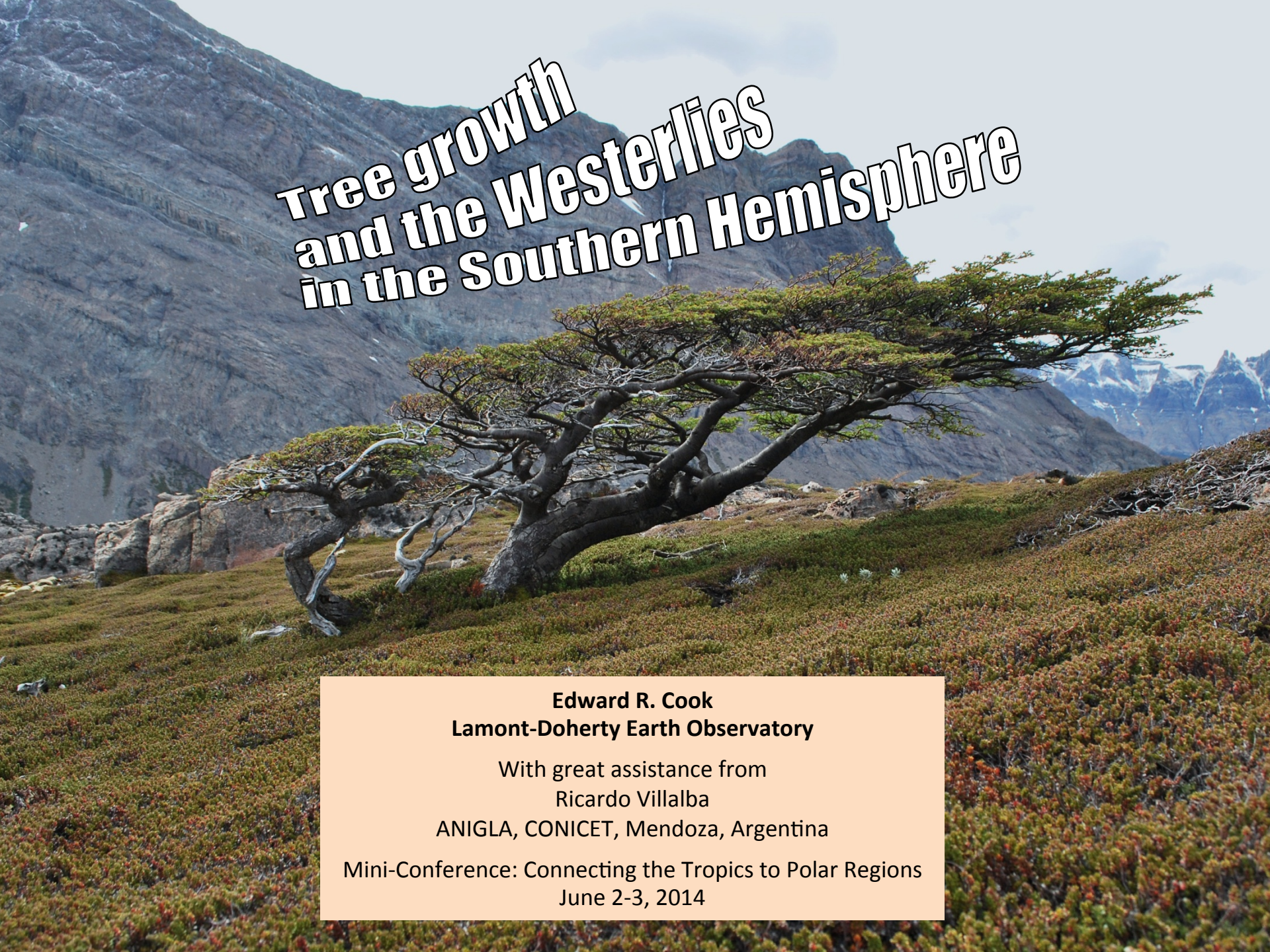

Tree growth and the Westerlies in the Southern Hemisphere

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Lamont-Doherty Earth Observatory

With great assistance from
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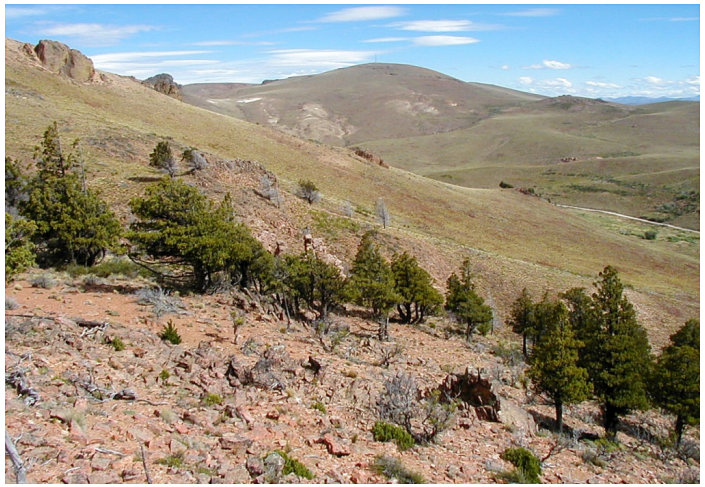
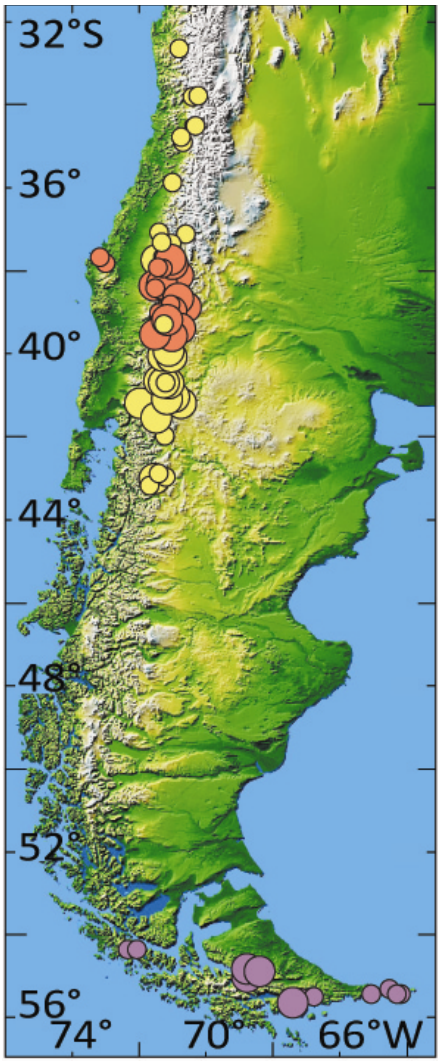
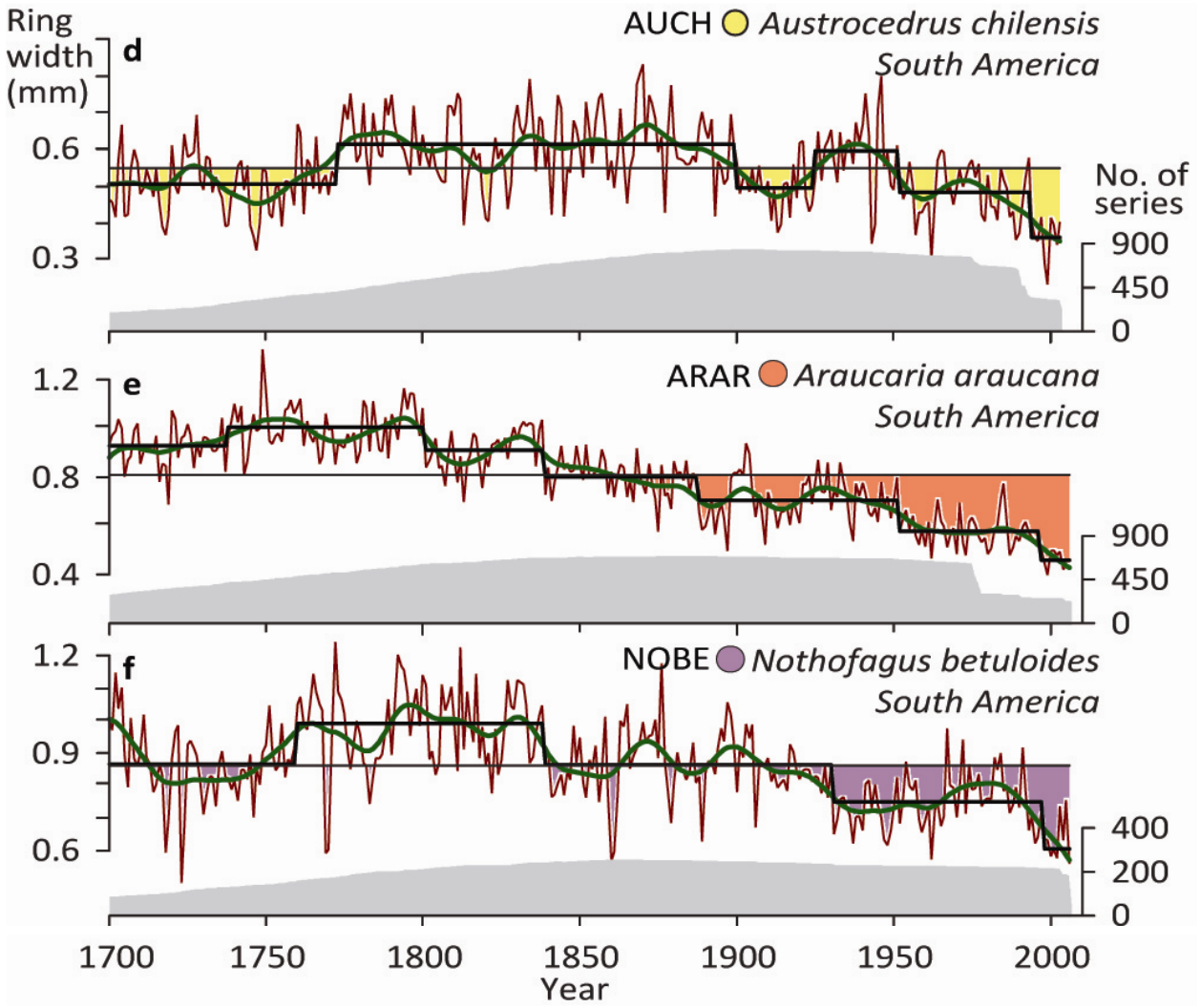
Mini-Conference: Connecting the Tropics to Polar Regions
June 2-3, 2014

