

## **Lecture 6.**

*The challenges in founding trends in global cloud cover from satellite and ground-based observations.*

### Outline:

1. Background materials.

2. Papers for class discussion:

*Wylie D., et al., Trends in global cloud cover in two decades of HIRS observations, Journal of Climate, 18, 3021-3031, 2005.*

*Warren S.G. and Hahn C.J., Clouds/Climatology, in: Encyclopedia of Atmospheric Sciences (Eds. J.R. Holton, J.A. Curry, and J.A. Pyle), Academic Press, pp.476-483, 2002.*

### Additional reading:

*Hahn, C.J., W.B. Rossow, and S.G. Warren, 2001: ISCCP cloud properties associated with standard cloud types identified in individual surface observations. J. Climate., 14, 11-28.*

## **Background materials.**

### Cloud classification

Clouds are classified into a system that uses Latin words to describe the appearance of clouds as seen by **an observer on the ground**. The four principal components of this classification system are cumulus, stratus, cirrus and nimbus.

#### **Latin Root Translation Example**

cumulus	heap	fair weather cumulus
stratus	layer	altostratus
cirrus	curl of hair	cirrus
nimbus	rain	cumulonimbus

Further classification identifies clouds by height of cloud base. For example, cloud names containing the prefix "cirr-", as in cirrus clouds, are located at high levels while cloud names with the prefix "alto-", as in altostratus, are found at middle levels. The first three groups are identified based upon their height above the ground. The fourth group consists of vertically developed clouds, while the final group consists of a collection of miscellaneous cloud types.

High clouds: make up the family of clouds found above 6 km (20,000ft). Because of the lack of water vapor and cold temperatures of the upper troposphere, high clouds are composed of ice crystals. *Examples:* cirrus, cirrocumulus and cirrostratus

Middle clouds: occur in a range from 2 to 6 km (6500 to 20,000 ft). These clouds are composed of water droplets. Middle clouds usually have a distinct outline. *Examples:* altocumulus and altostratus.

Low clouds: occur below 2 km (6500ft).

*Examples:* stratus, stratocumulus, and nimbostratus.

Clouds of vertical development:

These clouds can not be categorized as high, middle or low clouds because they may occupy more than one height range. In other words, the base of the cloud may begin in the low cloud range and extend up into the middle or high cloud range.

*Examples:* cumulus and cumulonimbus.

Classification table that is commonly used by meteorologists

<b>High clouds</b>			
Type	Precipitation (ppn) etc.	Range of cloud base	C code
<b>Cirrus (Ci)</b>	No ppn. Halo may occur. Dense patches may veil or hide the sun	Usually 20,000-40,000 ft	0
<b>Cirrocumulus (Cc)</b>	No ppn. Position of sun/moon can usually be seen	If at a non-aviation station the height cannot reasonably be estimated, the British practice is to use a nominal height of 25,000 ft, and 35,000 ft for any higher cloud	1
<b>Cirrostratus (Cs)</b>	No ppn. Halo often occurs. Outline of sun normally visible	Cs may thicken to become As	2

<b>Medium clouds</b>			
Type	Precipitation (ppn) etc.	Range of cloud base	C code
<b>Altostratus (As)</b>	Often continuous ppn reaching the ground with sun/moon hidden. Thinner As shows sun/moon as ground glass appearance	Altostratus may thicken with progressive lowering of the base to become Ns	4
<b>Nimbostratus (Ns)</b>	Normally continuous ppn (sometimes moderate/heavy) with sun/moon hidden	Usually between the surface and 10,000 ft	5

