Application of Satellite Estimates of Rainfall Distribution to Simulate the Potential for Malaria Transmission in Africa

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Abstract

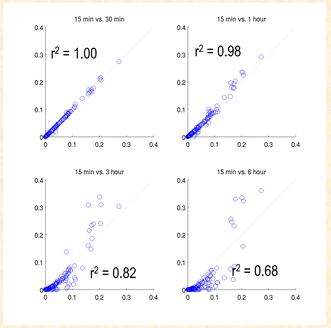
The Hydrology, Entomology and Malaria Transmission Simulator (HYDREMATS) is a mechanistic model developed to assess risk of malaria transmission in areas where the disease is water-limited. This model relies on precipitation inputs as its primary forcing. Until now, applications of the model have used ground-based precipitation observations. However, rain gauge networks in the areas most affected by malaria are often sparse. The increasing availability of satellite based rainfall estimates could greatly extend the range of applicability of the model. The minimum temporal resolution of precipitation data needed was determined to be about one hour. The CPC Morphing technique (CMORPH) distributed by NOAA fits this criteria, as it provides 30-minute estimates at 8km resolution. CMORPH data were compared to ground observations in three West African villages, and calibrated to reduce overestimation and false alarm biases. The calibrated CMORPH data were used to force HYDREMATS, resulting in outputs for mosquito populations, vectorial capacity and malaria transmission.

Primary Question: Can data from satellites be used to mechanistically model mosquito populations?

Resolution of precipitation

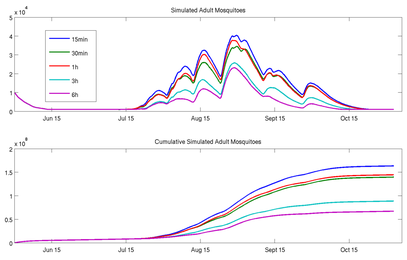
The temporal resolution of rainfall required by HYDREMATS in order to properly simulate mosquito habitats was assessed by comparing model simulations using various precipitation resolution, ranging from 15 minutes to 6 hours.

Proportional area of mosquito breeding habitat



We determined that HYDREMATS requires precipitation inputs at a resolution of at least 1 hour in order to properly simulate mosquito populations.

Simulated mosquito populations under varying resolutions of precipitation input



Satellite Data

CMORPH is a rainfall product available every 30 minutes at 8 kṁ resolution. CMORPH combines rainfall estimates from a number of passive microwave (PMW) sensors. Time steps where PMW data is not available are filled in by using infrared data to determine the movements of precipitating systems between consecutive PMW measurements.

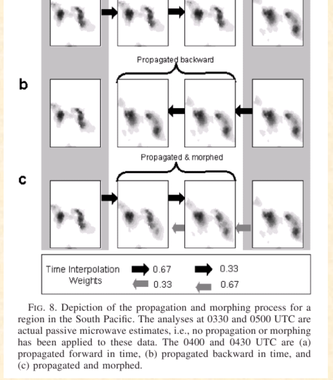


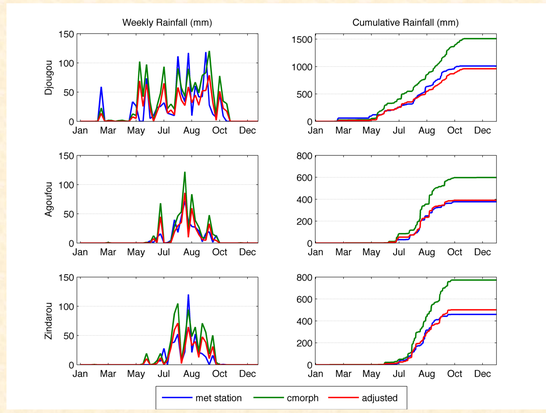
FIG. 8. Depiction of the propagation and morphing process for a region in the South Pacific. The analyses at 0330 and 0500 UTC are actual passive microwave estimates, i.e., no propagation or morphing has been applied to these data. The 0400 and 0430 UTC are (a) propagated forward in time, (b) propagated backward in time, and (c) propagated and morphed.

Figure from Joyce et al., 2004

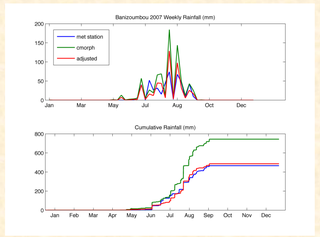
CMORPH data was compared to 3 ground stations in West Africa: Agoufou, Mali, Zindarou, Niger, and Djougou, Benin.

