Earth Systems and Climate Science
SFS 3601

Syllabus
4 credits

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.

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COURSE CONTENT SUBJECT TO CHANGE

Please note that this is a copy of a recent syllabus. A final syllabus will be provided to students on the first day of academic programming.

SFS programs are different from other travel or study abroad programs. Each iteration of a program is unique and often cannot be implemented exactly as planned for a variety of reasons. There are factors which, although monitored closely, are beyond our control. For example:

- Changes in access to or expiration or change in terms of permits to the highly regulated and sensitive environments in which we work;
- Changes in social/political conditions or tenuous weather situations/natural disasters may require changes to sites or plans, often with little notice;
- Some aspects of programs depend on the current faculty team as well as the goodwill and generosity of individuals, communities, and institutions which lend support.

Please be advised that these or other variables may require changes before or during the program. Part of the SFS experience is adapting to changing conditions and overcoming the obstacles that they may present. In other words, this is a field program, and the field can change.

Course Overview

Many national and international reports support the statement that "climate change and global warming is the mother of all battles because it is a battle for humanity's survival", but, it is more than this. Patagonia is a privileged location for climate change studies in the Southern Hemisphere, given its unique and continuous extent below 45 °S latitude. This region is considered a "hotspot" of paleoclimatic information that has witnessed, in different time scales, abrupt global changes, providing a natural laboratory for the study of past climate processes.

In the context of the present and future impact of climate change, Patagonia also has a lot to say, since its ecosystems are affected by drivers of global climate change, and science is becoming more able to detect these rapid changes and explain these processes. In addition, ongoing research shows that to answer "big questions" about climate change, an interdisciplinary vision and collaboration between different disciplines is mandatory.

This course provides an overview of the Earth Systems – geosphere, cryosphere, hydrosphere, and atmosphere – the dynamic interactions between them, and the unique characteristics that these components display in Patagonia. The course covers Systems Theory, the overall characteristics of each system, and why we should think of the Earth as a system that is more than the sum of its parts. We will examine all systems in detail and find the relationship between them and switch the different time scale over which they operate. The course emphasizes the cryosphere and climate science and how these components interact in Patagonia and what will happen with them under climate change scenarios.

Learning Objectives

Successful completion of this course means that you will have learned about the myriad components of the Earth's systems and their interactions, with a notable emphasis on how our climate system works in a continuous flow of matter and energy. You will use class lectures and discussions; readings from scientific literature or recognized source; also you will test your ability to observe, question and conclude used to problem assignments; field exercises; and exams, in other to understand each of the key components of Earth's system, that is, the atmosphere, hydrosphere, cryosphere, geosphere, and biosphere, and they interactions.

You will learn to identify the roles of each system in determining a region's climate, and landforms and in forcing climate to change along various time frames, ranging from mere years to millions of years. Understanding the dynamic between climate and the cryosphere in Patagonia will be another part of the outcomes you will obtain from this class, and its interaction with the other components of the earth system will have a special focus on Patagonia. In addition to theoretical concepts, you will learn various field skills. You will know different techniques of the use of GPS and drone to build Digital Elevation Models (DEM) with hydroclimatic and glaciology applies.

Thematic Components and Research Direction

The large-scale question we address in this course is:

How is climate change affecting different components of the terrestrial system in Patagonia?

1. Subtheme 1

The scarcity of ground stations and hydroclimatic studies in southern Patagonia creates difficulties in monitoring and evaluating the ways that climate is changing in the area. One way to mitigate this situation is to install a long-term monitoring station in the area. In order to install a station in a significant location, it is important to first evaluate areas that could be candidates and conduct characterization of these areas in order to select a candidate watershed.

2. Subtheme 2

Southern Patagonia has complex, interconnected lacustrine and stream systems that directly depend on mountain and glacier hydrology. Furthermore, they support the various economic pillars of this region, namely livestock, mining, and tourism. Given the implications of climate change on they hydrosphere, it is imperative to assess the variability and possible trends on the hydroclimatic system and its impacts on hydrology.

