THE GENERAL CIRCULATION

AS IT IS MANIFESTED IN
WEATHER & CLIMATE
PATTERNS & PROCESSES

TROPICAL vs EXTRA-TROPICAL ATMOSPHERES

TROPICS: (barotropic atmosphere)

-- Coriolis effect weak, CF = zero at the equator, spinning motions (vorticity) hard to initiate

-- Tropopause level is high

-- Temp & pressure gradients are weak and nearly parallel

-- Little horizontal temperature contrast and little vertical wind shear

TROPICS – cont.

(barotropic atmosphere)

-- Temperatures are warm; water vapor content of atmosphere high, deep convection, low cloud bases & great cloud heights possible

-- Upward motions generally need to be started by orographic uplift or surface heating

-- once upward motions are started, the release of LATENT HEAT drives convection, vertical motions and precipitation

EXTRA-TROPICS (baroclinic atmosphere)

-- Coriolis force increases with latitude, more spinning motions (vorticity)

-- horizontal thermal contrasts are often sharp; esp where unlike air masses converge

-- wind speeds increase with height in proportion to the strength of the horizontal thermal contrast

--Tropopause level is lower; abrupt height change where horizontal thermal contrasts are sharp; jets streams can be associated with these sharp contrasts

EXTRA-TROPICS – cont.
(baroclinic atmosphere)

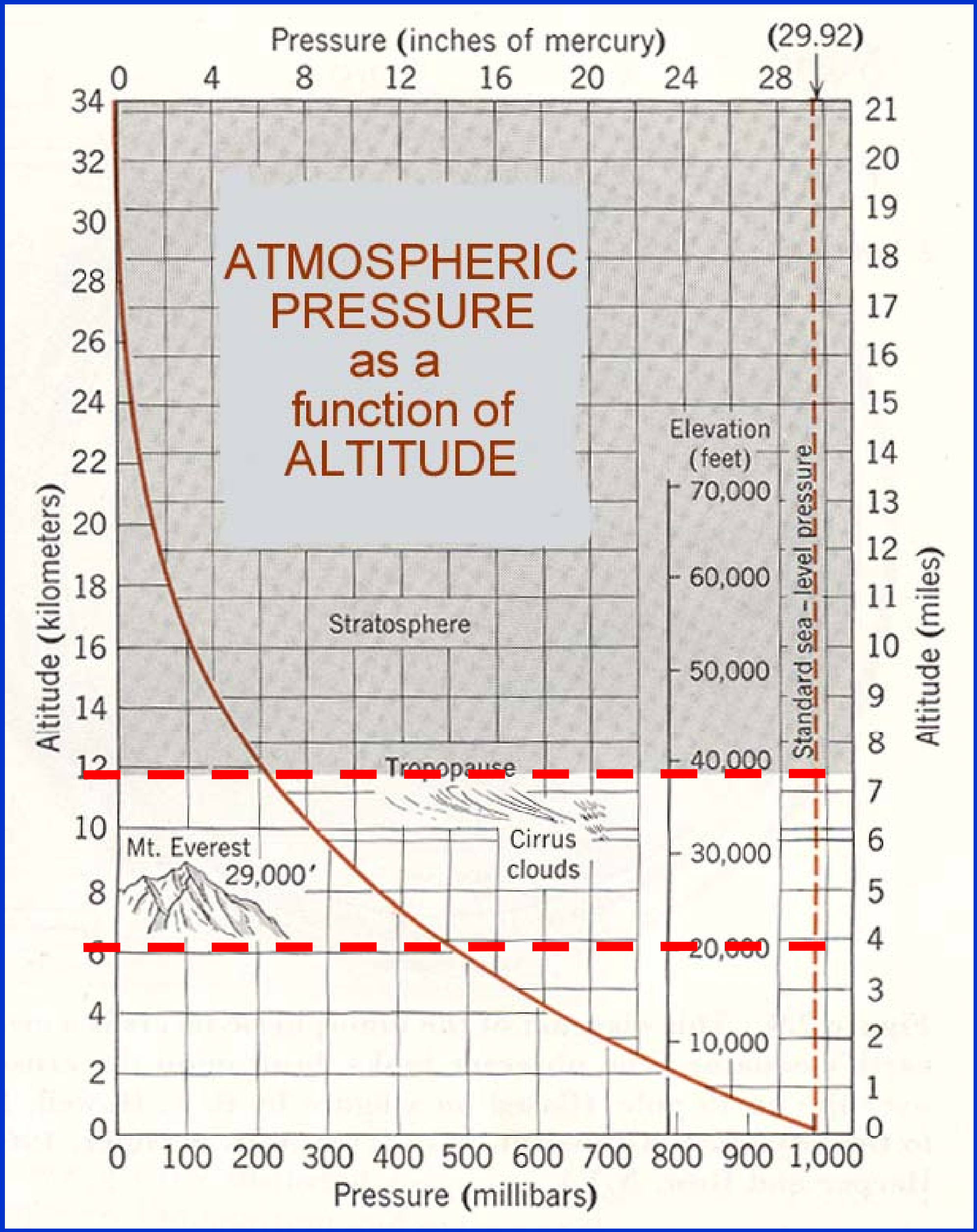
-- horizontal convergence ➔ vertical motions, cooling, condensation and precipitation

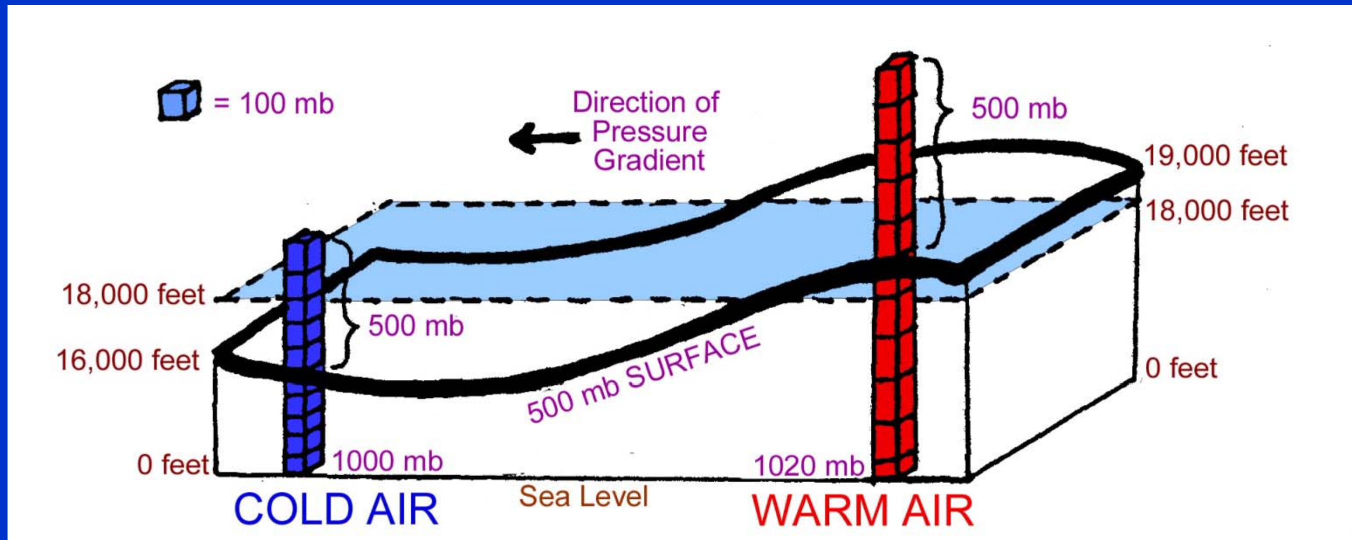
-- water vapor content of atmosphere lower than in tropics, higher cloud bases & lower cloud heights

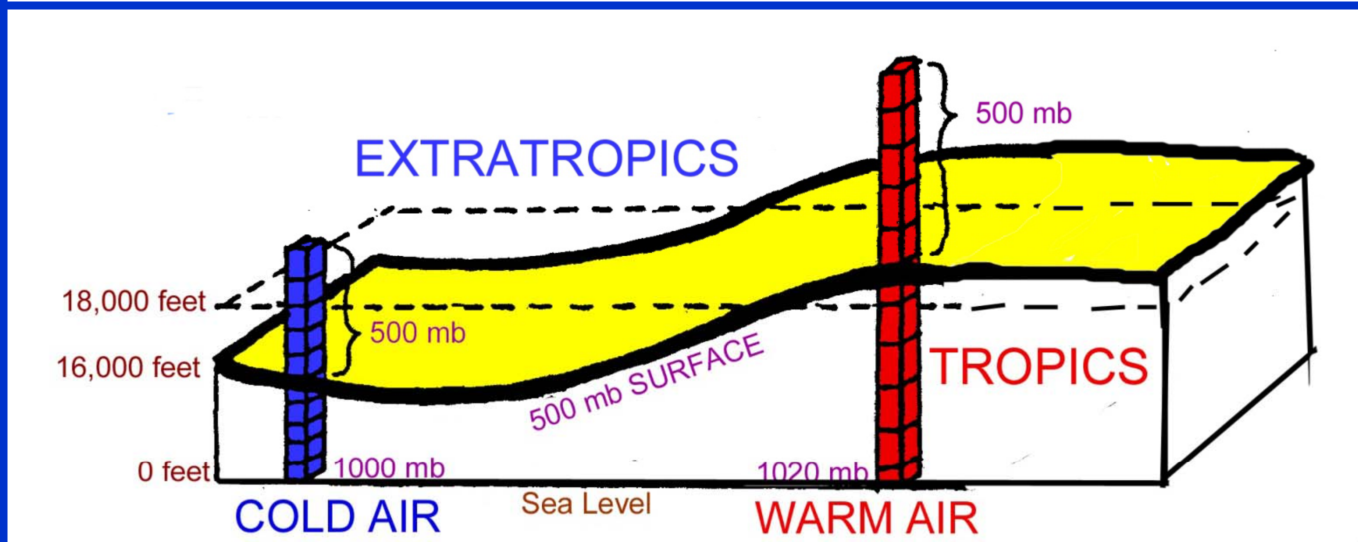
-- hydrodynamic processes most associated with large areas of vertical motion, but orographic effects also play a role

Tropopause →

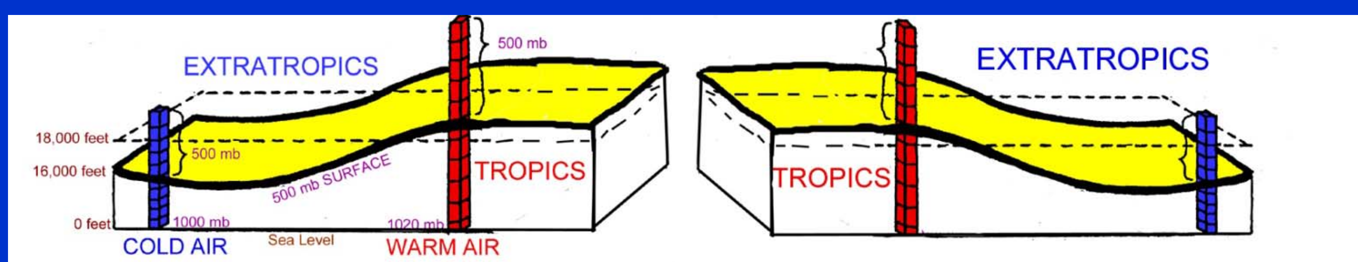
500 mb level →







North Pole

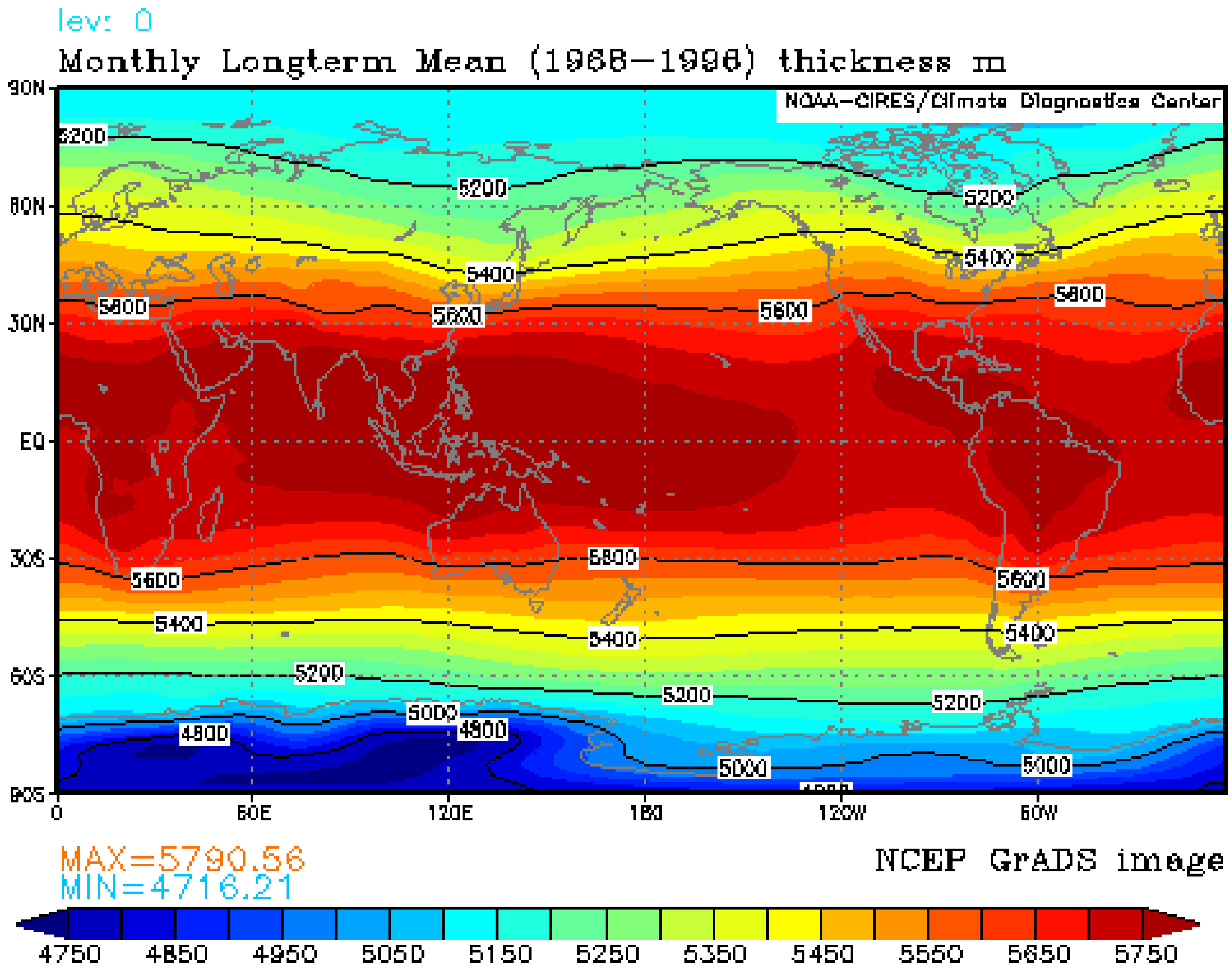


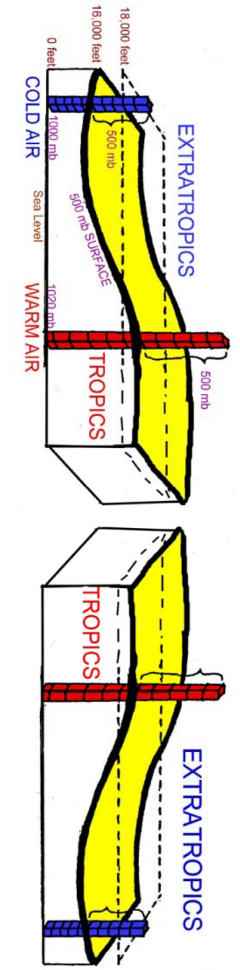
South Pole

THICKNESS of the ATMOSPHERE

between 1000 & 500 mb (in meters)

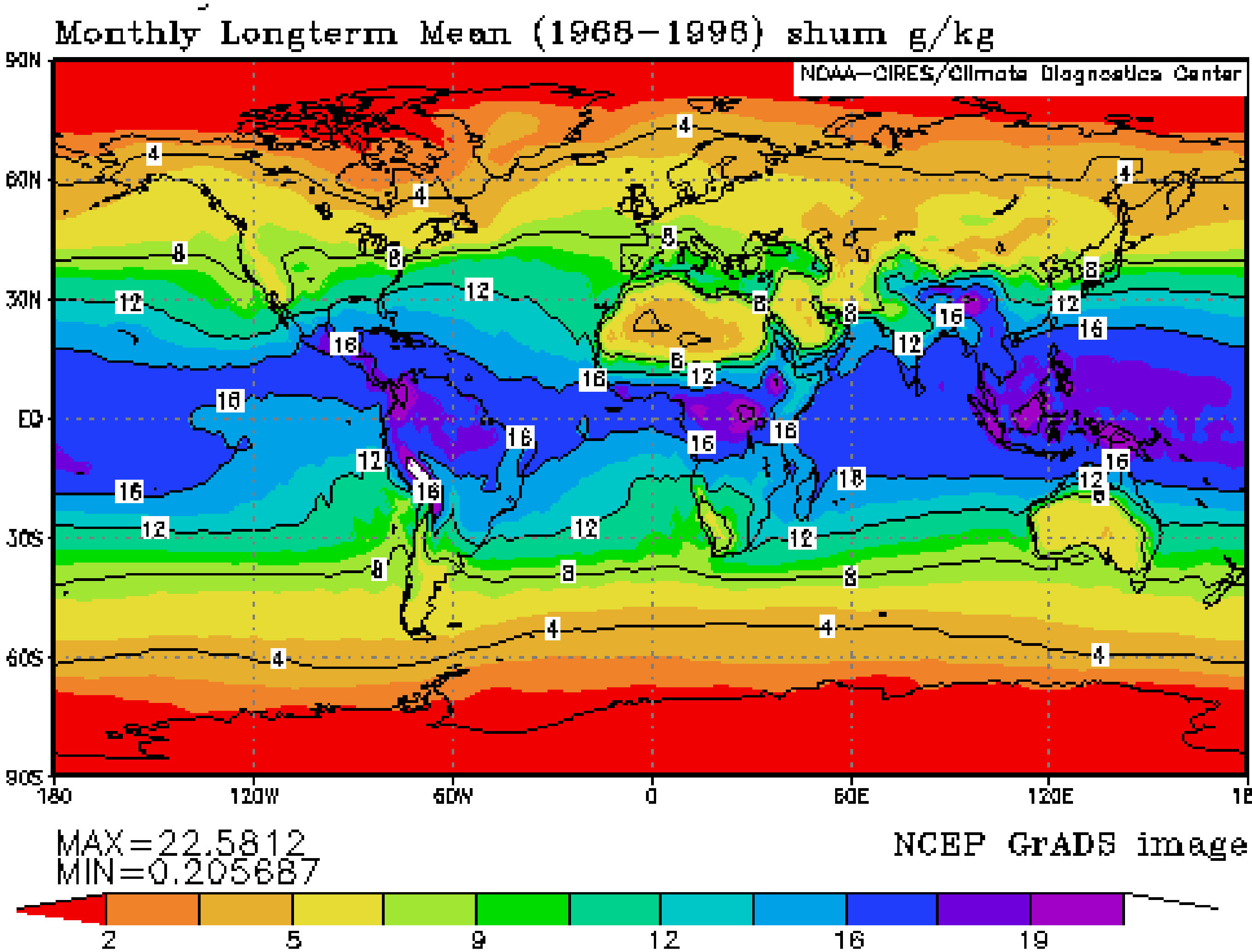
Annual (Jan – Dec) Longterm Monthly Mean

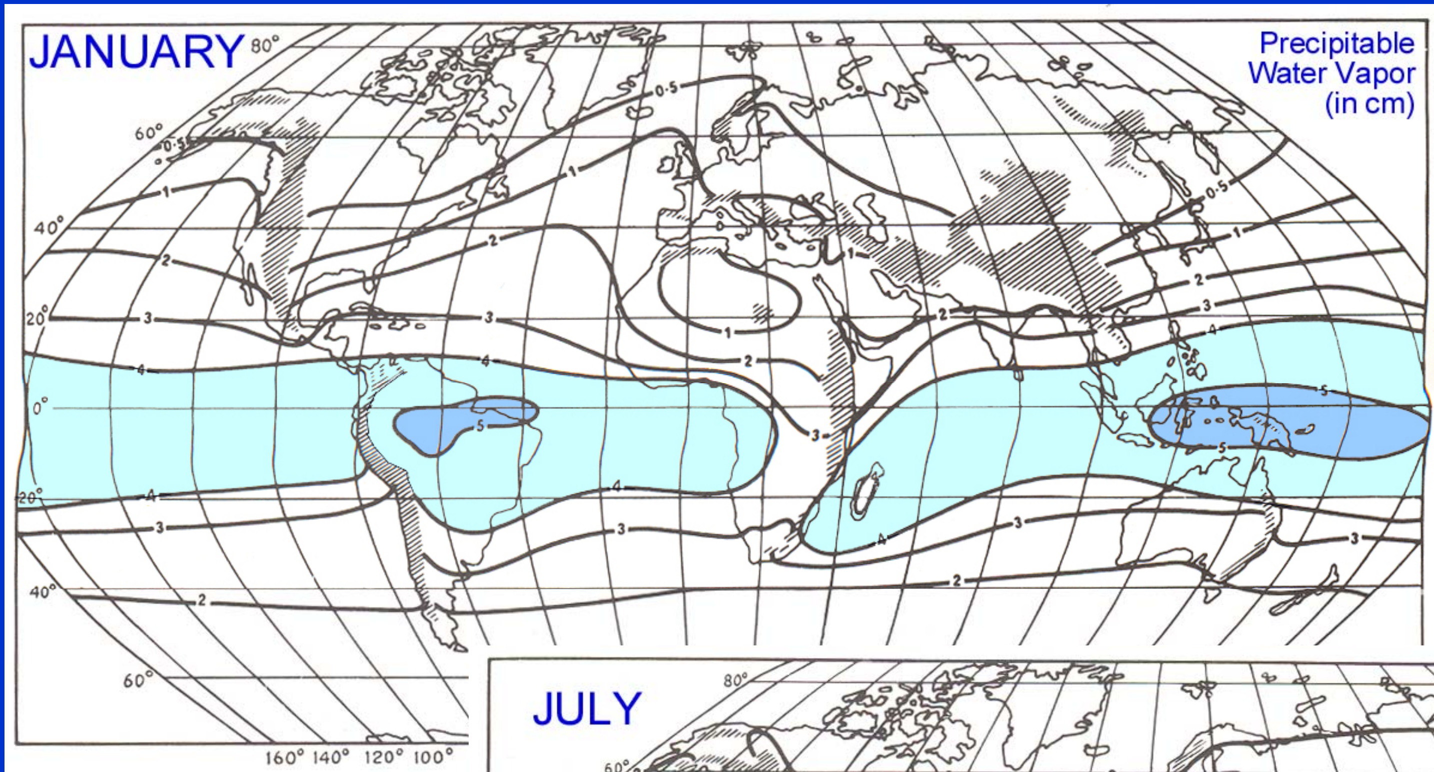


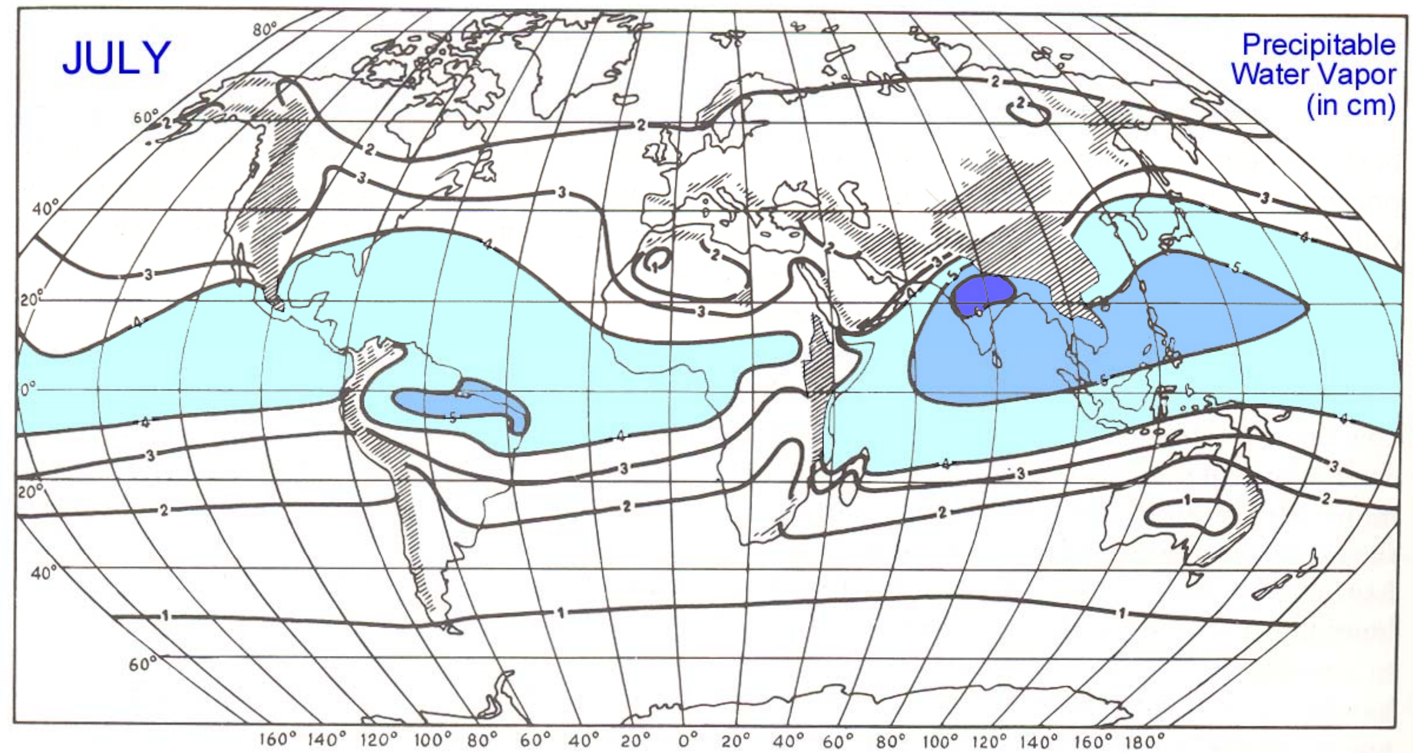


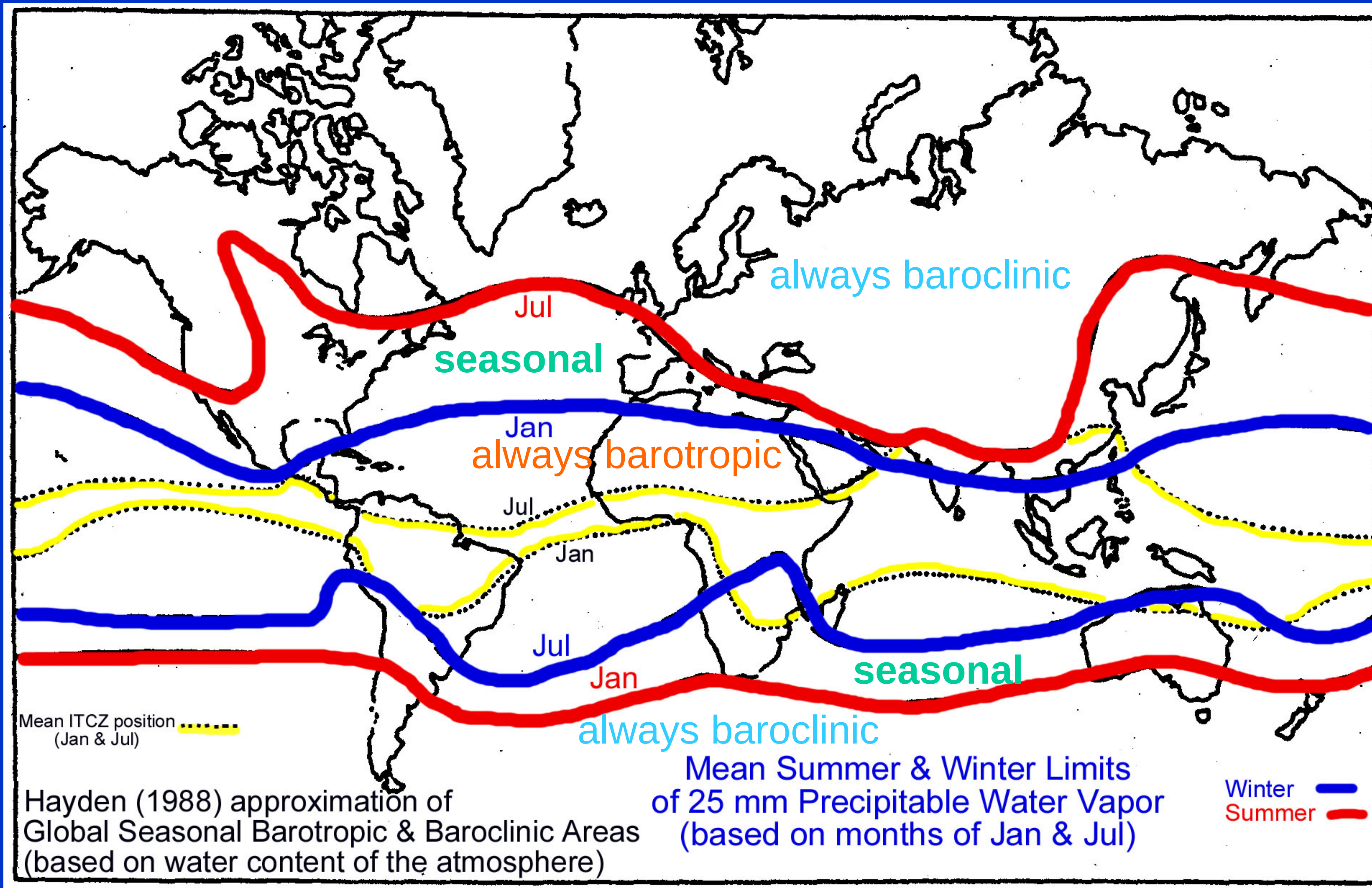
MEAN SPECIFIC HUMIDITY at 1000 mb

Annual (Jan – Dec)

