



Correction of CGCM-Based Global Prediction Using Artificial Neural Network

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**Nov 9-11, 2004
Busan, S. Korea**



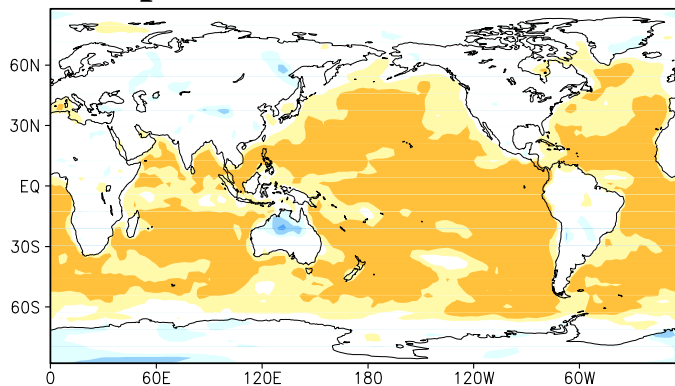
Motive/ Purpose

- All of the physically based climate model results have bias due to various model uncertainties.
- The model bias makes the predictions of weather and climate difficult.
- In order to improve the model predictability, the CGCM hindcast bias has been corrected with the aid of Artificial Neural Network(ANN)

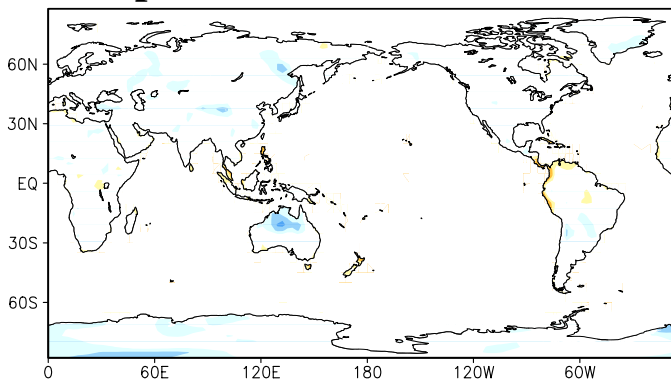
Temporal Correlation Coefficients between Model and OBS

CCM3 stand-alone 10 Ensemble 30-year(1971-2000) DJF Simulation with real SST

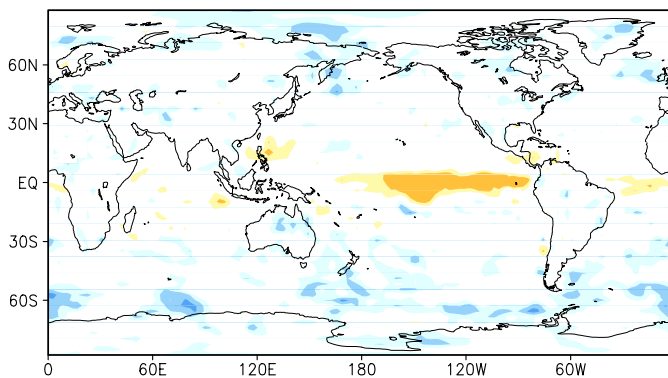
Temperature



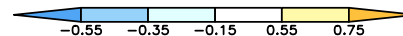
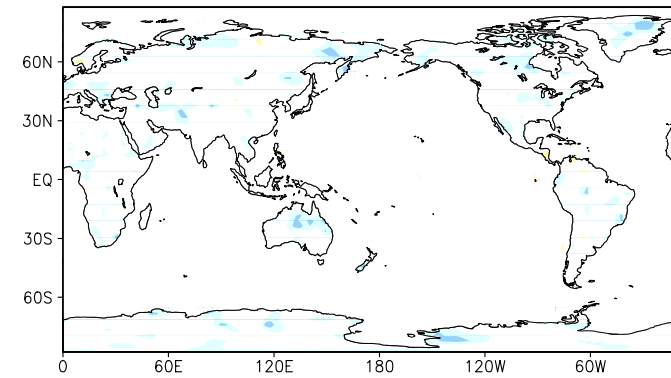
Temperature



