From Models to Data

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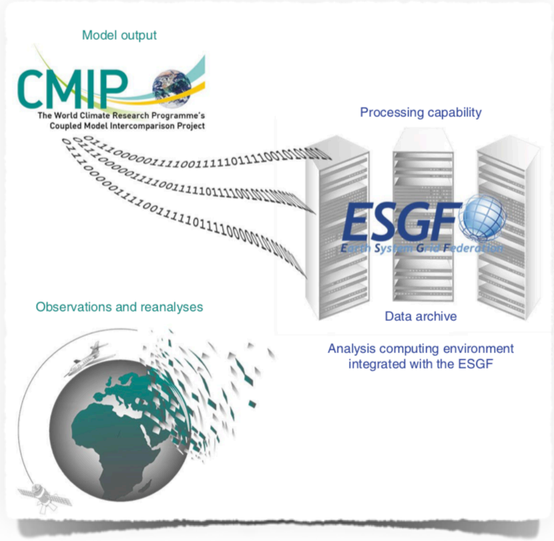
The narrative



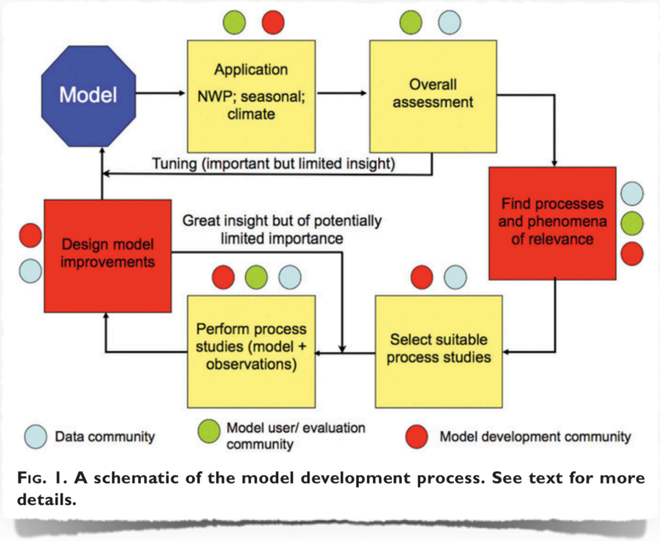
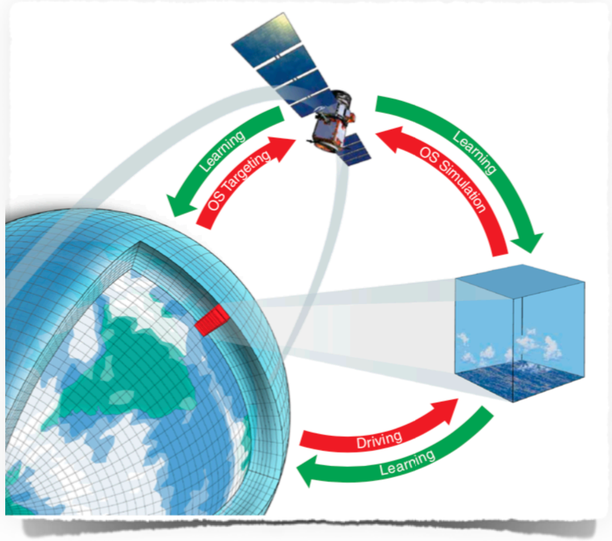


FIG. 1. A schematic of the model development process. See text for more details.



Eyring et al., *Nature Climate Change* 2019, Jakob *BAMS* 2010, Schneider et al., *GRL* (2018)

Working Hypothesis:

Data, in the form of new observations, or more precisely measured parameters, has become irrelevant for the Climate (& NWP) Modeling enterprise.

So why measure?

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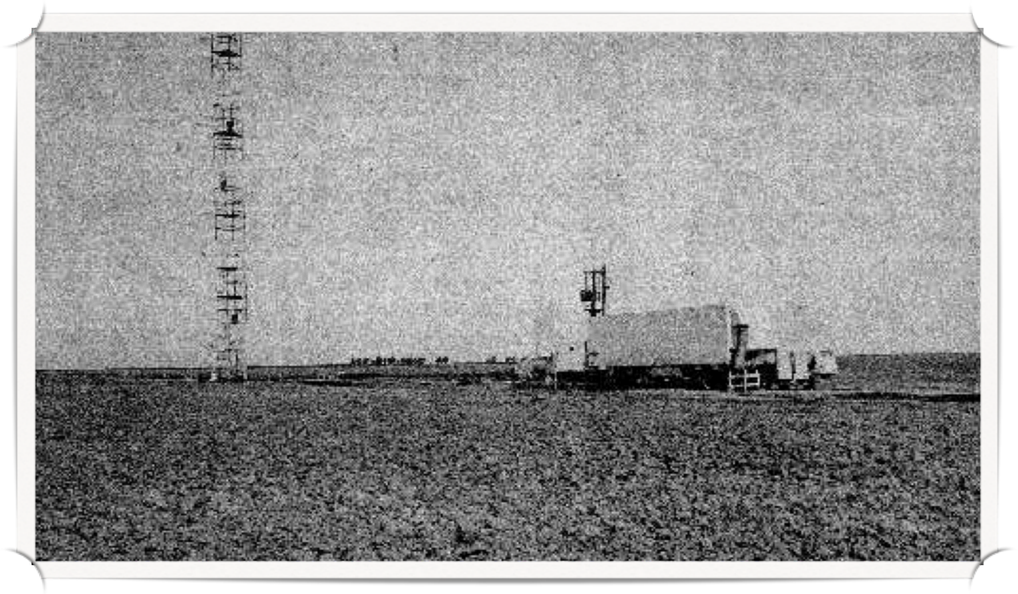
It wasn't always like this … the 1965, 66 and 68 Kansas Experiment



The GEWEX Cloud System Study

TABLE 1. Past and future field experiments addressing cloud system problems (not exhaustive).

