Sensitivity of the North Atlantic storm track to regional drivers of change

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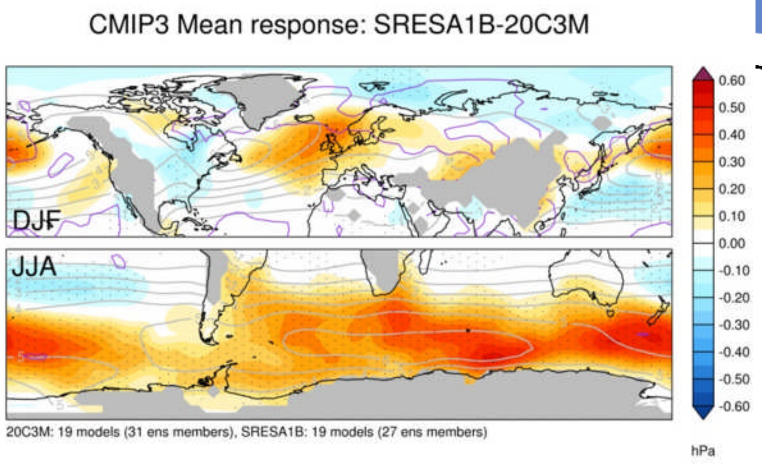
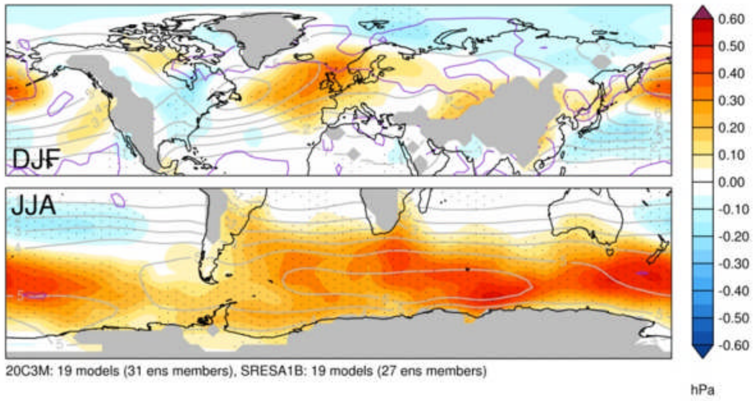
NATURAL
ENVIRONMENT
RESEARCH COUNCIL

Storm
risk mitigation


CMIP3 Mean response: SRESA1B-20C3M
DJF
JJA
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
hPa
20C3M: 19 models (31 ens members), SRESA1B: 19 models (27 ens members)

CMIP3 Mean response: SRESA1B-20C3M



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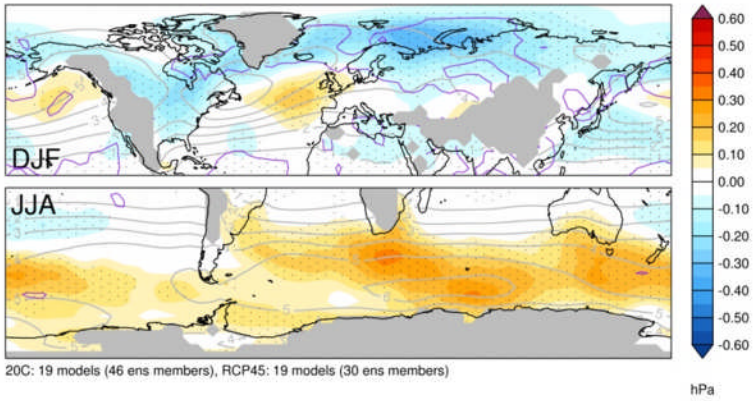
CMIP5 Mean response: RCP45-20C



20C: 19 models (46 ens members), RCP45: 19 models (30 ens members)

CMIP3/CMIP5 differences:

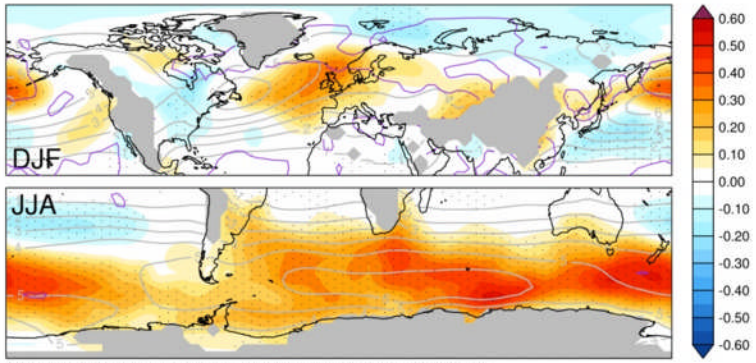
- Scenario (SRESA1B vs RCP4.5)

  Ensemble mean Tas responses:

  CMIP3 = 2.8 K

  CMIP5 = 1.9 K

- CMIP5 higher average resolution
- Several `high-top’ models in CMIP5



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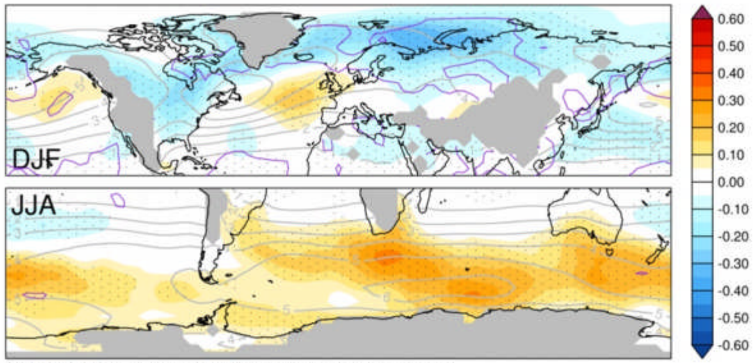

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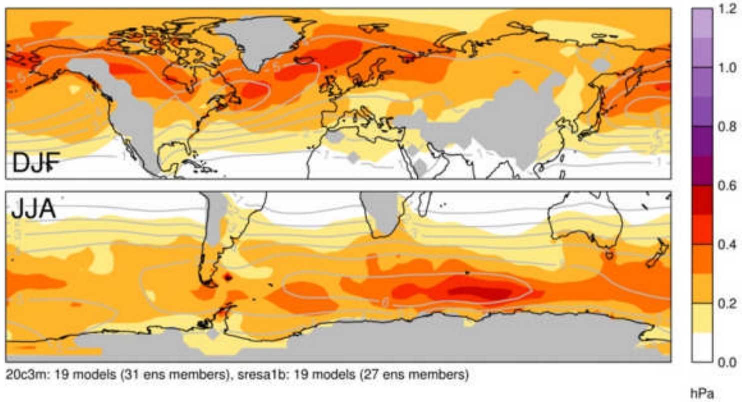
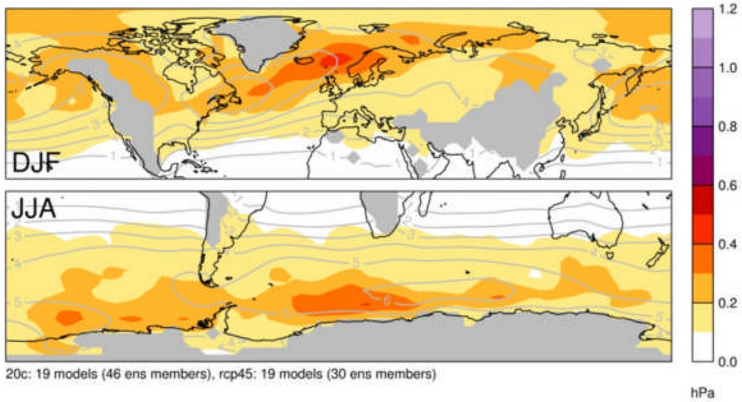


