

ARRCU Workshop: Application, Analysis and Collaborative Development with Canada's Earth System Model (CanESM)

Paul Kushner (U Toronto, ARRCU chair, organizing committee chair) thanks the teams:

Organizing committee: Neil Swart (ECCC), Ellie Farahani (ECCC), Nathan Gillett (ECCC), Shawn Marshall (U Calgary/ECCC), Julie Thériault (UQAM), Kirsten Zickfeld (SFU)

Panelists: Joe Melton (ECCC), Paul Myers (U. Alberta), Hansi Singh (U Victoria), Julie T, Kaley Walker (U Toronto), Kirsten Z

ARRCU executive + advisory board: Adam Monahan (U Vic, vice chair), Pierre Gauthier (UQAM, secretary/treasurer), Hind Al-Abadleh (Wilfred Laurier U), Yanping Li (U. Sask), Paul M, Roland Stull (UBC), Neil Tandon (York), Bruno Tremblay (McGill), Aldona Wiacek (St. Mary's U)

Agenda:

Time	Topic
2:30-2:40	Introduction, workshop goals (Paul K)
2:40-3:10	The CCCma strategic plan and building a collaborative CanESM (Neil S)
3:10-3:30	Results of ARRCU community survey (Paul K)
3:30-3:45	Break
3:45-5:00	Panel discussion - use cases, broader context.
5:00-5:30	Break, followed by open discussion, next steps.

This meeting is being recorded



Workshop goals

- Part of ARRCU focus on Earth System Modelling in Canada, for 2020-2021
- Report on status and plans of the “more collaborative” CanESM
- Summarize results of recent community survey
- Hear about different use cases and thoughts on broader implications of this initiative
- Get community feedback, solicit interest in further proposal and project development.

Context: CCCma Strategic Plan



Our focus today is here

But we should be keeping in mind the big picture and what's being enabled.

Neil Swart: “The CCCma strategic plan and building a collaborative CanESM”

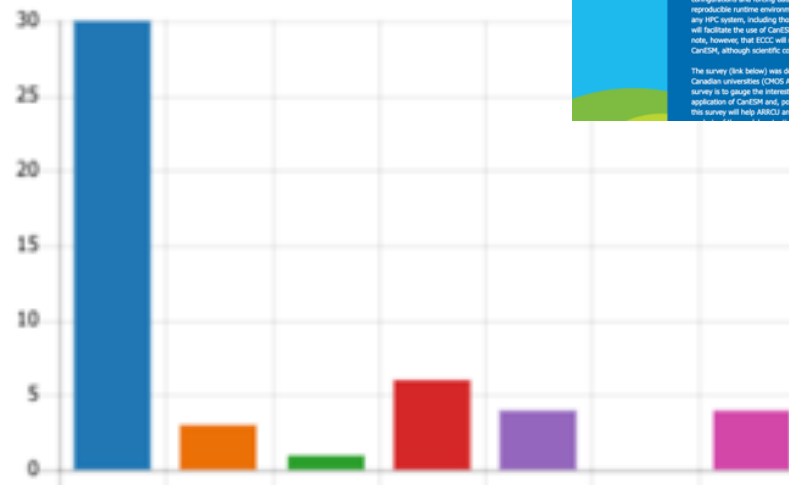
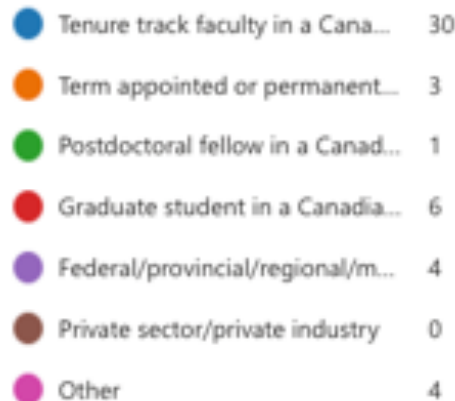
Survey review (Paul K)

ARRCU CanESM Survey 2021: A community snapshot

- 48 respondents: Thank you!
 - Jan. 4– 15 2021
 - 30 tenure stream faculty, 6 students, 4 federal ...

4. Please describe your primary appointment

[More Details](#)



Survey: Collaborative Earth System Modelling using Canada's Earth System Model, CanESM

Update: January 15, 2021

The survey is now closed for open participation. If you would still like to complete the survey, please contact Paul Kushner at paul.kushner@utoronto.ca and he will send you a link to complete the survey.

The Canadian Earth System Model (CanESM) is a comprehensive coupled model, developed by the Canadian Centre for Climate Modelling and Analysis (CCCma) of Environment and Climate Change Canada (ECCC), for the purposes of climate projection and seasonal to decadal prediction. The latest version, CanESM5, is described in Swart et al. (2017): <https://doi.org/10.5194/gmd-10-4623-2017>. CanESM participates in internationally coordinated modelling activities, such as CMIP and the resulting data are made publicly available. These data have been broadly used in numerous scientific and climate services applications domestically and internationally.

Key components of CanESM have been developed in collaboration with the Canadian academic community. CCCma has also collaborated with academia on the application of CanESM to address scientific questions. However, to date, these collaborations have been constrained by the fact that CanESM could only be used on ECCC's internal, restricted access, high performance computing (HPC) systems.

In accordance with its new strategic plan, CCCma is working towards the development of a collaborative version of CanESM based on the existing open-source codebase. CCCma will make available pre-set model configurations and forcing data, model documentation and contributor guides. CCCma will also make available a reproducible system environment ("container") that can be used to compile, configure and run the model on any HPC system, including those from Compute Canada. The intent is to create an open version of CanESM that will facilitate the use of CanESM by the broader Earth system modelling community in Canada. It is important to note, however, that ECCC will not be providing direct system-level support for the open-source version of CanESM, although scientific collaborations will continue and should be enhanced by this new capability.

The survey (link below) was developed by the CHOS special interest group on atmosphere-related research in Canadian universities (CHOS-ARRCU SIG), in consultation with colleagues at ECCC's CCCma. The intention of the survey is to gauge the interest of the Canadian academic community in the collaborative development and application of CanESM and, potentially, other ECCC modelling systems and products in the future. Feedback from this survey will help ARRUCI and ECCC assess the level of community interest in collaborative development and

Primary expertise related to ESMs: Climate and atmospheric science!

