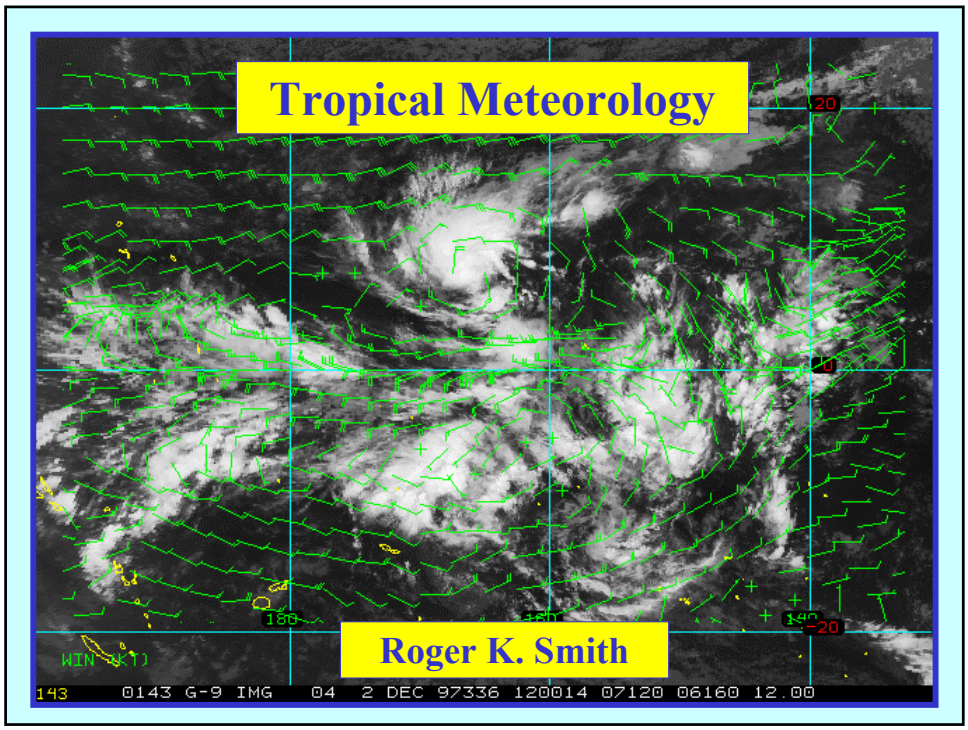
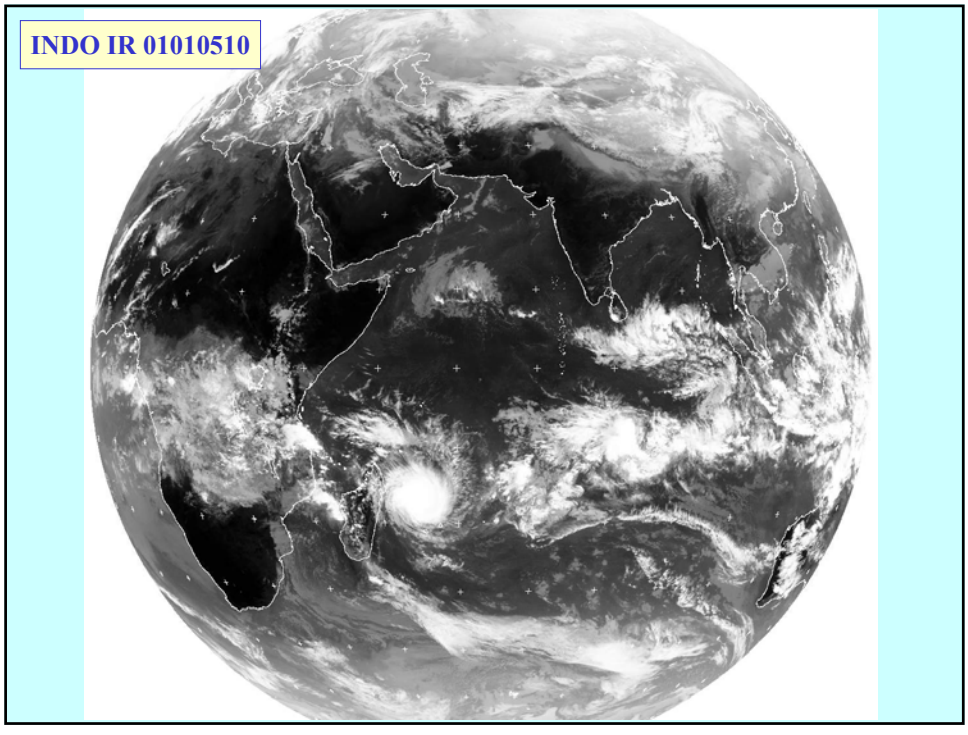
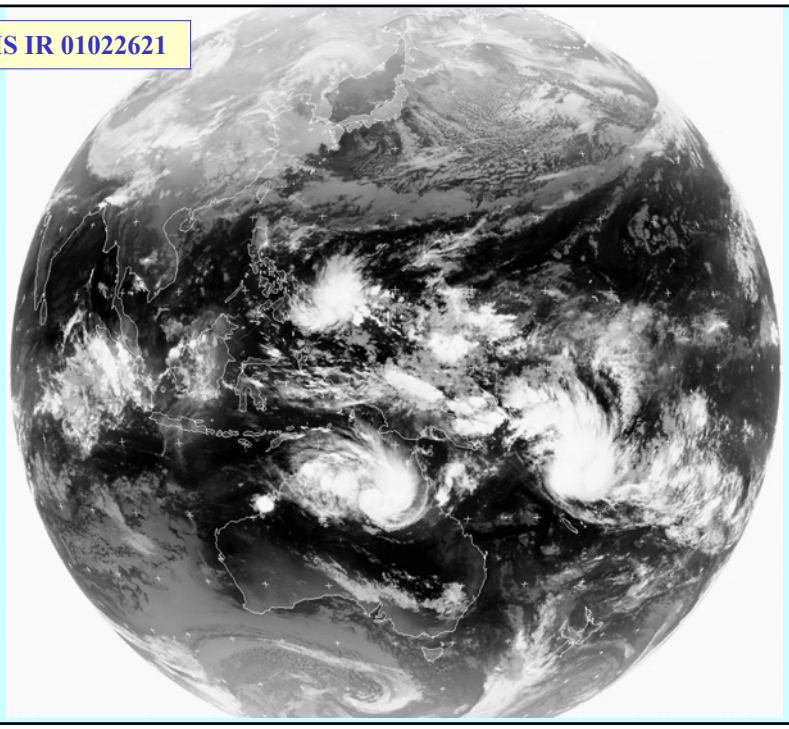
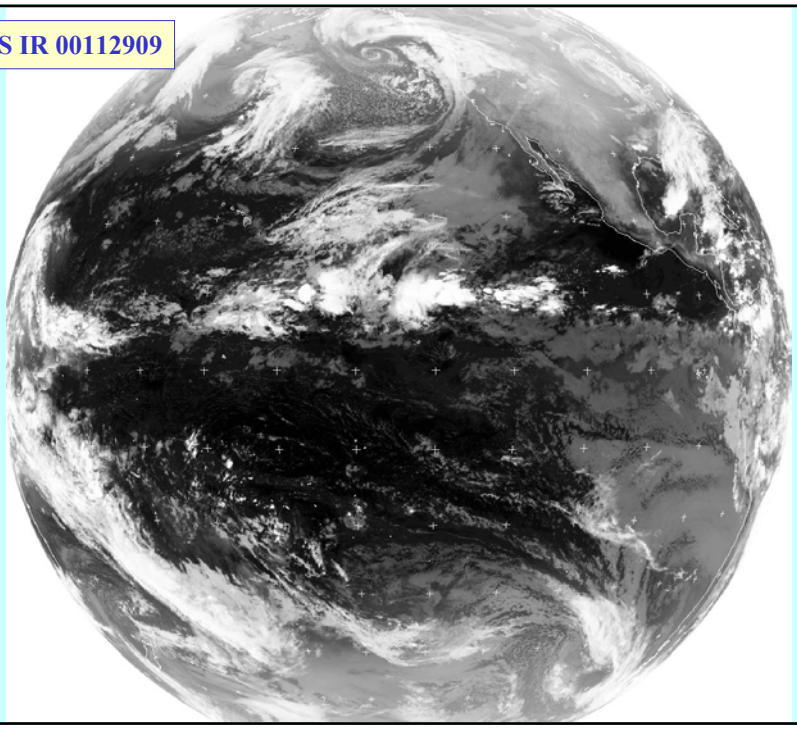

