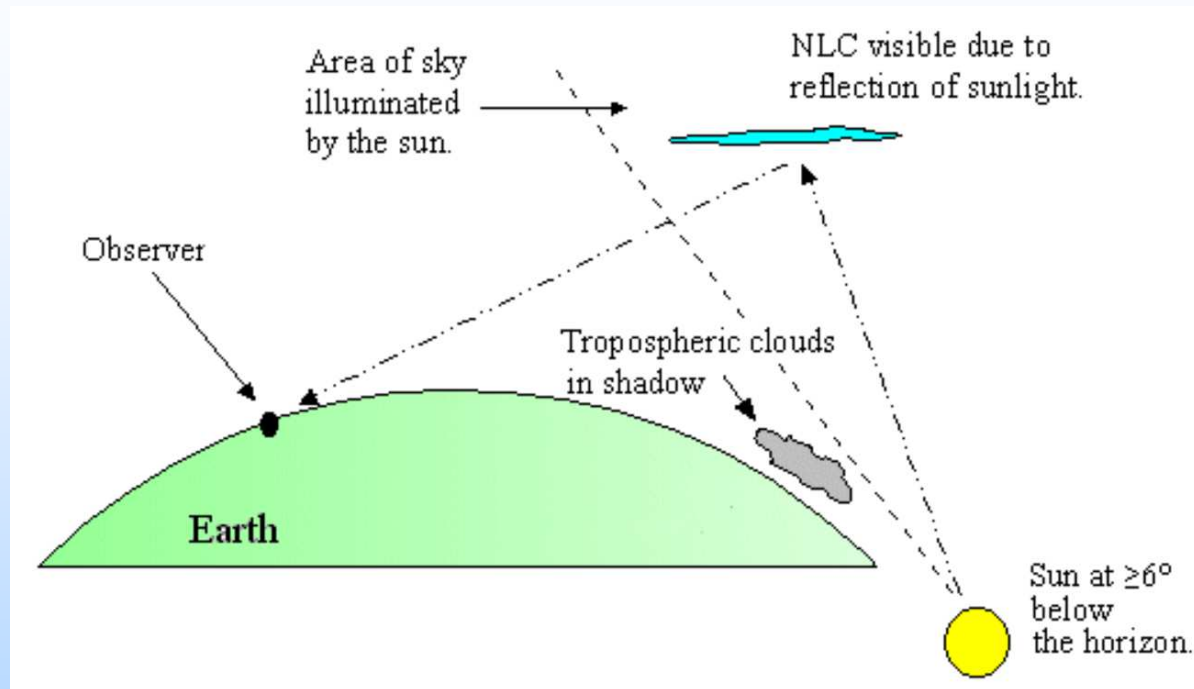


# ---Mesospheric Clouds--- Noctilucent Clouds (NLCs)



# Noctilucent Clouds



The literal meaning of 'noctilucent' is "lit at night" or "night shining". This refers to the fact mentioned above that Noctilucent Clouds (NLCs) are only seen in the deep twilight when, because they are so high, they are still sunlit. The best time to look for NLCs is when the Sun lies between 6 - 16 degrees below the horizon. Look from west to north 60 to 90 mins after sunset, and if you see luminous blue-white tendrils spreading across the sky you've probably spotted a noctilucent cloud. Alternatively, book a trip to the ISS - they've been photographed from there as well!

# Noctilucent Cloud (NLC) Characteristics

- NLCs are the highest altitude clouds in our atmosphere
  - They form near 83 km altitude, almost the edge of space
- NLCs occur pole-ward of 50° degrees latitude, in both hemispheres
- NLCs occur only during summer
- NLCs form at the coldest place on earth (130 K):
  - The mesopause in polar summer
- NLCs are composed of water ice crystals
  - 50 nanometers in radius
  - (the radius of human hair is 500 times larger)

Noctilucent means “night shining”

NLCs are also known as “polar mesospheric clouds” (PMCs)

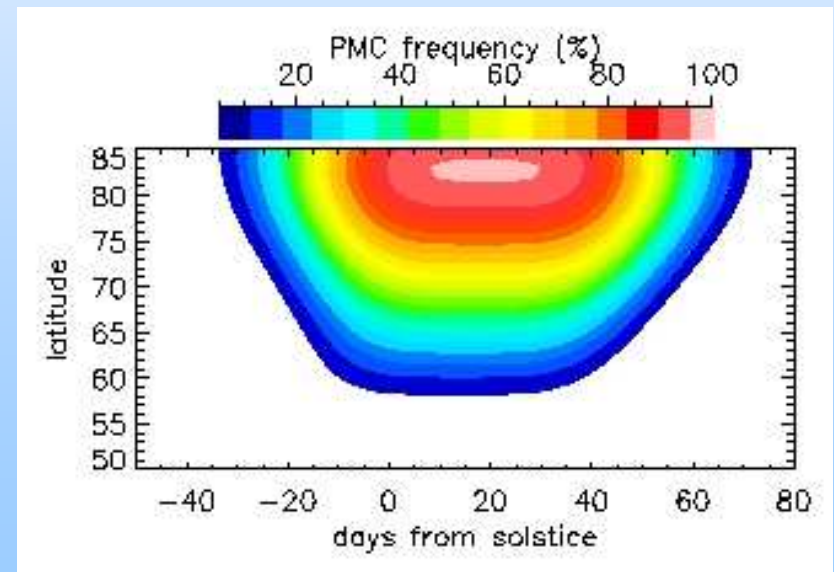
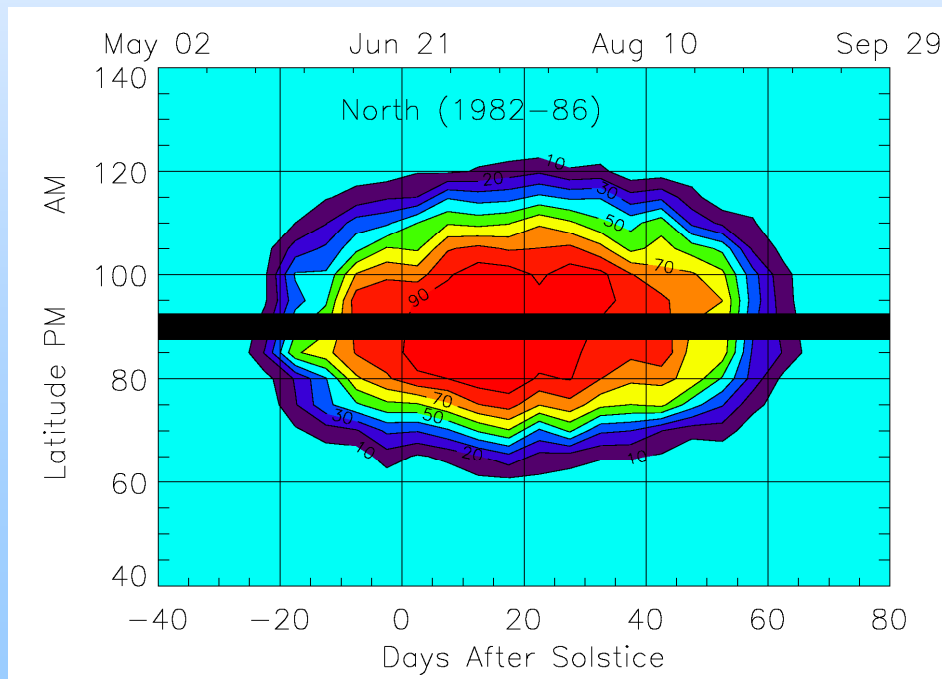


