Climate Predictability at Decadal Scale in Chile

Rocío Ormazábal R.
MSc(c) in Meteorology and Climatology

University of Chile
Center for Climate and Resilience Research - CR2
1. Introduction
   a) General overview of climate features in Chile
   b) Influence of internal and external climate variability
   c) The current Mega Drought
   d) Decadal prediction: how can it help?
   e) Objectives of my work

2. Data and methodologies
   a) Data and models
   b) Forecast quality assessment: temperature and precipitation
   c) Indirect ways to get temperature and precipitation

3. Preliminary Results
   a) External forcing in Chilean Climate

4. Conclusions
General overview of climate features in Chile

- Southern Hemisphere, west coast of South America
- Bound by the Andes mountain range to the east and Pacific Ocean to the west
- Long and narrow country, most of the population in central zone
- Differents climate patterns along and across (height, proximity to the sea and insolation)
General overview of climate features in Chile

Modified de Garreaud (2009) and Barrett et al. (2011)
General overview of climate features in Chile

Main Los Andes effects:
- Anticyclone location (enhanced subsidence)
- Cold tongue SST

SLP long term mean - NCEP Reanalysis

SST long term mean - NOAA Optumum Interpolation (OI)
General overview of climate features in Chile

- Southeast Pacific Subtropical Anticyclone (SPSA)
- Seasonal Changes of SPSA
- Precipitation Assymetry (zonal and meridional)
- Bolivian High modulate precipitation over the Chilean Altiplano, only for summer season (DJF).

Main Los Andes effects:

- Austral Summer
- Austral Winter

Garreaud et al., 2007
General overview of climate features in Chile

- Maximum precipitation over Austral zone (NS asymmetry), related to storm track position and SPSA.
- Zonal asymmetry for topography effect

\[ TP = \text{Extratropical cyclons} + \text{orographic precipitation} \]
General overview of climate features in Chile

Four precipitation patterns:
- Altiplano
- Coastal desert
- Frontal Systems
- Frontal Systems + Orographic
General overview of climate features in Chile

First let’s see the temperature!

Frontal + orographic

Trend 1979 - 2014

Boisier et al., 2016
General overview of climate features in Chile

Temperature patterns over SA

Seasonal long-term mean 2-m air temperature [°C]
U. Delaware

Temperature zonal asymmetry and seasonality
General overview of climate features in Chile

Andes (East)

Andes (West)

Central Valley

Coast

Ocean

Changes in local temperature.

Andes (east and west) and central valley are warming

Coast and South-East Pacific Ocean is cooling

Andes warming is strongest

Internal / natural variability or external forcings?

Falvey y Garreaud, 2009
Influence of internal and external climate variability

Internal/natural variability

Precipitation
Central-south zone

Temperature
South (SAM) and coastal north zone (PDO and ENSO)

Annual mean Precip/SAT regressed upon index of large-scale modes (50 years of data)

Garreaud et al. 2002
Influence of internal and external climate variability

External forcing variability

Less precipitation and higher temperature is consistent with the Hadley expansion


200 hPa wind, summer

Lu et al., 2009
Influence of internal and external climate variability

<table>
<thead>
<tr>
<th>Internal variability vs external forcing?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSO, PDO/IPO, SAM</td>
</tr>
<tr>
<td>Hadley cell expansion, Strengthening of SPSA, Increase of upwelling</td>
</tr>
</tbody>
</table>

Both!

Let’s see an example...
The current Mega Drought

Is the future now?

• Uninterrupted sequence of 8 dry years (25-45% anomalies)
• Reached farther south than previous droughts
• Warm decade anomaly in central Valleys (~1°C)

Central-southern Chile:
- Most important cities are there
- About 9 millions inhabitants
- Agricultural and wine industry
The current Mega Drought
The current Mega Drought

Garreaud et al. 2017
The current Mega Drought

Natural variability (PDO) \(\frac{1}{4}\) + Antropogenic Climate Forcing \(\frac{1}{4}\) = \(\frac{1}{2}\) Megadrought
The current Mega Drought

Rainfall anomaly wrt 1970-2000

Rainfall deficit wrt 1970-2000

Climate Change Signal

Unlikely
Likely
Very unlikely

Recent Past
Mega Drought
Next Decade
Mid Future RCP8.5
Far Future RCP8.5

MD Forcing
(*): Anthropogenic
(**): Natural (ENSO, PDO, Internal)
Why decadal predictions?

