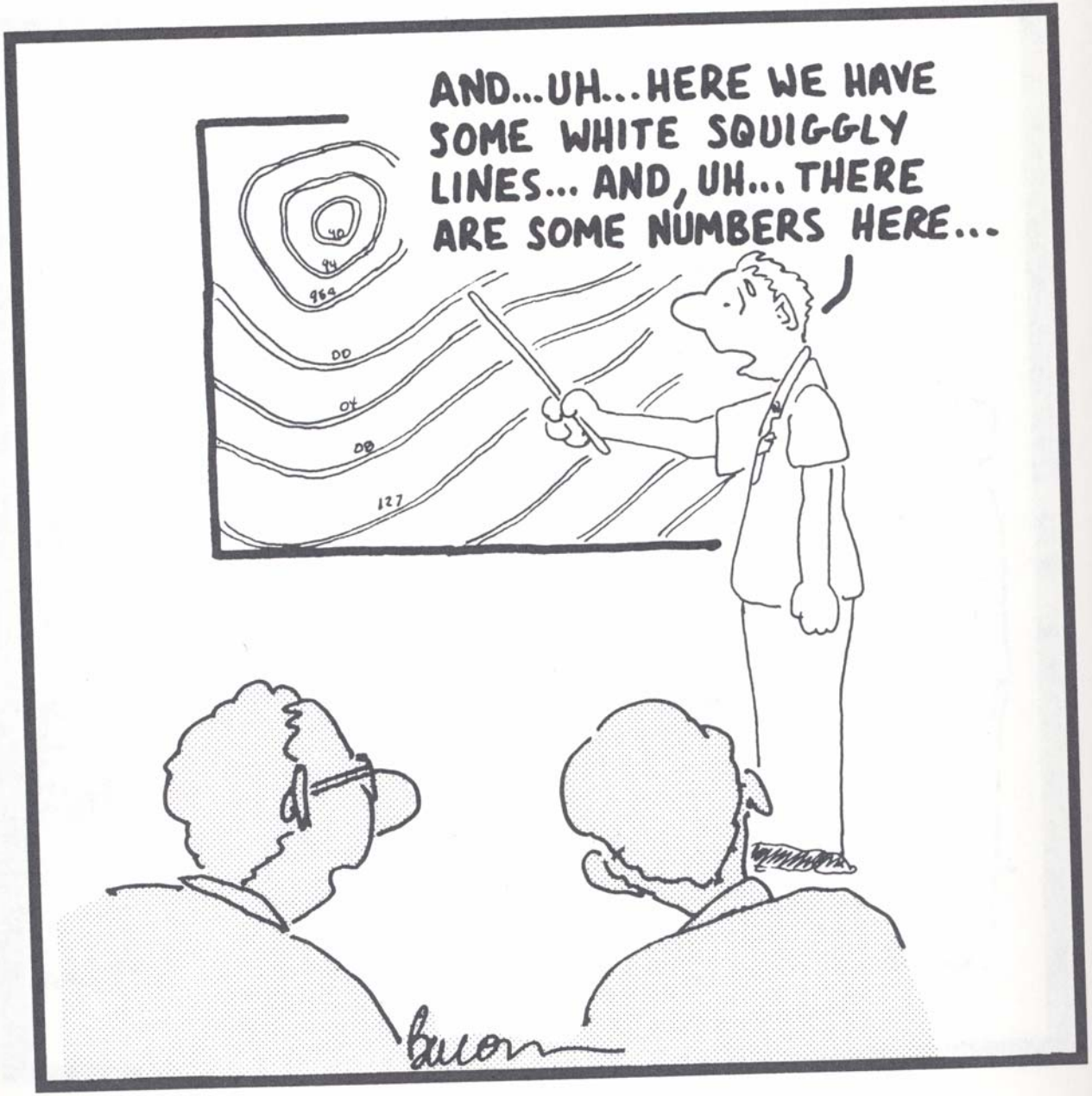
Weather for the Mariner



"Uh oh. . . looks like we have another one of those lateral-transfer meteorologists."

OBJECTIVES

- Air Masses
- Fronts
- Wind/Waves
- Sea State
- Clouds
- Wx Charts

Air Masses & Fronts

- Air masses
  - Source regions
  - Classification
  - Introduce Stability
  - Air masses of North America
- Fronts

Air Masses

Q1: An air mass is a large body of air whose properties are fairly similar in any horizontal direction at any given altitude. *Which two properties?*

–*Temperature & Humidity (moisture)*

Part of weather forecasting is a matter of determining…

–air mass characteristics,

–predicting how and why they change, and

–in what direction these systems will move.

Types of Air Masses

What are the 4 basic types of air masses?

cP = continental Polar
cT = continental Tropical
mP = maritime Polar
mT = maritime Tropical

What is cA?

cA = continental Arctic

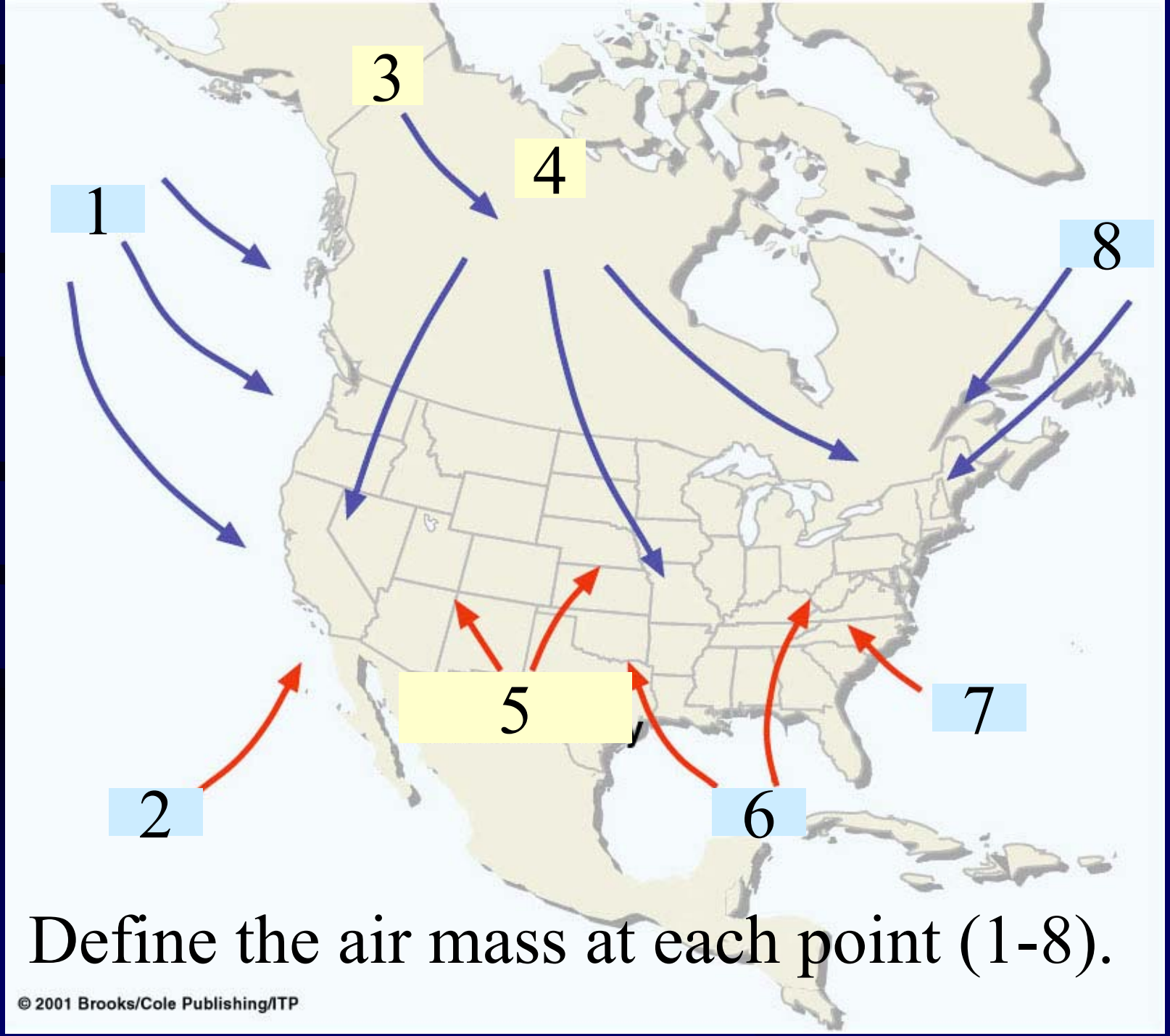
cP, mP, cT, mT, cA, mE

cP = Continental Polar – dry, cold air
mP = Maritime Polar – moist, cold air
cT = Continental Tropical – dry, warm air
mT = Maritime Tropical – moist, warm air

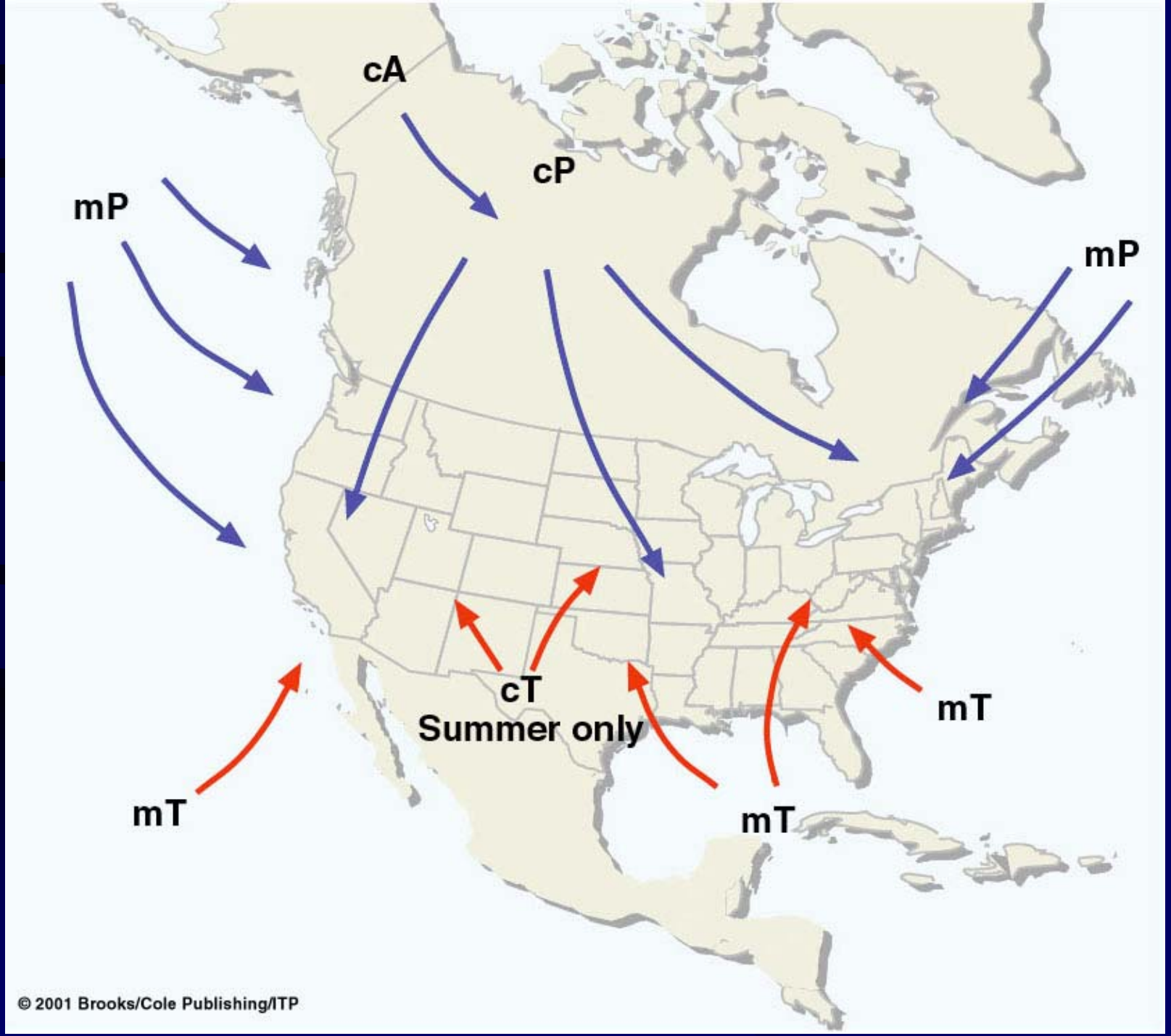
cA = Continental *Arctic* = *dry, extremely cold cP air*

4 Classifications: *Humidity & Temperature*

- c = Continental
  - –over land (dry)
- m = Maritime
  - –over water (moist)
- P = Polar
  - –Polar latitudes (cold)
- T = Tropical
  - –Tropical regions (warm)



Define the air mass at each point (1-8).



Source Regions—Origin of Air Masses

- Uniform characteristics develop…
  - in a region that is generally flat and of uniform composition,
  - The longer the air remains stagnant over its source region, the more likely it will acquire properties of the surface below.
- This describes areas of (low/high) pressure.

What direction are the winds circulating around a high pressure system?

High and Low Pressure Systems

Low Pressure

Cyclonic Turning:

Surface Convergence leads to <u>upward</u> vertical motions.

High Pressure

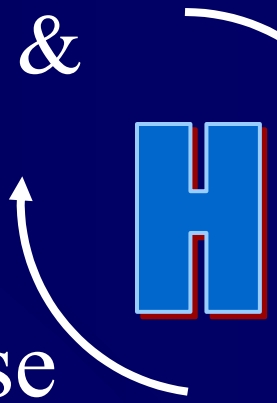
Anti-Cyclonic Turning:

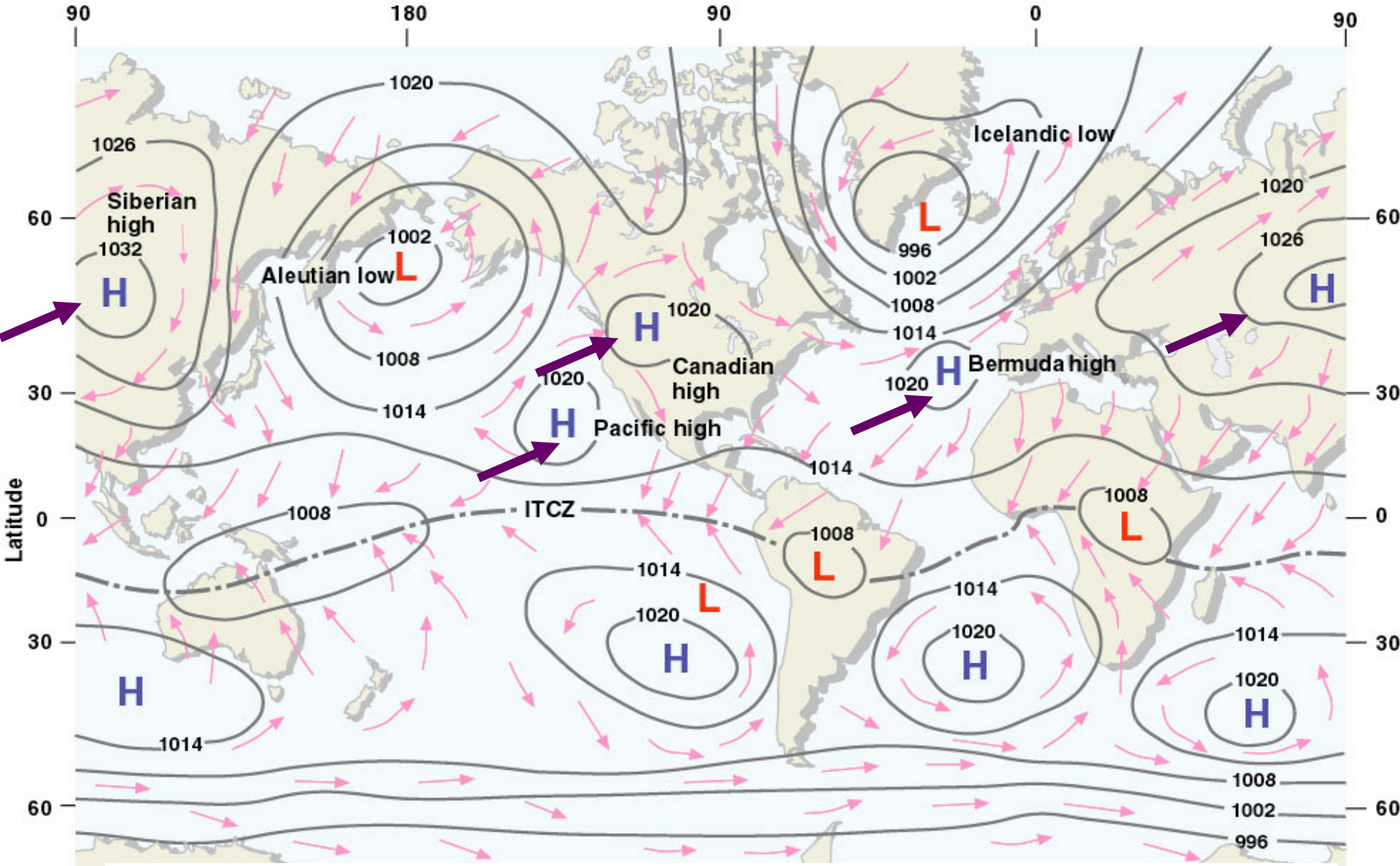
Surface Divergence leads to <u>downward</u> vertical motions.

Source: USA TODAY research by Chad Palmer, Graphic by Kevin A. Kepple

High Pressure Systems (ANTI-CYCLONES)

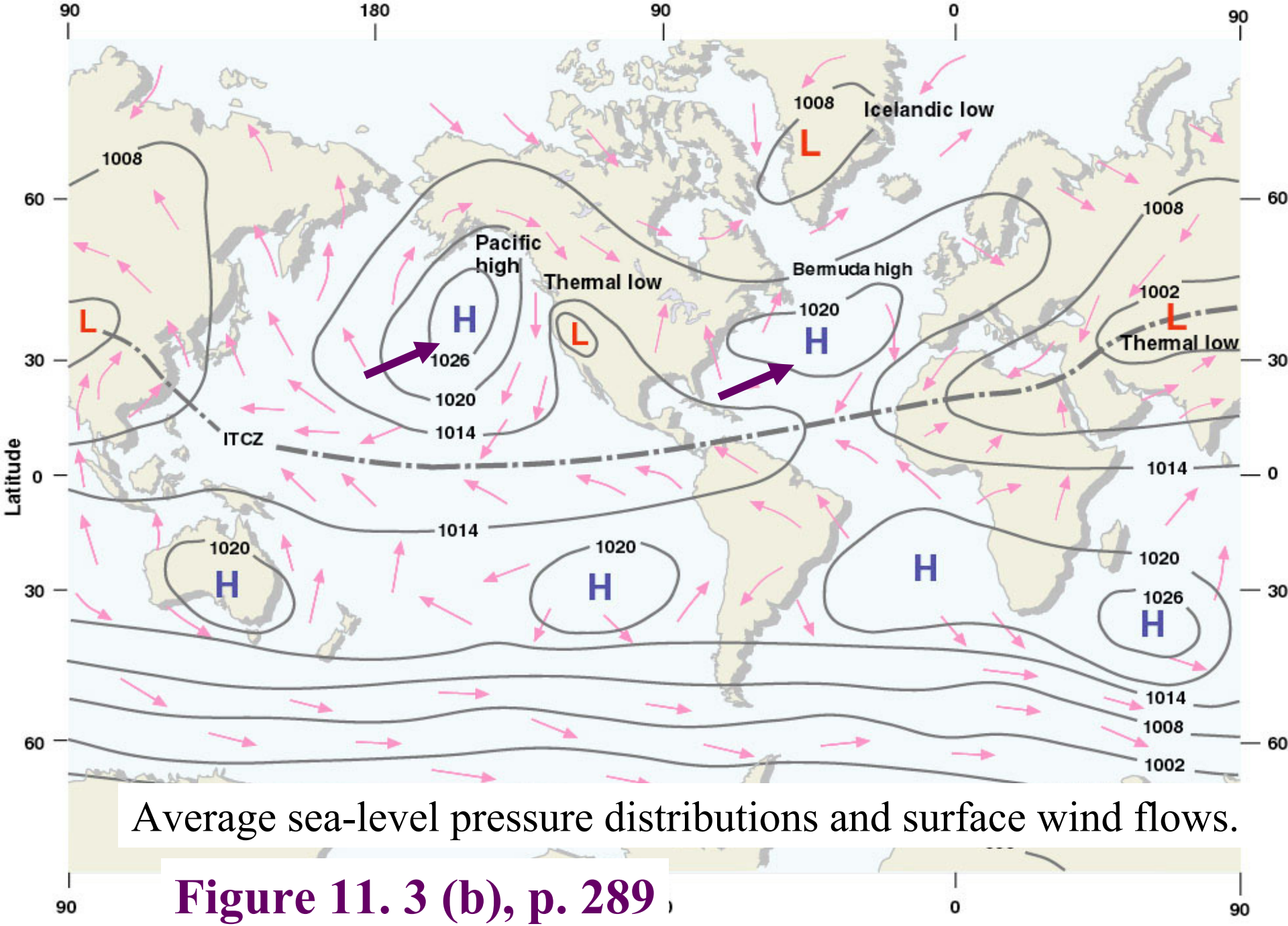
- Northern Hemisphere: in the subtropical region (15-40^{o} Latitude)
  - Bermuda High
  - Pacific High
- "Thermal" Highs – domes of cold air mass
  - Develops in the wintertime over Siberia & Canada





Average sea-level pressure distributions and surface wind flows.

Figure 11. 3 (a), p. 288



Average sea-level pressure distributions and surface wind flows.

Figure 11. 3 (b), p. 289

Intro to Stability

A

B

- STABLE – why?
  - Warm air is less dense
  - Cold air is more dense
  - Little mixing

  ∴ Stable environment

- UNSTABLE – why?
  - Since warm air is less dense and cold air is more dense—the warm air wants to rise and the cold air wants to sink
  - Lots of vertical mixing

  ∴ Unstable environment

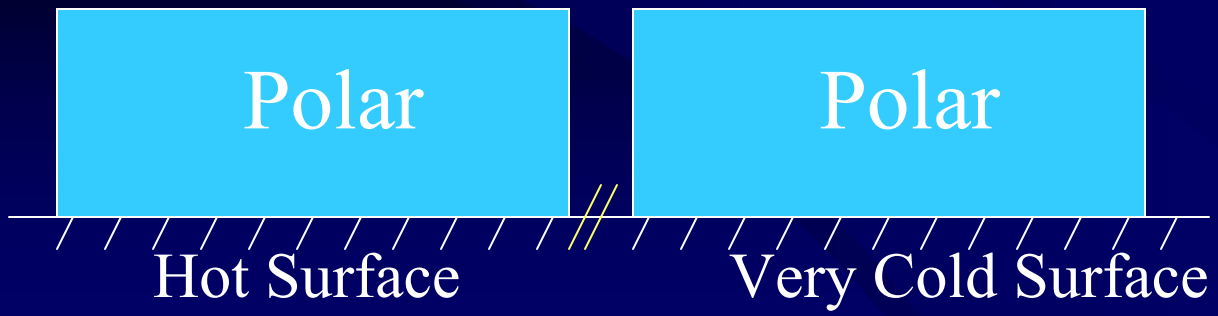
Movement of air masses

Air masses move in response to winds aloft…

Becomes modified by surfaces of different temperatures and moisture content

How can you determine the *stability* of the air mass?

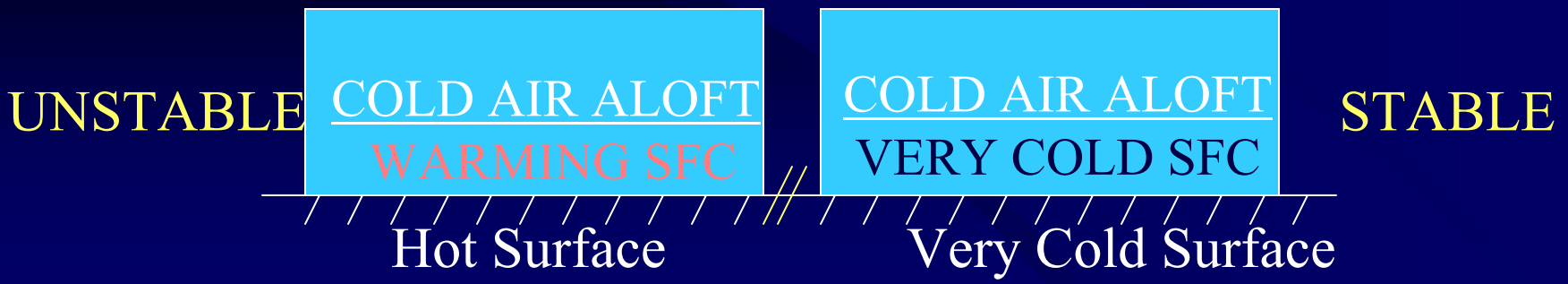
- By looking at *how the air mass is being modified by the surface*:



Movement of air masses

The hot surface is warming the lower layers of the polar air mass. This leads to what kind of stability?

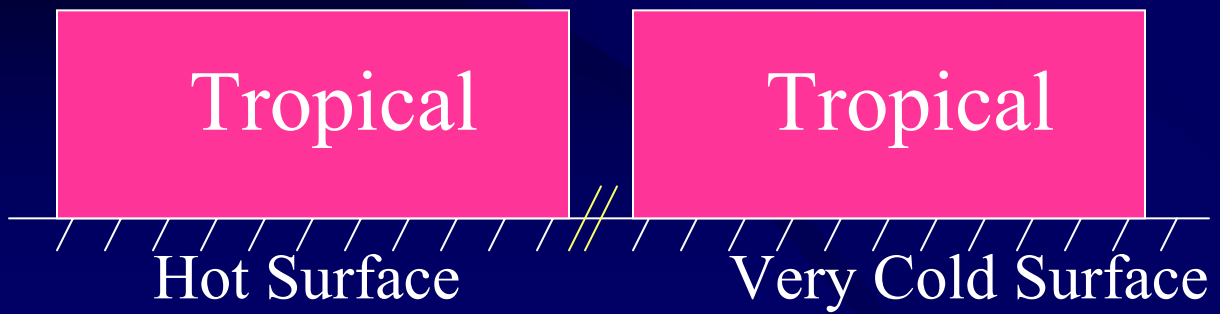
The cold surface is cooling the lower layers of the polar air mass even more. Stability?



Movement of air masses

How about for a *tropical* air mass?

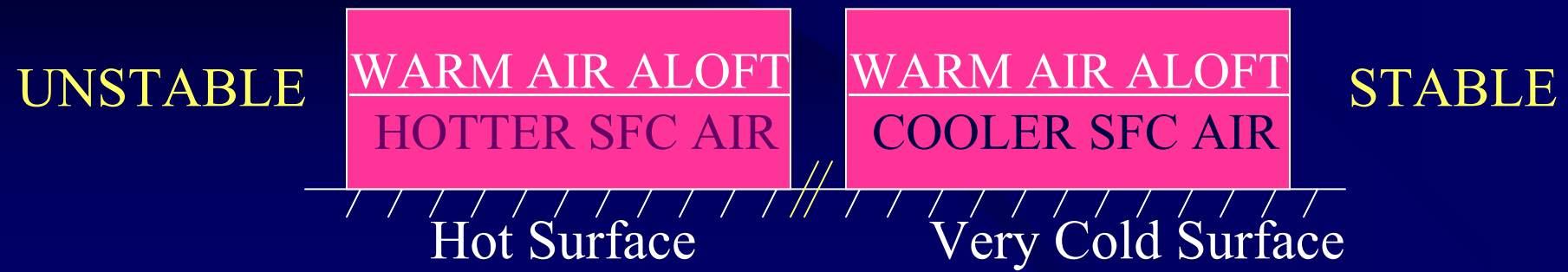
How would stability be affected for the two situations?



Movement of air masses

How about for a *tropical* air mass?

- How would stability be affected for the two situations?
- The hotter the surface air becomes, the more buoyant it is = unstable = more mixing



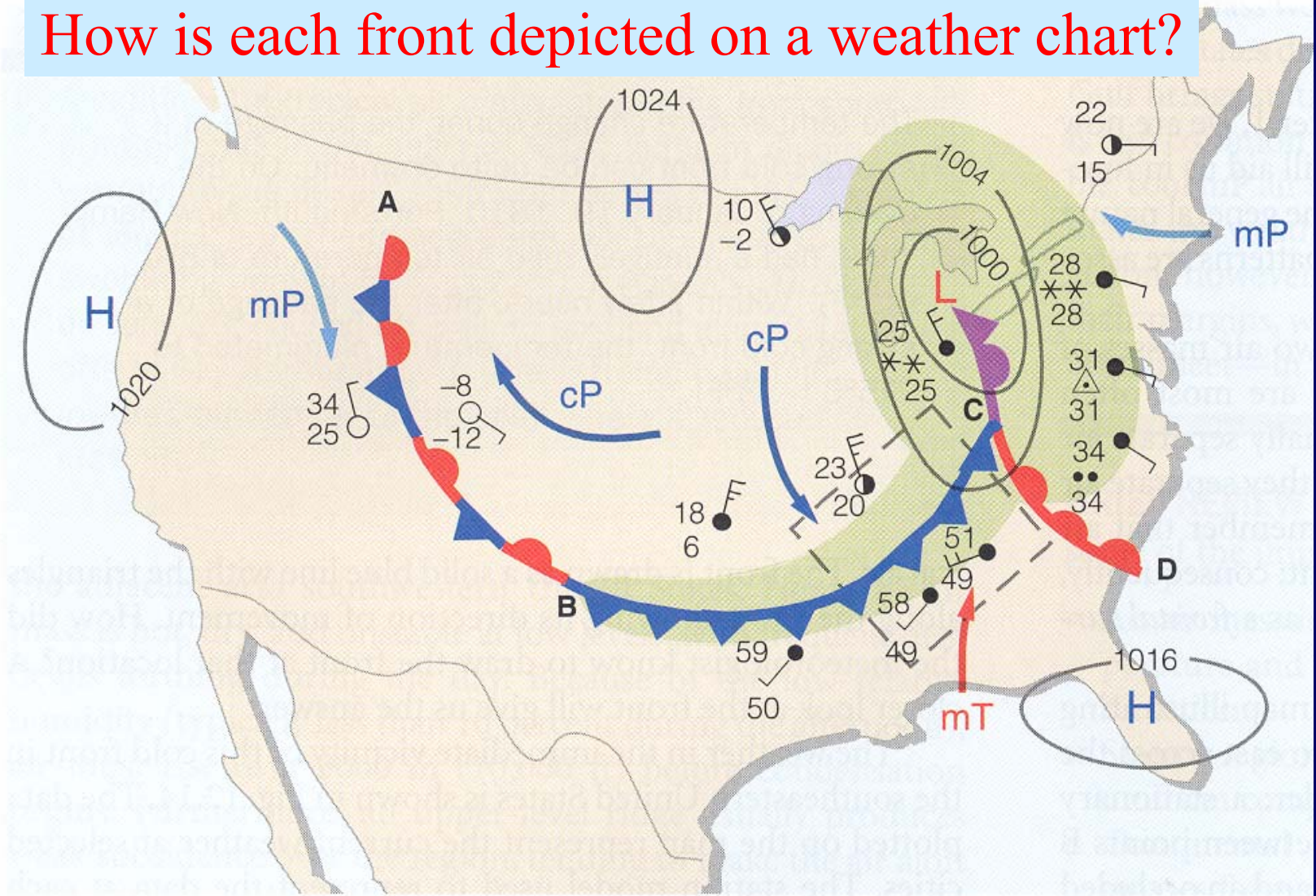
Moist air vs Dry air: Which is heavier? Which is more unstable?