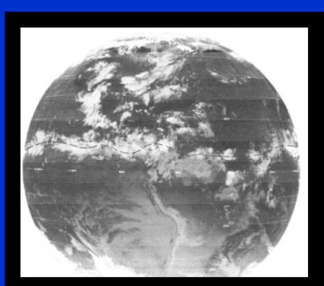



JANUARY
Precipitable
Water Vapor
(in cm)
160° 140° 120° 100°

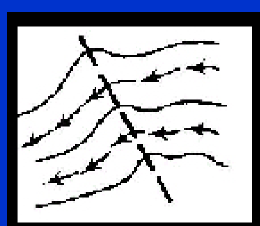

JULY
Precipitable
Water Vapor
(in cm)
160° 140° 120° 100° 80° 60° 40° 20° 0° 20° 40° 60° 80° 100° 120° 140° 160° 180°


always baroclinic
Jul
seasonal
Jan
always barotropic
Jul
Jan
Jul
Jan
seasonal
always baroclinic
Mean ITCZ position
(Jan & Jul)
Hayden (1988) approximation of
Global Seasonal Barotropic & Baroclinic Areas
(based on water content of the atmosphere)
Mean Summer & Winter Limits
of 25 mm Precipitable Water Vapor
(based on months of Jan & Jul)
Winter
Summer

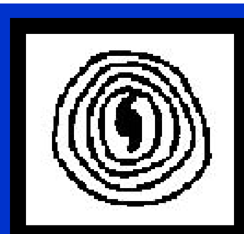
	SCALE OF DISTANCE: 10,000 km	1000 km	100 km	10 km	0 km
	WORLD SCALE	SYNOPTIC SCALE	MESO-SCALE	CONVECTIVE OR SMALL SCALE	
Extra-Tropical	Long or Rossby waves Hadley cells or subtropical anticyclones	Depressions Anticyclones	Fronts Lee waves Squall lines in troughs	Cumulonimbus showers Tornadoes	
Tropics	I.T.C.Z. Easterly waves	Cloud clusters Tropical cyclones	Meso-scale convective cells	Convective elements	
SCALE OF TIME	1000 h	100 h	10 h	1 h	0 h



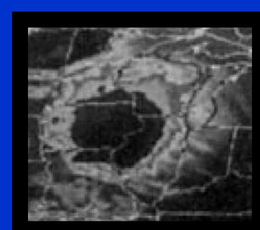
ITCZ



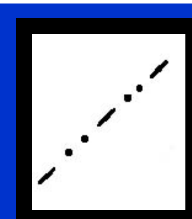
EASTERLY WAVE



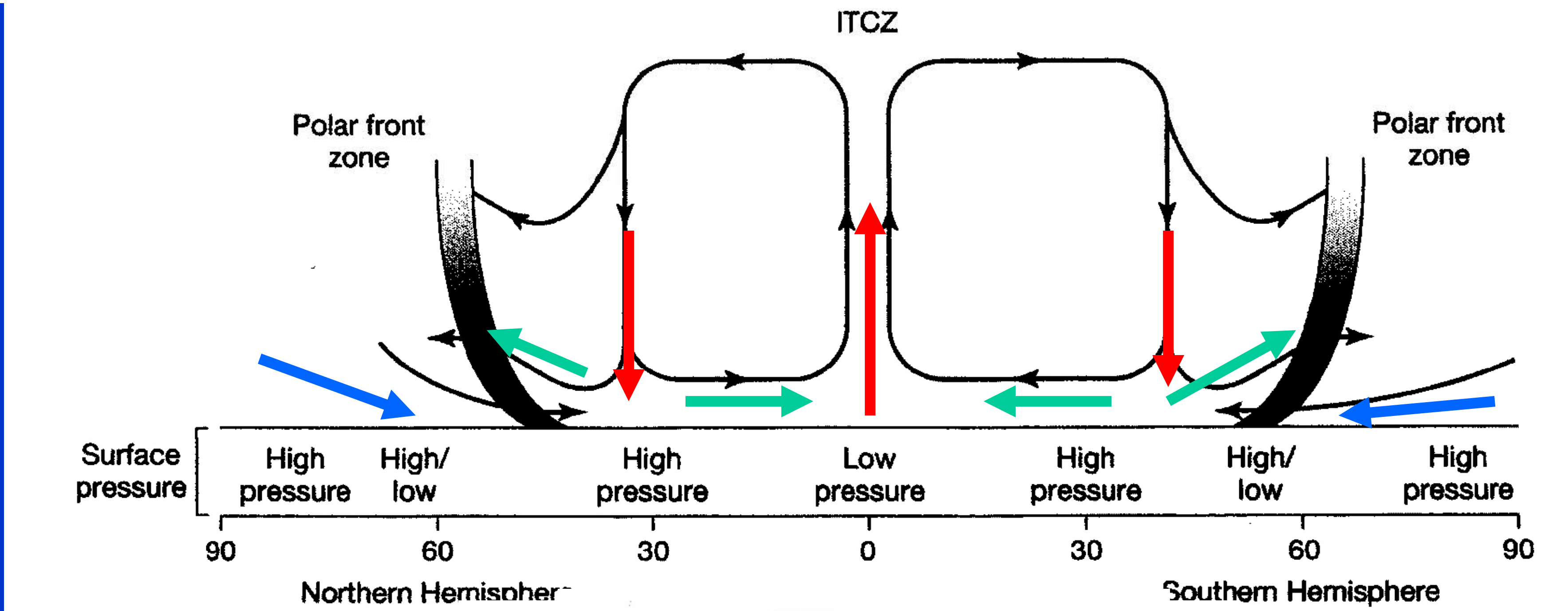
TROPICAL STORM

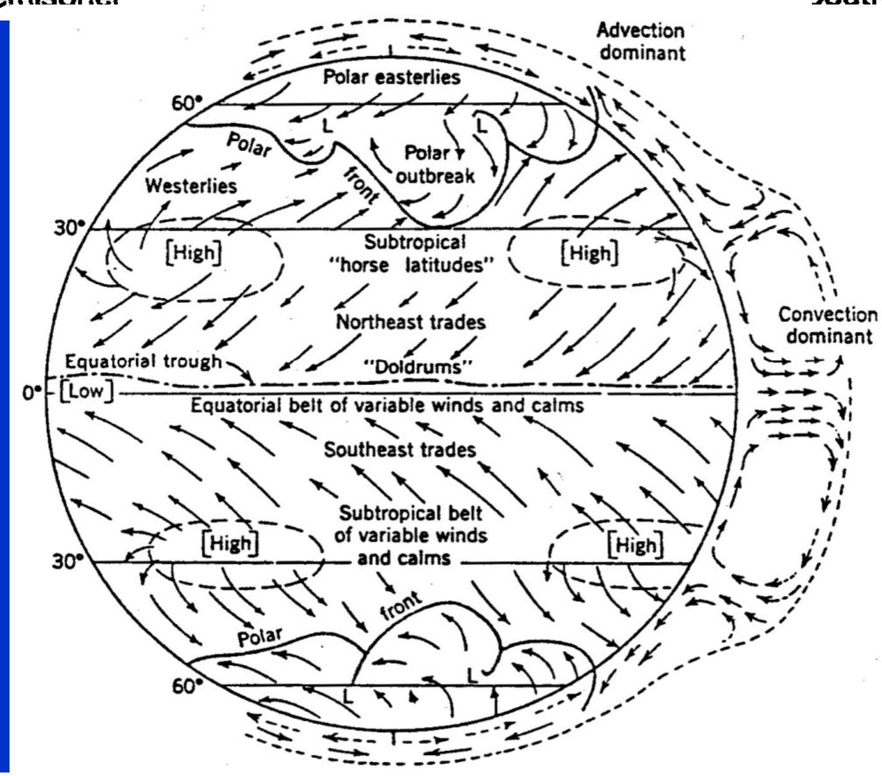


MESOSCALE CONVECTION

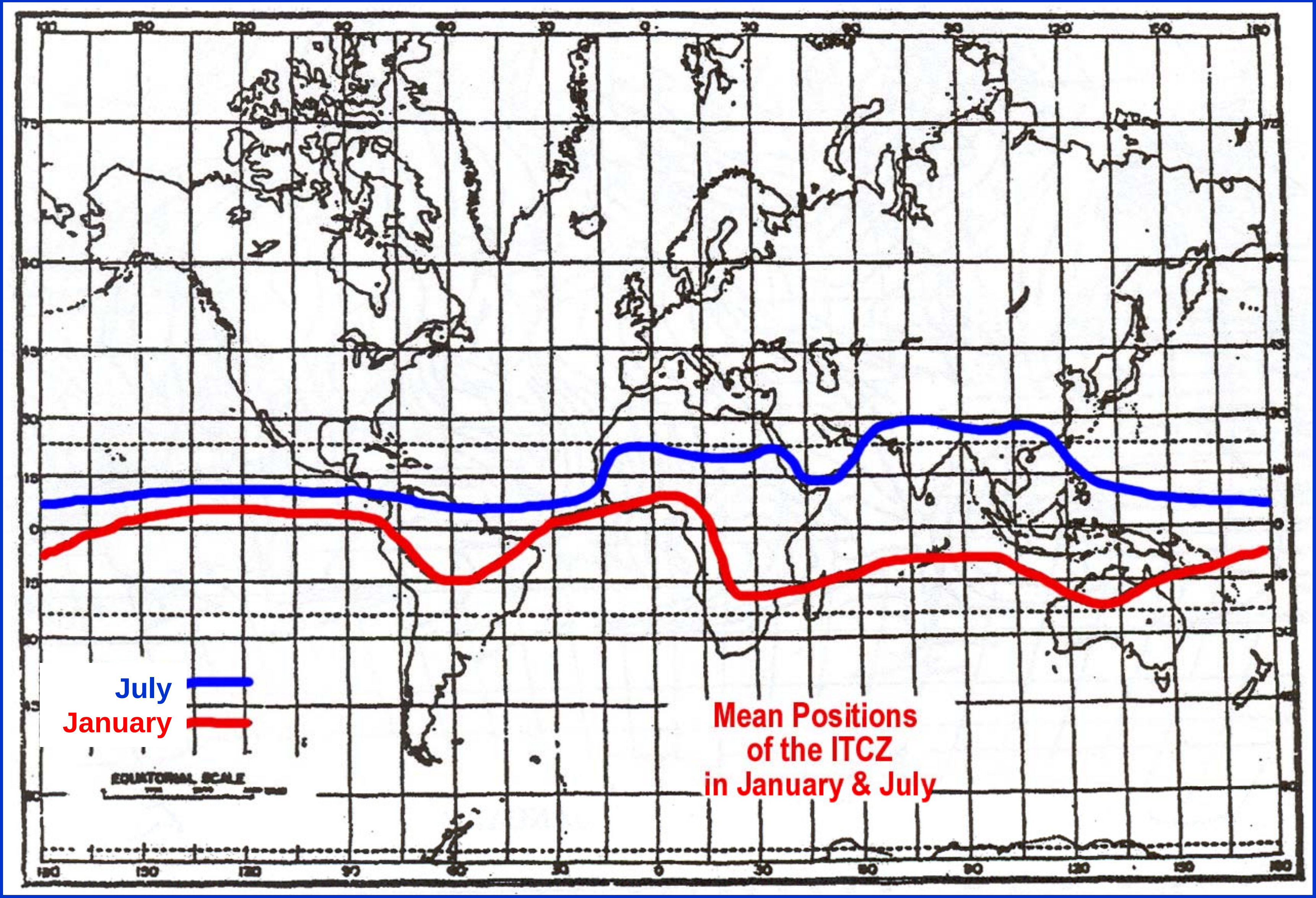


ORGANIZED CONVECTION

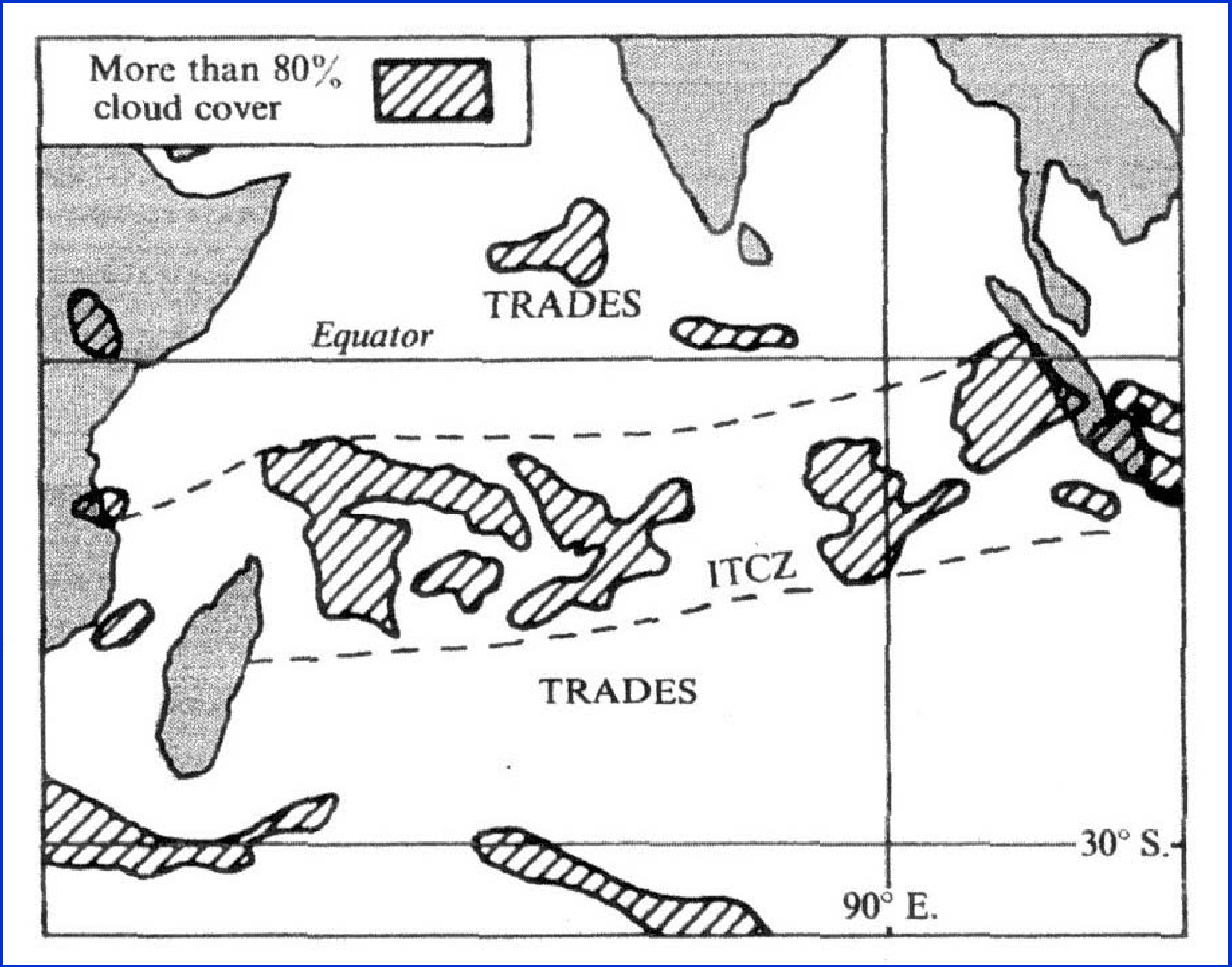

ITCZ
Polar front zone
Polar front zone
Surface pressure
High pressure
High/ low
High pressure
Low pressure
High pressure
High/ low
High pressure
90
60
30
0
30
60
90
Southern Hemisphere


Advection dominant
Polar easterlies
60°
L
L
Polar
Polar outbreak
front
Westerlies
30°
[High]
Subtropical "horse latitudes"
[High]
Northeast trades
Equatorial trough
"Doldrums"
Convection dominant
0°
[Low]
Equatorial belt of variable winds and calms
Southeast trades
Subtropical belt of variable winds and calms
[High]
[High]
30°
front
Polar
L
L
60°

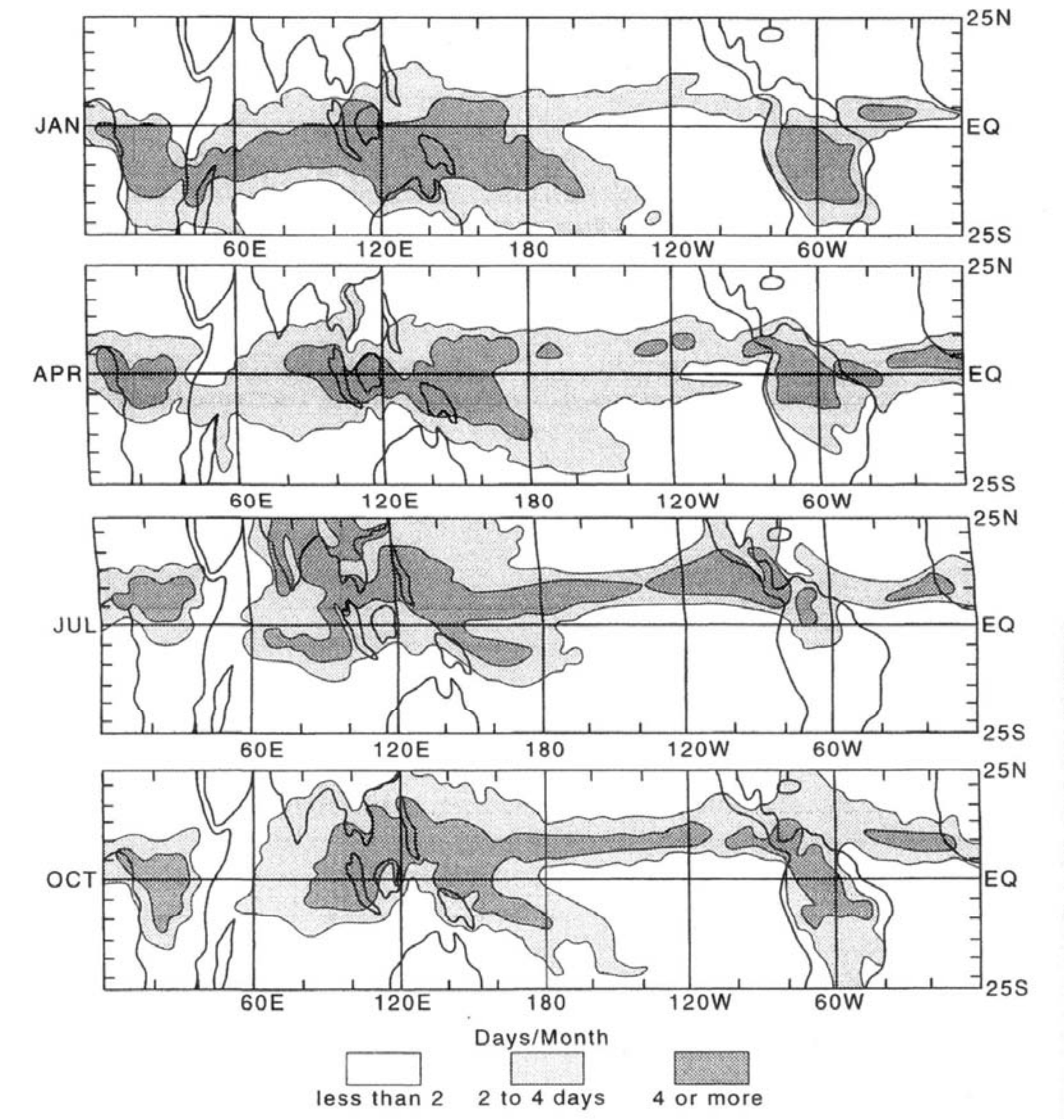
Intertropical Convergence Zone



Intertropical Convergence Zone



The ITCZ - detail: Latitudinal Variation & Longitudinal zones

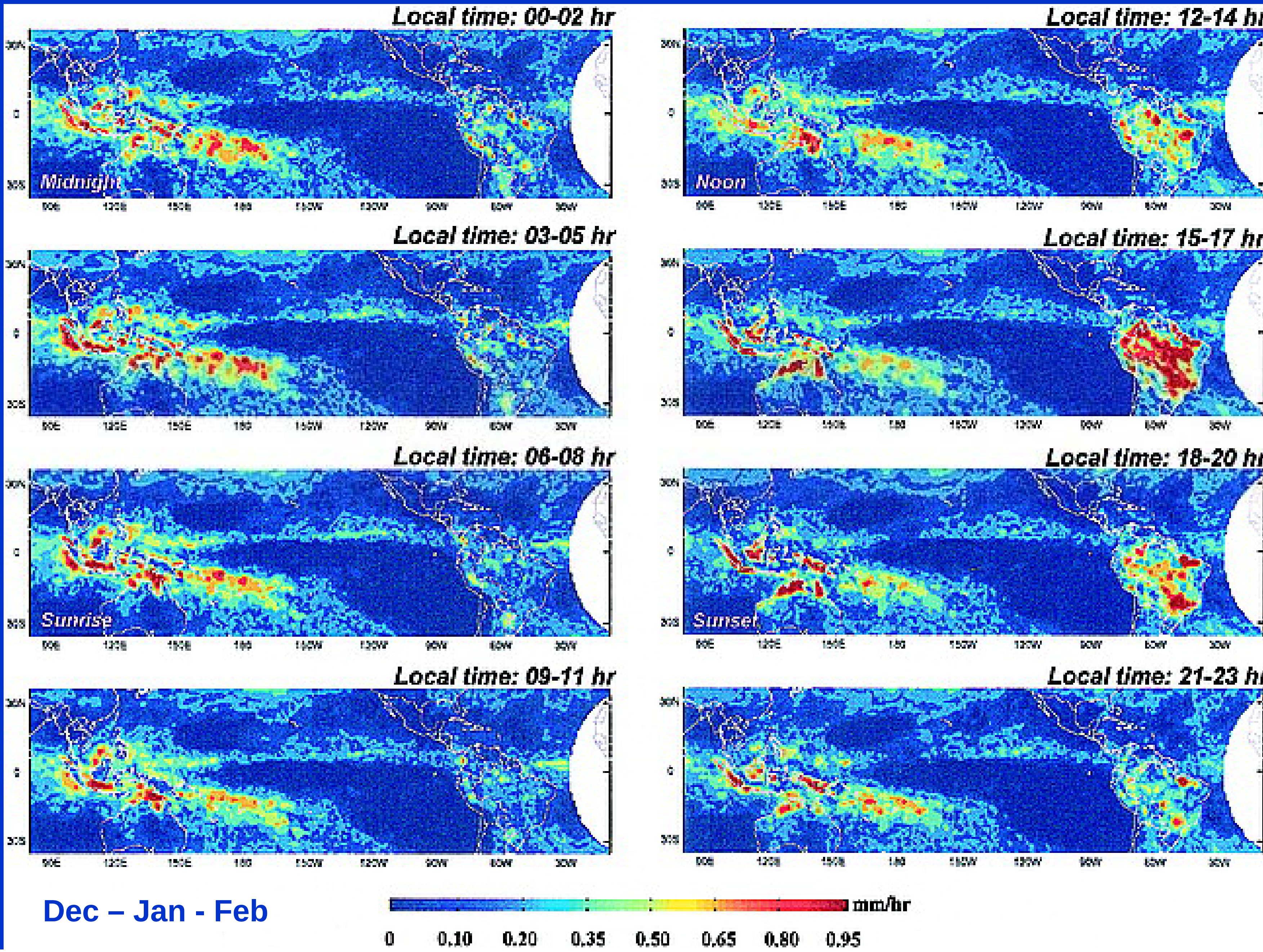


# of days per month of highly reflective clouds

Table 5.1 Seven ITCZ zones (Waliser and Gautier, 1993)

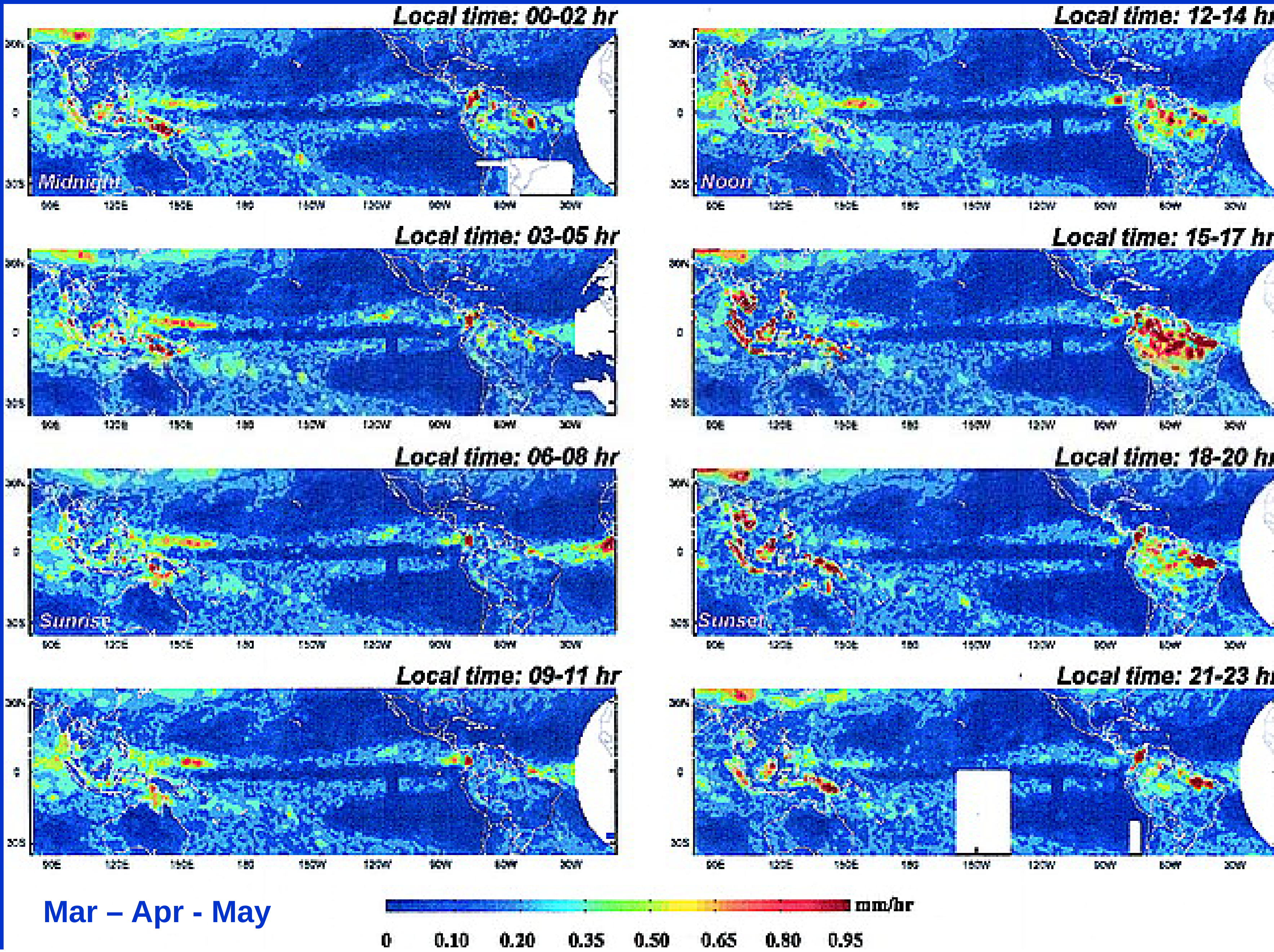
Zone	Longitude limits
Africa	10–40°E
Indian	60–100°E
West Pacific	10–150°E
Central Pacific	160–160°W
East Pacific	100–140°W
South America	45–75°W
Atlantic	10–40°W

Seasonal climatological averages of PERSIANN estimated 2-hour rainfall (in mm / hr) based on one year (Aug 1998-Jul 1999)   (Sorooshian et al., J. of Climate, 2002.)