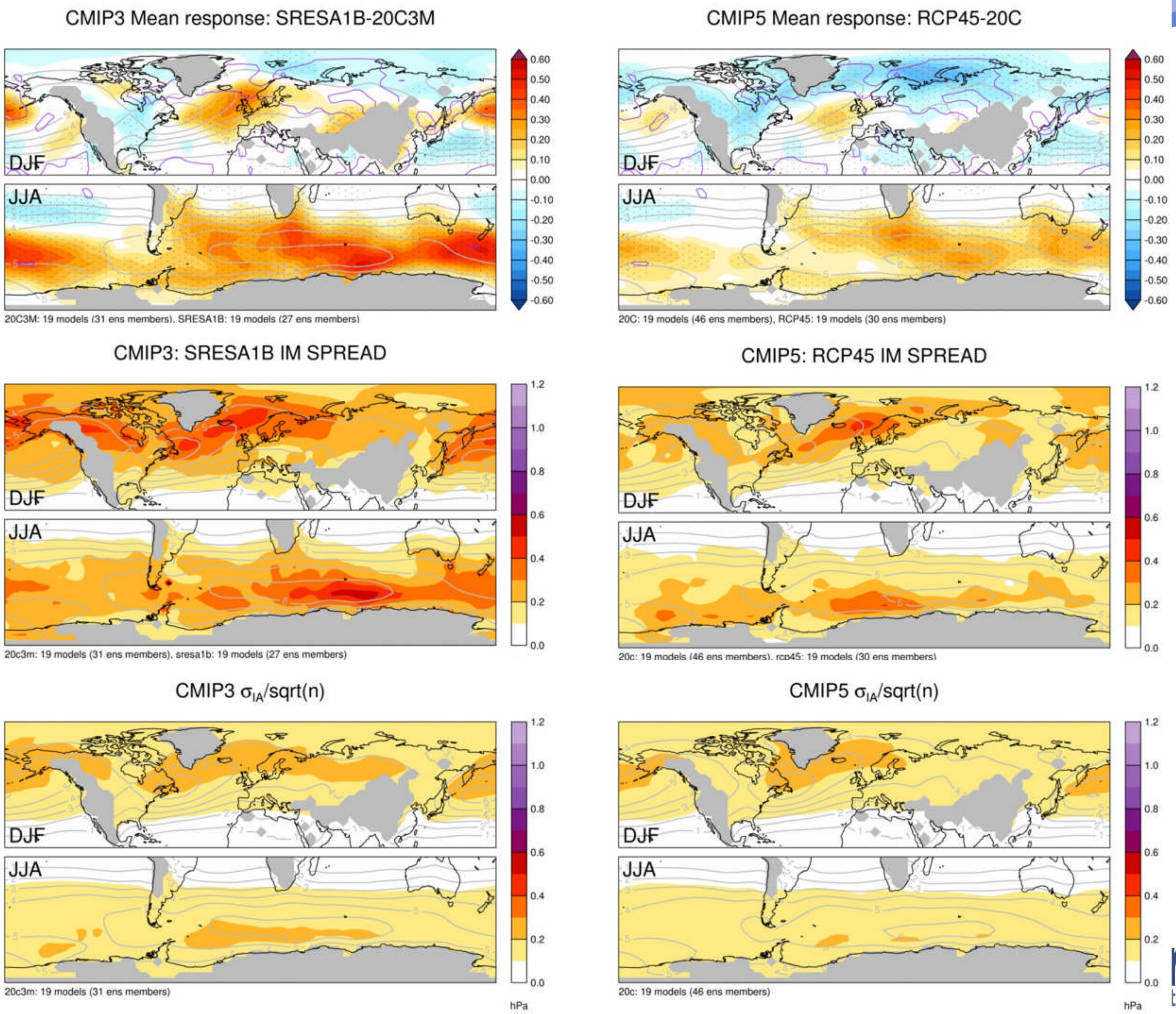
CMIP3: SRESA1B IM SPREAD

20c3m: 19 models (31 ens members), sresa1b: 19 models (27 ens members)



CMIP5: RCP45 IM SPREAD

20c: 19 models (46 ens members), rcp45: 19 models (30 ens members)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CMIP5: RCP45 IM SPREAD

20c3m: 19 models (31 ens members), sresa1b: 19 models (27 ens members)

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CMIP3 σ_{IA}/sqrt(n)

CMIP5 σ_{IA}/sqrt(n)

20c3m: 19 models (31 ens members)

20c: 19 models (46 ens members)

Key question

- What are the physical mechanisms causing the inter-model spread in the storm track responses?

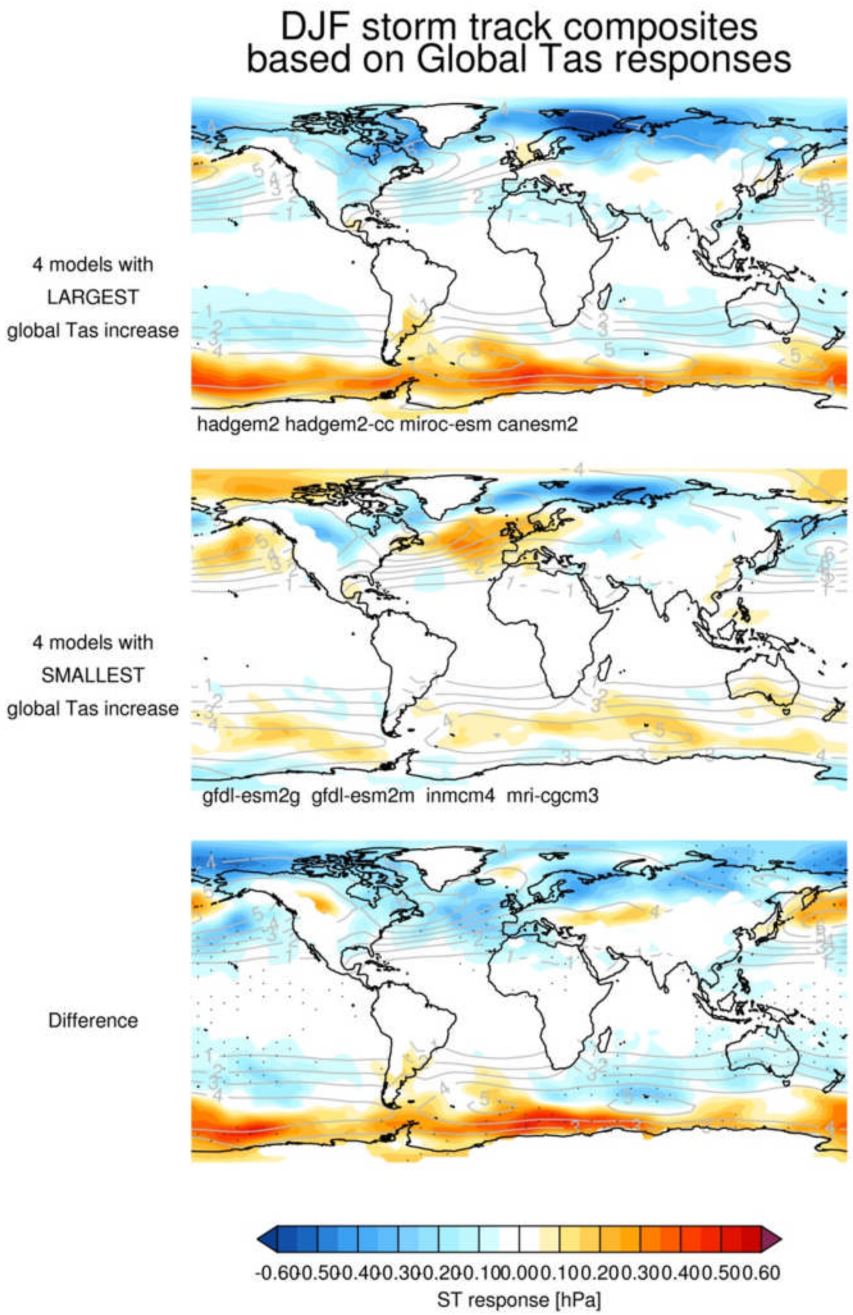
Talk Outline

- Part I: What can we learn from the CMIP model runs?
- Part II: Some AGCM experiment results

