THE SCHOOL FOR FIELD STUDIES

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 the 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 the past climate processes and its interaction with the earth system.

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 sources; also you will test your ability to observe, question and conclude used to problem assignments, field exercises, and integrated discussions, in other to understand each of the key components of Earth’s systems, that is, the atmosphere, hydrosphere, cryosphere, geosphere, and biosphere, and their 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 research skills. You will learn different techniques of the use of GIS (Geographic Information System), drone applications, data management, and climate analysis with hydroclimatic and glaciological foci.

Assessment

Assessment Item	Value (%)
Final Exam	20
Field Notebook	15
Field Exercises	15
Quizzes	15
Class Activities	15
Participation	10
Integrated Discussion	10
TOTAL	**100**

Final Exam (20%)

Students will apply course topics and put skills into practice. The final exam will contain multiple choice plus three essay question options, where students will choose one to answer.

Field Notebooks (15%)

Each field expedition provides a unique opportunity for observation, learning, and connecting course concepts to real-world environments. As the semester progresses, students will increasingly recognize class themes manifesting in the landscape, deepening their earth system understanding. Maintaining a field notebook is essential for recording observations and reflections throughout the semester and the way to do it could be different for each student. Developing the habit of attentively observing surroundings and linking them to broader earth systems processes is a key goal of the course. Field excursions are invaluable for strength observational skills, and students are encouraged to use their field notebooks not merely for summarizing academic concepts but as a space for personal insights, thoughts, sketches, and reflections. The student should select 4 entries (2 for each half of the semester) to put on an online platform (as a trip-blog) to be reviewed and evaluated.

Field Exercises (15% - 7.5% each)

FEX 1: The Ice Path

Objective: This assignment is to practice observational field skills and connect a theoretical understanding of the glacial processes and landscape formation and use different technics to show these processes on the locations visited.
Skills to develop: GPS survey, GIS, Remote Sensing
Methods: We will use observation to find clues to the glacial process in the landscape and digital techniques. Students will produce a schematic and analysis drawing also including a digital map in a 1-page report. More detailed instructions are forthcoming.

FEX 2: Climate and its relationship with water pathways

Objective: This assignment is to apply both data analysis and connect a theoretical understanding of the relationship between the atmosphere and ecosystems.
Skills to develop: Data analysis, Climate Trends, Scientific writing
Methods: We will use scientific equipment that measures different climate variables. Students will produce a 2-page report with a description of the main processes involved. More detailed instructions are forthcoming.

Quizzes (15%)
This course contains short quizzes, each one to evaluate the contents of lectures and field activities.

Class Activities (15%)
Students will be assessed based on their ability to develop field observations and link them with class topics, working with field activities, required reports, and assigned class activities.

Participation (10%)
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 will actively participate and contribute to discussions that may arise during classroom and field lectures as being respectful to their peers in these activities as well. 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 specific topics.

Integrated Discussion (10%)
To review and develop our understanding of the topics explored in the field, we will have two integrated discussions. Since all field locations provide context for observation and learning, this activity will take advantage of your Field Notebook entries and class notes to integrate knowledge. For each integrated discussion, the class will be broken into four (4) groups, with each group overseeing connecting specific themes with specific field locations. More detailed instructions are forthcoming in the beginning for each activity.

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
Honor Code/Plagiarism – SFS places high expectations on their students and we hold students accountable for their behaviors. SFS students are held to the honor code below. SFS has a zero-tolerance policy towards student cheating, plagiarism, data falsification, and any other form of dishonest academic and/or research practice or behavior. Using the ideas or material of others without giving due credit is cheating and will not be tolerated. Any SFS student found to have engaged in or facilitated academic and/or research dishonesty will receive no credit (0%) for that activity.

> *"SFS does not tolerate cheating or plagiarism in any form. While participating in an SFS program, students are expected to refrain from cheating, plagiarism and any other behavior which would result in a student receiving credit for work which they did not accomplish on their own. Students are expected to report any instance of cheating or plagiarism by others."*

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 no longer be accepted. Assignments will be handed back to students after a one-week grading period. Grade corrections for any assessment item should be requested in writing at least 24 hours after assignments are returned. No corrections will be considered afterwards.

Content Statement – Every student comes to SFS with unique life experiences, which contribute to the way various information is processed. Some of the content in this course may be intellectually or emotionally challenging but has been intentionally selected to achieve certain learning goals and/or showcase the complexity of many modern issues. If you anticipate a challenge engaging with a certain topic or find that you are struggling with certain discussions, we encourage you to talk about it with faculty, friends, family, the HWM, or access available mental health resources.

