Met Office
Hadley Centre

The Future of Climate Modelling

with a lot of help from others including
Paul Selwood, Jonathan Gregory, Mike Cullen, Helene Hewitt, Michael Vellinga, Roger Saunders, Chris Folland, Chris Jones, Malcolm Roberts, Mike Rezner….

John Mitchell, MetOffice Hadley Centre

Ron Stouffer Symposium, 6 th June 2016

Setting the scene- whats changed over Ron's career? Then (late 1970's to present?)

Climate sensitivity
1.5 -4.5 (NAS 1979)

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Climate sensitivity 1.5 -4.5 (NAS 1979)

Drivers

Then

Science largely curiosity driven

Now

More user pull(especially IPCC)

Drivers

Then

Science largely curiosity driven

Now

More user pull(especially IPCC)

Then

Simple idealised experiments ($2xCO_2$)

Now

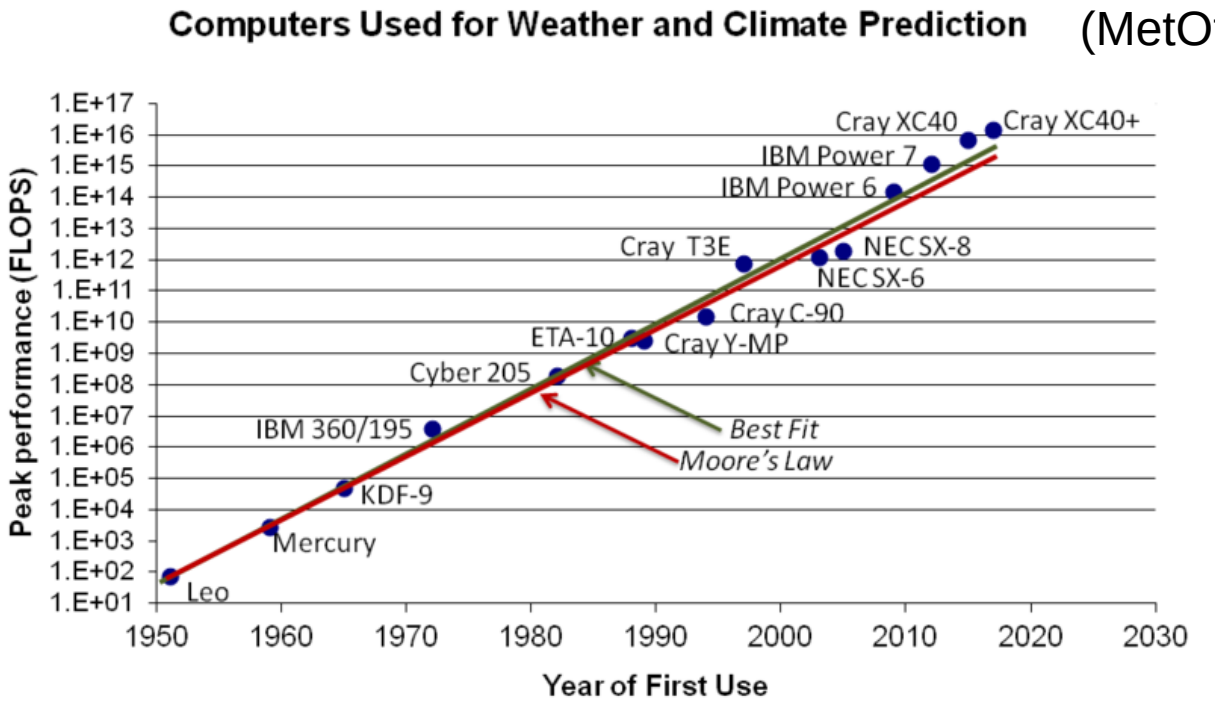
Idealised and complex experiments

“realistic” past,140 years, palaeo,

IPCC scenarios….

Computing

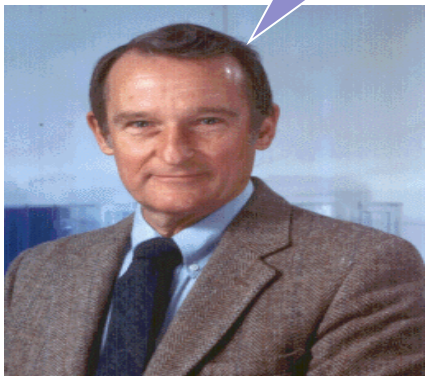
Then- 10MFlops (peak) **Now** PFlops



(MetOffice)

Whence Computer Architecture from 1970s?

If you were ploughing a field, which would you prefer? Two strong oxen or 1024 chickens?



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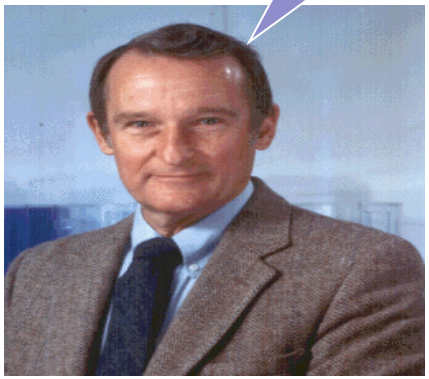


Froms 70s to present the chickens won

From Paul Selwood

Number of Centres/Models

Then

GFDL,NCAR,GISS,OSU, MetOff, (MPI, BMRC)

Now

60 models in 26 institutes (CMIP5)

