Questions & Answers Session 2

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Amita Mehta (amita@umbc.edu) or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: To what extent has the Ethiopian dam affected the flow of the Nile River through Egypt? Also, the area surrounding this dam is tectonically active so what are the risks of destroying this dam due to politics or a sudden earthquake in this area?
Answer 1: So for the first question - the influence of the dam on flow has yet to be known, exactly. They haven't begun to fill the reservoir to any significant extent. That will happen soon. When they do, there is an ongoing negotiation about when that filling will occur, and that's an ongoing question for Ethiopia and Sudan and that's in the realm of political discussion, and we're optimistic an equitable resolution will be made. The rate at which the reservoir is filled will have an impact on how the water flows downstream. It's a reservoir for a hydropower facility and the way you make power is putting water through turbines, and there's perhaps some evaporative loss, but there won't be continually diversion, that's mostly during the filling stage.

Second half of the question: certainly, I am no different than anyone else that such events are avoided, but I don't have the expertise to comment on the structure of the dam re: tectonics, but I can't comment any further.

Question 2: Is the correlation between area and ET estimates accounting for autocorrelation, spatial, and temporal?
Answer 2: Yes - we do account for temporal autocorrelation when doing significance tests of correlations, though note fit is useful almost regardless since in this application it's okay if autocorrelation contributes to the estimate of coefficients. But to make sure we're getting an unbiased estimate of significance of predictors we do test for significance with corrections for autocorrelation. Spatially, for the Sudd test case we're looking at an area total, so spatial autocorrelation doesn't really play in.

Question 3: Can you reverse calculate the effect on temperature maxima based on the amount of water removed from the wetlands?
Answer 3: Q both about base state and in case of diversion - how does that reduction in latent heat flux reduce temperature. That would be a neat thing to try. We'd have to think about atmospheric conditions, winds, everything you do to figure out air temperatures, so our analysis could contribute, but more data or models would be required to generate an estimate.

Question 4: Up to what size of river basin can GRACE data be used? How course is GRACE data?
Answer 4: GRACE data is - this is a point of caution - if you go online to the NASA websites you can download gridded GRACE data at 0.5 degree resolution (~50.5 km). That isn't GRACE's true resolution, you think of it as having a smoothing radius of 300 km, so you're talking about 200,00 km2 area for any one observation, and there's horizontal autocorrelation beyond that. I would not try to use GRACE on a river basin less than 3x3 degree size. And even that we would still want to look carefully at the analysis and look at neighboring areas. You don't want to just use GRACE for a point or 50 km watershed. You want to look at larger water basins.

Question 5: What is the difference between assimilating soil moisture data into a land surface model (LSM) and calibrating the LSM with soil moisture data?
Answer 5: Those are two powerful ways to make use of remote sensing data in modeling context. In data assimilation, you're correcting the model in run time. As the model runs forward, you don't change parameters of the model, you correct predictions. In calibration, you run in iterative mode and run through the simulation many times and adjust parameters until you get a better match between simulation and satellite observation. Both are good ways to use the data. We're doing assimilation because we're looking at adjusting runs as we go, rather than adjusting parameters, but both approaches are quite powerful.

Question 6: Instead of using GRACE data to calculate delta storage, can you use SMAP soil moisture (SM) to calculate delta storage, which I assume would be SMAP SM@time2 - SMAP SM@time1?
Answer 6: Right - you can use SMAP to calculate change in storage. Because GRACE responds to gravity, you're getting surface, groundwater, snow - that change is

showing *total* change in soil. SMAP is useful for looking at SM - particularly surface SM. You're looking at higher frequency changes in surface conditions as opposed to GRACE, which is longer-term storage conditions.

