Analysis of synoptic conditions during VOCALS-REx

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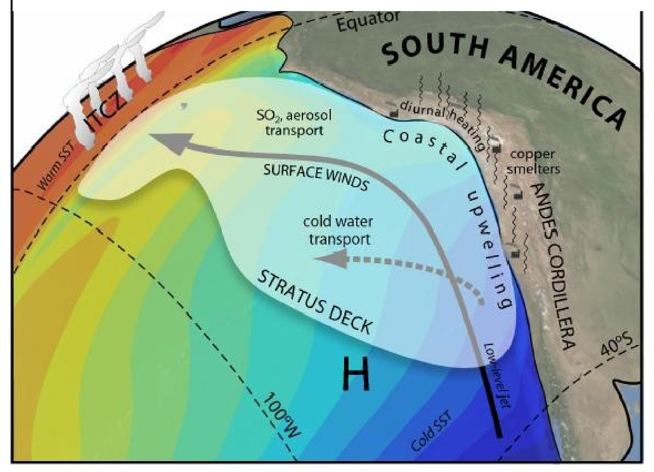
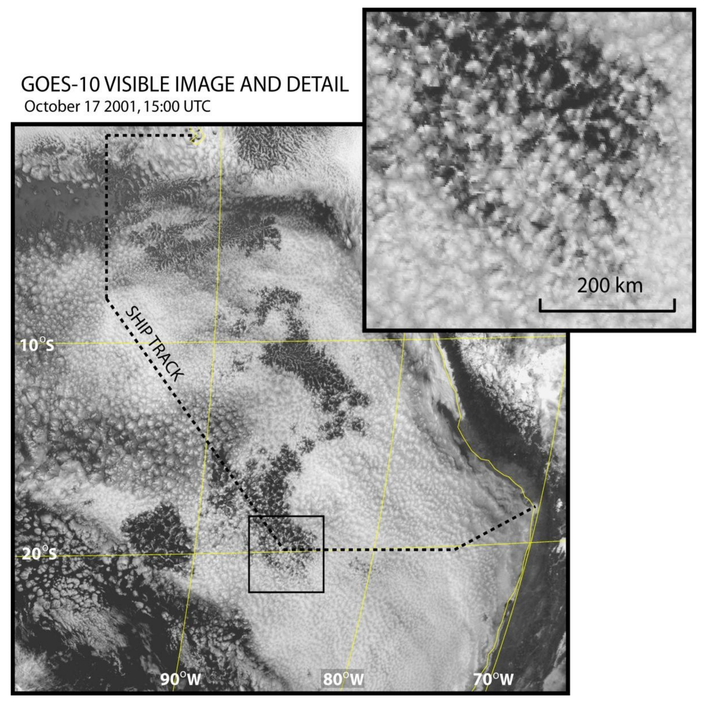
1. The Sc area of the SE tropical Pacific

Climatology and circulation of the South-East Pacific



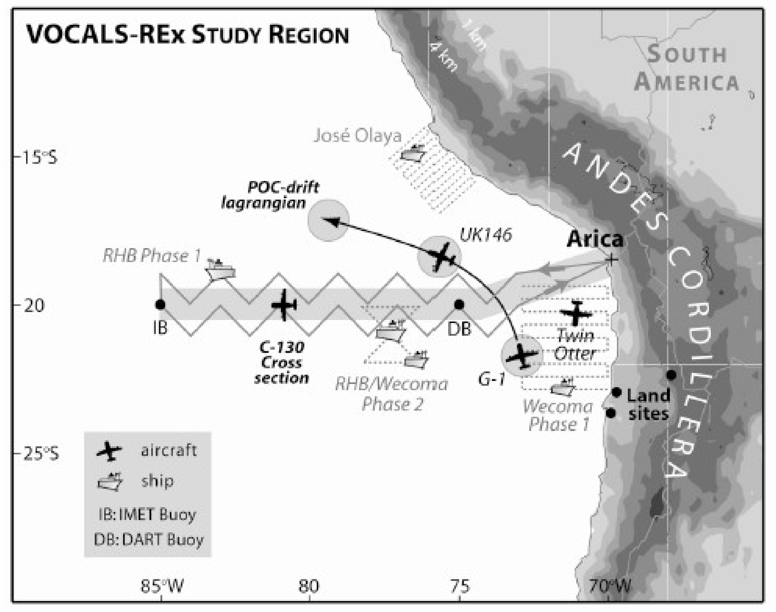
THE meteorology in the marine area of the south-eastern tropical Pacific (SEP) is dominated by the sub-tropical anticyclone which represents the descending branch of the Hadley-Walker circulation of the south Pacific, with which it interacts (Toniazzo 2010).



