Seasonal forecasts at the Canadian Meteorological Centre

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Outline

- Introduction
- History
- Current system of seasonal forecast
- Verification
- Conclusion
- Projects in 2009

Introduction

- The Canadian Meteorological Centre (CMC) is producing seasonal forecasts in operational mode since September 1995.
- Three-month temperature and precipitation anomaly outlooks in three equally probable categories “above normal”, “near normal” and “below normal”.
- Twelve three-month seasons
- Dynamical models are used for seasonal forecasts with zero and one-month lead time.
- A statistical model is used for seasons 2, 3 and 4 with 3, 6 and 9 months lead time respectively.
- The set-up for season 1 is also used for monthly temperature anomaly forecasts issued on the 1st and 15th days of each month.
- The CMC is a Global Producing Centre of Long-Range Forecasts collaborating with the WMO
- The CMC is a providing centre for the APCC MME system

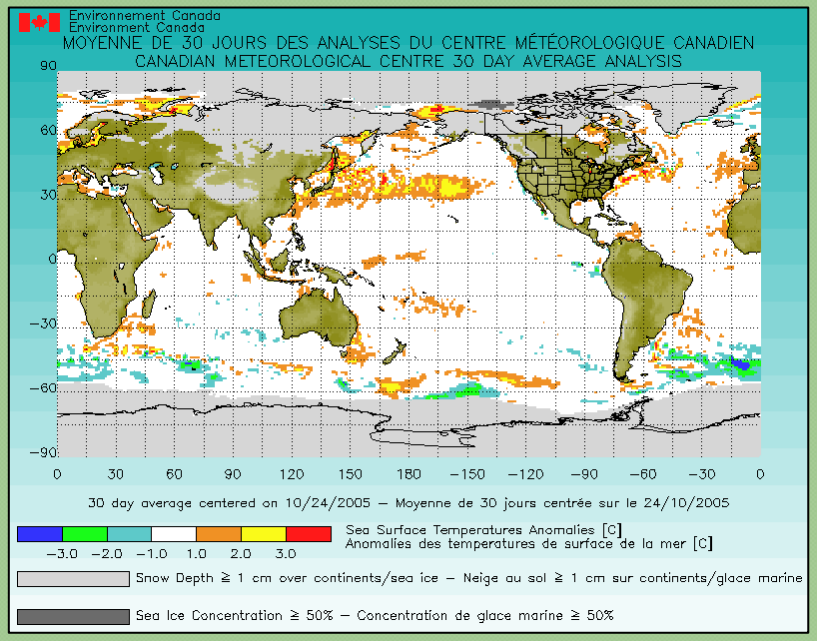
History

- 1995
  - *first automatic seasonal forecast*
  - *Two models : RPN SEF and CCCma GCM2, and six members by model, lagged of 24 hours*
  - *4 forecasts by year with 0 lead time : winter, spring, summer and autumn*
  - *Period of hindcast (HFP): 1969-1994*
- 2000
  - *monthly forecast of surface temperature*
- 2001
  - *replacement of SEF by RPN GEM*
  - *12 seasonal forecast with 0 lead time*
- November 2007
  - *replacement of GEM by GEMCLIM, addition of CCCma GCM3 and of RPN SEF*
  - *40 members system*

Current system

- Dynamical models used for season 1.
  - *Forecasts are issued on the first day of each month (12 seasons).*
  - *GEMCLIM: 2° 50 levels ptop 5mb*
  - *GCM2: T32 10 levels ptop 10 mb*
  - *GCM3: T63 32 levels ptop 5 mb*
  - *SEF: T95 27 levels ptop 10 mb*
- Historical forecasts (HFP2):
  - *35 years (1969-2003).*
  - *Equivalent to a single integration over 5360 years.*
  - *To assess skill of seasonal forecast system.*
  - *To calculate the climate of model.*

Current system



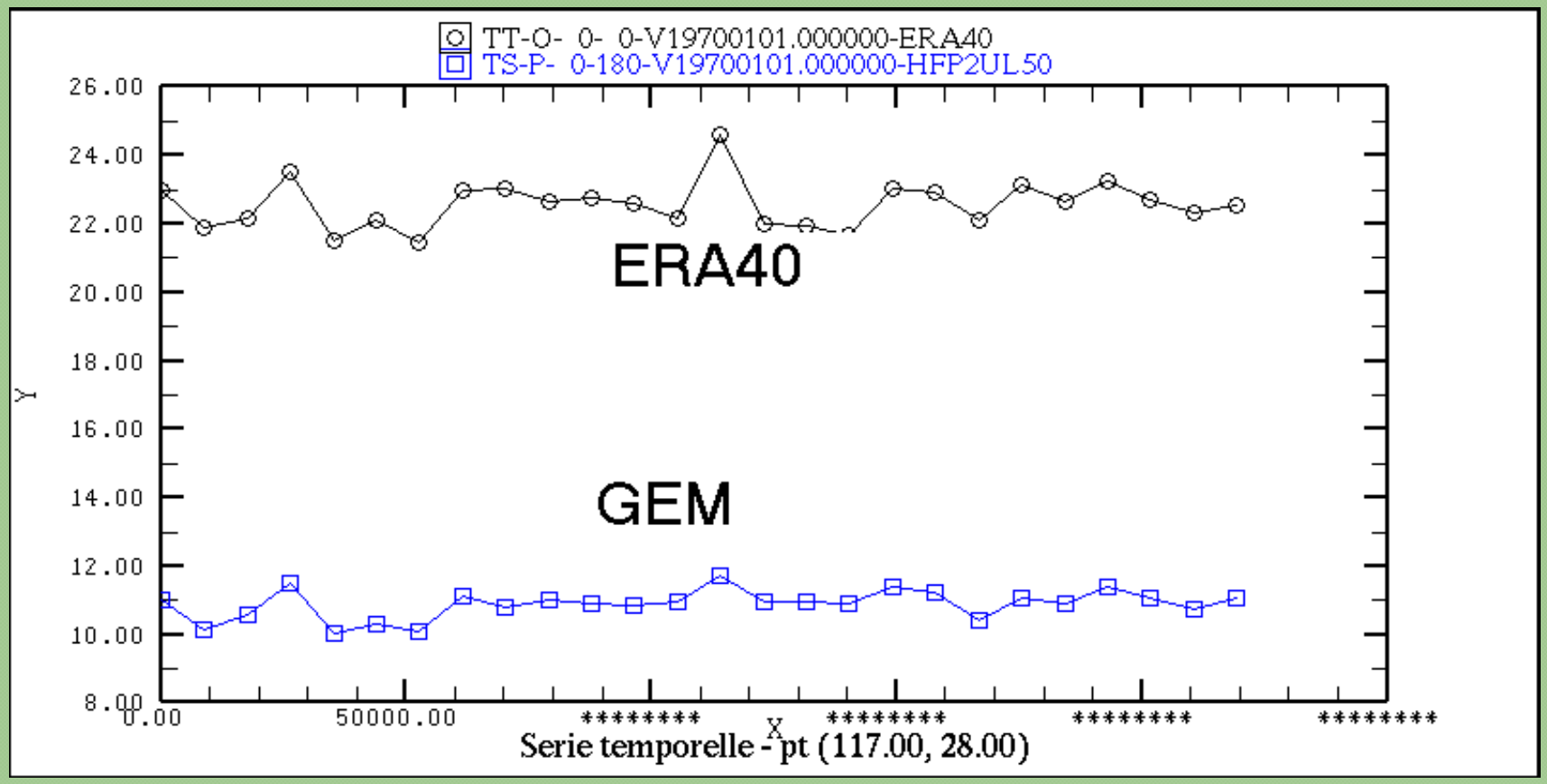
Four models
GEM + GCM2
+ GCM3 + SEF

SST
last 30-day anomaly persisted throughout

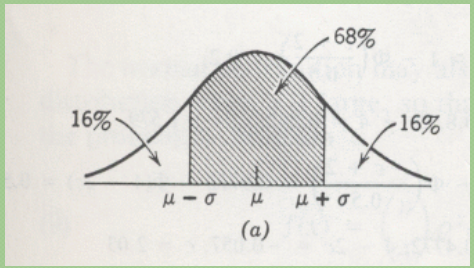
ICE	
GEM SEF GCM3 GCM2	CMC analysis relaxed to climatology during first 15 days (GCM2 is a step function)

SNOW	
SEF	CMC analysis relaxed to climatology during first 15 days
GEM GCM2 GCM3	prognostic variable

Time series of surface temperature for J-F-M for the period 1969-1994 (North of Chile)
Observations and model outputs

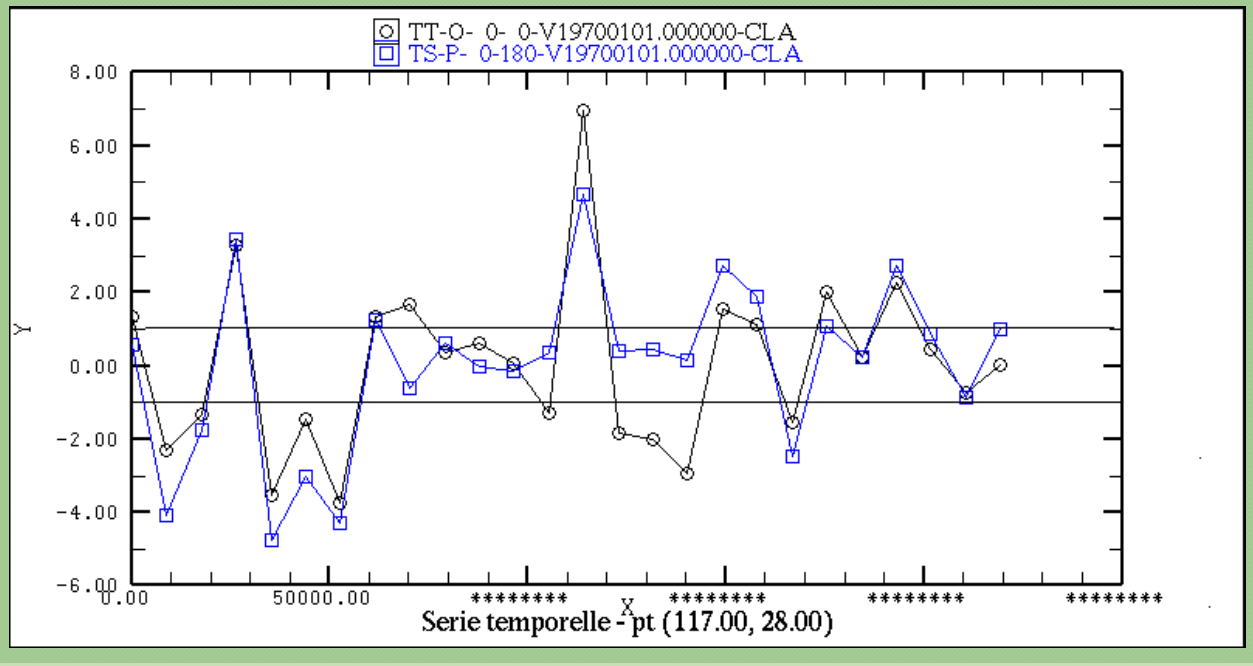


Normalisation

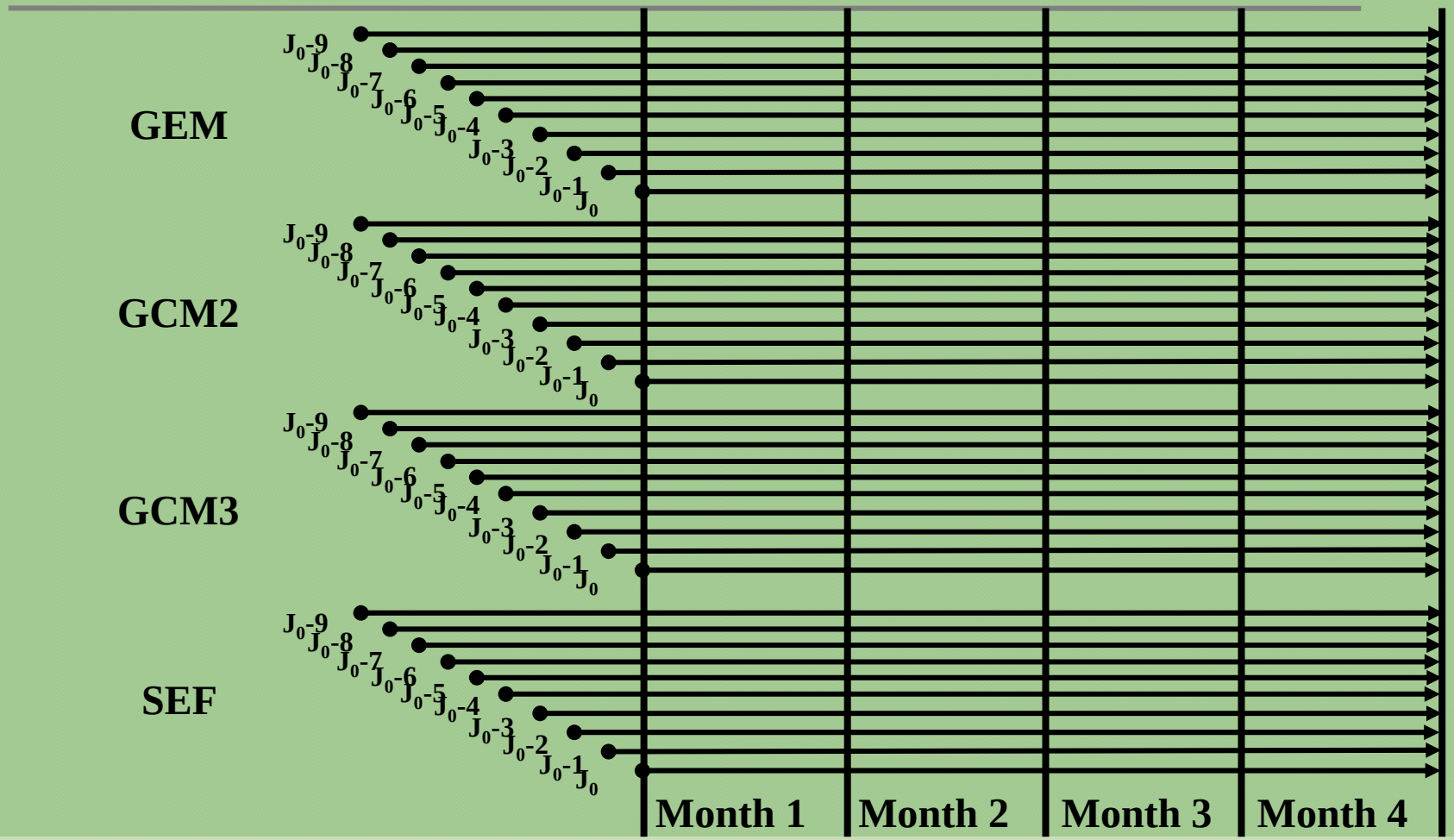


$$x' = \frac{x - \bar{x}}{0.43 \cdot \sigma}$$

$x' \prec -1$	below	normal
$-1 \prec x' \prec 1$	normal	
$1 \prec x'$	above	normal

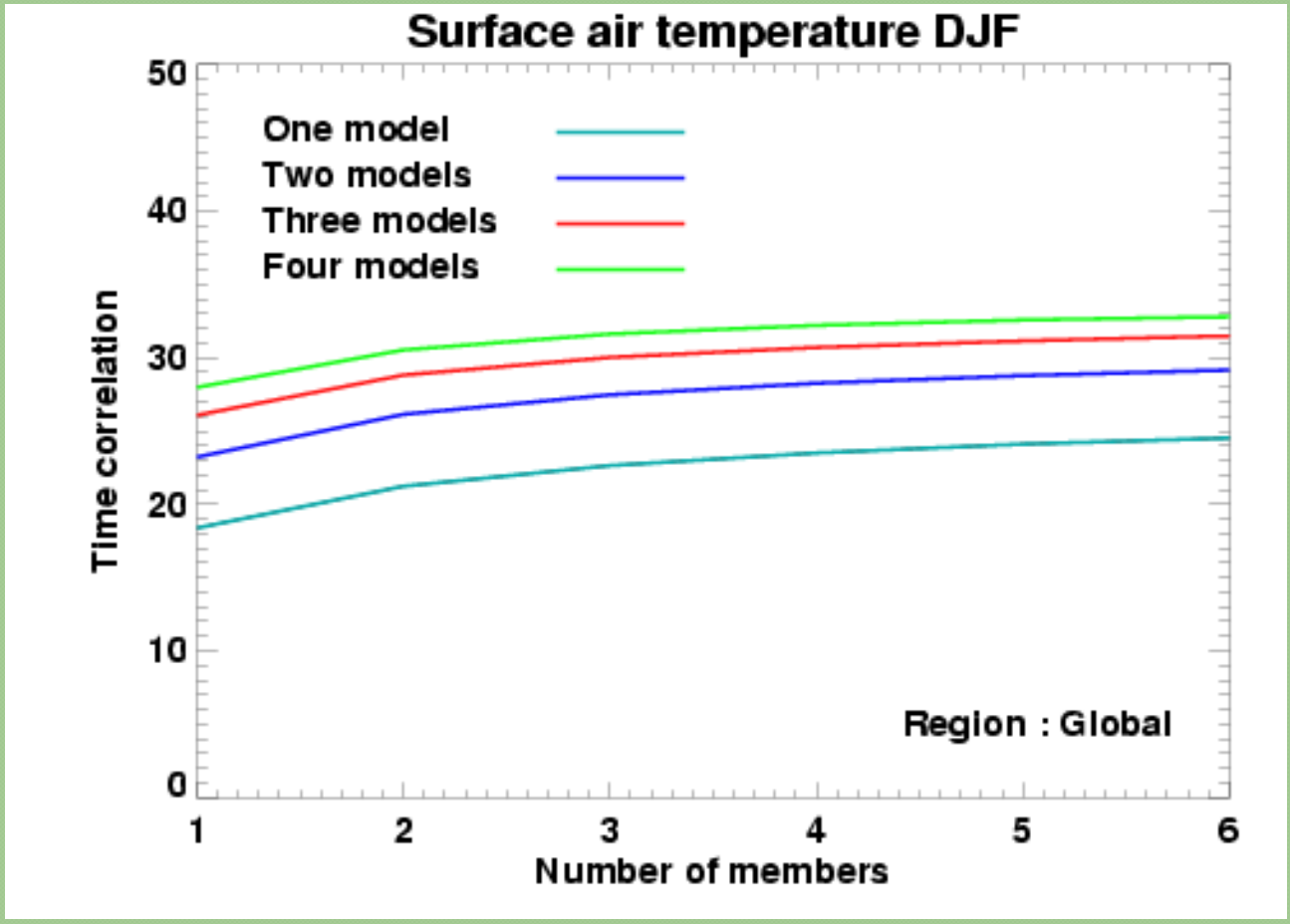


40 members system

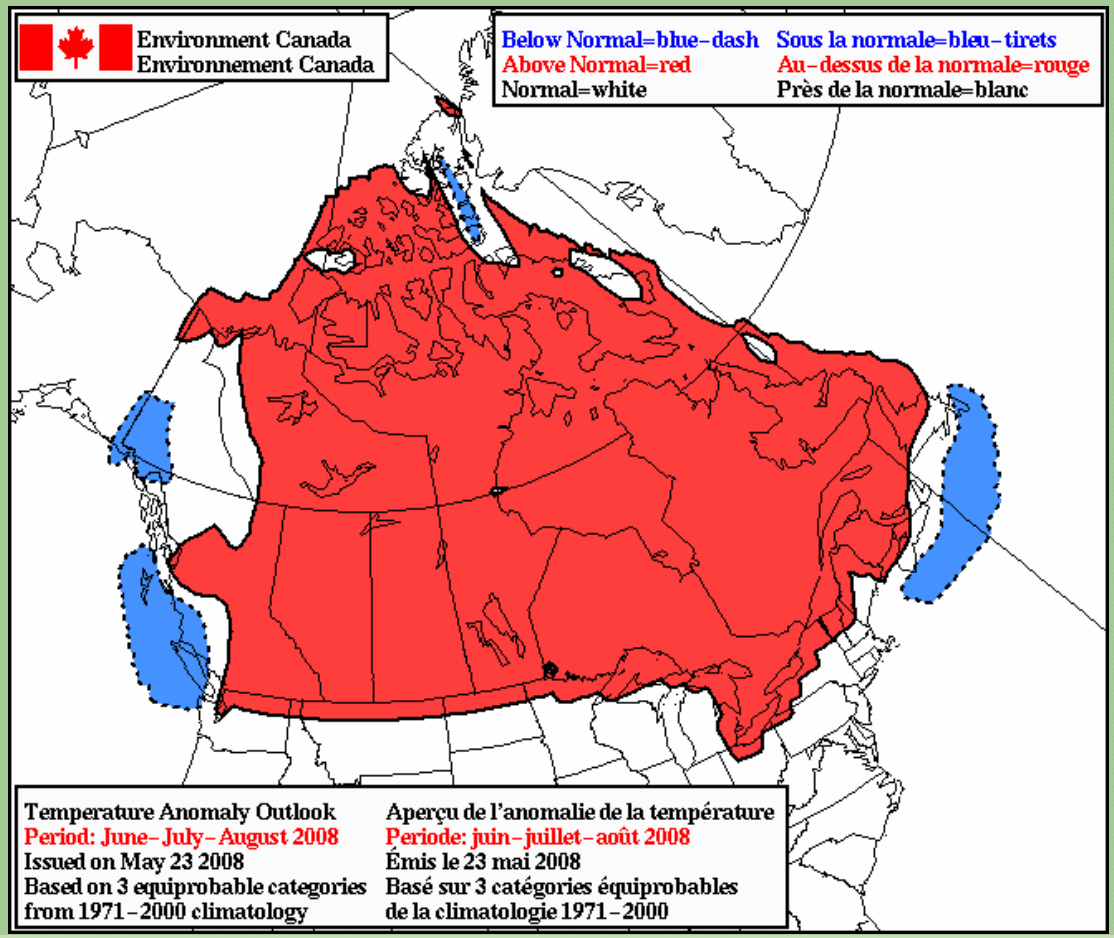


Are N models better than N-1 models?

