Overview

Tuesday morning
Session 1: Opening and introductions
Session 2: Overview of training and Princeton/Southampton research
Introduction to the EN-FDM
Regional perspectives (ENTRO, ACPC)

Tuesday afternoon
Session 1: Soil moisture remote sensing
Session 2: Technical overview of EN-FDM and introductory tutorial

Wednesday morning
Session 1: Estimating water balances
Session 2: Drought analysis and forecasting

Wednesday afternoon
Session 1: Group work
Session 2: Group work

Thursday morning
Session 1: Presentations and feedback
Session 2: Presentations and feedback

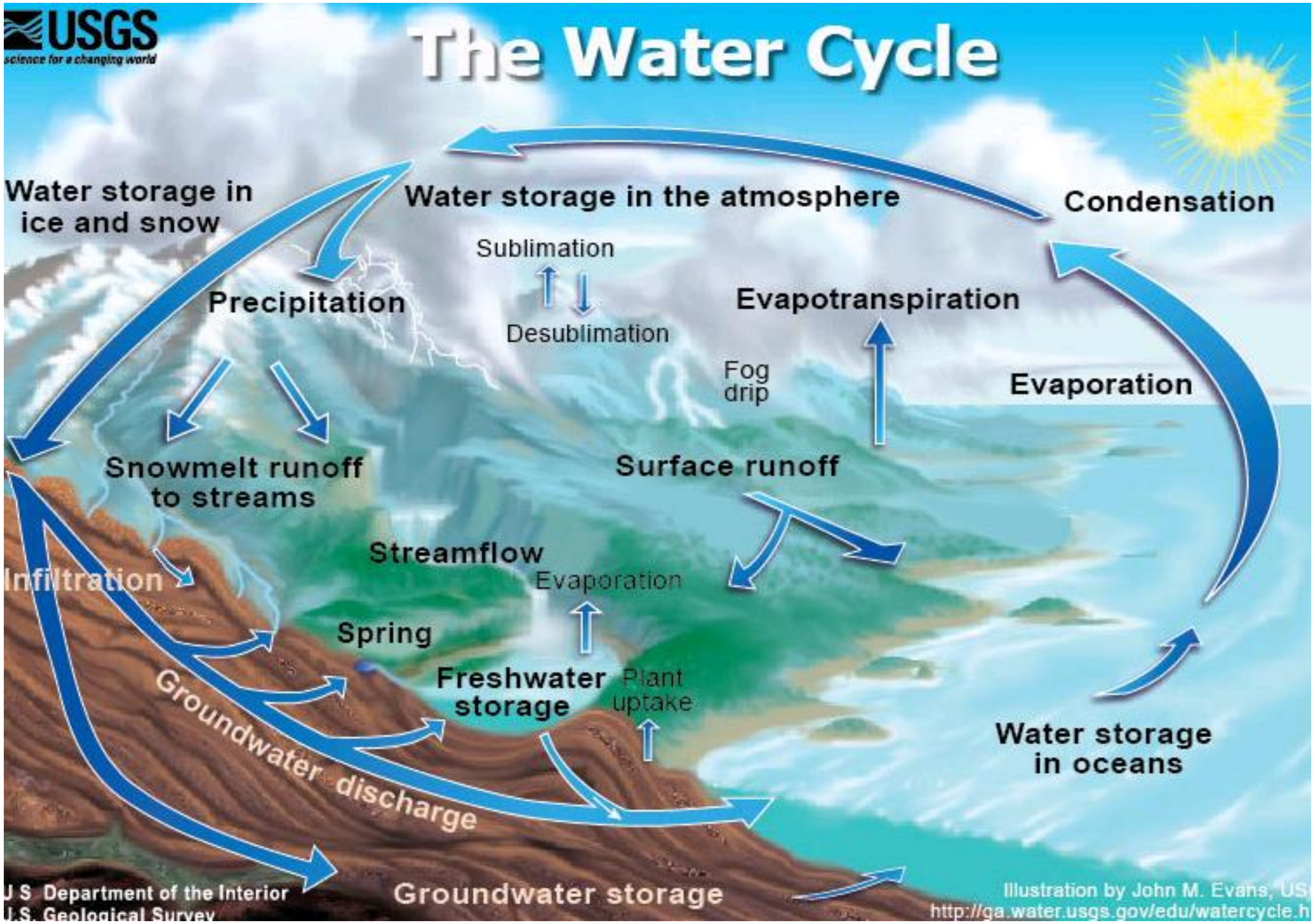
Thursday afternoon
Session 1: Feedback on the system, and discussion of future needs

The Terrestrial Water Budget

importance, definitions, water budget across scales, residence time, seasonality, estimating the budget, limitations/errors

Justin Sheffield, University of Southampton, Princeton University, Princeton Climate Analytics