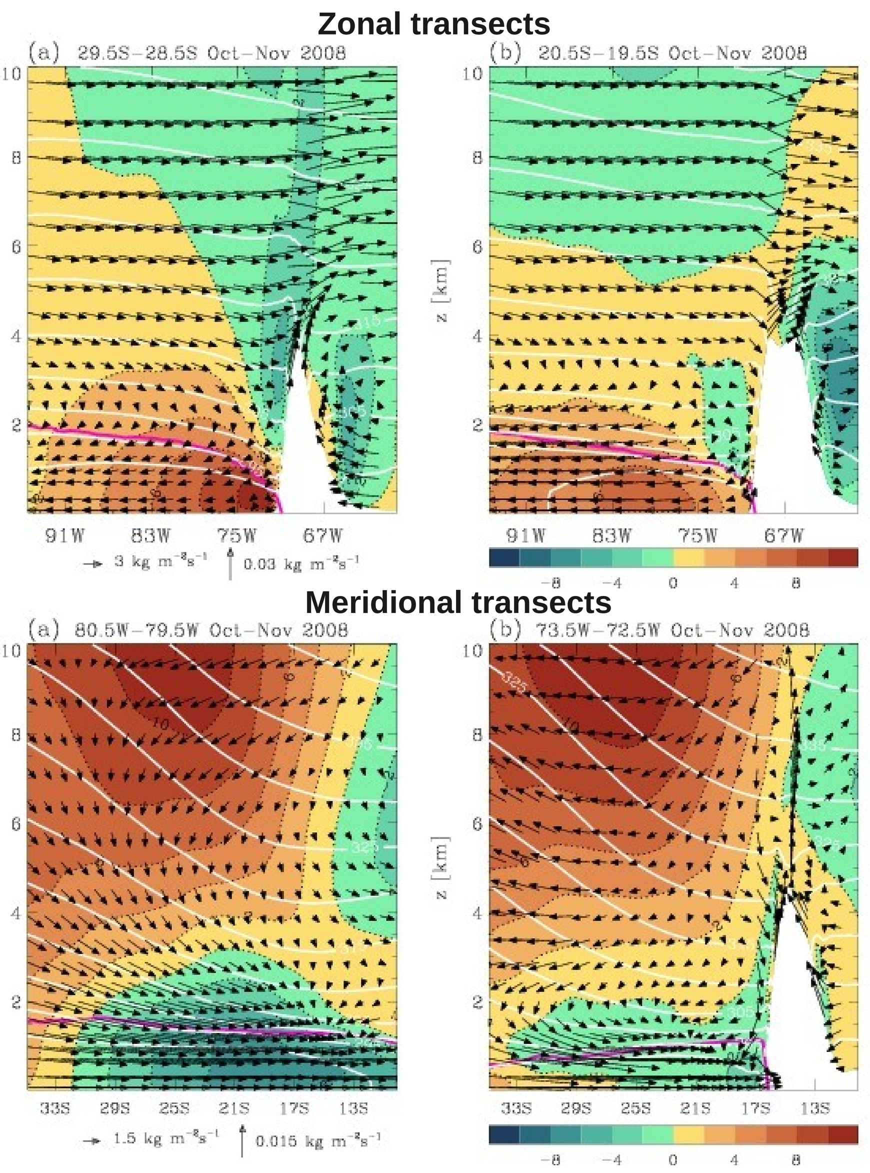
The area is characterised by extensive Sc cover, capped by a strong (~10-15 K) inversion separating the cool, moist PBL from the dry, stable free troposphere (FT). The Sc reflect about 70% of solar radiation, giving a significant negative contribution to the global heat budget. Far from uniform, the Sc cover displays significant variability, both temporal and spatial. While drizzle, aerosol processes, and meso-scale organisation contribute to that variability, the most noticeable correlation is with synoptic scales.

