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Techniques multi-échelles

interactions géophysique et systèmes urbains

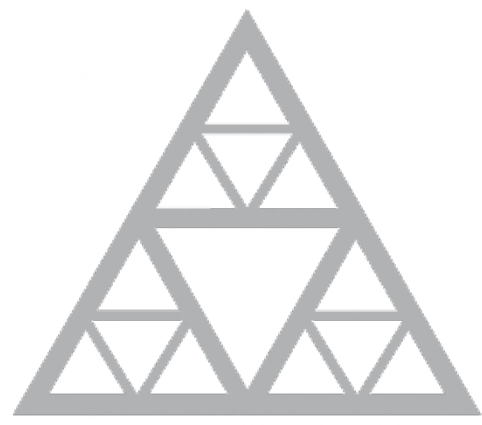
introduction

Daniel Schertzer

Ecole des Ponts ParisTech (ENPC), Hydrologie Météorologie et Complexité (HM&Co)

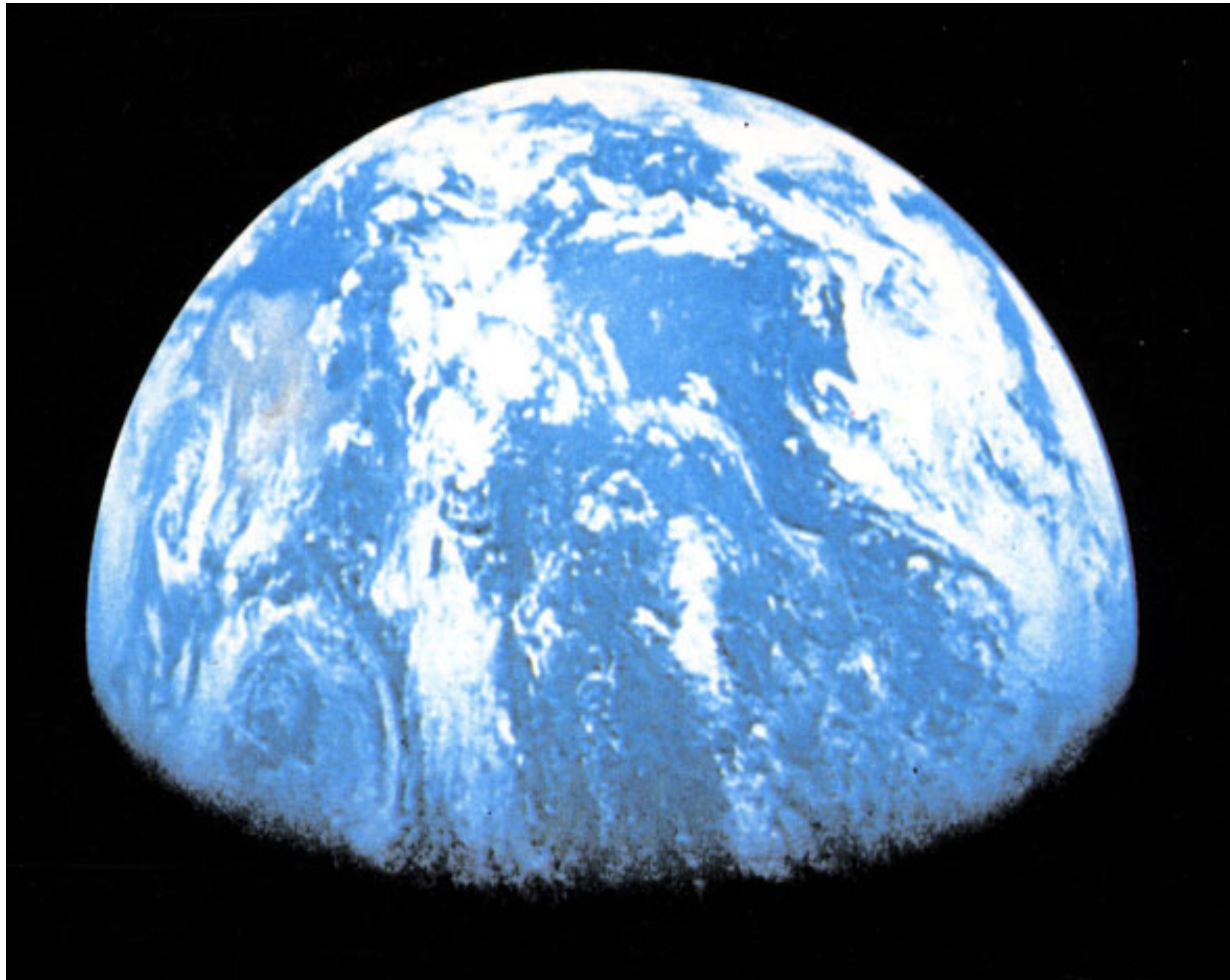
CIMPA Libreville

15-25/05/2023



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Our Blue Planet



DISCOVRS
DE LA METHODE

POVR BIEN CONDVIRE SA RAISON,
& chercher la verité dans les Sciences.

