

Factors Affecting Interannual Variability of Global Land-based Rainfall

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This project involves an analysis of the effects of various dynamical phenomena, or factors, on global rainfall.

Nine such factors are identified and described, and represented in the analysis by their time series.

- A multiple regression analysis is then performed on seasonal means of Global rainfall with these nine time series, point by point, and the pattern and magnitudes of influence of these factors are thus obtained.
- Australian rainfall is taken as an initial example, and has been used for testing the methodology.
- Separate analyses have been carried out for 1900-2008, and for 1950-2008.

The forcing factors considered, in no particular order, are:

- 1) Global warming: GW
- 2) Nino3.4 index Nino3.4
- 3) Indian Ocean Dipole IOD
- 4) Quasi-biennial Oscillation QBO
- 5) Sunspot number SSN 11-year solar cycle
- 6) Atlantic Meridional (Multidecadal) Oscillation AMO, or AMOC
- 7) Trans Nino Index TNI
- 8) Southern Annular Mode SAM
- 9) Pacific Gyre Oscillation PGO

In general terms, each of these represents a dynamical process.

These factors are represented by their “signature” time series.

Where do these come from?

Several of them are based on Sea Surface Temperature (SST)

Factor **GW** – “**global warming**” and

Factor **AMO** – the “**Atlantic Meridional (or Multidecadal) Oscillation**” are obtained from Global SST.

The data used is ersstV3b, being the most recent available.

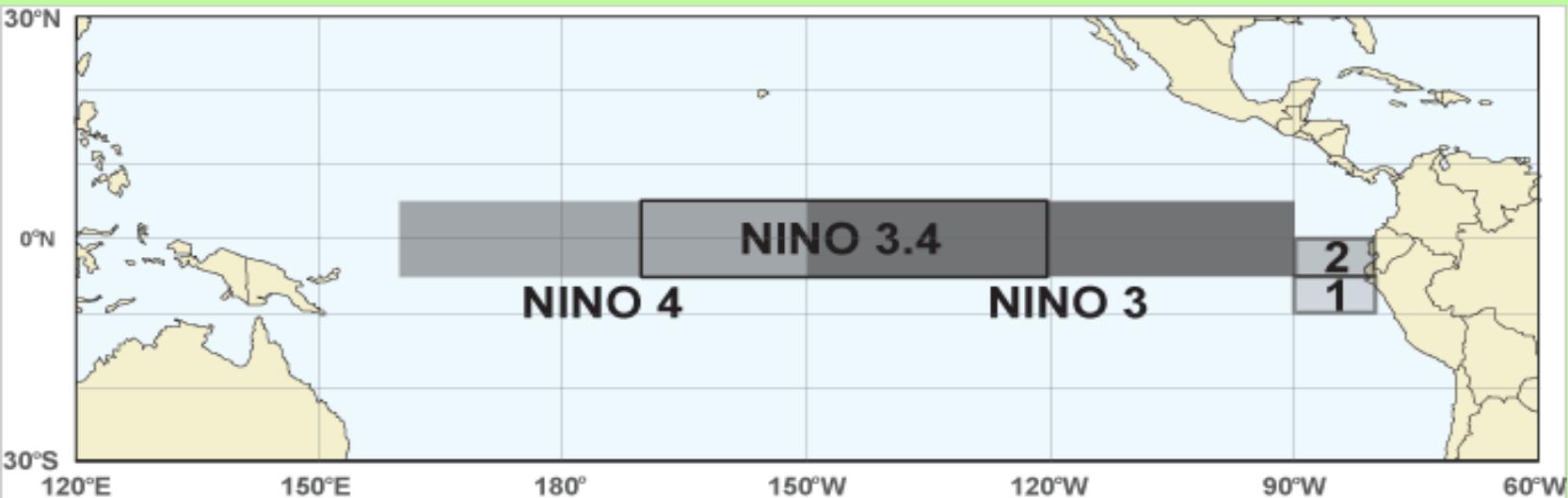
Five-year running means are taken of seasonal SST data (MAM, JJA, SON & DJF) from 1900 (or from 1950).

These two factors are then obtained as the time series of EOF1 and EOF3 respectively.

EOF2 of global SST is the “Pacific decadal oscillation”, but rather than use this, we use two indices representative of ENSO:

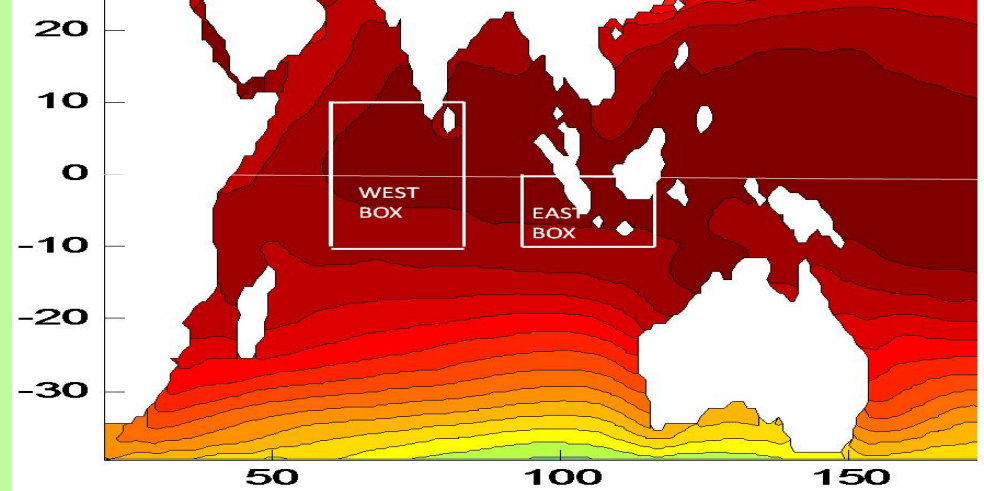
Nino3.4, the temperature in the box below,

and the Trans-Nino Index (Trenberth & Stepaniak2001):
the **TNI = Nino1+2 – Nino4**
- both with 5-month running mean.



Other factors are:
the **Indian Ocean Dipole**,
measured by the IOD Index:

$$\text{IOD} = \text{SST}_{\text{WestBox}} - \text{SST}_{\text{EastBox}}$$



The **Southern Annular Mode SAM** – the zonal mean surface
pressure at 40°S minus that at 65°S

- data from Jones, Fogt et. al. (2009) & Marshall (2003)

The **Sunspot Number SSN** – an index of the solar cycle

- data from SIDC, Belgium

The **Quasi-biennial Oscillation QBO** – the mean zonal velocity between
5N and 5S at 30 mb

- data from Bronnimann et al. (2007)

The 9th factor, the **PGO** – “**Pacific Gyre Oscillation**”, or more precisely the North Pacific Gyre Oscillation, is taken as the 2nd EOF of SST in the North Pacific.

The NPGO index is based on Sea Surface Height data (Di Lorenzo et al. 2008), but this is only available back to 1950.

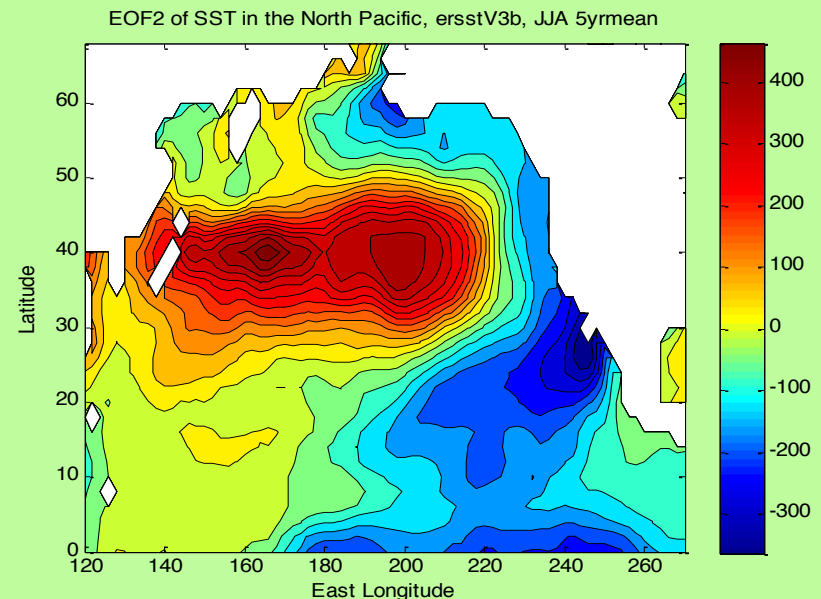
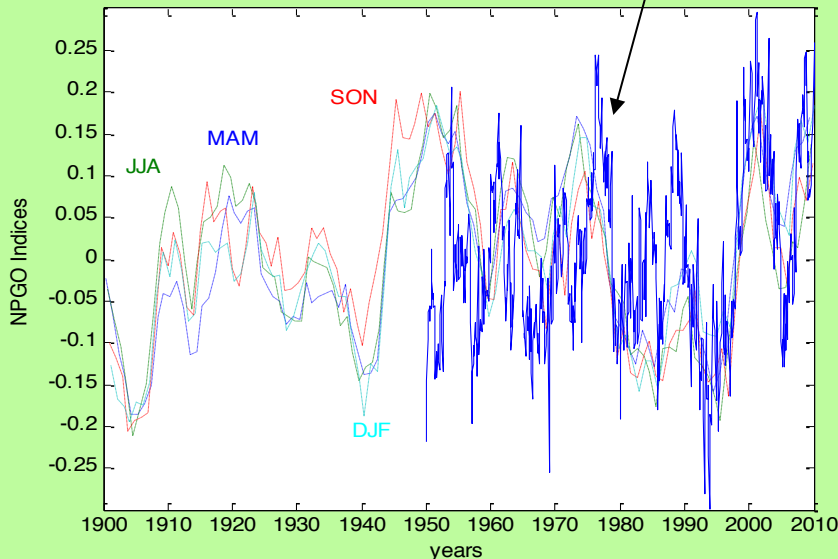
However, this is strongly correlated with the North Pacific SST EOF2, which is used here for analysis back to 1900.

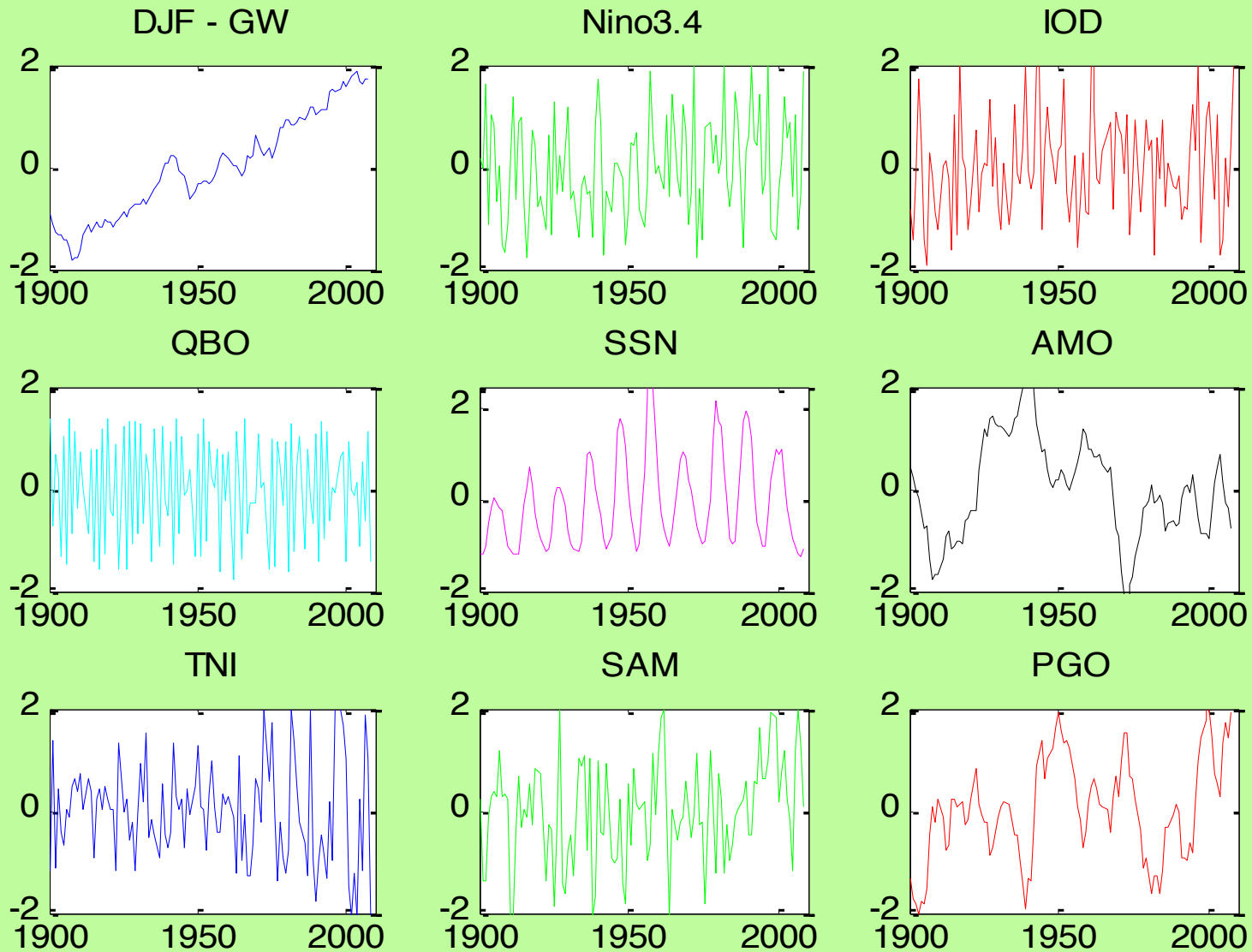
Time series for seasons

The NPGO index of Di Lorenzo &c(2008), compared with the SST based seasonal indices

Di Lorenzo index

SST EOF2 for JJA





Normalised time series for the various Factors for Season
December-February – **DJF**

Correlations between these are (mostly) small.

DJF	GW	Nino3.4	IOD	QBO	SSN	AMO	TNI	SAM	PGO
GW	1.00	0.169	0.102	0.004	0.212	0.00	-0.061	0.245	0.248
Nino3.4	0.169	1.00	-0.017	0.064	0.089	0.073	-0.453	-0.070	-0.207
IOD	0.102	-0.017	1.00	-0.037	0.063	0.102	0.006	0.127	0.086
QBO	0.004	0.064	-0.037	1.00	-0.03	-0.006	-0.032	0.022	0.009
SSN	0.212	0.089	0.063	-0.030	1.00	0.079	-0.146	-0.030	-0.051
AMO	0.00	0.073	0.102	-0.006	0.079	1.00	-0.194	-0.154	-0.265
TNI	-0.061	-0.453	0.006	-0.032	-0.146	-0.194	1.00	0.018	0.234
SAM	0.245	-0.070	0.127	0.022	-0.030	-0.154	0.018	1.00	0.187
PGO	0.248	-0.207	0.086	0.009	-0.051	-0.265	0.234	0.187	1.00

Correlation coefficients between the various factors for season DJF over the period 1900-2008.

Correlations > 0.2 are marked in red.

Some of these factors are predictable.

Hence, to this extent, if their influence on rainfall can be estimated from observations, a measure of predictability of rainfall may follow.

Next – the rainfall data

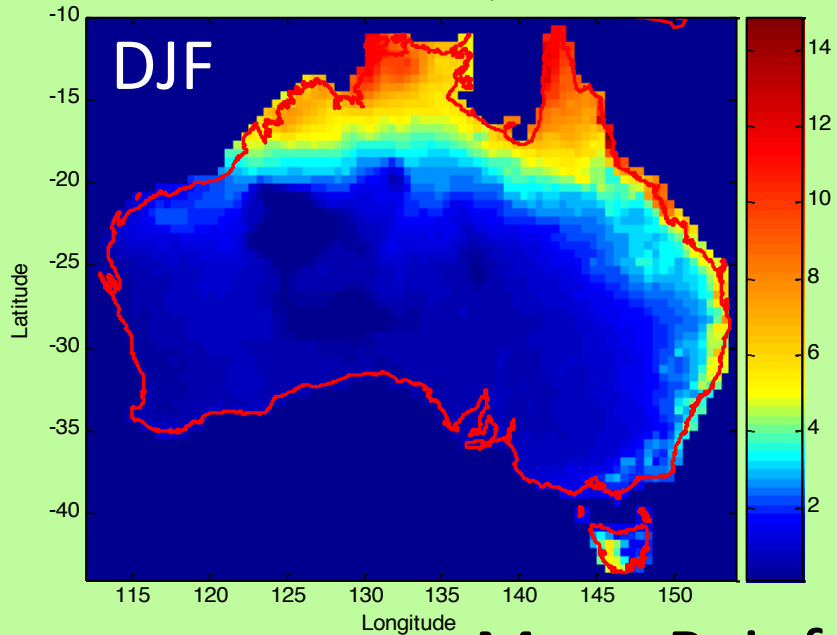
Rainfall data for Australia is from the Bureau of Meteorology, but was provided by CSIRO (via Peter Briggs).

It is grouped into seasons, with resolution of 0.5 degrees latitude and longitude for the whole continent.

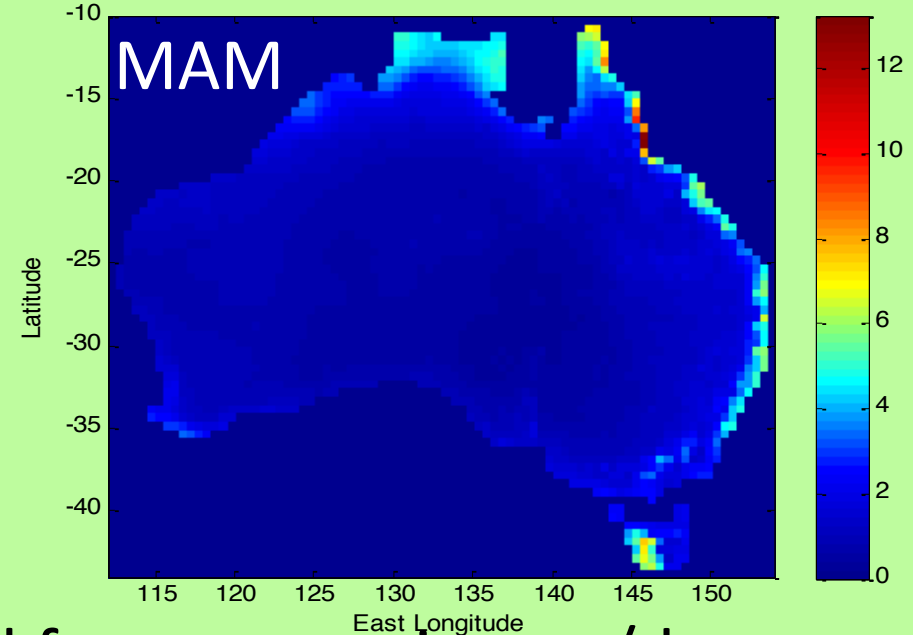
Location of rain gauges
collecting data since
1980
(from Jones &c 2007)



Mean rainfall for DJF, mm/day, 1910-2007

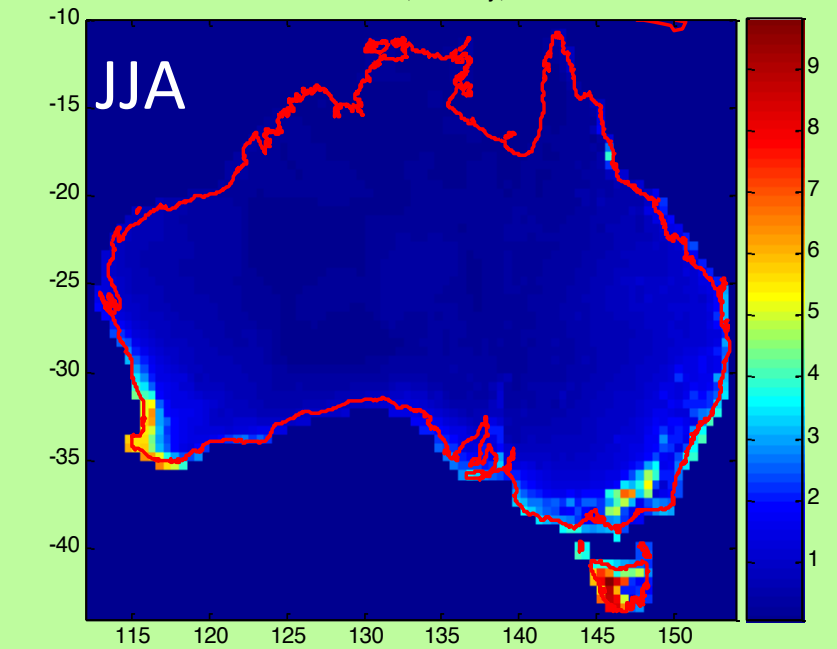


Mean Rainfall for MAM, mm/day, 1900-2009

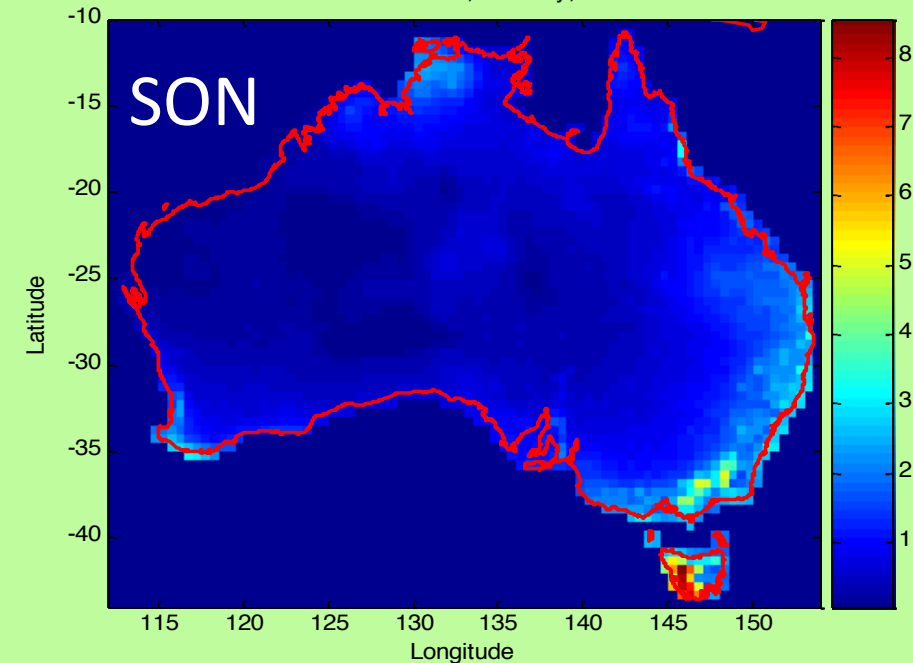


Mean Rainfall for seasons, in mm/day

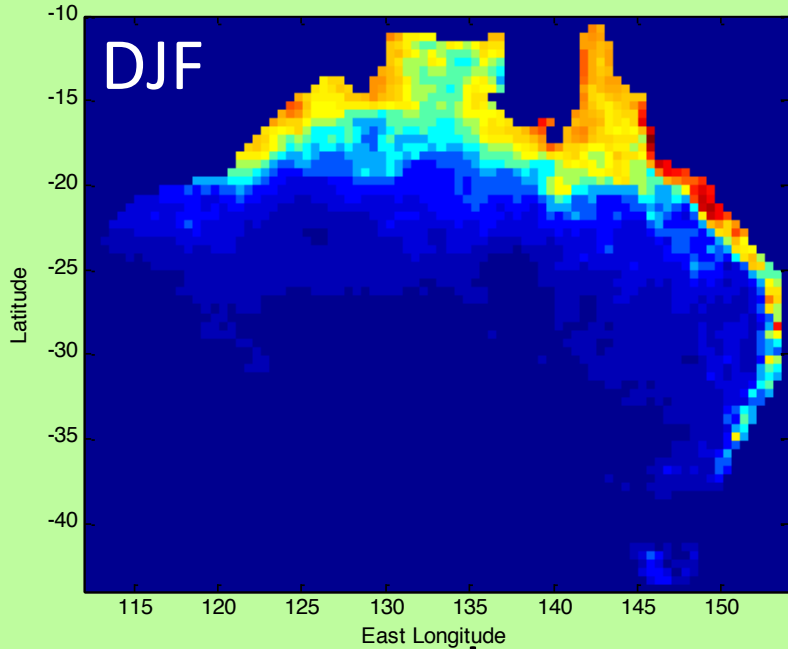
Mean rainfall for JJA, mm/day, 1910-2007



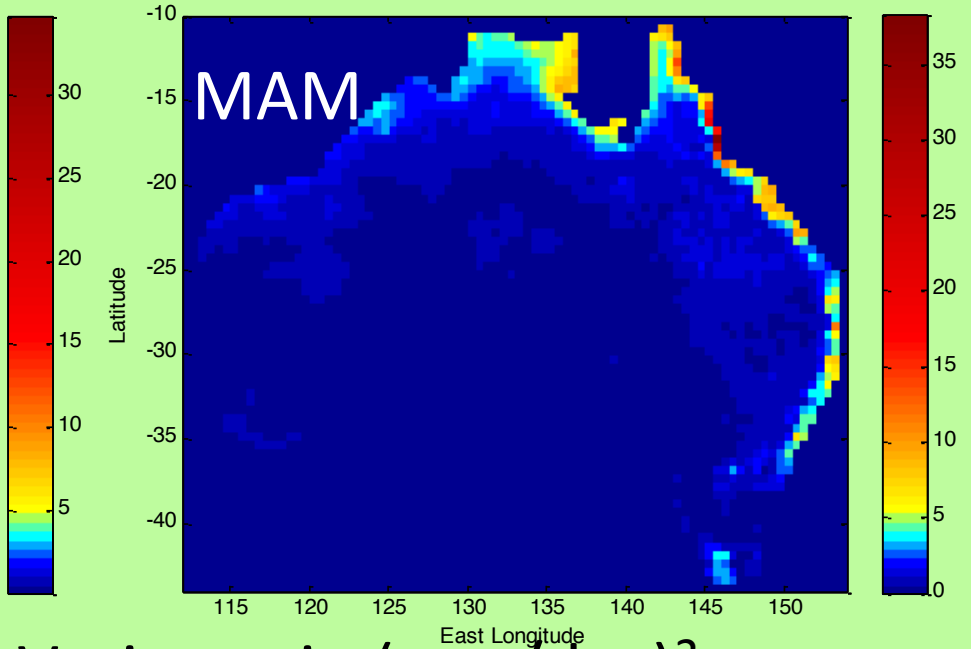
Mean rainfall for SON, mm/day, 1910-2007



Interannual variance of DJF Rainfall, (mm/day)²

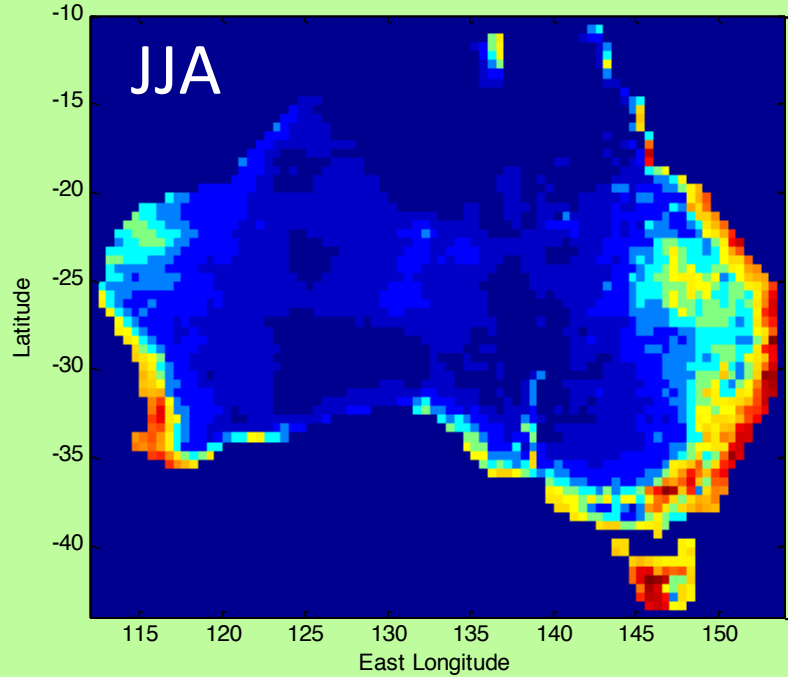


Interannual variance of MAM Rainfall, (mm/day)²

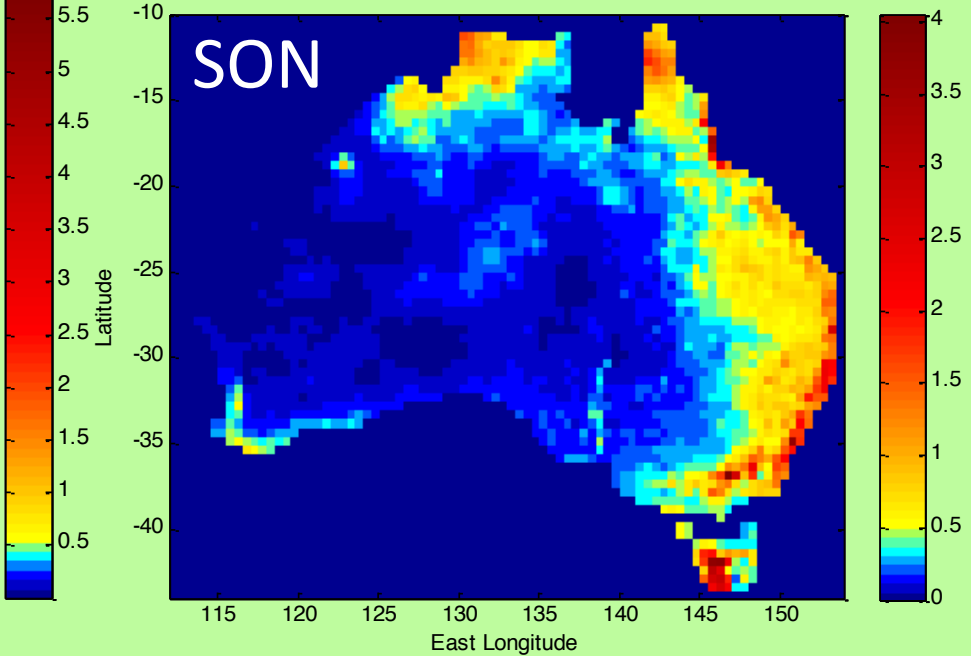


Interannual Variance in (mm/day)²

Interannual variance of JJA Rainfall, (mm/day)²



Interannual variance of SON Rainfall, (mm/day)²

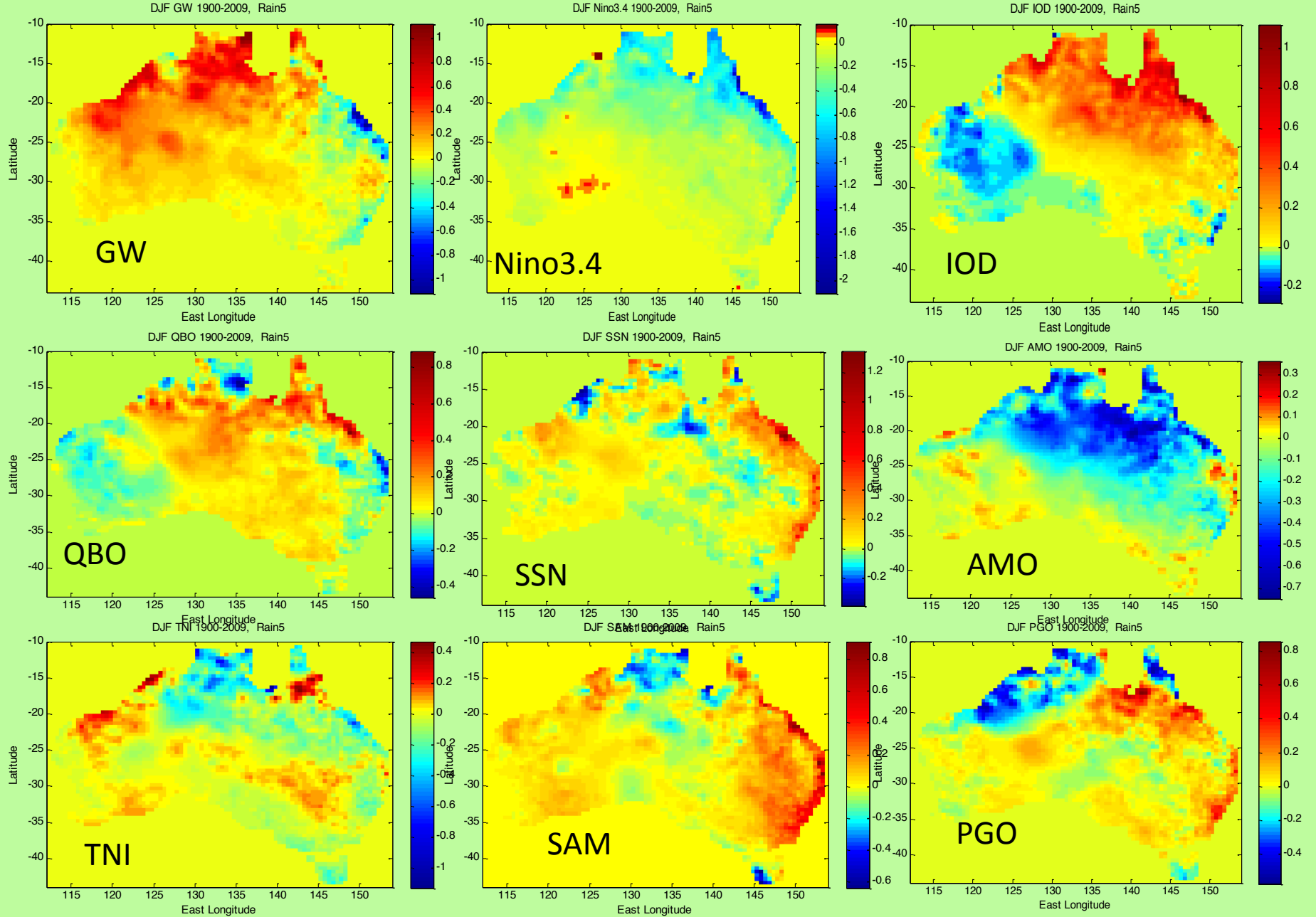


We are mainly interested in this variance, and the extent to which the interannual variability is dependent on the 9 factors listed.