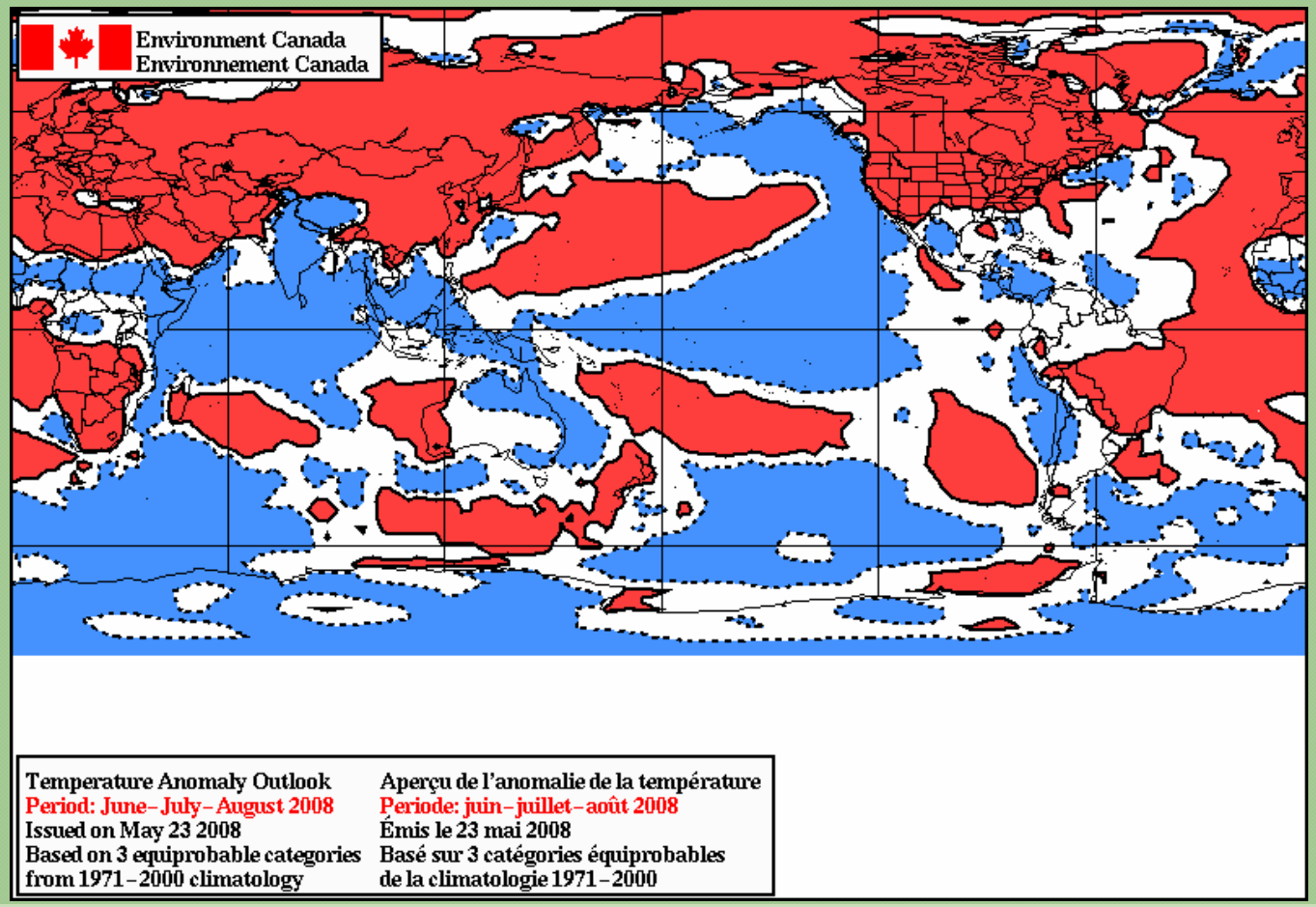
Yes, in general



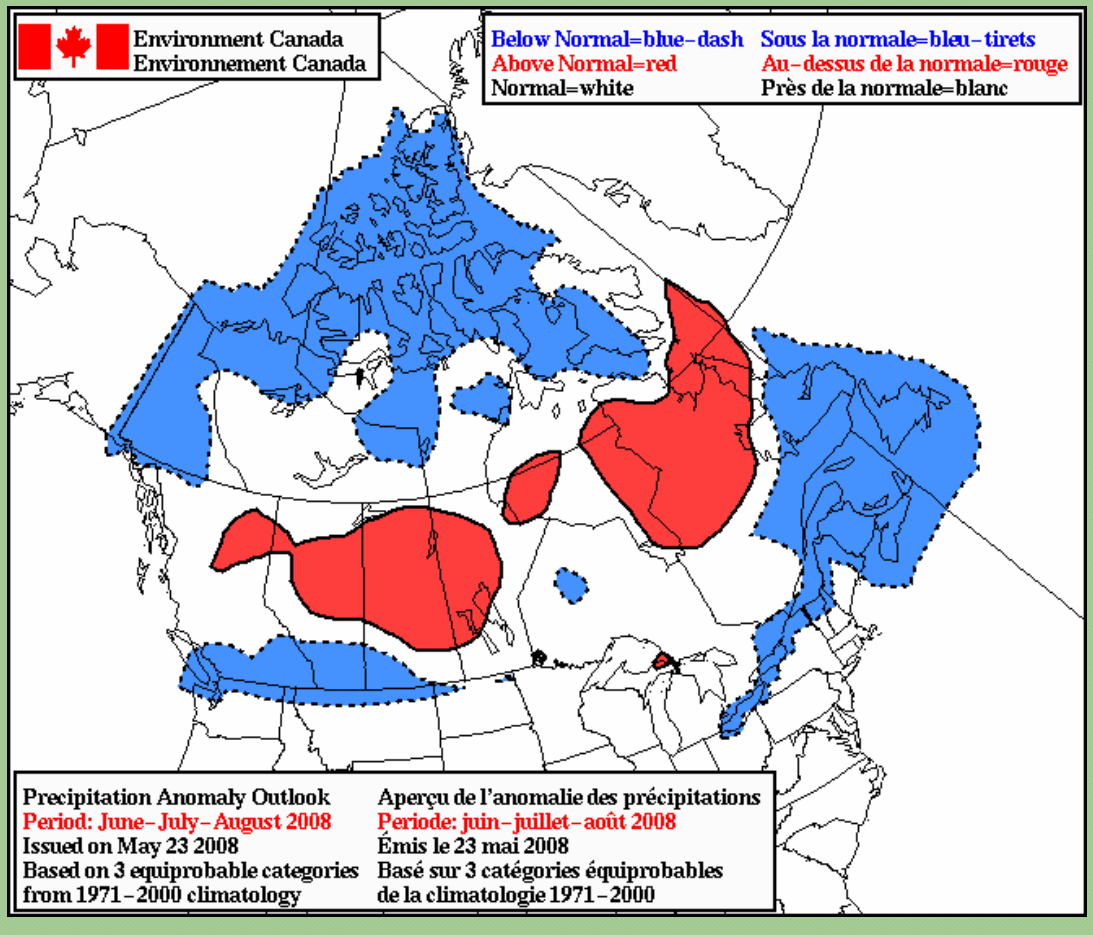
Seasonal forecast of temperature at 2m with 0 lead time for JJA



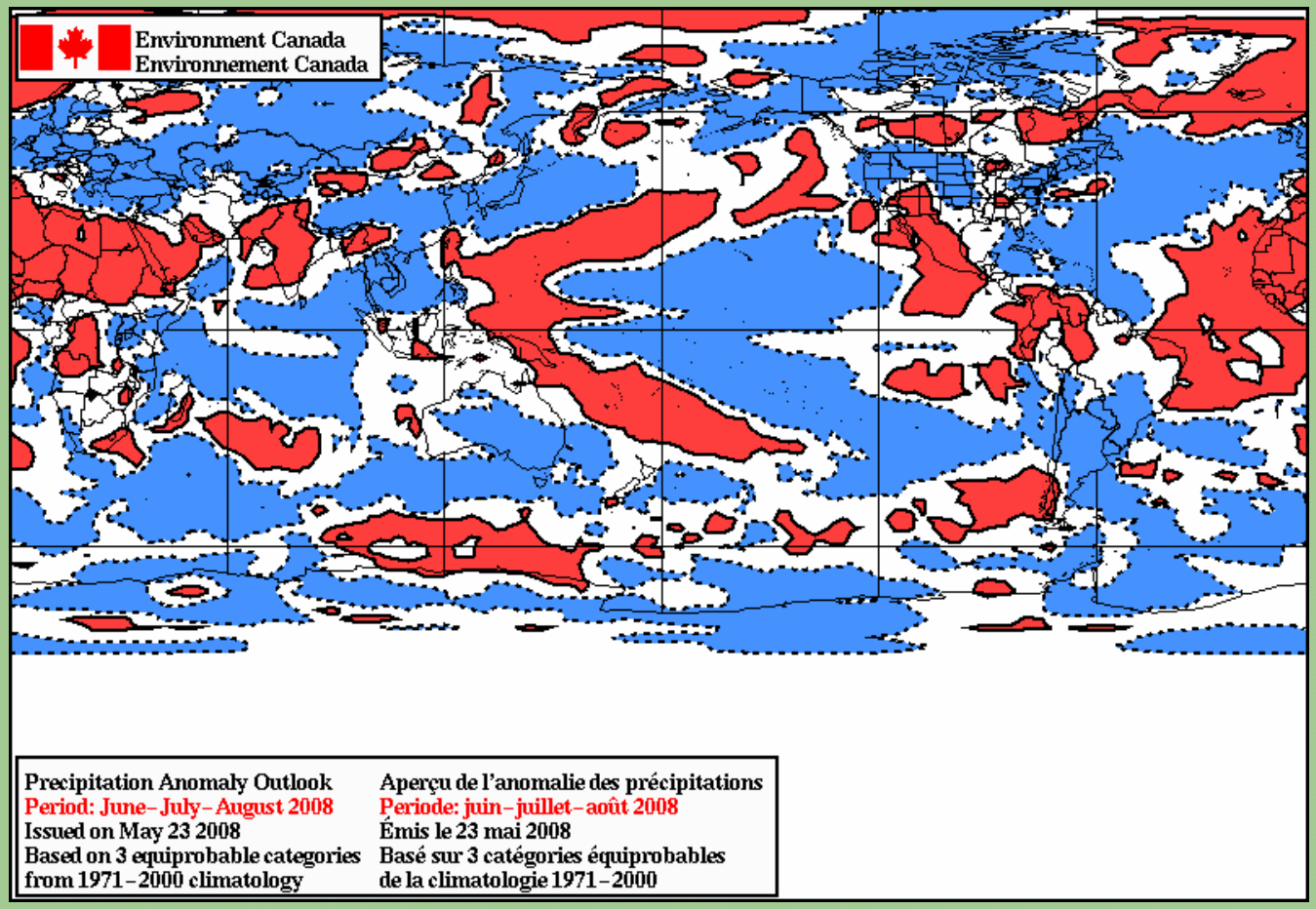
Seasonal forecast with 0 lead time of temperature at 2m for JJA



