2023SP **Roanoke College, Salem, VA**

INQ - 251 - A: Natural Hazards & Catastrophes (T, TH: 10:10 – 11:40 AM 362 Trexler)

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"The Earth is a very dynamic place. Sometimes conditions change across its diverse landscape, leading to situations where natural hazards can become disasters that threaten society."

Source: United States Geological Survey (USGS)

Background

Catastrophic consequences from the occurrence of natural hazards can be localized or far-ranging. In the United States, flood-related fatalities have been predominant for decades with only a few annual exceptions. However, heat related deaths have assumed the top spot in recent times. Human casualties aside, many other deleterious effects can occur from the collision of natural forces with the built environment such as, destruction of property, economic loss, damage to buildings, vehicles, infrastructure, population displacement, loss of crops and livestock, disruption of economic activity, explosions, increased exposure to pollution and environmental toxins.

Globalization of the economy requires international scrutiny of development and construction practices for sustainability. Increasingly, post disaster recovery and reconstruction must also be sustainable and subject to increasing regulations pertaining to emission reduction goals for greenhouse gases. Any examination in the aftermath of catastrophes must address not only the phenomena itself, but also the performance of the built environment in its ability to mitigate damage and loss of life, the vulnerability of physical assets and their resiliency.

Course description

Roanoke College draws most of its students from the Middle Atlantic states. The mid - Atlantic region is a bull's eye for excessive rainfall events, whether from targeting by remnants of tropical systems or summertime convective complexes, as flows of Gulf and Atlantic air masses provide copious amounts of atmospheric moisture. Moreover, the topography of Appalachia and the Piedmont contributes to enhanced precipitation from orographic lifting of air masses, and the ability of terrain to concentrate storm runoff quickly contributes to flash flood potential.

Middle Atlantic states

Students will be introduced to sources of data from extreme hazard events and how information from the past may be used in prediction, specifically to parameterize (computer) models. Historical evidence and documentation of flood events are available online, in libraries, county historical societies, and from government offices in a variety of formats (print, digital, microfilm, etc.) including, but not limited to, recorded observations (sensor data, watermarks, etc.), eyewitness accounts, photographs, studies, and reports.

This course will identify multiple natural phenomena that pose hazards to life and the built environment. The instructor will present basic probabilistic and statistical data analysis concepts to ascertain risk with methods to estimate vulnerability and resiliency measures for lifelines and infrastructure, and to parameterize various components that comprise a risk assessment matrix.

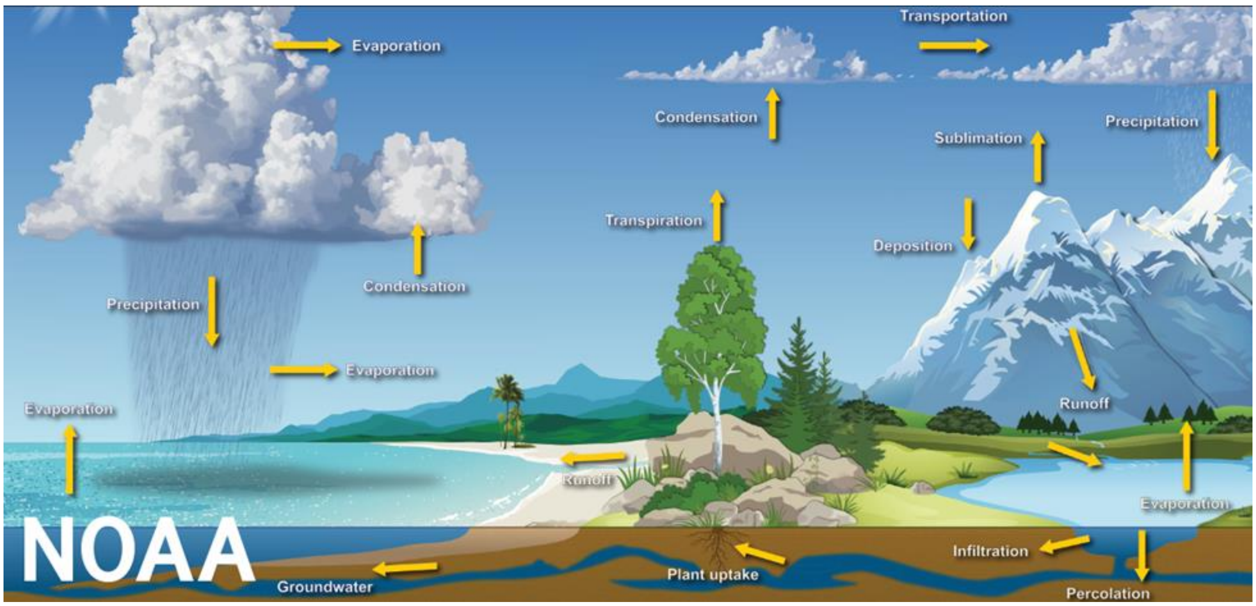
Students will be assigned an event (flood, drought, etc.) on which to prepare a brief and oral presentation. For each case study, participants will estimate an event's probability of occurrence, if possible, cite any infrastructure deficiencies and vulnerabilities that were contributory factors to loss of life and damages; suggest improvements to the response by societal (e.g., Red Cross) and governmental agencies (e.g., FEMA), and recommend resiliency measures. Students, through their discovery and use of critical thinking will provide input/suggestions as to how tragic consequences could have been averted or, at the very least, damages/loss of life mitigated.

Background information on natural hazards and their forcing mechanisms (physical processes) and the roles various governmental agencies have in warning and protecting life and property are provided below; however, this information is not intended to be all-inclusive.

Hydrologic cycle

The water or hydrologic cycle is the continuous movement of water in its various phases in the earth and atmosphere.

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change; IPCC has issued a series of (assessment) reports and attributes **intensification of the hydrologic cycle** (more extreme events such as flood and drought) to anthropogenically-caused climate change and hence is pushing its greenhouse gas (GHG) agenda to mitigate climate forcing, i.e., for the scenarios assessed, limit warming to around 1.5°C by requiring global greenhouse gas (GHG) emissions to peak before 2025 at the latest, and be reduced by 43% by 2030; at the same time, methane would also need to be reduced by about a third.



The hydrologic cycle

Snow

As part of the USDA Natural Resources Conservation Service, the National Water and Climate Center supports the Snow Survey and Water Supply Forecasting Program and Soil Climate Analysis Network (SCAN) Pilot Program for the U.S.

In 1935, the Natural Resources Conservation Service established a formal, cooperative Snow Survey and Water Supply Forecasting (SSWSF) Program to conduct snow surveys and develop accurate and reliable water supply forecasts <u>for the western U.S.</u> As most of the water in the West comes from the melting of winter snowpack, data on snow provide information critical to water managers, agriculture, dam operations, recreationists, and business.

In the early days of the SSWSF Program, snow surveyors on skis or snowshoes manually measured snowpack along a series of remote, high-elevation snow courses. The invention of over-snow machines, such as snowmobiles, made travel to snow courses less challenging. Later, aerial markers were introduced, allowing for snow measurement using airplane flyovers. The Program currently measures more than 1,300 snow courses and aerial markers.

In 1977, the automated Snow Telemetry (SNOTEL) system was introduced. SNOTEL sites are designed to operate continuously and unattended for up to one year. Since its inception, the network has grown to include over 800 automated SNOTEL and 50 semi-automated SNOLITE data collection sites across the West.

In addition to the data collected through the automated and manual collection processes, the SSWSF Program also incorporates precipitation, streamflow, and reservoir data from the U.S. Army Corps of Engineers (USACE), the U.S. Bureau of Reclamation (BOR), the Applied Climate Information System (ACIS), the U.S. Geological Survey (USGS), various water districts and other entities.

All the data collected are quality-controlled and placed in a comprehensive database known as the Water and Climate Information System (WCIS). Source: https://www.nrcs.usda.gov/wps/portal/wcc/home/aboutUs/snowProgramOverview

Avalanches

An avalanche is a rapid flow of snow down a hill or mountainside. Although avalanches can occur on any steep slope given the right conditions, certain times of the year and types of locations are naturally more dangerous. While avalanches are sudden, there are typically several warning signs you can look for or feel before one occurs. In 90 percent of avalanche incidents, the snow slides are triggered by the victim or someone in the victim's party. Avalanches kill more than 150 people worldwide each year.

Above: snow avalanche photograph by B. Tremper

Note: There are **rock** avalanches as well as **snow** avalanches. Rock avalanches result from rapid fragmentation of very fast-moving, initially intact rock masses during transport. Rock avalanches are a common form of mass movement where the transported material is dry rock or (low-temperature) ice that is fragmented before or during slope failure (Hungr et al., 2001).

Landslides can be classified as one or more of the following movements: falls, topples, slides (rotational and translational) and flows (lava flow, mud flow). Geologists also refer to the type of material involved in the movement, e.g., rock, debris, earth. A slide-type landslide is a downslope movement of material that occurs along a distinctive rupture or slip surface whereas a 'fall' involves the collapse of material from a cliff or steep slope. Falls usually involve a mixture of free fall through the air, bouncing or rolling. A fall-type landslide results in the collection of rock or debris near the base of a slope.

The National Weather Service provides current weather conditions and forecast information to regional snow avalanche forecast centers that in-turn issue avalanche forecasts. Avalanche warnings and special advisories are included on NWS websites and broadcast over **NOAA Weather Radio**.

NOAA Weather Radio

NOAA WEATHER RADIO ALL HAZARDS

NOAA Weather Radio All Hazards (NWR) is a nationwide network of radio stations broadcasting continuous weather information directly from the nearest National Weather Service office. NWR broadcasts official Weather Service warnings, watches, forecasts and other hazard information 24 hours a day, 7 days a week.

Working with the Federal Communication Commission's (FCC) Emergency Alert System , NWR is an "All Hazards" radio network, making it your single source for comprehensive weather and emergency information. In conjunction with Federal, State, and Local Emergency Managers and other public officials, NWR also broadcasts warning and post-event information for all types of hazards – including natural (such as earthquakes or avalanches), environmental (such as chemical releases or oil spills), and public safety (such as AMBER alerts or 911 Telephone outages).