Tropical Meteorology
Roger K. Smith
0143 G-9 IMG 04 2 DEC 97336 120014 07120 06160 12.00


INDO IR 01010510

GMS IR 01022621



GOES IR 00112909



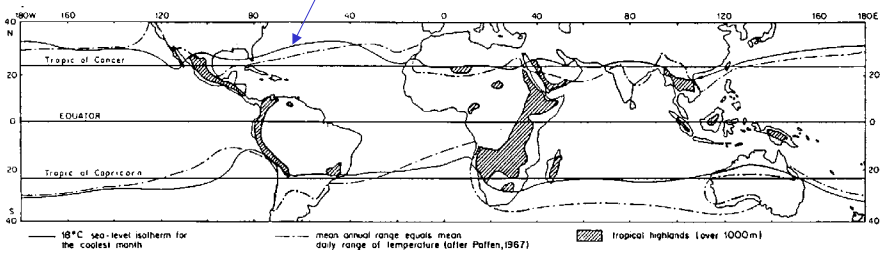
Topics

- Introduction to the tropics
- The zonal mean circulation (Hadley circulation)
- The data network in the tropics (field experiments)
- Macroscale circulations, Inter-Tropical Convergence Zone (ITCZ), Monsoons, The Walker circulation
- El Niño – Southern Oscillation
- The Madden-Julian Oscillation
- Westerly wind bursts

Topics

- Chapter 2 Equations and scaling at low latitudes
- Chapter 3 Diabatic Processes
- Chapter 4 Theory of the Hadley circulation
- Chapter 5 Wave motions in the tropics
- Chapter 6 The role of deep convection
- Chapter 7 Tropical cyclones

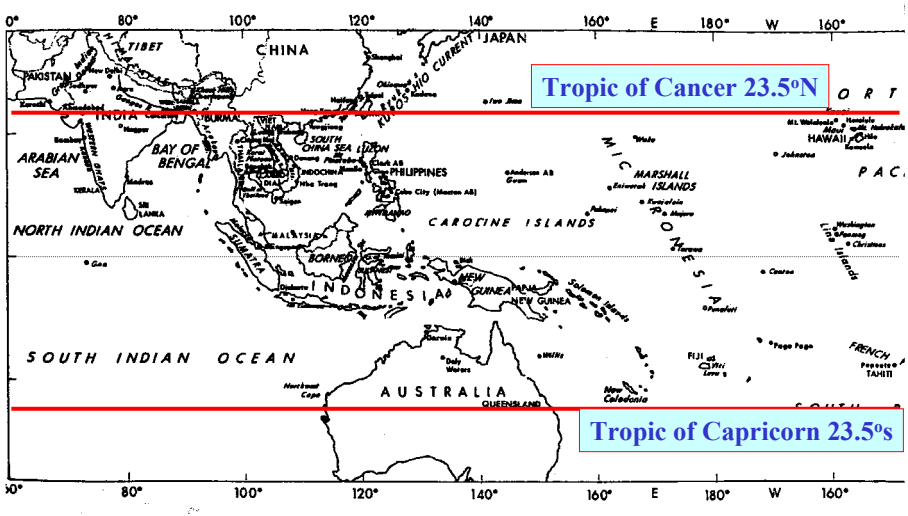
18°C sea level isotherm for the coolest month

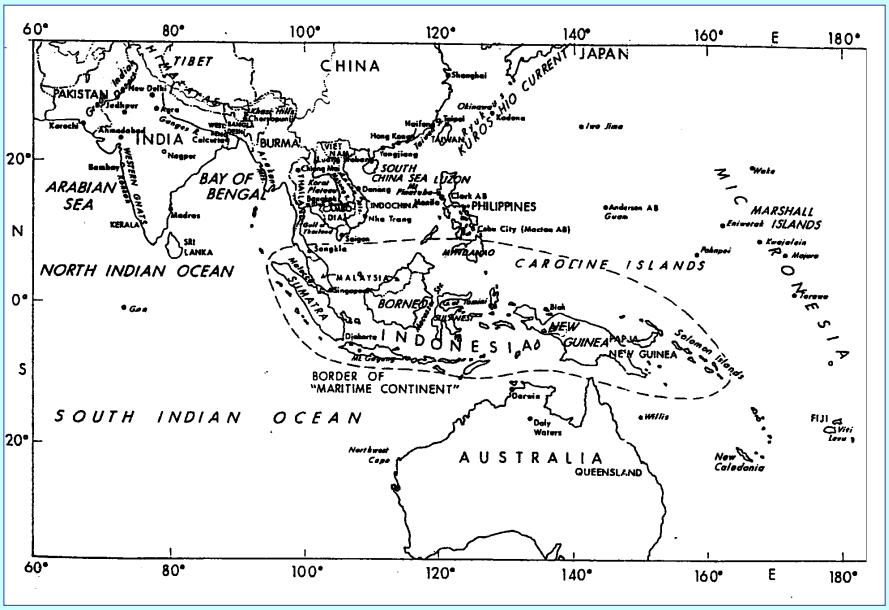


Principal land and ocean areas between 40°S and 40°N. The dot-dash line is where the mean annual range equals the mean daily range of temperature. The shaded areas show tropical highlands (over 1000 m).

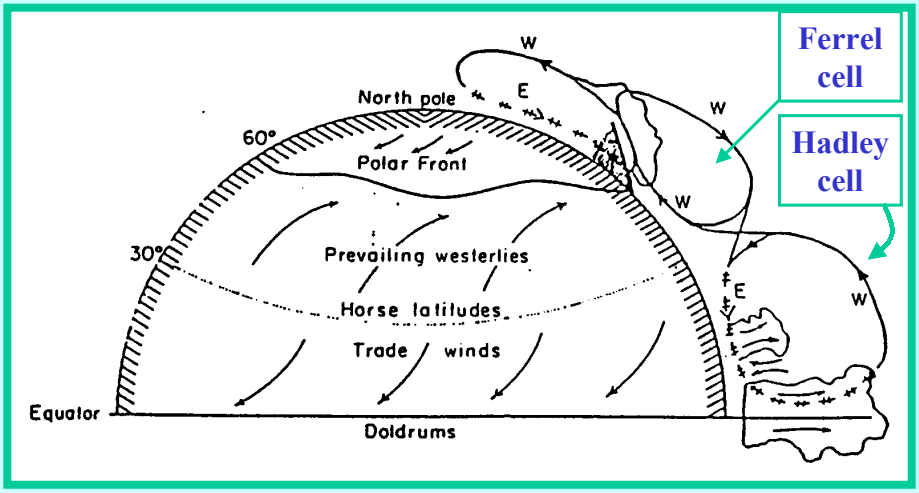
From Nieuwolt (1977)

How does one define the tropics?



