Soil moisture and temperature assimilation into the GEOS-5 land surface model

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Outline

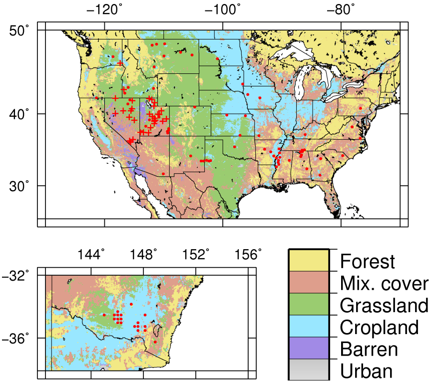
1. Assimilation of passive and active microwave C/X-band near-surface soil moisture retrievals
   - Improve model profile soil moisture
2. Calibration of microwave radiative transfer model
   - Enable direct assimilation of L-band brightness temperature observations, to improve model profile soil moisture and surface soil temperature
3. Assimilation of GOES skin temperature retrievals
   - Improve surface turbulent fluxes
   - Enhance assimilation of surface-sensitive radiances in GEOS-5 ADAS

1. Assimilation of passive and active microwave C/X-band near-surface soil moisture

More details: Draper et al (2012), GRL

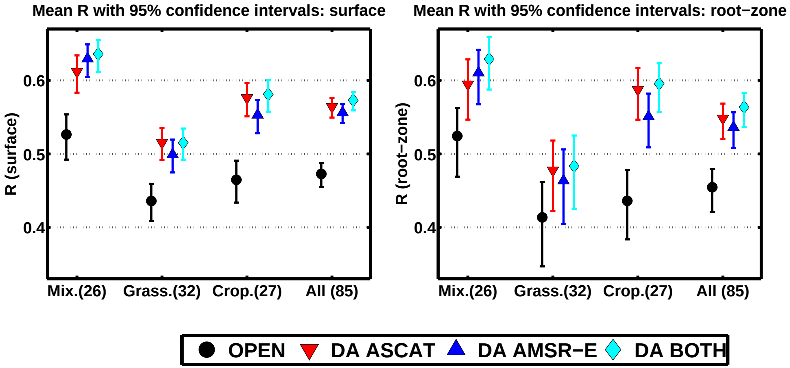
Outline

- Compare assimilation of near-surface soil moisture from passive (AMSR-E, LPRM, X-band) and active (ASCAT) microwave sensors into the Catchment model (GEOS-5 LSM) forced with MERRA atmospheric fields
- Assimilate with an EnKF from Jan. 2007 - May 2010
- Remove model-observation bias by CDF-matching the observations
- Evaluate against SCAN/SNOTEL & Murrumbidgee Soil Moisture Monitoring Network in situ observations



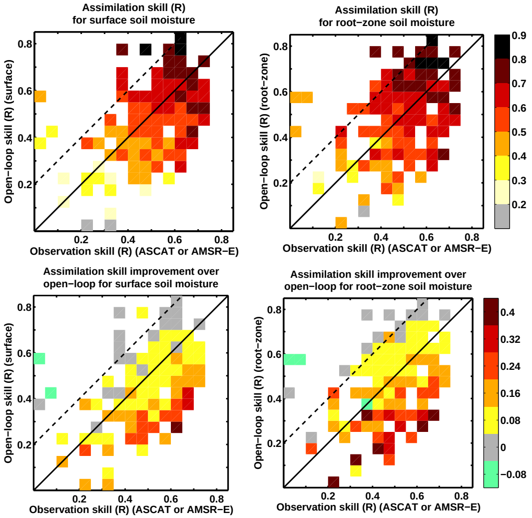
Assimilation skill by land cover class

Skill: anomaly correlation with in situ observations



- Mean root-zone R over all sites:
  OPEN 0.45, DA ASCAT 0.55, DA AMSR-E 0.54, DA BOTH 0.56

Contribution of observation skill to assimilation skill



- Based on assimilation of ASCAT or AMSR-E
- Confirms results from synthetic experiments of Reichle et al (2008)
- If (obs skill − open-loop skill) > -0.2, assimilation improved the model skill

Soil moisture assimilation summary

- Significant improvements to mean root-zone and near-surface soil moisture model skill from assimilation of ASCAT and/or AMSR-E near-surface soil moisture retrievals
- At individual sites observation skill must be substantially worse than model skill for assimilation to degrade the model soil moisture skill
- Recommend assimilation of both passive (AMSR-E, AMSR2) and active (ASCAT) near-surface soil moisture

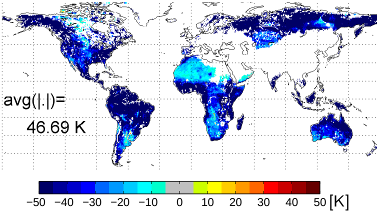
2. Calibration of microwave radiative transfer model

