WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity

Sandrine Bony & Bjorn Stevens

with
Dargan Frierson, Christian Jakob, Masa Kageyama, Robert Pincus, Ted Shepherd, Steven Sherwood,
Pier Siebesma, Adam Sobel, Masahiro Watanabe & Mark Webb

and input from Michela Biasutti and Aiko Voigt

WGCM-20 session, Princeton Univ, NJ, USA, Nov 2016

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?

Bony, Stevens, Frierson, Jakob, Kageyama, Pincus, Shepherd, Sherwood, Siebesma, Sobel, Watanabe and Webb, 2015 : Clouds, Circulation and Climate Sensitivity, Nature Geoscience, 4, 261-268

Workshops/conferences organized around the four questions

Shallow clouds, convective aggregation and climate sensitivity
International Space Science Institute, Bern (Switzerland), Feb 2016

Understanding clouds and precipitation through high-resolution models and observations
Berlin (Germany), Feb 2016

Cloud Feedback Model Intercomparison Project (CFMIP)
Trieste (Italy), Jul 2016

Modeling Hierarchies workshop
Princeton (USA), Nov 2016

Next:

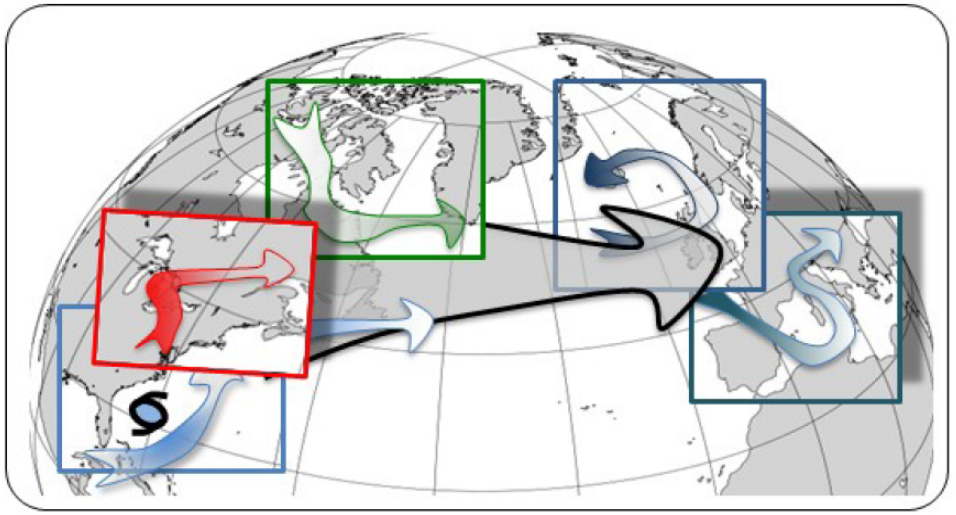
Workshop on the Future of convective parameterizations
Delft (Netherlands), 10-14 Jul 2017

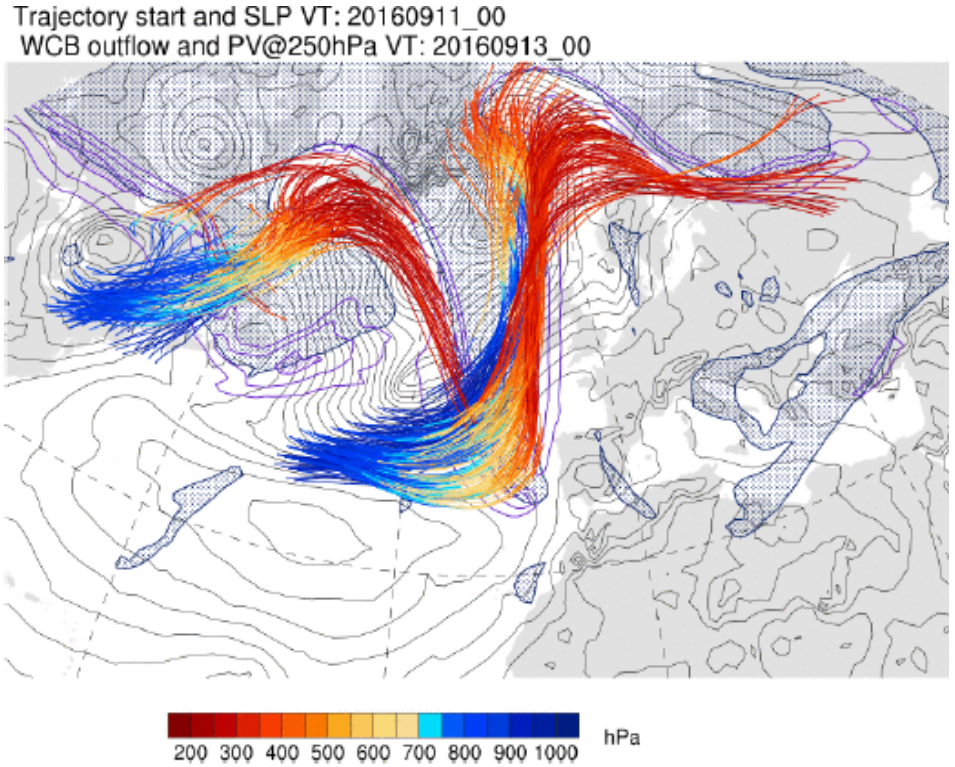
4th International Conference on Earth System Modelling (4ICESM)
Hamburg (Germany), 28 Aug- 1er Sep 2017 (http://www.mpimet.mpg.de/en/science/4icesm/)

