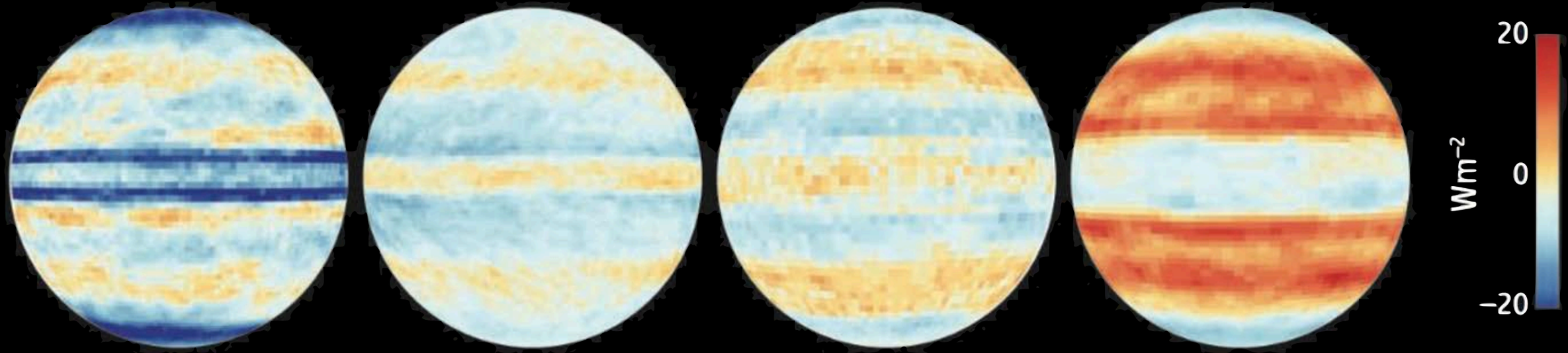
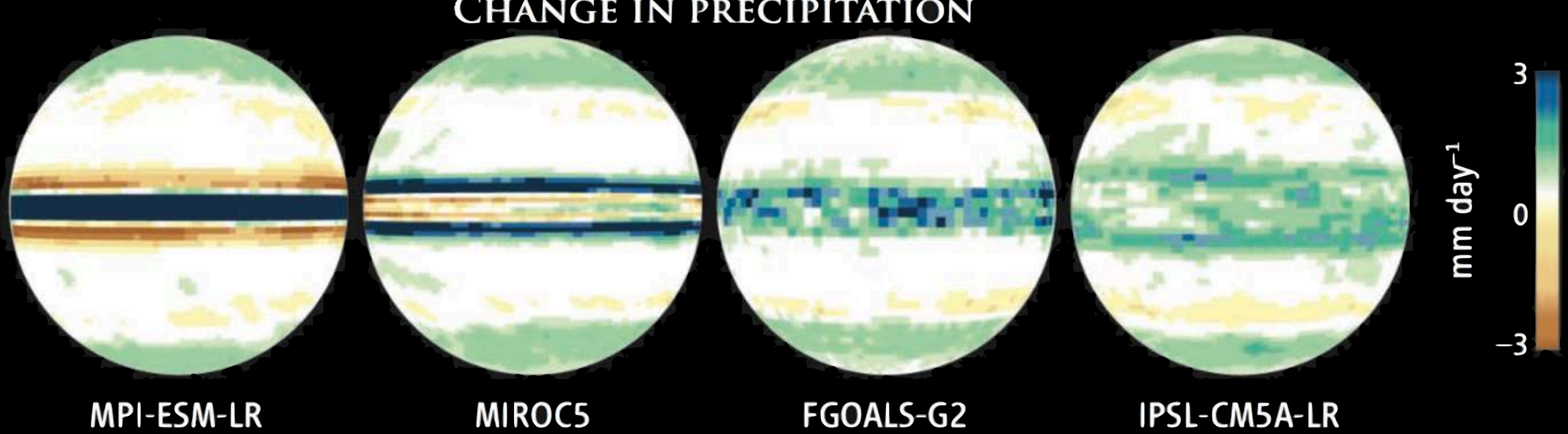
Clouds, Circulation and Climate Sensitivity

Coordinated by: Sandrine Bony (LMD/IPSL) & Bjorn Stevens (MPI)

Change in cloud radiative effects



Change in precipitation



Stevens and Bony, *Science* (2013)

1. **Climate Sensitivity (Temperature & Precipitation)**
   Steven Sherwood (UNSW, Australia) and Mark Webb (Met Office, UK)

2. **Coupling Clouds To Circulation**
   Dargan Frierson (U Washington, US) and Pier Siebesma (KNMI, Netherlands)

3. **Changing Patterns**
   Ted Shepherd (U Reading, UK) and Adam Sobel (Columbia U, US)

A. Leveraging the Past Record
Robert Pincus (NOAA, US) and Masa Kageyama (LSCE/IPSL, France)

B. Towards More Reliable Models
Christian Jakob (U Monash, Australia) and Masahiro Watanabe (U Tokyo, Japan)

Bony and Stevens, *Clouds, Circulation and Climate Sensitivity: How the interactions between clouds, greenhouse gases and aerosols affect temperature and precipitation in a changing climate* White Paper on WCRP Grand Challenge #4 *(2012)*

1. Identify Gaps

- What questions are not being asked?
- Where would more coordination be helpful?

