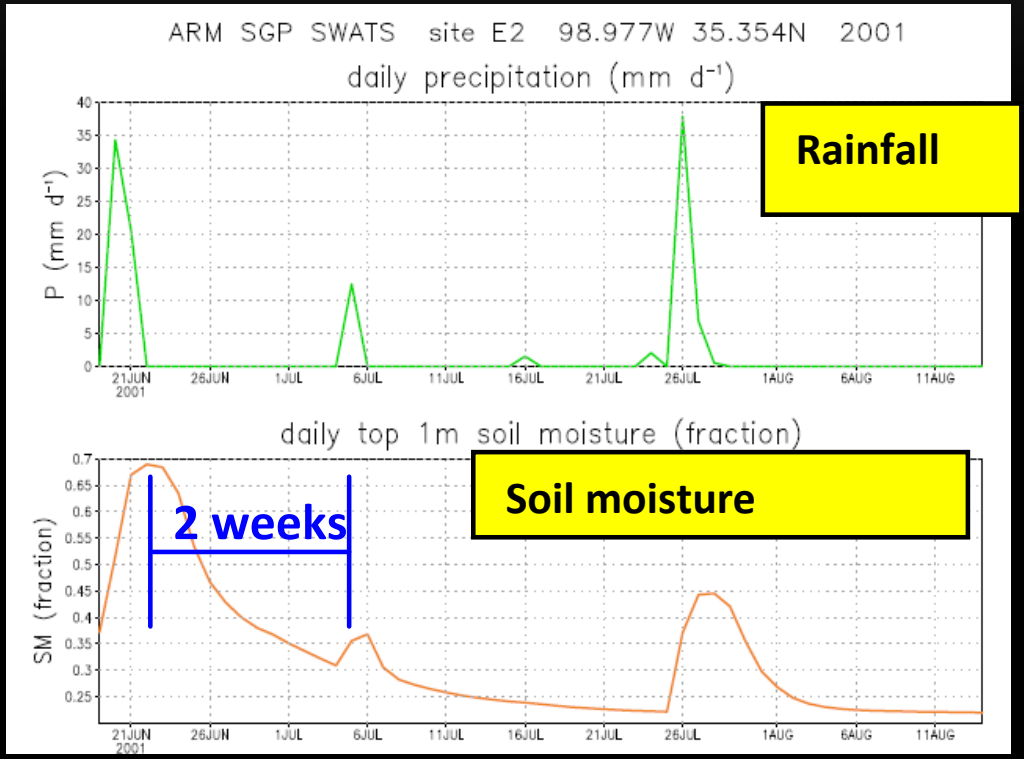
Predictability Sources

Three Categories of Predictability Sources

1. Inertia
2. Patterns of Variability (i.e., internal modes of climate variability)
3. External Forcing

1. Inertia

- Inertia: or “memory” of a climate variable
- Let’s consider soil moisture as an example: it increases with rainfall or snowmelt and decreases with evaporation or transpiration. The duration of a soil moisture anomaly depends on these fluxes relative to the size of the control volume.
- The anomalies of soil moisture can last much longer than the precipitation event that induces such anomalies.



Example of inertial memory (Fig. 2.3a in NAS report 2010)

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

Examples

- Upper ocean heat content: the upper ocean heat content is a known source of predictability on seasonal-to-interannual time scales.
  - Due to the large heat capacity and density, the upper 2.5 m of the ocean can, when cooling 1°C, can heat the entire column of air above it by 1°C (Gill 1982).
- Soil moisture: Its memory spans intraseasonal and longer time scales.
  - Model studies (Fischer et al., 2007) suggest that the dry soil moisture anomalies in the spring contribute to heat waves in the following summer.
  - Deeper soil moisture has a longer “memory”.
- Snow cover: snow can raise surface albedo and decouple the atmosphere from warmer underlying soil. Large snowpack anomalies over land during winter also imply large surface runoff and positive soil moisture anomalies during and following the snowmelt season.
- Polar sea ice: Sea ice is an active component of the climate system and is highly coupled with the atmosphere and ocean at time scales ranging from synoptic to decadal.

