SIO20R: The Atmosphere

Fall 2024

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Introduction

Important Note: *This syllabus, along with course assignments and due dates, are subject to change. It is the student's responsibility to check our course Canvas site for corrections or updates to the syllabus. Any changes will be clearly communicated by the instructor.*

The first step in studying the atmosphere is **M1 Describing the Atmosphere**. The key to Earth's unique atmosphere is **M2 Relating Temperature and Water**, because together they control the features of the atmosphere that sustain life on Earth. The altitude of the stratosphere is determined by **M3 Locating the Ozone Layer**, since its formation is the cause of the heating that creates this layer of warming. **M4 Balancing Solar and Terrestrial Radiation** is the way in which the atmosphere controls the temperature of the Earth's surface. While the naturally-existing greenhouse gases such as water make the Earth warm enough to live on, the recent trend toward **M5 Accumulating Greenhouse Gases** means that the Earth's temperature is getting warmer than since before living organisms evolved on its surface. In addition to gases, condensed components of the atmosphere contribute to **M6 Sizing Aerosol Particles**, and these sizes affect how much incoming solar radiation is reflected back to space.

One of the most distinguishing features of the Earth and an important player in controlling its climate is revealed through **M7 Characterizing Clouds** and their changing patterns in the atmosphere. Predicting how weather and climate will change in the future requires **M8 Tracking Transport** by following where air goes from one day to the next, from season to season, and from decade to decade. In many ways human prosperity relies on **M9 Predicting Precipitation** to identify where freshwater will be available to support plant and animal life on Earth. Since the atmosphere is continually changing, **M10 Sensing Climate Change** requires unraveling the forcings and feedbacks of the atmosphere through worldwide observations and targeted modeling.

R Course Logistics and Support: The R designation of SIO 20R means that this is a fully online course and all lecture material is provided asynchronously, so there are no scheduled course meeting times. Students are responsible for providing an appropriate place to learn the material and complete assignments as well as access to a device and internet, whether or not they have been granted classroom accommodations. Office Hours are synchronous on Zoom at the times posted on Canvas, but additional times and in-person meetings are available by appointment (i.e. just email the instructors to request a meeting). There is a time window for each assignment and exam, and the assignment must be completed within that window. Completing assignments and exams will require good internet access, an appropriate device, and compatible operating systems. It may be possible to complete some work on a smart phone, but a tablet or laptop will work better for some assignments and is expected for an R course. If you need assistance obtaining a laptop, please email the Student Affairs Technology Lending Program (SATLP) at satechlending@ucsd.edu. For more information, please see the SA Tech Lending Program FAQs.If you encounter any difficulties that affect your ability to complete assignments on time, please contact the instructors as well as the relevant tech support resources as soon as they happen.

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Learning Objectives

At the end of course, you will be able to:

1. Describe the atmospheric composition and structure.
2. Define the properties that control atmospheric processes.
3. Review the ways in which humans changed the ozone layer.
4. Relate the streams of energy in the atmosphere and their changes with temperature.
5. Explore the changes to the atmosphere from man-made greenhouse gases.

6. Examine how aerosol particles affect the atmosphere.
7. Describe the types of clouds and their roles on climate and weather.
8. Identify the role of wind in distributing heat in the atmosphere.
9. Explain how precipitation contributes to the Earth's hydrological cycle.
10. Describe the evidence and implications of climate change.

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Wrap Up

Putting these objectives together, we see important relationships that define the Earth's atmosphere (M1). The likely unique role of water in our atmosphere is illustrated by the process that connects water to the temperature (M2). The temperature of the atmosphere is also modulated by the formation of ozone from the sun's ultraviolet rays, which creates the layer we call the stratosphere (M3). Overall, the sun's energy warms the Earth, with its incoming shortwave streams and with the reflected and greenhouse streams controlling the temperature of the Earth, because this temperature sets the amount of outgoing longwave radiation (M4). Adding man-made greenhouse gases to the atmosphere changes the balance of incoming and outgoing radiation, which makes the temperature of the Earth increase (M5). Increasing aerosol particles as part of pollution reduces air quality and increases the reflected radiation (M6). An even more important effect on both reflecting incoming energy and trapping outgoing energy is clouds, which form when the amount of water is too high to remain as a gas and condenses (M7). The uneven distribution of energy between the equator and poles of the planet drives poleward transport of energy and differences in atmospheric pressure result in atmospheric circulation (M8). Clouds also change the water in the atmosphere by precipitation, with important consequences for distributing water around the globe (M9). All of these aspects of the Earth’s system change as climate changes, with devastating impacts for many human populations and ecosystems, which makes mitigating greenhouse gas emissions and investigating possible climate engineering methods important priorities (M10).