2. Articulate Questions

- And outline what answers might look like
- And empower people to answer them

3. Strengthen Existing Structures

- WGCM; CMIP; CLIVAR; GASS; SPARC; WGSIP

Constraining Hydrological and Climate Sensitivity (Sherwood and Webb)

1. Some Nagging Uncertainties
   - Large range of ECS and Hydrological sensitivity

2. Some Persistent Inconsistencies
   - Strong polar amplification & flat tropics in pliocene (Fedorov et al. 2013, Barriero and Philander 2008)
   - Observations of stronger hydrological sensitivity (Wentz et al. 2007, Durack et al. 2012)
   - Decadal variability larger than interannual in Obs (e.g. Ault et al. 2012)
   - Poleward shift of Hadley Cell under estimated by GCMs (Johansson and Fu 2008, Allen et al. 2012)

How do we constrain the variety of different modelled climate responses?

How do we identify and improve relevant observed behaviours that the models should reproduce but don't?

Six-Point Strategy includes: expanding the range of experimentation, more deeply analyzing models that demonstrate unusual behavior, and systematically explore emerging constraints

1. Climate Sensitivity (Sherwood and Webb)

1. COOKIE (clouds on-off klima intercomparison experiment)

- (CNRM, IPSL, MIROC, MPI, UKMO … NCAR/GFDL/NICAM)

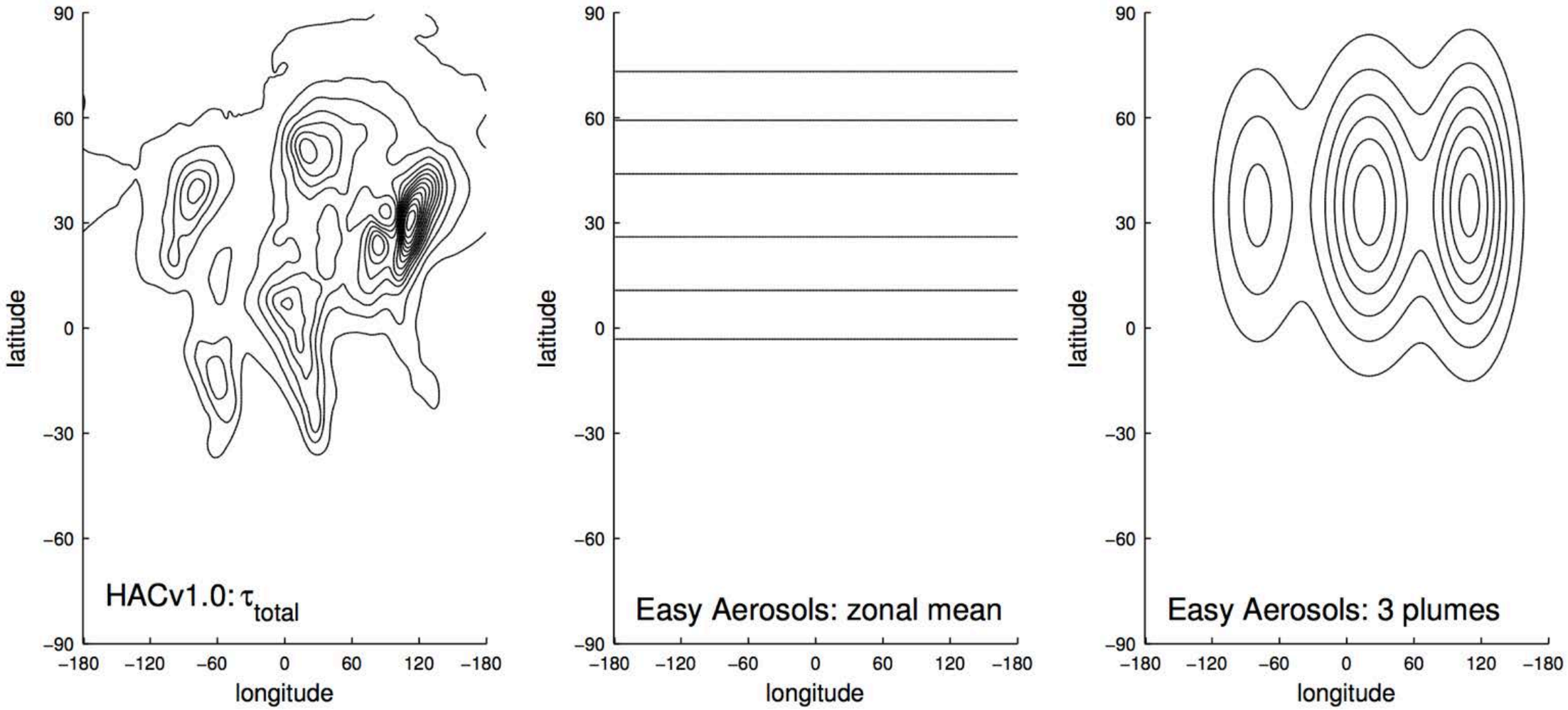
$$Q(z) = Q_{\mathrm{clr}}(z) + \beta Q_{\mathrm{cld}}(z)$$