This is done by a “multiple regression analysis”, in which the seasonal mean rainfall (for djf) is represented as:

$$R_{djf}(\mathbf{r}, year) = Rmean_{djf}(\mathbf{r}) + \sum_{n=1}^9 RCoef_n_{djf}(\mathbf{r}) \cdot FactorT_n(year) + Residual_{djf}(\mathbf{r}, year)$$

The spatial patterns $RCoef_n_{djf}(\mathbf{r})$ are obtained by a process of minimising least squares of R_{djf} , taken over the years 1900-2009 (or 1950-2009), for each spatial grid point, and each season separately.



DJF Regression Coefficients Aust. Rainfall 1900-2009

For significance of these statistics, one approach is to make a bi-directional quadratic fit to each regression pattern, and estimate the significance of each pattern.

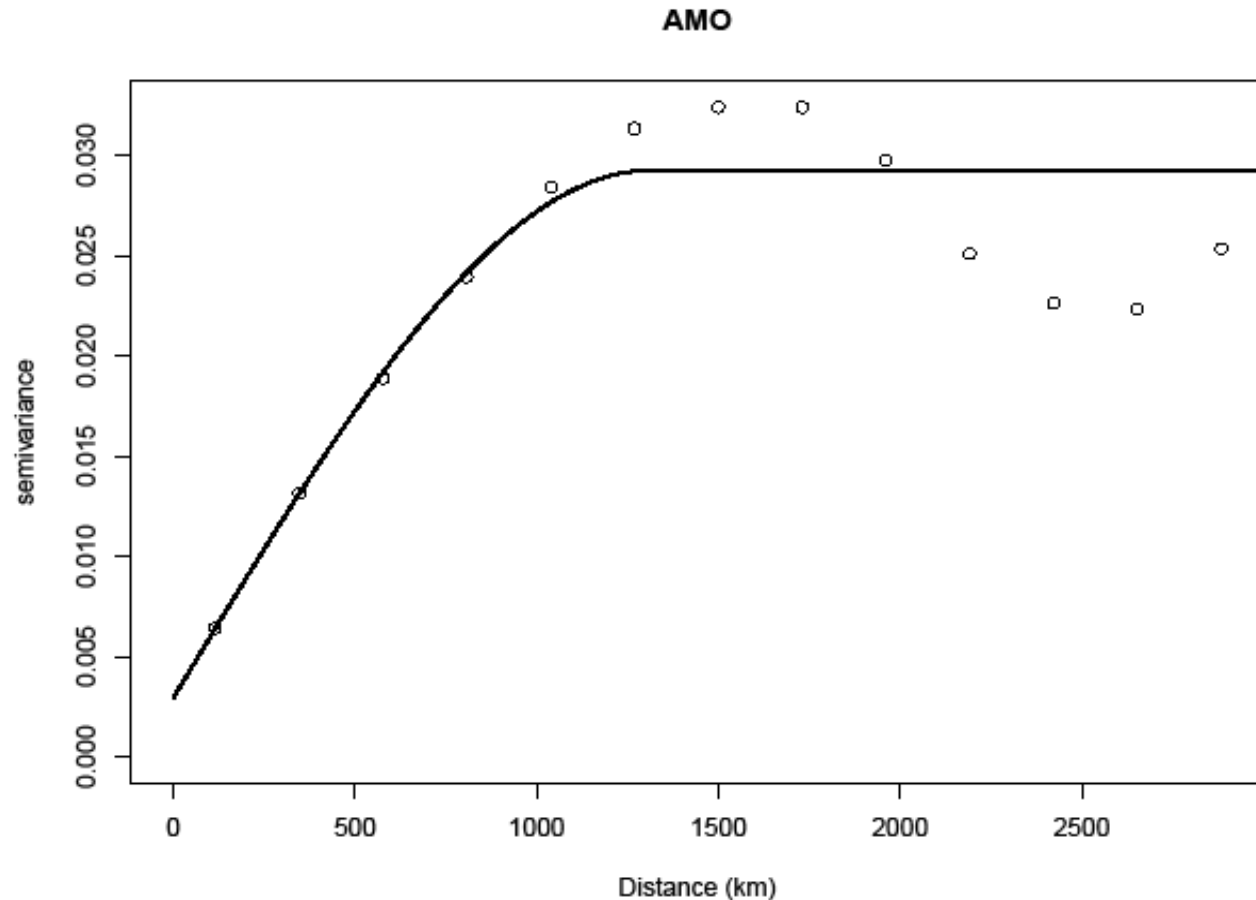
A variogram analysis of the roughness of each pattern has also been performed.

$$\text{Semivariance} = \gamma(\Delta x, \Delta y) = \frac{1}{2} E[(Z(x + \Delta x, y + \Delta y) - Z(x, y))^2]$$

where E denotes the statistical expectation operator, and Z the variable in question, in this case rainfall in mm/day.

- a measure of the roughness of the data

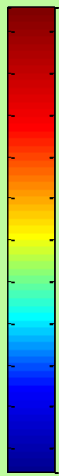
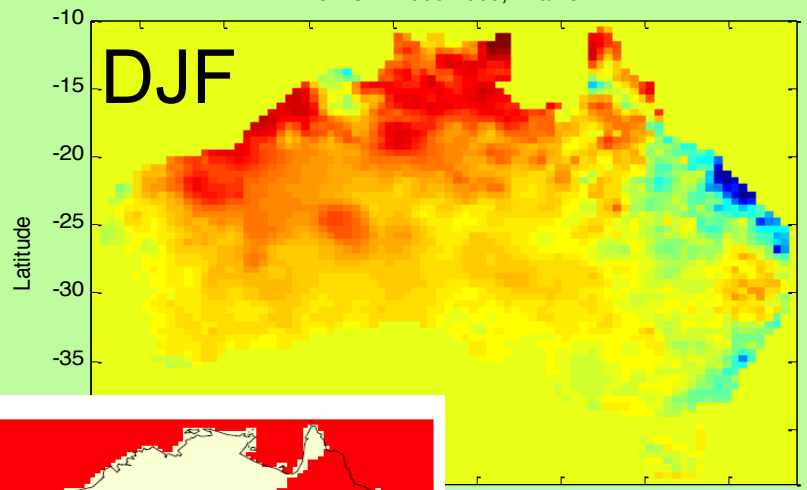
Variogram analysis, for the AMO for DJF



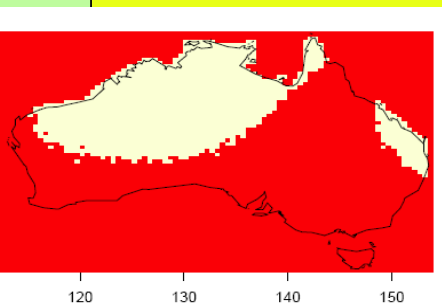
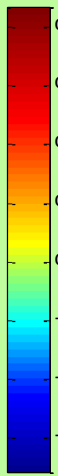
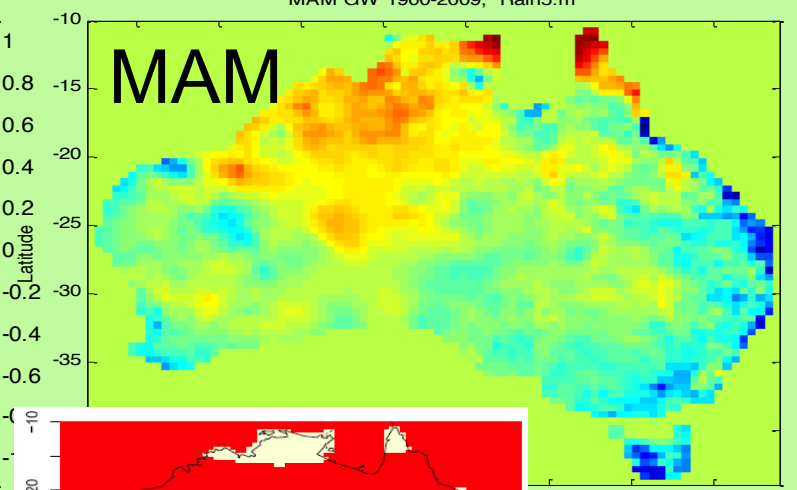
The semi-variance of the regression data, as a function of separation distance, for the AMO for DJF .

This distance of about 1000 km is typical for most of these factors.

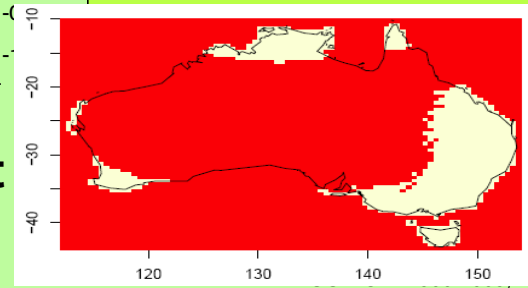
DJF GW 1900-2009, Rain5



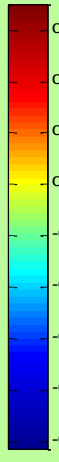
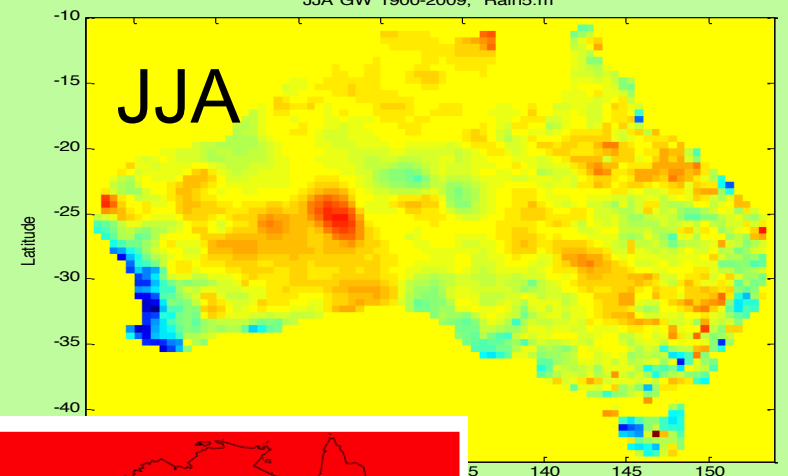
MAM GW 1900-2009, Rain5.m



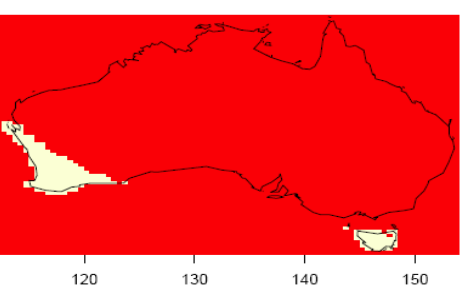
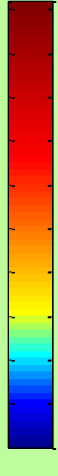
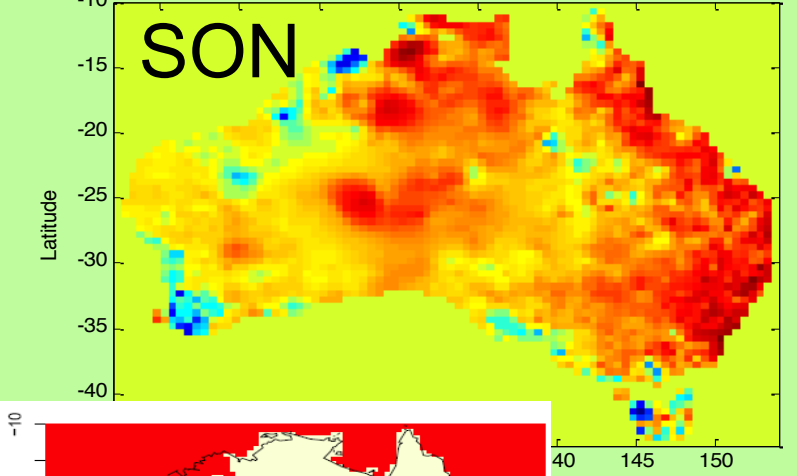
**White = significant
at 90% level**



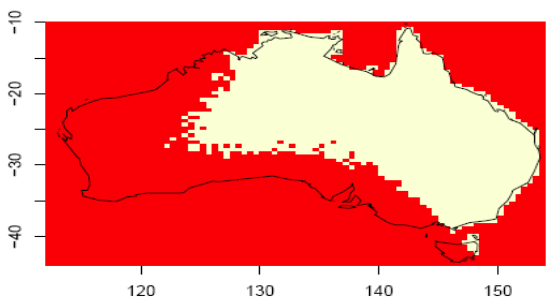
JJA GW 1900-2009, Rain5.m



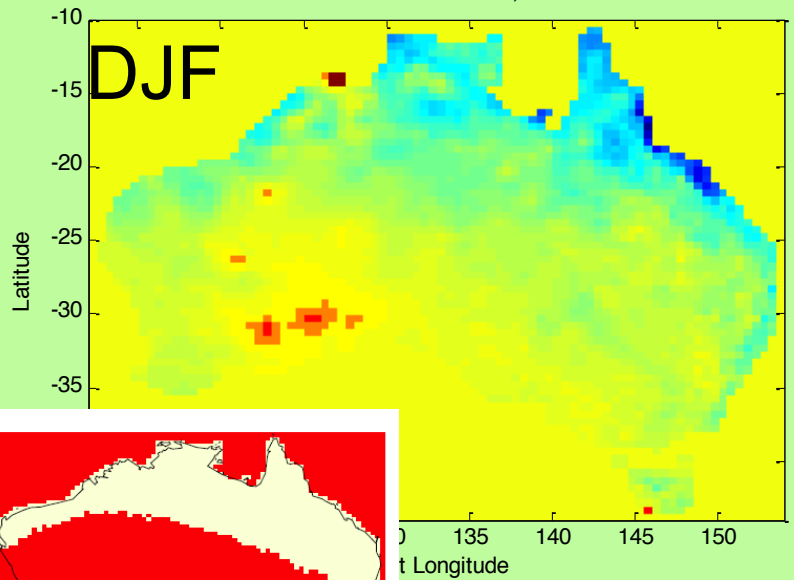
SON GW 1900-2009, Rain5.m



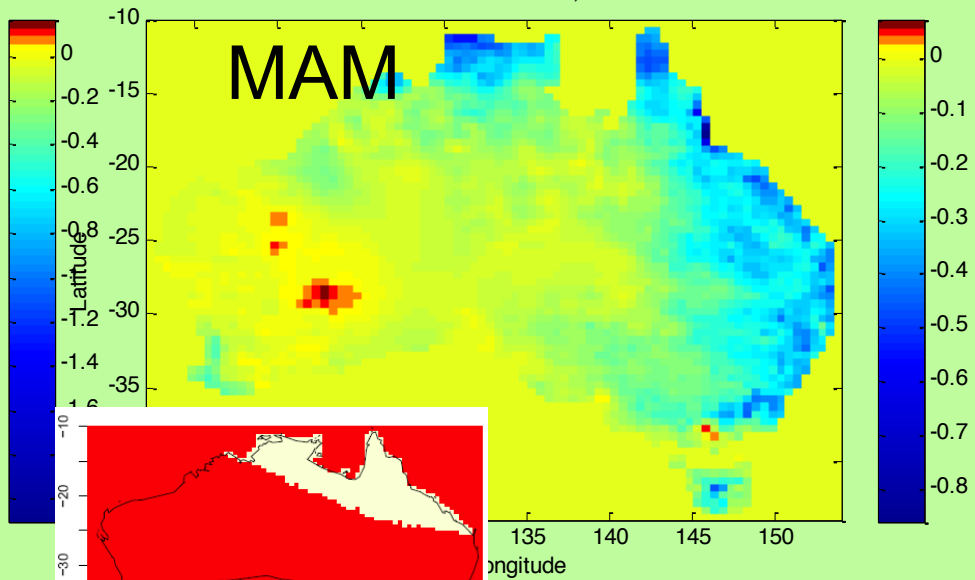
GW



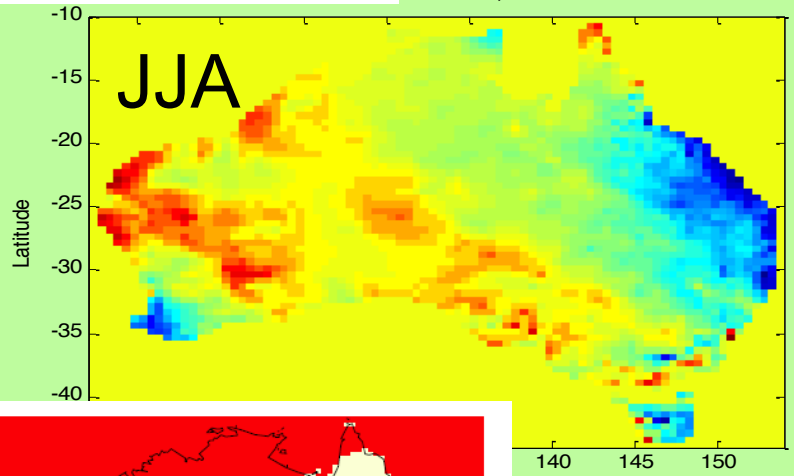
DJF Nino3.4 1900-2009, Rain5



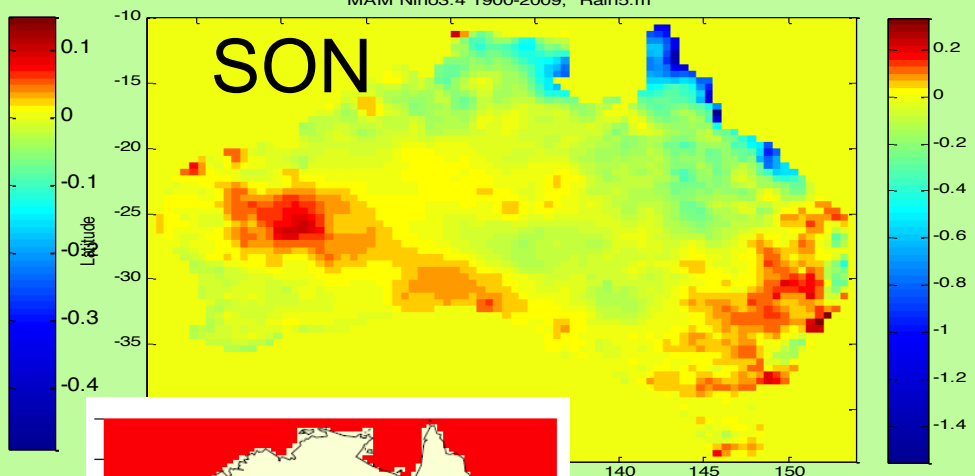
SON Nino3.4 1900-2009, Rain5



JJA Nino3.4 1900-2009, Rain5.m

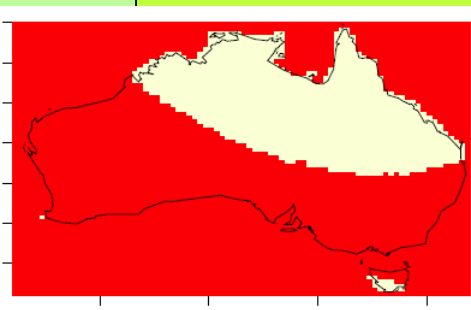
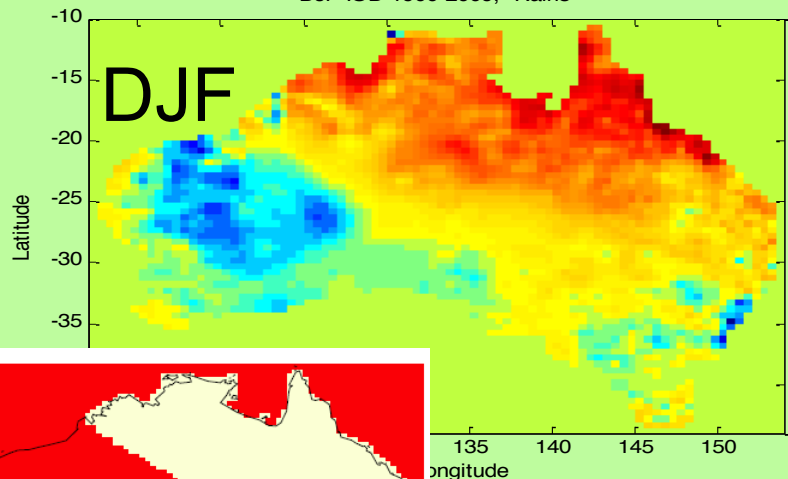


MAM Nino3.4 1900-2009, Rain5.m

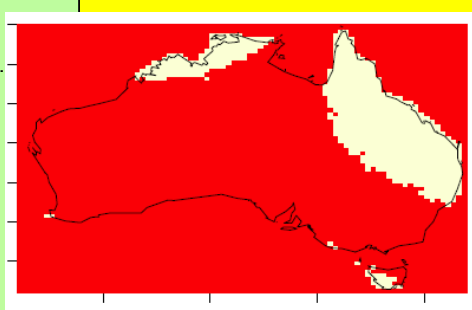
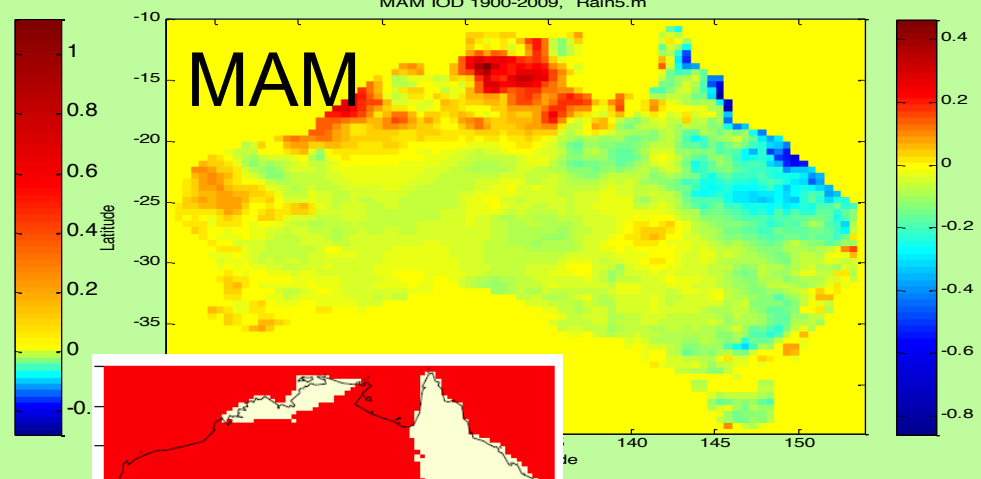


Nino3.4

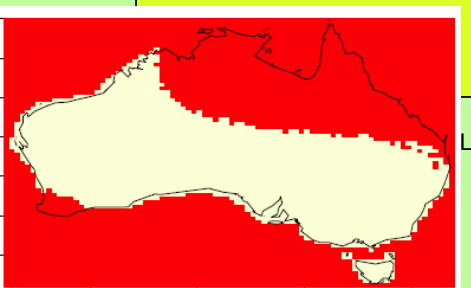
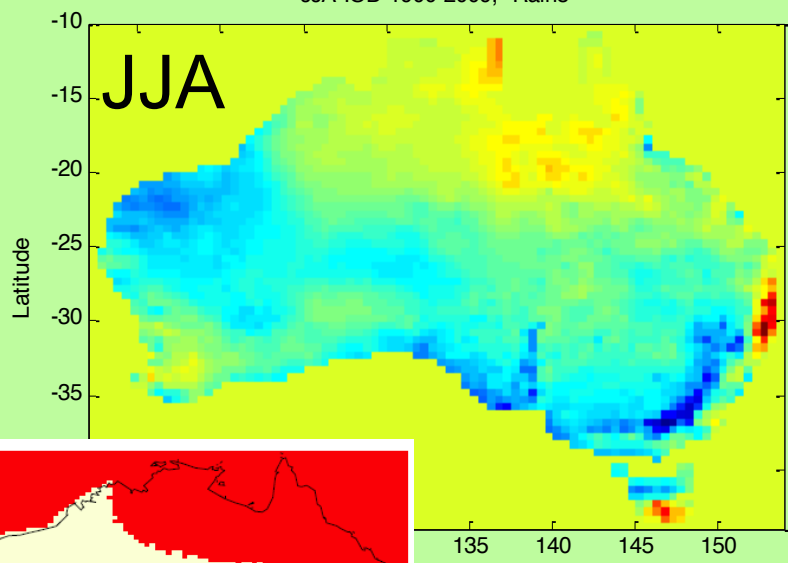
DJF IOD 1900-2009, Rain5



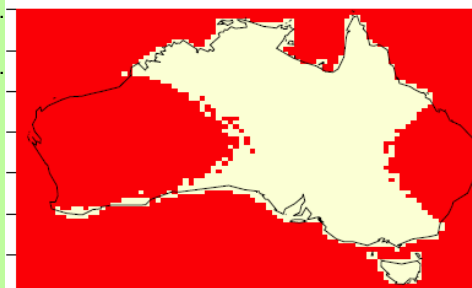
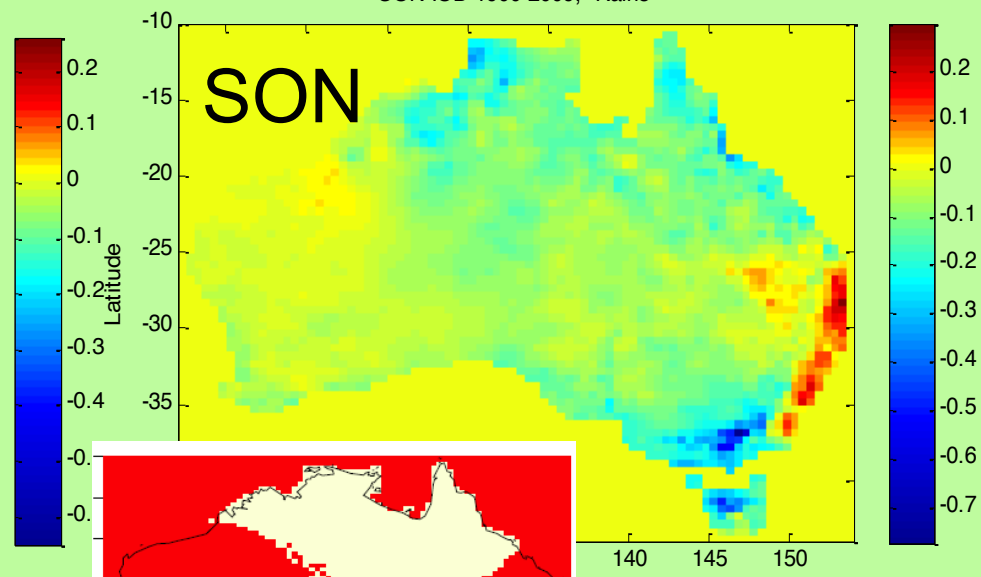
MAM IOD 1900-2009, Rain5.m



JJA IOD 1900-2009, Rain5

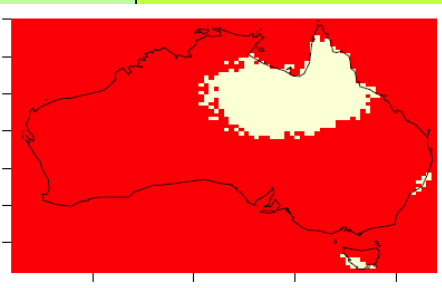
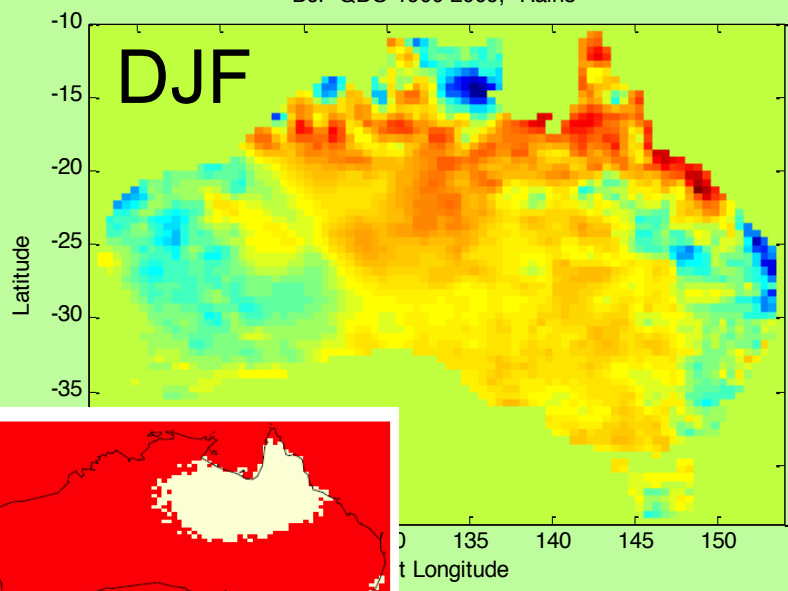


SON IOD 1900-2009, Rain5



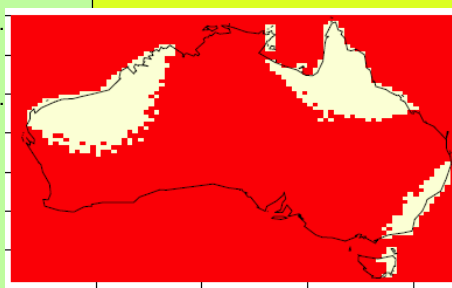
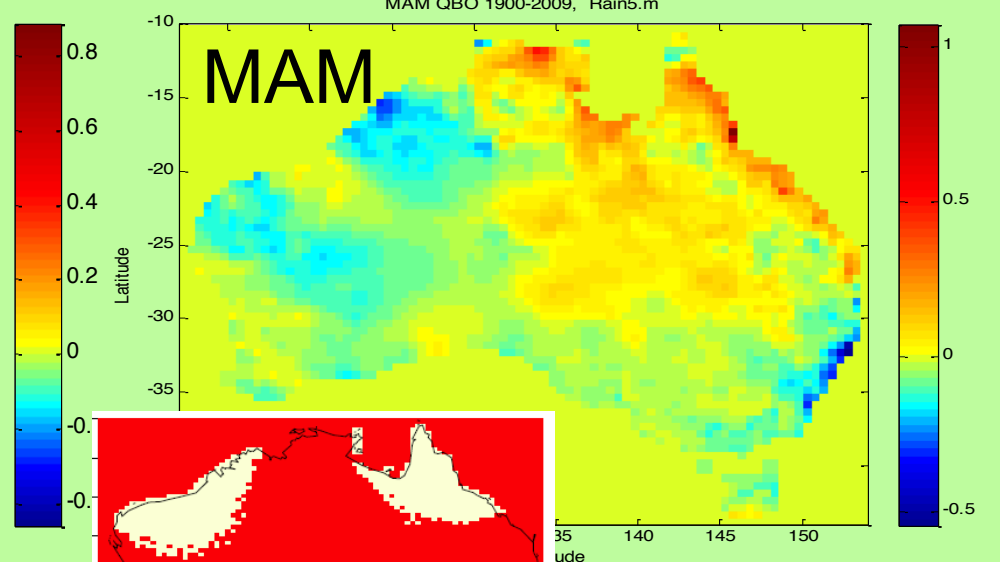
IOD

DJF QBO 1900-2009, Rain5



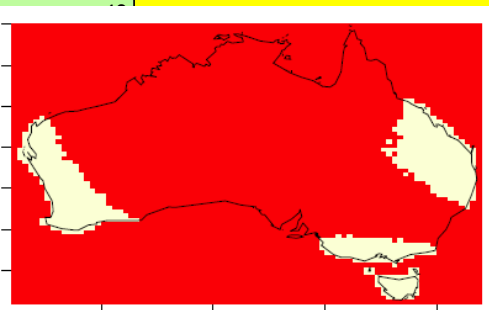
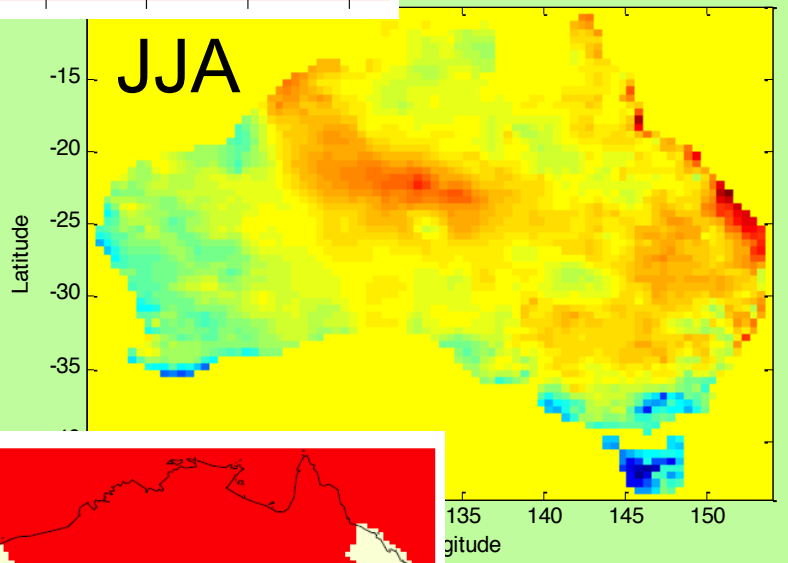
1900-2009, Rain5

