Hydrologie

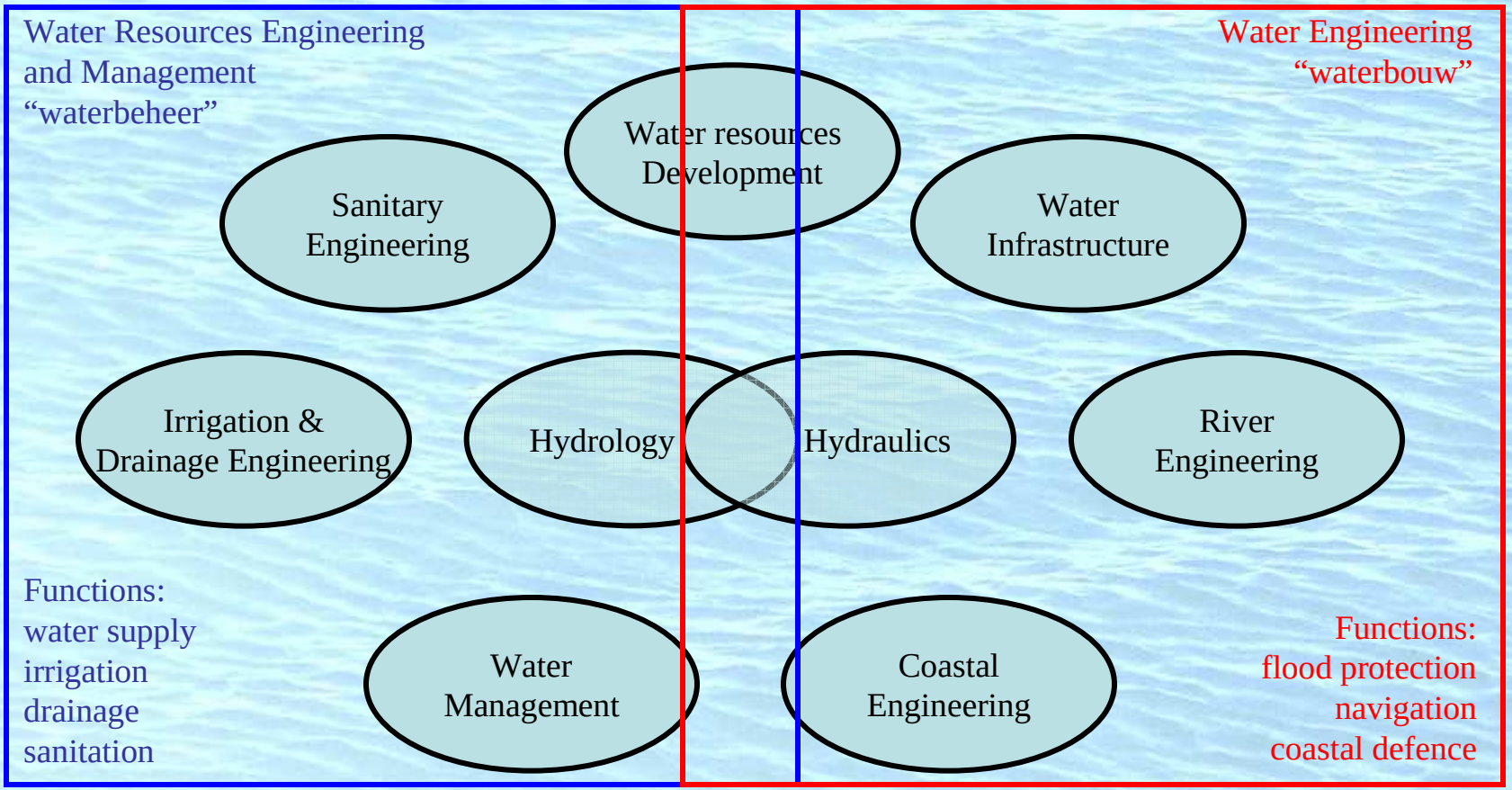
Het Hart van Water Resources Management

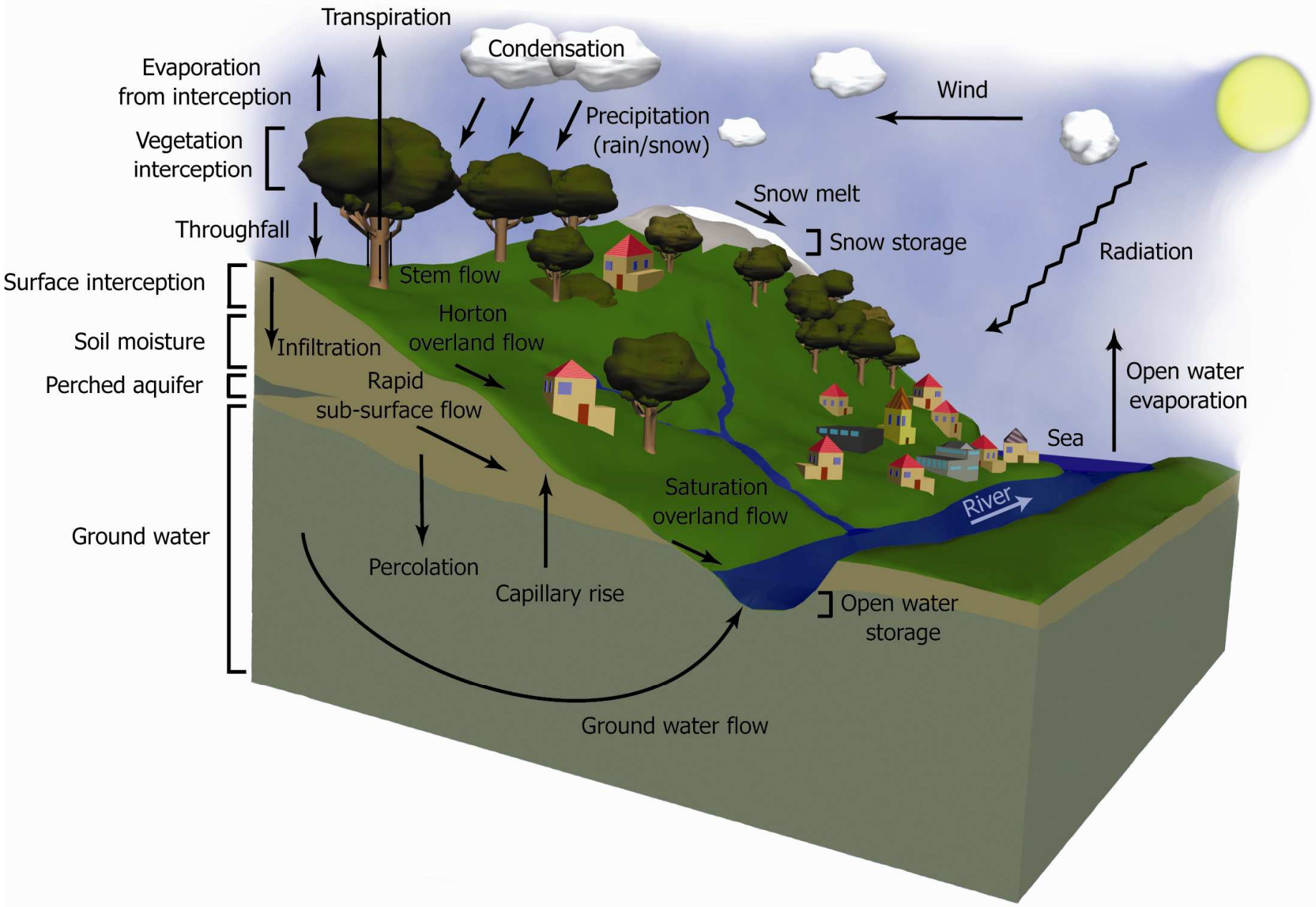
Prof.dr.ir. H.H.G. Savenije

What's in a name?

- Water engineering
- Water resources engineering
- Water management
- Water resources management
- Water resources development
- Hydrology
- Hydrological engineering
- Hydraulic engineering

Water Resources Engineering and Management




Transpiration
Condensation
Evaporation
from interception
Vegetation
interception
Precipitation
(rain/snow)
Wind
Throughfall
Snow melt
Snow storage
Radiation
Surface interception
Stem flow
Soil moisture
Horton
overland flow
Infiltration
Perched aquifer
Rapid
sub-surface flow
Open water
evaporation
Sea
Saturation
overland flow
River
Ground water
Percolation
Capillary rise
Open water
storage
Ground water flow

Hydrological Engineering

- Always in an engineering context
  - for water supply
  - for dimensioning hydraulic structures
  - for drainage & irrigation
  - for water management
  - for river and coastal zone management
  - for water resources development

Hydrological Engineering

- Close links with other sections
  - water resources assessment
  - safe yields
  - rainfall-runoff processes
  - interaction between systems (e.g. watershed-river-coastal; river-polder)
  - design criteria
  - effects of human interferences

Hydrological Engineering

- Focus within an engineering context
  - understanding the processes
  - watershed, river, estuary
  - quantity-quality connection
- Distinction from hydraulics
  - system based (water and matter balances)
  - aggregated scales

Important considerations for Research

- Based on our strengths and track record
  - we have a world reputation in water, both surface and groundwater
- Based on the Dutch main water issues
  - floods (origin, occurrence, frequency)
  - dry feet (land subsidence, rainfall intensity)
  - impacts of human interferences (land-use, climate, environmental quality)

Hydrological Engineering

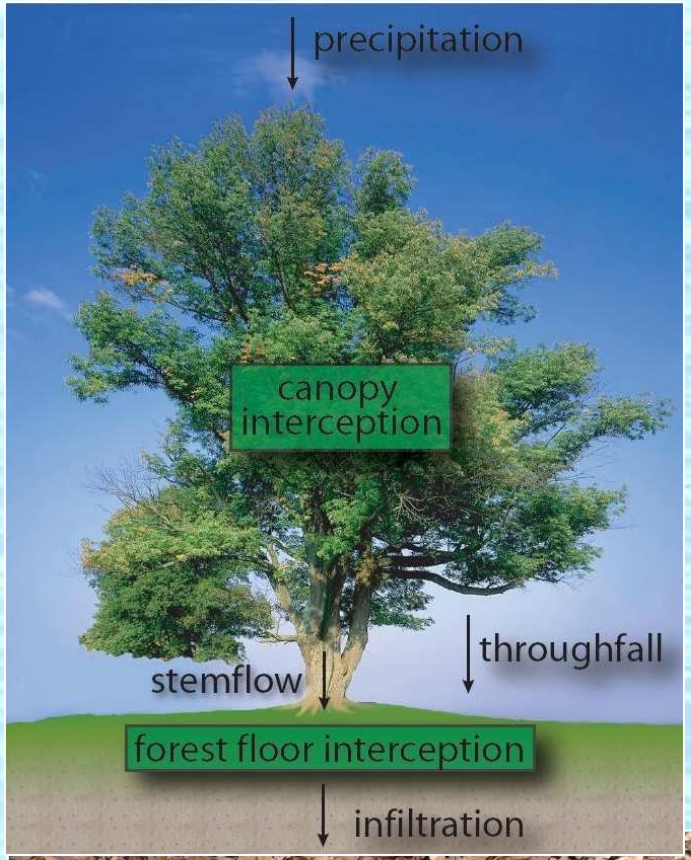
- Research lines surface water
  - Rainfall-Runoff processes (understanding runoff generation, genesis of floods)
  - Hydrology of Deltas (salt intrusion, tides)
- Research lines ground water
  - density driven flow, groundwater exploration
  - time series analysis and modelling

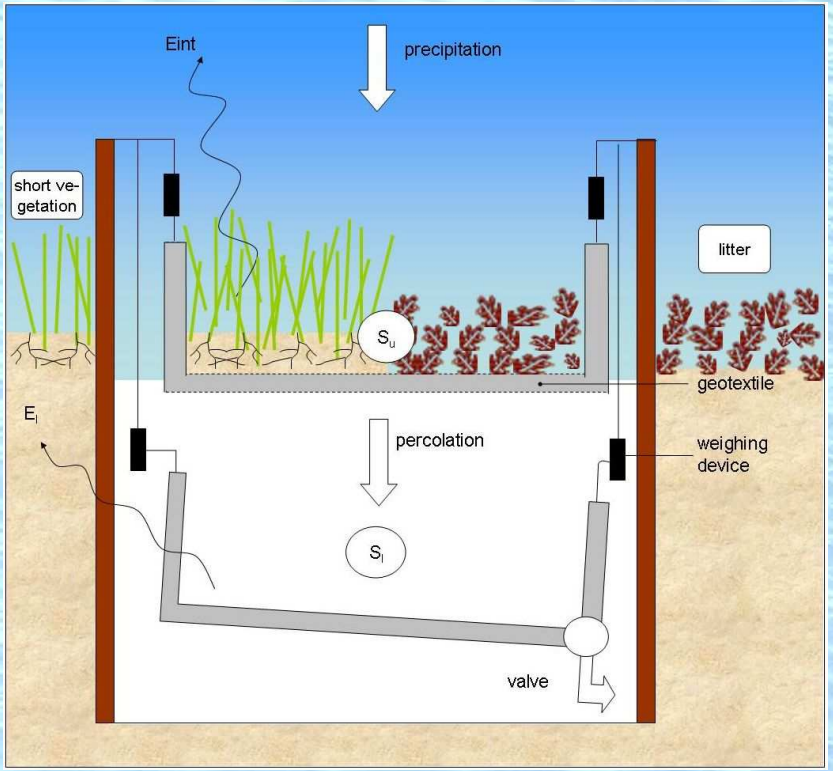
Wat voor dingen doen we ?

