THE SCHOOL FOR FIELD STUDIES

Earth Systems and Climate Science
SFS 3601

The School for Field Studies (SFS)
Center for Climate Studies (CCS)
Puerto Natales, Chile

This syllabus may develop or change over time based on local conditions, learning opportunities, and faculty expertise. Course content may vary from semester to semester.

Course Overview

This course focuses on the physical nature of landscapes and the geologic and seismic complexity of a region firmly situated along the 'ring of fire,' the edge of the Pacific Ocean basin where tectonic activity generates earthquakes and volcanic activity. On a planet whose surface is more than 70% ocean, we will also explore the important role of the oceans in the Earth Systems. We will study the science of climate past and current and the evidence for anthropogenic climate change.

As we build our understanding of how the globe functions, we will consistently ground our learning with our location in Patagonia. From the base of Puerto Natales, many national parks are only kilometers away. Glaciers that belong to the Southern Patagonian Ice Field, the world's second largest contiguous ice field outside the polar regions, will be visited. Chile's dynamic Andes range – which is still growing – and the active volcanoes of the lakes region of Chile are open to discovery. Fragile forests susceptible to wildfire will be examined.

One focus of this course will be the science of climate change, understanding the dynamics of the Quaternary Period (the time when periodic pulses of warm and cold influenced most earth systems; e.g., the ice ages) and the Anthropocene (the period where humans have begun to dominant earth systems). The Chilean Patagonia region, like other high-latitude regions, is hyper-susceptible to changes in climate, and the Southern Patagonian icefield is shown to be more vulnerable to climate change than other glaciers. Unpredictable rain- and snow-fall, glacial melt, temperature shifts, fires and droughts can wreak havoc on slow-growing plant ecosystems. Climatic shifts have effect on the trophic webs, freshwater catchments, and farming and ranching operations.

Understanding the geosphere, biosphere, the cryosphere (the frozen environment) and their interactions, we will weave the study of human action and impact throughout Earth Systems: our food systems, energy systems, and the nexus of water/energy/agriculture and climate. Chile is where climate change can be observed and measured in palpable ways.

Learning Objectives

Through participating in and reflecting on this class, students will be able to:

1. Accurately understand and articulate the mechanism of climate change and become articulate and conversant on the subject in both academic settings and living room conversations.
2. Understand Earth structures and systems including ocean circulation and wind patterns, and how planetary dynamics determine seasons and climate zones. Understand the evidence of how the climate is changing in Patagonia.
3. Be able to read, analyze, and interpret the Intergovernmental Panel on Climate Change reports as well as similar, international, scientific documents with an eye for first principles, rationale behind problems and solutions, and the basis for decisions about how to move forward.
4. Understand current climate commitments – Nationally Determined Commitments – in Chile and in their own home country, region, or city.

Thematic Components and Research Direction

The overarching question we address in the CCS curriculum is:

How can Chile respond to local and global challenges while securing the functionality of its natural and human systems?

Assessment

The evaluation breakdown for the course is as follows:

Assessment Item	Value (%)
Participation	10
Quizzes	10
Field Exercise 1	10
Field Exercise 2	20
Field Notebook	20
Exam	30
TOTAL	**100**

Participation and topic discussions (10%)

Everybody should be prepared for each academic session. This implies reading the materials for each session with enough detail to be able to ask relevant questions; and to participate in analytical discussions about the key issues. Active participation during classes, discussions, assignments and hikes is expected.

Quizzes (10%)

Three short quizzes will be used to evaluate the classroom and field lectures.

Field Exercises (FEX)

Two field exercises will be conducted. With these FEXs students will gain experience for the Directed Research component at the end of the semester. The FEXs require field observation, data collection and report writing.

Context: Science is based on intuition, logic and reason. The scientific method begins with an *observation*; we seek for *patterns* and then formulate *hypotheses* that could explain those patterns. We can also use experiments to test hypotheses. Finally, we conclude on the results thus contributing to a broad theory.

Objective: Our objective is to develop observation skills in the field and to learn the process of the scientific method.

