

Can stratospheric aerosol intervention save coffee and chocolate from climate change?

Nina Grant¹, Alan Robock¹, Lili Xia¹, Brendan Clark² and Jim Kiniry³

¹Department of Environmental Sciences, Rutgers University, New Brunswick, NJ, USA

²Department of Earth and Atmospheric Science, Cornell University, Ithaca, NY, USA

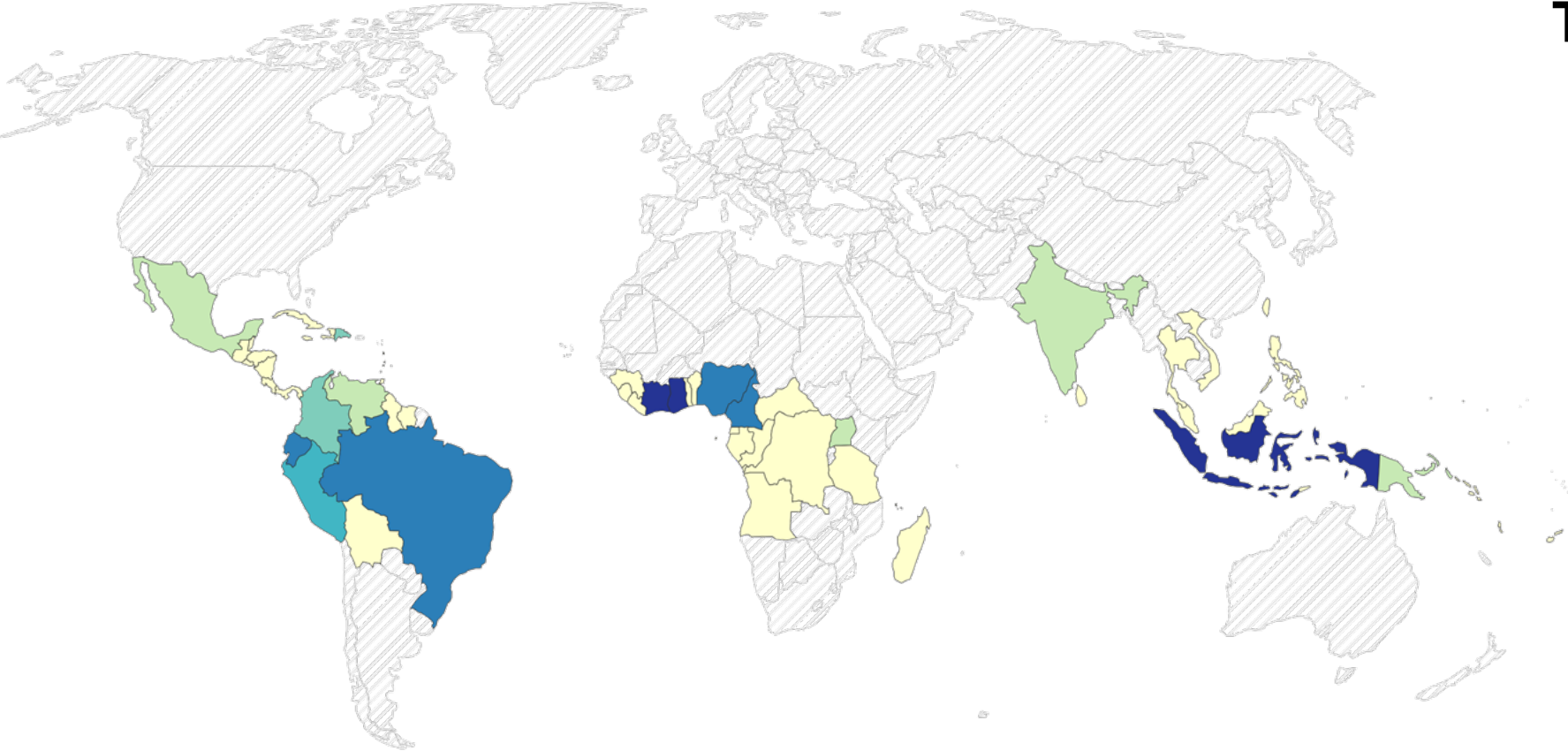
³Grassland Soil and Water Research Laboratory, USDA-Agricultural Research Service, Temple, TX, USA [Retired]



Why study coffee and cocoa?

Cocoa bean production, 2022

Cocoa bean production is measured in tonnes.



Top 5 Producers

- 1. Cote d'Ivoire
- 2. Ghana
- 3. Indonesia
- 4. Ecuador
- 5. Cameroon

A woman with dark skin, wearing an orange polo shirt and blue jeans, is bending over a large pile of cocoa pods on the forest floor. She is smiling and looking towards the camera. The pods are mostly green and yellow, with some showing signs of being harvested. The background is a lush green forest with many trees and leaves. A semi-transparent blue circle is overlaid on the right side of the image.