ALPEX	Alpine Experiment
AMEX	Australian Monsoon Experiment
AMTEX	Air Mass Transformation Experiment
ARM	Atmospheric Radiation Measurement
ASTEX	Atlantic Stratocumulus Transformation Experiment
ATEX	Atlantic Trade Wind Experiment
BASE	Beaufort and Arctic Storm Experiment
BOMEX	Barbados Oceanographic Meteorological Experiment
BOREAS	Boreal Ecosystems Atmosphere Study
CASP	Canadian Atlantic Storms Project
CLEOPATRA	Cloud Experiment Oberpfaffenhofen and Transports
COPT	Convection Profonde Tropicale
EMEX	Equatorial Mesoscale Experiment
EUCREX	European Cirrus Experiment
FIRE	First ISCCP Regional Experiment
FRONTS	A series of frontal observing programs mainly involving U.K. and France
GATE	(Global Atmospheric Research Program) Atlantic Tropical Experiment
GCIP	GEWEX Continental International Project
ICE	International Cirrus Experiment
JASIN	Joint Air–Sea Interaction Experiment
KONTROL	Convection and Roll Vortices Experiment
KONTUR	Convection and Turbulence Experiment
MCTEX	Maritime Continent Thunderstorm Experiment
SMONEX	Summer Monsoon Experiment
STORM	Stormscale Operational and Research Meteorology
STREX	Storm Transfer and Response Experiment
TAMEX	Taiwan Area Mesoscale Experiment
TOGA COARE	TOGA Coupled Ocean–Atmosphere Response Experiment
WAMFLEX	Wave and Momentum Flux Experiment
WMONEX	Winter Monsoon Experiment

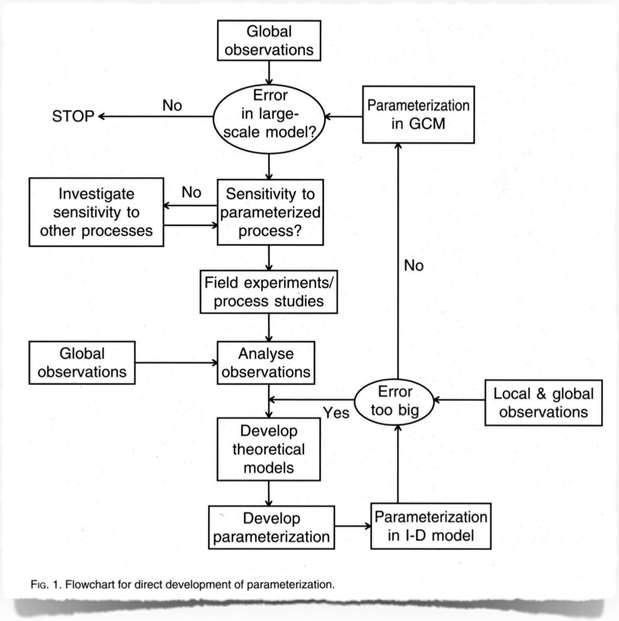


FIG. 1. Flowchart for direct development of parameterization.

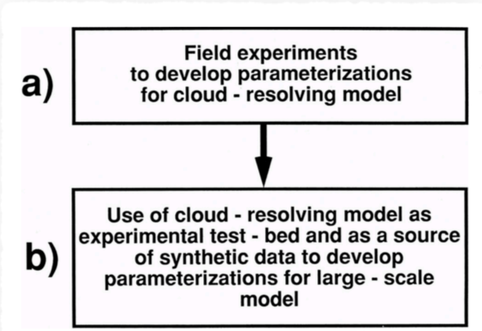


FIG. 2. Cloud-resolving models: a) derivation, b) use.

Browning et al., BAMS (1993)

… it's due to differences in entrainment.

TABLE 4. The averaged growth rate of the cloud-top height during the second hour of simulation.

LES	Averaged dz_i/dt (cm s^{-1})
KNMI	1.68
UOK	1.37
UMIST	0.94
NCAR	0.906
UKMO	0.856
CSU	0.686
UW	0.512
MPI	0.441
WVU	0.278
ARAP	0.236

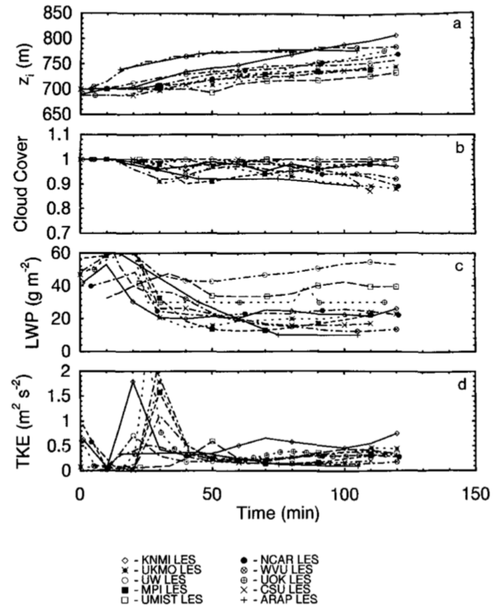
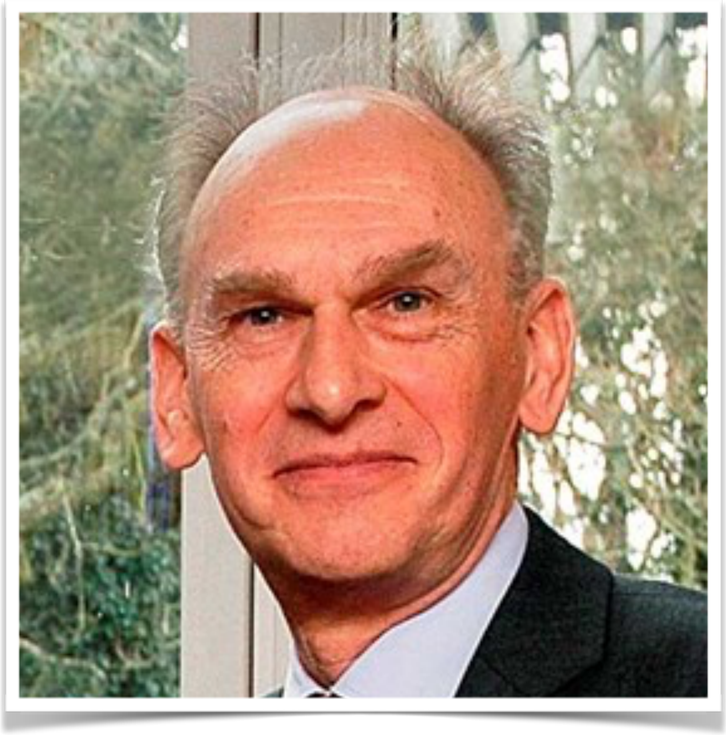
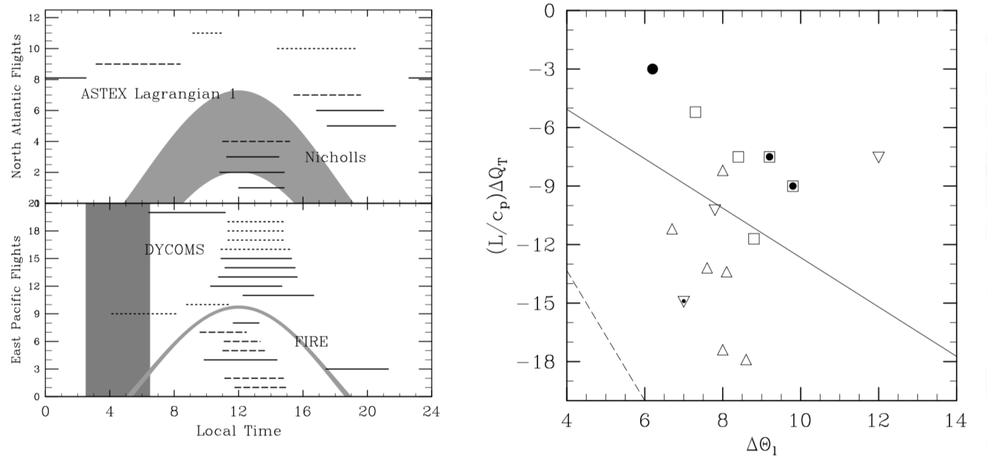