More details: De Lannoy et al (submitted), JHM

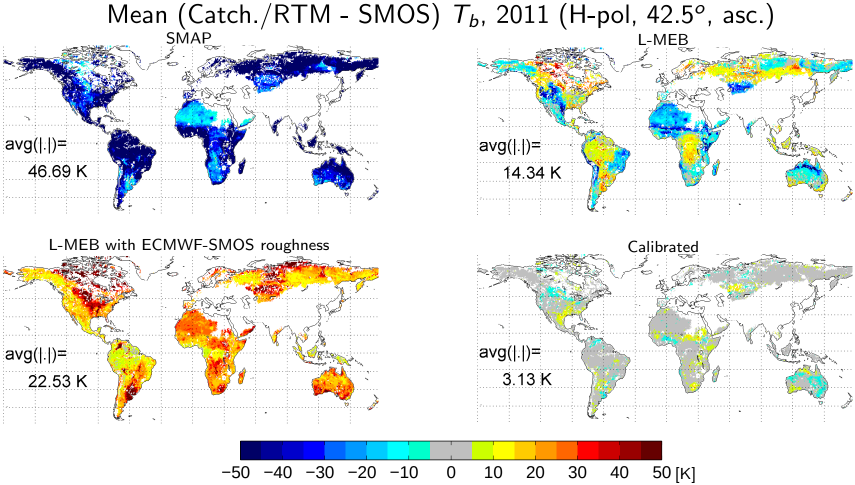
Radiative transfer model calibration

- Calibrate radiative transfer model parameters to reduce large biases between Catch./RTM and observed L-band brightness temperatures (T_B)
- Use L-band T_B from ESA's SMOS mission (launched 2009) in preparation for NASA's SMAP mission (scheduled 2014)
- Optimization of objective function measuring difference in long-term mean and standard deviation, and distance from prior
- Calibrate over 2010, validate over 2011

mean (Catch./RTM minus SMOS) T_B, 2011

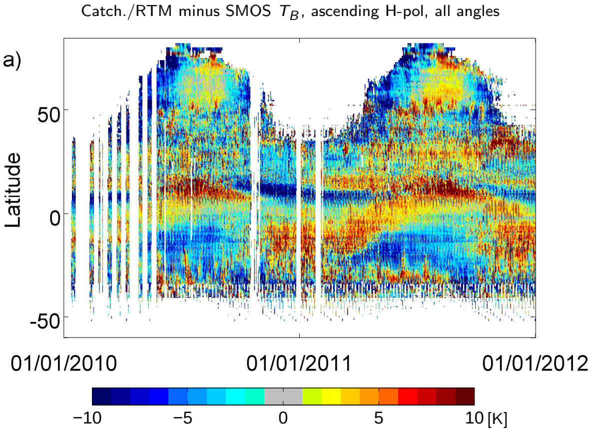


Reduction in bias from calibration



Best results: calibrate roughness, scattering albedo, and veg. optical depth

Remaining biases



Summary

- Calibration has greatly reduced the (very large) model-SMOS biases, allowing direct assimilation of L-band radiances (including SMAP)
- Remaining biases, due to both SMOS instrument calibration and Catch./RTM biases, are being addressed within assimilation

3. Assimilation of GOES skin temperature retrievals

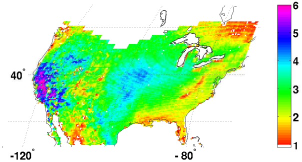
Outline

- EnKF assimilation of GOES-E/W skin temperature (T_{skin}) over North America, for JJA 2012
- Assign model-observation bias to the observations using a dynamic observation bias correction scheme
  - Bias estimates based on model-observation difference over previous 5-10 days
- Evaluate impact by comparison to twice-daily MODIS T_{skin} observations

GOES T_{skin} data

- Global high resolution T_{skin} product, provided by NASA Langley Research Center
  - Early results suggest comparable accuracy to MODIS
  - Currently available 3-hourly (cloud-free) at 0.25° resolution

T_{skin} observations per day (JJA 2012)

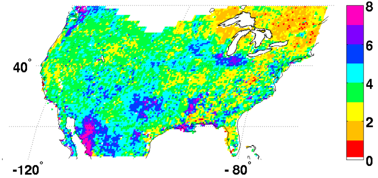


Scarino et al (submitted)

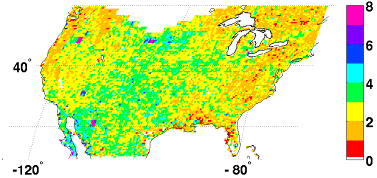
Daytime results (18:00 UTC)

