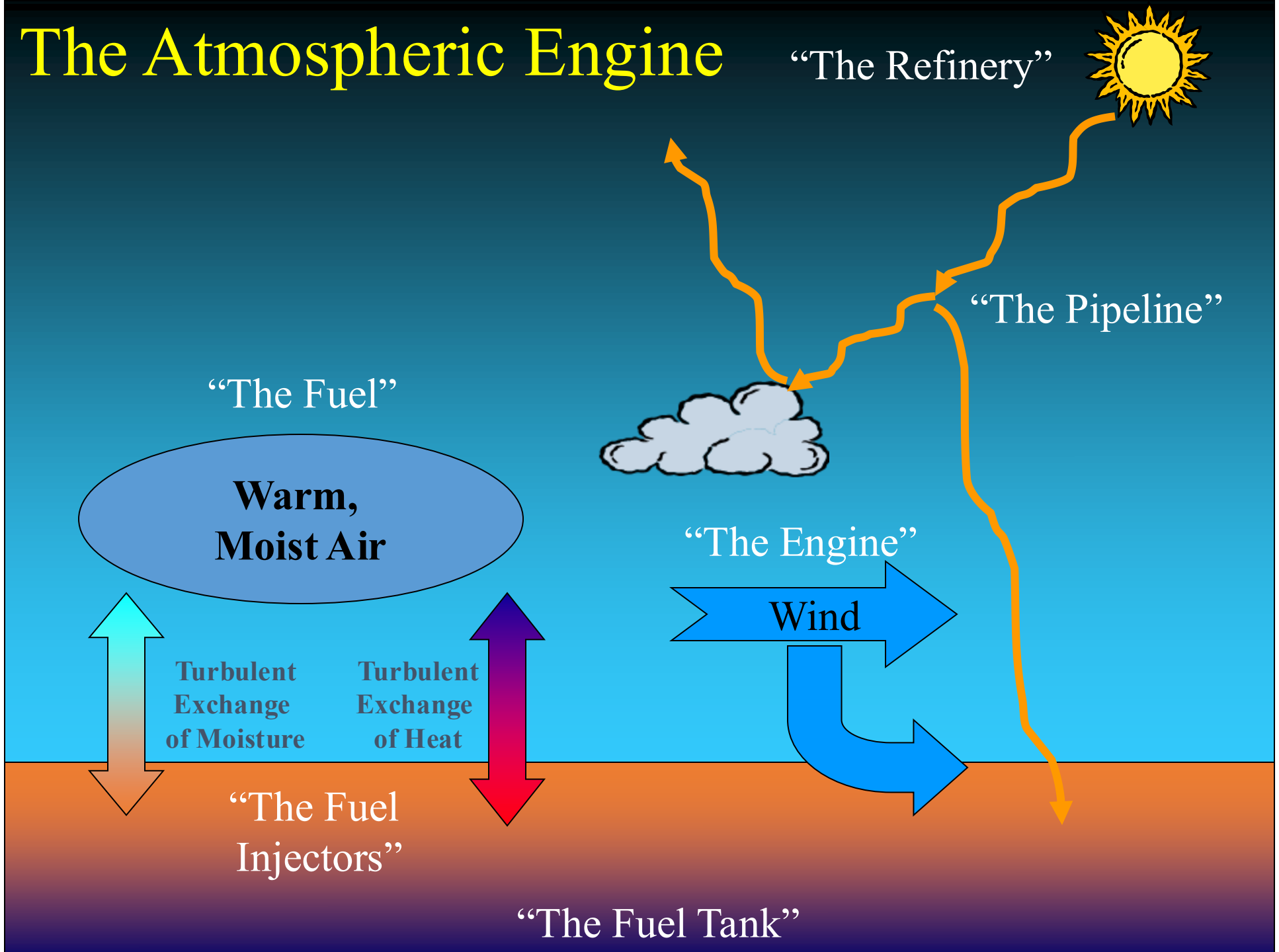
"Big whirls have little whirls,
That feed on their velocity;
And little whirls have lesser whirls,
And so on to viscosity."
Richardson….

(Probabilistic) Turbulent Region

The Fundamental Issue




The Atmospheric Engine
"The Refinery"
"The Pipeline"
"The Fuel"
Warm,
Moist Air
"The Engine"
Wind
Turbulent
Exchange
of Moisture
Turbulent
Exchange
of Heat
"The Fuel
Injectors"
"The Fuel Tank"


The Atmospheric Engine
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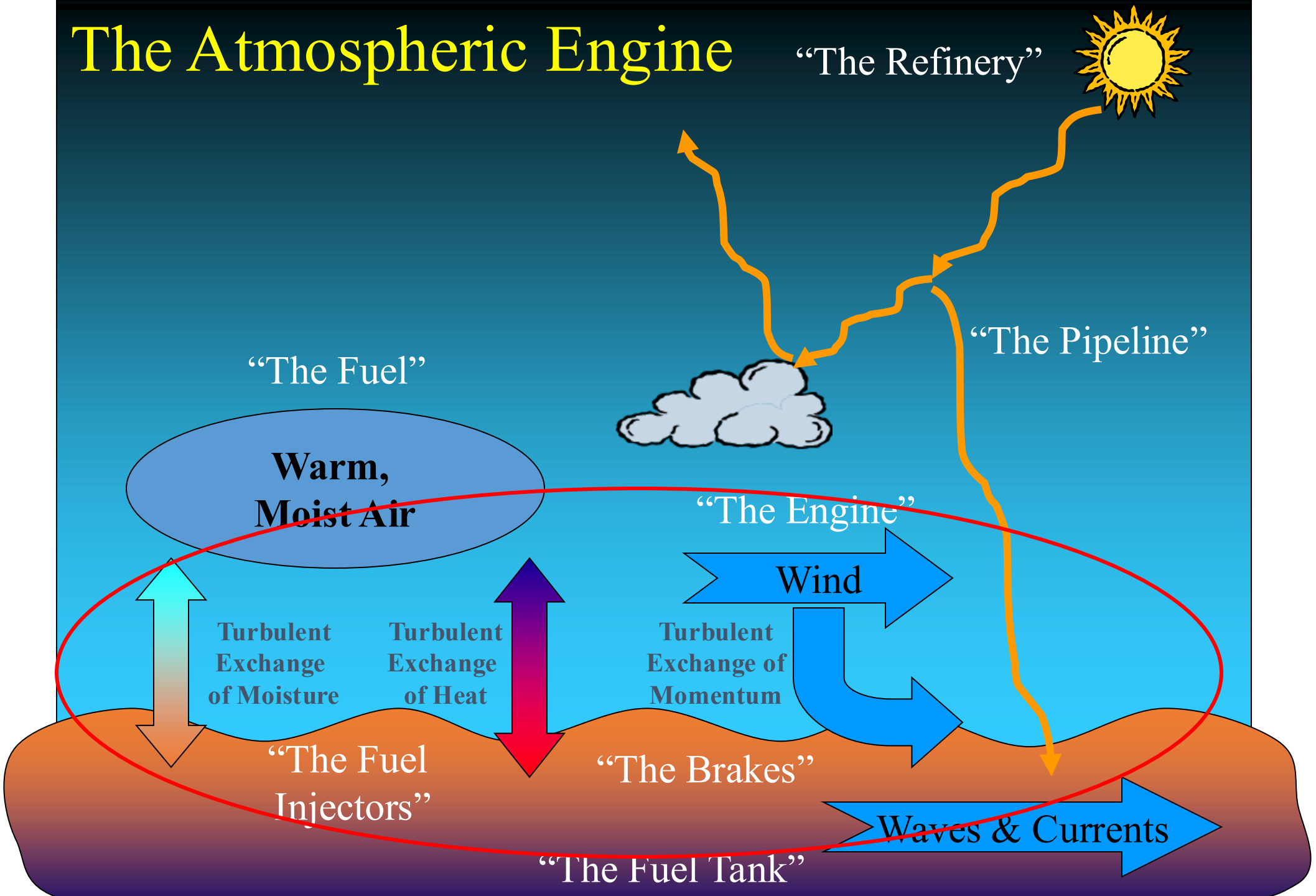
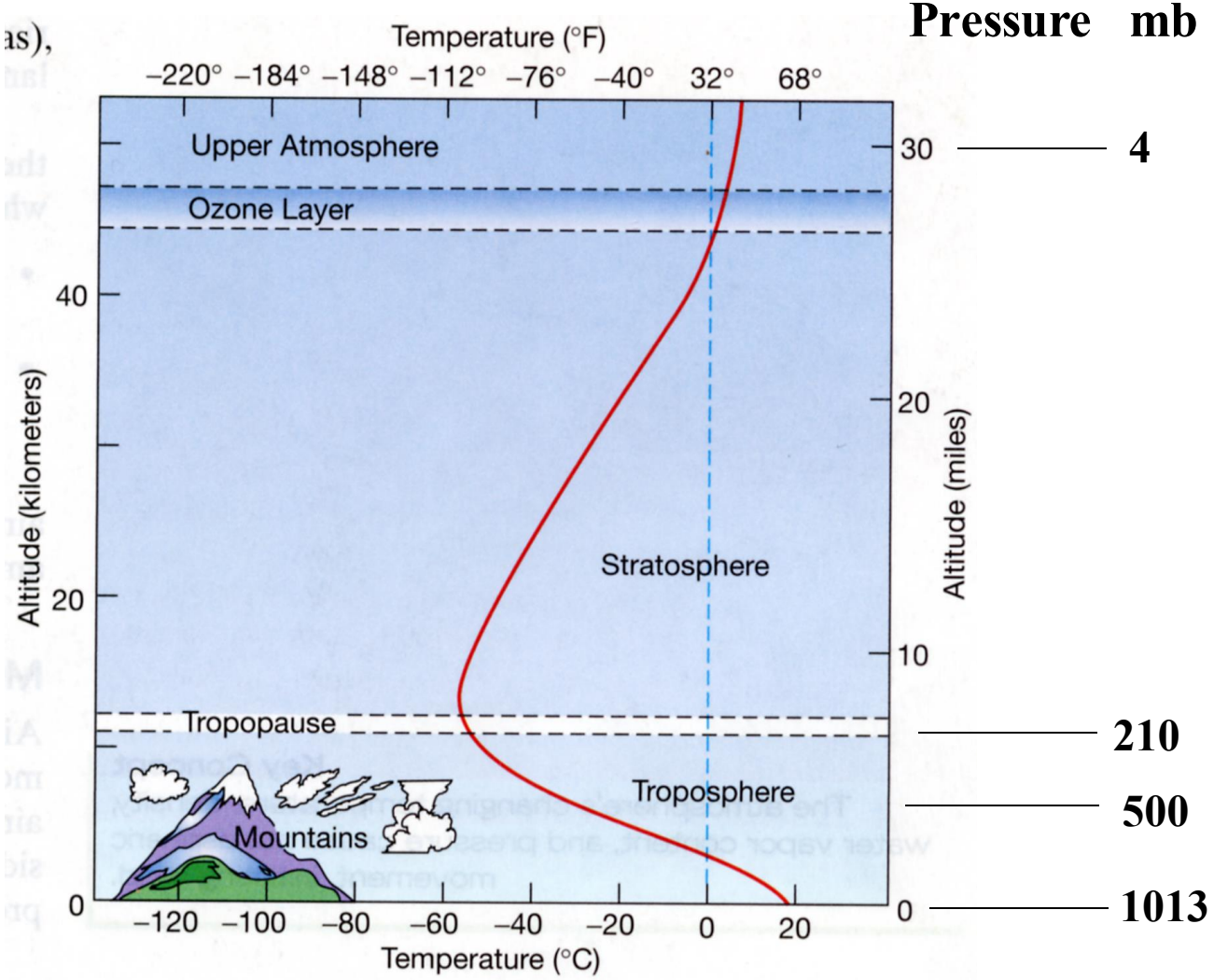
Exchange
of Moisture
Turbulent
Exchange
of Heat
"The Fuel
Injectors"
"The Fuel Tank"


The Atmospheric Engine
"The Refinery"
"The Pipeline"
"The Fuel"
Warm,
Moist Air
"The Engine"
Wind
Turbulent
Exchange
of Moisture
Turbulent
Exchange
of Heat
Turbulent
Exchange of
Momentum
"The Fuel
Injectors"
"The Brakes"
Waves & Currents
"The Fuel Tank"



Pressure mb

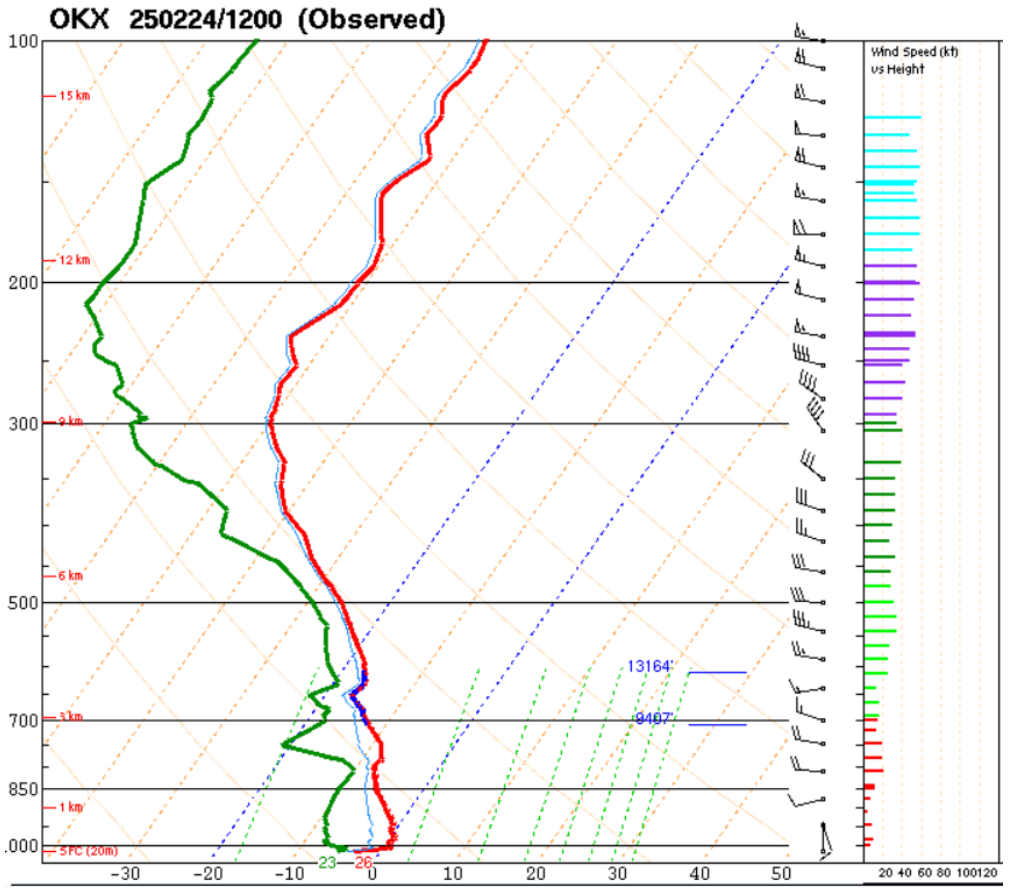
4

210

500

1013

Ideal

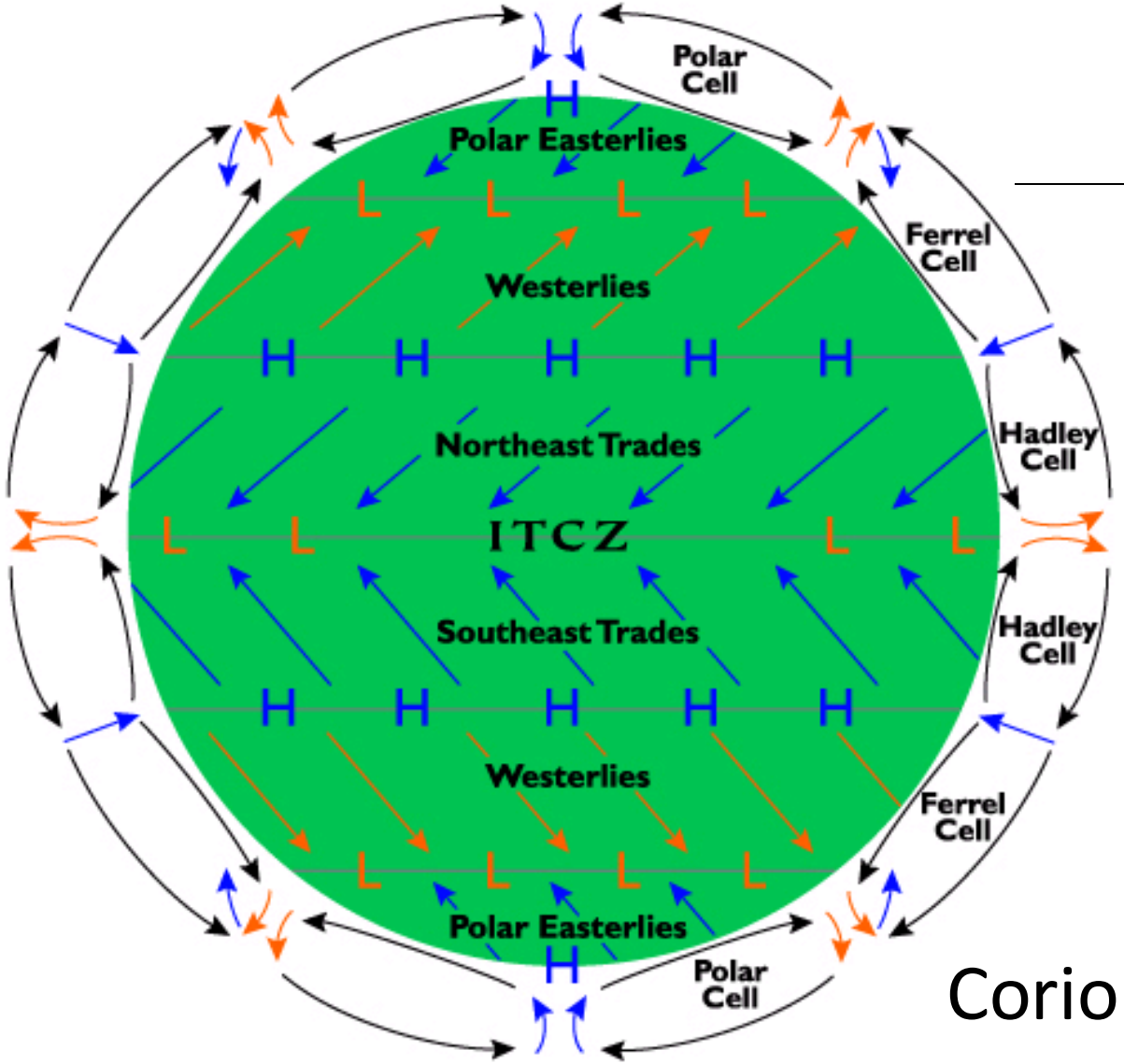


https://www.spc.noaa.gov/exper/soundings/

Observed

1013.25 millibar (mb) = 29.92 inches (in) of mercury (Hg) = 76 centimeter (cm)

The Effects all acting on the surface of a rotating spheroid



60°

30°

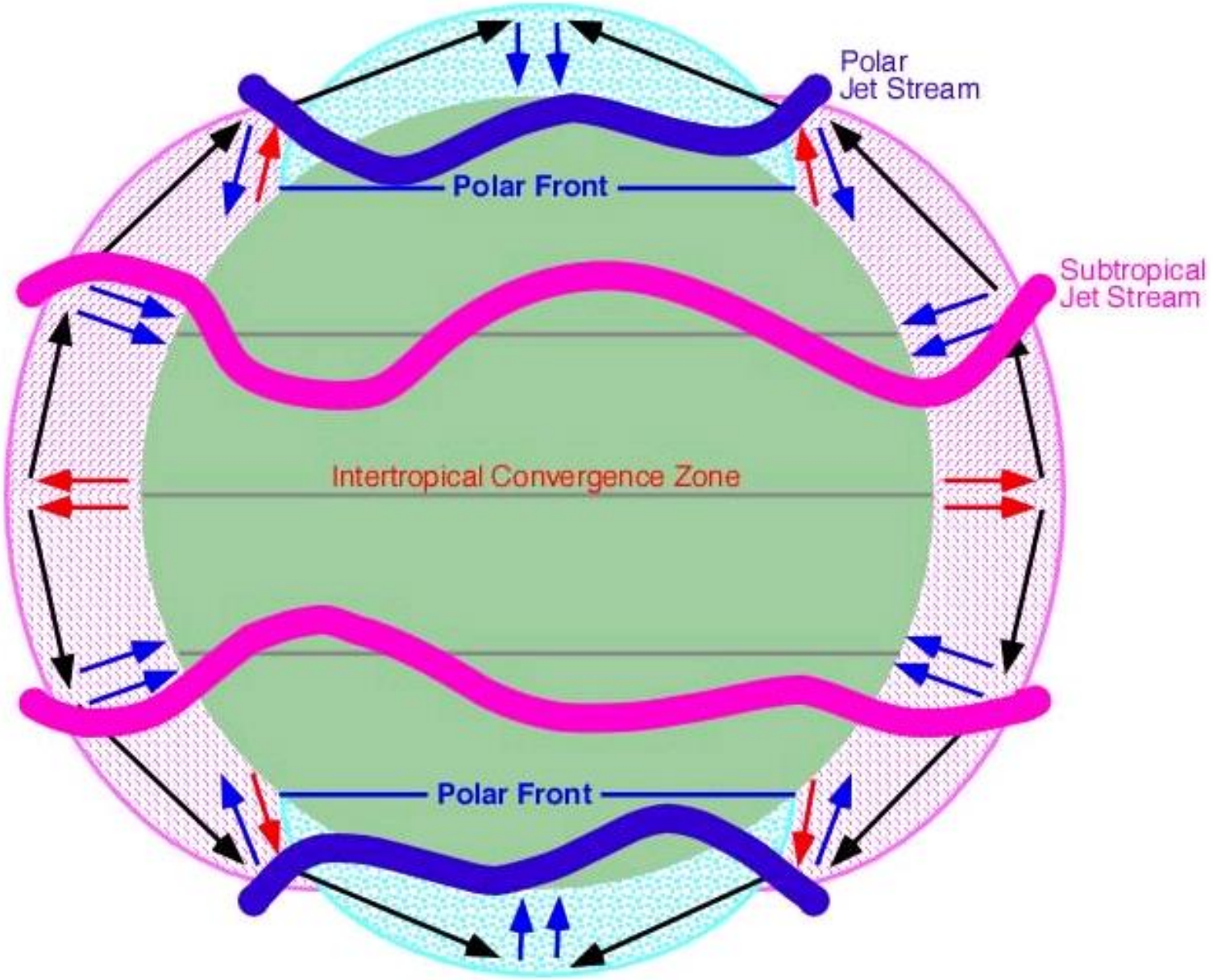
0°

Produced by the interaction of Pressure forces and Coriolis

Earth's rotation ↘ ↙ Latitude

$$\text{Coriolis Force} = 2\Omega \sin\phi \times \text{Speed}$$

Are Three Dimensional !!



Consider Atmospheric Implications of Coriolis Force Variations

IMPORTANT

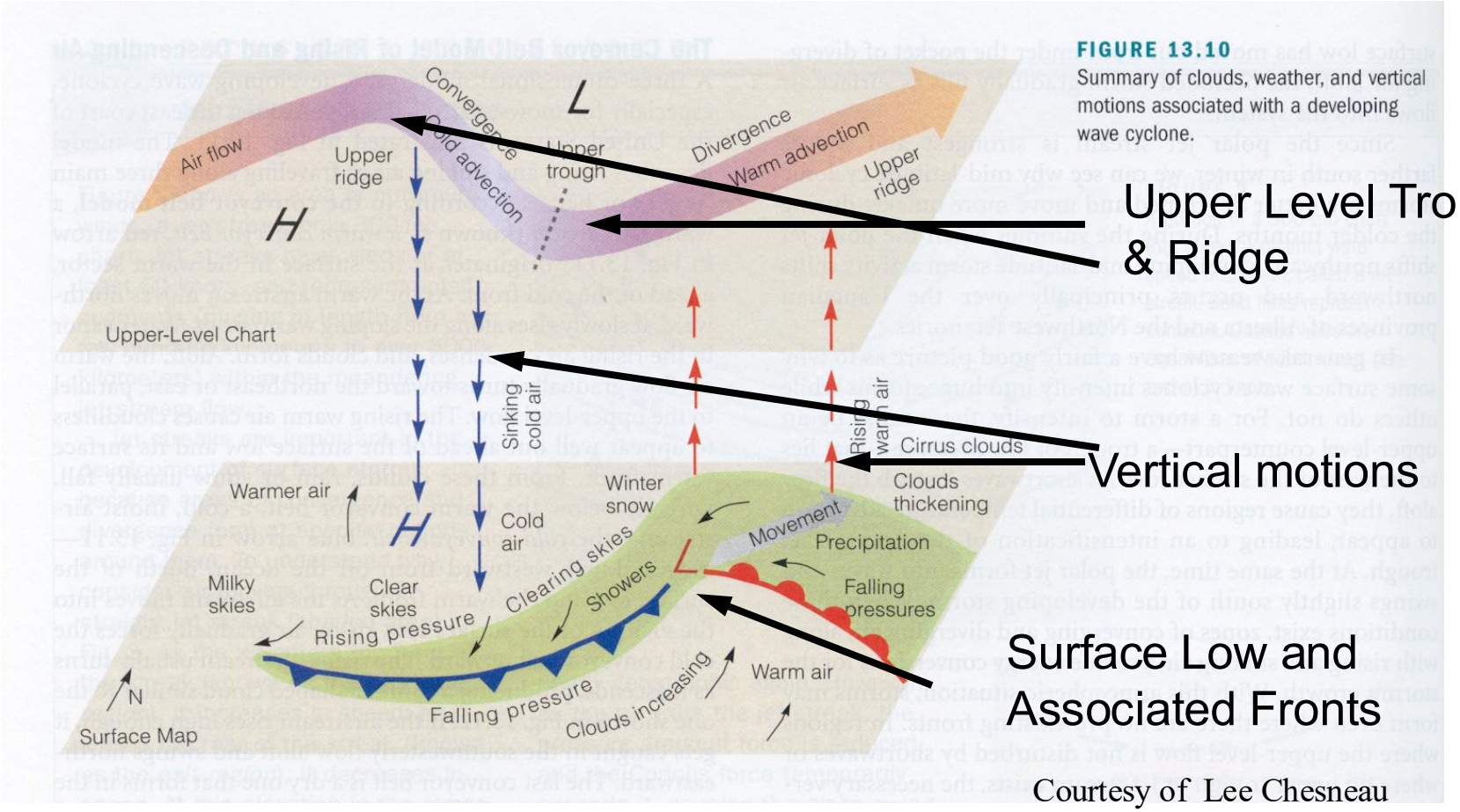


FIGURE 13.10
Summary of clouds, weather, and vertical motions associated with a developing wave cyclone.

