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Spatio-temporal post-processing of the CFSR daily precipitation across the Great Lakes region (Canada)

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1.Introduction

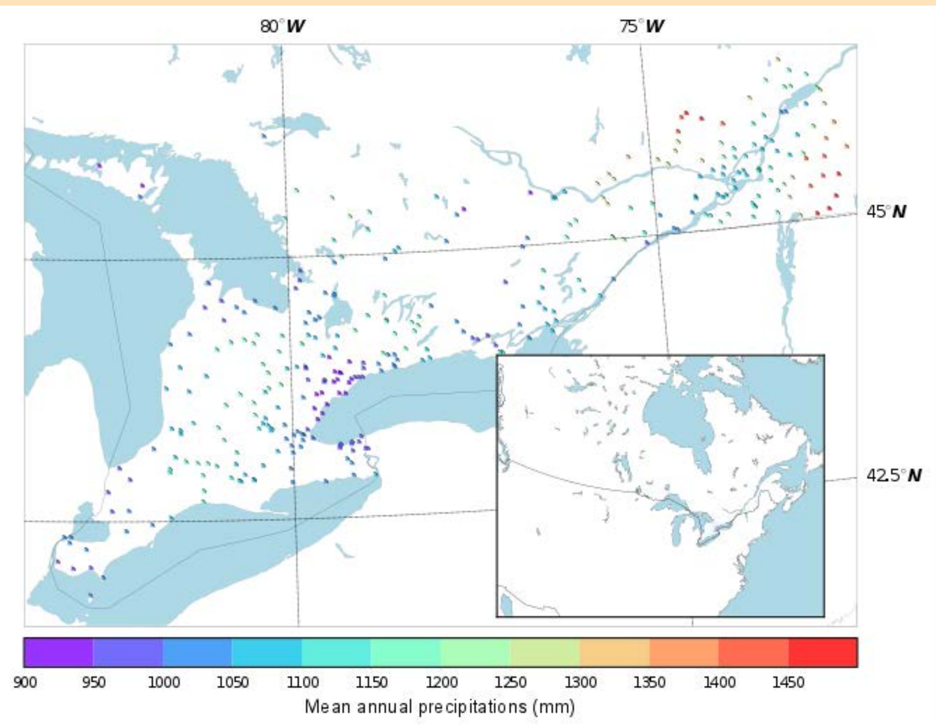
- Precipitation information at the local scale are needed for many fields, e.g. design of hydraulic infrastructures.
- Reanalysis datasets are an attractive alternative: the past state of the atmosphere is reconstructed using Numerical Weather Prediction (NWP) models assimilating past observations.
- Reanalysis datasets cover continuously past period across the earth with a relatively high temporal and spatial resolution for several climate variable as precipitation.
- However, reanalysis datasets cannot be directly used due to, among others, resolution mismatch and model bias. Therefore, reanalysis needs to be post-processed before they can be used.
- In this study, precipitation products are from one reanalysis: The Climate Forecast System Reanalysis (CFSR)

2.Objectives

- Apply stochastic downscaling approaches combined with meta-Gaussien latent field on CFSR precipitation in order to generate random daily sequences with local properties (as opposed to gridded value) and with spatio-temporal consistency.
- Regionalize the at-site downscaling parameters. As CSFR covers the whole territory, it will be then possible to generate daily precipitation datasets (not developed here).

3.Data

- Great Lakes region defined by Plummer et al. (2006)
- CFSR (Saha et al. 2010)
  Hourly datasets aggregated to daily
  Period: 1979-2009
  Resolution: ~ 38 km
  Coupled model: Ocean-Atmosphere-Land
- Observation network
  331 stations:
  Each year: less than 90% missing values
  Each station cover at least 10 years of the 1979-2009 period