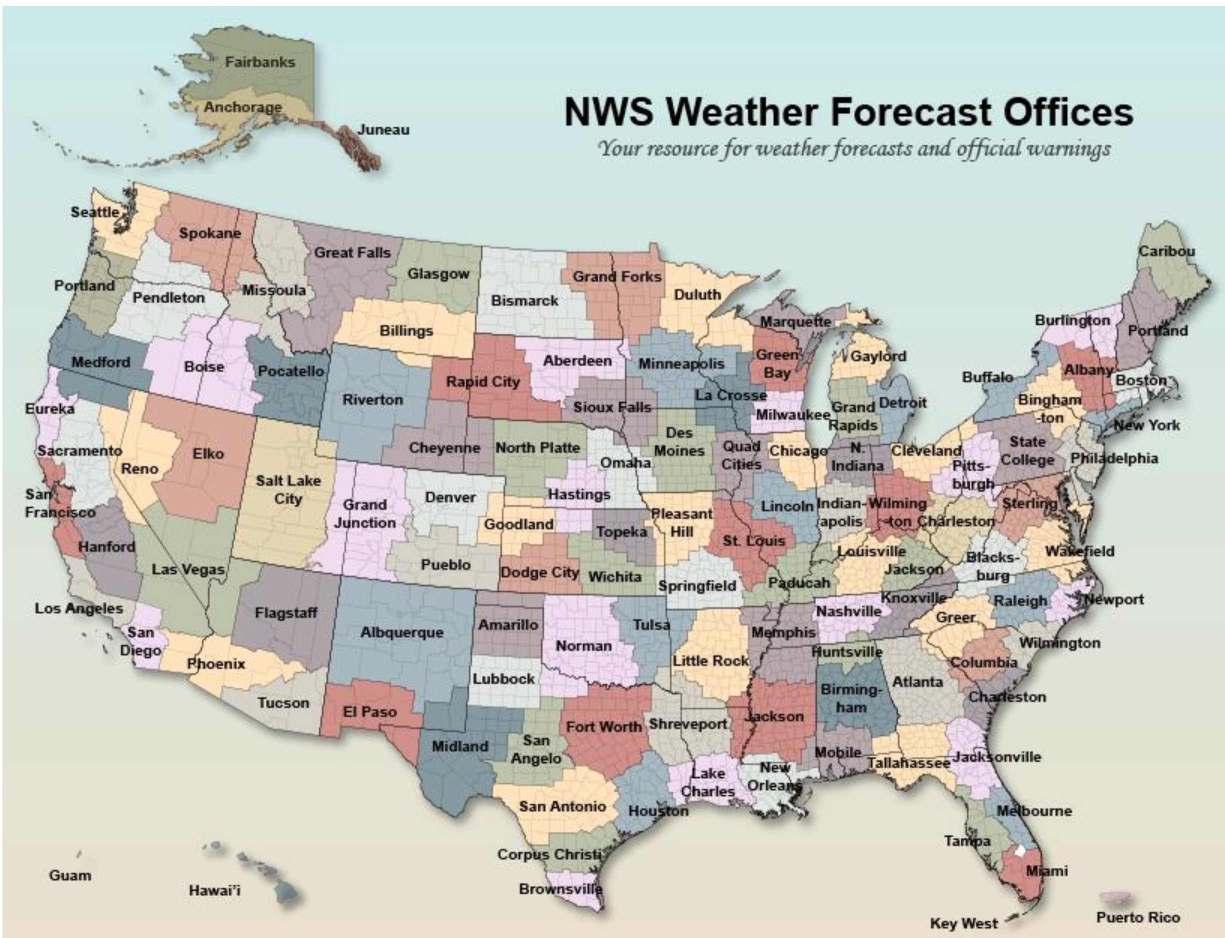
Known as the "Voice of NOAA's National Weather Service," NWR is provided as a public service by the National Oceanic and Atmospheric Administration (NOAA), part of the Department of Commerce. NWR includes more than 1000 transmitters, covering all 50 states, adjacent coastal waters, Puerto Rico, the U.S. Virgin Islands, and the U.S. Pacific Territories. NWR requires a special radio receiver or scanner capable of picking up the signal. Broadcasts are found in the VHF public service band at these seven frequencies (MHz):

162.400	162.425	162.450	162.475	162.500	162.525	162.550

Climate and weather

Whereas **weather** refers to short-term changes in the atmosphere, **climate** describes what the weather is like over an extended period in a specific area. Different regions can have different climates (source: NOAA/NWS).

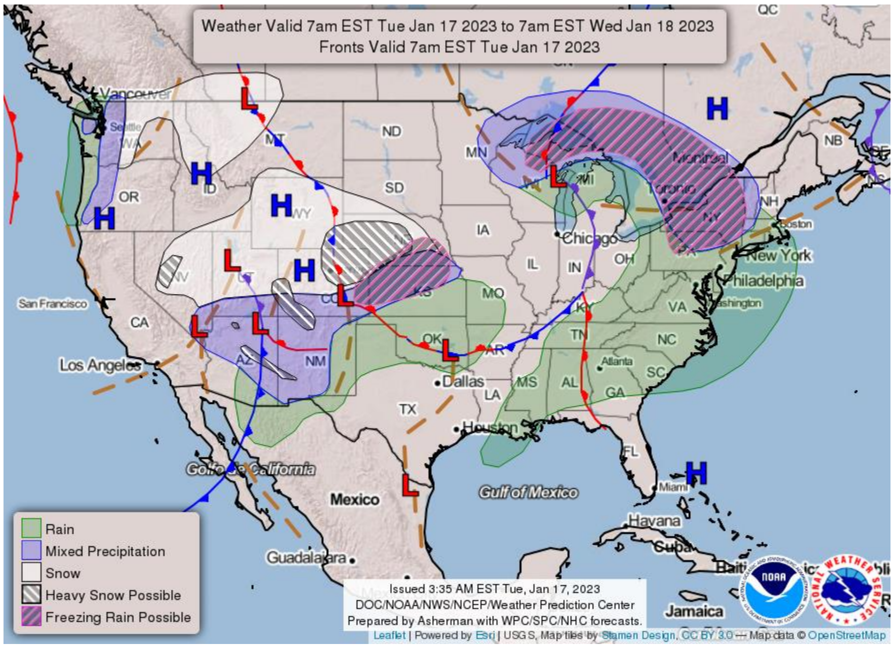
The National Weather Service has 122 Weather Forecast Offices (WFOs) across the United States, Puerto Rico and Guam staffed 24/7 with meteorologists dedicated to providing weather expertise at a more-localized level to the public.



NOAA/NWS Weather Forecast Offices

For the Roanoke – Blacksburg area: https://www.weather.gov/rnk/products.

The National Weather Service produces many types of weather and climate related products which have different update frequencies (https://www.weather.gov/gid/nwr_general).



National Forecast Chart (Source: [https://www.wpc.ncep.noaa.gov/#page=ovw)](https://www.wpc.ncep.noaa.gov/#page=ovw)

In addition to the 122 local NWS Weather Forecast Offices, NOAA/NWS has nine (9) National Centers for Environmental Prediction (https://www.weather.gov/ncep/) and thirteen (13) River Forecast Centers (below):

NOAA/NWS River Forecast Center areas of responsibility

<u>NOAA/NWS River Forecast Center locations</u>

Alaska-Pacific RFC, Anchorage AK **Arkansas-Red Basin RFC, Tulsa OK**

California-Nevada RFC, Sacramento CA **Colorado Basin RFC, Salt Lake City UT**

Lower Mississippi RFC, Slidell LA **Middle Atlantic RFC, State College PA**

Missouri Basin RFC, Pleasant Hill MO **North Central RFC, Chanhassen MN**

Northeast RFC, Taunton MA **Northwest RFC, Portland OR**

Ohio RFC, Wilmington OH **Southeast RFC, Peachtree City GA**

West Gulf RFC, Ft Worth TX

United States Army Corps of Engineers (USACE)

The U.S. Army Corps of Engineers (USACE) operates and maintains approximately 740 dams and associated structures nationwide that provide significant, multiple benefits to the nation—its people, businesses, critical infrastructure, and the environment. These benefits include **flood risk management**, navigation, water supply, hydropower, environmental stewardship, fish and wildlife conservation and recreation.

USACE's dams are part of our nation's landscape, integral to many communities and critical to watershed management. Our dam safety professionals conduct a dam safety program to ensure these projects deliver their intended benefits while **reducing risks** to people, property and the environment through continuous assessment, communication, and management. (By comparison there are more than 92,000 dams in the National Inventory of Dams (NID) that are federally, state, locally and privately operated and maintained.)

The U.S. Army Corps of Engineers' (USACE) Dam Safety Program uses a risk-based approach to inform how it manages the approximately 740 dams it operates and maintains, with life safety the highest priority. This approach is a best practice adopted to evaluate, prioritize, and justify dam safety decisions. Using risk information allows USACE to repair its dams in the most effective manner within a constrained budget.

There has been tremendous progress in the USACE Dam Safety Program over the past several years. The program has transitioned from testing new organizational policies, procedures, and organizational elements to operational and production mode, which includes major repair/rehabilitation. Many great ideas for different program elements have been put in place to include a new comprehensive dam safety policy that fully embraces USACE's risk-informed approach, as well as the establishment of production centers and an assortment of new management tools.

Why does USACE have a Dam Safety Program? As a self-regulated dam owner, USACE strives to deliver all the great benefits to our society for which the dams were built and **reduce flood risk** to the downstream public. Communication is important for all parties potentially affected by a dam, so they are aware of, and understand their risk. Local emergency management agencies and state dam safety officials are great sources of information in the event of an emergency (e.g., warning systems, evacuation plans, and emergency shelters, etc.). FEMA's "Living with Dams" is an excellent information source.

<u>**USACE Dam Safety Program Principles**</u>

Public safety is the primary focus.

Dam safety is a component of a broader flood risk management approach.

An effective safety program requires continuous and periodic project inspections and assessments.

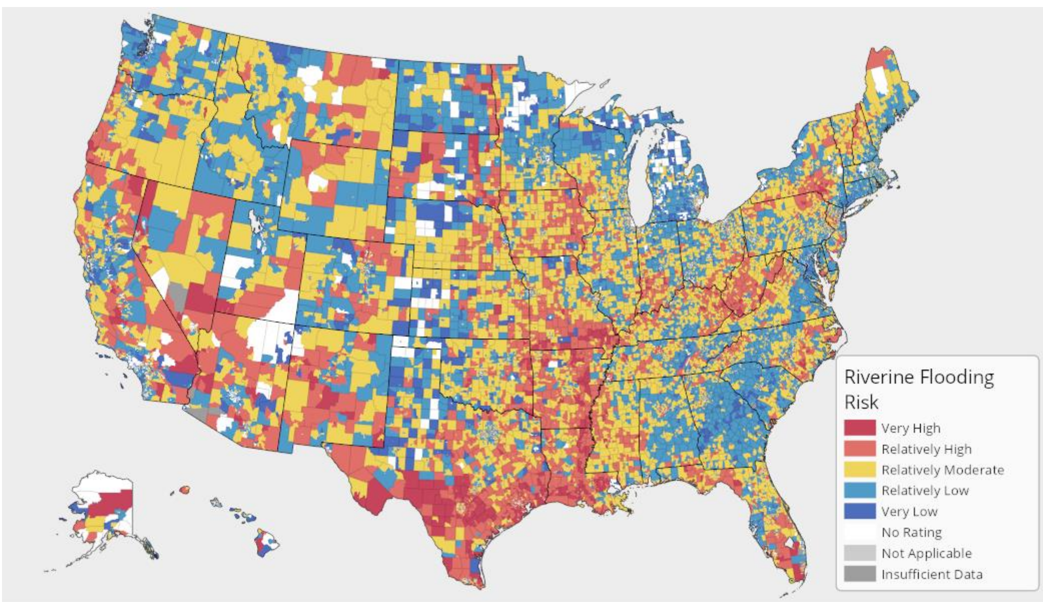
The sustainable, systems and collaborative approach is the most effective way to manage and assess dams.

