Transboundary Reservoir Outflow Estimation for Water Management:
SWOT-GPM Mission Interaction

Faisal Hossain
University of Washington

!!Presented (better) by the one and only Guy Schumann!!
OUTLINE

- **FIRST PART**: The importance of Transboundary Reservoir Outflow for Hydrologic Science and Society (Applications)

- **SECOND PART**: Assessment of Transboundary Reservoir Outflow Estimation leveraging Precipitation and Surface Water Missions

**Acknowledgements**: Safat Sikder, Matthew Bonnema, Yabin Mao, Xiaodong Chen, Hyongki Lee, Ismat Ara (IWM-Agency), Mahbubur Rahman (IWM-Agency)
LARGE RESERVOIRS IN THE 21st CENTURY

Historical Timeline

Looking Ahead up to 2030 AD

Current Situation

Expected Impact on Regulation and Fragmentation
How are Humans Impacting Surface Water?

Ecosystem  Energy

Fresh Water  Food  Health

Freshwater Volumetric Storage in Dams: ?

Population in Cities (70% of total by 2050)

World Population: 1950-2050

Population (billions)

Year


3 Billion  4 Billion  5 Billion  6 Billion  7 Billion  8 Billion  9 Billion

Population growth, Economic Development & Migration

Fresh Water

Population in Cities

Existing

Industrialized countries

Developing countries

Under construction

+ many more megacities

Industrialized countries

Developing countries

Existing

Under construction

Source: U.S. Census Bureau, International Data Base, June 2011 Update.
Where are We Today with Reservoir Estimation?

- Reservoir Storage change can be reasonably estimated using visible, near-IR imagery with nadir altimetry of heights. Well-established. A likely SWOT product.

- SWOT will improve Reservoir Storage change estimation in terms of sampling and accuracy.

- Reservoir Inflow can be reasonably estimated (i.e., precipitation induced flow or baseflow, upstream reservoir release using hydraulic/hydrologic models).

- However ‘Outflow’ – *what flows out of transboundary reservoirs* is a big piece of the puzzle. Time to think about it through Mission interactions (in this case – SWOT and GPM).
Why is Outflow Important for Societal Applications?

- Transboundary reservoirs and International River basins. Hydro-politics. Downstream nations need to know not just how transboundary storage is changing but also what’s flowing their way.

Ref: Aaron Wolf, Oregon State
A Real-World Example of Application Need

Google Earth (Pro) version of Altimeter Tool shown to South Asian water management agencies during Feb 2015 at a Training Workshop. Red, yellow and Green stations are crossings by JASON-2 and AltiKa.
IWM-WRP (a water management agency) immediately requested ‘research’ to understand altimeter-based reservoir storage changes and outflow releases using a ‘domestic reservoir.’ The GOAL – to be able to estimate outflow from 100s of large transboundary (Indian) reservoirs at monthly timescales in Ganges basin.
Why is Reservoir Outflow Important for Science?

- Better proxy of human impact of water cycle overland than just storage change (more integrated with precipitation)

- Knowledge of reservoir outflow can ‘refine’ surface water residence time with new set of dam building (future) and current conditions. Global surface water residence time appears to have increased 5 fold (3 more months) in 100 years. No thorough quantitative study available in pre-SWOT era. SWOT can shed light (for global hydrology & climate studies)

- Sedimentation (dependent on residence time) can be derived for reservoirs from outflow (the longer the water stays in a dam the more sedimentation occurs)

- Understanding Impact on Ecosystem function
Basic Concept of Reservoir Outflow Estimation

\[ O = I - E - \Delta S \]

- I = Total Inflow
- O = Reservoir Outflow (Discharge)
- E = Evaporation
- \Delta S = Reservoir Storage Change
ROLE OF GPM

- For stand-alone reservoirs (no regulation of reservoir inflow), precipitation can be used to estimate inflow with a process-based model.

Pre-GPM scale – typically 25 km³ hourly (3B42, CMORPH, PERSIANN-4km)

- GPM scale – 10 km³ hourly (IMERGE)

Upper Indus provides 70% of consumption

<table>
<thead>
<tr>
<th>Basin</th>
<th>Annual Average Inflow (MAF)</th>
<th>Normalized RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalabagh</td>
<td>87.22</td>
<td>71.6</td>
</tr>
<tr>
<td>Tarbela</td>
<td>60.41</td>
<td>82.38</td>
</tr>
<tr>
<td>Nowshera</td>
<td>21.96</td>
<td>53.65</td>
</tr>
<tr>
<td>Mangla</td>
<td>20.96</td>
<td>79.83</td>
</tr>
<tr>
<td>Marala</td>
<td>23.06</td>
<td>86.15</td>
</tr>
</tbody>
</table>

GPM

http://gpm.gsfc.nasa.gov
Current Altimetry Coverage (Note: Management Agencies want Reservoir Outflow now)
Role of Surface Water Mission (SWOT)

Key role to derive the Area-elevation (and Volume-elevation) curve for a reservoir.

- Many ways of doing it; Key idea is to match up height measurements (from SWOT/altimetry) with reservoir inundated area (pre-SWOT will be visible/NIR imagery)

- The curve is used in mass balance equation to estimate outflow
How Does Reservoir Outflow Estimation Look Now?

- 3B42 precipitation was used at 0.1 degree;
- IMERGE to be used for later
- 35 day repeat (AltiKa/Envisat)
- Simple Curve Number approach for precipitation-based inflow estimation

I – Inflow
S – Storage change
E – Evaporation

Black line - observed outflow
Blue line – storage change
Other lines – estimated outflow
How Does Reservoir Outflow Estimation Look Now?

- Process-based model required for inflow estimation in regions dominated by snow melt processes
- SWOT discharge upstream may help

- Mid-latitude dams are challenging due to snow-melt driven runoff (not modeled in CN approach)
- $E$ can be ignored at 35 day scales.
CONCLUSION

- SWOT will be able to refine, improve and even provide first estimates (where unavailable) of human regulation/impoundment of flow. Impact may be greatest in developing nations where dam building continues at an aggressive pace.

- We need to focus on transboundary reservoir outflow (in addition to inflow and storage change) – perfect case for mission interaction (with GPM) – STRONG AGENCY DEMAND

- Inflow requires more process-based models for mid-latitude reservoirs where snow dominates.

- Mission interactions like GPM-SWOT; SWOT-SMAP-GPM needs to be focused for both science and applications.