Basic Marine Weather

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Landfall Navigation
Marine Training Center (MTC)
Stamford CT
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Overview of the Course

The course covers the characteristics and understanding of the marine atmosphere: clouds, precipitation, winds, fronts and their descriptions on surface weather maps. Participants will learn the basics of these weather elements and where to find on-line marine weather information. The course provides the foundation for the MTC Intermediate and Advanced Marine Meteorology courses.

Goal of the Courses

To *weatherproof* you: recognize, understand, act!

Basic Marine Weather Topics

- **Causes of weather**: the atmosphere; observing cloud types and what they mean to a mariner; principles of how clouds and precipitation form (*cloud formation* exercise); haze and fog

- **Basic atmospheric pressure and wind concepts**: local and global

- **Surface weather maps**: an overview of weather systems including lows and troughs; highs and ridges; air masses and fronts (*find the front* exercise); tropical weather; understanding NOAA Ocean Prediction Center (OPC) and Tropical Prediction Center (TPC) surface weather maps; coastal buoy data

- **Finding essential weather information**: Internet sites identified and explored

This presentation is at www.sci.ccny.cuny.edu/~hindman

Certification

Upon completion of the course, you will receive a Landfall Navigation-Marine Training Center *Certificate of Completion in Basic Marine Weather*

References

Reeds Maritime Meteorology 3rd edition, Cornish & Ives
(ISBN: 0713676353, available from Amazon.com)

Weather at Sea 4th edition, Houghton
(ISBN: 1904475167, available from Landfall Navigation)

North U Weather for Sailors 2nd edition, Biewenga
(ISBN: 097446760X, available from Landfall Navigation)

Your course expectations?

Basic Marine Weather

Causes of weather: the atmosphere

(adapted from *Reeds Maritime Meteorology* 3rd Edition)

- Temperature and pressure decrease with increasing altitude.
- Troposphere is 'shallow' at the Poles and 'deep' at the Equator.
- Types of clouds and their levels are indicated.

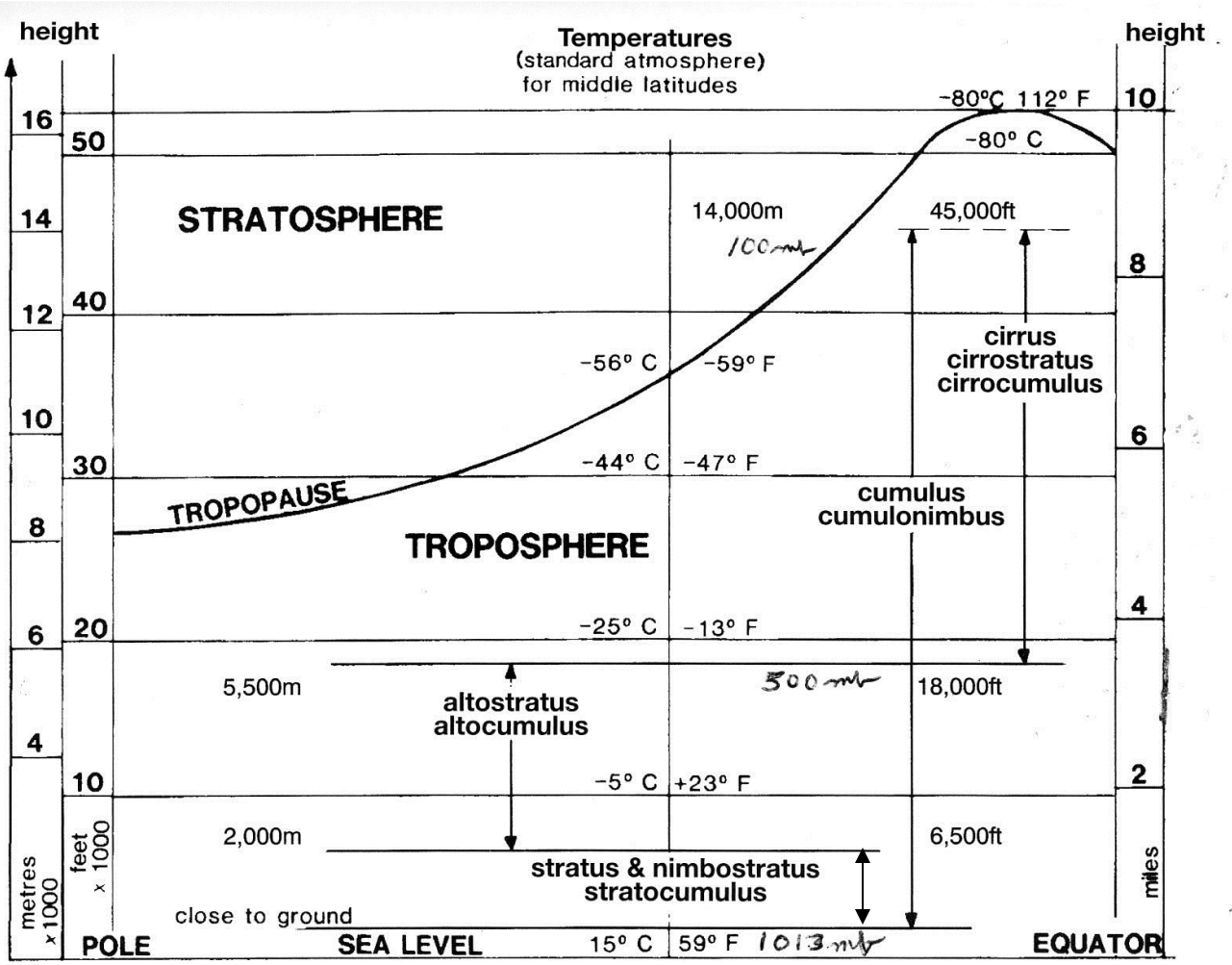


Fig 1.1

Note: Height equivalents are approximate

Causes of weather: the atmosphere

•Warm air is less dense than cold air, keeping water vapor content constant.

•Thus, pressure decreases less rapidly in the vertical in warm air than in cold air.

•This fact leads to the fundamental horizontal pressure-gradient force (PGF), the initiator of the winds.

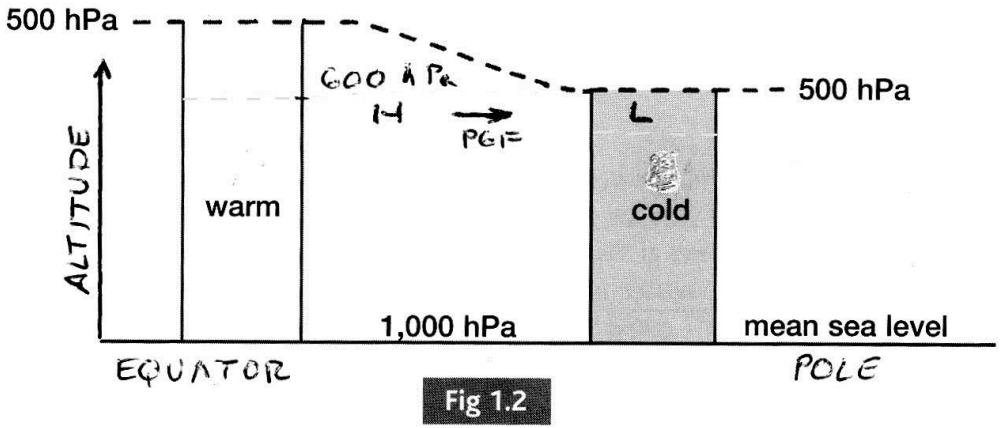


Fig 1.2

Causes of weather: the atmosphere

•The Polar regions are colder than the Equatorial regions because solar radiation received is less than infrared radiation emitted and vice versa for the Equatorial regions.

•There is an energy deficit in the Polar regions and excess in the Equatorial regions.

•The difference is balanced by atmospheric storms and ocean currents.

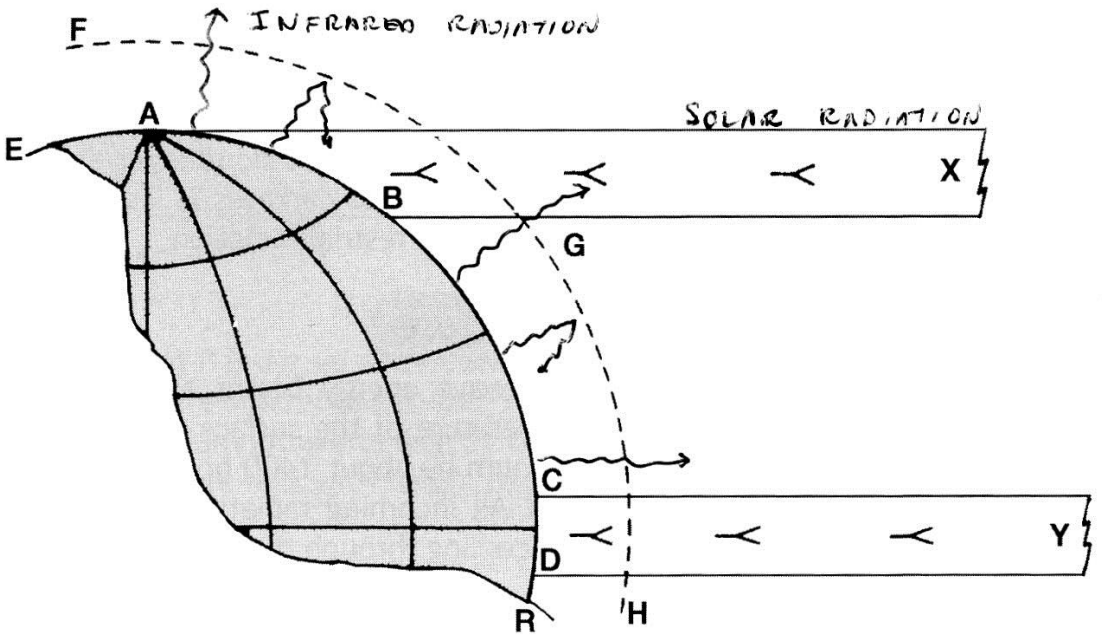


Fig 2.1

Causes of weather: the atmosphere

•Relative Humidity (%) = Abs. humidity at the dew-point temp. x 100
Abs. humidity at the air temp.
= (11g/m^3) x 100 = 55%
(20 g/m^3)

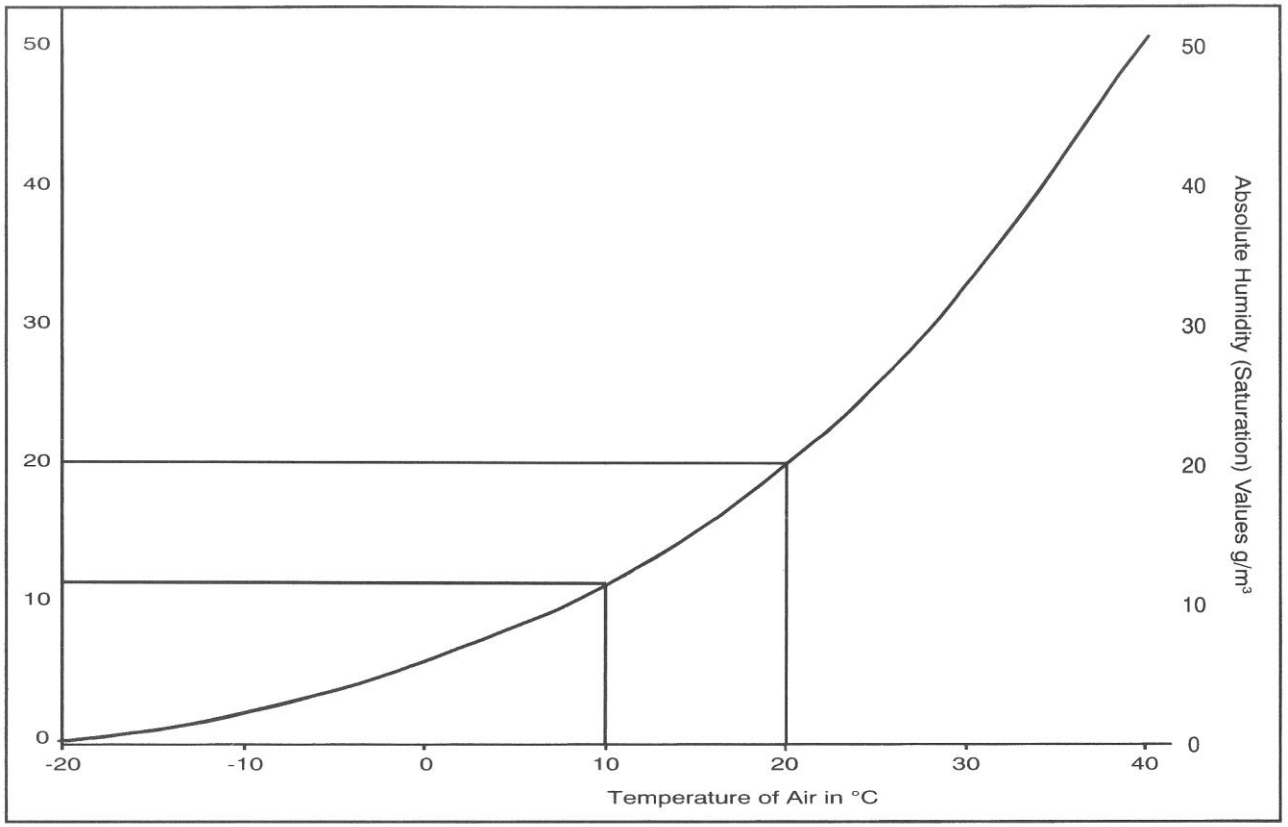


Fig 3.1

•At the same RH, there is more water vapor in the air in a subtropical desert than in the Polar regions. Hence, the Poles also are 'deserts'.

Causes of weather: observing cloud types and what they mean to a mariner

High clouds

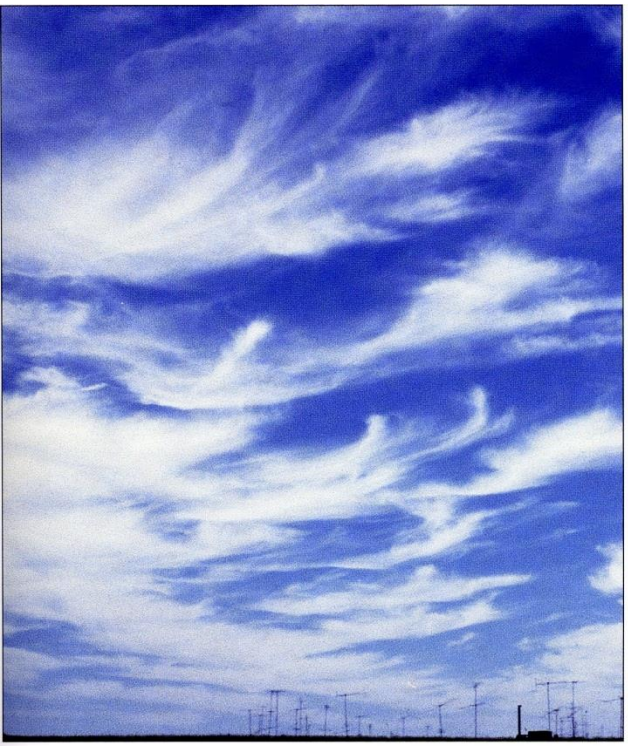


Photo 1 Cirrus

Photo 2 Cirrostratus

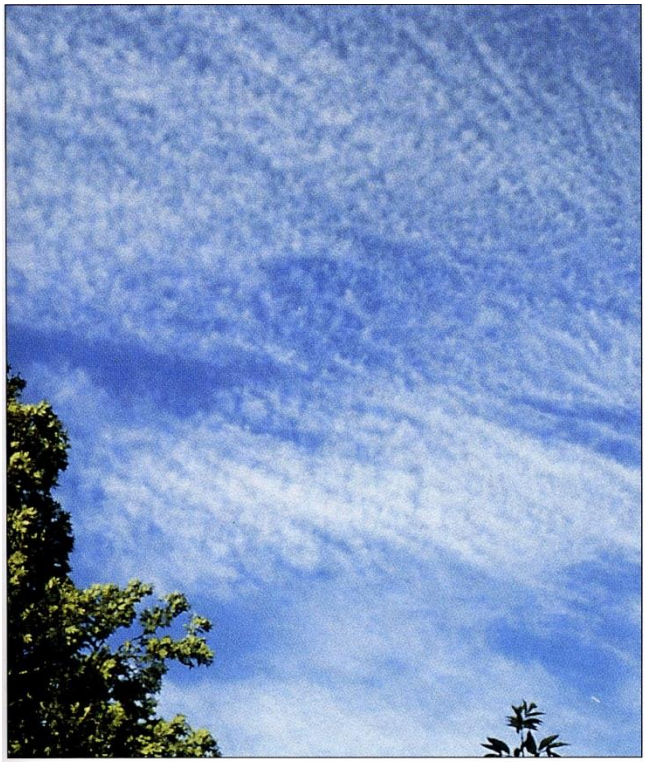


Photo 3 Cirrocumulus

Causes of weather: observing cloud types and what they mean to a mariner

Middle clouds

Photo 4 Altostratus (thin)

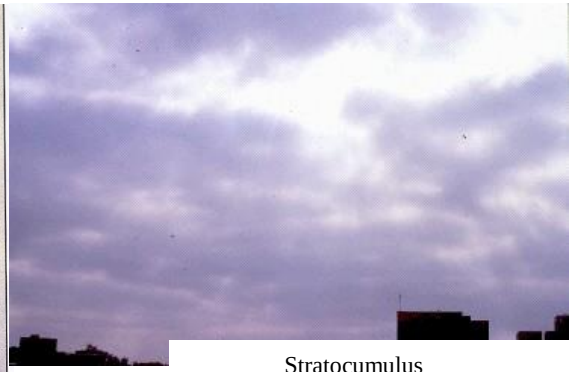
Altocumulus

Causes of weather: observing cloud types and what they mean to a mariner

Low clouds

Photo 7 Stratus (layer)

Photo 10 Nimbostratus



Stratocumulus

Causes of weather: observing cloud types and what they mean to a mariner

Clouds with vertical development

Photo 12 Cumulus

Photo 13 Towering cumulus (TCu) and cumulonimbus (Cb)

Cumulonimbus

Pictured is a typical sequence for an approaching line of thunderstorms (squall line)

When clouds appear like rocks and towers, the Earth's refreshed by frequent showers.

Causes of weather: observing cloud types and what they mean to a mariner

Approaching low pressure region

Photo 10 Nimbostratus

Photo 4 Altostratus (thin)

Photo 2 Cirrostratus

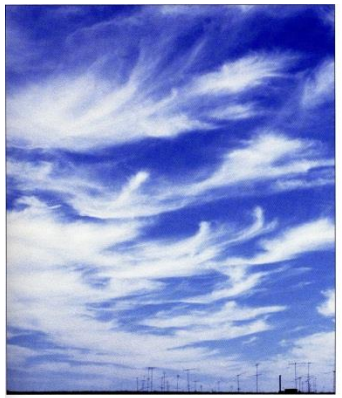


Photo 1 Cirrus

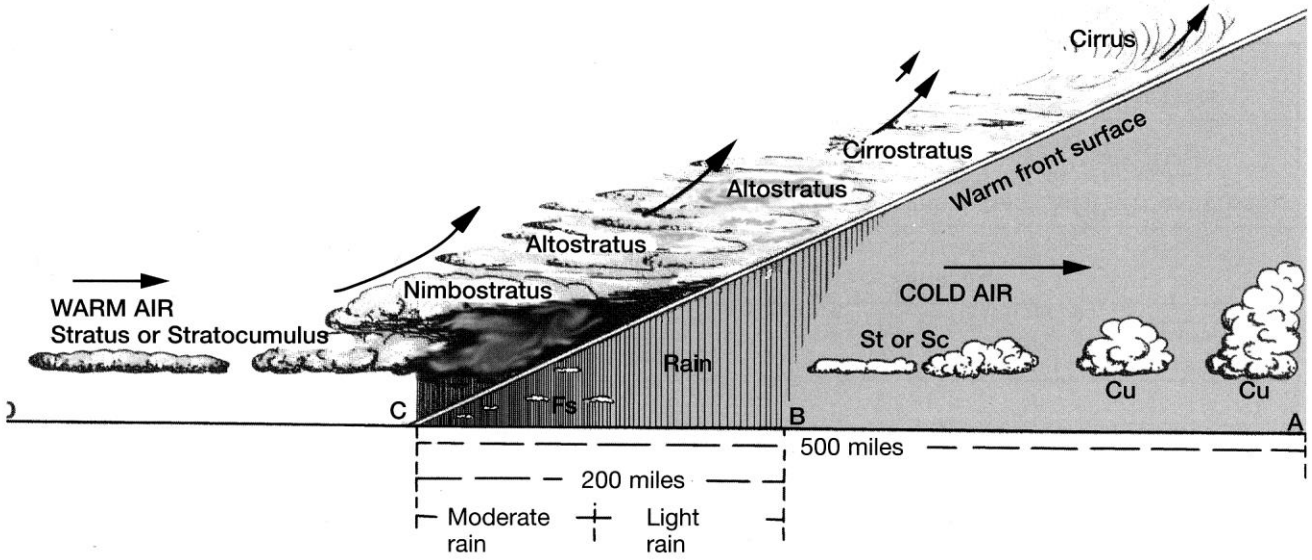


Fig 13.4 *Vertical section across an average warm front.*

Causes of weather: observing cloud types and what they mean to a mariner

Approaching low pressure region

A ring around the sun or moon, means rain or snow coming soon.

Mare's tails and mackerel scales make tall ships take in their sails.

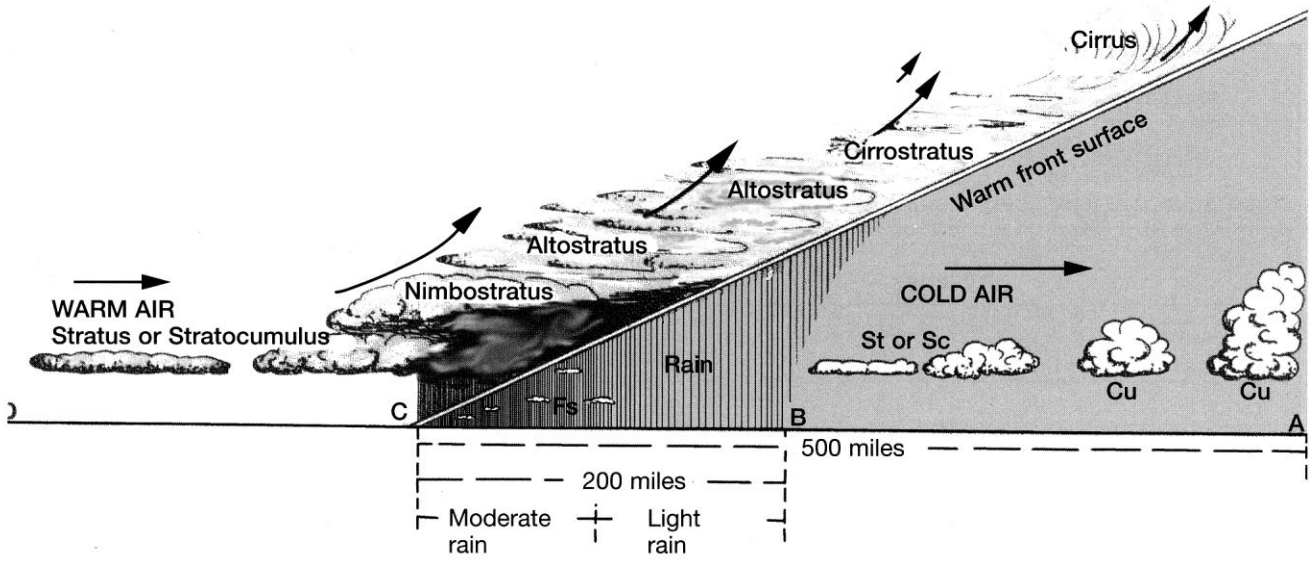


Fig 13.4 *Vertical section across an average warm front.*

Causes of weather: observing cloud types and what they mean to a mariner

Other common ‘clouds’

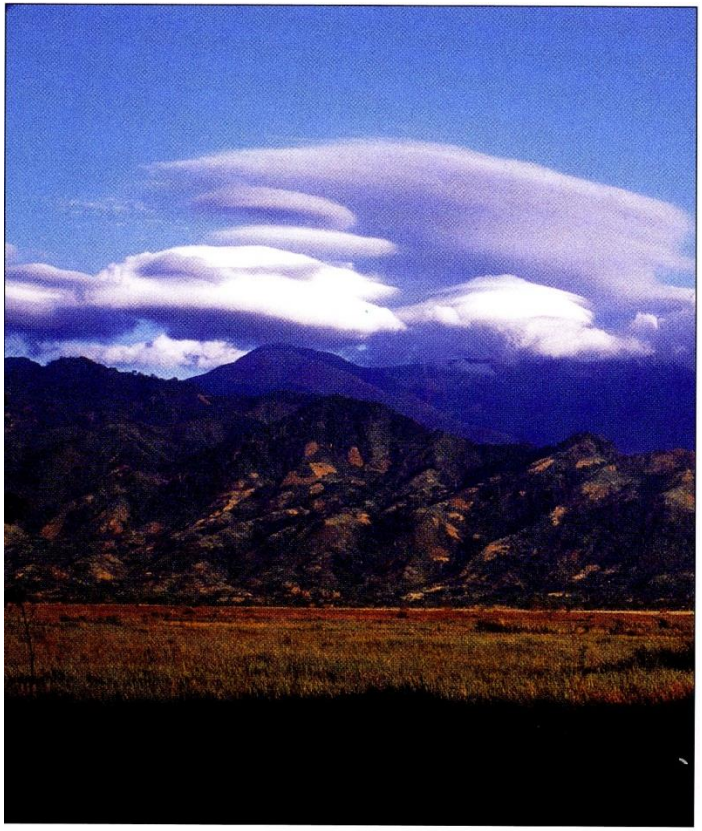


Photo 16 Orographic cloud

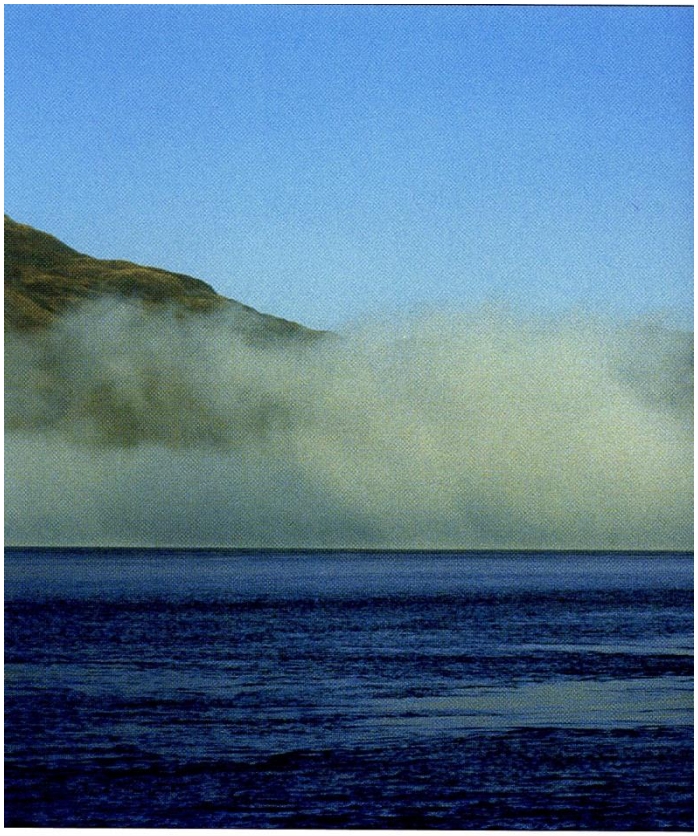
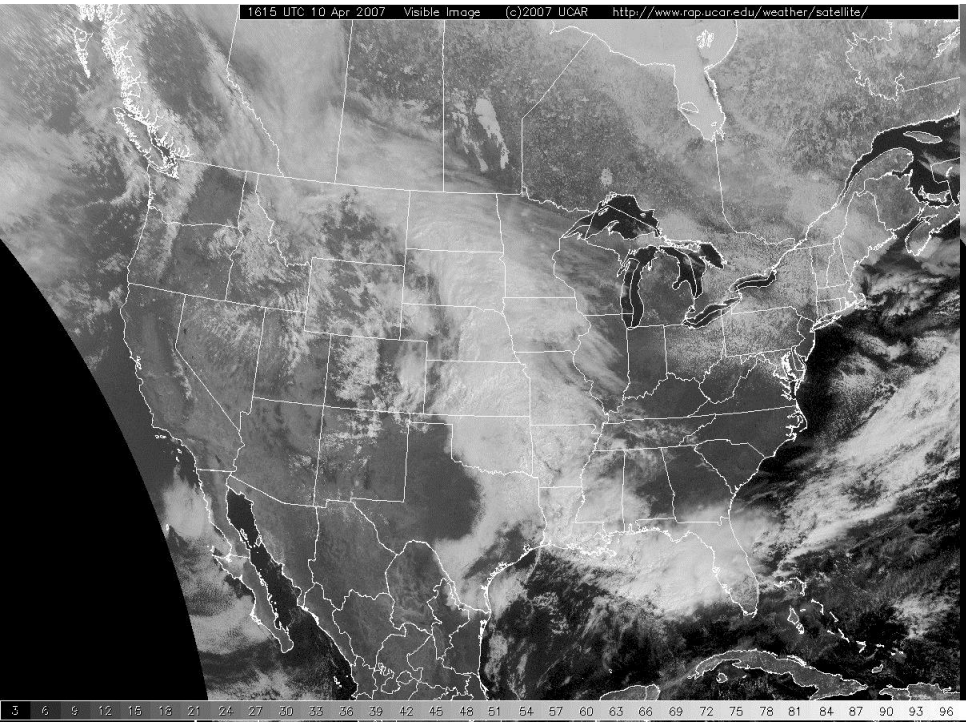


Photo 14 Sea fog

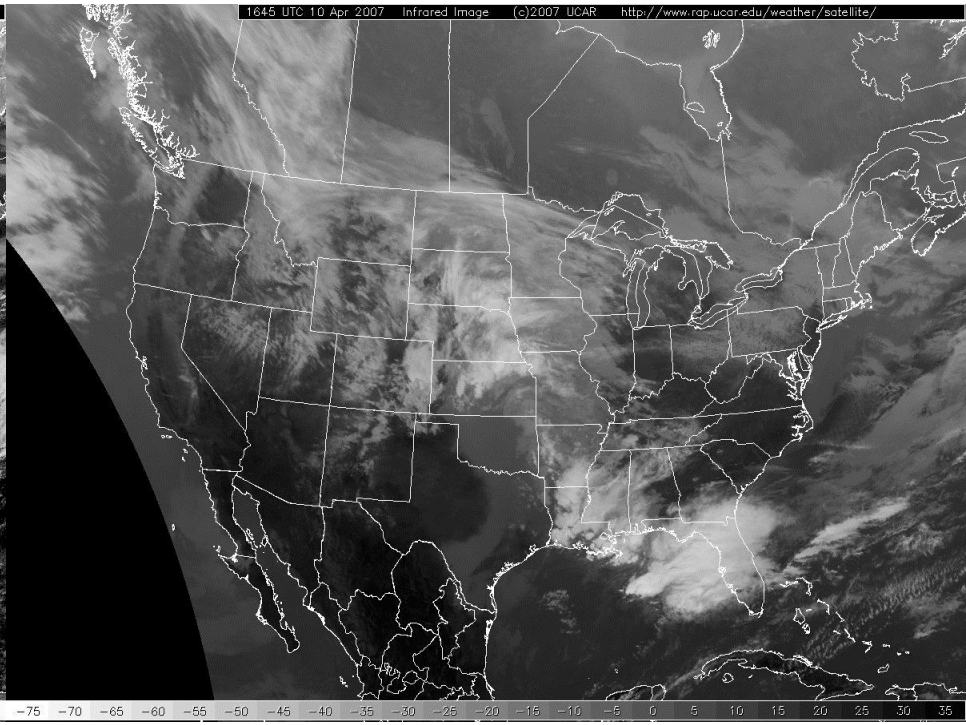
Causes of weather: observing cloud types and what they mean to a mariner

Clouds from space (www.aviationweather.gov/adds/satellite/)

Visible radiation



Infrared radiation



Causes of weather: principles of how clouds form

•Clouds are suspensions of water droplets and/or ice crystals.