Assessment

The evaluation breakdown for the course is as follows:

Assessment Item	Value (%)
Participation	15
Quizzes	15
Field Exercise 1	5
Field Exercise 2	10
Field Notebook	20
Field Reports	15
Final Exam	20
TOTAL	**100**

Participation (15%)

Grading of the participation component will be based on the following individual parts. All students should be prepared for each class by reading the required literature on each topic and asking or answering relevant questions to clarify concepts. It is also expected that all students actively participate and contribute to discussions that may arise during classroom and field lectures. Additionally, during the semester, all students will be required to briefly introduce a specific topic by presenting the main ideas of a paper and leading the discussion on the specific topics.

Quizzes (15%)

This course has five short quizzes, each one accounting for 3% of the overall grade, to evaluate the contents of lectures.

FEX 1: The Ice Path (5%)

Objective: This assignment is to practice observational field skills and connect a theoretical understanding of the glacial processes and landscape formation.

Methods: We will use observation to find clues to the glacial process in the landscape. Students will produce a schematic and analytical drawing, as well as a 1-page report. More detailed instructions are forthcoming.

FEX 2: Water and Carbon Pathways (10%)

Objective: This assignment is to apply both data analysis and connect a theoretical understanding of the relationship between the atmosphere and ecosystems.
Methods: We will use scientific equipment that measures the flows of H2O and CO2 between an ecosystem and the atmosphere. Students will produce a 2-page report with a description of the main processes involved in these gases exchanges and calculate the flows for a data record to be delivered. More detailed instructions are forthcoming.

Field Notebook (20%)

Each location we travel to provides a context for observation and learning. As we progress through the semester, the class themes will become easier to see in the landscape, and the things we see in a new location deepen the understandings we made in prior spaces. A field notebook is a physical means of capturing the observations and insights that you gain in the field over the course of the semester.

You should make personal observations in every field outing – apart from any formal academic activities (e.g., FEX, field lectures) that take place there. These personal observations can form the basis of entries written up in a designated field notebook. You can choose how you wish to develop your field notebook entries to best match your own observational and writing style. NOTE: the field notebook is a shared assignment across the core courses. It will be handed in twice during the semester: before the Midsemester Break and after the Final Exam. Keep in mind the following grading rubric:

- **Completeness (2%):** Your field notebook must have at least one entry per day in the field, and you must have at least one entry for each class at each hand-in. In addition, each individual entry must include the location, the date and time, the course to which the entry is directed, and – of course – the observation you made at the indicated date and time.
- **Coherence (5%):** Each entry should be coherent in the way it presents information. This includes legibility, clear argumentation, a connection of ideas, and concept development. If figures and drawings are included, coherence would mean placing them in their observed context and indicating how they connect with (or stand independent from) any accompanying writing.
- **Correctness (8%):** Each entry should connect with topics covered during lectures, discussions, readings, etc. In addition, the specifics contained in the entry must be factually correct. There is no requirement for formal citations.
- **Connection (5%):** Each entry should connect the field observation with something external to the location – ideally connecting to **themes** being built and discussed across your field notebook entries. Examples of themes: history of fire, the effects of wind, the impacts of conservation initiatives, and even comparisons with familiar landscapes back home. The key is to expand your entries beyond just the lectures or activities of the associated field trip and write your entries with the idea of using them to explore concepts and ideas throughout the semester, instead of having a set of disconnected entries.

Field Report (15%)

Students will be assessed based on their ability to develop field observations and linking with the class topics, making a small report for the indicated field activities.

Final Exam (20%)

A written final exam will be given at the end of this course. This will include a field observations component, and the topics will be based on material covered in lectures, readings, and previous field experiences.

Grading Scheme

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.

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.

Use of Computers - Personal screens (e.g., smartphones, tablets, and computers) cause distractions in the classroom, except for specific activities. Revising lecture notes manually has been shown in various studies to help with information retention and integration of concepts. In addition, working directly with written notebooks diminishes the distraction of those around you, which has been shown to increase with the general use of screens in a classroom setting. Finally, we actively discourage everyone from bringing tablets and computers on all day trips and nearly all multi-day trips out of the Center, due to concerns about the weather, breakage, and security. In sum, we encourage everyone to take handwritten notes, both in the classroom and in the field. Students with learning accommodation granted through the Office of Academic Affairs must talk with the Head of Faculty.