In this paper, we document the synoptic meteorology observed in the SEP during the VOCALS-REx observations campaing, and we analyse the relationship between Sc cover and the circulation on the SEP on synoptic spatio-temporal scales.

VOCALS-REx, an intensive campaign of observations of cloud/aerosol properties and upper-ocean/lower atmosphere conditions, was conducted in October and November 2008 by a consortium of US, Chilean, Peruvian, and UK research institutions. It was mainly based in the north-Chilean city of Arica (18S, 71W). Measurements included radiosonde/dropsonde profiles, C- and W-band radar and lidar (up- and down-looking) reflectivities, extensive particle sampling for aerosol and cloud-droplet characterisation, ship CTDs, and floats. Particular focus was put on sampling the zonal strip along 20S, where multi-annual dataset are available from two instrumented buoys deployed at 75W and 85W.



2. The average circulation and global atmospheric models

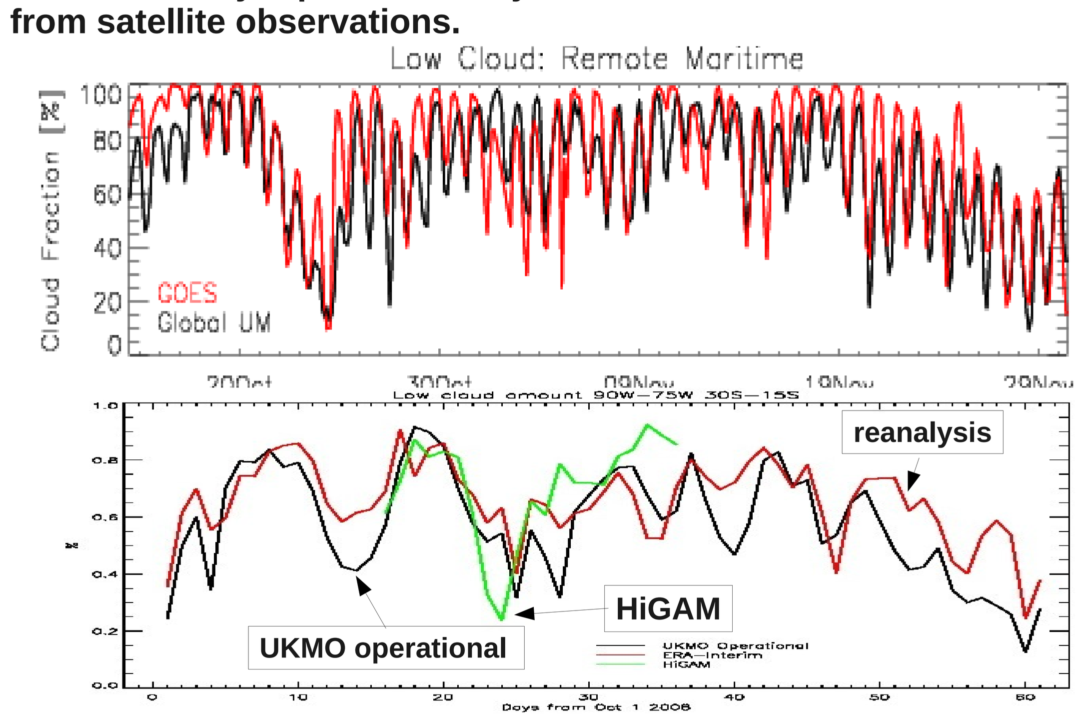


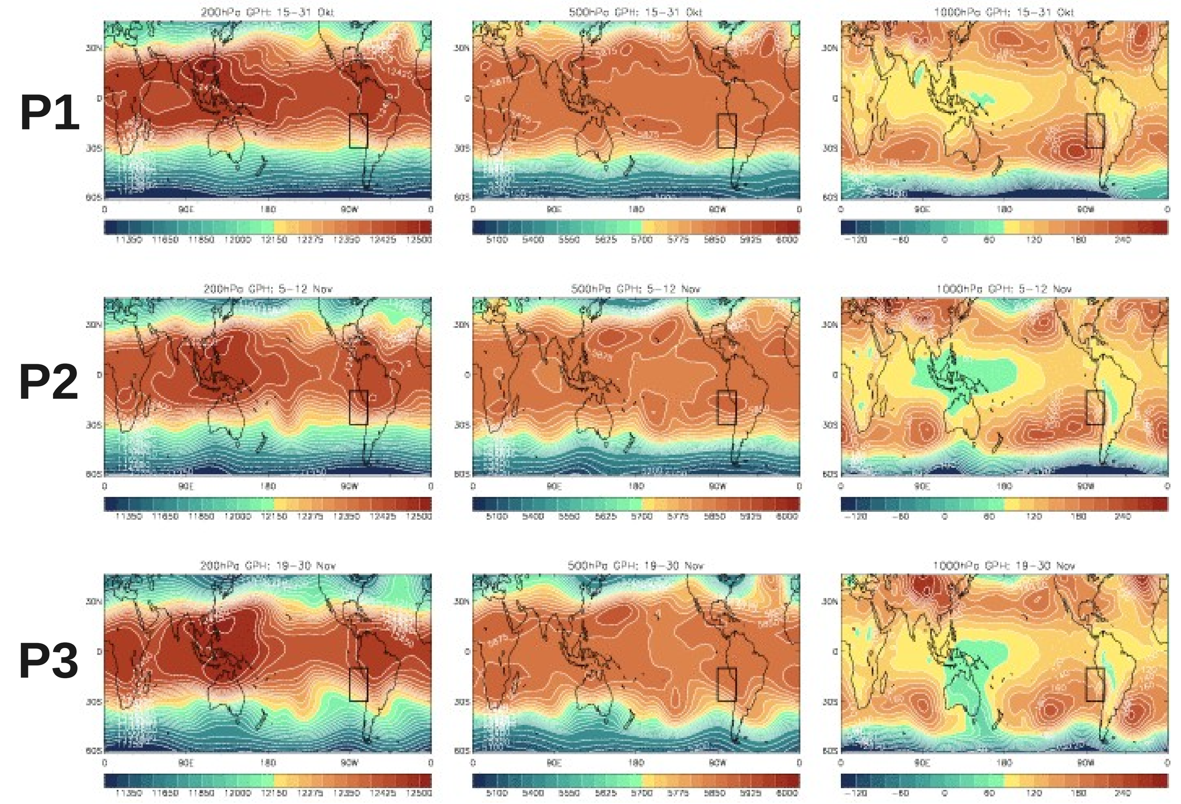
The mean flow is dominated by the zonal subtropical jet aloft, and radiatively induced mid-tropospheric subsidence that is accompanied by poleward flow aloft and equatorward flow in the PBL. Anticyclonic, divergent circulation is prevalent in the PBL, below the inversion, while Sverdrup balance regulates the meridional flow in the FT.

Near the orography, the diurnal land-sea and mountain breeze systems are associated with a mean convection cell which locally reverses the low-level zonal flow and with a southerly jet in the PBL near the coast.

Away from the coast, the circulation is well-represented by the UK Met Office 40km global operational reanalysis and 24h forecasts, on which we mainly based the current analysis.

In general, away from the coastal region models capture much of the synoptic variability in cloud cover as derived from satellite observations.





