

## Clouds

- Cloud - an aggregate of minute suspended particles of water or ice, or both, that are in sufficient concentrations to be visible
- Characteristics: clouds are *tenuous* and *transitory*, most small clouds in the lower atmosphere exist for only a few minutes
- Cloud particles vs precipitation (hydrometeor) particles
  - Cloud particle size < 10 microns (.000001 m)
  - Hydrometeor size > 1000 microns (.001 m)



## Classifying Clouds

- Classification system is based on what we see above us
- The classification is based somewhat on the *height of cloud base*
  - Consider cloud base heights somewhat flexible
  - An altocumulus might be considered a stratocumulus by observer on nearby mountaintop
- Classification also depends on *composition* (liquid, ice, or both) cirrus are ice clouds, altocumulus are liquid clouds
- *Other considerations:*
  - How much of sky is covered?
  - Does cloud obscure sun's disk?
  - Is disk sharply defined or diffuse?
  - Does cloud display a pattern (elements, billows, rows, undulations)?
  - Is rain or snow falling from it?
  - What is character of precipitation?
  - And more!



## Cloud classification (11 types)

	Cloud Height		
	Low	Middle	High
Stratiform	Stratus (St)	Altostratus (As)	Cirrostratus (Cs)
Cumuliform	Cumulus (Cu)	Alto cumulus (Ac)	Cirrocumulus (Cc)
Mixed	Stratocumulus (Sc)		
Fibrous			Cirrus (Ci)
Cumuliform clouds of great vertical development	— Towering cumulus (Tcu) — Cumulonimbus (Cb)		
Precipitating without lightning	Nimbostratus (Ns)		



## Approximate cloud base heights (middle latitudes)

Cloud Height Category	Cloud Base Height (above ground level)	
Low	below 6,500 ft	below 2,000 m
Middle	6,500 - 23,000 ft	2,000 - 7,000 m
High	above 16,000 ft	above 5,000 m

Note the overlap between middle and high cloud base heights. The boundary between middle and high clouds is higher near the equator and lower in the polar regions

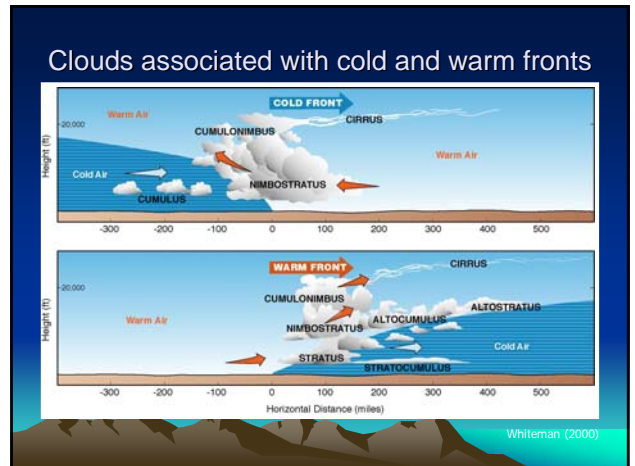




### Cloud classification scheme

Ns, Sc  
 © Ronald L. Holle photos  
 others  
 Whiteman photos

Whiteman (2000)



### Fog - cloud based at the ground

Whiteman photos

Whiteman (2000)

### Types of fogs

- Fogs are clouds based at the ground
- 1 m<sup>3</sup> of fog typically contains 0.1 g of liquid water dispersed over 1-10 million droplets with diameters between 1 and 20 micrometers. They can significantly restrict visibility.
- Types:
  - Upslope fog - moist air is cooled by lifting up terrain slopes
  - Radiation fog - nighttime outgoing longwave radiation cools near-surface air below its dew point temperature
  - Advection fog - warm air flows over cold surface and cools from below until saturation is reached
  - Evaporation-mixing fog - water evaporates and mixes with adjacent air, raising the mixture's dew point temperature. If sufficient moisture is present mixture becomes saturated. [steam fog, breath]
  - Ice fog - composed of small ice crystals. Can form in extremely cold air in areas (esp. valleys) with open sources of water vapor.

