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PC6 : calibration of climate models

Aurore Voldoire & Julie Deshayes

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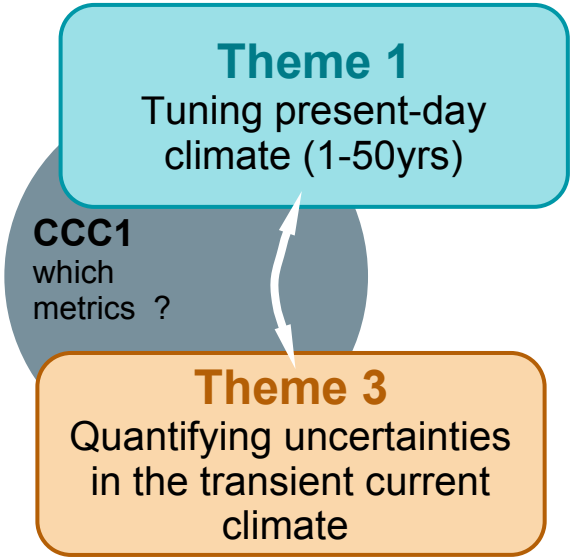
PC6-QUINTET = Calibration + observations constraints



→evaluate model developments
→calibrate fluctuations
→model hierarchies

→improves obs. constraints
→execute coupled PPE
→apply obs. constraints on CMIP

CCC = Cross Cutting Challenge

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TRACCS – others PCs

PC5, 7, 8, 9
developments for
CNRM-CM and IPSL-CM

better constrained
climate projections to
be used by
PC1, 2, 3, 4, 10

PC6-QUINTET

Theme 1
Tuning present-day
climate (1-50yrs)

CCC1
which
metrics ?

Theme 3
Quantifying uncertainties
in the transient current
climate

→evaluate model developments
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→improves obs. constraints
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Theme 1
Tuning present-day climate (1-50yrs)

CCC1
which
metrics ?

Theme 3
Quantifying uncertainties in the transient current climate

Theme 2
Addressing the longer timescales (>100 yr) and equilibration

→explore long simulations with paleo constraints
→accelerate equilibration
→better initialise historicals

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Tuning present-day climate (1-50yrs)

Theme 2
Addressing the longer timescales (>100 yr) and equilibration

Theme 3
Quantifying uncertainties in the transient current climate

CCC1
which metrics ?

CCC2
Beyond Gaussian Processes

CCC3
making the best of model hierarchies

CCC = Cross Cutting Challenge

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TRACCS – PC7
IMPRESSION-ESM
IMproving the physical **PR**oc**ESS** representat**ION** in **E**arth **S**ystem **M**odels

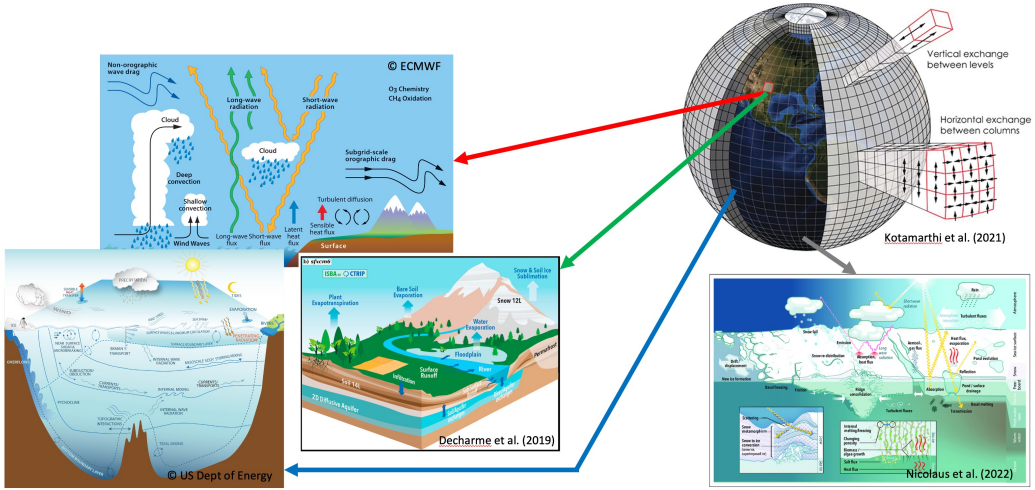
Coordinators: R. Roehrig (CNRM), M. Vancoppenolle (IPSL), N. Jourdain (IGE)
Partners: Météo-France, CNRS (IPSL, IGE) et CEA (LSCE), 34+ collaborateurs

