Propagation of Precipitation Uncertainty in Terrestrial Hydrological Modeling — Case Study over West Africa

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ALMIP AMMA Land surface Model Intercomparison Project Phase 2

1 Introduction and Background

Several recent studies have shown the importance of land surface atmosphere coupling in the monsoon system of the West Africa. The African Monsoon Multidisciplinary Analysis (AMMA) has provided an opportunity to investigate model deficiencies in land surface process by providing high resolution datasets. In participation with the **A**MMA **L**and Surface **M**odel **I**nter-comparison **P**roject Phase **2** (**ALMIP2**), a global land surface model is regionalized for conducting a high space-time resolution (0.05°, 30 minutes) experiment over three distinct meso-scale domains in West Africa (see Fig.1).

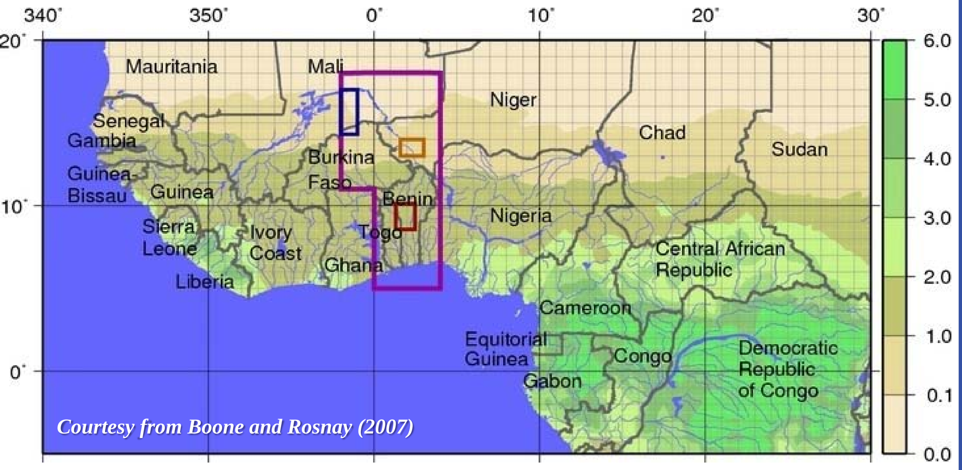
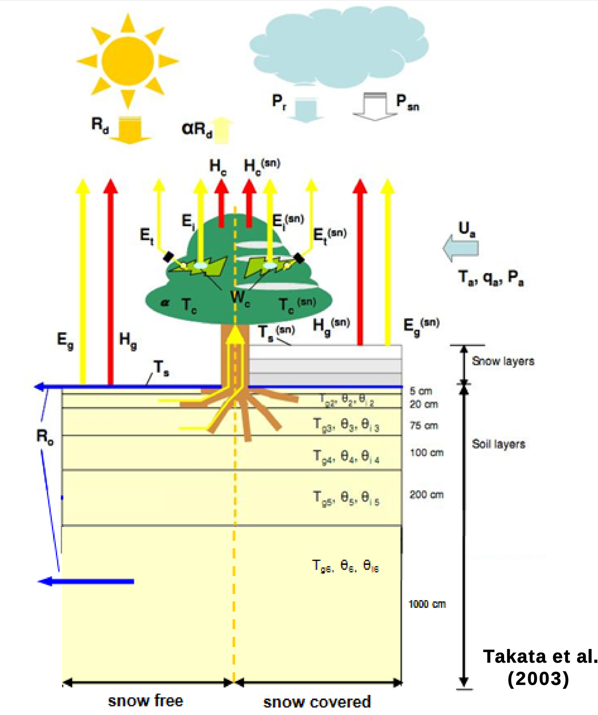


Fig.1 Location of three meso-scale sites: Oueme-Benin (red), South-West Niger (orange) and Gourma-Mali (blue). Contours correspond to the annually-averaged Leaf Area Index (LAI m^2m^{-2})

The **objective** of this research is to investigate the impacts of uncertainty of precipitation on the surface fluxes and hydrological responses through LSM. Specifically, we estimate the uncertainty in observed precipitation due to different interpolation methods (Lagrangian-krigged and Thiessen) and its propagation to the simulated evapotranspiration and runoff.