•Clouds form when air either cools to the dew-point temperature or moistens to the dew-point temperature.

•Rising air cools and sinking air warms:

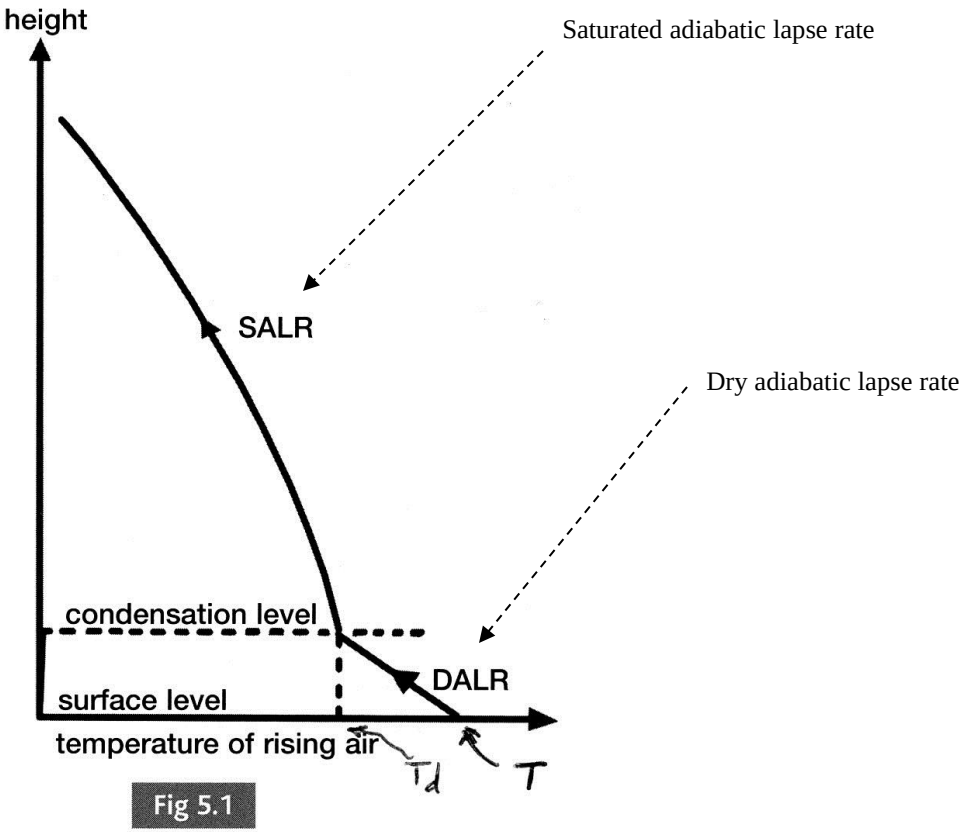


Fig 5.1

Causes of weather: principles of how clouds form

•The vertical temperature distribution of the static (environment) air takes different forms

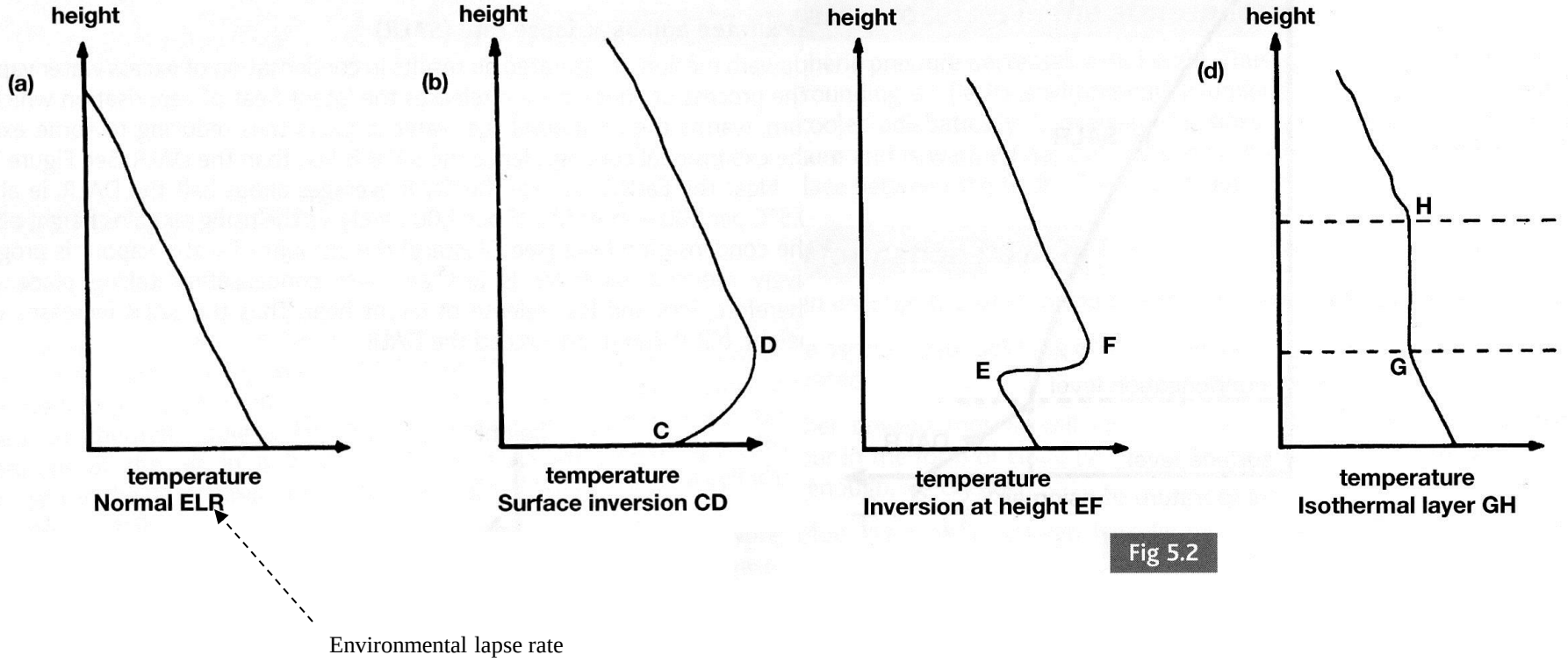


Fig 5.2

Causes of weather: principles of how clouds form

•The vertical temperature distribution of the static (environment) air determines if a 'segment' of air will either rise, remain stationary or sink.

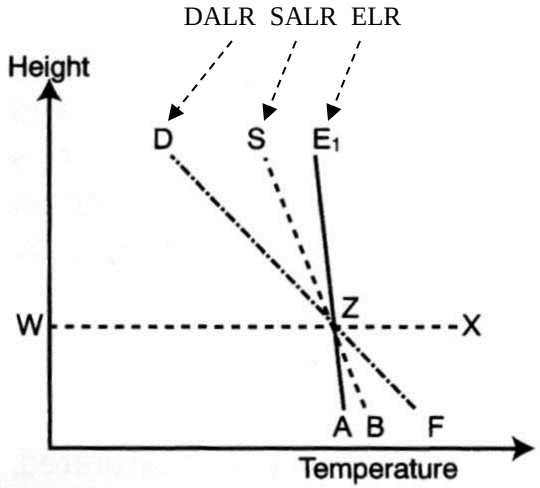


Fig 5.3a STABLE

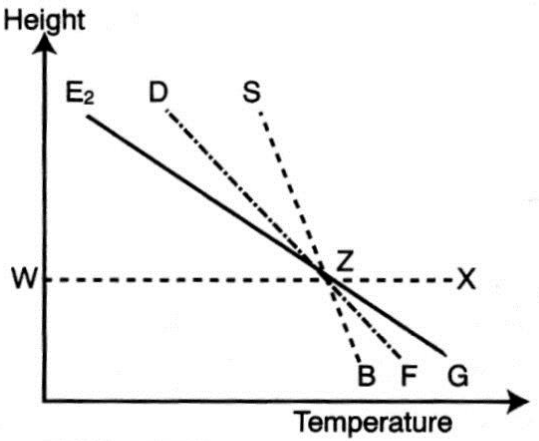


Fig 5.3b UNSTABLE

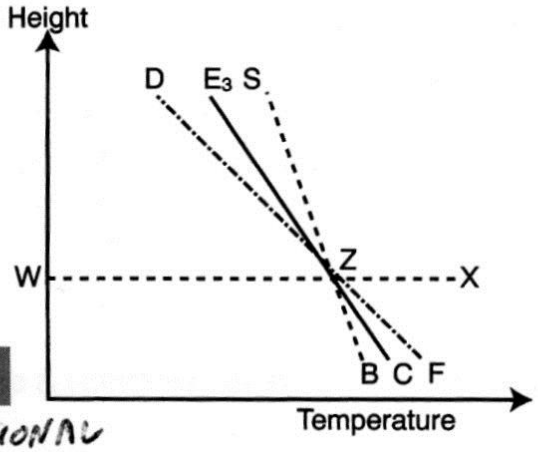


Fig 5.3c CONDITIONAL

Causes of weather: principles of how clouds form

•Moist, unstable air can lead to the formation of clouds

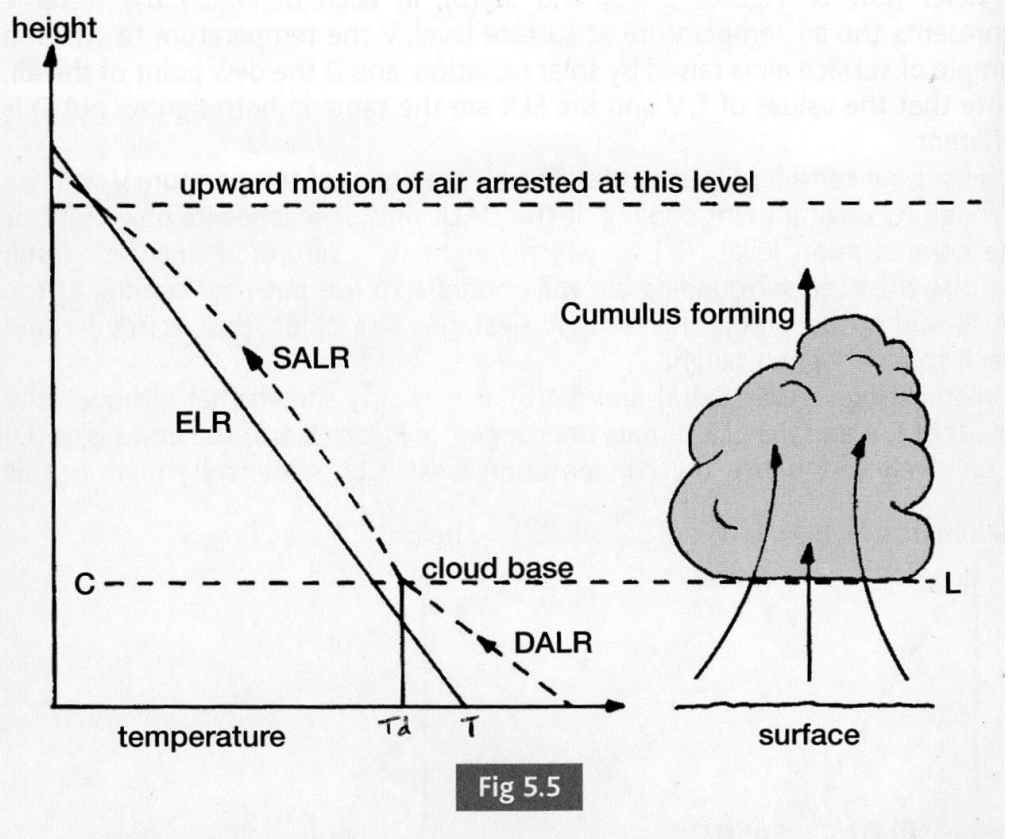


Fig 5.5

Causes of weather: principles of how clouds form

•The deeper the unstable layer, the taller the cloud grows

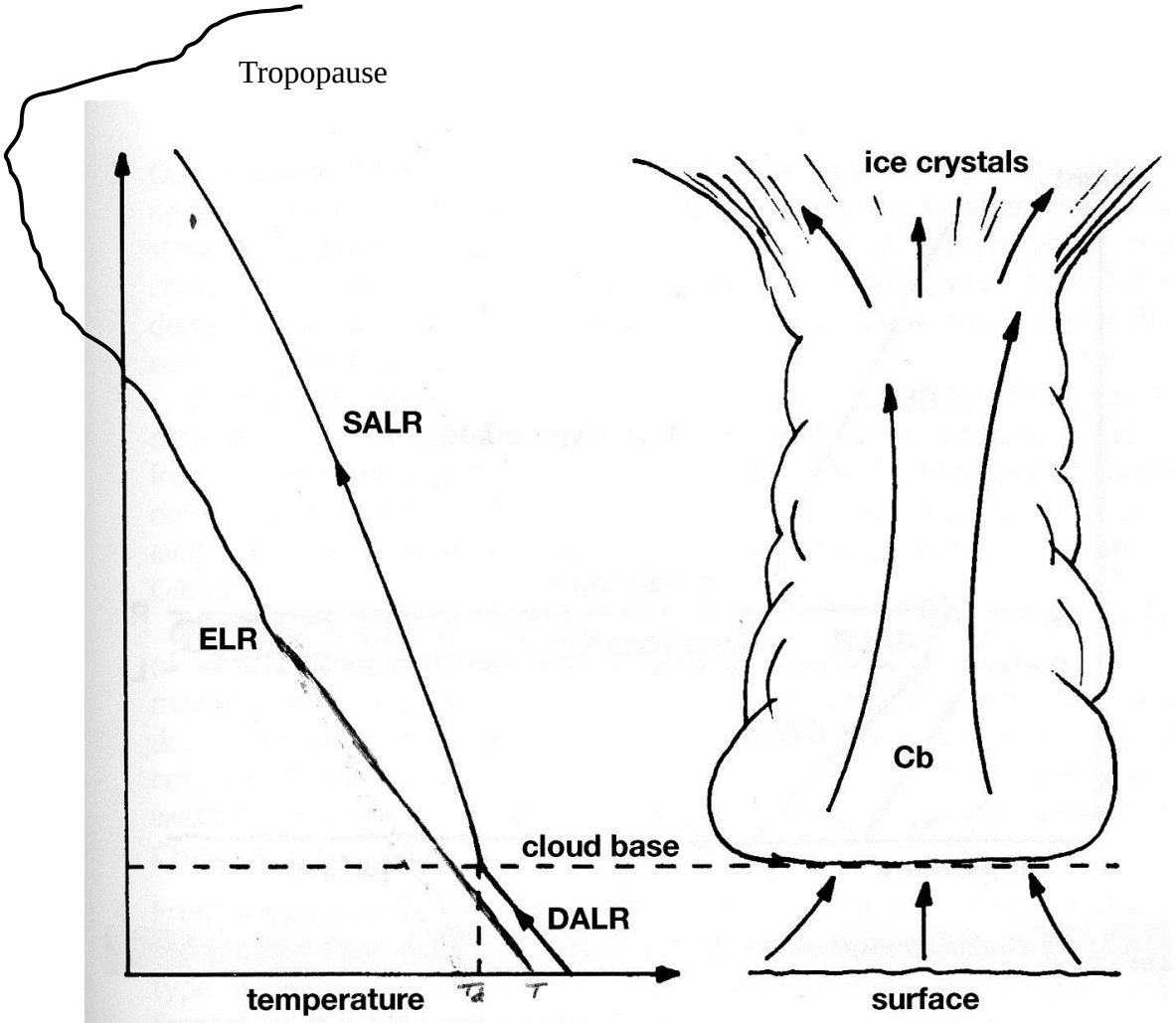


Fig 5.6 *Unstable atmosphere.*

Causes of weather: principles of how clouds form

•Formation of stratocumulus clouds

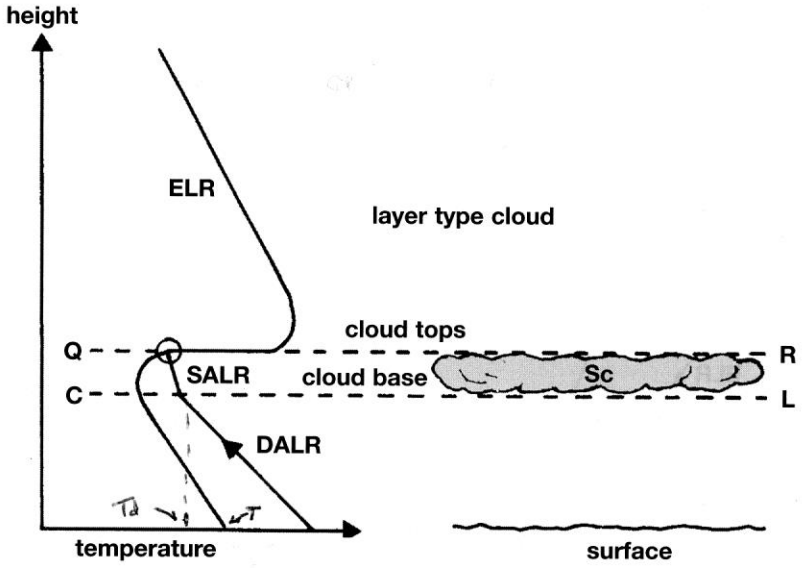


Fig 5.7 *Stable atmosphere.*

•Stratocumulus clouds cannot form

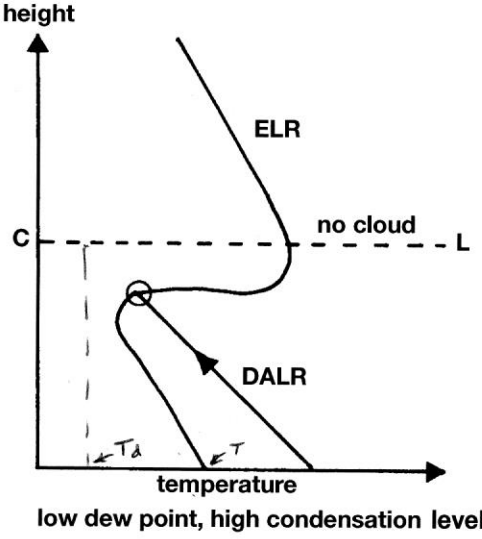


Fig 5.8 *Stable atmosphere.*

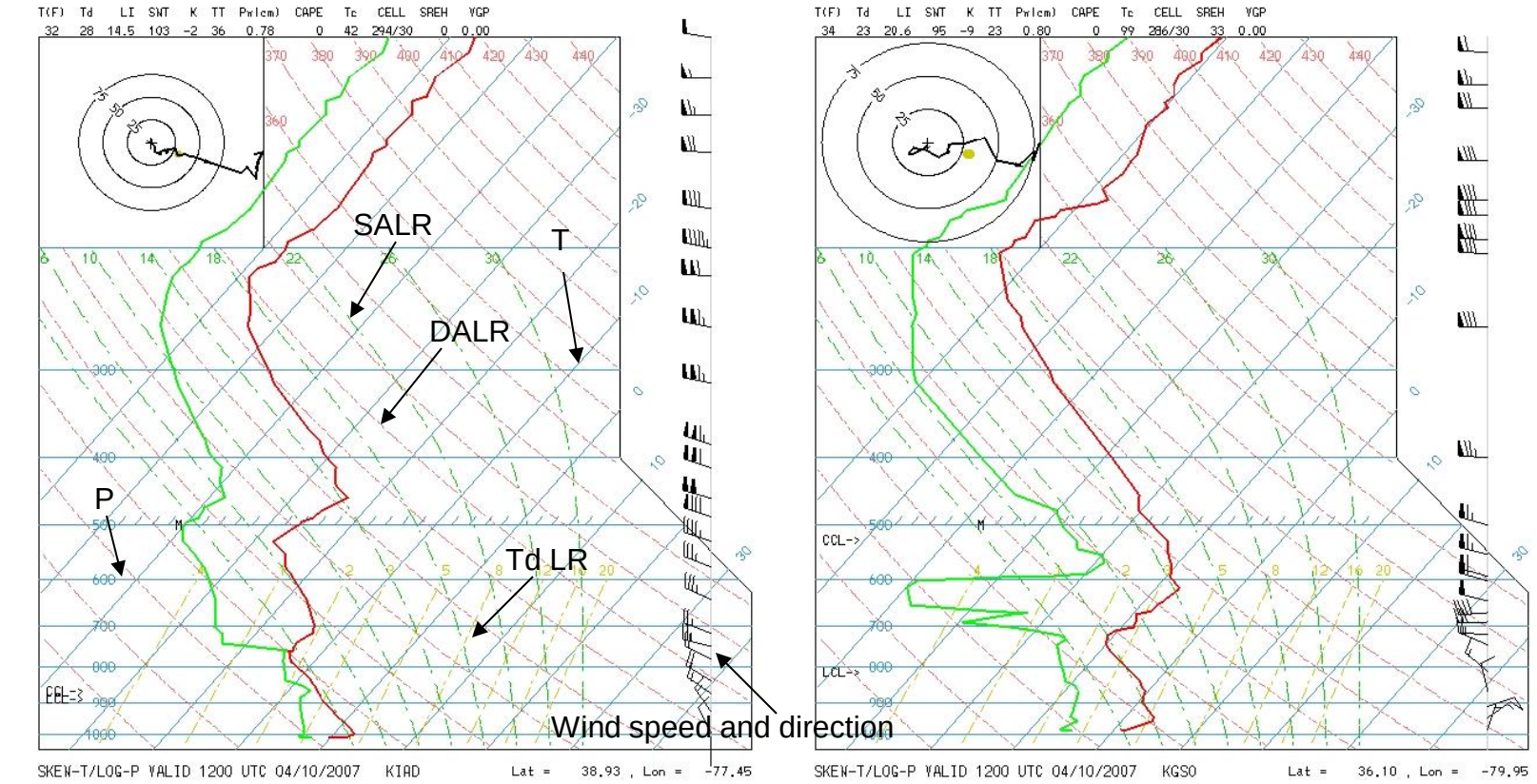
Causes of weather: principles of how clouds form

Cloud formation exercise (handout exercise):

•Given the predicted surface high temperature and early morning atmospheric temperature profile, determine if cumulus clouds will form. Verify your prediction using satellite data.

