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Data Assimilation for Hydrology using Multi-sensor Observations

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Overview

- **Past DA work done (CBM/CABLE)**
  - Synthetic Twin
  - In-situ one-dimensional observations
  - Spatial remotely sensed observations
- **Issues/Limitations Identified**
- **Current Work – ARC Project**
- **Summary/Future Directions**

Motivation

- **Which observations are best for constraining particular quantities in hydrologic cycle?**

- **All possible land surface model data assimilation approaches for hydrology not fully explored in research literature (and not with CBM/CABLE)**
  - Many examples of soil moisture and some of skin surface temperature assimilation studied with different models
  - Assimilation of LE and H observations, or combinations of different variables has not been explored in depth

- **Better understand data assimilation impacts on CBM/CABLE.**

CBM / CABLE Specs Relevant to Assimilation

- **Model forced at each time step by:**
  - Incoming short wave and long wave radiation; Air temperature; Rainfall; Wind speed; Specific humidity; Air pressure.

- **Soil Moisture and soil temperature for 6 soil layers are the prognostic state variables**
  - Traditional state updating applied with assimilation – no parameter optimisation.

- **Skin surface temperature is the sum of the radiative temperature from the soil and from vegetation → Strong link to surface soil temperature, leaf canopy temperature in the model.**

Ensemble Kalman Filter (EnKF) used:

- **Perturbed ensembles of initial conditions, and forcing time series data (eg. Turner *et al*., 2008)**
  - Results in model prediction ensembles for error covariances

- **Observation ensembles → normally distributed random perturbations added to observation value**

Observations used for data assimilation experiments: Energy and water balance data types related to remote sensing…….

	Specs	Pros	Cons
Soil Moisture (passive microwave)	• Once every 1-3 days; • 10's km resolution	• Insensitive to clouds; • Higher res. airborne data can supplement satellite data	• Sensitive to thick vegetation/forest cover; • Top few cm of soil; • Low spatial resolution.
Latent (LE) & Sensible (H) heat fluxes	• Twice daily to fortnightly; • 1 km to 100's m resolution	• Measure over different vegetation; • More direct link to energy balance driving water cycle	• Sensitive to cloud cover; • Higher res. data on longer timescale; • Hard work to validate.
Skin Surface Temperature	• Twice daily to fortnightly; • 1 km to 100's m resolution	• Measure over different vegetation; • More direct link to energy balance driving water cycle	• Sensitive to cloud cover; • Higher res. data on longer timescale