3. General large-scale conditions and observed regimes

Three distinct regimes were identified during 15 Oct – 30 Nov:

1) **15-31 Oct: strong surface anticyclone, unstable subtropical jet; conditions in the first half of October were similar**

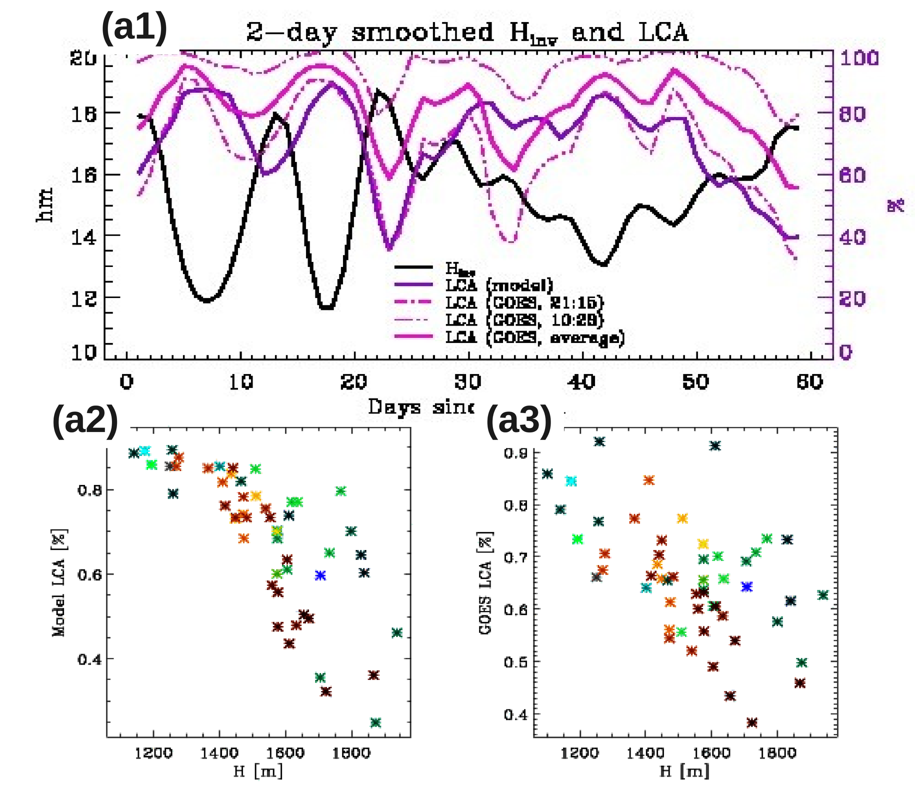
2) **3-12 Nov: mid-tropospheric anticyclone, zonal steady jet; terminated by cut-off low 13-16 Nov**

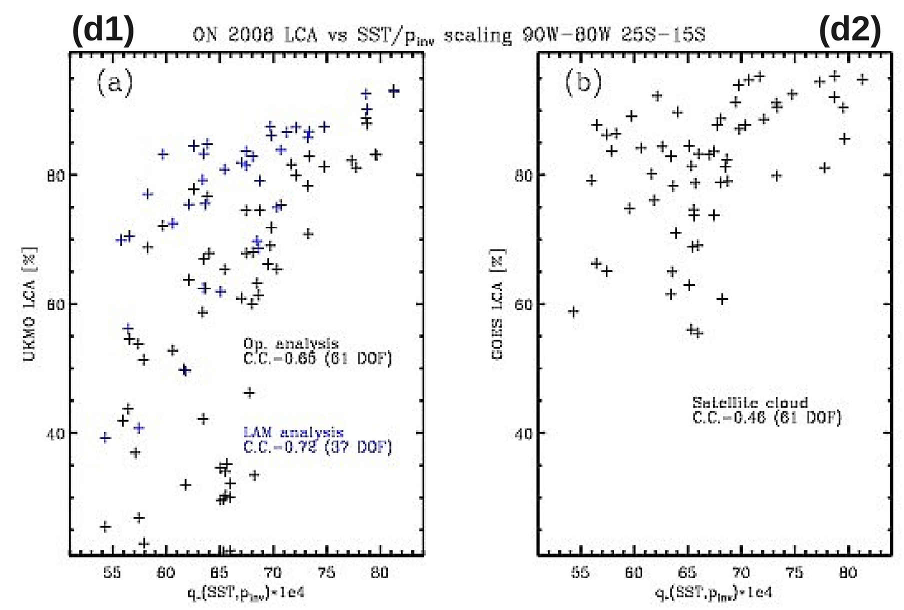
3) **17-30 Nov: weak surface anticyclone; steady, strong flow aloft with poleward component**