Because CMORPH significantly overestimated rainfall in our 3 comparison areas, a correction factor of 0.73 was applied to all CMORPH data.

Weekly and cumulative rainfall from ground stations (blue), CMORPH (green), and adjusted CMORPH (red).

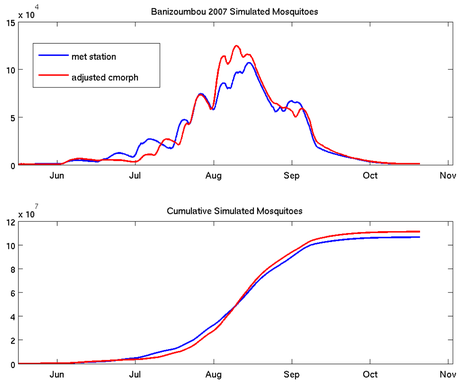


Results



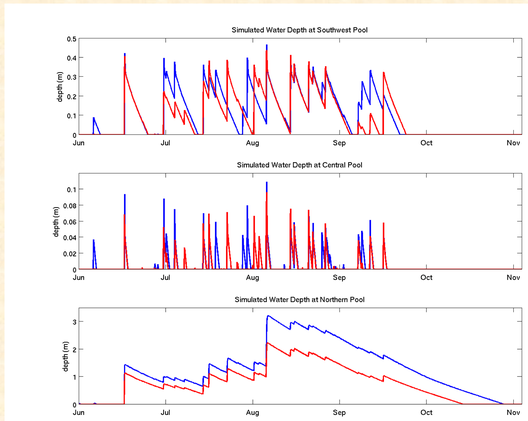
(Above) Weekly and cumulative rainfall in Banizoumbou 2007

When CMORPH data were adjusted based on the correction factor determined above, and were used to force HYDREMATS, the entomology and hydrology outputs were similar to what they are when ground observations of rainfall are used.



Simulated mosquito populations from HYDREMATS

Simulated depths of 3 pools when HYDREMATS is forced with ground observations (red) and CMORPH estimates (blue) of rainfaill.

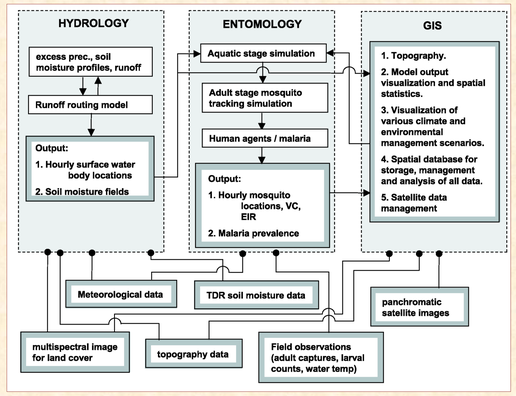


Central Pool

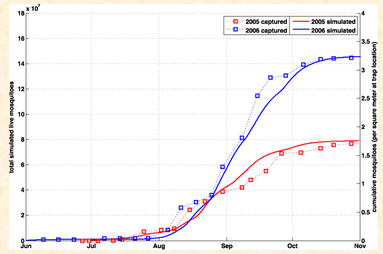
Northern Pool

Modeling Approach

HYDREMATS is a mechanistic coupled hydrology and entomology model developed by Bomblies et al. (2008) to simulate local malaria dynamics in semiarid environments.



HYDREMATS has been field validated at our study site in Banizoumbou, Niger.



Simulated and captured mosquitoes in Banizoumbou 2005-2006 *Bomblies, 2008*

Conclusions

The results of this study show that satellite derived estimates of rainfall can be used in a mechanistic model to simulate mosquito populations and malaria transmission. In the future, we envision a system by which a large portion of the inputs to HYDREMATS could be obtained by satellite and archived data sets. These inputs include temperature, humidity, wind speed and direction, topography, soil characteristics, and location of residences. If these data could all be applied to the model, the range of applicability of HYDREMATS could be extended to every village in Western Africa, as well as any other area where malaria transmission is limited by the availability of water. HYDREMATS could be a valuable tool for researchers and those working in malaria control programs.

References

Bomblies, A., Duchemin, J. B., & Eltahir, E. A. B. (2008). Hydrology of malaria: Model development and application to a sahelian village. *Water Resour.Res, 44*

Joyce, R. J., Janowiak, J. E., Arkin, P. A., & Xie, P. (2004). CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution. *Journal of Hydrometeorology, 5*(3), 487-503.