Satellite soil moisture data assimilation into the Australian Water Resources Assessment modelling system

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Water Resources Information in Australia

- Commonwealth Water Act 2007
- Australian Bureau of Meteorology (BoM)
  - Mandate: "Manage Australia’s water resources information …";
  - new responsibilities; new BoM Water Division formed.
- National water accounts & assessments

- Water Information Research & Development Alliance
  - WIRADA: An R & D initiative between the BoM and CSIRO;
  - partnership of $50M over 5 years (July 2008 – June 2013)

- Australian Water Resources Assessment (AWRA) system
  - Comprehensive reconstruction of the water balance for the whole country
  - Scale and accuracy acceptable for water resources management

[Links]
- Water balance across Australia (2000-2006)
**AWRA system**

*Australian Water Resources Assessment modelling system*

- Developed CSIRO-BoM for reporting on WRA and NWA

**System model components**

- **AWRA Landscape model (AWRA-L)**
  - Hybrid land surface model / conceptual RR model
  - Daily time step
  - 0.05-degree resolution grid across continent
  - Top-layer ($S_0$), shallow root ($S_s$) & deep root ($S_d$) soil layers

- **AWRA River model (AWRA-R)**
  - Node-link model (simplified sourceRivers)

- **AWRA Groundwater model (AWRA-G)**
  - Models aquifer dynamics SW-GW processes (incl. lateral transfer between cells, SW-GW interactions, recharge from overbank flows, models impact of extraction, ..)

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**Overall goal:** Develop and deploy a modelling environment to integrate surface measurement and remote sensing data systems for comprehensive water balance

* e.g. Streamflow, water table, bore data, reservoir data;

  vegetation indices, soil moisture, land surface temperature

**Specific goals of this study:**

Evaluate assimilation satellite soil moisture retrievals on soil water representation in AWRA-L

* Assess active and passive remotely-sensed soil moisture retrievals constraint on AWRA-L top-layer and shallow root-zone moisture estimates.

* Evaluate modelling against *in situ* measurements & cosmic-ray data

**Method summary:**

Sequential updating of AWRA-L model states (soil water storages) using the Ensemble Kalman Filter (EnKF) based on perturbed forcing and triple collocation for errors on satellite soil moisture products
1. Vrije Universiteit Amsterdam (VUA) – NASA soil moisture products
   - Volumetric soil moisture (m³m⁻³)
   - 0.25° x 0.25° - NN resampling to 0.05 ° x 0.05 °
   - Top ~1-2cm soil layer

2. Technische Universität Wien (TUW) soil relative wetness products
   - Estimates derived from active microwave ASCAT backscatter signal using the change detection algorithm (Wagner et al., 1999, Rem. Sens. Environ.)
   - Surface degree of saturation (0-1)
   - 0.125° x 0.125° - NN resampling to 0.05 ° x 0.05 °
   - Top ~1-2cm soil layer

Soil moisture data sets
Pattern and magnitude of errors appear consistent with others work, e.g. Dorigo et al., 2010, HESS.

Continental error estimates: using triple collocation (CDF* matched SM obs)

- VUA – AMSR-E
- TUW – ASCAT

Relative wetness
Continental satellite DA into AWRA-L

AWRA-L Relative wetness for 7 July 2009

- Continental AWRA-L data assimilation
  - EnKF using perturbed forcing
    - multiplicative perturbation on rainfall
    - Additive perturbation on air temp and shortwave radiation
  - Details in Renzullo et al., 2013, J Hydrol. (in prep)

- Simulations over the last 13 years. (~2-day turn around)
Soil moisture assimilation

ASCAT

AMSR-E

ASCAT & AMSR-E

Top layer relative wetness

0.0 0.2 0.4 0.6 0.8 1.0


Open loop
Assimilation
Observations

Evaluation @ OzNet • CosmOz • OzFlux
Evaluation: AWRA-L top-layer SM estimation

- 45 OzNet top-layer (0-8 cm) in situ measurement sites

- Percentage relative difference between open-loop ($r^0$) and analysis ($r^a$) correlation

- Correlation between model and in situ moisture for 1 July 2007 – 31 May 2011
Evaluation: AWRA-L shallow root-zone

- 36 OzNet shallow root-zone (0-30 cm and 0-90 cm) in situ measurements
- Percentage relative difference between open-loop ($r^0$) and analysis ($r^a$) correlation
- Correlation between model and in situ moisture for 1 July 2007 – 31 May 2011
Evaluation: AWRA-L shallow root-zone

- Cumulative distribution of the **analysis increments** of the AWRA-L soil water storage states (normalised by the forecast states estimates) pooled across the OzNet site and only for those times when satellite SM were available for assimilation
Evaluation: AWRA-L shallow root-zone

- Evaluation against cosmic-ray probes (CosmOz)

![Graphs and charts showing soil moisture and correlation for Baldry, Daly, Robson, Tullochgorum, Weany, and Yanco with AWRA-L 95% ensemble range.](image)
Conclusions & future directions

- A system for continental-scale data assimilation has been developed for Australian water resources assessments
  - Currently ingest satellite soil moisture retrievals into AWRA-L
  - Modular in design can be extended to assimilate wider range of gridded data products (e.g. other SM, evapotranspiration, vegetation indices, ...)
  - Further work will focus on coupling the landscape model (AWRA-L) and river model (AWRA-R) for streamflow DA.
- EnKF method is applied pixel-wise for the whole of Australia
  - Perturbed rainfall, radiation and air temperature
  - Future work will examine spatially-varying perturbations across the continent
  - Model error will be revisited
- AWRA-L soil moisture evaluation against ground data
  - AWRA-L open-loop simulation of top- and shallow-root layer SM highly correlated with in situ (OzNet) measurements
  - Soil moisture assimilation improved AWRA-L top-layer estimation when open-loop simulations were less correlated with in situ data than satellite SM
  - AWRA-L shallow-root zone (0-30 cm) estimates improved almost always after assimilation; 0-90 cm variable (but biggest improvements when AWRA-L open-loop estimates were poor).
  - CosmOz data promising new network to extend satellite and model evaluation to variety of landscapes around Australia
- Future: SM assimilation impact on wider water balance estimation
  - E.g. evaluation of AWRA-L runoff estimates – preliminary findings showed degradation, which points to inconsistency between soil water and runoff components in AWRA-L which needs to be explored.
Thank you

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