4. Method

4.1 Stochastic post-treaments of precipitation (Wong et al. 2014)

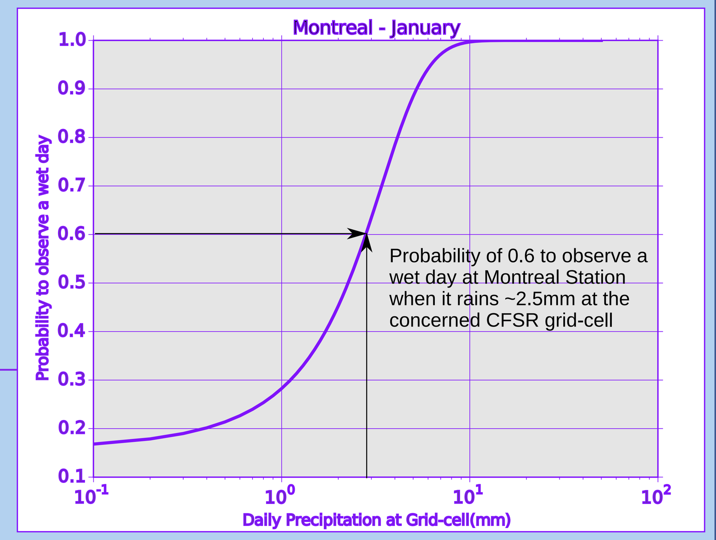
4.1.a. Logistic Regression (LR) is used to estimate local precipitation occurence probabilities

- LR aims at modelling the pattern of dry and wet days at sites

$$\log\left(\frac{p_i}{1-p_i}\right) = \alpha_0 + \alpha_1 \log(x_i+1) + \dots$$
$$\alpha_2 \cos(2\pi d/T) + \alpha_3 \sin(2\pi d/T)$$

probability of rain at a given site conditionnal on the intensity estimated by the reanalysis x_i for the same day i

- α_k are estimated by the maximum-likelihood method



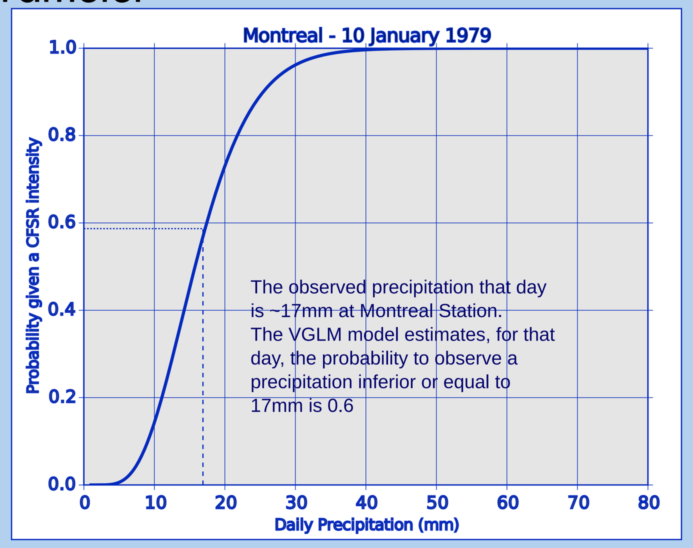
4.1.b. Vector Generalized Linear Model (VGLM) is used to estimate the precipitation intensity

- Daily precipitation distribution is represented by a two-parameter Gamma distribution (μ, γ), [position and shape]
- VGLM models allow the daily precipitation parameters at sites to be functions of daily precipitations estimated by CFSR through the following expression:

$$\begin{cases} \mu_i = \mu_0 + \mu_1 \log(1+x_i) + \mu_2 \cos(2\pi d/T) + \mu_3 \sin(2\pi d/T) \\ \gamma_i = \gamma_0 + \gamma_1 \log(1+x_i) \end{cases}$$

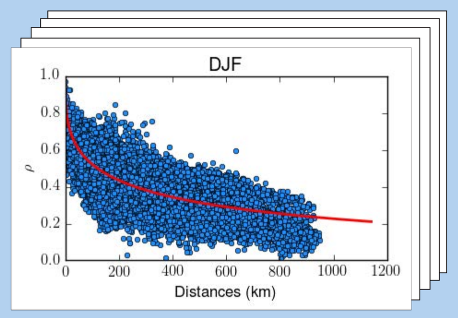
$$\Pr(Z \le z_i \mid X = x_i) = F_\Gamma(\mu_i, \gamma_i; x_i)$$