39th annual meeting of the WGNE, 4-8 November 2024, Toulouse, France

Motivation and objectives

IMPRESSION-ESM ambitions to ***improve the representation of key Earth system physical processes*** in the two French ESMs to

- Enhance our ***understanding*** of the Earth system
- Increase the ***confidence*** in ESM output
- Provide ***high-quality climate*** information
- Train the ***next generation*** of climate modelling scientists



by

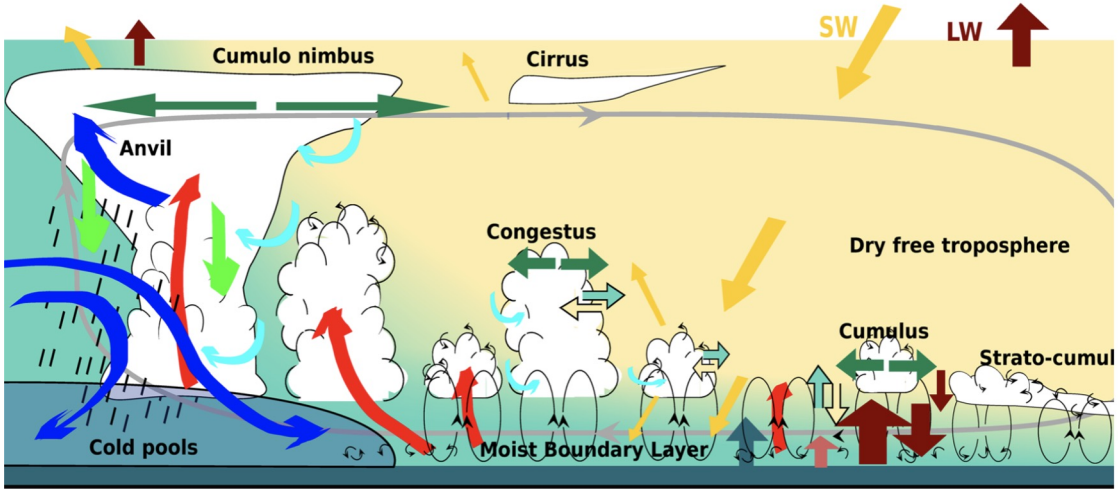
- Advancing ***theoretical models*** of physical processes
- Fully benefit from ***process/high-resolution models*** and most recent ***observations***
- Exploring the potentiality of ***AI***-based techniques

Tackled processes - Atmosphere

ARPEGE, LMDZ

- ***Shallow-to-deep transition*** of convection (congestus)
- ***Mesoscale convective organisation*** and its role on the energy/water cycle and the large-scale circulation

- ***Single-column/large-eddy modelling*** for conceptual developments and their validation
- Also exploit regional/global ***km-scale models***



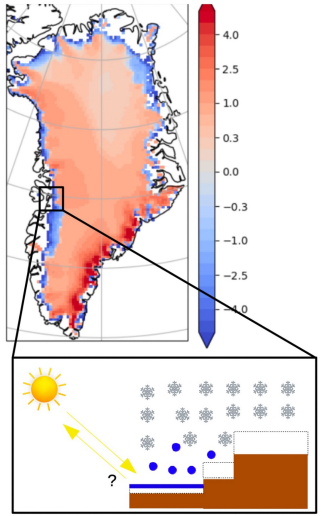
Convective processes to be parametrized? (Rio et al. 2019)