3 Model

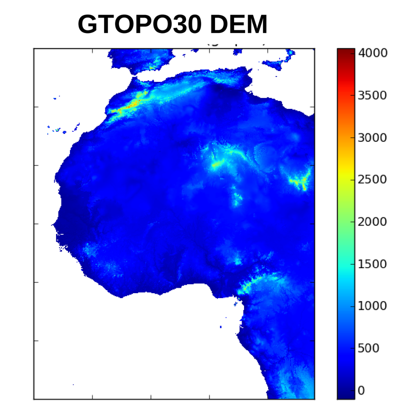
Land Surface Model

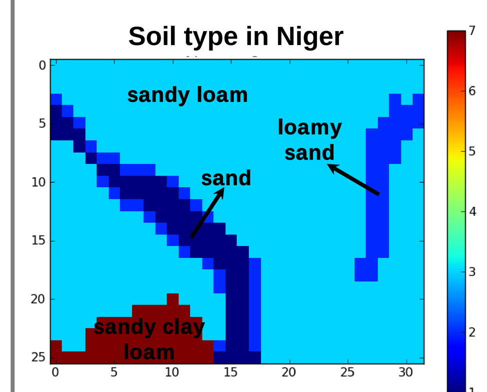


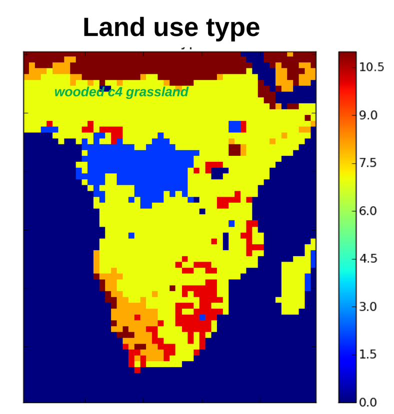
Schematic representation of Minimal Advanced Treatments of Surface Integration and Runoff (MATSIRO) is presented in the above figure. It solves the water and energy balance at ground and canopy surfaces in snow-covered and snow free areas within a grid cell.

External Parameters

Name	Source
Sand Fraction	ECOCLIMAP2
Clay Fraction	ECOCLIMAP2
Vegetation type map	GLOBAL MAP
Ground albedo (visible)	ECOCLIMAP2
Ground albedo (near infrared)	ECOCLIMAP2
Mean slope	GTOPO30
Standard deviation of Topography	GTOPO30
Leaf Area Index	ECOCLIMAP2







GTOPO30 is used to estimate the subgrid topography. Soil type is classified at each grid based on the sand fraction and clay fraction provided by ECOCLIMAP2 (Champeaux et al., 2004). Vegetation map is referred from the global land use map.

