QuEST – EOAS Quantitative Earth Science Transformation project

Recommendations for reinvigorating quantitative learning in Earth, Ocean and Atmospheric Sciences

https://blogs.ubc.ca/eoasquest.

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FACULTY DISCUSSIONS

The links in the following tables point to materials at https://blogs.ubc.ca/eoasquest/.

This PDF contains reports or summaries of discussions about courses, degrees and curriculum in quantitative Earth science disciplines, in the order (by date) given in the following tables. The Pg column is the page number for that section in this PDF.

QuEST Progress as of Aug 16, 2022

These tasks are either **completed** or in **progress** - i.e. more than "just started". *Brown italics file paths* are documents in QUEST folder space on EOAS NextCloud or the QuEST Google Drive space being used with summer student Kristie Tai. The "***Chapters***" are those described in the project proposal's "*Project Work Plan, Timeline & Milestones*" section.

Re. Chapter 1 – An Overview of QES in EOAS: Data Collection and Analysis

A) Characterize the present state of QES (Quantitative Earth Sciences) in EOAS

May '22 – present

- **Learning tasks** that students experience in EOAS: qualtrics survey only - data to be gathered early Sept, 2022.
- **CTLT (Carrie Hunter)** agreed to conduct paired interviews in Fall to "*explore the identity of our programs individually and collectively*".
- **EOSC courses mapped against the 2011 EGBC requirements:** see file "*.\QUEST\careers-etc\EGBC-etc\APEGBC-Geo-Syllabus-Geophysics-2011.docx*".
- **Syllabi reviewed** for 27 QES courses (QES only, no engineering courses. Results in "*.\curriculum\syllabi & CLOs\Syllabi-characteristics.xlsx*". **Goal** is to consider options for using syllabi (and other info) to characterize existing QES curriculum, including building consistent CLOs for all courses. Also gain inspiration for faculty interviews – what to discuss? See files "*.\curriculum\syllabi & CLOs\QES syllabi notes.docx*" and "*.\curriculum\instructor-interviews-220509.docx*".
- **Data from EOAS retreats (2019 & 2020) and other background information:** survey results, QES skills "needed", specialization descriptions: there are summaries in file "*PriorArt-220603.docx*", GDrive folder "*background*", but most are incomplete and unknown authors. However, they are an indication of Dep't perceptions about QES curriculum at that time, although based on incomplete sampling.
- **Data from 2015 EOAS alumni survey:** open responses to question "What additional skills or experiences could have been a part of your EOAS degree?" coded and summarized. See "*alumnidata-2015.xlsx*".

Dec '21 – Apr '22

- **Syllabi request** sent for 29 QES courses to instructors from 2021W; April 11, 2022.
- **QES dependencies interactive maps** summarizing relationships between EOAS's QES courses & prerequisite math, physics, compsci courses. See https://www.eoas.ubc.ca/~quest/. Files in folder "*.\curriculum\the ~quest webpage*".
- **QES Prerequisites** are also summarized as a matrix: "*.\curriculum\the ~quest webpage\AllPrereqs.xlsx*". Summary version of the matrix is at https://www.eoas.ubc.ca/~quest/.
- **Observations and comments** about QES course dependencies based on interactive maps: see file "*.\curriculum\the ~quest webpage\curriculum-analysis.docx*".
- **Quantitative skills in EOAS courses** from instructors: we have 28 out of 32 respondants.
    - Data in "*.\curriculum\QES course outlines\QES-coursematrix-220216.xlsx*"; i.e. "outline" files for each course returned from instructors.
    - An overarching summary is in file "*QESoutlines-summary.docx*".
- AGU **poster** presented. See poster at AGU or locally on EOAS server.
- EOAS **faculty interview** design in file "*.\curriculum\instructor-interviews-220302.docx*".
    - Concrete feedback from CTLT (Carrie Hunter) is being used to refine the protocol.
    - Second version shipped for feedback March 3rd.
    - 3rd version in "*.\curriculum\QES course outlines\instructor-interviews-220307.docx*"
    - Could be discussed with QuEST committee.

Before Dec 2021

- **Curriculum review background** summarized in "*.\curriculum\QES-baseline-tasks.docx*". Meetings with C. Hunter (CTLT curriculum support) helped establish these "next steps" as of July 2021.
- **Quantitative skills in EOAS courses**: Open questions requested for 32 courses (Feb-Dec 2021)

B) Why now? The case for renewal of quantitatively oriented curriculum in EOAS

May '22 – present

- CSIC is interested in supporting **career-related** research regarding QES occupations.
- **Background research: A Zotero** reference list generated, many annotated; ongoing.

Dec '21 – Apr '22

- Establish communications with **Dawson Club** president (geophysics student) Mehek Mathur. Goal is to discuss with students how they see the relationship between their studies at UBC and their aspirations for occupations beyond.
    - Reconnecting with Mehek – Mar 7th.
- **Student interview procedure**:
    - Ver1 with excellent feedback from CTLT (Carrie Hunter) to refine the protocol.
    - Ver2 in file "*.\careers\engage-students-220228.docx*".
- Discussion with Shaun Barker re**. training needs at MDRU**, both for students and ProD for professionals. See FJ OneNote *takeaway messages* under "meetings", Feb 22, 2022.

Before Dec 2021

- Summarize "**Student Experiences in EOAS** Specializations" (A. Jolley, March 2020). "*.\sources\EOAS Specializations survey notes 210705.docx*".
- **One-on-one discussions**, CS with colleagues in EOAS (documented in notes & emails and "*.\background\QUEST-summaryfor-deptreview-210430.docx*" dated April 2021).
- Relevant sections of **AGU publication** "Vision and Change in the Geosciences: The Future of Undergraduate Geoscience Education" summarized in "*.\sources\AGI Vision&Change summary.docx*".
- Feedback survey involving current & former students of EOAS **geophysics** program (A. Jolley, 2018). Short report in file "*.\sources\EOAS GEOP Survey Report 2019.pdf*".
- "EOS Survey of **Hiring Practices** in Geoscience Industries, 2010". Also "*.\sources\geosci-hiringpractices-2010.pdf*".
- Data from Dep't spring **retreats**, 2019 and 2020. File "*.\sources\concepts & tools retreat 200721.docx*".

Re. Chapter 2 – Beyond EOAS: Engagement and Market Research

A) Relationships with people at peer institutions, alumni and industry

May '22 – present

- Letter to request showcase information is being prepared (see Google Drive). Also a model for showcase pieces (also a Google Doc).
- Example showcase page (FJ) is on Quest Blog here.
- List of potential employed individuals to interview is in progress. Goal is to showcase QES occupations & impacts on society. Possible interview questions are being compiled.

Dec '21 – Apr '22

- **Engage with BC Geophysical Society** http://www.bcgsonline.org/
    - Attended 2021 AGM (Dec 2021) and KEGS / BCGS breakfast at Vancouver Roundup (Jan 2022)
    - FJ has joined BCGS and KEGS executive with three longer-term goals:
        - Increase awareness of geophysics scholarships and increase number of UBC students who apply;
        - Increase student engagement in BC (and Canada) society activities;
        - Leverage society membership to showcase breadth of inspiring geophysical activities in the service of society.
        - Seek opportunities for EOAS faculty to connect with BCGS activities (occasional seminar, etc.)
    - March 9th: highly effective meetings with KEGS Foundation BOD, "councilors" and AGM. These represent important networking links into consulting, industry, government and academic people involved in "geophysics". This enables us (QuEST) to **help mobilize the pan-Canadian geophysical community** to take

actions related to **promoting** and **supporting** quantitative Earth science learning within degree programs and beyond.
See FJ's file "*.\Nextcloud\FJwork\bcgs-kegs\KEGS\KEGS-ActionOptions-220309.docx*".
    - BCGS **internship** awards given to 4 UBC students (no other applicants).
- New **community** connections: **U. Calgary** (Brandon Karchewski) is renewing their complete Geoscience curriculum.
- Initiated **communication with MDRU** regarding increasing needs for geophysics expertise in resource exploration and management for the "greening" of world economies. See FJ OneNote *takeaway messages* under "meetings", Feb 22, 2022.

