The Climatology of Clouds using surface observations

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Encyclopedia of Atmospheric Sciences

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Cloud Climatology

- The time-averaged geographical distribution of cloud properties and the diurnal, seasonal, and interannual variations of those properties

Importance

- The radiative effects of clouds on climate and the extent to which interannual and multidecadal changes in the Earth's radiation budget can be attributed to changes in clouds

Application

- Assessing the prediction of clouds by climate models
- Assessing the significance of chemical interactions in clouds
- Quantifying climate feedbacks involving clouds
- Estimating the radiative forcing by anthropogenic aerosols
- Selecting sites for astronomical observatories and atmospheric field experiments
- Assessing the potential for solar energy developments

Comparison between surface observation and satellite observation

Surface observations

- Using cloud by type
- Related to meteorology and could processes

i)Low clouds
ii)Multiple cloud layers
iii)Some clouds difficult to detect from satellite such as clouds over the snow (by albedo) and low clouds at night (by temperature)
iv) Inter-decadal variations and trends ← available for several decades with no change

disadvantages:
spatially inhomogeneous and temporally irregular observation

Satellite observations

- Using radiative properties

i) The altitude of the cloud top (infrared emission temperature)
ii) Cloud optical thickness (reflectance)
iii) Vertically integrated liquid water contents
iv) The effective radius of droplet

The criteria of satellite measurements for a cloud climatology
i) Pixel size is at most a few kilometers
ii) Temporal sampling at regular intervals throughout the day and night
iii) Global coverage
iv) A long period of record

Objectives

1. Computing the average cloud amounts
2. Assessing global average cloud in terms of geographical, diurnal, seasonal, and interannual variations
3. Presenting the future of cloud observations

Approach

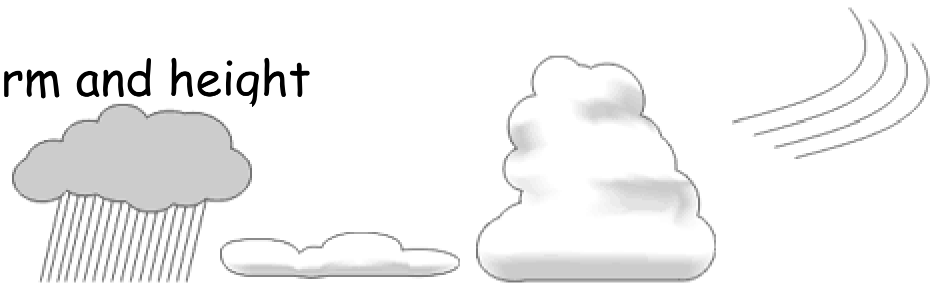
Properties of Cloud most important for climate

Radiation, Precipitation, Cloud Height, Thickness, Horizontal thickness and horizontal variability, Water content, Phase (liquid or ice), Droplet and crystal sizes

Climate effects of cloud depend on
Geographical location of the clouds, the albedo and temperature of the underlying surface, the seasons and time of day

Cloud classification according to form and height

Weather chart



Cloud information in surface weather reports

Land stations (180km), 6500 stations
0000, 0600, 1200, 1800 UT

Ocean station (600km)
0300, 0900, 1200, 2100 UT

Synoptic code

- total cloud cover
- low or middle cloud amount
- low/middle/high cloud types
- present weather
- base height of the lowest cloud

Approach

Computation of average cloud amounts

→ Frequency-of-occurrence

fraction of weather observation in which a cloud of this type is present, whether visible or hidden

→ Amount-when-present

the average fraction of the sky covered by this cloud type when it is present, whether visible or hidden

- Cloud atlas includes the average amount of each cloud type for each season in grid-boxes of 5 degree by 5 degree as well as diurnal cycle and interannual variation