Dam safety information and risk communication must be accurate, timely and clear so individuals can understand risks to make informed decisions about their safety.

Flood and drought

Advancements in data collection, sensor technology, computer hardware and software for hydrometeorological models have contributed to improved prediction of extreme events, such as flood and drought. Scientists and engineers use meteorological data and topological information such as land use and land cover in hydrologic models to simulate rainfall patterns and runoff processes of watersheds for a variety of scenarios. Numerical simulations strive to simulate the spatial and temporal variation of flows in rivers and streams, and these simulations can be run for various watershed conditions, e.g., antecedent soil moisture, and with different evapotranspiration rates from trees and vegetation. Today, hydrological models incorporate Geographical Information System (GIS) technology to input high-resolution gridded precipitation and land cover data for improved detail.

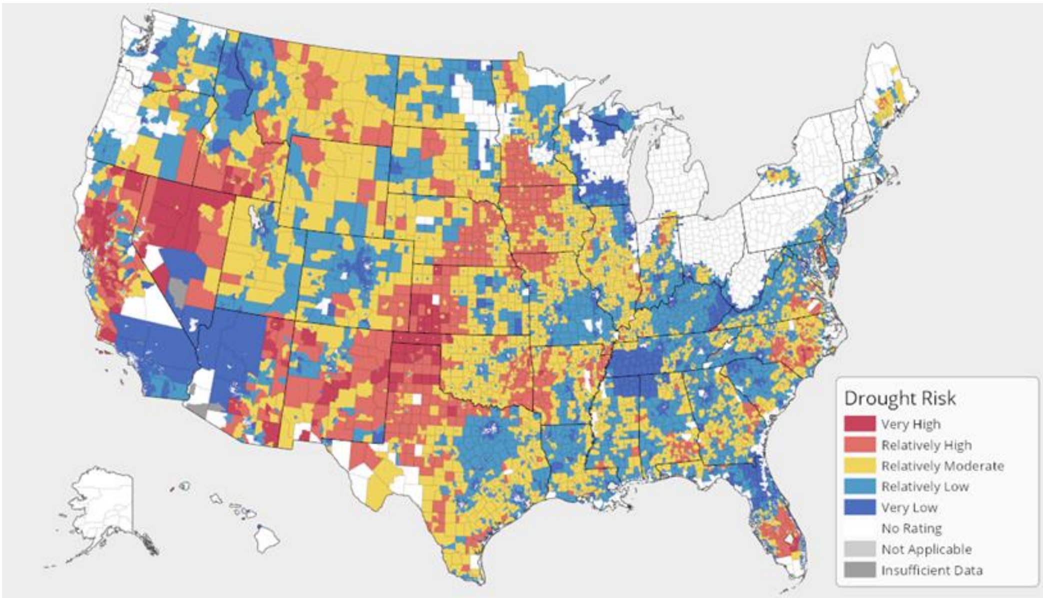
The Riverine Flooding Risk Index score and rating map (below) from the Federal Emergency Management Agency (FEMA) indicates a community's relative risk for riverine flooding when compared to the rest of the United States.



Riverine flooding risk map (source: Federal Emergency Management Agency)

Flooding can assume many forms: fluvial or riverine, pluvial, coastal, urban, etc. Sometimes, failure of infrastructure can cause catastrophic flooding, e.g., dam or levee break. A sinkhole may develop from a water main break and collapse a roadway. Cities like Miami, FL and Norfolk, VA, now experience many 'sunny day' flooding episodes annually due to sea level change/wind and or tidal factors. Sea level rise may be attributable to anthropogenically-induced climate change.

FEMA's Drought Risk Index score and rating map (below) represents a community's relative risk for droughts when compared to the rest of the United States.

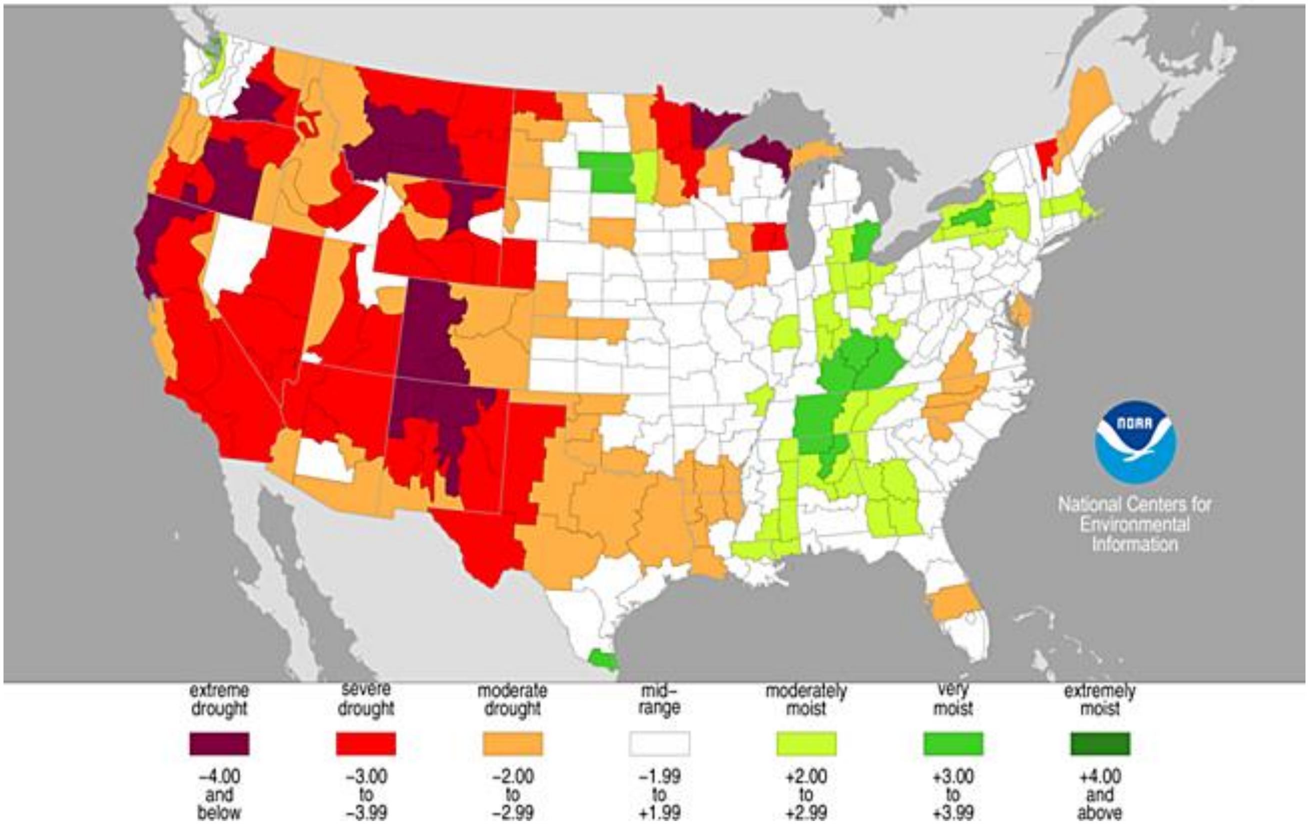


Drought risk map (source: Federal Emergency Management Agency)

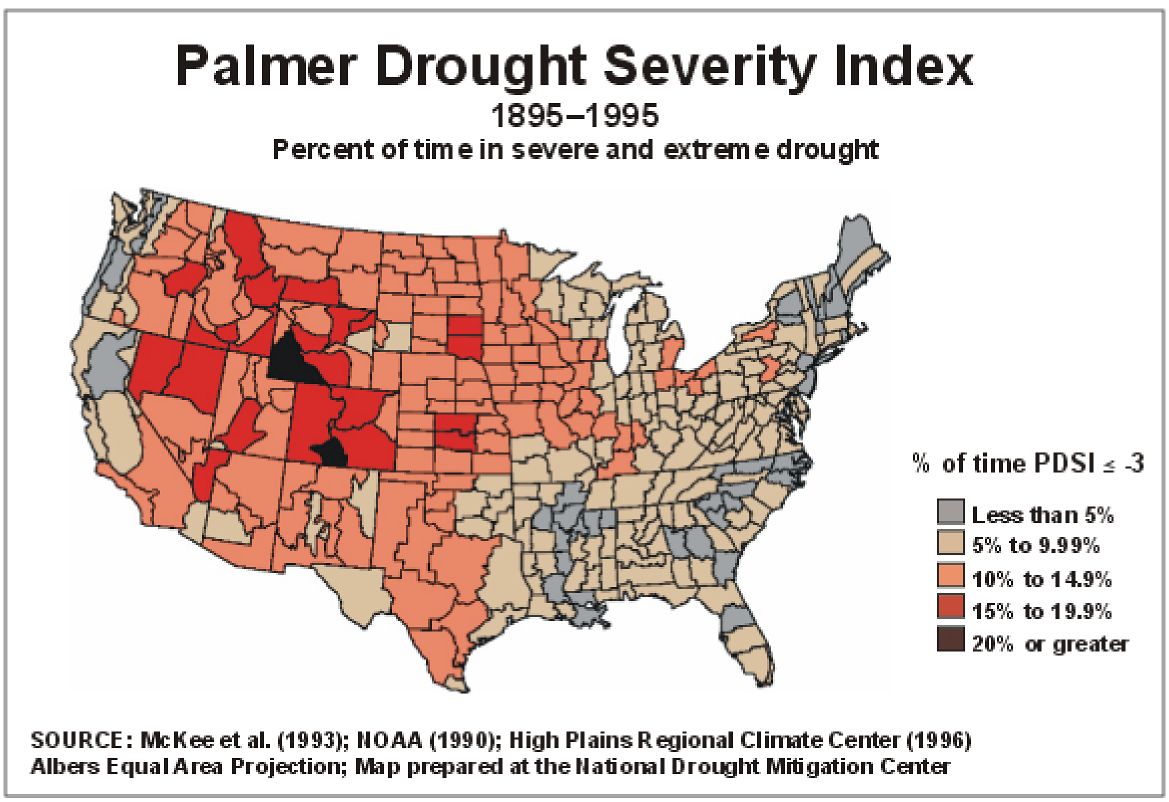
Palmer Drought Severity Index (PDSI)

The PDSI is a standardized index based on a simplified soil water balance and estimates relative soil moisture conditions. The magnitude of PDSI indicates the severity of the departure from normal conditions. The PDSI uses temperature and precipitation data to estimate the relative dryness of a region on a scale ranging from -10 (very dry) to +10 (very wet) with 0 being normal. A PDSI value for a moderate drought is -2 while conditions of extreme drought start at -4.