•Predicted high temperature for Dulles Airport (IAD), 52F (11C) and Greensboro SC (GSO), 62F (17C) (www.weather.unisys.com/forecast.php?Name=KIAD & KGSO)

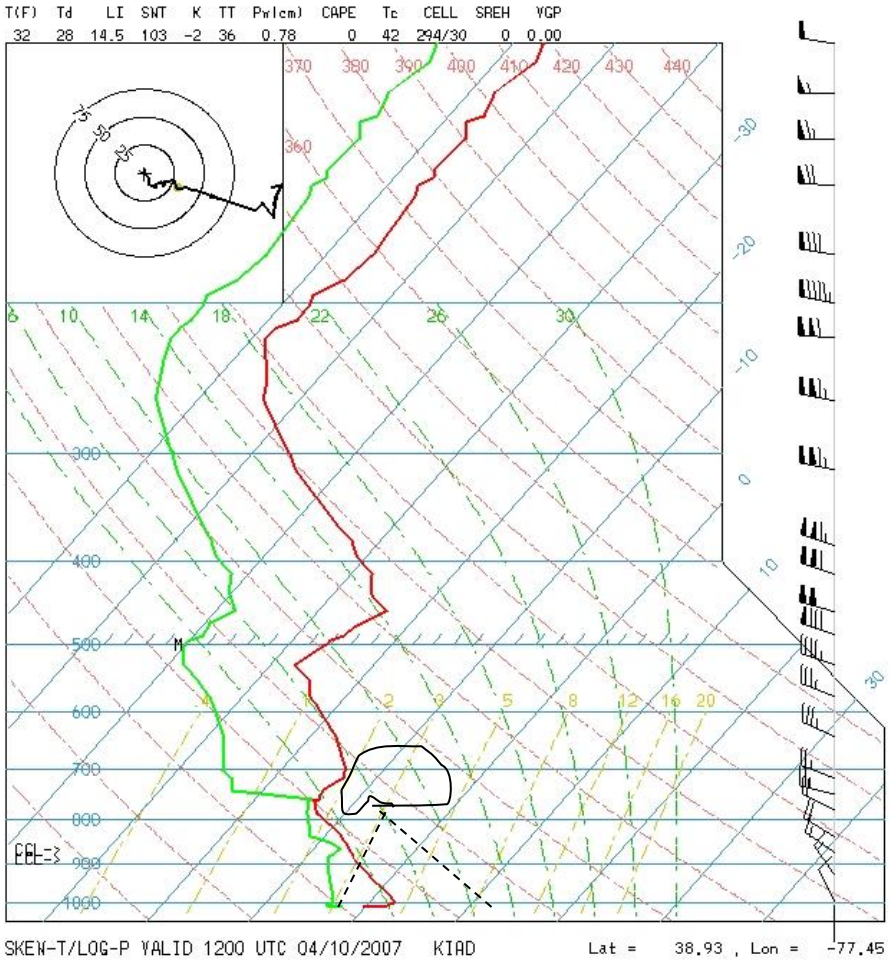
•Morning atmospheric sounding data for IAD and GSO obtained from weather.rap.ucar.edu/weather/upper/

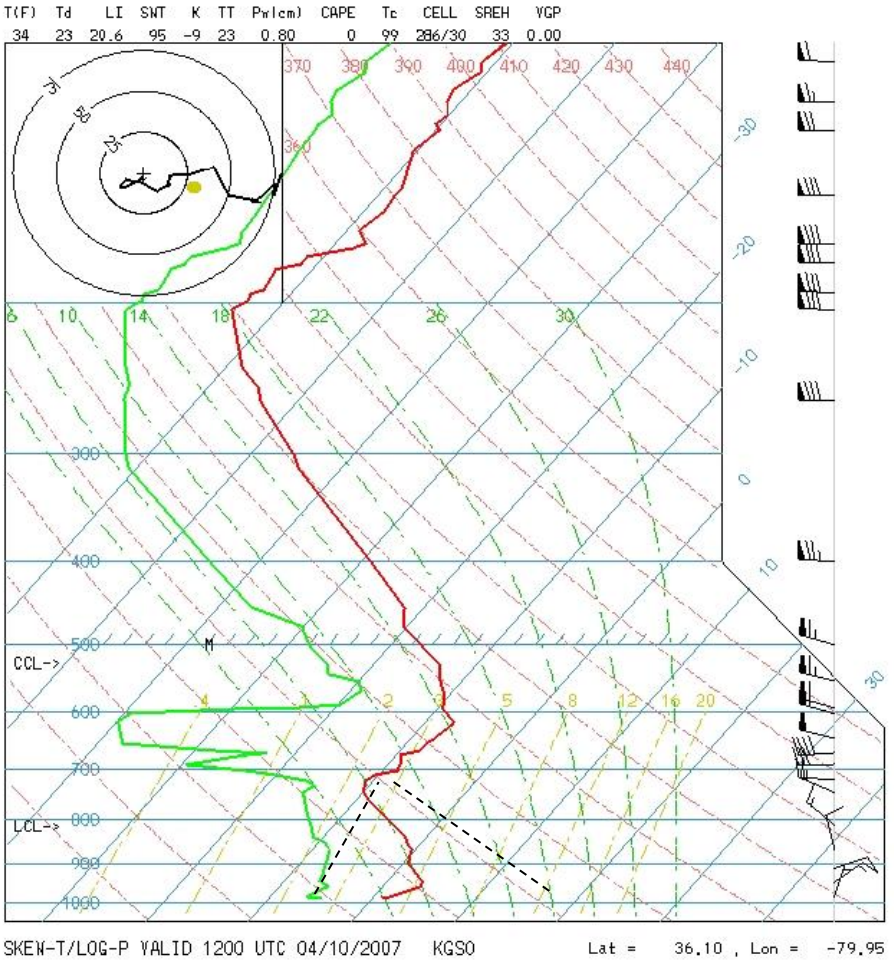


Causes of weather: principles of how clouds form

Cloud formation exercise - analyze the soundings:

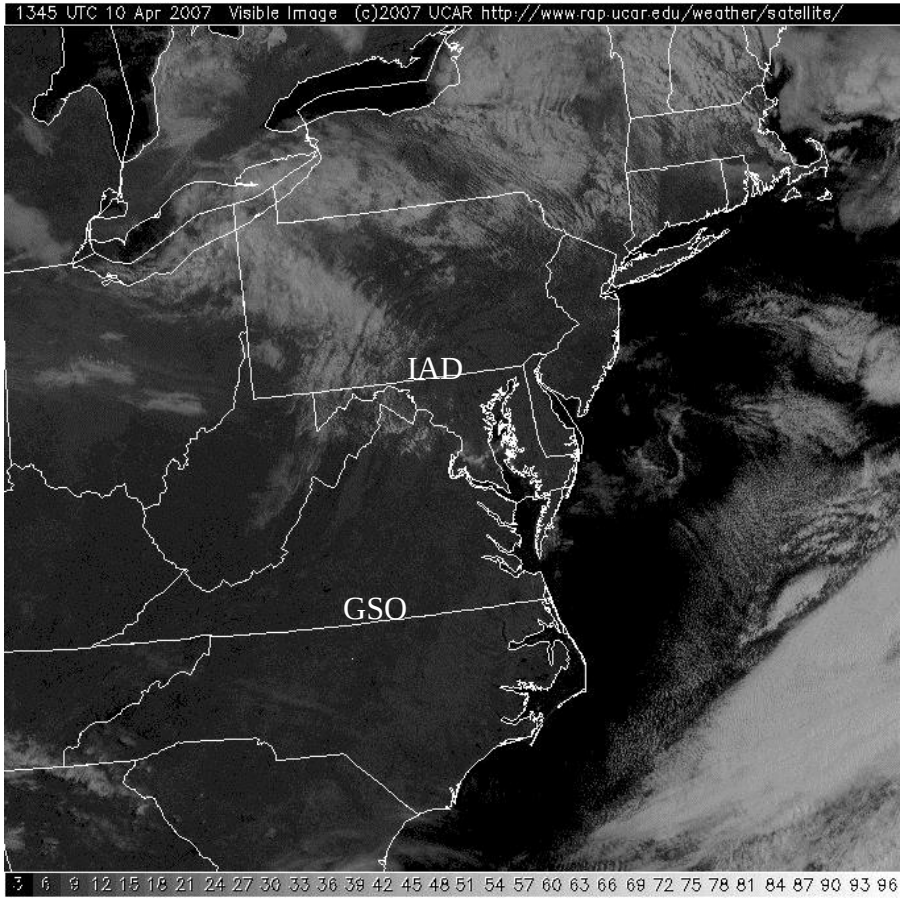
- Plot the surface Td and Tmax values
- Trace up the TdLR slope from the Td value and up the DALR slope from the Tmax value
- If the lines intersect before reaching the temperature inversion, a cumulus cloud will form and vice versa

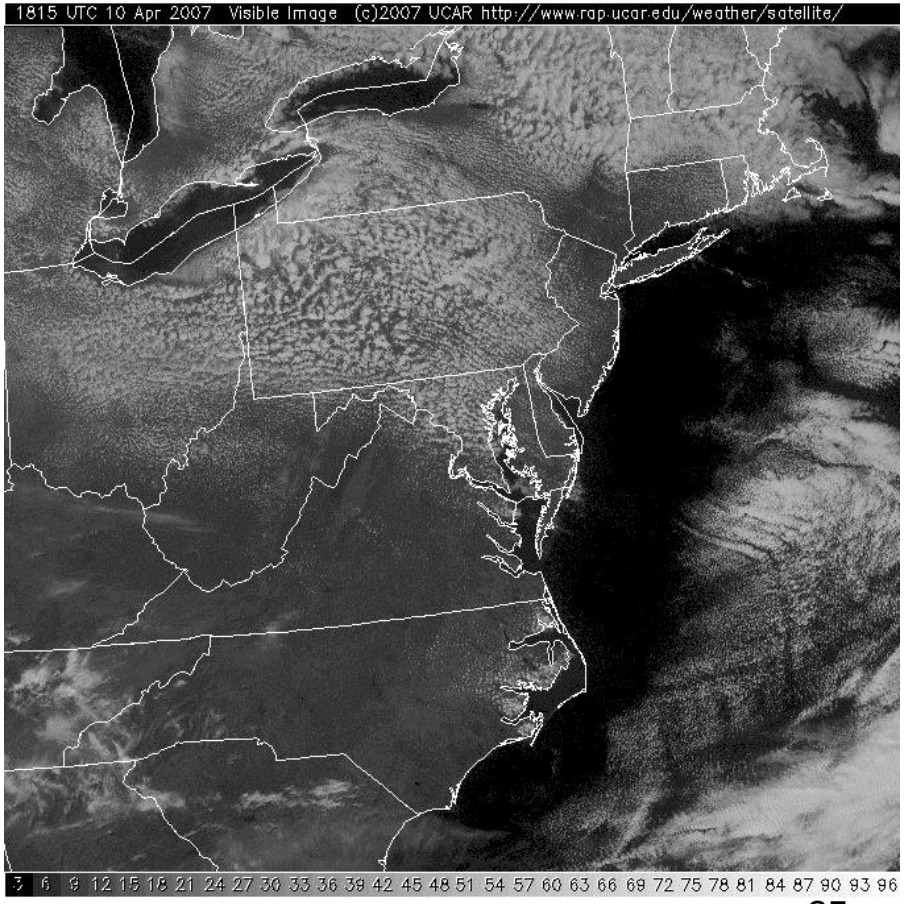




Causes of weather: principles of how clouds form

•Cloud formation exercise – validate the predictions that Cu are expected to form at IAD but not GSO. Early morning (left) and early afternoon (right) visible radiation satellite images centered on Baltimore/Washington Airport (BWI) obtained from www.aviationweather.gov/adds/satellite/:





Causes of weather: principles of how precipitation forms

•Types of precipitation: rain, freezing rain, sleet, snow, hail.

•Two main rain-forming mechanisms: collision and coalescence of cloud droplets (‘warm rain’) and formation of ice crystals which aggregate to form snowflakes which melt (‘cold rain’).

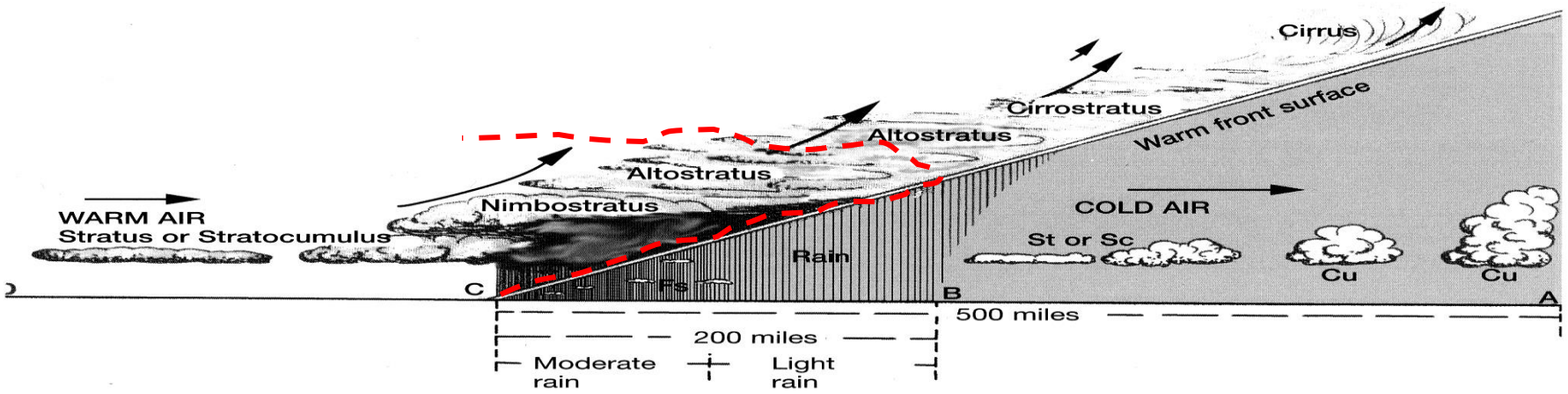
•‘Warm rain’ mechanism active mainly in the Tropics while the ‘Cold rain’ mechanism is active mainly in the Mid-latitudes.

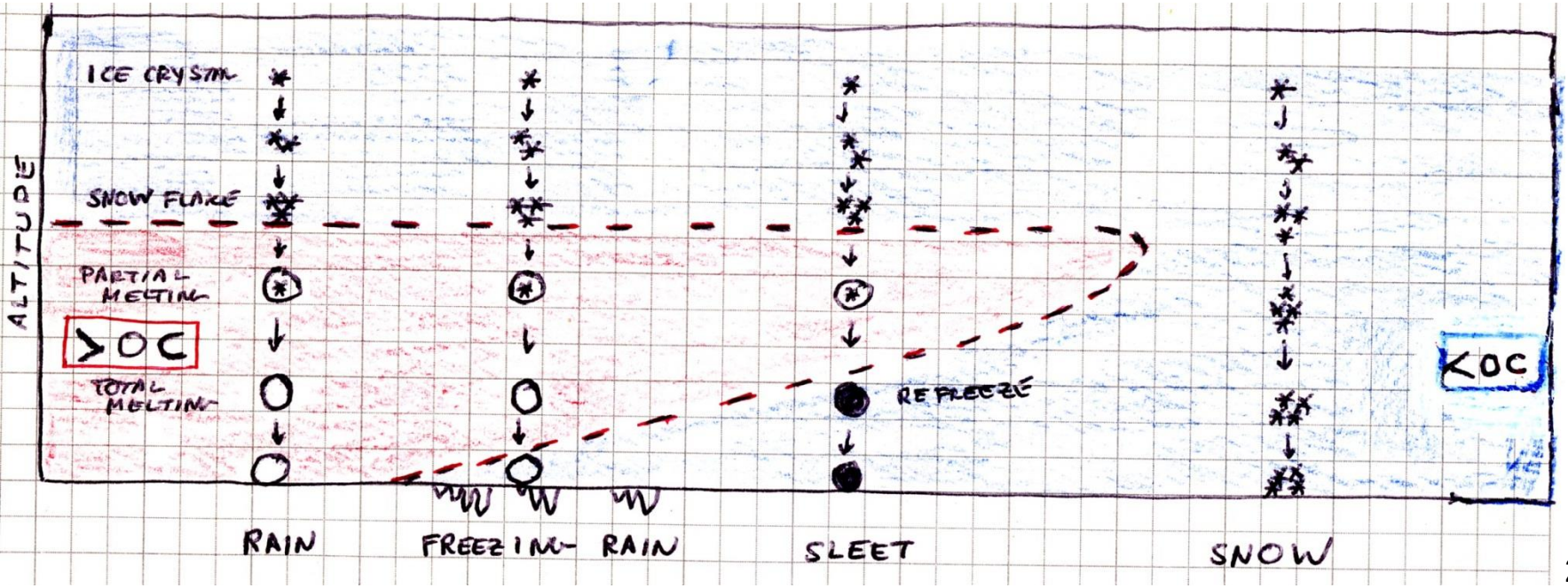
•The Warm front associated with the Mid-latitude cyclone (cyclone detailed later) can produce, simultaneously, rain, freezing rain, sleet and snow.

•Hail is only produced in the Cumulonimbus cloud.

Causes of weather: principles of how precipitation forms

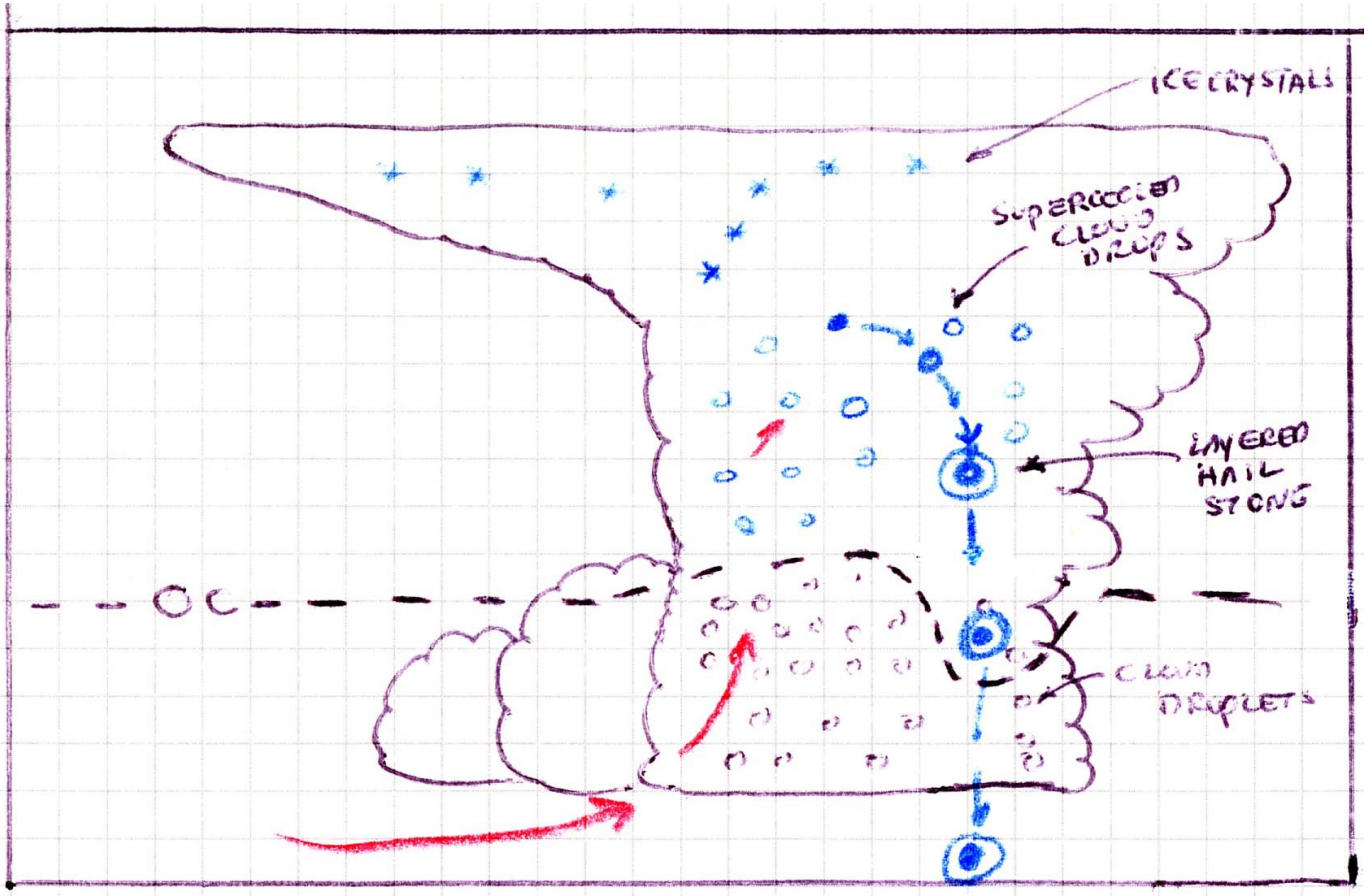
•Formation of rain, freezing rain, sleet and snow:





Causes of weather: principles of how precipitation forms

•Formation of hail:



Causes of weather: haze and fog

•Haze consists of suspended droplets that grow (shrink) with increasing (decreasing) RH. The droplets have not ‘nucleated’ to form fog (cloud) droplets.

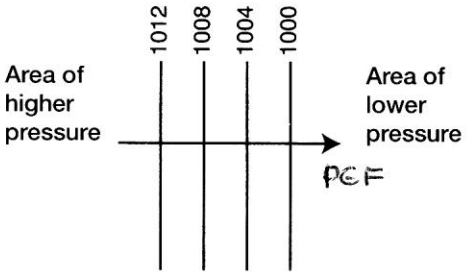
•Fog is a cloud in contact with the surface.

•Fogs form when the atmosphere either cools to the dew-point temperature or moistens to the dew-point temperature:

- •Cools – radiation and advection fogs
- •Moistens – warm frontal fog

Basic atmospheric pressure and wind concepts: local

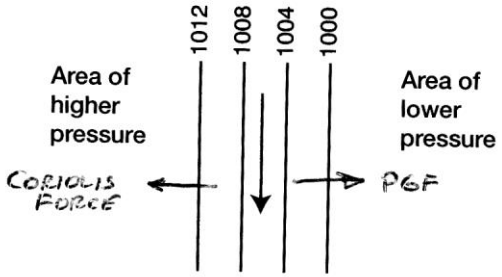
•Wind is the movement of air caused by the pressure-gradient force:



The arrow indicates the direction of the pressure gradient force

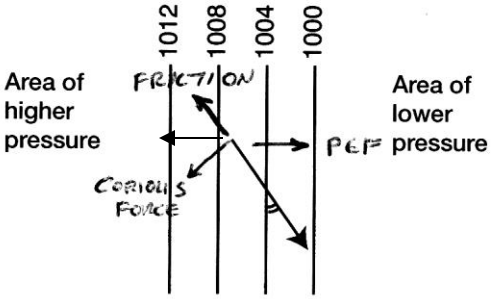
Fig 9.1

•Wind directed by the Coriolis and friction forces:



The arrow indicates the direction of the geostrophic wind in the northern hemisphere

Fig 9.2



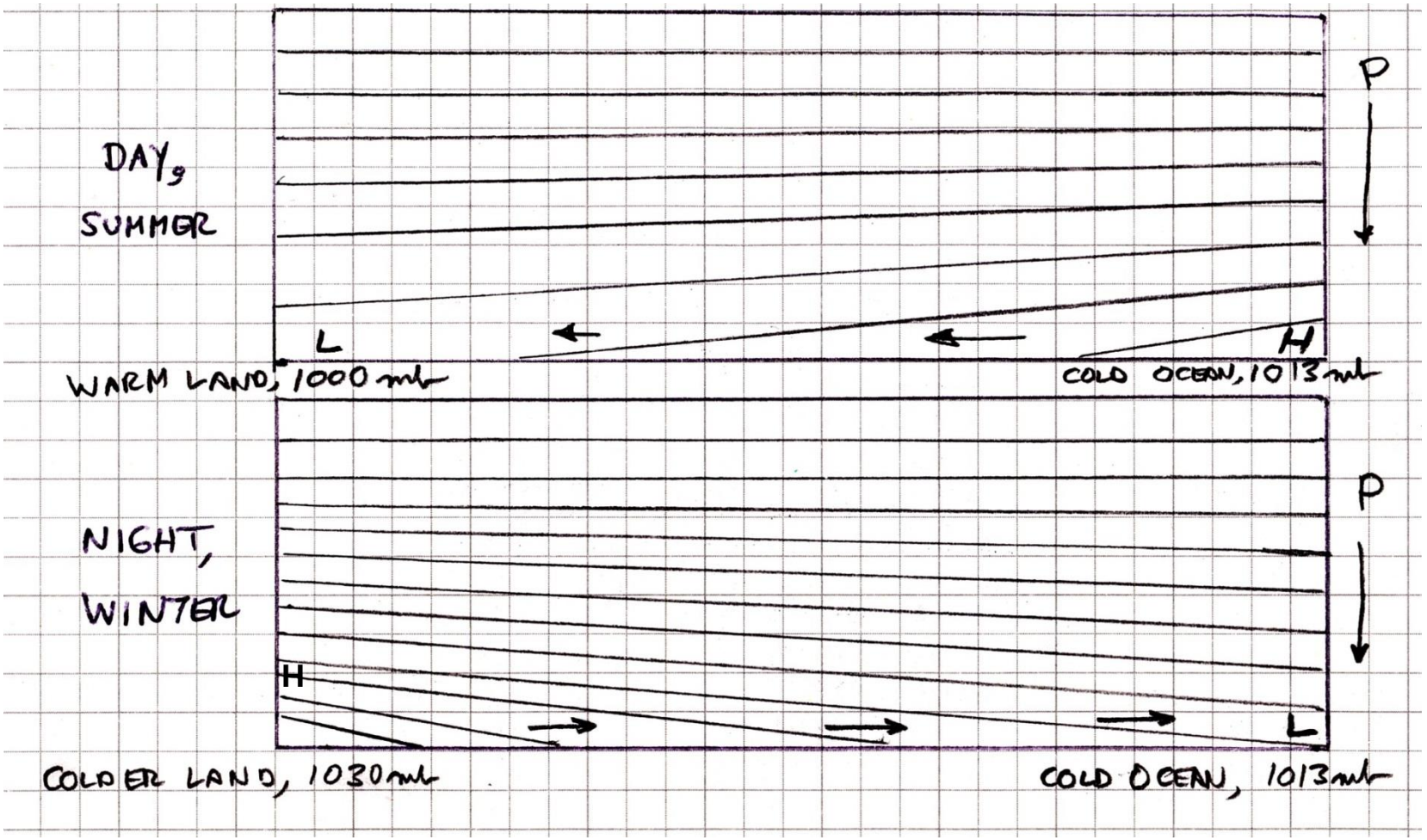
The arrow indicates the direction of the surface wind in the northern hemisphere

Fig 9.4

Buys Ballots law: Back to wind, rotate 30 degrees clockwise, left hand points towards center of low

Basic atmospheric pressure and wind concepts: local

•Temperature affects pressure which, in turn, effects winds:



Houghton discusses this principle in describing the sea-breeze which is developed in "Intermediate Marine Meteorology"

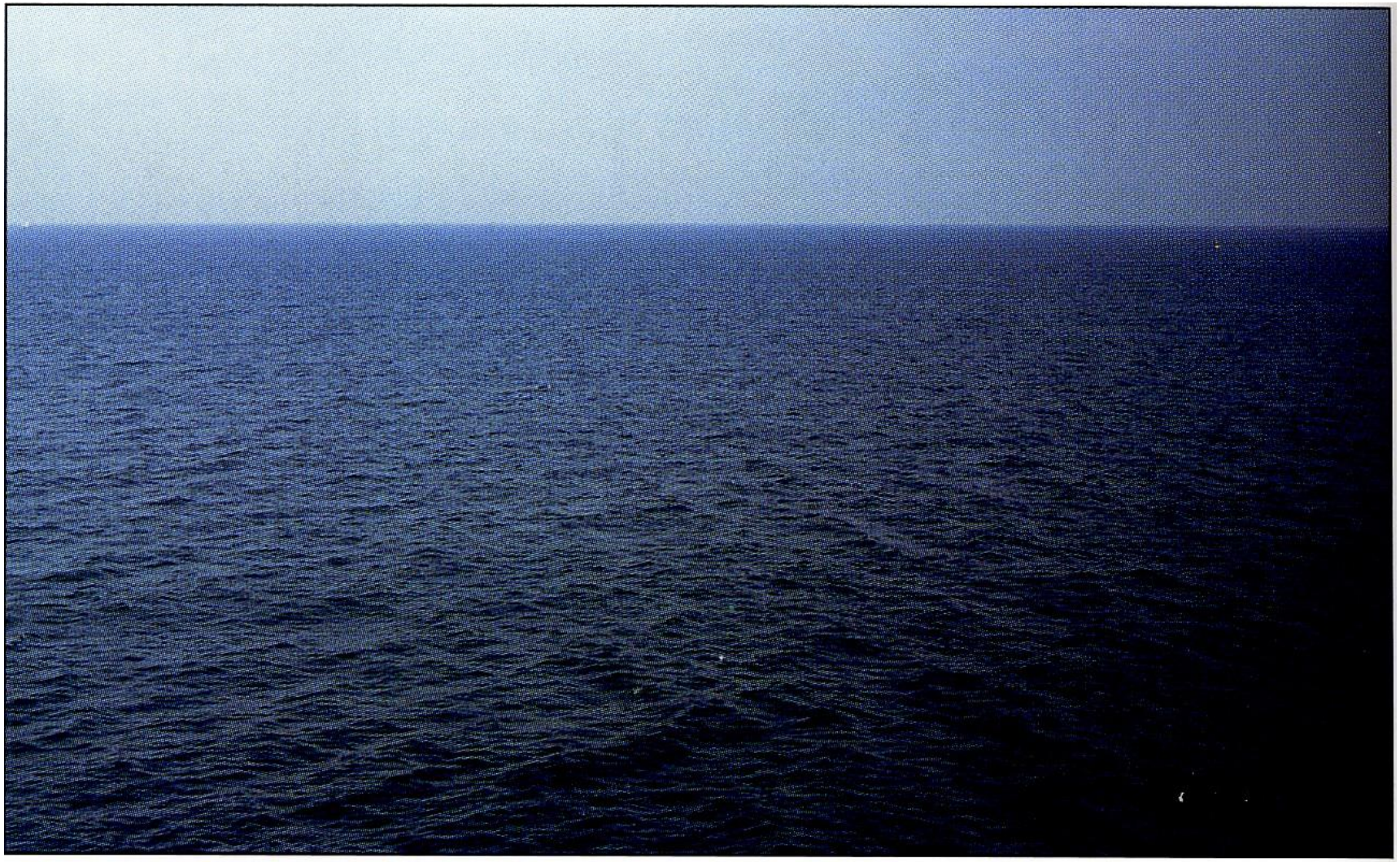
Basic atmospheric pressure and wind concepts: local (Beaufort wind scale)

