Impacts of modes of climate variability, monsoons, ENSO, annular modes

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Modes of variability - preferred patterns of variability. Can be associated with Sea Surface Temperature anomalies, large scale atmospheric circulation anomalies, convection anomalies in distant places.
How to identify?

Correlation analyses

\[ \sum_{i=1}^{N} \frac{(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{N} (y_i - \bar{y})^2}} \]

Y: Position of point P
X: all the other points

Standard deviation

P (0, 120W)
EOF analysis

• Anomalies in a domain during a period
• Apply the method
• Get: % of variance related to the total variance
• The dominant modes will be represented by the modes with large % of variance
• The timeseries of the amplitude of each mode.
Modes of variability can be related to teleconnections

- Relation between variability between distant places (tele: distant connection: relation)

Example: Southern Oscillation
El Niño-Southern Oscillation (ENSO)

**Normal or La Nina**
December - February La Niña Conditions

**El Niño**
Anomalous convection over central and eastern Pacific
December - February El Niño Conditions
Global influences

El Nino years

La Nina years

Ropelewski and Halpert 1986
El Nino Canonical and El Nino Modoki+A

Canonical

(a) ENC – SON

(b) ENM – SON

(c) ENC – DJF

(d) ENM – DJF

Impact over South America

Canonical

(a) ENC – SON

(b) ENM – SON

Modoki+A

(a) ENC – SON

(b) ENM – SON

(c) ENC – DJF

(d) ENM – DJF

Tedeschi et al. 2012
Polade et al. 2013

CMIP5 JFM

Polade et al. 2013
EN and LN intensity

Collins et al. 2010
EL Nino

Changes in Pacific SST
Variability of ENSO in models

Projection changes CMIP3

Standard deviation of SLP (SOI)
Collins et al 2010

Standard deviation of Nino 3 SST
CMIP5
SST Changes

Shading: historical
Contour: future projection rcp8.5

SON

28°C

26°C

22°C

SON

HADGEM2-ES (1980-2005) & (2074-2099)
Modes of variability in the Northern Hemisphere

- North Atlantic Oscillation (NAO)
- Pacific North America (PNA)
- Northern Annular mode (NAM)

- Multidecadal Oscillations: Pacific (PDO or PMO)
- Atlantic (AMO)
NAO influences

A pattern of lower than normal atmospheric pressure over the Arctic leads to strong westerly winds in the upper atmosphere at northern latitudes.

With higher than normal atmospheric pressure in the central Atlantic, strong westerly winds push warmth and precipitation toward northern Europe.

The Mediterranean region experiences drought conditions.

Strong trade winds prevail in the subtropics.

With lower than normal atmospheric pressure in the central Atlantic and weak westerlies over northern Europe, storms develop over the Mediterranean region.

Weak trade winds prevail.

Northern Europe and Asia get hit with cold Arctic air.

With westerlies weak, cold Arctic air reaches more southerly latitudes; the U.S. gets a cold winter.

Strong westerlies keep cold Arctic air to the north; the United States gets a warm winter.

A pattern of higher than normal atmospheric pressure over the Arctic leads to weaker westerlies in the upper atmosphere.
Teleconnections in the N.H.

Wallace e Gutzler 1981

Horel and Wallace 1981
EAST PACIFIC PATTERN (EP)

January

April

July

October

-75 -50 -25 25 50 75
Simulated PNA  BESM

Nobre et al. 2013
Annular modes

Geo at 850 hPa

Geo at 1000 hPa

zonal wind

Thompson and Wallace, 2000
Simulation of North Annular Mode
Main Modes of variability in the Southern Hemisphere

Southern Annular Mode (SAM)

Pacific South America (PSA) pattern
How anomalies in tropical regions can be connected to anomalies in a distant place?

Rossby wavetrains

Convection

SST anomalies

divergence

Ascent

Low pressure

Anticyclonic circulation

equator
What is the influence of this pattern in Brazil and South America?

South Atlantic Convergence Zone
SACZ
Simulation PSA   BESM

Nobre et al. 2013
Representation of the 2 modes in model simulation

HadGEM2-ES historical

EOF1 anogeo250 DJF (1979–2004) HADGEM2_historical

SAM

EOF2 anogeo250 DJF (1979–2004) HADGEM2_historical

PSA
Changes in the Pacific South America pattern due to changes in Pacific SST: influences over southeastern SA

HADGEM2-ES Simulation

HADGEM2-ES Projection

Zonal anomaly: PSA EOF1

Cavalcanti and Shimizu 2013
Changes in the South Atlantic Convergence Zone
Intensification of the southern center

historical

Rcp 8.5

Cavalcanti and Shimizu 2013

Also in Junquas et al 2013
Southern Annular Mode

Opposite anomalies between polar region and middle latitudes

**JAN**

Positive phase: Strong polar jet and weak subtropical jet

**JUL**

Negative phase: Weak polar jet and strong subtropical jet
Increase of the positive phase of SAM indicates a southward displacement of the storm tracks.
Changes in storm tracks

Stippling marks locations where at least 90% of the models agree on the sign of the change.

Storm track density

AR5
Projected Changes in the jet streams

1980 to 1999 to 2081–2100 in zonal mean CMIP5
Projected changes in NAO, NAM, SAM

37 CMIP5 models’ merged historical and RCP 4.5 simulations (black) for each season. Colored lines show observational annular mode indices. Simulated anomalies are shown relative to an 1861–1900 climatology.

Gillet&Fyfe 2013.
Projected changes for NAM and SAM

changes between 1861–1910 and 2050–2099 for each season in the individual CMIP5 models and in the multi-model ensemble mean (bottom bars).

Gillet&Fyfe 2013.
Observed trends in PNA and PSA

(g) PNA indices, DJFM means
- Centers of action (NNR)
- RPC

(h) PSA1 mode indices (NNR), 24-mon r.m.
- PSA1 PC
- Karoly PSA
- Yuan&Li (-1)*PSA
MONSOONS
NH: May to September
SH: November to March

AR5, Kitoh et al 2013
Precipitation changes (2080-2099)- (1986-2005)
Precipitation changes (2080-2099)- (1986-2005)
Changes in vertically integrated water vapor flux and convergence

Between (1986–2005) and the future (2080–2099) in the RCP8.5 scenario.

Kitoh et al. 2013
American Monsoon regions
Precipitation Difference (DJF-JAS) or (JJA-DJF) \( \geq 2.0 \) mm/day

Carvalho and Cavalcanti, 2015
Changes in the American Monsoon

Changes in the area of monsoon

Changes in the humidity flux

Prec (mm/day) (DJF–JJA) (1980–2005), (2075–2100) ENSEMBLE

humidity flux 850 hPa HADGEM2 rcp8.5 JAN (F–P)

Carvalho and Cavalcanti, 2015
Global features
Summary

• Main modes of variability- ENSO, NAO, PNA, PSA, NAM, SAM
• The models can represent the patterns
• Projections: Large uncertainty in NAO but slight trends to positive phase
• Trend to positive phase in NAM and SAM
• Poleward displacement of storm tracks
• Observed positive trend in PNA and negative trend in PSA
• Changes in the position and intensity of PSA centers