Precipitation-Induced Surface Sensible Heat Flux: Comparison of Observed and Reanalysis Estimates in Darwin, Australia

Gabriel Taylor (gtaylor2021@my.fit.edu)

Dr. Pallav Ray, Dr. Milla Costa, Connor Welch, Florida Institute of Technology

Introduction

- Surface sensible heat flux induced by precipitation (Q_P) is dependent on two fluctuating variables: rain rate (R), and the temperature difference between the raindrops and the surface (T_0 - T_R).
- This primarily has a cooling effect at the surface but is a notably small flux which is not taken into account by most climate models (Curry et al., 1999).
- During extreme rainfall events, Q_P can exceed both sensible and latent heat flux on hourly time scales.
- In high-rainfall regions, this flux plays a considerable role in the earth-atmosphere energy balance.

Location and Data (Datasets from 2009)

Observed Data

- U.S. DOE Tropical Western Pacific (TWP) site C3.
- Atmospheric Radiation Measurement (ARM) site collected various atmospheric properties used to estimate hourly Q_P.

Reanalysis Data

- ERA5 Land data used to estimate hourly Q_P.

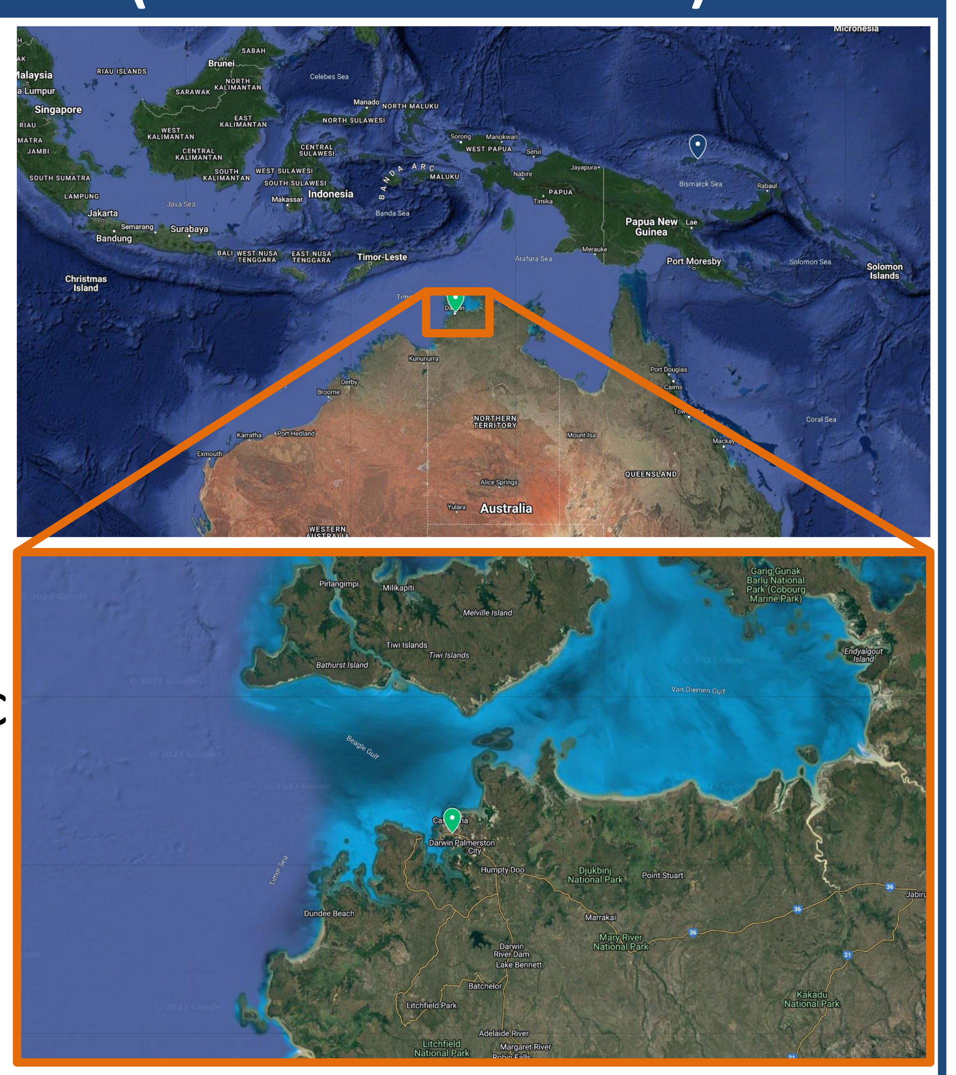

