"The Grand Challenges are the scientific backdrop for CMIP6"
(Meehl et al. EOS 2014)

Overview of

WCRP Grand Challenges (or equivalent)

and their connection to CMIP6

Thanks to all contributors...

What is a Grand Challenge ? (according to WCRP)

• **High priority and exciting research** that requires international partnership and coordination

• A Grand Challenge is both ***highly specific and highly focused*** identifying a specific barrier preventing progress in a critical area of climate science.

• This focus enables the development of ***targeted research efforts*** with the likelihood of significant progress over 5-10 years

→ Identify critical science questions, fill gaps, exploit opportunities

Current Grand Challenges:

6 WCRP GCs:
• Cryosphere in a changing climate (CLIC)
• Regional sea level rise (CLIVAR)
• Changes in water availability (GEWEX)
• Changes in climate extremes (GEWEX)
• Provision of regional information on regional scale (WGRC)
• Clouds, circulation and climate sensitivity (WGCM)

+ Biogeochemical forcings and feedbacks (**AIMES & WGCM**)

WCRP Grand Challenge on

Cryosphere in a Changing Climate

Input from Vladimir Kattsov, Greg Flato, Gerhard Krinner et al.

Science Questions:

- the prospect of an ***ice-free Arctic Ocean***; the differences between recent sea-ice extent ***trends in the Antarctic vs. the Arctic***

- the fate of mountain glaciers providing ***fresh water*** to hundreds of millions of people worldwide;

- the strength of positive feedbacks between the warming climate and ***natural emissions of GHGs*** from the thawing permafrost (both terrestrial and sub-sea);

- the role of ice-sheet dynamics in amplification of ice sheets' contribution to the ***global SLR***.

Links to WGCM and CMIP6

The Climate and Cryopshere (CliC) core project has initiated several targeted activities and organizational entities to ensure better linkage to the WGCM, and to ensure strong representation of the cryosphere (and the cryosphere grand challenge) in CMIP6 planning. Specifically:

- Sea-ice and climate modelling forum to bring the community together and provide an efficient means of assembling data requests and diagnostic projects aligned with CMIP6 (co-chairs: D. Notz, MPI, and A. Jahn, NCAR).

- Arctic and Antarctic groups focused on sea-ice and ice-ocean observations and process studies.

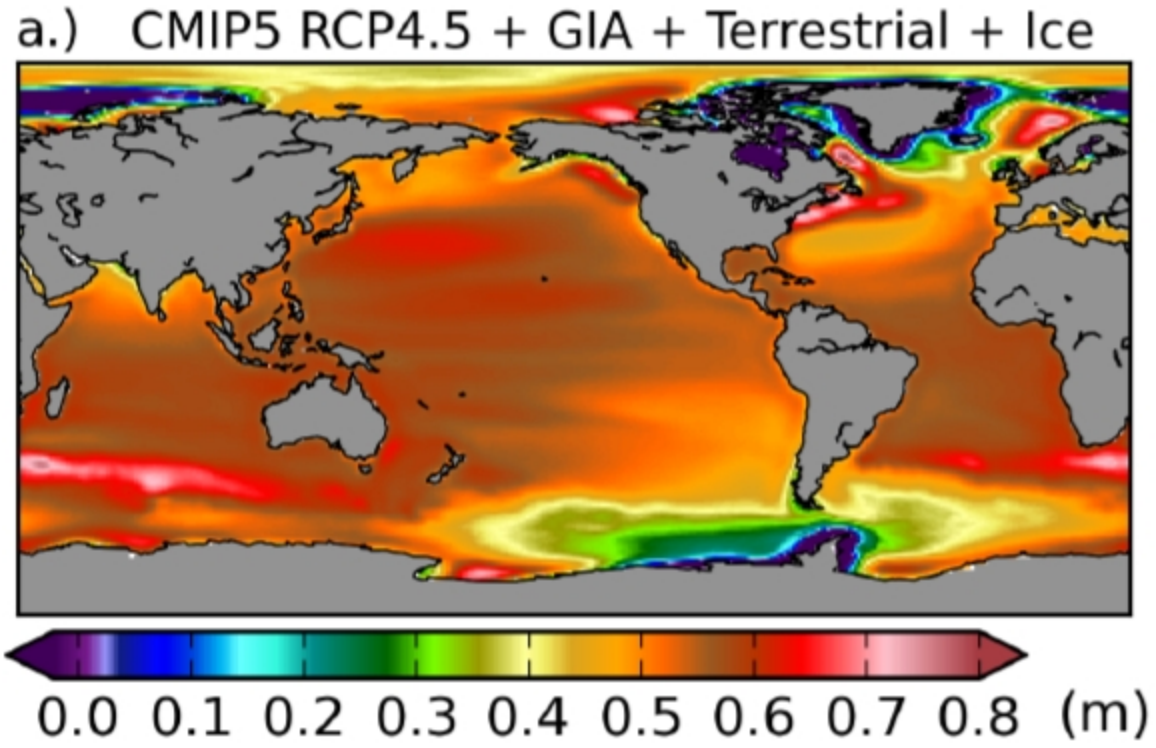
- Permafrost and climate modelling forum being established to serve a similar role and provide better connection to the permafrost research community.

