Earth & Environmental Systems Modeling

Modes of Variability and Teleconnections, Trends

Jerry Meehl (NCAR), Paul Ullrich (LLNL), John Fasullo (NCAR), Maria Molina (NCAR), Jim Benedict (LANL)

U.S. DEPARTMENT OF ENERGY | Office of Science

2024 EESM PI Meeting
August 6–9, 2024

Challenges:

Uncertainties and forcing influences on MOVs: Quantifying and addressing uncertainties in model forcings, particularly aerosols, and their seasonality, and understanding their impact on modes of variability.

Understanding and addressing model biases in MOVs: In particular, there seems to be significant model biases in variability (particularly decadal variability), as well as biases in persistence of atmospheric blocking. Need for simpler models to better understand the key drivers of this variability.

Human connections: Influence of aerosol emissions (industrial or biomass burning) on modes of variability and resulting feedbacks. Oscillations in human systems: Does ENSO manifest in GCAM?

An Appeal

E3SM High Resolution (28km) Large Ensemble

- Better representation of AMOC
- Better representation of topographic feedbacks
- Allows for studying of teleconnections impacting tropical storms

Challenge 1:

Better understanding of potential multiyear memory in MoV

Better understanding of aerosol remote impacts

Significant model biases in decadal and total variability (including atmospheric blocking) – more need for simple models?

Need for high-resolution (28km) large ensembles

Grand challenges (1):

1. **Interactions Between Decadal Variability and ENSO**:
   - Understanding the complex interplay between decadal variability and ENSO, including their combined effects on climate patterns.
2. **Uncertainties and Forcing Influences on MOVs**:
   - Quantifying and addressing uncertainties in model forcings, particularly aerosols, and their seasonality, and understanding their impact on modes of variability (MOVs).
3. **Climate Model Representation of MOVs**:
   - Improving how models represent MOVs and their connections to extremes by integrating physical processes to better capture oceanic and atmospheric variability.
4. **Disentangling External Forcing from Internal Variability**:
   - Differentiating between internal climate variability and external forcing effects, such as aerosols and land use changes, in climate models and observations.

Grand challenges (2)

5. **Model Biases and Systematic Errors**:
    - Diagnosing and reducing systematic biases in climate models, including those related to SST, teleconnections, and blocking events.
6. **Understanding Aerosol-Climate Interactions**:
    - Improving understanding of the seasonal and spatial effects of aerosols on climate feedbacks, cloud formation, and SST.
7. **Model Representation of Internally Generated Decadal Variability Patterns versus Forced Responses**:
    - Addressing the ability of models to simulate decadal variability patterns and constraining them with observations.

Research gaps

1. **Seasonality of Aerosols**:
   - Further research on the seasonality of sulfate aerosols, particularly in summer, and their impact on climate feedbacks and SST.
2. **Model Uncertainty and Forcing**:
   - Quantifying uncertainties in model forcings and their incorporation into climate models to reduce uncertainties.
3. **Impact of Aerosols on ENSO**:
   - Researching how aerosols affect ENSO dynamics and its broader climate impacts.
4. **Reanalysis (observational) Uncertainty**:
   - Addressing large uncertainties in upper-level divergence and heating data from reanalysis studies to improve model accuracy.
5. **Biases in Climate Models**:
   - Diagnosing and correcting biases in climate models (e.g. blocking events and teleconnections)

Opportunities (1)

1. **High Resolution Modelling**:
   - Addressing model biases with high resolution simulations to explore the physical processes responsible for canonical model bias.
2. **Machine Learning for Internal Variability**:
   - Utilizing machine learning to estimate and better understand internal climate variability and discrepancies between models and observations**.**
3. **Cloud Feedback and Predictability**:
   - Techniques such as cloud locking experiments to explore the impact of clouds on climate predictability and sensitivity.
4. **Model Assessments Beyond PCA/EOF**:
   - Developing methodologies that go beyond traditional statistical methods, such as PCA/EOF, to focus on physical processes in climate models.
5. **Improving MJO / Stratospheric Interactions**:
   - Enhancing the coupling of the Madden-Julian Oscillation (MJO) with QBO in climate models.

Opportunities (2)

6. **Land Use Change Impact on Climate Trends**:
    - In connection with MSD, investigating the impact of land use changes on climate trends and MOVs through targeted simulation studies.
7. **Weather Regimes and Extreme Events**:
    - Improving the skill in predicting weather regimes and extreme events over North America (connect to MSD)
8. **Leveraging Large Ensembles for Understanding the Intrinsic Variability of Modes**:
    - Using large multi-model ensembles to understand mode characteristics and their changes under various emissions scenarios.
9. **Operationalizing Forcings and Emissions**:
    - Developing frameworks for integrating annual forcing updates for climate studies, also for