4 Similarity of Two Interpolation Scheme

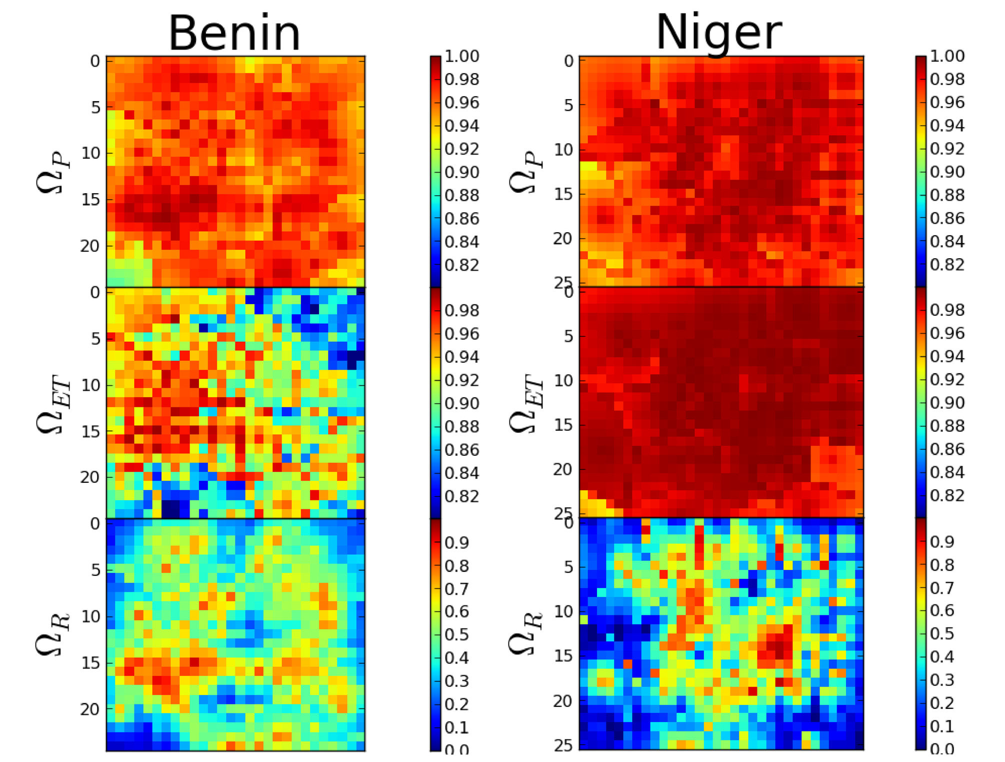


Fig.3 Comparison of the similarity of ensemble members (Ω_P, Ω_{ET}, and Ω_R) in Benin and Niger (monthly variation).

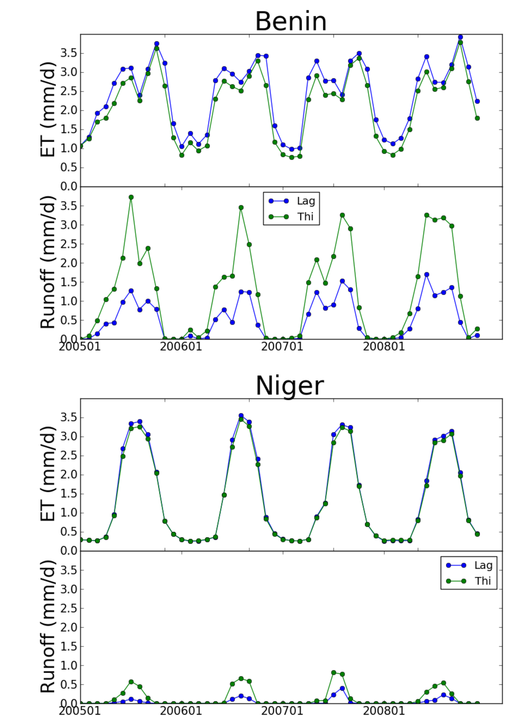
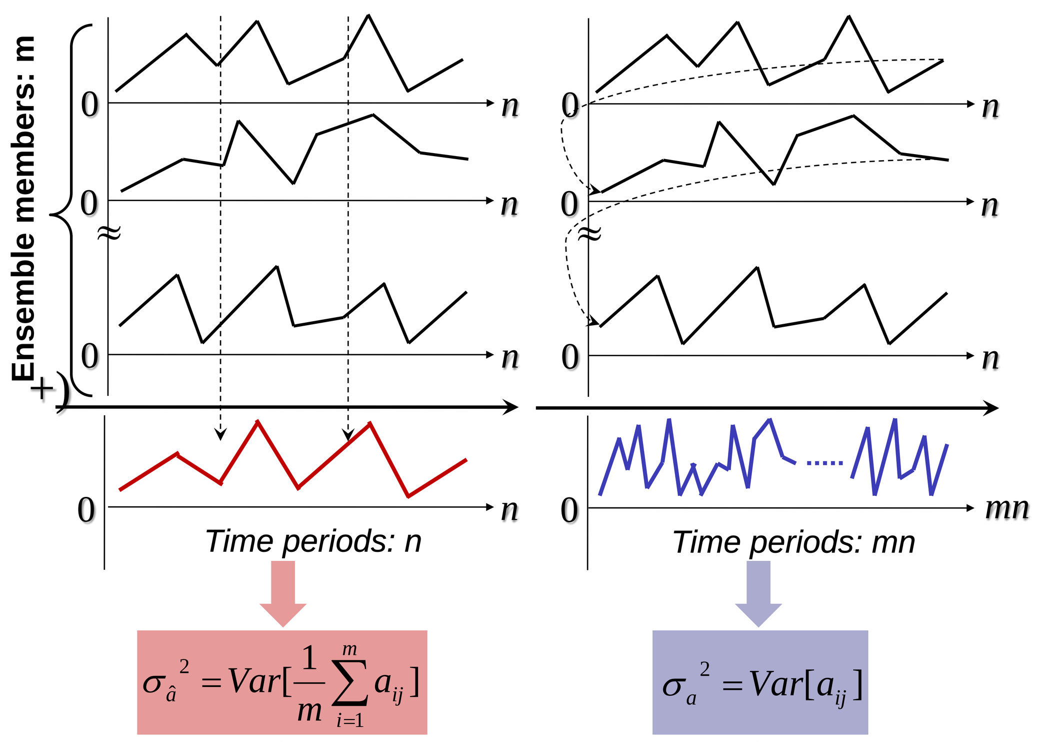


