Earth System Modelling in WCRP breakout session

Gerhard Krinner and Pierre Friedlingstein
+ Helene Hewitt and Michael Ek

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In a Nutshell

- Systematic biases. Improved physics, high resolution vs. ESMs
- Towards Regional ESMs consistent with Global ESMs
- Seamless predictions and ESMs components
- Decadal predictability of climate and carbon
- Human systems, cities in climate/ESMs
- WCRP-Future Earth-GCP interaction

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Systematic biases

- Tropical rainfall, impact on vegetation, carbon,…
- High latitude temperature, impact on permafrost, carbon, …
- Southern ocean circulation, impact on carbon sinks, biogeochemistry, …

- If higher resolution helps, how to ensure ESMs are not always 10 years behind?

Need to develop new approaches such as **Hybrid/ asynchronous coupling** to tackle these biases, improving physics and ESM processes at the **same** time

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Regional ESMs

- Regional climate models are including more processes such as aerosols (dust, biogenic, biomass burning), atmospheric chemistry, …
- R-ESMs ranges of applications include climate change, but also tropospheric chemistry, air quality,…

Need to ensure co-development, consistency and interaction between global ESMs and regional ESMs*. Regional ESMs as a testbed?

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Seamless predictions and ESMs

- Going from weather prediction to multi-century projections requires very different level of interactive ESM components
- Users of prediction will need different level of information (beyond "just" weather/climate).

Need to develop a strategy to ensure models across the spectrum (from "NWP" to "WGCM") do account for the right level of complexity providing the relevant services.

Climate and carbon decadal predictions

- Paris agreement and stocktaking will require a robust understanding of fate of CO_2 emissions on decadal time-scales ("real-time" verification of emission, assessment of climate mitigation,…)

Need to develop a clear model/observation strategy to provide robust understanding of carbon and climate on decadal time scale (hindcast and forecast).

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Human/Urban systems

- Impact of human alteration of land (land management, water management, urban expansions on local/regional to global climate

Need to assess importance of these processes depending on the spatial scale ("regional yes, global no?") and the area of impact (climate, water resources, air quality,…)

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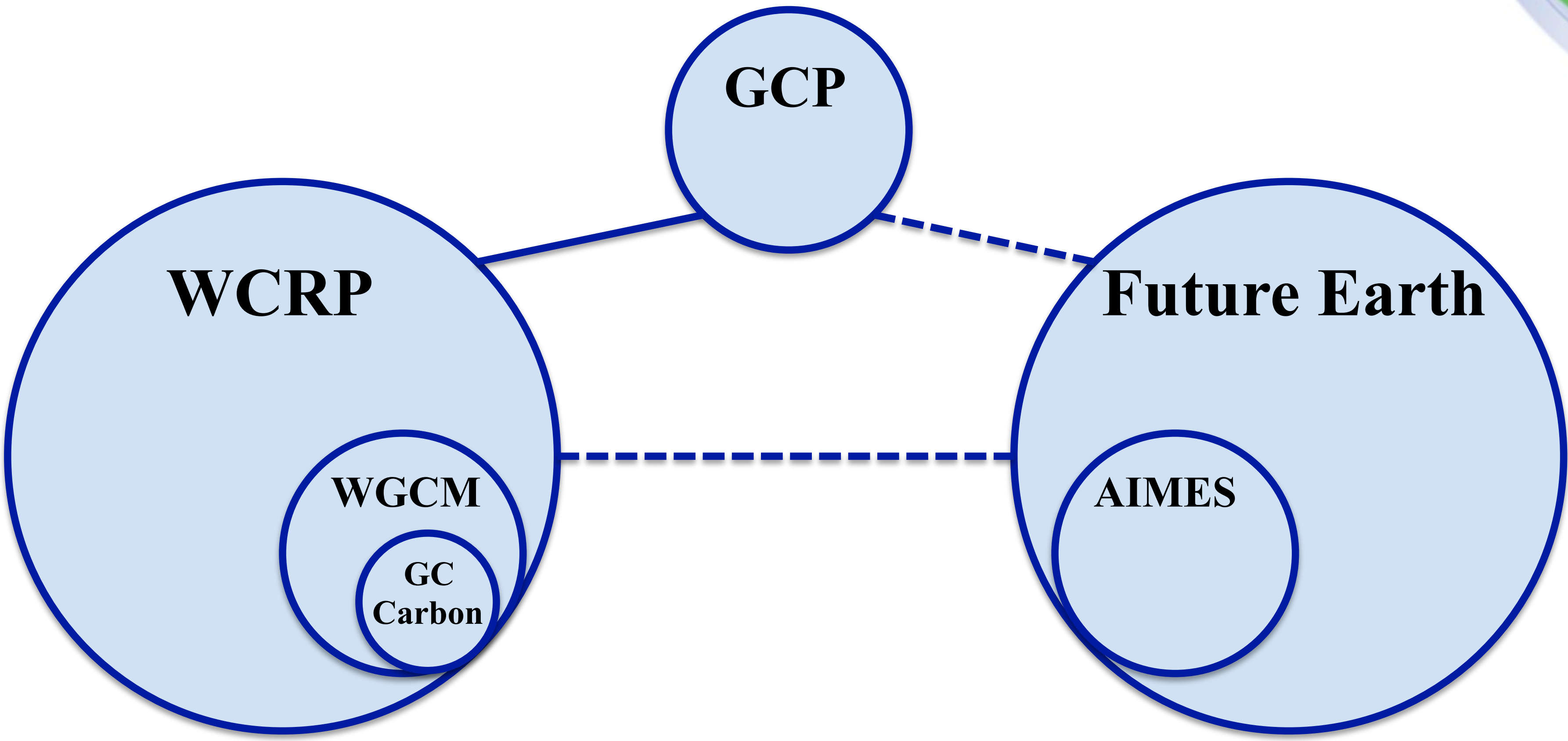
WCRP-Future Earth-GCP links



