Estimating the risk of collapse of the AMOC

Peter Challenor and the RAPIT Team

RAPIT

- Consortium of NOC, Universities of Reading, Durham and Oxford, Imperial College, London School of Economics, the British Antarctic Survey and the UK Met Office
- Set up at a NERC ‘Sandpit’

- What is the risk that the AMOC will shut down (or slow)?
- No philosophy talk

Models

- Uncertainty in climate models
  - Input uncertainty (initial conditions, parameters, forcings)
  - Structural uncertainty

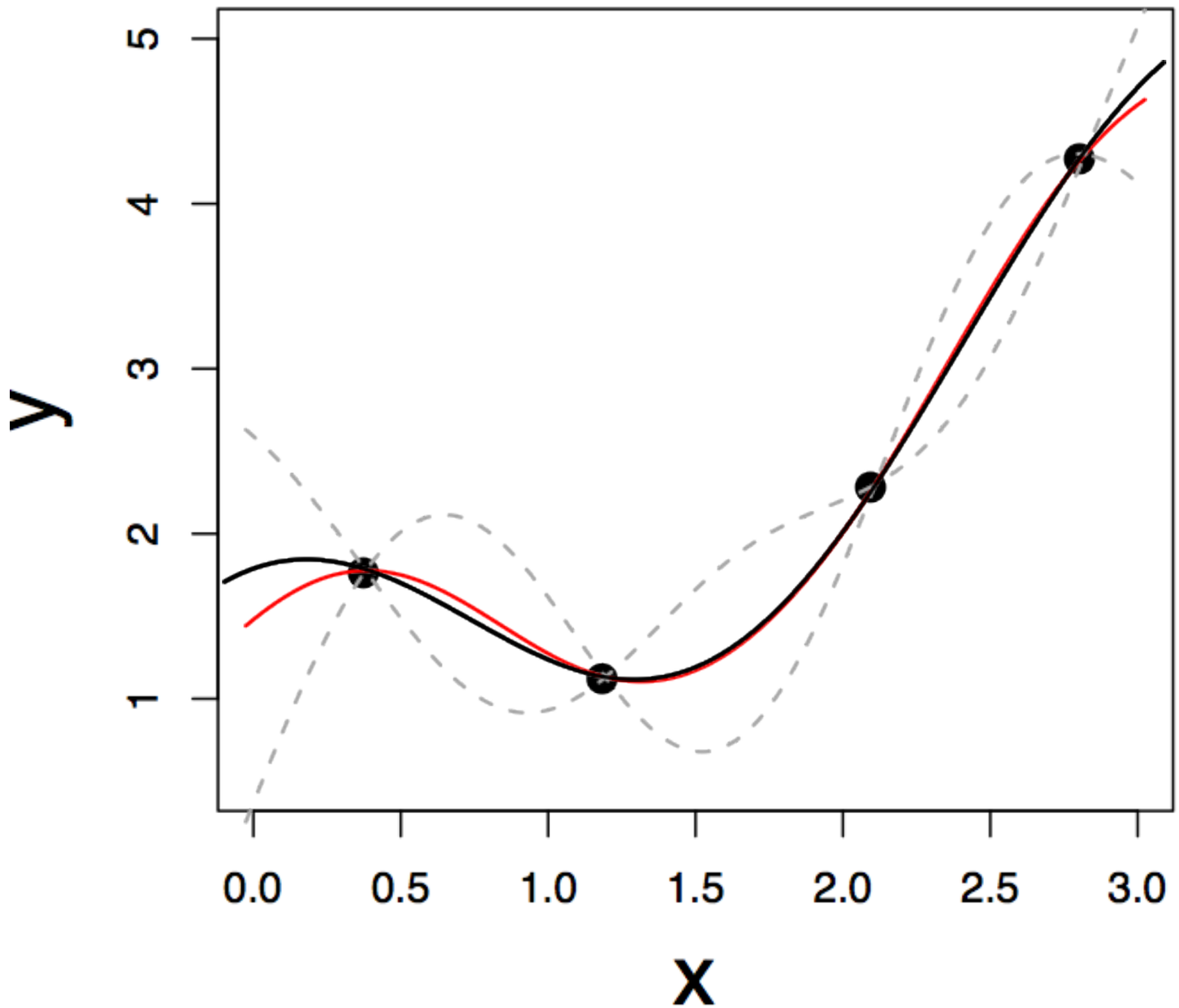
Tuning and Discrepancy

- Input uncertainty
  - Tuning, calibration
- Structural uncertainty, error
  - Model discrepancy

Emulators

- Climate models are expensive to run
- An emulator is a statistical model of the climate model