Resolution

Then

Atmosphere ~500km, 9 layers

Now

Atmosphere ~ 200–100km, 40-50 layers

Ocean ~ 1^0, ~40 layers

Then

Single simulations with a single model

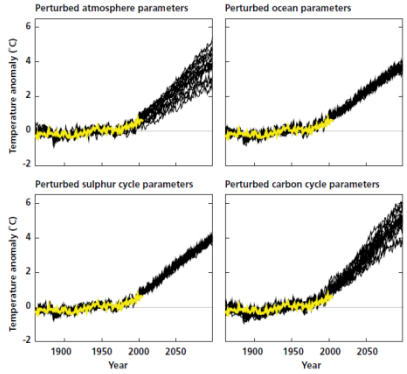
Then

Single simulations with a single model

Now

Multiple simulations , with multiple models

17



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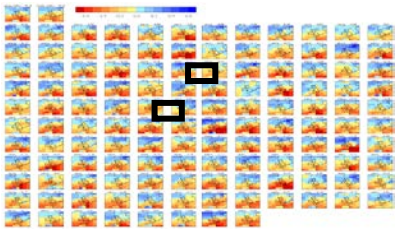
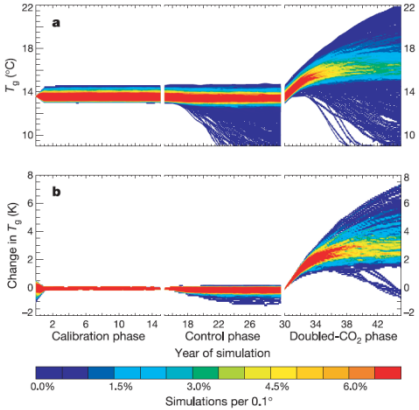
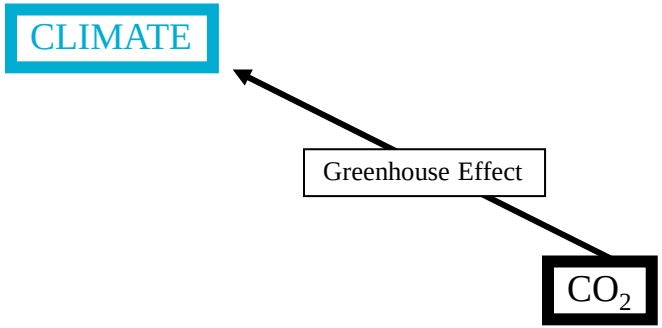




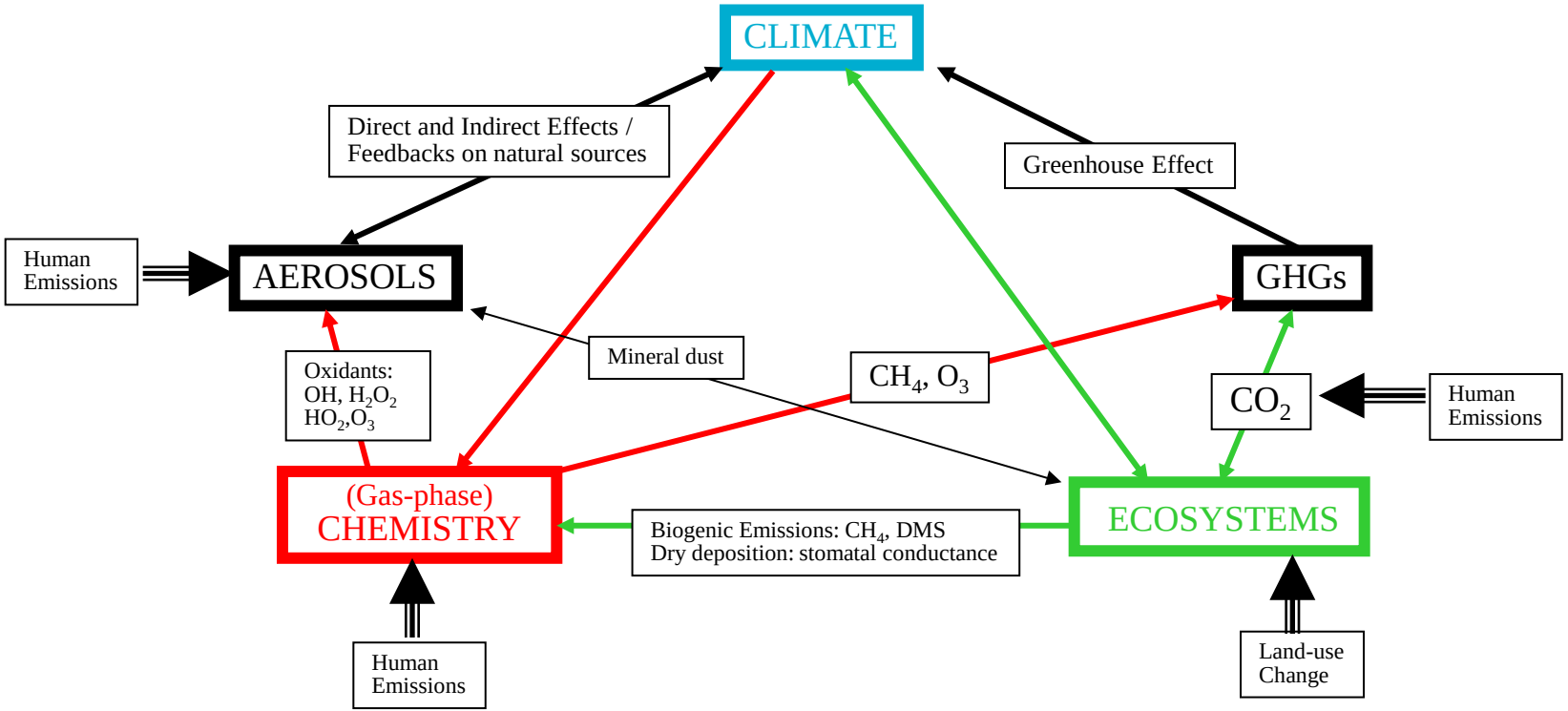
~2000

Stainforth et al, 2005

Complexity **Then**



Complexity **Now** (HadGEM2)



