Adding Insult to Injury:

Climate Change and the Aral Sea Basin

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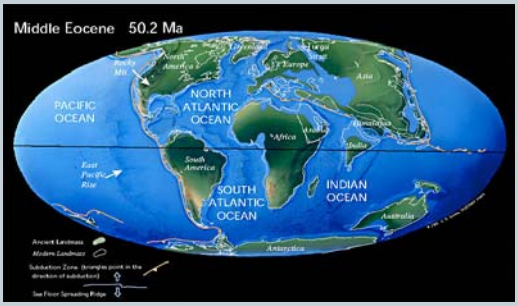
Objectives of Talk

- Integrate Aral Sea discussion with global models where appropriate
- Are there aspects of regional problems that can be generalized and applied elsewhere? (e.g. California)
- Recognize model limitations
- Critical need for more time series data

Talk outline

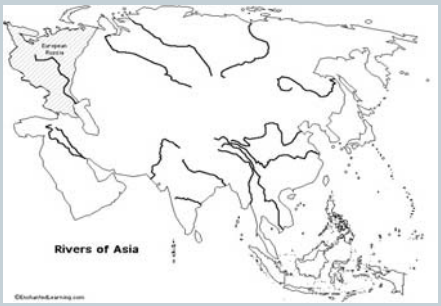
- Introduction
- Nested hydrologic budgets
- Receding glaciers and fluvial discharge
- Climate change predictions
- Uncertainties and policy discussions
- Concluding remarks

The Earth 50 m.y. ago



The Earth 14 m.y. ago

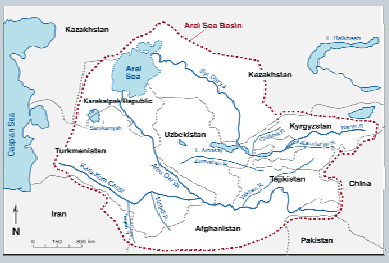
River drainage in Asia



Rivers of Central Asia

Aral Sea Watersheds

(Micklin, 2007)



Aral Sea has fluctuated through time

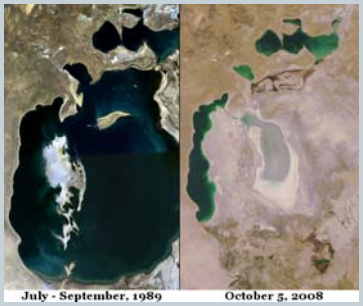
Butakoff, 1853

- Most terminal lakes in Northern Hemisphere reached maximum extent during deglaciation period ca. 8000 years ago
  - (Broecker, 2009, pers. comm.)
- Northward movement of ITCZ increased precipitation
- During times of contraction, loss of lake effect results in hotter summers, colder winters

Aral Sea variability

(IFAS, 1997)

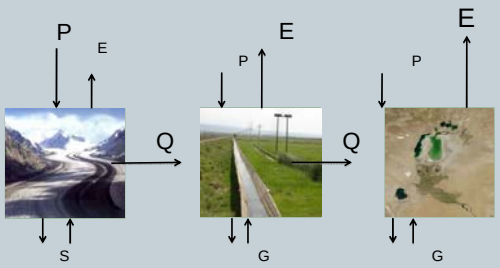
The Aral Sea hydrologic budget



$Q_{in} + P - E = \Delta S$

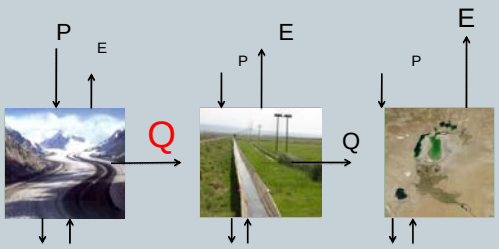
Must consider budgets for large and small seas separately