PLVS

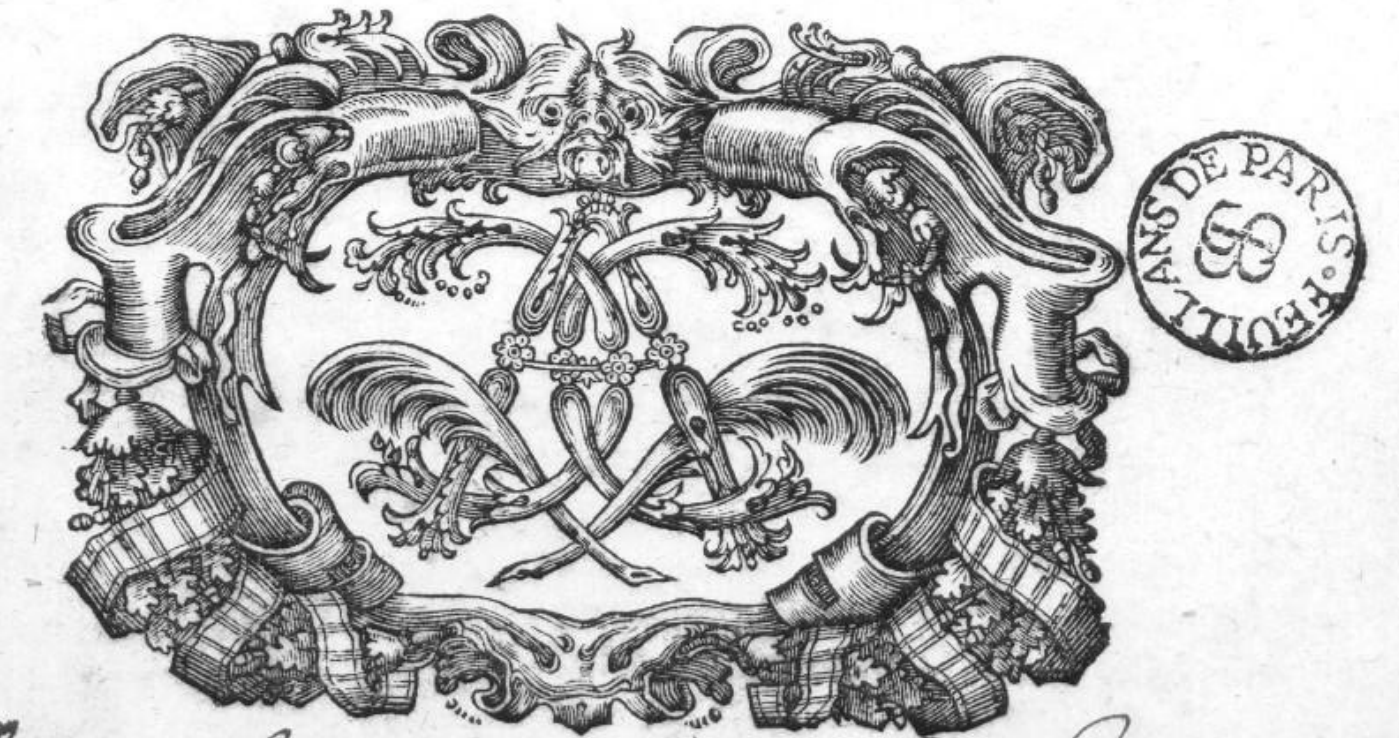
LA DIOPTRIQUE, LES METEORES,

LA MECHANIQUE,

ET LA MVSIQUE, Qui sont des essais de cette METHODE

PAR RENE' DESCARTES.

Auec des Remarques & des éclairciffemens necessaires.



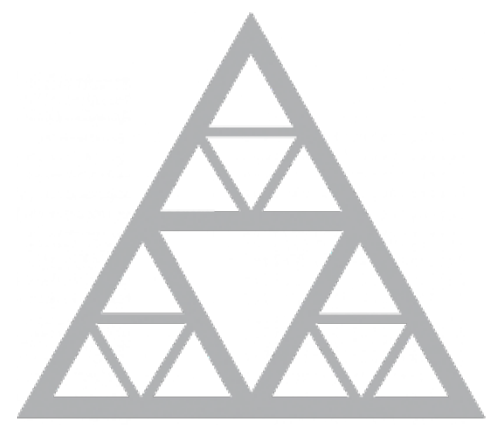
Ex Bibliotheca Aulicorum Sti Bernardi Parisiensis
A PARIS,

Chez CHARLES ANGOT, rue saint Iacques,
au Lion d'Or.

M. DC. LXVIII.

AVEC PRIVILEGE DV ROY.

3485



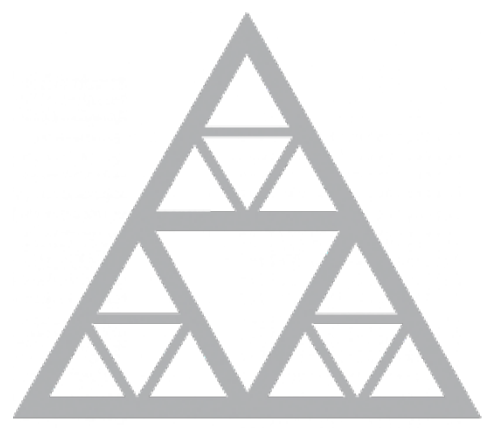
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UN sustainable development



“Brundtland Report”, published on October 1987, "900-day" international exercise.





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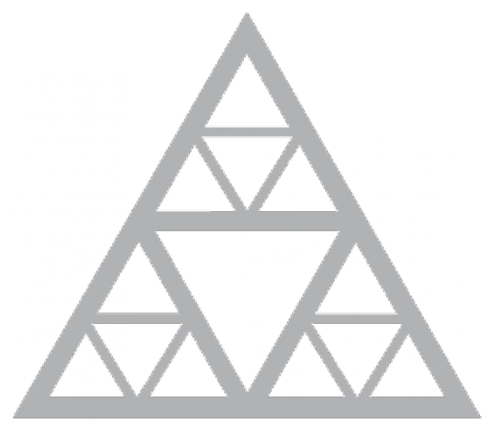
UN SDGs



- UN 2030 Agenda and follow-ups: a **vibrant call to engineering intelligence**
- not achievable without
 - **advanced observation technologies** (e.g. small radars and lidars)
 - **innovations** (e.g., Blue Green/Nature Based solutions)
 - **disruptive methodologies** (multiscale analysis, simulation and modelling)
 - **synergic, integrative approaches** overcoming the traditional silo thinking

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD





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Data era and sciences



- a multiscale question
 - from local authorities
 - to international bodies
- not only open data
 - INSPIRE directive
- open access to
 - concepts
 - simulations (SaaS platforms)
- how to invest for these developments?