MAM QBO 1900-2009, Rain5.m



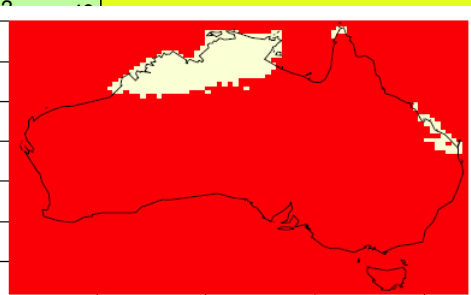
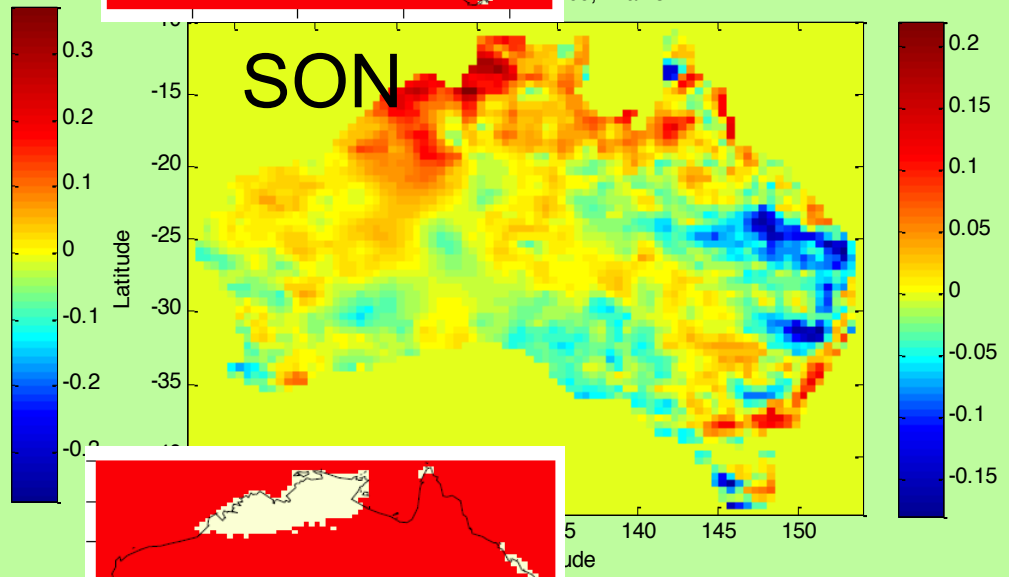
1900, Rain5

JJA



1900-2009, Rain5

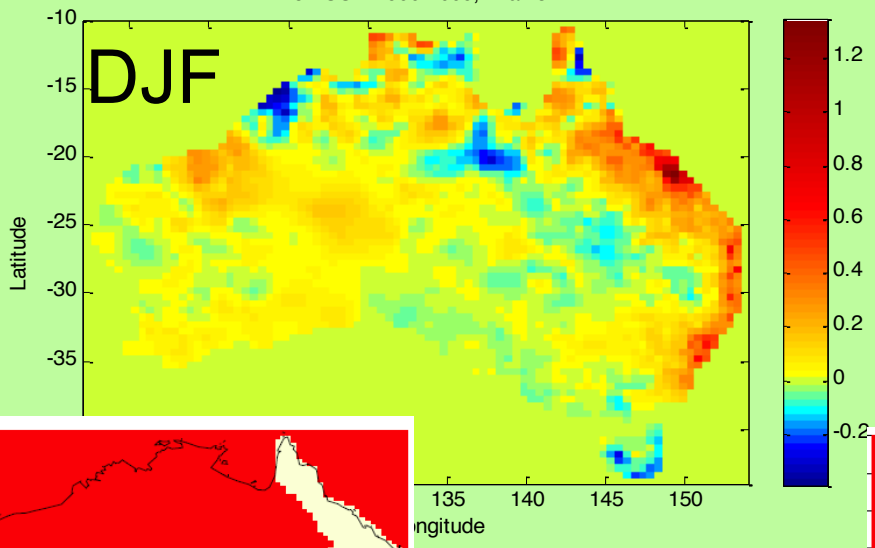
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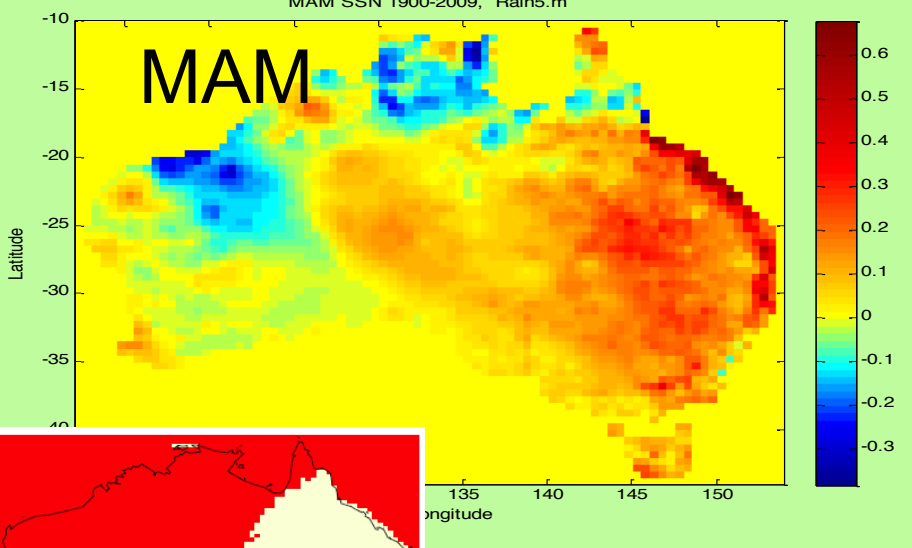
1900, Rain5

QBO

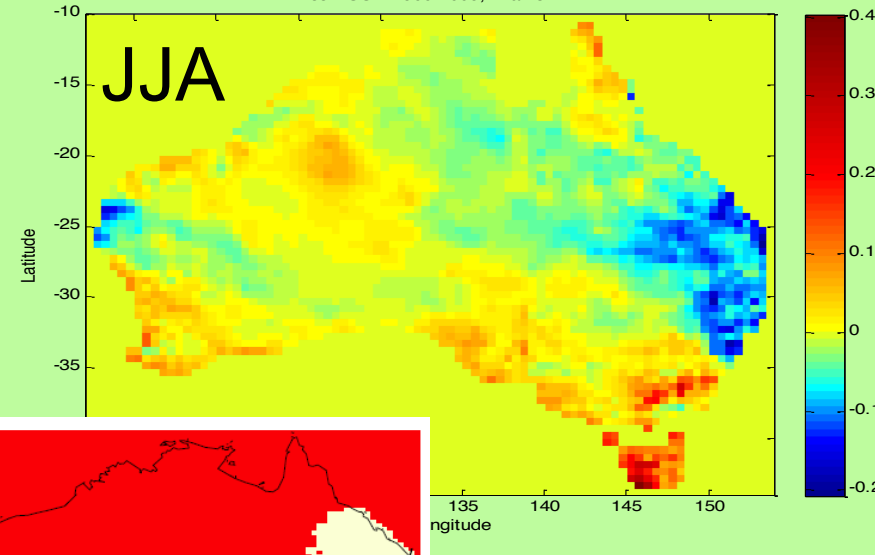
DJF SSN 1900-2009, Rain5



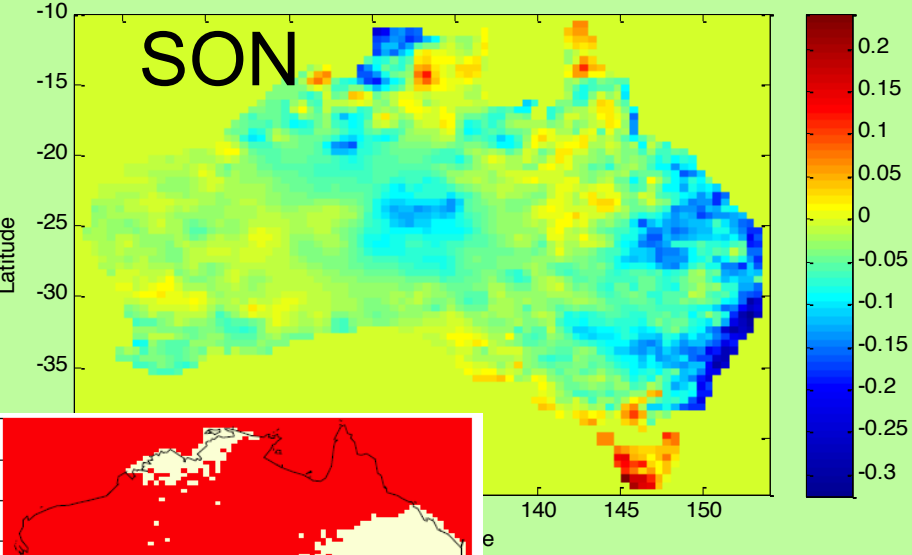
MAM SSN 1900-2009, Rain5.m



JJA SSN 1900-2009, Rain5

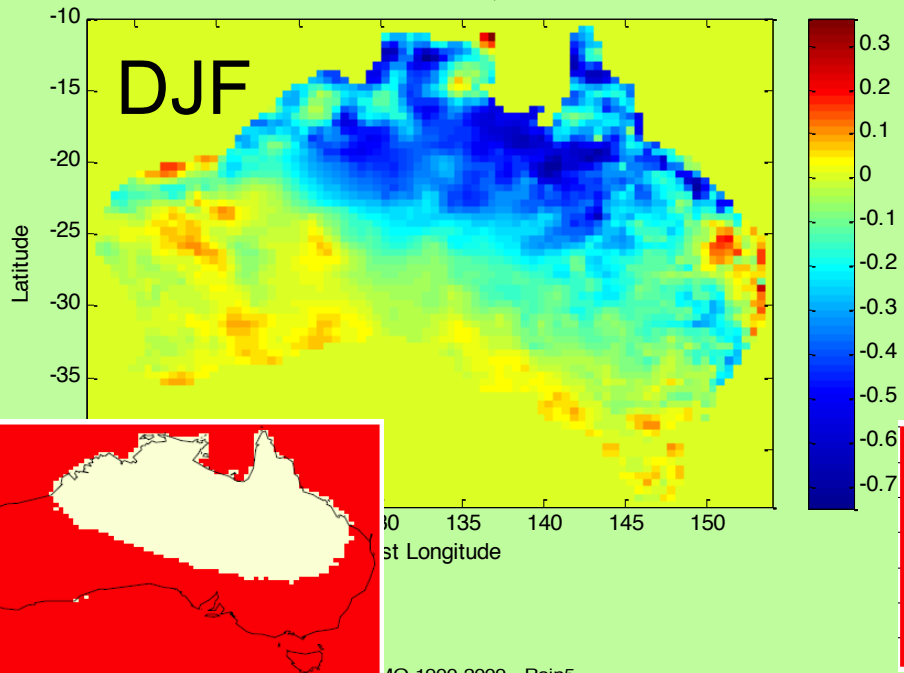


SON SSN 1900-2009, Rain5

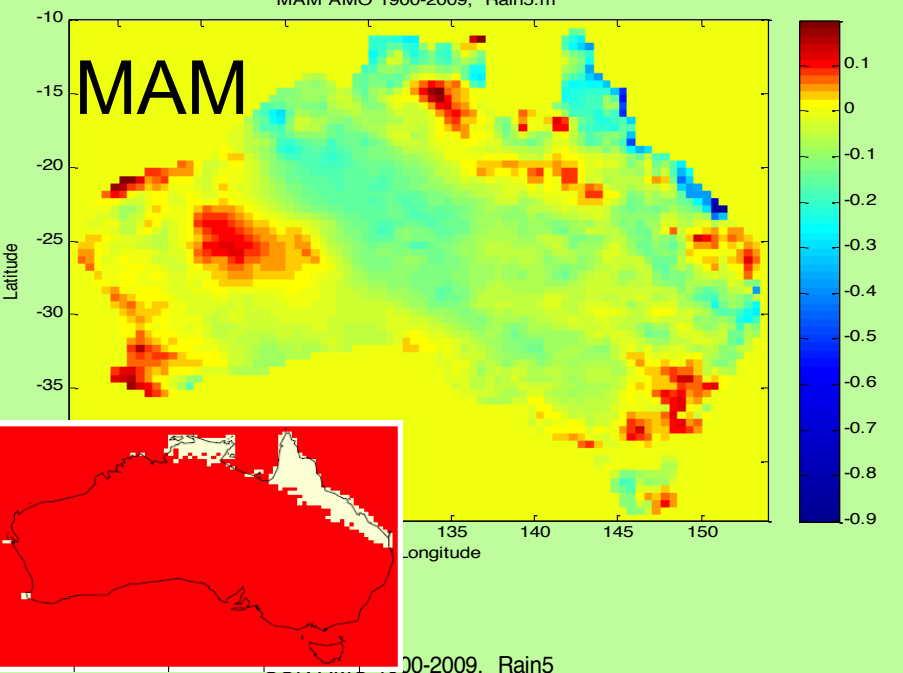


SSN

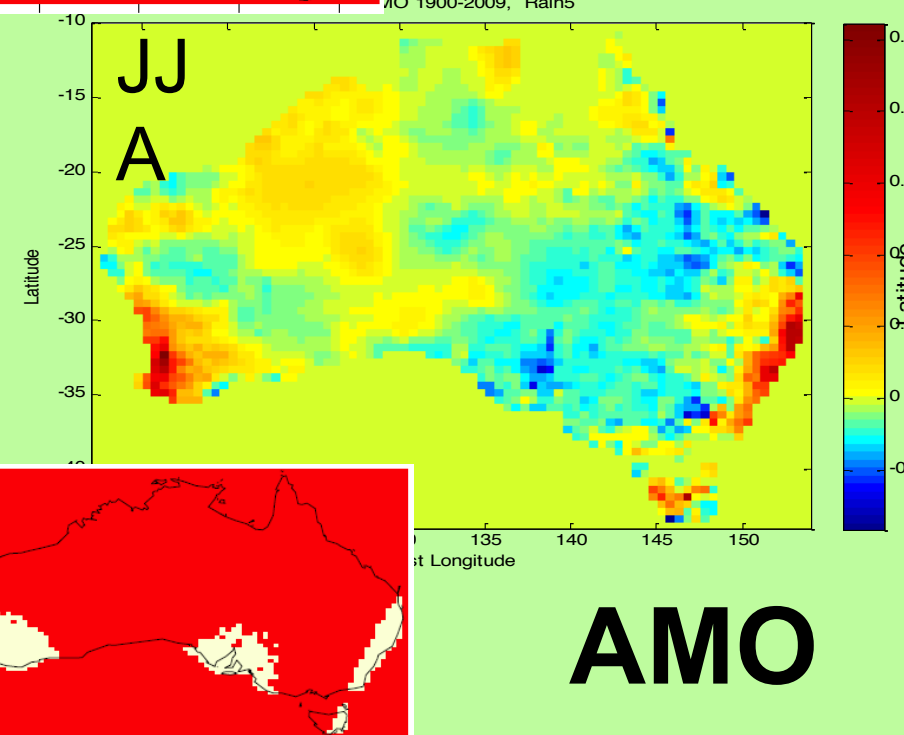
DJF AMO 1900-2009, Rain5



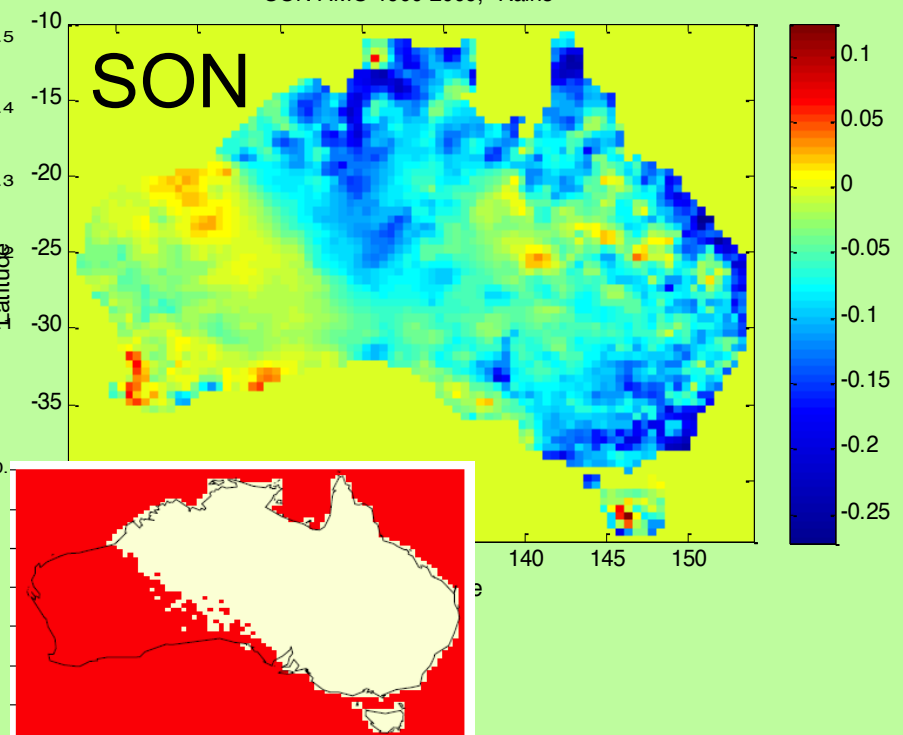
MAM AMO 1900-2009, Rain5.m



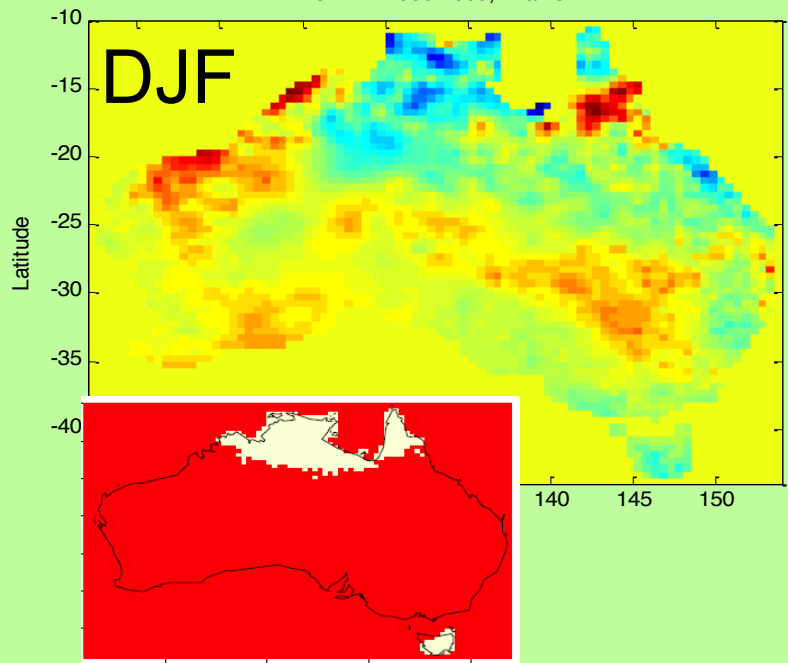
JJA AMO 1900-2009, Rain5



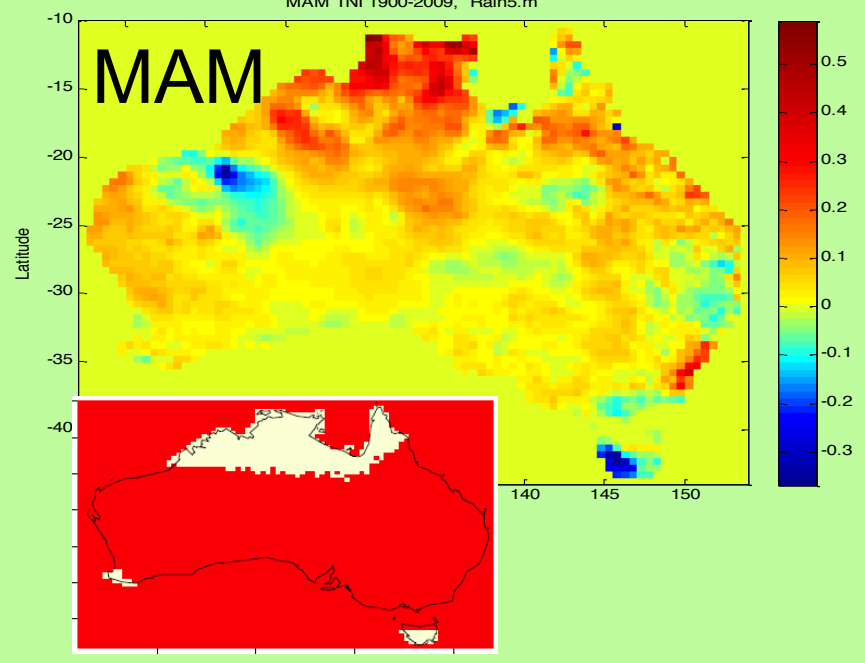
SON AMO 1900-2009, Rain5



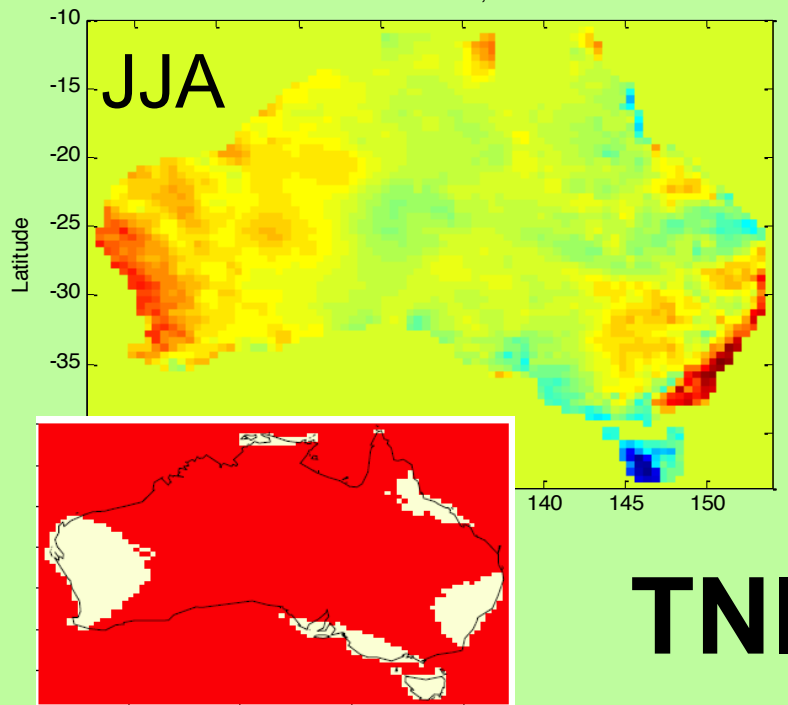
DJF TNI 1900-2009, Rain5



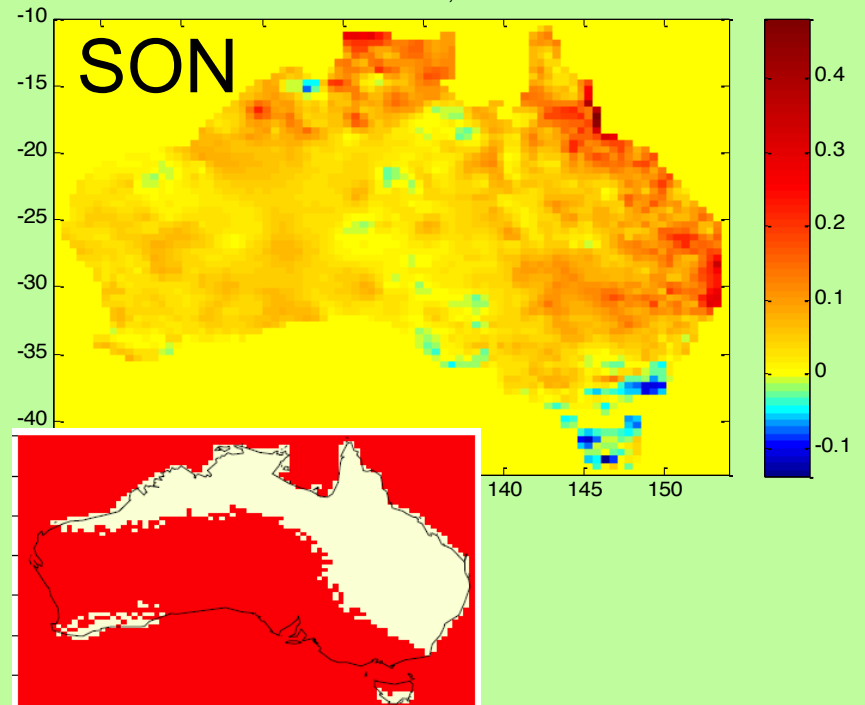
MAM TNI 1900-2009, Rain5.m



JJA TNI 1900-2009, Rain5

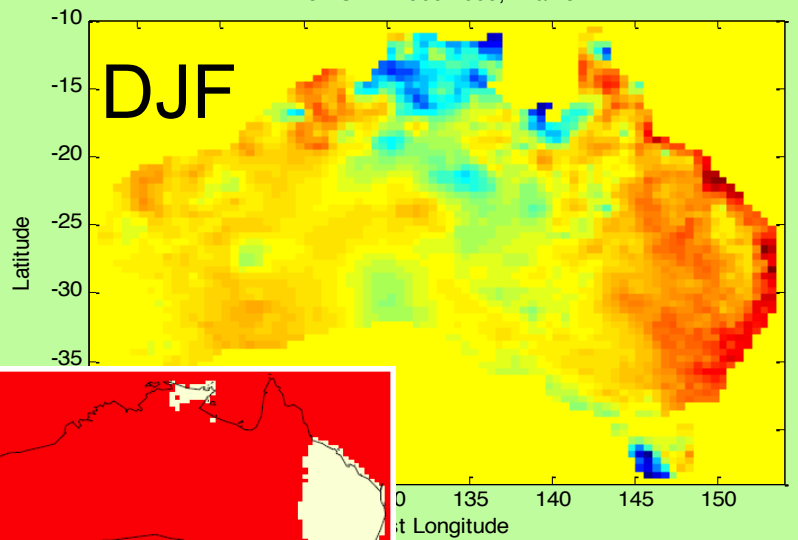


SON TNI 1900-2009, Rain5

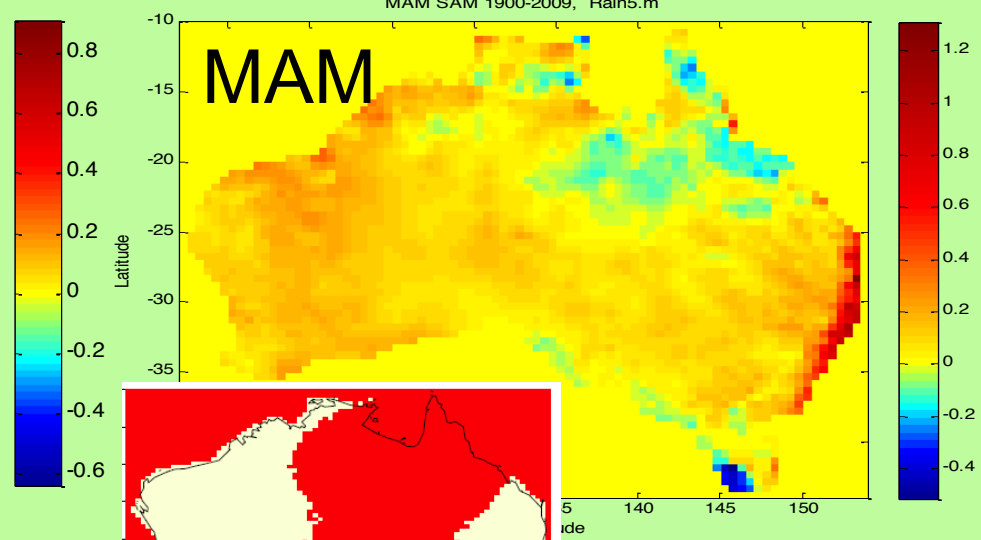


TNI

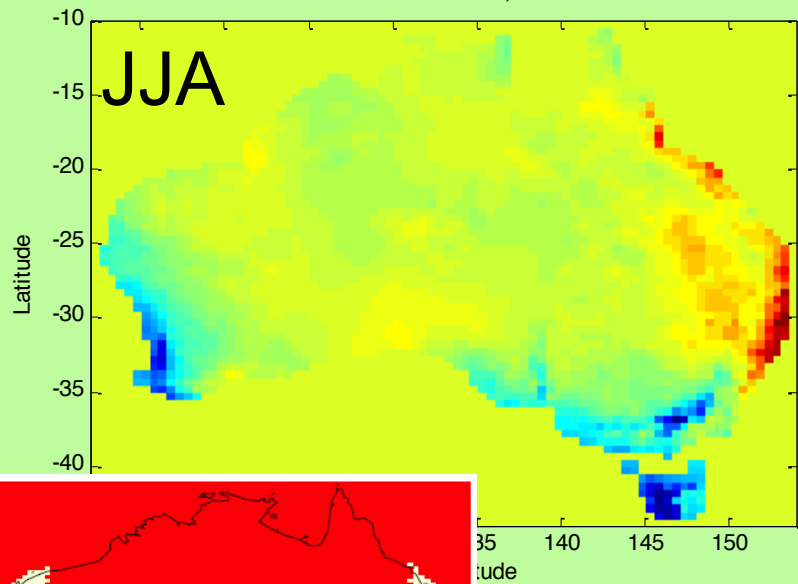
DJF SAM 1900-2009, Rain5



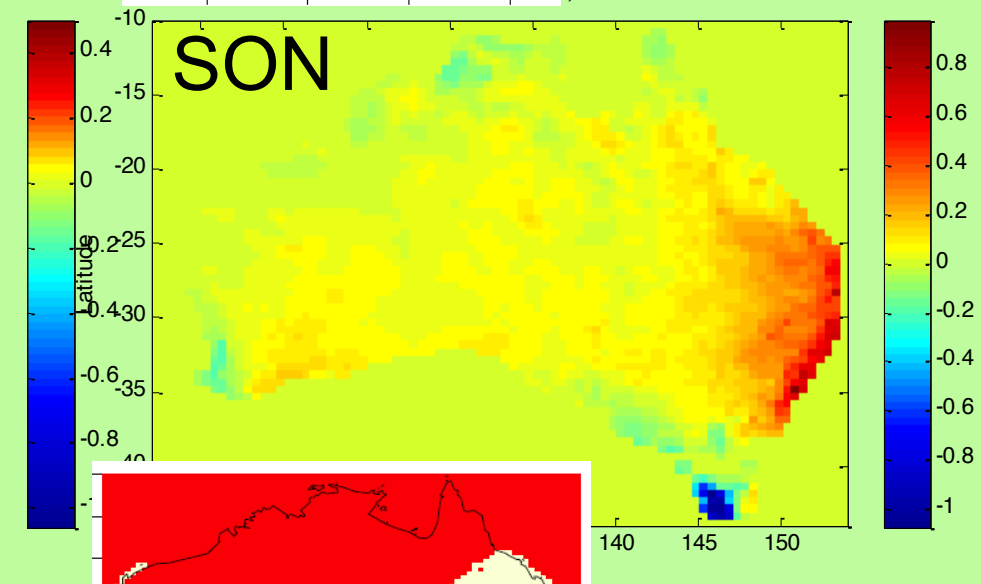
MAM SAM 1900-2009, Rain5.m



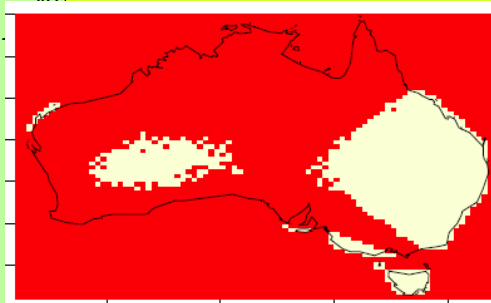
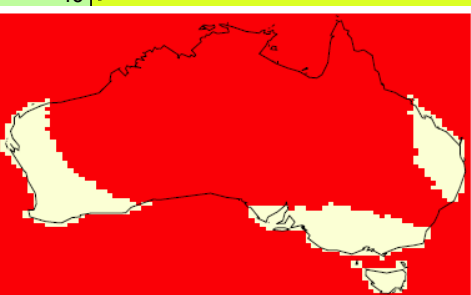
JJA SAM 1900-2009, Rain5