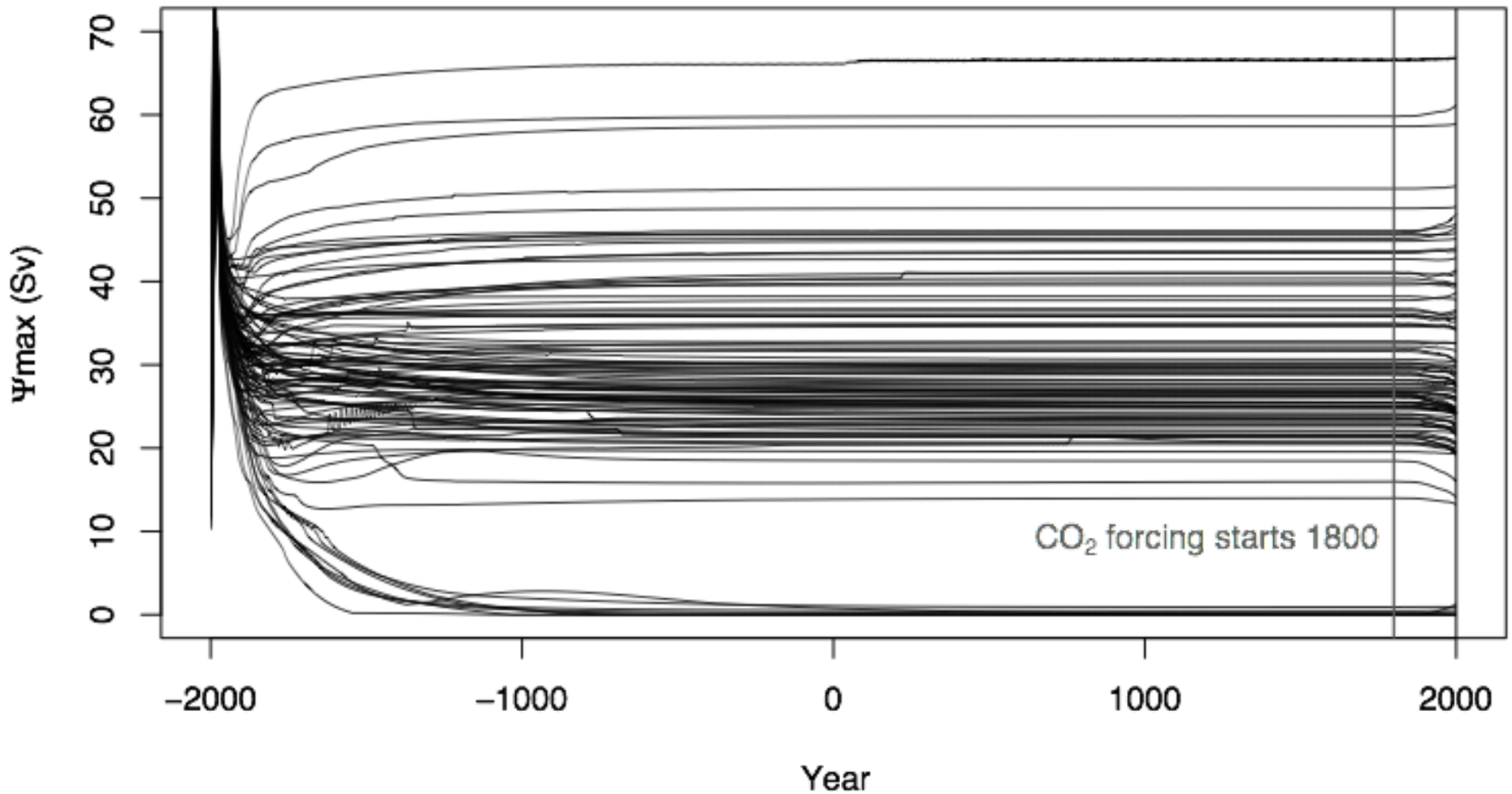
An Example

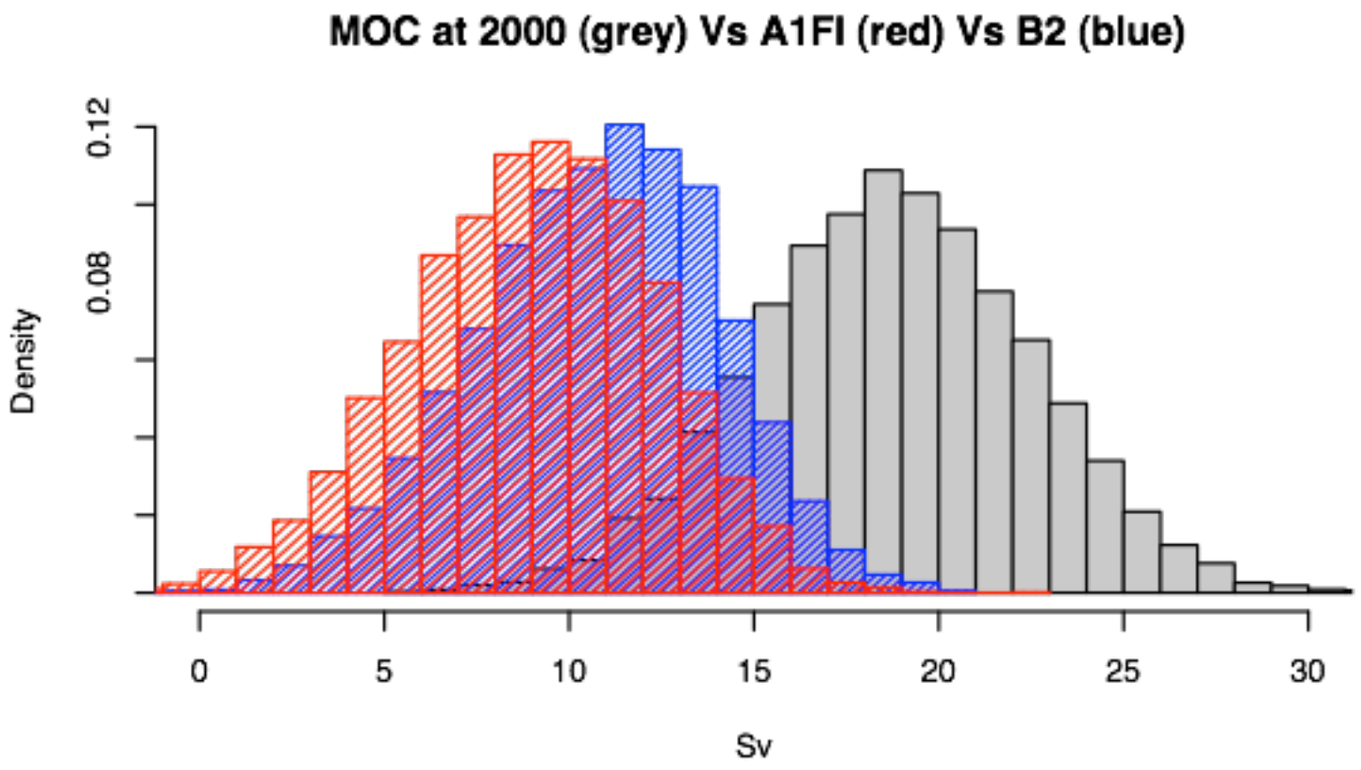


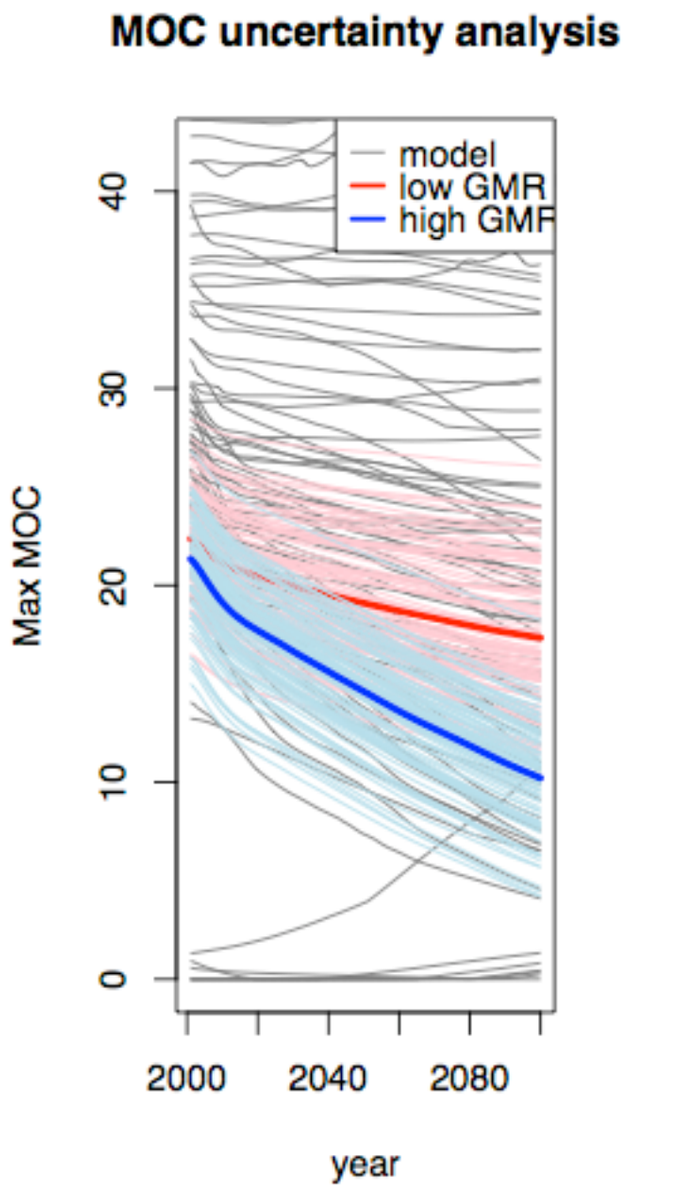
Procedure

- Run an ensemble of climate models in a designed experiment
- Build emulator
- Validate
- Use emulator inferences about the model and via model discrepancy real climate

GENIE Training Set

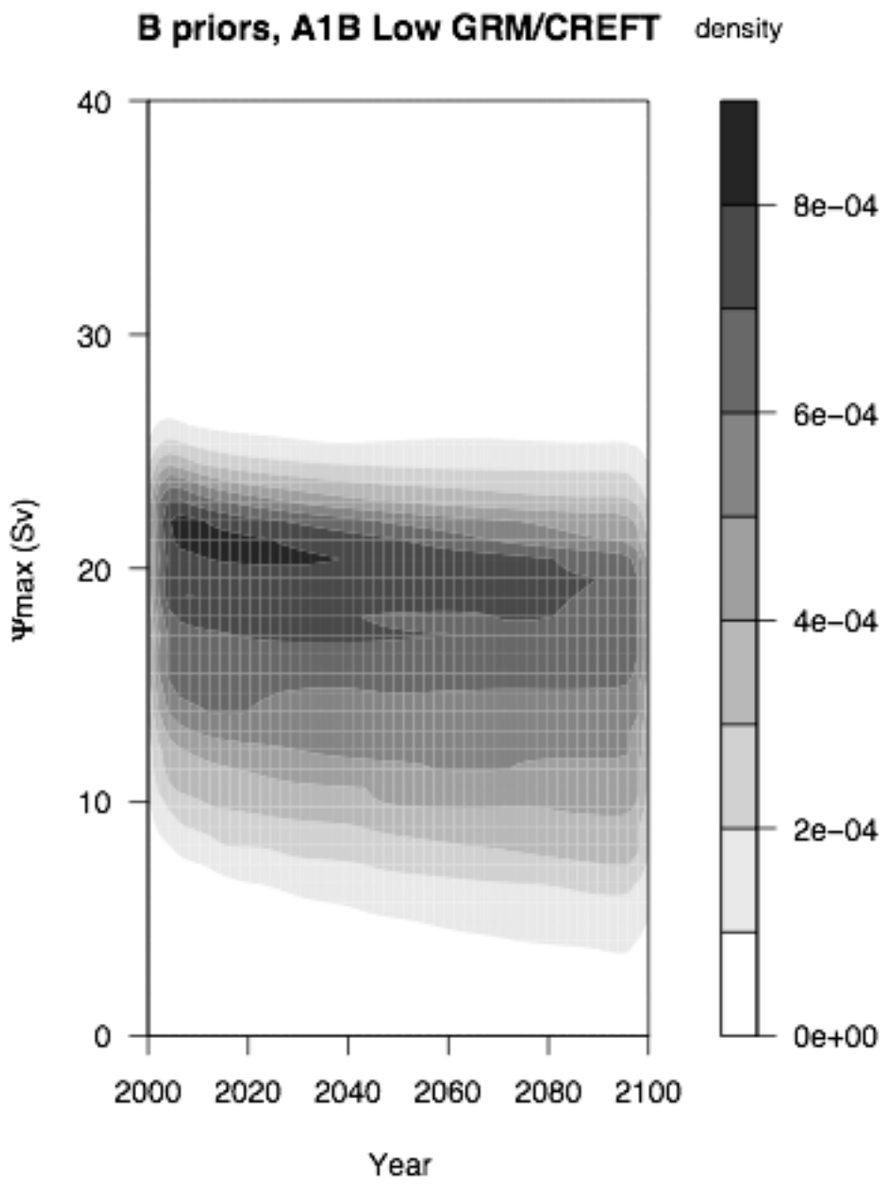




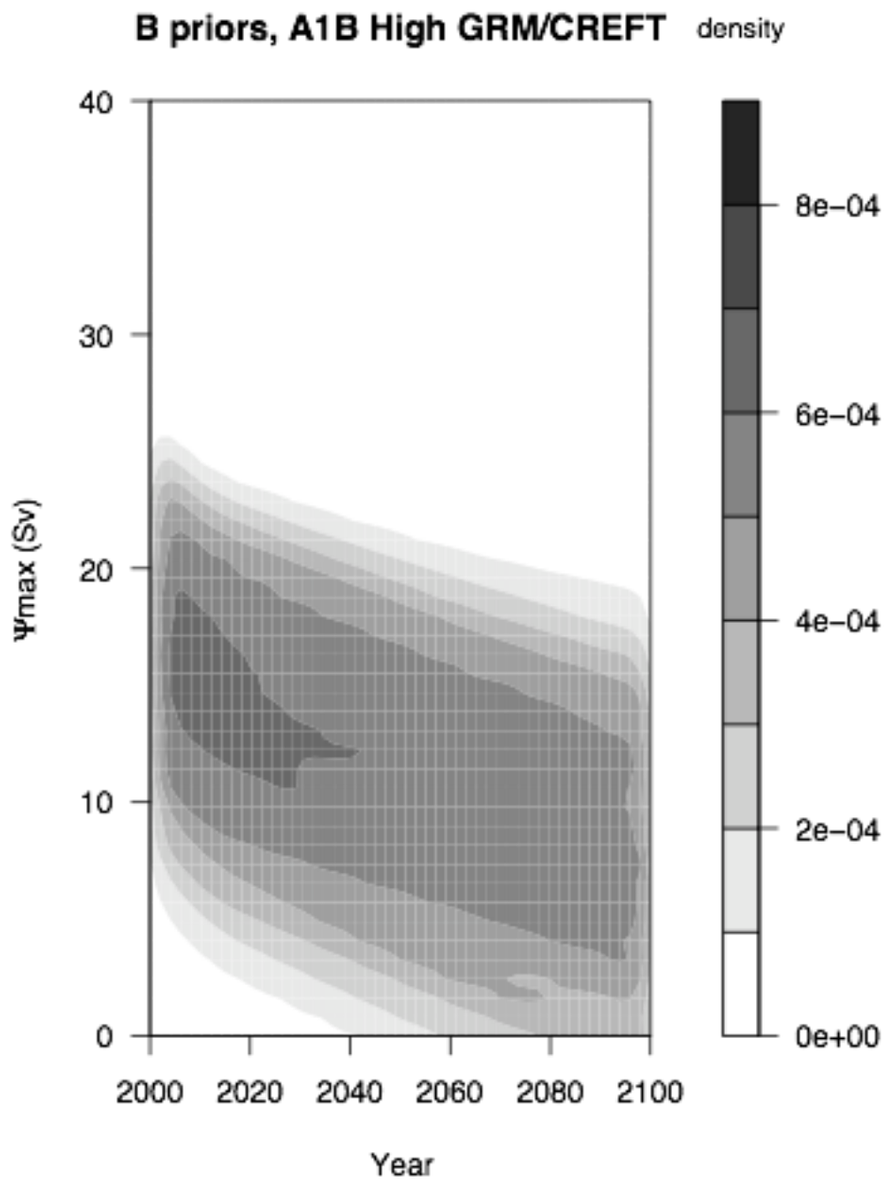


Challenor et al 2010

Estimated Decline in the Strength of the MOC from GENIE



Low Greenland melting rate



High Greenland melting rate

Genie Results

Scenario	Low Melt Rate for Greenland	High Melt Rate for Greenland
A1B	0.09	0.35
A2	0.10	0.33
B1	0.10	0.30