Climate science, climate change impacts, regional climatology, climate informatics

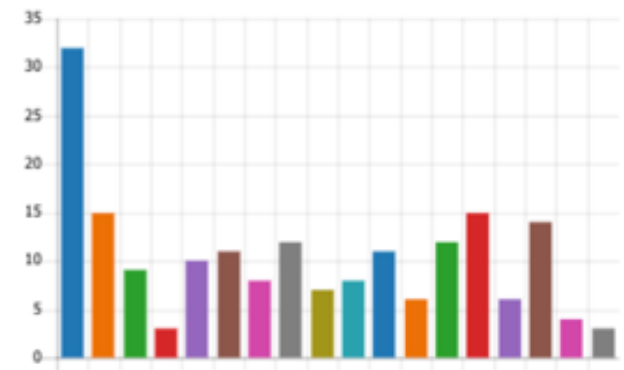
Meteorology, dynamic meteorology, mesoscale meteorology, cloud microphysics, radiative transfer, data assimilation, atmospheric chem/air quality

numerical modelling/HPC • cryosphere • oceanography • land surface • BGC

7. What are your primary areas of expertise related to your use of Earth System Models (select all that apply)

[More Details](#)

Climate science	32
Climate change impacts resear...	15
Meteorology	9
Data assimilation	3
Regional climatology	10
Cloud microphysics and preci...	11
Radiative transfer and radiatio...	8
Dynamic meteorology	12
Mesoscale meteorology	7
Atmospheric chemistry/air qu...	8
Land-surface-atmosphere inte...	11
Hydrology	6
Oceanography/marine proces...	12
Cryosphere (sea ice/snow/lan...	15
Biogeochemical cycles	6
Numerical modelling and high...	14
Climate informatics/climate da...	4
Other	3



Which aspects of ESM climate research are you involved in?

Use of model outputs

Experimentation with existing models

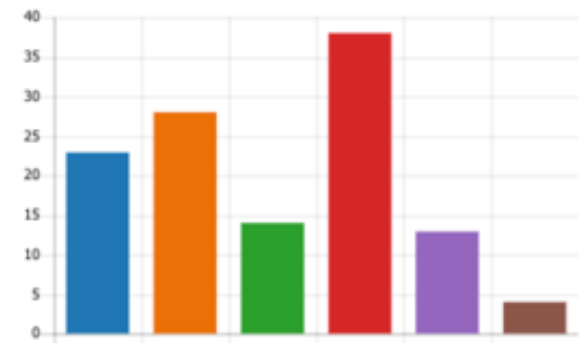
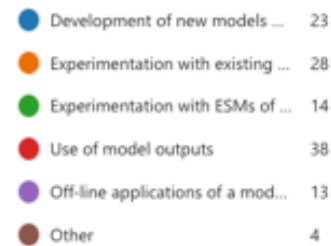
Development of new models

Experimentation with simplified models/EMICS

- off-line applications

9. Which aspects of earth-system model related climate research are you involved in (select all that apply)?

[More Details](#)



Which ESMs/tools/components do you use?

CMIP model output

ECCC CanESM • NCAR CESM • NCAR WRF • Other

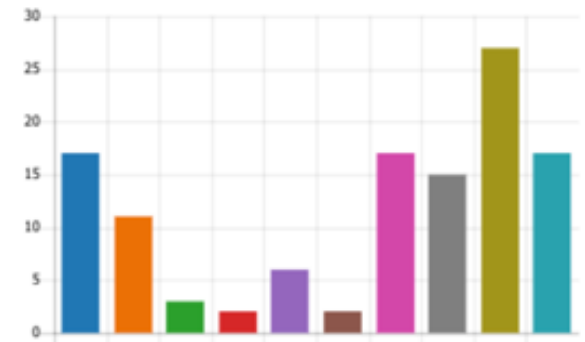
ECCC GEM

ESCER/UQAM GEM/CRCM

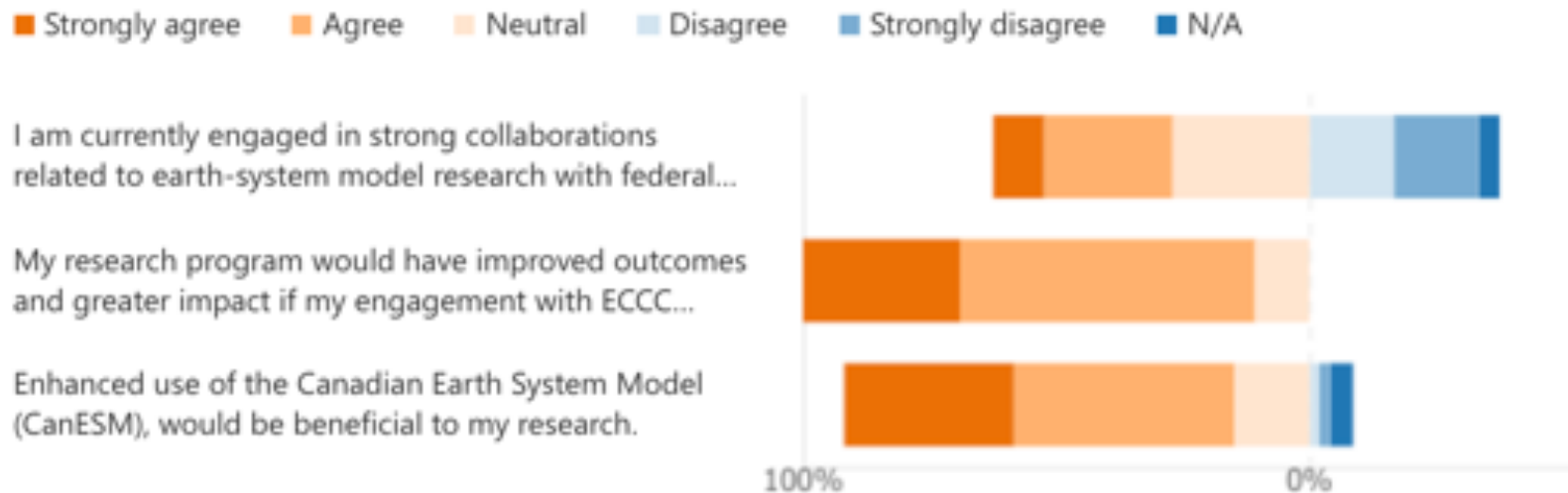
11. Which ESMs, components, or other numerical tools are you using for your research (select all that apply)?