- West Antarctic Glacier-Ocean Modelling (WAGOM) targeted activity focusing on ice-shelf-ocean interactions and modelling.

- CliC is actively involved in supporting development of the **ISMIP6** and **LS3MIP** proposals, as they link directly to the grand challenge.

WCRP Grand Challenge on Regional Sea Level Change

Input from Detlef Stammer et al



Carson et al. 2014

GC Sea Level

Five science foci :

- An integrated approach to historic sea level (paleo time scale)
- Process understanding of fast ice sheet dynamics (contemporary)
- Causes for contemporary regional sea level variability and change
- Predictability of regional sea level
- Sea level science for coastal zone management

CMIP6 Issues

Still too poor understanding in Detection-Attribution

•Is the regional variability in sea level only due to internal climate variability or can we already **detect the fingerprint** of anthropogenic forcing? When should the anthropogenic signal emerge out of the natural variability? Are climate modes realistic in models?

Large uncertainties in long-term global mean sea level projections

•How reliable **are ice sheet dynamics and land hydrology** projections for the 21st century and beyond?

Lack of knowledge about ice sheet abrupt changes

•Thresholds? Tipping points?

Lack of decadal sea level projections/previsions

•How reliable is the natural/internal variability in climate models? **Is sea level predictable**?

Large uncertainties in long-term regional sea level projections

•Need to accurately account for all processes (including ocean dynamics) giving rise to regional variability. Need for GIA modeling improvements

Lack of understanding of coastal impacts of sea level rise & extreme events

What are the (non linear**) interactions between sea level rise and coastal processes** (sediment supply, shoreline morphology, atm. forcing, river runoff, waves & currents…)?

WCRP Grand Challenge on Water Availability

Input from Sonia Seneviratne et al.

Water availability GC

Four main themes (white paper + post-AR5 workshop):

- **Precipitation on land**
- **Land surface processes and hydrology (evapotranspiration)**
- **New observations**
- **Predictability**

Major uncertainties:

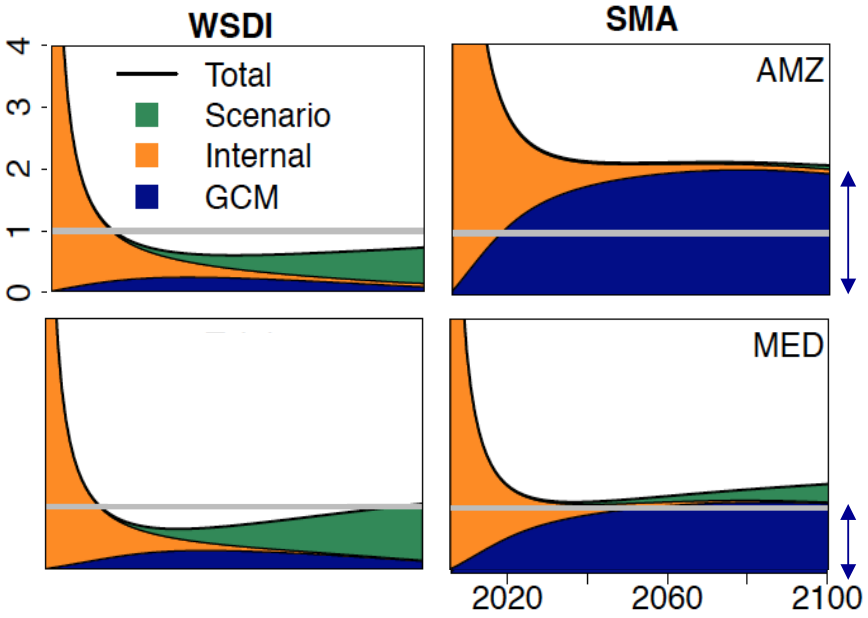
$$\sigma_{tot}/\Delta = (\sigma_{scen} + \sigma_{int} + \sigma_{GCM})/\Delta$$