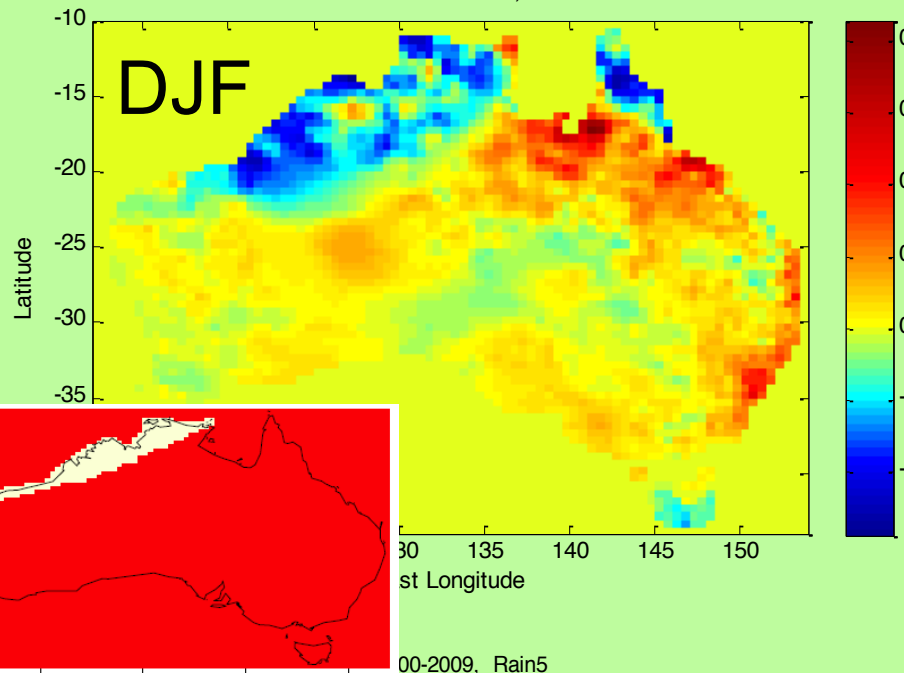
SON SAM 1900-2009, Rain5



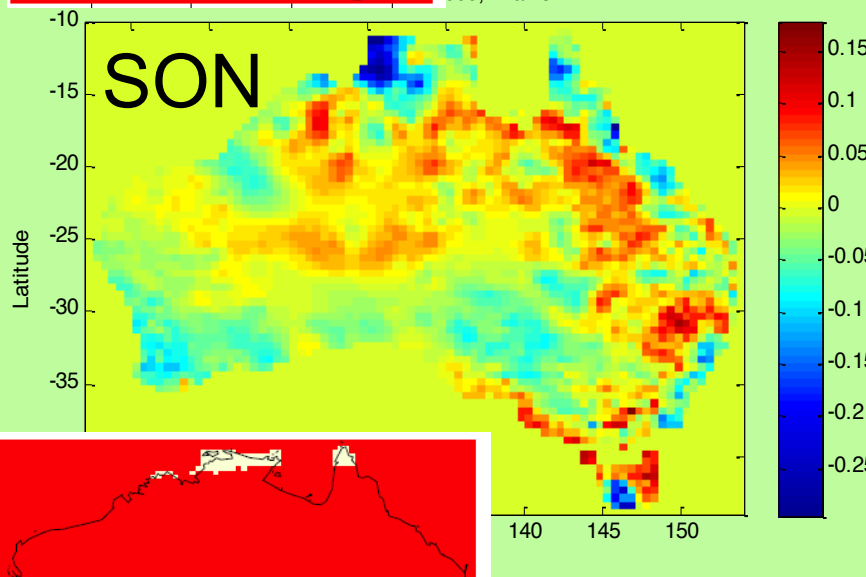
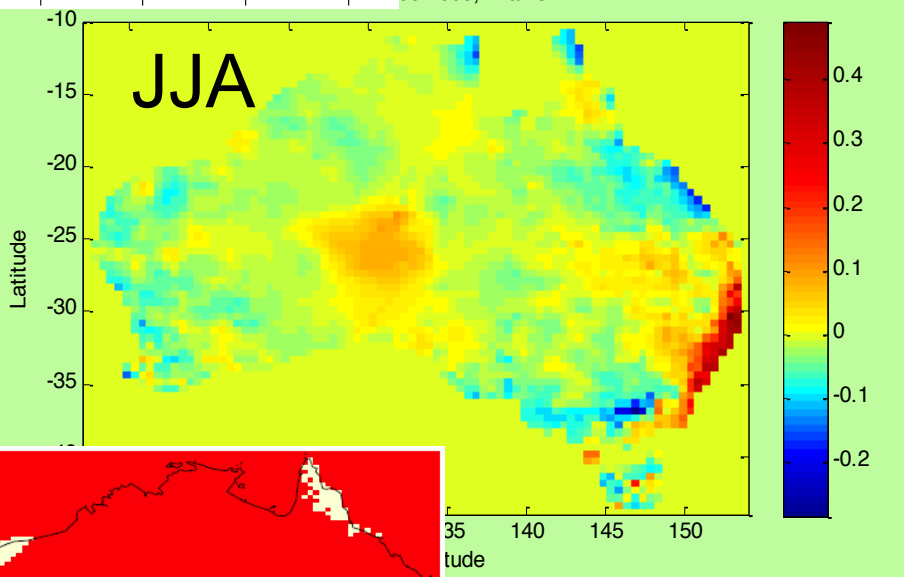
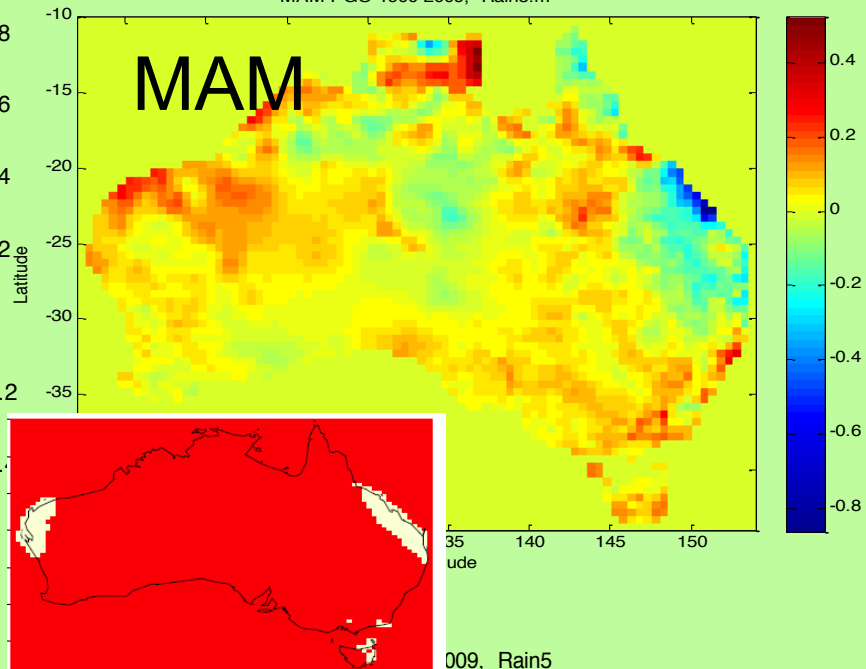
SAM



DJF PGO 1900-2009, Rain5



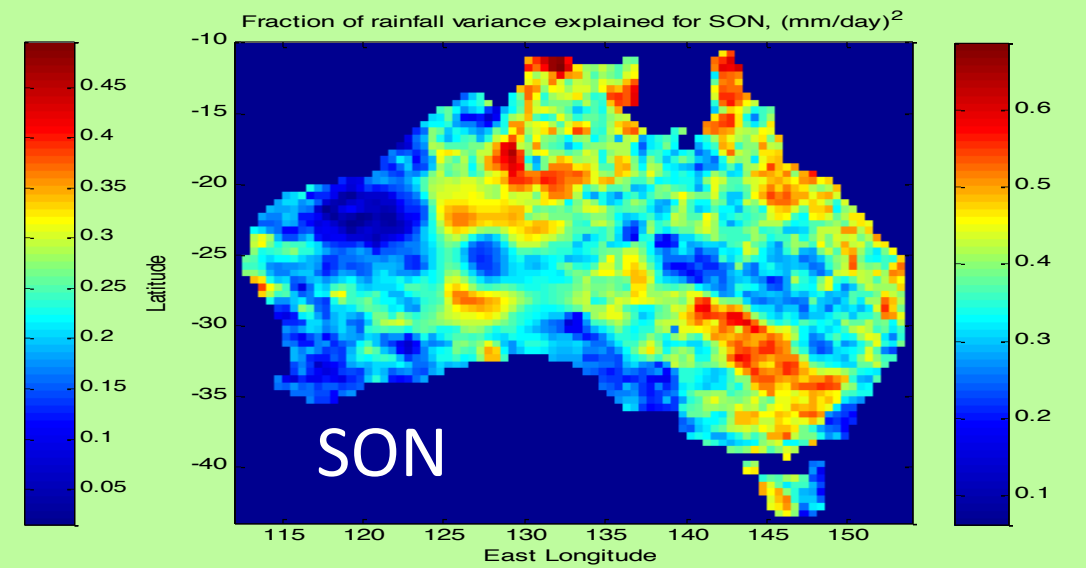
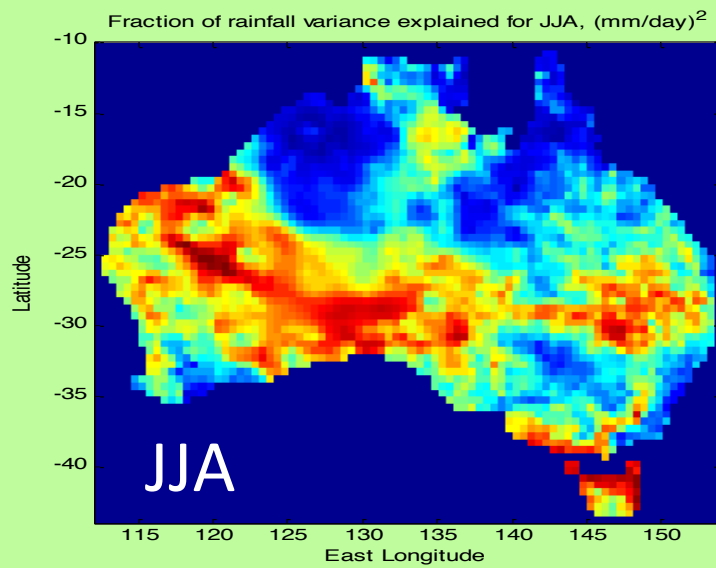
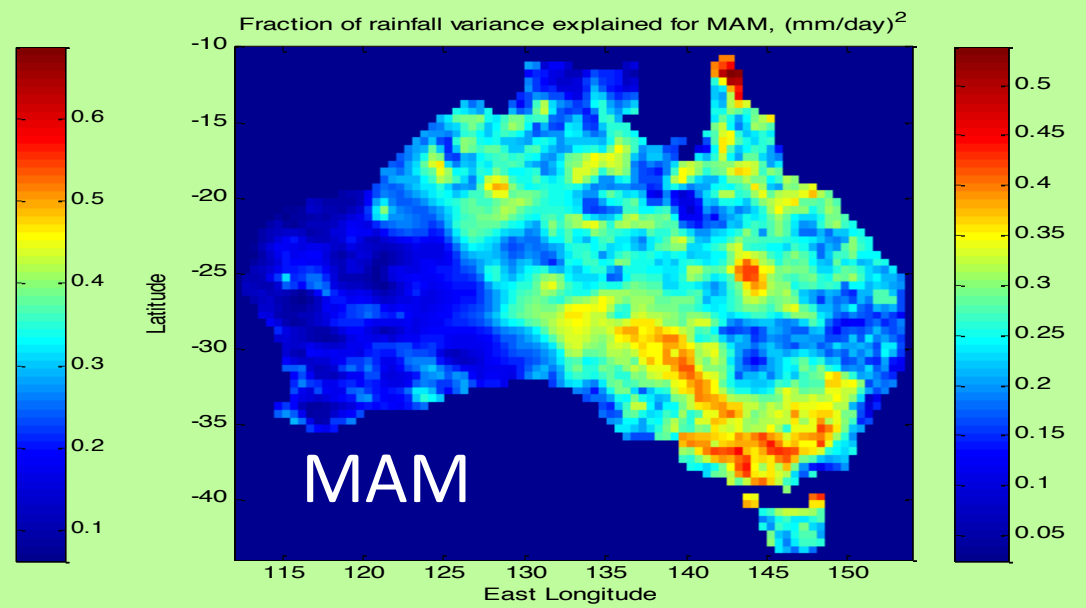
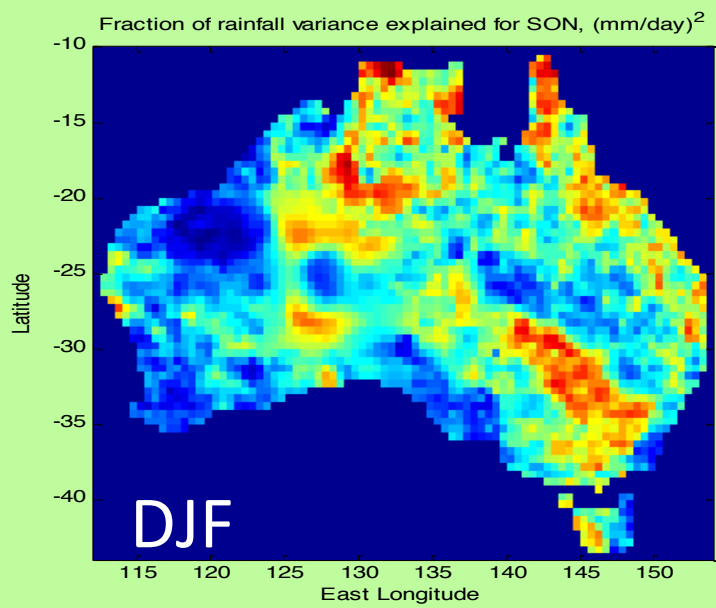
MAM PGO 1900-2009, Rain5.m



PGO

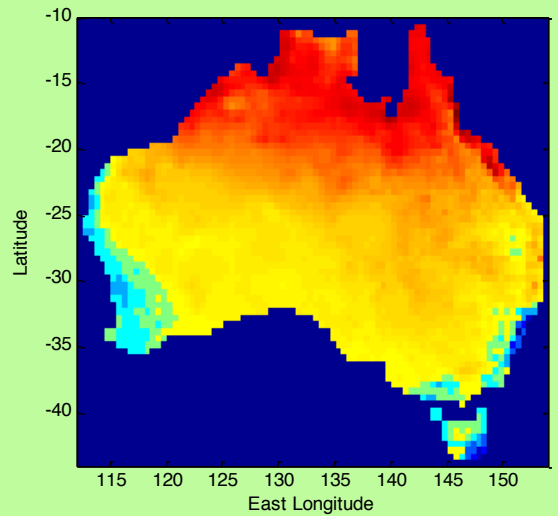
The influence of most of these factors varies considerably from season to season.

But how much of the total variance do they cover?

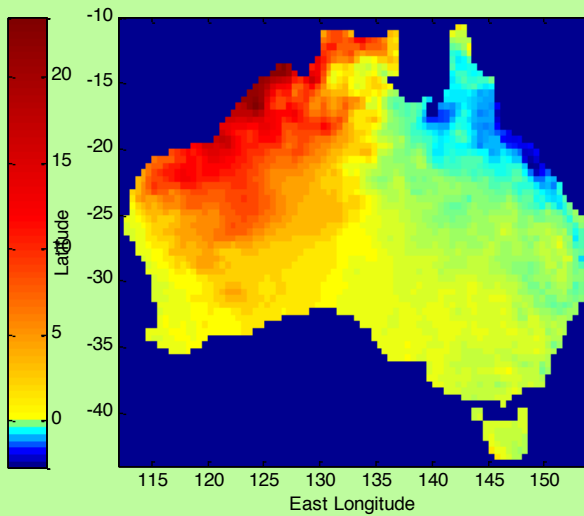


The fraction of variance explained by the sum of the 9 factors, 1950-2009.

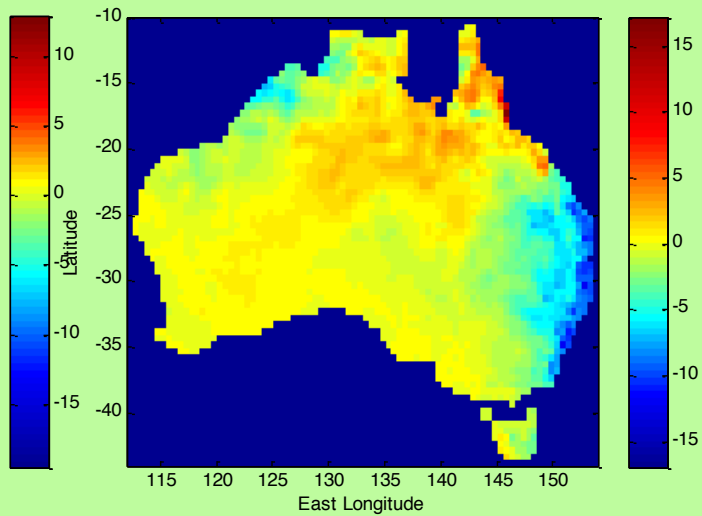
DJF - EOF1 of Residual rainfall



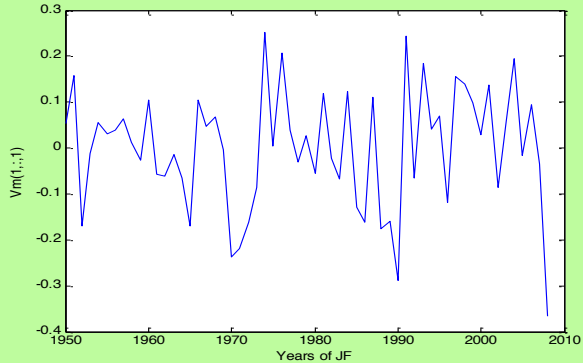
DJF - EOF2 of Residual rainfall



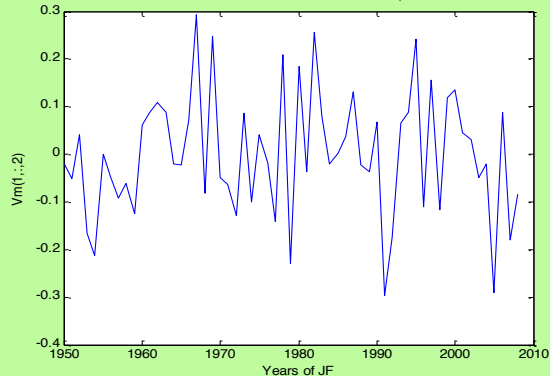
DJF - EOF3 of Residual rainfall



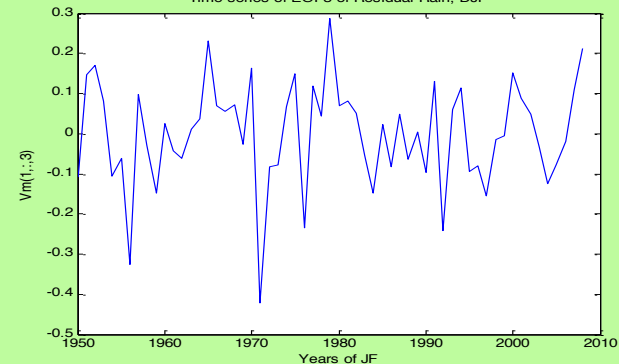
Time series of EOF1 of Residual Rain



Time series of EOF2 of Residual Rain, DJF



Time series of EOF3 of Residual Rain, DJF



Proportion of Variance of the residual rainfall:

31.6%

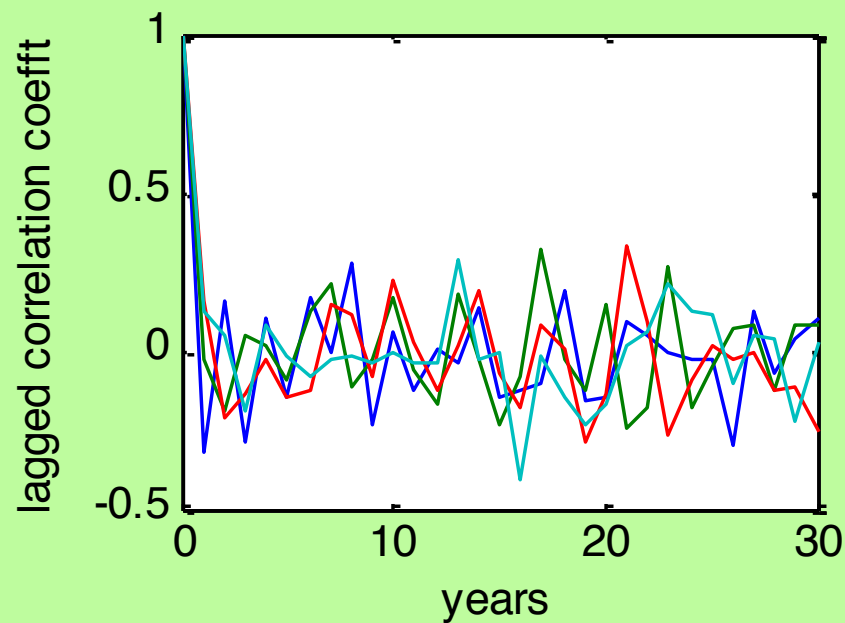
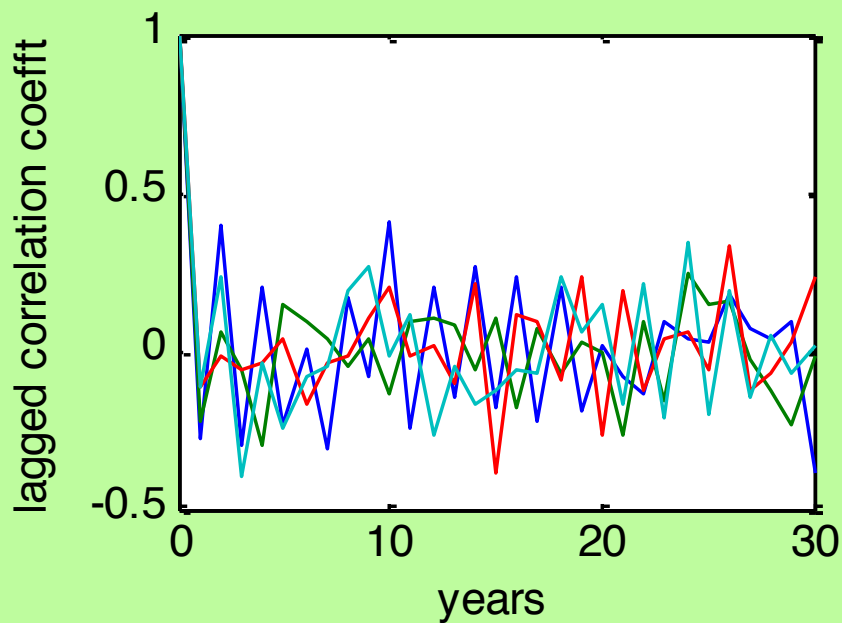
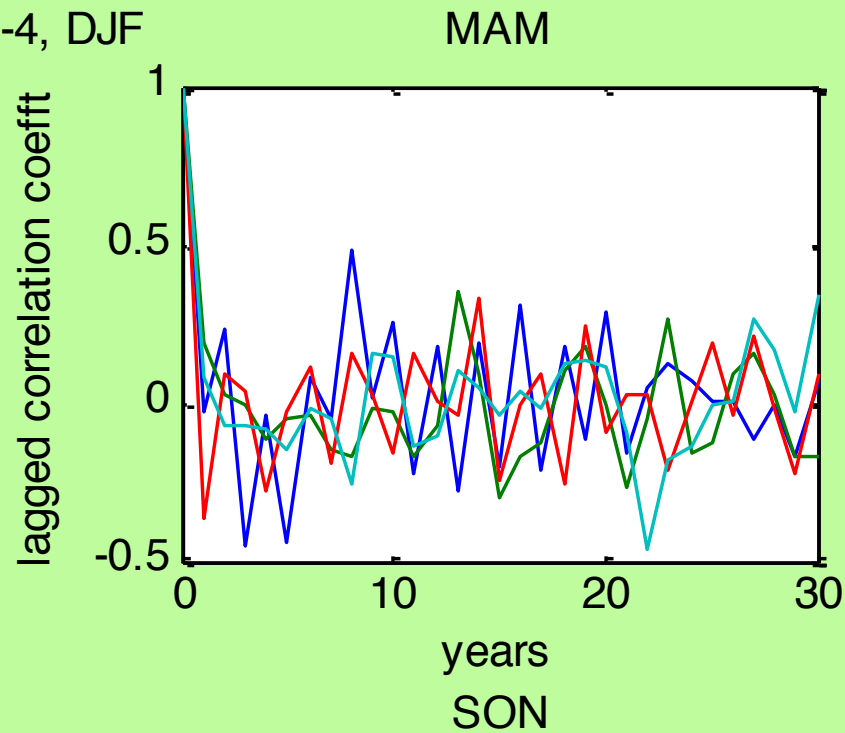
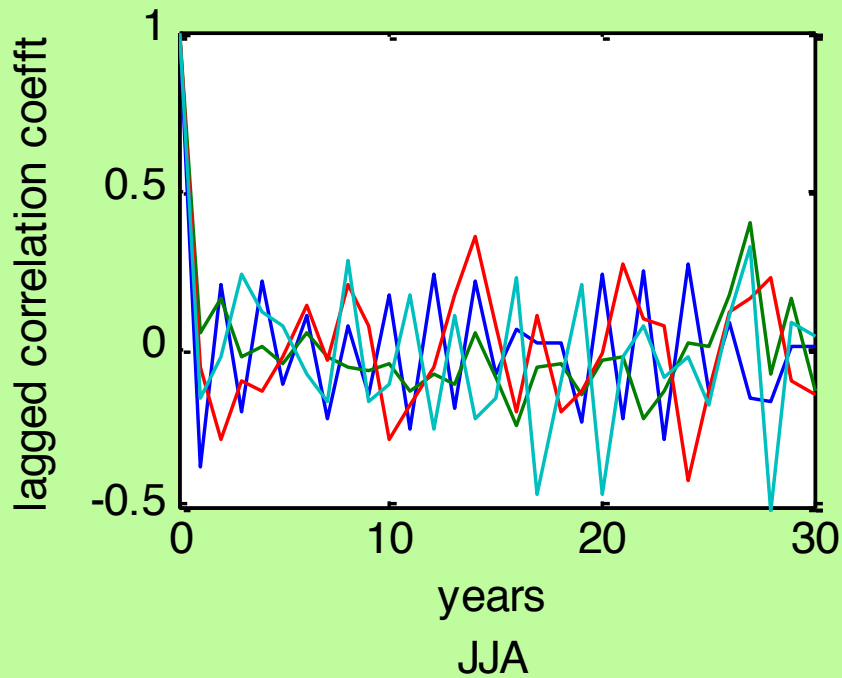
12.5%

7.8%

EOFs 1, 2 and 3 of the Residual Rainfall for **DJF**, after removal of the 9 factors.

Units: mm/day

Resid rain 1949-2009, lagged corr. EOFs 1-4, DJF



Features of the Australian Analysis.

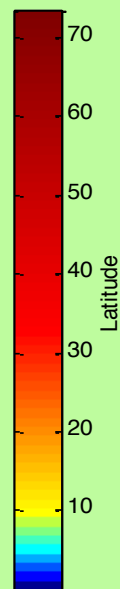
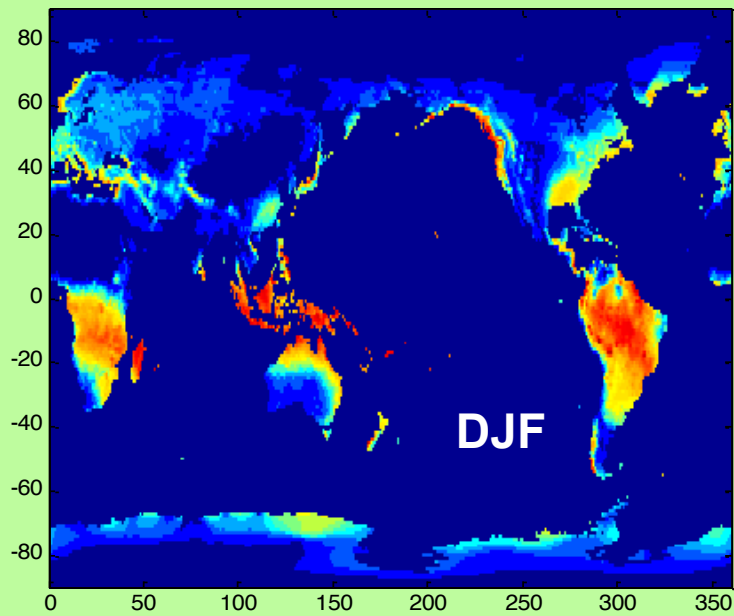
1. The Indian Ocean Dipole (in positive phase) gives increased rainfall in Northern Australia in DJF, but reduced rainfall in the coastal regions of Queensland in MAM, and reduced rainfall in the continental southeast in JJA and SON.
2. The presence of sunspots is associated with more rainfall in eastern Australia in MAM, but less in SON.
3. The Atlantic Meridional/Multidecadal Oscillation is associated with reduced rainfall in Northern Australia in DJF, MAM and SON.
4. The positive phase of the Southern Annular mode is associated with reduced rainfall in Tasmania in all seasons, and in the southern part of the continent in JJA.
5. The positive phase of the PGO is associated with reduced rainfall in northern Australia in DJF and MAM.
6. As expected, a positive Nino3.4 index is associated with reduced rainfall in Northern Australia in SON, DJF and MAM, and reduced rainfall in Eastern Australia in JJA and SON.
7. The Trans Nino Index in positive phase is associated with increased rainfall in Northern Australia in MAM, and in eastern Australia in SON.

Next, we consider a global analysis covering the period 1950-2008, when the overall quality of data is expected to be better. This applies particularly to the PGO.

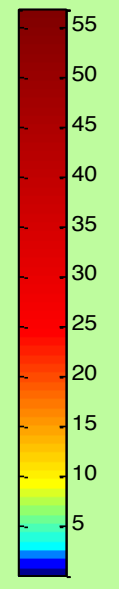
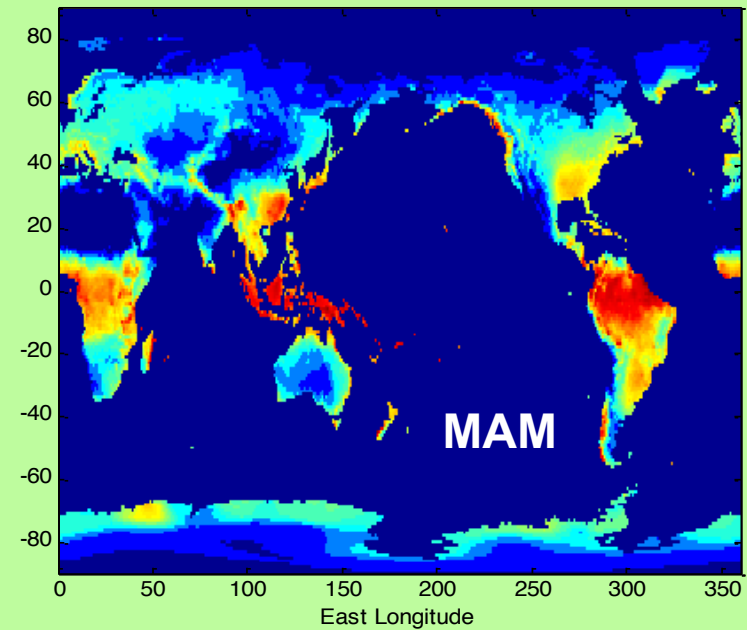
The results are plotted in two parts, for better visualisation – first we show results for Eurasia, and then for the Americas.

I do not have significance plots for the following results, but in general the regions shown in red or blue are expected to be significant, whereas those in orange, yellow or green are not.

