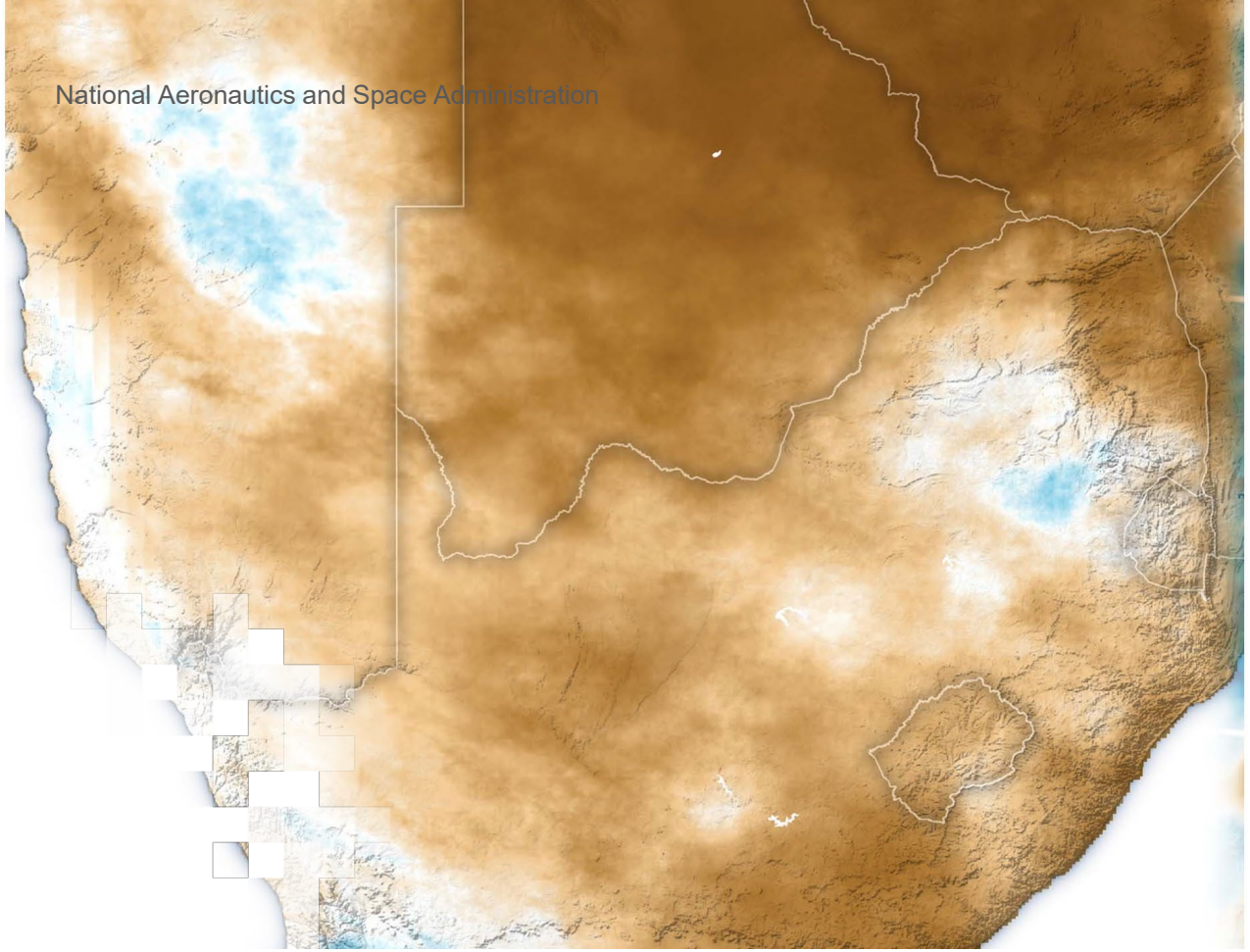
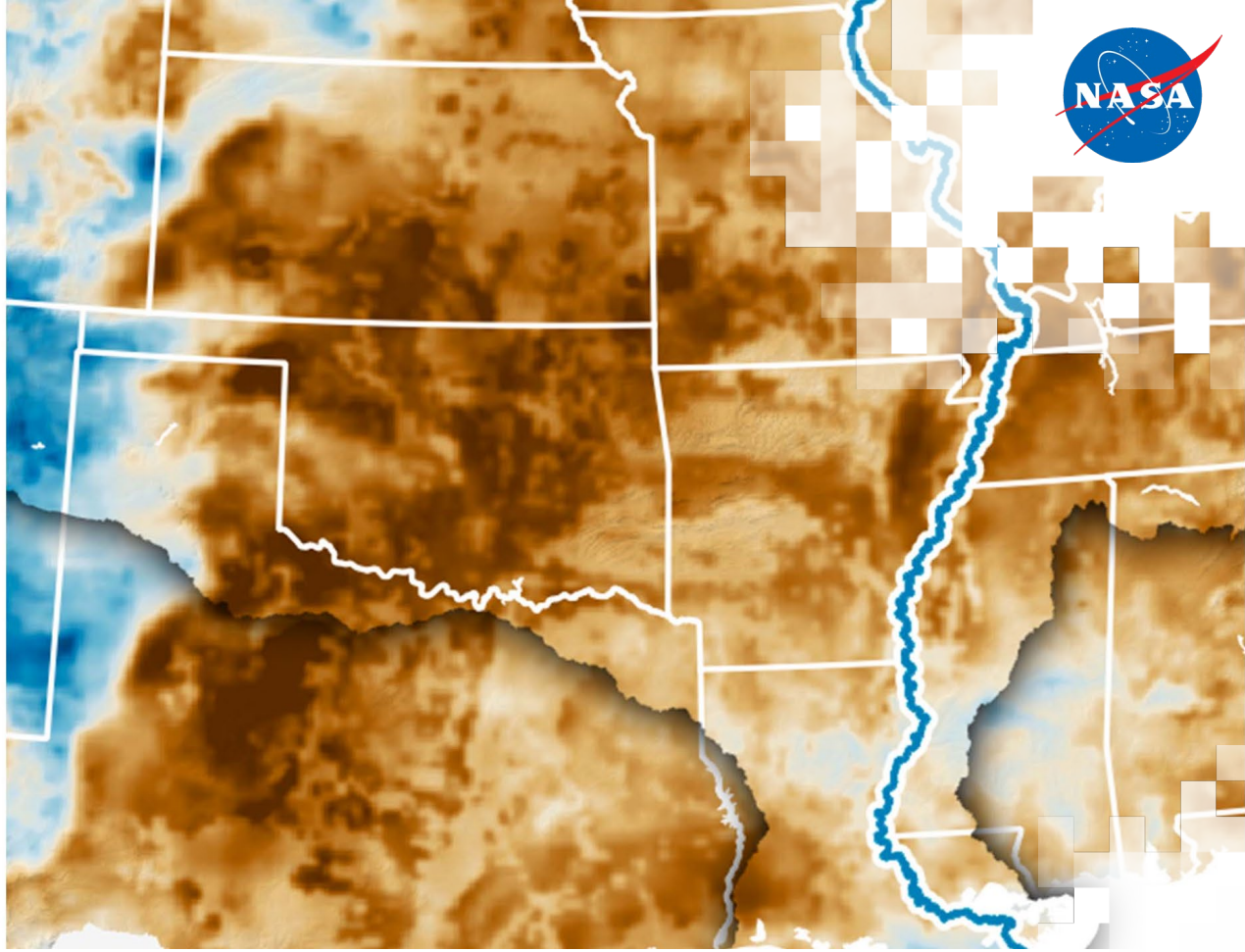




Drought Monitoring, Prediction, and Projection using NASA Earth System Data

Part 3: Climate Change Projections and Droughts

Amita Mehta

30 July 2024

Training Outline

Part 1
Overview of Drought Monitoring Data and Tools using Earth Observations

July 23, 2024

Part 2
Drought Prediction using NASA Sub-seasonal to Seasonal (S2S) Predictions

July 25, 2024

Part 3
Climate Change Projections and Droughts

July 30, 2024

Part 4
Demonstration of Regional Drought Monitoring Tools

August 1, 2024

Homework-3

Opens July 30 – Due August 15 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Part 2 Review

- Overview of GMAO Sub-seasonal to Seasonal (S2S) Predictions
  - The S2S prediction system uses coupled Earth-System models and analyses in conjunction with satellite and in situ observations to study and predict phenomena that evolve on sub/seasonal to decadal timescales.
- Example of S2S data applications
  - Includes drought forecasting & water resources forecasting, studying dust sources in the US, soil moisture, precipitation, temperature for landslide prediction, ecological forecasting, data to drive a pest model
- Examined S2S ensemble mean predictions of surface temperature and precipitation anomalies using QGIS to examine areas of dry/warm conditions in next three months
- Data for users, upon request, are distributed from an ftp site.
- Maps of 2-m temperature and precipitation monthly anomaly predictions for 9 months are available from GMAO Atmospheric Anomalies site.
- Specific S2S data can be requested by contacting Dr. Andrea Molod (andrea.m.molod@nasa.gov).

Part 3 Objectives

- Recognize functionality of NASA Earth Exchange Global Daily Downscaled Projections for Coupled Model Intercomparison Project Phase 6 (NEX-GDDP-CMIP6) climate projection dataset

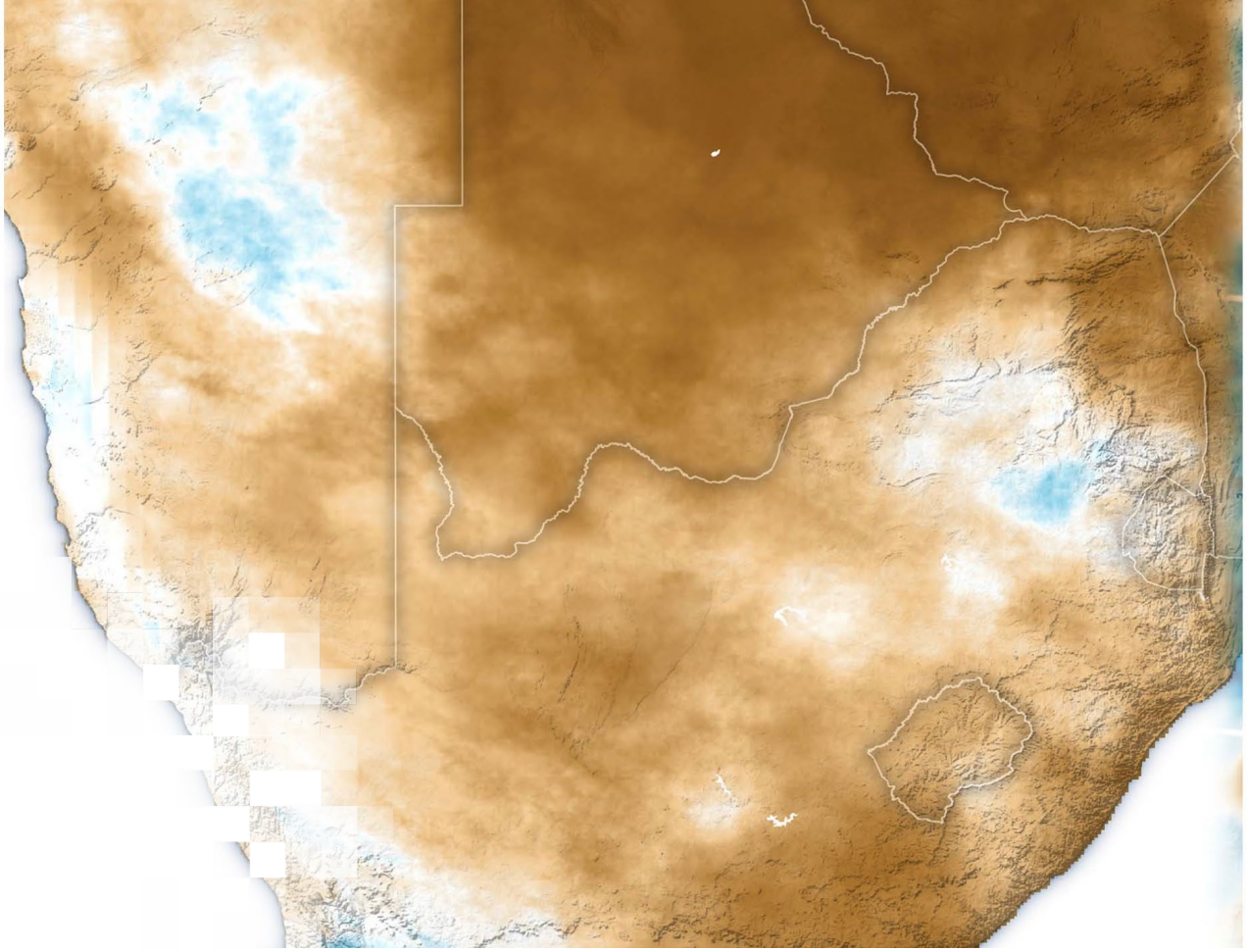
- Access NEX-GDDP-CMIP6 climate change projections to assess long term drought conditions for a region of interest