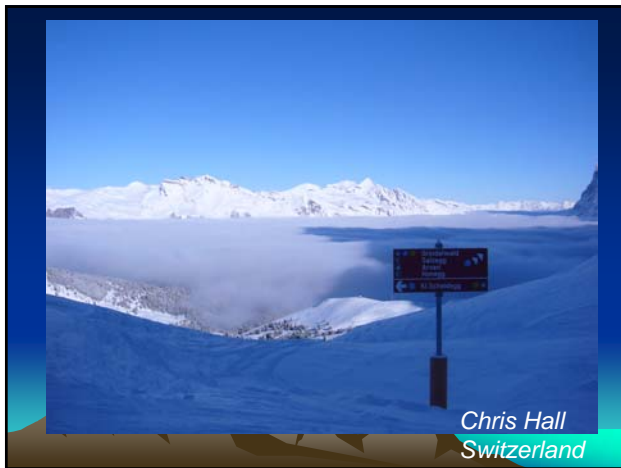


J. Horel

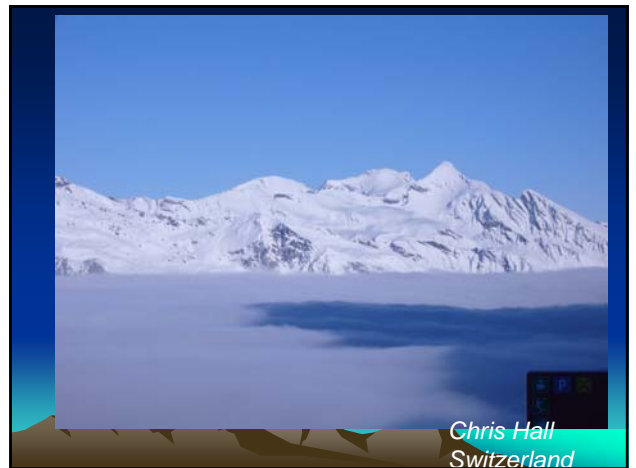
Sawtooth Mtns



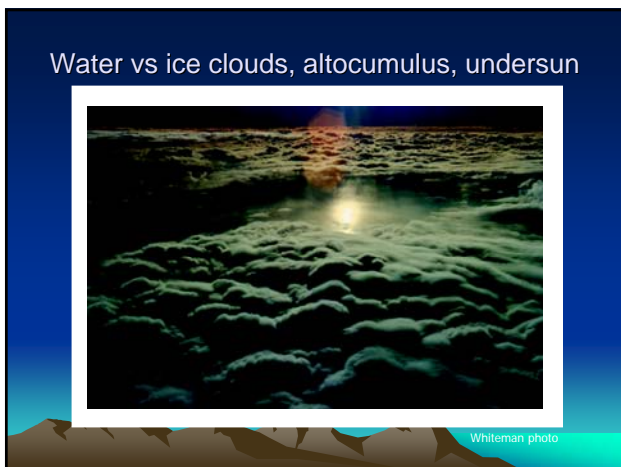
Chris Hall  
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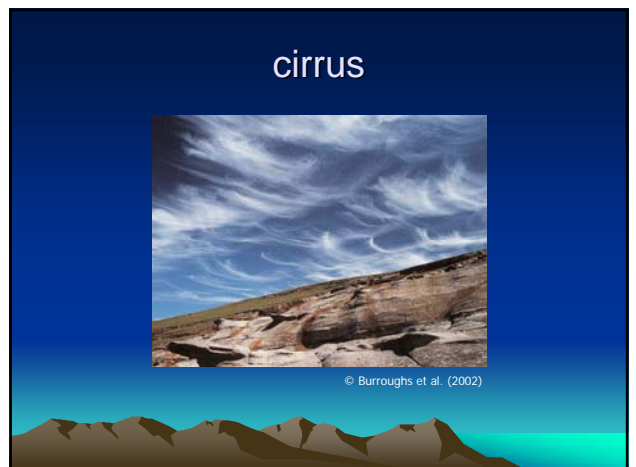
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Switzerland



Chris Hall  
Switzerland



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## cirrostratus



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## cirrocumulus



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Cu elements less than one finger width (otherwise Ac)

## altostratus



© Burroughs et al. (2002)

## altocumulus 1



© Burroughs et al. (2002)

## altocumulus 2



Mackerel sky

© Burroughs et al. (2002)

Cu element larger than 1 finger width

## stratus



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stratocumulus



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cumulus



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cumulonimbus



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cumulonimbus anvil (incus)