Then

Centres worked largely in isolation, held on to data

No standardization of expts, diagnostics, formats

(Evaluating models for the first IPCC assessment was a nightmare)

Then

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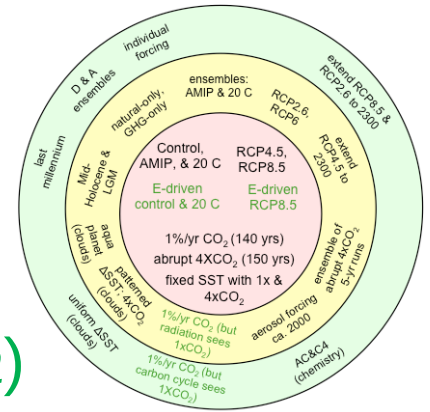
Now

Co-ordination, sharing of data by CMIP etc

Standardized expts, diagnostics, formats

(*26 groups 2323 papers 330Kyrs 2Pb data*)



Stats from Karl Taylor)

Observations

Then

Sparse surface temperature record

Only 20 years of radio sonde data, CO2 data

Start of sateillite record

CLIMAP 1976, CoHMAP started 1970s

Observations

Then

Sparse surface temperature record

Only 20 years of radio sonde data, CO2 data

Start of sateillite record

CLIMAP 1976, CoHMAP started 1970s

Now

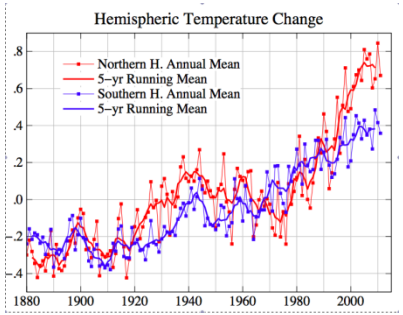
140 years of record with uncertainty estimates

60 years RS data, 40 years sat data

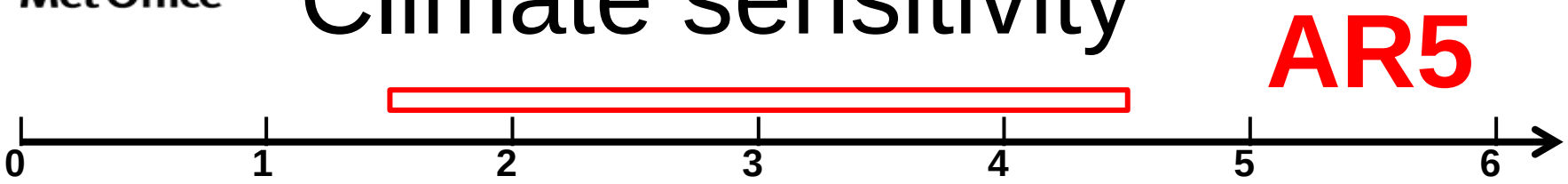
Sateillite derived quantities

Data assimilation, reanalyses

ARGO floats



NOW
Climate sensitivity



(Some things don’t change…)

NOW
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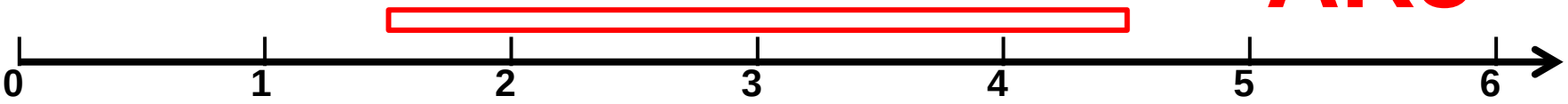


(Some things don't change…)

Ron

Me

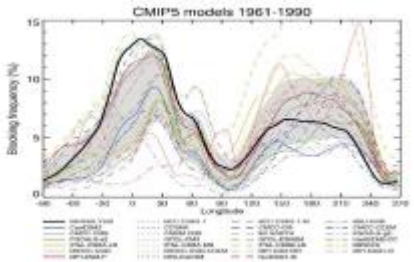
(and some do!)

The future…?

Drivers- Scientific Curiosity

Understanding natural variability

The recent “pause” - and earlier ones
Seasonal+ forecasting-
Why is mid-latitude predictability underestimated in models?



