Projecting Changes in Extreme Precipitation over the Coming Decades

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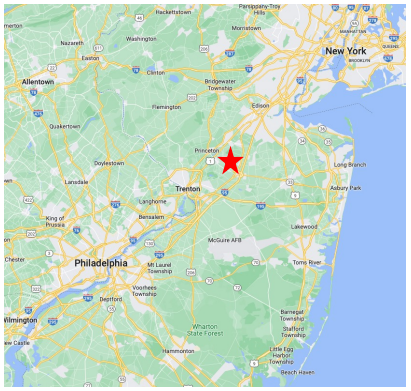

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Geophysical Fluid Dynamics Laboratory

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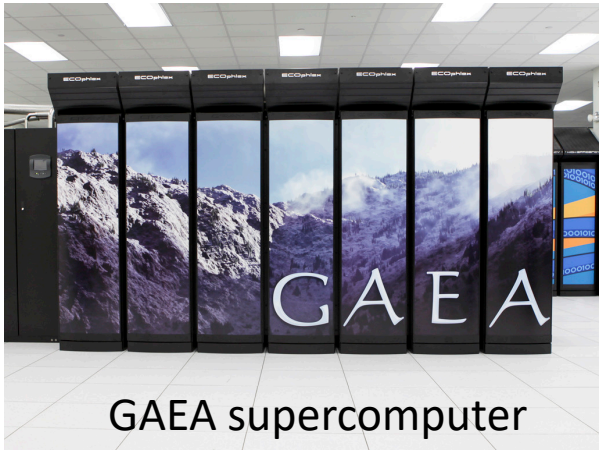


GAEA supercomputer

MISSION:

The GFDL mission is to be a **world leader in the development of** comprehensive, integrated and **unified models of the Earth system** … and **application of these models for** the seamless **understanding, predictions and projections of the Earth system** … from global-to-regional spatial scales, accounting for natural variations and forced changes.

Models and model components developed at GFDL have helped NOAA applications, including:

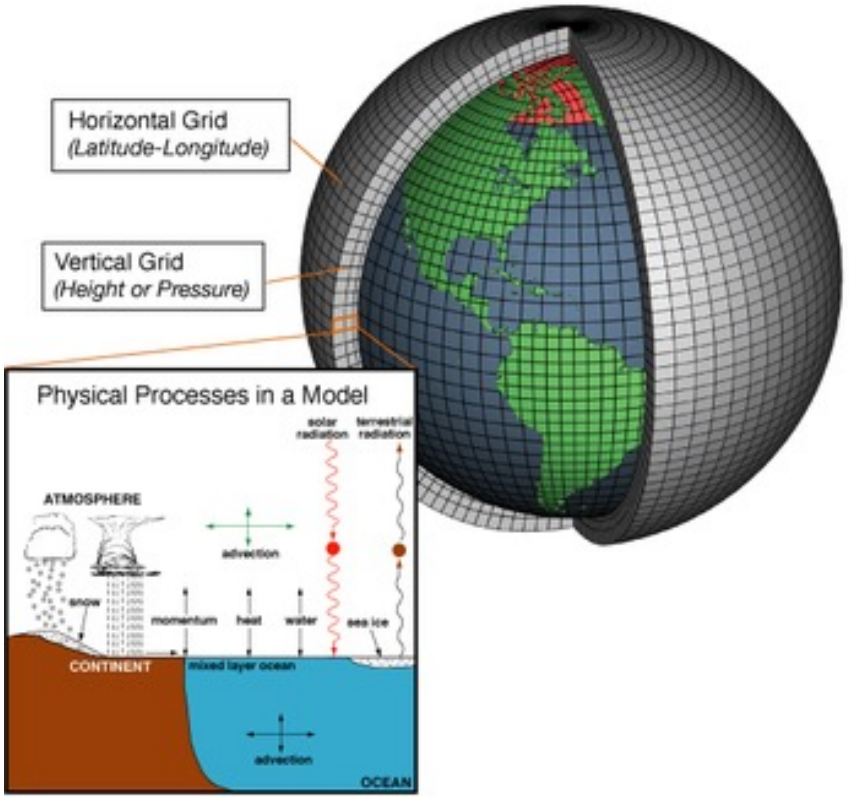
- Daily weather forecasts
- Seasonal climate outlooks & seasonal hurricane outlooks
- Decadal climate predictions & IPCC/multidecadal climate change projections

Projecting Changes in Extreme Precipitation over the Coming Decades

What is a climate model?

