

# **Systeme de prévisions saisonnieres au CMC**

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# Plan de présentation

- **Introduction.**
- **Historique**
- **Ancien système de prévisions saisonnières**
  - **Caractéristiques**
- **Nouveau système de prévisions saisonnières**
  - **Caractéristiques**
  - **Exemples de prévisions**
- **Vérification**
- **Conclusion**



# Introduction

- Le Centre météorologique canadien produit des prévisions saisonnières en mode opérationnel depuis septembre 1995.
- Les prévisions saisonnières sont complètement objectives et automatisées.
- Les prévisions saisonnières donnent un aperçu des anomalies de trois mois de température et de précipitation dans trois catégories définies *a priori* : **sous la normale**, **au-dessus de la normale** et **près de la normale**
- Douze saisons :

<b>DJF</b>	<b>JFM</b>	<b>FMA</b>	<b>MAM</b>	<b>AMJ</b>	<b>MJJ</b>
<b>JJA</b>	<b>JAS</b>	<b>ASO</b>	<b>SON</b>	<b>OND</b>	<b>NDJ</b>

- Des modèles dynamiques sont utilisés pour des prévisions saisonnières à zéro préavis et 1 mois de préavis.
- Ce même système produit des prévisions mensuelles le 1<sup>er</sup> et 16 de chaque mois
- Un modèle statistique est utilisé pour des prévisions saisonnières à 3, 6 et 9 mois de préavis.



# Historique

- **1995: premières prévisions saisonnières automatisées**
- **Deux modèles: RPN SEF et CCmaC GCM2 et six membres par modèle décalés de 24 heures**
- **4 prévisions par année avec 0 échéance: hiver (déc-jan-fév), printemps (mars-avril-mai), été (juin-juillet-aôut) et automne (sept-octobre-nov)**
- **Période du hindcast (HFP): 1969-1994**
- **2000: prévisions mensuelles de température à la surface**
- **2001: remplacement de SEF par GEM**
- **12 prévisions saisonnières par année avec 0 échéance**
- **Novembre 2007: remplacement de GEM par GEMCLIM, ajout du CCmaC GCM3 et du RPN SEF**
- **Système à 40 membres**

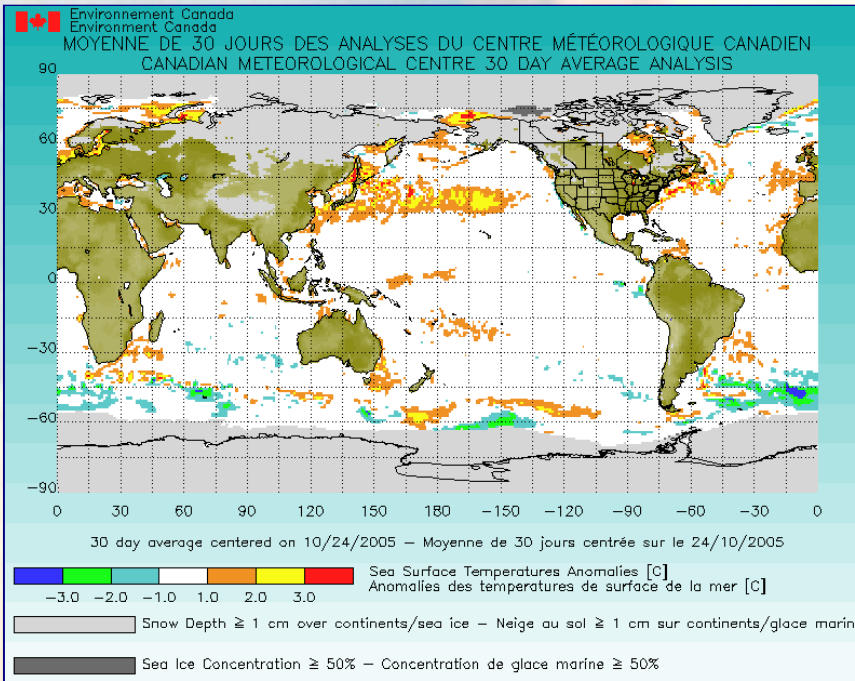


# Ancien système

- **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).
  - Equivalent to a single integration over 5616 years.
  - Equivalent to 312 years of forecast for each three-month period.
  - To calculate each model's own climate.
  - To assess skill of seasonal forecast system.



# Ancien système



**Two models  
GEM + GCM2**

**SST  
last 30-day anomaly  
persisted throughout**

## ICE

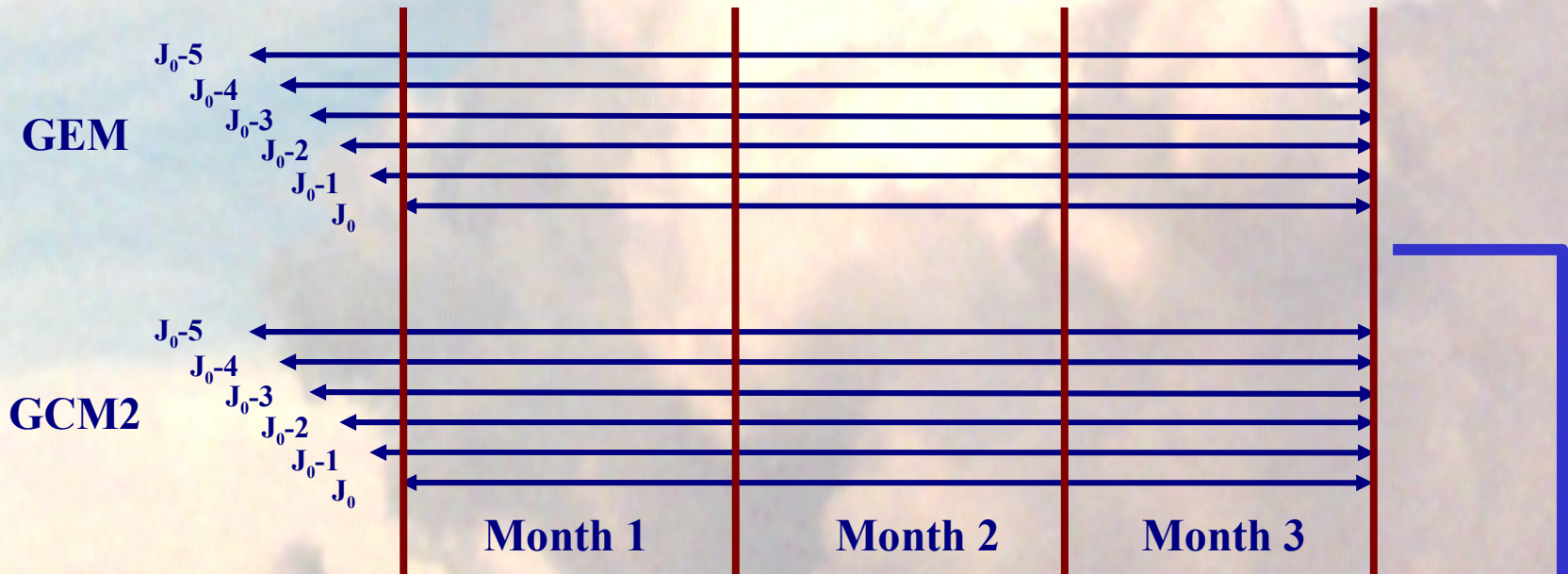
<b>GEM:</b>	<b>CMC analysis relaxed to climatology during first 15 days</b>
<b>GCM2:</b>	<b>climatology</b>

## SNOW

<b>GEM:</b>	<b>CMC analysis relaxed to climatology during first 15 days</b>
<b>GCM2:</b>	<b>prognostic variable</b>



# Ancien système



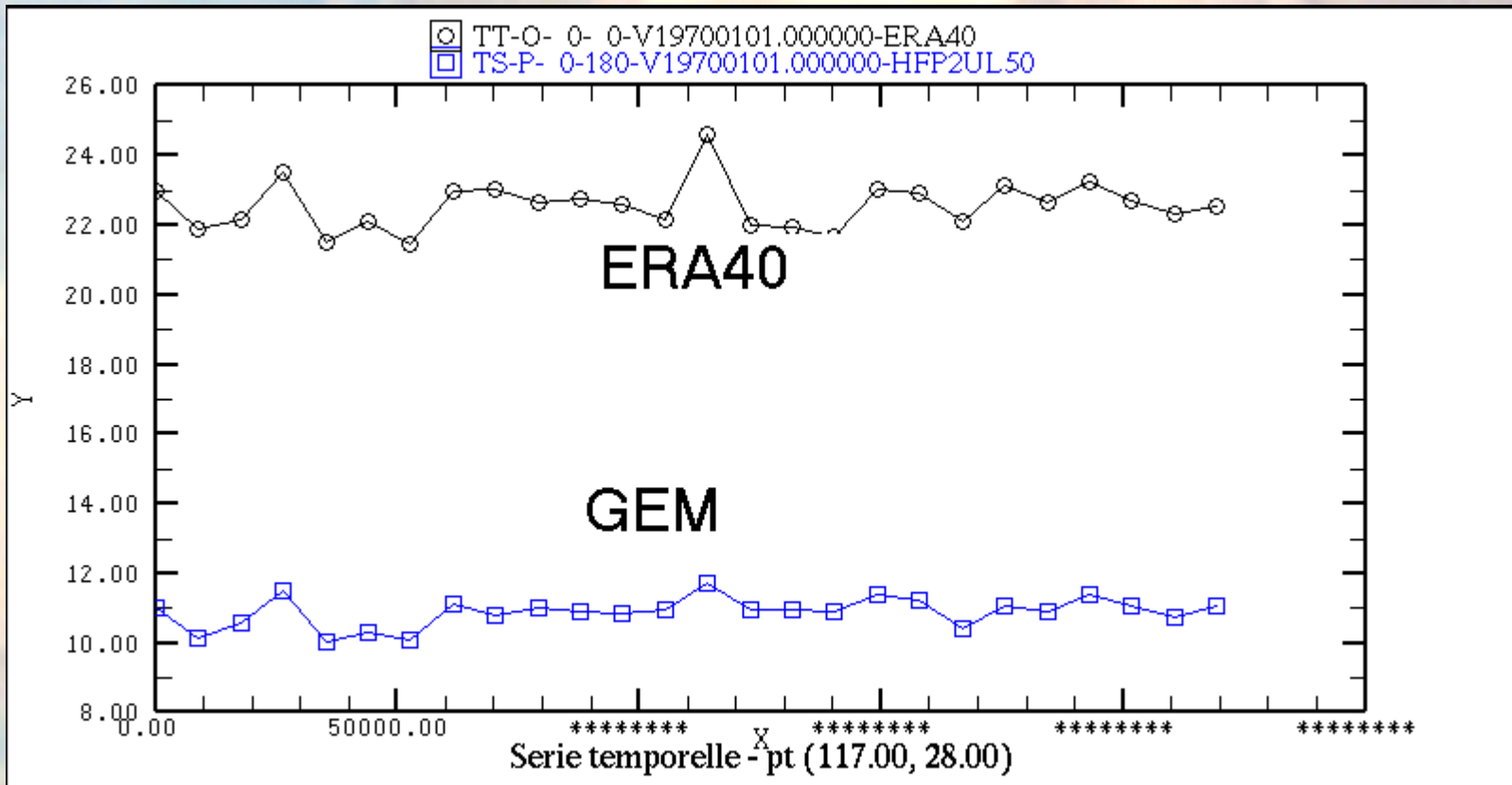
6 lagged runs of GEM + GCM2

12 member ensemble



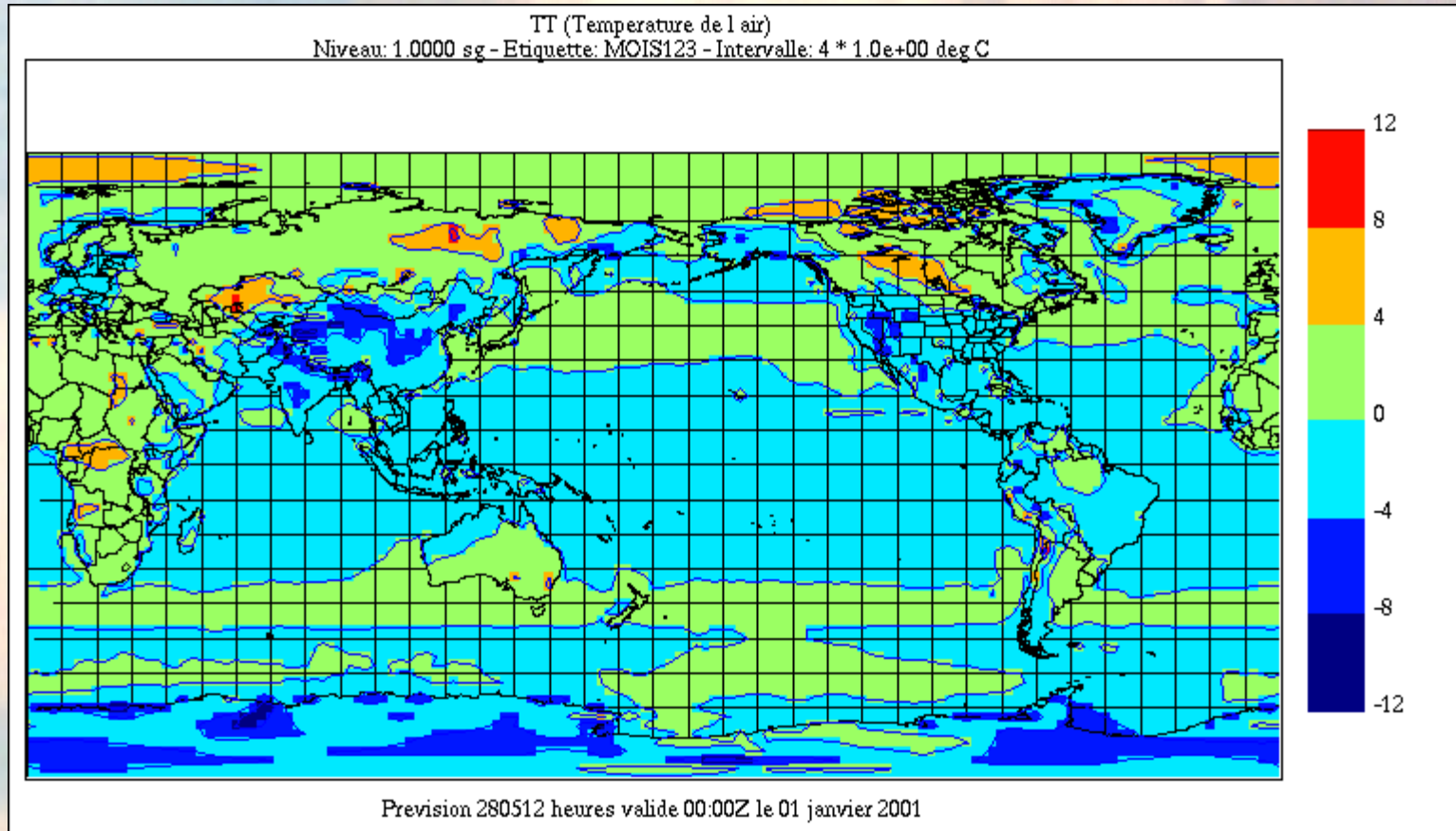
# Série temporelle de température pour la période J-F-M sur l'intervalle 1969-1994 (nord du Chili)

## Observations et sorties de modèle

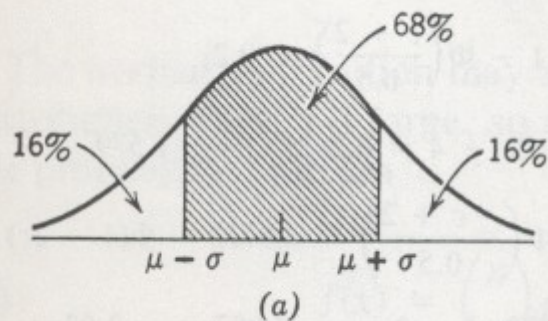




# Biais du modèle GEMCLIM pour JFM (température à 2 m)



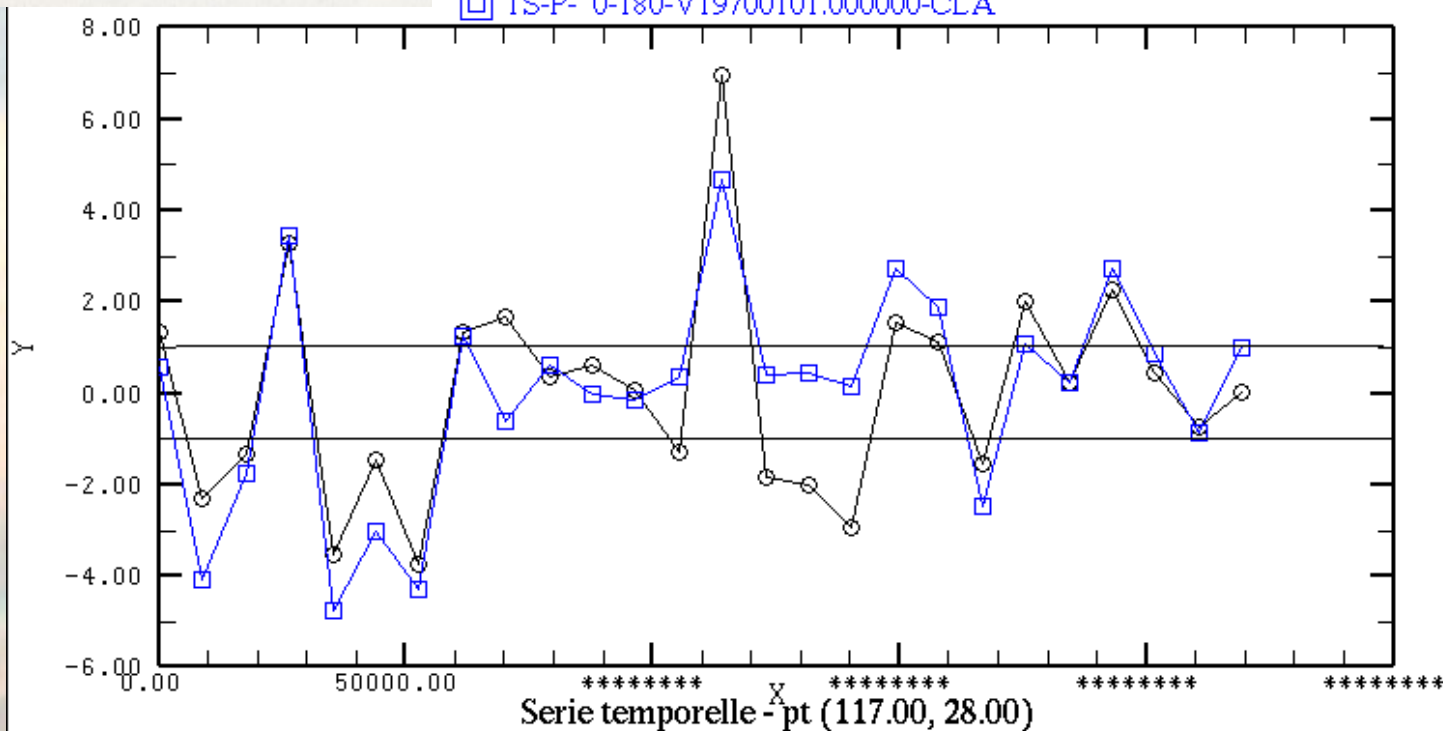
# Normalisation



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

$x' < -1$	below normal
$-1 \leq x' \leq 1$	normal
$x' > 1$	above normal

□ TT-O- 0- 0-V19700101.000000-CLA  
□ TS-P- 0-180-V19700101.000000-CLA



## Combinaison de deux modèles : température

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

$$T_{\text{category forecast}} = \frac{T_{\text{anomaly forecast}}}{0.43 \cdot \sigma_{T, 2\text{modèles}}^{1969-1994}}$$