RAPIT Experiment

- Use HADCM3 rather than Genie
- Run large ensemble on *climateprediction.net*
- ‘Calibrate’ HADCM3
- Relate the model to reality (discrepancy)
- Estimate the risk of AMOC collapse in the real, not model, world

climateprediction.net

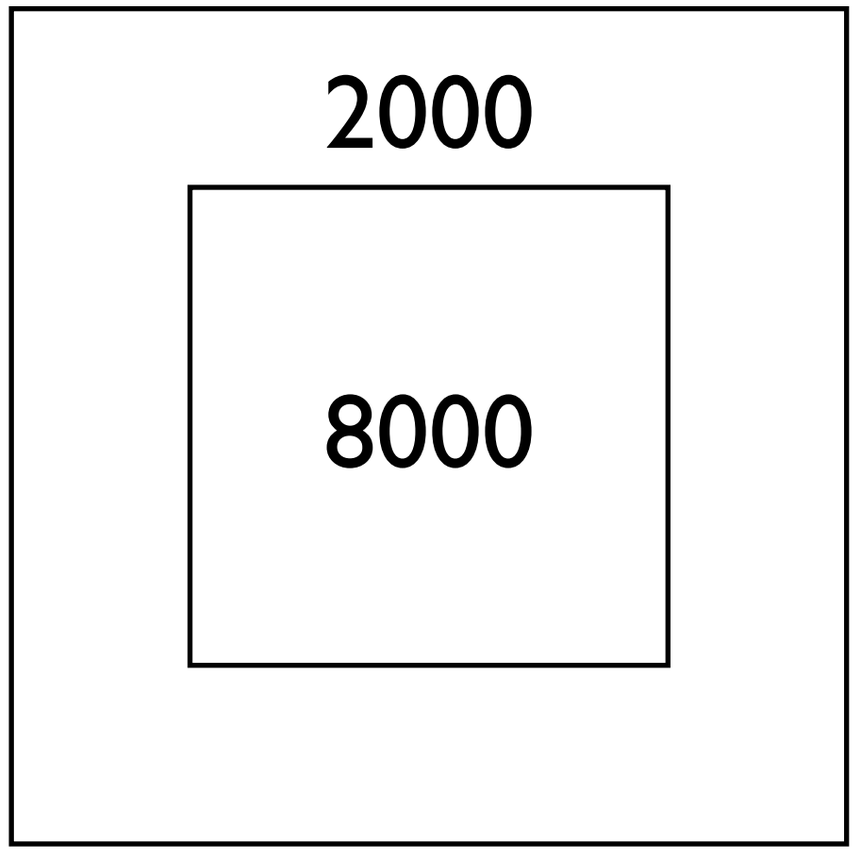
- Runs climate models (32-bit HADCM3) on home PC's
- Based at Oxford University
- Enables us to run large (c10000) ensembles
- But slow and not reliable
- Run 40 year pieces
- Don't get all the output back (bandwidth)

The RAPIT ensemble

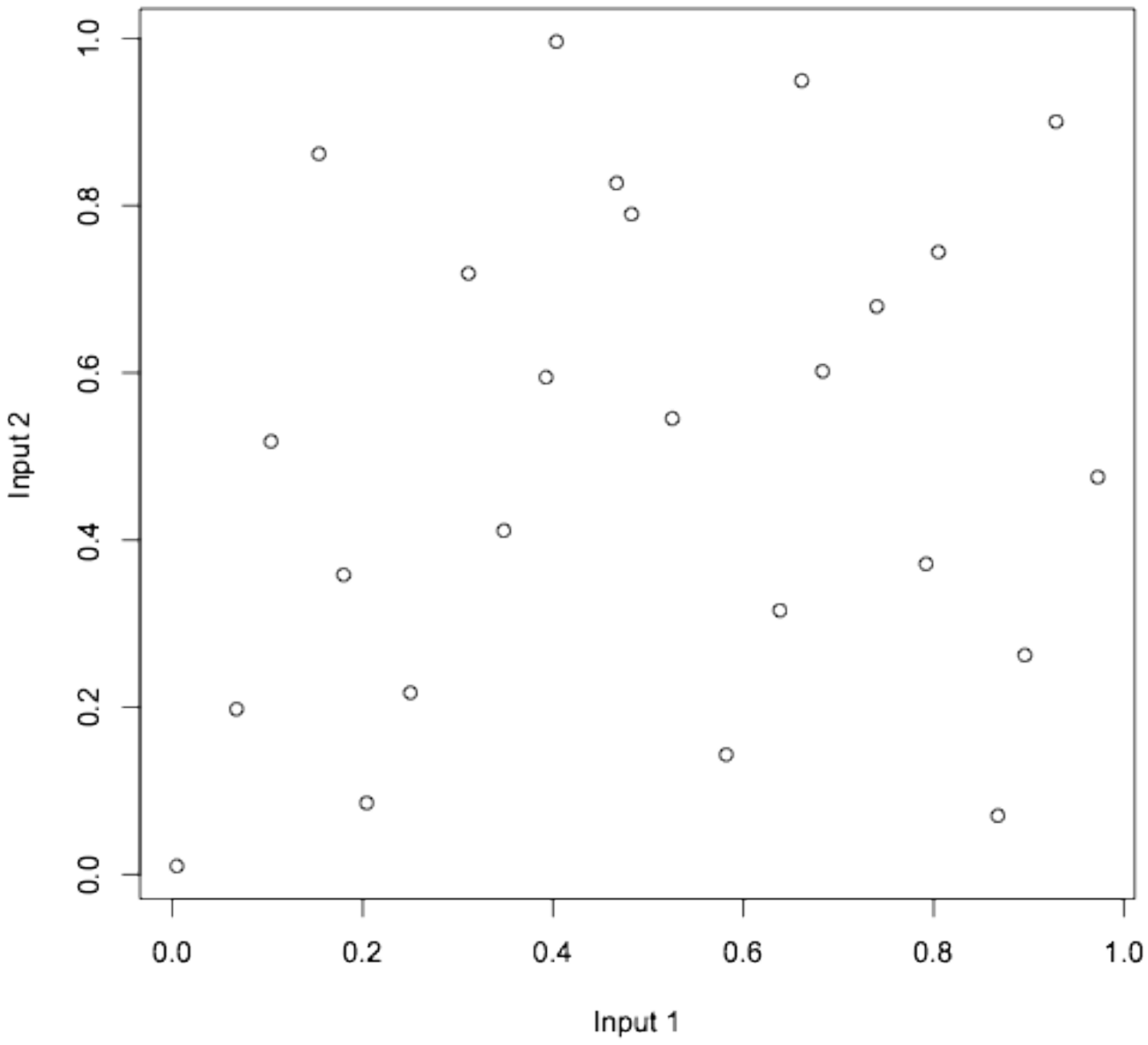
- Run in 40 year lengths
- All runs duplicated
- Control runs - just keep running
- CO_2 forcing - spread of CO_2 increase 0-4%
  - 40 year control; 10 year control 30 year increase; 40 year increase
- 20^{th} Century
  - 120 year control + 20^{th} century forcing
- 21^{st} Century
  - 20^{th} century + CO_2

The RAPIT Design

- Nested nearly-orthogonal Latin Hypercubes
- Central one based on Met Office ranges for parameters (8000)
- Outer one with extended ranges (2000)