Multiple equations describe evolution of atmosphere, ocean, land, sea ice within each "grid box, and solved by computer

Bigger, faster computer means smaller "grid boxes" and more realistic simulations and predictions



GFDL models include:

(a) Global models with 3 km resolution for weather

(b) "High-resolution" global coupled ocean-atmosphere models for seasonal to multidecadal predictions

(c) Global coupled atmosphere-ocean-biogeochemistry for century scale climate change

Projecting Changes in Extreme Precipitation over the Coming Decades

- **Predictions**: detailed track of hurricane over the next few days

  Detailed real-time observations go into model ➔ predicts hurricane track and intensity

- **Projections:** How the statistics of hurricanes will change over the coming decades

  Estimates of future changes in greenhouse gases go into model ➔ project changes in hurricane characteristics

Our goal: Build and use computer modeling system for predictions and projections across time scales (seasonal to multidecadal)

Method: Improve understanding → Better Models → Better Predictions and Projections

SPEAR : **S**eamless system for **P**rediction and **EA**rth system **R**esearch

➔ We use this modeling system both for real-time seasonal predictions and decadal to centennial scale climate change projections.

Projecting Changes in Extreme Precipitation over the Coming Decades

PREDICTIONS

(Initial Value Problem)

Current Observed Conditions
(temperature, winds, etc)

↓

SPEAR assimilation & initialization system

↓

SPEAR model

↓

Seasonal predictions
(North American Multimodel Ensemble)
Decadal predictions
(World Meteorological Organization)

PROJECTIONS

(Boundary Value Problem)

Atmospheric composition changes (aerosols, ghgs, etc)

↓

SPEAR model

↓

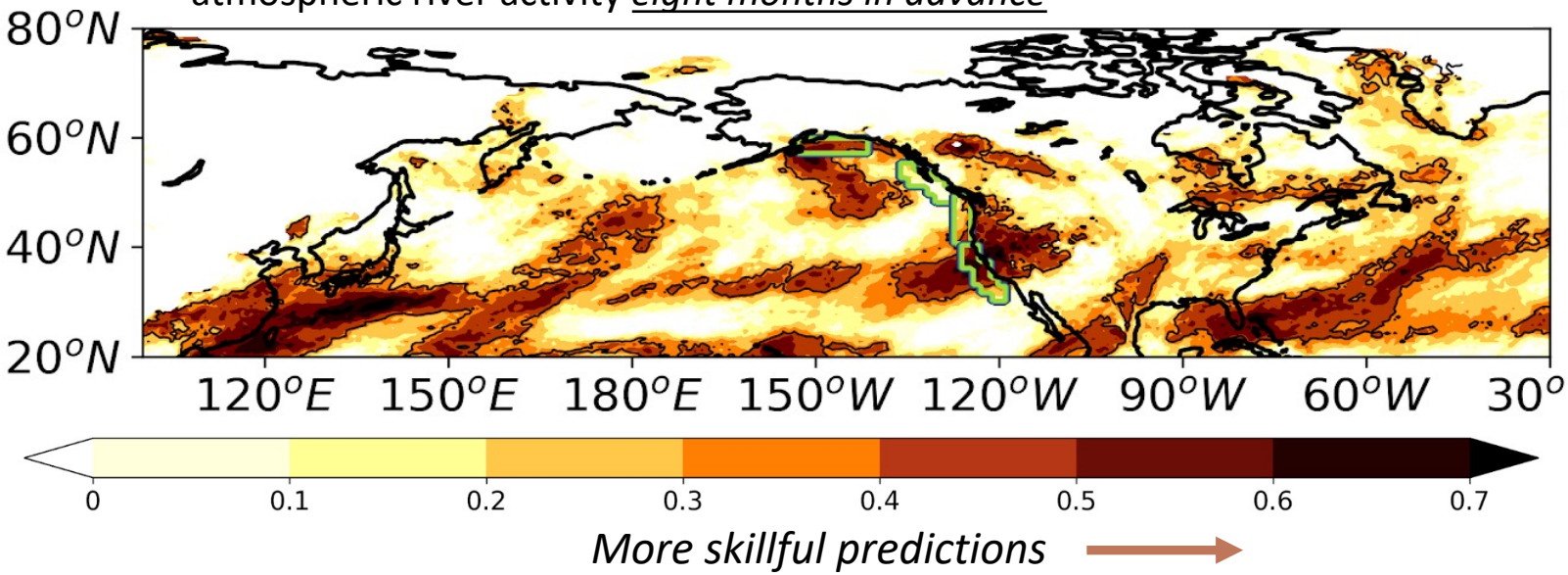
Decadal and longer climate change projections
(Climate Risk Assessment/IPCC)