Seasonal forecast of precipitation with 0 lead time for JJA

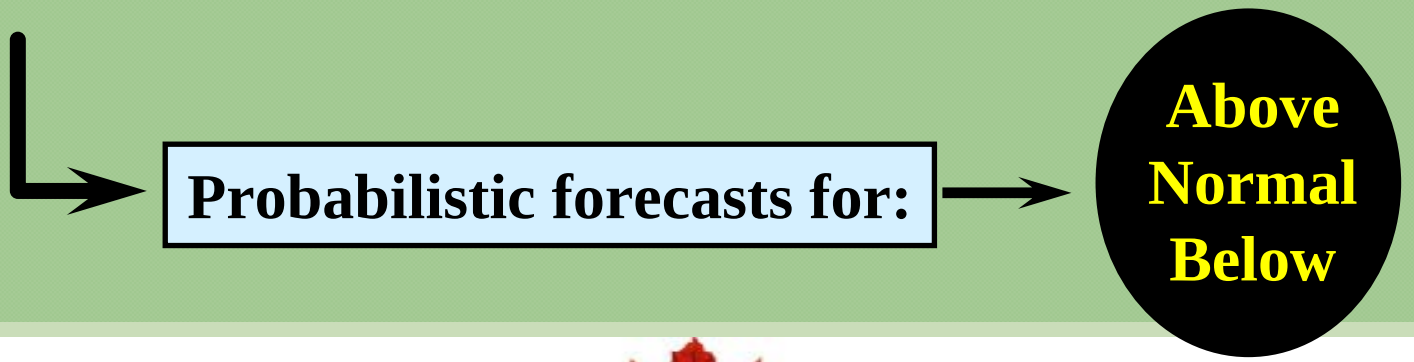


Seasonal forecast of precipitation with 0 lead time for JJA

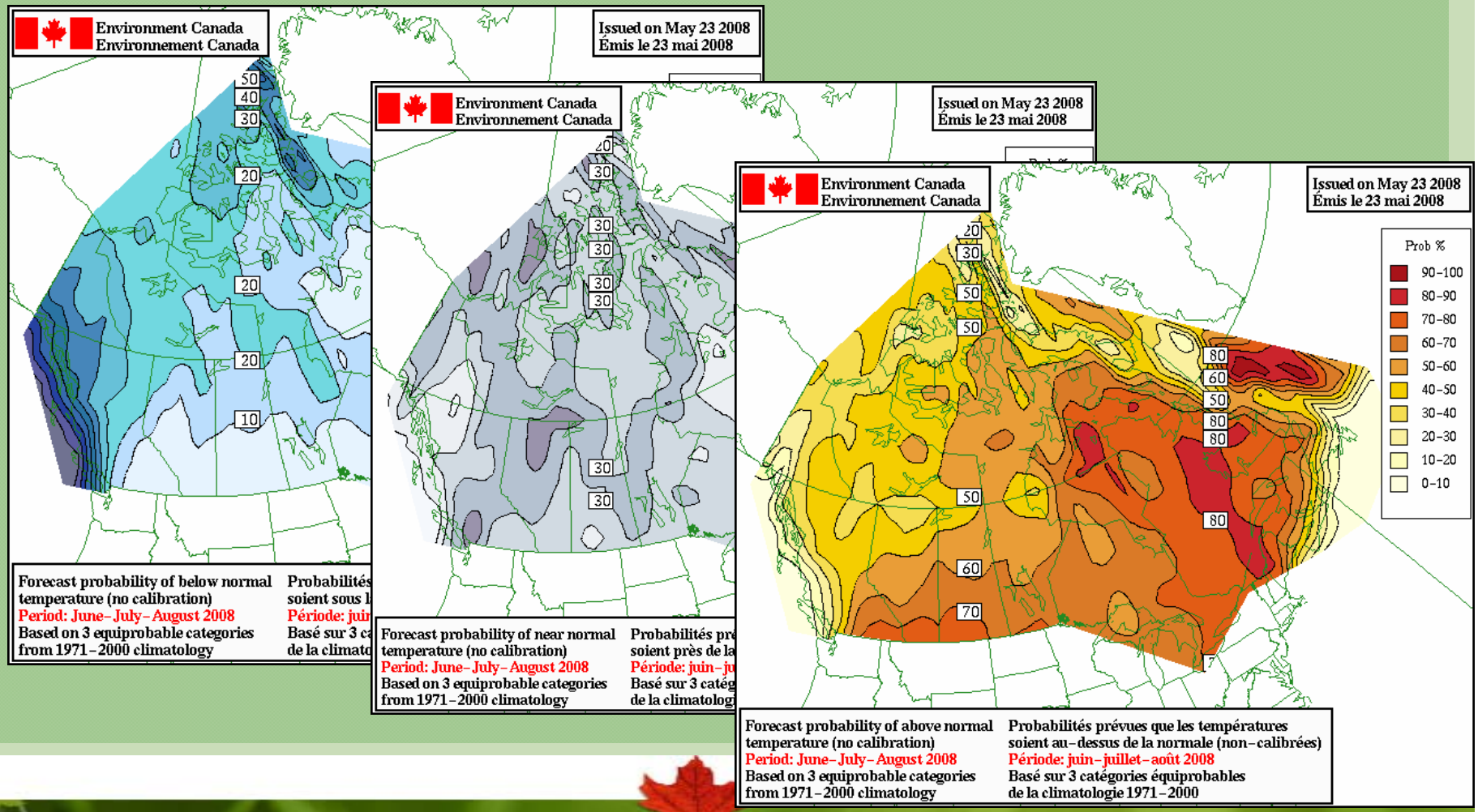


Probabilistic forecasts

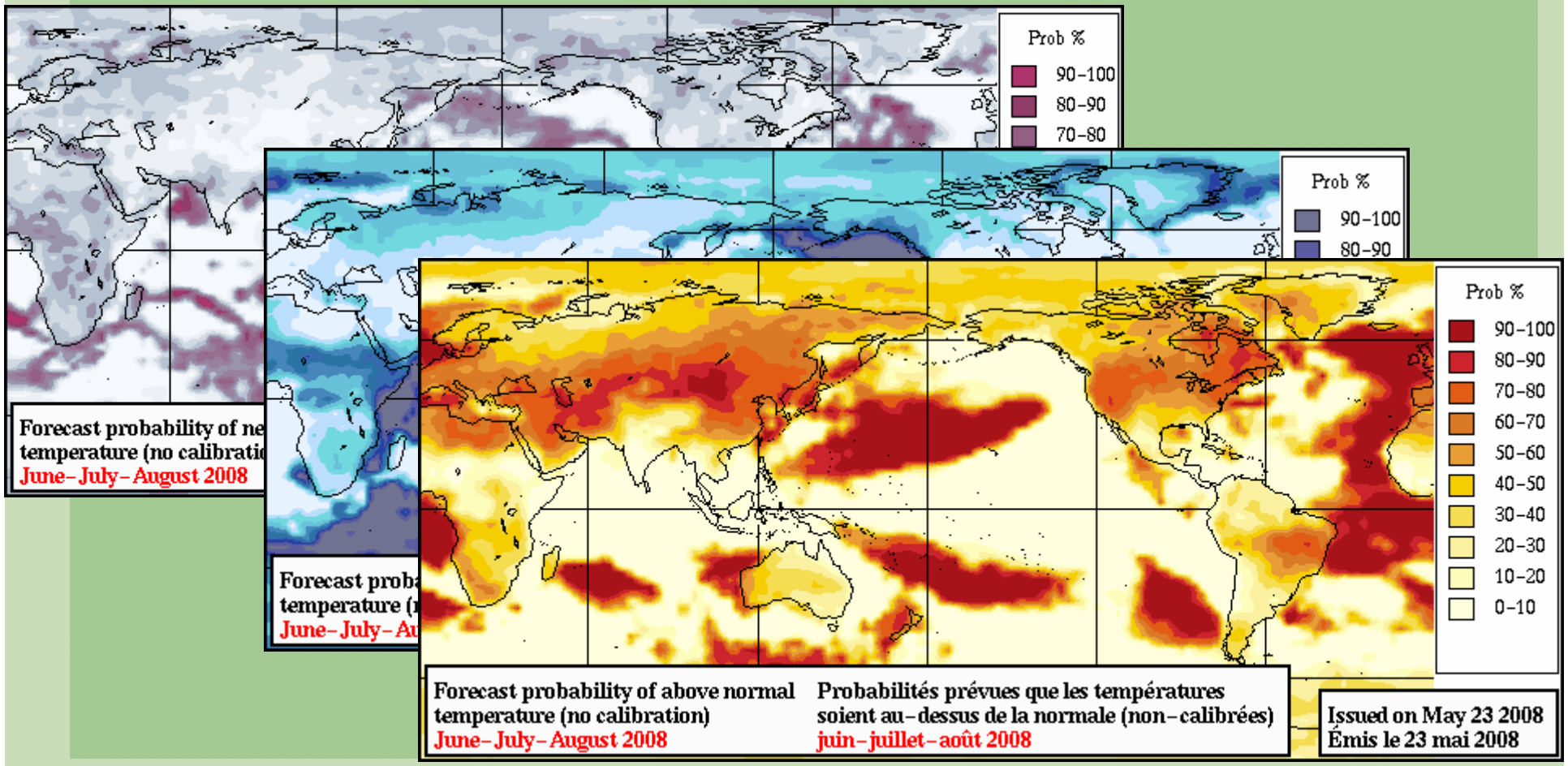
- **To generate probabilistic forecasts:**
  - ***Calculate forecast anomaly for each member of the ensemble using each model's own climatology***
  - ***Classify the forecast anomalies into three equally probable categories using 0.43 s as threshold (above, normal, below)***
  - ***Count the number of members in each category***
  - ***Divide by the total number of members (40) and multiply by 100***



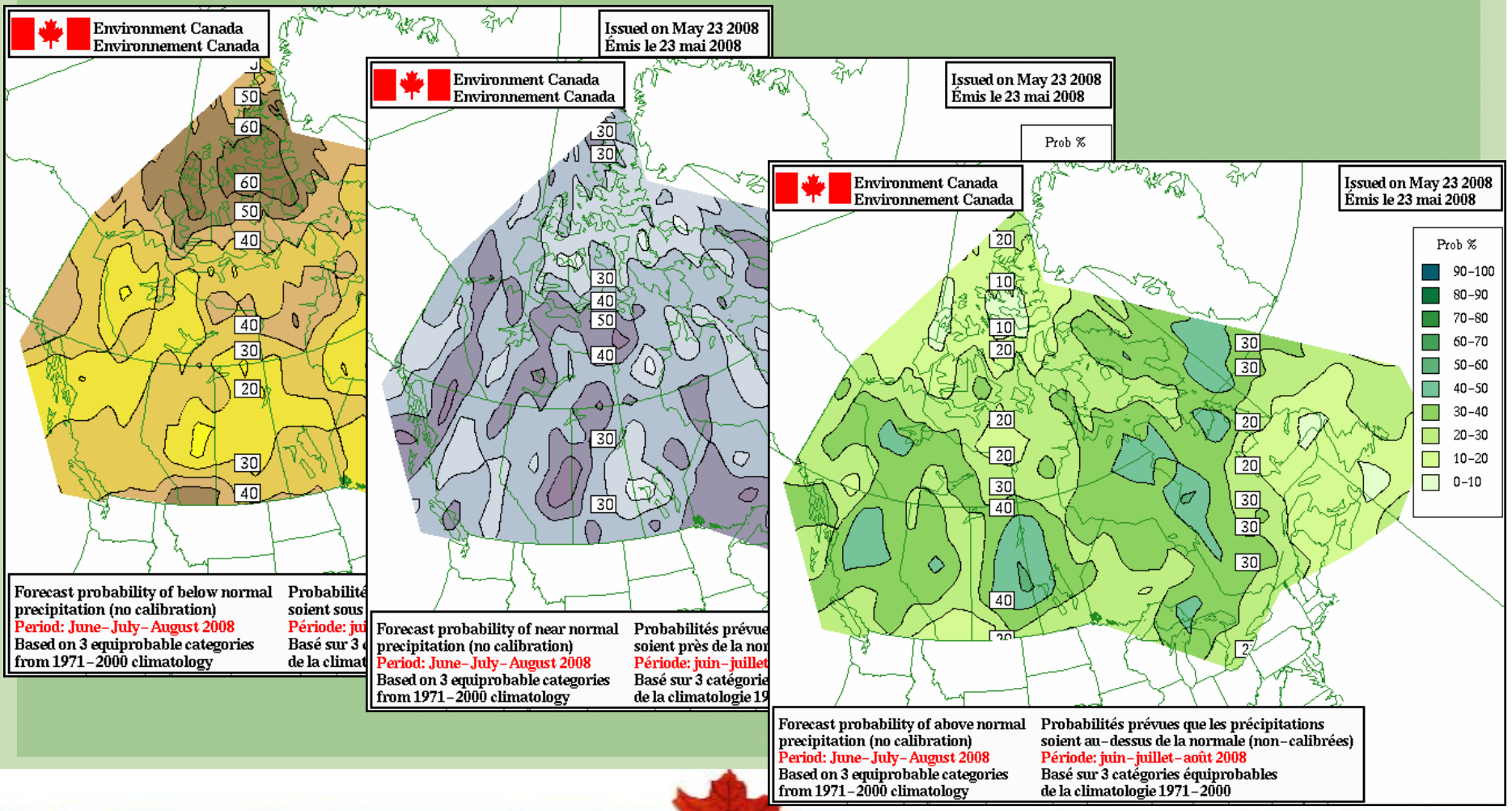
Probabilistic seasonal forecast : surface temperature



Probabilistic seasonal forecast : surface temperature



Probabilistic seasonal forecasts : precipitation

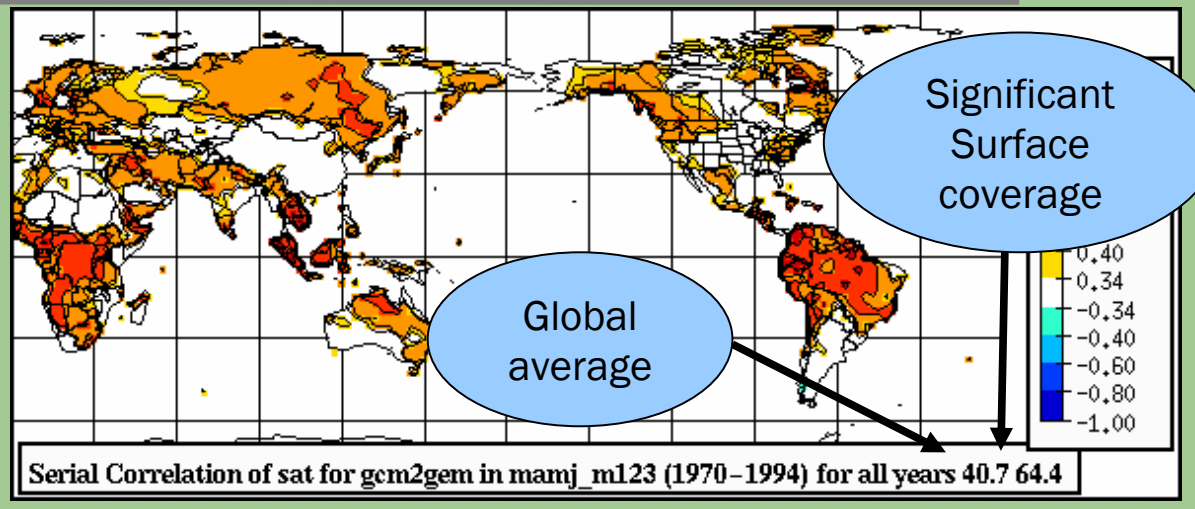


Verification

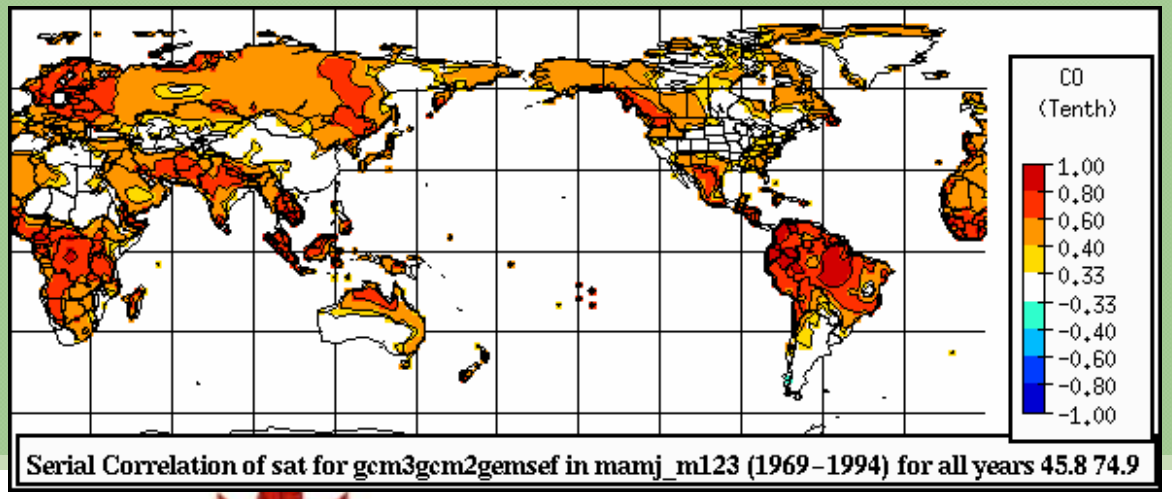
- Deterministic scores
  - *Correlation*
  - *Percent correct*
- Probabilistic scores
  - *Reliability*

Correlation

GCM2-GEM
12 members



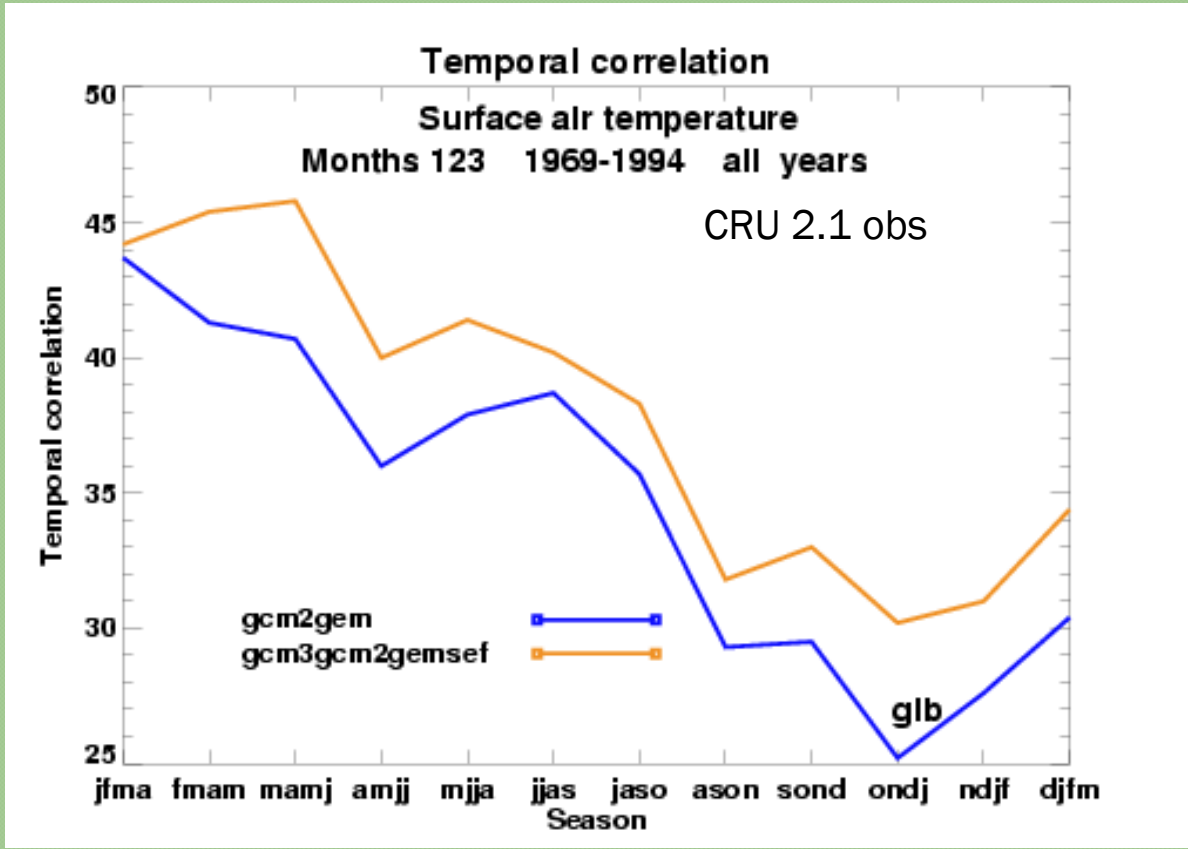
GCM3-GEMCLIM
SEF-GCM2
40 members



Correlation (Globe)

Average for gcm3gcm2gemsef 37.98%

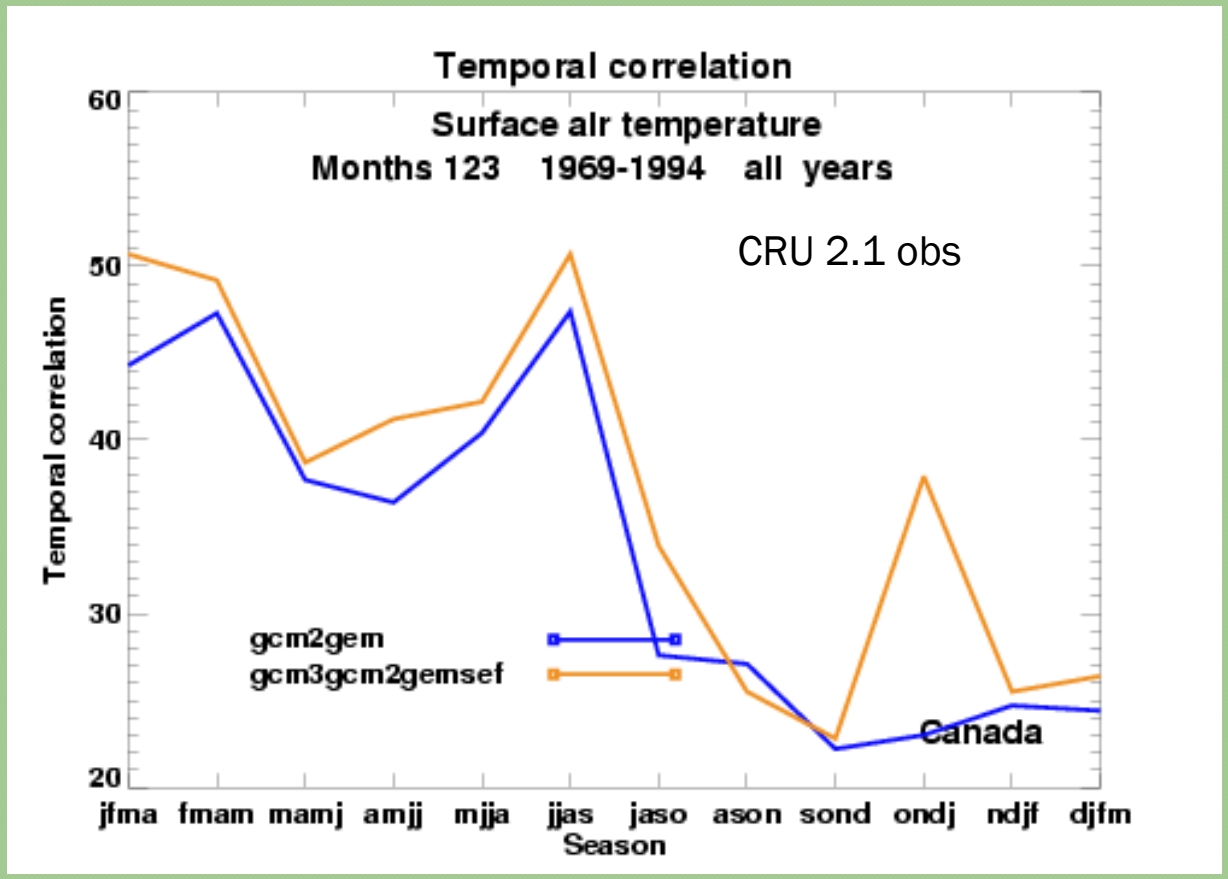
Average for gcm2gem 34.67%



Correlation (Canada)