Daily local gamma distribution conditionnal, where z_i is local daily precipitation, to the simulated intensity x_i

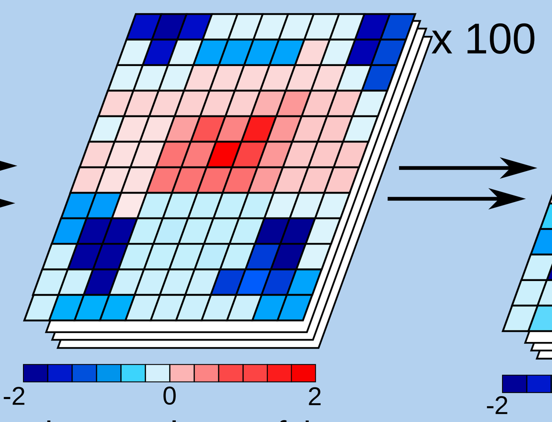


- μ_k, γ_m are estimated by the maximum-likelihood method

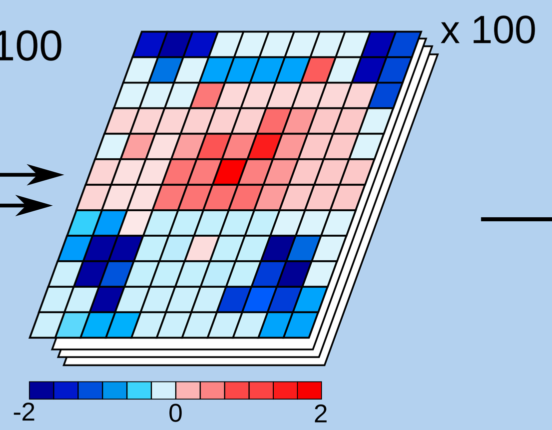
4.2. Random meta-Gaussian latent field definition (Serinaldi et al. 2014)



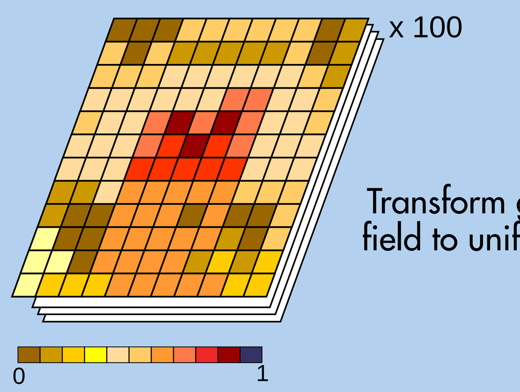
Fit spatial covariance function of the observed daily precipitation for each season



Random simulation of the gaussian field, y(s), at each CFSR grid-cell coordinates



Append the temporal persistence, ρ, to the random field (Podgorski & Wegener,2012):



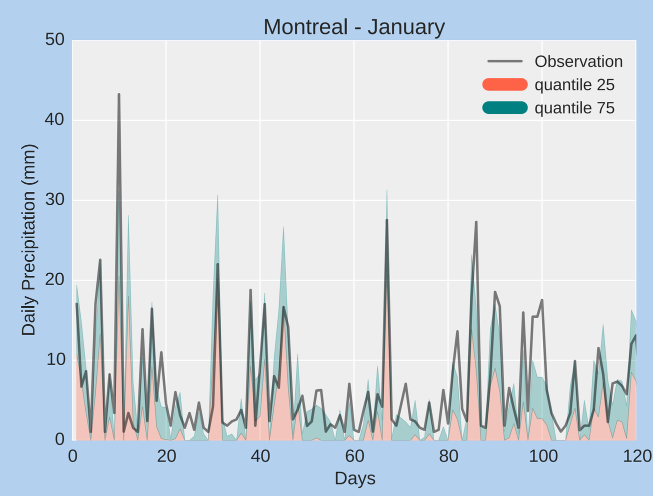
Transform gaussian field to uniform field