**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.**



## Combinaison de deux modèles : précipitation

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

$$P_{\text{category forecast}} = \frac{P_{\text{anomaly forecast}}}{0.43 \cdot \sigma_{P, 2\text{modèles}}^{1969-1994}}$$

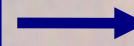


## Ancien système : prévisions probabilistes

- **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  $0.43 \sigma$  as threshold (above, normal, below)
  - Count the number of members in each category
  - Divide by the total number of members (12) and multiply by 100



**Probabilistic forecasts for:**



**Above  
Normal  
Below**

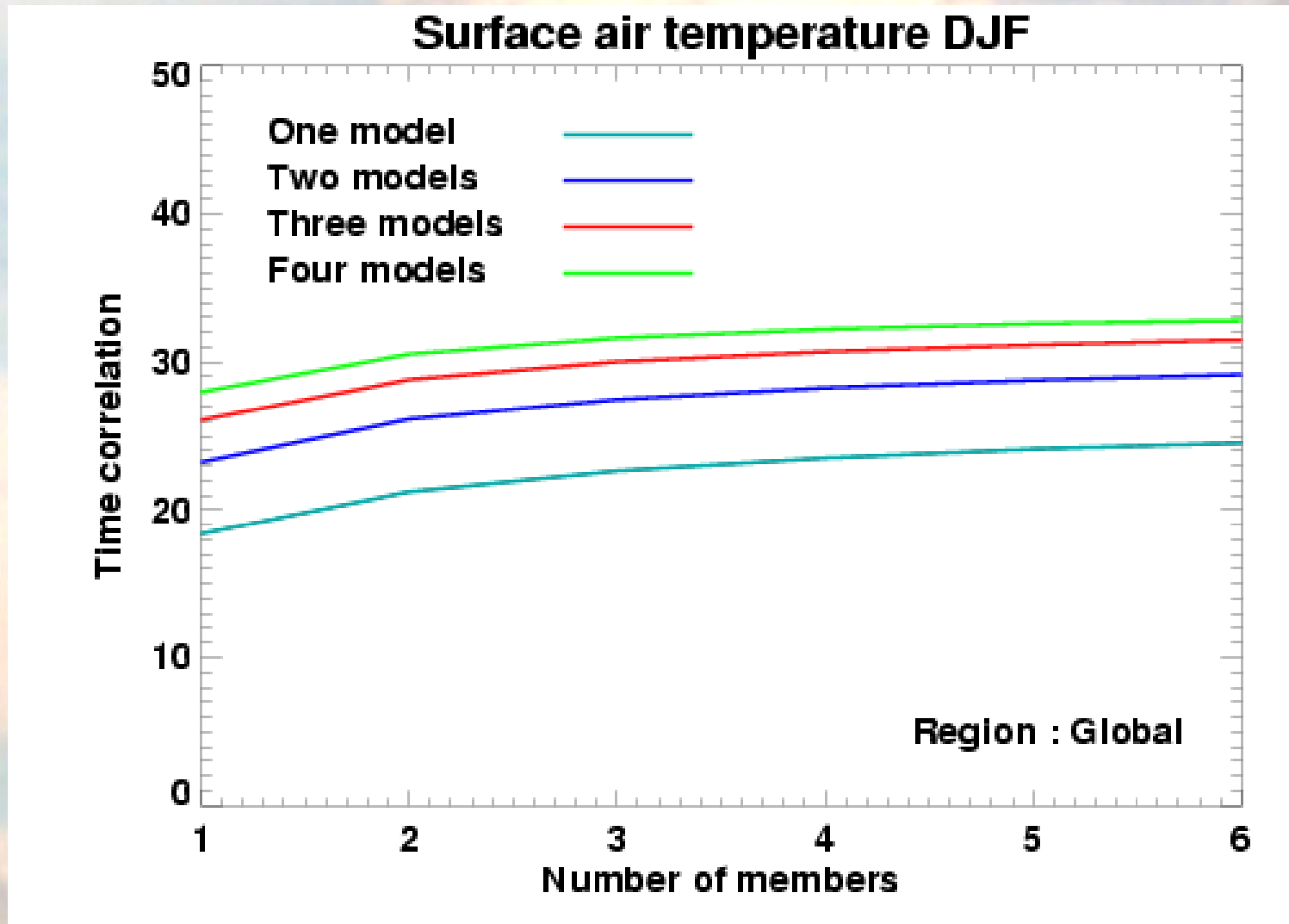


## Ancien système : prévisions probabilistes

Number of members	Probability (%)	Bin (%)
0	0.00	0-9
1	8.33	0-9
2	16.67	10-19
3	25.00	20-29
4	33.33	30-39
5	41.67	40-49
6	50.00	50-59
7	58.33	50-59
8	66.67	60-69
9	75.00	70-79
10	83.33	80-89
11	91.67	90-100
12	100.00	90-100



# Est-ce que N modèles c'est mieux que N-1 modèles?



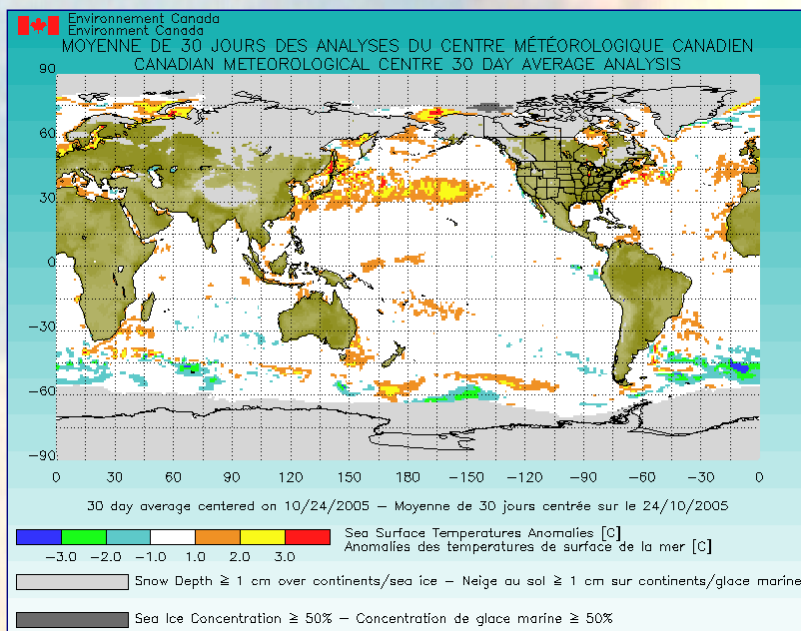
## Nouveau système : caractéristiques

- **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).
  - 3840 runs for each model (12 four-month periods, 10 runs, 32 years).
  - Equivalent to a single integration over 5360 years.
  - **To calculate model climate.**
  - **To assess skill of seasonal forecast system.**





# Nouveau système : caractéristiques



**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)
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## SNOW

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



**GEM**

$J_0-9$   
 $J_0-8$   
 $J_0-7$   
 $J_0-6$   
 $J_0-5$   
 $J_0-4$   
 $J_0-3$   
 $J_0-2$   
 $J_0-1$   
 $J_0$

**GCM2**

$J_0-9$   
 $J_0-8$   
 $J_0-7$   
 $J_0-6$   
 $J_0-5$   
 $J_0-4$   
 $J_0-3$   
 $J_0-2$   
 $J_0-1$   
 $J_0$

**GCM3**

$J_0-9$   
 $J_0-8$   
 $J_0-7$   
 $J_0-6$   
 $J_0-5$   
 $J_0-4$   
 $J_0-3$   
 $J_0-2$   
 $J_0-1$   
 $J_0$

**SEF**

$J_0-9$   
 $J_0-8$   
 $J_0-7$   
 $J_0-6$   
 $J_0-5$   
 $J_0-4$   
 $J_0-3$   
 $J_0-2$   
 $J_0-1$   
 $J_0$

**Month 1**

**Month 2**

**Month 3**

**Month 4**



# Nouveau système : caractéristiques

10 lagged runs of  
GEM + GCM2 + GCM3 + SEF

40 member  
ensemble

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



# Nouveau système : caractéristiques

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

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

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.



# Nouveau système : caractéristiques

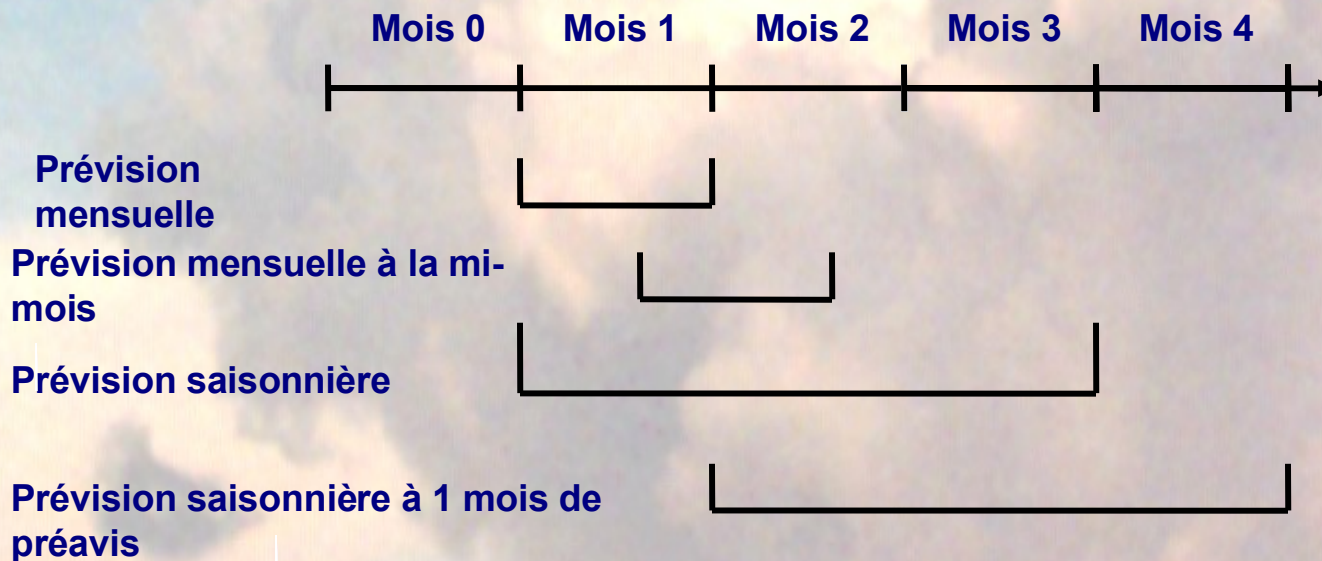
Number of members	Probability (%)	Bin (%)
0	0.00	0-9
1	2.50	0-9
2	5.00	0-9
3	7.50	0-9
4	10.00	10-19
5	12.50	10-19
6	15.00	10-19
7	17.50	10-19
8	20.00	20-29
9	22.50	20-29
10	25.00	20-29
11	27.50	20-29
12	30.00	30-39
13	32.50	30-39
14	35.00	30-39
15	37.50	30-39
16	40.00	40-49
17	42.50	40-49
18	45.00	40-49
19	47.50	40-49
20	50.00	50-59

Number of members	Probability (%)	Bin (%)
21	52.50	50-59
22	55.00	50-59
23	57.50	50-59
24	60.00	60-69
25	62.50	60-69
26	65.00	60-69
27	67.50	60-69
28	70.00	70-79
29	72.50	70-79
30	75.00	70-79
31	77.50	70-79
32	80.00	80-89
33	82.50	80-89
34	85.00	80-89
35	87.50	80-89
36	90.00	90-100
37	92.50	90-100
38	95.00	90-100
39	97.50	90-100
40	100.00	90-100

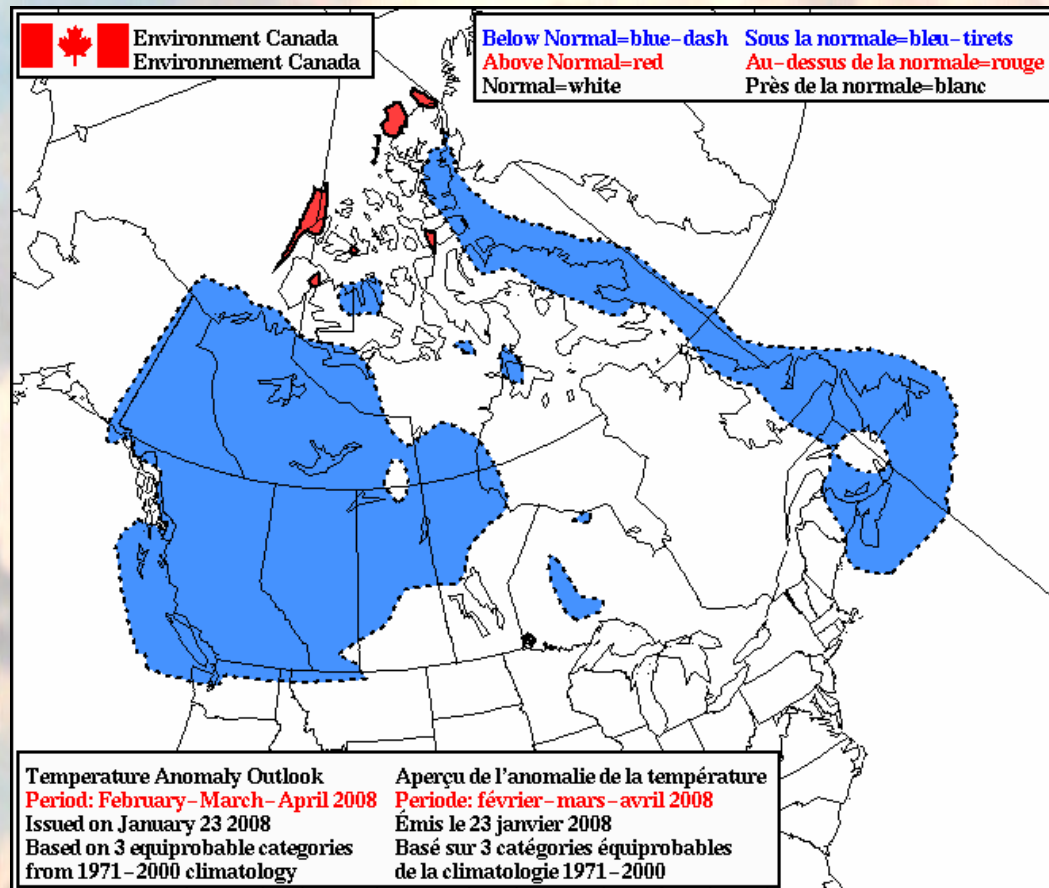
**Probability forecasts are not calibrated.**