Cloud Feedback Model Intercomparison Project (CFMIP)
Tokyo (Japan), 25-28 Sep 2017 (http://www.miroc-gcm.jp/cfmip2017/)

Paleoclimatic Model Intercomparison Project (PMIP)
Stockholm (Sweden), 28 Aug- 1er Sep 2017

NAWDEX (North Atlantic Waveguide and Downstream Impact Experiment)





Objective: to understand the influence of diabatic processes (i.e. clouds) on midlatitude Rossby waves and weather systems.

- Airborne field campaign (Sep-Oct 2016)

- Associated modeling activities:
  - High resolution (1 km) simulations
  - Transpose AMIP
  - Model evaluation

Emerged from the WMO THORPEX programme, contributes to the High Impact Weather project of WWRP.

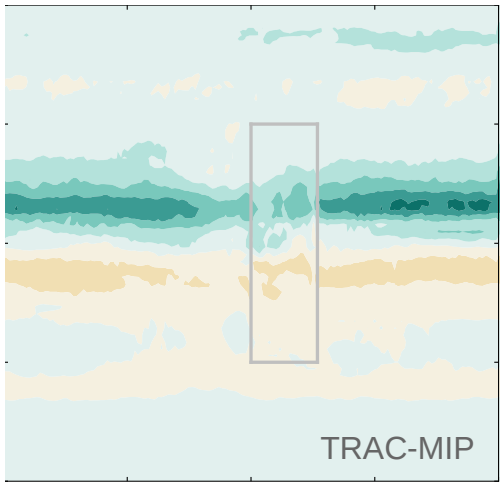
TRAC-MIP (Tropical Rain belts with an Annual cycle and Continent MIP)

An integrated view of Monsoons and the ITCZ across time and space scales.

Michela Biasutti[1], Aiko Voigt[1], William R. Boos[2], Pascale Braconnot[3], Julia C. Hargreaves[4], Sandy P. Harrison[5], Sarah M. Kang[6], Brian E. Mapes[7], Jacob Scheff[1], Courtney Schumacher[8], Adam H. Sobel[1,9], & Shang-Ping Xie[10]

Outcome of the 2015 ITCZ/monsoon GC workshop

TRAC-MIP: model experiments aimed at understanding shifts of circulation and precipitation (intermediate complexity between ESMs and fixed-SST aquaplanets)



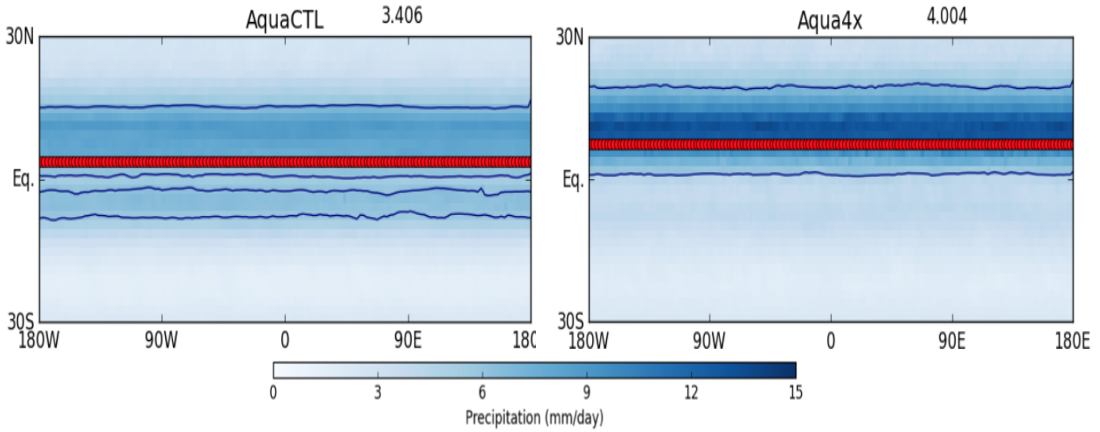
- Targets the essential dynamics of tropical rain belts with interactive SST (slab)
- Considers the main forced cycles (diurnal and annual)
- Compares zonally symmetric (ITCZ) and asymmetric ("monsoon") cases
- Considers both future (CO_2) and past (precession) forcings