Noise-to-signal ratio (adapted from Hawkins and Sutton 2009)

From soil moisture drought in the Amazon region (AMZ) and the Mediterranean (MED): **Noise from model uncertainty is so large that it masks most of the scenario uncertainty!**

NB: The model uncertainty for SMA is larger than for precipitation alone…

Warm spell duration index *Soil moisture anomalies*



(Orlowsky and Seneviratne 2013, HESS)

Water availability GC

	Short name of MIP	It is proposed to use as the scientific backdrop for CMIP6 the six WCRP Grand Challenges (GC), and an additional theme encapsulating questions related to biospheric forcings and feedbacks. Could you please rank the WCRP GCs and theme of collaboration in order of importance for and input from your MIP (from 1-7 with 1 being most important and 0 for not relevant at all)						
		Clouds, Circulation and Climate Sensitivity	Changes in Cryosphere	Climate Extremes	Regional Climate Information	Regional Sea-level Rise	Water Availability	Theme for collaboration: biospheric forcings and feedbacks
1	AerChemMIP	2	5	3	4	0	0	1
2	C4MIP	0	3	0	0	0	2	1
3	CFMIP	1	4	6	2	7	3	5
4	DAMIP	4	3	2	1	6	5	7
5	DCPP	3	3	3	1	3	2	3
6	FAFMIP	3	4	0	2	1	0	0
7	GDDEX	5	5	1	1	3	3	5
8	GeoMIP	1	3	4	2	0	5	6
9	GMMIP	2	0	4	1	0	3	0
10	HighResMIP	1	5	3	4	6	2	7
11	ISMIP6	5	1	6	4	2	3	7
12	JCOMM*	tbd	tbd	tbd	tbd	tbd	tbd	tbd
13	LS3MIP	0	2	3	4	5	1	6
14	LUMIP	0	0	4	2	0	3	1
15	nonlinMIP	4	7	6	1	3	2	5
16	OCMIP6	2	7	1	3	7	7	2
17	PDRMIP	1	0	2	4	0	3	0
18	PMIP	2	3	5	4	6	7	1
19	RFMIP	1	7	4	2	5	6	3
20	ScenarioMIP	7	6	3	1	4	5	2
21	SensMIP	1	6	4	3	7	2	5
22	VolMIP	1	4	5	3	6	7	2

Ranking for water availability GC:

Essential:
LS3MIP (including DECK LMIP simulations)

Important:
HighresMIP/GDDEX
LUMIP

Relevant:
CFMIP
DAMIP
DCPP
PDRMIP
SensMIP

WCRP Grand Challenge on

Climate Extremes

Input from Sonia Seneviratne, Lisa Alexander,

Gabi Hegerl, Xuebing Zhang

Extremes GC

Identified key 8 questions addressed across WCRP community – White paper (bold: relevant to CMIP6 plans)

1: improved quality of ground-based and remote-sensing based datasets for extremes *(GEWEX: GHP and GDAP)*

2: improved models for simulations of extremes *(GEWEX/CLIVAR/WGCM)*

3: interactions between large-scale drivers and regional-scale land surface feedbacks affecting extremes *(GEWEX: GLASS)*

4: role of external (e.g. anthropogenic) forcings vs internal variability for changes in intensity and frequency of extremes *(ETCCDI/IDAG/CLIVAR)*

5: factors contributing to the risk of a particular observed event *(ACE/ETCCDI/IDAG/CLIVAR)*

