Modifying Regional Amplification in the AMAP Climate Emulator

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Photo Credit: www.amap.no

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Climate Modelling and Emulators

- Climate models are mathematical representations of Earth's climate system components (atmosphere, land, ocean, ice) used to project surface temperatures
- Climate forcers with a short atmospheric lifetime that exist in trace amounts produce high uncertainties even in ESMs

Comprehensive Models	Climate Emulators
- non-linear model - finer spatial resolution (order of 10-100km) - resource-intensive - long run-time	- greatly simplified, linearized energy model - usually a hemispheric or global resolution - less resource-intensive - short run-time

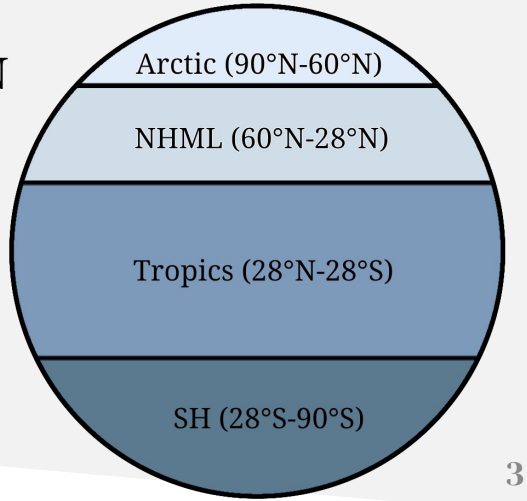
Climate Modelling and CMIP

- Coupled Model Intercomparison Project (**CMIP**): an international effort to improve climate models by comparing model simulations to observations and to each other.
- Specifies a range of projected scenarios for socio-economic "storylines" (**SSPs**) with specific profiles of emissions of greenhouse gases, other pollutants, and land-use change
  - 5 umbrella narratives for socio-economic development
  - **SSP5-8.5**: fossil fuel development

Image Credit: arctic-council.org

The AMAP Climate Emulator

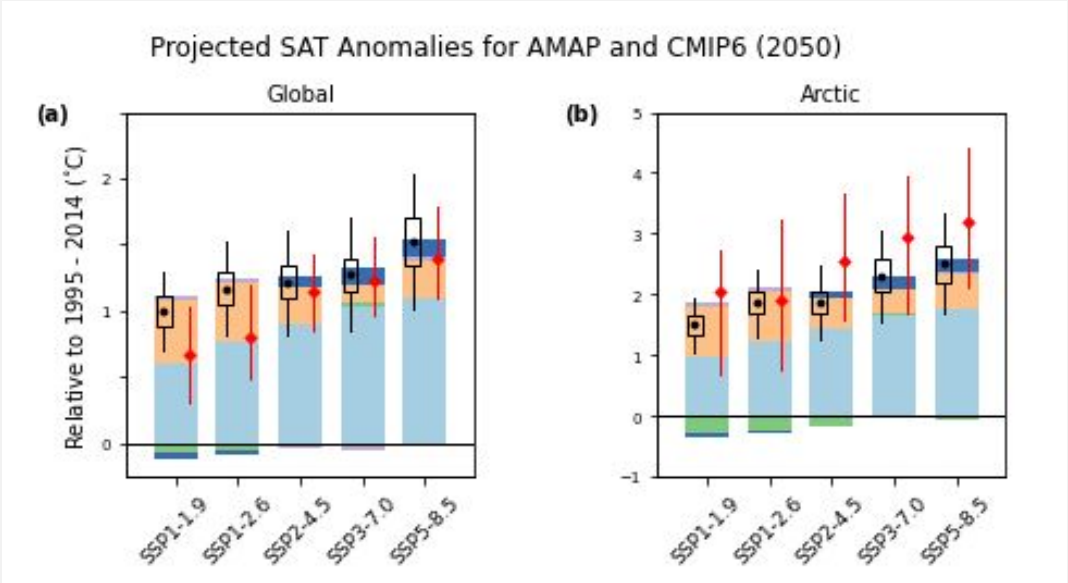
- **AMAP**: Atmospheric Monitoring and Assessment Programme
- Impulse response climate emulator
- Species: CH_4, OC, BC, SO_4, O_3, CO_2
- The emulator outputs mean surface air temperature for **4 regions**:
  - Arctic: 90°N-60°N
  - Northern Hemisphere Midlatitudes: 60°N-28°N
  - Tropics: 28°N-28°S
  - Southern Hemisphere: 28°S-90°S



Arctic Warming is Underestimated

$$\Delta_{rel} = \frac{1}{5}\sum_{i=1}^{5}\frac{dT_{AMAP_i} - dT_{CMIP6_i}}{(dT_{AMAP_i} + dT_{CMIP6_i})/2} \cdot 100\%$$

	Region	Δ_{rel}
2030	Arctic	-5.0 ± 31.5%
	Global	20.5 ± 15.7%
2050	Arctic	-22.4 ± 27.0%
	Global	19.3 ± 16.0%