A Latin Hypercube



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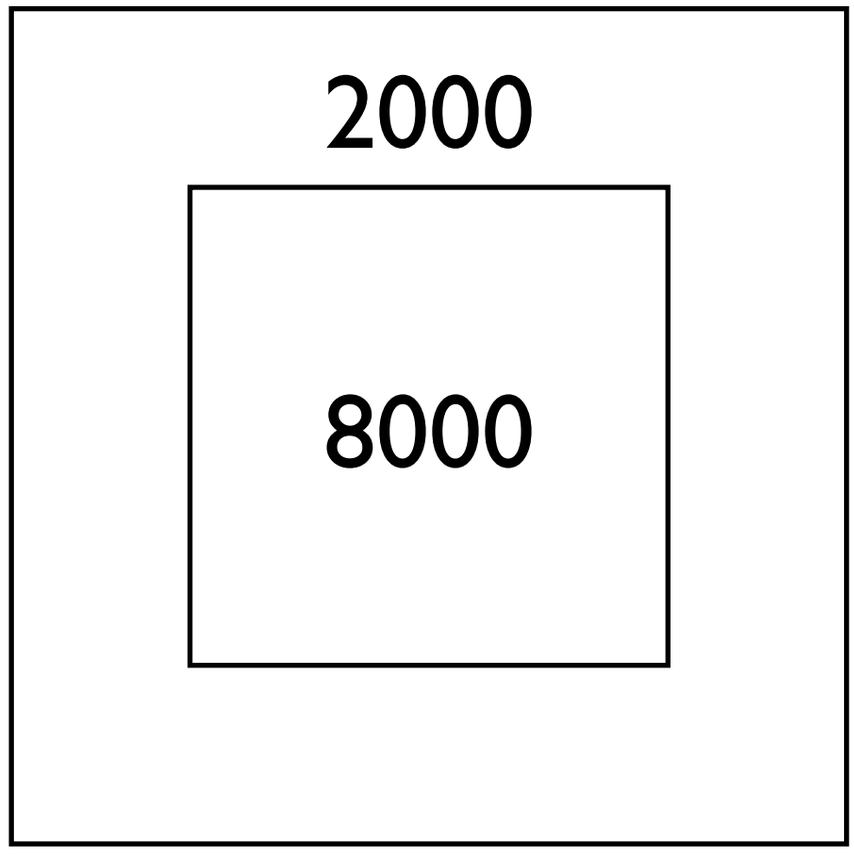
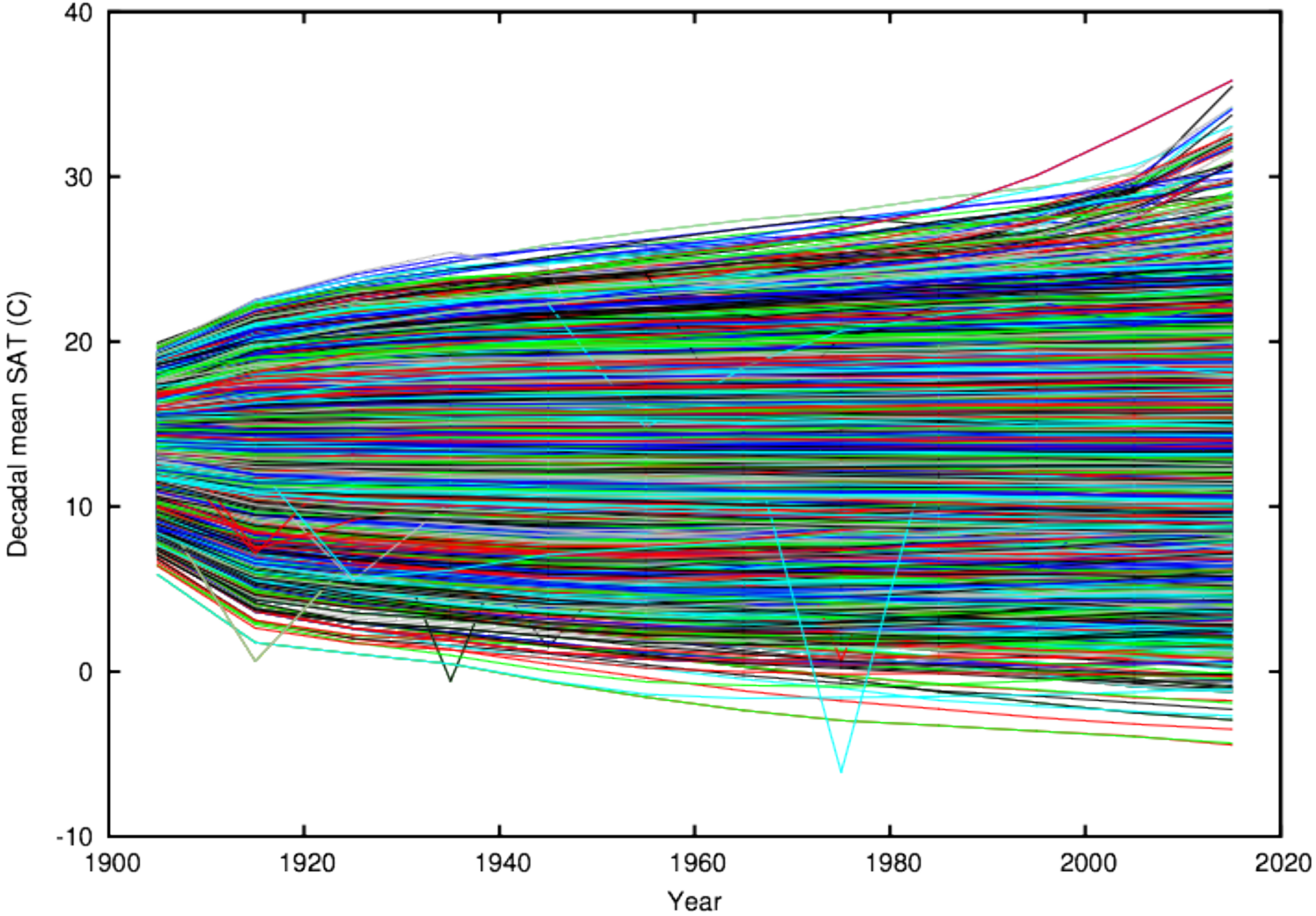
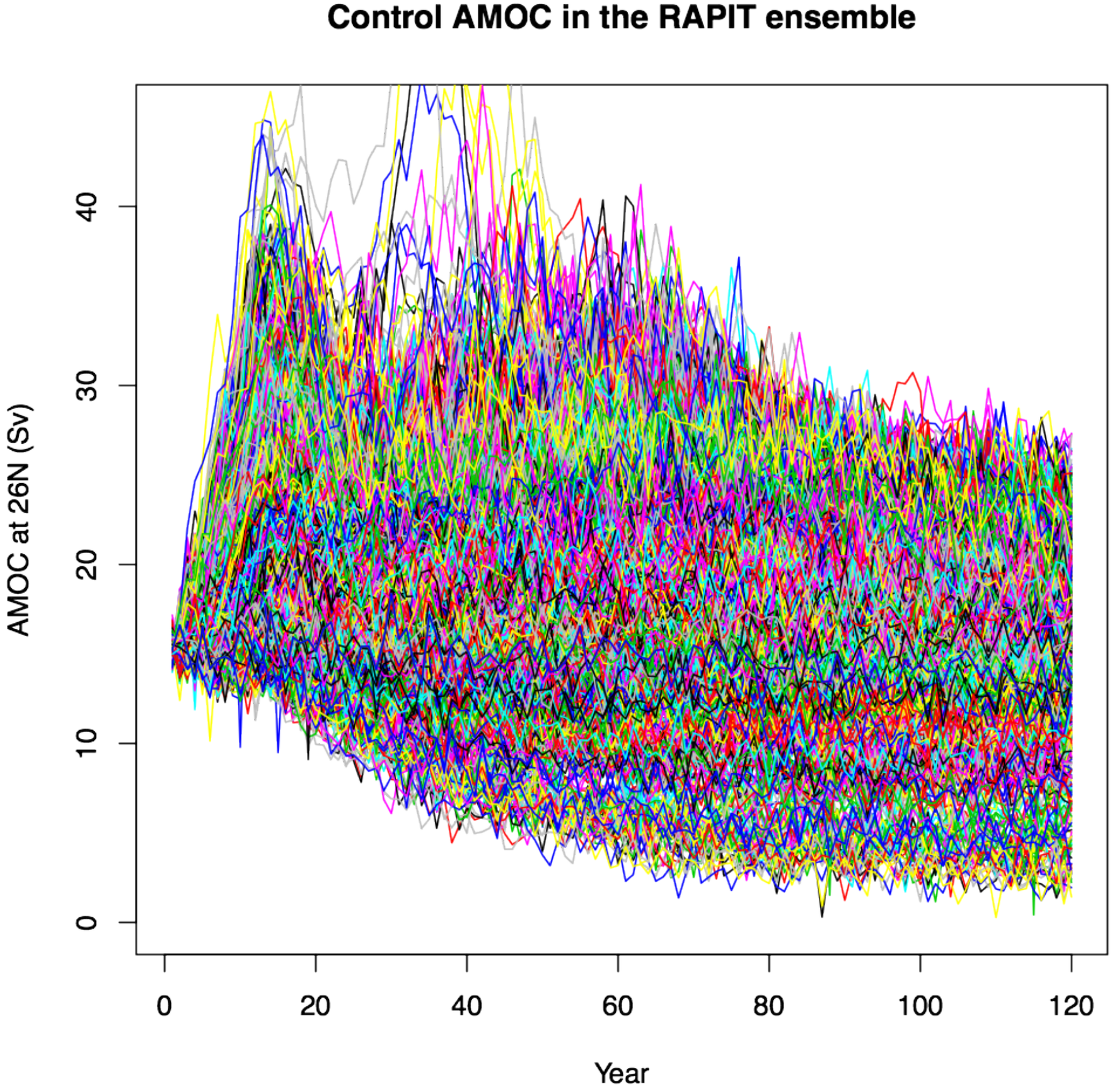
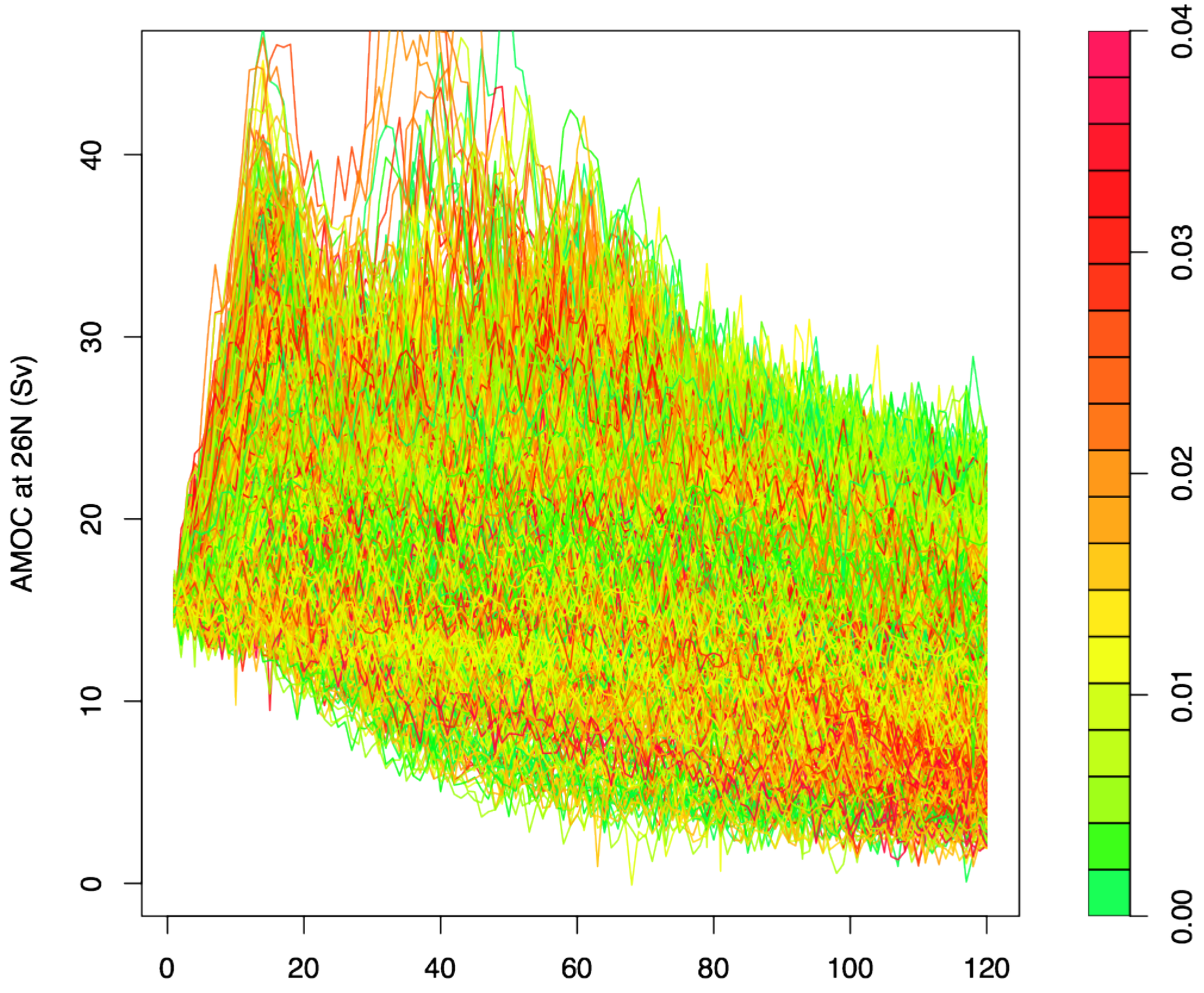


Important Point

- We run all simulations to the end regardless of how ‘bad’ the climate they give is


40
30
20
10
0
-10
Decadal mean SAT (C)
1900
1920
1940
1960
1980
2000
2020
Year


Control AMOC in the RAPIT ensemble
AMOC at 26N (Sv)
0
10
20
30
40
0
20
40
60
80
100
120
Year


Transient AMOC in the RAPIT ensemble
AMOC at 26N (Sv)
0
10
20
30
40
0
20
40
60
80
100
120
0.00
0.01
0.02
0.03
0.04

History Matching

- Rather than try to find the best set of parameters
- Find which regions of input space which implausible