- Luxemburg veldonderzoek
  - Interceptiemetingen
  - Temperatuurmetingen
- Nieuwe observatietechnieken
  - GRACE
  - SEBAL
- Modelleren
  - Luxemburg
  - Zambezi

Veldwerk Luxemburg

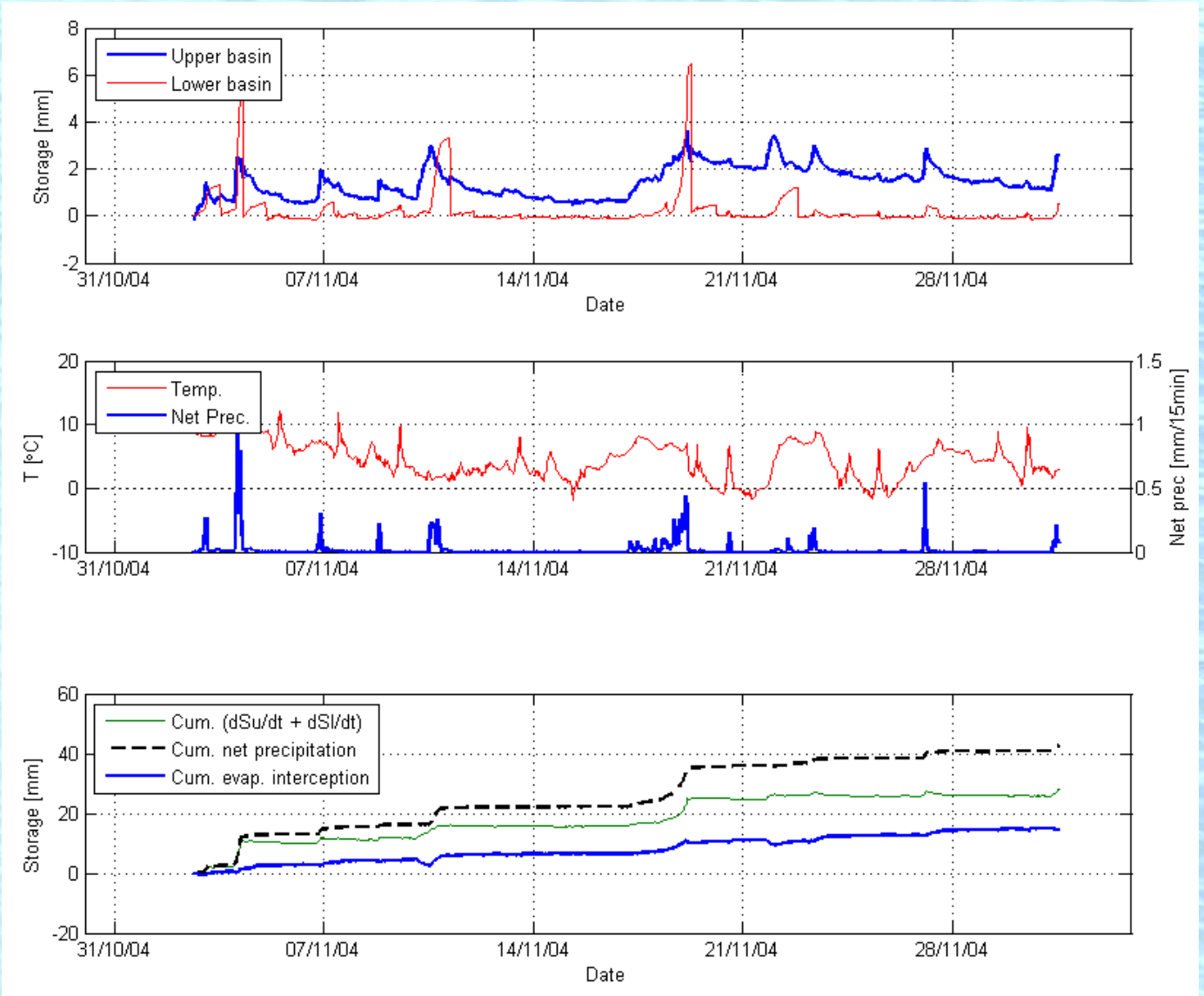
Interceptiemetingen

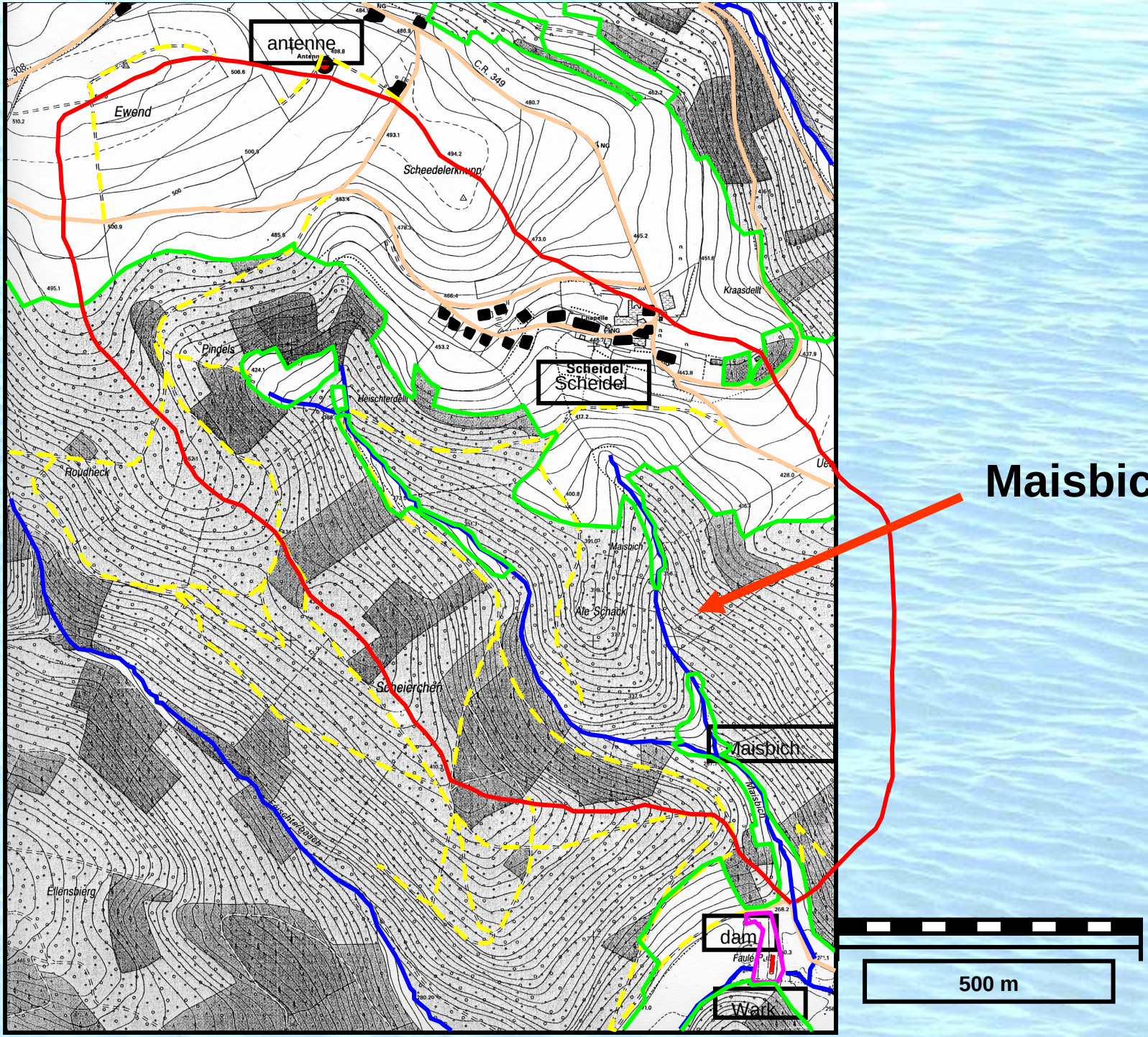




$$E_{\text{int}} = P_{net} - \left(\frac{\mathrm{d}S_{upper}}{\mathrm{d}t} + \frac{\mathrm{d}S_{lower}}{\mathrm{d}t} \right)$$