# Noctilucent Cloud (NLC) Characteristics

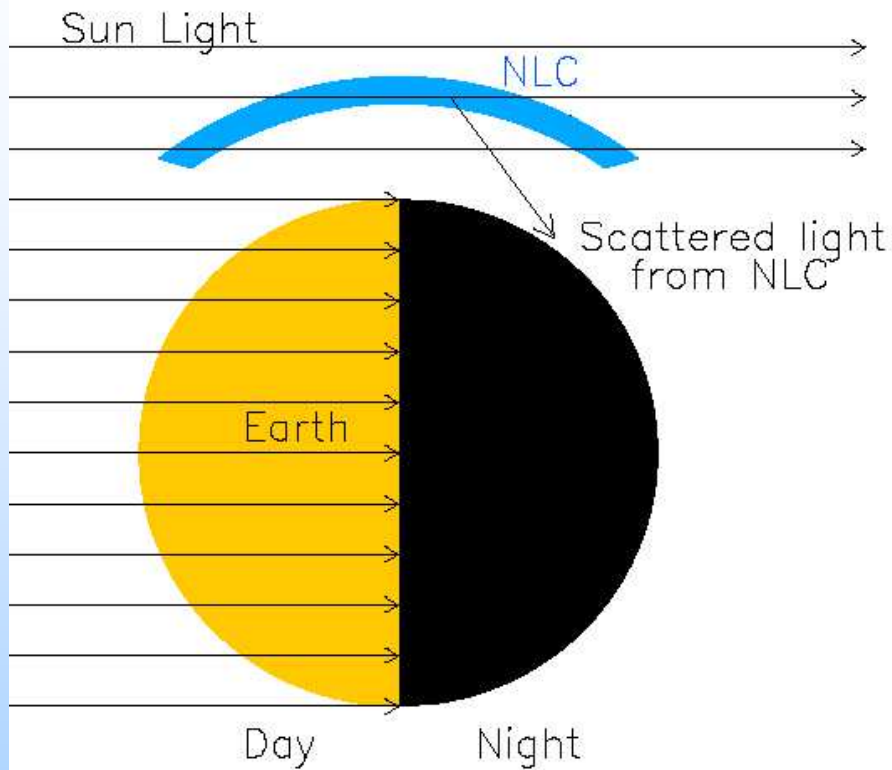
PMCs usually occur in the polar regions during a 12 week period centered about two weeks after solstice

Each year, NLC incidence tends to peak just prior to and for a few weeks after the summer solstice - from mid-May to mid-August for northern hemisphere observers.

PMC climatology based on Solar Mesosphere Explorer (SME) measurements



# NLCs are visible from the ground



Shortly after sunset, the observer is in darkness, but the NLC is still in sun light

NLC over Finland, photo by Pekka Parviainen



# NLC Structure

PMCs display complicated structure driven by atmospheric motion



**Billows**

**Bands**

# NLC Formation

- Global circulations cause rising air in the polar summer mesosphere
- This rising air results in cooling of the mesosphere during summer

- Temperatures reach the frost point near the mesopause (88 km)

Frost point temperatures near the mesopause are very low, 150 K (-123° C)

This is because of the low atmospheric pressure (0.06 mb) and low water vapor mixing ratios (5 ppmv)

- Ice particles form near 87 km
- These ice particles fall and accumulate near 83 km to form NLCs