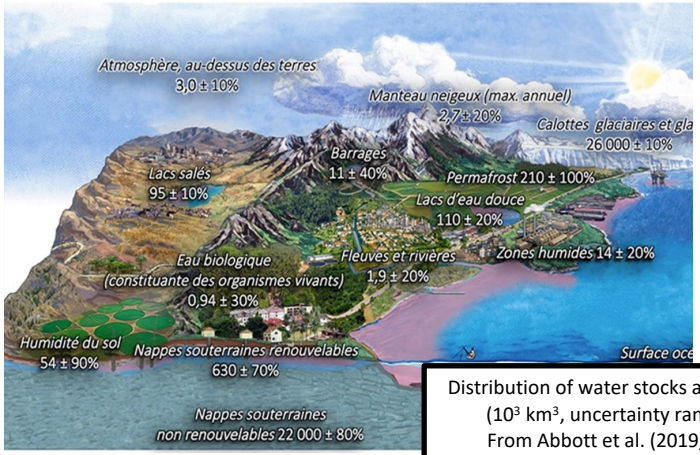
Tackled processes – Land surface and snow

ORCHIDEE, SURFEX

- ***Land heterogeneity*** for land-atmosphere coupling and the water cycle over land
- ***Human impacts*** on the water cycle

Greenland surface mass balance as simulated with ORCHIDEE (with new snow module) [mm/d]





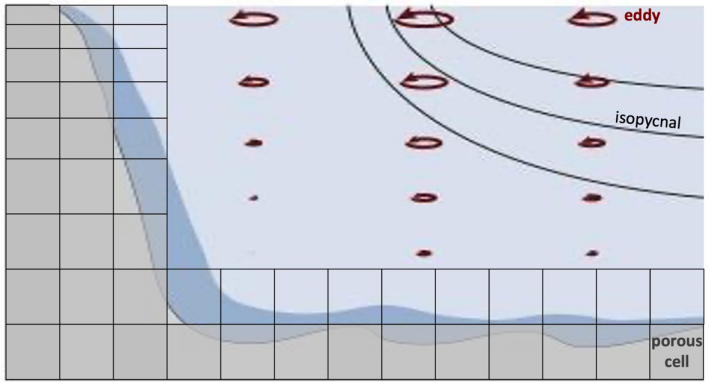
Distribution of water stocks at global scale (10^3 km^3, uncertainty range in %). From Abbott et al. (2019, Nature)

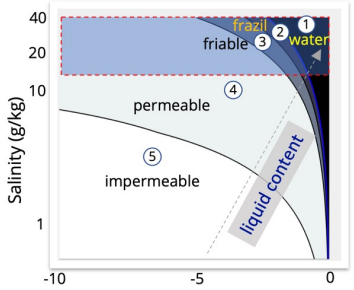
- ***Consistent snow representation at mid-latitudes and over ice sheets***
  - Precipitation phase, snow melting and aeolian transport
  - Spectrally-resolved albedo, aerosol deposition
  - Subgrid-scale topography

Tackled processes – Ocean and sea ice

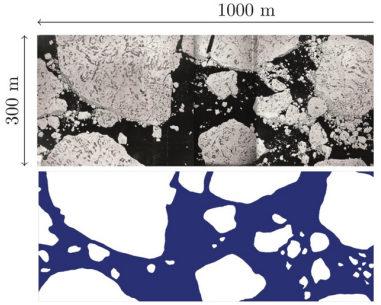
NEMO, SI3

- Physical frameworks for ***mesoscale eddy mixing***
- ***Flow-topography interactions*** using new numerical approaches