[More Details](#)

● ECCC CanESM	17
● ECCC GEM	11
● ECCC CanRCM	3
● ECCC/DFO/DND CONCEPTS P...	2
● ESCER/UQAM GEM/CRCM	6
● UVic ESM	2
● NCAR CESM	17
● NCAR WRF	15
● CMIP model output archives	27
● Other	17



Engagement and Partnership with ECCC



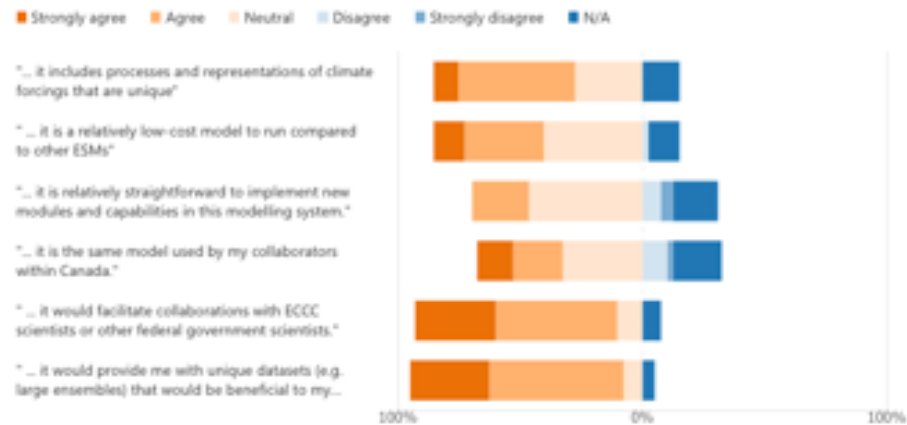
- 35% agree* they are engaged in strong collaborations with ECCC scientists.
 - (And a fair amount of disagreement.)
- **90% agree that increased engagement with ECCC scientists would benefit their research.**
 - (Zero disagreement.)
- 75% agree that enhanced use of CanESM would benefit their research.

*agree = “agree” or “strongly agree”

Use of CanESM

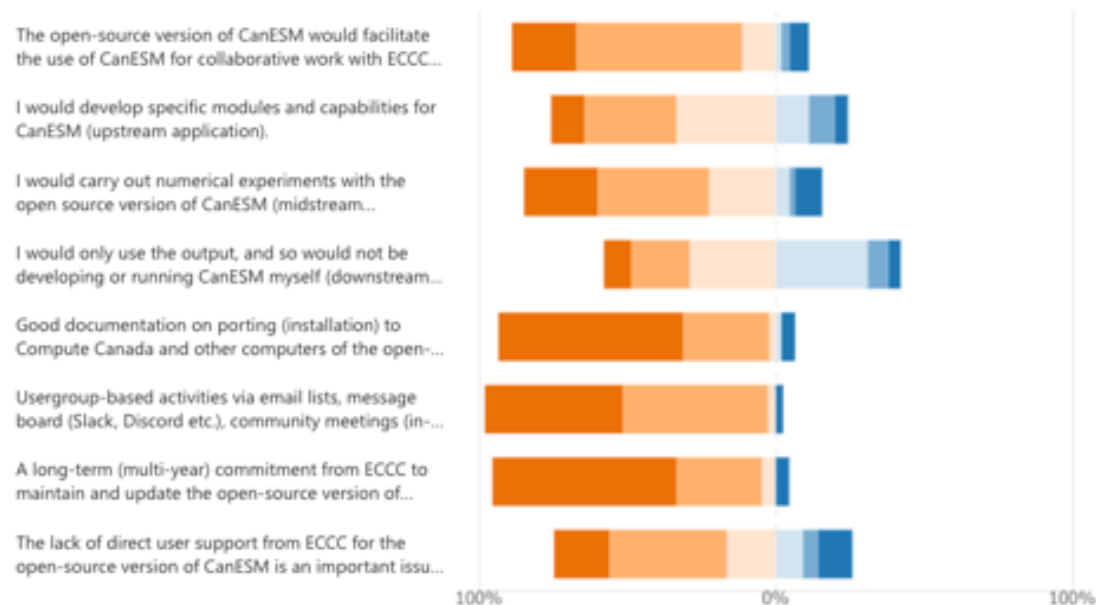
15. If you agreed to some extent with the statement in Question 14 that enhanced use of CanESM would benefit your research, please indicate your agreement or disagreement with the following statements: "CanESM5 would be useful to me because ..."

[More Details](#)



- 35%: CanESM is same model used by my collaborators
- 40-50%: CanESM represents unique processes and is low-cost
- 80-90%: it would provide unique datasets, **facilitates collaboration with ECCC**
- 60%: aware of available CanESM datasets

The “More Collaborative” Version of CanESM



- 95% agree that usergroup-type activities would be beneficial.
- 90% agree that a long-term commitment and good documentation would be beneficial.
- 80% agree that it would **facilitate collaborations with ECCC**
- 60% agree that the lack of direct user support is an important issue (some disagreement)
- 40% would develop specific modules and capabilities for CanESM (some disagreement)

Other ECCC models

- 70% agree that, apart from CanESM, enhanced use of other modeling products from ECCC would be beneficial. Examples ...
 - ECCC GEM, EnVar, GEM-AQ, regional forecasts, air quality, GDPS, RDPS, HRDPS
 - Data assimilation systems
 - CanRCM/regional climate models
 - NEMO, linkage to CONCEPTS
 - ANHA configuration of NEMO/LIM2
 - CMAM
 - Land surface modules for the Arctic, CLASS *
 - ...

* Open source version already available – see Joe M's talk

What did we learn from this community snapshot?

- Healthy interest, from a scientifically diverse community, with reasonable expectations.
- There is a potentially great user group to develop there. Lots of insightful commentary.
- 30 faculty = 100+ users now and many more users down the road.
- Messages (to ECCC and Tri-Council):
 - Most feel they don't have strong collaborations with ECCC, and most feel that their research would benefit by increased collaboration with ECCC.
 - Most of those who want to increase use of CanESM would do so (at least in part) to increase collaboration.
 - Most are looking for good documentation and a long-term commitment to CanESM.
 - A smaller majority is worried about the lack of direct support.
 - Most are interested in enhanced access to *other* ECCC models (CanRCM, GEM, GEM-AQ, GDPS/RDPS etc.)

This community sees the enhanced collaborative versions of models from ECCC as tools of research partnership and collaboration, for a wide variety of applications.

Break (15 min)