# NLC Measurements

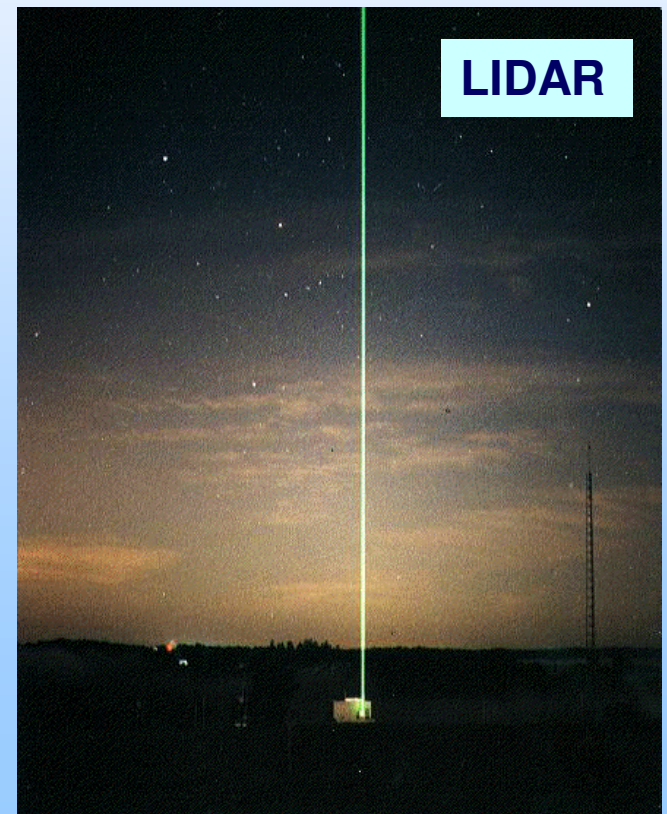
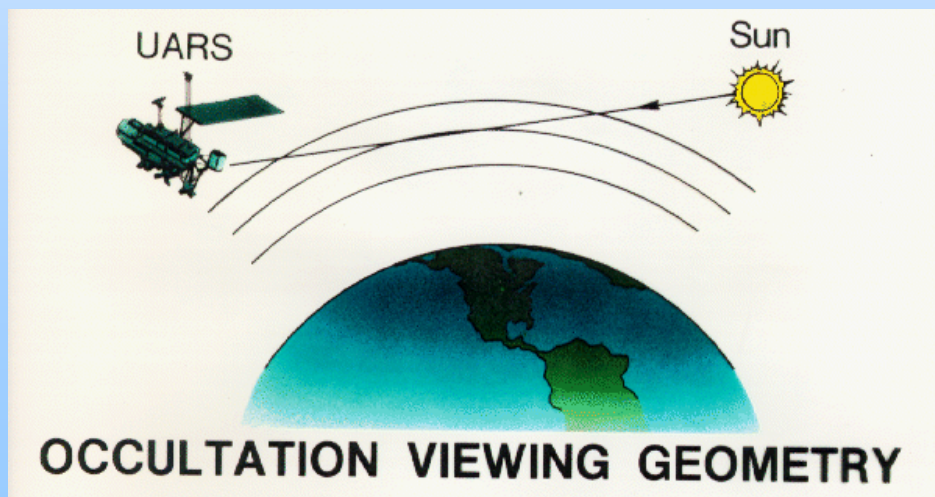
**In Situ Measurements** (instrument in contact with the subject)

- Rockets

(Balloons and Airplanes can't fly high enough)

**Remote Measurements** (instrument is far from the subject)

- Ground observers: visual, cameras
- LIDAR (light detection and ranging)
- RADAR (radio detection and ranging)
- Satellites: mapping, solar occultation

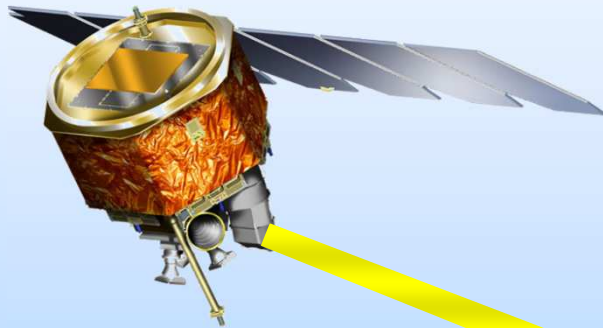




# NLC measurements from satellite

Two examples of satellite measurements: Solar Occultation and Nadir imaging

**Solar occultation measures the light that passes through NLCs along the limb of the Earth's atmosphere (tangent to the earth's surface).**