The title slide clearly shows that the SH Westerlies can influence tree growth in rather extreme ways, but even in more normal forested settings the annual rings of trees can tell us a lot about how the Westerlies have influenced the climate that affects radial tree growth.

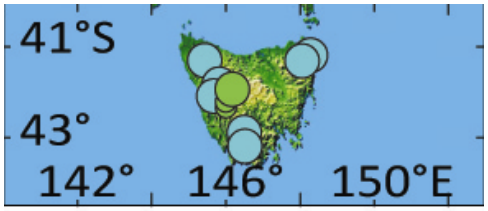


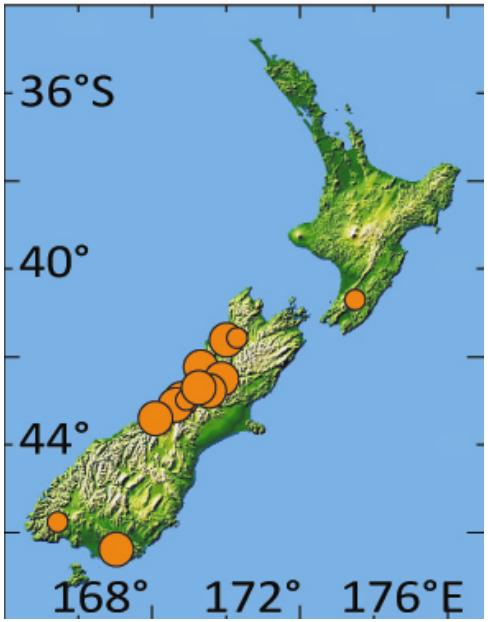
Variations in tree growth in temperate forests from South America show profound changes in growth over the past 300 years

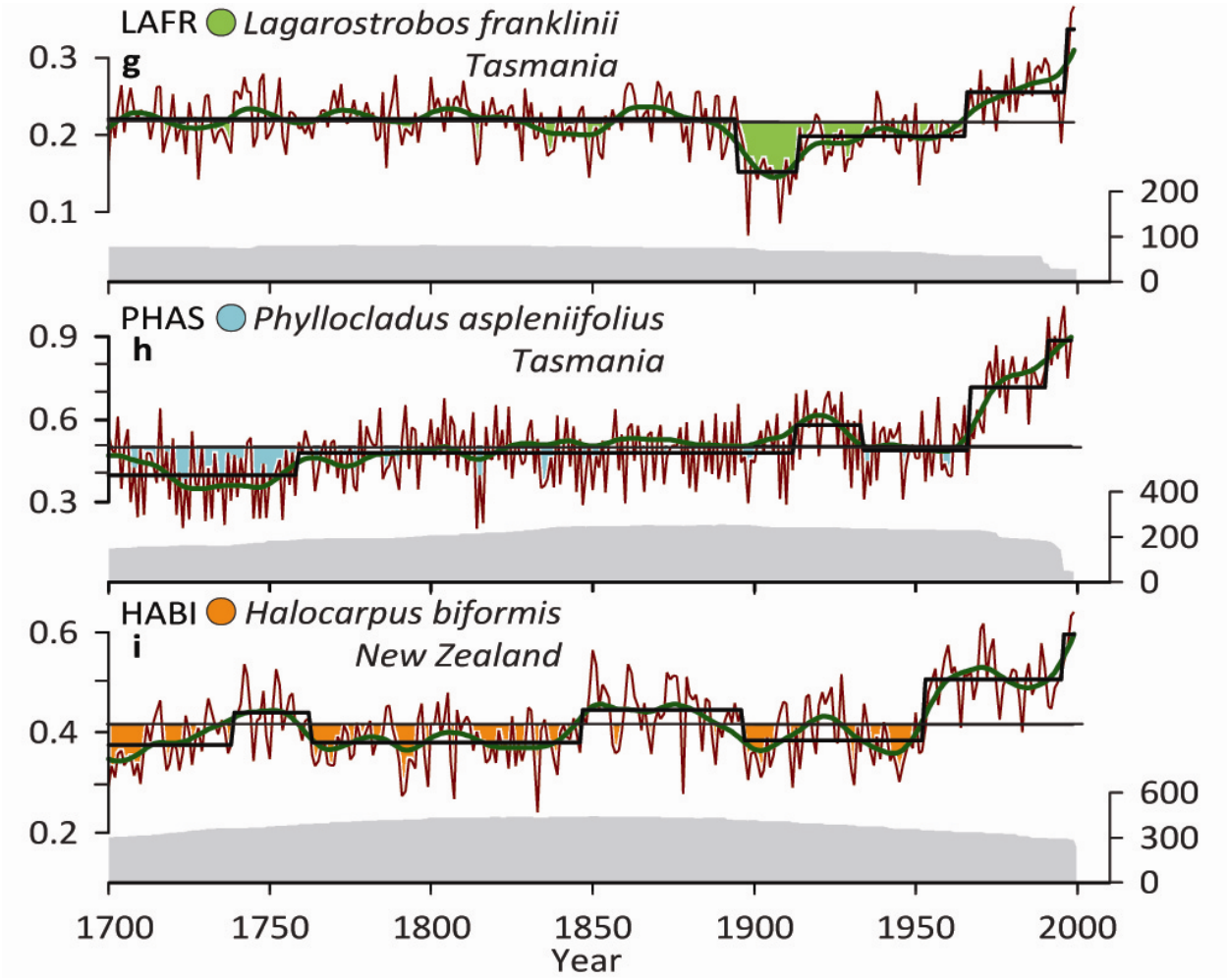




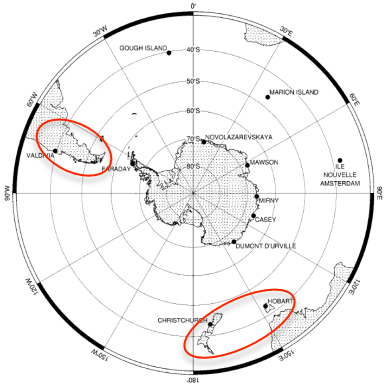
Variations in tree growth in temperate forests from Tasmania and New Zealand likewise show profound changes in growth over the past 300 years



