Climate Variability
Mechanisms and Influences on Synoptic Weather

MET 171B
SJSU

Lecture Topics
Intra-seasonal modes of climate variability
- Madden Julian Oscillation (MJO)
- Pacific North American Oscillation
- North Atlantic Oscillation
Inter-annual modes of climate variability
- El-Nino Southern Oscillation
Inter-decadal modes of climate variability
- Pacific Decadal Oscillation

Role of Atmospheric Circulation
Preferred large scale modes of low-frequency variability

Example of Footprint
14 Dec 08 – 3 Jan 09
Climate Variability

- Climate is defined by the aggregate of weather conditions averaged over a sufficiently long time period.
- But... as weather varies from day-to-day, climate conditions fluctuate intra-seasonally and inter-annually.
  - "The last 2 weeks of January was much wetter than the last two weeks of December this year in CA"
  - "The snowpack in the Sierra this winter is much greater than last winter." (or this April was much colder and wetter than last April)

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Climate Variability

Defined
- Fluctuations in climate about a mean state that occur with preferred patterns and recurrence intervals.
- Climate variability is considered "natural" or part of the climate system that would occur in the absence of humans.

Periodicity
- Not usually cyclical
- But have preferred time scales
  - Multi-decadal (PDO)
  - Inter-annual (ENSO)
  - Intraseasonal (MJO, PNA, NAO)

Oscillations

Defined: Any phenomenon that varies about a mean state with some recurrence and periodicity

Can be either forced by boundary conditions (SST, land cover anomalies) or be part of atmospheric preferred state

Periodicity: Unlike in classical oscillations, nonlinearities and stochastic forcing in climate system results in irregularities in oscillation: hence generally not predictable cycles

The Weather-Climate Gap

Fundamental Question: Is weather predictable at lead times longer than those of deterministic numerical weather forecasts?

Need added predictive skill in the weather-climate gap.

MJO: El Nino’s Speedy Cousin

- Eastward propagating equatorial wave (tropical convection)
- Intraseasonal timescales of 30-60 day, intraseasonal variability

The MJO cloud-system ‘envelope’
“Global-scale circulation cells in the tropics with a 40-50 day period”

Direct signal fades in cooler SST east of dateline

What is the MJO?
Ocean-Atmosphere interaction fuels convective complex systems
Coupled Kelvin-Rossby wave allows for eastward propagation 5 m/s
Convective instability processes important

Kelvin Waves in the Atmosphere

Features:
Convective plume enhanced tradewinds AHEAD of the convection, low level moisture feeds convective activity as system moves eastward

Features:
Alternating areas of high and low pressure.
Features:

An area of upper-tropospheric DIVERGENCE, best seen in the VELOCITY POTENTIAL.

Circumnavigating the Globe?

- Madden and Julian originally believed that this area of convection propagated all the way around the world every 40-50 days.
- But this isn’t exactly right.

However, the region of upper-level divergence WILL generally travel all the way around the world as a Kelvin Wave.

Kelvin Wave – A type of low frequency gravity wave trapped to a vertical boundary, or the equator, which propagates counterclockwise around a basin (in the N.H.).

MJO influences ‘round the world

The MJO is a key problem for weather-climate research not only in the tropics, but also around the world.

MJO: Madden-Julian Oscillation

Characterized by eastward propagating Kelvin-Rossby wave in tropics w/ coherent longitudinal dipole of convection over the warm waters of the Indian & W. Pacific
- A tropical feature with extratropical impacts: teleconnection patterns

OLR anomalies. Blue (Red) indicates enhanced (suppressed) convection
**MJO Implications**

MJO event increases the potential for extreme precipitation events in W. US (Jones et al, 2004).

**Why/How?**

A. Enhanced convection over tropical Pacific
B. Upper-level divergence alters the jet
C. Rossby wave pattern ~ PNA
D. Conduit for tropical moisture to ride the subtropical jet into W. U.S.

**MJO Teleconnection to the West Coast**

- Active phases of the MJO can provide enhanced predictability of extreme events well downstream
- Example: Heavy winter precipitation events along the West Coast
- How: Teleconnection via two important processes

**An Example: Jan 6-11, 2005**
Strong subtropical jet + active tropical convection: Pineapple Connection

20+ causalities
100+ million in damages

The un-La-Nina like winter of 2007-08: Blame in on the MJO

Pacific North American (PNA) Pattern
Most prominent mode of low-frequency variability in the Pacific sector
Extratropical Rossby wave-like pattern emanating from the subtropics
Quadrapole patterns extending from tropical Pacific to SE US

PNA

Time to Use Your Recall Skills

PNA index is defined by analysis of geopotential height field departure from mean
- Positive → More meridionally developed flow
- Negative → More zonally oriented flow
The Pacific/North American teleconnection pattern (PNA) is one of the most prominent modes of low-frequency variability in the Northern Hemisphere extratropics. The positive phase of the PNA pattern features above-average heights in the vicinity of Hawaii and over the intermountain region of North America, and below-average heights located south of the Aleutian Islands and over the southeastern United States. The PNA pattern is associated with strong fluctuations in the strength and location of the East Asian jet stream. The positive phase is associated with an enhanced East Asian jet stream and with an eastward shift in the jet exit region toward the western United States. The negative phase is associated with a westward retraction of that jet stream toward eastern Asia, blocking activity over the high latitudes of the North Pacific, and a strong split-flow configuration over the central North Pacific.

The positive phase of the PNA pattern is associated with above-average temperatures over western Canada and the extreme western United States, and below-average temperatures across the south-central and southeastern U.S. The PNA tends to have little impact on surface temperature variability over North America during summer. The associated precipitation anomalies include above-average totals in the Gulf of Alaska extending into the Pacific Northwestern United States, and below-average totals over the upper Midwestern United States. Although the PNA pattern is a natural internal mode of climate variability, it is also strongly influenced by the El Niño/Southern Oscillation (ENSO) phenomenon. The positive phase of the PNA pattern tends to be associated with Pacific warm episodes (El Niño), and the negative phase tends to be associated with Pacific cold episodes (La Niña).
Lecture Outline

Climate Modes Continued…

- Pacific Decadal Oscillation
- Madden Julian Oscillation
- Pacific North American Oscillation
- Annular Modes (NAO, AO)

NAO: North Atlantic Oscillation

Identified by the large scale meridional seesaw in atmospheric mass between the subtropical Azores high and the subpolar Icelandic low. Positive phase refers to deeper than normal Low and stronger than normal high (read: stronger gradient).

North Atlantic Oscillation

Negative

Positive

Part of the broader annular mode phenomenon: N/S pressure oscillations between the poles and midlatitudes

Impacts: latitude of jet/ shift in precip/temp patterns

Primarily impacts Europe and eastern US

Unlike ENSO, the NAO is primarily an atmospheric phenomenon, and occurs without boundary forcing.

Some consider the NAO on interannual or decadal scales

Low frequency forced by boundary conditions: SST, sea-ice, and stratospheric wind anomalies.

High Frequency component of the NAO

Stochastic problem: Prominent mode of atmospheric internal variability.

Feldstein (2000) showed that the NAO operates on a two-week timescale...

- Driven by nonlinear eddy vorticity fluxes, and variations in eddy momentum flux.