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Assignments and Grading

The course includes two types of assessments that will be used to allow students to practice and demonstrate their mastery of the ten learning objectives for the course. The first type is the **video homeworks with discussions**, which are designed to allow students to reflect on how the concepts from the course relate to their own lived experiences and interests. These videos are posted to discussions boards so that

students may share the experiences of others and engage in online conversations about the material. The second type is the **quizzes and exams**, which test understanding of basic concepts. Approximately one minute is allotted for each question, allowing time to flip through the lecture slides to find key numbers so that familiarity with course material but not memorization is expected. However, there is not enough time to re-watch all of the videos during the quizzes, so students should review the course material before attempting the quizzes and exams. The assignments are:

Assignment Group	Description	Weight
Video Homework with Discussion	The homework assignments provide students the opportunity to explain key concepts of the course in their own words, relating them to their own experiences. The format is a video starring themselves, which will be reviewed by the instructors with feedback provided. This video is a remote version of a presentation and should clearly show the speaker, but special effects or editing is not needed -- simply a video of the student answering the three questions in their own words. The videos will be shared with a group of other students, and students are asked to comment on at least two videos that they viewed. The two lowest homework grades (including late penalties) are dropped.	35%
Weekly Quizzes	Multiple choice, multi-answer, true-false, and numerical timed quizzes are provided on Canvas each week for students to test their understanding of the videos for that week. Students can attempt each quiz up to two times before the due date, questions are selected randomly each time, and the highest grade is recorded. The two lowest quiz grades are dropped. Students should avoid taking the quiz for the second time after the due date, as the late penalty will apply if it is the higher grade earned.	35%

Midterm Exam	The midterm is scheduled for the end of week 5 and will consist of an online exam with 100 questions from Modules 1-5. The exam will be 2-hr long and timed within a 3-day window, and all questions need to be answered sequentially as in the weekly quizzes. Students can take the exam during any contiguous 2-hr time block within the window that it is offered. Students can attempt the exam up to two times, with questions selected randomly each time, and the highest grade is recorded.	15%
Final Exam	The final exam is scheduled for Finals week and will consist of an online exam with 100 questions from Modules 6-10. The exam will be 2-hr long and timed within a 5-day window (note that this is different from the midterm), and all questions need to be answered sequentially as in the weekly quizzes. Students can take the exam during any contiguous 2-hr time block within the window that it is offered. Students can attempt the exam up to two times, with questions selected randomly each time, and the highest grade is recorded.	15%

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Late Policy

- Exams will only be graded if completed during the scheduled date window in order to support equity and integrity, unless documentation of a reason beyond your control is provided (e.g. a letter from a medical doctor, your college dean, or a government agency).
- Quizzes, homework, and other assignments need to be completed on time in order to allow for discussions, feedback, and timely progress. Late assignments (including 2nd quiz attempts) will lose 10% per day. The generous policy of dropping two quiz and two homework grades is designed to allow flexibility

without providing a reason.

- If there is a reason beyond your control that you need to turn in an assignment late, please notify the instructors when it is due and then submit a “Late Penalty Waiver Request” at 10th If you have completed all other assignments on time and you have a documented reason that was reported in a timely way to the instructors, a late penalty may be waived at the end of the quarter.
    - Joining the course late associated delays in access to Canvas course materials is not a reason to waive a late penalty, however assignments missed in the first weeks can count as your dropped grades.