FORCE 0 (CALM) Wind speed less than 1 knot

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

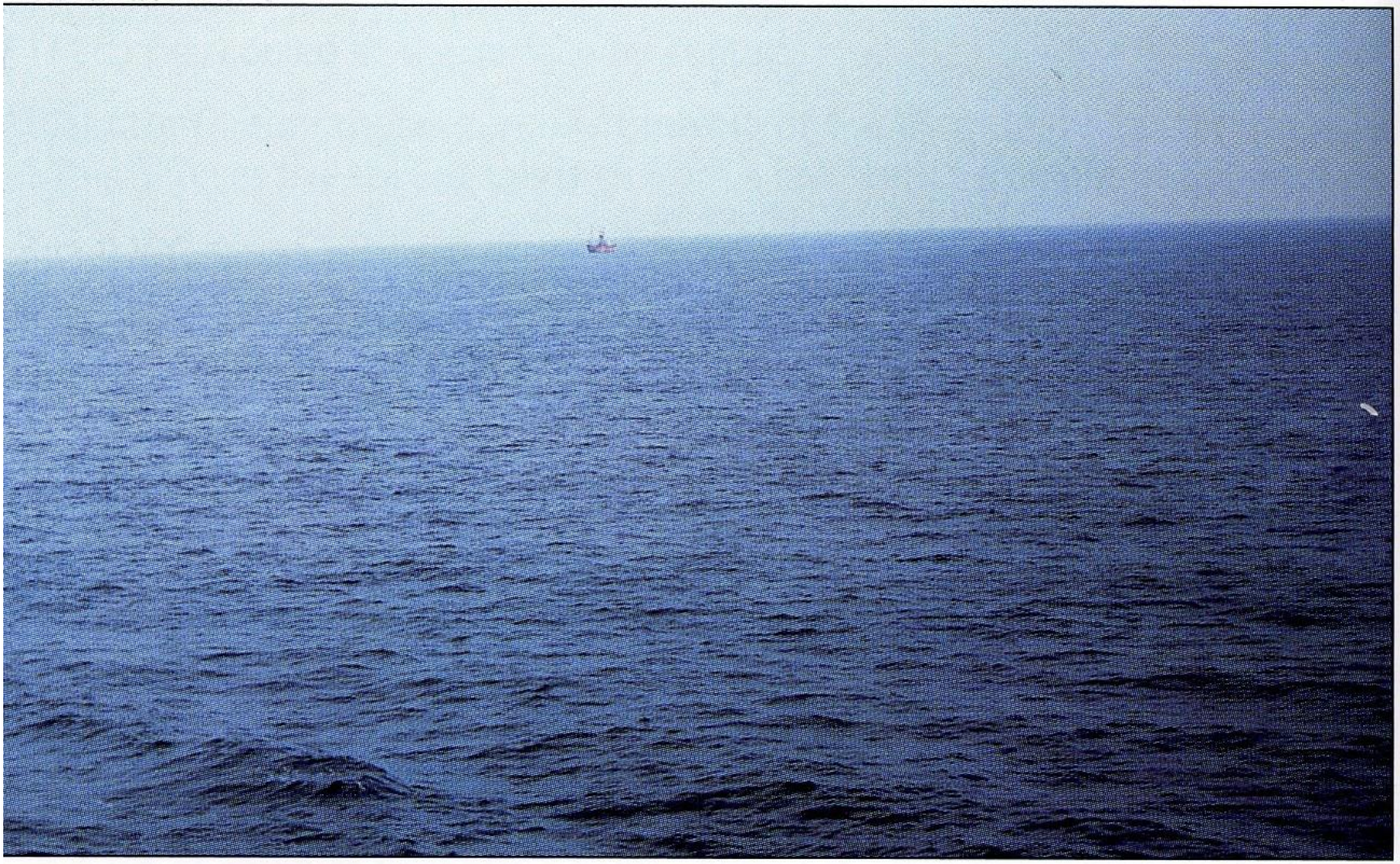
FORCE 1 (LIGHT AIR) Wind speed 1–3 knots: mean, 2 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)



FORCE 2 (LIGHT BREEZE) Wind speed 4–6 knots: mean, 5 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)



FORCE 3 (GENTLE BREEZE) Wind speed 7–10 knots: mean, 9 knots

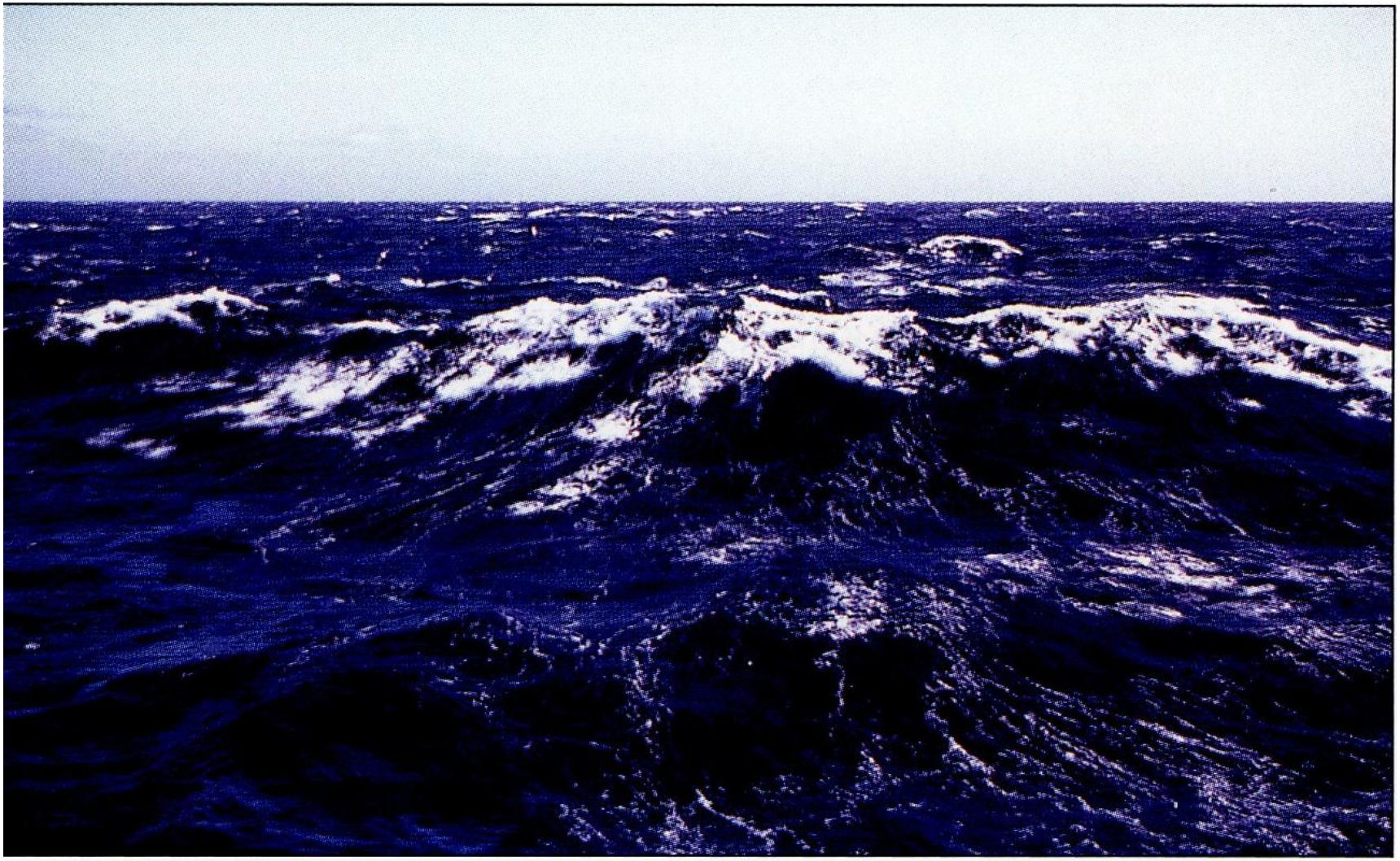
Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

FORCE 4 (MODERATE BREEZE) | Wind speed 11–16 knots: mean, 13 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

FORCE 5 (FRESH BREEZE) | Wind speed 17–21 knots: mean, 19 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)



FORCE 6 (STRONG BREEZE) Wind speed 22–27 knots: mean, 24 knots

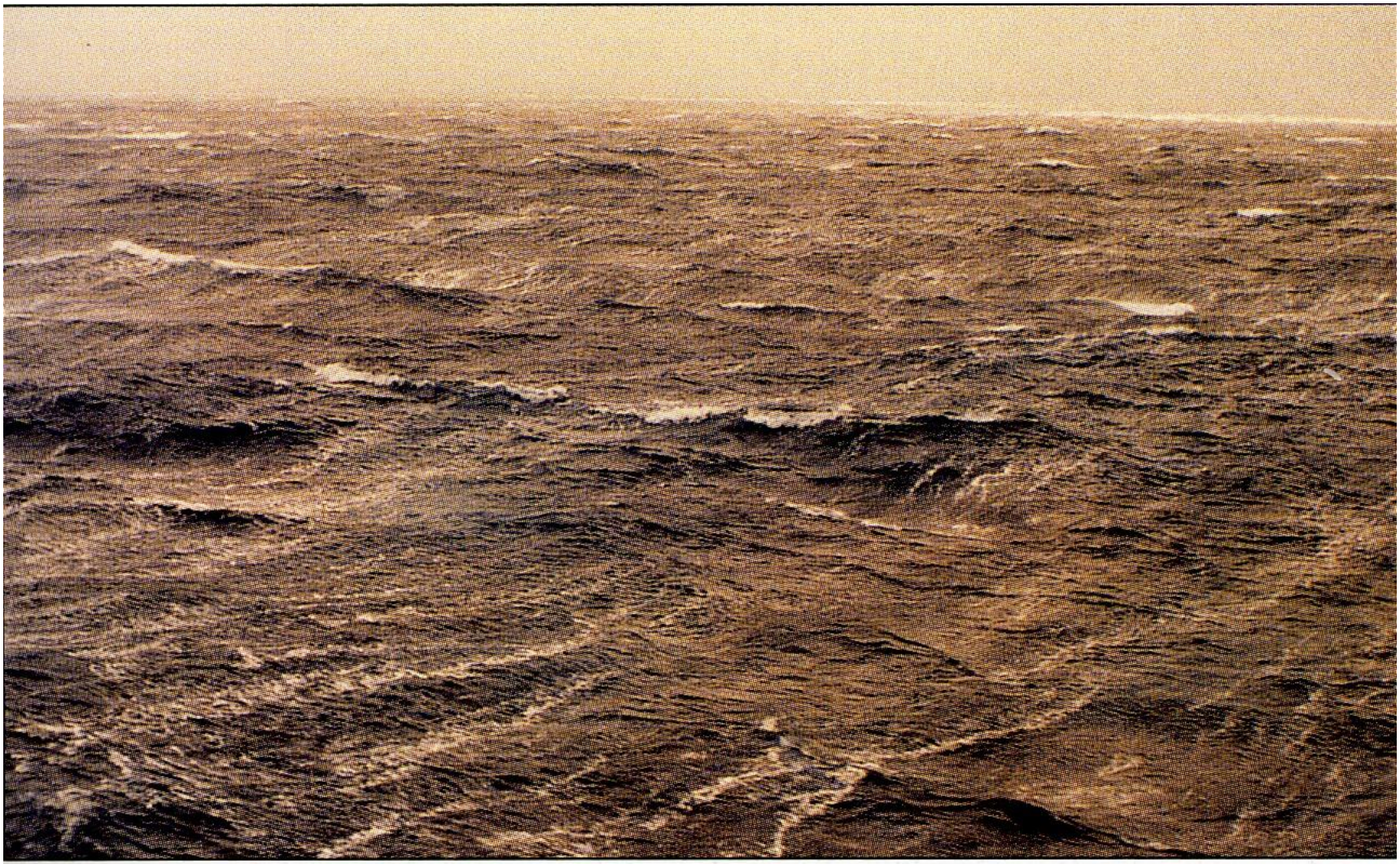
Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

FORCE 7 (NEAR GALE) Wind speed 28–33 knots: mean, 30 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

FORCE 8 (GALE) Wind speed 34–40 knots: mean, 37 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

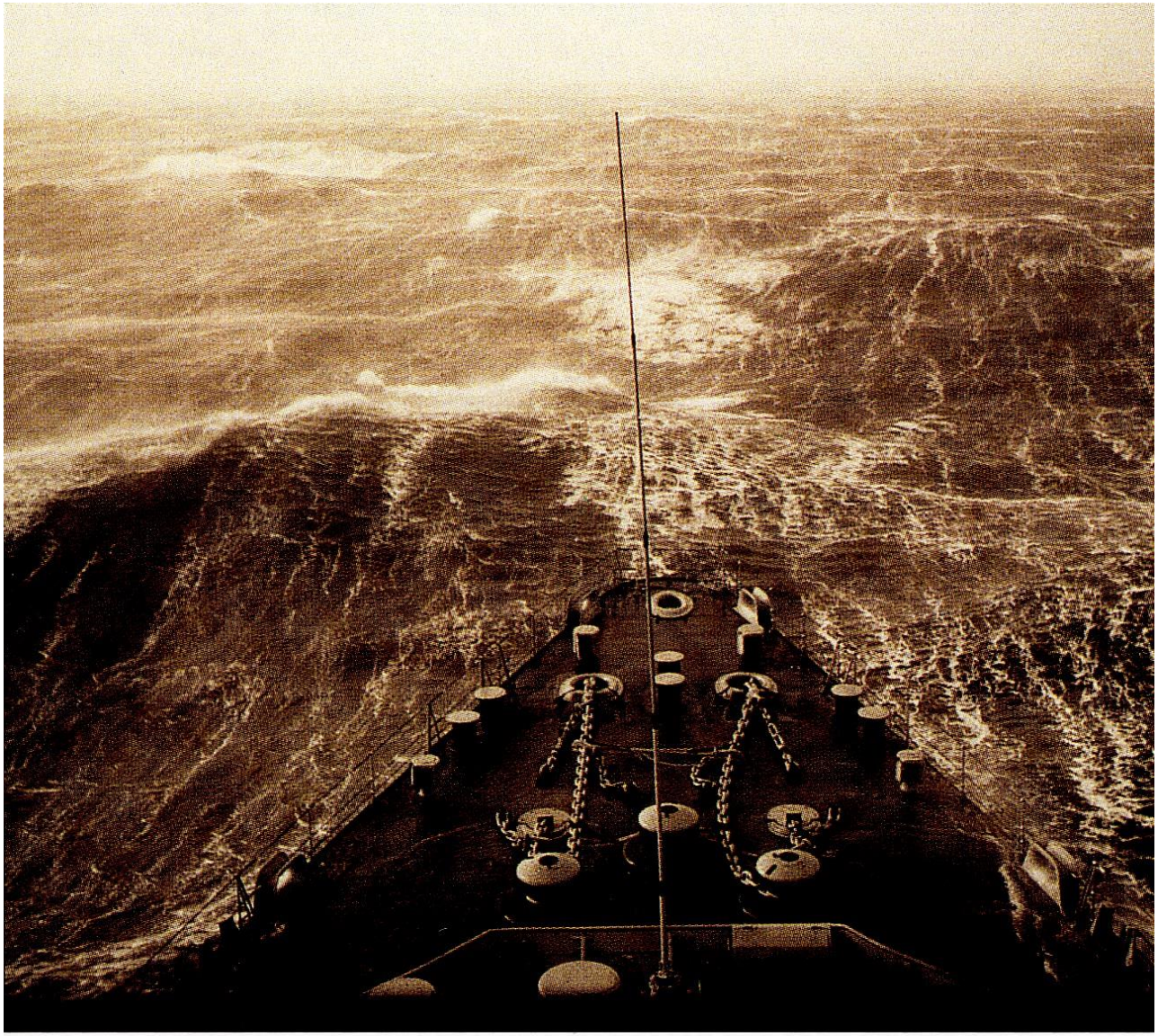


FORCE 9 (STRONG GALE) Wind speed 41–47 knots: mean, 44 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)

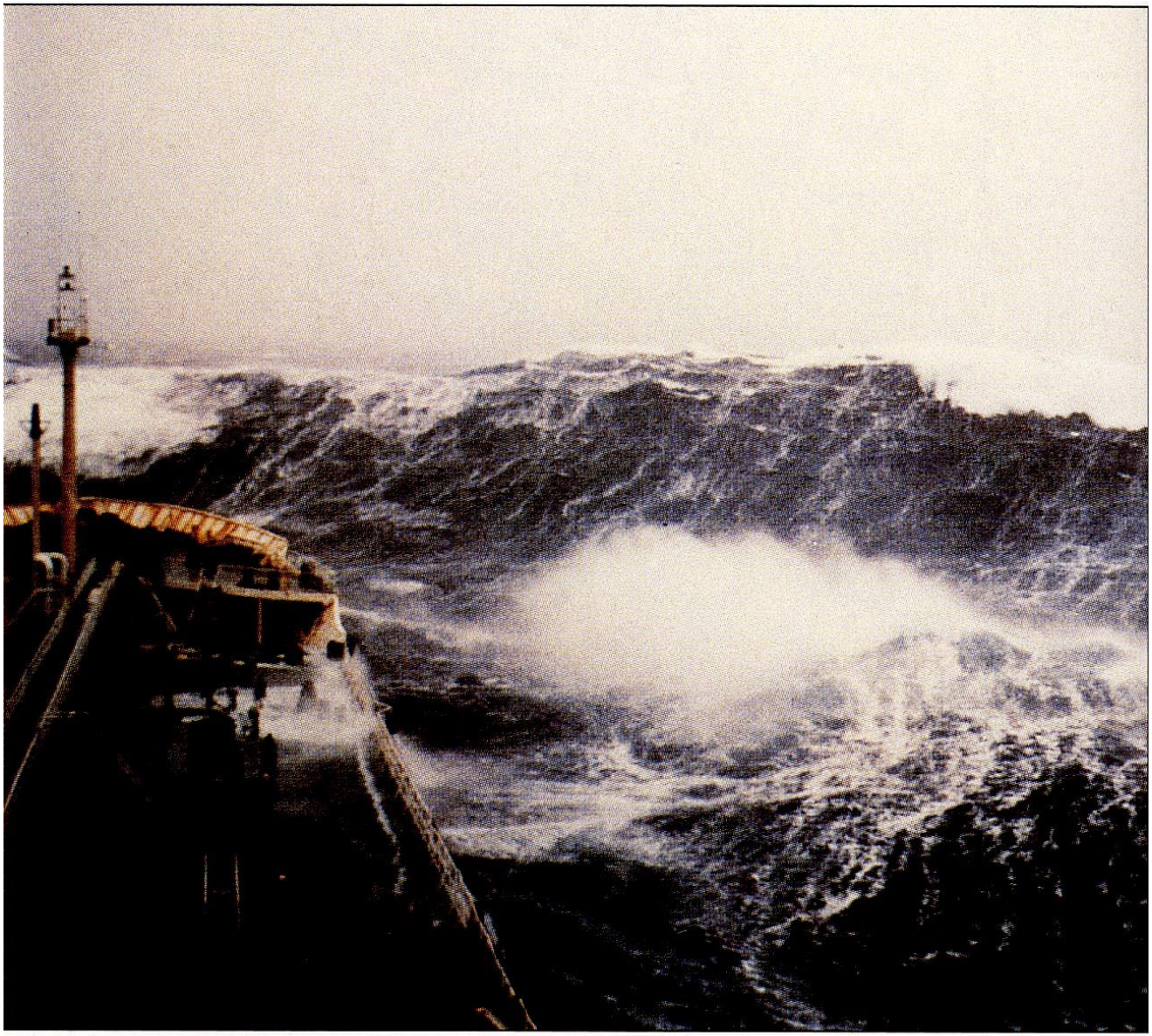
FORCE 10 (STORM) Wind speed 48–55 knots: mean, 52 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)



FORCE 11 (VIOLENT STORM) Wind speed 56-63 knots: mean, 60 knots

Basic atmospheric pressure and wind concepts: local (Beaufort wind scale, contd.)



FORCE 12 (HURRICANE) Wind speed greater than 63 knots

Basic atmospheric pressure and wind concepts: global

•Uneven heating of the Earth's surface produces semi-permanent high and low pressure regions and the resulting global wind system:

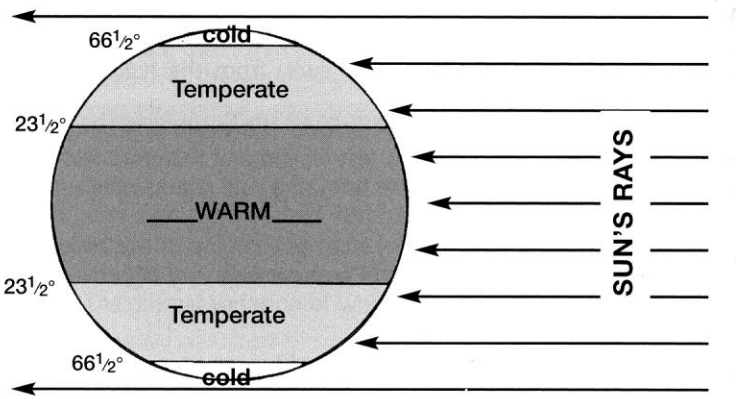


Fig 9.6

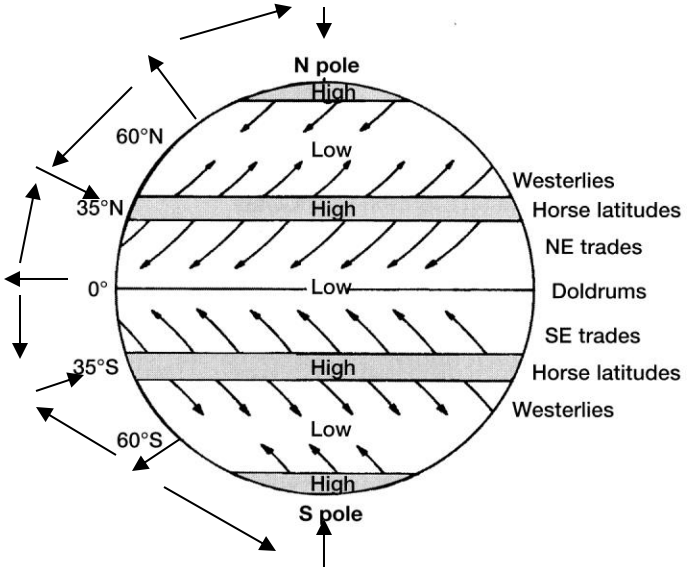


Fig 9.7

Basic atmospheric pressure and wind concepts: global

•The Earth's seasons modulate the semi-permanent pressure regions:

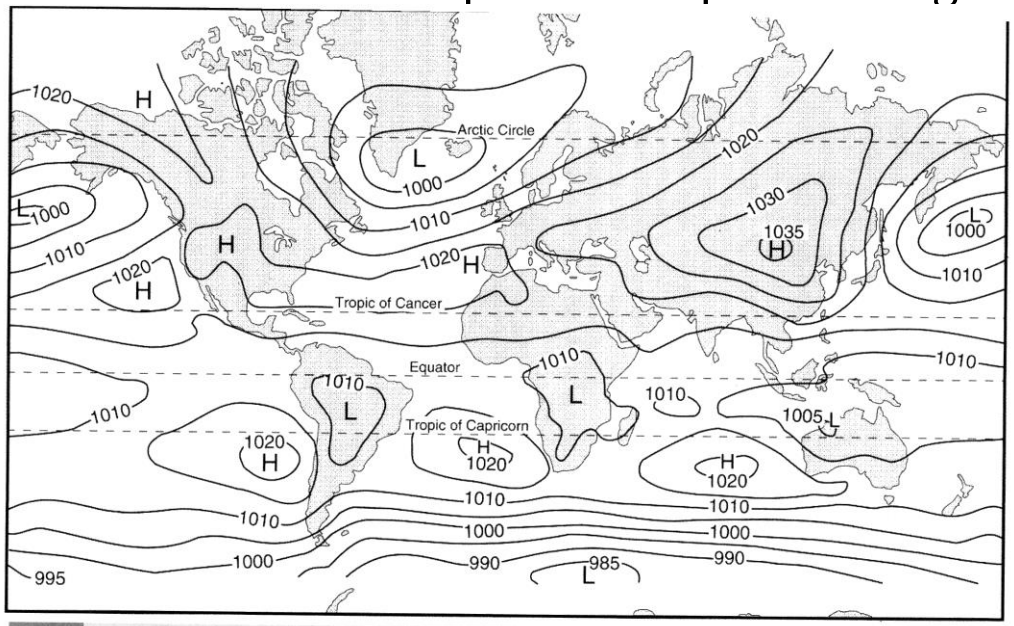


Fig 9.8 *Average pressure at mean sea level in January.*

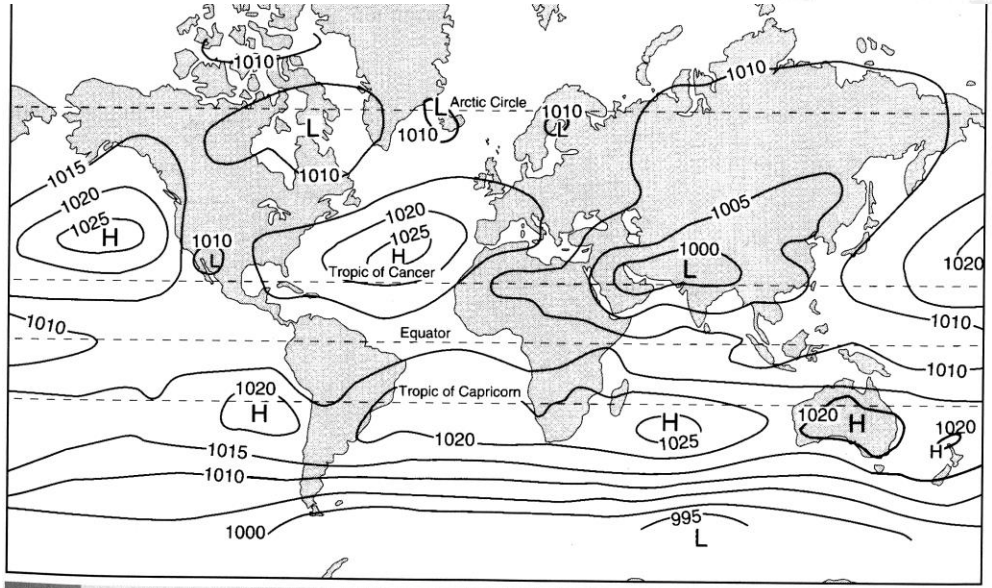


Fig 9.9 *Average pressure at mean sea level in July.*

Basic atmospheric pressure and wind concepts: global

•The Earth's seasons modulate the semi-permanent wind systems:

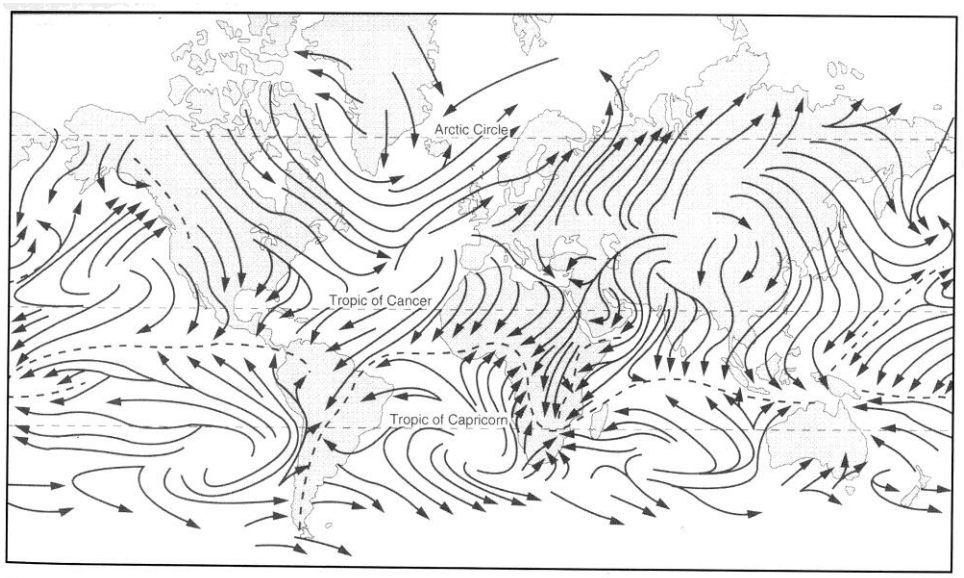


Fig 9.10 *Mean surface winds in January.*

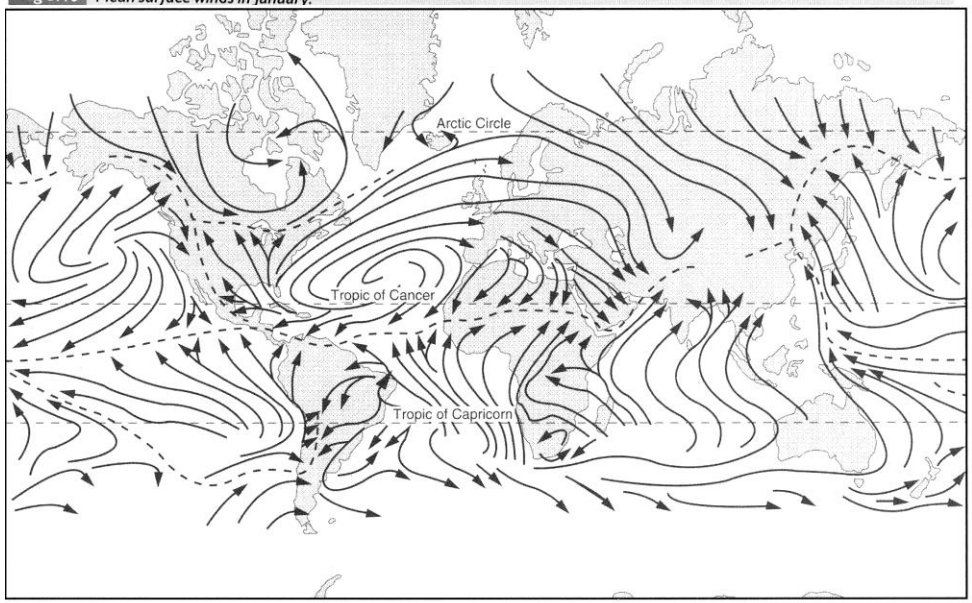


Fig 9.11 *Mean surface winds in July.*

Surface weather maps: lows and troughs

•In regions of low pressure (British call depressions) at the surface in the NH, the air spirals inward, counter-clockwise (clockwise in SH), the air rises, cools and condensation and precipitation occur.

