The Canadian Precipitation Analysis (CaPA)

Description and Current Status

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Environment Canada
www.ec.gc.ca

Principal Collaborators

CaPA started in November 2003

- Meteorological Research Division
  - *Stéphane Bélair*
  - *Barbara Casati (Ouranos)*
  - *Louis Garand*
  - *Jean-François Mahfouf (Météo-France)*
  - *Pierre Pellerin*
  - *André Tremblay*

- Meteorological Service of Canada
  - *Pierre Bourgouin*
  - *Bruce Brasnett*

- Québec Region : Environment Canada
  - *Stéphane Gagnon*
  - *Jacques Marcoux*
  - *Linh Chi Nguyen*
  - *Sylvain St-Germain*
  - *Viateur Turcotte*

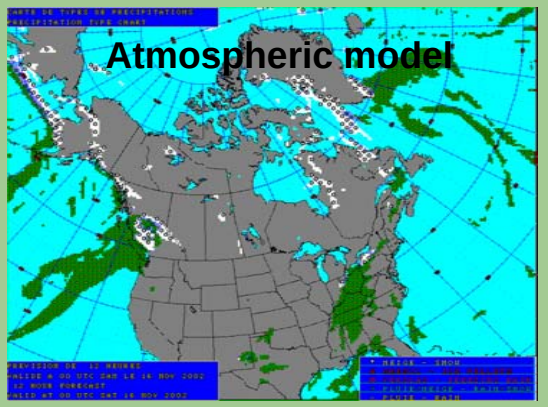
Objectives : Canadian Precipitation Analysis (CaPA)

- *Combine different sources of information on precipitation into a single, near real-time analysis.*

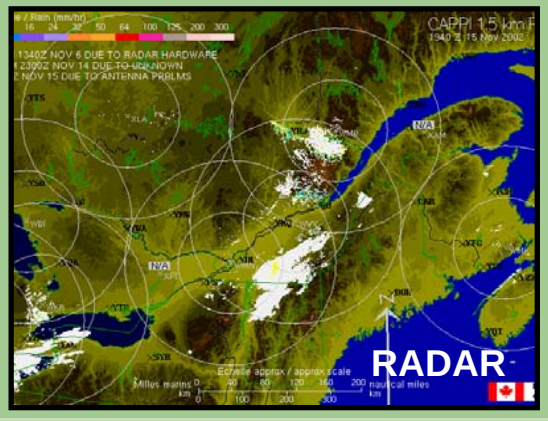
- *Use this analysis to :*
  - *perform quantitative precipitation forecast (QPF) verification;*
  - *provide input precipitation forcing for Environment Canada's land-surface and hydrology modeling systems, including the Canadian Land Data Assimilation System (CaLDAS) which is currently under development;*
  - *perform nowcasting of precipitation;*
  - *climate and drought monitoring and case study analysis*

Information Sources : Precipitation

Direct and Indirect measurements



CaPA



Characteristics of each data source

- Surface network in Canada
  - *Density is often less than the correlation length scale*
  - *Direct interpolation of station data can be dangerous*
- Radar data in Canada
  - *Incomplete radar coverage*
  - *Calibration issues still need to be resolved*
- Satellite imagery at latitudes > 45º
  - *Detection of clear sky areas possible*
  - *Quantitative precipitation estimates lack the necessary accuracy*
- Short-term forecast from atmospheric model
  - *Available everywhere*
  - *relatively good quality for lead times between 6h and 24h owing to the data assimilation process used to initialize the model*

Issues : Production of precipitation analysis

- *Precipitation phenomenon : Wide range of spatial and temporal scales and discontinuous in nature;*
- *Poor density of operational surface network (rain gauge) in Canada;*
- *Important influence of orography over the western part of Canada;*
- *Large fraction of annual precipitation falls as snow which is difficult to measure accurately.*

CaPA Methodology

- *CaPA is designed to combine different types of observations of precipitation with a first guess (or background field) to obtain a gridded analysis of precipitation.*

- *CaPA is constructed using the Optimum Interpolation (OI) procedure, which is already used at the Canadian Meteorological Centre to produce screen-level analyses of several meteorological variables (e.g., SST, snow depth, dew point depression).*

- *The OI technique performs the analysis on innovations (differences between an observation and the corresponding background value). The OI technique requires the specification of error statistics associated with each piece of information used to construct the analysis (i.e., observations and background field).*

Background Field for CaPA

- *Background field (or first-guess) is a 6-hour precipitation forecast from the regional GEM (Global Environmental Multiscale) model. The regional GEM model is currently run at 15 km resolution.*

- *The use of model precipitation information within CaPA is necessitated by the low density of the observational network in the northern regions of Canada. A number of applications require precipitation estimates even where no observations are available.*

- *For reasons related to model spin up problems, the background 6-hour regional GEM model precipitation forecast is either a 6-12 hr or 12-18 hr forecast initialized at 0000 or 1200 UTC .*