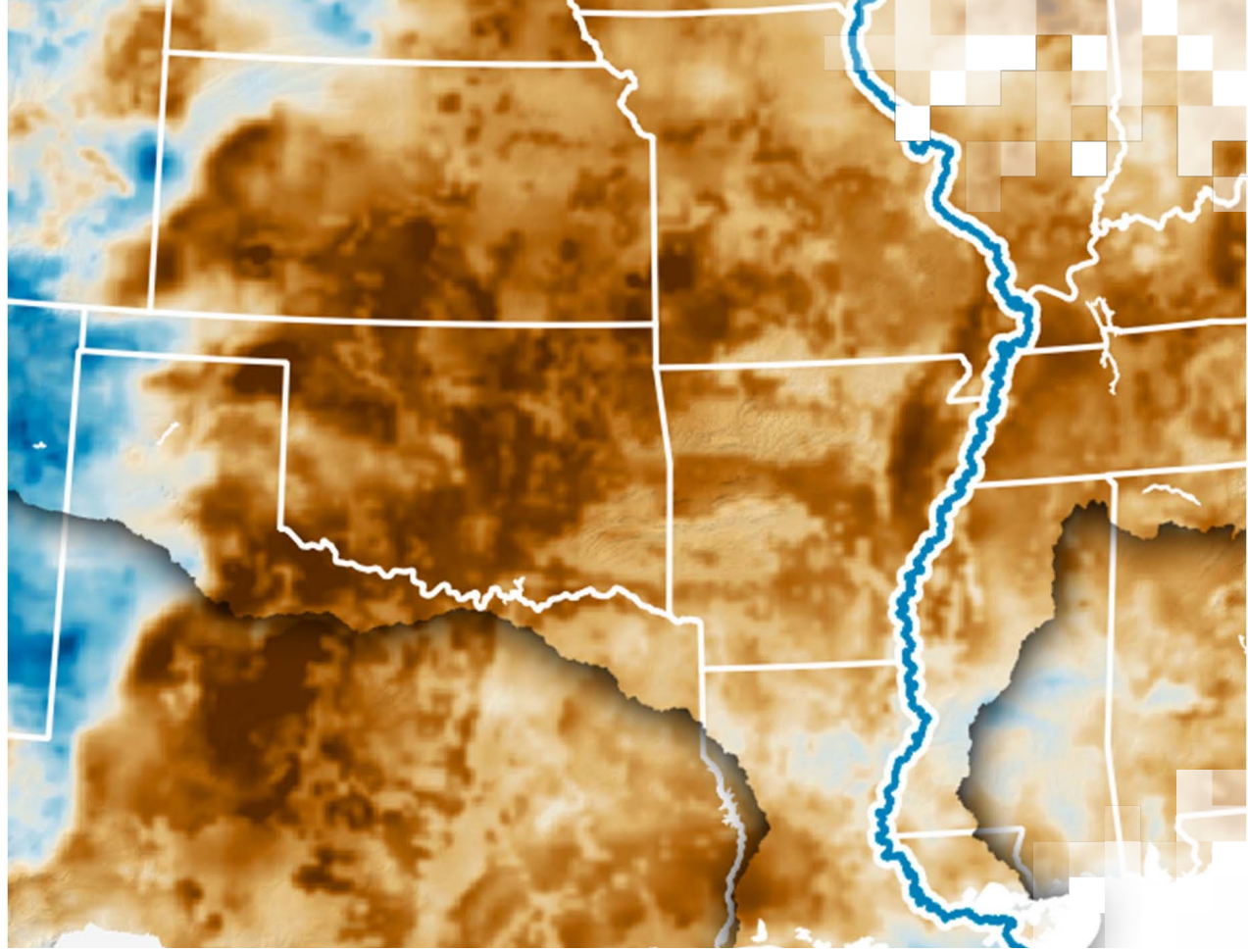
Outline

- CMIP6 and Climate Change Projections
- Overview of NEX-GDDP-CMIP6
- Demonstration: NEX-GDDP-CMIP6 Projection Data Access and Analysis in Goggle Earth Engine for Drought Assessment

How to Ask Questions

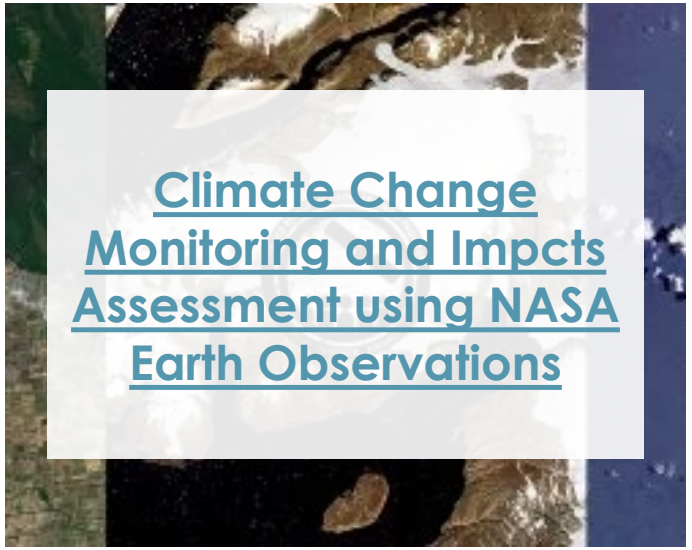
- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.





CMIP6 and Climate Change Projections

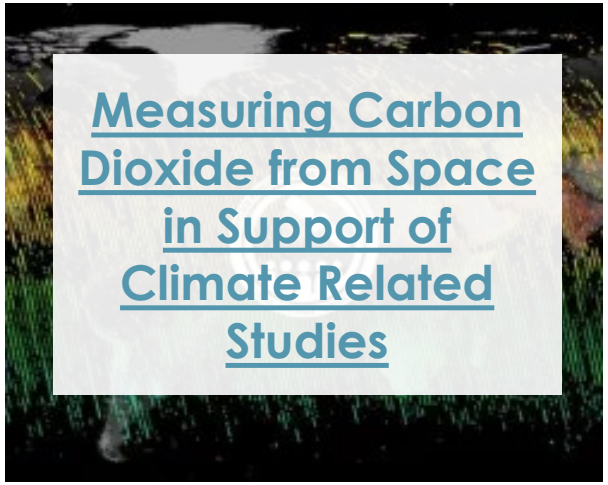
ARSET Trainings – Climate



Climate Change Monitoring and Impcts Assessment using NASA Earth Observations

Selecting Climate Change Projection Sets for Mitigation, Adaptation, and Risk Management Applications

Building Climate Risk Assessments from Vulnerability and Exposure

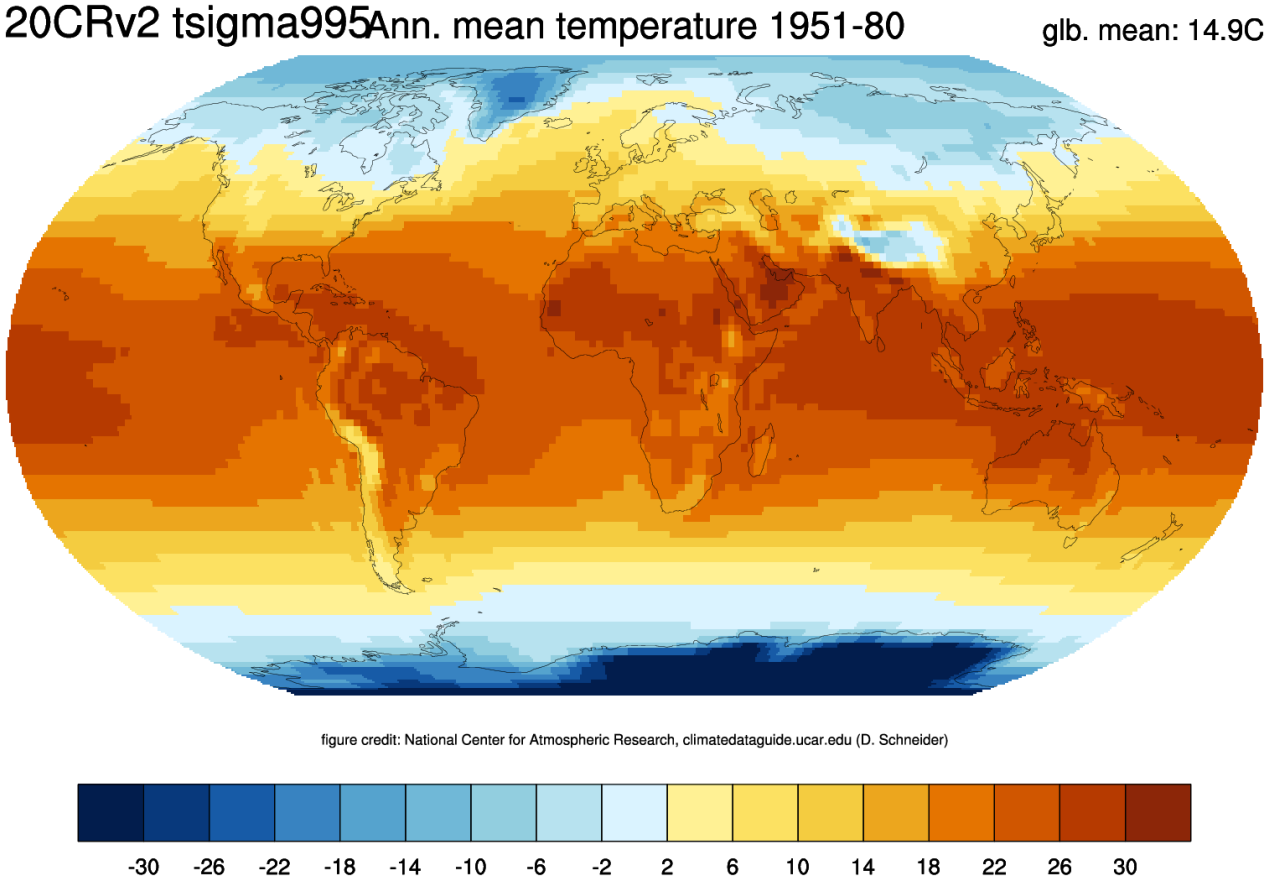


Measuring Carbon Dioxide from Space in Support of Climate Related Studies

Introduction to NASA Resources for Climate Change Applications

What is Climate?

