

## **Report of GC on Clouds, Circulation and Climate Sensitivity**

The activities of this GSC aim at promoting and focusing research on four science questions which are critical for the understanding and prediction of climate change ([Bony, Stevens et al., 2015](#)). For this purpose, this GSC promotes a few strategic initiatives that have the potential to significantly accelerate progress and to get the best of the complementarity between modelling, observation, process studies and paleo-climate studies.

### **1. Highlights for JSC**

#### ***A strategy to narrow bounds on Radiative Forcing and Equilibrium Climate Sensitivity:***

For several decades, climate change studies have suffered from the lack of precise bounds on two key quantities: the Equilibrium Climate Sensitivity (ECS) and the Aerosols Radiative Forcing from the pre-industrial period to present (referred here as the aerosol Effective Radiative Forcing or ERF). A particular problem in quantifying plausible bounds for ECS and ERF has been to account for all of the diverse lines of relevant scientific evidence. To better constrain these bounds and to help articulate the science needed to narrow the range further, this GSC has promoted a strategy ([Stevens et al. 2016](#)) which consists in developing and refuting physical storylines (or hypotheses) for values outside any proposed range. The application of this strategy forms the basis of two community assessments organized by this GSC: one on Climate Sensitivity (led by S. Sherwood and M. Webb) which has followed a Ringberg workshop organized in 2015, and one on Aerosol Radiative Forcing (led by N. Bellouin and J. Quaas) which has been kicked off by another [Ringberg workshop in Feb 2018](#). The plan is to publish these assessments in 2018, thereby supporting the 6<sup>th</sup> Assessment Report of the IPCC. Our understanding is that presently the ECS assessment has been endorsed by the WCRP, we ask that the Aerosol ERF assessment be likewise endorsed as an officially WCRP sanctioned activity.

#### ***A field study to test mechanisms that control the low-cloud feedback in climate models:***

As emphasized by the IPCC AR5, the main source of uncertainty in model estimates of climate sensitivity remains the cloud feedback associated with shallow-cumulus clouds. Physical mechanisms for this feedback have been proposed based on model studies, but they have not been tested so far owing to the lack of appropriate observations. To fill this gap, we are organizing a field study named EUREC<sup>4</sup>A (Elucidating the role of clouds-circulation coupling in climate) on Jan-Feb 2020 in the lower North-Atlantic trades near Barbados ([Bony, Stevens et al. \(2017\)](#), [www.eurec4a.eu](http://www.eurec4a.eu)) It will be based on very comprehensive measurements from (at least) two aircraft equipped with the most advanced remote sensing instrumentation, a number of Research Vessels and the Barbados Cloud Observatory. Beyond the

question of cloud feedbacks, the campaign also aims at studying the role of mesoscale ocean eddies on ocean-atmosphere interactions (as discussed during the [CLIVAR Atlantic Regional Panel \(ARP\)](#) and the [Ocean mesoscale eddies and air-sea interactions workshop](#)), and at assessing and improving the representation of clouds, convection, radiation and winds in process, weather and climate models (discussed at the last [GEWEX Pan-GASS conference](#)), and retrievals of clouds and winds from two flagship space missions (EarthCARE and ADM-Aeolus).

### ***A modelling strategy to accelerate understanding of the role of clouds in climate:***

To decipher cloud-climate interactions more easily and formulate hypotheses that may then be tested using observations, the GSC has promoted the use of a model hierarchy ([2016 GSC/WGCM workshop](#)) and the coordination of model inter-comparison projects based on this approach. Five such projects are presently being promoted: (1) [CFMIP](#) (the *Cloud Feedback Model Intercomparison Project*) that aims at addressing the four questions of this GSC through a hierarchy of models and experiments ([Webb et al., 2017](#)), (2) [TRAC-MIP](#) (*Tropical rain belts with an Annual cycle and Continent MIP*) that aims at understanding the position, strength and variability of the ITCZ and monsoons, and on which a [summer school will be organized at ICTP in 2018](#), (3) [Easy-Aerosols](#), that aims at pointing out robust impacts of aerosols on the large-scale circulation and regional precipitation patterns ([Voigt et al., 2017](#), [Stevens et al. 2017](#)), (4) [RFMIP](#) (the *Radiative Forcing Model Intercomparison Project*, [Pincus et al. 2017](#)) and (5) [RCEMIP](#) (*Radiative-Convective Equilibrium Model Intercomparison Project*, [Wing et al., 2018](#)), that aims at running Radiative-Convective Equilibrium simulations both with General Circulation Models and Cloud-Resolving Models to study the physics and impact on climate of convective organization; and (6) [DYAMOND](#), the first ever inter-comparison of global cloud resolving models (presently five modelling groups are registered to perform 40 day global simulations with ca 3 km grid-spacing).

## **2. Early success**

*Highlights from the past year:*

- On-going community assessment on Equilibrium Climate Sensitivity; Final workshop planned in 2018; Publication timed to allow full consideration by IPCC AR6.
- Launch of community assessment on Aerosol Radiative Forcing triggered by the [2018 Ringberg workshop](#); Publication timed to allow full consideration by the AR6.
- [GSC session at EGU](#) (European Geophysical Union, Vienna Austria, Apr 2017)
- [Workshop on the Future of Convective Parameterization](#), (Delft, Netherlands, Jul 2017)
- GSC session at the [4ICESM conference](#) held in Hamburg, Germany Aug 2017)
- [CFMIP workshop](#) on GSC topics, Tokyo, Japan, (Sep 2017). Initiation of [DYAMOND](#) the first ever Global Cloud Resolving Model intercomparison study, now on-going.
- [Special Issue of Surveys in Geophysics](#) (16 articles) on "Shallow clouds, water vapour, circulation and climate sensitivity", also edited as an ISSI book (published in Nov 2017).
- [ISSI \(International Space Science Institute\) international science team](#) on the mesoscale organization of shallow convection.
- Discussions at the [CLIVAR Atlantic Regional Panel](#) and the [Ocean mesoscale eddies and air-sea interactions workshop](#) about the opportunity to add an oceanographic component to the [EUREC<sup>4</sup>A field campaign](#) (Feb 2018)