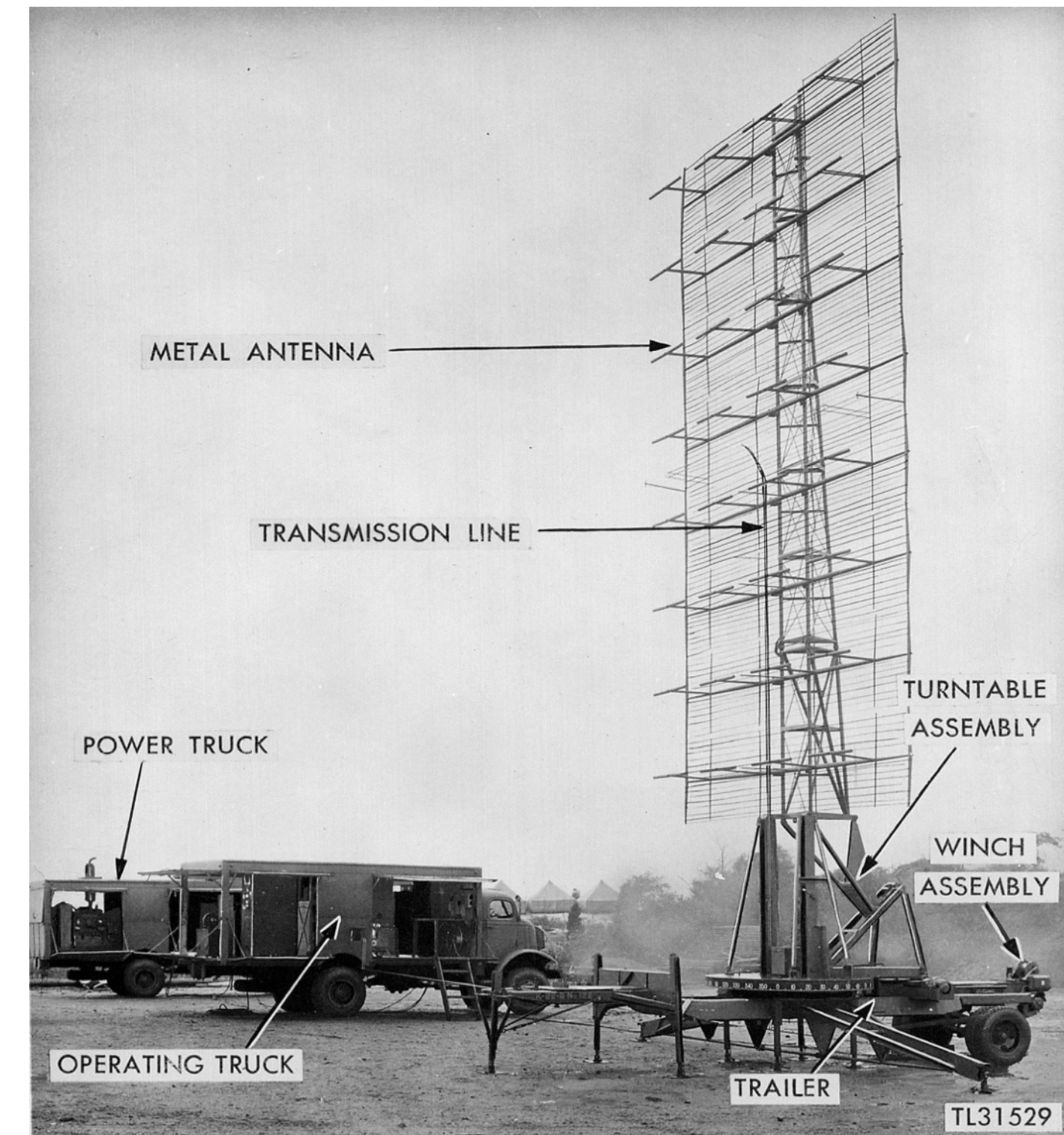
Marshal & Palmer
Z-R relationship
(McGill U., Montreal)

- **Radio Detection And Ranging**
(US Navy, ca. 1936)
- An electronic instrument used for the detection and ranging of distant objects of such composition that they scatter or reflect radio energy.

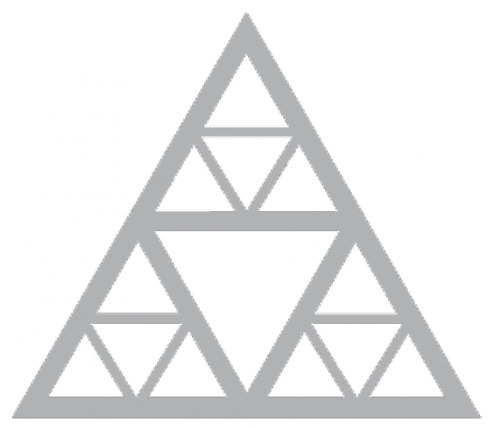
Radar ?



David Atlas: first operational radars
(US Air Force, MIT)