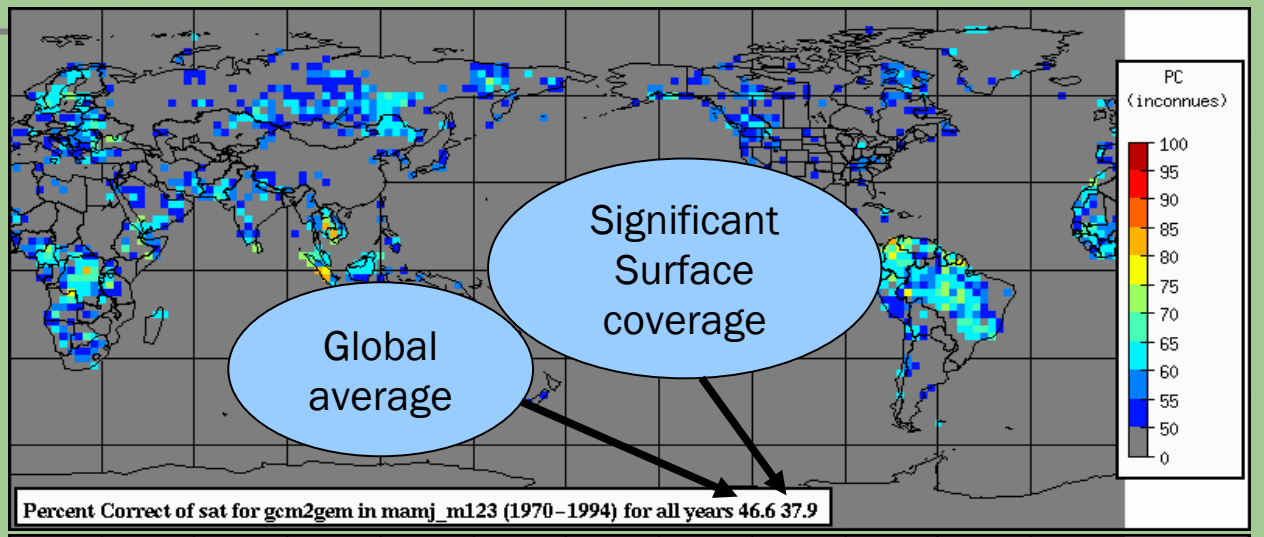
Average for gcm3gcm2gemsef 37.06%

Average for gcm2gem 33.54%

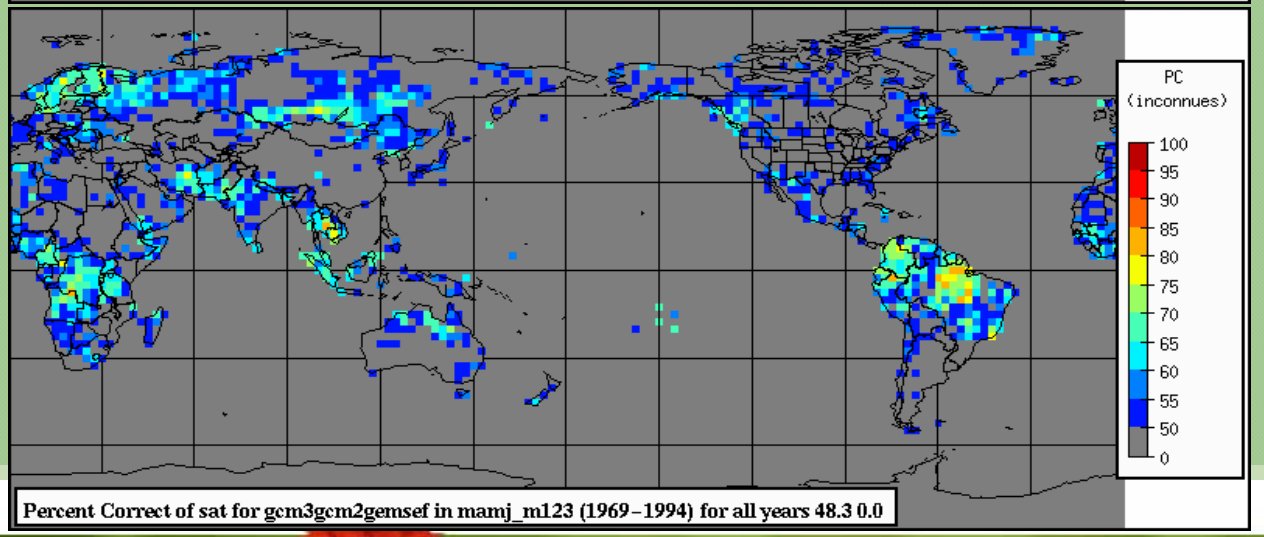


Percent correct

GCM2-GEM
12 members



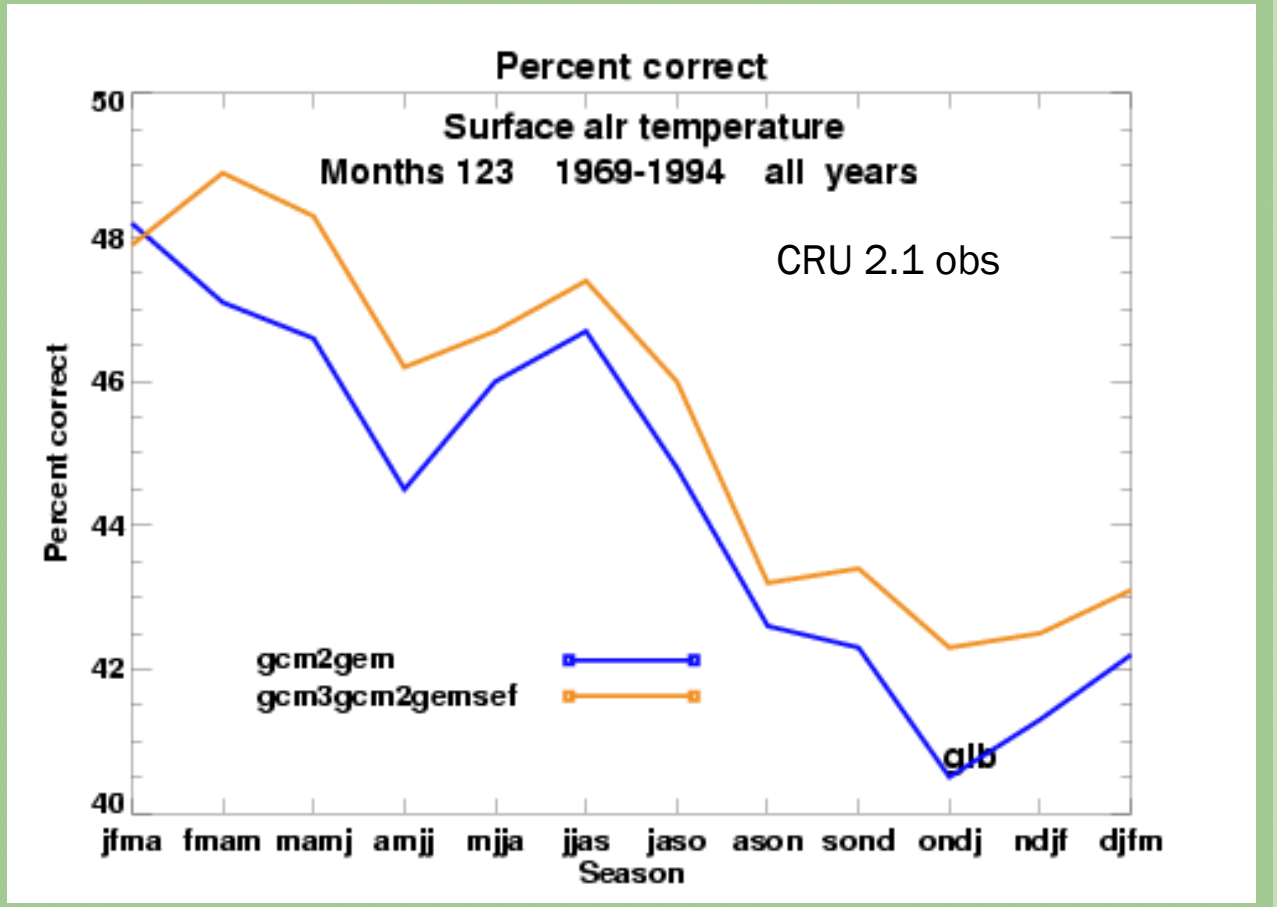
GCM3-GEMCLIM
SEF-GCM2
40 members



Percent Correct (Global)

Average for gcm3gcm2gemsef 45.49%

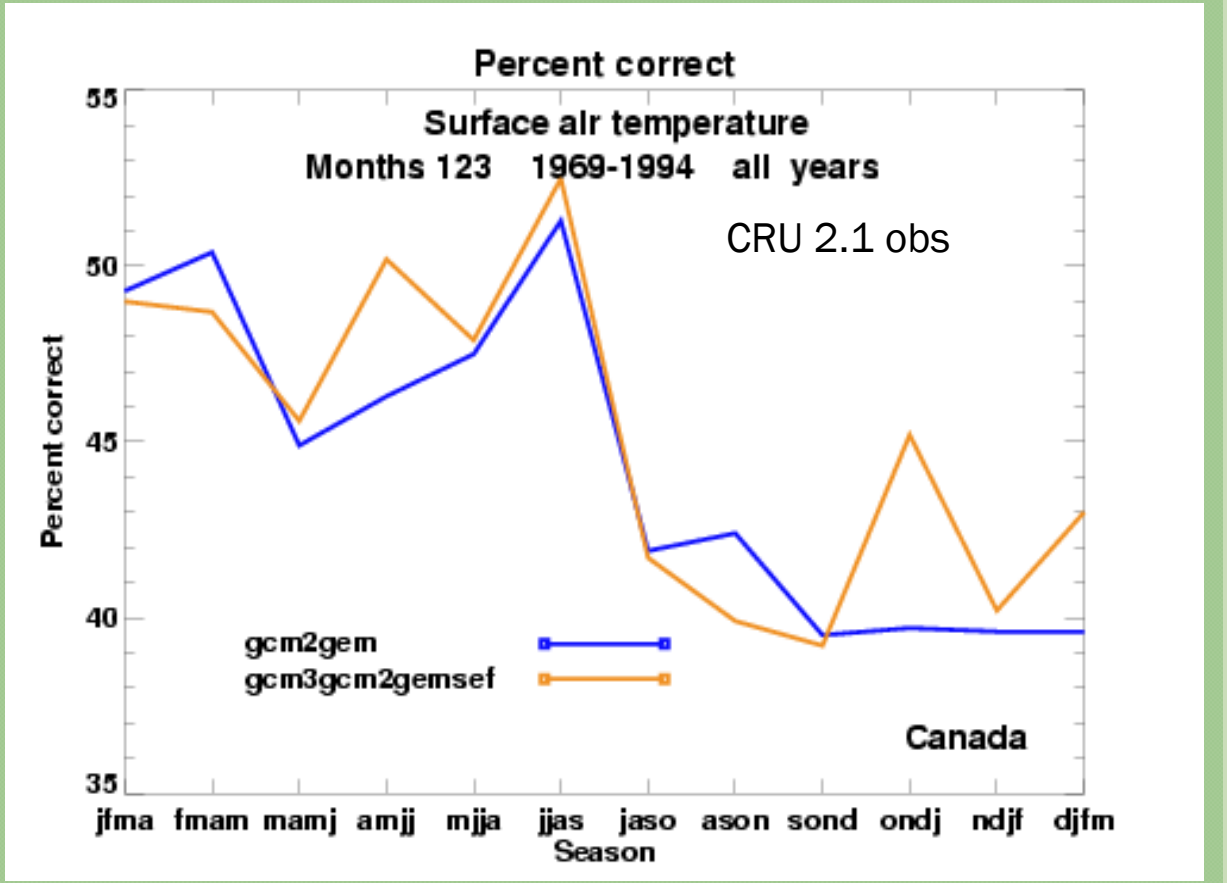
Average for gcm2gem 44.4%



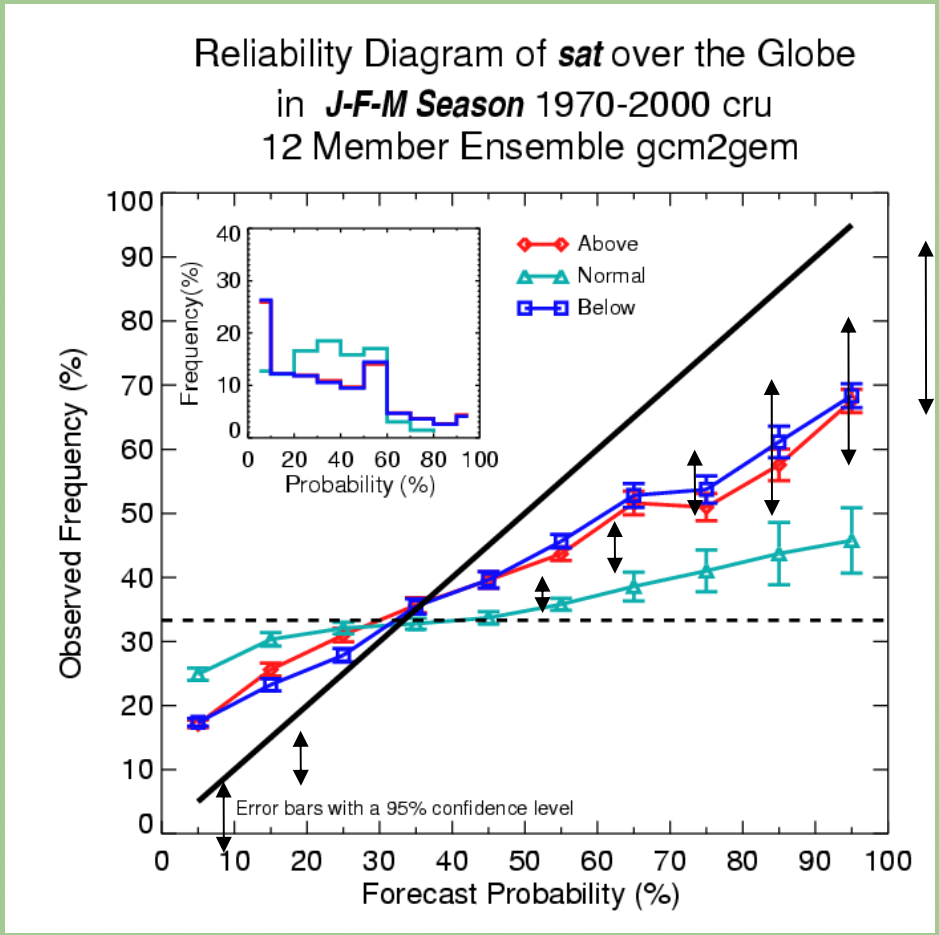
Percent Correct (Canada)

Average for
gcm3gcm2gemsef
45.25%

Average for
gcm2gem
44.37%



Reliability Diagram



Reliability index:

Average distance between the 10 values and the diagonal

smaller is better

Reliability index (Global)

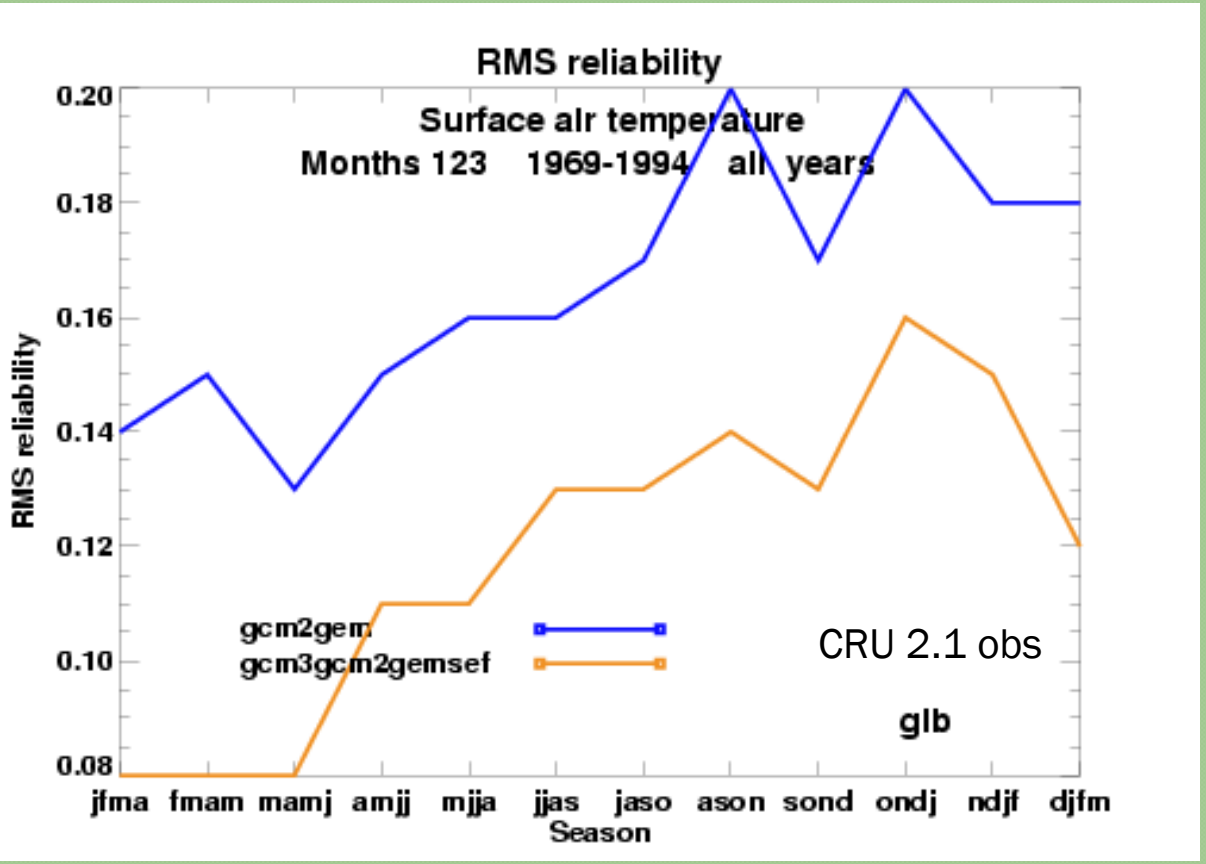
Reliability index:

Average distance between the 10 values and the diagonal

smaller is better

Average for gcm3gcm2gemsef
0.12

Average for gcm2gem
0.17



Reliability index (Canada)

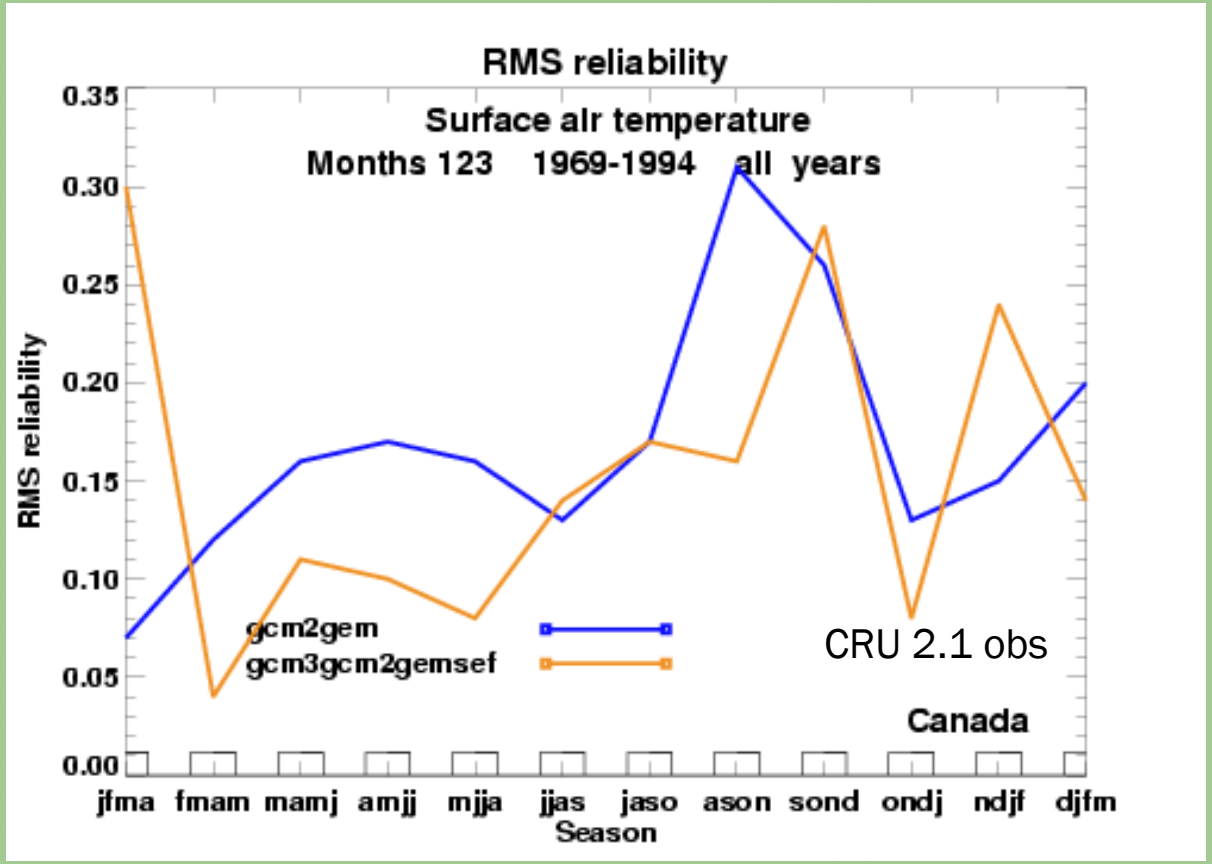
Reliability index:

Average distance between the 10 values and the diagonal

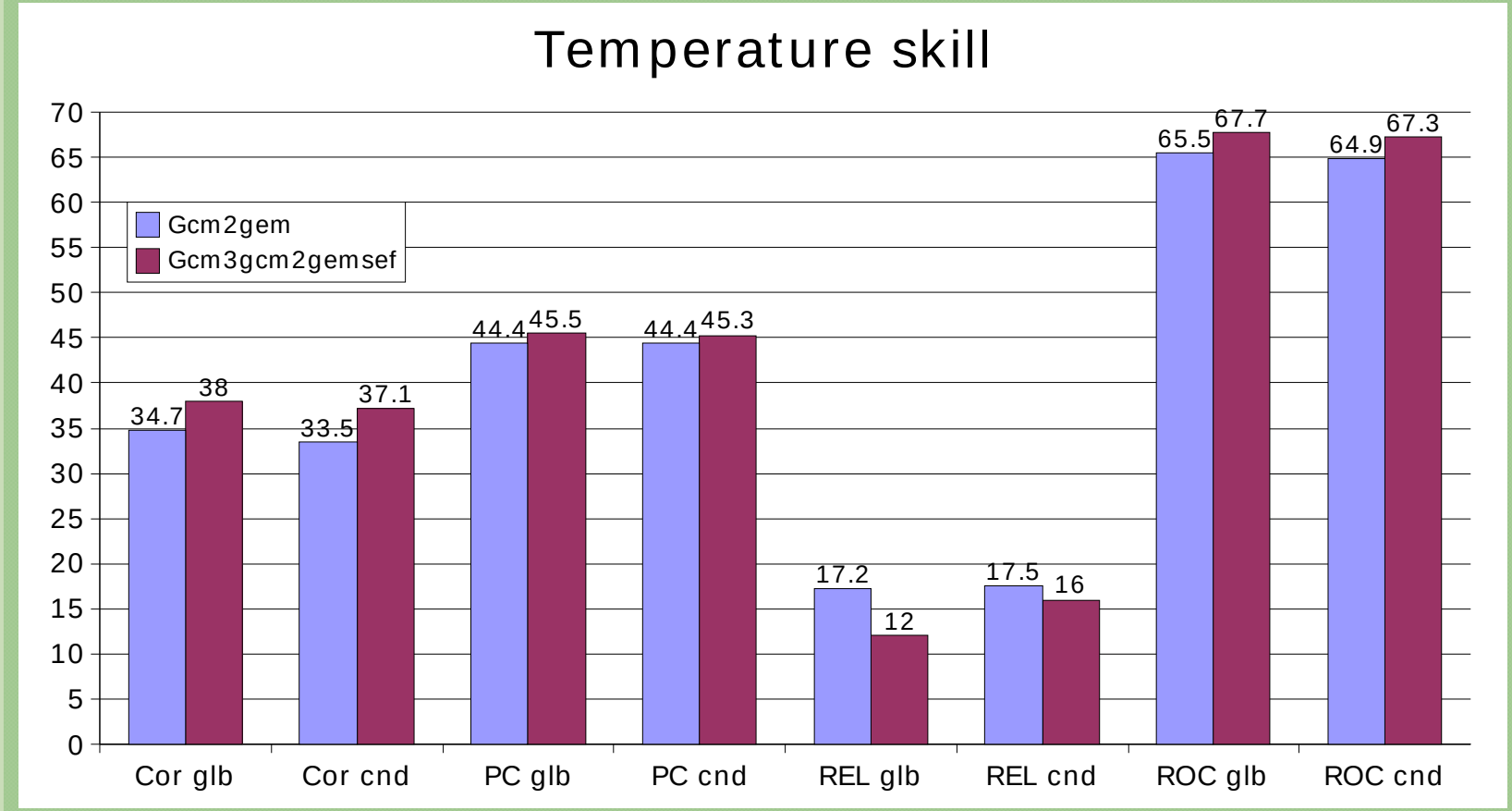
smaller is better

Average for gcm3gcm2gemsef 0.16

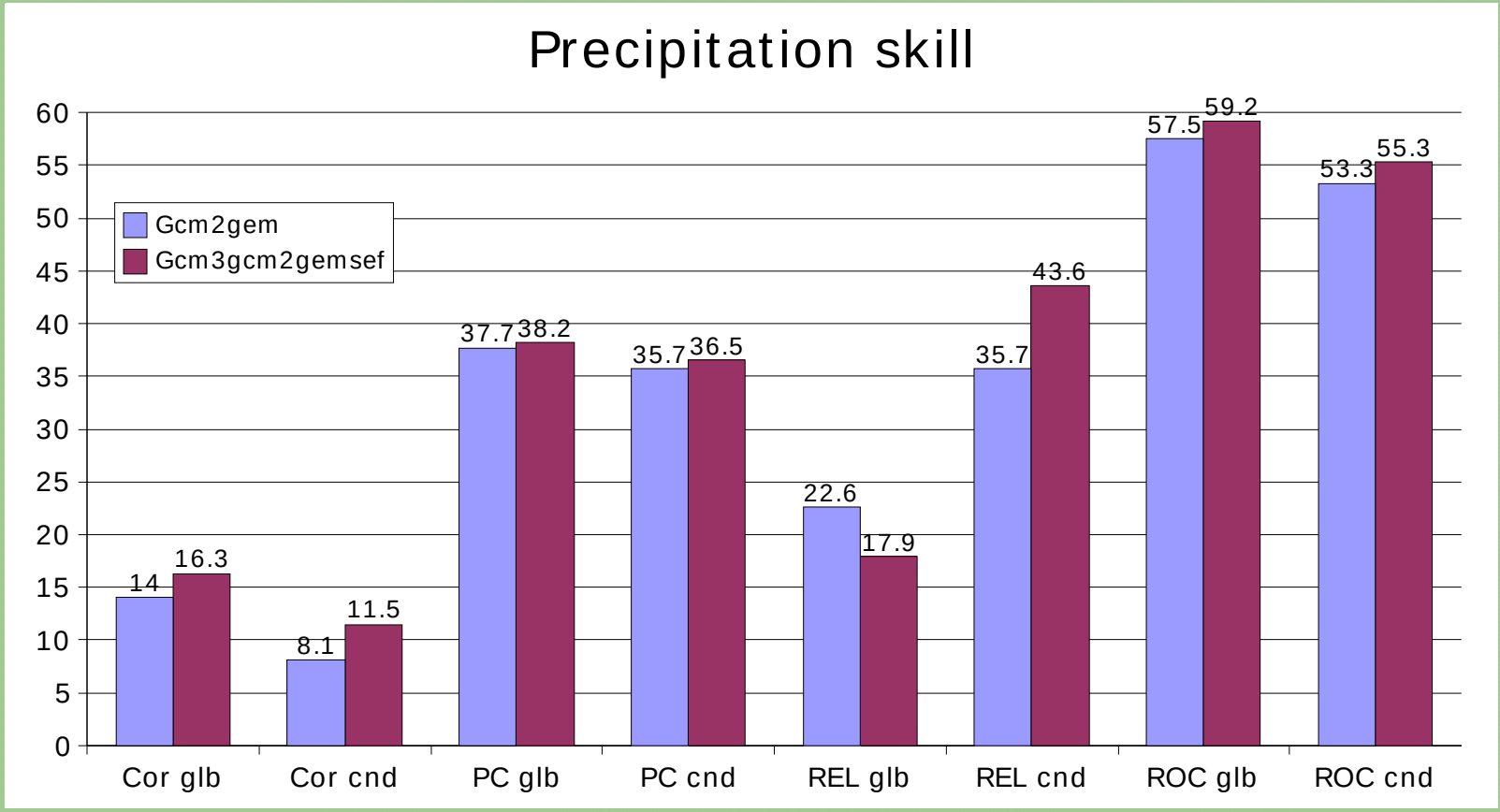
Average for gcm2gem 0.175



Summary Temperature



Summary Precipitation

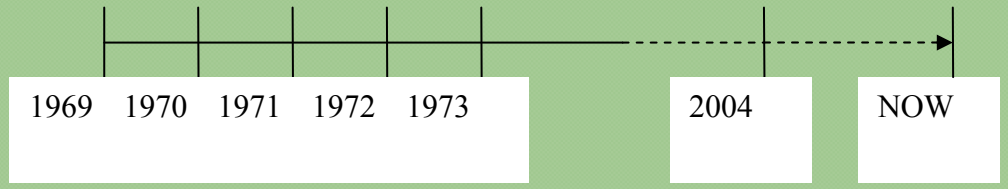


Conclusion

- *The new 4 model system and 40 members performs better than the old system with 2 models and 12 members, in terms of correlation, percent correct, reliability and signal detection.*
- *Maybe slight decrease of the sharpness*
- *Precipitation scores are significantly less good than those of surface temperature*

Projects in 2009

- Continuous HFP2



- Statistical model Canonical Correlation Analysis (CCA) running every month (in this moment, we produce forecast four times a year
- Implement of a new calibration for probabilistic forecasts

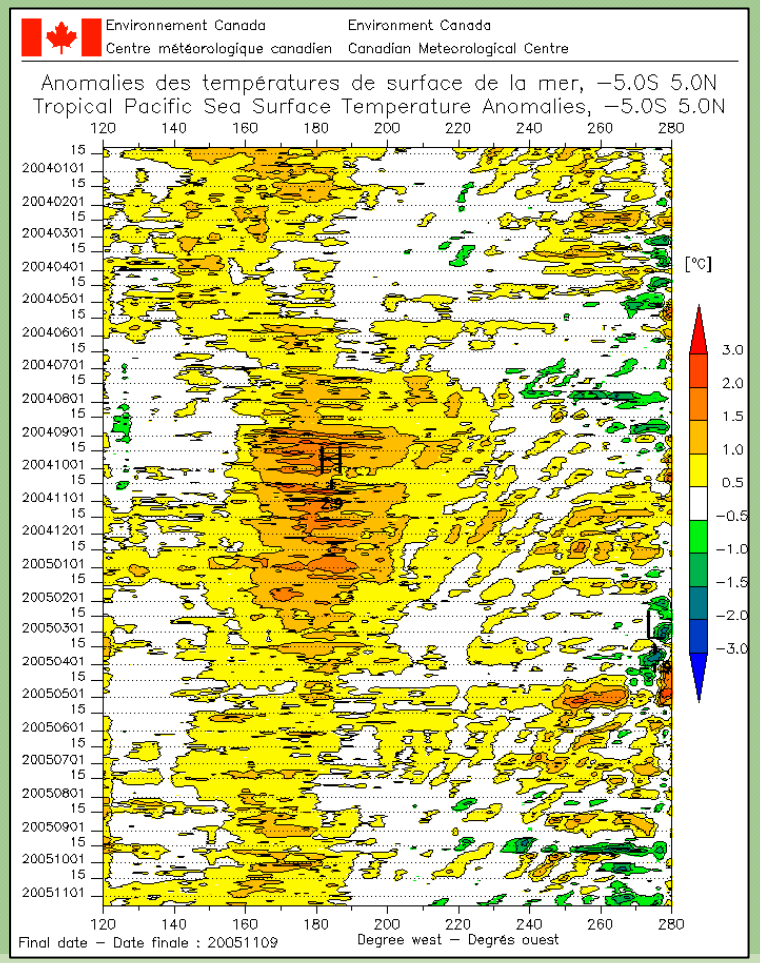
Gracias !

Calibration of probabilistic forecasts

- We determine the three categories on fitting a normal distribution to the multimodel ensemble
- Two methods, for ocean and land :
  - *Over the land, the mean of the distribution is provided by the ensemble mean of the forecast, and the ensemble spread is provided by the spread of the hindcast*
  - *Over oceans, the multi-model ensemble mean, and the ensemble spread are rescaled such to maximize the sum of the Brier score in the training period*

Current seasonal forecasting set-up: CCA

- Canonical Correlation Analysis (CCA) statistical model is used for seasons 2, 3 and 4.
- A multivariate linear statistical technique to establish lagged relationships between low frequency variation in global SST, 500 hPa circulation and temperature / precipitation anomaly over Canada.
- A linear relationship was developed using the principal components of SST anomaly EOFs over a 39 year period (1956-1994) to estimate seasonal temperature and precipitation anomalies over Canada.
- CCA forecasts are available at 51 stations for temperature anomaly and 69 stations for precipitation anomaly.



Deterministic forecast

$$T_{\text{anomaly forecast}} = \frac{1}{4}\left[\frac{\overline{T}^{\text{10 runs}}_{\text{GEM}} - \overline{T}^{\text{1971–2000}}_{\text{GEM}}}{\sigma^{\text{1971-2000}}_{T,\text{GEM}}} + \frac{\overline{T}^{\text{10 runs}}_{\text{GCM2}} - \overline{T}^{\text{1971–2000}}_{\text{GCM2}}}{\sigma^{\text{1971-2000}}_{T,\text{GCM2}}} + \frac{\overline{T}^{\text{10 runs}}_{\text{GCM3}} - \overline{T}^{\text{1971–2000}}_{\text{GCM3}}}{\sigma^{\text{1971–2000}}_{T,\text{GCM3}}} + \frac{\overline{T}^{\text{1971–2000}}_{\text{SEF}} - \overline{T}^{\text{1971–2000}}_{\text{SEF}}}{\sigma^{\text{1971-2000}}_{T,\text{SEF}}}\right]$$

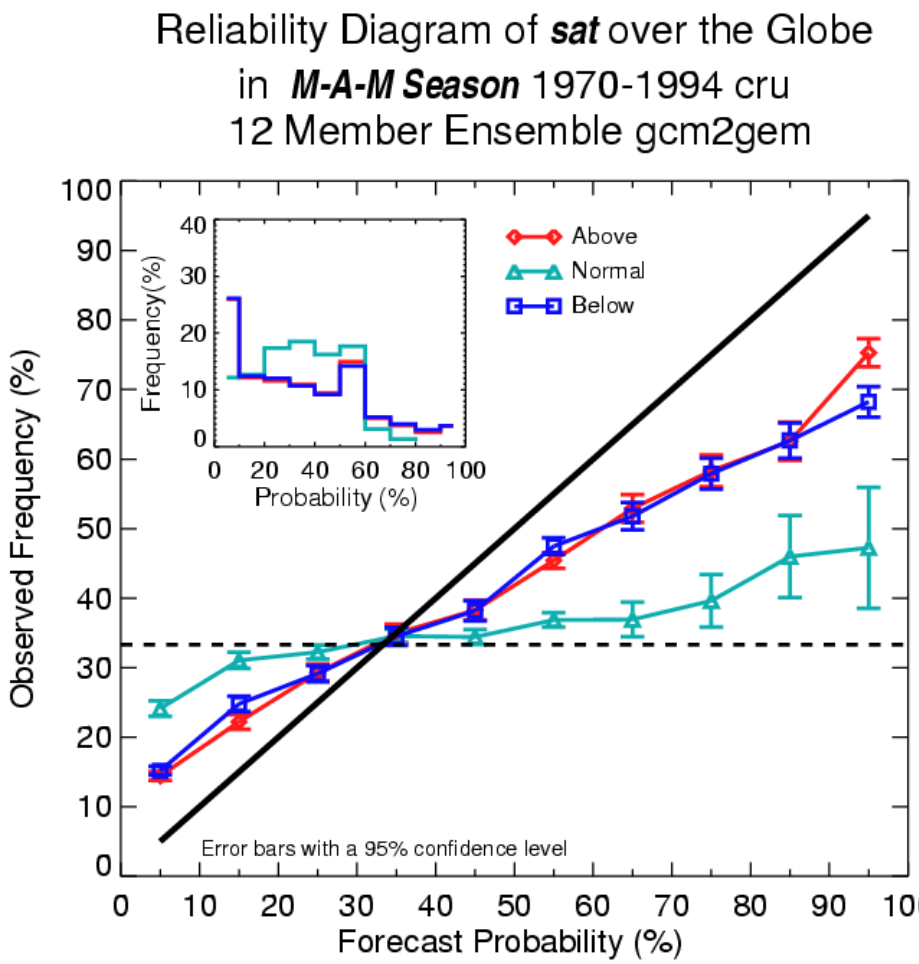
$$P_{\text{anomaly forecast}} = \frac{1}{4}\left[\frac{\overline{P}^{\text{10 runs}}_{\text{GEM}} - \overline{P}^{\text{1971–2000}}_{\text{GEM}}}{\sigma^{\text{1971-2000}}_{P,\text{GEM}}} + \frac{\overline{P}^{\text{10 runs}}_{\text{GCM2}} - \overline{P}^{\text{1971–2000}}_{\text{GCM2}}}{\sigma^{\text{1971-2000}}_{P,\text{GCM2}}} + \frac{\overline{P}^{\text{10 runs}}_{\text{GCM3}} - \overline{P}^{\text{1971–2000}}_{\text{GCM3}}}{\sigma^{\text{1971–2000}}_{P,\text{GCM3}}} + \frac{\overline{P}^{\text{1971–2000}}_{\text{SEF}} - \overline{P}^{\text{1971–2000}}_{\text{SEF}}}{\sigma^{\text{1971-2000}}_{P,\text{SEF}}}\right]$$

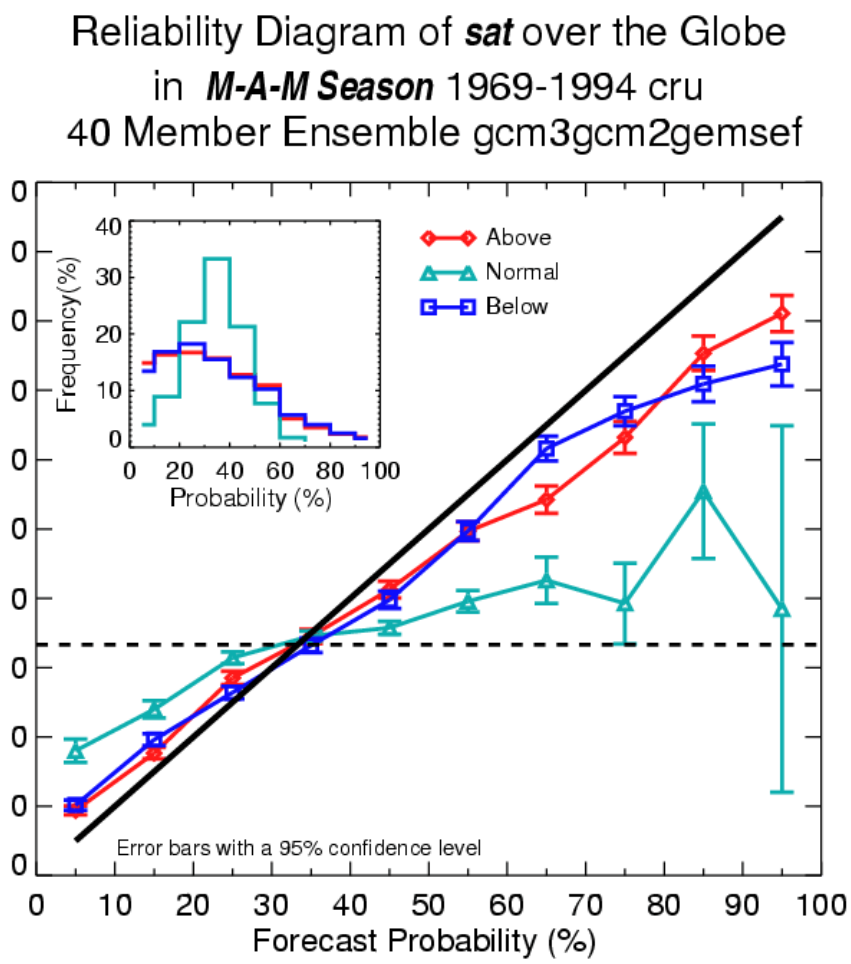
Anomalies classified into three equally probable categories using 0.43 $\sigma_T^{1971-2000}$ for temperature anomaly and 0.43 $\sigma_P^{1971-2000}$ for precipitation anomaly.