**Nadir imaging instruments can take pictures of NLCs by looking down from space.**



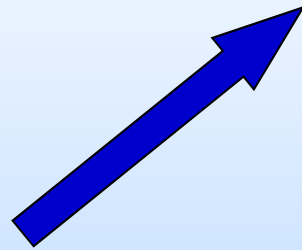
# Space Station PMC Photograph

*Donald Pettit, Space Station Science Officer*

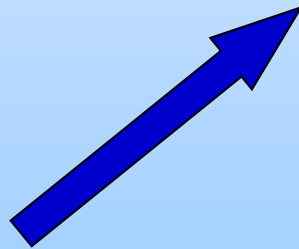


# Why do we study PMCs: These clouds are changing

**Increasing numbers are occurring**



**NLCs are moving equatorward**

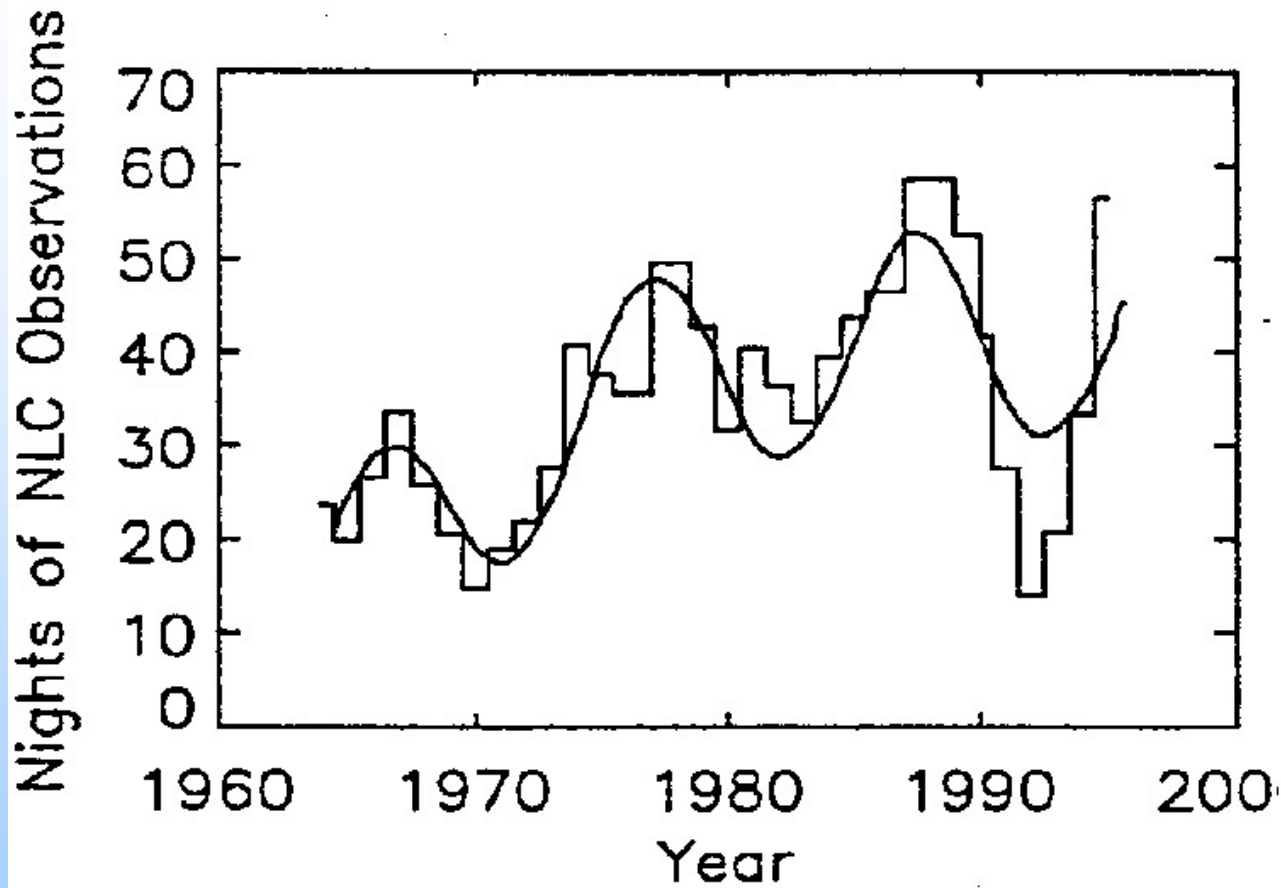


**Brighter clouds are being observed**

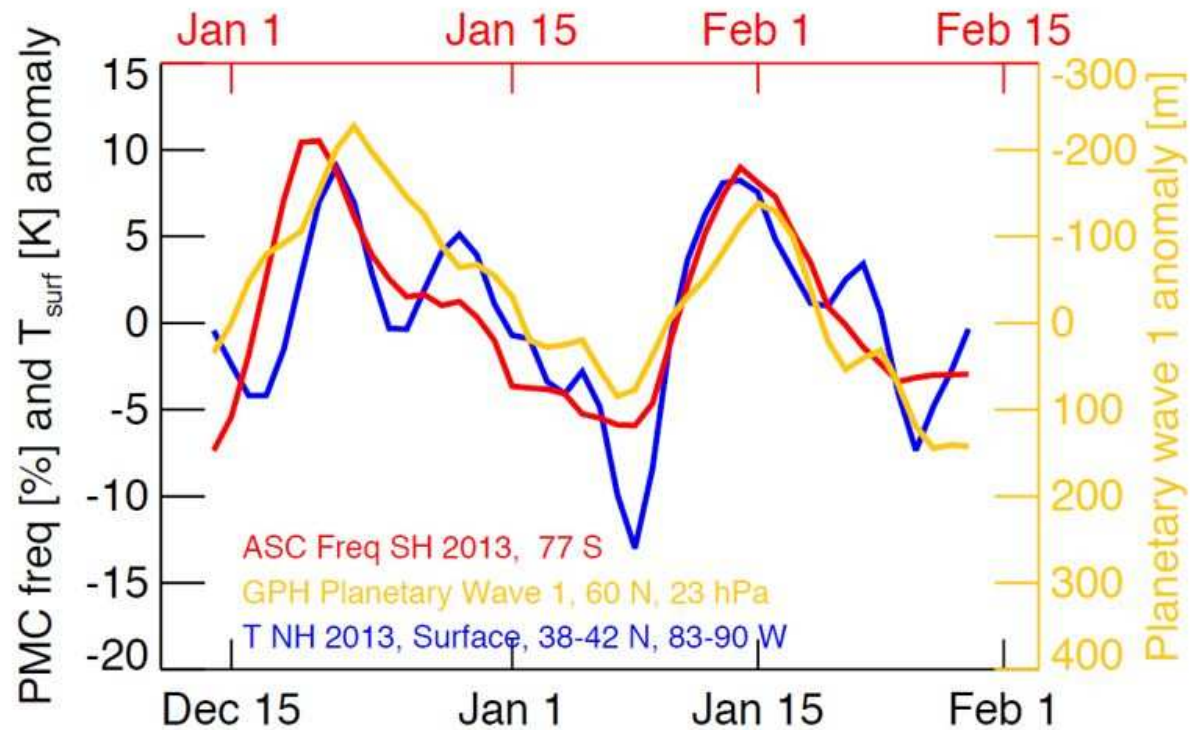
## WHY ?

RELATION TO  
CLIMATE CHANGE !!!

# NLC Occurrence Versus Time



NLCs occur nearly twice as often as they did 35 year ago.  
Note on the cyclic variation on the order of 10-11 years !!...