Projecting Changes in Extreme Precipitation over the Coming Decades

Conduct real-time predictions (seasonal forecasts) and climate change projections (for decades in advance) in a unified system

One example: seasonal prediction of atmospheric river activity

Darker shading on map shows areas with greater skill in predicting atmospheric river activity *eight months in advance*



Other seasonal prediction examples include:
Extreme heat, snowpack, tropical cyclone activity

We use the same model to project changes in atmospheric rivers in response to global warming

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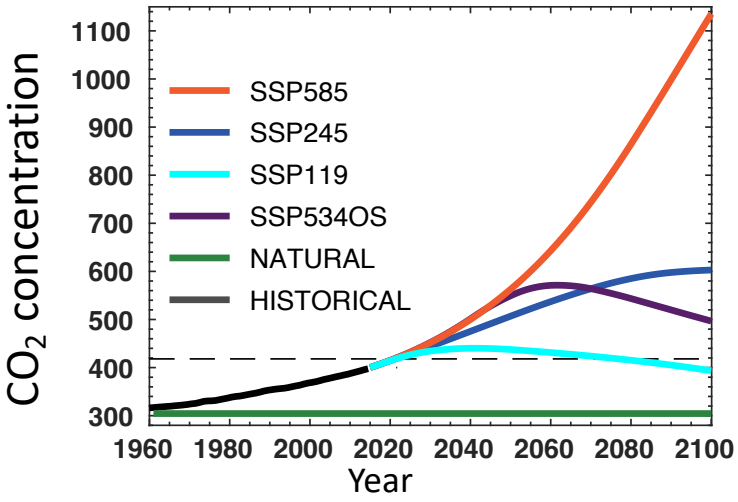
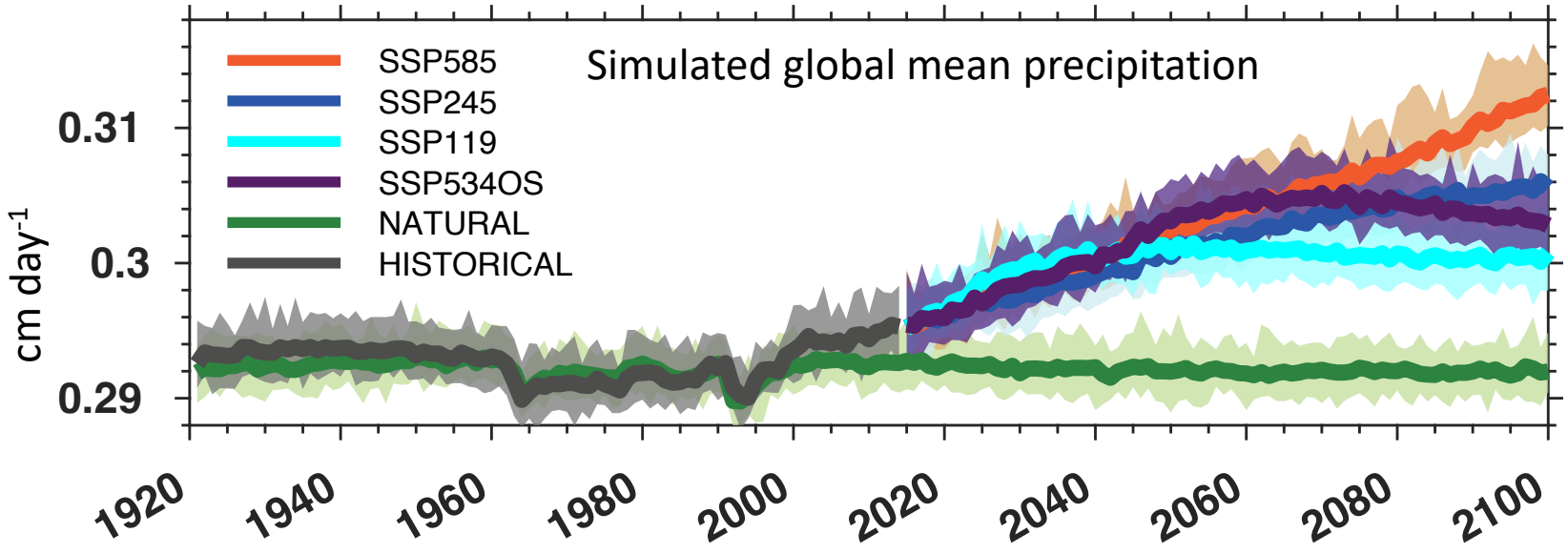
For projecting climate change we run large ensembles … many (30+) realizations of the same model but with different initial conditions. This allows us to see spread of natural variability, and this better characterize the probability of extreme changes.



