SOUTH PACIFIC WAVE PROPAGATION AND SUMMER TEMPERATURE ANOMALIES IN NORTHERNMOST ANTARCTIC PENINSULA

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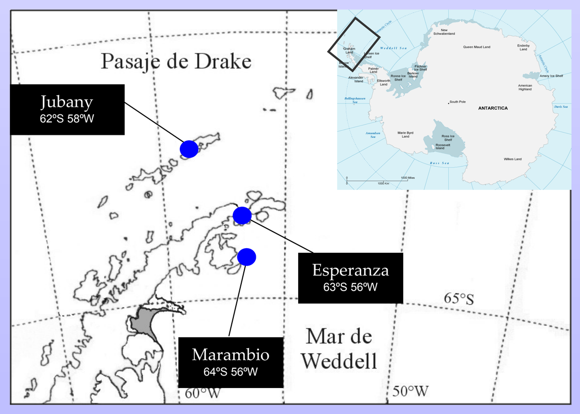
AIM: To analyze the tropospheric circulation in the Southern Hemisphere (SH) associated to anomalously cold summers (ACS) and anomalously warm summers (AWS) (Dec-Feb) in the period 1981-2010, over Northernmost Antarctic Peninsula (NAP).

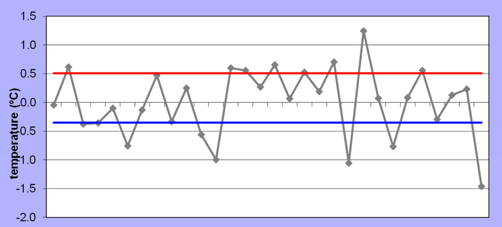
Data and Methodology

Near surface temperature data (ºC) from Servicio Meteorológico Nacional (the Argentine Weather Service) for 3 Argentine Antarctic stations are considered: Jubany (62ºS 58ºW), Esperanza (63ºS 56ºW) and Marambio (64ºS 56ºW), located over northernmost Antarctic Peninsula (NAP), as indicated in the figure (right). Since summer mean temperatures are well correlated amongst the stations (significant at 99%), it is decided to device a summer temperature index (STI) as the average amongst them. Hence the STI timeseries well represents the areal near surface summer temperature variability over NAP. Anomalously cold summers (ACS) and warm summers (AWS) are indentified using the quartile criterion for the detrended STI timeseries distribution in the period 1981-2010.



A wave-activity flux for stationary quasi-geostrophic eddies on a zonally varying basic flow, derived by Takaya and Nakamura (2001), is used as a diagnostic tool to study QSW propagation from the Pacific Ocean. According to Nishii and Nakamura (2005) this flux is suited for representing the 3D propagation of Rossby wave packets imbedded in a zonally varying time-mean flow. A Marshall SAM index is used to study the SH pattern related to AWS over NAP.

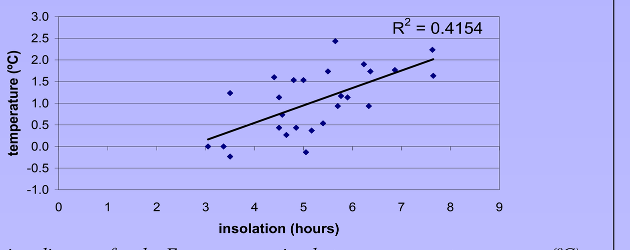
Anomalously Cold and Warm Summers over NAP



Detrended STI timeseries (ºC) from 1981 to 2010 and thresholds at -0.35 ºC and 0.51ºC according to the first (blue line) and third (red line) quartile, respectively.