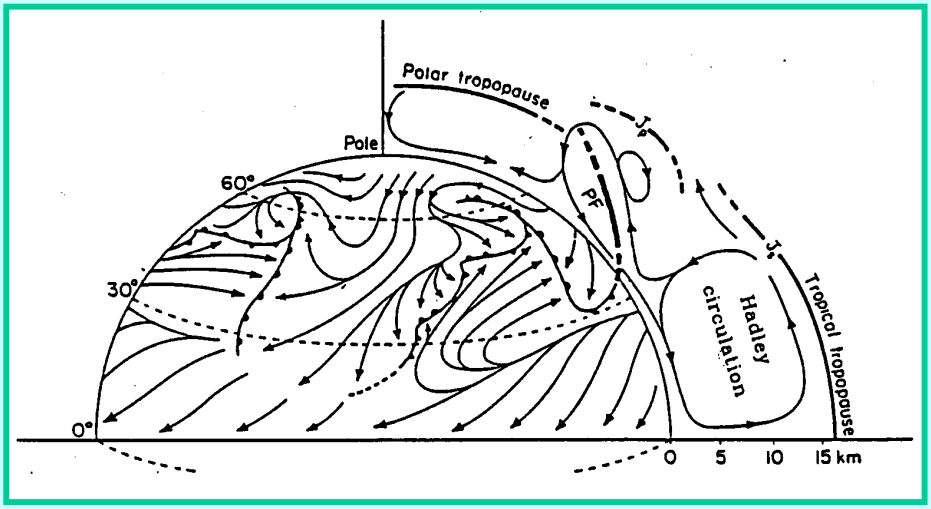


Zonal mean meridional circulation



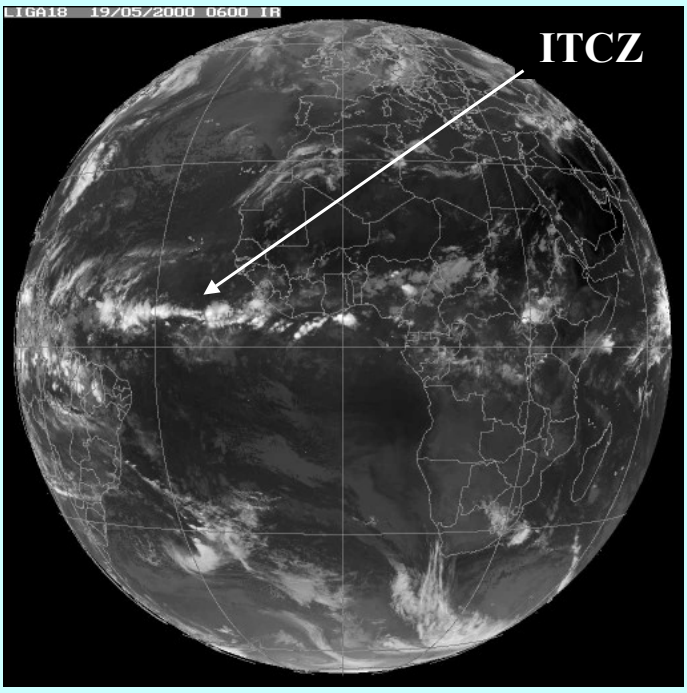
The three-cell meridional circulation pattern

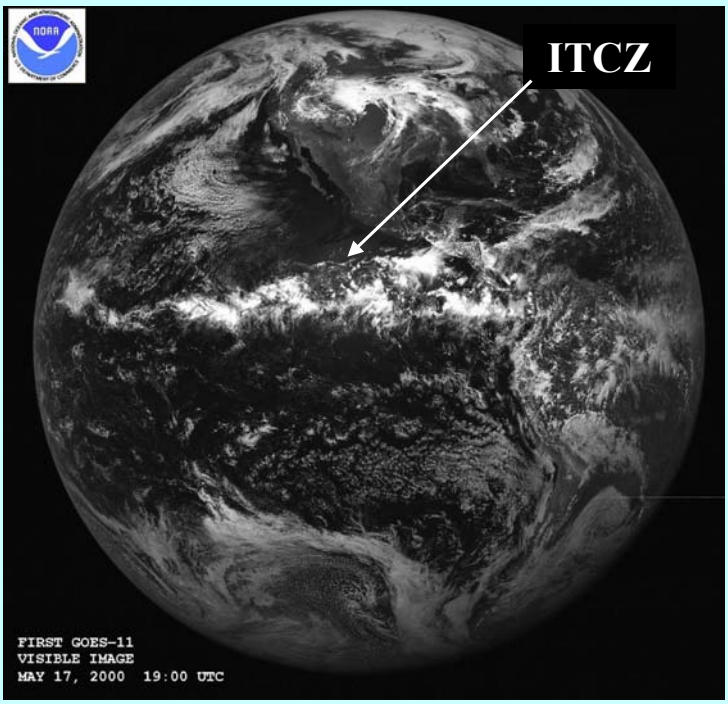
(after Rossby, 1950)

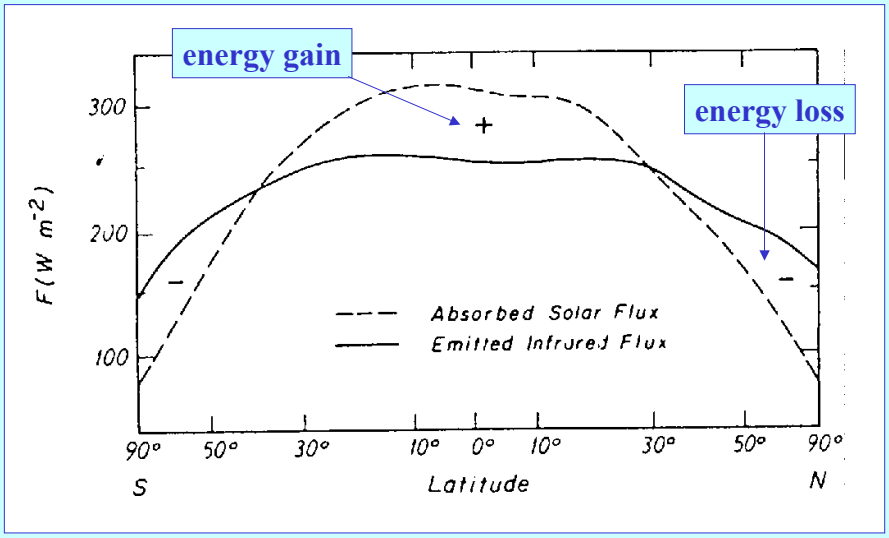


The mean meridional circulation and main surface wind regimes.

