Implementing multi century hourly stochastic precipitation using CMIP6 - A trade-off approach

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Introduction

Objective
- Landform design requirements => 300 yrs. 30 min. precipitation in South Africa (limited records)

Problem
- Current climate change models only provide projections up until the year 2100.
- Most of GCM are at daily scale. SA does not great historical records.

Study Focus
- Limitations for historical records and support projection under climate change.

Methodology
- Baseline Meteorology for precipitation
- Stochastic precipitation model
- Global circulation model (GCM)
Climatic Influence

![Graph showing climatic influence with correlation, standard deviation, and RMS error.]

**Mean annual precipitation**

Background: CHIRPS, Points: South African DB

![Map showing mean annual precipitation with varying colors indicating different levels of precipitation.]

**Sources:**
- CHIRPS
- ERA5-Land
- GPM
- MERRA2
Historical Precipitation

- Quantile Delta Mapping (QDM) was applied to bias correct CHIRPS to extend Maartenshoop data.
- CHIRPS / GPM showed similar elevation gradients with SAWS, with GPM being more regionally representative; however, it does not match Maartenshoop record extension.
Historical Precipitation

• Both extended Maartenshoop and 30-min GPM data showed an average annual rainfall of ~700 mm/year from 2000-2021, confirming their regional accuracy.

• Daily: Maartenshop extended with CHIRPS with QDM

• Hourly: GPM at Maartenshoop
Stochastic Precipitation

Stochastic model: Bartlett-Lewis Poisson Process (Hyetos Minute)

- Implementation by R library HyetosMinute (Mazi et al, 2020).

Storms time series:
- 1 hr.
- 6 hrs.
- 12 hrs.
- 24 hrs.

Optimization
- mean,
- variance,
- Covariance; and,
- dry period probability

Parameters: $\lambda, \alpha, v, \kappa, \phi, \omega, \mu_X$
Stochastic Precipitation - Historical

Stochastic model:
Bartlett-Lewis Poisson Process
(Hyetos Minute)

1 hr. => GPM at Maartenshoop
6 hrs. => GPM at Maartenshoop
12 hrs => GPM at Maartenshoop
24 hrs => Maartenshoop extended with CHIRPS with QDM

Parameters:
λ, α, v, κ, φ, ω, and μX

Optimization

- mean,
- variance,
- Covariance; and,
- dry period probability
Climate change evaluation

- **Data Source:** NEX-GDDP.
- **Bias Correction:** NEX-GDDP => Bias Corrected Maartenshoop with CHIRPS data (daily)
- **GCM Evaluation:** A total of 127 GCMs for four greenhouse gas emission scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5). Period: 2070 to 2099.
Stochastic Precipitation – Climate Change

Stochastic model:
Bartlett-Lewis Poisson Process
(Hyetos Minute)

1 hr. => GPM at Maartenshoop, GCM scaled¹
6 hrs. => GPM at Maartenshoop, GCM scaled¹
12 hrs => GPM at Maartenshoop, GCM scaled¹
24 hrs => GCM corrected by Maartenshop extended with CHIRPS with QDM

mean, variance, Covariance; and,
dry period probability

Parameters:
\( \lambda, \alpha, \nu, \kappa, \phi, \omega, \text{ and } \mu_X \)

¹ Scaled to align historical GCM with GPM at Maartenshoop
Stochastic Precipitation – Climate Change

Stochastic model:
Bartlett-Lewis Poisson Process
(Hyetos Minute)

1 hr. => GPM at Maartenshoop, GCM scaled\(^1\)
6 hrs. => GPM at Maartenshoop, GCM scaled\(^1\)
12 hrs. => GPM at Maartenshoop, GCM scaled\(^1\)
24 hrs. => GCM corrected by Maartenshop extended with CHIRPS with QDM

Optimization

Parameters: \(\lambda, \alpha, \psi, \kappa, \phi, \omega, \) and \(\mu_X\)

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\(^1\) Scaled to align historical GCM with GPM at Maartenshoop
Stochastic evaluation - Historical

(A) Bartlett-Lewis based on Historical records at Maartenshoop
(300 years)

(B) GPM at Maartenshoop
(2000 – 2022)
Stochastic evaluation - Historical

(C) Historical - maximum precipitation in 6, 12 and 24 hrs

Source Comparison

- Smithers et al., 2002
Climate change evaluation - Projection

Time series selected as representative for the GCM variability

notes: arbitrarily red lines selected as a site references for GCM models
Summary

- Landform design => hourly precipitation data ranging 100 to 1000 years. However, the output do not align with the Global Climate Model (GCM) results.

- This approach aims to encapsulate GCM variability, but questions remain about the Bartlett-Lewis pulse's capability to accurately mirror this variability.

- The presented methodology is not a definitive solution for GCM integration. Instead, it's an attempt (trade-off) to infuse GCM into the hourly results.
Thanks for your attention in this almost last presentation!

Well done yourself!

Any question?