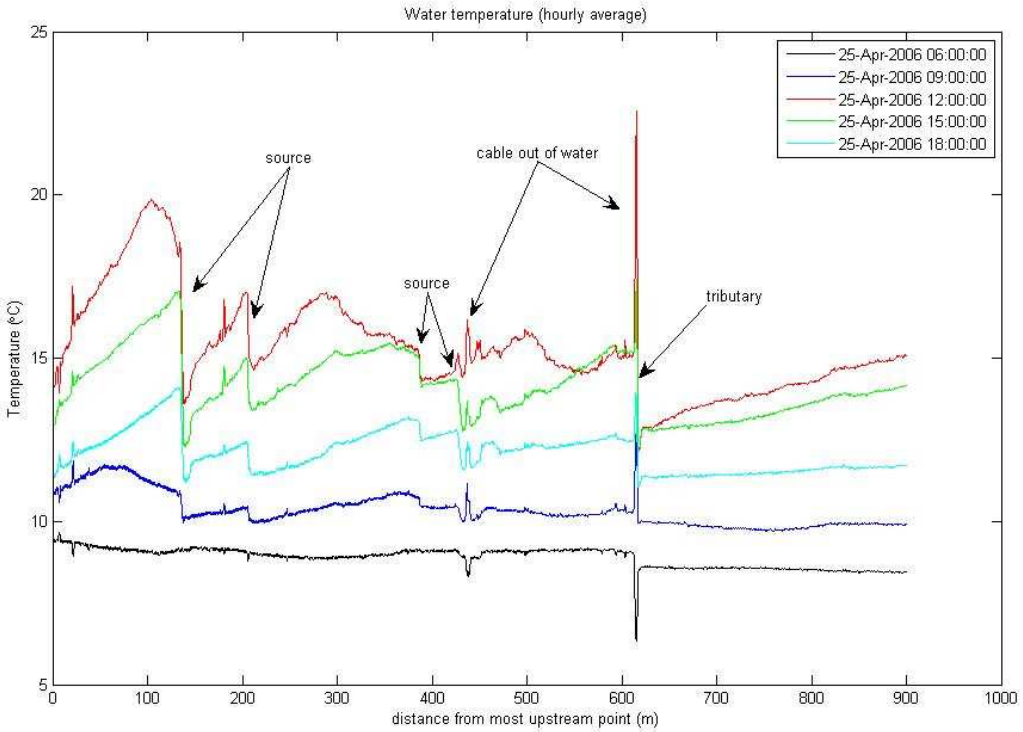
Forest floor interception

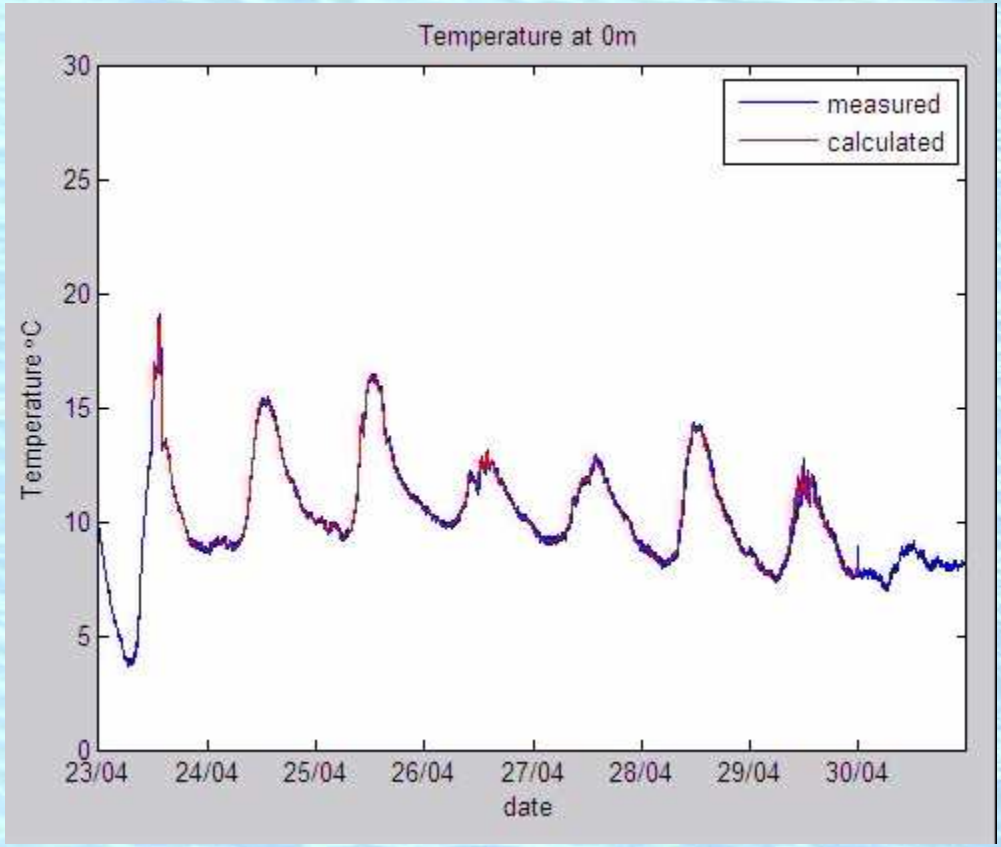



antenne
Ewend
C.R. 349
Scheedelerknupp
Kraasdelli
Pindels
Scheidel
Scheidel
Heischterdelli
Roudheck
Maisbich
Ale Schack
Scheierchen
Maisbich
Maisbich
Ellensbierg
dam
Wark
Maisbich
500 m

Distributed Temperature Sensing

- Glasvezel kabel
- Temperatuur over hele lengte




Temperature at 0m
measured
calculated
Temperature °C
30
25
20
15
10
5
0
23/04
24/04
25/04
26/04
27/04
28/04
29/04
30/04
date

Wat voor dingen doen we ?

- Luxemburg veldonderzoek
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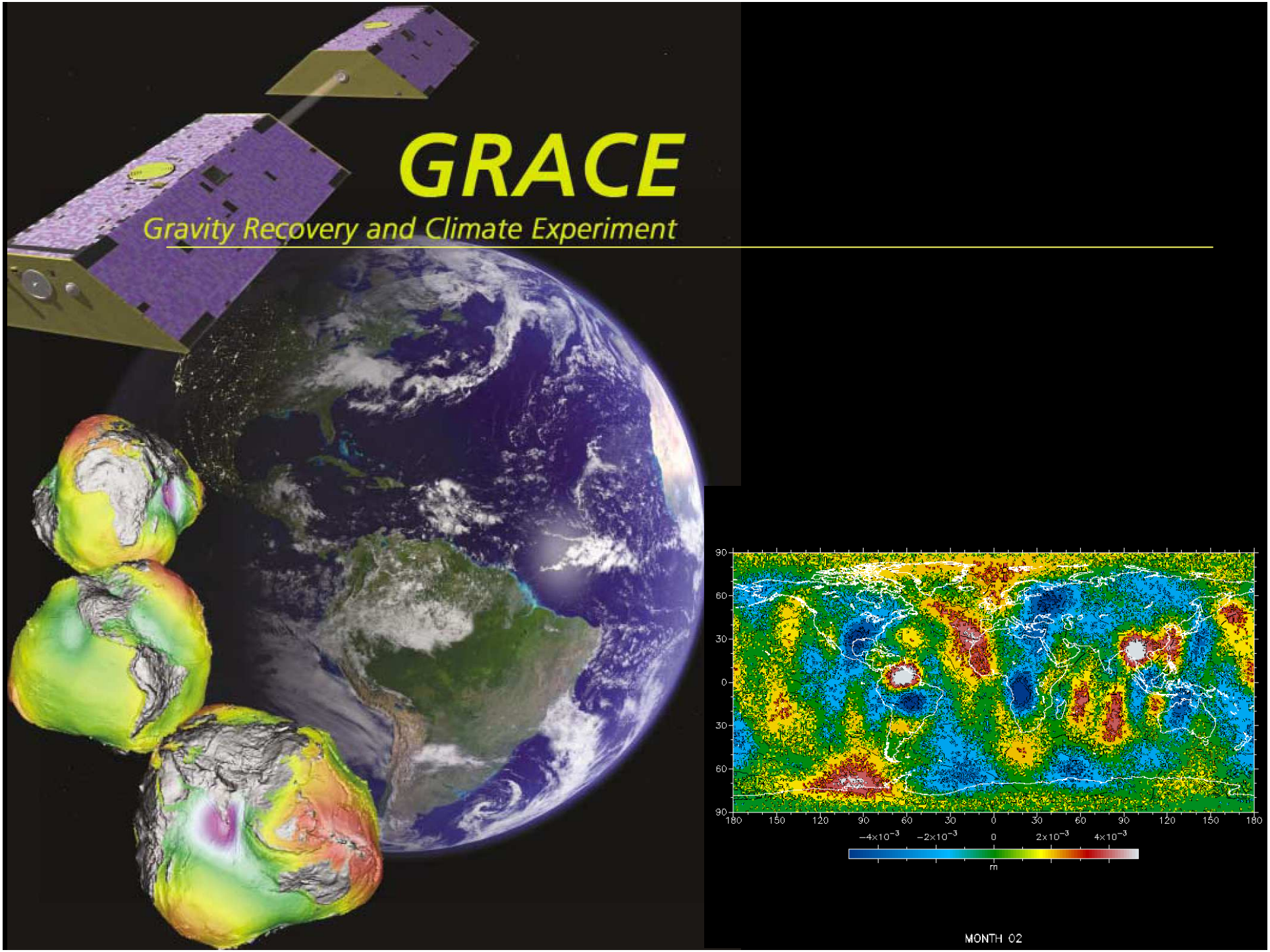
- Nieuwe observatietechnieken
  - GRACE
  - Evaporation sensing
- Modelleren
  - Luxemburg
  - Zambezi