A Note on Class Readings - Many classes have two or more papers associated with them. In these cases, different readings will be assigned to different reading groups. The members of each group will be expected to have read the critical portions of their article for the upcoming class, to help lead the discussion on the topics covered in their paper. Many of the articles are written for specialists, thus the material may not be easy to understand. We have part of ESCS02 to review strategies for reading scientific papers and I will advise you of the required sections for each reading during the semester.

Course Content

Type: CA: Class activity, **D**: Discussion, **FL:** Field Lecture, **GL:** Guest Lecture, **FEX:** Field Experience, **L**: Lecture, **O**: Orientation

*Not all readings are required. See above note on class readings.

No	*Title and outline*	*Type*	*Hours*	*Readings*
1	**Course Introduction** Description of the course, principal themes, and methodology	O	1.0	
2	**A) Introduction to Earth Systems and Climate Sciences** General description of Earth Systems and Climate Sciences with emphasis on Patagonia and define different time scales to study these systems. **B) Read papers by groups** Strategy and methods to read papers **C) Climate Systems-Atmosphere** General description of the energy fluxes between Earth systems, general description of the interaction between atmosphere and climate **D) Introduction of Glacier Systems** Description of cryosphere, introduction to glacier systems and their process, description of the interaction between glaciers and the landscape	L; CA	4.0	Steffen et al., 2020 Colling & Open University. Oceanography Course Team., 2001 Vaughan et al., 2013
3	**Fluctuations and landscape evidence of glaciations** Identify and interpret the processes on the landscape	FL	1.0	Sagredo et al., 2011
4	**A) Glaciology and Climate Changes** How ice records and responds to Climate Variability. **B) Frontal Glacier reconstruction** GIS Introduction **C) Glacier History** Review of glacier history in Patagonia **D) Student reading and Presentations**	L; CA	4.0	Broecker & Denton, 2015 Hock et al., 2017 Kilian & Lamy, 2012 Moreno et al., 2015
5	**FEX 1: The Ice Path** Reconstruction of glacier history - draw and interpret the glacier processes and their evidence on the landscape.	FL	2.0	García et al., 2012
6	**Reconstruction of Past Climatic Condition** Find and discuss past climate conditions and processes around the Cueva del Milodón and how they are recorded by nature.	FL	1.0	Kilian & Lamy, 2012
7	**A) Hydrosphere and Cryosphere** Introduction to the hydrosphere, the water cycle in Patagonia, ice and water interactions in a changing world. **B) Student Activities** Hydrosphere and cryosphere interactions, data repositories **C) Changes in the Stream and Lacustrine Systems** Recent changes in the stream-lacustrine systems in Patagonia.	L; CA	4.0	Allan et al., 2020 Hock et al., 2019

No	Title and outline	Type	Hours	Readings
8	**Volcanism and Climate** Description of volcanism and climate interactions, and explain Pali Aike volcanism process	FL	1.0	Ross et al., 2011
9	**Geosphere and Volcanism** Description of geosphere systems and their principal processes, with a focus on the volcanic and layering process	FL	1.5	Douet, 2019
10	**Soils** Description of the process of soil profile development with an emphasis on coal formation and environmental risk	FL	1.0	Otero et al., 2012
11	**Stream and Lacustrine Systems** Recognition of stream and lacustrine systems and discuss their changes over the last years.	FL	1.5	Huggett, 2016 Chap. 10
12	**A) Climatic Change and Air Quality** Description of air quality management **B) Student Activities** GIS Introduction **C) Climatic Change and Air Quality, Part 2** How these processes are affected in a warming world and the different feedback between the Earth systems components. **D) Paper Discussions**	L; CA	4.0	Cordero et al., 2022 Jacob & Winner, 2009 Kinney, 2008
13	**Wildfires and Climate** Description of climate and fire interactions.	FL	1.5	Turetsky et al., 2015
14	**A) Physical Glaciology** Physical processes of glacier formation, and its sensitivity and feedback on climate variability. **B) GIS Activities 2** **C) Control on glacier cycles** Glacial cycles, great past climatic events and global drivers **D) Data analysis exercises**	L; CA	4.0	Cuffey & Paterson, 2010 Broecker & Denton, 2015 Oerlemans, 2001 Oerlemans, 2005
15	**Integrated discussion**	D	1.0	
16	**Overview of Los Lagos Trip**	L	1.0	
17	**Seismicity, Earthquakes and Tsunamis** Earthquakes of Chile, evidence, and records focusing on the great earthquake of 1960 in Chiloé	FL	1.0	Plafker & Savage, 1970
18	**A) Biogeochemical Cycle** Biogeochemical cycle as part of Earth systems and climate science. **B) FEX 2: Water and Carbon Pathways** Understand the eddy covariance measurement technique and process and interpret its different flows	FL; FEX	2.0	Baldocchi, 2014
19	**A) Volcanic Systems** Volcanic systems and process in Los Lagos Region.	FL	4.0	Castruccio et al., 2016

