Clouds Circulation and Climate Sensitivity

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

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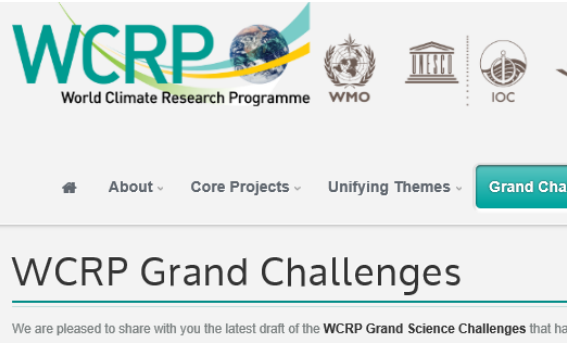
Our Odyssey for 2012-2014

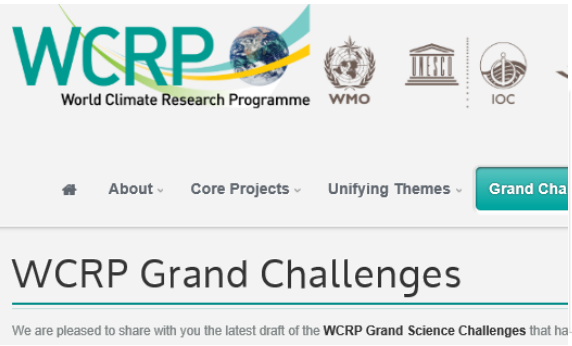


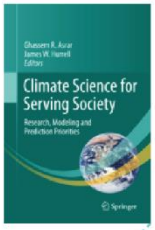
JSC33

07.2012

- Clouds, Circulation and Climate Sensitivity
- Changes in Cryosphere
- Climate Extremes
- Regional Climate Information
- Regional Sea-level Rise
- Water Availability

Our Odyssey for 2012-2014





JSC33 07.2012

WGCM 09.2012

White Paper 11.2012

Team

WCRP Volume

WGNE, ISCCP 04.2013

CFMIP 06.2013

Les Houches 07.2013

GEWEX/CLIVAR

07.2014 JSC35, Heidelberg

05.2014 PMIP

03.2014 **Ringberg**

02.2014 **Lorenz Center, MIT**

11.2013 Royal Society Chicheley Hall

10.2013 WGCM

09.2013 AeroCom

WCRP/IPCC Bern

10.2014 ESA Climate Symposium

Easy Aerosol

Ringberg 2014: Cloud, Circulation and Climate Sensitivity

- 43 participants by invitation
- A diverse group of people interested in the role of clouds/convections in the climate system

Issues and aims of the workshop

- To advance the articulation of this GC
- Initially proposed scientific issues were discussed broadly and then condensed further

A1: Changing Patterns (Ted/Adam)
A2: Cloud Circulation Coupling (Dargan/Pier)
A3: Climate & Hydrological Sensitivity (Steve/Mark)
B1: Using Observations, from isotopes to satellites (Masa/Robert)
B2: Advancing Model Development (Christian/Masahiro)

} **Mantra "*Less is better*"**

We identified Four Questions

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

We identified Four Questions

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Many key issues appeared in this meeting can be addressed with the four questions

Emergent Constraints, Hadley Cell Expansion, Walker Circulation Slowdown, Storm Track Shift, Regional Precip Changes, ITCZ Shift, Aerosol-Cloud-Radiation Interaction, etc.

It is featured on this months cover

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

It is featured on this months cover

Seems to be generating some interests

- Heike Langenberg: "the article has already proved very popular".
- Feature prominently in the social media.
- Will serve to stimulate and focus activities within the GC
- Will hopefully attract bright minds to important problems in the field.

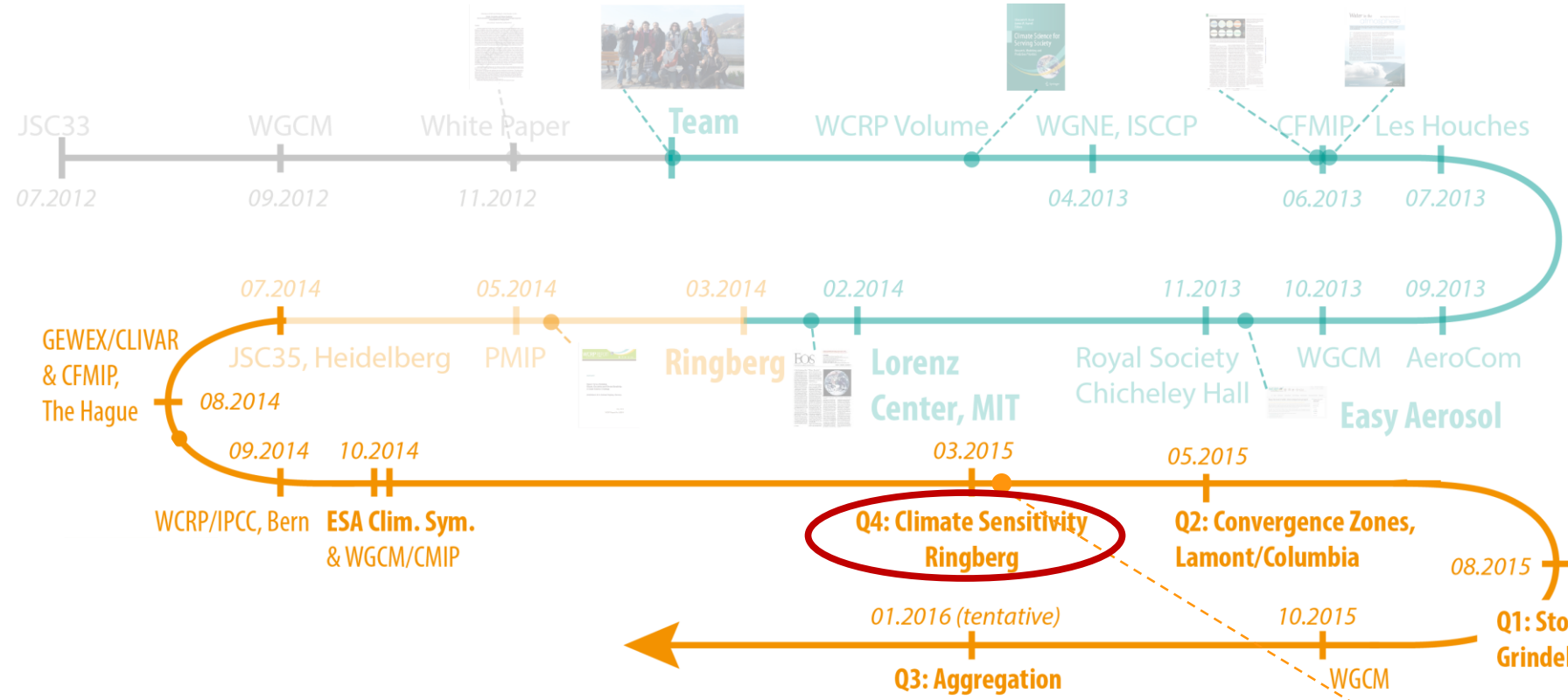
Bony, Stevens, Frierson, Jakob, Kageyama, Pincus, Shepherd, Sherwood, Siebesma, Sobel, Watanabe & Webb, 2015: Clouds, Circulation, and Climate Sensitivity. *Nature Geoscience*, **4**, 261-268