- Chapter 5 - p. 126
  FOCUS Section
- At the same temp and pressure level, humid air weighs less than dry air
- Moist air tends to be lighter, more *buoyant*
- More unstable – more mixing

- Dry air is heavier, tends to sink
- More stable – little mixing

FRONTS

How is each front depicted on a weather chart?



SIMPLIFIED KEY

Cold front B-C

Warm front C-D

Occluded front

Stationary front A-B

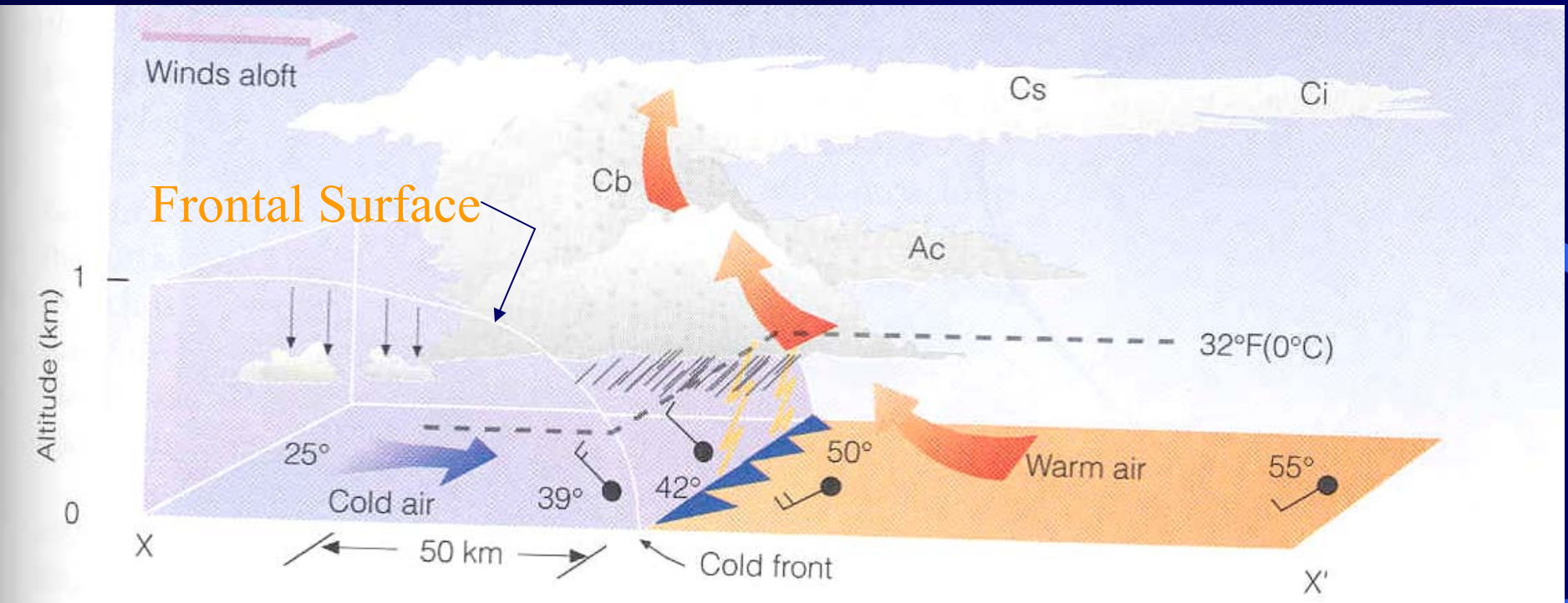
Low pressure-C

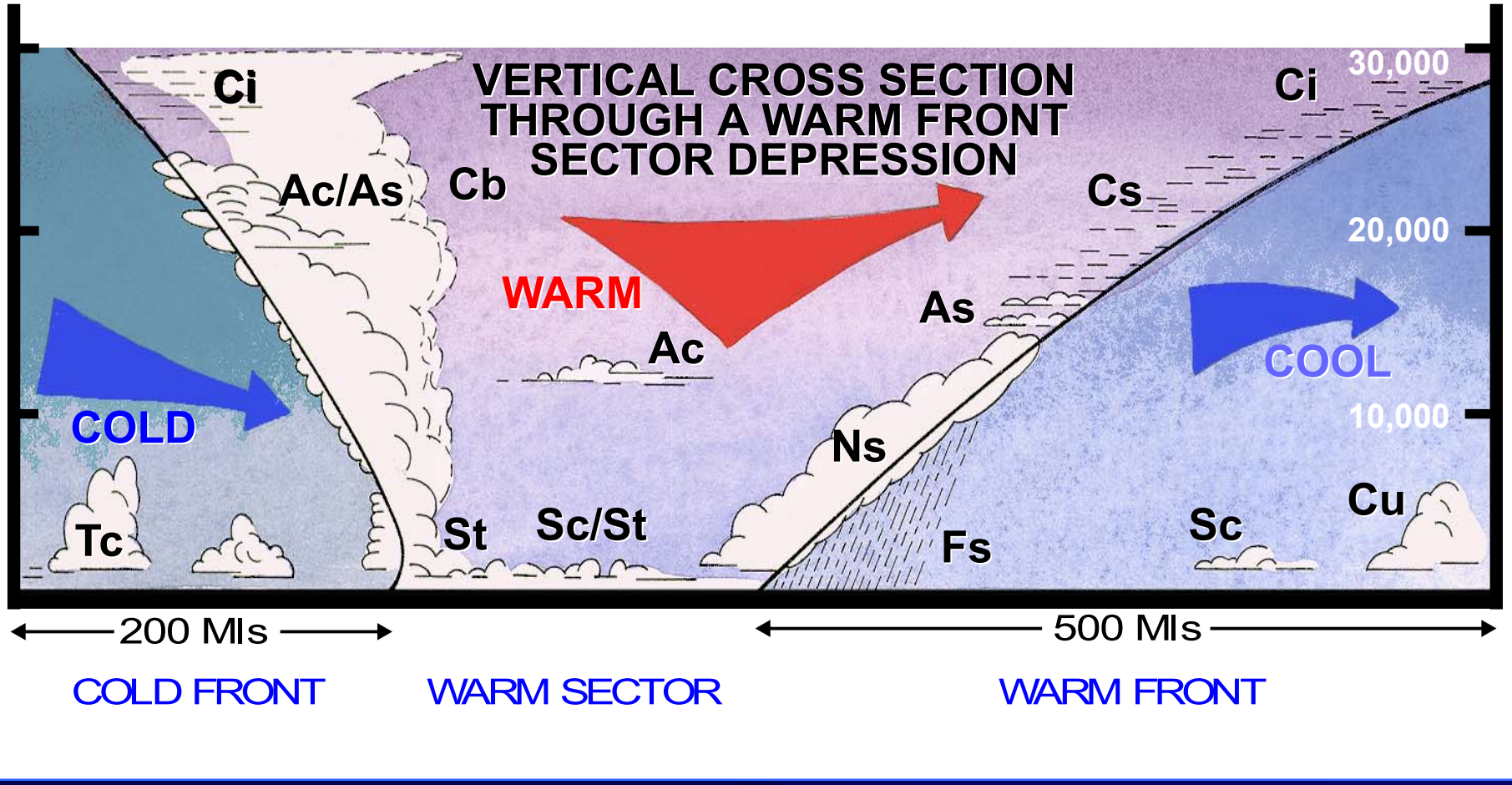
What are the 5 ways of locating a front on a surface weather map?

1. Sharp temperature changes over a relatively short distance
2. Changes in the air's moisture content (changes in dew point)
3. Shifts in wind direction
4. Clouds and precipitation patterns
5. Pressure and pressure changes

What do fronts depict?

- The transition zone between 2 air masses of different densities
- Density differences → Temperature differences → Humidity differences




VERTICAL CROSS SECTION
THROUGH A WARM FRONT
SECTOR DEPRESSION
Ci
Ac/As
Cb
Cs
Ci
30,000
20,000
10,000
WARM
As
Ac
COOL
COLD
Ns
Cu
Tc
St
Sc/St
Fs
Sc
200 Mls
500 Mls
COLD FRONT
WARM SECTOR
WARM FRONT

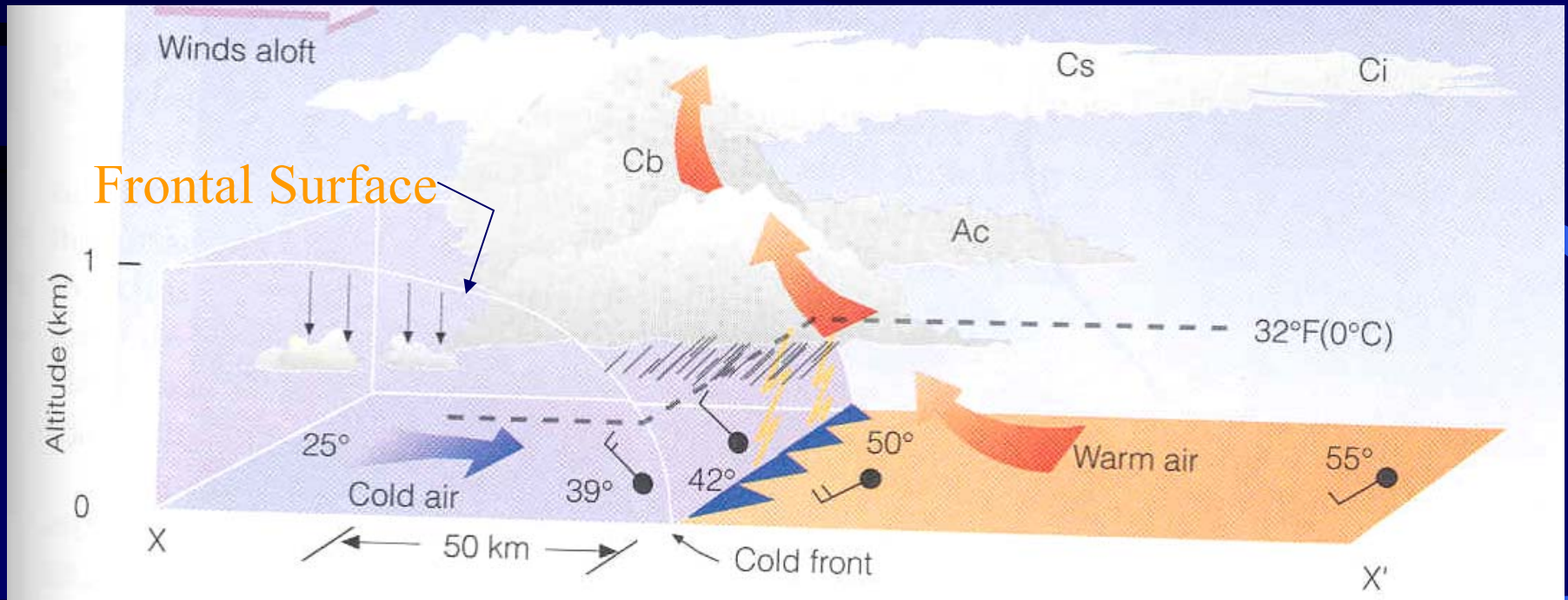
Cold front is the leading edge of a cold air mass (cP or mP)

As the cold front plows into warmer, lighter air, it produces towering clouds, precipitation and sometimes, thunderstorms.

Source: USA TODAY research by Chad Palmer, Graphic by John Herne

Cold front's leading edge

- Steep – due to surface friction
- Fast-moving front - Slope is 1:50 (vertical rise to horizontal distance in km) = "katafronts"
- Slow-moving front – Slope is much more gentle = "anafronts"



COLD FRONTS: Slow vs Fast moving fronts

- Which of the above fronts has a broad cloud cover behind the front? Why?
  - –Slow-moving fronts: The more gentle slope allows clouds to form behind the front.
  - –This makes it difficult to depict the surface front from the satellite imagery.

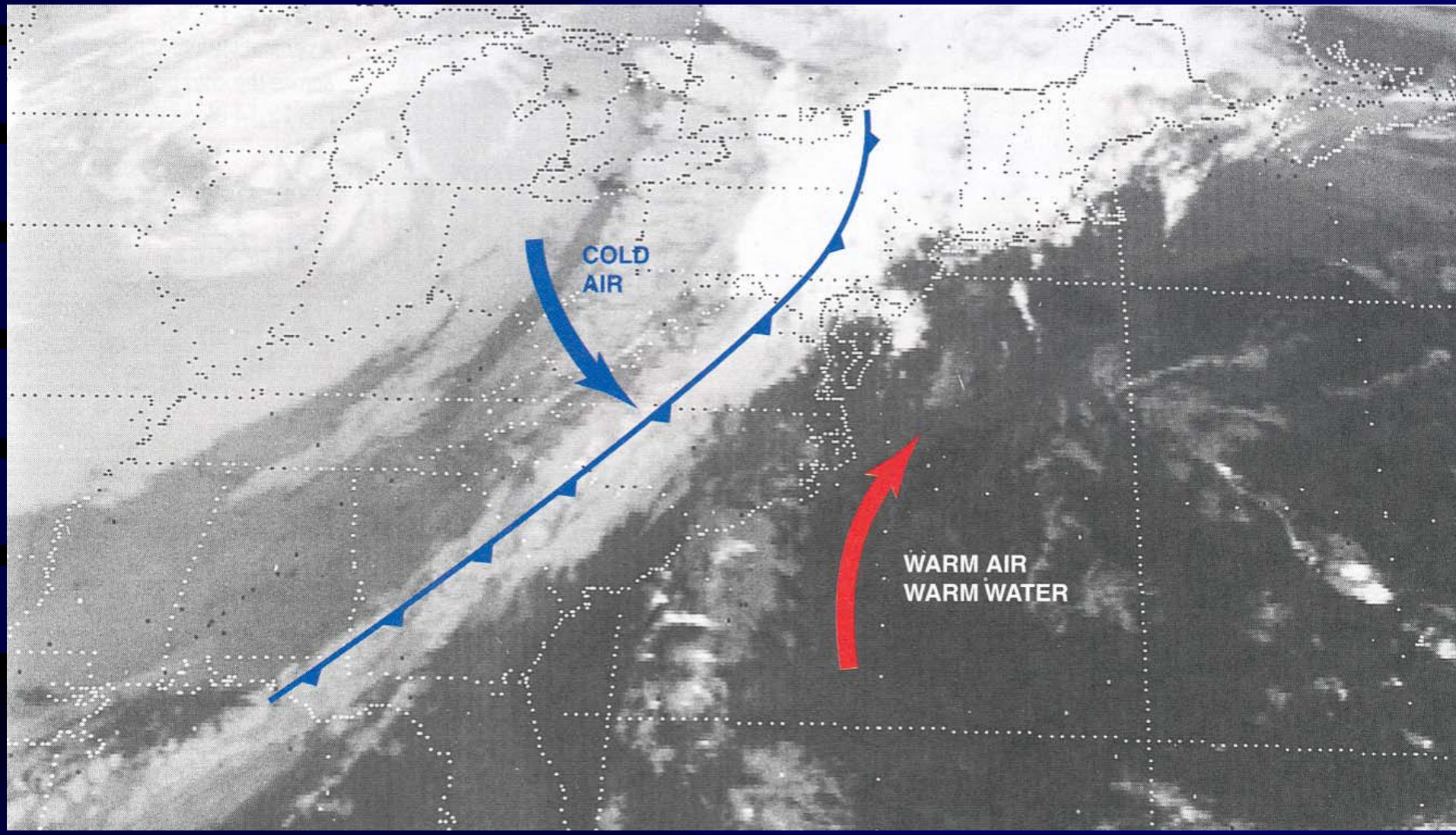
Fast Moving Cold Fronts

- Fast-moving fronts:
  - have a line of active showers and thunderstorms
  - "squall line" - develops parallel to and often ahead of the advancing front—producing heavy precipitation & strong gusty winds.

The *steep slope* of the front pushes the weather ahead of the front.

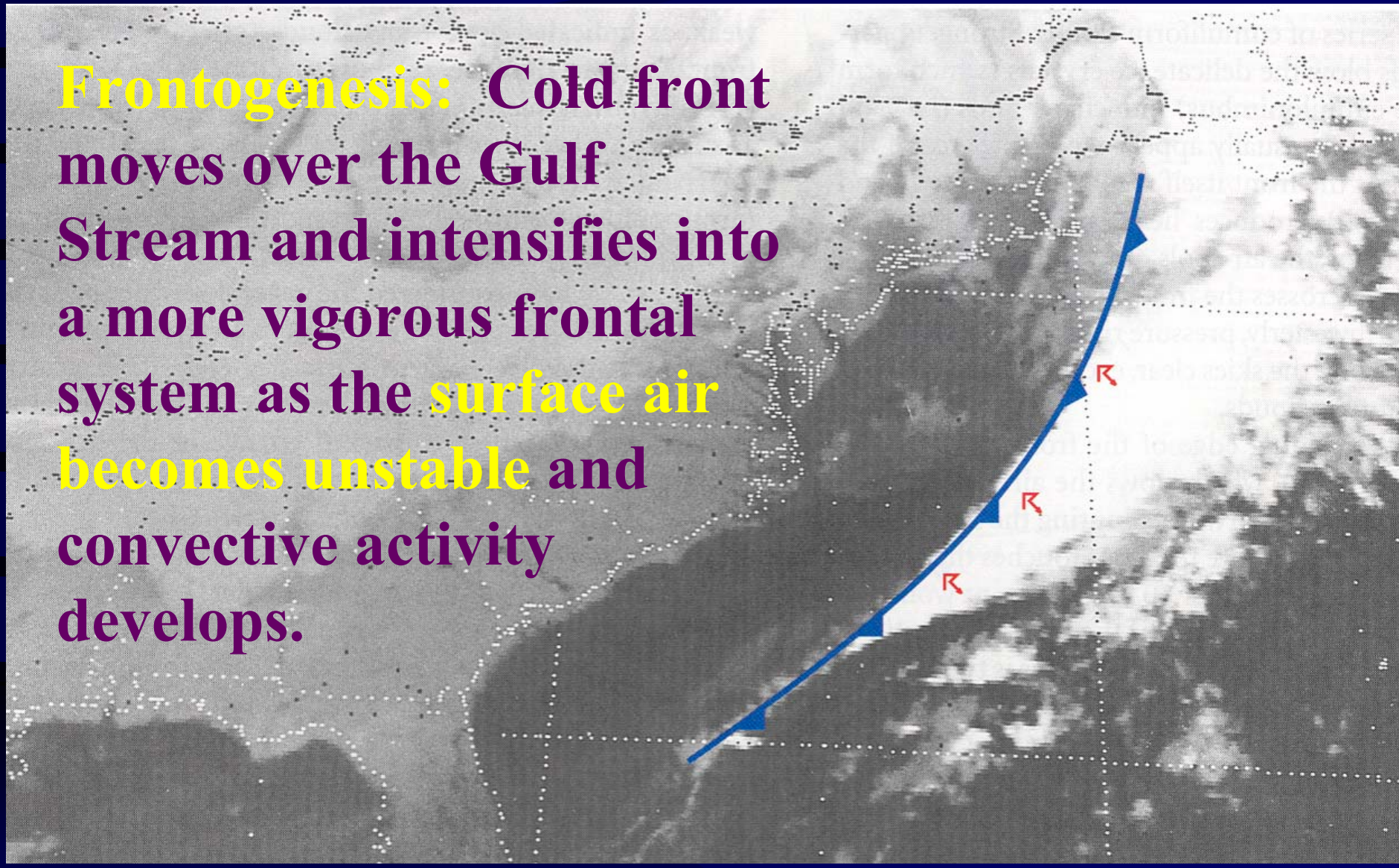
Definitions: Frontolysis vs Frontogenesis

- **Frontolysis** – when the temperature contrast across a front lessens, causing the front to weaken and dissipate
  - A dying frontal system
- **Frontogenesis** – an increase in the temperature contrast across a front can cause it to strengthen and re*generate* into a more vigorous system
  - A frontal system has developed



Frontolysis or Frontogenesis?

Frontolysis: Cold front is starting to weaken as it moves through the Appalachian Mountains (shear, moisture dries out)


Frontogenesis: Cold front moves over the Gulf Stream and intensifies into a more vigorous frontal system as the surface air becomes unstable and convective activity develops.

Typical Weather Conditions Associated with a Cold Front

TABLE 12.2 Typical Weather Conditions Associated with a Cold Front

WEATHER ELEMENT	BEFORE PASSING	WHILE PASSING	AFTER PASSING
Winds	South or southwest	Gusty, shifting	West or northwest
Temperature	Warm	Sudden drop	Steadily dropping
Pressure	Falling steadily	Minimum, then sharp rise	Rising steadily
Clouds	Increasing Ci, Cs, then either Tcu or Cb	Tcu or Cb*	Often Cu
Precipitation	Short period of showers	Heavy showers of rain or snow, sometimes with hail, thunder, and lightning	Decreasing intensity of showers, then clearing
Visibility	Fair to poor in haze	Poor, followed by improving	Good except in showers
Dew point	High; remains steady	Sharp drop	Lowering

*Tcu stands for towering cumulus, such as cumulus congestus; whereas Cb stands for cumulonimbus.

Know the wind shifts, the temperature and pressure changes.

When a cold front passes?

Wind: Veers

Pressure: Rises

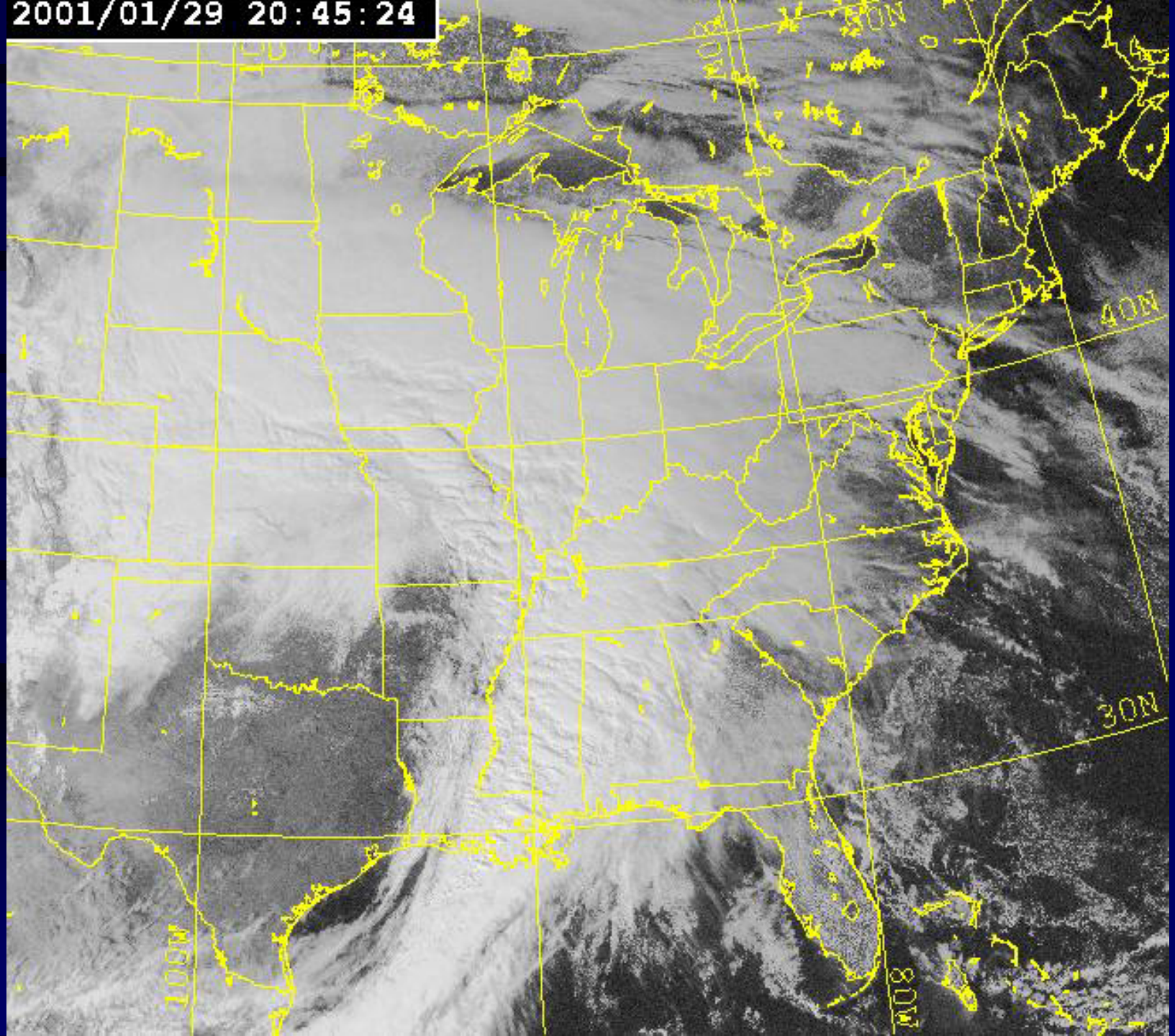
Temperature: Falls

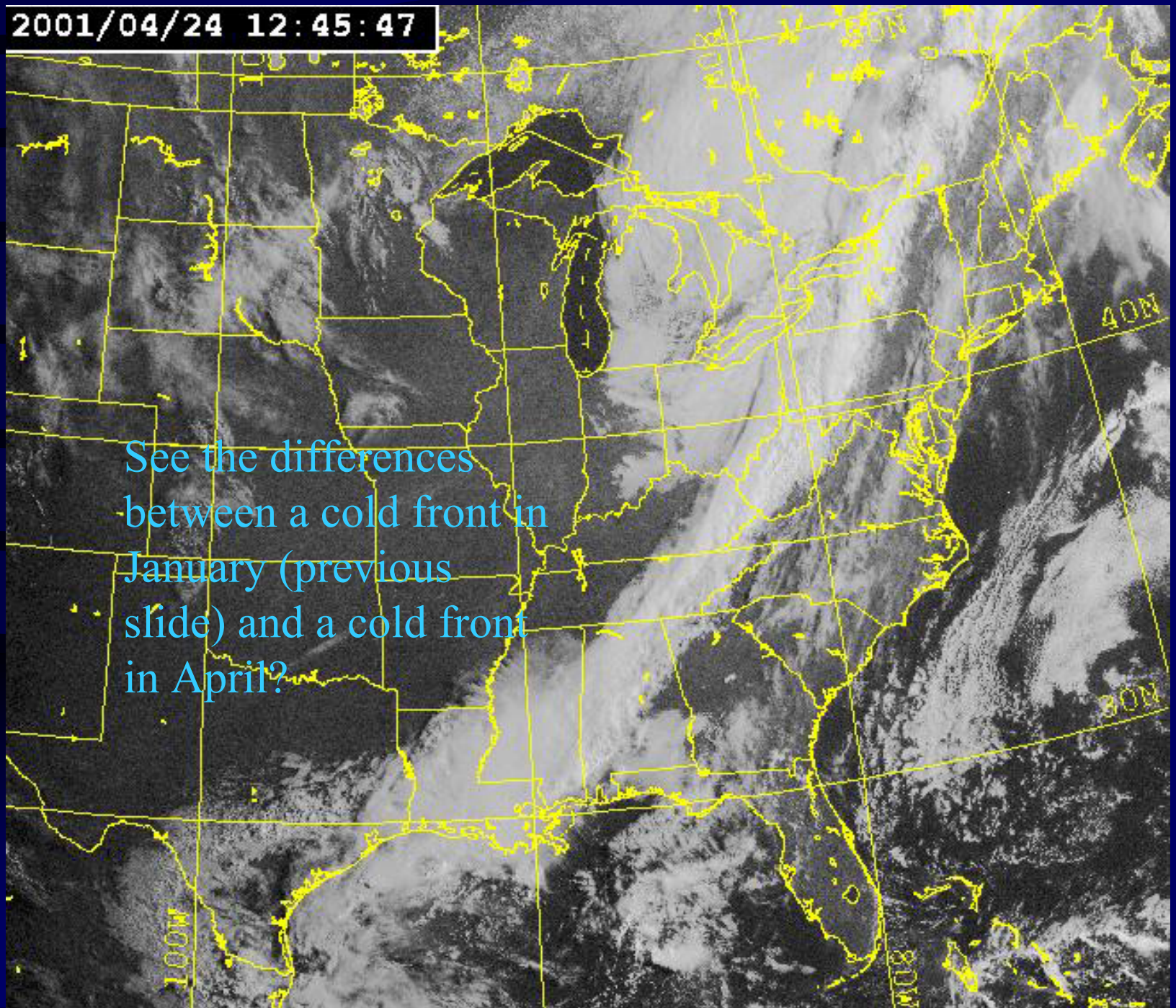
Dew Point: Falls more

Cloud Base: Rises

Weather: Rain then showers

Visibility: Improves


2001/01/29 20:45:24
40N
30N
100W
80W


2001/04/24 12:45:47
40N
30N
100W
80W
See the differences between a cold front in January (previous slide) and a cold front in April?