FEX 1 (10%)

Subject: Observational skills and hypothesis testing

Methods: In this exercise, we will use qualitative and quantitative observation to gain experience with basic geoscience field and research skills including rock and mineral identification, surficial and bedrock geologic mapping, relative dating, soil sampling, and identification of geological structures. Students will compare two locations: Torres del Paine National Park and the landscape surrounding the Strait of Magellan. Data will be used to build a geologic map of the region to be housed at the Center for Climate Studies. Students will submit reports discussing spatial and temporal relationships between elements on the map.

FEX 2 (20%)

Subject: Experimental design in geology

Methods: Students will investigate questions related to glacial formation, retreat, and effects on the landscape by mapping a glacial moraine using topographic physical maps, measurements in the field,

and geospatial digital maps (i.e. Google Earth, QGIS, etc.). Questions are developed through a class discussion and divided among students for elaboration. Students will also tie their findings to climate and geological histories.

Assessment: Students will be assessed based on their ability to develop a sound hypothesis, data collection effort, and the written report.

Field notebook (20%): You will develop a comprehensive program field notebook that documents and captures your on-the-ground learning experiences and serves as your primary record of content and reflections during the course. This notebook should accompany you at all times: in the classroom, guest lectures, and the field. All class notes, field notes, data from field exercises, reflective comments and questions on course material, notes from discussions, and short written assignments should be contained in this notebook, which will serve as your main study tool. You may want to develop sections for observations during travel, translations or words in local languages, notes to remember for your directed research, cultural notes, and reflective writing on how this experience is reshaping your understanding of people and the environment. Keep this separate from personal journaling you may do. Additional course handouts should be kept a separate folder.
When using citable material from your field notebook in written assignments, use the following format to acknowledge the source: (James Cramer, Field notes, Chiloé Island, 12 October 2019). Whenever possible, use the name of the person providing the information; if not possible, cite descriptively, for example: "Ranger at Glacier Grey in Torres del Paine."

Exam (30%)
One exam will be given based on material covered in lectures, readings, and field experiences.

Grade corrections in any of the above items should be requested in writing at least 24 hours after assignments are returned. No corrections will be considered afterwards.

Grading Scheme

A	95.00 - 100.00%	B+	86.00 - 89.99%	C+	76.00 - 79.99%	D	60.00 - 69.99%
A-	90.00 - 94.99%	B	83.00 - 85.99%	C	73.00 - 75.99%	F	0.00 - 59.99%
		B-	80.00 - 82.99%	C-	70.00 - 72.99%		

General Reminders

Plagiarism – using the ideas or material of others without giving due credit – is cheating and will not be tolerated. A grade of zero will be assigned for anyone caught cheating or aiding another person to cheat either actively or passively.

Deadlines – Deadlines for written and oral assignments are instated to promote equity among students and to allow faculty ample time to review and return assignments before others are due. As such, deadlines are firm; extensions will only be considered under extreme circumstances. Late assignments will incur a penalty of 10% of your grade for each day you are late. After two days past the deadline

assignments will not be accepted anymore. Assignments will be handed back to students after a one-week grading period.

Participation – Since we offer a program that is likely more intensive than you might be used to at your home institution, missing even one lecture can have a proportionally greater effect on your final grade simply because there is little room to make up for lost time. Participation in all components of the course is mandatory, it is important that you are prompt for all activities, bring the necessary equipment for field exercises and class activities, and simply get involved.

Course Content

Type: L: Lecture and discussion, **FL:** Field Lecture, **GL:** Guest Lecture, **FEX**: Field Exercise, **GP**: Group Project

