CRESCENDO

Coordinated **R**esearch in **E**arth **S**ystems and **C**limate: **E**xperiments, k**N**owledge, **D**issemination and **O**utreach

www.crescendoproject.eu

Coordinator: Colin Jones: University of Leeds/NCAS

Project start : Nov 1st 2015, Duration : 5 years

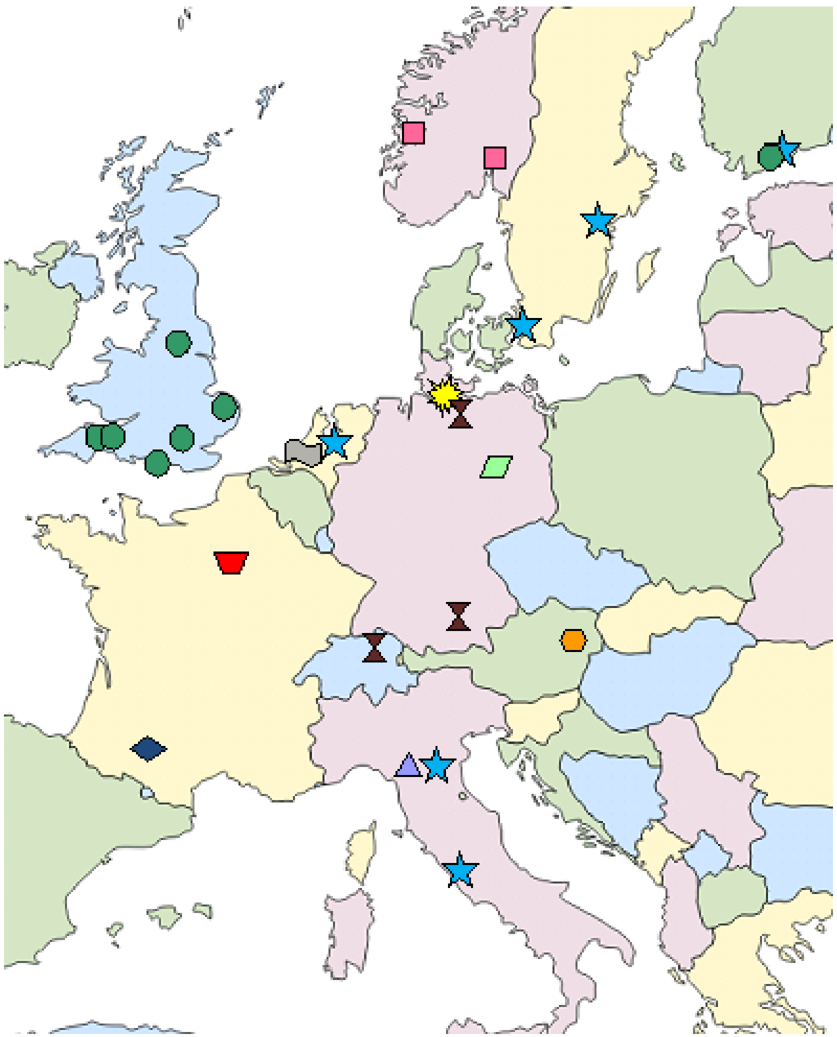
Developing, using and evaluating **Earth system models**

CRESCENDO primary science objectives

- Improve the representation of key (terrestrial & marine) biogeochemical & aerosol processes in seven European ESMs
- Develop process-level methods/diagnostics to evaluate the process improvements
- Further develop a community ESM evaluation tool (ESMValTool) and develop and apply methods to evaluate the performance of the ESMs
- Through development of suitable emergent constraints reduce uncertainty in future Earth system feedbacks and target areas for future model improvement
- Coordinate a European contribution to key CMIP6 MIPs: C4MIP, AerChemMIP, OMIP, LUMIP, LS3MIP and ScenarioMIP
- Develop new emission & land-use (SSP/RCP) scenarios for CMIP6 ScenarioMIP

25 CRESCENDO partners from 10 countries

7 Earth System Models and 3 Integrated Assessment Models



Earth System Model *(Contributing partners)*

- CNRM-ESM *(MF-CNRM)*
- CMCC-ESM *(CMCC)*
- EC-Earth *(ENEA, FMI, CNR, KNMI, SMHI, ULUND)*
- IPSL-ESM *(CNRS-IPSL)*
- MPI-ESM *(MPG)*
- NorESM *(UiB, METNO)*
- UKESM *(MOHC, NOC, UNEXE, UEA, UNIVLEEDS, UREAD, FMI)*