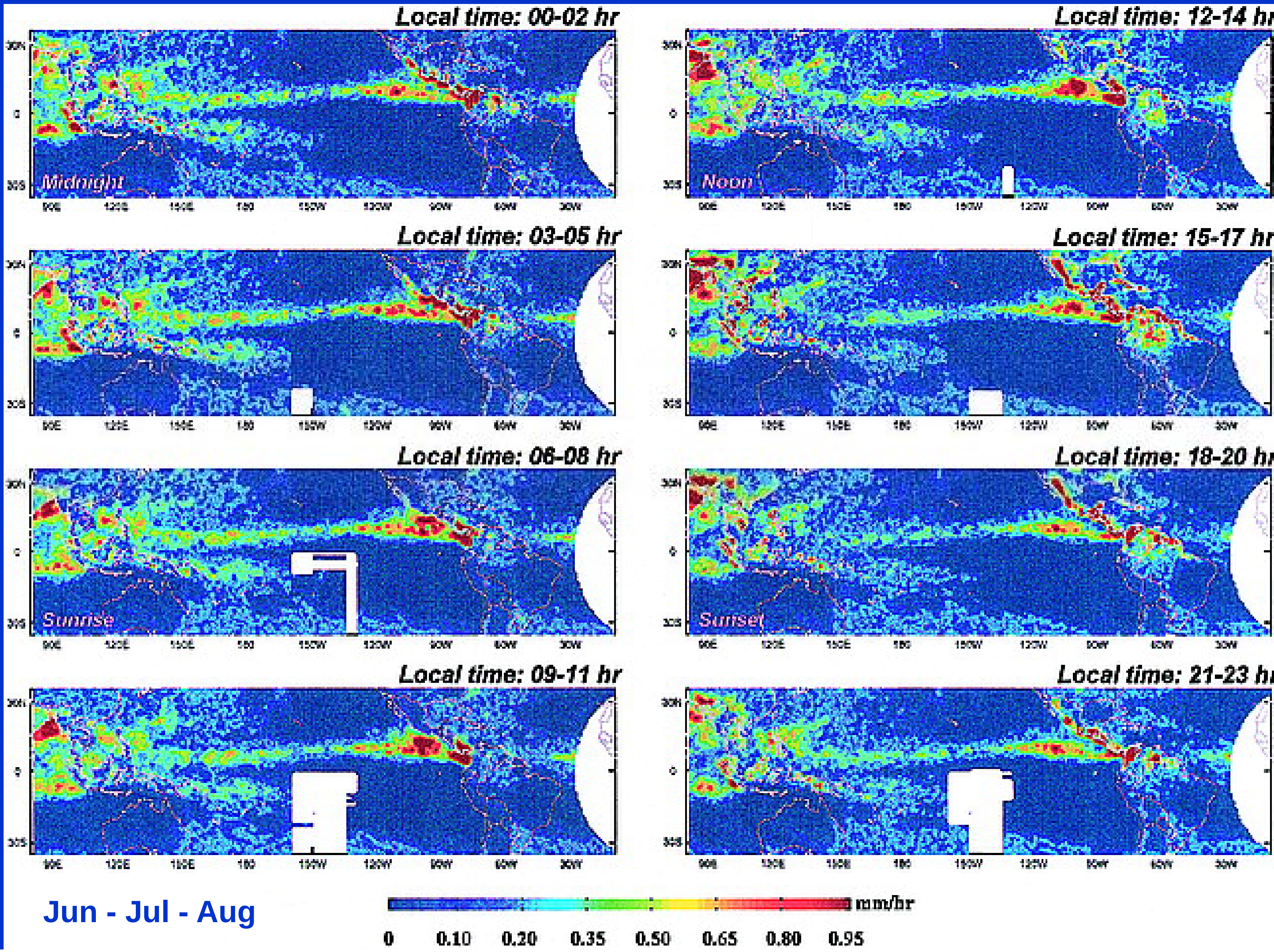


Dec – Jan - Feb

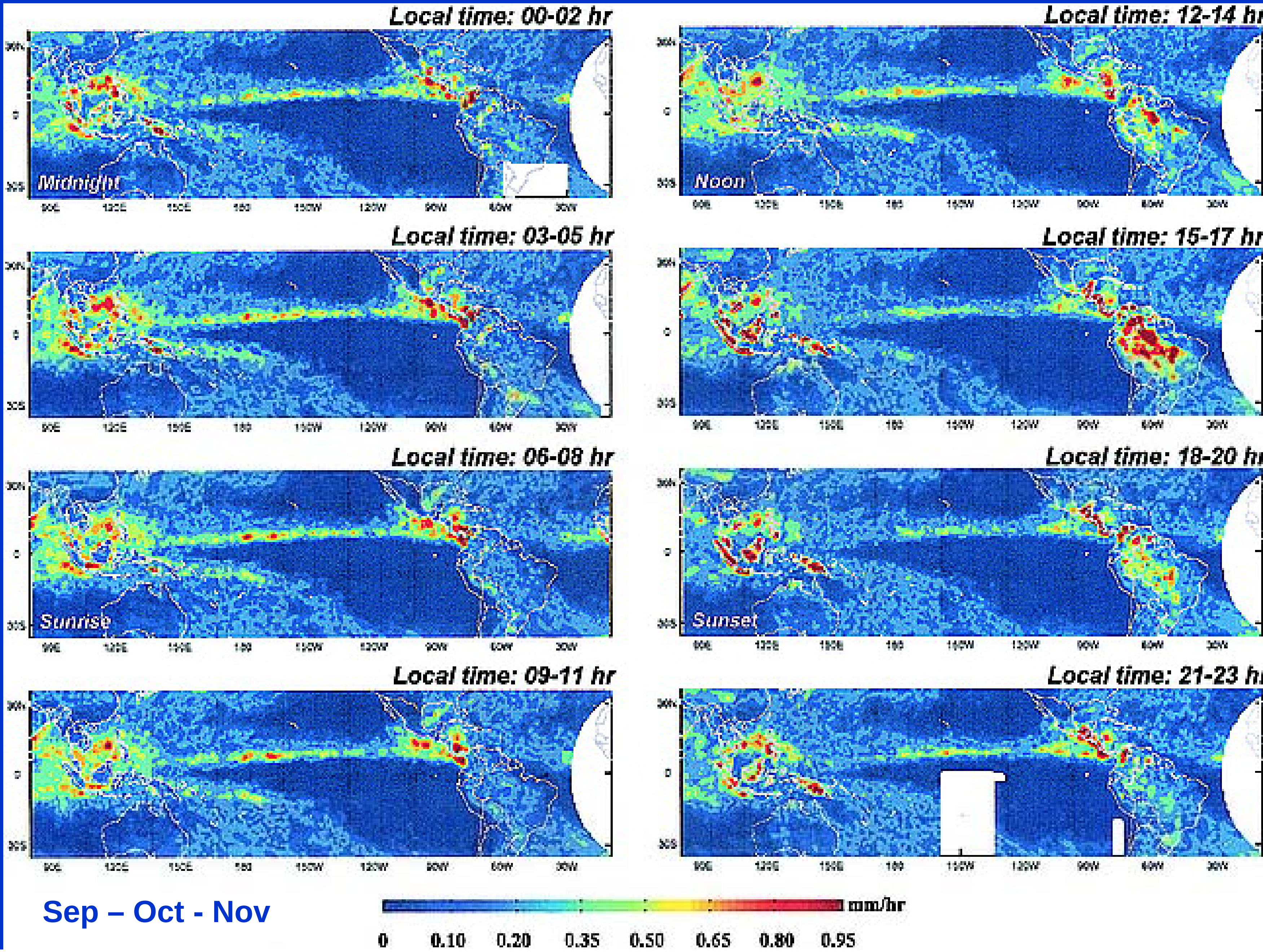
Seasonal climatological averages of PERSIANN estimated 2-hour rainfall (in mm / hr) based on one year (Aug 1998-Jul 1999) (Sorooshian et al., J. of Climate, 2002.)



Seasonal climatological averages of PERSIANN estimated 2-hour rainfall (in mm / hr) based on one year (Aug 1998-Jul 1999)   (Sorooshian et al., J. of Climate, 2002.)



Seasonal climatological averages of PERSIANN estimated 2-hour rainfall (in mm / hr) based on one year (Aug 1998-Jul 1999)   (Sorooshian et al., J. of Climate, 2002.)

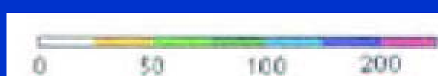


Sep – Oct - Nov

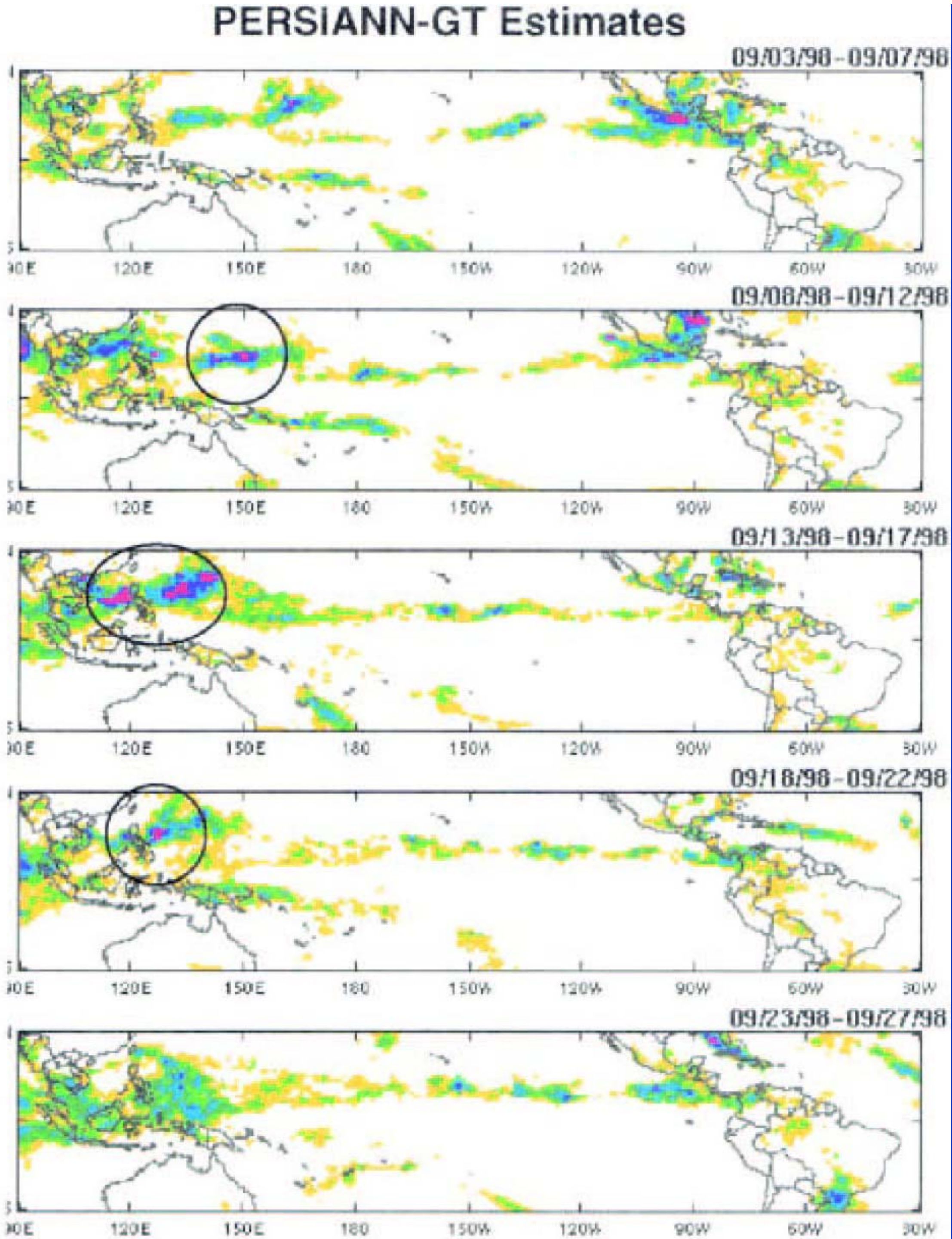
Week-to-week changes in ITCZ Convection & Rainfall

(based on PERSIANN estimates)

Sept 3 – 27, 1998

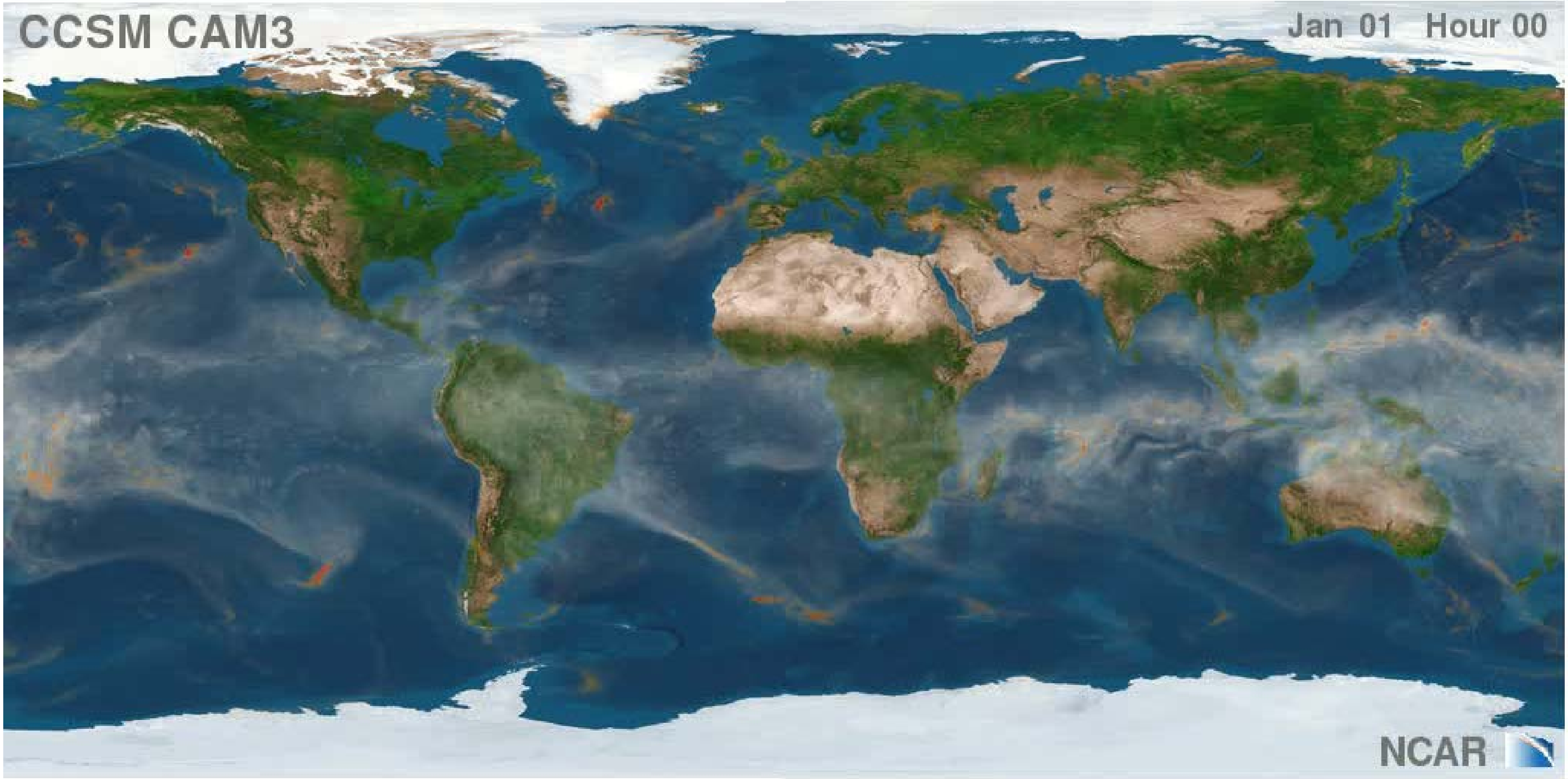


mm per 5-day interval



(Sorooshian et al., Bulletin of AMS, 2000)

WHITE = Column summed water vapor ORANGE = Precipitation rate



http://www.vets.ucar.edu/vg/T341/index.shtml

T341 resolution (1024 x 512 gridpoints)
(Resolves features as small as 37 kilometers)

LOOK FOR:

-- Jan: Indian Ocean cyclone

-- Aug: two super typhoons SE of Japan

Mean Annual Rainfall in the Tropics

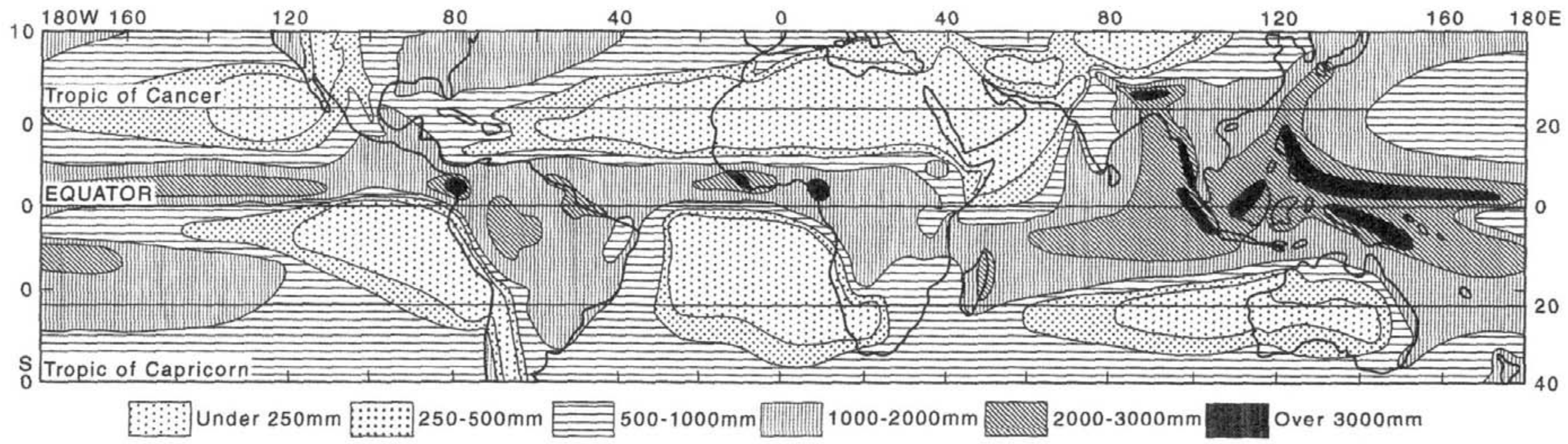


Figure 10.2 Mean annual rainfall

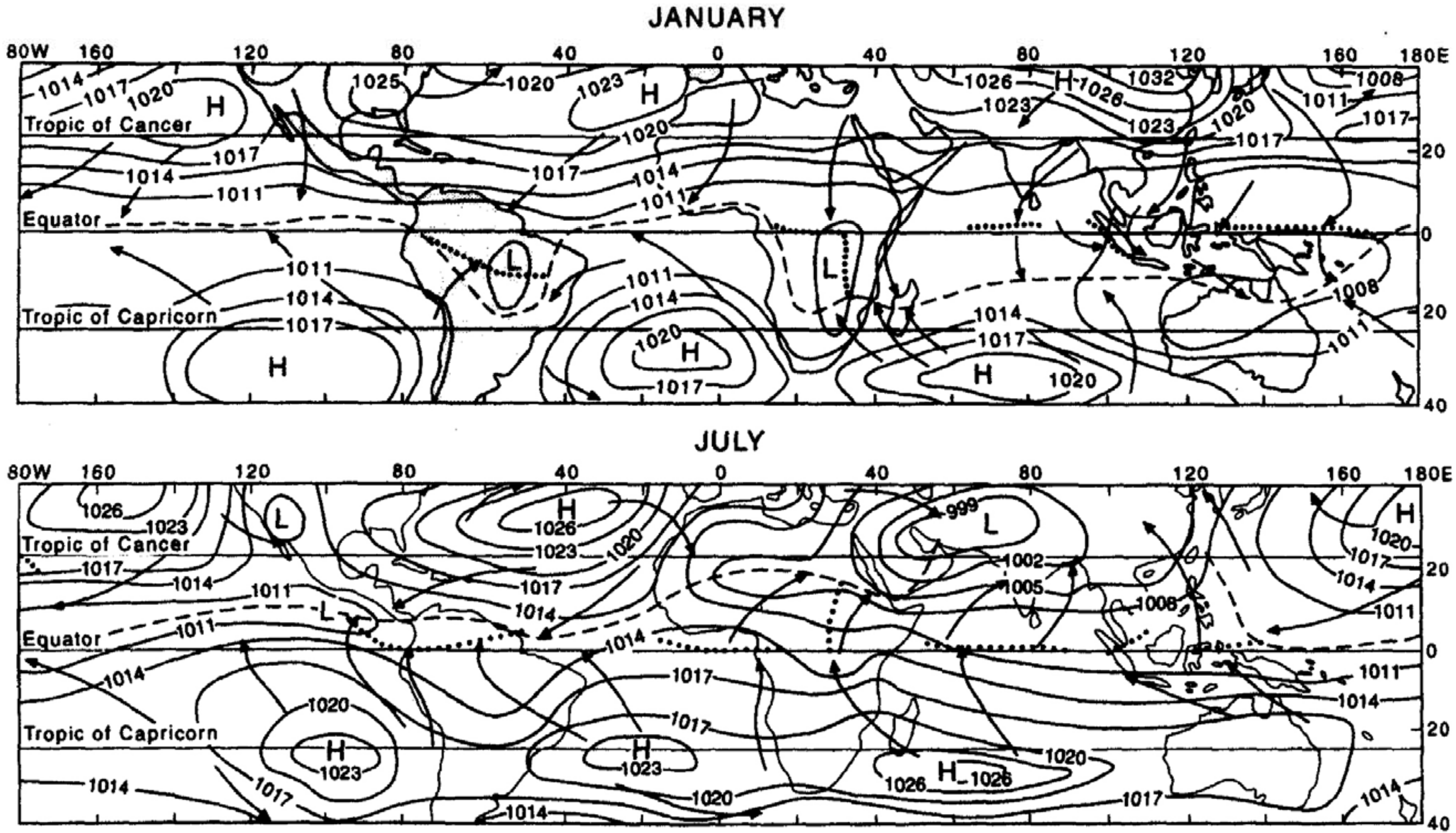
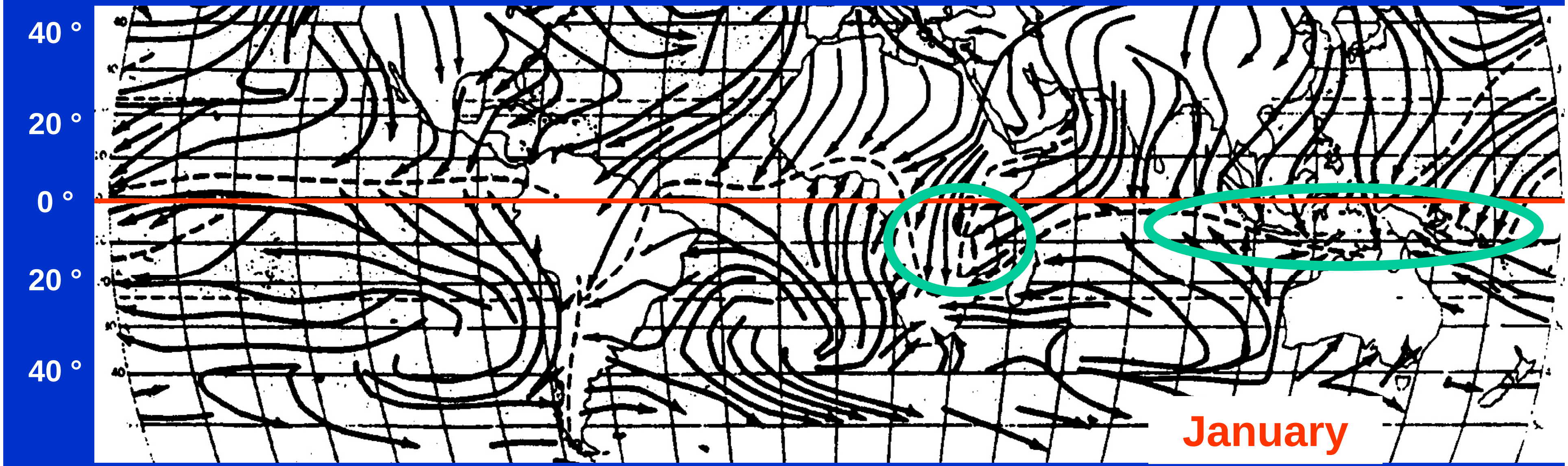
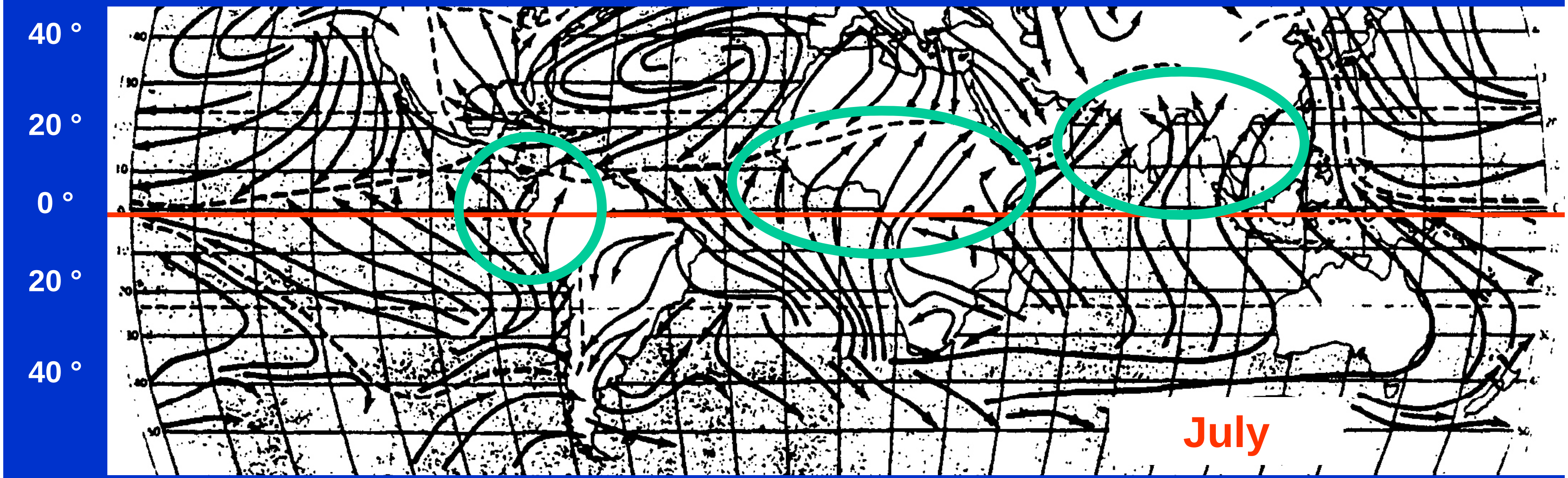
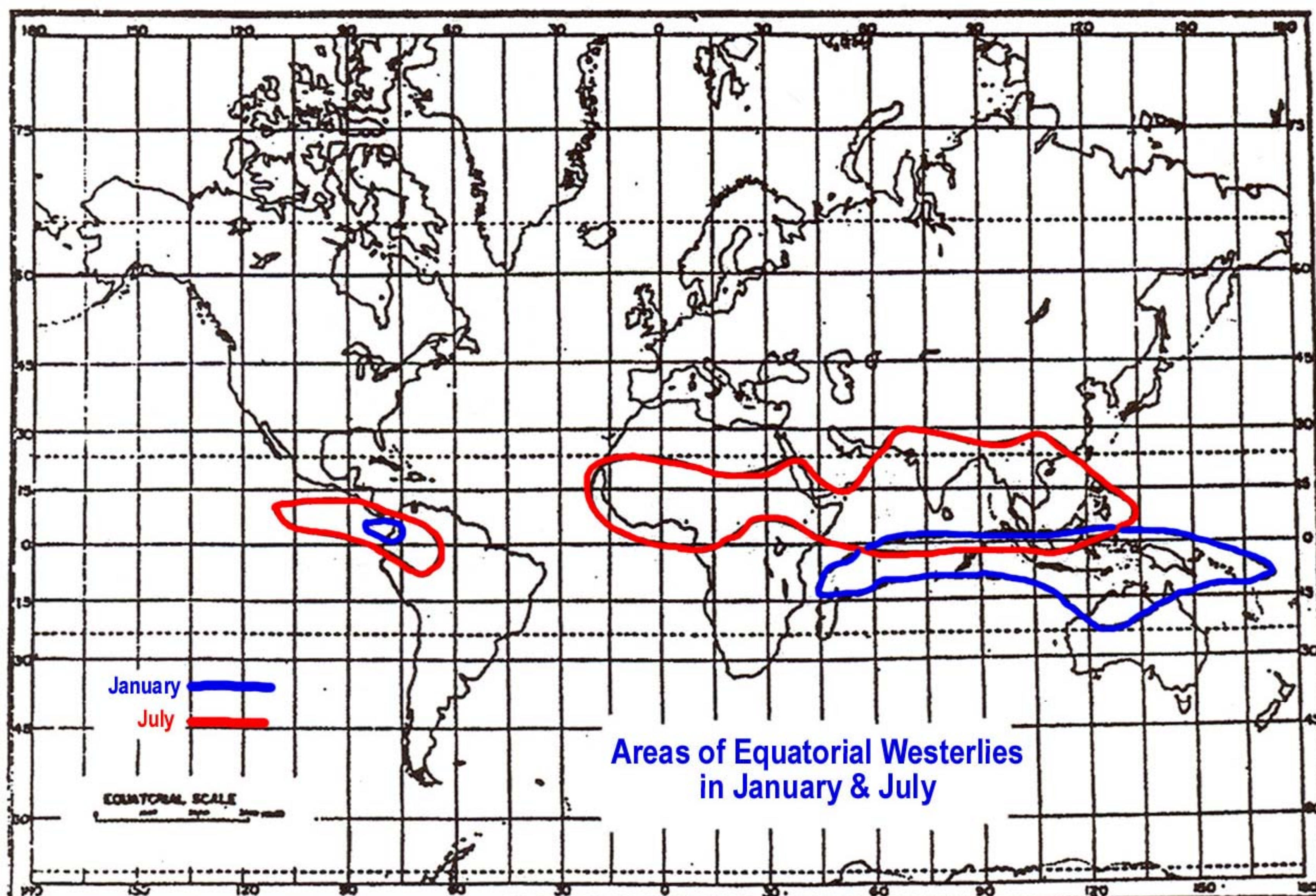


Figure 5.2 Mean sea level pressure and predominant surface winds in January and July. Dashed line is the mean position of the ITCZ. Dotted lines are secondary convergence zones