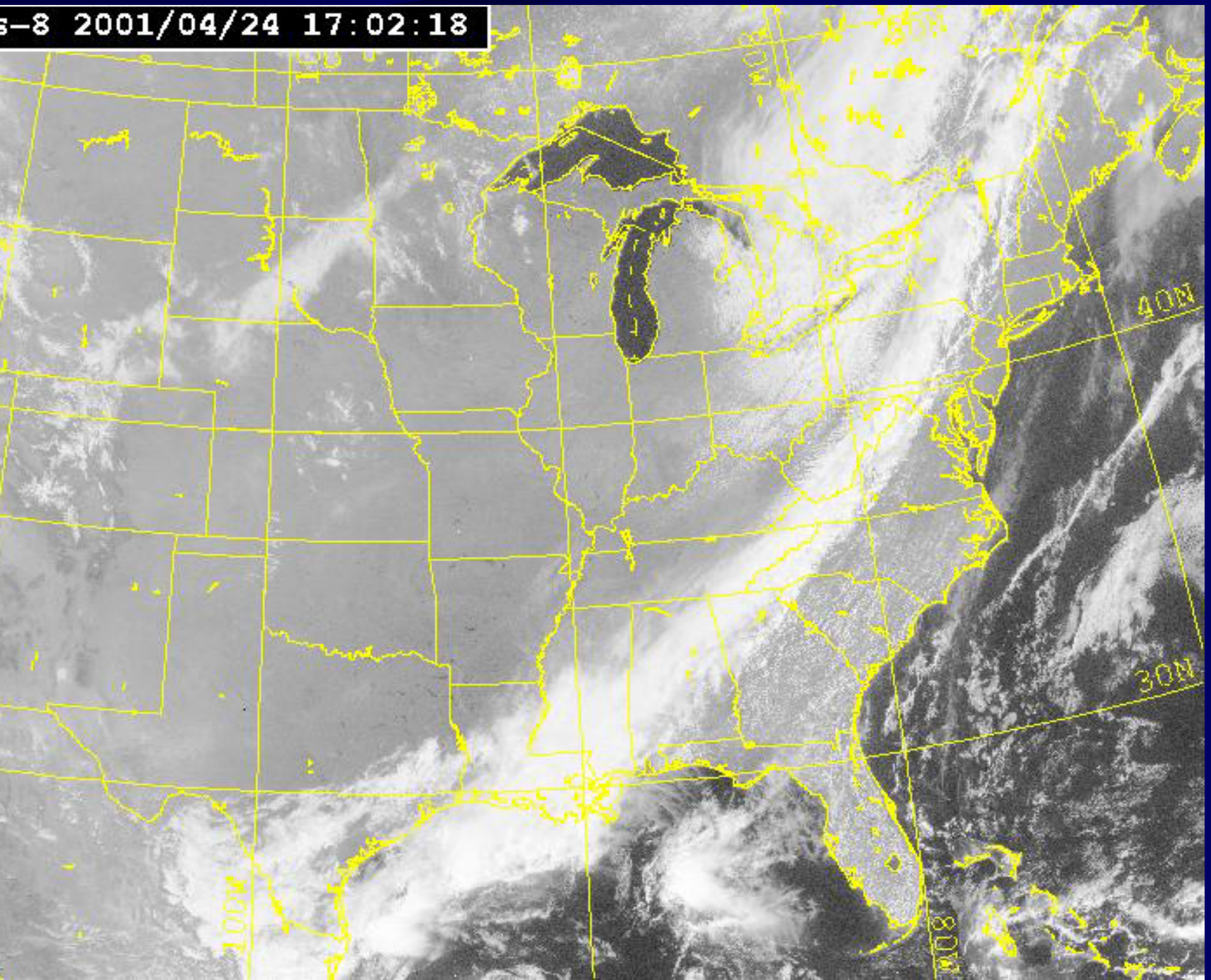
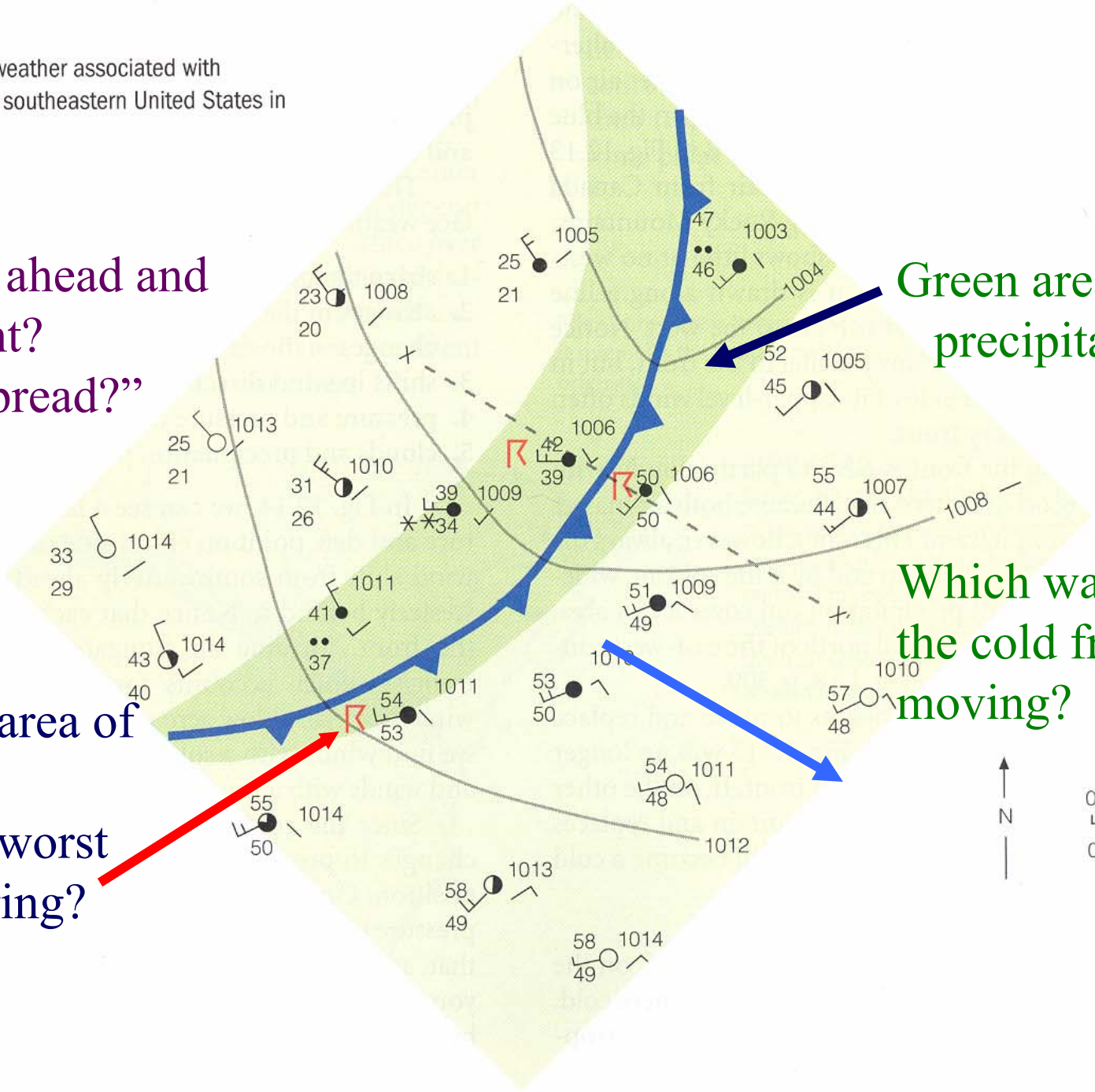

s-8 2001/04/24 17:02:18
40N
30N
100W
80W

FIGURE 12.14
A closer look at the surface weather associated with the cold front situated in the southeastern United States in Fig. 12.13.

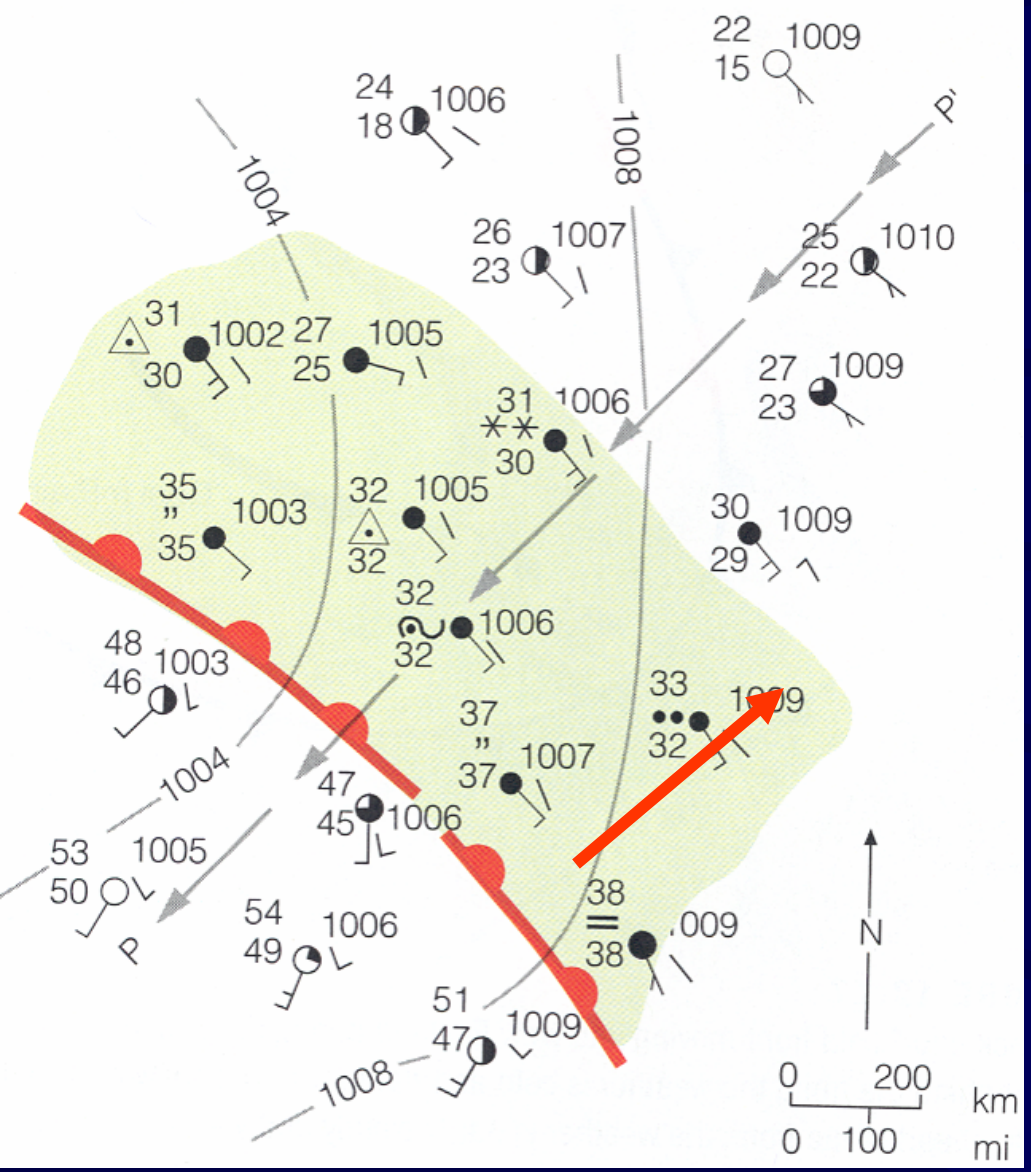
-Wind shift?
-Temperatures ahead and behind the front?
-"Dew-point spread?"



Green area = precipitation

Which way is the cold front moving?

- Where is the area of precipitation?
- Where is the worst weather occurring?



Warm Front

What do you look for when locating a warm front?

-Δ Temperature?

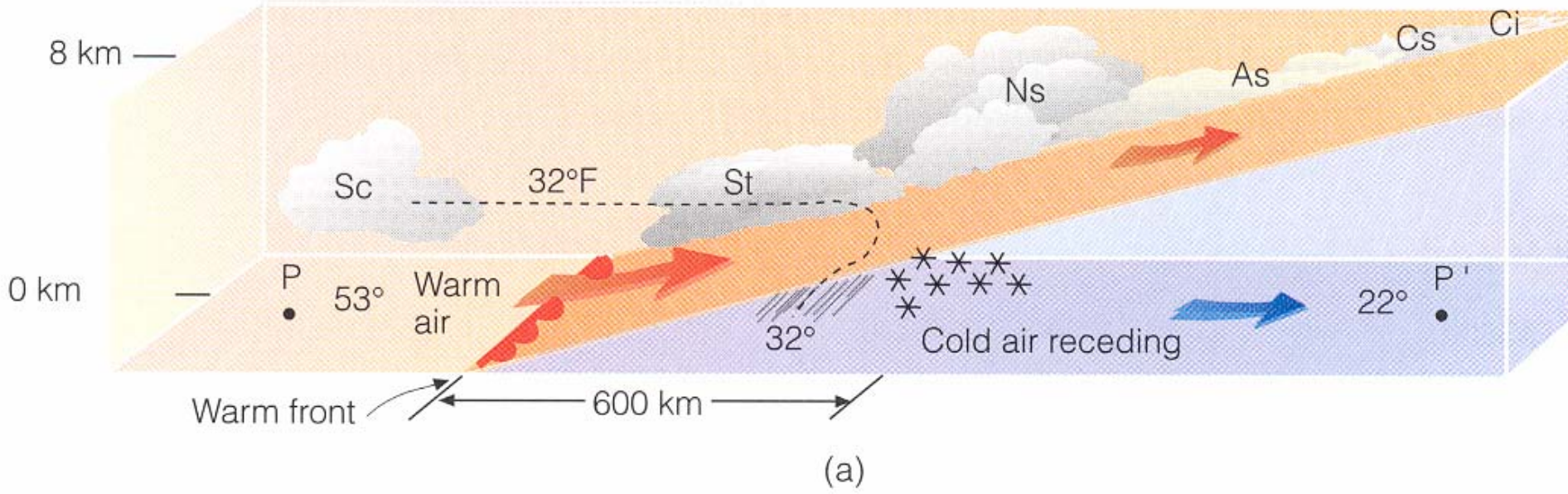
- Δ Pressure?

-Wind shift?

- Significant weather occurring?

-Which way is the warm front moving?

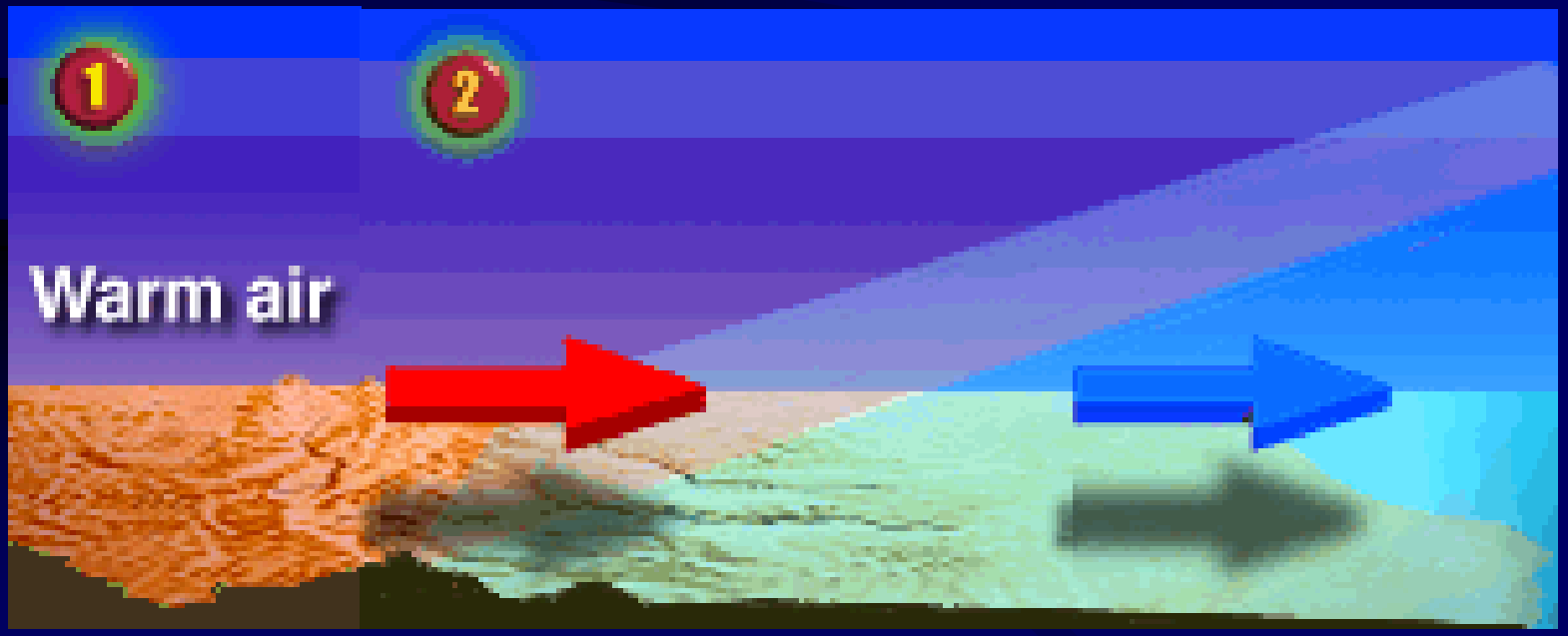
WARM FRONT



Notice the slope is much more gentle…1:150 to 1:200. The cloud cover is usually (ahead/behind) of the warm front.

Warm front is the leading edge of warm air (mT or cT)

Heavier, denser cold air retreats slowly as warm air rides up and over the cold air, producing widespread clouds and precipitation



Source: USA TODAY research by Chad Palmer, Graphic by John Herne

When a warm front passes?

Wind:	Veers
Pressure:	Falls then steadies
Temperature:	Rises
Dew Point:	Rises
Cloud Base:	Falls
Weather:	Rain to drizzle
Visibility:	Deteriorates

Typical Weather Conditions Associated with a Warm Front…

TABLE 12.3 Typical Weather Conditions Associated with a Warm Front

WEATHER ELEMENT	BEFORE PASSING	WHILE PASSING	AFTER PASSING
Winds	South or southeast	Variable	South or southwest
Temperature	Cool to cold, slow warming	Steady rise	Warmer, then steady
Pressure	Usually falling	Leveling off	Slight rise, followed by fall
Clouds	In this order: Ci, Cs, As, Ns, St, and fog; occasionally Cb in summer	Stratus-type	Clearing with scattered Sc; occasionally Cb in summer
Precipitation	Light-to-moderate rain, snow, sleet, or drizzle	Drizzle or none	Usually none; sometimes light rain or showers
Visibility	Poor	Poor, but improving	Fair in haze
Dew point	Steady rise	Steady	Rise, then steady

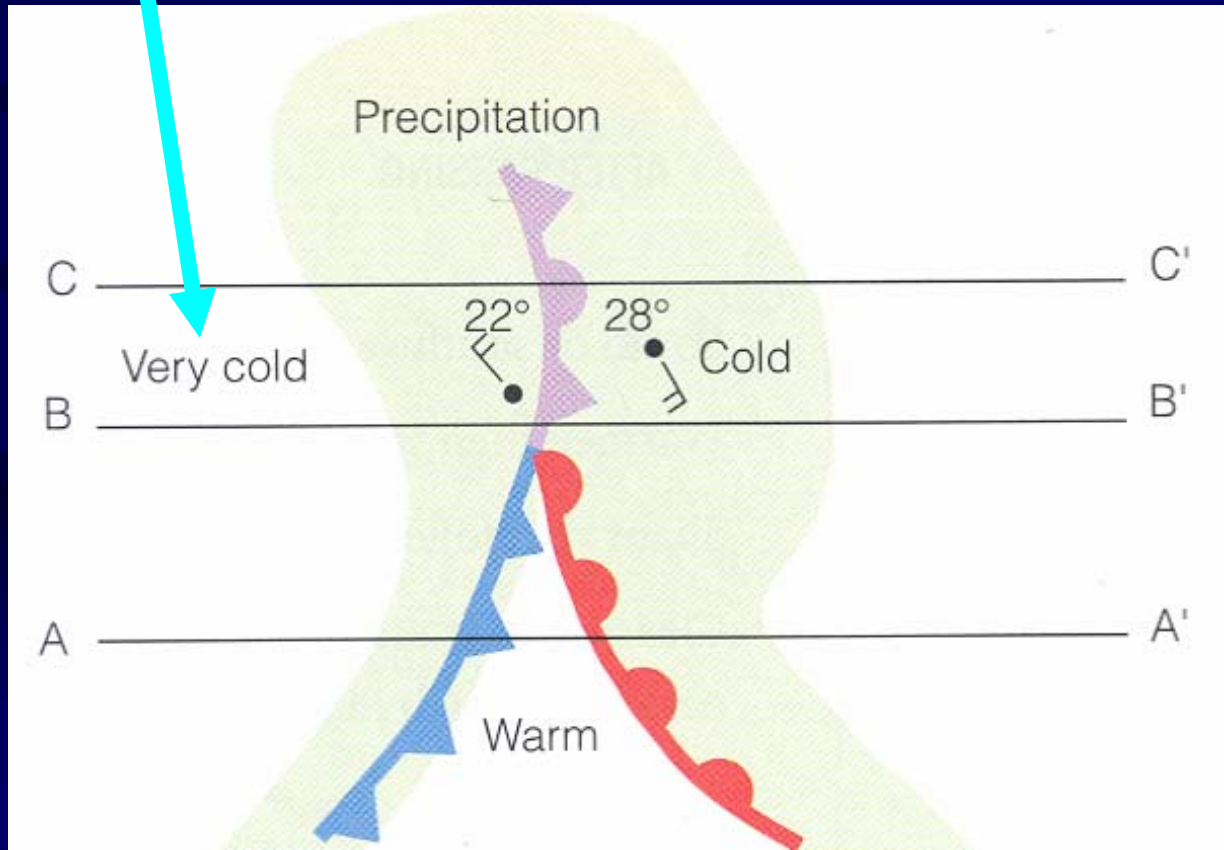
Know the wind shifts, the temperature and pressure changes.

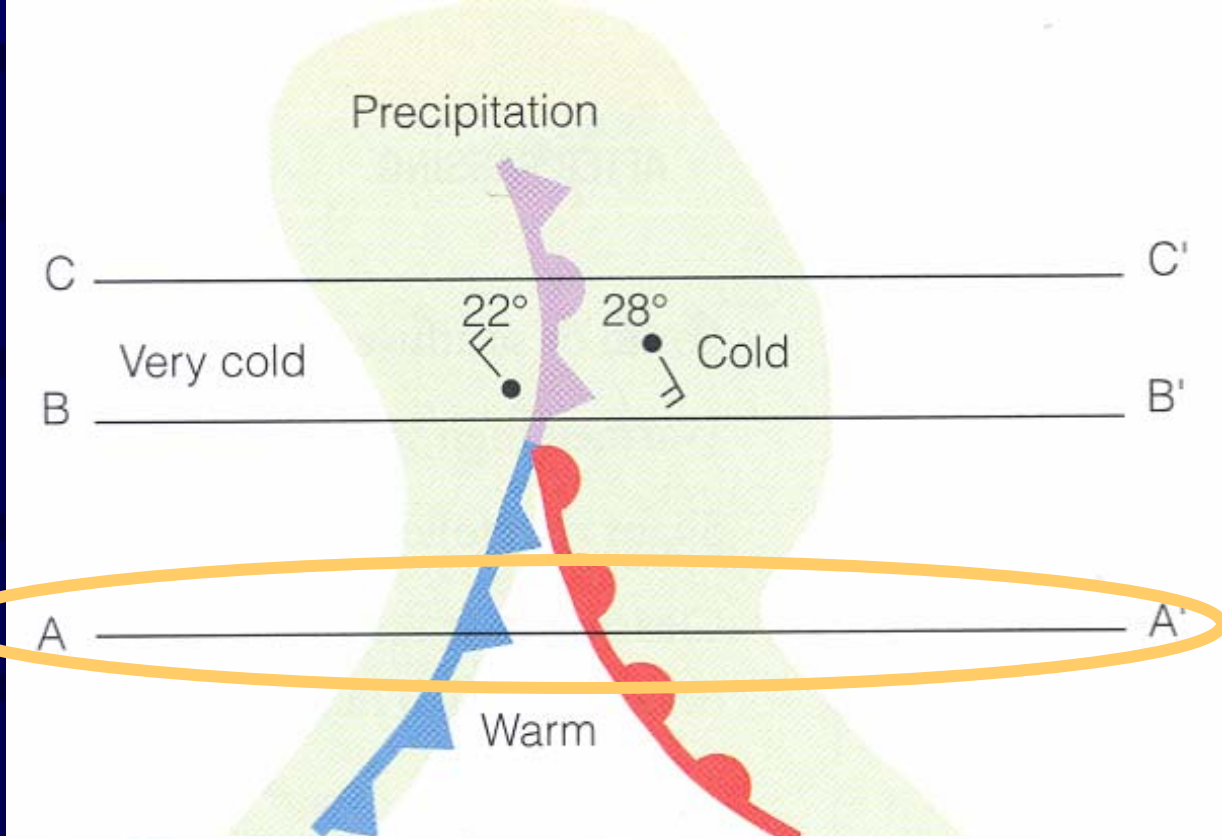
Occluded Front

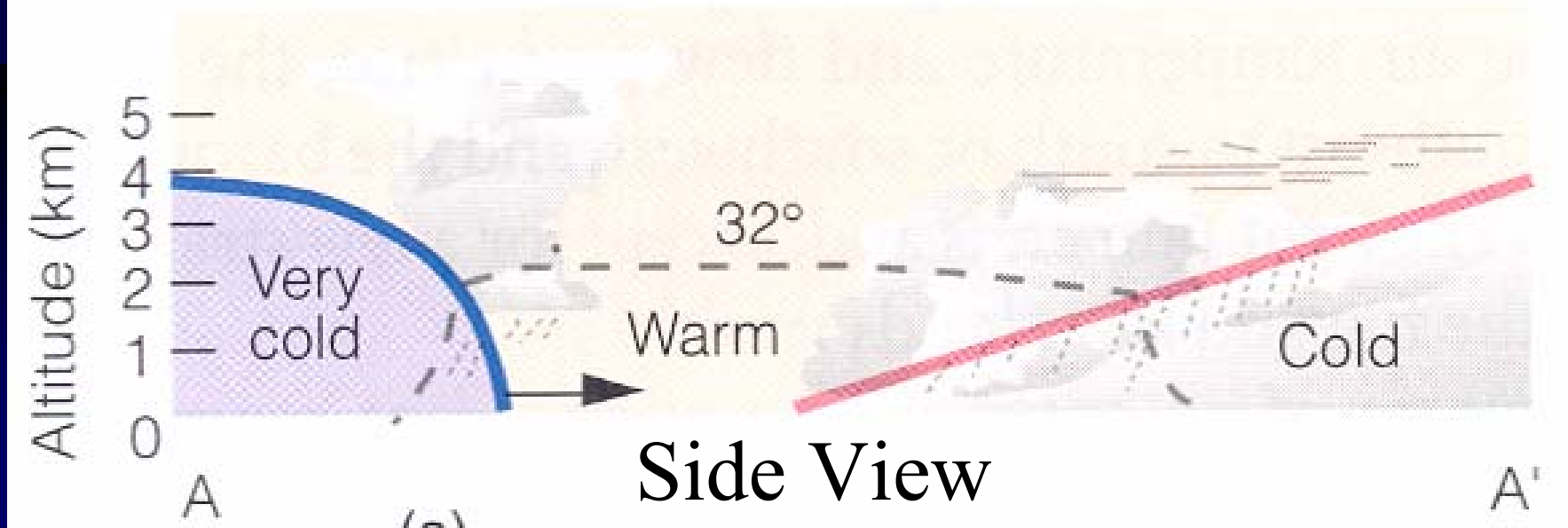
- When frontal systems are born, there are 2 fronts: a cold front and warm front.
- Cold fronts are usually *faster* than warm fronts.
- Eventually the cold front will catch up to the warm front
- The combination of the two fronts produces an **occluded front**, where some of the most severe weather conditions exist, especially near the **triple point**, where all three fronts meet (cold, warm & occluded).
- Indicates the later stages of a storm's life cycle

Occluded Fronts: Cold vs Warm Type

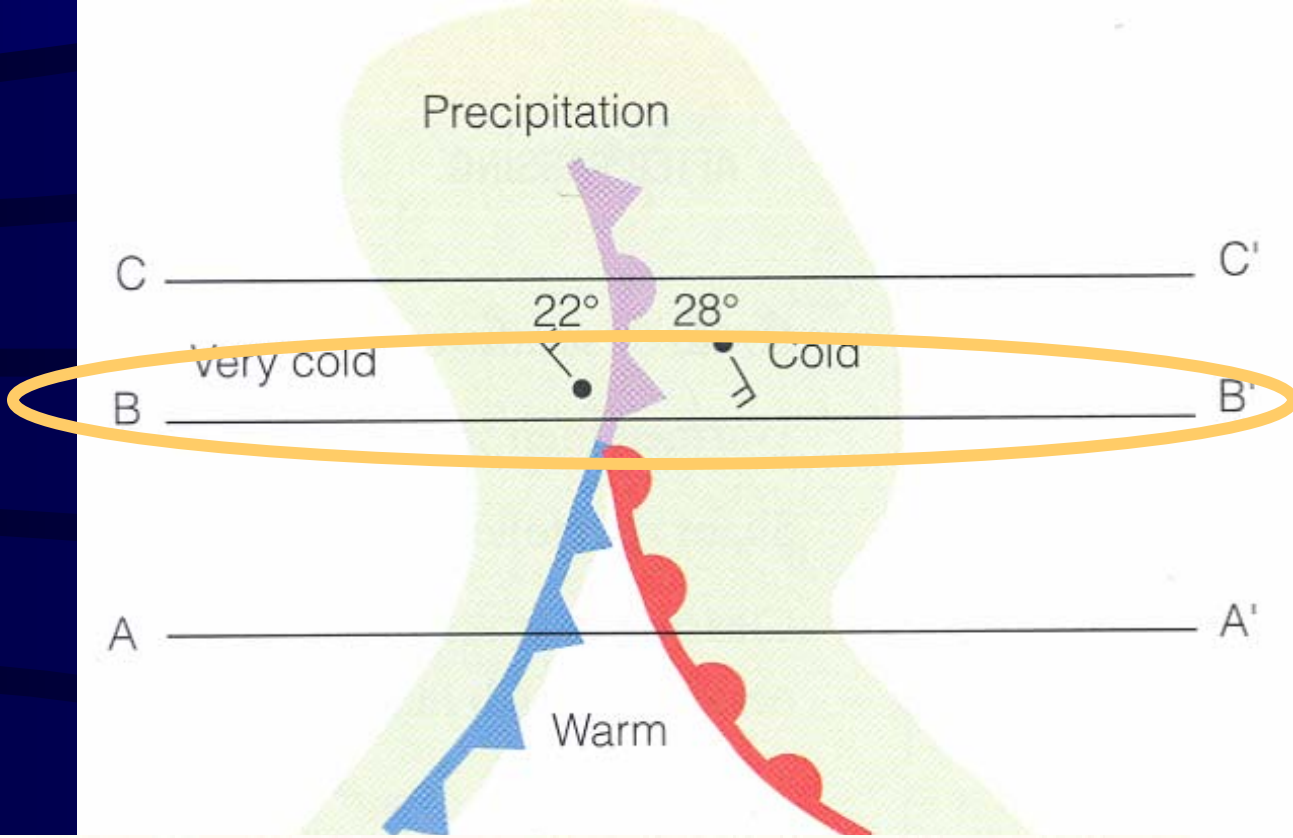
- Cold Occlusion: When the air behind the occlusion is colder than the air ahead of it.