Integrated Assessment Model *(Contributing partners)*

- IMAGE *(PBL)*
- MESSAGE/GLOBIOM *(IIASA)*
- REMIND/MAgPIE *(PIK)*

Partners expert in ESMVal Tool and Emergent Constraints

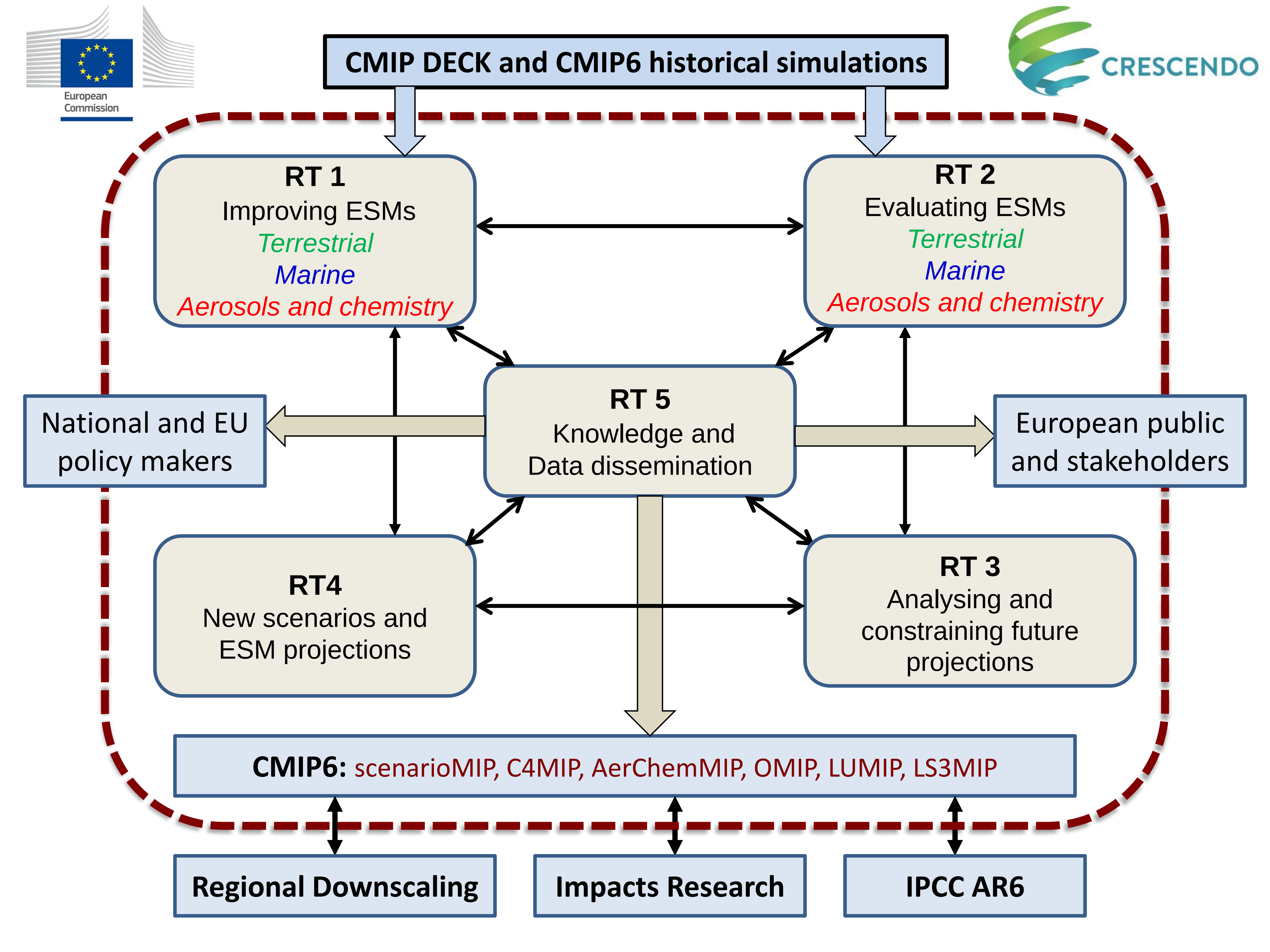
- *DLR, ETH, UHAM , LMU*

ESMs in CRESCENDO

Probable "higher" and "lower" resolution CRESCENDO ESM versions

Model	"Higher" resolution models		"Lower" resolution models	
	Atmosphere	*Ocean*	*Atmosphere*	*Ocean*
CNRM-ESM	T359	0.25°	T127	1°
CMCC-ESM	1°	0.25°	1°	1°
EC-Earth	T255	1°	T159	1°
IPSL-ESM	1.3° x 0.65°	0.25°	2.5° x 1.25°	1°
MPI-ESM	T127	0.4°	T63	1.5°
NorESM	0.9° x 1.25°	0.25°	1.9° x 2.5°	2°
UKESM	0.6°	0.25°	1.5°	1°

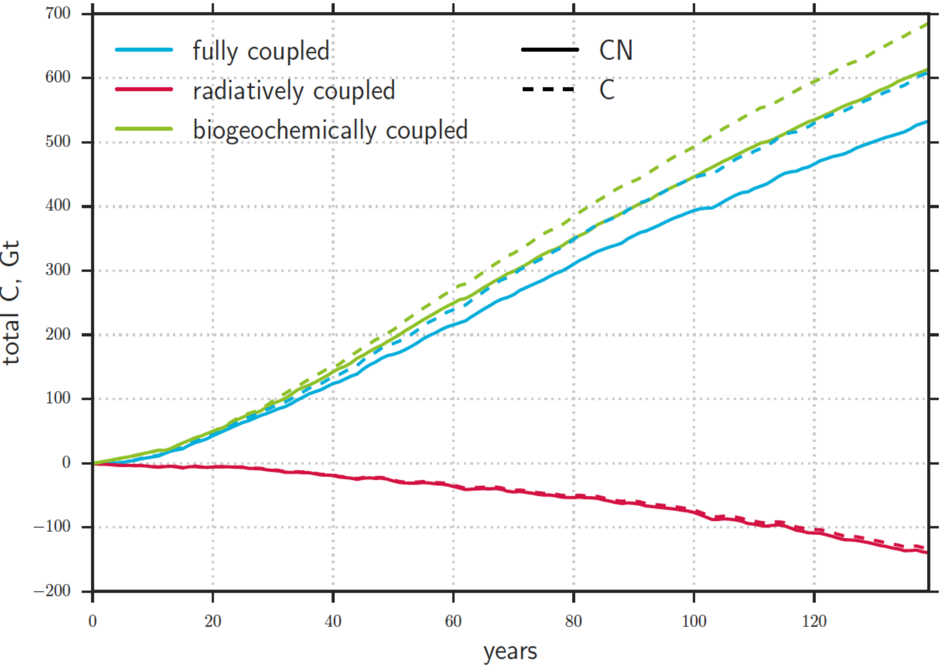
CRESCENDO



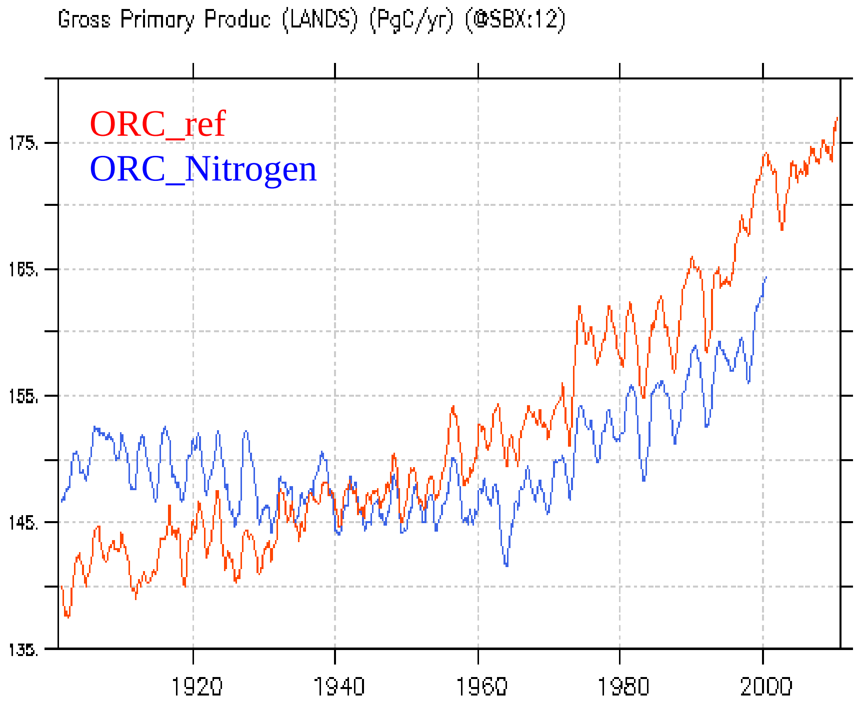
European Commission
CRESCENDO
CMIP DECK and CMIP6 historical simulations
RT 1
Improving ESMs
Terrestrial
Marine
Aerosols and chemistry
RT 2
Evaluating ESMs
Terrestrial
Marine
Aerosols and chemistry
National and EU policy makers
RT 5
Knowledge and Data dissemination
European public and stakeholders
RT4
New scenarios and ESM projections
RT 3
Analysing and constraining future projections
CMIP6: scenarioMIP, C4MIP, AerChemMIP, OMIP, LUMIP, LS3MIP
Regional Downscaling
Impacts Research
IPCC AR6

WP1: Improving terrestrial models: carbon-nitrogen interactions

JSBACH (MPI-ESM), 1%-CO_2 offline run with (CN) & without (C) N limitation: Terrestrial carbon uptake decreases by 90 Gt C (13%) due to N limitation



ORCHIDEE (IPSL), historical offline run: N-cycle leads to GPP reduction, optimization of CN interactions still ongoing