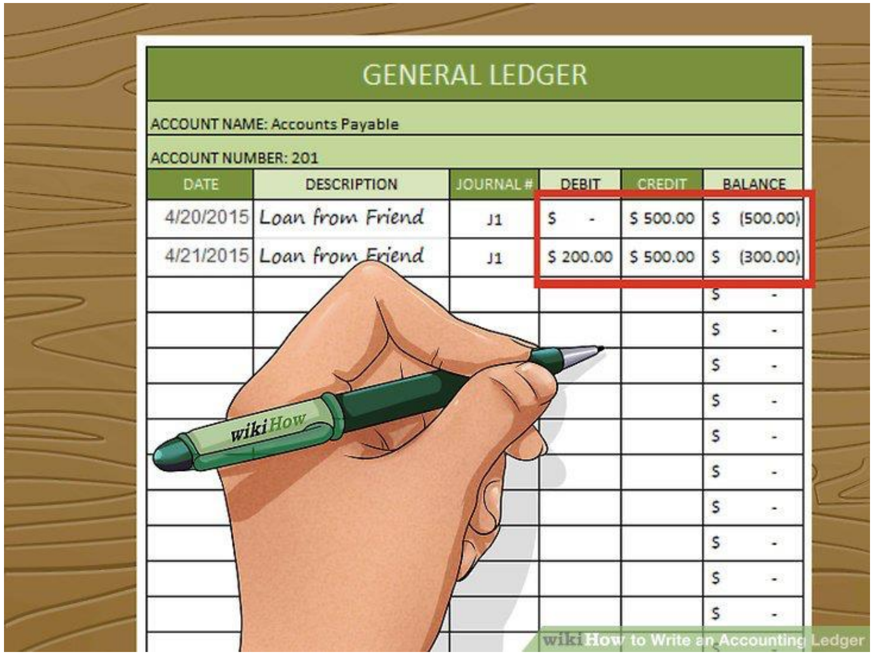
The Terrestrial Water Budget – how big is it and how does it vary?



The Terrestrial Water Balance or Budget

- A water budget is an accounting of the rates of water movement and the change in water storage in all or parts of the atmosphere, land surface, and subsurface.

- Although simple in concept, water budgets may be difficult to accurately determine.



Why is it important?

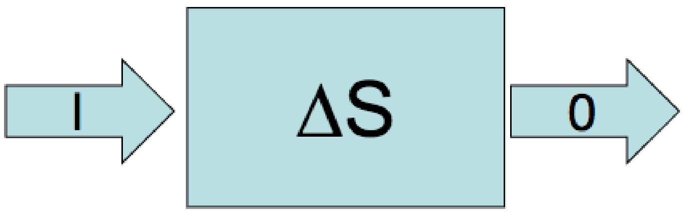
- Conducting water balance estimation provides you with a comprehensive understanding of the water flow system and water resources in your area
- Water balance estimation is an important tool to assess the current status and trends in water resource availability in an area over a specific period of time.
- Water balance estimates strengthen water management decision-making, by assessing and improving the validity of visions, scenarios and strategies.

The Water Balance and the Principle of Conservation

- Principle of Conservation:

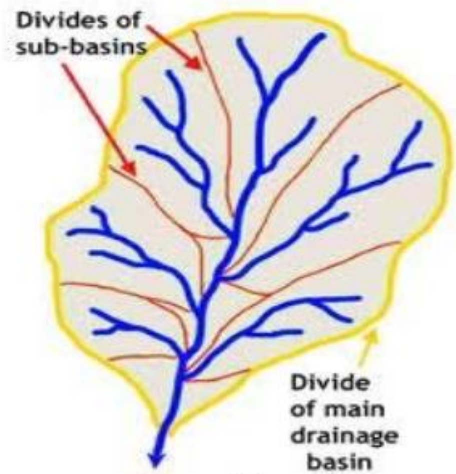
  inputs – outputs = change in storage

  $$I - O = \Delta S$$



- The water balance strictly refers to a control volume, but often applied to a geographic region, most commonly a large basin or a catchment/watershed

watershed



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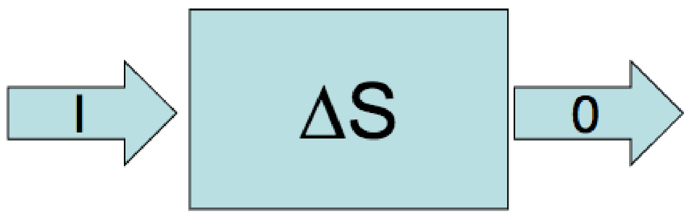
The Water Budget Equation