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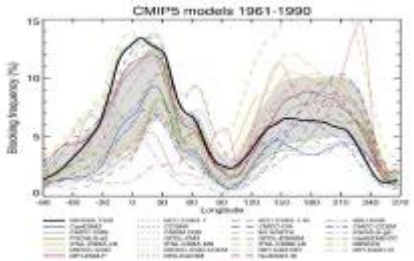

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& Dynamical aspects of climate change

Underpins regional climate, extreme events

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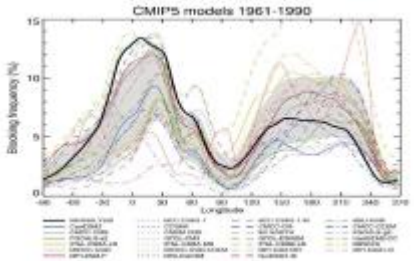

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Drivers – IPCC

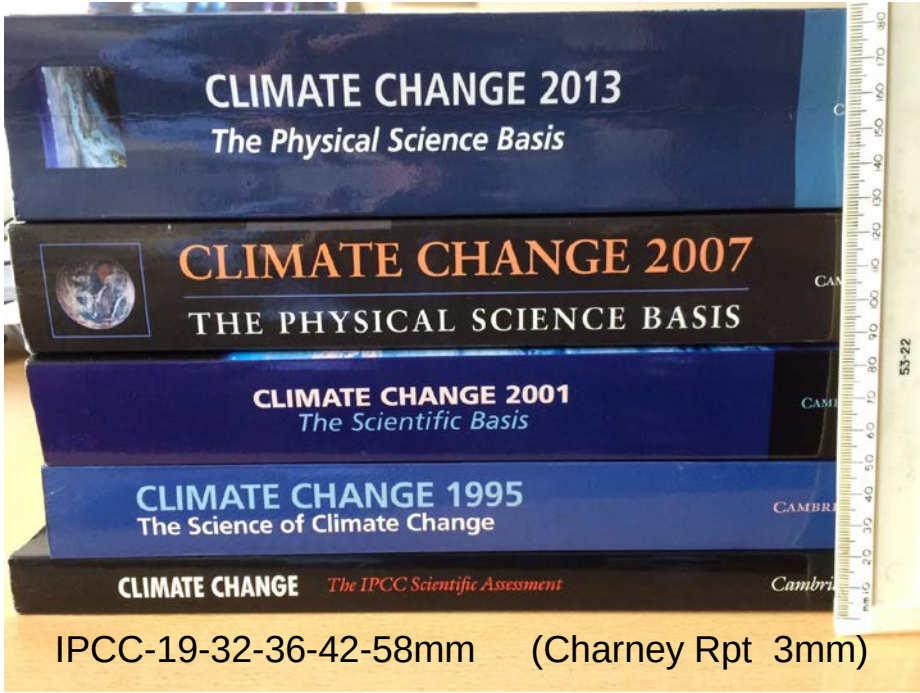
How will it continue to evolve?

Dangers

More not always better

Author fatigue- loss of interest

6 year cycle- short circuits model development



IPCC-19-32-36-42-58mm (Charney Rpt 3mm)

Drivers – IPCC

How will it continue to evolve?

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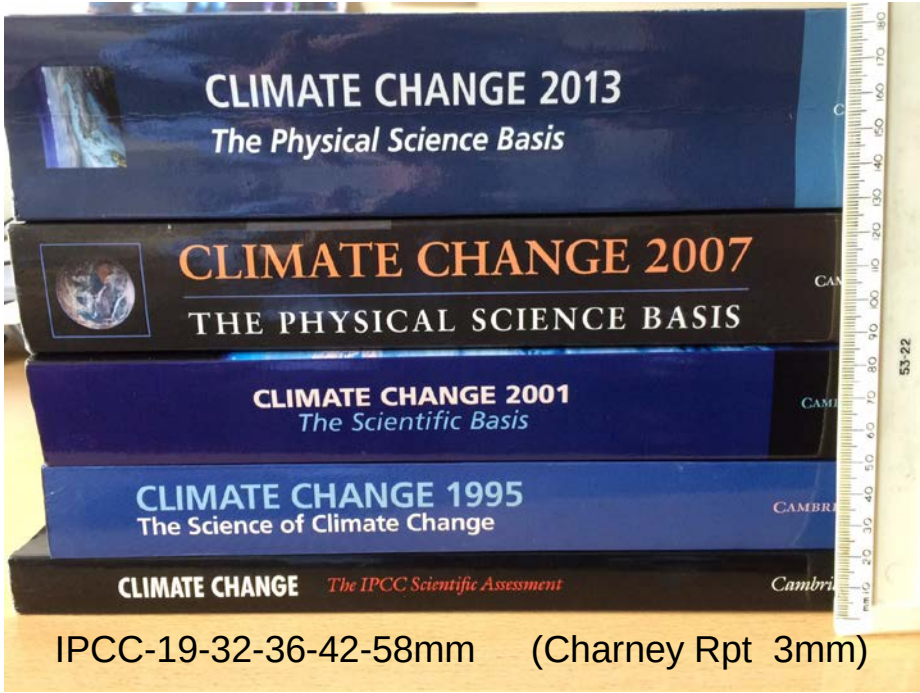
and possible responses?

-Concentrate on a few specific questions set in the synthesis report (rather than ape a textbook?)

-Enforce page limits (and not cite everything?)

-Assess, not review?



