What is the problem?

Water is essential to all life, but at what time scale do we see a tipping point?
Learning Objectives

1. To understand basic ideas of the estimation of water availability

2. To familiarize with the data and data products for the derivation of different water availability terms

3. To understand the possibilities, limitations and for estimation of water availability using different approaches

4. To familiarize with the applications

Let there be water cycle - the source of life and carrier of heat and energy

(Su et al., 2010)
Part I

Basic principles –

Energy and mass conservation
(a) Land Energy & Water budgets

Change of the energy ($S_E$) stored at the land surface, largely expressed as a change in land surface temperature

$$\frac{dS_E}{dt} = R^\downarrow - H - \lambda E - G_0 - A \quad (2)$$

$$R^\downarrow = (1 - \alpha)R^\uparrow + R^\downarrow_i - R^\uparrow_i \quad (3)$$

$$\frac{\partial S_w}{\partial t} = P - E - R_0 - R_n \quad (4)$$

(b) Atmospheric water budget

$$\frac{\partial \rho q}{\partial t} = -\nabla \cdot (\rho vq) + \rho (E - P)$$

$$\nabla \cdot (vq) = \overline{E - P}$$
Part II

Observations – Process understanding in energy and mass conservation
- In-situ observations
- Satellite observations
Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs)

Su et al. 2011, Hydrol. Earth Syst. Sci.,
www.hydrol-earth-syst-sci.net/15/2303/2011/

Tibet-Obs: Maqu site
Station description (Maqu)

- 2/3 soil moisture & temperature probes
- 5, 10 & 20 cm deep (few profiles deep 80 cm)
- 1 datalogger
- data collected every 15 min
- memory capacity of 1 year
- completely buried
- site revisit to download data:
  - beginning and end of monsoon season in Maqu

Maqu Network: Soil moisture at 5 cm depth of all the stations

[Graph showing soil moisture data over time for different stations, with markers for Organic soils and Sandy loam soil]
Part III

- Reliability of global data products

**ESA STSE programme:**

Water Cycle Multimission Observation Strategy (WACMOS)

- **Clouds** (Precipitation, 100%)
- **Water vapour** (transport to land 35%, condensation 65%)
- **Soil Moisture**
- **Evaporation** (land 65%, ocean 100%)
- **Discharge to ocean** (35%)
- **Groundwater Storage & Flow**
- **Water Storage in ice and Snow**
- **Water Resources Management**
Future R&D needs – consistency of ECVs (essential Climate Variables) (Closing the Water Cycle with Earth Observation)

http://www.esa-soilmoisture-cci.org/node/127

The WACMOS global soil moisture product

The Tibetan Plateau observatory of plateau scale soil moisture and soil temperature (Tibet-Obs) for quantifying uncertainties in coarse resolution satellite and model products

Z. Su¹, J. Wen², L. Deute³, R. van der Velde⁴, L. Wang¹, Y. Ma¹, K. Yang¹, and Z. Hu²

Evaluation of ECMWF’s soil moisture analyses using observations on the Tibetan Plateau

Z. Su¹, P. de Rrownay², J. Wen³, L. Wang¹, and Y. Zeng¹
Quantification of uncertainties in global products (Su et al., 2011, HESS)

The AMSR-E, ASCAT-L2 and SMOS soil moisture retrieval the Maqu area vs observations at 5 cm soil depth (20 stations)

How good is soil moisture analysis/assimilation? (Su & de Rosnay, et al. 2013)

Soil texture: major cause of uncertainty
How good is soil temperature simulation/analysis? (Su & de Rosnay, et al. 2013)

Maqu SMST Network – validation
Ngari SMST Network – validation

- SEBS algorithm updated/validated for different land covers (forest, cold/arid regions, glaciers/snow and water surface, & low vegetations)
- A processing chain developed in the ESA WACMOS project (wacmos.itc.nl)

References:
Yearly average of (a) downward shortwave radiation (SWD), (b) downward longwave radiation (LWD), (c) upward shortwave radiation (SWU), (d) upward longwave radiation (LWU) from 2000 to 2010.

(Chen et al. 2013, Development of an 11 years (2000-2010) land surface energy balance product in China (in review))

Multiyear mean of the retrieved fluxes (2000-2010), (a) sensible heat flux (H), (b) latent heat flux (LE), (c) net radiation (Rn), (d) ground heat flux (G0).
SEBS input and output variables vs measurement at Yucheng station

SEBS input and output variables vs measurement at SACOL station
(Semi-Arid Climate and Environment Observatory of Lanzhou University)
Average sensible heat flux (a) March-May (MAM), (b) June-August (JJA), (c) September-November (SON), (d) December-February (DJF) from 2000-2010.

A 10-year heat fluxes dataset for China.
Climate change impacts and adaptation in River Basins

Cumulative discharge anomalies (right axis) and TWS estimated from GRACE observations and GLDAS state variables (measured discharge at Lanzhou station)
Example of the Yellow River Basin (upper basin vs whole basin)

\[ \text{TWSC3} = \text{TRMM_PC} - \text{GLDAS_ETC} - \text{In-situ RC} \]

\[ \text{GLDAS_TWSC2} = \text{P} - \text{ET} - \text{R} \]

(anomaly of total water storage change)

(anomaly of total water storage change)
Describe
• Trends (change)
• Variability (natural cycle)
• Outliers

Understand
• Attribution (variability vs. error)
• Consistency Process (e.g. Volcanic eruption, fire/aerosol)
• Feedback links (e.g. ENSO teleconnection)

Detect
• Hot Spot
• Quality issue
• Outside Envelope

Predict
• Impacts

Adapt
• Consequences

What is Drought?

Dry Condition: No transpiration

What is Drought?
Drought Monitoring & Prediction

1. To derive land surface biophysical parameters using MODIS and AATSR data
2. To apply SEBS to derive surface energy balance terms (net radiation, soil heat flux, sensible heat flux, latent heat flux and evaporation)

Materials (Prepared by Lichun Wang, ITC)

- Practical SEBS exercise (MODIS part) – Exercise 1 & 2
- Practical SEBS exercise (AATSR part) – Exercise 3

Software

- ILWIS, ModisSwathTool, HDFView
- BEAM


