Tempo-spatial analysis of the interaction between river water and groundwater in the Heihe River basin, China
Background
The Heihe River

Length  821 km

Rank  the second largest river in the interior of Northwest China

Direction  originates in the Qilian Mountains and flows to the Gobi desert.
Heihe River Basin

Basin area: 143 X10^3 Km^2

Precipitation: less amount and uneven distribution (200-600 mm/y in the upstream, 100-250 mm/y in the midstream and less than 60 mm/y in the downstream)

Evaporation: intense and uneven (increases gradually from upstream to downstream, with a range of 700-3700 mm/y)

River runoff: 3 X10^9 m^3/y at the outlet of mountainous area and gradual decline in the mid-downstream. 70% of the total river runoff concentrates in June to September.
Existing Problems

Mountainous area (upstream)

glacier melting and
drought events
aggravated water shortage
Existing Problems

Oasis plain area (midstream)

Agricultural irrigation leads to frequent transformation between river water and groundwater and reuse of water resources.
Existing Problems

Gobi Desert area (downstream)

Reduced water caused rivers and lakes dry-up, land desertification, biodiversity loss, sandstorm disasters and other ecological problems.
NSFC Projects

“Systematic behavior and regulation of hydrological processes”

Reproducing the tempo-spatial distribution of water resources in the basin

The influences of topography, geology, hydrology, meteorology and human activities on the water cycle process
Data and Methodology

Part 2
Channel Water Balance Equation

\[ \sum Q_{up} - Q_{dn} + Q_{sr} + Q_{pr} - Q_{evp} + Q_{gr} - Q_{wd} = 0 \]

- Inflow - outflow
- Exchange volume between river and groundwater
- Water intake from channel
- Lateral runoff recharge
- Precipitation (mm)
- Runoff coefficient
- Catchment area (Km^2)
Tempo-spatial scale

Spatial scale
upstream
midstream
downstream

Temporal scale
summer(Jun-Sep)
winter(Dec-Mar)
spring-fall
Results and Analysis
The terrain in the upstream is very steep while those in the mid-downstream are flat relatively.
Geophysical Characteristic

Human activities are mainly concentrated in the middle reaches of the Heihe River.

<table>
<thead>
<tr>
<th>Region</th>
<th>water resource holding areas</th>
<th>high evaporation areas</th>
<th>human activity areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>forest grass water body marsh land</td>
<td>obi desert saline-alkali land bare land</td>
<td>agricultural land urban land</td>
</tr>
<tr>
<td>upriver</td>
<td>34.12 41.58 1.78 0</td>
<td>0 0 0 21.40</td>
<td>0.96 0.16</td>
</tr>
<tr>
<td>midstream</td>
<td>9.45 29.80 2.19 0.07</td>
<td>19.88 6.18 3.40 12.39</td>
<td>15.31 1.34</td>
</tr>
<tr>
<td>downstream</td>
<td>1.54 27.10 0.82 0.41</td>
<td>32.71 7.28 2.59 22.68</td>
<td>4.35 0.52</td>
</tr>
</tbody>
</table>
### Meteorological Characteristics

Table 3 Mean difference between precipitation ($Q_{pr}$) and evaporation ($Q_{evp}$) in the upstream, midstream and downstream segment of the Heihe River for different irrigation periods during 1994-2008

<table>
<thead>
<tr>
<th>River reach</th>
<th>major-irrigation period (Jun-Sept)</th>
<th>medium-irrigation period (Apr-May, Oct-Nov)</th>
<th>minor-irrigation period (Dec-next Mar)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$Q_{pr}$ (1) $Q_{evp}$ (2) $Q_{pr} - Q_{evp}$ (2)-(1)</td>
<td>$Q_{pr}$ (1) $Q_{evp}$ (2) $Q_{pr} - Q_{evp}$ (2)-(1)</td>
<td>$Q_{pr}$ (1) $Q_{evp}$ (2) $Q_{pr} - Q_{evp}$ (2)-(1)</td>
</tr>
<tr>
<td>upstream</td>
<td>0.02 0.03 -0.01</td>
<td>0 0.02 -0.02</td>
<td>0 0.01 -0.01</td>
</tr>
<tr>
<td>midstream</td>
<td>0.02 0.20 -0.18</td>
<td>0.01 0.17 -0.16</td>
<td>0 0.07 -0.07</td>
</tr>
<tr>
<td>downstream</td>
<td>0.04 0.69 -0.65</td>
<td>0.01 0.76 -0.75</td>
<td>0.01 0.30 -0.29</td>
</tr>
</tbody>
</table>

Evaporation is always greater than precipitation no matter which river section.
**Hydrological Characteristics**

- **Upper reach**
  - Outflow is greater than inflow all year around

- **Middle reach**
  - Outflow is greater than inflow only in Winter

- **Lower reach**
  - Outflow is less than inflow all year around
River-groundwater Interaction

<table>
<thead>
<tr>
<th>Segment</th>
<th>major-irrigation period (Jun-Sept)</th>
<th>medium-irrigation period (Apr-May, Oct-Nov)</th>
<th>minor-irrigation period (Dec-next Mar)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sum Q_{up} - Q_{dn}$</td>
<td>$Q_{wd}$</td>
<td>$Q_{gr}$</td>
</tr>
<tr>
<td>Upper reach</td>
<td>-3.10</td>
<td>0</td>
<td>1.27</td>
</tr>
<tr>
<td>Middle reach</td>
<td>7.18</td>
<td>6.18</td>
<td>-7.20</td>
</tr>
<tr>
<td>Lower reach</td>
<td>1.52</td>
<td>0.55</td>
<td>-6.67</td>
</tr>
</tbody>
</table>

Unit: $10^8$ m$^3$

Note: 1. Volume difference between inflow and outflow $\sum Q_{up} - Q_{dn}$ is calculated by multiplying the difference between upstream inflow and downstream outflow by the irrigation time period.

2. Positive value of “river-groundwater exchange $Q_{gr}$” means groundwater discharge to the river, and negative values for $Q_{gr}$ seepage from the river to the ground.

3. Annual river-groundwater exchange by summing $Q_{gr}$ in all months: upstream $2.57 \times 10^8$ m$^3$, midstream $-5.29 \times 10^8$ m$^3$, downstream $-10.39 \times 10^8$ m$^3$.

Upper reach river channel gains water from aquifers all year around.

Middle reach groundwater discharges to river channel only in winter.

Lower reach river leaks to the ground all year around.
Conclusions
The river–groundwater exchanges vary geographically along the Heihe River from the upstream mountain region to midstream agriculture area and to the downstream desert region and also changes with seasons.

The interaction between river water and groundwater in the Heihe river basin is influenced by many factors such as topography, meteorology and human activities. River-groundwater interaction in the upstream area is governed by topography and precipitation. As for the midstream area, the interaction is dominated by agricultural irrigation and evaporation. To the downstream area, evaporation is the primary factor affecting the interaction.
Thanks for listening!