“re-curving” of Trade Winds from Easterlies to Westerlies

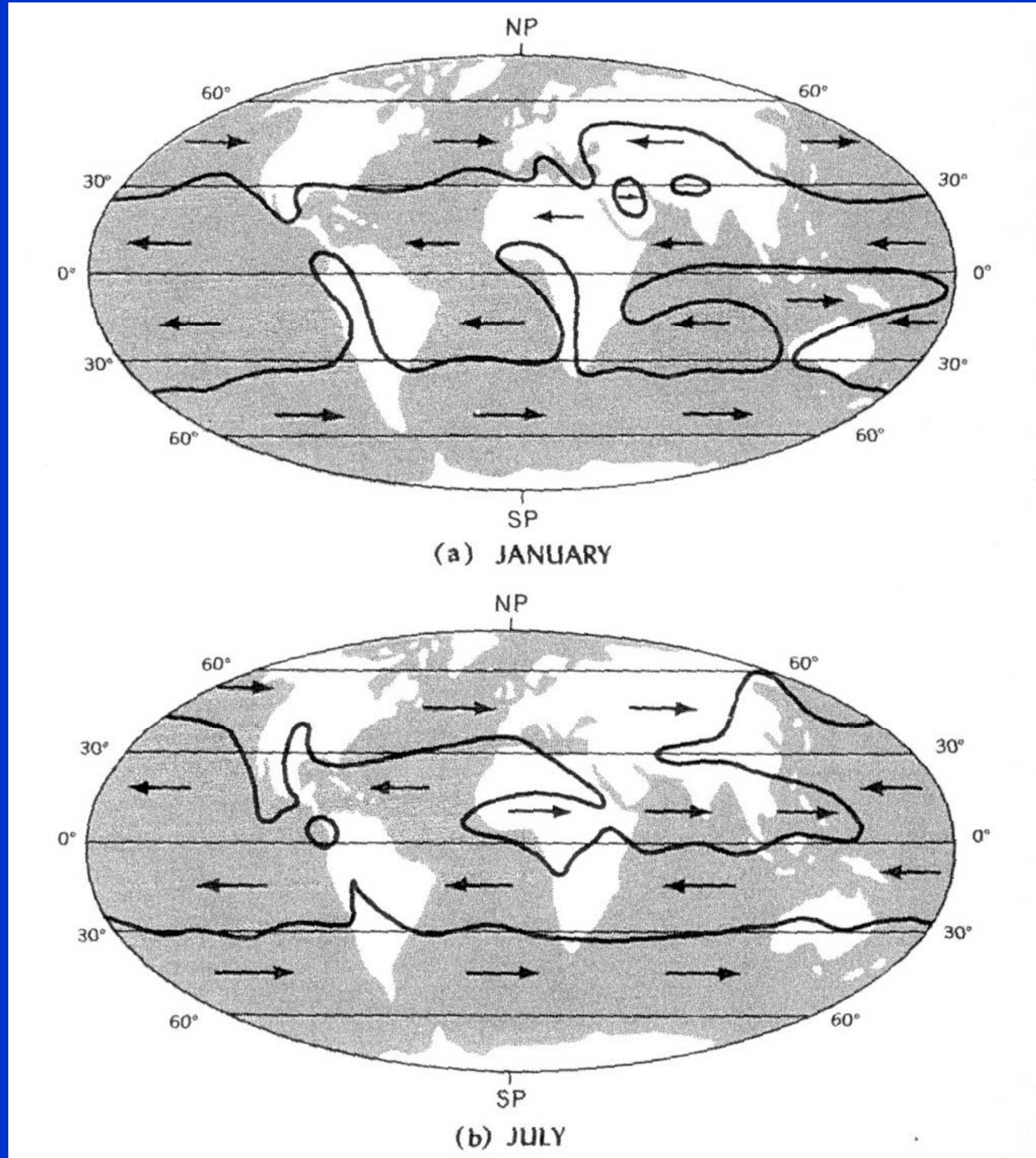



January
July
EQUATORIAL SCALE
Areas of Equatorial Westerlies
in January & July

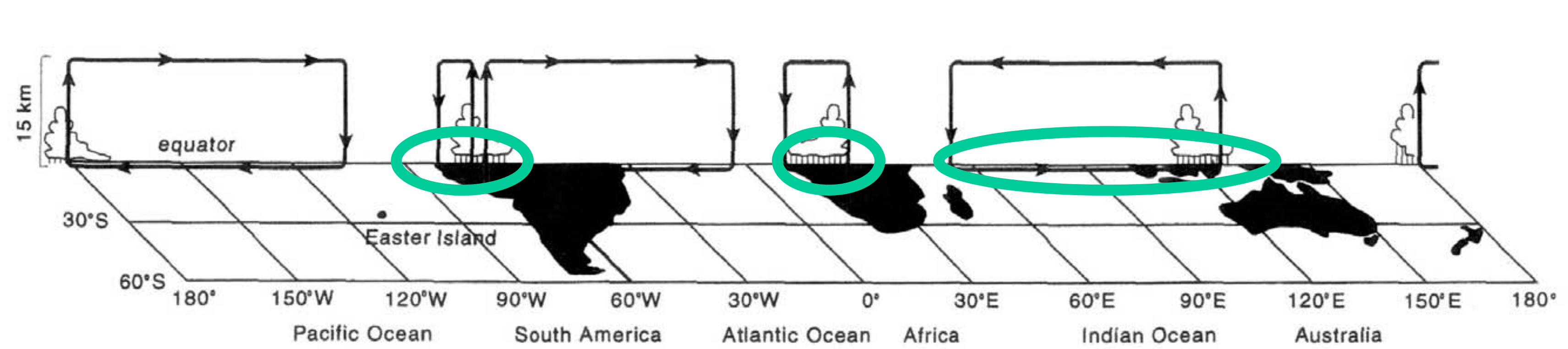
TROPICAL EASTERLIES & WESTERLIES

Geographical distribution of the west-east component of the mean surface wind.

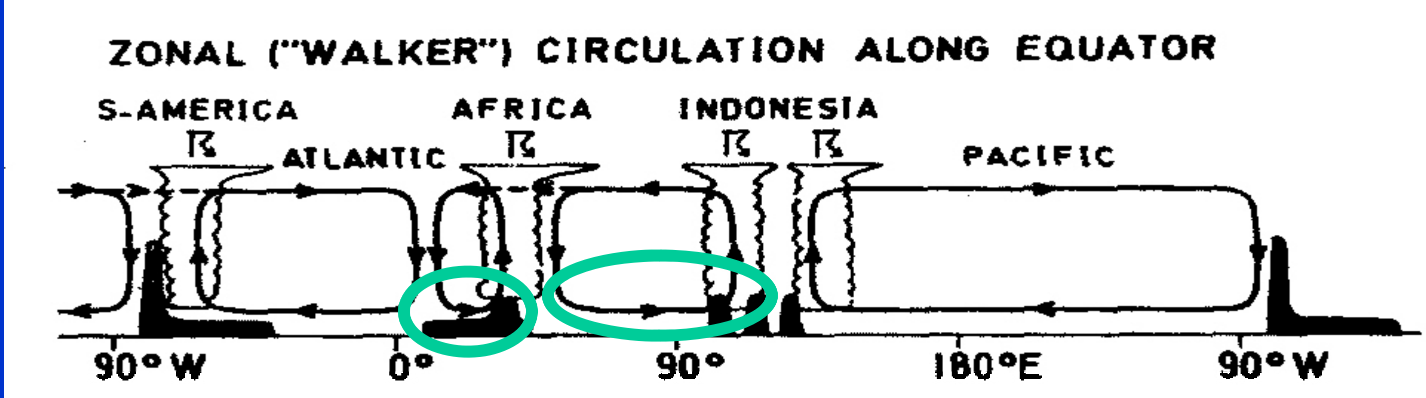
Heavy lines separate tropical easterlies from westerlies, both in equatorial and mid-latitudes.



THE WALKER CIRCULATION

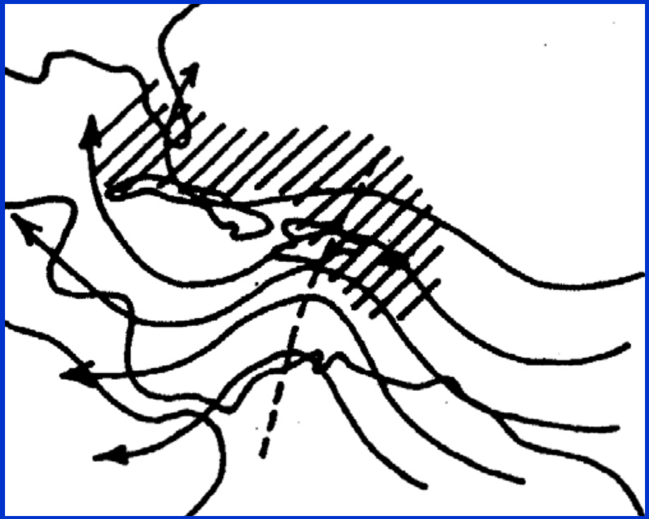


Two cross-sectional views along the equator

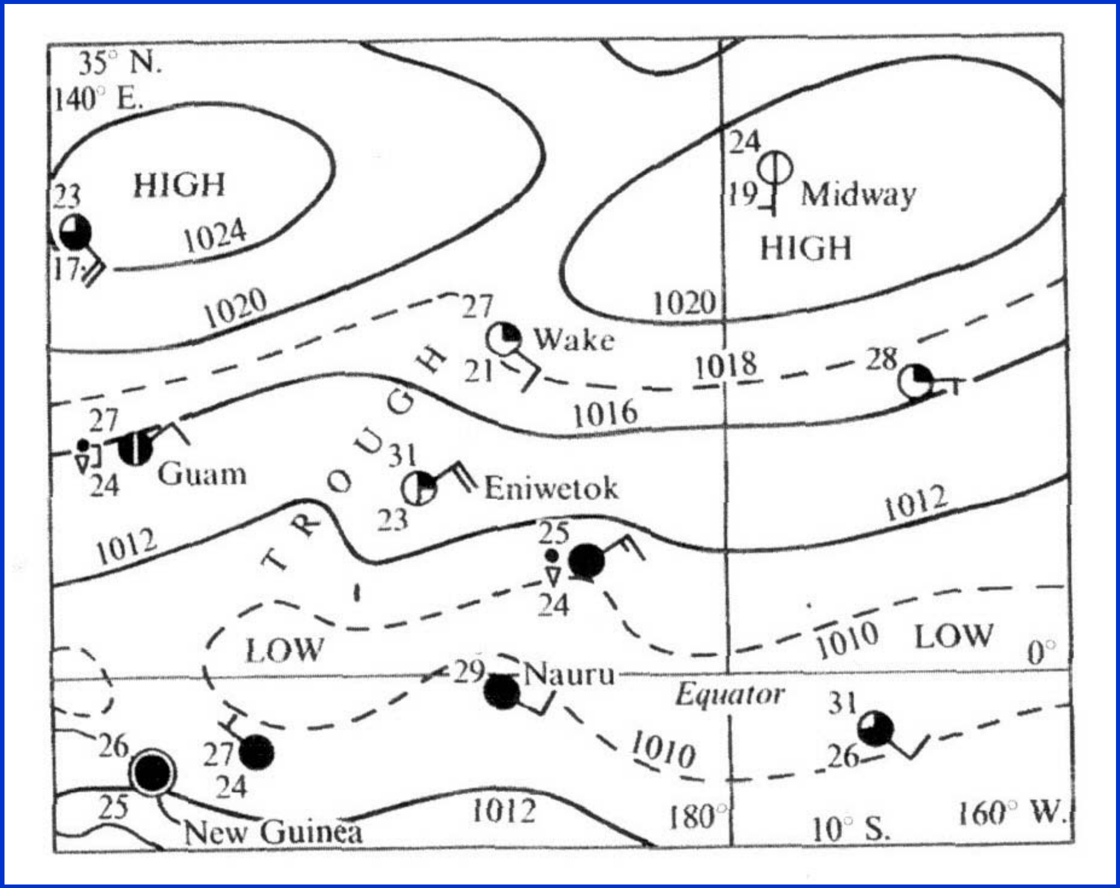


The Walker circulation consists of large east-west cells oriented along the equator. As a consequence some longitudes have more precipitation than others.

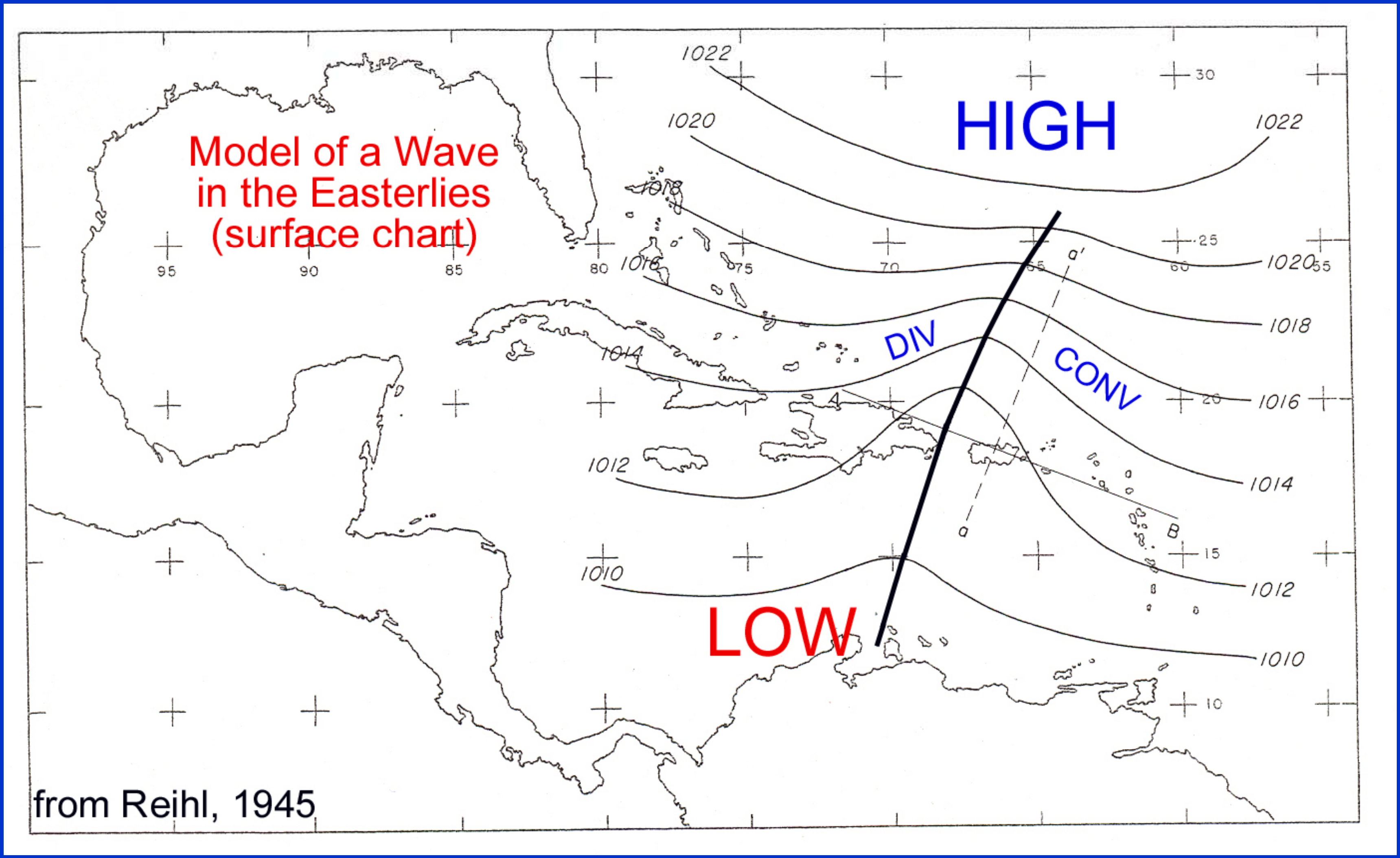
EASTERLY WAVES



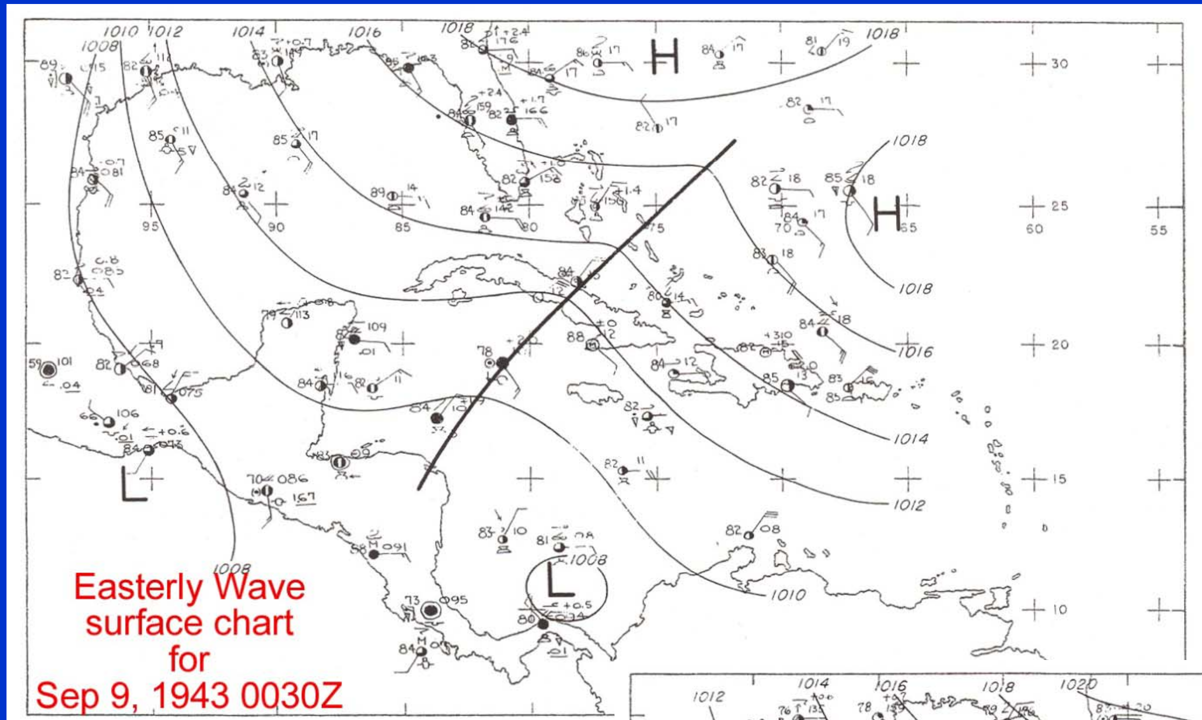
An easterly wave centered over the Dominican Republic on August 13, 1969. The dashed line indicates the axis of the easterly wave trough. The arrows indicate the prevailing airstreams and the cross-hatched area is the region of cloud masses.

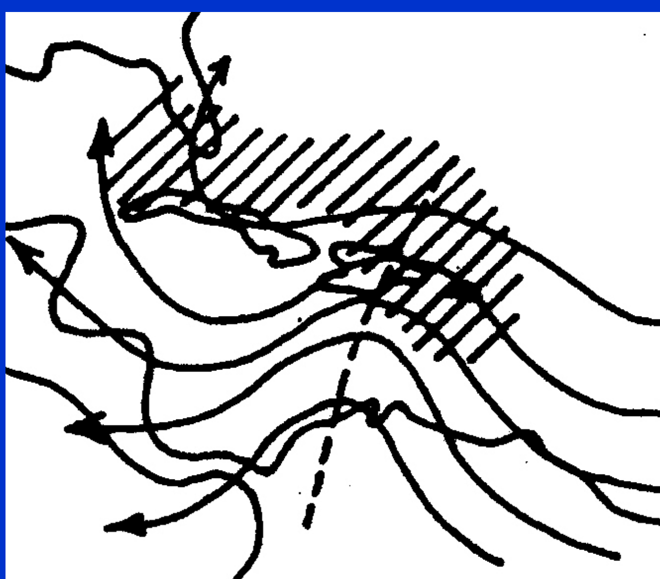


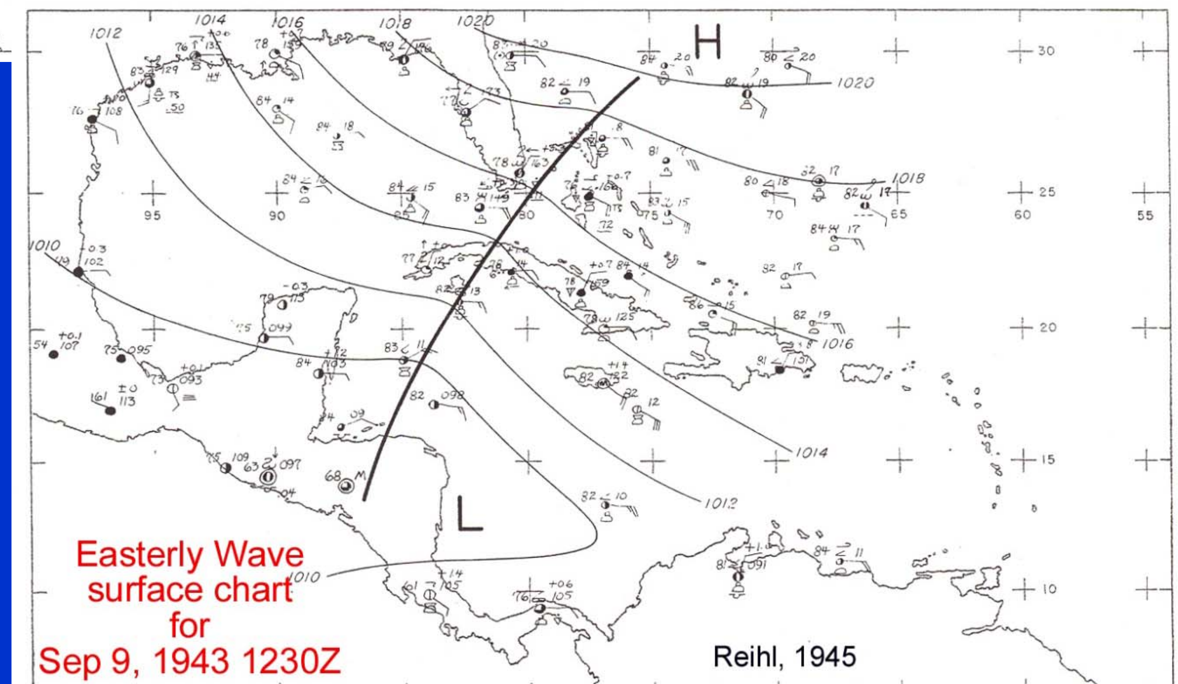
Marshall Islands, Pacific Ocean 28 April 1951

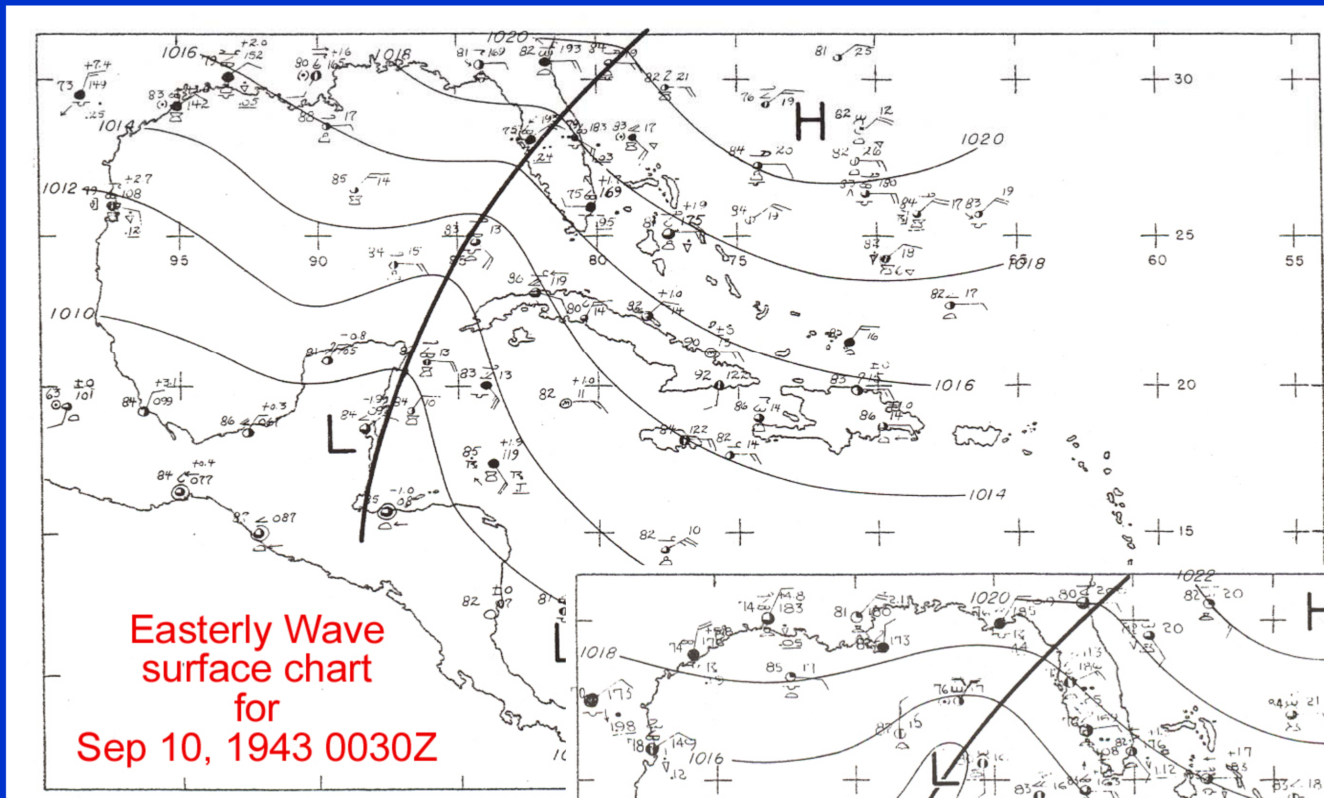


Model of a Wave
in the Easterlies
(surface chart)
HIGH
LOW
DIV
CONV
1022
1020
1018
1016
1014
1012
1010
30
25
20
15
10
95
90
85
80
75
70
65
60
55
A
B
a
a'
from Reihl, 1945

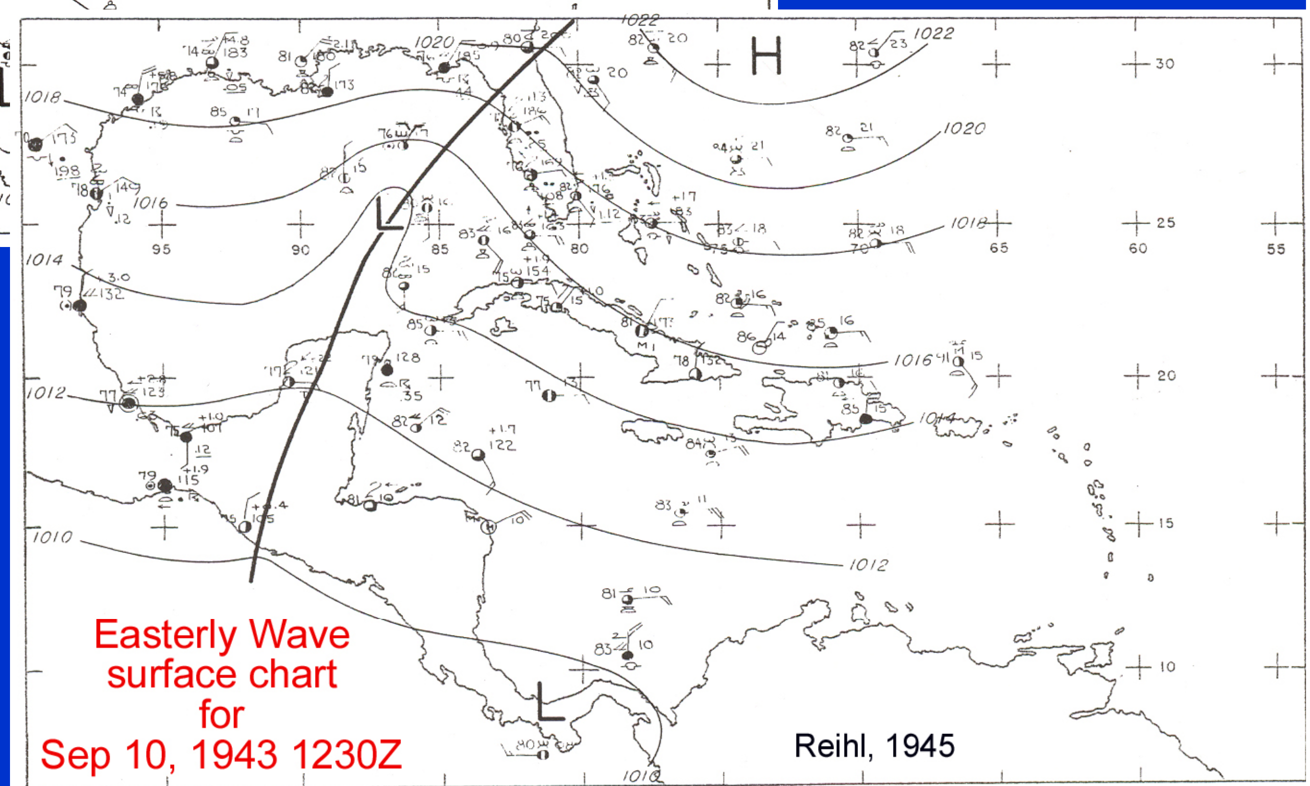

Easterly Wave
surface chart
for
Sep 9, 1943 0030Z




Easterly Wave
surface chart
for
Sep 9, 1943 1230Z
Reihl, 1945



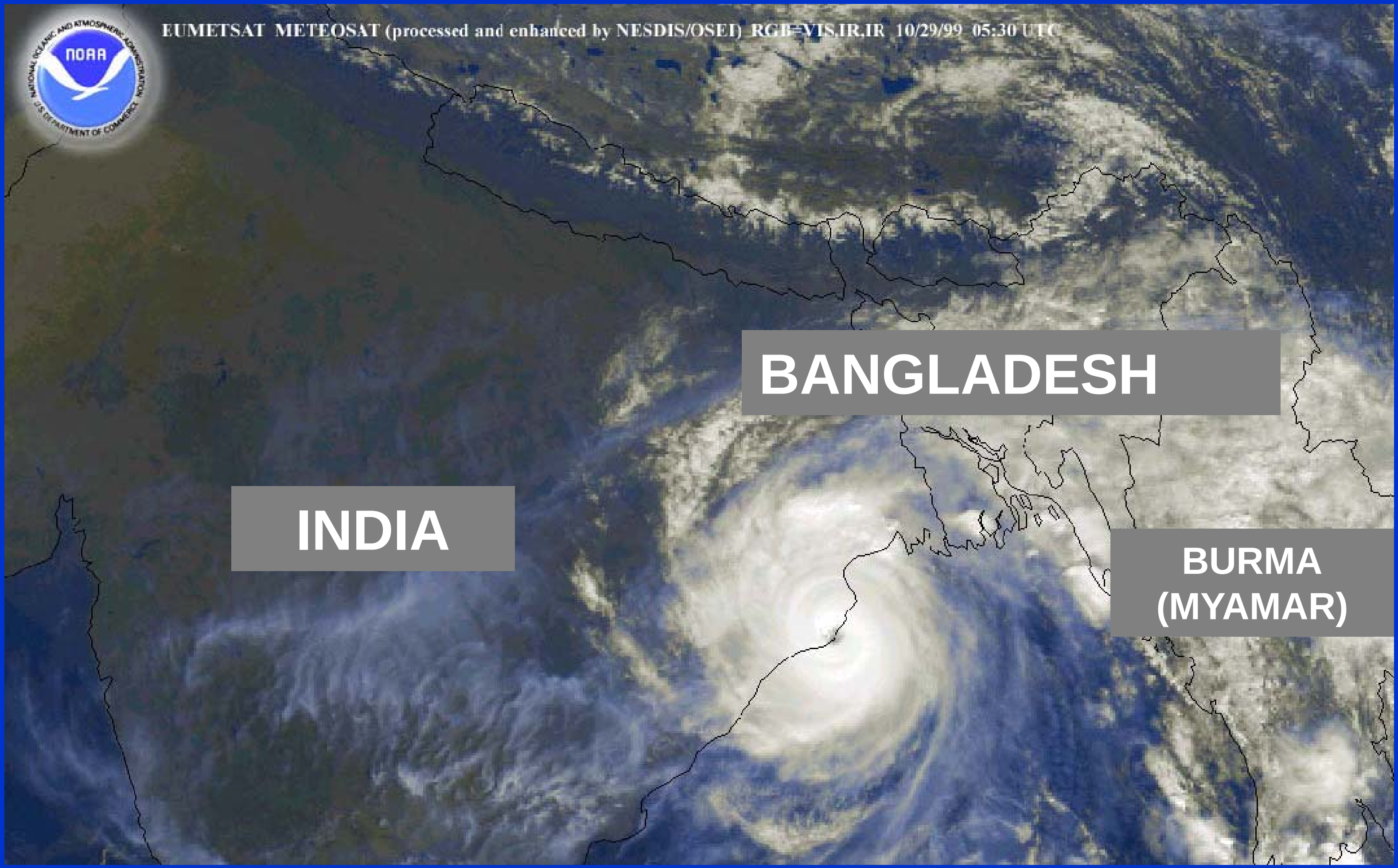
Easterly Wave surface chart for Sep 10, 1943 0030Z