Before Dec 2021
- Summary of **geophysics programs** at 5 peer institutions, (C. Hunter, 2020) summarized by FJ in file "*./peer_institutions/geop-prgms-summary.docx*".
- Preliminary list of **peers, alumni & industry contacts** is ".\careers\outside-UBC-contacts.xlsx".
- **One-on-one discussions**, CS with colleagues at 7 peer institutions; summarized in "*./peer_institutions/specific feedback/peer-institution_summary.docx*".
- **Alumni**: Preliminary contact with Kim Duffel, regarding Faculty of Science alumni. Also, results of EOAS alumni survey from 2015 in "*.\marketing\alumni\EOAS Alumni Survey 2015 Report JM.pdf*". Also other docs in that folder.

B) Enhance the visibility of QES in EOAS, including recruitment

May '22 – present
- **EOAS website updates:** Undergrad section adjustments are progressing (Aug 10). See GDrive "marketing" folder.
- **Worklearn student** job proposal approved for winter 2022W. Work priorities depend on project committee priorities and student's interests / skills. They'll work 10hrs/wk between Sept 1 and April 30, for up to 300hrs total.
- Recommendations for EOAS website updates from student's (Kristie Tai) perspective (Undergrad & Education sections) is in progress.
- A flyer about QES is being prepared, for public, prospective students, and others.
- Marketing ideas – in progress.
- List of jobs available in June 2022 to QES graduates (via LinkedIn & UBC career support) is in progress. We'll likely generate some guidelines for students to help them begin their own searches.
- List of potential employed individuals to interview is in progress – see Ch2 (A) above.
- Poster presented for UBC's TLEF showcase event, May 9th, 2022. Title: "**Re-invigorating Quantitative Curriculum for Earth, Ocean & Atmospheric Science Specializations**".
- Letter to principal of UHill Secondary – see email sent June 15, 4:35pm.

Dec '21 – Apr '22
- Researched **Canadian scholarship** opportunities for geophysics (and similar) students. See file "*.\FJwork\bcgs-kegs\geophysics-scholarships.docx*".
    - BCGS/KEGS scholarship opportunities summarized and shipped to UBC ugrads and EOAS faculty.
    - Notes about scholarships are accumulating in file "*.\FJwork\bcgs-kegs\scholarships-notes-220210.docx*".
- Listing of recommended **EOAS website updates** is in progress (file "*.\marketing\EOAS-website\EOAS website recommendations 210705.docx*"), including clearer information for students about scholarships and awards they can apply for (QES focus for now), pointers to various UBC and Faculty of Science geophysics, ATSC, and OCGY career pages, summary of alumni information derived from LinkedIn (eg here), pointers to geoscience societies, and more.
- **Worklearn student** job proposal approved for summer 2022s. Work priorities depend on project committee priorities and student's interests / skills. They'll work ½ time between May 1 and Aug 31, for up to 300hrs total.
- **Worklearn student**: Kristie Tai, atsc 4th year student chosen – hiring is under way (Apr 01)
- **Student engagement**: recommendations reworked for discussion with Mitch. Goal is to improve student experiences, motivation, career options, networking opportunities and visibility of QES in EOAS. See FJ's OneNote under quest "meetings", April 4th.

Before Dec 2021

- New EOAS **website** makes QES more visible, including: a) New "Education" section, b) enhanced "Undergrads" section, c) Improved "degrees" and "careers" sections for undergraduates, d) Alumni and student success / stories are more prominent
- **Website** content to be further improved during a second round of EOAS website updates. Ideas in *".\marketing\EOAS-website\EOAS website recommendations 210705.docx*".
- Faculty of **Science Co-op** web pages related to EOAS specializations have been updated (Sept 9, 2021). See:
    - https://sciencecoop.ubc.ca/employers/disciplines/eosc
    - https://sciencecoop.ubc.ca/prospective/apply/eos
- Connection with **Geering Up** established (first contact only – *zoom meeting, May 7, 2021*)
- Possible partnering with "Empower the Future" initiated, possibly in partnership with PME (*emailed June 17th*) and Bean Sherman and EOAS undergrads (to be pursued).
- New **first year course** concept begun: "Climate Physics", or similar. (*G-Doc by CS, with RW comments.*)
- Introducing quantitative / conceptual **climate content into eosc1xx** courses via OCESE (Stephanie W. is lead). Any lessons learned or resources generated could benefit a new first year course. See the Google sheet with listings and pointers.
- **EOSC1xx course demographics** and grades summarized to help argue for a new eosc1xx course with more quantitative perspectives. See summary in file "*.\first year course\ eosc1xx-demographics.docx*".
- EOAS version of **DSCI100**, "intro to data science": **OCESE** is converting this from R to Python. L. Heagey will teach R-version in January 2022. A version with EOAS context is being prepared for introduction in teaching season 2022W.
- Preliminary meetings with **Heads of** Math, CS, Phys, Stats regarding potential to include EOAS "guest lectures" in early quantitative course in other departments. (One meeting only so far)
- **MATH courses**: changes in progress (January 2022) with strong Math Education support and expertise. Ongoing interactions are in progress: contacts are Head, Matt Coles (Education Program Director), Gaitri Yapa (SES). QuEST goal: better characterization of "coverage" in QES math prerequisite courses. That means helping them articulate useful course learning outcomes (CLOs).
- Preliminary discussions about increasing visibility of QES in **Vantage College** (BG now on leave until July '22)

Re. Chapter 3 – Pathways forward: Curricular Recommendations

A) Curriculum renewal: articulating the forward-looking needs of students, preferences of faculty, and resulting opportunities for enhancing QES curriculum in EOAS.

May '22 – present

- **Project documentation (blog)** at https://blogs.ubc.ca/eoasquest/. This can be edited by faculty, staff or students with a CWL. Other options (Jupyter Book, CMS website, Wiki, GoogleDocs) are less flexible or less well organized.
- **Capstone projects and courses**: Carrie Hunter has prepared a very nice summary of the types, roles, benefits and keys to success. See document "*.\background\Capstone Courses and Projects.docx*".
- **Interviews** with faculty are in progress (Kristie Tai). Focus is on how they balance learning about discipline-specific fundamentals and "career preparation". See Google Sheet for summary.
- **Project report:** report outline is in "*.\admin&rprts\QuEST-rprt_outline-220810.docx*". Also notes on content in "*.\admin&rprts\QuEST-rprt-notes.docx*".
- CSIC provided a preliminary list (including search methods) of articles about **embedding career development within geophysics or math** ugrad degrees. See "*.\background\sources\QuEST_Geoph-Math_LitReview-FJ.docx*". Notes on ways we might incorporate some of those ideas into QES curricula are included.
- CSIC is eager to contribute expertise related to **balancing career preparation and discipline-specific learning**, as well as "**curriculum mapping**".

Dec '21 – Apr '22

- Initiated contact with **UBC Centre for Student Involvement and Careers** – Kimberley Rawes.
    - First meeting Feb. 3rd, 2022. Goal is to partner with them to benefit from expertise on careers and enhancing the relationship between curriculum and career options.

    - Mar 7^{th} a second meeting is being arranged to (a) learn about how science programs balance the competing curricular goals of "career development" versus "gaining fundamental knowledge", and (b) discuss ways that CSI&C can assist with QuEST.
- Regarding **curricular dependencies** among ATSC, EOSC, and ENVR courses: see early observations and recommendations in "*.\curriculum\the ~quest webpage\curriculum-analysis.docx*".
- Recommended **QuEST project actions** are in "*.\admin&rprts\QuEST-recommendations220524.docx*".

Before Dec 2021

- **Goals** are to (a) generate options for enhancing QES curriculum and degree options and (b) implement means of recruiting suitable students into QES courses and specializations.
- Needs **discussion** with committee members.
- **Micro credentialling options**: Some thoughts on options, methods, precedent and local examples of delivering short prgrms to grads, non UBC students, industry or other interested parties: See CS's notes in file *.\curriculum\micro-credential-ideas.docx*.

Quantitative Earth Sciences at UBC: challenges and opportunities

Prof. C. Schoof, April 2021.

Background

The Department of Earth, Ocean and Atmospheric Sciences at UBC (EOAS) has been hosting three degree programs in quantitative Earth Sciences (QES), excluding geological engineering: geophysics, atmospheric sciences and a combined major in oceanography and physics. (Roughly speaking, by QES we mean Earth Science content requiring fluency on graduation in advanced math - linear algebra, differential equations - modern data analysis, coding, and parts of second- to third-year physics.) These programs continue teaching activities that predate the foundation of the department. They can be traced to the former Department of Astronomy and Geophysics (geophysics), the Department of Geography (atmospheric sciences) and the former School of Oceanography (oceanography and physics). Enrollments have shrunk significantly in geophysics (32 students across all years in 2015 to 20 students now) and atmospheric sciences (29 students in 2011 to 10 students now) while oceanography & physics has always had small student numbers (~ 2). As a result, enrollment in many core courses has shrunk to critical levels (5-10). Atmospheric sciences underwent a significant curriculum reorganization in 2015 that led to the cancellation of low-enrollment courses. This has not led to a rebound in program enrollment, but the remaining program courses have sustainable student numbers due to cross-over with the Environmental Sciences program. The same curriculum change has also represented a move away from traditional QES, with core material such as Geophysical Fluid Dynamics and Dynamical Meteorology no longer offered regularly to undergraduates.