No	Title and outline	Type	Hours	Readings
	B) Volcanic History Volcanic history of North Patagonia and its evidence on Los Lagos Region. **C) Volcanic History** Volcanic history of North Patagonia with a focus on Volcán Osorno **D) Volcanic Products and Shapes** Recognition of forms and processes on Volcán Osorno.			Bechon et al., 2022
20	**Data Analysis and Climatic Trends**	CA	1.0	
21	**A) Coastal Systems/Fjords** Chilean Patagonian fjords in a warming world **B) Review/Discussion FEX2** **C) Review and discuss glacier and ocean interactions**	L; CA	3.0	Davies et al., 2020
22	**Torres del Paine** Geological and glaciological processes in Torres del Paine Massif	FL	1.5	Davies et al., 2020
23	**Alpine Geomorphology** Evolution of mountain landscape from original uplift to weathering and glaciation impacts.	FL	1.5	Huggett, 2016
24	**Rapid Climatic Change Event** Review and discussion about the recent and rapid changes on Grey Glacier.	FL	2.0	Weidemann et al., 2018
25	**Overview of last trip**	CA	1.0	
26	**A) Global and Patagonian Climate** Characterization of the climate in Patagonia **B) Student Presentations and Discussion** Earth Systems and Past Global Changes; Recent evidence of climate change on Patagonia **C) Climate over the last 2000 years** Review of climate change over the last 2000 years and its impact on the Earth Systems **D) Future Climate** Predictions, models, and their implication for Earth Systems in Patagonia	L; CA	4.0	Aguirre et al., 2021 Garreaud et al., 2013 Moreno et al., 2014 Meehl et al., 2020
27	**Integrated discussion**	D	1.5	
28	**Final Exam**		3.0	
	Total Hours		60	

Reading List

*Not all readings are required. See above note on class readings.

1. Aguirre, F., Squeo, F. A., López, D., Grego, R. D., Buma, B., Carvajal, D., Jaña, R., Casassa, G., & Rozzi, R. (2021). Gradientes Climáticos y su alta influencia en los ecosistemas terrestres de la Reserva de la Biosfera Cabo de Hornos, Chile. Anales Del Instituto de La Patagonia, 49.
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10. Corbella, H., & Lara, L. E. (2008). Late Cenozoic Quaternary Volcanism in Patagonia and Tierra del Fuego. Developments in Quaternary Science, 11, 95–119. https://doi.org/10.1016/S1571-0866(07)10006-3
11. Cordero, R. R., Sepúlveda, E., Feron, S., Wang, C., Damiani, A., Fernandoy, F., Neshyba, S., Rowe, P. M., Asencio, V., Carrasco, J., Alfonso, J. A., MacDonell, S., Seckmeyer, G., Carrera, J. M., Jorquera, J., Llanillo, P., Dana, J., Khan, A. L., & Casassa, G. (2022). Black carbon in the Southern Andean snowpack. Environmental Research Letters, 17(4), 044042. https://doi.org/10.1088/1748-9326/AC5DF0
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