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: CA: Class Activity, **FEX:** Field exercise, **FL:** Field Lecture, **L:** Lecture, **O:** Orientation

Code	Title and outline	Type	Hours	Readings
ESCS 01	**Course Introduction:** General description of the course, the principal themes, and methodology	O	0.5	Syllabus
One-day Field expedition: Cerro Benitez				
ESCS 02	**Earth Systems:** Introduction of the main topic and field elements	O; FL	1.5	
ESCS 03	**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	L	1	Steffen et al., 2020
ESCS 04	**GIS and FEX 1 introduction**	CA	2	Moreno et al., 2014 Sagredo et al., 2011
ESCS 05	**Introduction of Glacier Systems:** Description of cryosphere, introduction to glacier systems and their process, description of the interaction between glaciers and the landscape	L	1	Davies et al., 2020 Sagredo et al., 2011
Multiday Field expedition: Torres del Paine				
ESCS 06	**Fluctuations and landscape evidence of glaciations:** Identify and interpret the processes on the landscape (FEX 1, Site 1)	FL; FEX	1.5	

ESCS 07	**Rapid Climatic Change Event:** Review and discussion about the recent and rapid changes on Grey Glacier (FEX 1, Site 2)	FL; FEX	2.0	Weidemann et al., 2018
ESCS 08	**Global and Patagonian Climate:** Characterization of the climate in Patagonia	L	0.5	Aguirre, et al., 2021 Garreaud et al., 2013
ESCS 09	**Climate over the last 2000 years:** Review of climate change over the last 2000 years and its impact on the Earth Systems	L	0.5	Moreno et al., 2014
ESCS 10	**Future Climate:** Predictions, models, and their implications for Earth Systems in Patagonia	L	1.0	
ESCS 11	**GIS and FEX 1 Final Workshop**	CA	2.0	
One-day Field expedition: Reserva Explora				
ESCS 12	**Study and evidence of climate change:** Explore and interpret the evidence of climate change on the landscape	FL	1.0	
ESCS 13	**Workshop:** Remote sensing applications	CA	4.0	
Multiday Field expedition: Tierra del Fuego – Pali Aike				
ESCS 14	**Cyanobacteria and its relevance on Patagonia**	FL	2.0	Zaytseva et al., 2021
ESCS 15	**Volcanism - Explosive:** analysis of an ash layer in Porvenir, it is important to distinguish and see the differences with Pali Aike	FL	2.0	McCulloch et al., 2005
ESCS 16	**Volcanism - Effusive:** analysis of why and how it is one of a kind in Chile, seeing how it is relevant for the geological context of Patagonia	FL	2.0	
One-day Field expedition: Sierra Baguales				
ESCS 17	**Past-landscape evidence:** Exploring Sierra Baguales	FL	2.0	
ESCS 18	**Integrated discussion:** A student-led exploration combining themes and locations visited during the first half of the course	CA	4.0	
Multiday Field expedition: El Calafate and Patagonia Rupestre – Pingo Salvage				
ESCS 19	**Glacier Dynamics:** Analyze glacier dynamics, directly evidenced in the Perito Moreno Glacier.	FL	2.0	
ESCS 20	**Study and evidence different changes and time scales:** Explore and interpret the evidence of different time scale changes on the landscape	FL	2.0	
ESCS 21	**Watershed in a warming world:** Exploring the different components of the water cycles and their changes in a warming world	FL	2.0	
ESCS 22	**Wetland:** Explore and understand the geomorphological processes on Laguna Sofia and its relationship with climate change	FL	1.0	
ESCS 23	**Data Analysis exercise, Workshop FEX-2**	CA	2.0	
Multiday Field expedition: Punta Arenas				
ESCS 24	**Soils, water supply and climate:** Description of the process of soil profile development with an emphasis on coal formation, environmental risk, and las minas watershed	FL	1.5	Otero et al., 2012