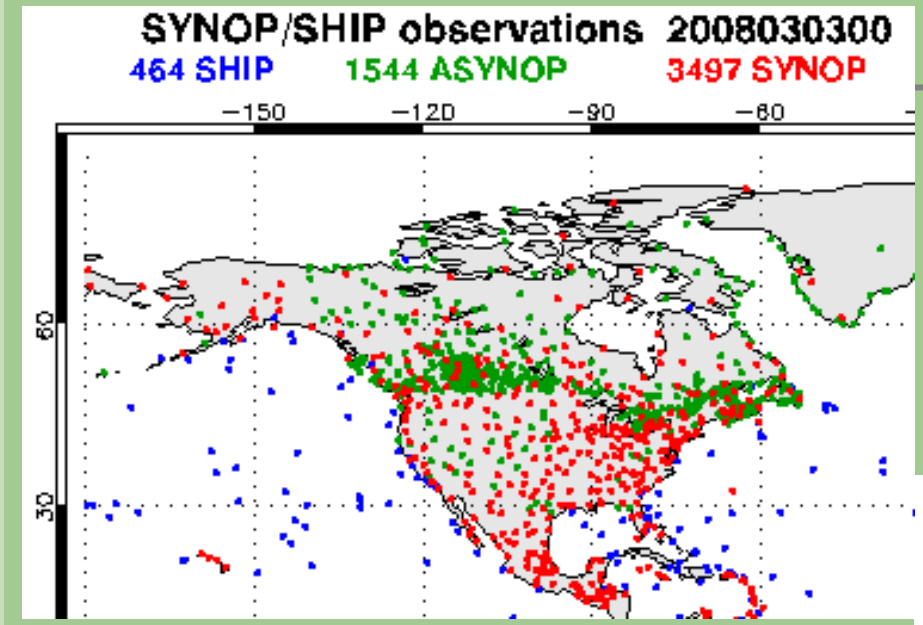
Observational Database

- *Observational database used by CaPA consists of surface synoptic reports of 6-hour precipitation accumulations from the SYNOP network.*

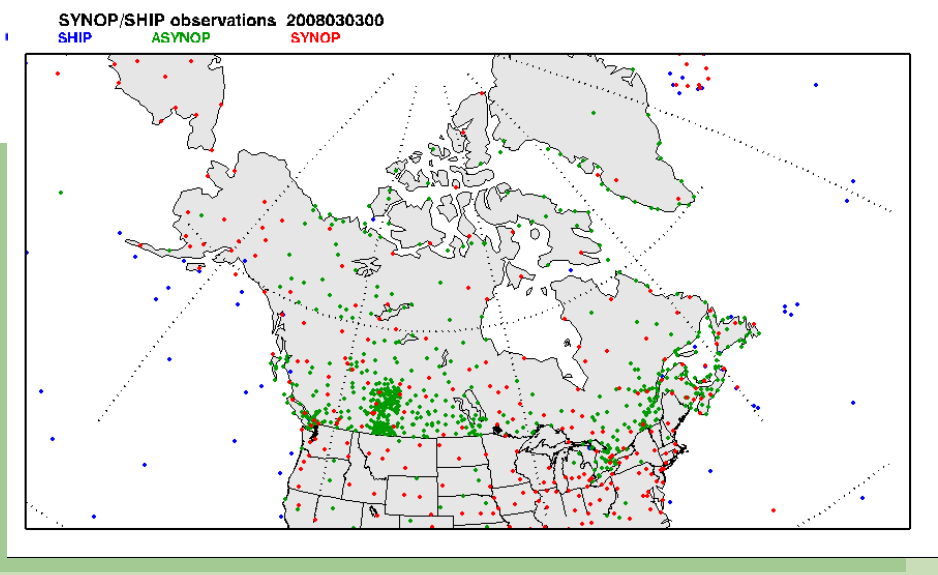
- *Two networks, a regional surface network RMCQ (Réseau Météorologique Coopératif du Québec) and a MESONET network enhance the CaPA observational database within the province of Quebec (hope to incorporate data from other provincial cooperative networks).*

- *Cooperative (COOP) network of precipitation measurements from the U.S. The COOP network is used for the 24-hr CaPA analysis from 1200 UTC to 1200 UTC.*