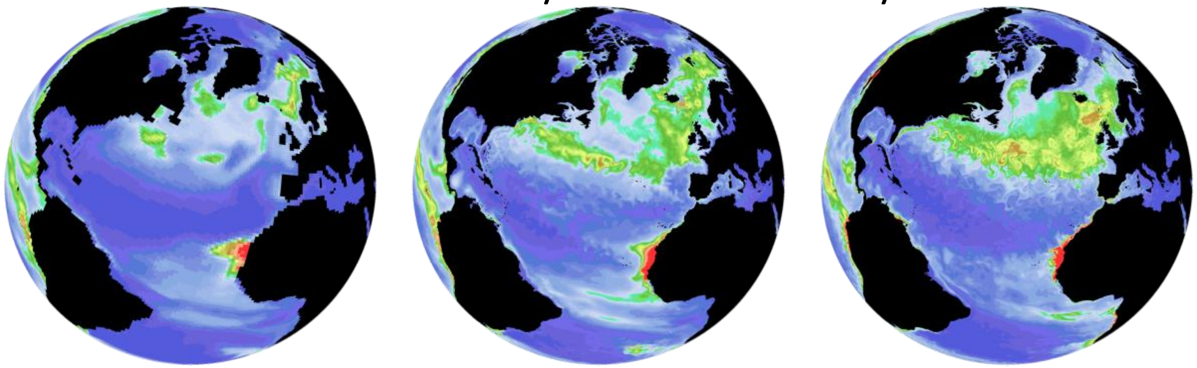
CRESCENDO ESMs plan to use interactive CN land models in CMIP6, final calibration of coupled carbon-nitrogen models

WP2 : Improved representation of marine biogeochemistry

Ocean Physics

Effects of increased resolution on marine Net Primary Production

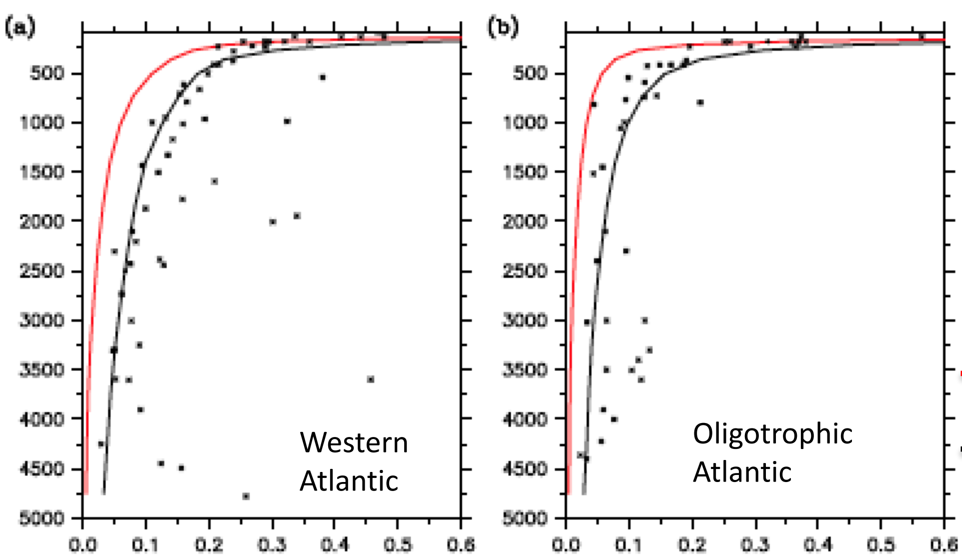
1° | 1/4° | 1/12°



Model : NEMO-MEDUSA
Resolution : 1°→1/12°
Period : 1990-2015
Partner : NOC, UK

Ocean Biogeochemistry

Introduction of a Reactive Continuum Model for Marine Particles



Particle Concentrations (µmolC/L)

x Data
PISCES standard
PISCES with RCM

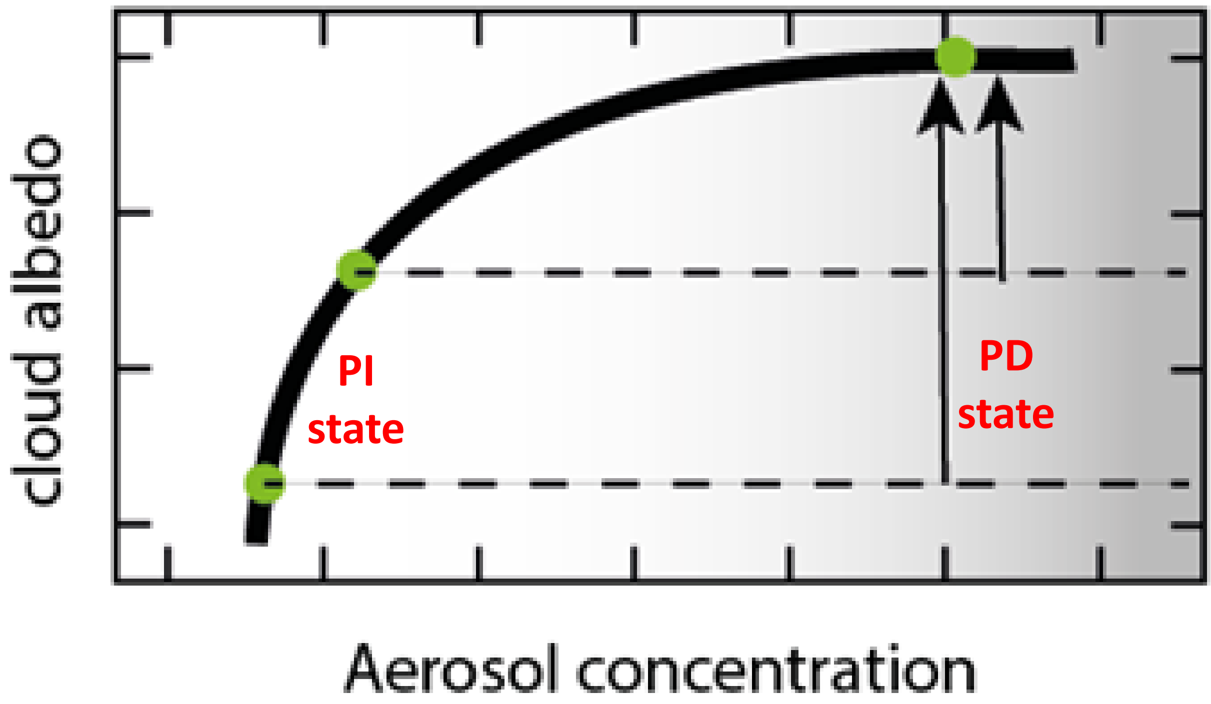
Model : NEMO-PISCES
Partner : IPSL, France

Aumont et al., Biogeosci. Disc.

WP3: Improving aerosol-chemistry schemes in ESMs

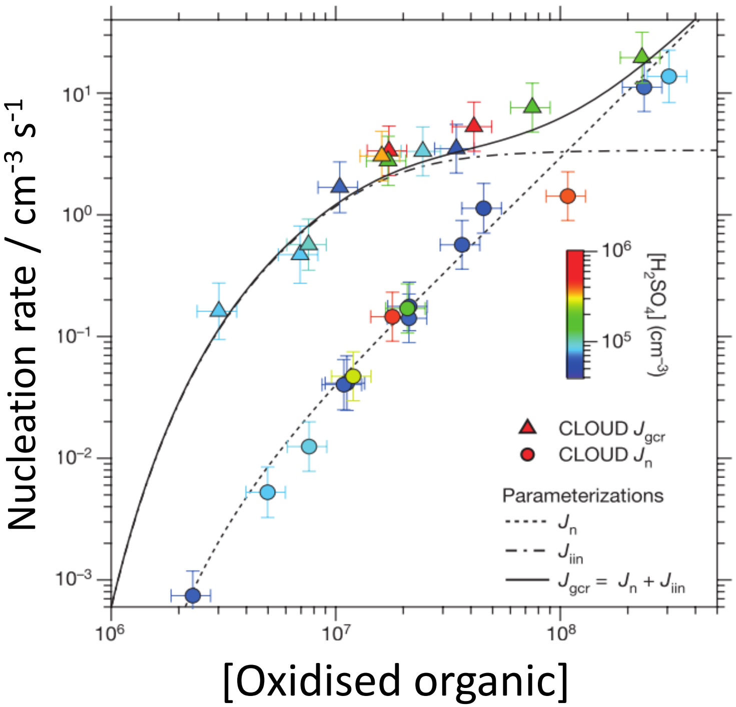
Improved representation of natural (pre-industrial) aerosols

- Pre-industrial (PI) to present day (PD) aerosol radiative forcing is sensitive to the simulated PI baseline (mostly natural) aerosol state (Carslaw et al., Nature, 2013)
- Two recent developments significantly affect natural aerosol concentrations, and through this the PI to PD historical radiative forcing.



