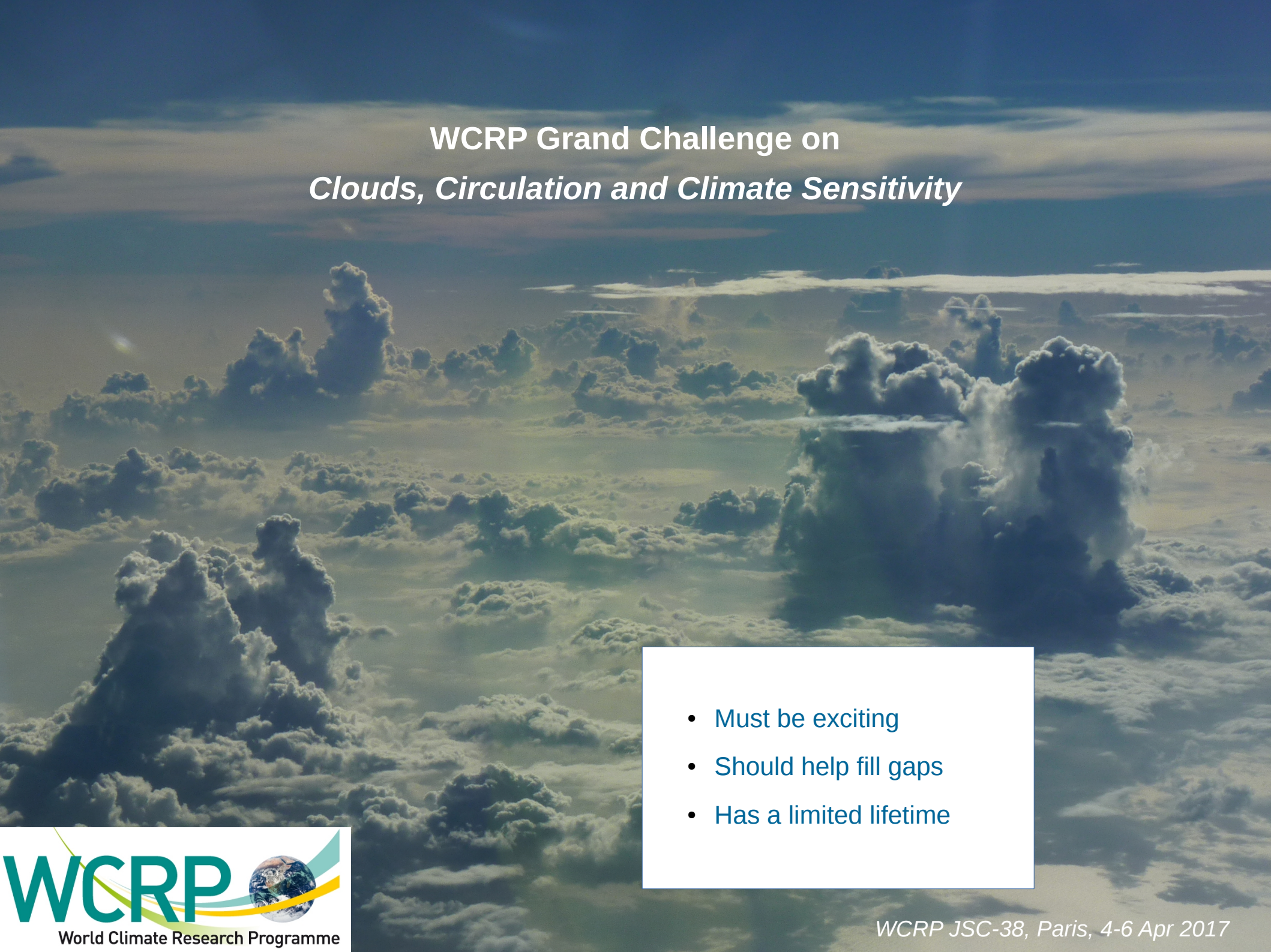
WCRP Grand Challenge on
Clouds, Circulation and Climate Sensitivity

Bony, Stevens, Frierson, Jakob, Kageyama, Pincus, Shepherd,
Sherwood, Siebesma, Sobel, Watanabe & Webb

World Climate Research Programme

WCRP JSC-38, Paris, 4-6 Apr 2017



WCRP Grand Challenge on

Clouds, Circulation and Climate Sensitivity

- Must be exciting
- Should help fill gaps
- Has a limited lifetime

World Climate Research Programme

WCRP JSC-38, Paris, 4-6 Apr 2017

Grand Challenge timeline

2012 – 2014 : Definition phase

Four science 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?

Highly Cited Paper

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

Grand Challenge timeline

2015 – 2020 : Development phase

The 4 questions are being addressed through a number of activities and strategies that aim at filling gaps

2021 – 2022 : Summary and conclusion phase

What have we learned from this Grand Challenge?

Time to (re)discuss the articulation of this GC with WCRP core projects
(strengthening current activities, taking-over some of them in the future?)

Workshops/conferences organized around these 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 (GC/WGCM)
Princeton (USA), Nov 2016

ISSI international science team
Bern (Switzerland), Mar 2017

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- 1 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

ISSI International Science Team on the organization of shallow clouds
Bern (Switzerland), Nov 2017

TRAC-MIP summer school on tropical rain belts
ICTP, Trieste (Italy), Jul 2018

Climate Sensitivity Assessment
TBD

Follow-up workshops on storm tracks and convective aggregation

What controls the position, strength and variability of tropical rain belts?