RMSD between model/GOES and MODIS T_{skin}, after removing 3-month bias

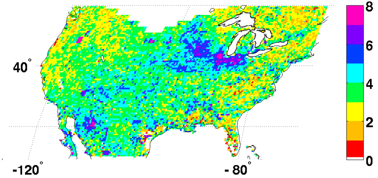
ubRMSD OPENLOOP (mean: 3.7 K)



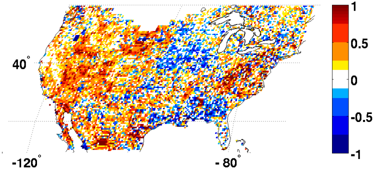
ubRMSD GOES (mean: 2.6 K)



ubRMSD GOES bias corrected to model (mean: 3.6 K)



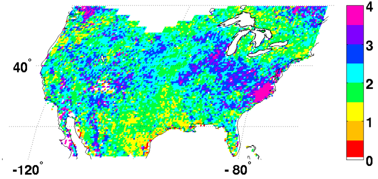
ubRMSD OPENLOOP - ASSIM. (mean: 0.15 K, 67% +ve)



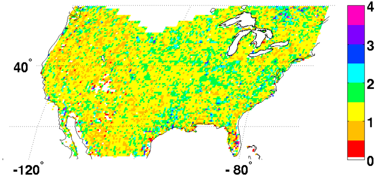
Nighttime results (06:00 UTC)

RMSD between model/GOES and MODIS T_{skin}, after removing 3-month bias

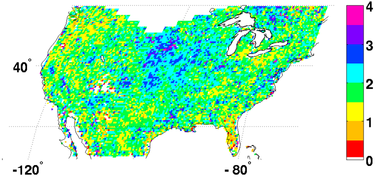
ubRMSD OPENLOOP (mean: 2.2 K)



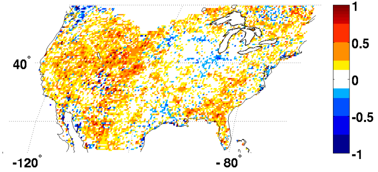
ubRMSD GOES (mean: 1.3 K)



ubRMSD GOES bias corrected to model (mean: 1.9 K)



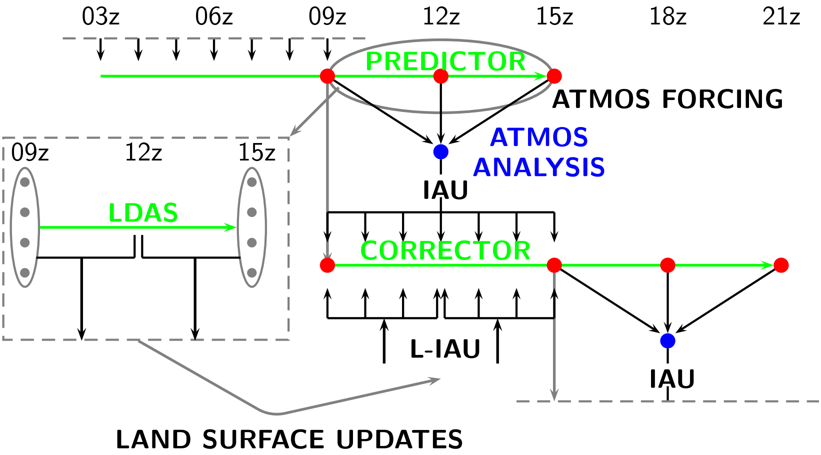
ubRMSD OPENLOOP - ASSIM. (mean: 0.13 K, 80% +ve)



T_{skin} assimilation summary

- GOES offers T_{skin} observations with high spatial resolution and temporal frequency
- Offline assimilation of GOES T_{skin} brings model closer to MODIS T_{skin}
- Next: assimilate GOES T_{skin} data into GEOS-5 atmospheric DAS/model, test impact on assimilation of atmospheric observations

Implementing the land data assimilation in GEOS-5



THANK YOU FOR LISTENING.

- Further details: clara.draper@nasa.gov

- MORE DETAILS
  ▷ De Lannoy, G., Reichle, R., Pauwels, V. (submitted), Global Calibration of the GEOS-5 L-band Microwave Radiative Transfer Model over Land Using SMOS Observations, *J. Hydromet.*
  ▷ Draper, C., R. Reichle, G. De Lannoy, and Q. Liu (2012), Assimilation of passive and active soil moisture retrievals, *Geophys. Res. Lett.*, 39, L04401.