Examples of PDSI maps are shown below.

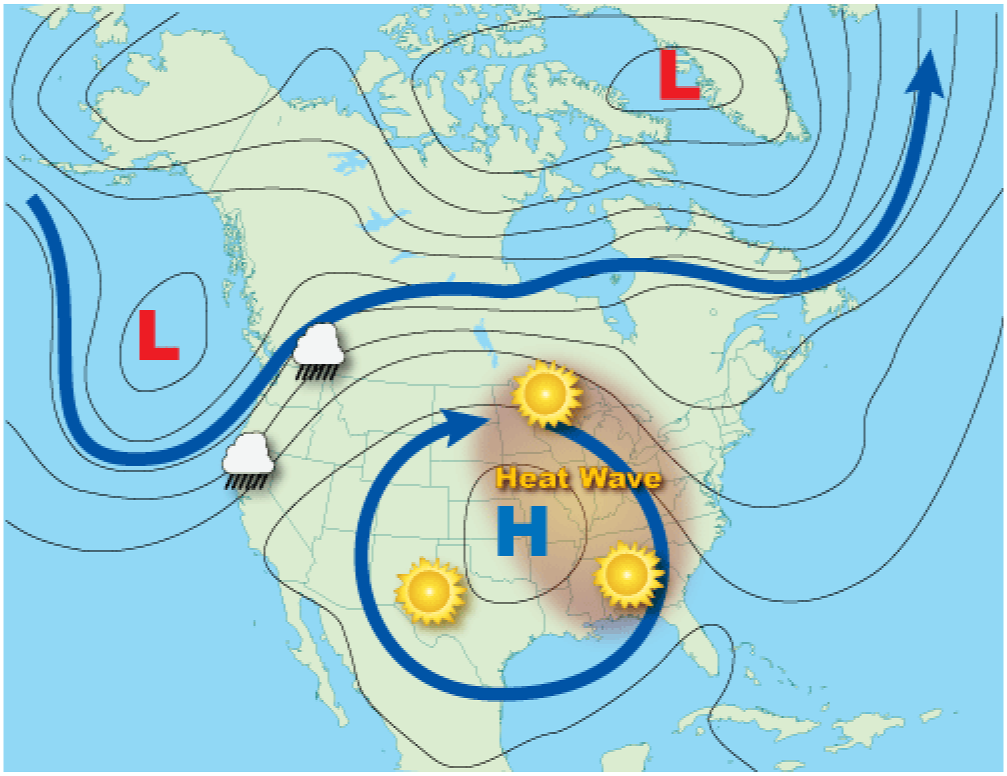


Above: Palmer drought severity index (January 2022)



Atmospheric blocking patterns

Climate change may be responsible for an increase in the frequency of large-scale atmospheric pressure patterns with little or no movement - referred to as atmospheric blocking. Blocking patterns occur when centers of high pressure and/or low pressure set up over a region in such a way that they prevent other weather systems from moving through. When the blocking pattern is in place, other systems are forced to go around it.

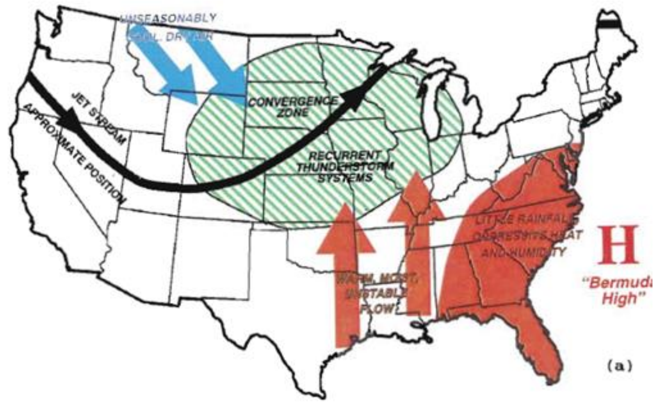


A blocking high (source: National Weather Service)

In summer, blocking can cause flood, drought, or extreme heat. A highly anomalous and persistent atmospheric pattern of excessive rainfall occurred across much of the upper Mississippi River valley and the northern and central Great Plains during June, July and the first half of August 1993, generating devastating record flooding along the upper Mississippi and lower Missouri Rivers and many of their tributaries.

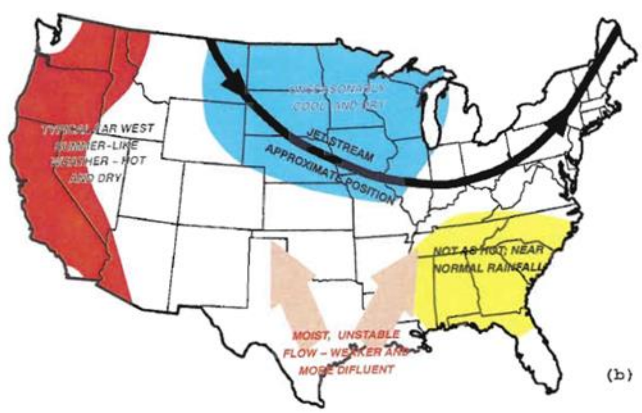
During the summer of 1993, the mean position of the jet stream had become firmly established over the northern portion of the Mississippi River basin with a southwest-northeast orientation. The quasi-stationary jet stream aloft was associated with a stationary surface front that allowed frequent and overrunning of the cooler air to the north by the moisture-laden air from the south.

The front also served as preferred location for unusually strong and frequent cyclones, spawned by the combination of the unseasonably vigorous jet stream overhead and the strong frontal boundary at the surface.



Source: NOAA/NWS

Finally, by late July and August of 1993, a change in the upper air circulation pattern brought drier conditions to the Midwest as the trough shifted eastward.



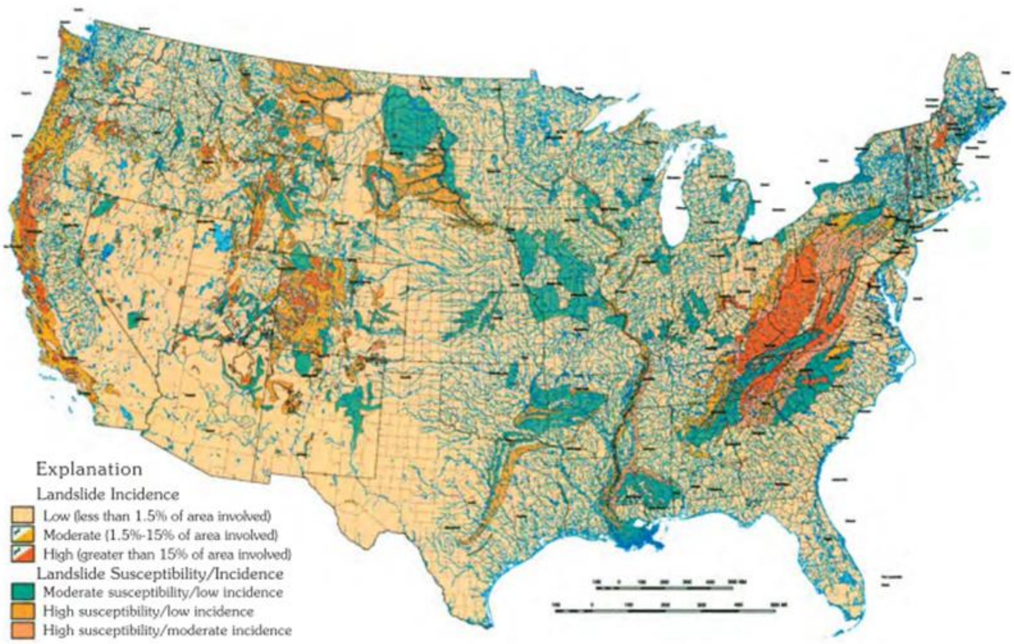
Source: NOAA/NWS

An El Nino/Southern Oscillation (ENSO) episode occurred during 1992 and 1993. In 1992, similar but less intense circulation features were observed; however, no extreme flooding occurred in the United States. Nonetheless, the long-lived ENSO event contributed to the large-scale atmospheric features associated with the persistent 1993 Mississippi and Missouri River valley flooding.

As time in the semester permits, other historical extreme weather events such as heat waves and prolonged periods sub-freezing temperatures caused by atmospheric blocking patterns will be investigated particularly regarding electrical power consumption and outages, and impact on infrastructure.

Mass wasting

Another prevalent regional hazard is mass wasting which is the geologic term used to describe the natural downward movement of landforms (e.g., soil and rocks) due to gravity. Most mass wasting events are caused by the natural processes of erosion as well as precipitation and infiltration of water. Geological evidence of mass wasting events such as alluvial fans and landslides abound in the region in places such as Augusta and Nelson Counties in Virginia.