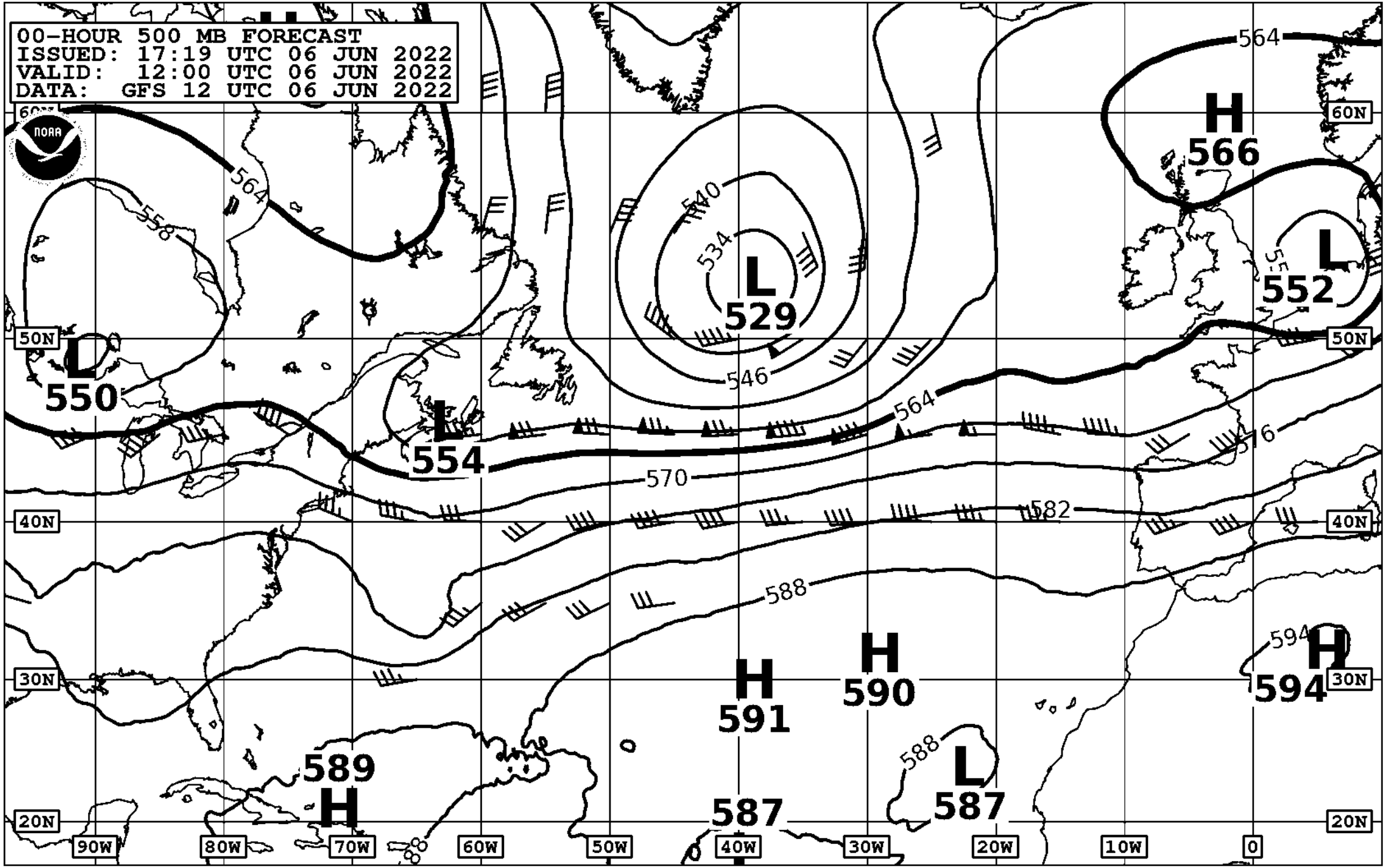
Upper Level Trough & Ridge

Vertical motions

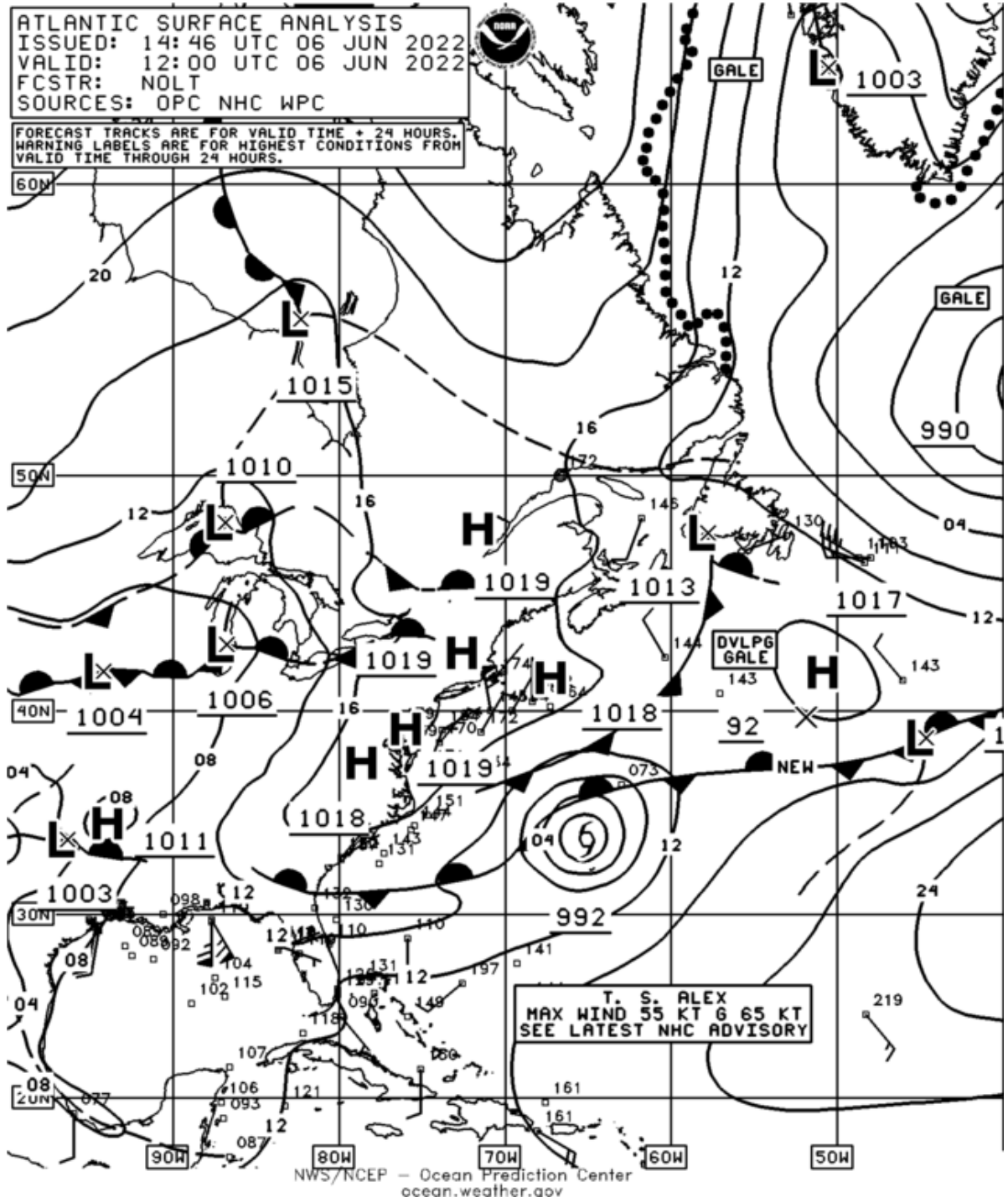
Surface Low and Associated Fronts

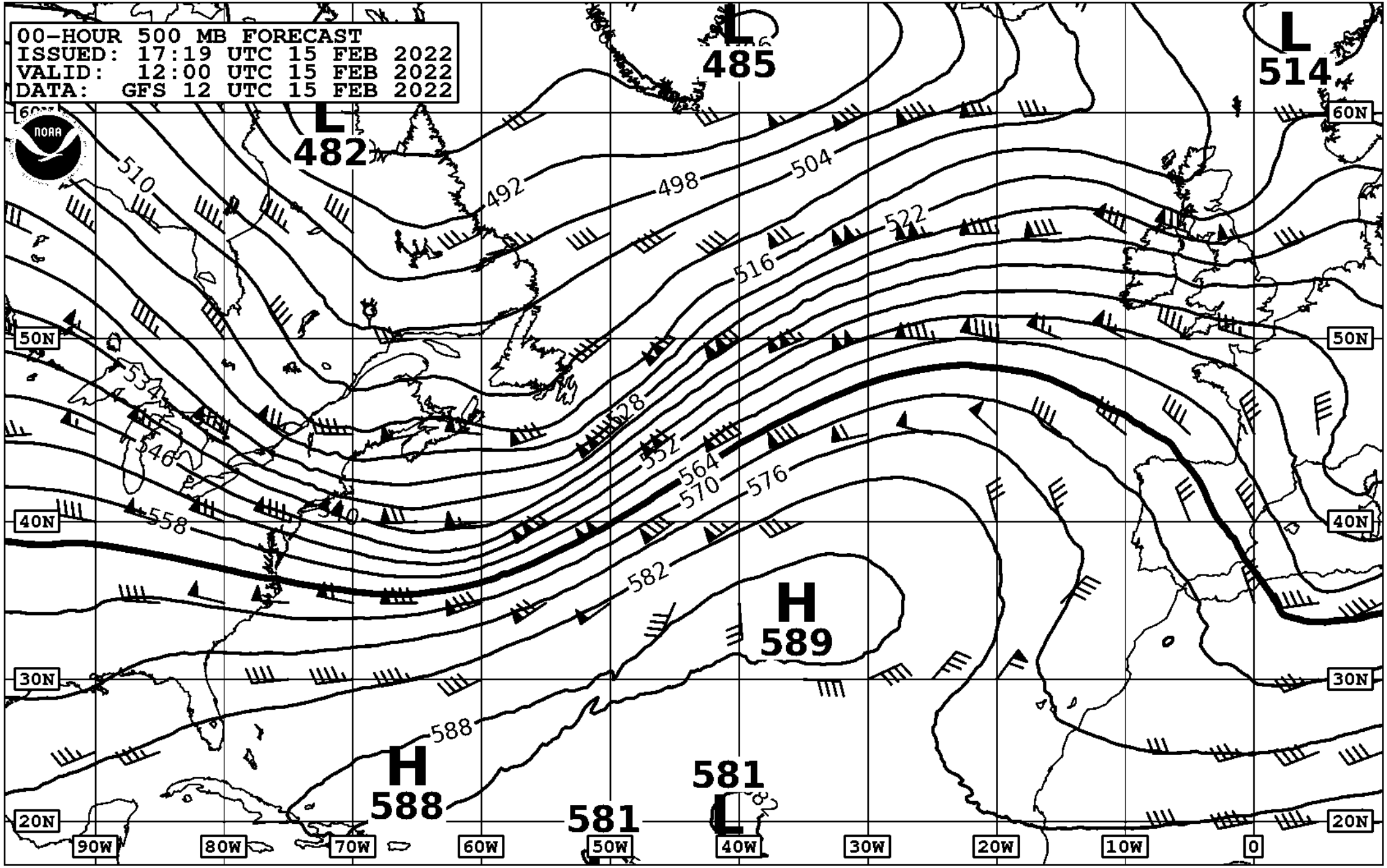
Courtesy of Lee Chesneau

Undulating motions of upper-level fronts produces ridges and troughs. Ridges support <u>surface</u> high pressure systems and troughs support <u>surface</u> low pressure systems

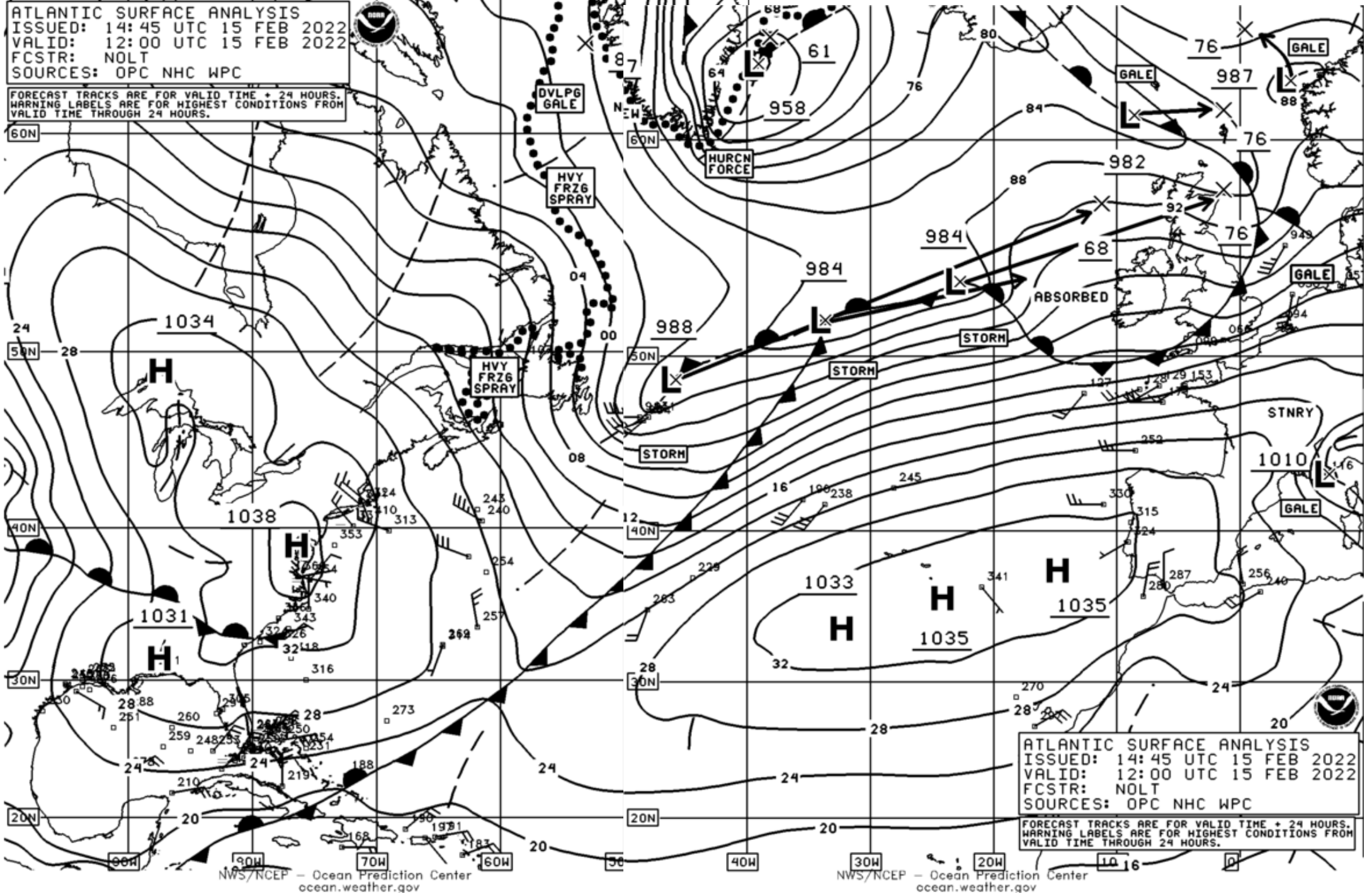


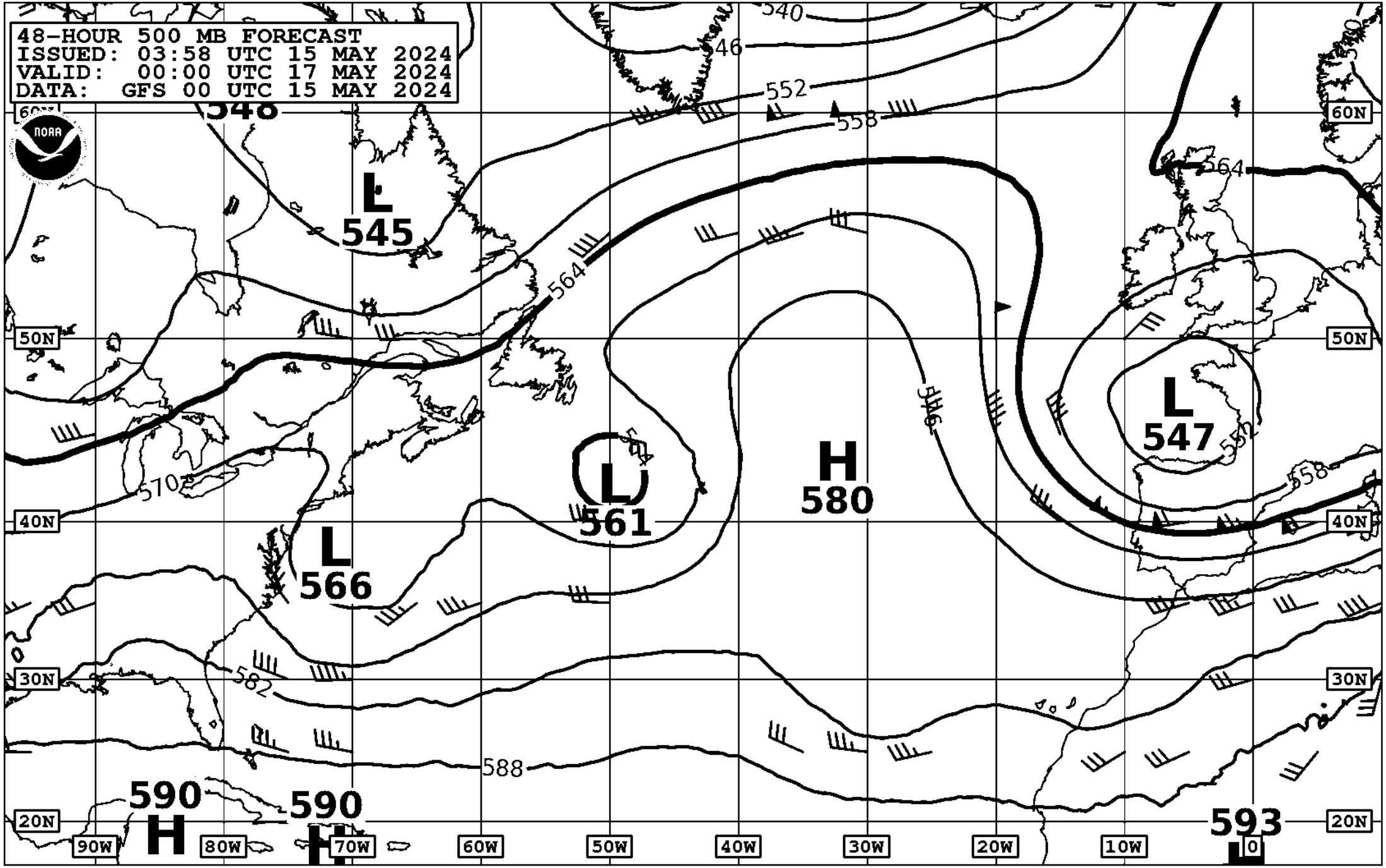
NWS/NCEP - Ocean Prediction Center
https://ocean.weather.gov


ATLANTIC SURFACE ANALYSIS
ISSUED: 14:46 UTC 06 JUN 2022
VALID: 12:00 UTC 06 JUN 2022
FCSTR: NOLT
SOURCES: OPC NHC WPC
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
GALE
DVLPG GALE
T. S. ALEX
MAX WIND 55 KT G 65 KT
SEE LATEST NHC ADVISORY
60N
50N
40N
30N
20N
90W
80W
70W
60W
50W
NWS/NCEP – Ocean Prediction Center
ocean.weather.gov



NWS/NCEP - Ocean Prediction Center
https://ocean.weather.gov


ATLANTIC SURFACE ANALYSIS
ISSUED: 14:45 UTC 15 FEB 2022
VALID: 12:00 UTC 15 FEB 2022
FCSTR: NOLT
SOURCES: OPC NHC WPC
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
DVLPG GALE
HVY FRZ6 SPRAY
HVY FRZ6 SPRAY
HURCN FORCE
GALE
GALE
GALE
GALE
STORM
STORM
STORM
ABSORBED
STNRY
1034
1038
1031
1033
1035
1035
1010
958
987
982
984
984
988
61
68
76
76
76
60N
50N
40N
30N
20N
90W
70W
60W
40W
30W
20W
10
0
NWS/NCEP – Ocean Prediction Center
ocean.weather.gov
ATLANTIC SURFACE ANALYSIS
ISSUED: 14:45 UTC 15 FEB 2022
VALID: 12:00 UTC 15 FEB 2022
FCSTR: NOLT
SOURCES: OPC NHC WPC
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
NWS/NCEP – Ocean Prediction Center
ocean.weather.gov



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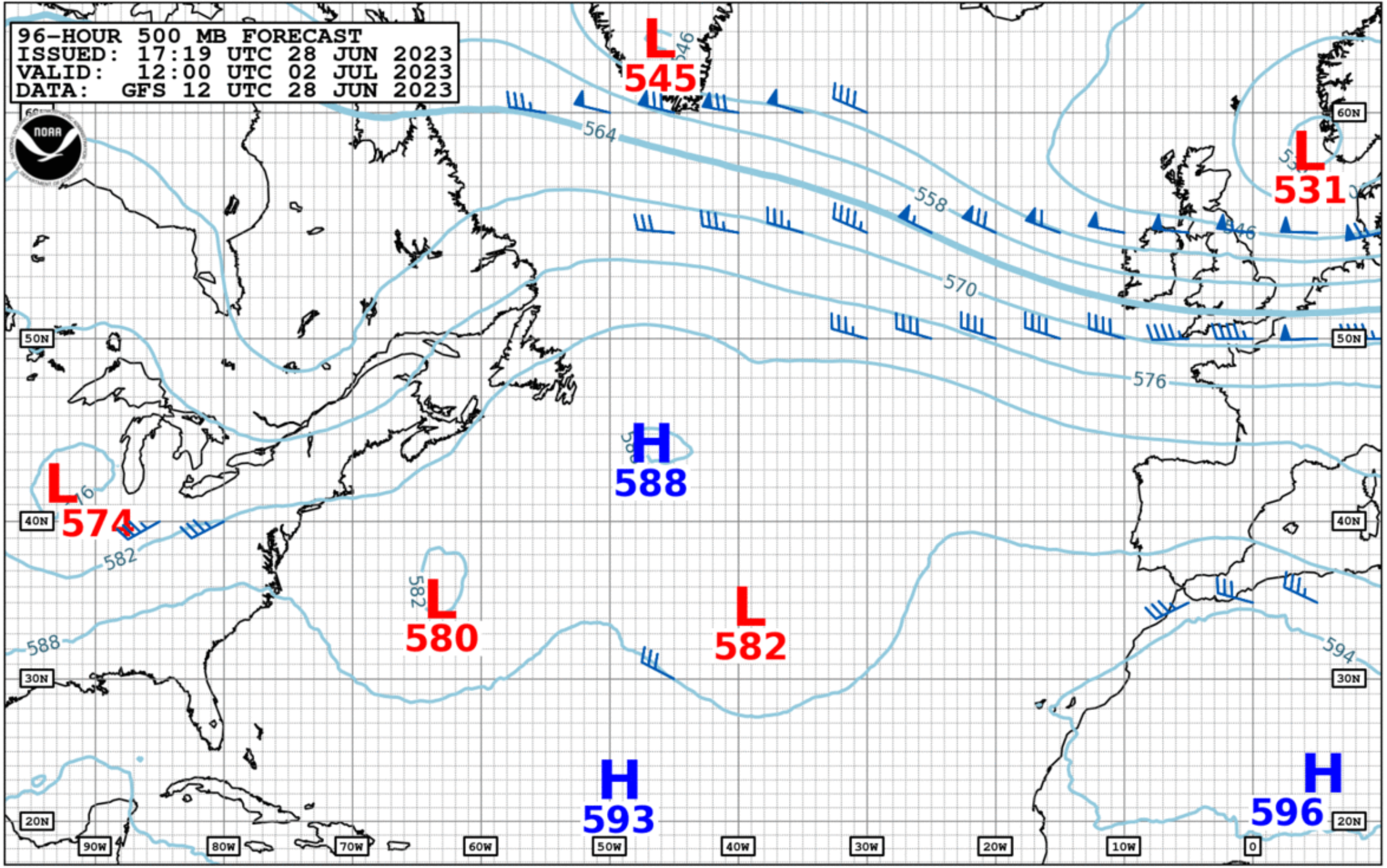