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

2. Patterns of Variability

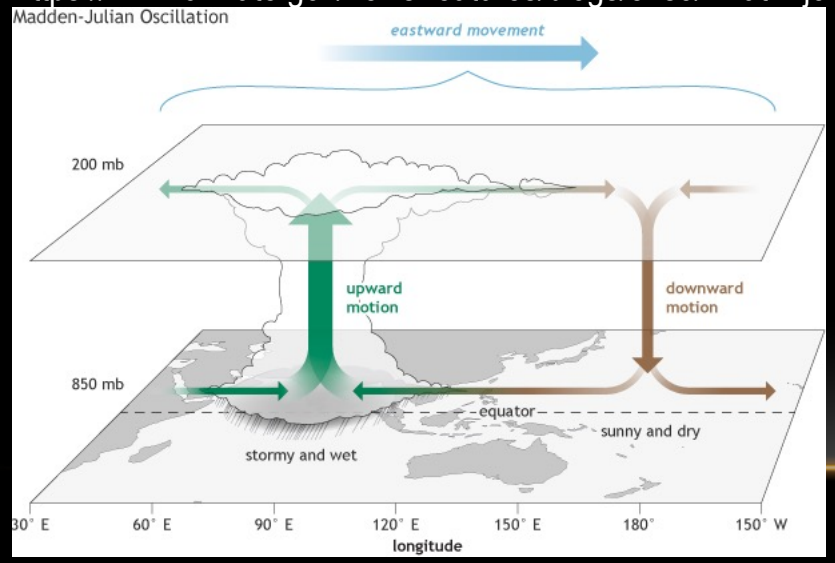
- These modes of variability are typically composed of amplification and decay mechanisms that result in dynamically growing and receding (and in some cases oscillating) patterns.
  - Such as the El Niño-Southern Oscillation (ENSO), Madden-Julian Oscillation (MJO), and North Atlantic Oscillation (NAO).
  - Climate modes are often associated with “teleconnections”, or impacts over relatively large geographic distances
  - The predictable characteristics of such modes and their impacts make them useful sources of predictability.

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

Examples of Climate Modes

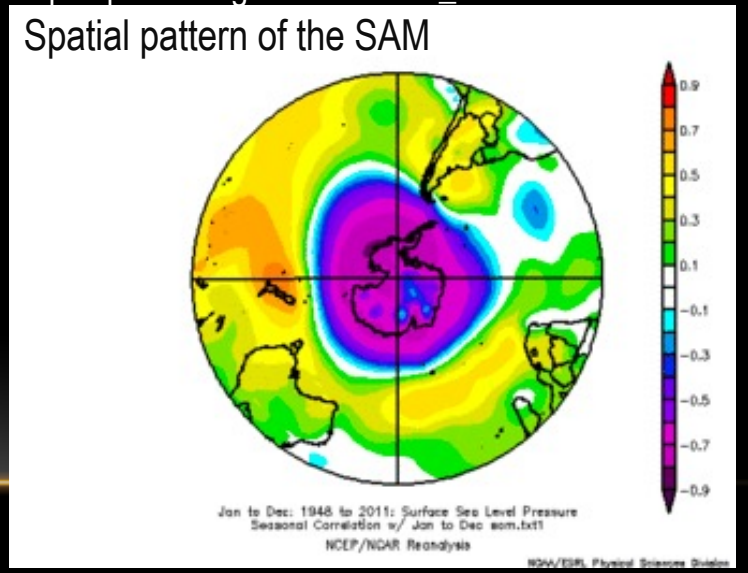
- Madden-Julian Oscillation (MJO): The MJO is the dominant mode of intraseasonal variability in the tropics. They strongly influence the onsets and breaks of the Australian and Asian monsoons and also have impacts in the extratropics.
- Annular Modes (including Northern and Southern Annular Modes, known as NAM and SAM): The Annular Modes are refereed to as the Arctic Oscillation in the Northern Hemisphere, or the Antarctic Oscillation in the Southern Hemisphere. They are dominant modes of variability outside the tropics. The manifestation of the Arctic Oscillation in the Atlantic sector is commonly referred to as the North Atlantic Oscillation (NAO).