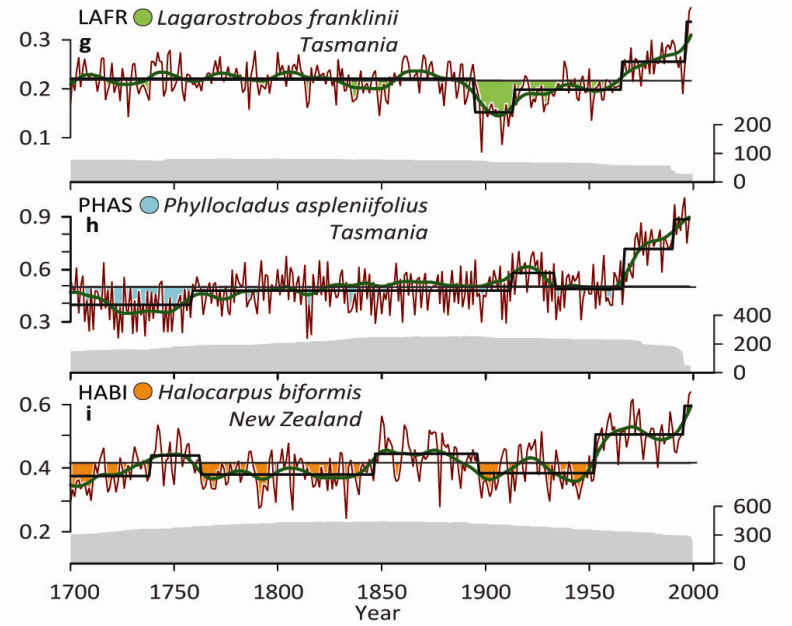




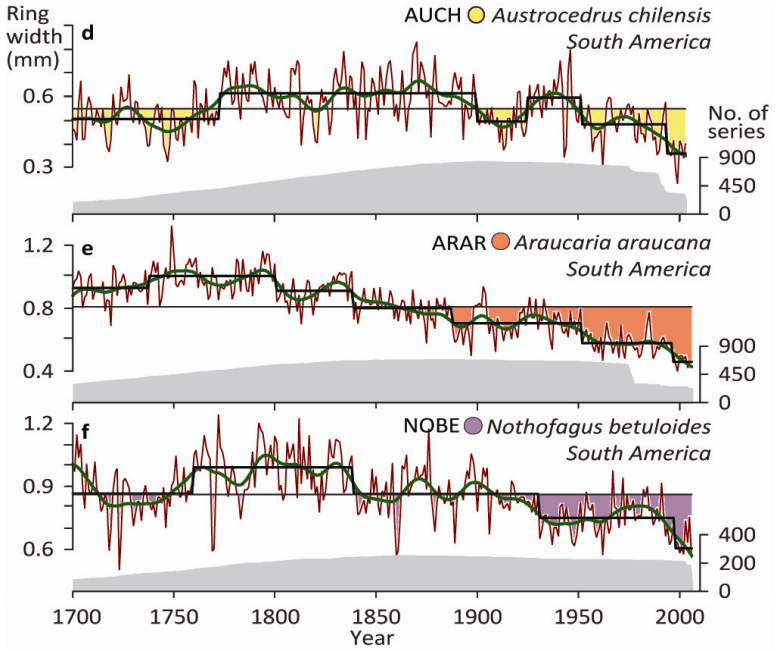
But interestingly, these regional growth patterns on opposite sides of the SH are largely anti-phased. What is this interesting behavior related to?



Tasmania-New Zealand



South America

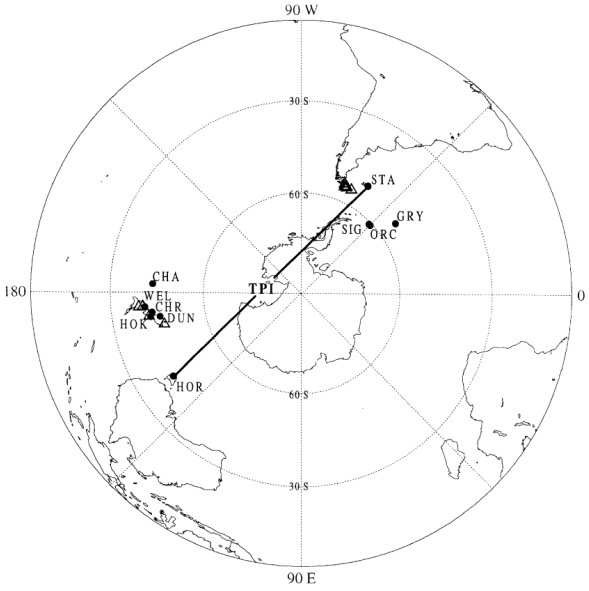


Sea-level pressure variability around Antarctica since A.D. 1750 inferred from subantarctic tree-ring records

R. Villalba[1,5], E.R. Cook[1], R.D. D'Arrigo[1], G.C. Jacoby[1], P.D. Jones[2], M.J. Salinger[3], J. Palmer[4] *Climate Dynamics* (1997) 13:375-390

The "Trans-Polar Index" (TPI): First described by Pittock (1980) in characterizing the anti-phased patterns of sea level pressure, temperature, and precipitation between South America and Australia-New Zealand. Pittock posited that it is related to the eccentricity of the circumpolar vortex circulating around Antarctica.

The TPI was originally based on the pressure difference between between Hobart, Tasmania and Stanley, South Atlantic Ocean. When the TPI is positive the subtropical anticyclones and the westerlies are displaced further south in the Australian-New Zealand sector. In contrast, in the South American sector the subtropical anticyclone and the westerlies will be shifted towards the equator resulting in major precipitation and temperature variations in the affected regions. *This affects tree growth in both locations.*

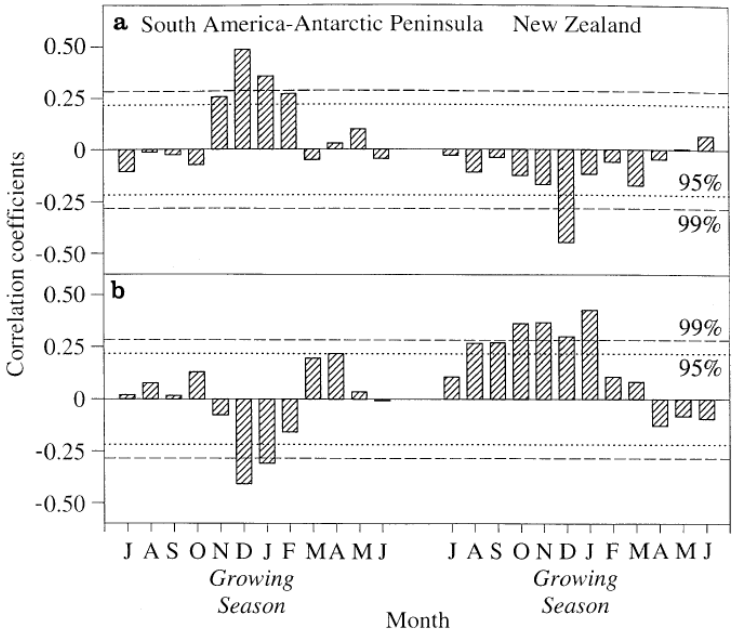


Tree rings and SLP in Tierra del Fuego and New Zealand.

Correlation and Reconstruction back to 1746.

Tierra del Fuego tree rings correlate positive with SA SLP.

New Zealand tree rings Correlate positive with SA SLP.