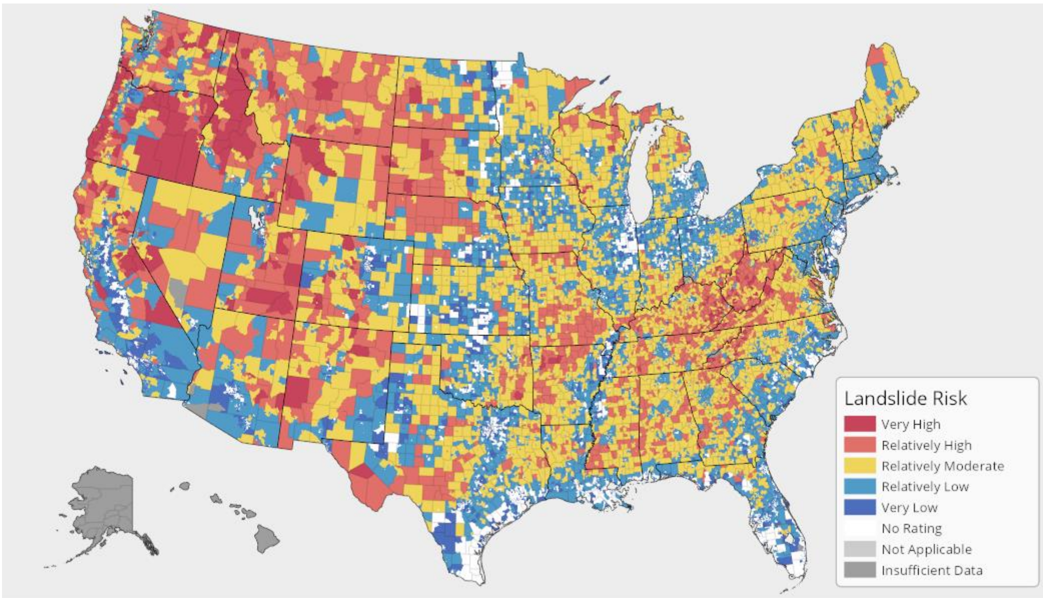
Landslide overview map of the conterminous United States. Different colors denote areas of varying landslide occurrence. From U.S. Geological Survey, 1997, Digital compilation of landslide overview map of the conterminous United States: U.S. Geological Survey Open-File Report 97–0289, digital compilation by Jonathan W. Godt, available on the web at http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-97-0289/.

Landslide incidence map over contiguous United States (USGS)

A landslide is defined as the movement of a mass of rock, debris, or earth down a slope. Landslides are a type of "mass wasting," which denotes any down-slope movement of soil and rock under the direct influence of gravity. The term "landslide" encompasses five modes of slope movement: falls, topples, slides, spreads, and flows. These are further subdivided by the type of geologic material (bedrock, debris, or earth). Debris flows (commonly referred to as mudflows or mudslides) and rock falls are examples of common landslide types.

Almost every landslide has multiple causes. Slope movement occurs when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope. Causes include factors that increase the effects of down-slope forces and factors that contribute to low or reduced strength. Landslides can be initiated in slopes already on the verge of movement by rainfall, snowmelt, changes in water level, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbance by human activities, or any combination of these factors. Earthquake shaking and other factors can also induce landslides underwater. These landslides are called submarine landslides. Submarine landslides sometimes cause tsunamis that damage coastal areas.

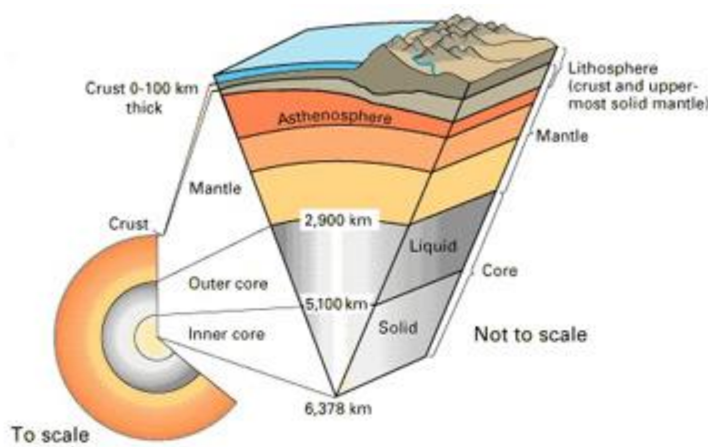
The Landslide Risk Index score and rating map (below) represents a community's relative risk for landslides when compared to the rest of the United States.

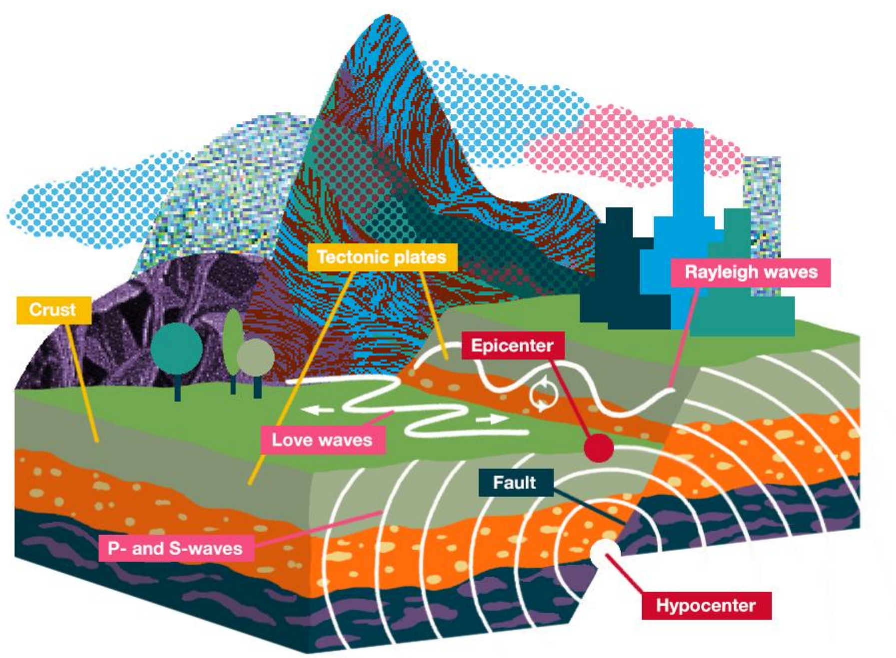


Landslide risk map (source: Federal Emergency Management Agency)

Seismic activity

Most people associate earthquakes with tectonic plates sliding against each other in fault zones; however, a variety of human activities can induce seismic responses such as drilling, ground water withdrawals, impoundment filling, etc. The 2011 event, which occurred in Mineral, VA, about eighty-four miles southwest of Washington, D.C., and damaged the Washington Monument, has been attributed to mantle degradation/thinning.

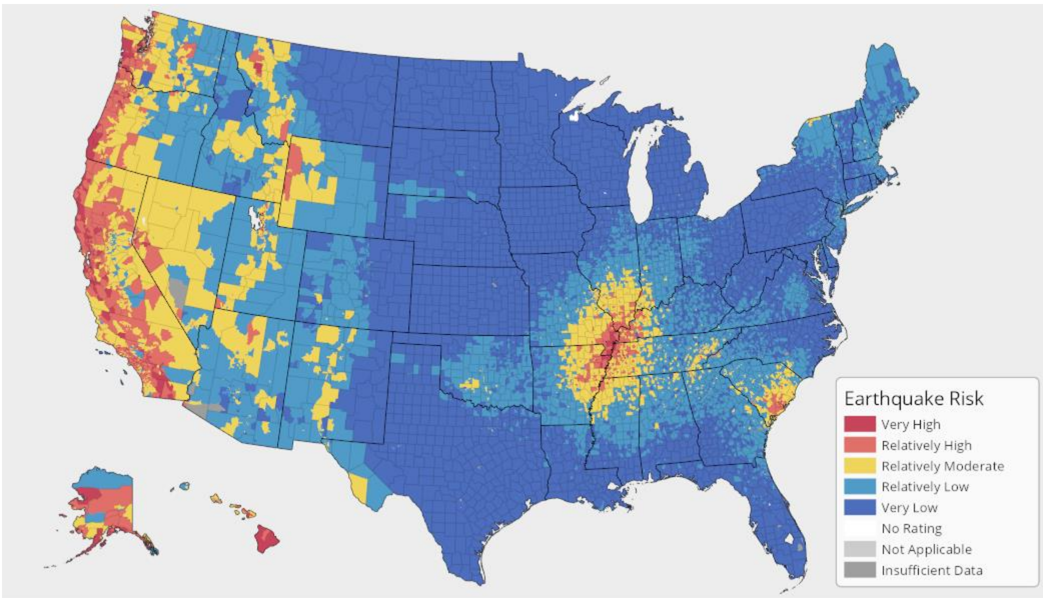




Credit: © Agata Nowicka/Marlena Agency for Caltech Science Exchange

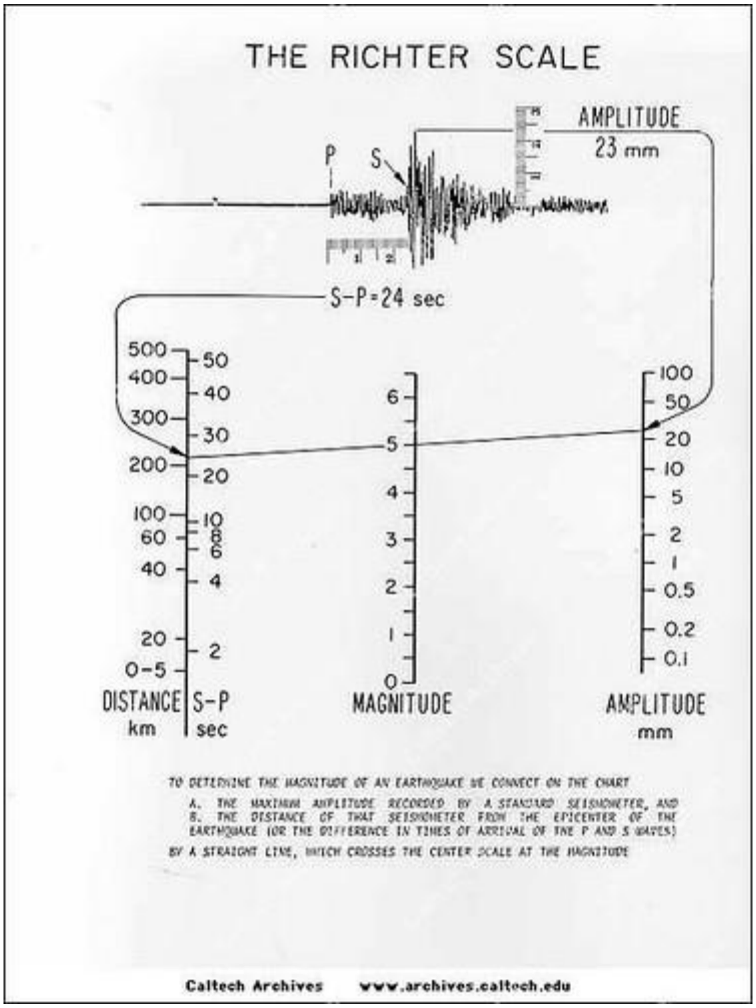
Resource: https://www.usgs.gov/faqs/how-do-i-sign-shakealertr-earthquake-early-warning-system

The Earthquake Risk Index score and rating map (below), produced by the Federal Emergency Management Agency (FEMA), represent a community's relative risk for earthquakes when compared to the rest of the United States.



Earthquake risk map (source: Federal Emergency Management Agency)

Metrics used to measure earthquake magnitude (size) and equivalent energy released, and location-based intensity will be presented.