Implausibility

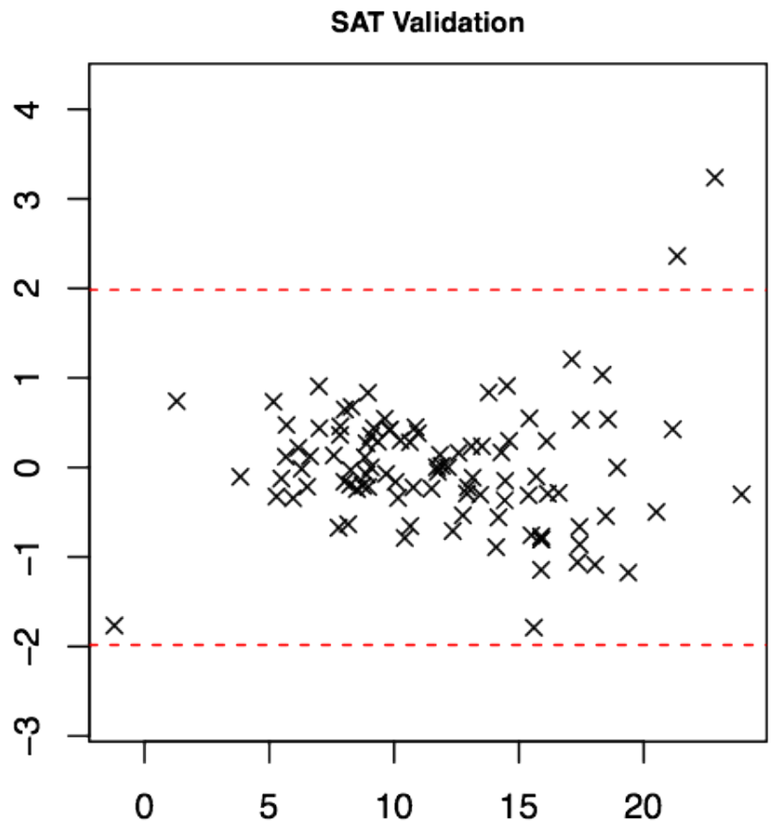
- Define a measure of implausibility (I_{mp})

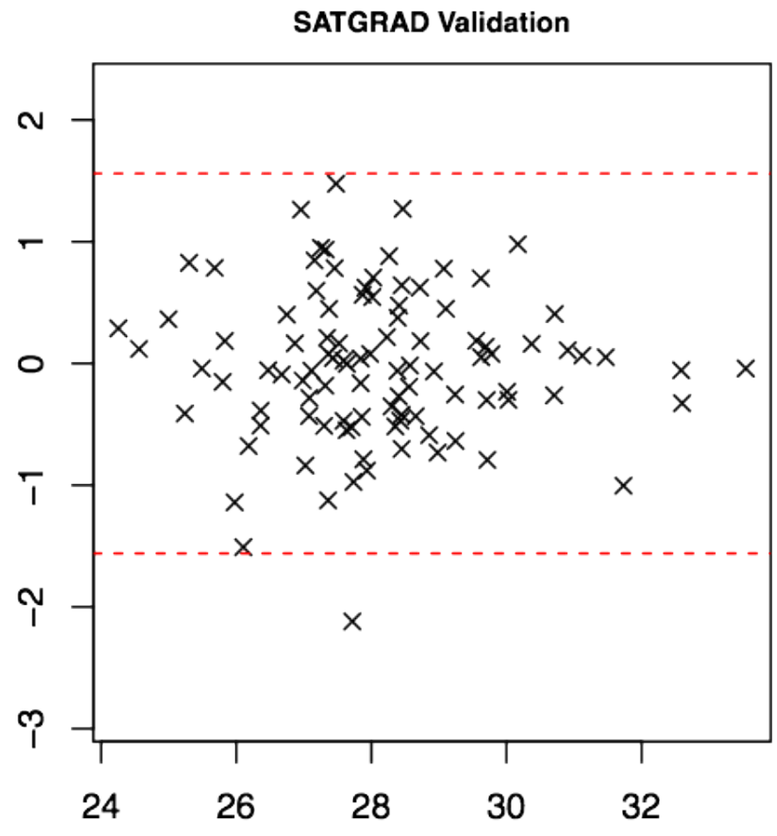
$$I_{mp}^2 = \frac{\left(x_{obs} - x_{emul}\right)^2}{\sigma_{emul}^2 + \sigma_{obs}^2 + \sigma_{discrep}^2}$$

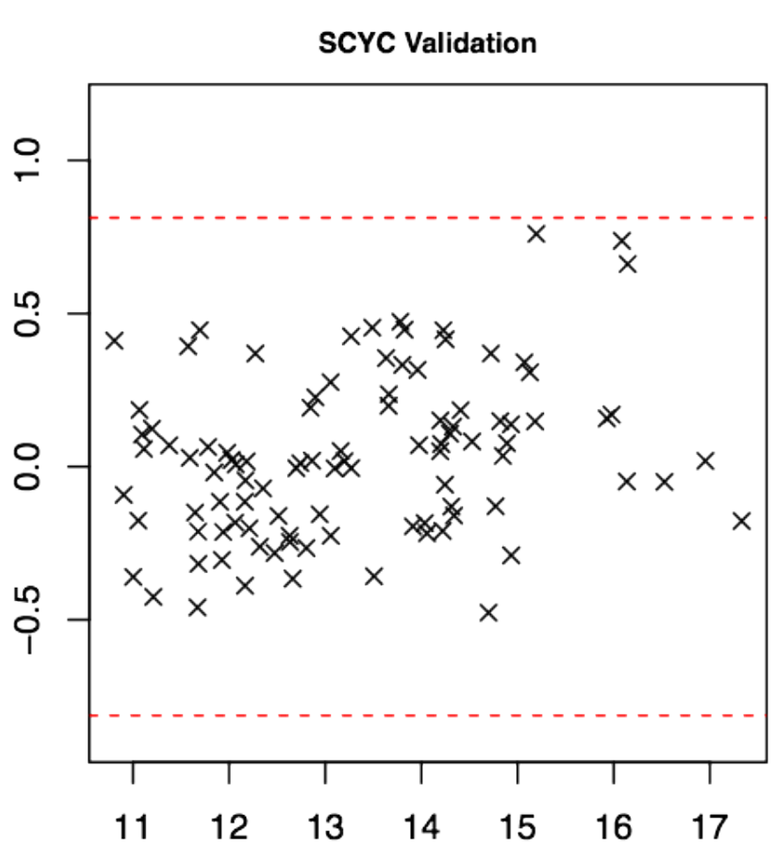
- If the implausibility is greater then ±3 those values of the inputs are deemed implausible
- Because this is a function of the emulator not the original simulator runs we calculate it everywhere in input space

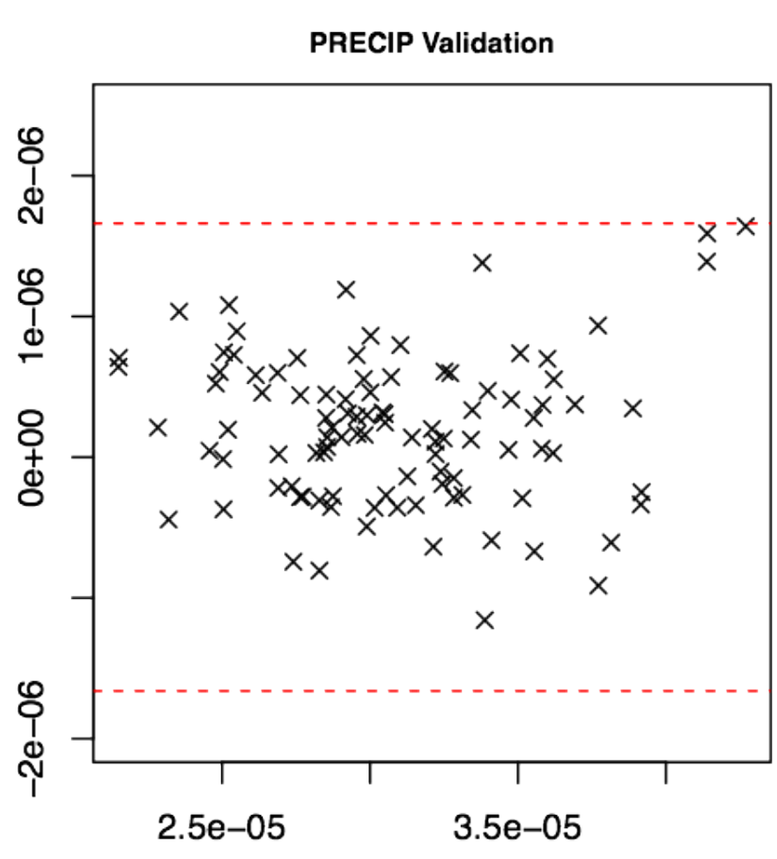
History Matching in RAPIT

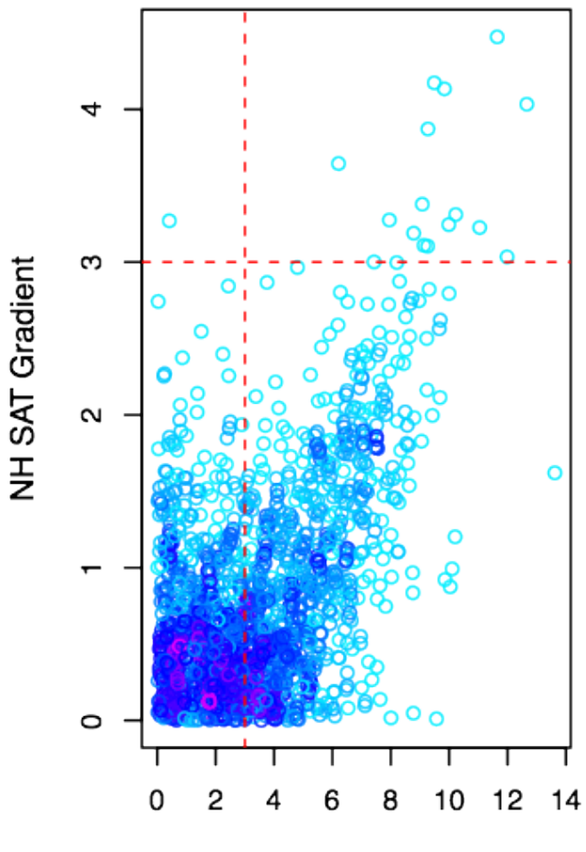
- Only pre-industrial runs so far
- Estimates of pre-industrial
  - SAT
  - N. Hemisphere-SATgradient
  - Seasonal cycle in SAT
  - Global precipitation