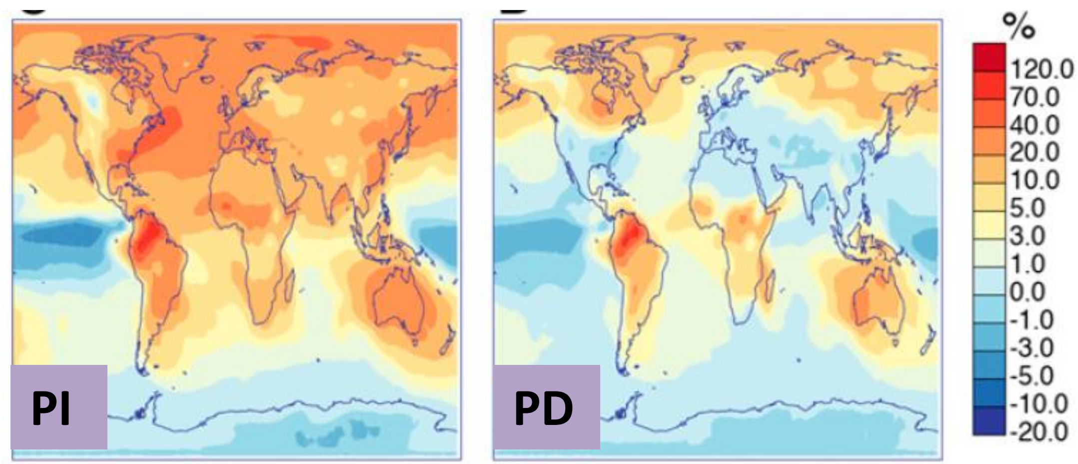
WP3: Natural aerosols: “Pure biogenic” aerosol/droplet nucleation

CERN CLOUD chamber:
Fast aerosol nucleation from oxidised a-pinene (not H_2SO_4) can explain large nucleation rate in “clean” atmosphere



Kirkby et al., Nature, 2016

Percent change in CCN from inclusion of new biogenic nucleation for PI and PD state



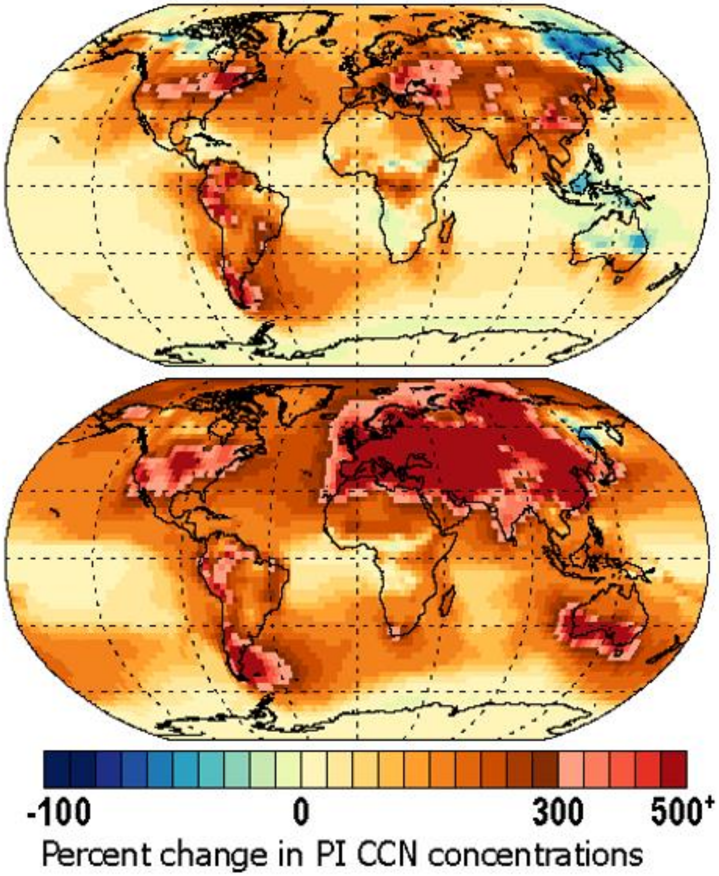
Historical (PI to PD) aerosol forcing reduced by 15-30% due to larger impact of biogenic nucleation on pre-industrial CCN: Test in UKESM1

Gordon et al., PNAS, 2016 in press

WP3: Fire emissions and impact on pre-industrial aerosols

- Fire emissions are typically scaled with population.
- New fire models account for more realistic changes in Land Use and Land Cover etc.
- Higher fire emissions in the pre-industrial potentially have a substantial impact on aerosols and historical aerosol forcing

Percent change in PI CCN due to inclusion of updated fire models vs standard Aercom models



BLAZE/Aerocom in the PI

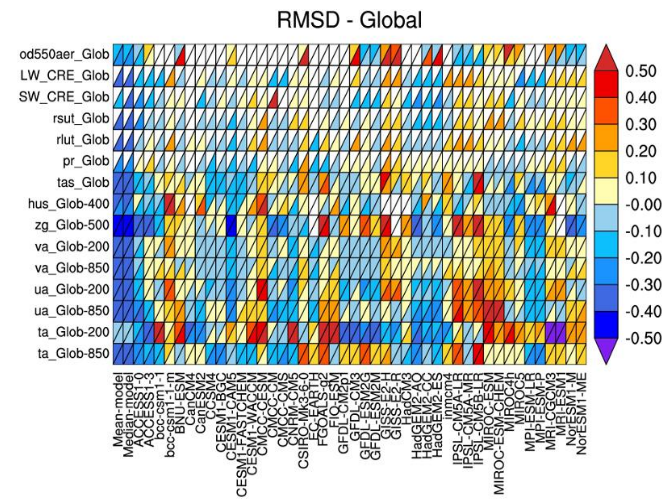
LMFire/Aerocom in the PI

In the GLOMAP aerosol model, the effect is to reduce PI to PD aerosol forcing by 40 to 88%