Regional Temperature-Change Potentials

- Regional Temperature-Change Potential (**RTP**) [K]: equilibrated temperature response to a steady forcing.
  - Obtained from GISS-ER
- The RTP for region *m* of the 4 regions is: $RTP_m = \sum_{l=1}^{4} k_{lm} \delta F_{0l}$

$$ECS = \frac{F_{2x}}{\delta F_0} \sum_{m}^{4} \sum_{l}^{4} k_{lm} \delta F_{0l} z_m = \lambda F_{2x}$$

- From CMIP6, 2.5 < ECS < 4.0 K
- **Underestimated by emulator!** ECS is scaled from 2.7 to 3.7
- Equilibrium Climate Sensitivity (**ECS**): global surface temperature response from doubling Earth's atmospheric CO2 concentration.

Modifying RTP Coefficients

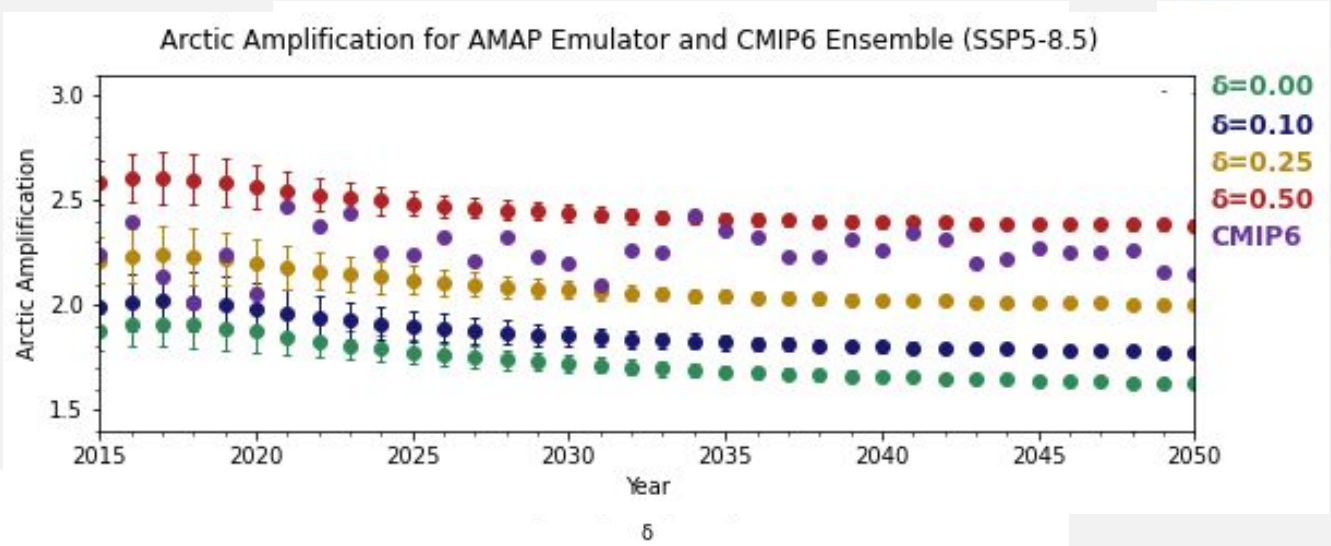
- To increase Arctic warming, k_{lm} for RTP_{Arctic} were adjusted.
- To preserve the ECS, the other coefficients have an area-weighted decrease.

	RTP_{Arctic}	RTP_{NHML}	$RTP_{Tropics}$	RTP_{SH}
k_{Arctic}	Increase by δ	Area-weighted decrease $\theta \in (28°N\text{-}60°N)$	Area-weighted decrease $\theta \in (28°S\text{-}28°S)$	Area-weighted decrease $\theta \in (90°S\text{-}28°S)$
k_{NHML}				
$k_{Tropics}$				
k_{SH}				