The GC has spawned some high-profile papers in the literature

1. C. Jakob, 2014: Going back to basics, *Nature Climate Change*, 4, 1042-1045
2. T. Shepherd, 2014: Atmospheric circulation as a source of uncertainty in climate change projections, *Nature Geoscience*, **7**, 703-708.
3. Voigt and Shaw, 2015: Circulation response to warming shaped by radiative changes of clouds and water vapor, *Nature Geoscience*, **8**, 102-106.
4. Tan et al., 2015: Increases in tropical rainfall driven by changes in frequency of organized deep convection, *Nature*, **519**, 451-454.
5. S. Sherwood et al., 2015: Adjustments in the forcing-feedback framework for understanding climate change, *BAMS*, in press.
6. T. Mauritsen and B. Stevens, 2015: Missing iris effect as a possible cause of muted hydrological change and high climate sensitivity, *Nature Geoscience*, **8**, in press
7. B. Stevens, 2015: Rethinking the lower bound on aerosol radiative forcing, *J. Climate*, in press.

… and probably more

Coming Steps, 2015-



Additional Reviewe Articles, Perspectives and Technical Contributions are expected from Four Question Workshops....

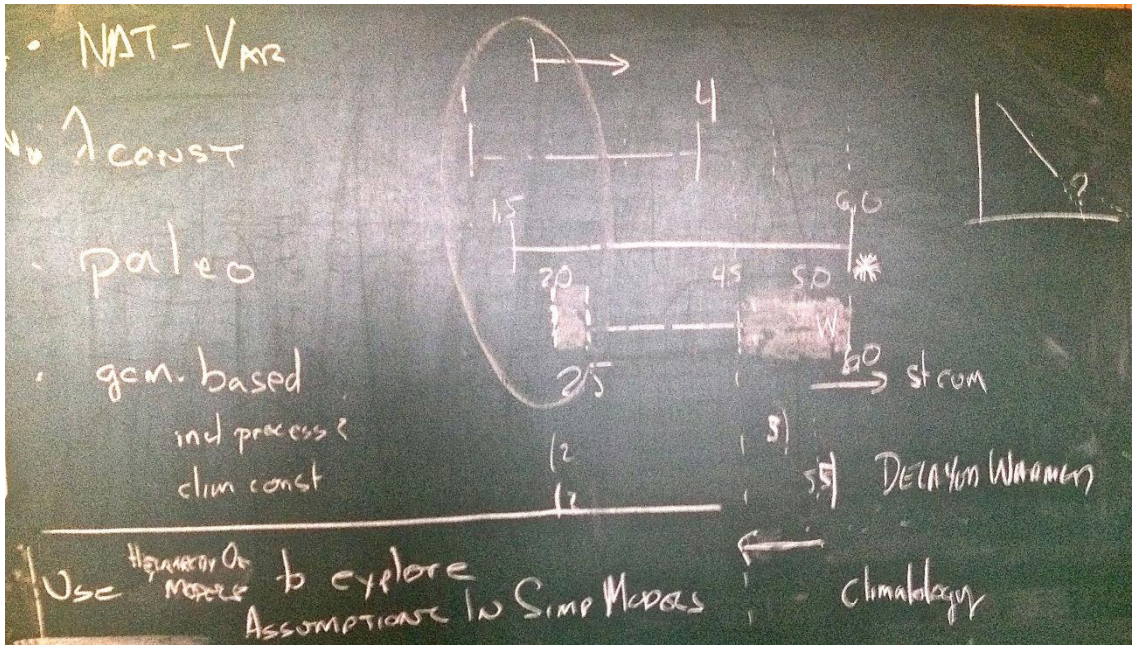
Ringberg 2015: Earth's Climate Sensitivities

- 32 participants by invitation
- Organised around specific themes: palaeo record, historical warming, insights from comprehensive climate modeling, variability and ocean heat uptake, etc

Issues and aims of the workshop

- Aim to assess current understanding, or rather gaps in understanding, of climate sensitivity
- How to reconcile estimates from models, instrumental record, palaeo record, etc
- Focus on testable physical hypotheses or 'story lines' for low and high sensitivities

Ringberg 2015: Earth's Climate Sensitivities



Workshop recommendations (selected)