Fig.4 Simulation of evapotranspiration and runoff forced by Lagrangian-krigged and Thiessen rainfall

- High values of Ω index for precipitation demonstrate that Lagrangian-krigged and Thiessen method have similar temporal variability between each other.
- High values of Ω_{ET} means high similarity between two time series of ET.
- Ensemble similarity of runoff (Ω_R) shows stronger spatial heterogeneity and its relative lower values demonstrate that simulated runoff tends to have inconsistent temporal variability.

2 Methodology



$$\sigma_a^2 = Var[\frac{1}{m}\sum_{i=1}^{m} a_{ij}]$$

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$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix}$$

Ensemble Coherence Index: Ω

Index to measure the **similarity** of individual time series of ensemble members [Koster et al., 2000]

$$\Omega_a = \frac{m\sigma_{\bar{a}}^2 - \sigma_a^2}{(m-1)\sigma_a^2}$$

High-resolution observational data based on dense gauge station networks provides a good chance for us to compare the biases among different precipitation products. Here we use Ω index to evaluate the similarity between the ensemble members. Temporal variation of them can be seen in Fig. 2. For uncertainty propagation analysis, **only ALMIP2 data** is used.

Multi-Precipitation

Atmospheric Reanalysis

JRA-25 (JMA-CRIEPI): T106 (~ 110km), 6 hourly

Satellite Observation

GPCP V2.2 — 1.0° — Monthly

Gauge Observation

GPCC	1.0°	Monthly
PREC/L	1.0°	Monthly

ALMIP2 (in situ)