GRACE

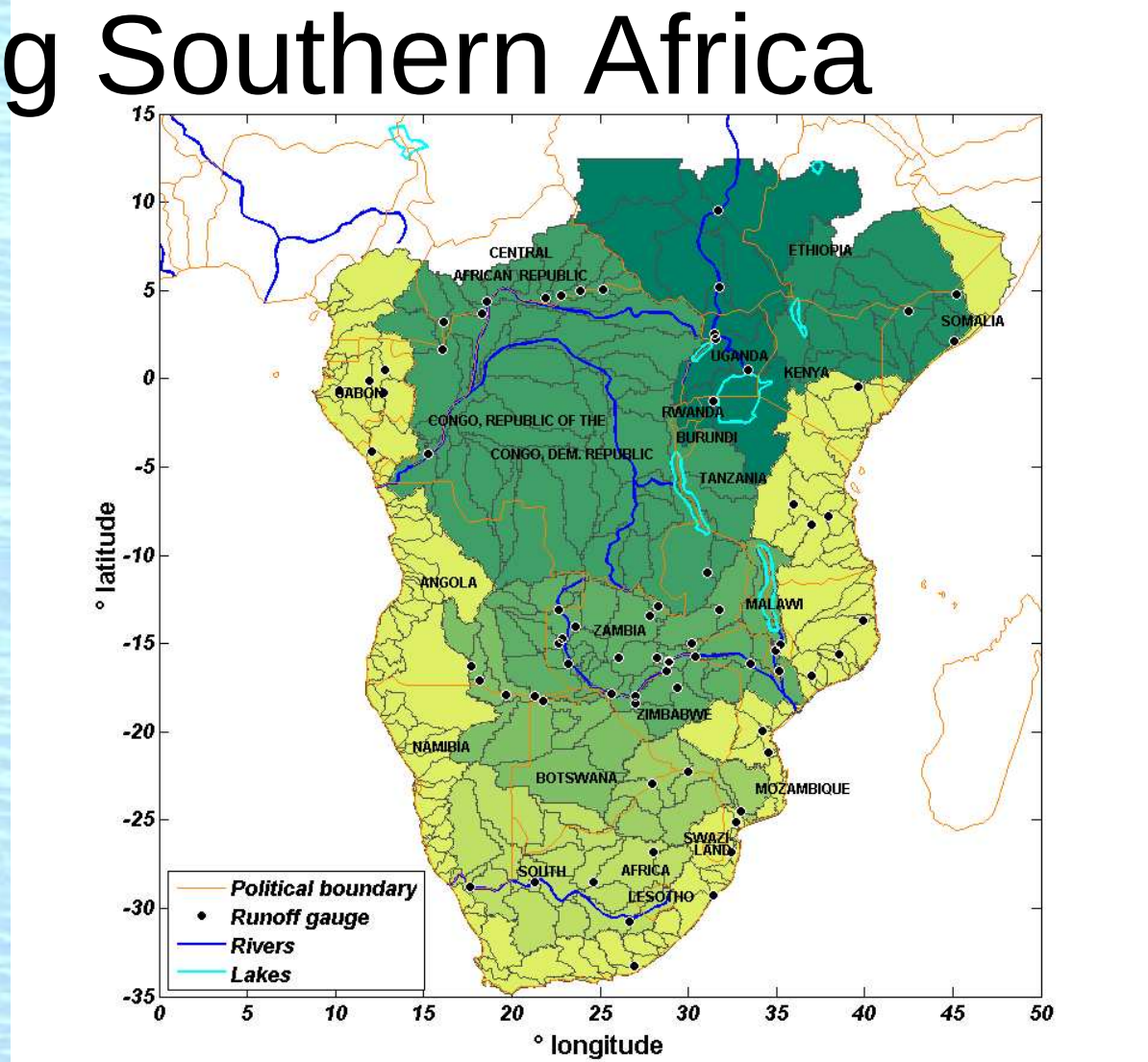
Gravity Recovery and Climate Experiment

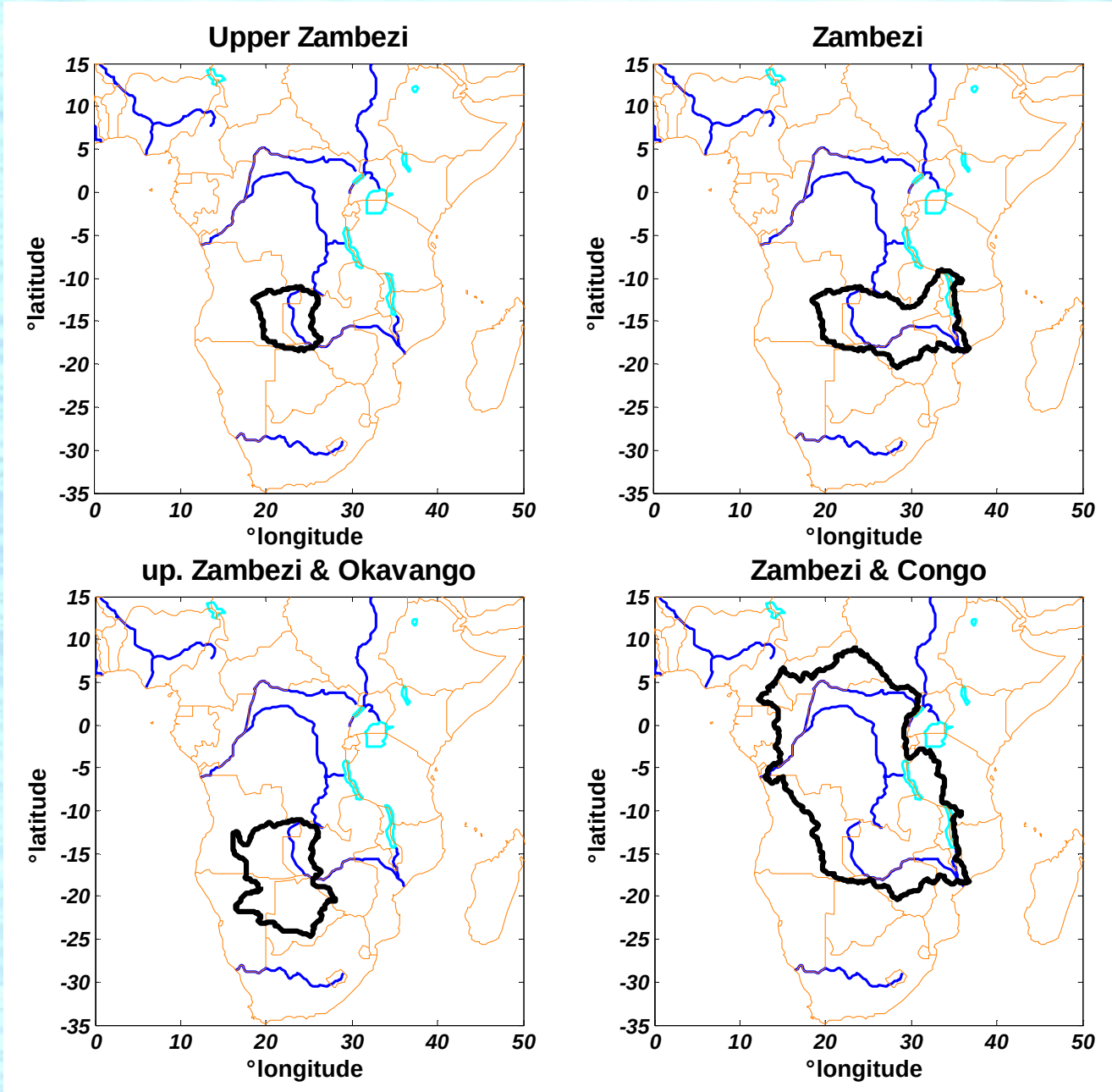


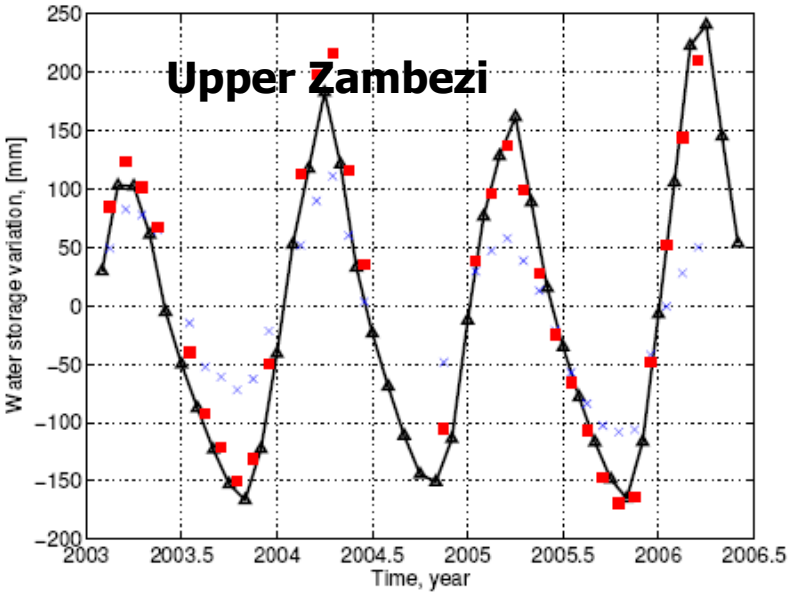
Modelling Southern Africa

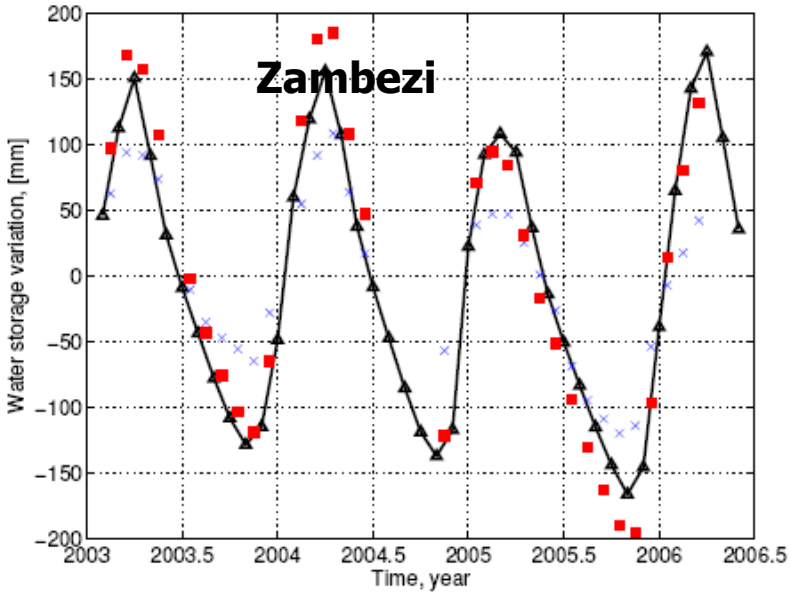
From GRACE

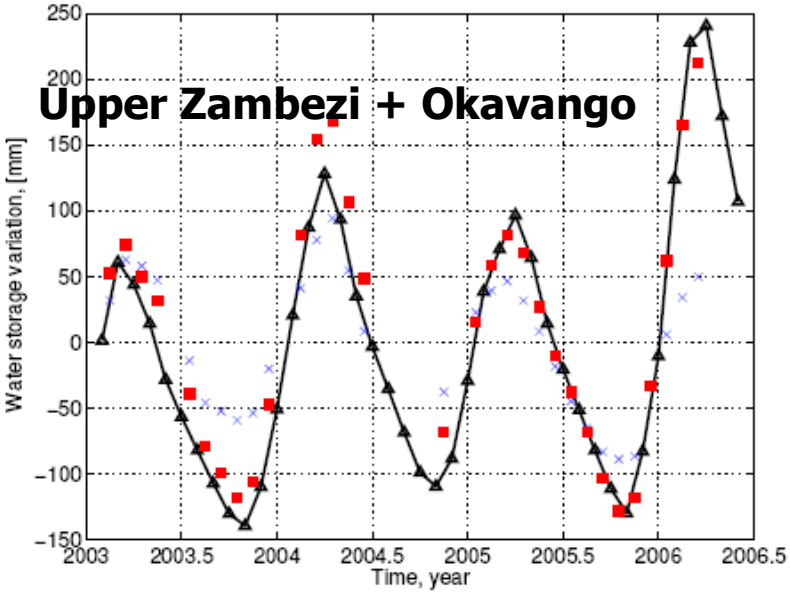
$$\frac{\mathrm{d}S}{\mathrm{d}t} = P - E - Q$$

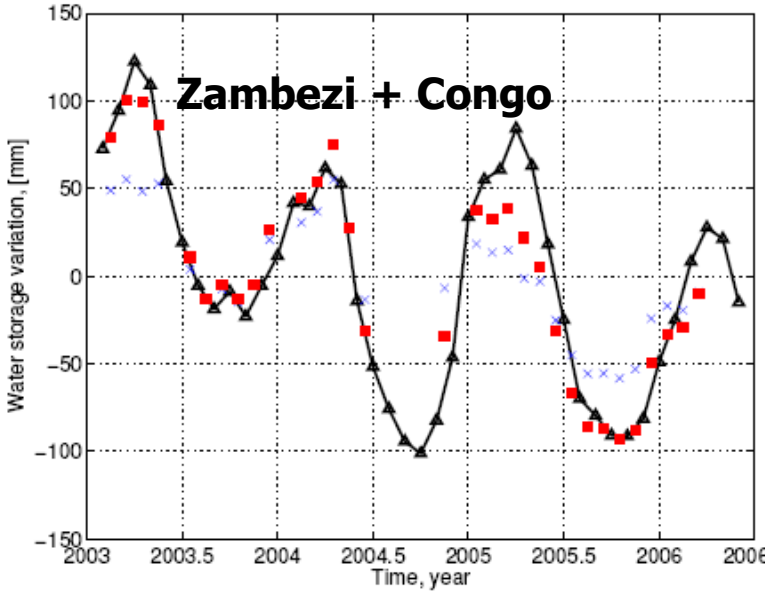



Upper Zambezi
Zambezi
up. Zambezi & Okavango
Zambezi & Congo
°latitude
°longitude
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
0
10
20
30
40
50


Upper Zambezi
Water storage variation, [mm]
Time, year
250
200
150
100
50
0
−50
−100
−150
−200
2003
2003.5
2004
2004.5
2005
2005.5
2006
2006.5

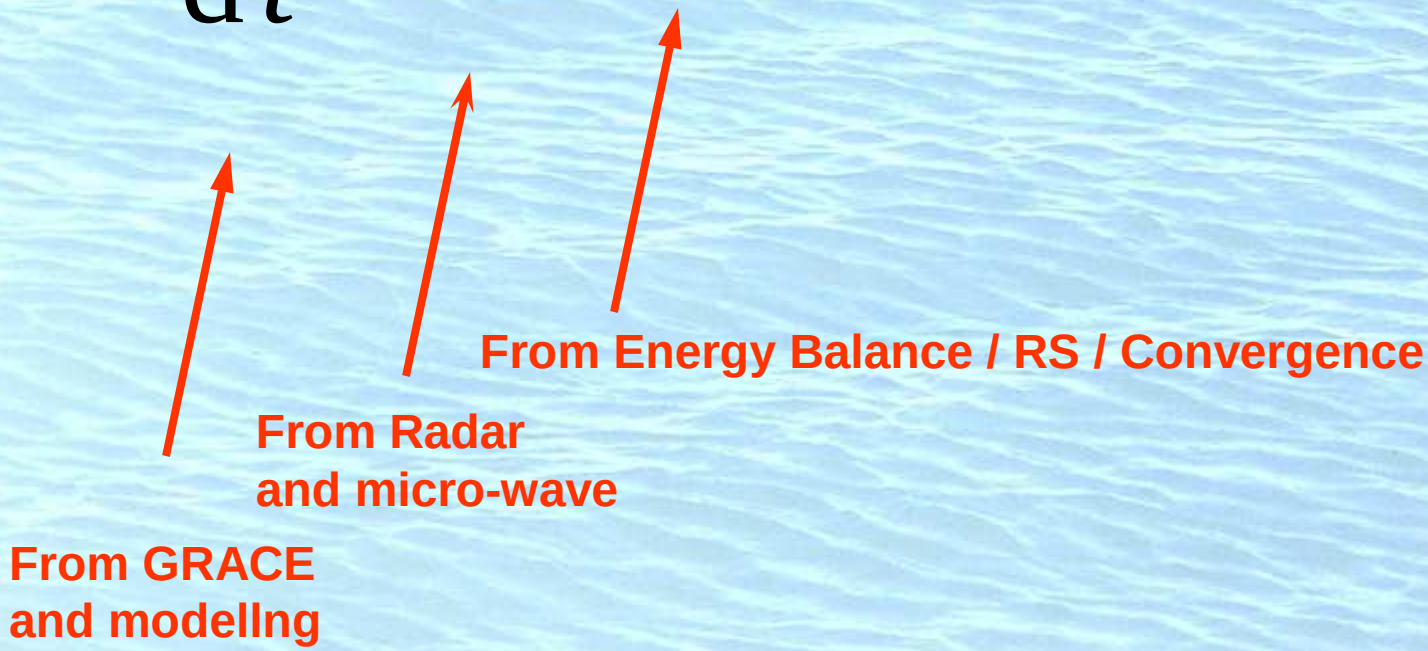

Zambezi
Water storage variation, [mm]
Time, year
200
150
100
50
0
−50
−100
−150
−200
2003
2003.5
2004
2004.5
2005
2005.5
2006
2006.5


Upper Zambezi + Okavango
Water storage variation, [mm]
Time, year
250
200
150
100
50
0
−50
−100
−150
2003
2003.5
2004
2004.5
2005
2005.5
2006
2006.5


Zambezi + Congo
Water storage variation, [mm]
Time, year
150
100
50
0
−50
−100
−150
2003
2003.5
2004
2004.5
2005
2005.5
2006