4.3. Daily precipitation at sites

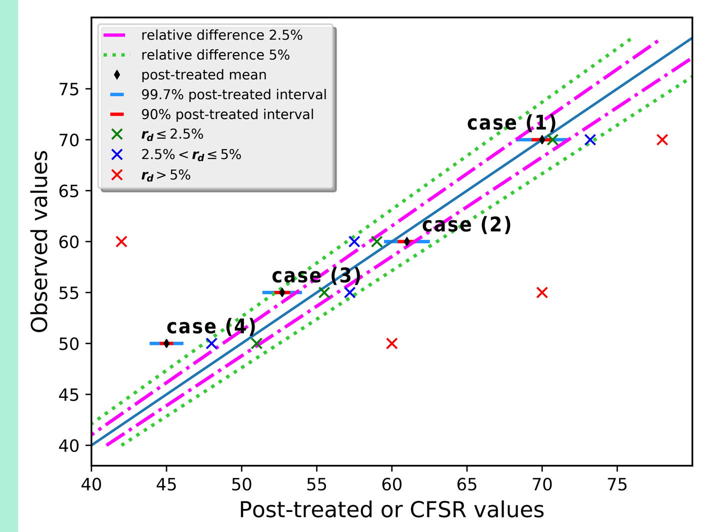
- Combine the probability of occurrence and intensity to define the local daily precipitation distribution:

$$\Pr(Z \le z_i) = p_i F_\Gamma(\mu_i, \gamma_i; x_i) + (1-p_i)$$

- Generate from that distribution with the uniform random field obtained by the meta-gaussian definition



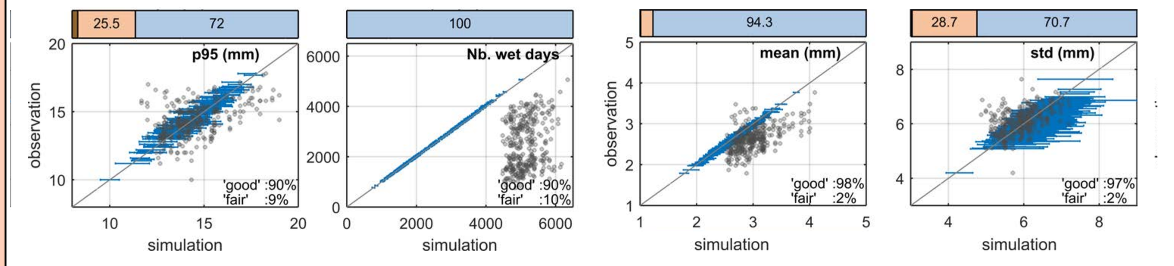
5. Evaluation

Metrics to be evaluated	CASE* framework evaluation
Climate evaluation of the daily precipitation → Mean, mean on wet days, number of wet days, 95th percentile Spatial evaluation → Spatial correlation of the the daily precipitation at the pair of sites Annual evaluation → Climate indices from the ETCCDI indices (World Meteorological Organization's Expert Team on Climate Change Detection and Indices) Annual cycle of the precipitation	

*Comprehensive And Systematic Evaluation

6. Results

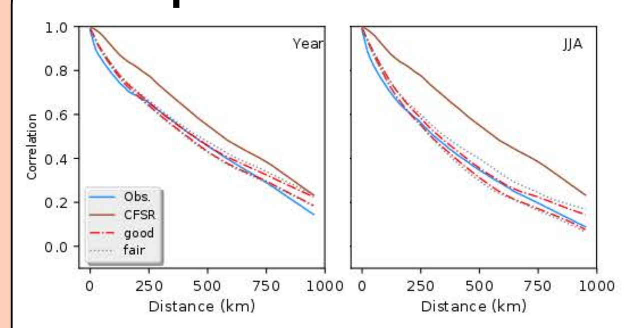
Climate evaluation of the daily statistics