- Long-term (30+ years) average characteristics of geophysical quantities in temperature, precipitation, and humidity at a regional or global scale



NOAA 20th Century Climate Reanalysis

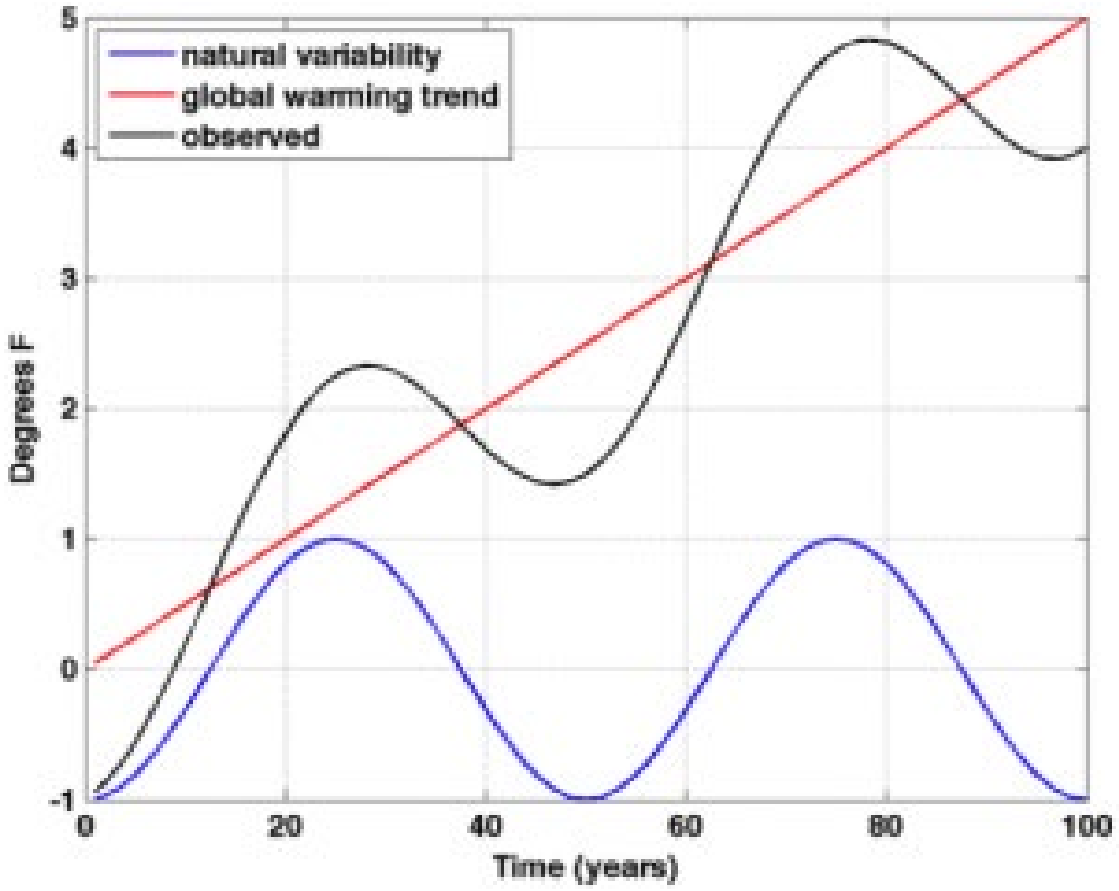
Climate Variability and Change

Natural Climate Variability and Change:

- Resulting from natural—not anthropogenic—causes such as:
  - Ocean-atmosphere-land interactions
  - Variability in incoming solar radiation
  - Volcanic activity
  - Earth's orbital variations
- Examples: El Nino – Southern Oscillation
  Pacific Decadal Oscillation

Anthropogenic Climate Change:

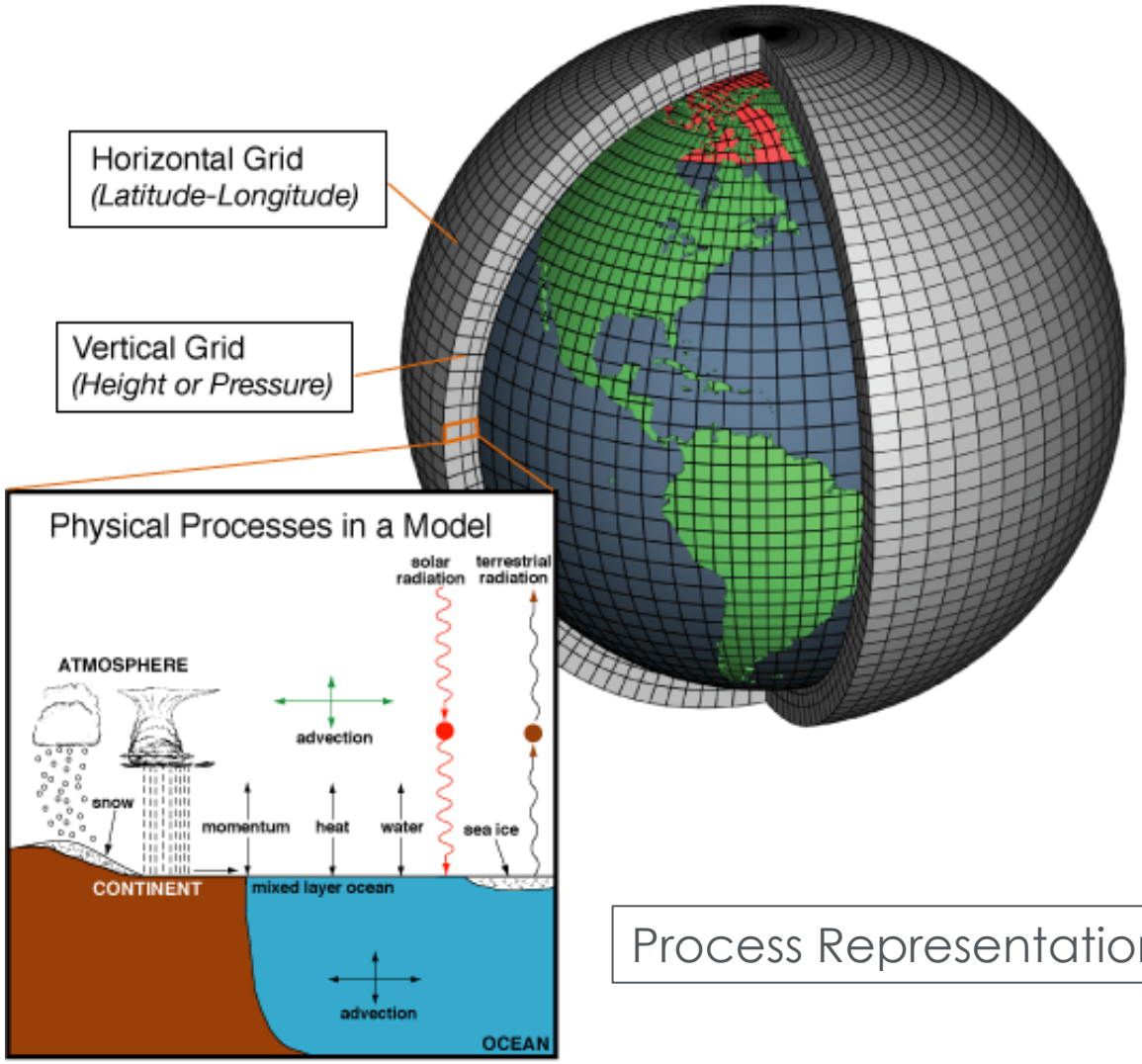
- Increasing greenhouse gases and aerosols in the atmosphere due to fossil fuel burning, industrial waste, deforestation



Climate Impact Group, University of Washington

Global Climate Models

- Climate models are often designed to capture global signals, with regional signals likely including biases.
- Observations are an important part of model development for initial and boundary conditions, and for validation and bias correction.
- Require super computers and big data management



Process Representation

Adapted from NOAA:
https://www.climate.gov/maps-data/primer/climate-models

Global Climate Models

- There are 100+ **Earth System Models** (ESMs) from 50+ modeling institutions.
- Leading modeling groups have coordinated simulations of climate change scenarios within the auspices of the **Coupled Model Intercomparison Project** (CMIP; Phase 6 now available).
- Modeling institutions are **constantly improving** their models.
  - Higher resolution, improved physics and chemistry, more processes
- CMIP provides important **diagnostic and evaluation information** for each ESM.

Coupled Model Intercomparison Project Phase 6 (CMIP6)

https://wcrp-cmip.org/cmip6/ https://pcmdi.llnl.gov/CMIP6/

- The CMIP program is organized by the World Climate Research Program, currently on Phase 6, with the goal to understand past, current, and future climate change occurring in response to natural and anthropogenic causes using multi-model framework.
- The program has evolved since 1995 in which multiple models participate to 1.) assess model performance during a historical period (1850–2014) and 2.) produce future climate projections.
- Common experiments and forcing data are used by all models.
- A major goal is to quantify and understand the spread found among the model projections.