2. SPOOKIE (selected process on-off klima intercomparison experiment)

- (MIROC, MPI, UKMO, MRI, IPSL?)

Model	Clouds On	Clouds Off
HadGem	0.25	-0.05
MRI	0.10	-0.08
MIROC	-0.22	0.18

2. Changing Patterns (Shepherd and Sobel)



Connecting Atmospheric Dynamics to Clouds, Precipitation and Climate Change … i.e., what is the robust response to the gravest mode of the anthropogenic aerosol signal? *(MPI and IPSL, soon AEROCOM)*

Voigt et al., (2013) in preparation.

3. Coupling Clouds and Circulation (Frierson and Siebesma)

"… we need to articulate science problems - that is, questions about nature, rather than models. One that I like is ***convective self-aggregation***. How do convective clouds organize themselves into large clusters? What physical processes are part of it and how do they work? What suppresses it? What physical phenomena (MJO, tropical cyclogenesis, cloud feedbacks on climate...) are influenced by it?" (Adam Sobel, 2013)

$$Q = Q_0 \left(1 + \alpha \frac{s'}{s_0}\right) \quad \text{and} \quad \mathcal{E} = \mathcal{E}_0 \left(1 + \gamma \frac{s'}{s_0}\right)^{-1}$$

1. GASS–WTG MJO Test Case

- http://www.lists.rdg.ac.uk/mailman/listinfo/met-gasswtg.

2. Also COOKIE and SPOOKIE

3. WGNE-GASS Greyzone Project

Bony and Emanuel, *JAS* (2005)

A. Towards More Reliable Models (Jakob and Watanabe)

"... the grandest challenge in all the grand challenges ... ***improving the energy and water cycles in the models*** … I see little concrete action anywhere to achieve this … The number of papers already pointing out the myriad of things wrong with the CMIP5 models beggars belief and is growing rapidly" (Christian Jakob 2013)

1. Parameterization Development Summer School

- June 2015 in Hamburg
- Every two years thereafter to be hosted by a different modeling center
- Will be based on the host models SCM, but may include other models and TAMIP?

2. Collecting Tools

- SCMs from GASS-WTG
- Diagnostic Packages (e.g., MJO working group, Veronika's work, the Metrics Panel)

3. Focus on Systematic Biases

- Interpreting model biases in terms of dynamical biases (outcome of WGNE workshop)
- Raised as a major issues by centers since the beginning of CMIP
- Has never been sufficiently highlighted nor addressed within CMIP (CFMIP diagnostics)

A. Leveraging the Past Record (Pincus and Kageyama)

1. Observing Networks

- Thinking big (WATER) about the missing empiricism (water and dynamics in atmosphere)
- GC sessions at the EUMETSAT Climate Symposium.
- Multi-scale structure of observational record (a gap).
- Refocusing surface based remote sensing networks around clouds.

2. Modeling the more recent past

- Many past anthropogenic forcings are uncertain.
- CMIP should consider past scenarios (e.g., land-surface changes, and the aerosol).

3. Paleo Modeling

- Involving CFMIP in PMIP (Mark Webb will join) and link to CMIP6
- Involving Paleo community strongly in grand challenge (Abbot, Hargreaves, Harris, Prentice, Risi among others will be at GC workshop in Ringberg)
- Exploring analysis tools of present day to last-glacial maximum to test understanding

Workshop on Clouds, Circulation and Climate Sensitivity

March 24-28, 2014
Schloss Ringberg
3700 Rottach-Egern, Germany

Abbot, Bauer, Biasutti, Bony, Clement, Del Genio, Douville, Emanuel, Frierson, Hargreaves, Harrison, Held, Hoskins, Jakob, Kageyama, Kang, Kawai, Klein, Loeb, Mapes, Mauritsen, Miller, Muller, Pincus, Prentice, Risi, Satoh, Schumacher, Seifert, Shepherd, Sherwood, Siebesma, Sobel, Stevens, Watanabe, Webb, Wielicki, Yoshimori, Zuidema

All participants confirmed.