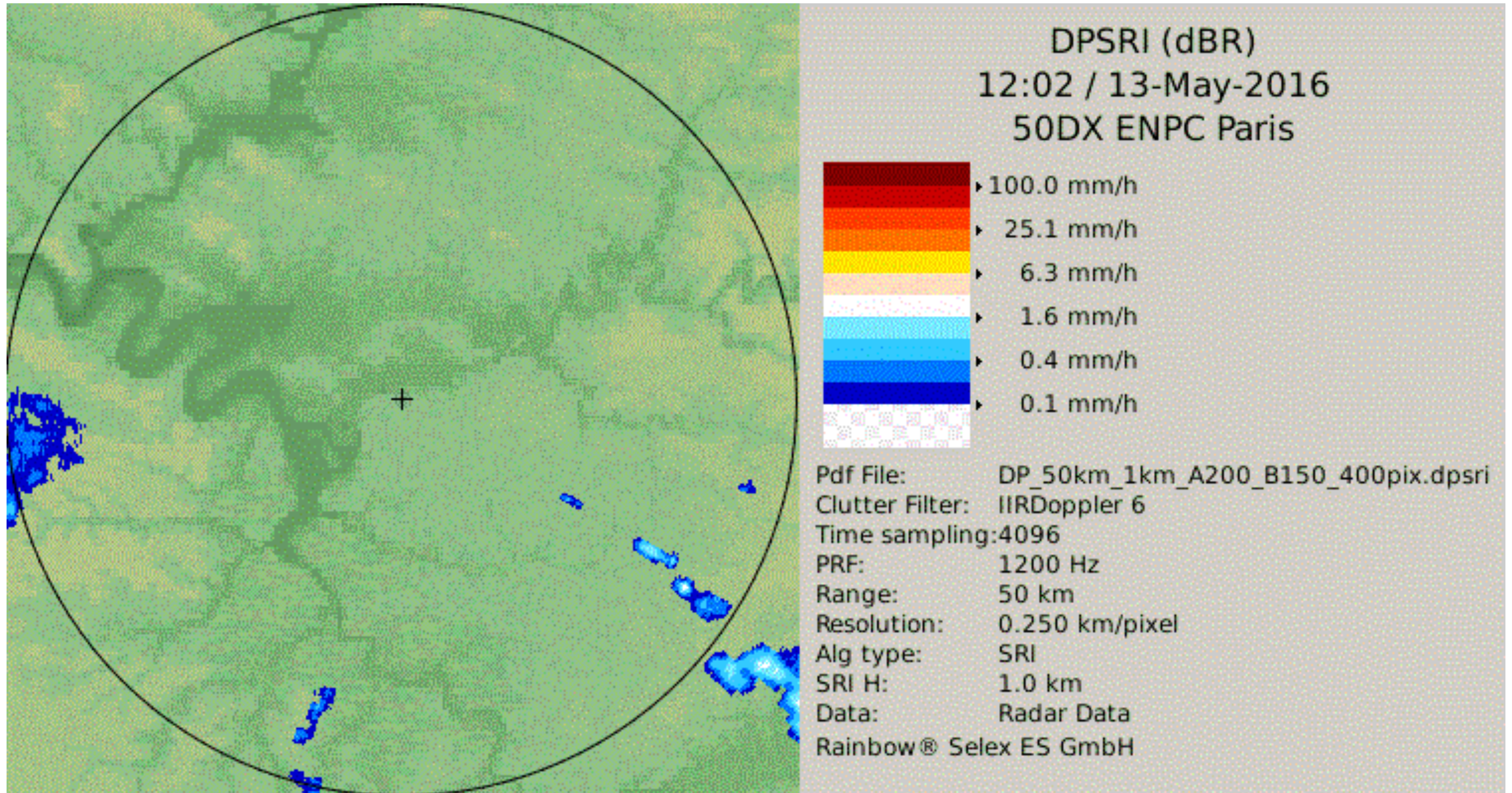


Signal Corps Radio model 270



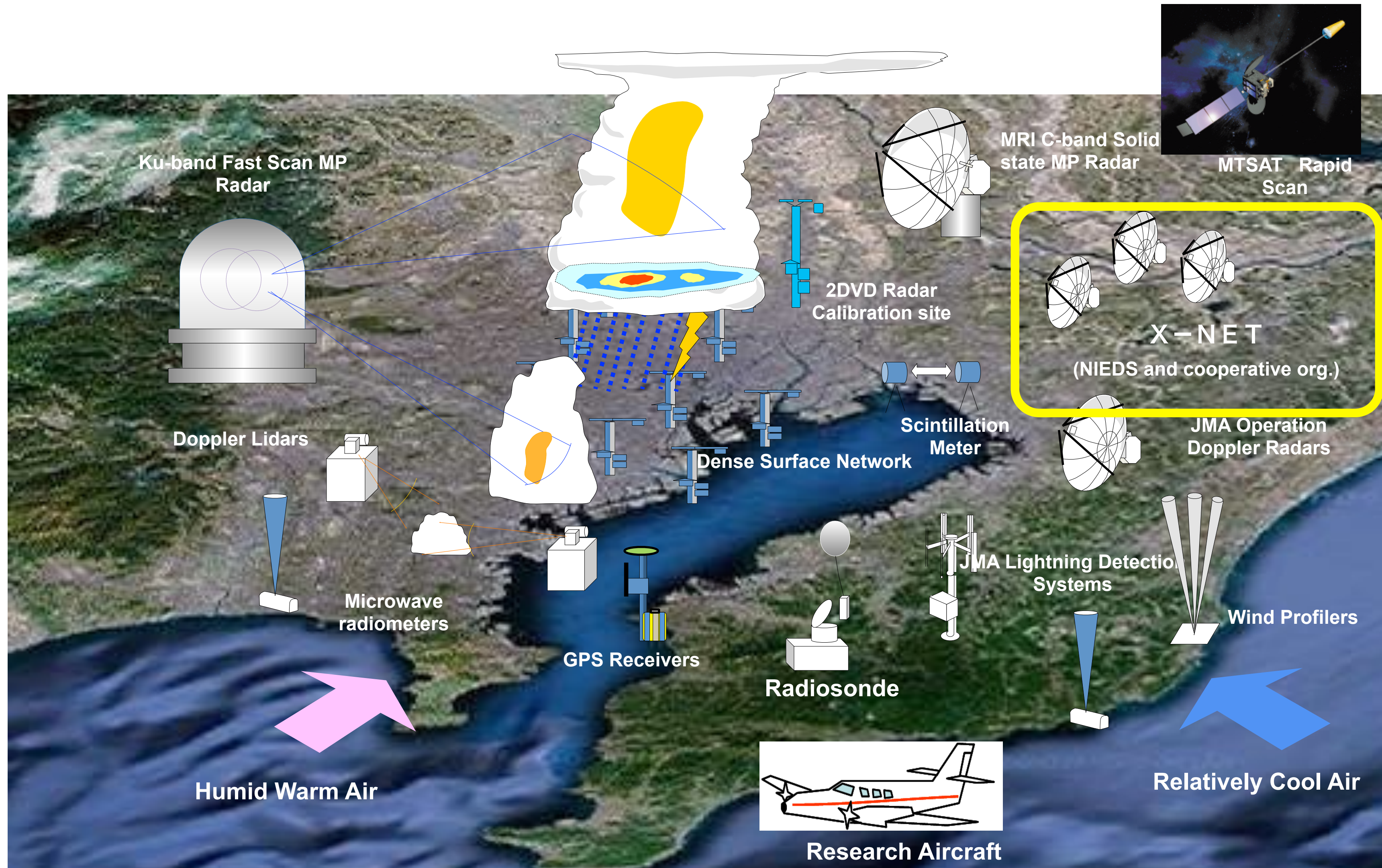
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Close to a major flood in Paris: (13 May 2016)



Field Campaign (2010-2013)

TOMACS (Tokyo Metropolitan Area Convection Study) with a dense observation network by MRI, NIED and 12 research groups in the summers of 2010-2013, as testbed for deep convection.

