Course Title: Rocky Mountain Ecosystems: A Global Change Perspective
Course Instructor: Dr. Kaysee Arrowsmith (kcarrows@utexas.edu)
Course Description: This field-based course provides students with an introduction to the diverse methods that field ecologists use to study patterns of environmental change in the montane ecosystems of the Rocky Mountains. The Rockies have experienced nearly 2˚C of warming over the past century and we could see an additional 1˚C of warming in the next 25 years. These warming trends have been associated with earlier snowmelts, altered species ranges, and mismatches in the timing of biological events, among many other impacts. But environmental changes occur on time scales and across geographic ranges that are hard to observe first-hand. How do scientists study these processes?

In this course, students will be introduced to research studying the effects of environmental change in the Rocky Mountains. We will discuss the methods that researchers use to measure changing environments, from long-term monitoring of temperature and precipitation to discrete measurements of streamflow and land cover. We will also interact with scientists who experimentally manipulate environmental conditions to identify how these changes affect specific biological processes like pollination and plant reproduction. Finally, we will explore how natural history museums provide valuable opportunities to study how species' distributions, traits, and life histories have changed over time. Students taking this course should expect to spend substantial time outdoors, including moderate hiking, but accommodations will be available for any students experiencing any limitations with these activities. By the end of this course, students will be familiar with the flora and fauna of diverse mountain ecosystems and will be equipped with a wide range of research methods to apply to their own questions related to global environmental change.

Course Objectives

1. *Ecological content*
    a. Students will be able to communicate the goals and methods of multiple research groups at the Rocky Mountain Biological Laboratory who are studying elements of global environmental change.
    b. Students will be able to identify major ways in which global change is affecting montane ecosystems.
    c. Students will be able to describe and measure specific environmental variables and discuss how these variables can provide information about broad-scale global change trends.
2. *Scientific literacy*
    a. Students will be able to identify credible, peer-reviewed journal articles relating to their topics of research interest.
    b. Students will be able to understand and synthesize information from published scientific literature.
    c. Students will be able to identify flaws in published research and propose ideas for how these flaws could be remedied using the researchers' original data or in future scientific studies.

    d. Students will be able to write their own research findings in the style of a peer-reviewed journal.
3. *Research methodology*
    a. Students will be able to formulate a research question and hypotheses relevant to that question.
    b. Students will be able to select appropriate methodologies to measure environmental change at spatial and temporal scales relevant to a desired outcome.
    c. Students will be able to develop research plans to relate environmental variables (e.g., temperature, precipitation, snowmelt, land cover, streamflow) to biological processes (e.g., emergence from overwintering, predation, pollination, reproduction).
    d. Students will be able to analyze data and discuss results using statistical results and figures.

Grading

Students will receive a numeric grade for each day (10 points per day). Over the eight course periods, these daily grades will yield a final grade of 80 total points at the end of the course. Daily grades will be based on the following criteria:

- Maintaining a field notebook (5 points/day, 40 points total)
    - Students will be required to keep a field notebook. In that field notebook, they should record relevant details and notes from each site visit.
    - Details of specific information that should be in field notebooks for each site visit will be provided prior to each site visit.
- Reading and discussing journal articles (2 points/day, 16 points total)
    - Students will be given time in-class to read journal articles and will be asked to discuss them with their peers in small groups and/or with the entire class.
    - To receive all points for a day, students must be respectfully engage in these discussions. Points will be deducted if students are disruptive or do not participate in journal discussions.
- Engaging with research teams during site visits (2 points/day, 16 points total)
    - Students will visit a research team at RMBL on each course day. During these visits, they will be expected to ask questions and engage with the researchers who are introducing their field work to the class in order to earn full points.
    - Engagement could include, but is not limited to, asking questions of the researchers, answer questions when asked of the group, and participating in field activities related to the research as assigned.
- Participating in other course activities and with peers (1 point/day, 8 points total)
    - Throughout the course, students will be asked to collaboratively support their own and others' learning. Students will receive full points for the day if they are productively pursuing their own educational goals and are not engaging in behavior that interferes with other students' abilities to do likewise.

Week 1: Intro to Field Research & Measuring Abiotic Variables

- **Thursday June 12 – morning session (9am – 12pm)**
  Introduction to field ecology
  - Journal article: Rapid range shifts of species associated with high levels of climate warming (Chen et al. 2011)
  - Classroom activity: Developing research questions and hypotheses

- **Thursday June 12 – afternoon session (1pm – 5pm)**
  Measuring the environment
  - Site Visit: billy barr
  - Classroom Activity: Intro to R and working with data
  - Field Notebooks:
    - Site schematic and description of environment
    - Description of how data are collected (methods)
    - Possible biases or challenges to data collection
    - What is one research question of interest to you that these data could be used for? What would your hypotheses be for this question?

