Collaborative CanESM

Neil Swart on behalf of CCCma
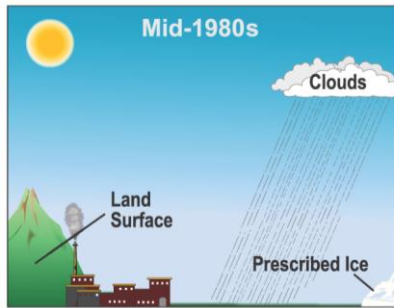## CP4C workshop
21 April 2022

Outline

1. Recap: CanESM history and strategic plan

2. CanESM status and development plan

3. Progress on developing a collaborative version of CanESM

History of CCCma modelling & science
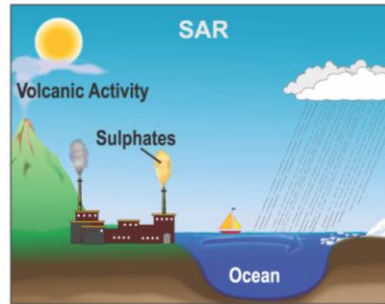
Models

AGCM1
Boer and McFarlane (1979)

AGCM2
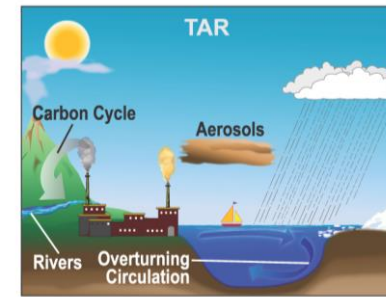McFarlane et al. (1992)

CGCM1
Flato et. al (2000)

CGCM2

CGCM3
McFarlane et. al (2005)
Scinocca et al. (2008)

CanESM1
Christian et al. 2010

CanESM2 / CGCM4

CanESM5
Swart et al. 2019

Atmosphere only

Coupled to ocean

Carbon cycle

1970   1980   1990   2000   2010   2020

Assessments & MIPs

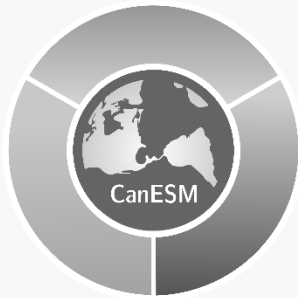|								
WCRP MIPs:		CMIP1	CMIP2	CMIP3		CMIP5	CMIP6	
IPCC assessments:		AR1 1990	AR2 1995	TAR 2001	AR4 2007	AR5 2013	SR15 2018 SROCC 2019	**AR6 2021**
Canadian climate assessments:						CCC 2014	CCCR 2019	
WMO Scientific Assessment of Ozone Depletion:				2006	2010	2014	2018	

CanESM Community Engagement

Adopting open source and portability policies, **CanESM** development and analysis now can more easily facilitate collaboration with Canadian universities and external partners.

A two-way benefit:

- Standardized modelling framework and community tools enable wider collaborations
- Technical user guides and training materials support external users
- Collaborative analysis and development of **CanESM** expands model expertise and resources
- More collaborations train and engage more users, and enhance climate science expertise in Canada
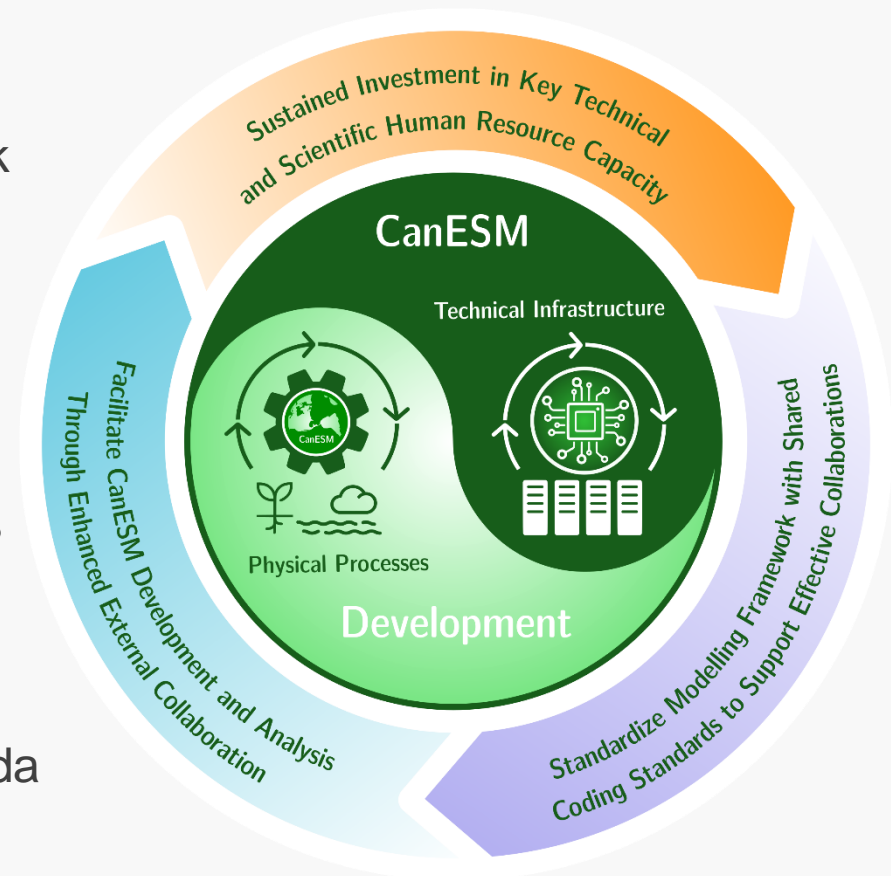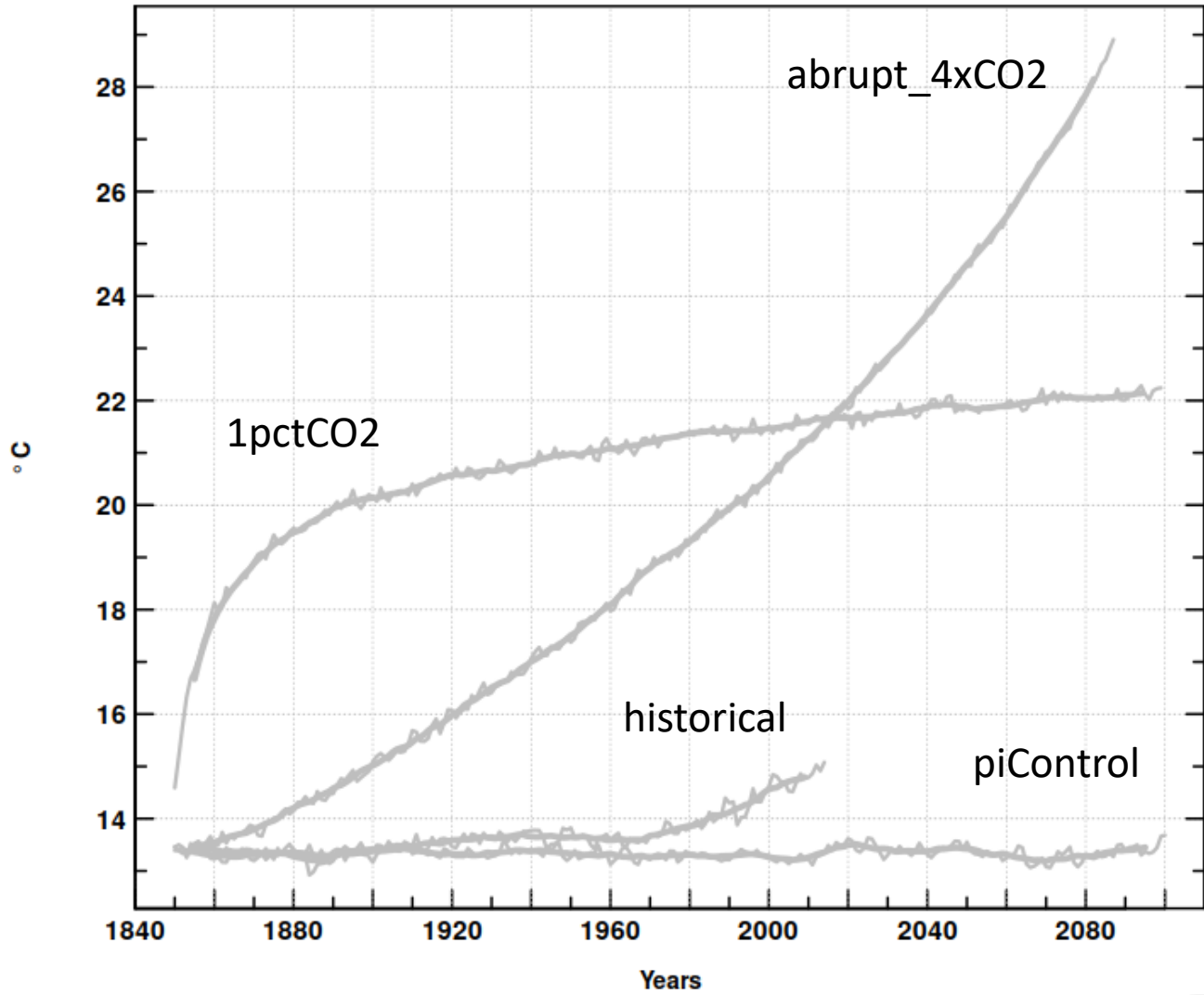
Development since CanESM5.0
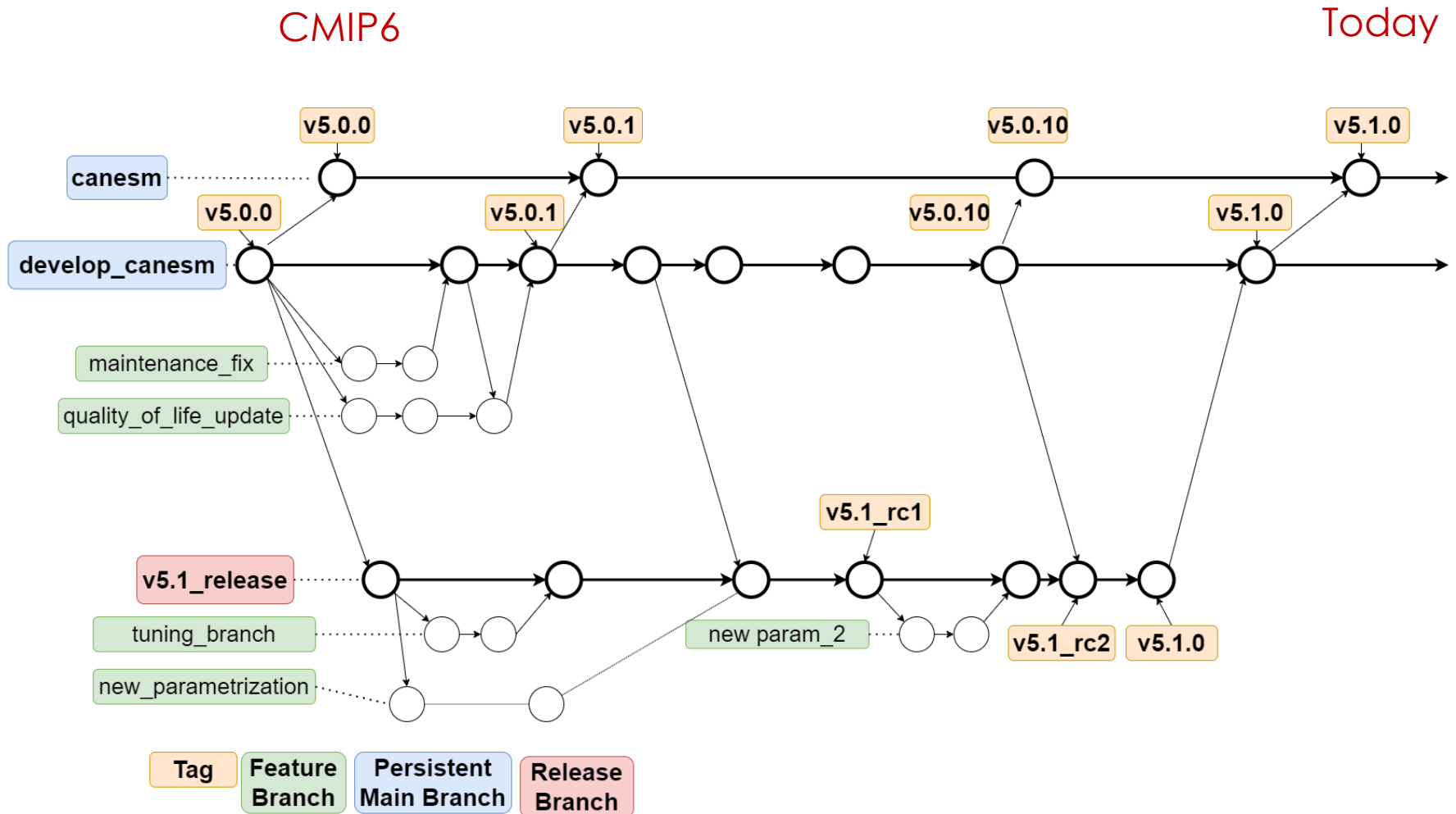
CanESM5.1 summary