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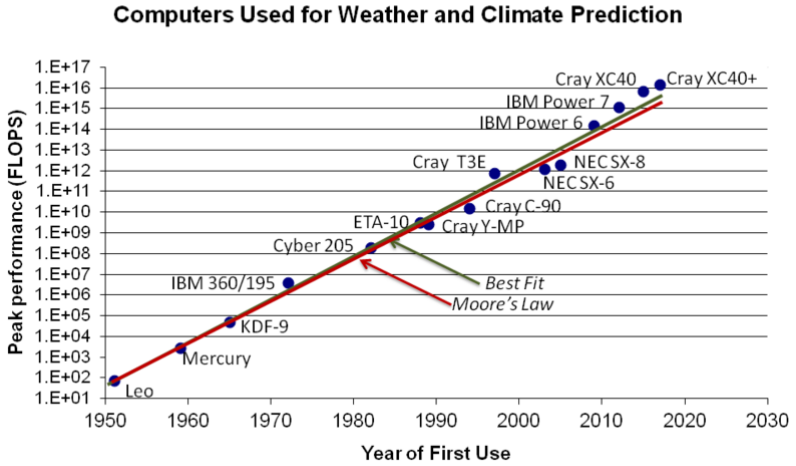
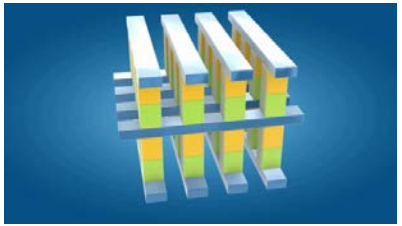
Computing

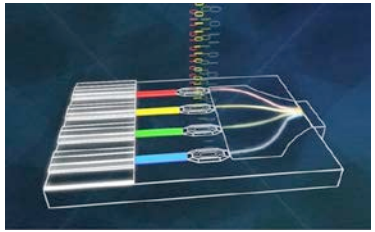
Can Moore's "law" be sustained?



Computer Architecture

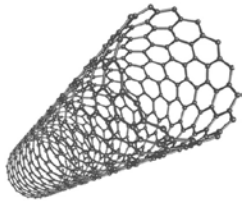


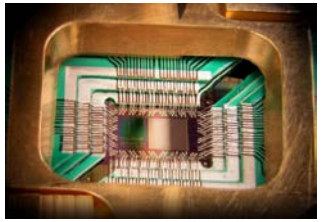
Memory-
3D cross
point



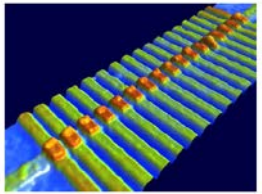
Silicon
photonics

Carbon
nanotubes





Quantum
computing



Biological
/analogue

From Paul Selwood

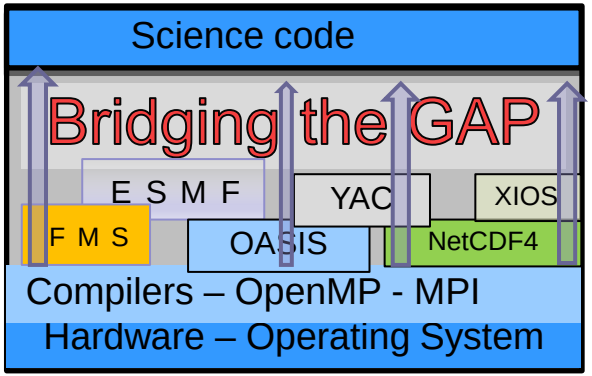
Thousands of Canaries or Millions of Bees?

Other computing related aspects

Earth System Modelling Standards

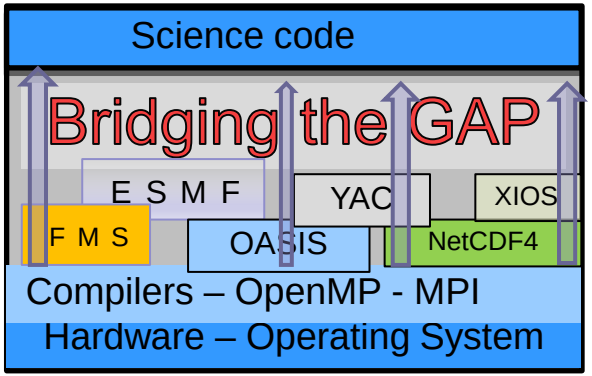
Need to bridge the gap between

Science ⟺ Compilers and hardware



Adapted from Mike Rezner

Other computing related aspects



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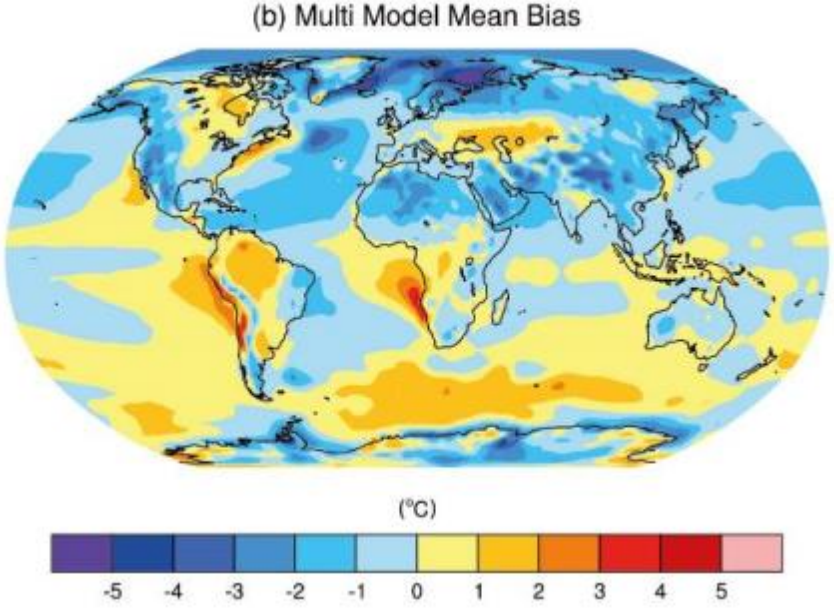
Earth System Modelling Standards