Precipitation



Precipitation

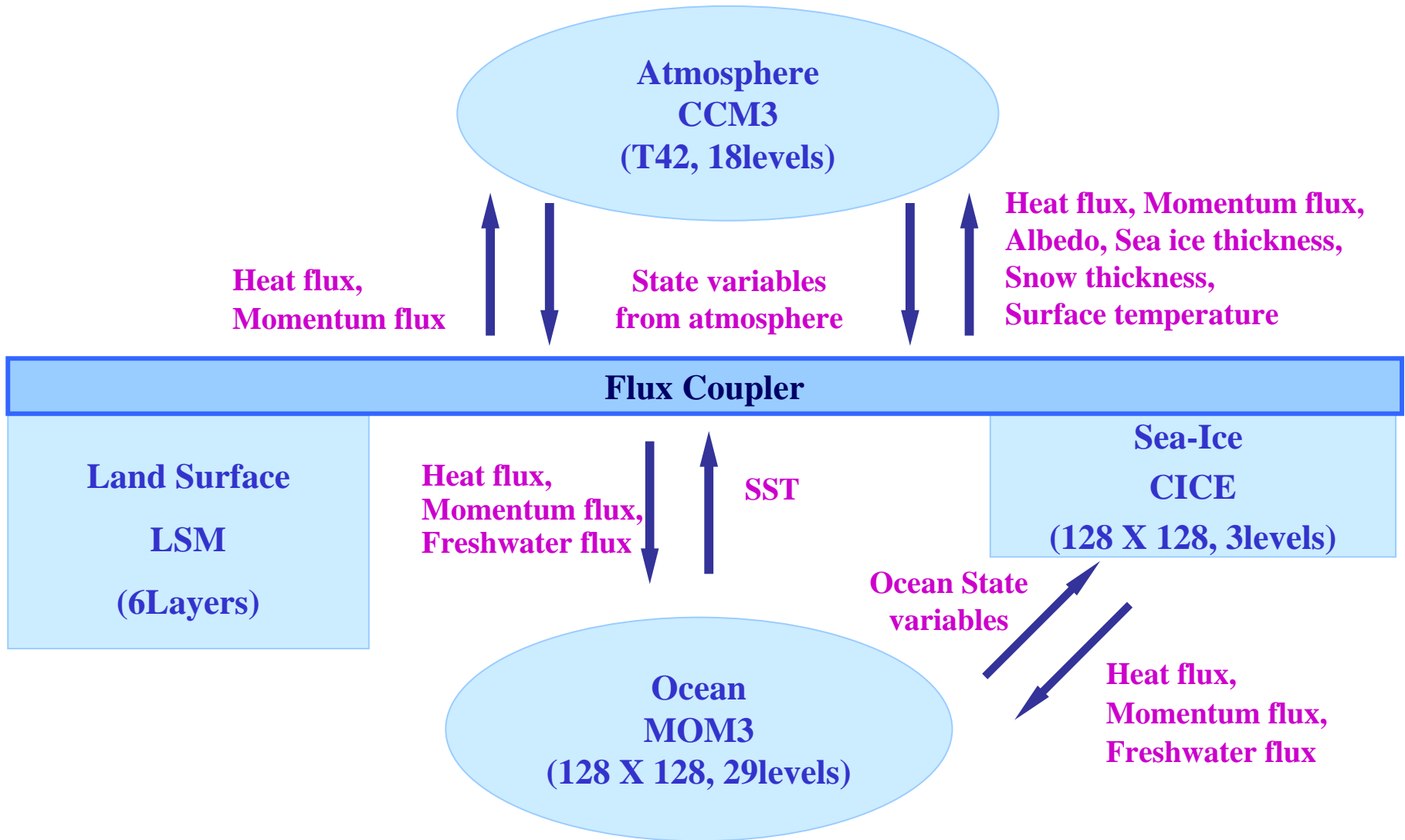




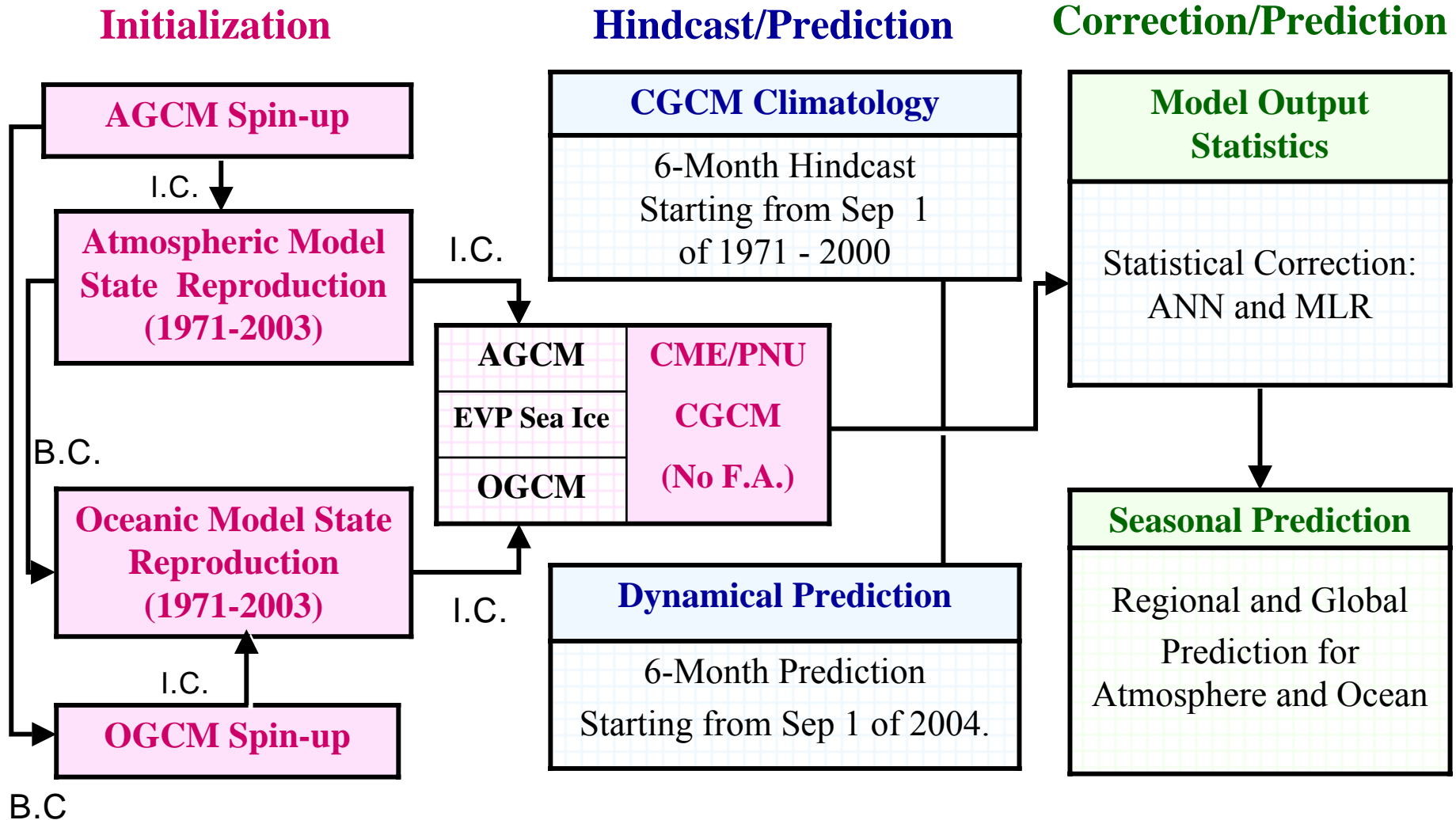
Motive/ Purpose

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Structure of CME/PNU CGCM

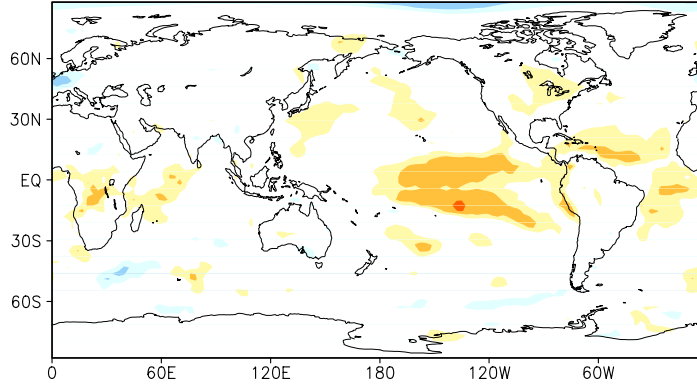


Dynamical Prediction Processes for CME/PNU CGCM

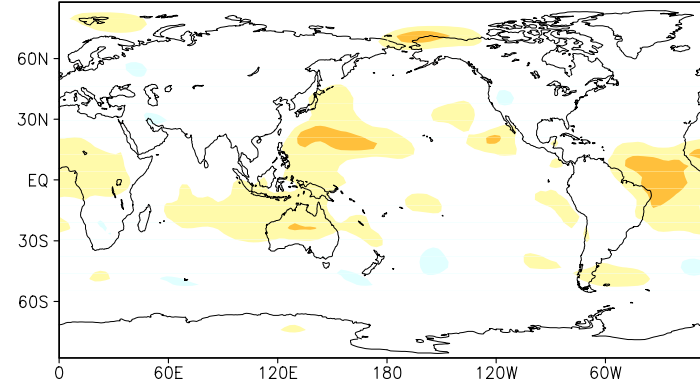


Temporal Correlation Coefficients Between OBS and 3~5-Month Lead CGCM Hindcast

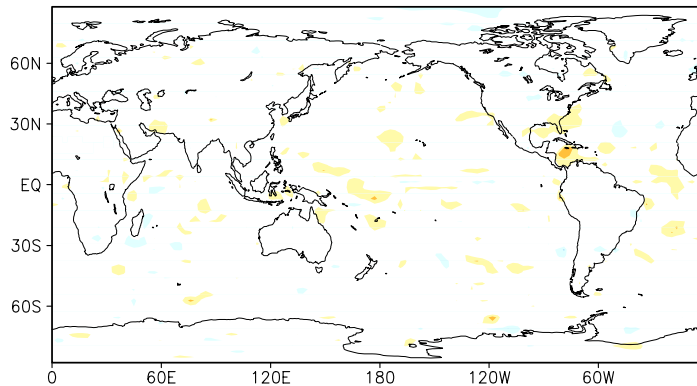
Temperature **DJF**



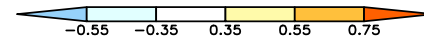
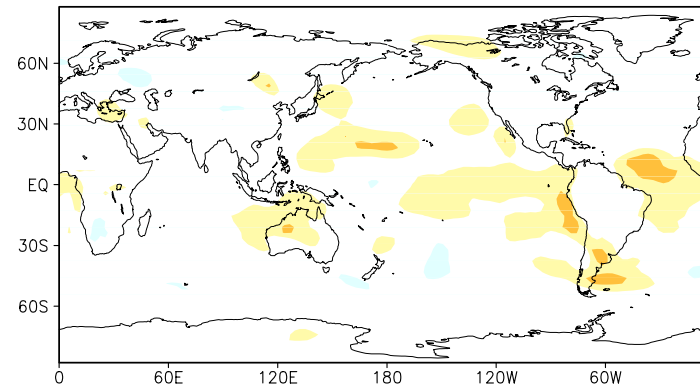
Geopotential Height **DJF**



Precipitation **DJF**



Sea Level Pressure **DJF**

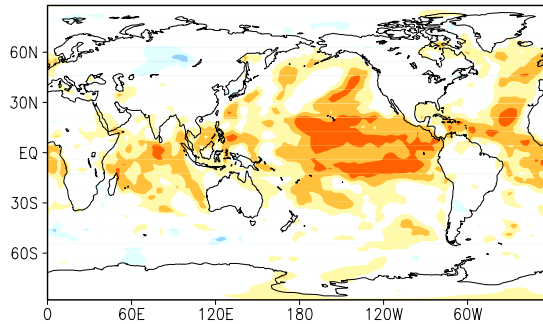


Temporal Correlation Coefficients

Temperature for Different Leads

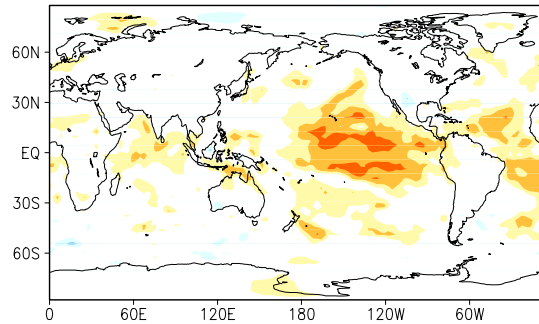
Lead 0

Sep



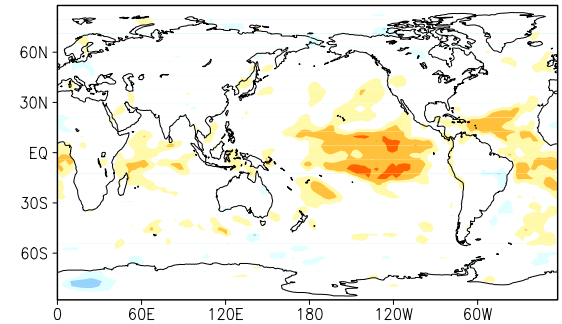
Lead 1

Oct



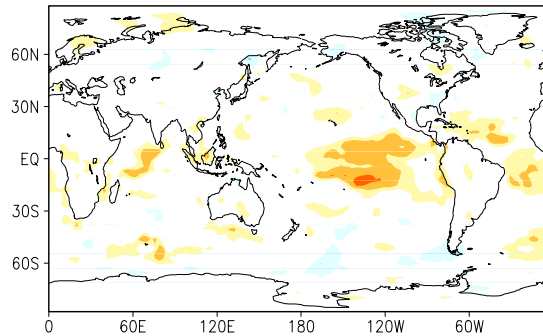
Lead 2

Nov



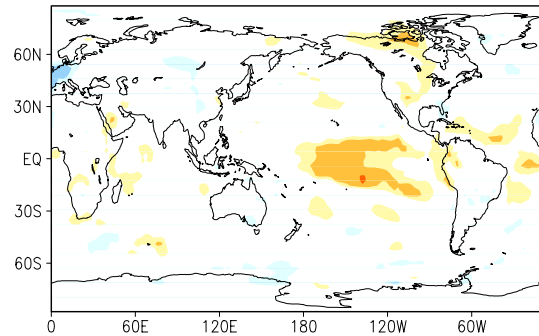
Lead 3

Dec



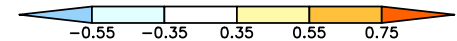
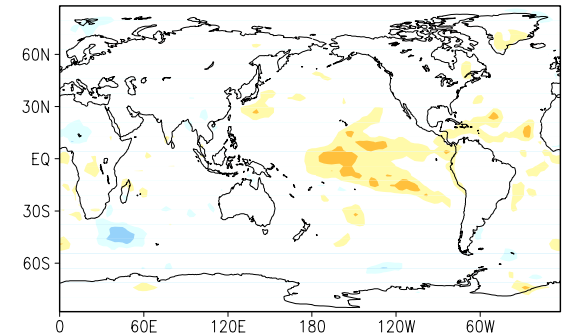
Lead 4