Contributions from 14 models;

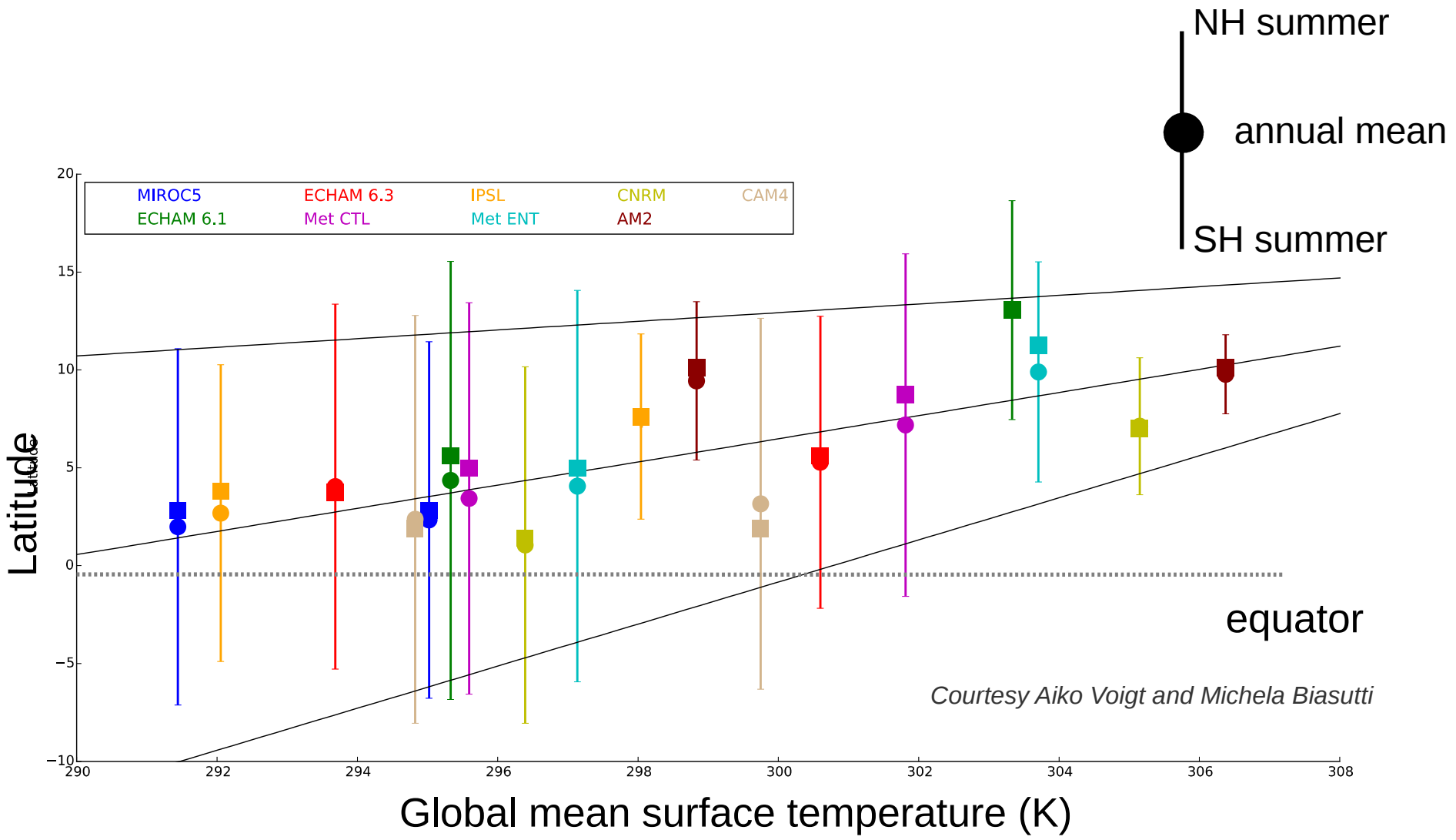
Links to PMIP, specifically Mid-Holocene monsoon changes. Possible link to GMMIP.