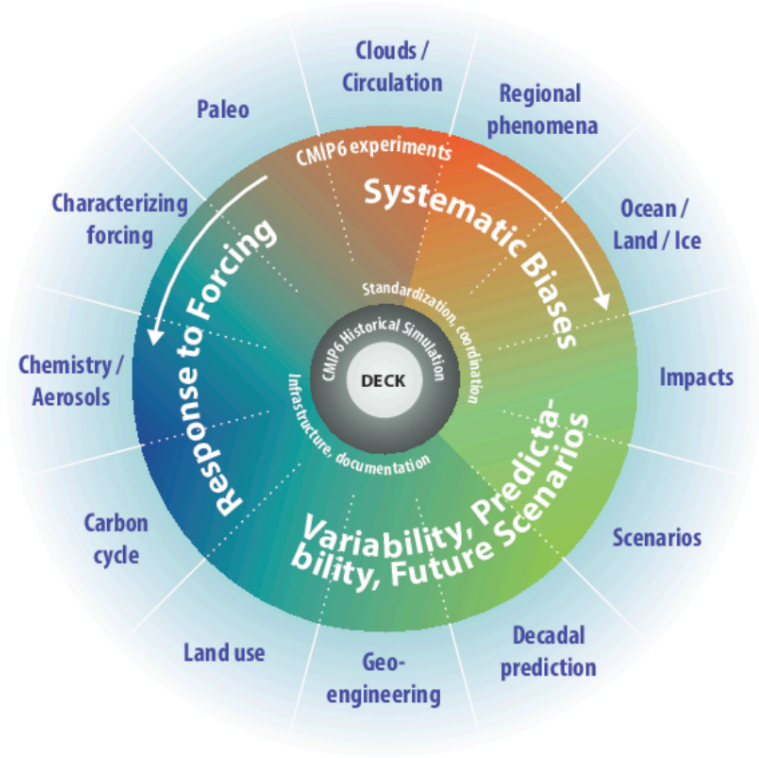
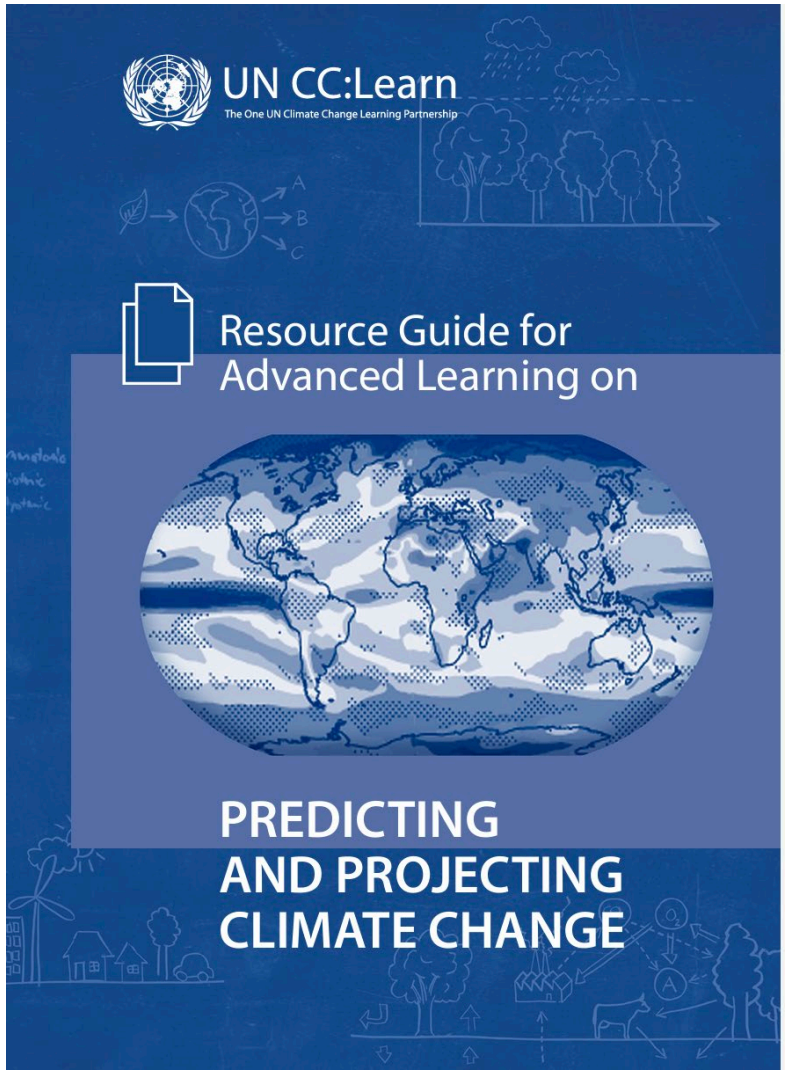


Figure 2. Schematic of the CMIP/CMIP6 experiment design. The inner ring and surrounding white text involve standardized functions of all CMIP DECK experiments and the CMIP6 historical simulation. The middle ring shows science topics related specifically to CMIP6 that are addressed by the CMIP6-Endorsed MIPs, with MIP topics shown in the outer ring. This framework is superimposed on the scientific backdrop for CMIP6 which are the seven WCRP Grand Science Challenges.

Eyring et al., 2016: https://doi.org/10.5194/gmd-9-1937-2016

Climate Prediction and Projection – What is the Difference?

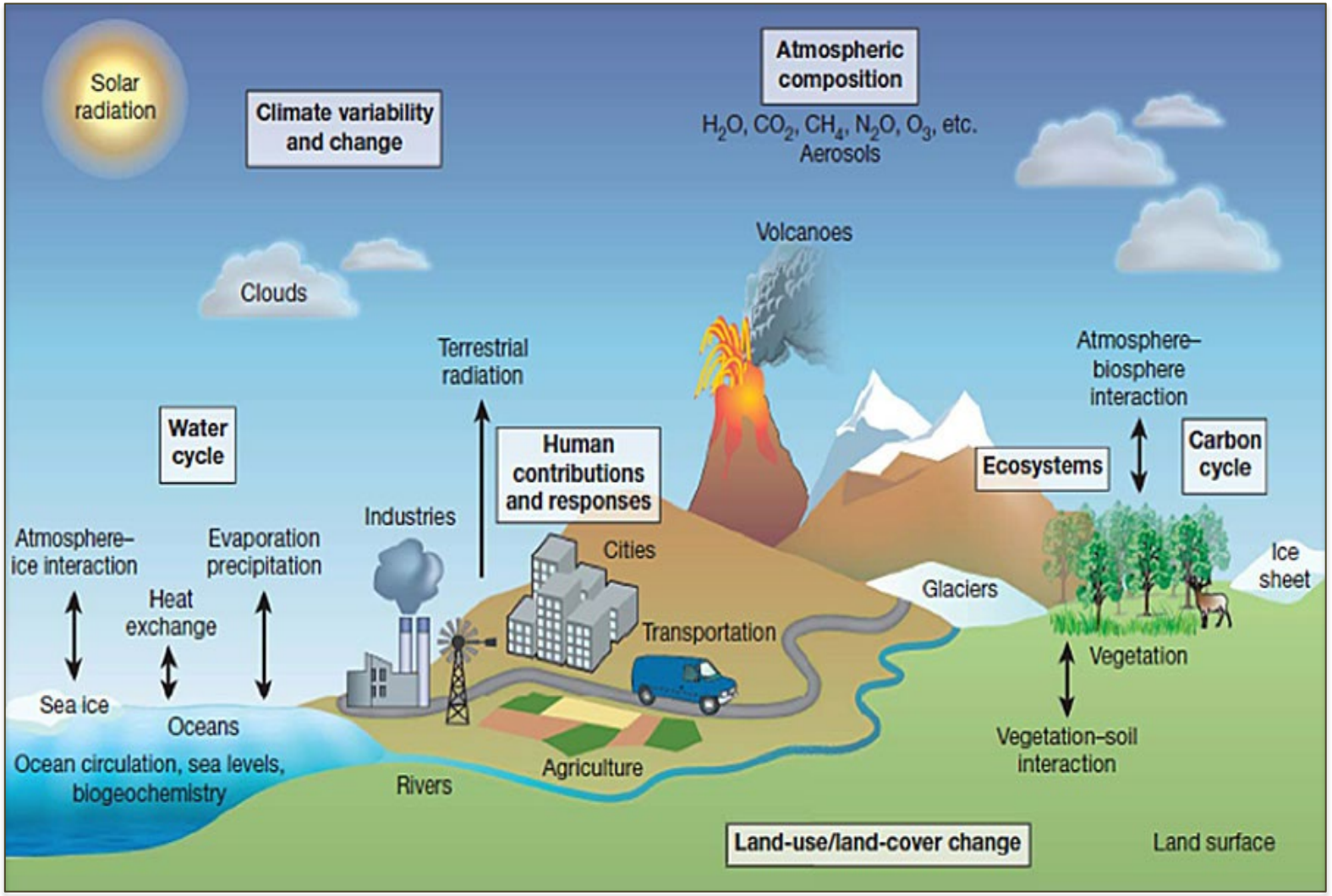
- Climate predictions are estimates of future natural conditions.
- Climate projections are estimates of future climates under various assumptions of future human related activities -- socioeconomic and technical developments.
- Climate projections have less certainty as they are based on assumptions which may not evolve as expected.



UN CCL Resource Guide

Modeling and Projecting Human-Driven Climate Change

- The foundation of climate change projections comes from simulations that capture human influence on the climate system.
- Requires radiation physics, atmospheric dynamics, chemistry, oceans, biosphere, cryosphere, and human-driven shifts in emissions and land-use.



Moss et al., 2010 (https://doi.org/10.1038/nature08823)

Climate Change Scenarios and Storylines

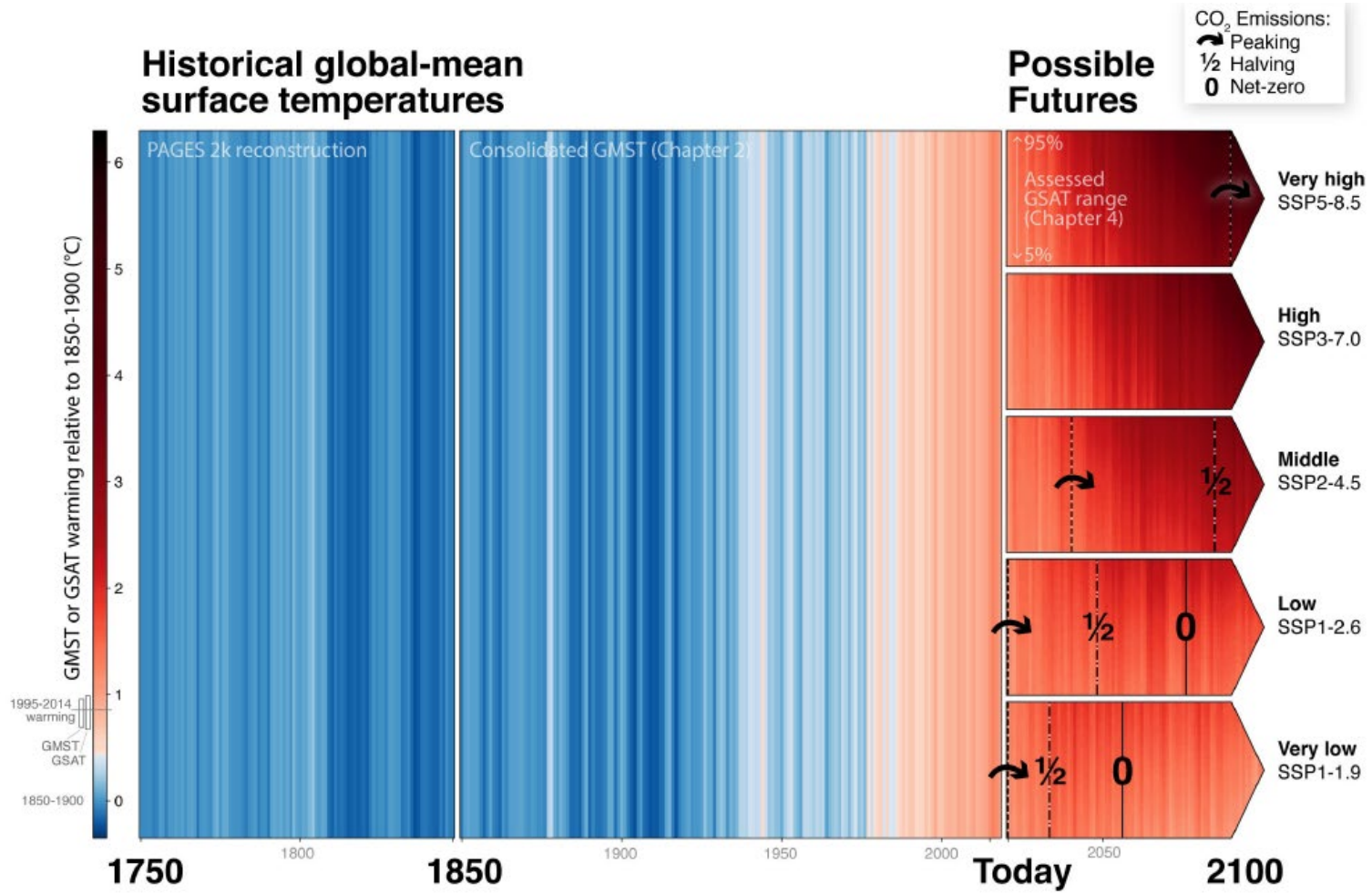
- **Scenarios:** Describe a future world through a plausible and internally consistent set of assumptions, potentially including greenhouse gas and aerosol emissions, land use change, socioeconomic development, and technological change.
- **The IPCC notes that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions.**

- **Storyline**: A way of making sense of a situation or a series of events through the construction of a set of explanatory elements. Usually, it is built on logical or causal reasoning.
- Storylines can have societal and physical elements, e.g.:
  - The physical implications of a given amount of global warming
  - Potential impact of increasing population
  - The ramifications of a given policy or new financing being implemented

See IPCC AR6 WGI Glossary for more information.