* Two small biases that oppose each other and are unique to ship observations

i) The fair-weather bias (more ship to enter a grid-box on days of fair weather)

ii) The foul-weather bias (ships to oversample stormy or foggy weather)

iii) The diurnal sampling bias (more reports are transmitted during the day than at night)

iv) The trend bias (sampled by more ship in later years than in earlier years)

v) The night-detection bias (observations are hindered by inadequate illumination of the clouds)

Results: Global Average

Cloud cover from surface observations

Table 1 Annual average cloud cover from surface observations (1982–1991)

	Land	*Ocean*	*Globe*
Average total cloud amount (%)	54	68	64
Day–night difference (%)	+3	0	+1

Cloud properties from ISCCP

Table 2 Annual average cloud properties from the International Satellite Cloud Climatology Project (1986–1993)

	Land	*Ocean*	*Globe*
Average total cloud amount (%)	58	72	68
Day–night difference (%)	+5	−2	0
Cloud top temperature (°C)	−20	−7	−11
Day–night difference (°C)	+12	+2	+5
Cloud top pressure (hPa)	490	620	580
Cloud optical thickness	4	4	4
Cloud-water path (g m^{-2})	76	61	66

Satellite data < Aircraft measurement

Probably due to horizontal inhomogeneity of the clouds

Cloud type from surface observations

Table 3 Cloud type amounts and heights from surface observations

Cloud type	*Annual average amount (%)*		*Base height (meters above surface)*	
	Land	*Ocean*	*Land*	*Ocean*
Fog	1	1	0	0
Stratus	5	11	500	400
Stratocumulus	12	22	1000	600
Cumulus	5	12	1100	600
Cumulonimbus	4	6	1000	500
Nimbostratus	5	6		
Altostratus	4	22 (Altostratus + Altocumulus)		
Altocumulus	17			
High (cirriform)	22	13		
Clear sky (frequency)	22	3		

- Ocean, the more low cloud type, the less cirroform cloud
- Completely clear sky is common over the land but rare over the ocean
- Cumulonimbus amount exceeds 10 % in a narrow band along the ITCZ and over a much broader region of warmer water in the western Pacific " warm pool"