Observation Networks



SYNOP Network



Cooperative Observing Network in Quebec

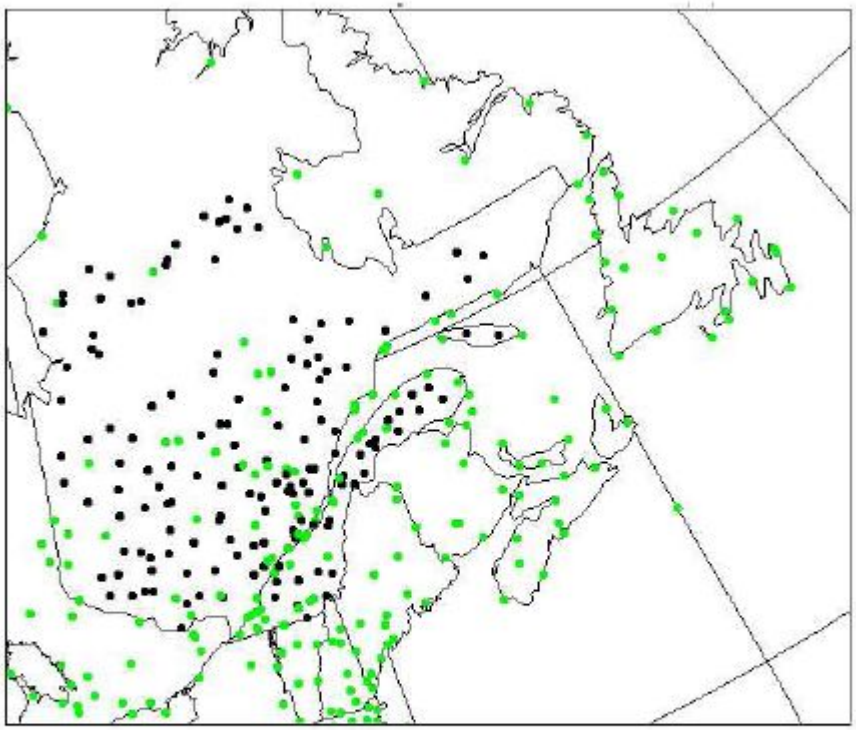


Figure 2: Analysis domain over Québec, The surface stations correspond to available 6-h accumulated precipitation from SYNOP, METAR (grey circles) and RMCQ (black circles) reports for the 02 August 2003 between 06 Z and 12 Z. The number of reports is 404.

- **100 SYNOP**
- **110 RMCQ-BUFR**
- **200 RMCQ-BDQ**

Optimum Interpolation

- *Correction to a background or first guess field by means of a weighted average of the innovations (differences between observations and background values)*

$$x_a^j = x_b^j + \sum_{i=1}^{N} w^{ij} \overbrace{(y_o^i - y_b^i)}^{\text{innovations}}$$

background spatially interpolated to observation location

- $\{y_o^i, i=1..N\}$: *precipitation observed at station i*
- $\{y_b^i, i=1..N\}$: *precipitation predicted at station i*
- $\{x_b^j, j=1..M\}$: *precipitation predicted at station j*
- $\{x_a^j, j=1..M\}$: *precipitation analyzed at grid point j*
- $W=\{w^{ij}\}$: *weights given to station i for the analysis at grid point j*

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Estimation of Weights

- *Estimation of the weights $W=\{w^{ij}\}$, obtained by minimizing the variance of the analysis error*

$$W=(B+O)^{-1}b$$

  - *b is error covariance vector between an observation i and a background value j;*
  - *B is the covariance matrix of background errors between points at observation locations.*
  - *O is the covariance matrix of observations errors;*
  - *To solve for the matrix of weights, W, we reduce the number of observations that can influence the analysis at a grid point to 16*

For more details, see Mahfouf et al. (2007) Atmosphere-Ocean

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Estimation of parameters : OI Method

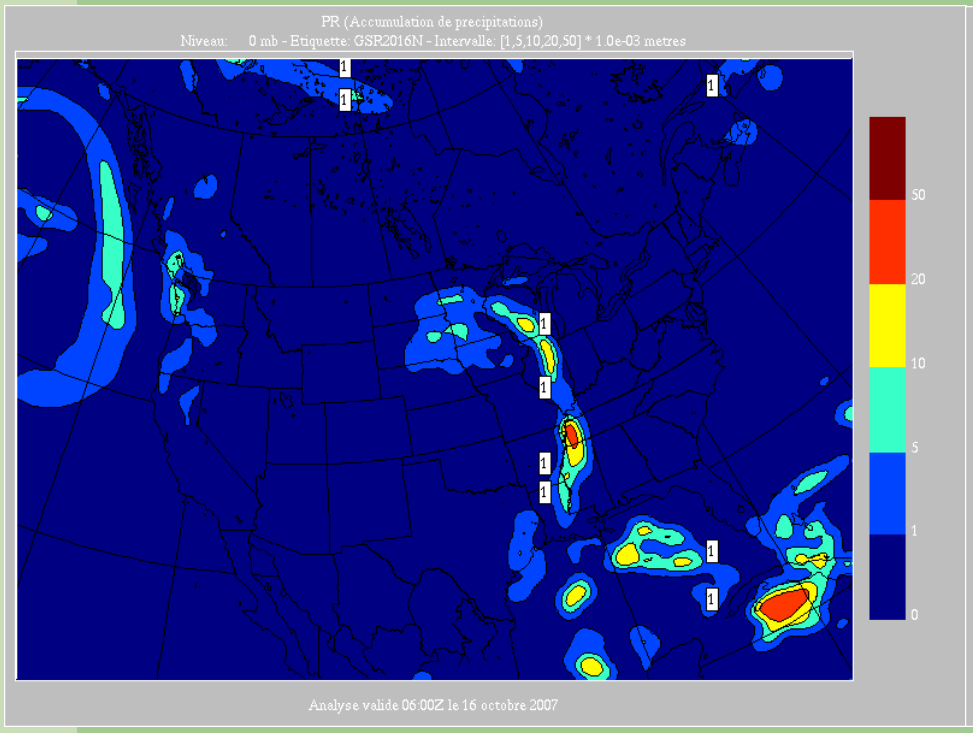
- *Three important parameters are needed to specify the background and observation errors for the OI method.*
  - σ_b *background error*
  - σ_o *observation error*
  - *L : characteristic length scale (distance to which the influence of a given observation extends).*