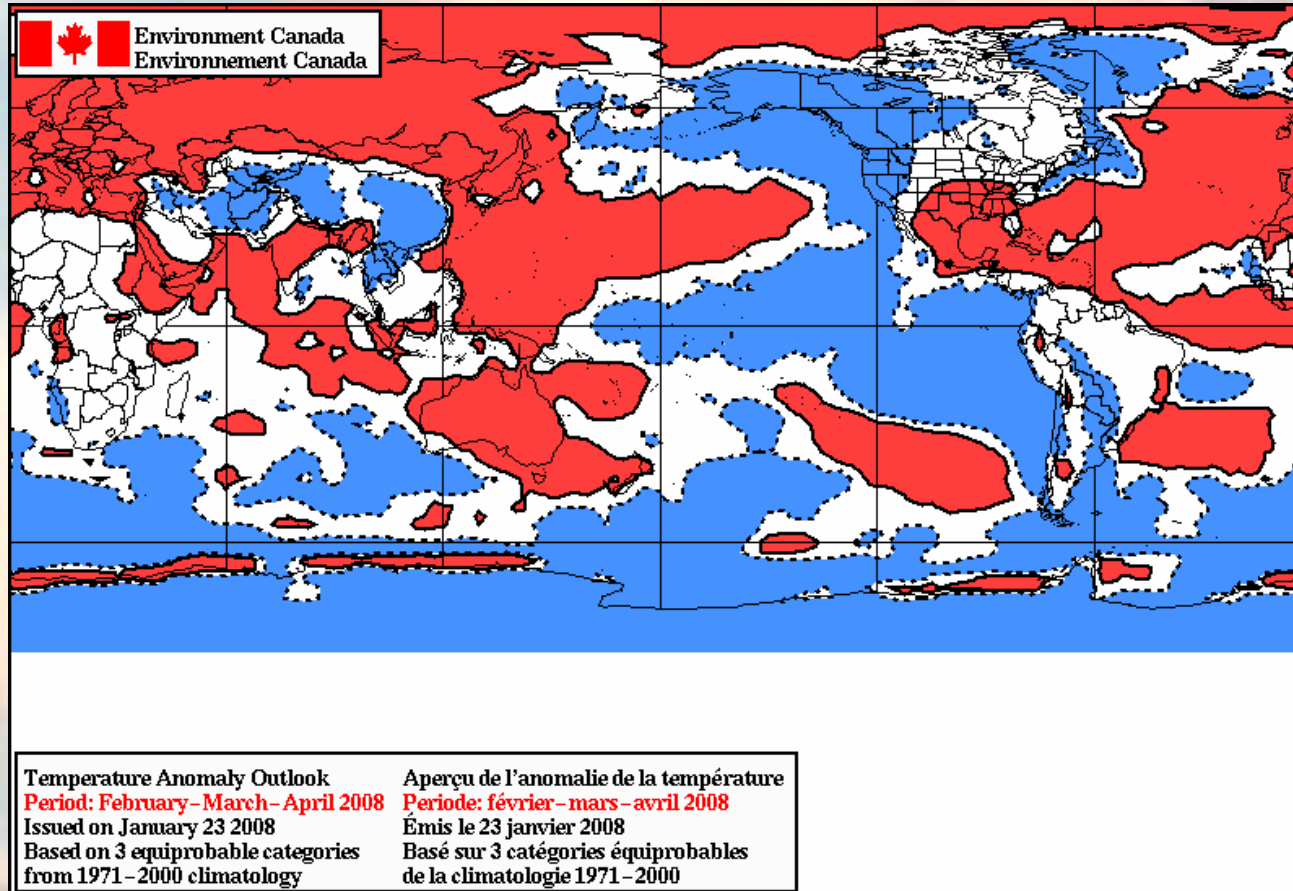
# Périodes calculées



# Prévision saisonnière de température à 2 m pour la saison février-mars-avril



# Prévision saisonnière de température à 2 m pour la saison février-mars-avril



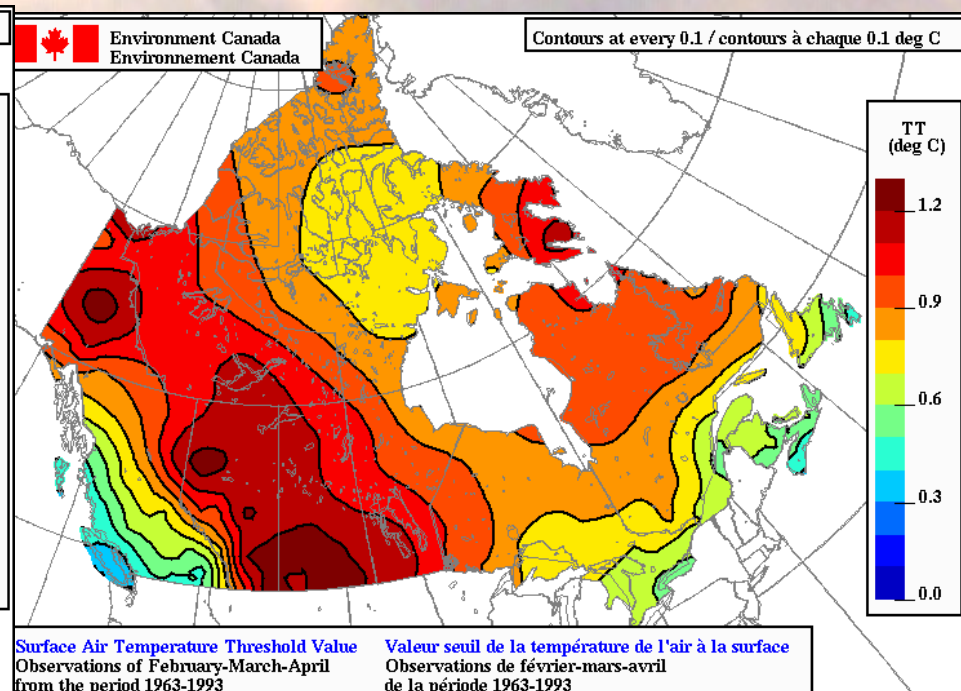
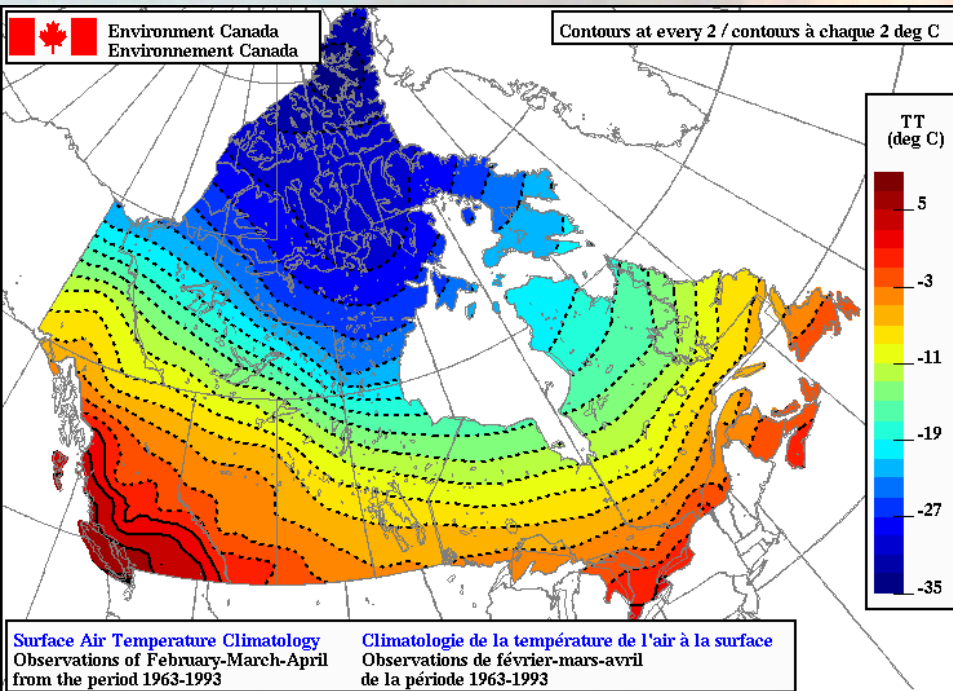


# Calcul des seuils

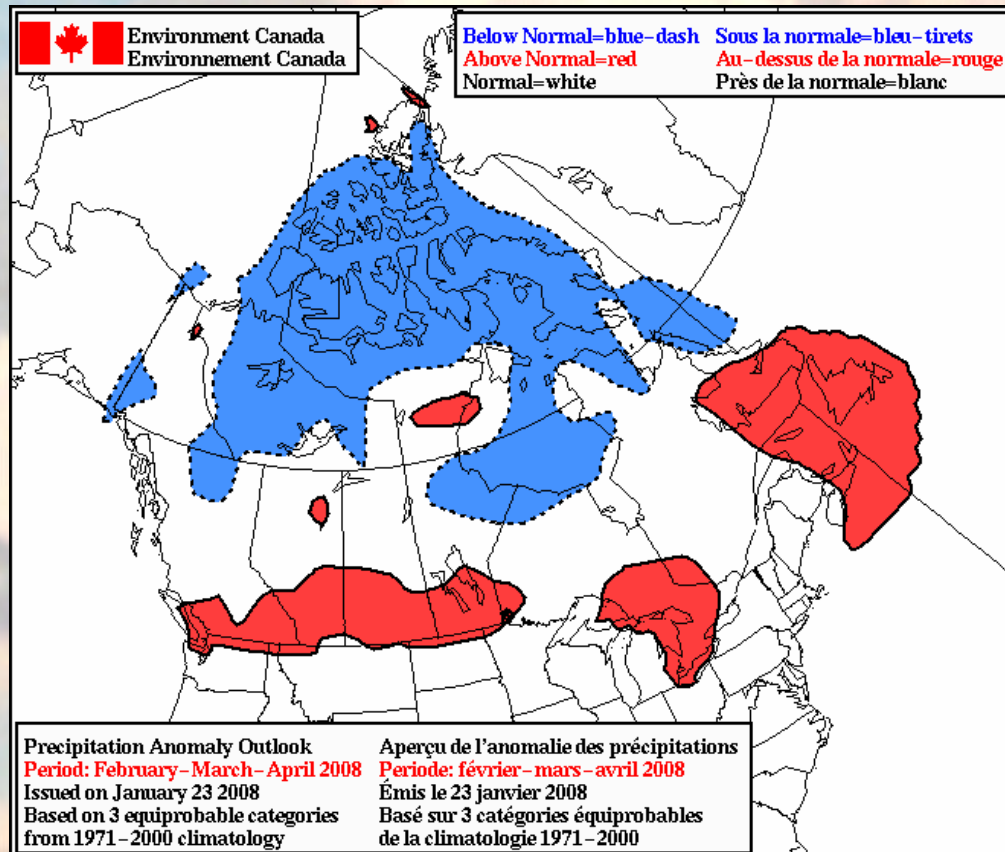
$T < \bar{T} - 0.43 \cdot \sigma$  below normal

$\bar{T} - 0.43 \cdot \sigma < T < \bar{T} + 0.43 \cdot \sigma$  normal

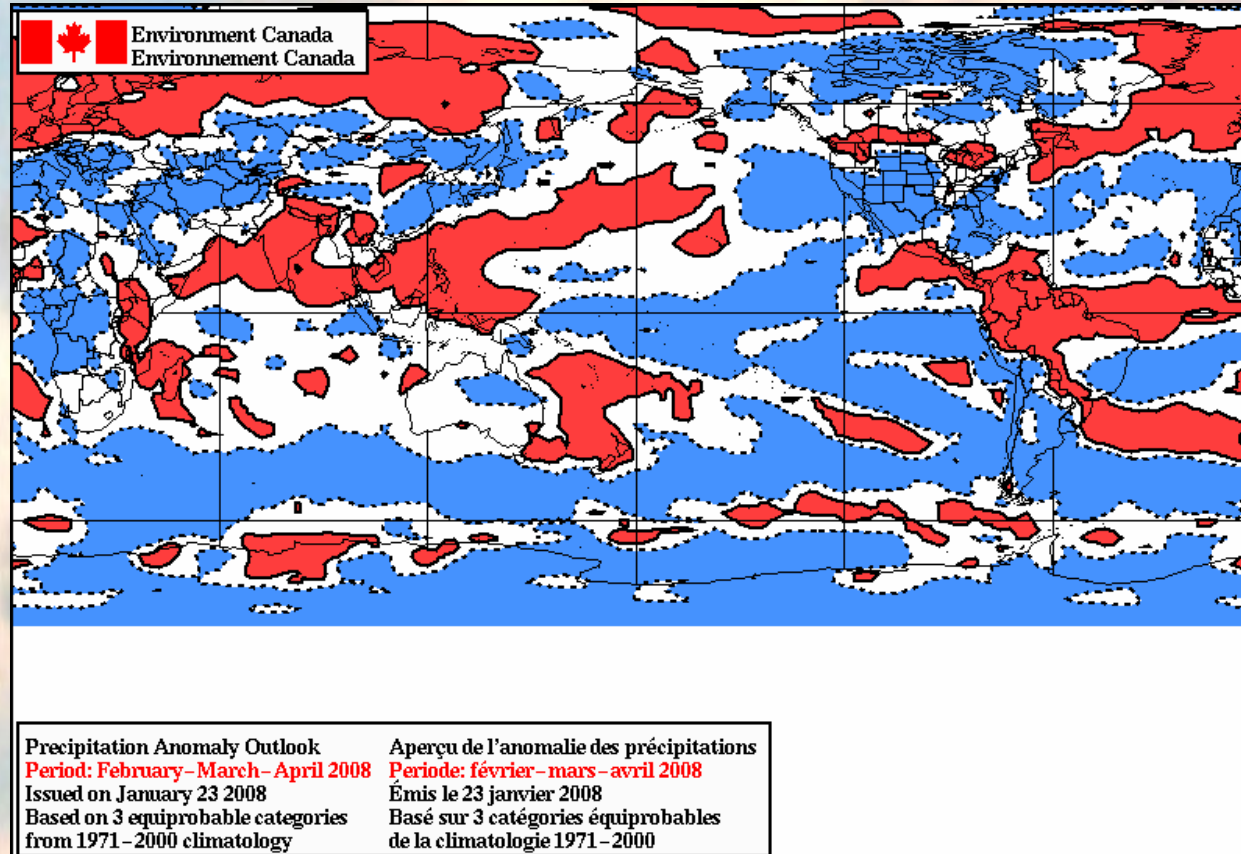
$T > \bar{T} + 0.43 \cdot \sigma$  above normal



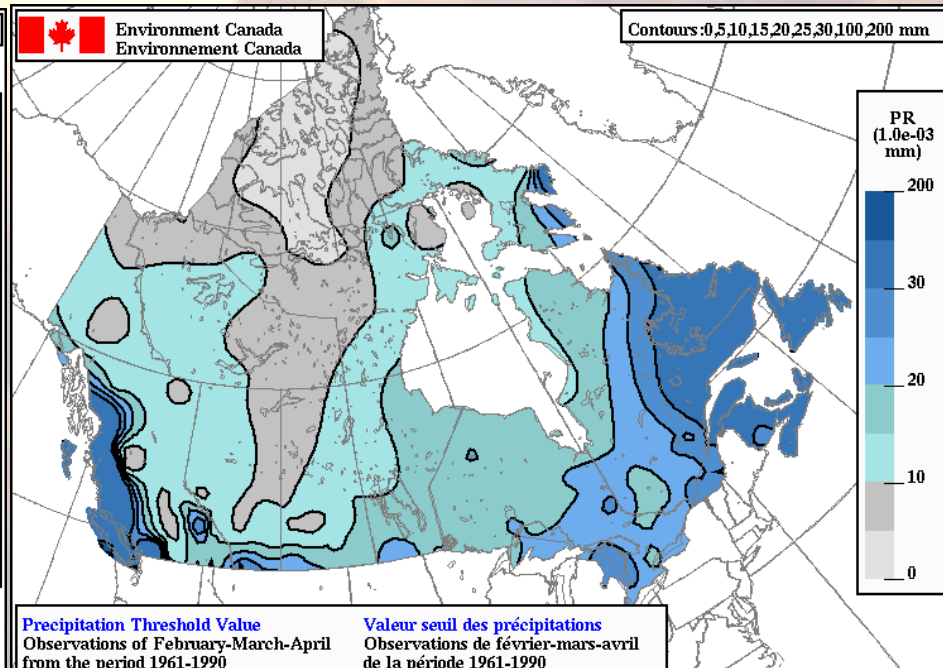
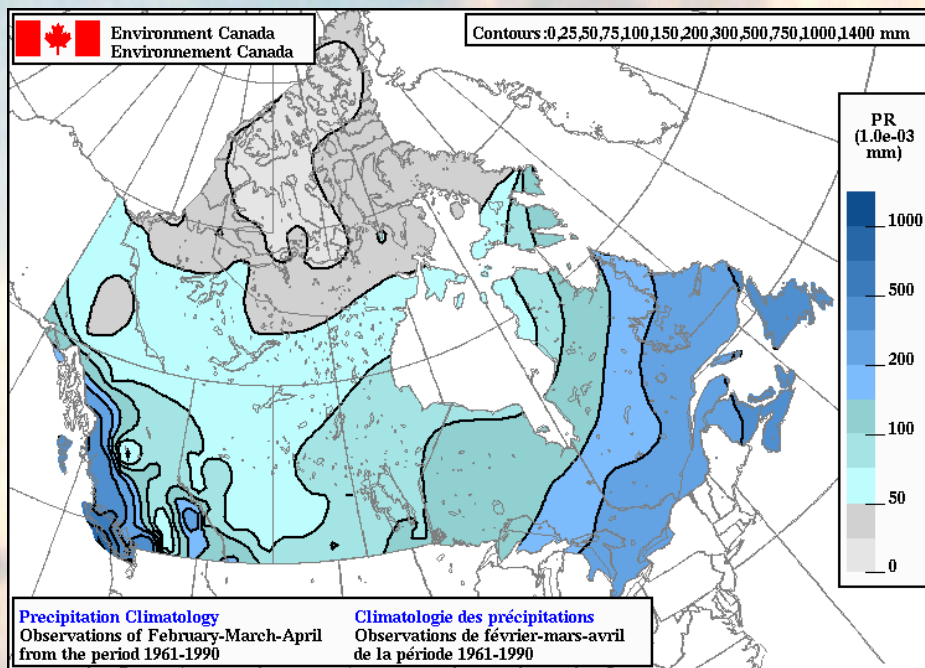
# Prévision saisonnière de précipitation pour la saison février-mars-avril



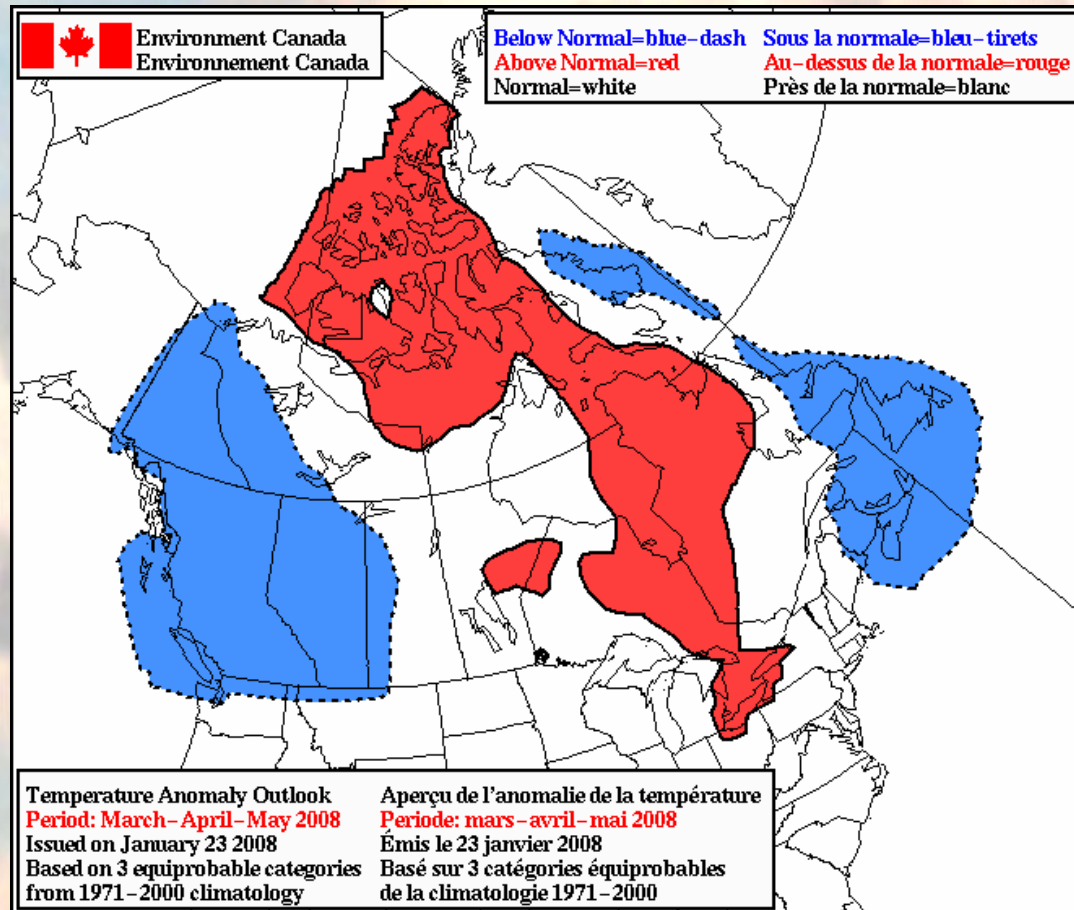
# Prévision saisonnière de précipitation pour la saison février-mars-avril



