Constraining Hydrological and Climate Sensitivities

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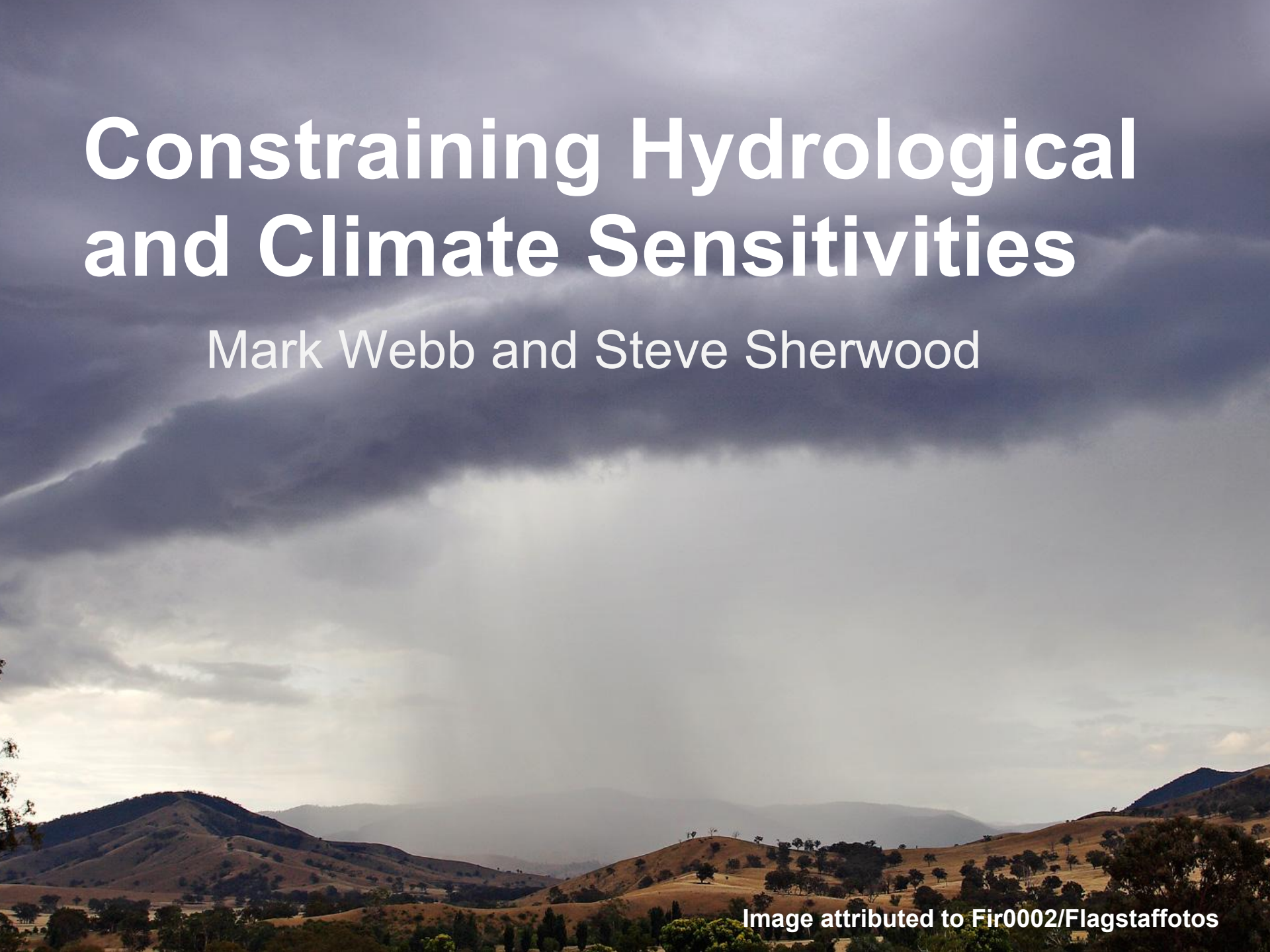

Image attributed to Fir0002/Flagstaffotos

Problem A: Climate models show a persistent range of global and regional temperature and precipitation responses to CO_2 forcing.