Scenarios and Storylines

- **SRES**: Special Report on Emissions Scenarios developed for IPCC TAR (2000) – [A2, B1, A1B]
- **RCP/SSP-RCP**: Representative Concentration Pathways or Shared Socioeconomic Pathways (or combined)
- **GWLs**: Global Warming Levels
- **NDCs**: Nationally-Determined Contributions

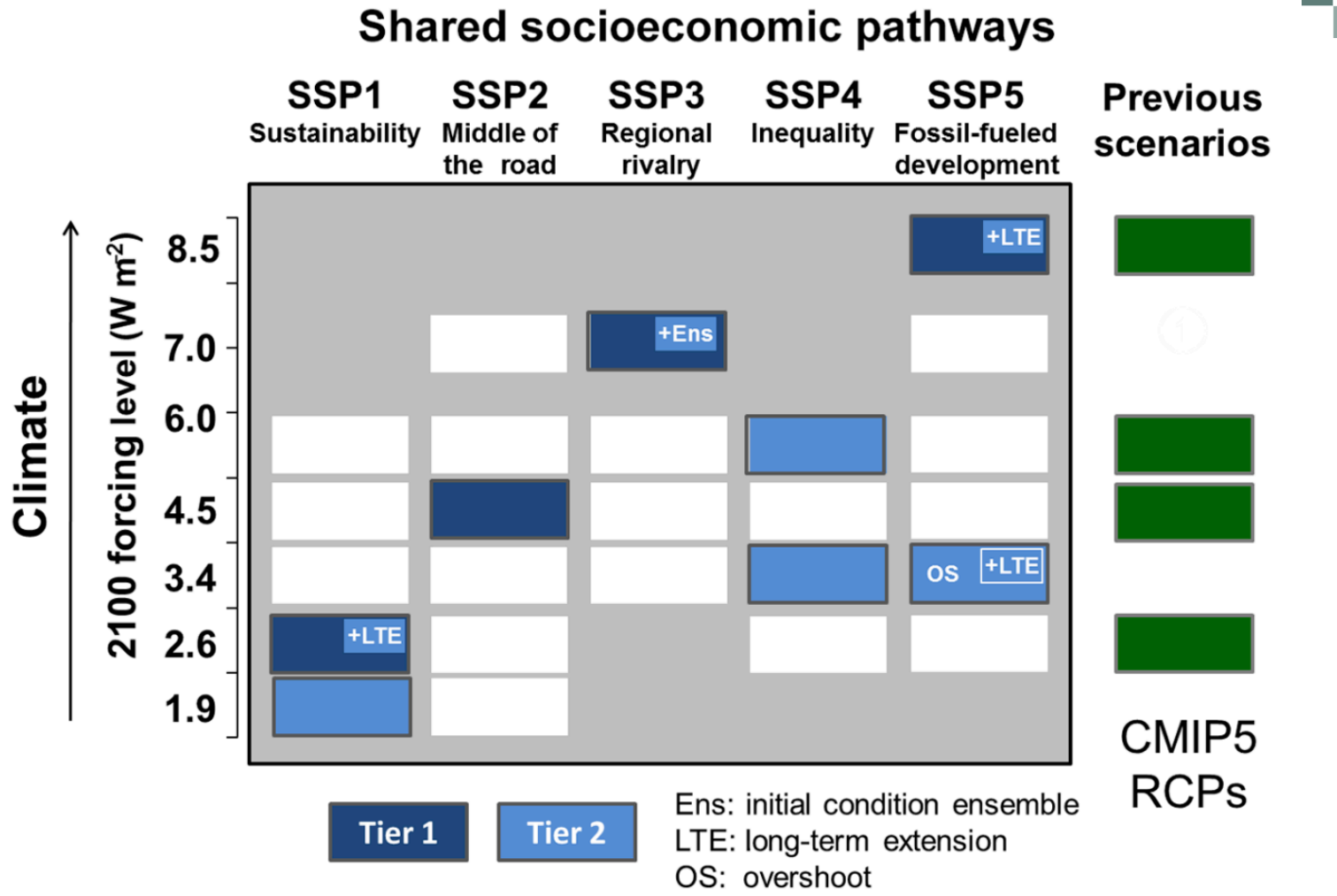


IPCC AR6 WGI

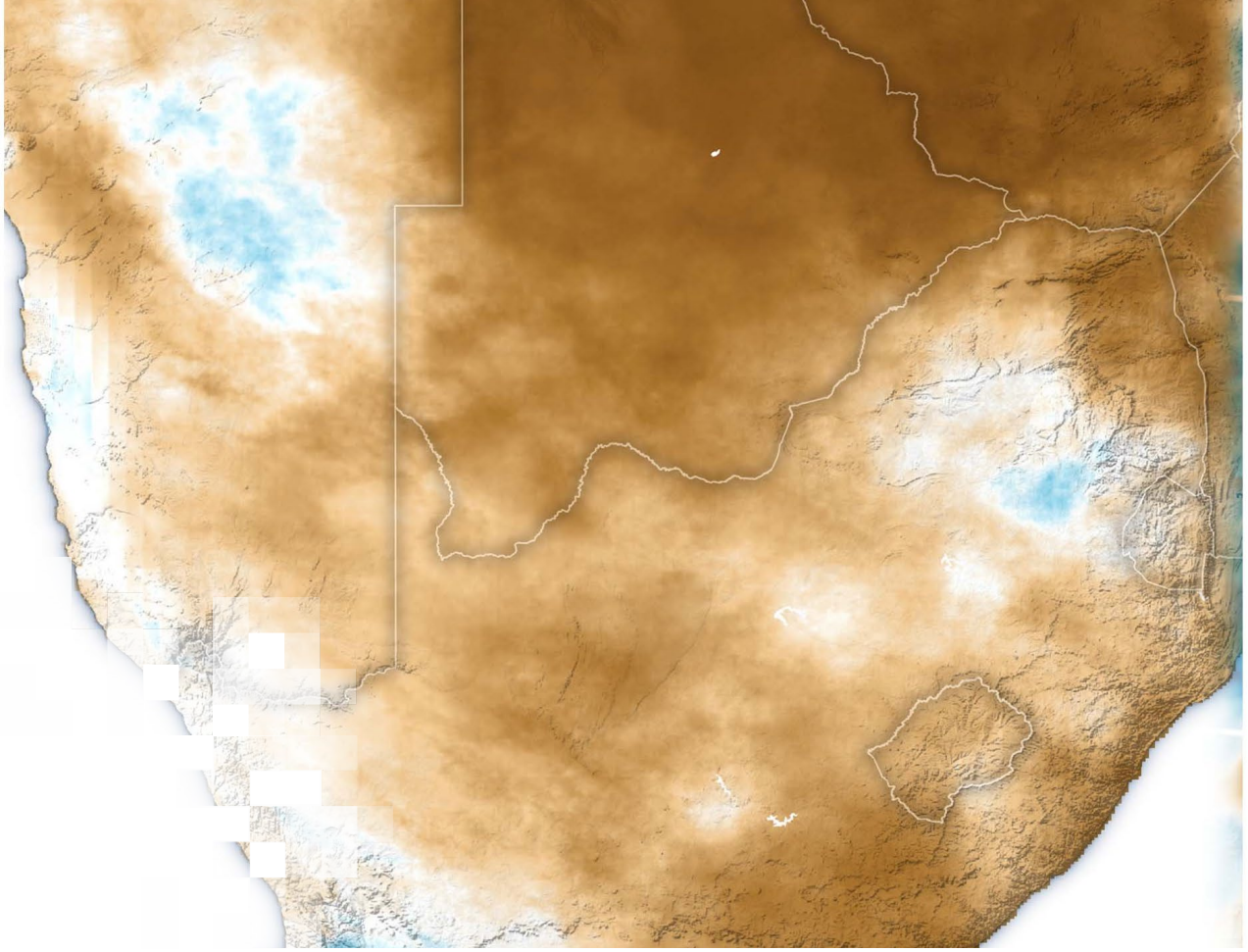
Chen et al., 2021 Figure 1.25

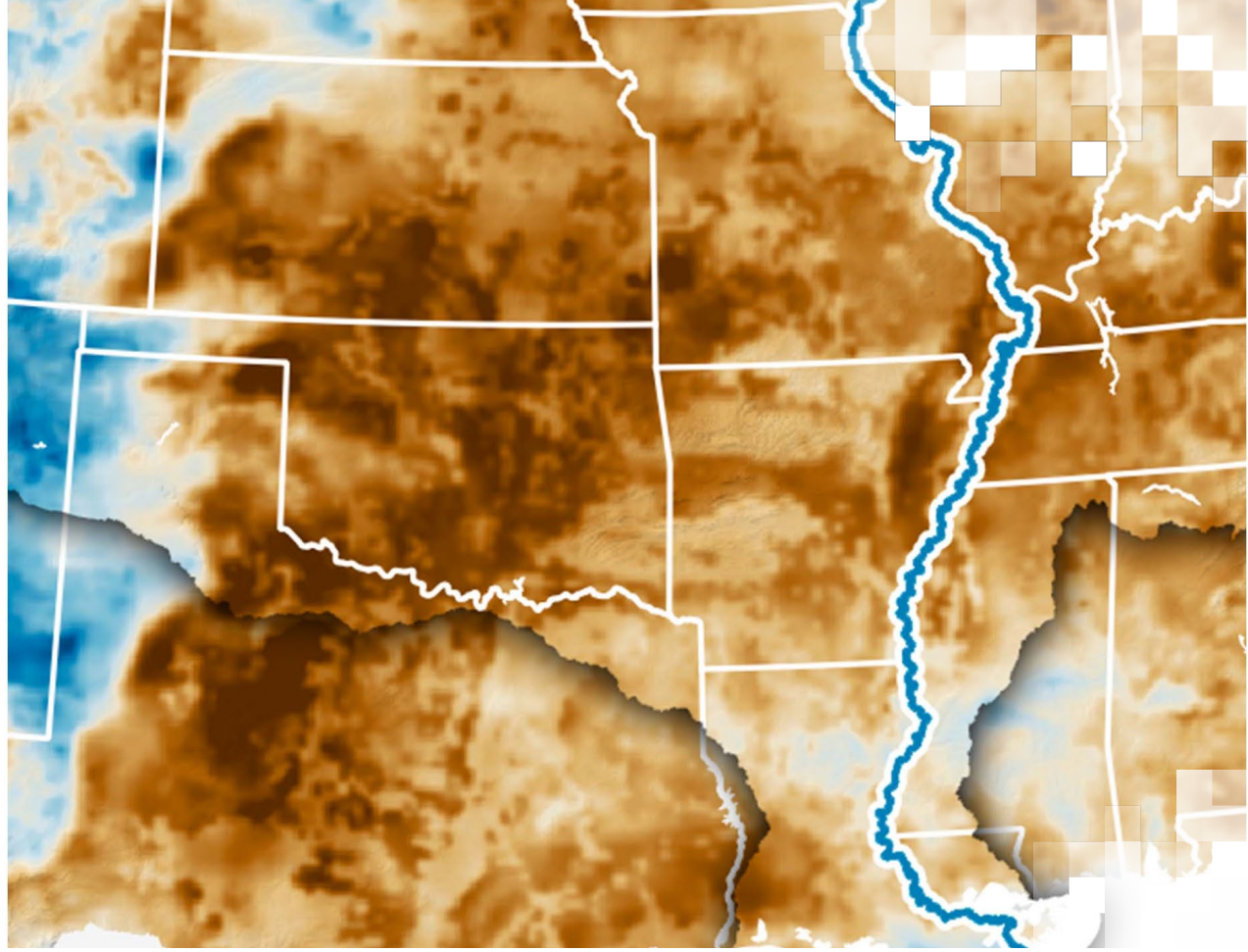
Scenarios and Storylines

- SSPs describe socioeconomic development.
- RCPs describe greenhouse gas concentrations.
- These can be related, and mitigation can create unique combinations.
- Each SSP leads to a given RCP without mitigation, but mitigation can lower RCPs.