Contact: tracmip@gmail.com https://sites.google.com/site/tracmip

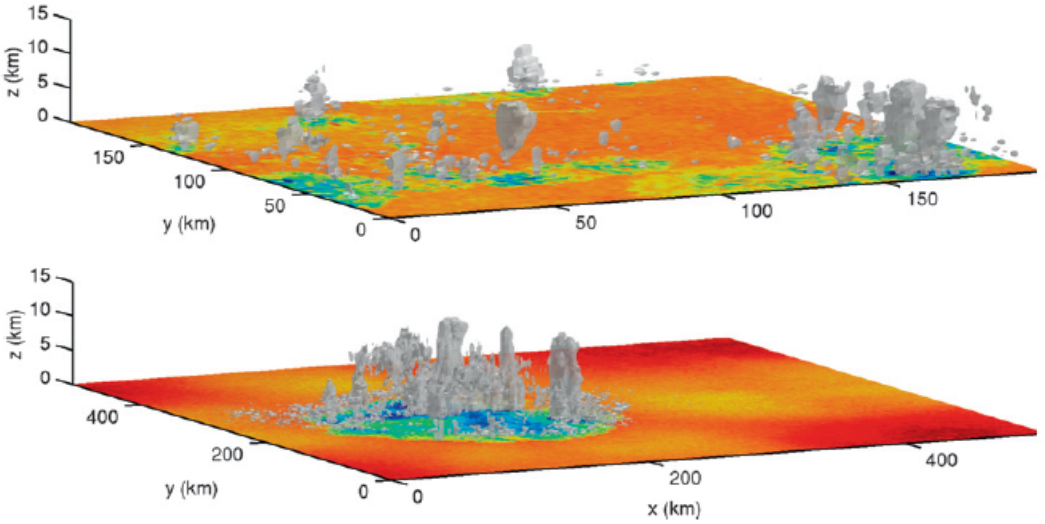
Co-chairs: Michela Biasutti, Aiko Voigt and Jack Scheff

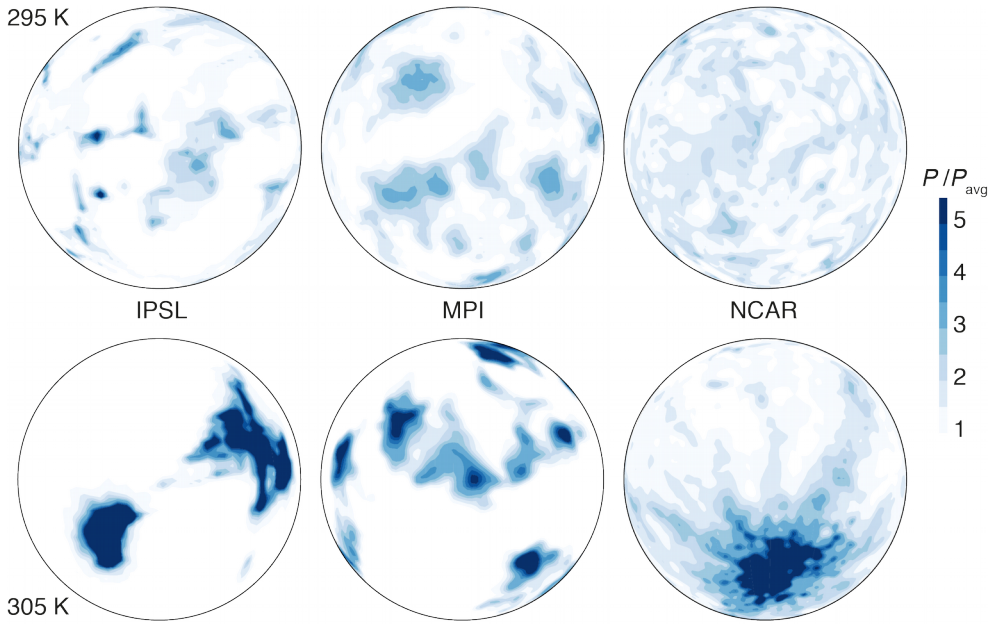


Aquaplanet Ctrl & 4xCO2: Seasonal range of ITCZ shrinks in warmer climates.