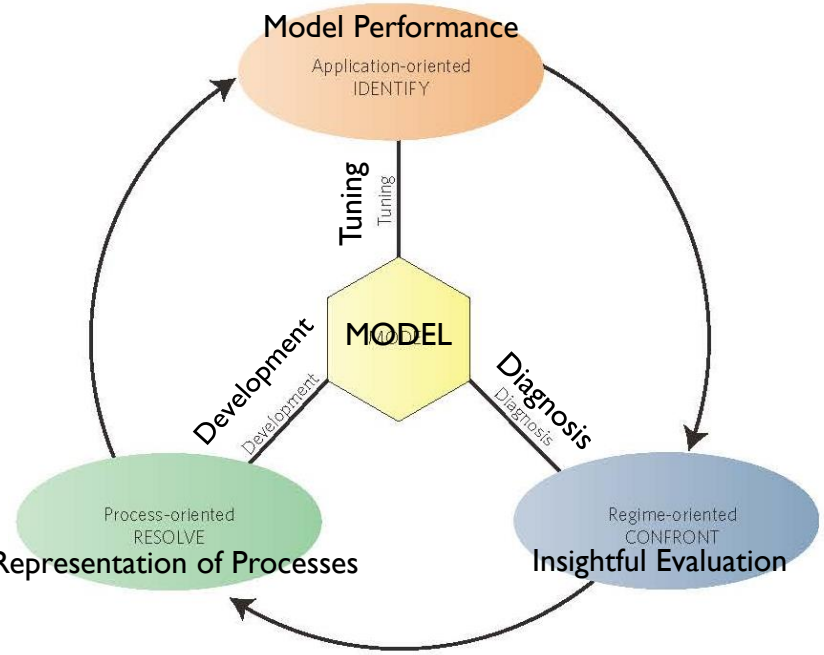
- All sensitivity estimates rely on models, which still have biases – should be focused more on
- Characterising forcing within CFMIP is imperative – more attention to historical period
- Need to understand dependence of climate feedback parameters on state or forcing type
- Great promise for narrowing uncertainty by working through specific hypotheses for low (<2K) and high (>4K) ECS
- WCRP, through Grand Challenge, should initiate and endorse a formal assessment process of climate sensitivity, leading to a report in 2019

Workshops are being organized around the Four Questions

1. **What role does convection play in cloud feedbacks?**
   - *Ringberg, March 2015*
2. **What controls the position, strength and variability of storm tracks?**
   - *Grindelwald, August 2015 (joint with SPARC, WWRP?)*
3. **What controls the position, strength and variability of the tropical rain belts**
   - *Columbia/LDEO, September 2015*
4. **What role does convective aggregation play in climate?**
   - *Special Session at EGU, ISSI Feb 2016*

… but also coordinated research activities

Need to improve models to challenge 'old' difficulties



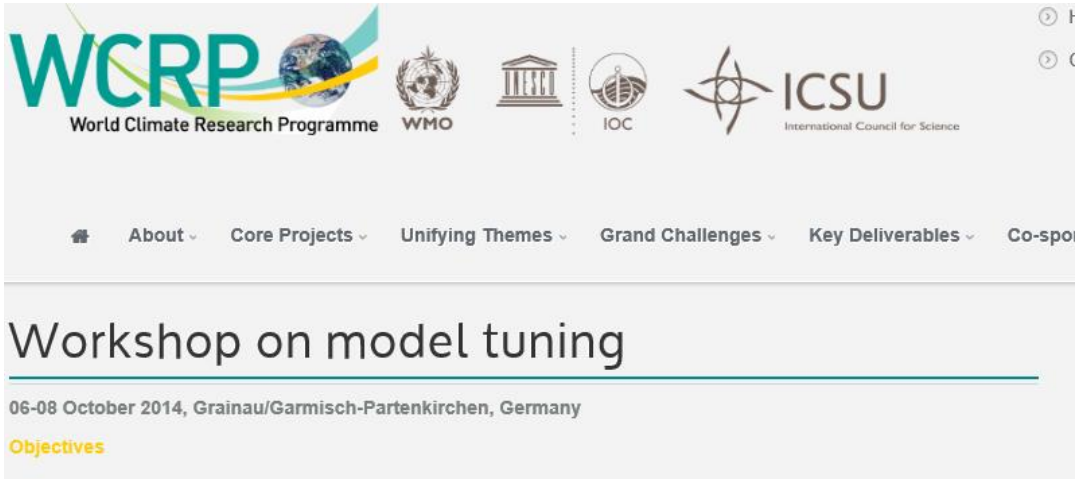
Jacob (2014 NCC)

Especially, processes governing

- Convective organization
- Shallow/deep convective mixing
- Aerosol-cloud-radiation interaction

need to be better presented in models

Exchange experiences/knowledge among 'CMIP modelers'

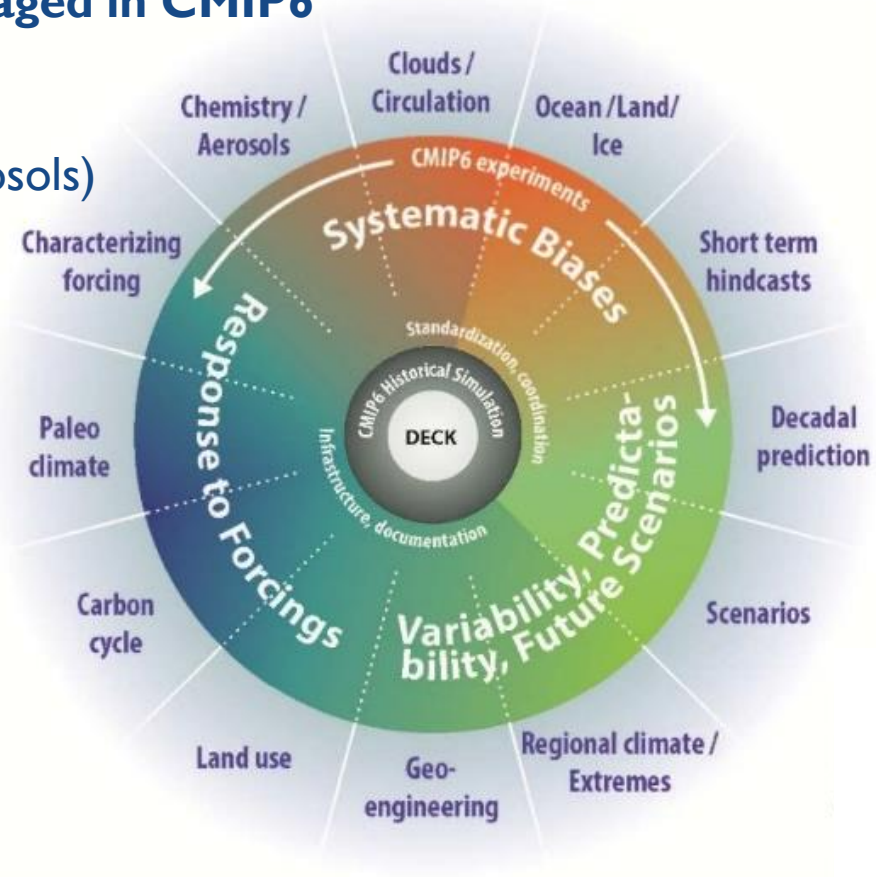


Improve habitat of 'endangered species'