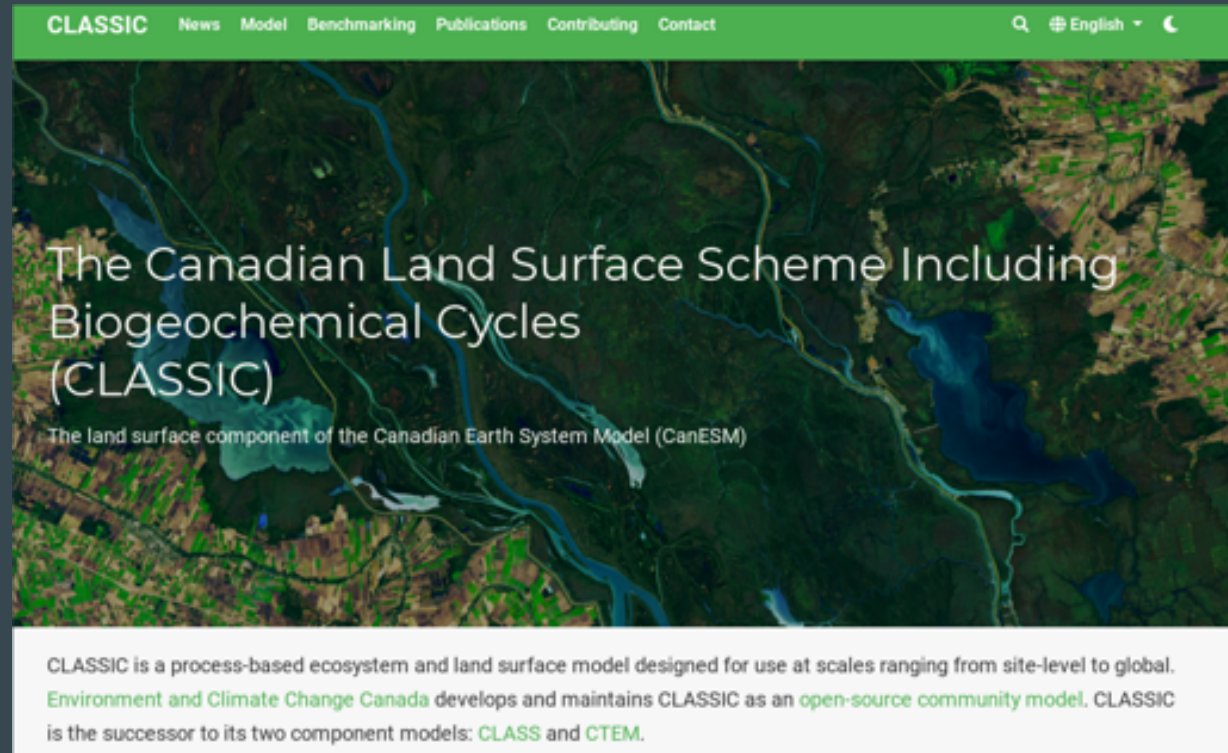
Panel (starting at 3:45)

- Panelists were asked the following (which they could choose to answer, or not!):
 - **How do you envision using, and/or see others using, the collaborative version of CanESM for analysis, application, and development?**
 - **What immediate advantages do its collaborative features – open-source, portable, well documented, etc. – bring?**
 - **Which conditions could enable you and/or the broader research community to further tap its potential?**
- We'll go in family-name alphabetical order: Joe, Paul, Hansi, Julie, Kaley, Kirsten
- Attendees, think about these questions too!
- Please ask questions via chat/raise hand, at least while the panellists are presenting.

Joe Melton

Transforming ECCC's CLASS-CTEM into the open-source community model CLASSIC

- CLASS developed internally since late 1980's. CTEM since the early 2000's
- The complexity of land surface modelling developing rapidly - but ECCC resources less so
- Move to open-source community structure to encourage adoption and development of model within Canadian research started in ca. 2018



CLASSIC News Model Benchmarking Publications Contributing Contact

English

The Canadian Land Surface Scheme Including Biogeochemical Cycles (CLASSIC)

The land surface component of the Canadian Earth System Model (CanESM)

CLASSIC is a process-based ecosystem and land surface model designed for use at scales ranging from site-level to global. Environment and Climate Change Canada develops and maintains CLASSIC as an open-source community model. CLASSIC is the successor to its two component models: CLASS and CTEM.

https://ccma.gitlab.io/classic_pages/

CLASSIC v. 1.0 released in 2020

Geosci. Model Dev., 13, 2825–2850, 2020
<https://doi.org/10.5194/gmd-13-2825-2020>
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CLASSIC v1.0: the open-source community successor to the Canadian Land Surface Scheme (CLASS) and the Canadian Terrestrial Ecosystem Model (CTEM) – Part 1: Model framework and site-level performance

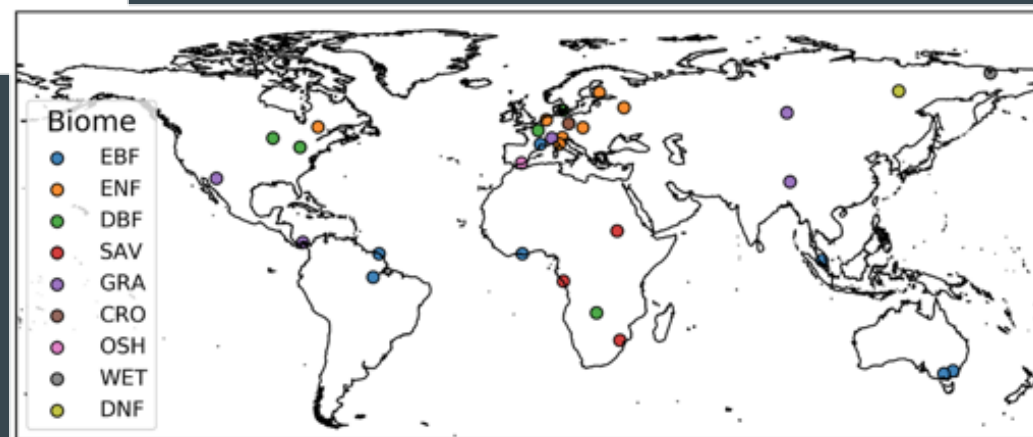
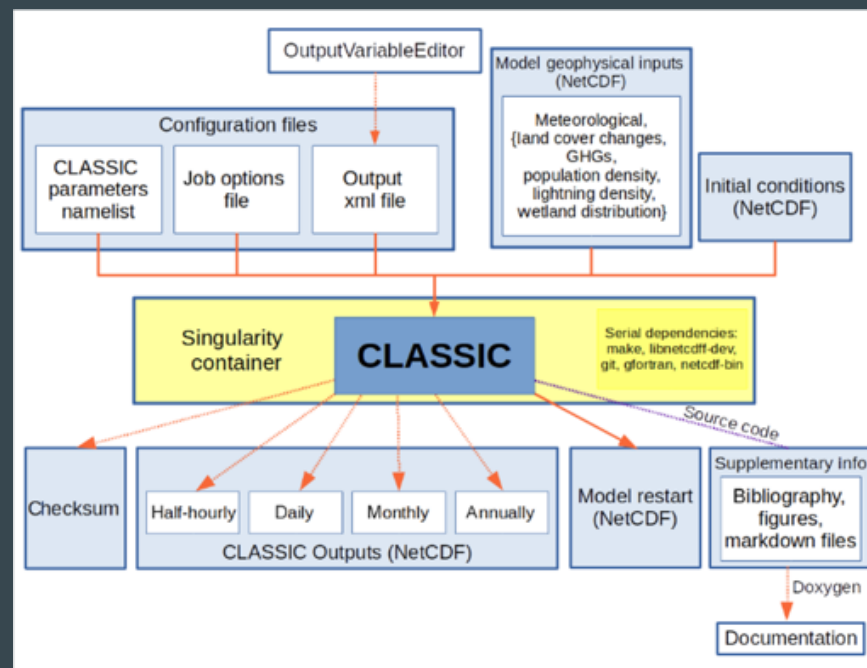
Joe R. Melton¹, Vivek K. Arora², Eduard Wisernig-Cojoc¹, Christian Seiler¹, Matthew Fortier¹, Ed Chan³, and Lina Teckentrup⁴



CLASSIC v1.0: the open-source community successor to the Canadian Land Surface Scheme (CLASS) and the Canadian Terrestrial Ecosystem Model (CTEM) - Part 2: Global Benchmarking

Christian Seiler¹, Joe R. Melton¹, Vivek K. Arora², and Libo Wang³

Significant investments to make model easier to work with: self-documentation, website, container, I/O, benchmarking, biweekly open meetings/Slack channel, capability to run site-level (column) and grid, code modernization, software tools,...