6: causes of drought changes in past and future *(GEWEX/CLIVAR/GDIS)*

7: predictability of changes in frequency and intensity of extremes at seasonal to decadal time scales *(WGSIP/CLIVAR/GEWEX)*

8: role of large-scale phenomena (monsoons, modes of variability) for past and future changes in extremes *(CLIVAR/GEWEX)*

Extremes GC

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21	SensMIP	1	6	4	3	7	2	5
22	VolMIP	1	4	5	3	6	7	2

Ranking for extremes GC:

Essential:
DAMIP
HighResMIP/GDDEX (focus similar)
LS3MIP

Important:
LUMIP
DCPP

Relevant:
GMMIP
PDRMIP
VolMIP
CORDEX

Relevance to be clarified:
OCMIP6 (possible mistake in table?; relevance not clear from proposal despite ranking as #1)

WCRP Grand Challenge on

Regional Information

The REGIONAL CLIMATE INFORMATION GRAND CHALLENGE

Initially established as 3 time-scaled frontiers with a 4th frontier on how to transform this knowledge into decision relevant information

Frontier 1**: Intraseasonal and seasonal predictability and prediction**
Frontier 2: **Decadal variability, predictability and prediction**
Frontier 3: **Reliability and value of long-term regional climate change projections**
Frontier 4: **Informing the risk management and decision making space**

In order to bring cross-WCRP expertise together in an integrated way it is proposed to instead:

- Consider the issues in Frontiers 1, 2 and 3 through the 'lens' of ***informing the risk management and decision making***,
- Adopt a focus on cross-regional and cross-timescale issues
- Seek to provide information that constitutes a solid and targeted basis for decision making concerning risk management with active and two-way involvement with stakeholders.

Emerging issues

- A major gap is the lack of a framework to translate climate data and output into regional climate information and guidance

- The Regional Climate Information grand challenge can provide ‘regional laboratories’ for facilitating capacity building and the use of data and modelling resources, integrated with other capacity building intitiatives

- The research community needs to come together to understand sources of model uncertainty from a regional perspective, including feedback from users (recognising that there is a large range of users)

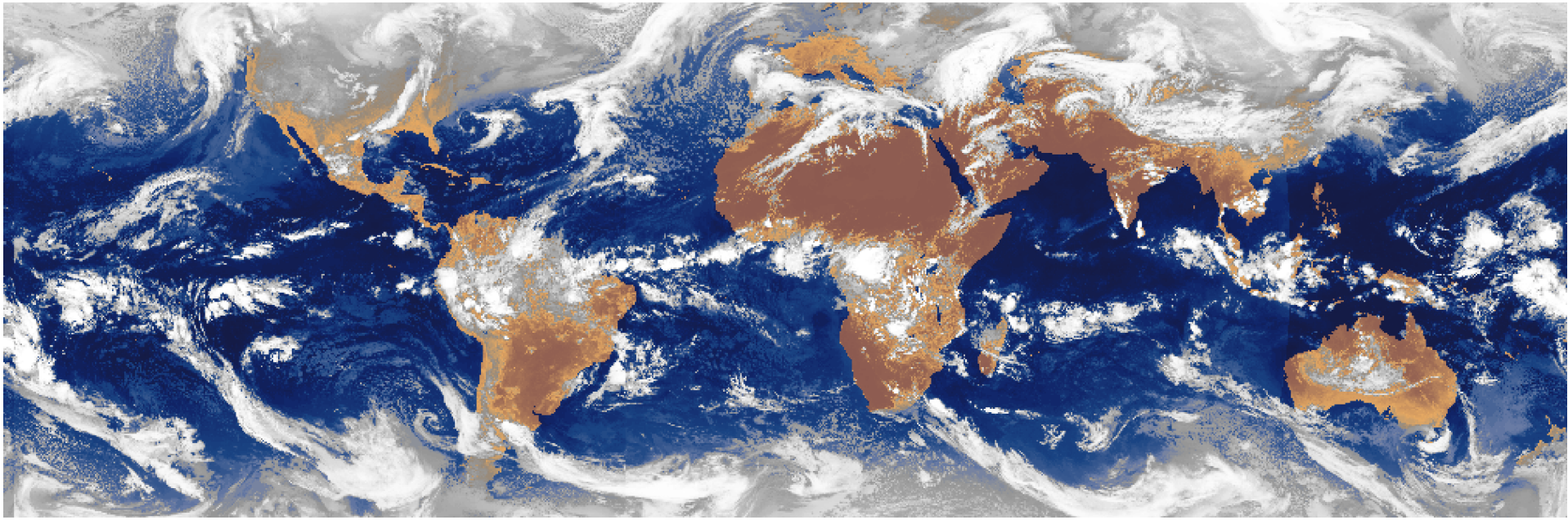
- Evaluating models, especially high resolution, is a challenge given the lack of high-quality regional observations; there is also a need to improve understanding of processes to include in ESMs – which has implications for observational needs; such needs provide a motivation for building and improving reanalyses