Temperature (°C)
Sea-ice liquid fraction
and its link to sea-ice phenology



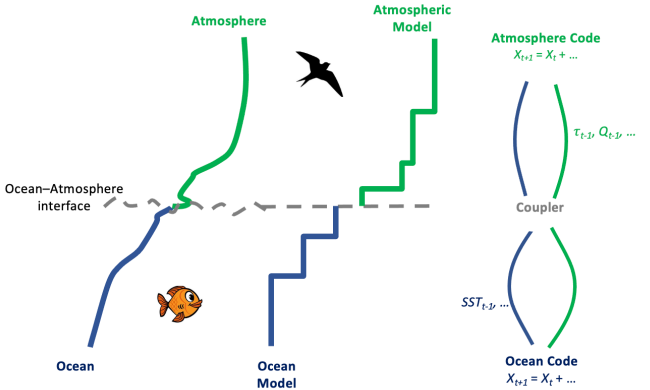
Ice-floe modelling of a realistic test case
(Rabatel et al. 2015)

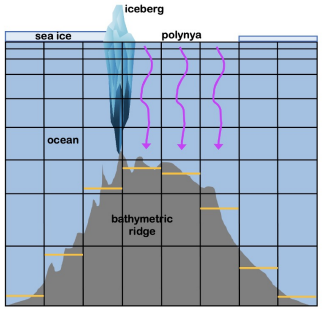
- ***Sea-ice multi-phase thermodynamics*** including the role of liquid water in sea ice
- ***Sea-ice dynamics*** with improved brittle rheology, using explicit modelling of sea-ice floes

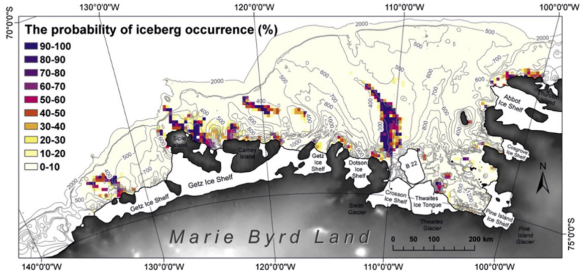
Tackled processes – Couplings

CNRM-CM, IPSL-CM
= ARPEGE/LMDZ, NEMO, SI3, OASIS

- ***Ocean-atmosphere*** coupling: numerics, subgrid-scale processes







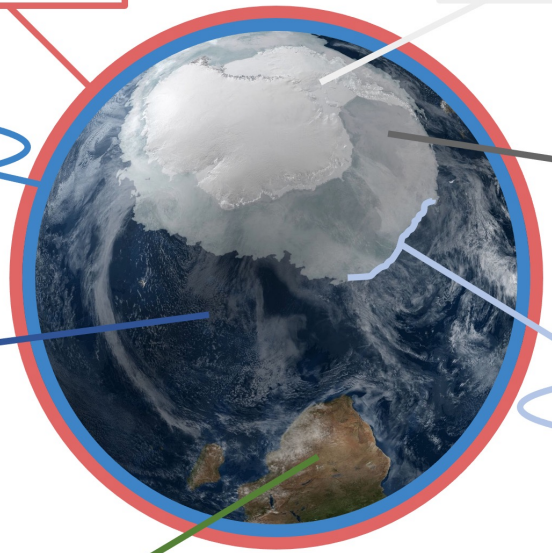
Example of the Amundsen Sea: many icebergs grounded on shallow ridges (Mazur 2017)

- ***Ocean-sea-ice-iceberg continuum***, role of bathymetry and polynyas

ATMOSPHERE
Convection, clouds, transitions, organisations, breezes

SNOW
Unified approach, topography, albedo

OCEAN–ATMOSPHERE INTERFACE
Boundary layers, mesoscale, numerics



SEA ICE
Multi-phase physics, rheology

OCEAN
Macroturbulence, energy dissipation, bathymetry

OCEAN–SEA-ICE–ICEBERGS
Bathymetry, polynyas

LAND SURFACE
Heterogeneities, scale-awareness

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Biogeochemical cycles in Earth system models (CYCL-ESM)

Lead: Yves Balkanski (LSCE/IPSL)
Co-Lead: Roland Séférian (CNRM/Météo-France)

