Assignment 04: Seasonal Multi-Model Ensemble Analysis with CMIP6 Models

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1. Introduction

This assignment focuses on the analysis of seasonal climate variability using a multi-model ensemble approach. Students will work with monthly precipitation data from four CMIP6 models: **CESM2-WACCM**, **CMCC-CM2-HR4**, **FIO-ESM-2-0**, and **TaiESM1**. The goal is to compute seasonal means for DJF, MAM, JJA, and SON, and to construct a multi-model ensemble (MME) to assess the mean and spread across models. This exercise will enhance students' skills in climate data analysis, ensemble modeling, and scientific visualization.

2. Objectives

- Load and explore climate data from multiple CMIP6 models in NetCDF format.
- Compute seasonal means (DJF, MAM, JJA, SON) for each model.
- Construct a multi-model ensemble and compute ensemble mean and standard deviation.
- Visualize seasonal ensemble means and inter-model spread.
- Interpret seasonal differences and model variability.

3. Dataset

The analysis will use monthly mean surface air temperature (`tas`) data from the following CMIP6 models:

- CESM2-WACCM
- CMCC-CM2-HR4
- FIO-ESM-2-0
- TaiESM1

Each dataset should span at least the period 1850–2014 and be provided in NetCDF format with global coverage.

4. Workflow

1. Load the NetCDF files for each model using `xarray`.
2. Group monthly data into seasons: DJF, MAM, JJA, SON.
3. Compute seasonal means for each model.
4. Stack the seasonal means across models to compute:
    - Ensemble mean
    - Ensemble standard deviation
5. Create visualizations:
    - Maps of ensemble mean temperature for each season
    - Maps of inter-model spread (standard deviation)
6. Analyze and interpret the results.

5. Tools

- Python libraries: `xarray`, `numpy`, `matplotlib`, `cartopy`, `seaborn`
- Optional: Climate Data Operators (CDO) for preprocessing

6. Deliverables

- Python scripts used for data processing and analysis.
- Visualizations: seasonal maps of ensemble mean and spread.
- A short report including:
    - Methodology
    - Key findings
    - Interpretation of seasonal and inter-model differences

7. Optional Extensions

- Compare ensemble results with observational datasets (e.g., ERA5).
- Analyze seasonal trends over time.
- Investigate the impact of extreme events on seasonal means.

8. Evaluation Criteria

- **Correctness and completeness of analysis (40%)**: Proper seasonal averaging and ensemble computation.
- **Code quality and reproducibility (20%)**: Well-structured and documented scripts.
- **Clarity of visualizations (20%)**: Effective use of maps and plots.
- **Quality of written report (20%)**: Clear explanation of methods and results.