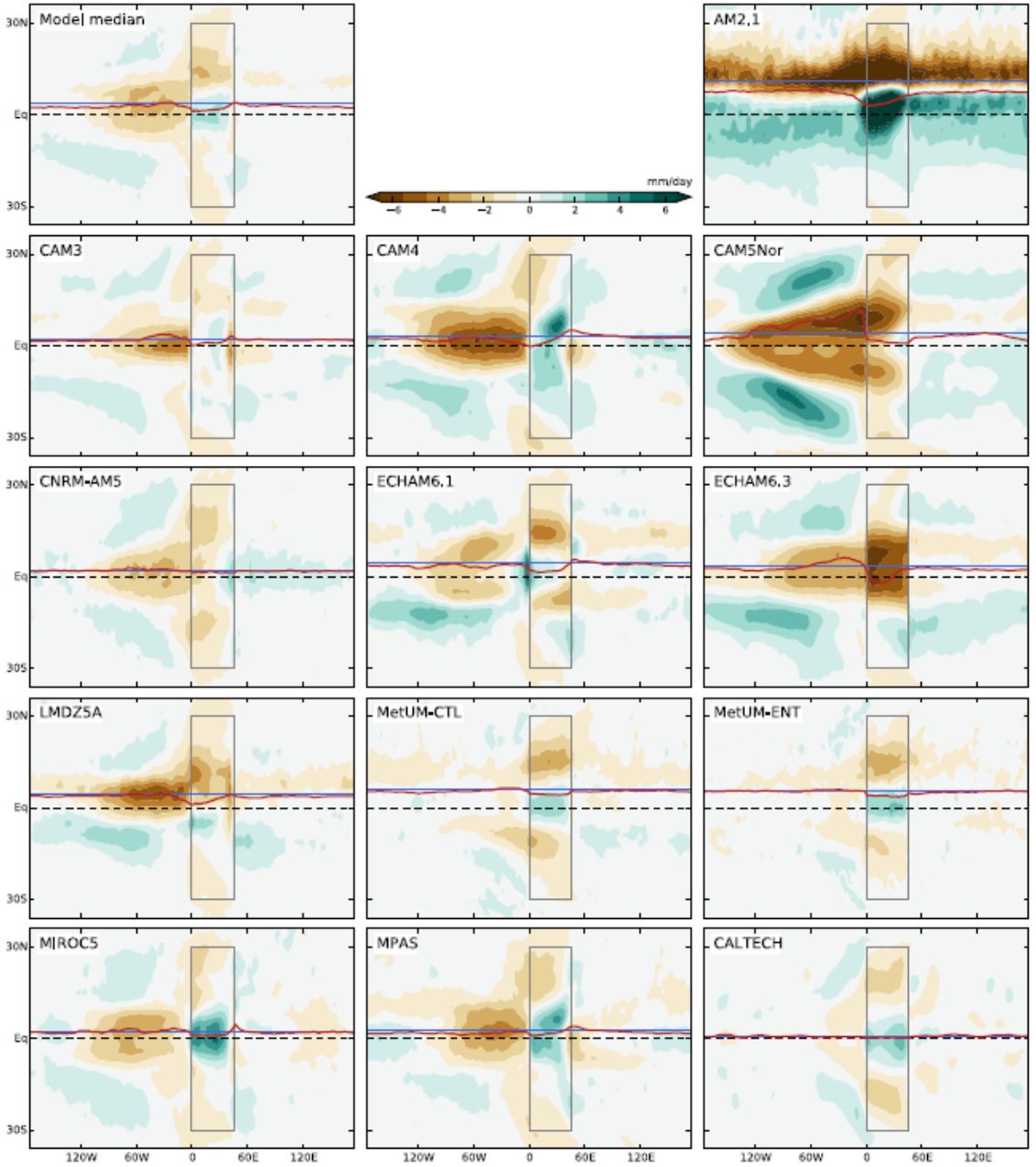


Figure 11. Impact of the tropical continent on precipitation: annual-mean precipitation temperature difference between LandControl and AquaControl. The continent is indicated by the gray box. To highlight the impact on tropical precipitation, the plot is restricted to latitudes between 40°N and 40°S. The blue and red lines show the location of the precipitation centroid (defined between 30°N/30°S) at every longitude in AquaControl and LandControl, respectively.

Tropical Rain Belts with an Annual cycle (TRAC-MIP)

Response of tropical rain belts
to past and future radiative forcings
through idealized simulations
(aquaplanet, idealized continent)

Michela Biasutti, Aiko Voigt, Jack Scheff et al.

Annual-mean impact of a
tropical continent on precipitation

Voigt et al., JAMES (2016)

What controls the position, strength and variability of tropical rain belts?