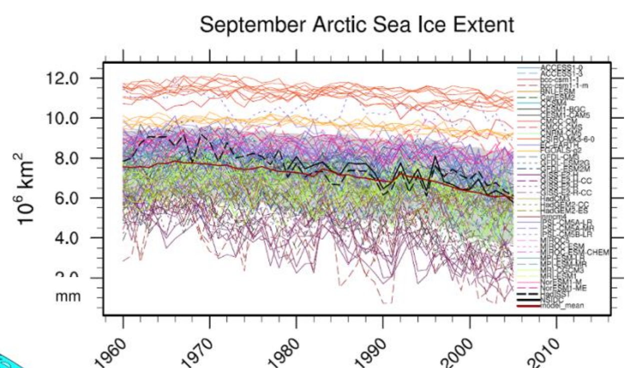
Hamilton, et al., submitted 2016

WP7: Towards routine benchmarking of ESMs

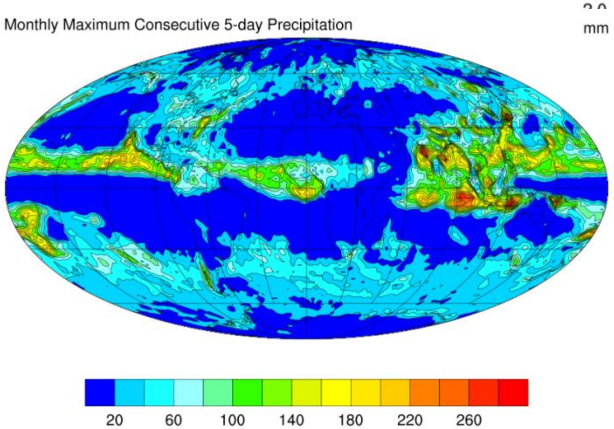
- Further development of the ESMValTool (Eyring et al., GMD, 2016) for routine evaluation of ESMs in CMIP6 and at individual modelling centers
- Implementation of new diagnostics (e.g. IPCC chapter 9 & 12, biogeochemical and aerosol process metrics and emergent constraints) in ESMValTool
- Coupling to the Earth System Grid Federation (ESGF) at selected supernodes so the tool can be run directly on CMIP6 model output
- Further technical development of the ESMValTool, including
  - Development of a new backend using Iris (towards a merge of ESMValTool and Auto-Assess)
  - Improved documentation and visualization

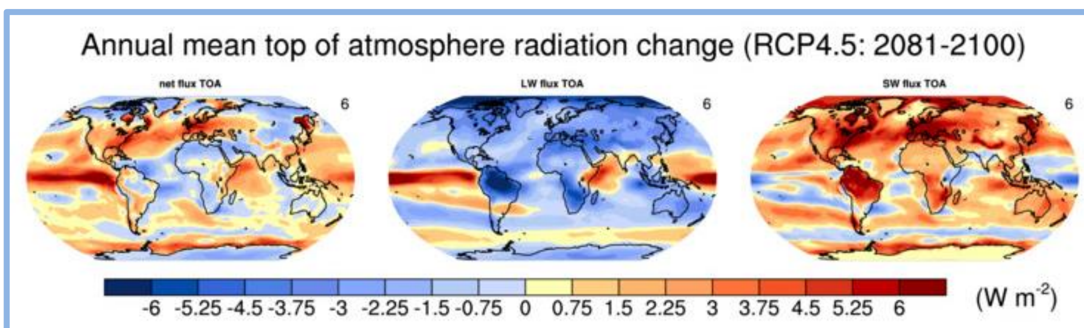


ESMValTool
Earth System Model eValuation Tool

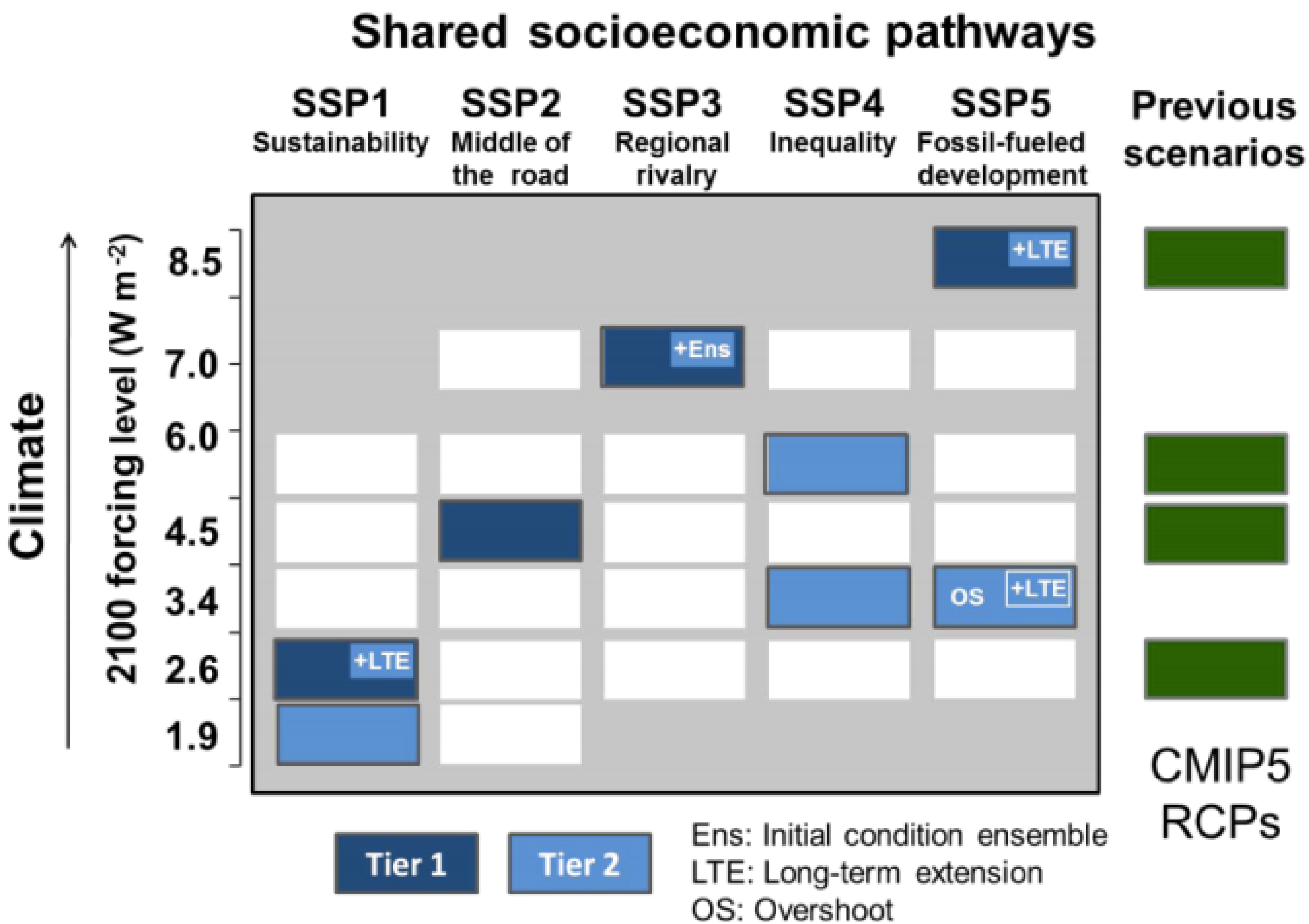


Extreme Events





WP10: Developing SSP/RCP scenarios for CMIP6 ScenarioMIP



WP10: Timing of SSP/RCP scenarios

– IAM scenarios : complete except RCP1.9 W/m2 (1.5°C warming)
– Land use & emission harmonisation / downscaling → aimed at December, 31 2016
– Further translation of emission data into consistent GHG concentration files (and maps) → March, 2017.
– Last review → May, 2017

Thank you!

WP13

CRESCENDO SCHOOLS

Network of Schools for Earth System Modelling & Climate Change

Overall aim to help define and develop a suit of **education resources** on the science of climate change and climate modelling, while allowing students to learn **new skills**, benefit from the **experience** and have **fun**.