ScenarioMIP Shared Socioeconomic Pathways
from O'Neill et al., 2016 (doi:10.5194/gmd-9-3461-2016)

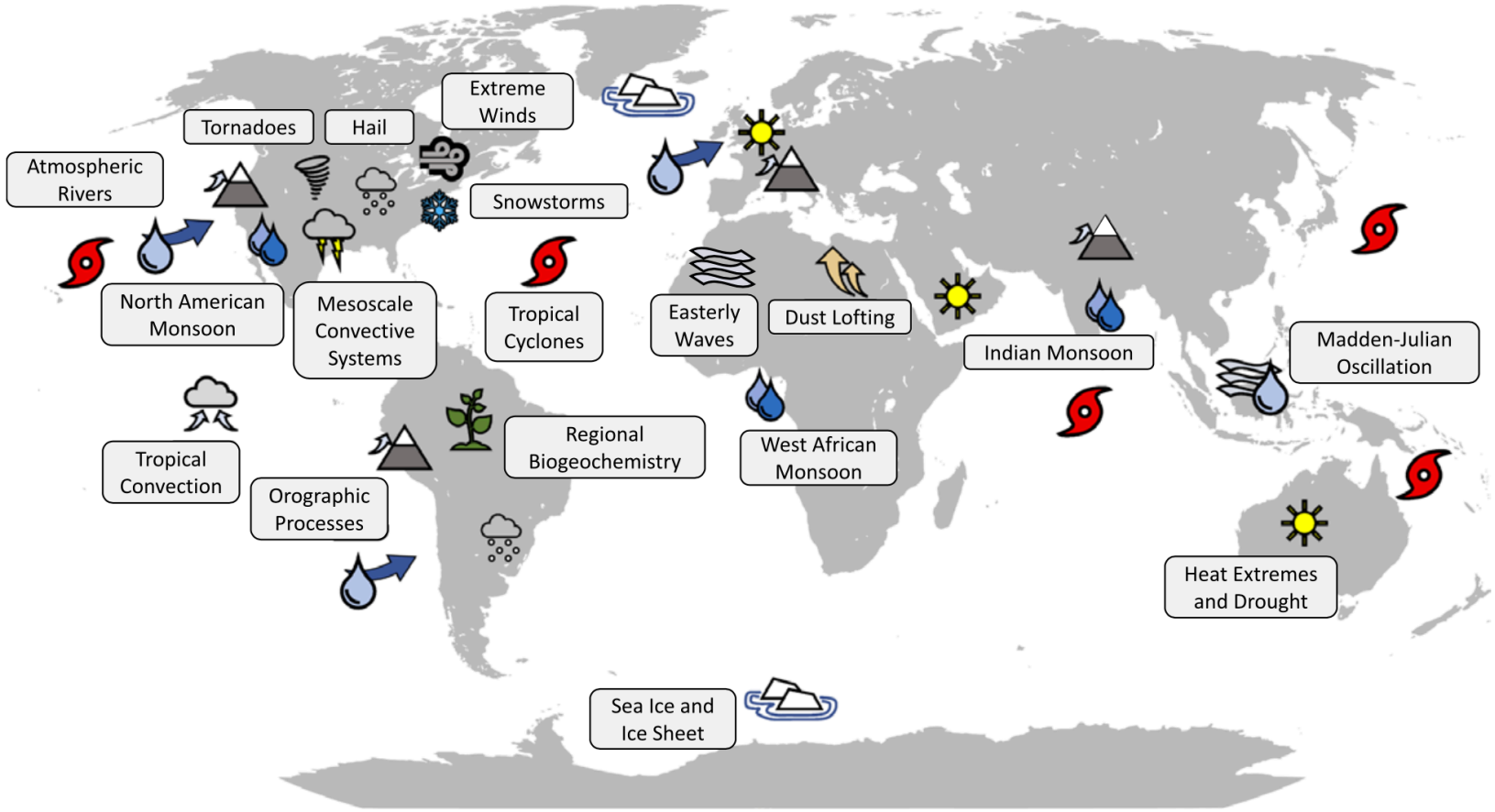




Overview of NEX-GDDP-CMIP6

Downscaling

- Analyses designed to bring global model information to finer resolution, potentially including:
  - Representation of finer-scale features such as land use, mountains, and coastlines
  - Physical processes associated with finer resolution dynamics
- Necessary for assessing climate impacts on local/regional scale



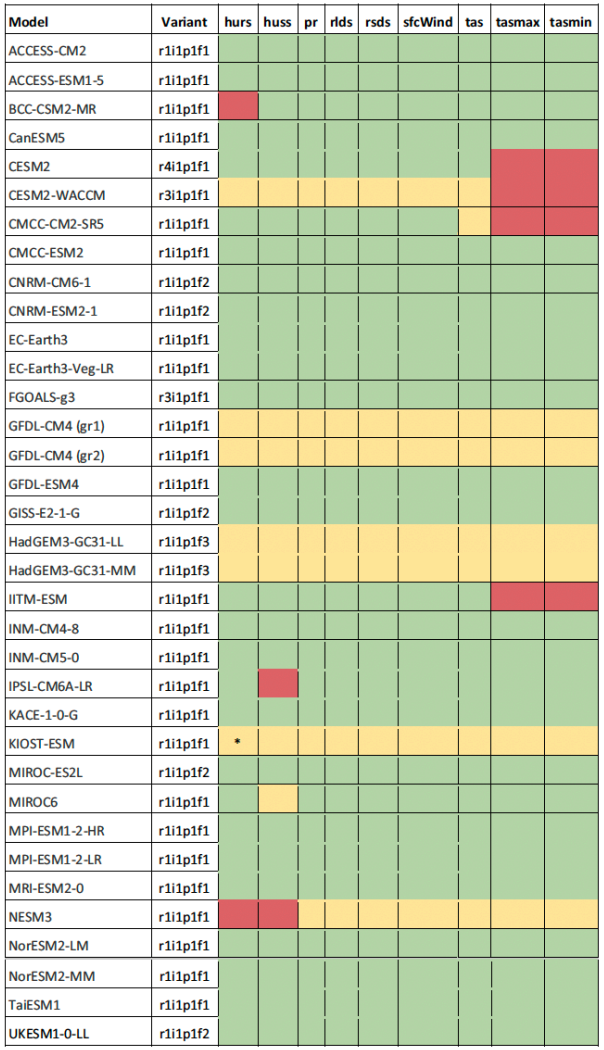
Features of Climate System that Might Benefit from More Fine-Scale Regional Modeling

From Gutowski et al., 2020, Figure 1 – (doi:10.1175/BAMS-D-19-0113.1)

NEX-GDDP-CMIP6

- **NEX-GDDP:**
  - Initiated in 2015 with CMIP5 project to downscale GCMs
  - Updated with CMIP6 with newer climate projections
  - 35 CMIP6 global models are included in the downscaling
  - A number of geophysical parameters are downscaled from most models

Thrasher, B., Wang, W., Michaelis, A. *et al.* NASA Global Daily Downscaled Projections, CMIP6. *Sci Data* **9**, 262 (2022). https://doi.org/10.1038/s41597-022-01393-4



Model	Variant	hurs	huss	pr	rlds	rsds	sfcWind	tas	tasmax	tasmin
ACCESS-CM2	r1i1p1f1									
ACCESS-ESM1-5	r1i1p1f1									
BCC-CSM2-MR	r1i1p1f1									
CanESM5	r1i1p1f1									
CESM2	r4i1p1f1									
CESM2-WACCM	r3i1p1f1									
CMCC-CM2-SR5	r1i1p1f1									
CMCC-ESM2	r1i1p1f1									
CNRM-CM6-1	r1i1p1f2									
CNRM-ESM2-1	r1i1p1f2									
EC-Earth3	r1i1p1f1									
EC-Earth3-Veg-LR	r1i1p1f1									
FGOALS-g3	r3i1p1f1									
GFDL-CM4 (gr1)	r1i1p1f1									
GFDL-CM4 (gr2)	r1i1p1f1									
GFDL-ESM4	r1i1p1f1									
GISS-E2-1-G	r1i1p1f2									
HadGEM3-GC31-LL	r1i1p1f3									
HadGEM3-GC31-MM	r1i1p1f3									
IITM-ESM	r1i1p1f1									
INM-CM4-8	r1i1p1f1									
INM-CM5-0	r1i1p1f1									
IPSL-CM6A-LR	r1i1p1f1									
KACE-1-0-G	r1i1p1f1									
KIOST-ESM	r1i1p1f1	*								
MIROC-ES2L	r1i1p1f2									
MIROC6	r1i1p1f1									
MPI-ESM1-2-HR	r1i1p1f1									
MPI-ESM1-2-LR	r1i1p1f1									
MRI-ESM2-0	r1i1p1f1									
NESM3	r1i1p1f1									
NorESM2-LM	r1i1p1f1									
NorESM2-MM	r1i1p1f1									
TaiESM1	r1i1p1f1									
UKESM1-0-LL	r1i1p1f2									

Table 2. CMIP6 models included in downscaled archive . Key: Green = all experiments available; yellow = historical & some SSP(s) available; red = no data available. *Original GCM output for hurs SSP245 missing year 2058

List of GCMS and Parameters

NEX-GDDP-CMIP6 Downscaling Methodology

- Statistical downscaling method used a daily variant of the monthly bias correction/spatial disaggregation (BCSD) method.
- Observational data and reanalysis data at 0.25° scale are used for bias correction.
- After the bias correction, spatial disaggregation merges observed historical climatology at each time step with changes from GCM simulations to produce final downscaled products.

BCSD code used to generate the downscaled outputs is available on Github
https://github.com/bthrasher/daily_BCSD

Wood, et al. (2002): J. of Geophysical Research-Atmospheres 107. Wood, et al. (2004)" Climatic Change 62, 189–216.