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Extra Credit

There are a few opportunities to earn extra credit in the course:

- Write New Quiz Questions (up to 2% extra credit): To review the course material before the Midterm and Final Exams, students will write five of their own quiz/exam questions (due before each exam), noting where in the course the answers are provided.
- Attend Office Hours and post questions to the Office Hours Q&A Forum (up to 2% extra credit)
    - You are encouraged to go to as many office hours as you would like.
    - After you attend an office hour, post a question to the Office Hours Q&A Discussion forum with the question and answer discussed during office hours.
    - You can earn credit for up to 2 questions per week.
    - If you post 10 questions total, you can earn 2% extra credit.
- Complete the SET and R-Course surveys at the end of the course (1% extra credit available for each).

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Lectures and Reading

This course includes approximately five Lecture videos for each Module and then additional videos that go “behind the scenes” to explore further the graphical information in the course, the atmospheric processes in the course, the demonstrations in the course, and the types of careers relevant to the course. The Lecture videos summarize

information from the readings and highlight important points. The Lecture and “behind the scenes” videos are arranged in the order that builds from introductory concepts to more advanced ones, but you can watch them in any order. You may wish to watch some of them twice as you prepare for the quizzes and exams.

BehindTheGraph videos provide an opportunity to explore the numerical information using the Google Sheets provided. Students are encouraged to click the link provided in Canvas to open the Google Sheet to follow along with the description. Students can also make a copy of the Google Sheet to their own Google Drive, and then they can edit the numbers, formulae, and graphs to explore analyses of their own (although this is not required). For this course, students will need to be able to read information from the graphs shown and use it to answer questions.

BehindTheProcess videos provide a visual representation of an important process in the atmosphere. These animations provide a good way to think about different components of the process and how they interact with each other.

BehindTheDemo videos show hands-on demonstrations of atmospheric phenomena, some of which you may be able to try at home with inexpensive, everyday supplies. Here the idea is that “seeing is believing” and these videos don’t lie!

BehindTheCareer videos feature a selection of atmospheric scientists at different career stages who talk about their career path and their current work. Many of the scientists are young UCSD alums, and others are from around the country and the world. Each video includes a discussion about processes and properties of the atmosphere and what they find interesting about the atmosphere.

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Modules Descriptions

This course is divided into ten Modules that describe the atmosphere, its structure and features, and the key properties and processes that determine how the atmosphere works. For a 10-week course, students should complete one module each week.

M1: The first step in studying the atmosphere is **Describing the Atmosphere**. From a general perspective, the Atmospheric Features provide a description of the components, patterns, and layers of air. A brief perspective from Paleoclimatology provides the historical context of how the Earth’s atmosphere has changed. The atmosphere has two types of patterns called Weather and Climate that are distinguished by their time scale and impacts. The structure of the atmosphere consists

of two important lower layers – the Troposphere and Stratosphere. These two layers are distinguished by whether the air temperature increases or decreases as altitude increases, which is illustrated graphically in BehindTheGraph: Standard Atmosphere. Pressure and concentration of air molecules both decrease with altitude, making air expand and cool as it rises as shown by BehindTheProcess: Rising Air Expands.

M2: The key to Earth's unique atmosphere is **Relating Temperature and Water**, because together they control the features of the atmosphere that sustain life on Earth. Intrinsic to the relationship between temperature and water are the concepts of Atmospheric Thermodynamics and Phase, which determine the formation of clouds and the circulation of air around the planet. The Temperature and Lapse Rate provide the metrics that describe atmospheric conditions and structure. The atmosphere is constantly changing, and much of how that happens is by Heat and Adiabatic Processes. But different parts of the Earth system take up heat in different amounts, which is illustrated in this demonstration of Heat Capacity for water and air. Because the properties of water and air are so different, the amounts of the Water Vapor and Relative Humidity in the air cause big changes in how air behaves. An important aspect of these changes is illustrated by BehindTheGraph: Water Saturation, which shows how the amount of water at saturation increases very strongly with temperature. This tight relationship between water and temperature means that the Dew and Frost Points describe how close water is to changing phase in the atmosphere, creating or evaporating clouds.