How can it help?

Predictability of Chilean Climate = External forcings + Natural variability

Meehl et al., 2009
Why decadal predictions?

Decadal prediction in South America

Gonzalez and Goddard, 2015

Saurral et al., 2018

Mehta et al., 2018
Introduction: Objectives of my work

Main objective
Examine the predictability of temperature and precipitation at decadal scales in Chile.

Specific objectives
• Evaluate the performance of historical simulation to represent typical climate patterns in Chile.
• Evaluate the impact of the initialization of the models comparing the forecast quality of historical simulations with decadal predictions.
• Apply predictability analysis on Chile: temperature and precipitation.
• Predictability of the mega-drought (2010-2015).
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Data and models

Models (CMIP5)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Nombre CMIP5</th>
<th>Modelo</th>
<th>Resolución</th>
<th># Ensambles DP</th>
<th># Ensambles Históricos</th>
<th>Disponibilidad temporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>tas, pr, psl, tos, ua (200hPa) y zg (500 hPa)</td>
<td>bcc-csm1-1</td>
<td>2.79° x 2.81°</td>
<td>4</td>
<td>3</td>
<td>1960-2006</td>
</tr>
<tr>
<td>Precipitation</td>
<td></td>
<td>CanCM4</td>
<td>2.79° x 2.81°</td>
<td>10</td>
<td>10</td>
<td>1960-2009</td>
</tr>
<tr>
<td>Sea level pressure</td>
<td></td>
<td>EC-EARTH</td>
<td>1.12° x 1.12°</td>
<td>10</td>
<td>10</td>
<td>1960-2006</td>
</tr>
<tr>
<td>Sea surface temp.</td>
<td></td>
<td>HadCM3</td>
<td>2.50° x 3.75°</td>
<td>10</td>
<td>10</td>
<td>1960-2009</td>
</tr>
<tr>
<td>Zonal wind 200 hPa</td>
<td></td>
<td>MIROC5</td>
<td>1.40° x 1.40°</td>
<td>6</td>
<td>5</td>
<td>1960-2009</td>
</tr>
<tr>
<td>Geopotential 500 hPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observations

- **Reanalysis**
  - ERA40 (1961 - 1978) and ERAinterim (1979-2016)

- **Gridded products**
  - GPCP, GHCN and ERSST

- **Meteorological Stations**
  - DGA and Meteochile

Servers

(CR)²

Center for Climate and Resilience Research

BSC

Barcelona Supercomputing Center

Centro Nacional de Supercomputación
Forecast quality assessment: temperature and precipitation

**Direct**

Comparison between decadal predictions, historical (non-initialized) and observations

- Deterministic: ACC and RMSE.
- Probabilistic: BS, RCP and CRPS

Use relations with other variables for evaluate the quality assessment of the prediction of temperature and precipitation

- Sea level pressure
- Geopotential 500 hPa (SAM)
- Zonal wind 200 hPa
- SST (ENSO, PDO, IPO)

**Indirect**

Quantify the added value of initialize the models for get temperature and precipitation in Chile

Compare with estándar forecast systems: persistence and climatology
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External forcing in Chilean Climate: Temperature

Climatologies
1961 – 2006

Multimodel
Ensemble Mean

INIT YR=1
No-INIT
OBS

No-INIT - OBS
INIT - OBS

INIT and No-INIT overestimate the SST in Pacific Ocean in front of Chile y Perú
External forcing in Chilean Climate: Temperature - Chile

- Models underestimate temperature over coast and valleys
- Models overestimate temperatures over Los Andes
- Problems in the Altiplano
External forcing in Chilean Climate: Precipitation

- Big differences in tropics
- Altiplano and Southern Chile differences
External forcing in Chilean Climate: Precipitation - Chile

- INIT YR=1
- No-INo INIT
- OBS

- No-INo INIT - OBS
- INIT - OBS

• INIT and No-INo INIT underestimate precipitation over Altiplano
• Problems with orographic precipitation
Conclusions

• The main characteristic of temperature and precipitation over Chile are decently reproduced with both INIT and No-INIT simulations.

• Models have problems with orographic precipitations and stratocumulus cloud cover.

• Is difficult for models to identify changes in temperature and precipitation for Los Andes Mountains.
Gracias!