(after Defant, 1958)

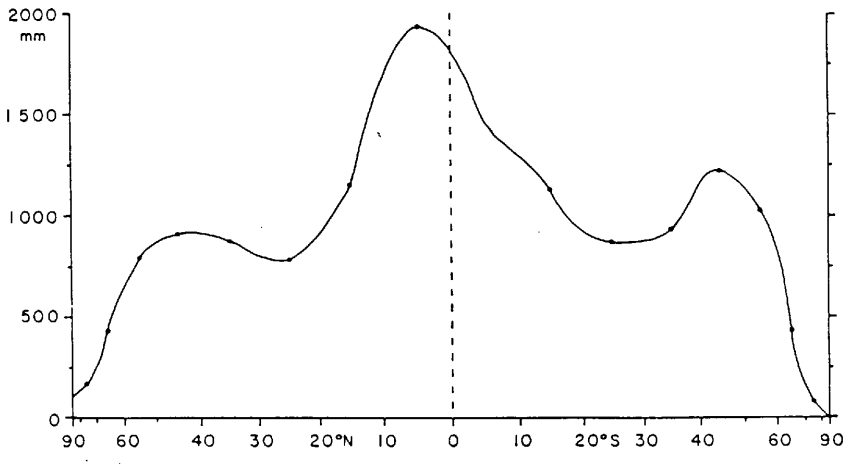






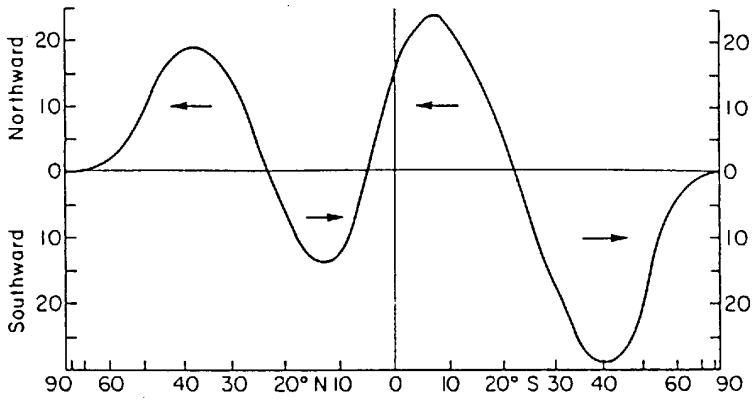
Zonally averaged components of the absorbed solar flux and emitted thermal infrared flux at the top of the atmosphere.

(after Vonder Haar and Suomi, 1971, with modifications)



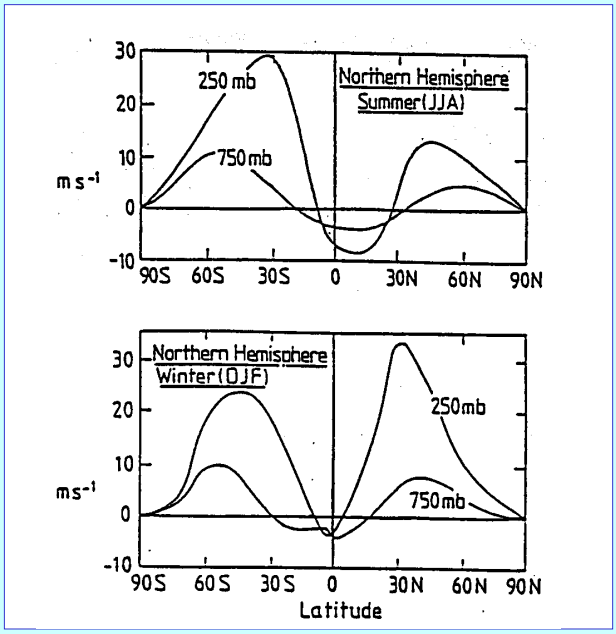
Mean annual precipitation as a function of latitude.

(after Sellers, 1965)

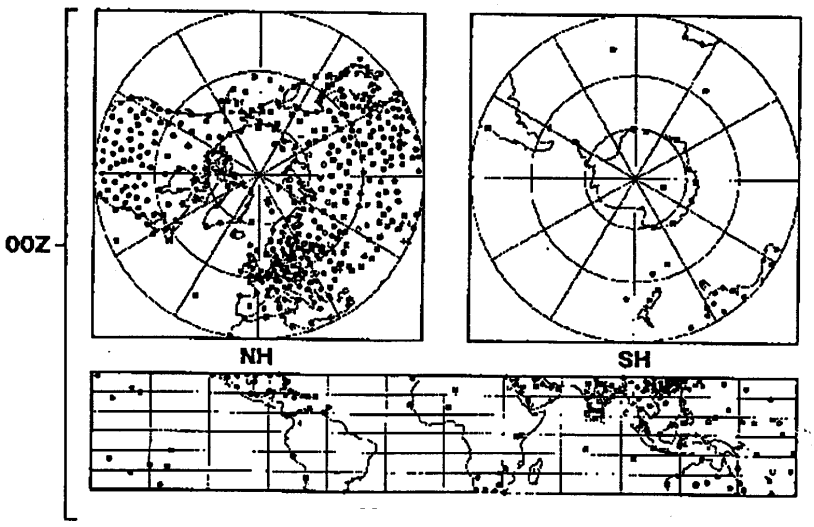


The mean annual meridional transfer of water vapour in the atmosphere (in 10^{15} kg).

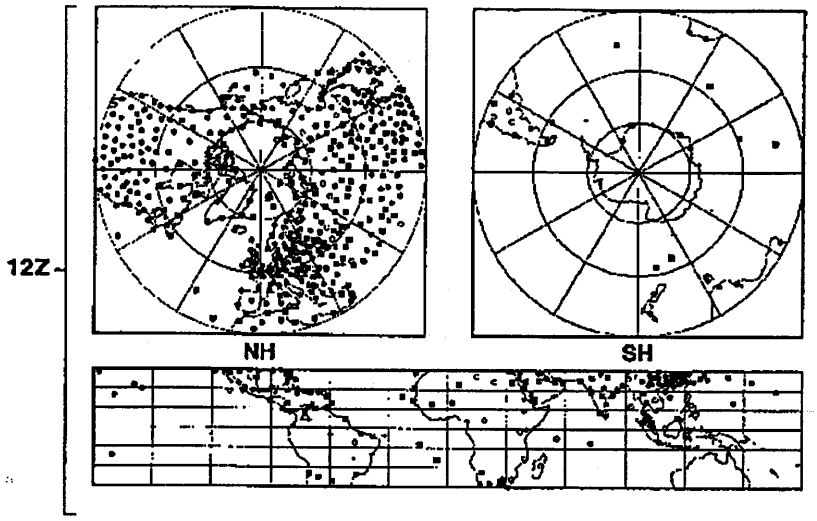
(after Sellers, 1965)



The zonally averaged wind for the NH summer and winter



Distribution and reception rate of radiosonde ascents, from land stations, received at ECMWF at 00 UTC during April 1984.



Distribution and reception rate of radiosonde ascents, from land stations, received at ECMWF at 12 UTC during April 1984.