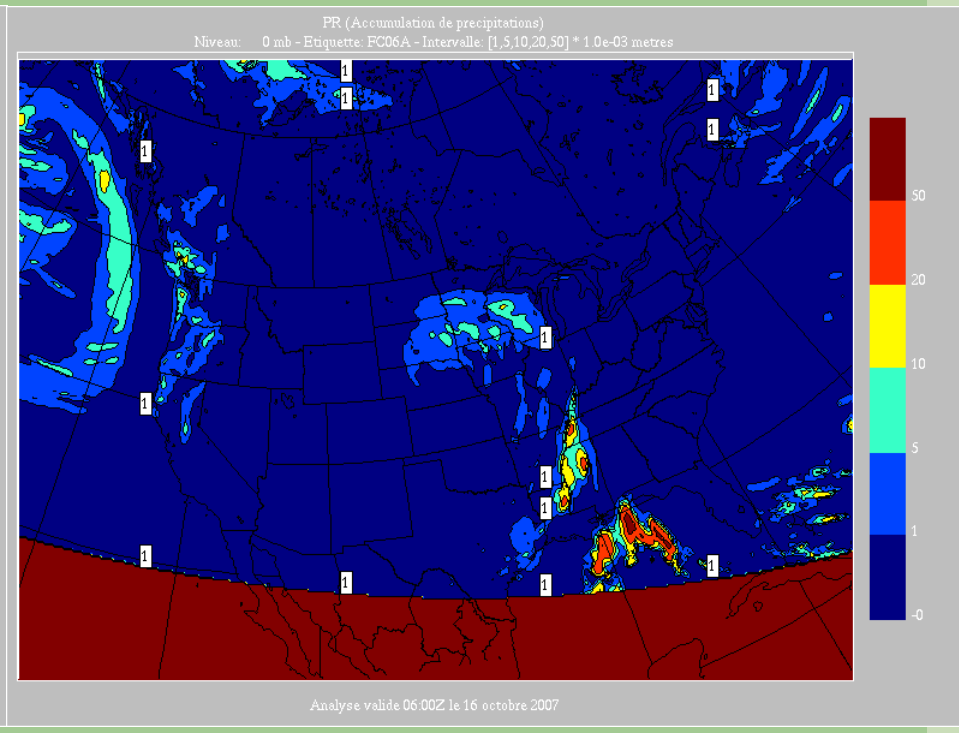
- *In the current global OI precipitation analysis σ_b, σ_o and L are fixed. For CaPA, σ_b, σ_o, and L are estimated at each analysis time from a theoretical fit to the experimental semivariogram. An exponential filter is applied to give preferential weight to the more recent observations.*