Jan



Lead 5

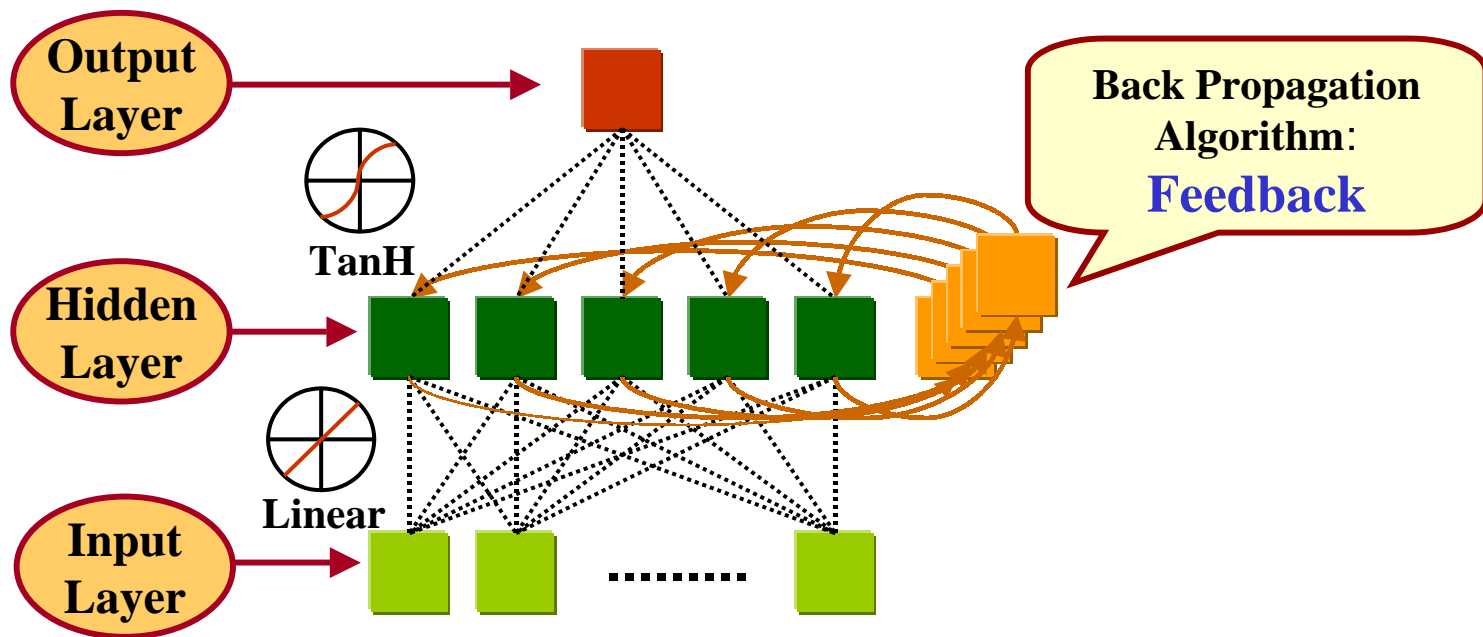
Feb



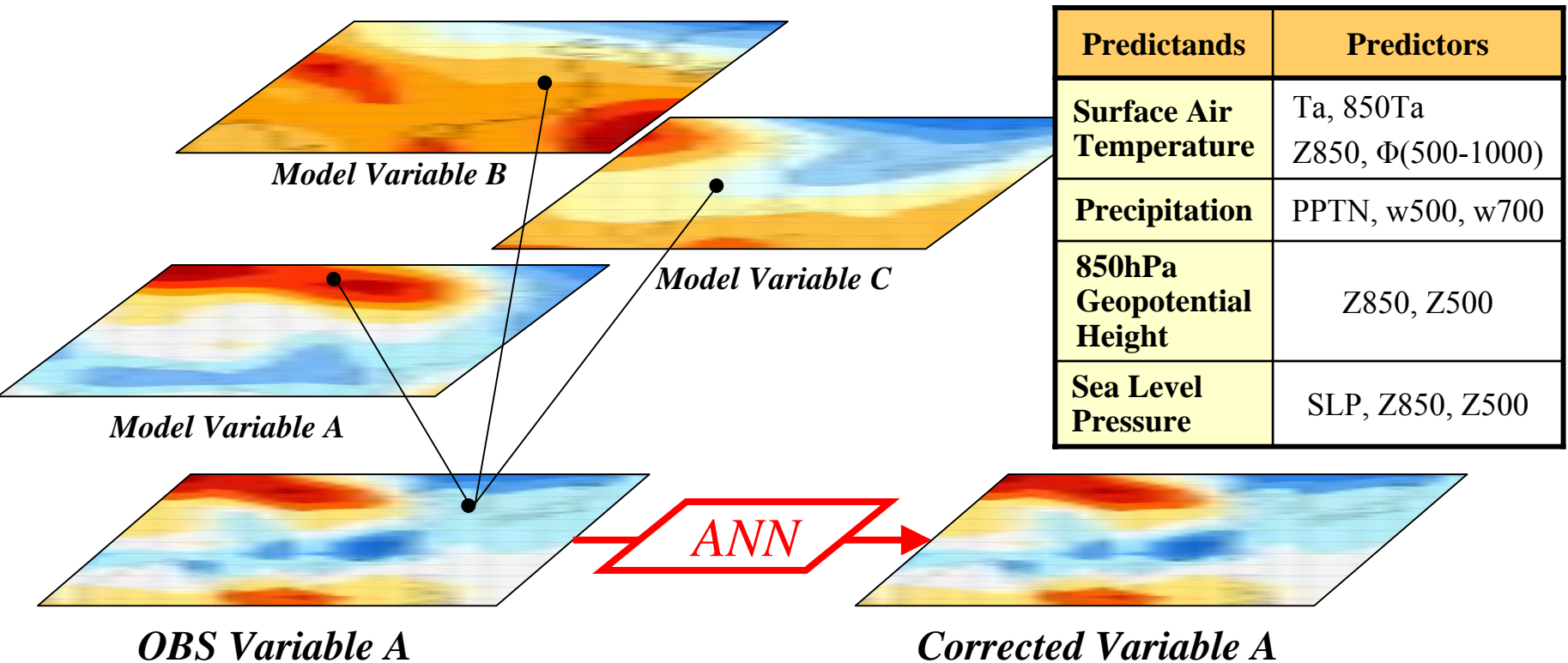
Structure of the Artificial Neural Network (ANN)

Artificial neural network is a data modeling tool that is able to capture and represent complex input/output relationships. The artificial neural network performs "intelligent" tasks similar to those performed by the human brain. Neural networks resemble the human brain in the following ways:

1. A neural network acquires knowledge through learning.
2. A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights

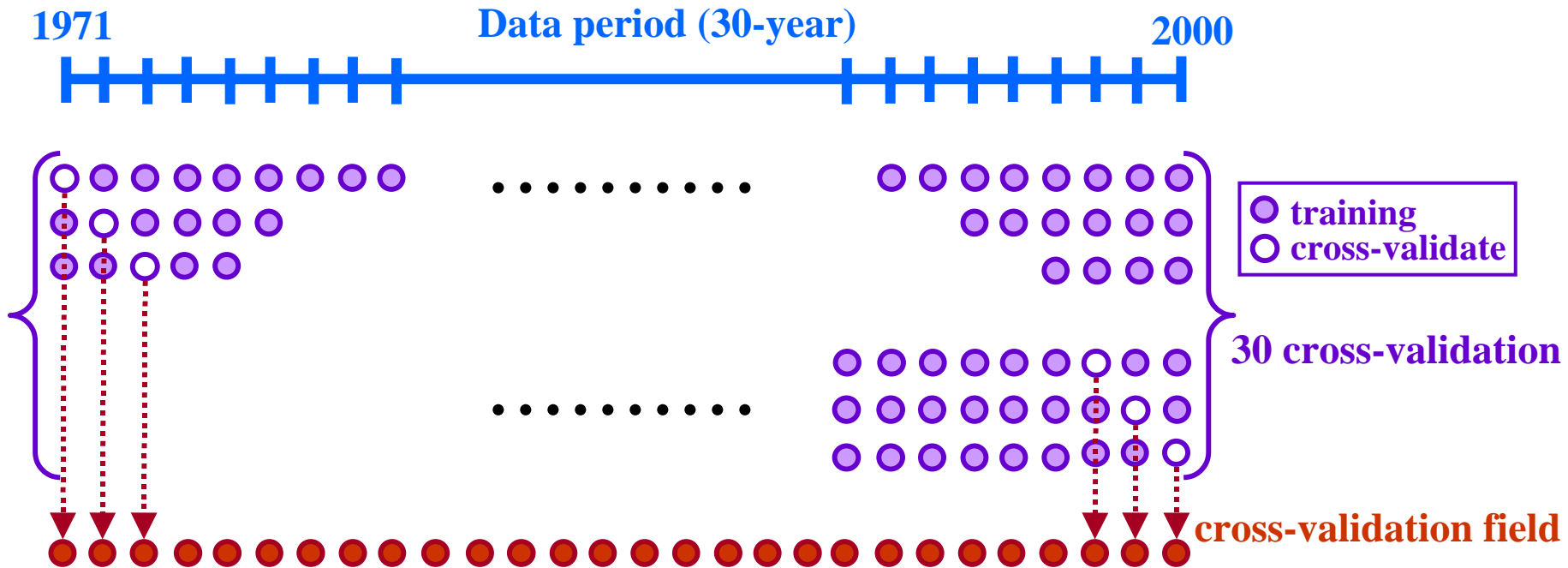


Correction Method



- Predictors for each variable and grid point are selected after searching for the points which have the highest correlation with the point from the whole domain of possible predictor variables.

Cross-Validation

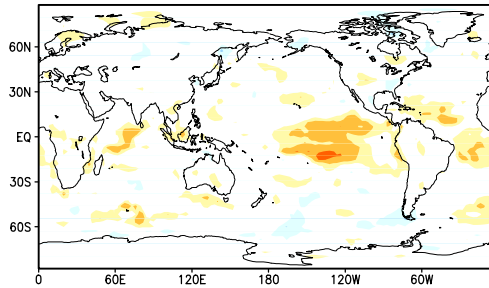


- Taking out one sample out of the whole data period.
- Building ANN model with the rest of the period and applying the model to the sample taken out.
- Repeating this procedure until the whole cross-validation field completed.

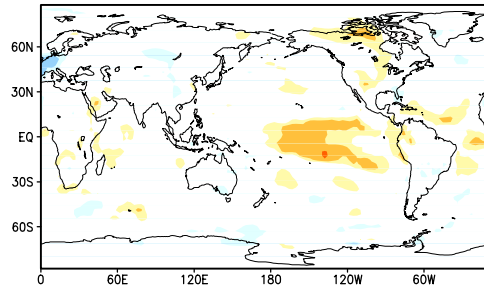
Temporal Correlation Coefficient for Temperature

No
Correction

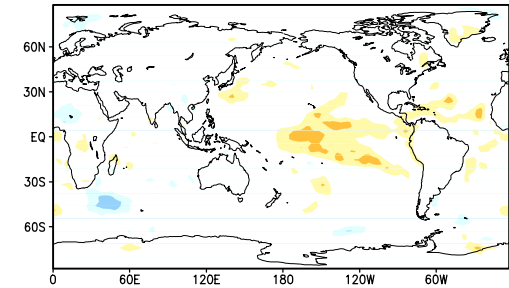
December



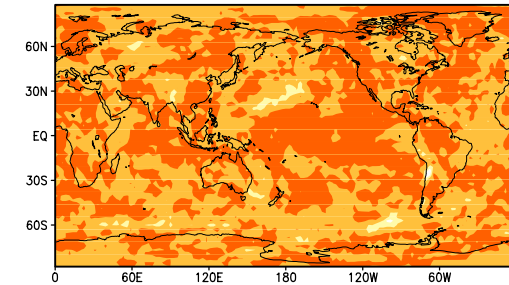
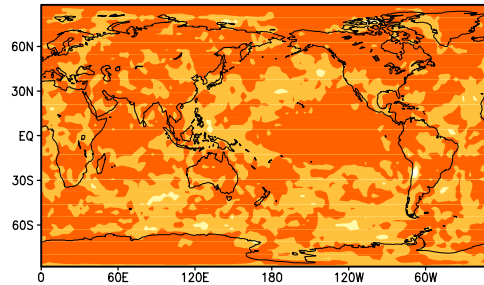
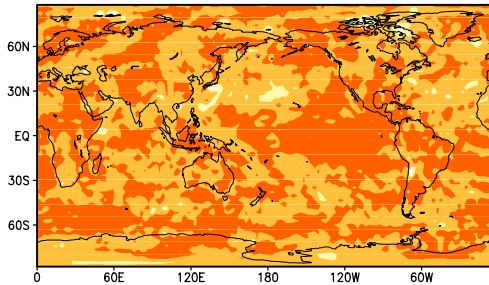
January



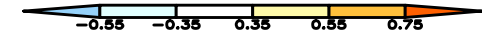
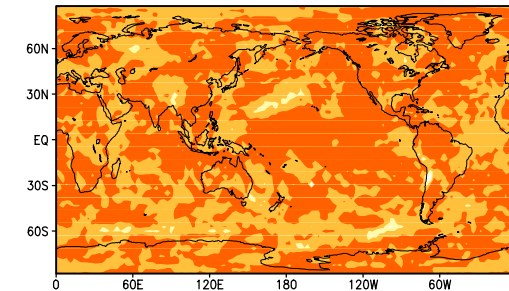
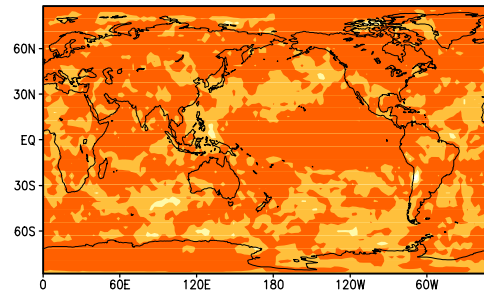
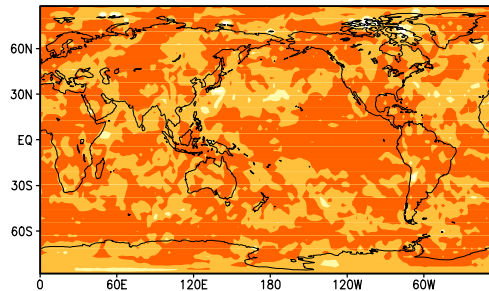
February



Correction
by MLR
(training)



Correction
by ANN
(training)