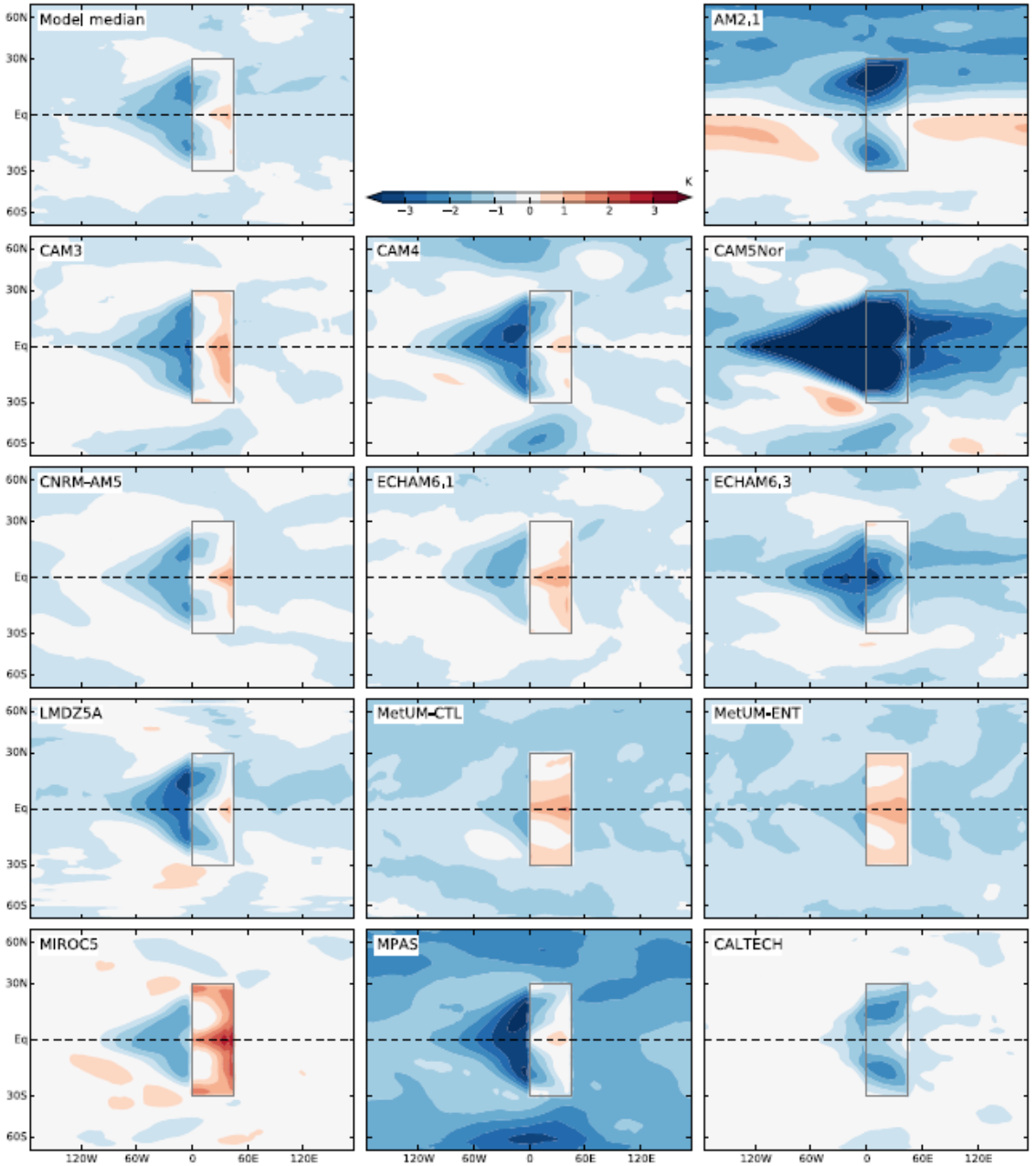


Figure 10. Impact of the tropical continent on surface temperature: annual-mean surface temperature difference between LandControl and AquaControl. The continent is indicated by the gray box.

Tropical Rain Belts with an Annual cycle (TRAC-MIP)

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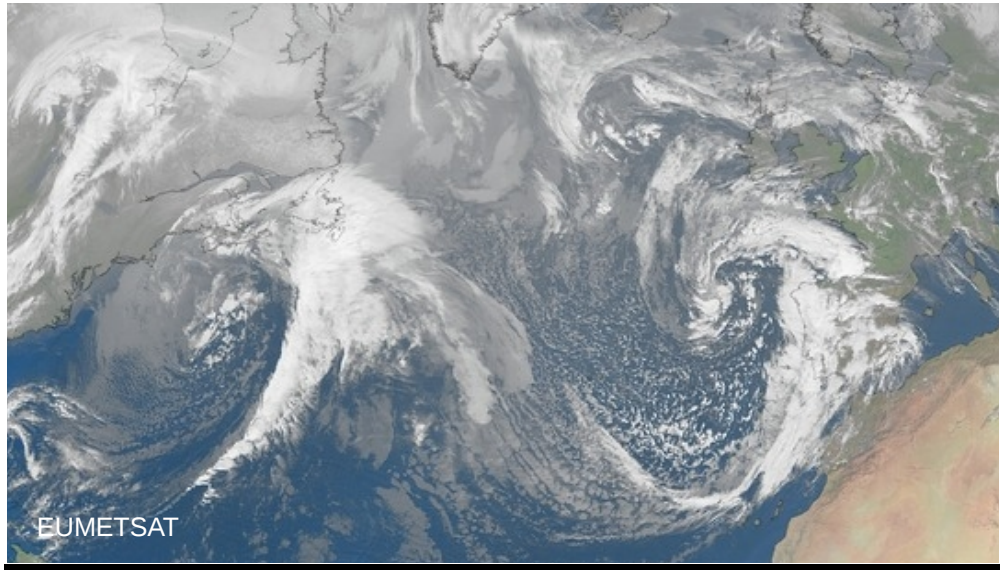
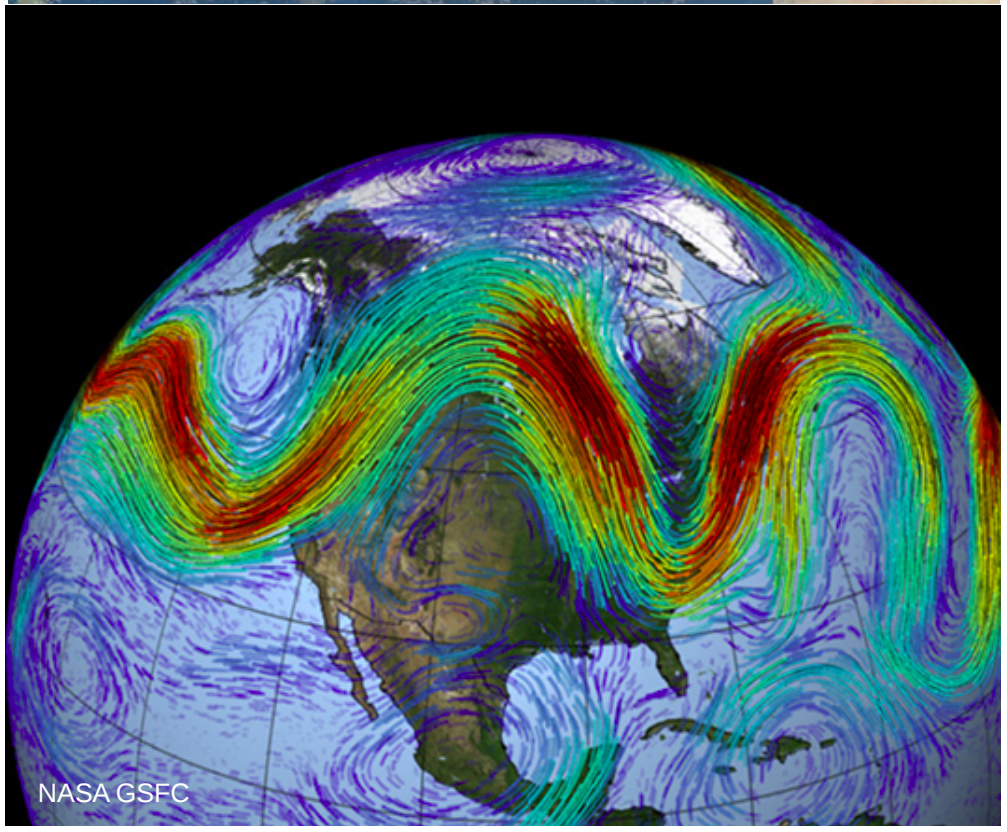
Voigt et al., JAMES (2016)