Paul Myers

Questions for our panelists: Paul Myers

How do you envision using, and/or see others using, the collaborative version of CanESM for analysis, application, and development?

As an Ocean Modeller, using the NEMO model that is also part of CanESM, I see links in terms of further development of the ocean model development and application. But also, the more groups running CanESM could provide more scenarios to use to drive forced ocean models for example, improve representation of runoff, etc.

What immediate advantages do its collaborative features – open-source, portable, well documented, etc. – bring?

The more people using it, the more I can see us learning about the ocean (in my case), testing parameterizations, improving understanding, developing and sharing forcing, etc.

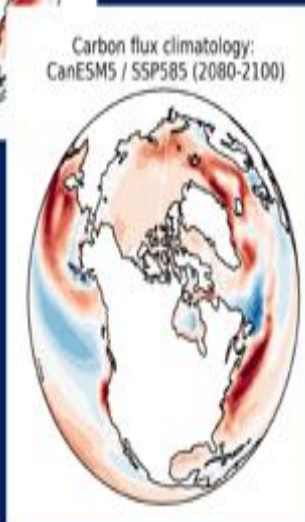
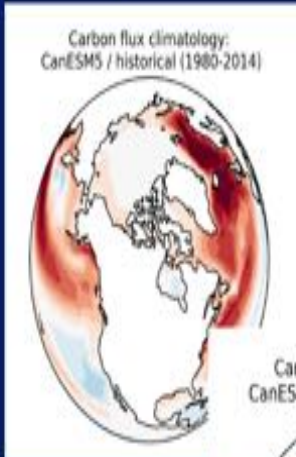
Which conditions could enable you and/or the broader research community to further tap its potential?

Greater ease for sharing code and output – academia and government. More ability for both groups to be part of the same projects, share HQP, etc.



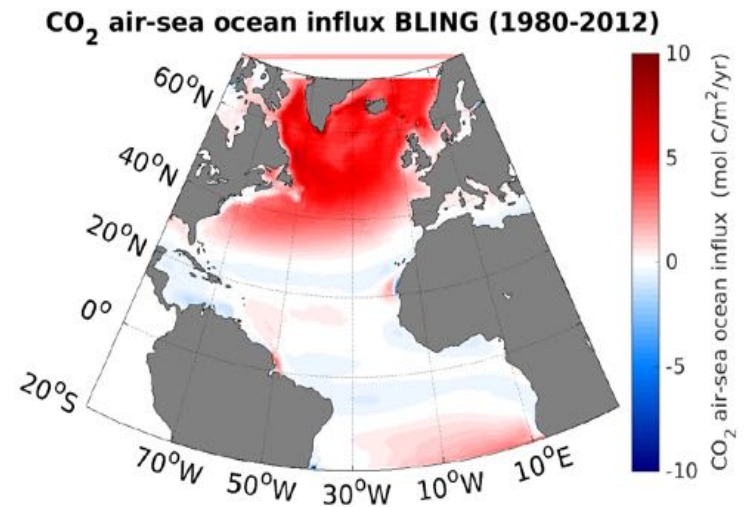
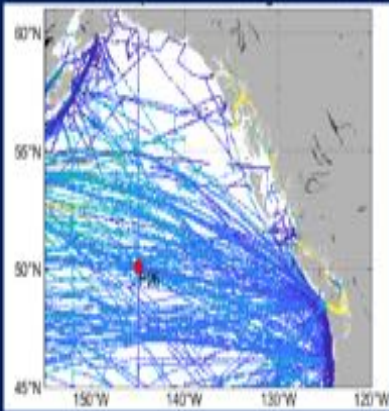
Canada's Marine Carbon Sink Project

Roberta Hamme (Uvic) lead PI



Objective 4: Evaluate model skill and improve parameterizations

- Assess multiple model configurations with data
- Identify key processes / resolution
- Improve parameterizations
- Assess spatial variability
 - Myers (Alberta), Fennel (Dal), Steiner (DFO/ECCC), Swart (ECCC)
 - but also involve observation folks – happening regionally – need for more?



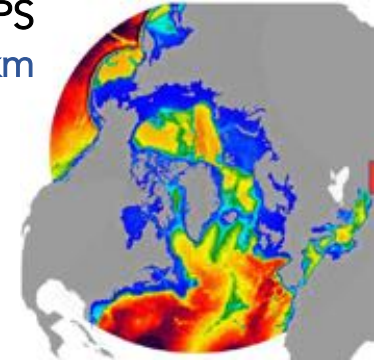
Government-led coastal ocean modelling systems for short-term prediction

NEMO-based, developed under ECCCC/DFO/DND Canadian Operational Network of Coupled Environmental Prediction Systems (CONCEPTS)

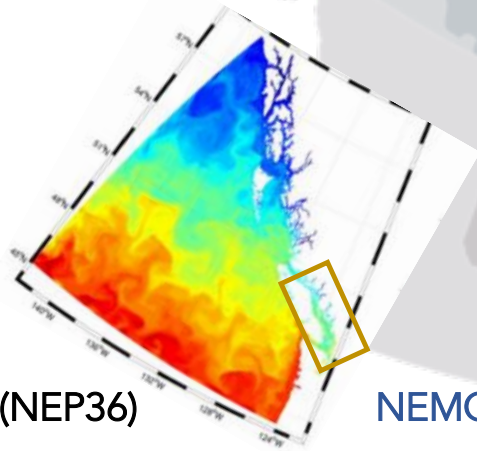
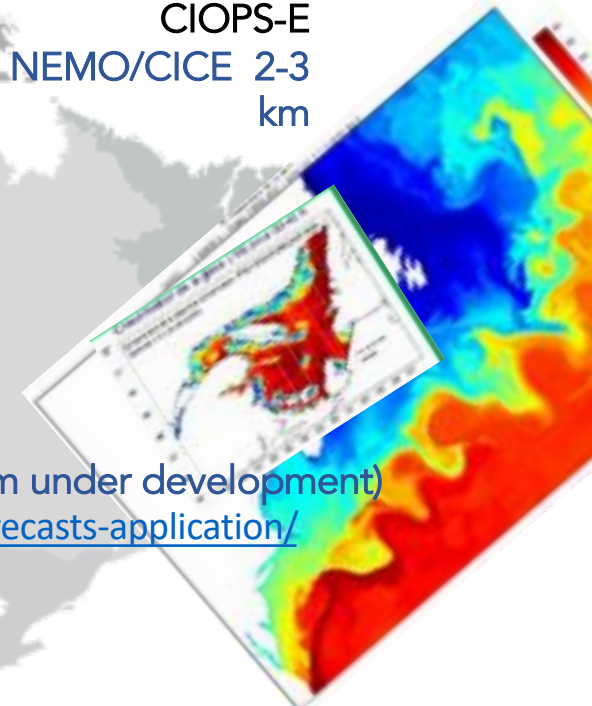
https://www.ic.gc.ca/eic/site/063.nsf/eng/h_97620.html