UDelaware Rainfall data, Mean for DJF, 1900-2008, mm/day

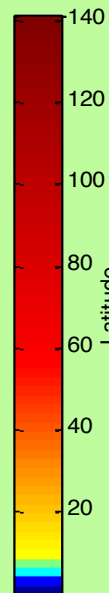
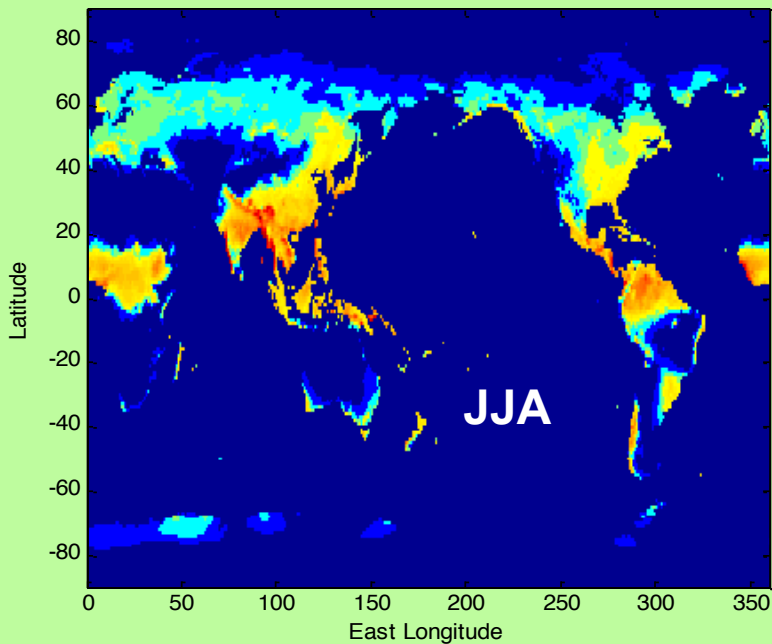


UDelaware Rainfall data, Mean for MAM, 1900-2008

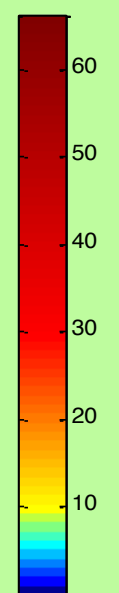
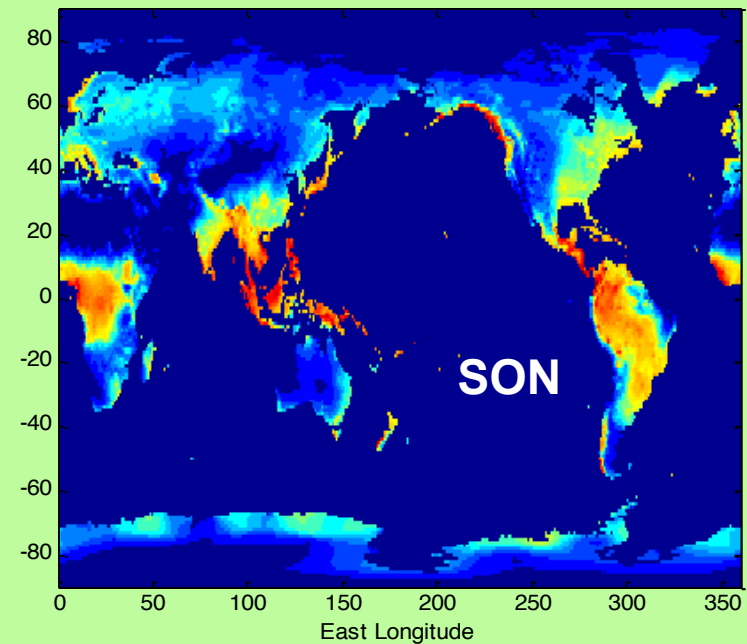


Mean Seasonal Rainfall

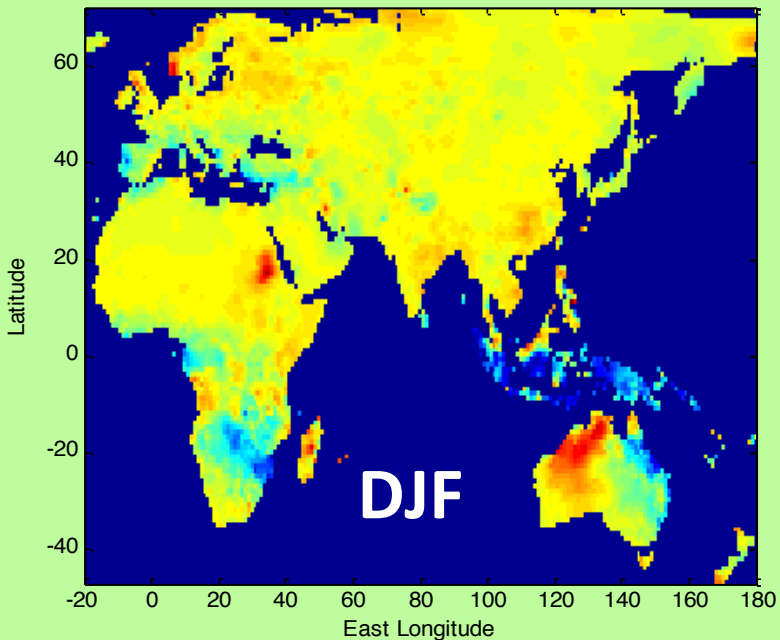
UDelaware Rainfall data, Mean for JJA, 1900-2008



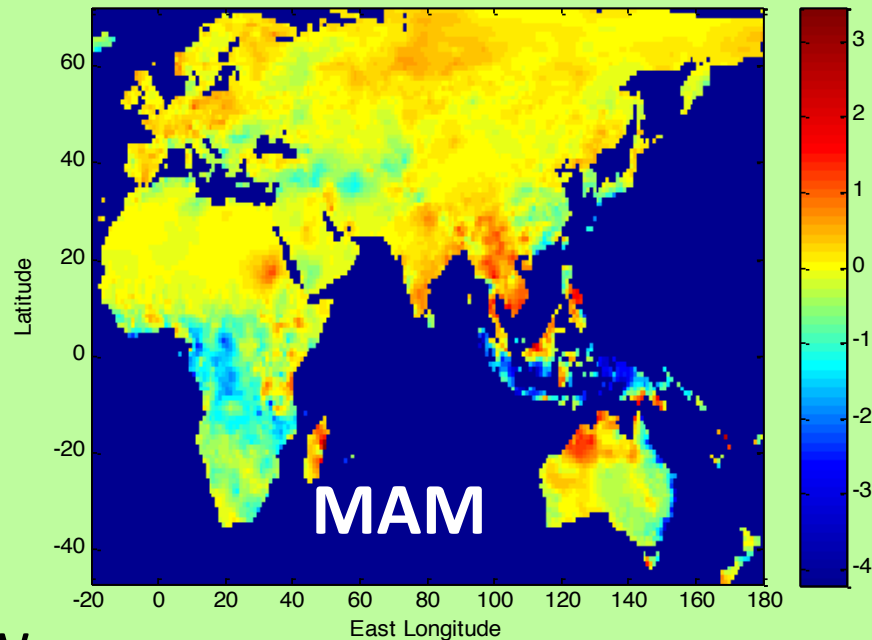
UDelaware Rainfall data, Mean for SON, 1900-2008, mm/day



Regression Coeffts for Pacific GW on Rainfall, Udel1deg DJF 1950-2008



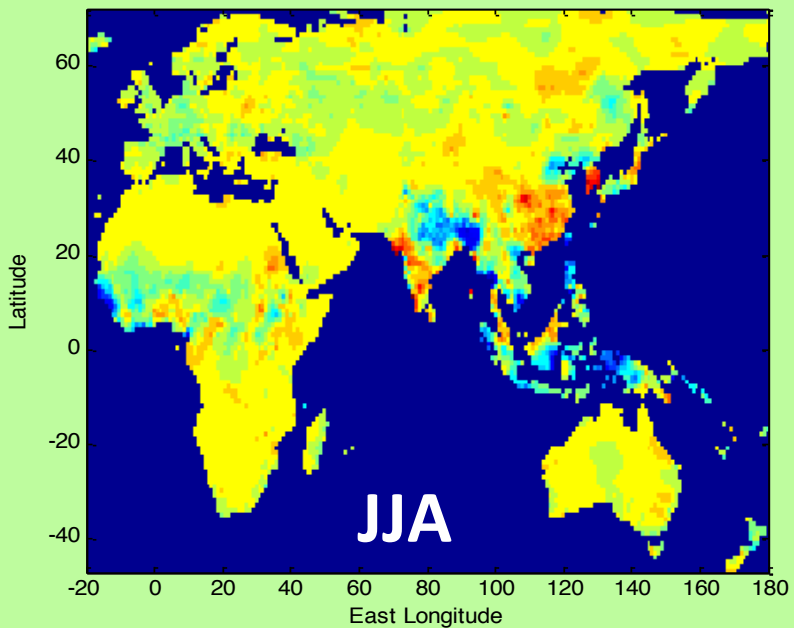
Regression Coeffts for Pacific GW on Rainfall, Udel1deg MAM 1950-2008



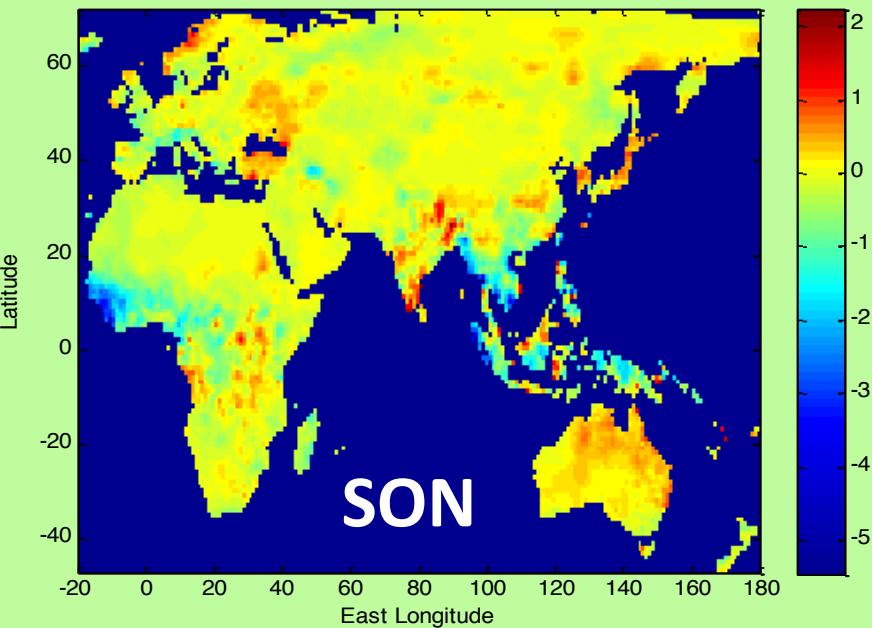
GW

1950-2008

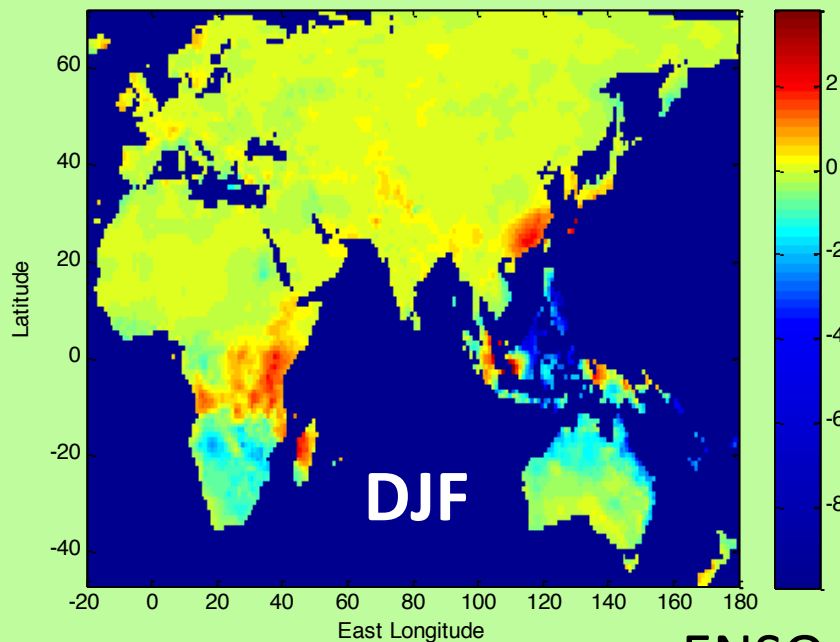
Regression Coeffts for Pacific GW on Rainfall, Udel1deg JJA 1950-2008



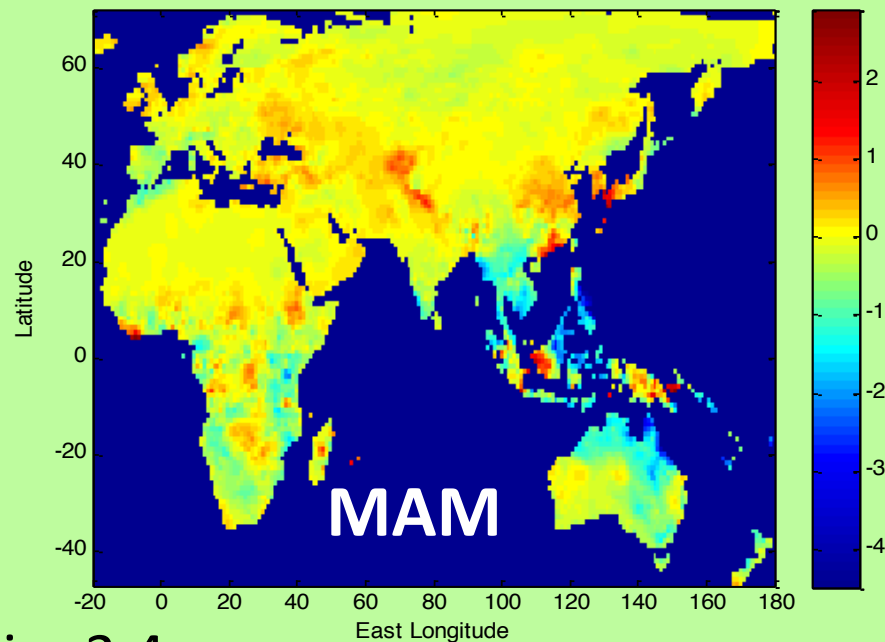
Regression Coeffts for Pacific GW on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for ENSO Nino3.4 Index on Rainfall, Udel1deg DJF 1950-2008



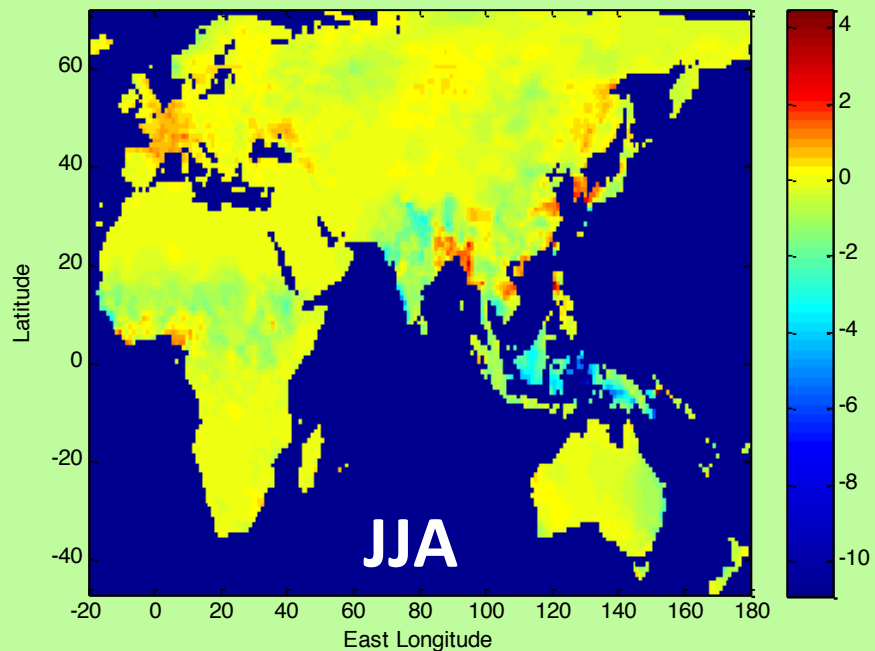
Regression Coeffts for ENSO Nino3.4 Index on Rainfall, Udel1deg MAM 1950-2008



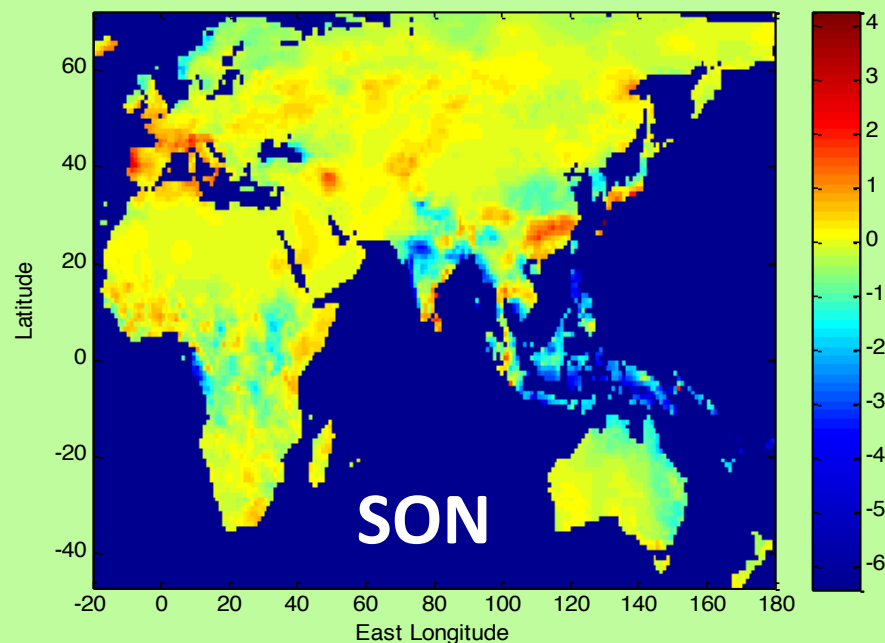
ENSO-Nino3.4

1950-2008

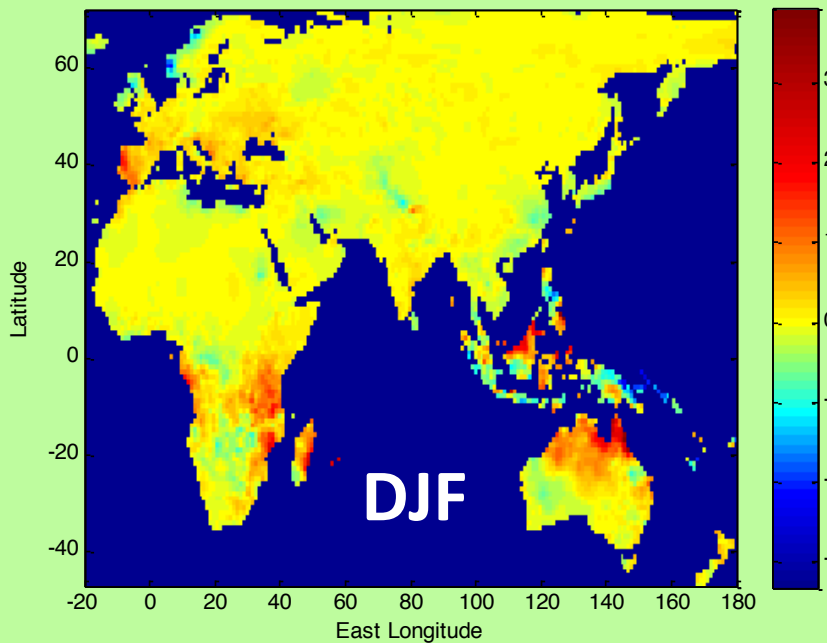
Regression Coeffts for ENSO Nino3.4 Index on Rainfall, Udel1deg JJA 1950-2008



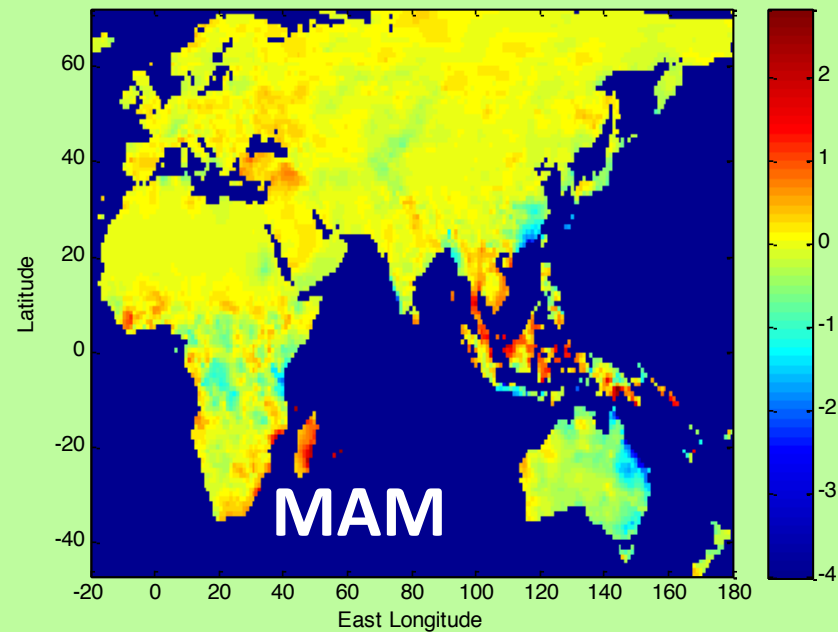
Regression Coeffts for ENSO Nino3.4 Index on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Indian Ocean Dipole on Rainfall, Udel1deg DJF 1950-2008



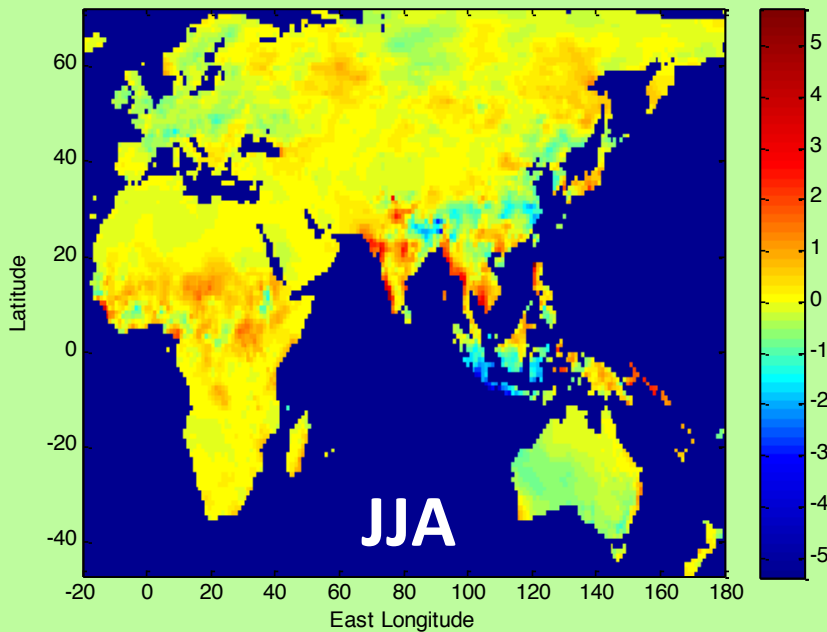
Regression Coeffts for Indian Ocean Dipole on Rainfall, Udel1deg MAM 1950-2008



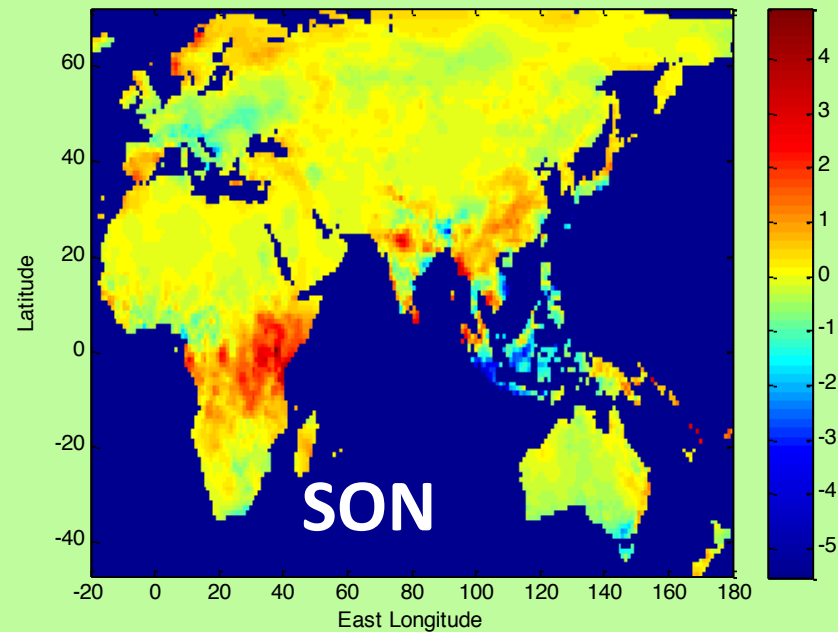
IOD Index

1950-2008

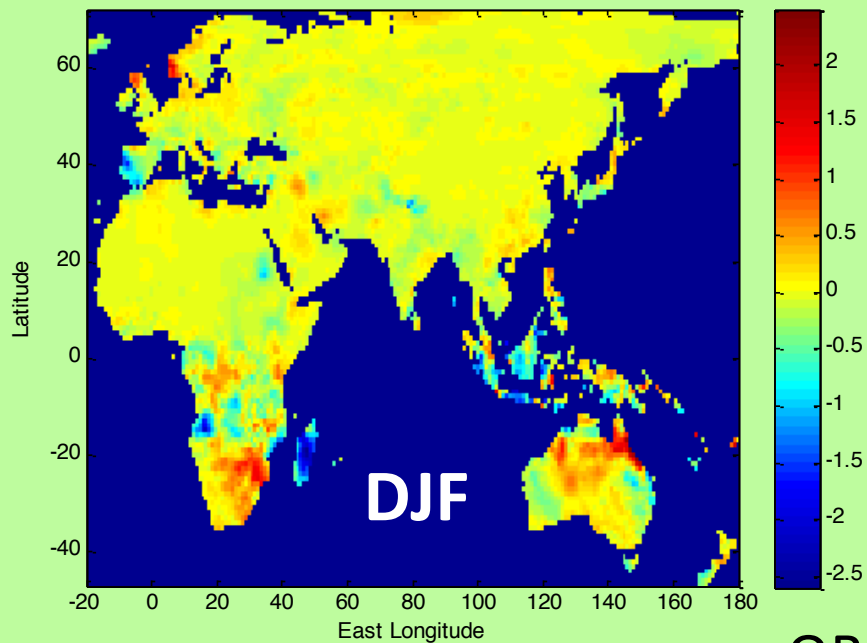
Regression Coeffts for Indian Ocean Dipole on Rainfall, Udel1deg JJA 1950-2008



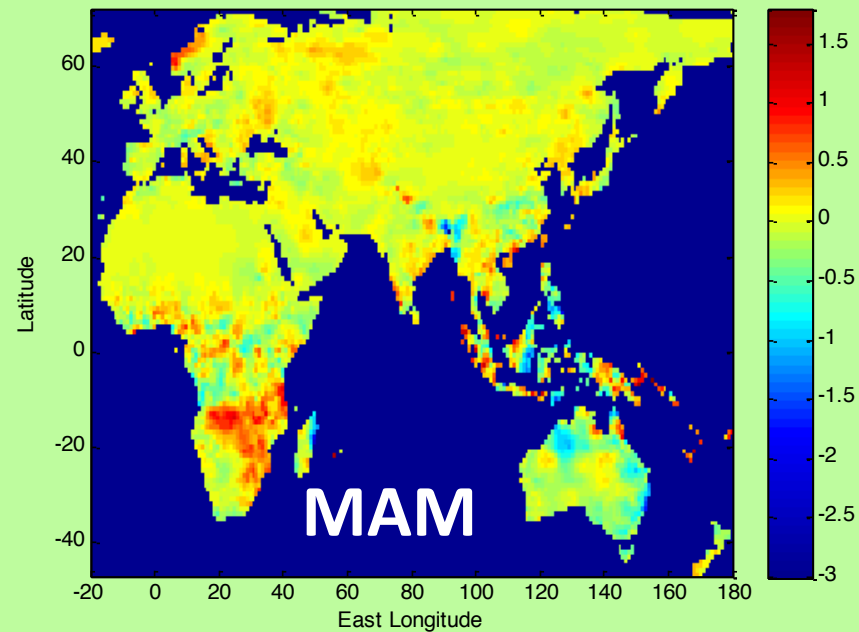
Regression Coeffts for Indian Ocean Dipole on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg DJF 1950-2008



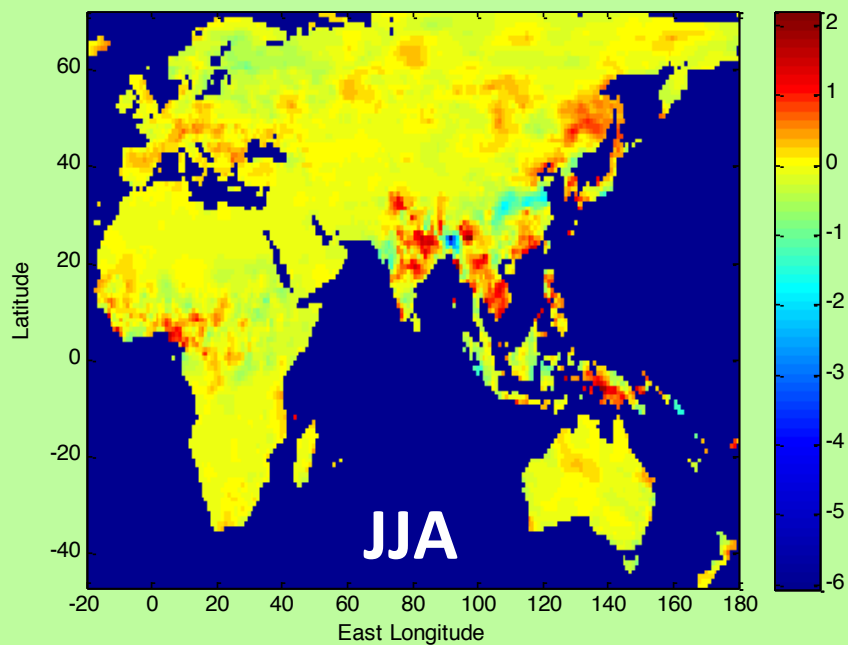
Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg MAM 1950-2008



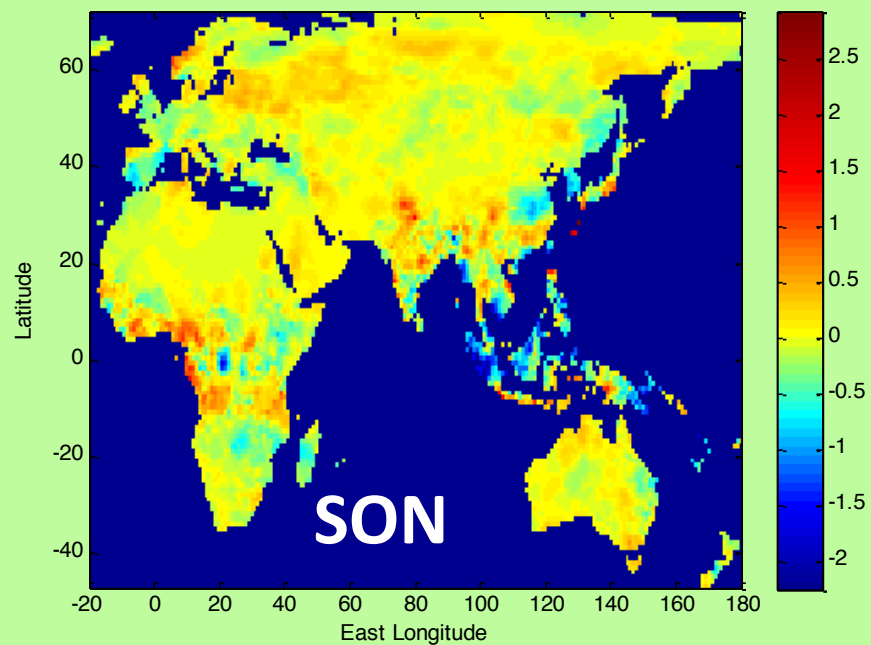
QBO

1950-2008

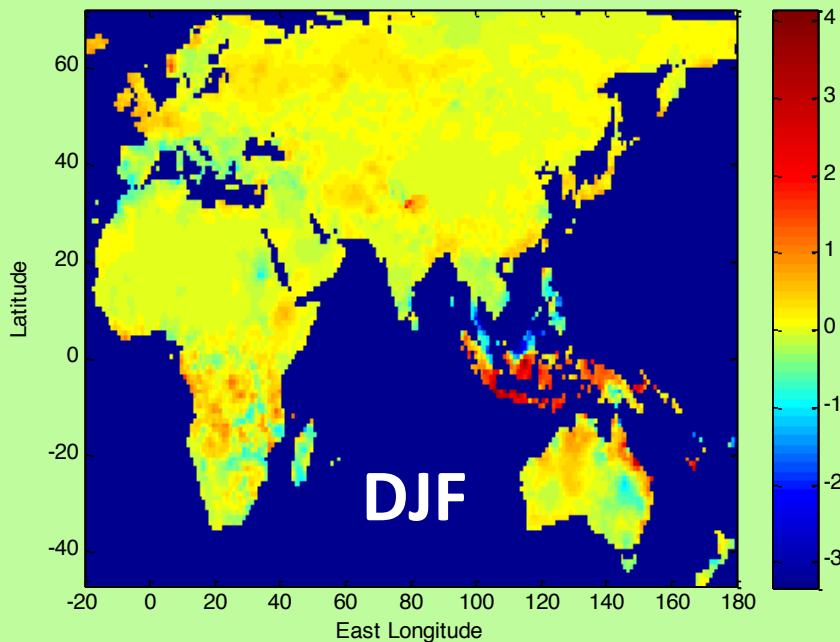
Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg JJA 1950-2008



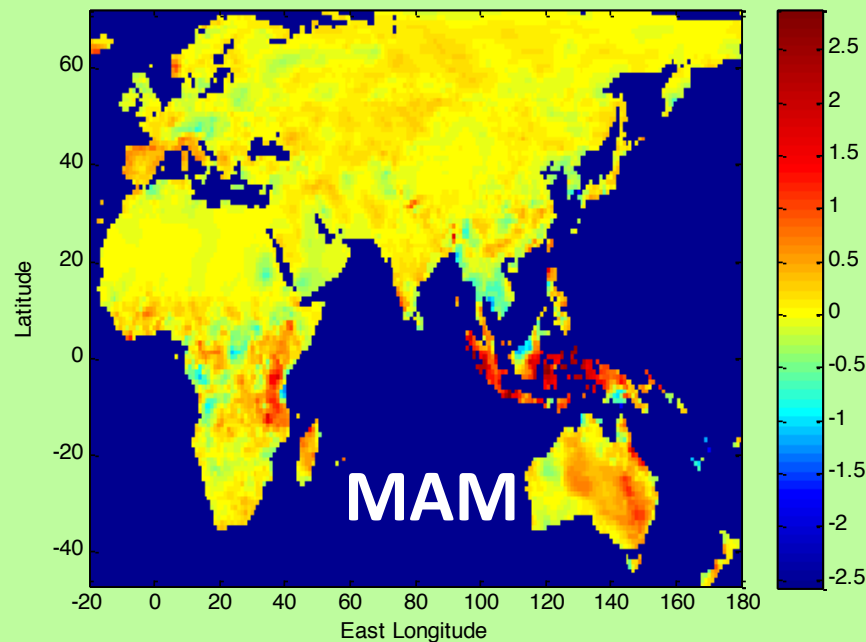
Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Sunspot Number on Rainfall, Udel1deg DJF 1950-2008



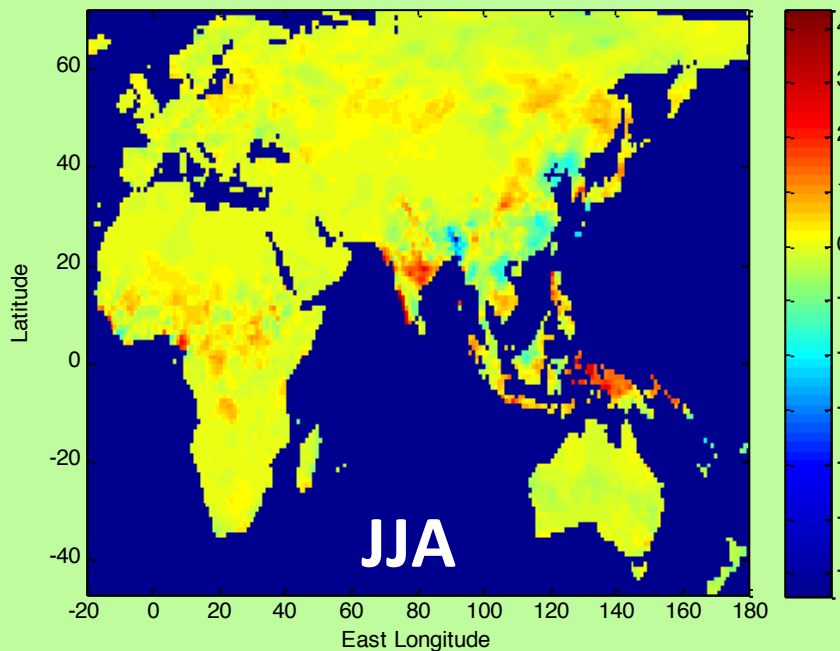
Regression Coeffts for Sunspot Number on Rainfall, Udel1deg MAM 1950-2008