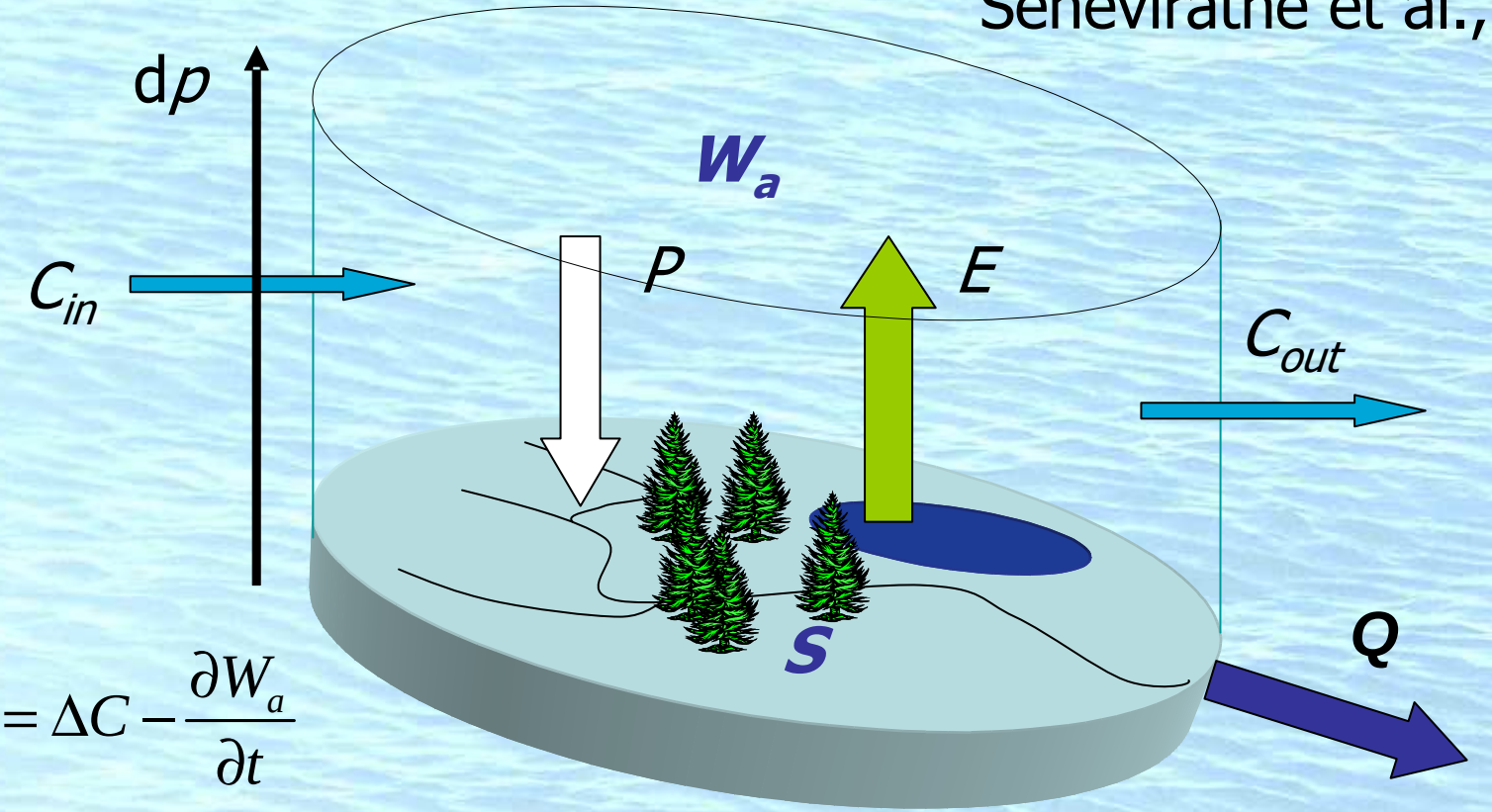
Evaporation sensing

$$\frac{\mathrm{d}S}{\mathrm{d}t} = P - E - Q$$



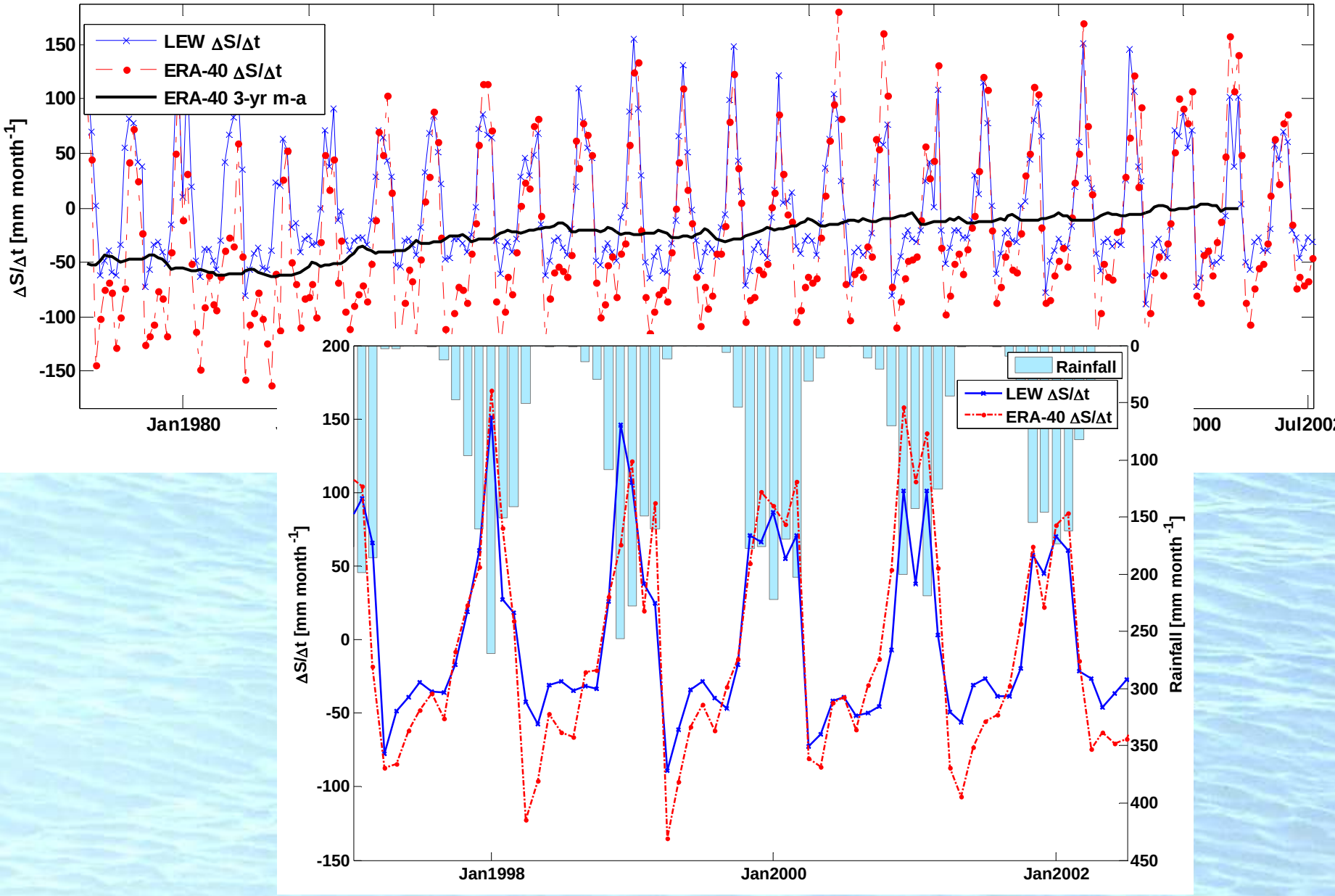
Atmospheric Moisture Convergence

Seneviratne et al., 2004



$$P - E = \Delta C - \frac{\partial W_a}{\partial t}$$

$$P - E = \frac{\partial S}{\partial t} + Q$$


LEW ΔS/Δt
ERA-40 ΔS/Δt
ERA-40 3-yr m-a
ΔS/Δt [mm month-1]
Jan1980
Jul2002
Rainfall
LEW ΔS/Δt
ERA-40 ΔS/Δt
ΔS/Δt [mm month-1]
Rainfall [mm month-1]
Jan1998
Jan2000
Jan2002

Wat voor dingen doen we ?

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  - GRACE
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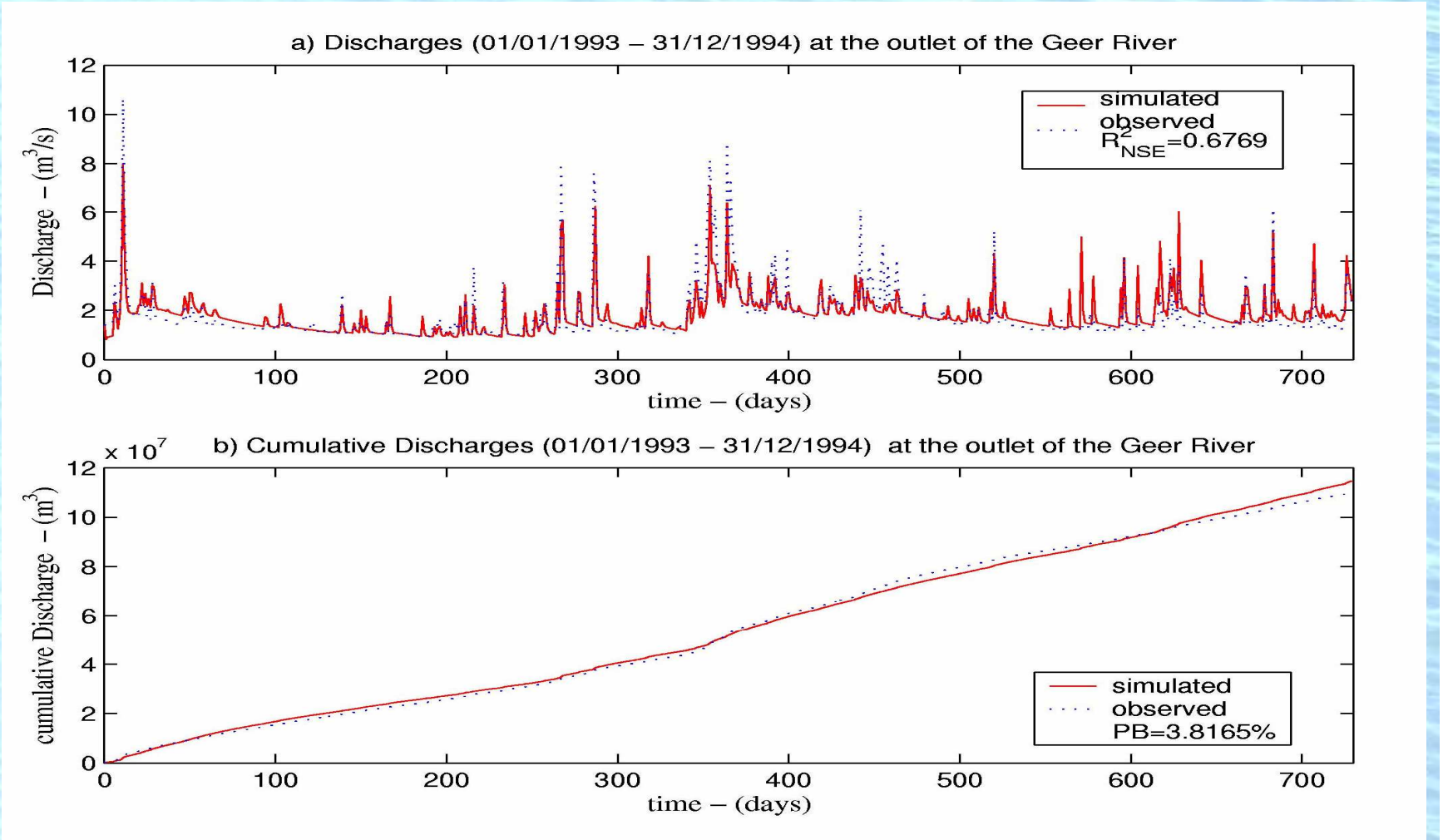
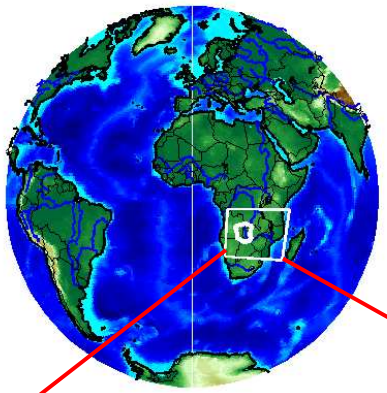
- Modelleren
  - Luxemburg
  - Zambezi