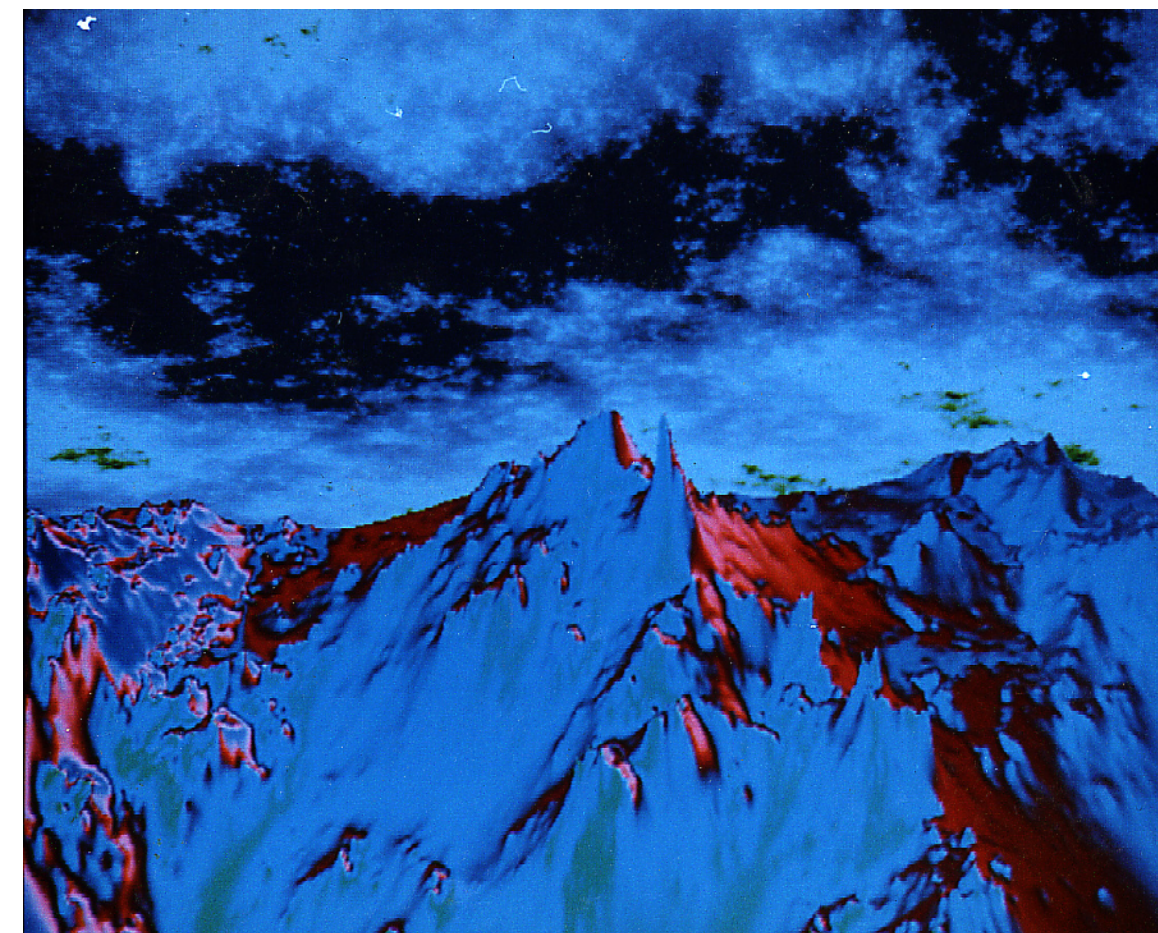


Nobel 2021 : complexity and heterogeneity

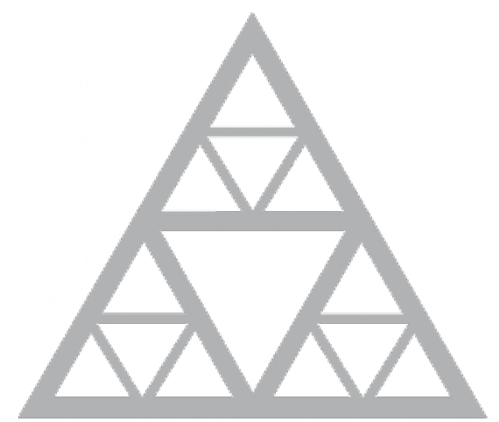
- Nobel Prize in Physics 2021 awarded to Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi "for groundbreaking contributions to our understanding of **complex physical systems**"



Three different approaches, but a common object: our planet!



Emphasis of the “scientific background” of the prize on intermittency (*)



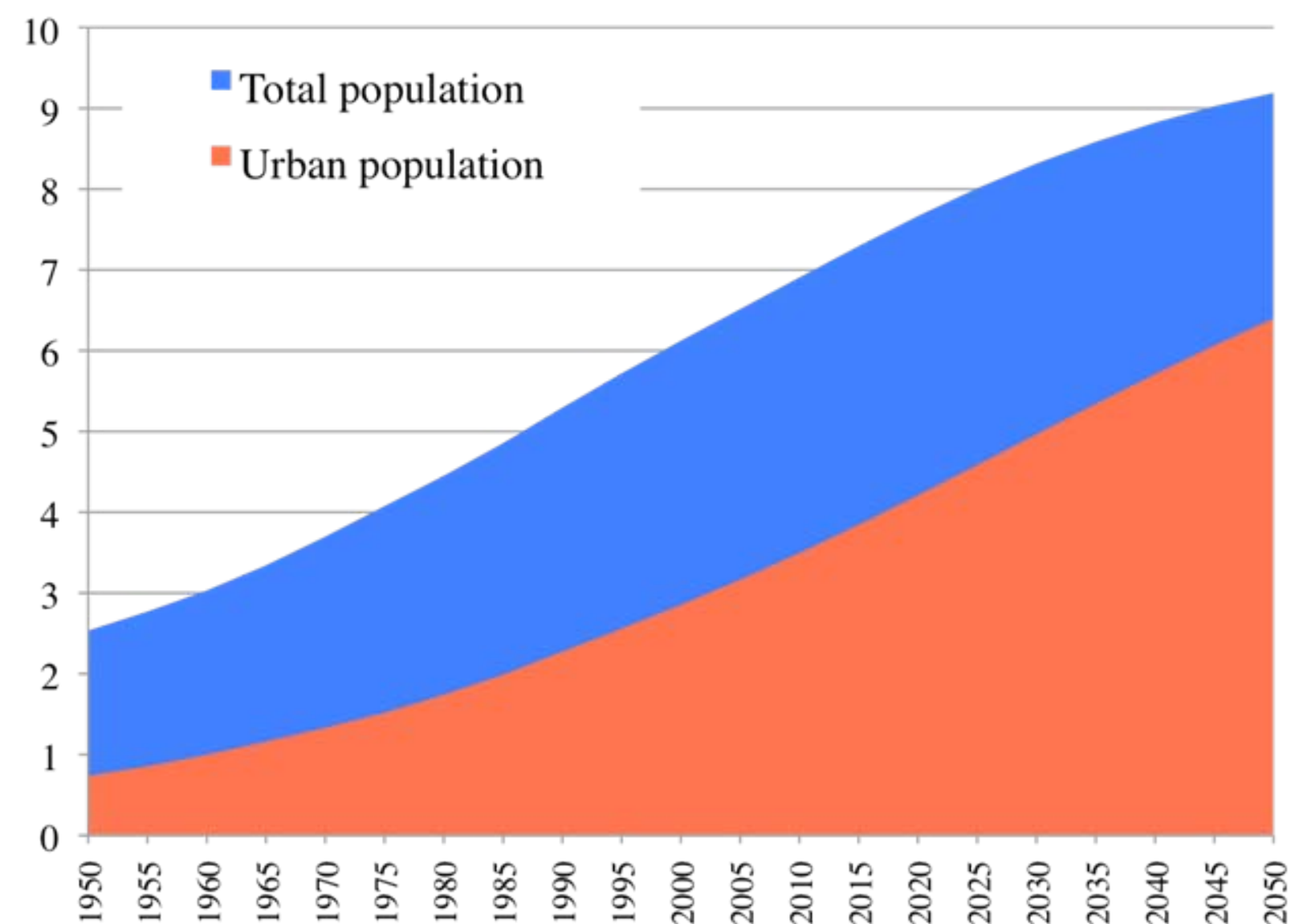
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Urban and rural populations 1950-2050 (UN projections)