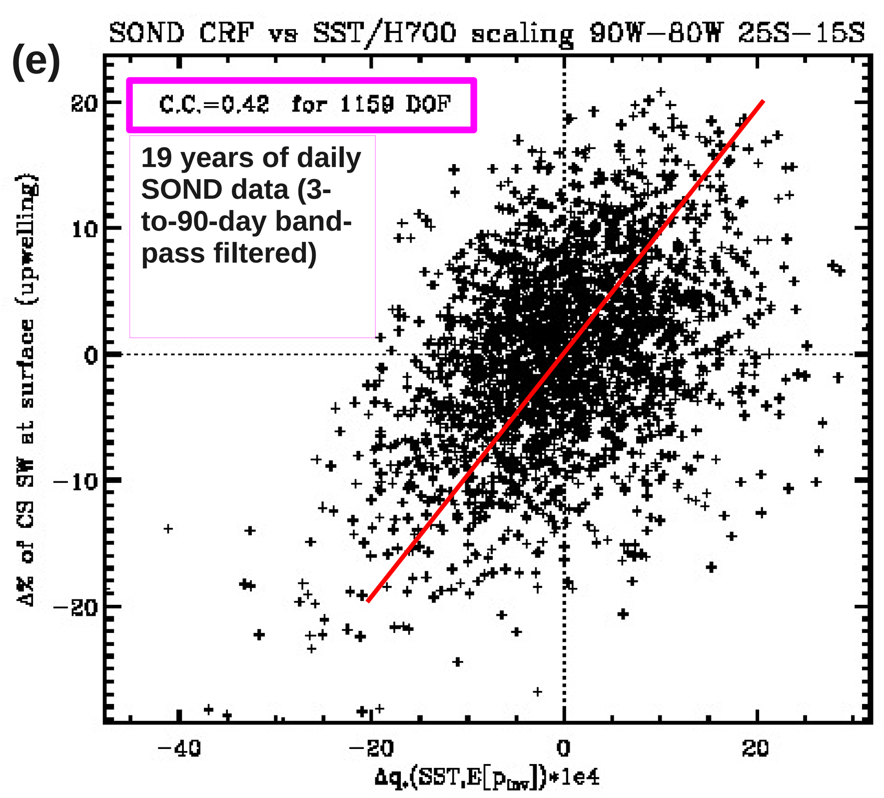
Between these phases local conditions were characterised by the evolution and dissipation of synoptically forced, coastal cut-off lows, peaking in 1 Nov and 15 Nov. Other occurrences of CLs were during 22-25 Oct and later during 30/11-2/12. The first was particuarly strong.

The overall evolution of the circulation in the SEP partly reflected the progression of the seasonal cycle, with higher wavenumber planetary modes connected with the West Pacific and the Indian Ocean establishing themselves as the jet stream migrated southwards.