Nested hydrologic budgets

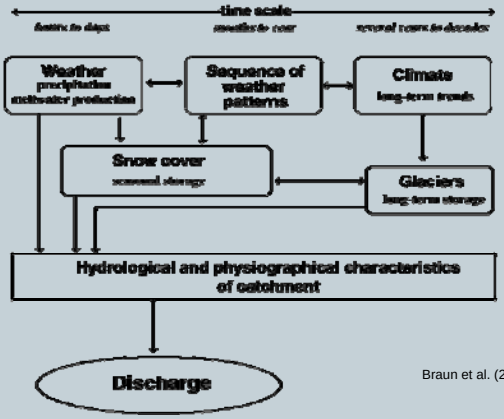


Q_{AMU} = 79 km³, Q_{SYR} = 37 km³

What happens with climate change?

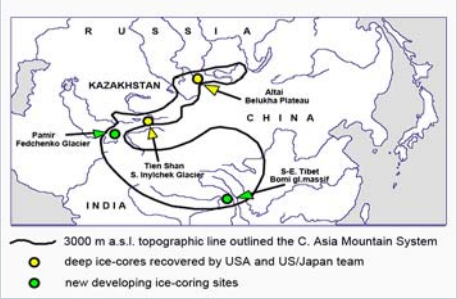


Current climate models (e.g. Held & Solden, 2006) predict that wet regions of Earth will become wetter, and dry regions drier. What effect will this have on these hydrologic systems?

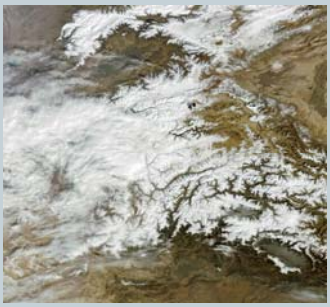


Braun et al. (2000)

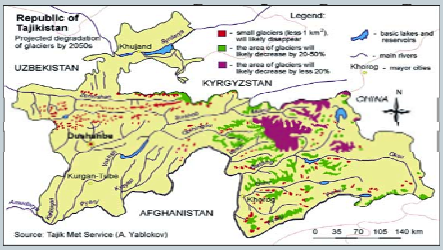
Glaciated region of Asia



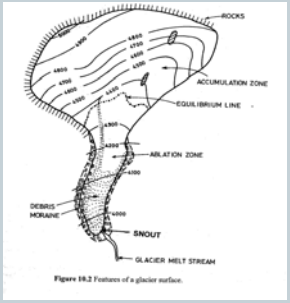
Source region for Amu Darya & Syr Darya contains est. 20,000 glaciers



Projected degradation of glaciers by 2050 (Perelet, 2007)



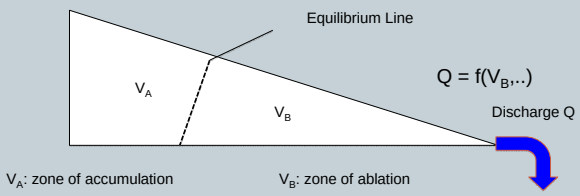
Typical mountain glacier



Singh & Singh (2001)

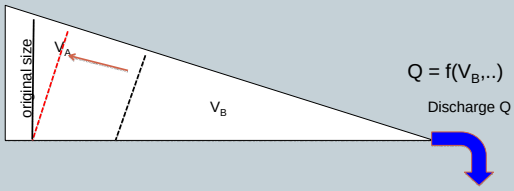
Glacial snout

Schematic glacier cross section



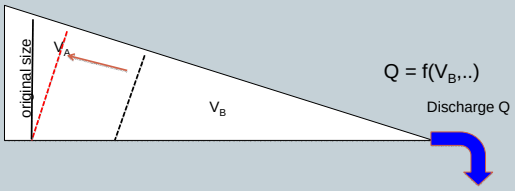
As T rises, equilibrium line moves up, V_A shrinks, V_B expands, but total volume V shrinks