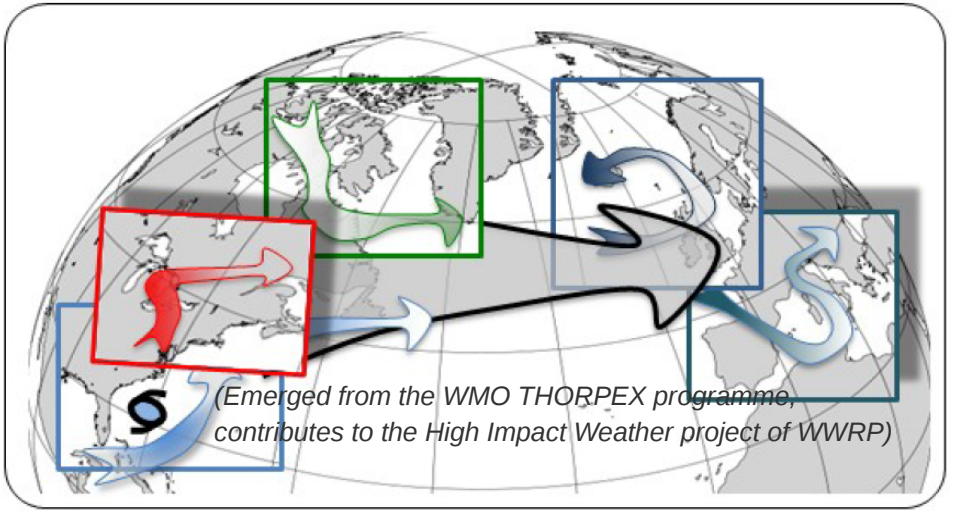
What controls the position, strength and variability of the storm tracks?





Influence of cloud diabatic processes on weather systems and storm tracks

- CFMIP/CMIP6 simulations (present & future climate)
  + DynVar (SPARC) diagnostics
- NAWDEX airborne field campaign (Sep-Oct 2016)