Results: Geographical variation

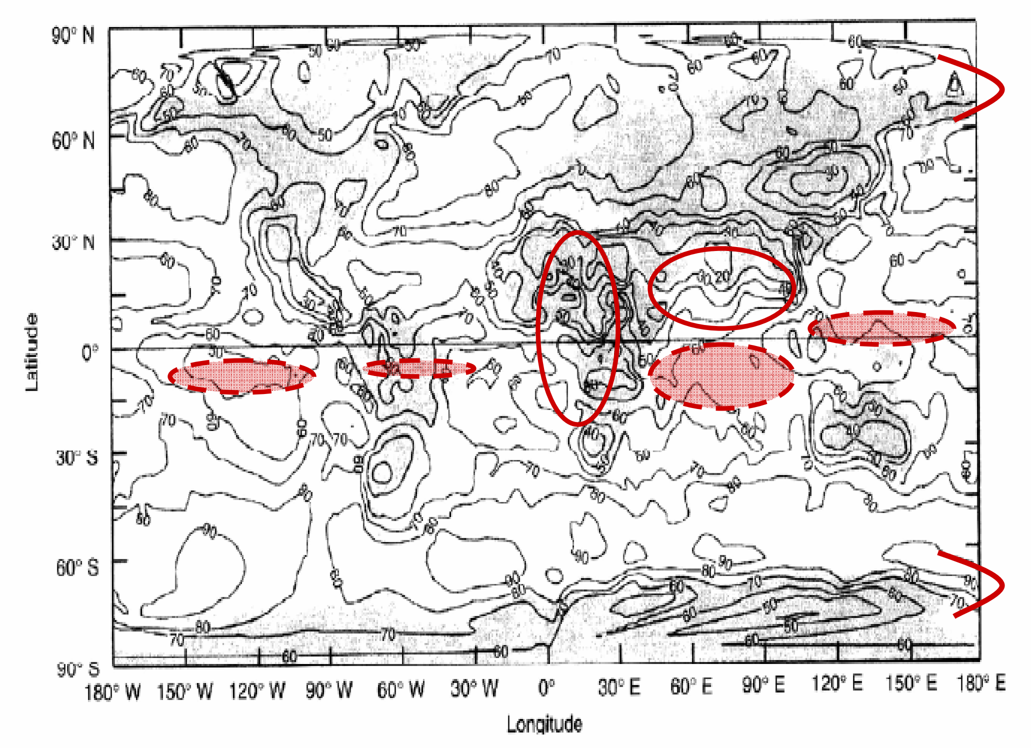


Figure 1 Percent total cloud cover for December–January–February from surface observations (weather stations on land, ships in the ocean) for the 10-year period 1982–1991, average of day and night.