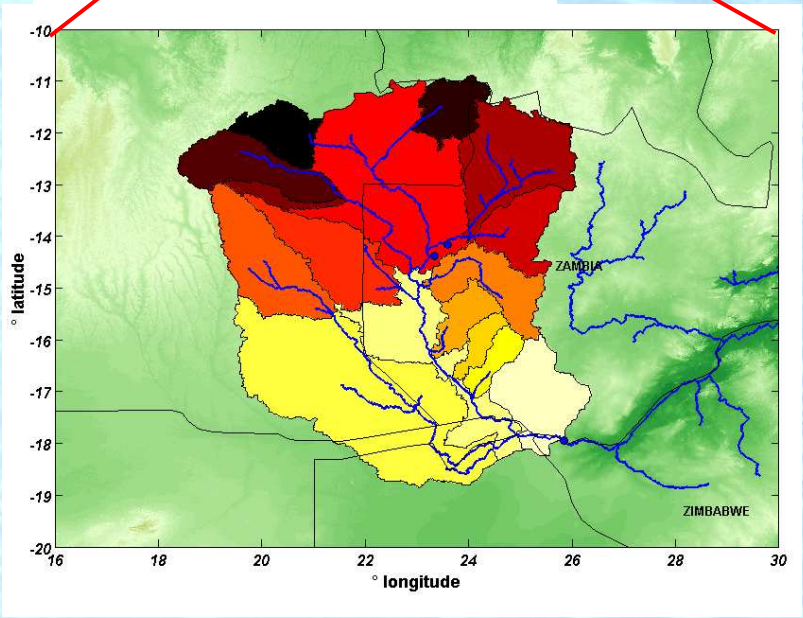
Modellering De Geer

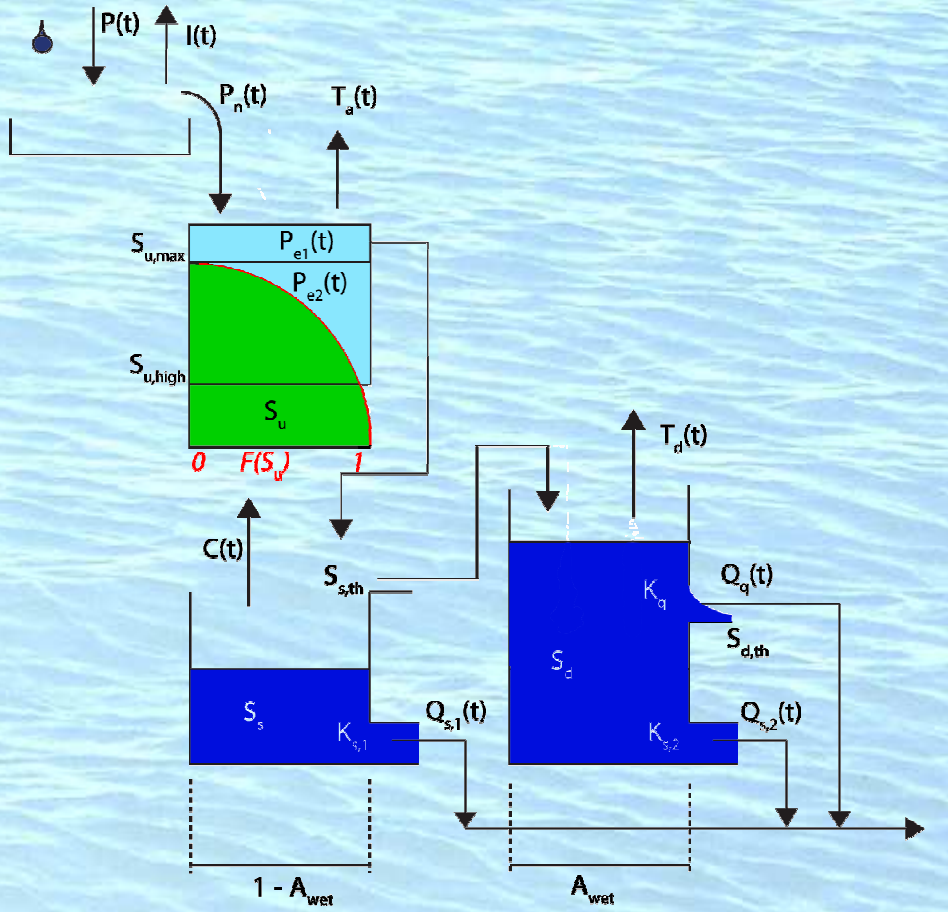



Zambezi

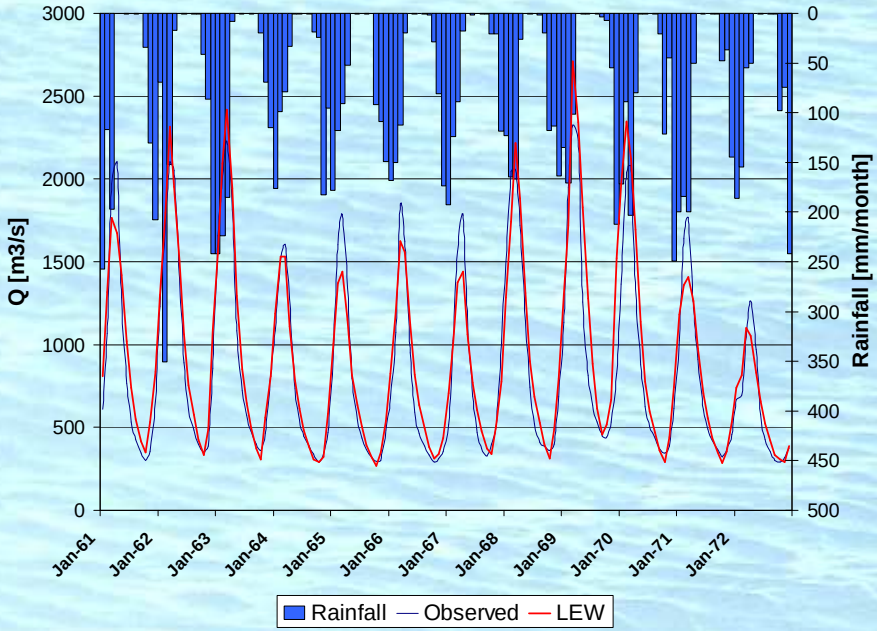
Zambezi Model



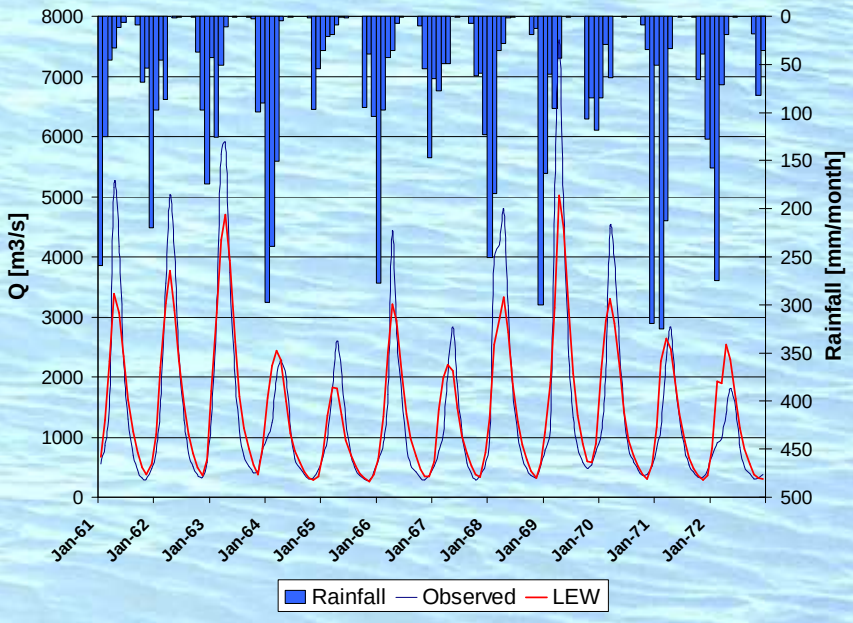




Zambezi Model



Lukulu



Victoria Falls


ISUZU

Hydrologie van Extreme Gebeurtenissen

Prof. dr. ir. H.H.G. Savenije

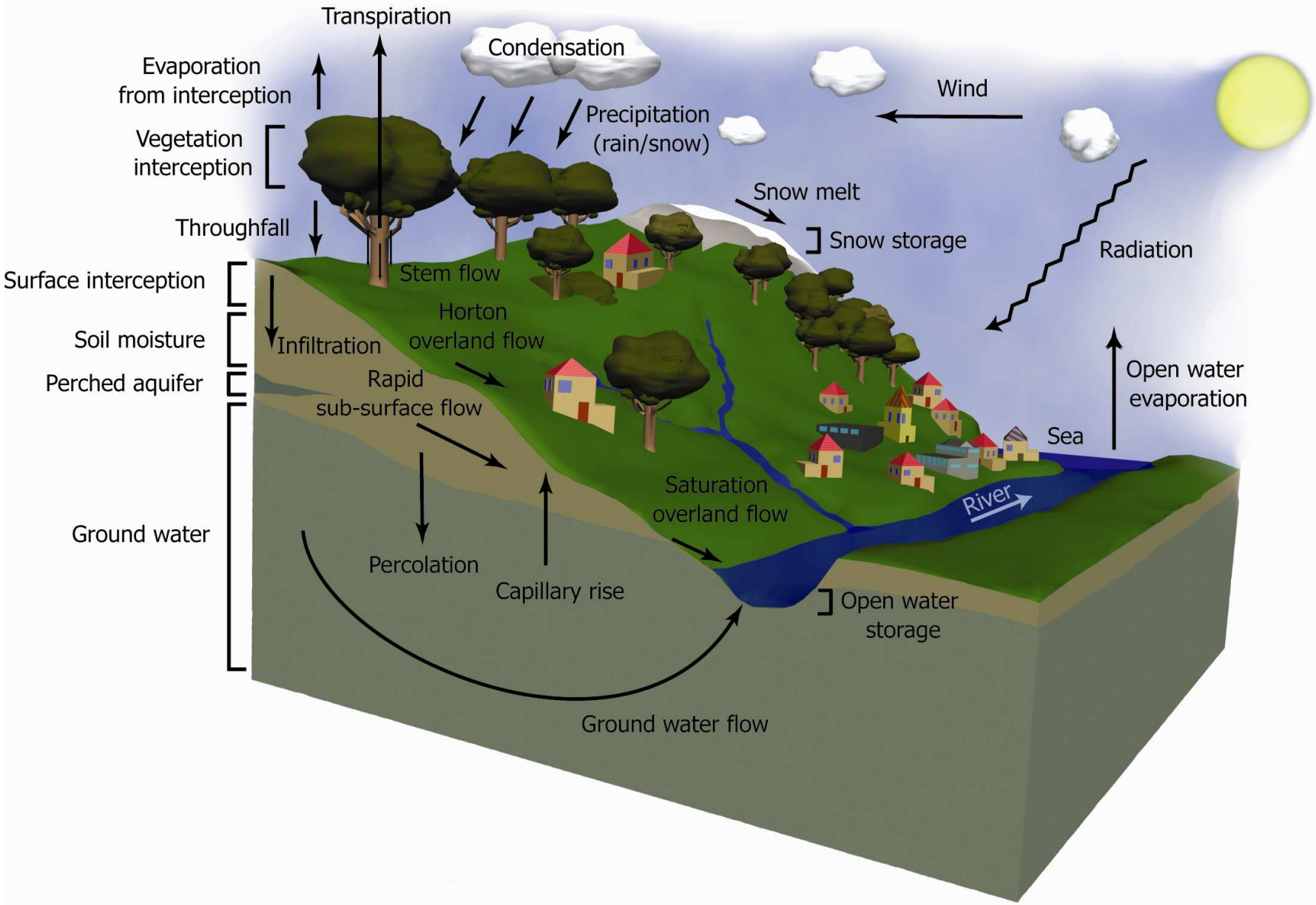
TU Delft

Hydrologie: de grote vragen

- Waar komt het water vandaan?
- Hoeveel water is er?
- Hoe houden we het droog?
- Hoe houden we een gezond ecosysteem?
- Wat is de invloed van menselijk handelen?
- Wanneer krijgen we overstromingen?

Waar komt het water vandaan?