Field Experiments in the Tropics 1969 - 1974

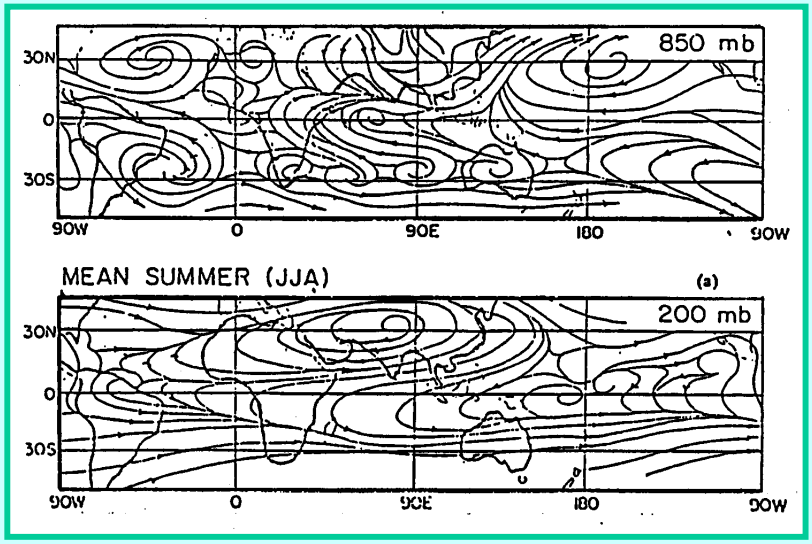
- **BOMEX** (1969)
  - **B**ermuda **O**ceanographic and **M**eteorological **EX**periment
  - Holland & Rasmusson, (1973), MWR, **101**, 44-55.
- **GATE** (July 1974)
  - **G**lobal **A**tmospheric **R**esearch **P**rogramme (**GARP**) **A**tlantic **T**ropical **E**xperiment
  - GARP: Fleming *et al*., (1979), BAMS, **60**, 649-659.
  - GATE: Kuettner *et al*. (1974) BAMS, **55**, 711-744.

Field Experiments in the Tropics 1978 - 1979

- **MONEX (Winter December 1978; Summer May – August, 1979)**
  - **The MONsoon EXperiment (WMONEX, SMONEX)**
  - **Winter MONEX: Greenfield & Krishnamurti (1979), BAMS, 60, 649-659.**
  - **Summer MONEX: Fein & Kuettner (1980) BAMS, 61, 461-474.**

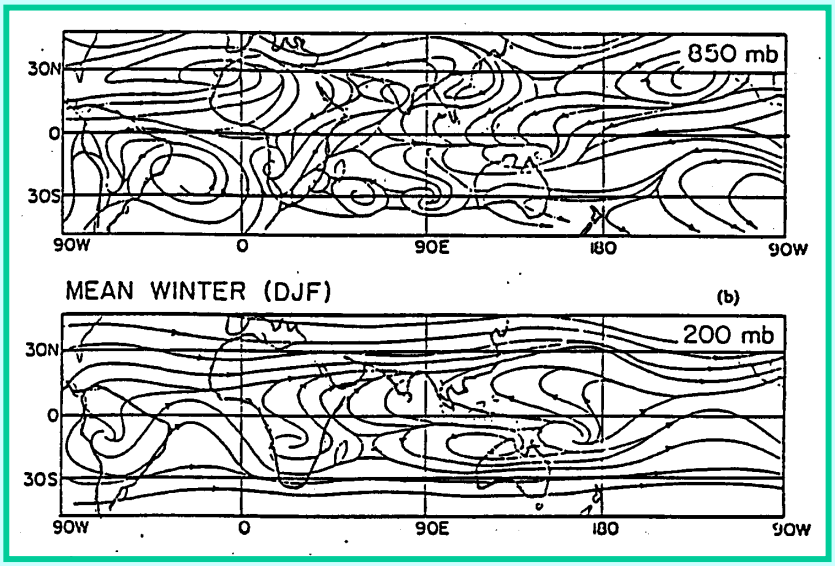
Field Experiments in the Tropics 1987 -

- **AMEX – EMEX (January – February 1987)**
  - **Australian Monsoon EXperiment & Equatorial Mesoscale EXperiment**
  - **AMEX Holland *et al.* (1986), BAMS, 67, 1466-1486.**
  - **EMEX Webster & Houze (1991), BAMS, 72, 1481-1505.**
- **TOGA COARE (November 1992 – February 1993)**
  - **Tropical Oceans Global Atmosphere Couple Ocean Atmosphere Response Experiment**
  - **Webster & Lucas (1992), BAMS, 73, 1377-1416.**



Mean streamline patterns at 850 mb and 200 mb during the Northern Hemisphere summer (JJA).

(From Webster *et al.*, 1977)



Mean streamline patterns at 850 mb and 200 mb during the Northern Hemisphere winter (DJF).

(From Webster *et al.*, 1977)

Velocity potential

We can separate the three-dimensional velocity field into a rotational part and a divergent part (see e.g. Holton, 1972, Appendix C.)

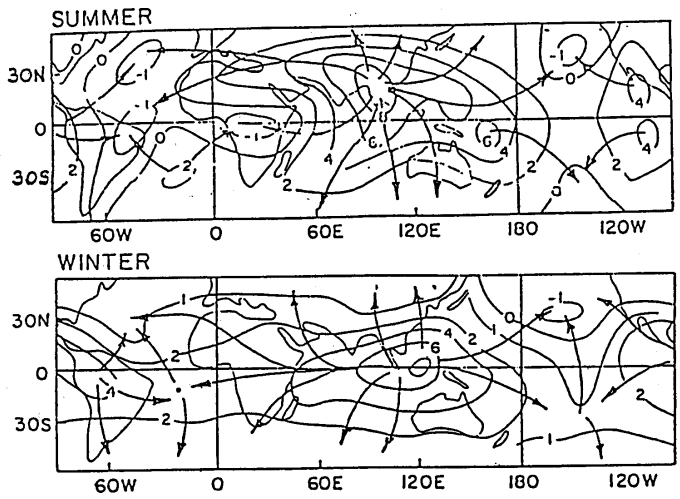
$$\mathbf{V} = \mathbf{k} \wedge \nabla\psi + \nabla\chi$$

rotational nondivergent

irrotational divergent

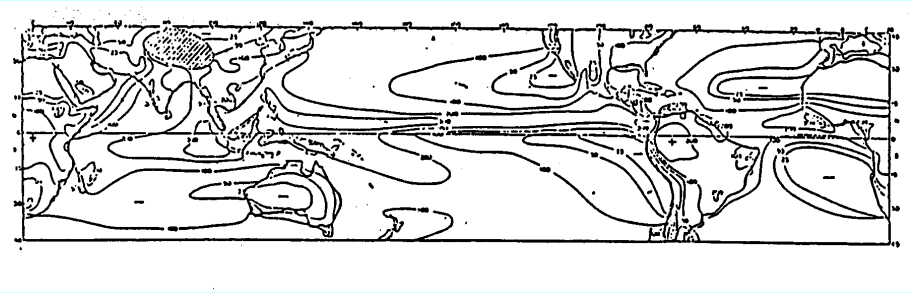
$$\nabla \wedge (\mathbf{k} \wedge \nabla\psi) = \mathbf{k}\nabla^2\psi$$
$$\nabla \cdot (\mathbf{k} \wedge \nabla\psi) = 0$$

$$\nabla \wedge (\nabla\chi) = \mathbf{0}$$
$$\nabla \cdot (\nabla\chi) = \nabla^2\chi$$



Upper tropospheric (200 mb) mean seasonal velocity potential indicating the divergent part of the mean seasonal wind which is proportional to χ.