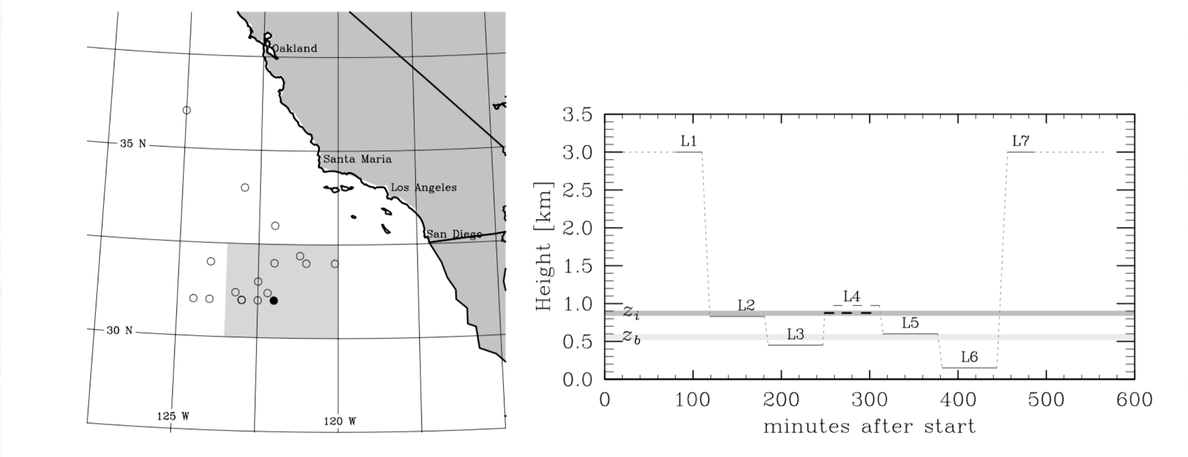
FIG. 3. Time evolution of (a) horizontally averaged cloud-top height, (b) fractional cloud cover, (c) liquid water path, and (d) TKE averaged over the whole PBL from the 10 LES simulations.



Moeng et al., *BAMS* (1996)

DYCOMS-II (the proposal)





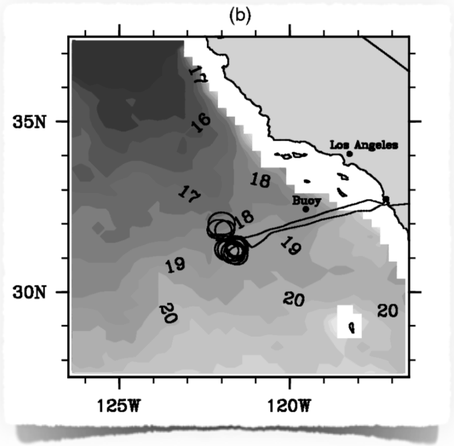
4 Proposed research

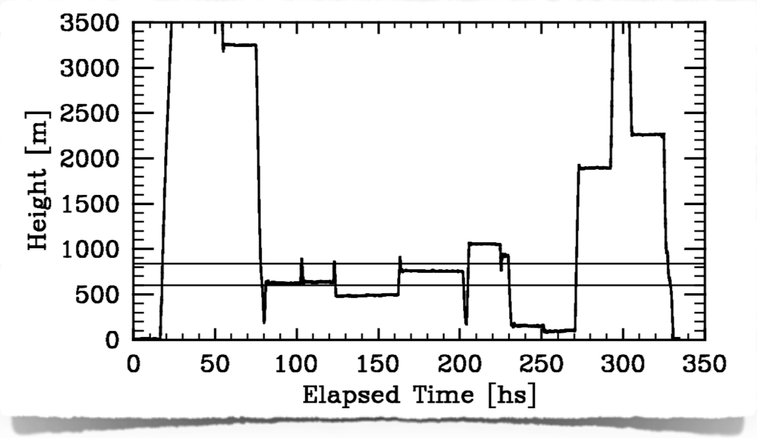
Given the background as reviewed above, a program tailor-designed to testing LES of the nocturnal STBL is proposed. The program has three components: data collection, analysis, and simulation. Each is discussed separately below.

a. The field program – DYCOMS-II

Because stratocumulus are known to have a climatological peak in precipitation in the early morning hours and because remote sensing within the cloud fields (i.e., by a cloud radar) would significantly complement the remote sensing of the cloud boundaries using SABL and the in situ measurements, we are actively pursuing collaborations with cloud radar groups. Bruce Albrecht of the University of Miami has recently developed a cloud radar which he has tested on a helicopter and has already agreed to come to our workshop;

DYCOMS-II (the measurements)