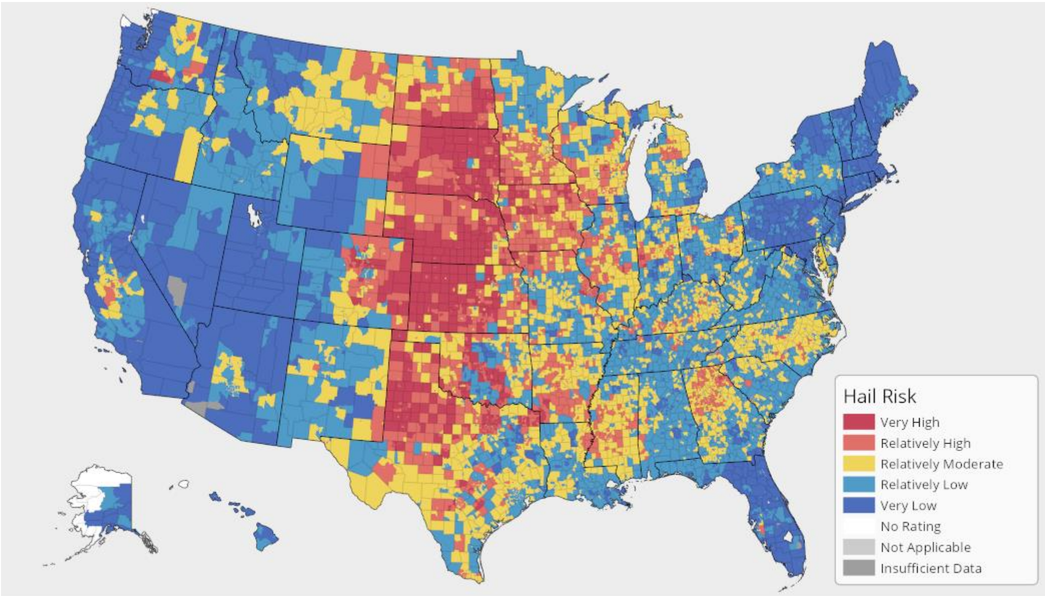
Earthquake size, as measured by the Richter Scale (above) is well known, but this magnitude scale has been replaced by other methods for determination of magnitude. A new technique, *moment magnitude*, provides a more reliable estimate of earthquake size.

Earthquake magnitude, energy release, and shaking intensity are all related measurements of an earthquake that are often confused with one another. Their dependencies and relationships can be complicated, and even one of these concepts alone can be confusing.

Source: https://www.usgs.gov/programs/earthquake-hazards/earthquake-magnitude-energy-release-and-shaking-intensity

Hail

Hail is a form of precipitation that occurs during thunderstorms when raindrops, in extremely cold areas of the atmosphere, freeze into balls of ice before falling towards the earth's surface (FEMA). The Hail Risk Index score and rating from FEMA represent a community's relative risk for hail when compared to the rest of the United States.

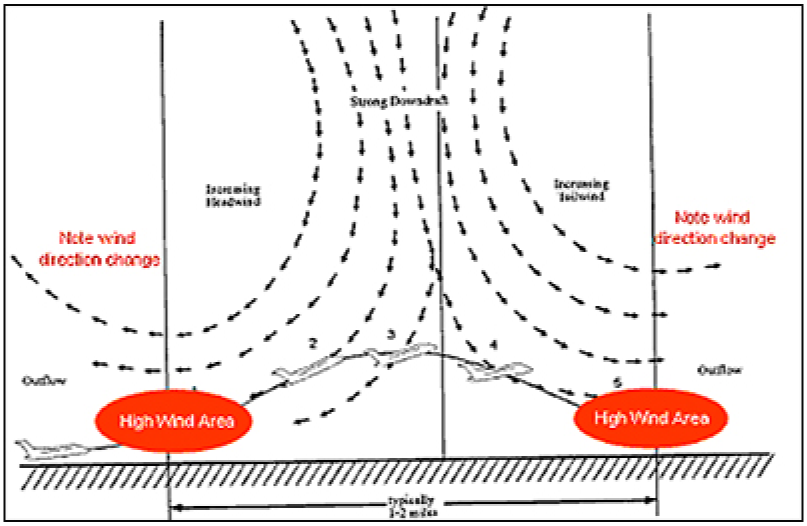


Hail risk map (source: Federal Emergency Management Agency)

Wind

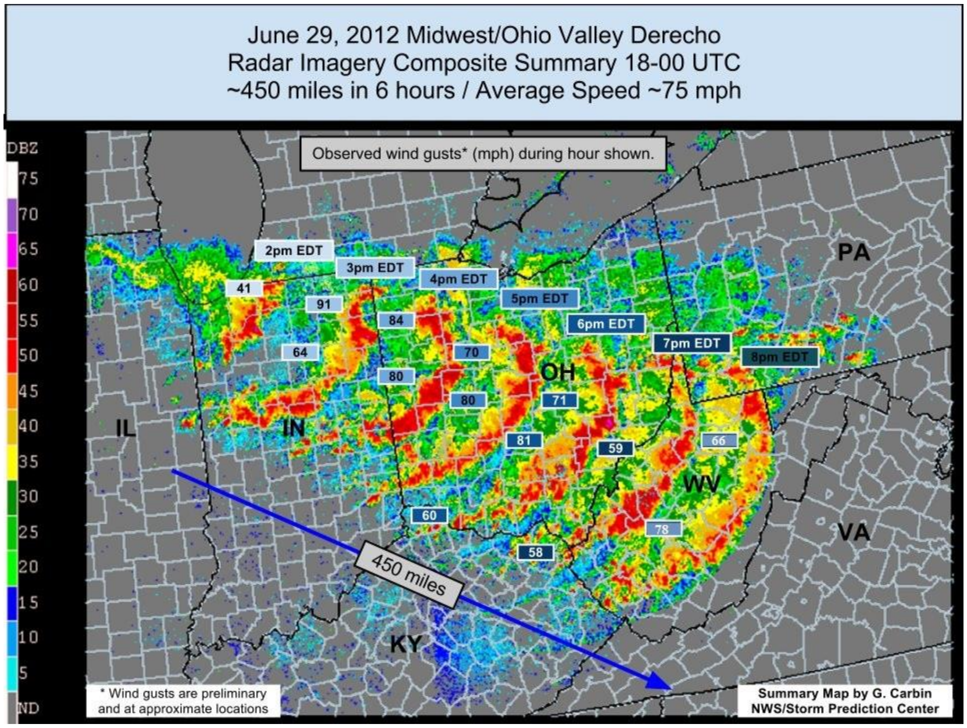
When most people think about winds associated with a thunderstorm, they think tornadoes; however, most years there are far more damage reports from thunderstorm straight line winds than from tornadoes. Straight line winds are thunderstorm winds that have no rotation, i.e., not a tornado.

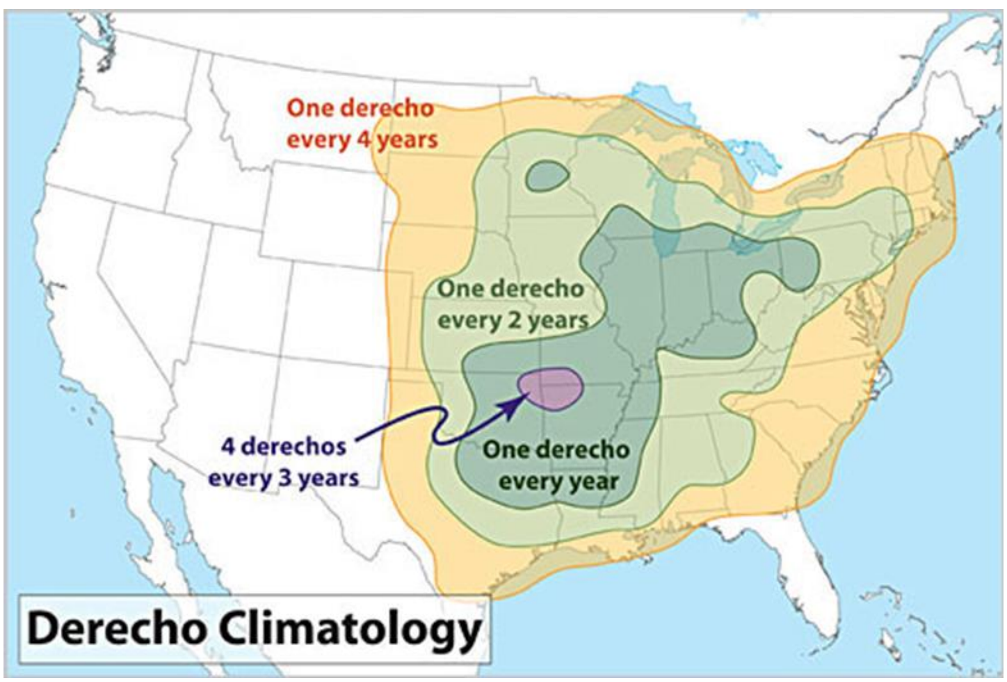
Downbursts are a common cause of wind damage from a thunderstorm. They can reach over 100 mph and are caused by air being dragged down by precipitation. When the air reaches the ground, it spreads outward across the surface of the land it encounters in a straight line.



A **Derecho** is a very long lived and damaging thunderstorm. A storm is classified as a derecho if wind damage swath extends more than 240 miles and has wind gusts of at least 58 mph or greater along most of the length of the storm's path.

Remnants of hurricanes and tropical storms that migrate to the Mid-Atlantic region are usually an important concern because of the significant amount of precipitable water they carry and their flood-producing potential; moreover, cyclonic winds contribute to coastal flooding and storm surge. However, the Region has also experienced its share of damage from straight-line winds. The June 2012 derecho that hit Virginia left half the Commonwealth without electrical power during a period of extreme heat.





Derecho frequency map

(source: NOAA/National Weather Service Storm Prediction Center (SPC))

Tornado - a violently rotating column of air touching the ground, usually attached to the base of a thunderstorm.

Tornadoes are nature's most violent storms. Spawned from powerful thunderstorms, tornadoes can cause fatalities and devastate a neighborhood in seconds. Winds of a tornado may reach 300 miles per hour. Damage paths can be more than one mile wide and 50 miles long. Strong downburst (straight-line) winds may also occur due to the same thunderstorm. Hail is very commonly found very close to the tornadoes, as the strongest thunderstorms that spawn tornadoes are formed under the atmospheric conditions that are also highly likely to make hail. Every state is at some risk from this hazard.

Some tornadoes are clearly visible, while rain or nearby low-hanging clouds obscure others. Tornadoes develop extremely rapidly and may dissipate just as quickly. Most tornadoes are on the ground for less than 15 minutes.