Convective self-aggregation in CRMs and in GCMs





Idealized Radiative-Convective Equilibrium: bridging the gap between CRMs and GCMs.

Mechanisms of self-aggregation and of its sensitivity to surface temperature unraveled.

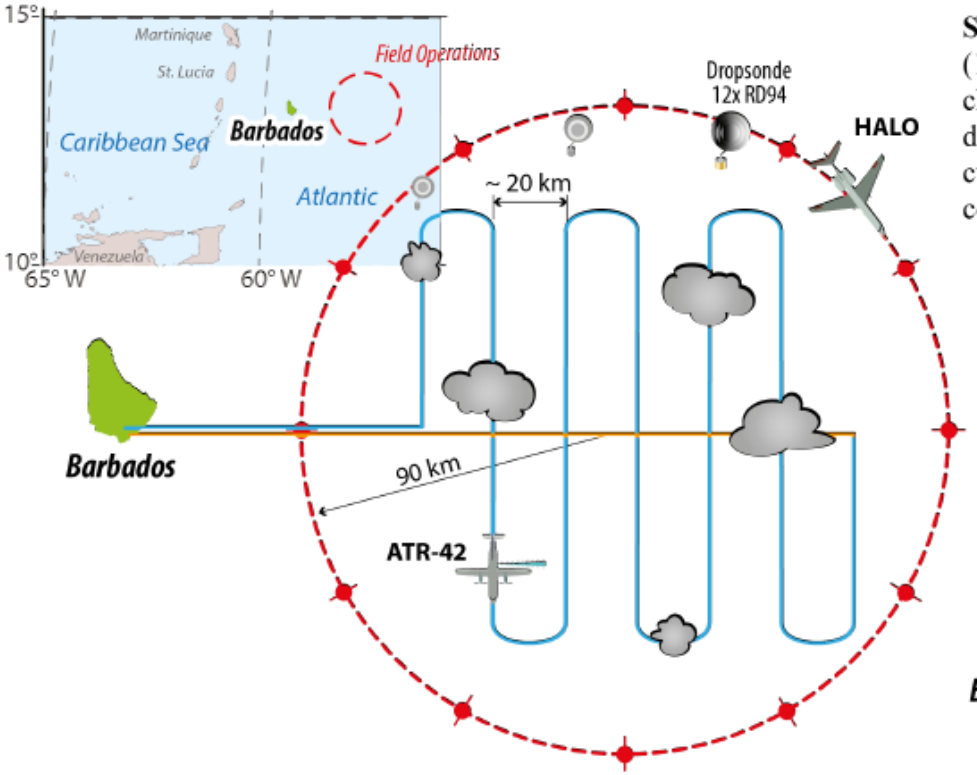
Investigations under way to understand the role of this phenomenon in climate (e.g. MJO, cloud feedbacks and climate sensitivity)

Intercomparison of CRMs/GCMs in RCE?
To be discussed this week at the workshop on model hierarchies

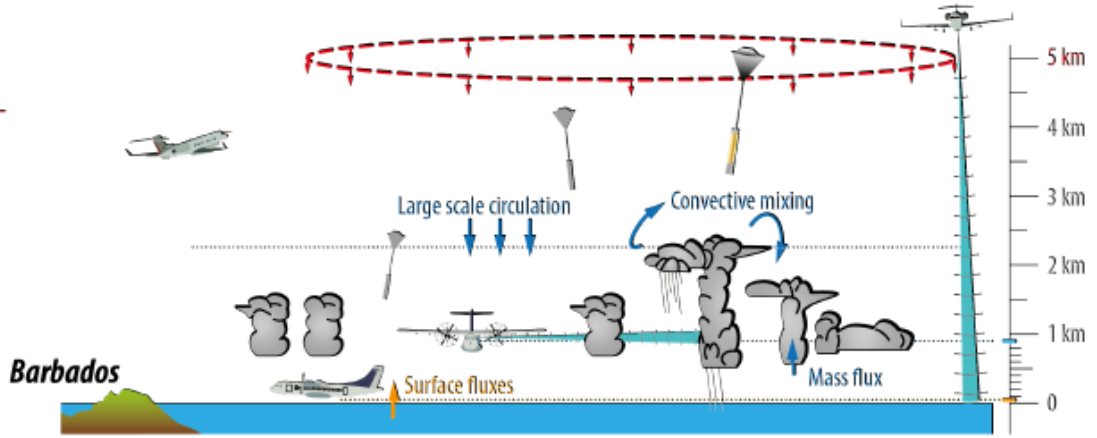
Muller and Held, JAS (2012); Bony et al., PNAS (2016)