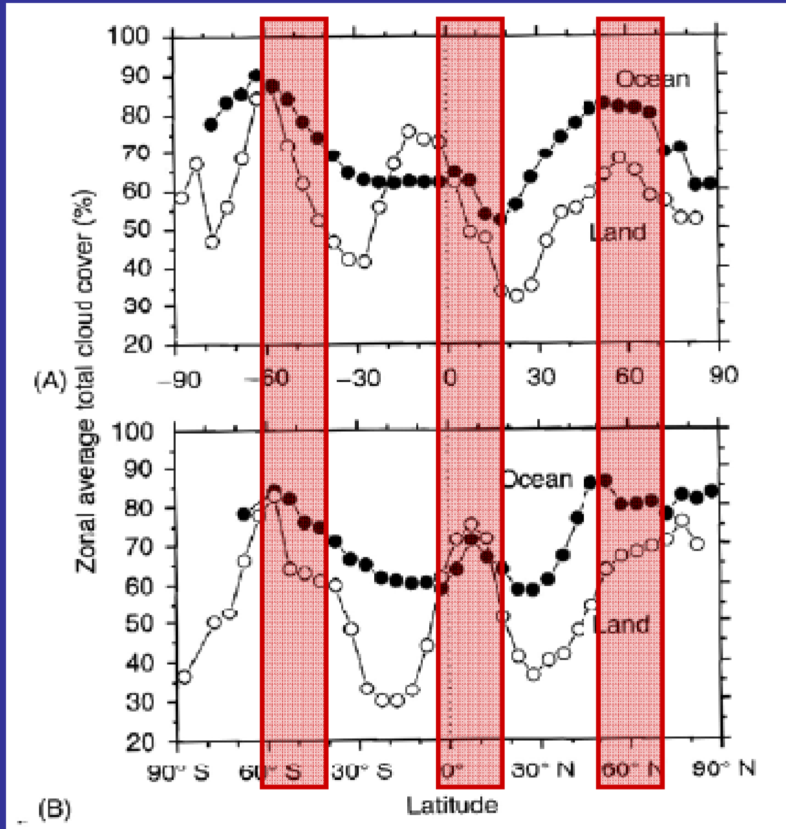


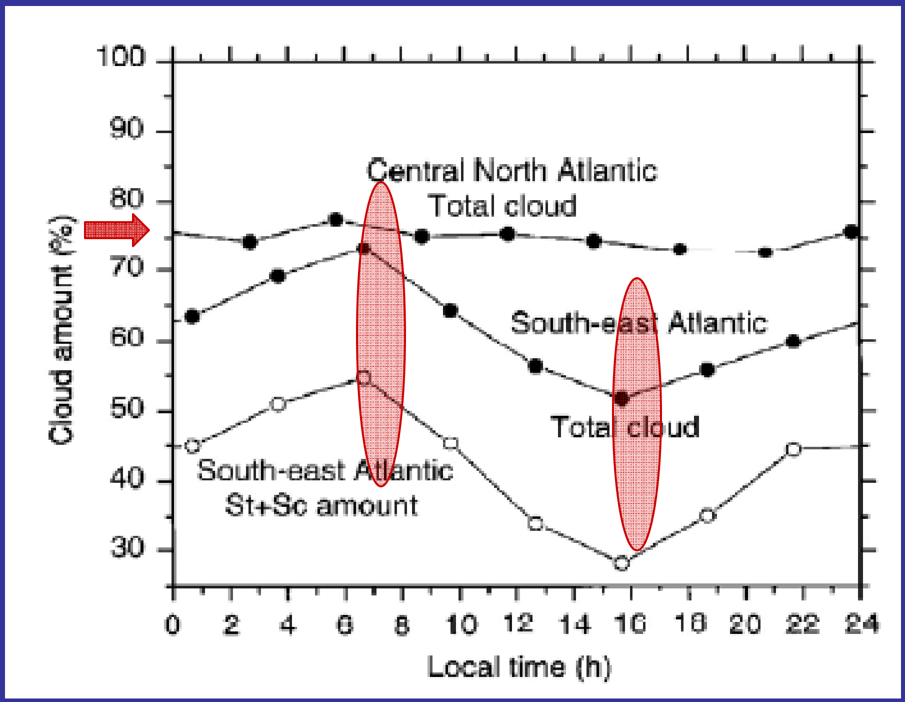
Figure1. Percent total cloud cover for DJF

Figure2. Zonal average total cloud cover for 5 degree latitude zones
(A) DJF (B) JJA

The only season (DJF) in which complete global coverage is available from sea surface observation because it is accessible to the Antarctic Ocean.
Indian subcontinent: 20~30%
Desert area: below 40%, Sahara desert (20~5%)

Average cloud cover: land < ocean
Latitudinal variation: land > ocean
Latitude of maximum cloud cover: 60 degree
Minimum cloud cover: great deserts

Results: Diurnal Variation



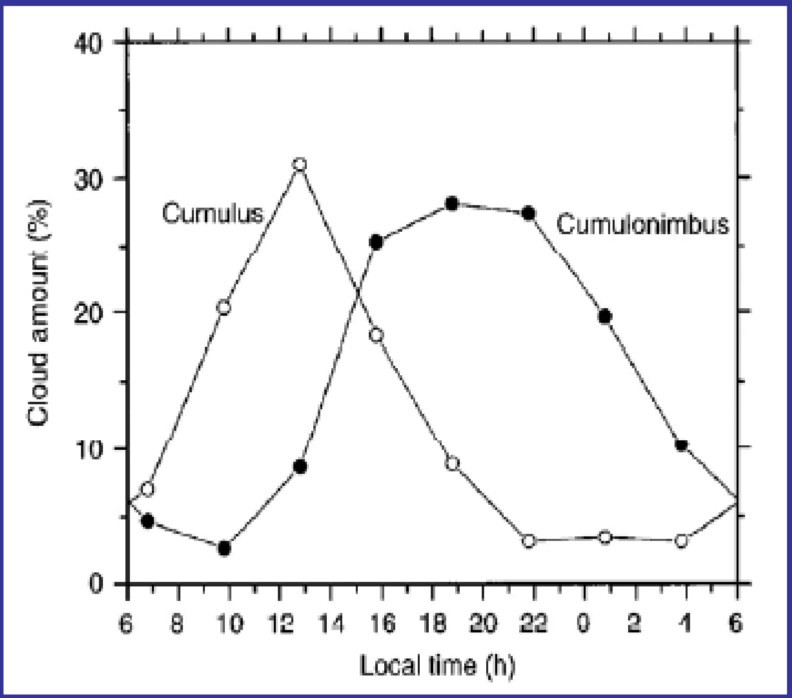


Figure 3 Diurnal cycles of oceanic cloud, from ship-observations in DJF

No diurnal variation in Central North Atlantic
Max at 07.00 and min at 16.00 in South-east Atlantic

Figure 4 Diurnal cycles of cumulus and cumulonimbus amounts reported from weather stations in Central America in summer

• Cumulus clouds in the morning
← Solar heating of the surface begins at sunrise
• Further develop into cumulonimbus in the afternoon
• Continuing precipitating into the evening