… but also coordinated research activities

1. Coordinated Modeling Activities engaged in CMIP6

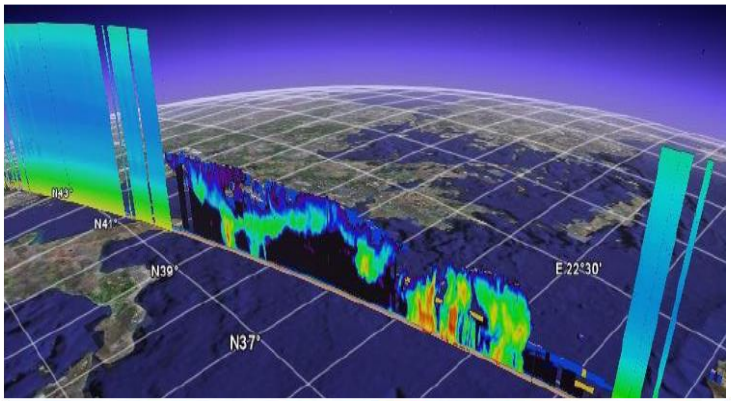
- CFMIP (cloud feedbacks)
- RFMIP (radiative forcing, especially aerosols)
- PMIP (palaeo climate)
- Others (VolMIP, DAMIP, PDRMIP, etc)
- Other independent initiatives
  (e.g. Easy Aerosol)

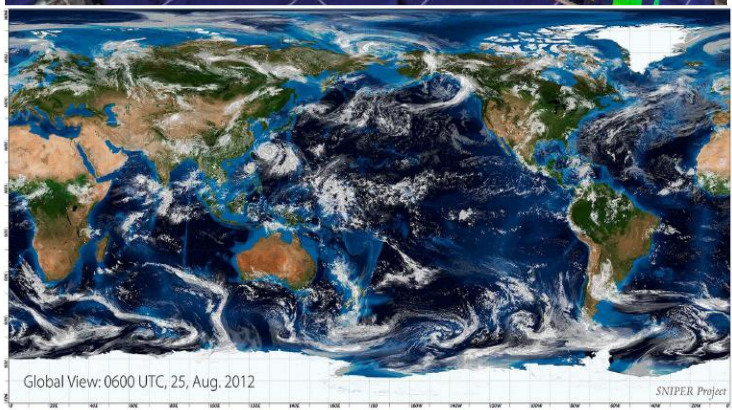


… but also coordinated research activities

2. New/Future Observations

- Capabilities by active remote sensing (lidars, radars), constellations (A-Train, GPM)
- Field experiments related to GC questions, e.g.,
  - T-NAWDEX (diabatic processes, Fall 2016)
  - NARVAL-II (convective organization, Aug 2016)





3. Next Generation of Modeling

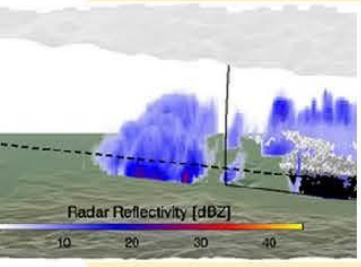
- Bridging large spectrum of models
  (e.g. theoretical, LES, GCMs)
- Development of (very) high-resolution models
- Synergy b/w climate and weather communities

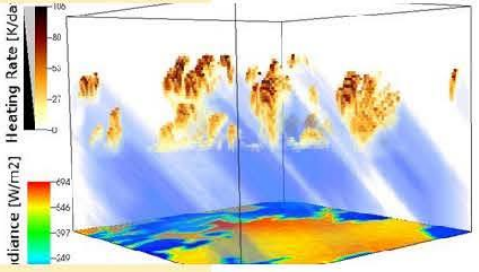
Workshops are being organized around the Four Questions

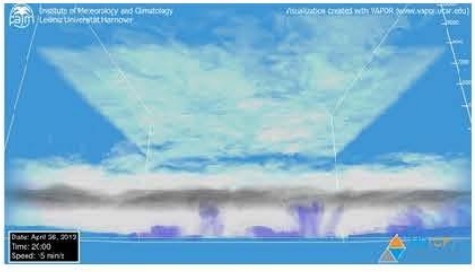
Understanding clouds and precipitation
through highly resolved process modelling and observations