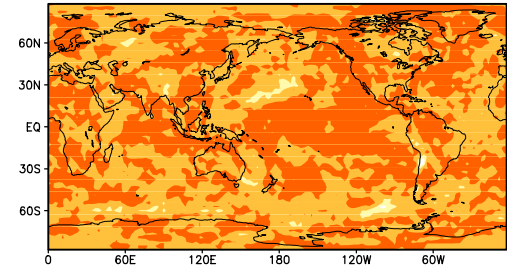
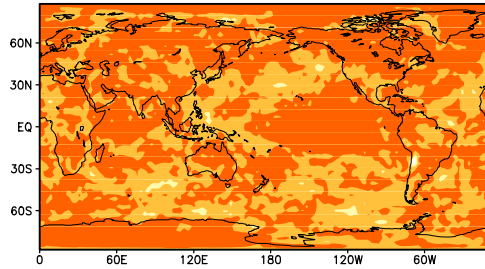
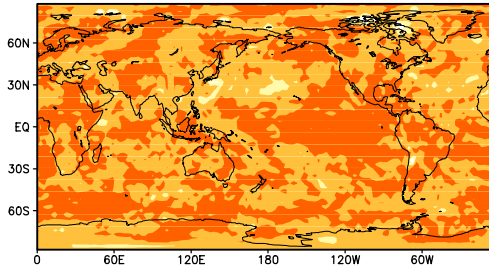
Temporal Correlation Coefficient for Temperature

December

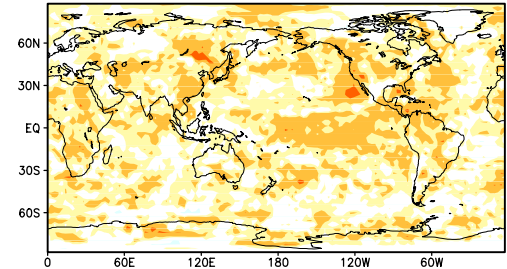
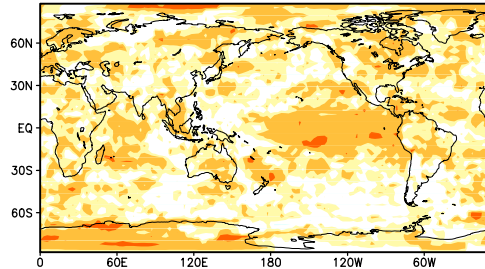
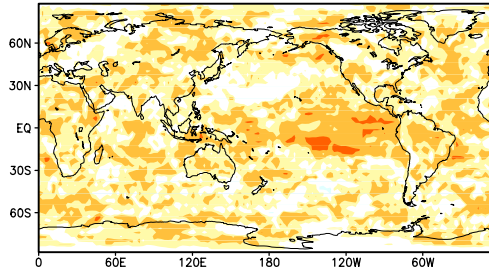
January

February

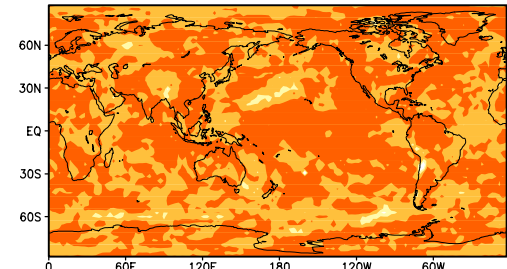
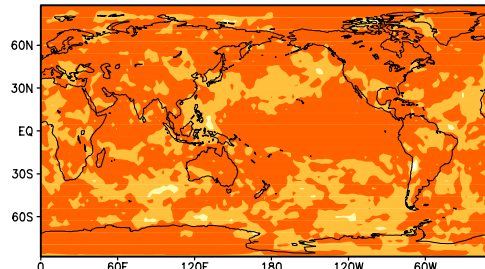
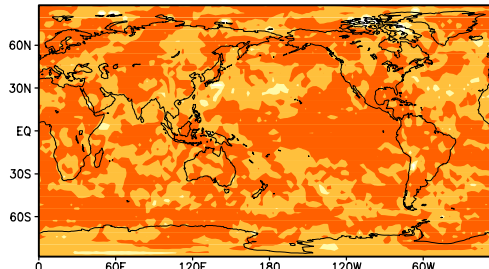
MLR
training



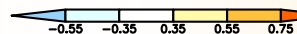
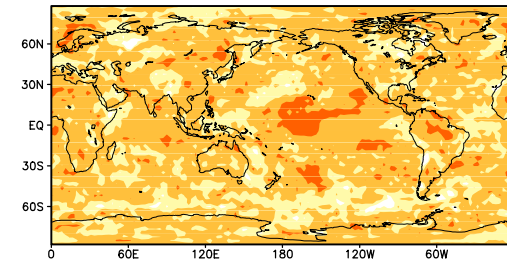
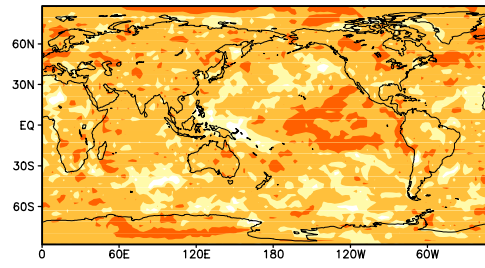
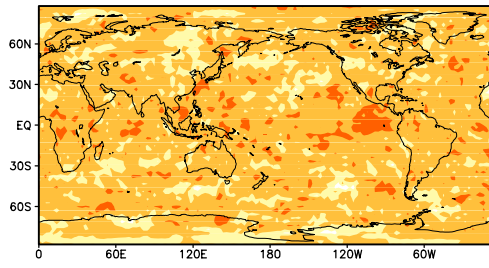
MLR
cross-
validated



ANN
training



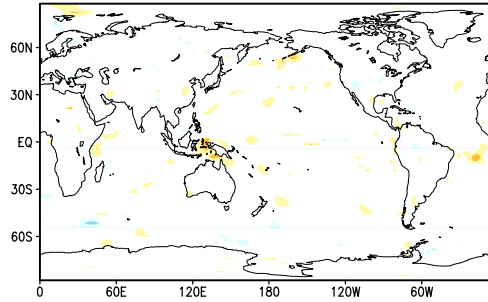
ANN
cross-
validated



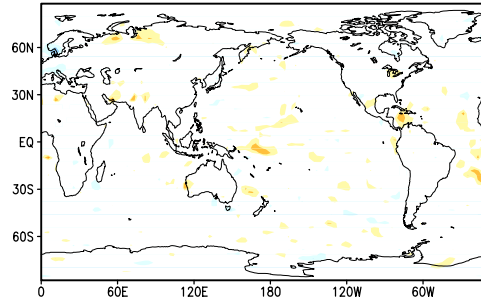
Temporal correlation coefficient for precipitation

No
Correction

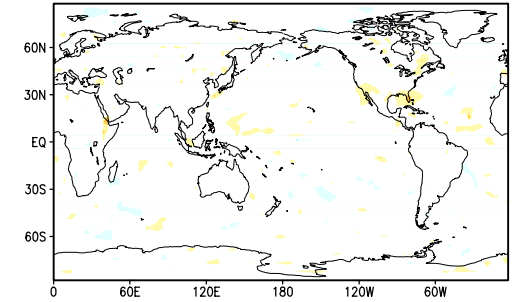
December



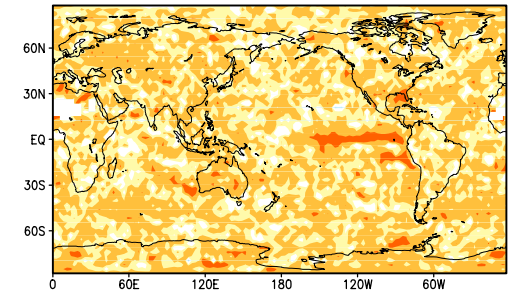
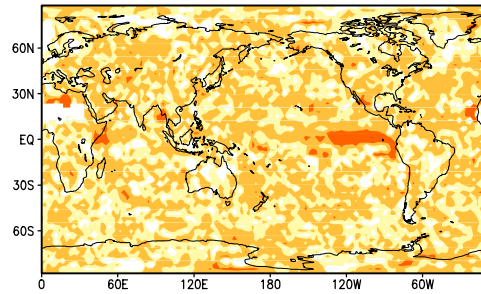
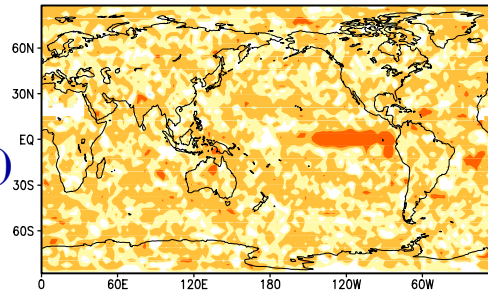
January



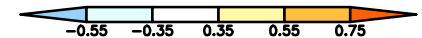
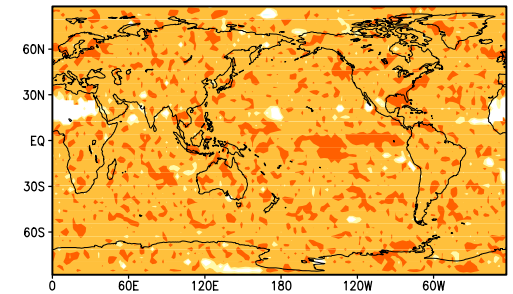
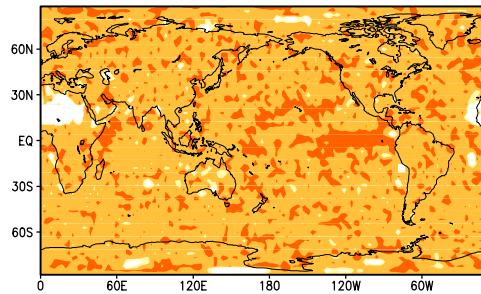
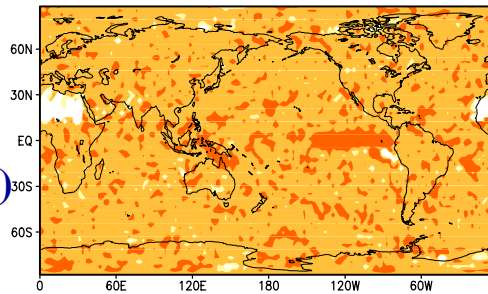
February



Correction
by MLR
(cross-validation)



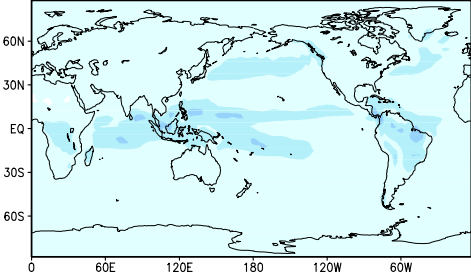
Correction
by ANN
(cross-validation)