Lagrangian-krigged	0.05°	30 mins
Thiessen	0.05°	30 mins

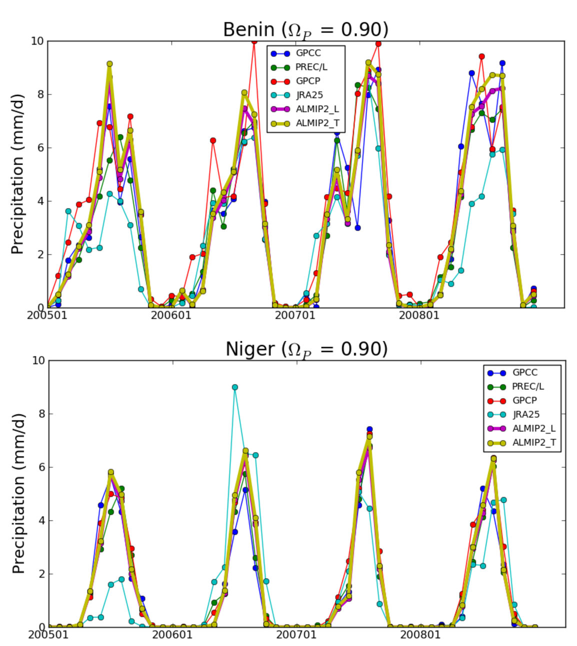
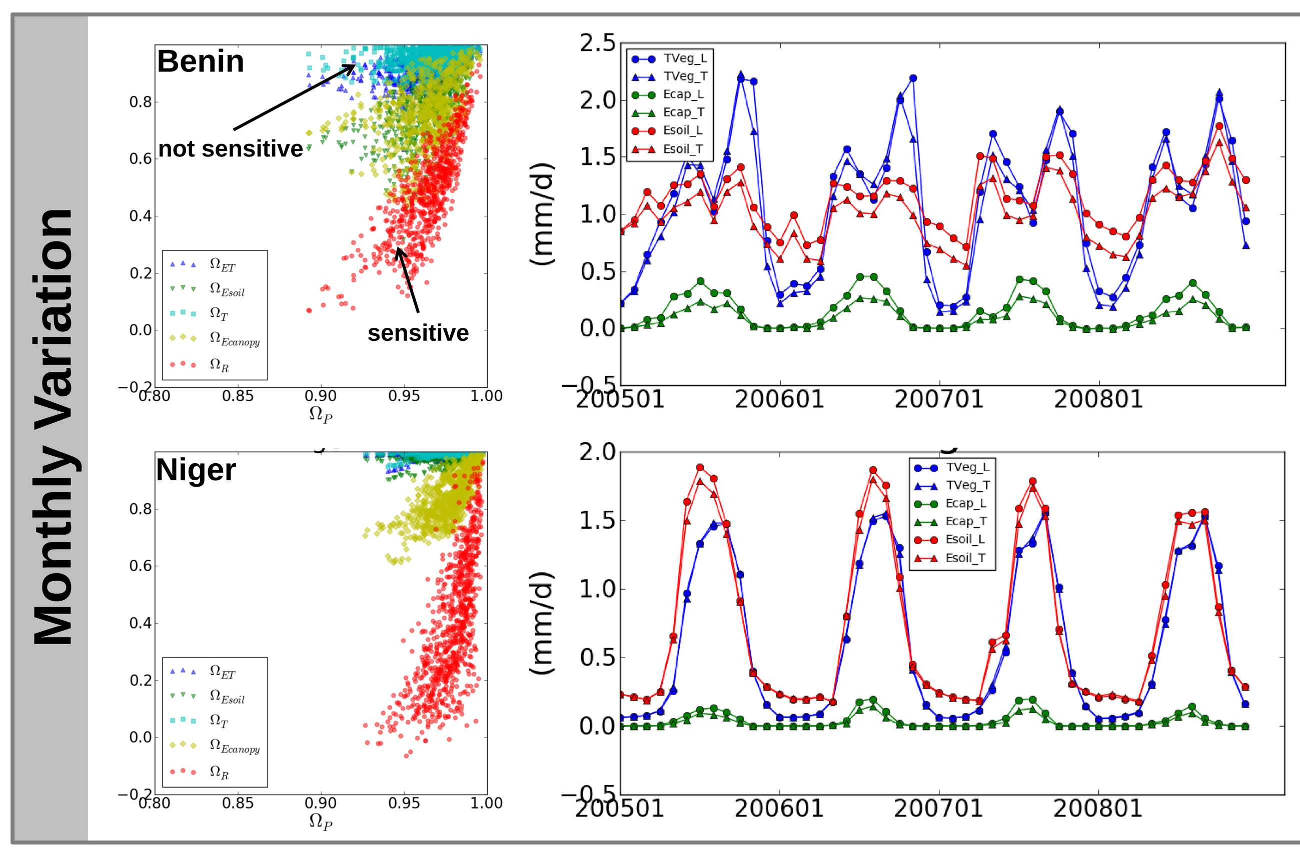


Fig.2 Time series and Ω index for 6 precipitation products in Benin and Niger.