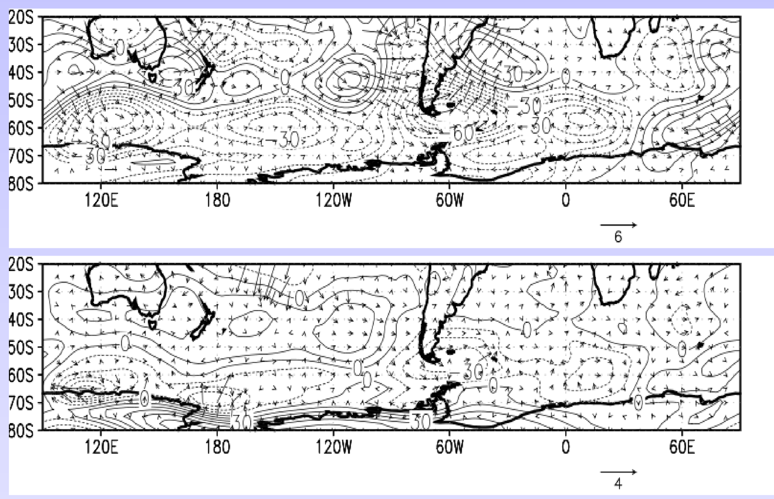
Anomalously cold summers (ACS) and warm summers (AWS) are indentified using the quartile criterion for the detrended STI timeseries distribution in the period 1981-2010. STI values below the first quartile (-0.35ºC) corresponds to the ACS: 1983, 1984, 1986, 1991, 1992, 2001, 2004 and 2010. The summer of 2010 appears to be the coldest one in the 30-year period detrented timeseries. Hence the analysis of this ACS is compared with the ACS composite previous to 2010.
STI values above the third quartile (0.51ºC) corresponds to the AWS: 1982,1993,1994, 1996, 1998, 2000, 2002, 2006.

The dispersion diagram between the summer mean daily insolation and summer mean temperature from 1981 to 2010 is shown for the Esperanza station. There is an overall linear-fit behaviour showing correlation of 0.65, significant at 95%. Thus colder (warmer) summers are associated with less (more) daily insolation which in turn can be linked to higher (lower) cloudiness anomalies at high-to-polar Antarctic latitudes (Dutton et al. 1991).



Dispersion diagram for the Esperanza station between summer temperature (ºC) and summer daily average insolation (hours) from 1981 to 2010. Correlation coefficient is 0.65, significant at 95% of confidence.

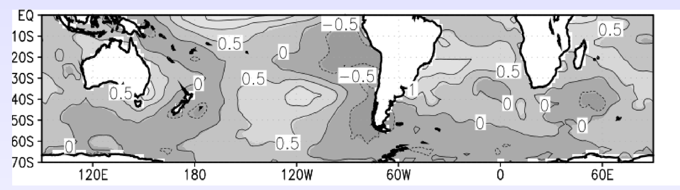
Quasi-stationary wave propagation for coldest 2010 summer



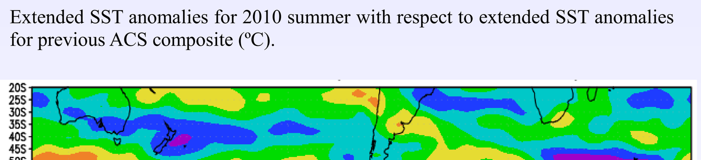
GPH zonal asymmetries *(streamfunction temporal anomalies minus streamfunction zonal average)* for 2010 singularly-cold summer at 300hPa (top) and 850hPa (bottom), and associated horizontal component of the wave-activity flux (vectors). Dashed contours correspond to negative GPH zonal asymmetries. The contour interval is 10 m. Vector units are $m^2 s^{-2}$.

For the 2010 ACS, GPH asymmetric anomalies show the typical zonally extended cyclonic anomaly to the north of the NAP, over the Drake Passage. Unlike previous ACS composite, the cyclonic anomaly is not generated by a QSW propagating over the South Pacific, but to a regionally located QSW crossing southernmost South America, from the southeast Pacific, and propagating towards the northeast over the southwestern South Atlantic. The regionally localized QSW cannot be associated with anomalous deep convection since relevant OLR anomalies are not observed there (not shown).

The upper-level wave activity flux shows an eastward wave-energy emanation from a source region near 40ºS-120ºW. Extratropical transient eddies can interact with stationary wave activity through convergence/divergence of eddies vorticity fluxes (Plumb, 1985). Nonetheless the source region is located over positive 2010 summer SST's anomalies, estimated with respect to previous ACS composite, as can be evidenced in the figure on the right (top). Meridional SST's gradients due to positive SST's anomalies could be involved in the generation of locally increased mean flow baroclinicity, which, in turn, induces positive wind shear anomalies over the area due to the thermal wind relationship. Therefore, the mean-flow potential energy generated by the locally increased baroclinicity is available to be converted into kinetic energy for transient eddies.