On the role of convection in low-cloud feedback processes

NARVAL2 (Aug 2016) & EUREC⁴A (Elucidating the role of cloud-circulation coupling in climate, planned in early 2020)



Schematic of EUREC⁴A Field Campaign: The campaign will take place east of Barbados (13N, 59W) and involve two research aircrafts equipped with advanced instrumentation for characterizing clouds (lidar and radar) and their large-scale environment (extensive dropsondes). The **EUREC⁴A** campaign will investigate, for the first time, how the shallow cumulus cloud field (including the cloud fraction and its spatial organization) relates to convective-scale and large-scale circulations.



Contact: Sandrine Bony & Bjorn Stevens
http://www.mpimet.mpg.de/en/science/the-atmosphere-in-the-earth-system/narval2-eurec4a/

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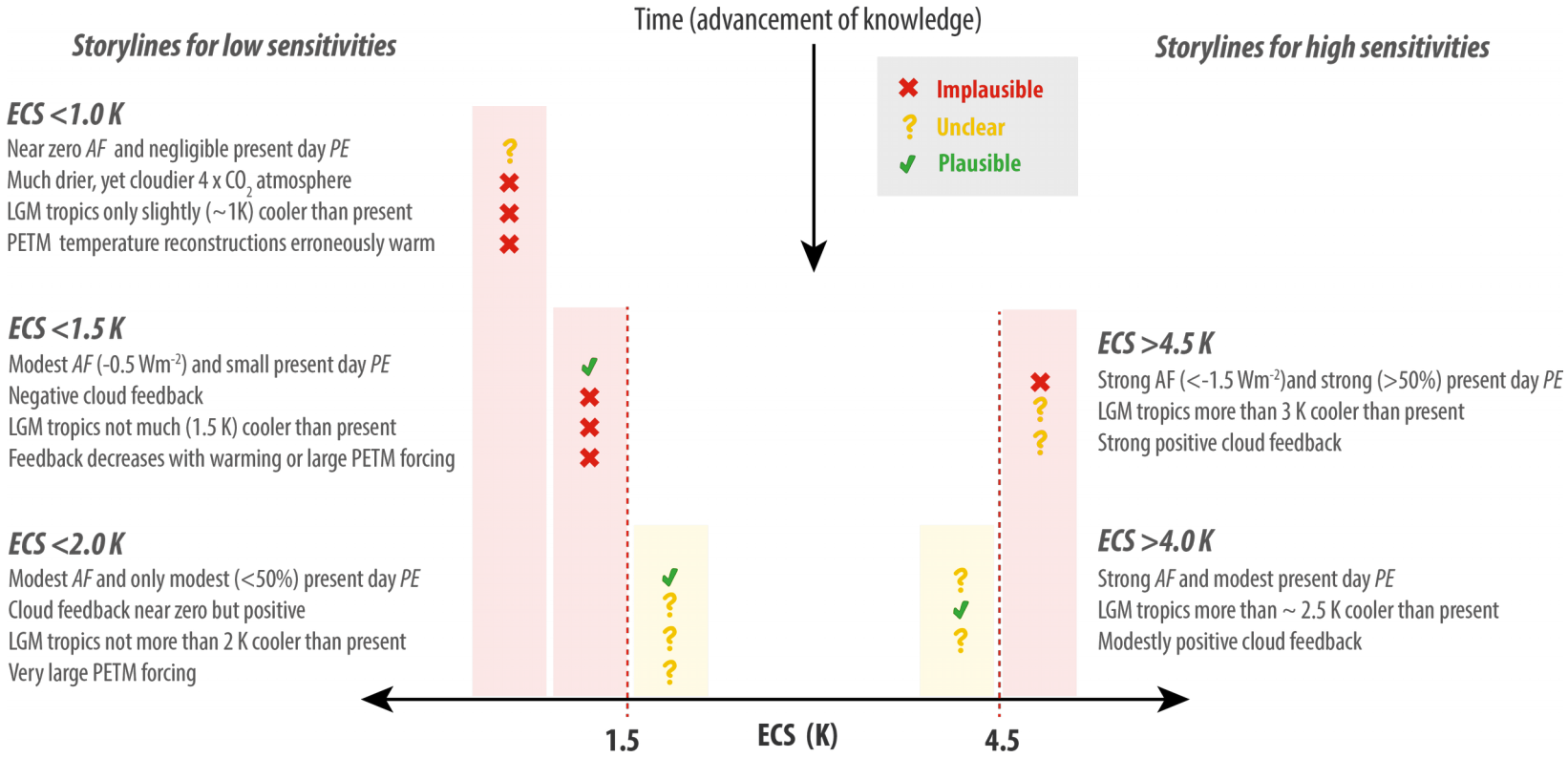
Applying reasoning by refutation to storylines for high and low climate sensitivities