M3: The altitude of the stratosphere is determined by **Locating the Ozone Layer**, since its formation is the cause of the heating that creates this layer of warming. Ozone absorbs ultraviolet radiation from the Sun, which causes the heating that makes the air warmer at higher altitudes. The ozone formation is illustrated by BehindTheProcess: Making Ozone, which shows how ultraviolet radiation makes ozone from the oxygen molecules in the air. Looking BehindTheGraph: Ozone Formation by Altitude calculates where ozone forms because ultraviolet light is available and because pressure is high enough to make a lot of ozone. The result is the 10-20 km thick Ozone Layer, which covers the Earth and prevents ultraviolet radiation from making it to the surface. Unfortunately What is the Ozone Hole? shows how ozone has been depleted globally and especially in the polar regions. The Chemical Causes of the Ozone Hole are man-made emissions of chlorofluorocarbons (CFCs) and other compounds that catalyze ozone destruction. But those ozone destruction reactions require both sunlight and polar stratospheric clouds, thus ozone would not be depleted without the additional Meteorological Causes of the Ozone Hole – the cold and isolated air within the polar vortex that releases the ozone-destroying chlorine catalysts when the Sun comes up in

the springtime.

M4: **Balancing Solar and Terrestrial Radiation** is the way in which the atmosphere controls the temperature of the Earth's surface. The Electromagnetic Spectrum includes shortwave visible and longwave infrared types of radiation, where their wavelength difference means they are reflected and absorbed differently by the components of the atmosphere. The incoming Solar Radiation is largely composed of visible wavelengths since the Sun's temperature is 6000K, and about 30% of the incoming visible light is reflected by the Earth's albedo. The outgoing Terrestrial Radiation is infrared since the Earth's temperature is less than 300K, with its flux determined by the Earth's temperature to the fourth power. The Earth's Energy Budget explores the many streams of energy in the atmosphere and how they can be simplified into incoming, reflected, greenhouse, and outgoing. These four simplified streams are the focus of the calculations in BehindTheGraph: Radiation and Temperature, which shows how temperature and radiation are related. These relationships are visualized by BehindTheProcess: Earth's Radiation Balance, showing the roles of the albedo and the greenhouse effect. Combining these simplified energy streams provides the link to Earth's Global Surface Temperature, illustrating why it has changed when greenhouse gases have increased.

M5: While the naturally-existing greenhouse gases such as water make the Earth warm enough to live on, the recent trend toward **Accumulating Greenhouse Gases** means that the Earth's temperature is getting warmer than since before living organisms evolved on its surface. The concept of trapping solar heating by not letting warmed air escape is established by reviewing What is a Greenhouse? The Greenhouse Effect in the atmosphere is a modification of this concept because it is infrared radiation rather than warmed air that is trapped to cause a warming. The natural and man-made atmospheric components that trap radiation are called Greenhouse Gases, of which water provides the largest contribution to Earth's warming. Carbon Dioxide is the largest contribution to recent warming because its emissions have increased since the 1850s because of fossil fuel combustion. The sources and sinks of the Carbon Cycle include the natural roles of photosynthesis for removing carbon dioxide and of respiration for producing carbon dioxide. Putting these together, BehindTheGraph: Keeling Curve shows the springtime increases and autumn decreases that are measured each year while revealing the accelerating rate of increasing annual average carbon dioxide concentrations. Methane, another by-product of fossil fuel usage, further contributes as a particularly effective greenhouse gas despite its low concentration and short lifetime.

M6: In addition to gases, condensed components of the atmosphere contribute to **Sizing Aerosol Particles**, and these sizes affect how much incoming solar radiation is

reflected back to space. What is an Aerosol? explains how an aerosol encompasses both the tiny liquid and solid particles that are emitted by natural and man-made sources and the gases in which they are suspended, since the two phases are continuously interacting. Counting the particles in several different ranges of size provides Particle Size Distributions, which document the physical aspects of air quality in the atmosphere. BehindTheProcess: Particle Lifetimes explains why particles of different sizes persist in the atmosphere for different lengths of time. A persistent and severe type of aerosol is Smog, which forms in urban regions like Los Angeles as the result of vehicle emissions and reactions driven by sunlight. To illustrate this secondary type of aerosol production, BehindTheDemo: Orange Haze shows that ozone can oxidize organic vapors to grow particles that are big enough to scatter a laser beam. Some aerosol particles may also be large enough and water-soluble enough to act as Cloud Condensation Nuclei, which serve as sites on which water condenses to form cloud droplets.