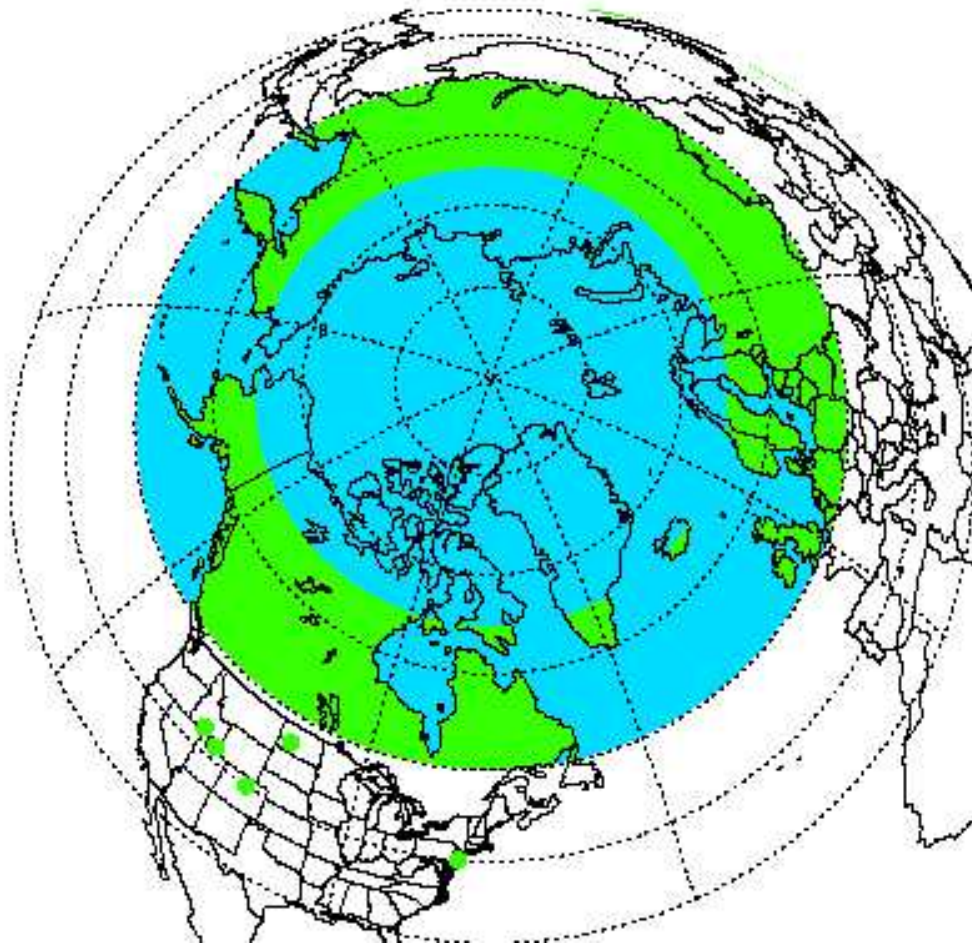


**Figure:** Changes in surface temperatures near Indianapolis, IN (blue, left and bottom scales) are well correlated with changes in the Arctic stratosphere (orange, right and bottom scales) and with changes in noctilucent clouds (PMCs) at 77°S latitude two weeks later (red, left and top scales).

# NLC are moving towards the equator

NLCs are occurring over 700 miles farther south than ever before

Blue & green: region where NLCs typically occur  
Green: land areas where NLCs are typically observed  
Green dots: US towns where NLCs were recently observed

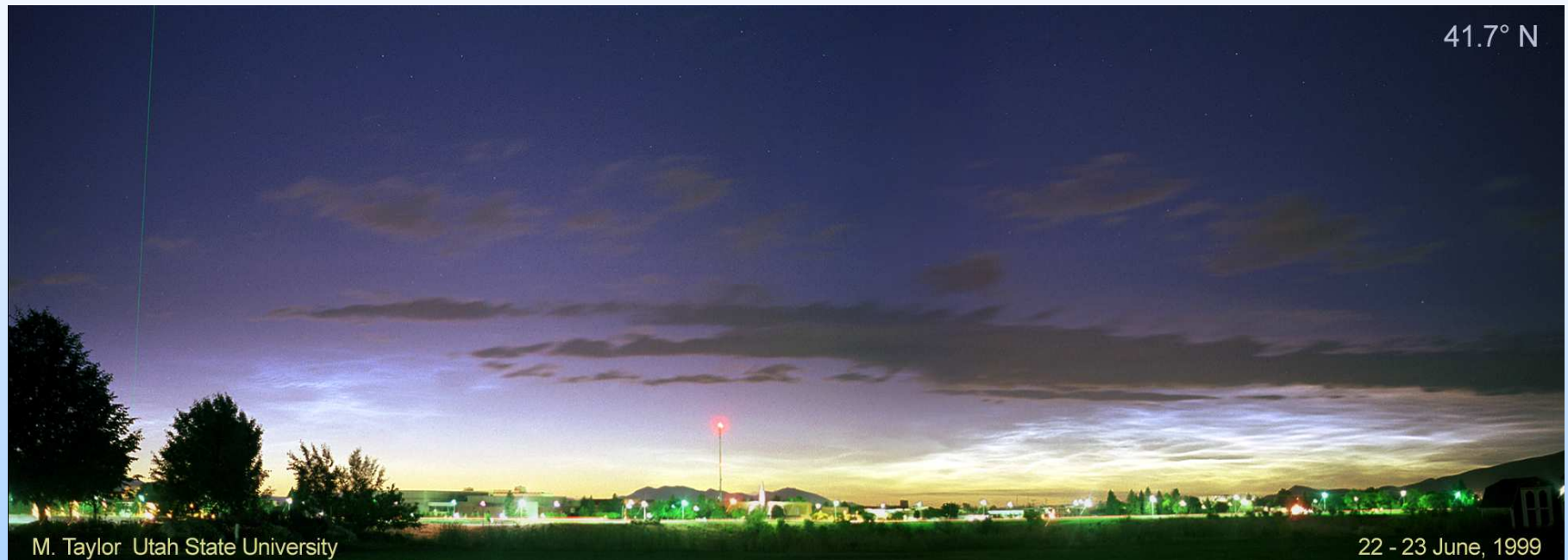


US Towns where NLCs were recently sighted:

Twin Falls, Idaho  
Logan, Utah  
Boulder, Colorado  
Glen Ullin, North Dakota  
McGuire, New Jersey



**A spectacular but unexpected event:  
NLCs were observed over Logan, Utah on June 22, 1999**



**A PMC is observed and photographed at 40° latitude for the first time!  
By Aim Co-Investigator Dr. Michael Taylor**

# What is causing the changes in NLCs?



NLC over Finland, photo by Pekka Parviainen

# A connection between NLCs and global climate change

- NLCs respond to atmospheric temperature and humidity  
Temperature is affected by carbon dioxide (CO<sub>2</sub>)  
Humidity is affected by methane (CH<sub>4</sub>):
- CO<sub>2</sub> and CH<sub>4</sub> are increasing due to human activities
- Increasing CO<sub>2</sub>:  
warms the troposphere, “greenhouse effect”  
cools the mesosphere, where NLCs occur
- Increasing CH<sub>4</sub>:  
CH<sub>4</sub> oxidizes with OH in the stratosphere to become water:  
 $\text{CH}_4 + \text{OH} > \text{CH}_3 + \text{H}_2\text{O}$
- NLCs are therefore a visible indication of climate change

