



**Large TLEF Transformation Project – Proposal Form**

**Project Title (200 characters max.)**

*Do not use all-caps.*

Embedding Open-source Computational Tools into the Quantitative Earth Science Specializations

**Principal Applicant**

*For administrative purposes, there must be one Principal Applicant only who should be a full-time UBC faculty or staff member.*

Principal Applicant’s name:

Tara Ivanochko

Principal Applicant’s title(s) (e.g. Assistant Professor, Instructor, Professor of Teaching, etc.):

Senior Instructor

Principal Applicant’s primary (UBC) email address:

tivanoch@eoas.ubc.ca

**Co-Applicants & Project Team Members**

*Please indicate all other co-applicants’ names as well as their corresponding titles, affiliations, role in the project and UBC email address, separated by commas (e.g. Jane Doe, Associate Professor, History, Faculty of Arts, jane.doe@ubc.ca). If your proposal is successful, this list will be published on the UBC website (emails will be removed).*

- Co-Applicants:
- Susan Allen, Professor, EOAS, Faculty of Science, [sallen@eoas.ubc.ca](mailto:sallen@eoas.ubc.ca)  
Dr. Allen participated in the transformation of ATSC 409 to python and Jupyter notebooks and currently has the skills to help train others in using python and Jupyter-based active pedagogies in the classroom.
  - Phil Austin, Associate Professor, EOAS, Faculty of Science, [paustin@eoas.ubc.ca](mailto:paustin@eoas.ubc.ca)  
To date, Dr. Austin has transformed three courses to use python and Jupyter notebooks and is the liaison between this proposal and the Data Science minor proposal. He is engaged with the Faculty of Science initiative to provide student computation support on the cloud and chair of the Infrastructure Sub-committee for the Faculty of Science Data Science Committee.
  - Roger Beckie, Professor, EOAS, Faculty of Science, [rbeckie@eoas.ubc.ca](mailto:rbeckie@eoas.ubc.ca)  
Dr. Beckie participated in the transformation of EOSC 213 and currently has the skills to help train others in using python and Jupyter-based active pedagogies in the classroom.
  - Michael Bostock, Professor, EOAS, Faculty of Science, [bostock@eoas.ubc.ca](mailto:bostock@eoas.ubc.ca)
  - Eldad Haber, Professor, EOAS, Faculty of Science, [ehaber@eoas.ubc.ca](mailto:ehaber@eoas.ubc.ca)
  - Mark Jellinek, Professor, EOAS, Faculty of Science, [mjellinek@eoas.ubc.ca](mailto:mjellinek@eoas.ubc.ca)
  - Catherine Johnson, Professor, EOAS, Faculty of Science, [cjohnson@eoas.ubc.ca](mailto:cjohnson@eoas.ubc.ca)
  - Mark Johnson, Associate Professor, EOAS / IRES, Faculty of Science, [mjohnson@eoas.ubc.ca](mailto:mjohnson@eoas.ubc.ca)
  - Valentina Radic, Associate Professor, EOAS, Faculty of Science, [vradic@eoas.ubc.ca](mailto:vradic@eoas.ubc.ca)
  - Stephanie Waterman, Assistant Professor, EOAS, Faculty of Science, [swaterman@eoas.ubc.ca](mailto:swaterman@eoas.ubc.ca)



**Collaborators:**

Sarah Bean Sherman, Science Education Specialist, EOAS, Faculty of Science, [ssherman@eoas.ubc.ca](mailto:ssherman@eoas.ubc.ca)  
Based in EOAS, Dr. Sherman oversees the *Teaching Start-up* program for the Faculty of Science.  
Alison Jolley, Science Teaching and Learning Fellow, EOAS, Faculty of Science, [ajolley@eoas.ubc.ca](mailto:ajolley@eoas.ubc.ca)

**Project Summary (150 words max.)**

*Describe your project in a manner that is accessible to a non-specialist. Please specify what you hope to change or see as an impact resulting from this project. If your proposal is successful, this summary will be published on the UBC website.*