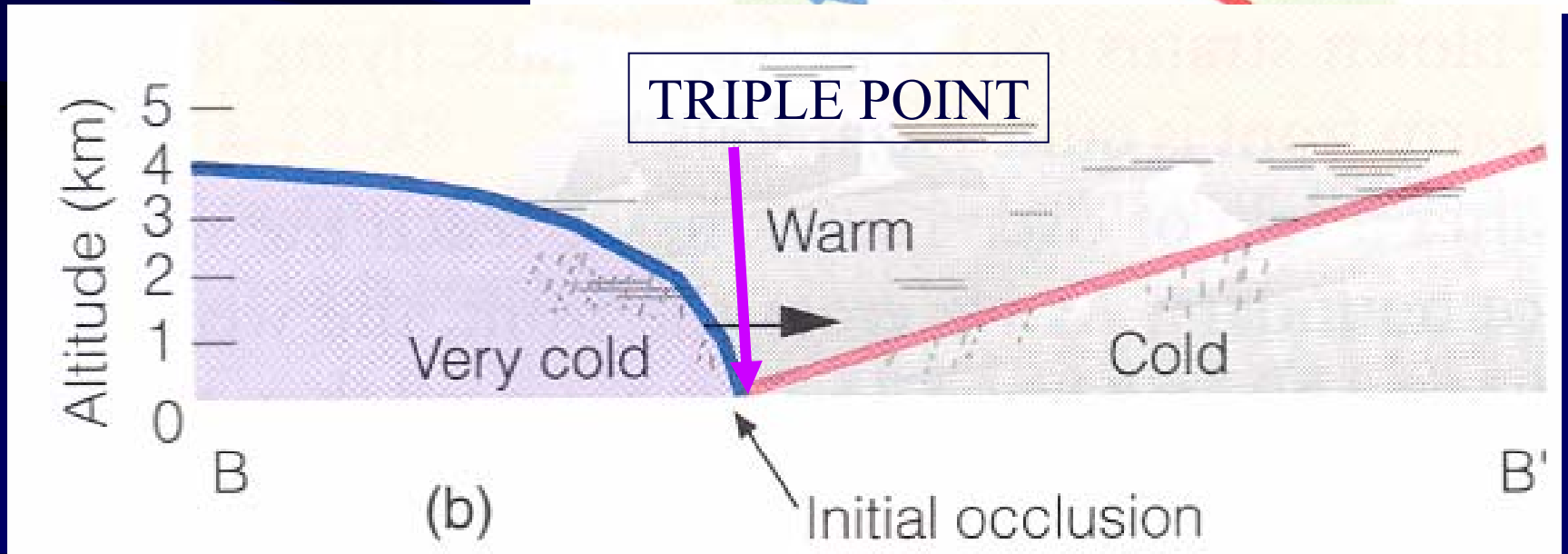


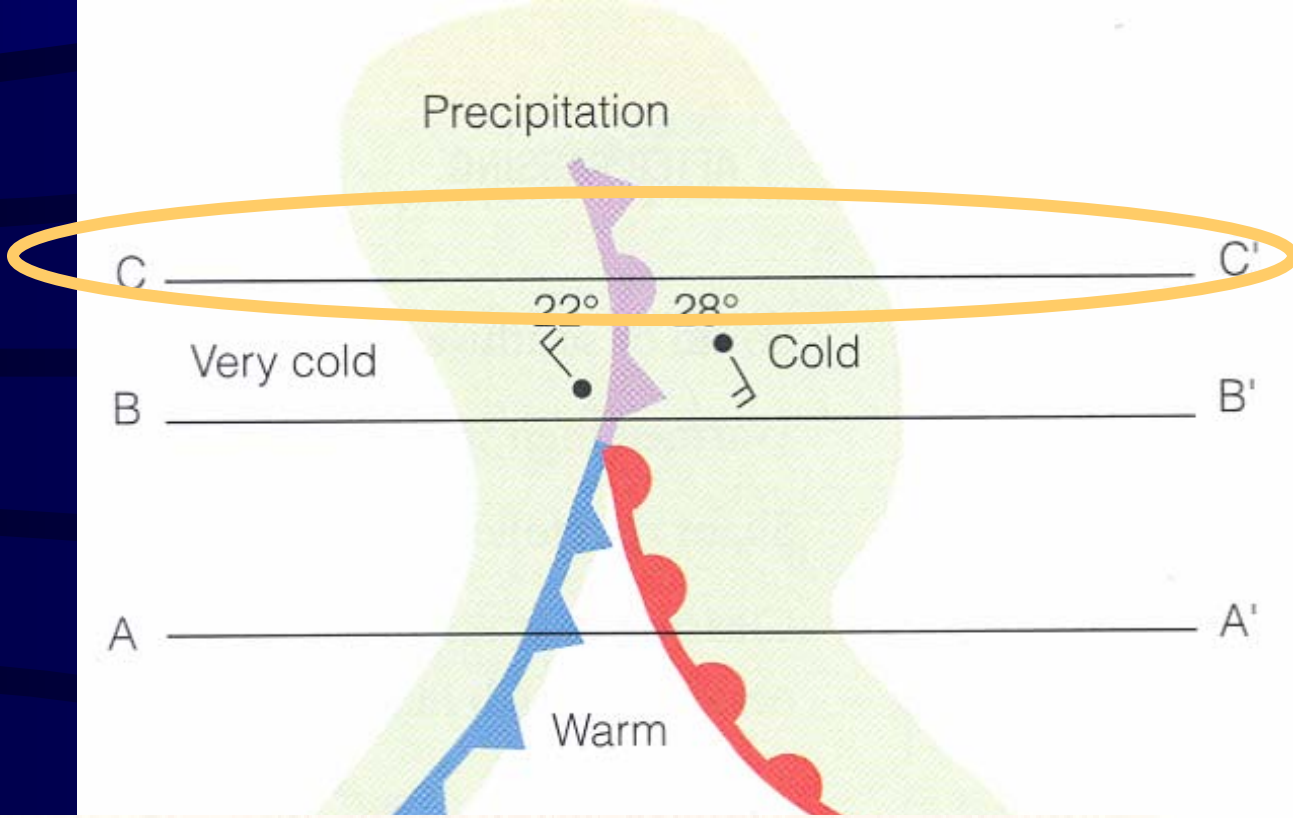

Precipitation
C
C'
22°
28°
Very cold
Cold
B
B'
A
A'
Warm

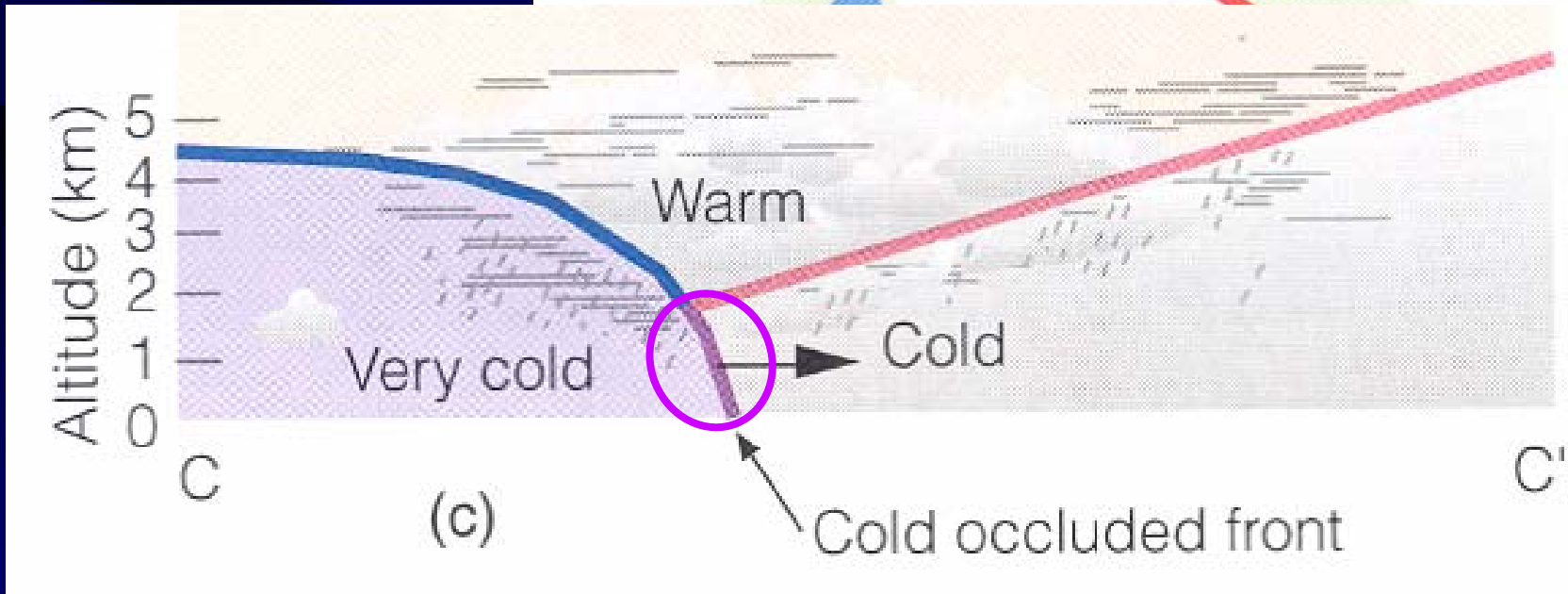

Altitude (km)
5
4
3
2
1
0
Very cold
32°
Warm
Cold
A
A'

Side View


Precipitation
C
C'
22°
28°
Very cold
Cold
B
B'
A
A'
Warm


TRIPLE POINT
Altitude (km)
5
4
3
2
1
0
Warm
Very cold
Cold
B
B'
(b)
Initial occlusion

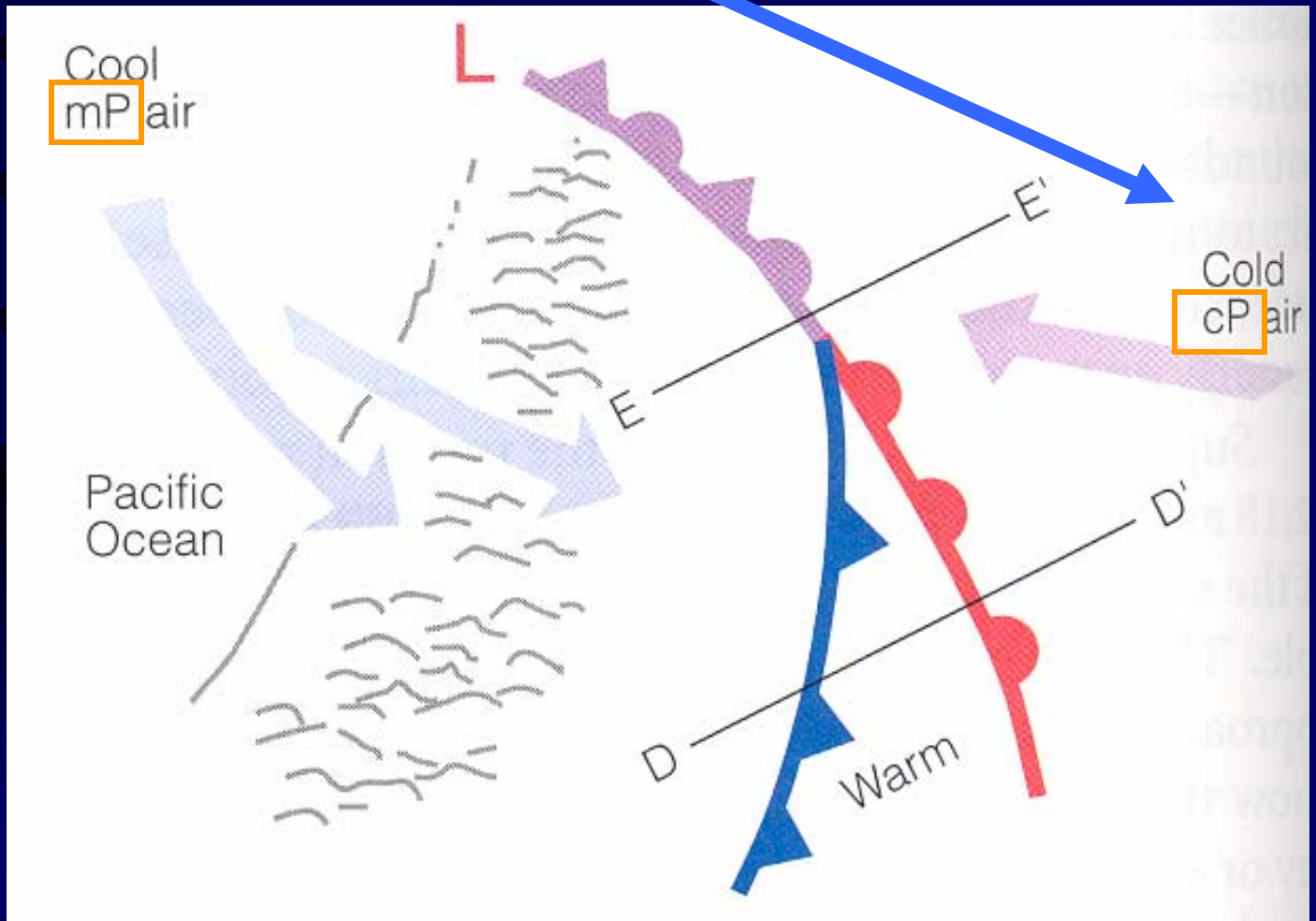

Precipitation
C
C'
22°
28°
Very cold
Cold
B
B'
A
A'
Warm

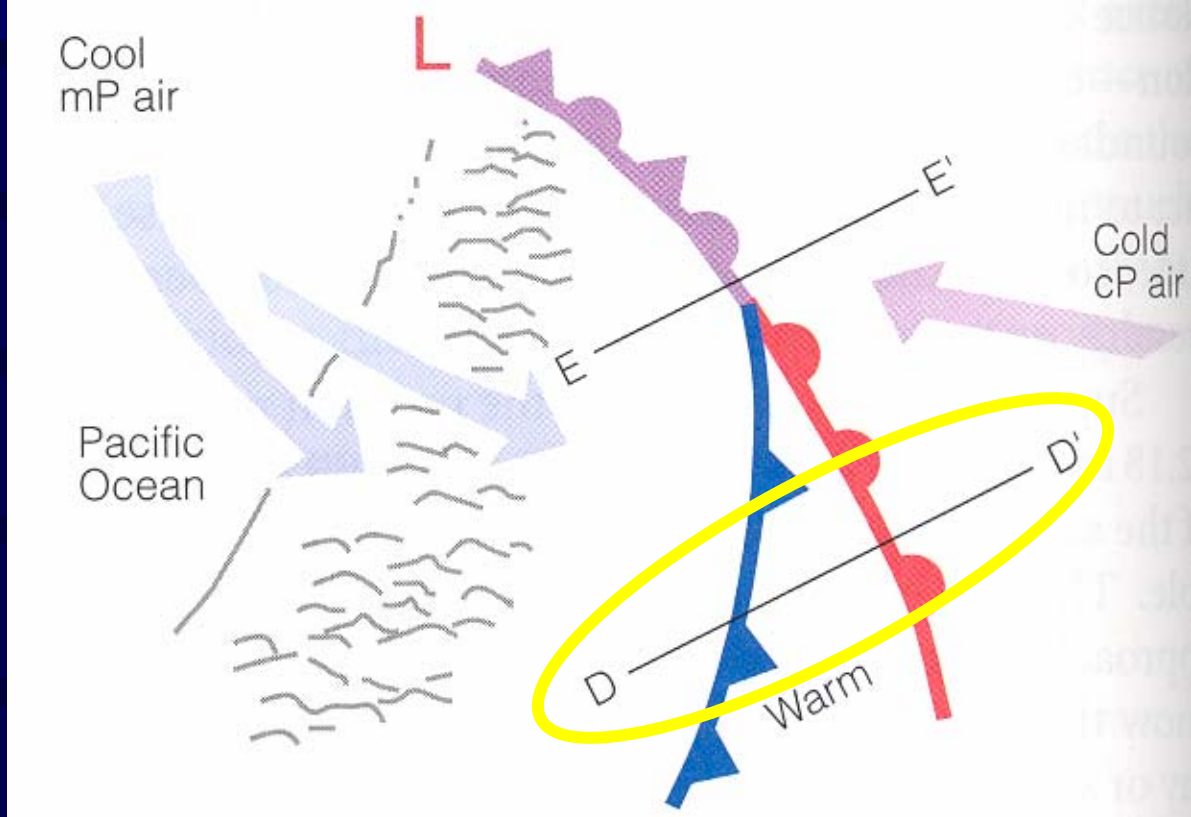

Altitude (km)
5
4
3
2
1
0
Warm
Very cold
Cold
C
C'
(c)
Cold occluded front

Colder air behind the occlusion plows into the cooler air ahead of the front, similar to a cold front.

Source: Chad Palmer, USATODAY.com Weather team, graphic by David Evans

Warm-type Occluded Front: When the air behind the occlusion is cool compared to the cold air ahead of it.

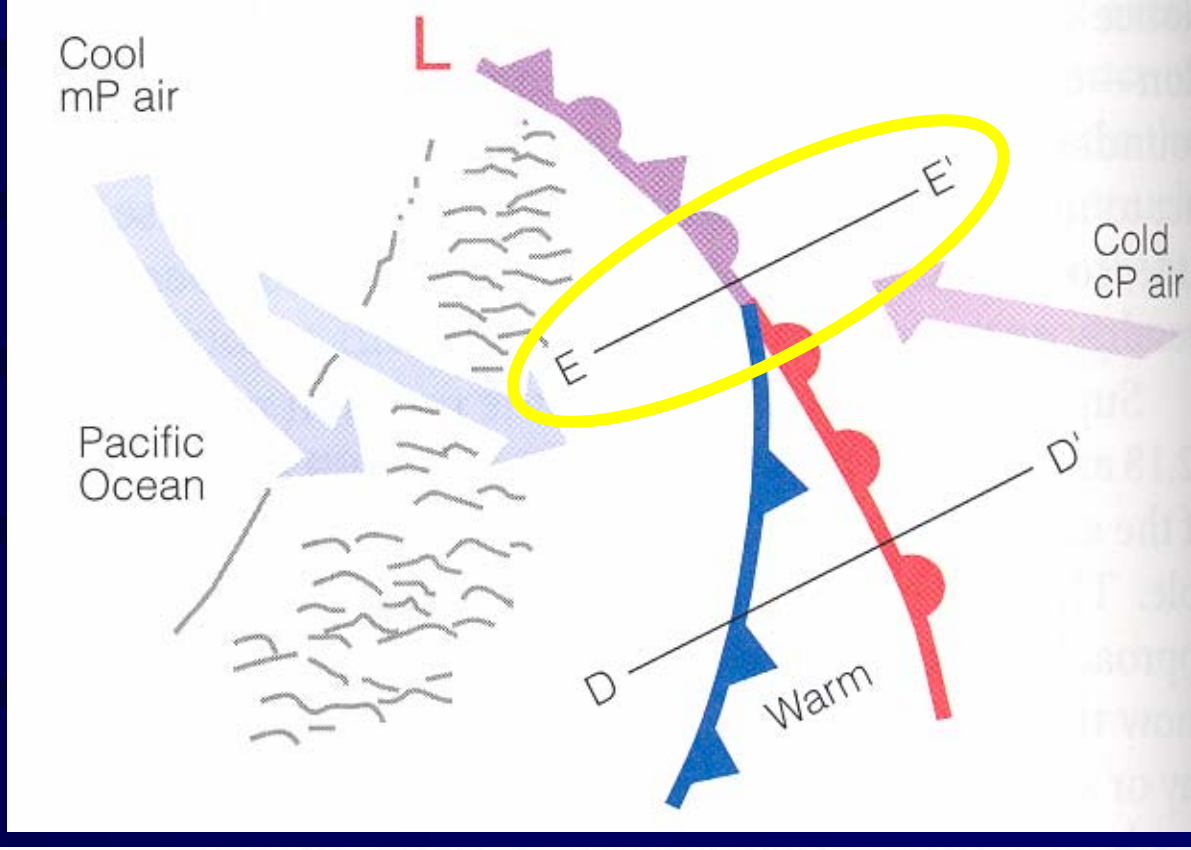


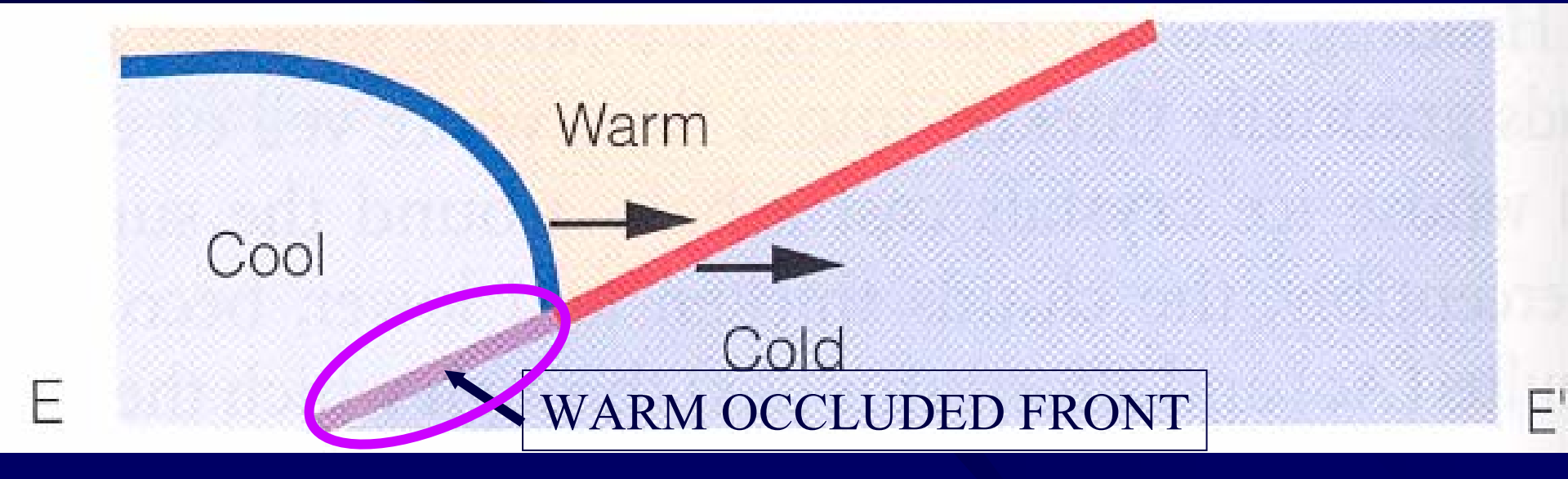

Cool
mP air
L
E'
Cold
cP air
E
Pacific
Ocean
D'
D
Warm

Side View

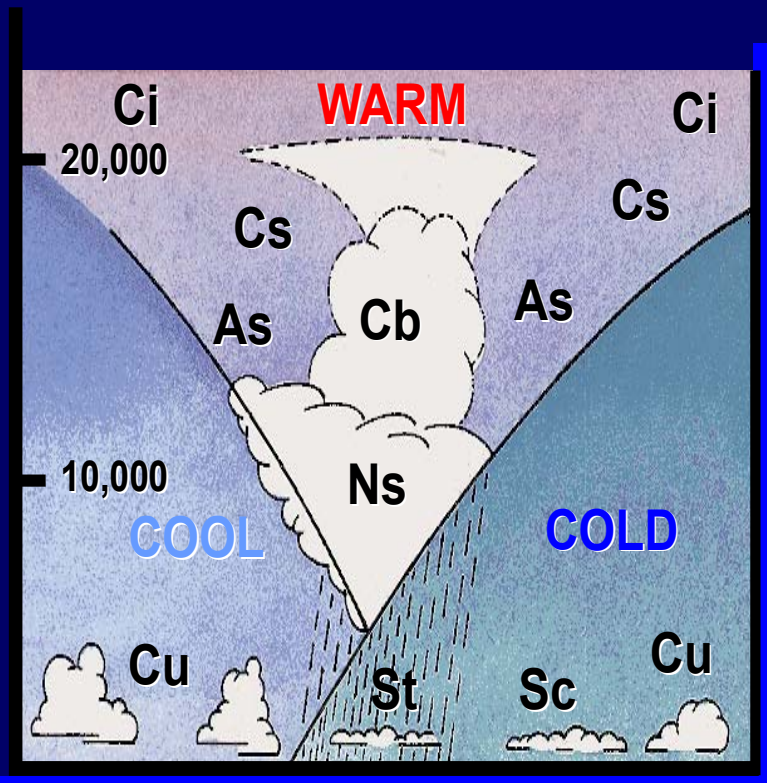

Cool
Warm
Cold
D
D'

- Notice how the cool air is lifted above the colder air ahead of the warm front

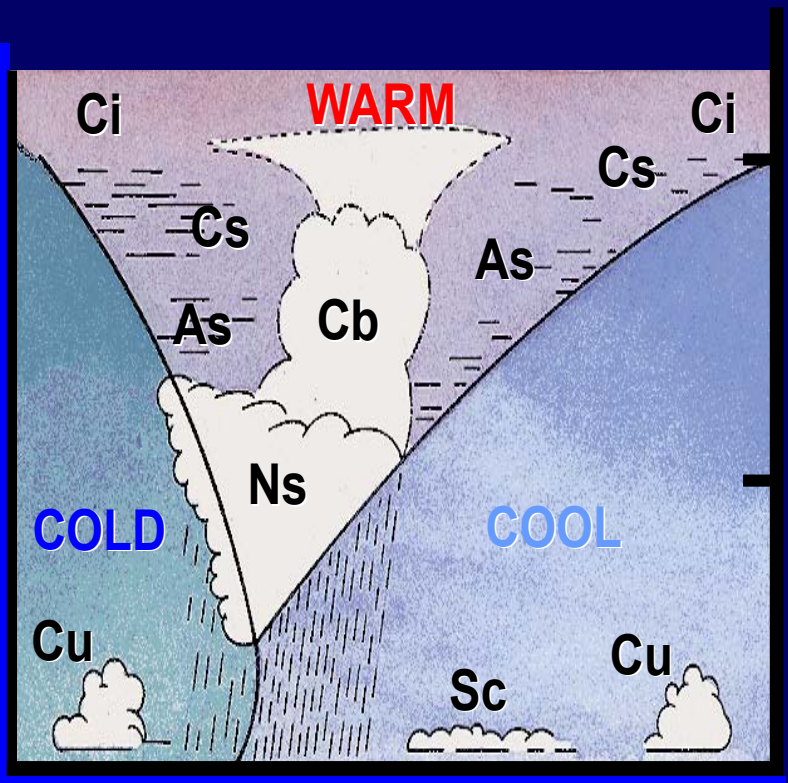




WARM OCCLUDED FRONT



WARM OCCLUSION
RAIN AHEAD OF SURFACE
OCCLUSION



COLD OCCLUSION
RAIN BELT BOTH SIDES
OF SURFACE OCCLUSION

Cool air behind the occlusion, rises up and over the colder air ahead of the front.

Source: Chad Palmer, USATODAY.com Weather team, graphic by David Evans

Typical Weather Conditions Associated with Occluded Fronts…

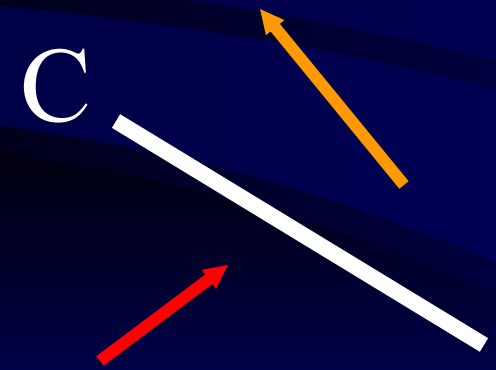
TABLE 12.4 Typical Weather Most Often Associated with Occluded Fronts

WEATHER ELEMENT	BEFORE PASSING	WHILE PASSING	AFTER PASSING
Winds	East, southeast, or south	Variable	West or northwest
Temperature			
Cold type	Cold or cool	Dropping	Colder
Warm type	Cold	Rising	Milder
Pressure	Usually falling	Low point	Usually rising
Clouds	In this order: Ci, Cs, As, Ns	Ns, sometimes Tcu and Cb	Ns, As, or scattered Cu
Precipitation	Light, moderate, or heavy precipitation	Light, moderate, or heavy continuous precipitation or showers	Light-to-moderate precipitation followed by general clearing
Visibility	Poor in precipitation	Poor in precipitation	Improving
Dew point	Steady	Usually slight drop, especially if cold-occluded	Slight drop, although may rise a bit if warm-occluded

Know the differences between a cold type vs a warm type occluded front.

Fronts

Determine the types of fronts associated with A, B, & C.



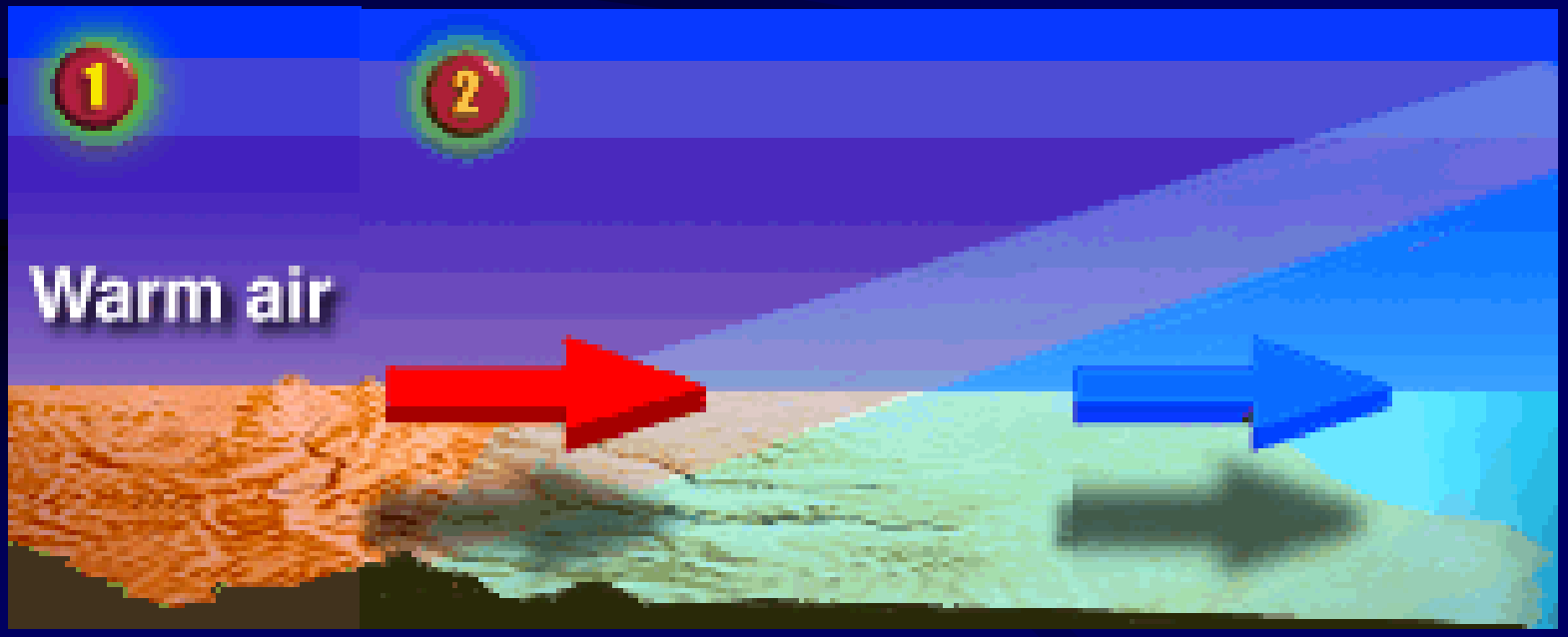
What is the overall movement of each of the fronts?