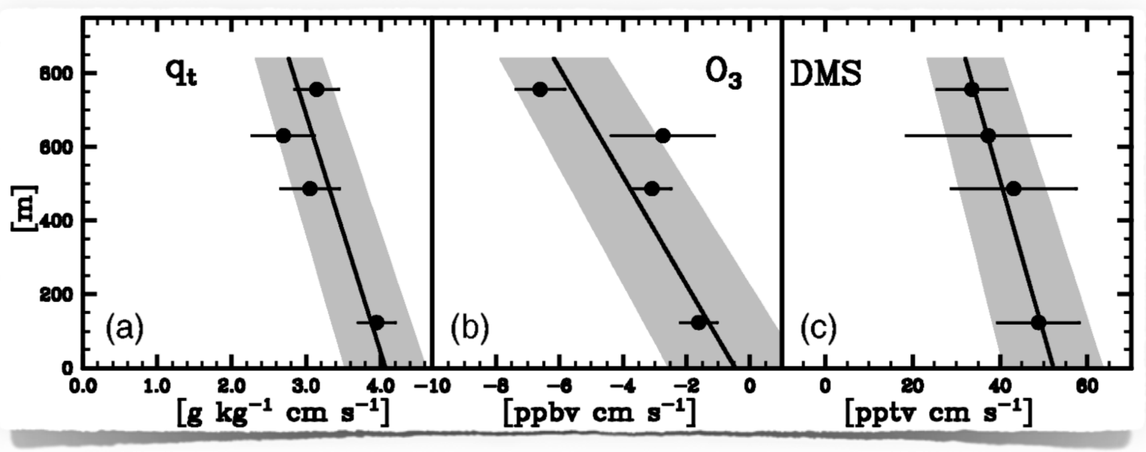


TABLE 2. ENTRAINMENT VELOCITY ESTIMATES

Method	Estimate (cm s^{-1})
q_t budget	0.34 ± 0.11
s_l budget	0.46 ± 0.08
q_t cloud-top flux	0.37 ± 0.06
O_3 cloud-top flux	0.27 ± 0.09
DMS cloud-top flux	0.53 ± 0.11
Weighted average	0.39 ± 0.04

See text for explanation of symbols.

Stevens et al., QRRMS (2003)

DYCOMS-II (the modelling)

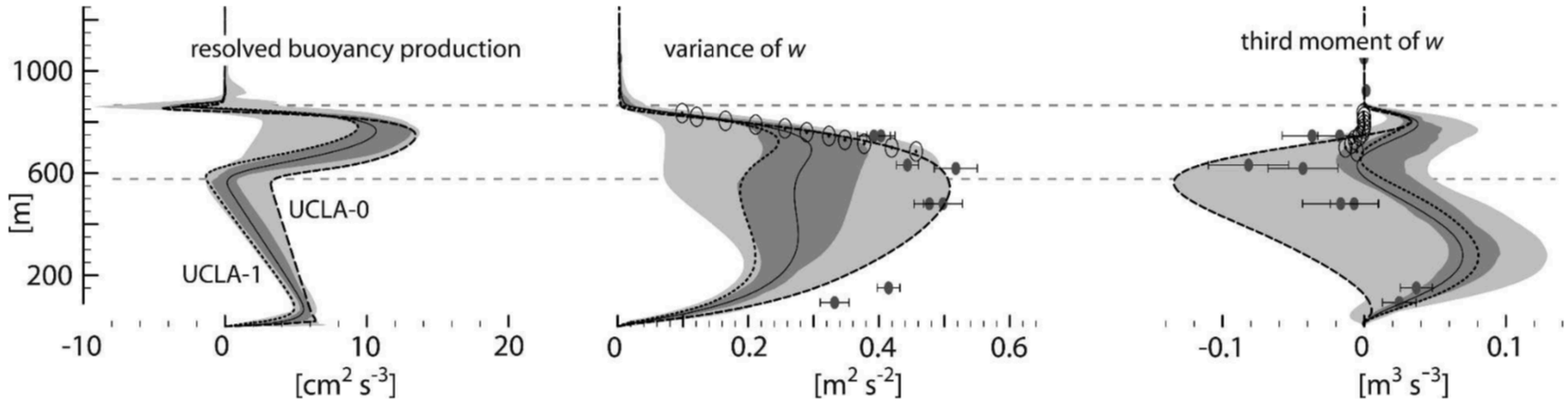
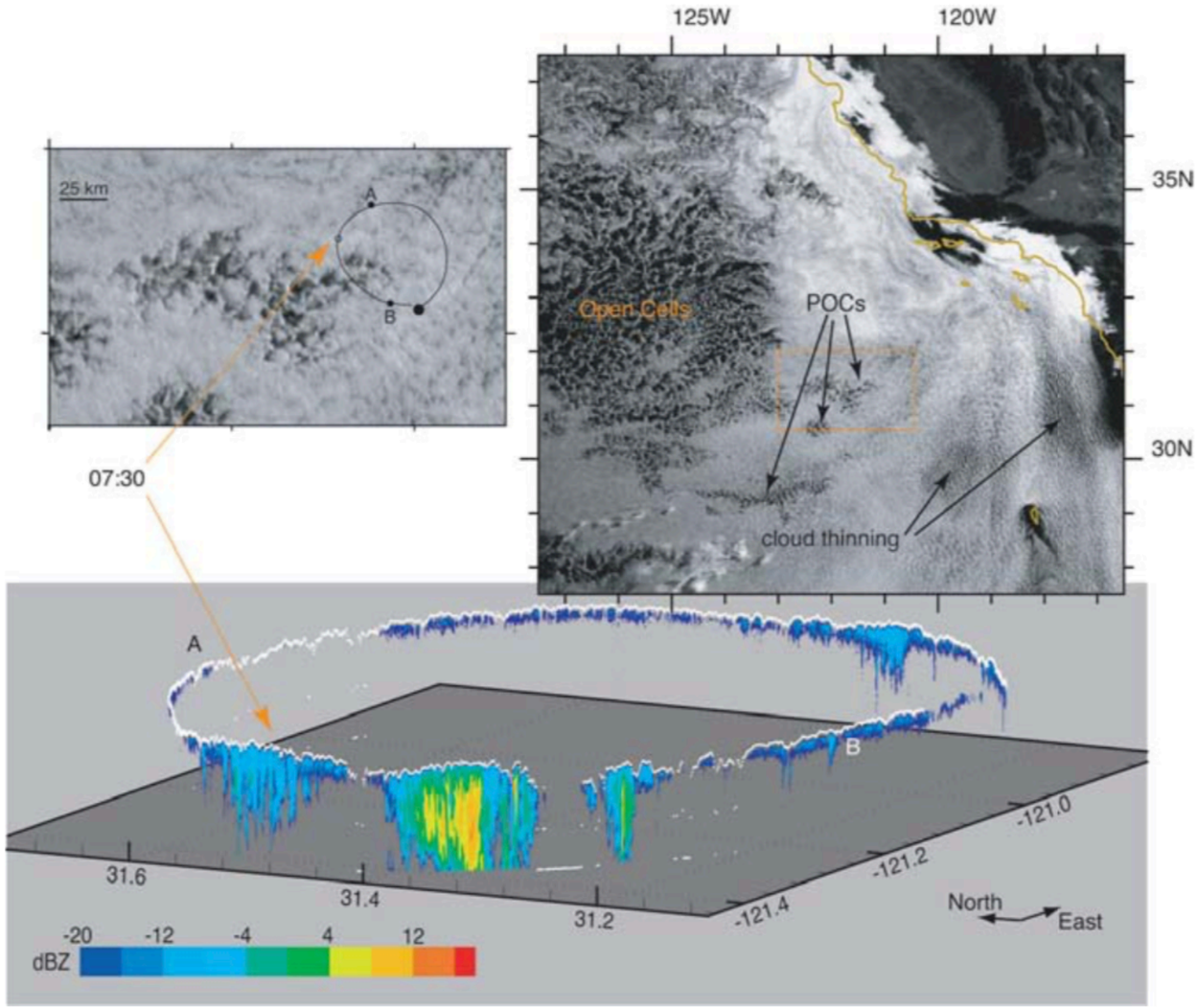