- Partnering some of our research institutes with a nearby school (~16-18 yr old science students);
- Work with students to "co-develop" informative materials on climate change, climate models etc;
- Along the way students gain: increased knowledge of the subject, transferable skills and develop material for the wider community;
- Aim to invite some of the students (from the 3 schools) to our GA in 2017 to present some of the things they have been working on to the wider project and meet each other.

Who's involved?

In this first year, one school in Sweden (SMHI), France (IPSL), and UK (NCAS, MOHC & UEXE)

Kunskapsgymnasiet

ÉCOLE Jeannine Manuel
International understanding through a bilingual education

COOMBESHEAD ACADEMY

Earth System Models in CRESCENDO

CNRM-ESM : Meteo-France

CMCC-ESM : CMCC

EC-Earth : ENEA, FMI, CNR, KNMI, SMHI, ULUND

IPSL-ESM : CNRS-IPSL

MPI-ESM : MPI-M, MPI-BGC

NorESM : UiB, met.no

UKESM1 : Met Office, NOC, UNEXE, ULEEDS, UREAD, UEA

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CRESCENDO work packages

WP1: Improving terrestrial biogeochemical processes

WP2: Improving marine biogeochemical processes

WP3: Improving natural aerosol and trace gases in ESMs

WP4: Evaluating terrestrial processes in ESMs

WP5: Evaluating marine processes in ESMs

WP6: Evaluating natural aerosol and trace gases in ESMs

WP7: Benchmarking and evaluation of ESMs

WP8: Understanding and constraining model projections

WP9: Quantify aerosol/biogeochemical forcing and feedbacks

WP10: IAM scenarios for ESM projections: ScenarioMIP

WP11: Traceability of ESM performance and projection response to ESM resolution

WP12:ESM simulations for ScenarioMIP

WP13: CRESCENDO data dissemination

WP14: CRESCENDO knowledge dissemination

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WP1: Improving terrestrial biogeochemical models

WCRP recently developed a new Grand Challenge on carbon-climate feedbacks

https://www.wcrp-climate.org/grand-challenges/gc-carbon-feedbacks

Key questions are:

- What drives carbon sinks?
- How might climate feedbacks amplify climate change?
- How will vulnerable carbon stores respond to climate?

A priority is better constraining the response of the carbon cycle to increasing CO_2

- CO_2 fertilisation (increased photsynthesis as CO2 increases) is the largest uncertainty in carbon cycle feedbacks
- Nitrogen availability limits the amount of future CO2 fertilisation increases
- Inclusion of a N cycle may dramatically change future terrestrial C-uptake

WP5: Evaluating marine processes in ESMs

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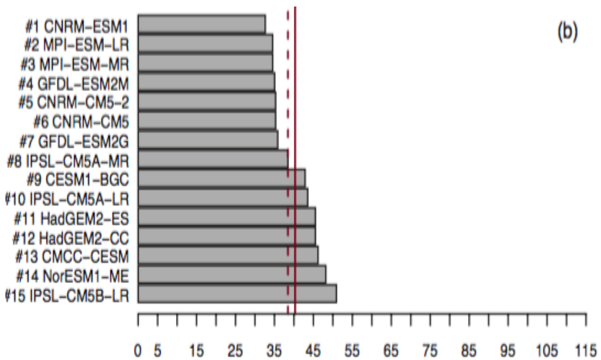
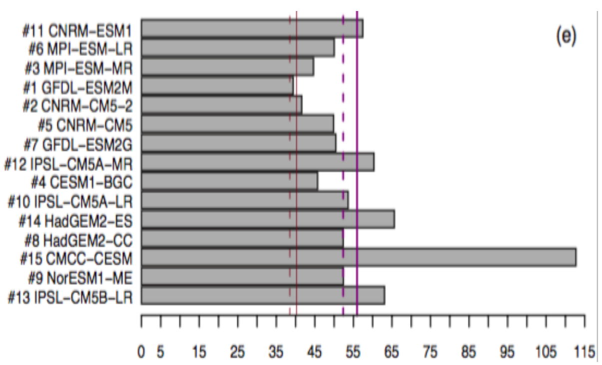
⇒ **Develop process-based metrics to evaluate marine component of ESMs**
⇒ **Develop standard metrics to evaluate improved/new processes in marine component of ESM**

Mean-state/variability

Impact of model drift in skill-score metrics (Séférian et al., 2016)



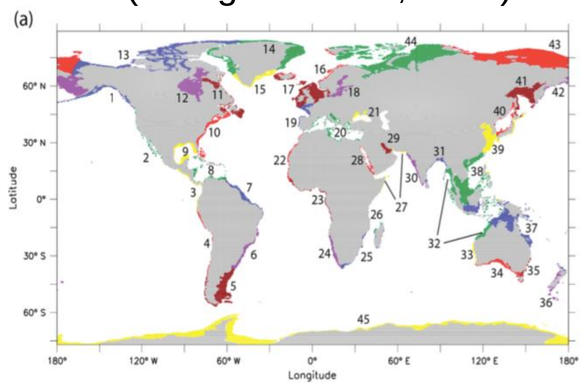
Model-data O_2 RMSE (µmol/L) – not penalized



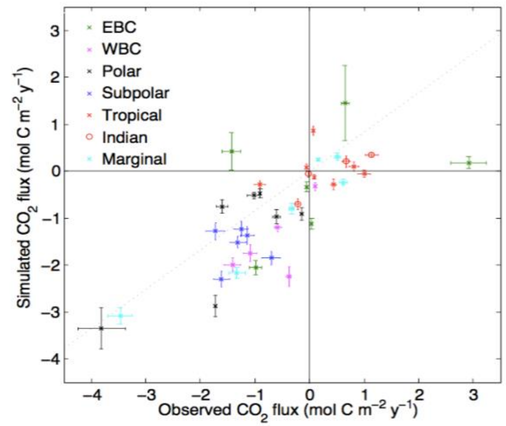
Model-data O_2 RMSE (µmol/L) – drift-penalized

Higher resolution & regional focus

Coastal CO_2 fluxes (Bourgeois et al., 2016)



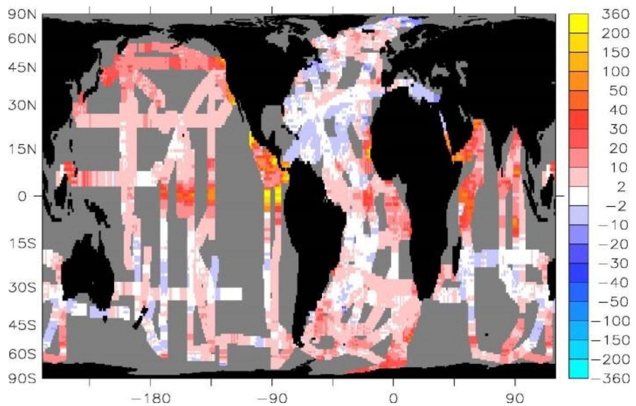
MARCATS from Laruelle et al., 2013)



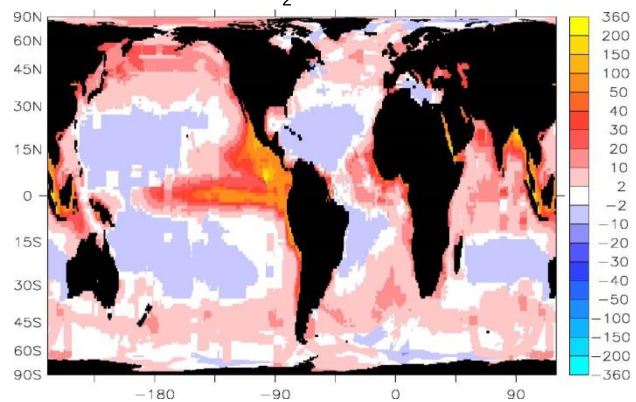
Model-Data Scatter plot for Coastal CO_2 fluxes

New processes & new database

Evaluation of N_2O fluxes (Buitenhuis et al., in prep)



MEMENTO N_2O database



Simulated N_2O with NEMO-Planktom5

WP8: Emergent Constraints

Evaluating future climate change feedbacks using observed variability

Using Earth System Models to identify systematic relationships between observable contemporary climate variations and aspects of future climate (change) sensitivity

Enable multi-model ensembles to be

more than the sum of the parts.