© Marc Attinasi

nimbostratus

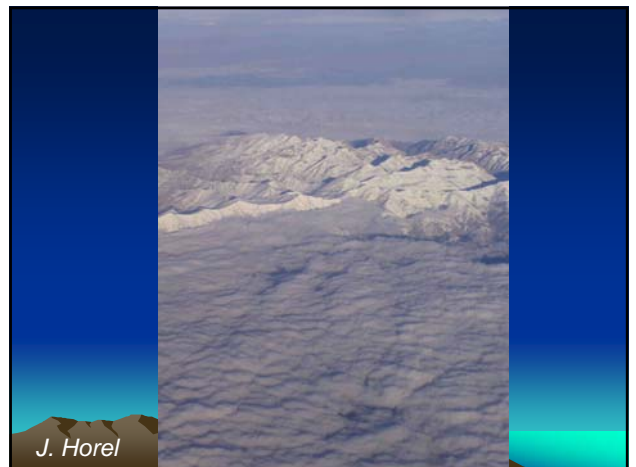
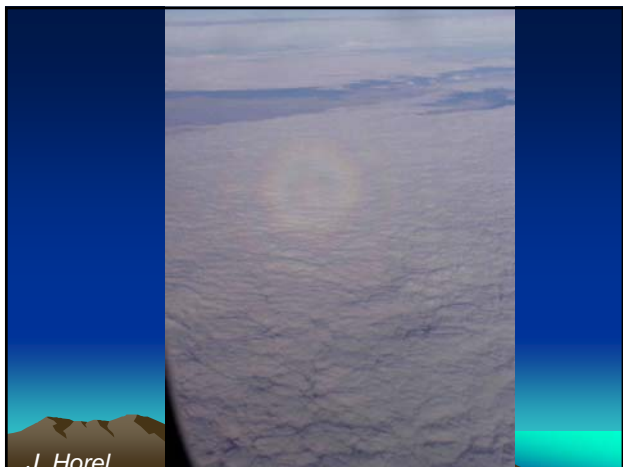
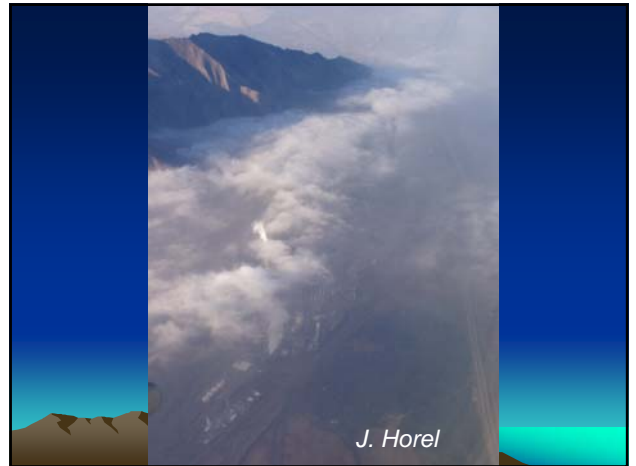
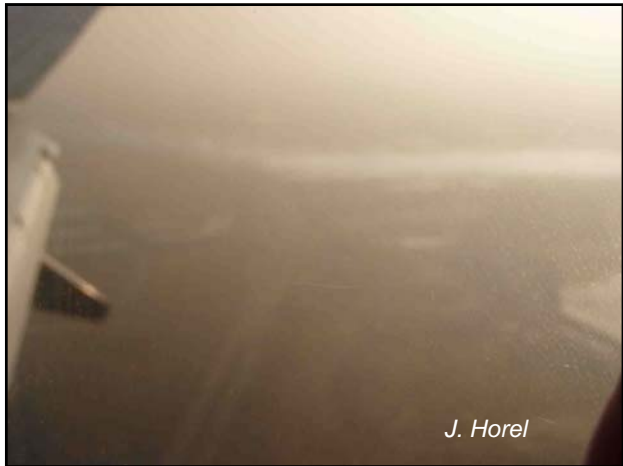
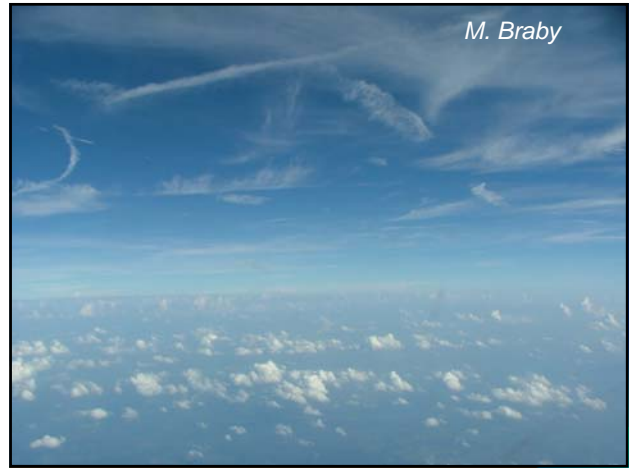


Whiteman photo

M. Braby









### Lenticular clouds

Whiteman (2000)

a, b, g  
© B. Martner photos  
others  
Whiteman photos

Whiteman (2000)