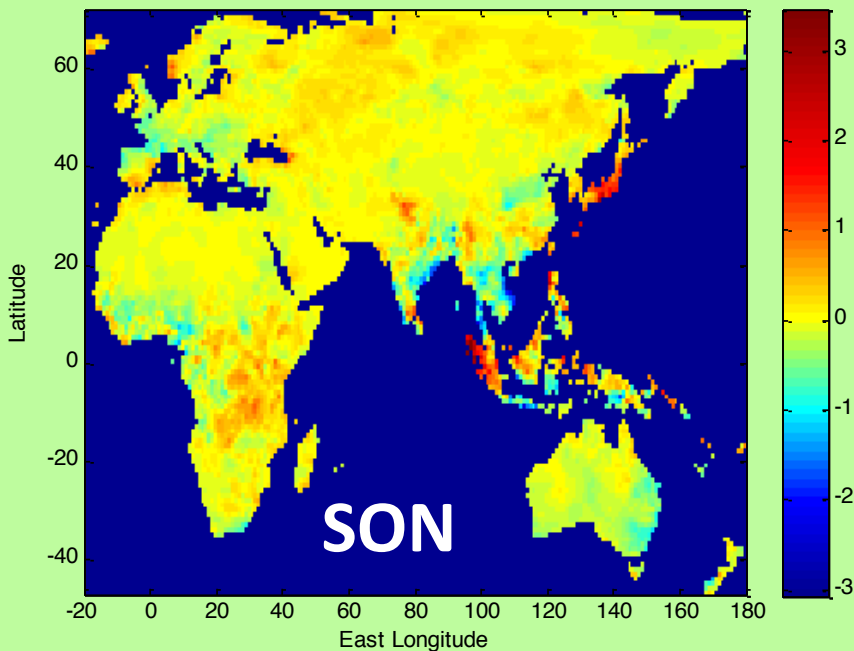
1950-2008

Sunspot Number

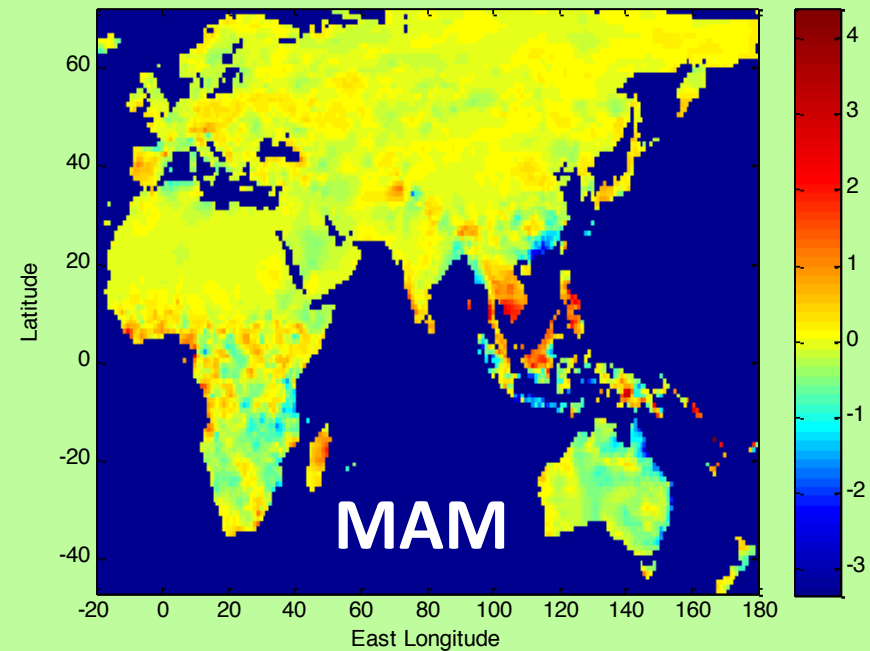
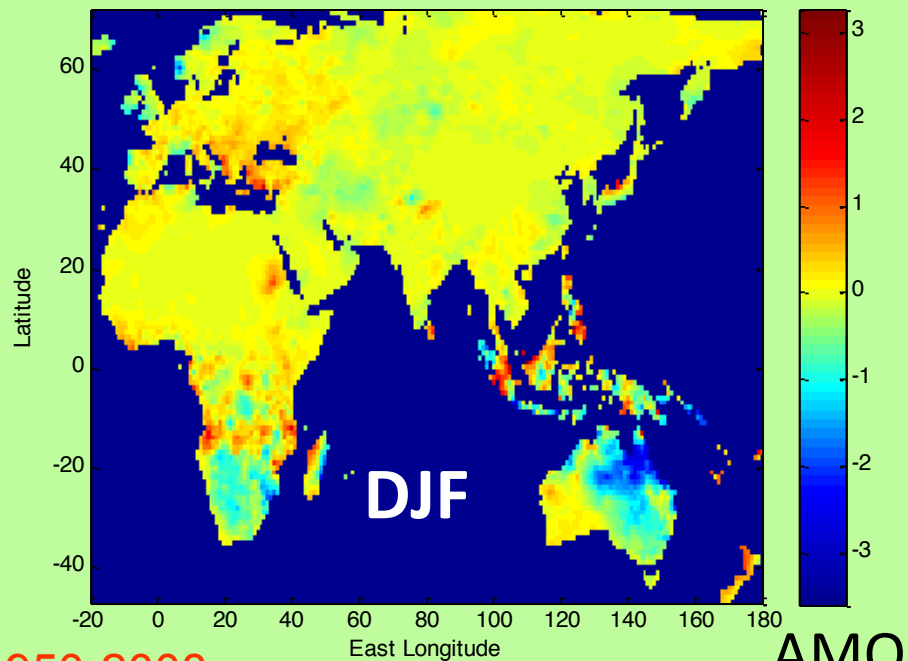
Regression Coeffts for Sunspot Number on Rainfall, Udel1deg JJA 1950-2008



Regression Coeffts for Sunspot Number on Rainfall, Udel1deg SON 1950-2008



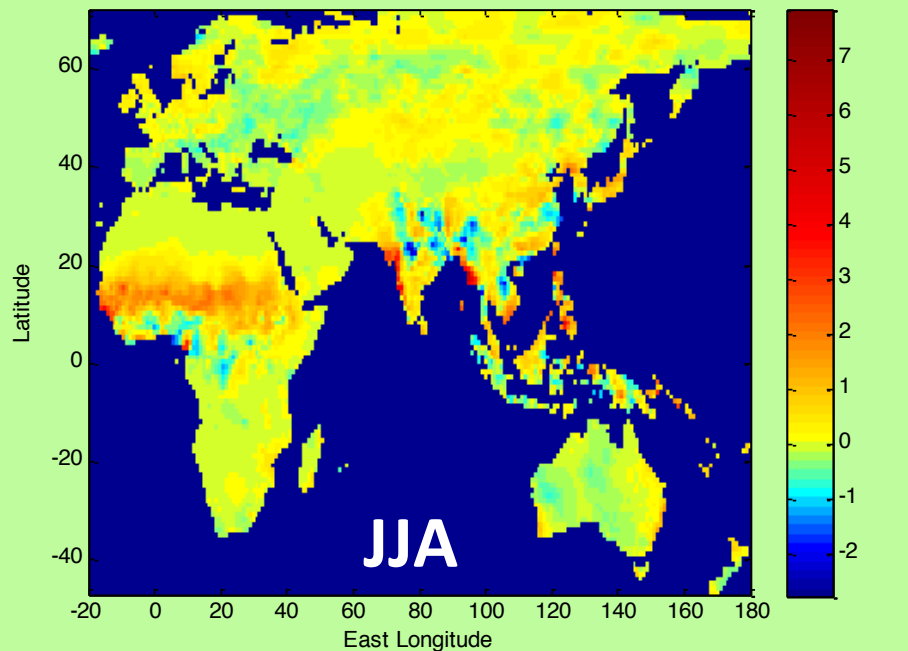
Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg DJF 1950-2008



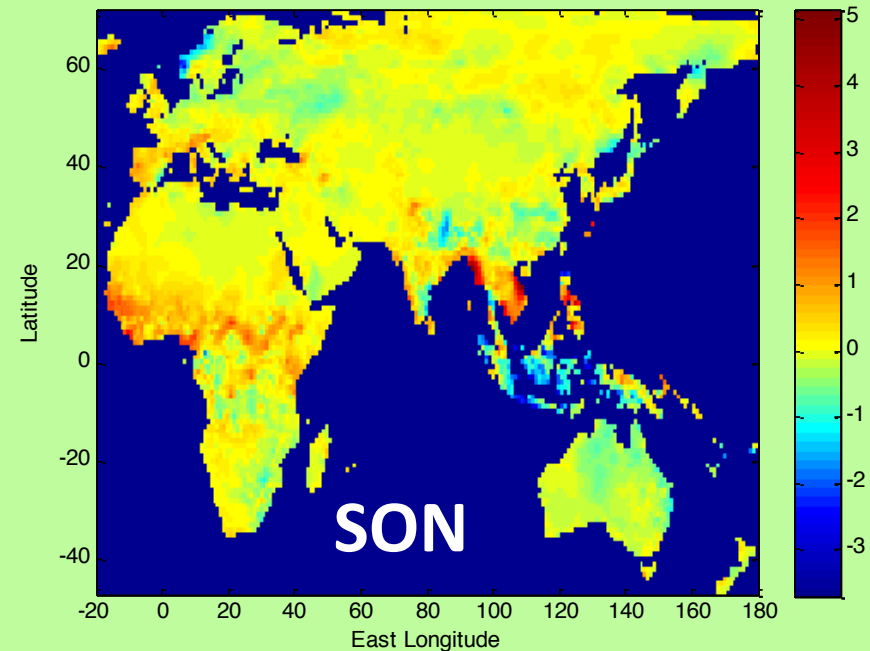
1950-2008

AMO

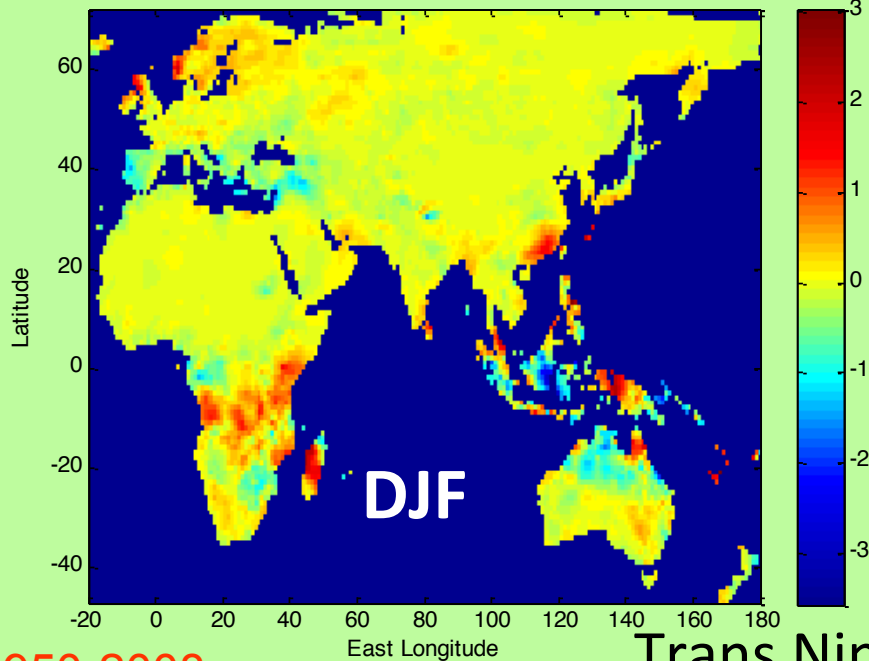
Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg JJA 1950-2008



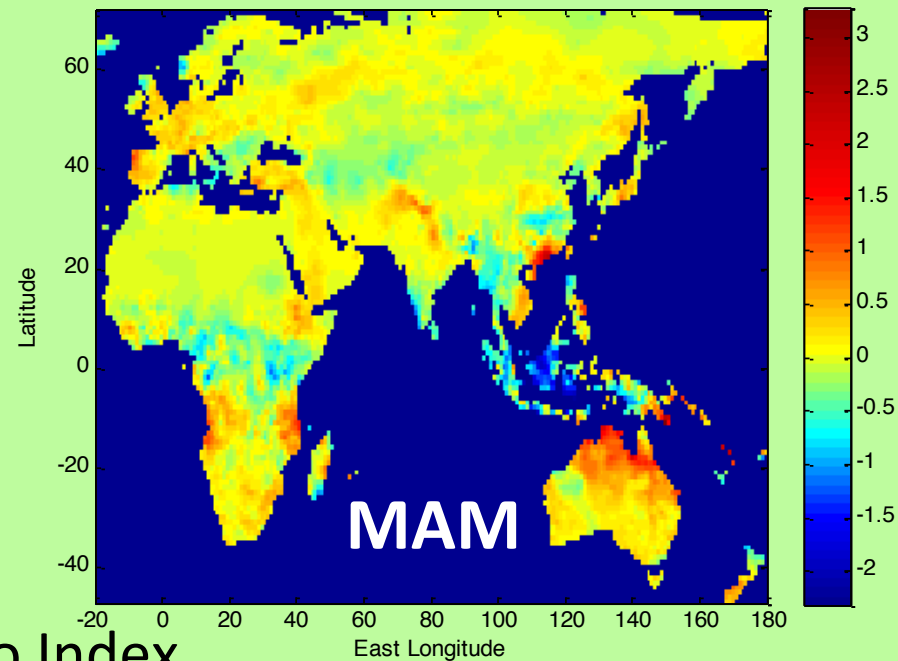
Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg DJF 1950-2008



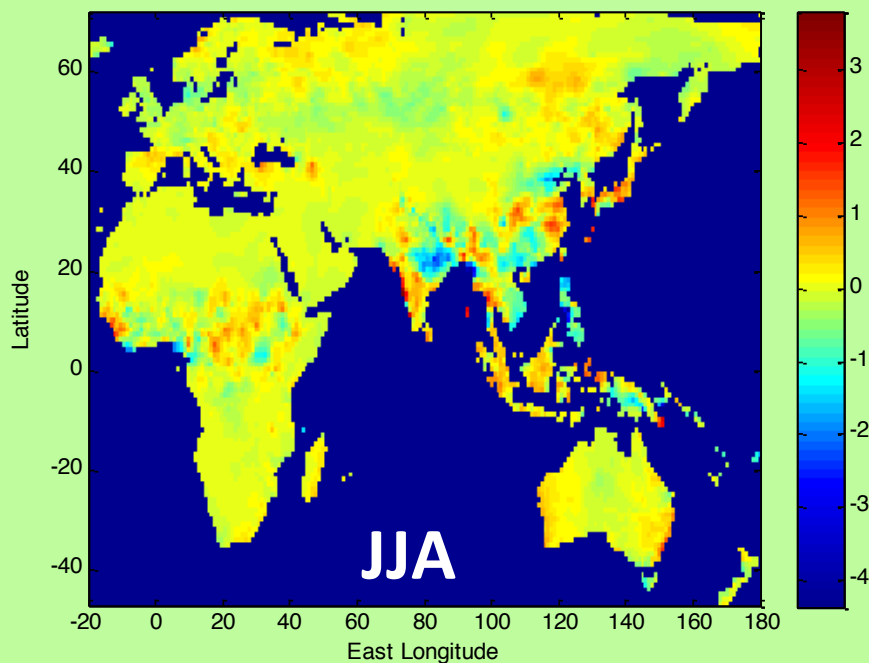
Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg MAM 1950-2008



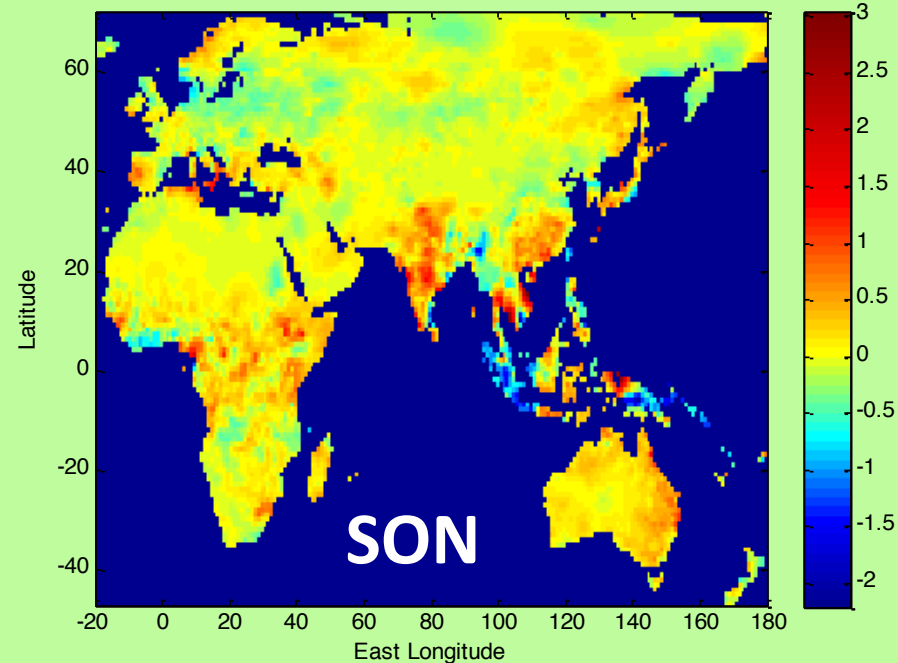
1950-2008

Trans Nino Index

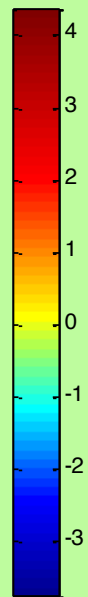
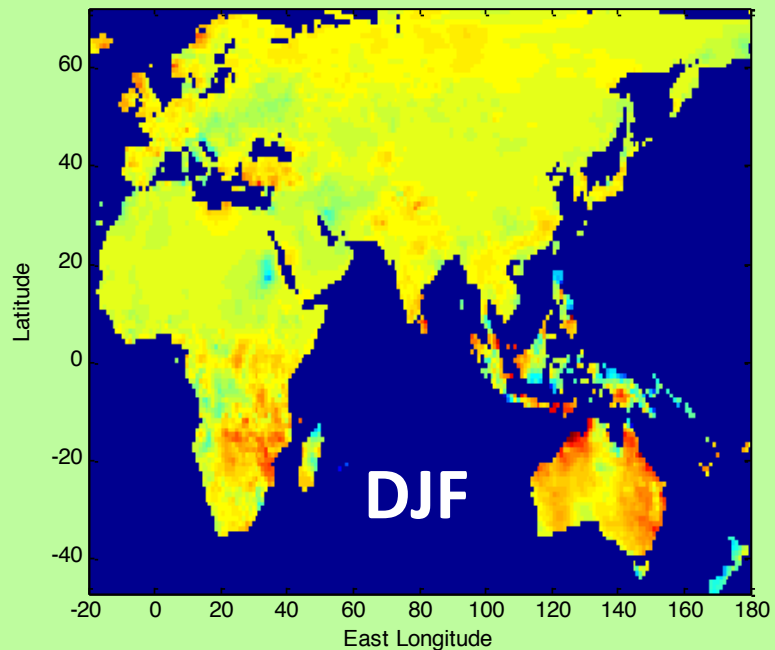
Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg JJA 1950-2008



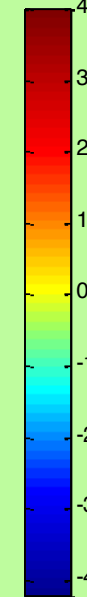
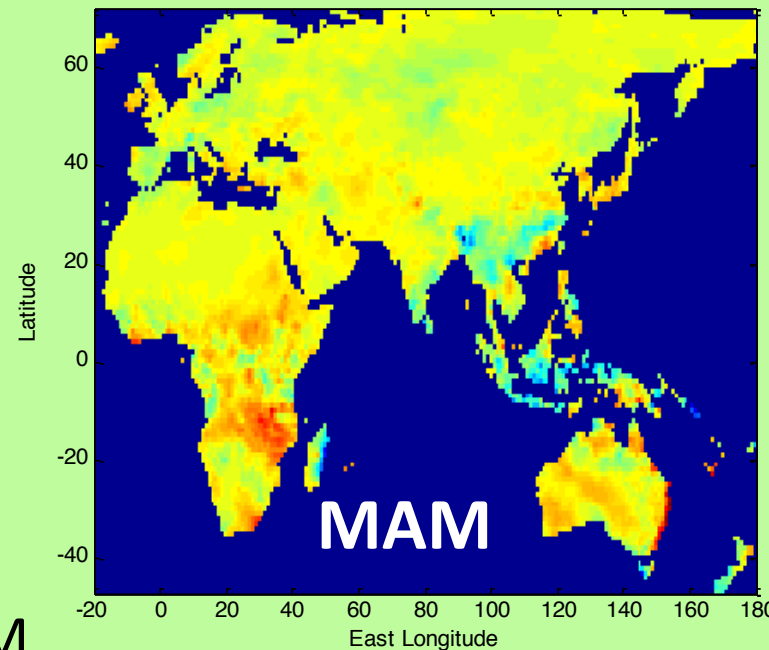
Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Southernn Annular mode on Rainfall, Udel1deg DJF 1950-2008



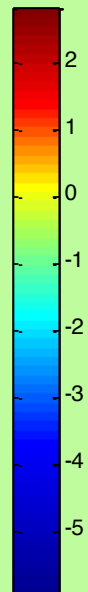
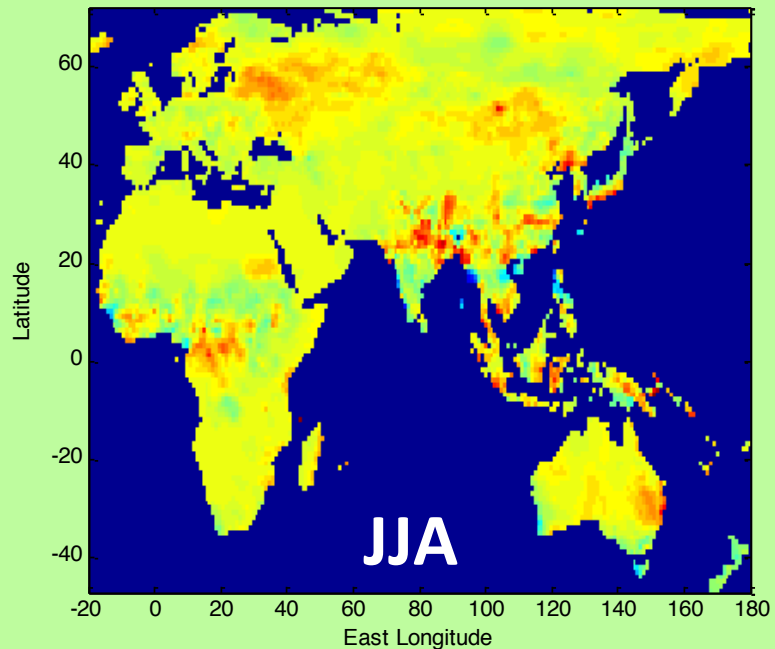
Regression Coeffts for Southernn Annular mode on Rainfall, Udel1deg MAM 1950-2008



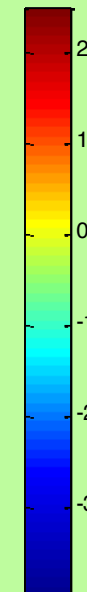
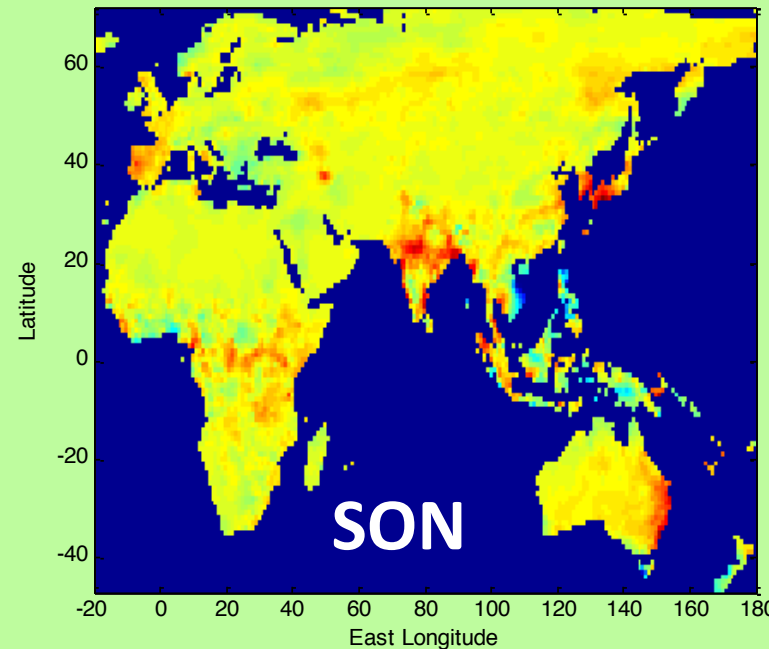
SAM

1950-2008

Regression Coeffts for Southernn Annular mode on Rainfall, Udel1deg JJA 1950-2008



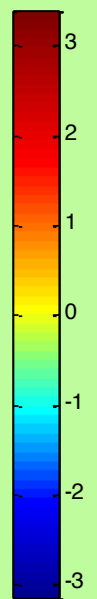
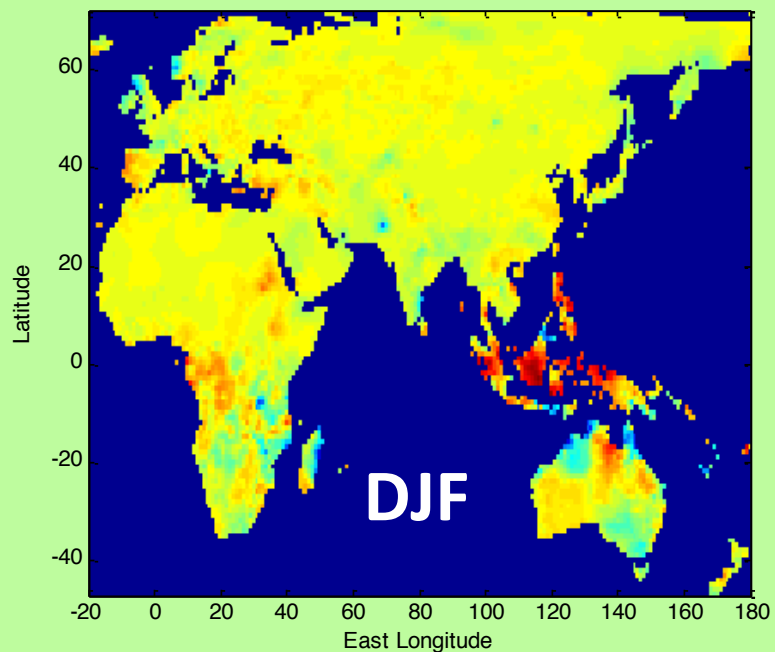
Regression Coeffts for Southernn Annular mode on Rainfall, Udel1deg SON 1950-2008



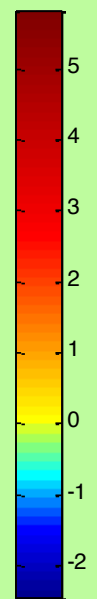
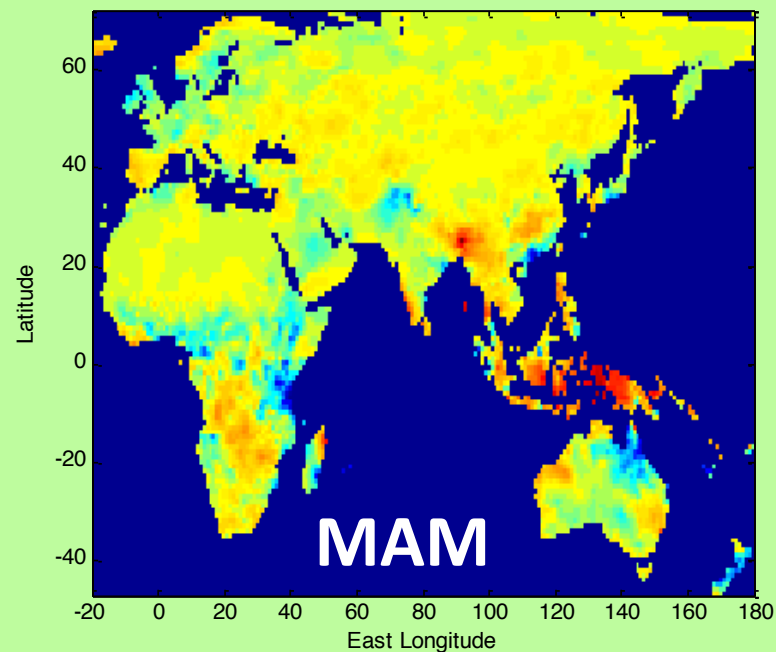
JJA

SON

Regression Coeffts for N Pacific Gyre Oscillation on Rainfall, Udel1deg DJF 1950-2008

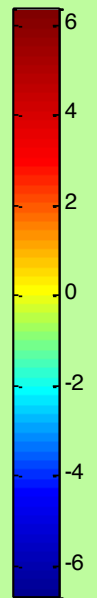
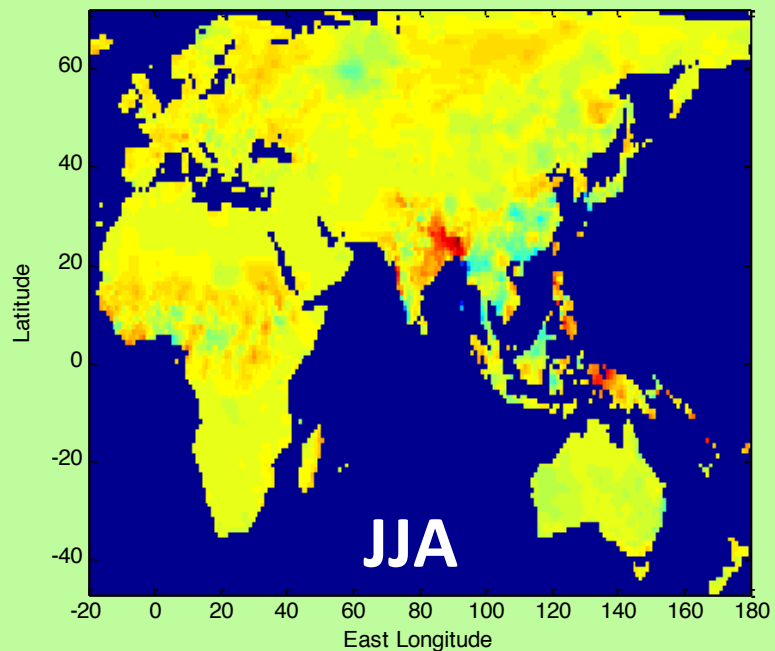


Regression Coeffts for N Pacific Gyre Oscillation on Rainfall, Udel1deg MAM 1950-2008



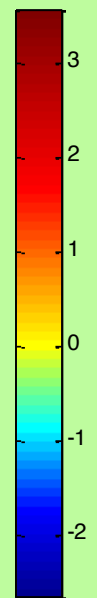
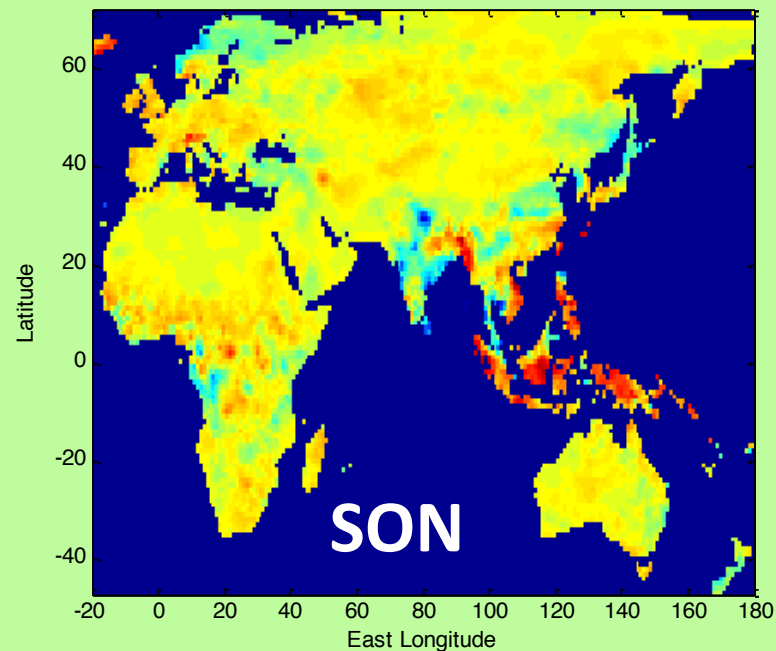
1950-2008

Regression Coeffts for N Pacific Gyre Oscillation on Rainfall, Udel1deg JJA 1950-2008



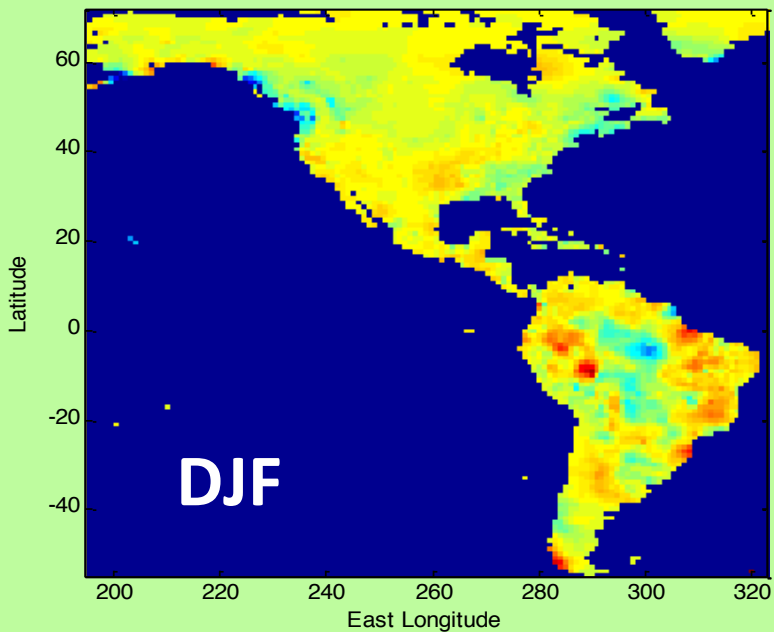
PGO

Regression Coeffts for N Pacific Gyre Oscillation on Rainfall, Udel1deg SON 1950-2008