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  ▷ Dorigo, W., K. Scipal, R. Parinussa, Y. Liu, W. Wagner, R. de Jeu, and V. Naeimi (2010), Error characterisation of global active and passive microwave soil moisture datasets, *Hydrol. Earth Syst. Sc.*, *14*, 2605–2616.
  ▷ Friedl and coauthors (2002), Global land cover mapping from MODIS: algorithms and early results, *Remote Sens. Environ.*, *83*, 287–302.
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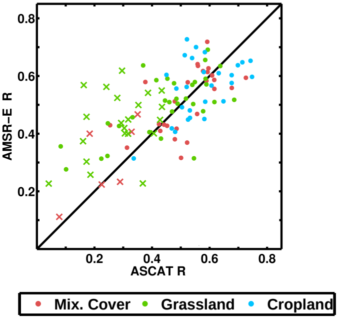
  ▷ Young, R., J. Walker, N. Yeoh, A. Smith, K. Ellett, O. Merlin, and A. Western (2008), Soil Moisture and Meteorological Observations From the Murrumbidgee Catchment, Department of Civil and Environmental Engineering, The University of Melbourne.

Remotely sensed near-surface soil moisture data

- AMSR-E: LPRM X-band (38 km resolution, depth < 1cm)
- ASCAT: C-band (25 km resolution, ~ 1cm depth)
- Both scaled into Catchment climatology using CDF-matching

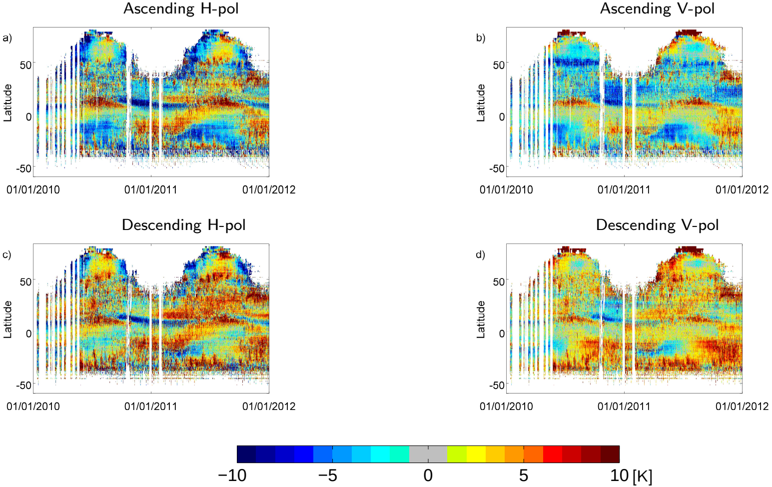


- ASCAT skill significantly lower for topographic complexity $> 10\%$ (crosses): data discarded
- Otherwise skill of ASCAT and AMSR-E is broadly similar (skill is anomaly correlation with in situ observations)

de Jeu and Owe (2003), Wagner et al (1999)

Remaining biases

Mean (Catch./RTM - SMOS) T_b (all angles)



Dynamic observation bias correction

Dynamically correct the observations to remove the model-observation bias

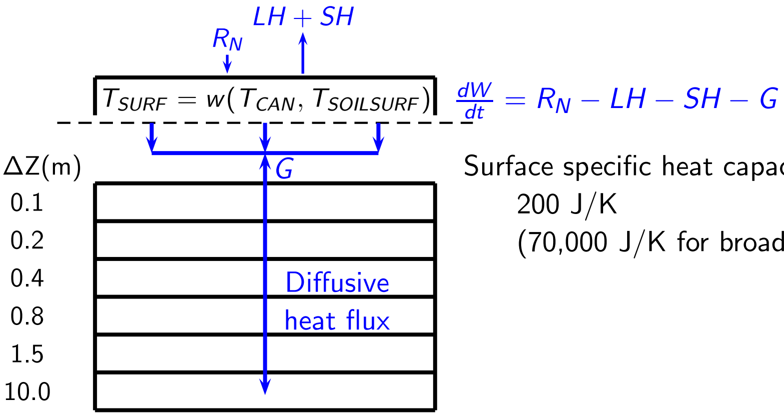
$x^{-}(t) = M(x^{+}(t-1))$
$x^{+}(t) = x^{-}(t) + K[Hx^{-}(t) - (y^{o}(t)) + Hb^{o-}(t))]$

$b^{o-} = b^{o+}(t-1)$
$b^{o+}(t) = b^{o-}(t) + \lambda[(Hx^{+}(t) - y^{o}(t)) - Hb^{o-}(t)]$
$\lambda = (1 - e^{-\Delta t/\tau})$

- Δt is time since last observation
- τ is time scale of bias memory (5 days)
- Separate bias model for each time of day

T_{SURF} in Catchment model

- T_{SURF} is blackbody radiative temperature, controlled by balance of surface fluxes



Surface specific heat capacity:

200 J/K

(70,000 J/K for broad-leaf)