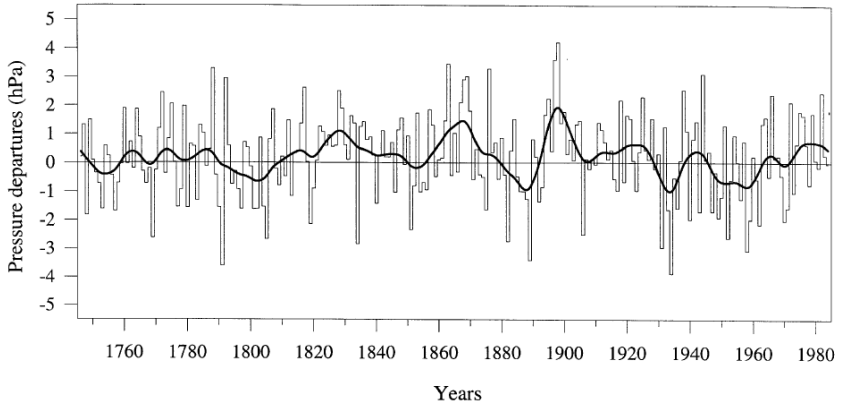


Tierra del Fuego tree rings correlate negative with NZ SLP.

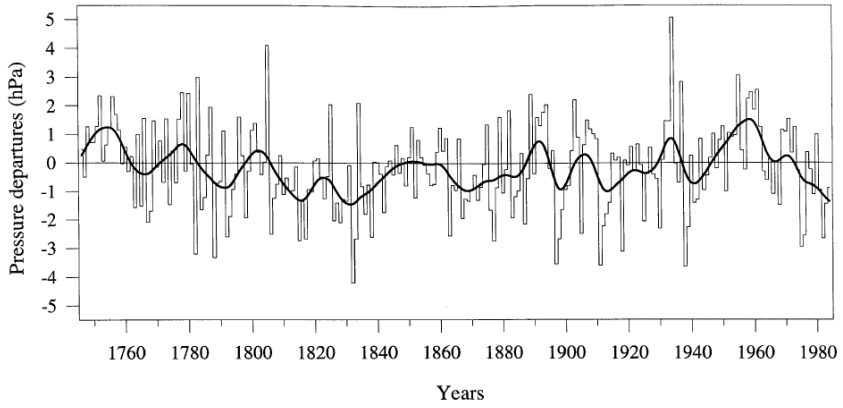
New Zealand tree rings correlate positive with NZ SLP.

Note the largely anti-phased low-frequency variability between the reconstructions.

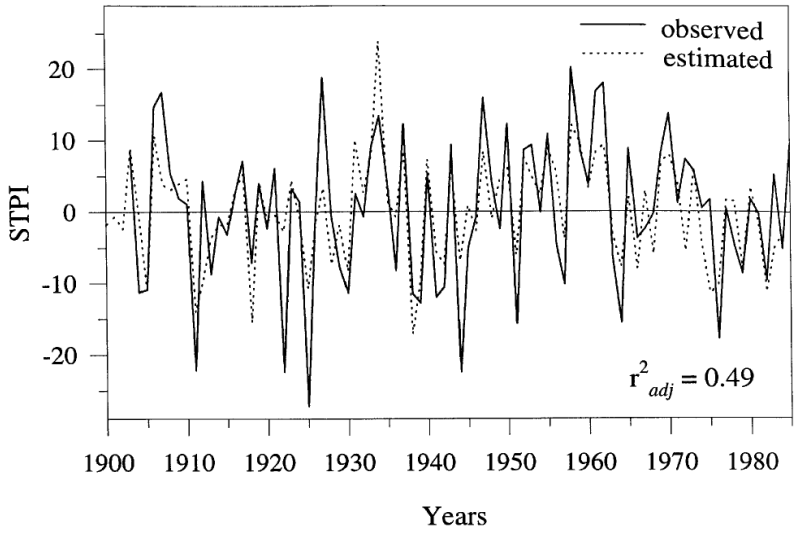
South America Nov-Feb SLP Recon

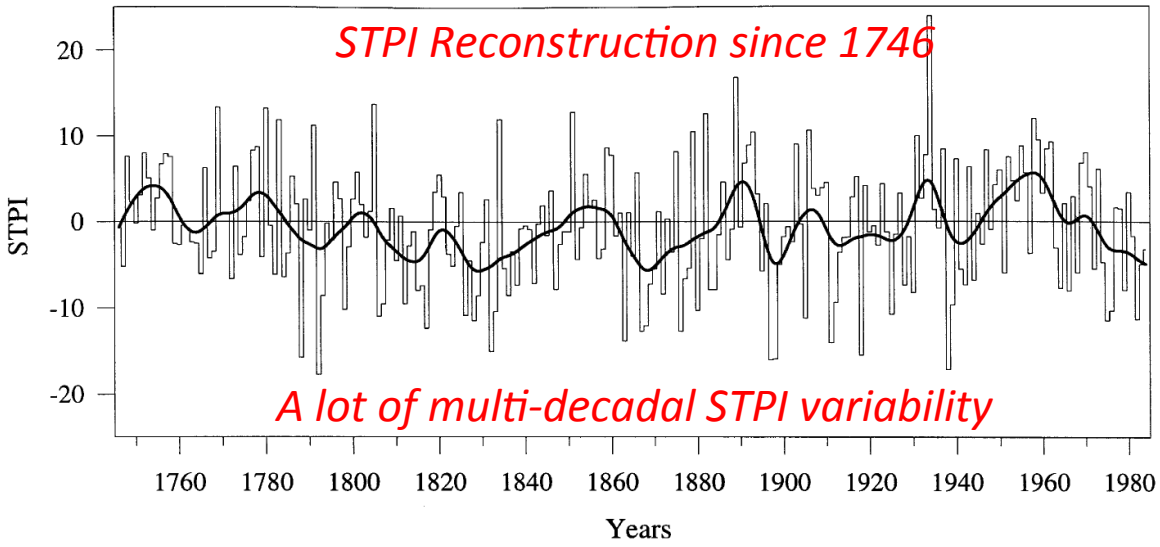


New Zealand Nov-Feb SLP Recon



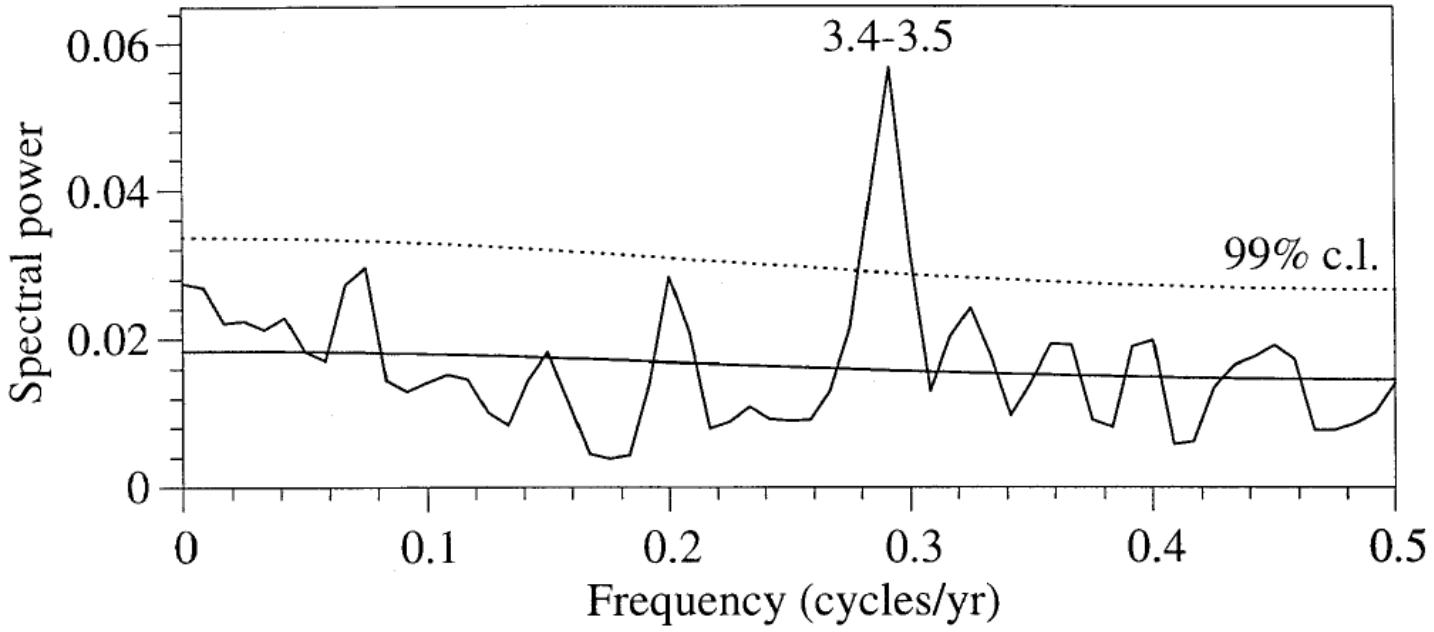
Reconstruction of the summer TPI (STPI) using jointly the tree-ring chronologies from both Tierra del Fuego and New Zealand.





