LESSON 4:

# CLIMATE CHANGE IN MOUNTAINS


## Driving Question:

What is the nature of climate change in high-elevation regions?

## Sub-questions:

- What are climate feedback loops?
- How are climate change trends different in the San Juans compared to the rest of the planet?
- How is climate change affecting high-elevation species?
- Why are glaciers retreating so quickly?
- How does dust-on-snow impact snowmelt patterns?

## Goal:

Students will be able to identify how high-elevation regions such as the San Juan Mountains are changing in the face of climate change, and connect ecological and economic impacts as discussed in previous lessons.

## Grade Level:

9th Grade

Lesson time: 1.5 hours

## Climate literacy principle addressed:

- Principle 4 - Climate varies over space and time through both natural and man-made processes.
- Principle 7 - Climate change will have consequences for the Earth system and human lives.

## Learning Objectives:

- Students will discover different physical processes that could be important in driving significant climate changes in high elevation regions.
- Students will learn why mountain regions could be more susceptible to climate change.
- Students will learn the concepts of feedback loops.

## Colorado State Standards & 9R Dashboards for Earth Systems Science - High School:

- Earth Sciences Standard #4: Climate is the result of energy fluxes and moisture transport among the atmosphere, hydrosphere, geosphere, and biosphere
- HSS 4b: Analyze and interpret data on Earth's climate
- HSS 4c: Explain how a combination of factors such as earth's tilt, seasons, geophysical location, proximity to oceans, landmass locations, latitude and elevation determine a location's climate.

## Prior Knowledge Required:

- Students must have knowledge of greenhouse effect. They should also understand the climate at a location is affected by the fluxes of energy and moisture.

## Common student misconceptions and prior understandings:

- Global climate change means that all places on earth are warming and all at the same rate.

## Lesson 4 Materials and Handouts:

- Homework: TBD
- Glacial Calving video: http://www.youtube.com/watch?feature=player_embedded&v=hC3VTgIPoGU
- BINGO game attachment
- Post-assessment questions

## Background Information:

- Report on Mountains and Climate Change from the Centre for Development and Environment, Institute of Geography, University of Bern: http://www.cde.unibe.ch/userfiles/Fullversion_low_Mountains_and_Climate_Change.pdf
- Study of San Juan mountain temperatures: Rangwala and Miller. *Twentieth Century Temperature Trends in Colorado's San Juan Mountains*
- Dust on snow: National Snow and Ice data Center, University of Colorado; University of Utah, and Center for Snow and Avalanche Studies. http://wwa.colorado.edu/climate/iwcs/archive/IWCS_2008_July_feature.pdf
- Dust on snow, High Country News. http://www.hcn.org/issues/323/16326/article_view?b_start:int=1
- Dust on snow NASA: http://www.jpl.nasa.gov/news/news.php?release=2010-306
- Sea Ice and glacial loss background: http://environment.nationalgeographic.com/environment/global-warming/big-thaw/#page=2
- Climate Change Assessment for San Juan Mountains from the Mountain Studies Institute and U.S. Forest Service report to be found at: http://www.mountainstudies.org/index.php?q=content/san-juan-climate-initiative

## Lesson 4 (1.5 hours)

1. Importance of mountain regions: Brainstorm (5-10 min.)
    - "Water Towers": Mountains provide freshwater to half the world's population
    - Home to many biodiversity hotspots
    - Recreation

2. Why are mountains ecosystems more susceptible to climate changes? Have students brainstorm and have a conversation on different physical processes that could make mountains more vulnerable to global climate change. Some following topics to discuss: (15 mins.)
    - Changes in snowpack and snow cover because of early snowmelt from higher temperatures, and precipitation falling more as rain than snow because of the upward shift in the snowline. For every increase in 1 degree Celsius the snowline will decrease in elevation almost 500 feet. Earlier snowmelt patterns are predicted that could have a significant effect on mountain ecosystems as well as on streamflow within mountains and in downstream regions.
        - Reduce snow cover could further lead to additional warming because of the snow albedo feedback loop
        - Earlier snowmelt and higher evaporation because of higher temperatures could lead to drier soils later in the season as could cause further warming (**soil moisture feedback loop**). These could create more likelihood for drought conditions in late spring and summer, including conditions favorable for wildfires.

3. During winter, high elevation regions are more sensitive to increases in atmospheric water vapor (humidity), which produces a strong greenhouse effect in these regions. Atmospheric humidity has been increasing in recent decades and is expected to further increase as earth's atmosphere warms in future (**water vapor feedback loop**).

4. Mountain feedbacks: show and discuss PowerPoint (20 min.)

5. Dust on snow: Quick lecture and PowerPoint on Dust on snow with attached background materials and then complete a BINGO game using attached game board and instructions. (25 min.)

6. Climate Change in the San Juan Mountains:
    - Temperature trends in the 20th century: cool period between 1910 and 1930, warming between 1935-1955, cooling between 1955-1975, and rapid warming of about 1 degree Celsius 1995-2005. Overall-an increase of a little over 1 degree Celsius has been seen.[1]
    - The rate of change in temperature is what is completely abnormal in this data in that almost all the warming occurred between 1990 and 2005
    - Temperatures are expected to further increase by 2-4 degrees Celsius with largest warming predicted in summer[2].

7. Glacial depletion: watch video of largest glacial calving ever filmed: (10 min.) http://www.youtube.com/watch?feature=player_embedded&v=hC3VTgIPoGU
    - It is important to note that this is not in a mountain system, but a similar phenomenon is happening to smaller mountain glaciers.

8. Ending assessment (15 min.)

[1] Rangwala and Miller. *Twentieth Century Temperature Trends in Colorado's San Juan Mountains. Arctic, Antarctic, and Alpine Research, Vol. 42, No. 1, 2010, pp. 89-97.*

[2] Rangwala I., J. Barsugli, K. Cozzetto, J. Neff and J. Prairie, (2012). Mid-21st Century Projections in Temperature Extremes in the Southern Colorado Rocky Mountains from Regional Climate Models. Climate Dynamics. Volume 39, Issue 7-8, pp 1823-1840