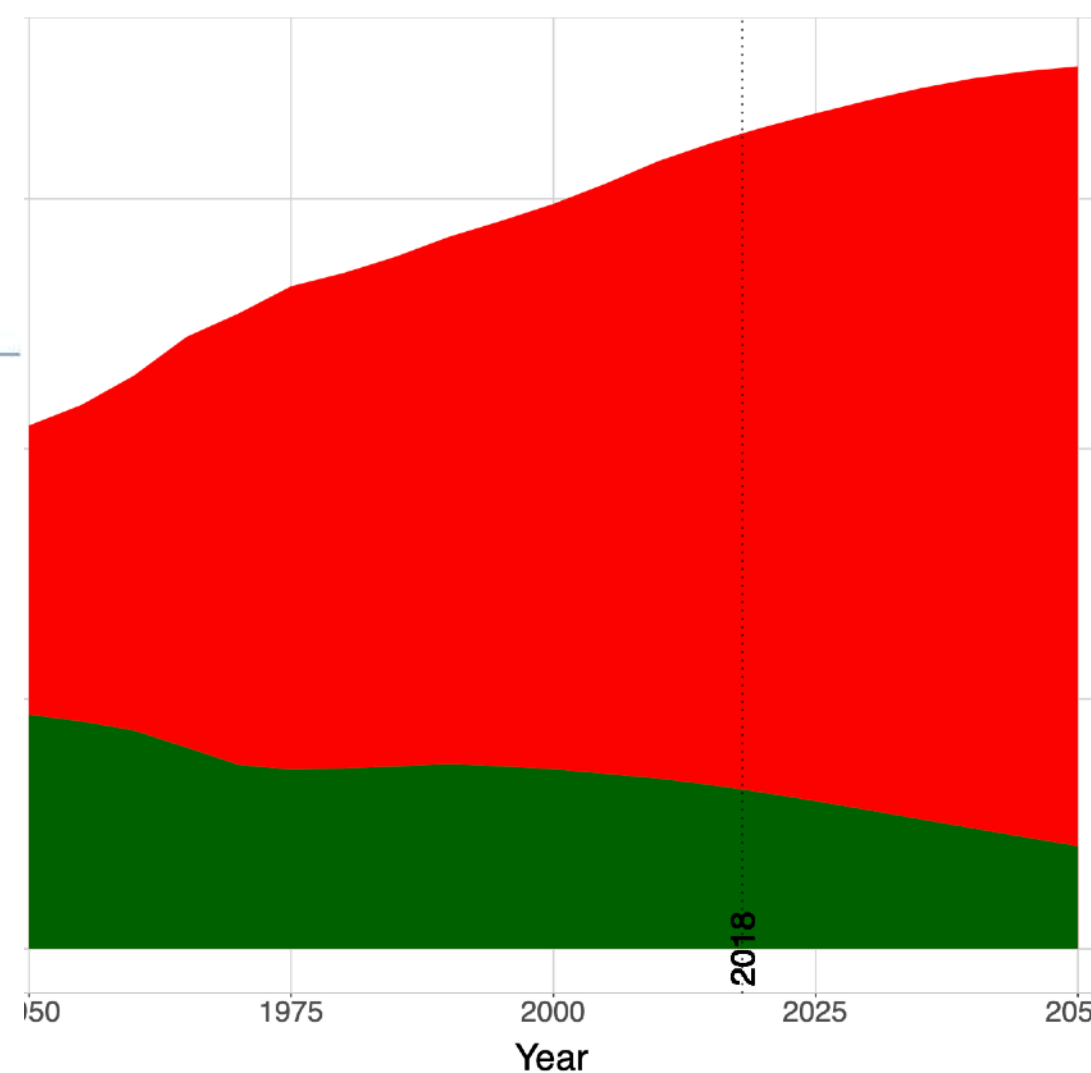


Growing Urban Population

(Billion)