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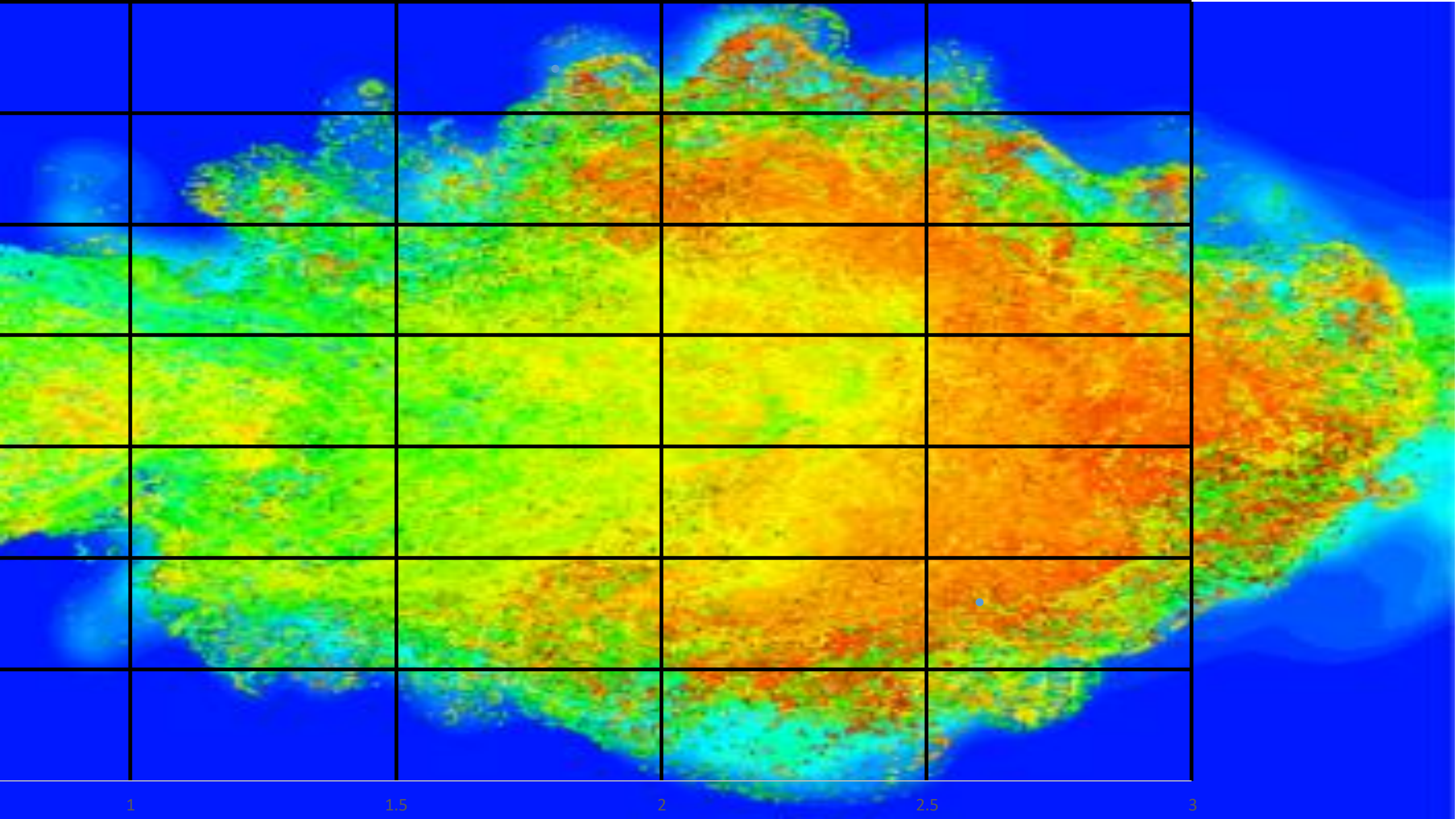
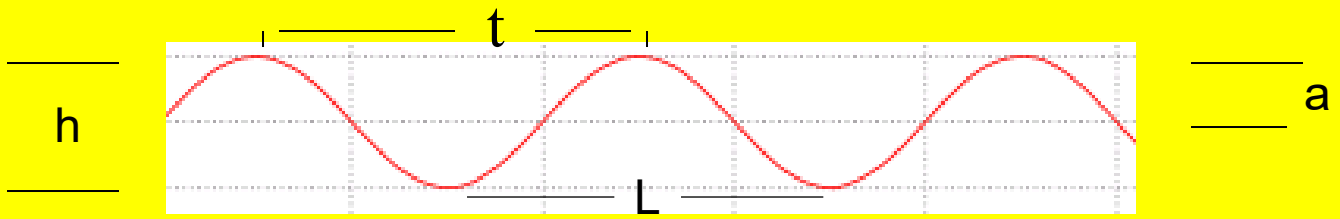

1
1.5
2
2.5
3

Meteorological Forecast Models

- **Global Forecast System (GFS)** (https://www.ncei.noaa.gov/products/weather-climate-models/global-forecast)
  The GFS model is a coupled, hydrostatic, global weather forecast model run four times a day on a horizontal resolution of **13 km** reported at **25km**
- **Global Ensemble Forecast System (GEFS)**
  The GFS model run 31 times to produce an ensemble of forecasts to quantify uncertainly. **GEFS runs four times each day with forecast going out to 35 days** with a **25km** horizontal resolution
- **Integrated Forecast System (IFS)** (Forecasts | ECMWF)
  IFS is a global, non hydrostatic, forecast model referred to as the ECMWF or "Euro" model.
  The Hi-Res version runs every 6 hours out to 10 days providing 9km resolution.
  A 51 member ensemble is run every 12hrs out to 15 days with a 18km resolution.
- **Unified Model (UKMET)**
  An operational model system run in a number of configurations. The global version provides forecasts out to 7 days on a resolution of 16 km for the ensemble
- **High Resolution Rapid refresh (HRRR)** (https://www.spc.noaa.gov/exper/hrrr/) is an hourly updated updated assimilation and model forecast system, based on the WRF (Weather Research and Forecasting) model which provides 3 km resolution out to approximately 31 hours

Surface waves

Winds produce Waves !



The size (heights and lengths) of wind waves depends on

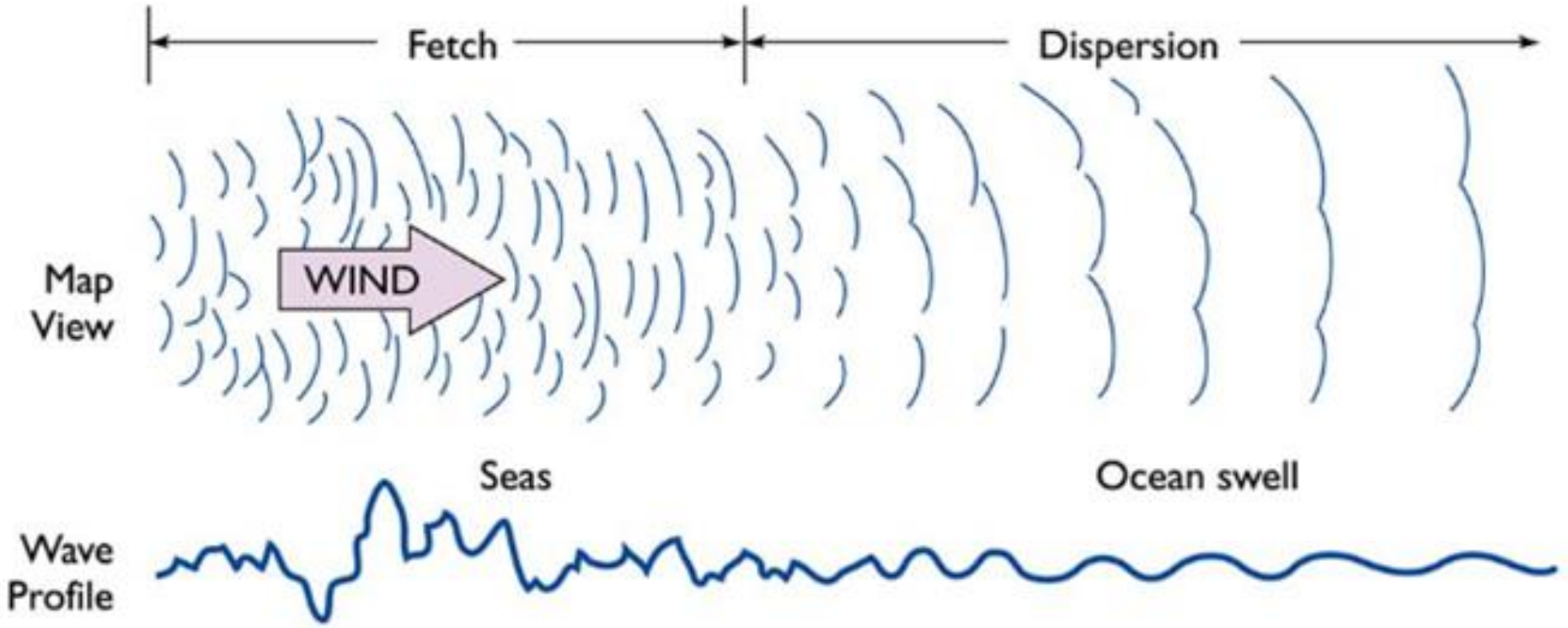
- *Wind Speed* and direction

- *Duration*

- *Fetch* – overwater distance on which wind acts

The result is a variety of waves of differing lengths and heights !

Deep Water Transformations



C = Speed of Advance = Celerity

$$C = \sqrt{gL/2\pi}$$

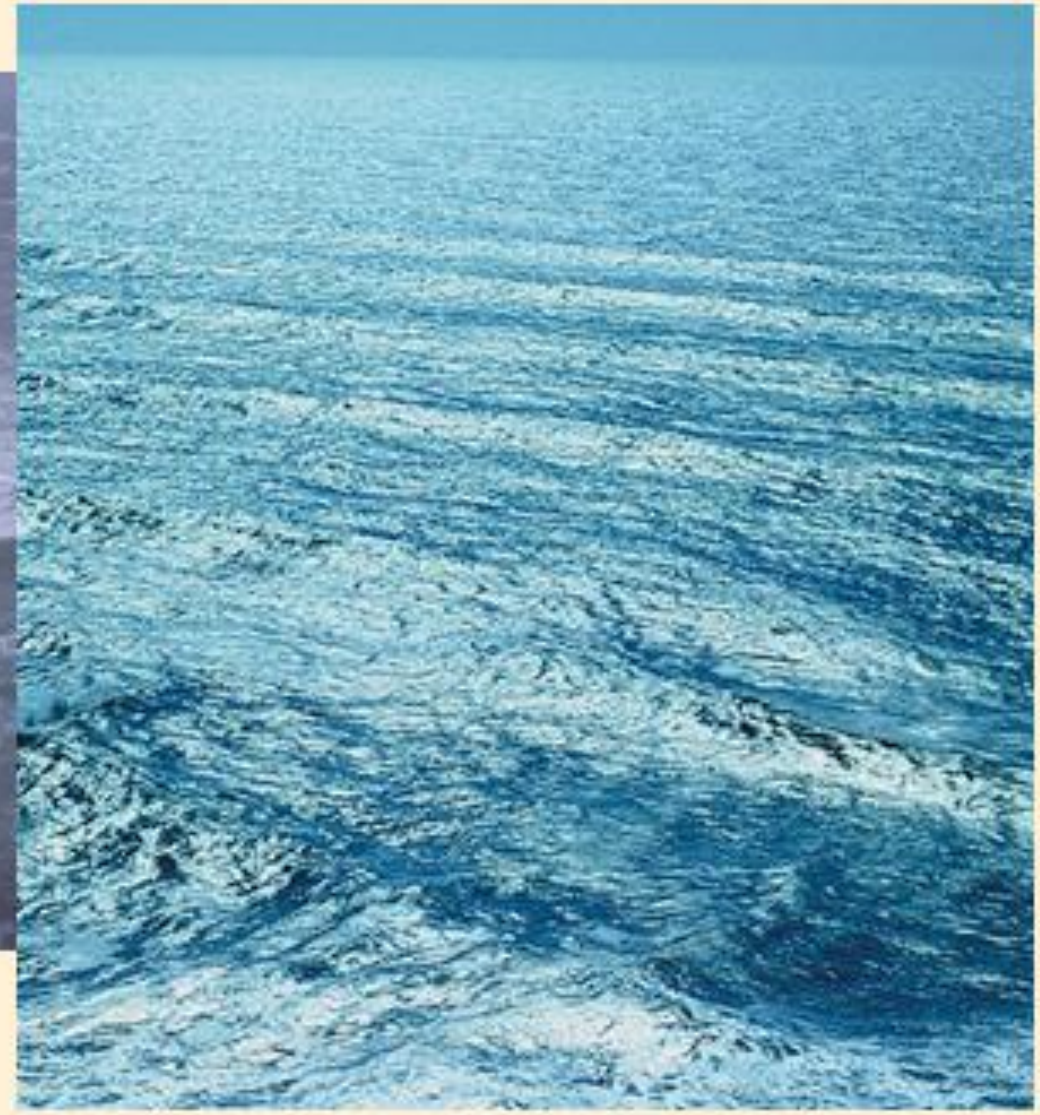
g = Acceleration of Gravity

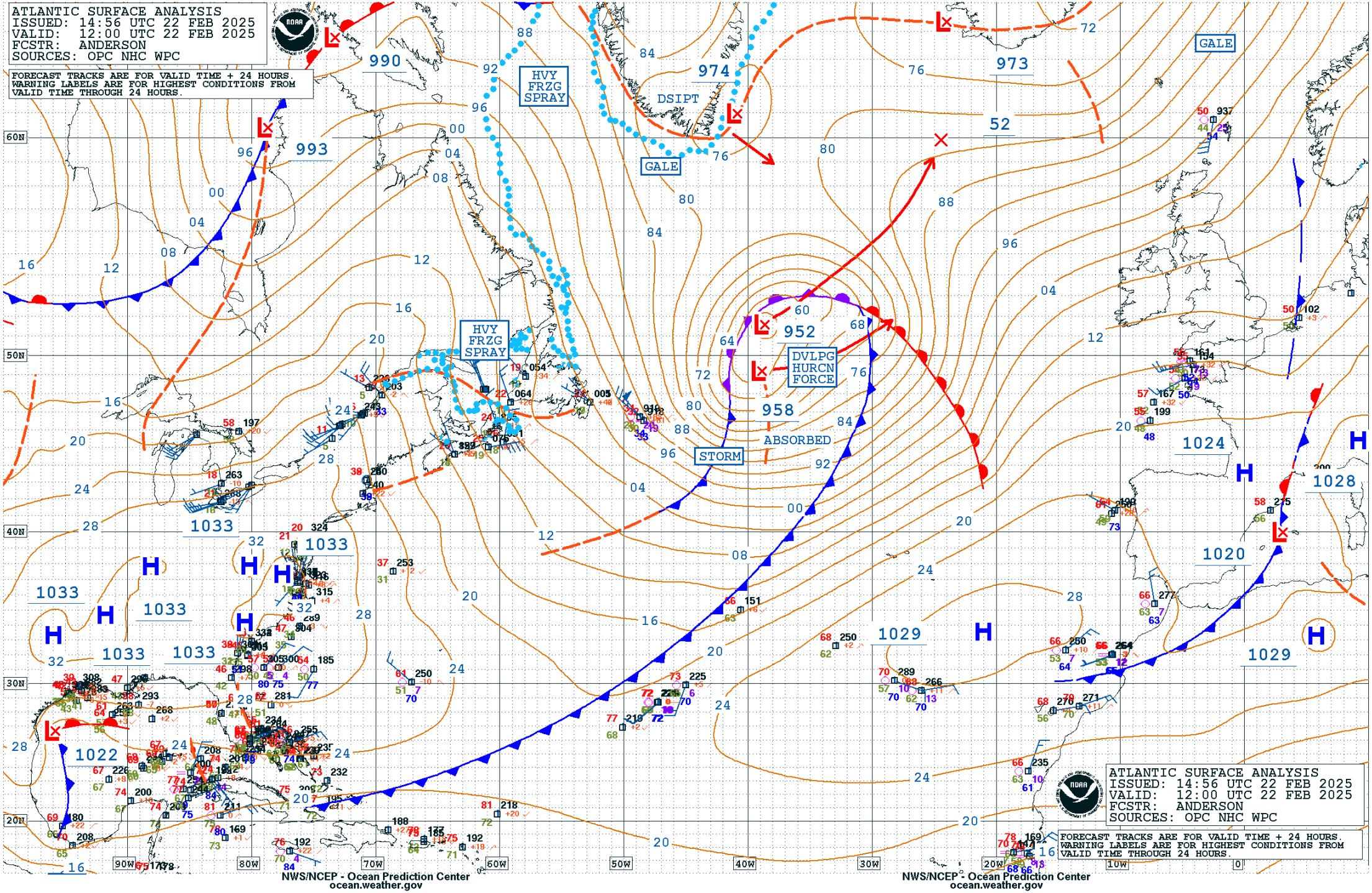
$$L = 5.12\ T^2$$

T = Wave Period in sec.

Chaotic seas
inside fetch area.

Swells: wave
type found
outside the fetch.





ATLANTIC SURFACE ANALYSIS
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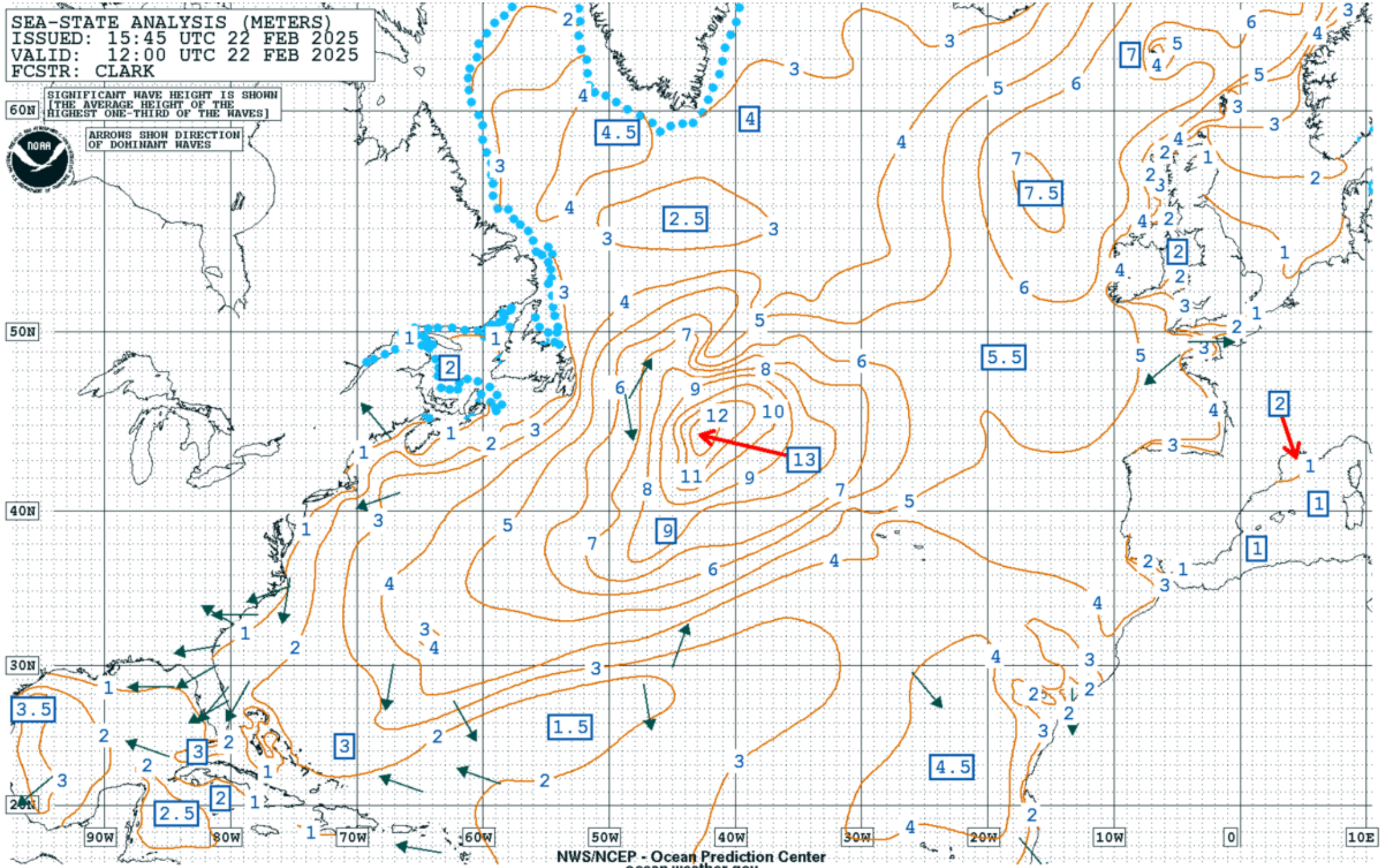
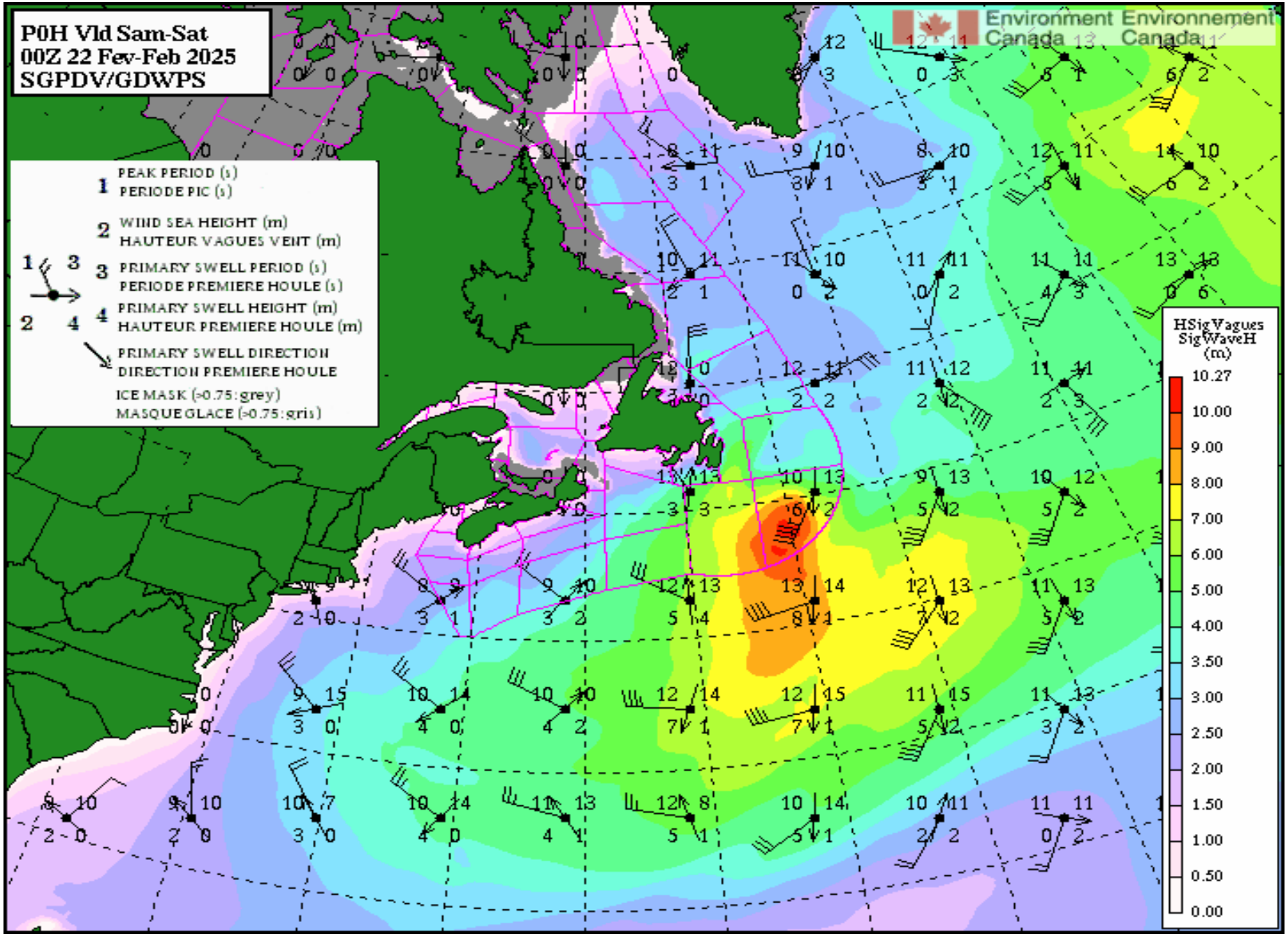
VALID: 12:00 UTC 22 FEB 2025
FCSTR: ANDERSON
SOURCES: OPC NHC WPC
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM
VALID TIME THROUGH 24 HOURS.
NWS/NCEP - Ocean Prediction Center
ocean.weather.gov