Fig. 1 & 2 (top & bottom). satellite view of TWP region, green marker indicates ARM site location in Darwin, Australia.

Fig. 3. aerial view of the Central Facility in Darwin, Australia.

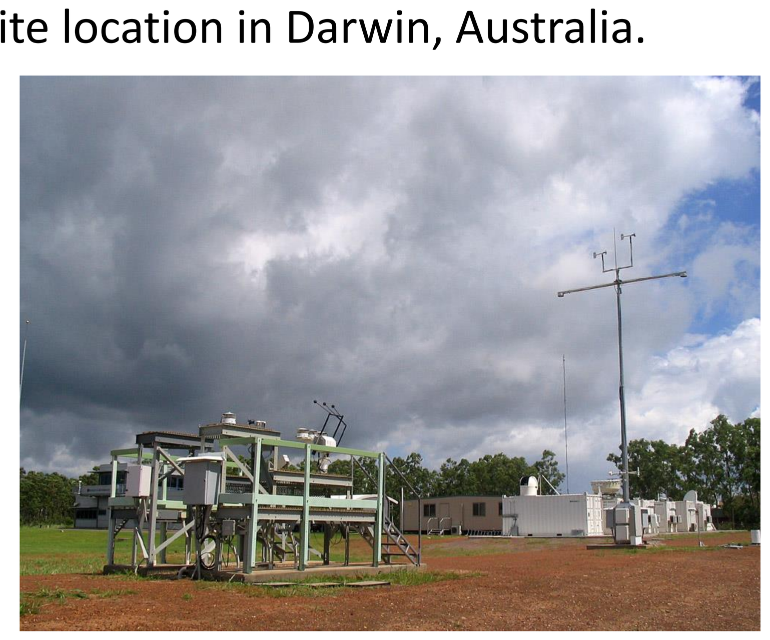

Fig. 4. ARM data collection equipment.

Methods (Estimating Sensible Heat of Rainfall)

$$Q_P = C_W \times \rho \times R \times (T_0 - T_R) \quad (1)$$

- C_W = specific heat of rainwater [$4{,}128\ \mathrm{J\ kg^{-1}\ K^{-1}}$]
- ρ = density of rainwater [$1{,}000\ \mathrm{kg\ m^{-3}}$]
- R = rain rate [$\mathrm{m\ s^{-1}}$], T_0 = skin temperature [K]
- T_R = raindrop temperature [K], which is estimated by using the wet bulb temperature (Gosnell et al., 1995)

Methods

- Observed data from the ARM site in Darwin was used to determine the error of reanalysis Q_P (from ERA5-Land) during 2009 and for each season.
- Additional comparisons were made using Q_P calculated from the two altering variables in Q_P:
  - ARM rain rate and ERA5-Land T_0 - T_R
  - ERA5-land rain rate and ARM T_0 - T_R
- These Q_P estimates were compared to observed Q_P to determine which of the two variables (rain rate and T_0 - T_R) from reanalysis have the greatest bias and which one may provide relatively accurate data.