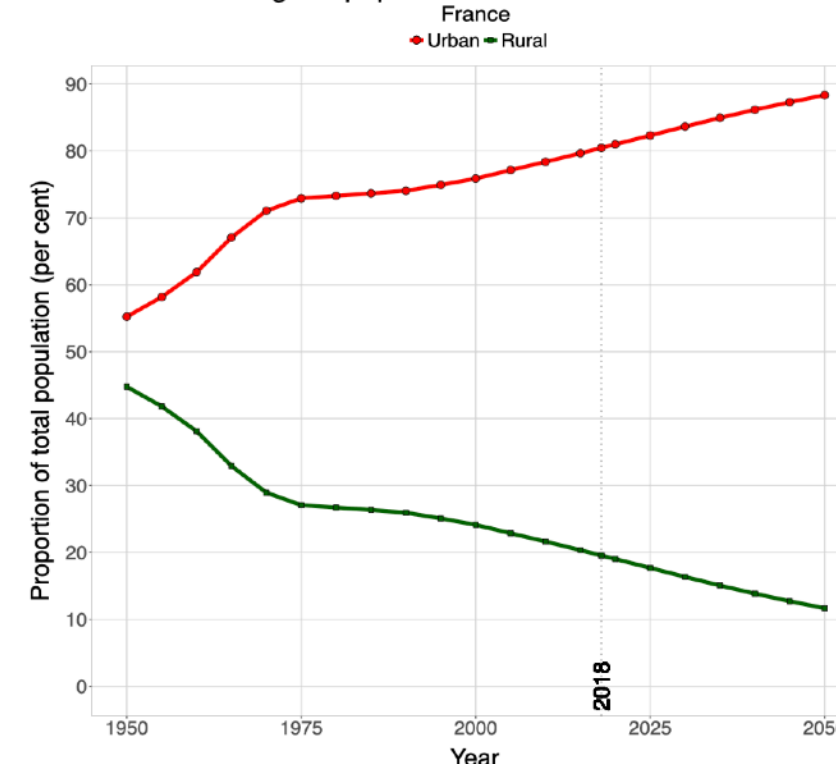


Urban and rural population
France



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Percentage of population in urban and rural areas
France