Easterly Wave surface chart for Sep 10, 1943 1230Z

Reihl, 1945

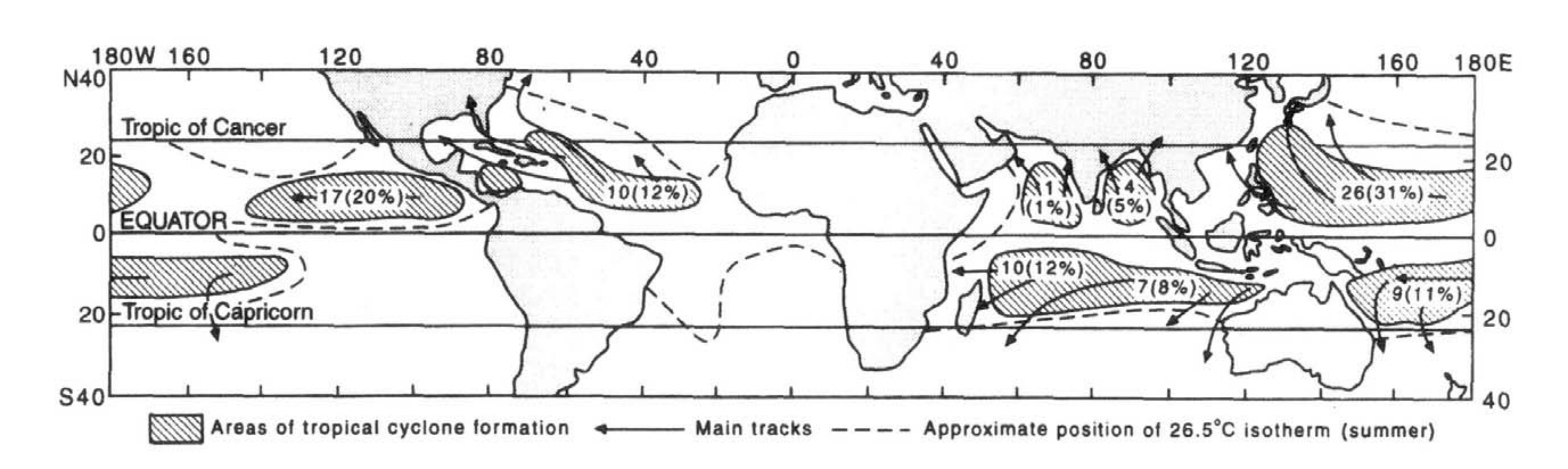
Tropical Cyclones



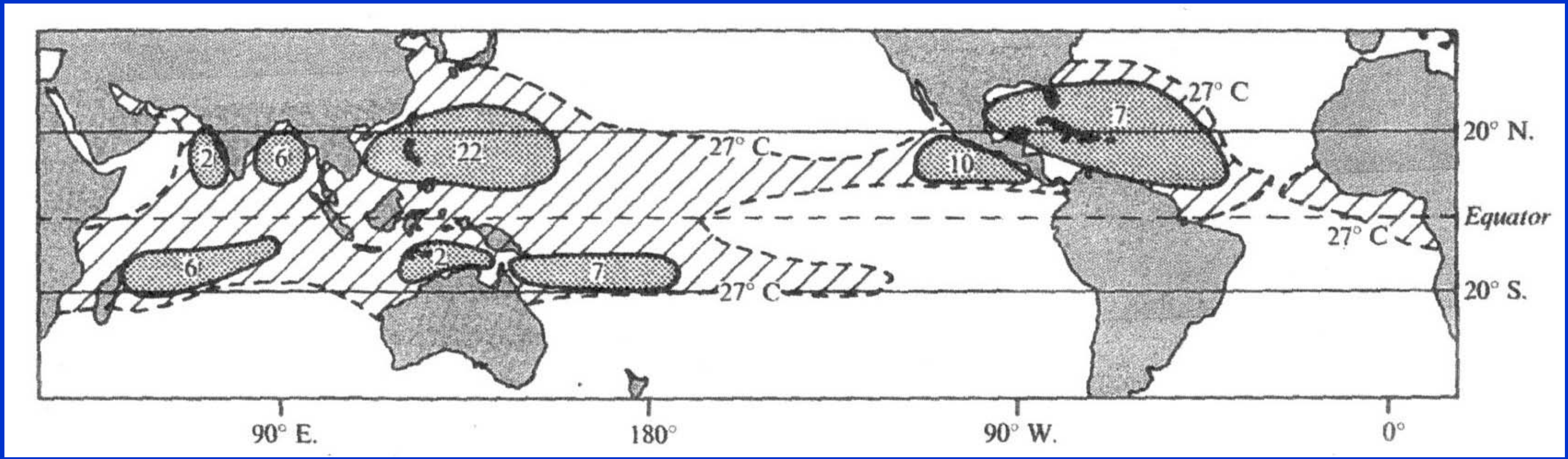
Tropical Cyclone 05B, 10-29-99, very heavy rain, winds 135 knots, second cyclone in two weeks

HURRICANE "INGREDIENTS":

- *Coriolis effect* must exceed a certain minimum value (> 5° lat; most common between 10°-20°lat)
- large area of ***warm SST's*** (>26°C, 81°F)
- enhanced by weak trade wind inversion
- ***weak upper level winds***, weak vertical wind shear, not near STJ
- preexisting ***synoptic-scale disturbance***, i.e., easterly wave to start off convergence
- enhanced by ***unstable air aloft***; i.e. organized upper level divergence as in trough aloft

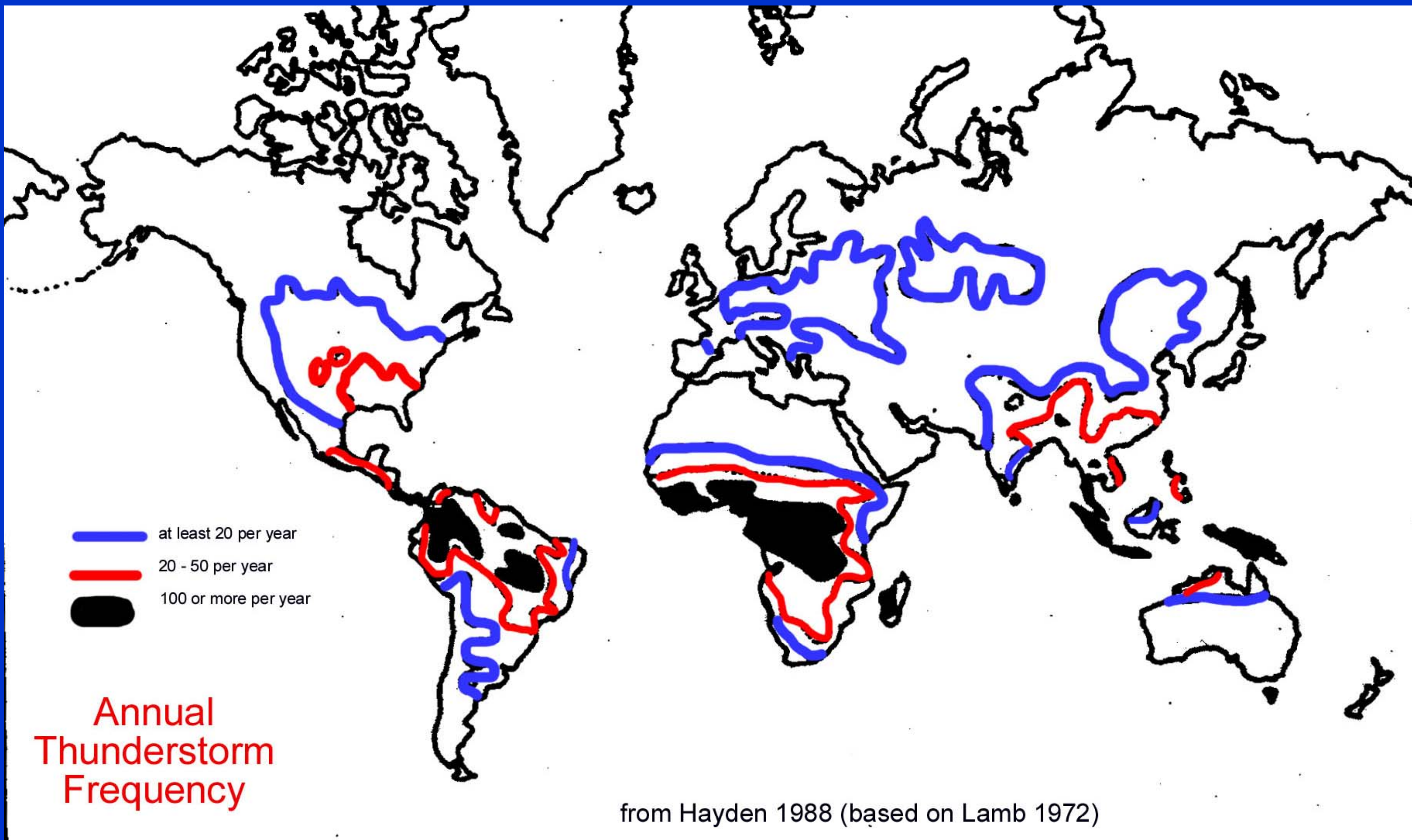


Main zones of tropical cyclone formation & predominant tracks
annual numbers (%) for tropical storms (> 17 m/s)



Areas of development of tropical storms w/ average number per year

THUNDERSTORMS



THUNDERSTORMS & MCC's

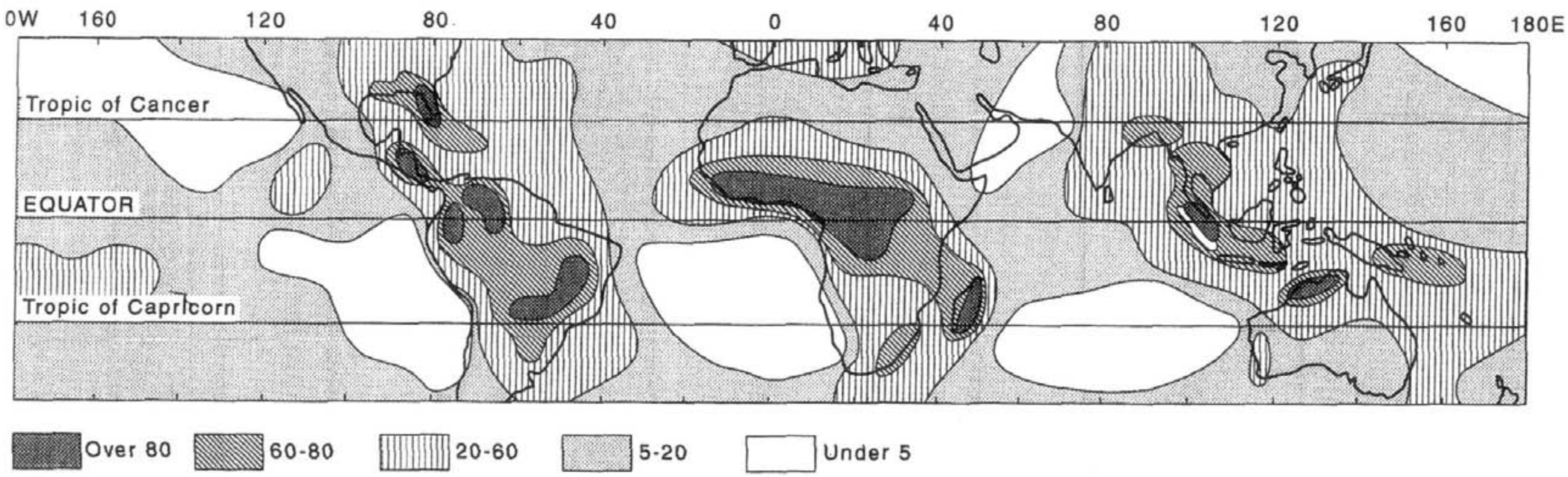
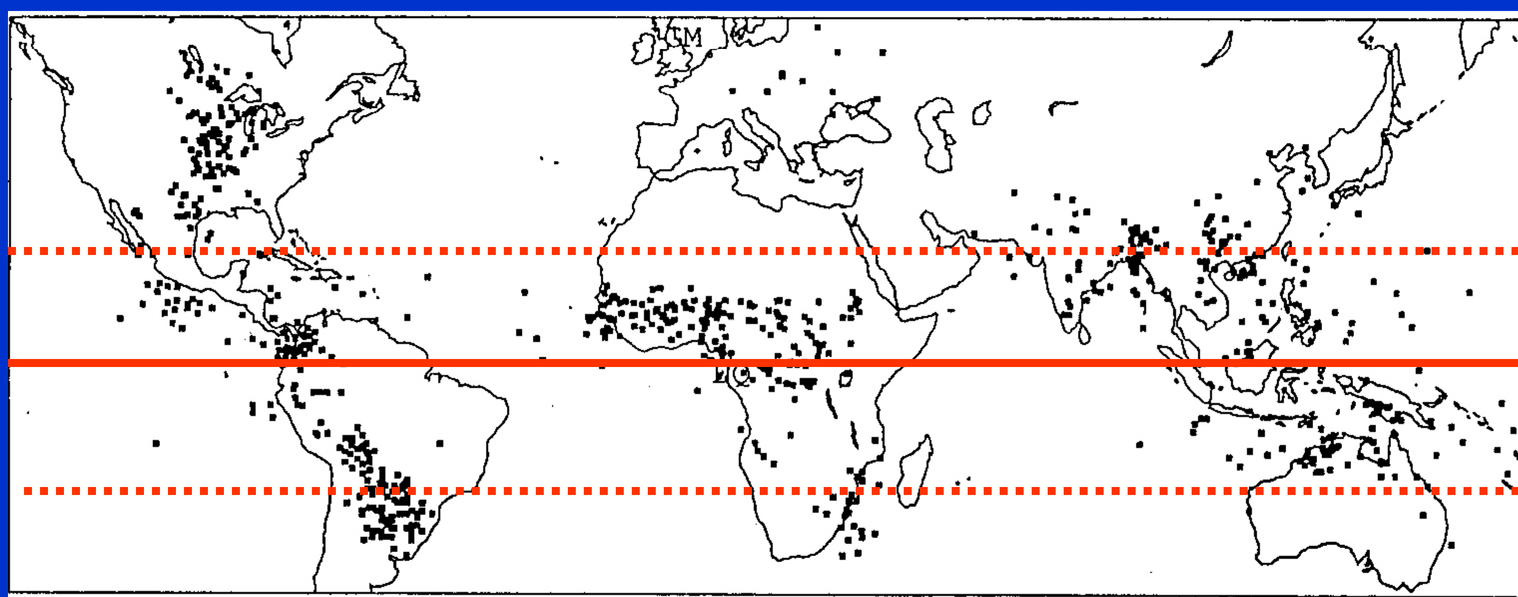
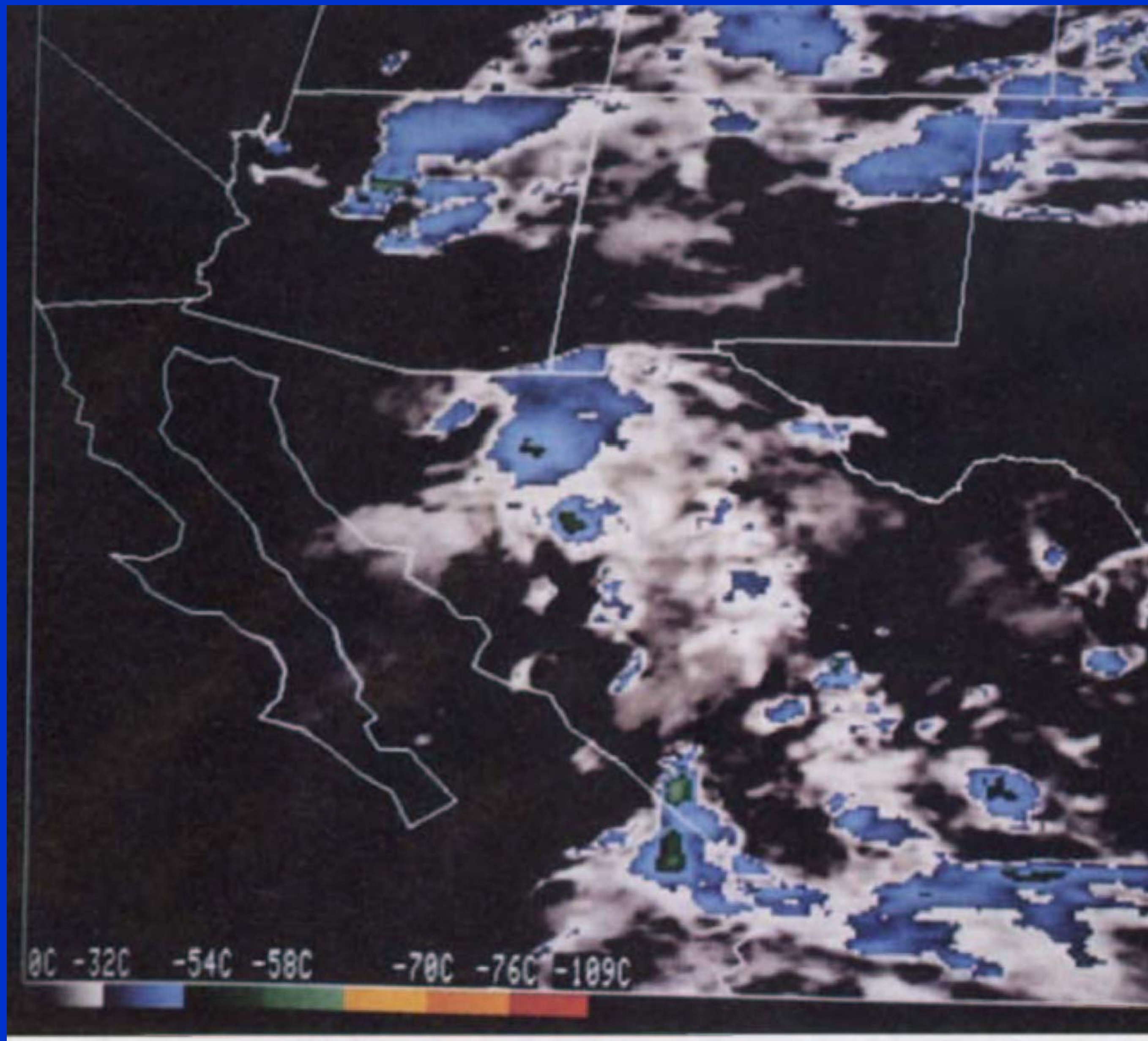


Figure 8.1 Mean number of days with thunderstorms per year

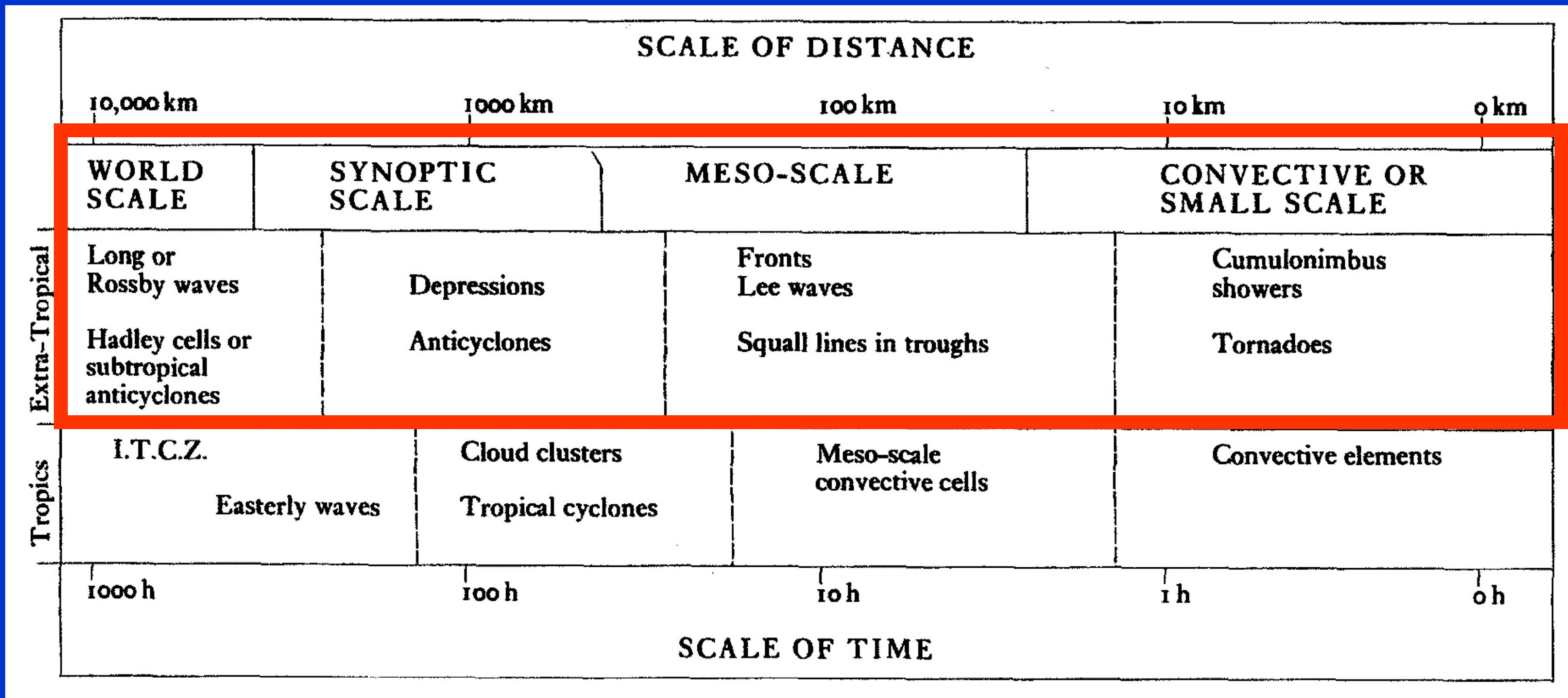


Mesoscale Convective Complexes & Systems (MCC's & MCS's)

- Huge, highly organized, multiple celled and convectively induced and maintained thunderstorm systems
- Defined on the basis of satellite imagery: large, circular or oval shaped region
- Composed of clouds that become colder (higher) toward center of the system
- Large areal extent (40,000 mi2)
- Long duration (6 –36 hours)
- May have multiple supercell thunderstorms, locally intense precipitation
- MCS's less well defined than MCC's



0C -32C -54C -58C -70C -76C -109C



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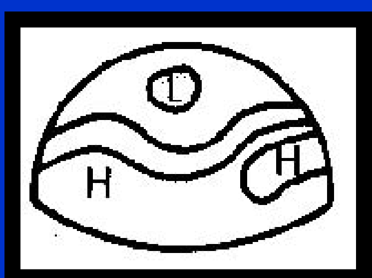
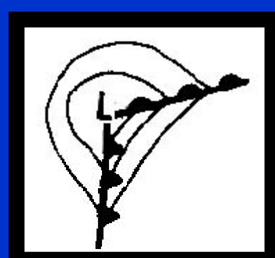
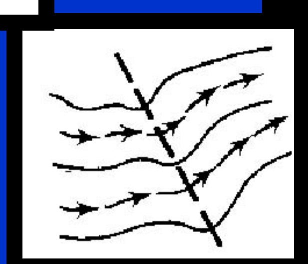
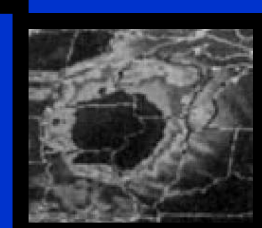
SCALE OF TIME	1000 h	100 h	10 h	1 h / 0 h