Canadian Three Oceans Downscaling Initiative (canTODs)

RIOPS
NEMO/CICE ~5 km



CIOPS-E
NEMO/CICE 2-3 km



CIOPS-W (NEP36)

km

<https://ogsl.ca/en/ocean-forecasts-application/>

→ soon: *SalishSeaCast* subdomain

NEMO/CICE 2-3

Gulf of St. Lawrence

NEMO/CICE 5km (0.5 km under development)

<https://ogsl.ca/en/ocean-forecasts-application/>

+ FVCOM downscaling to port scale for Ocean Protection Plan

Toward an integrated Canadian ocean modelling community

CONCEPTS

CONCEPTS Round
Table
telecons+science talks

CONCEPTS webinars
<https://bulletin.cmos.ca/?s=eccc+dfo+concept>
Data assimilation

Model development

Ocean prediction systems

GODAE OceanView/
OceanPredict

Special sessions at
conferences &
workshops
HQP training

NEMO-Canada Slack
channel

MEOPAR

Hansi Singh

Hansi Singh

How do you envision using, and/or see others using, the collaborative version of CanESM for analysis, application, and development?

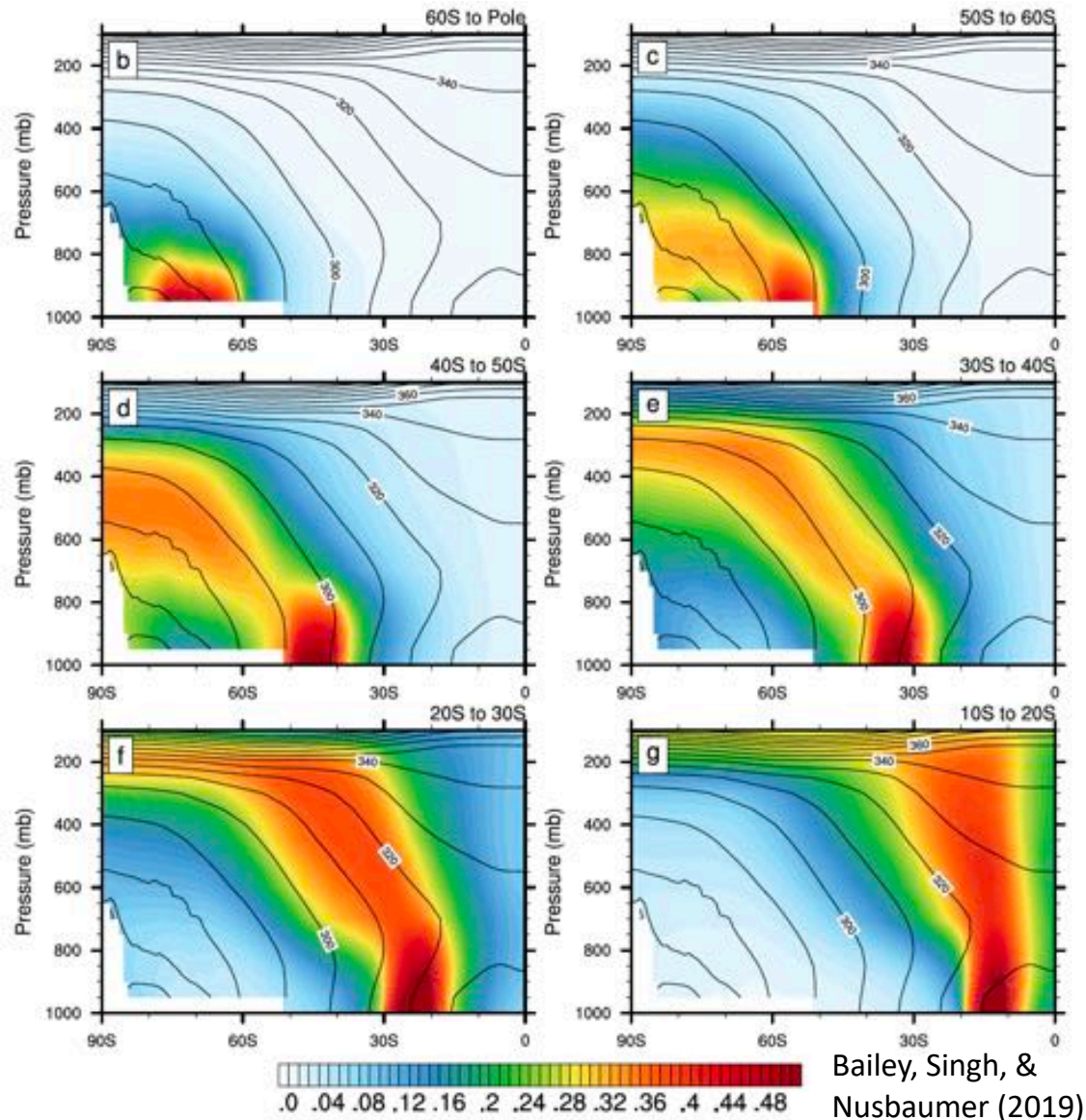
User and abuser of global climate models. I work primarily with analysis and applications, rather than development. Development work is usually within our group and collaborators.

What immediate advantages do its collaborative features – open-source, portable, well documented, etc. – bring?

It would be advantageous to modify the model and run our own experiments with the CanESM5, rather than being limited to using MIP output.

Which conditions could enable you and/or the broader research community to further tap its potential?





Example Use Case: *Numerical Water Tracers Implemented in the Community Earth System Model*

With numerical water tracers in the CESM, we can investigate the following:

- How does moisture move from equator to pole?
- How does moisture transport to the Antarctic continent change as the planet warms?
- How does moisture transport to Greenland change as the planet warms, and how does this impact Greenland Ice Sheet melt?
- How do changes in the hydrologic cycle impact water isotopes, and are these changes detectable?
- How do we understand past climates from ice core records?

Figure: Atmospheric moisture (sourced from different latitude bands; colors) follows moist isentropic surfaces (contours) as it moves towards the pole.