- CanESM5.1 is very similar, physically, to CanESM5.0, but has widespread syntax/structural changes.
- [CanESM5 #203](#) documents ~25 accepted MRs that form v5.1 (+440 commits)

- Technical changes
  - CanAM F90 syntax update, array structures
  - Full CanAM-GEM compatibility
  - Multiple quality of life improvements (level coding, configuration, namelists)
  - Multiple bugfixes (I/O, integer sizes, PHYS arrays, etc)

- Physics & forcing changes
  - A to O remapping changed to conservative2
  - Update AMIP BCs (1-1-6-v6) and solar forcing file

- Tuning:
  - Retune hybridization parameters (eliminate dust spikes and stratospheric warmings)
  - Default (v5.0) tuning = p1 and best-to-date objective tuning = p2

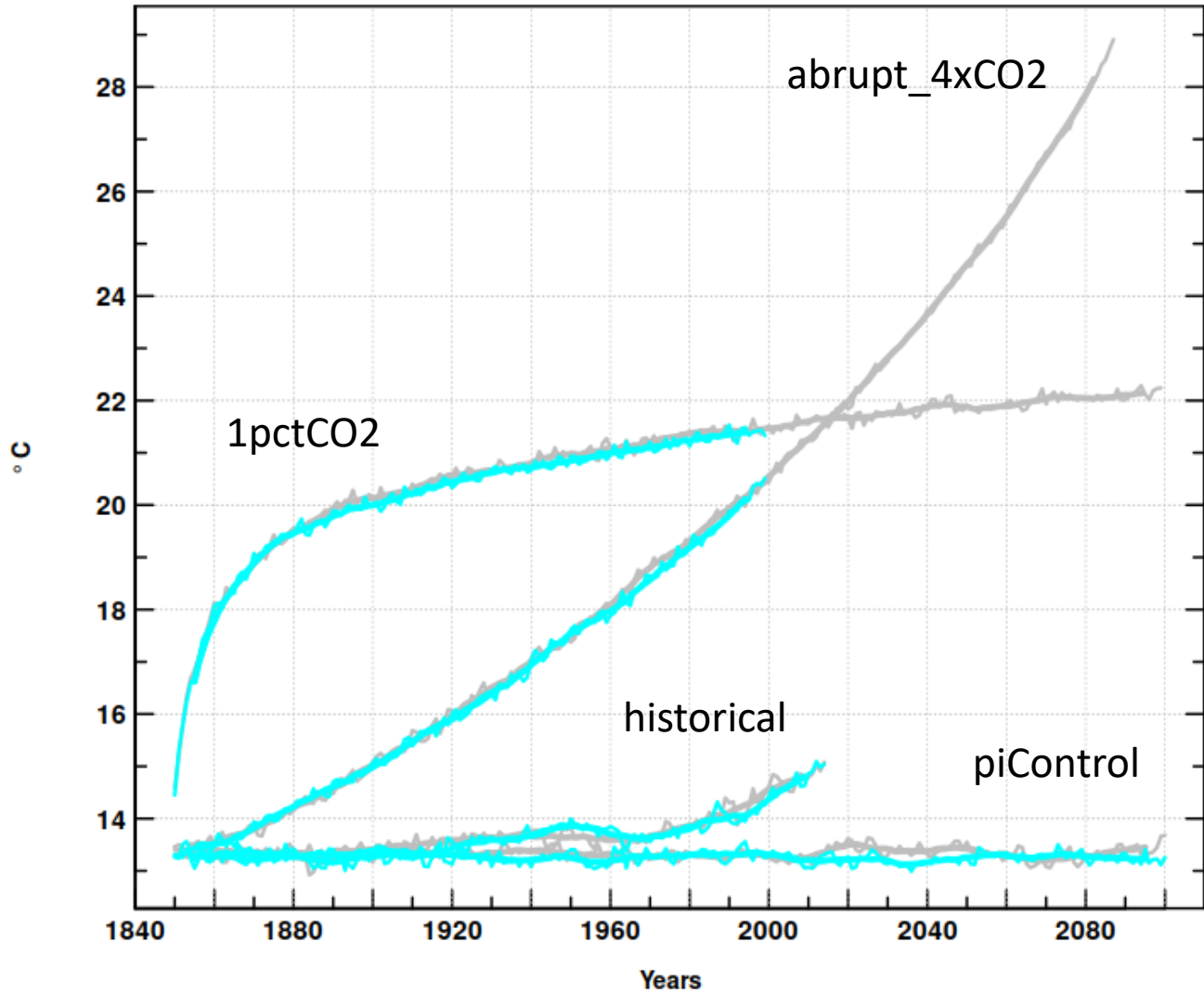## Annual screen temperature over globe

CanESM5.0_p2

Annual screen temperature over globe

— Annual — 11-yr moving mean
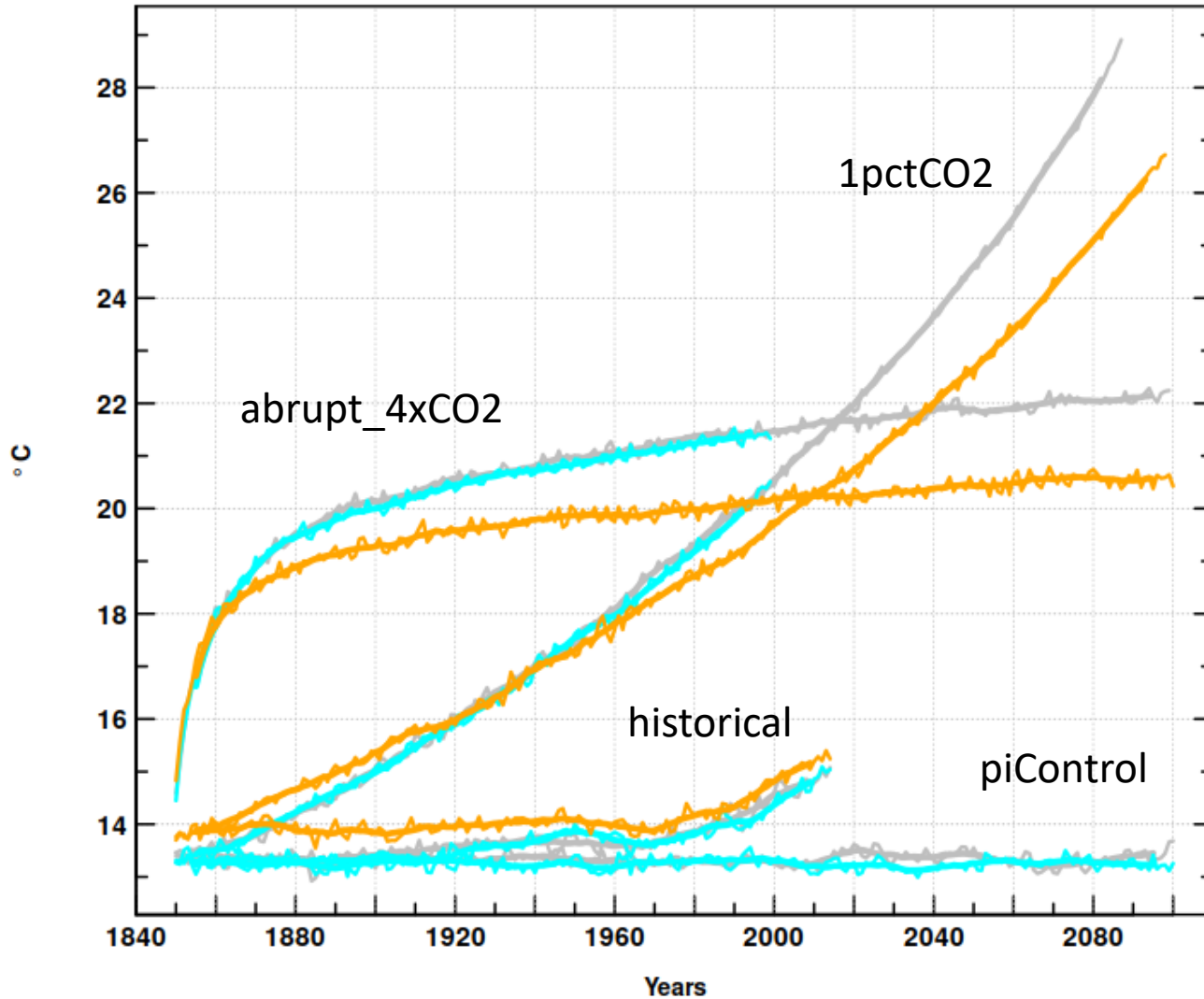
abrupt_4xCO2

1pctCO2

historical

piControl

CanESM5.0_p2
CanESM5.1_p1

°C

Years

Annual screen temperature over globe

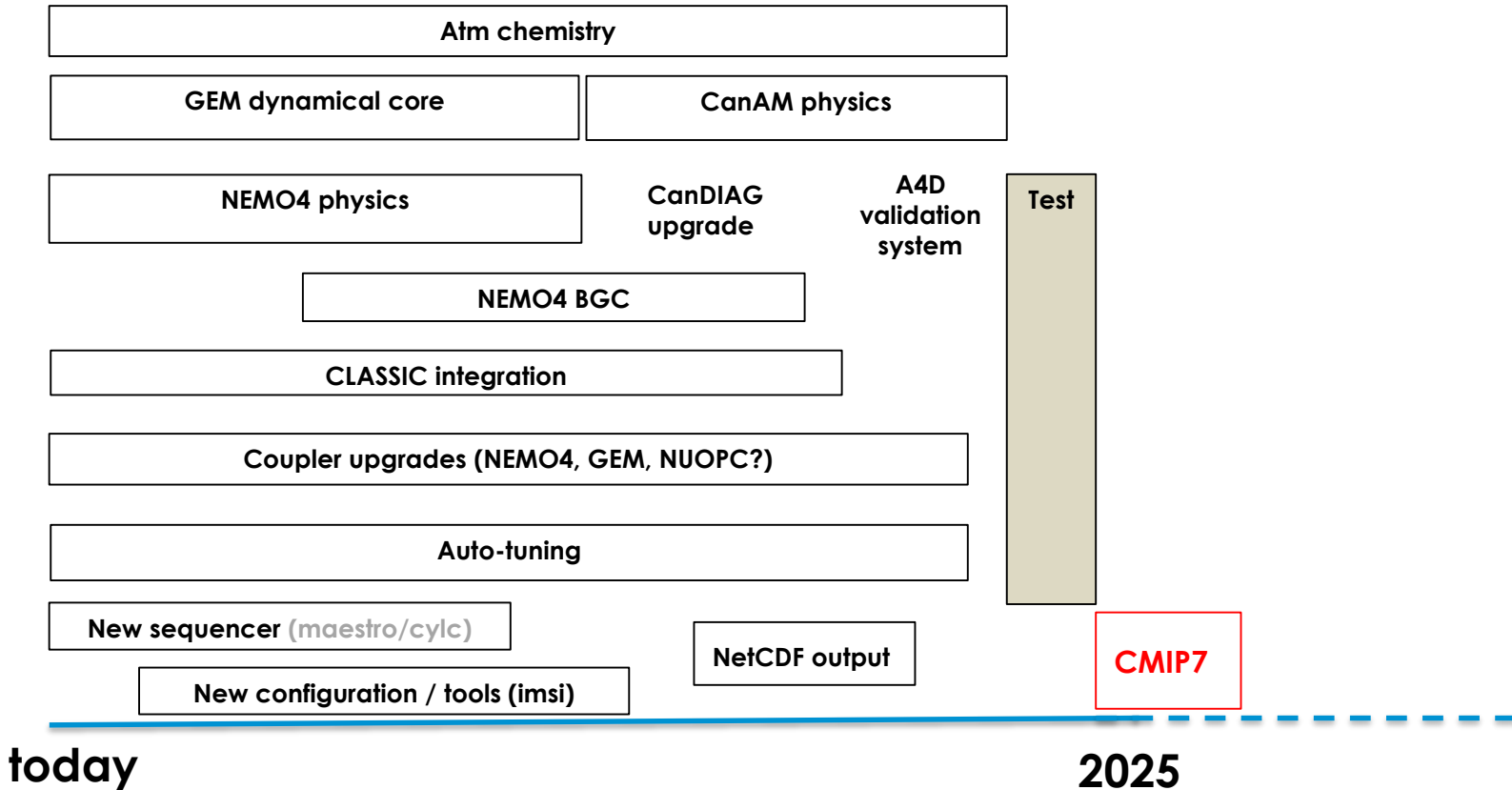CanESM5.0_p2
CanESM5.1_p1
CanESM5.1_p2

The future of CanESM

CanESM5.0 (CMIP6)