No	*Title and outline*	*Type*	*Time (hrs)*	*Required Readings*
EC 1	**Commitment to diversity, inclusion and equity – making the classroom a place that enhances all students' learning.** Orientation, discussion, and exploration of equity in different learning styles, perspectives, and lived experiences. (Shared class session with Patagonian Ecology.)	L	2.5	(Barnes, Marín-Spiotta, & Morris, 2018; Crosby, 2018; hooks, 1994; Prescod-Weinstein, 2017)
EC 2	**Introduction to Earth Systems and Climate:** Review syllabus, field exercises, questions and expectations for the semester.	L	2.0	Chapters 2-3 from Denny (2008) (Ruddiman, 2014b, 2014c, 2014d; Schneider, 2000)
EC 3	**Earth Structure, Geologic history and plate tectonics:** Dynamics of our planet and why coastal Chile is part of the "Ring of Fire"?	L	2.0	(Ammon, 2018; Moreira-Muñoz, 2011; Moreno & Gibbons, 2007) (Marshak, 2015a)
EC 4	**Climate variability and climate history.** Weather and climate: a) What's the difference between climate and weather? b) The history of formal climate studies c) Orographic (mountain) precipitation in the Andes and the resulting rain shadow	L	1.5	Selection from Latorre et al. (2007) (NASA, 2005; Pielke et al., 1998; Ruddiman, 2014b)
EC 5	**Anthropogenic climate change** Discussion and activity-based understanding of how greenhouse gases in the atmosphere trap heat;	L/GP	2.5	(Rostin & Migliozzi, 2015; Ruddiman, 2014a; Schmidt, 2018)

No	Title and outline	Type	Time (hrs)	Required Readings
	exploration of scientific evidence for the "human fingerprint" of climate change			
EC 6	**Ocean circulation and Ocean-atmosphere interactions:** the Coriolis effect; winds and currents. The southern Pacific and Atlantic Ocean dynamics	FL	2.0	Chapters 7-8 from Denny (2008) Review Ch. 8 in Denny 2008
Multi-day trip to Torres del Paine National Park (TPNP)				
EC 7	**The Geology of Torres del Paine** Reading the landscape, understanding the physical features of the park and their influence on geological and ecological dynamics.	FL	2.0	
EC 8	**FEX 1: Introduction to observations and mapping in the geosciences** First location for collecting quantitative and qualitative data on landscape variables to build geologic map of the region.	FEX	3.0	
EC 9	**Alpine Glaciers, Glaciers and climate change**: Melting glaciers in the Southern Patagonia Icefield Glaciers as a source of freshwater for human communities	FL	1.0	(McKibben, 2018; Pelto, 2017) (Bury et al., 2011; Hansen, 2018)
Multi-day boat expedition: fjords, Strait of Magellan, Cape Horn, and penguin colony				
EC 10	**Museum visit** (Strait of Magellan Park/Museum, before boarding the ship): History of navigation at Cape Horn	FL	1.0	Optional reading: Chapter 1 from Denny (2008)
EC 11	**Forces carving the physical landscape**: geology, glaciers, and the fjords (Boat expedition)	FL	1.0	Review from (Marshak, 2015a)
EC 12	**FEX 1: Observations and mapping in the geosciences** (during boat	FEX	3.0	

No	Title and outline	Type	Time (hrs)	Required Readings
	expedition). Second location for data collection.			
EC 13	**Long-term monitoring**: daily on the boat expedition, varies with current projects conducted in collaboration with researchers at the Universidad de Magallanes. Potential sampling and monitoring includes: ocean water chemistry, phenology of flowering plants on land, and the impact of invasive mammals on seabird nesting success (Boat expedition)	FEX	6.0	
EC 14	**Climate-change impacts at high latitudes** (Boat expedition) Effects of global change in polar regions, land ice versus sea ice, impacts on terrestrial and marine ecosystems	FL	1.0	Selections from (Krupnik & Jolly, 2002) and (Larsen, 2014)
Mid-semester break				
EC 15	**Soils: overview** Understanding the origin and generation of fragile Patagonian soils and the dynamics of plant cover	L	1.0	(Chapin III, Matson, & Mooney, 2002)
EC 16	**Soil: survey techniques** Identification of soil characteristics, composition, and texture.	FL	2.0	
EC 17	**Land use and land cover** Observation and discussion of human land use patterns in remote regions of Patagonia	L	1.0	(Foley et al., 2005)
EC 18	**Ecology and biodiversity** Connecting earth systems and climate to patterns of global and regional biodiversity	L	1.0	(Editor, 2018)
Multi-day expedition to Perito Moreno Glacier and Glaciarium Museum in El Calafate, Argentina				
EC	**Glaciers (Glaciarium museum visit)**:	FL	1.0	