The generated series displayed good climate characteristics (good representation of the marginals: occurrence and intensity)

Noticeable improvement compared to CFSR

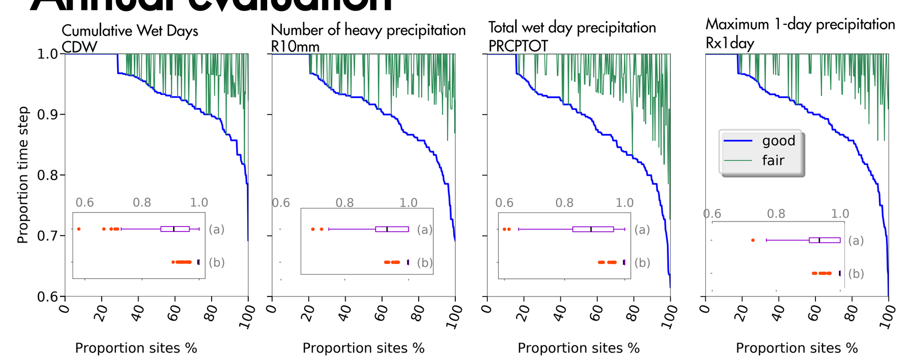
Spatial evaluation



The meta-Gaussian field enabled the generation accurate spatial correlation even at the season scale

CFSR overestimated the spatial correlations of the daily precipitation

Annual evaluation



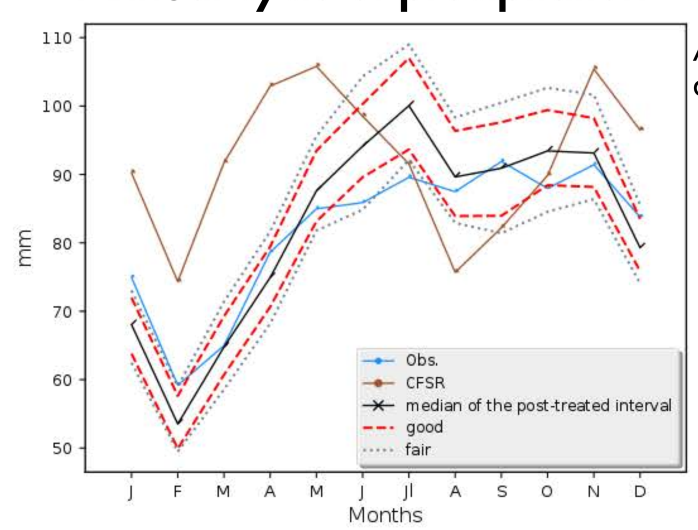
Fraction of annual values displaying a good or fair performance for each sites

Around 30% of sites had 100% of their annual index series in the good category

For the remaining sites, this percentage dropped between 60 to 90% and for the same series, while the remaining years fell in the fair category

Here again, post-processed CFSR showed for the majority of sites and index, better estimates than CFSR

Annual cycle of precipitation



Annual cycles estimated from regionally-averaged daily precipitation

Post-processed series enabled the simulation of the regional annual cycle of the precipitation

Good or fair estimates of regional month amounts were generrally obtained in post-processed series

CFSR cycle was not concordant with the observed cycle

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7. Conclusion

- The stochastic post-treatment is used to correct and downscale CFSR precipitation
- Post-processing of reanalysis series is achieved in two steps : one for the precipitation occurrence (LR model) and one for the precipitation intensity (VGLM model)
- Post-processing approach demonstrated high potential for providing precipitation that reproduce at-site statistics, indices, and the specific annual cycle of the Great-Lake region
- The meta-Gaussian latent field can be used to generate spatially consistent precipitation series with adequate temporal persistence
- The next step is to interpolate (e.g. kriging) the LR and the VGLM parameters to post-process reanalysis series at sites without historical records