CanAM5 (2.8°)

sub-grid LAKES

CLASS3.6 +CTEM

NEW CanCPL

LIM2 ice

CanNEMO (v3.4.1 ORCA1)

CMOC* or CanOE

CCCma environment + tools

→

CanESM6.0 (CMIP7)

CanAM6-GEM5 (<1°)

sub-grid LAKES

CLASSIC

COMMUNITY COUPLER

SI3

CanNEMO (+v4.0 <ORCA025)

CMOC* or CanOE
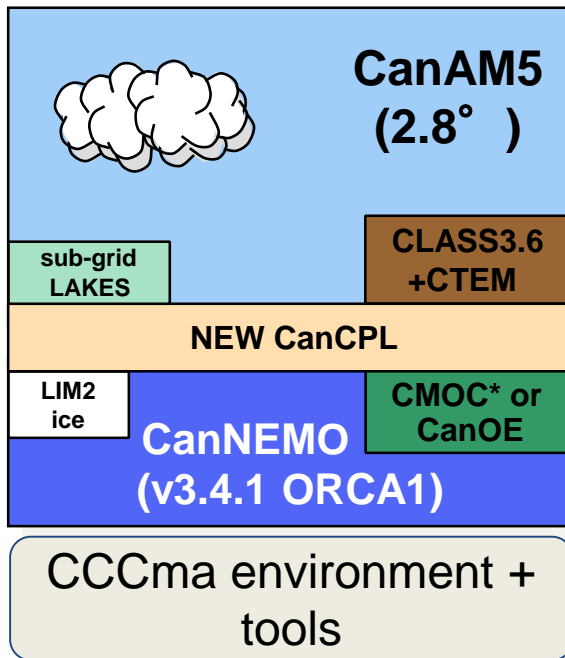
Collaborative environment + tools
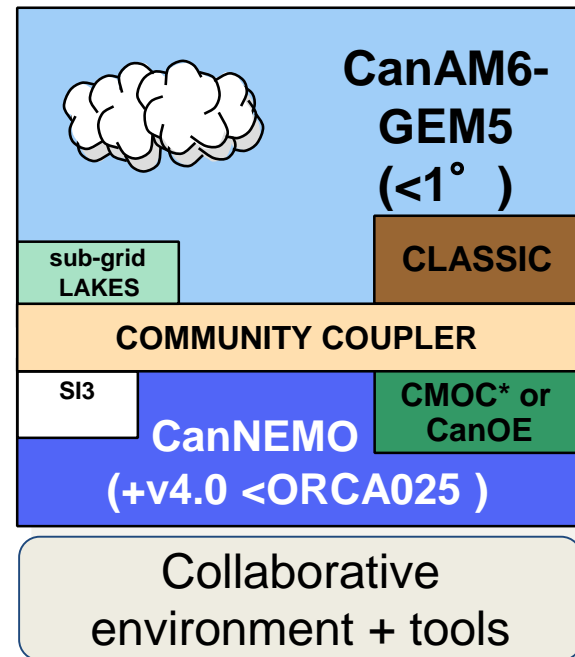
Major Projects for CanESM6

Atm chemistry

GEM dynamical core	CanAM physics

NEMO4 physics	CanDIAG upgrade	A4D validation system	Test

NEMO4 BGC

CLASSIC integration

Coupler upgrades (NEMO4, GEM, NUOPC?)

Auto-tuning

New sequencer (maestro/cylc)

New configuration / tools (imsi)	NetCDF output	CMIP7

today   **2025**

Collaborative CanESM
Recap from April 2021

10 Elements of a collaborative CanESM

1. A new philosophy
2. Open code base
3. A reproducible environment (container)
4. Portable, standards compliant code
5. Experiment configuration & forcing
6. Usable in/out files and diagnostic capability
7. Portable compilation & sequencing utilities
8. Current documentation and user/dev guides
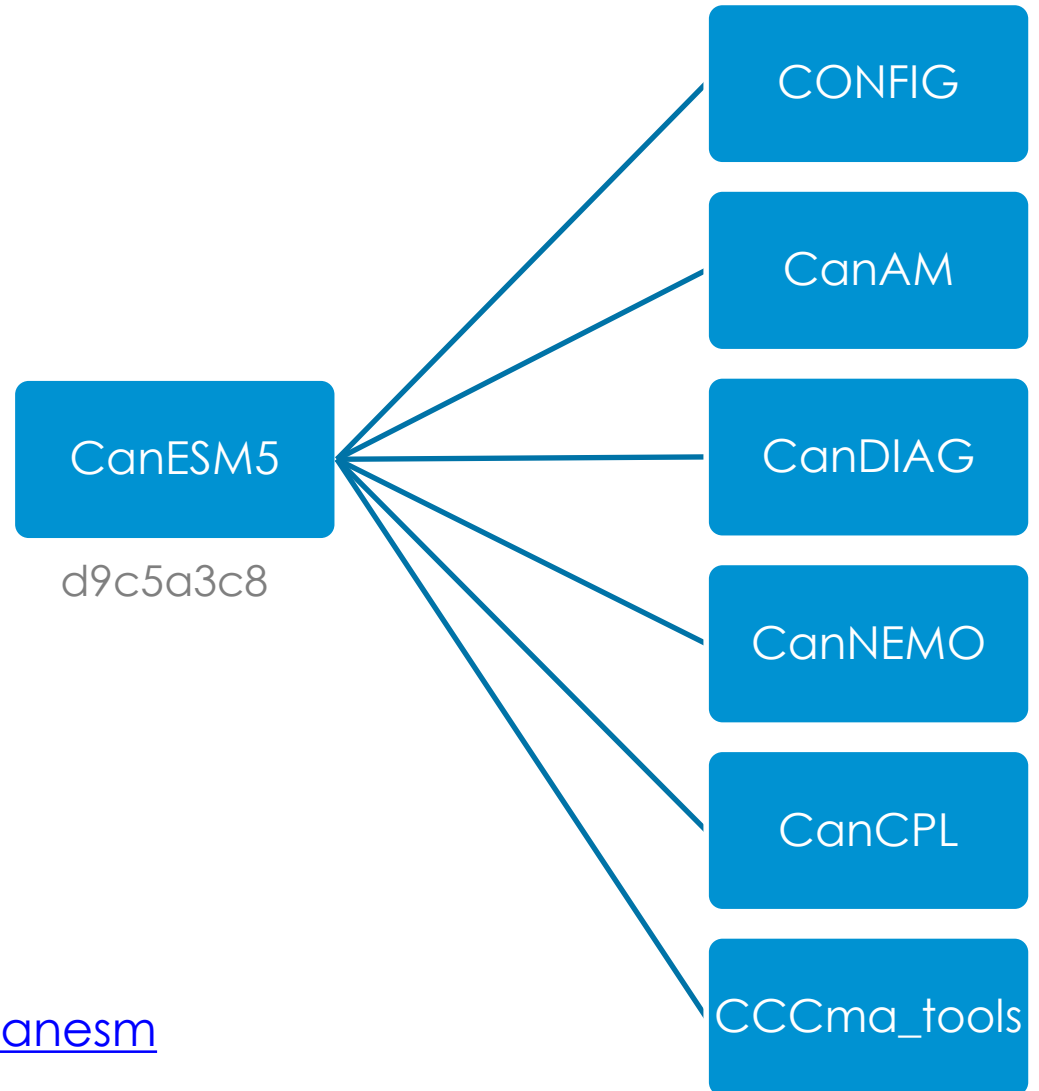9. Robust testing and Quality Assurance
10. Collaboration philosophy & support