Results

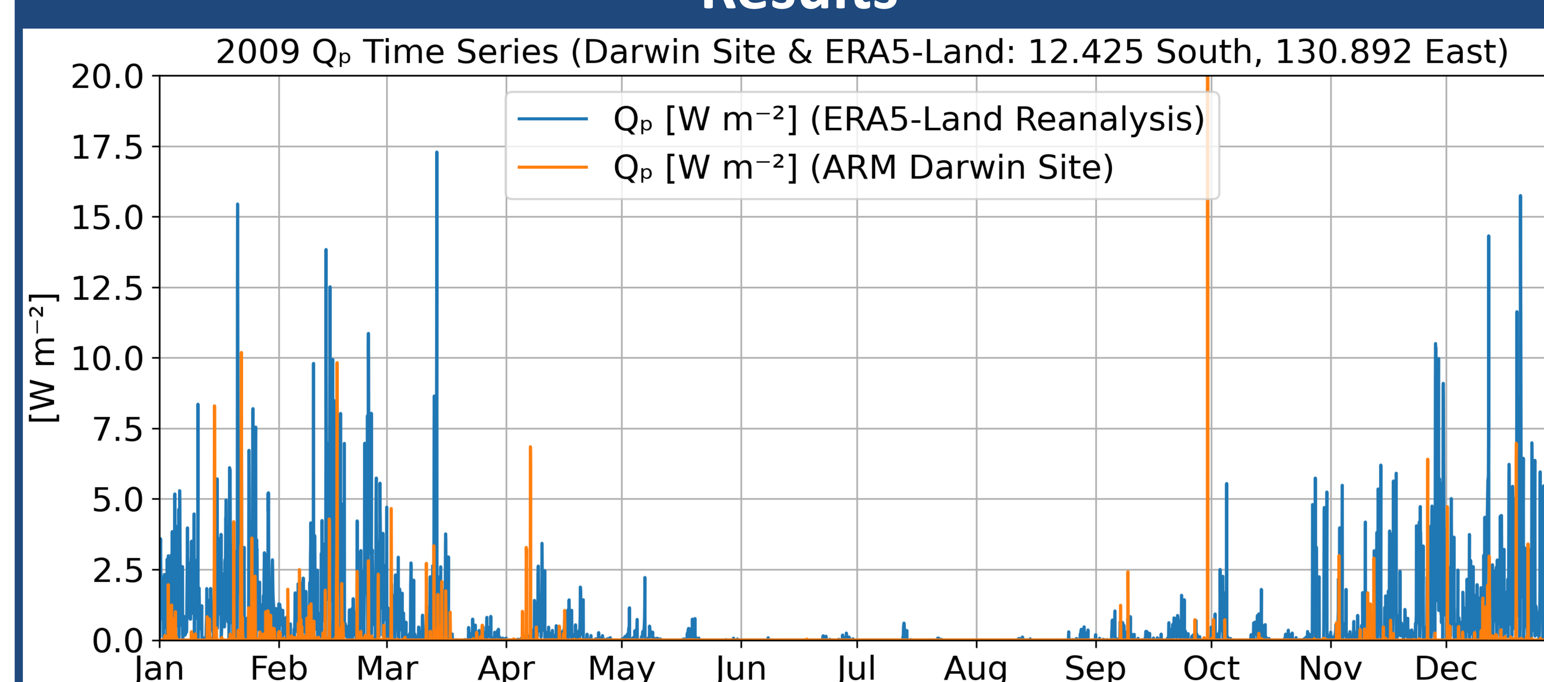

Fig. 5. Hourly time series of ARM Q_P and ERA5-Land Q_P for the year 2009 at the Darwin, Australia Central Facility, units are W m^{-2}.

Table 1

ERA5 vs. ARM Q_P	Mean Error	RMS Error	Std. Dev.
Yearly	0.497	1.747	1.675
DJF	1.442	2.340	1.843
MAM	0.207	0.827	0.801
JJA	0.009	0.045	0.044
SON	0.347	2.476	2.452