An informal survey of colleagues in peer programs elsewhere (University of Alberta, University of Calgary, University of Toronto, McGill university, Memorial University, Georgia Tech, Colorado School of Mines, Stanford University) has revealed a similar picture, with the programs most closely identified with resource extraction and fossil fuels most heavily affected. It is unclear whether this is due to a lack of desire to work in these industries, or due reduced employment opportunities due to the depressed price of oil. A common refrain has been the impression that quantitatively-inclined students have heavily drawn into computer science, limiting recruitment.

This situation represents a challenge as well as an opportunity. Faculty in EOAS have significant strengths in quantitative disciplines that would be under-or unutilized were these programs, and a complete refocusing on non-quantitative programs represents a challenge to retention and complicates aligning the expertise and research directions of future hires with core teaching activities. At the same time, quantitative Earth sciences provide a rich environment for context-driven teaching of material drawn from mathematics, statistics and physics, with unique opportunities in areas such as data and image analysis, inverse modelling and topical issue-driven content such as climate physics. Career opportunities for quantitatively-trained students are many; already we have numerous geophysics alumni who are employed in tech companies, and they report a well-trodden path from numerate science degrees other than computer science into tech sector, primarily in data science.

The remainder of this document sketches some of the strategies we are initiating in order to capitalize on these opportunities.

A way forward

The challenge in maintaining a viable QES program is two-fold: i) to create an attractive set of course choices that is not closely tied to cyclical or sunset industries with an image problem, and ii) to effectively advertise the training and career opportunities beyond these industries that come with a QES degree.

To create an attractive program, we have begun to reconfigure the geophysics curriculum to focus less on solid Earth material while maintaining a path to accreditation as a professional (exploration) geophysicist. This has led to a core of 'methods' courses in mathematical techniques, continuum mechanics and data analysis, and a choice of application courses spanning traditional solid Earth geophysics as well as environmental material in hydrology and a revived dynamical meteorology / geophysical fluid dynamics, with an upper-level climate physics course in preparation, and a course on image analysis anticipated. While enrollment is low, some of these application courses will be taught in alternate years, and we hope to attract a small number engineering or physics students who would be qualified to take these as technical electives. This new curriculum was recently approved by the Faculty of Science at UBC.

In terms of applications, our vision behind our curriculum reform is to integrate a broader range of `hard science' courses aligned with attractive and relevant environmental and climate topics, aimed at a more quantitative demographic than the Environmental Sciences program in EOAS, and to reflect the breadth of `geophysics' as represented by e.g. the American Geophysical Union. In terms of preparation for future careers, we intend to focus on transferable quantitative skills, with greater emphasis on data analysis and computing, including practical skills in demand by potential employers (e.g. multi-generational, collaborative open-source code package development). While the separate programs in atmospheric sciences and oceanography are likely to remain, we intend to recreate a quantitative path through the existing Atmospheric Science program that shares a common core with geophysics and thereby consolidate our student cohorts.

A greater challenge is advertising this program to the intended audience of quantitatively-inclined students. Campus events (`Meet your Major') have proven ineffective, and there is poor awareness of QES material among Faculty of Science Students. We have identified several issues:

1) High school courses in Earth Sciences in BC, where available, stress qualitative aspects of the subject.

2) First year EOAS courses focus on descriptive material and leave the impression that EOAS is not home to `hard' sciences.

We have two projects aimed at alleviating this: i) the new Data Science 100 course at UBC will have an Earth-Sciences-focused section to be taught by EOAS faculty in collaboration with Statistics and ii) we are in the early stages of developing a 100 level Physics of Climate course that would integrate first year material from Mathematics and Physics into an attractive topic, to capitalize on a new Faculty of Science breadth requirement that obliges students to take courses from 6 out of 7 different areas of science.

3) Low visibility of QES offerings to students in Math, Computer Science, Physics.

Visibility of our programs and courses to students in these traditionally quantitative science departments is likely to be key to our success since we expect these departments to continue attracting the majority of students in the target demographic for QES courses. In our informal survey of peer programs, the only program not reporting a significant drop in student numbers was the Geophysics Specialist program at the University of Toronto, which is housed in the Department of Physics and run in collaboration with Earth Sciences. Guest lecturing in 1st and 2nd year classes in other departments is a pathway to increased visibility that has reportedly worked well for the geophysics program at Stanford University, and the Math and Physics Departments at UBC have indicated a willingness to facilitate guest lectures. In the long run, closer and more formal links may be necessary as even students who are aware of our programs and courses may choose to stay in a traditional quantitative science program due to better perceived employment prospects: a physics degree may be seen as more valuable in the job market than an EOAS-based degree, regardless of actual content. As a first step, we have implemented a defined geophysics minor program in order to create an easy path through QES for students majoring in another discipline.

4) Numerous websites still hosted by EOAS, the Faculty of Science and beyond continue to give a limited, overly disciplinary perspective of `geophysics' focused on the resource sectors.

We have begun to identify online advertising material related to QES content at UBC, whether controlled by EOAS or not, and are developing a strategy to reorient that material, including participation in a redevelopment of the public-facing EOAS website.

This set of strategies is not guaranteed to succeed; if it does not and UBC decides strategically to maintain a presence in areas such as geophysics, then alternative solutions such as more cross-appointments of faculty in these areas in other departments, where their expertise aligns more closely with teaching opportunities, may need to be explored in future.

EOAS 2021: A Vision for Integrated Earth Science

P. Tortell, Dec 7, 2021

The UBC Department of Earth, Ocean and Atmospheric Science (EOAS) is the largest and most intellectually-diverse of its kind in Canada, and widely recognized as a global leader in research, education and training. Over the past 25 years, since the formation of EOAS in 1996, Earth Sciences have been revolutionized by new measurement technologies and computing power, and a growing awareness of the complex interactions linking different components of the Earth System. We now have tools and methods to observe, understand and predict coupled Earth System processes across unprecedented space and time scales. At the same time, the last quarter century has seen a rapidly growing imprint of human activities on planet Earth, from global climate change to impacts on fresh water, marine systems and mineral resources. Motivated by these grand challenges, and inspired by a curiosity about the natural world, ***we seek to advance fundamental Earth Science knowledge, and guide informed application of this knowledge for broad societal benefit***.

EOAS 2021: A Vision for Integrated Earth Science represents our collective aspirations for EOAS during its 25th anniversary year, and a strategic plan outlining priorities, goals and actions to achieve this vision. We seek to ***build on our existing core strengths*** in the geological sciences (geology, geochemistry, geophysics), geological engineering, oceanography and atmospheric science, while ***fostering new interdisciplinary collaborations*** in teaching and research. We also seek to engage with civil society, ***informing public debate and driving science-based solutions*** to the environmental challenges of the Anthropocene.

Using advanced laboratory and field-based analytical tools, combined with computational and mathematical methods, we aim to stimulate new research collaborations examining the dynamics of planet Earth in a number of ***thematic areas, including climate change, geohazards, and mineral, water and renewable energy resources***. We will continue to ***innovate in the development of new research tools and infrastructure***, exploring the natural laboratories of British Columbia, with an eye to understanding global-scale processes.

We strive to further enhance our world-class teaching programs, using evidence-based pedagogical methods built on active and experiential learning. We will place a ***greater emphasis on field-based education*** across our undergraduate specializations, and ***expand the use of quantitative and open-source computational methods*** to address a range of Earth Science questions through advanced data analysis and modelling methods. Our teaching efforts will target both specialists and non-majors students, providing foundational understanding of core scientific concepts underlying the dynamics of planet Earth and its sensitivity to a range of perturbations. We will also ***expand opportunities for training of off-campus professionals through micro-credentialing and the development of certificate programs***. Through this work, we will train the research pioneers of tomorrow, while also providing a pool of highly skilled graduates to support evolving needs of our non-academic partners. Closer interaction with these partners will provide our trainees with expanded mentoring opportunities, and exposure to a wide range of career paths beyond academia.