NEX-GDDP-CMIP6 Data

- The GDDP data are available for the following climate projection scenarios: **Historical, SSP126, SSP245, SSP370, and SSP585**
- Quality-checked data are available at **daily** time scale with **0.25 x 0.25-degree** spatial resolution

SSP1: low challenges for mitigation (resource efficiency) and adaptation (rapid development)
SSP3: high challenges for mitigation (regionalized energy/ land policies) and adaptation (slow development)
SSP4: low challenges for mitigation (global high tech economy), high for adaptation (regional low tech economies)
SSP5: high challenges for mitigation (resource/ fossil fuel intensive) and low for adaptation (rapid development)
(narratives in O'Neill et al., 2016, Glob Env Change, online first)

UNCCC SSP Overview

Selecting Climate Change Projections

- Understand the differing needs of mitigation, adaptation, and risk management applications
- Recognize the main components and distinguishing factors of climate projection sets
- Summarize the benefits and tradeoffs of different climate projection sets and versions
- Discuss selection of the best climate projection set for various application needs

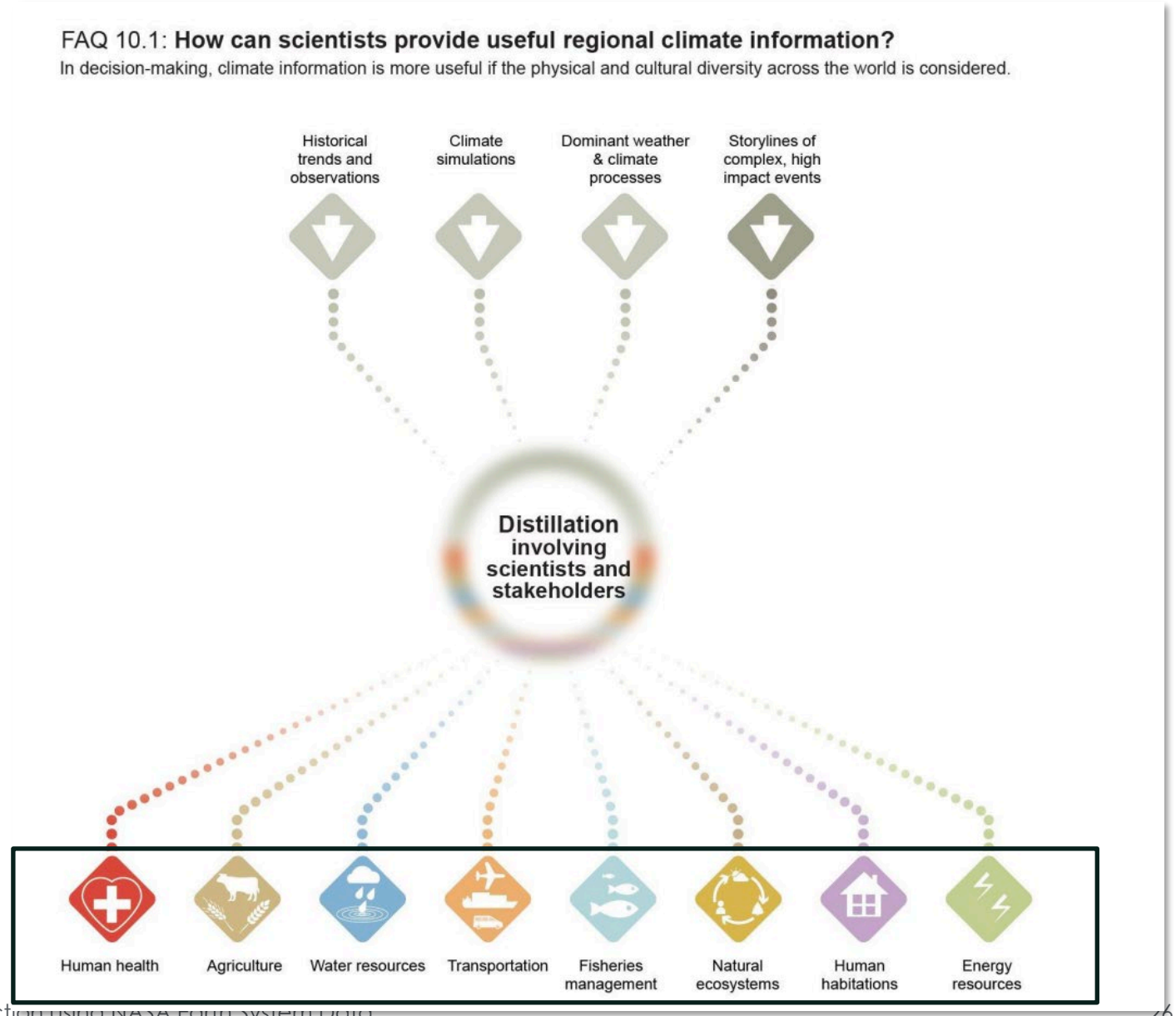
Note: ARSET does not recommend any particular model or scenario for climate change but provides general steps to access and analyze GCM data to facilitate your efforts in gauging climate change in the region of your interest.

ARSET Training: Selecting Climate Change Projection Sets for Mitigation, Adaptation, and Risk Management Applications

Selection of Climate Change Projections

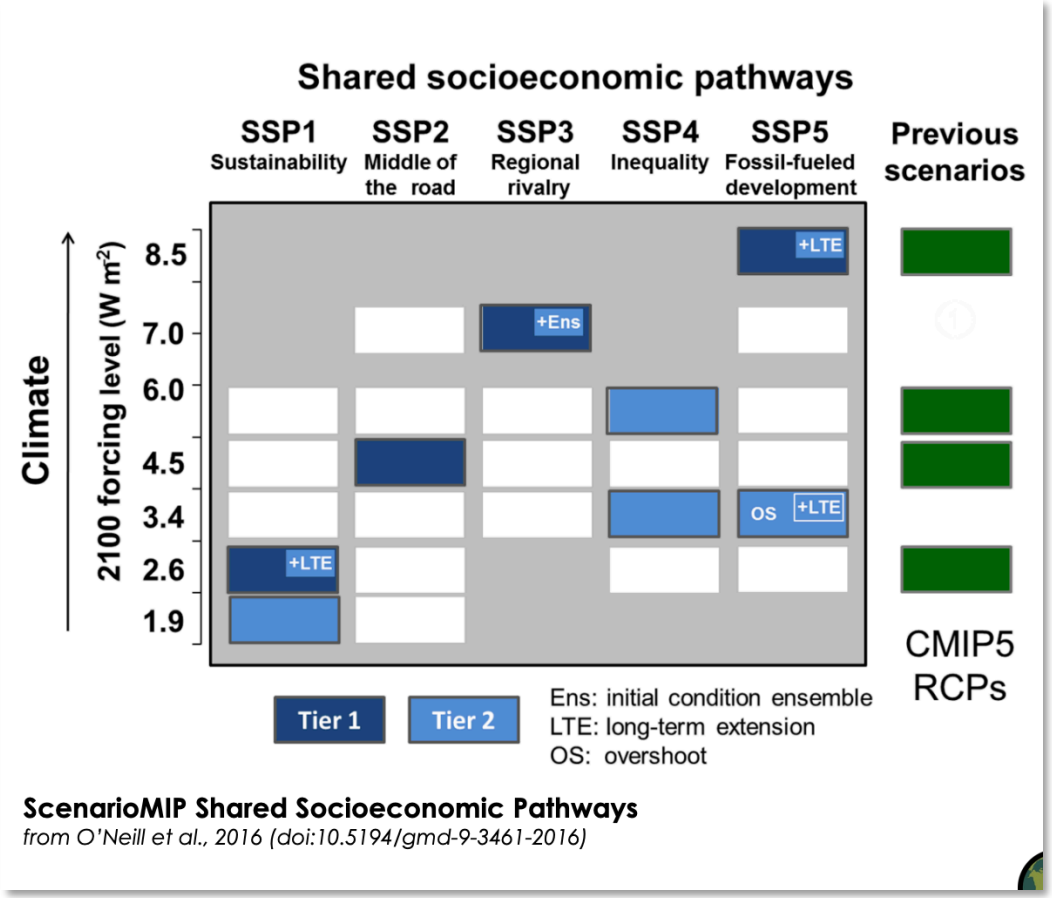
Based on:

- Applications and decision-making needs
- Physical and cultural diversity
- Interactions among climate scientists and stakeholders



Selecting Climate Change Projections

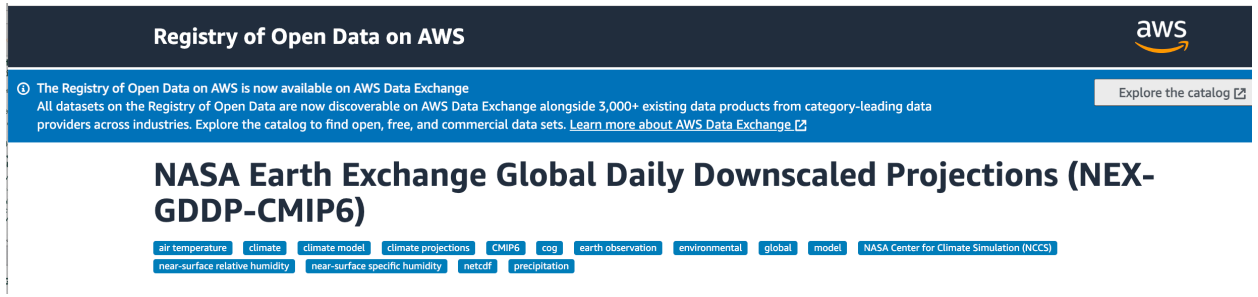
- Overview of application areas (mitigation, adaptation, risk)
- Where climate projection sets come from
- Key distinguishing features between climate projection sets
- Tradeoffs in using more complex climate projection sets
- **Selecting an appropriate climate projection set given application needs**
- Downscaling, Spatial & Temporal Resolutions
- Post-Processing and Bias Correction
- Application-Ready Parameters (*Temperature, Precipitation, Soil Moisture, Evapotranspiration, Runoff, Snow & Ice, Climate Indices)*



ScenarioMIP Shared Socioeconomic Pathways
from O'Neill et al., 2016 (doi:10.5194/gmd-9-3461-2016)

NEX-GDDP-CMIP6 Data Access

Data available from [Amazon Web Service (AWS) NEX-GDDP-CMIP6]



Resources on AWS

Description

The NEX-GDDP-CMIP6 archive. Files are in NetCDF format with the CF-1.7 metadata conventions.

Resource type

S3 Bucket

Amazon Resource Name (ARN)

`arn:aws:s3:::nex-gddp-cmip6`

AWS Region

`us-west-2`

AWS CLI Access (No AWS account required)

```
aws s3 ls --no-sign-request s3://nex-gddp-cmip6/
```

Explore

Browse Bucket

License

As noted in the metadata of each file, the NEX-GDDP-CMIP6 archive was initially made available through a CC-BY-SA 4.0, as required by the standard data license of the original CMIP6 data. In June 2022, the CMIP6 community updated their underlying licenses https://wcrp-cmip.github.io/CMIP6_CVs/docs/CMIP6_source_id_licenses.html, thereby allowing the NEX-GDDP-CMIP6 data license to also be updated. As of September 2022, all NEX-GDDP-CMIP6 outputs are made available under a blanket Creative Commons Zero license (CC0) license.

Documentation

https://doi.org/10.7917/OFSG3345

Managed By

See all datasets managed by NASA.