Need to bridge the gap between

Science ⇔ Compilers and hardware

- New numerical algorithms
- Maths- Better understanding of equations

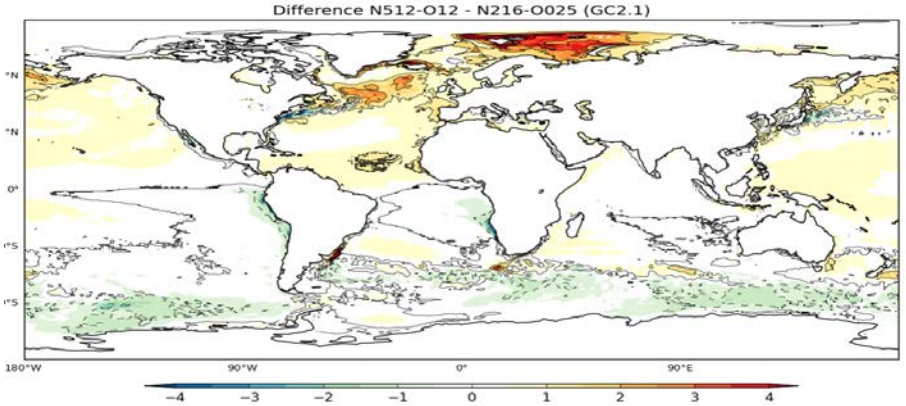
Impact of resolution: Systematic errors



AR5, Flato , Marotzke et al

SST change

25km $1/12^0$ minus 60km $1/4^0$

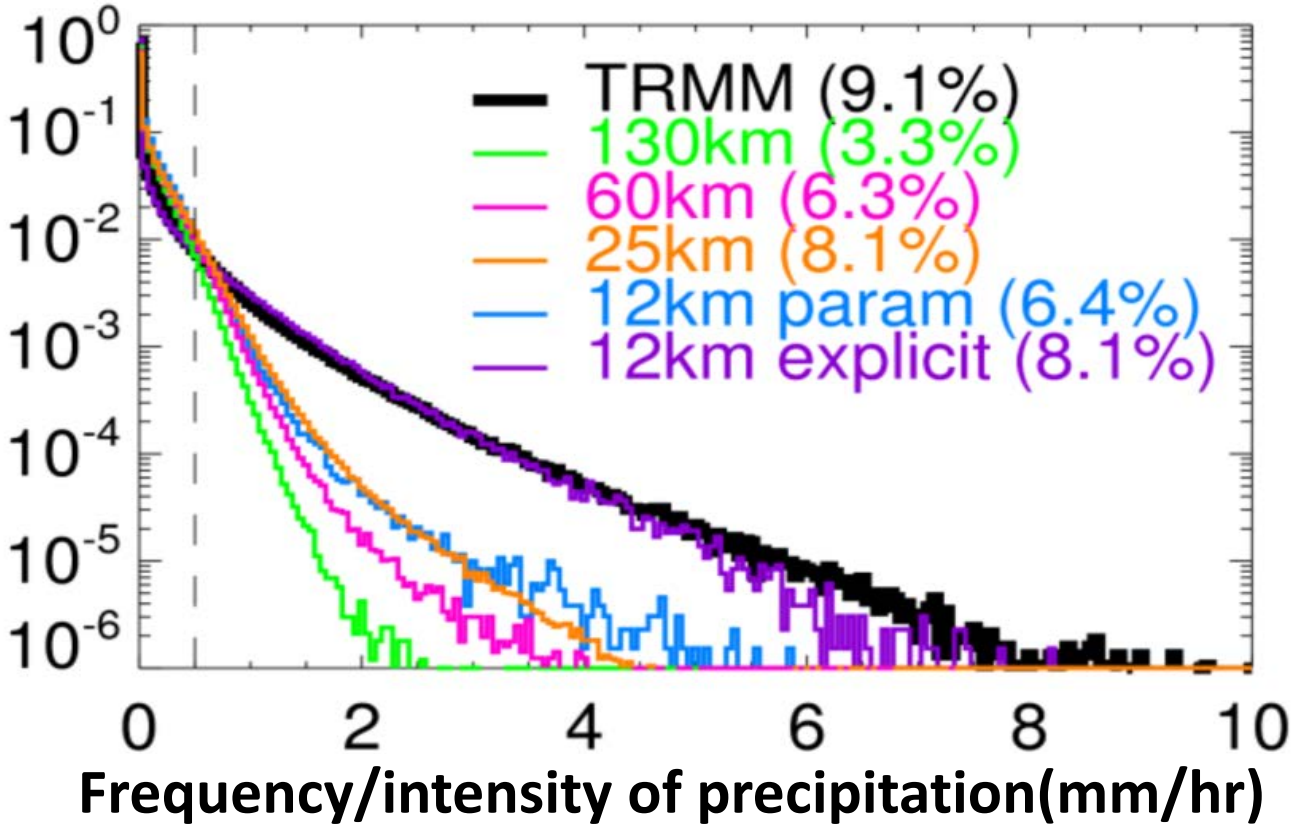


Enhanced resolution:
reduces SST biases &
improves northward heat transport
via increased AMOC