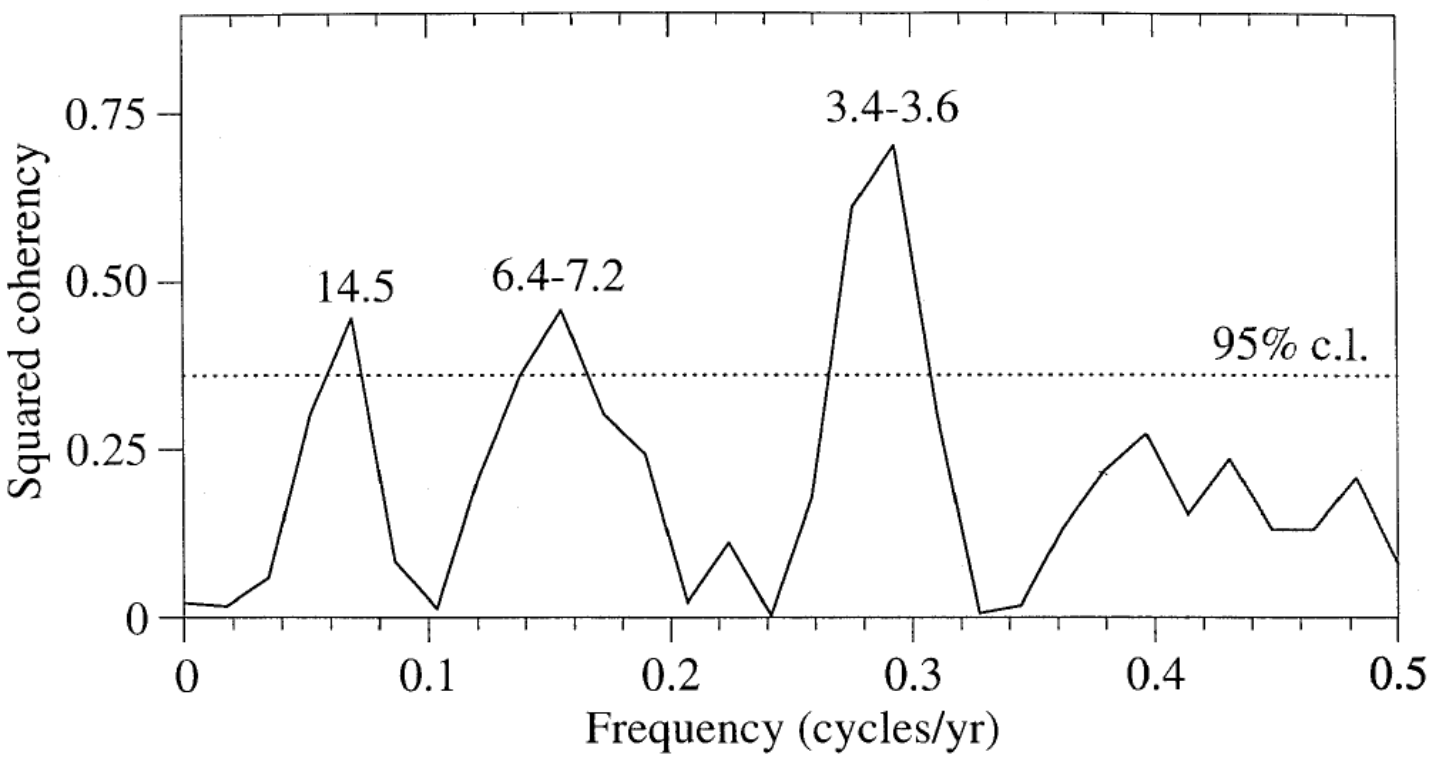
How might the variability in the STPI be related to tropical forcing?

What does the power spectrum of the STPI reconstruction look like?



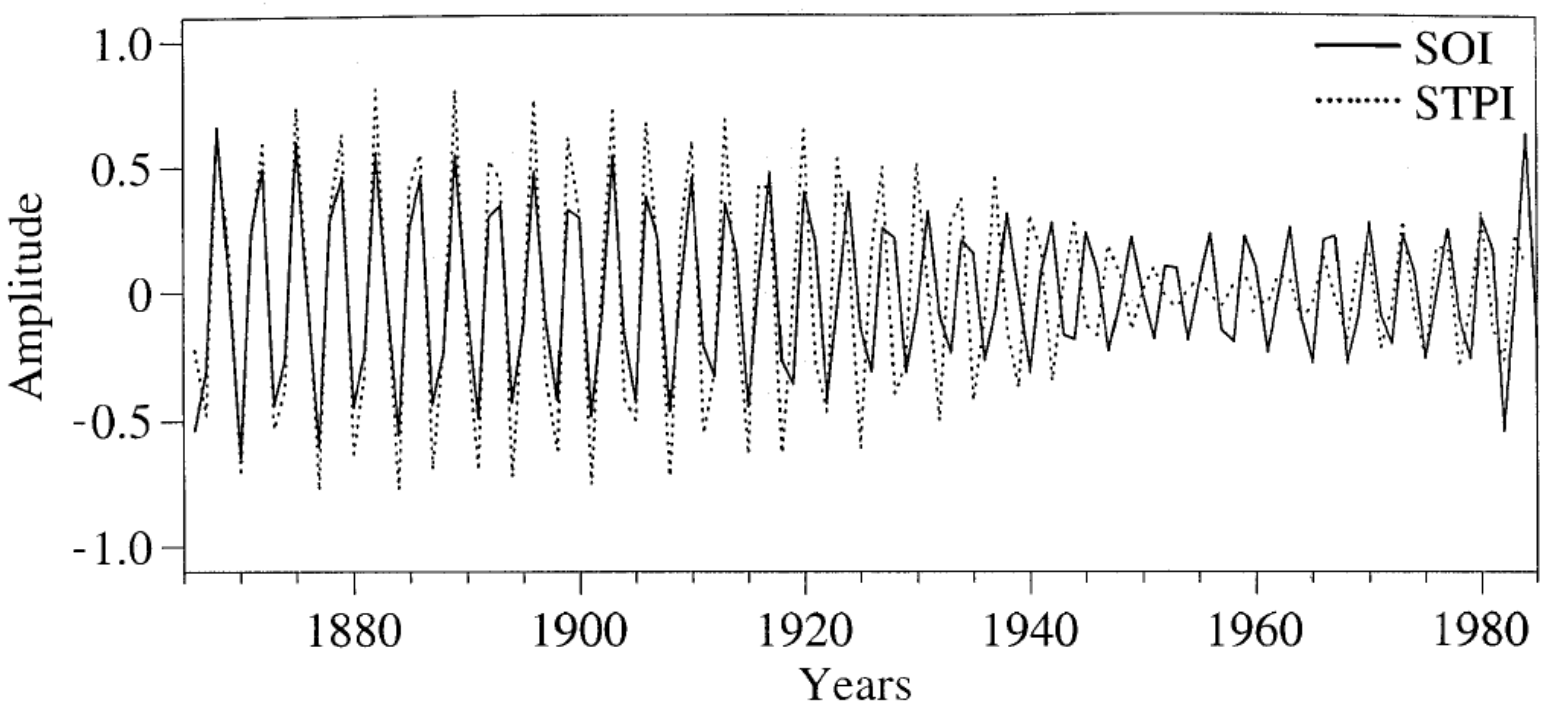
The significant peak at 3.4-3.5 years looks suspiciously like ENSO. But is the STPI recon phase coherent with ENSO?