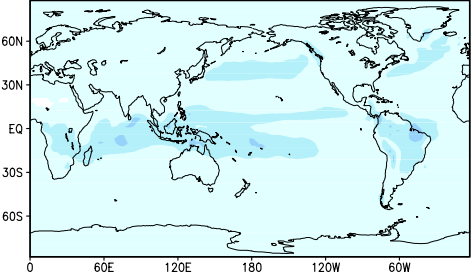
Precipitation

Observation

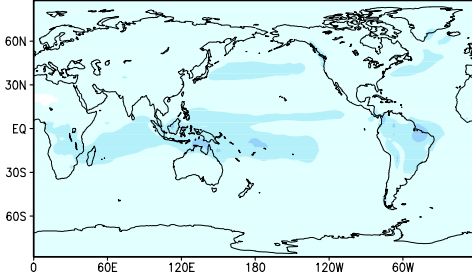
December



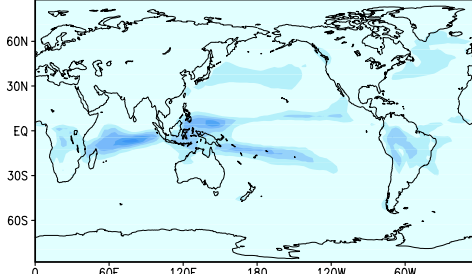
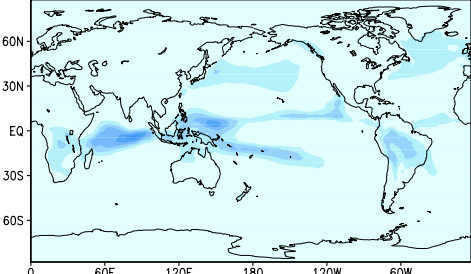
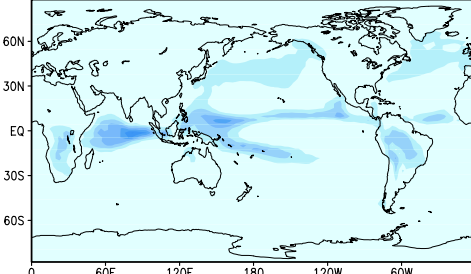
January



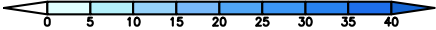
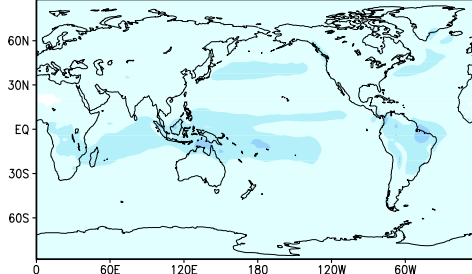
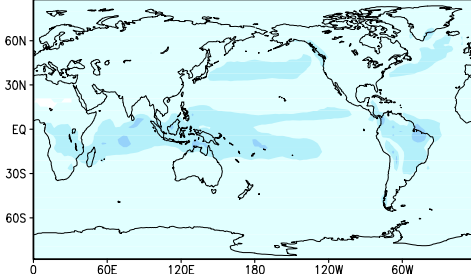
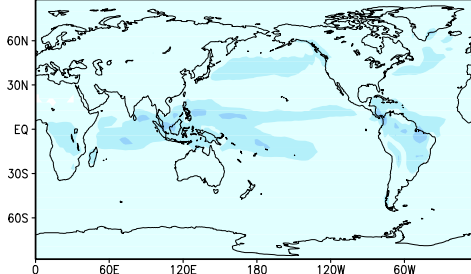
February



**No
Correction**



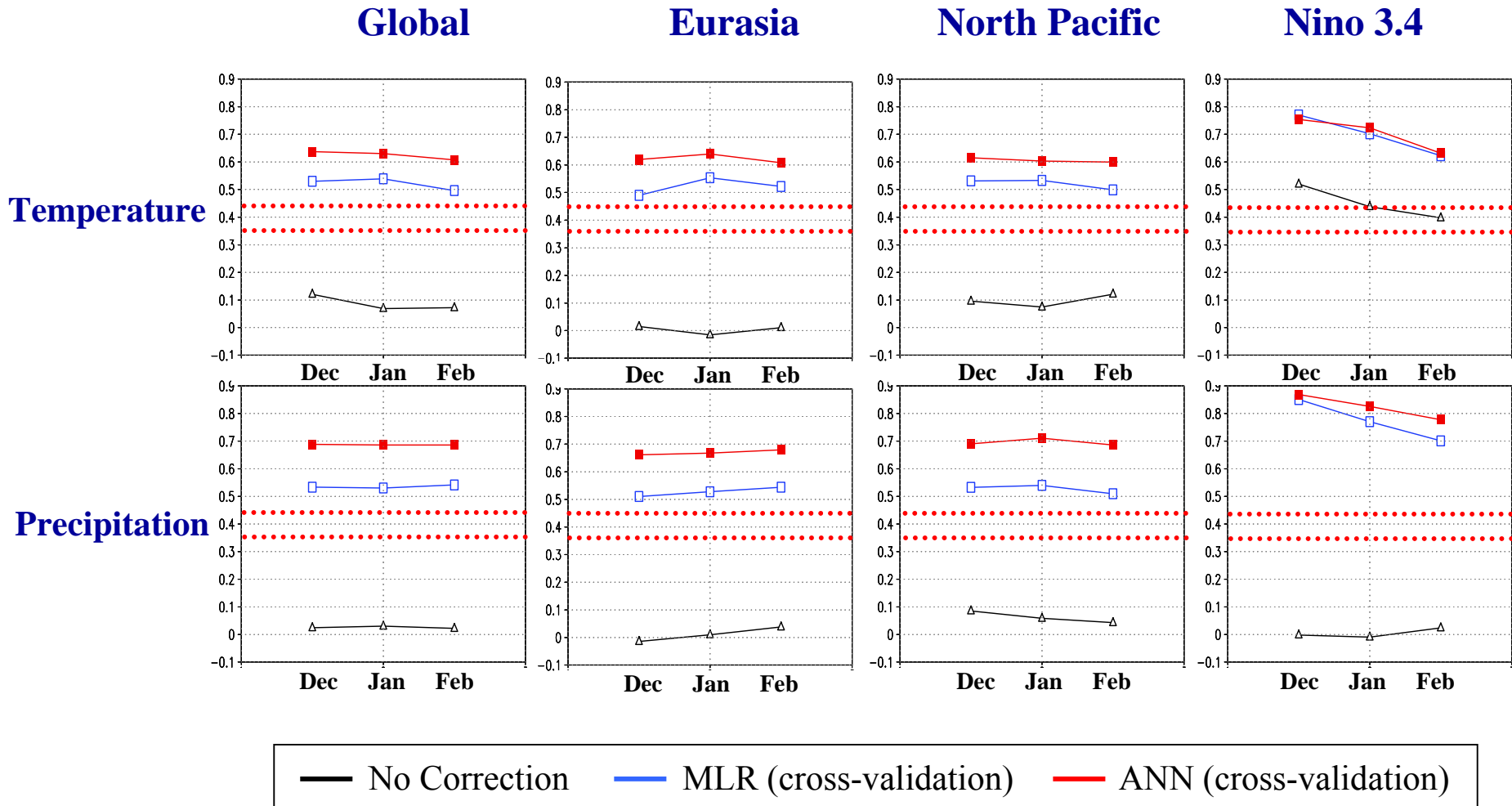
**Correction
by ANN
(cross-validation)**



Regional Verification



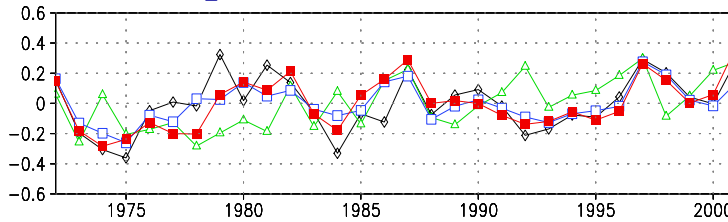
Pattern correlation



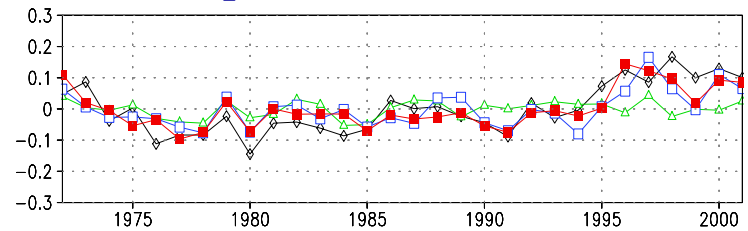
Anomaly Time Series

Global

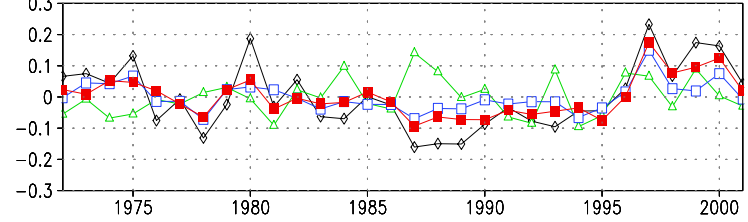
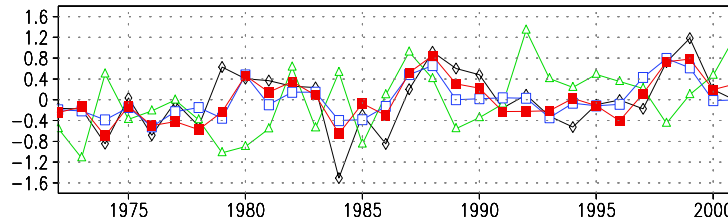
Temperature(cross-validation)



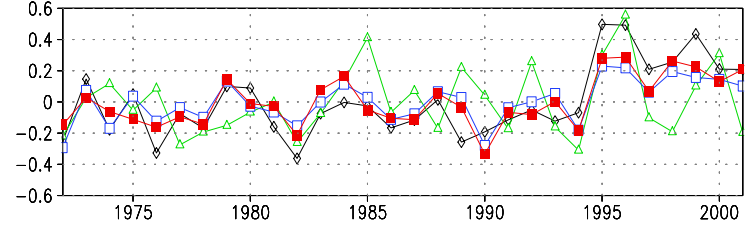
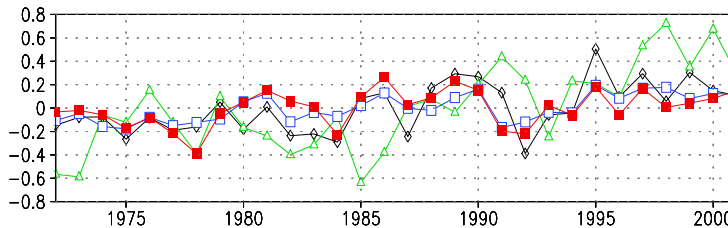
Precipitation(cross-validation)



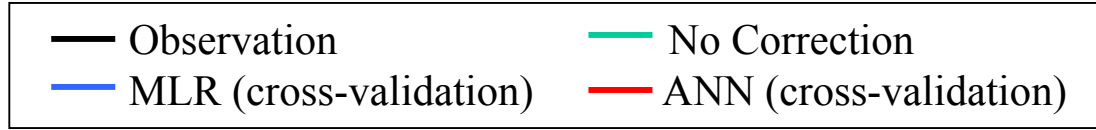
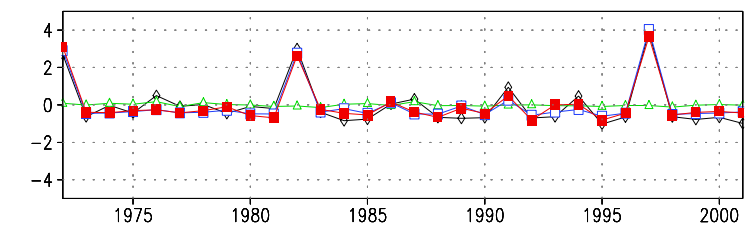
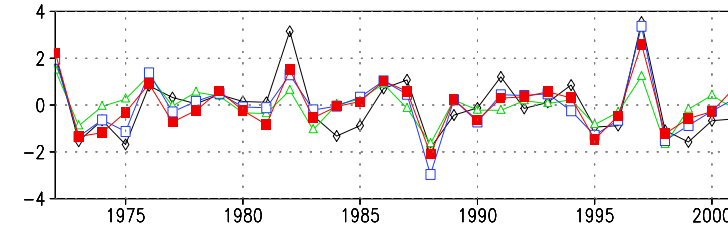
Eurasia