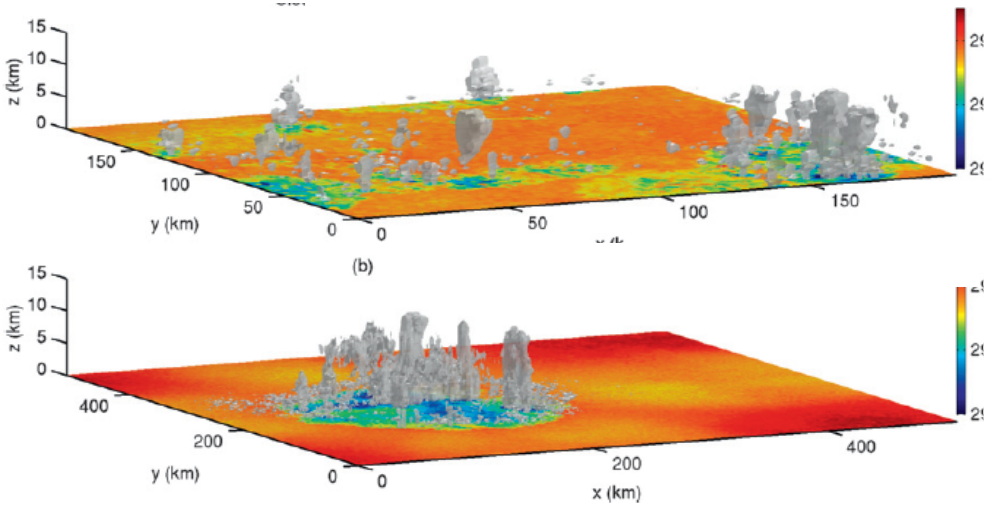


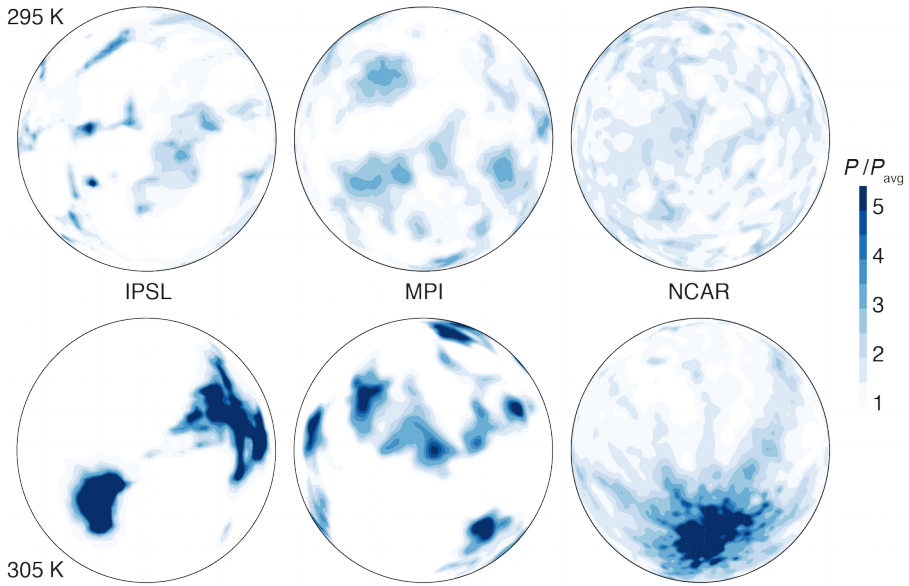
(Emerged from the WMO THORPEX programme, contributes to the High Impact Weather project of WWRP)

Interest for:
- High resolution simulations (1 km)
- Transpose AMIP simulations (climate models)

→ coordination? (WGNE?)

What role does convective aggregation play in climate?





Evidence from numerical models:

- Atmospheric convection can organize spontaneously
- It matters for the large-scale atmospheric state
- Convective aggregation depends on temperature

→ Physical mechanisms?

→ Connection to observations?

→ Role in climate? (e.g. MJO, ITCZ, tropical cyclones, cloud feedbacks, climate sensitivity)

On-going activities:

→ RCE-MIP (idealized Radiative-Convective Equilibrium simulations, bridging the gap between CRMs and GCMs)

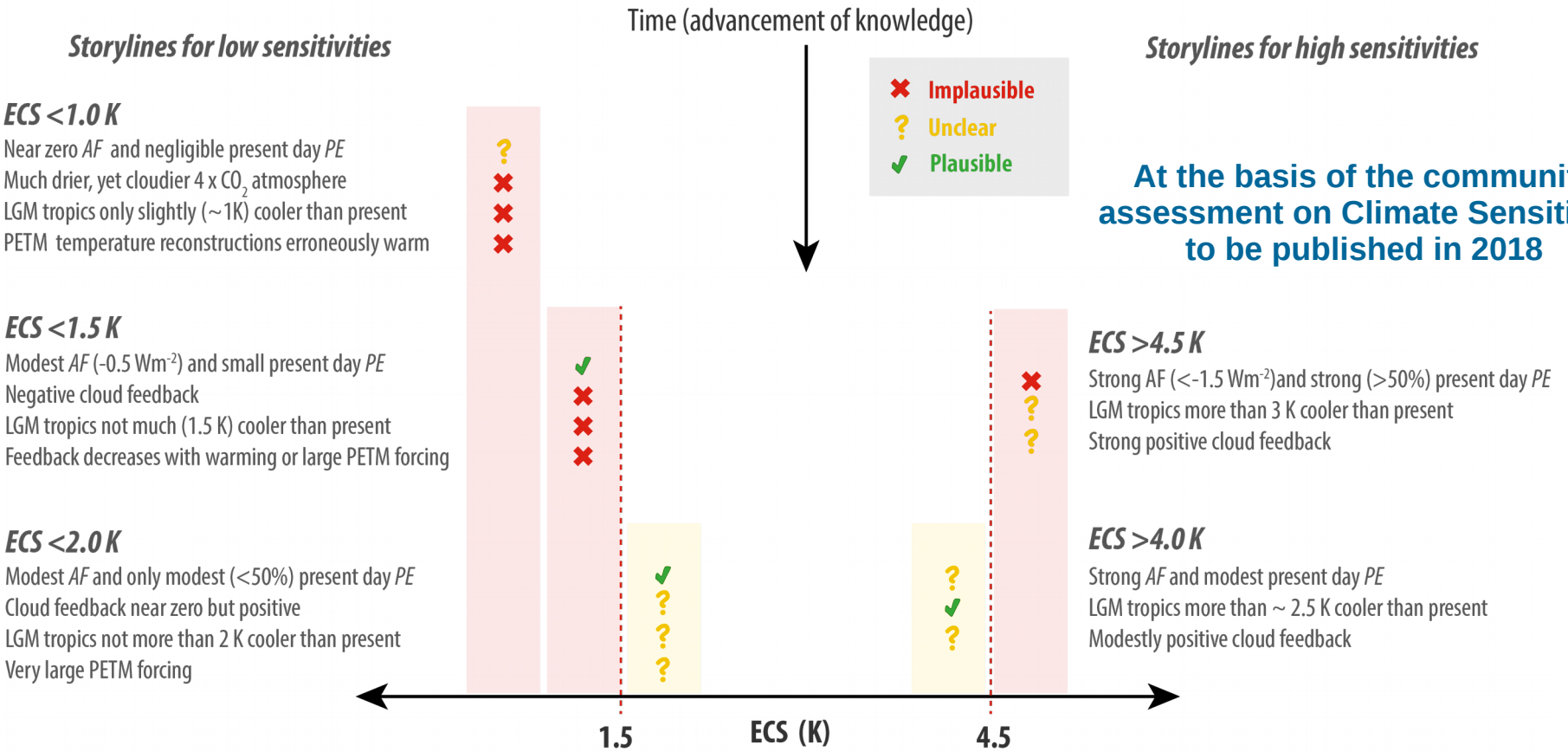
→ Observational analyses (ISSI workshop and book)