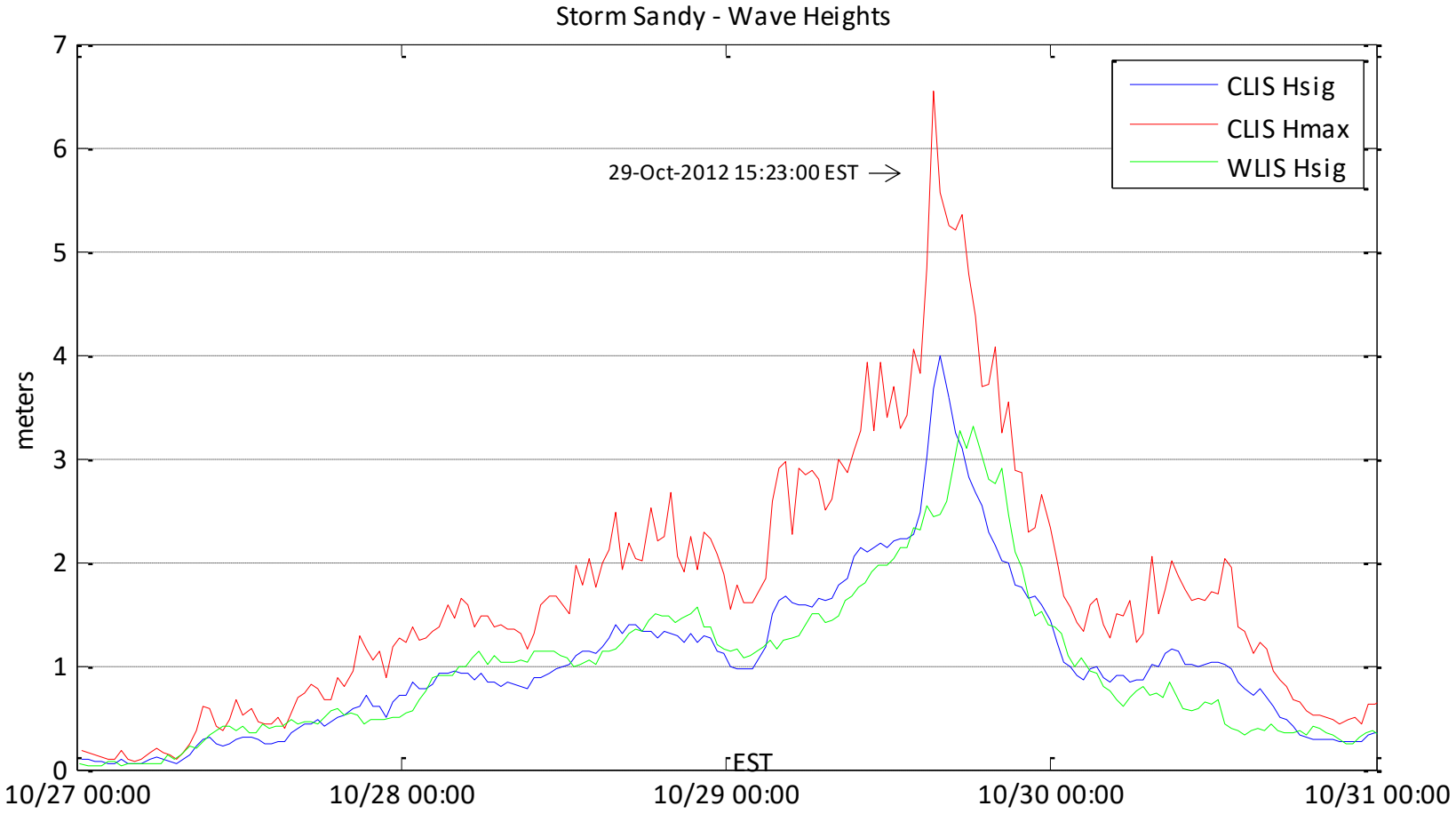

SEA-STATE ANALYSIS (METERS)
ISSUED: 15:45 UTC 22 FEB 2025
VALID: 12:00 UTC 22 FEB 2025
FCSTR: CLARK
SIGNIFICANT WAVE HEIGHT IS SHOWN [THE AVERAGE HEIGHT OF THE HIGHEST ONE-THIRD OF THE WAVES]
ARROWS SHOW DIRECTION OF DOMINANT WAVES
60N
50N
40N
30N
20N
90W
80W
70W
60W
50W
40W
30W
20W
10W
0
10E
NWS/NCEP - Ocean Prediction Center
ocean.weather.gov



[Wave Model Charts - Environment Canada]

University of Connecticut

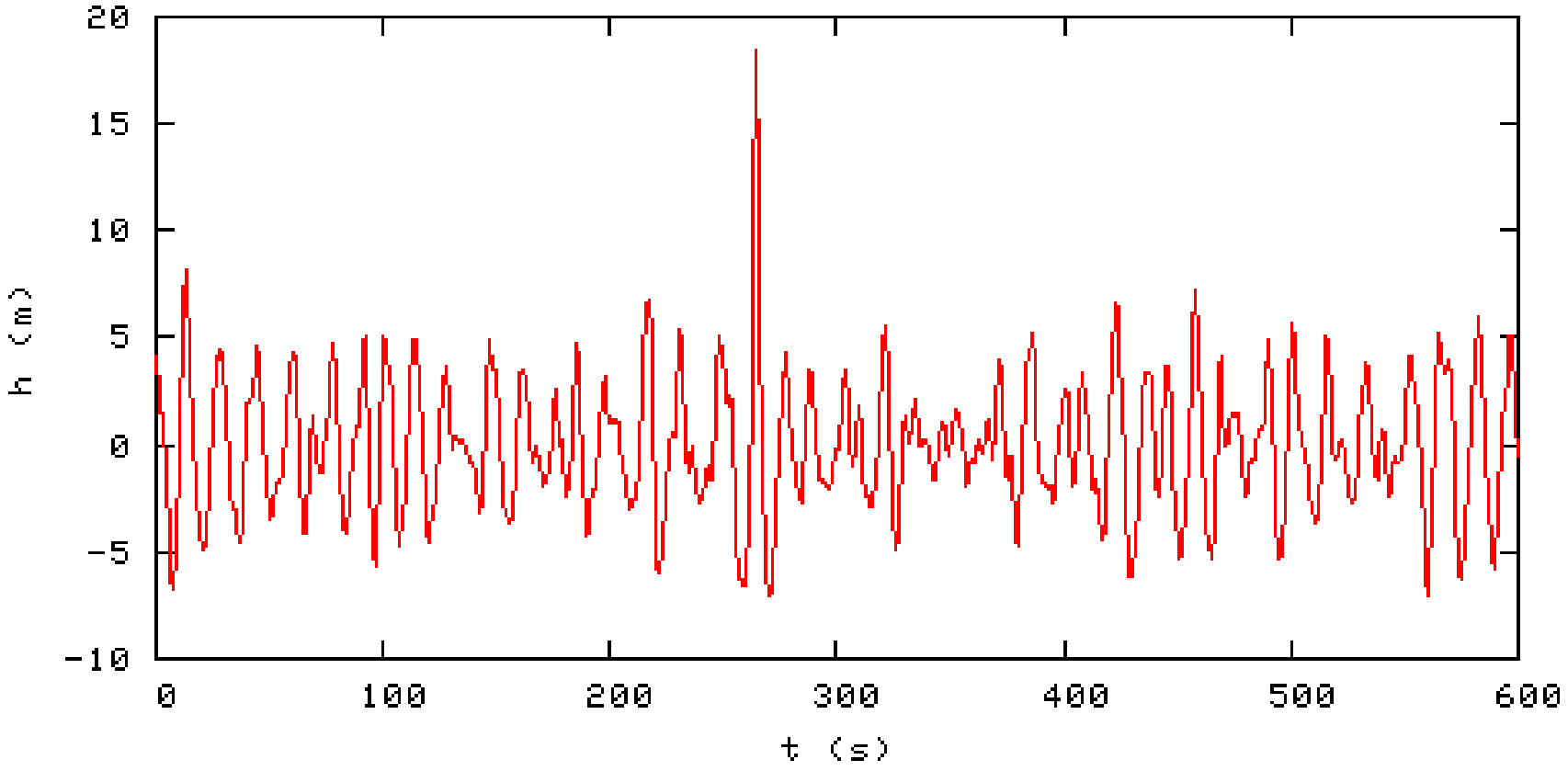
Department of Marine Sciences



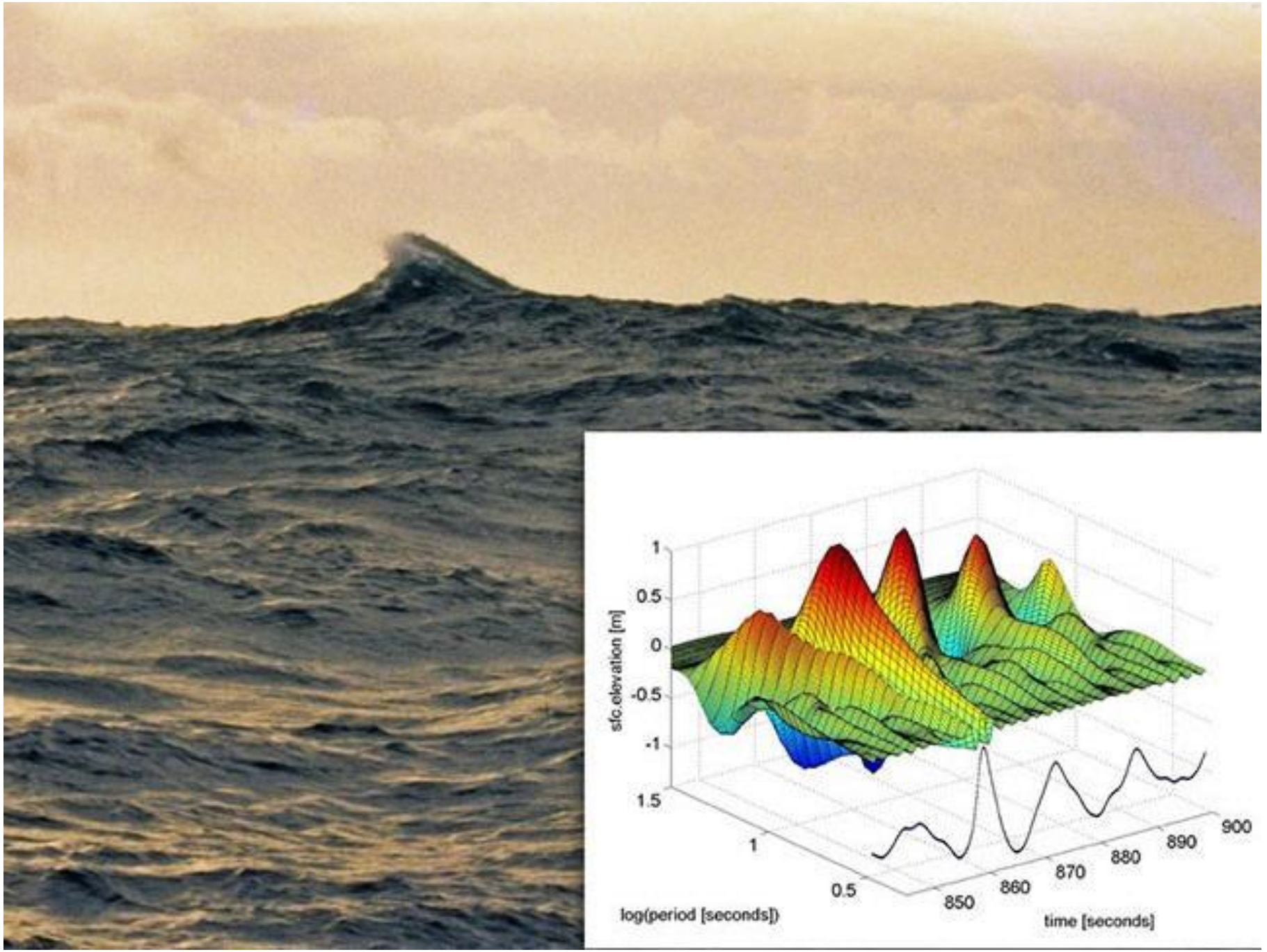
Long Island Sound Integrated Coastal Observing System – lisicos.uconn.edu
A component of NERACOOS – neracoos.org
Warning : data is considered provisional and subject to change.

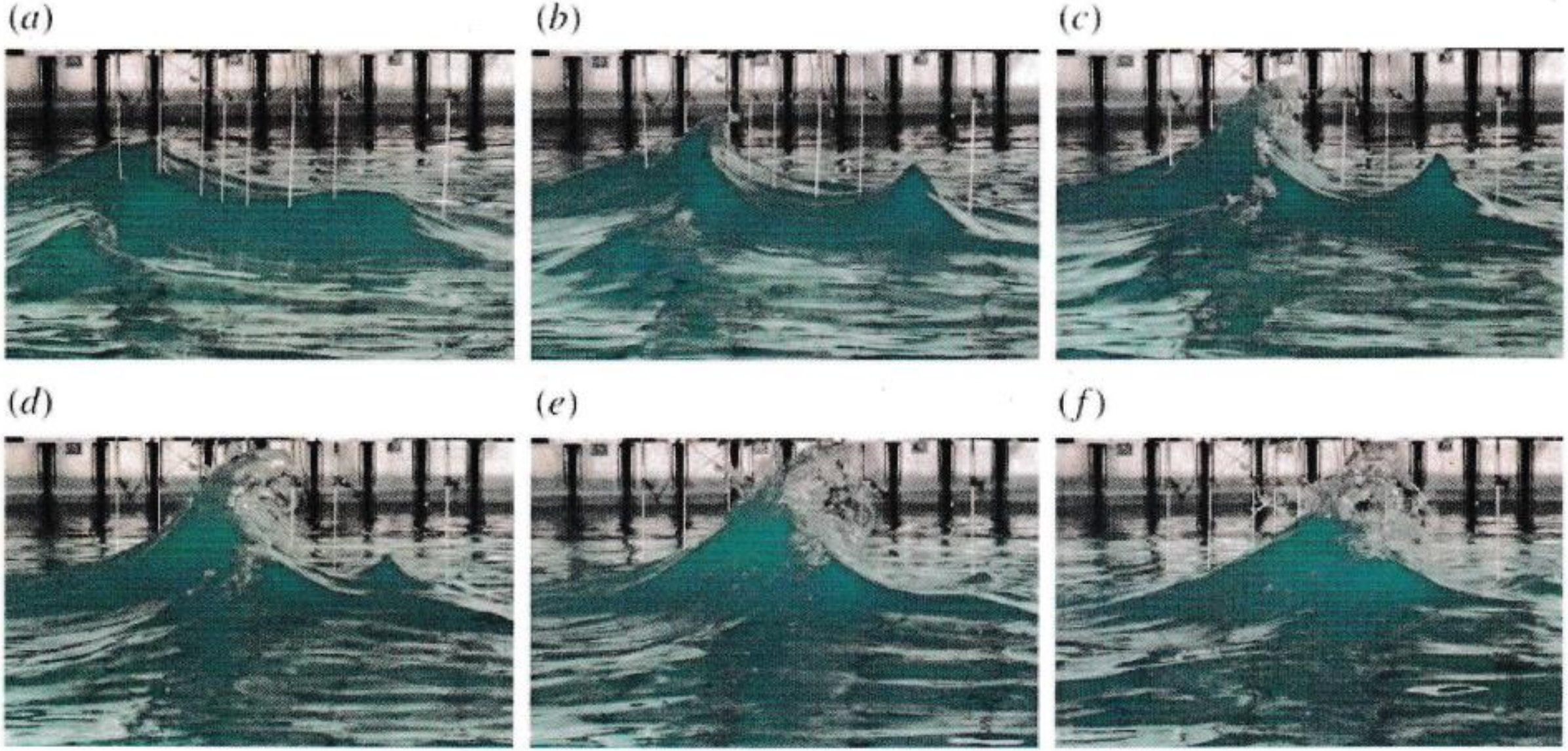
Hsig = significant wave height
Hmax = maximum wave height

Rogue Wave - Draupner Platform - January 1, 1995



Rogue Wave ….waves whose height is more than twice the significant wave height (SWH)! ?

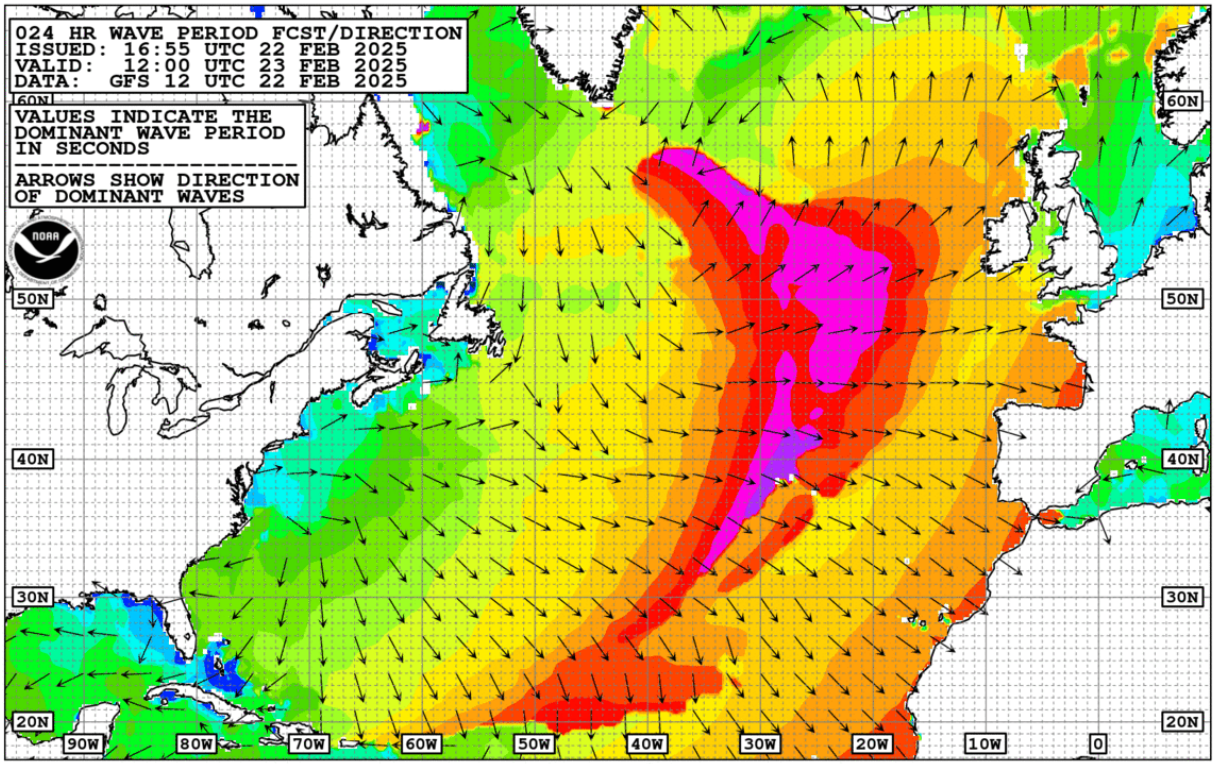

1
0.5
0
-0.5
-1
sfc.elevation [m]
1.5
1
0.5
log(period [seconds])
850
860
870
880
890
900
time [seconds]



Still images showing the most successful reconstruction of the Draupner wave.

Seeking to understand how freak waves form, the team of researchers set out to reproduce the Draupner wave under laboratory conditions at the FloWave Ocean Energy Research facility at the University Of Edinburgh. What they discovered was that that they could recreate the wave using two smaller wave groups that crossed at a specific angle – approximately 120 degrees.

"When waves are not crossing, wave breaking limits the height that a wave can achieve. However, when waves cross at large angles, wave breaking behavior changes and no longer limits the height a wave can achieve in the same manner," the researchers noted.



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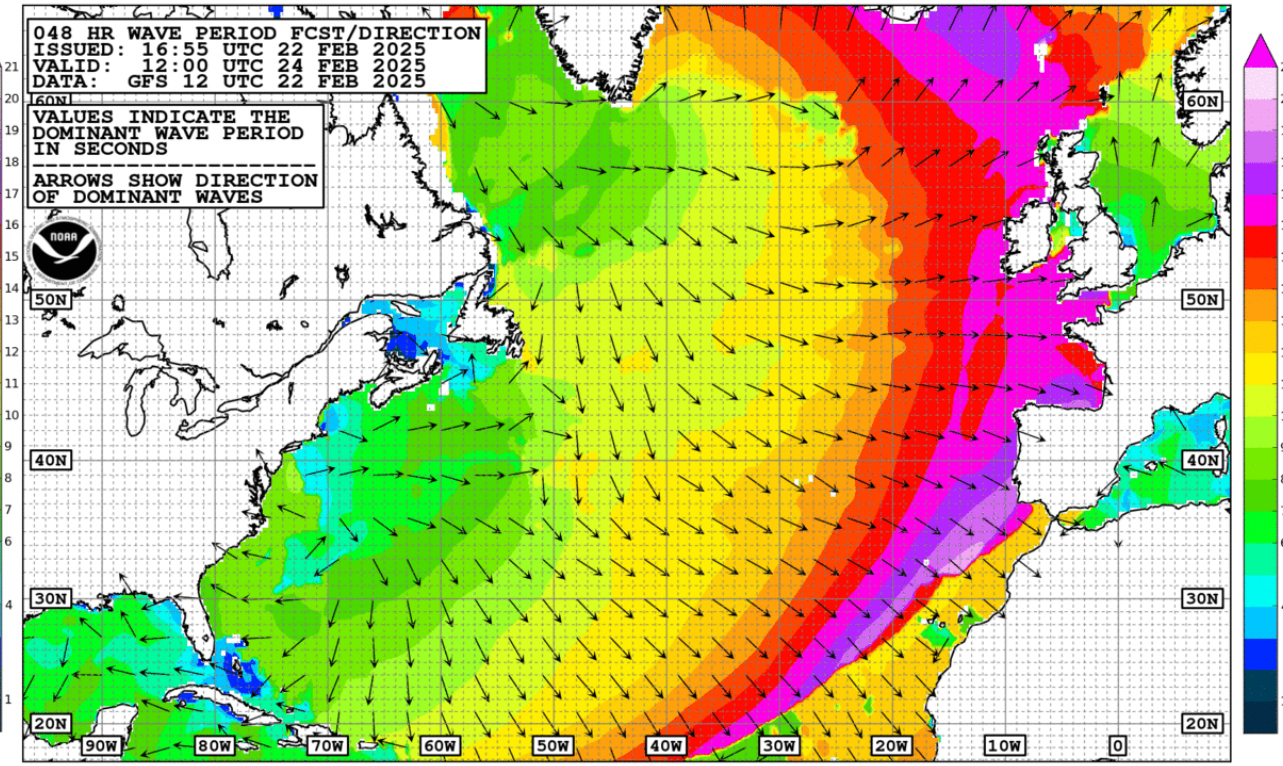
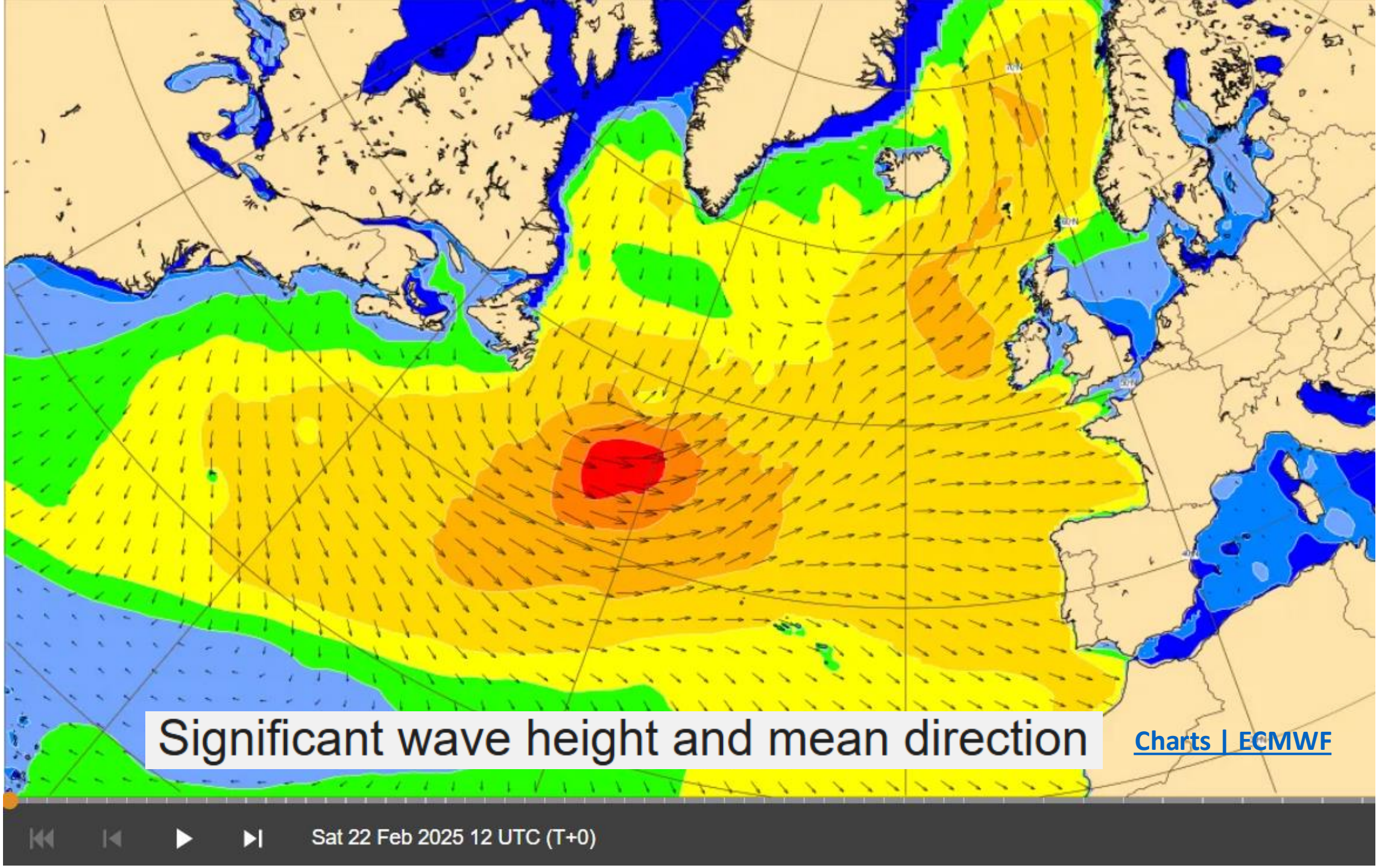
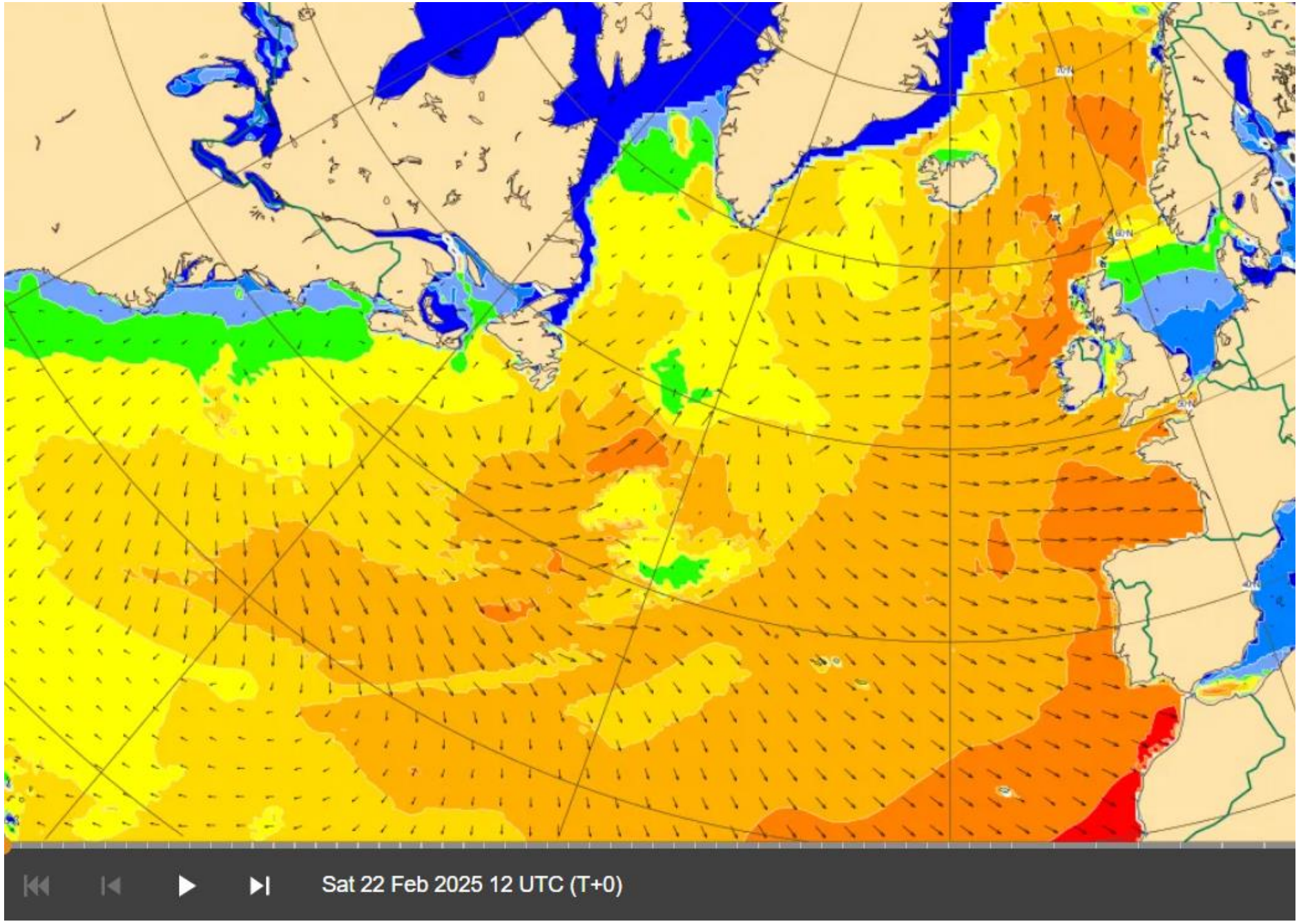