Results: Seasonal variations

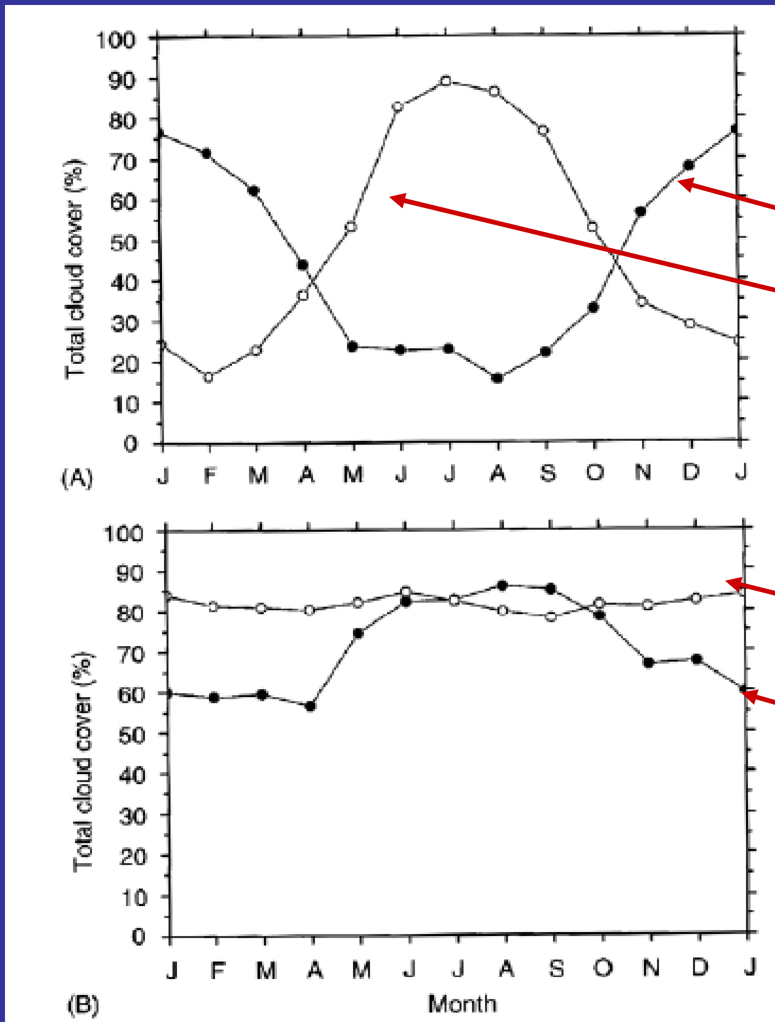


Figure 5 seasonal cycles of total cloud cover
(A) Land (B) Ocean

The largest seasonal variation of cloud cover: Subtropical monsoons of Africa, south America, India, and Australia

Austrian monsoon: cloud and rainy summer

Indian monsoon: average total cloud cover 16% in Feb to 89% in July

North Atlantics: no seasonal variation

Central Arctic ocean
: a peculiar boxlike seasonal cycle
Great cloud cover from June to September due to mainly the low, thin 'Arctic summer stratus' clouds

Results: Interannual variations and trends

A powerful way to assess the validity of observed cloud changes is to identify likely causes (changes in SST or atmospheric circulations) and effects (diurnal temperature range) to correlate these related climatic variables to the cloud changes

Figure 6 seasonal average daytime amounts of St + Sc and seasonal average SST for two grid boxes in JJA

(a) a long-term trend (the error in a seasonal mean due to random sampling of weather situations during particular season is small)

(b) seasonal means suffer from sampling error and the correlation of St + Sc with SST is not as strong as (a)