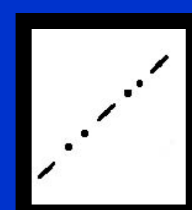


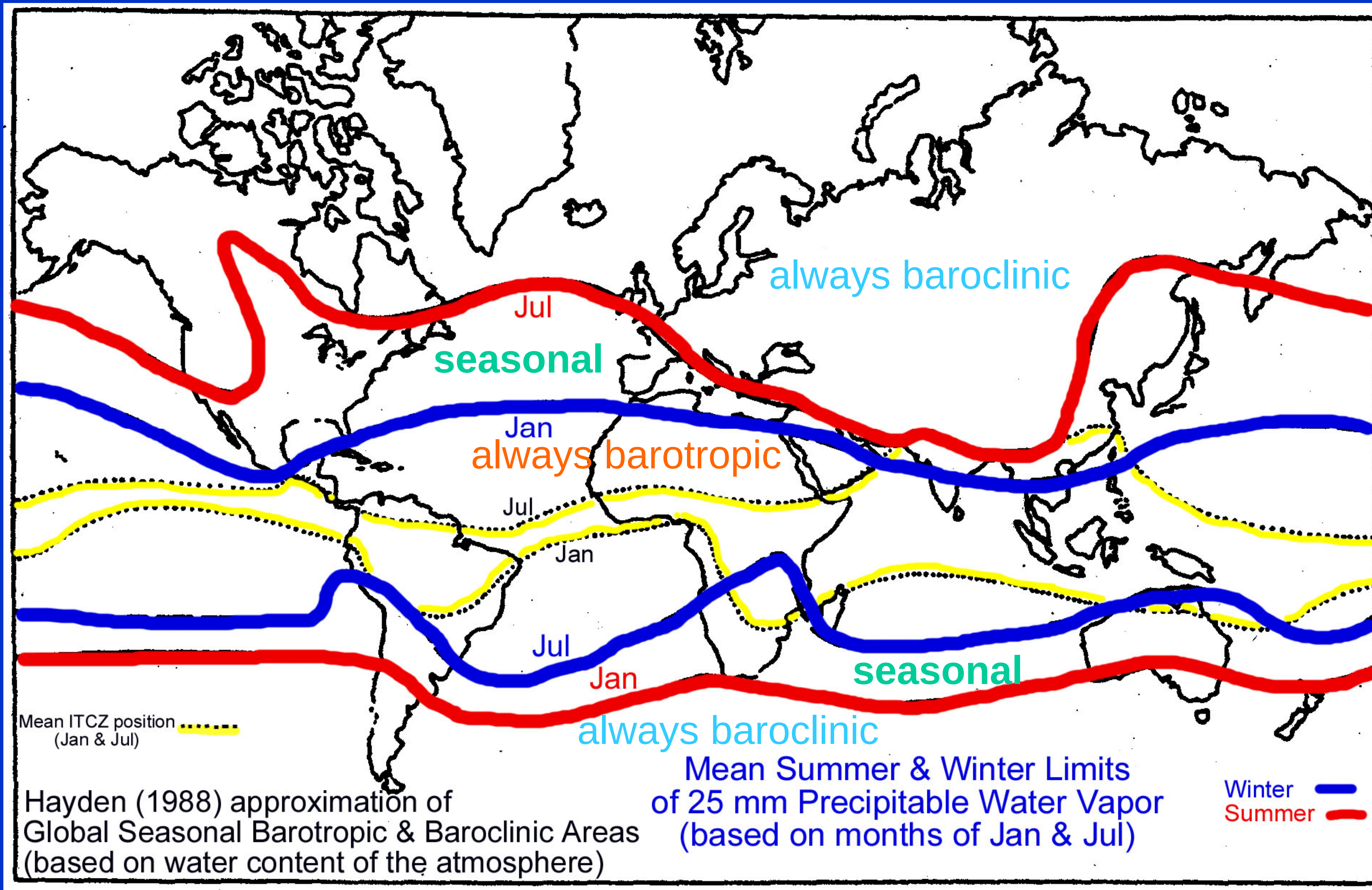


EXTRATROPICAL CLIMATOLOGY





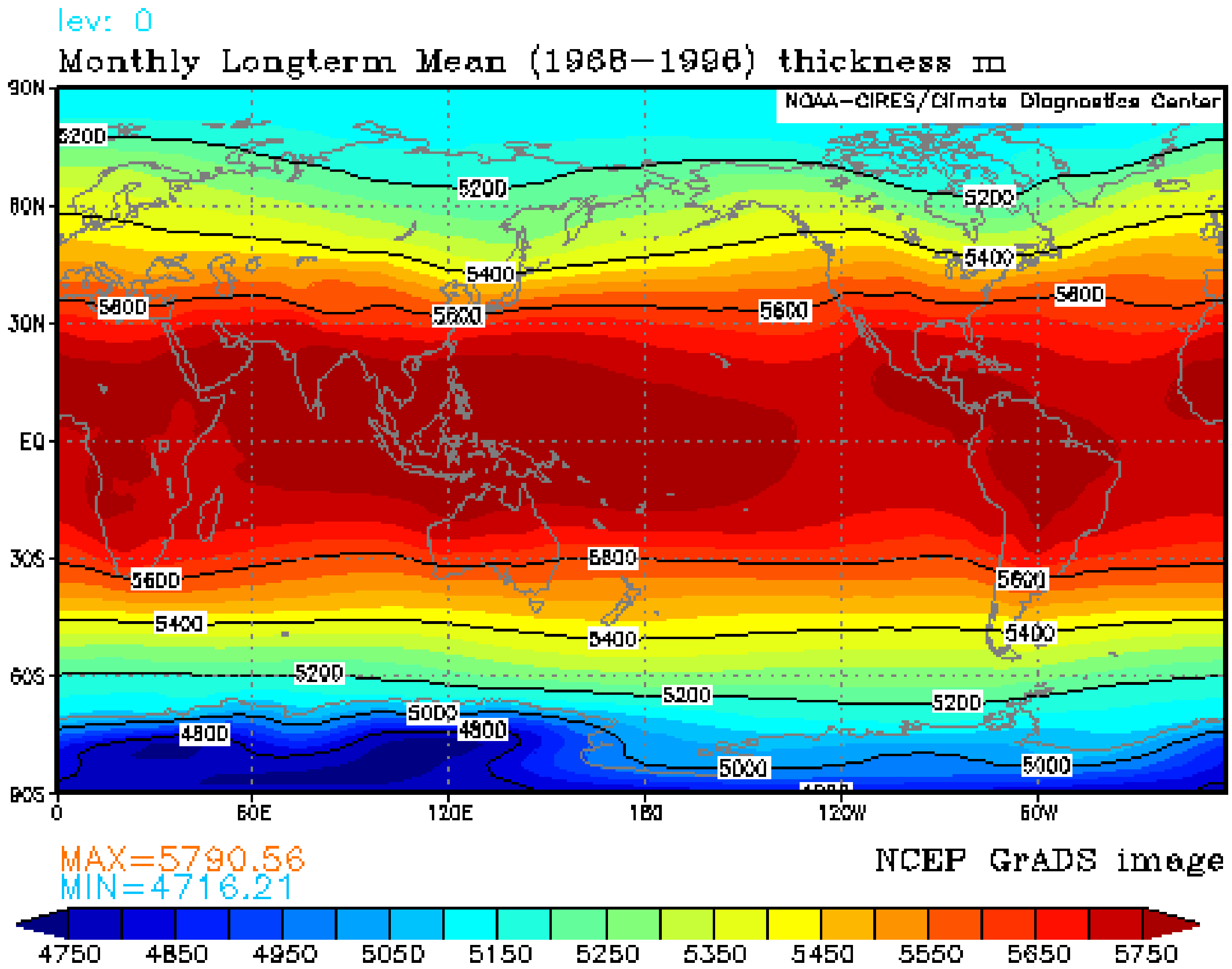


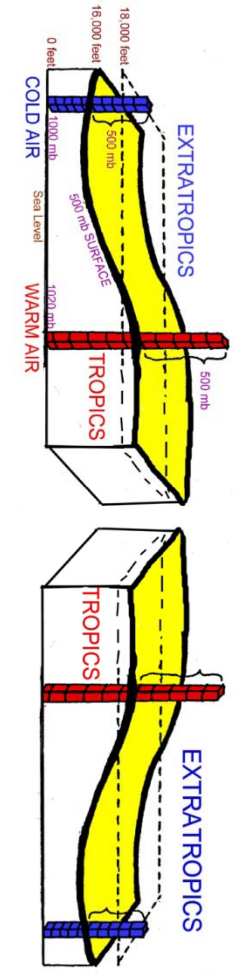

always baroclinic
Jul
seasonal
Jan
always barotropic
Jul
Jan
Jul
Jan
seasonal
always baroclinic
Mean ITCZ position
(Jan & Jul)
Hayden (1988) approximation of
Global Seasonal Barotropic & Baroclinic Areas
(based on water content of the atmosphere)
Mean Summer & Winter Limits
of 25 mm Precipitable Water Vapor
(based on months of Jan & Jul)
Winter
Summer

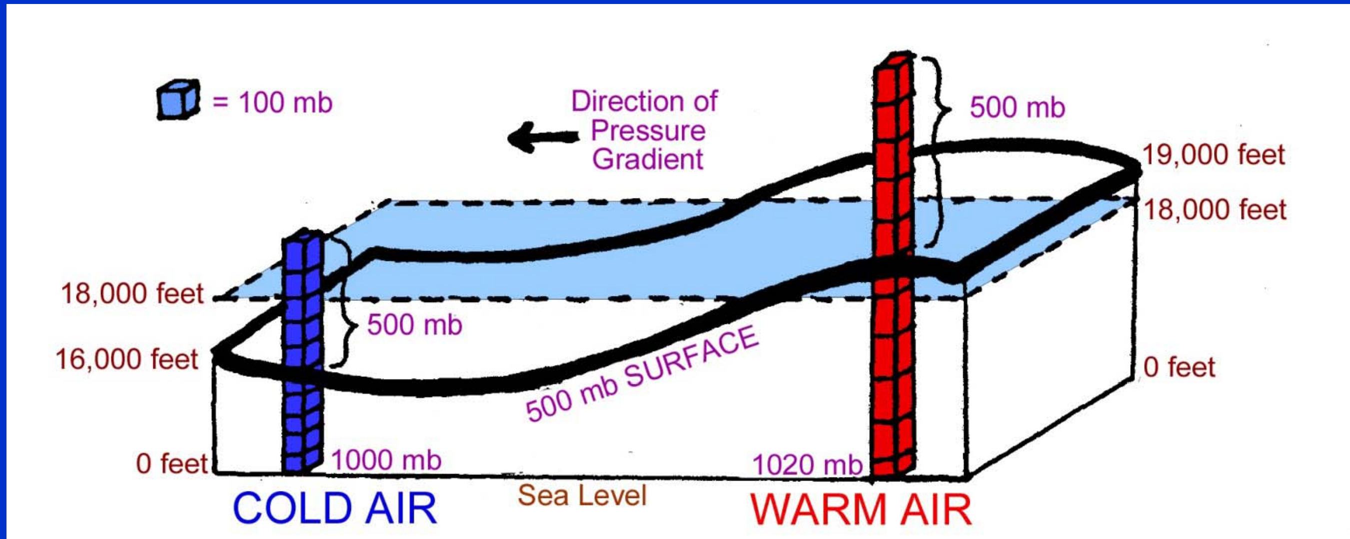
THICKNESS of the ATMOSPHERE

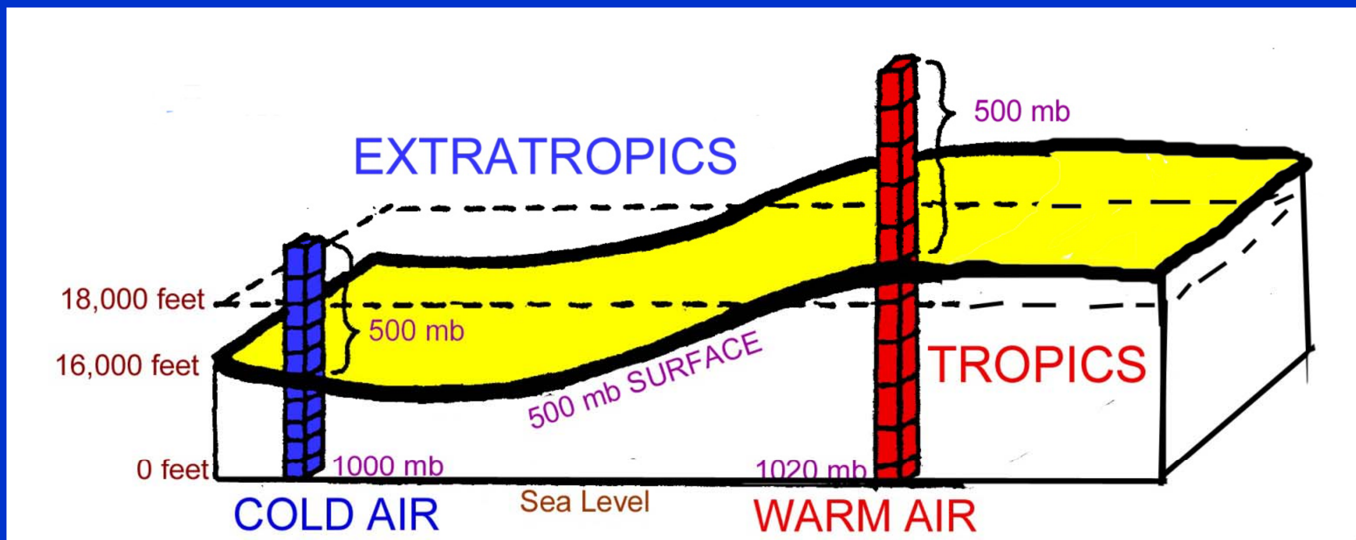
between 1000 & 500 mb (in meters)

Annual (Jan – Dec) Longterm Monthly Mean

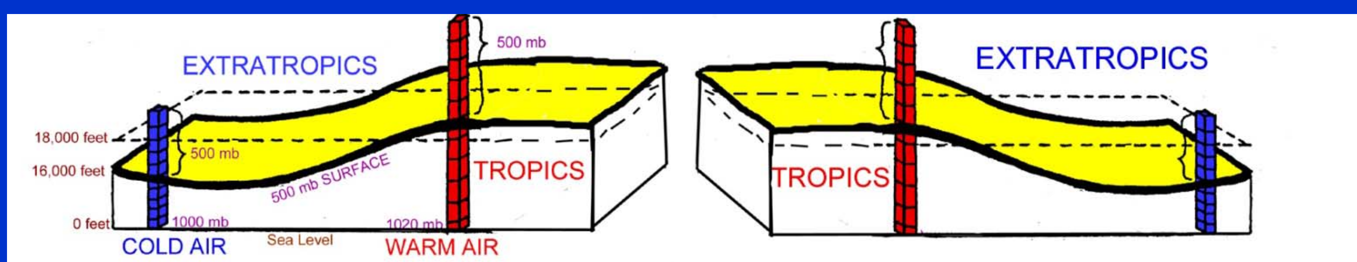




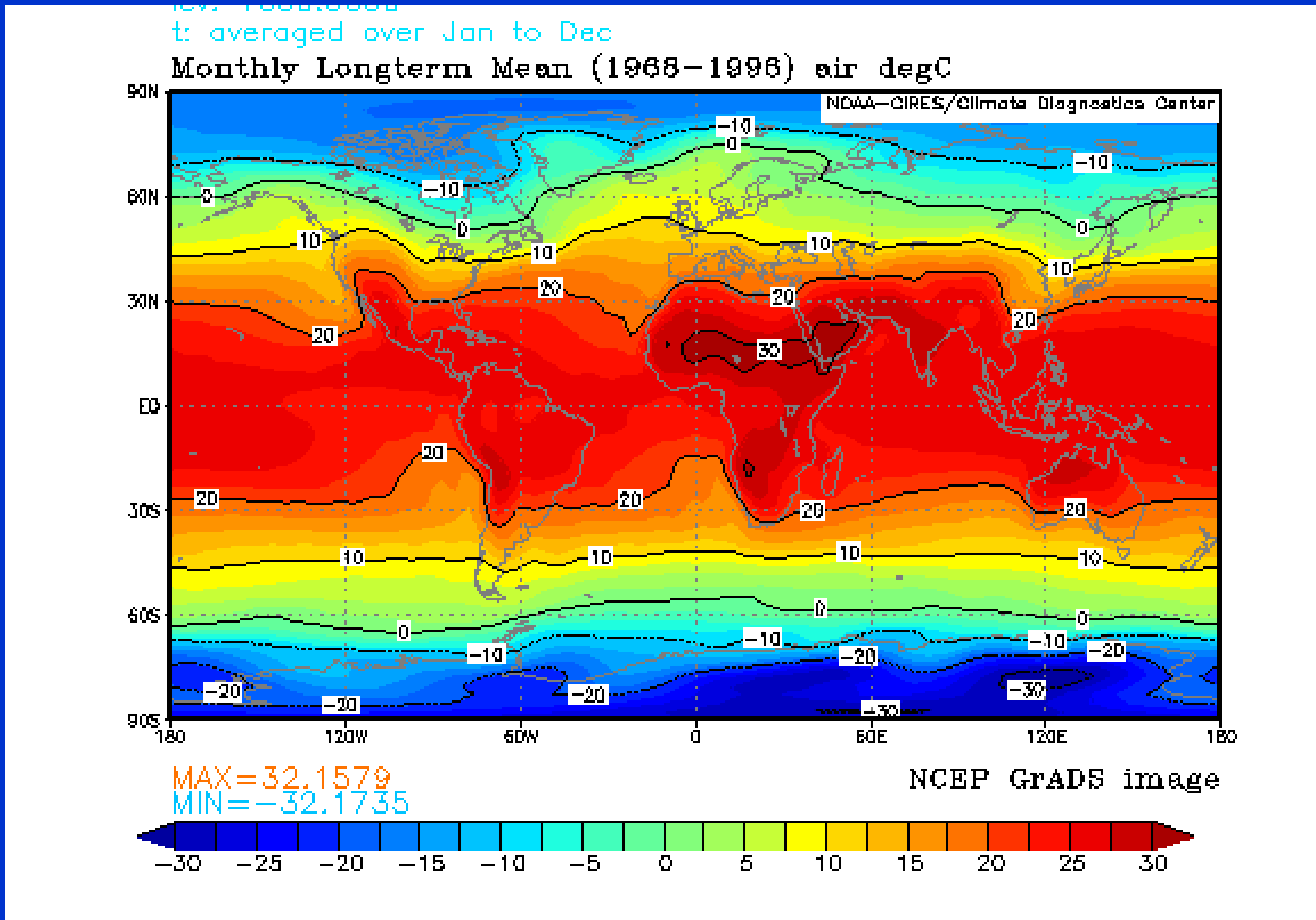




North Pole

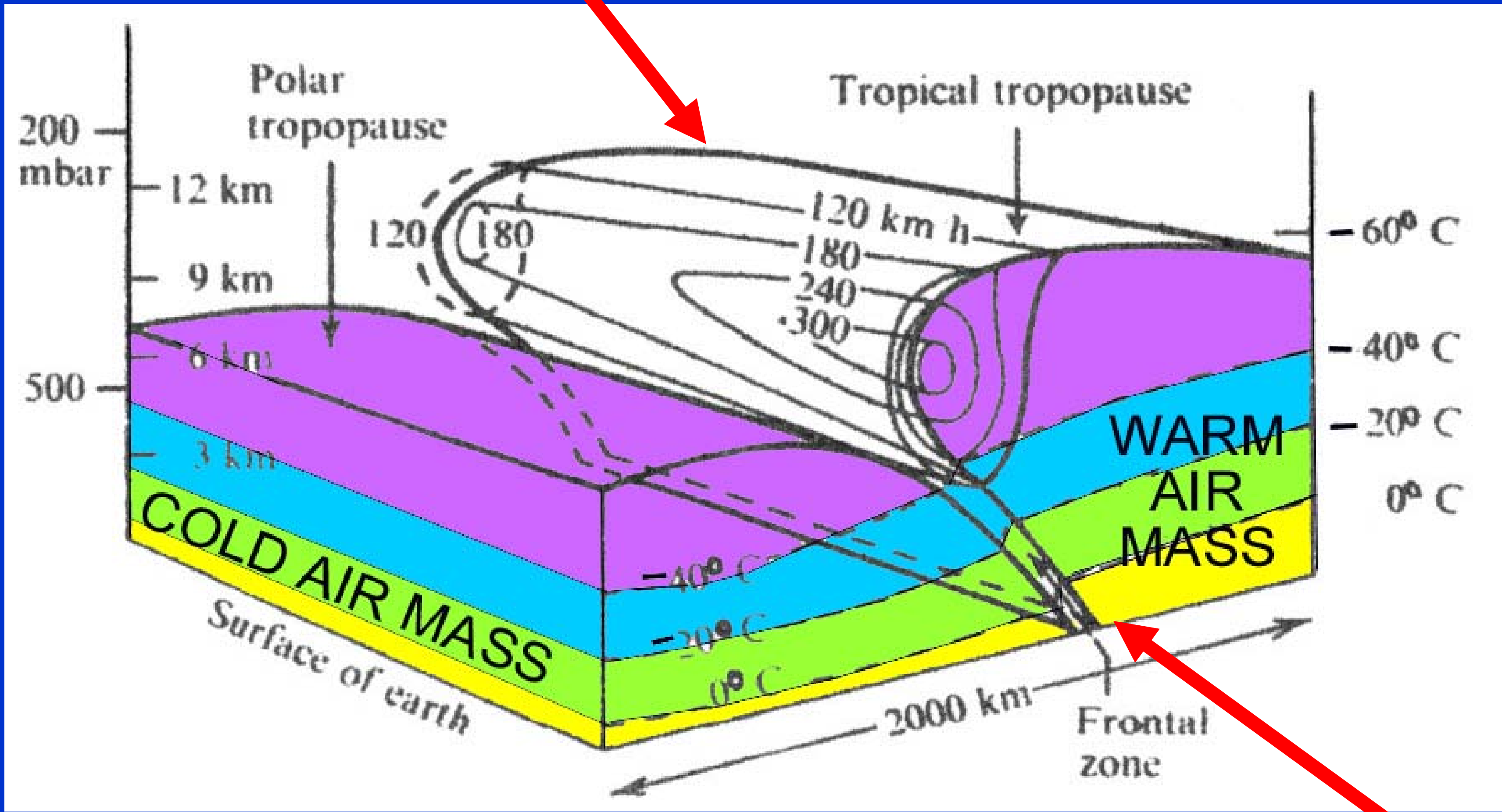


South Pole



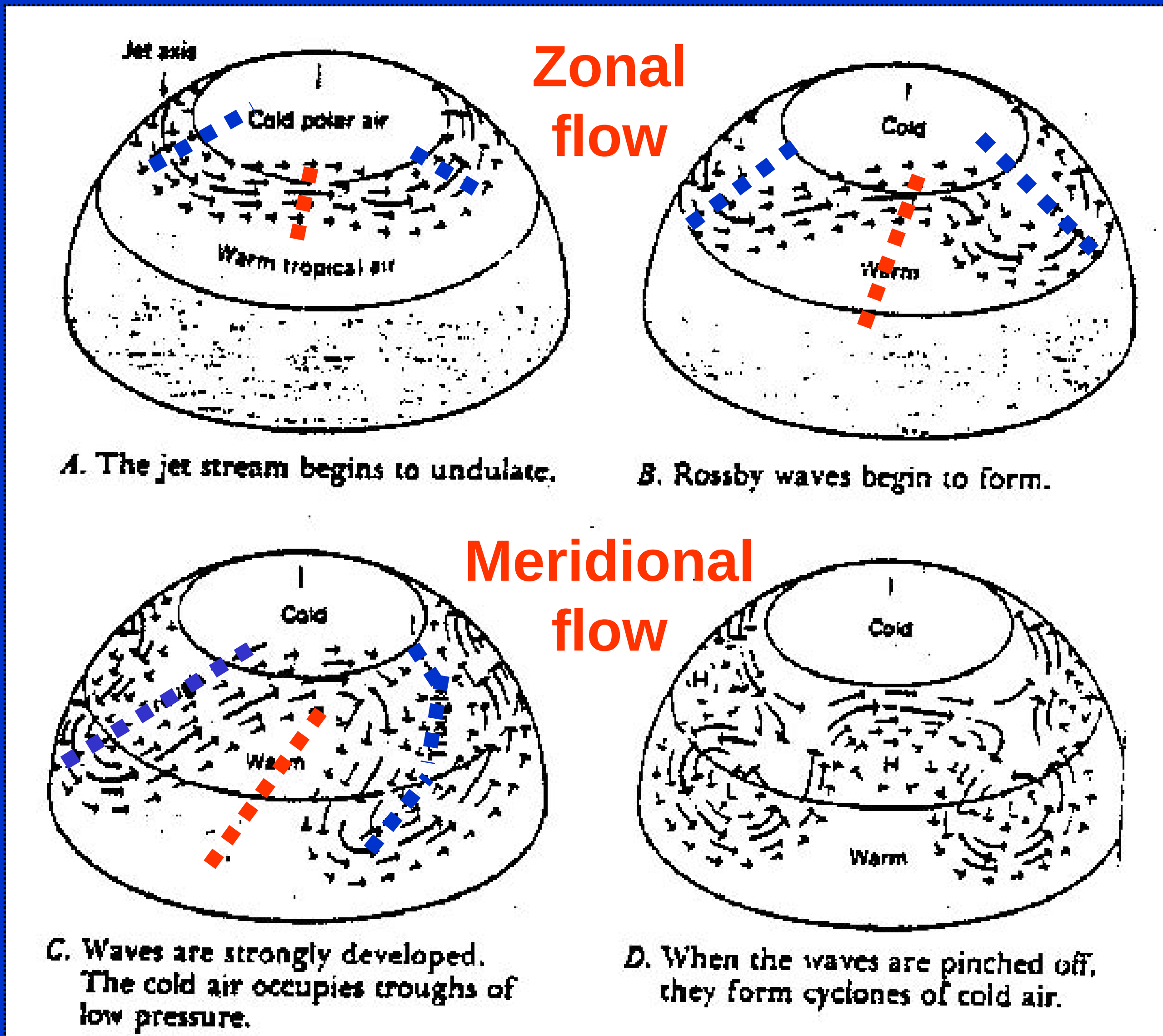
Global Mean Annual Temperature

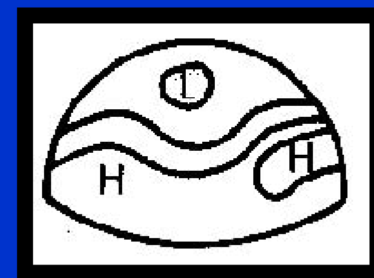
High speed upper level winds

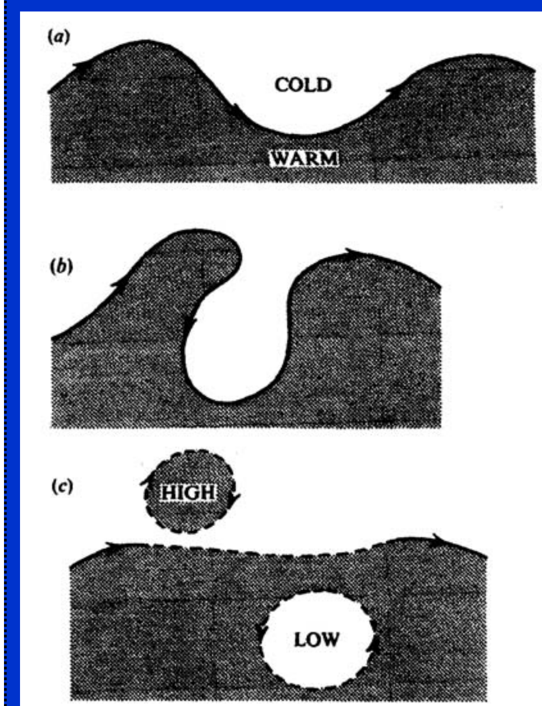


Abrupt change in temperature & thickness along polar frontal zone w/ jet stream aloft

GLOBAL / HEMISPHERIC SCALE



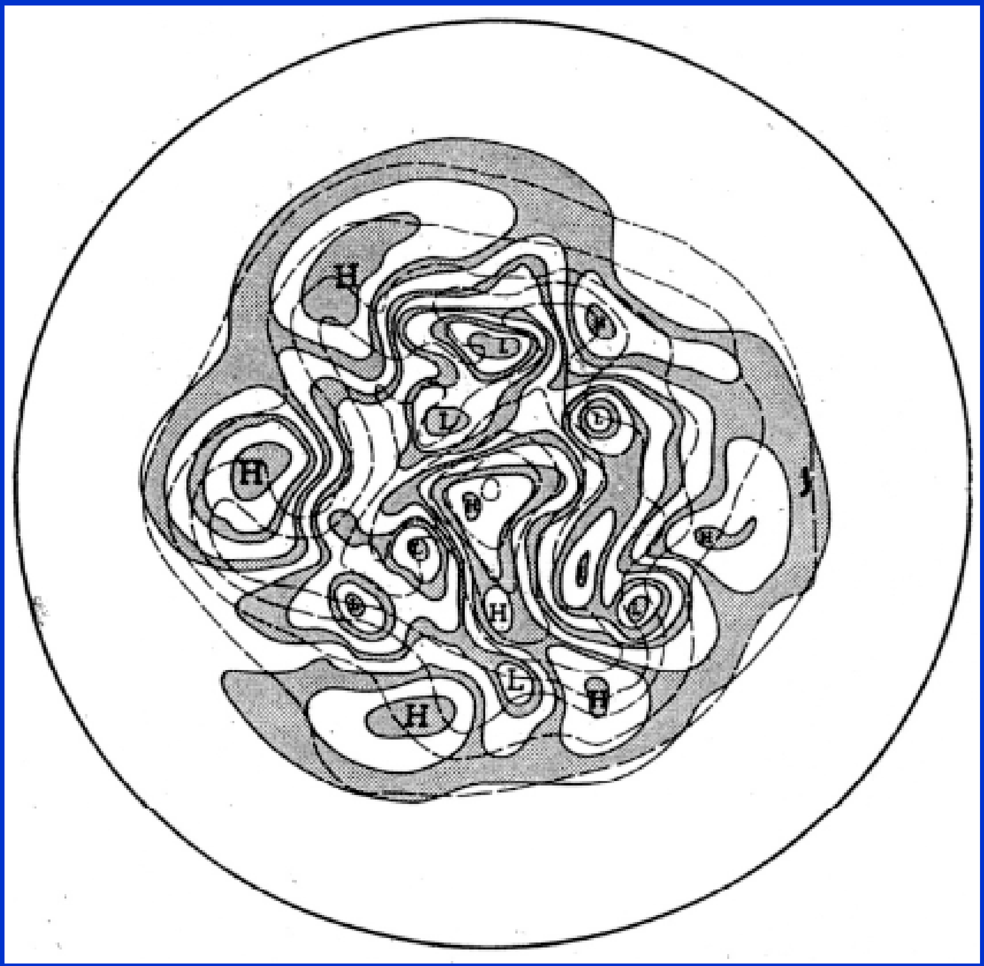




“long-wave transport”

dishpan circulation / circumpolar vortex

“long-wave transport”