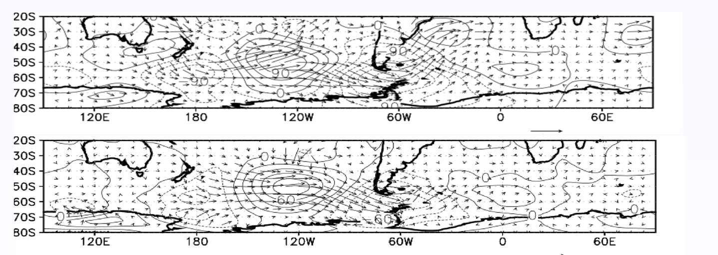


Extended SST anomalies for 2010 summer with respect to extended SST anomalies for previous ACS composite (ºC).



Eady growth rate (EGR) maximum anomalies for 2010 summer with respect to EGR anomalies for previous ACS composite. Shading is labelled every 0.05 day^{-1}.

$$EGR = 0.31 * f * \left|\frac{\partial u}{\partial z}\right| * N^{-1}$$

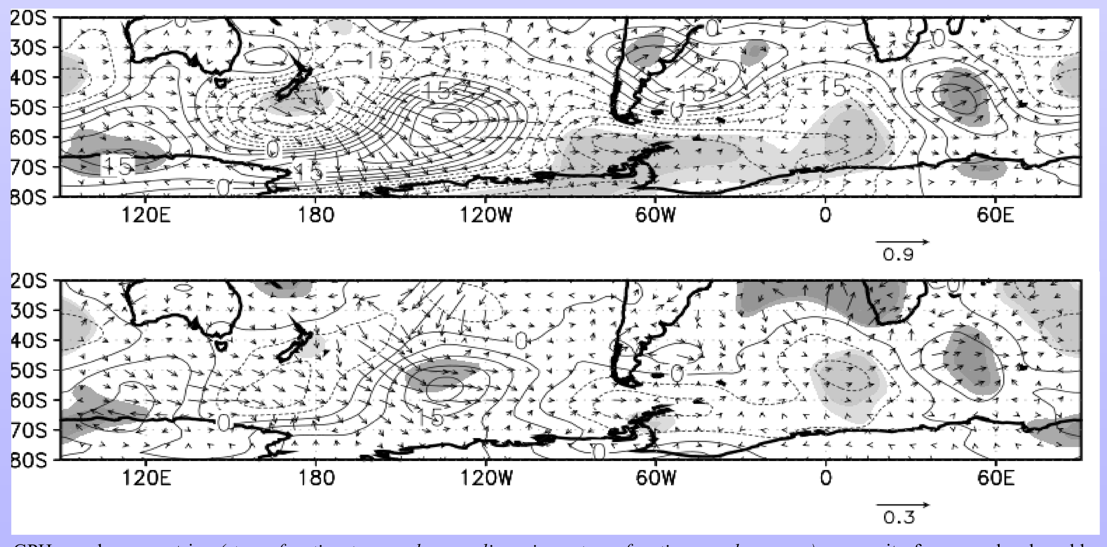


GPH zonal asymmetries *(streamfunction temporal anomalies minus streamfunction zonal average)* for 2009 spring at 300hPa (top) and 850hPa (bottom), and associated horizontal component of the wave-activity flux (vectors). Dashed contours correspond to negative GPH zonal asymmetries. Vector units are $m^2 s^{-2}$.