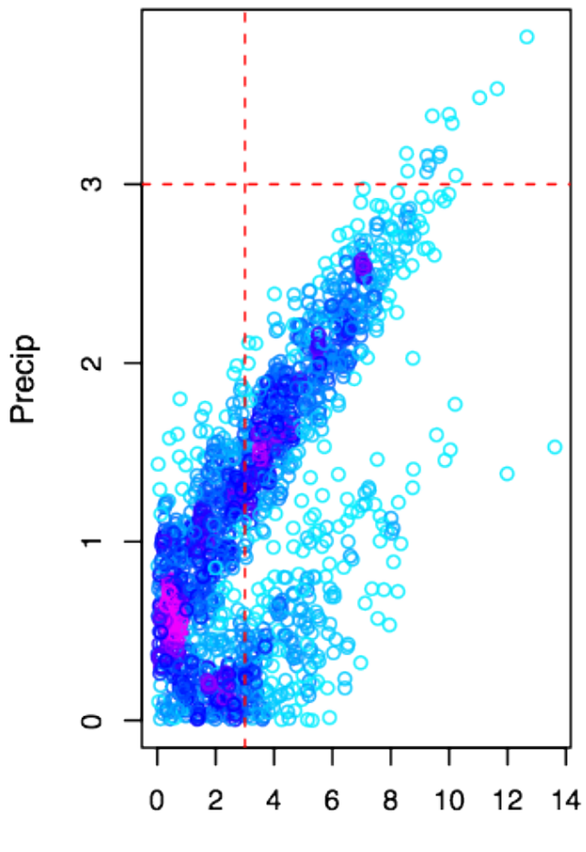

SAT Validation
4
3
2
1
0
−1
−2
−3
0
5
10
15
20

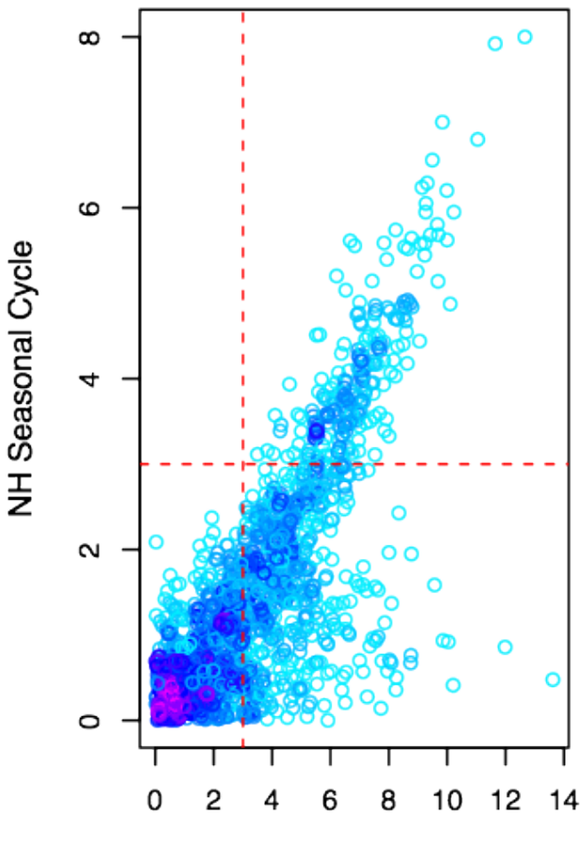

SATGRAD Validation
2
1
0
−1
−2
−3
24
26
28
30
32

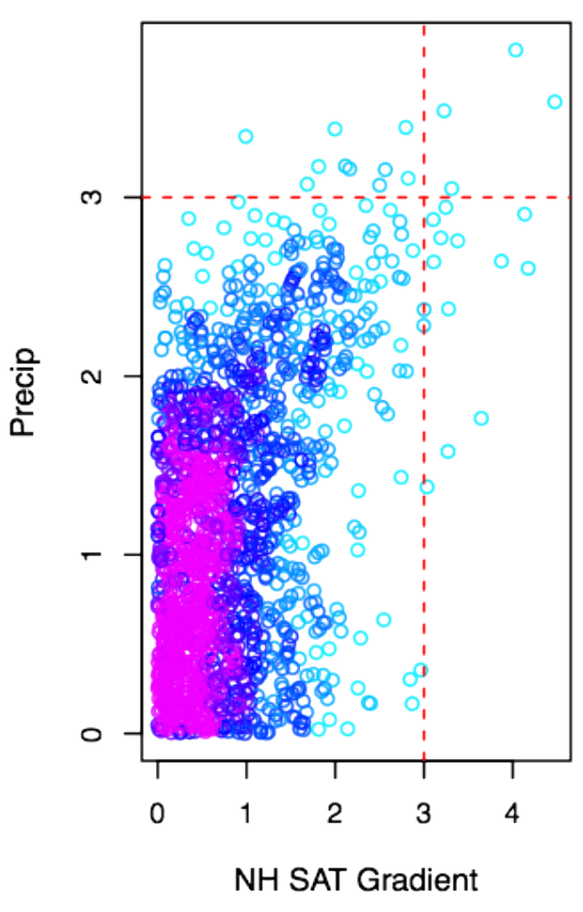

SCYC Validation
1.0
0.5
0.0
−0.5
11
12
13
14
15
16
17

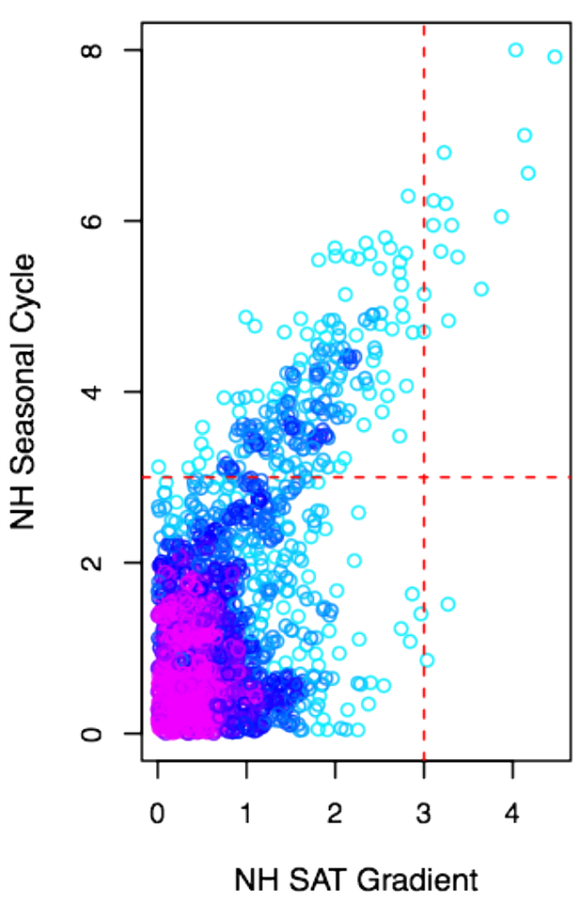

PRECIP Validation
2e−06
1e−06
0e+00
−2e−06
2.5e−05
3.5e−05

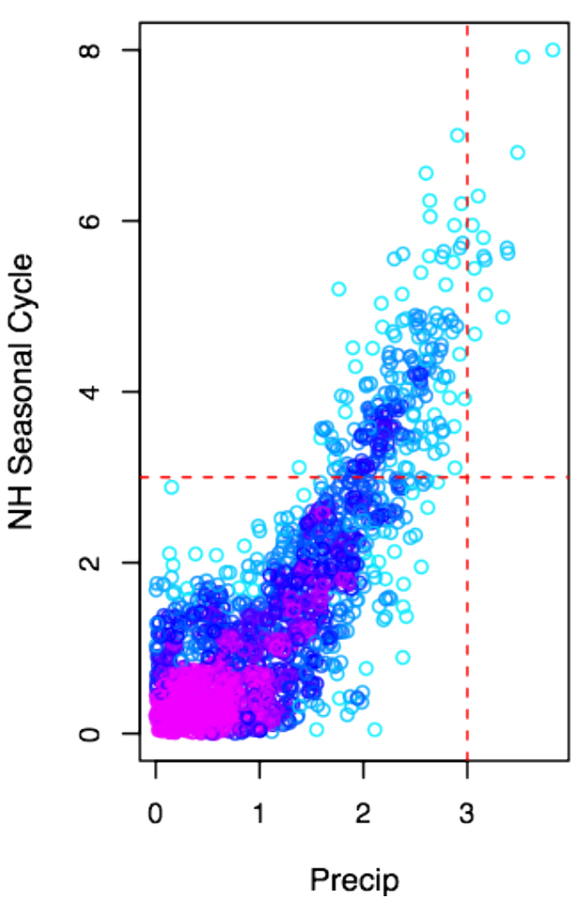

NH SAT Gradient
SAT
0
1
2
3
4
0
2
4
6
8
10
12
14

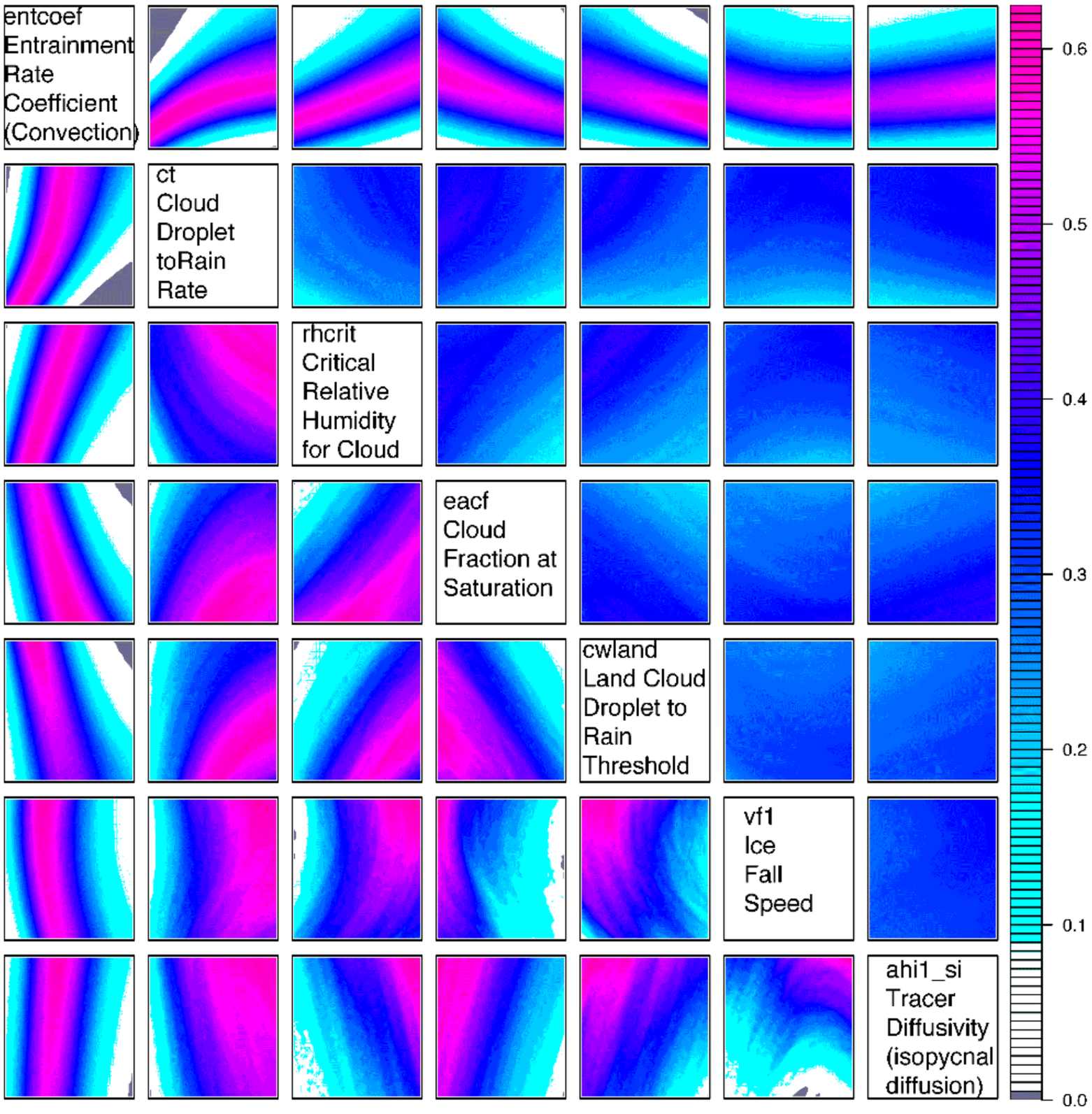

Precip
SAT
0
1
2
3
0
2
4
6
8
10
12
14

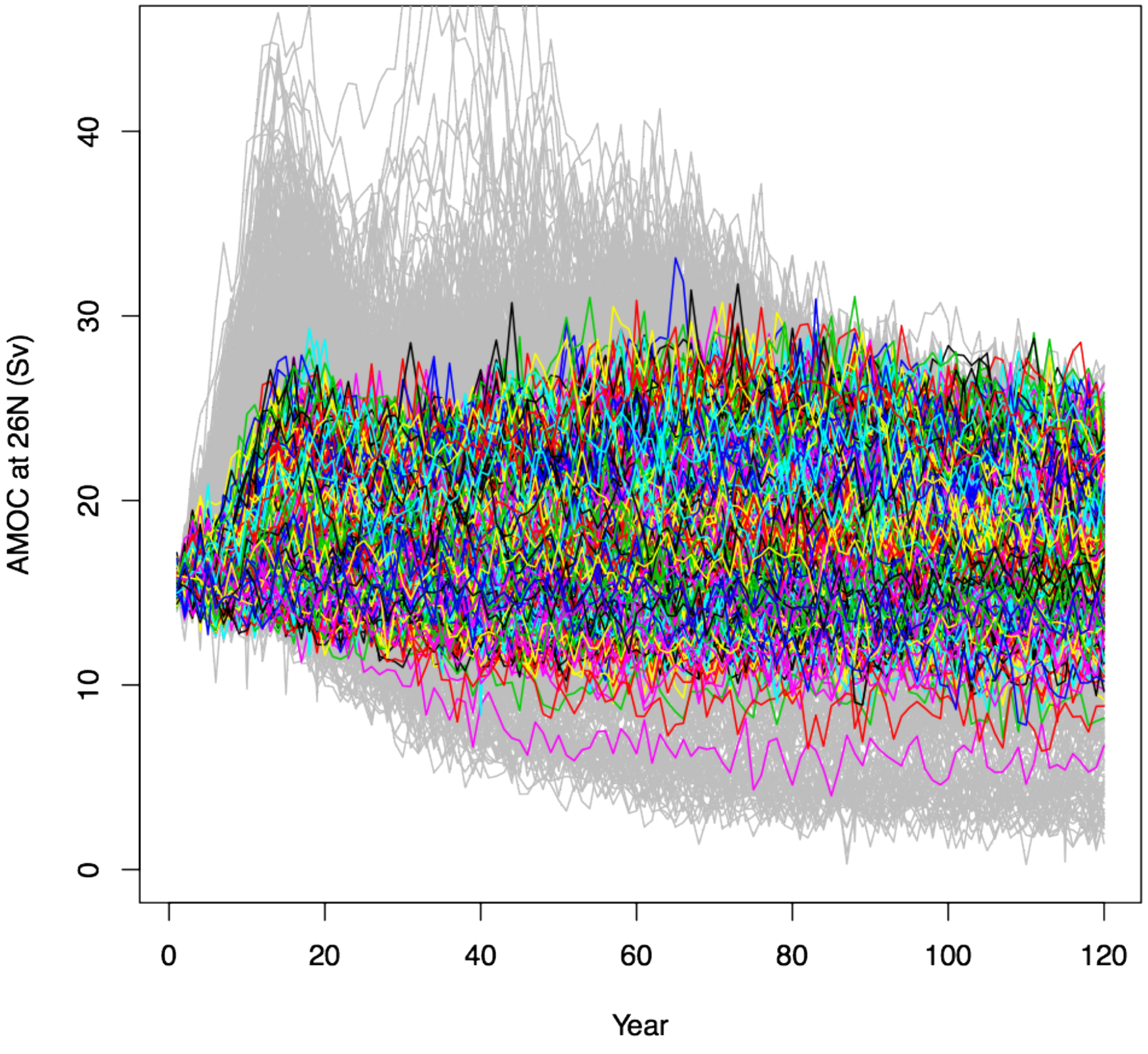

NH Seasonal Cycle
SAT
0
2
4
6
8
0
2
4
6
8
10
12
14


Precip