Hewitt et al., 2016

Impact of resolution: precipitation extremes

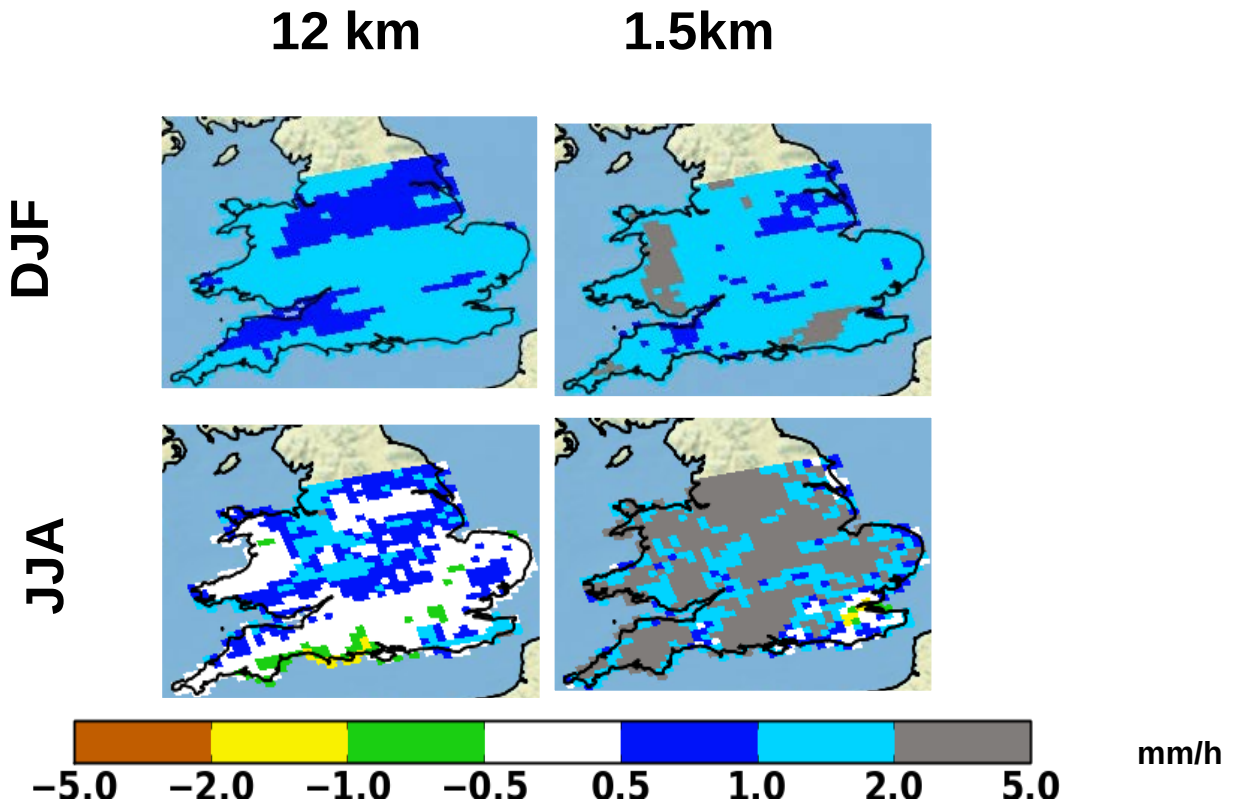
Probability of precipitation rate exceeding a given threshold: Sahel



Vellinga et al. 2015

Impact of resolution- climate change

Future change in rainfall RATE (RCP8.5)

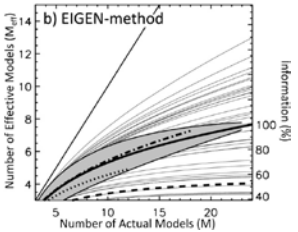


Based on Kendon et al, 2014

Resolution/complexity/ensembles/centres

- A “CERN” to hasten advent of convective scale global models? (eg Palmer,2016)
- A few centres gradually working towards convective scale global models?

CERN



No of ind models

Pennel and Reichler, 2011

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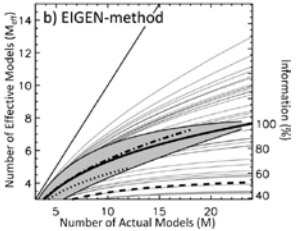

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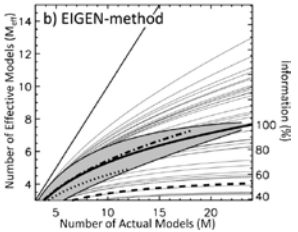

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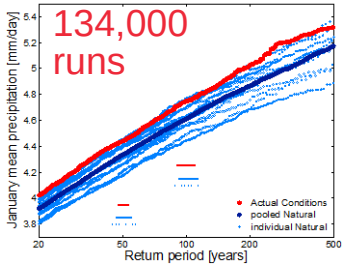

Return period, SE England Jan pptn (Schaller et al,2016)

weather@home

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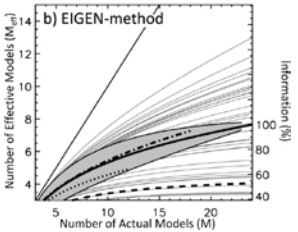
- A few centres gradually working towards convective scale global models?
- Continued increase in models as more nations can afford climate modelling?
- Running many (>1000) variants of lower resolution models?
- Earth system models with full biology, atmospheric chemistry, ice sheets…..?

CERN



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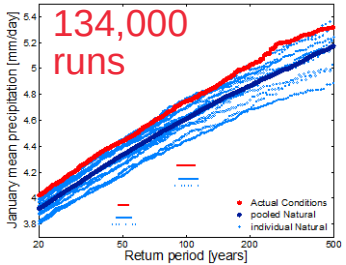

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weather@home

How will/should CMIP develop?