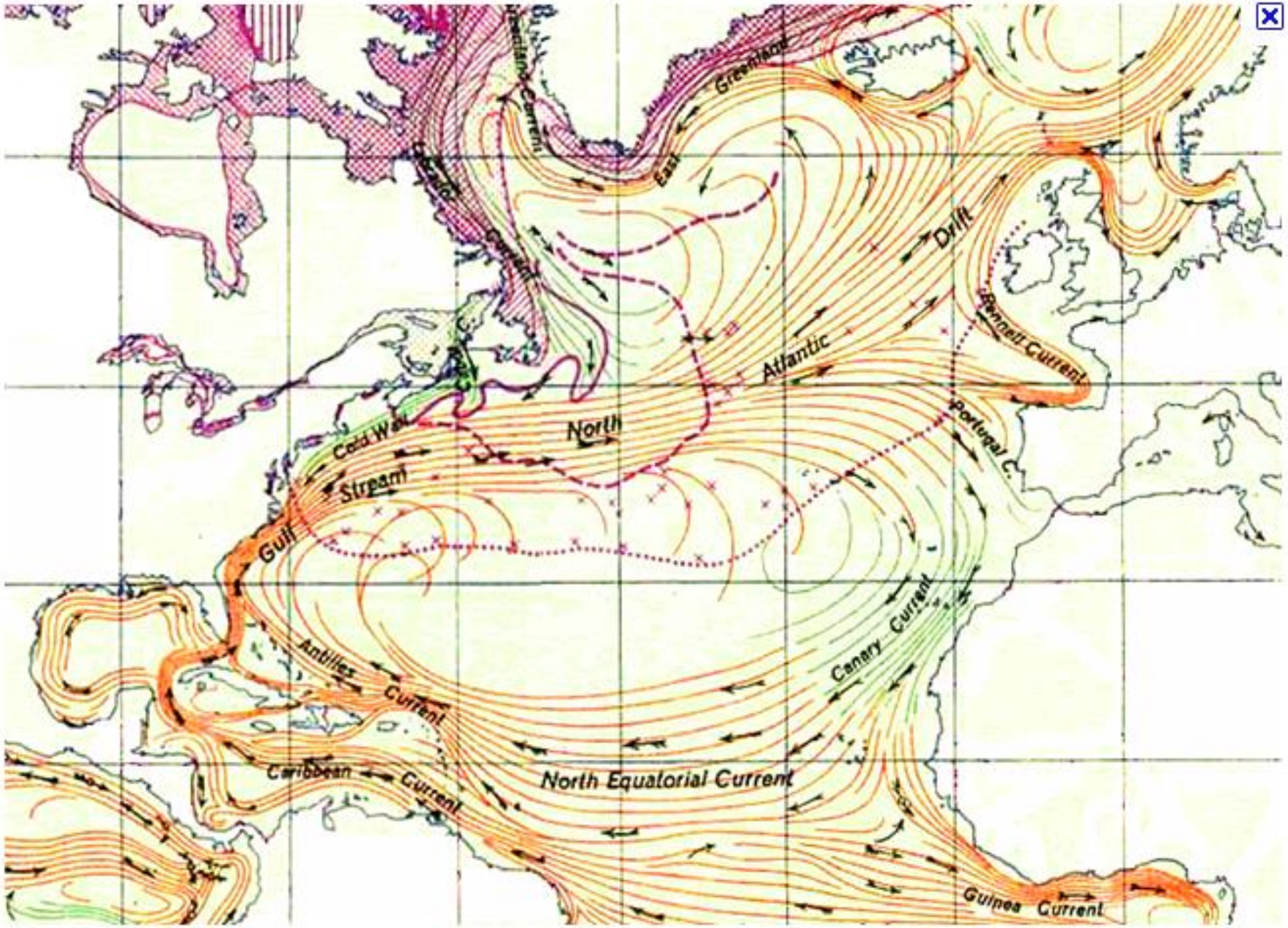
NWS/NCEP - Ocean Prediction Center
https://ocean.weather.gov


Significant wave height and mean direction
Charts | ECMWF
Sat 22 Feb 2025 12 UTC (T+0)

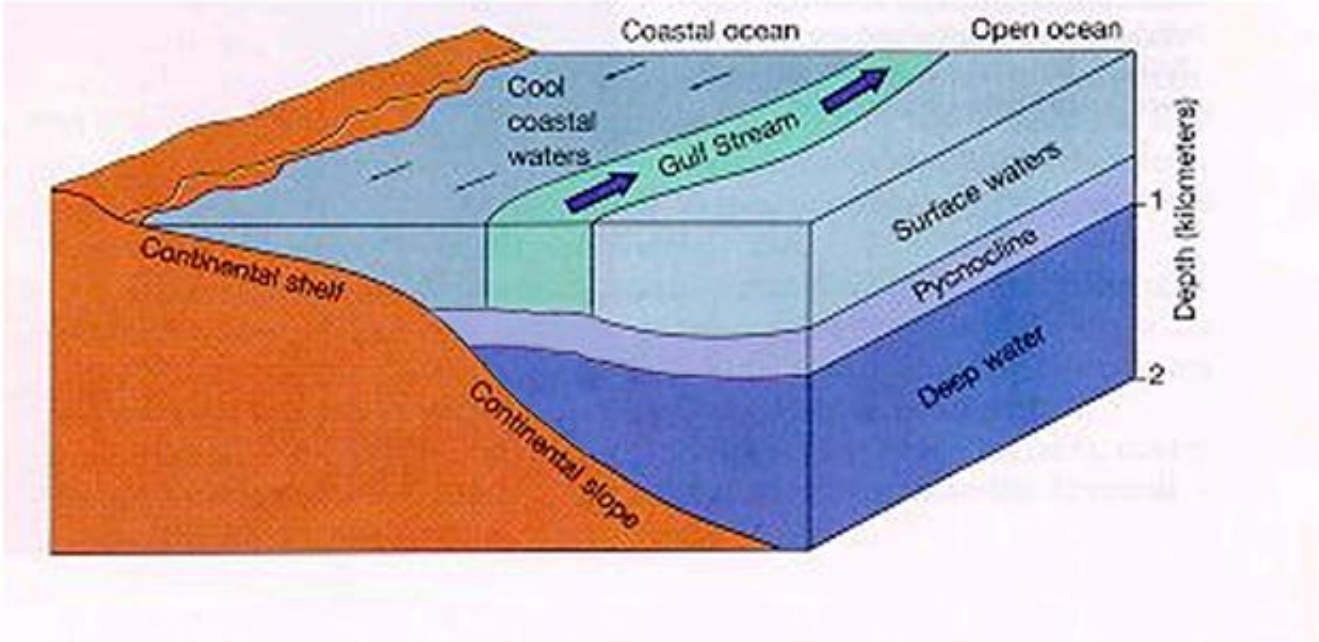


Total swell: mean period and mean direction

Charts | ECMWF



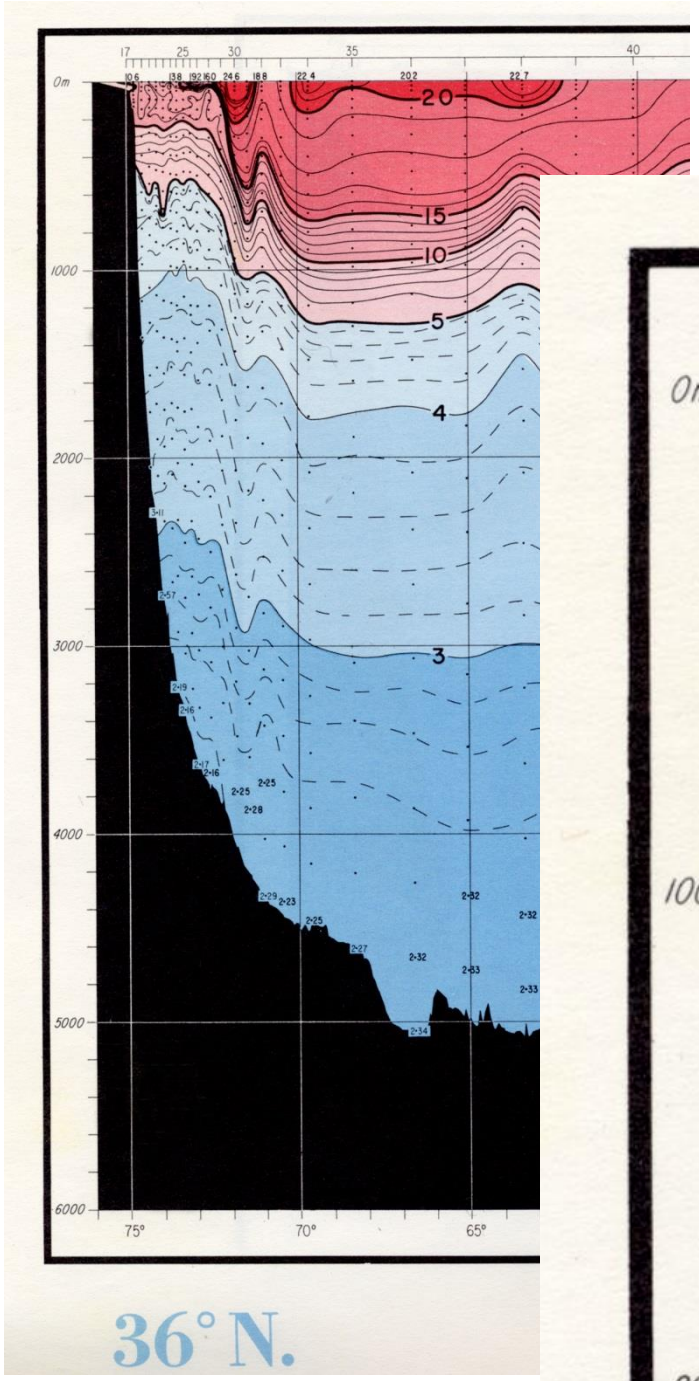
North Atlantic Gyre – Largely Wind Driven

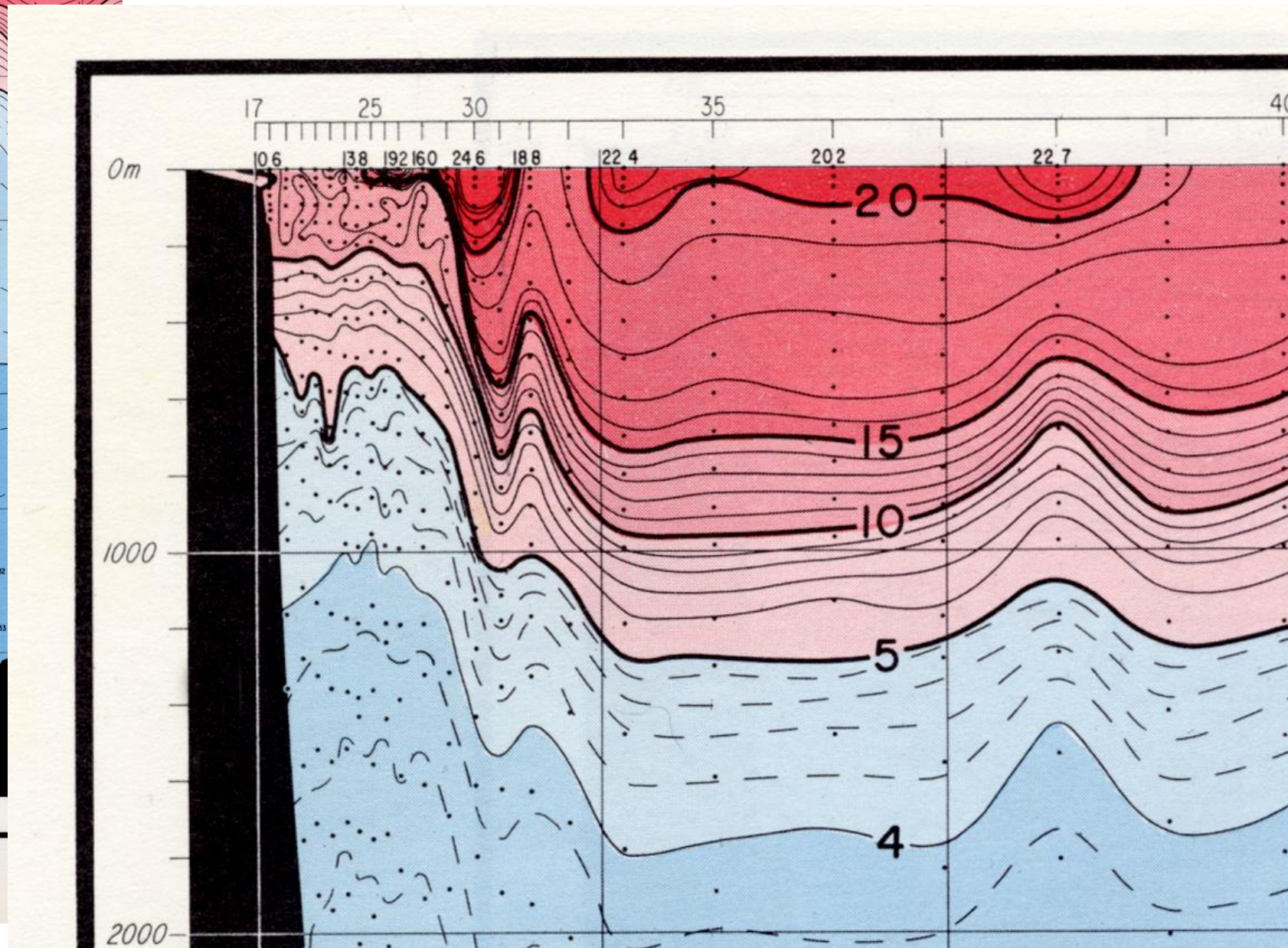


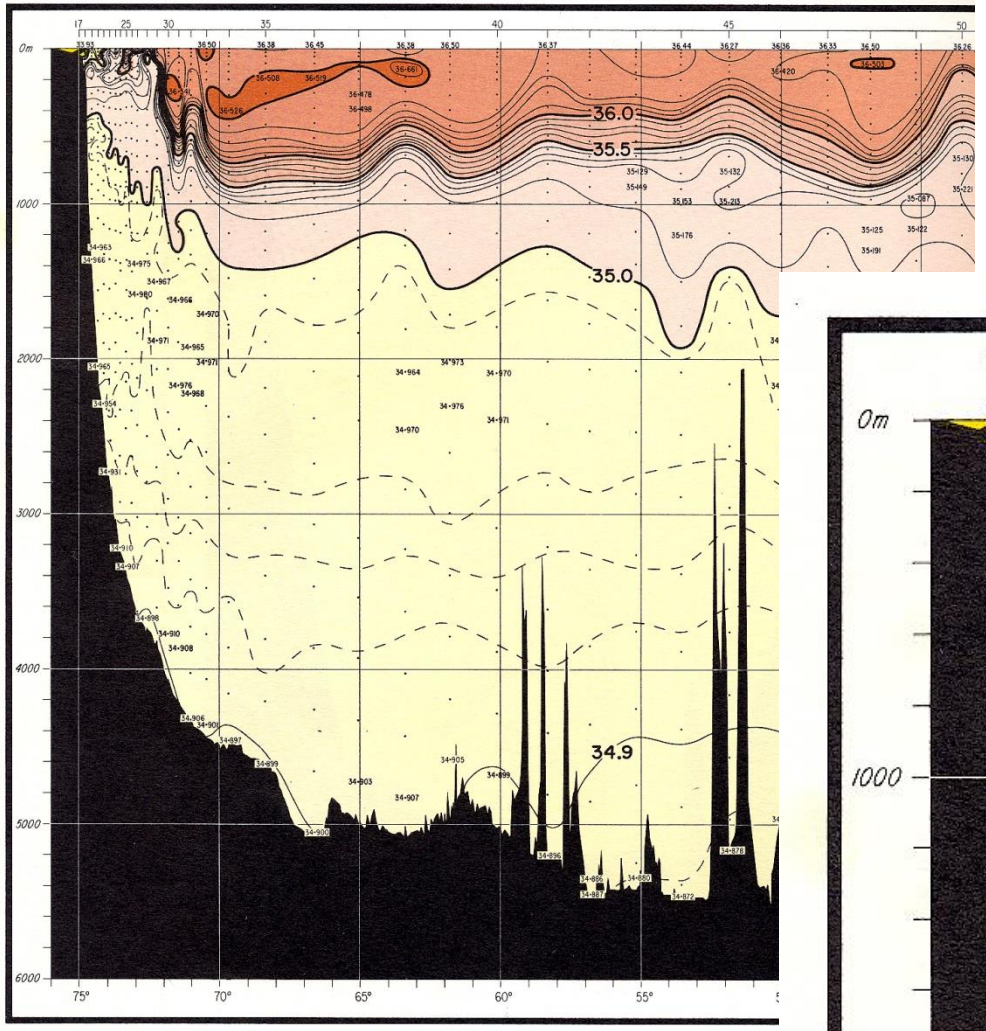
The Gulf Stream is an example of a Western Boundary Current

A boundary between cold shelf water and warm Sargasso Sea water

Water Temperatures … *IMPORTANT* !!

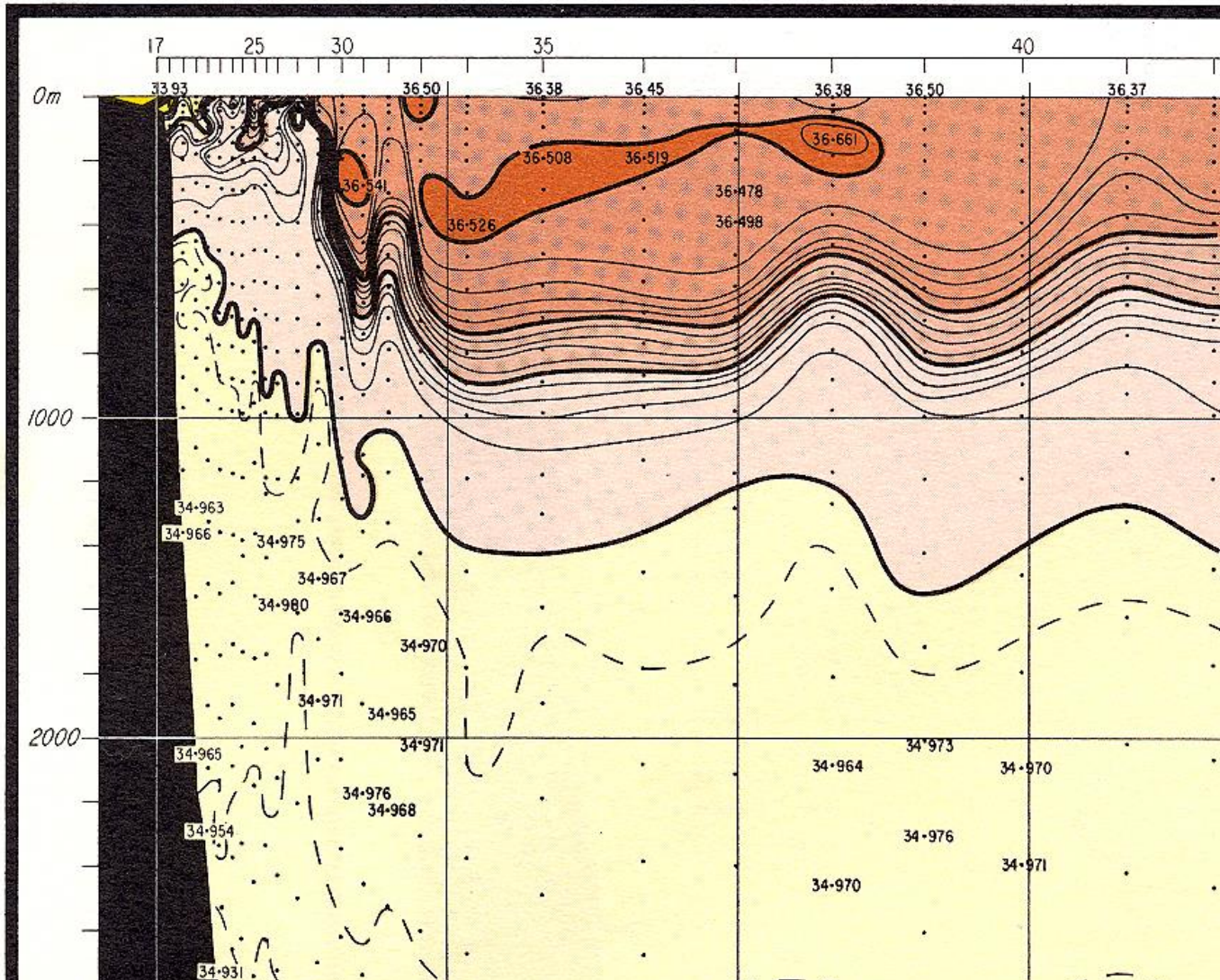




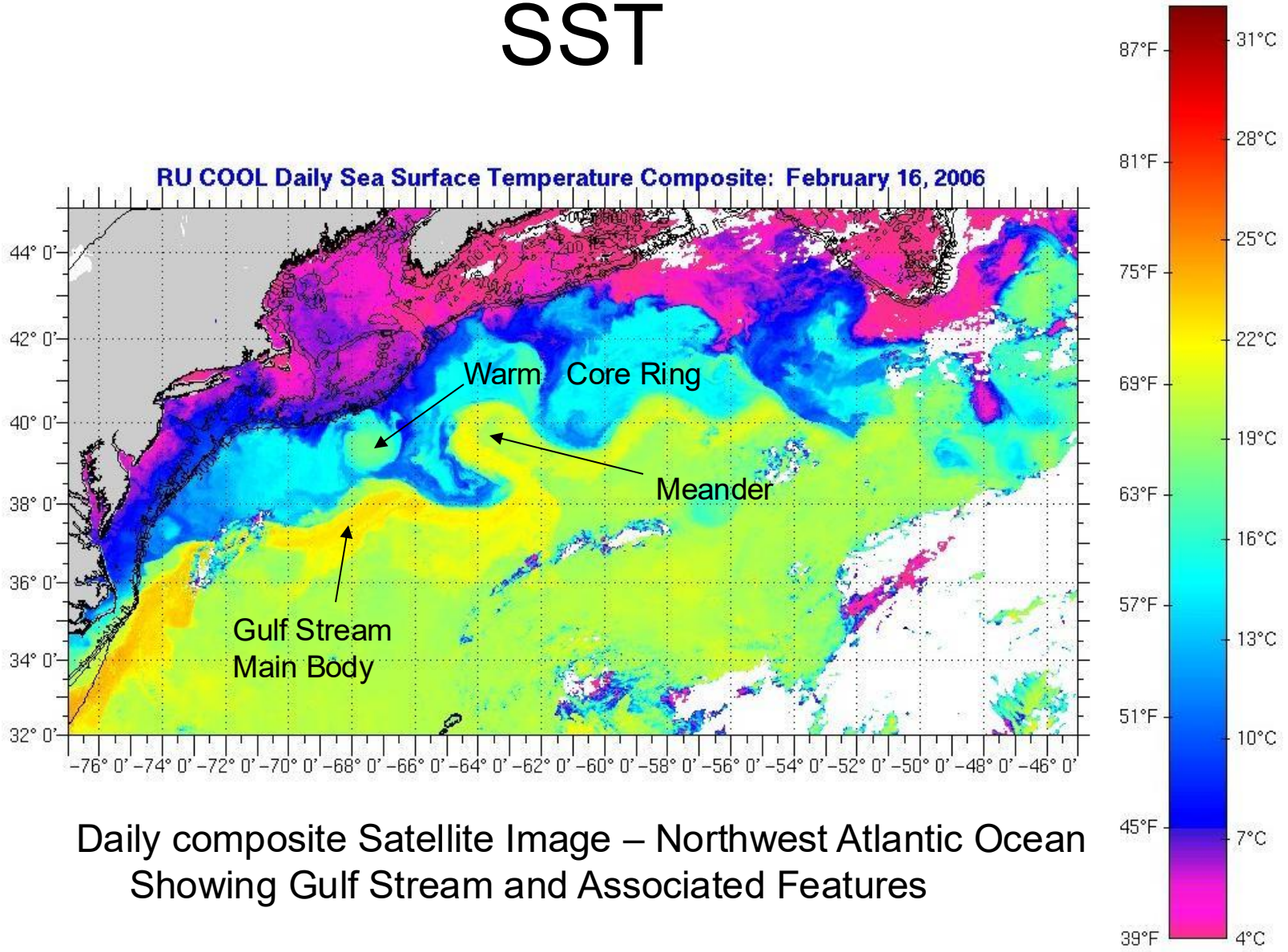


36° N.

and Salinity Gradients !