NH SAT Gradient
0
1
2
3
4
0
1
2
3

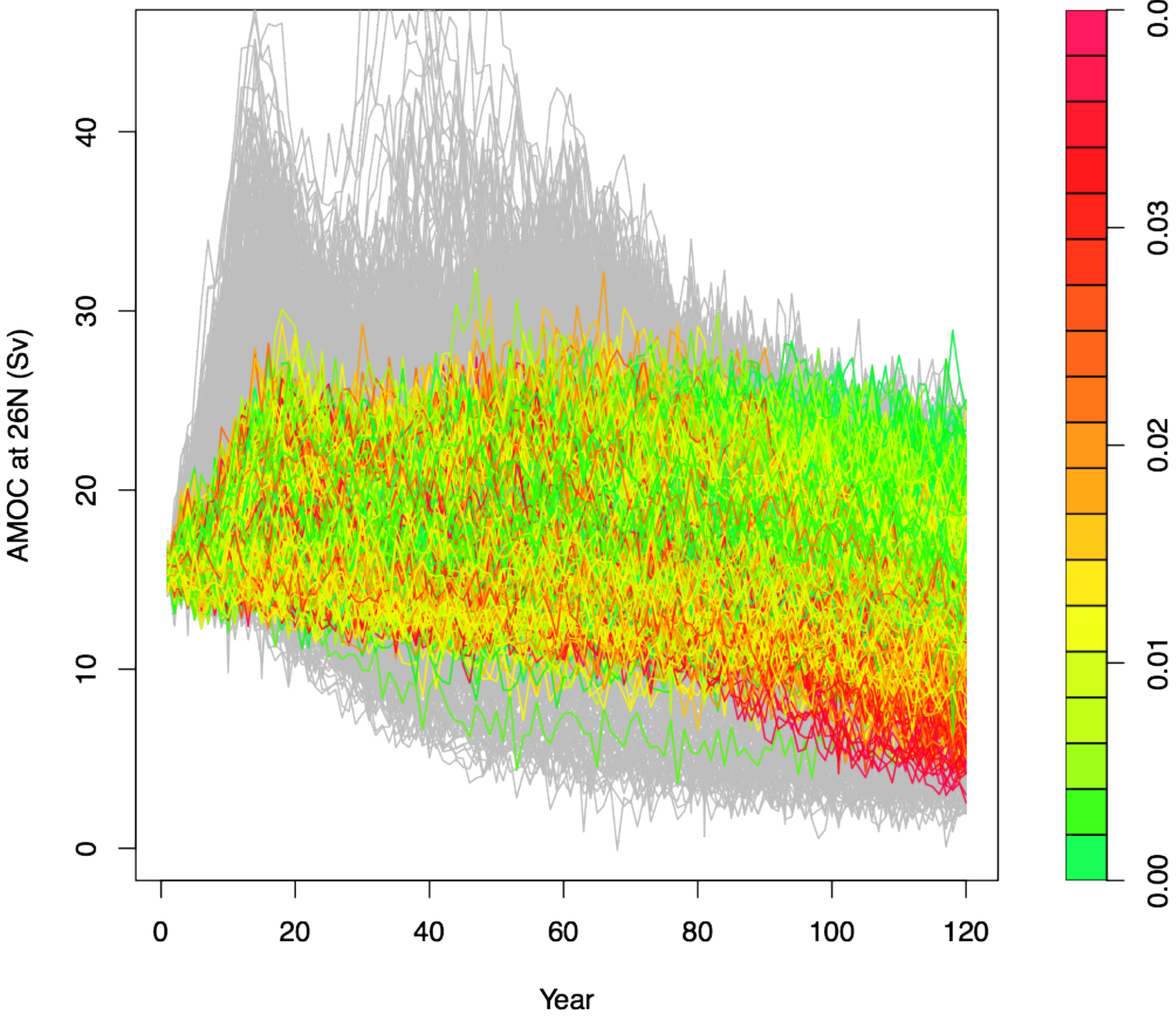

NH Seasonal Cycle
NH SAT Gradient
0
2
4
6
8
0
1
2
3
4

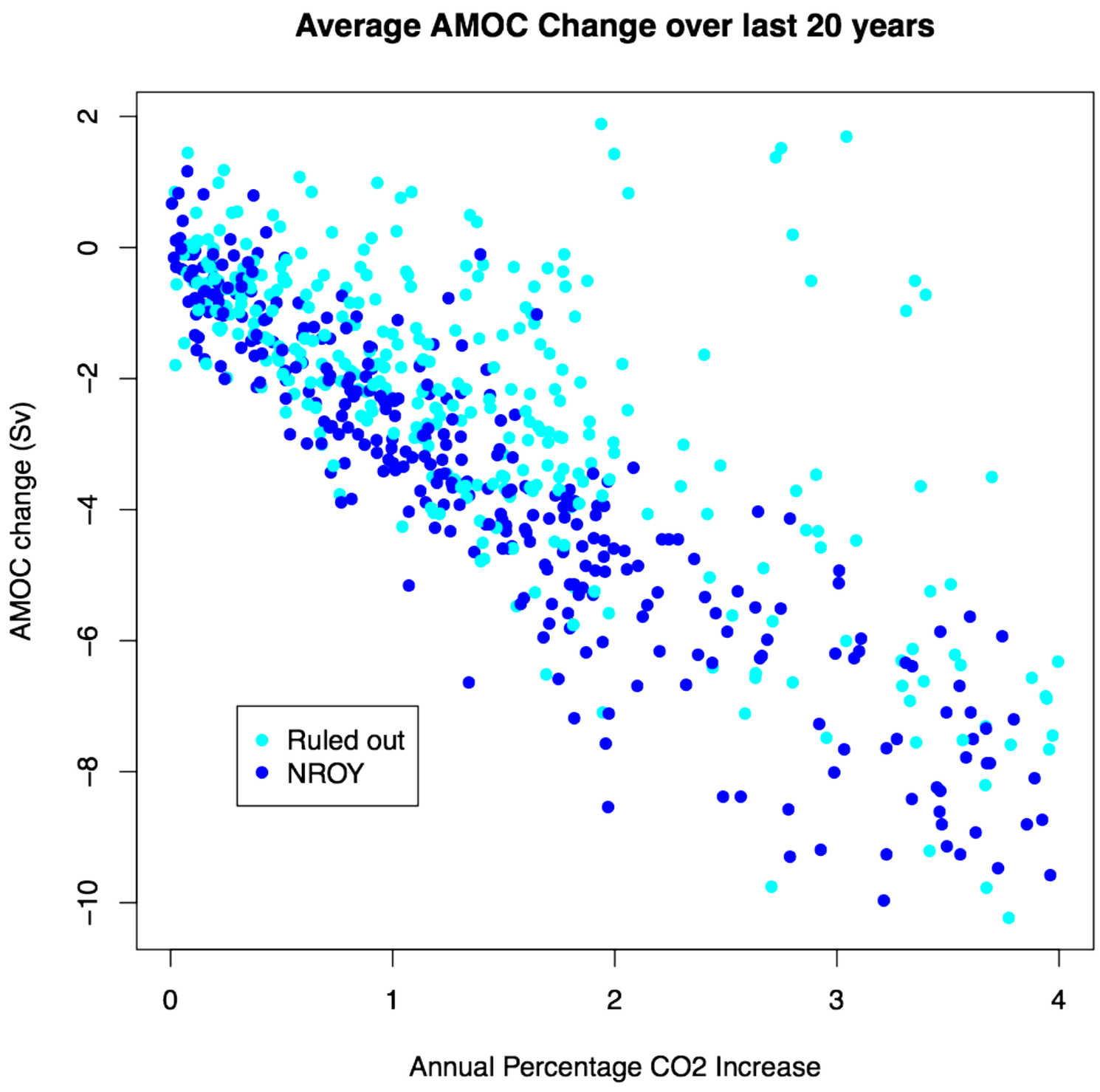

NH Seasonal Cycle
Precip
0
2
4
6
8
0
1
2
3

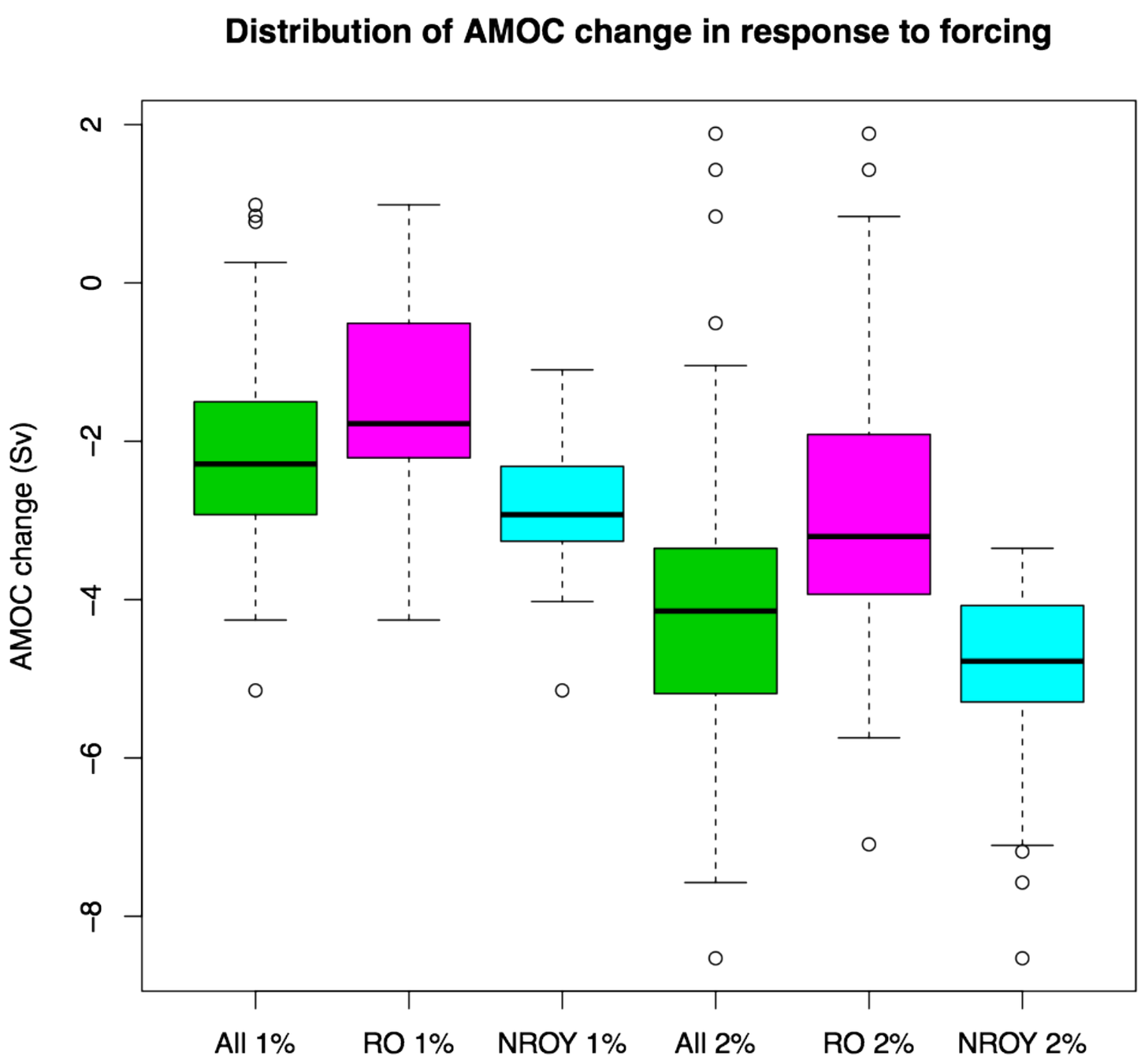

entcoef
Entrainment
Rate
Coefficient
(Convection)
ct
Cloud
Droplet
toRain
Rate
rhcrit
Critical
Relative
Humidity
for Cloud
eacf
Cloud
Fraction at
Saturation
cwland
Land Cloud
Droplet to
Rain
Threshold
vf1
Ice
Fall
Speed
ahi1_si
Tracer
Diffusivity
(isopycnal
diffusion)
0.6
0.5
0.4
0.3
0.2
0.1
0.0

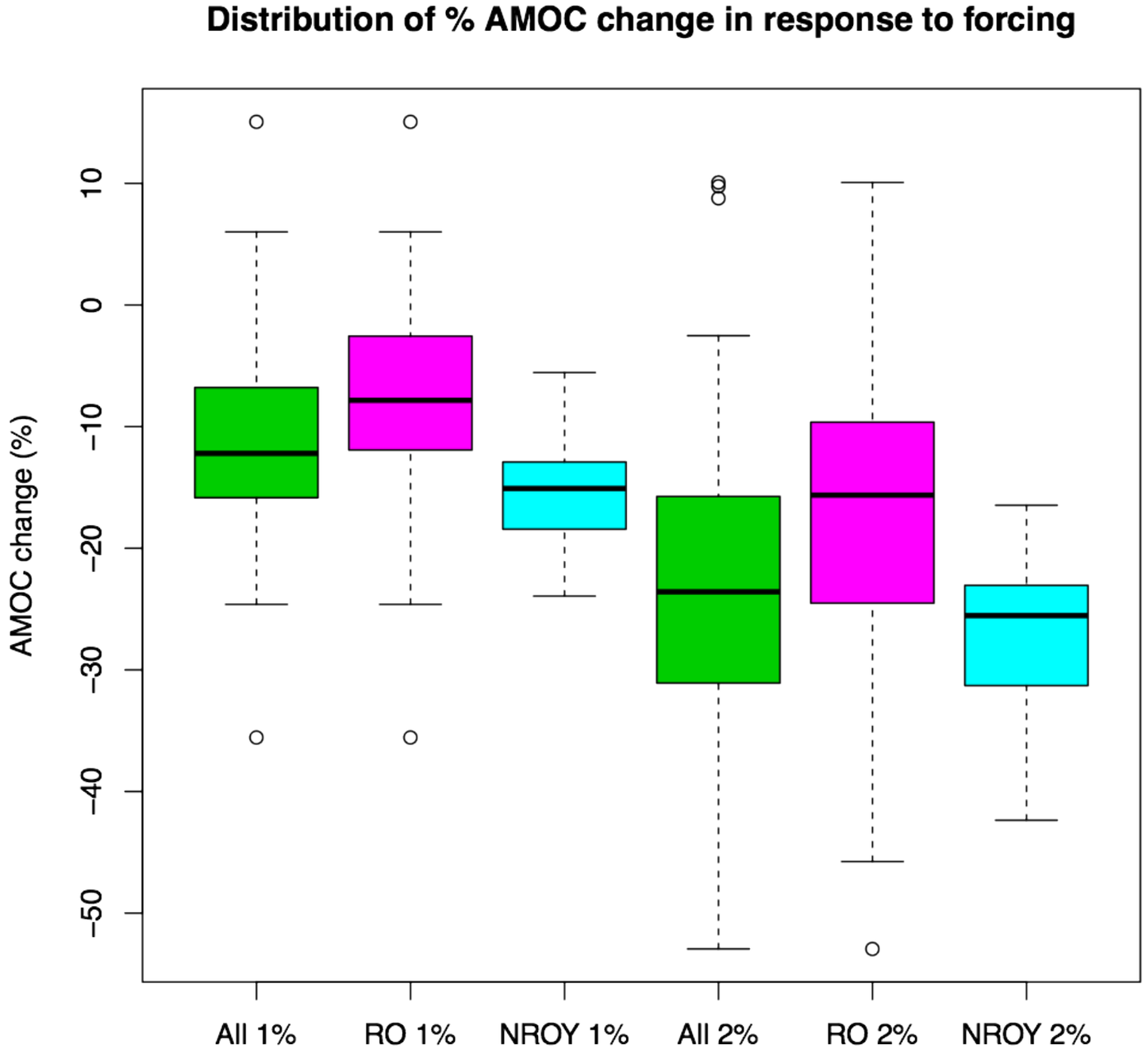

NROY Control AMOC in the RAPIT ensemble
AMOC at 26N (Sv)
0
10
20
30
40
0
20
40
60
80
100
120
Year

Transient NROY AMOC in the RAPIT ensemble




Average AMOC Change over last 20 years
AMOC change (Sv)
2
0
−2
−4
−6
−8
−10
Ruled out
NROY
0
1
2
3
4
Annual Percentage CO2 Increase


Distribution of AMOC change in response to forcing
AMOC change (Sv)
2
0
−2
−4
−6
−8
All 1%
RO 1%
NROY 1%
All 2%
RO 2%
NROY 2%


Distribution of % AMOC change in response to forcing
AMOC change (%)
10
0
−10
−20
−30
−40
−50
All 1%
RO 1%
NROY 1%
All 2%
RO 2%
NROY 2%

Conclusions

- We are building the machinery for risk estimation
- The RAPIT ensemble has more than 4 Million years of HADCM3 output
- Anyone is free to use it
- 20th Century coming soon