No	Title and outline	Type	Time (hrs)	Required Readings
19	sea-level glaciers, as distinct from alpine glaciers, and how glacial studies provide a record of past climate			
EC 20	**FEX 2: Mapping moraines** Students develop research questions to investigate glacial history, estimate retreat, and map sediments.	FEX	4.0	
EC 21	**Earth Systems review**: geosphere, biosphere, oceans, and atmosphere a) Their interactions b) Potential disruptions to current systems behavior or tipping points	FL	2.0	(Gattuso et al., 2015; Gruber, 2011)
EC 22	**The Quaternary and the Anthropocene**: What is meant by the geologic epoch of the "Anthropocene" when human influences dominate Earth processes?	FL	1.0	(Elena M Bennett et al., 2016) Optional reading: (Elena M. Bennett, 2018) and https://theanthropocene.org/
EC 23	**Energy**: renewable energy, fossil fuels, and energy policy in Chile	FL	1.0	Chile's long-term energy policy: "Energy 2050" and (Proaño, 2018)
EC 24	**Chilean climate commitments within the international community**: Intended Nationally Determined Commitments	L	1.0	(Siemens, 2015)
EC 25	**Climate solutions**: student inquiry into proposed Chilean climate solutions, within the framework of the Paris Accord of 2015 or the further challenge of limiting average warming to 1.5°C Student inquiry into solutions from their home town/city/regions Climate adaptation and climate mitigation plans; local coastal plans as relevant	GP	3.0	(IPCC, 2018a, 2018b)
EC	**Climate grief and ecological grief**	L	1.5	(Cunsolo & Ellis, 2018; Holthaus,

No	Title and outline	Type	Time (hrs)	Required Readings
26	(Shared class session with Patagonian Ecology)			2018; Lin, 2018; Sinclair, 2018) Optional reading: (Macy, 1991)
EC 27	Review session for Exam	L	2.0	
EC 28	Exam 2		2.0	
Multi-day trip to Puerto Montt region: La Arena; Osorno Volcano; and Chiloé Island				
EC 29	**Natural hazards, natural processes**: the "fire" in Fire and Ice – volcanoes – and earthquakes in Chile.	FL	2.0	(Barrientos, 2007; Stern et al., 2007) Optional reading: (Marshak, 2015b, 2015c) Review Chilean volcanoes reading (Stern et al., 2007)
EC 30	**Freshwater and hydrology** Understanding the development and importance of Lakes Region of northern Patagonia	FL	1.0	Review (Bury et al., 2011) Selection from Muñoz, Fernández, and Varas (2007)
EC 31	**Global and regional food systems**: Patagonian agriculture of northern Patagonia and agriculture and climate connections.	FL	1.0	(Kremen, 2017; Mackendrick, 2014) Selection from Ruddiman (2010)
EC 32	**Making connections** the nexus of climate, agriculture, water and energy	FL	1.0	Further selection from Ruddiman (2010)
EC 33	**Comparison and synthesis** high-latitude, alpine-dominated environments, and the mild, temperate climate of Chiloé Island (Puerto Montt region)	FL	1.0	Discussion during Puerto Montt/Chiloé expedition
	Total contact hours		**60**	

Reading List

Ammon, C. J. (2018). Introduction to Plate Tectonics, from http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/plate_tect01.html

Barnes, R. T., Marín-Spiotta, E., & Morris, A. R. (2018). Building community to advance women in the geosciences through the Earth Science Women's Network. In B. A. Johnson (Ed.), *Women and Geology: Who Are We, Where Have We Come From, and Where Are We Going?* (Vol. 214, pp. 121-129). Boulder, Colorado: Geological Society of America.

Barrientos, S. E. (2007). Earthquakes in Chile *The Geology of Chile*. Bath, UK: Geological Society of London.