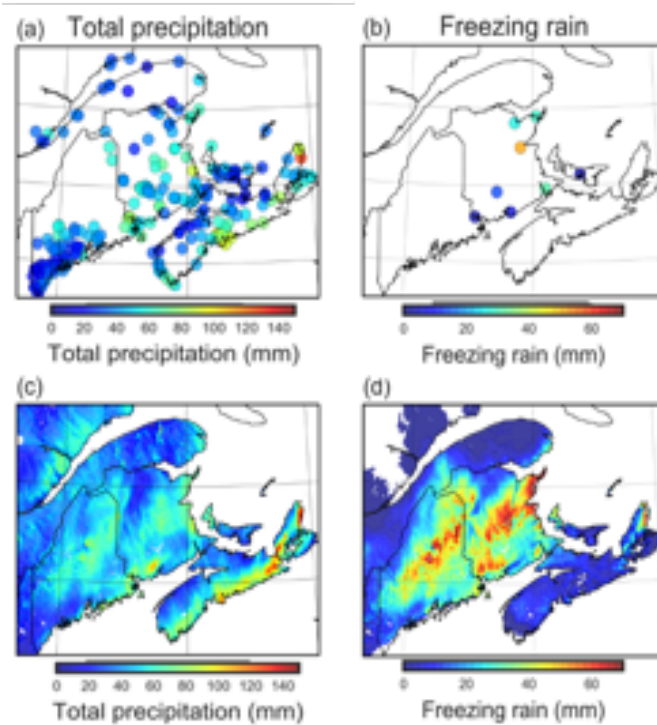
Julie Thériault

Introduction

My research mainly focuses on precipitation when the temperature is near 0°C. I use models, theory and field measurements. I am not a direct user of CanESM but I support the effort of building an open source model.

1-km GEM
simulations of
the 24-26
January 2017

Thériault et al. (2021),
In prep.



Sain John River Experiment on Cold Season Storms (SAJESS)



Questions for our panelists: Julie Thériault

How do you envision using, and/or see others using, the collaborative version of CanESM for analysis, application, and development?

- *CanESM outputs could be used in my research as forcing fields for very-high resolution regional climate projections.*

What immediate advantages do its collaborative features – open-source, portable, well documented, etc. – bring?

- *Flexibility in the simulations available to the scientific community and build on this initiative with other atmospheric models in Canada.*

Which conditions could enable you and/or the broader research community to further tap its potential?

- *Participate in the development of scientific and infrastructure proposals to foster collaboration towards open-source climate and weather models.*

Kaley Walker

Questions for our panelists: Kaley Walker

How do you envision using, and/or see others using, the collaborative version of CanESM for analysis, application, and development?

- *Analysis & Application: Using Space-Based Earth Observation results for model-measurement comparisons*
- *Assessing model performance and determining improvements that can be made*
 - *My focus is on atmospheric chemistry – others in atmospheric dynamics, convective processes, etc.*
- *Gives opportunity (for my group and others) to do small experiments to understand what we are seeing*

What immediate advantages do its collaborative features – open-source, portable, well documented, etc. – bring?

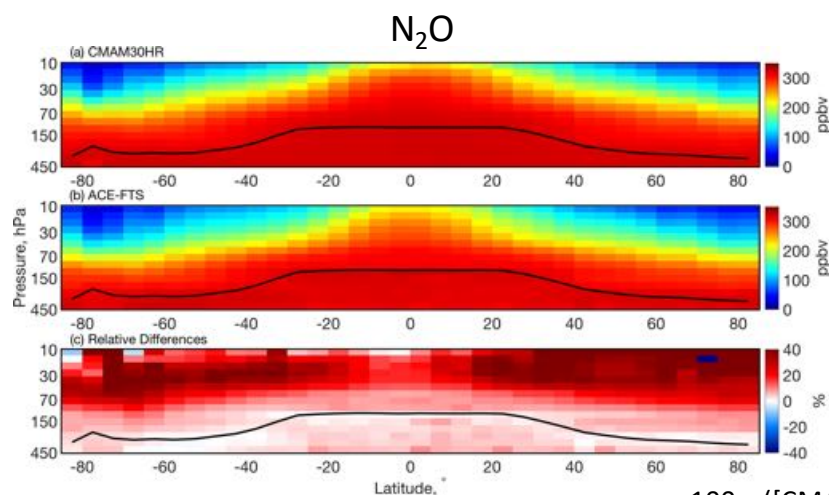
- *Being able to strengthen our scientific collaborations with CCCma on atmospheric-related work on CanESM*
- *Open-source, well-documented so we can get into working more with the model independently*

Which conditions could enable you and/or the broader research community to further tap its potential?

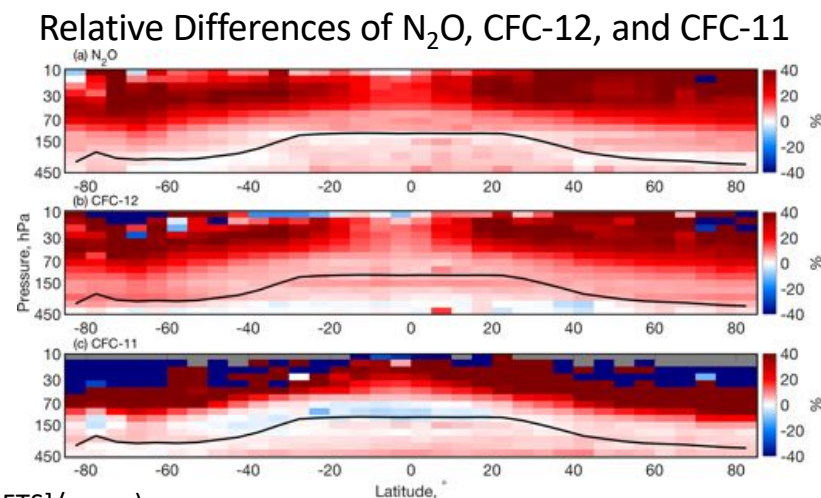
- *Support for collaborations where HQP can visit CCCma for longer periods to work with model & scientists*
- *Funding for graduate students and postdocs needed to get the work – individual, network/alliance grants*
- *Access to high-performance computing resources are needed – SciNet, CFI*

Use Cases – Model-Measurement Comparisons

- Working with Canadian Middle Atmosphere Model (CMAM-SD) and Canadian atmospheric satellite instruments (ACE-FTS and OSIRIS)
 - Specified dynamics nudges meteorology to reanalysis to enable 1-to-1 comparisons
- Examined atmospheric transport in model using long-lived gases
 - Better comparisons achieved than picking closest grid box by accounting for extent of satellite measurements (Kolonjari et al., 2018)