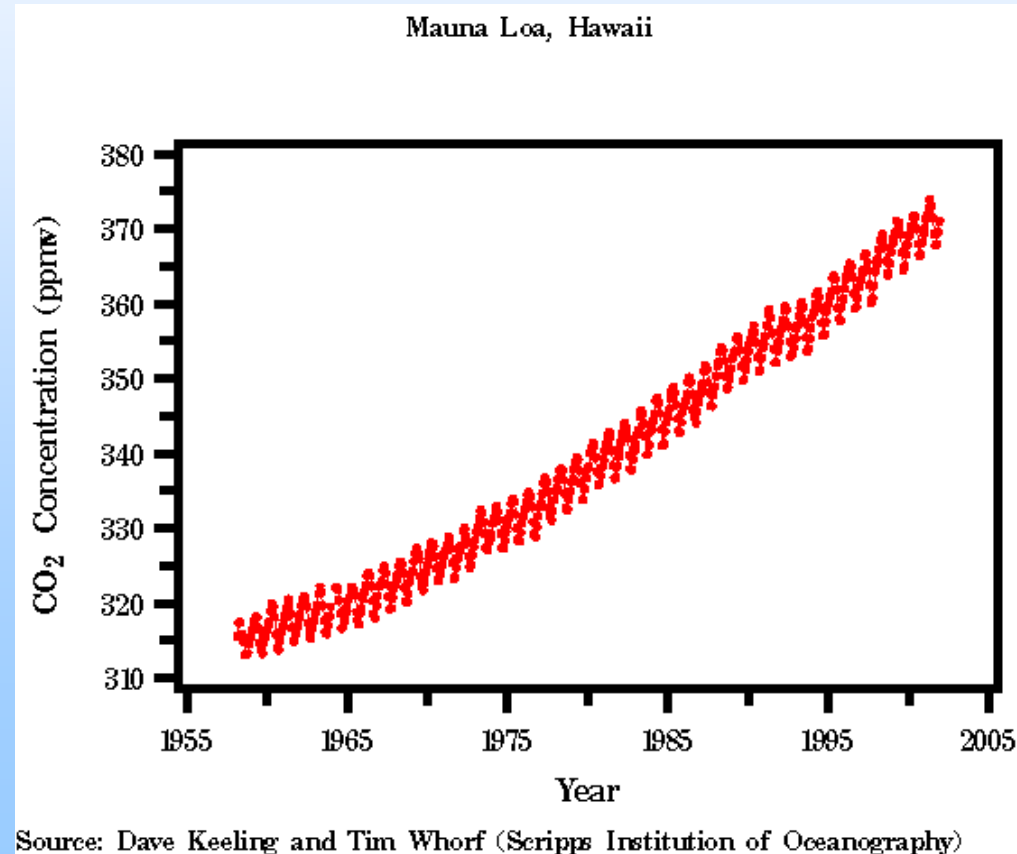


“The miners canary”  
of climate change

# Increasing CO<sub>2</sub> in the Atmosphere

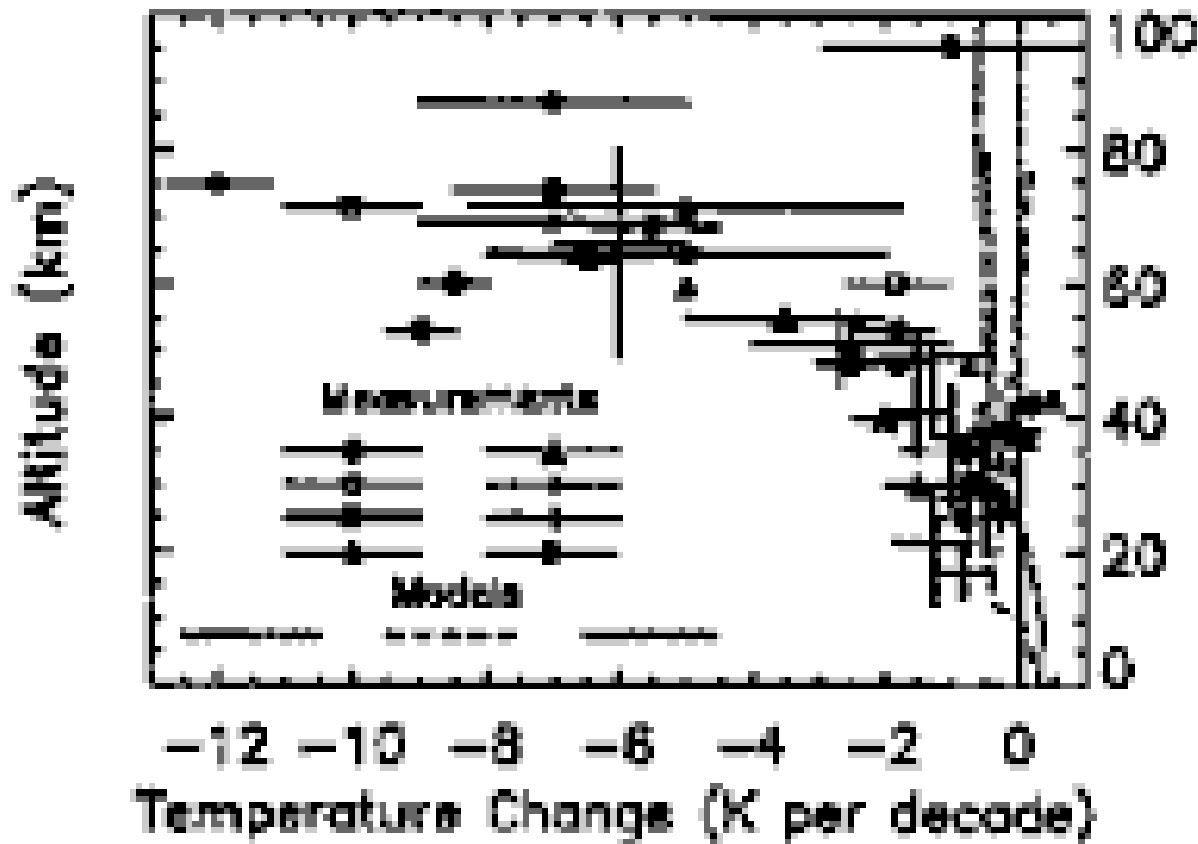
The increase in CO<sub>2</sub> is due to human activities

Increasing CO<sub>2</sub> cools the upper atmosphere



# Temperature in the Mesosphere is decreasing

Temperatures near 80 km have cooled by almost 5 K every 10 years, since measurements were started in the 1950's