Berlin, February 15-19, 2016

HD(CP)²



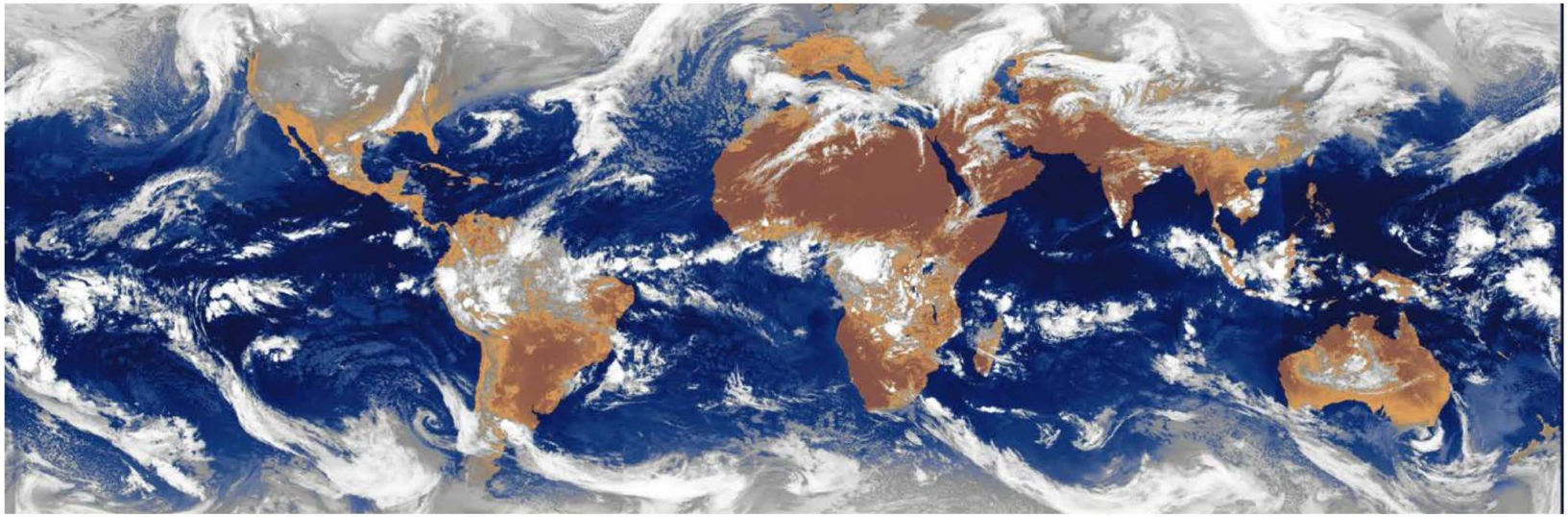


The problem to understand and simulate clouds and precipitation is longstanding and unequivocal in its importance for our community. It is also multidimensional: observation, theory and model development must go hand in hand to improve our understanding. The processes involving clouds and precipitation span scales ranging from the microphysical to radiative and thermodynamic effects that are emergent globally. They cannot be subsumed by one single computer simulation but must always be treated in a unified combination of pro-

Timeline

- July 15th, 2015: Abstract submission and registration starts.
- **September 15th, 2015. Abstract submission ends.**
- October 15th, 2015: Notification about abstract acceptance.

Thank You



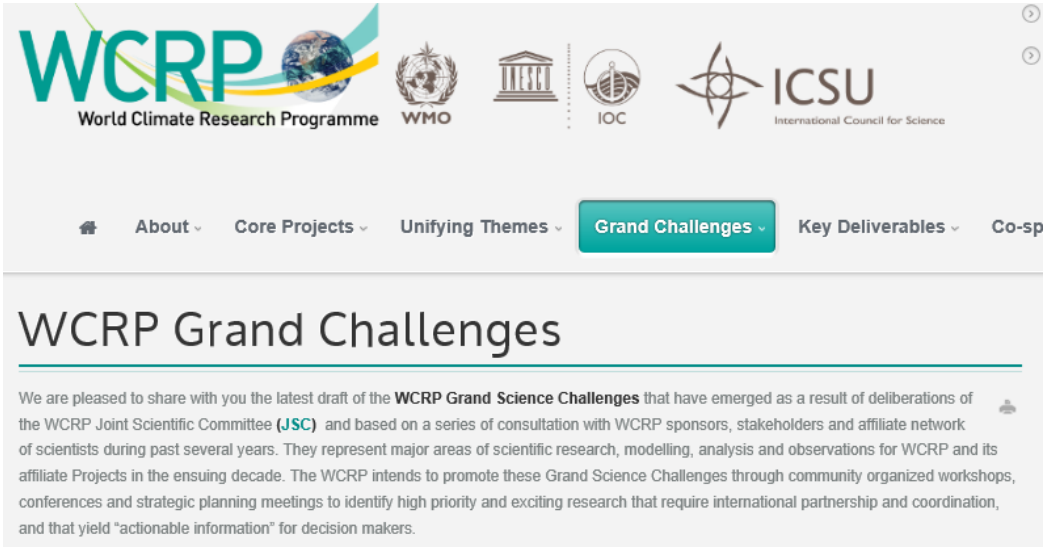
http://www.wcrp-climate.org/grand-challenges/gc-clouds

You could find more at

Google | WCRP Cloud GC

WCRP
World Climate Research Programme

WCRP Grand Science Challenges

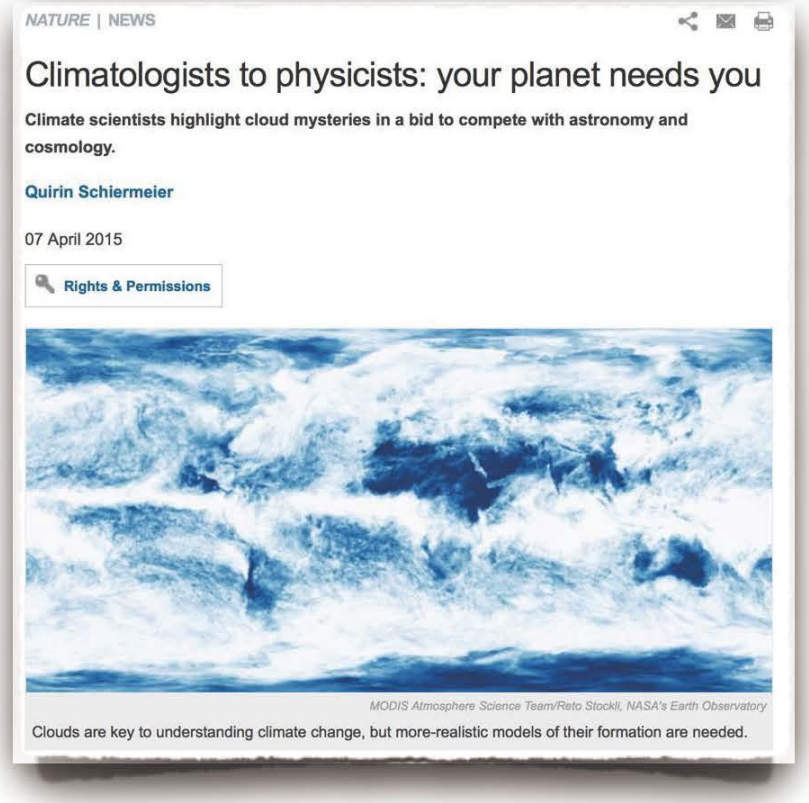


http://www.wcrp-climate.org/grand-challenges

- Clouds, Circulation and Climate Sensitivity
- Changes in Cryosphere
- Climate Extremes
- Regional Climate Information
- Regional Sea-level Rise
- Water Availability

