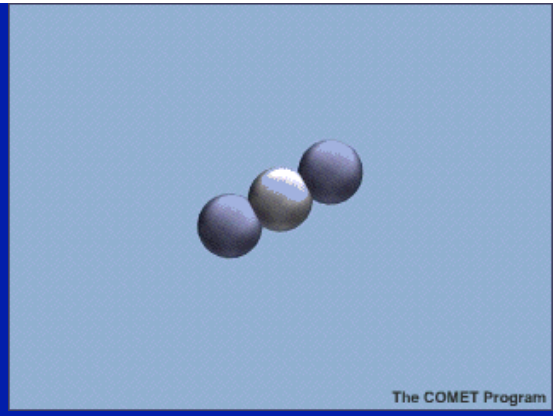


# *Our* Climate: A Global Challenge

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April 9, 2015
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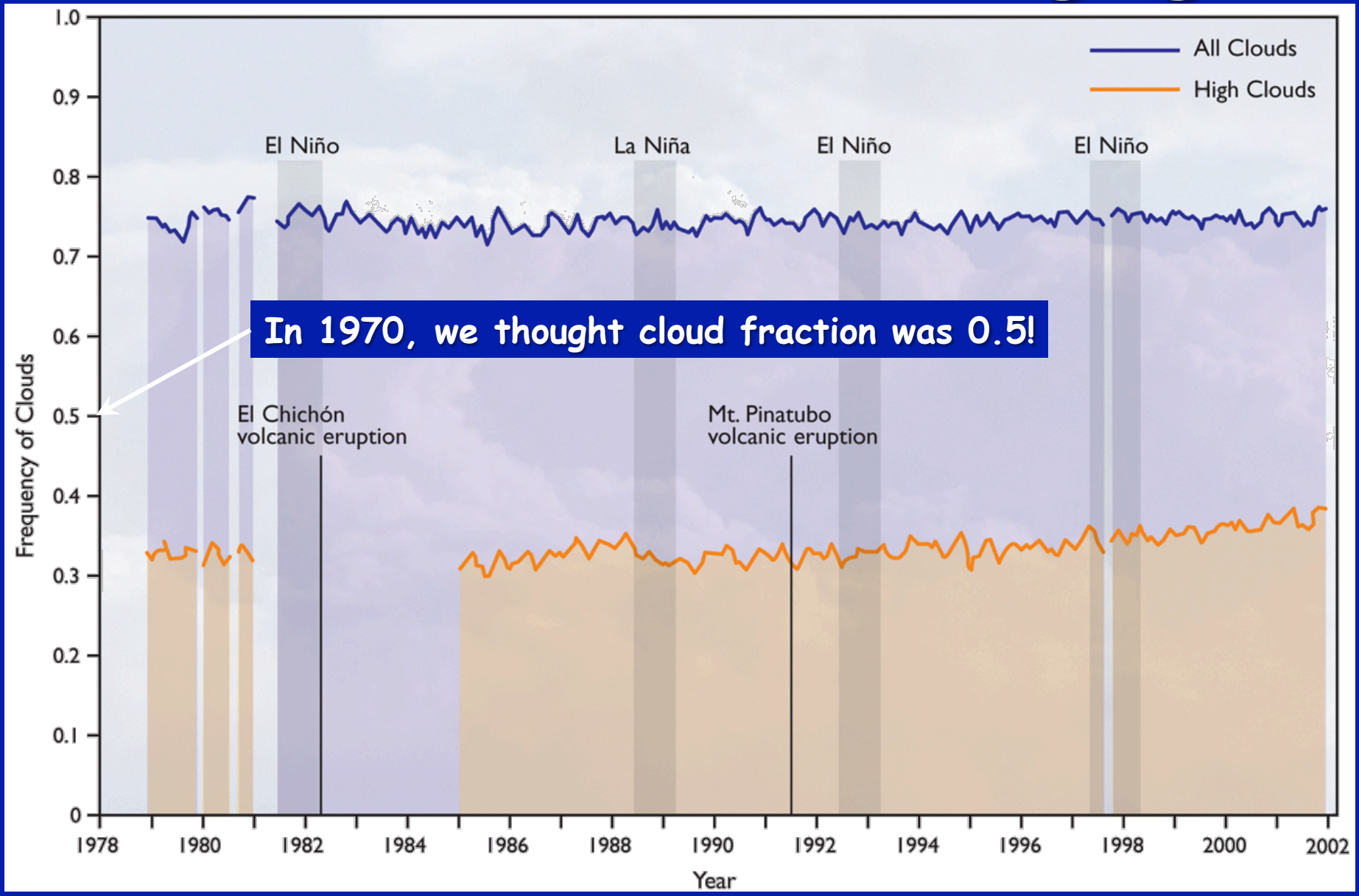
# clouds