A – **Stationary Front** – No Movement
B – **Cold Front** – Moving Southwest
C – **Warm Front** – Moving Northeast

North

What are the 5 ways of locating a front on a surface weather map?

1. Sharp temperature changes over a relatively short distance
2. Changes in the air's moisture content (changes in dew point)
3. Shifts in wind direction
4. Clouds and precipitation patterns
5. Pressure and pressure changes



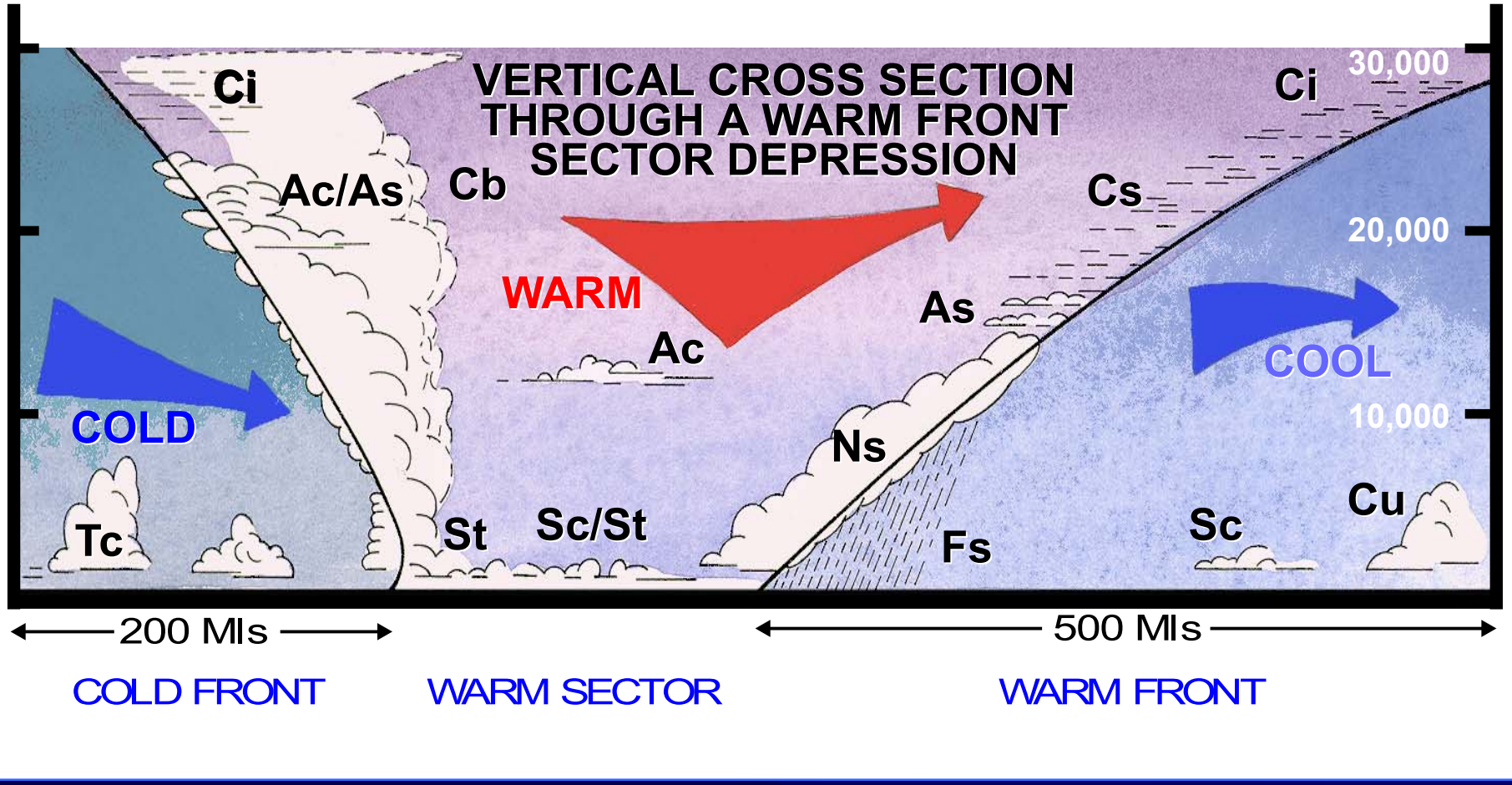
Source: USA TODAY research by Chad Palmer, Graphic by John Herne

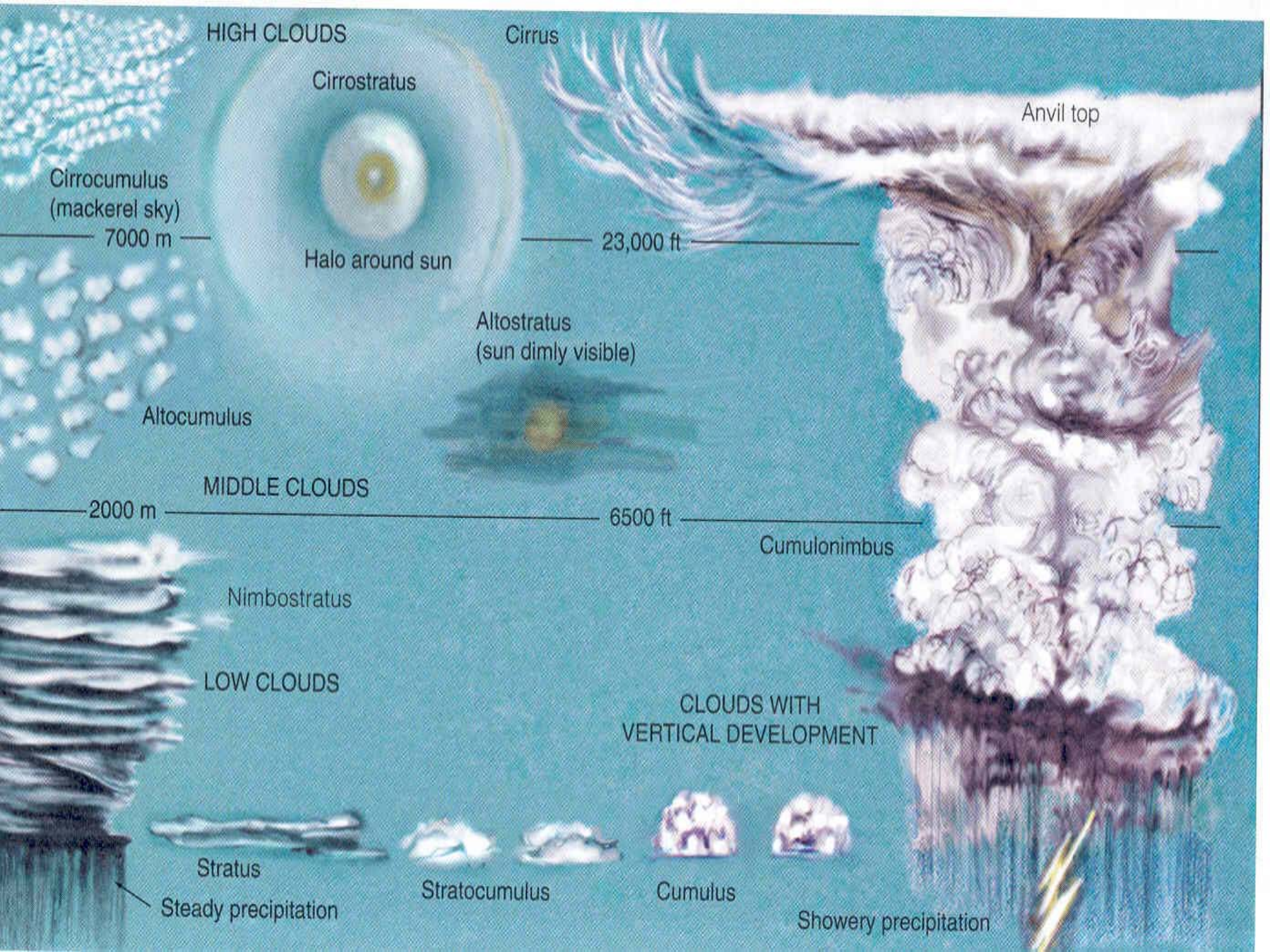
Scenario 1 is a (warm/cold) occlusion.

Scenario 2 is a (warm/cold) occlusion.

Source: Chad Palmer, USATODAY.com Weather team, graphic by David Evans

CLOUDS


VERTICAL CROSS SECTION
THROUGH A WARM FRONT
SECTOR DEPRESSION
Ci
Ac/As
Cb
Cs
Ci
30,000
20,000
10,000
WARM
As
Ac
COOL
COLD
Ns
Cu
Tc
St
Sc/St
Fs
Sc
200 Mls
500 Mls
COLD FRONT
WARM SECTOR
WARM FRONT


HIGH CLOUDS
Cirrus
Cirrostratus
Anvil top
Cirrocumulus
(mackerel sky)
7000 m
Halo around sun
23,000 ft
Altostratus
(sun dimly visible)
Altocumulus
MIDDLE CLOUDS
2000 m
6500 ft
Cumulonimbus
Nimbostratus
LOW CLOUDS
CLOUDS WITH
VERTICAL DEVELOPMENT
Stratus
Steady precipitation
Stratocumulus
Cumulus
Showery precipitation

CLASSIFICATION OF CLOUDS

- HEIGHT OF BASE

CLASSIFICATION OF CLOUDS

- HEIGHT OF BASE
  - HIGH (*CIRRO-*)

Cirrus

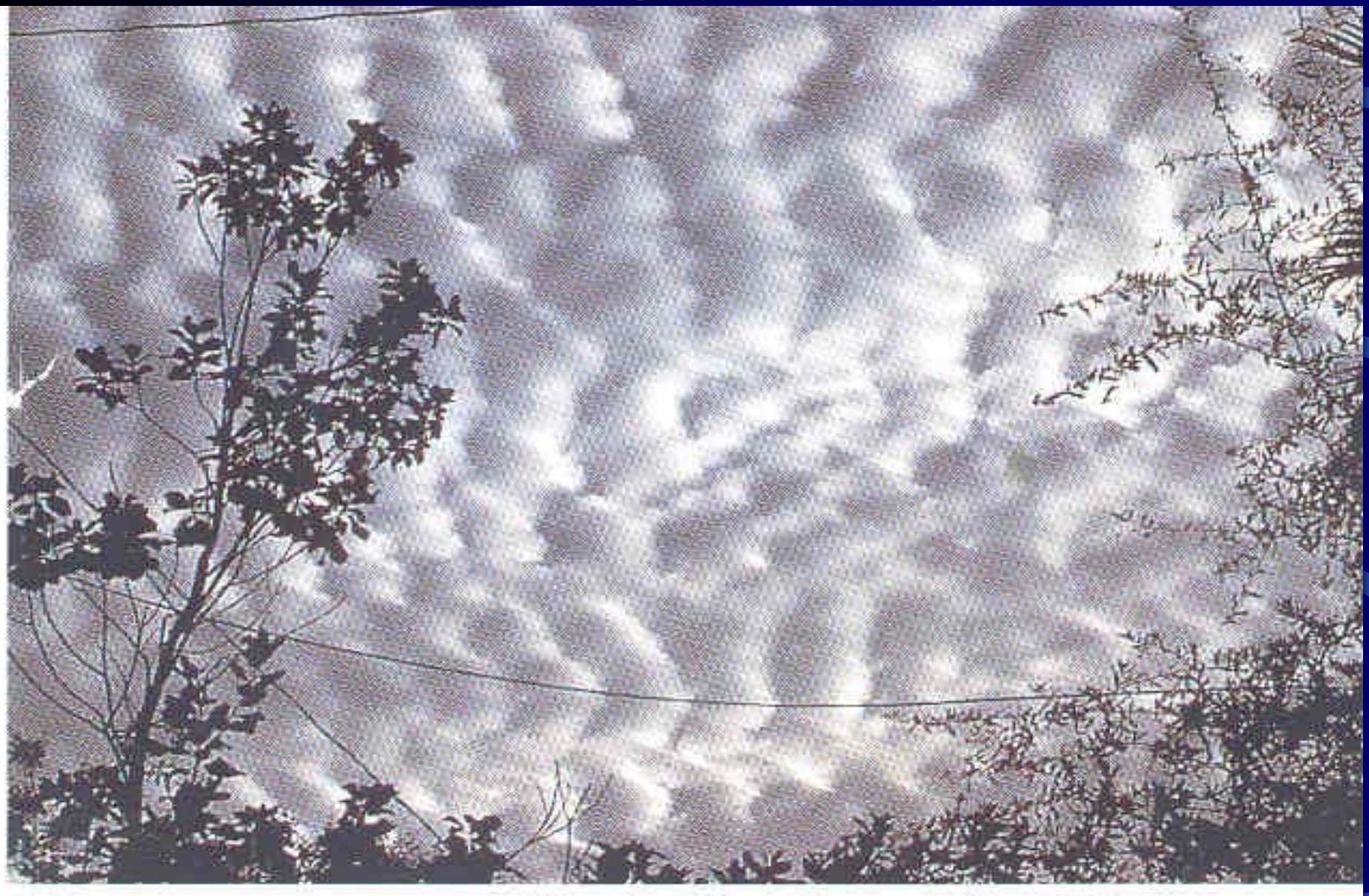
Cirrus

CLASSIFICATION OF CLOUDS

- HEIGHT OF BASE
  - HIGH (*CIRRO-*)
  - MEDIUM (*ALTO-*)

Alto-Stratus

Alto-Cumulus



CLASSIFICATION OF CLOUDS

- HEIGHT OF BASE
  - HIGH (*CIRRO-*)
  - MEDIUM (*ALTO-*)
  - LOW

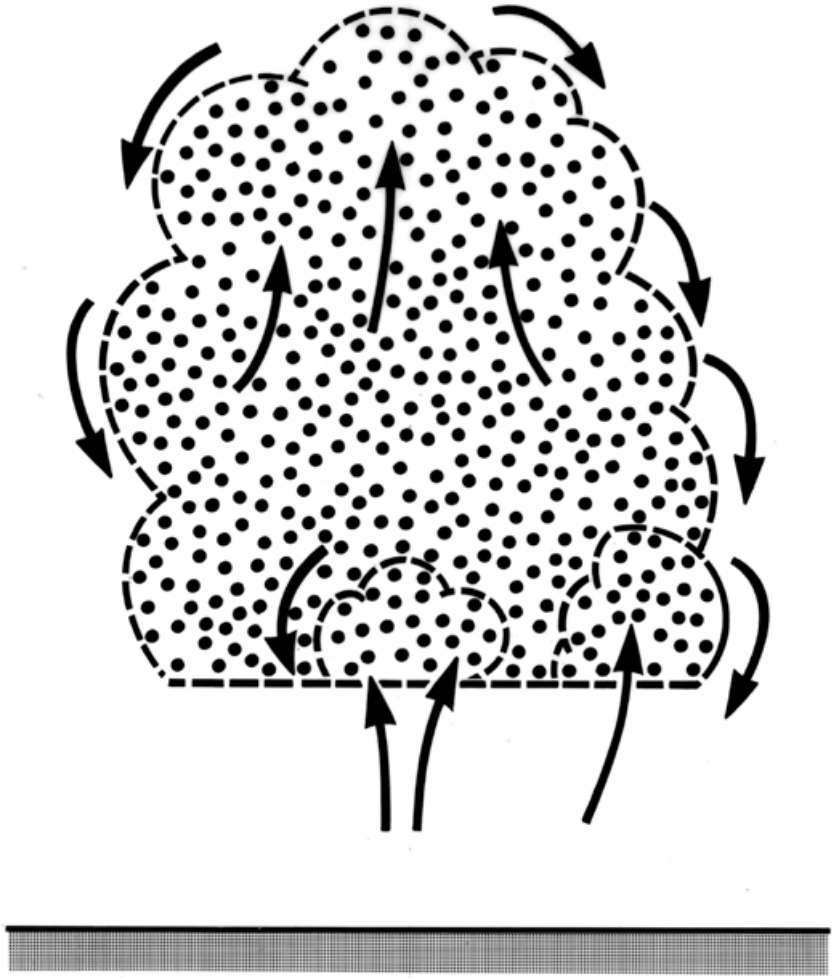
CLASSIFICATION OF CLOUDS

- HEIGHT OF BASE
  - HIGH (*CIRRO-*)
  - MEDIUM (*ALTO-*)
  - LOW
- FORMING PROCESS

CLASSIFICATION OF CLOUDS

- HEIGHT OF BASE
  - HIGH (*CIRRO-*)
  - MEDIUM (*ALTO-*)
  - LOW
- FORMING PROCESS
  - CONVECTIVE (*CUMULI-FORM*)

CONVECTION CLOUD



Cumulus Fractus

Cumulus Congestus

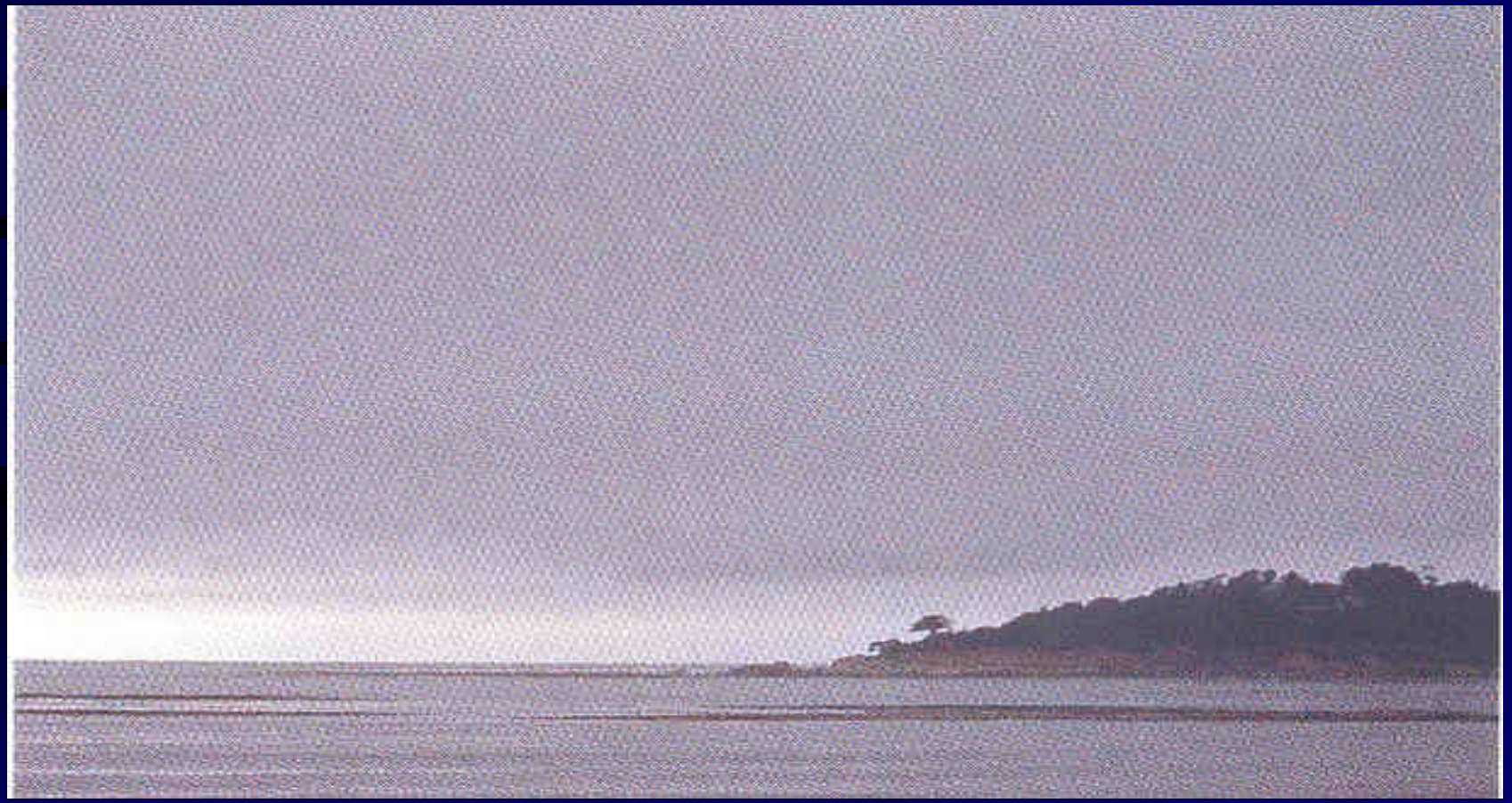
Towering Cumulus

CLASSIFICATION OF CLOUDS

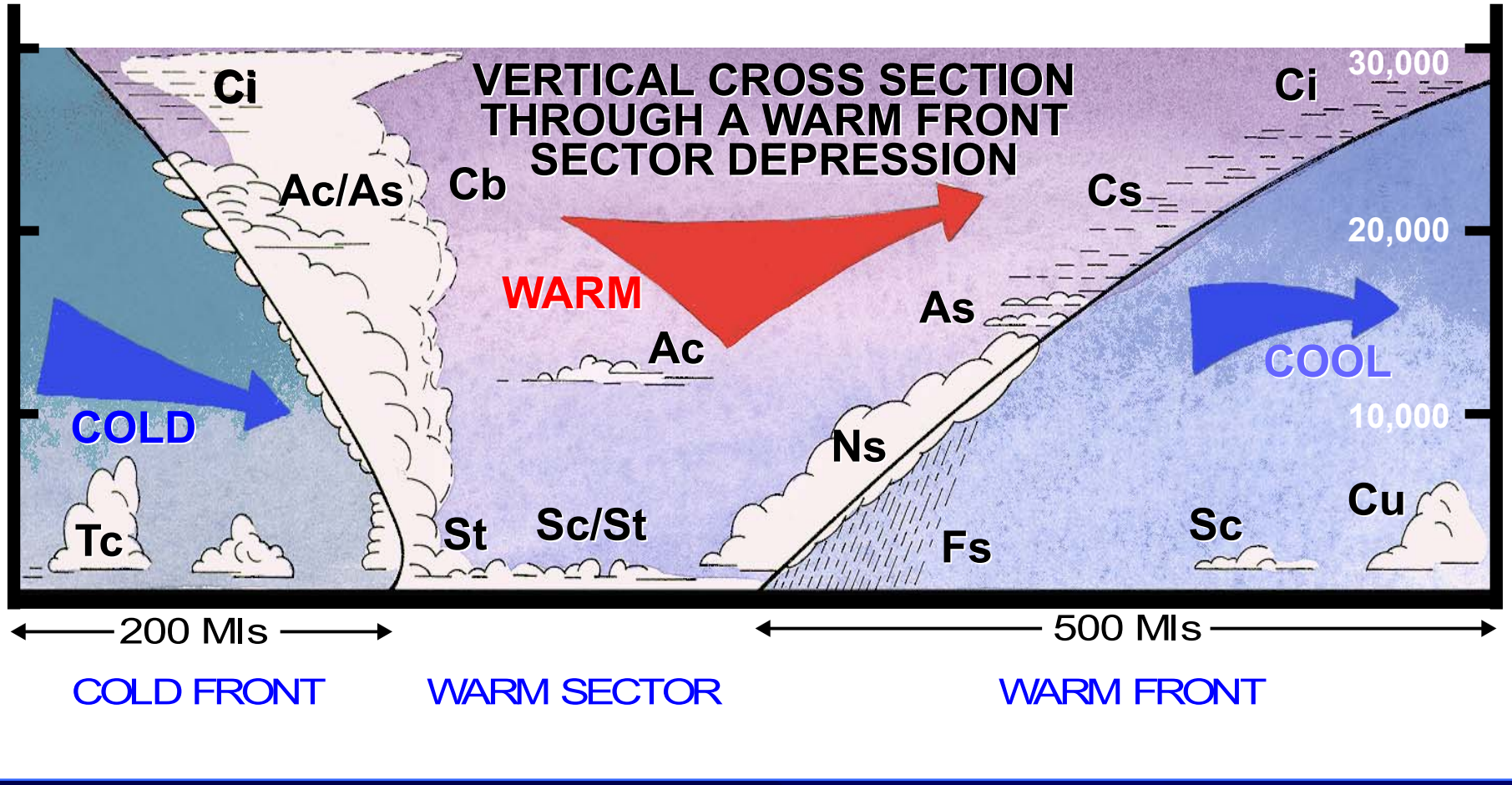
- HEIGHT OF BASE
  - HIGH (*CIRRO-*)
  - MEDIUM (*ALTO-*)
  - LOW
- FORMING PROCESS
  - CONVECTIVE (*CUMULI-FORM*)
  - NON-CONVECTIVE (*STRATI-FORM*)

Stratus

Stratus



Strato-Cumulus


VERTICAL CROSS SECTION
THROUGH A WARM FRONT
SECTOR DEPRESSION
Ci
Ac/As
Cb
Cs
Ci
30,000
20,000
10,000
WARM
As
Ac
COOL
COLD
Ns
Cu
Tc
St
Sc/St
Fs
Sc
200 Mls
500 Mls
COLD FRONT
WARM SECTOR
WARM FRONT

Wind and Waves

Wind and Waves

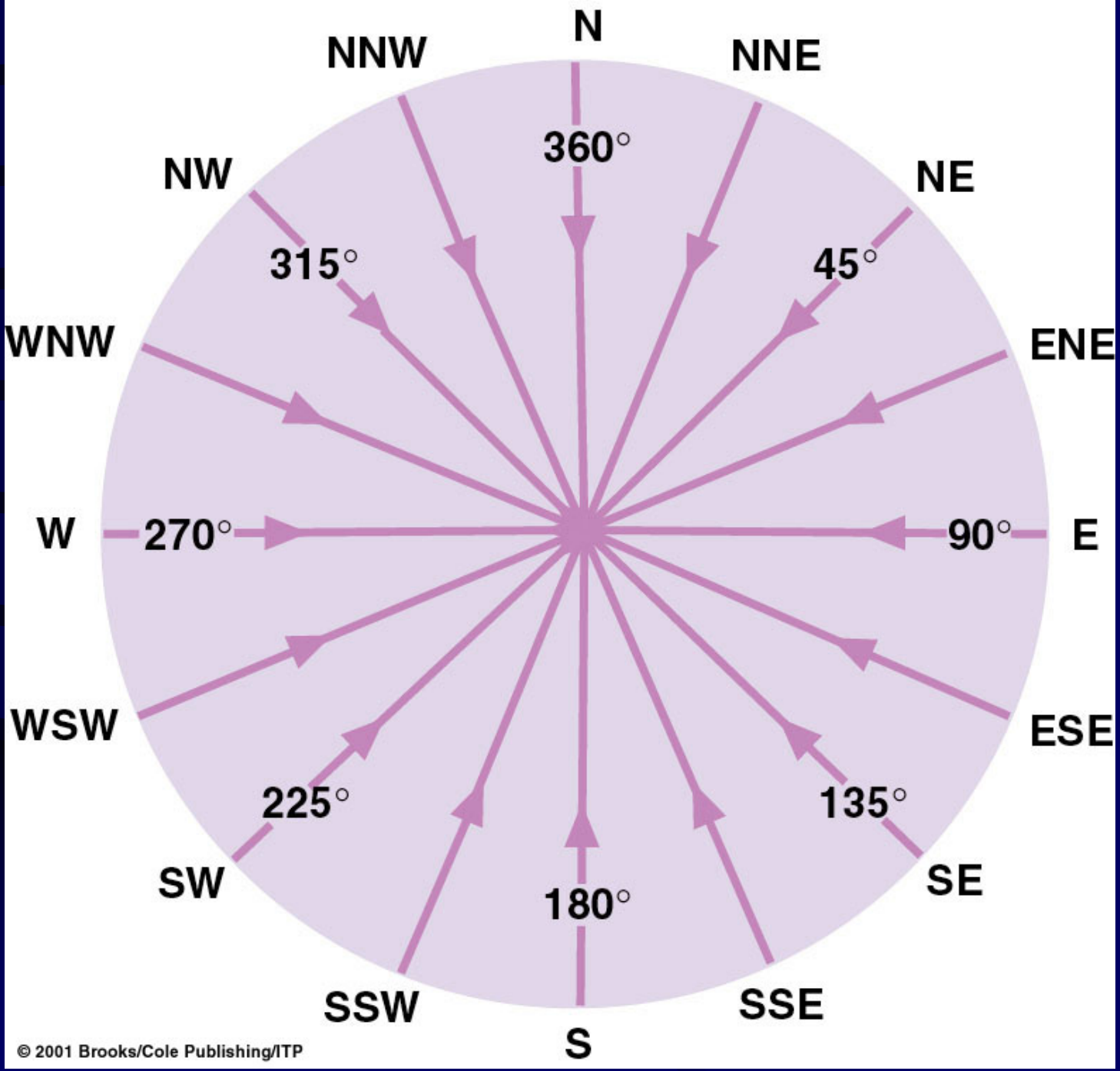
- Waves forming by wind blowing over the water surface = wind waves
- As wind waves move into a region of weaker winds, their crests become lower and more rounded = swells
- Waves are created as frictional drag of the wind transfers energy to the water.