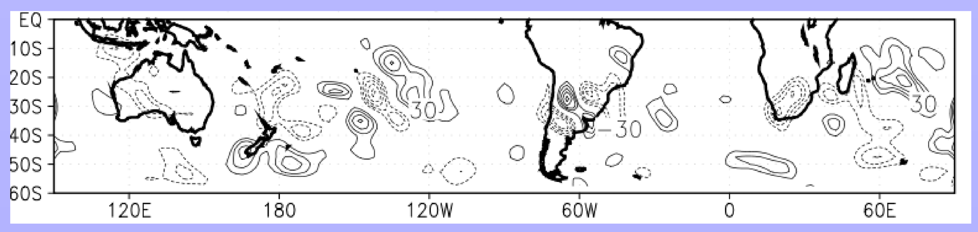
The summer positive SSTs anomalies over southeastern South Pacific could be induced by low level circulation anomalies during the previous season (SON) of 2009. In the previous spring a prominent mid-latitude South Pacific QSW propagation is observed extending from New Zealand to the east, probably preconditioning the SSTs anomalies in the area. Further analysis is required.

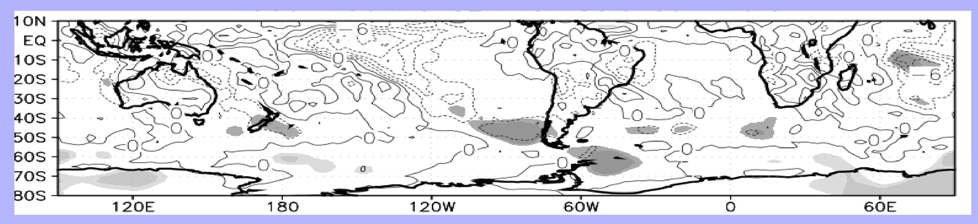
Quasi-stationary wave propagation for ACS

For ACS composite previous to 2010 geopotential heights (GPH) asymmetric anomalies in the upper (300hPa) and lower (850hPa) troposphere shows a wave-train propagation over the South Pacific originating near New Zealand which, in turn, seems to be preconditioned by another wave-train propagating eastward from the Indian Ocean. The QSW propagation over the Pacific reaches southern South America and the NAP region. Therefore, stationary cyclonic anomalies zonally extended over NAP are generated, which could be responsible for the occurrence of ACS over the area. Cyclonic anomalies are dynamically favourable for enhanced cloudiness conditions. This is consistent with the direct relationship found between STI and insolation in the region. Hence ACS appear to be associated with anomalous cyclonic circulation.
Likewise, this cyclonic anomaly generates an easterly wind component anomaly over the NAP. In general, the mountainous spine along the NAP acts as a dividing barrier between the relatively warmer climate of the west coast and much colder climate of the east coast affected by cold continental air masses (King and Turner, 1997). Therefore, anomalous easterly wind component could further favour cold anomalies over the AP.



GPH zonal asymmetries *(streamfunction temporal anomalies minus streamfunction zonal average)* composite for anomalously-cold summers previous to 2010 at 300hPa (top) and 850hPa (bottom), and associated horizontal component of the wave-activity flux (vectors). Dashed contours correspond to negative GPH zonal asymmetries. The contour interval is 5 m. Vector units are $m^2 s^{-2}$. Grey scale shaded indicates 90-95% significance levels for negative (lighter grey) and positive (darker grey) asymmetries of GPH.



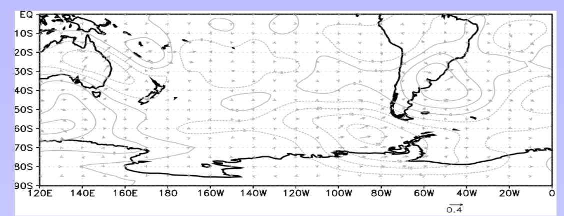


Summer Rossby Wave Source (RWS) anomalies due to planetary vorticity-divergence and the wind divergence components of the vorticity anomaly budget at 200hPa (top) and 1000-100hPa summer OLR anomalies and 90-95% significance *(grey shaded)* (bottom), for ACS composite previous to 2010. Dashed lines correspond to negative values.