We seek to increase the impact of our research and teaching by ***engaging broadly with public audiences***. Our goal is to inspire curiosity about the Earth System, and inform meaningful debate about the wise stewardship of its resources. We also seek to ***build equitable and mutually beneficial partnerships with Indigenous groups***, embracing their unique and valuable perspectives on Earth Science education and research. Strengthened public outreach and educational programs will help us improve scientific literacy and attract a wider diversity of applicants to our programs. Through this and other initiatives, we seek to ***address a systemic under-representation of marginalized groups in Earth Sciences***, and to identify and eliminate historical barriers to success in our field.

QuEST – EOAS Quantitative Earth Science Transformation project

Reinvigorating quantitative learning in Earth, Ocean and Atmospheric Sciences

Concepts, tools and programs; early ideas

Synthesized from deliberations during summer 2020 and at Dep't retreats of 2019 and 2020.

Contents

1. Program learning objectives (PLOs):

These are "generic" since they are not about any specific degree specialization. They are meant to articulate priorities and expectations for quantitative BSc degrees in Earth Science such as geophysics, atmospheric science, physical oceanography, etc.

Students will …

1. … choose and apply foundational math and physics concepts (to 2nd or 3rd year level) to address problems involving the physics of Earth or planets and describe the techniques used to explain planetary physical processes.
2. … be ready for research/industry/government positions, not limited to Earth-science related fields: transferable skill is central to what we teach (similar to physics, but more applicable)
3. … apply physical, mathematical, computational and Earth science concepts to explain and address society's challenges as they relate to geosciences. Examples include climate change, water & resource

exploration & management, natural hazard forecasting & mitigation, and others.

4. … gain sufficient awareness of how observational geoscience works either explicitly or by implication during QES courses, so they can contribute knowledgeably in geoscience teams.

Comment: These are on the right track, but could be refined. Consider synthesizing a broadly applicable set of PLOs based on current PLOs for ATSC, OCGY and GEOP specializations (summarized here), with additional insights from EOAS service course PLOs.

2. Concepts to be learned

The table below summarizes concepts that several faculty members listed as priorities for any quantitative Earth sciences degree. Math and geophysics were emphasized but few "geoscience" concepts were listed.

In future discussions, it should be recognized that the Earth system context is what makes a QES degree from this Department unique. Geoscientific "thinking" is as distinct as mathematical or physics-based thinking, so exposure to, and practice using, observational Earth science ways of thinking do need to be incorporated into a QES degree program. This aspect can be addressed without too many "extra" courses by carefully weaving geoscience contexts into existing courses, but that needs to be explicit, by design, and with relevant components for practice and corresponding assessment.

Many of these are already taught – see the "Current EOAS course content" page. Not all concepts would be required to complete a QES degree. Also, these are not meant to map one to one onto individual courses.

FUNDAMENTAL CONCEPTS	EARTH-SCIENCE CONCEPTS	METHODS, TOOLS, STRATEGIES
• conservation laws, mechanics, thermodynamics • equations of state, constitutive laws • waves (how? to what degree of sophistication?) • diffusion, damping, advection • signals and noise • forcing and feedback, stability, bifurcation • scientific hypothesis testing by both experimentation and observation • simulation and prediction using empirical / statistical models	• continuum mechanics (plus basic classical mechanics) • fluids, solids, porous media • GFD • convection in a variety of settings • hydrology & hydrogeology • seismic wave propagation • potential fields: gravity, magnetics, EM in context • climate physics	• ODEs and PDEs (initial and boundary value problems) • scaling & dimensional analysis • systematic model simplification, heuristic lumped (box) models • dynamical systems • numerical methods for deterministic models, discretization methods • inverse models • spectral analysis, signal analysis • data analysis, image analysis • statistics • machine learning etc.

3.Course ideas

1. Austin: Predicts ~15 students / yr in a course that uses a text like Denis Hartmann's Global Physical Climatology (free if you're on our vpn). Example 3rd yr course taught at U. Washington (https://atmos.uw.edu/~dennis/321/) or grad course at https://atmos.washington.edu/~dennis/571/. Links are "old" but were valid 231006.
2. Austin: Consider broadening topics in ATSC 409/EOSC 511 (numerical methods) and offer it every year. That way, 3rd yr students experience simulation/model building as soon as they've completed ODEs.
3. A good example of a new course design can be seen for DSCI 100/ Their new, purpose built textbook and problem sets – are a good example of course design that balances fundamentals and applicability. See also a course design talk by course developer Prof. T. Timbers.
4. Brian Rose's SUNY climate modeling course, modeling software (docs) https://brian-rose.github.io/ClimateLaboratoryBook/courseware/models-budgets-fun.html
5. Haber's imaging course (proposed before 2020)
6. Heagy's rejuvenated applied geophysics EOSC 454 + grad version, hopefully to be taught in Jan. 2024.
7. Climate physics – P. Austin and R. White (details?)
8. others please …

CGS comment: Climate science is a great objective here. This is a relatively new, unique strength in EOAS, with faculty from multiple disciplines. In EOAS, "climate" is not the purview of atmospheric science, or even seen predominantly through that lens. EOAS faculty include Rachel White, Anais Orsi, Mitch Darcy, Stephanie Waterman, Valentina Radic, Mark Johnson, Christian Schoof, Mark Jellinek, Phil Austin, Susan Allen and others, making for an excellent QES climate core.

FJ comments: Agreed. "Climate science" or "climate physics" (or similar) represents a timely and appropriate opportunity for defining a QES domain to focus upon. In addition, consider developing creative ways of incorporating the Department's solid and fluid QES expertise into these courses. Also – avoid fixating on "physics" to the total exclusion of "Earth". QES is the focus but context must be included or this is not an Earth sciences degree. This may seem obvious and well understood, but it is mentioned here so the issue is visible.

4. Eldad's sketch for a program

(This outline may date from ~2018 and some aspects may already be incorporated into the current 2023 Geophysics curriculum.)

General principle

Geophysics is the physics of the earth and planets. The main disciplines are solid earth geophysics, physical oceanography, atmospheric science, hydrology.

FJ comment: agreed, except to recognize that words matter – and "geophysics" (although correct) may be understood by others more narrowly, resulting in misconceptions about what can be involved and what opportunities there are for future occupations.

Goals of a QES program

1. The main goal of any QES program would be for students to learn and practice the mathematical and scientific techniques needed to (a) understand the dynamic Earth, oceans & atmosphere, and (b) address corresponding societal priorities.
2. Students should also be able to explain to society and discuss common problems in the physical geosciences, including (but not limited to) climate change, water management, resource exploration & stewardship, and others.

The common thread in these disciplines are

1. Math: calculus, linear algebra and O/PDEs
2. Physics: mechanics, electrodynamics, waves, some thermodynamics, emphasis on continuum mechanics, fluid flow, elasticity.
3. Statistics: basic probability and statistical thinking
4. Computing: programming, signal processing, image processing, data science, AI / ML. (As mentioned above, choice of terminology matters. The term "computer science" implies – to some people – details about how computers work, databases, algorithms, etc. That is the domain of Dep't Computer Science, and they don't like others treading on their turf.)
5. Field & measurement techniques: data collection, wrangling and processing.

Missing from this list is recognition that an Earth science degree (as opposed to a math or physics degree) should include exposure to the unique styles of thinking necessary for tackling pressing problems related to how Earth works, including geology, hydrogeology, climate science and so on. This does not mean students qualifying with a QES degree should be able to compete with geologists or geography majors. But geoscience thinking has unique aspects that QES specialists should encounter so they can contribute effectively in the teams they will work with.

Major principles of the program

1. Let lowest level courses be taught at their home departments.
2. Get the students as early as possible for science courses that are not basic.
3. Go hard in first/second year on basic science and prepare students to a serious discussion about geoscience in third/forth year.
4. **FJ comment**: OK, and motivation also matters. Students learn better when context is meaningful. Early learning activities related to "why we're learning this" are well worth while. And as many learning activities (lessons, activities, assignments, projects, etc) as possible should be carried out within an ex-

plicit, concrete context. Some creativity may be needed, but including context is always feasible without compromising fundamentals. Students will learn and retain new concepts better, and they will be more highly motivated when they can personally relate to the “point” of gaining those skills.