CaPA vs Current Global OI Precipitation Analysis

6-hr Precipitation Accumulation Ending

0600 UTC 17 October 2007 (mm)





Global OI Precipitation Analysis

Meso-global GEM as background

CaPA Precipitation Analysis

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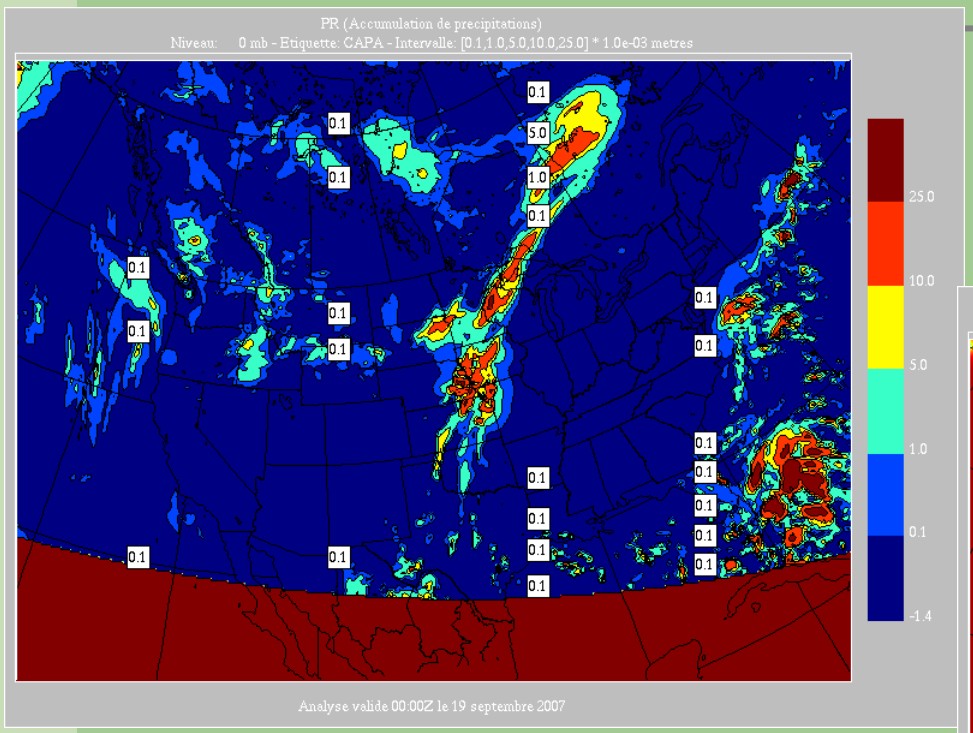
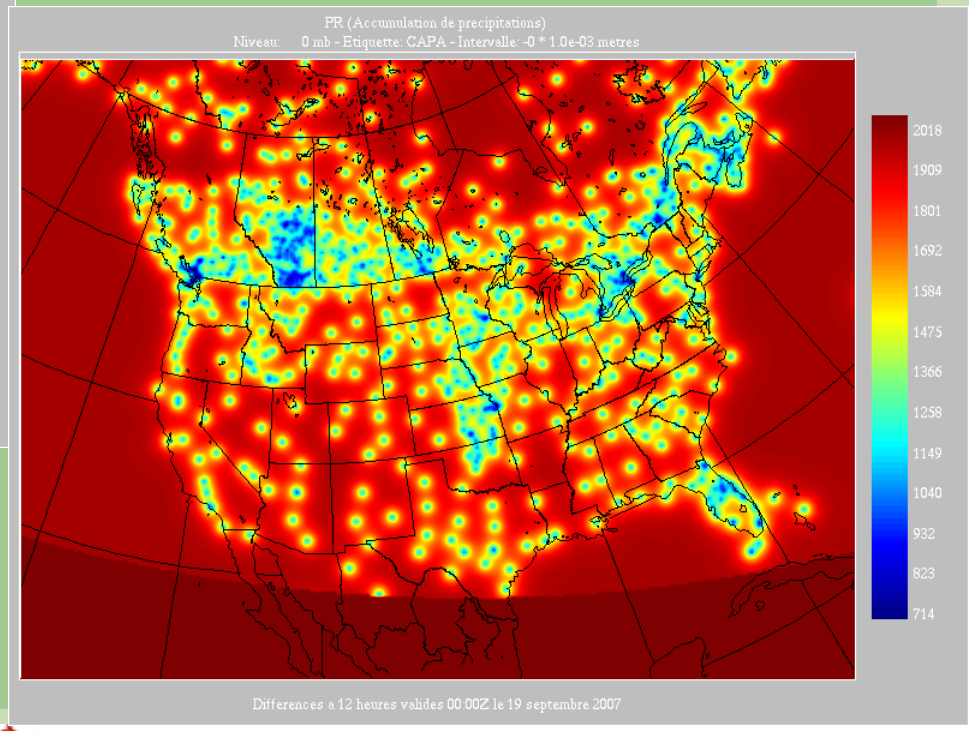
Figures Produced every 6-hours