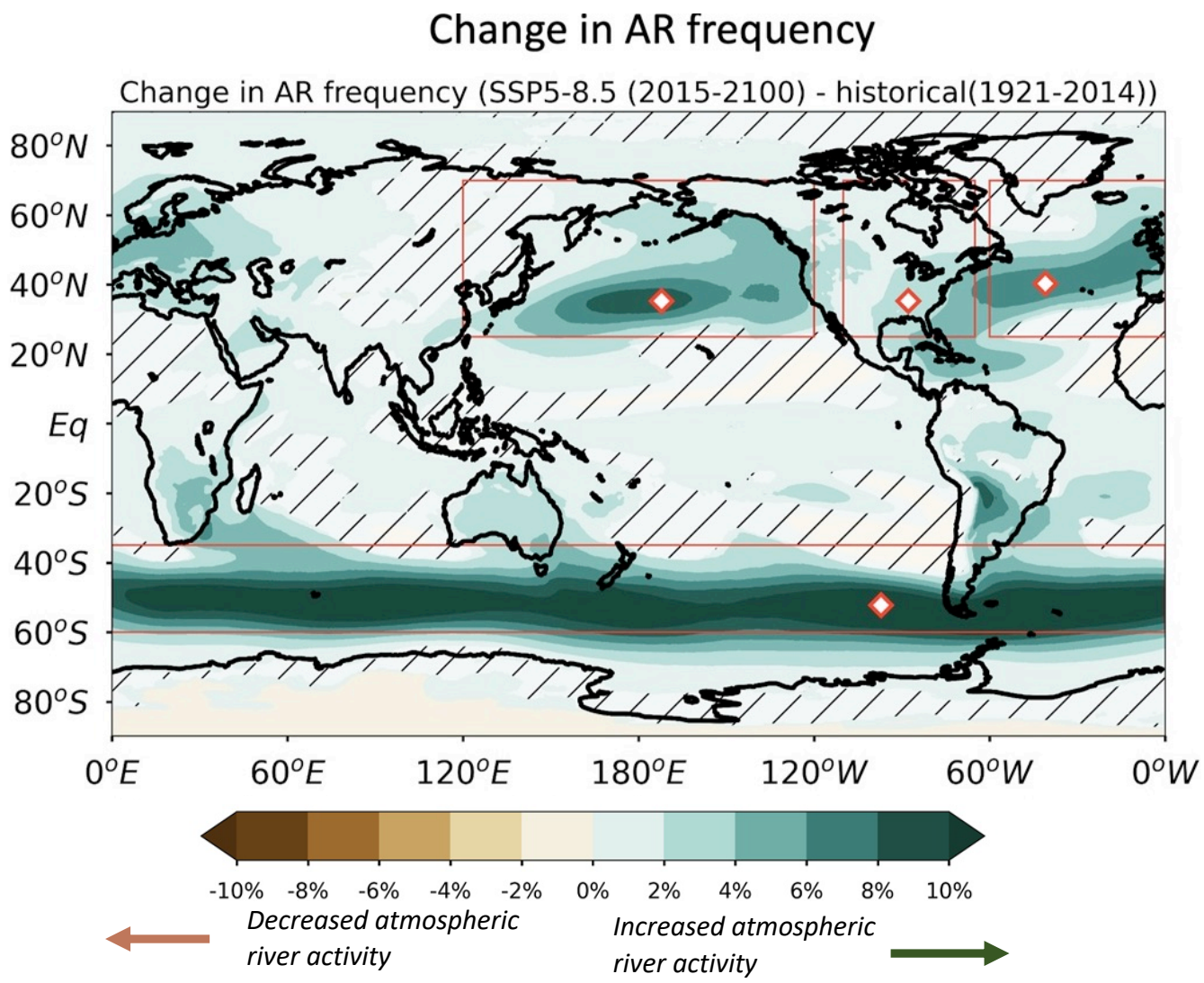
First need some assumed future behavior for greenhouse gases.
"SSP" = "Shared Socioeconomic Pathway"