Particular Courses

NOTE the geophysics curriculum was updated recently (2018?) and the following outline is essentially the same as current geophysics requirements. See https://vancouver.calendar.ubc.ca/faculties-colleges-and-schools/faculty-science/bachelor-science/geophysics

Courses should include settings that involve “*thinking about the physical Earth*”. Focus is to be on specific skills (like ODEs etc.), but they are tools to address meaningful situations, not only abstract notions. Take-home messages for students are about “transferable skills” (i.e. methods), but capabilities fostered by learning in context will include >motivation to learn at the time, >deeper understanding, >better retention, and >abilities to apply “methods” in novel settings. These “benefits” need to be clearly and repeatedly emphasized for students in the courses they take (as per recommendations regarding “transparency in learning and teaching”, Winkelmes, 2023).

Year 1

- Calculus 1 & 2 (MATH 100/102/104 & MATH 101/103/105 & MATH 200)
- EM and waves (PHYS 107 & 108. These provide crucial introductory exposure. Students do not yet have multivariable / vector calculus)
- Data science (DSCI 100 represents first exposure to stats & programming. EOSC211 is in 2nd yr)
- A new first year course? “the quantitative Earth”, “climate physics” or equivalent. (is this to be a “required elective”?)

Year 2

- Statistics may be managed on “as needed” basis. (DSCI100 is req’d) (Stats 200 may not be very helpful for us; mainly pvalues / type I / type II errors, etc.)
- Linear algebra (MATH 221/223) (Be careful to not students to progress too quickly. Gaining mathematical “maturity” takes time, although a few can advance quickly.)
- Mechanics (CGS PHYS 107)
- Programming (EOSC 211)
- Intro physics of earth and planets (EOSC 212) (212 has little “physics” – it is more like a first exposure to scientific earth and planetary science literature.).
- Vector calculus and intro to differential equations / math modelling in context (EOSC 250)

Year 3

- ODEs, PDE's (MATH 215 & MATH 316/PHYS 312)
- Continuum mechanics (EOSC 352 ["cont. dynamics"],
- Fluid dynamics (EOSC 352)
- Signal processing (EOSC 354)
- Image processing / remote sensing (Currently no requirement, Eldad has interest in developing) (Is this the right level? Maybe an elective?)
- Data science: AI/ML (EOSC 410)

Year 4

Many of these should be considered "technical electives". Students should seek advice to identify choices consistent with their interests and abilities. Based on student feedback, they need to be able to meet professional requirements if they want to go that route.

- Elasticity via seismology (EOSC 353)
- Geophysical fluid dynamics (potentially EOSC 477 / ATSC 414 – currently dormant, not required, potential for co-listing with EOSC 512)
- Physical oceanography? (EOSC 471)
- Upper level ATSC?
- Geophysical solid mechanics (no obvious course – probably rely on 353 to cover this)
- Hydrology and fluids in the earth – EOSC329 Groundwater.
- Climate change or physics (Phil & Rachel working on EOSC595, and a split of 340 into quantitative / non-quantiatitve is on the cards, we'd use the quantitative version here)
- Will most likely retain EOSC450 (currently essentially "potential fields", which is fine).
- Retain EOSC453 (Physics of the Earth and other planets) as a common capstone across the program?
- May need to align multiple options with corresponding grad course and run in alternate years to make viable.
- EOAS-based courses:
  - Likely core pathway 211,212,250,352,354,410,453
  - Options out of 353,450,477,329, Climate
- Note: 353,329 are 3rd year, others are 4th year / undefined. This is apparently not a UBC graduation requirements issue.

Other issues to adjust in existing geophysics curriculum, aligned with the above

Note at 2023, these points may be out of date.

- Stratigraphy course requirement EOSC222 redundant if broadening scope of GEOP degree as advertised; drop and free up this space? Or make it 222 or EOSC2xxx / Other Subject 2xx?
- EOSC211 – scope for making optional with other computing offerings across campus? Not a priority, and may not be popular in EOAS as an idea

- Thermodynamics course (currently PHYS203) – make this PHYS203 or CHEM205; absolutely needed in program?
- EM PHYS301 already not widely taken – not sure I really see the rationale but there is precedent. In the context of broadening geophysics, we could make this one of PHYS301, EOSC350 (applied geophysics), MATH345 (applied nonlinear dynamics and chaos, MATH215 is a prerequisite but included in GEOP curriculum, must score 68% or higher – this covers the dynamical systems tools area). The proposed set of options covers a greater range of future specializations. Can add (i) ATSC specialized option if available and (ii) Catherine's planned global geophysics class here too.

QuEST – EOAS Quantitative Earth Science Transformation project

Reinvigorating quantitative learning in Earth, Ocean and Atmospheric Sciences

Priorities, summer 2020

Contents

1. Introduction

These notes summarize discussions between May and Sept 2020 about the QuEST project's scope and priorities. Factors contributing to discussions included:

- goals and plans in the QuEST project proposal that garnered funding;
- loosely documented options discussed at EOAS retreats in 2019 and 2020;
- previously undocumented priorities of individual faculty members;
- approaches to curricular review and renewal, based on post-secondary educational expertise within EOAS, at UBC, and from relevant literature.

There was some debate about the QuEST project's goals and priorities. Were we expecting to take concrete action towards implement existing ideas? Were we to carry out "due diligence" & background research regarding the current state of curriculum in EOAS, and the needs, expectations & opportunities for BSc graduates? Did we expect to "make changes" or "recommend actions to make changes"? What combination of these ideas would be most appropriate for steering QuEST project activities?

There was certainly a desire to take concrete steps as soon as possible. At the same time, it is recognized that the challenges imposed by 2 years of COVID did delay progress. Moving forward into 2024 and beyond, the department can hopefully find the enthusiasm, energy and commitment to tackle some selected priorities. It is hoped that the QuEST project documentation offers some viable options, with appropriate background details to help justify suggestions, roughly predict costs and commitments, and inform decisions.

The following lists represent my (FJ's) interpretation of the main priorities emerging from discussions. Rather than concrete expectations, they are lists of ideas and issues raised. They are not presented here in any particular order. If these lists are incomplete or incorrect in any way, the fault is mine, not those who contributed.

2. What kinds of students are targeted for a rejuvenated curriculum?

1. One question often discussed is whether students would be best served by offering traditional QES career paths (eg. geophysics) or whether to offer a more general quantitatively oriented curriculum. End-members of the discussion look like: (1) "*university education is not about setting up students for specific careers*", versus (2) "*students should be prepared to enter specific career paths upon graduation*". The reality probably lies somewhere between these two end-members. Many aspects of QuEST work relate to this conversation.
2. The students targeted by QES curriculum renewal will most likely be a small population of rigorously inclined students, perhaps ~15-25.
3. Are any such students in the ENSC and related programs?
4. There needs to be an awareness of the distinction between recommendations aimed at enhancing quantitative capabilities of "all" geoscience students versus those targeting the teaching of quantitatively inclined specialists.
5. Care needs to be taken to avoid describing aspirations for *undergraduate* programs at the *graduate student*
6. Is there energy and justification for developing a new consolidated degree program encompassing a range of disciplines that is both appealing and develops rigorous capabilities such as process modelling & data science? The pros & cons and costs & opportunities are still debated, but a more practical, incremental pathway may be more likely to succeed.

3. What changes to existing EOAS programs are appropriate at this time?

Discussions during summer 2020 certainly revealed a desire for concrete action soon. The following are specific suggestions. They are not in any particular order, nor are "costs" and requirements discussed here.

1. Gradually changing content of existing courses was discussed as more practical than introducing new courses and dropping old ones. However, given the number of new EOAS faculty between 2018 and 2024, new courses will no doubt emerge.
    1. Adjusting existing courses or building new ones should not occur in isolation. Changes should be predicated by a vision & planning sequence, otherwise progress will be piece-meal and curricular flow for students may be compromised.
    2. If gradual adjustments are intended to contribute in the long term towards a new degree specialization, then courses that are applicable within the geophysics curriculum may be the most

likely candidates for evolution.