Prospects for Narrowing Bounds on Earth's Equilibrium Climate Sensitivity

Bjorn Sevens[1]*, Steven C. Sherwood[2], Sandrine Bony[3], and Mark J. Webb[4]

An outcome of the 2015 Ringberg GC workshop On Earth's Equilibrium Climate Sensitivities



AF (Aerosol Radiative Forcing);PE (Pattern Effect); LGM (Last glacial maximum, 21 ky before present); PETM (Paleocene Eocene Thermal Maximum)

A particular problem in quantifying plausible bounds for ECS has been how to account for all of the diverse lines of relevant scientific evidence. It is argued that developing and refuting physical storylines (hypotheses) for values outside any proposed range has the potential to better constrain these bounds and to help articulate the science needed to narrow the range further.

Stevens et al., Earth's Future (in press)

Community assessment on Equilibrium Climate Sensitivity (leads: Steven Sherwood and Mark Webb)

Purpose:

1) To make thorough assessment of climate sensitivity, combining all of the useful lines of evidence so as to assess the likelihood of very low or high ECS; clarify the nature and limitations of key evidence; and provide robust 5-95% confidence ranges for ECS and TCR.

2) To highlight future research directions most likely to yield stronger constraints in the future.

3) To provide guidance on the relationship between ECS and TCR and the time evolution of global temperature if necessary .. e.g. utility of these concepts.

TCR will also be addressed, but not at same level as ECS.

Output:

Review paper of about 20 pages

Authors:

25 people; lead authors and coordinators already identified

Timetable:

Outline draft: 15 Nov. 2016

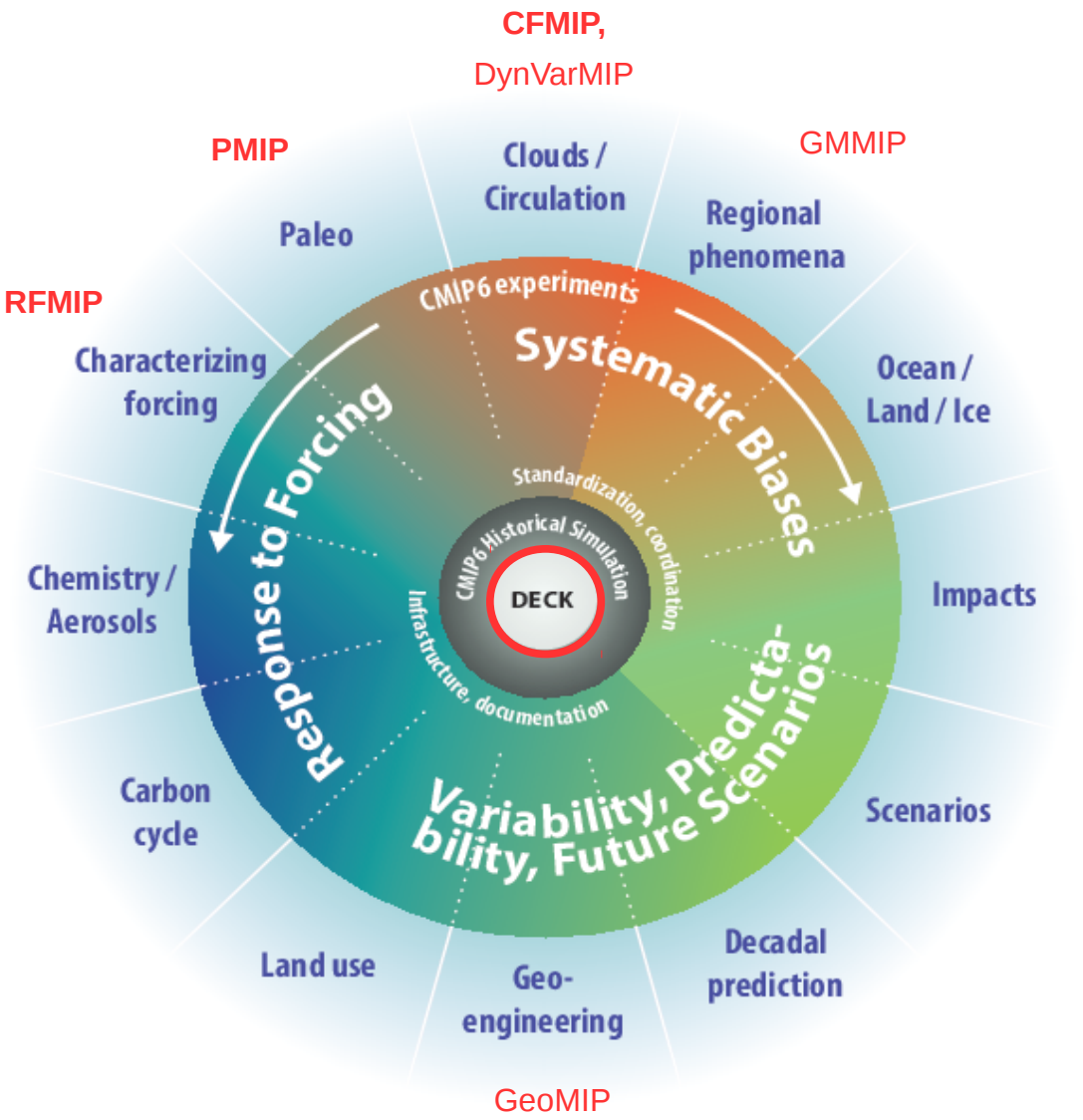
First draft: 15 Apr 2017

Second draft: by 15 Sept. 2017

Final draft: March 2018 (latest useful submission ~Dec. 2018 for AR6)

Connection to climate and process modeling

CMIP6 and CMIP6-endorsed MIPs



Other initiatives

- CFMIP Tier2 (circulation & precipitation)
- CGILS (CFMIP/GASS: LES vs GCMs)
- TRAC-MIP (ITCZ and monsoons)
- Easy-Aerosols (aerosols-circulation)
- Transpose-AMIP and high-res modeling focused on NAWDEX & NARVAL2
- RCE-MIP? (CRMs vs GCMs, *TBD this week*)

And also:

- 2017 workshop on the Future of convective parameterizations (Jakob & Siebesma)
- 2018 summer school on tropical rainbelts and TRAC-MIP? (Michela Biasutti, ICTP)
- Precipitation initiative? (Christian Jakob)

Connection to observations

Thinking about the future of observing systems

- Participation in the Climate Symposium (Asrar et al, BAMS, 2015)
- Contribution to the GEWEX PROES initiative on high-clouds (Paris, Nov 2015)
- Recommendations to GCOS (Amsterdam, Mar 2016)
- Participation in the NASA Decadal Survey
- Participation in the European survey *Next Generation of Copernicus Space Component*
- ISSI (International Space Science Institute), Bern:
  → a workshop organized on "*Shallow cloud feedbacks and convective aggregation*"
  → a book in preparation (Pincus et al.) + publication in *Surveys of Geophysics*
  → a science team has been selected for 2 yrs (satellite, in-situ, airborne instrumentation + process/climate modelling) on "*The role of shallow circulations in organizing convection and cloudiness in the tropics"*

Connection to field campaigns

- NAWDEX (North Atlantic weather systems)
- NARVAL2 (Transition between shallow and deep convection in the Atlantic trades)
- EUREC^{4}A (Elucidating the role of clouds-circulation coupling in climate): an international field study in preparation

Where do we stand?

- Four exciting science questions
- Integration of modelling (with a hierarchy of models and experiments), observations (from field campaigns to satellites), paleoclimates, and new ideas (e.g. convective self-aggregation)
- Many on-going activities, strong involvement of early-career scientists, fast scientific progress
- It’s fun!

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- Many on-going activities, strong involvement of early-career scientists, fast scientific progress
- It's fun!
- But Grand Challenges are meant to have a finite life-time…
- Three phases:
  - 2012-2015: Definition phase (Ringberg workshops, 4 questions, etc)
  - 2015-2020: Mature phase (ECS assessment, EUREC^{4}A field study, TRAC-MIP, etc)
  - 2020-2022: Summary phase


Thank You