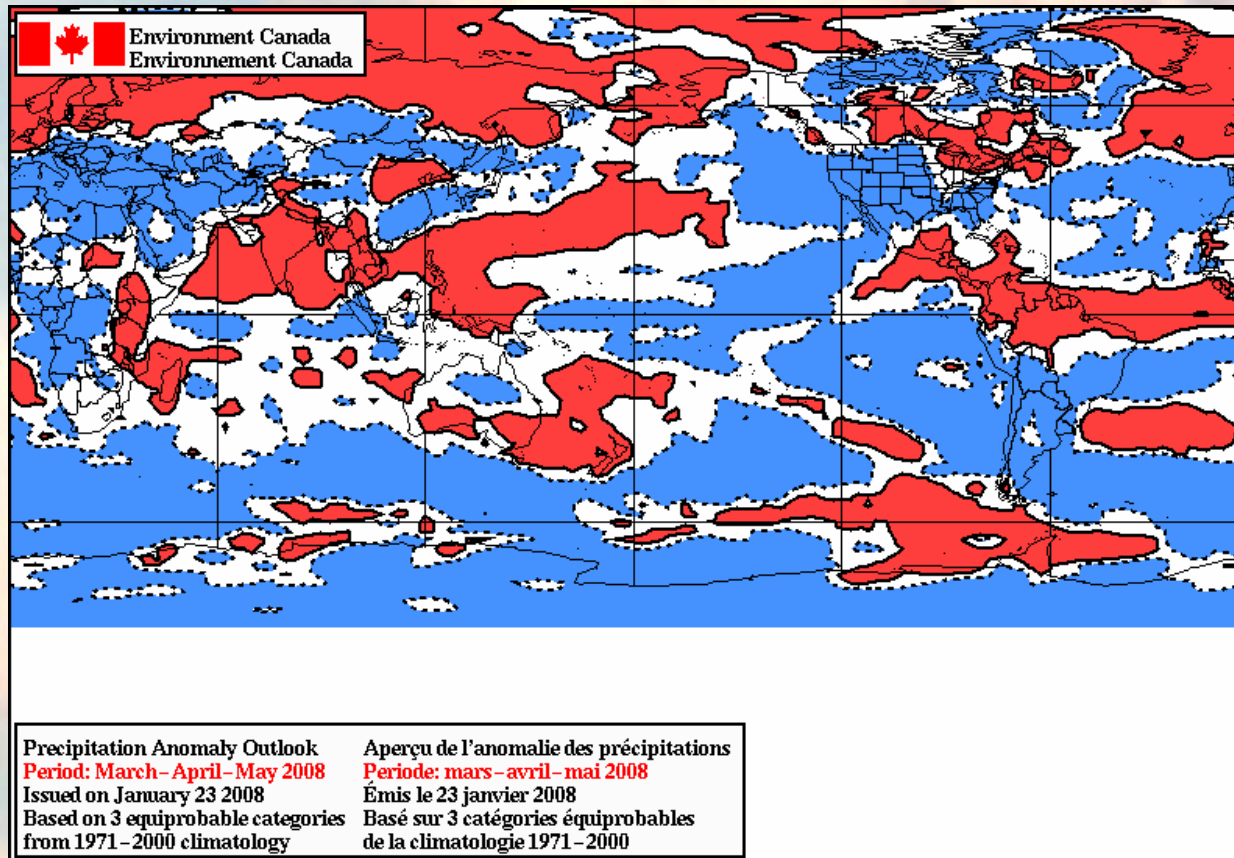
# Seuils



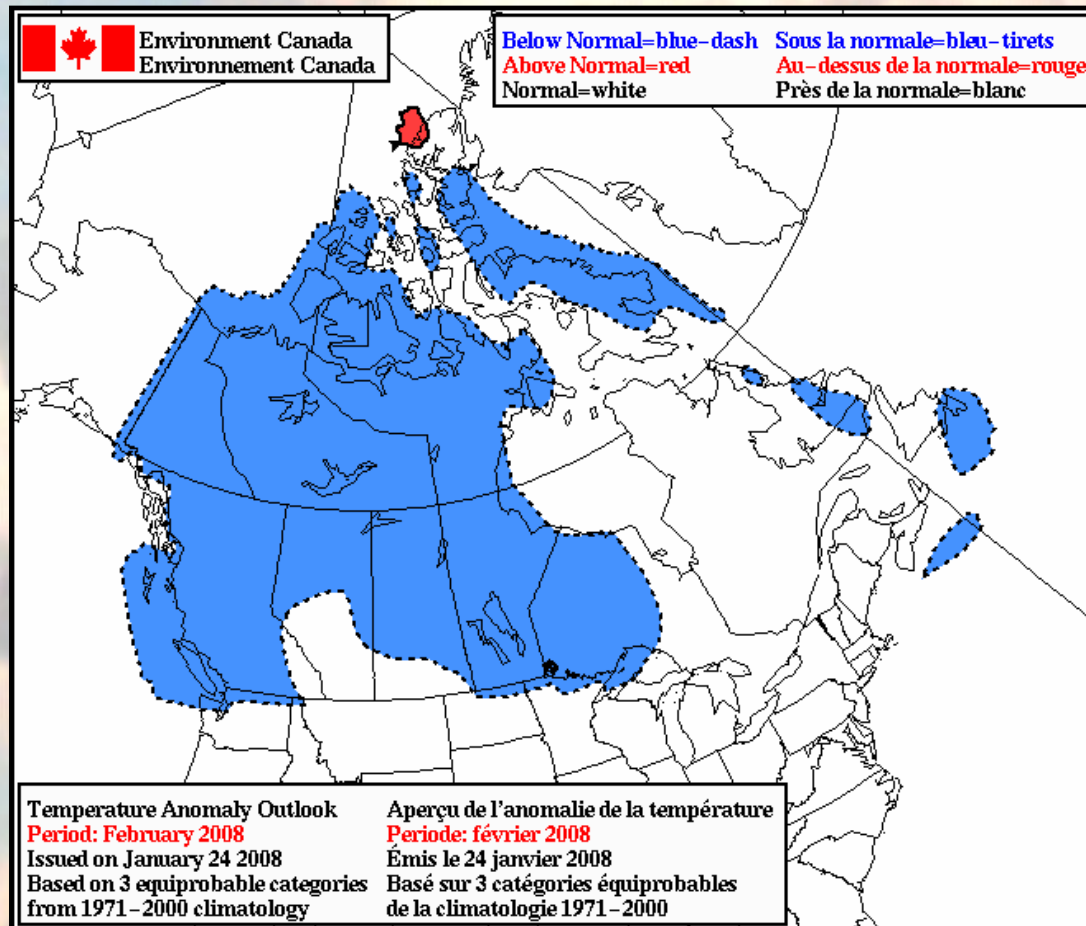
# Prévision saisonnière de température à 2 m pour la saison mars-avril-mai (1 mois de préavis)



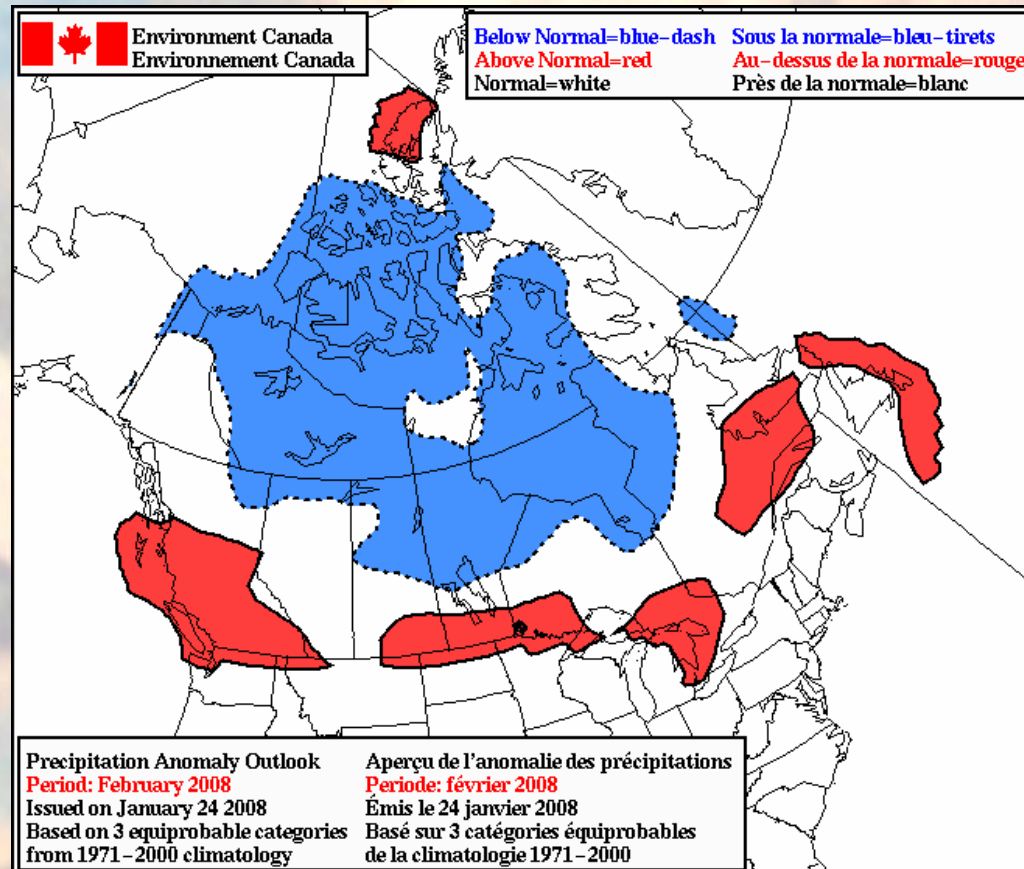
# Prévision saisonnière de température à 2 m pour la saison mars-avril-mai



# Prévision mensuelle de température à 2 m pour le mois de février

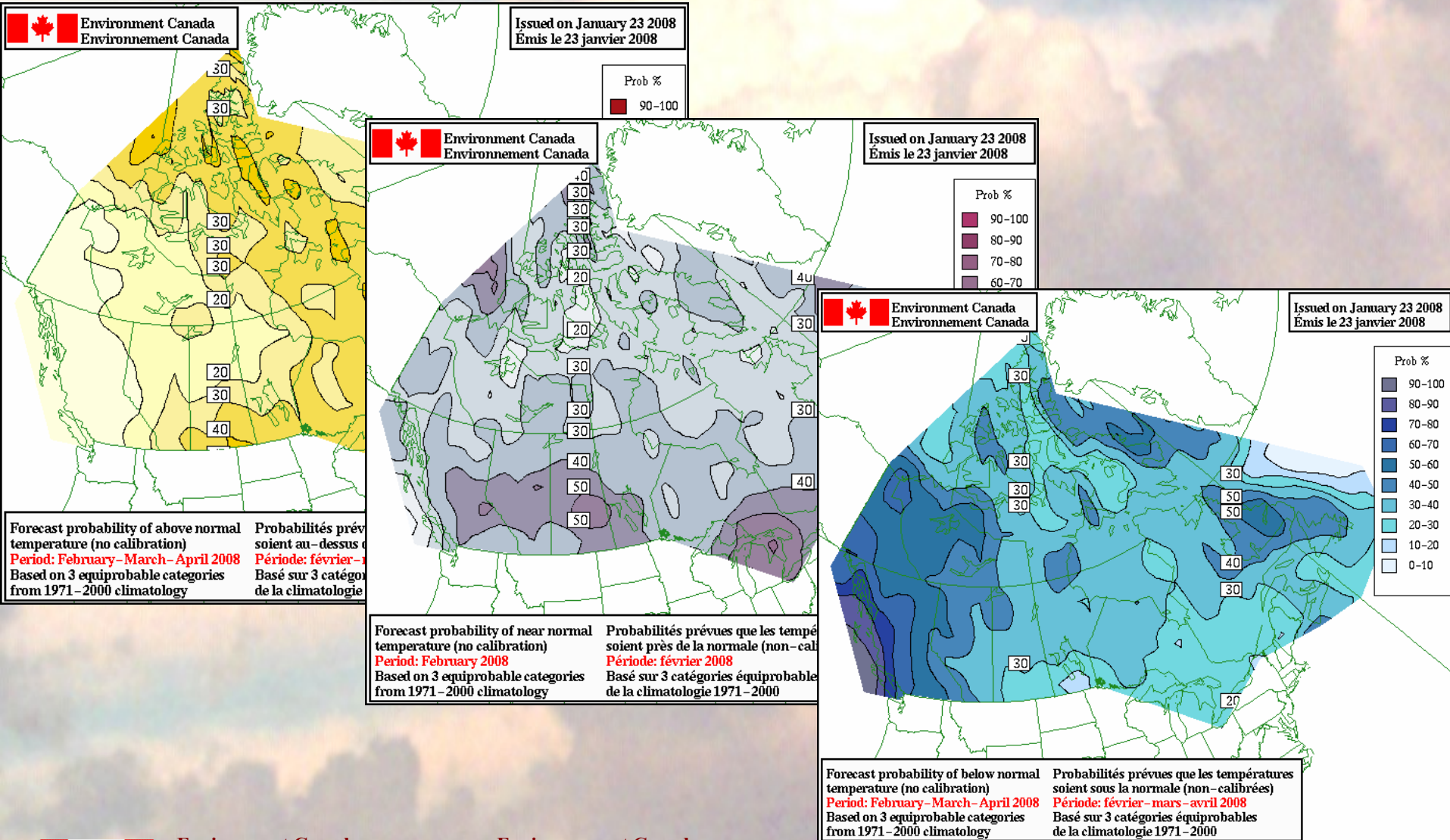


# Prévision mensuelle de précipitation pour le mois de février

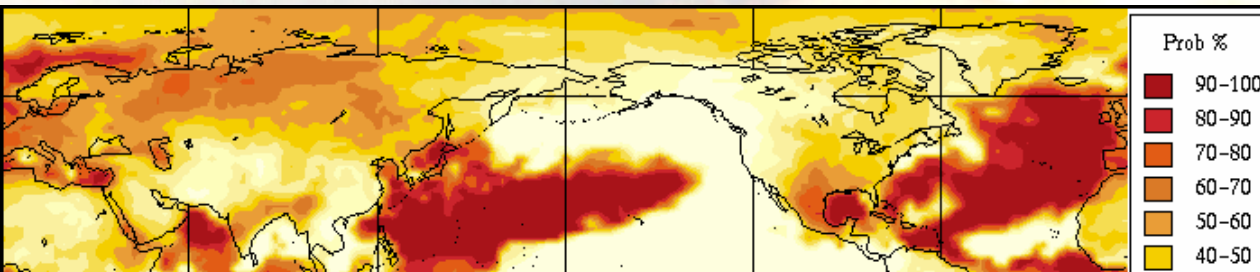




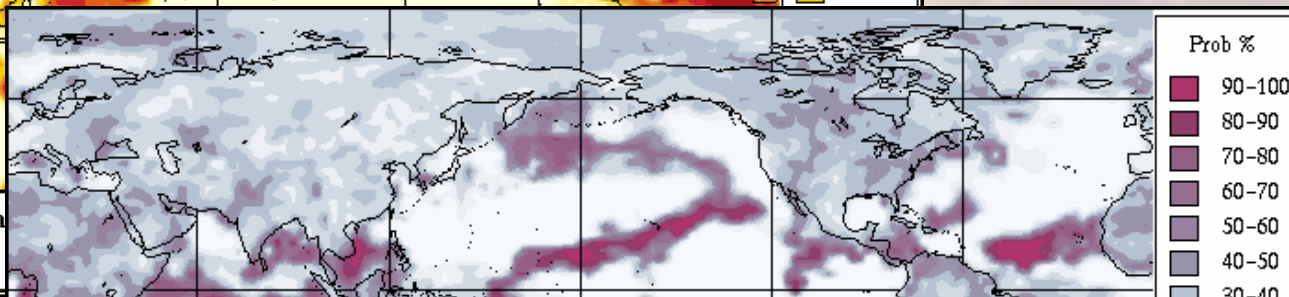
# Prévisions probabilistes



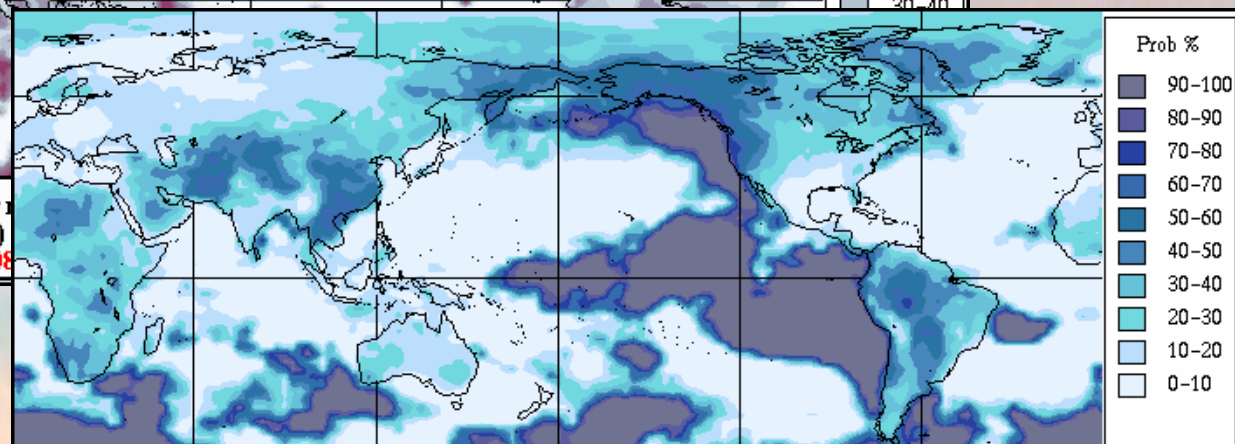
# Prévision probabilistes



Forecast probability of above normal temperature (no calibration)  
February-March-April 2008



Forecast probability of near normal temperature (no calibration)  
February-March-April 2008



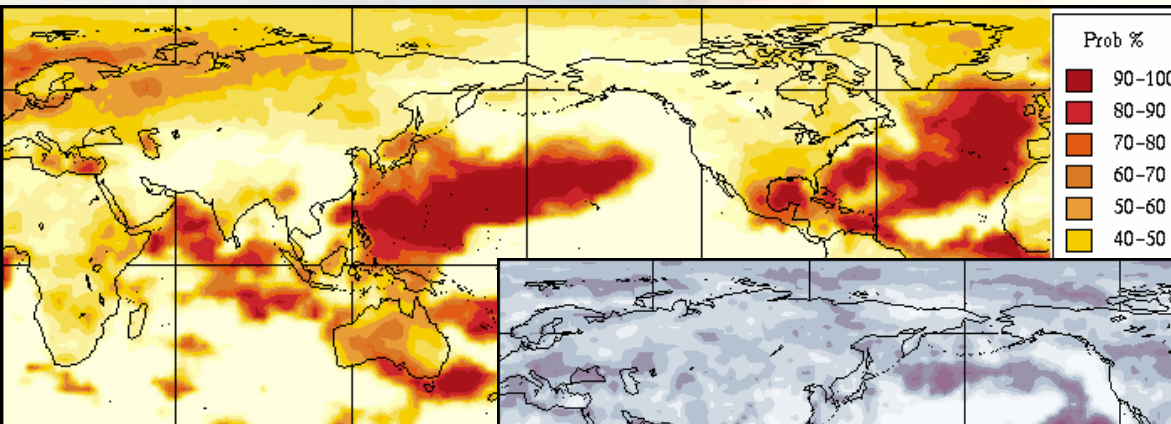
Forecast probability of below normal temperature (no calibration)  
February-March-April 2008

Probabilités prévues que les températures soient sous la normale (non-calibrées)  
février-mars-avril 2008