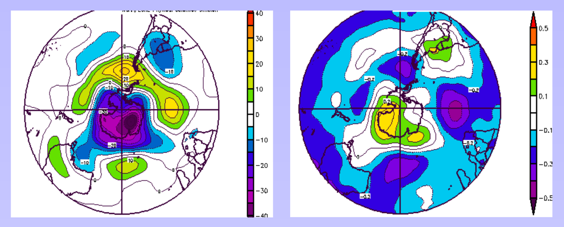
The phase coincidence between wave anomalies at lower and upper levels of the tropopshere reveals a barotropic nature of the QSWs, which suggests a barotropic Rossby wave origin.
The wave activity flux over the South Pacific seems to emanate from large Rossby Wave Source (RWS) anomalies zonally extended to the south of New Zealand. The RWS anomalies are co-located with significant negative OLR anomalies linked to anomalous deep convection near New Zealand.

Note the RWS anomalies are co-located over significant negative OLR anomalies in the western Indian Ocean, near Madagascar. This probably generates a wave-train over the Indian Ocean reaching New Zealand and, thus, generating a cyclonic circulation anomaly over there which, in turn, is related to anomalous convection activity over the area.

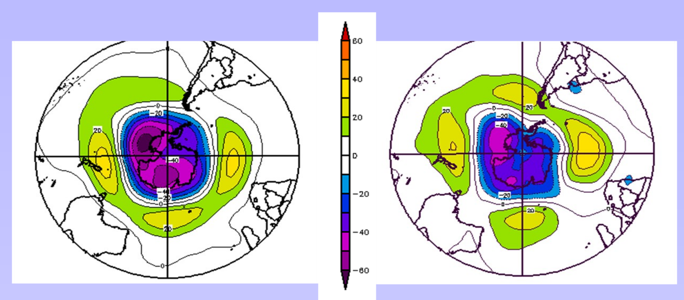
SH circulation for AWS



Streamfunction zonal asymmetries *(streamfunction temporal anomalies minus streamfunction zonal average)* composite for AWS at 300hPa and associated horizontal component of the wave-activity flux (vectors). Dashed contours correspond to negative GPH zonal asymmetries. The contour interval is 5 m. Vector units are $m^2 s^{-2}$.



300hPa Geopotential Height (left) and Temperature (right) anomaly corresponding to the AWS composite.



SAM Regression upon 500hPa Mean Summer Geopotential Height (left) vs. Composite Difference between AWS and CWS (right).

Summary

• The summer mean conditions over Northernmost Antarctic Peninsula (NAP) are driven by the SAM (Solomon and Thompson, 2002). Anomalouly cold summers (ACS) are related with SAM negative phase whereas anomalously warm summers (AWS) with SAM positive phase. The correlation between STI and SAM index is 0.57 (α<0.05).

• ACS previous to 2010 over NAP are characterized by a QSW train propagation in the South Pacific from a region of anomalous convection near New Zealand, as evidenced by significant negative OLR anomalies over the region, generating a significant anomalous cyclonic circulation throughout the troposphere and lower stratosphere to the northwest of the NAP.

• This cyclonic anomalies generates anomalous easterly wind component and upper troposphere dynamic conditions favourable to positive cloudiness anomalies, leading to near surface lower temperatures.

• The summer of 2010 shows the typical cyclonic anomaly to the north of the NAP that is responsible for lower temperatures, though slightly northward displaced. Unlike the ACS composite, this anomaly is not generated by QSWs propagation over the South Pacific, but is related to a regionally located QSW crossing South America from the southeast South Pacific to the southwest South Atlantic. The regionally localized QSW cannot be associated with anomalous deep convection since relevant OLR anomalies are not observed over the source region in the southeast South Pacific. Instead, the source region is co-located with an area of positive SST's anomalies which is associated with increased transient activity due to changes in the local mean baroclinicity.

• A strong QSW propagation over the Pacific is observed in the previous spring of 2009. This previous spring QSW could be probably acting to preconditionate summer SST's anomalies over midlatitude South Pacific linked to the QSW propagation in the following summer. Further analysis is required.

• AWS are characterized by an enhance in barotropic anomalies over Southern South America suggesting circulation anomalies - anticyclonic over the Drake Passage and cyclonic over southern South America - favorable to a blocking of the mean flow. This is possible related to transient activity blocking and to interaction with lower stratosphere.

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