Before a tornado hits, the wind may die down and the air may become very still. A cloud of debris can mark the location of a tornado even if a funnel is not visible. Tornadoes generally occur near the trailing edge of a thunderstorm. It is not uncommon to see clear, sunlit skies behind a tornado. (Preceding paragraphs are edited from FEMA source: https://www.fema.gov/hazard/tornado/index.shtm)

The Enhanced Fujita Scale or EF-Scale

The EF-Scale is a rating of how strong a tornado was. The rating is calculated by surveying the damage and comparing it with damage to similar objects at certain wind speeds. The EF-Scale is not meant to be used as a measure of how strong a tornado currently on the ground is.

The EF Scale was implemented across the country in February of 2007. The EF-Scale is meant to further refine the tornado wind-force classifications begun using the F-Scale. The use of the EF-Scale should lead to more accurate and uniform tornado strength estimates by investigators as it uses 28 damage indicators (https://www.spc.noaa.gov/efscale/).

DO NOT HIDE UNDER A HIGHWAY OVERPASS CROSSING DURING A TORNADO

Vortices created under bridge – wind tunnel effect – flying debris danger

Wind causes two important loads, one called static and the other dynamic. A static wind load is the horizontal pressure that tries to push a bridge sideways. Dynamic wind load gives rise to vertical motion, creating oscillations in any direction.

Dead load is the weight of the **permanent**, non-movable parts of a structure, such as the towers, cables, and roadway of a bridge

Live load is defined as the weight of a structure's **nonpermanent**, moveable parts, contents, or "users," such as the traffic, people, and equipment; environmental loads, such as wind, rain, and earthquakes, which can affect a structure temporarily are also live loads.

Hurricane /Typhoon:

A tropical cyclone in which the maximum sustained surface wind (using the U.S. 1-minute average) is 64 kt (74 mph or 119 km/hr) or more. The term hurricane is used for Northern Hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. The term typhoon is used for Pacific tropical cyclones north of the Equator west of the International Dateline. Hurricanes can spawn tornadoes.

There are distinct stages of hurricane formation that vary greatly from storm to storm. As the pressure drops in the center of the storm, the winds that rotate around the center increase. Narrow cloud bands form, spiraling inwards. The center of the storm, or the eye, is where the lowest pressure is found. The eye wall at the edge of the eye has some of the strongest winds and intense thunderstorms, but the eye itself is characterized by calm. The hurricane-force winds may extend out from the eye for 300 km (~186 miles). The strongest winds occur towards the right-hand side of the center in the direction of the cyclone's path, so a storm moving north will have the strongest winds in the northeastern quadrant (Source: https://www.e-education.psu.edu/earth107/node/1045#:~:text=Hurricanes%20form%20from%20a%20cluster,pressure%20center%20called%20the%20eye).

Review question:

In reference to the above photo, assume a tornado is approaching, and you are in your car what is your best option?

- **(a) Stay in your car and keep driving**
- **(b) Pull off the road, get out of your vehicle and shelter under the bridge in the crevice.**
- **(c) Pull off the road, leave your vehicle and lay face down in a ditch or lowest point off the highway.**

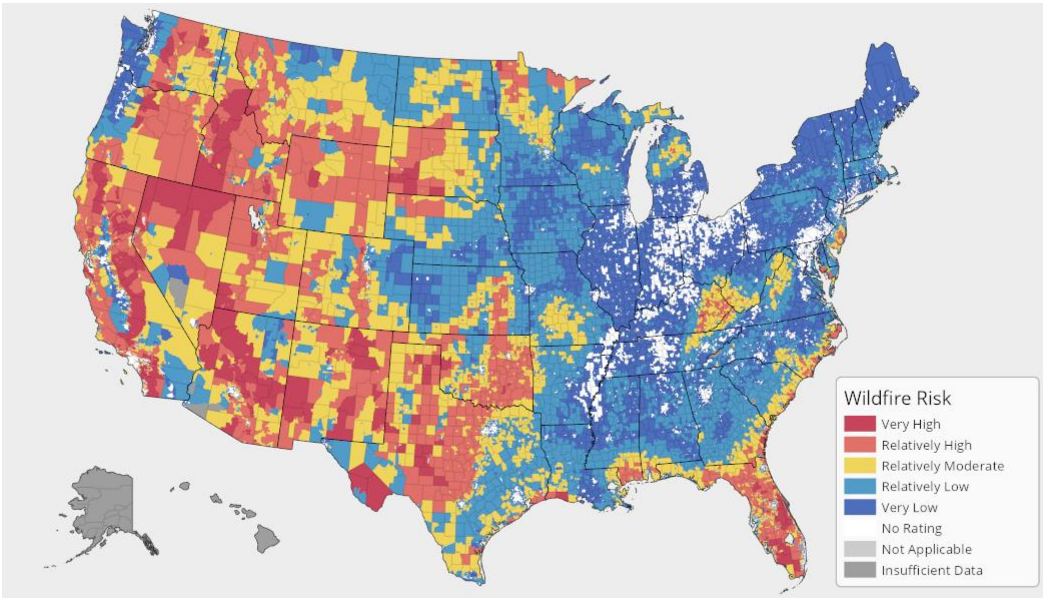
Actual event:

The NWS urged residents in the Quad Cities to take cover at 2:10 p.m. on Monday, January 16, 2023, as a tornado was seen on the ground north of Interstate 80 about 3 miles east of Conroy in central Iowa. The NWS said the EF-1 tornado had estimated peak winds of 90 mph and spanned almost a quarter-mile wide.

Massive funnel cloud spinning across Interstate 80, near Williamsburg, IA (Matt Krieger via Storyful)

Wildfire

A Wildfire is an unplanned fire burning in natural or wildland areas such as forests, shrub lands, grasslands, or prairies. The Federal Emergency Management Agency produces risk and annualized frequency maps for many natural hazards. The Wildfire Risk Index score and rating map (below) represents a community's relative risk for wildfires when compared to the rest of the United States.



Wildfire risk map (source: Federal Emergency Management Agency)

Recent research has focused on the growing threat to (potable) water systems from wildfires. When wildfire destroys residential service lines, depressurization of the water distribution system can occur from leakage and firefighting demand; a drop in line pressure enables contaminants to enter the network. Airborne, as well as soil/ground -based contaminants can find their way into a compromised water system. Increasing use of plastics, such as cross-linked polyethylene (Pex) pipe in residential systems, and in a variety of water service appurtenances, e.g., valves, gaskets, wyes, and tees, makes thermal degradation more likely in a wildfire event.

Notable extreme weather events that impacted the Middle Atlantic region

Nelson County, VA

Hurricane Camille arrived in Virginia on the night of August 19, 1969, as a tropical depression following landfall in Mississippi as one of only four category five storms ever to make landfall in the United States since record-keeping began. One of the worst natural disasters in Virginia's history, the storm produced what meteorologists (at the time) guessed might be the most rainfall "theoretically possible. Overnight, rainfall accumulations were measured at about ten inches between Charlottesville and Lynchburg, with Nelson County receiving the brunt of the storm with at least twenty-seven inches of rainfall. So much rain fell in such a brief time in Nelson County that, according to the National Weather Service, the amount was deemed "the probable maximum rainfall which meteorologists compute to be theoretically possible." Within an 8-hour period at least 71 cm (28 in) of rain fell.

https://pubs.usgs.gov/of/1999/ofr-99-0518/ofr-99-0518.html

Storms and Floods of July 30, 2016, and May 27, 2018, in Ellicott City, Howard County, Maryland

Ellicott City, MD experienced 2 excessive rainfall (1000-year return period) events in about a 2-year time span (2016 -2018). On July 30, 2016, and May 27, 2018, the downtown area of Ellicott City was severely flooded by intense, short-duration rainfall that resulted in loss of life; considerable damage to buildings, roads, infrastructure; and hundreds of vehicles were washed away. Precipitation from the 2016 event totaled about 6.60 inches in 3 hours (National Oceanic and Atmospheric Administration, 2016). Precipitation from the 2018 storm totaled 6.56 inches in 3 hours (National Oceanic and Atmospheric Administration, 2018).

https://pubs.usgs.gov/fs/2021/3025/fs20213025.pdf

Storms and Floods in Buchanan County, VA (2022)

On the evening of Tuesday, July 12th, into the early morning hours of Wednesday, July 13th, 2022, torrential rain fell across the mountainous terrain of Buchanan and Tazewell Counties in southwest Virginia. Rainfall amounts of 4-6"+ were estimated in the span of a few hours. The highest rainfall totals were caused by training thunderstorms in advance of a slowly approaching cold front. These high rainfall rates, combined with the local topography, resulted in life-threatening flash flooding that washed away homes, roads, and bridges.
https://storymaps.arcgis.com/stories/fcb54c51bde7480da7f065844626c62b

Richmond, VA, has recorded devastating flooding dating back to the 1700s to Hurricanes Connie and Diane in rapid succession in 1955, the above-mentioned Camille, to Agnes in 1972 through the Madison County event of 1995 to Fran and Floyd to close out the 1990s.

Learning outcomes

Upon successful completion of this module, students will be able to:

1. Apply scientific methodologies and concepts appropriate for natural hazard and risk assessment.
2. Write about natural hazards and ancillary topics clearly and effectively. Ancillary topics include, but are not limited to, societal and governmental response to disasters, levels of risk and resilience, likelihood of threats and hazards, control measures for risk mitigation and resilience augmentation.
3. Communicate effectively about natural hazards and ancillary topics in an oral format.
4. Interpret quantitative information related to natural hazards and ancillary topics.

Tentative course schedule

The following schedule table is approximate and subject to change except for the test dates. The table, albeit subject to modification, should provide a general picture of the timing for content presentation and assignments.