The Faculty of Science (FoS) has a strategic goal to develop data science opportunities for undergraduate students in order to build their capacity and skills for future careers in industry and research. In alignment with that goal, EOAS has begun to incorporate open source computational tools and transform teaching practices to support hands-on interdisciplinary learning in data-driven scientific exploration. Using open source, cloud-based computing we aim to integrate computational and quantitative skills more comprehensively into the EOAS curriculum, incorporating real world examples and datasets into existing courses. New Jupyter [1] notebook based modules and activities will be threaded throughout core courses in Geophysics, Atmospheric Sciences, Oceanography and Geological Engineering bridging traditional disciplinary boundaries. This proposed curriculum transformation will happen alongside a re-evaluation of quantitative EOAS course offerings across disciplines. The end result will reposition the UBC Earth Science specializations as opportunities for quantitative and computational learning in a highly interdisciplinary domain.

[1] [Barba, L., 2019: Teaching and Learning with Jupyter, accessed 2019/7/2](#)

**Students Reached by the Project**

*Please fill in the following table with all known courses and sections that will be reached by your project and in which academic year (e.g. HIST 101, 002, 2018/2019, Sep).*

Course Code	Section	Academic Year	Term (Sep/Jan/May)
ENVR 300	201	2020/21	Jan
EOAS 211	101	2021/22	Sep
EOAS 354	101	2021/22	Sep
EOAS 410	201	2021/22	Jan
DSCI 100	201	2021/22	Jan
ENVR 420	201	2021/22	Jan
EOAS 372	101	2022/23	Sep
EOAS 329	101	2022/23	Sep
EOAS 471	101	2022/23	Sep
EOAS 442	101	2022/23	Sep
EOAS 373	201	2022/23	Jan
EOAS 429	201	2022/23	Jan
EOAS 442	201	2022/23	Jan



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How many students overall do you estimate will be reached by this project annually? (Please provide a number)

950
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**Project Objectives (500 words max.)**

Clearly state the project's rationale, overall objectives, and expected impacts/changes with particular reference to how it meets TLEF criteria.

The quantitative Earth Science disciplines use concepts and skills from Math, Physics and Computer Science to tackle some of society's most pressing environmental problems. The Earth Science research community has broadly adopted Python, and more specifically Jupyter notebooks as tools to tackle these challenges. Teaching these tools at the undergraduate level gives students direct access to freely available programs and datasets that are used by scientists, preparing them for the workforce with relevant skills and experience.

This project will:

- 1) Increase computational and numerical literacy among EOAS graduates and improve teaching in Earth Science disciplines by developing quantitative and computational skills in parallel using Jupyter notebooks and active pedagogies.
- 2) Engage new and existing faculty in the development and dissemination of cutting-edge Earth Science curricula.
- 3) Introduce students to current challenges in Earth Science through applied quantitative / computational capstone experiences.
- 4) Contribute to a parallel the Faculty of Science strategic initiative of creating a minor in Data Science through the development of appropriate upper-level, applied data science courses and Earth Science assignments, activities and assessments for DSCI 100.

As the student demand for computational BSc options grows, we see an opportunity to showcase EOAS as an excellent learning environment to develop applied quantitative and computational skills in context. This project is targeting courses that fall into three categories:

**1) Reforming assignments and activities in EOAS courses that target a broad student audience:** New Jupyter-based assignments / activities will be developed for EOAS 372, EOAS 373 and ENVR 300. In these assignments, students will primarily engage with the Jupyter dashboard to investigate Earth Science datasets.

**2) Completing full course transformations / development for programming and data science courses:** EOAS 211 and EOAS 442 are currently courses that teach Matlab™ programming. Both of these courses will be transformed to python courses. To support data science education within the Faculty of Science, we will develop the equivalent of one section of materials (assignments, activities and assessments) for DSCI 100 with that are based on Earth Science datasets.

**3) Integrating scaffolded assignments in courses for the quantitative Earth Science specializations:** An iterative approach will be used to progressively develop concepts and skills through scaffolded assignments in a series of quantitative Earth Science core courses. Within this core series, students will analyze Earth Science data sets (e.g. satellite-based observations, ocean data sets), and use models to simulate and predict Earth system processes. Through regular cycles of abstraction / modelling, data analysis and validation students will develop higher level skills to engage with quantitative Earth Sciences concepts and solve authentic problems. The final capstone projects will have students working on real



world problems in Earth Science. In addition to benefiting students in EOAS, a select number of these courses will be identified as electives for the new Data Science minor.