### Lenticulars/Kelvin-Helmholz

Upper left - © Doug Cruikshank, Mt. Hood, OR  
Upper right - © Jeff Grandy, 1986, Inyo Nat'l Forest, CA  
Lower right - © Adventure Guides International, Mt. Rainier, WA  
Lower left - © R. Joseph Dunn, Bear Butte, WY

Kelvin-Helmholz Instability Cloud & Lenticular Cloud above Bearhawk, Bear



## Lenticular with rotor



Whiteman photo

## Billow clouds



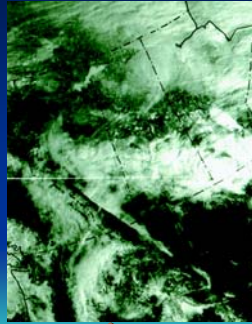
NOAA photo

© B. Martner photo

## Chinook arch



© P. Lester photo



NOAA satellite photo

## More mountain clouds

*Upper left:* Etna smoke ring, July 2000, from the eastern vent of Bocca Nuova  
*Upper right:* © James Michael Baumgardt, Image Counts, Inc., E. Sierra Nevada in July  
*Lower left:* © James Michael Baumgardt, Image Counts, Inc., near Monument Valley  
*Lower right:* © Ronald G. Warfield photo, 1999, Mt. Rainier



## Cap cloud



B. Martner photo

## Chinook wall cloud



Whiteman (2000)

Ronald L. Holle photo

### McKinnon Pass waterfall cloud



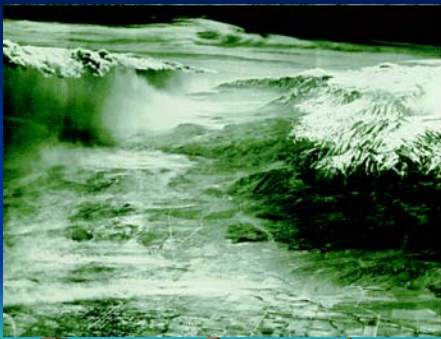
Whiteman photo

### Waterfall cloud, NZ Alps near Mt. Cook



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### Sierra wave



USAF, Robert Symons photo

### Sierra wave photo

View is toward south from 11 km height. Airflow is from right to left. The cloud mass on the right is plunging down the lee slope of the Sierra Nevada; the near-vertical ascending cloud wall of the mountain wave is on the left. The turbulent lower part of the cloud wall is a "rotor"; the smooth upper part is the "lenticular" or "wave cloud". The cloud mass to the right is a "cap cloud" (= Föhn-Mauer); the cloud-free gap (middle) is the "Föhn gap" (= Föhn-Lücke).



Kuettner/  
Kliether 1952

### Matterhorn banner cloud



Whiteman photo

### Handies Peak rotating cloud



Whiteman photo

## Jet stream cirrus



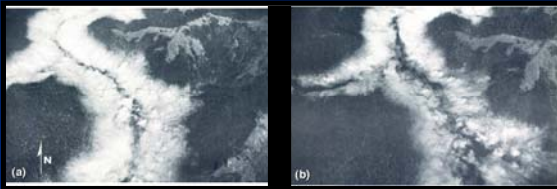
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## Fractocumulus



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## Breakup of valley stratus



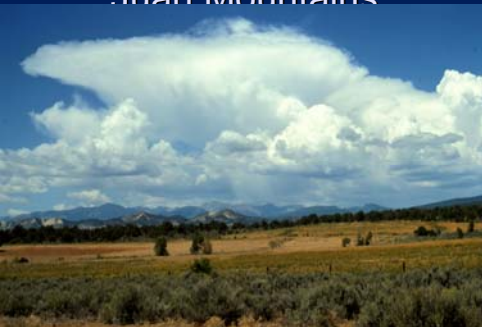
E. Hindman photos

## Prescribed fires in western OR



Oregon Dept of Forestry photo

## Mountain thunderstorm in San Juan Mountains



Whiteman photo

## Graupel shower, rainshaft, and virga



Rocky Mountain National Park, CO  
Graupel shower at 9000 ft MSL



Mesa Verde National Park, CO  
Rainshaft and virga

Whiteman photos

## Frontal passage rain line



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## Alto cumulus and glaciation



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## Sources

- Lecture by C. David Whiteman
- Photographs from Ronald L. Holle, Brooks Martner, Edward Hindman III, and others are copyrighted. The Whiteman photos are also copyrighted by Oxford University Press. Please do not reproduce without permission. Some web URLs are provided in PP notes.
- A fantastic source of cloud photographs:  
Mühr, B., 2000: Der Karlsruher Wolkenatlas, Karlsruhe, Germany, CD ROM and web archive of cloud photographs at [www.uni-karlsruhe.meteor.de](http://www.uni-karlsruhe.meteor.de)