FIG. 5. Profile of vertical velocity statistics—(left) resolved buoyancy production, (middle) variance of w, and (right) third moment of w—from master ensemble averaged over the fourth hour. Markers indicate estimates of vertical velocity second and third moments as derived from in situ (solid with bar) and radar (circle–dot). Details of data analysis provided by Stevens et al. (2003a). As labeled in the left panel, the dashed lines are two simulations drawn from the master ensemble: UCLA-0 (long dash) and UCLA-1 (short dash). Horizontal dashed lines delimit cloud area. The shading is as in Fig. 2 and as described in the text.

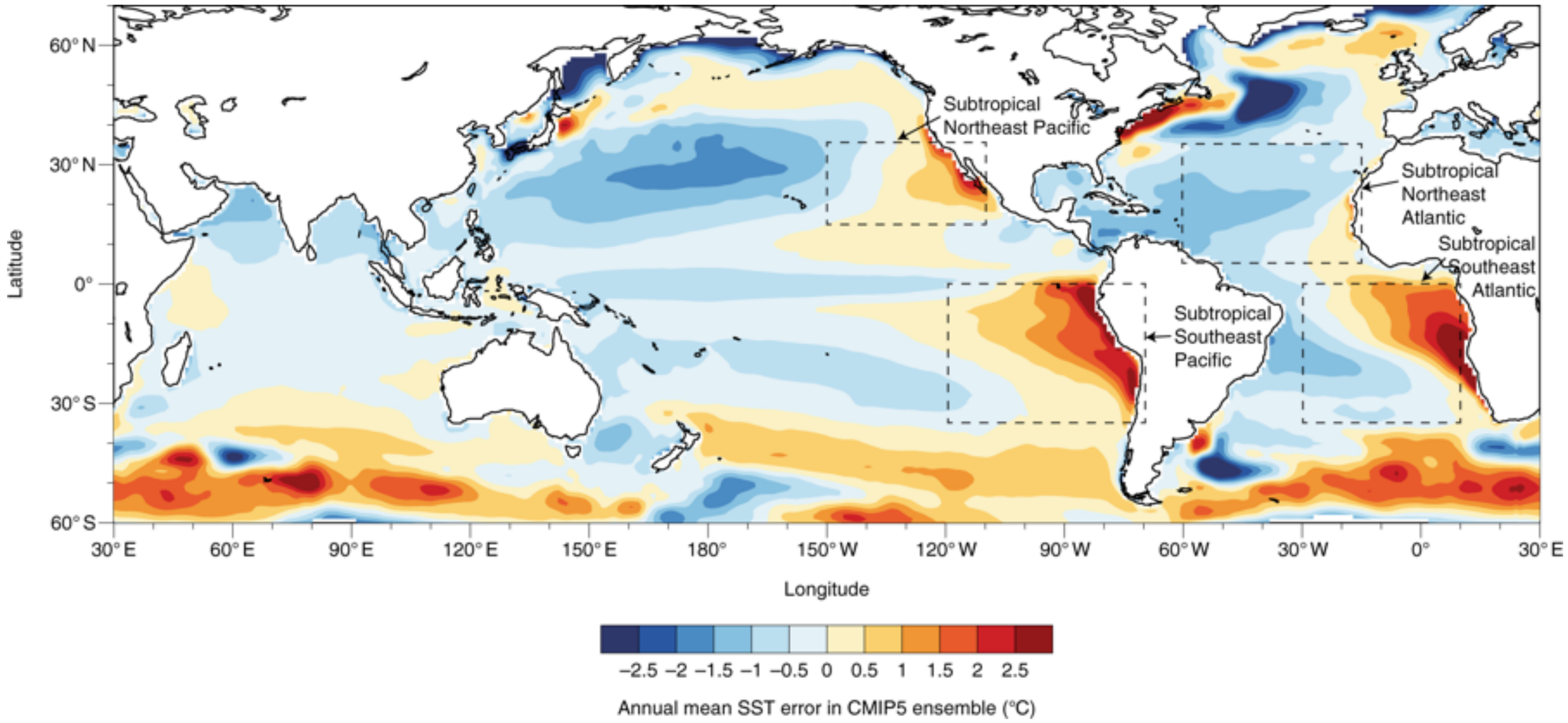
Stevens et al., Mon. Wea. Rev. (2005)

DYCOMS-II (the bonus)



Stevens et al., BAMS (2005)

DYCOMS-II (the difference)