~70% of global
cocoa comes from
West Africa

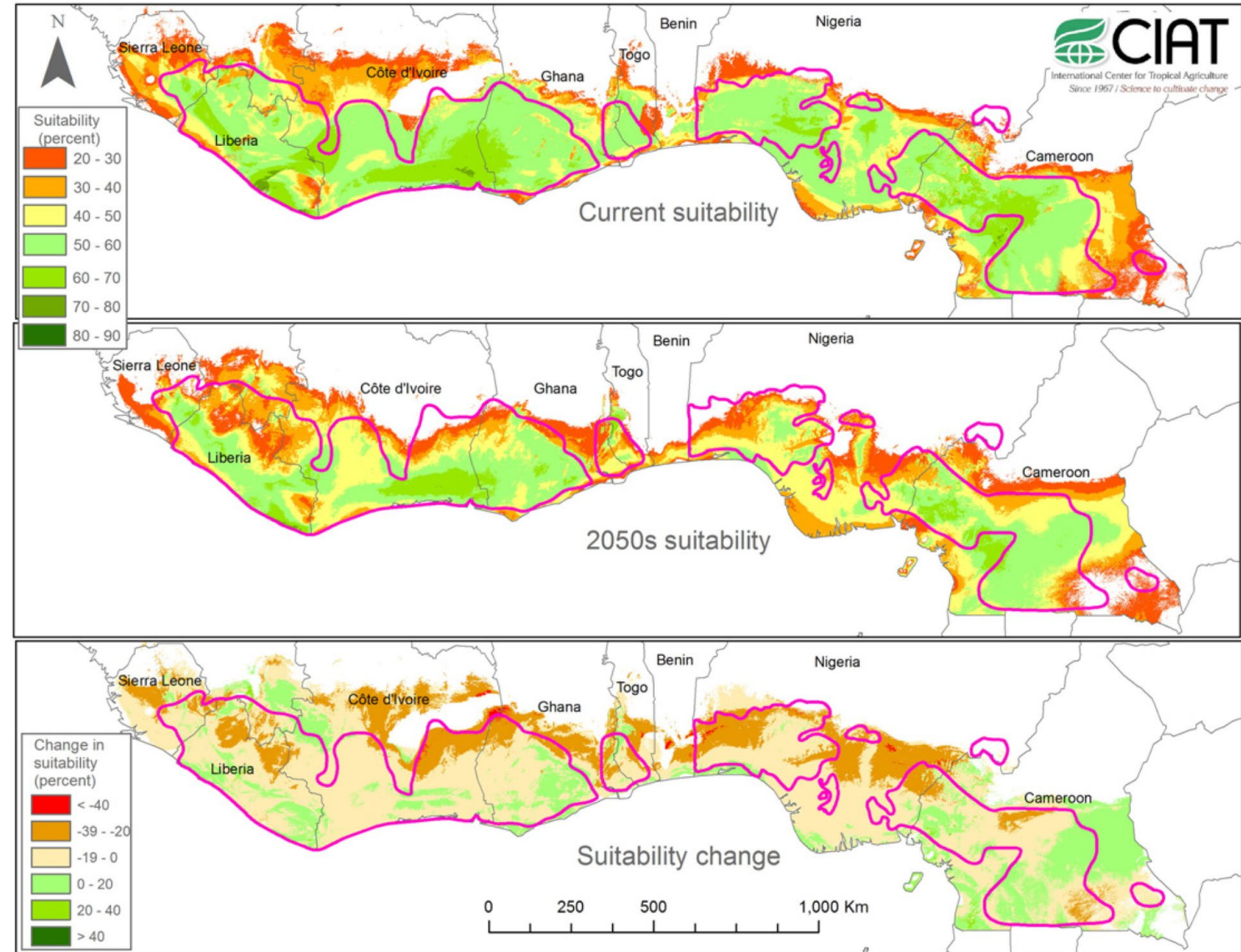
Tree Crops

- Take 3-5 years to start producing
- Live for decades (30-40 years but up to 80-200!)
- **Age and accumulate stress over the years**
- Bean quality dependent on specific climate conditions