North Pacific



Nino 3.4



Verification

- **Hit rate** = $\frac{A + F + K}{P}$

- **False alarm rate** = $\frac{(E+I)+(B+J)+(C+G)}{(P-D)+(P-H)+(P-L)}$

- **Heidke Score** = $\frac{(A + F + K) - C1}{P - C1}$

| | | | | |
|---------------------|----------|----------|----------|--------------|
| O \ F | + | 0 | - | Total |
| + | A | B | C | D |
| 0 | E | F | G | H |
| - | I | J | K | L |
| Total | M | N | O | P |

$$C1 = 0.3*(M+O) + 0.4*N$$

- **Brier Score(BS)** = $\frac{M}{P} \left(\frac{A}{M} - \frac{A}{D} \right)^2 + \frac{N}{P} \left(\frac{F}{N} - \frac{F}{H} \right)^2 + \frac{O}{P} \left(\frac{K}{O} - \frac{K}{L} \right)^2 + \frac{M}{P} \left(\frac{A}{D} - \frac{(A+F+K)}{P} \right)^2$
 $+ \frac{N}{P} \left(\frac{F}{H} - \frac{(A+F+K)}{P} \right)^2 + \frac{O}{P} \left(\frac{K}{L} - \frac{(A+F+K)}{P} \right)^2 + \frac{(A+F+K)}{P} \left(1 - \frac{(A+F+K)}{P} \right)$

| | Below Normal | Normal | Above Normal |
|---------------|--------------|-------------------|--------------|
| Temperature | -0.5 | -0.5 < and < +0.5 | +0.5 |
| Precipitation | 70% | 70% < and < 120% | 120% |

Temperature Verification

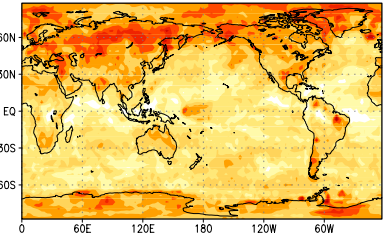
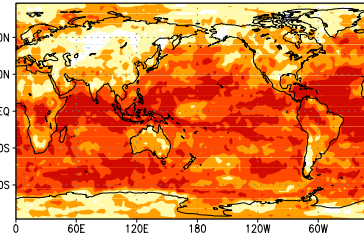
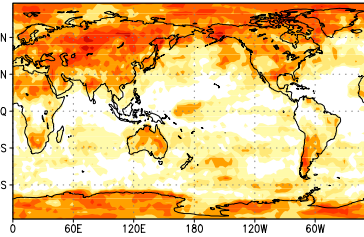
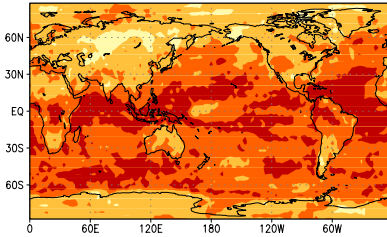
Hit rate

False alarm rate

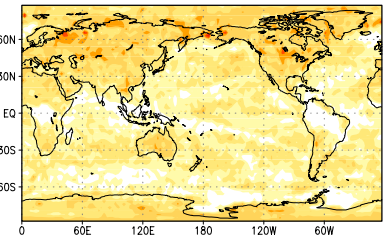
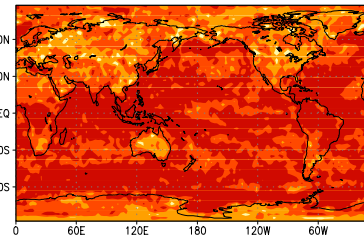
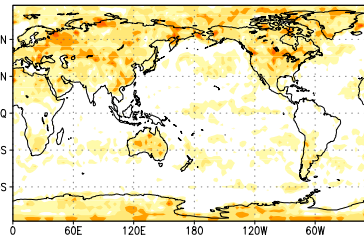
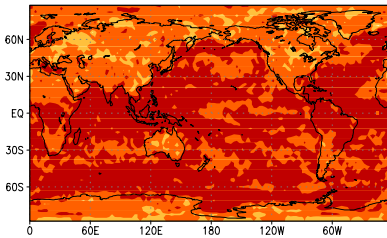
Heidke Score

Brier Score

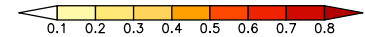
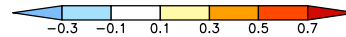
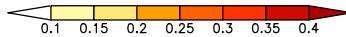
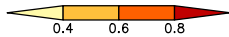
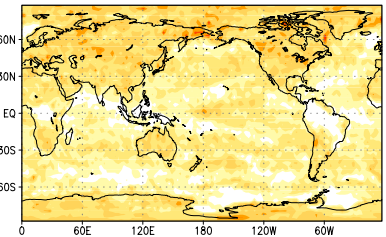
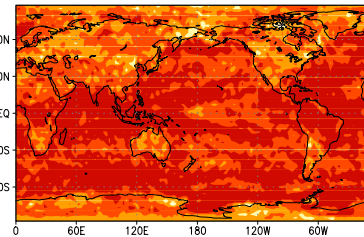
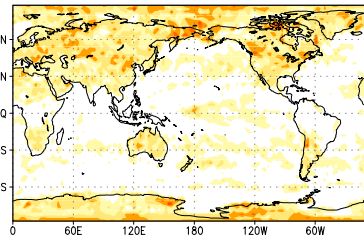
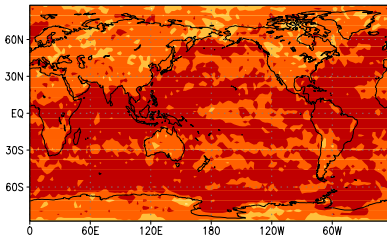
No
Correction



MLR
cross-
validated



ANN
cross-
validated



Precipitation Verification

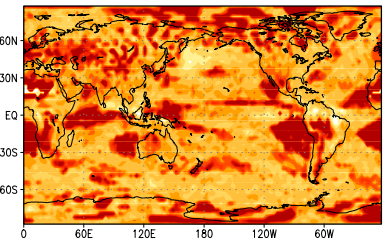
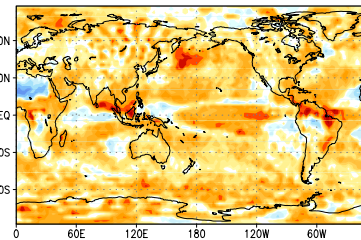
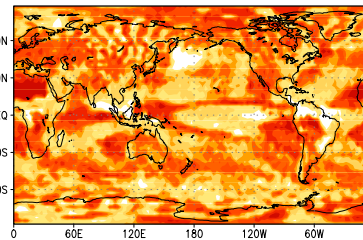
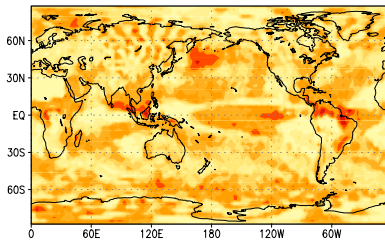
Hit rate

False alarm rate

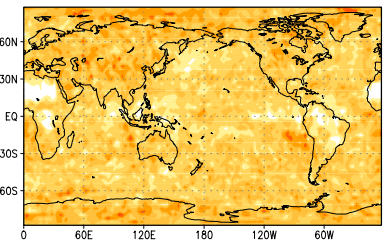
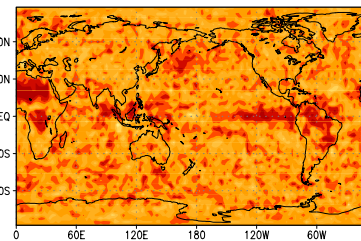
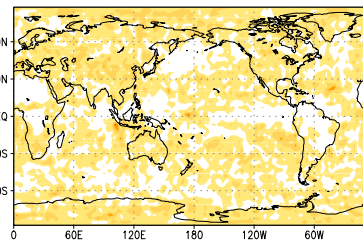
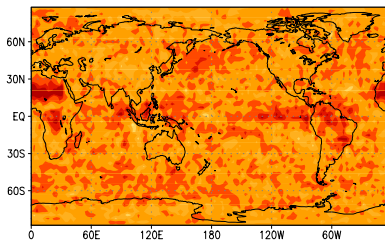
Heidke Score

Brier Score

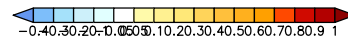
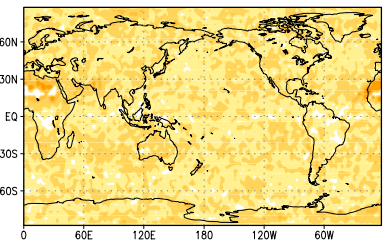
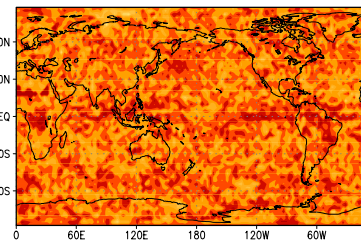
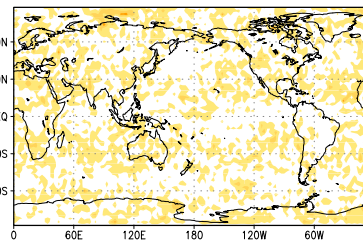
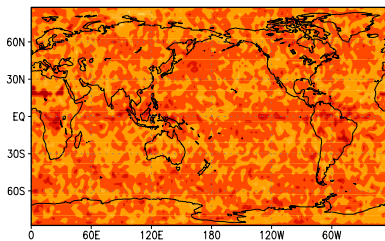
No
Correction