Wind speed ↑ , ↑ Energy, thus Wave Hgt ↑

- Amount of Energy Depends on 3 factors:
  - Wind speed
  - Length of *time* that the wind blows over the water
  - *Fetch,* or distance, of deep water over which the wind blows

Determining Wind Direction & Speed

- Wind direction is given as the direction (toward/from) which it is blowing
- Onshore vs Offshore winds
  - Onshore – from water to land "Seabreeze"
  - Offshore – from land to water "Landbreeze"
- Prevailing wind: the direction most often observed during a given time period


N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
360°
45°
90°
135°
180°
225°
270°
315°
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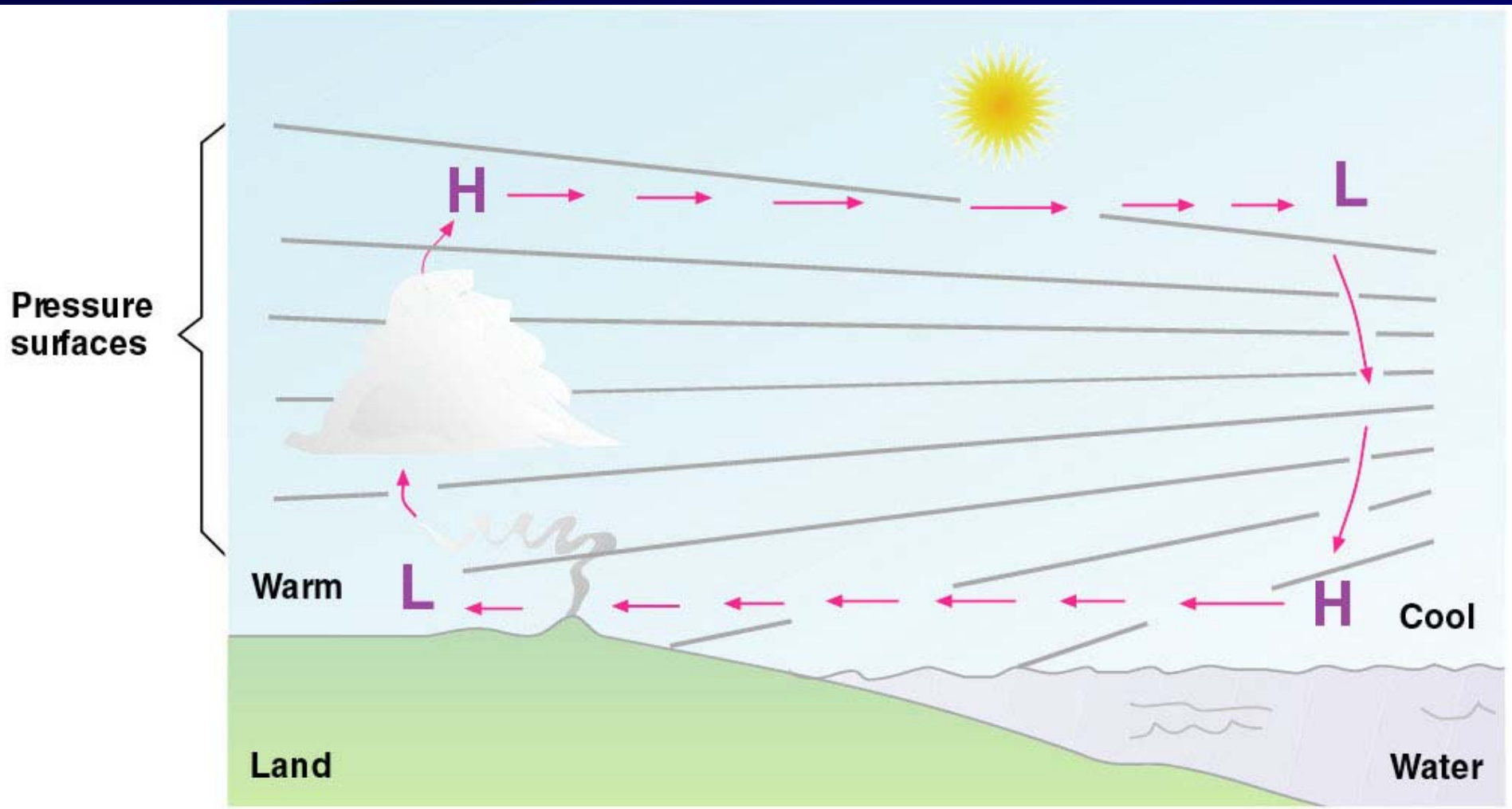
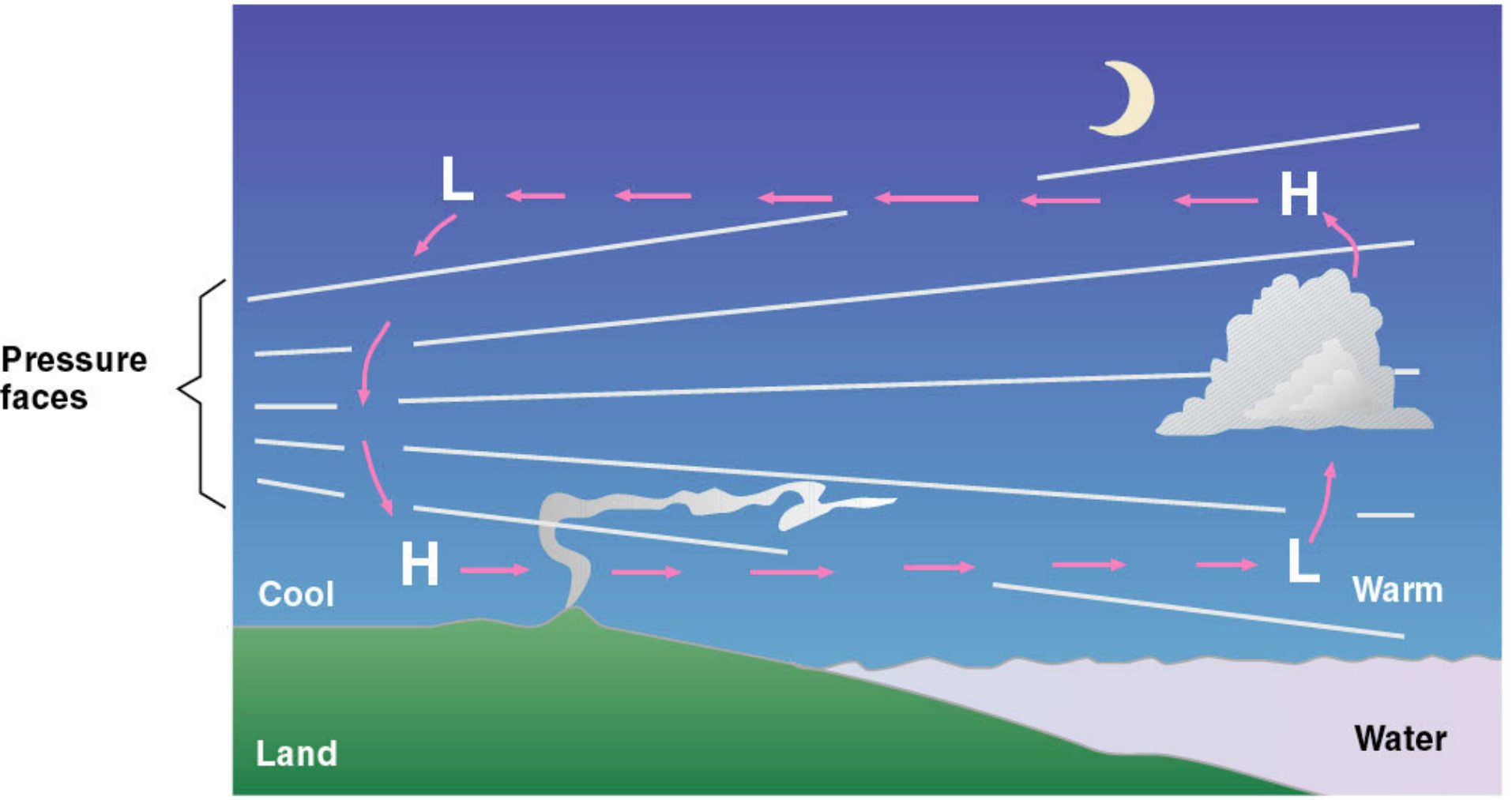
Sea Breeze & Land Breeze

- Types of thermal circulation - what scale?
- Uneven heating rates of land and water is due to?
  - Higher specific heat capacity of water vs land
- Which occurs during the day? The night?
- Demonstrate the setup for a sea/land breeze
- Overall effect: Pressure distribution due to thermal heating/cooling creates the sea/land breeze



(a) Sea breeze



(b) Land breeze

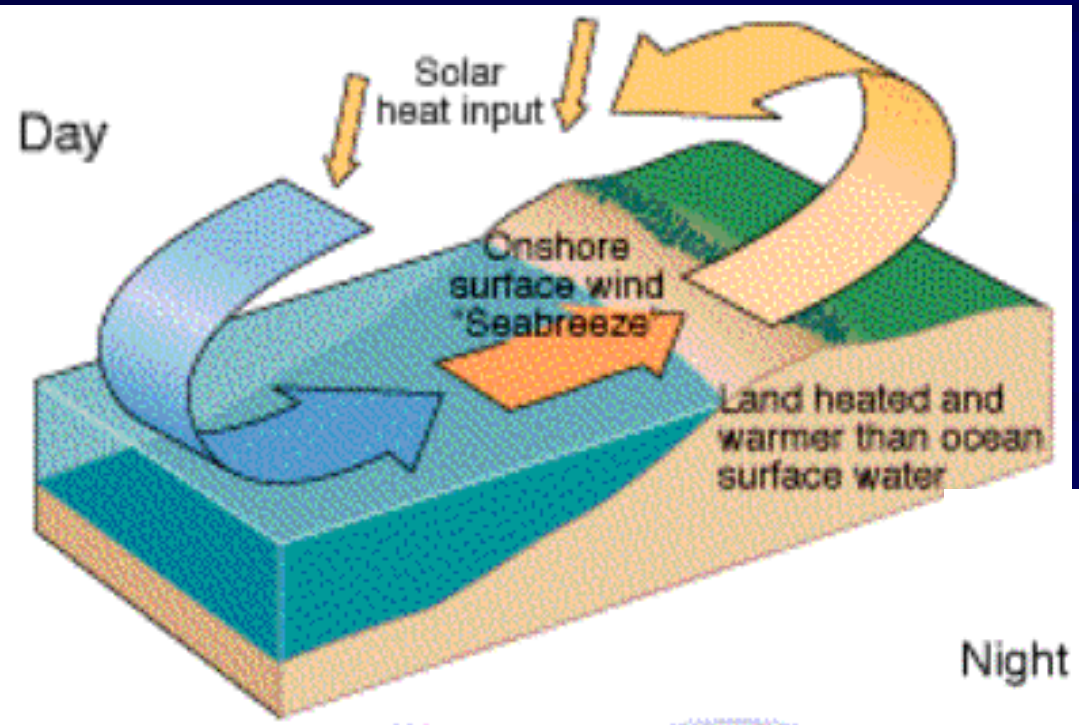
Sea Breeze vs Land Breeze

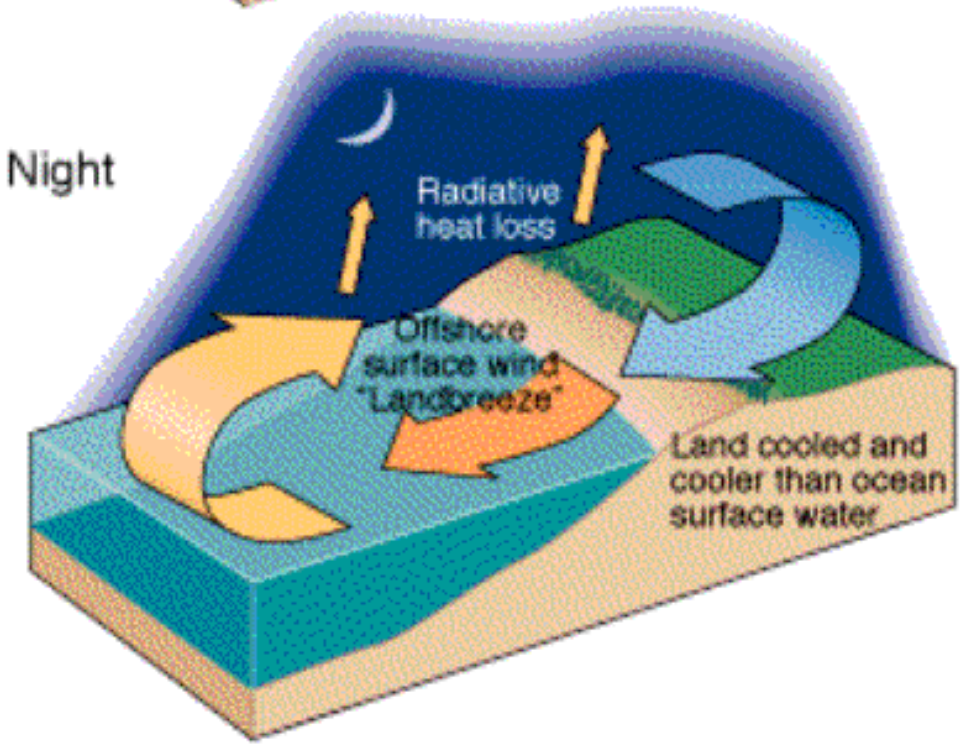
- Which is stronger? Why?
  - Sea breeze: Temperature contrast between land and water are much larger during the day compared to the night
- Where do convective clouds form?
  - Where you have *upward* vertical motions…
  - Over land for a sea breeze; over the water for a land breeze

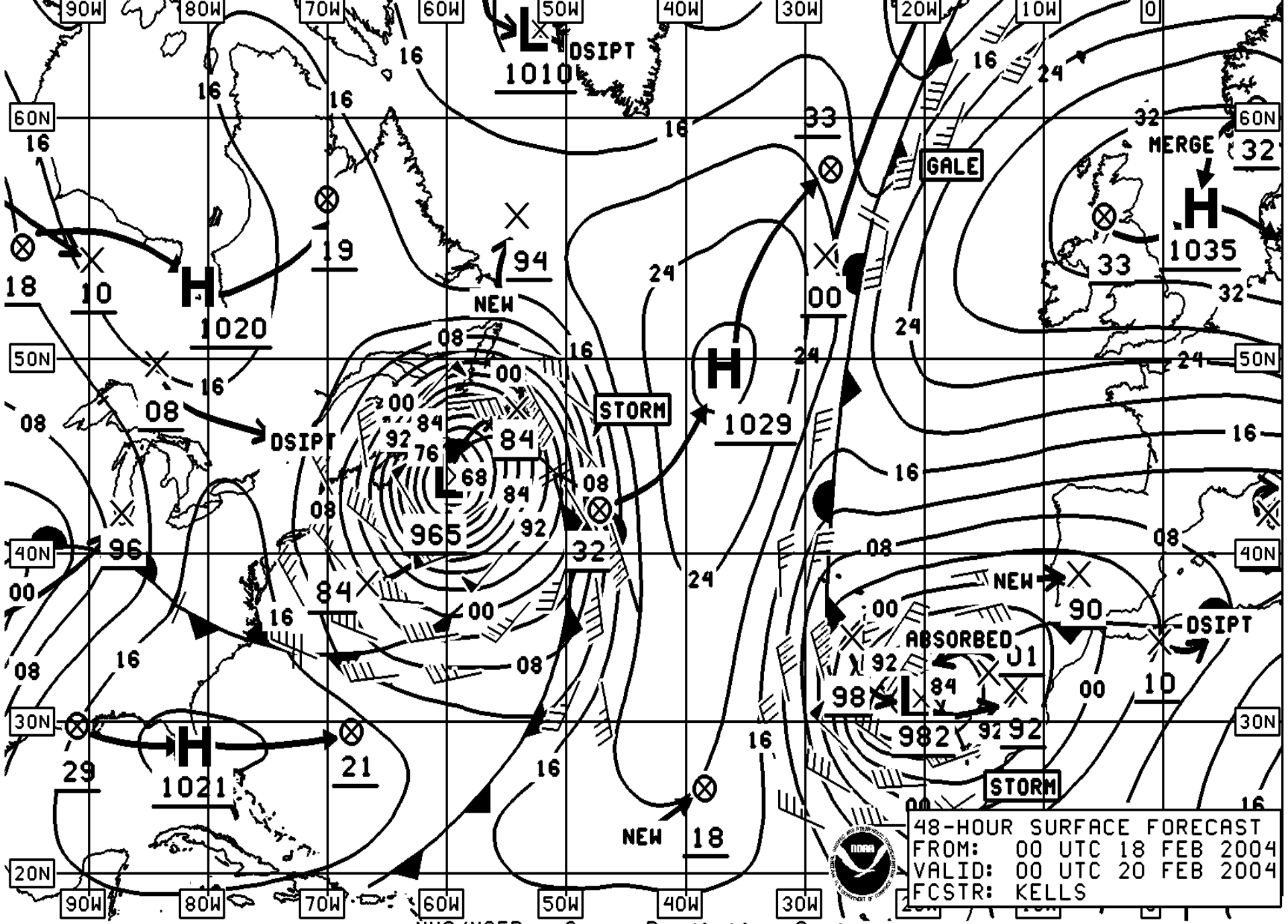
Passage of the sea breeze...

- By identifying its sea breeze front...
  - Wind shift from west to east along the *East Coast*
  - A "smoke" front or "smog" front if the ocean air is highly concentrated with pollutants, nuclei
  - If the ocean air becomes *saturated*, a mass of low clouds and fog mark the leading edge
  - If conditionally unstable atm exists, thunderstorms may form.
  - A few km away from the coast, thunderstorms may develop. Why?
    - Due to the *upward* vertical motion that completes the sea breeze circulation

Seabreeze / Landbreeze



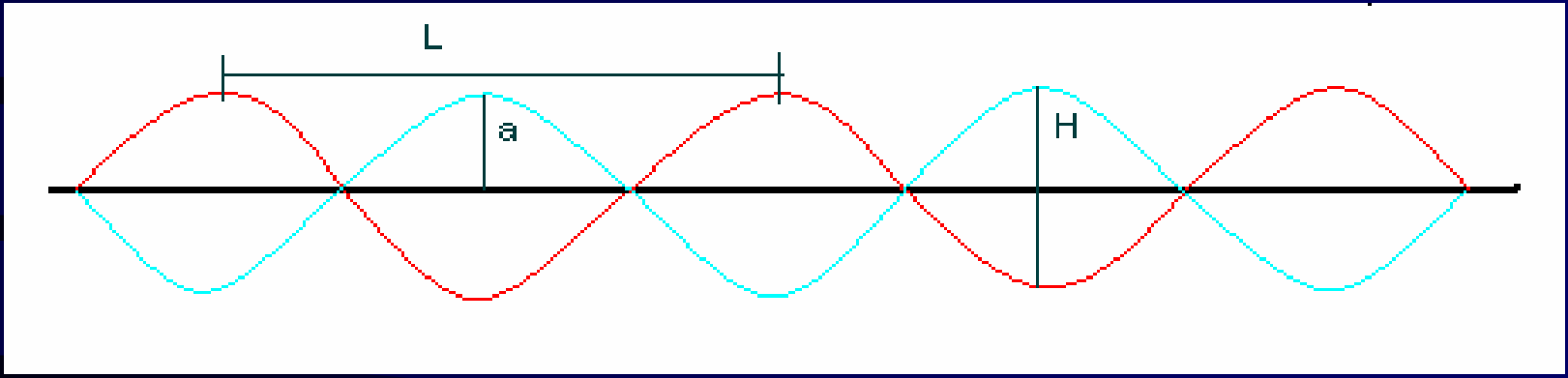




NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov

Waves and Swell

Definitions



- Wavelength (L) - horizontal distance between consecutive crests
- Amplitude (a) - one half of the wave height.
- Wave height (H) - distance between crest and trough.
- Wave period - time interval between successive troughs or crests.
- Significant wave height - average height of the third of the waves.

Type of waves

- Wind Waves (Sea) - Gravity waves generated by wind blowing over the sea surface. They appear to be short-crested, with many different heights, lengths and periods identifiable.

- Capillary Waves - The surface of relatively quiet water, reveal very small wave disturbances which have distinctly different appearance from small wind waves.

- Swell - These represent wind waves which have traveled out of the area they were generated, or can no longer be sustained by the winds in the generating area.

Types of waves

- Tides - behave as long waves and are influenced by the configuration of basins and the coriolis force.
- Storm Tides - Persistence winds combined with high tides and low pressure, pile up water giving unusually high sea levels. These effects are treated like long period waves.
- Seiches - Are generated by changes in met conditions and tidal forces, and are the oscillations set up in a body of water.
- Tsumamis - Waves caused by seismic disturbances on the sea bed.

Sea Waves

- To forecast sea wave characteristics at a point the following info is needed:
  - Wind Velocity
  - Duration of wind
  - Fetch area

Typical Fetches

- Area of sea, where a constant wind is blowing, or has been blowing

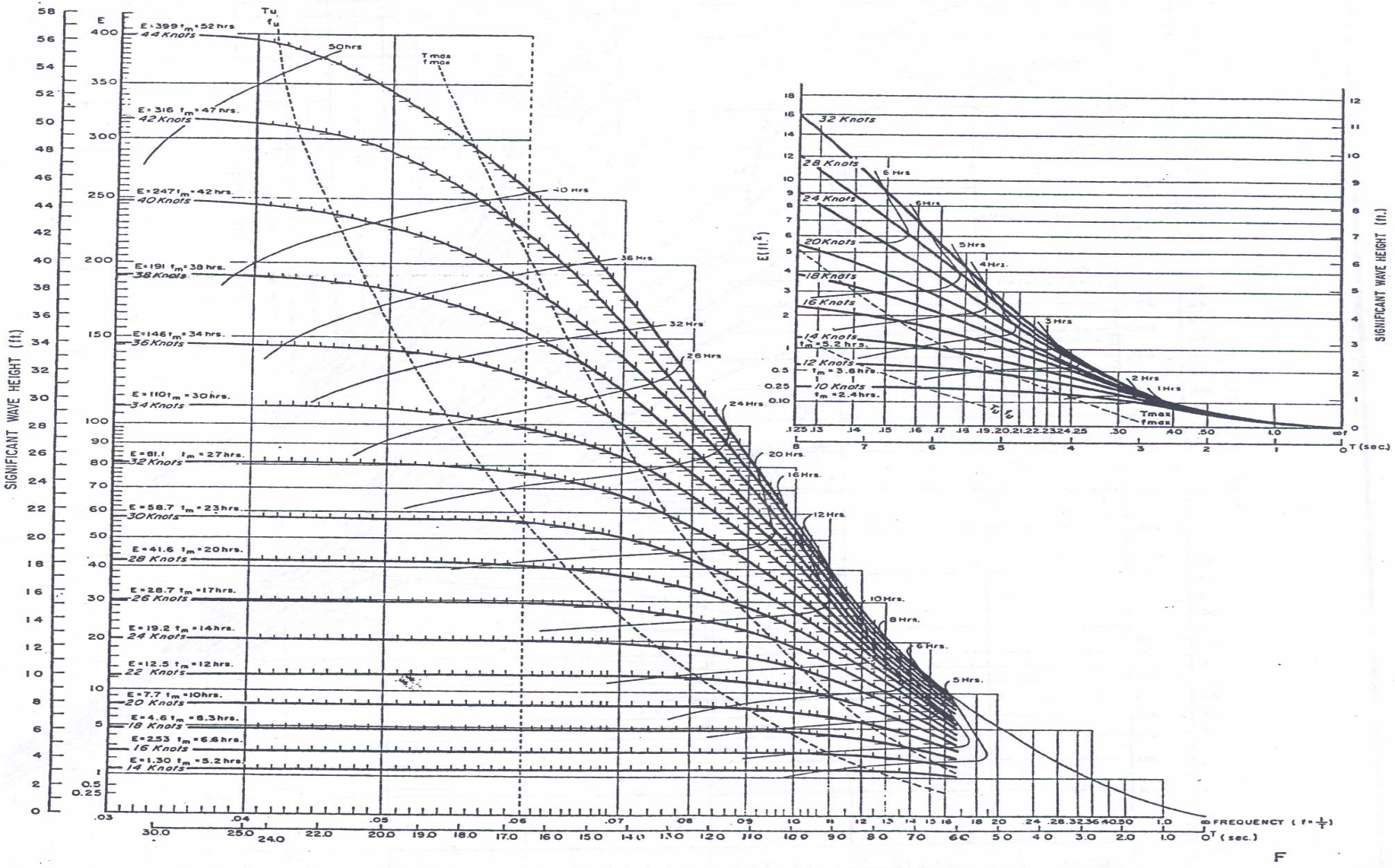
- Fetch boundaries:
  - coastlines
  - met fronts
  - isobaric curvature A
  - fanning out of boundaries B

Wind and Sea Scale for Fully Arisen Sea

WIND AND SEA SCALE FOR FULLY ARISEN SEA

SEA STATE	SEA-GENERAL DESCRIPTION	WIND BEAUFORT WIND FORCE	WIND DESCRIPTION	WIND RANGE (KNOTS)	WIND VELOCITY (KNOTS)	SEA WAVE HEIGHT FEET AVERAGE	SEA WAVE HEIGHT FEET SIGNIFICANT	SEA WAVE HEIGHT FEET AVERAGE 1/10 HIGHEST	SEA SIGNIFICANT RANGE OF PERIODS (SECONDS)	SEA (PERIOD OF MAXIMUM ENERGY OF SPECTRUM)	SEA AVERAGE PERIOD	SEA AVERAGE WAVE LENGTH	SEA MINIMUM FETCH (NAUTICAL MILES)	SEA MINIMUM DURATION (HOURS)
0	Sea like a mirror.	0	Calm	Less than 1	0	0	0	0	-	-	-	-	-	-
	Ripples with the appearance of scales are formed, but without foam crests.	1	Light Airs	1 - 3	2	0.05	0.08	0.10	up to 1.2 sec	0.7	0.5	10 in.	5	18 min
1	Small wavelets, still short but more pronounced; crests have a glassy appearance, but do not break.	2	Light Breeze	4 - 6	5	0.18	0.29	0.37	0-4-2.8	2.0	1.4	6.7 ft	8	39 min
	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	3	Gentle Breeze	7 - 10	8.5	0.6	1.0	1.2	0-8-5.0	3.4	2.4	20	9.8	1.7 hrs
2					10	0.88	1.4	1.8	1.0-6.0	4	2.9	27	10	2.4
					12	1.4	2.2	2.8	1.0-7.0	4.8	3.4	40	18	3.8
3	Small waves, becoming larger; fairly frequent white horses.	4	Moderate Breeze	11-16	13.5	1.8	2.9	3.7	1.4-7.6	5.4	3.9	52	24	4.8
					14	2.0	3.3	4.2	1.5-7.8	5.6	4.0	59	28	5.2
					16	2.9	4.6	5.8	2.0-8.8	6.5	4.6	71	40	6.6
4	Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray).	5	Fresh Breeze	17-21	18	3.8	6.1	7.8	2.5-10.0	7.2	5.1	90	55	8.3
					19	4.3	6.9	8.7	2.8-10.6	7.7	5.4	99	65	9.2
5					20	5.0	8.0	10	3.0-11.1	8.1	5.7	111	75	10
	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray).	6	Strong Breeze	22-27	22	6.4	10	13	3.4-12.2	8.9	6.3	134	100	12
					24	7.9	12	16	3.7-13.5	9.7	6.8	160	130	14
6					24.5	8.2	13	17	3.8-13.6	9.9	7.0	164	140	15
					26	9.6	15	20	4.0-14.5	10.5	74	188	180	17
	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. (Spindrift begins to be seen).	7	Moderate Gale	28-33	28	11	18	23	4.5-15.5	11.3	7.9	212	230	20
					30	14	22	28	4.7-16.7	12.1	8.6	250	280	23
					30.5	14	23	29	4.8-17.0	12.4	8.7	258	290	24
					32	16	26	33	5.0-17.5	12.9	9.1	285	340	27
7	Moderately high waves of greater length; edges of crests break into spindrift. The foam is blown in well marked streaks along the direction of the wind. Spray effects visibility.	8	Fresh Gale	34-40	34	19	30	38	5.5-18.5	13.6	9.7	322	420	30
					36	21	35	44	5.8-19.7	14.5	10.3	363	500	34
					37	23	37	46.7	6.20.5	14.9	10.5	376	530	37
					38	25	40	50	6.2-20.8	15.4	10.7	392	600	38
					40	28	45	58	6.5-21.7	16.1	11.4	444	710	42
8	High waves. Dense streaks of foam along the direction of the wind. Sea begins to roll. Visibility affected.	9	Strong Gale	41-47	42	31	50	64	7-23	17.0	12.0	492	830	47
					44	36	58	73	7-24.2	17.7	12.5	534	960	52
					46	40	64	81	7-25	18.6	13.1	590	1110	57
9	Very high waves with long overhanging crests. The resulting foam is in great patches and is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes a white appearance. The rolling of the sea becomes heavy and shock-like. Visibility is affected.	10	Whole Gale	48-55	48	44	71	90	7.5-26	19.4	13.8	650	1250	63
					50	49	78	99	7.5-27	20.2	14.3	700	1420	69
					51.5	52	83	106	8-28.2	20.8	14.7	736	1560	73
					52	54	87	110	8-28.5	21.0	14.8	750	1610	75
					54	59	95	121	8-29.5	21.8	15.4	810	1800	81
	Exceptionally high waves (Small and medium-sized ships might for a long time be lost to view behind the waves.) The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	11	Storm	56-63	56	64	103	130	8-5-31	22.6	16.3	910	2100	88
					59.5	73	116	148	10-32	24	17.0	985	2500	101
	Air filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	12	Hurricane	64-71.	>64	>80	>128	>164	101(35)	(26)	(18)	~	~	~

Duration Limited Graph



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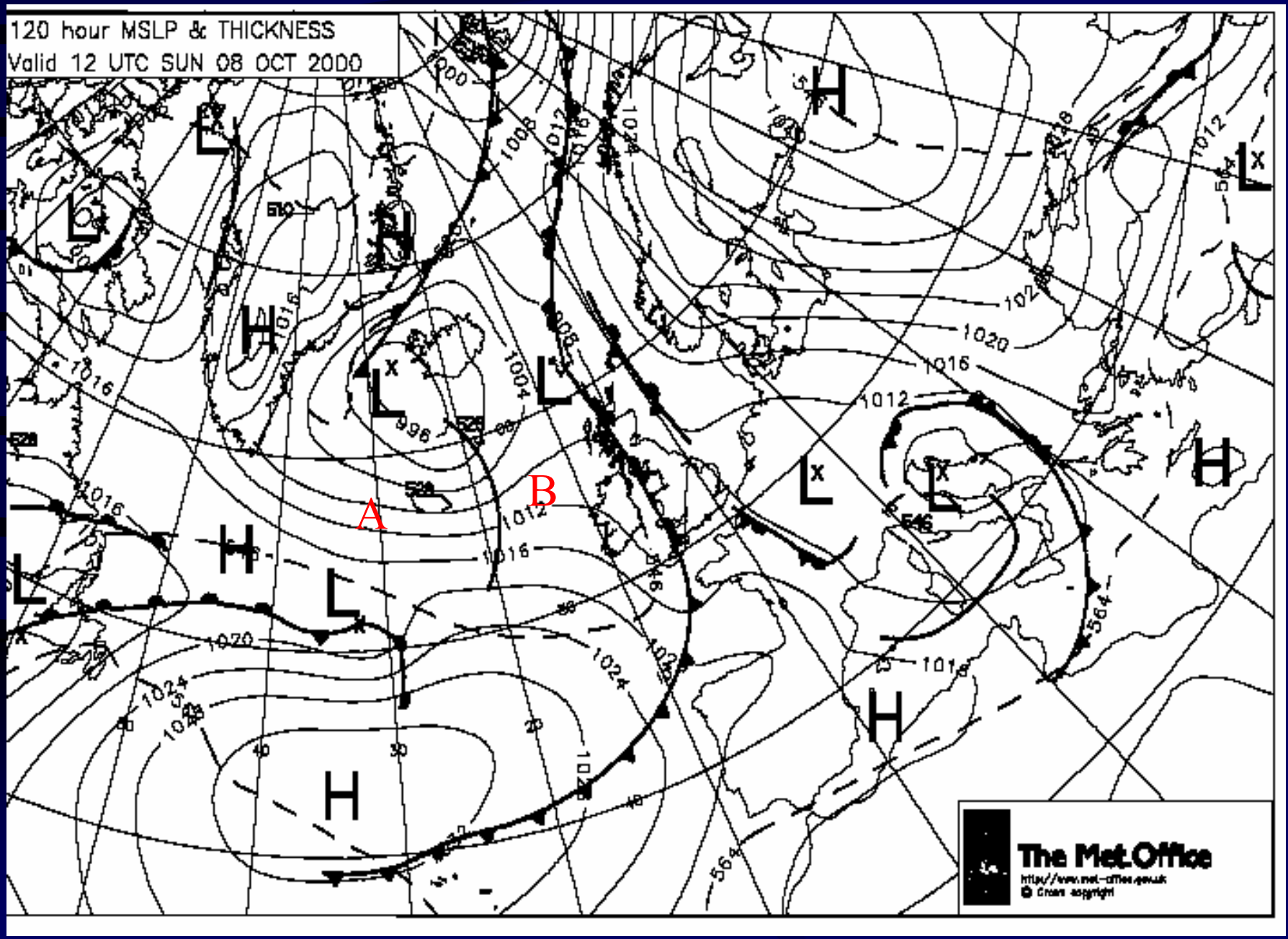
AG.680

Figure 14-7.—Sea and swell graph 1a. Distorted C. C. S. (duration graph-wind speeds 10-44 knots).