4. PBL-top characteristics, cloud cover, synoptic controls, and teleconnections





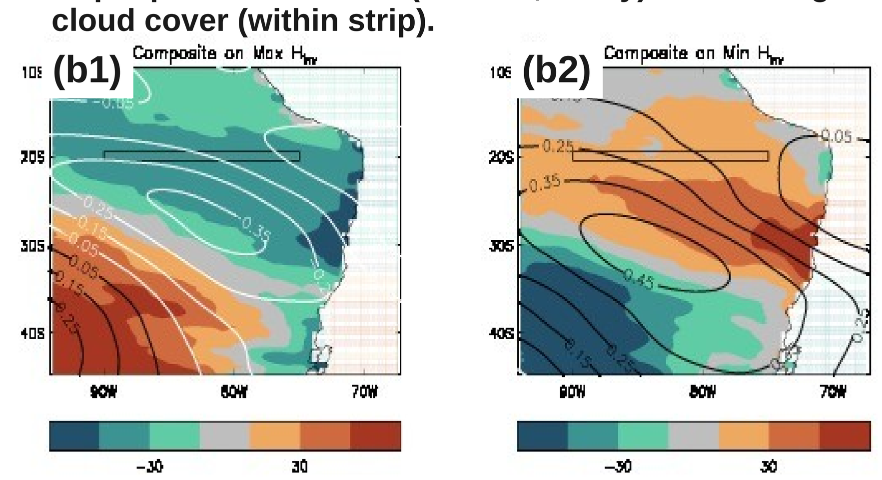


Both in the model and in the observations, over spatial scales ≥ 1000 km and temporal scales of a few days, Sc cover was inversely correlated with the height of the inversion **(a1-3)**.
In the spatial average, optically thicker cloud tends to be geometrically thinner; and a lower, stronger inversion is found in coincidence with warmer conditions in the FT **(b1), (b2)**.
These relationship are confirmed from reanalysis and other long-term observations **(c1),(c2)**, and may be understood in terms of the basic constraints of mass and energy equilibrium for the PBL top on the circulation in the anticyclone, and the properties of the moist entrainment process at the cloud-top that mediates it.
The result is a tendency towards homogeneisation of the wet-bulb potential termperature across the inversion, giving a scaling law that can be summarised as

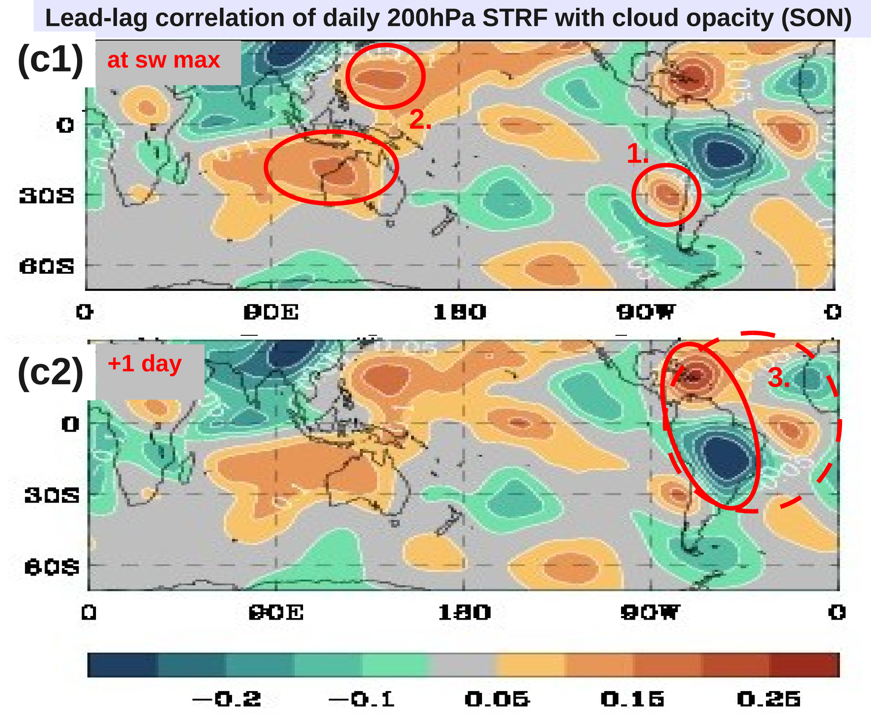
$$\langle LCA \rangle \sim q^*[\theta_{PBL}, p_i]$$

An elevated inversion tends to be weaker and with less liquid water mixing ratio (in the large spatial average). This relation, noticed in the VOCALS-REx period **(d1),(d2)**, appears to hold in a statistical sense over the historically observed period **(e)**.
As a result, the inversion height and cloud cover inversely correlate with the mid-tropospheric geopotential height, which can „explain" a significant fraction of surface short-wave radiation variability in the SEP area.
As well as due to synoptic disturbances, the correlation patterns are suggestive of teleconnected anomalies, consistently with the day-to-day phenomenology observed in VOCALS-REx; and such teleconnections arise normally in the progression of the annual cycle **(f)**, particularly during southern Spring.