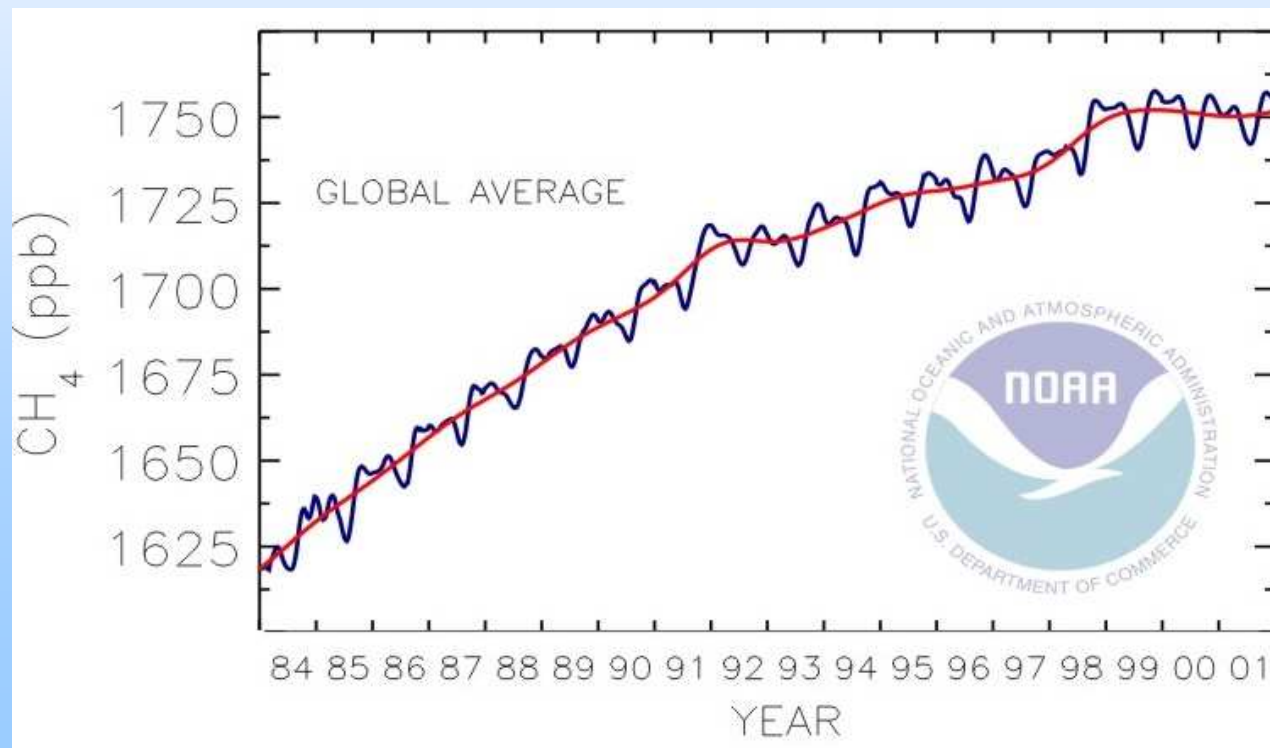
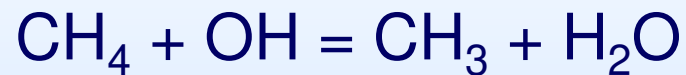


This cooling is related to the increase in CO<sub>2</sub>

# Increasing methane (CH<sub>4</sub>)

The CH<sub>4</sub> increase is due to human activities

CH<sub>4</sub> oxidizes with OH in the stratosphere to become water:

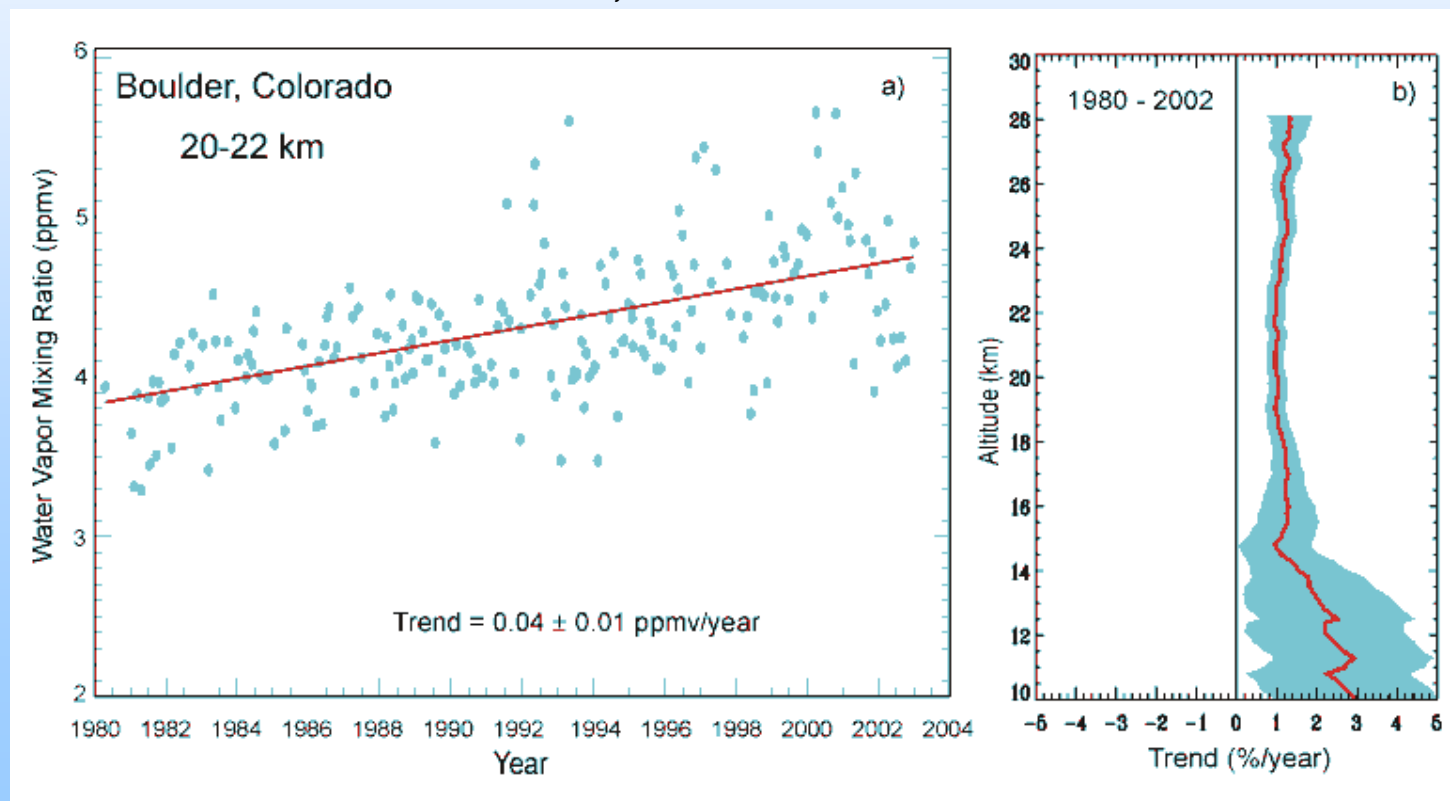




# The upper atmosphere is becoming more humid

Approximately 30% of the water vapor increase can be accounted for by the anthropogenic increase in CH<sub>4</sub>