Synthetic Twin Data Assimilation Experiment

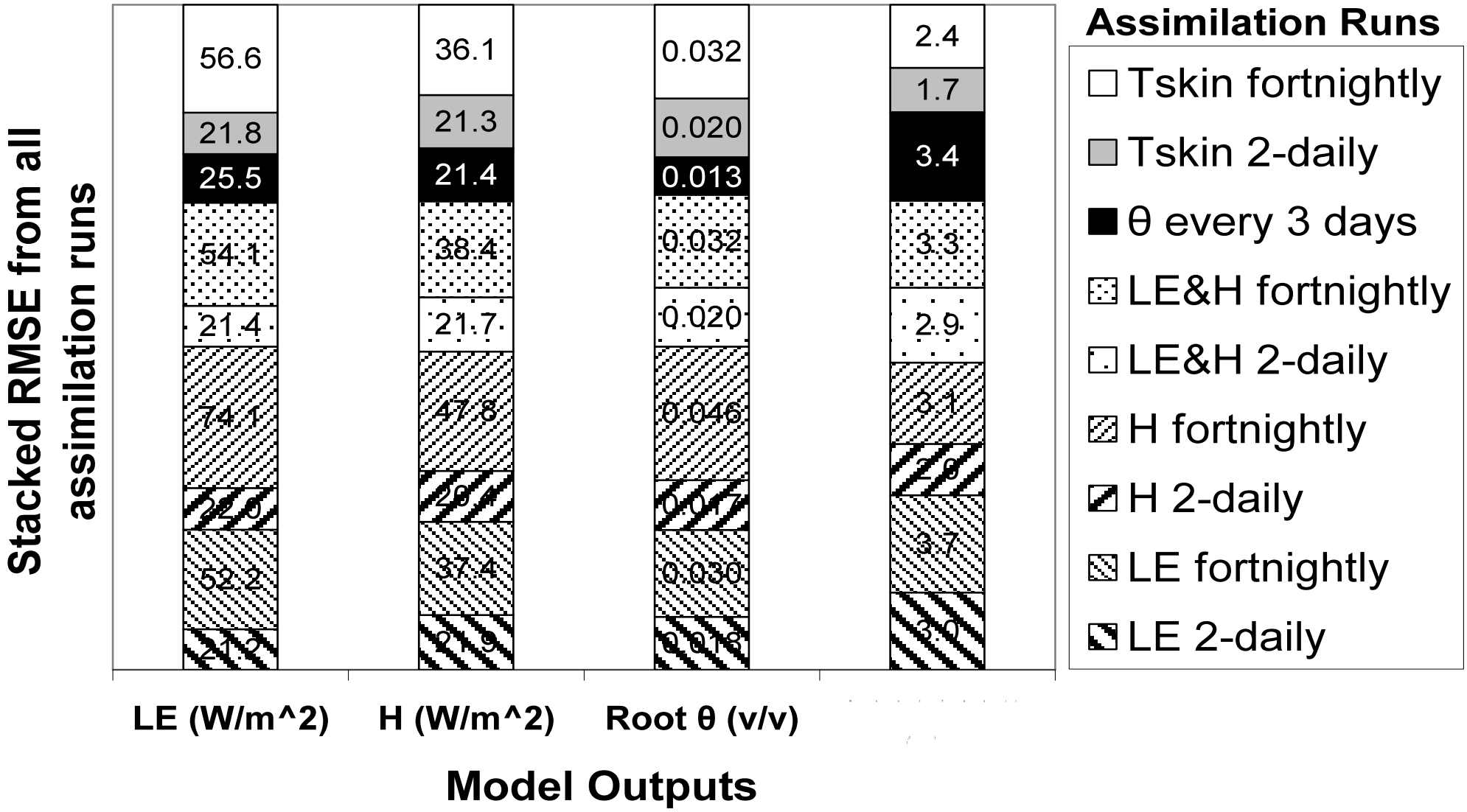
- **Proof-Of-Concepts Study**

- **Investigate the assimilation of different remote sensing data types and their impact on CBM/CABLE**
  - Assimilate synthetically derived LE, H, soil moisture and skin surface temperature observations on remote sensing time-scales
  - Examine how different observations impact on key hydrologic variables.

- **Published:**

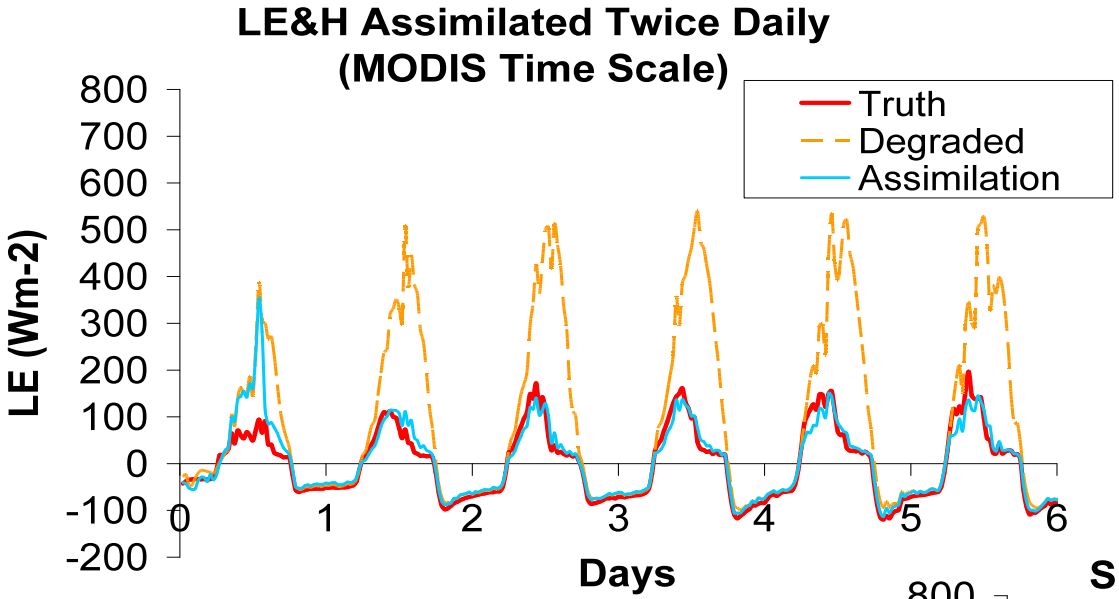
  Pipunic *et al*., 2008, Remote Sensing of Environment, vol. 112

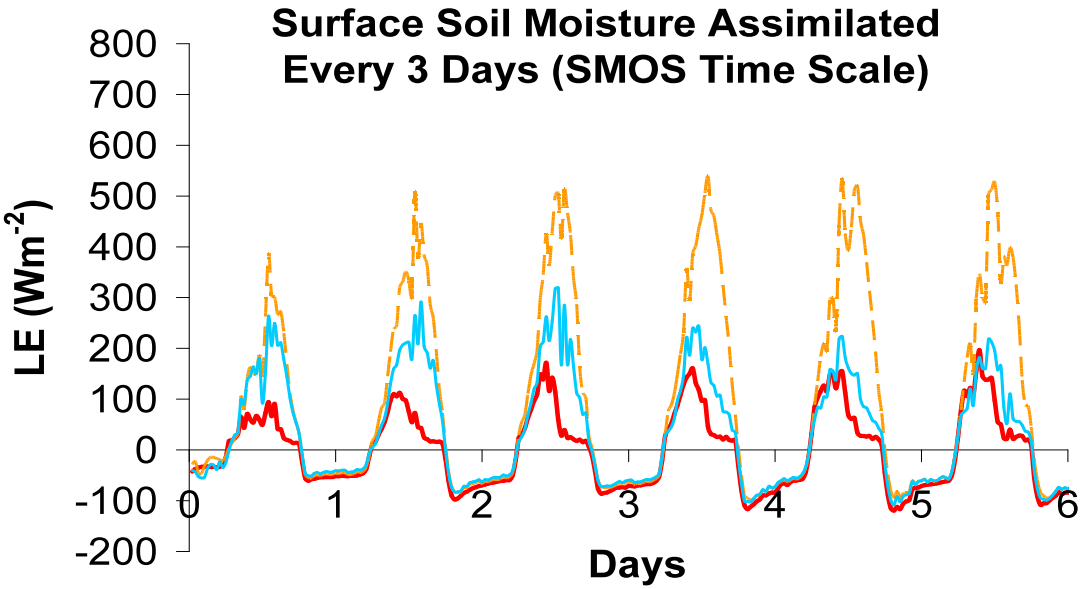
Multi-sensor Data Assimilation - Hydrology