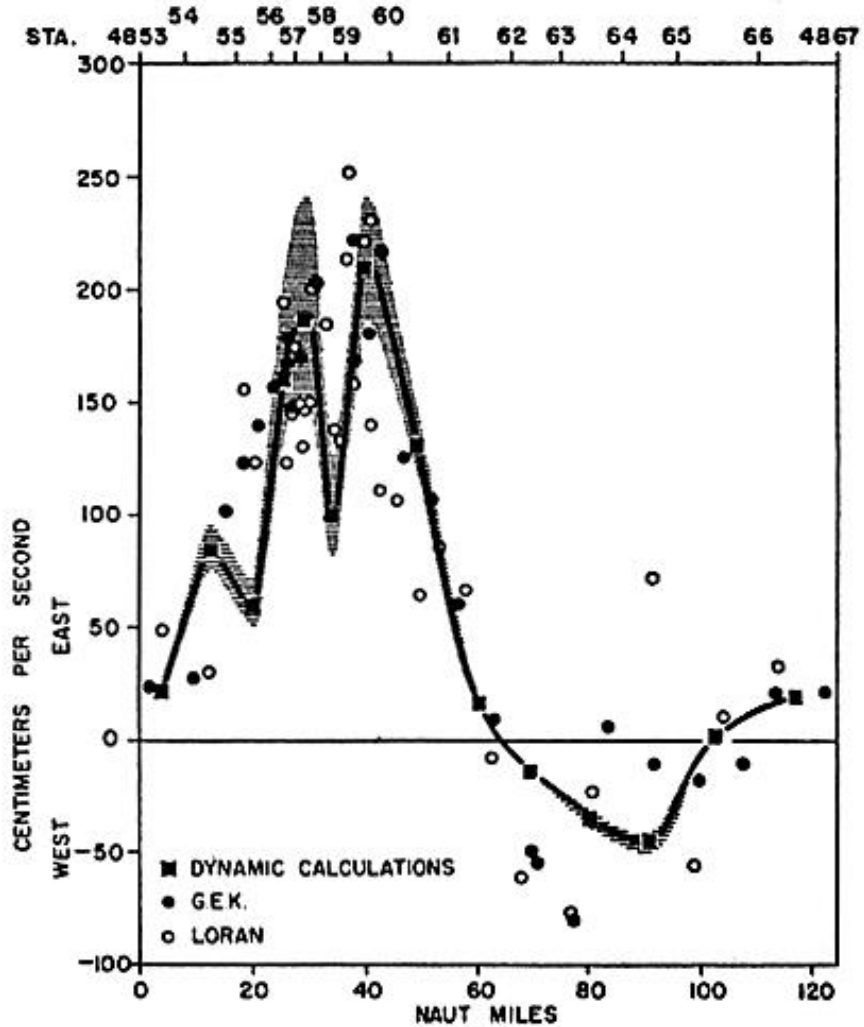
SST



Daily composite Satellite Image – Northwest Atlantic Ocean
Showing Gulf Stream and Associated Features

Source: **http://rucool.marine.rutgers.edu/**

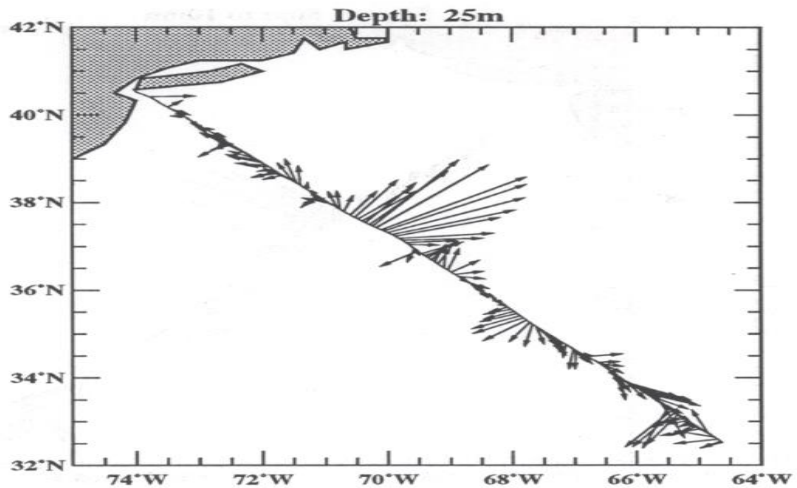
Typical Main Body Structure

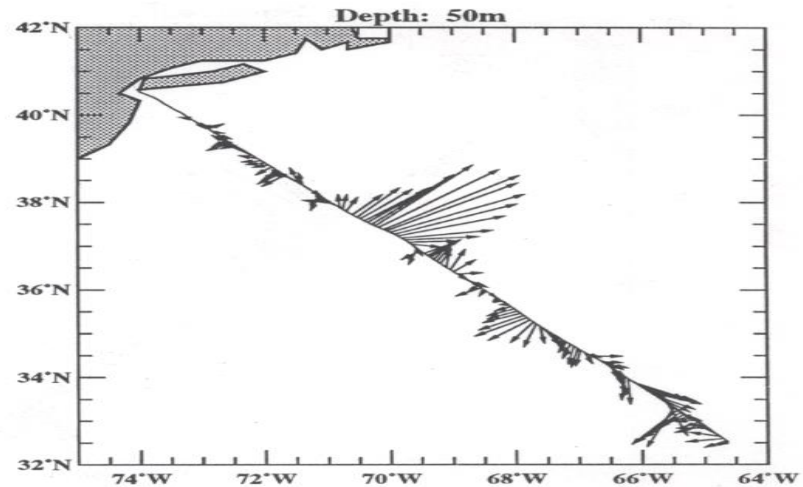


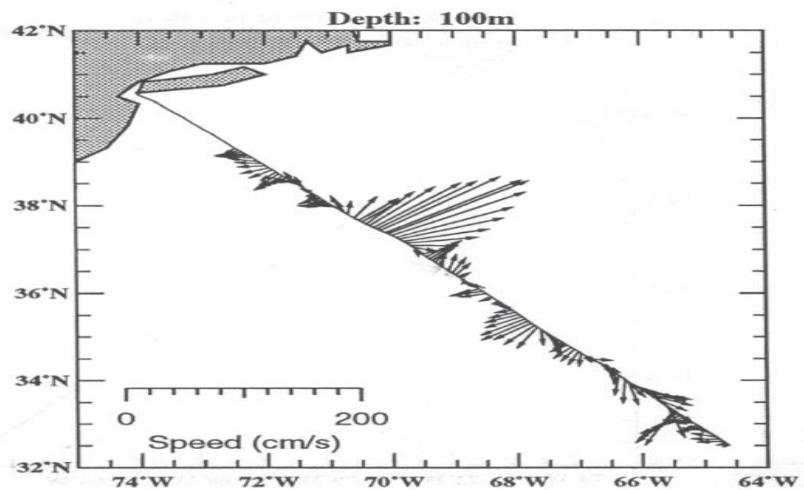
From: Stommel, , *The Gulf Stream , 1965*

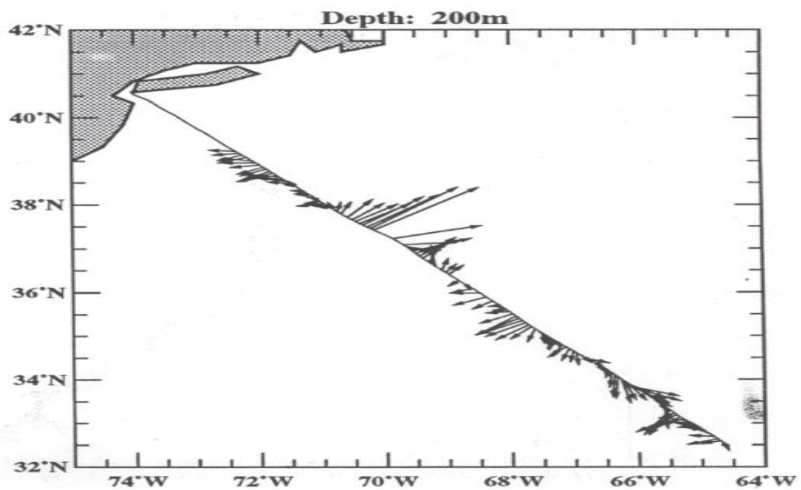
Oleander ADCP Velocities

Cruise # 059-061 (98/03/13 08:22:59 to 98/03/16 14:50:05 Outbound)



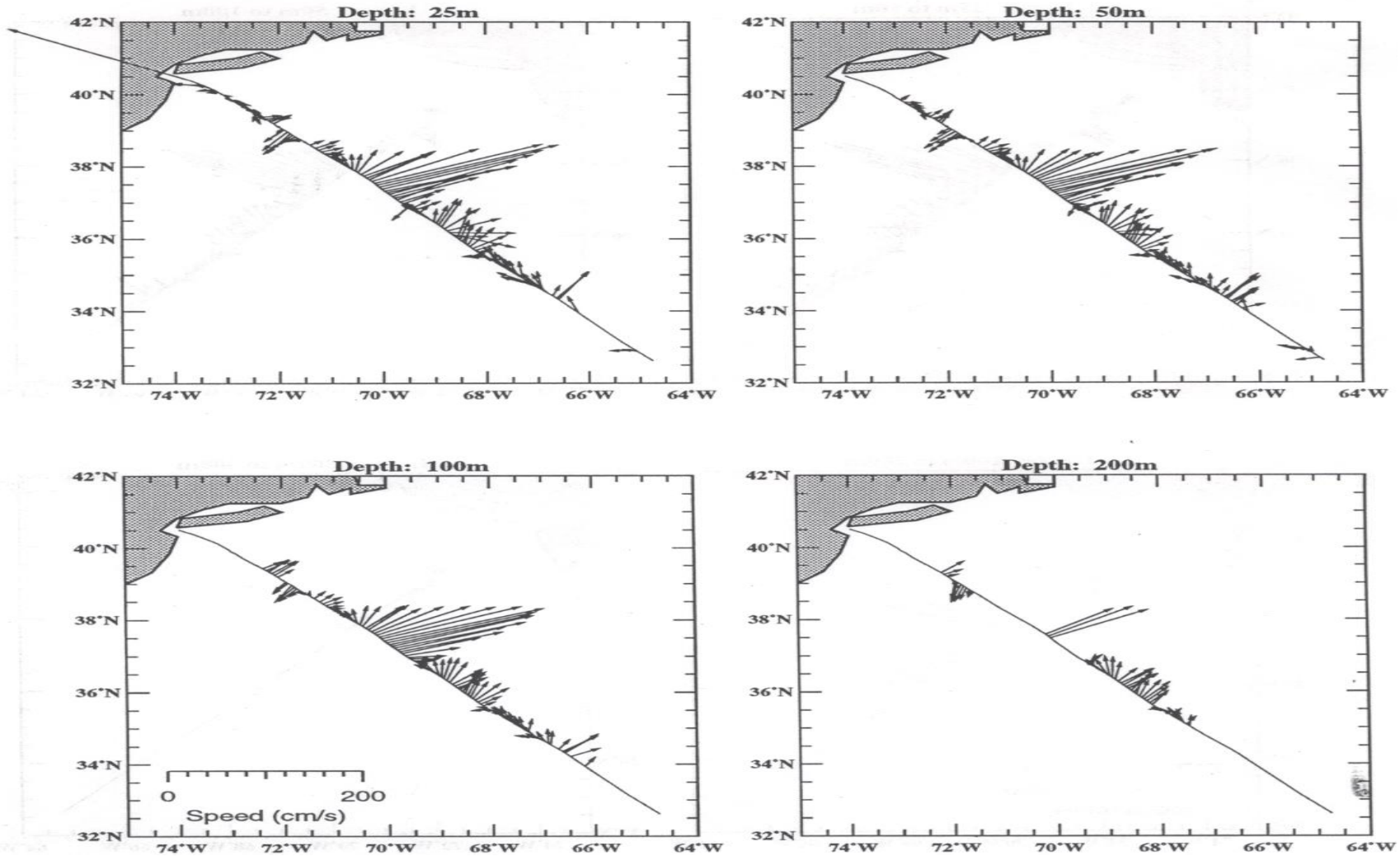






Oleander ADCP Velocities

Cruise # 062-064 (98/03/16 14:55:06 to 98/03/19 17:21:32 Inbound)



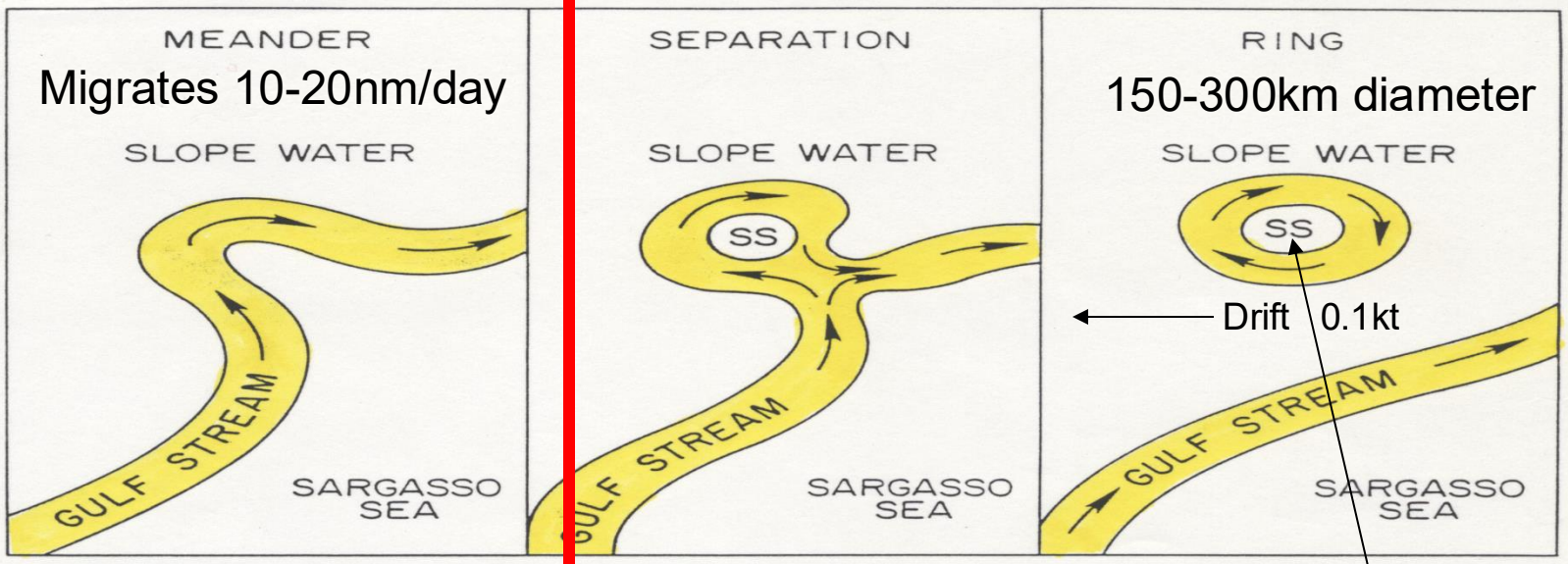


Figure 1. Three stages in the formation of a warm-core ring from a Gulf Stream meander. The core is water from the Sargasso Sea (SS).

Warm Core

Cold Core

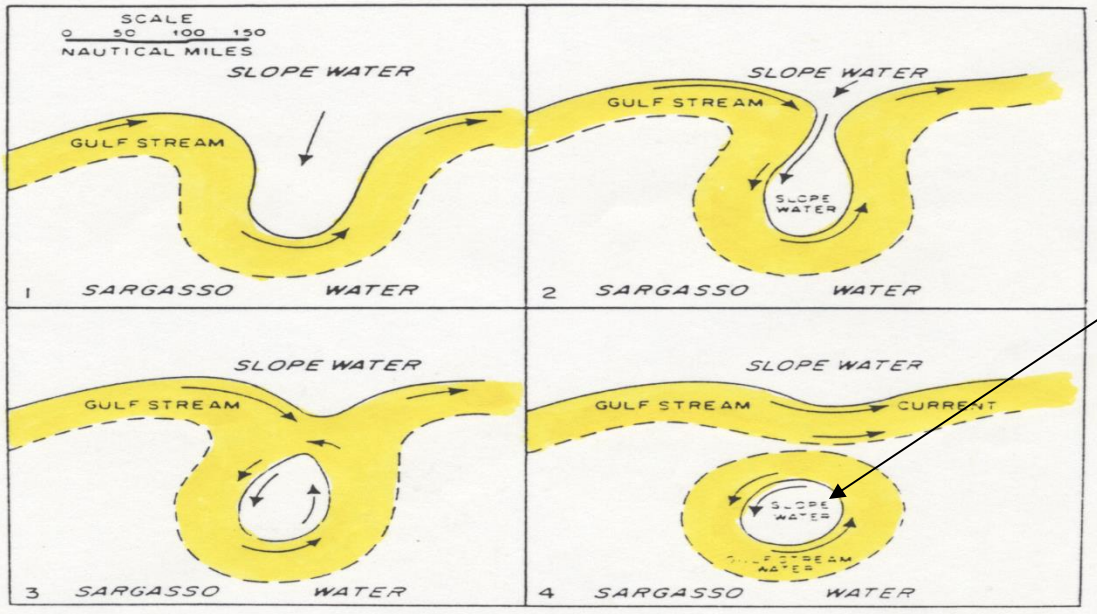
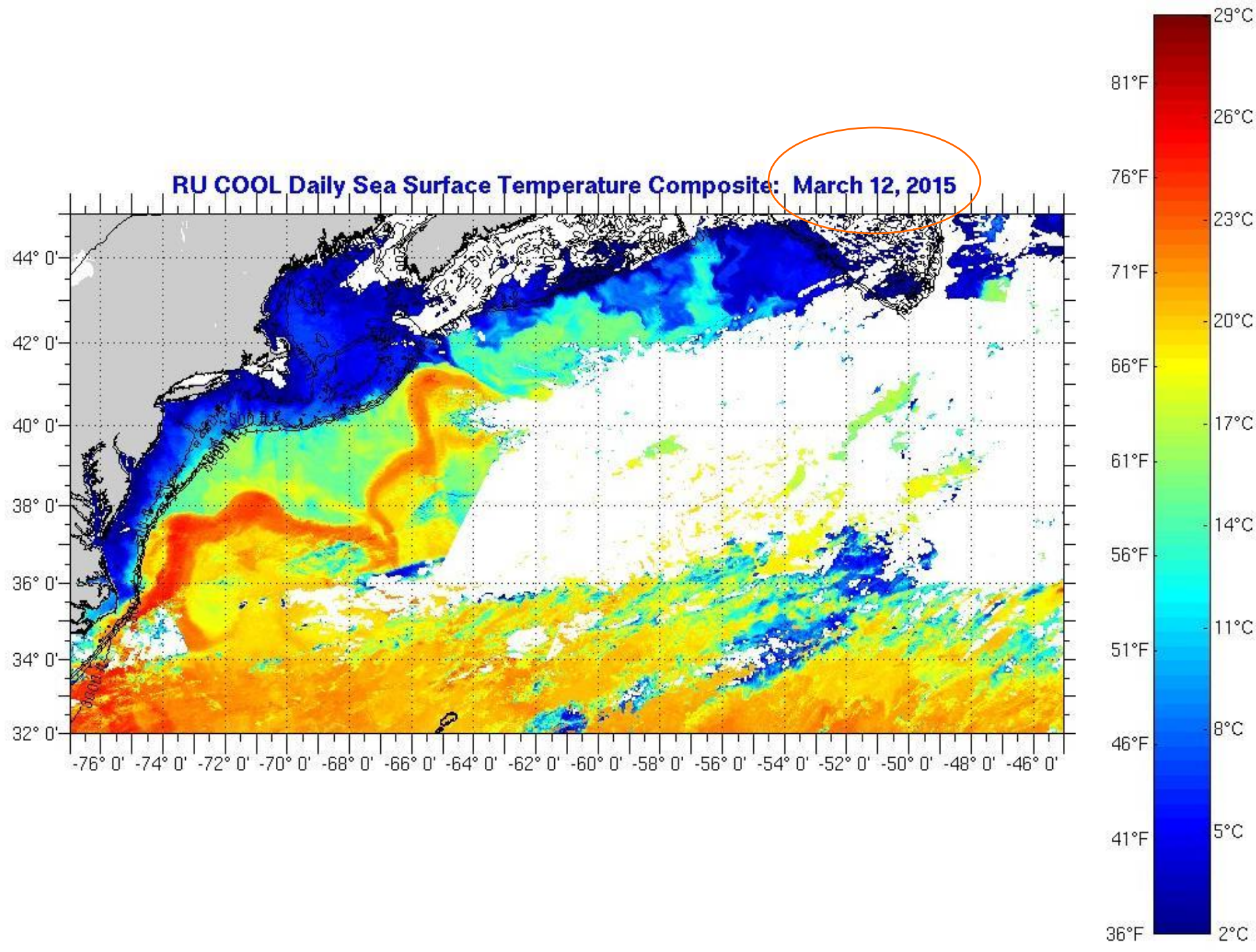
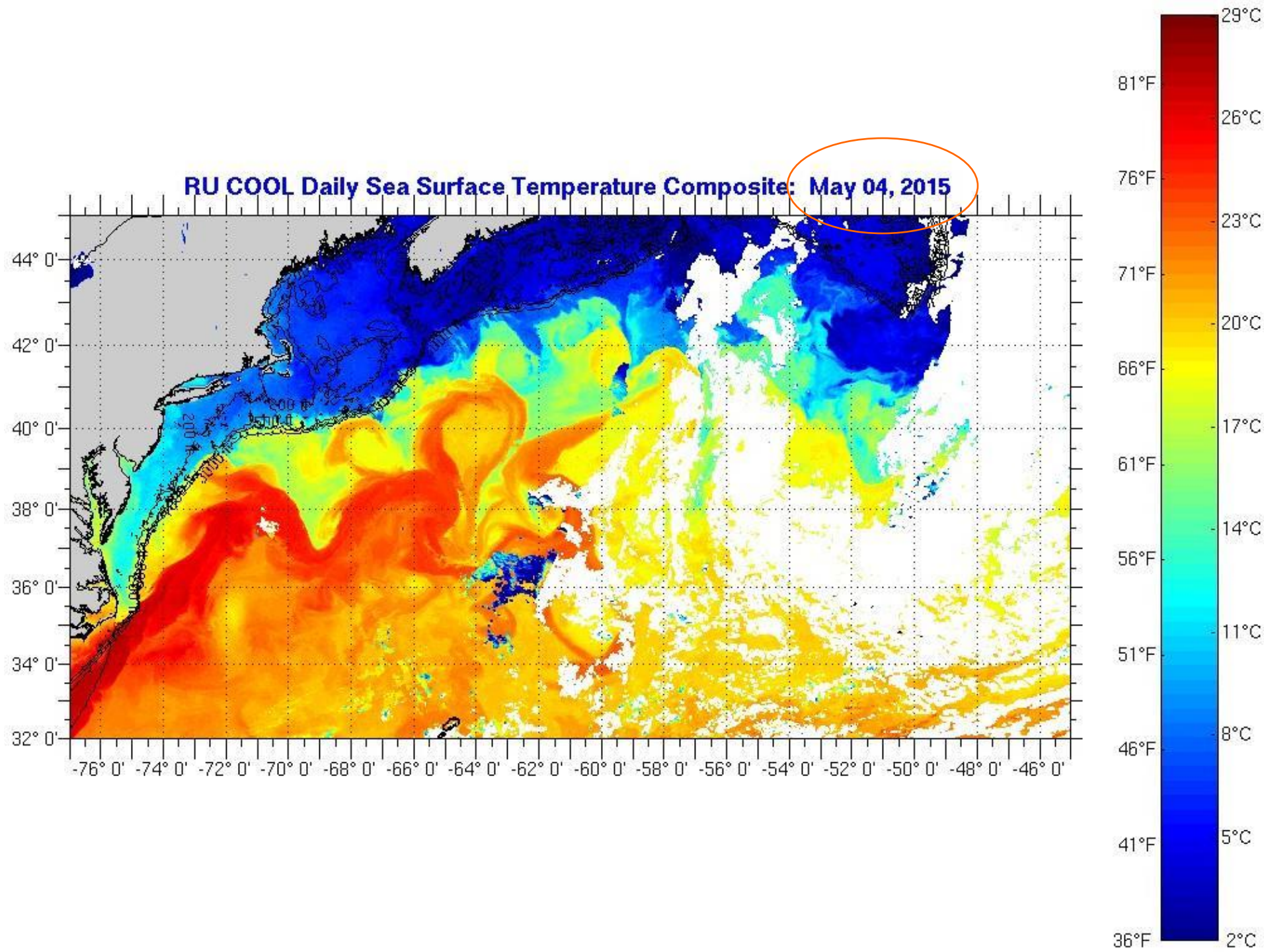
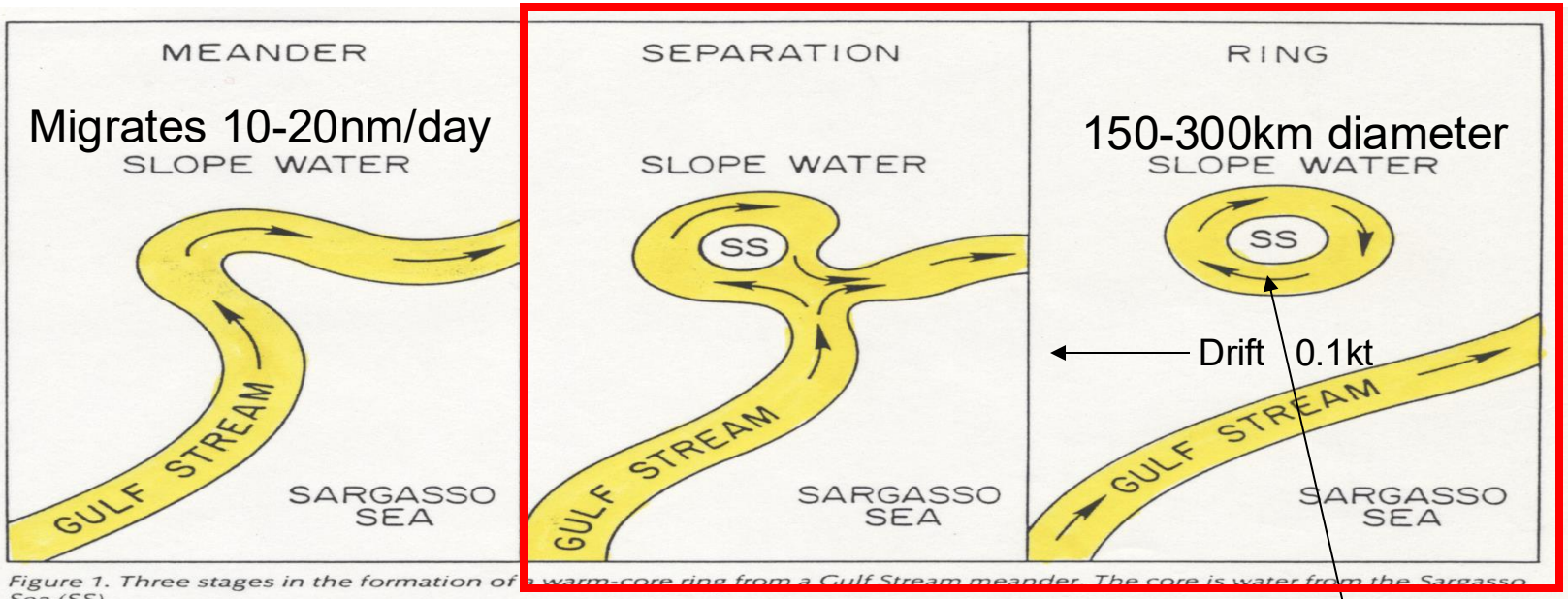