(Adapted from Krishnamurti *et al.*, 1973).



Distribution of annual rainfall in the tropics. Contour values marked in cm.

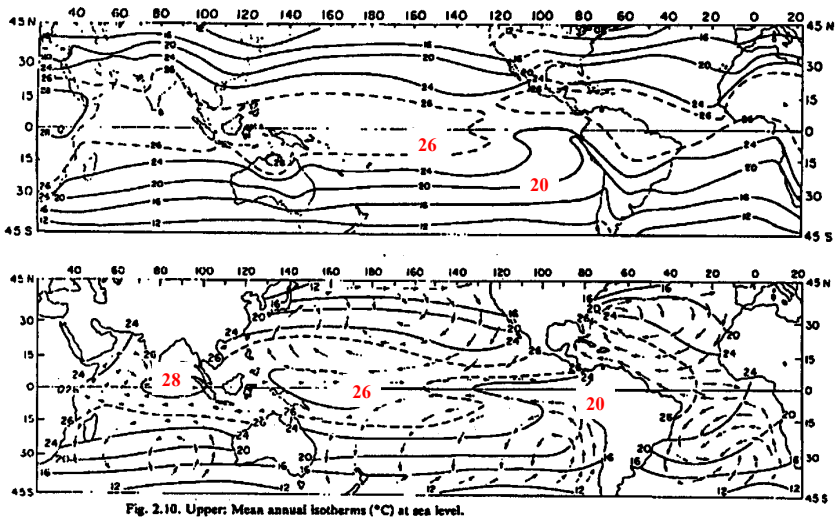
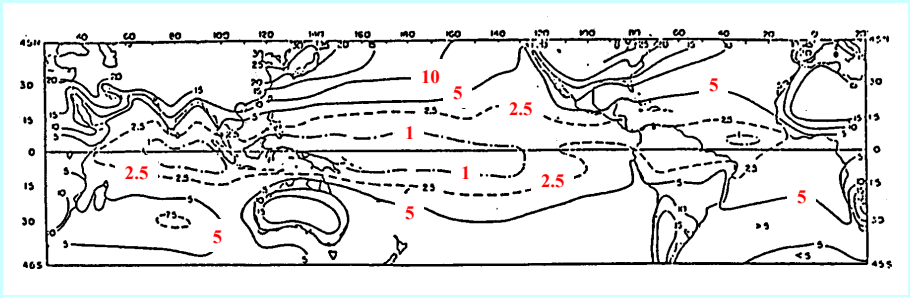
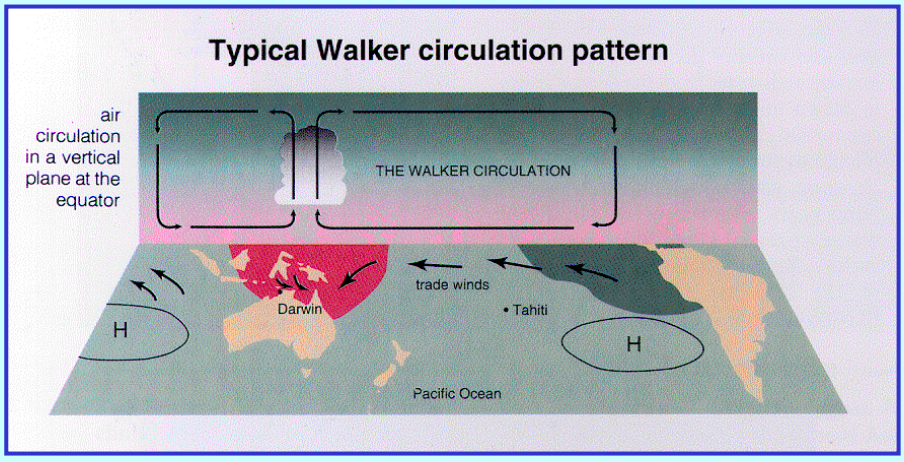


Fig. 2.10. Upper: Mean annual isotherms (°C) at sea level.
Fig. 2.11. Lower: mean annual sea surface temperatures and sketch of ocean currents, August (9, 35).

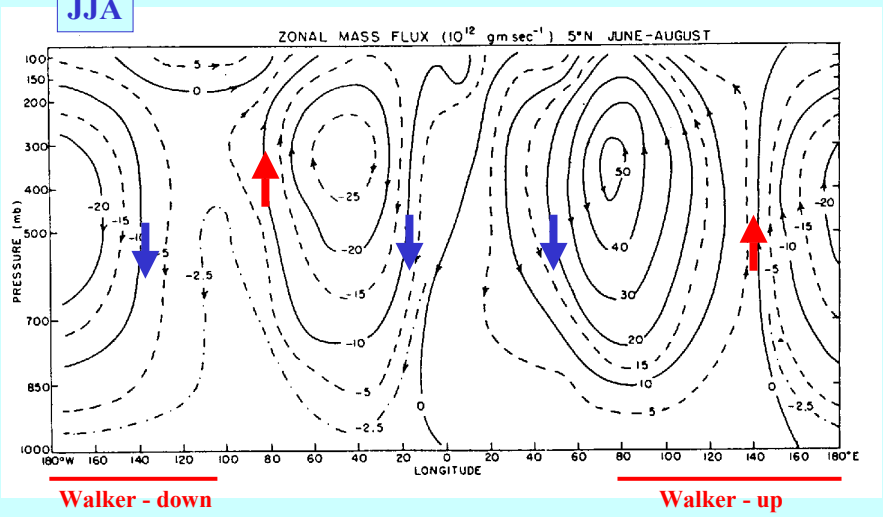
Mean annual surface air temperature (upper panel) and sea surface temperature (lower panel) in the tropics.



Mean annual temperature range (°C) of the air near sea level.