Currently, the cloud GC is perhaps one of the most active initiatives

It seems to be generating some interest



NATURE | NEWS

Climatologists to physicists: your planet needs you

Climate scientists highlight cloud mysteries in a bid to compete with astronomy and cosmology.

Quirin Schiermeier

07 April 2015

Rights & Permissions

MODIS Atmosphere Science Team/Reto Stockli, NASA's Earth Observatory

Clouds are key to understanding climate change, but more-realistic models of their formation are needed.

- Heike Langenberg: "the article has already proved very popular".
- Featured prominently in the social media.
- Covered by many of the authors's own countries and institutes.
- Will hopefully attract bright minds to important problems in the field.

… but most importantly it is serving to organize and focus activities within the grand challenge.

Should help address some of the key uncertainties highlighted by IPCC assessments

Especially :

- **Assess cloud feedbacks and Climate Sensitivity**
  A fundamental scaling factor of global and regional climate changes; Long-standing uncertainty

- **Understand changing patterns of temperature and precipitation in a changing climate**
  A first-order control on regional climate changes, air quality and biogeochemical feedbacks

  Most reported impacts of climate change are attributed to warming and/or to shifts in precipitation patterns. – WGII AR5 TS

- **Identify robust climate responses to anthropogenic forcings**
  Including the impact of GHG and aerosol radiative forcings on 20C and 21C climates

- **Improve the predictive capabilities of models on all time scales, linking weather to climate**
  Including extreme events, regional features (monsoons, ITCZ), modes of natural variability

Ringberg 2015: Earth's Climate Sensitivities

Workshop presentations (relevant to cloud feedbacks)

- Robust non-cloud feedbacks (temperature, water vapour, snow/sea ice) imply an ECS of about 2K (Stevens)
- We expect a robust positive effect from increasing cloud altitude (Fixed Anvil Temperature hypothesis) adding 0.4 K (Zelinka, Stevens, Dessler)
- Modelling evidence suggests positive low cloud feedbacks (Stevens, Bony, Dessler, Webb)
- Hard to make a physically credible argument for ECS below 2K.
- Possibilities discussed – negative cloud feedbacks from Iris effect (Mauritsen), strong negative cloud adjustment (Allen) - not credible?
- Hard to justify ECS > 4.5K: IPSL feedbacks likely too strong (Bony), GASS/CFMIP Large Eddy Simulations predict weak feedbacks (Stevens)
- 'Emergent constraints' favour higher sensitivity models (Bony)

Summary courtesy of M Webb

We identified Four Questions

1. **What role does convection play in cloud feedbacks?**
2. **What controls the position, strength and variability of storm tracks?**
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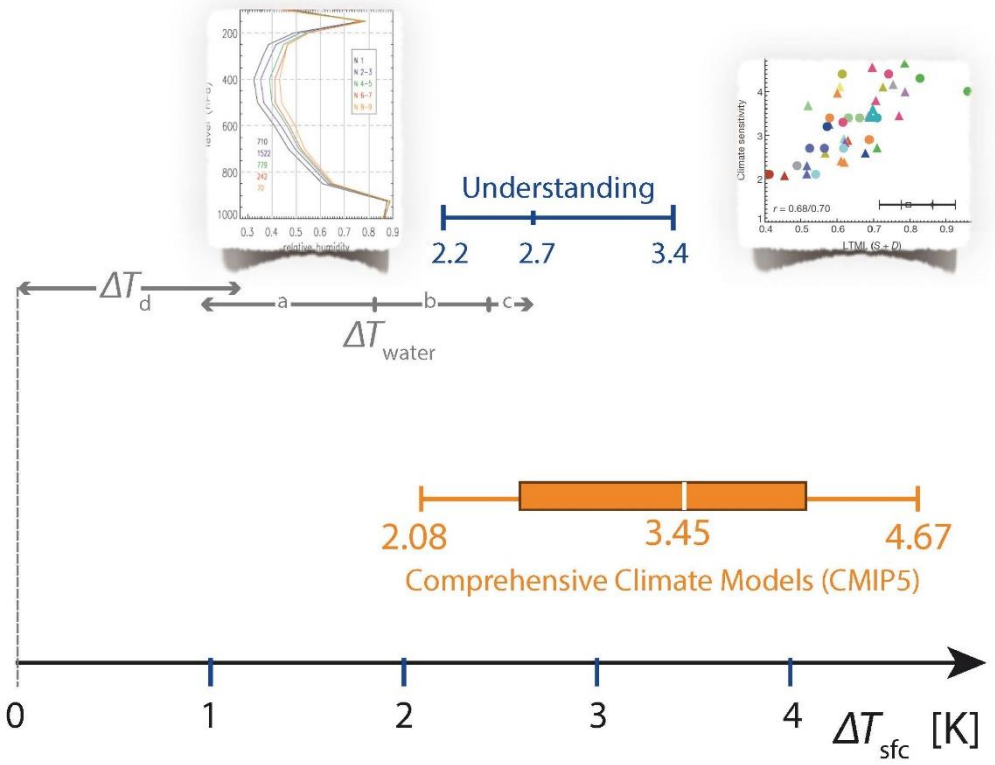
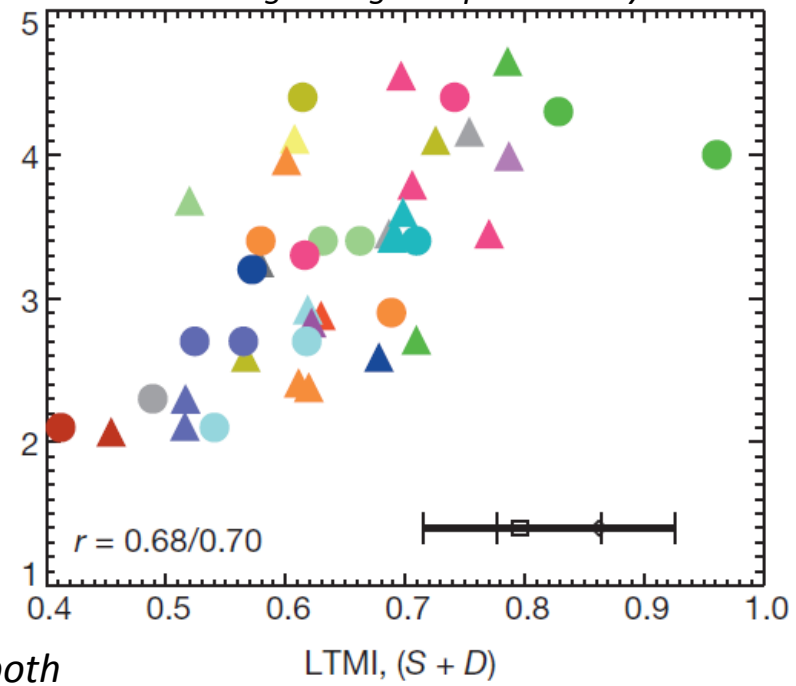