Additional Resources:

- Annotated Chen et al. 2011
- billy barr: video by AP News
- billy barr: video by The Atlantic

Week 2: Proxies for Temperature and Precipitation Changes

- **Monday June 16 – morning session (9am – 12pm)**
  Logistics of field work – field safety and accessibility
  - Journal Article: Safe fieldwork strategies for at-risk individuals, their supervisors and institutions (Demery & Pipkin 2021)
  - Classroom Activity: field safety but make it D&D
  - Classroom Activity & Discussion: planning methods/data collection

- **Monday June 16 – afternoon session (1pm – 5pm)**
  Elevation as a proxy for temperature
  - Site visit: Gunnison Basin ecotones
  - Classroom Activity: design an experiment that utilizes an elevational gradient to understand an element of global change
  - Field Notebook:
    - Short description of each stop (description of environment— vegetation, soil types, weather— as well as if there was any evidence of animals or other relevant notes)
    - Note any safety or accessibility concerns for each stop

- **Thursday June 19 – morning session (9am – 12pm)**
  Changing temperature and precipitation in the Rocky Mountains
  - Journal Article: Snow melt timing acts independently and in conjunction with temperature accumulation to drive subalpine plant phenology (Jerome et al. 2021)
  - Discussion: TBD
  - Classroom Activity: proposal feedback session

- **Thursday June 19 – afternoon session (1pm – 5pm)**
  Snowmelt timing
  - Site Visit: Dylan Simpson, snowmelt manipulation
  - Site Activity: TBD
  - Field Notebook:
    - Site schematic
    - Description of the two plots
    - In-field measurements

Additional Resources:

- Vegetation of the Upper Gunnison Basin (US Forest Service)

Week 3: Land Cover and Seasonal Cycles

- **Monday June 23 – morning session (9am – 12pm)**
  Introduction to seasonality
  - Journal Article: Scale gaps in landscape phenology: challenges and opportunities (Park et al. 2021)
  - Discussion: comparing primary research article with perspectives/commentary/review articles
  - Classroom Activity: R workshop

- **Monday June 23 – afternoon session (1pm – 5pm)**
  Remote sensing
  - Site Visit: Ian Breckheimer, remote sensing
  - Classroom Activity: NDVI maps
  - Discussion: opportunities and constraints of drone imagery or other remote sensing
  - Field Notebook:
    - Necessary information for drone operation
    - Diagram of drone flight plan
    - Environmental conditions that might affect images

- **Thursday June 26 – morning session (9am – 12pm)**
  Hydrological Cycles in the Mountains
  - Journal Article: Forest catchment structure mediates shallow subsurface flow and soil base cation fluxes (Pennino et al. 2024)
  - Classroom Activity: TBD

- **Thursday June 26 – afternoon session (1pm – 5pm)**
  TBD
  - Site Visit: TBD
  - Site Activity: TBD
  - Field Notebook: TBD

Additional Resources:

- Ologies podcast on seasons/phenology

Week 4: Short-Term Effects of Global Change: Phenology and Community Dynamics

- **Monday June 30 – morning session (9am – 12pm)**
  Intro to Phenology
  - Journal Article: Section 3 of Inouye 2022
  - Classroom Activity: Phenology worksheet, R analysis

  Monday June 30 – afternoon session (1pm – 5pm)
  Plant Phenology
  - Site Visit: Phenology Team
  - Site Activity: Plant surveys (take note of assigned focal plant!)
  - Classroom Activity: Phenology worksheet, informal presentations on focal plant
  - Field Notebook:
    - Site diagram
    - Methods and data
    - Plant ID notes
    - Notes specific to your assigned focal plant

- **Thursday July 3 – morning session (9am – 12pm)**
  Biotic Interactions/Disruptions
  - Journal Article: Inouye 2022 – sections 5-7
  - Classroom Activity: TBD
  - Discussion: How do phenology and biotic interactions influence one another?

- **Thursday July 3 – afternoon session (1pm – 5pm)**
  Plant-Pollinator Networks
  - Site visit: Annie Colgan, plant-pollinator networks
  - Site Activity: Plant-pollinator visitation surveys
  - Classroom Activity: Networks in R
  - Field Notebook:
    - Site diagram
    - Methods and data
    - Notes about differentiating between different insect groups

Week 5: Long-Term Effects of Global Change

- **Monday July 7 – morning session (9am – 12pm)**
  Museums, Herbaria, and Long-Term Data
  - Site Visit: Rick Williams
  - Site Activity: Collect a plant specimen, mount a pre-dried specimen
  - Field Notebook:
    - Information about the specimen that you collected including location, environment, other plants that were in the same area
    - What type of research uses data from the herbarium?
    - What are the pros and cons of studying herbarium samples vs. fresh samples?

- **Monday July 7 – afternoon session (1pm – 5pm)**
  Course Wrap-Up
  - Classroom Activity: open work time for project – discuss problems that you've been having, decisions you've had to make, etc.
  - Wrap-up and final reflection