CYCL-ESM in a nutshell

Key objectives:

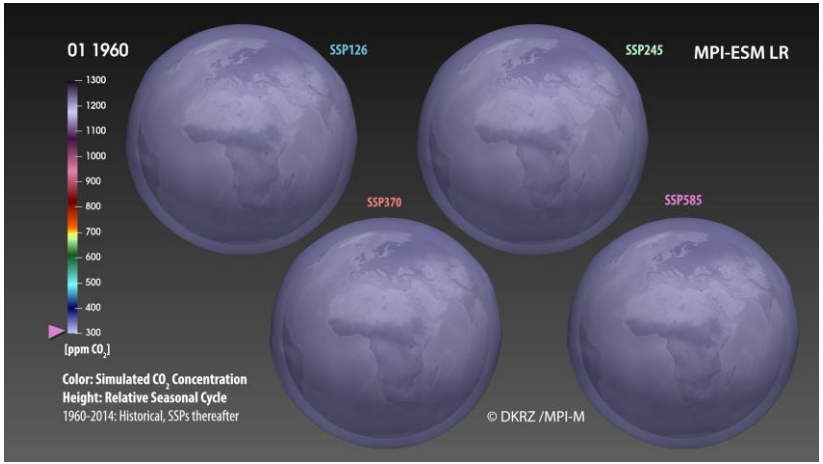
1) Improve the representation of key biogeochemical cycles in French ESMs
2) Improve coupling and nexuses with other components of the physical system (water, energy, movement)
3) Enhance the capability and the flexibility of IPSL and CNRM Earth system models for a wider range of application: climate to biodiversity, vulnerabilities, and mitigation.

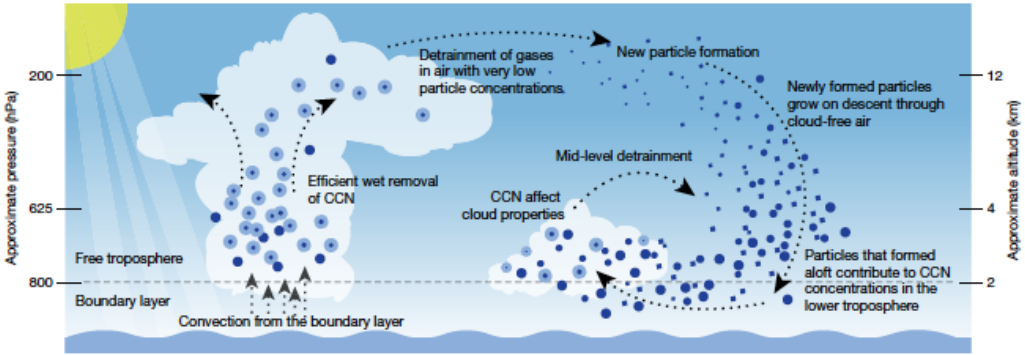
Duration : 8 years (May 2024 – Apr 2032)

Funding : 4.3 M€

CYCL-ESM: why ?

Biogeochemical cycles are a key components of the Earth system linking emissions to climate change
They are utterly perturbed by human interferences





Williamson et al., 2019 Nature

⇒ Uncertainties from biogeochemical feedbacks are poorly integrated/represented in the current generation of ESMs

⇒ The chain of processes from emissions to clouds and/or radiative feedbacks is not represented in the current generation of models

CYCL-ESM: How ?

Four research axes across Earth system components

1) Nexus between nutrients and carbon cycles
2) Land-use and ecosystem management
3) Fire in the Earth system (from the vulnerability of semi-arid regions to the aerosols emissions)
4) Nexus between Chemistry-Aerosols with a focus on volatile organic compounds

Tools/Approach:

1) French ESMs: IPSL-ESM and CNRM-ESM
2) Exploration of IA-based tools (acceleration, spin-up, emulation or complexity/information analysis)
3) Connection with other TRACCS PCs and EU/Int. research program