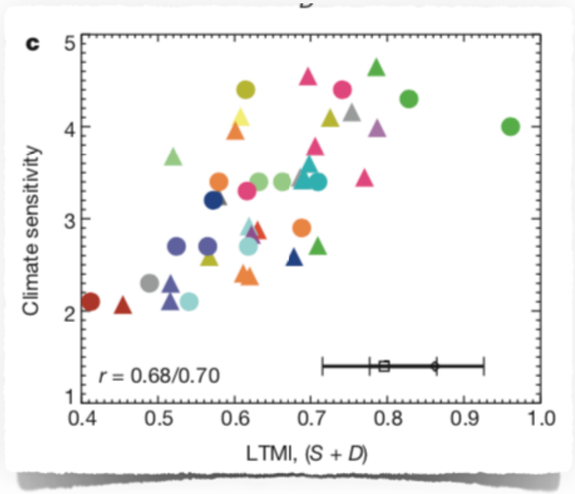


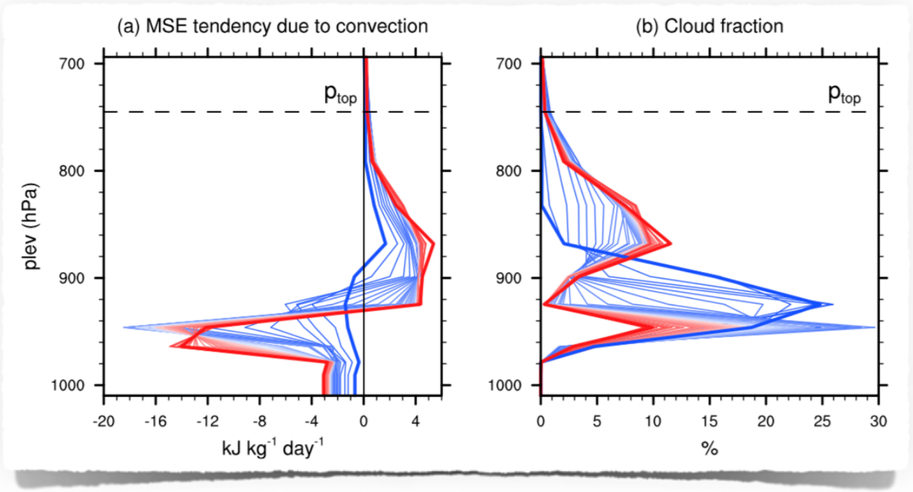
Eyring et al., *Nature Climate Change*, (2019)

Remarks

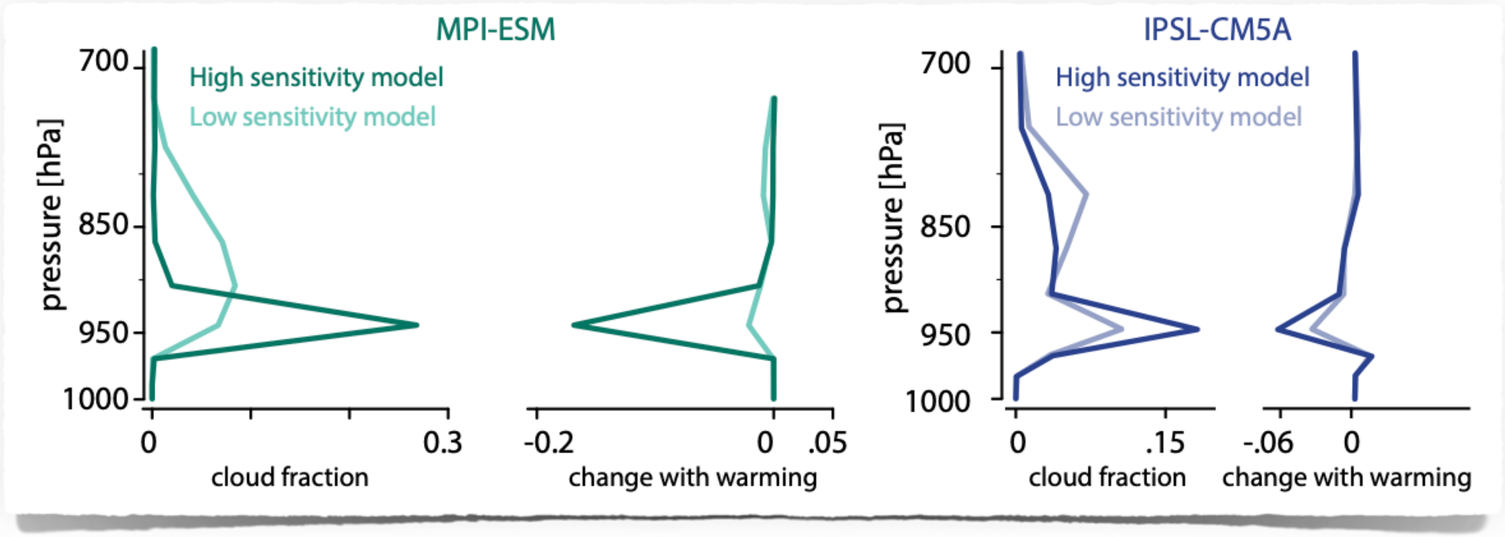
- DYCOMS-II emerged out of modelling … and like the Kansas experiment benefitted from repetition.
- Structurally the large-scale models proved ill suited to incorporate advances in understanding, but process level models were well attuned to the measurements.
- As a result DYCOMS-II measurements advanced understanding, and set the foundation for improved process models. They remain the benchmark for every LES of stratocumulus, to the present day.
- In the process our minds were opened to new ideas, and new methods were developed which influence field studies to this day.