- Conservation of mass requires that, within a specific area over a specific period of time, water inflows are equal to water outflows, plus or minus any change of storage within the area of interest.
- The water entering an area has to leave the area or be stored within the area.
- The simplest from of water balance equation is as follows:

$$I - O = \Delta S$$

$$P - ET - R = \Delta S$$



Components of the water budget:

P = Precipitation (flux)

ET = Evapotranspiration (flux)

R = Runoff (flux)

= or Q when referring to river discharge

ΔS = Change in storage (change in state)

More complex forms

- An expanded form of the water budget appropriate for many hydrologic studies can be written as (Scanlon et al., 2002):

  $$P + Qswin + Qgwin = ETsw + ETgw + ETuz + \Delta Ssw + \Delta Ssnow + \Delta Suz + \Delta Sgw + Qgwout + RO + Qbf$$

  where the superscripts refer to surface water (*sw*), ground water (*gw*), unsaturated zone (*uz*); *RO* is surface runoff; *Qgwout* refers to both ground-water flow out of the site and any withdrawal by pumping; and *Qbf* is base flow (ground-water discharge to streams).

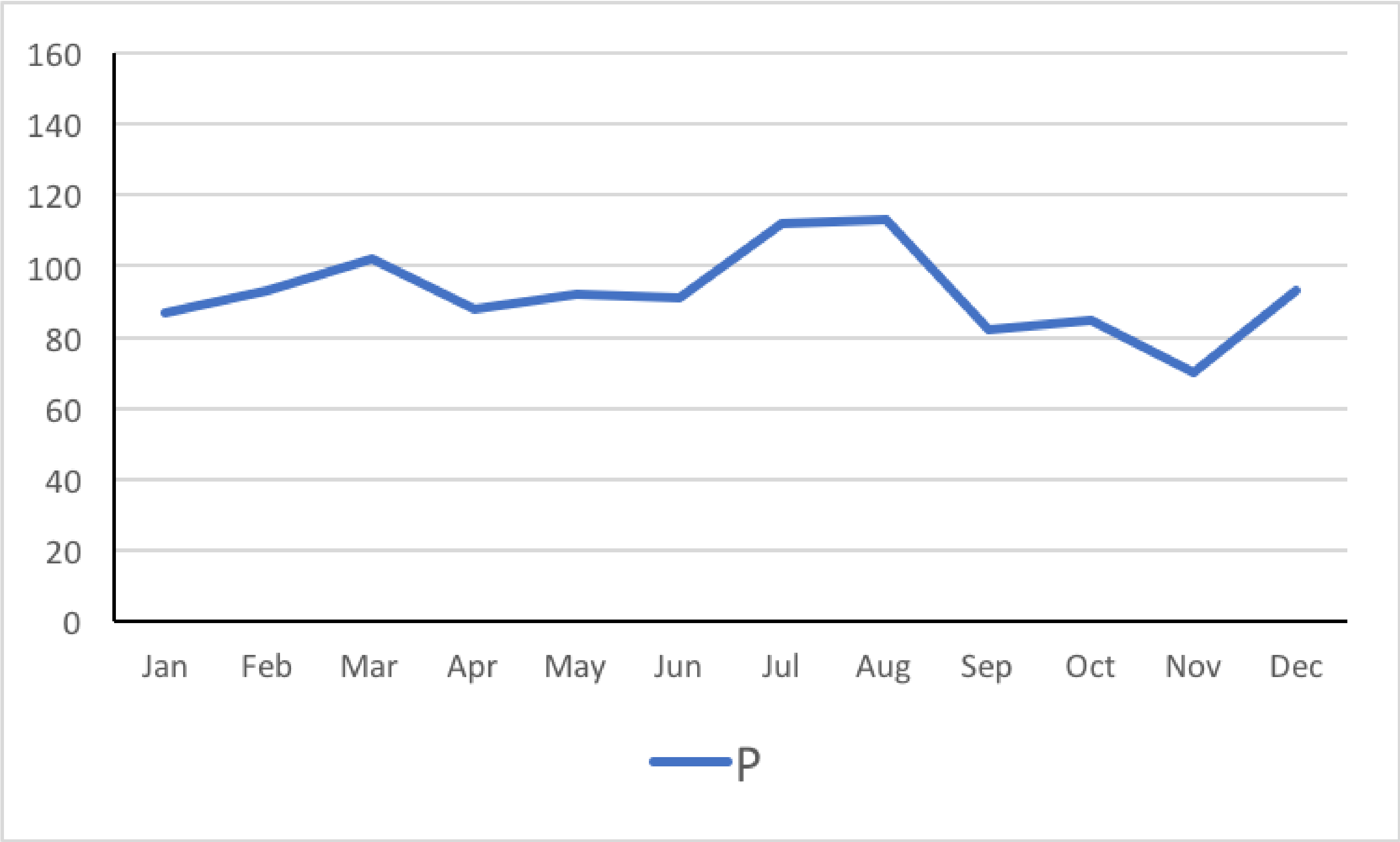
- It is unlikely that all elements in the above equation will be of importance at any one site; some will be of negligible magnitude and can be ignored.