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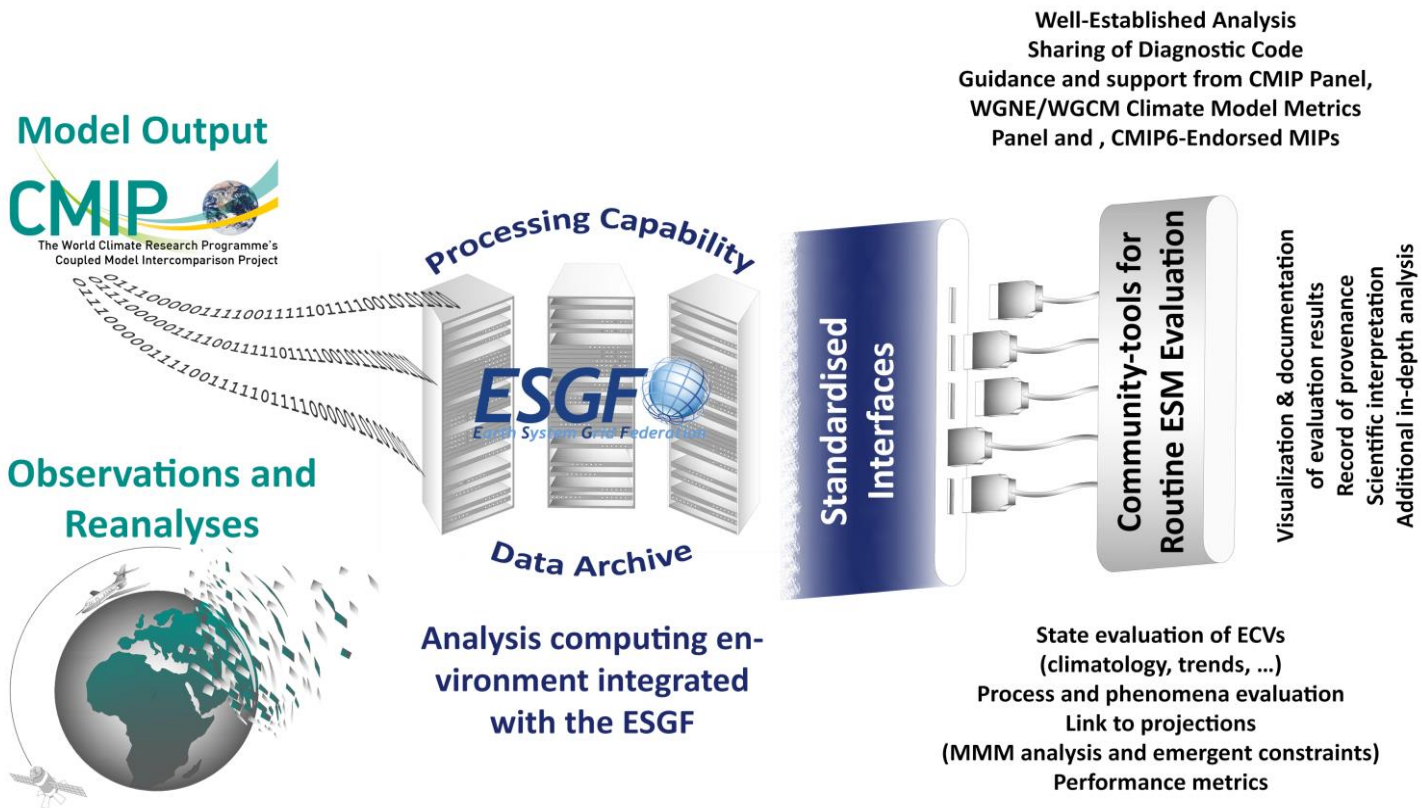
WP7: Envisaged Workflow for Model Evaluation in CMIP6

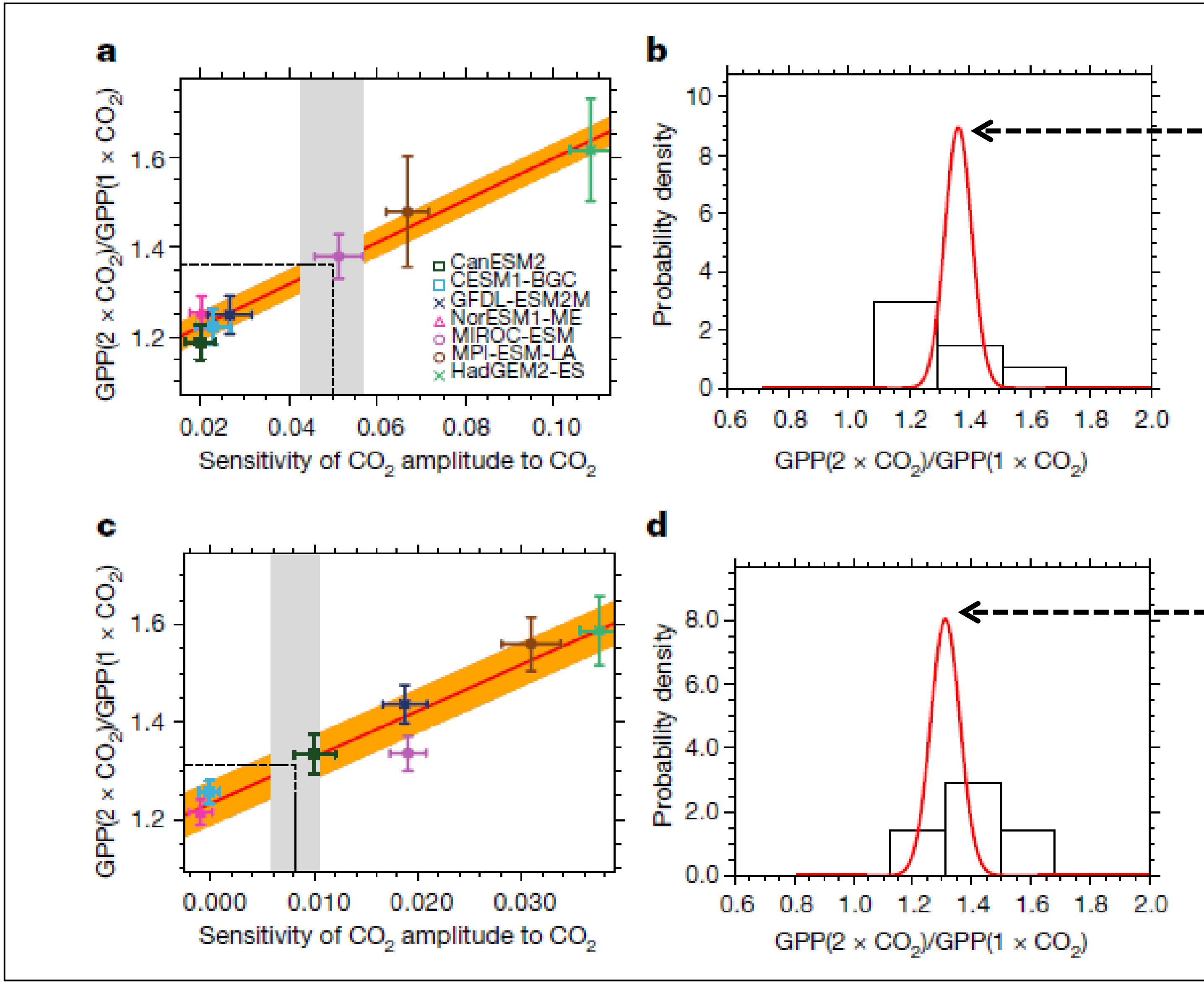
- We argue the community has reached a critical point at which many baseline aspects of ESM evaluation need to be performed more efficiently
- The resulting, increasingly systematic characterization of models will, compared with earlier CMIPs, more quickly and openly identify strengths & weaknesses of the simulations
- This activity also aims to assist modelling groups in improving their models
- ESMValTool running alongside the ESGF, as soon as the output is published