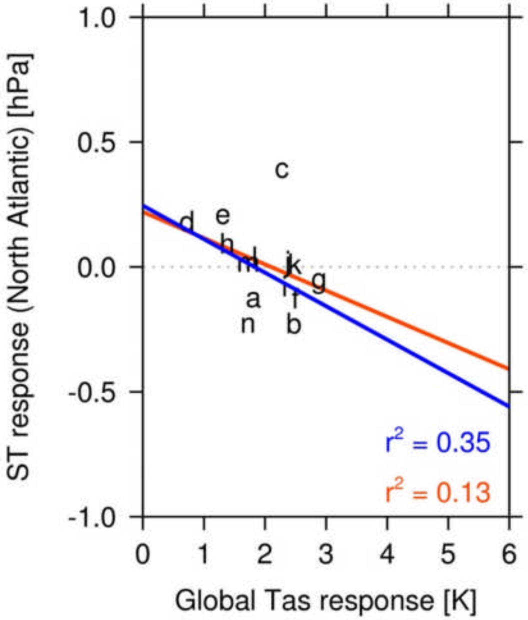
Climate sensitivity composites

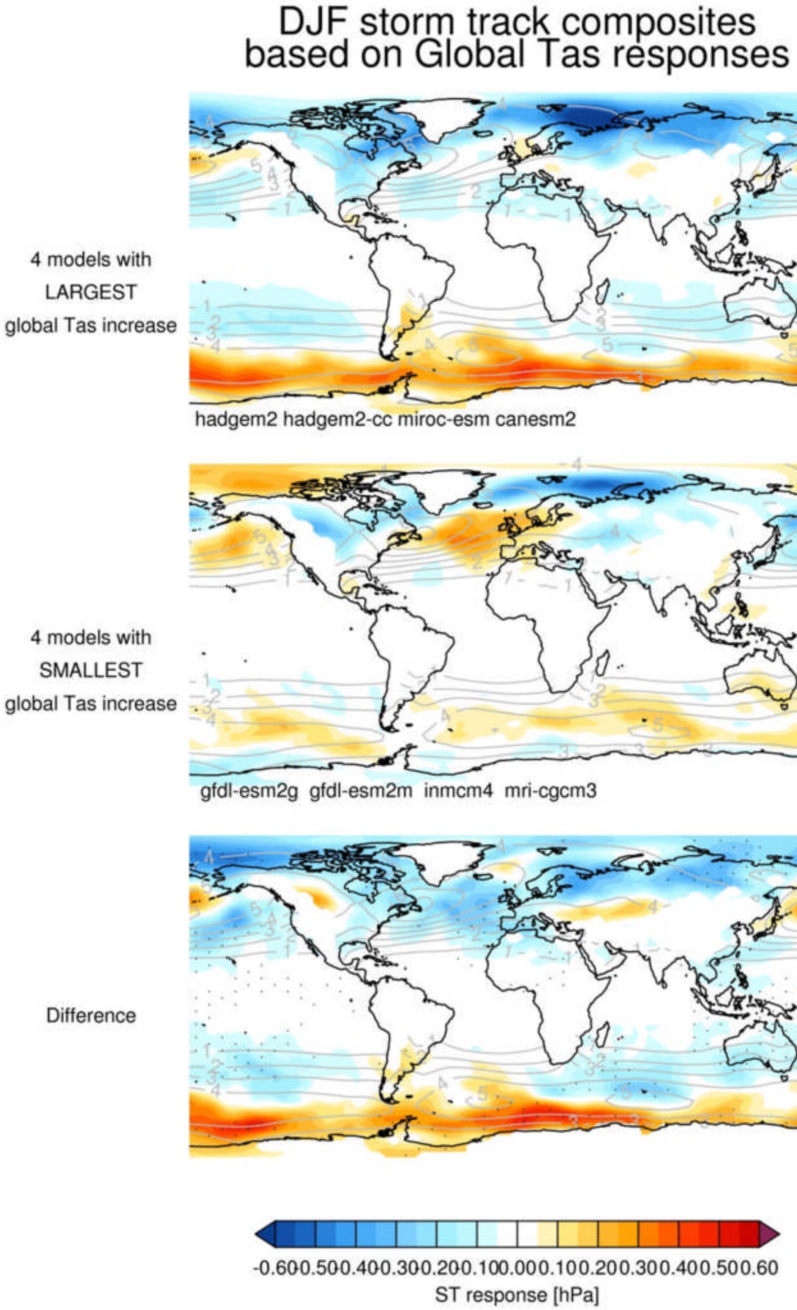
- Based on 14 CMIP5 models
- Scenario: RCP4.5
- Range of Tas responses:

  0.7 – 2.8 K

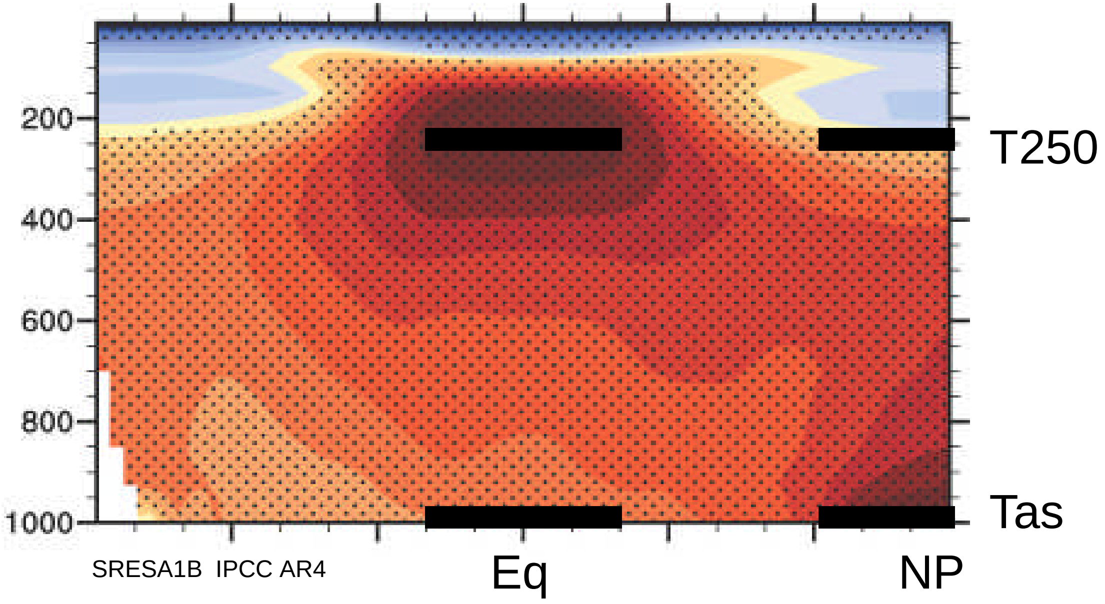


Climate sensitivity composites



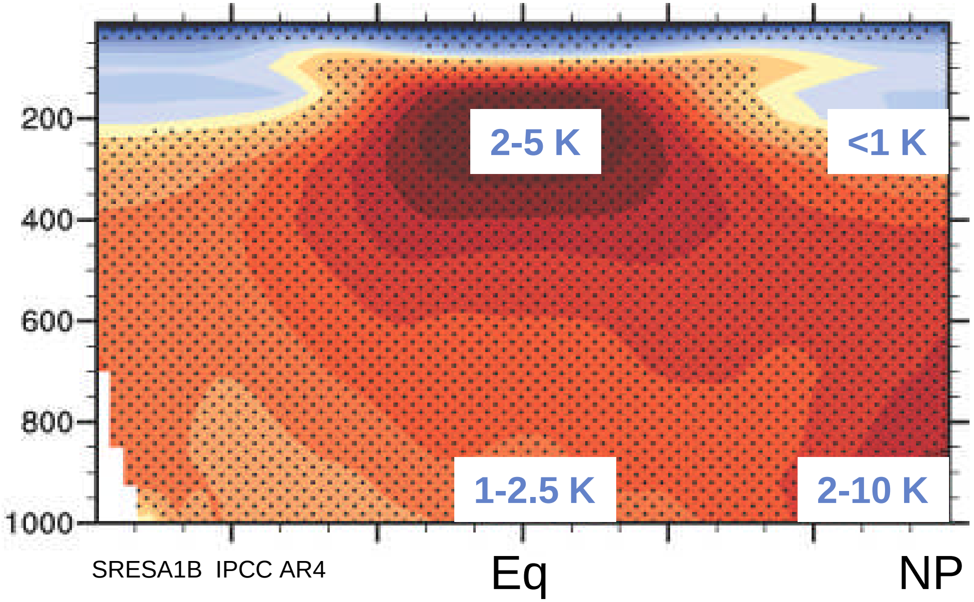


Meridional T gradient composites

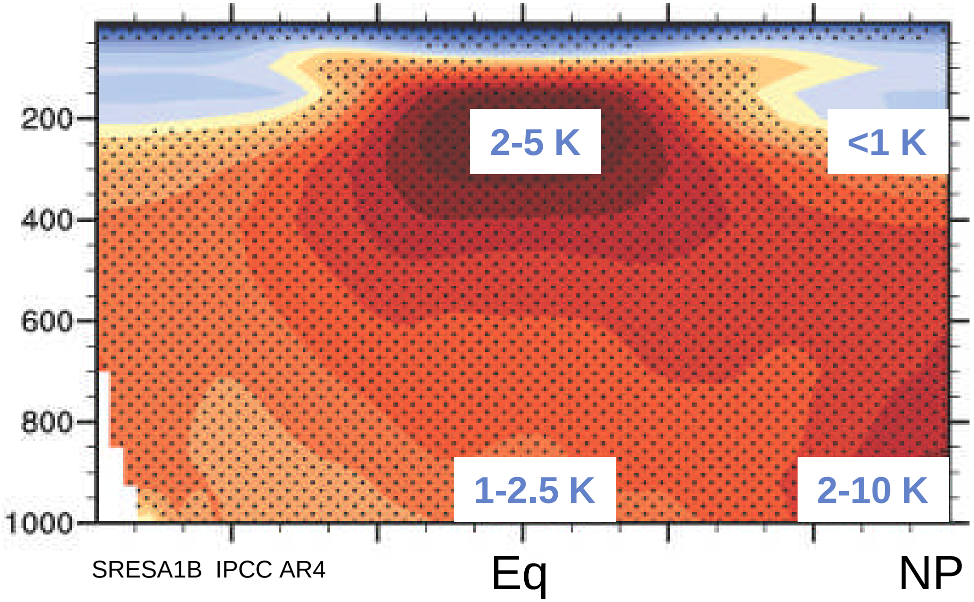


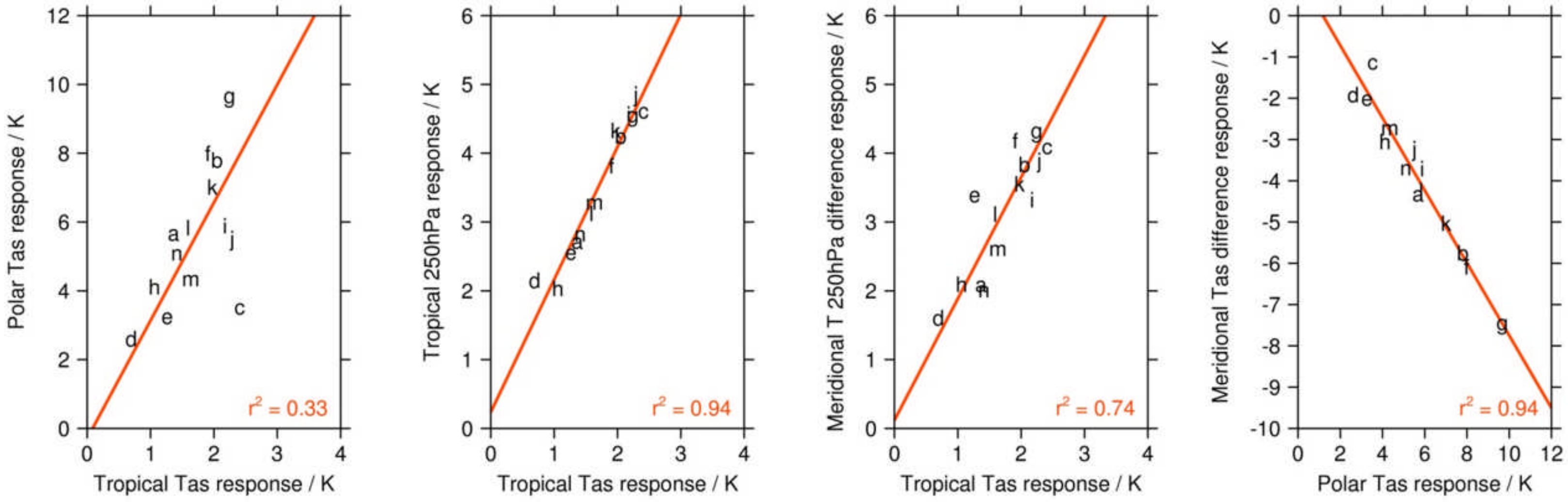
SRESA1B IPCC AR4

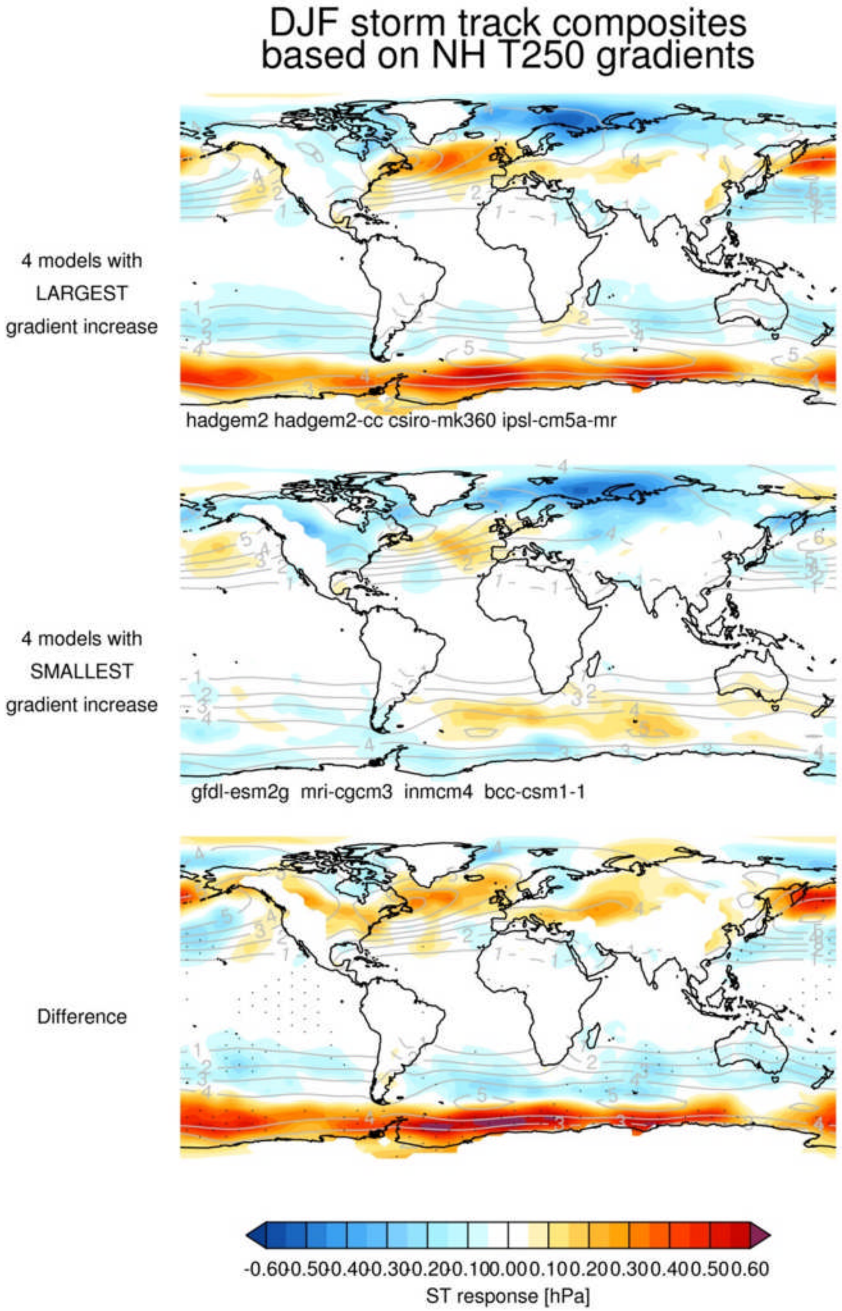
Meridional T gradient composites

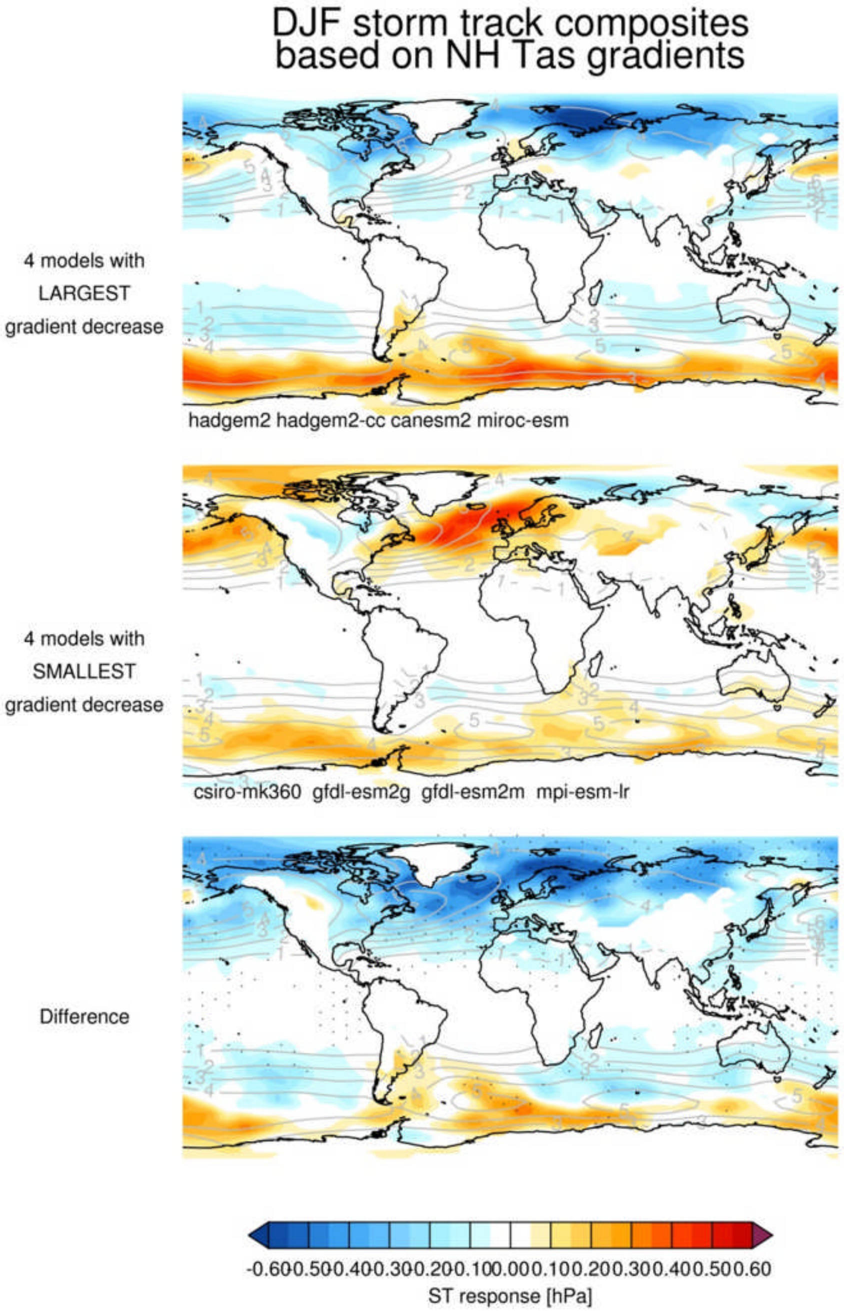


Meridional T gradient composites