$$\frac{dV_A}{dT} < 0 \qquad \frac{dV_B}{dT} > 0 \qquad \frac{dV}{dT} < 0$$



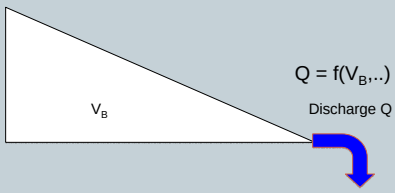
Short term rise in Q

$$\frac{dV_B}{dT} > 0 \qquad \frac{dQ}{dT} > 0$$

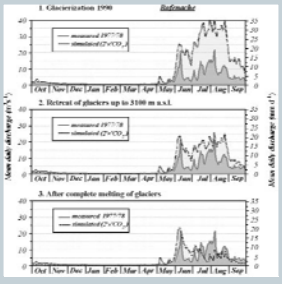


Q initially rises, but then falls

$$\frac{dQ}{dT} > 0$$ until $V_A = 0$, then $$\frac{dQ}{dT} < 0$$



Numerical experiments with Alpine glaciers (Braun et al., 2000)



- Runoff with 2 x P_{CO2}
- Where are we on these graphs?
- Do current river flows include this effect?
- What about timing of precipitation during the year?

Glacier cover vs. runoff variability

(Fountain et al., 1997)

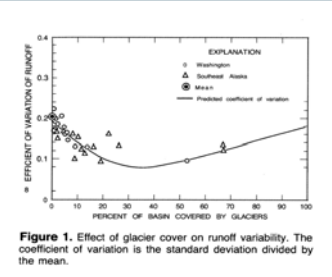
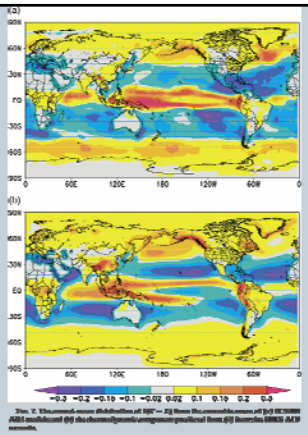


Figure 1. Effect of glacier cover on runoff variability. The coefficient of variation is the standard deviation divided by the mean.

Other factors affecting Q

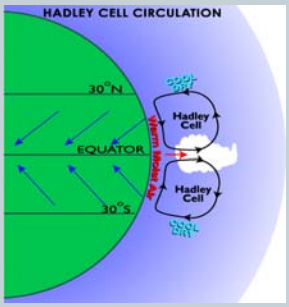
- Stability of Lake Sarez, Tajikistan, created by 1911 landslide in a seismically active region
- Increased water demands from Afghanistan as peace returns to that land

Deserts of the World

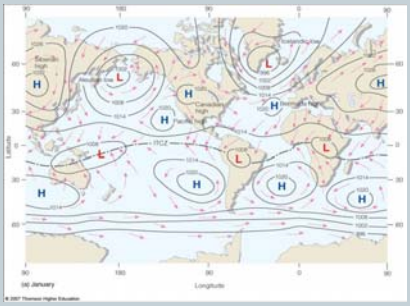


The wet get wetter,
the dry get drier.
How certain are we?

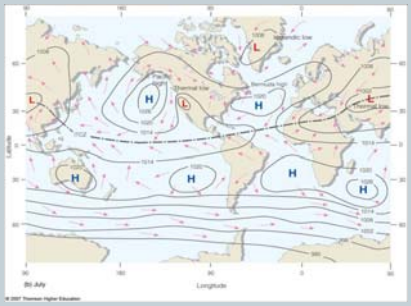
Held & Solden (2006)



Typical 500 mb map for January



Typical 500 mb map for July



Copenhagen, 2009

- Who will pay?
- Effectiveness of remedies difficult to demonstrate and uncertainties remain
- CO_2 residence time and *committed climate change*
- need to focus on adaptation, not finger-pointing

Conclusions

- Aral Sea also affected by global processes
- Critical need for more time series data
- Climate models suggest wet areas will become wetter and dry areas drier
- Discharge from glaciated regions may increase, then decrease
- Precipitation will likely become more variable