2. Could QES specializations &/or courses be consolidated into a program that is appealing and appropriate for students who would otherwise consider physics? Two examples of appropriate subject areas are *process modelling* and *data science*. There are certainly others.
    1. This would initially target ~15-25 students.
    2. Common 2nd & 3rd year, specialization at 4th year (eg solid or fluid).
    3. Consider new 3rd 4th year options in hydrology, geophysical fluids for atsc / ocgy, climate.
    4. A degree specialization name change could be considered, eventually.
3. Engage with Environmental Sciences. Ideas include:
    1. Establish an optional QES stream within the ENSC specialization involving existing EOAS courses. Ensure it is characterized to attract and inspire appropriate students.
    2. Determine if there could be QES components as part of the Faculty of Science's sustainability and ENSC ideas and aspirations. (T. Ivanochko would be first point of contact for such discussions.)
4. Examine potential joint, minor or other degree or credential options
    1. With Physics? EngPhys, a minor in geophysics? Needs inspiring marketing.
    2. Math? Maybe a credential in geophysics (geophysical fluids or inversion perhaps) or atmospheric sciences (fluids or numerical methods perhaps)
    3. Computer science? Maybe less likely, unless a friendly CPSC colleague can be convinced.
5. Who could/should be involved?
    1. A balance is needed between "too many cooks" and individuals simply forging ahead without consultation and planning. This requires careful coordination to manage varying expectations and the practicalities of curricular change within the UBC "system".
    2. EOAS faculty will want to apply their own expertise to define learning priorities. Fair enough – also engage educational expertise about curriculum design & best practices with UBC support and with reference to precedent (the geosci and QES literature).
    3. Time and energy needed to make progress is considered daunting by some. Therefore, Departmental support such as teaching or committee duty buy-outs may be important.
6. What are the key QES skills that students should develop?
    1. Faculty members are of course experts in their areas of discipline-specific research. However, most are under-informed about the needs of the non-academic occupations that students will take on after graduating. The QuEST project addresses these issues.
    2. Foundational concepts, tools & methods were discussed at Department retreats in spring 2019 and 2020 and are summarized elsewhere.
    3. Defining QES curriculum is a balance between generalities & specifics. "Academic freedom" is fine but students need to know what KINDS of problems they'll learn to solve. Appropriate program and course learning objectives must inform students as well as faculty and these objectives may require examples to clarify.

4. Outreach, recruiting, marketing & student support or advising

The desire to take concrete steps as soon as possible was particularly evident regarding efforts to attract appropriate students. Here are ideas that were discuss. Many have been initiated – see QuEST marketing actions and recommendations for details.

1. Outreach: target high schools and UBC's Vantage college.
   1. Ideas for targeting schools were discussed – see QuEST marketing recommendations. A primary goal is to dispel the notion that Earth sciences are "soft".
   2. Target high school teachers and career advisers, how apparently tell students that the Earth sciences do not involve much "hard science". We (EOAS) tend to reinforce this by the qualitative nature of most first year EOAS courses.
   3. However, "marketing" to these targets was recognized as challenging and time consuming.
   4. These challenges are not unique to UBC – see for example. Lyon etal 2020.
2. Improve all EOAS **and** UBC web content relating to EOAS degrees and occupations. This was done in 2020-21 but deserves as second round of improvements, ideally with advice from EOAS faculty
3. Inject EOAS context into the (then) new DSCI-100 course taught by Statistics.
4. Provide more substantial help for students to map their strengths & interests onto opportunities. In other words, improve advising so that students are more aware of rewarding opportunities and benefits of pursuing QES degrees.
5. Clarify relevant industry workforce situations and opportunities for students, based on academic, government and professional societies information.
6. Relate opportunities for physics students to QES. Start here.
7. Increased inspiring & relevant contexts for learning in existing QES courses. This means relatively minor adjustments to content, assignments and assessments, including (for example) instigating capstone opportunities that relate to occupations students may encounter in the one to two years following their graduation.

5. A new first year course

This was considered during deliberations to be a high priority. Unfortunately, no further work was completed other than some discussion and background research about first year students in other EOSC 1xx courses, perhaps due to lack of resources and other priorities during COVID. However, the Department could now (2023) consider whether this can be elevated again to a high priority.

See the separate page for details about a proposed new first year course, including a synthesis of earlier deliberations and resulting recommendations.

First year course

Some time in 2020

Rationale

One major item on this year's agenda for the quantitative earth sciences committee is to design a first year course that reflects the nature of the quantitative program(s) in the department - ultimately, whatever collection of courses we will end up bundling under the QUEST umbrella as the "revamped geophysics".

To set the background here - as a working assumption, revamped geophysics will mean anything that is under the umbrella of what e.g. the American Geophysical Union does that involves advanced physics, mathematics, data analysis.

The target of this program would be to output students well grounded in Earth Science, with a certain degree of choice in specialization (solid earth, fluid earth, hydrology/hydrogeology, climate/earth systems science) who are also (age-appropriately) fluent in math up to pdes and linear algebra, in scientific computing, in data analysis, and in the physical foundations behind this (mechanics/continuum mechanics, thermodynamics, electromagnetism where required).

Our challenge is perhaps less to construct a 2nd year+ program than it is to attract students into it (even if partially through whatever joint programs). The first year course idea is one strand of this. Our current EOSC1xx / ATSC1xx offerings do not signal the content I've described above, which most likely means that the students we want would not even consider taking our programs. The point of a first year course is to change that perception and create visibility.

Key is the new breadth requirement - everyone in science has to take something from 6 out of 7 pre-defined categories, so physics / math / compsci students have to take courses from some traditionally descriptive fields, see http://www.calendar.ubc.ca/vancouver/index.cfm?tree=12,215,410,1663

Our hope is to fill that part of that niche with quantitative content, which should appeal to students not keen on taking life sciences or descriptive earth & planetary sciences. Our challenge is that astronomy is part of the same category as EOAS, ENVR and ATSC, which may attract many physics students. Therefore, we must be creative and proactive in marketing the course to appropriate students.

Action items

We have a pretty blank canvas here. A few ideas - climate physics and earth systems science first and foremost - have been suggested. I'd like to turn this around - in order to attract the audience we want, let's start with what they are likely to be attracted to:

1) What abstract tools, methods, concepts should we illustrate using Earth Science examples? How do those fit in with first year material concurrently taught? For instance, I can see lots of ways of making first year math come alive (especially calculus). What is likely to be attractive? What can we build on later. *Note: data science aspects of earth science are taken care of separately through a new DSC 100-level course in which EOAS gets to teach a section.*

2) Which Earth science subfields should we touch on? More? Fewer, to keep it focused? What does past experience tell us?

3) Is there an overarching theme that lends itself to points 1,2. Catchy title? As above, climate physics and Earth systems science have been suggested.

4) Single versus multiple instructors - again, keeping students engaged by having continuity versus student getting exposed to a wider set of approaches and not having a course moulded to a single individual as instructor.

5) Lab versus lecture. I bring this up because of an abortive attempt 20 years ago to create something similar as a lab-based 1st year course, which died again because 1st year requirements were changed, although this time in a way that didn't favour us. Current circumstances do not favour lab-based courses.

Here's where you put your stuff under each of the bullets above. Leave a name or initials if you are happy to so I can follow up. Also, if you correct someone else's stuff, please use the "suggesting" mode rather than default "editing".

CGS = Christian Schoof

RHW = Rachel White

FJ = Francis Jones

FJ: These five points do provide a useful starting point. Also, well-established course development tactics should ideally be followed. It is useful to concentrate first on the course's intentions by focusing on what we want students to come away with. **Then** the "tactics" can be addressed. Let's not mix these up. For example, instructing models (eg one or few or many instructors) can be debated independently from defining the course. Also, specific tactics such as use of Jupyter notebooks, other creative learning activities, the balance of scripted vs unscripted lessons, etc.; all these details can be discussed and developed, AFTER agreeing on what knowledge, attitudes, skills, and habits students will learn and how they will demonstrate that they've learned them. This boils down to defining "Course Learning Objectives" or CLOs that will inform the design of learning, assessment and instruction. CLOs do invariably evolve as course development proceeds, but establishing a first draft of 5 – 8 CLOs is a useful and commonly accepted first step.

1) Abstract tools, methods, concepts

CGS: A few math concepts I'd like to introduce in a first year appropriate way:

- differentiation - derivative as a "local" constant of proportionality linking change in one property to change in another (e.g. displacement is expected to be proportional to time elapsed, so long as you're looking at short times elapsed; velocity is the constant of proportionality)
- ii) integration as a Riemann sum independently of anti-derivatives: e.g. summing over local density*small volume to get mass
- iii) integration as anti-derivative: summing changes in one quantity dx gives sum in v dt etc
- iv) simple differential equations from first principles, plus solution by separation of variables (and why that is necessary)
- v) the concept of stability of equilibrium solutions
- vi) even some simple bifurcation stuff involving hysteresis (though I would not let the word "bifurcation" pass my lips! Hysteresis - yes). I can map these onto most science subjects; they are pretty universal and would give context to the context-free math they are likely doing in MATH101/102. I can also explain these without the full math machinery being in place.