DJF storm track composites based on NH T250 gradients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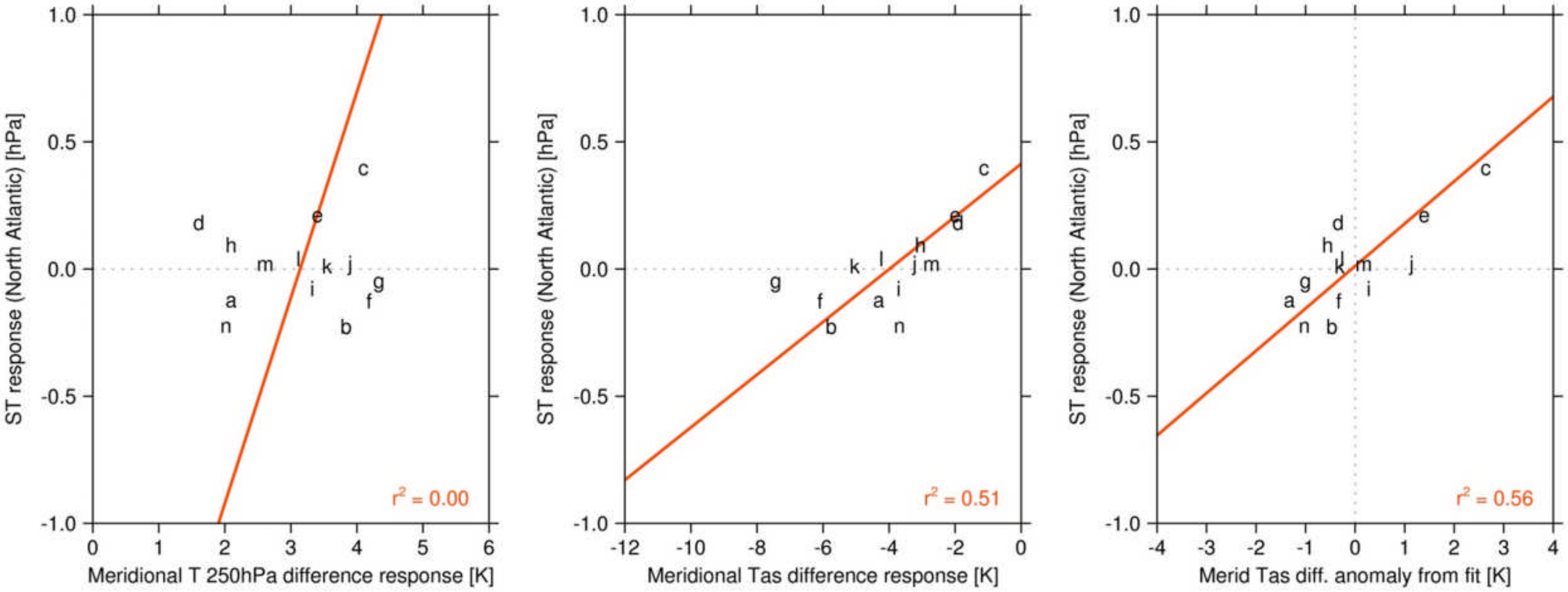
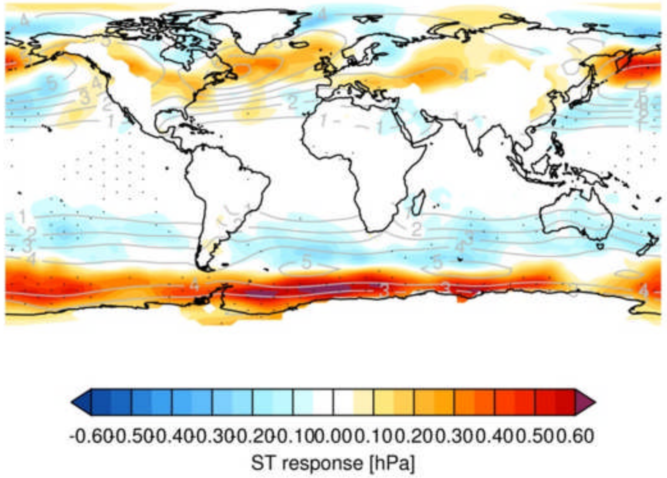
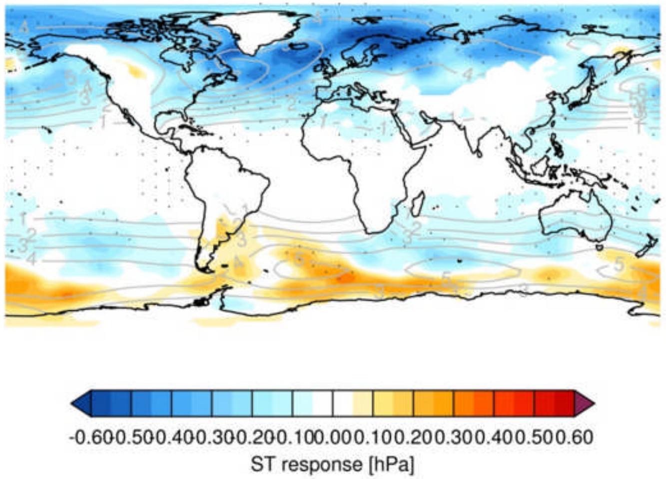


Difference

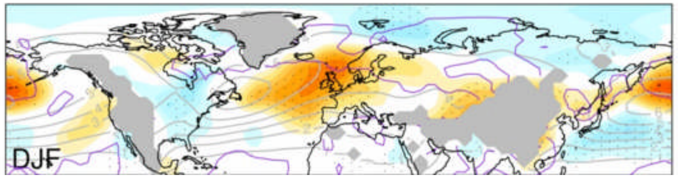


Difference

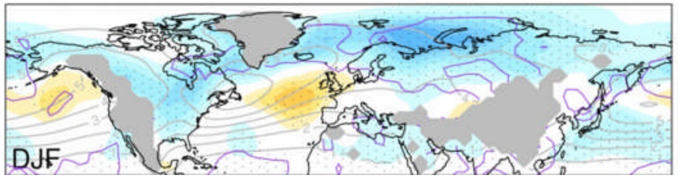


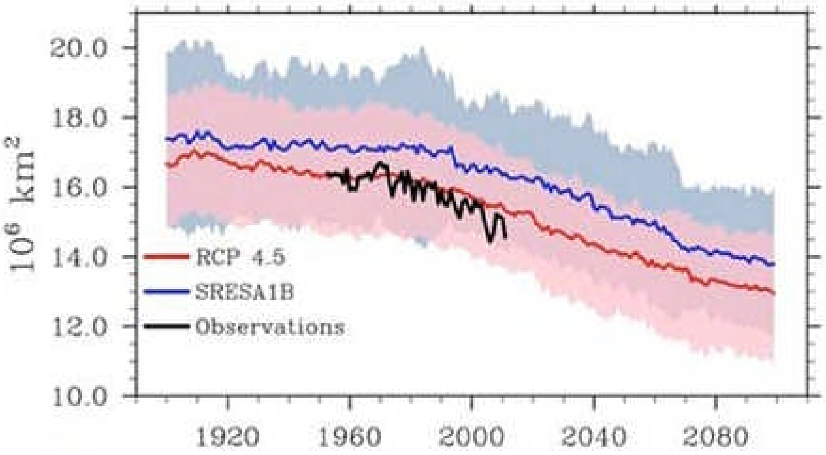
Consistent with CMIP3/CMIP5 differences?