How phase coherent is the STPI Reconstruction with ENSO?



The significant 3.4-3.5 peak is highly phase coherent with ENSO!

How do the time-wise expressions of this phase-coherent variability between STPI and ENSO match?



The independently extracted SSA waveforms of STPI and ENSO are largely in phase and the modulation matches very well!

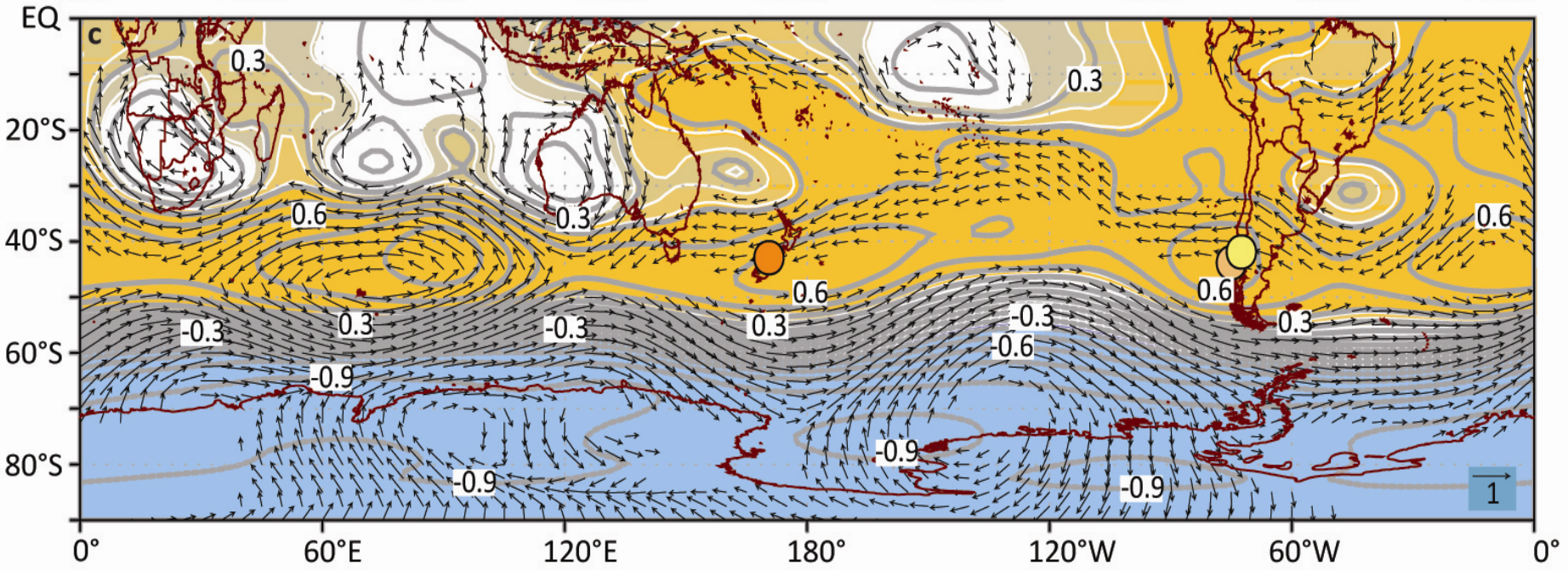
Conclusions up to this point:

- SLP patterns in the SH tend to be anti-phased between Australia-New Zealand and South America due to eccentricity in the circum-polar vortex around Antarctica. This is reflected in what Pittock called the *Trans-Polar Index* (TPI), the SLP difference between Hobart and Stanley.
- This anti-phasing affects the local climates of the two regions and is strongly expressed in tree growth of various tree species growing there.
- These anti-phased signals in the tree rings can be used to reconstruct Austral summer patterns of sea level pressure independently in both regions and jointly reconstruct the summer TPI (STPI).
- The STPI reconstruction has a prominent and highly significant ($p<0.01$) spectral peak at 3.4-3.5 years that is strongly phase coherent ($p<0.01$) with ENSO and the extracted waveforms match each other remarkably well.
- *This rarely cited 1997 result still provides some of the strongest statistical evidence for long-term forcing of the Southern Hemisphere Westerlies by ENSO yet produced.*

Now more briefly on to the

Southern Annular Mode (SAM) and Tree Rings

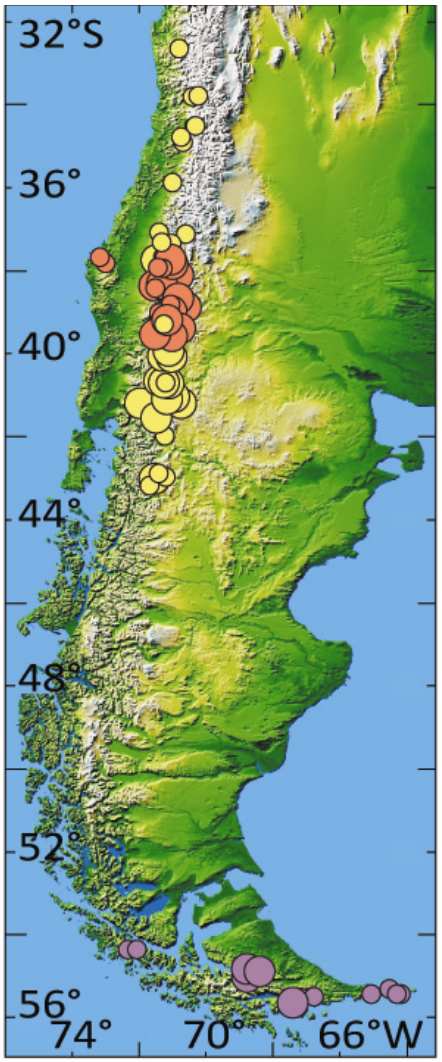
The dominant pattern of climate variability at mid and high-latitudes in the Southern Hemisphere