Eyring et al., ESD (2016)

ESMValTool
Earth System Model eValuation Tool

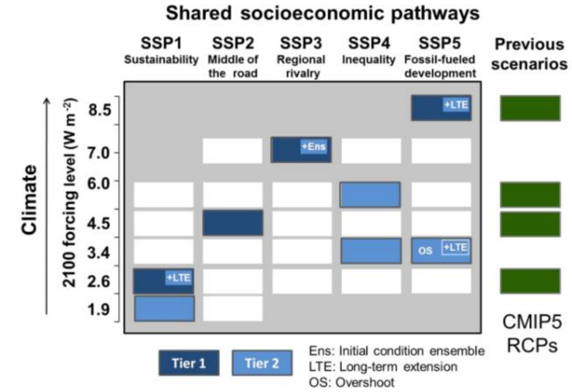
WP8: Emergent Constraints on CO_2 Fertilization from trends in CO_2 amplitude (Wenzel et al., *Nature*, 2016)



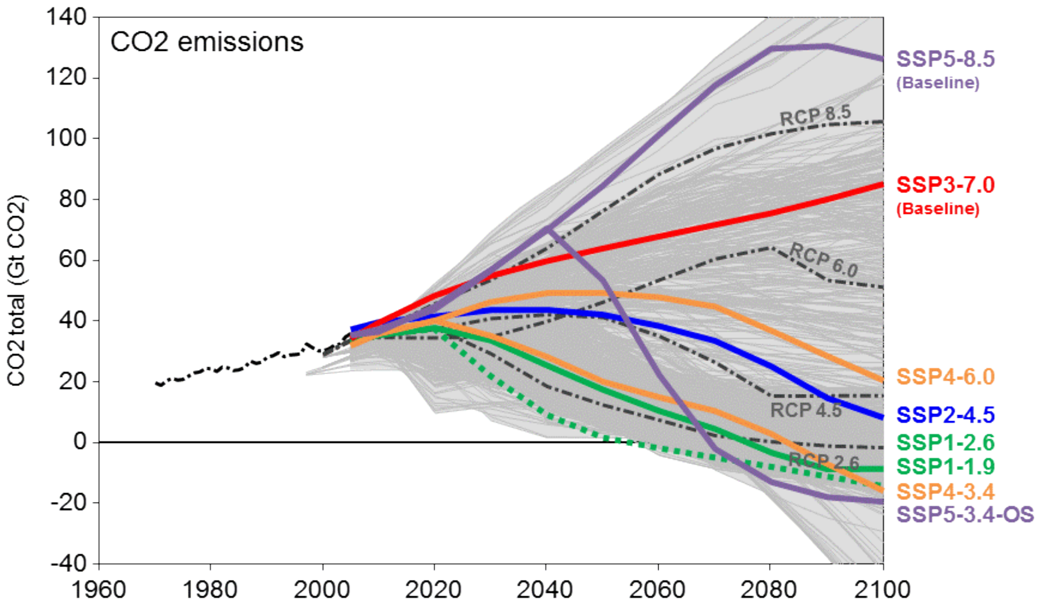
60°N-90°N
~37% reduction in spread

30°N-90°N
~32% reduction in spread

WP10: Developing SSP/RCP IAM scenarios for CMIP6 ScenarioMIP

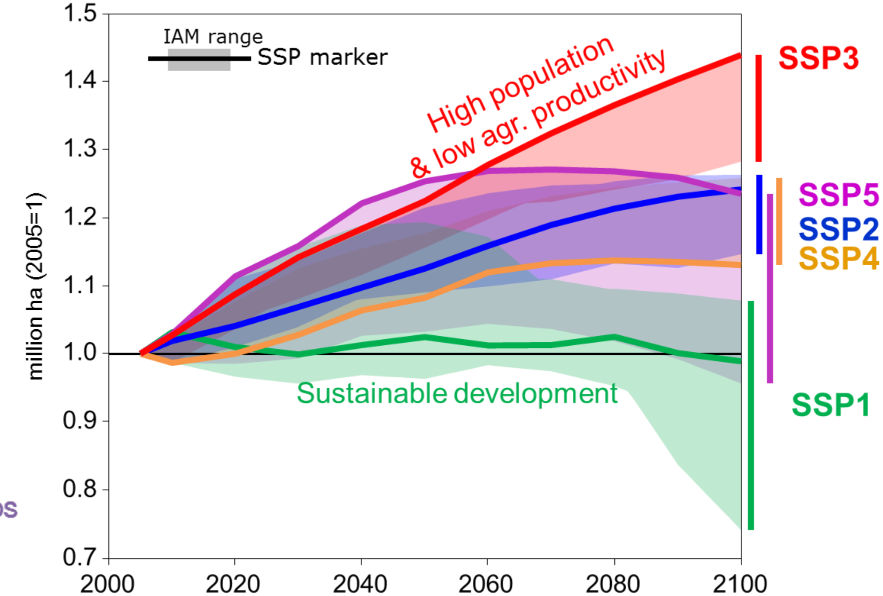


CO2 Emissions



Land use

Reference scenarios, relative to 2005 = 1)



Work on SSP scenarios now complete and documented in Special Issue Global Environmental Change (16 papers; published November 2016)

Based on Riahi et al., 2016

Next activity IAM → ESMs

Variable	Subcategories	Resolution	Sources
Land use	Crop, pasture, urban area, vegetation, forest (latter two both primary and secondary).	Spatial maps indicating land use and transition matrices	Methods for historical data and scenarios developed by LUMIP
Emissions of long-lived greenhouse gases	CO_2, N_2O, halogenated gases	Spatial maps and/or emissions by region.	Historical data described in Meinshausen et al. (2016)
Concentrations of long-lived greenhouse gases	CO_2, N_2O, halogenated gases	Time series	
Emissions of air pollutants	CH_4, SO_2, NO_x, VOC, CO, NH_y, BC, OC	Spatial maps	Historical data described to be provided by the Community Emissions Data System (CEDS) project (http://www.globalchange.umd.edu/ceds/ceds-cmip6-data/)
Short-lived forcing	Ozone, optical depth	Spatial maps