How does the water budget change over time?

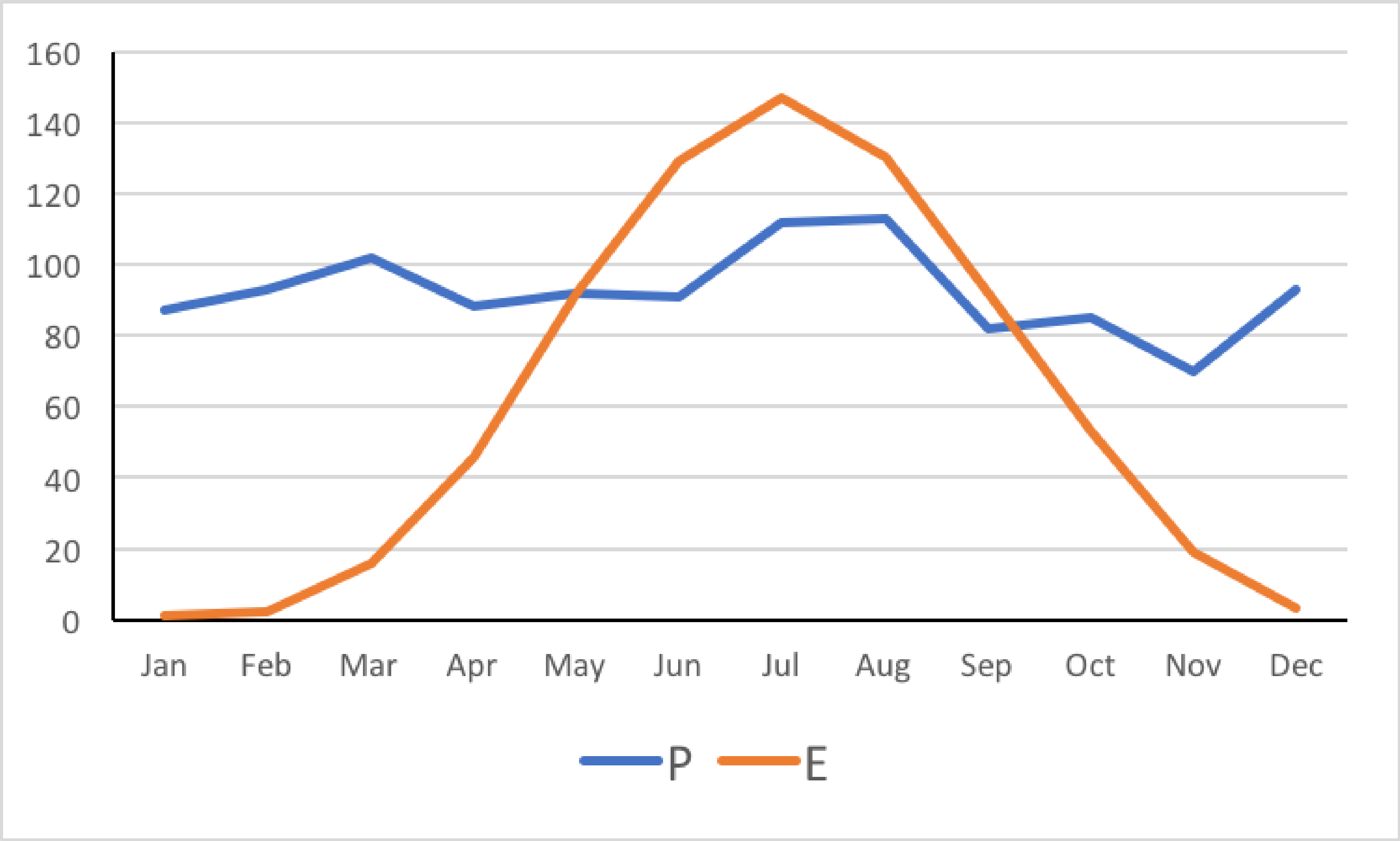
Typically, water budgets are tabulated in spreadsheets or tables such as that shown in table below, which contains monthly and yearly data for Seabrook, New Jersey, USA

Month	P	E	R	ds/dt
Jan	87	1	61	25
Feb	93	2	76	15
Mar	102	16	81	5
Apr	88	46	61	-19
May	92	92	31	-31
Jun	91	129	15	-53
Jul	112	147	8	-43
Aug	113	130	4	-21
Sep	82	92	2	-12
Oct	85	53	1	31
Nov	70	19	1	50
Dec	93	3	37	53
Total	1108	730	378	0