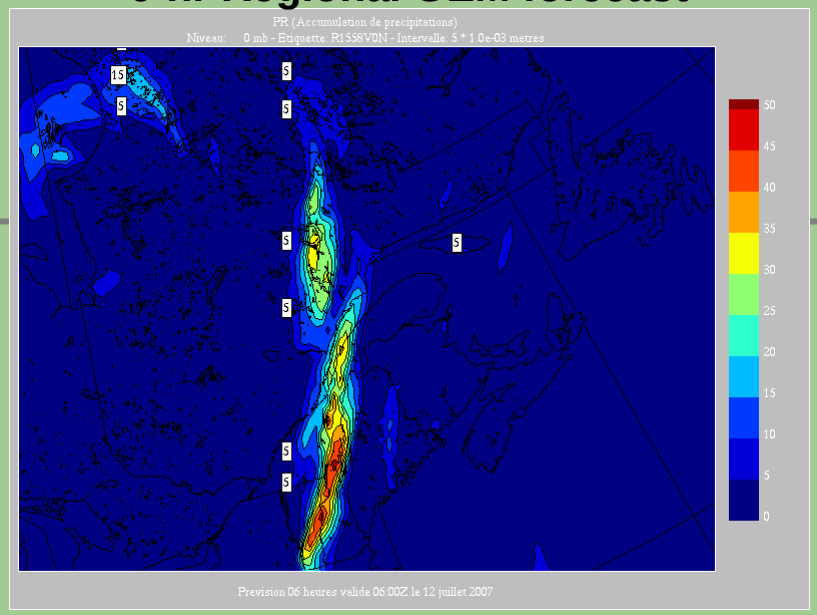
CaPA Analysis

Standard Error of CaPA Analysis

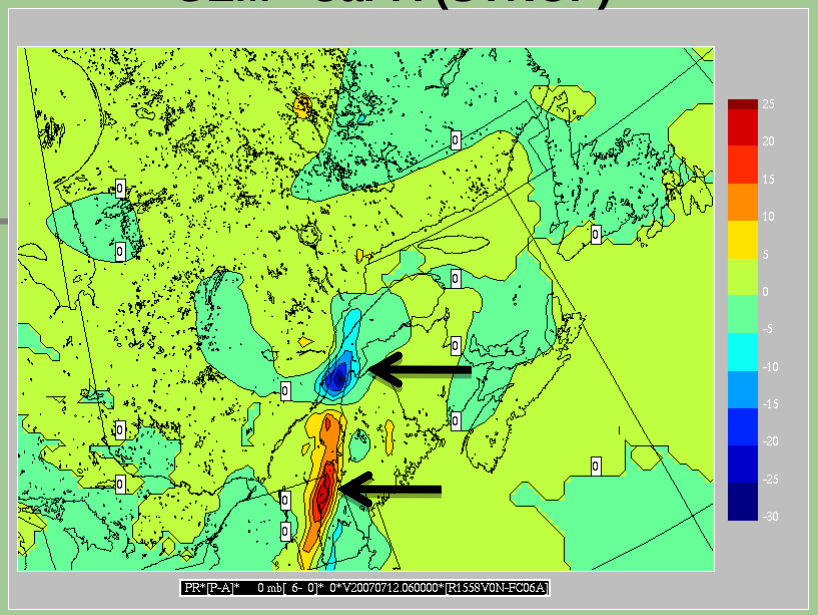
High network density corresponds with lower standard errors