EUREC⁴A another example



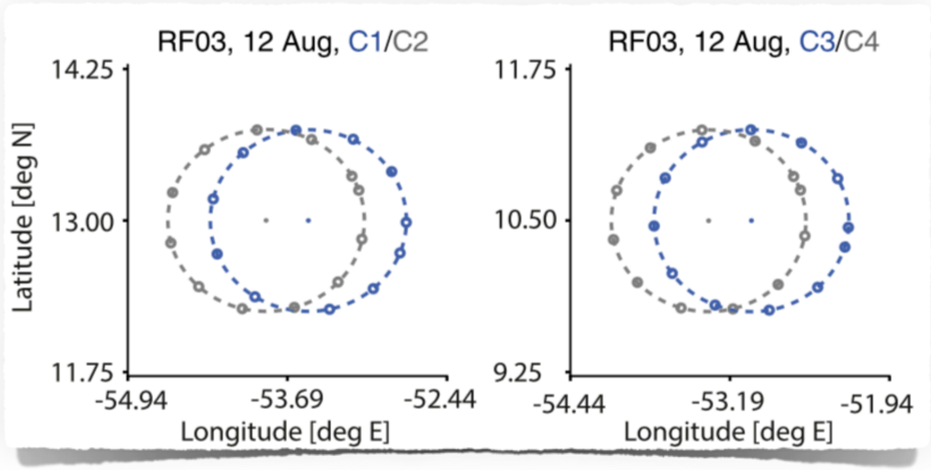


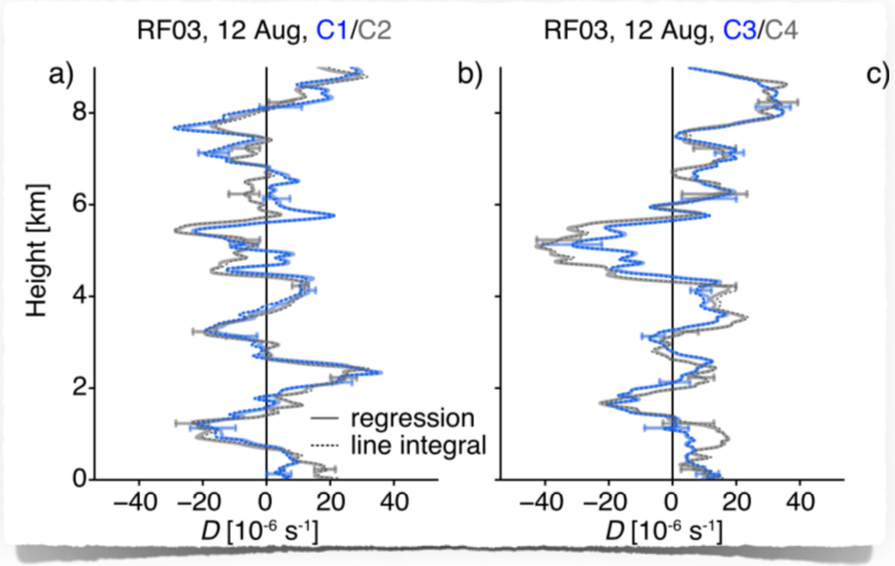
Starting from the physical hypothesis that the low cloud feedback in models is driven by a sensitivity they imply between convective mixing and the sub-cloud layer structure.



Sherwood et al., *Nature* (2014), Vial et al., *J. Adv. Mod. Earth Syst.* (2018), Stevens et al., *BAMS* (2016)

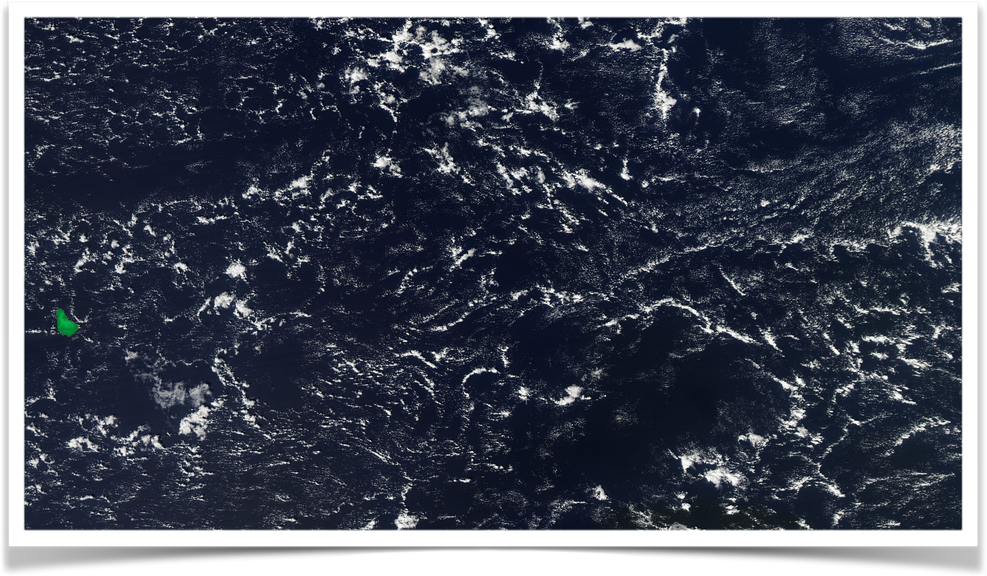
Testing of new measurement methods during NARVAL2



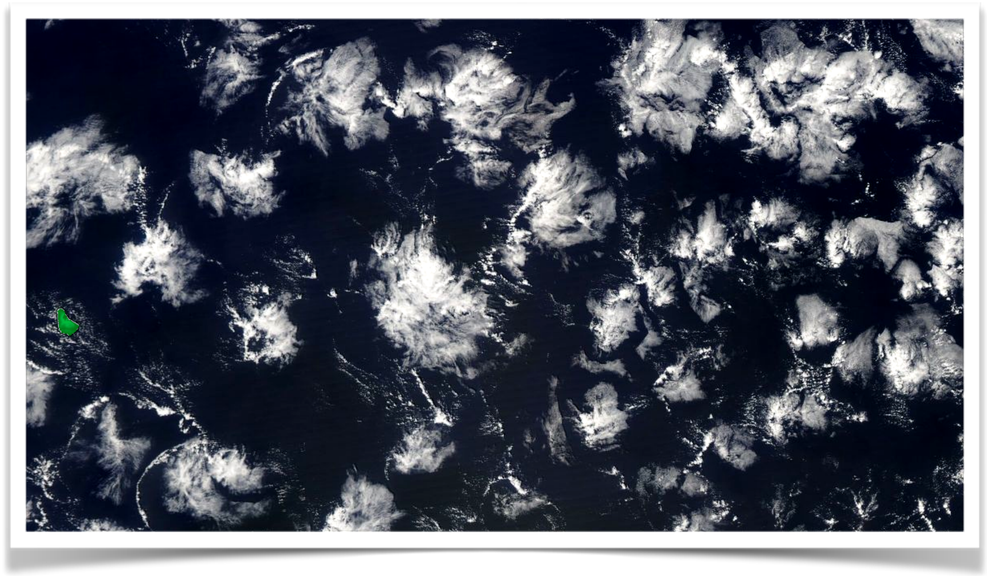


Bony and Stevens, *J Atmos. Sci* (2019)