CMIP3 Mean response: SRESA1B-20C3M



CMIP5 Mean response: RCP45-20C



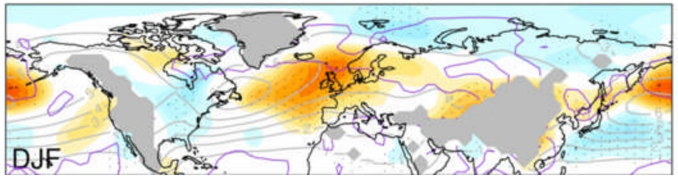


Stroeve et al (2012)

- Ice losses are similar
- Global Tas response is about 1.5 times larger in CMIP3 than CMIP5

Storm risk mitigation

Consistent with CMIP3/CMIP5 differences?



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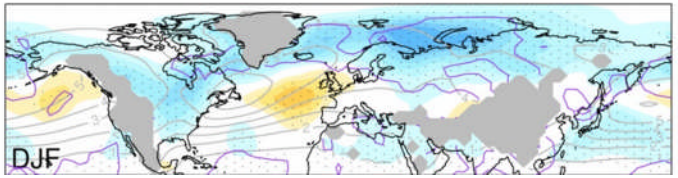
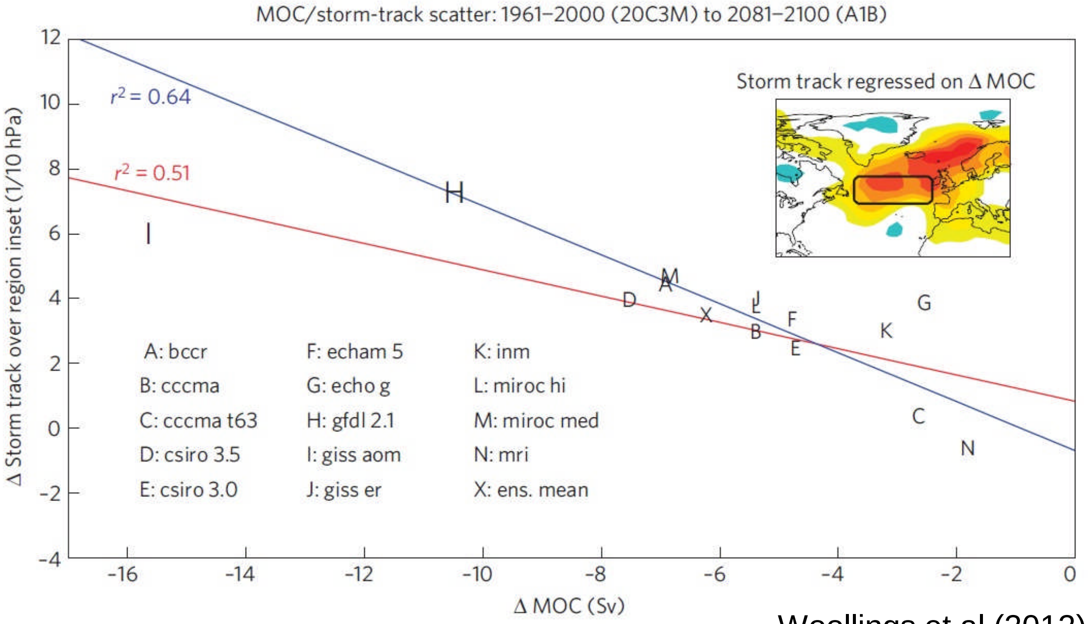


CMIP5 Mean response: RCP45-20C

Is this a causal relationship between sea ice and storm tracks?



MOC/storm-track scatter: 1961–2000 (20C3M) to 2081–2100 (A1B)

Woollings et al (2012)

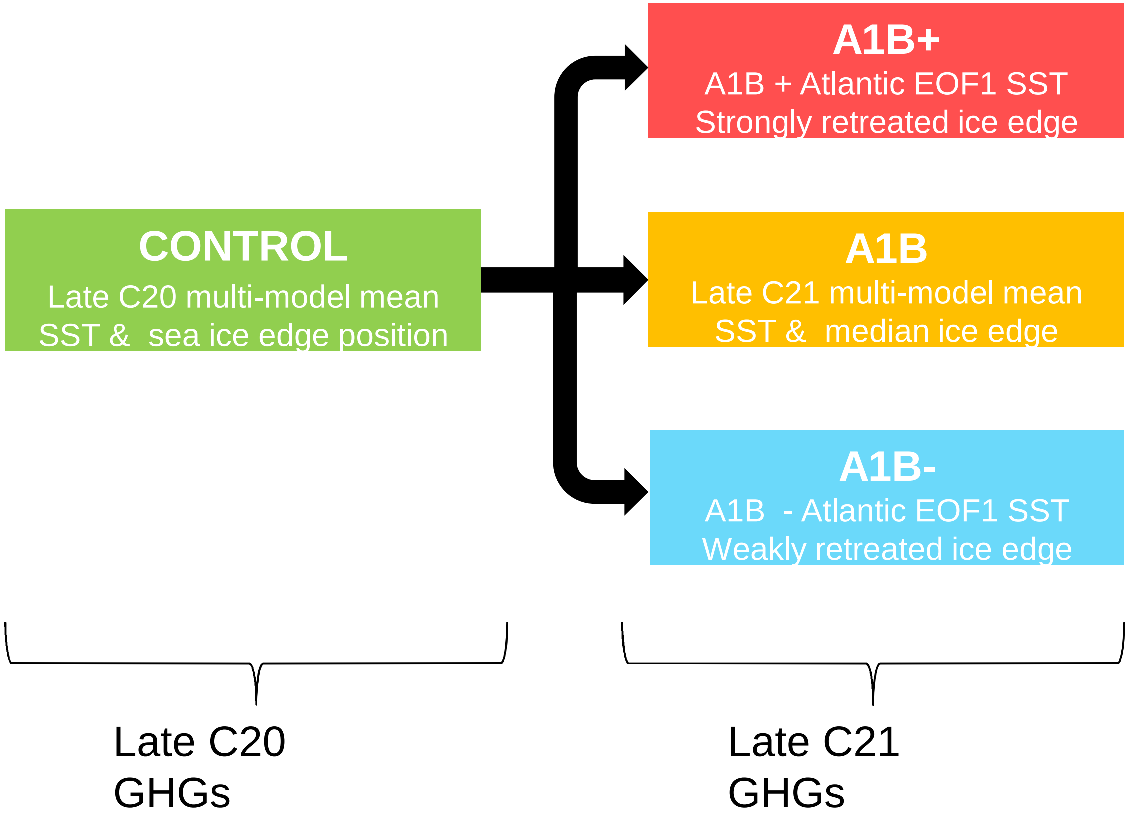
Conclusions to Part I

- Spread in both CMIP3 and CMIP5 ensembles > sampling error
- Composite plots suggest that meridional temperature gradients can explain some of the spread in the CMIP5 storm track responses
- Southern Hemisphere and Pacific storm tracks: poleward shift is related to change in upper level temperature gradient
- North Atlantic storm track: opposing impacts from upper and lower level temperature gradients
  - Lower level: strong gradient decrease (ice loss?) linked to storm track reduction
  - Upper level: strong gradient increase (large climate sensitivity?) linked to storm track intensification
- However, can’t distinguish between local SST changes and larger scale temperature gradients via compositing method

→ Motivates experiments

Experimental design

- Force an atmosphere GCM (HadGAM1.2) with a set of SST and sea ice fields designed to capture the spread in the CMIP3 model responses