Seasonal Cycle of Precipitation

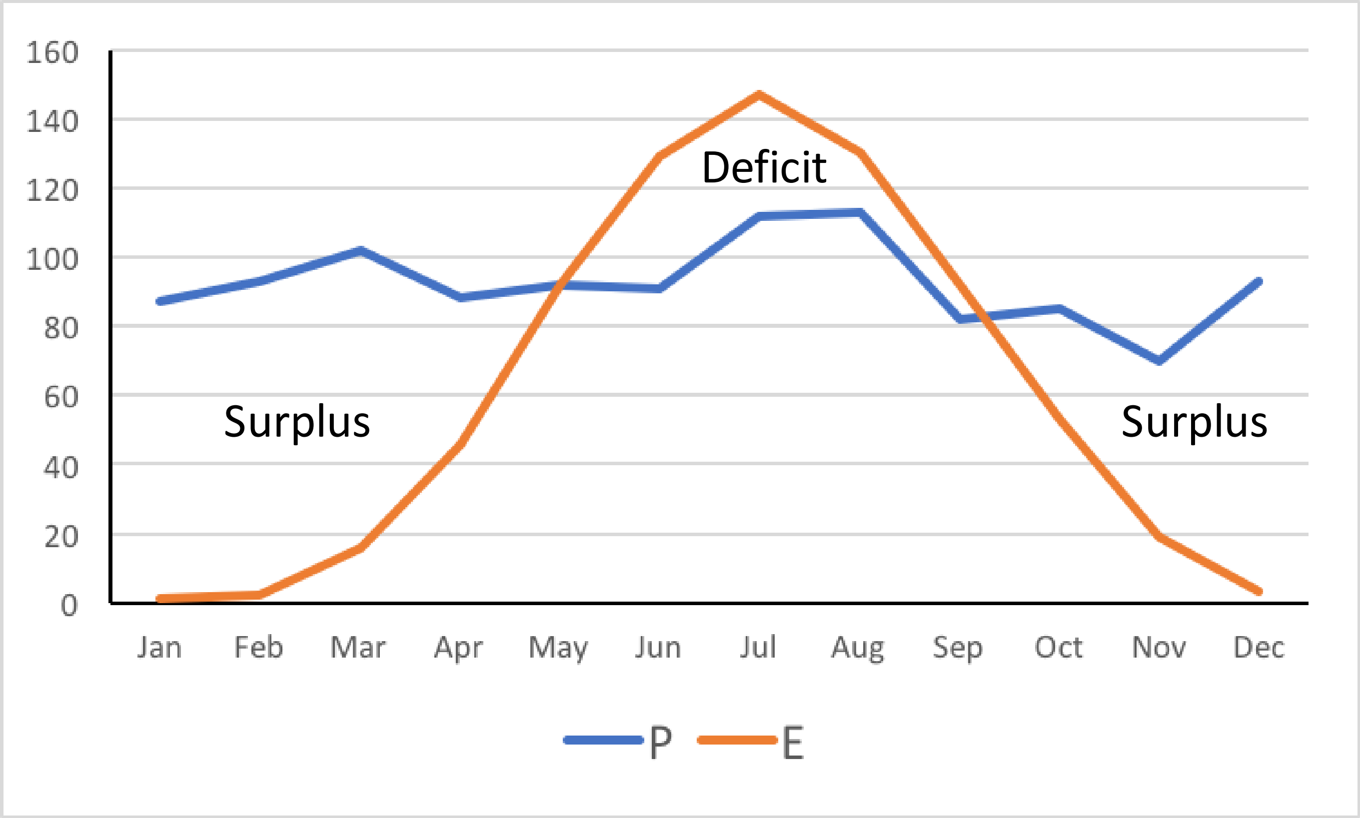


Seasonal Cycle of Evapotranspiration



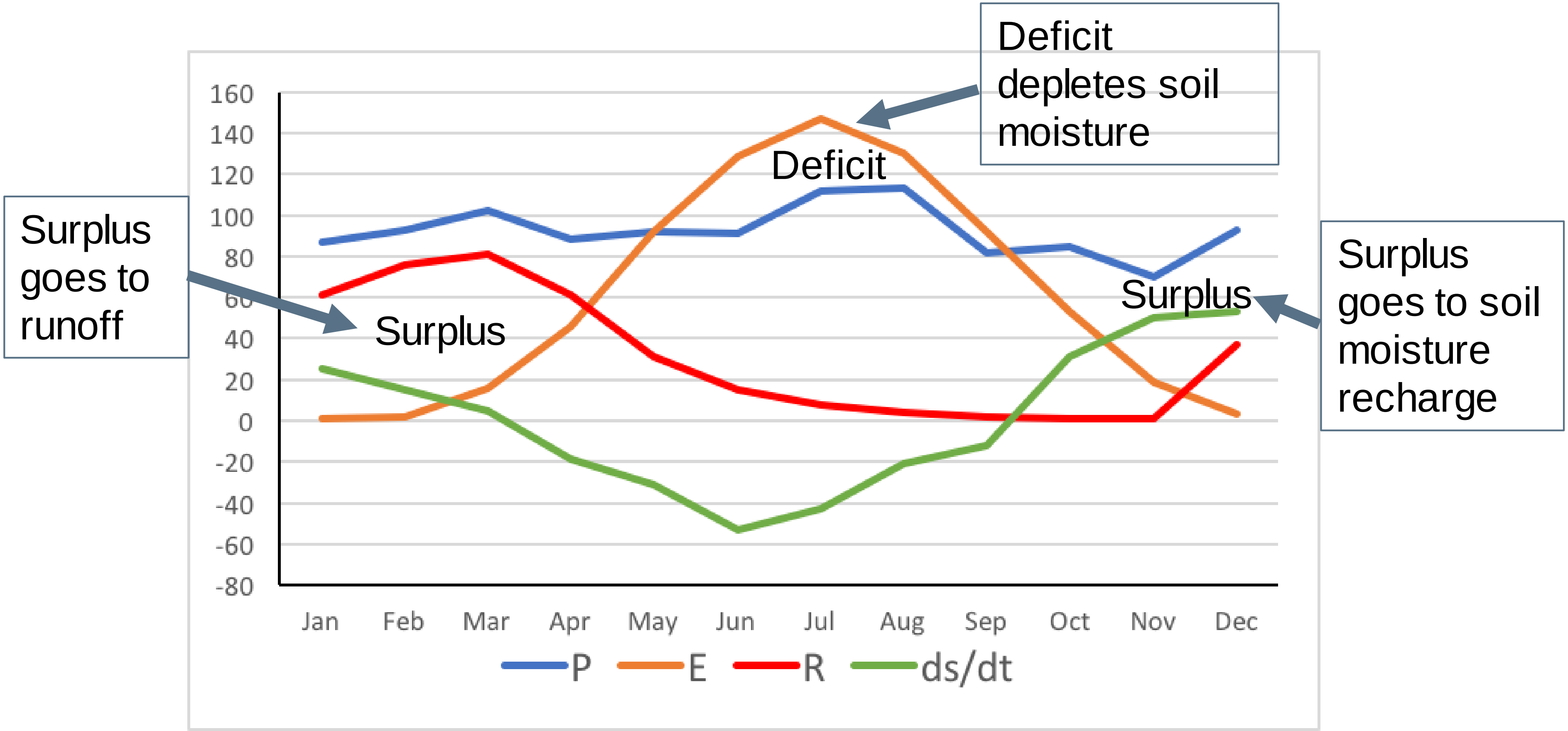
Surplus and Deficit

- When P > E there is a water surplus
- When E > P there is a water deficit - a loss of soil moisture and a deficit in the water budget