Figure 4.8 Diagram of Gulf Stream ring generation from meander formation to separation. (Parker, 1971.)


RU COOL Daily Sea Surface Temperature Composite: March 12, 2015
44° 0'
42° 0'
40° 0'
38° 0'
36° 0'
34° 0'
32° 0'
-76° 0' -74° 0' -72° 0' -70° 0' -68° 0' -66° 0' -64° 0' -62° 0' -60° 0' -58° 0' -56° 0' -54° 0' -52° 0' -50° 0' -48° 0' -46° 0'
29°C
26°C
23°C
20°C
17°C
14°C
11°C
8°C
5°C
2°C
81°F
76°F
71°F
66°F
61°F
56°F
51°F
46°F
41°F
36°F


RU COOL Daily Sea Surface Temperature Composite: May 04, 2015
44° 0'
42° 0'
40° 0'
38° 0'
36° 0'
34° 0'
32° 0'
-76° 0' -74° 0' -72° 0' -70° 0' -68° 0' -66° 0' -64° 0' -62° 0' -60° 0' -58° 0' -56° 0' -54° 0' -52° 0' -50° 0' -48° 0' -46° 0'
81°F
76°F
71°F
66°F
61°F
56°F
51°F
46°F
41°F
36°F
29°C
26°C
23°C
20°C
17°C
14°C
11°C
8°C
5°C
2°C



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Warm Core

Cold Core

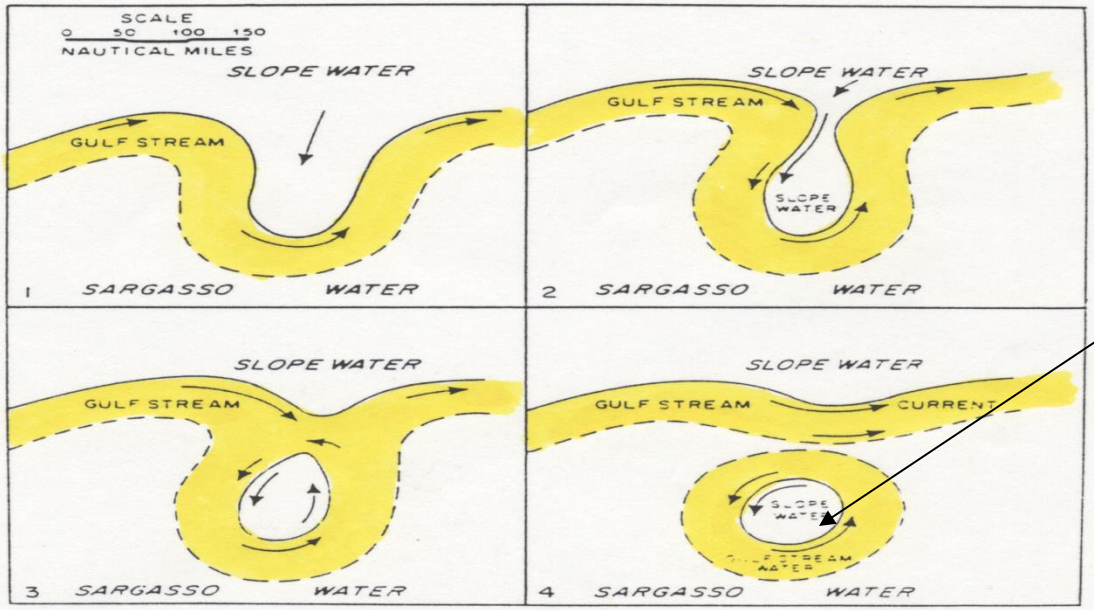
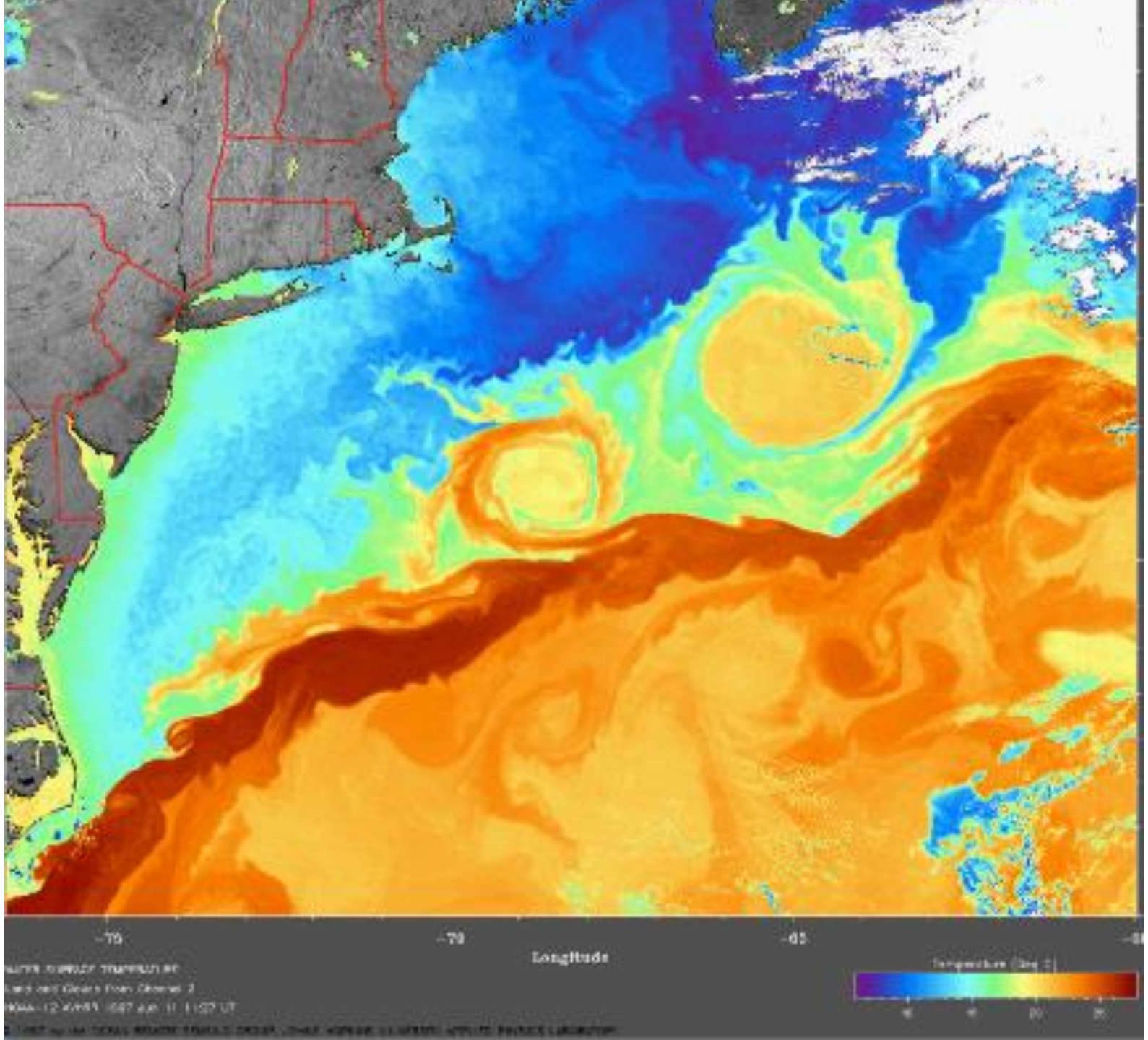


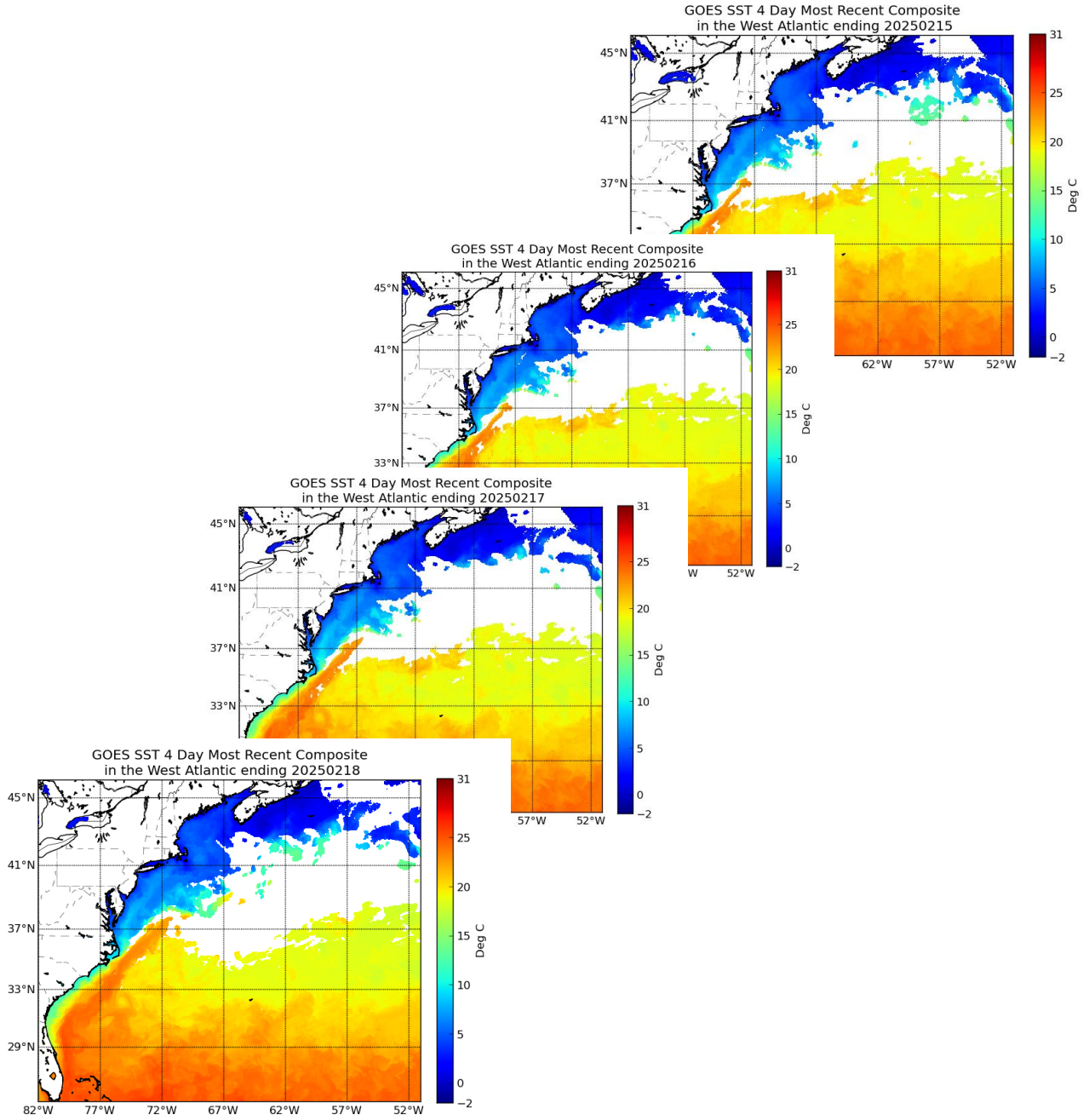
Figure 4.8 Diagram of Gulf Stream ring generation from meander formation to separation. (Parker, 1971.)


-75
-70
-65
Longitude

A look over the past few days
and what do we see… ?

CLOUDS !!

Start Study Early !



Using a Variety of Resources

Keeping in mind…….

- Scales of Variability
- Needed/Desired Accuracy
- Reception Limitations
- Sensory Overload

Gulf Stream and Weather Information on the WEB

Bohlen @ uconn.edu

Rev 2/25

****National Weather Service http://www.nws.noaa.gov or

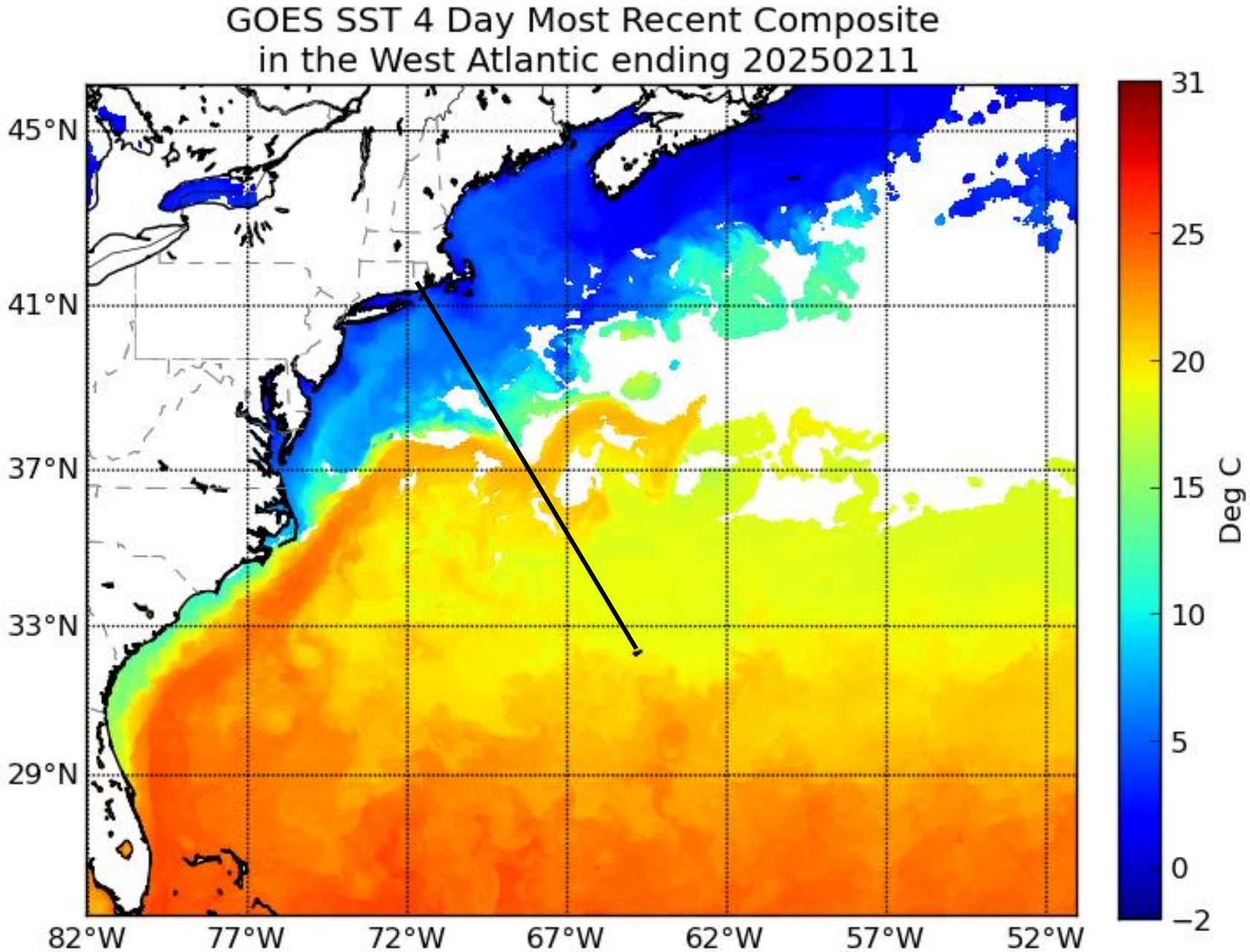
https://ocean.weather.gov/

The National Weather Service site and the Ocean Prediction Center site both with an abundance of products including marine forecasts and satellite imagery. Valuable resources for the study of weather. Look particularly at the NWS Ocean Prediction Center and their Probabilistic Guidance. **These sites must be studied !**

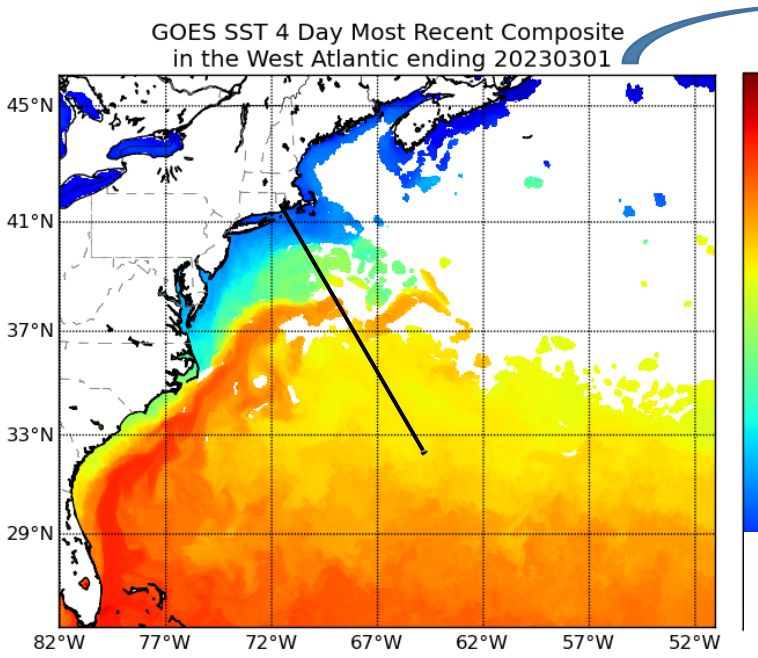
National Weather Service Environmental Modeling Center https://polar.ncep.noaa.gov/global/fronts/

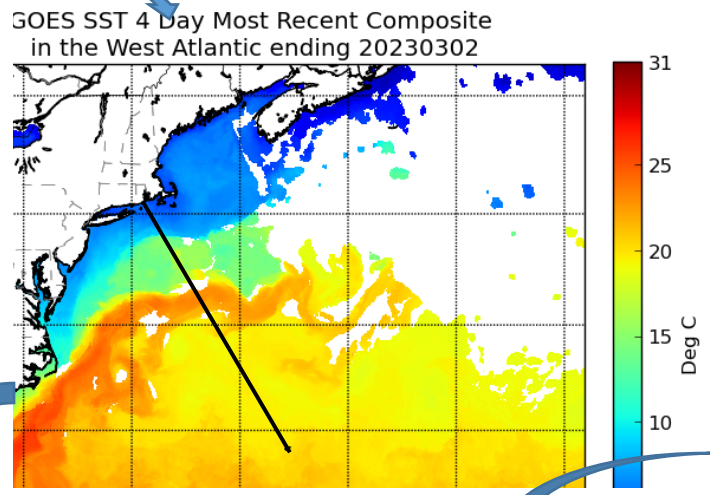
The National Weather Service's Environmental Modeling Center and home to the Global Real Time Ocean Forecast System model (RTOFS). This site is no longer maintained but contains some useful information on model characteristics. Global RTOFS High Resolution Oceanic Model (weather.gov) . provides up-to-date model results. Since many use this model in routing it's useful to compare model results to direct satellite observations to develop confidence in model simulations. This model provides 1/12 degree resolution and is the result of collaboration between NOAA and the U.S. Navy Research Laboratory and others. Also see:

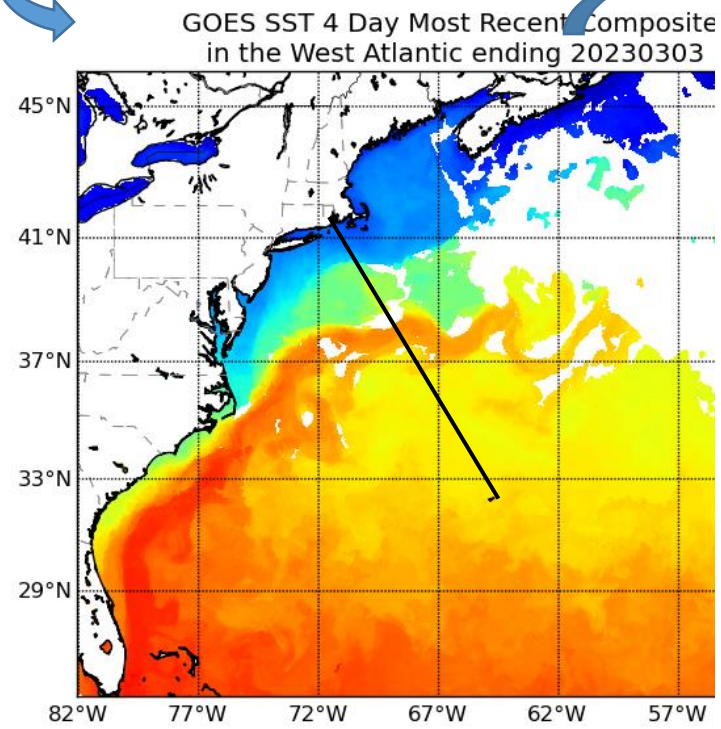
https://ocean.weather.gov/Loops/ocean_guidance.php?model=NCOM&area=Useast&plot=current&day=1&loop=0