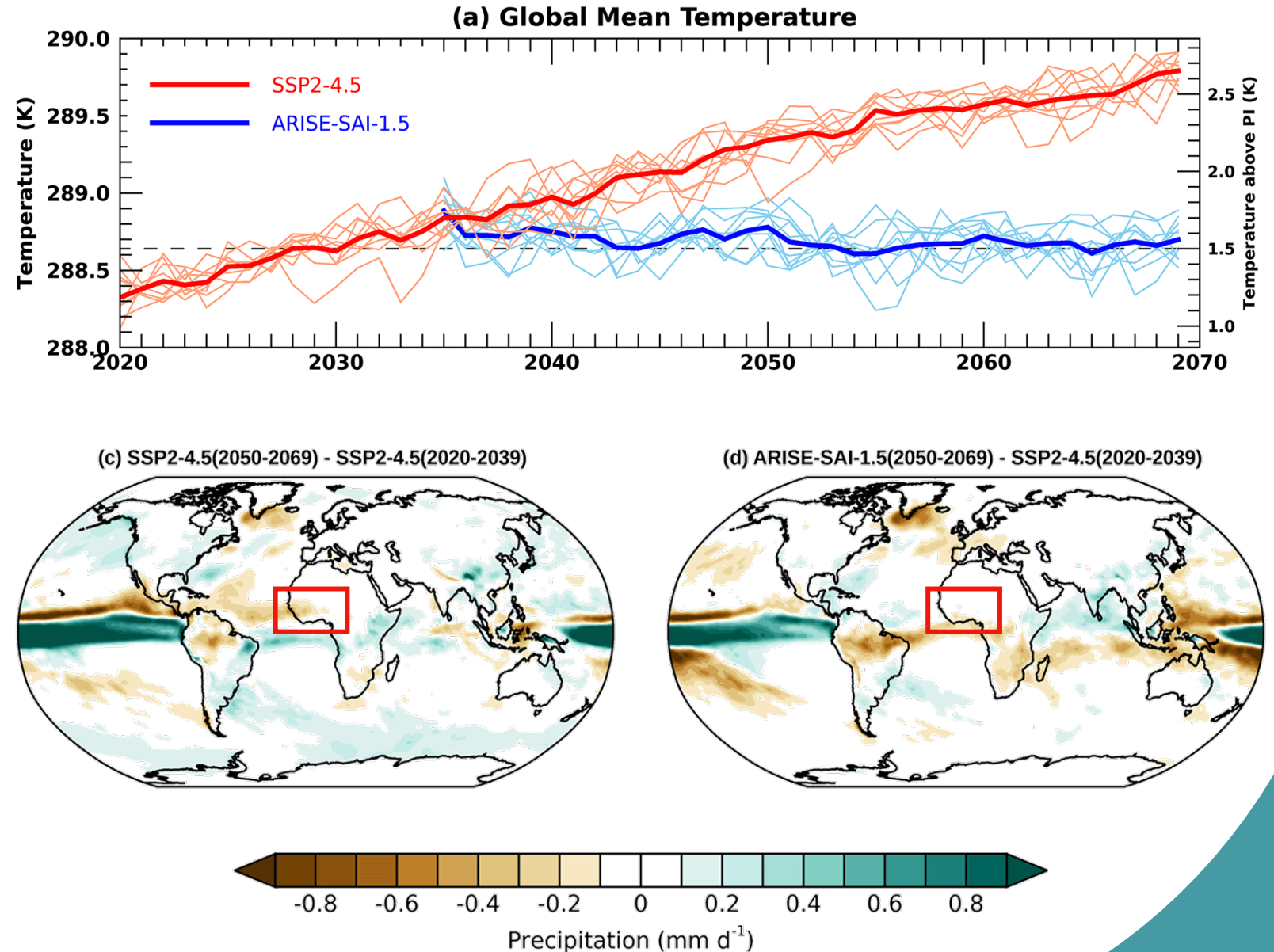
What will global warming do?

Current studies predict **rising temperatures** and a **longer dry season** will **diminish the suitable area** for cocoa and therefore yields



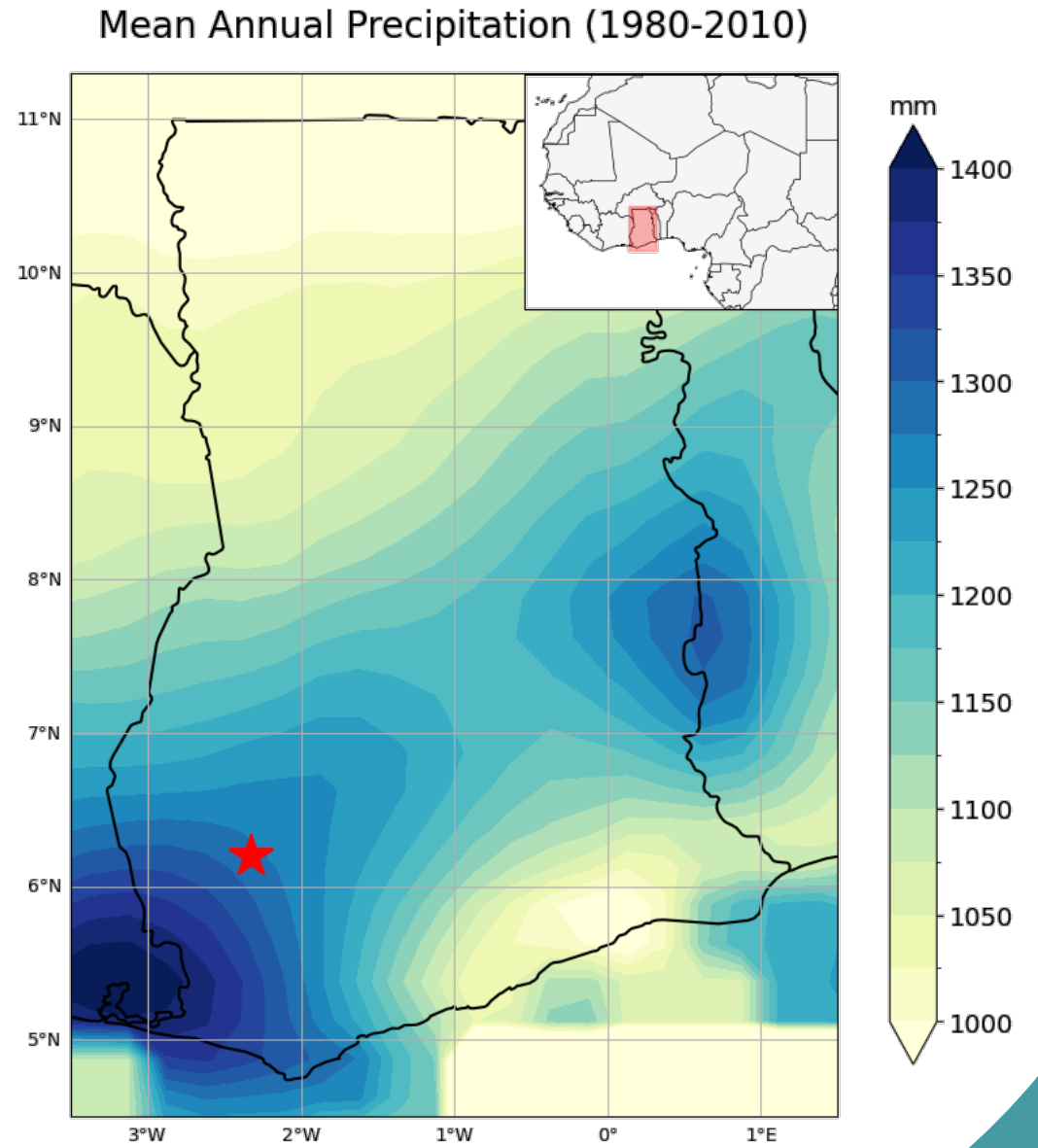
What might SAI do?