https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care



https://psl.noaa.gov/data/20thC_Rean/timeseries/monthly/SAM/

Spatial pattern of the SAM

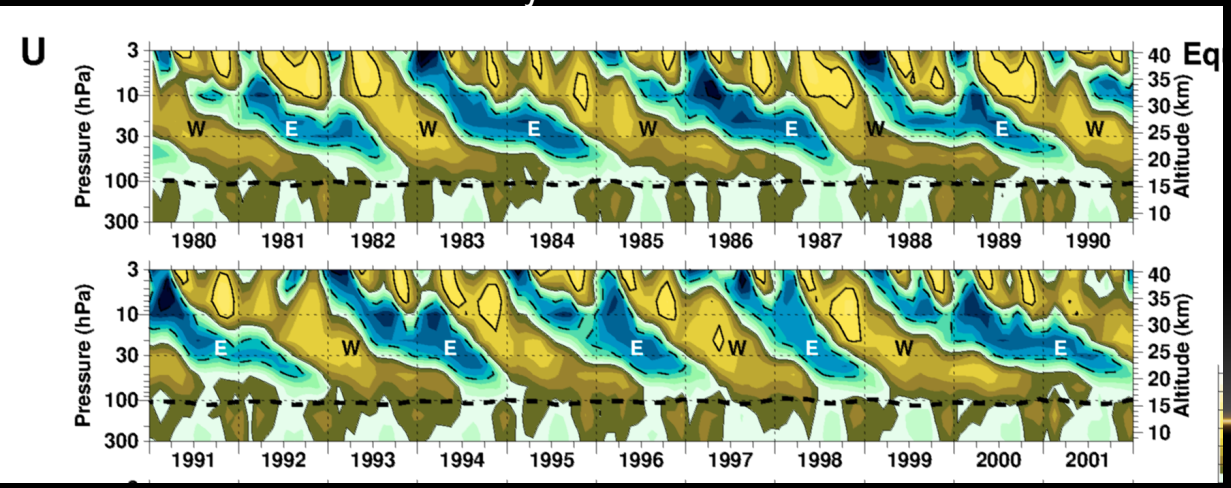


National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

Examples of Climate Modes (cont'd)

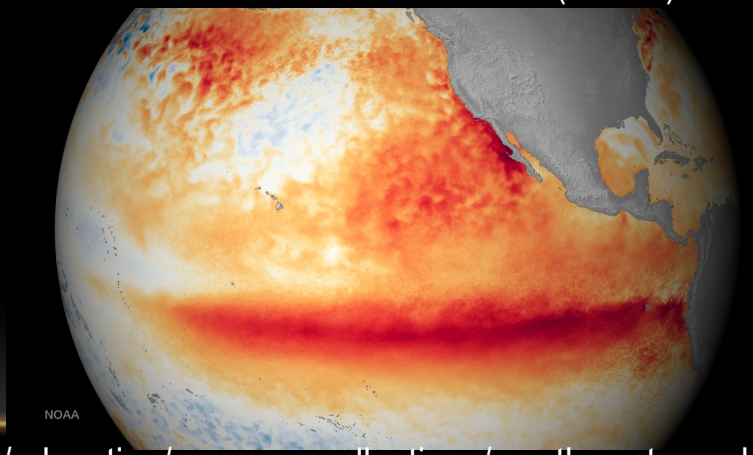
- Stratosphere-Troposphere Interaction: is also an important process for climate variability and prediction. The stratospheric circulation can be highly variable, with a time scale much longer than that of the troposphere. The variability of the stratospheric circulation can be characterized mainly by the polar vortex. The variability modes, such as the Quasi-Biennial Oscillation (QBO) and sudden stratospheric warmings (SSWs), offers a source of predictability for the tropospheric climate.
- El Niño-Southern Oscillation (ENSO) is the most important mode of interannual variability. The evolution of ENSO can be predicted one to a few seasons in advance using coupled atmosphere-ocean models (e.g., Zebiak and Cane, 1987), and SST anomalies in the tropical Pacific Ocean can contribute to predictions of the global atmospheric circulation via teleconnections at seasonal leads (e.g., Shukla, 1998).

Zonal wind with the annual cycle removed



https://acd-ext.gsfc.nasa.gov/Data_services/met/qbo/qbo.html

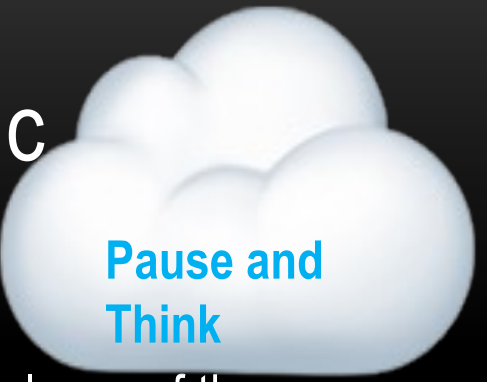
The El Niño Southern Oscillation (ENSO)