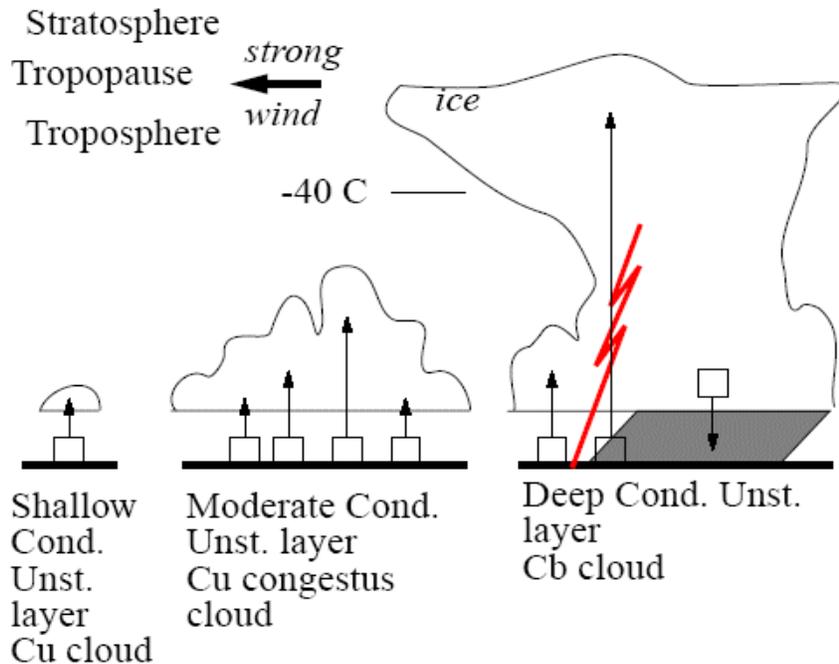
Low clouds			
Type	Precipitation (ppn) etc.	Range of cloud base	C code
<b>Stratocumulus (Sc)</b>	Normally no ppn, but slight ppn possible over coasts/hills. Can be thick enough to hide sun/moon	Usually between 1,000 ft* and 4,500 ft but may often be observed to 6,500 ft	6
<b>Stratus (St)</b>	Near coasts/hills, ppn can be considerable, but it may be falling from higher cloud such as Ns. Can be thick enough to hide sun/moon. However when thin, sun/moon can be clearly visible	Usually between the surface and 2,000 ft but may sometimes be observed to 4,000 ft	7
<b>Cumulus (Cu)</b>	Light showers are possible	Usually between 1,000 ft and 5,000 ft, but may sometimes be observed to 6,500 ft. After initial formation, a rise in temperature often leads to a rise in cloud base	8
<b>Cumulonimbus (Cb)</b>	Always reported when showers/thunderstorms/hail occurs. Squally winds are also common	Usually between 2,000 ft and 5,000 ft, but may sometimes lower to near surface, or be as high as 6,500 ft	9

Cloud Atlas: shows great pictures of all types of clouds

<http://www.atmos.washington.edu/gcg/Atlas/>

Some examples:

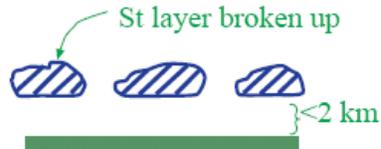
### CONVECTIVE CLOUDS



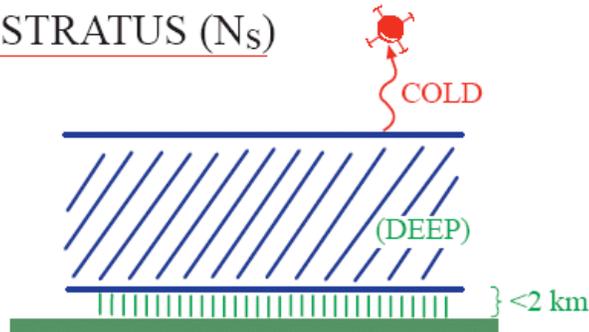
STRATUS (St)