- ARISE-SAI-1.5
 - CESM2-WACCM
 - 2035-2069
 - Background scenario: SSP2-4.5
 - Target: maintain global temps at 1.5K
- Past studies found drying due to SAI, but ARISE-SAI maintains rainfall in West Africa
- High CO₂ + equal temp + equal rain = ??



Method

- Ghana: 6.2N, 2.33W
- ISIMIP Bias Adjustment and Downscaling
 - SSP2-4.5 (2050-2069)
 - 6 models | 1 ensemble member each
 - GFDL-ESM4
 - IPSL-CM6A-LR
 - MPI-ESM1-2-HR
 - MRI-ESM2-0
 - UKESM1-0-LL
 - CESM2-WACCM
 - ARISE-SAI-1.5 (2050-2069)
 - 1 model | 1 ensemble member
 - CESM2-WACCM



Crop Model: ALMANAC

Kiniry et al. (1992)



Developed to model competition among crops and grasses



Daily timestep, process-based, site-based model



Growing degree day (GDD) system for phenological development



Captures these processes:

- Light interception, dry matter production, and biomass partitioned into plant parts
- Stress due to drought, flooding, temperature, nitrogen, and phosphorus

Agricultural Land Management Alternative with Numerical Assessment Criteria (ALMANAC)

Kiniry et al. (1992)

Daily Variables:

Maximum Temperature

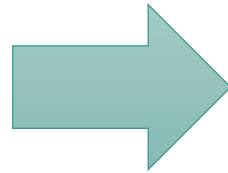
Minimum Temperature

Precipitation

Relative Humidity

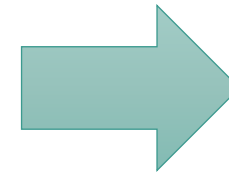
10-m Wind

Solar Radiation



ALMANAC

Permanently 10-year-old trees to isolate climate impact

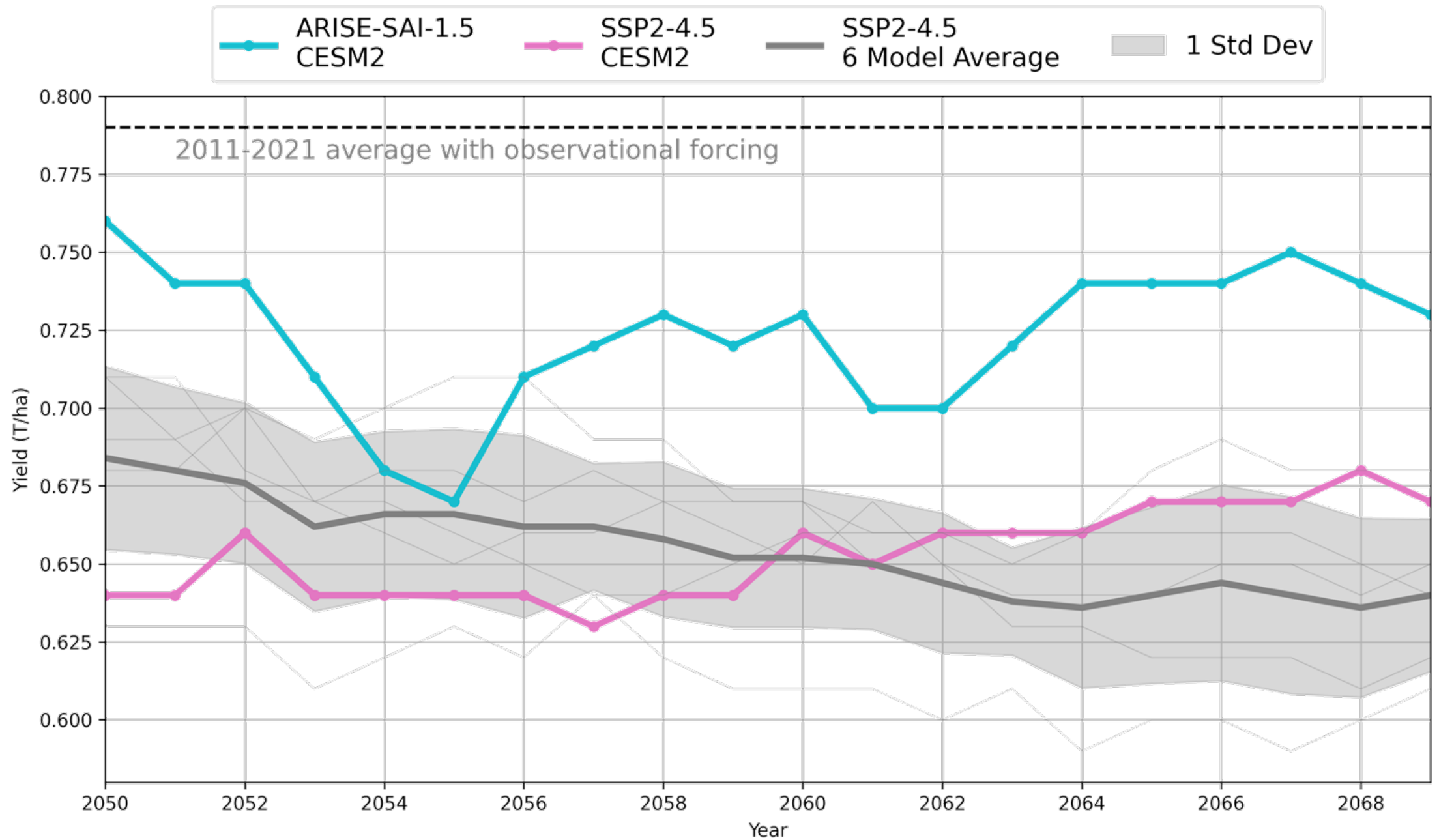


Yields

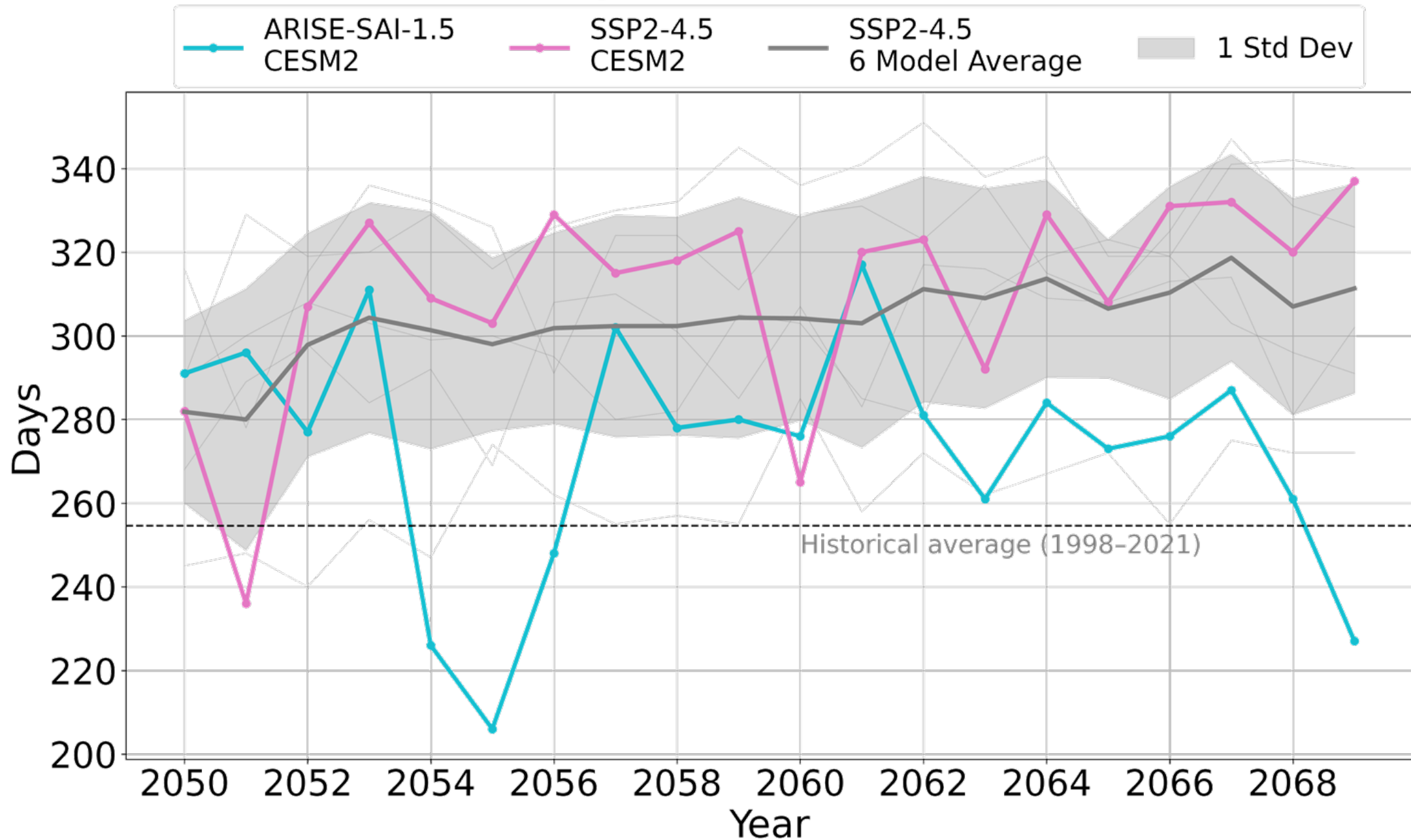
Stress days

PRELIMINARY Results

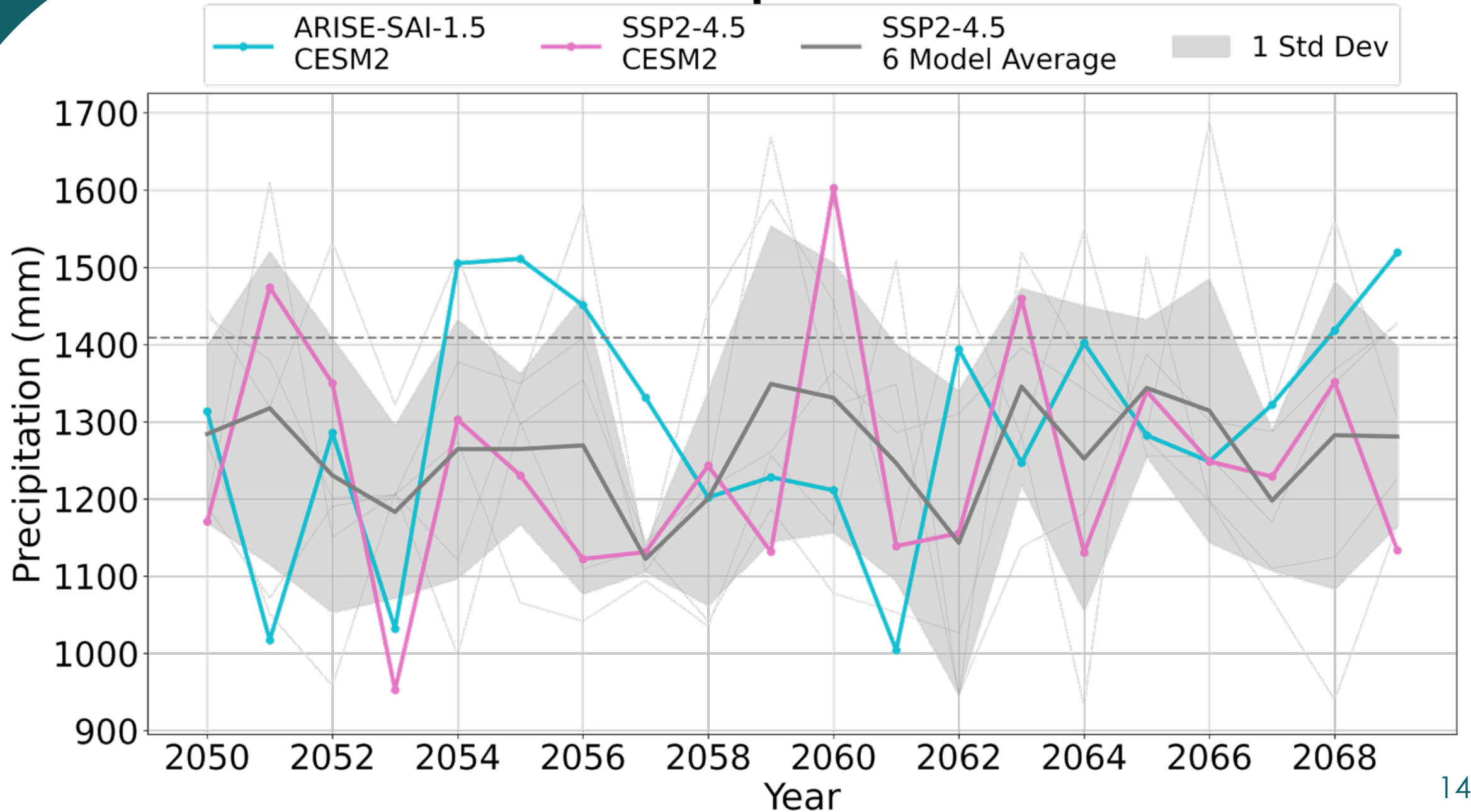
Cocoa yields in Southwestern Ghana in ARISE-SAI-1.5 and SSP2-4.5