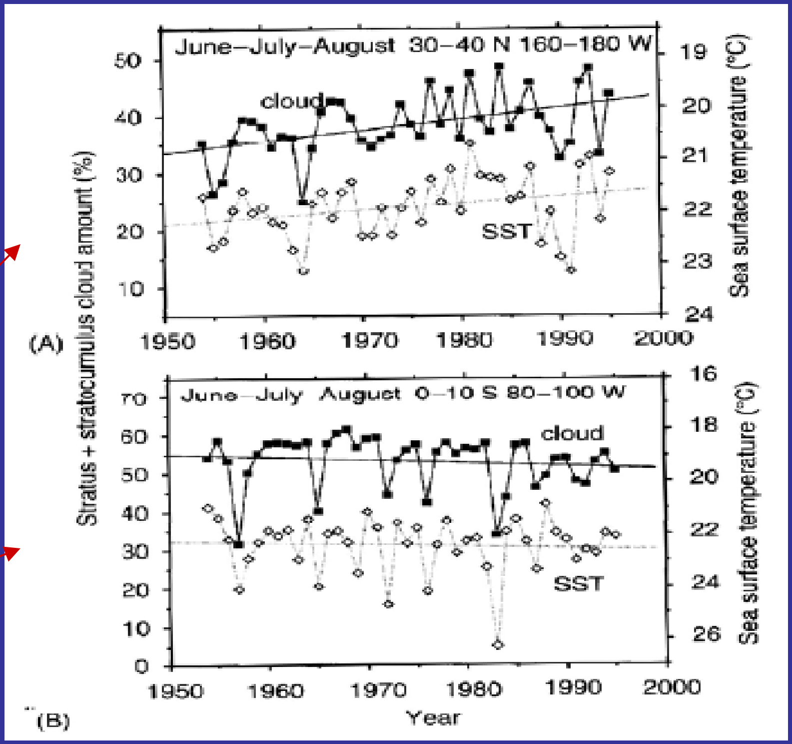
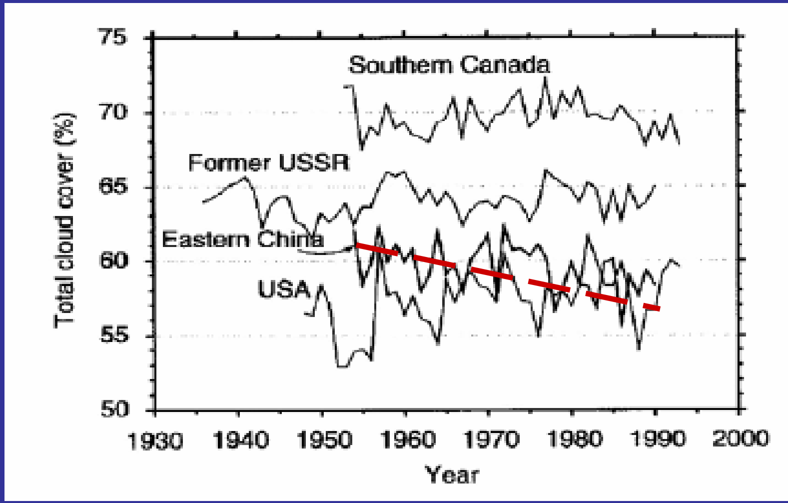


Figure 7. variations of total daytime cloud cover reported over last half-century for four large regions of the Northern Hemisphere.

A significant trend in eastern China.



The future of cloud observations

The long time-span of cloud reports is a valuable resource. However, it is difficult to infer reliable climatic changes over a span of years

←changes of codes
←changes of observational methods (laser ceilometers in place of the human eye)
←changes of station location

It is difficult to obtain reliable multilayer trends of cloud amounts from satellite observation

←the short lifetimes of individual satellite
←the difficulty of inter-calibrating instruments on different satellite

Much effort needs to these problem to meet an increase in the use of satellite observations for the climatology of clouds

- Clouds are strongly affected by **local meteorological factors and weather.**
- Clouds are representative phenomena of **regional climate.**
- **Intensive and continuous surface observation** for monitoring regional climate should be made in order to complement the satellite observation and to make more accurate assessment of the climatology of clouds.