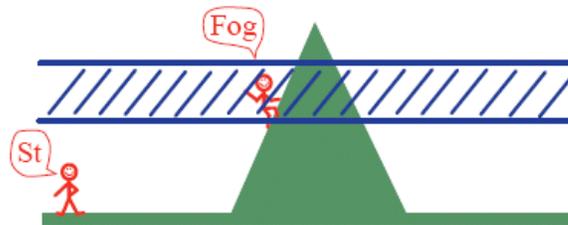
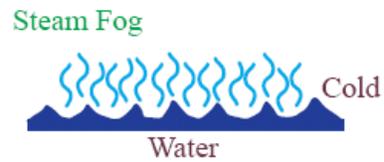
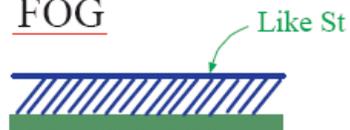
STRATOCUMULUS (Sc)



NIMBOSTRATUS (Ns)



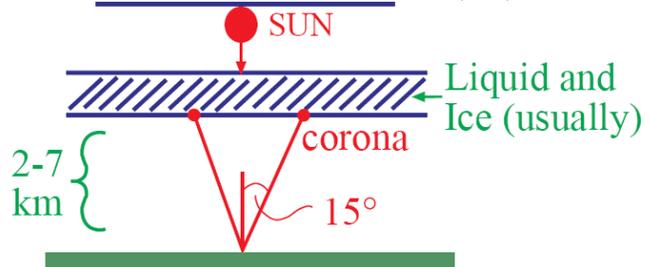
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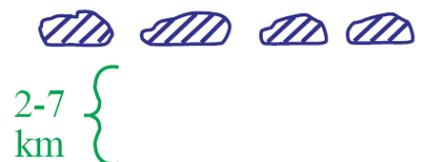
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MIDDLE CLOUDS (bases 2 - 7 km A.G.)

ALTOSTRATUS (As)

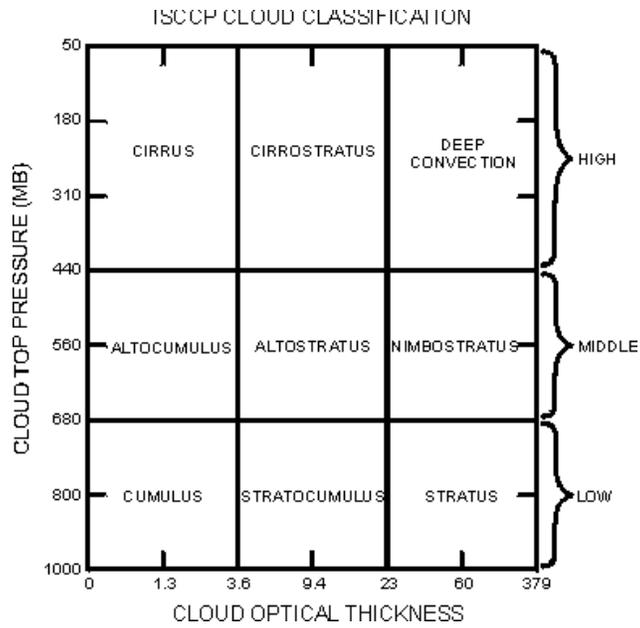


ALTOCUMULUS (Ac)



Cloud classification used in satellite remote sensing

<http://isccp.giss.nasa.gov/>



### **Discussion summary**

Advantages and disadvantages of satellite vs. ground-based observations of clouds for climate studies

Type of observation	Advantages	Disadvantages
Ground-based	<ul style="list-style-type: none"><li>• direct observations</li><li>• history (long records)</li><li>• can often distinguish between cloud types</li><li>• other complimentary measurements</li><li>• cost/automatic/frequent observations</li><li>• provide validation to satellite observations</li></ul>	<ul style="list-style-type: none"><li>• non-uniform coverage</li><li>• human error</li><li>• multi-layer cloud impacts</li></ul>
Satellite	<ul style="list-style-type: none"><li>• global coverage</li><li>• system consistency</li><li>• easier to model (radiative transfer codes)</li><li>• sensitive to vertical structure with potential for vertical resolution</li></ul>	<ul style="list-style-type: none"><li>• short lifetime of an individual satellite</li><li>• difficulty of inter-calibrating instruments on different satellites</li><li>• problems in distinguishing multi-layered clouds, lower clouds and fog</li><li>• high cost</li></ul>