Bennett, E. M. (2018). Bright spots in the Anthropocene, 2018, from http://www.futureearth.org/bright-spots-seeds-good-anthropocene

Bennett, E. M., Solan, M., Biggs, R., McPhearson, T., Norström, A. V., Olsson, P., . . . Biermann, F. (2016). Bright spots: seeds of a good Anthropocene. *Frontiers in Ecology and the Environment, 14*(8), 441-448.

Bury, J. T., Mark, B. G., McKenzie, J. M., French, A., Baraer, M., Huh, K. I., . . . López, R. J. G. (2011). Glacier recession and human vulnerability in the Yanamarey watershed of the Cordillera Blanca, Peru. *Climatic Change, 105*(1-2), 179-206.

Chapin III, F. S., Matson, P. A., & Mooney, H. A. (2002). Geology and soils *Principles of Terrestrial Ecosystem Ecology* (pp. 46-67). New York, NY: Springer-Verlag.

Crosby, J. R. (Writer) & Stanford_First_Generation_Low_Income_Partnership (Director). (2018). What I Wish My Professor Knew.

Cunsolo, A., & Ellis, N. R. (2018). Ecological grief as a mental health response to climate change-related loss. *Nature Climate Change, 8*(4), 275.

Denny, M. (2008). *How the ocean works: an introduction to oceanography*. Princeton and Oxford: Princeton University Press.

Editor, E. (2018, 12 March 2018). What is biodiversity and why does it matter to us?, *The Guardian*.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., . . . Snyder, P. K. (2005). Global consequences of land use. *Science, 309*(5734), 570-574. doi: 10.1126/science.1111772

Gattuso, J. P., Magnan, A., Bille, R., Cheung, W. W. L., Howes, E. L., Joos, F., . . . Turley, C. (2015). Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. *Science, 349*(6243). doi: 10.1126/science.aac4722

Gruber, N. (2011). Warming up, turning sour, losing breath: ocean biogeochemistry under global change. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences, 369*(1943), 1980-1996. doi: 10.1098/rsta.2011.0003

Hansen, K. (2018). Melting beauty: the Patagonian Icefields Retrieved Nov 2018, from https://climate.nasa.gov/news/2763/melting-beauty-the-patagonian-icefields/

Holthaus, E. (2018, 15 October 2018). If you're suffering from climate grief, you're not alone. *Grist Magazine, Inc.*

hooks, b. (1994). Engaged Pedagogy *Teaching to Trangress: Education as the Practice of Freedom* (pp. 13-22). New York, NY: Routledge.

IPCC. (2018a). Global Warming of 1.5°C: Summary for Policy Makers. http://ipcc.ch/report/sr15/: IPCC.

IPCC. (2018b). Global Warming of 1.5°C: Technical Summary http://ipcc.ch/report/sr15/: IPCC.

Kremen, C. (2017, 7 July 2017). How to feed the world without killing the planet? Retrieved from https://blog.nature.org/science/2017/07/07/feed-world-without-killing-planet-agriculture-food-security/

Krupnik, I., & Jolly, D. (2002). *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change. Frontiers in Polar Social Science*: ERIC.

Larsen, J. N., O.A. Anisimov, A. Constable, A.B. Hollowed, N. Maynard, P. Prestrud, T.D. Prowse, and J.M.R. Stone. (2014). Polar regions. In V. R. [Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (Ed.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution*

of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1567-1612). Cambridge, UK: Cambridge University Press.

Latorre, C., Moreno, P., Vargas, G., Maldonado, A., Villa-Martínez, R. P., Armesto, J. J., . . . Grosjean, M. (2007). Late Quaternary environments and paleoclimate. In T. Moreno & W. Gibbons (Eds.), *The Geology of Chile* (pp. 309-328). Bath, UK: Geological Society of London.

Lin, D. (Writer). (2018). Rise: a poetry expedition to Greenland's melting glaciers. In O. Go (Producer).

Mackendrick, N. (2014). Foodscape. *Contexts, 13*(3), 16-18.

Macy, J. (1991). Despair Work *World as Lover, World as Self: Courage for Global Justice and Ecological Renewal* (pp. 15-28). Berkeley, CA: Parallax Press.