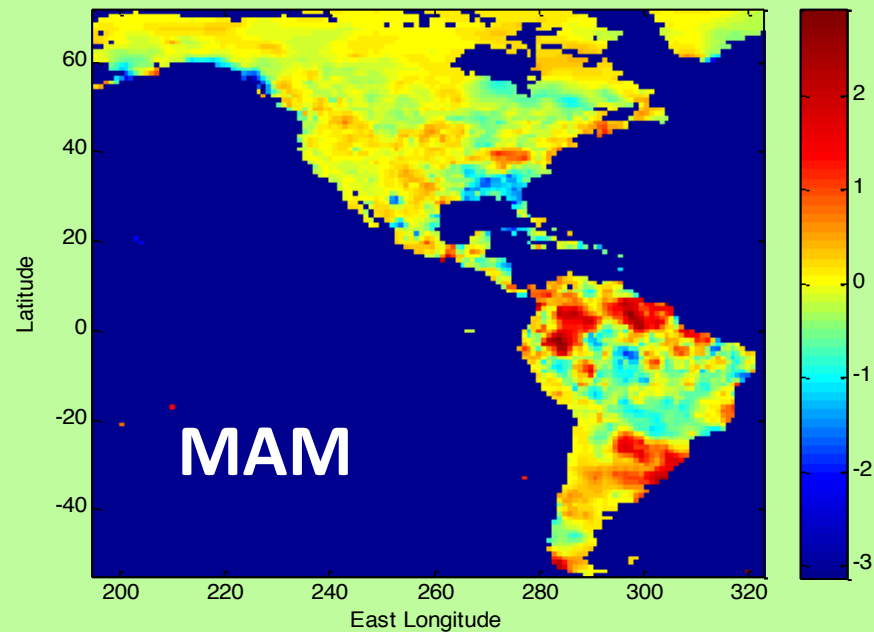


- 1. The GW pattern gives a picture of regions that have increased or decreased over this period. In particular, the rainfall of the equatorial maritime continent has largely decreased in all seasons.**
- 2. Nino3.4 in positive phase gives increased rainfall in equatorial East Africa and eastern China, reduced rainfall in Southern Africa in DJF**
- 3. The IOD in positive phase gives increased rainfall in East Africa from 20S to 5N in SON and DJF, and increased rainfall in India in JJA.**
- 4. The QBO in positive phase gives increased rainfall in southern Africa (20S-40S) in DJF, and Eastern Africa from 10S-30S in MAM.**
- 5. Sunspots are related to increased rainfall in the Indonesian region, in all seasons but particularly in DJF and MAM.**
- 6. The positive phase of the AMOC is associated with increased rainfall in the African Sahel region in JJA and SON, and in the IndoChina region in MAM, SON**
- 7. The TNI (positive phase) gives increased rainfall in Africa 5S-20S in SON, DJF and MAM, and in India and China in SON.**
- 8. The positive phase of the PGO is associated with increased rainfall in the maritime continent, in all seasons.**

Regression Coeffts for GW on Rainfall, Udel1deg DJF 1950-2008



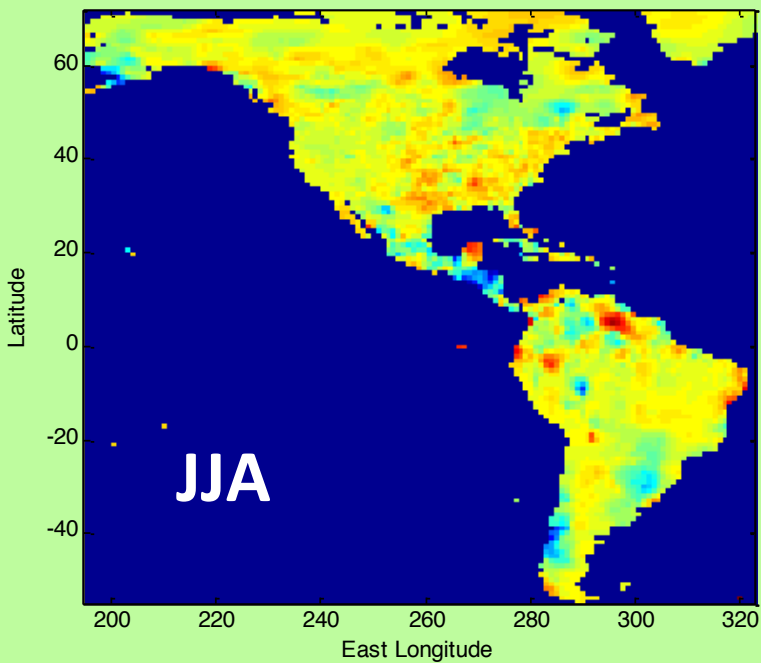
Regression Coeffts for GW on Rainfall, Udel1deg MAM 1950-2008



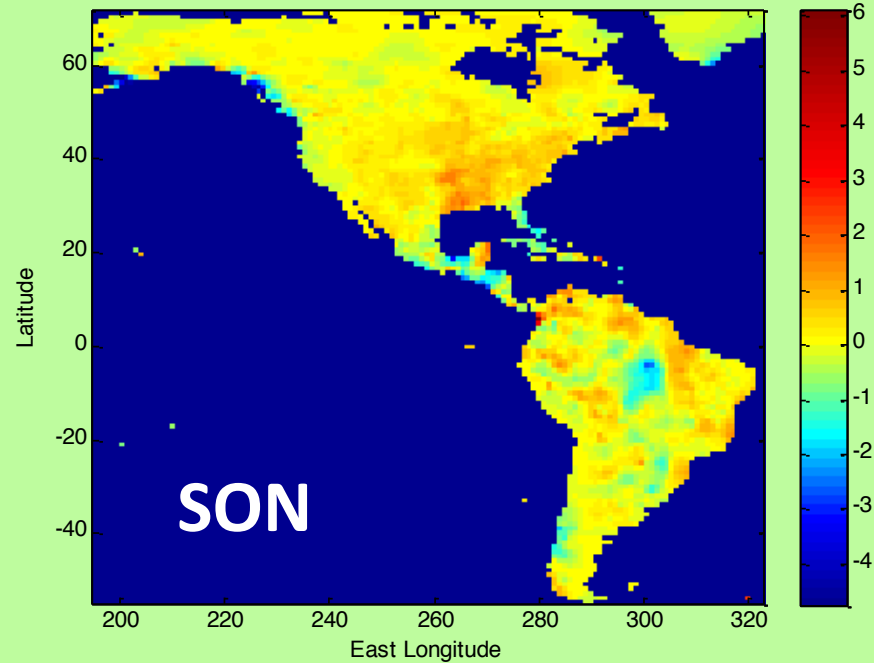
GW

1950-2008

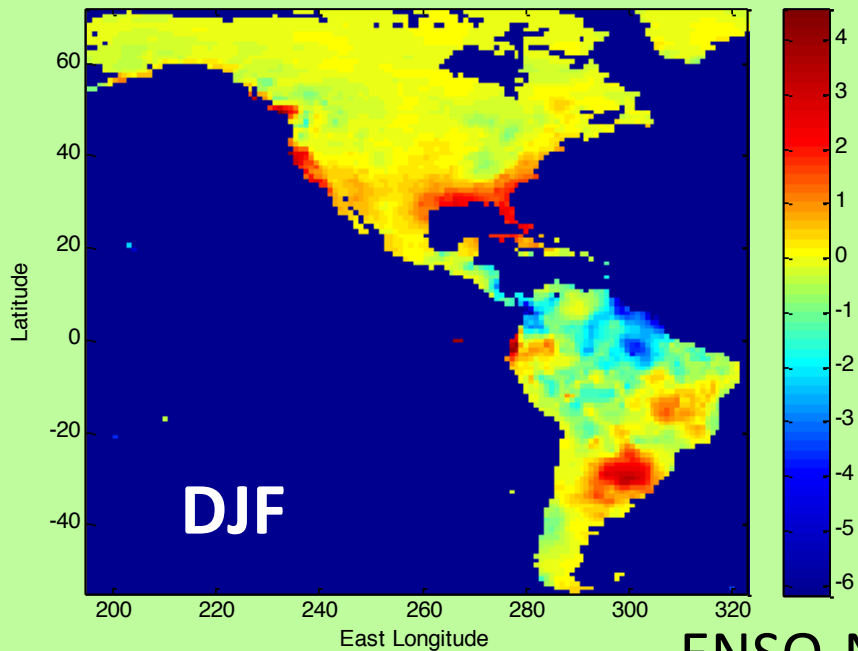
Regression Coeffts for GW on Rainfall, Udel1deg JJA 1950-2008



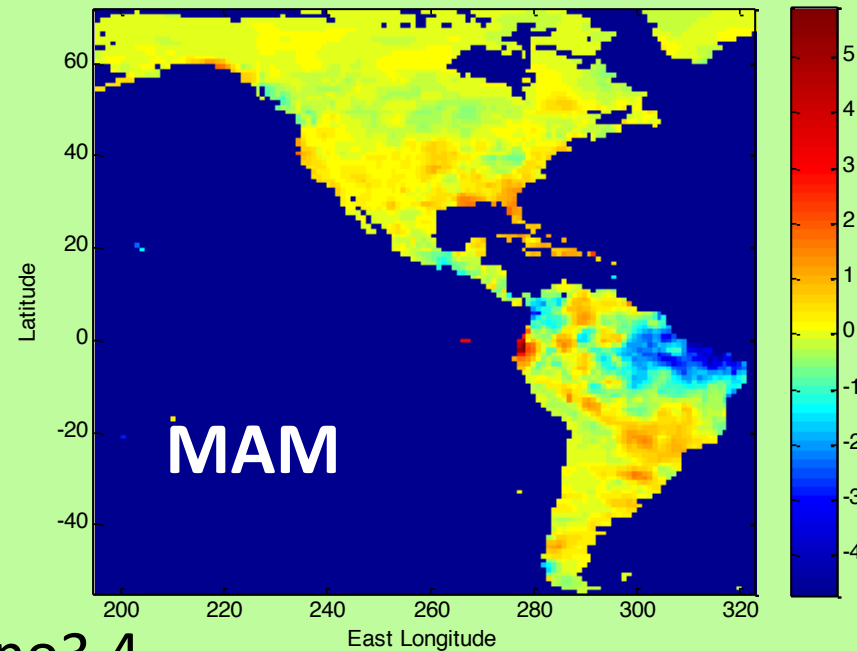
Regression Coeffts for GW on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Nino3.4 Index on Rainfall, Udel1deg DJF 1950-2008



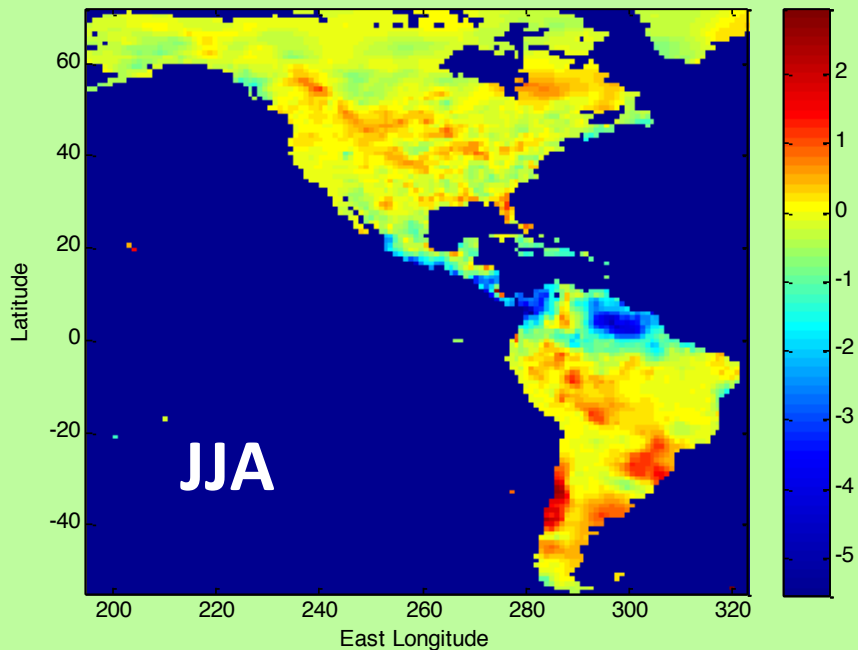
Regression Coeffts for Nino3.4 Index on Rainfall, Udel1deg MAM 1950-2008



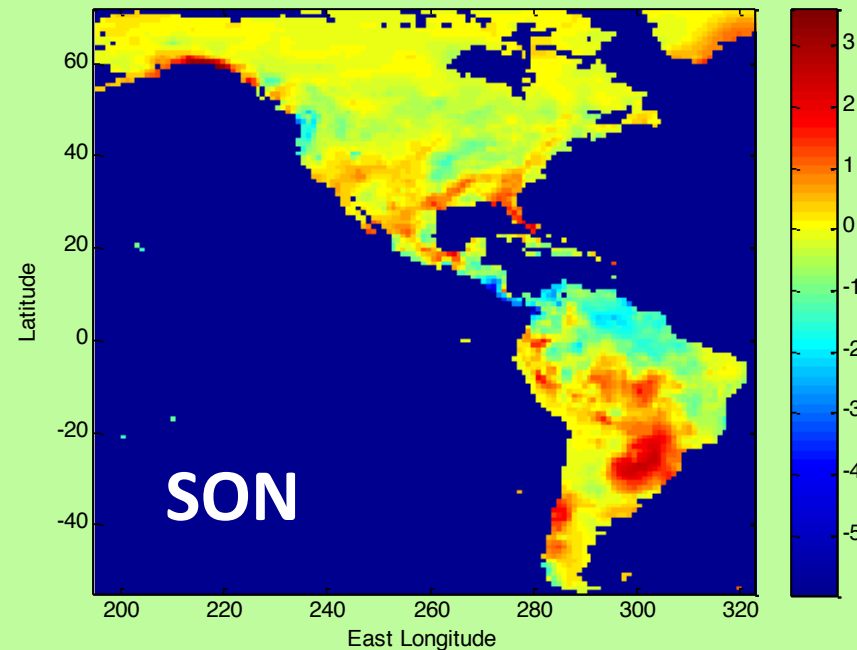
ENSO-Nino3.4

1950-2008

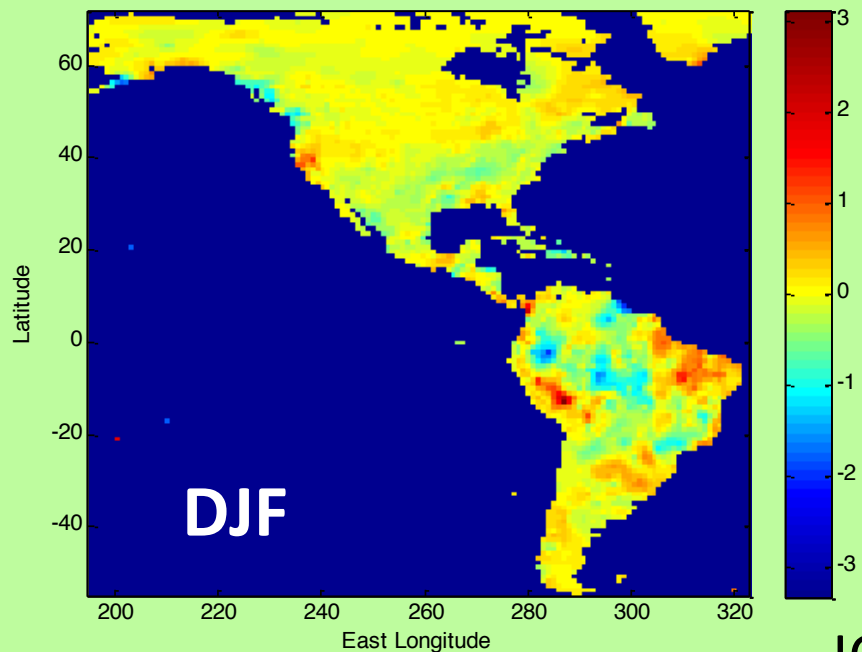
Regression Coeffts for Nino3.4 Index on Rainfall, Udel1deg JJA 1950-2008



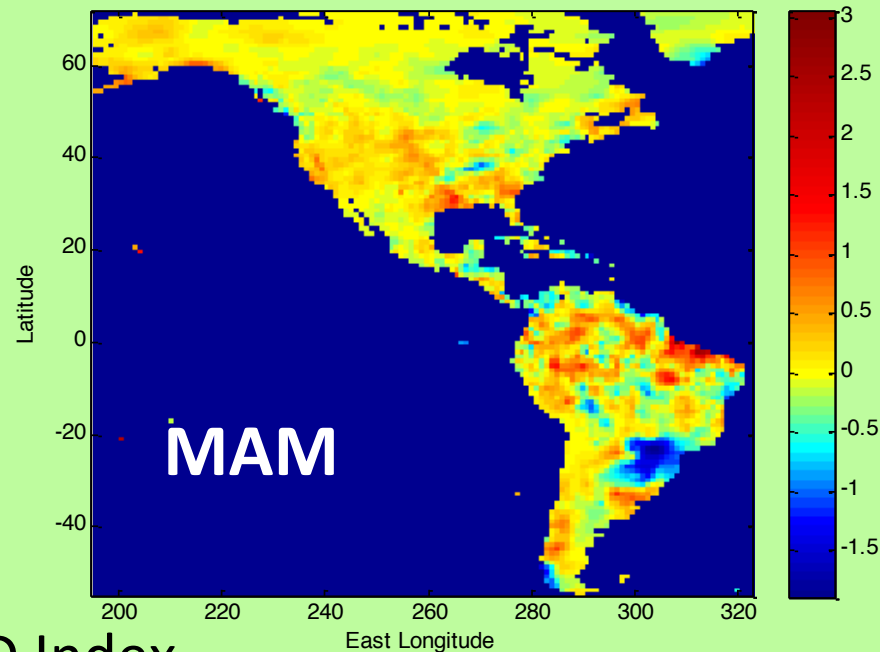
Regression Coeffts for Nino3.4 Index on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Indian Ocean Dipole Index on Rainfall, Udel1deg DJF 1950-2008



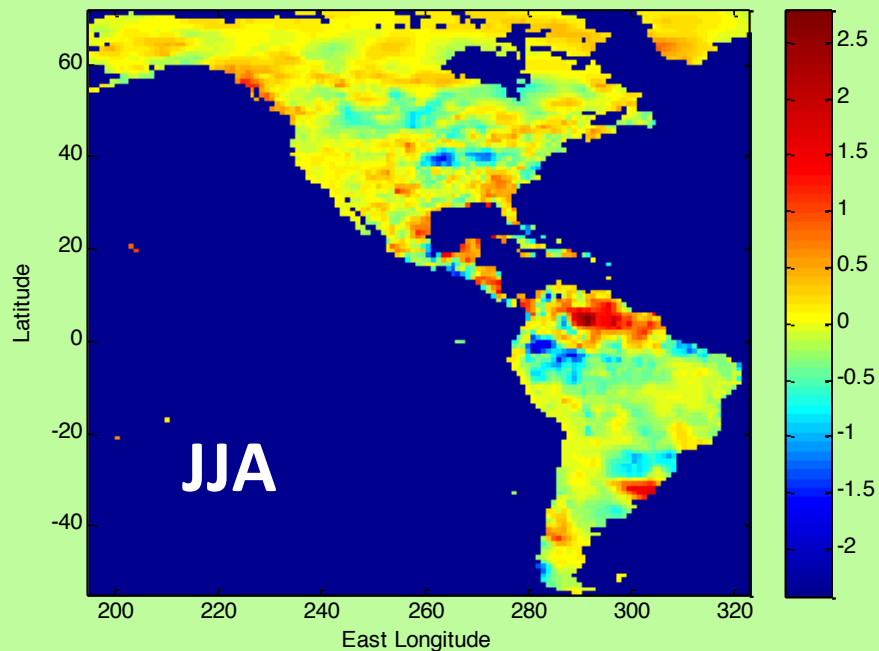
Regression Coeffts for Indian Ocean Dipole Index on Rainfall, Udel1deg MAM 1950-2008



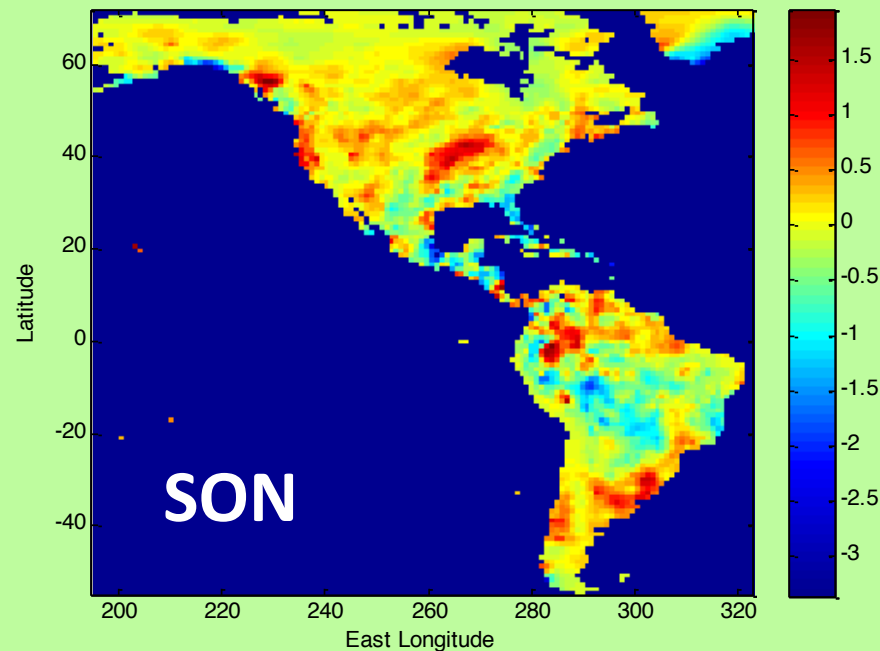
IOD Index

1950-2008

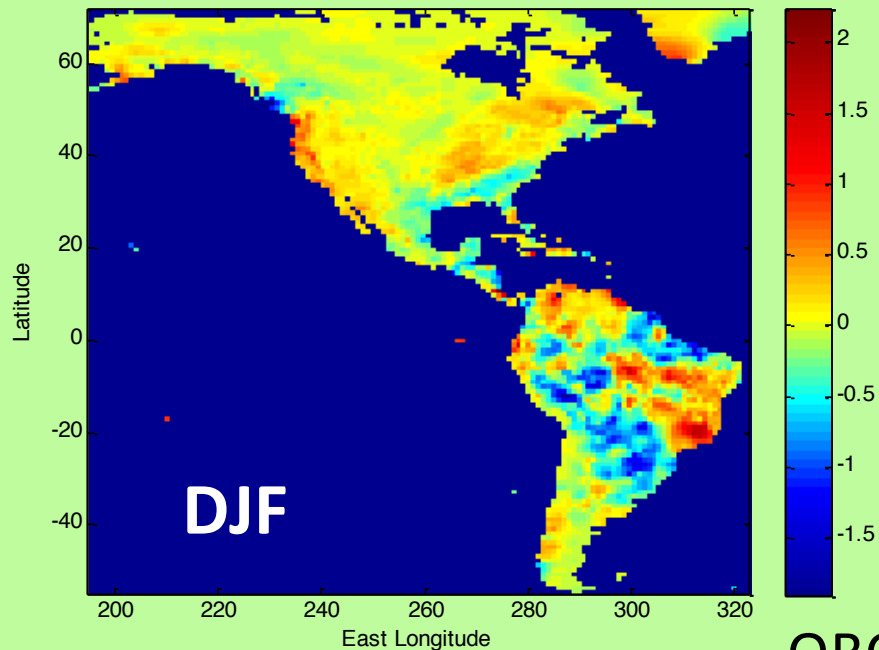
Regression Coeffts for Indian Ocean Dipole Index on Rainfall, Udel1deg JJA 1950-2008



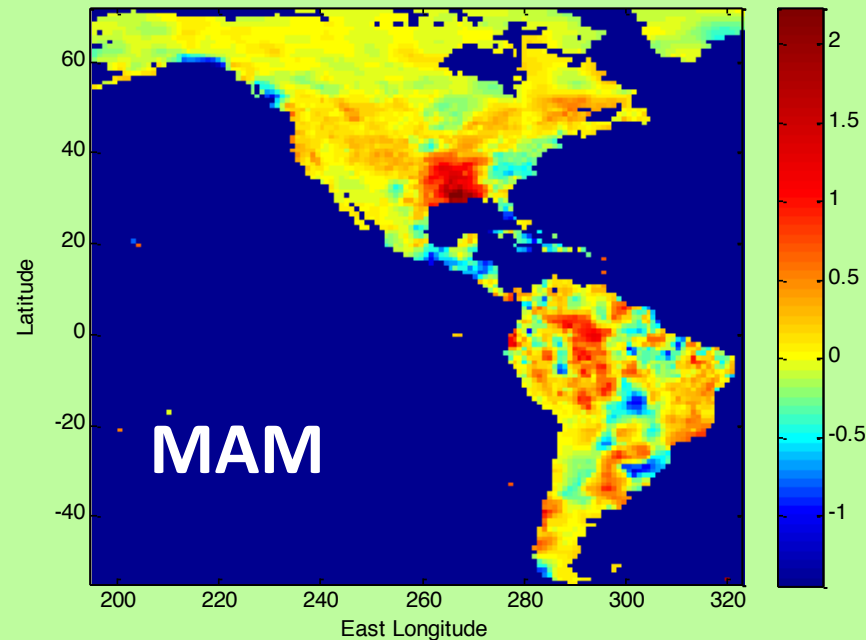
Regression Coeffts for Indian Ocean Dipole Index on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg DJF 1950-2008



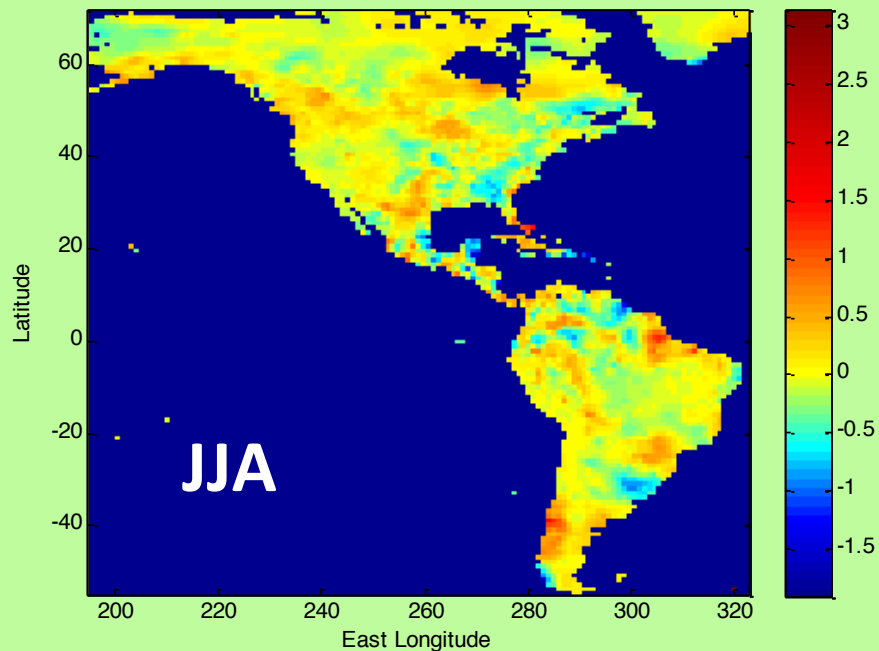
Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg MAM 1950-2008



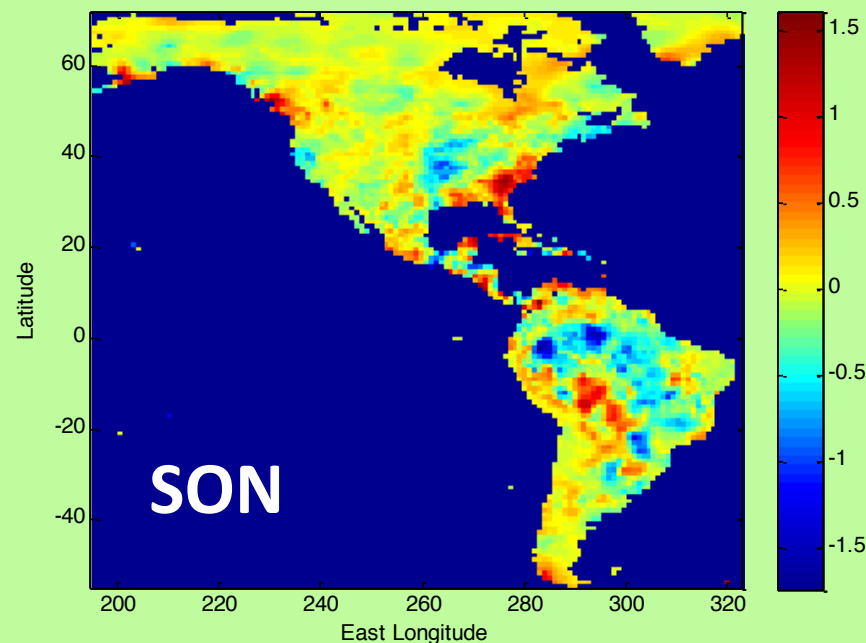
QBO

1950-2008

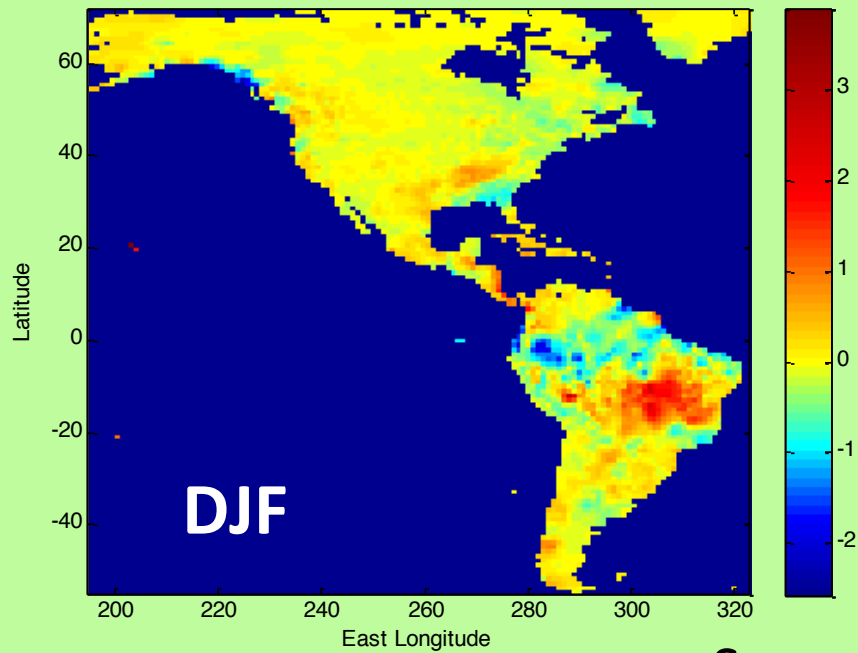
Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg JJA 1950-2008



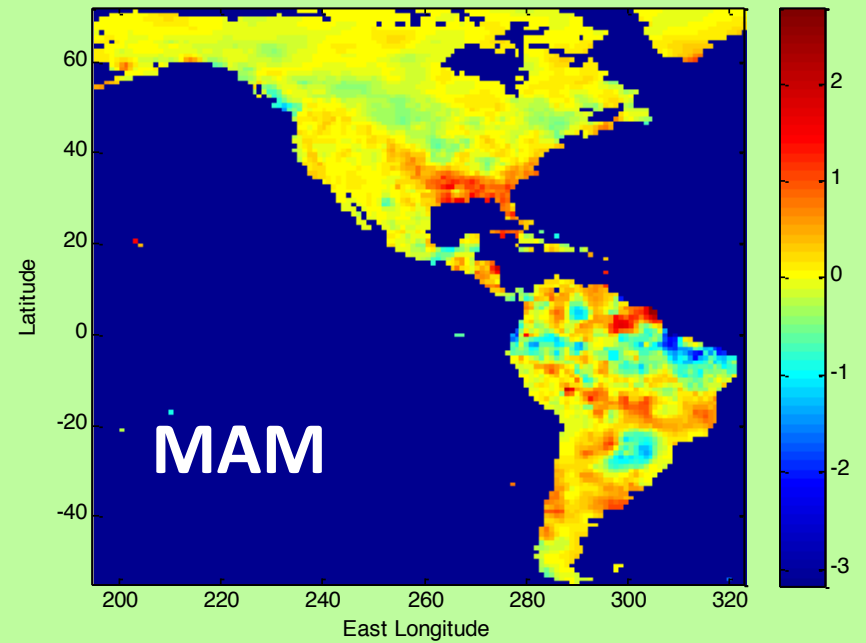
Regression Coeffts for Quasi-Bienn. Oscillation on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Sunspot Number on Rainfall, Udel1deg DJF 1950-2008