Question 7: Would the LDAS products be suitable for water balance analysis in small scale catchments?
Answer 7: Possibly. You know the precipitation best you can get from NASA and related products range in resolution from 5 km grid to 25 km grid. And you can make estimates at that scale. That'll drive the LDAS which has parameters that are high resolution. As you go to larger areas, you typically get that errors balance each other out. But the models in the LDAS, because of their assumptions about lateral transport, you want to look at watersheds that are averaging over catchment areas rather than one slope. Once you're over a certain area, the models are reasonable.

Question 8: What is the minimum size of the basin for which we can use GRACE to estimate storage? If our basin is part of the bigger basin would it be correct to use proportion of GRACE estimates for storage?
Answer 8: If you have a GRACE estimate for a large basin, and you want to do a localized estimate for a subbasin, can you use a proportion of GRACE estimates for storage? Be careful. The large basin might not be uniform. If some portions have more or less water storage variability, you might get an incorrect estimate. But there are ways to be clever about combining GRACE with other aggregations - for example, that's one motivation for data assimilation with GRACE, since it allows us to weight GRACE at sub-observation resolution based on higher resolution data.

Question 9: In slide 14, storage is higher than precipitation for Blue Nile. How can it be possible?
Answer 9: Storage being higher than precipitation - we're always looking at changes in storage over time - it is possible for storage to be higher than precipitation at any given time.

Question 10: Will estimation of the river discharge be used from satellite be used for hydrologic/hydraulic modelling? Does this river discharge be used for monitoring river discharge instead of river gauges?

Answer 10: Yes - we already use altimeters - these active radar emissions - to look at stages of the river - height of the river. In places that can be associated with discharge flow through rating curve you can have synthetic gauges and when you have a satellite overpass you have an estimate. There are some disadvantages, but it's been quite useful in some large rivers. Right now, with future missions like SWOT - will provide power to do that altimetry on smaller river, and hopefully we'll see a proliferation of satellite data as synthetic gauges.

Question 11: Why was the difference between the Alexi and the LDAS when analyzing in parallel? In the northern part of the Nile is it better to use the GPM and the Alexi?
Answer 11: There are different reasons ALEXI is different than LDAS. In the northern part of the Nile, it's lower - that's quite dry - your choice of precipitation product doesn't really matter. Using ALEXI and comparing to simulation that includes irrigation was the best we could think to do. In the headwaters of the Nile, you have a choice between GPM and LDAS to get an ET estimate or use ALEXI (an inverse method getting at ET through energy balance). This is an open question - each is open to uncertainty, and limitations. In hydrologically complex areas, if it's a place we know the model doesn't quite have the info it needs, I would put more faith in ALEXI as closer to an observation. If we're looking at Nile highlands of Ethiopia with steep topography, and ALEXI is going to have uncertainty because of shadows and view angle, there could be benefits to the GPM/LDAS approach, and I'd view them as two, independent methods and try to constrain uncertainty by using both. I wouldn't be comfortable saying one is definitely better than the other without in situ data.

Question 12: How did you estimate other water users in the basin like Municipal and Industrial water use?
Answer 12: We didn't. Our assumption here is irrigation is the largest consumptive use of water in this basin. That's a reasonable assumption for this basin. But in getting into details, particularly in urban areas, you want to account for such users.

Question 13: What is the latency of the TRMM/GPM, ALEXI, and GRACE data, i.e. how soon after image acquisition can one get Precipitation, Evapotranspiration, and Storage?
Answer 13: Latency is a big issue if you want to do this in real time. GPM is fast, you get that within 4-5 hours, at least for some of the products. ALEXI has some latency,

but talking around 4 weeks. GRACE is just slow - just now starting to work on near real-time (NRT) products, but those can be a couple of months behind, so it's more useful for retrospective. Part of research trying to use GRACE for NRT and hopefully that work will reduce latency. GRACE-FO has specifications that include the goal of reducing latency times to less than a month.