•Troughs are 'cyclonic kinks' in the isobars.

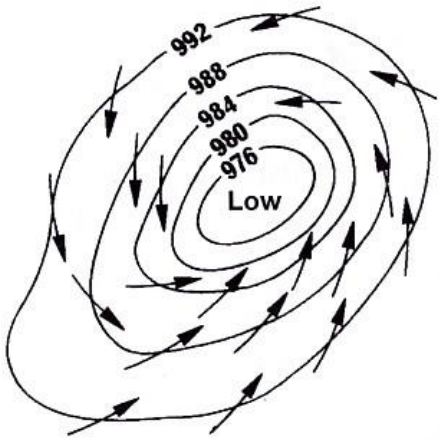


Fig 12.1 *The Isobaric pattern of a depression*

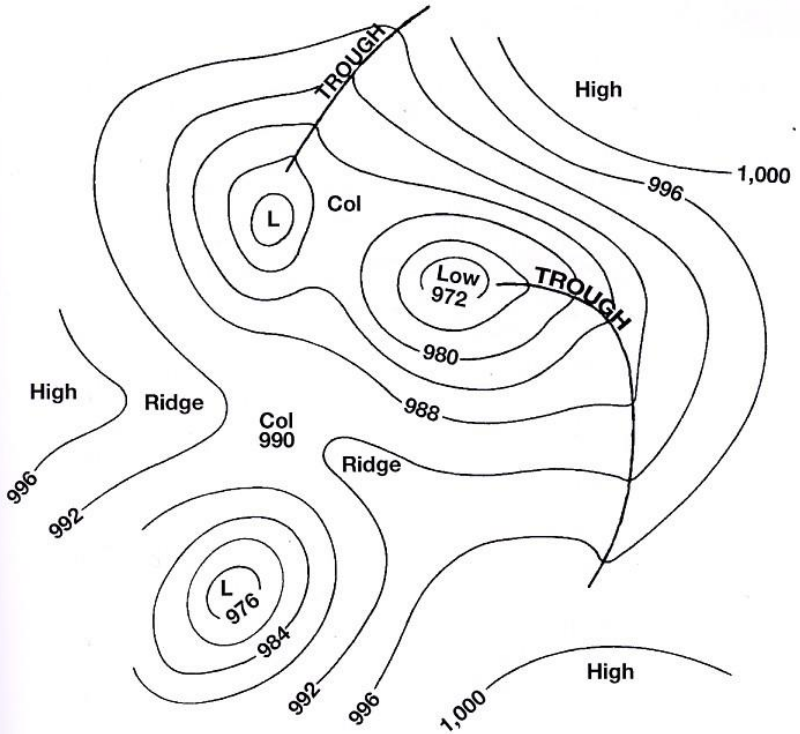


Fig 12.6 *Isobaric pattern illustrating high, low, trough, ridge and col.*

Surface weather maps: highs and ridges

•In regions of high pressure (British call anticyclones) at the surface in the NH, the air spirals outward, clockwise (counter-clockwise in SH), the air descends, warms and clouds and precipitation evaporate.

•Ridges are ‘anti-cyclonic kinks’ in the isobars.

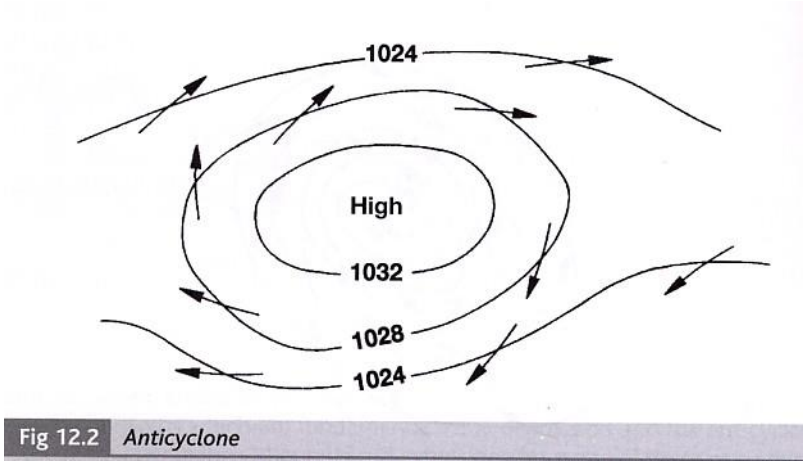


Fig 12.2 *Anticyclone*

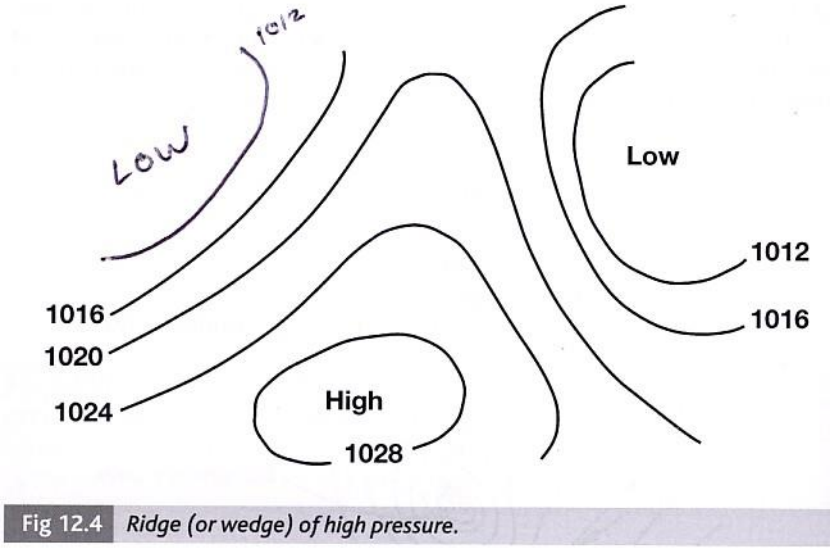


Fig 12.4 *Ridge (or wedge) of high pressure.*

Surface weather maps: air masses

•An 'air mass' is a region at the Earth's surface with relatively uniform temperature and moisture content. Hence, there are four major air masses: cold and dry (Pc), cold and moist (Pm), warm and dry (Tc) and warm and moist (Tm):

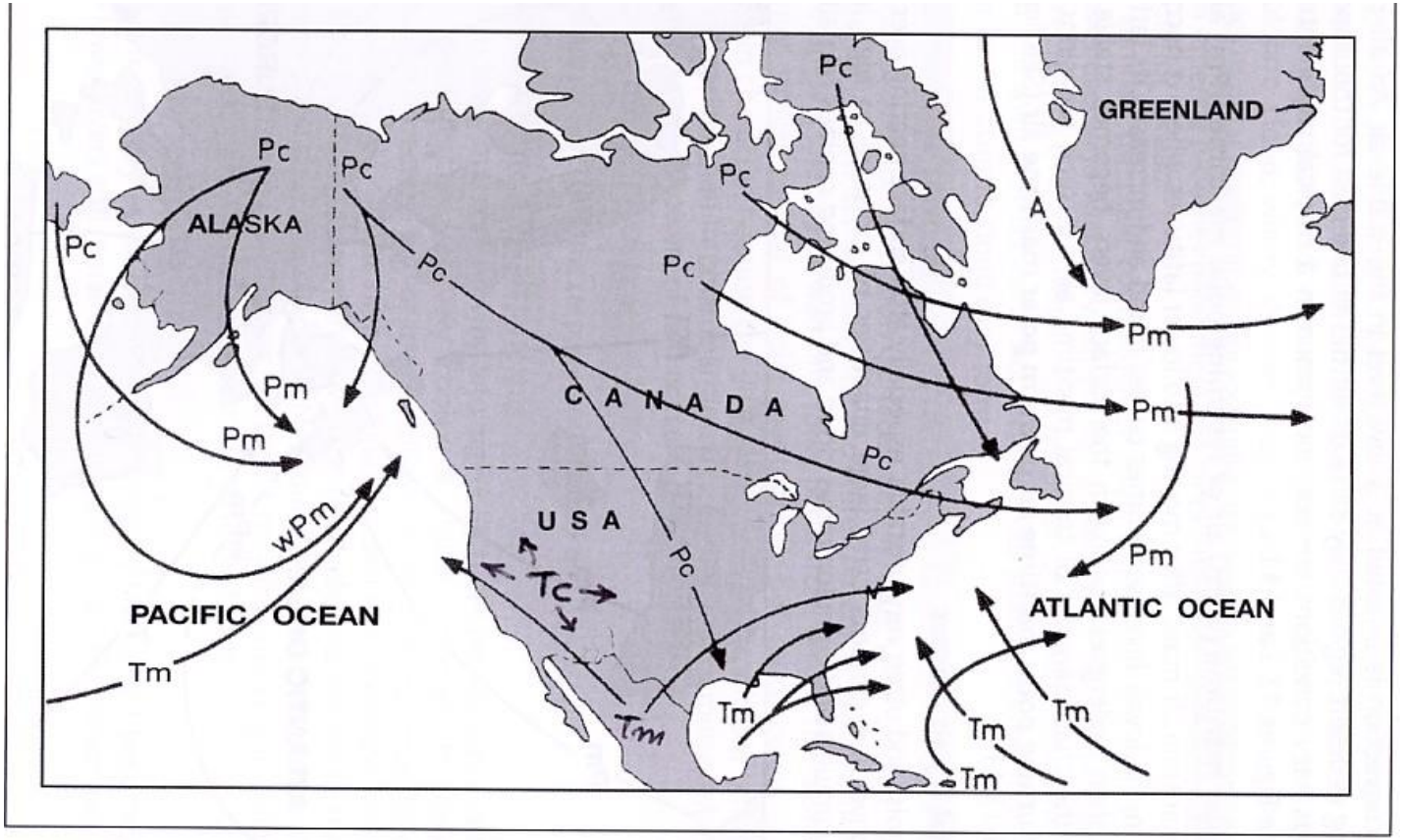


Fig 11.4 *Some paths of typical air masses of the N American continent and adjacent waters*

Surface weather maps: fronts

•A front is a boundary between two air masses Polar (P) and Tropical (T); the main front is called the Polar Front (PF).

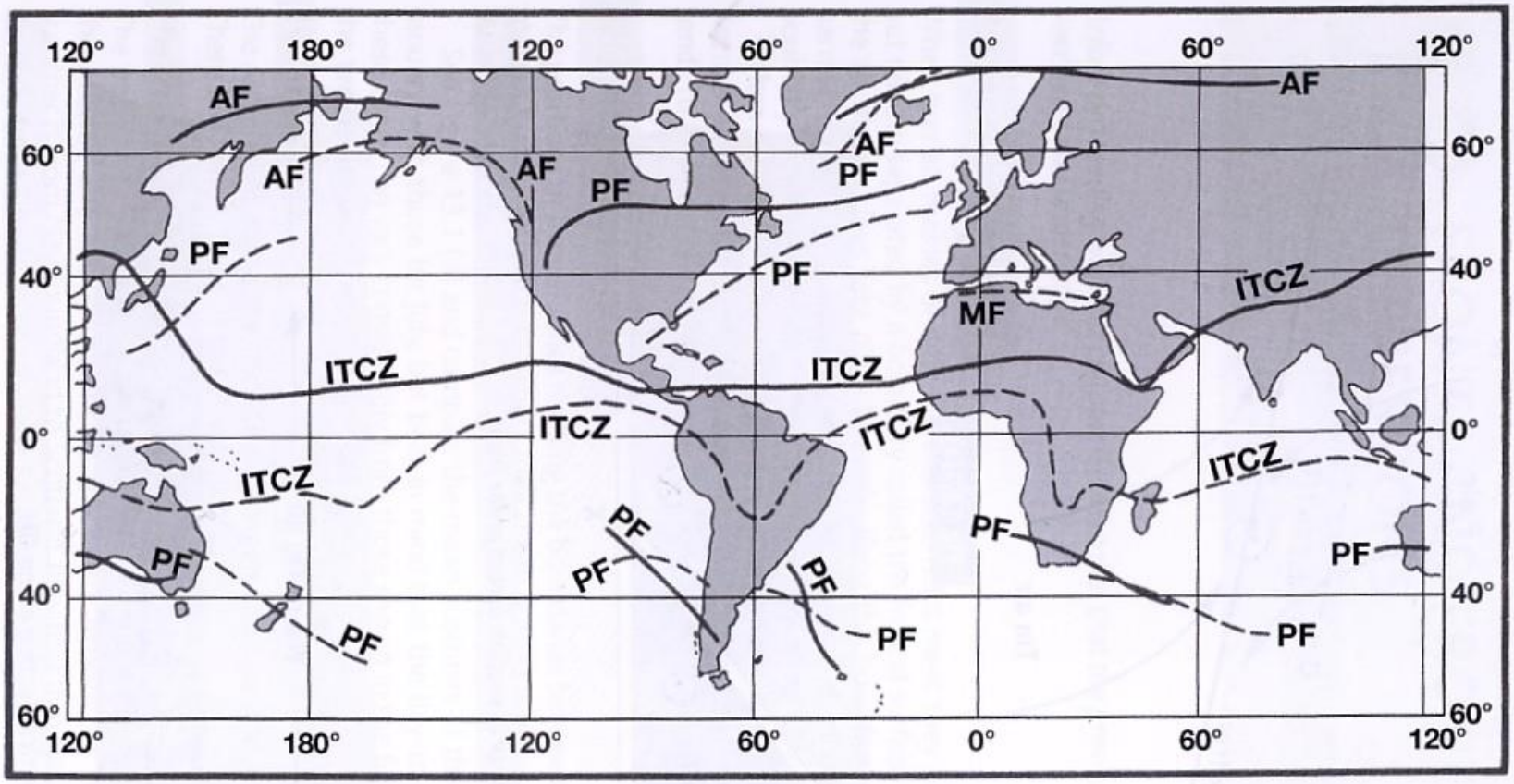


Fig 13.1(d) *Approximate mean positions of frontal zones.*

Surface weather maps: fronts

The segments of the Polar Front are named for the invading air mass:

- Cold front - Pc replacing Tm
- Warm front -Tm replacing Pm
- Occluded front - either Pc replacing Pm or Pm replacing Pc
- Stationary front – no movement of the air masses

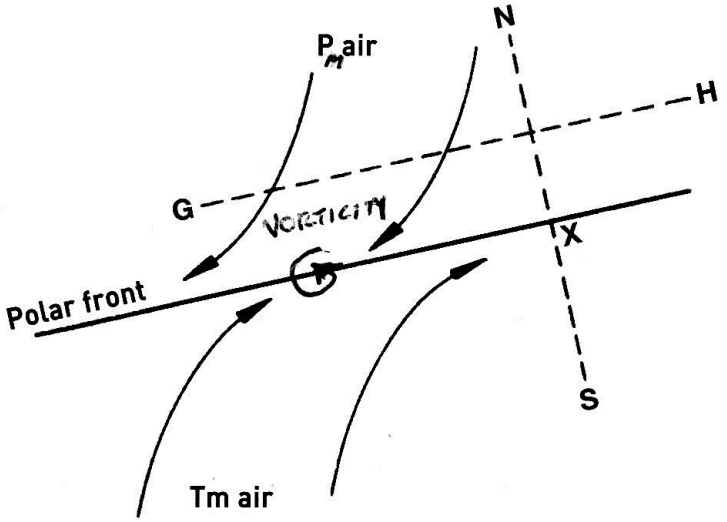


Fig 13.1(a)

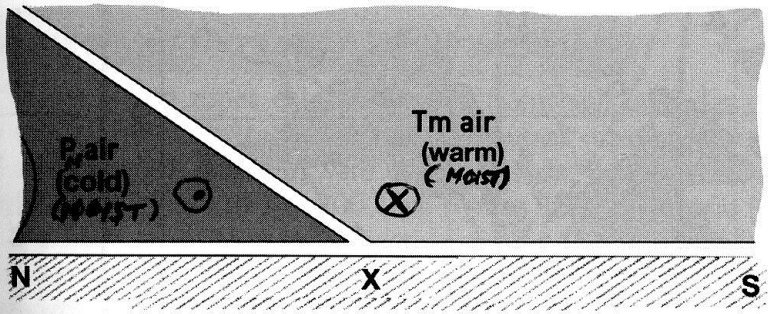


Fig 13.1(b) *Vertical section across polar front.*

Surface weather maps: fronts

•Cold front - Pc replacing Tm

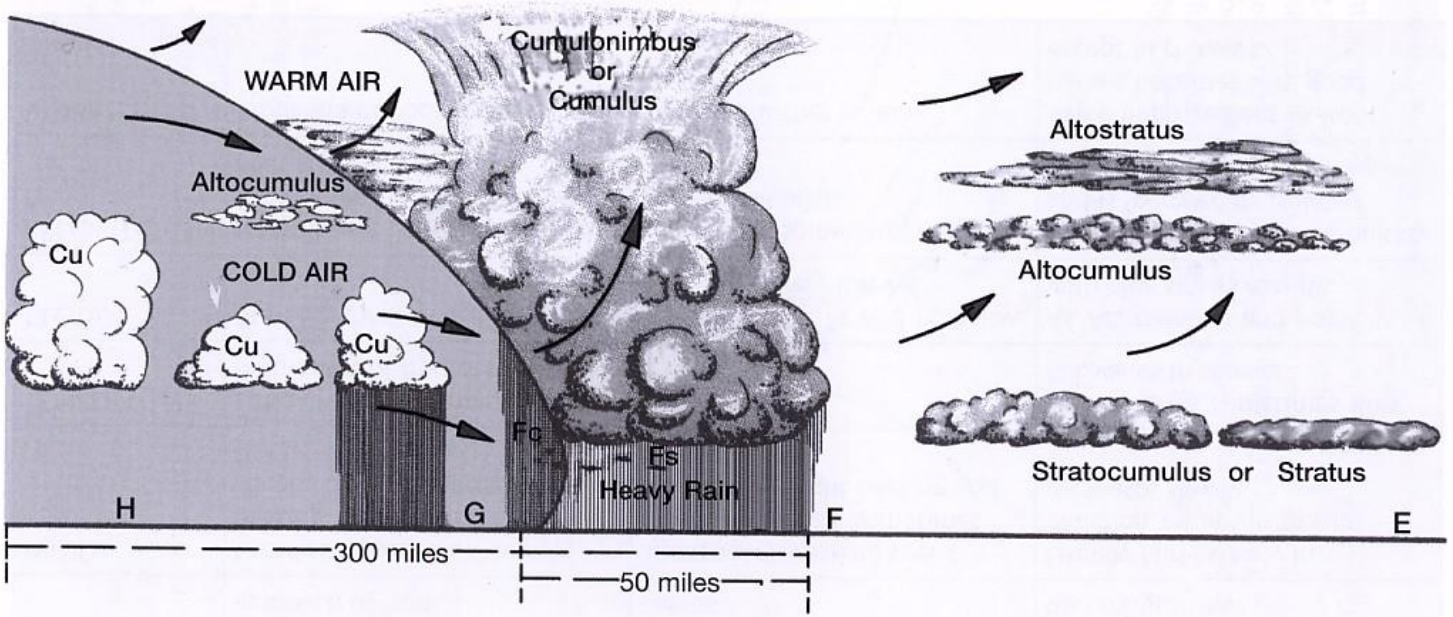


Fig 13.5 *Vertical section across an average cold front.*

Quick to come , quick to pass……

Surface weather maps: fronts

•Warm front -Tm replacing Pm

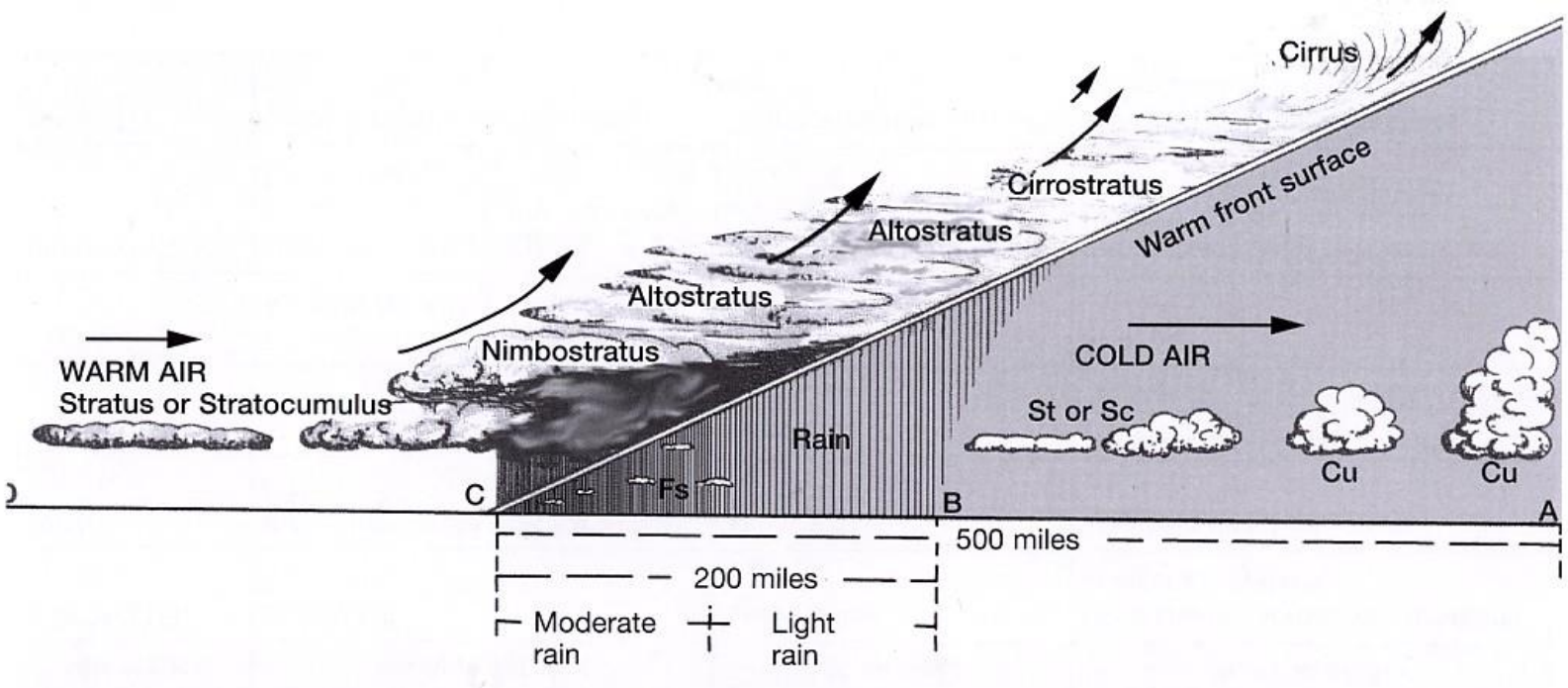


Fig 13.4 *Vertical section across an average warm front.*

…….Slow to come, slow to pass.

Surface weather maps: fronts

•Occluded front - either Pc replacing Pm or Pm replacing Pc

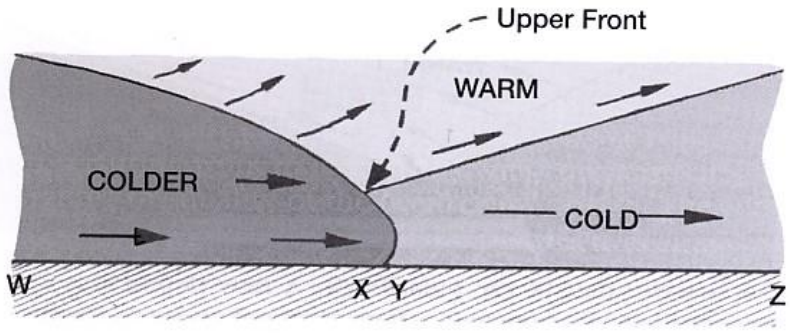


Fig 13.9(b) *Vertical section across cold occlusion.* (East coast USA)

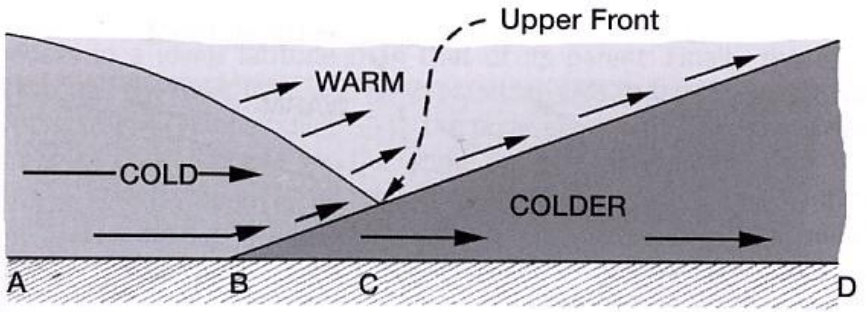


Fig 13.8(b) *Vertical section across warm occlusion.* (West coast USA)

Surface weather maps: fronts – 'birth', 'mature' and 'death'