M7: One of the most distinguishing features of the Earth and an important player in controlling its climate is revealed by **Characterizing Clouds** and their changing patterns in the atmosphere. The formation of clouds is caused by Changing Vapors to Liquids because there is too much water to be vapor so the extra water will become liquid. The amount by which the water in the air exceeds the maximum amount that the air can include as a vapor is called the Supersaturation. This amount included as a vapor decreases as temperature decreases, which explains why BehindTheDemo: Expansion Cloud shows that the cloud forms when the air cools, if there are aerosol particles present for the water to condense on. This role of aerosol particles in enabling cloud drop formation illustrates why Cloud Properties may be different under different conditions. The particles enable Nucleation of the new liquid water phase as droplets, providing the starting points that join with air motion and supersaturated water vapor to influence the development of cloud components and morphology. Moreover, BehindTheProcess: Cloud Formation shows how cloud formation is made possible by the evaporation of water from the oceans, the cooling of air to reduce the water present as vapor, and the formation of the new liquid drops. Because these processes work differently depending on the motion of the air, its water amount, and its temperature, Cloud Types at different altitudes have very different shapes, radiation effects, and precipitation.

M8: Predicting how weather and climate will change in the future requires **Tracking Transport** by following where air goes from one day to the next, from season to season, and from decade to decade. This motion of air known as Winds brings heat, water, and other components from one region to another and from one altitude to another. An important feature of air motion is the Equator-to-Pole Transport of heat caused by the

higher amount of incoming solar radiation at the equator relative to the lower amount at the poles. This aspect of atmospheric circulation drives Hadley, Ferrel, and Polar Cells to carry warmer air poleward aloft or at the surface, while returning cooler air towards the equator. This longitudinal motion is deflected by the rotation of the Earth which causes the Coriolis Effect, making air in the northern hemisphere rotate clockwise and air in the southern hemisphere rotate counter-clockwise. The combination of these motions gives rise to Jet Streams and Trade Winds that cause latitudinal circulation to the east and to the west, respectively. Interactions of air motion, heat, and water mean that Convection and Storms form in the atmosphere, creating large weather events and affecting climate. Differences in how land and water take up heat also give rise to persistent weather patterns such as Land-Sea Breezes in coastal areas.

M9: In many ways human prosperity relies on **Predicting Precipitation** to identify where freshwater will be available to support plant and animal life on Earth. Precipitation is defined as water falling faster than the air is rising and delivers water to the land and oceans in many different forms. Rain (Warm Precipitation) is the liquid water that can range from a light drizzle of slow, small drops to a torrential downpour of fast-falling, multi-millimeter drops. When temperatures drop below freezing, water forms Snow and Ice (Cold Precipitation) which includes a variety of types such as snowflakes and hailstones. Higher intensity and extended duration events of precipitation often take the form of Storms that are characterized by high wind speeds. Since these weather events can interfere with activities and damage infrastructure, Forecasting with weather models can provide advance warning of extreme events. Precipitation is also the driving force of The Hydrological Cycle, redistributing and purifying water from the oceans to support crop growth and lake replenishment. But precipitation can also be contaminated by pollution, causing Acid Rain which can damage vegetation and structures.

M10: Since the atmosphere is continually changing, **Sensing Climate Change** requires unraveling the forcings and feedbacks of the atmosphere through worldwide observations and targeted modeling. Temperature records show evidence of Climate Change on many scales of time and region, but direct measurements in the last century document unprecedented changes in the rate and amount of warming. Associated with these temperature changes are a diverse array of Climate Impacts that affect plant, animal, and human populations as well as the natural and built environment. To attribute the causes of these effects, Climate Modeling shows that atmospheric and ocean processes can only reproduce observations when human activities are included. Climate models need to also predict the internal responses of the Earth system that enhance or diminish the effects of human activities (and other outside influences), because these Climate Feedbacks need to be included to predict changes in temperature and precipitation. BehindTheProcess: Water Vapor Feedback illustrates the

largest positive feedback, which is the Earth's response to warming from increased carbon dioxide, which increases both ocean evaporation and water saturation to put more water in the air, further enhancing the initial warming. To incorporate these responses in the understanding of climate changes, the Climate Sensitivity accounts for both forcings and feedbacks in determining the overall temperature change. Innovative ideas for Climate Engineering have been proposed to offset global temperature increases by intentional emissions into the atmosphere, but the effectiveness and societal implications of these proposed actions lack the research needed for reliable implementation.