- Uit de grond als groot ondergronds reservoir (klassieke oudheid)
- Van de regen (Aristoteles 350 BC)
- Uit regen en uit zee via ondergrondse aderen (Leonardo da Vinci, 1452-1519)
- Uit grotten in de bergen (Edmund Halley 1656-1742)
- Van de Regen (Perrault 1608-80)


Transpiration
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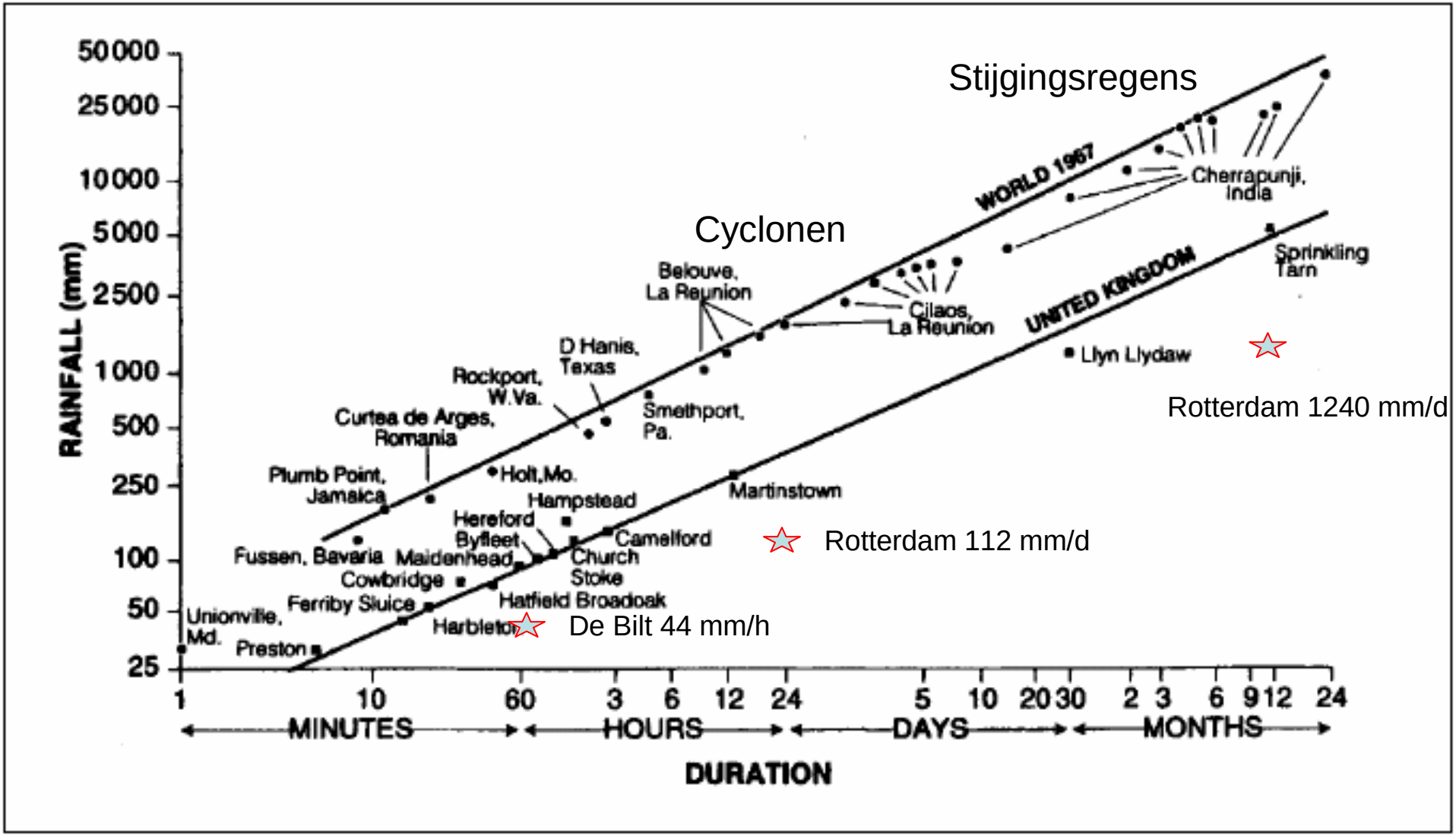
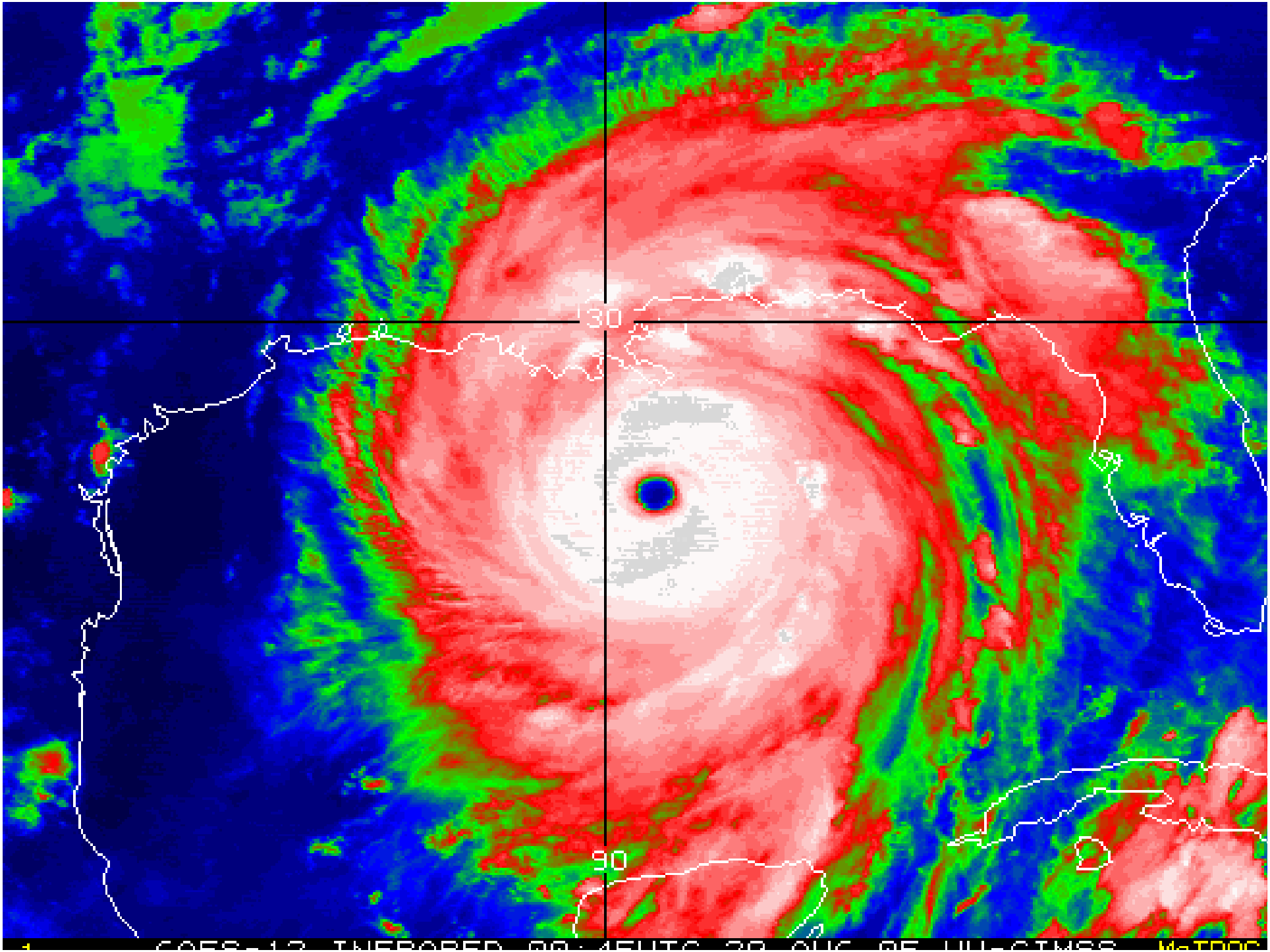
Rapid
sub-surface flow
Open water
evaporation
Sea
Saturation
overland flow
River
Ground water
Percolation
Capillary rise
Open water
storage
Ground water flow

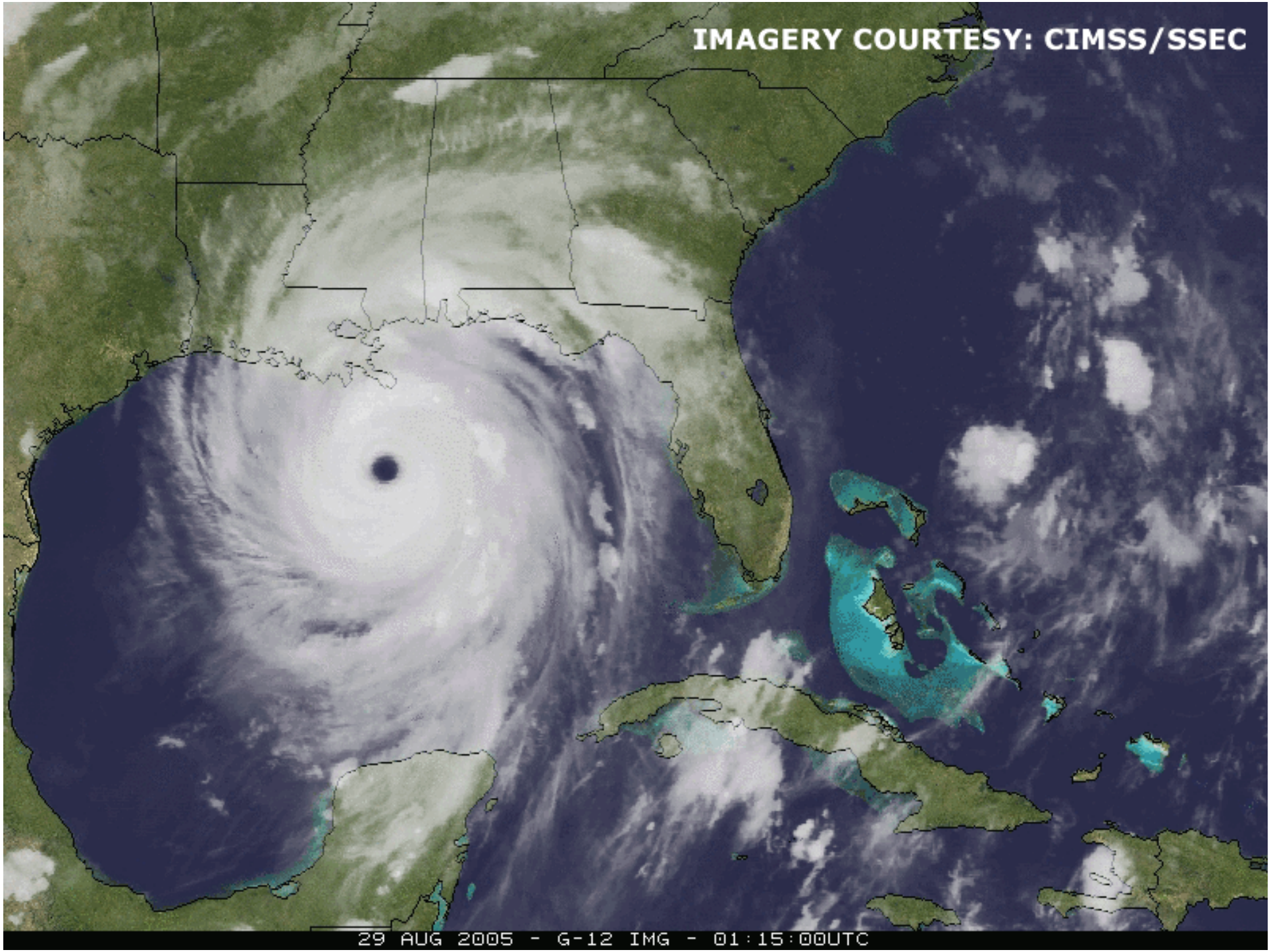
Wanneer krijgen we overstromingen?