FJ: Are these desirable because they are "fundamental" or because the are necessary to address the course content that is being prepared? Is this a "methods course" with Earth or climate for context, or an "Earth and climate" course that introduces abstract methods on an as-needed basis? Ideally the focus of the course needs defining first, then the necessary abstract tools, methods and concepts can be identified, along with the appropriate level of "master" expected for a rigorous 1st year course. I think it would be more productive for discussions to focus on the inspiring Earth & climate concepts we want students to become conversant with, then the necessary abstract methods will become evident.

RHW: These sounds good to me. Without much experience yet of what students learn where, I don't have many strong views on concept - I'll keep thinking though.

RHW: I think Jupyter notebooks could be a good tool to use to demonstrate quite a lot of these points in a tangible way, while also giving students some python coding experience (without needing any prior experience coding). But, I can also see disadvantages of this in terms of (a) work to set things up initially, and (b) continuity throughout the course if we have different instructors. That being said, if we have funding to pay undergrads to create the notebooks at the beginning, as Phil has been doing, even instructors who don't use jupyter could relatively easily create some interactive notebooks. Indeed, this could potentially lend a sense of continuity through the course. I like the idea of students learning something analytically, and then seeing this applied in a notebook to solve some Earth science problem. FJ – sure, BUT – start with the earth science problem (motivation) and offer analytical approaches as means of addressing it.

CGS: nice idea; how much does it force an incoming instructor to stick with a pre-set script? We do want the course to "flow" and be internally well aligned, so lots of structure is good, but I've never been able to lecture using someone else's notes. Perhaps notebooks are a bit different.

RHW: In my head the general idea is from the flipped classroom perspective, the notebooks are what the students work through on their own, with the lectures then focusing on aspects of this. I guess if we went down the one main lecturer + guest lecturer thing, then guest lecturers could use jupyter notebooks if they wanted to, or not? If we create a series of notebooks at the beginning of this course design then incoming lecturers would either have to stick to the notebooks (aka using someone else notes - though the actual lecture content could be a little different?), OR be able to program in python to change up the notebooks.

CGS sounds good

FJ: The course needs to be engaging, yet efficient. Jupyter notebooks are certainly an effective tool. This and many other tactical ideas can be developed, then the most efficient, sustainable and "transferable" (from one instructor to the next) teaching model can be chosen. Course developers will benefit from exploring the large global community of educators who teach geoscience "first-exposure" courses, especially NAGT and the SERC repository of geoscience teaching wisdom. The best ideas will serve as inspiration for adaptation to the EOAS context and the particular needs of this new course.

2) Earth science subfields

CGS: Following this morning's conversation with Philippe (he backs the "physics of climate" theme, in fact, seems to think that's what it should be, there is a plausible "spheres" split (atmsophere, ocean, cryosphere, surface processes / longer-term geochemical stuff - the latter Mark J also reiterates in both of his 2xx and 4xx courses so perhaps it's ok to stick with nearer-term climate, up to perhaps glacial cycles.

RHW: I like the spheres theme. Don't know whether hydrosphere would be split into ocean and surface water, quite possibly it should be actually.

FJ: A framework for the whole course, like spheres, will be very useful. Perhaps the interconnectedness of spheres is a theme? Further debate about what to include and what to leave out (or simply hint at) will be needed - and interesting! It will be OK to start with a long list of possibilities, but the final result should be a "brutal" cull to find the minimum that results in a cohesive course. The goal after all is to inspire students and leave them wanting more, not to somehow cram the whole discipline into a short time.

FJ: Consider thinking in terms of modules. If carefully designed, these may be swapped in and out according to the preferences of each instructor. Varying the modules from year to year will also result in a course that is a little different each term (always a good thing). If modules are ~3 weeks each (9hrs of lessons + ~15hrs homework), then there is room for four. This model is used successfully in DSCI-100. They have four statistical concepts that students are to learn and practice. A relevant problem is identified for each concept, the challenges and possible solutions are considered, then details associated with the statistical thinking, necessary mathematics, and corresponding programming or visualization skills are developed (in "R" or Python, depending on course section). For an EOAS1xx course, modules could be independent (like in DSCI-100) or they could be coupled using the framework of "spheres", or along some other form of climate or Earth science relationships.

During course design, it might be useful to specify the first four modules to be taught, but design five or six so the course is ready for the first few seasons. The department should then commit to supporting development of one module perhaps every 3-4 years. Adapting or developing new modules (under supervision) make good jobs for worklearn or graduate student employees.

3) Overarching Theme

CGS: I think climate science is a great objective here; we need to draw on the unique strength in EOAS in having faculty from multiple disciplines, so "climate" is not the purview of atmospheric science, or even seen predominantly through that lens - Rachel White, Anais Orsi, Mitch Darcy, Ali Ameli, Stephanie Waterman, Valentina Radic, Mark Johnson, Christian Schoof, Mark Jellinek, Phil Austin, Susan Allen and probably others make a good QES climate core

RHW: I like the idea of a climate focus, and I agree that it isn't just atmospheric sciences. I also wonder if we could make it even more broad, some sort of 'critical problems in Earth and Climate Sciences'? Some student feedback from questionnaires for the Climate Change credential/certificate working group questioned the possible "left-ist agenda" of a climate change specified.

CGS: I see where the leftist agenda thing is going but if we start changing the title (rather than demonstrating that climate *science* is apolitical), are we simply playing into this preconception? "The physics of climate" should be ok. We're not calling it "Global Warming" or even "Climate Change", presumably

RHW: "Physics of the Earth and Climate"?

CGS: Plausible, need to think about the other EOS1xx courses. "Earth" may have a preconceived (solid earth?) meaning

RHW: good point. I like The Physics of (the Earth's?) Climate, that's hopefully pretty broad in the minds of students (I don't have a good sense of what the average first year thinks when they hear 'climate' - do they just think climate change?)

Maybe Climate Sciences (to emphasize the different sub-fields/sciences within the broader scope of the climate system)?

FJ: All good thoughts. It does seem as if "Climate Sciences" or "Climate Physics" or something similar is timely, inspiring, appropriate given the Dep't goal for this course (introducing quantitative Earth sciences), and feasible given EOAS faculty expertise. With a little creativity, any EOAS faculty member should be able to lead this course.

4) Single versus multiple instructors

RHW: I like the idea of multiple instructors, for giving a sense of how these fundamental maths tools are applicable across a wide range of Earth Science problems, as well as promoting the diversity in research and researchers across the department. Perhaps one way of doing this could be to have one instructor throughout the term for the more abstract maths concepts, e.g. giving one or two lectures a week, and then one lecture each week is given by “guest” lecturers, each of whom is there for maybe two lectures (i.e. two weeks) a term to give more applied, topic-based instruction and examples for the concepts introduced that week. I realize this could end up with about 6 instructors in one term, but 5 of them would only be teaching two lectures - I don’t know if this is really a thing that people would buy into or not, but it would be a bit different, and could be appealing to students? Sounds like (from discussion in breakout rooms today in the faculty meeting) that this could potentially work well, if all instructors felt they had enough of a role in deciding what concepts their material was focused on, not just being told: here, teach hydrology using ODEs, for example.

CGS: I’ve just talked with Philippe and he suggested 3-4 instructors max, but the guest lecturer plus main lecturer model is interesting

RHW: potential other benefit of main + guest lecturer model is that this could give clear leadership coming from the main lecturer, to help guide design etc and make sure it feels like one cohesive course, not 4 3-week courses run one after the other - still with input from potential guest lecturers about what they want to teach and where, but with the final say/responsibility from the main lecturer (I say all this with zero experience of what designing a course like this would be like in EOAS, so feel free to tell me I’m way off base here!)

CGS: I think we’re in the same boat. I’ve never taught “my” stuff to undergrads before (as in, cryosphere, not fluid dynamics, plenty of that), don’t know how easy it is to set up for someone else to do the bulk of it but we’re talking first year so the ~~didactic~~ pedagogic aspects are much more important than expert content. There is also the practical question of teaching credit and how that would be split.

RHW: I heard some feedback from others during the last faculty meeting that there is a marine pollution class that is run similarly (i.e. multiple guest lecturers), and is very successful and the students really enjoy it. Though I forgot the course number unfortunately - maybe 474?) In terms of teaching credit, yeh, I have no idea how that would work out logistically I’m afraid!