Grand Challenge Presentations and Discussions

- Universities of Leeds and Reading (February, UK)
- WGNE Meeting (April, Exeter)
- ISCCP 30th Birthday (April, New York)
- EUCLIPSE Annual Meeting (June, Hamburg)
- CLIVAR Meeting (May, Kiehl)
- EUCLIPSE Summer School (June, Les Houches)
- AEROCOM Meeting (September, Hamburg)
- GEWEX Water Vapor Assessment Workhop (October, Ft. Collins)

- Chicheley Hall Meeting (November, London)
- SPARC Meeting (November?, New Zealand)
- Lorenz Center (February, MIT)
- Ringberg Workshop (March, Ringberg)
- CFMIP Meeting (July, Holland)
- Pan GEWEX/CliVAR meeting (July, Delft)
- EUMETSAT Climate Syposium (October, Darmstadt)

High Profile Publications

1. GC White Paper, and a fairly descriptive website (http://www.wcrp-climate.org/index.php/gc-clouds) hosted by WCRP.
2. Bony, S., et al. (2013). Carbon Dioxide and Climate: Perspectives on a Scientific Assessment. In J.W. Hurrell & G.Asrar (Eds.), *Monograph on Climate Science for Serving Society: Research, Modelling and Prediction Priorities*, Berlin: Springer.
3. Stevens, B., & Bony, S. (2013a). What Are Climate Models Missing? *Science*, **340**, 1053–1054.
4. Stevens, B., & Bony, S. (2013b) Water in the atmosphere. *Physics Today*, **66**(6), 29–34. doi: 10.1063/PT.3.2009

5. News and Views planned for *Nature* in October
6. A Model development essay (Jakob et al., 2013) and a number of high-profile review/synthesis papers, and a version of the GC white paper for the peer reviewed literature are in preparation.

Water in the atmosphere

Bjorn Stevens and Sandrine Bony

Much of what we know, and even more of what we don't know, about Earth's climate and its propensity to change is rooted in the interplay between water, air circulation, and temperature.

Every schoolchild learns about the role of the atmosphere in Earth's water cycle. But few get the chance to learn about water's role in determining the properties of the atmosphere. Water determines not only how the Sun's energy is partitioned through the atmosphere and across Earth's surface but also the character of the large-scale circulations, which that energy drives. Recognition of the fundamental influence of water even predates formal scientific thinking. In the Judeo-Christian creation myth, for instance, one of the creator's first tasks, after separating darkness from light, was to separate water from water to create the sky.

That water assumes such a defining place in the sky is remarkable given that it only accounts for 0.25% of the total mass of the atmosphere. That's the equivalent of a liquid layer only 2.5 cm deep, barely enough to make a global puddle, distributed through the atmosphere almost entirely (99.5%) in the form of vapor. By way of comparison, the global ocean, if spread uniformly over Earth's surface, would have an average depth of about 2.8 km. Fresh water on Earth's terrestrial surface—ice sheets, lakes, rivers, wetlands, and soils—is 2000 to 3000 times more abundant than atmospheric water. No matter how you look at it, being suspended in the atmosphere is an exceedingly unlikely state for a water molecule to find itself in; but while in that state, water makes a world of difference.

An absorption virtuoso

Water stands out because of its physical and radiative properties. As figure 1 shows, it is a small molecule with a large appetite for IR radiation. The water molecule is endowed with a plethora of rotational absorption modes, which result from the tumbling of its strong electric dipole around three small and disparate moments of inertia. These modes contribute to a rich set of spectral lines that stretch from the near-IR into the microwave. Some of them arise because the rotational modes ornament three vibrational modes that form the fundamental rotational–vibrational (ro-vibrational) bands. One, $\lambda_2 = 6.3$ μm, is associated with H-O-H bending; the other two, λ_1 and λ_3, associated with symmetric and asymmetric stretching, are located near 2.7 μm and overlap with an overtone of the bending mode.

Bjorn Stevens directs the Max Planck Institute for Meteorology in Hamburg, Germany, and **Sandrine Bony** is a CNRS senior scientist at the Laboratoire de Météorologie Dynamique in Paris.

ERIK CHRISTENSEN, PORKERI

- It has been an exciting and active year in which many initiatives have been started, individuals have been recruited and a great deal of awareness has been raised.

- We will use the Ringberg meeting to identify ***those few*** key questions that should be incorporated into CMIP6.

- **For Input**
  - An additional cross-cutting activity on training the next generation? (Les Houches, Schools – planned for 2016; Idea Repository).
  - Are there specific model biases that we should prioritize?
  - Are modelling centers interested in participating in model development schools?