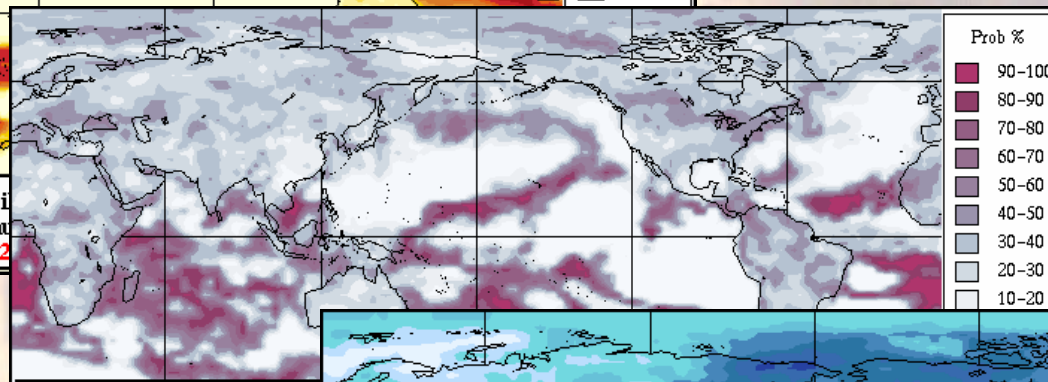
Issued on January 23 2008  
Émis le 23 janvier 2008



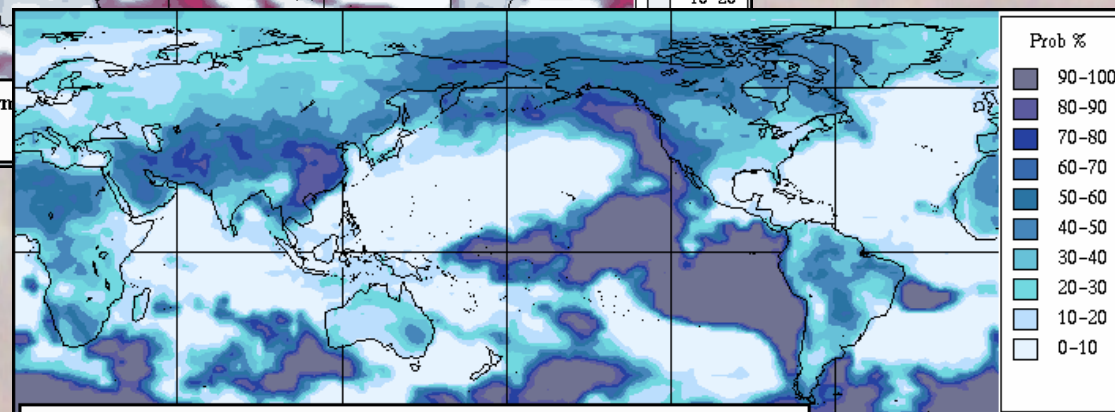
# Prévision mensuelle probabiliste



Forecast probability of above normal temperature (no calibration) **February 2008**  
 Probabilités prévues que les températures soient au-dessus de la normale (non-calibrées) **février 2008**



Forecast probability of near normal temperature (no calibration) **February 2008**

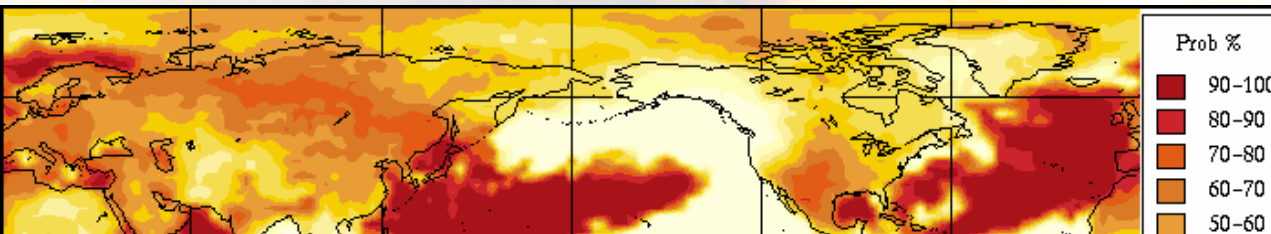


Forecast probability of below normal temperature (no calibration) **February 2008**  
 Probabilités prévues que les températures soient sous la normale (non-calibrées) **février 2008**

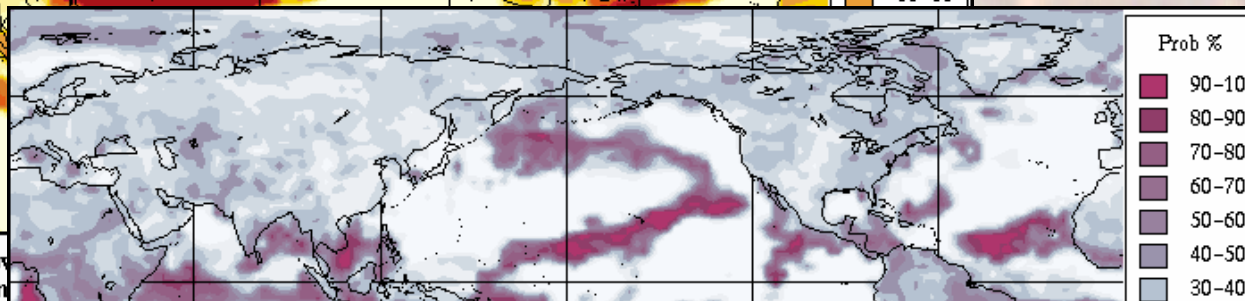
Issued on January 23 2008  
 Émis le 23 janvier 2008



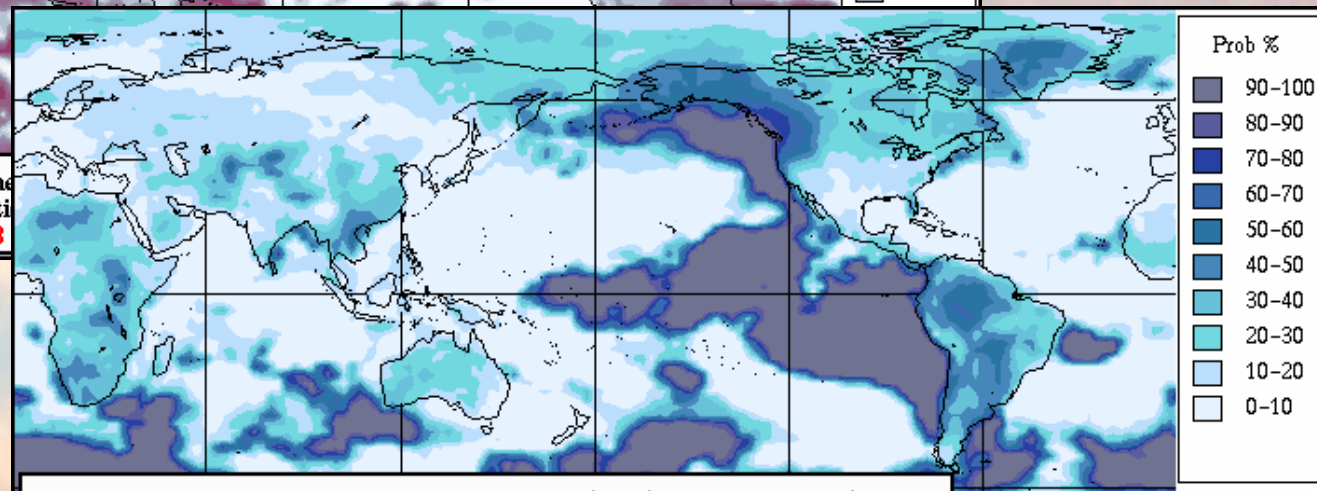
# Prévision saisonnière probabiliste à un mois de préavis



Forecast probability of above-normal temperature (no calibration)  
March-April-May 2008



Forecast probability of near-normal temperature (no calibration)  
March-April-May 2008



Forecast probability of below normal temperature (no calibration)  
March-April-May 2008

Probabilités prévues que les températures soient sous la normale (non-calibrées)  
mars-avril-mai 2008

Issued on January 23 2008  
Émis le 23 janvier 2008



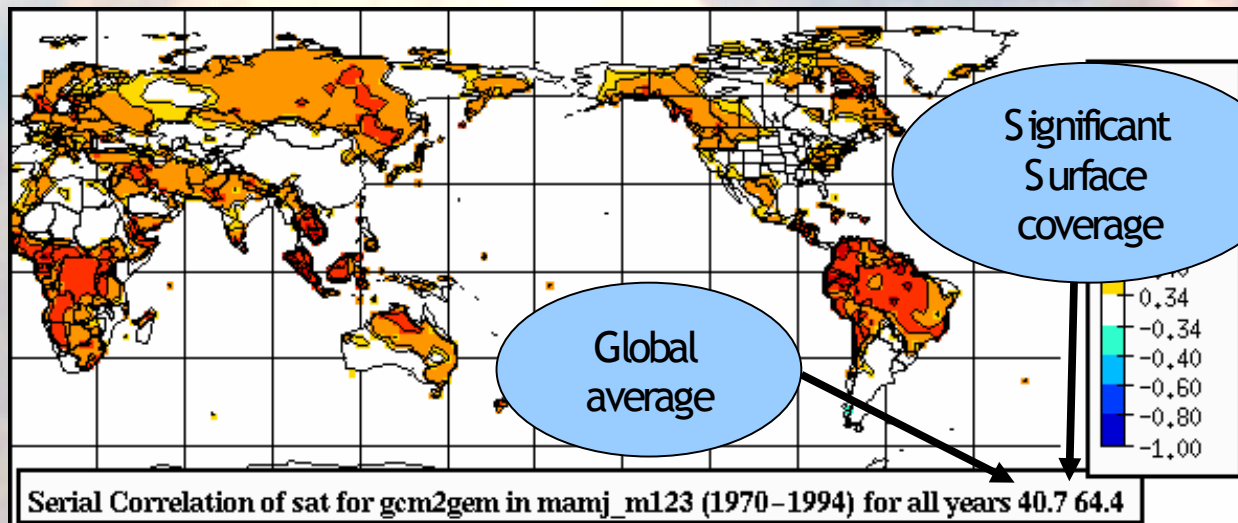
# Vérification

- **Scores déterministes**
  - **Corrélation**
  - **Pourcent correct**
- **Scores Probabilistes**
  - **Reliability**
  - **Sharpness**
  - **ROC**