5 Propagation of Uncertainty in Forcing Data through LSM Simulation



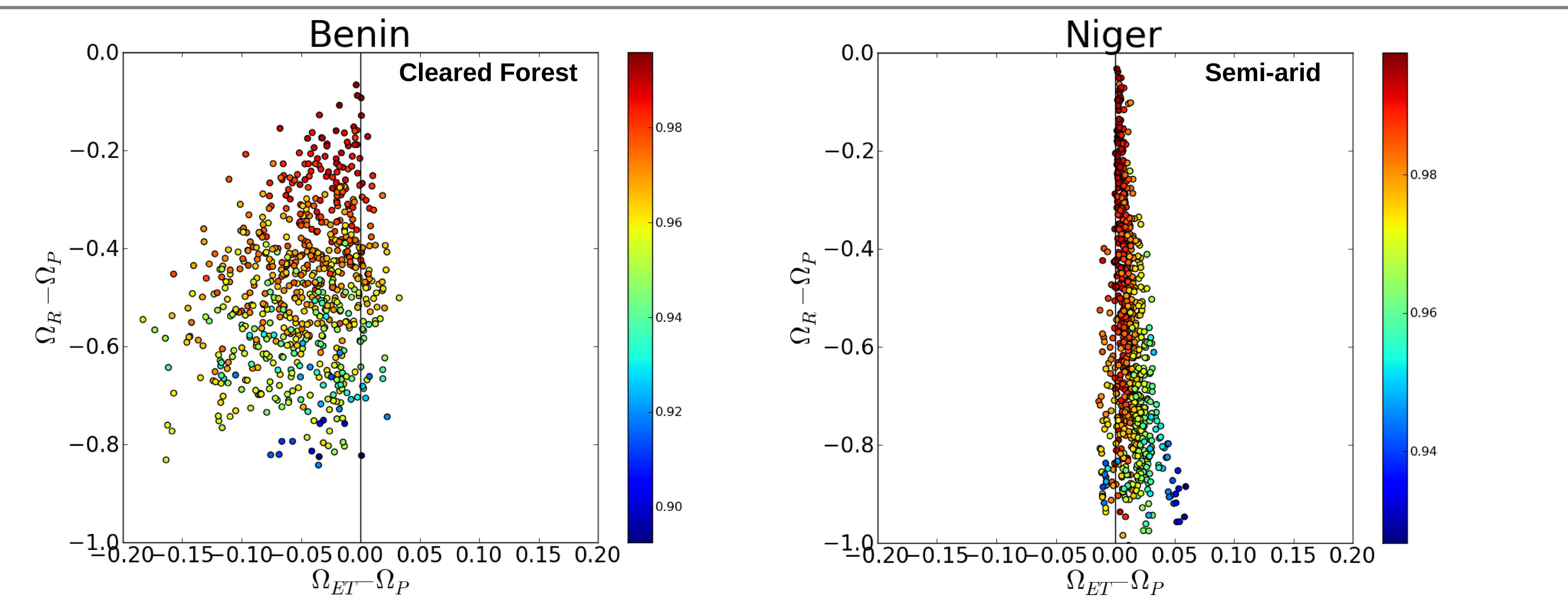
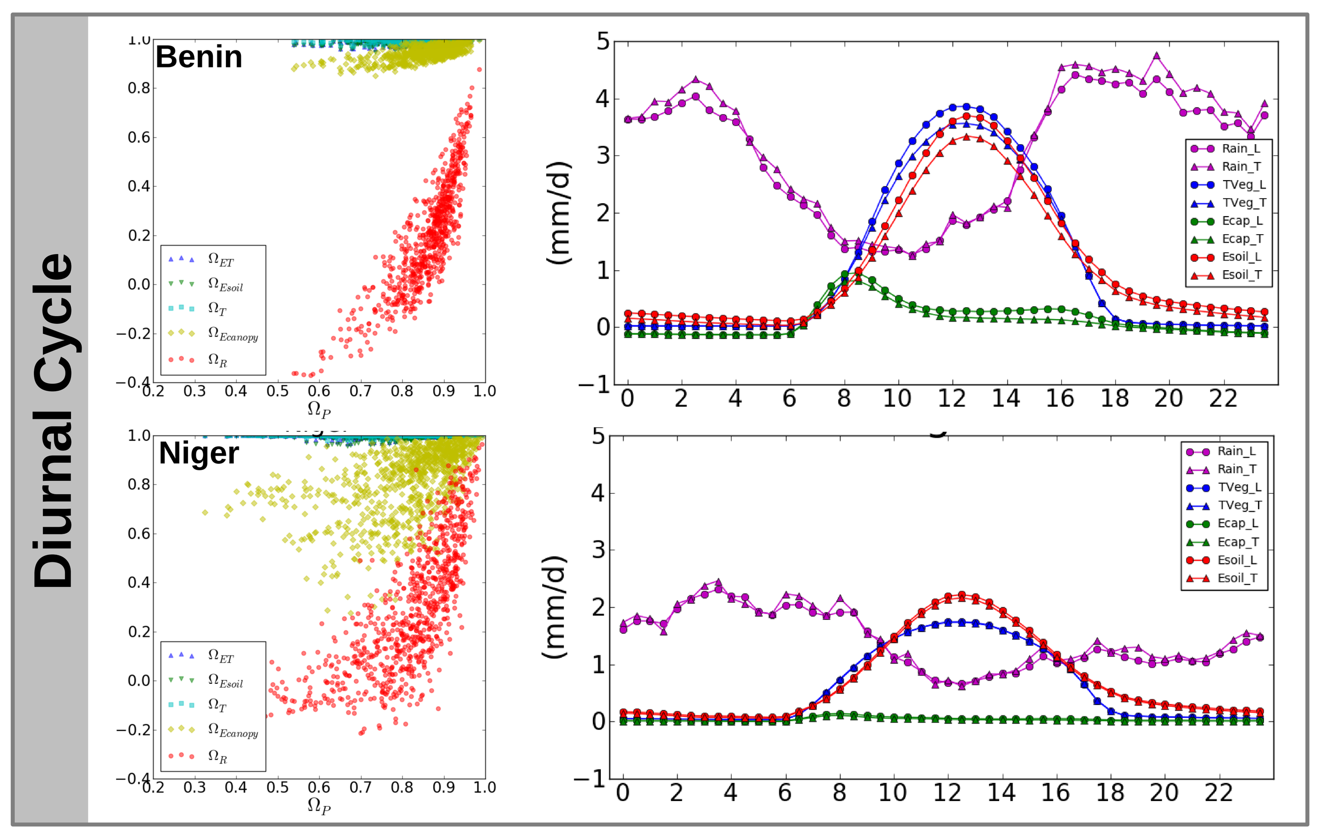