SSP585 assumes very high future levels of CO_2
SSP119 assumes modest future levels of CO_2



Using Large Ensembles of GFDL SPEAR to Project Changes in Atmospheric Rivers

Source:
Tseng et al.
(2022, JGR Atmospheres)



Significant 21st century increases of atmospheric river activity.

➔ *Emergence of clear signal of increased atmospheric river activity for US West Coast by around 2060*

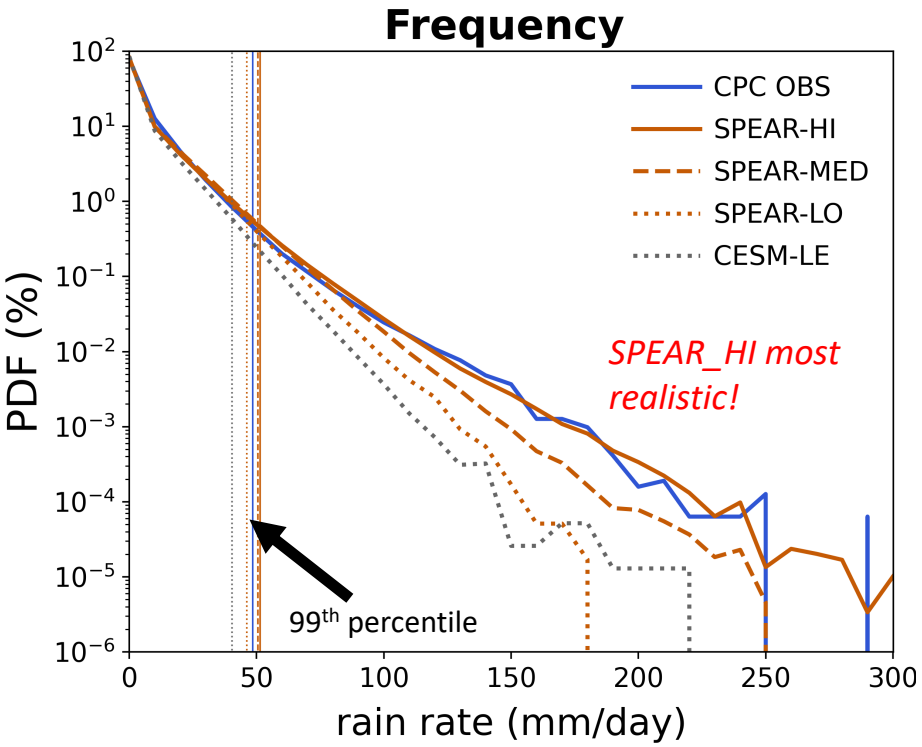
Projecting Regional Changes in Extreme Precipitation