New insights already emerging well before the field campaign



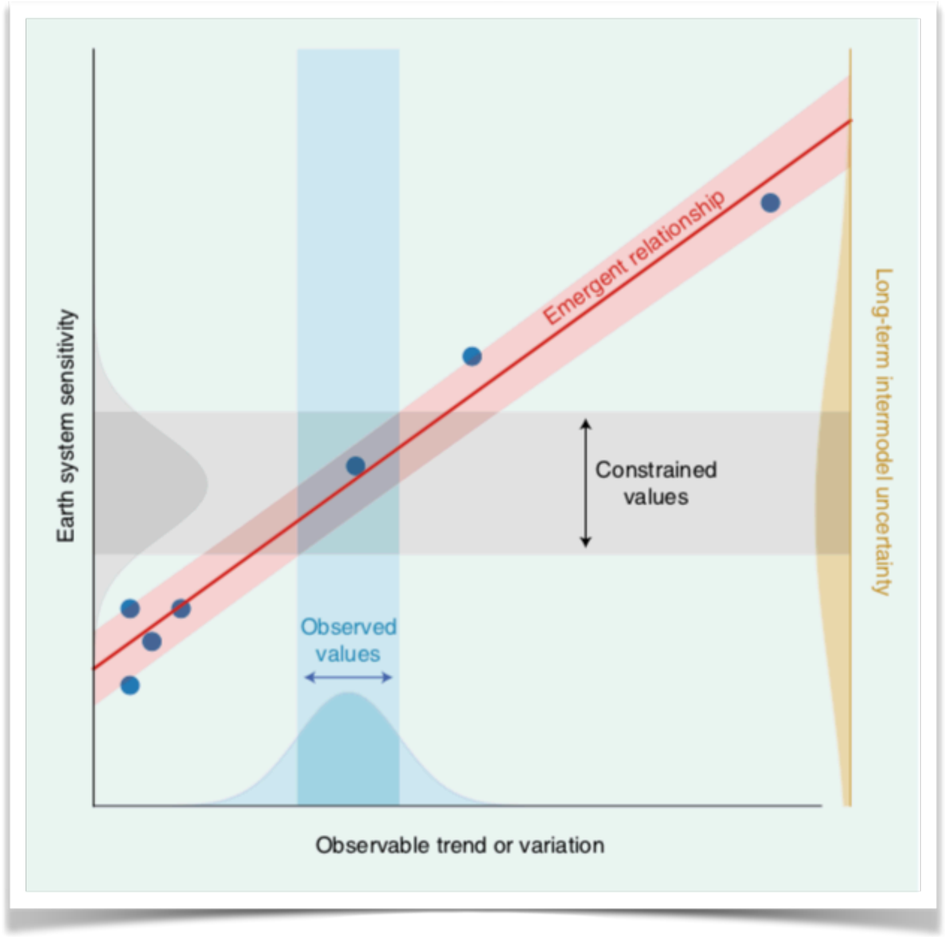
Gravel



Flowers

Stevens, Bony et al,QJRMS (2019)

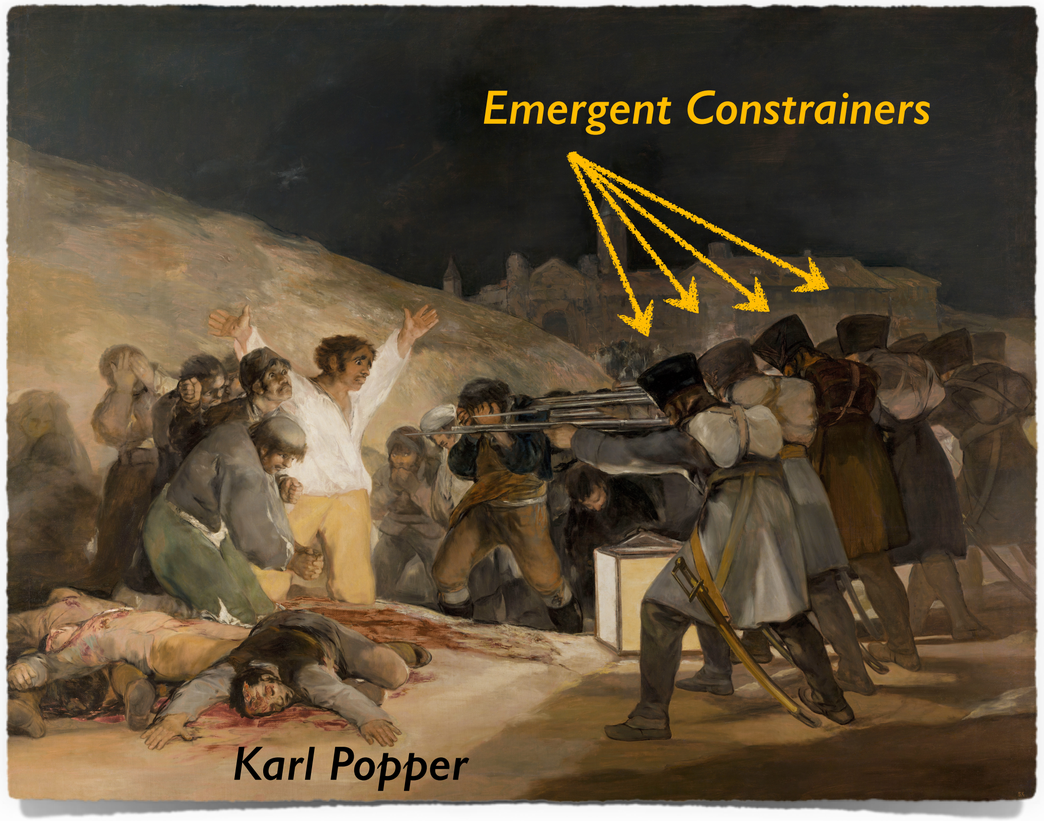
Emergent Constraints?



New life for observations in the Earth System?

1. Measurements
2. Relationship (model)
3. Physical Hypothesis

'Emergent Constraints' … the counter revolution



What I've been advocating is the other way around

1. Physical Relationship
2. Relationship (model)
3. Measurements

its more about ideas.

Conclusions

- The traditional narrative as to how models and observations link together is not a compelling one.
- In most cases emergent constraints are a parody of the scientific practice
- Measurements can be motivated by ritual/tradition, nostalgia, or rebellion.
- Rebellion is the most compelling motivation
  - resist the hegemony of global modelling
  - subordinate models to measurements
  - reassert the value of understanding
- Measurements associated with big ideas often develop through iteration
- In almost every measurement campaign I have been involved, nature introduces me to new ideas in ways that models rarely do.

Most importantly measurements need modelers, but this involves changing the culture of modelling so as to emphasize ideas rather than prediction.