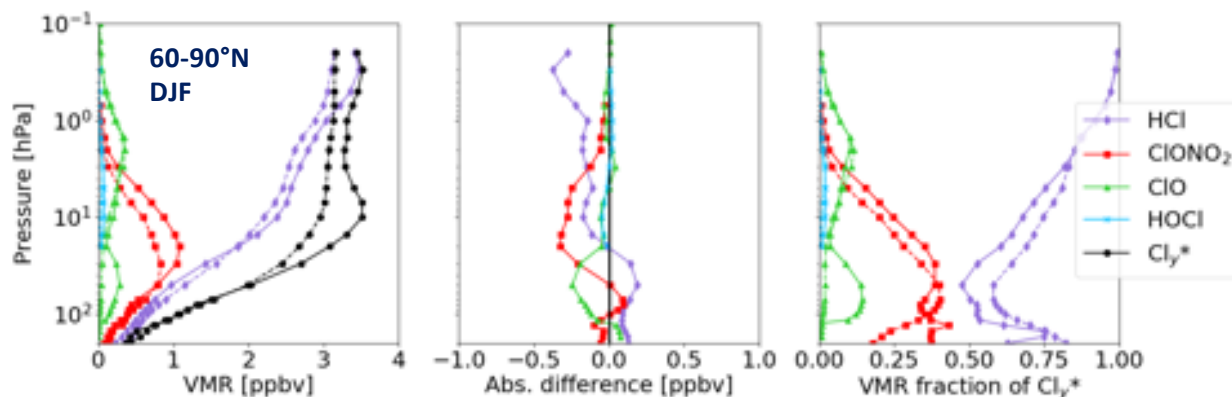
100 x $[(\text{CMAM30HR} - \text{ACE-FTS})/\text{mean}]$



F. Kolonjari et al., ACP, 18, 6801–6828, 2018

Use Cases – Model-Measurement Comparisons

- Utilized for assessing natural variability in ozone and impact on validation
 - How close should coincident satellite measurements for validation of results?
 - Sampled CMAM-SD and two other SD models as ACE-FTS and OSIRIS and compared differences seen (Sheese et al., 2021)
- Evaluating representation of chlorine chemistry in CMAM39
 - Critical for predicting ozone depletion processes in a changing climate
 - Comparing total amount of inorganic chlorine (Cl_y^*) as well as individual species between ACE-FTS+ satellite measurements and model



L. Saunders, N. Ryan et al., in preparation.

Kirsten Zickfeld

Questions for our panelists: Kirsten Zickfeld

How do you envision using, and/or see others using, the collaborative version of CanESM for analysis, application, and development?

- *Mostly application, i.e. running of model simulations*
- *Development if opportunity arises (HQP, collaboration with CCCma scientists)*

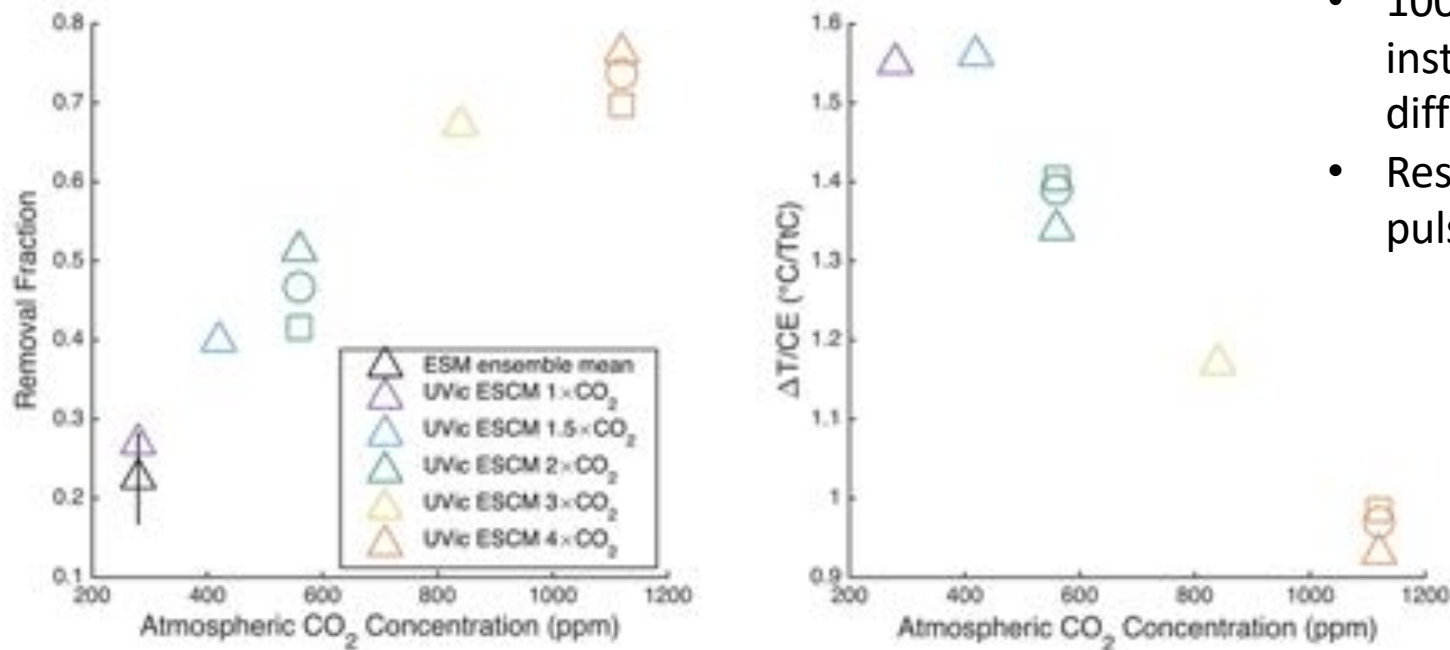
What immediate advantages do its collaborative features – open-source, portable, well documented, etc. – bring?

- *Ready access to an additional tool for hypothesis testing and verifying robustness of EMIC results*

Which conditions could enable you and/or the broader research community to further tap its potential?

- *Model is easily portable, well documented; user forum*
- *Funding for graduate students, post-docs*
- *Access to high performance computing resources (Compute Canada, RAC allocation)*

Use case: Climate-carbon cycle response to carbon dioxide removal



- Simulations with UVic ESCM
- 100, 500, 1000 PgC removed instantaneously from different equilibrium states
- Results shown 100 yrs after pulse removal

Zickfeld et al., 2021, accepted

- Removal fraction *increases* with increasing background atmospheric CO₂
- Warming per unit CO₂ removed *decreases* with increasing background CO₂

Follow-on discussion (before break)

Break (a few minutes) + open discussion

Next steps, actions from this meeting, thoughts ...

- What can we plan with ECCCC/CCCma's strategic plan in mind?



Next steps, actions from this meeting, thoughts ...

- CMOS ESM session follow on: side meeting?
- Development of community platform proposal for Compute Canada if this compute resource stream is available in fall 2021.
- Funding/partnership? CFI? CSA? NSERC?
- User group/community group/slack etc.?
- First science meeting/update in January 2022?