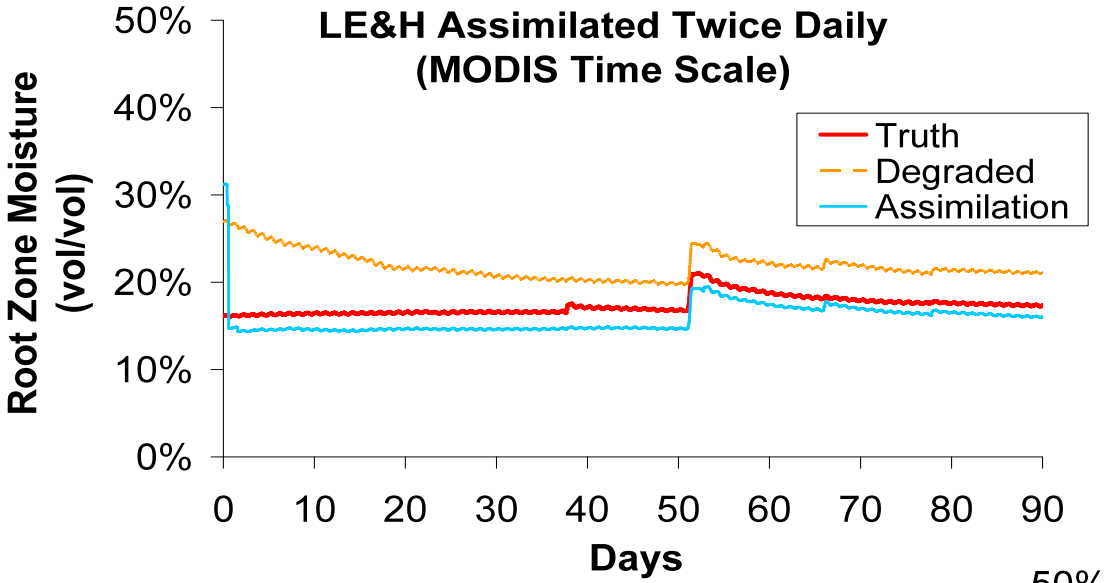
Pipunic et al., 2008. Remote Sensing of Environment, Vol. 112

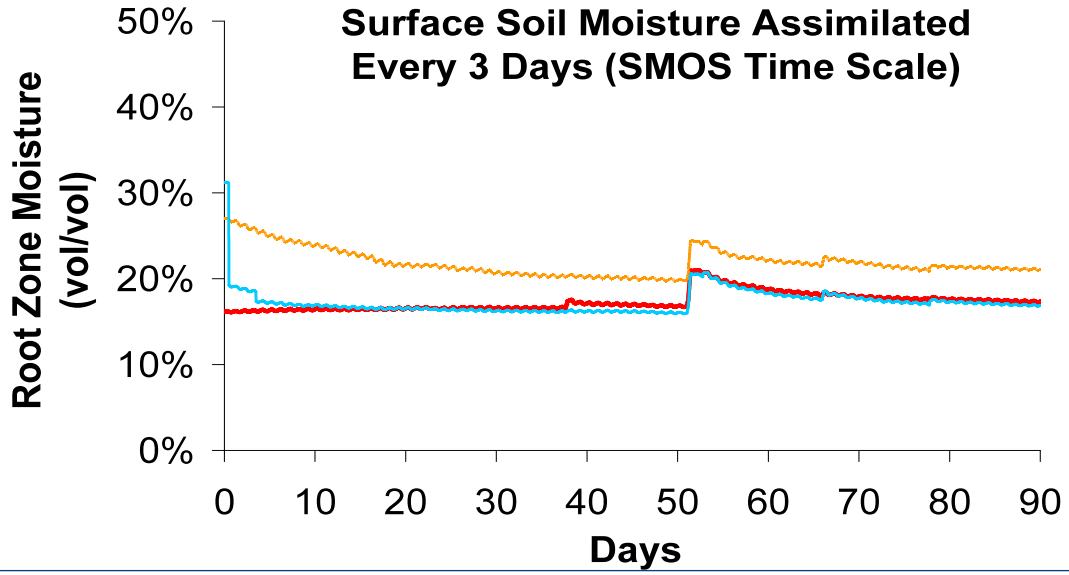
Multi-sensor Data Assimilation - Hydrology