Climate Sensitivity vs convective mixing strength in present-day climate



Convective processes are key factors in the story-line for both a high and a low sensitivity world.

Sherwood et al. (2014 Nature)

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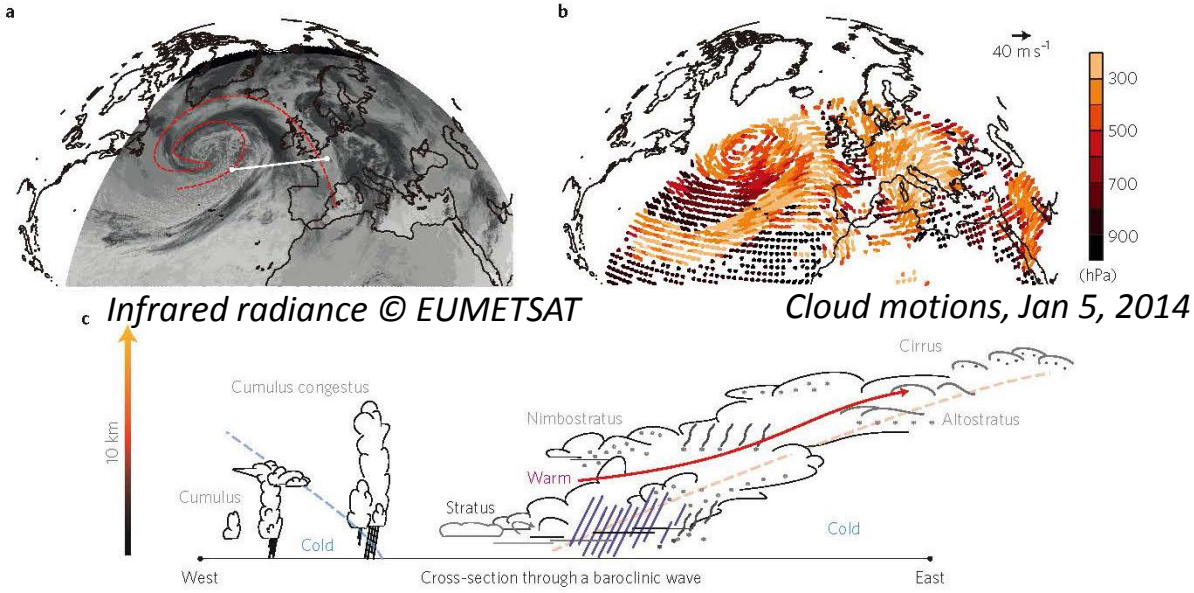
No doubt about the importance of storm tracks in weather & climate



Infrared radiance © EUMETSAT

Cloud motions, Jan 5, 2014

- *What is the role of moist, diabatic processes?*
- *How might the balance between moist & dry dynamics change as climate warms?*
- *How do the storm tracks interact with the changing tropics & polar regions?*

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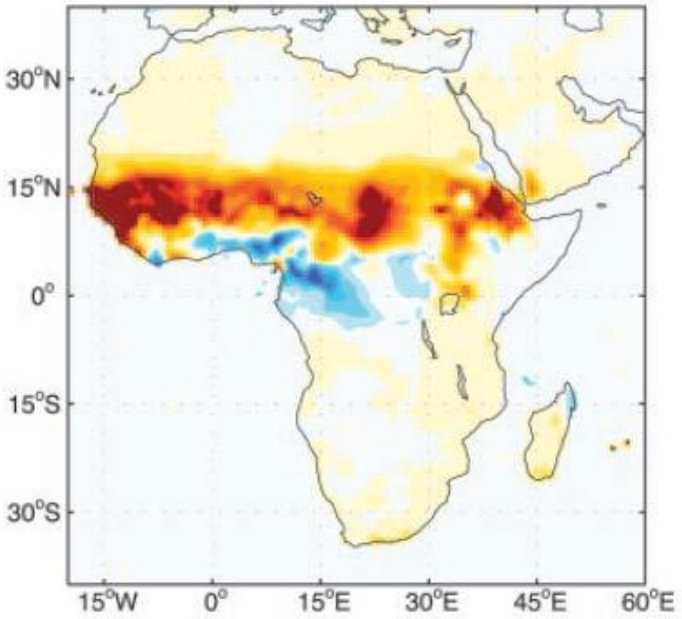
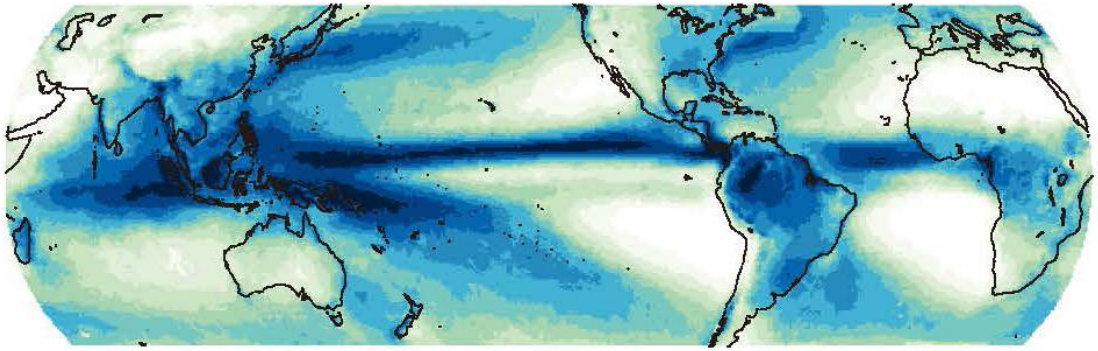
Observed JAS rainfall trends for 1951-2000