Week	Dates	Lecture material	Assignments
1	1/16 – 1/20 No classes 1/16	Introduction; major historical disasters; climate change; begin assignment of students' topics	
2	1/23 – 1/27	Basics of technical writing & oral presentation; finish assignment of topics to students; terminology for natural hazards and defining risk	
3	1/30 – 2/3	Basic concepts of probability and statistics Test #1	
4	2/6 – 2/10	Using EXCEL, Minitab for statistical computations and data analyses; continue probability and statistics	
5	2/13 – 2/17	Data (collection, gaps, variability); uncertainty Review of Test #1	
6	2/20 -2/24	Test #2; continue computer-based exercises/ statistics	
7	2/27 – 3/3	Review of Test #2 performance; continue computer-based exercises/ statistics	
8	3/13 – 3/17	Infrastructure and lifelines (vulnerability, capacity, loading, resiliency); control measures	
9	3/20 -3/24		
10	3/27 -3/31	Test #3; conclude computer-based exercises/ statistics	
11	4/3 -4/7	Review of Test #3 performance; constructing a risk assessment matrix	
12	4/10 – 4/14	Disaster recovery and reconstruction Sustainable practices The IPCC report	Written assignment due
13	4/17 – 4/21	Student presentations	Oral presentations
14	4/24 – 4/25 April 25 last day of classes	Student presentations/course review	
Final examination period		**4/27 – 5/2**	

Attendance policy

Class attendance is an especially important aspect of a student's success in this course. ***Each student is expected to attend every class and is accountable for missed content and assignments.*** If you have a temperature of 100.4 or higher or other COVID symptoms, do not come to class. Call Health Services IMMEDIATELY. Do not come to class or go to any public area on campus. For your absence to be excused, you must give Health Services permission to notify the instructor that you have consulted them about COVID symptoms. If Health Services informs you that you should isolate and not attend class for multiple days, inform the instructor so that arrangements can be made to keep you current in the course. All absences effected by consultation with Health Services about Coronavirus symptoms or isolation ordered by Health Services will be excused, but students will need to complete required work and graded assignments even if over an extended deadline.

Athletic commitments

College athletes must notify the instructor of any scheduled absences or unavoidable post-injury absences.

Masks

The college is starting the term without a specific mask mandate. Some offices on campus may require that masks be worn (such as Health Services). For this class, masking is optional.

or

The College has issued a mask mandate for the start of the semester that requires masks to be worn properly in indoor common spaces such as our classroom. While the mandate is in effect, you must wear a mask in this class. Once the mandate has expired, you're welcome to continue to wear your mask if you prefer. If you arrive without a mask, you will not be allowed to stay and may lose credit for attendance or in-class work. The bookstore in Colket Campus Center sells masks if you need to make a quick purchase.

Course materials

(1) Textbook: There is no specific textbook required. The instructor will provide (a) handouts for each class and digital content on Inquire, (b) non-RC books on reserve at Fintel, (c) Fintel library has many excellent texts available as listed below.

(2) Calculator: A scientific or graphing calculator is required.

(3) Software: Microsoft Excel (data analysis add-on required) or Minitab (a statistical software package available on most Roanoke College computers). If you use your personal copy of Excel in the Microsoft Office suite, make sure it has the data analysis 'ToolPak' installed. Ample class time will be set aside for instruction in software usage; the instructor will upload resources for EXCEL, Minitab, etc. to Inquire.

Structure and grading

A letter grade will be assigned after final grades are computed for the term as per the scale below. Attendance and class participation will be considered when determining marginal grades.

Grading scale

A (100-93)   A-(92.9-90)

B+ (89.9-87)   B (86.9-83)   B- (82.9-80)

C+ (79.9-77)   C (76.9-73)   C- (72.9-70)

D+ (69.9-67)   D (66.9-63)   D- (62.9-60)   F (59.9 and down)

The (numerical) final course grade will be determined from the five (5) assessments listed below. Each weighted similarly (20%) for a total of 100%

Assessment	Weighting	Date
Test #1	20%	TBD
Test #2	20%	TBD
Test #3	20%	TBD
Writing assignment w/ oral presentation	20%	TBD
Final examination	20%	TBD
Total	100%	

In-class assessments or tests will have both quantitative and qualitative content, the former being probability and statistical concepts and the latter comprising open-ended type questions which, by their nature, force students to think critically.

All in-class tests including the final examination are closed book/ notes. The instructor shall provide an equation/formula sheet and/or permit students to develop their own reference sheet.

Homework (including required reading) and class notes are absolutely the best sources of review! Tests will not be designed to be cumulative, but as with any course involving mathematics, material from previous tests can be thought of as a prerequisite for future tests. The final examination will be cumulative.

Test make-up policy

Test make-ups are administered in accordance with Roanoke College policy. Anticipated, excused absences must be reported to the instructor with appropriate certification well before the scheduled test date. Legitimate emergency absences must be reported with appropriate documentation within one week of returning to class. No other make-ups will be given.

Corrections to grading

If you think an error may have been made in the grading of your test, carefully review either the answer key posted on Inquire or instructor - provided solutions and then contact the instructor within 1 week of the test's return with your question. Do NOT alter the original work. The entire test may be re-graded and the test grade is subject to remain the same, increase or decrease at the discretion of the instructor.

Final examination

The final exam will be comprehensive. As with the tests, it will emphasize both mathematical computations and critical thinking. The best way to review for the final is to review your performance on the four assessments; focus on material that you did not master the first time around and review the topics that you did master.

Expected work policy

This course requires you to spend at least 2 hours of study outside of class for every class hour which is a minimum of 12 hours total work each week inside and outside of class.

Electronic devices

You can use only your calculator during class. On days when we use EXCEL or Minitab for statistical calculations you may break out your notebook or laptop PC. I prefer cell phones be left in your backpack and set on silent mode; however, I understand you may need your cell phone active in anticipation of a medical-related call, for example, if you have an immediate family member hospitalized.

Inquire policy

Students are required to be knowledgeable of all postings on Inquire. Each student shall regularly monitor Inquire for course information. Any assignment that requires an Inquire upload will not be accepted in any other form. Uploaded files must be PDF format and readable on the instructor's college computer. Each student must ensure the successful submission of any document and resolve technology problems through the college's IT department.

Academic integrity

Students shall follow the rules outlined in Academic Integrity policies of Roanoke College because your learning and integrity are at the core of your RC education.

http://www.roanoke.edu/academicintegrity

https://www.roanoke.edu/aihandbook

In-class assessments will be closed book/notes; therefore, students are not permitted to consult any texts, notes, or other prepared materials during a testing period as such action is a violation under cheating.

All graded work shall be your own work! Questions about how these policies apply to our class should be directed to the instructor. Any violations of AI policies will automatically be turned over to the Academic Integrity Council.

All source material must be properly cited using the MLA conventions and use paraphrases or quotations when appropriate. Drafts must include citations. Note that paraphrasing is more than re-arranging a few words. I am happy to help, but also encourage you to use the Writing Center at all stages of your paper writing. The instructor will address the need for proper citation and references pertaining to the writing assignment

Online testing – the instructor does not anticipate quizzes or tests administered via Inquire unless there is another coronavirus outbreak or similar pandemic. In the event of going online, the instructor will address policy regarding open book/notes. Any use of outside assistance for online assessments such as 'web-based apps and Chegg, Course Hero, and "R homework help" sites is not allowed; further, upload of any quiz or test questions to such sites is forbidden.

Accommodations

If you may require an accommodation in this course, please provide me with your documentation within the first 2 weeks of the semester. I must have your documentation at least 48 hours prior to any accommodation made. (Check with the Center for Learning and Teaching for their scheduling guidelines.)

Subject Tutoring

Subject Tutoring, located on the lower level of Fintel Library (Room 5), is open 4 pm – 9 pm, Sunday – Thursday. We are a Level II Internationally Certified Training Center through the College Reading and Learning Association (CRLA). Subject Tutors are friendly, highly-trained Roanoke College students who offer free, one-on-one tutorials in a variety of general education and major courses such as: Business, Economics, Mathematics, INQ 240, Modern Languages, Lab Sciences, INQ 250, and Social Sciences (see all available subjects at www.roanoke.edu/tutoring).

Tutoring sessions are available in 30 or 60-minute appointments. Schedule an appointment at www.roanoke.edu/tutoring, or contact the center at (540) 375-2247 or subject_tutoring@roanoke.edu.

Writing Center

The Writing Center at Roanoke College offers tutorials focused on writing projects and oral presentations for students working in any field. Writers and presenters at all levels of experience may consult the Writing Center at any point in their process— including brainstorming, drafting, organizing, editing, or polishing presentation skills—to talk with trained peer tutors in informal, one-on-one sessions. Schedule an appointment at www.roanoke.edu/writingcenter, where our staff members and workshops are also posted. Questions? Email the center: writingcenter@roanoke.edu.

Accessible Education Services (AES)

AES is in the Goode-Pasfield Center for Learning and Teaching in Fintel Library (clt@roanoke.edu)

AES provides reasonable accommodations to students with documented disabilities. To register for services, students must self-identify to AES, complete the registration process, and provide current documentation of a disability along with recommendations from the qualified specialist. To schedule an appointment, call (540) 375-2247 or e-mail aes@roanoke.edu.

If you have registered with AES in the past and would like to receive academic accommodations for this semester, please contact the AES at your earliest convenience to schedule an appointment and/or obtain your accommodation letter for the current semester.

References

Hardcopy books available at Roanoke College/ Fintel Library*

Asimov, Isaac. *A Choice of Catastrophes: The Disasters That Threaten Our World*. New York: Simon and Schuster, 1979. Print (GB5018. A84).

McGuire, Bill. *A Guide to the End of the World: Everything You Never Wanted to Know*. Oxford; New York: Oxford UP, 2002. Print (GB5018. M34 2002).

Newton, David E. *Natural Disasters: A Reference Handbook*. 2019. Print. Contemporary World Issues (GB5014. N49 2019).

Vallero, Daniel A., and T. M. Letcher. *Unraveling Environmental Disasters*. Boston: Elsevier, 2013. Print (GE146. V45 2013).

Waltham, Tony. *Catastrophe: The Violent Earth*. New York: Crown, 1978. Print (GB5018. W34 1978).

*substantial online access material available in this category at Fintel; search the digital catalog

On reserve (courtesy of Dr. J. F. Pescatore)

Bell, A. and W. Strieber, *The Coming Global Superstorm*. New York: Simon and Schuster, 2000.

Leet, L. Don. *Causes of Catastrophe*. New York: McGraw-Hill, 1948.

McCullough, D. *The Johnstown Flood*. New York: Simon and Schuster, 1968.

Officer, C., and J. Page. *Tales of the Earth*. New York: Oxford University Press, 1993.

Hydrology of Disasters, Singh, Vijay P. (ed.). Dordrecht: Kluwer, 1996 (ISBN 0-7923-4092-2)

Natural Hazard Uncertainty Assessment: Modeling and Decision Support, Riley, K., Webley, P., and M. Thompson (eds.). Hoboken: Wiley & Sons, 2017 (ISBN: 978-1-119-02786-7).

Schwartz, R. *Hurricanes and the Middle Atlantic States*, Blue Diamond Books, 2007.

Digital resources

The Intergovernmental Panel on Climate Change (https://www.ipcc.ch/)

IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Weather Related Fatality and Injury Statistics (https://www.weather.gov/hazstat/)

FEMA maps (https://hazards.fema.gov/nri/natural-hazards)

2012 Virginia derecho

https://storymaps.arcgis.com/stories/f7e1ca794a494a8c85f9564c11b05678