Multi-sensor Data Assimilation - Hydrology



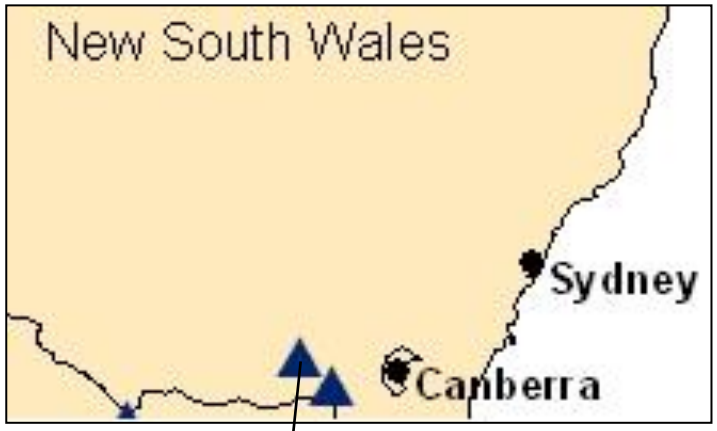


Synthetic Twin Summary

- **Soil moisture assimilation best for soil moisture → Does not necessarily translate to the best LE predictions**

- **LE, H and Skin surface temperature assimilation give overall better LE and H predictions on MODIS remote sensing time scale → More direct impact on model's energy balance**

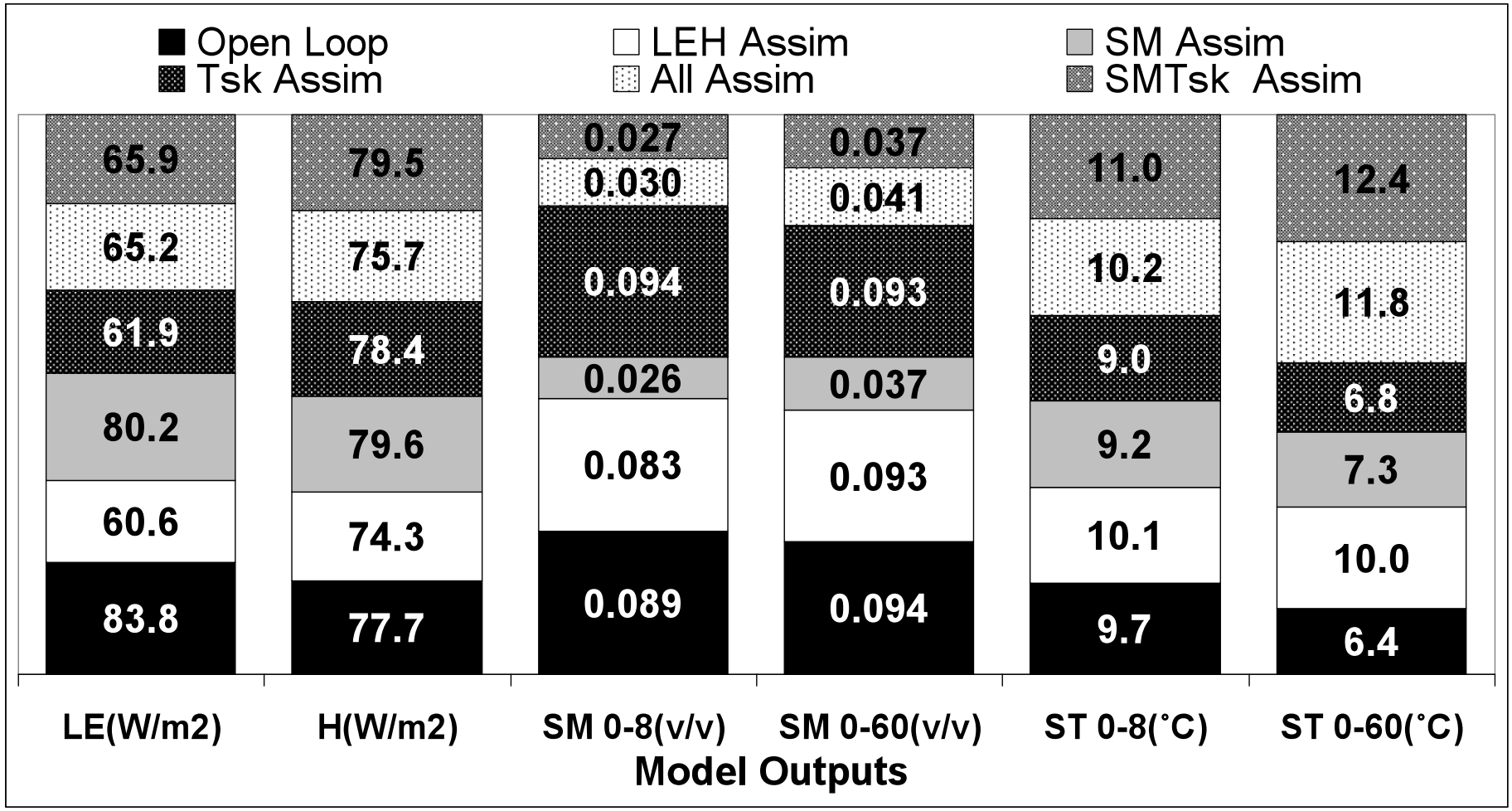
- **Alternatives to soil moisture assimilation seem promising for improving fluxes → Warrants further testing with real data……**