FJ: Leadership and consistency is very important to students. They generally do not thrive in courses that “change” from week to week. At the same time, they benefit and enjoy opportunities to interact with experts. I think the main+guests model can be made to work very well. The “serial monogamy” model with a sequence of 4-6 instructors rotating into the “main role” results in a fragmented experience that is counterproductive in a course that has a single main theme – such as climate physics in this case. The fragmented model also results in instructors who are not well-motivated to put in suitable effort.

As this is a first-year course, it should be true that any EOAS faculty member could take on the “main” teaching role for the course, even if they initially feel otherwise. Making guest contributions in a first year course ought be considered a privilege rather than a chore. Also, I believe the main+guests model could enhance the Department’s sense of community. We are all eager to promote our science, and making small contributions for eager young first year students is an ideal - and efficient - opportunity to do just that. Course designers can work towards optimizing both the efficiency and efficacy of instructional delivery and student learning & assessment. All it needs is some creativity with support of geoscience education expertise.

5) Lab versus lecture

FJ: Given past experience, and benefits (to instructors and students) of clarity & simplicity, let’s keep it straight forward; no fancy or unusual scheduling or pedagogic needs, and no labs that end up needing resources, personnel, TA training, etc. With creativity we can accomplish the goals without labs. (By the way, ATSC 113 has good examples of creative approaches to engaging learning at this level.)

Next steps

FJ: Suggested next steps:

- Summarize / list key points from this discussion to make it easier for others to grasp the thinking so far.
- Identify a "project PI" to move project forward.
- Generate a first draft (~2pgs) of a proposed course description, with a few tentative course learning objectives, suggested assessment & instructional tactics, and a brief estimate of resources, time & funding needed. Perhaps include a proposed time-line towards first-offering.
- List first thoughts about marketing. What types of students should thrive in this course? What prior capabilities will they need to succeed? How will we convince them that this course is a worth-while first year option? Will we somehow deny others (eg 3rd & 4th year students) from taking it as an elective? And other aspects of making the course visible and attractive to appropriate students.
- Project PI to present the proposal to the Department, then engage one-on-one with faculty who are interested, to address questions, concerns and suggestions.
- A second version of the proposal will emerge, to be used as the basis for a funding request (perhaps a small TLEF, or other UBC / FoS / EOAS funding opportunity).

EOAS micro-credential / certificate programs

1. What we have done already
    a. Erik: Professional course base Meng
    b. ATSC: Diploma in meteorology

2. What we want to do
    a. Resources….

M.eng. Geological Engineering

This came into force in the 1970s. It is a professional masters degree - students doing a course-based masters. They graduate ~ 40 geo. Eng. per year, mostly go right into industry - consulting. It's a 1 year focused. ~ half of the revenues come back to the department. UBC / province has caps on domestic tuition. Not on international students. Significant financial 'up-side' on international students, break even on domestic students. About 75% of our students are domestic. Mining Eng. take a much larger share of international students. At present industry people will periodically act as sessionals, but generally there are few contributions from industry people. But they are interesting in being more involved.

The graduate courses in this program are well subscribed - 15 - 30 enrollments (many are actually MEng students crossing over from Civil and Mining). A handful of them (5-10) also tend to enroll in our 4th year/grad cross-listed courses.

They do 'zero marketing' for the program.

Some challenges:

- Quality control. Program doesn't always attract "top" students. Some folks are seeking credentials because they can't get promotions the old fashioned way.
- Very little admin support. Selection of courses, day to day guidance falls largely to profs.
- MEng graduating papers and directed studies are like mini theses that are time consuming to supervise.
- Not clear where financial benefits flow for all the effort.
- Not all grad course styles are conducive to online or modular/short format (e.g. literature discussions, field trips).
- Competition from other programs who are ahead of us in this mode of delivery (e.g. Arizona).
- How to mesh our program effectively with Civil, Mining MEng and certificate programs.

Many people who are interested in certificate programs would be interested in on-line courses - to make it easier to work full time.

How to bring different learners together: examples and ideas.

- Oldenburg's group does a lot of courses to train professionals in the use of software / inversion tools to get better results. Generate open sources resources available broadly. E.g. how to invert magnetic data - short course. They provide code and take

them through data sets with hands on exercises. People learn about the methods and applications to their own problems. Typically this would run over a couple of days. Has mostly been taught by grad students and PDFs from GIF. The courses are typically free - but targeted to sponsoring companies.
- CODES - would run a distributed program based on 2 week block course modules.
- MDRU short-courses run with external lecturers - e.g. bring in an expert on machine learning to lead a course.
- https://www.utas.edu.au/codes/masters-short-courses: It's an M.Sc. level course, but a lot of the material is at a sr. undergrad level.

How:

- On-line teaching can target international participants.
- Modularalize different size 'chunks' of course sizes - blocks of modules can be mixed and matched.
- MDRU future model. It would be good to 'formalize' the offerings to give credentials / certificates. Re-package / re-utlize existing material, and add some additional material led by industry professionals, and add some some practical field-based training and a co-op program with placements. Focusing on research that is done - promoting new techniques and stimulating application of those methods.
- How to balance the desire for open source materials readily available to lift up the field and do good. But then also need a longer-term revenue model. Perhaps you can monetize the credential.
- Don't want separate tracks for research students and industry people. We want people to come out of the program with good skills, and subject to an evaluation.
- Focus on inter-disciplinary projects - people to communicate across boundaries - courses that are problem-driven.
- Asynchronous components are helpful
- For reach more international students, Brett Gilley could provide ideas about working with students from different cultural backgrounds.
- Regarding online courses: Sample of hybrid online (first-year) course with short (3 minute) video snippets, see: https://www.eoas.ubc.ca/courses/eosc114/storms-oe/day1/eosc114-oe-storms-day1.html
- Example Engineers and Geoscientists BC course: Characterization and Management of Metal Leaching and Acid Rock Drainage. 1 day course, $523 https://www.egbc.ca/Events/Events/2021/21FEBCAM (What are funds "for"?)

Why are we doing this?

- Upgrading skills for students / employees who are coming out of developing countries.
- help the community
- help our undegrad network
- it is a pipeline to build connections with industry
- Stakeholder meetings have been very productive in letting us.

Environment Certificate Program:

- Probably a large audience.

- Could aim to provide short courses to help candidates achieve Environment Professional (EP) certification, such as the ECO program.
- https://www.eco.ca/ep-designation/
- Could span almost all branches of our department.

ATSC Certificate Program:

From email, R. Stull, 2019

The Atmospheric Science professors met today (1 Aug 2019) to discuss OLAF, Diploma programs, Certificate programs, and new online courses. The marketing info provided by the OLAF team was invaluable, and helped us reach the following decisions. Thanks team.

1) We will eliminate the existing Diploma of Meteorology program.

2) We will consider creating a Certificate of Meteorology focused on the big societal issues related to over population, for which practicing meteorologists would likely want retraining:
Issues:
- air quality (ATSC has strength in this area)
- renewable energy (the ATSC 313 course with Skylight funding)
- climate change (a new prof was hired in this area)

Tools:
- big data (stats, machine learning, python programming)
- GIS & remote sensing

3) The ATSC faculty felt it was too early to go fully online with a certificate program. Some concerns were:
- how would online-course creation & teaching count towards tenure of new faculty?
- does OLAF funding allow for a mix of online, blended, and traditional courses?
- in any one course, what is the right balance between online and face-to-face meetings?
- if answers escape into the internet, how can cheating be reduced without imposing a burdensome workload on the prof?
- will OLAF fund creation of online micro modules, which could be combined into different courses.
- can upper-level courses be created with sufficient quantitative rigor online? This is a big issue.

4) Bottom line, the ATSC faculty wants to wait and see whether we can make our first new online upper-level course work successfully. If successful, then I think there will be much greater buy-in for adding more online upper-level courses.

5) The ATSC faculty gave solid endorsement to go ahead and create ATSC 313 Renewable Energy Meteorology, regardless of whether it is part of OLAF or whether it is required for ATSC majors or for a Certificate program. The course already has Science Skylight funding, and course-content creators have been hired. The new-course proposal is making its way through EOAS and Fac. of Sci. committees.

We are aiming for a first offering of ATSC 313 in Fall 2020 or Spr 2021. That is why we request a delay in the full OLAF proposal. We first need to see if ATSC 313 can be successful.

Cheers,
-Roland

P.S. We invite Simon Bates to come to an EOAS dept faculty meeting to give a presentation to share his vision of the future of online courses at UBC. This would help a lot of entrenched profs to realize that change is in the air.