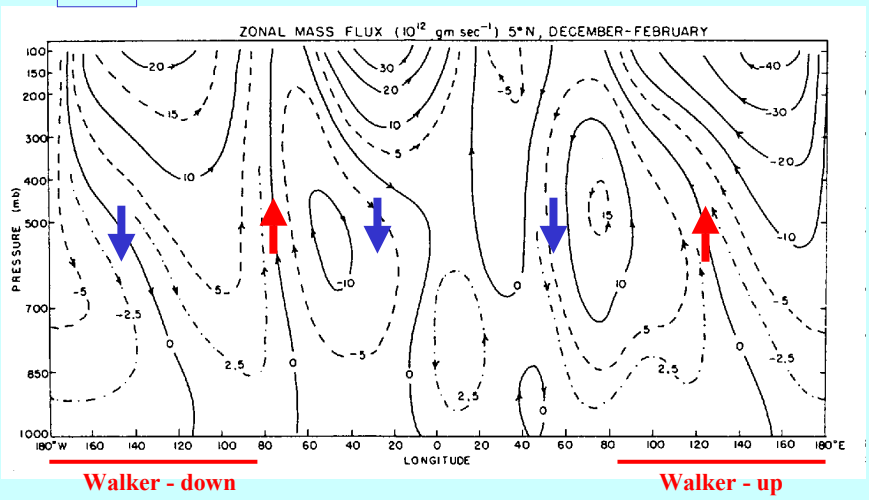


JJA



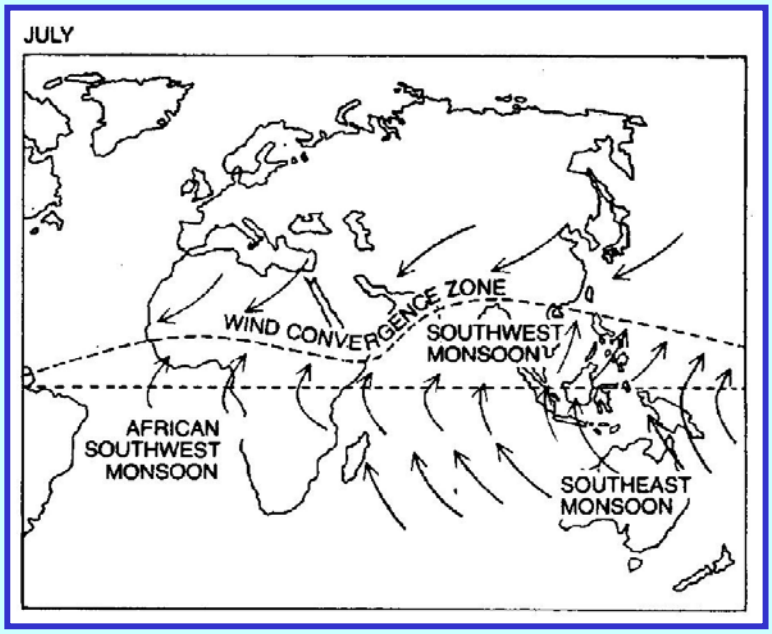
Deviations of the zonal mass flux, averaged over the latitude belt 0 – 10°N, from the zonal mean.

DJF

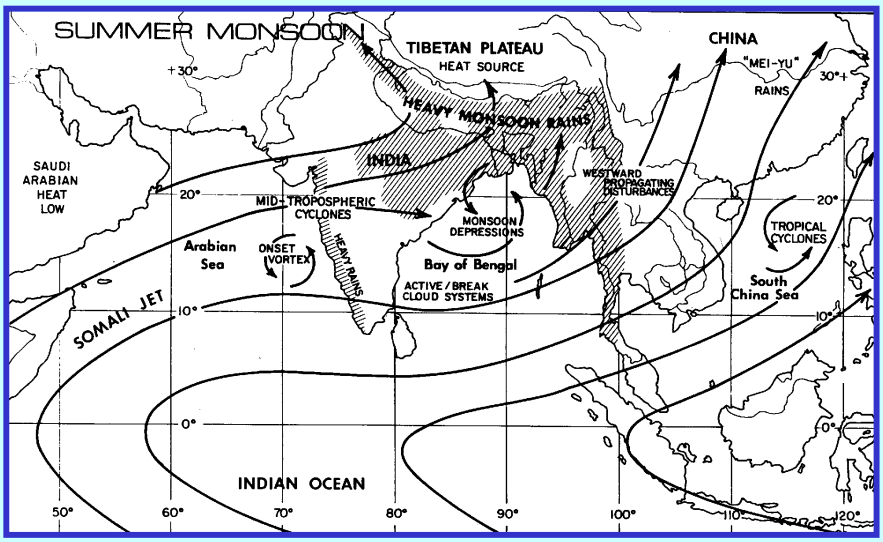


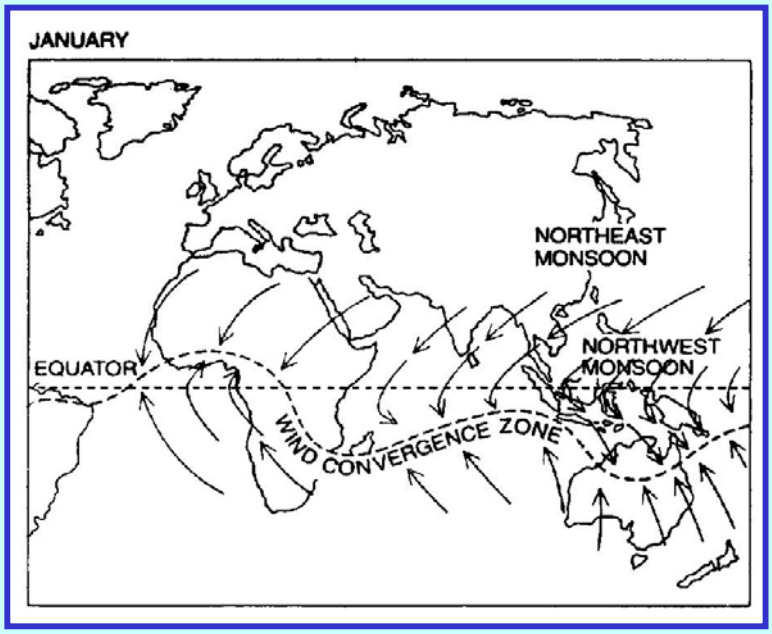
Deviations of the zonal mass flux, averaged over the latitude belt 0 – 10°N, from the zonal mean.