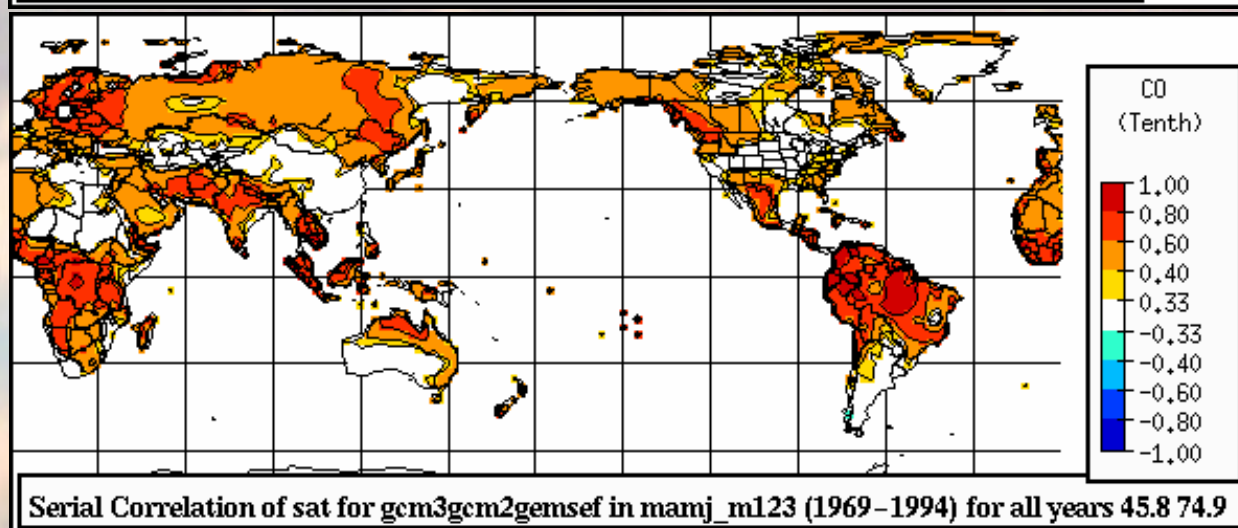


# Corrélation

GCM2-GEM  
12 members



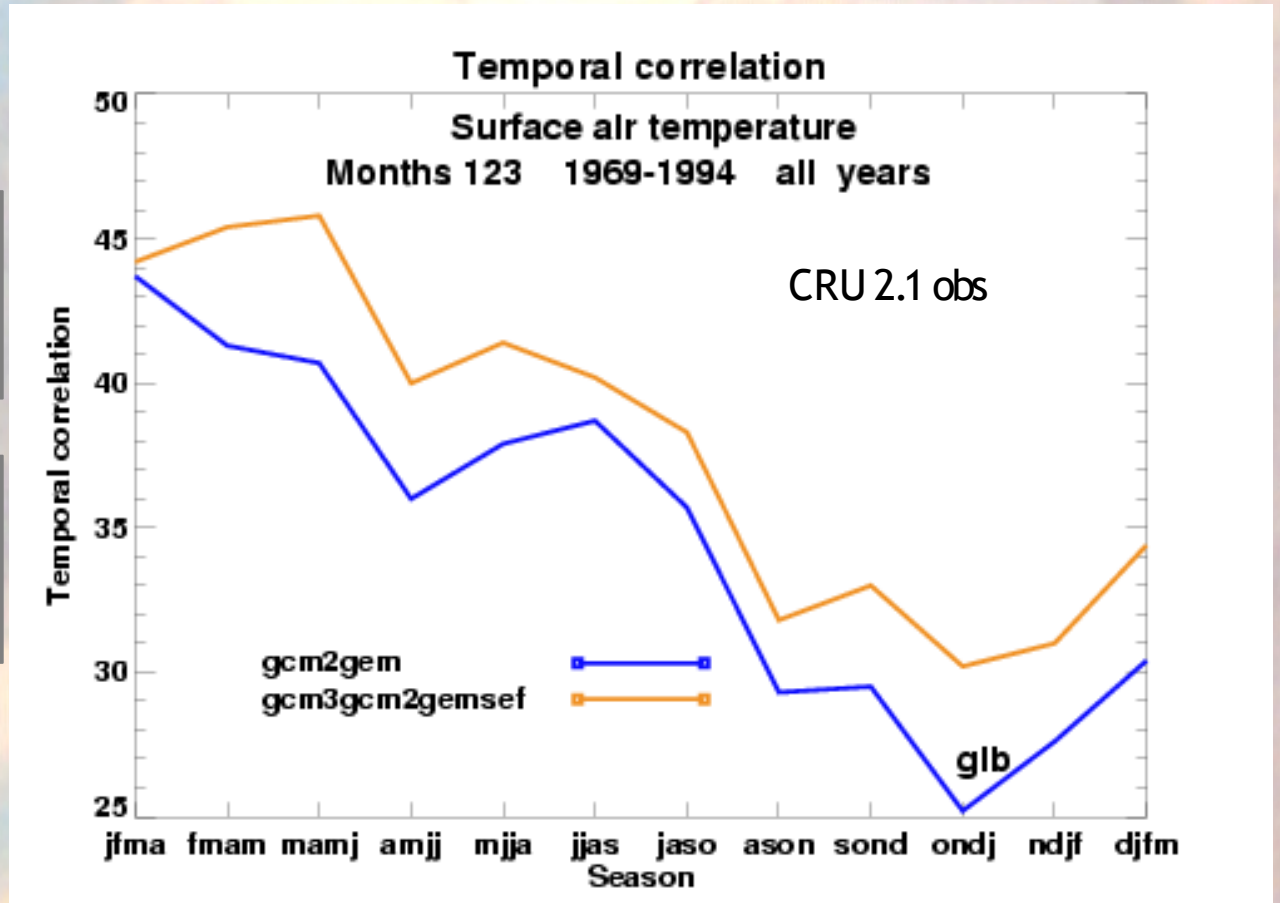
GCM3-GEMCLIM  
SEF-GCM2  
40 members



# Corrélation (Globe)

Average for  
gcm3gcm2gemsef  
37.98%

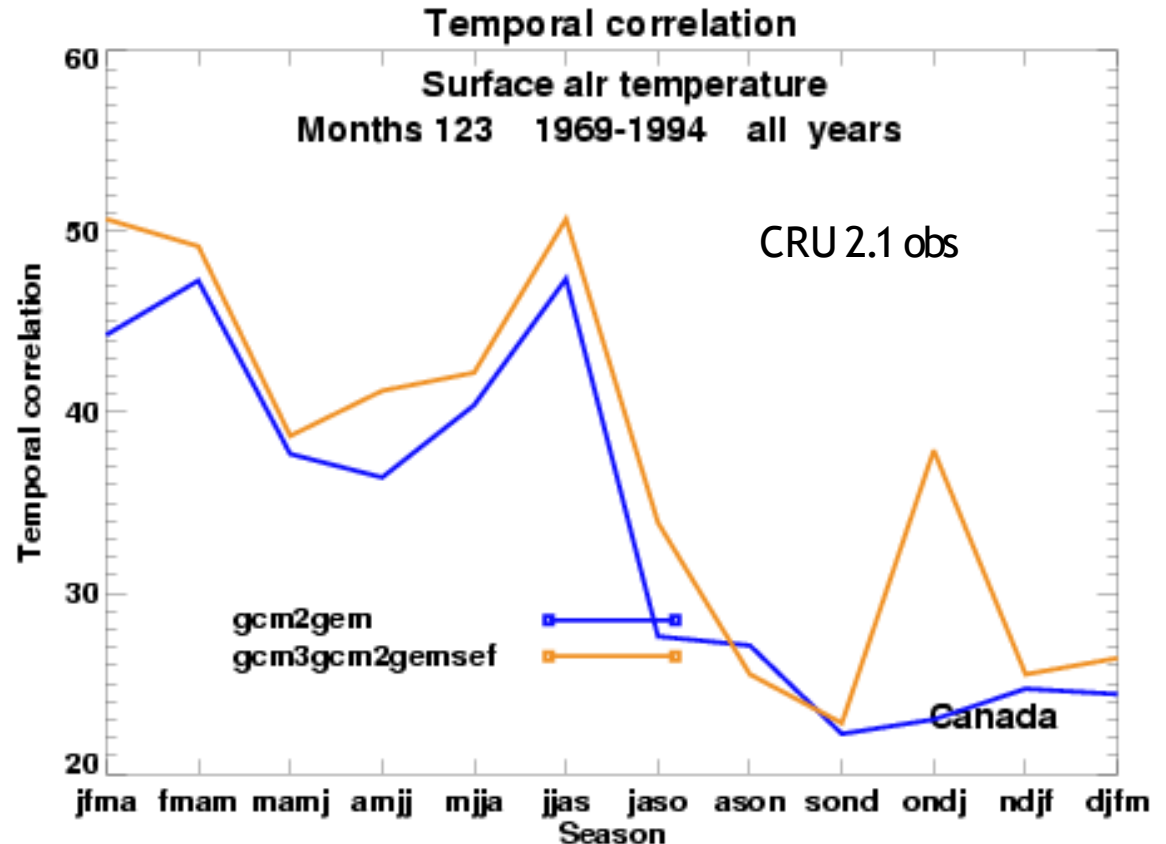
Average for  
gcm2gem  
34.67%



# Corrélation (Canada)

Average for  
gcm3gcm2gemsef  
37.06%

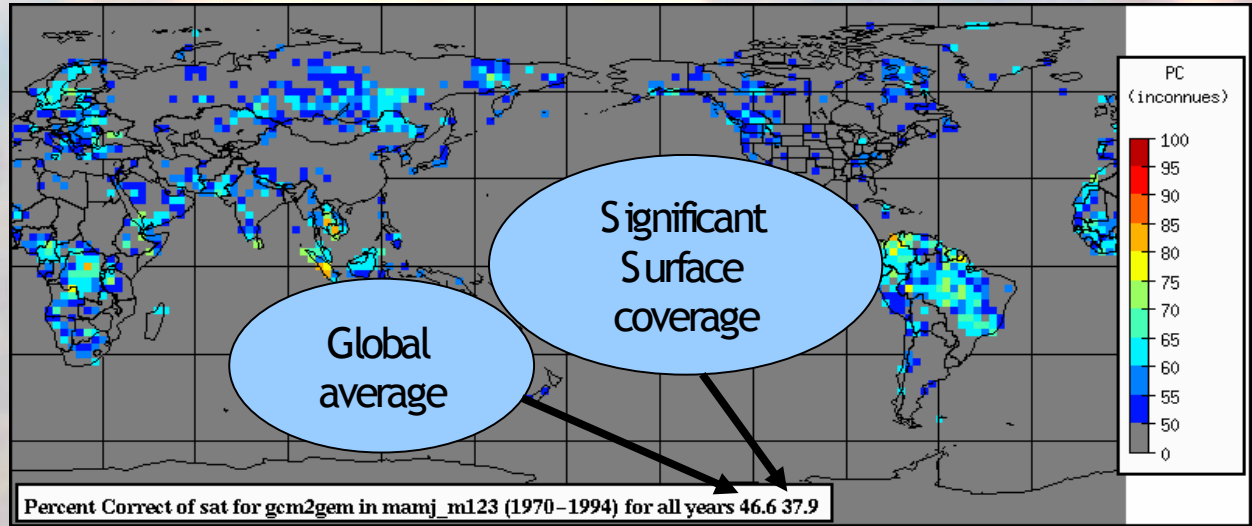
Average for  
gcm2gem  
33.54%



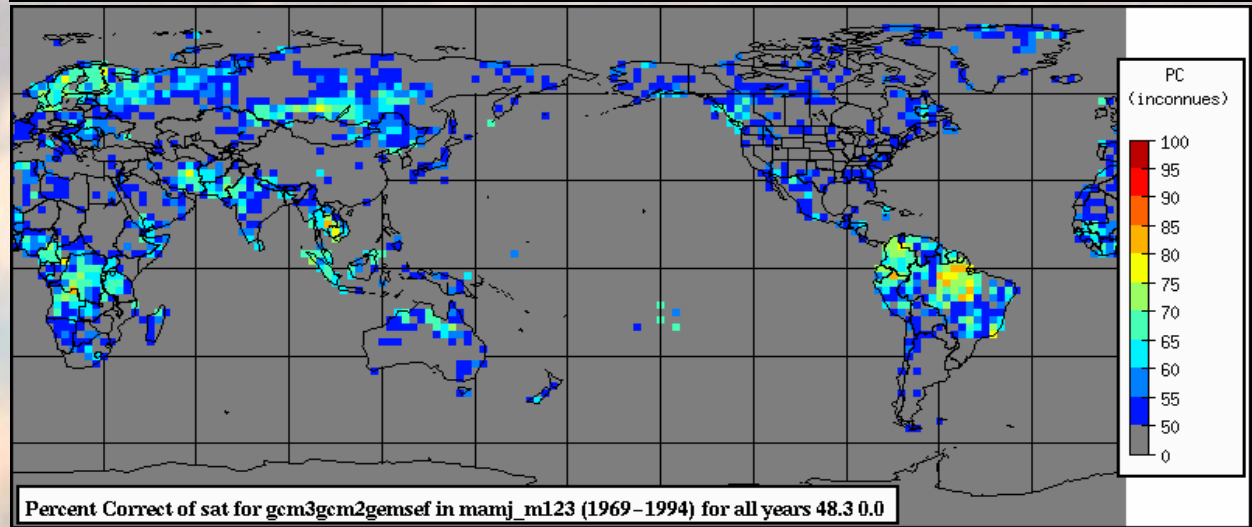


# Pourcent correct

GCM2-GEM  
12 members



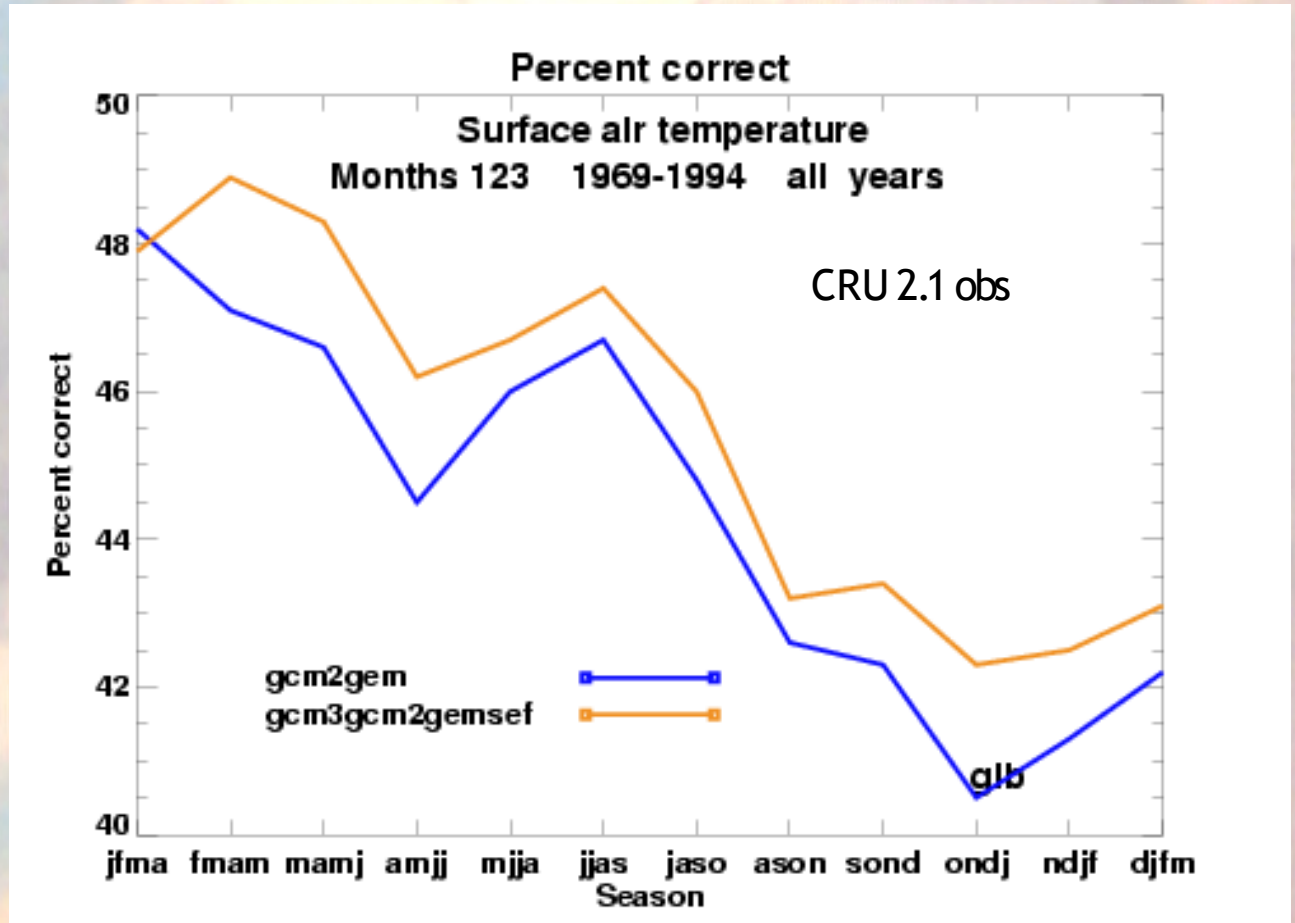
GCM3-GEMCLIM  
SEF-GCM2  
40 members



# Pourcent Correct (Global)

Average for  
gcm3gcm2gemsef  
45.49%

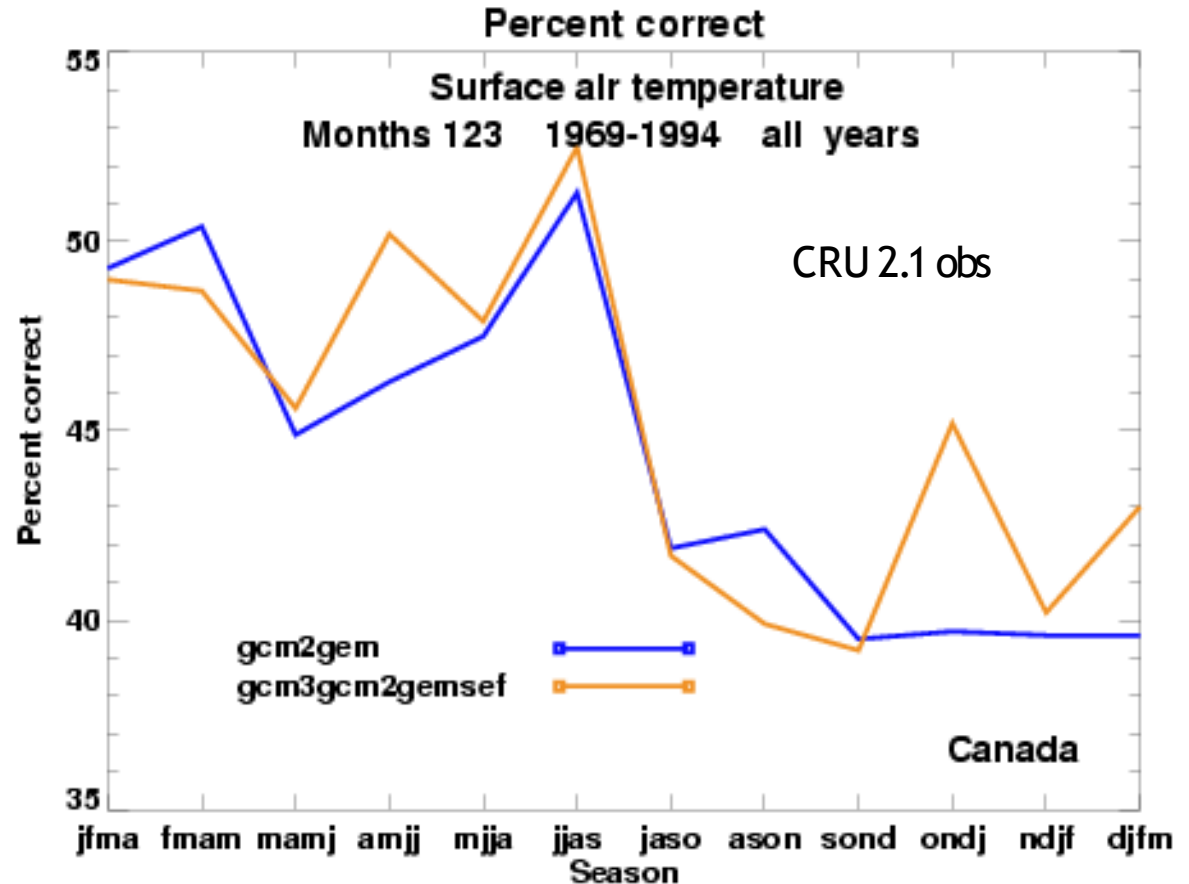
Average for  
gcm2gem  
44.4%



# Pourcent Correct (Canada)

Average for  
gcm3gcm2gemsef  
45.25%

Average for  
gcm2gem  
44.37%



# 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.\***

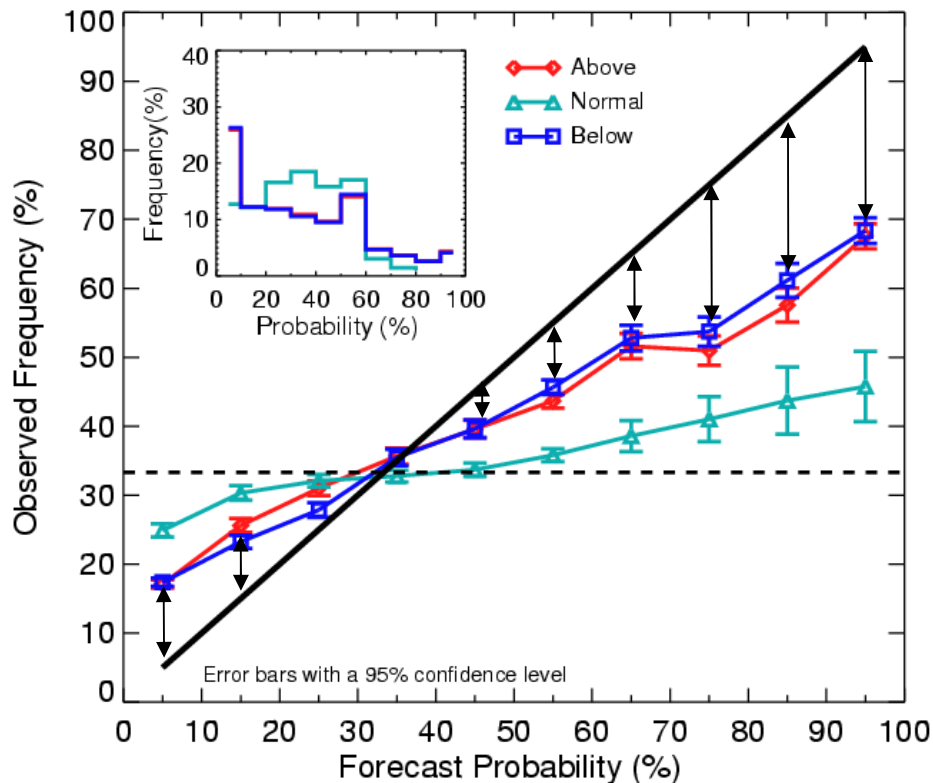
\* From MSC EPS Training, R.Verret

<http://collaboration.cmc.ec.gc.ca/cmc/ensemble/Formation-Training/Read-me.html>



# Reliability Diagram

Reliability Diagram of *sat* over the Globe  
in **J-F-M Season** 1970-2000 cru  
12 Member Ensemble gcm2gem

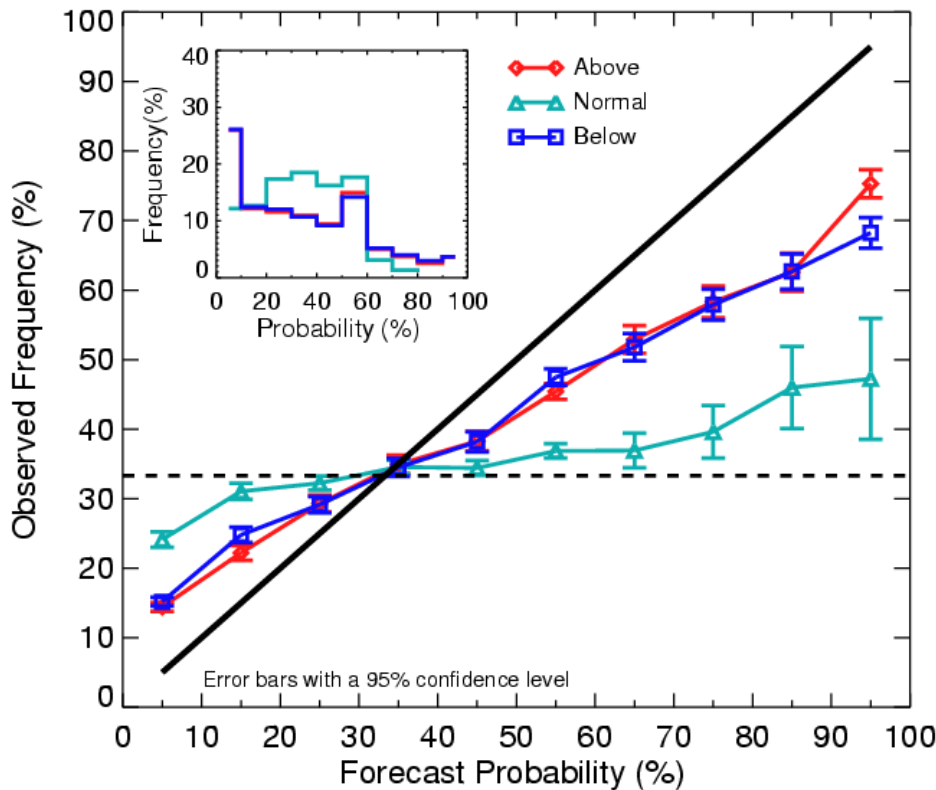


**Reliability index:**  
Average distance between  
the 10 values and the  
diagonal  
  
smaller is better

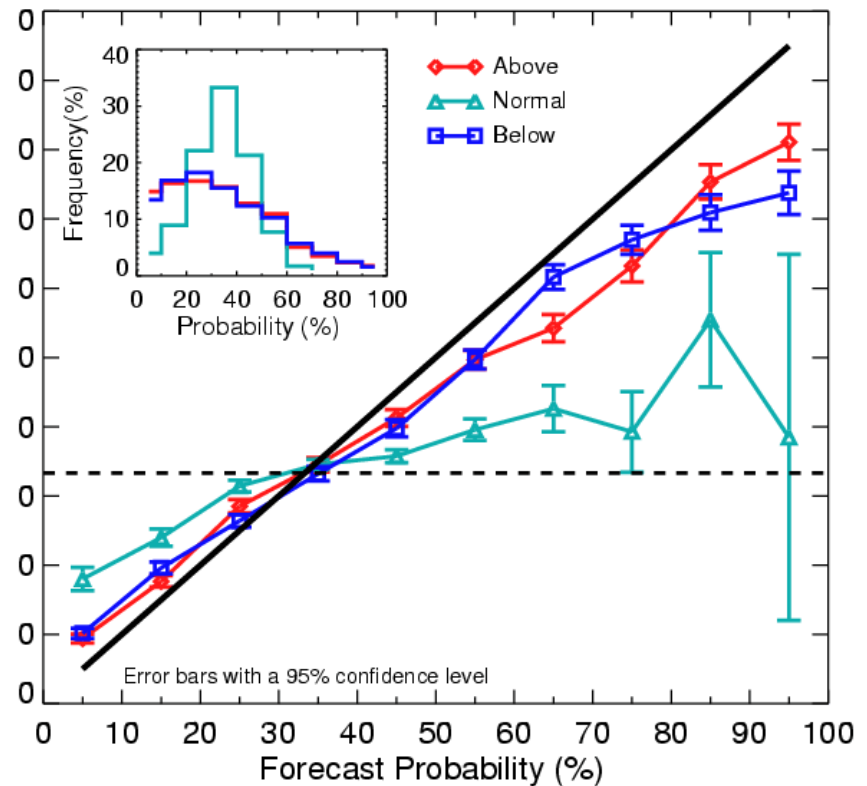


# Reliability Diagram

Reliability Diagram of *sat* over the Globe  
in *M-A-M Season* 1970-1994 cru  
12 Member Ensemble gcm2gem