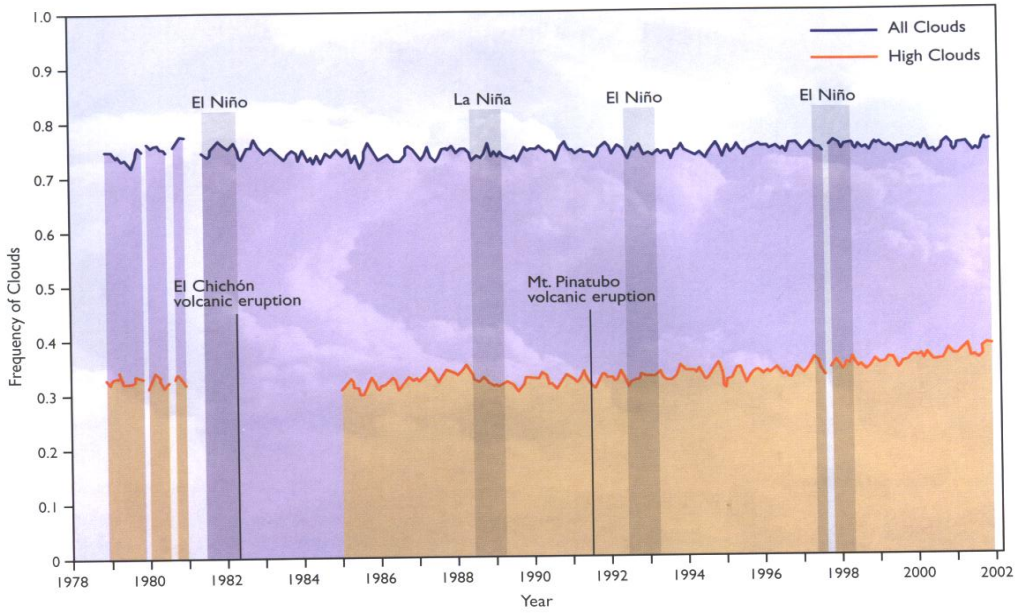
violent storms

# Is cloud amount changing?



# Clouds

- Clouds cover about 70% of the planet.
- Cloud cover has stayed constant in spite of global warming. The feedbacks are not well understood.




- The ocean stores a tremendous amount of thermal energy, and the timescale for its release is much longer than studies to date. The fact that the atmosphere is completely saturated with water vapor is probably important.
- Clouds are the subject of intensive current research using NASA satellites.


stratocumulus
cirrus
Note differences in surface reflectivity
Clouds, too, have different reflective properties.

# Low-level cloud types

cumuliform cloud
(cumulus)

weak reflection
weak greenhouse

stratiform cloud
(stratocumulus)

strong reflection
weak greenhouse

**net effect?**

**cumulus – not clear**

**stratocumulus: some cooling**

# Upper-level cloud types

cirrus clouds
(cirrus)

weak reflection
strong greenhouse

mid level cloud
(altostratus)

intermediate reflection
intermediate greenhouse

**net effect?**

**altostratus – not clear**
**cirrus: some warming**

# Thick cloud types

deep convective clouds
(cumulonimbus)

strong reflection
strong greenhouse

frontal cloud
(nimbostratus)

strong reflection
strong greenhouse

**net effect? not so clear**

# Cloud radiative feedbacks

## Warming
## Positive cloud feedbacks

- decreased low-level cloud cover
- decreased low-level cloud reflectivity
- increased high-level cloud cover
- increased height of high-level cloud cover

## Cooling
## Negative cloud feedbacks

- increased low-level cloud cover
- increased low-level cloud reflectivity
- decreased high-level cloud cover
- decreased height of high-level cloud cover

What is actually happening to clouds? Probably not much. Very difficult to tell.

See: **http://agwobserver.wordpress.com/2009/09/10/papers-on-global-cloud-cover-trends/** for more information.

# Subtle effects

- Ice and water droplets have different reflective and emissive properties
- More condensed water increases clouds reflectivity (a net cooling effect)
- Higher clouds are colder, decreasing their radiative properties ($T^4$), so they cause warming

# One detailed investigation (Joel Norris)

- low-level stratiform cloud cover and reflected incoming radiation have increased over mid-latitude oceans
- low-level stratiform cloud cover and reflected incoming radiation have decreased over eastern sub-tropical oceans
- these cloud changes since 1952 have had a net cooling effect on the Earth

# Conclusions

- clouds have strong and varying radiative impacts on the climate system
- clouds are the largest source of uncertainty in quantifying climate feedbacks and sensitivity
- it is very difficult to simply and accurately parameterize the small scale processes affecting clouds in a global climate model
- anthropogenic aerosol might have a large influence on cloudiness, but the overall impact is unknown
- this is also difficult to parameterize in a global climate model

Credit: Joel Norris