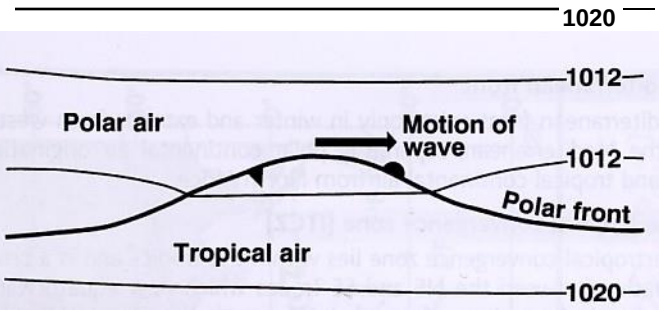


Fig 13.2 *Birth of a depression on polar front.*

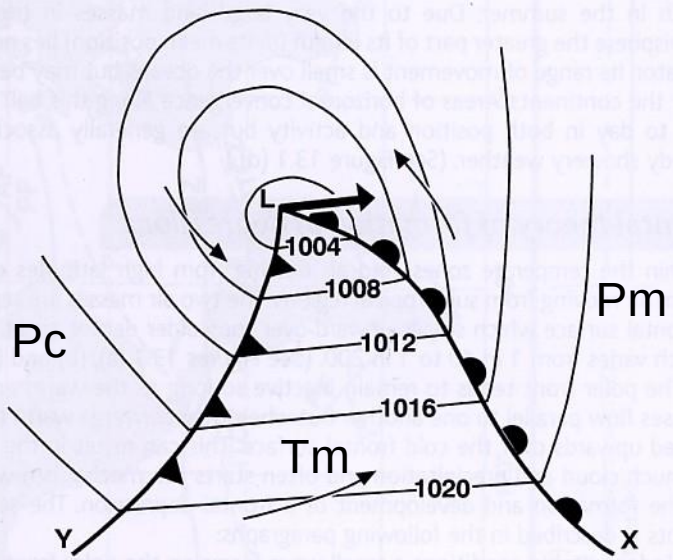


Fig 13.3 *Early development.*

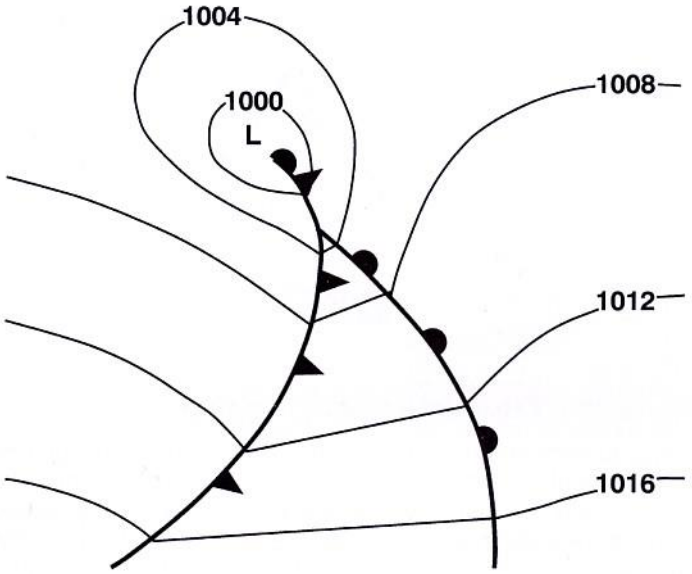


Fig 13.6 ***Occlusion begins (mature)***

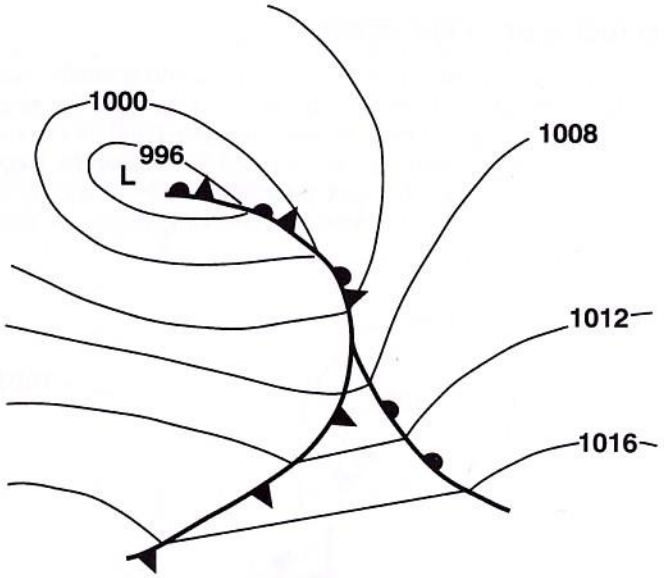
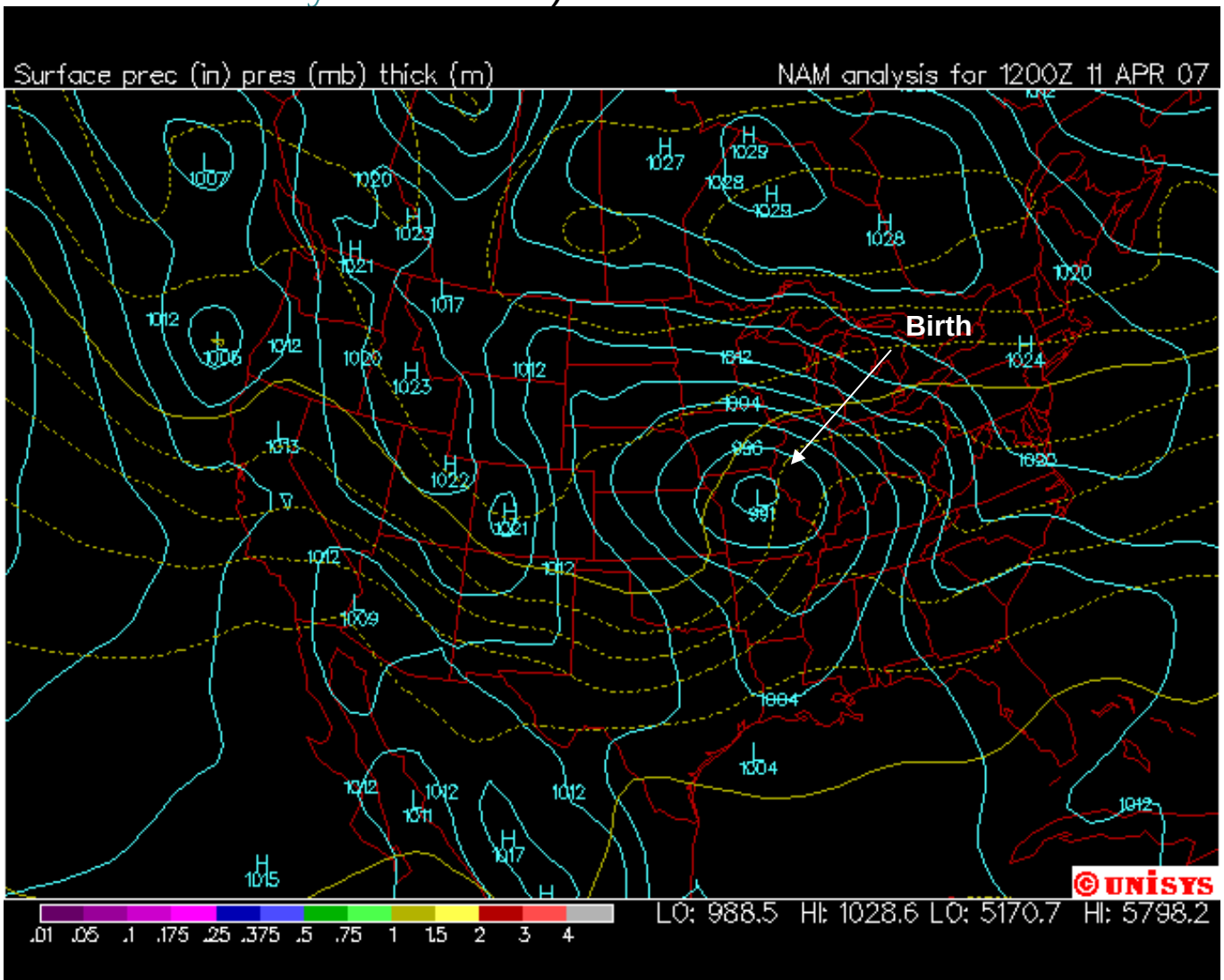


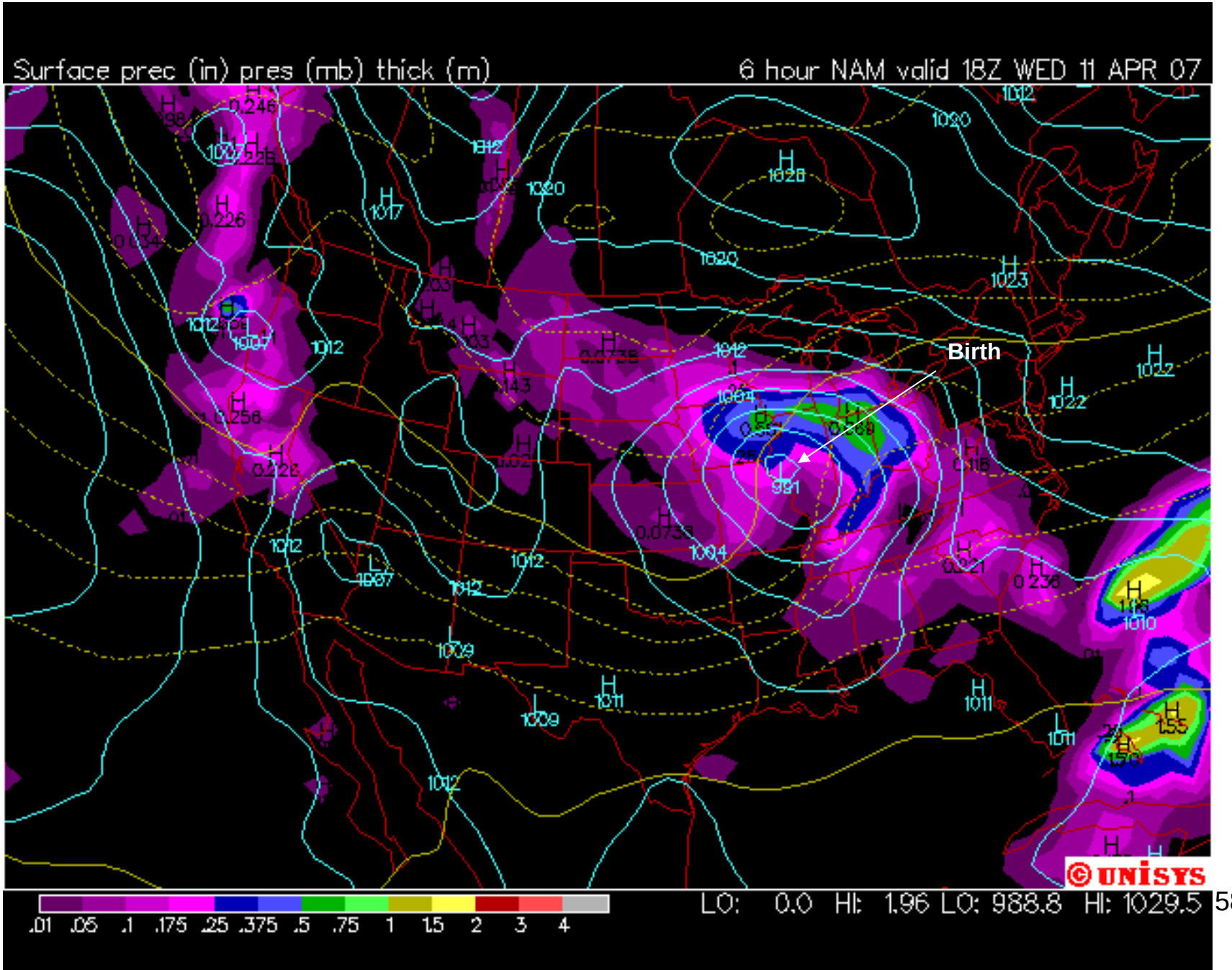
Fig 13.7 ***Deepens then begins to fill; 'death'***

Surface weather maps: fronts – virtual 'field trip'

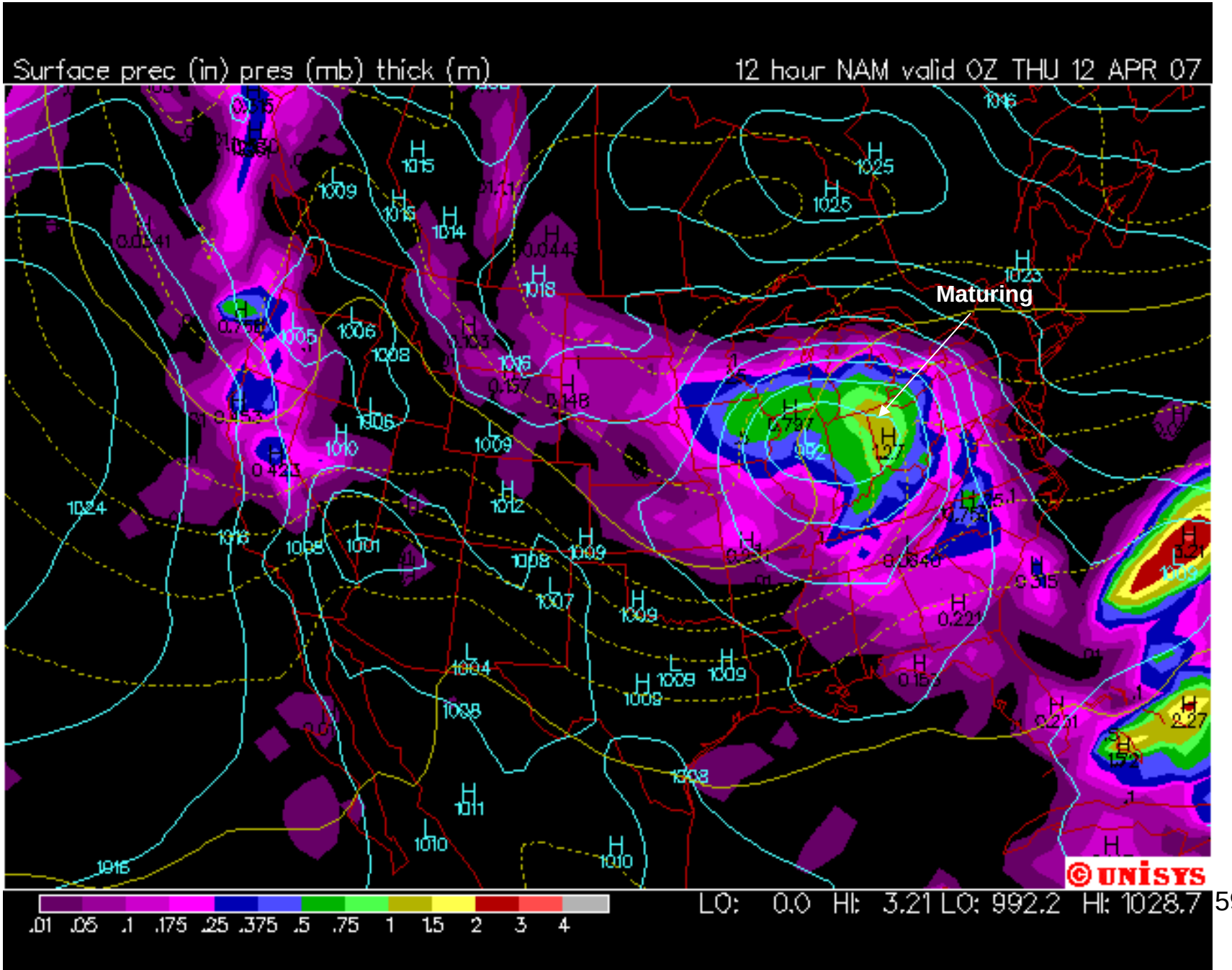
•Let's visit the National Oceanographic and Atmospheric Administration (NOAA) – National Centers for Environmental Prediction (NCEP) in Washington D. C. Let's search their forecast weather maps for the 'birth', 'mature' and 'death' of a mid-latitude cyclone (www.weather.unisys.com/nam/):



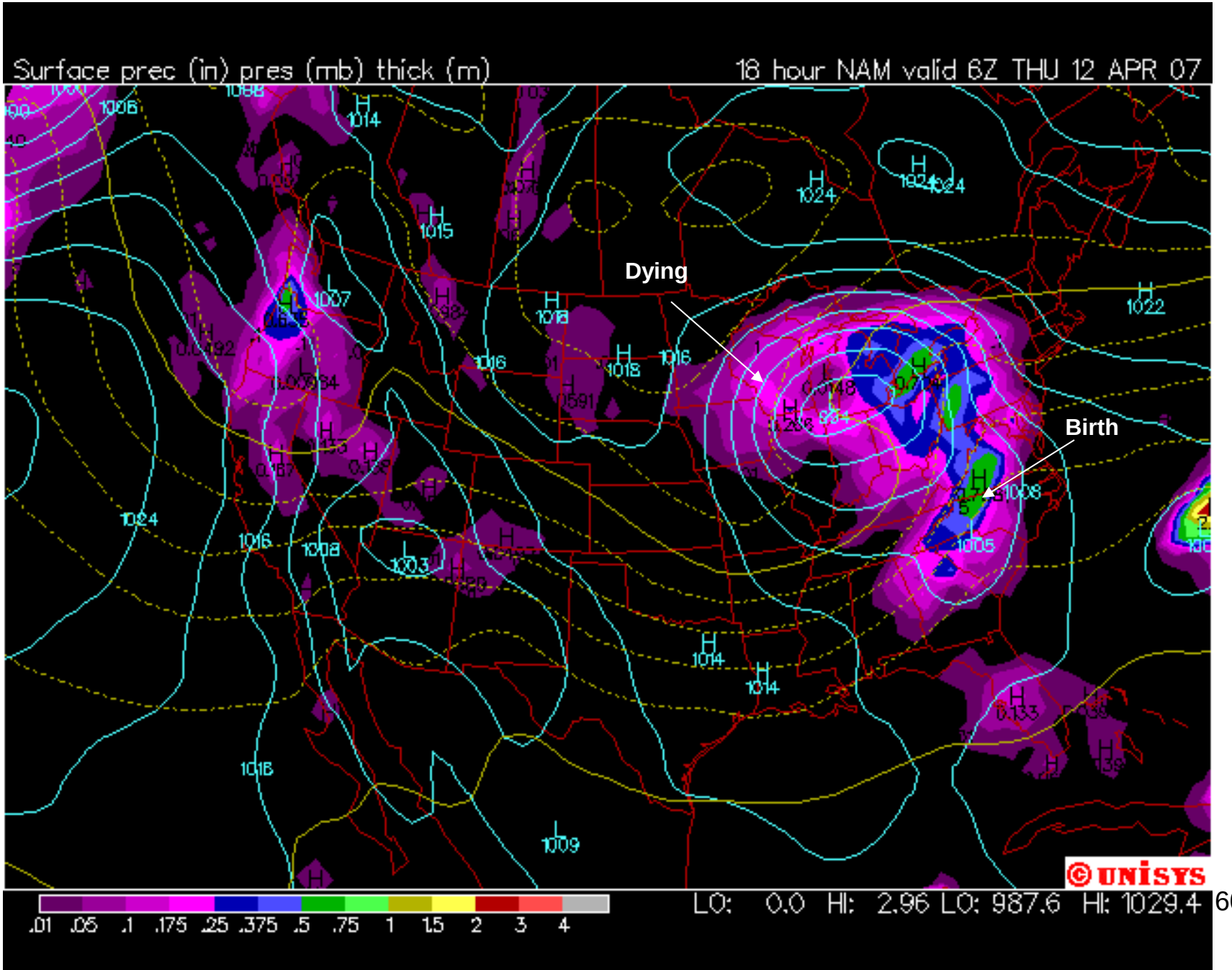
Surface weather maps: fronts – virtual 'field trip'



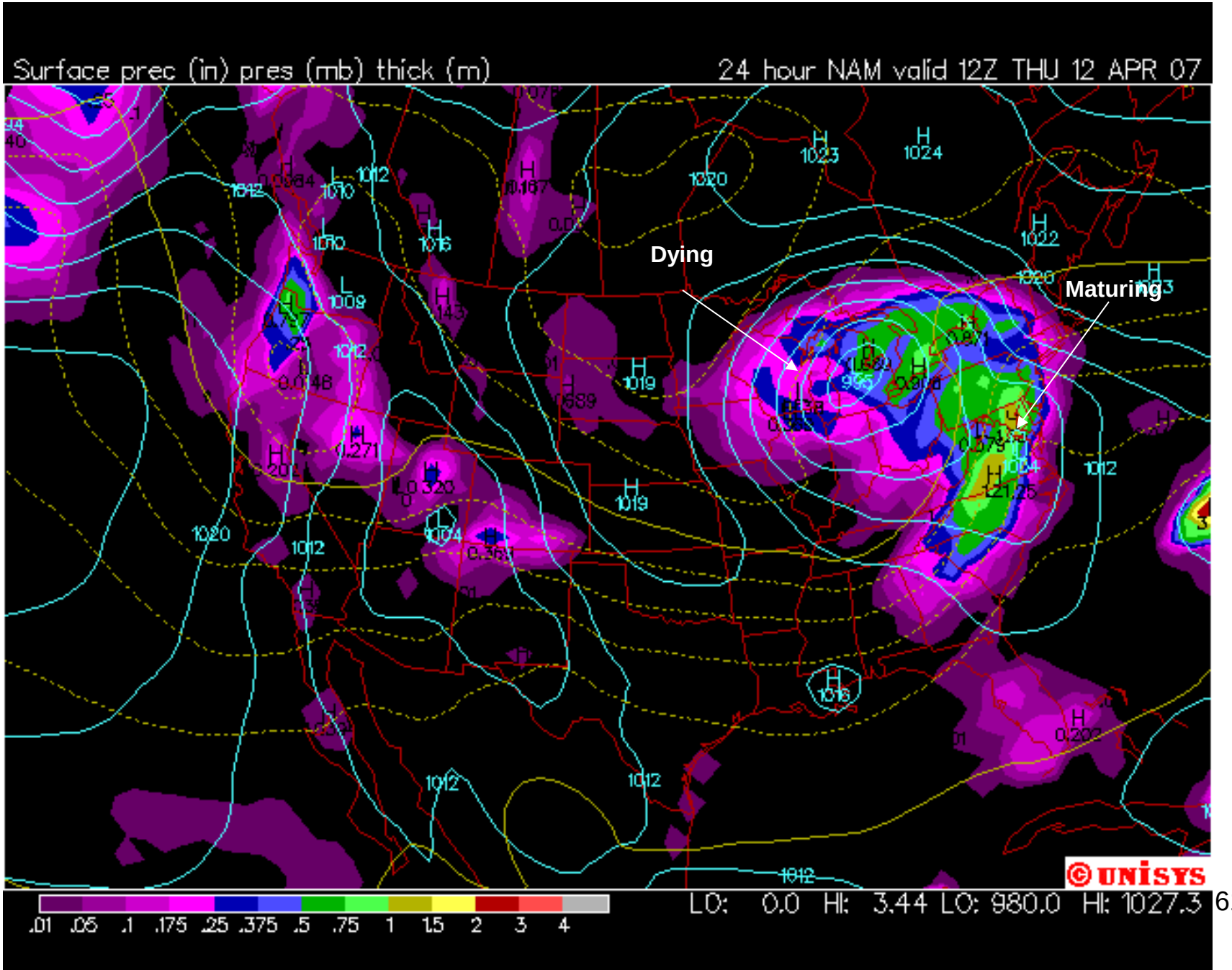
Surface weather maps: fronts – virtual 'field trip'



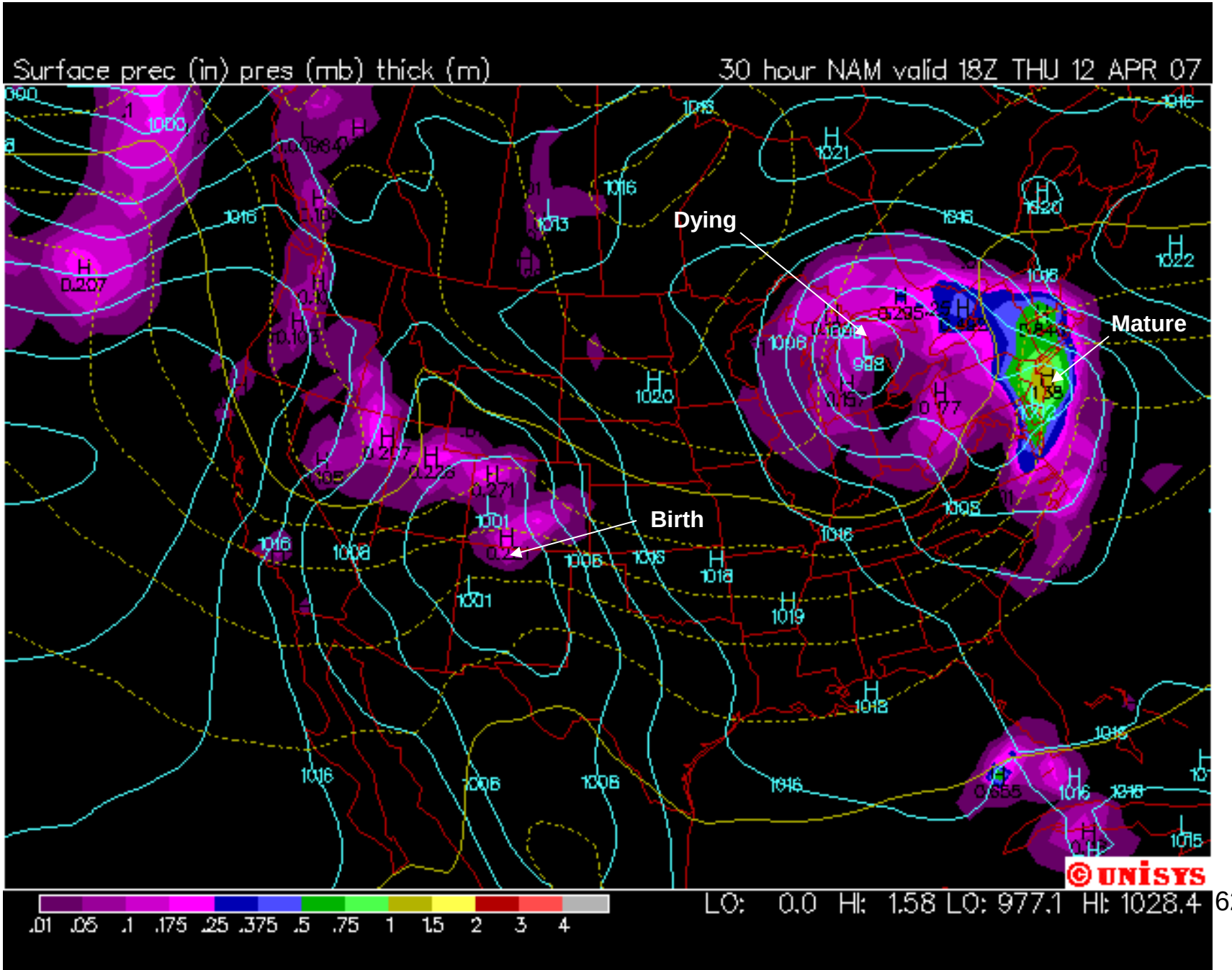
Surface weather maps: fronts – virtual 'field trip'



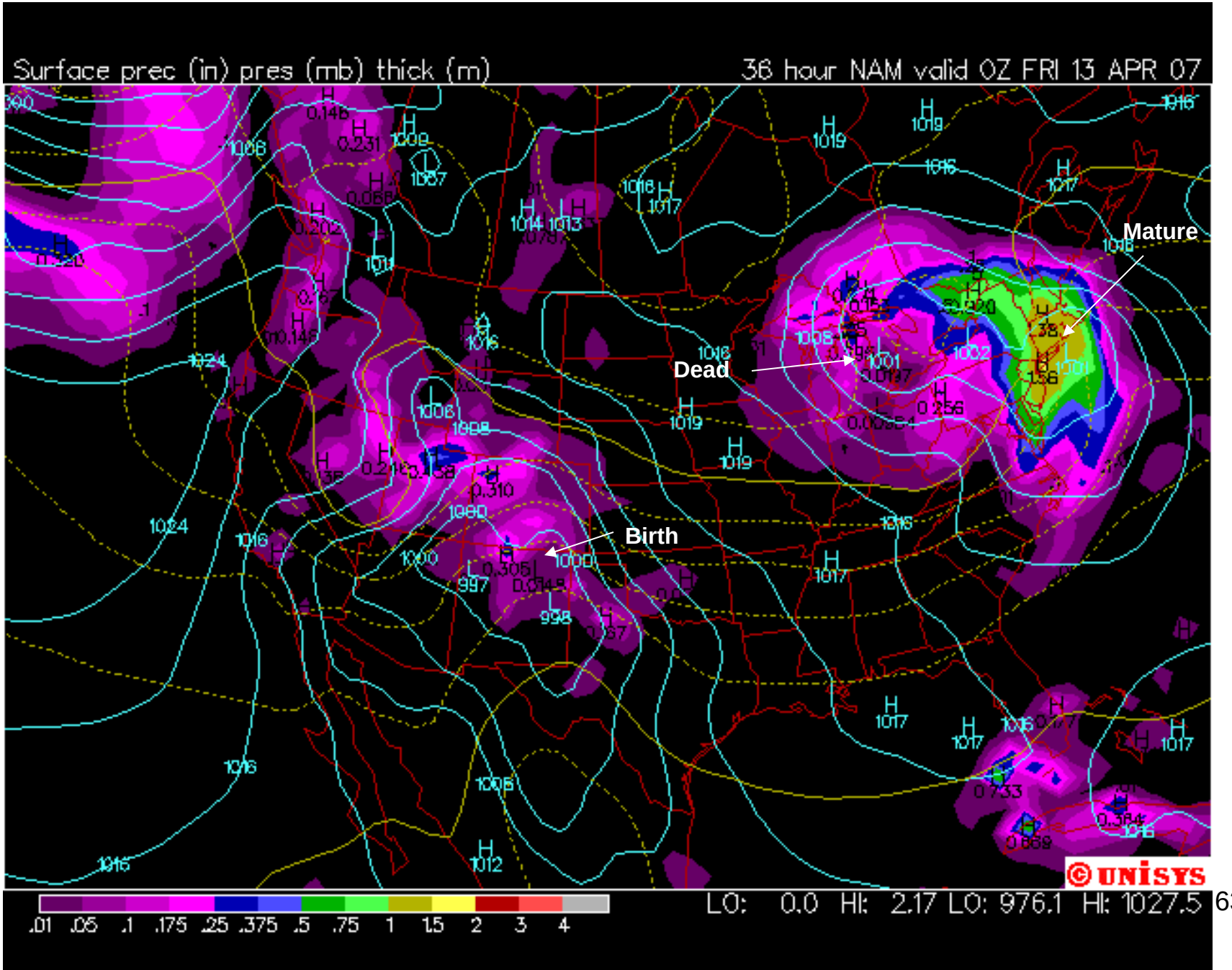
Surface weather maps: fronts – virtual ‘field trip’