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

Narrowing bounds on Equilibrium Climate Sensitivity estimates

A particular problem in quantifying plausible bounds for ECS has been how to account for all of the diverse lines of relevant scientific evidence.

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.



At the basis of the community assessment on Climate Sensitivity to be published in 2018

Stevens et al, Earth's Future (2016)

Community assessment on Equilibrium Climate Sensitivity (led by 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.

Output:

Review paper of about 20 pages

Authors:

25 people; lead authors and coordinators identified

Structure:

Evidence from Paleoclimate observations (led by Julia Hargreaves and Pascale Braconnot)

Evidence from the historical instrumental temperature record (led by Piers Forster and Gabi Hegerl)

Evidence from contemporary observations and process modelling (led by Steve Klein and Masahiro Watanabe)

Synthesis methodology (led by Mark Webb and Steve Sherwood)

Timetable:

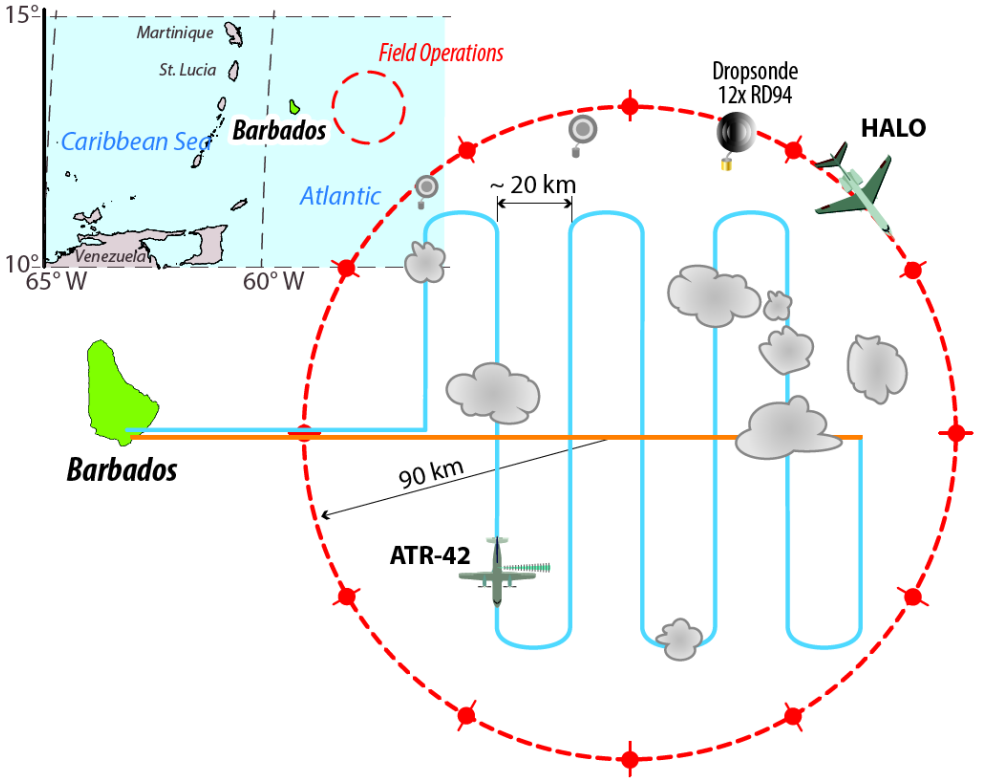
Assessment available for review in early 2018

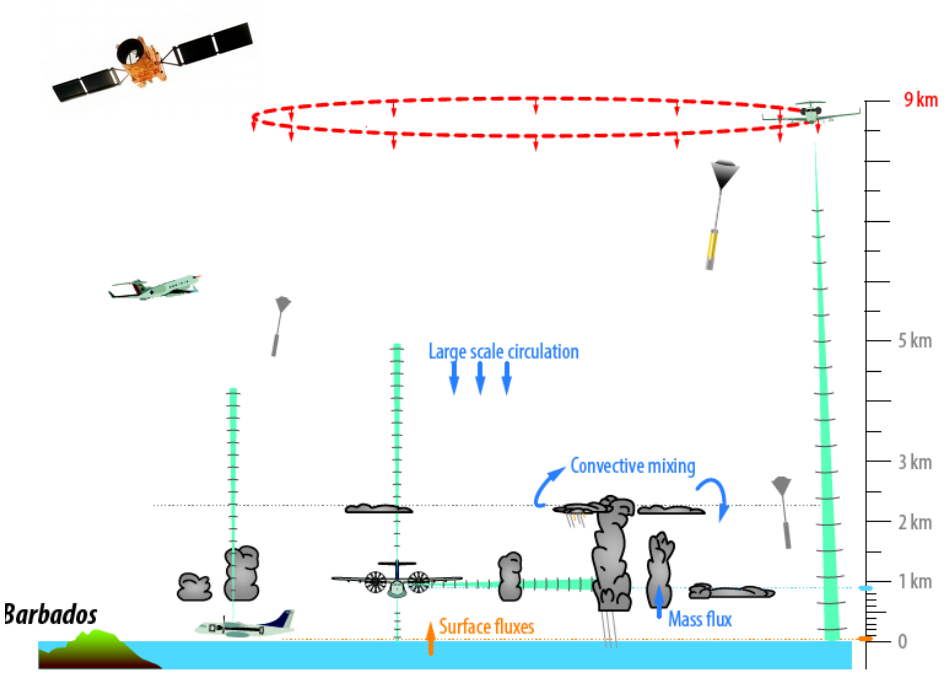
Submission for publication by late 2018 (timely for AR6)