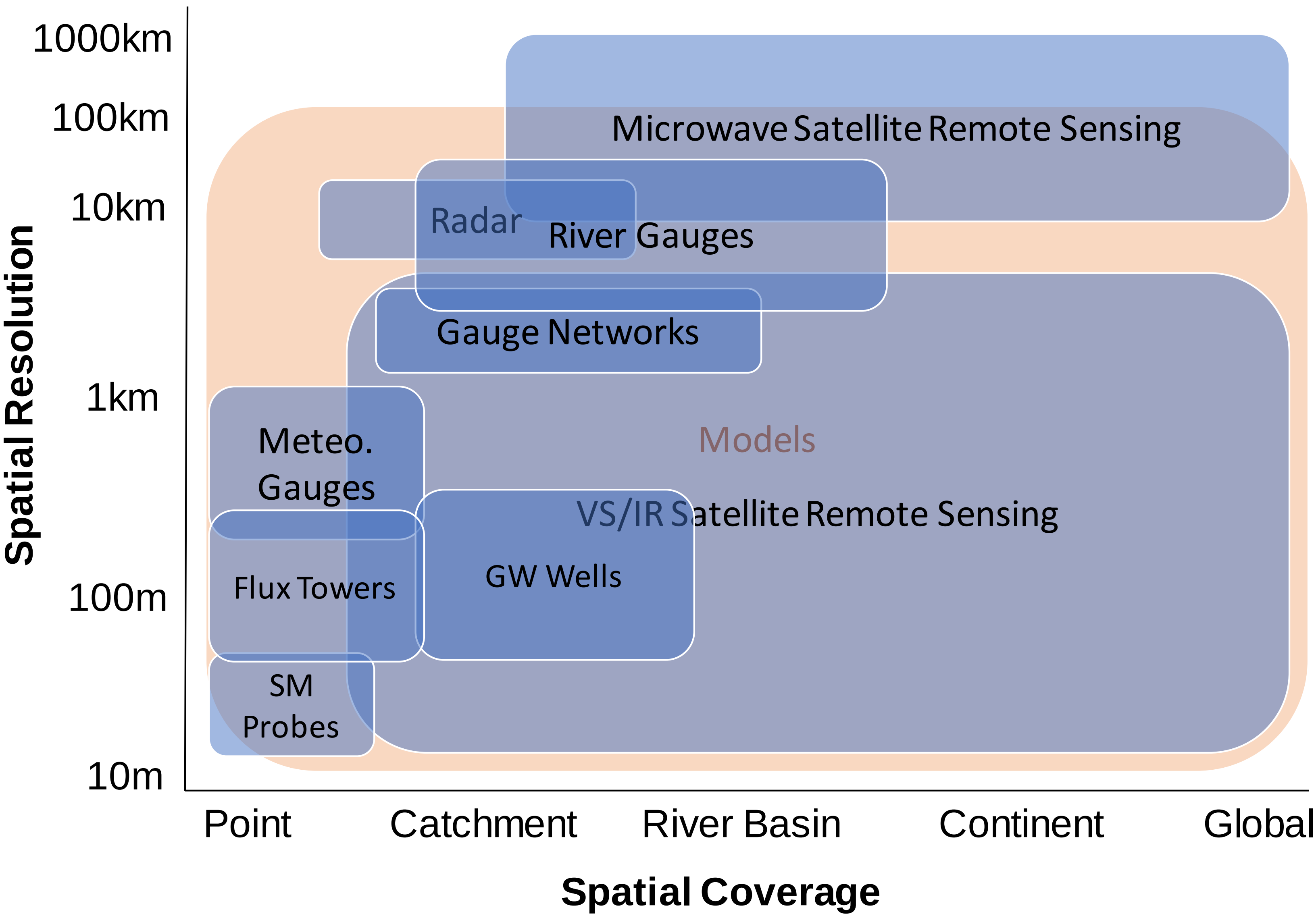


Surplus and Deficit

- When P > E there is a water surplus
  - which goes to runoff and/or soil moisture/groundwater (recharge)
- When E > P there is a deficit
  - Which is a loss of soil moisture and a deficit in the water budget