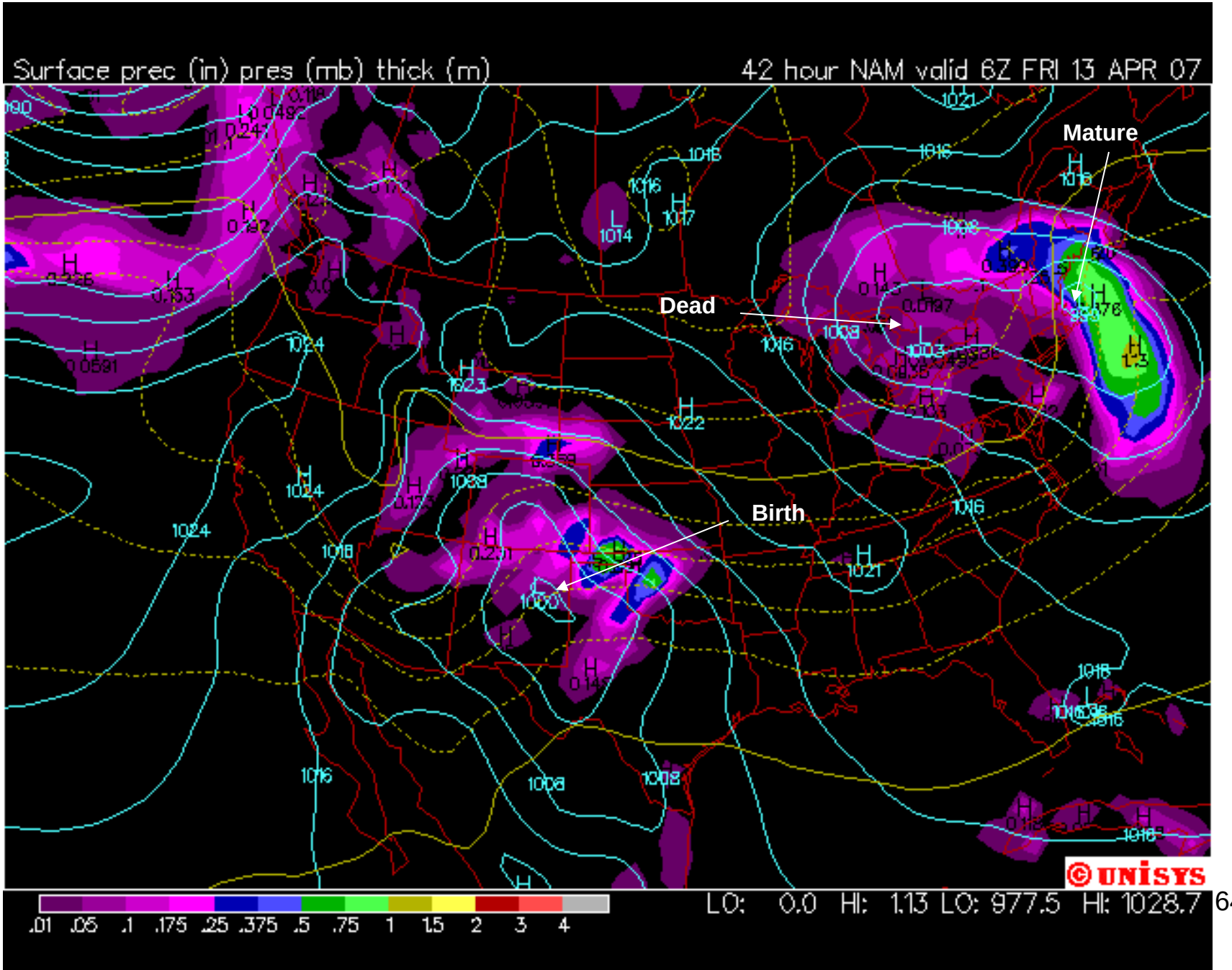
Surface weather maps: fronts – virtual 'field trip'



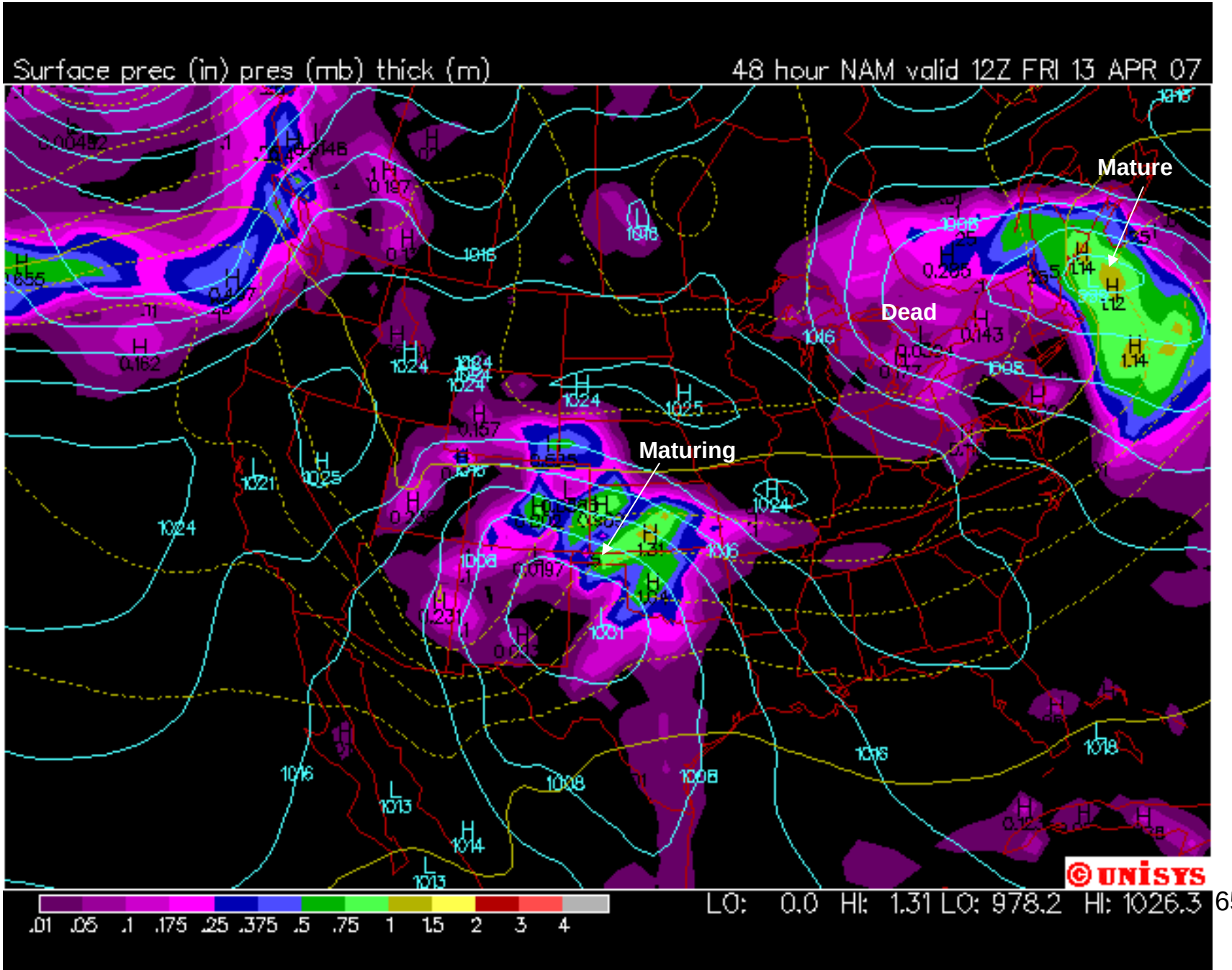
Surface weather maps: fronts – virtual 'field trip'



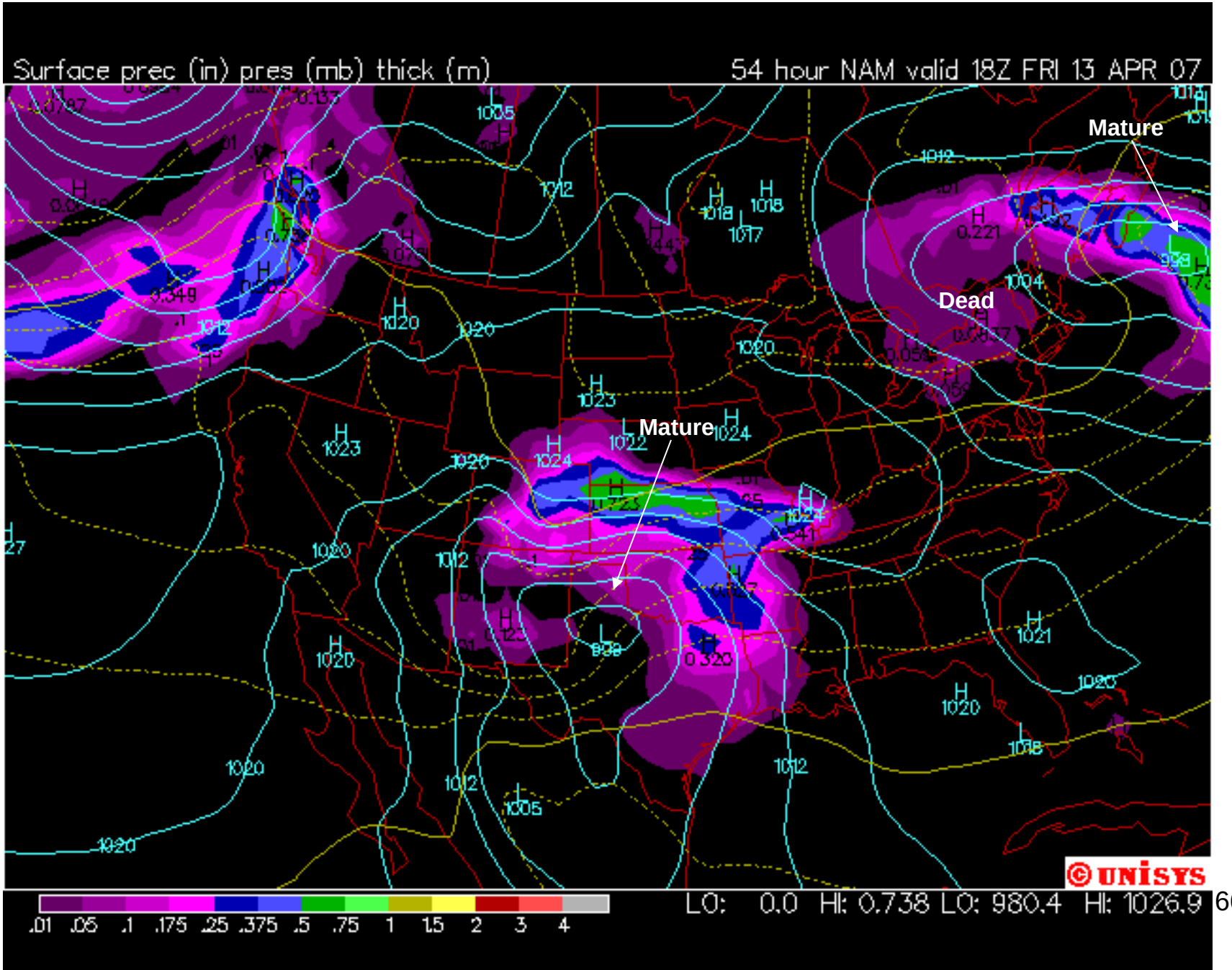
Surface weather maps: fronts – virtual 'field trip'



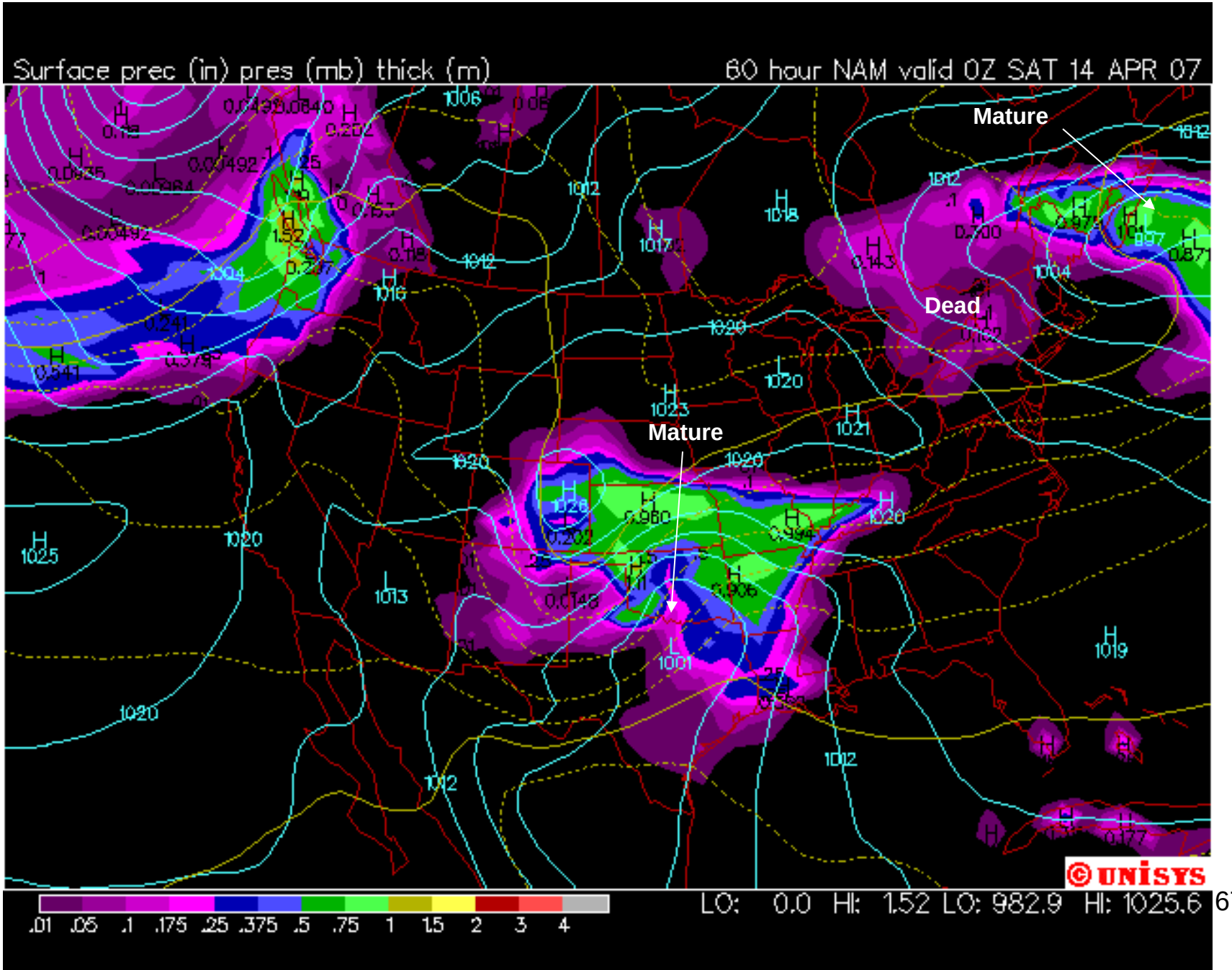
Surface weather maps: fronts – virtual 'field trip'



Surface weather maps: fronts – virtual 'field trip'



Surface weather maps: fronts – virtual 'field trip'



Surface weather maps: fronts –

With knowledge of the High-Low-High structure and West to East movement of the mid-latitude Cyclone, the following weather proverbs can be understood:

Evening red and morning grey, two sure signs of one fine day.

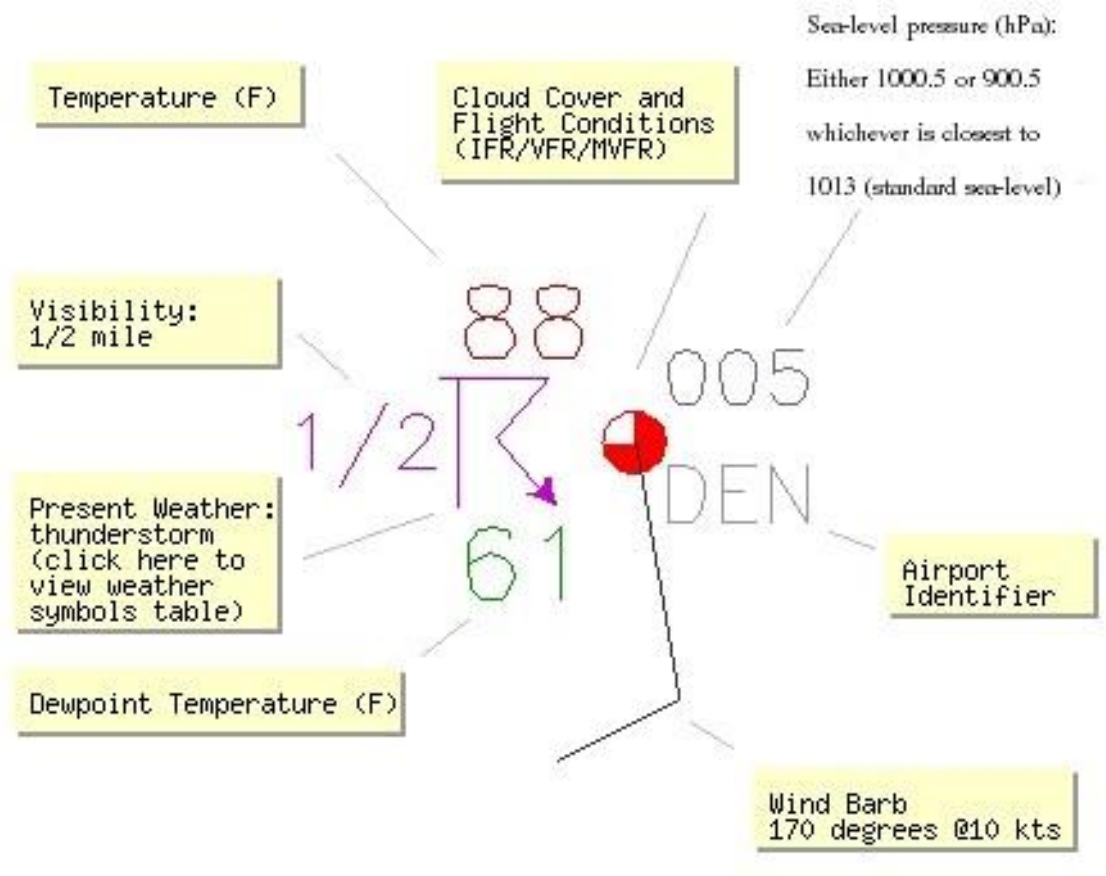
A rainbow in the morning, is the mariner's warning, a rainbow at night is the mariner's delight.

When the wind is in the east, 'tis neither good for man nor beast.

Red sky at night, sailor's delight. Red sky in the morning, sailor take warning.

Surface weather maps: fronts – *find the front* exercise

- Strong fronts separate air masses with significantly different T and/or T_d values and wind directions
- Surface data explanation in 'Help Pages'(weather.rap.ucar.edu/info/):

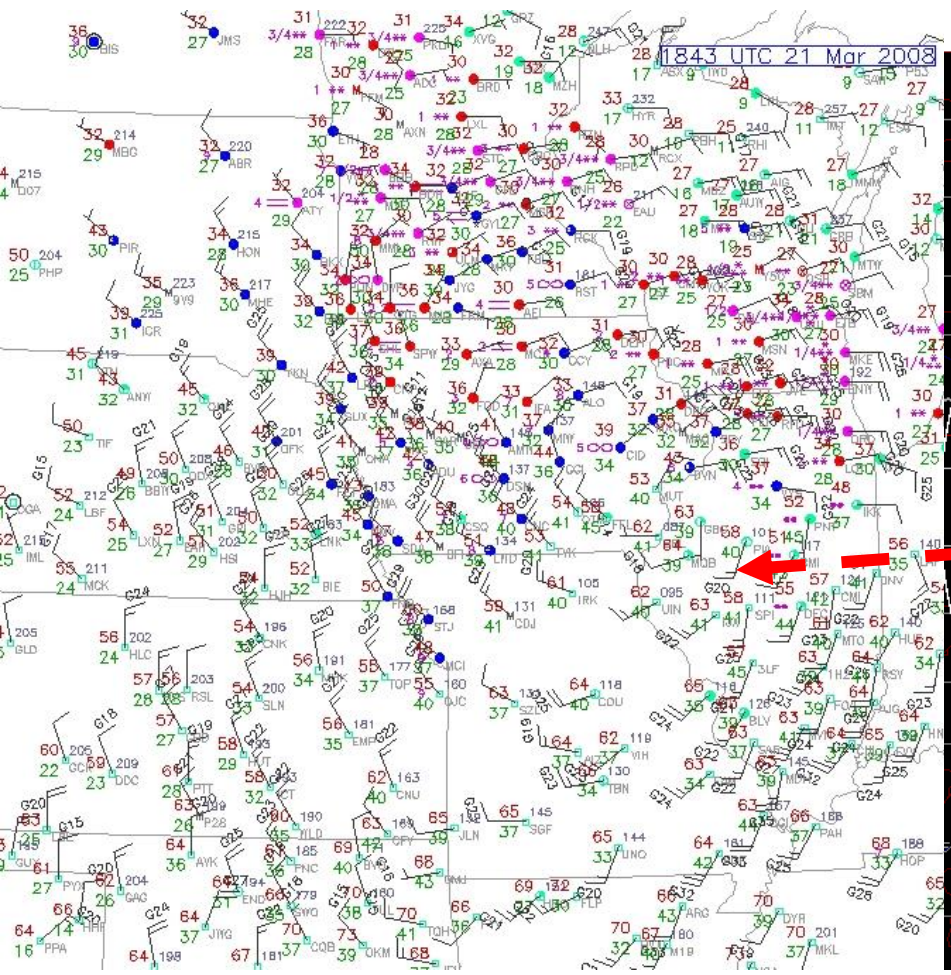


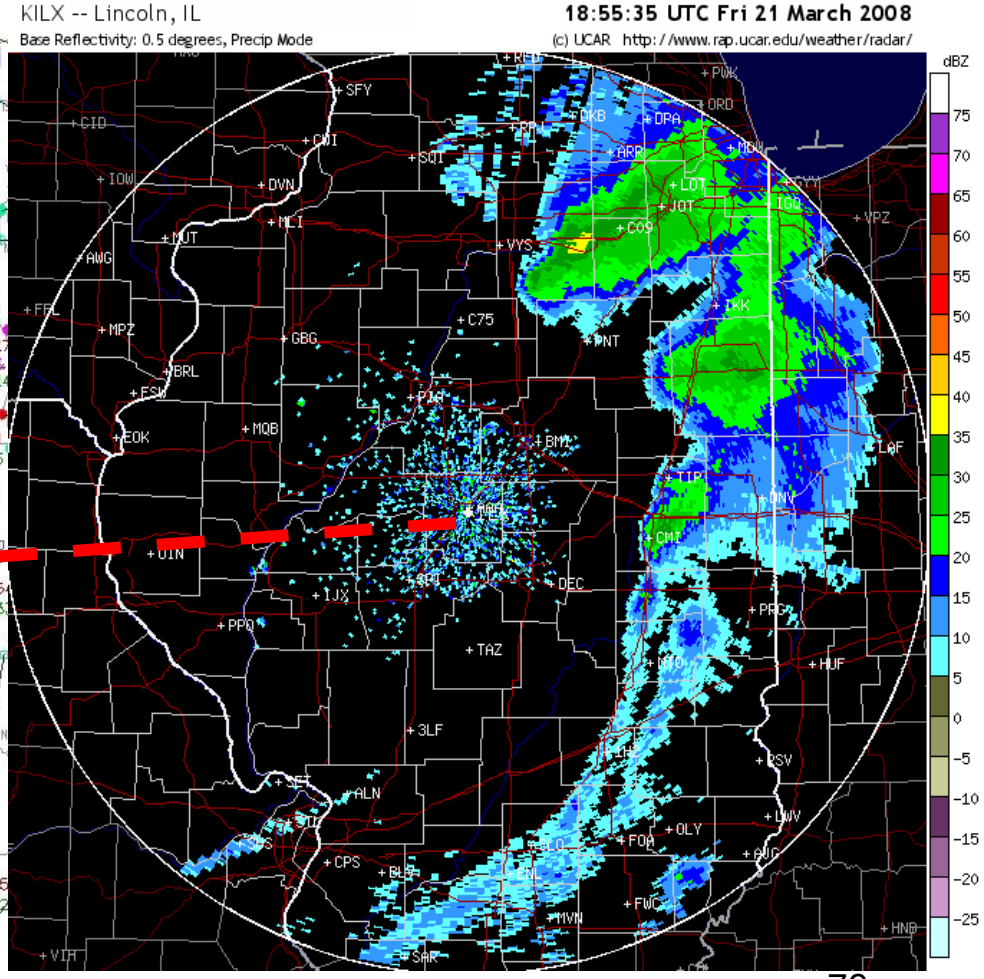
Hand out *Find the warm and cold front* exercise

Surface weather maps: fronts – *find the front* exercise

•Obtained surface data from weather.rap.ucar.edu/weather/surface/

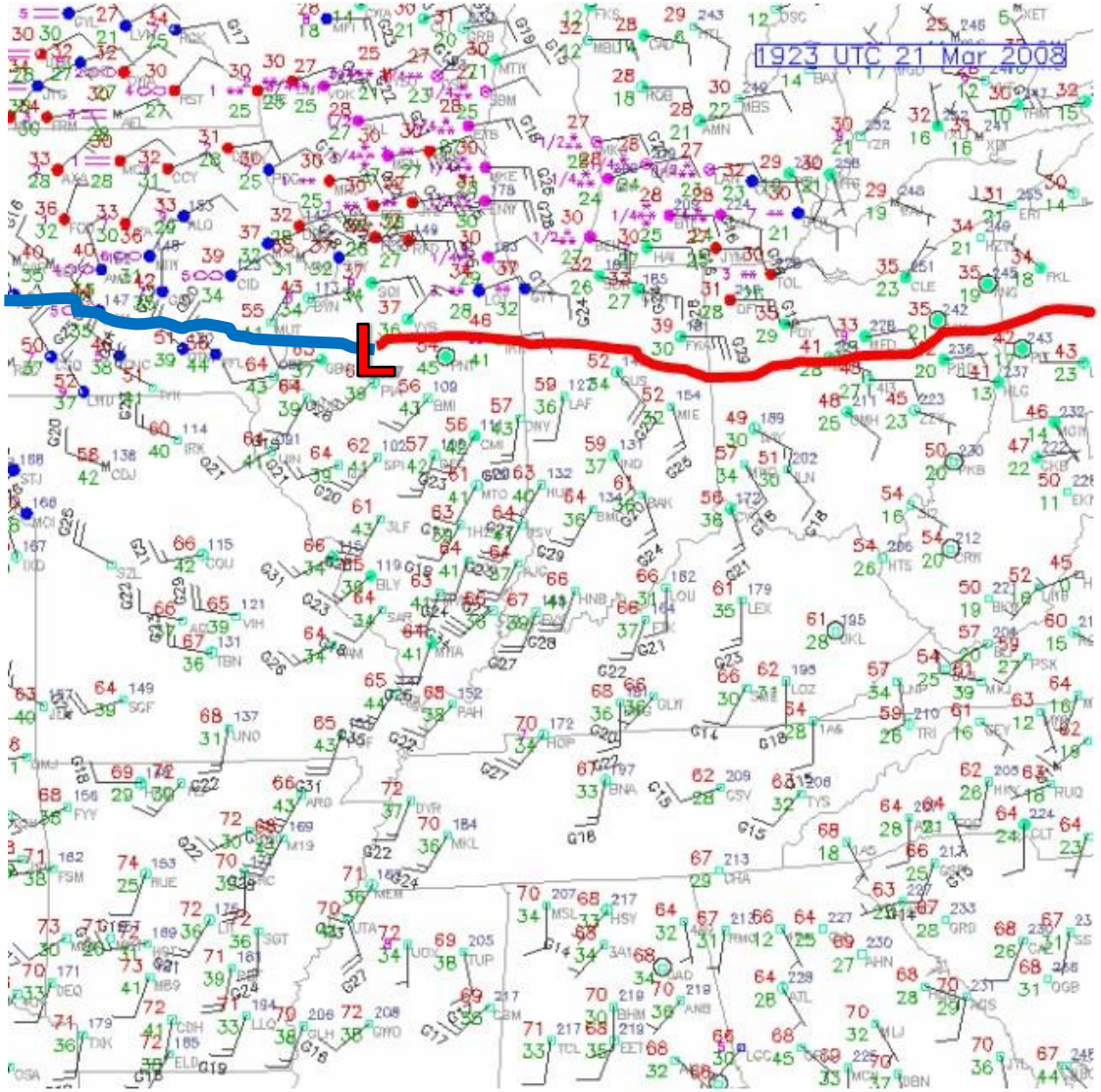
▪Obtained near-simultaneous radar data from weather.rap.ucar.edu/weather/radar/





Surface weather maps: fronts – *find the warm and cold fronts* exercise

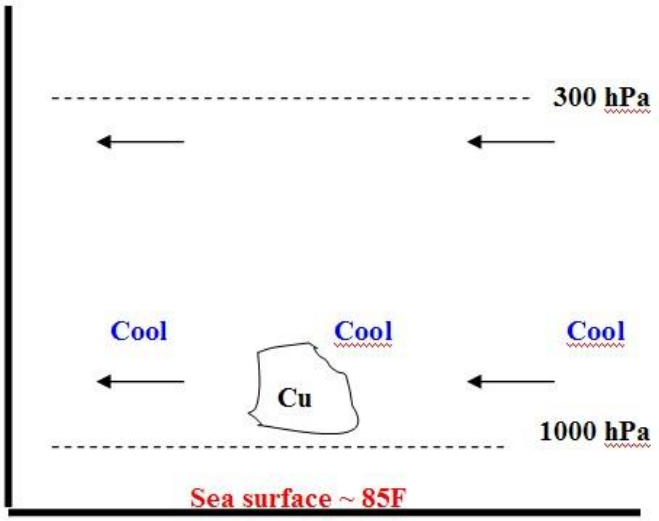
Answer:



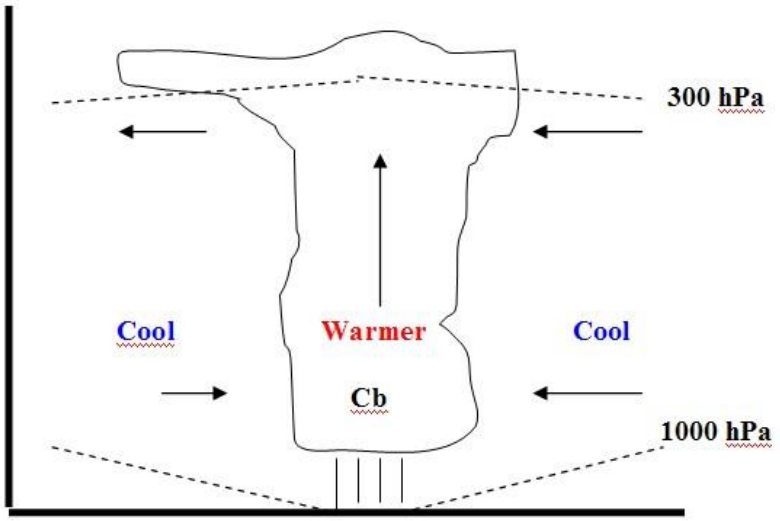
Surface weather maps: tropics

•Only one air mass in the tropics, therefore there are no fronts. How, then, can the tropics have weather?