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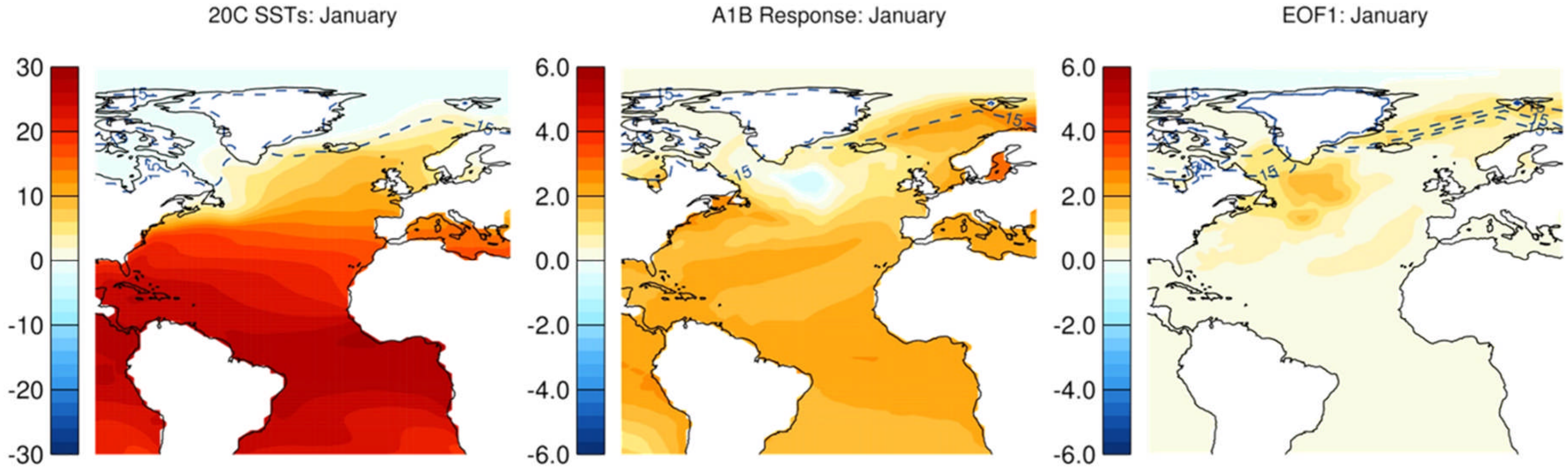


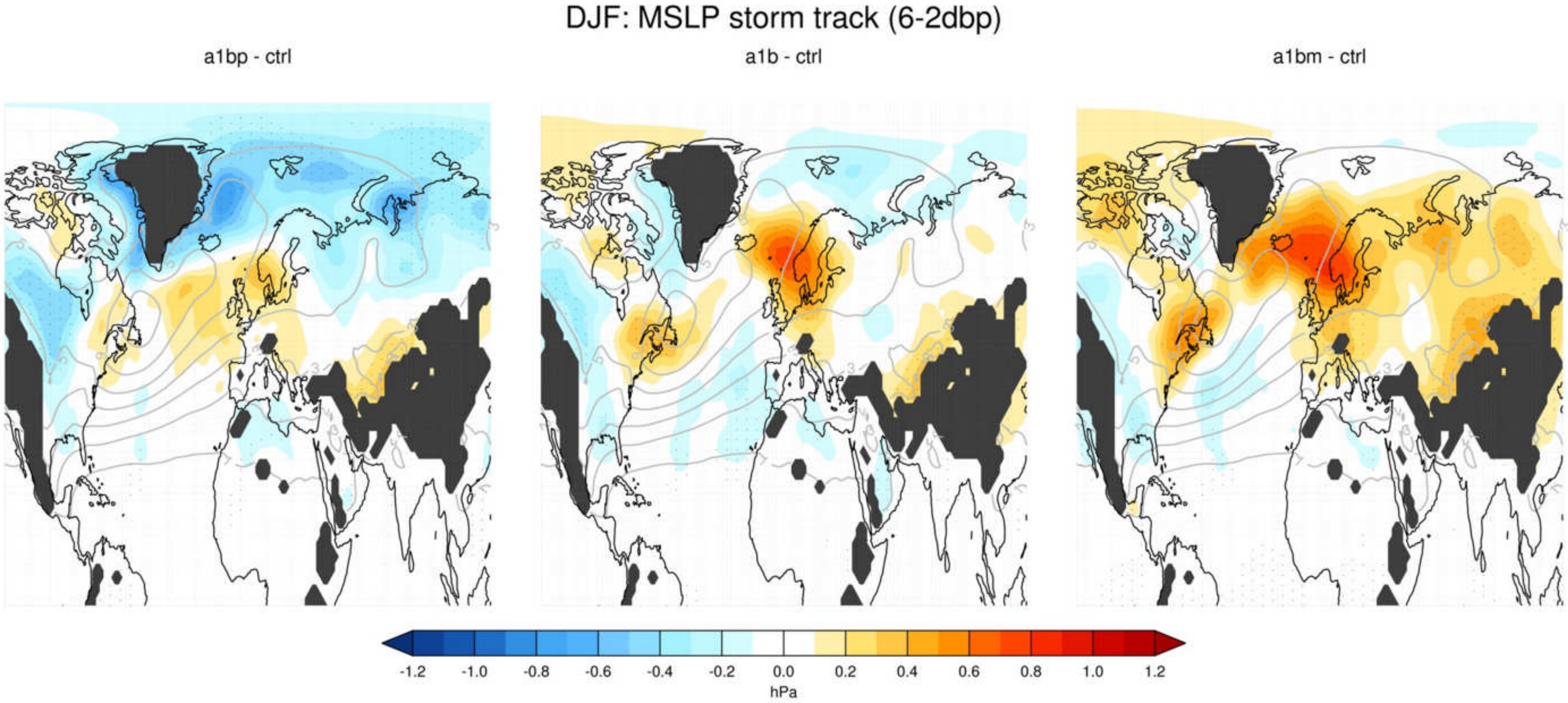
CONTROL
Late C20 multi-model mean
SST & sea ice edge position

A1B
Late C21 multi-model mean SST
& median ice edge retreat

A1B-
A1B - Atlantic EOF1 SST
Weakly retreated ice edge

A1B+
A1B + Atlantic EOF1 SST
Strongly retreated ice edge

Some results…



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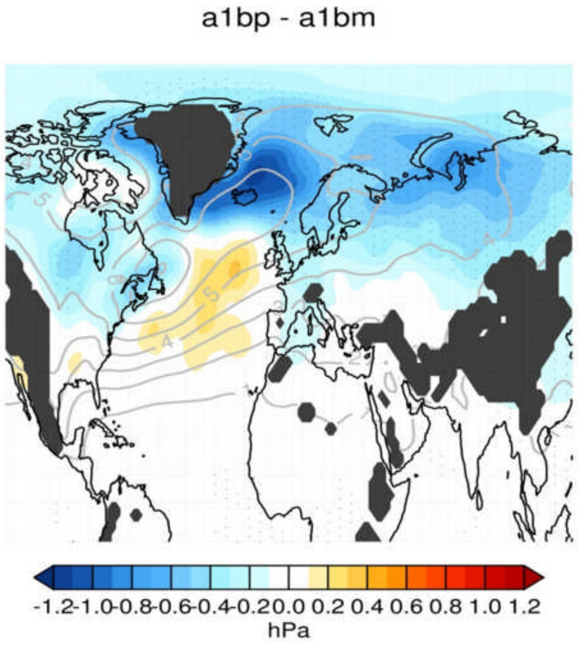
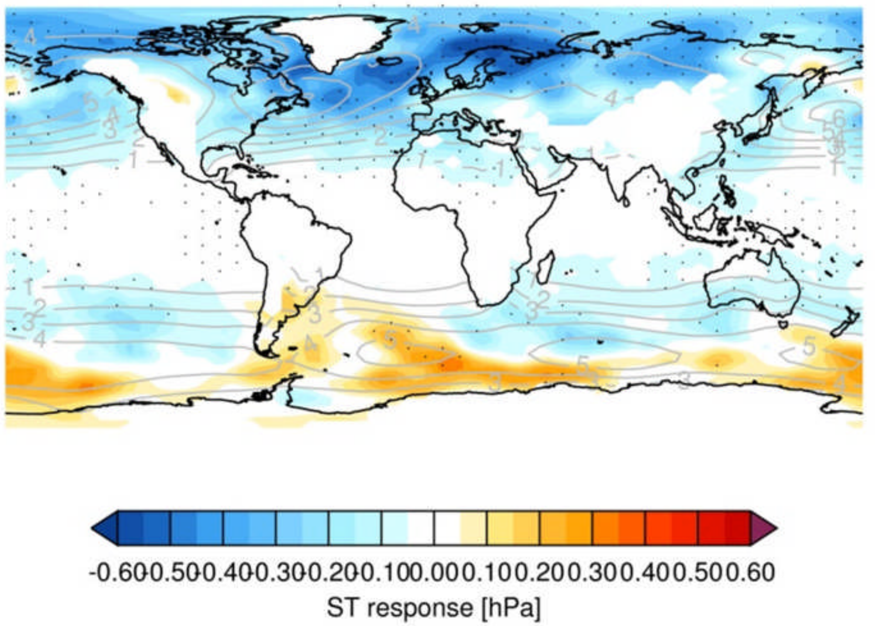
Storm
risk mitigation