E.g. multi-model climate sensitivity estimates:

FAR slab	1990	1.9-5.2K (3.3)
SAR/CMIP1 slab	1995	2.1-4.6K (2.5)
TAR/CMIP2 slab	2001	2.2-5.1K (2.9)
AR4/CMIP3 slab	2007	2.1-4.4K (2.3)
AR5/CMIP5 coupled	2012	2.1-4.7K (2.6)

Problem B: Inconsistencies between observed and modelled phenomena - are discrepancies due to GCM clouds/convection/hydrological cycle, or observational error/variability?

- Strong polar amplification and flat Tropical temperatures in early Pliocene (Fedorov et al. 2013, Barriero and Philander 2008)
- Recent observational estimates suggesting stronger hydrological cycle intensification than in models (Wentz et al. 2007, Durack et al. 2012)
- Decadal variability of T, rain, drought stronger than interannual in obs but not in GCMs (e.g. Ault et al. 2012)
- Poleward shifts of general circulation underestimated by GCMs (Johansson and Fu 2008, Allen et al. 2012)

Initiative #1 Constraining Hydrological and Climate Sensitivities*

Purpose: To more effectively constrain large-scale temperature and precipitation responses in climate models to external forcings.

Strategy: Understand better the different model responses in regional cloud, temperature and precipitation to CO_2 forcing, and develop targeted tests to constrain them.

* Note that we are using climate sensitivity as shorthand for the impact of cloud responses on ECS, TCR and the hydrological cycle via feedbacks and adjustments

Science questions

1. What are the physical mechanisms underlying robust model responses and inter-model differences?
2. Could unexpected phenomena suggested by observations, such as extreme polar amplification in pre-Quaternary climates, be explained by missing cloud feedbacks?
3. Are unusual low-cloud feedbacks seen in some GCMs credible?
4. Are strong cirrus cloud feedbacks likely? By what mechanism?
5. What processes (large-scale dynamics, microphysics, convection, boundary layer, ...) are crucial to get cloud feedback right?
6. Can a rigorous physical basis be developed for "model weighting" to narrow prediction uncertainty?
7. ...

Strategy options

1. Improve/ease efforts to test candidate mechanisms across model hierarchies and against observations:
   a. Promote hypothesis testing through sensitivity tests
   b. Infrastructure/coordination through GASS/CFMIP?
2. Find ways of "opening up" the model space other than perturbed parameter and ensemble of opportunity
3. Expand CGILS and related approaches e.g. RCE
4. Encourage wider provision of process-related quantities in models (e.g. tendencies, simulators in CFMIP)
5. Focus on understanding unusual but potentially credible model responses
6. Attempt model convergence/simplification by switching off various processes in turn - e.g. shallow convection
7. Seek more "emergent constraints", establish their robustness and test physical mechanisms
8. ...

Hypothesis-based research

We should also encourage basic research into understanding observed climate phenomena - e.g. by developing and rigorously testing physical hypotheses, for example using model sensitivity experiments

e.g. FAT/PHAT, longwave/shortwave cancellation in deep convective areas, hemispheric albedo symmetry, ...

When models reproduce these, what can we do to break them?

This is good practice in any case but it may help to relate model responses to observations

Gaps

Better bridges between the process based cloud/hydrological cycle community and:

- Observational community
- Palaeo community
- Energy Balance Modellers
- Detection and Attribution community
- Statistical/Synthesis community
- ....

What's next?

Discussion!

Sharpen strategy for initiative #1 - refine what is currently in the white paper based on suggestions made here and between now and GC workshop in March 2014

Discussions/break out groups on moving specific activities forward at next CFMIP meeting (Summer 2014)

Acknowledgements:

Thanks to Sandrine, Bjorn and the many people in the WCRP, CFMIP, WGNE and Emergent Constraints communities who have already contributed ideas. Please keep them coming.

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"If we are facing in the right direction, all we have to do is keep on walking." *Buddhist Proverb*

Supplementary slides

Opportunities

An inter-connected cloud research community with existing strategies and tools - e.g. CFMIP, GASS, observing communities

CMIP, CFMIP, CGILS, COOKIE

A 'golden age' of modern Earth observations and growing paleaoclimate archive

High resolution modelling (LES, CRM, SP)