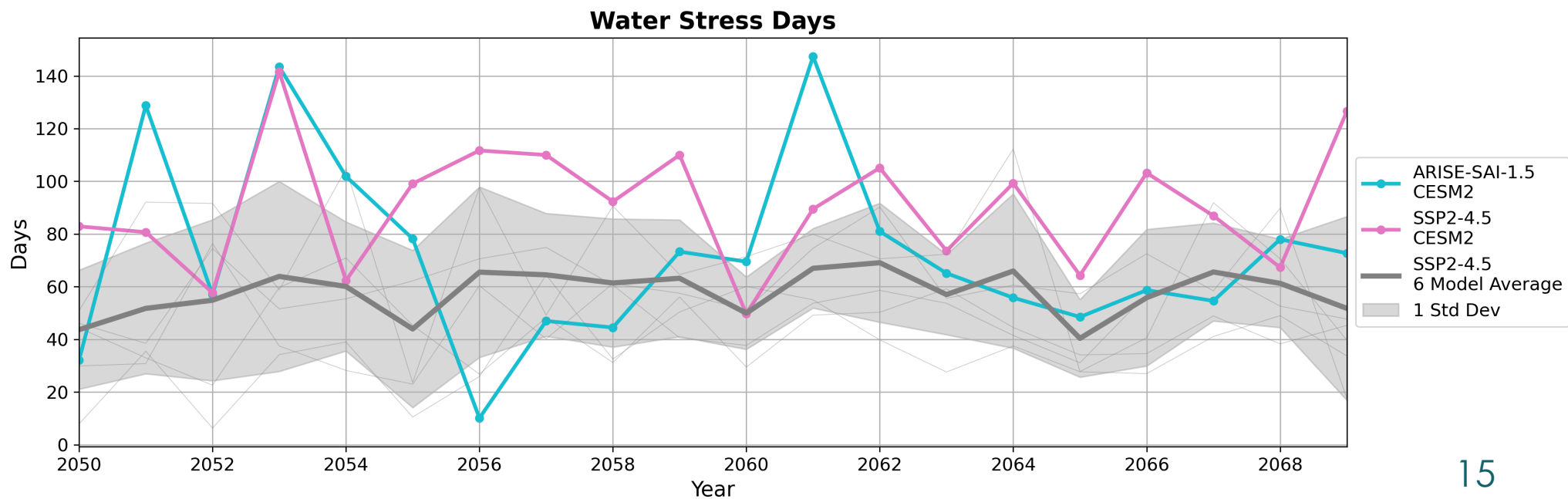
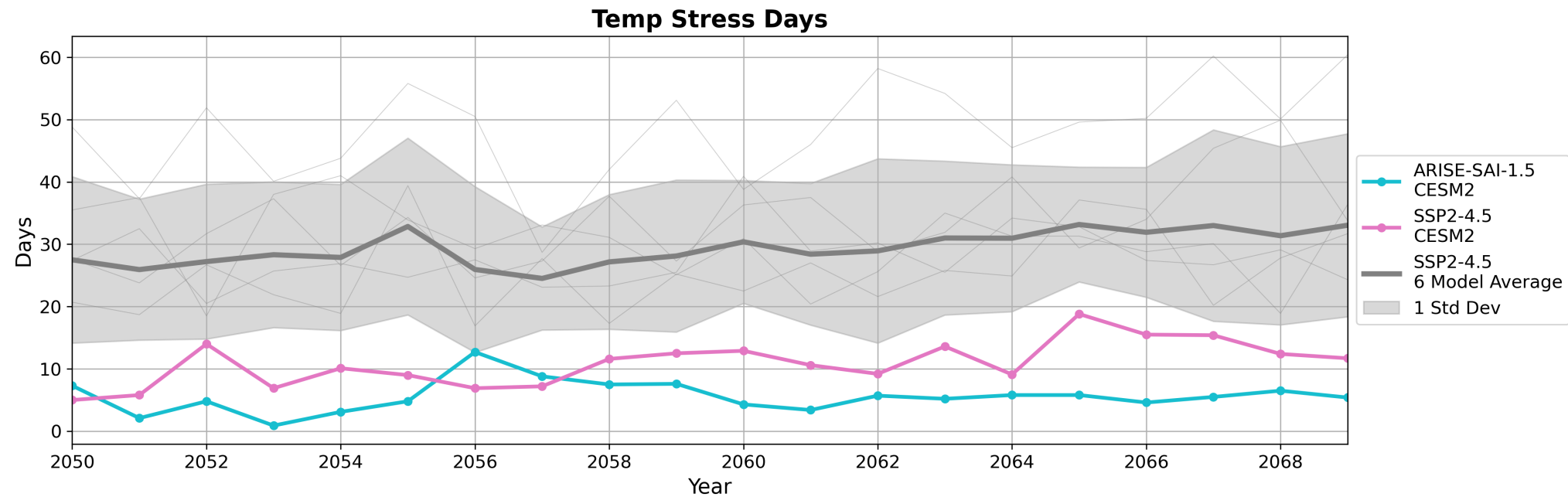
Hot Days over 32°C in Ghana