- There is a need to increase the use of observations in the development of evaluation metrics, and in bias correction and statistical downscaling; this will help in communicating and convincing about the accuracy/reliability of model-based products

WCRP Grand Challenge on

Clouds, Circulation and Climate Sensitivity

(Coordinated by WGCM)



GC on Clouds, Circulation and Climate Sensitivity

PLENARY SESSION 1: IPCC WGI AR5: EMERGING THEMES AND KEY UNCERTAINTIES
[12 minute keynote presentations followed by 5 minutes Q&A]

10:20–10:37	*Longstanding Uncertainties in IPCC Assessments (Thomas Stocker and Gian-Kasper Plattner)*
10:37–10:54	*Regional Climate Change (Krishna Kumar Kanikicharla and Bruce Hewitson)*
10:54–11:11	*Decadal Prediction and Projections (Scott Power and Rowan Sutton)*
11:11–11:28	*Carbon Cycle–Climate Interactions (Corinne Le Queré and Fortunat Joos)*
11:28–11:45	*Climate Targets Beyond Temperature (Reto Knutti and Elmar Kriegler)*
11:45–12:02	*Aerosols, Air Quality and Climate (Jean-Francois Lamarque and Piers Forster)*
12:02–12:30	Open Discussion

These seemingly unrelated topics depend, to a large extent, on the answer to two questions:

- How much does the temperature rise for a given radiative forcing? (climate sensitivity)
- How does the atmospheric circulation respond? (changing patterns)

To make progress: fill science gaps, use new opportunities, focus on key questions:

- Coupling between clouds and circulation
- Test key ideas, hypotheses or story lines by integrating insights from modeling (large-scale, process-scale, NWP), theories, observations, paleo.

GC on Clouds, Circulation and Climate Sensitivity

Four Questions:

1. ***What controls the position, strength and variability of storm tracks?***
2. ***What controls the position, strength and variability of tropical rain belts?***
3. ***What role does convection play in cloud feedbacks?***
4. ***What role does convective aggregation play in climate?***

More information in: Stevens et al. (WCRP report, 2014); Bony et al. (in prep)

+ documents and presentations on *http://www.wcrp-climate.org/index.php/gc-clouds*