Contact

support@nccs.nasa.gov

How to Cite

NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) was accessed on `DATE` from https://registry.opendata.aws/nex-gddp-cmip6. NEX-GDDP-CMIP6 data was accessed on [date] from https://registry.opendata.aws/nex-gddp-cmip6

Usage Examples

Tools & Applications

- NEX-GDDP-CMIP6 Dashboard by NASA

Publications

- AWS NASA and ASDI announce no-cost access to important climate dataset on the AWS Cloud by Dr. Manil Maskey and Ana Pinheiro Privette
- NASA Global Daily Downscaled Projections, CMIP6 by Thrasher, B., Wang, W., Michaelis, A., Melton, F., Lee, T. and Nemani, R.

NEX-GDDP-CMIP6 Data Access

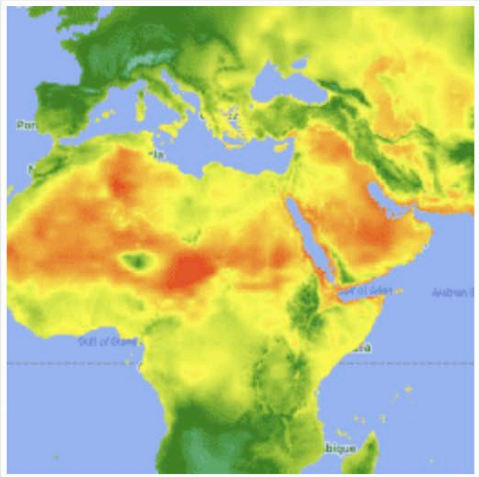
- A subset of data also available from AWS NEX-GDDP CMIP6
  - Models: GFDL-CM4 and GISS-E2-1-G
  - SSPs: ssp245 and ssp585
- The data are available in Cloud-Opimized GeoTiff format.

- The data is divided into 3 sub-products:
  - daily: source data with daily timestamps.
  - monthly: monthly aggregations across both models.
  - crossing: a single data product for each ssp indicating the number of years until the average daily temperature crosses 2-degree limit from the Paris Agreement, at each position on Earth.

NEX-GDDP-CMIP6 Data From Google Earth Engine (GEE)

- Data can be accessed and analyzed on GEE:NEX-GDDP-CMIP6

NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Downscaled Climate Projections



Dataset Availability

1950-01-01T00:00:00Z–2100-12-31T00:00:00Z

Dataset Provider

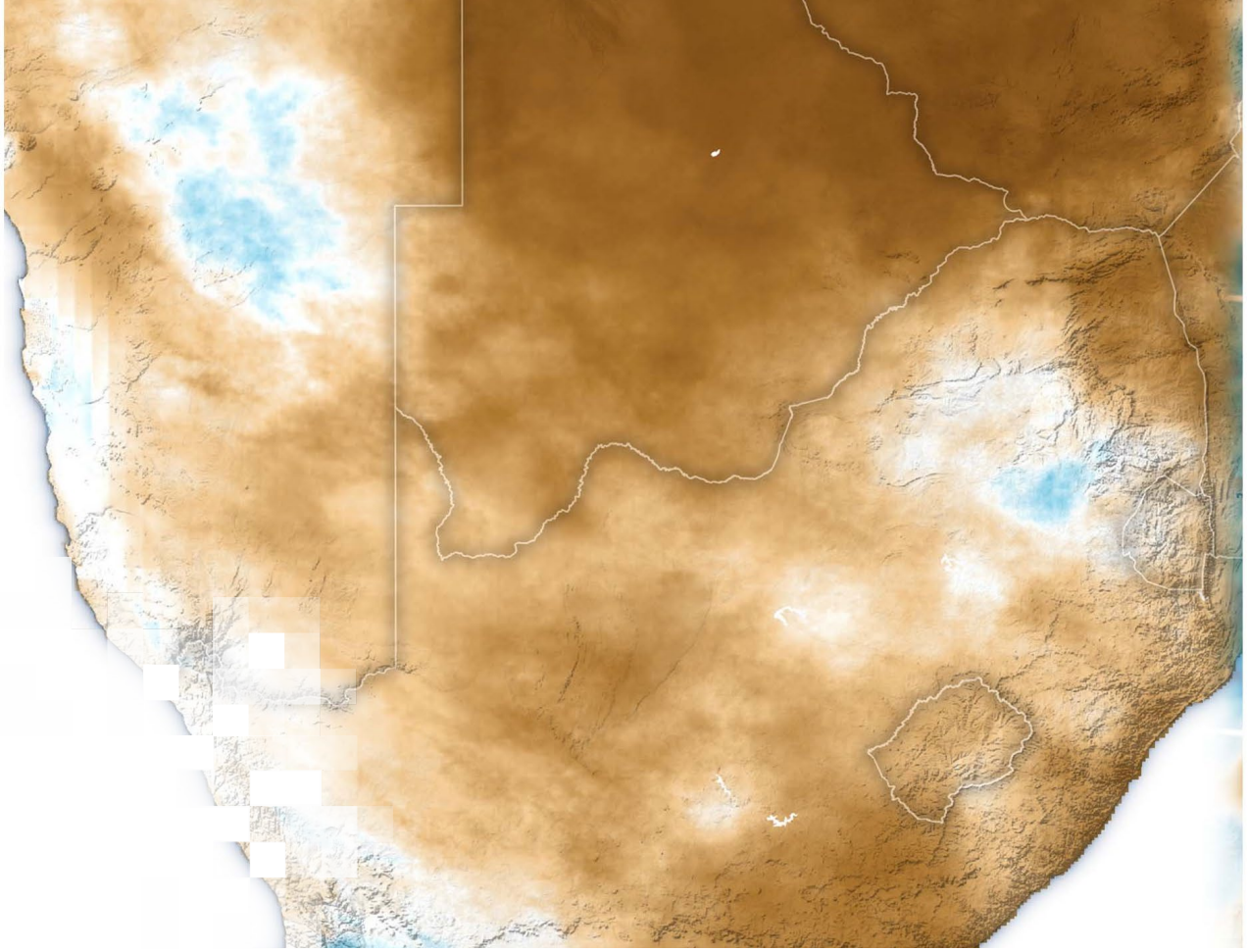
NASA / Climate Analytics Group

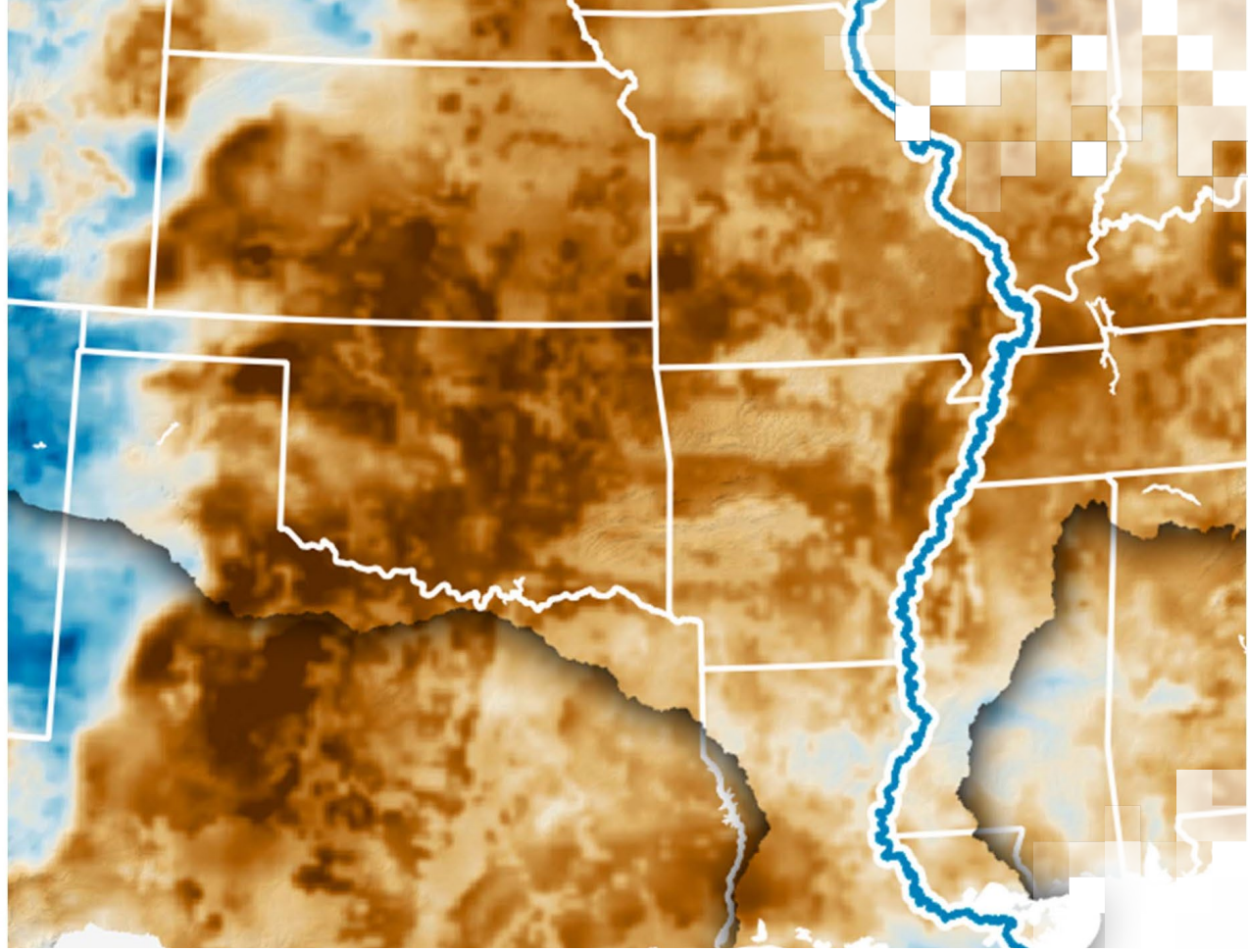
Earth Engine Snippet

```
ee.ImageCollection("NASA/GDDP-CMIP6")
```

Tags

cag | climate | gddp | geophysical | nasa | nex | precipitation | temperature





Demonstration
Access and Analysis of NEX-GDDP Projection Data for Drought Assessment

Summary

- **Climate** is the long-term mean (30+ years) of characteristics of geophysical parameters.
- Climate variability and change are due to:
  - **natural changes** in solar radiation and Earth's orbital variations, e.g. ocean-atmosphere-land interactions
  - **anthropogenic causes**, e.g. increase on greenhouse gases and aerosols due to industries, transportation, and land-use change.
- **Global climate models** capture both natural and anthropogenic climate variability and change.
- **CMIP** allows inter-comparison of model outputs to understand differences (now in phase 6).
- **NEX-GDDP uses statistical methodology** to downscale outputs for five different climate projections of several CMIP6 models at 0.25 x 0.25 degree spatial resolution.
- **NEX-GDDP data are available** from Amazon Web Service and also from GEE (for two climate projections).
  - As an example, NEX-GDDP temperature and precipitation changes over Ethiopia were examined between 2020 and 2100 using GEE.

Looking Ahead to Part 4

- Overview of regional tools, to facilitate drought monitoring and assessment.
- Demonstration of DSET and SFMIS

Homework and Certificates

- **Homework:**
  - One homework assignments
  - Opens **8/1/2024**
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 08/15/2024**

- **Certificate of Completion:**
  - Attend all four live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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- ARSET Website
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Resources

- Coupled Model Intercomparison Project Phase 6 (CMIP6)
- NEX-GDDP
- NEX-GDDP-CMIP6 Data Access and Analysis


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TRAIN - EMPOWER - ADVANCE

Thank You!