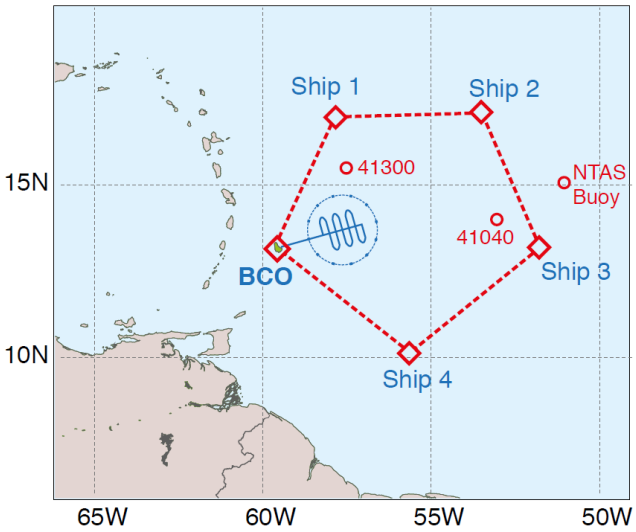
On the role of convection in low-cloud feedback processes

EUREC⁴A (Elucidating the role of cloud-circulation coupling in climate)

An international, WCRP endorsed, field study planned on 20 Jan – 20 Feb 2020, East of Barbados (tropical Atlantic)







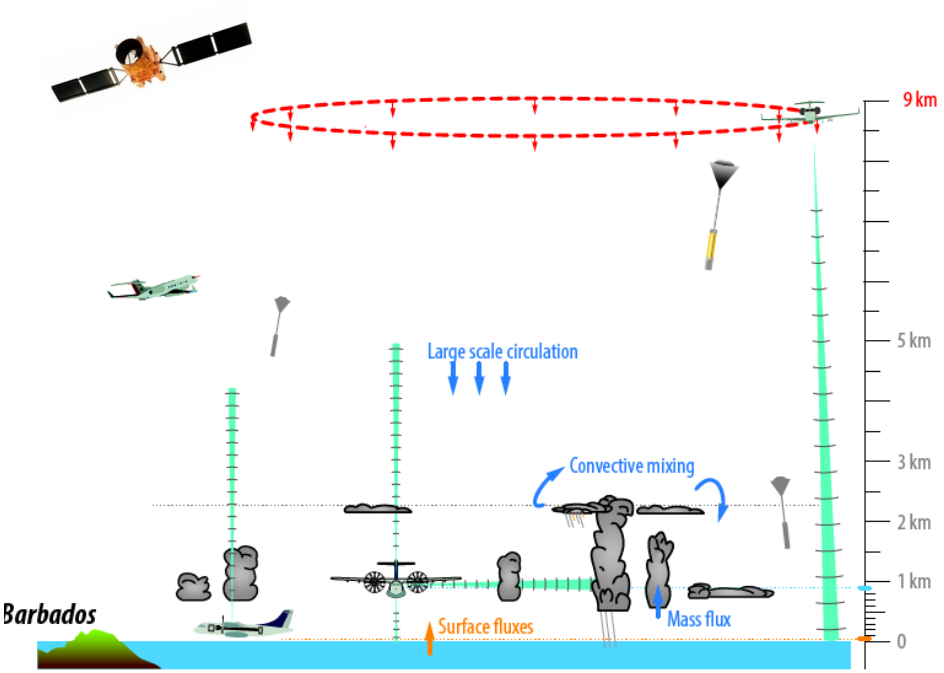
Contact: Sandrine Bony & Bjorn Stevens; http://eurec4a.eu

EUREC^{4}A (Elucidating the role of cloud-circulation coupling in climate)

An international, WCRP endorsed, field study planned on 20 Jan – 20 Feb 2020, East of Barbados (tropical Atlantic)

Several components:

- Coupling between clouds, convection and circulation
- Process, NWP and climate modelling (workshop in 2018)
- CalVal of space missions (e.g. ADM-Aeolus and EarthCARE)
- Cloud microphysics
- Vertical momentum transport by shallow convection
- Water isotopes
- Role of ocean mesoscale eddies in air-sea coupling



→ ***Further contributions from WCRP core projects?*** *e. g.*

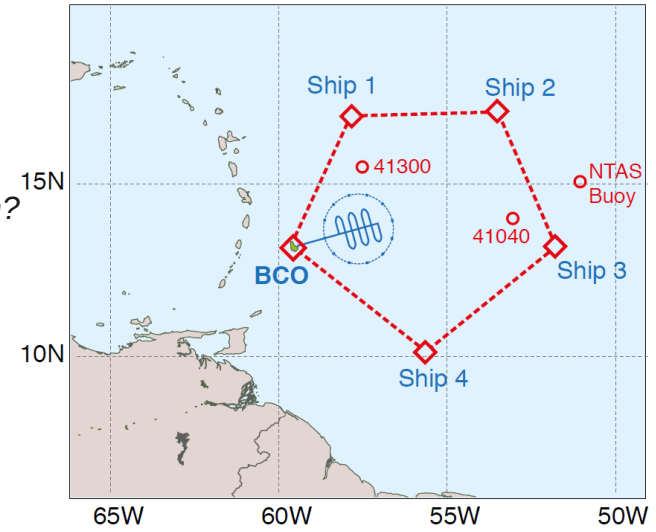
WGNE & GEWEX: NWP, model parameterizations, case study?