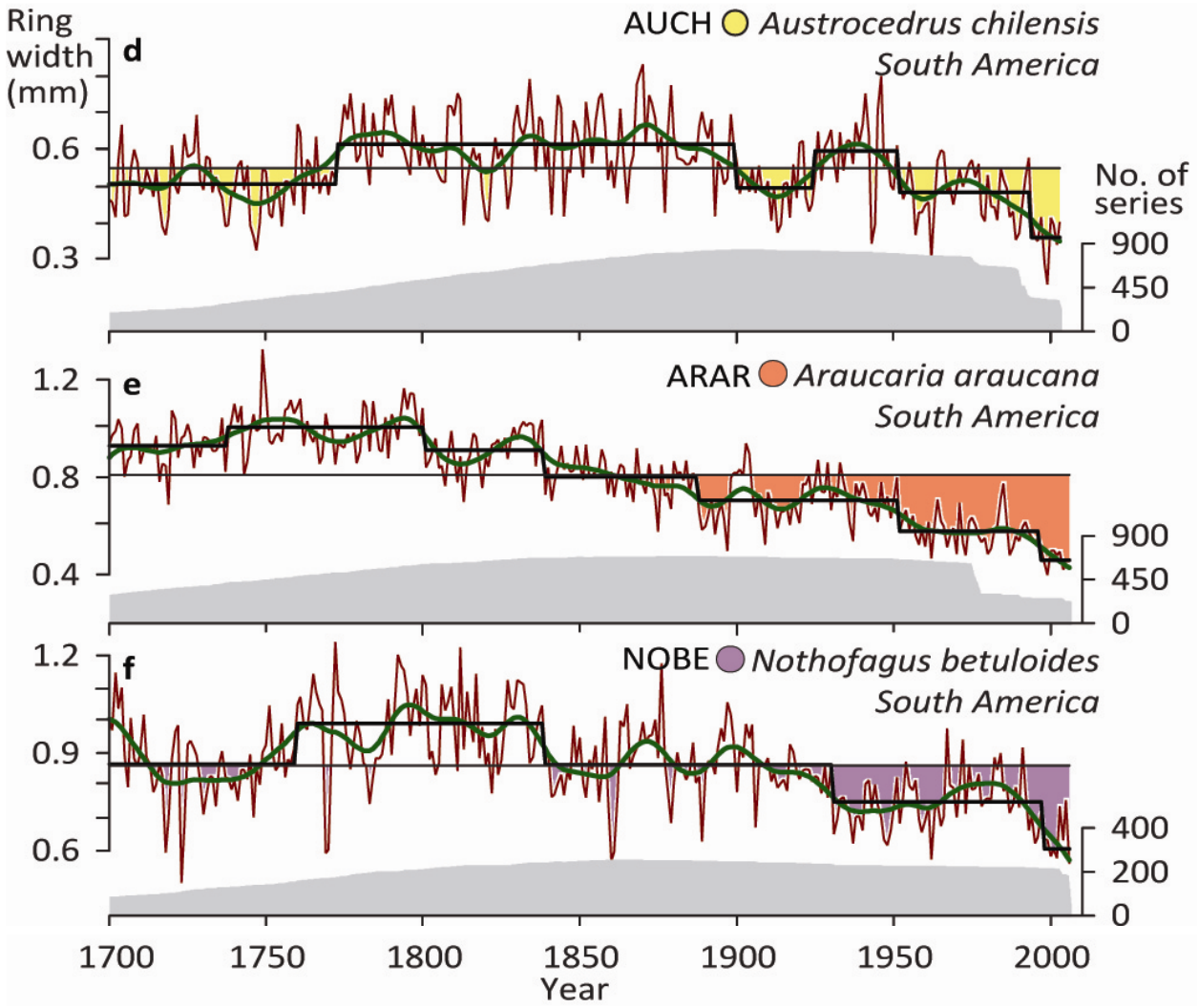


nature geoscience
LETTERS
PUBLISHED ONLINE: 28 OCTOBER 2012 | DOI: 10.1038/NGEO1613

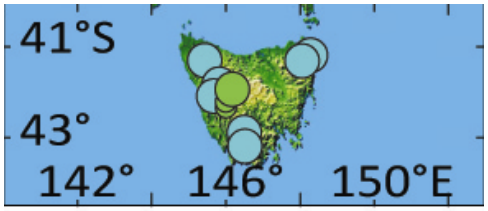
Unusual Southern Hemisphere tree growth patterns induced by changes in the Southern Annular Mode - Villalba et al. 2012

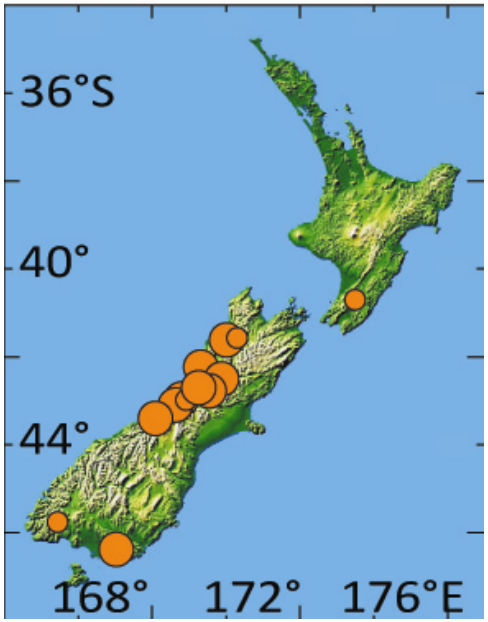
This work is again based on tree growth in temperate forests from South America …

