Using Remote-Sensed Data to Improve Recharge Estimates

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by

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Importance of Knowing Recharge

- **Amount of discharge** is a function of **amount of recharge**

- It’s the **true amount of water** available for natural discharge and pumping (MAGs from DFCs are calculated estimates)

- Recharge typically the **greatest uncertainty** in water budgets

- Water-resource management tools (i.e., models) strongly **dependent on recharge**

- Recharge is **highly variable**, subject to periods of drought

- Within enclosed watershed, **all recharge is from precipitation**

- Remote-sensed data offer **new opportunities** to resolve recharge.
Example:
Devils River Watershed
Recharge Calculated from Precipitation

NEXRAD Database

- June 11, 2007: 2"
- May 1, 2007: 4.5"
- August 17, 2007: 10"
Actual recharge is dependent on **antecedent moisture**, precipitation frequency, duration, intensity, plus ET, temperature, vegetation, soil, etc.
Average recharge decreases with decrease in average precipitation and becomes negligible at some threshold.
Recharge rate calculated from river baseflow...
...recharge then correlated with precipitation

South Concho River January to March 2005

Discharge (m^3/s)

1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0

Days

Storm flow

Baseflow
Annual precipitation varies from 15 to over 30 in/yr in south-central Texas.
Recharge rates corrected for actual groundwater catchment areas
Distributed recharge is negligible when precipitation is less than 16-17 inch/year. Below the threshold, focused recharge.
Recharge is highly dependent on **antecedent soil moisture**...

...however, this weighting is highly uncertain.
What if we could use remote-sensed data from satellites to “measure” soil moisture at larger scales over short-time intervals?
Scientific satellite launches dramatically increased over last decade, smaller and cheaper...
Over 800 CubeSats have been launched
(10×10×10 cm and less than 3 lbs)
There is no single satellite that directly measures soil moisture/recharge...
...need to **combine information** from an assortment of satellites to “resolve” soil moisture/recharge.
Which satellites and what kind of data will help resolve recharge depends on landscape, environment, climate, etc...
This effort targets arid and semi-arid lands in Texas and elsewhere.
Arid/semi-arid landscape

Humid sub-tropical landscape
Half of the continental United States averages less than 20 inches precipitation per year.

Almost half of continental United States is semi-arid or drier.
Repurposing or Extending Remote-Sensed Data
Targeting visual/infrared and radar spectra
SENTINEL-1 (2014- present) Active RADAR 2 satellite constellation, 6-day global revisit

Very good at identifying where rain hits the ground
Active RADAR failed
CYGNSS – Cyclone Global Navigation Satellite System

Constellation of eight small satellites (CubeSats) (2016–present)

Couple ocean surface properties, moist atmospheric thermodynamics, radiation, and cyclone convective dynamics
GOES – Geostationary Operational Environmental Satellite

GOES-East (2017–present), GOES-West due later

Provides data for vertical atmospheric temperature and moisture profiles, surface and cloud top temperature, and ozone distribution
GRACE – Gravity Recovery and Climate Experiment
(2002-2017)

Measured changes in total water content:
surface water + soil moisture + storage
Satellite Data Integration

- **SMAP:** Passive Radar; Depth – 5 cm
  - Large-scale changes in surface radar properties

- **SENTINEL-1:** Active Radar; Depth – 2 cm
  - surface properties (outcrops versus soil; irrigation; plowing)
  - Improves “footprint” of storms

- **CYGNSS:** Passive GPS-Radar; Depth – 5 cm
  - Calculate flooding extent (overland flow?)

- **GOES:** Visible and Infrared Light
  - Estimate surface temperature change (re: soil moisture & ET)
Importance of Radar in Soil Moisture

- **Rain** reflects radar, gives **location and magnitude**

- **Radar signal changes** indicate **surface water and soil moisture storage changes**

- Radar signal **dependent on:**
  - **surface texture and look angle** (which side of a hill)
  - outcrops, topography, and **surface changes** (plowing)
  - **Vegetation**
Spatial Resolution
Varies with Platform

- **SENTINEL 6-day orbit**: 10 m
- **GOES hourly**: 14 km
- **CYGNSS sub-daily**: 25 km
- **SMAP 3-week orbit**: 40 km
- **GRACE monthly**: 1 degree

Recharge zone
San Antonio
CYGNSS can improve estimates/measurements of both distributed and focused recharge.
SENTINEL-1 can improve measurement of precipitation location and magnitude

Minimal Precipitation in NEXRAD Data

Major Discharge Event

Devils River Precipitation vs Discharge
Example of Gap in NEXRAD Data
State of the Science

Improvements in Soil Moisture Using Remote-Sensed Data

- Sentinel-1 **improves precipitation** footprint & surface changes
- CYGNSS offer possibility to **identify overland runoff** – important to **focused recharge**
- Algorithms being developed to **automatically account** for plowing, irrigation etc.
- **Ground-based soil-moisture measurement** modified from sole-source of data to groundtruthing
- **Integration of all remote-sensed data** for resolving soil moisture continuing
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