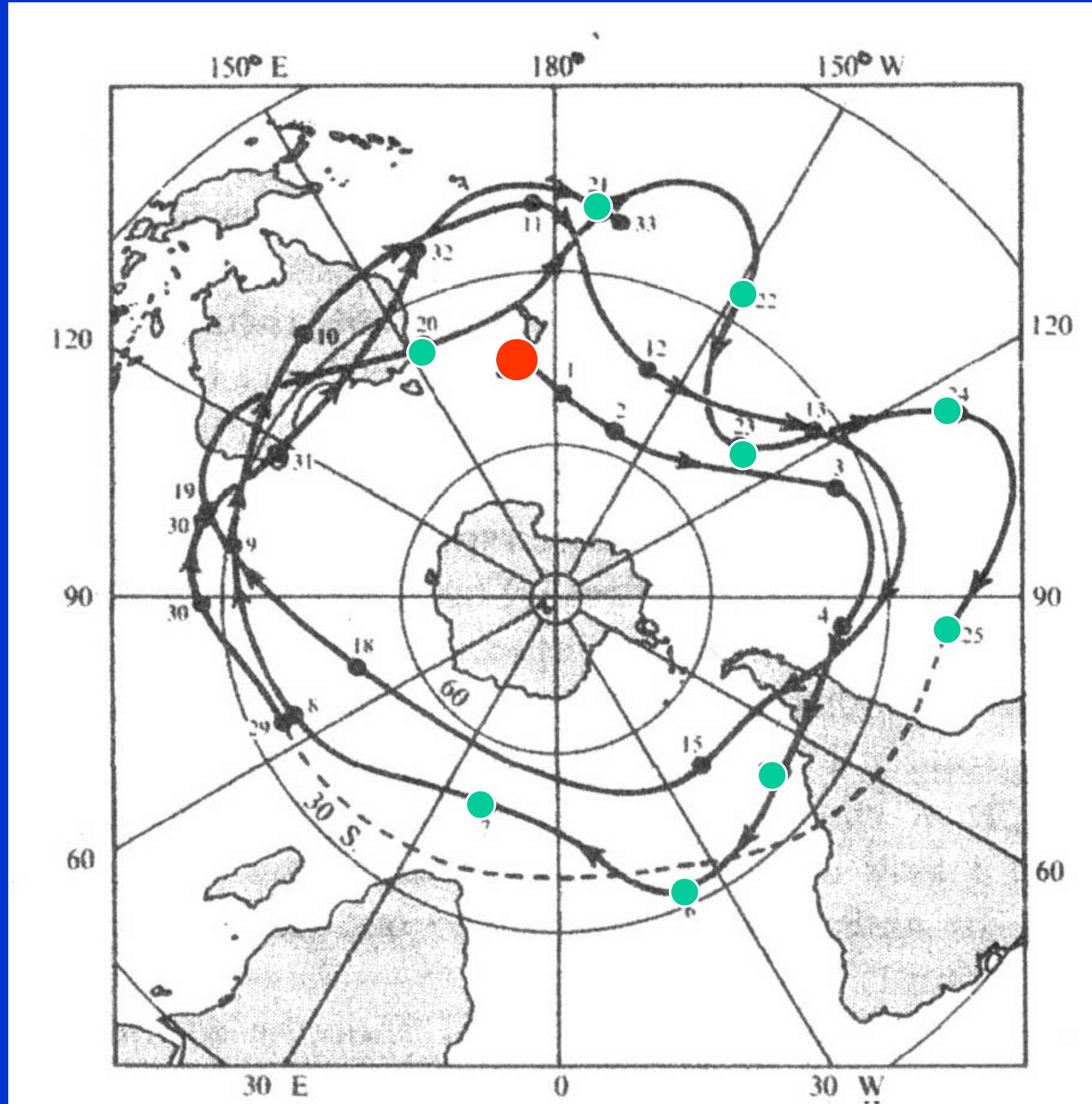


dishpan circulation / circumpolar vortex

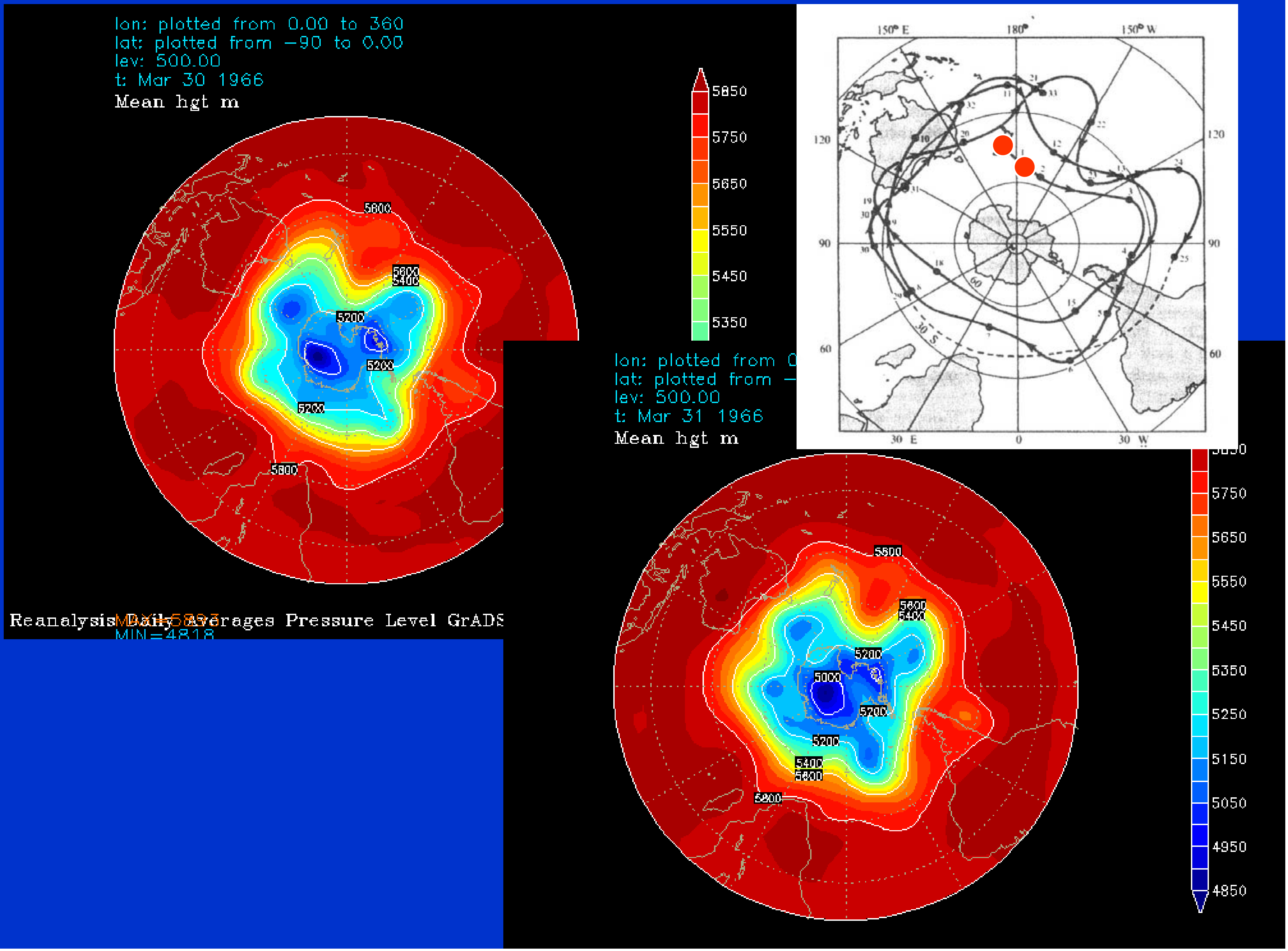
BALLOON TRAJECTORY

Launched from New Zealand on March 30, 1966

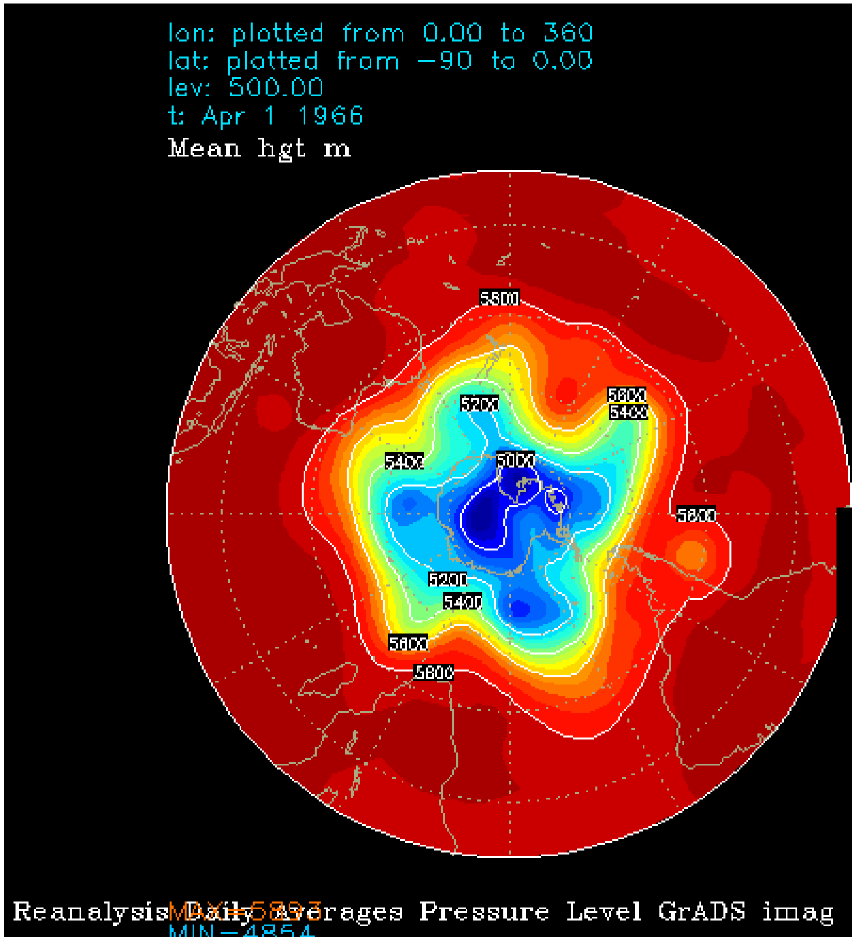
at altitude of 12 km

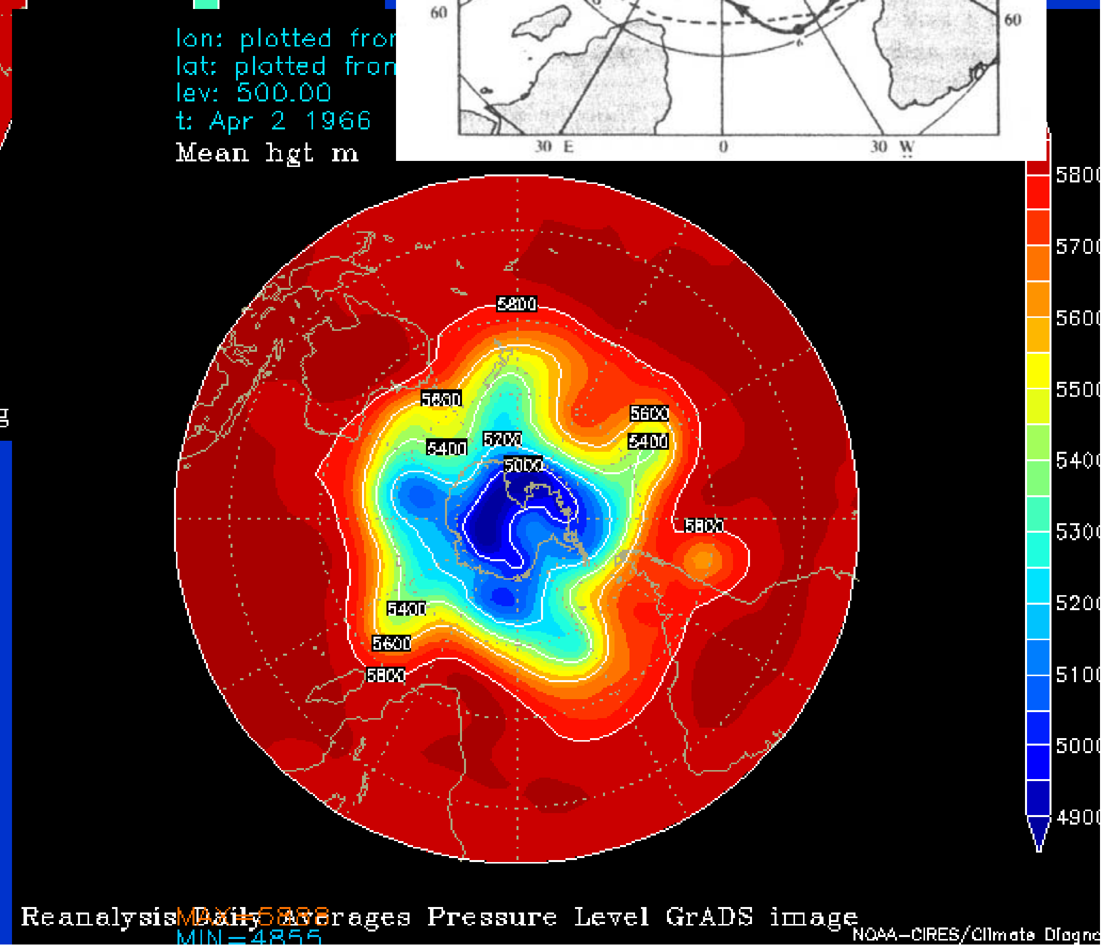


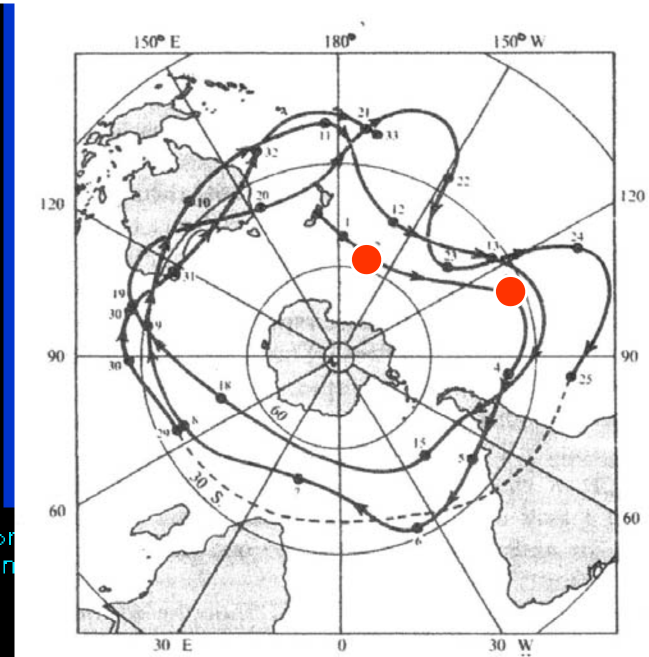
= long wave patterns

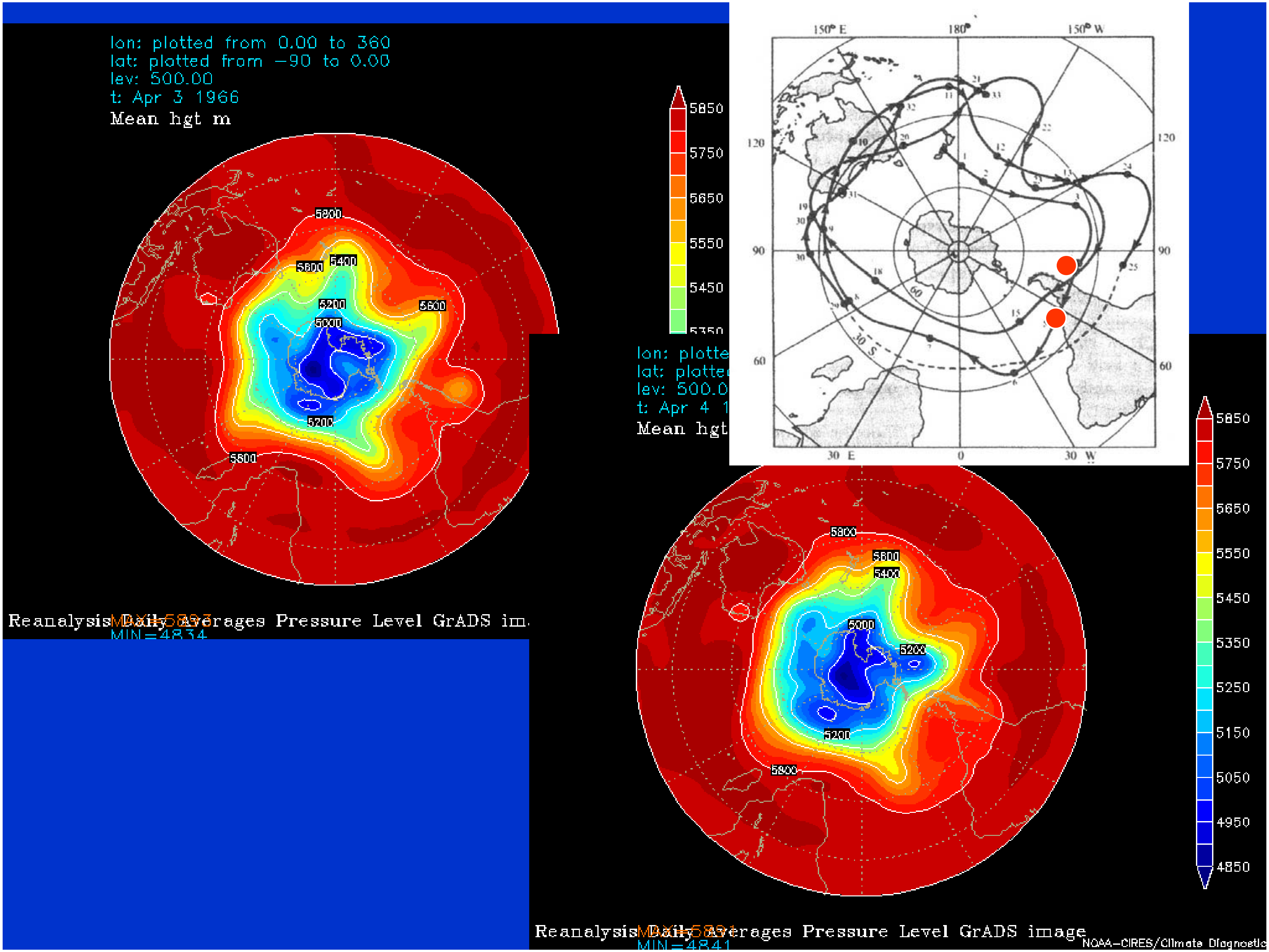


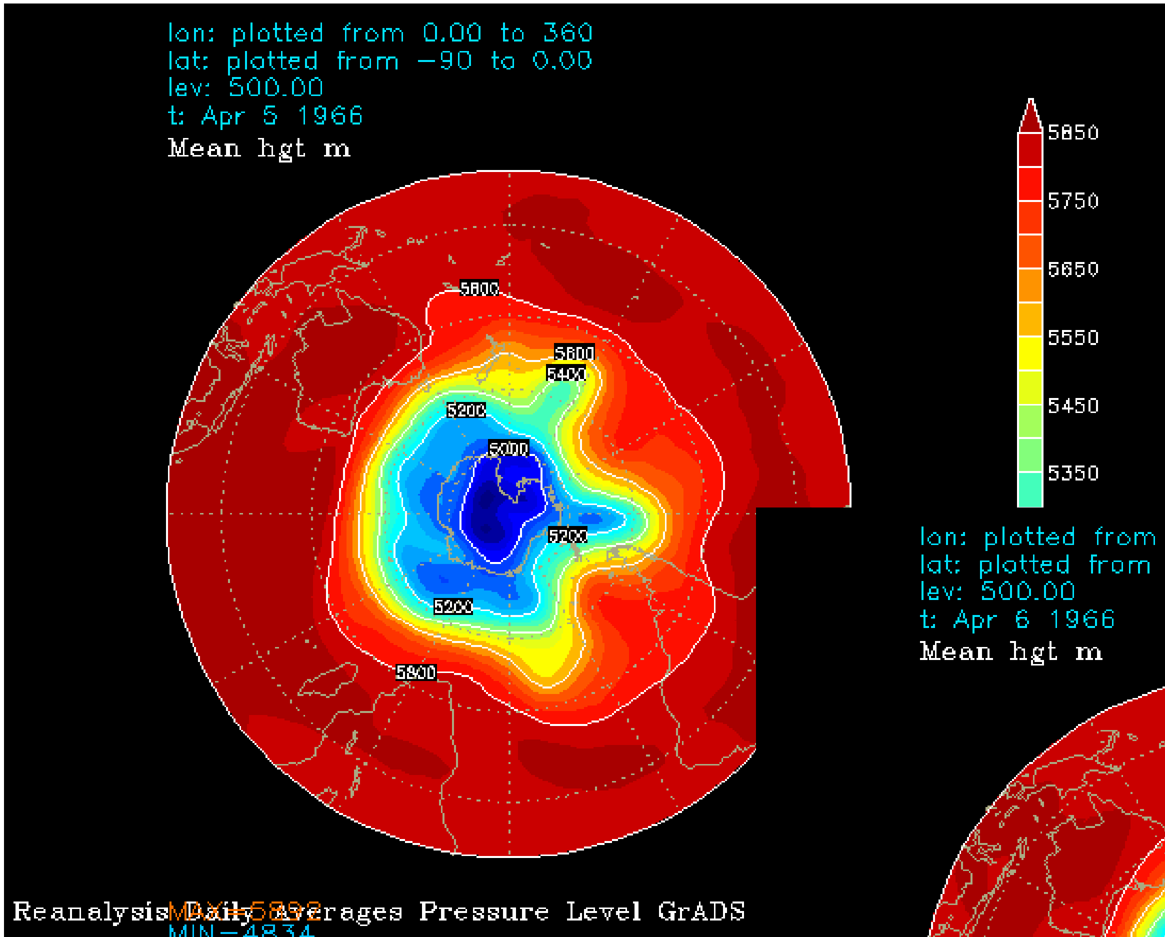
lon: plotted from 0.00 to 360
lat: plotted from −90 to 0.00
lev: 500.00
t: Mar 30 1966
Mean hgt m
5800
5600
5400
5200
5850
5750
5650
5550
5450
5350
Reanalysis Daily Averages Pressure Level GrADS
MIN=4818
lon: plotted from
lat: plotted from
lev: 500.00
t: Mar 31 1966
Mean hgt m
5000
5750
5650
5550
5450
5350
5250
5150
5050
4950
4850
150° E
180°
150° W
120
90
60
30 E
0
30 W
30 S

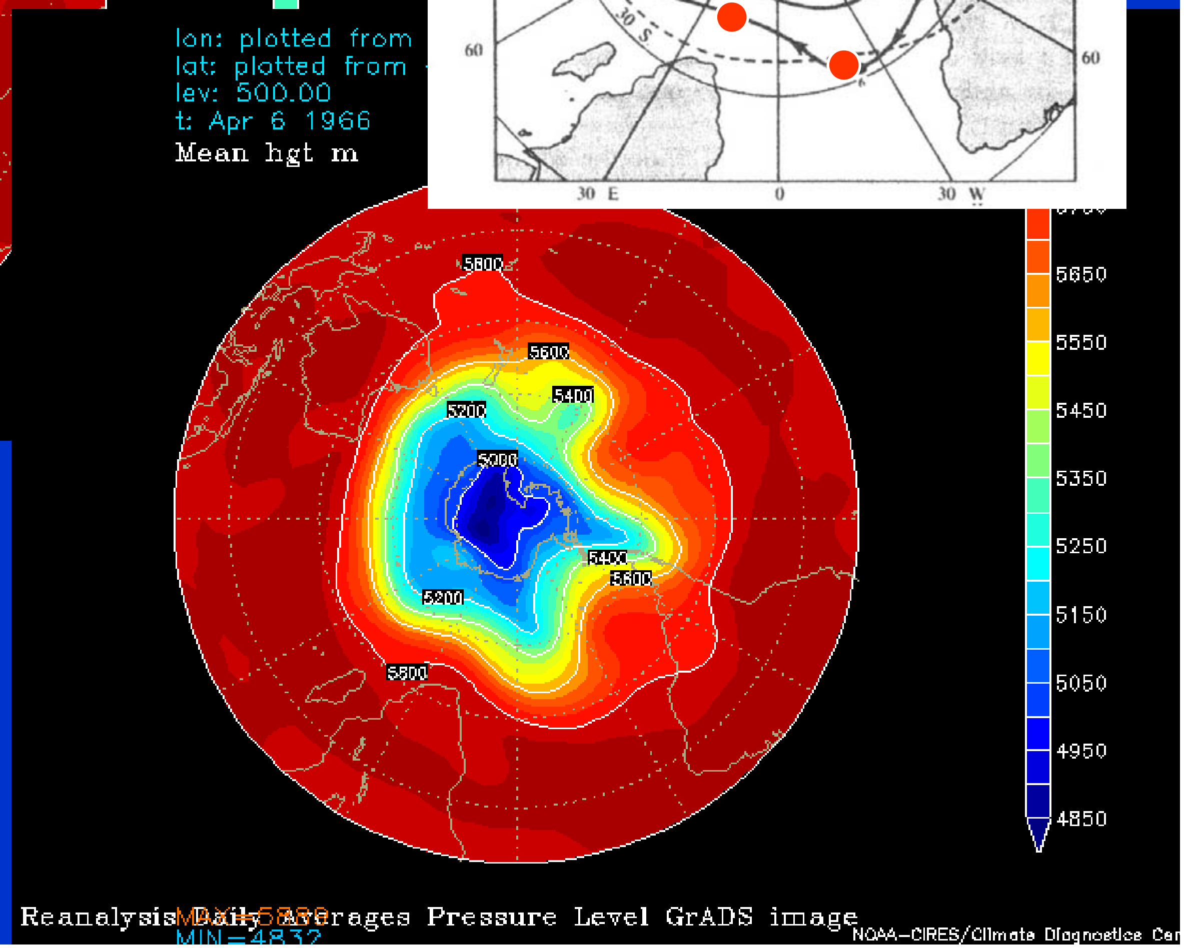

lon: plotted from 0.00 to 360
lat: plotted from −90 to 0.00
lev: 500.00
t: Apr 1 1966
Mean hgt m
5800
5700
5600
5500
5400
Reanalysis Daily Averages Pressure Level GrADS imag
MIN=4854

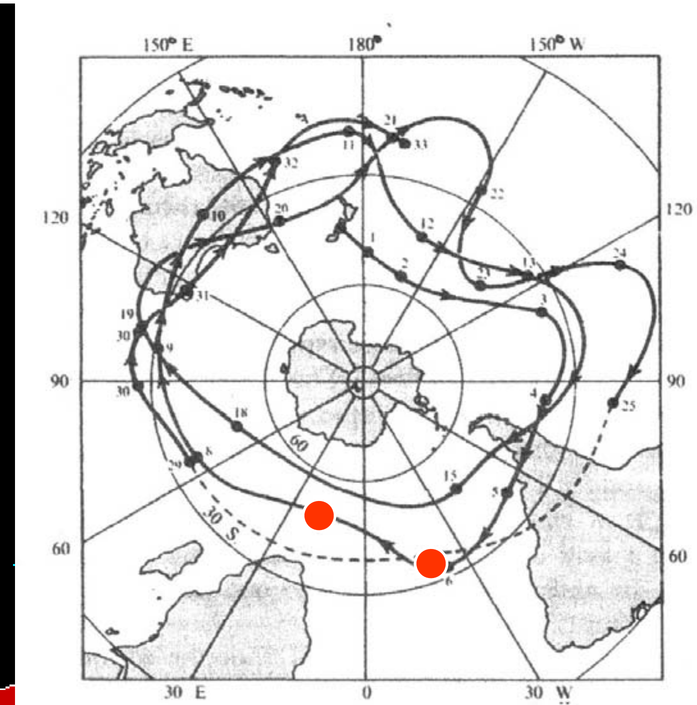

lon: plotted fro
lat: plotted fro
lev: 500.00
t: Apr 2 1966
Mean hgt m
Reanalysis Daily Averages Pressure Level GrADS image
MIN=4855
NOAA-CIRES/Climate Diagno


150° E
180°
150° W
120
90
60
30 E
0
30 W
30 S

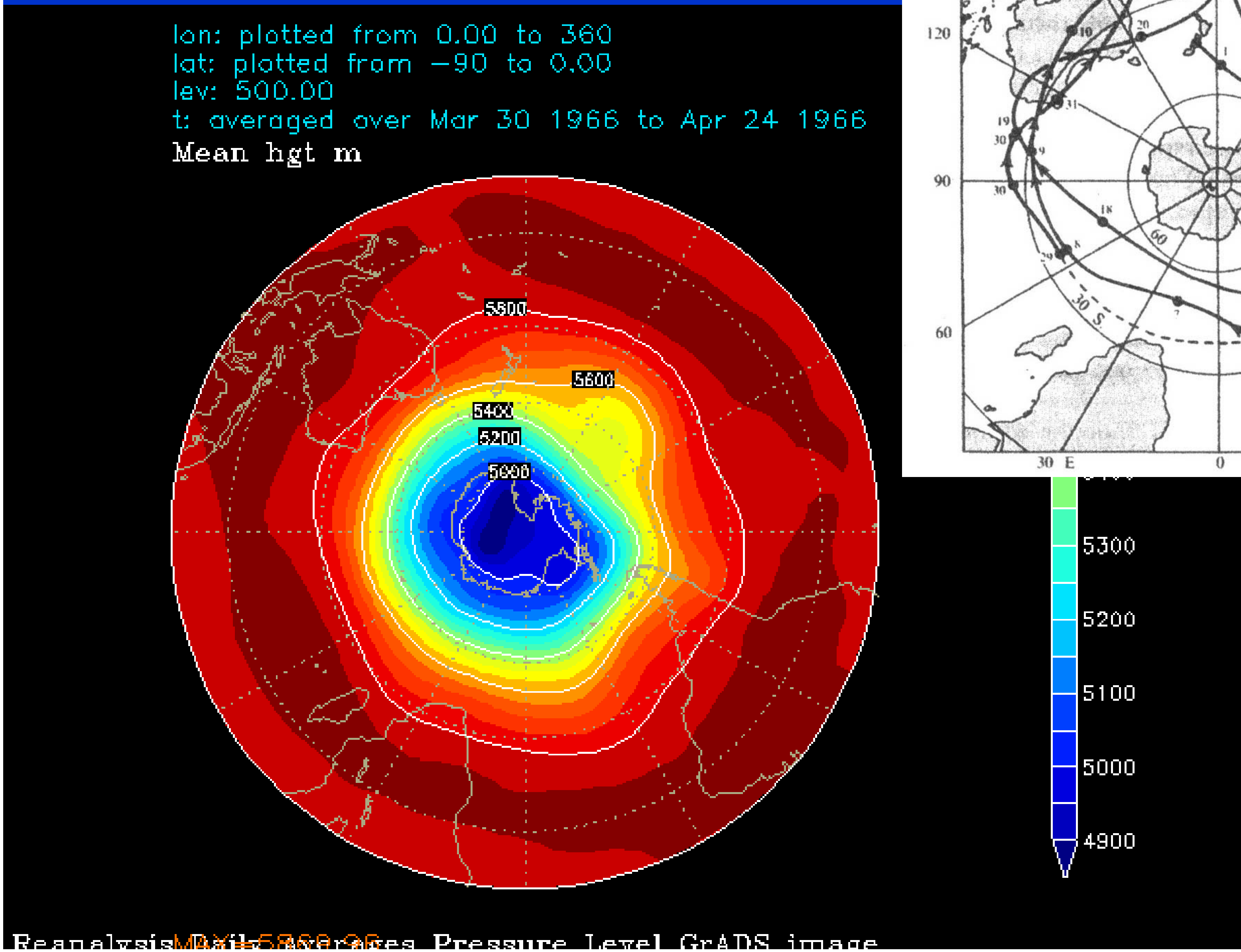

lon: plotted from 0.00 to 360
lat: plotted from −90 to 0.00
lev: 500.00
t: Apr 3 1966
Mean hgt m
5850
5750
5650
5550
5450
5350
5800
5600
5400
5200
5000
Reanalysis Daily Averages Pressure Level GrADS im
MIN=4834
150° E
180°
150° W
120
90
60
30 E
0
30 W
30 S
lon: plotte
lat: plotte
lev: 500.0
t: Apr 4 1
Mean hgt
4950
4850
5050
5150
5250
Reanalysis Daily Averages Pressure Level GrADS image
MIN=4841
NOAA-CIRES/Climate Diagnostic