Reliability Diagram of *sat* over the Globe  
in *M-A-M Season* 1969-1994 cru  
40 Member Ensemble gcm3gcm2gemsef



# Reliability index (Global)

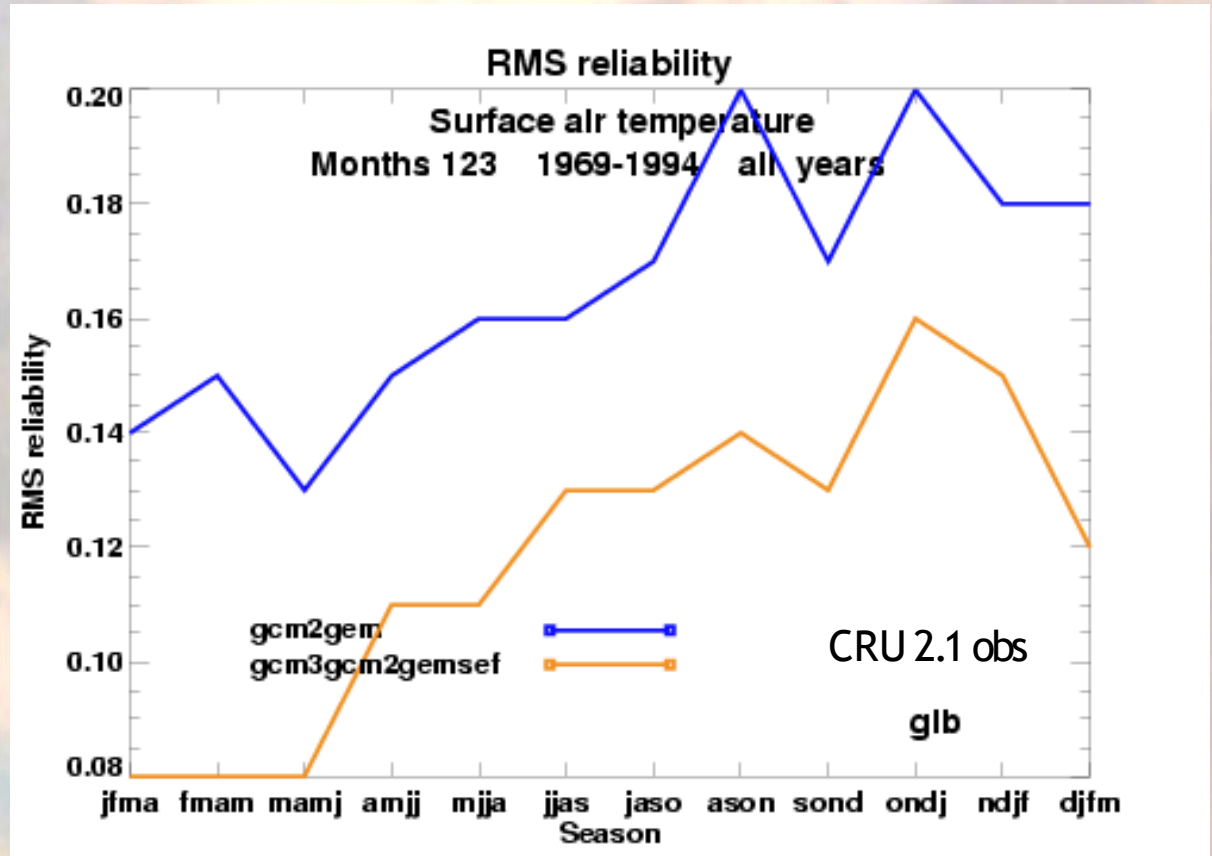
## Reliability index:

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)

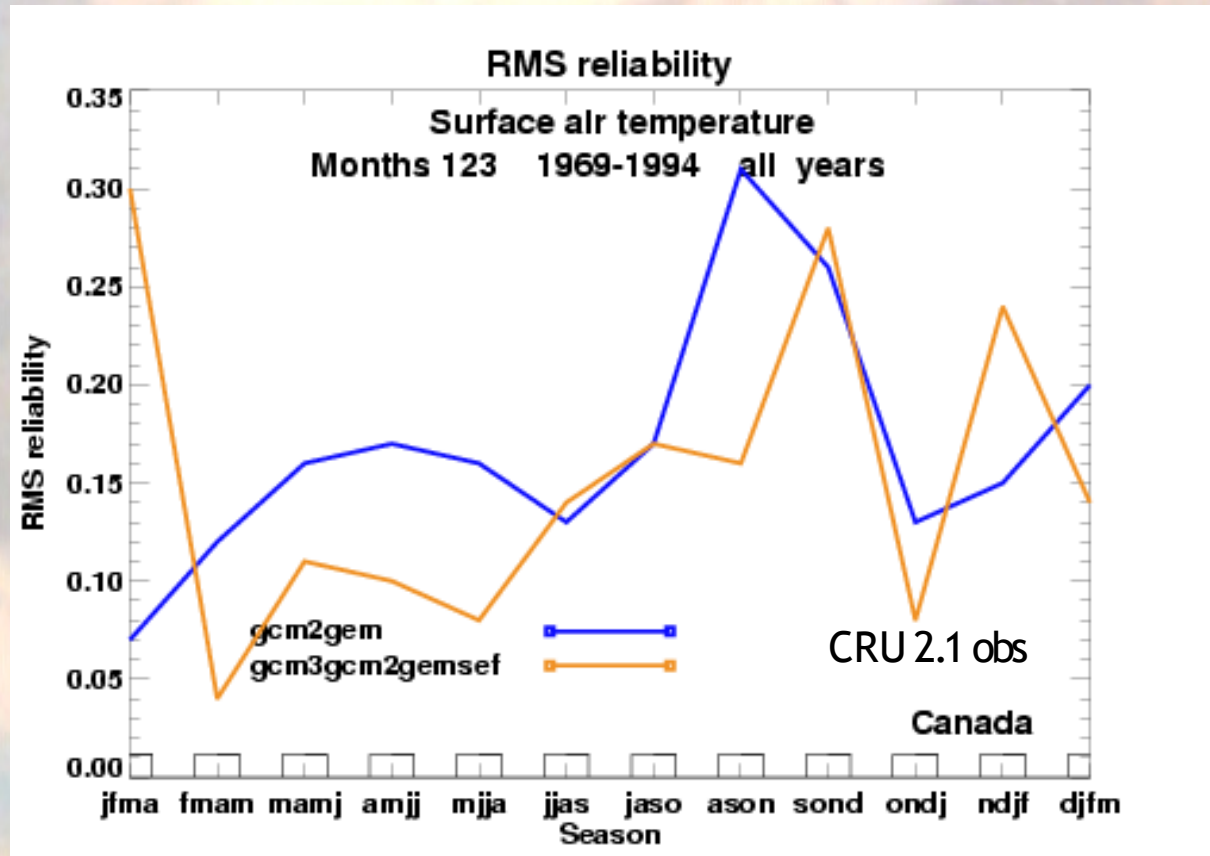
## Reliability index:

Average distance between the 10 values and the diagonal

smaller is better

Average for  
gcm3gcm2gemsef  
0.16

Average for  
gcm2gem  
0.175





# 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.**

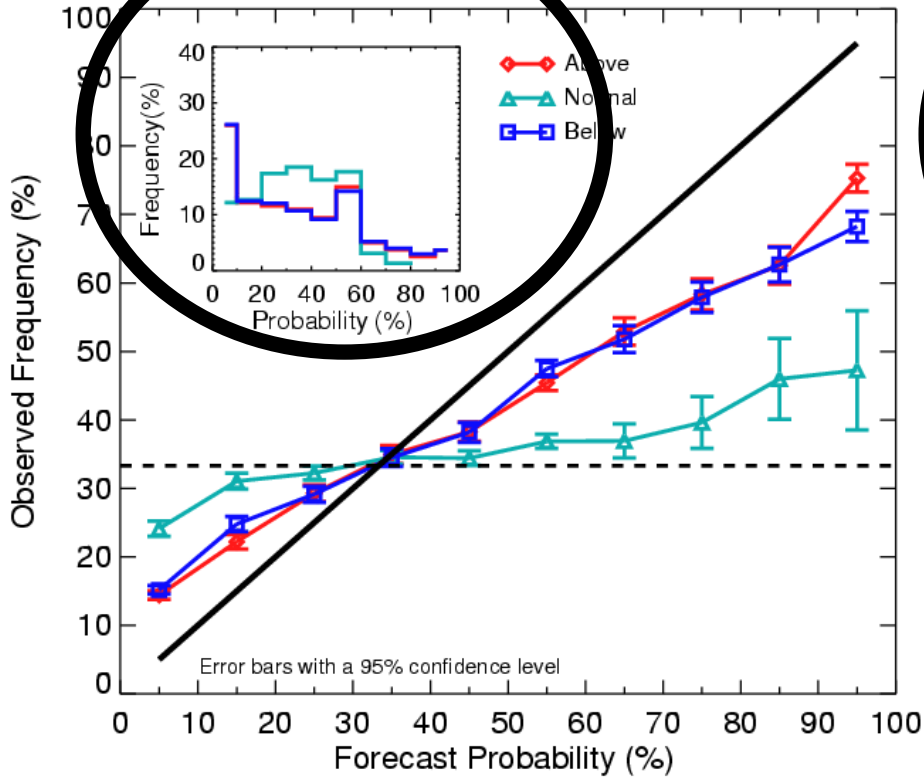
**\* From MSC EPS Training, R.Verret**

**<http://collaboration.cmc.ec.gc.ca/cmc/ensemble/Formation-Training/Read-me.html>**

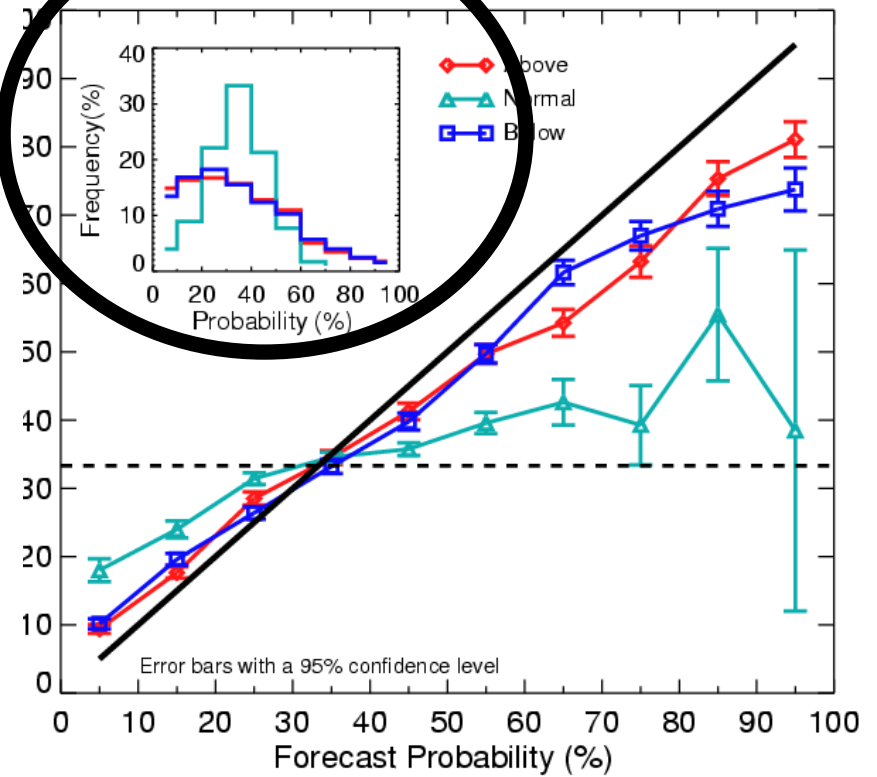


# Frequency Diagram

Reliability Diagram of *sat* over the Globe  
in *MAM Season* 1970-1994 cru  
12 Member Ensemble gcm2gem



Reliability Diagram of *sat* over the Globe  
in *MAM Season* 1969-1994 cru  
10 Member Ensemble gcm3gcm2gemsef

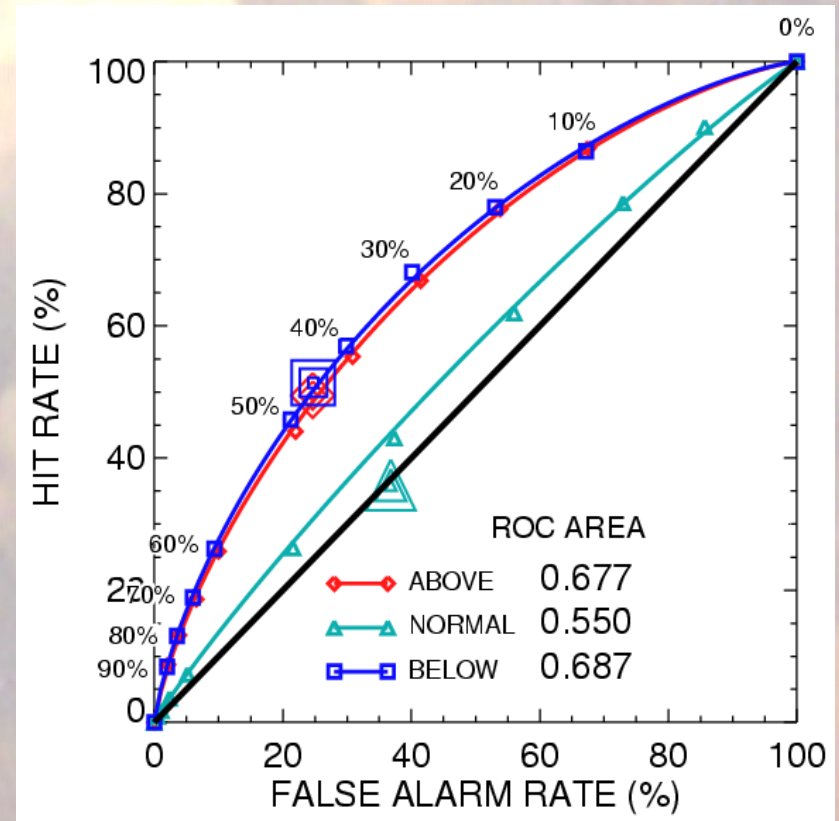


# Relative Operating Characteristic (ROC)

- The ROC represent the forecast skill in terms of signal detection

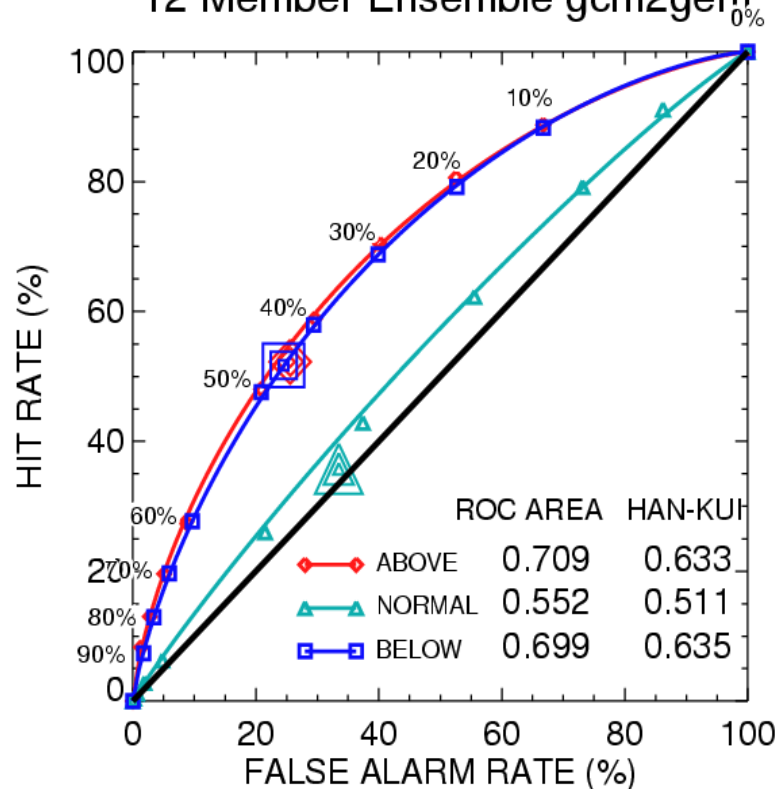
		Observations	
		event	No event
Forecasts	event	A	B
	No event	C	D

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

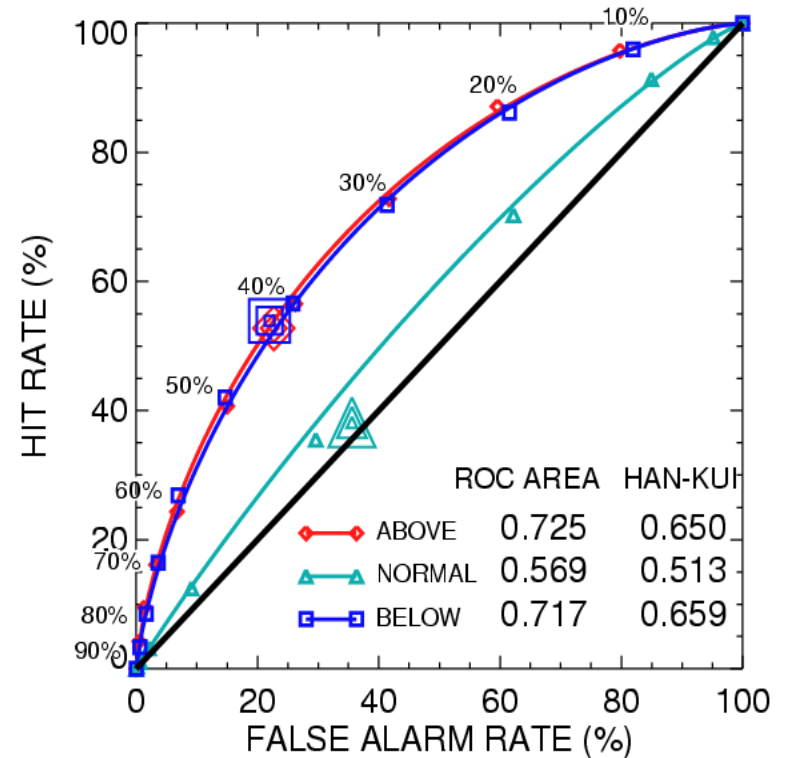


# ROC Diagram

ROC of *sat* over the Globe  
in *M-A-M Season* (HFP 1970-1994)  
12 Member Ensemble gcm2gem



ROC of *sat* over the Globe  
in *M-A-M Season* (HFP 1969-1994)  
40 Member Ensemble gcm3gcm2gemse