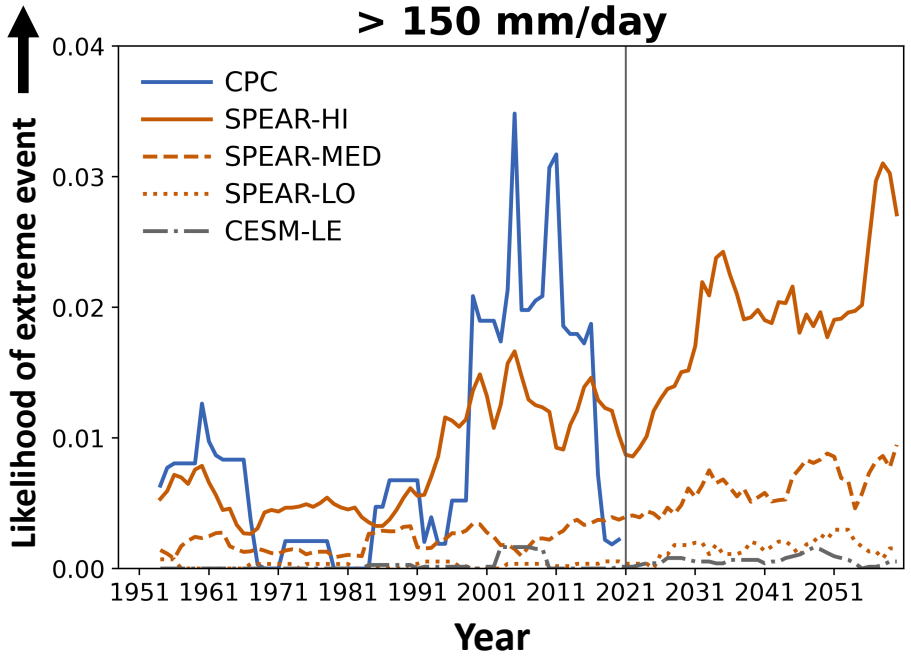
➔ Focus on Northeastern US during the Fall season

Jong et al, submitted

➔ *This shows that a 25 km resolution version of SPEAR can successfully simulate the most extreme observed rainfall events*

➔ *Frequency of occurrence of the most extreme rainfall events (past and future)*





Key Point: Large ensembles of high resolution models provide powerful tool for realistically projecting future changes in extreme rainfall on regional basis.

Projecting Regional Changes in Extreme Precipitation

Model output from these large ensembles of climate change projections is available at: https://www.gfdl.noaa.gov/spear_large_ensembles/

Access GFDL/NOAA climate projection data

➔ What you could get: 30 separate projections of daily time series of precipitation for years 1921-2100 on a 50km grid.

Feedback on the utility of the data and needs for other forms of data is very welcome!

As we move forward we are developing improved versions of our models with better physics and at ever higher spatial resolutions (smaller grid boxes) to provide better predictions that may be of greater practical utility.

➔ A key rate limiting step is supercomputer power available.

Available variables

Variable	Long name	Frequency
tas	Near-Surface Air Temperature	day, Amon
ta	Air Temperature	Amon
tasmin	Daily Minimum Near-Surface Air Temperature	day
tasmax	Daily Maximum Near-Surface Air Temperature	day
pr	Precipitation	day, Amon
hus	Specific Humidity	Amon
psl	Sea Level Pressure	day, Amon
zg	Geopotential Height	Amon
sfcWind	Near-Surface Wind Speed	Amon
uas	Eastward Near-Surface Wind	day, Amon
vas	Northward Near-Surface Wind	day, Amon
ua	Eastward Wind	Amon
va	Northward Wind	Amon
rlut	TOA Outgoing Longwave Radiation	Amon
rsut	TOA Outgoing Shortwave Radiation	Amon
rsdt	TOA Incident Shortwave Radiation	Amon
tos	Sea Surface Temperature	Omon
areacella	Grid-Cell Area for Atmospheric Variables	fx
areacello	Grid-Cell Area for Ocean Variables	Ofx

➔ *30 ensemble members run for years 1921-2100*