Need to ensure **collaboration** on ESM developments, process understanding, range of applications and dissemination of knowledge

- 1. Human dimension in models: Include urban effects: land use/effect on water cycle and energy budget ("heat islands", other anthropogenic heating), human water management, land use more generally, e.g. agriculture, biomass burning and forest fires (human-caused, as well as natural).
- 2. Carbon cycle, vegetation: We need to better "close the carbon budget". I added vegetation here since this is an important component for the carbon cycle, as is the ocean-atmosphere change with respect to carbon. Other BGC cycles include nitrogen (e.g. for land/vegetation) and iron (oceans BGC).
- 3. Chemistry: Atmospheric aerosols, dust, etc, plus marine and terrestrial chemistry for different BioGeoChemical cycles of interest/required for complete ESMs? Land-atmosphere/ocean-atmosphere interaction important for transport of e.g. dust, ocean aerosols, etc. Just how much chemistry can we include (afford) in NWP models vs climate models?
- 4. Regional ESMs vs global ESMs: I'm not sure this captures all that was discussed, but in this regard, a main point was the use of regional ESMs as a testbed for global ESMs.
- 5. Ensemble size for ESMs: I didn't have too much information on this, other than if we add complexity to our models (i.e. increased run time), then we may not be able to afford as many ensemble members. How to prioritize/ balance this? Certainly for operational (NWP/seasonal) ESMs, this is an important consideration.
- 6. Seamlessness: processes at high- vs coarse-resolution, for different time and spatial scales. Seamlessness requires scale-aware physics, i.e. parameterized vs resolved processes (e.g. convection), with "seamless" connection between. Requires downscaling "tools" to connect scales, e.g. initializing the model at whatever resolution is required for a particular component.
- Final points not included in the items above:
- -I (Mike Ek) provided a few slides on "Hierarchical Model Development" --mostly focused on physics. Nils pointed out that dyanmics could/should be included. I would add data assimilation (for all ESM components) to this.
- -improvements to our model (e.g. physics, other) mentioned here can hopefully improve (directly or indirectly) our model's ability to provide better predictions of "...rainfall patterns in tropics, high-latitude temperatures, winds over southern oceans."
- -we also need to increase our ability to assimilate many (new) earth system variables.
- -in not currently a part, our models should include groundwater (natural or human-influenced).
- -information on ice sheets and paleoclimate was discussed, but I'll leave that to the notes from the other breakout group.

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