A complete, open and controlled code base

One hash to rule them all

Every single piece of >3m SLOC defined by an 8 character CanESM5 hash and open on:

GitLab

https://gitlab.com/cccma/canesm

CanESM5

d9c5a3c8

CONFIG

CanAM

CanDIAG

CanNEMO

CanCPL

CCCma_tools

CanESM container
Proof of concept

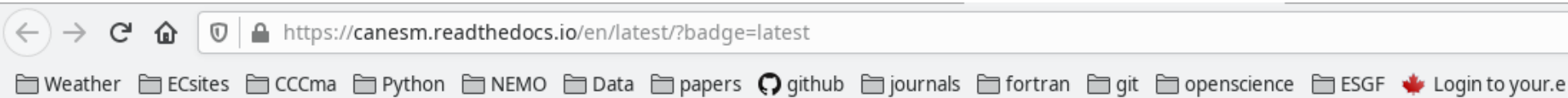A reproducible runtime environment allowing the same code to operate on a diversity of host platforms / OSs.

Dockerfile container definitions live on gitlab
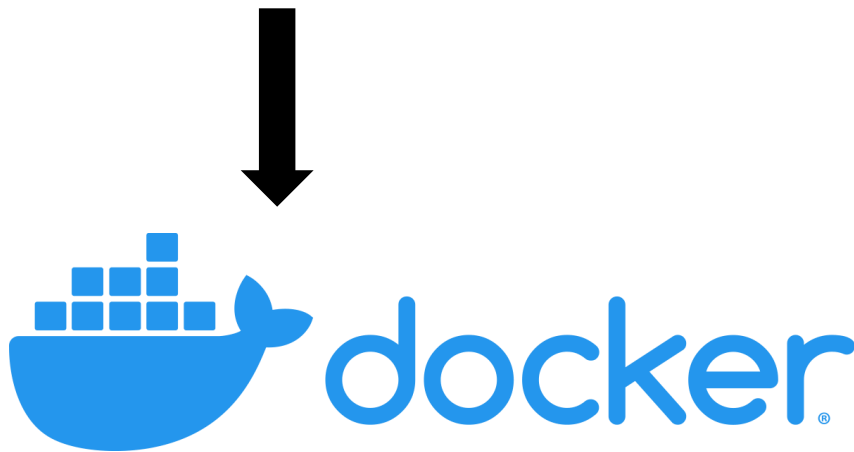
Built container image lives on dockerhub

Docker to Singularity conversion in 1 line (for HPC systems).

https://hub.docker.com/repository/docker/swartn/canesm-docker

Documentation and user guides

Computing platforms tested

Initial testing on laptop and GCP. Any other cloud vendor should work too.

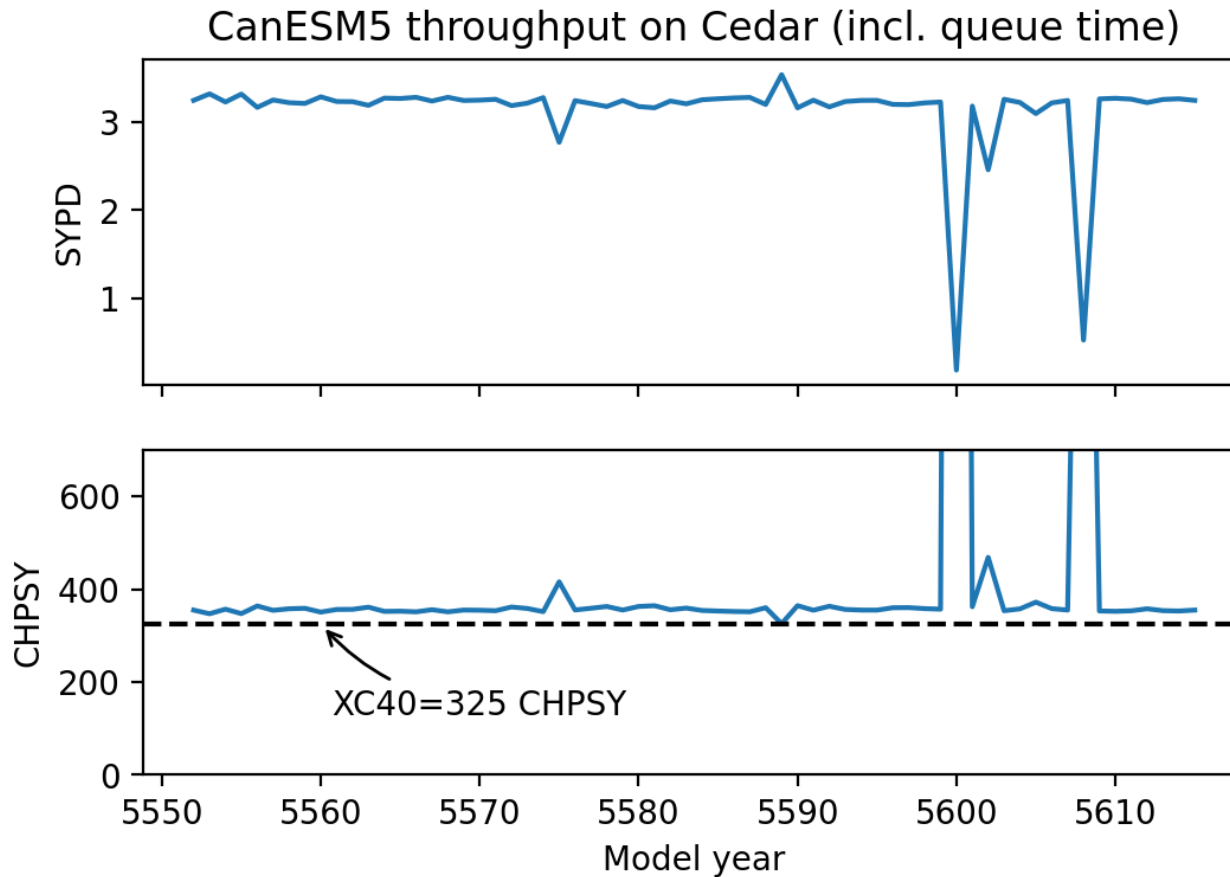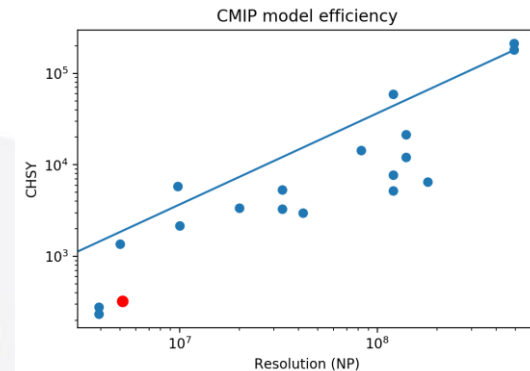**Google** Cloud Platform