Kyeamba Creek

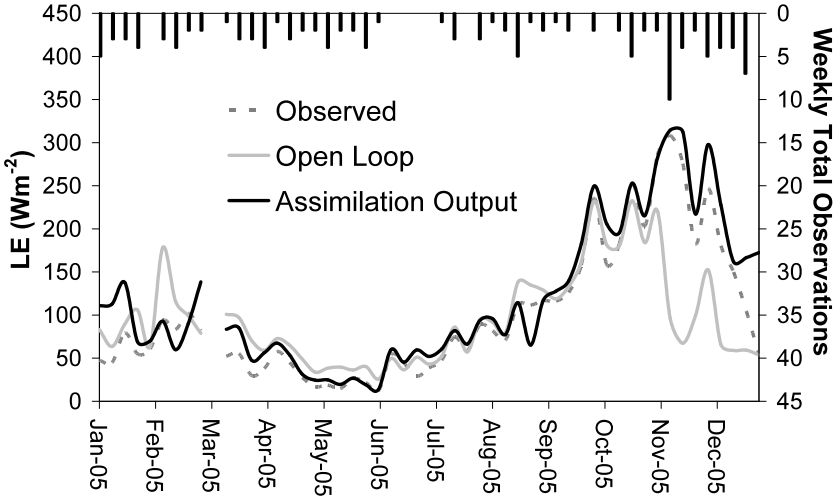
- Assimilation experiments with real 1D scale field data in Murray Darling Basin
- In-situ ET – Eddy covariance, Soil moisture, Skin temperature
- Observations sampled on remote sensing time scales (include cloud filtering for skin temp and flux data)