Reliability

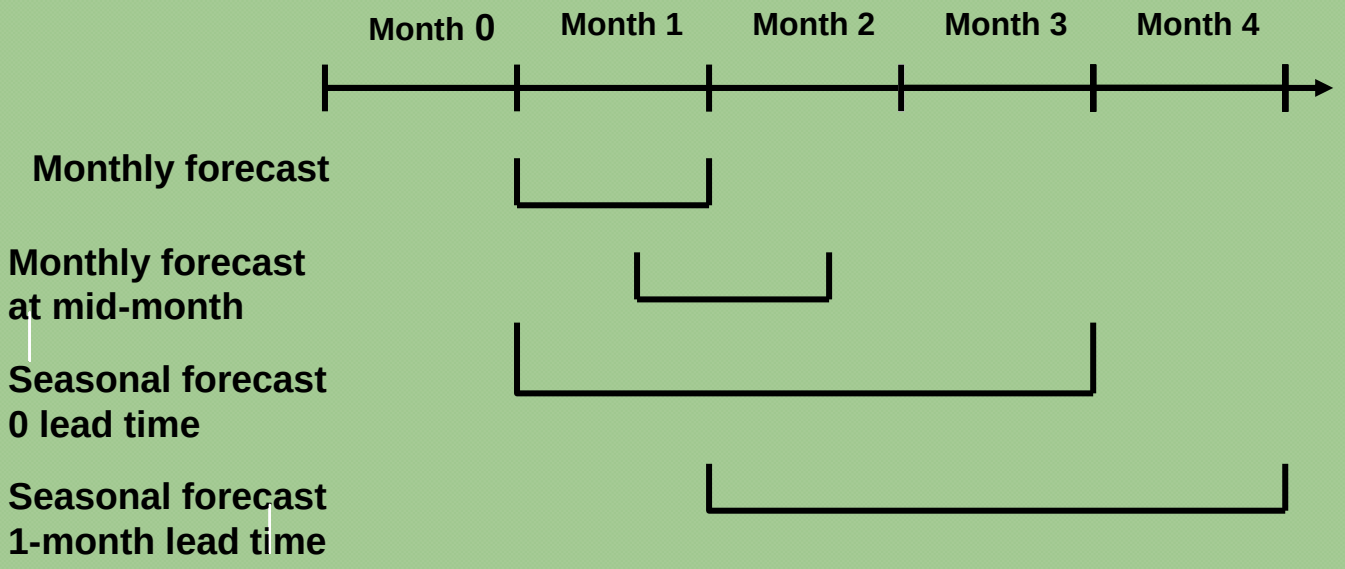
- Average agreement between the forecast values and observed values (bias). For probabilistic forecasts, it measures the agreement between the forecast probabilities and the observed frequencies of the event.*

Reliability Diagram

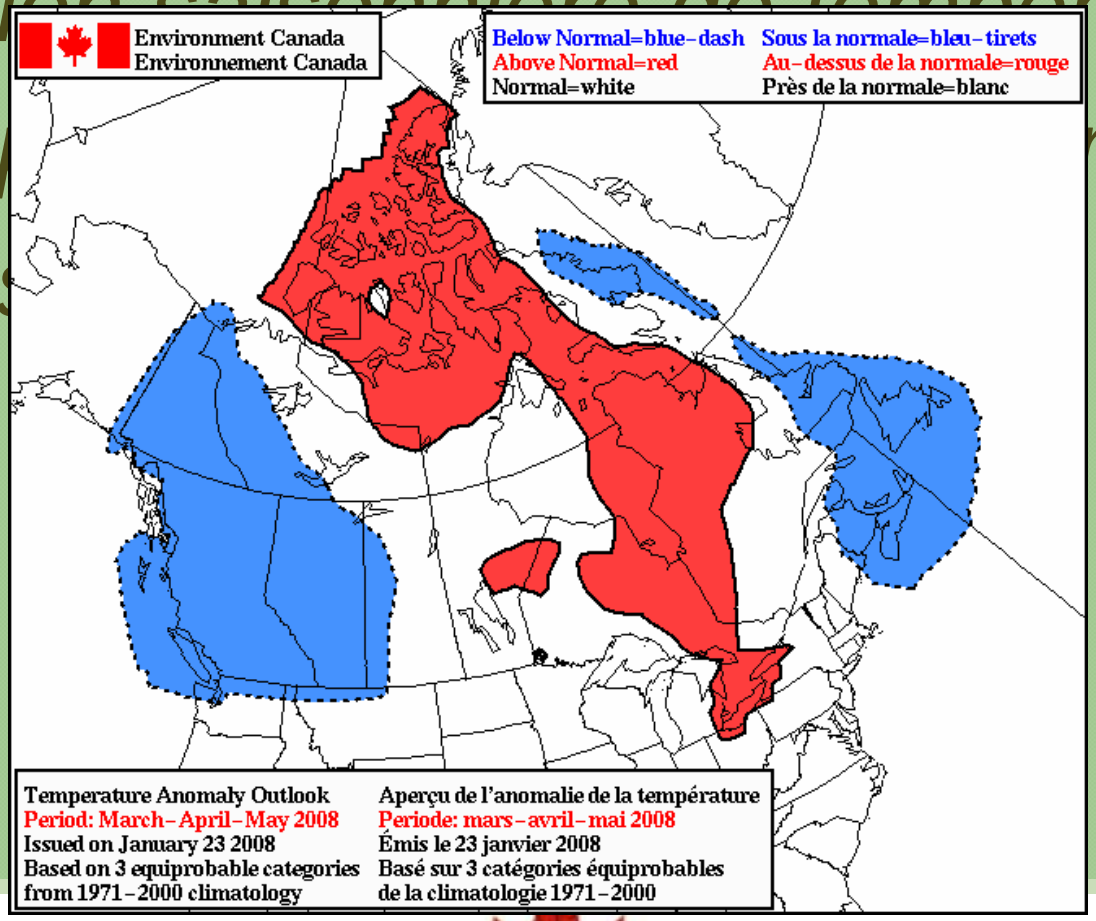




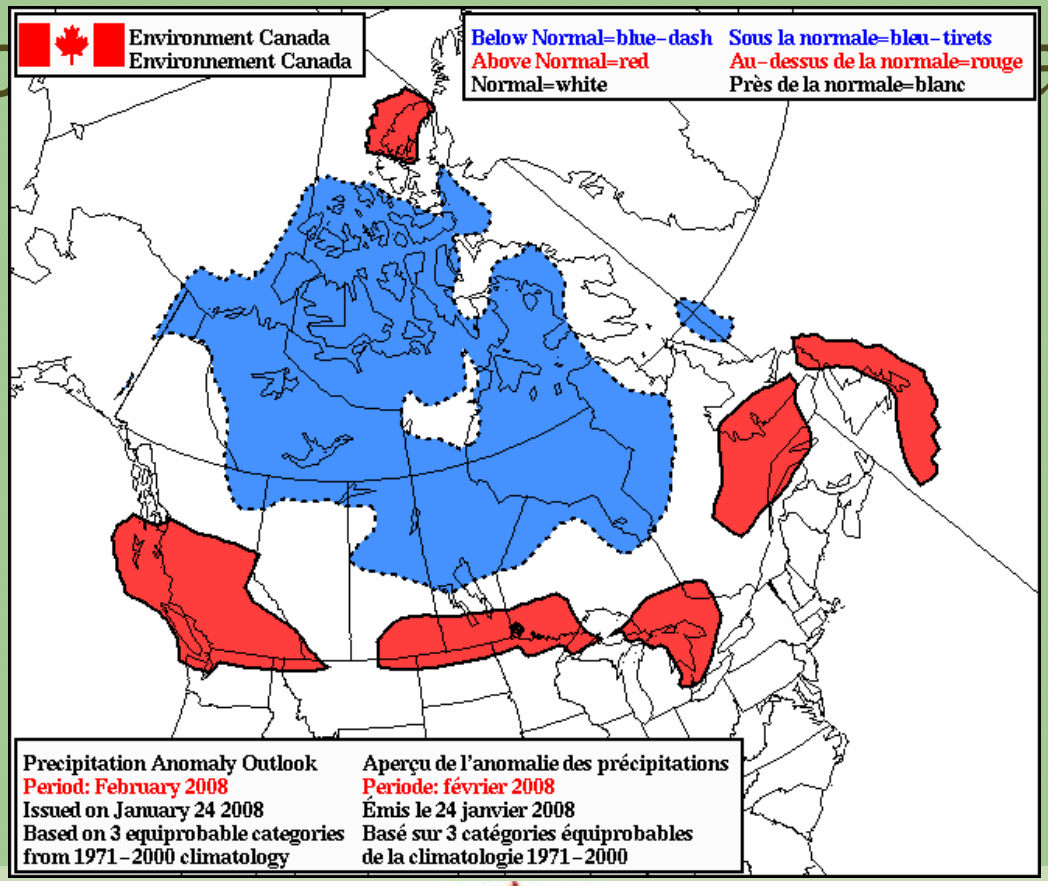
Slices calculated



Prévision saisonnière de température à 2 m pour mai (1 mois)



Prévisio ation pour le

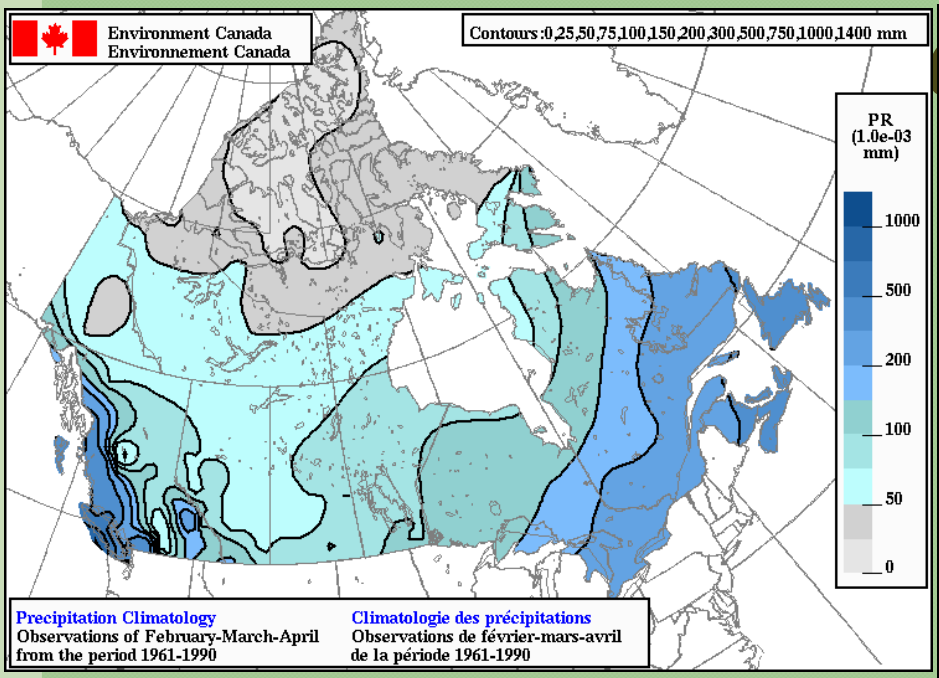


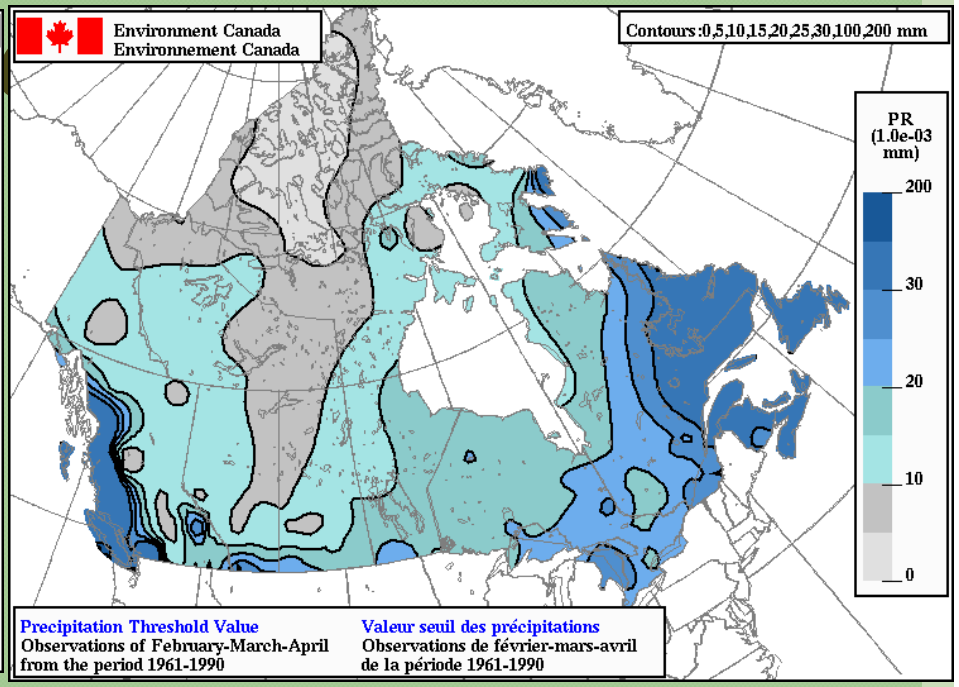
Combination of two models : temperature

$$T_{\text{anomaly forecast}} = \frac{1}{2}\left[\frac{\overline{T}^{\,6\text{ runs}}_{\text{GEM}} - \overline{T}^{\,1969-1994}_{\text{GEM}}}{\sigma^{\text{1969-1994}}_{T,\text{GEM}}} + \frac{\overline{T}^{\,6\text{ runs}}_{\text{GCM2}} - \overline{T}^{\,1969-1994}_{\text{GCM2}}}{\sigma^{\text{1969-1994}}_{T,\text{GCM2}}}\right]$$

$$T_{category\ forecast} = \frac{T_{\text{anomaly forecast}}}{0.43 \cdot \sigma^{\text{1969-1994}}_{T,\text{2mod?es}}}$$

Anomalies classified into three equally probable categories using 0.43 $\sigma_T^{1969-1994}$ for temperature anomaly and 0.43 $\sigma_P^{1969-1994}$ for precipitation anomaly.


Environment Canada
Environnement Canada
Contours :0,25,50,75,100,150,200,300,500,750,1000,1400 mm
PR
(1.0e-03
mm)
1000
500
200
100
50
0
Precipitation Climatology
Observations of February-March-April
from the period 1961-1990
Climatologie des précipitations
Observations de février-mars-avril
de la période 1961-1990

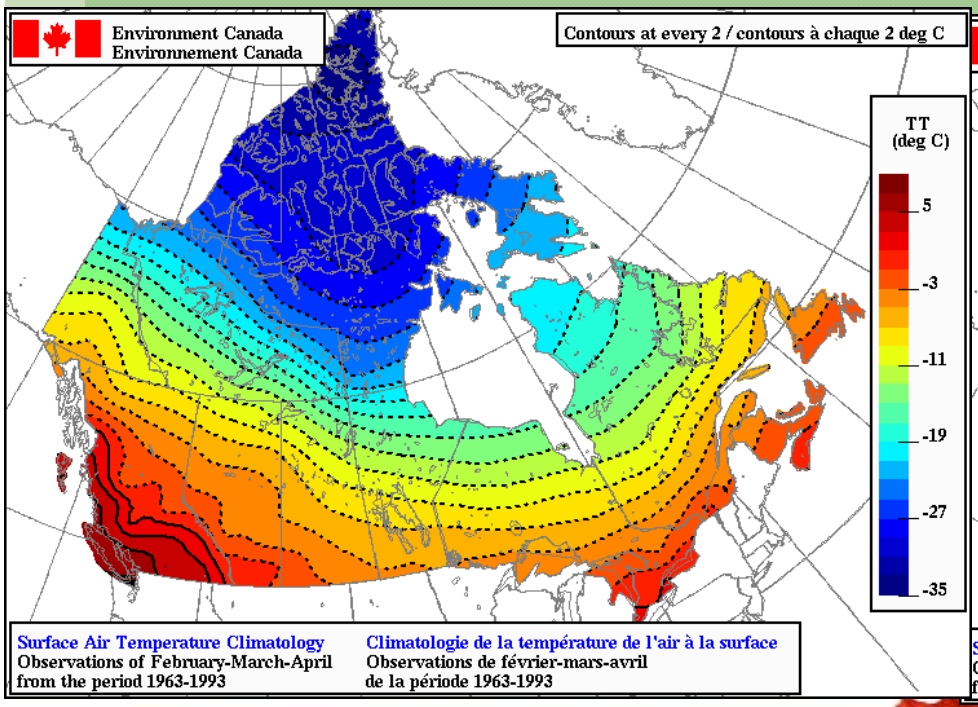

Environment Canada
Environnement Canada
Contours :0,5,10,15,20,25,30,100,200 mm
PR
(1.0e-03
mm)
200
30
20
10
0
Precipitation Threshold Value
Observations of February-March-April
from the period 1961-1990
Valeur seuil des précipitations
Observations de février-mars-avril
de la période 1961-1990

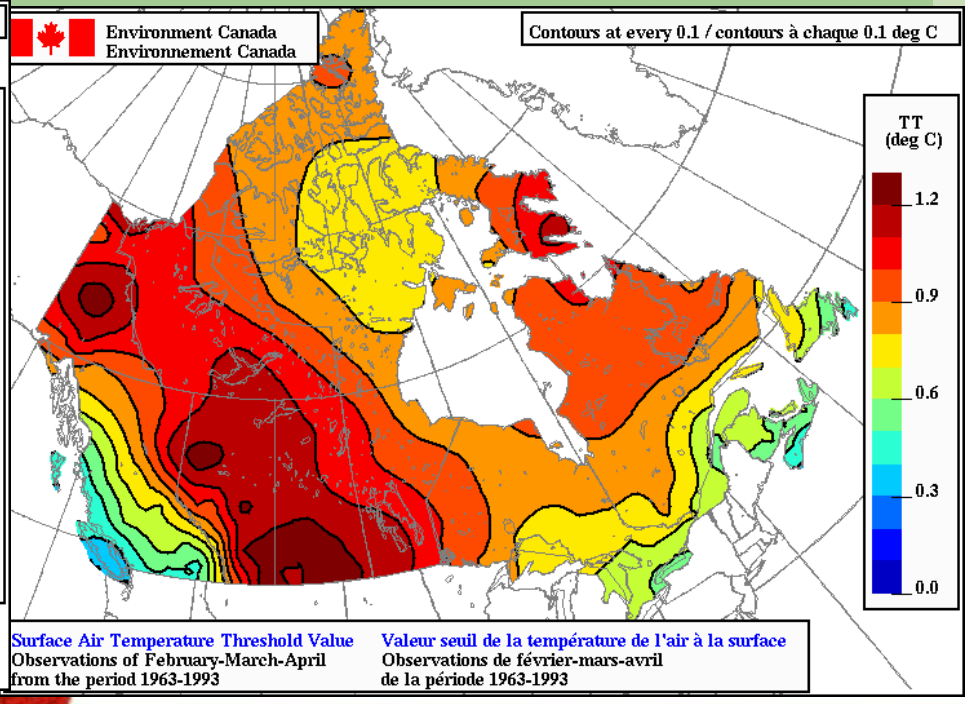
Thresholds of temperature

$$T \prec \overline{T} - \mathbf{0.43} \cdot \sigma \qquad \textbf{below normal}$$

$$\overline{T} - \mathbf{0.43} \cdot \sigma \prec T \prec \overline{T} + \mathbf{0.43} \cdot \sigma \qquad \textbf{normal}$$

$$\overline{T} + \mathbf{0.43} \cdot \sigma \prec T \qquad \textbf{above normal}$$





- Dynamical models used for season 1:
  - Forecasts are issued on the first day of each month (12 seasons).
    - GEM: 1.875° 50 levels ptop 5 mb
    - GCM2: T32 10 levels ptop 10 mb
- Historical forecasts (HFP1):
  - 26 years (1969-1994).
  - 1872 runs for each model (12 three-month periods, 6 runs, 26 years).