120 hour MSLP & THICKNESS
Valid 12 UTC SUN 08 OCT 2000
A
B
The Met.Office

Change of wind direction

- When wind direction changes two things will happen:
  - The new wind will build up a new sea, causing a confused sea for a time.
  - If wind changes direction by less than 30º then wave characteristics are calculated as if there had been no change in wind direction.

Fully Developed Sea

- Development is subject to duration and fetch.
- If development is curtailed by lack of time, it is ‘duration limited’.
- If development is curtailed by lack of fetch, it is ‘fetch limited’.
- A fully arisen sea from calm to gale force will take approximately 24 hrs.

Swell

- Once the wind which produced the SS alters direction or speed, then the sea will decay as swell, using 2 processes:
  - Dispersion
  - Angular Spreading

Shallow water

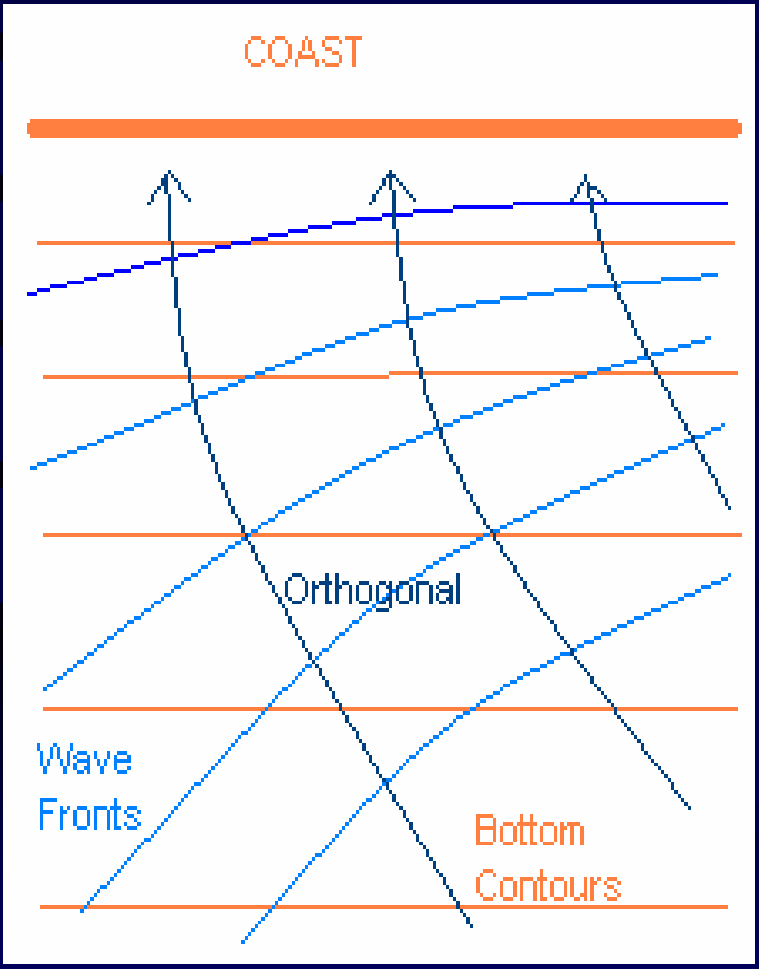
- Lower frequency wave are effected by the seabed.
- Waves are effected when the depth of water is less than half the wavelength of the waves.

Effects of shallow water

- Interaction with the seabed will cause energy loss through frictional effects, acting as a low frequency cut-off.

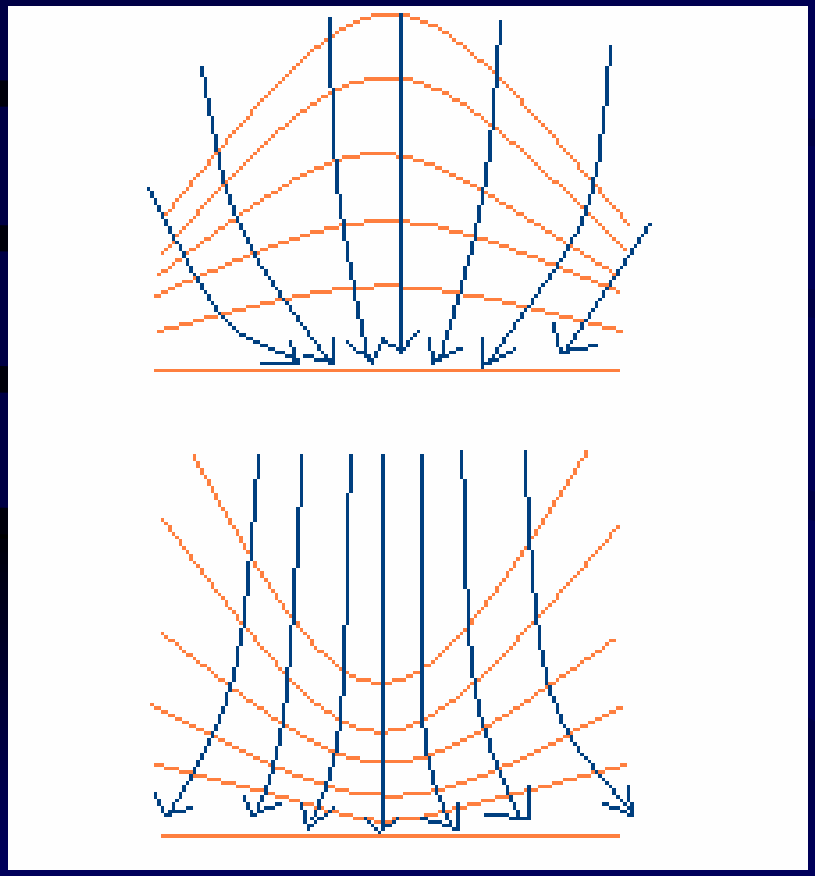
- Lines of waves moving obliquely towards the shore line, are subject to progressive, curving and refraction.

Refraction of waves



- The figure illustrates the effect of refraction of a simple wave.
- The Orthogonal represents the direction wave fronts travel.
- Orthogonals become curved during the process of refraction, tending to converge or diverge.

Wave refraction



- Convergence at the head of a submarine ridge.
- Divergence at the head of a submarine valley.

Sea State Presentation

Sea State	Number	Wind Force	Wave Height(m)
Calm(glassy)	0	0	0
Calm(rippled)	1	1	0 - 0.1
Smooth(wavelets)	2	2/3	0.1 - 0.5
Slight	3	3/4	0.5 - 1.25
Moderate	4	4/5	1.25 - 2.5
Rough	5	6	2.5 - 4.0
Very Rough	6	7/8	4.0 - 6.0
High	7	8/9	6.0 - 9.0
Very High	8	10	9.0 - 14.0
Phenomenal	9	10+	>14.0

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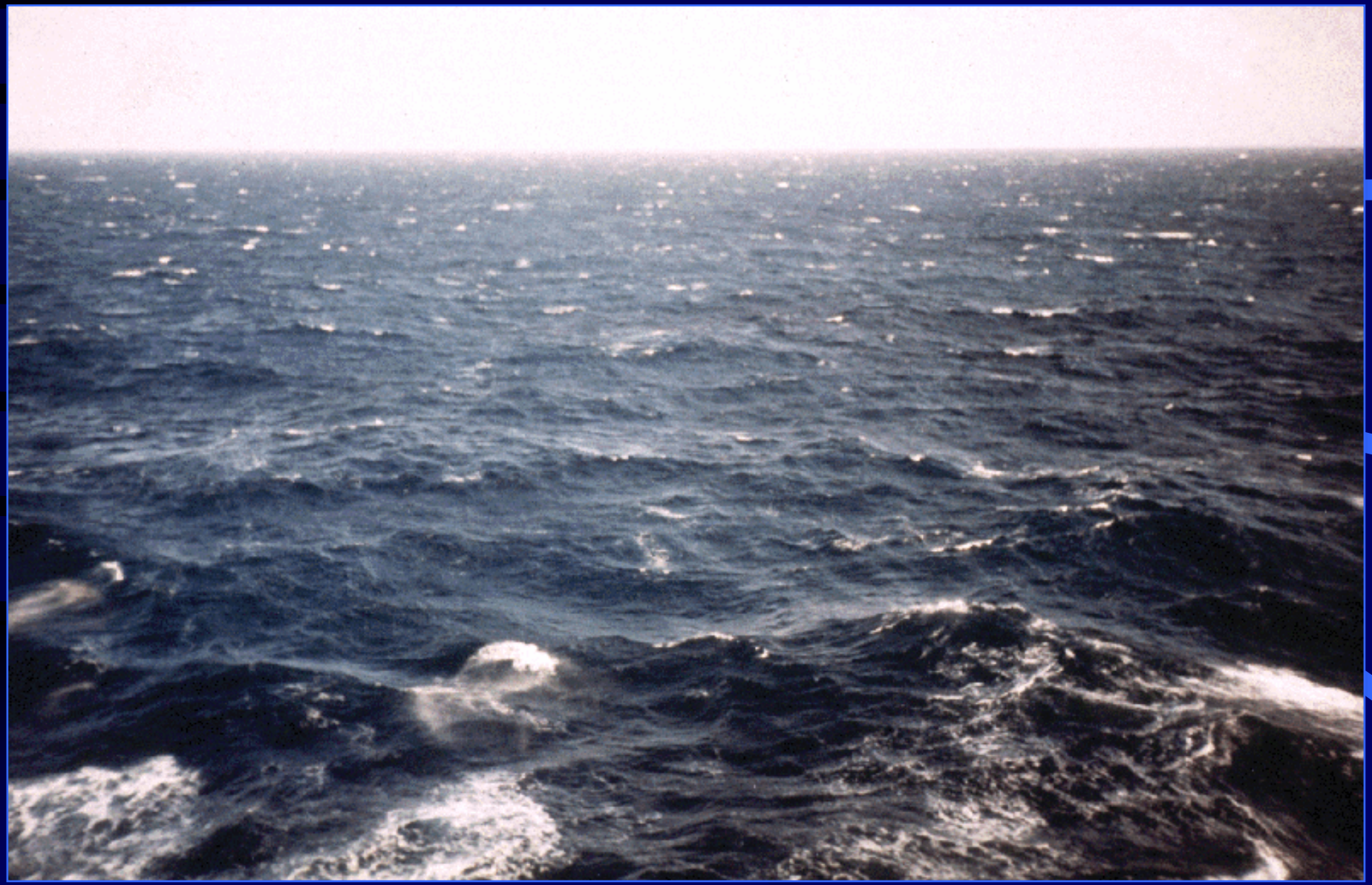
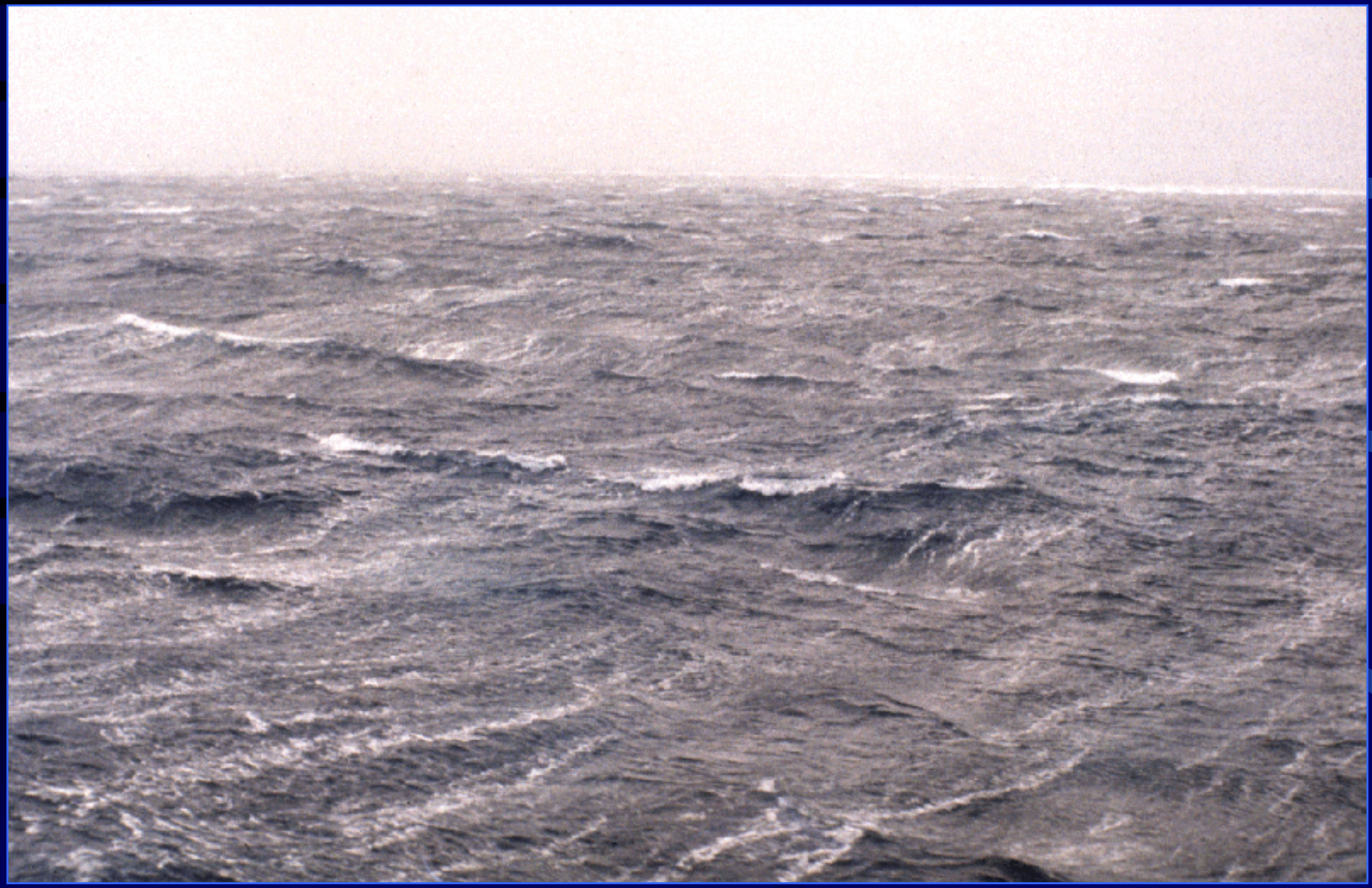
Very High	8	10	9.0 - 14.0
Phenomenal	9	10+	>14.0



Sea State Presentation

Sea State	Number	Wind Force	Wave Height(m)
Calm(glassy)	0	0	0
Calm(rippled)	1	1	0 - 0.1
Smooth(wavelets)	2	2/3	0.1 - 0.5
Slight	3	3/4	0.5 - 1.25
Moderate	4	4/5	1.25 - 2.5
Rough	5	6	2.5 - 4.0
Very Rough	6	7/8	4.0 - 6.0
High	7	8/9	6.0 - 9.0
Very High	8	10	9.0 - 14.0
Phenomenal	9	10+	>14.0



Sea State Presentation

Sea State	Number	Wind Force	Wave Height(m)
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Calm(rippled)	1	1	0 - 0.1
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Slight	3	3/4	0.5 - 1.25
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High	7	8/9	6.0 - 9.0
Very High	8	10	9.0 - 14.0
Phenomenal	9	10+	>14.0

Swell Forecast Presentation

- Swell Wavelength:
  - Short up to 300ft (with a period of less than 7.6 sec)
  - Average 300-600ft (period of 7.6 to 10.8sec)
  - Long over 600ft (period greater than 10.8 sec)

Swell Forecast Presentation

- Swell Height:

– Very Low	1m or less	3.3ft or less
– Low	1-2m	3.3-6.6ft
– Moderate	2-4m	6.6-13ft
– Heavy	over 4m	over 13ft

  - Swell direction is given to the nearest two compass points

HF WxFax

NATIONAL WEATHER SERVICE/USCG BOSTON RADIOFAX SCHEDULE PART 1 - EFFECTIVE 28 NOV 00

TIME	AREA	CHART
0230Z		TEST PATTERN
0233Z	1	00Z PRELIM SFC ANAL
0243Z		SCHEDULE PART 1
0254Z		SCHEDULE PART 2
0305Z		REQ FOR COMMENTS
0315Z	1	00Z SEA STATE ANAL
0325Z	2	00Z SFC ANAL PART 1
0338Z	3	00Z SFC ANAL PART 2
0351Z	5	SATELLITE PICTURE
0402Z	2	RETRANSMIT 0325Z
0415Z	3	RETRANSMIT 0338Z
0428Z	4	00Z 500 MB ANALYSIS
0438Z		END TRANSMISSION
0745Z		TEST PATTERN
0755Z	1	06Z PRELIM SFC ANAL
0805Z	1	24HR SFC VT 00Z
0815Z	1	24HR WIND/WV VT 00Z
0825Z	1	24HR 500 MB VT 00Z
0835Z	4	36HR 500 MB VT 12Z
0845Z	4	48HR 500 MB VT 00Z
0855Z	4	48HR SFC VT 00Z
0905Z	4	48HR WIND/WV VT 00Z
0915Z	4	48HR WV PERIOD VT 00Z
0925Z	2	06Z SFC ANAL PART 1
0938Z	3	06Z SFC ANAL PART 2
0951Z	6	SATELLITE PICTURE
1002Z	2	RETRANSMIT 0925Z
1015Z	3	RETRANSMIT 0938Z
1028Z		END TRANSMISSION
1400Z		TEST PATTERN
1405Z		SCHEDULE PART 1
1420Z		SCHEDULE PART 2
1433Z		REQ FOR COMMENTS
1443Z		PRODUCT NOTICE BUL
1453Z	1	12Z PRELIM SFC ANAL
1503Z	5	SATELLITE PICTURE
1515Z	1	12Z SEA STATE ANAL
1525Z	2	12Z SFC ANAL PART 1
1538Z	3	12Z SFC ANAL PART 2
1551Z		END TRANSMISSION
1600Z		ICE CHARTS
1720Z		TEST PATTERN
1723Z	2	RETRANSMIT 1525Z
1736Z	3	RETRANSMIT 1538Z
1749Z	4	12Z 500 MB ANALYSIS
1759Z	4	12Z SEA STATE ANAL
1809Z		END TRANSMISSION
1810Z		ICE CHARTS

CONTINUED ON SCHEDULE PART 2

NATIONAL WEATHER SERVICE/USCG BOSTON RADIOFAX SCHEDULE PART 2 - EFFECTIVE 28 NOV 00

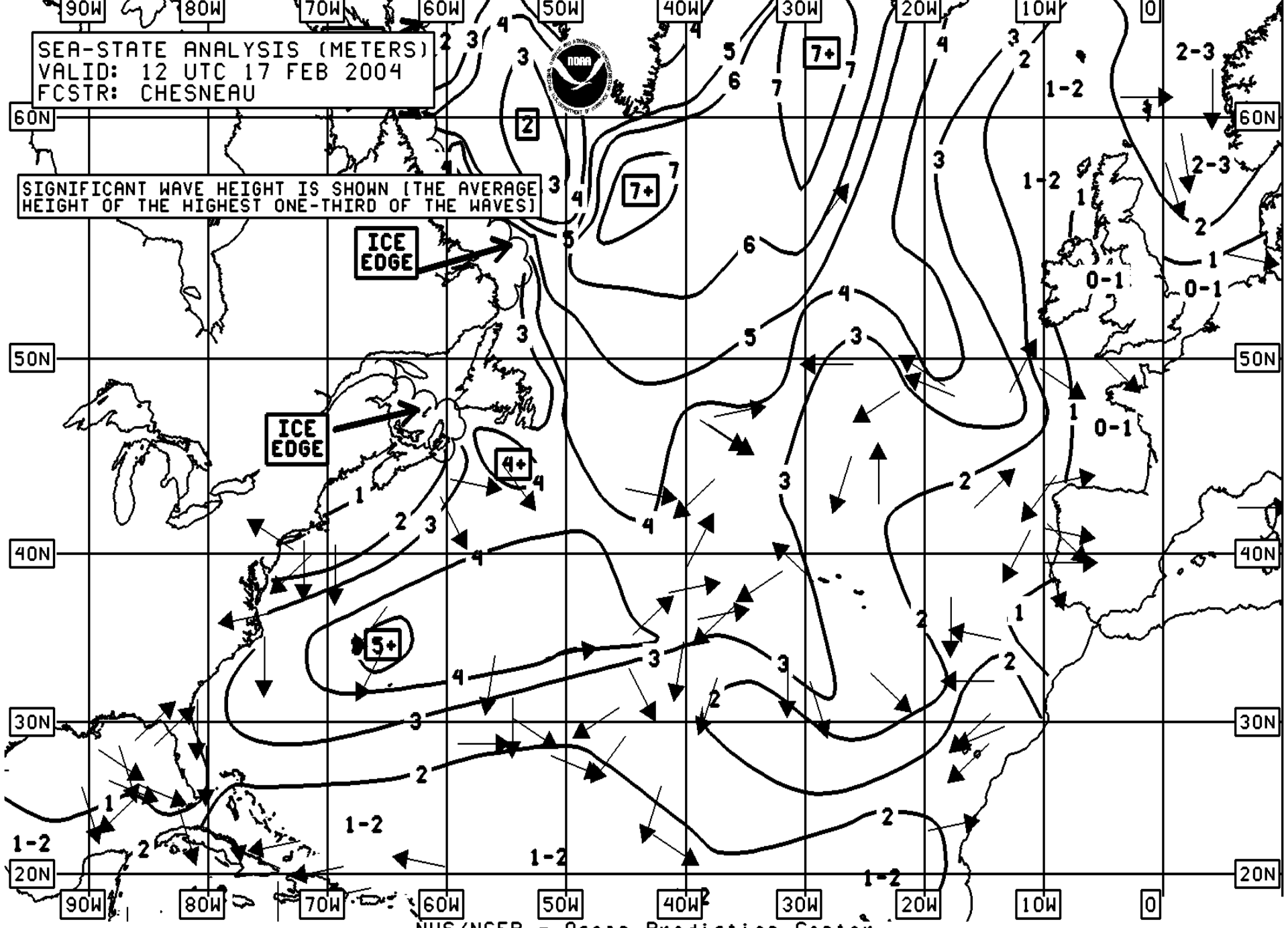
TIME	AREA	CHART	TIME	AREA	CHART
1900Z		TEST PATTERN	2045Z	4	96HR SFC VT 12Z
1905Z	1	24HR SFC VT 12Z	2055Z	4	96HR WIND/WV VT 12Z
1915Z	1	24HR WIND/WV VT 12Z	2105Z	4	96HR WV PERIOD VT 12Z
1925Z	1	24HR 500 MB VT 12Z	2115Z	4	RETRANSMIT 2045Z
1935Z	4	36HR 500 MB VT 00Z	2125Z	2	18Z SFC ANAL PART 1
1945Z	4	48HR 500 MB VT 12Z	2138Z	3	18Z SFC ANAL PART 2
1955Z	4	48HR SFC VT 12Z	2151Z	6	SATELLITE PICTURE
2005Z	4	48HR WIND/WV VT 12Z	2202Z	2	RETRANSMIT 2125Z
2015Z	4	48HR WV PERIOD VT 12Z	2215Z	3	RETRANSMIT 2138Z
2025Z	1	18Z PRELIM SFC ANAL	2228Z		END TRANSMISSION
2035Z	4	96HR 500 MB VT 12Z			

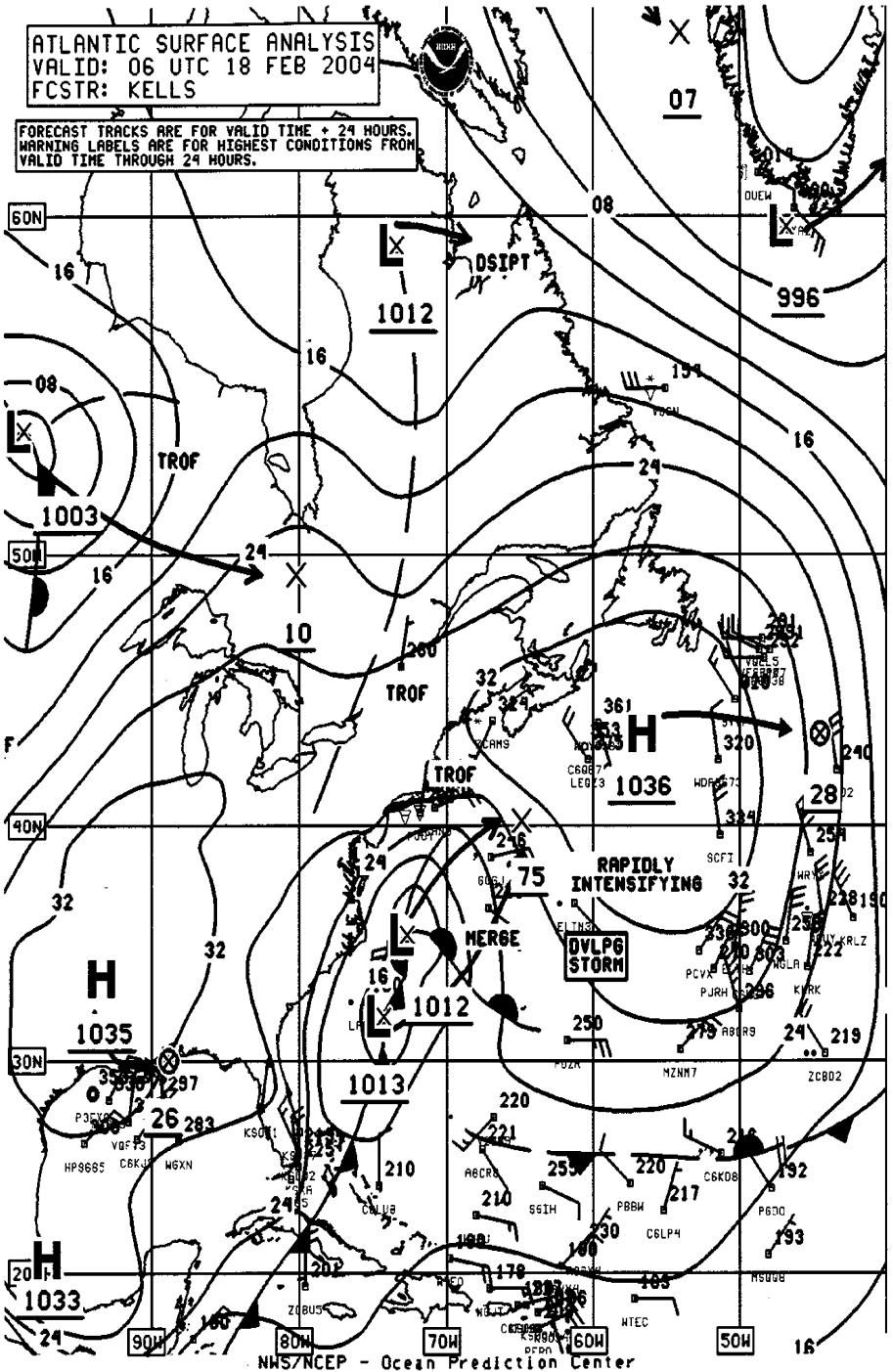
ASSIGNED FREQS: DAY = 6340.5/9110/12750 KHZ, NIGHT = 4235/6340.5/9110 KHZ
CARRIER FREQUENCY IS 1.9 KHZ BELOW ASSIGNED FREQUENCY

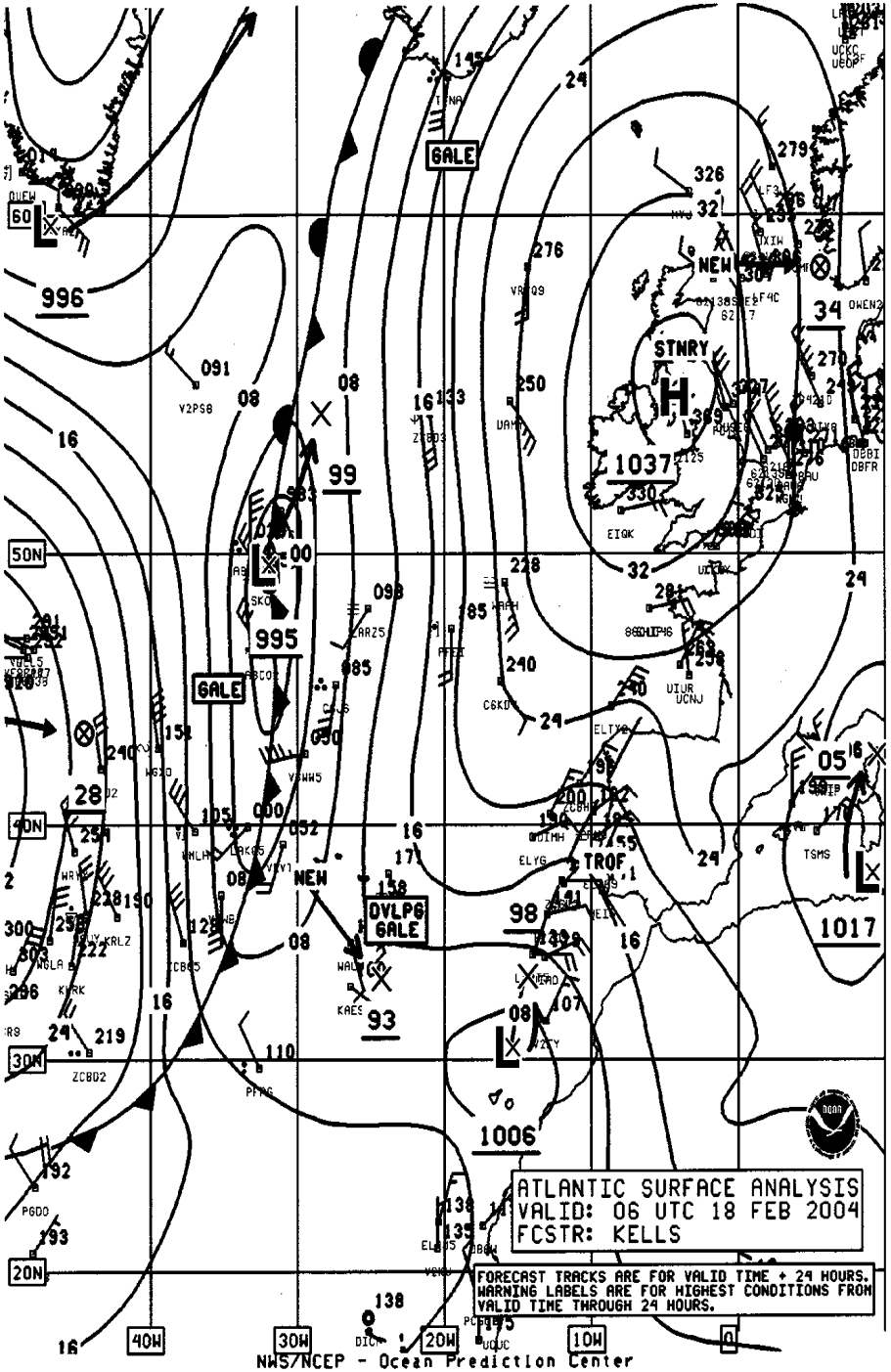
AREAS: 1=28N-52N, 45W-85W 2=15N-65N, 10E-45W
3=15N-65N, 40W-95W 4=15N-65N, 10E-95W
5=20N-55N, 55W-95W 6=00N-60N, 40W-130W