Held et al. (2005 PNAS)

- *Rain belt shifts (ITCZ, monsoons) responsible for severe droughts (e.g. Sahelian droughts)*
- *How will rain belts respond to anthropogenic forcing?*
- *Increasing evidence of the magnitude of ITCZ shifts depending on cloud processes*



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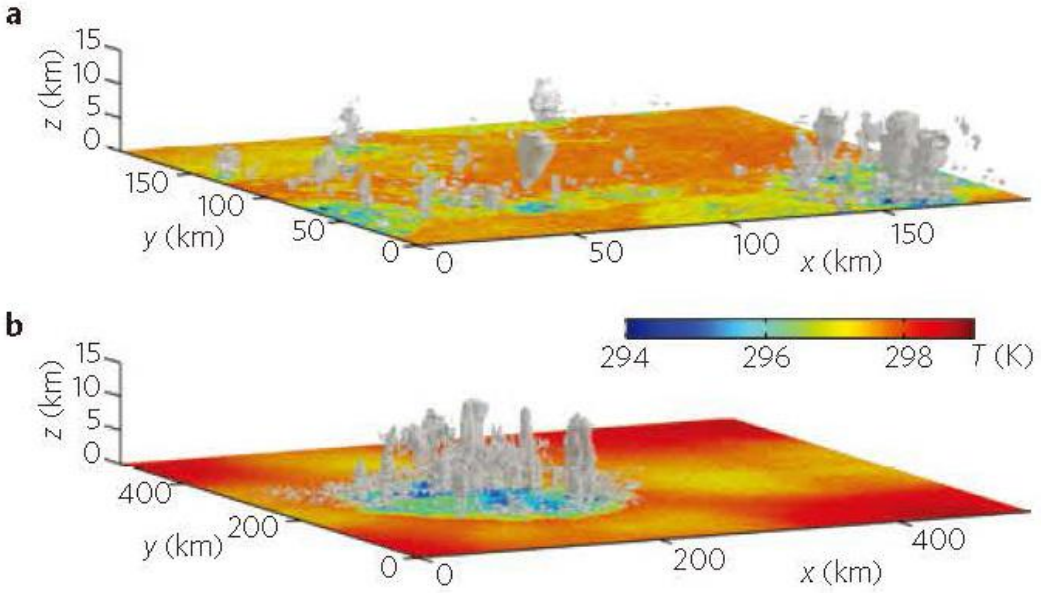
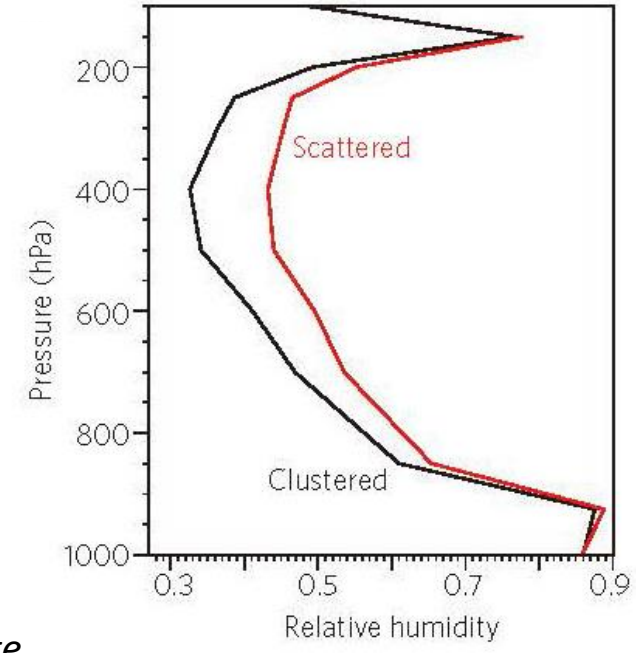


Muller et al. (2012 JAS)

How much does this control the efficiency of radiative cooling?



Tobin et al. (2012 JC)

Even in the absence of external forcing, convection can aggregate spontaneously, perhaps more extensively with increasing temperature

And is giving impulse to other high-profile meetings

1. **GEWEX Open Science Conference, the Hague, July 2015**
2. **The Climate Symposium, Darmstadt, October 2014**
3. **WCRP/IPCC workshop Bern, September, 2014.**
4. EGU Vienna (next week)
5. CliVar ENSO working group (July, 2015) & CliVar OSC (next year, hopefully)
6. Gordon Research Conference (August 2015, Maine).
7. SPARC Workshop on Blocking and Extremes (Spring 2016, Reading).
8. Tropical Cyclone Workshop (joint with Extremes, Fall 2016, NY).
9. HD(CP)^2 High Resolution Climate Modelling (Feb 2016, Berlin)
10. IC***ESM-5***, Hamburg and Royal Society Meeting (on the drawing board for 2017)

… very strong links to extremes, especially through Bony, Sherwood, Shepherd, Sobel.