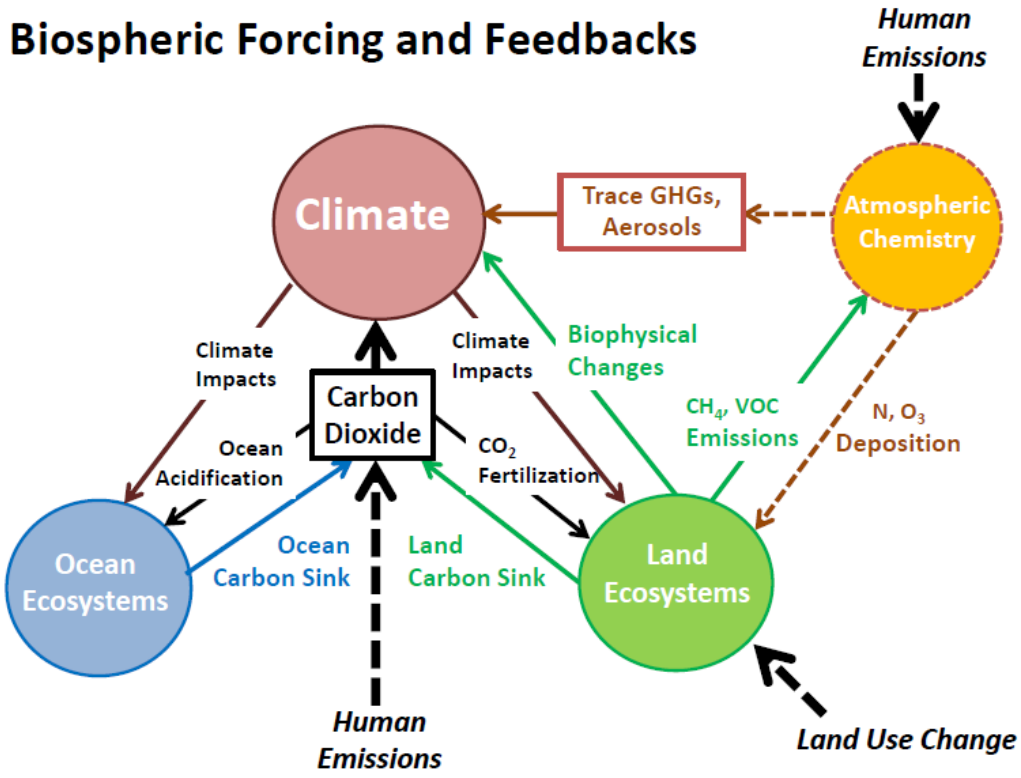
Link to CMIP6 :

- **MIPs directly connected to this GC: CFMIP, RFMIP, PMIP**
- Other relevant MIPs: GeoMIP, HighResMIP, PDRMIP, sensMIP, VolMIP
- Importance of idealized experiments, hierarchy of configurations (OAGCM, AGCM, aqua), process outputs (e.g. clouds, dynamics, including in the DECK)
- NB: Additional complementary coordinated experiments (not proposed to CMIP6):

  COOKIE/SPOOKIE in CFMIP3, Easy Aerosols, etc

AIMES-WGCM "Topic of Collaboration" (or Grand Challenge) on Biogeochemical Forcings and Feedbacks

(Input from Peter Cox and Jean-François Lamarque)



Courtesy Peter Cox

Motivating Questions for a Grand Challenge on **Biogeochemical Forcing and Feedbacks**

How important are biogeochemical processes and feedbacks for climate projections?

- What is the risk of amplification of climate change via biogeochemical processes and feedbacks?

- How do changes in climate, CO_2 and nutrient availability affect the exchange of carbon and trace gases between the atmosphere and ocean, and the atmosphere and land ?

- How do GHG fluxes from highly vulnerable carbon pools (e.g. permafrost) respond to changing climate including climate extremes and abrupt changes?

Related MIPs: C4MIP, LUMIP, OCMIP

Motivating Questions for a Grand Challenge on **Biogeochemical Forcing and Feedbacks**

To what extent does climate change affect air pollution and vice versa?

- How do aerosols and other short-lived climate forcers affect circulation, weather, and climate across spatial scales? How do the effects compare to those of long-lived GHGs?

- How do we improve the understanding and quantification of aerosol-cloud interactions using observations, process understanding, and models?

- What is the importance of the natural aerosol and its dependence on anthropogenic loading and climate evolution?

- Which climate mitigation measures have air quality co-benefits and/or penalties? Which air quality mitigation measures climate co-benefits and/or penalties? How will the meteorology under climate change affect air quality?

Related MIPs: AerChemMIP, RFMIP, ScenarioMIP, DAMIP, LUMIP

Connection between GCs, CMIP6 and modeling groups

"The Grand Challenges are the scientific backdrop for CMIP6" (Meehl et al. EOS 2014)

WGCM will propose the GCs to :

- Review and comment on the MIPs proposals (identify gaps, opportunities, overlaps, comments on design, etc)
- Highlight which of the MIPs and MIPs experiments/outputs are the most relevant to address their key questions, and why.

Opportunities:

- The GCs could take advantage of the MIPs to interact with the modeling groups and model developers
- The MIPs could take advantage of the GCs to highlight the importance of specific experiments
- The modeling groups could take advantage of the GCs to advocate for support to participate in MIPs