MLR
cross-
validated

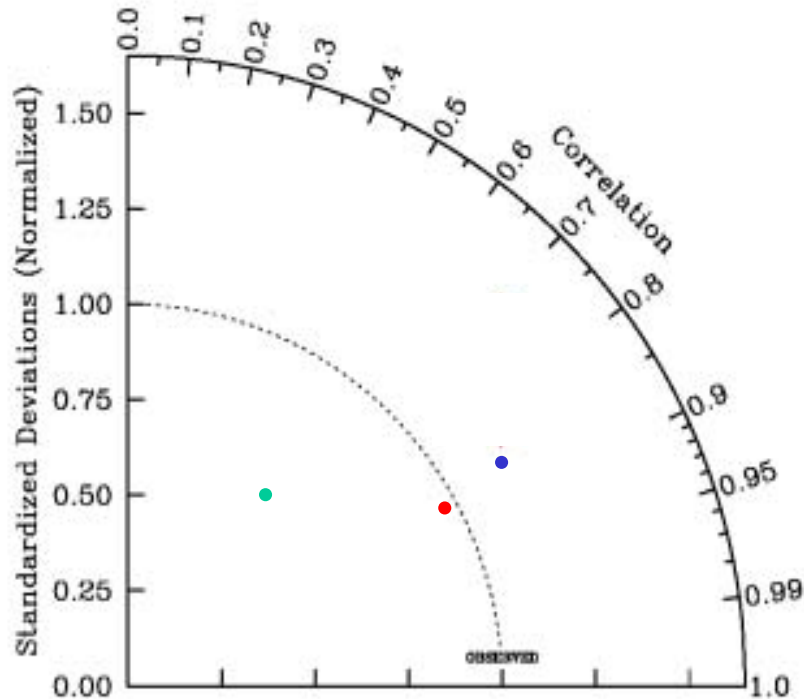


ANN
cross-
validated

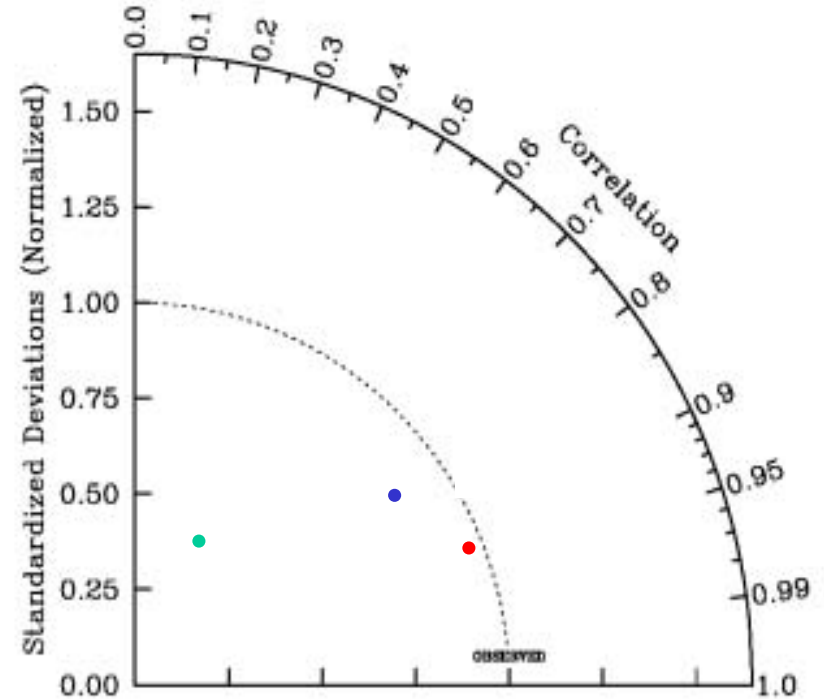


Taylor Diagram for CME CGCM

Temperature (DJF)



Precipitation (DJF)



$$\gamma \text{ (radial distance from the origin)} \\ = \sqrt{\delta^2_{\text{mod}} / \delta^2_{\text{obs}}}$$

- No Correction
- MLR (cross-validation)
- ANN (cross-validation)



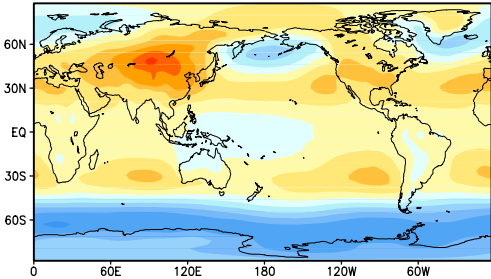
Conclusions

- Cross-validated analysis shows that MLR and ANN are able to correct model bias once appropriate predictors are selected
- ANN seems to correct nonlinear model bias more successfully than MLR
- ANN can be a powerful tool for the correction of climate model bias.

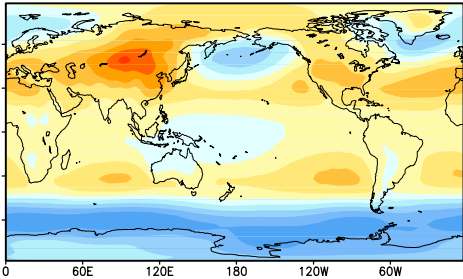
Sea Level Pressure

Observation

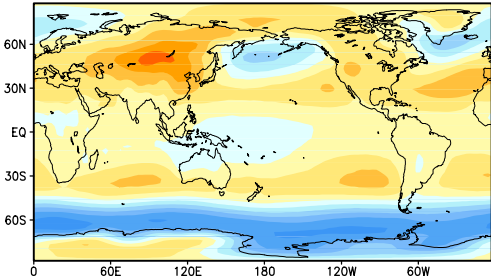
December



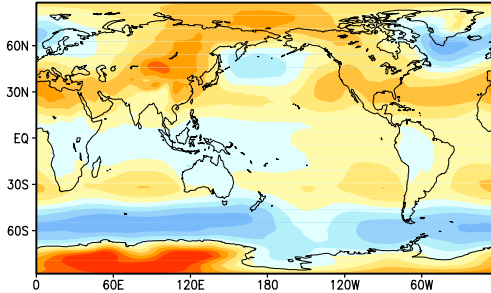
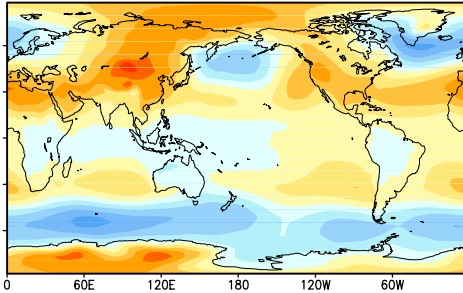
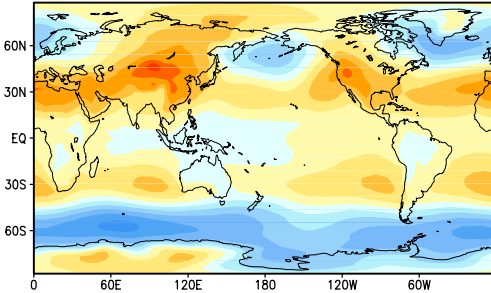
January



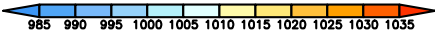
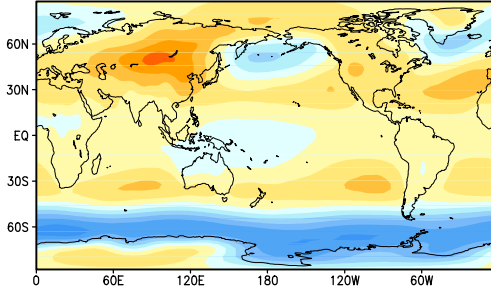
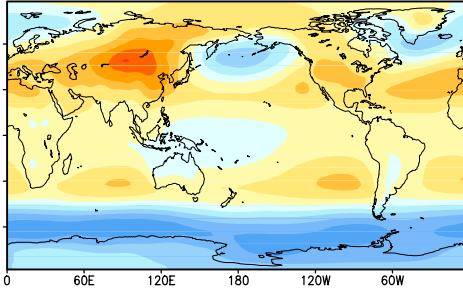
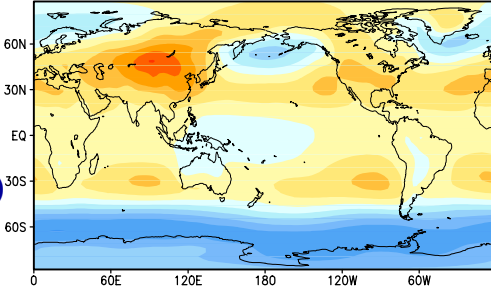
February



No Correction



Correction by ANN (cross-validation)



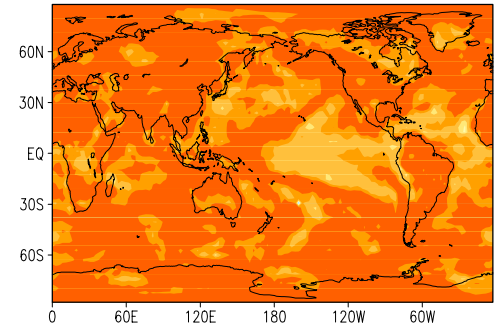
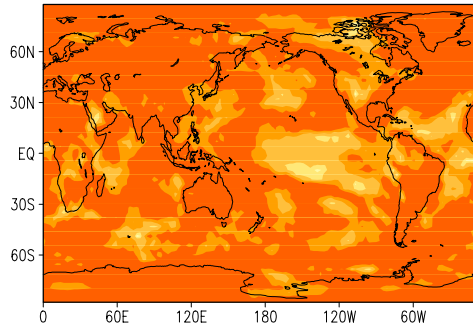
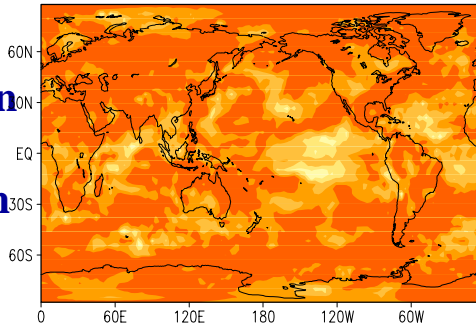
Difference between the ANN Corrected and No-corrected Temporal Correlations

December

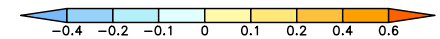
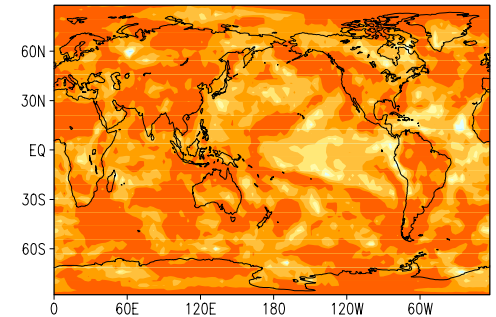
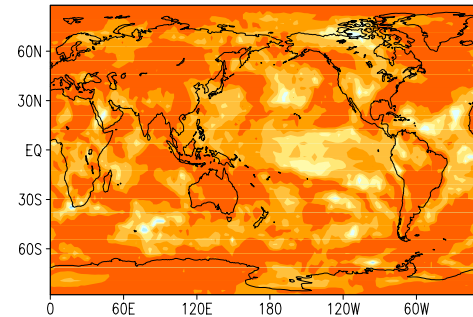
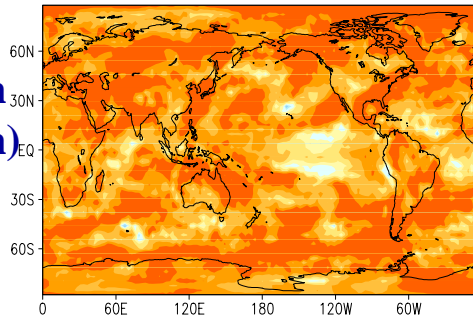
January

February

**ANN correction
(training)
- No correction**



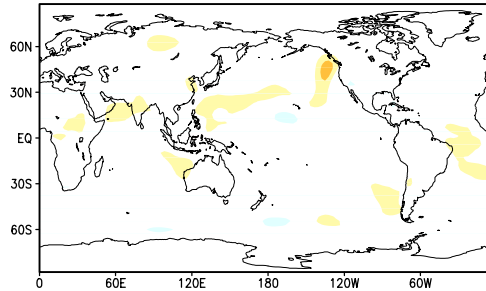
**ANN correction
(cross-validation)
- No correction**