Is expansion sustainable, desirable? If not, what?

- Is more less? (models, data, experiments, papers)

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- What is order of priorities

  Standardizing evaluation of models?

  Improving scientific understanding?

  Supporting IPCC through running scenarios?

How will/should CMIP develop?

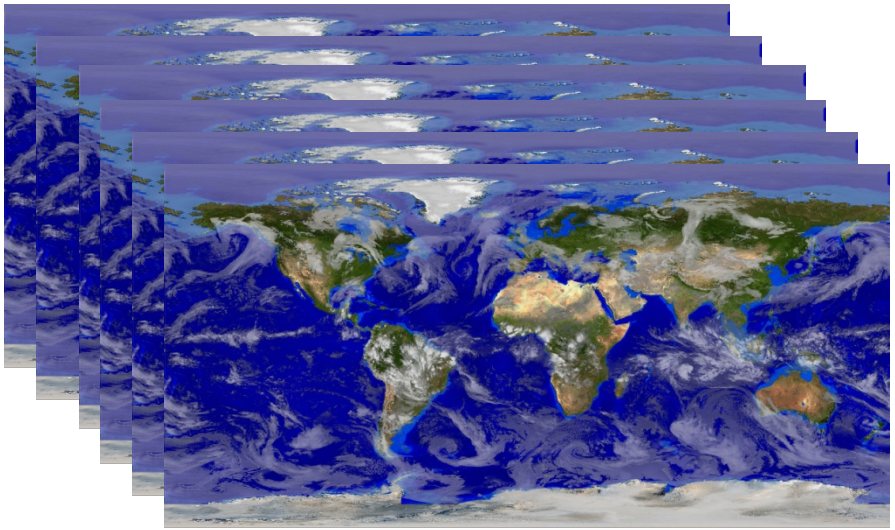
Is expansion sustainable, desirable? If not, what?

- Is more less? (models, data, experiments, papers)

- What is order of priorities
  Standardizing evaluation of models*? (the Deck)*
  Improving scientific understanding?
  Supporting IPCC through running scenarios?

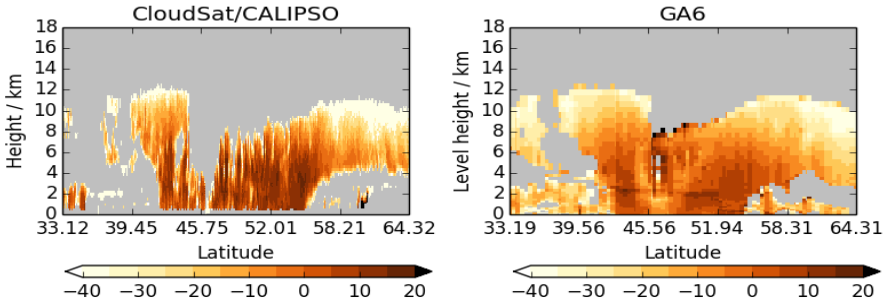
- Design choices (will depend on question being asked)
  Resolution vs number of ensemble members
  Uniformity of design vs exploring full model spread,
  Complexity vs understanding

Dealing with big data- part of the future for CMIP?



From Paul Selwood

Observations

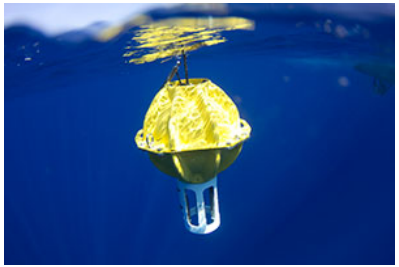


Sateillites etc

- GPS occultation
- Hyper spectral data
- Better error estimates

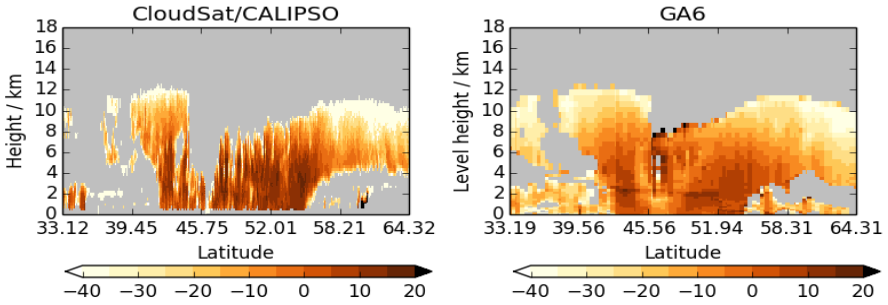
Other data

- Extension of reanalyses into past/ increased use to validate models/attribute change
- Deeper Argo floats-
  heat content, ocean circulation



- Longer observational record- better constraints? – detection/attribution

Observations



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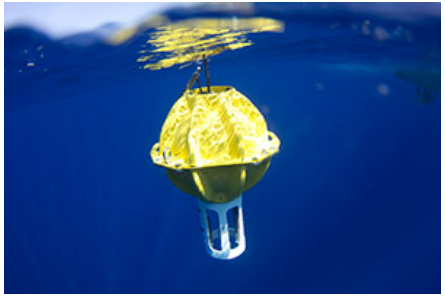

Random remarks

- People needed

  Those able to understand how models work as they become increasingly complex

  Those with wide and deep enough knowledge to build/improve models

Finally …

Climate sensitivity?

Finally …

Climate sensitivity?

Ron and me?