**Project Work Plan, Timeline & Milestones (1000 words max.)**

*Provide a clear work plan for how you will achieve the stated objectives of the project. Please include major milestones to indicate when you will initiate project development, when you will implement the project with students, and when you will evaluate whether your project's intended impact has been achieved.*

**Prior to April 2020:**

- EOAS faculty have agreed to use Python and Jupyter notebooks for undergraduate computational curriculum development.
- EOAS is currently advertising for a faculty hire in Computational Earth Science.
- Experience has been gained from pilot course transformation: EOAS 213, was transformed in 2018/19 to Python using Jupyter notebooks hosted on Google cloud nodes. ATSC 301, 409 are now currently taught using Jupyter notebooks on student laptops/departmental lab machines.
- Through paired teaching, two faculty members were trained to teach using Jupyter-based activities last year (2018/19) and one more faculty member is being trained this year.
- An EOAS committee is envisioning curricular change in the quantitative EOAS specializations. Consultation with CTLT, has begun.
- Ongoing collaboration with Statistics and Computer Science regarding DCSI 100, the Data Science Minor, and computing infrastructure needs and solutions.
- Combined Majors in Science (CMS) has approved changing EOAS 442 from Matlab™ to python.
- A pending NSERC CREATE application creating novel collaborations by bridging oceanography, geophysics, computer science and statistics.

**Project Approach:**

The development of open source tools (like Jupyter notebooks and Python libraries) is a priority for UBC as well as Earth Science funding agencies. Within EOAS, two pilot courses (EOAS 213, ATSC 409) have now been transformed to employ new Jupyter-based assignments and activities. This experience has built departmental capacity as well as student and faculty support to comprehensively embed open source computational tools into our quantitative course offerings.

Building on the current *Teaching Start-up* partnerships in EOAS<sup>1</sup> that trains new instructors to teach using student focussed, active pedagogies, paired-teaching assignments will be used to train EOAS instructors to build and execute Jupyter-based class activities and assignments. The teaching pair will be comprised of two faculty members: one with Jupyter / Python experience and one without. The teaching pair will be supported by a Science Teaching and Learning Fellow (STLF), a Graduate Research Assistant (GRA) and/or an Undergraduate Assistant (UA). Through the paired teaching experience, both instructors will gain new skills in developing and implementing evidence-based pedagogies using Jupyter notebooks. Both participating faculty members will receive full credit for the teaching assignment.

After a paired experience, faculty members will proceed to transform additional courses with the support of a STLF and / or a GRA or participate in a new paired teaching assignment. In this way, we are building capacity to use these new tools and transform courses efficiently. In addition, participating faculty

<sup>1</sup> <https://doi.org/10.1080/87567555.2018.1463505>



members will gain insight on what is being taught by others in the departments and build new interdisciplinary collaborations.

EOAS is currently expanding the number of Faculty members who use data science tools to investigate earth systems. Two recent hires (Earth System Science and Earth and Planetary Atmospheres) are complete and a new search in Earth Data Science is underway. The addition of these three new faculty members allow us to undertake this project and build further capacity in EOAS to teach undergraduate students using these new tools.

Year 1:

- Literature review to determine current evidenced-based practices in computational (earth) science education.
- **EOSC 211:** Development of new materials, activities, assignments, assessments and pre/post tests.
- **ENVR 300 (term 1):** 2 new activities - environmental datasets
- **ENVR 300 (term 2):** deployment of new activities
- **Quantitative core series:** planning and development of integrated curriculum
- **Community of practice:** four EOSC lunches (two per term) will be held to co-develop goals, share experiences, build a community of practice and provide feedback on the larger project.
- **Faculty training:** develop and run a Python and Jupyter notebook carpentry session focused on earth science datasets for interested EOAS Faculty, Postdocs and Graduate students .
- **Evaluations:** student surveys to evaluate ENVR 300 activities, pre-post testing in EOSC 211 to capture baseline