Normal Tropical Atmosphere

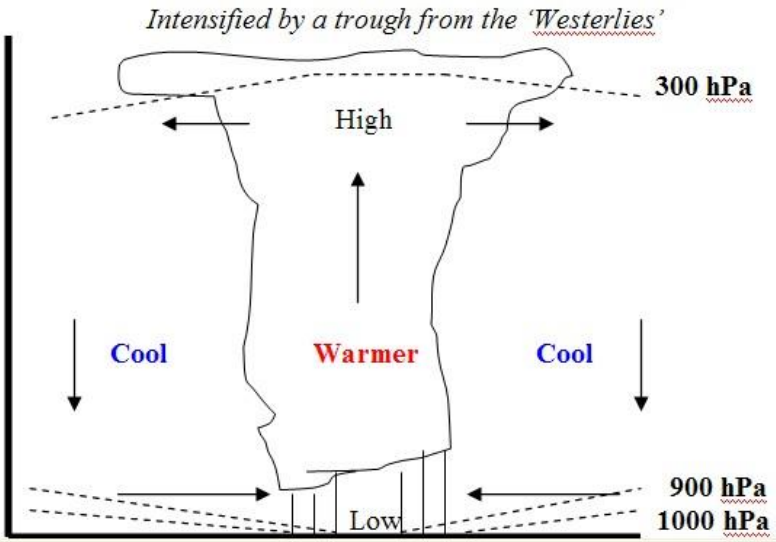


Tropical Depression (many)



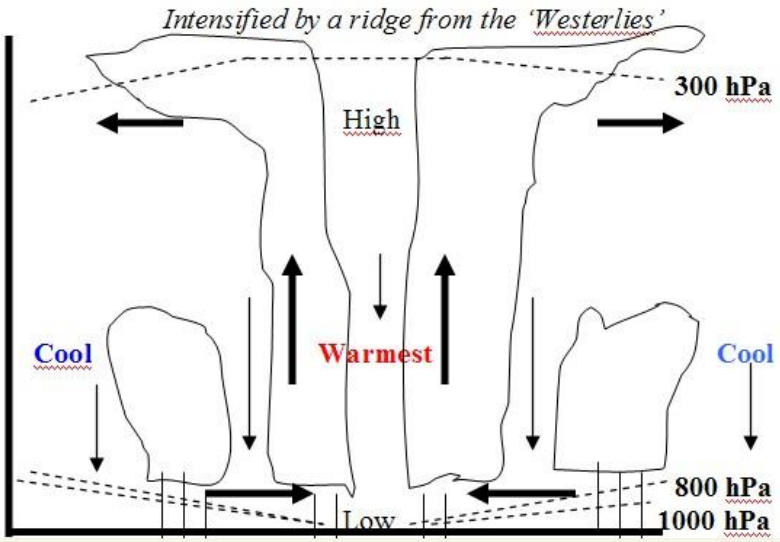
Tropical Storm (fewer)

Intensified by a trough from the 'Westerlies'



Hurricane (fewest)

Intensified by a ridge from the 'Westerlies'



Surface weather maps: tropics

•Tropical cyclones drift westward in the Trade winds and frequently re-curve into the Westerlies:

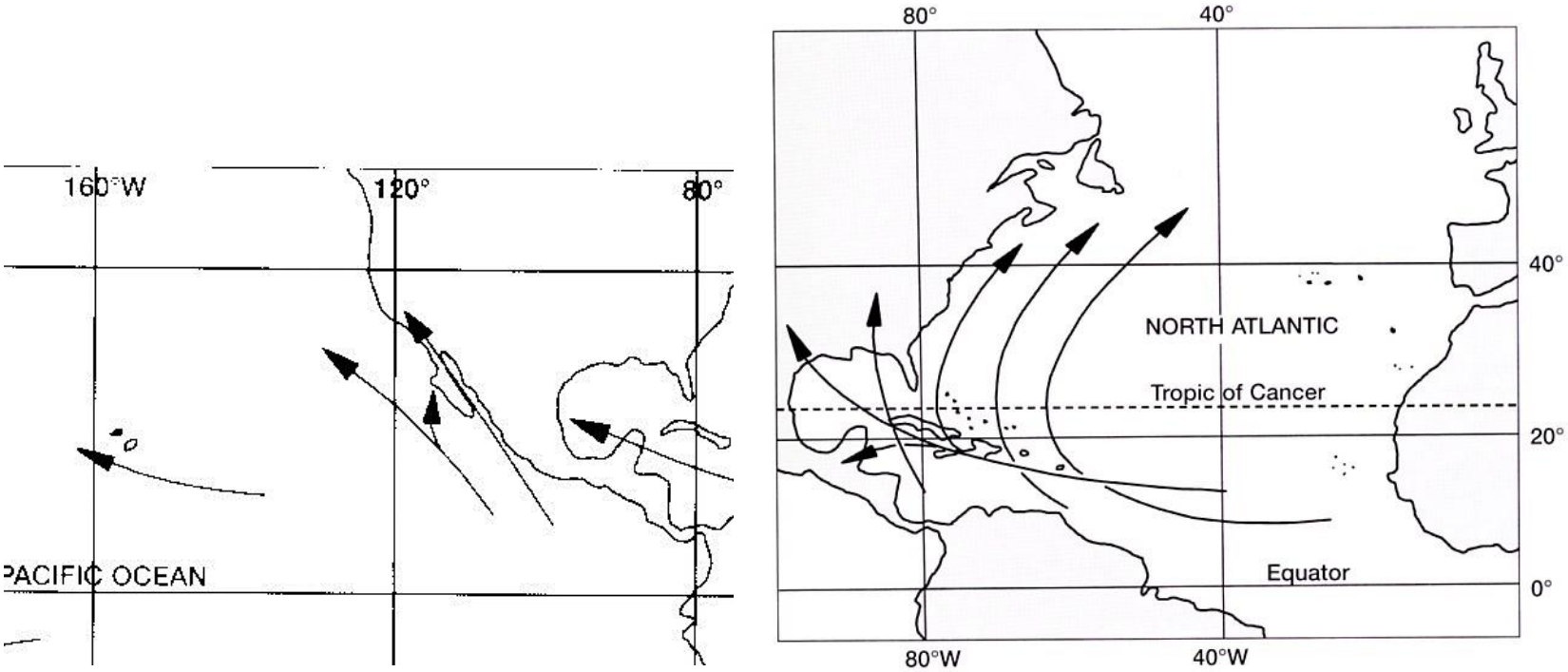
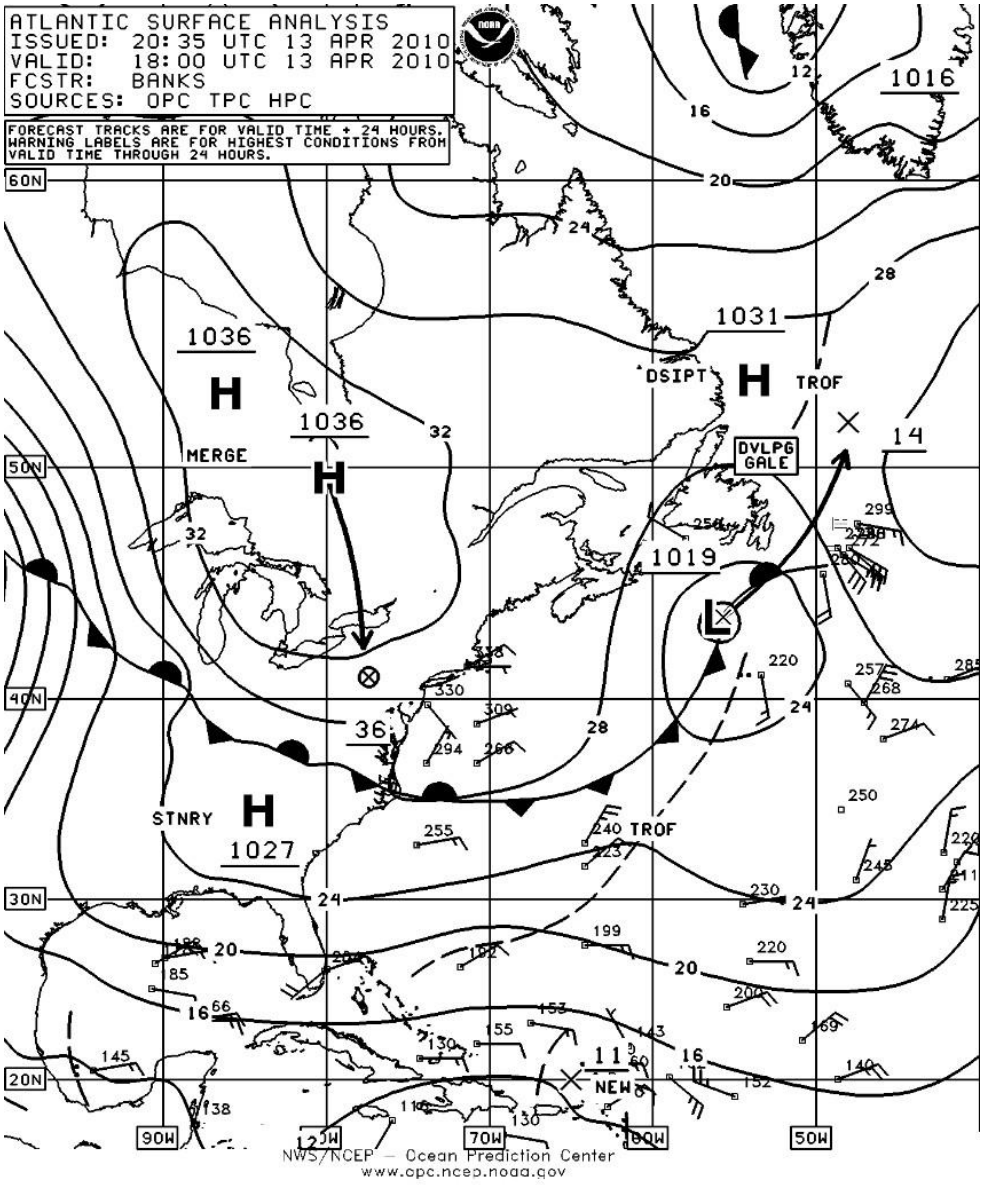


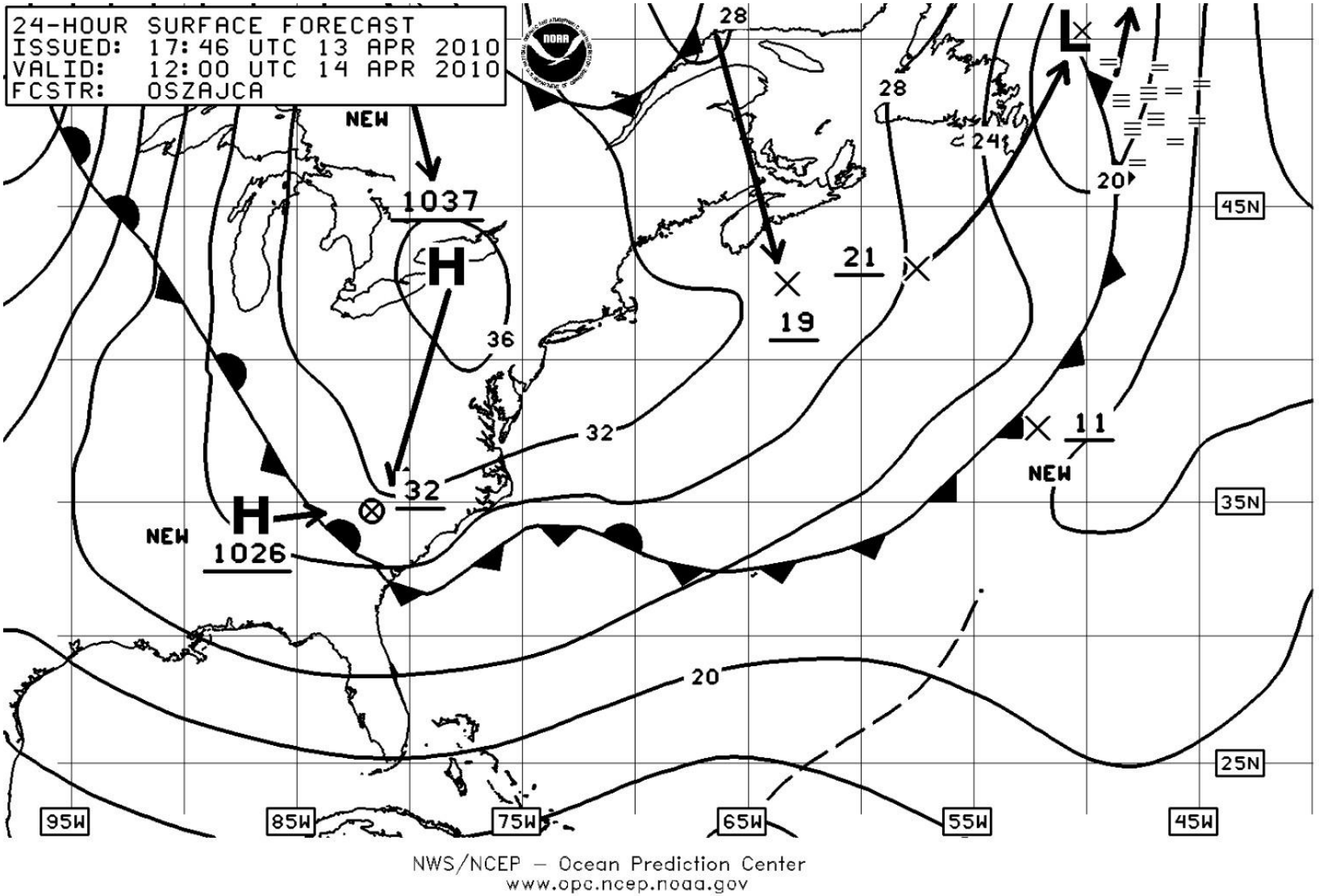
Fig 16.2 *Some typical tracks of tropical revolving storms.*

Understand NOAA Ocean Prediction Center (OPC) surface weather maps (analyses): www.opc.ncep.noaa.gov, click on 'Atlantic Marine' then 'W Atlantic'



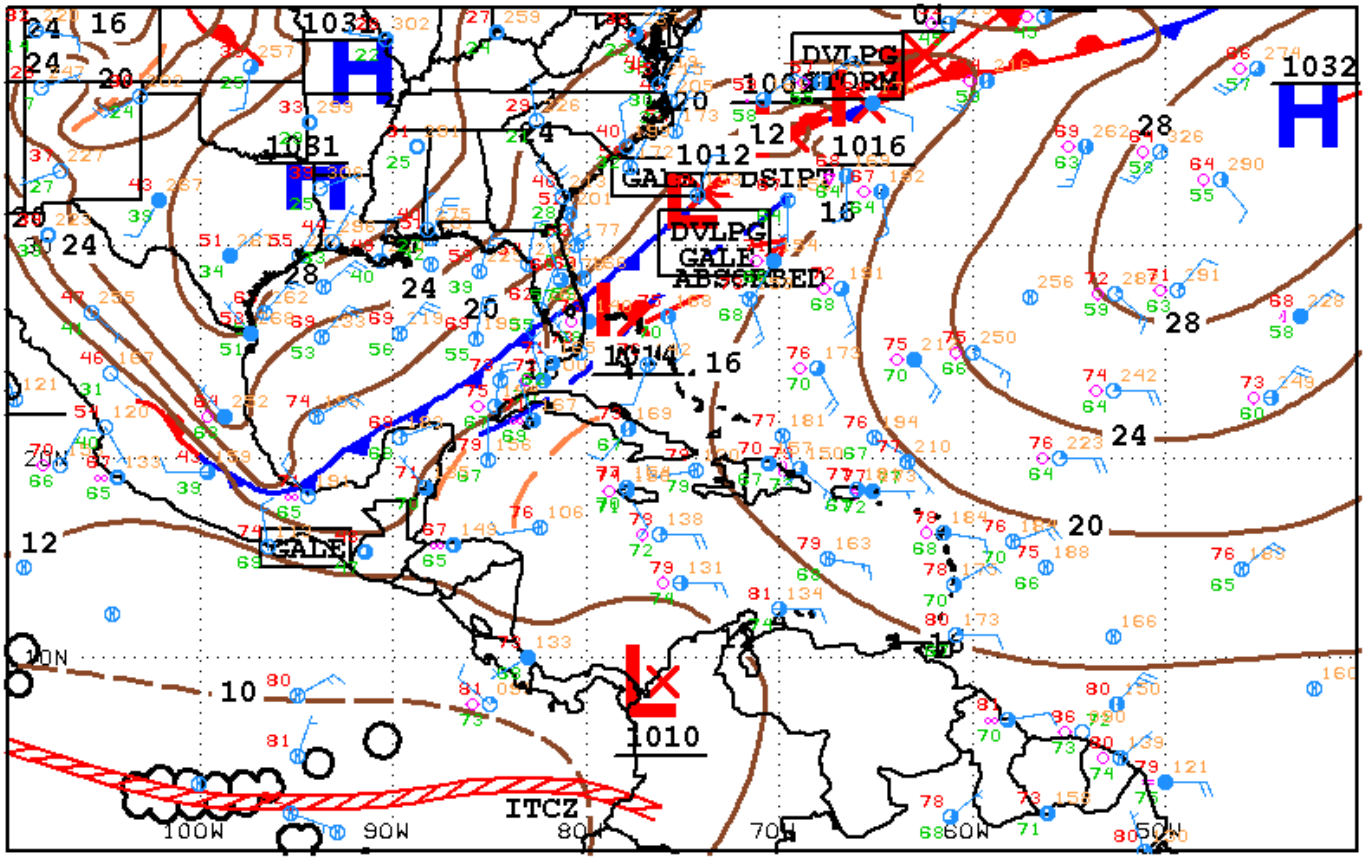
See Biewenga, Chapter 6 for detailed interpretations.
Additional analyses at www.nws.noaa.gov/om/marine/

Understand NOAA Ocean Prediction Center (OPC) surface weather maps (forecasts): www.opc.ncep.noaa.gov, click on 'Atlantic Marine' then '24-hour surface'



See Biewenga, Chapter 6 for detailed interpretations.
Additional analyses and forecasts at www.nws.noaa.gov/om/marine/

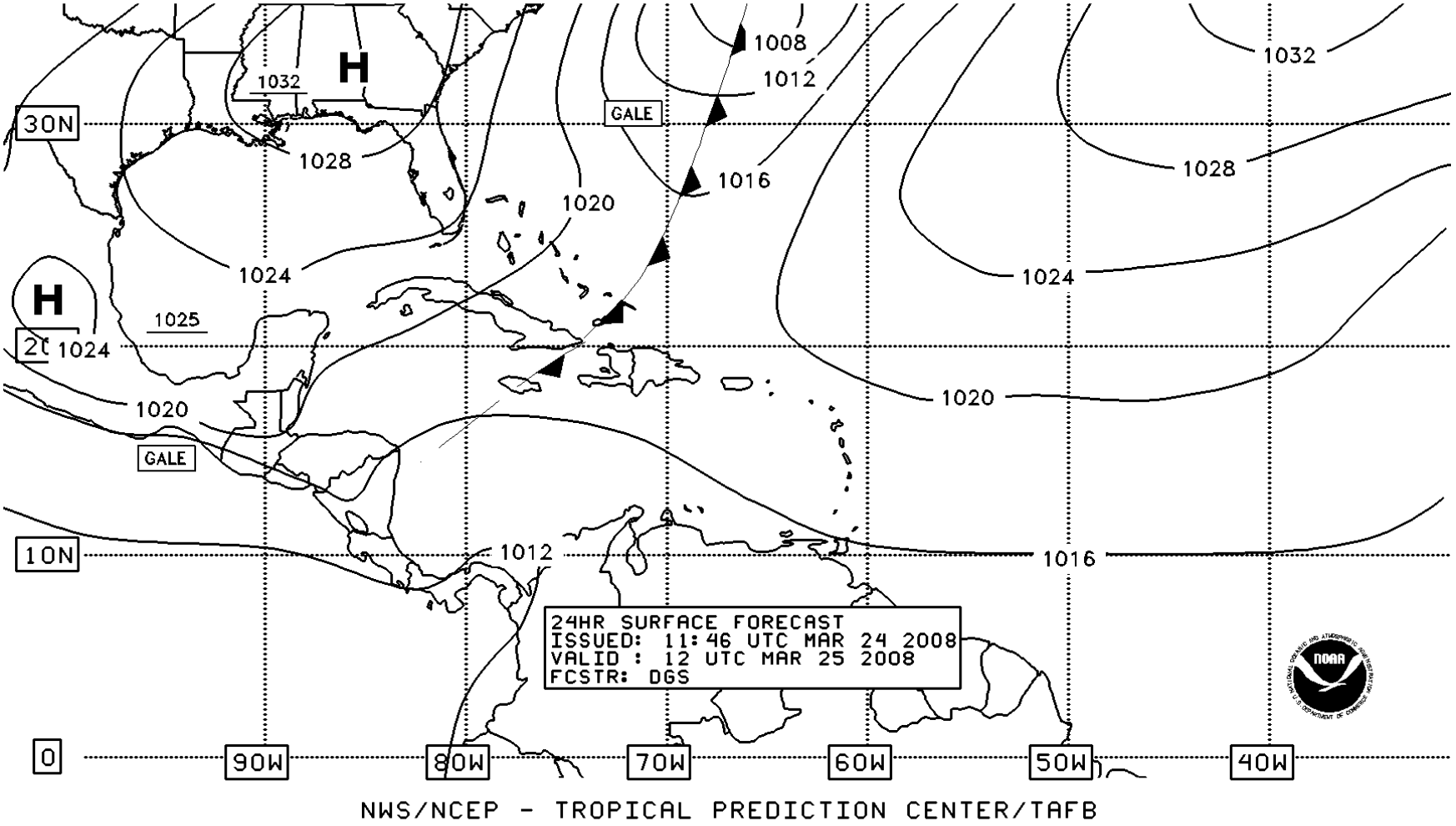
Understand NOAA Tropical Prediction Center (TPC) surface weather maps (analyses): www.nhc.noaa.gov/marine/, scroll down to 'Graphical Products, Atlantic' and, then, to the 'SW North Atlantic' chart ('Graphical Products Legend' at page bottom)



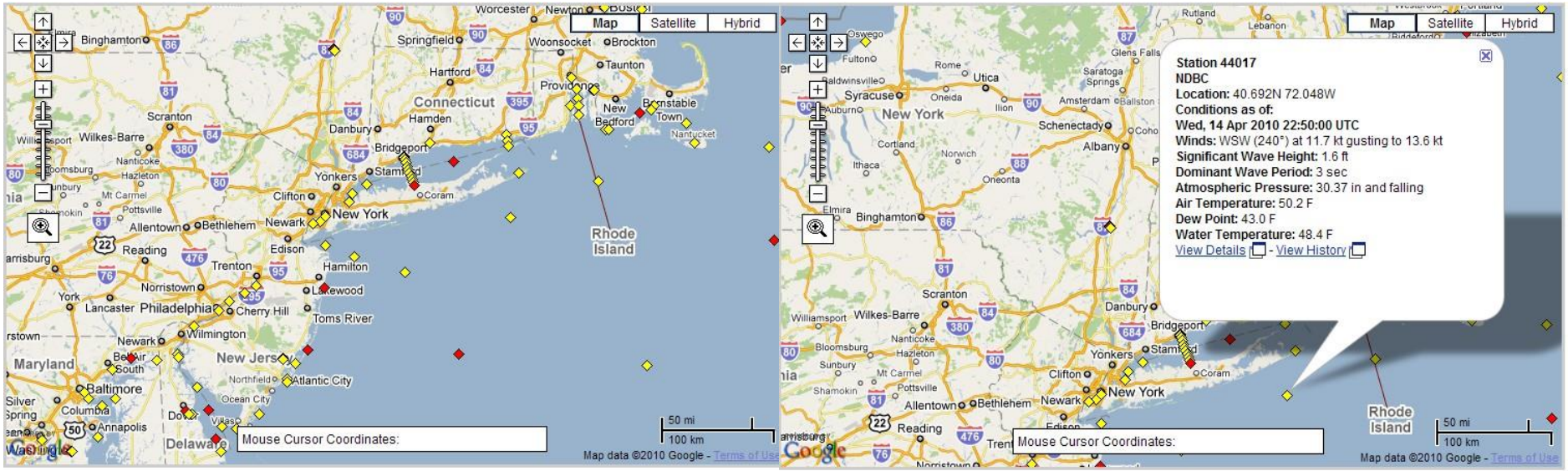
12Z SOUTHWEST NORTH ATLANTIC SFC ANALYSIS
ISSUED: Mon Mar 24 14:41:25 UTC 2008
THUNDERSTORMS: SCALLOP LINES

TROPICAL PREDICTION CENTER
MIAMI, FLORIDA
BY TAFB ANALYST: JC
COLLABORATING CENTERS: TPC OPC HPC

Understand NOAA Tropical Prediction Center (TPC) surface weather maps (forecasts): www.nhc.noaa.gov/marine/, scroll down to 'Graphical Products, Atlantic' and, then, to the 'Surface Forecasts, 24-hour | resized' chart



NOAA National Data Buoy Center (www.ndbc.noaa.gov): move map to desired location and blow up to find buoy, click on buoy for data.



Stations with recent data
Stations with historical data only
Stations with no data in last 8 hours
(24 hours for tsunami stations)
Tsunami station in event mode
(within previous 24 hours)

1055 stations deployed
816 have reported in the past 8 hours

Disclaimer

Get Observations by Program as KML

Get Observations by Owner as KML

Finding weather information:

Summary of web-sites visited in "Basic Marine Weather":

- Clouds from space (www.aviationweather.gov/adds/satellite/)
- Predicted weather for Dulles Airport (IAD) (www.weather.unisys.com/forecast.php?Name=KIAD)
- Atmospheric sounding data for IAD (www.rap.ucar.edu/weather/upper/)
- Forecast weather maps of a mid-latitude cyclone (www.weather.unisys.com/nam/)
- Current land surface data (weather.rap.ucar.edu/weather/surface/)
- Current radar data (weather.rap.ucar.edu/weather/radar/)
- Surface and radar data help (weather.rap.ucar.edu/info/)
- Ocean surface weather maps: East Coast (www.opc.ncep.noaa.gov/)
- Tropical surface weather maps: Atlantic, Caribbean, etc. (www.nhc.noaa.gov/marine/)
- Current coastal buoy data (www.ndbc.noaa.gov)
- Marine forecasts (www.nws.noaa.gov/om/marine/)

Demonstration: NOAA "All-hazards radio"

End of '**Basic Marine Weather**'