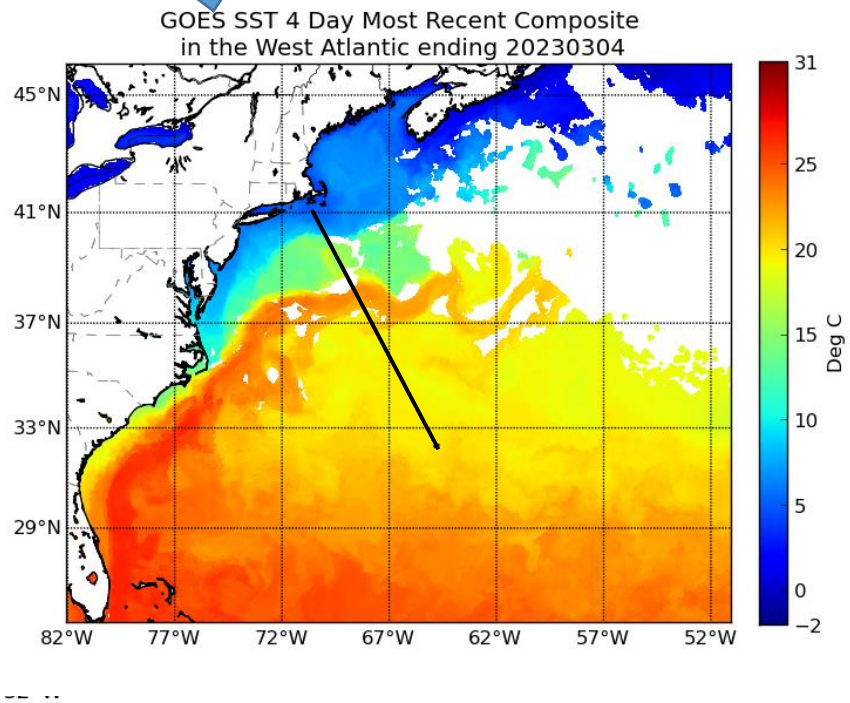


GOES Satellite-Derived Sea Surface Temperatures



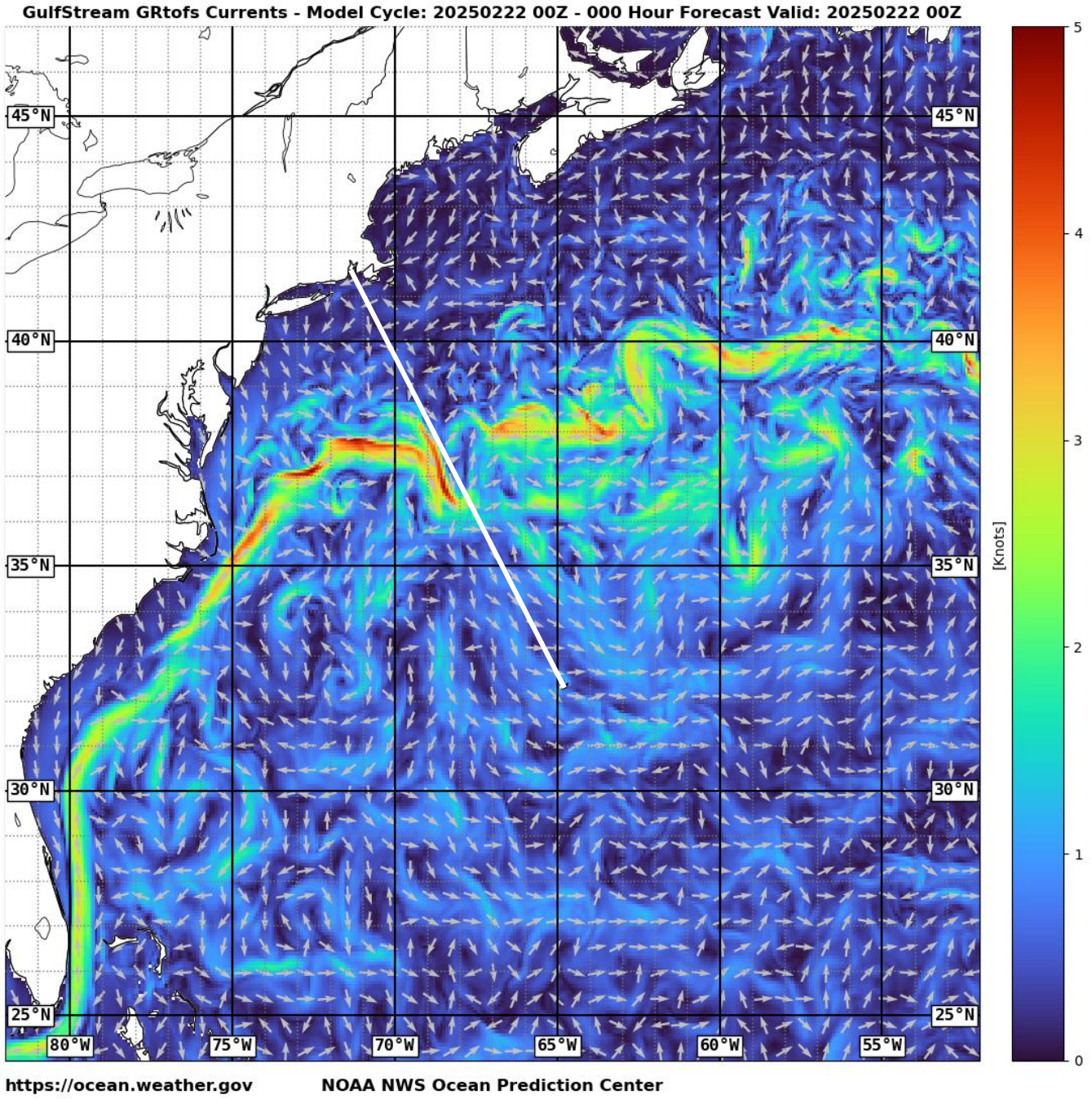




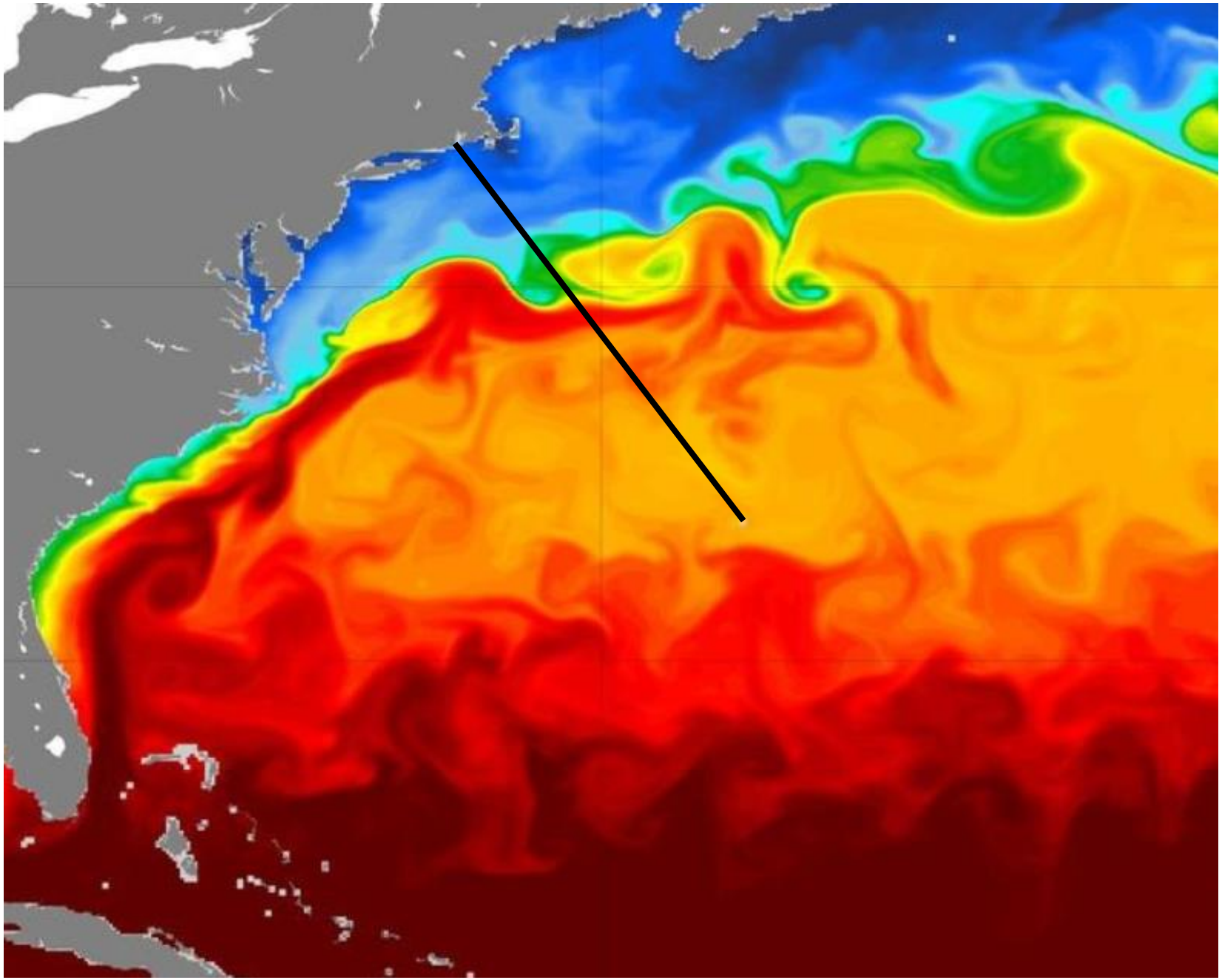


OPC 4 – Day Composite Time Series

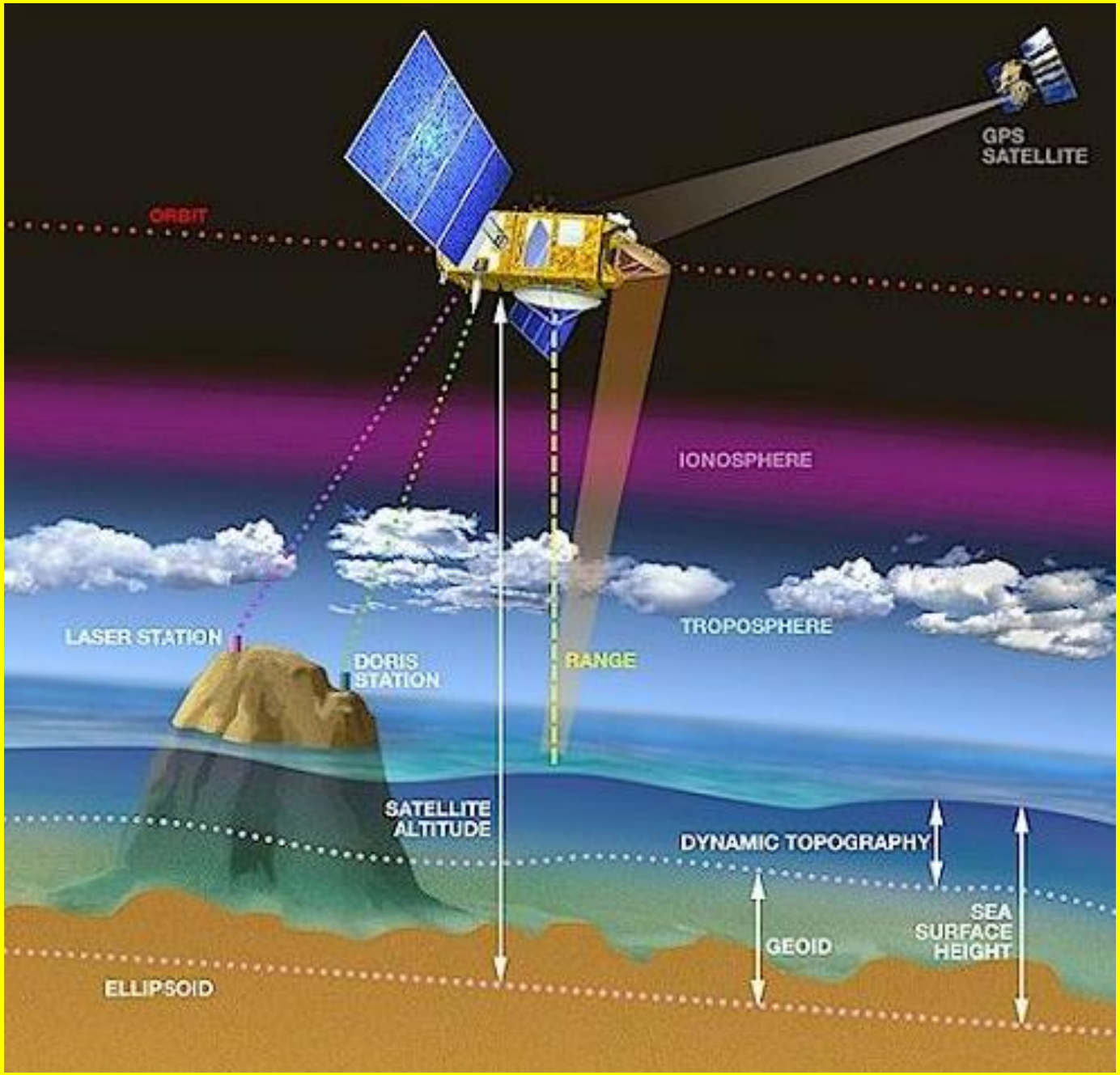
[GOES Satellite-Derived Sea Surface Temperatures (weather.gov)]



Global RTOFS High Resolution Oceanic Model



Daily Global Physical Bulletin at 1/12° - Ocean Forecasts - Mercator Ocean

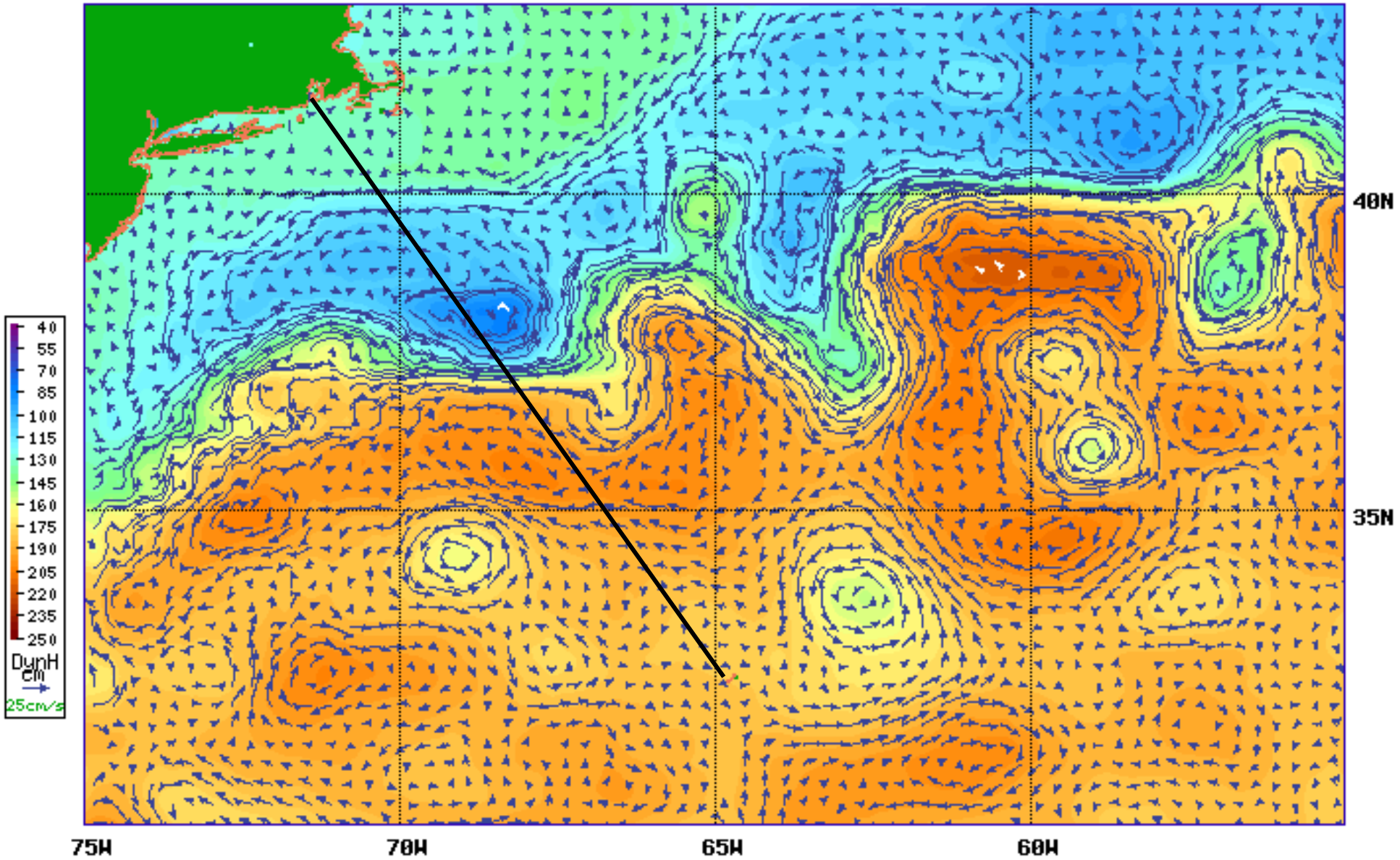


Satellite Altimetry (Geodesy)

FEB-15-2025

CoastWatch NOAA/AOML

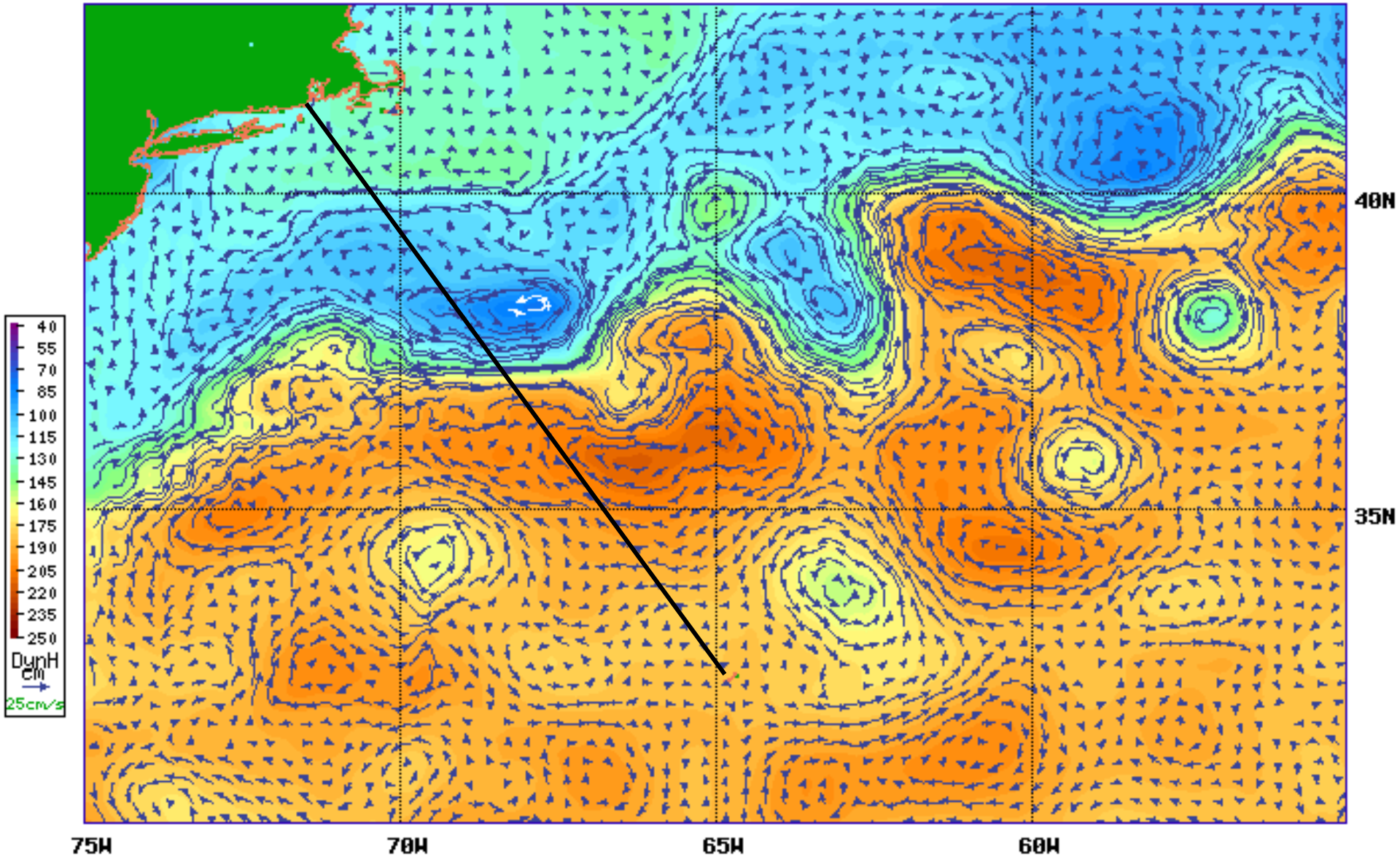
Altimeter/GTS Interface



FEB-22-2025

CoastWatch NOAA/AOML

Altimeter/GTS Interface



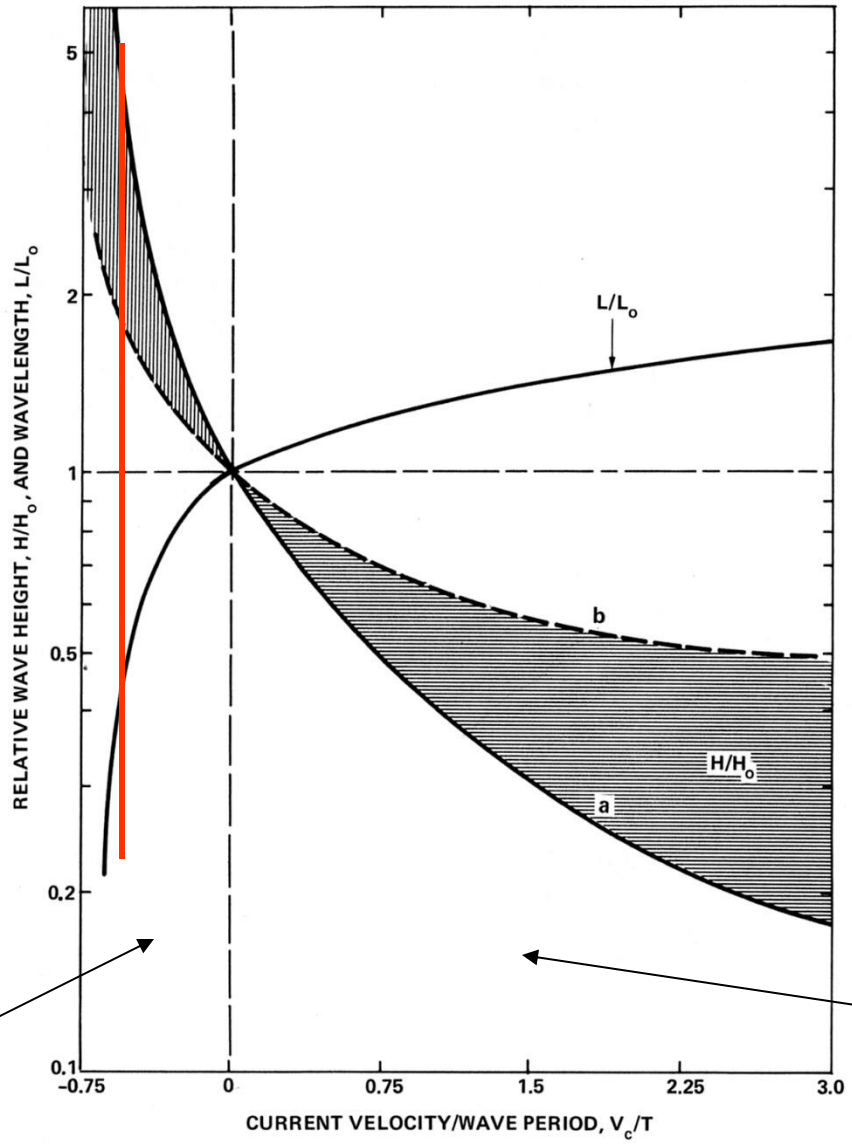


Fig. 87. Influence of contrary (negative) and following (positive) currents of velocity V_c on relative wave height and wavelength, for waves of period T seconds. The shaded band gives the range of variation from pure, periodic swell *(a)* to a random sea *(b)*. No swell can propagate against a current $V_c > 0.75T$ knots.

Ocean Wave Periods

T typical = 10 sec

$V_c = \sim$ *5kts*

Winds against the current

Winds with the current

Source: van Dorn 1993 Oceanography and Seamanship 2nd ed.

Things to be remembered……..

- Start Study well before the start of the Race
  Navigator/Skipper/Watch Captains
  Communicate in Plain language - “No Riddles”
  Consider - https://sas.cruisingclub.org/weather/online
- Weather is the result of air mass collisions
- Geophysical flows (i.e. winds and currents are turbulent and characterized by significant spatial and temporal variability
- Model (MetOC) resolution is limited –both spatial and temporal
- Develop a limited number of favored source of MetOc data and the means to receive them offshore
- Pay attention to Sensory overload