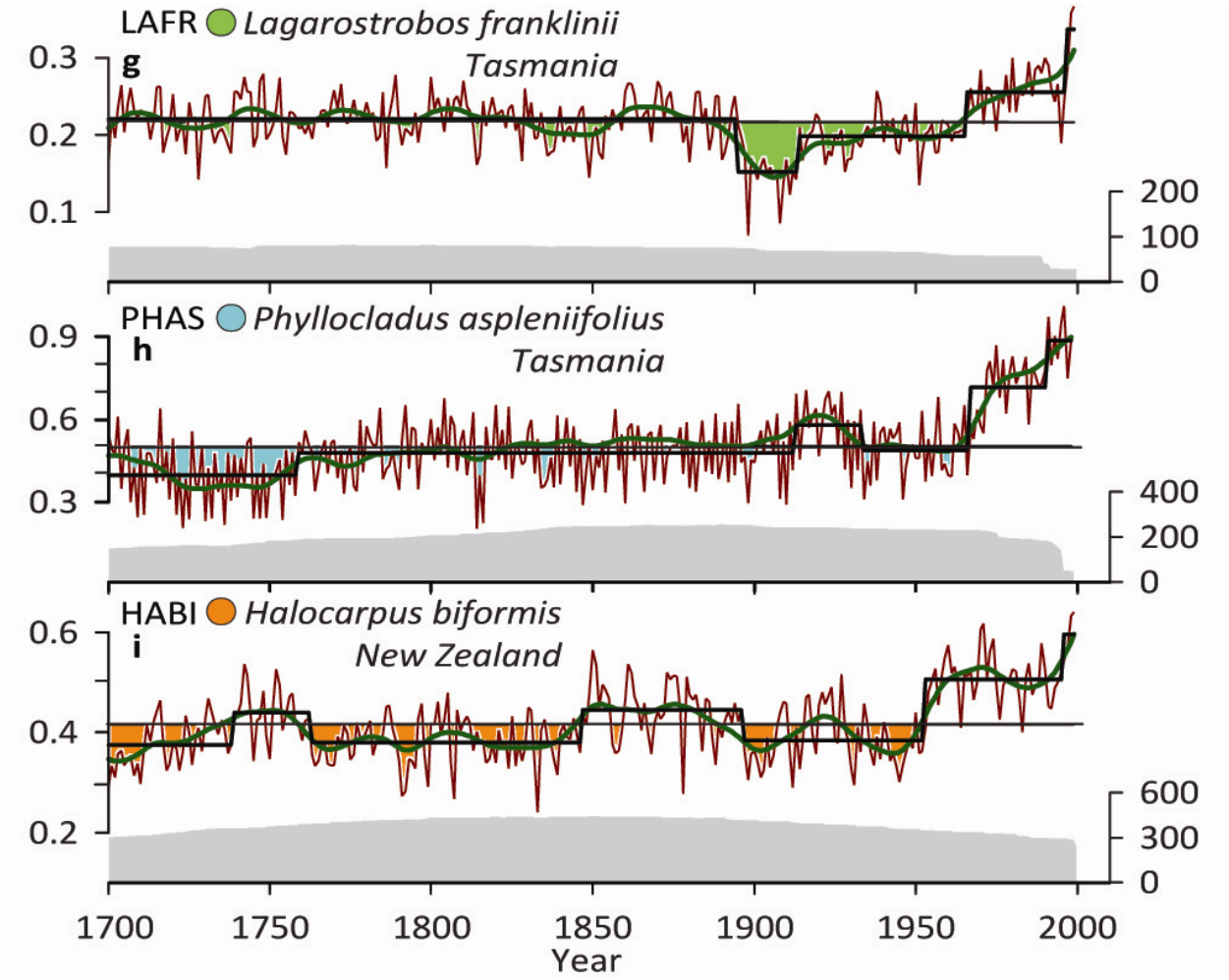




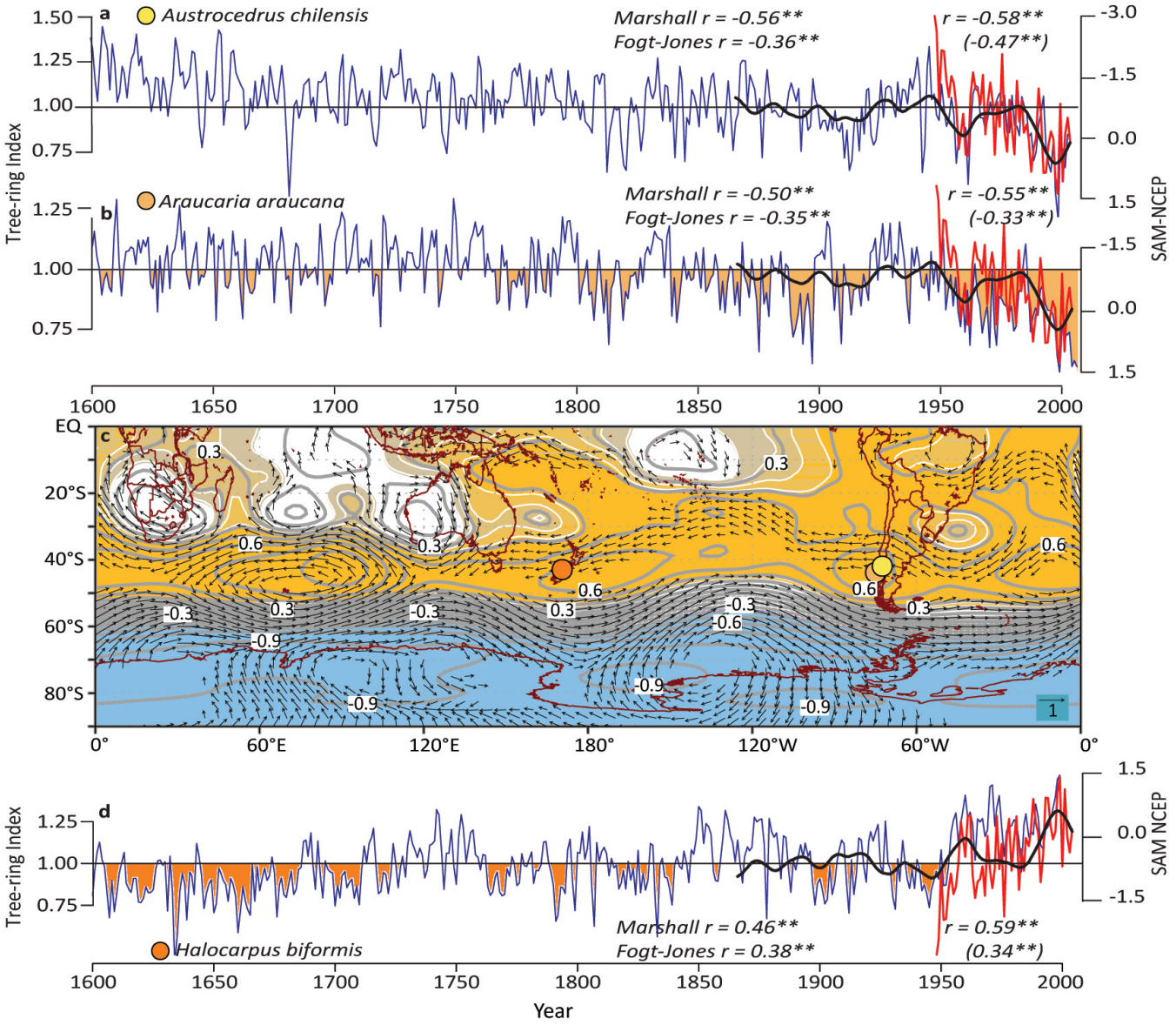
… and on tree growth in temperate forests from Tasmania and New Zealand



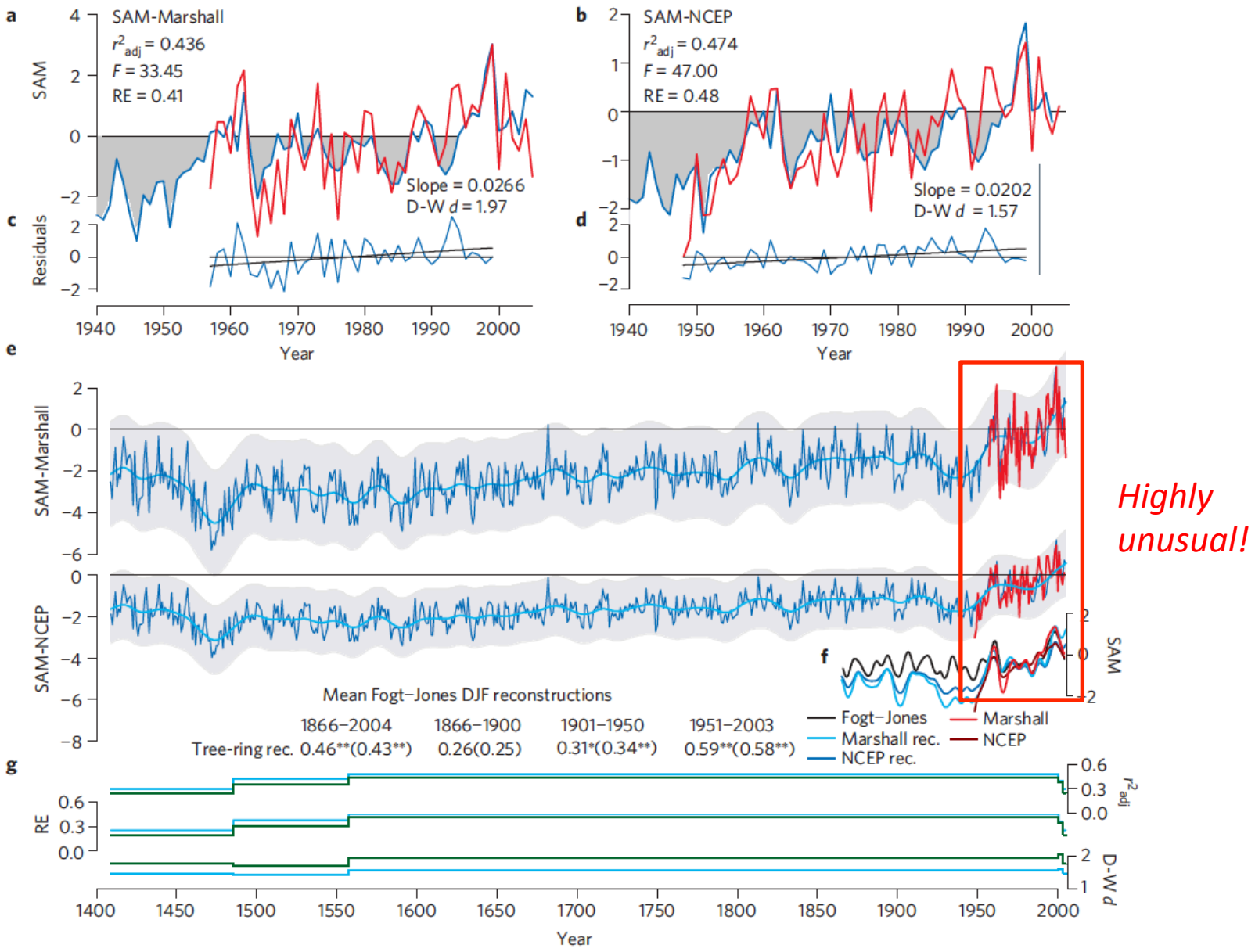




Correlations between tree growth and three summer SAM indices from NCEP, Marshall and Fogt-Jones – *the anti-phasing is again apparent.*



Southern Annular Mode Reconstructions (SAM): 1409-2006



Highly unusual!

Tree growth and the Westerlies in the Southern Hemisphere

1. The documented growth rate of woody species in the temperate forests of the Southern Hemisphere in recent decades is unusual in the context of the last 400-500 years.

Tree growth and the Westerlies in the Southern Hemisphere

2. Variations in the Southern Annular Mode (SAM) account for 12 to 48% of the variability in the growth of the studied species over the past 50 years.

Tree growth and the Westerlies in the Southern Hemisphere

3. SAM reconstructions based on growth rings indicate that atmospheric circulation in the SH during the recent 30-40 years is unprecedented in the context of the last 600 years.

Tree growth and the Westerlies in the Southern Hemisphere

4. Recent studies indicate that the SAM has changed because of tropospheric ozone depletion at high latitudes, suggesting that this is one of the causes of the growth anomalies of temperate forests in the SH.

Tree growth and the Westerlies in the Southern Hemisphere

Thank you!