Hydrology, weather and groundwater

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• groundwater supplies 50% of world’s drinking water

Kundzewicz and Döll (2009)
• and 42% of the water used globally in irrigation

Siebert et al. (2010)
Intensification of precipitation under climate change

- fewer, low and medium intensity precipitation events
- more, very heavy precipitation events (i.e., “extreme events”)


“It is likely that the frequency of heavy precipitation... will increase in the 21st century over many areas of the globe. This is particularly the case in... tropical regions”

IPCC SREX (p. 10, 18 November 2011)
increased water storage is central to strengthening resilience to climate variability & change

Grey and Sadoff (2007)
groundwater storage

- critical role to be played by distributed groundwater storage in strengthening resilience to climate variability & change

MacDonald et al. (2012)

- groundwater storage is 10-100 x mean annual river discharge
• To what extent is the use of groundwater storage sustainable?
• groundwater depletion observed in California Central Valley, North China Plain, High Plains Aquifer, NW India and Bangladesh, threatens global food security

Rodell et al. (2009); Chen et al. (2010); Longuevergne et al. (2010); Famiglietti et al. (2011); Scanlon et al. (2012); Shamsudduha et al. (2012)

Famiglietti et al. (2011)
new 7-year, £12 million programme:

**Unlocking the Potential for Groundwater for the Poor (Sub-Saharan Africa)**

“an international programme funding interdisciplinary research generating evidence and innovative tools to enable developing countries and their partners in sub-Saharan Africa to use groundwater in a sustainable way for the ultimate benefit of the poor”
How will climate change affect replenishment of groundwater by recharge?

see comprehensive review in the next (April) issue of *Nature Climate Change*
Taylor et al. doi:10.1038/nclimate1744

pastoralists using open (scoop) wells to ater cattle in a sand river, headwater of the Great Ruaha River, Tanzania
long-term observations of the relationship between climate and groundwater recharge from borehole hydrographs are few...
• longest, published record of groundwater levels in the tropics
recharge and hydrological extremes

• recharge results disproportionately from extreme seasonal rainfall

• recharge occurs episodically - on average, just once or twice each decade

Taylor et al. (2012) doi:10.1038/nclimate1731
• AR4 & AR5 projections show the increase in heavy (90\textsuperscript{th} percentile) rainfall is greater than the mean in central Tanzania

• this projected intensification of rainfall favours recharge

Taylor et al. (2012) doi:10.1038/nclimate1731
Do impact models reflect the relationship between heavy rainfall and groundwater recharge observed in the long record at the Makutapora Wellfield?

Sampling a production borehole in the Makutapora Wellfield for groundwater-age tracing (October 2010)
contemporaneous hindcast of subsurface runoff using the JULES Land-Surface Model reproduces this ‘hockey-stick’ relationship

plot prepared by Roz Price and Prof Martin Todd (USussex)
EU-WATCH Ensemble: WaterGAP

- contemporaneous hindcast of **subsurface runoff** using the Global Hydrological Model **WaterGAP** does not – linear

WaterGAP (1963 – 2001), GPCC rainfall data (34E,36E,5S,7S)

*plot prepared by Roz Price and Prof Martin Todd (USussex)*
• current reliance of global recharge projections on a single model (WaterGAP) is problematic

Döll and Florke (2005) cited in AR4

• a further stumbling block is the absence of a global database of recharge observations to calibrate impact models
output from simple soil-moisture balance models applied in Uganda and Nigeria reflect disproportionate contribution of heavy rainfall to groundwater recharge

Taylor and Howard (1996); Eilers et al. (2007)

Is the ‘hockey-stick’ relationship observed at a few locations in the tropical Africa widespread?
• widespread conversion of perennial vegetation to cropland in many regions can profoundly impact terrestrial water balances
example: “Sahelian Paradox”

- rising water tables (from increased recharge) observed during a period of anomalously low rainfall in Niger

Favreau et al. (2009)
opportunity for impact model integration?

• both crop models (e.g. GLAM) and groundwater recharge models (e.g. soil-moisture balance model) use climate, soil and vegetation data to model the soil-water budget

• Might an ensemble of hydrological and crop models provide more skilful predictions than single models?

• Such an integration of impact models is patently sensible:
  - extends seasonal weather forecasts: recharge (groundwater abstraction) and runoff (flood risk, reservoir management)
  - better constrains impact models (observation dependent)
  - linked projections (water availability and irrigation demand)
Final thoughts

- apparent dependence of groundwater recharge on extreme (heavy) rainfall in the tropics – *floods can be good*

- critical need to expand our database of groundwater observations in order to constrain impact models

- opportunity for integrated impact modelling – demand driven?