More comprehensive testing on Compute Canada's *Cedar* system.

SLURM is a challenge. Much improvement still to be made.

Throughput and efficiency

CanESM5 throughput on Cedar (incl. queue time)

See update
from Jack

XC40=325 CHPSY

CMIP model efficiency

Test on one node = 40 cores on Cedar

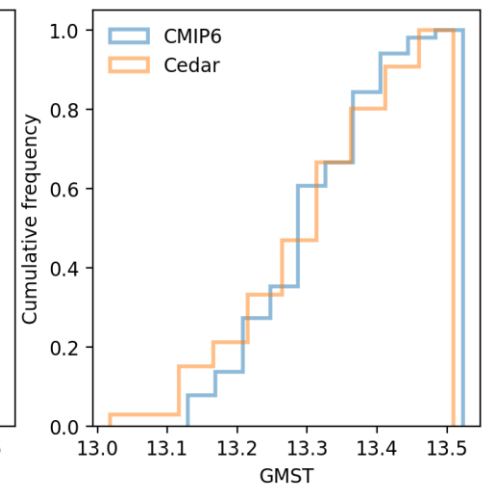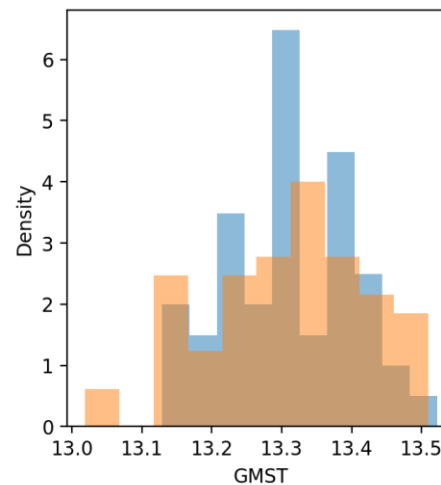# Surface air temperature

CanESM5 GMST on Cedar vs CMIP6
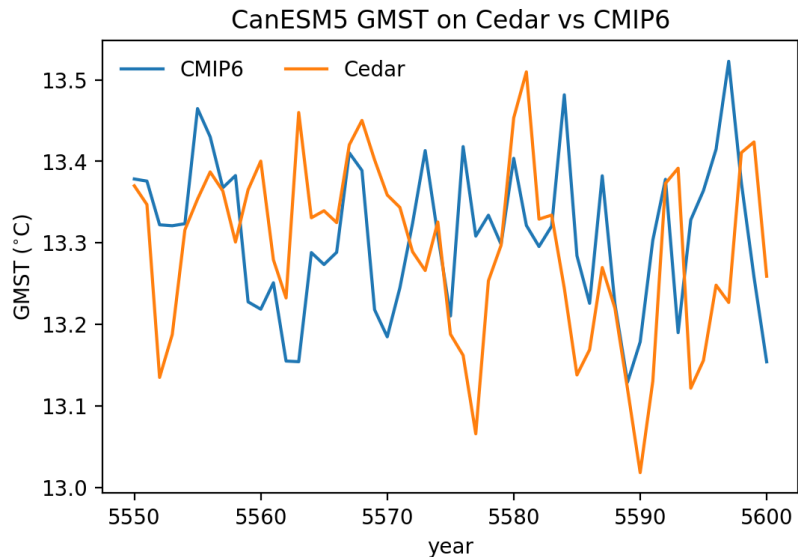
See update
from Haruki

T-test (means)   : p=0.86
F-test (variance)   : p=0.95
KS test (distribution) : p=0.76

i.e. results are indistinguishable
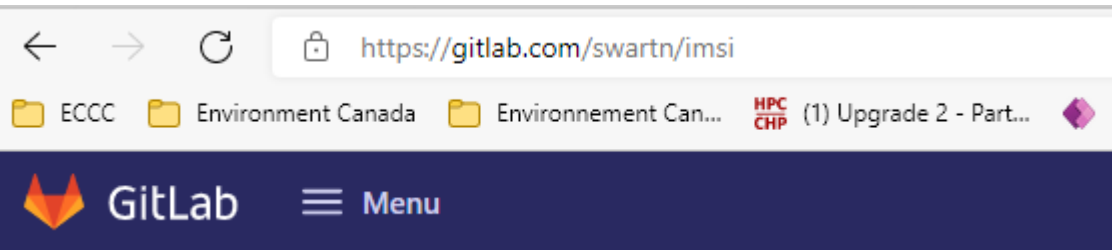
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   • CanAM and CanDIAG are particular challenges

5. Experiment configuration & forcing (WIP)

6. Usable in/out files and diagnostic capability

   • CanAM CCCma format / CanDIAG &CMIP netcdf pipeline

7. Portable compilation & sequencing utilities (WIP)

8. Current documentation and user/dev guides (WIP)

9. Robust testing and QA (WIP)

10. Collaboration philosophy & support

   • ECCC commitment to open platform and collaboration, but no mandate or resources for direct user/platform support. Requires community ingenuity. Philosophy TBD.