$\delta \in \{0, 0.1, 0.25, 0.50\}$

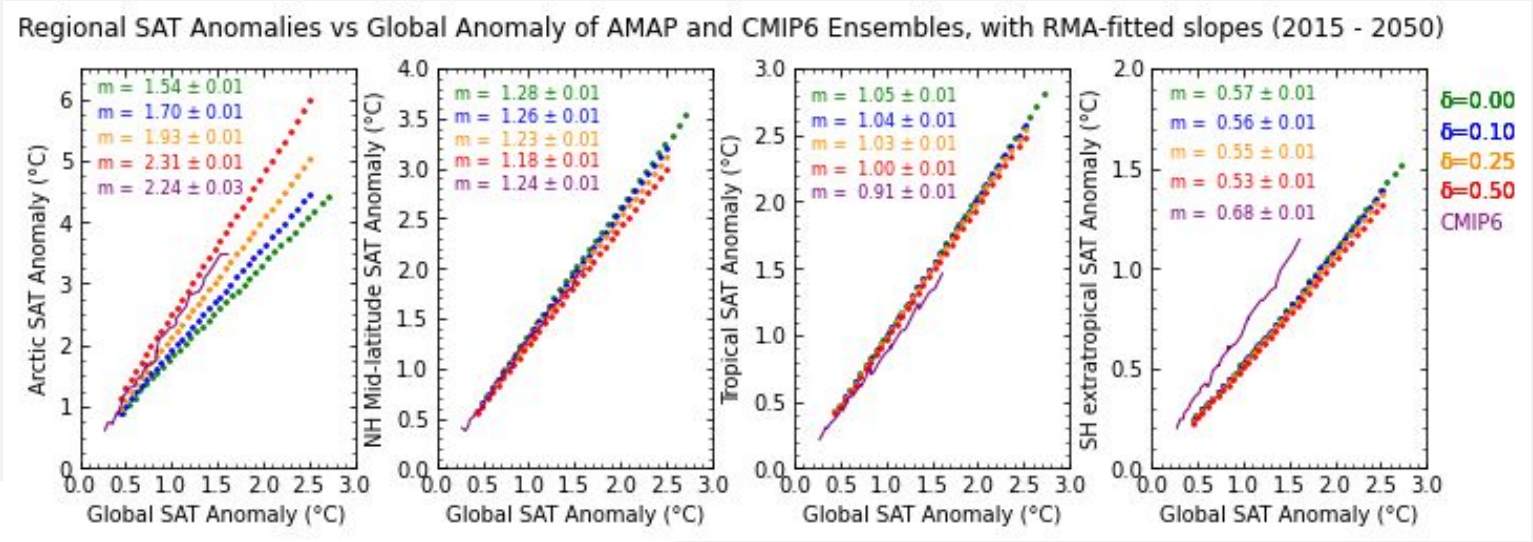
Arctic Amplification with tweaked RTPs

- Focusing on SSP5-8.5: the most warming
- The mean SAT anomaly passes between the median value from CMIP6 between δ=0.25 and 0.50



RMA Fitting to represent Regional Amplification

- Minimize the orthogonal distance from the line in both directions
- SH matchup with CMIP6 results lessen as RTP_{Arctic} increases



Conclusions and Other Work

- The RTP coefficients in the AMAP emulator underestimate Arctic warming, and a scaling between δ=0.25 and 0.5 is recommended
  - Impacts on warming for other regions
  - ECS considerations
- Other aspects of emulator evaluation and testing
  - Temperature-methane emissions feedback loop
  - Atmospheric lifetime of methane

THANK YOU

Do you have any questions?

Photo Credit: www.amap.no

Creating and AMAP and CMIP6 ensemble

AMAP Ensemble (for each SSP)

- 24 emulator realizations
- ECS = {2.59, 3.70, 5.00}
- aerosol perturbation values (a high and a low value)
  - aerosol/cloud interactions
  - aerosol/radiation interactions
  - aerosol/snow interactions

CMIP6 Ensemble (for each SSP)

- 27 realizations from 27 ESMs included in CMIP6

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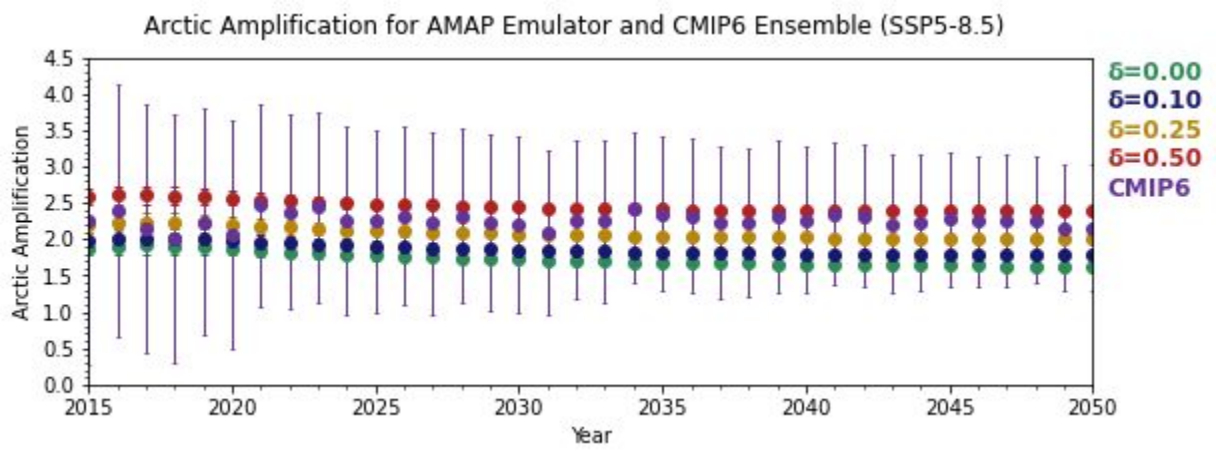

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