Joint assimilation of SMOS brightness temperature and GRACE terrestrial water storage observations for improved soil moisture estimation

Motivation & Hypothesis

- **Soil moisture** plays a key role in weather & climate dynamics.
- Accurate estimates of soil moisture will enhance weather and climate forecast skill and will improve flood prediction and drought monitoring capability.
- We can improve soil moisture profile estimates by merging both SMOS and GRACE satellite based observations into a land surface model.

Measuring Soil Moisture from Space

**Soil Moisture and Ocean Salinity (SMOS):**
- L-band brightness temperature (Tb) at multiple incidence angles
- Launched Nov. 2009

**Gravity Recovery and Climate Experiment (GRACE):**
- Gravity observations to provides Terrestrial Water Storage (TWS) anomalies
- Launched Mar 2002

**PROS:**
- Tb depends on soil moisture
- Frequent obs. (1 obs./2-3 days)
- Good spatial resolution (~40 km)
- Only sensitive to surface soil moisture

**CONS:**
- TWS components: root zone soil moisture
- Coarse temporal resolution (monthly)
- Coarse spatial resolutions (~300 km)

Modeling Soil Moisture

**Catchment Land Surface Model (LSM), GEOS-5:**
- Surface soil moisture [0-5 cm]
- Root zone soil moisture [0-100 cm]
- Groundwater, and TWS

**NOTE:** rainfall is the main prognostic controlling modeled groundwater

**Pros:**
- Radiative Transfer Model (RTM) to estimate Tb
- Experiment specifics:
  - From Jan. 2010 through Jan 2015;
  - CONUS domain spatial res. 36 km EASEv2 grid;
  - MERRA-2 forcings [Serio et al. 2017]

Joint Assimilation Methods

**Assimilated Obs:**
- GRACE: TWS anomalies
- SMOS: Tb Vertical and Horizontal Polarizations (Tb1, Tb2) at 40°

**Run A:**
1) One month forecast ensemble integration with SMOS-Tb assimilation (SMOS run A)
2) GRACE-DA: Calculate model TWS observation prediction through spatial aggregation (model-to-observation grid) and temporal aggregation (daily to monthly). Calculate the increments via 3DEnKF analysis. Rewind the model to the beginning of the month and apply the GRACE increments (Girotto et al., 2016)
3) Run B: Integrate the model from the 1st- to the last day and re-perform SMOS-Tb assimilation (SMOS run B). Repeat for the following month.

Results: Validation

**Blue colors:** data assimilation (DA) is better than openloop (or model only, OL); **red colors:** OL better than DA

**Results: Impact on Soil Moisture Profile**

- GRACE-DA improves groundwater while SMOS-DA improves surface and rootzone soil moisture.
- The joint GRACE-TWS & SMOS-Tb assimilation maintains good skills in TWS, groundwater, surface and rootzone soil moisture.
- GRACE and SMOS-DA are complementary as:
  - GRACE-DA is responsible for most of the ensemble spread reduction in deeper moisture layer (i.e., rdzmc).
  - SMOS-DA is responsible for most of the ensemble spread reduction in shallower moisture layers (i.e., sfmc).

Conclusions

**References:**


**Acknowledgment:**

This study was supported by the NASA Terrestrial Hydrology, Water & Air Quality, Active Precipitation (WARP) mission, and GRACE and GRACE Follow-On (GFO) Mission programs.