Collaborative CanESM Progress to April 2022

Created a new, improved, portable model configuration system:
(in beta)

← → C 🔒 https://gitlab.com/swartn/imsi

📁 ECCC 📁 Environment Canada 📁 Environnement Can... HPC/CHP (1) Upgrade 2 - Part... ◆

GitLab ≡ Menu

Integrated Modelling System Infrastructure (IMSI)

docs passing

The Integrated Modelling System Infrastructure (IMSI) is a comprehensive python based package used to download, configure, build and run the suite of models in the CCCma Integrated Modelling System.

- Documentation: https://imsi.readthedocs.io.

License

- Open Government License - Canada version 2.0

Ported CanESM5.0 to Niagara
using imsi and the native intel compiler
and libraries (i.e. bare metal port)

Supported 3 students (UofT, Uvic) in
conducting several hundreds of years of
CanESM5.0 simulation

Developed new sequencing capacity using the portable community tool **cylc** (in alpha)
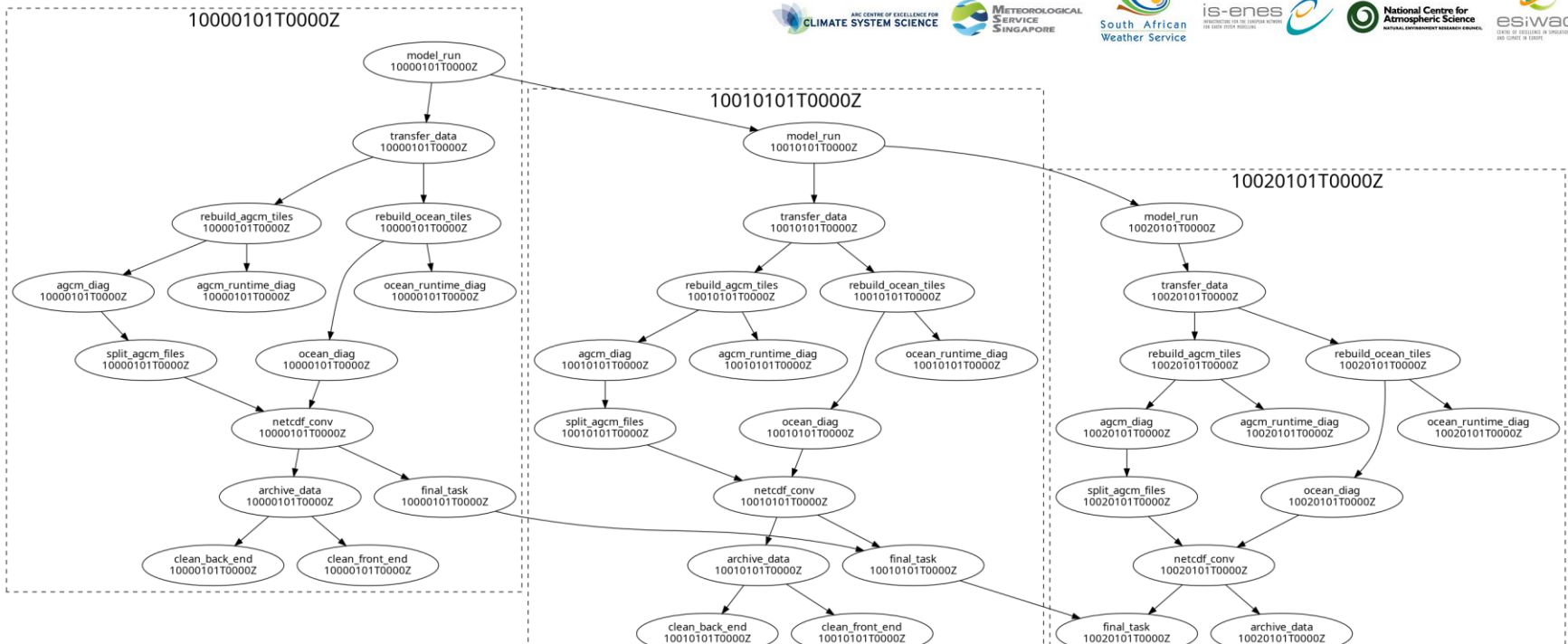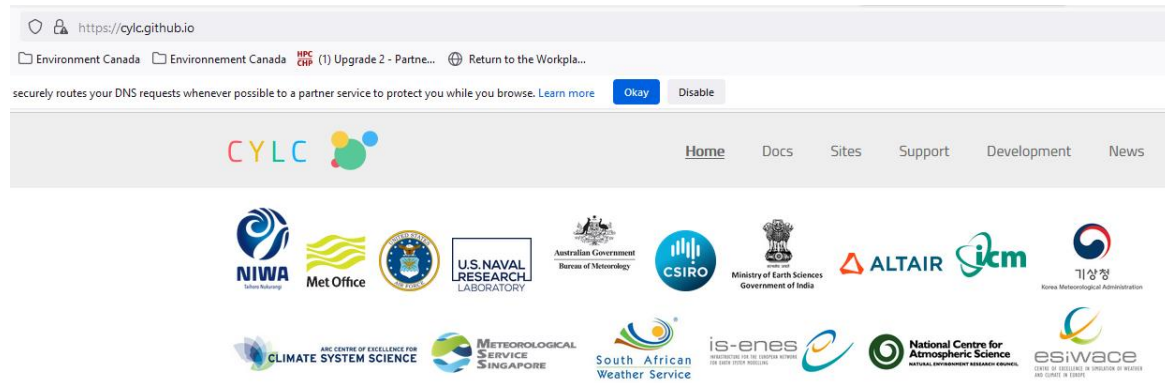
10 Elements of a collaborative CanESM

1. A new philosophy

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3. A reproducible environment (container)

4. Portable, standards compliant code

   • CanAM and CanDIAG are particular challenges ⟶ Improved in 5.1

5. Experiment configuration & forcing (WIP) ⟶ IMSI

6. Usable in/out files and diagnostic capability

   • CanAM CCCma format / CanDIAG &CMIP netcdf pipeline ⟶ IMSI/CYLC

7. Portable compilation & sequencing utilities (WIP)

8. Current documentation and user/dev guides (WIP)

9. Robust testing and QA (WIP)

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