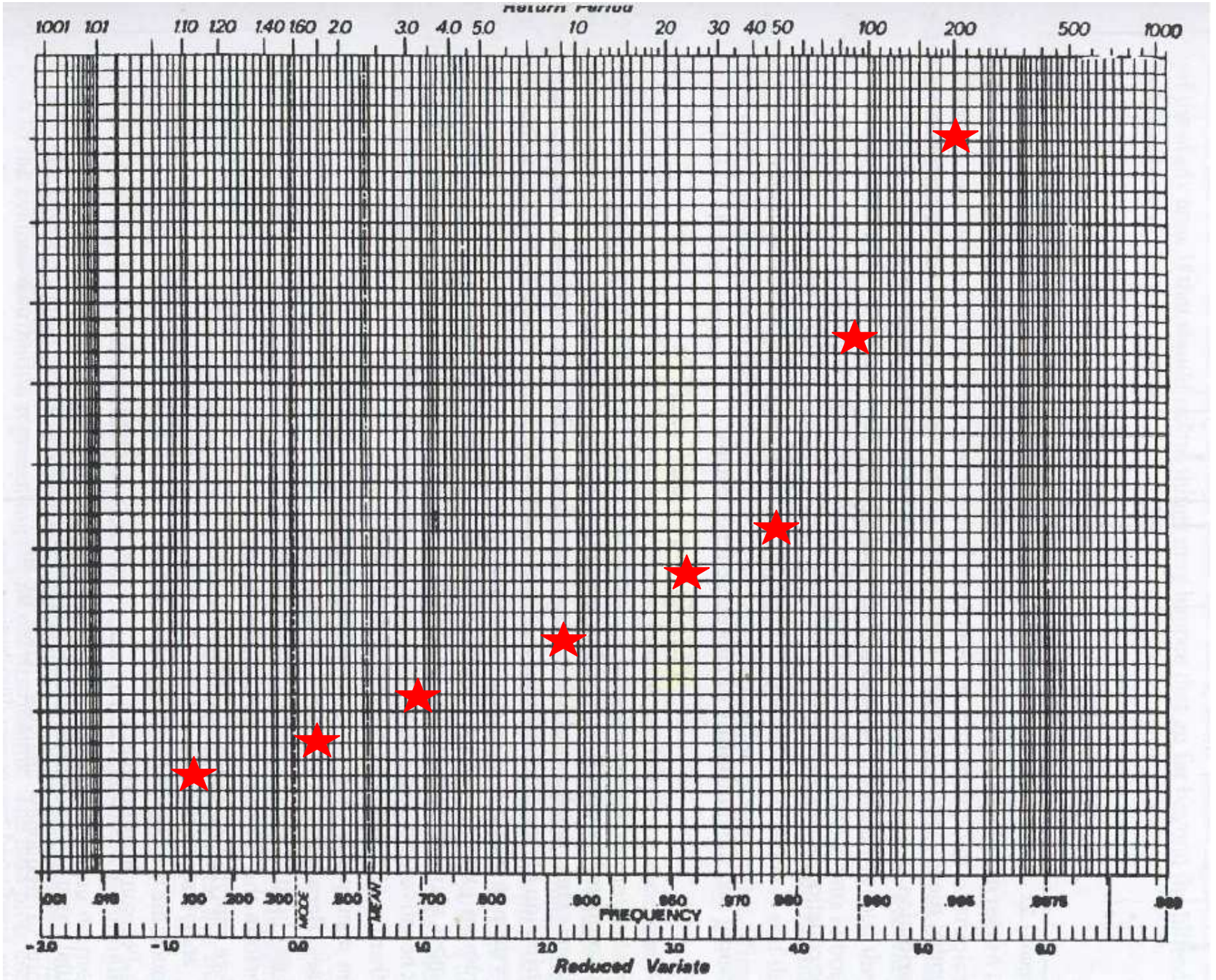
- Waar en hoe hoog?
  - flood mapping,
  - flood modelling
- Wanneer?
  - flood forecasting
- Hoe vaak?
  - flood frequency analysis

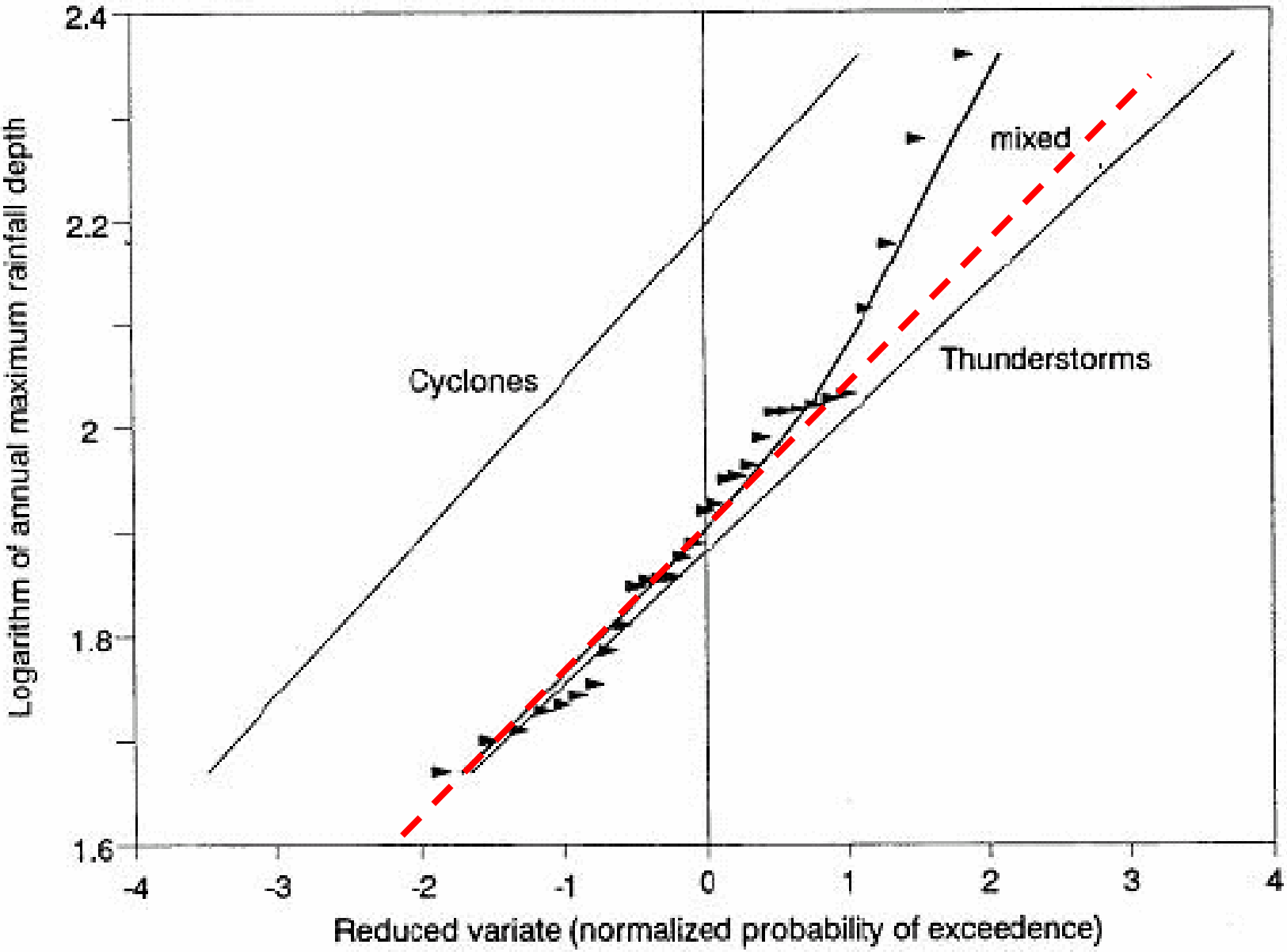
Extreme Regenval




30
90


IMAGERY COURTESY: CIMSS/SSEC
29 AUG 2005 - G-12 IMG - 01:15:00UTC


Return Period
1001 101 1.10 1.20 1.40 1.60 2.0 3.0 4.0 5.0 10 20 30 40 50 100 200 500 1000
.001 .010 .100 .200 .300 .500 .700 .800 .900 .950 .970 .980 .990 .995 .9975 .999
MODE
MEAN
FREQUENCY
-2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0
Reduced Variate


2.4
2.2
2
1.8
1.6
-4
-3
-2
-1
0
1
2
3
4
Logarithm of annual maximum rainfall depth
Reduced variate (normalized probability of exceedence)
Cyclones
mixed
Thunderstorms

Murphy’s Law of Floods

- Extreem hoogwater treedt op:
  - ‘s Nachts als iedereen slaapt
  - In het weekend als kantoren dicht zijn
  - Na heftige storm en regenval als wegen kapot zijn en communicatielijnen verbroken
  - Als iedereen wil bellen en het netwerk op tilt is
  - Als bruggen kapot zijn en het wegennet verstopt is

Tijdens de cycloon in Mozambique

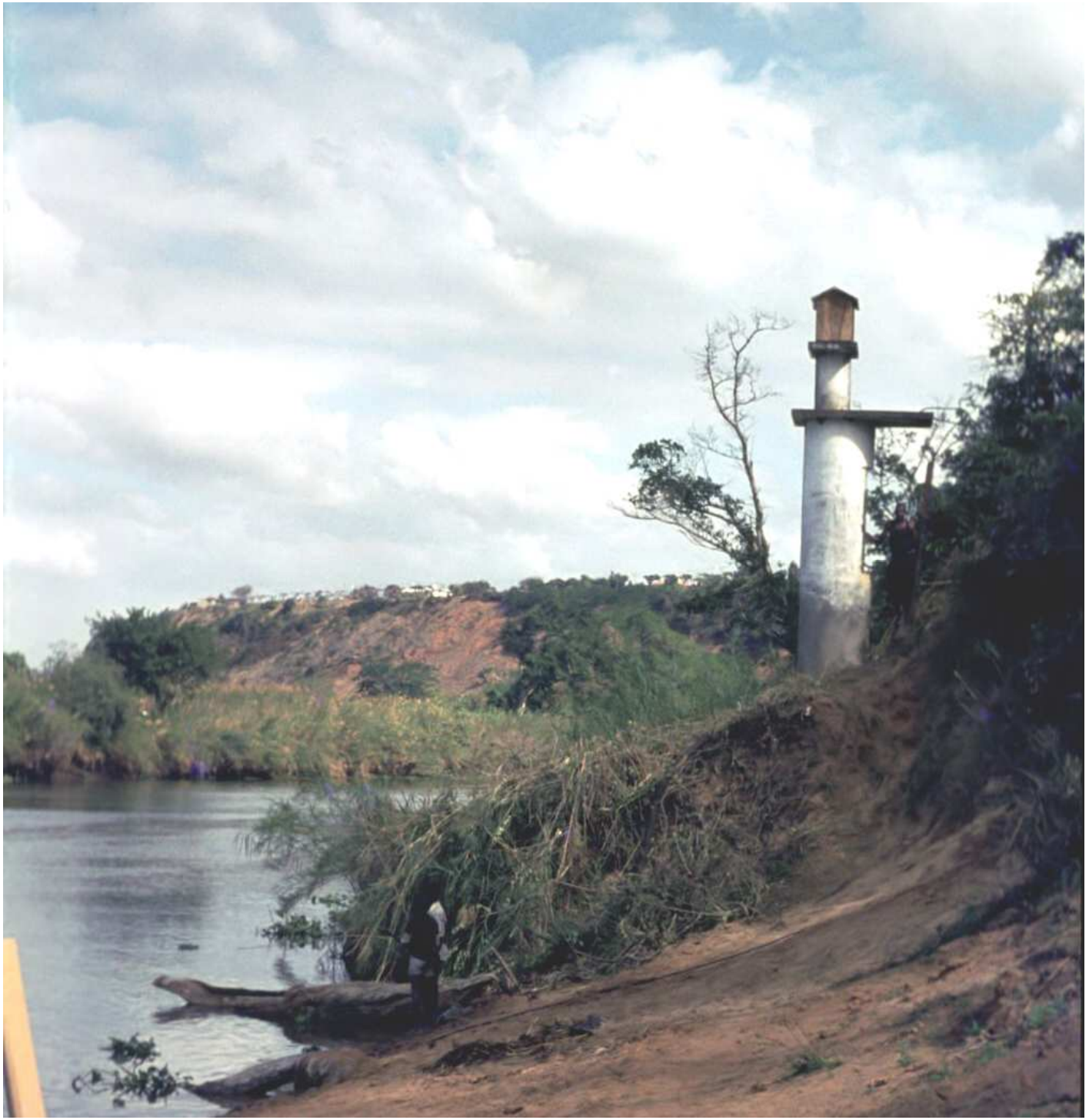
- Was het meetstation overspoeld
- Was de batterij leeg
- Konden we het station niet bereiken
- Was de meetstuw kapotgegaan
- Werd het propellor meetinstrument meegesleurd door drijvend materiaal

Les:

- Als het echt spannend wordt:
  - Doet niks het meer
  - Zou je willen meten maar kan het niet
  - Is er paniek
  - Zijn we slecht voorbereid

Dus:

- Voorbereid zijn op dat het mis gaat
- Metingen “morning after”
- Goede voorspellingsmodellen
- Goede rampenplannen en nazorg




TOYOTA
M_L-23-09


1985-1977