Old System (2000-November 2007)

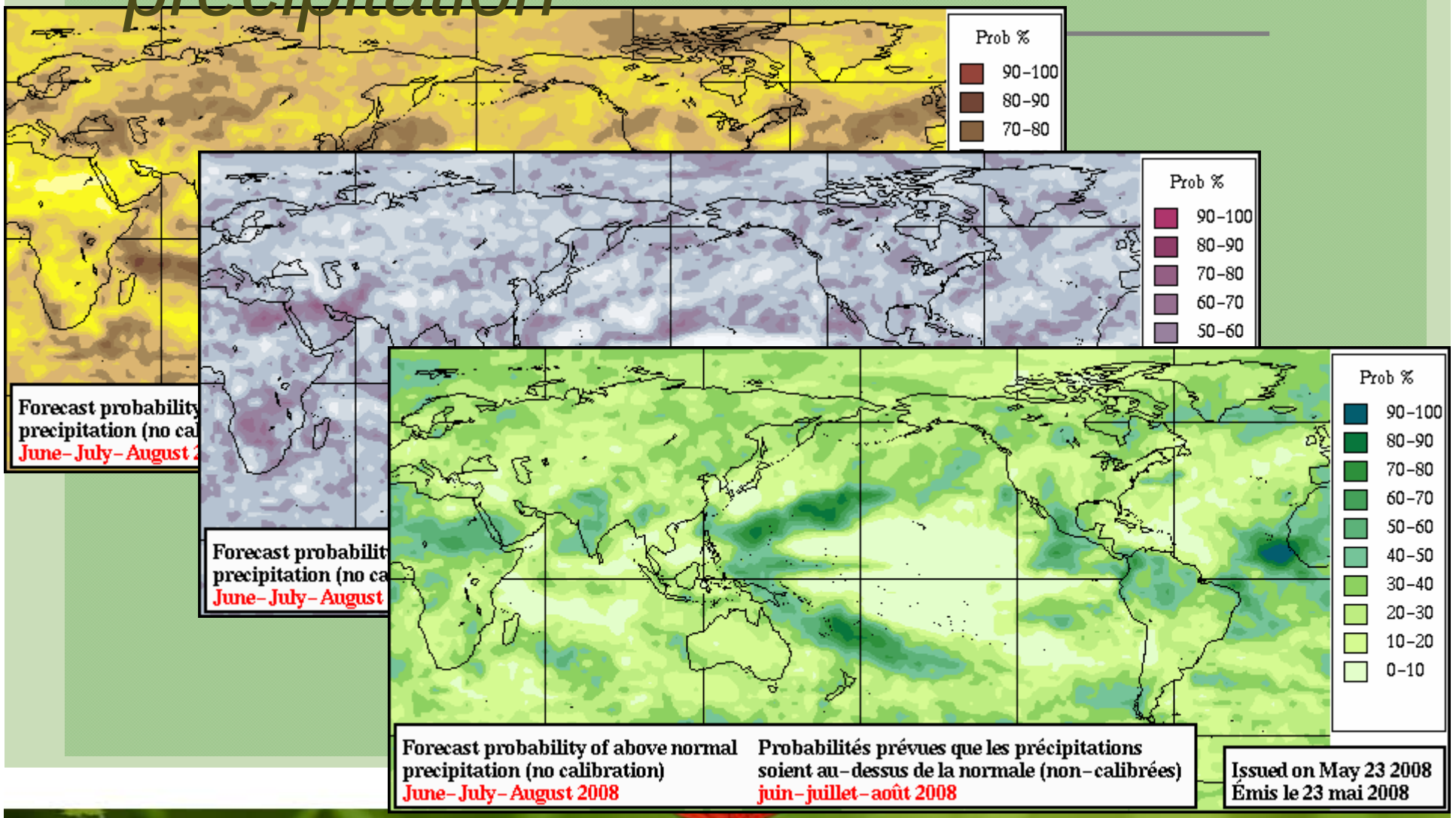
New

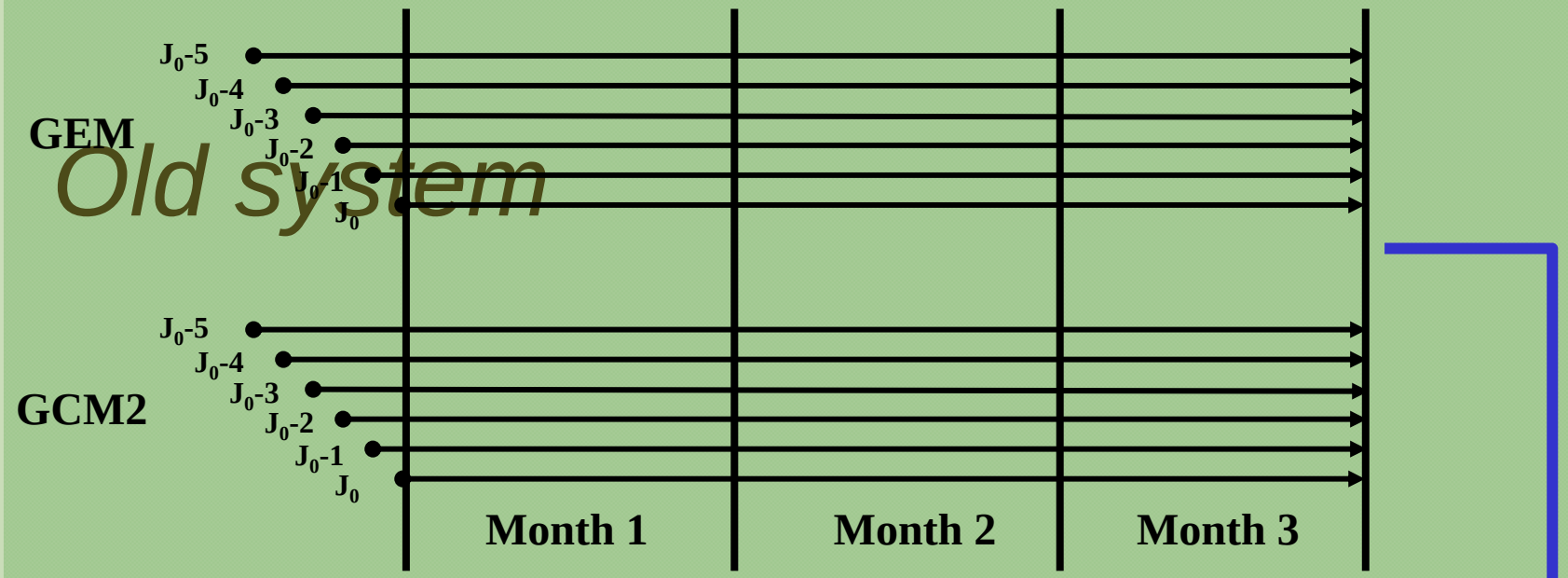
- Four-month integrations:
  - *Zero lead time forecasts*

$$P_{\text{anomaly forecast}} = \frac{1}{2}\left[\frac{\overline{P}^{\text{6 runs}}_{\text{GEM}} - \overline{P}^{\text{1969–1994}}_{\text{GEM}}}{\sigma^{\text{1969-1994}}_{P,\text{GEM}}} + \frac{\overline{P}^{\text{6 runs}}_{\text{GCM2}} - \overline{P}^{\text{1969–1994}}_{\text{GCM2}}}{\sigma^{\text{1969-1994}}_{P,\text{GCM2}}}\right]$$

$$P_{\textit{category forecast}} = \frac{P_{\text{anomaly forecast}}}{0.43 \cdot \sigma^{\text{1969-1994}}_{P,\text{2mod?es}}}$$

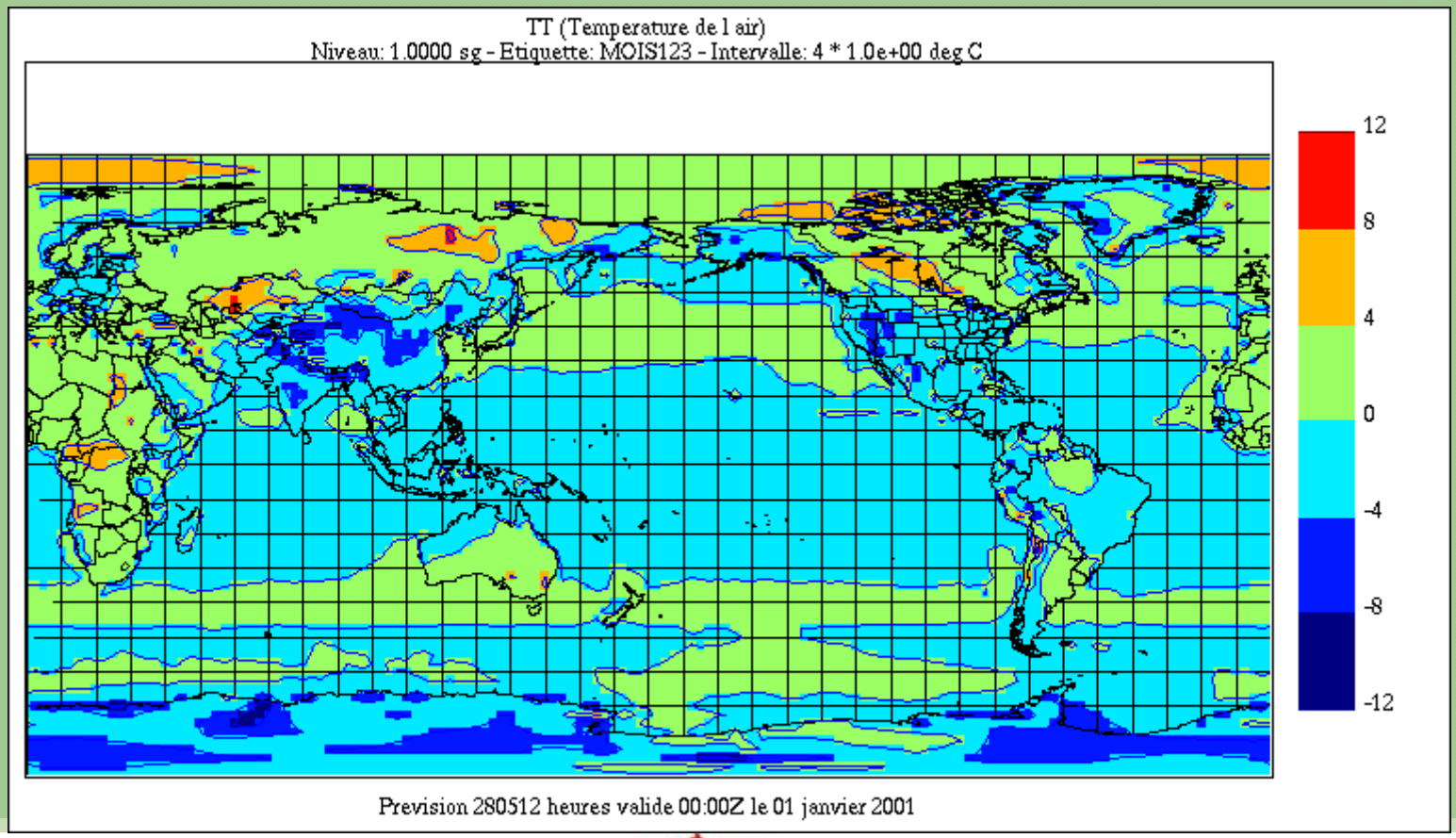
Probabilistic seasonal forecasts : precipitation

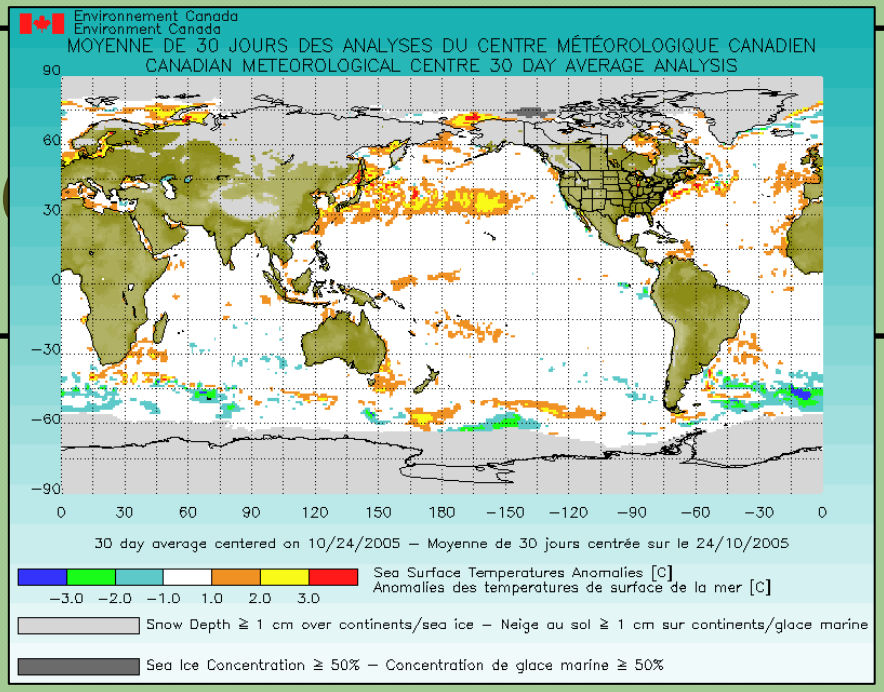




6 lagged runs of GEM + GCM2 → **12 member ensemble**

Bias of GEMCLIM for JFM (temperature at 2 m)





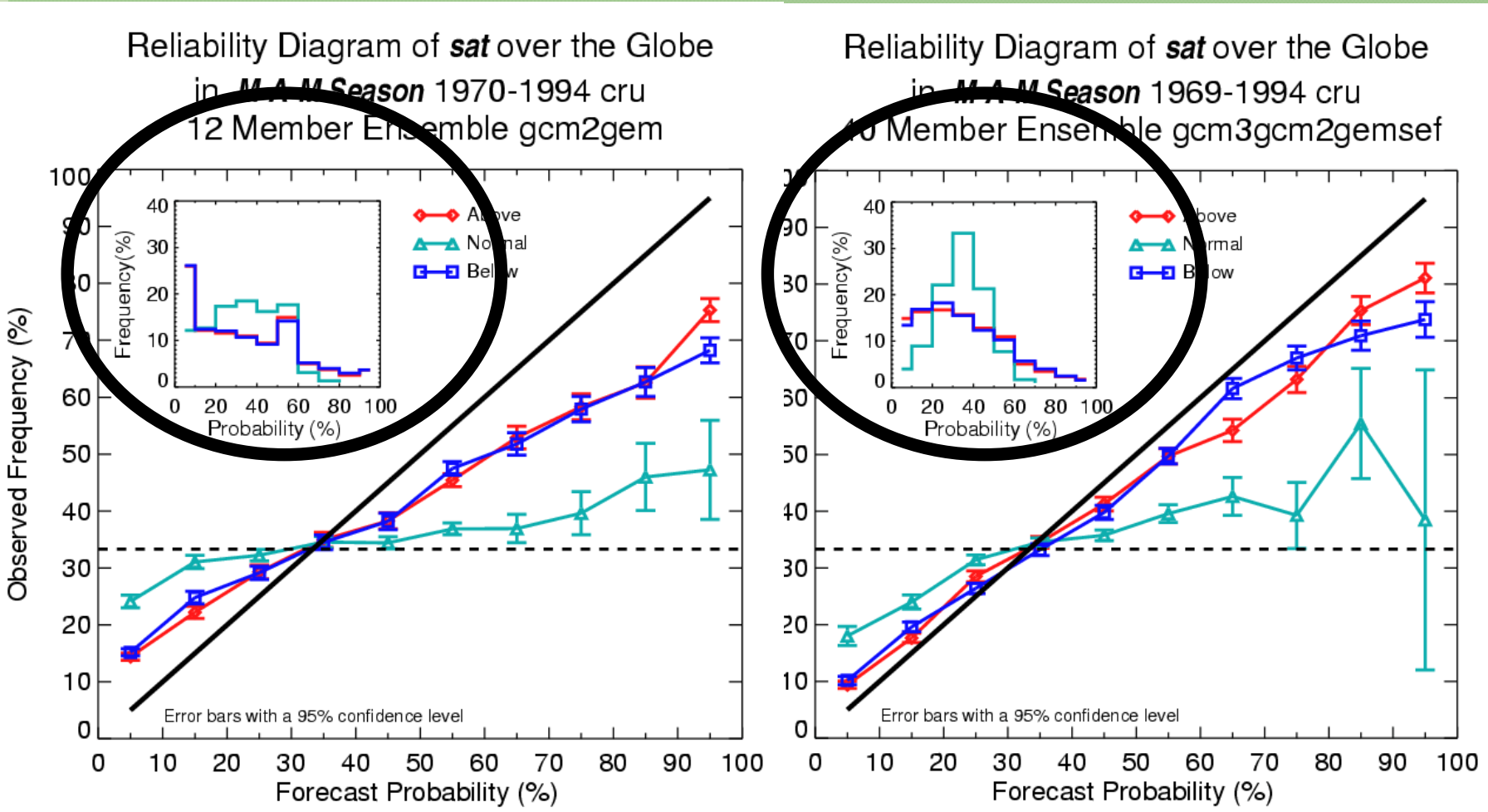
Two models
GEM + GCM2

SST
last 30-day anomaly persisted throughout

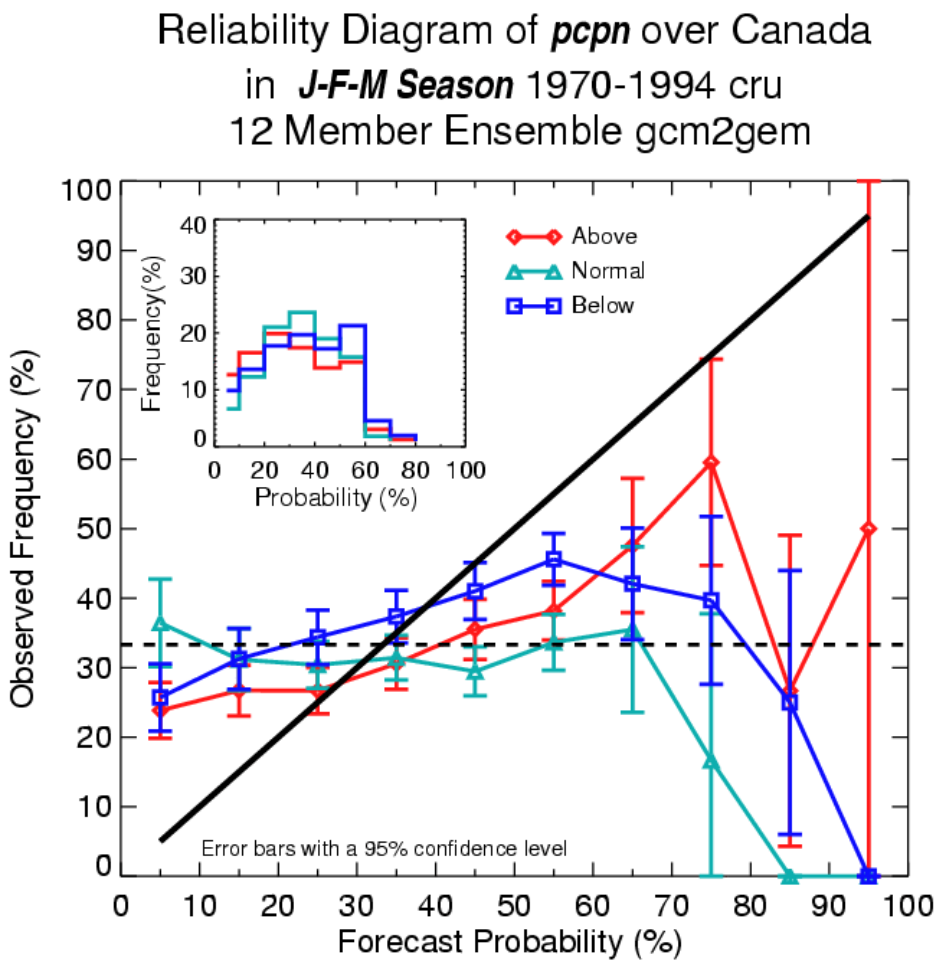
ICE	
GEM:	CMC analysis relaxed to climatology during first 15 days
GCM2:	climatology