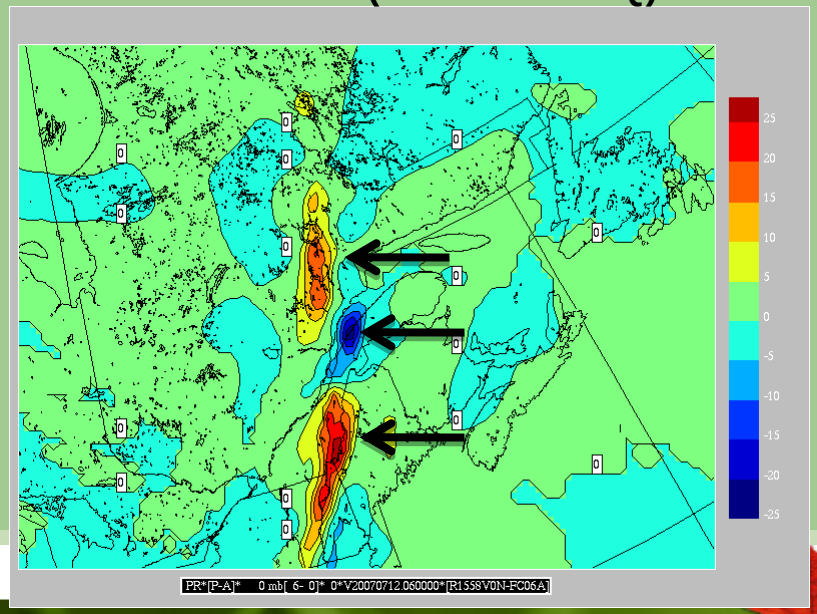
6-hr Regional GEM forecast



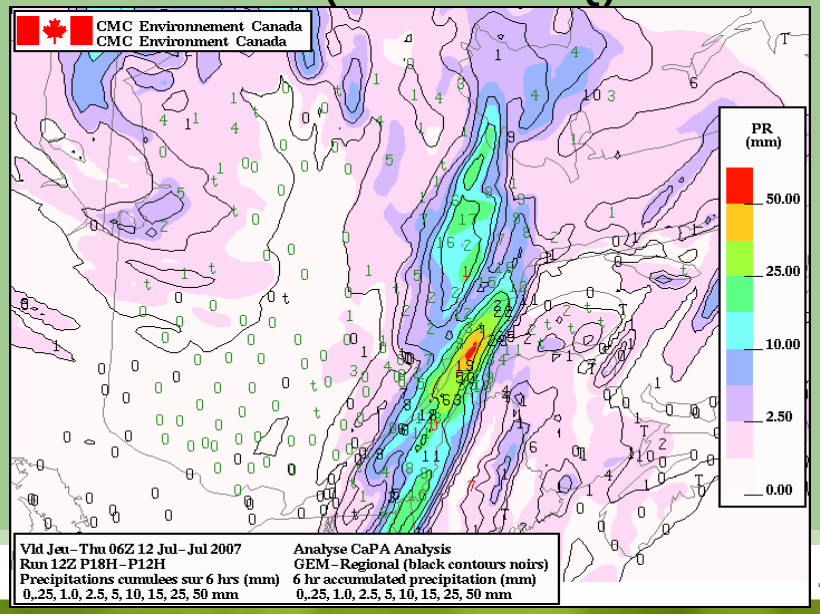
GEM - CaPA (SYNOP)



GEM - CaPA (SYNOP+RMCQ)

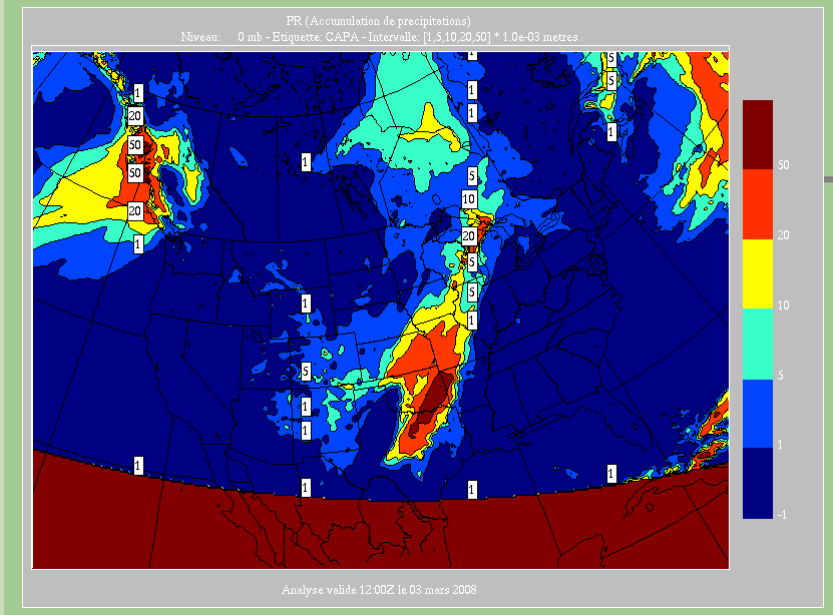


CaPA (SYNOP+RMCQ)

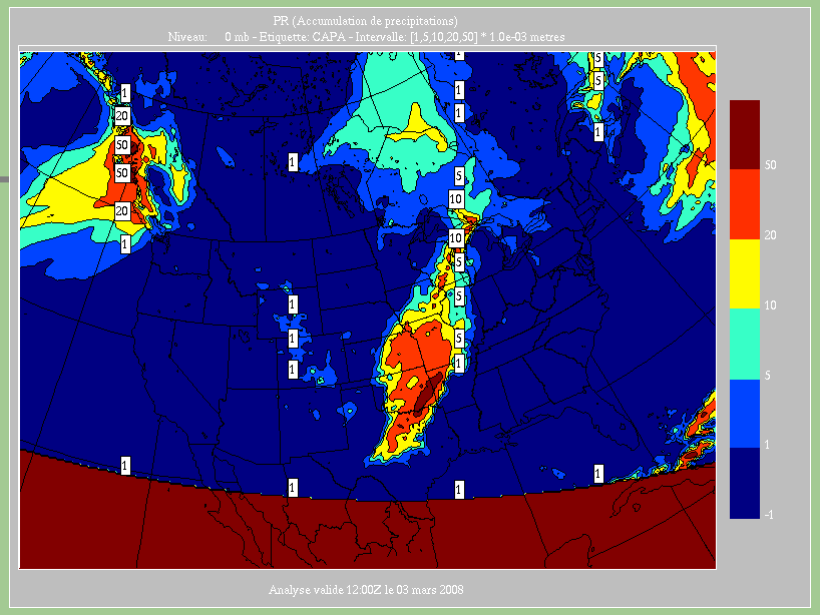


6-hr Precipitation Accumulation ending 0600 UTC 12 July 2007 (mm)