- Proposals for joint atmospheric modeling activities related to the EUREC<sup>4</sup>A field campaign discussed at the [GEWEX Pan-GASS conference](#) (Feb 2018). White papers and project descriptions:
  - o [Hierarchical modelling of Tropical Convection](#)
  - o [Phase II of Greyzone project linked to EUREC4A](#)
  - o [Project on surface drag and momentum transport](#)
- Grand Challenge related and supported funding proposals:
  - o Qsat (water vapour satellite) in response to ESA Earth Explorer 10 Call
  - o CONSTRAIN (Support for GSC activities submitted in response to H2020 call)
  - o ExtremeEarth (CSA proposal submitted in response to DG Connect Flagships on Future and Emerging Technology)
- Publications on key GSC activities: [EUREC<sup>4</sup>A](#), [CFMIP](#), [RFMIP](#), [RCMIP](#), [Easy Aerosols](#), [PMIP](#)
- [Cloud-GC recommendations to GCOS](#) and to the NASA decadal survey recognized and taken into account.

*Planned activities in 2018/2019:*

- Apr 2018: [GSC session at EGU](#) (European Geophysical Union), Vienna (Austria)
- May 2018: Workshop on the Climate Sensitivity community assessment, Edinburgh (UK)
- Jul 2018: [GC/ICTP 2nd Meeting \(and summer school\) on Monsoons and Tropical Rain Belts](#)
- Aug 2018: Workshop on storm tracks (led by R. Caballero and Y. Kaspi), Stockholm (Sweden)
- Oct 2018: CFMIP workshop, Boulder (USA)
- Early 2019: Workshop on EUREC<sup>4</sup>A modelling activities, location and dates TBD.
- Jul 2019: ICTP summer school on convective organization (led by A. Tompkins), Trieste (Italy)

**3. Partners for GSC implementation** (within and outside WCRP community)

- GEWEX-GASS & WGNE: community modelling activities around EUREC<sup>4</sup>A (see above)
- CLIVAR: discussion of oceanographic component of EUREC<sup>4</sup>A (see above)
- SPARC: will hopefully be a partner of the 2018 workshop on storm tracks
- WWRP: will hopefully be a partner of the 2018 workshop on storm tracks
- PAGES: through PMIP, partner of the paleoclimate component of activities on tropical rain belts and monsoons, storm tracks, cloud feedbacks and climate sensitivity.
- GCOS: attempt to take into account two recommendations of this GSC regarding future space missions (two actions included in the [GCOS AOPC-22 report](#) to be considered together with the GCOS implementation plan: one on the 'implementation of space-based clouds and aerosols profiling' and one on 'Water vapour profiles in low tropical troposphere').
- [EUREC<sup>4</sup>A campaign](#) primarily funded by the European Research Council (S Bony), the Max Planck Society (B Stevens), DFG, CNRS, DLR; Pending proposals to NASA (D Winker), NOAA (C Fairall), NERC (A. Blyth), ONR (P. Chuang) for additional participation to the campaign (airplanes, ships).
- [ISSI](#) (International Space Science Institute): workshops, science team, book
- [ICTP](#) (International Center for Theoretical Physics, Trieste): workshops and summer schools

#### 4. Overall GSC timeline

- 2012-2015: Definition Phase (concluded)
- 2016-2020: Mature Phase (field campaign, modelling projects):
  - o *Milestone*: Successful completion of EUREC4A field study
  - o *Milestone*: Publication of ECS assessment
  - o *Milestone*: Publication of Aerosol ERF assessment
  - o *Milestone*: Publication of RCEMIP results
  - o *Milestone*: Publications summarizing understanding of storm-track and rainband changes.
- 2021-2022: Summary and Conclusion Phase:
  - o *Milestone*: Overview paper on EUREC<sup>4</sup>A results
  - o *Milestone*: Review paper on what have we learned from this GSC
  - o *Milestone*: Forward looking Ringberg workshop and WCRP report (addressing for instance, strategies for advancing research on the themes of this Grand Challenge after the end of the Grand Challenge)

#### 5. Issues and challenges:

- Our understanding is that presently the ECS assessment has been endorsed by the WCRP, we ask that the Aerosol ERF assessment be likewise endorsed as an officially sanctioned WCRP report.
  - We see a need for WCRP to work together with ESA and the European Commission to better exploit the use of satellite data, something similar to the NASA ROSEs initiative that was so successful in advancing the use of A-train data. This type of initiative could also provide a template of the types of discussions WCRP and the EC should engage in to support WCRP priorities, overall a closer connection between EC framework-programmes and WCRP strategic planning is essential.
  - We are working increasingly closely with GASS, which resides within GEWEX. If this cooperation is successful and GASS re-establishes itself within GEWEX and within the community (something to ask GEWEX) we see this as a natural link and point of continuity (along with WGCM/CFMIP) for the themes being addressed within our GSC.
  - We wish a stronger interaction with PAGES could be established through PMIP to identify (potentially new) proxies that would be relevant for palaeo cloud and circulation changes.
  - As attention turns to how atmospheric and oceanic circulation responds to warming, the increase in modelling capacity at cloud resolving scales, and active remote sensing is supporting a growing and active research community with many outstanding young (within five years of PhD) scientists increasing taking on leadership roles.
-