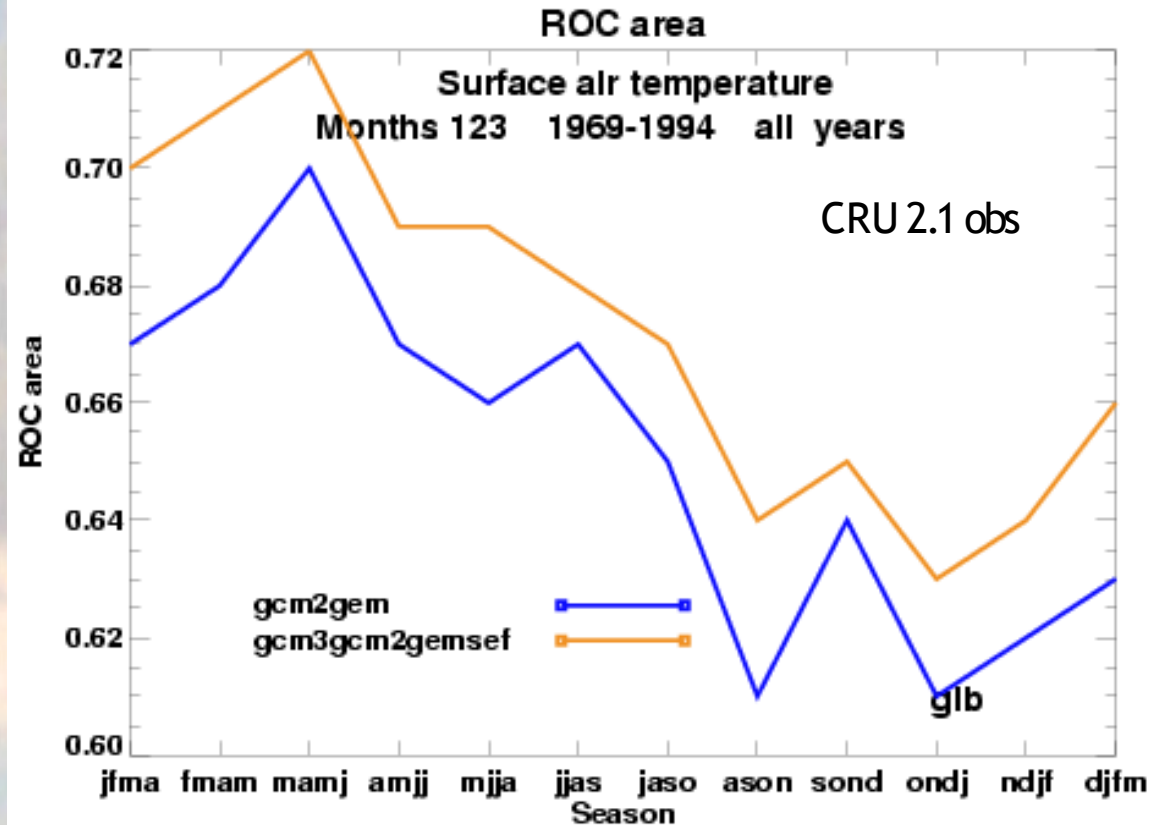


# ROC Score (Global)

ROC score:  
average of above  
and below area

Average for  
gcm3gcm2gemsef  
0.677

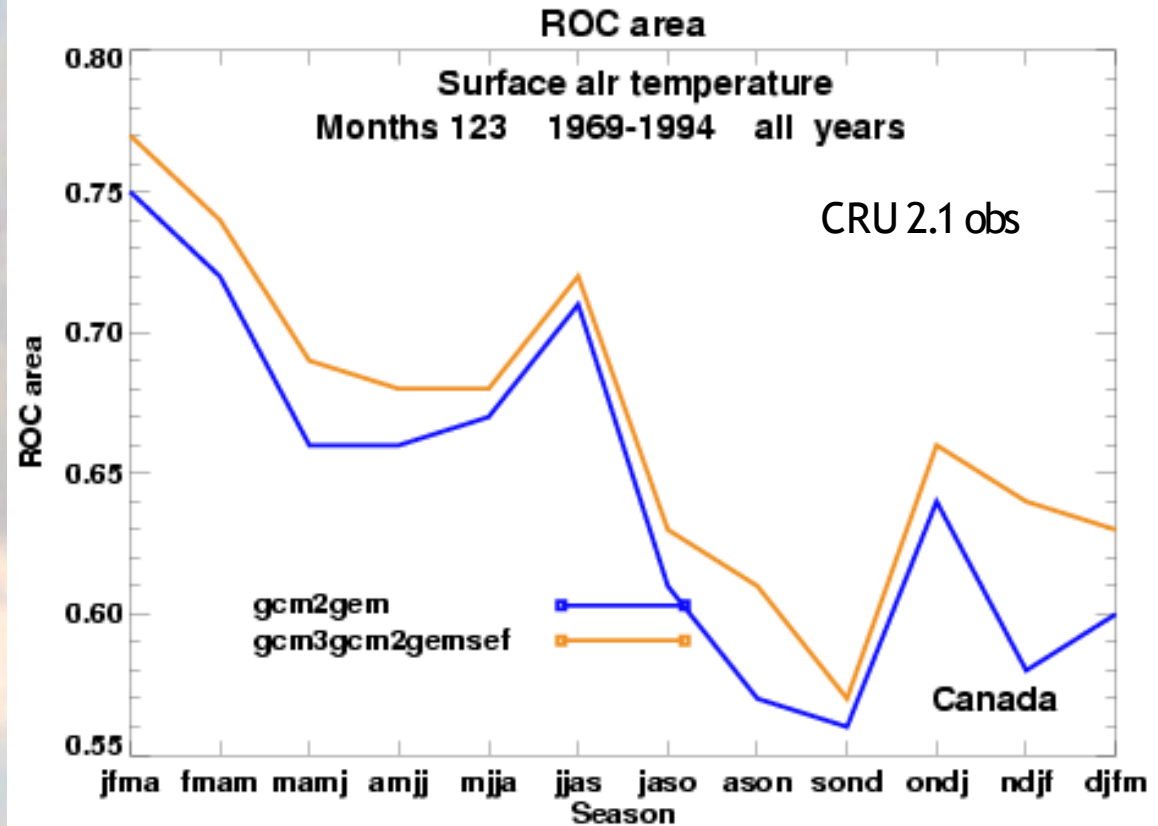
Average for  
gcm2gem  
0.655



# ROC Score (Canada)

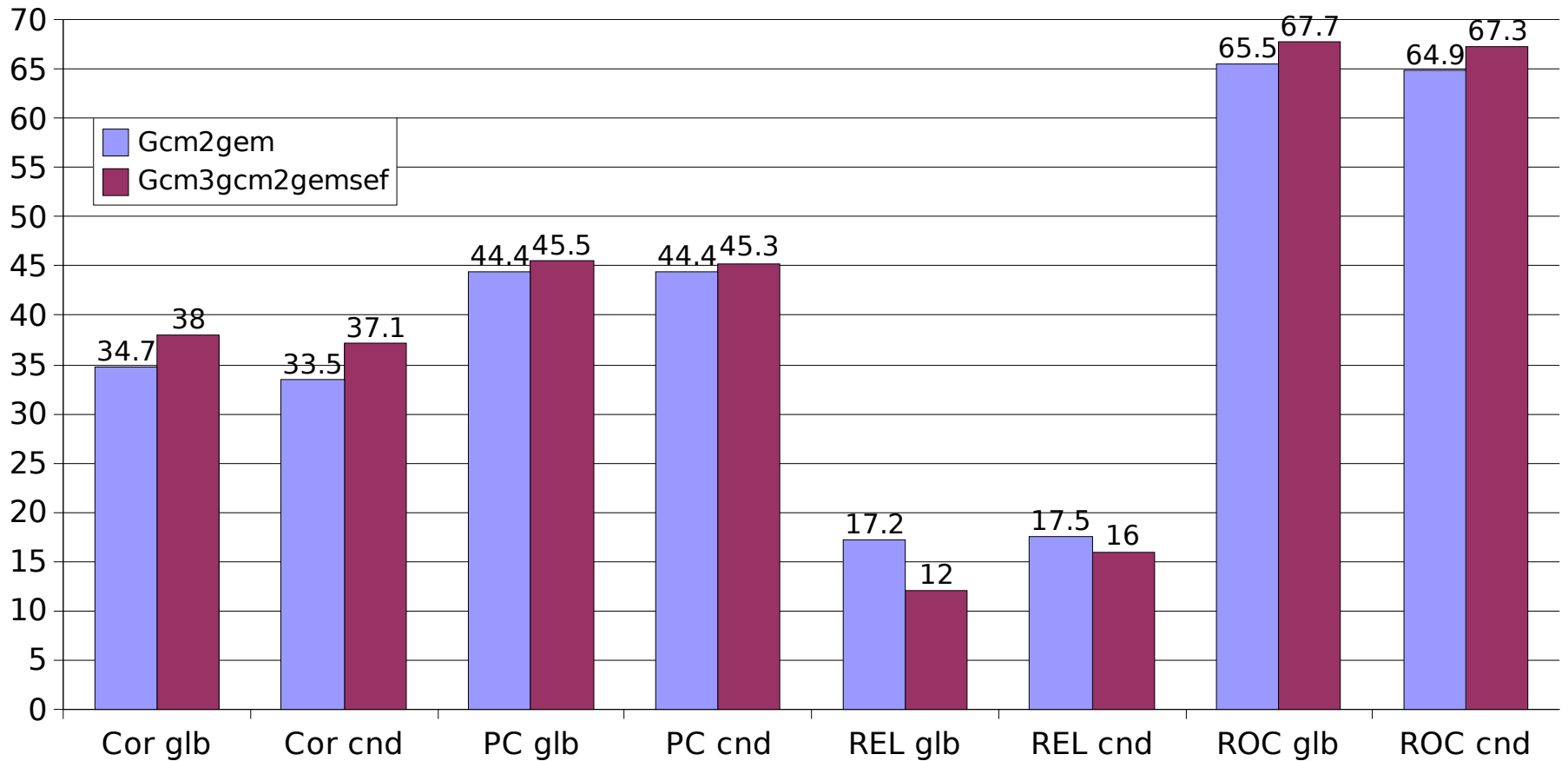
Average for  
gcm3gcm2gemsef  
0.673

Average for  
gcm2gem  
0.649



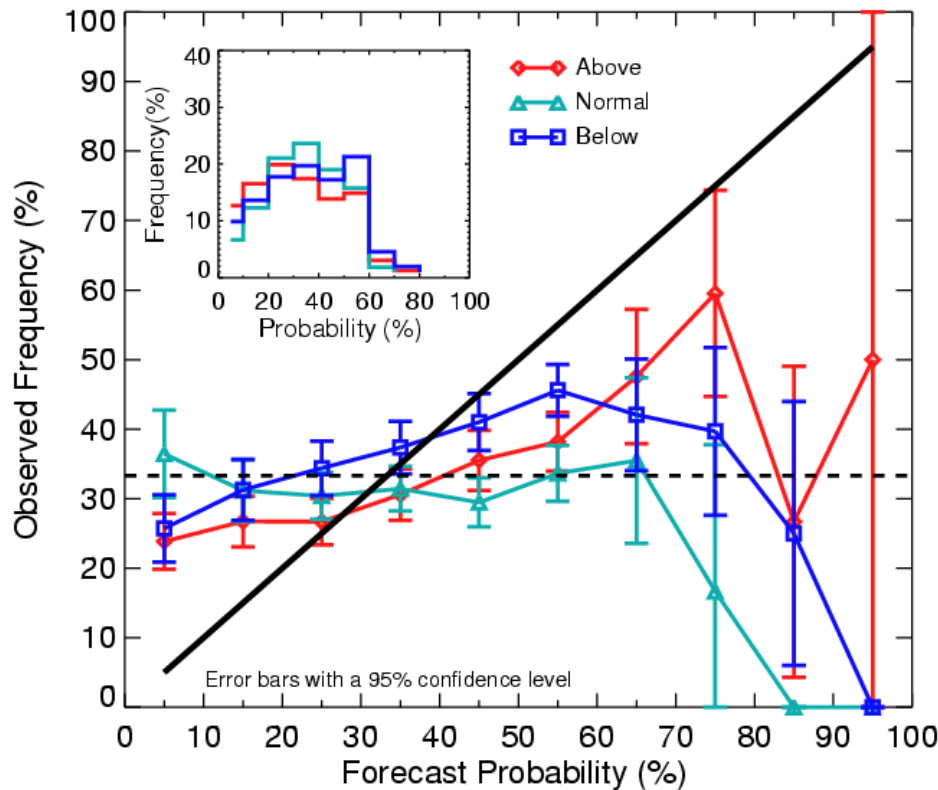
# Summary Temperature

## Temperature skill

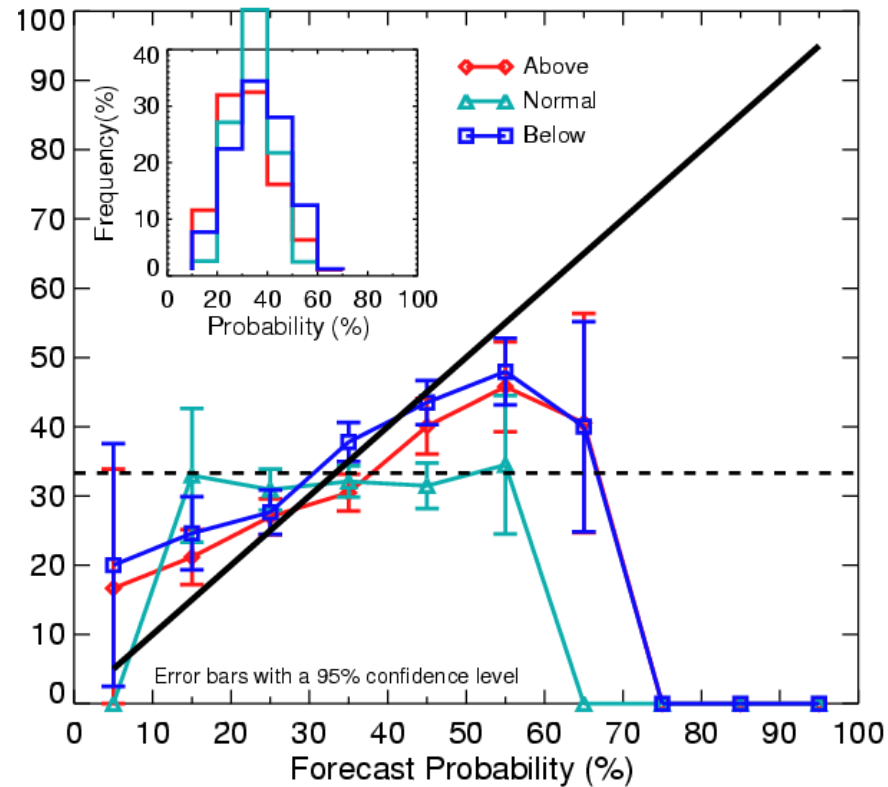


# Reliability Diagram Precipitation

Reliability Diagram of *pcpn* over Canada  
in **J-F-M Season** 1970-1994 cru  
12 Member Ensemble gcm2gem



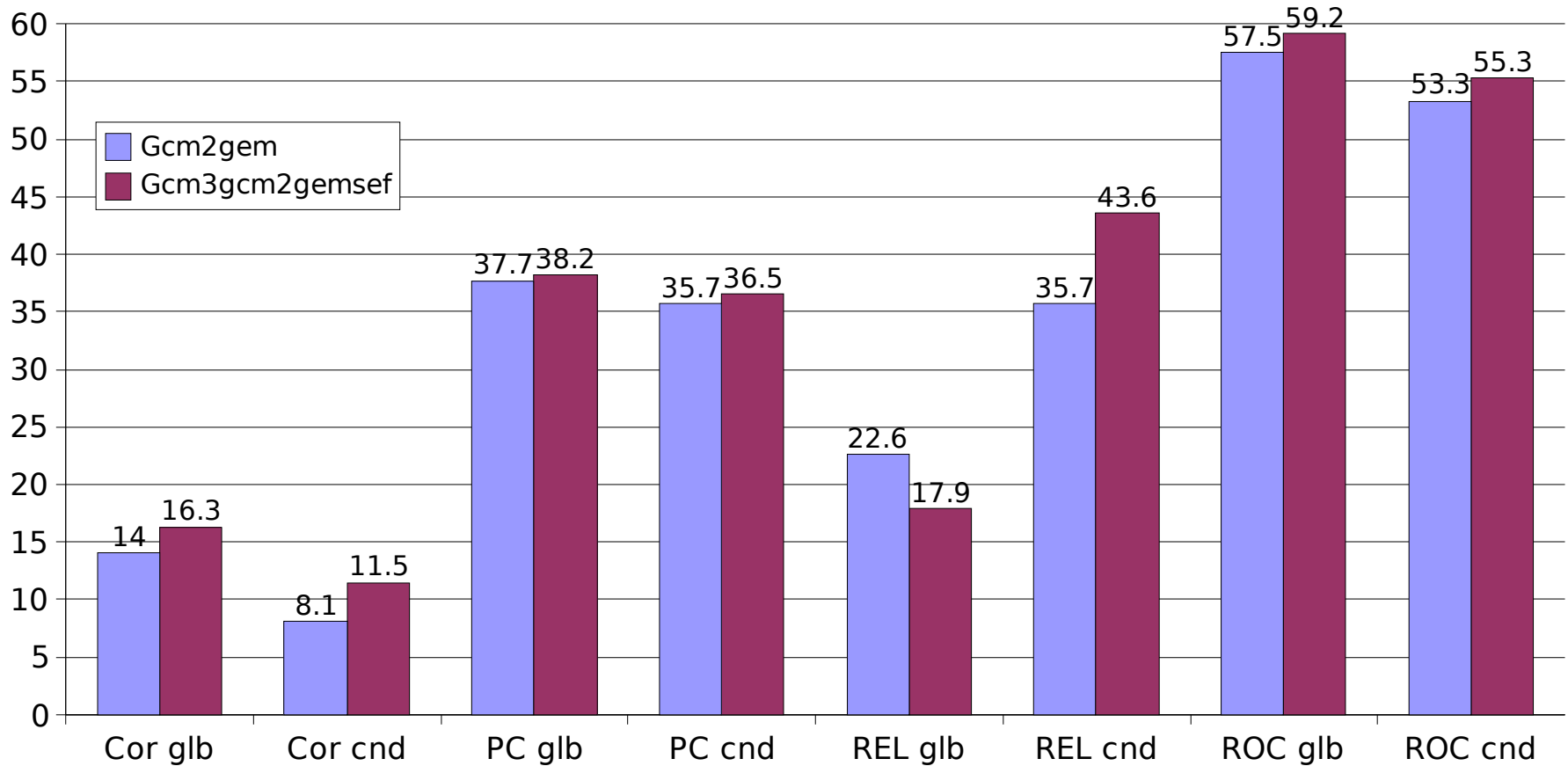
Reliability Diagram of *pcpn* over Canada  
in **J-F-M Season** 1969-1994 cru  
40 Member Ensemble gcm3gcm2gemsef





# Summary Precipitation

## Precipitation skill



# Conclusion

- **Le nouveau système à quatre modèles et quarante membres performe mieux que l'ancien système à deux modèles et douze membre en termes de corrélation, pourcentage correct, fiabilité et détection de signal**
- **Une légère diminution de l'acuité**
- **Les scores de précipitation sont significativement moins bons que ceux de la température à la surface**
- **Des améliorations en post-processing à venir devraient permettre une amélioration de ces scores**



# MERCI



**Environment Canada**  
**Meteorological Service of Canada**  
**Canadian Meteorological Centre**

**Environnement Canada**  
**Service météorologique du Canada**  
**Centre météorologique canadien**