https://www.noaa.gov/education/resource-collections/weather-atmosphere/el-nino

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

3. External Forcing: natural and anthropogenic

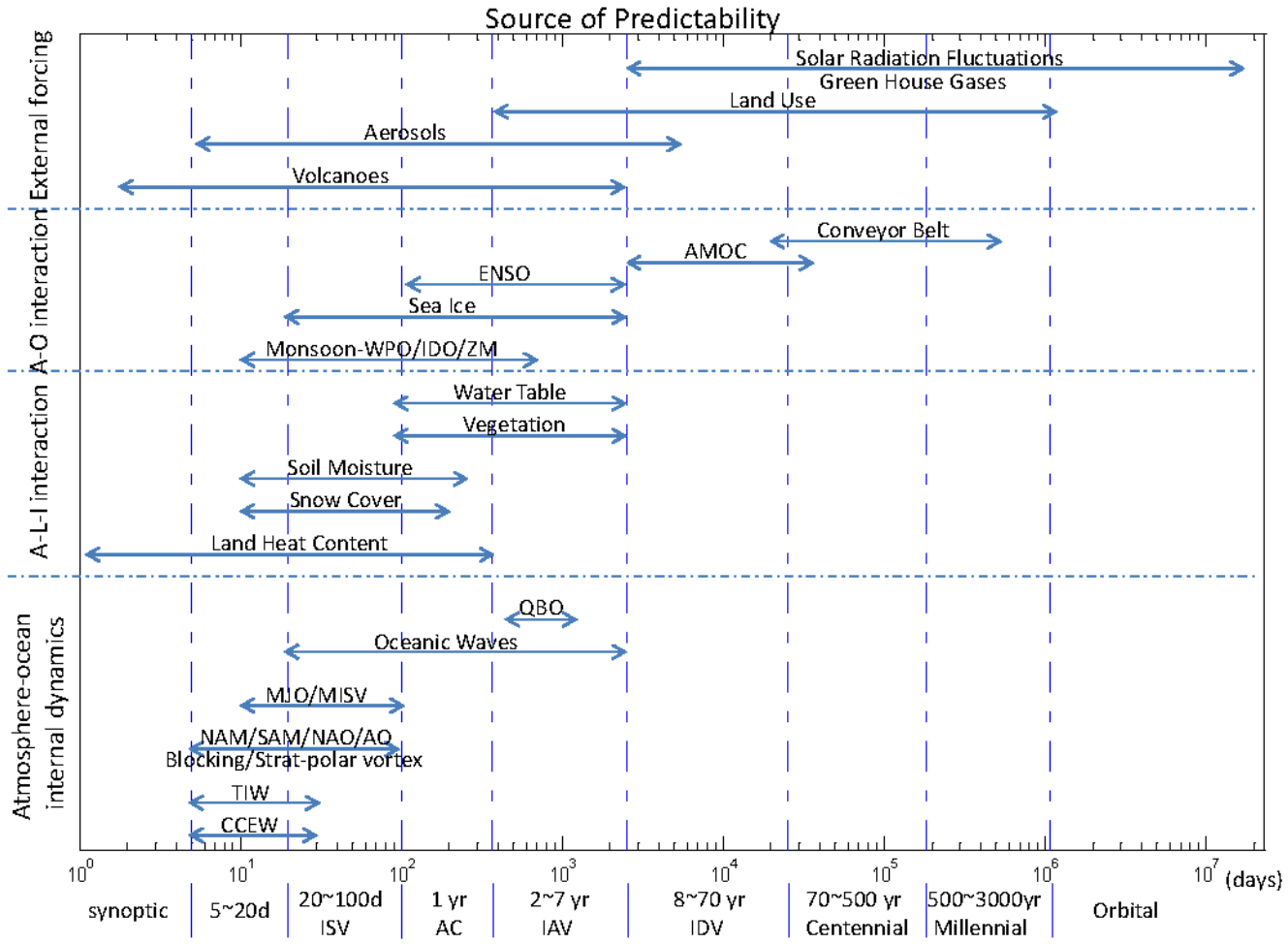


What external forcing can you think of ?

- Greenhouse gases (CO_2, etc.): Greenhouse gases have a direct impact on the radiation balance of the atmosphere: increases in greenhouse gas concentrations warm the global climate.
- Anthropogenic Aerosols: Atmospheric aerosols, which affect the radiation budget of the Earth, include sulfate aerosols from fossil fuel combustion and organic aerosols from biomass burning and land use change.
- Land use change: Humans have had a marked impact on the character of the land surface through deforestation, agricultural conversion, and urbanization.
- Fluctuations in solar output: The sun provides the energy that powers the Earth's climate system. Its output varies slightly with an 11-year cycle, and larger changes may occur on longer time scales.
- Other forcing: Volcanoes and forest fires

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

Summary



- Processes that act as sources of climate predictability extend over a wide range of timescales, and involve interactions among the atmosphere, ocean, and land.
- On different time scales, the dominant sources of predictability are different.

CCEW: convectively coupled equatorial waves (in the atmosphere); TIW: tropical instability wave (in the ocean); MJO/MISV: Madden-Julian Oscillation/Monsoon intraseasonal variability; NAM: Northern Hemisphere annular mode; SAM: Southern Hemisphere annular mode; AO: Arctic oscillation; NAO: North Atlantic oscillation; QBO: quasi-biennial oscillation, IOD/ZM: Indian Ocean dipole/zonal mode; AMOC: Atlantic meridional overturning circulation. For the y-axis, “A” indicates “atmosphere;” “L” indicates “land;” “I” indicates “ice;” and, “O” indicates “ocean.”

National Research Council. 2010. *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. https://doi.org/10.17226/12878.

References

- NAS report: "*Assessment of Intraseasonal to Interannual Climate Prediction and Predictability* ", Section 2.2