Some results…





A1B-
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Weakly retreated ice edge

–

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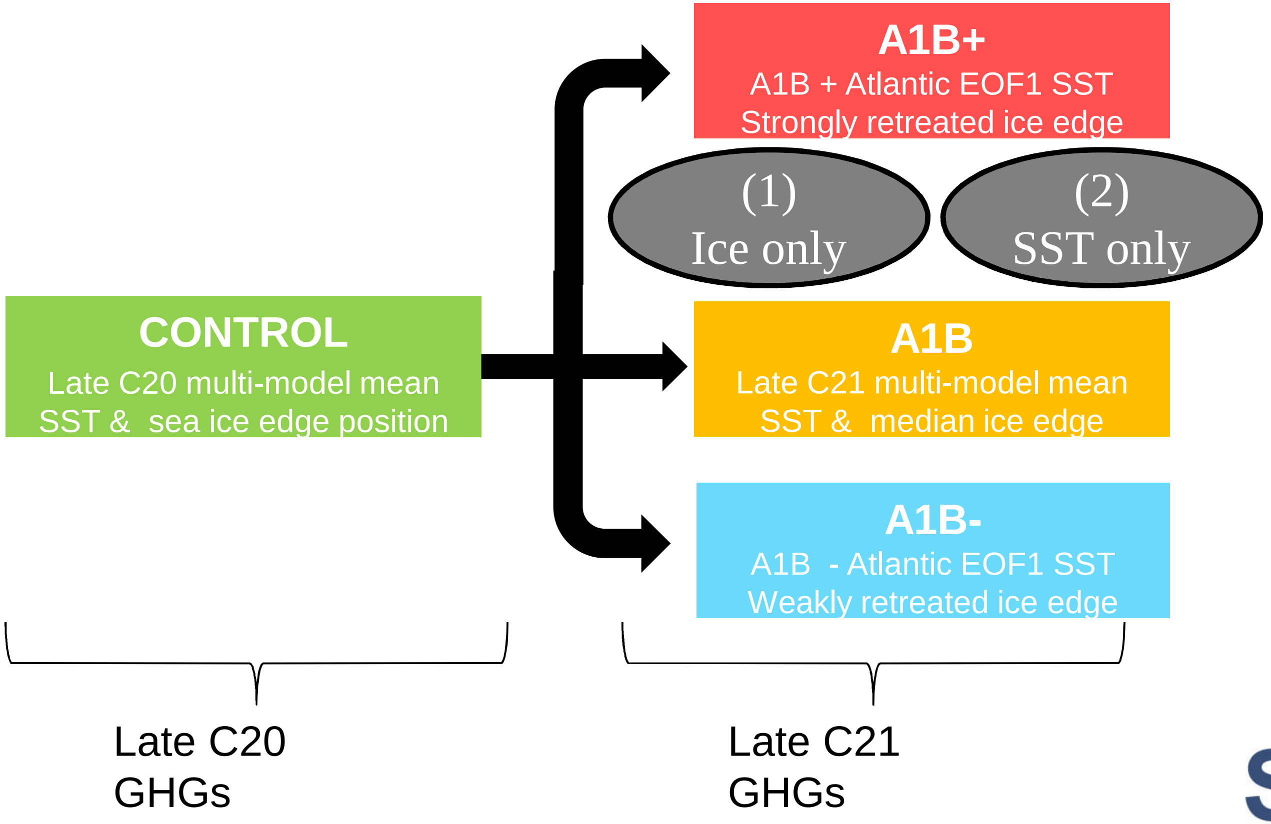

A1B+
A1B + Atlantic EOF1 SST
Strongly retreated ice edge

(1)
Ice only

(2)
SST only

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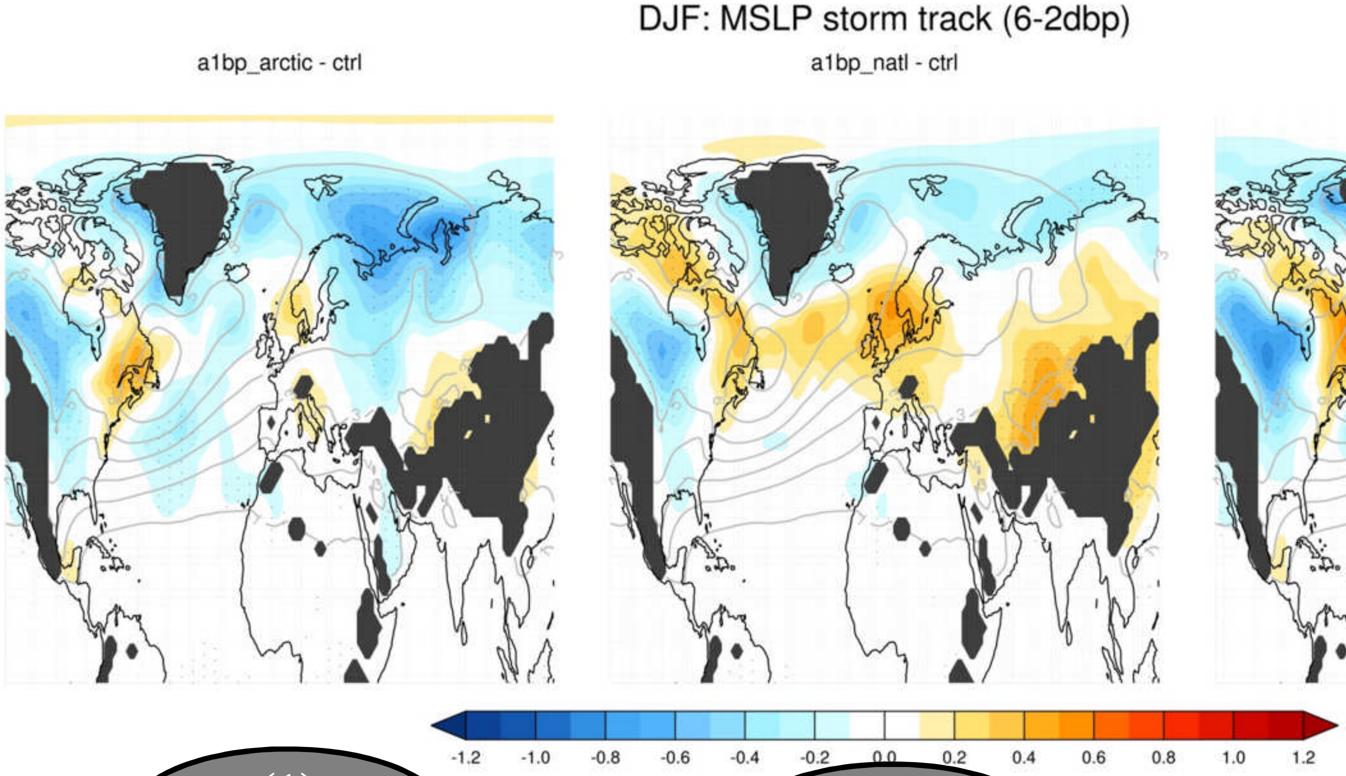
Late C20
GHGs

Late C21
GHGs

Some results…


DJF: MSLP storm track (6-2dbp)

(1)
Ice only

(2)
SST only

Combined

Storm risk mitigation

Conclusions to Part II

- Atmospheric GCM experiments agree qualitatively with the conclusions from Part I:
  - Global warming with weak ice loss (and cool N Atlantic SSTs) results in a storm track intensification
  - Global warming with strong ice loss (and warm N Atlantic SSTs) results in a storm track weakening
- However, the precise locations of the responses appear to be model dependent
- Split forcing experiments suggest ice loss plays a larger role than sub-polar gyre SSTs in mediating the storm track intensification (although longer runs needed)

What’s next?

- Further experiments…
  - A1B- partial-forcing experiments
  - Investigate relationship with upper level temperature gradient (impose a globally uniform SST anomaly?)
  - Repeat experiments using more realistic control SST and sea ice fields

- Further CMIP analysis…
  - Perform compositing/correlation analyses using tracking data

Thank you for listening!