Kyeamba Creek Stacked RMSE

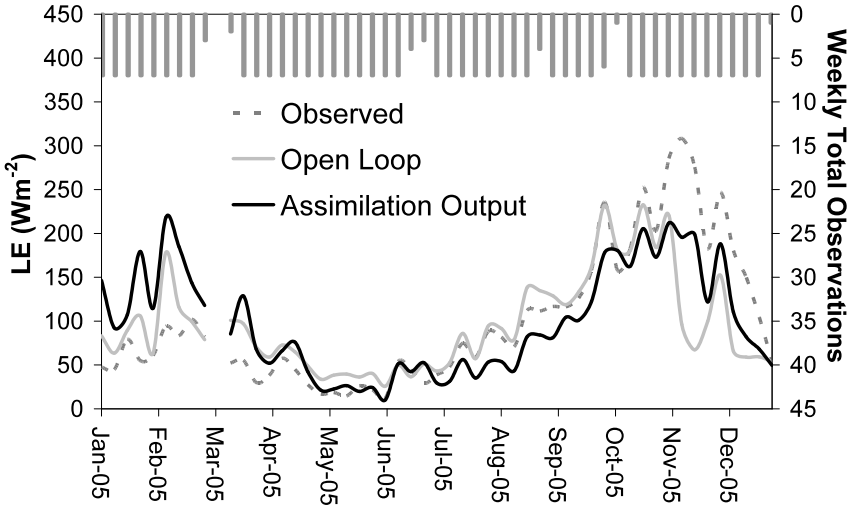


Kyeamba Creek study – LE Output

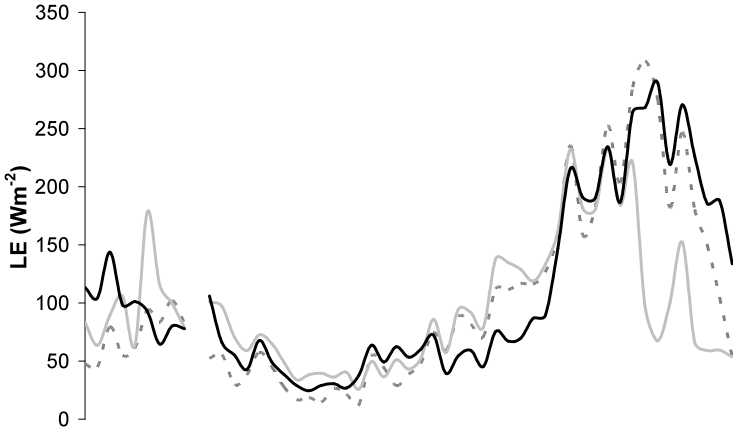
LE&H Assimilation



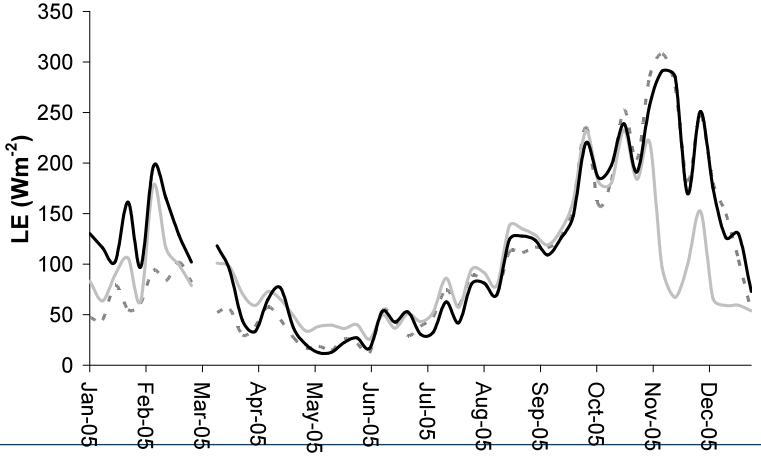
SM Assimilation



Skin Temp Assimilation



All Assimilated



Kyeamba Creek study – Surface Moisture Output (same as observation depth 0-8cm)

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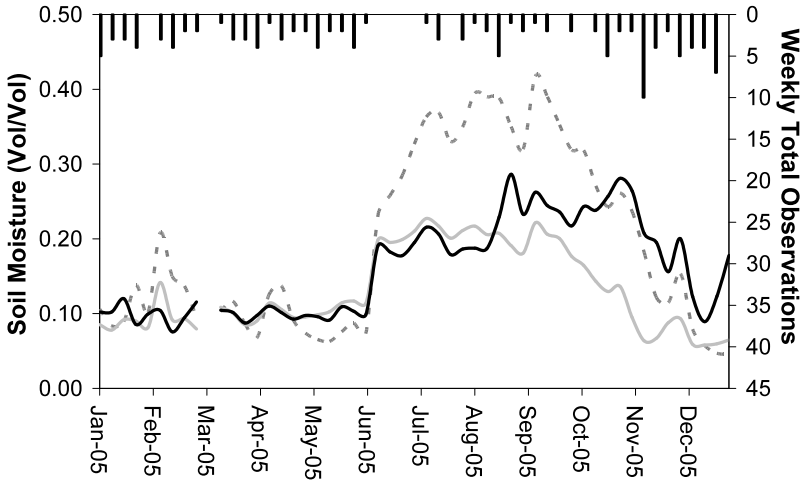
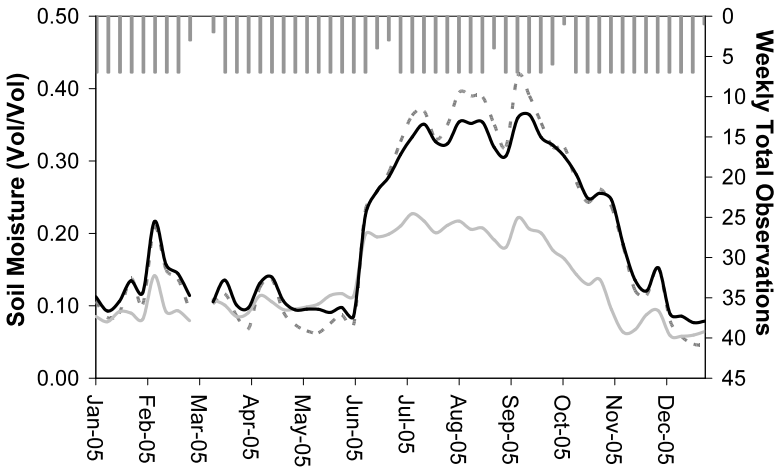
LE&H Assimilation



SM Assimilation



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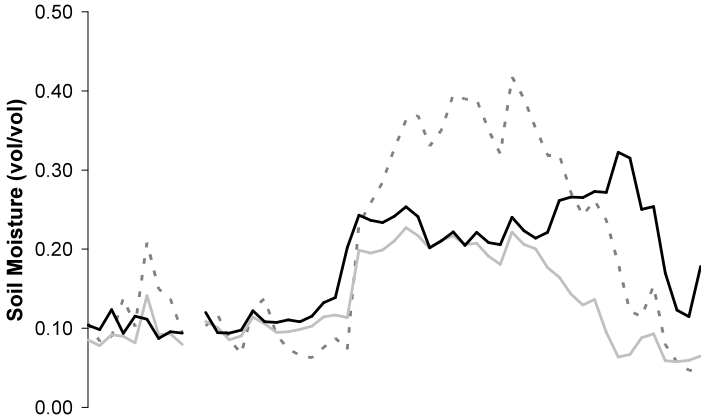