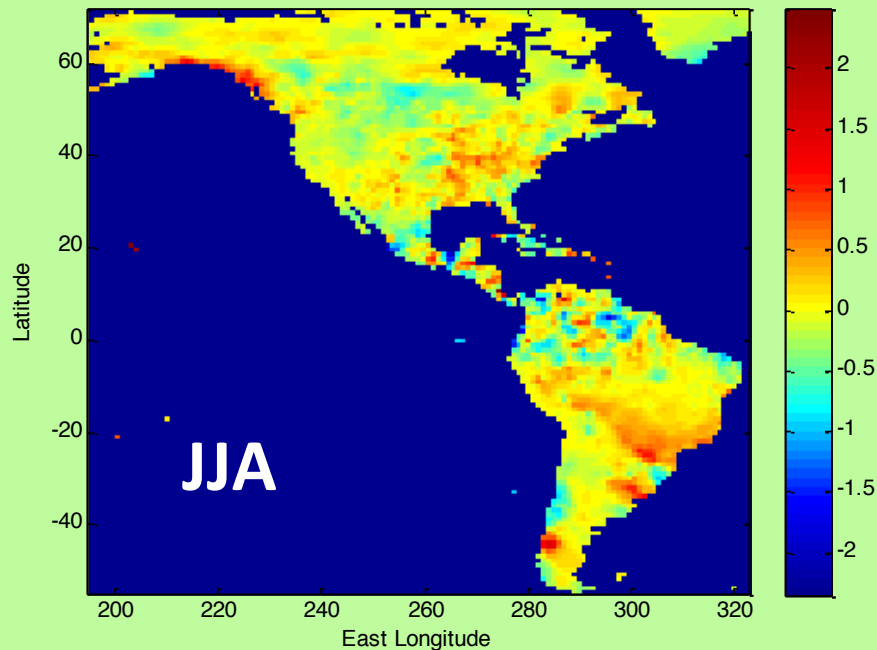


Regression Coeffts for Sunspot Number on Rainfall, Udel1deg MAM 1950-2008

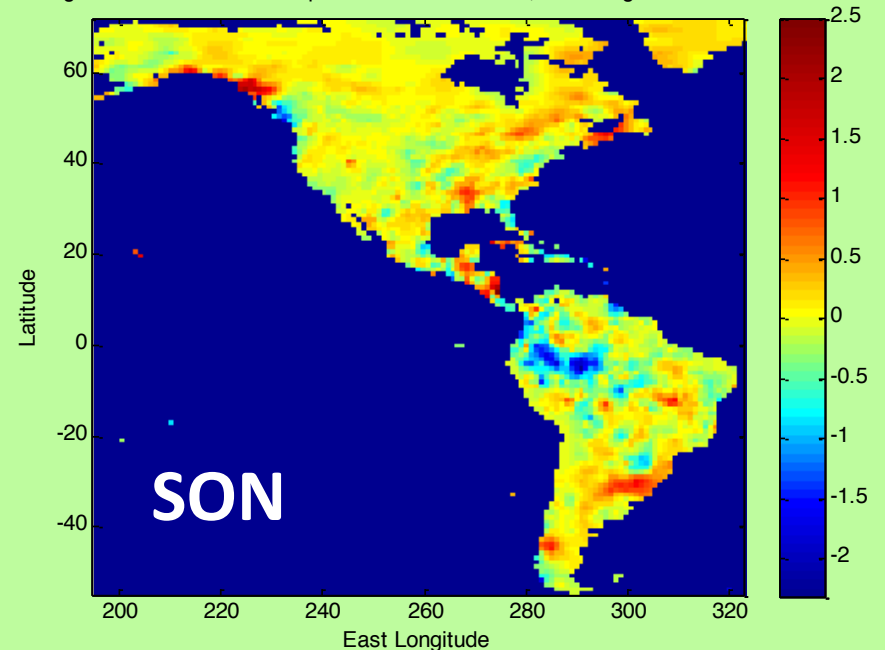


Sunspot Number

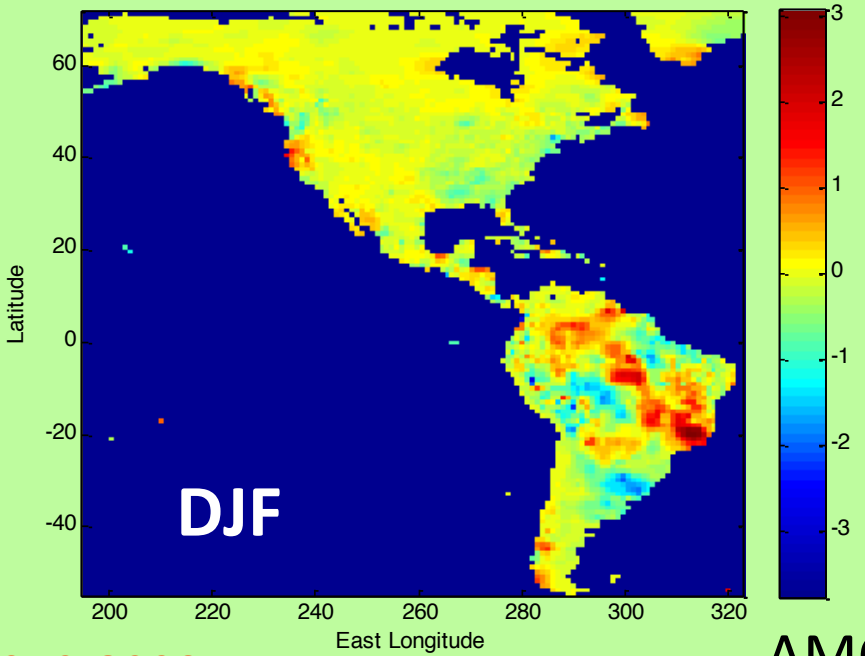
Regression Coeffts for Sunspot Number on Rainfall, Udel1deg JJA 1950-2008



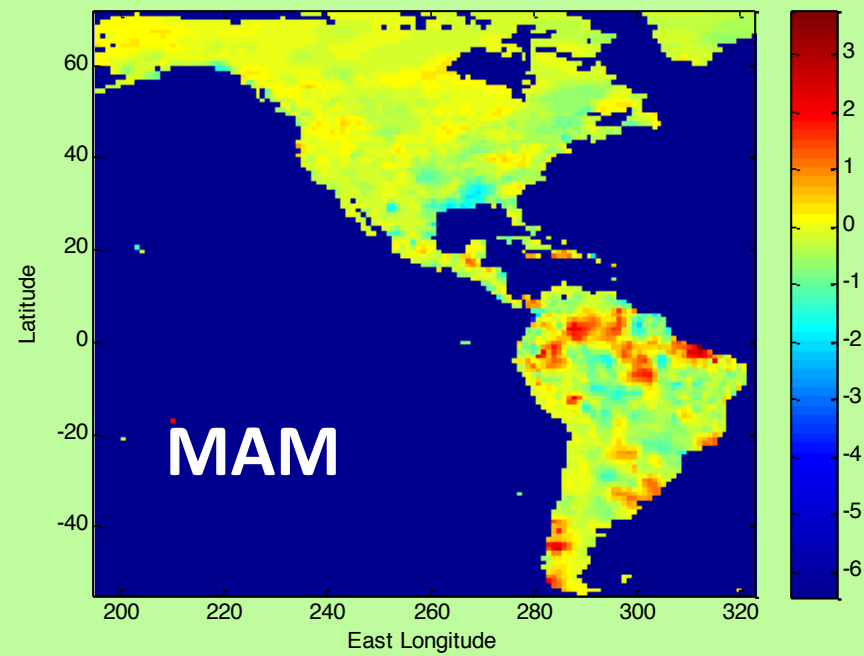
Regression Coeffts for Sunspot Number on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg DJF 1950-2008



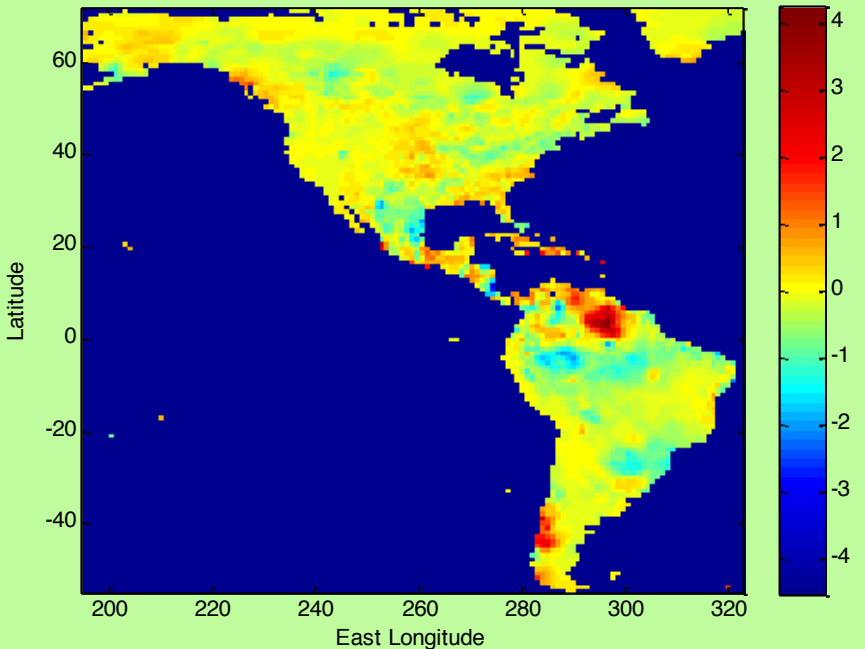
Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg MAM 1950-2008



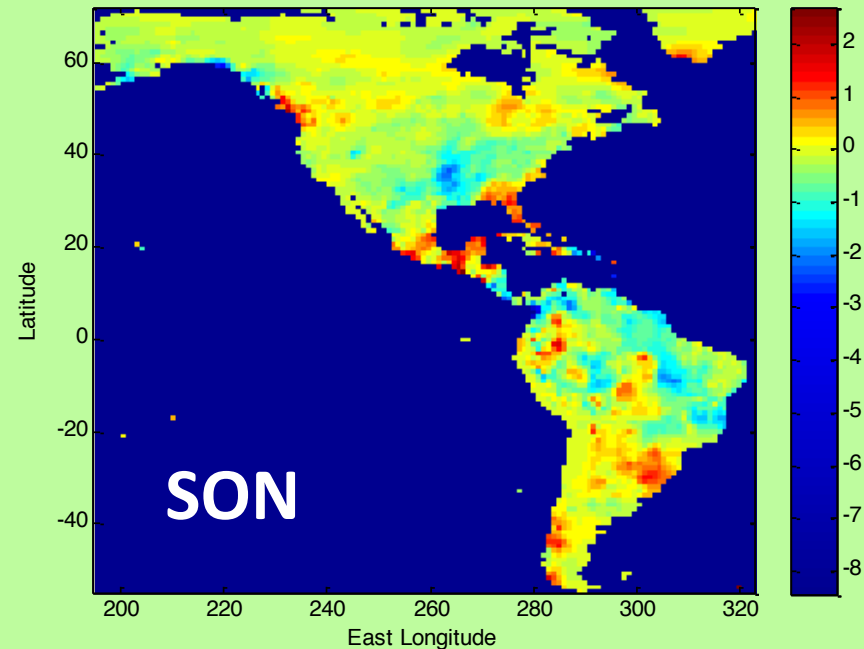
1950-2008

AMO

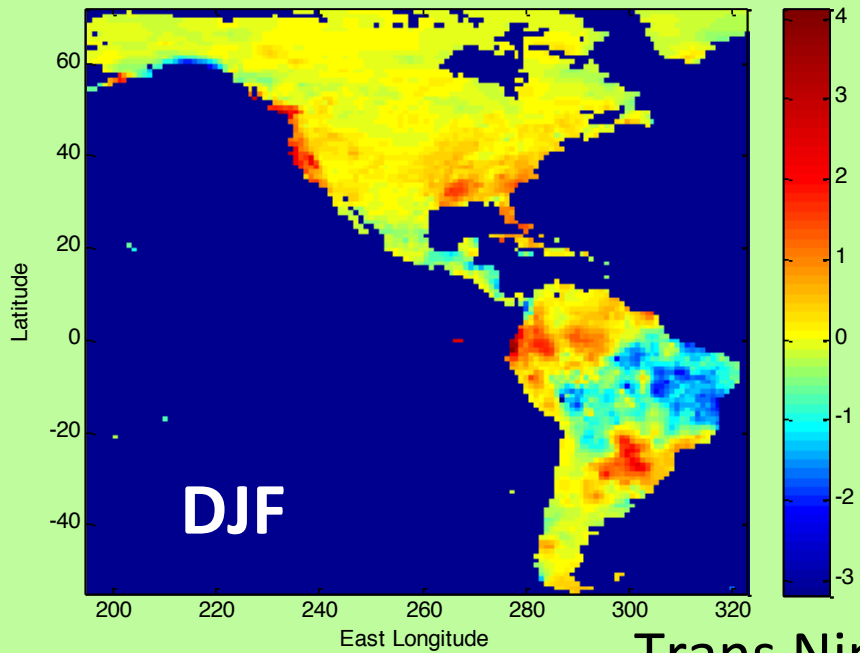
Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg JJA 1950-2008



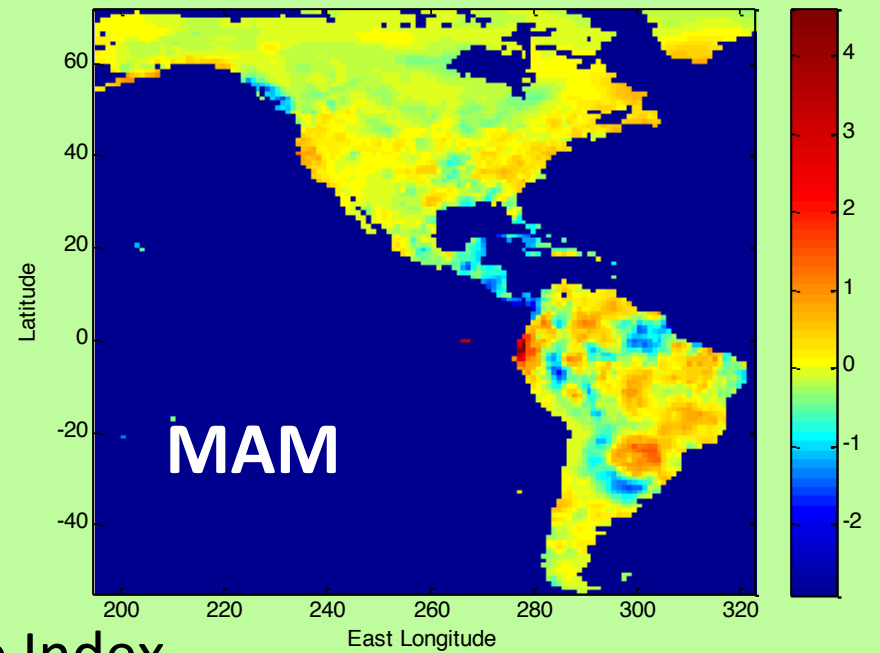
Regression Coeffts for Atlantic Meridional Oscillation on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg DJF 1950-2008



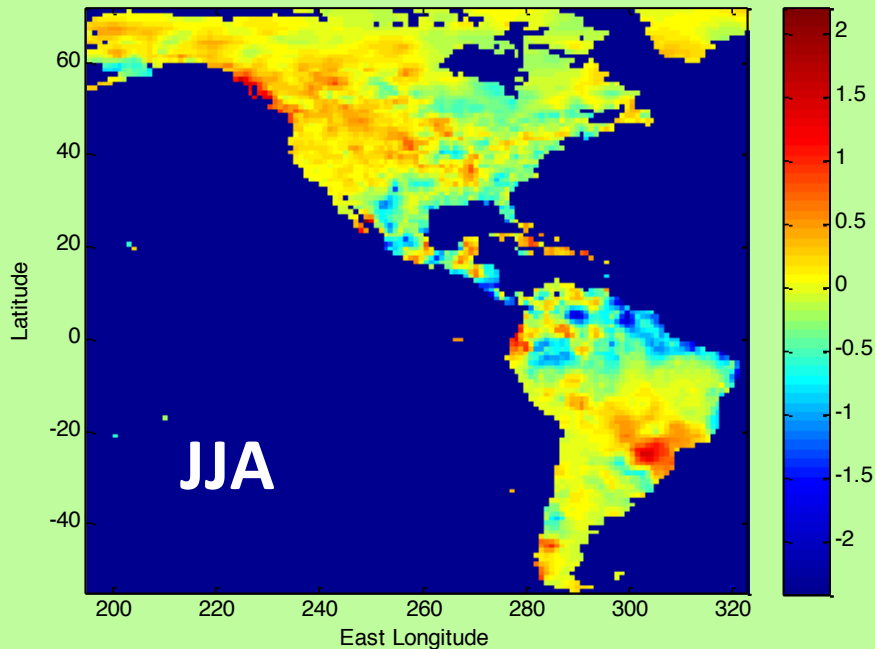
Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg MAM 1950-2008



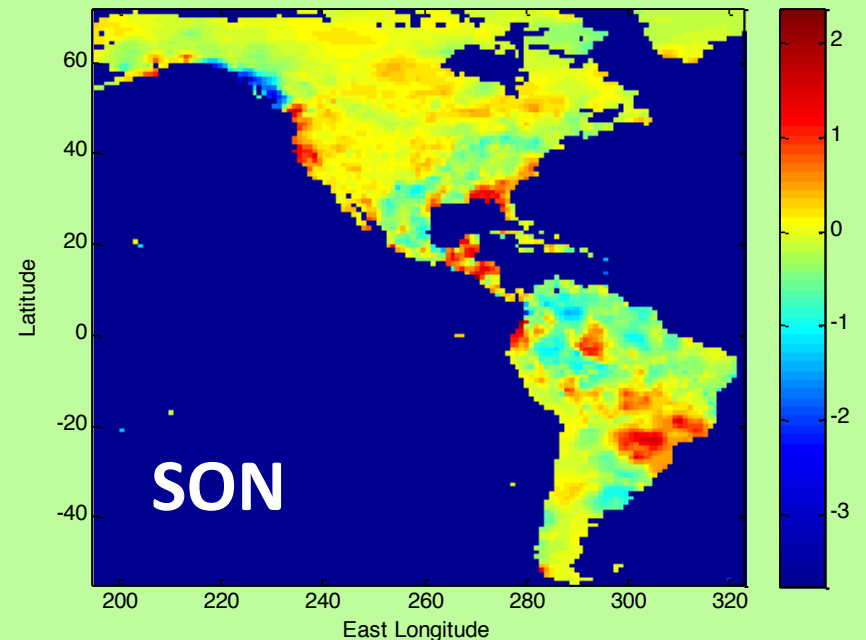
Trans Nino Index

1950-2008

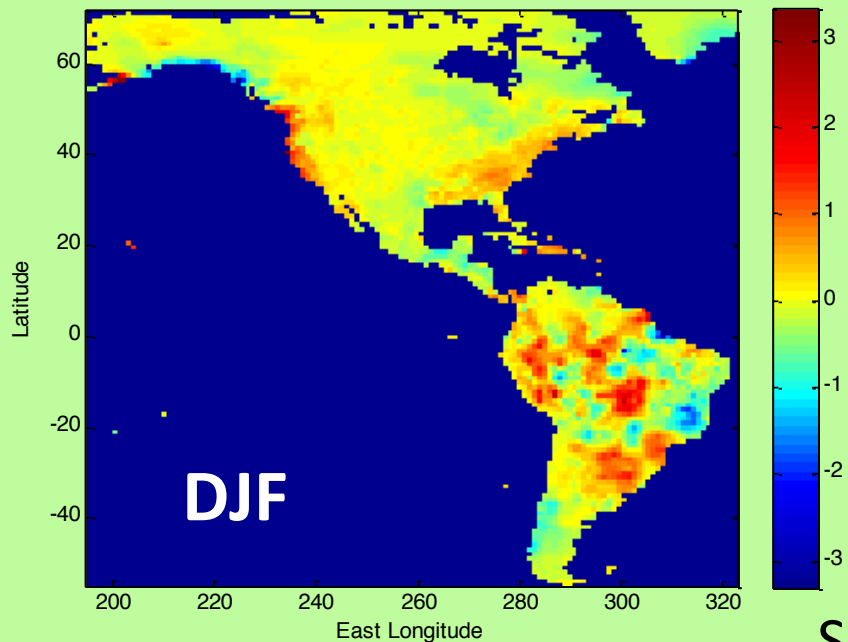
Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg JJA 1950-2008



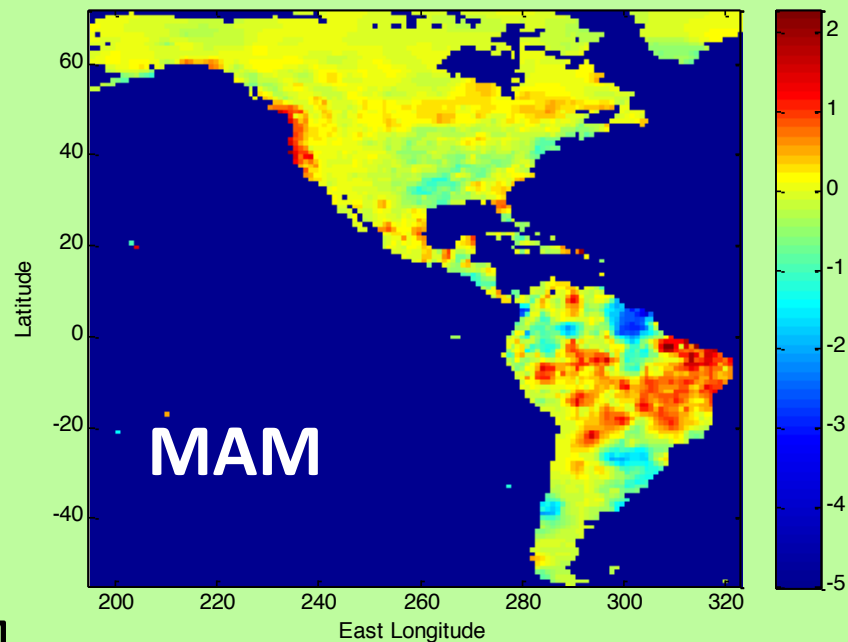
Regression Coeffts for Trans Nino Index on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Southern Annular Mode on Rainfall, Udel1deg DJF 1950-2008



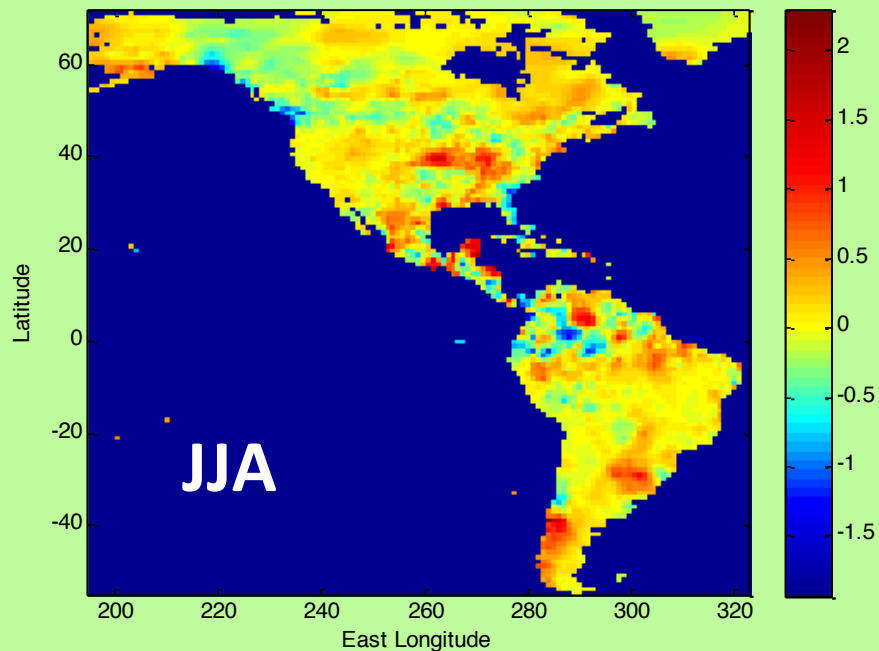
Regression Coeffts for Southern Annular Mode on Rainfall, Udel1deg MAM 1950-2008



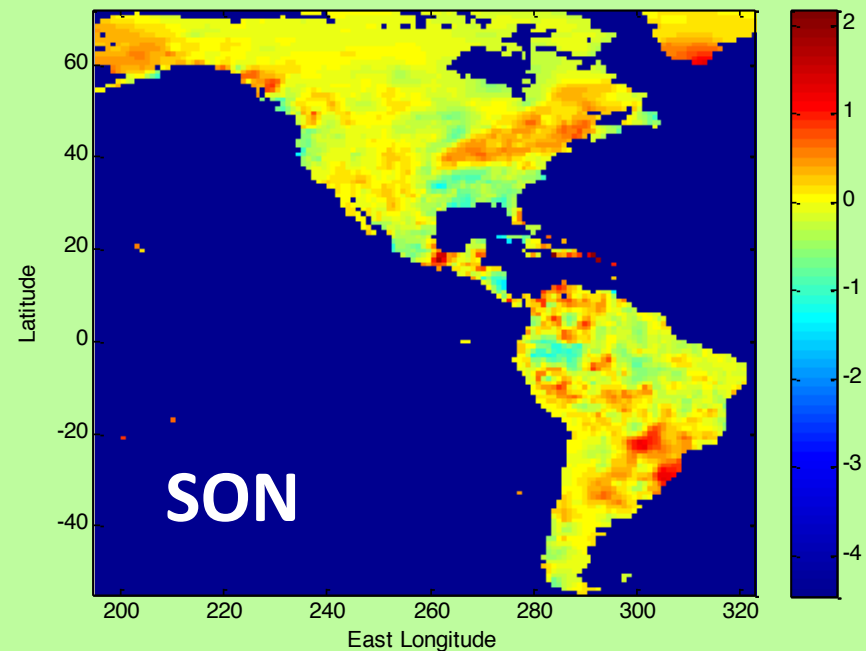
SAM

1950-2008

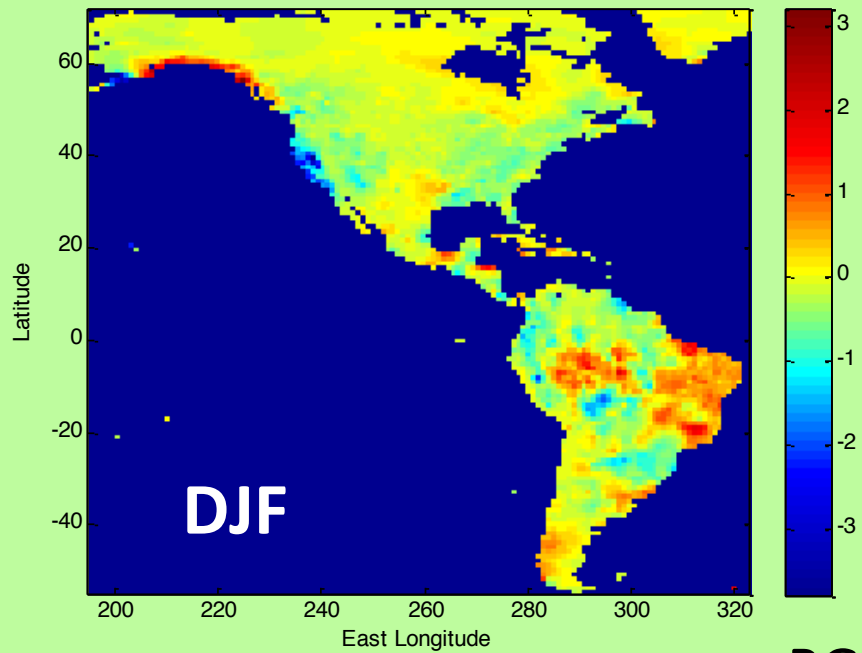
Regression Coeffts for Southern Annular Mode on Rainfall, Udel1deg JJA 1950-2008



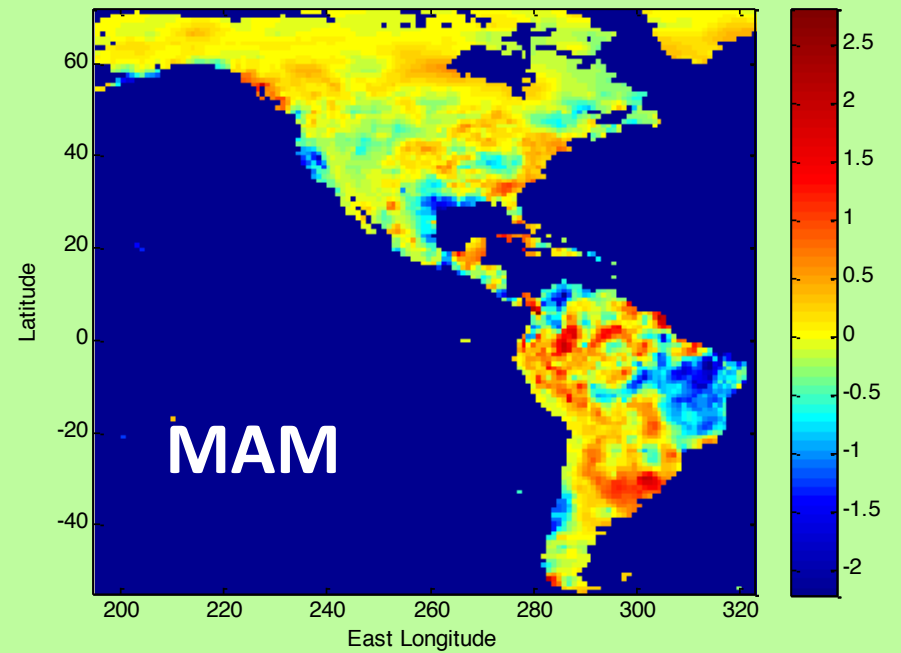
Regression Coeffts for Southern Annular Mode on Rainfall, Udel1deg SON 1950-2008



Regression Coeffts for Pacific Gyre Oscillation on Rainfall, Udel1deg DJF 1950-2008



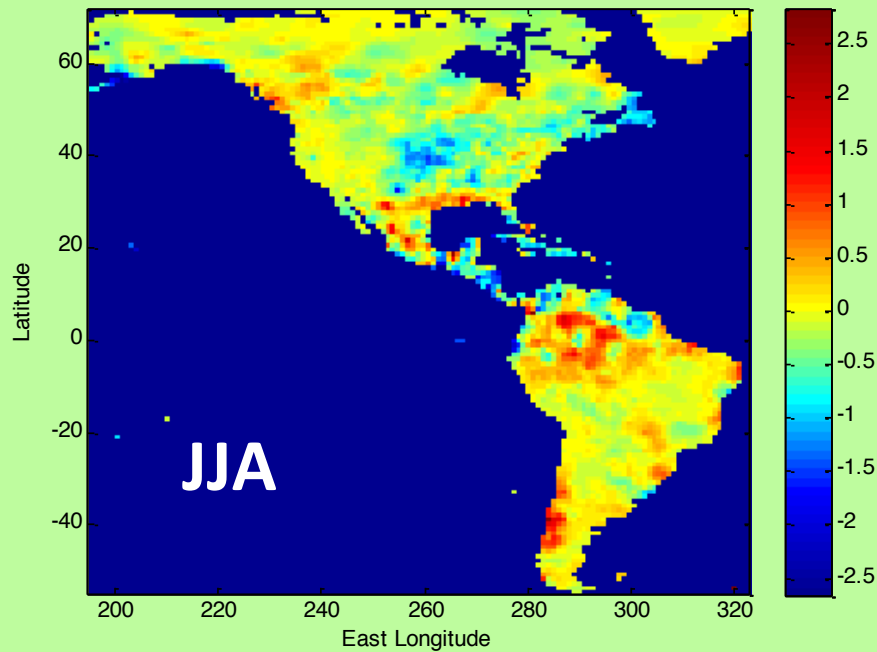
Regression Coeffts for Pacific Gyre Oscillation on Rainfall, Udel1deg MAM 1950-2008



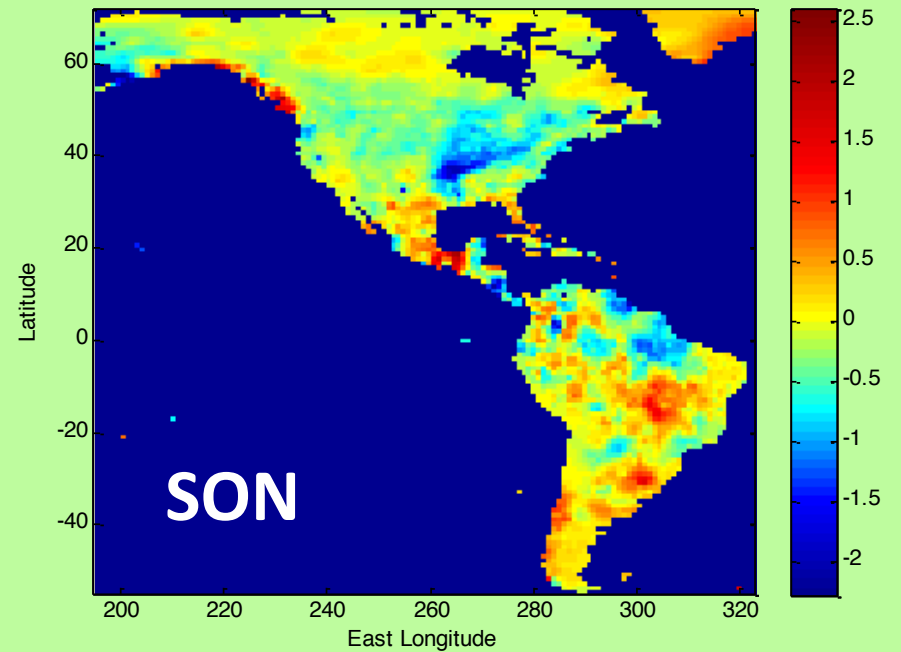
1950-2008

PGO

Regression Coeffts for Pacific Gyre Oscillation on Rainfall, Udel1deg JJA 1950-2008



Regression Coeffts for Pacific Gyre Oscillation on Rainfall, Udel1deg SON 1950-2008



- **Features of the Global Analysis, 1950:2008: Americas.**
- 1. Nino3.4 – positive phase implies increased rainfall in southern USA (20N-40N) in SON & DJF, reduced rainfall in Northern South America and equatorial regions, all seasons.
- 2. Symmetrically, there is increased rainfall in Southern South America (20S-40S), particularly in SON & DJF.

Conclusions

1. The effect of 9 factors (GW, AMO, Nino3.4, TNI, IOD, SSN, SAM, QBO and PGO) on Australian and Global rainfall has been examined.

Several of these appear to have particular spheres of influence, that differ from season to season.

2. Since there is some predictability to some of these factors, there is some forecasting potential in these results, but they represent patterns of predictability rather than forecasts.

3. They also present a challenge to indentify the dynamical processes that may link regional rainfall variations to the factors causing them.

4. However, more than half the total variance in each season is not attributable to any of these factors. This “residual rainfall” appears to have an essentially random nature, with no obvious dependence on the external forcings considered.