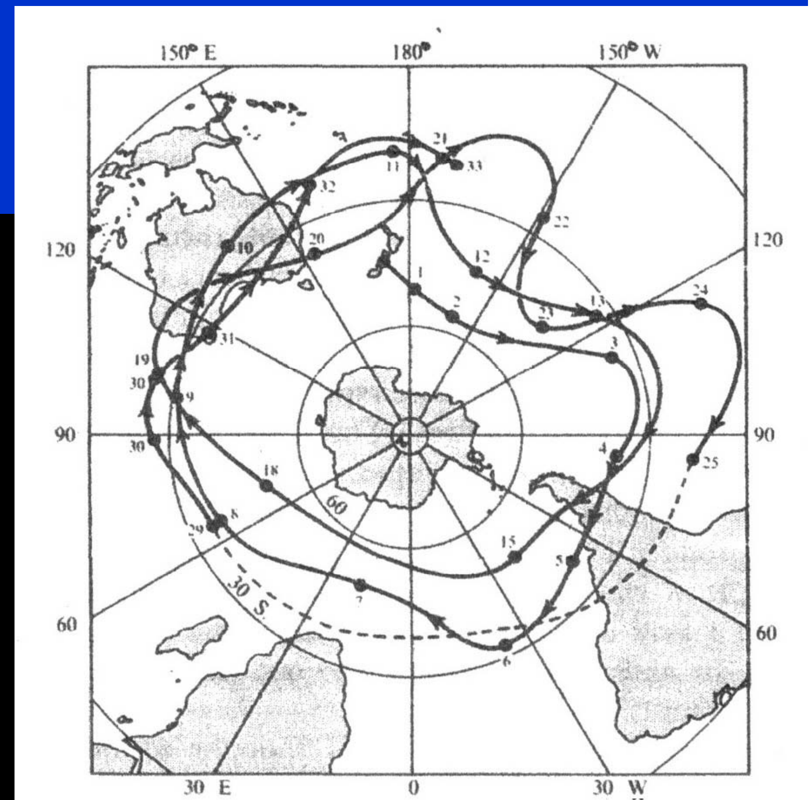

lon: plotted from 0.00 to 360
lat: plotted from −90 to 0.00
lev: 500.00
t: Apr 5 1966
Mean hgt m
5850
5750
5650
5550
5450
5350
5800
5600
5400
5200
5000
Reanalysis Daily Averages Pressure Level GrADS
MAX=5892
MIN=4834


lon: plotted from
lat: plotted from
lev: 500.00
t: Apr 6 1966
Mean hgt m
5650
5550
5450
5350
5250
5150
5050
4950
4850
5800
5600
5400
5200
5000
Reanalysis Daily Averages Pressure Level GrADS image
MAX=5898
MIN=4832
NOAA–CIRES/Climate Diagnostics Cen


150° E
180°
150° W
120
90
60
30 E
0
30 W
30 S
60

Mean 500 mb pattern for entire 25 day period



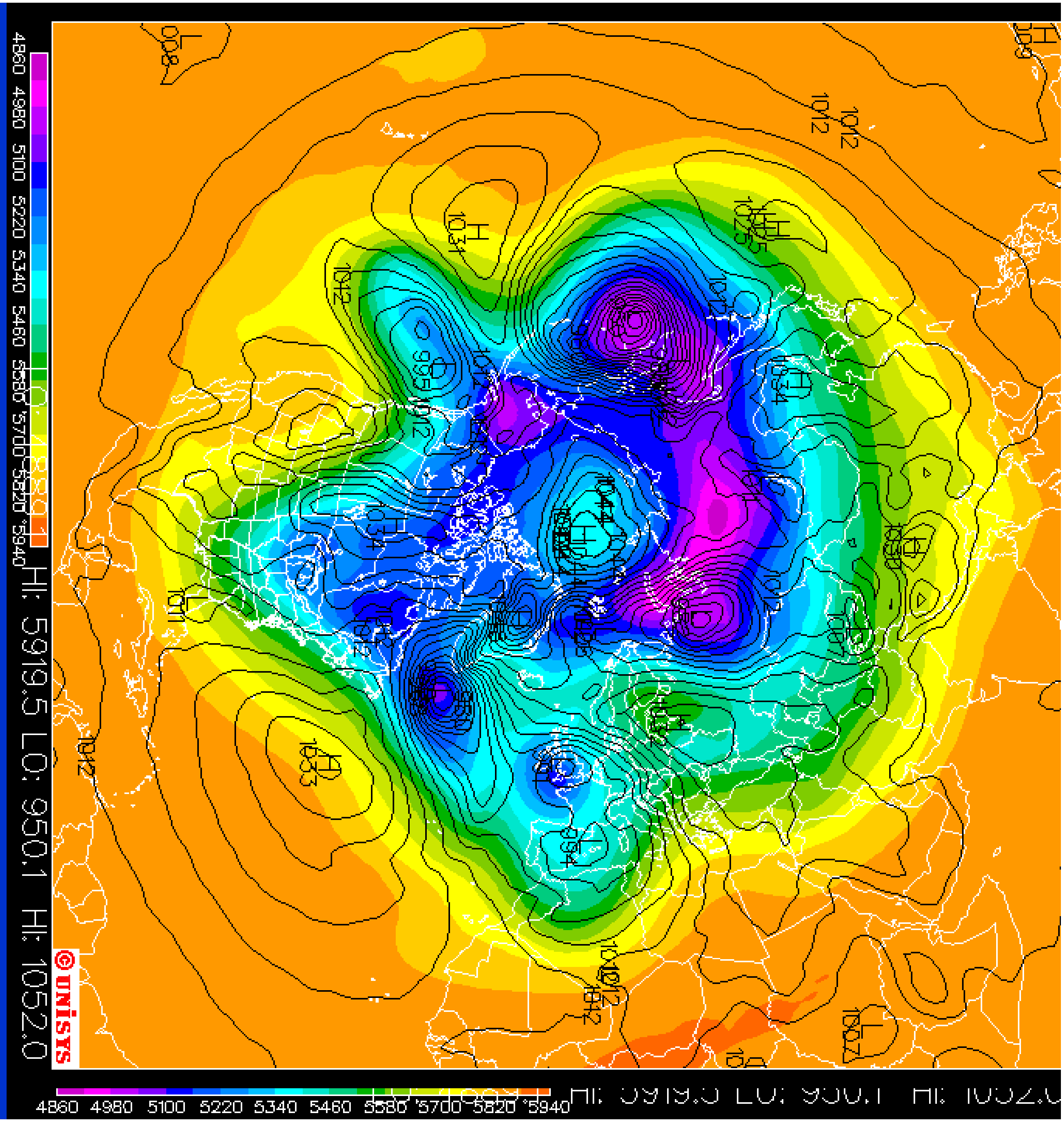


N.H. 500 mb Chart for single point in time

3 Feb 09

00z = 5 pm (Feb 2) MST

(UTC minus 7 hrs)

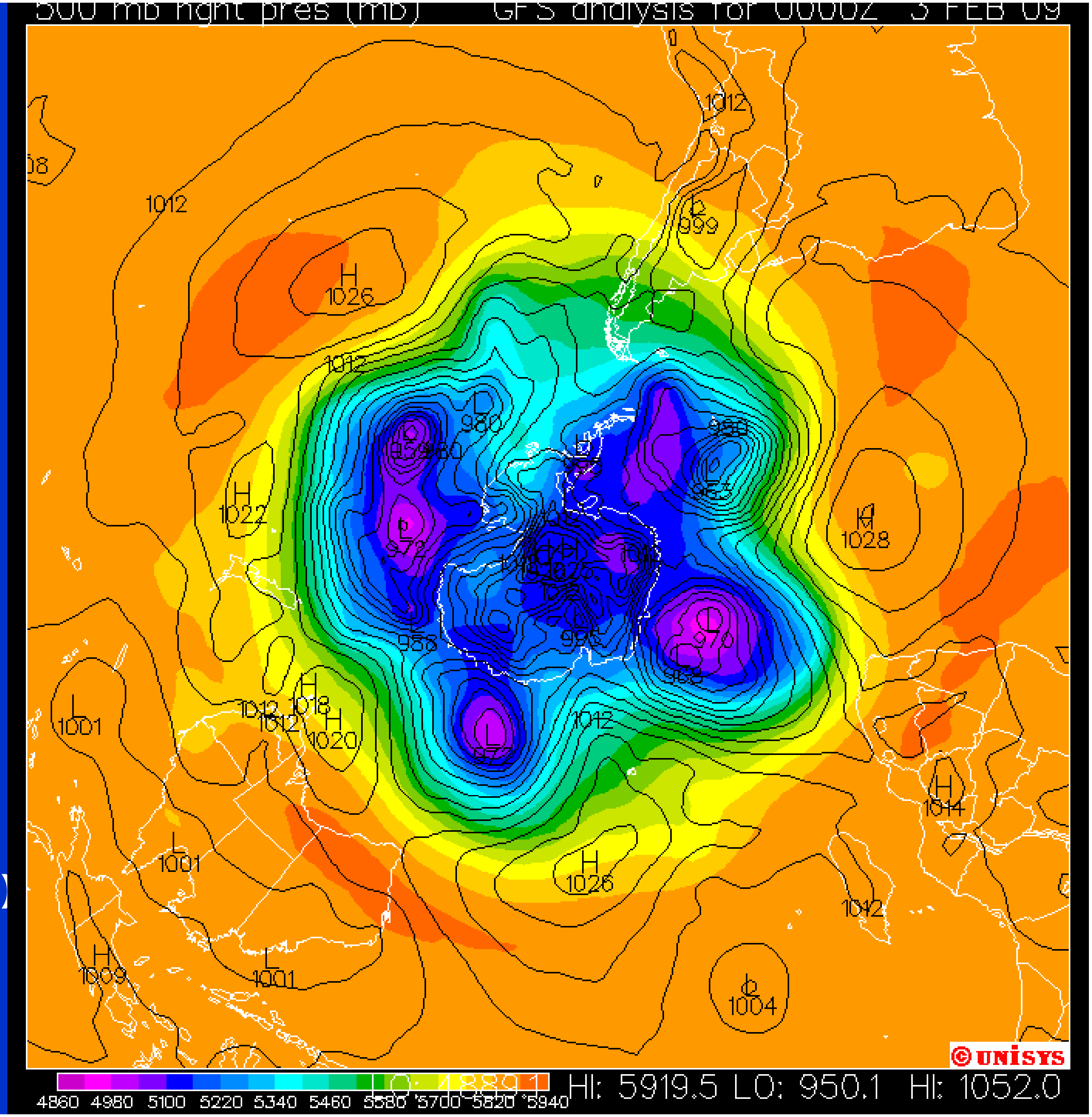


S.H. 500 mb Chart for single point in time (colors)

3 Feb 09

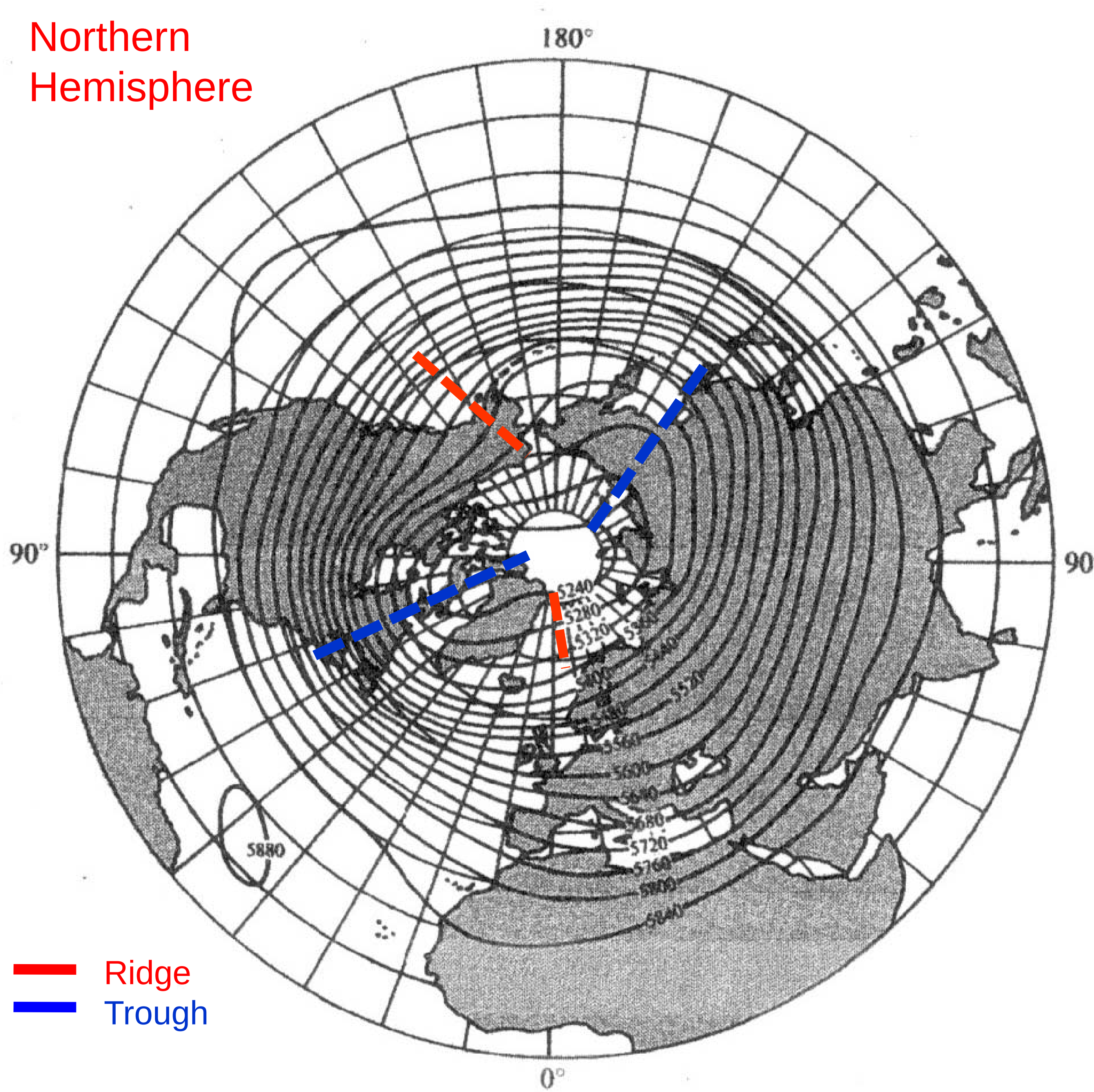
00z = 5 pm (Feb 2) MST

(UTC minus 7 hrs)



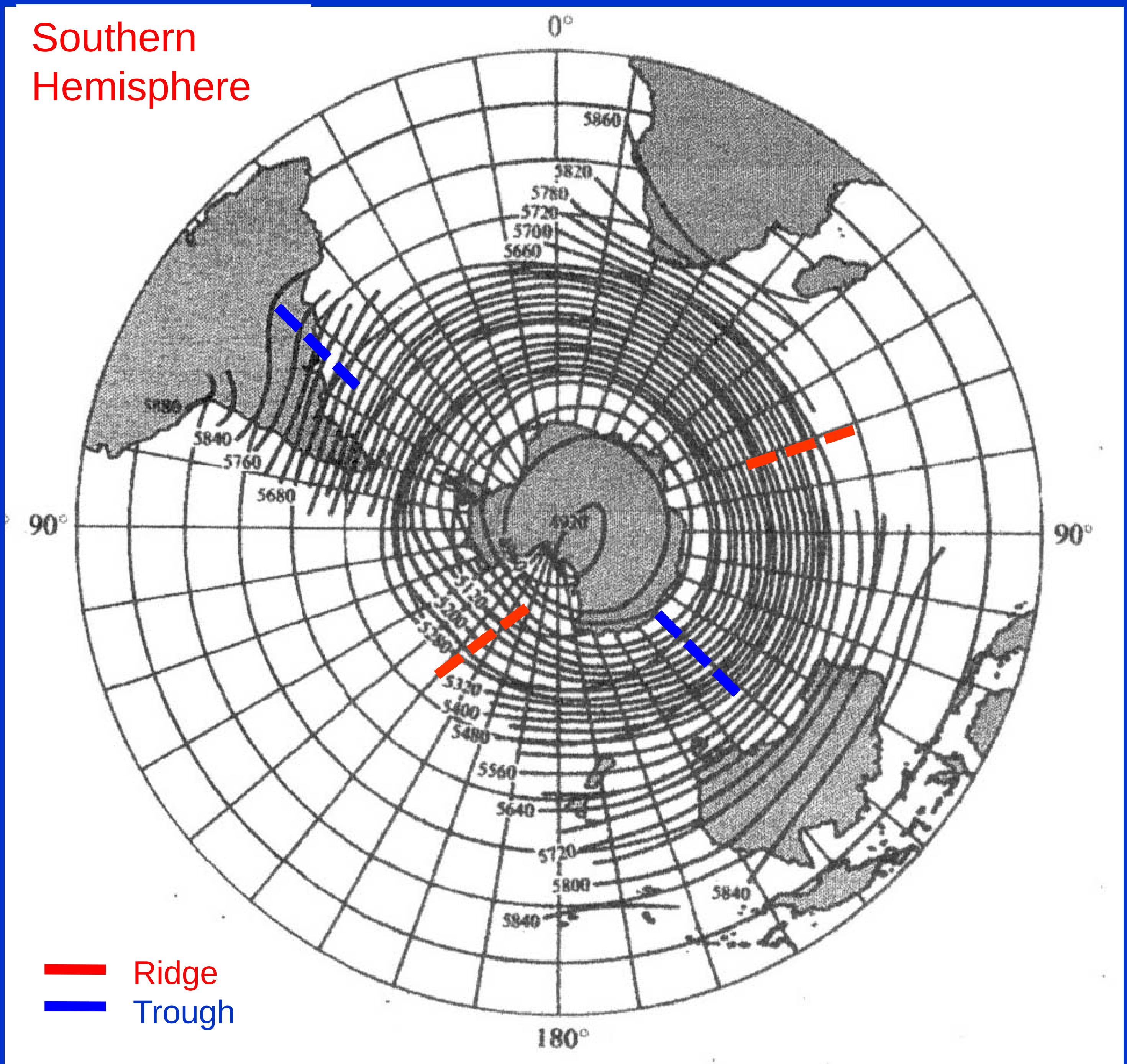
Mean height (in meters) of the 500 mb surface

<u>Very</u> subtle mean ridge & trough positions



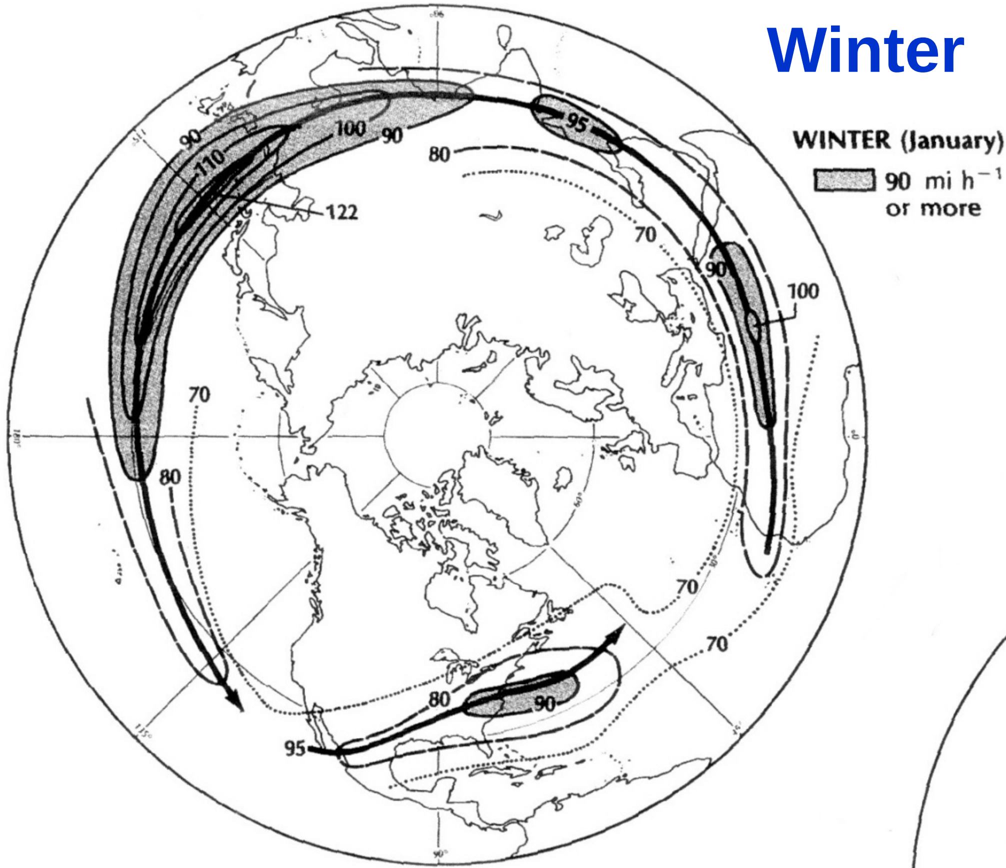
Mean height (in meters) of the 500 mb surface

<u>Very</u> subtle mean ridge & trough positions



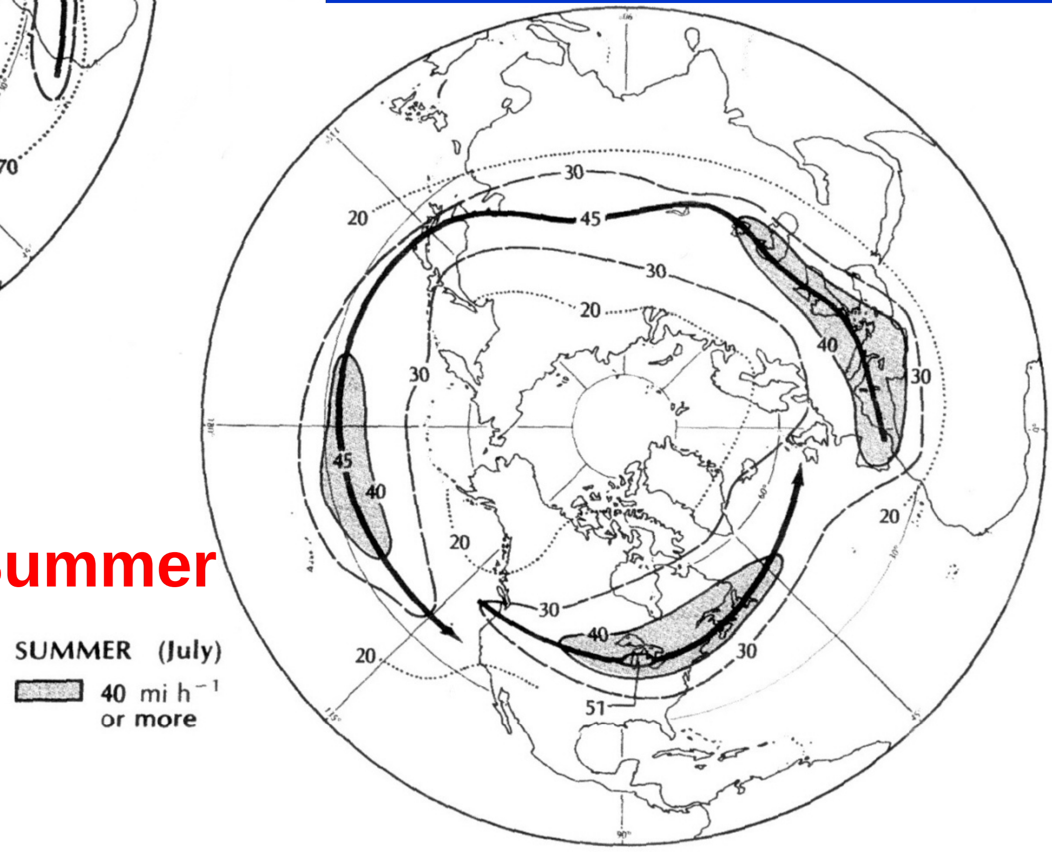
Jet Stream

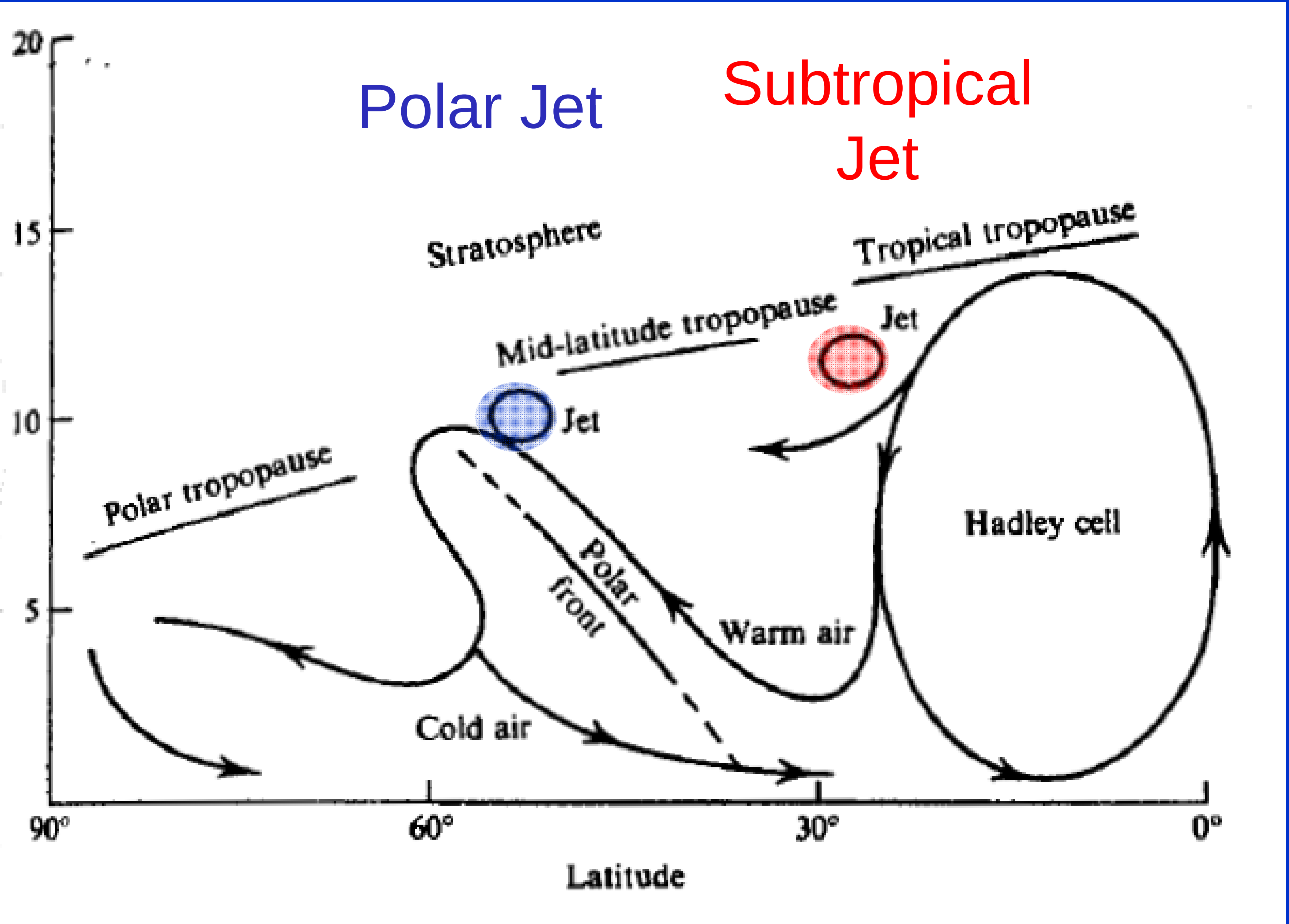
Winter



Upper level winds increase in velocity during winter & over land / ocean boundary

Summer




Polar Jet
Subtropical Jet
20
15
10
5
Stratosphere
Tropical tropopause
Mid-latitude tropopause
Jet
Jet
Polar tropopause
Hadley cell
Polar front
Warm air
Cold air
90°
60°
30°
0°
Latitude

Northern Hemisphere Winter