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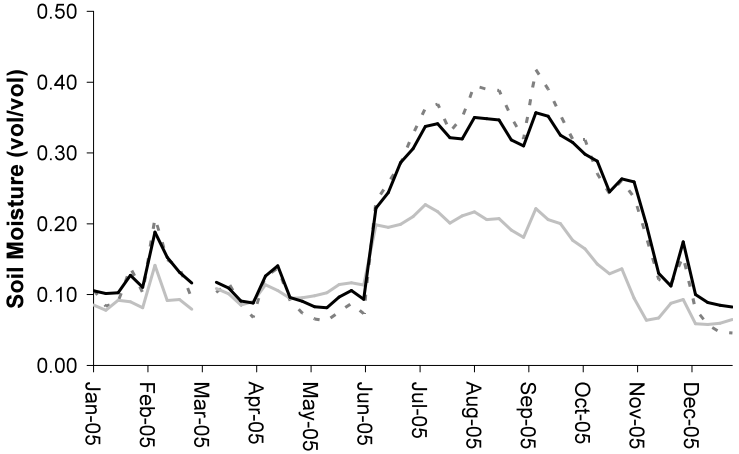

Spatial Remote Sensing Data Assimilation

- **Include AMSRE soil moisture observations (25km) and LE and H instantaneous products at 5km (SEBS algorithm – Su, 2002)**

- **Modelling over 25km AMSRE soil moisture pixel domain for Kyeamba Creek area. Model simulation resolution 5km.**

Spatial RS Assimilation – Soil moisture

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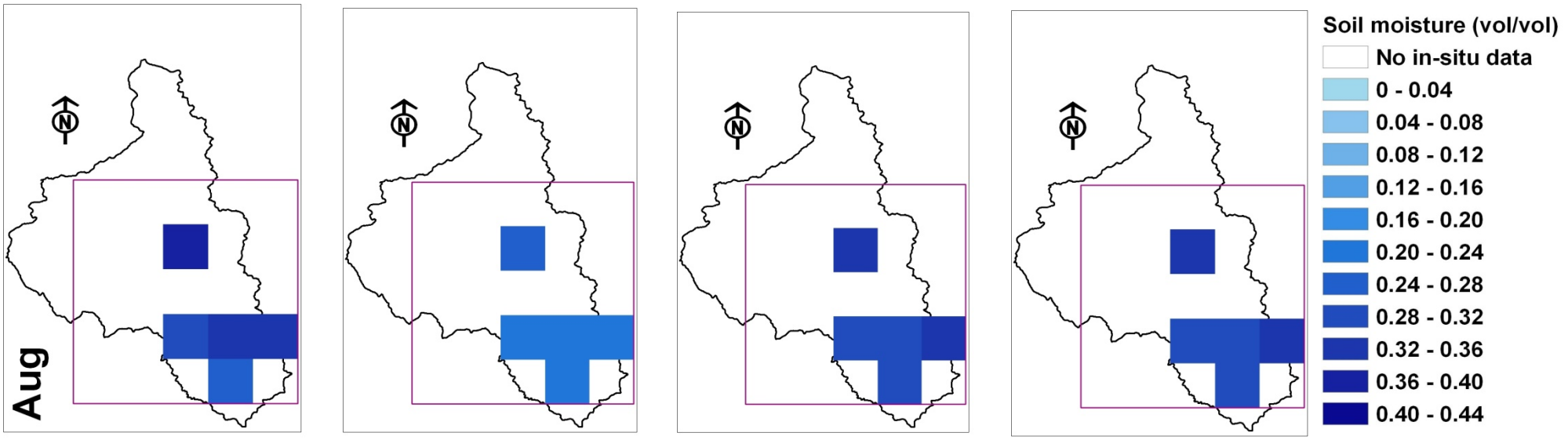
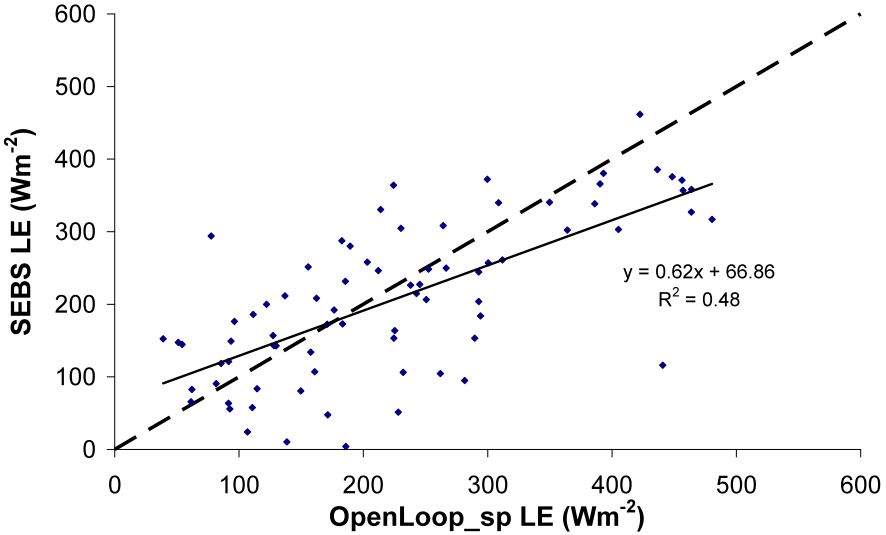
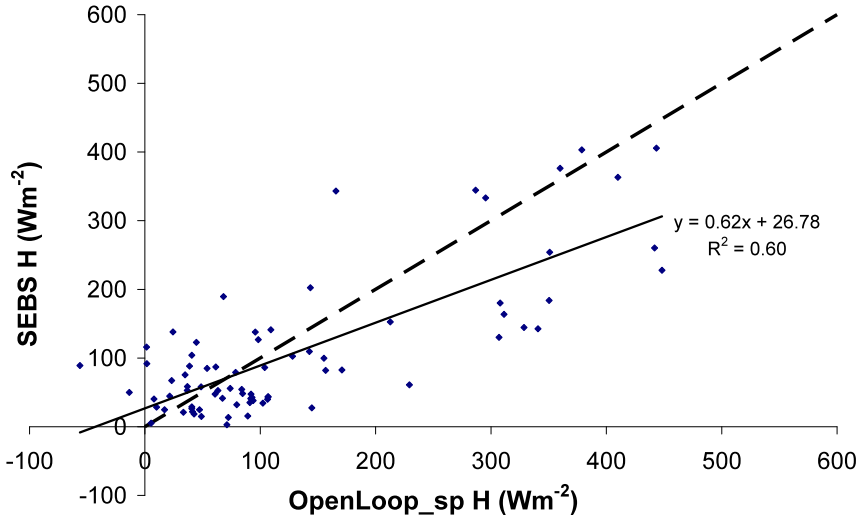
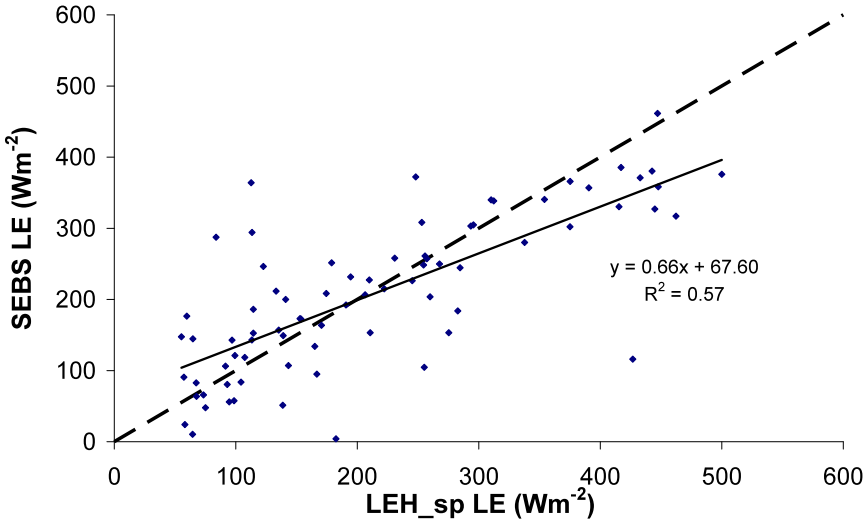
Obs in-situ | **Open Loop** | **SM Assim** | **Flux and SM Assim**