Marshak, S. (2015a). Part I: Our Island in Space *Earth: Portrait of a Planet* (Fifth ed., pp. 12-115). New York and London: WW Norton & Company.

Marshak, S. (2015b). A Violent Pulse: Earthquakes *Earth: Portrait of a Planet* (Fifth ed., pp. 312-358). New York and London: WW Norton & Company.

Marshak, S. (2015c). The Wrath of Vulcan: Volcanic Eruptions *Earth: Portrait of a Planet* (Fifth ed., pp. 272-311). New York and London: WW Norton & Company.

McKibben, B. (2018, 12 September 2018). High ice and hard truth: the poets taking on climate change, *The Guardian*. Retrieved from https://www.theguardian.com/environment/2018/sep/12/high-ice-hard-truth-a-poetry-expedition-to-greenlands-melting-glaciers-bill-mckibben

Moreira-Muñoz, A. (2011). The Extravagant Physical Geography of Chile *Plant geography of Chile* (Vol. 5, pp. 351). Dordrecht Heidelberg London New York: Springer Science & Business Media.

Moreno, T., & Gibbons, W. (Eds.). (2007). *The Geology of Chile*. Bath, UK: Geological Society of London.

Muñoz, J., Fernández, B., & Varas, E. (2007). Chilean Water Resources. In T. Moreno & W. Gibbons (Eds.), *The Geology of Chile* (pp. 215-230). Bath, UK: Geological Society of London.

NASA. (2005). What's the difference between weather and climate? , from https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

Pelto, M. (2017). Alpine Glaciers: An Introduction *Recent climate change impacts on mountain glaciers* (pp. 1-9). Oxford, UK: John Wiley & Sons.

Pielke, R. A., Avissar, R., Raupach, M., Dolman, A. J., Zeng, X., & Denning, A. S. (1998). Interactions between the atmosphere and terrestrial ecosystems: influence on weather and climate. *Global change biology, 4*(5), 461-475.

Prescod-Weinstein, C. (2017). Black women physicists in the wake: science and slavery are inextricably intertwined in our history. *Medium*.

Proaño, M. (2018, 9 July 2018). Is an energy revolution underway in Chile?

Rostin, E., & Migliozzi, B. (2015). What's Really Warming the World? *Bloomberg Businessweek*.

Ruddiman, W. F. (2010). *Plows, plagues, and petroleum: how humans took control of climate*: Princeton University Press.

Ruddiman, W. F. (2014a). Causes of Warming Over the Last 125 Years *Earth's Climate: Past and Future* (Third ed., pp. 375-392). New York: W.H. Freeman and Company

Ruddiman, W. F. (2014b). Climate Archives, Data, and Models *Earth's Climate: Past and Future* (Third ed., pp. 55-77). New York: W.H. Freeman and Company

Ruddiman, W. F. (2014c). Earth's Climate System Today *Earth's Climate: Past and Future* (Third ed., pp. 19-54). New York: W.H. Freeman and Company

Ruddiman, W. F. (2014d). Overview of Climate Science *Earth's Climate: Past and Future* (Third ed., pp. 3-17). New York: W.H. Freeman and Company

Schmidt, G. (2018). How Scientists Cracked the Climate Change Case, *The New York Times*. Retrieved from https://www.nytimes.com/2018/10/24/opinion/climate-change-global-warming-trump.html

Schneider, S. H. (2000). Why Study Earth Systems Science? In W. G. Ernst (Ed.), *Earth Systems: Processes and Issues* (pp. 5-12). Cambridge, UK and New York, NY, USA: Cambridge University Press.

Siemens, M. (2015). Chile's Intended Nationally Determined Contribution on Climate Change, from https://unfccc.int/sites/default/files/chile_indc.pdf

Sinclair, P. (2018). Scientists weigh public's emotional responses to climate risks Yale_Climate_Connections.

Stern, C., Moreno, H., López-Escobar, L., Clavero, J., Lara, L., Naranjo, J., . . . Skewes, M. (2007). Chilean Volcanoes *The Geology of Chile* (pp. 147-178). Bath, UK: Geological Society of London.