CLIVAR: additional measurements? ocean eddies?

SPARC: momentum transport?

PAGES & GEWEX: isotopic modelling?

GEWEX: closure of the energy and water budgets of the atmospheric column?



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Help fill gaps in the observing system

- **Participation in:**

  → Climate Symposium (Asrar et al, BAMS, 2015)

  → NASA Decadal Survey

  → European survey *Next Generation of Copernicus Space Component*

- **ISSI (International Space Science Institute), Bern:**

  → workshop organized on "*Shallow cloud feedbacks and convective aggregation*"

  → book in preparation + special issue in *Surveys of Geophysics*

  → international science team on 'the role of shallow circulations in organizing convection and clouds in the tropics"

ISSI volume / Special Issue of Surveys in Geophysics on Shallow clouds and water vapor, circulation and climate sensitivity

List of submitted / accepted papers (Apr 2017):

Shallow circulations: relevance and strategies for satellite observation
Gilles Bellon, Oliver Reitebuch, Ann Kristin Naumann

EUREC^{4}A: a field campaign to elucidate the couplings between clouds, convection and circulation
Sandrine Bony, Bjorn Stevens, Felix Ament , Susanne Crewell, Julien Delanoë, David Farrell, Cyrille Flamant, Silke Gross, Lutz Hirsch, Bernhard Mayer, Louise Nuijens, James H. Ruppert Jr., Irina Sandu, Pier Siebesma, Sabrina Speich, Frederic Szczap, Raphaela Vogel, Manfred Wendisch Martin Wirth

Observing Convective Aggregation
Christopher E. Holloway, Allison A. Wing, Sandrine Bony, Caroline Muller, Hirohiko Masunaga, Tristan S. L'Ecuyer, David D. Turner, Paquita Zuidema

Airborne Lidar Observations of Water Vapor Variability in Tropical Shallow Convective Environment
Christoph Kiemle, Silke Gross, Martin Wirth, Luca Bugliaro

An observational view of radiation circulation feedbacks on convective aggregation
Matthew D. Lebsock, Tristan S. L'Ecuyer, Robert Pincus

Importance profiles for water vapor
Brian Mapes, Arunchandra S. Chandra, Zhiming Kuang, Paquita Zuidema

Emerging Technologies and Synergies for Airborne and Space-Based Measurements of Water Vapor Profiles
Amin R Nehrir, Christoph Kiemle, Mathew Lebsock, Gottfried Kirchengast, Stefan A Buehler, Ulrich Löhnert, Cong-Liang Liu, Peter Hargrave, Maria Barrera-Verdejo, David Winker

Implications of warm rain in shallow cumulus and congestus clouds for large-scale circulations
Louise Nuijens, Kerry Emanuel, Hirohiko Masunaga, Tristan L'Ecuyer

The distribution of water vapor over low-latitude oceans: Current best estimates, errors, and impacts
Robert Pincus, Anton Beljaars, Stefan A Buehler, Gottfried Kirchengast, Florian Ladstaedter, Jeffrey S Whitaker

Using Megha-Tropiques and radiosonde data to constrain simulations of convective environments: a Northern Australian test case
Abhnil Amtesh Prasad, Steven Sherwood, Hélène Brogniez

Structure and dynamical influence of water vapor in the lower tropical troposphere
Bjorn Stevens, Hélène Brogniez, Christoph Kiemle, Jean-Lionel Lacour, Cyril Crevoisier, Johannes Killiani

Mechanisms and model diversity of trade-wind shallow cumulus cloud feedbacks : a review
Jessica Vial, Sandrine Bony, Bjorn Stevens, Raphaela Vogel

Convective Self-Aggregation in Numerical Simulations: A Review
Allison A. Wing Kerry Emanuel, Christopher E. Holloway Caroline Muller

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- **Recommendations to GCOS:**

  #1 Implementation of space-based clouds and aerosols profiling (follow-on lidar-radar space mission)

  #2 Develop a strategy for measuring lower-tropospheric water vapour from space

To the attention of the JSC and Core Project leaders

- Grand Challenges initiate or promote exciting research activities, fill gaps, generate momentum.
- Strong integration in WGCM activities (CFMIP, PMIP, CMIP) - *our host*
- Some of the GC activities are relevant for core projects + GCs have a limited lifetime.

Time to strengthen the articulation with Core Projects and WGs?

Opportunity:

- **To get more involved in current activities**
- **To take-over or progressively take ownership of some activities (if relevant/desired)**

e.g.

- Strengthen the weather-climate collaboration around NAWDEX and clouds/circulation (WGNE?)
- ITCZ/monsoon studies using idealized frameworks (CLIVAR & GEWEX monsoon panels?)
- EUREC4A field campaign (GEWEX-GASS/GDAP?, CLIVAR-Atlantic?)
- Studies of convective aggregation with high-resolution and climate models (WGNE? GEWEX?)


Thank You