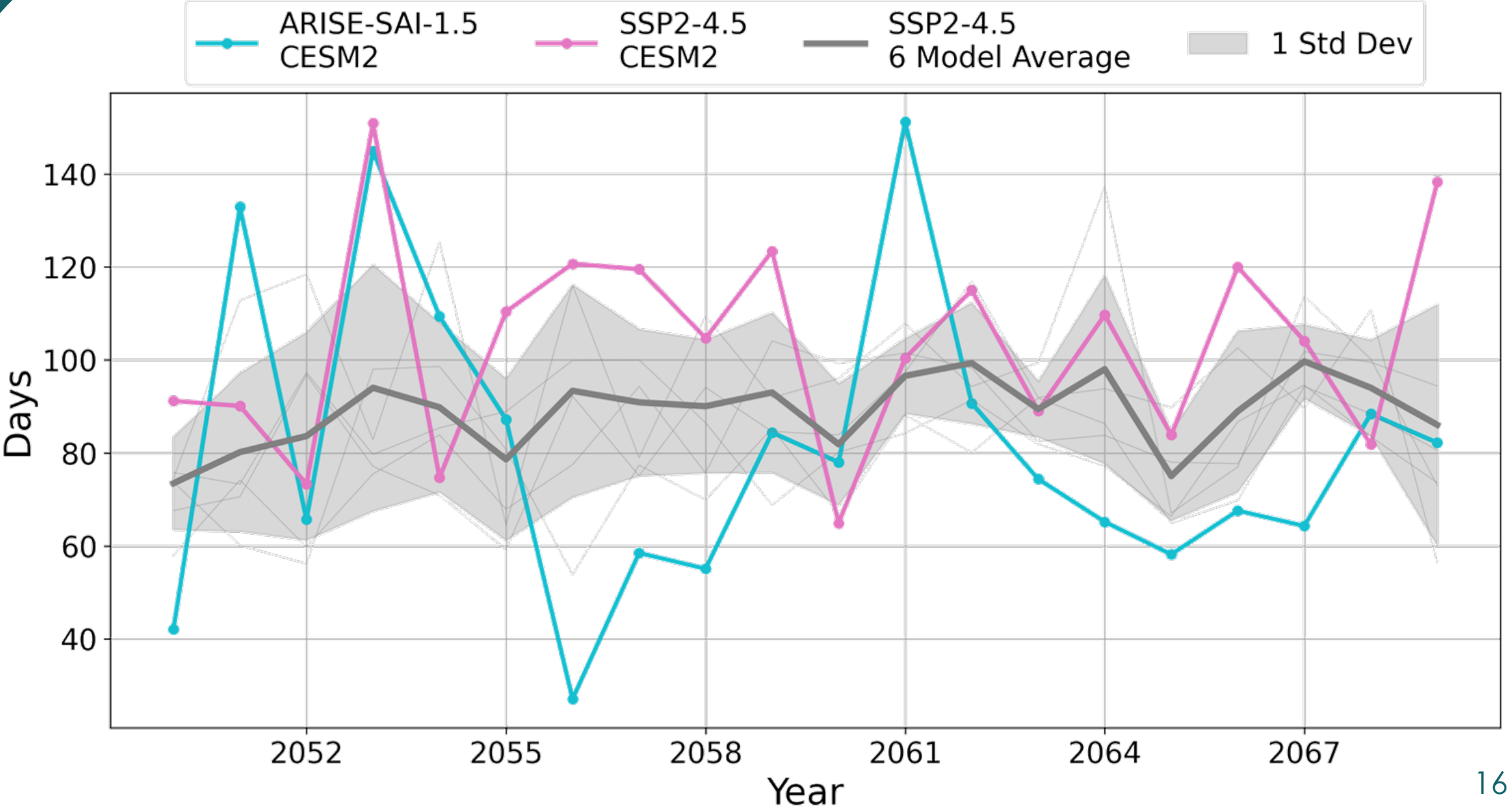
Annual Precipitation in Ghana



Stress days =
days when the
dominant (or
limiting) stress
was temperature
or water



Total Stress Days



Takeaways



Doesn't say: SAI inherently/definitely can save cocoa yields. Just one site in Ghana might **not be representative of the country or West Africa.**

- Assumes management doesn't change and trees don't age
- Need more ensemble members



Does say: *At this one specific location*, as simulated by our crop model and CESM, **SAI improves yields** compared to climate change without it.

- Same temp + same rainfall + high CO2

Thank you



nina.grant@rutgers.edu



<https://www.linkedin.com/in/nina-grant-2021/>