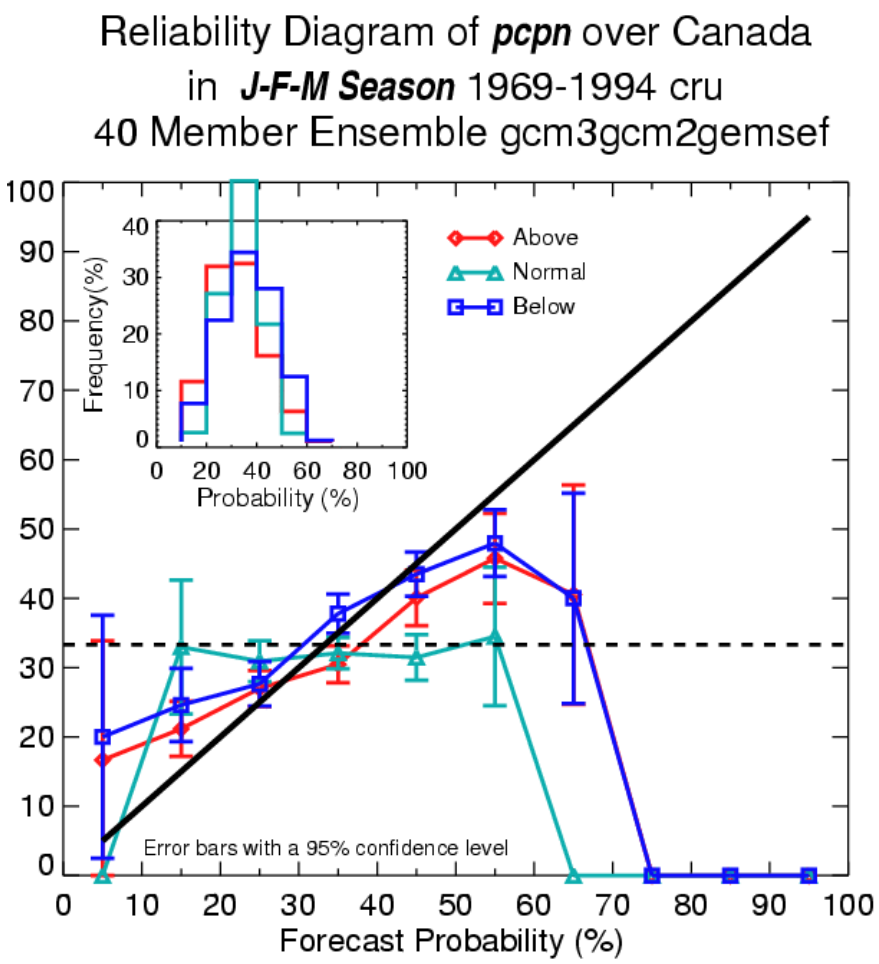
SNOW	
GEM:	CMC analysis relaxed to climatology during first 15 days
GCM2:	prognostic variable

Frequency Diagram



Reliability Diagram Precipitation

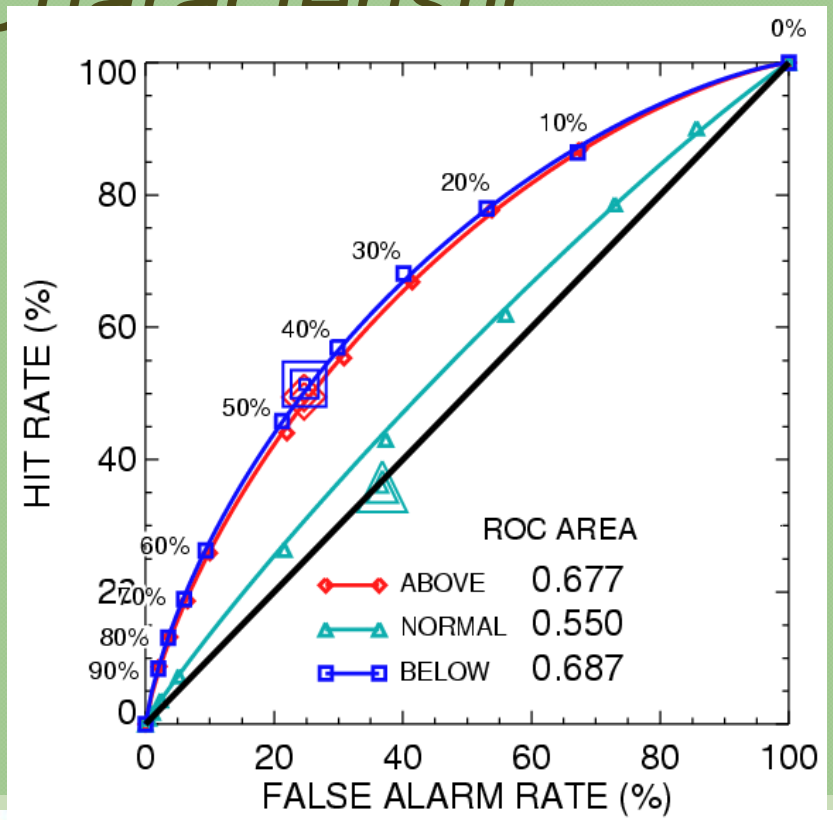




- The ROC represent the forecast skill in terms of *Relative Operating Characteristic (ROC)*

Forecasts	Observations: event	Observations: No event
event	A	B
No event	C	D

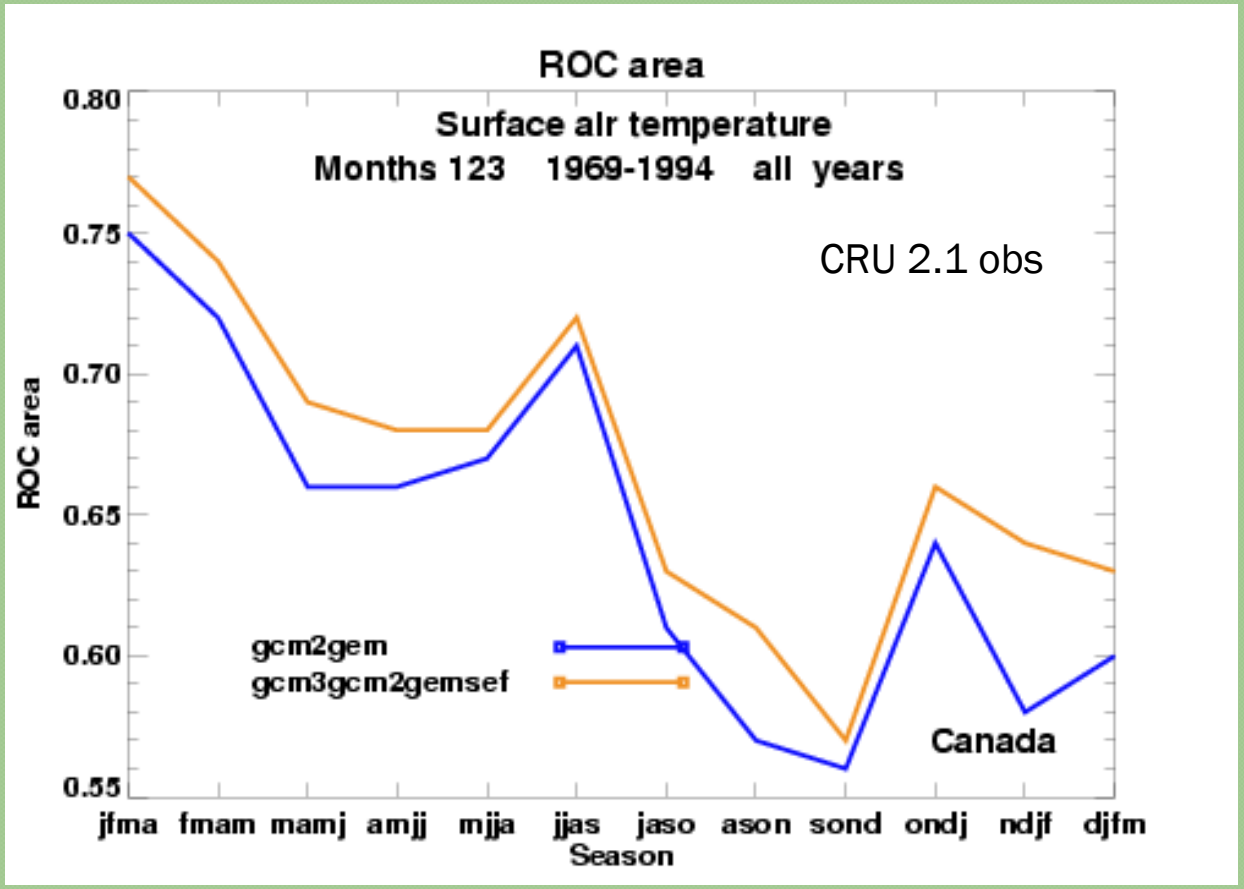
- Hit rate = A/(A+C)
- False alarm rate= B/(B+D)



ROC Score (Canada)

Average for
gcm3gcm2gemsef
0.673

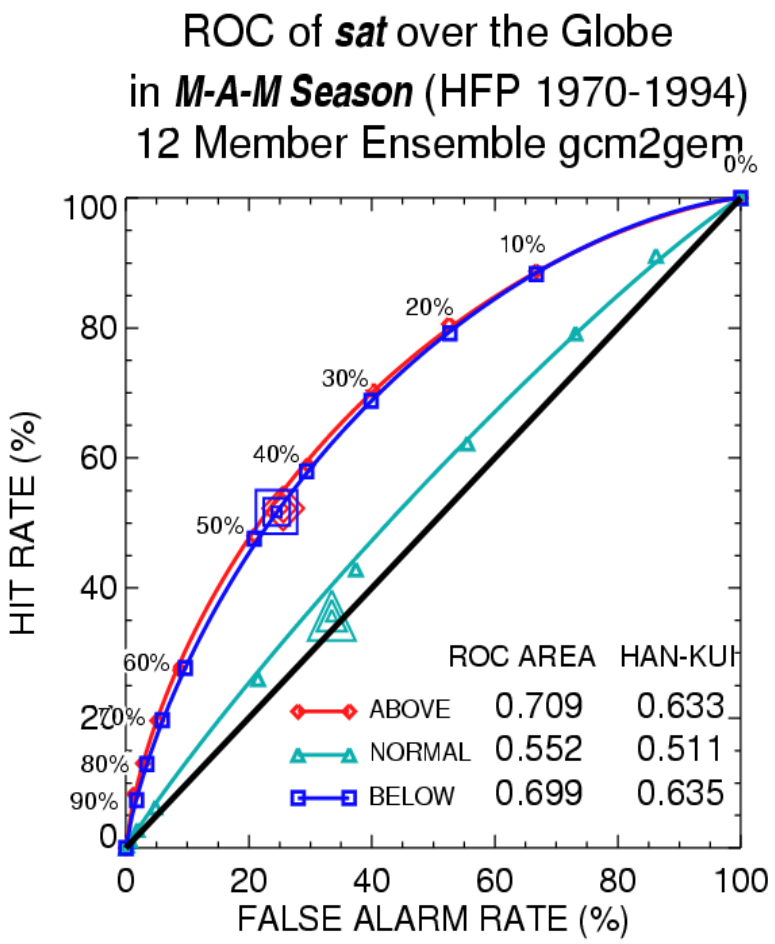
Average for
gcm2gem
0.649

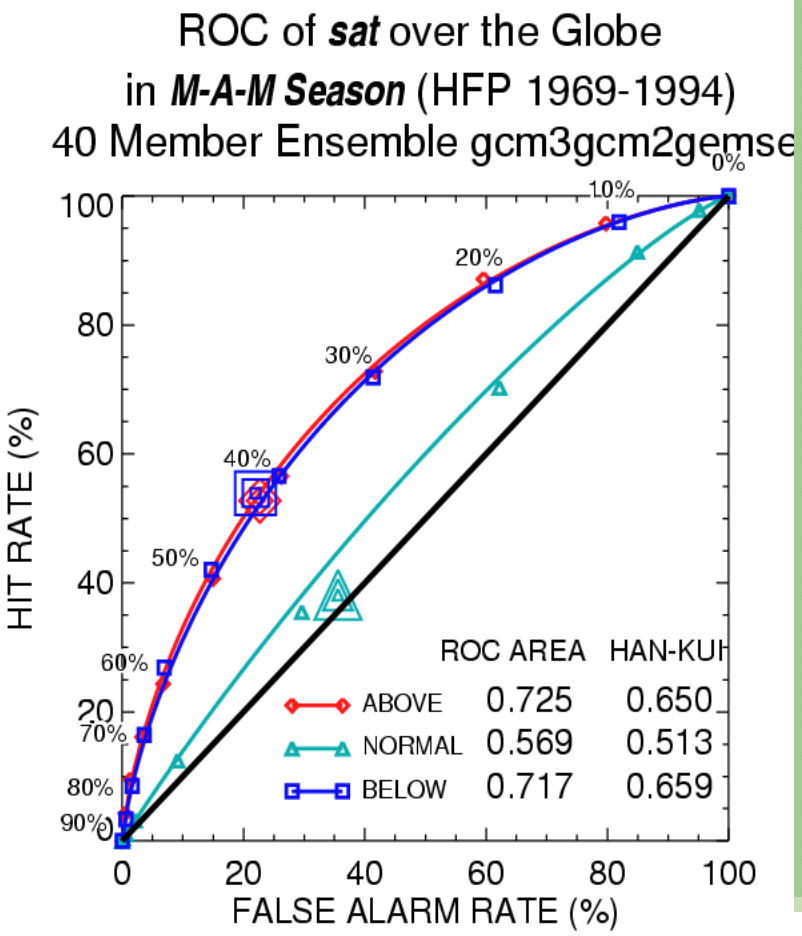


Sharpness

- Tendency to forecast toward extreme values (0 and 100% for probabilistic forecasts). For probabilistic forecasts, it measures the tendency toward categorical deterministic forecasts. Sharpness can be increased but only to the expense of reliability.

ROC Diagram


ROC of *sat* over the Globe
in *M-A-M Season* (HFP 1970-1994)
12 Member Ensemble gcm2gem
HIT RATE (%)
FALSE ALARM RATE (%)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
ROC AREA HAN-KUI
ABOVE 0.709 0.633
NORMAL 0.552 0.511
BELOW 0.699 0.635

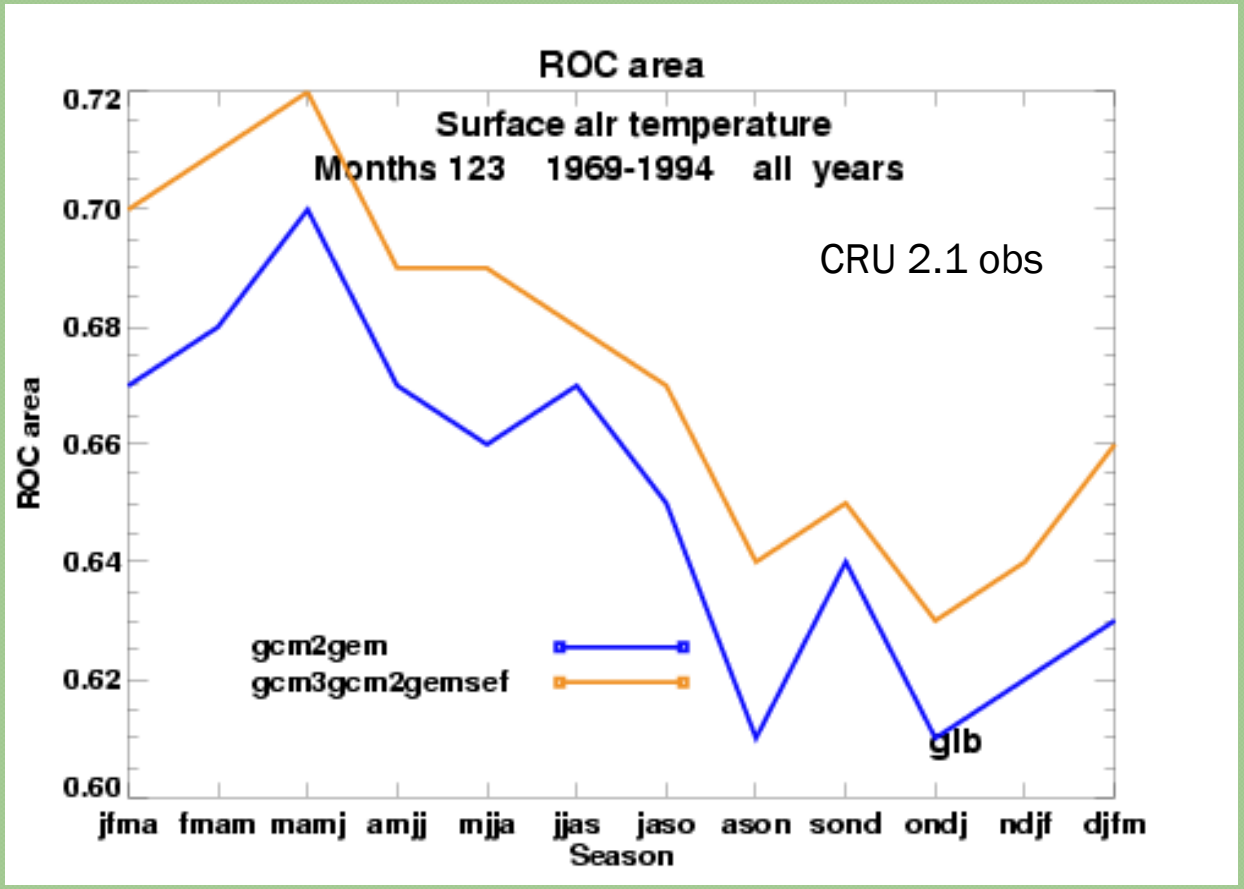

ROC of *sat* over the Globe
in *M-A-M Season* (HFP 1969-1994)
40 Member Ensemble gcm3gcm2gemse
HIT RATE (%)
FALSE ALARM RATE (%)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
ROC AREA HAN-KUI
ABOVE 0.725 0.650
NORMAL 0.569 0.513
BELOW 0.717 0.659

ROC Score (Global)

ROC score:
average of above and below area

Average for gcm3gcm2gemsef
0.677

Average for gcm2gem
0.655



Thank You!