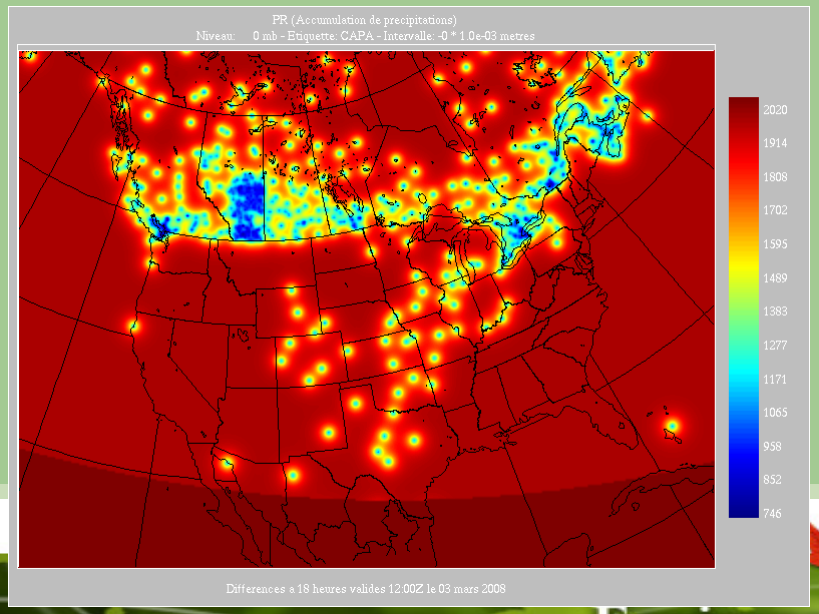
CaPA : SYNOP



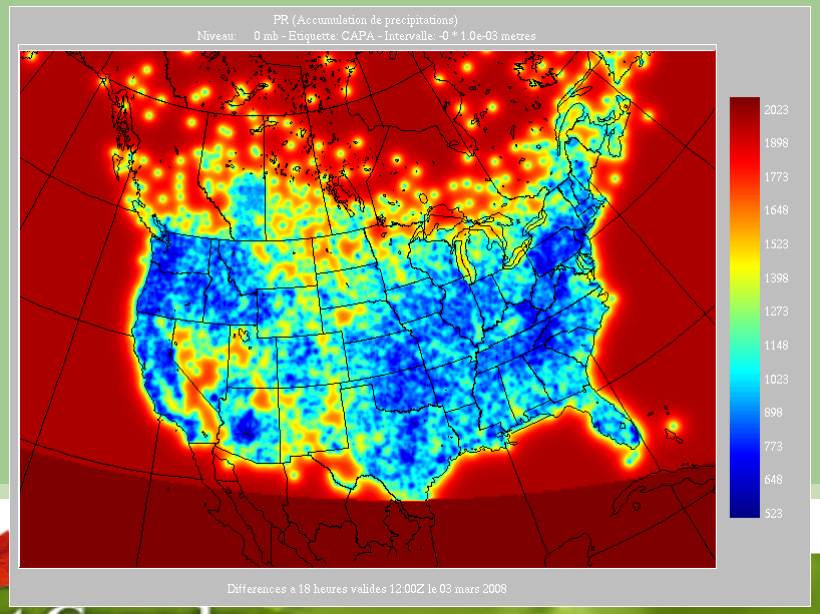
CaPA : SYNOP + SHEF



Standard Error



Standard Error



24-hr Precipitation ending 1200 UTC 3 March 2008

Summary : Verification Comparison

- *Prior to the operational release of CaPA a quantitative objective comparison study was performed against the current global OI precipitation analysis.*
  - *CaPA 6-hr precipitation analysis is not always better than the global precipitation product based on the meso-global GEM model (e.g., MSE, Threat Score).*
  - *CaPA is superior for categorical scores for small precipitation quantities (PR ≤ 0.25mm/24h) (Bias and False Alarm Rate)*
  - *CaPA is superior for categorical scores for precipitation quantities (PR > 1mm/24h) (Bias and False Alarm Rate).*
  - *The bias is reduced in CaPA as compared to the global OI product. This result is important for hydrological modeling which is sensitive to the total of amount of water falling over a basin over a given period of time.*

CaPA : Current Status

- *CaPA has official been accepted as an operational product and will enter into the operational suite in a parallel run mode.*
- Two analyses will be delivered :
  - *6-hour analysis (every 6-hours) based upon SYNOP data*
  - *24-hour analysis using both SYNOP and US Cooperative data (12Z-12Z)*
  - *The analysis error will be provided for each analysis.*
  - *Users can simply add up successive 6-hour analyses to produce a 24-hour analysis for other time intervals (e.g., 00z-00z)*
  - *Data cut-off will be first tested with a cut-off time of +4hrs.*

- *Available : CaPA retrospective analyses based upon SYNOP data going back to October 2001.*

Future plans for CaPA

- *Incorporate observations from other real-time, quality-controlled, provincial surface co-operative observing networks;*
- *Make use of geostationary satellite data and nowcasting tools to delineate non-precipitating regions;*
- *Develop tools and algorithms to resolve outstanding issues with the incorporation of radar data into CaPA;*
- *Develop methods to reduce the inherent bias with snowfall measurements in CaPA.*