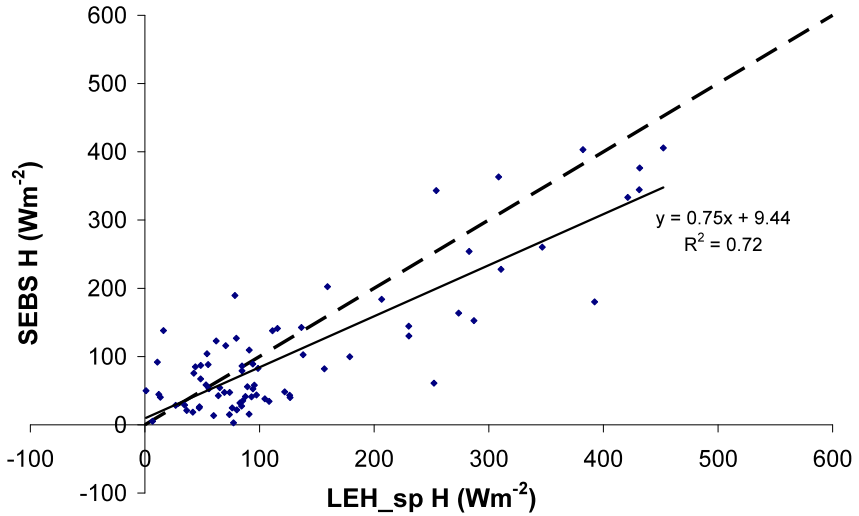


Spatial RS Assimilation – Fluxes









Summary

- No treatment of model structure, parameter error
- With more vegetation cover (higher LAI) skin temp has less relationship with prognostic state variables.
- With spatial RS data, number and scale of in-situ data inadequate to properly validate.

Current Work

- ARC Linkage Project with DPI Victoria
- Investigate data assimilation as a tool to highlight model deficiencies and target structural improvement.
- More detailed ground based monitoring activity to for Remote sensing calibration/validation.

Needs

- Greater observation network – different scales.
- Closer dialogue with model developers → want models with variables that are more closely matched to what we can observe