Balloon-borne frost point hygrometer measurements from Boulder, Colorado



# Climate Change and NLCs

- NLCs require water vapor and cold temperatures
- Therefore, increasing water vapor and cooling of the mesopause should lead to more NLCs
- The increase in humidity and decrease in temperature is consistent with increases in methane and carbon dioxide
- Thus, it appears that NLCs are another indication of climate change

# Observations of NLC by The Teton High School NLC Cameras

A joint project by NASA, GATS, and Teton High School

2 NLC cameras placed in Teton High School:

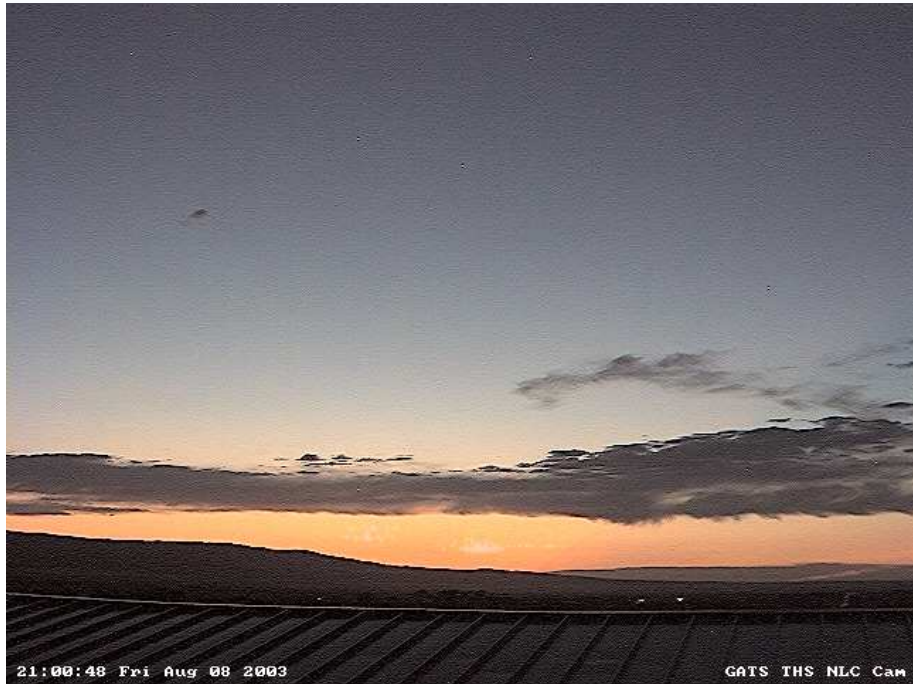
Driggs, Idaho

Fairbanks, Alaska

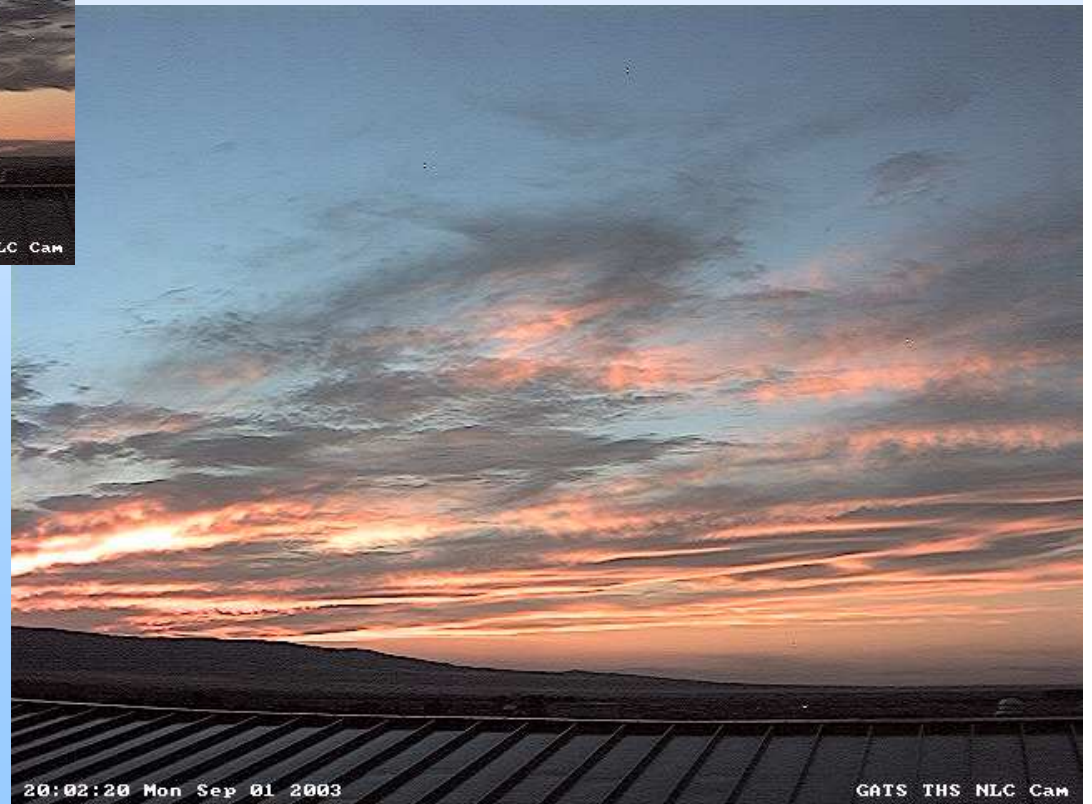
These cameras take pictures during every sunset to look for NLCs

They send the images to us automatically over the internet

# Pictures from the Driggs Cam



Any NLC in Driggs are not observed last summer



# Pictures from the Fairbanks Cam

**At least one NLC was observed with the Fairbanks NLC-Cam!**



The end