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Policies and Information

Our Virtual Classroom. I hope you will join me in creating a class that upholds these values to further enhance our learning as a community. For more information, please visit: **http://diversity.ucsd.edu.** All UC San Diego students are part of the UC San Diego community and are expected to follow university and UC-wide policies, including the Student Conduct Code. The UC San Diego Student Conduct Code represents the pride and values that define our community, and include the UC San Diego Principles of Community, which further illustrate the expectations for all members of our community.

Academic Integrity and Artificial Intelligence. Reports of alleged violations of academic integrity will be handled under the policies and procedures set forth in the UCSD Policy on Integrity of Scholarship. In this course, you may use artificial intelligence tools, such as Google search and ChatGPT, as an aid to finding answers to homework and quiz/exam questions, if you clearly cite these sources. (You may not use them for image modification in creating the video.) However, answers are considered correct based on the course material rather than cited sources, so please be sure that you verify information from other sources in the context of the course material.

Non-Discrimination and Sexual Harassment. The University of California, in accordance with applicable Federal and State law and University policy, does not discriminate based on race, color, national origin, religion, sex, gender identity, pregnancy, physical or mental disability, medical condition (cancer related or genetic characteristics), ancestry, marital status, age, sexual orientation, citizenship, or service in the uniformed services. The University also prohibits harassment on any of these bases, including sexual harassment, as well as sexual assault, domestic violence, dating violence, and stalking. This nondiscrimination policy covers admission, access, and treatment in university programs and activities. If students have questions about

student-related nondiscrimination policies or concerns about possible discrimination or harassment, they should contact the Office for the Prevention of Harassment and Discrimination (OPHD) at (858) 534-8298, ophd@ucsd.edu, or reportbias.ucsd.edu. Students are encouraged to seek assistance as soon as possible, as time limits may apply to complaint resolution processes. Reports of alleged violations involving sex offenses, including sexual assault and sexual misconduct, will be handled under the policies and procedures set forth in the University of California's Sexual Violence and Sexual Harassment Policy.

Land Acknowledgement. UC San Diego was built upon the territory of the Kumeyaay Nation. From time immemorial, the Kumeyaay people have been a part of this land.

Grading Criteria. Letter Grade: UC San Diego student will be provided a grade between A+ and F that reflects your performance in the course which is included in your grade point average (GPA) calculation. A passing grade counts toward your earned credit hours.

Resources. UCSD provides important services to support you in completing this course, including those listed below.

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Learning and Academic Support

- Ask a Librarian: Library Support Chat or make an appointment with a librarian to focus on your research needs
- First Gen Student Success Coaching Program Peer mentor program that provides students with information, resources, and support in meeting their goals
- Office of Academic Support & Instructional Services (OASIS) Intellectual and personal development support
- Writing Hub Services in the Teaching + Learning Commons One-on-one online writing tutoring and workshops on key writing topics
- Supplemental Instruction Peer-assisted study sessions through the Academic Achievement Hub to improve success in historically challenging courses

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Support for Well-Being and Inclusion

- Basic Needs at UCSD Any student who has difficulty accessing sufficient food to eat every day, or who lacks a safe and stable place to live is encouraged to contact: foodpantry@ucsd.edu | basicneeds@ucsd.edu | (858) 246-2632

- Counseling and Psychological Services Confidential counseling and consultations for psychiatric service and mental health programming
- Triton Concern Line Report students of concern: (858) 246-1111
- Office for Students with Disabilities (OSD) Supports students with disabilities and accessibility across campus

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Community and Resource Centers

- Office of Equity, Diversity, and Inclusion As part of the Office of Equity, Diversity, and Inclusion, the campus community centers provide programs and resources for students and contribute toward the evolution of a socially just campus (858).822-.3542 | diversity@ucsd.edu
- Get Involved Student organizations, clubs, service opportunities, and many other ways to connect with others on campus
- Undocumented Student Services Programs and services are designed to help students overcome obstacles that arise from their immigration status and support them through personal and academic excellence

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Course Calendar

Please refer to Canvas for the most up to date information on due dates.

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