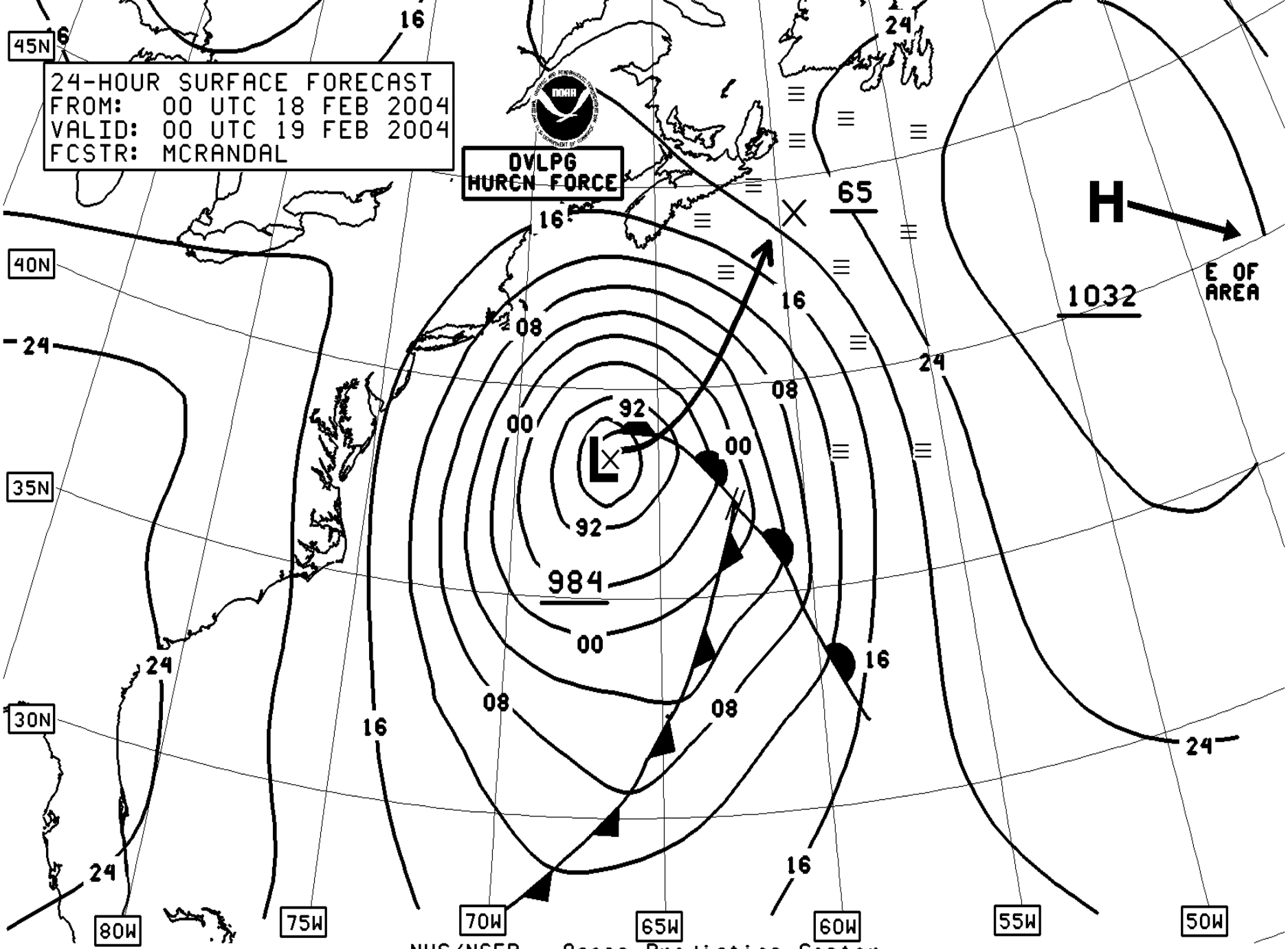
CONTRACTIONS: VT=VALID TIME, SFC=SURFACE, WV=WAVE, ATL=ATLANTIC
ANAL=ANALYSIS, PRELIM=PRELIMINARY

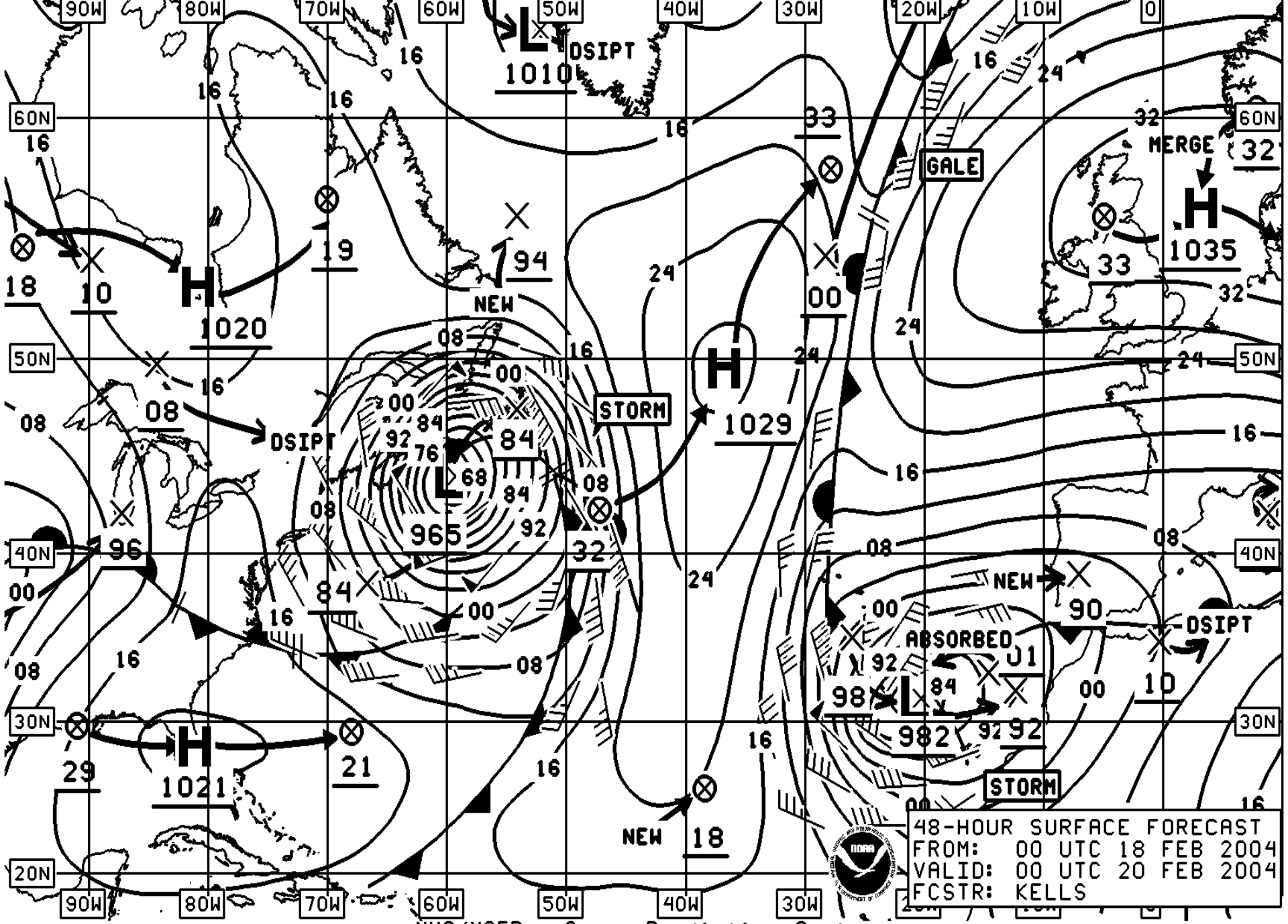
COMMENTS ON THIS SCHEDULE OR QUALITY OF CHARTS ARE INVITED.
WRITE TO: NATIONAL WEATHER SERVICE, WWBG ROOM 410,
5200 AUTH ROAD, WASHINGTON, D.C. 20233 ATTN: MPC
PHONE: 301-763-8441, PHONE FAX: 301-763-8085; EMAIL: David.Feit@noaa.gov


SEA-STATE ANALYSIS (METERS)
VALID: 12 UTC 17 FEB 2004
FCSTR: CHESNEAU
SIGNIFICANT WAVE HEIGHT IS SHOWN (THE AVERAGE HEIGHT OF THE HIGHEST ONE-THIRD OF THE WAVES)
ICE EDGE
ICE EDGE
90W
80W
70W
60W
50W
40W
30W
20W
10W
0
60N
50N
40N
30N
20N
NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov

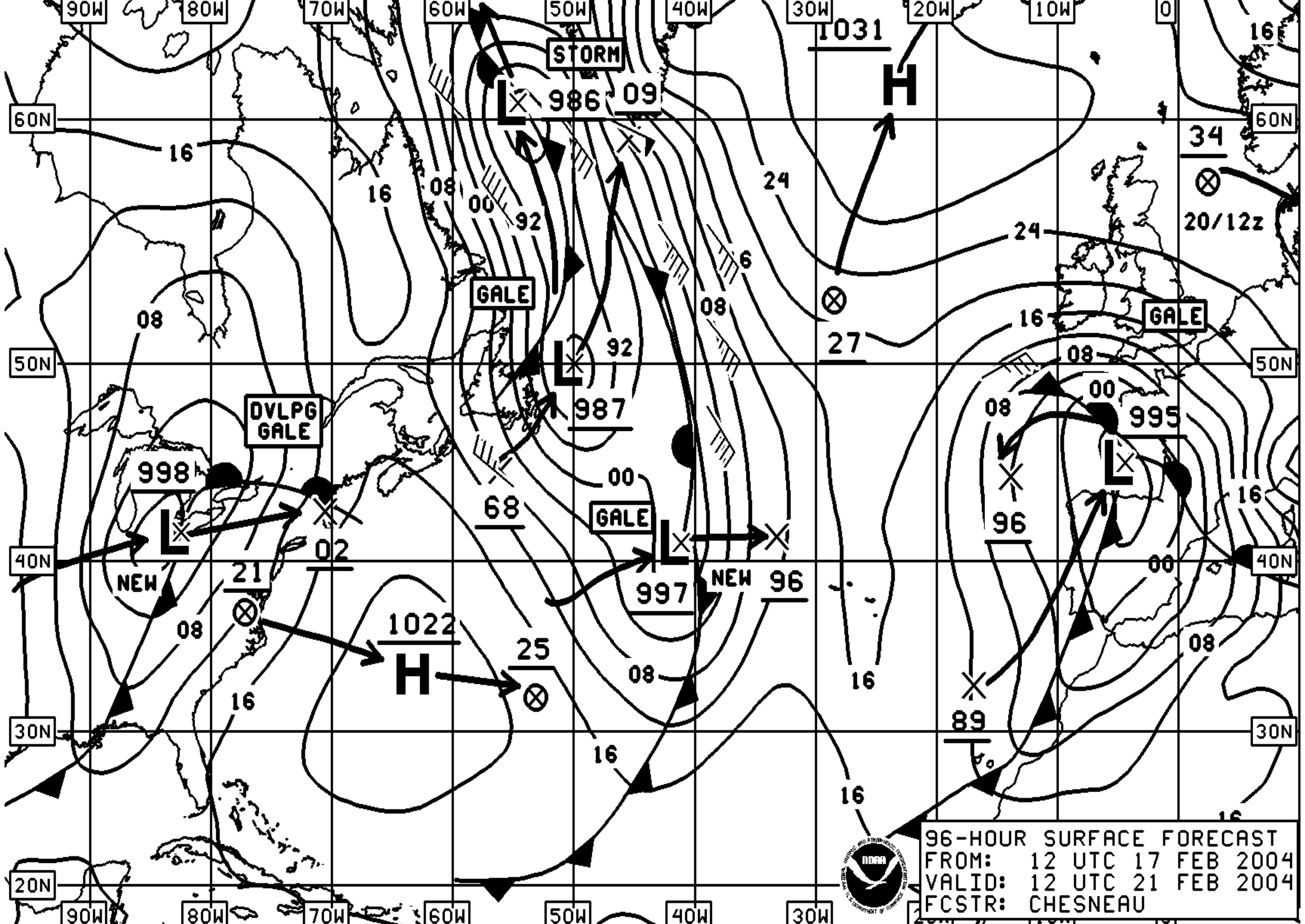

ATLANTIC SURFACE ANALYSIS
VALID: 06 UTC 18 FEB 2004
FCSTR: KELLS
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
TROF
DSIPT
RAPIDLY INTENSIFYING
MERGE
OVLPG STORM
1012
1003
1036
1035
1013
1033
996
60N
50N
40N
30N
20N
90W
80W
70W
60W
50W
NWS/NCEP - Ocean Prediction Center


GALE
NEW
STNRY
1037
995
OVLPG GALE
TROF
1017
1006
93
ATLANTIC SURFACE ANALYSIS
VALID: 06 UTC 18 FEB 2004
FCSTR: KELLS
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
60N
50N
40N
30N
20N
40W
30W
20W
10W
0
NWS/NCEP - Ocean Prediction Center

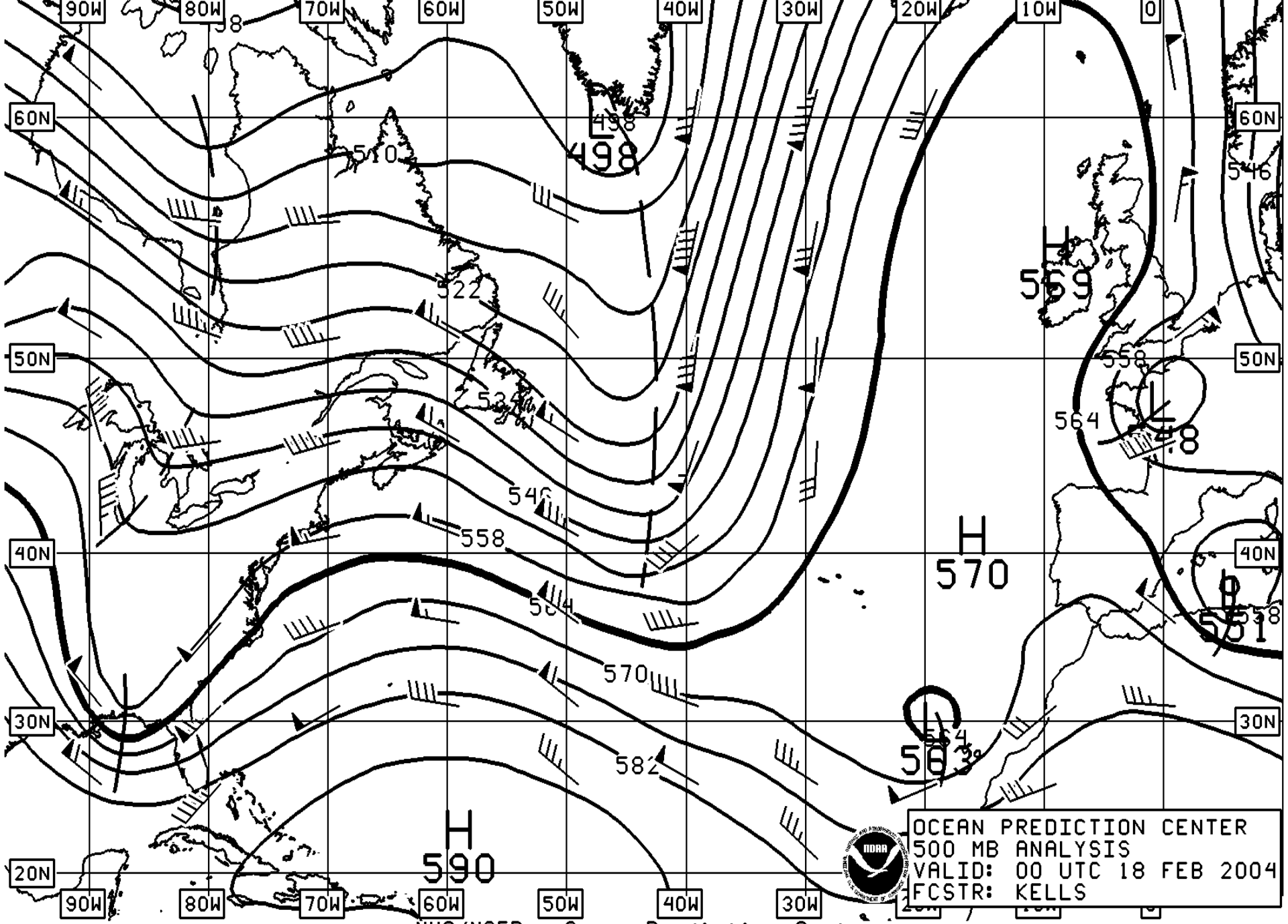

24-HOUR SURFACE FORECAST
FROM: 00 UTC 18 FEB 2004
VALID: 00 UTC 19 FEB 2004
FCSTR: MCRANDAL
DVLPG
HURCN FORCE
45N
40N
35N
30N
80W
75W
70W
65W
60W
55W
50W
L
984
92
00
08
16
24
H
1032
65
E OF
AREA
NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov



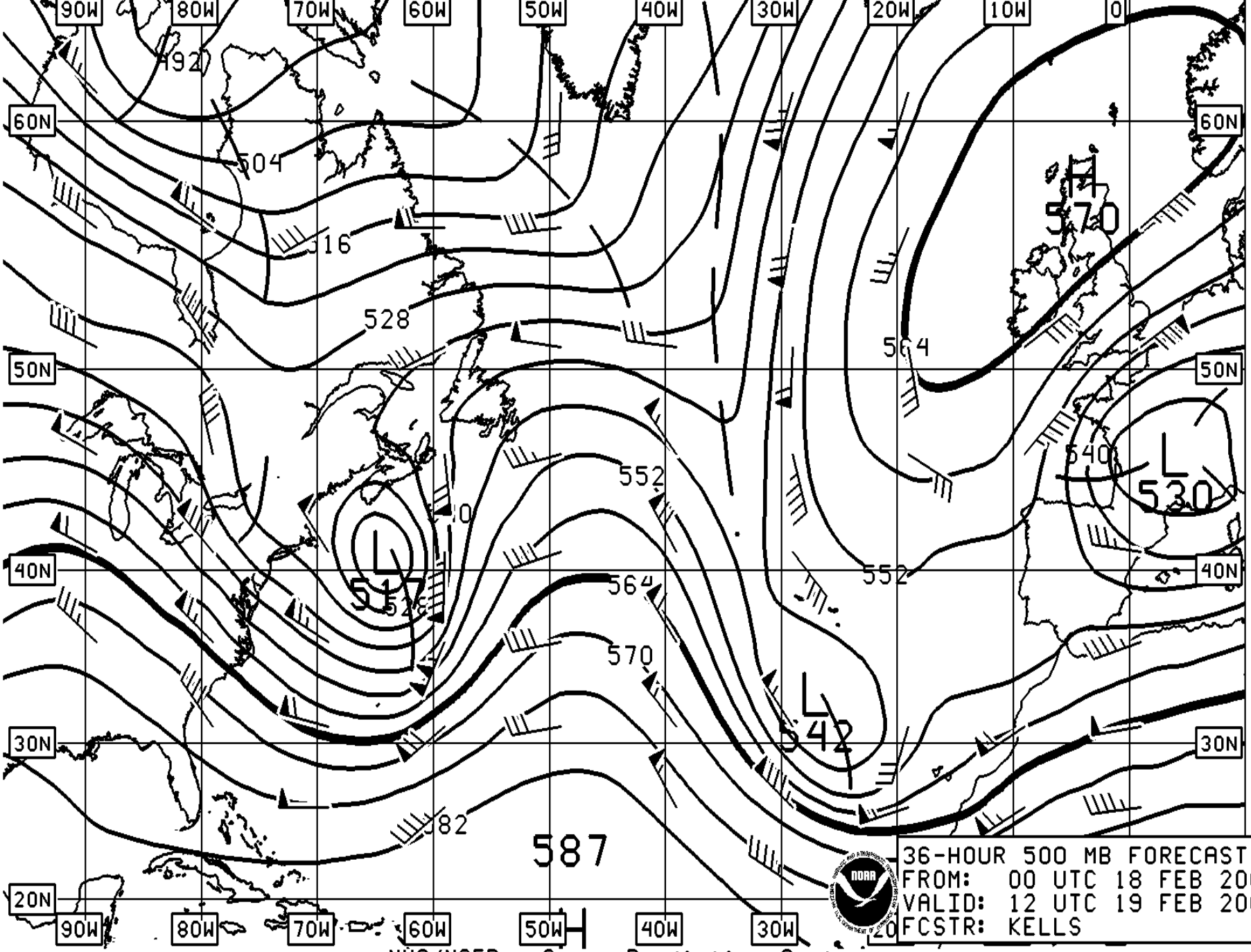
NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov

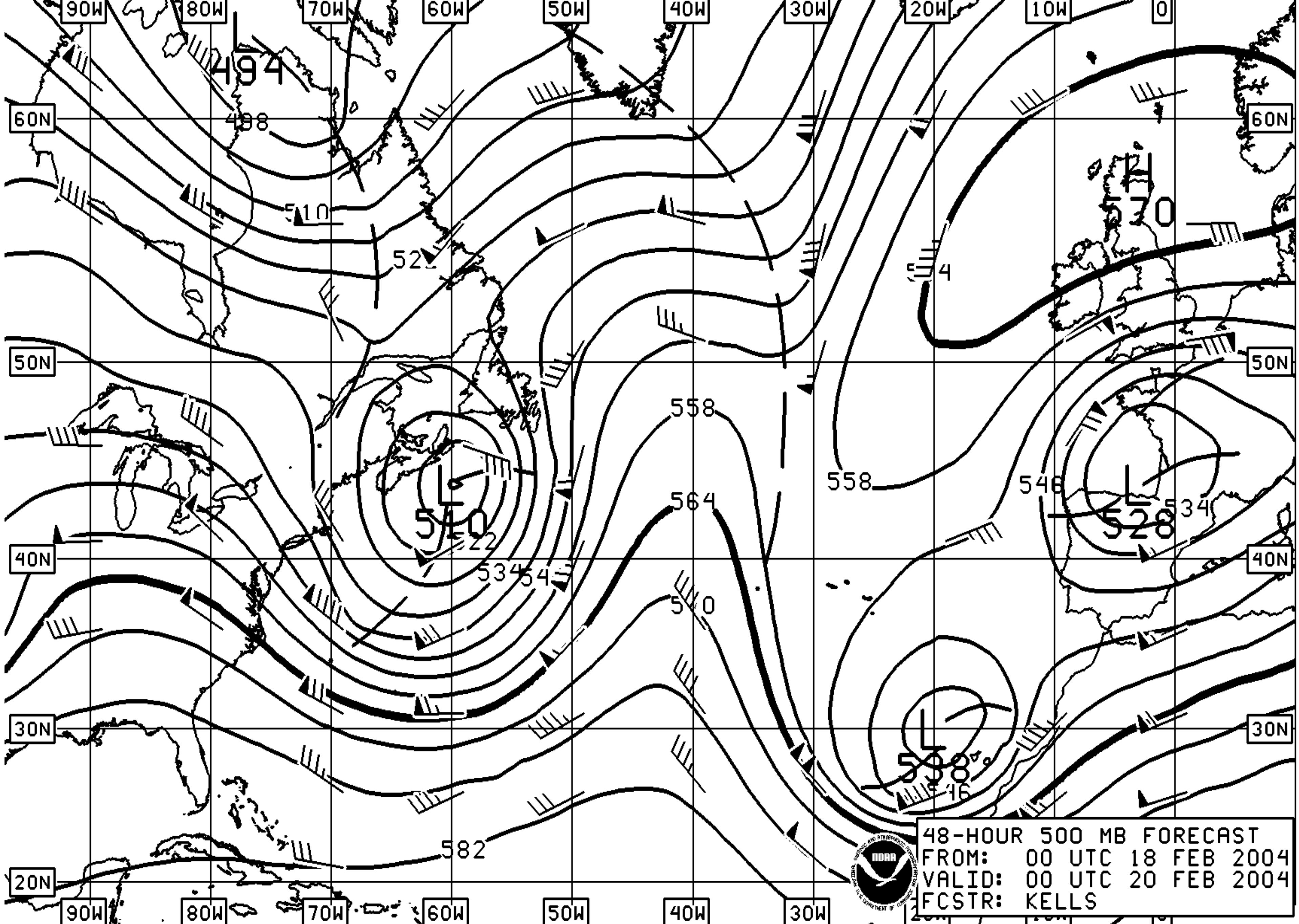


NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov

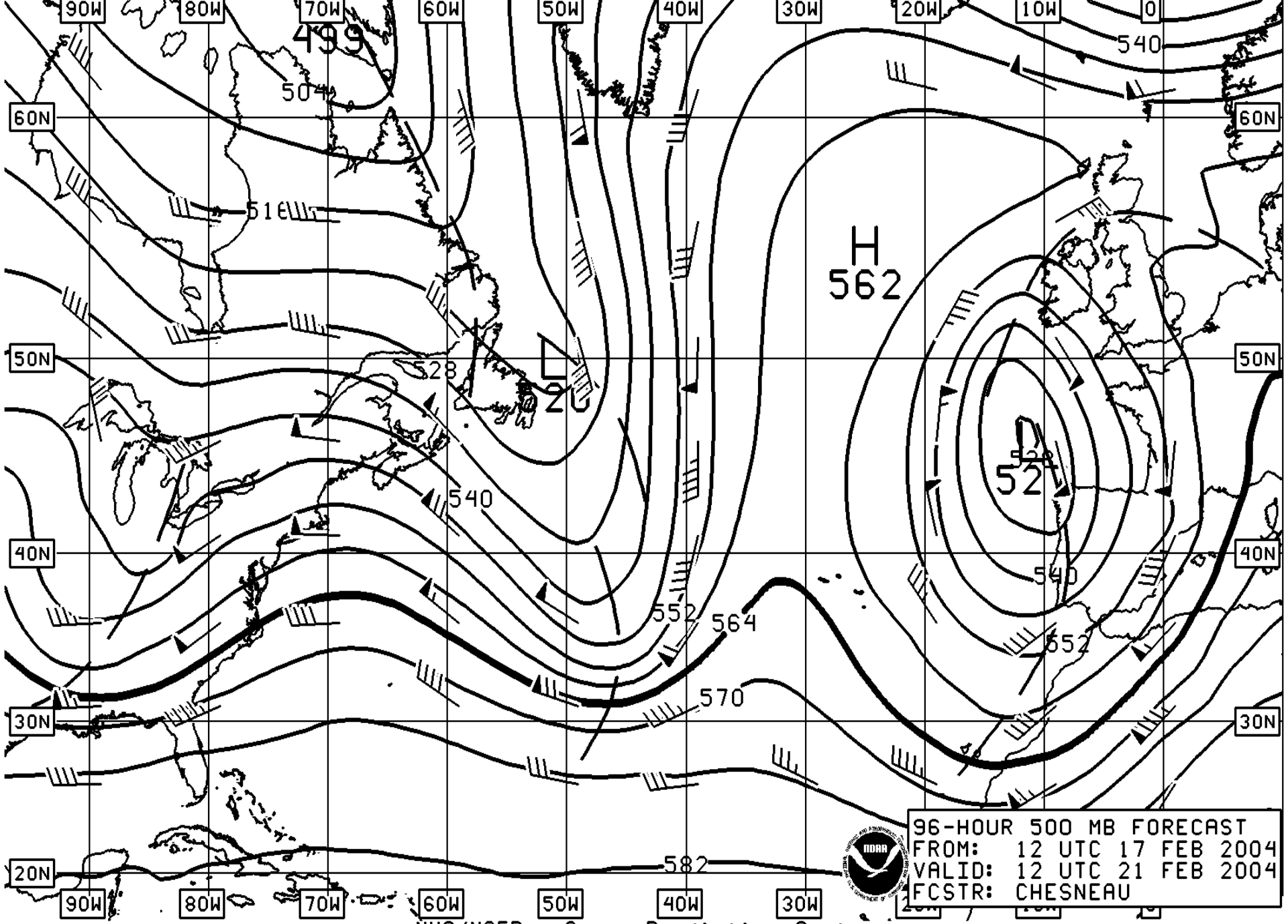


NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov


90W
80W
70W
60W
50W
40W
30W
20W
10W
0
60N
50N
40N
30N
20N
492
504
516
528
540
552
564
570
582
587
L
517
H
570
L
530
L
542
36-HOUR 500 MB FORECAST
FROM: 00 UTC 18 FEB 2004
VALID: 12 UTC 19 FEB 2004
FCSTR: KELLS
NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov



NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov


90W
80W
70W
60W
50W
40W
30W
20W
10W
0
60N
50N
40N
30N
20N
499
504
516
528
540
552
564
570
582
H
562
L
526
540
552
96-HOUR 500 MB FORECAST
FROM: 12 UTC 17 FEB 2004
VALID: 12 UTC 21 FEB 2004
FCSTR: CHESNEAU
NWS/NCEP - Ocean Prediction Center
www.opc.ncep.noaa.gov


Have a great Navy Day!
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Questions?