ESCS 25	**Long-Term climate monitoring at Punta Arenas:** Exploring one of the more important long-term sites in Patagonia (FEX 2)	FL; FEX	1.5	Aguirre et al., 2018
ESCS 26	**Climate DATA Analysis:** Data analysis, trends, filters and predictions	L	1.0	
ESCS 27	**Hydrosphere and Cryosphere:** Introduction to the hydrosphere, the water cycle in Patagonia, ice and water interactions in a changing world	L	1.0	Allan et al., 2020
ESCS 28	**Python and R exercises**	CA	2.0	
ESCS 29	**FEX 2 Workshops:** CLIM Hackathon!	CA	4.0	Fürst et al., 2024 Minowa et al., 2023
ESCS 30	**Biogeochemical Cycle:** Biogeochemical cycle as part of Earth systems and climate science	L	1.0	Baldocchi, 2014
ESCS 31	**Physical Glaciology:** Physical processes of glacier formation, and its sensitivity and feedback on climate variability	L	1.0	Cuffey & Paterson, 2010
One-day Field expedition: Rio Rubens				
ESCS 32	**Peatland monitoring and drone survey:** Use of drones for peatland monitoring. Explore and interpret the evidence of climate change in the landscape	FL	1.0	
ESCS 33	**Hydrological signature:** explore and understand different index on climate change context	L	2.0	McMillan, 2021
ESCS 34	**Integrated discussion:** A student-led exploration combining themes and locations visited during the first half of the course	CA	4.0	
ESCS 35	**End semester review**	CA	1.0	
		Total	60.5	

Reading List

Aguirre, F., Carrasco, J., Sauter, T., Schneider, C., Gaete, K., Garín, E., Adaros, R., Butorovic, N., Jaña, R., & Casassa, G. (2018). Snow Cover Change as a Climate Indicator in Brunswick Peninsula, Patagonia. Frontiers in Earth Science, 6, 130. https://www.frontiersin.org/article/10.3389/feart.2018.00130

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.

Allan, R. P., Barlow, M., Byrne, M. P., Cherchi, A., Douville, H., Fowler, H. J., Gan, T. Y., Pendergrass, A. G., Rosenfeld, D., Swann, A. L. S., Wilcox, L. J., & Zolina, O. (2020). Advances in understanding large-scale responses of the water cycle to climate change. Annals of the New York Academy of Sciences, 1472(1), 49–75. https://doi.org/10.1111/NYAS.14337

Baldocchi, D. (2014). Measuring fluxes of trace gases and energy between ecosystems and the atmosphere - the state and future of the eddy covariance method. Global Change Biology, 20(12), 3600–3609. https://doi.org/10.1111/gcb.12649

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Garreaud, R., Lopez, P., Minvielle, M., Rojas, M., Garreaud, R., Lopez, P., Minvielle, M., & Rojas, M. (2013). Large-Scale Control on the Patagonian Climate. Journal of Climate, 26(1), 215–230. https://doi.org/10.1175/JCLI-D-12-00001.1

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McMillan, H. K. (2021). A review of hydrologic signatures and their applications. Wiley Interdisciplinary Reviews: Water, 8(1). https://doi.org/10.1002/wat2.1499

Minowa, M., Schaefer, M., & Skvarca, P. (2023). Effects of topography on dynamics and mass loss of lake-terminating glaciers in southern Patagonia. Journal of Glaciology, 69(278), 1580–1597. https://doi.org/10.1017/JOG.2023.42

Moreno, P. I., Vilanova, I., Villa-Martínez, R., Garreaud, R. D., Rojas, M., & De Pol-Holz, R. (2014). Southern Annular Mode-like changes in southwestern Patagonia at centennial timescales over the last three millennia. Nature Communications, 5, ncomms5375. https://doi.org/10.1038/ncomms5375

Otero, R. A., Torres, T., Le Roux, J. P., Hervé, F., Fanning, C. M., Yury-Yáñez, R. E., & Rubilar-Rogers, D. (2012). A Late Eocene age proposal for the Loreto Formation (Brunswick Peninsula, southernmost Chile), based on fossil cartilaginous fishes, paleobotany and radiometric evidence. Andean Geology, 39(1), 180–200.

Sagredo, E. A., Moreno, P. I., Villa-Martínez, R., Kaplan, M. R., Kubik, P. W., & Stern, C. R. (2011). Fluctuations of the Última Esperanza ice lobe (52°S), Chilean Patagonia, during the last glacial maximum and termination. Geomorphology, 125(1), 92–108. https://doi.org/10.1016/J.GEOMORPH.2010.09.007

Steffen, W., Richardson, K., Rockström, J., Schellnhuber, H. J., Dube, O. P., Dutreuil, S., Lenton, T. M., & Lubchenco, J. (2020). The emergence and evolution of Earth System Science. Nature Reviews Earth & Environment 2020 1:1, 1(1), 54–63. https://doi.org/10.1038/s43017-019-0005-6

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Zaytseva, L. V, Samylina, O. S., & Prokin, A. A. (2021). Formation of Monohydrocalcite in the Microbialites from Laguna de Los Cisnes (Isla Grande de Tierra Del Fuego, Chile). Environmental Sciences Proceedings, 6(1), 2.