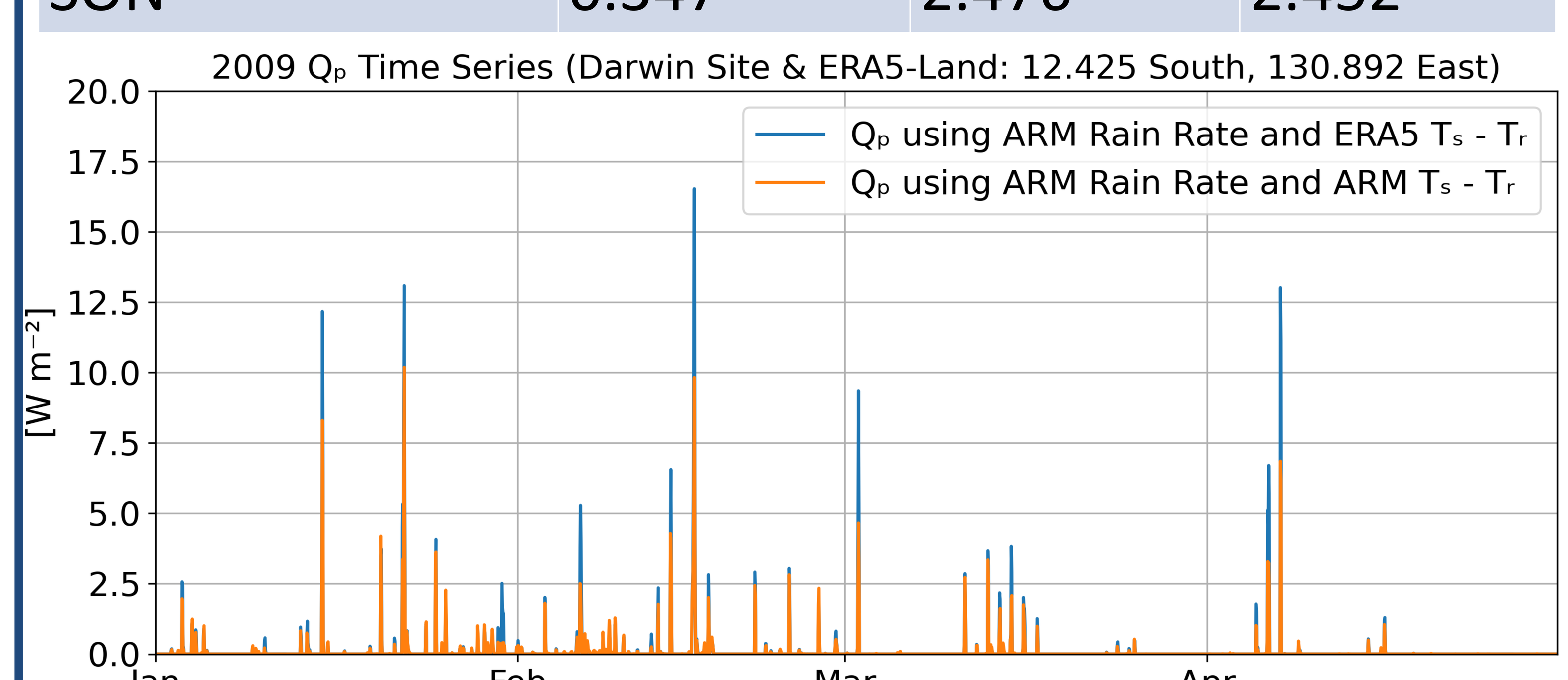

Fig. 6. Hourly time series of Q_P calculated from ARM rain rate and ARM T_0 - T_R and Q_P from ARM rain rate and ERA5-Land T_0 - T_R during JFMA of 2009, units are W m^{-2}.

Table 2

ARM Rain Rate	Mean Error	RMS Error	Std. Dev.
ERA5 ΔT vs. ARM ΔT	0.031	0.328	0.326