Year 2:

- **ENVR 300 (term 1):** revision of new activities
- **ENVR 300 (term 2):** deployment or revised activities
- **EOSC 372:** development of 3 new activities - ocean ecosystems
- **EOAS 373:** development of 3 new activities - ocean system dynamics
- **EOSC 211 (term 1):** first teaching term with transformed materials
- **EOSC 211 (term 2):** revise assignments and activities
- **DSCI 100 (term 1):** development of new materials, activities, assignments and assessments
- **DSCI 100 (term 2):** first teaching term with transformed materials
- **EOSC 442:** development of new materials, activities, assignments, assessments and pre/post tests
- **Quantitative core series:** new materials, activities, assignments, assessments and pre/post tests. **EOSC 354, EOSC 410, ENVR 420 :** first teaching terms with transformed materials
- **Community of practice:** four EOSC lunches (two per term) will be held to discuss goals, share experiences, broaden the Faculty engagement and provide feedback on the larger project.
- **Faculty training:** one Python and Jupyter notebook carpentry session focused on earth science datasets for interested EOAS Faculty, Postdocs and Graduate students
- **Evaluations:** student surveys to evaluate EOSC 372, EOSC373 and ENVR 300 activities; pre/post tests, class observations and faculty interviews for EOSC 211 and DSCI 100; pre/post tests in EOSC 442 for baseline; pre/post tests, courses class observations and faculty interviews in 3 core series courses

Year 3:

- **EOSC 372 (term 1):** deployment of new activities
- **EOAS 373 (term 2):** deployment of new activities
- **EOSC 442 (term 1):** first teaching term with transformed materials
- **EOSC 442 (term 2):** second teaching term with transformed materials
- **Quantitative core series:** continued  
**EOSC 471, EOSC 329, EOSC 429:** first teaching term with transformed materials



**EOSC 354, EOSC 410, ENVR 420:** second teaching term with transformed materials

- **EOSC 211** (term 1): second teaching term with transformed materials
- **DSCI 100** (term 1): revise assignments and activities
- **DSCI 100** (term 2): second teaching term
- **Community of practice:** four EOSC lunches (two per term) will be held to discuss goals, share experiences, broaden the Faculty engagement and provide feedback on the larger project.
- **Faculty training:** one Python and Jupyter notebook carpentry session focussed on earth science datasets for interested EOAS Faculty, Postdocs and Graduate students
- **Evaluations:** student surveys to evaluate EOSC 372/373 activities; pre/post tests in EOSC 442; pre/post tests, class observations and faculty interviews in 6 core series courses

**Project Outputs, Products or Deliverables (500 words max.)**

*List or describe the project's intended tangible outputs, products, or deliverables. What will the project do or create as a result of the implementation of its work plan?*

1. Approximately 8 short Jupyter-based activities will be developed for EOSC 372, EOSC 373, ENVR 300. These courses are taken by students in all EOAS specialization as well as other faculty of science specializations. These new Jupyter-based activities will enhance current course experiences, allowing students to evaluate concepts and test scientific decision making by interfacing with data through Jupyter dashboards.

- For example, in ENVR 300, students are asked to decide on an averaging window based on the inherent timescale of the process they are investigating. The Jupyter activity will allow students to understand the practical consequences of choosing different averaging windows.

2. New course assignments and activities will be developed for and scaffolded through a core series of 2nd, 3rd and 4th year courses required for students in:

- Geophysics, Physical Oceanography, Atmospheric Science: EOSC 354, EOSC 410, EOSC 471
- Geological Engineering: EOSC 213 (completed), EOSC 329, EOSC 429.

A selection of these courses will be made available as applied electives for students completing the new Data Science minor.

3. Two Matlab™-based courses will be transformed to use python. Jupyter-based activities will be developed to support the course learning goals.

- EOSC 211 is a required course for students in all three Combined Oceanography specializations, Geophysics, and Atmospheric Science. EOSC 211 is an optional course for students in Environmental Science, Geology, and Earth and Ocean Sciences.
- EOSC 442 is required for students in the Combined Major in Science specialization who have chosen the Earth and Environmental package. EOSC 211 is a prerequisite course for EOSC 442.