Monsoons

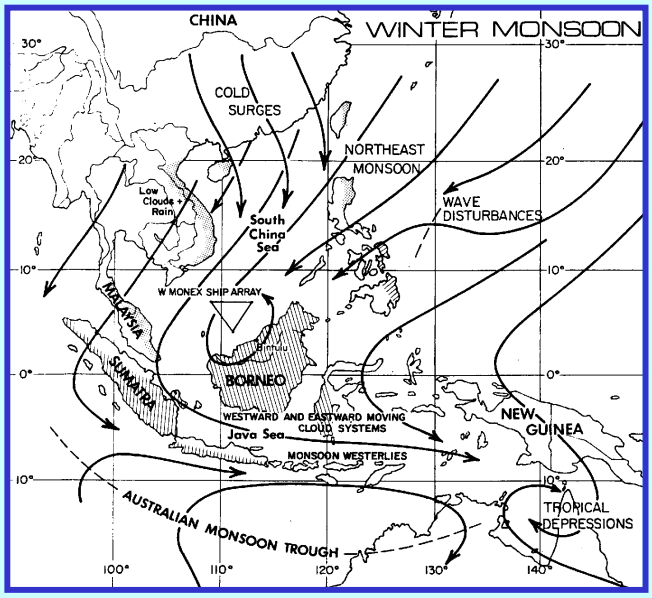

JULY
WIND CONVERGENCE ZONE
SOUTHWEST MONSOON
AFRICAN SOUTHWEST MONSOON
SOUTHEAST MONSOON

Indian Monsoon



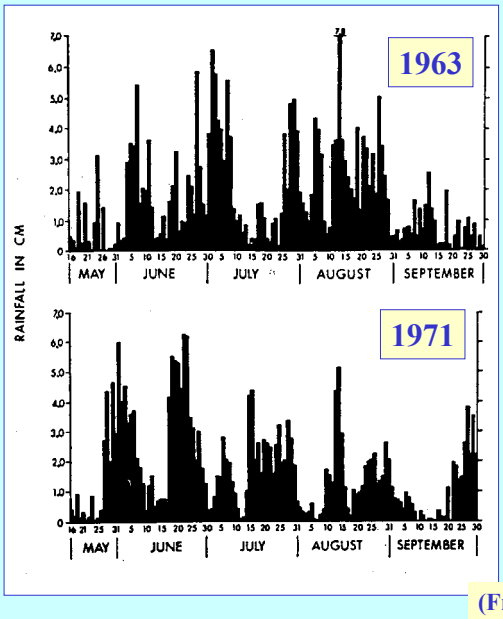


Australasian Monsoon



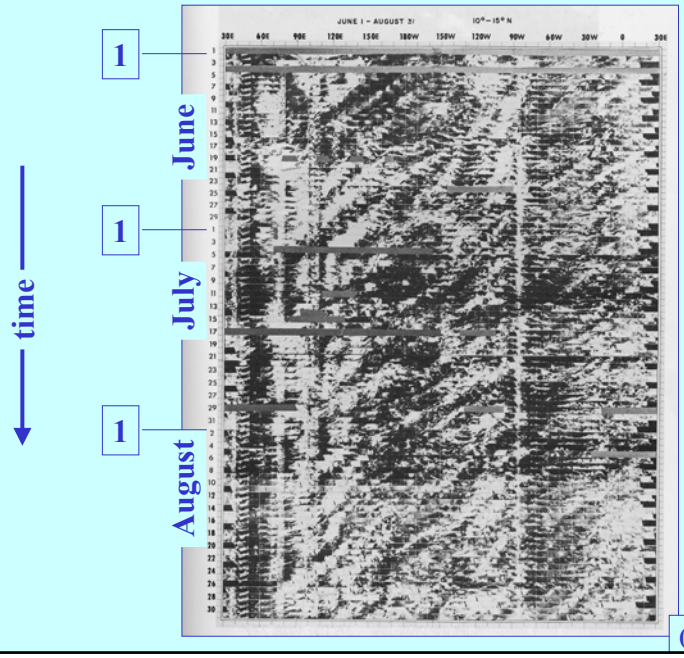
An example of monsoon variability

West coast of India



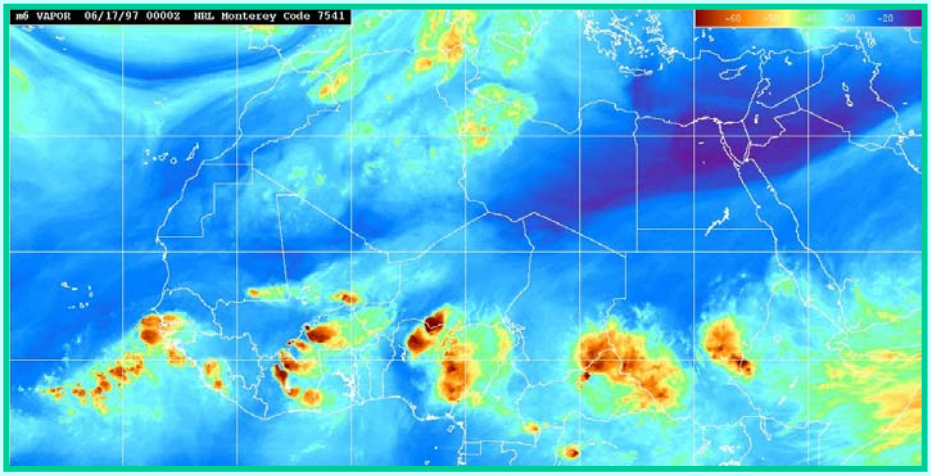
(From Webster, 1983)

Time-longitude section of vis imagery - latitude band 10 -15 N



(From Wallace, 1970)

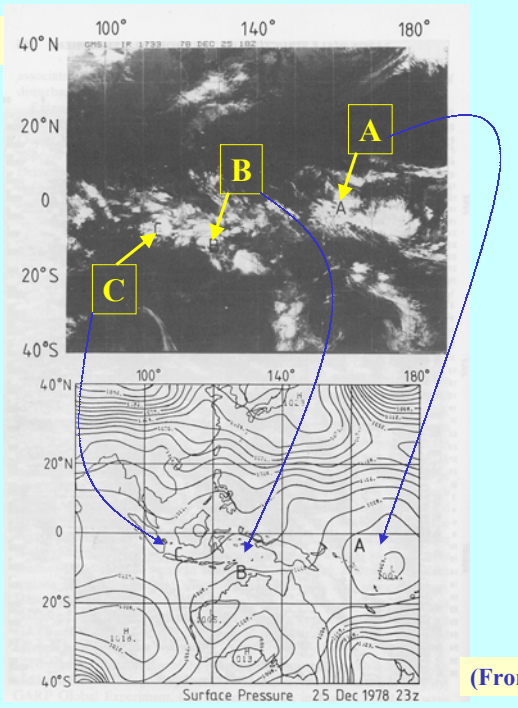
Easterly waves over Africa



WV Imagery 17 June 1997 00Z

Winter MONEX

GMS – IR
25 Dec 1978

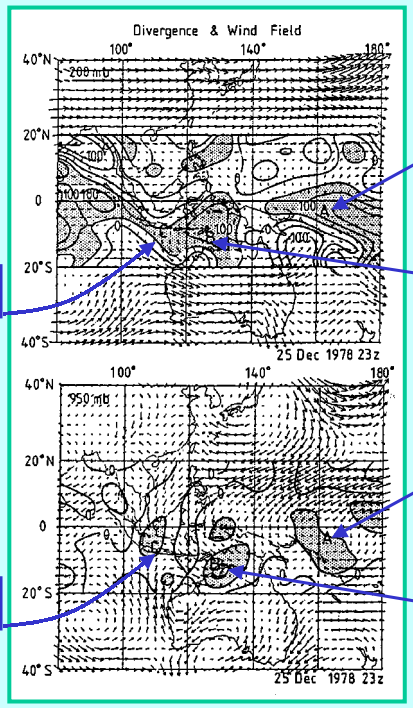


MSLP
25 Dec 1978

(From Webster, 1983)

Winter MONEX

250 mb
25 Dec 1978



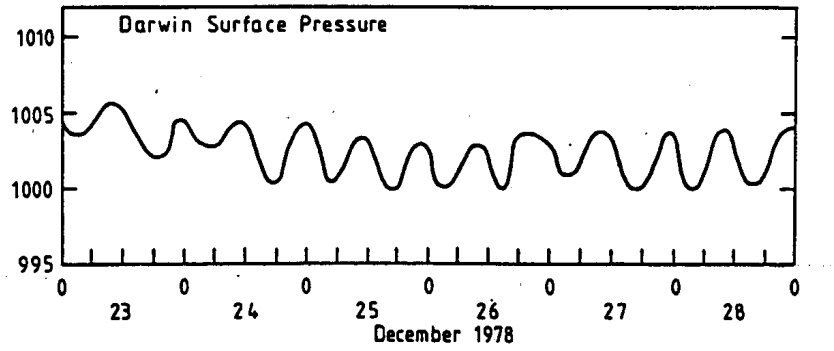
A
B
C

horizontal wind divergence

850 mb
25 Dec 1978

A
B
C

(From Webster, 1983)



The variation of surface pressure at Darwin for the period 23 - 28 Dec. 1978.

More ⇒