Question 14: You had mentioned that these are estimates, so how comprehensive should ground truthing be to make a viable decision from the regulators' point of view?
Answer 14: This is a big question and I don't think there's a single answer. I would say that there are advantages & disadvantages to using models/rs instead of in situ. In situ is always going to feel concrete, but it isn't always representative. River gauges are good integrated but rainfall gauges don't always capture diversity of landscape. In some ways, the question applies no matter what the data source is. How much information do you need? That's why this is a conversation - there has to be discussion with decision makers on what they have confidence to act on. Examples from US where regulatory decisions are made from remote sensing. In our experience in transboundary basins, it can encourage people to look at the problem through the same lens. There's good value in them already. The other part of this question is how much effort should we put into ground truthing, and as a hydrologist, I say as much as possible.

Question 15: Do climate change impacts feature as an input? This is important for those of us to do compliance monitoring of water resources over time.
Answer 15: The results showed today include climate change insomuch as climate change has occurred in the last several decades. We are not presenting projections, which is a different question. There's changes we see in the record and we think we're accounting for them. For future projections, you can use tools like the models we used coupled with climate models. In that context you aren't directly using the satellite data other than to evaluate the model, but you then take what you learn from retrospective analysis and apply it to a simulation of future conditions.

Question 16: Will the effects of the reduction in the SUDDS wetlands to flora, fauna and groundwater recharge from the wetlands be assessed?
Answer 16: I would certainly hope if the canal is brought back - if that plan comes back - there would be a thorough, neutral, objective of environmental impacts. Right now,

the Jonglei plan was abandoned and it isn't actively going forward. Should the plans be activated, that question is critical.

Question 17: I think there is an error in the example of the Jonglei channel. The surface should be in square kilometers and not in cubic kilometers?
Answer 17: Perhaps - we'll check the slides. If it's area, it should be square and not cubic. Volume is cubic.

Question 18: What are the basic requirements for monitoring and predicting water balance for a case study?
Answer 18: It's hard to answer that. It's a good, but general question. You need to start from your objective. Once you know what your goal is, how big is the area, what fluxes are most important, what resource questions are you trying to address. Then you can come back and go through requirements, and it really depends on context.

Question 19: Is it possible to estimate soil moisture flux using remote sensing?
Answer 19: Not sure what you mean by soil moisture flux. SM content - yes - we do that through passive microwave and active missions (e.g., SMAP). The flux - well, SM can flux through latent heat flux through the atmosphere (ET) or through drainage. Not aware of any satellite mission to monitor drainage.

Question 20: What is the spatial scale for evaporation?
Answer 20: We were using 5 km resolution - there are different - on the order of 5 km resolution.

Question 21: How did you estimate the errors on the remote sensing data (rainfall, land ET...)?
Answer 21: For rainfall: TRMM & GPM and all products are distributed with error estimates. We used NASA provided error estimates. For ET, ALEXI does not have as formal an estimate. They don't have spatially distributed estimates so we worked with data producers to estimate what we thought the error estimate was, but it was a more informal approach. When it comes to water storage from GRACE, that's distributed with error estimates.

Question 22: Can I know the difference between VIC model & ArcSWAT?

Answer 22: Didn't use VIC or ArcSWAT in this analysis. VIC is an advanced land surface model (we have an ARSET training on that!) - ArcSWAT (ArcGIS implementation of SWAT) semi distributed, and the water balance models - it doesn't solve for energy balance and has implications depending on your application. Two advanced modeling systems that, if you're trying to decide between the two, want to read up on how they've been applied in the past and see advantages/disadvantages. ArcSWAT is popular because of the way it's implemented. If you or your team are comfortable working in GIS and not command line, ArcSWAT is a great option.

Question 23: The water balance calculation of Sudd area seem did not consider the groundwater component. Why was this left out, and if it was to be included what source of remote sensing data could have been used?
Answer 23: Good point - so, we were really looking at this in terms of surface water fluxes in water storage since that's the largest variability. We did apply GRACE data (maybe I didn't show it today) to look at total water storage to see if there was a significant groundwater component not evident in surface water estimates. One could use a combination of methods, for example, you could use SAR radar data to look at water extent, altimetry to look at height estimate, and GRACE to look at water storage to find out what's going on at the surface. We looked at that and don't remember the details. But found surface water most relevant.