4. New materials for DSCI 100 that showcase Earth Science datasets will be developed, based on the learning objectives of the revised, upscaled version of DCSI 100.

5. Approximately 10 EOSC Faculty will be trained to develop and teach using evidence-based pedagogies supported by open source notebooks. Graduate students will also be able to receive TA training to use these activities in class and labs.

6. EOAS is the first department to transform courses based on the FoS Data Science Education strategic priority. As such, EOAS will document our approach and the professional development of faculty and graduate students to provide a model for other departments/programs who will engage with this reform in the future.




**Project Impact (500 words max.)**

*Referring to the project's objectives and expected outputs, what are the direct and short-term as well as sustainable benefits to students or instructors that you expect to achieve? What changes or impacts do you hope to see as a result of this project? Explain how these will contribute toward the enhancement of teaching and learning.*

The Impacts of this project are fourfold:

**1. Improving pedagogy in EOAS**

The EOAS courses targeted by this project fall into three categories: courses designed for EOAS and non-EOAS science students (eg EOSC 372), courses designed for all EOAS specializations (eg EOSC 211) and courses designed for the quantitative EOAS specializations: Geophysics, Physical Oceanography, Atmospheric Science and Geological Engineering. As a result this project will comprehensively change the student experience in EOAS.

This project will increase the overall computational and numerical literacy of EOAS graduates in all EOAS undergraduate specializations. Developing student quantitative and computational skills in parallel using Jupyter notebooks and active pedagogies will improve student scientific decision-making, metacognitive and problem-solving abilities.

More sophisticated computational techniques will be introduced as student assignments grow more realistic/complex in upper year courses. New skills will include the ability to use parallel algorithms, to profile code, to write code libraries with documentation and unit tests, to access and reduce petabyte datasets, and to test model predictions against satellite and ground-based measurements. Student notebooks and code libraries can also easily be transformed into web portfolios, so that students will be able to demonstrate concrete accomplishments by showcasing and distributing their work, and by contributing to open source software development in the broader earth science community.

**2. Enhancing data science education in the Faculty of Science:**

This project contributes to the larger Faculty of Science strategic initiative to develop a minor in Data Science. Through the generation of new 1st year Earth Science focused materials and the transformation of upper year courses, this project will support the Data Science minor by offering unique applied quantitative / computational experiences for Data Science students.

**3. Enhancing education at UBC**

By developing both Earth Science materials for DSCI 100 and courses appropriate as electives for the new Data science minor, this project will expose a broader range of students to the approaches used to tackle today's Earth Science challenges including climate change. UBC, as part of the inaugural U7 alliance (45+ universities from 23 nations), has committed to leading by example, recognizing that universities play a major role in addressing challenges such as climate change. This project helps UBC achieve this goal.

**4. Training new and existing faculty and researchers to use new, open source computational tools**

This project will engage new and existing faculty and their research groups in the development and dissemination of cutting-edge Earth Science curriculum. New training sessions will help faculty and researchers develop the skills to build Jupyter-based assignments and activities. The paired teaching partnerships, a proven model for faculty development, offer impacts far beyond the length of this project. This approach will build capacity in active learning, teaching with open source computational tools, and the links between the two. Through paired teaching experiences and supported a community of practice, new interdisciplinary faculty collaborations will be fostered.

**Evaluation Plan (500 words max.)**

*Describe how you will find out if the project resulted in the intended impact(s). What evaluation strategy will be used? What data will you collect to evaluate the project's impact(s), and how will you collect these data? Outline any key indicators that will be used to determine the project's success/performance.*

Project evaluation will vary depending on the scale and focus of teaching development (activity, module, course, faculty). A range of student and faculty data will be collected to evaluate the impact of the project on student literacy, student experience and faculty experience. Data and key impact indicators for each type of development in the project are described below:

- 1) New activities for broad audience (multiple small new activities, module for EOSC 373): Classroom observations will be conducted using the Classroom Observation Protocol for Undergraduate STEM (COPUS)<sup>2</sup> during activity implementation to determine the balance of student-centered and instructor-centered teaching and student engagement during this time. A uniform set of questions will be included with all versions of the activities and modules that evaluate: (1) the impact of the curricula on student computational / numerical literacy and (2) the student experience (interest and engagement, ease of use, perceived impact on learning). Collaborator Francis Jones has found this to be an efficient means of data collection on a previous TLEF funded project.
- 2) Full course transformations: COPUS observations will be conducted during the beginning, middle and end of the full course development to evaluate: (1) the balance of student-centered and instructor-centered teaching, (2) the frequency and timing of demonstrations, programming (an additional COPUS code may need to be created for this) and group work, and (3) student engagement in relation to computational components. Pre / post surveys will be given in these courses to evaluate the impact of the course on student numerical and computational literacy. Focus groups will be held with students in the course in the middle and at the end of the course to understand more about student perceptions of the computational components of the course and their impact on their learning, engagement with authentic earth science challenges. Comparative baseline data will be collected using pre/post surveys in the term prior to transformation.
- 3) Scaffolded / progressive series - across courses 2nd, 3rd, 4th year culminating in a capstone: Evaluation will focus on the 4th year courses to facilitate reflection on the series. Students will complete a survey to assess their perceptions of the clarity and impact of project sequencing on their engagement with authentic earth science challenges and computational / numerical literacy. Student artefacts will be collected from the final capstone project and analyzed for their alignment with learning objectives.
- 4) Faculty development: The evaluation of faculty development has been modeled after the successful Teaching Start-Up program offered in the Faculty of Science. Our project employs a novel application of the paired teaching approach, not only focusing on both active learning and open source computational problems, but with a differing emphasis on co-mentorship. The impact of this approach on faculty development (uptake and changes to practice and philosophy) will be evaluated through: (1) pre / post paired teaching interviews (2) written weekly reflections, (3) feedback forms completed at the end of the community of practice lunches (2 per term), and (4) longitudinal comparisons that may be made from repeated COPUS observations relating to numbers 1-3 above.

**Student Involvement (250 words max.)**

*Describe how students were consulted and involved in preparing and reviewing this proposal, and how they will be involved in the implementation of the project.*

Students have contributed to the development of this proposal. Student volunteers from the 4 different

<sup>2</sup> doi: [10.1187/cbe.13-08-0154](https://doi.org/10.1187/cbe.13-08-0154)





EOAS clubs (Dawson, ESSA, Oceanography, Storm) participated in a focus group. Overall, the students were very supportive of this initiative and recognized independently that gaining skills in python would benefit them upon graduation. Detailed feedback from the students has been incorporated into this proposal. The main concern of students was that during the transition phase students might be lacking python when they reach the upper level courses. This project has been designed to target the foundation course (EOAS 211) in the first year of the project and most upper level courses in years 2 and 3. We will be prepared to support students using both python and matlab in upper level courses during the transitional years of the project.

Throughout the project both Graduate and Undergraduate students will be involved in the development of new educational materials. We anticipate hiring two GRA's and two UA's each year for the duration of the project. Additionally, student feedback will be collected as part of the project evaluation process. Feedback questions will be collected through short surveys associated with the new Jupyter assignments and through focus groups for courses undergoing larger transformation.

**Special Classroom or Facilities Requirements (150 words max.)**

*Does the implementation of your project require any special classroom/facilities or scheduling support (e.g. video-conferencing, lecture capture, flexible classroom space, etc.)?*

EOAS computational courses will be taught using a mixture of python environments installed on student laptops and python run on clusters of compute nodes in the commercial cloud. There is currently a proposal before the UBC Capital Planning committee to fund cloud computing for a range of courses across the university. Based on extensive experience with the cloud-hosted <https://syzygy.ca> platform managed by the Pacific Institute for Mathematical Sciences, we estimate a cost of roughly \$6/student per course for lower level courses, and \$6-\$15/student per course for upper-level and capstone courses. EOAS IT personnel are currently working with PIMS and CTLT to set up cloud clusters, configure specialized user software for applications like remote sensing and geographic information systems, and manage student authentication and account quotas. Until cloud computing is broadly available to UBC students, we will support the installation of open source software on student laptops and provide laptops for loan when needed.