Results

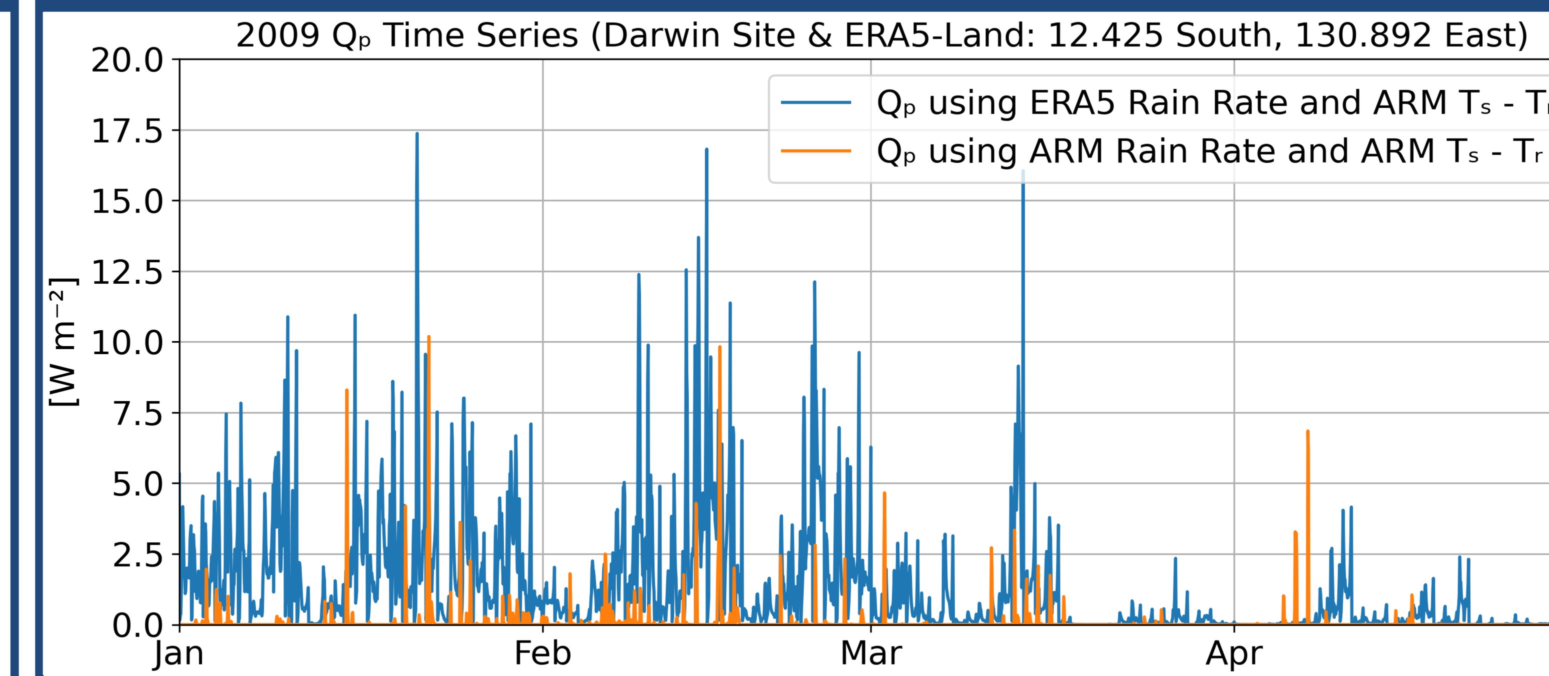

Figure 7: Hourly time series of Q_P calculated from ARM rain rate and ARM T_0 - T_R and Q_P from ERA5-Land rain rate and ARM T_0 - T_R during JFMA of 2009, units are W m^{-2}.

Table 3

ARM ΔT	Mean Error	RMS Error	Std. Dev.
ERA5 R vs. ARM R	1.144	2.258	1.947

Discussion

- ERA5-Land heavily overestimated Q_P during 2009 (fig. 5 & table 1).
- Although infrequent, there were some instances where ERA5-Land estimated less Q_P than observed by ARM (i.e. late September featured an event where observed Q_P exceeded 70 W m^{-2} because of a 2-hour event where rain rates of ~1.5 $inches\ hour^{-1}$ were recorded).
- Only similarity between ARM and ERA5-Land data is the seasonal trend (larger Q_P during wet season and less during dry season estimated by both datasets).
- JJA (peak of dry season) featured the best performance of ERA5-Land reanalysis data.
- ERA5-Land T_0 - T_R tends to be greater than ARM T_0 - T_R which led to overestimated Q_P values (fig. 6).
- ERA5-Land rain rate had the greatest bias between the two altering variables (fig. 7 & table 3).

References

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