Question 24: To what level of detail is it possible to estimate the ET with satellite images?
Answer 24: Landsat satellite-derived ET has resolution of as fine as 30m (METRIC ET), MODIS is 1km, ALEXI is 5 km, GLDAS is 0.25x0.25 degree.
Live: It's true that there are Landsat products that can get down to sub-100 m and some are at 1 km for MODIS, as well as at 4-5 km for geostationary. It depends on the product you're using. What limits your resolution is the thermal band, though some disaggregation is possible using thermal in combination with visible / near-infrared data. That's the resolution at which you can apply the satellite estimates.

Question 25: The proposed model for calculating Storage capacity is applicable only on a global scale?
Answer 25: No it is applicable to river basin scale --

The LDAS system is flexible and can be applied at gridded resolutions of 1 km or finer depending on input level. Storage measured by GRACE/GRACE FO is more limited and you'd be looking at larger basins on the orders of 100s of sq km

Question 26: How about the general resolution of Land data assimilation system?
Answer 26: The pre-existing products - GLDAS is .25 degree. The system itself, however, is flexible and can be implemented at any resolution you want. When implementing, it depends on what the true value-added resolution of your inputs is. If you're using a NASA precipitation product with 8 km resolution, you might decide to implement your model at that resolution. If you have topographic info at sub-km resolution, you might go to a higher resolution. Our app looked at 5 km resolution, which had to do with our inputs in the region we were studying.

Question 27: Has anyone looked at the SSEBop Evapotranspiration products from USGS? Simplified Surface Energy Balance (Senay et al, 2012)
Answer 27: Yes - absolutely. That has been looked at quite a bit. That product is used in Africa. One study, maybe more, has looked at ET products for this region. It does well. It's hard to determine whether SSEB or ALEXI is better, since both or similar and in situ data is limited. But that's a very good product, and I'd recommend it for this part of Africa.

Question 28: GRACE data contains a sometimes substantial amount of error (Landerer and Swenson, 2012). How do you incorporate error when comparing GRACE dTWS to water budget-derived dTWS?
Answer 28: We do it by using the errors reported to us by NASA and in papers like the one in your question. We understand the uncertainty in GRACE, you can also estimate the residual error in water storage. We view those in multiple estimations. We don't take sides. We look at them both and consider a consensus estimate. So for example, in a place with a strong groundwater trend - maybe due to ET from irrigation - we're trying to simulate that in our system, but some products don't account for that (like GLDAS). If a water storage estimate that uses GLDAS is different than the one we use GRACE in an area with irrigation, we might view that. We know GRACE can struggle in coastal regions and peninsulas where the ocean is hard to mask out - we might put more faith in an LDAS estimate in places like that.

Question 29: Is the total area of the Sudd by SAR derived from time series of images or simply one image?
Answer 29: That's a time series. The SUDD is changing in area all the time. We took multiple SAR images from different dates.

Question 30: Regarding land surface model what about if there are no trees in the area? Do we need vegetation to control water balance?
Answer 30: The land surface model can be applied in any ecosystem setting, so we run it in deserts, farmland - the idea is that it has parameters to account for that. In areas with trees, deeper rooting depth, more vegetation - that would be accounted for with more ET. If it's barren, the water would have to runoff and it would be largely inaccessible. You'd see that in the petitioning of the hydrologic fluxes.

Question 31 Is there a LDAS for Africa? Europe?
Answer 31: At present for Africa, the best operational, public LDAS is the famine early warning system LDAS. It simulates 3 different domains that collectively capture (I believe) all of sub-saharan Africa. That data is all available from NASA from GESDISC. It's at 10 km or .1 degree resolution and runs up to NRT. That's an excellent product for Africa, but it doesn't account for irrigation.
For Europe - I'll plead ignorance since I don't do much work there. GLDAS is available there, but I'd have to assume there are groups running high resolution analysis but not aware of product names.