Fig.5 Relation between the uncertainty propagation for evapotranspiration (Ω_{ET} - Ω_P) and runoff (Ω_R - Ω_P). Shaded color indicates the similarity of precipitation ensemble members (Ω_P).



- **For monthly variation**, large range and relatively lower values of Ω_{ET}, Ω_{Soil}, Ω_T and $\Omega_{Ecanopy}$ in Benin (cleared forest) indicate that evapotranspiration (and its components) is more *sensitive* to Ω_P compared to that in Niger (semi-arid). Inversely, Niger shows steeper slope between Ω_R and Ω_P which means in semi-arid region, uncertainty of simulated runoff is larger compared to cleared forest.

  Cleared forest and semi-arid regions have opposite tendency in the uncertainty propagation for ET $\Omega_{ET} - \Omega_P$ as presented in Fig. 5. Generally negative values in Benin illustrate that the uncertainty in precipitation is propagated in an *amplified* way. However, the generally positive values in Niger show that uncertainty translates relatively *reduced* in ET.

  Negative values of Ω_R - Ω_P, both in Benin and Niger, show that uncertainty propagation for runoff is *amplified* through land surface simulation.

- **For diurnal variation**, ET and its components are not sensitive to Ω_P except for $\Omega_{Ecanopy}$ in Niger, which indicates that simulation of canopy evaporation has larger inconsistency in diurnal cycle. However, compared to monthly variation, uncertainty propagation for ET in diurnal cycle is not considerably amplified.

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