Quantifying the Water Budget



A Challenge: Closing the water budget from different data sources

$$\Delta S = P - ET - Q$$

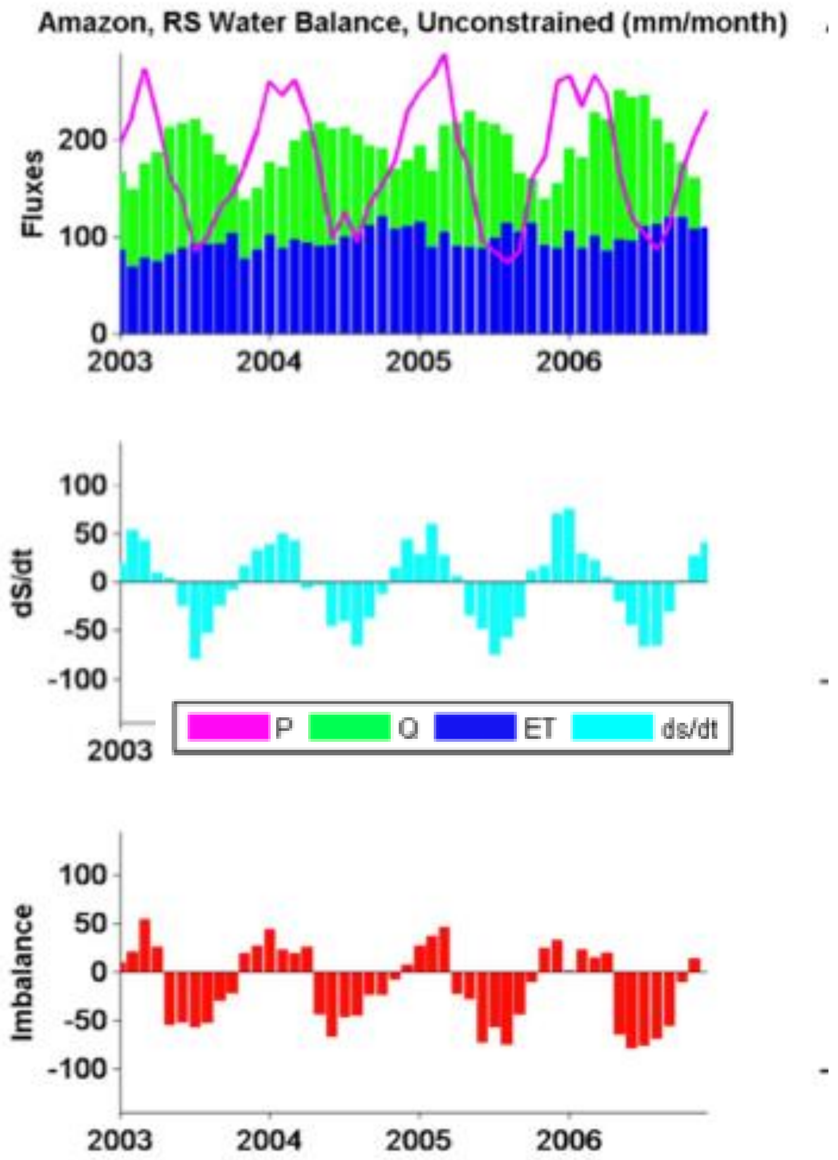
$$P - ET - Q - \Delta S = 0$$

From independent sources:

$$P - ET - Q - \Delta S = \varepsilon$$

Independent estimates of the water budget do not provide closure

How can the uncertainties be reduced ($\varepsilon = 0$) to close the water budget?



Questions?

Date, Evap (mm/day), Runoff (mm/day), Precip (mm/month)

Change in storage = P – E*30 - R*30

https://platform.princetonclimate.com

User: entroTestUser@princetonclimate.com

Password: PCA_entro_134!

vojislav@princetonclimate.com

Practical Exercises

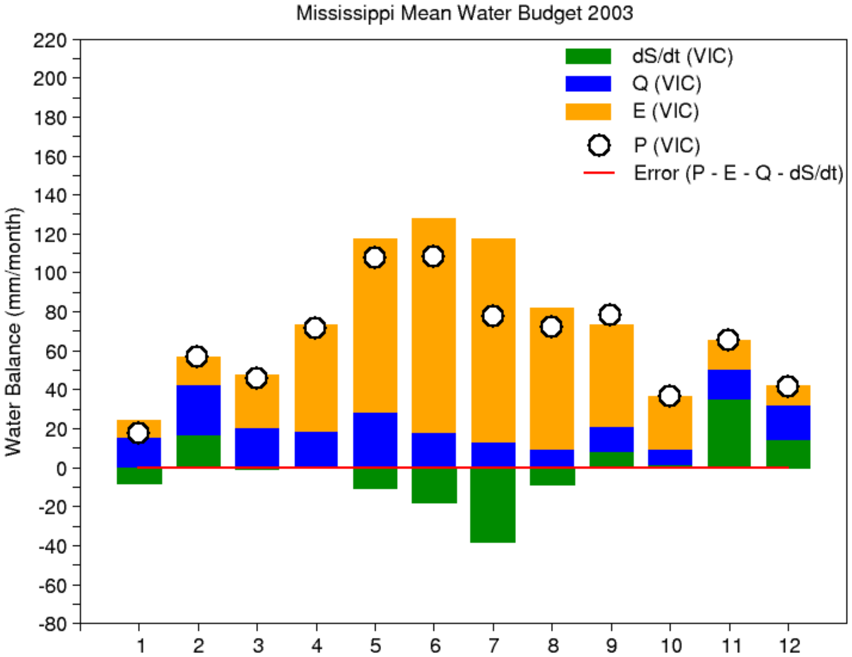
- You will quantify the water budget for some selected locations and the broader Lake Chad Basin to understand the available water resources
- You will apply the data to estimate how the water budget changes over time (e.g. seasonally and in wet and dry years), and spatially, and use it for some example applications, such as estimating potential groundwater recharge.

Quantifying the Water Budget from Satellites

The land water budget:

$$\frac{dS}{dt} = P - ET - Q$$

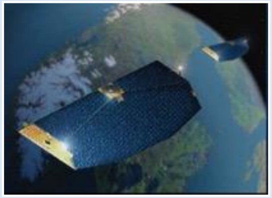
What the budget should look like?
(from modeling, forced closure)



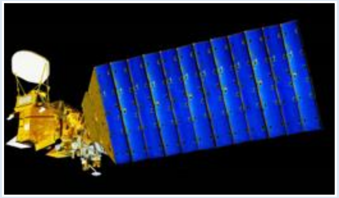
Sheffield and Wood, 2011

What if we calculated the water budget from satellite data?

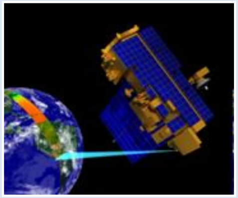
dS/dt from GRACE



ET from CERES / MODIS / AIRS



P from GPM



Q from TOPEX/POSEIDON/JASON