Question 32: The Noah Land Surface Model you mention is the one from WRF model? (https://ral.ucar.edu/solutions/products/unified-noah-lsm)
Answer 32: Yes. WRF runs with NOAA land surface model, and can run with NOAA multi parameterization

Question 33: I would like to ask about the scale. The Sudd has a big area that you can deal with RS resolution. Can we use the same technique in less scale for instance Marchal floodplain in Nile basin as well?
Answer 33: Yeah - excellent question. The Sudd is big, so that helped us. In smaller places, you can. You know, the ESA now has Sentinel-1 SAR in space, which is quite high resolution. You should be able to use that in smaller areas. I have not attempted

to do that in my own work, but it should provide high resolution with the same technique.

Question 34: GRACE captures gravity fluctuations, how other parameters affecting gravity are neglected from its data and only TWS is retained?
Answer 34: GRACE is estimating gravitational anomalies. The way other signals are filtered out are through several processes: atmospheric reanalysis, correcting for tides/ocean effects. Then you end up on a monthly time scale with a pretty good signal. Other geophysical phenomena tend to evolve on smaller time scales or be clear punctuations (e.g., a large Earthquake).

Question 35: How do you estimate the uncertainty in evapotranspiration remote sensing data when you have scarce land-based data conditions? And Is it possible to calibrate and validate this model approach with some existing field data?
Answer 35: ET is very difficult to evaluate because of limited in situ data everywhere. We were using a product with flux tower data to compare it to isolated sites in similar environments in the tropics and that was used to improve the satellite product. But the broader point of the need to evaluate the models against in situ data is tremendously important. It's an ongoing challenge to do that.

Question 36: What is the accuracy level of TRMM data compare with the ground condition?
Answer 36: TRMM and now GPM come with error estimates associated with them. And those depend on what spatial/temporal scale you're using them at, but on the order of - the accuracy might be around 10%, let's say. But there are some systematic biases known in these products. E.g., difficulties in high mountain regions or complex terrain. It's important to understand formal error estimates - but also to know if you're working in a place with systematic biases above and beyond reported error estimates. Certainly encourage anyone using this data to see if there's previous evaluations of accuracy in your region of study.

Question 37: How does ALEXI data compares to the Landsat METRIC?
Answer 37: There have been a number of different studies. ALEXI doesn't have the same spatial resolution, but has more frequent measurements. ALEXI depends on daily measurements. You might give up a little on spatial resolution and gain something in

temporal resolution. METRIC, when implemented correctly, can be quite good. ALEXI gives us broad spatial coverage. In this study, it would've taken a lot of work to use METRIC over many years over the basin we were studying.

Question 38: The most important data need is the availability of data at 30 m or less resolution. Is there a repository that contains this information?
Answer 38: It depends on your area of application what your resolution of interest is. For data at <30 m resolution, not aware of any repository that contains it all. 30 m is, of course, the Landsat resolution. For hydrology, there are no pure remote sensing precipitation products at that resolution. You could downscale, but there would be a lot of errors. That scale might be overkill. Terrain at that skill (ASTER, SRTM) can be useful for that. For ET, using something like METRIC would get you to the Landsat scale. Land cover can also be done with Landsat.

Question 39: I want some information to discuss about climate change related with change of use of land, can we study the contamination of water and air on cities, with remote sensing?
Answer 39: Those are a compelling set of research questions, and that represents a large field of research. We don't have time to get into the whole range of those questions right now, but we do have - ARSET has a number of trainings on those topics available as well.
The study of WQ is a major thrust in remote sensing. It might be good to do some quick google scholar searches or search "water quality remote sensing" and see a lot of work on that. Air quality has a lot of work - and there's some exciting geostationary satellites going up (TEMPO). For now, your best bet might be to start out with some internet research and see where the field stands.