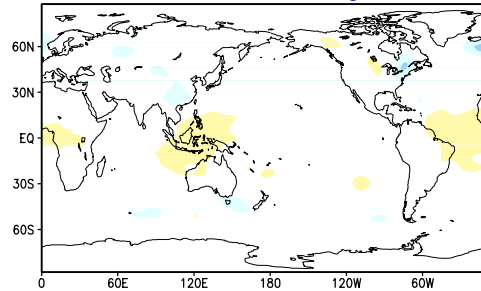
Temporal correlation coefficient for 850hPa Geopotential Height

No
Correction

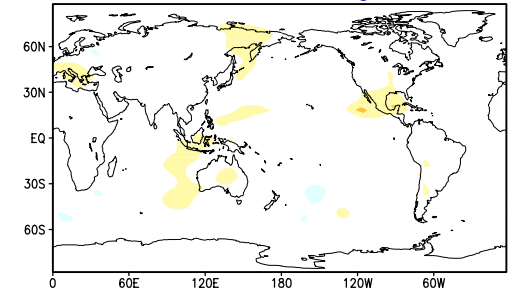
December



January

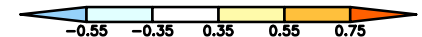
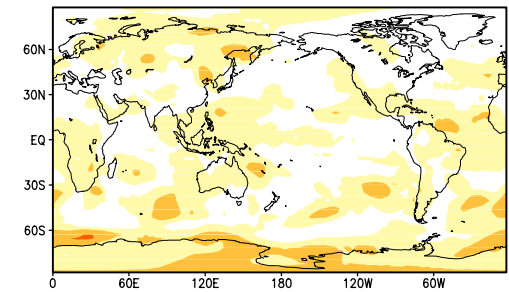
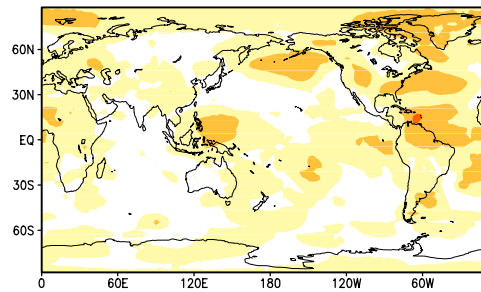
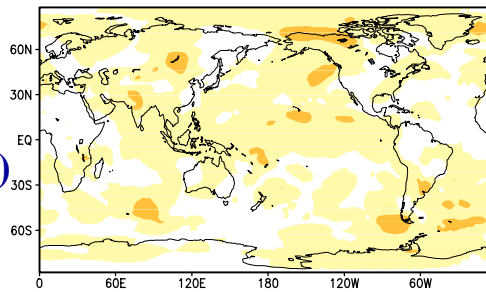


February



Correction
by MLR
(cross-validation)

Correction
by ANN
(cross-validation)



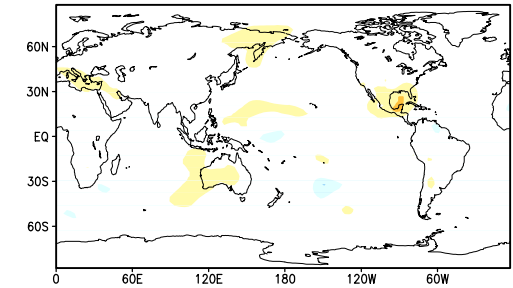
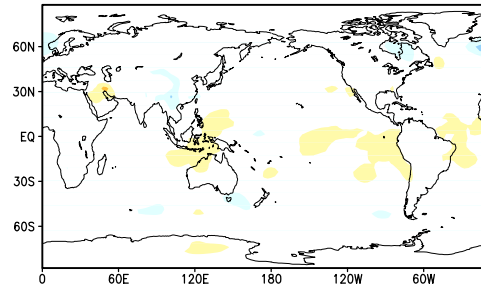
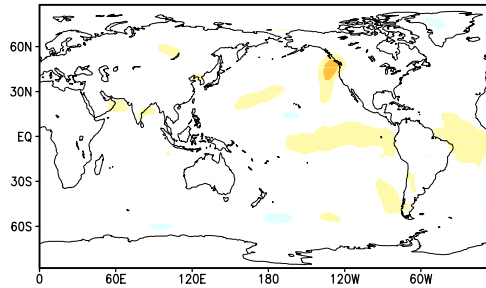
Temporal correlation coefficient for Sea Level Pressure

December

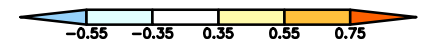
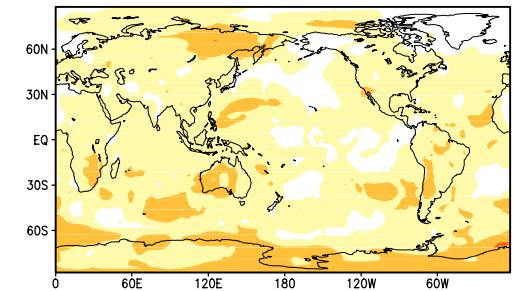
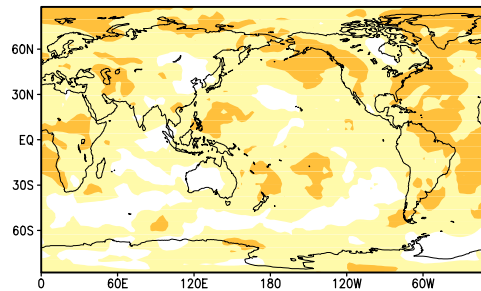
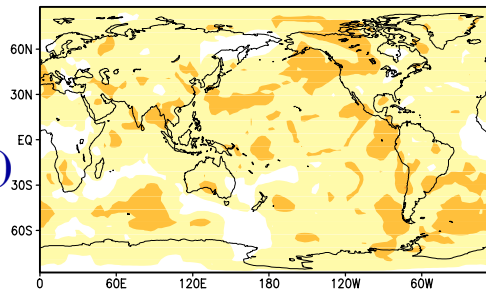
January

February

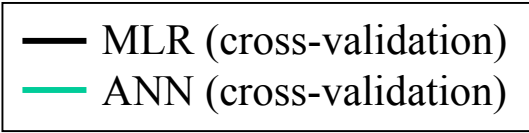
**No
Correction**



**Correction
by MLR
(cross-validation)**



Pattern correlation



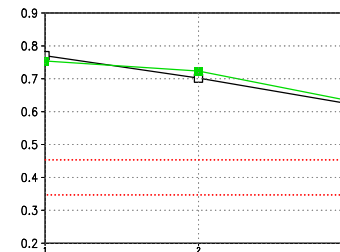
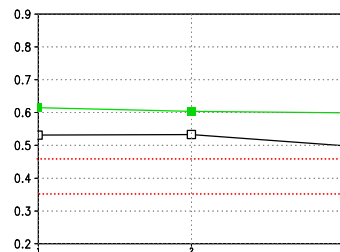
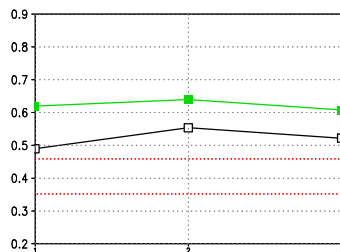
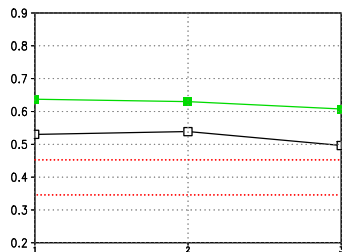
Global

Eurasia

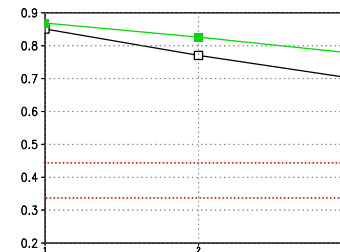
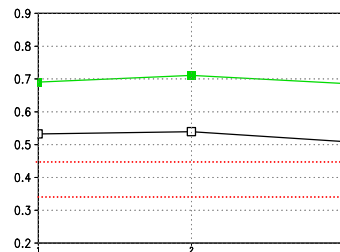
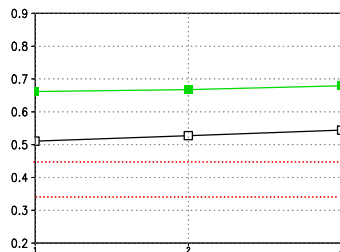
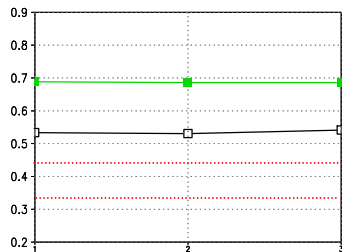
North Pacific

Nino 3.4

Temperature



Precipitation



Sea Level Pressure

850hPa Geopotential Height

Dec

Jan

Feb

Dec

Jan

Feb

Dec

Jan

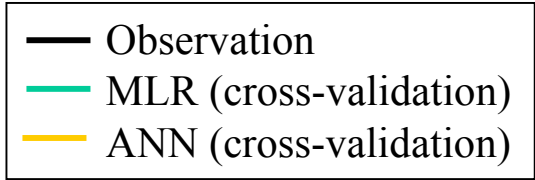
Feb

Dec

Jan

Feb

Anomaly Time Series



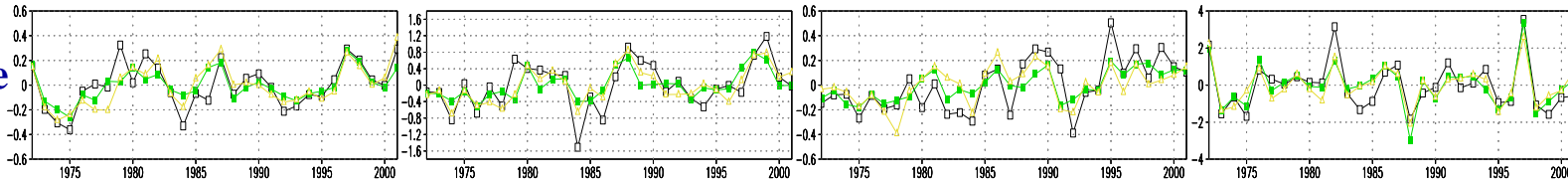
Global

Eurasia

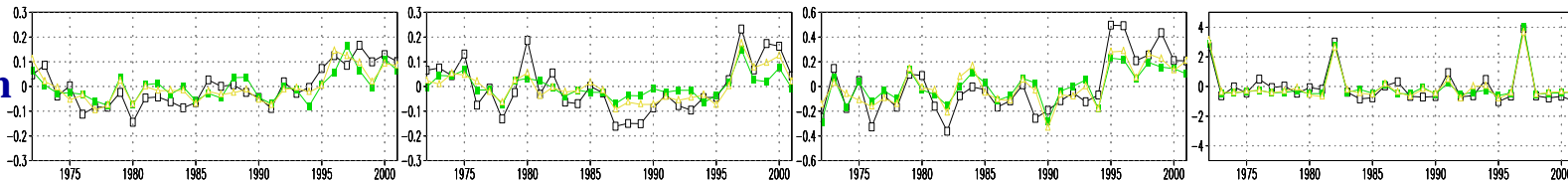
North Pacific

Nino 3.4

Temperature



Precipitation



Sea Level Pressure

850hPa Geopotential Height