Cyclonic (lines, left, Mm²/day) and anticyclonic (lines, right) perturbations associated with cold/warm free-tropospheric advection (colours, K/day) and low/high cloud cover (within strip).



Lead-lag correlation of daily 200hPa STRF with cloud opacity (SON)



1. **Cyclonic anomaly over Sc area**
2. **Intensified NW Pac STH and weakened STJ over W Australia – leading**
3. **Strengthened AC over SA Monsoon region and Caribbean (Matsuno pattern) – lagging?**

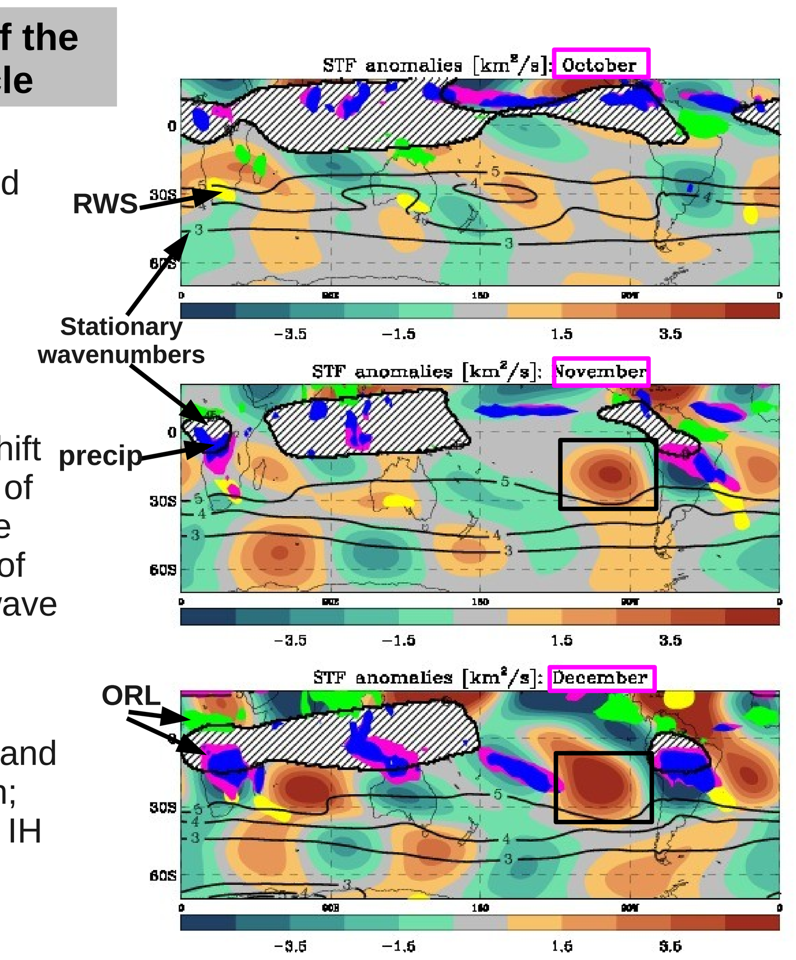
For connection with 3.: Wang, Lee, & Mechoso (2009) J.Clim.

(f) the march of the seasonal cycle

•**October:** central African ITCZ; S'ward shift of STJ over Tasman Sea.

•**November:** strong African ITCZ; SA Monsoon; S'ward shift of STJ; broadening of supported stat.wave spectrum; opening of inter-hemispheric wave pathway.

•**December:** SPCZ and Australian Monsoon; partial re-closure of IH pathway.



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Reference

Toniazzo T., et al., 2011, „Large-scale and synoptic meteorology in the south-east Pacific during the observations campaign VOCALS-REx in austral Spring 2008", Atmos. Chem. Phys. 11, 4877-5009