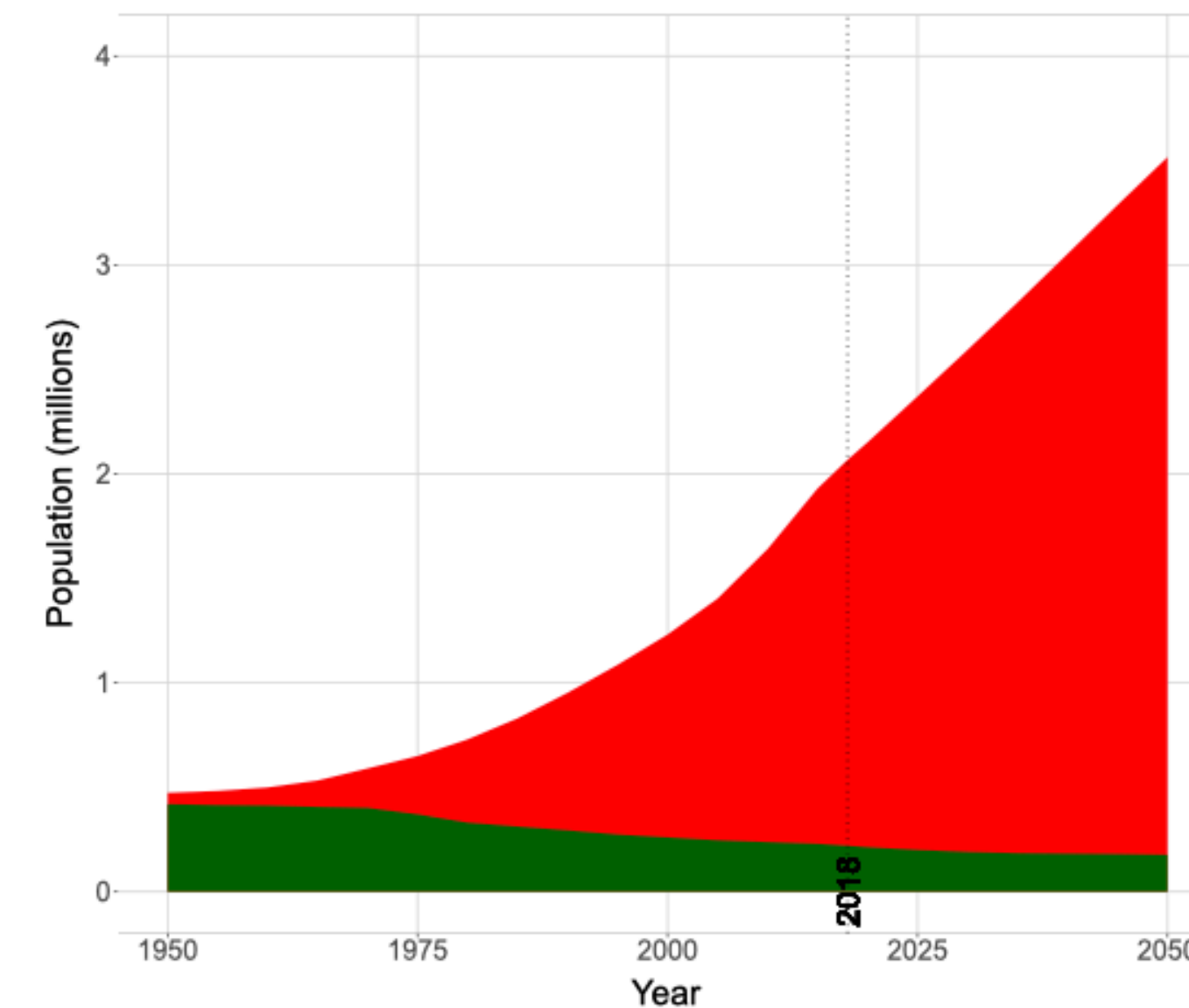


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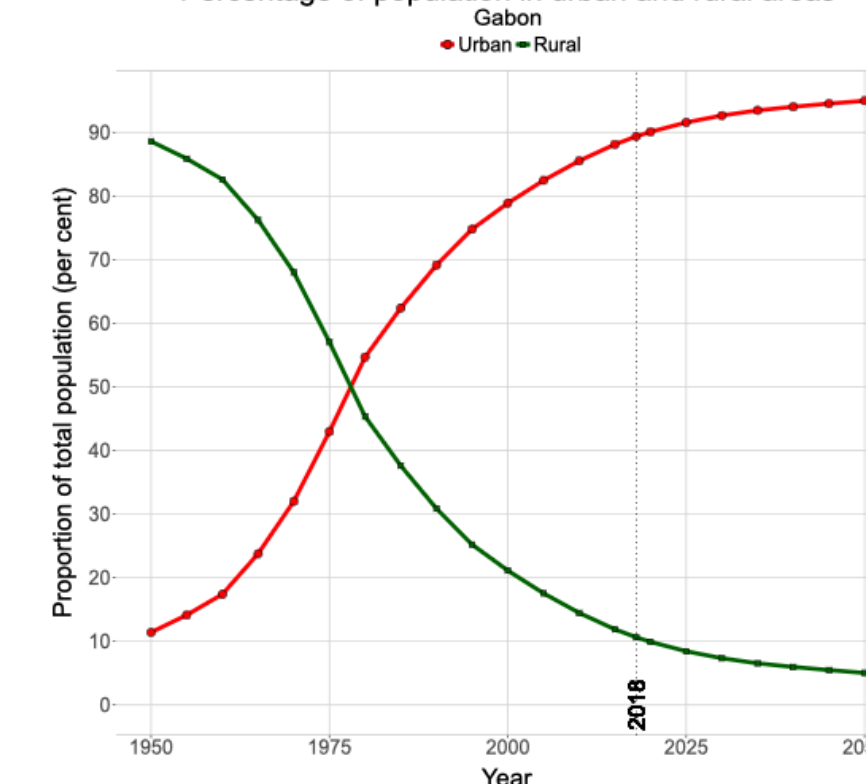
Note: Urban and rural population in the current country or area as a percentage of the total population, 1950 to 2050.

Data file

Urban and rural population
Gabon

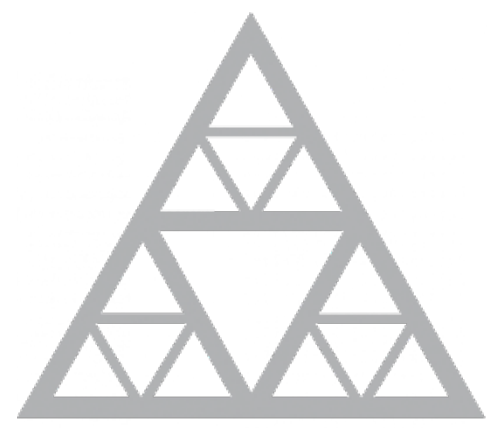


Percentage of population in urban and rural areas
Gabon



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Note: Urban and rural population in the current country or area as a percentage of the total population, 1950 to 2050.

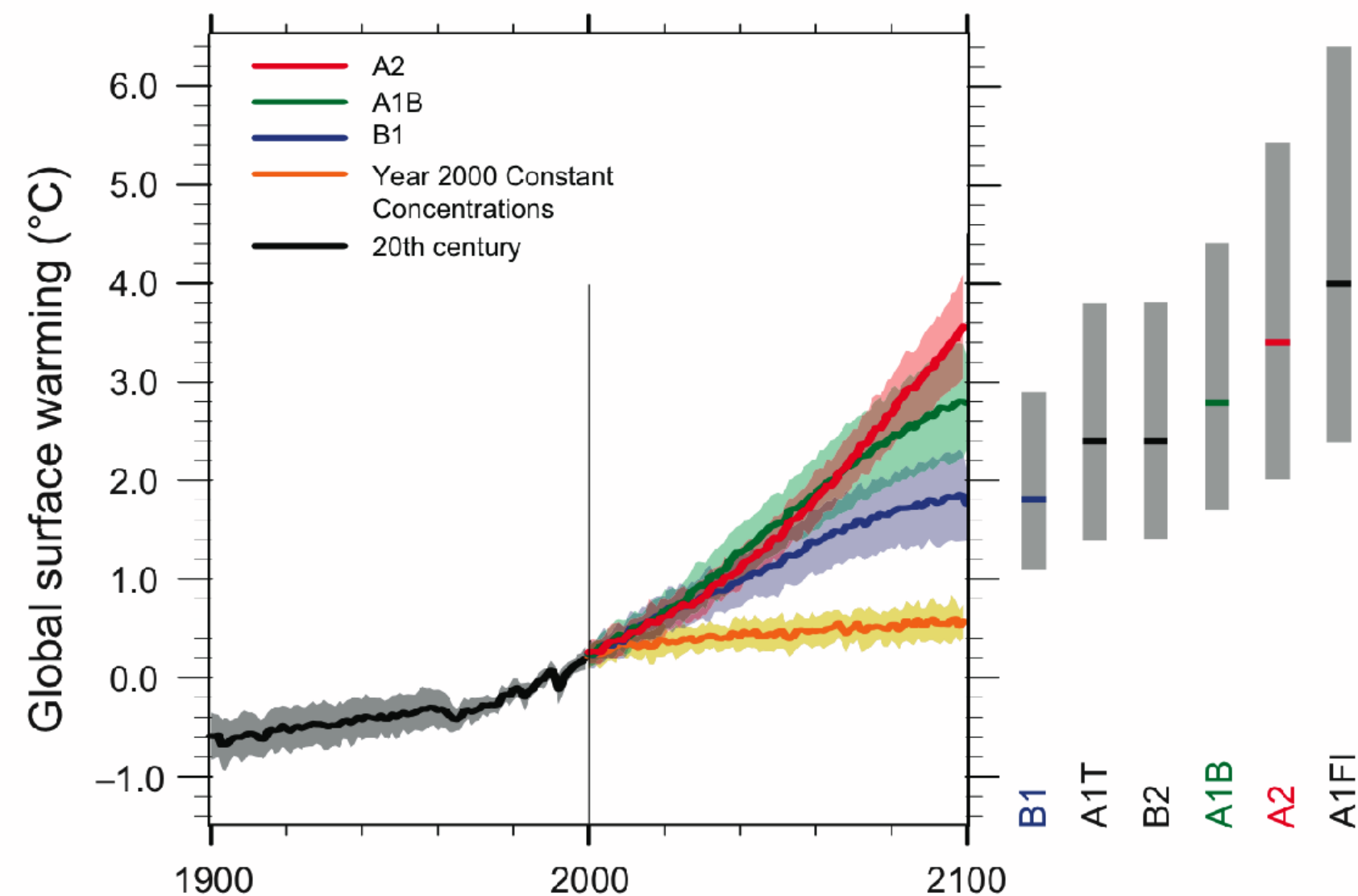


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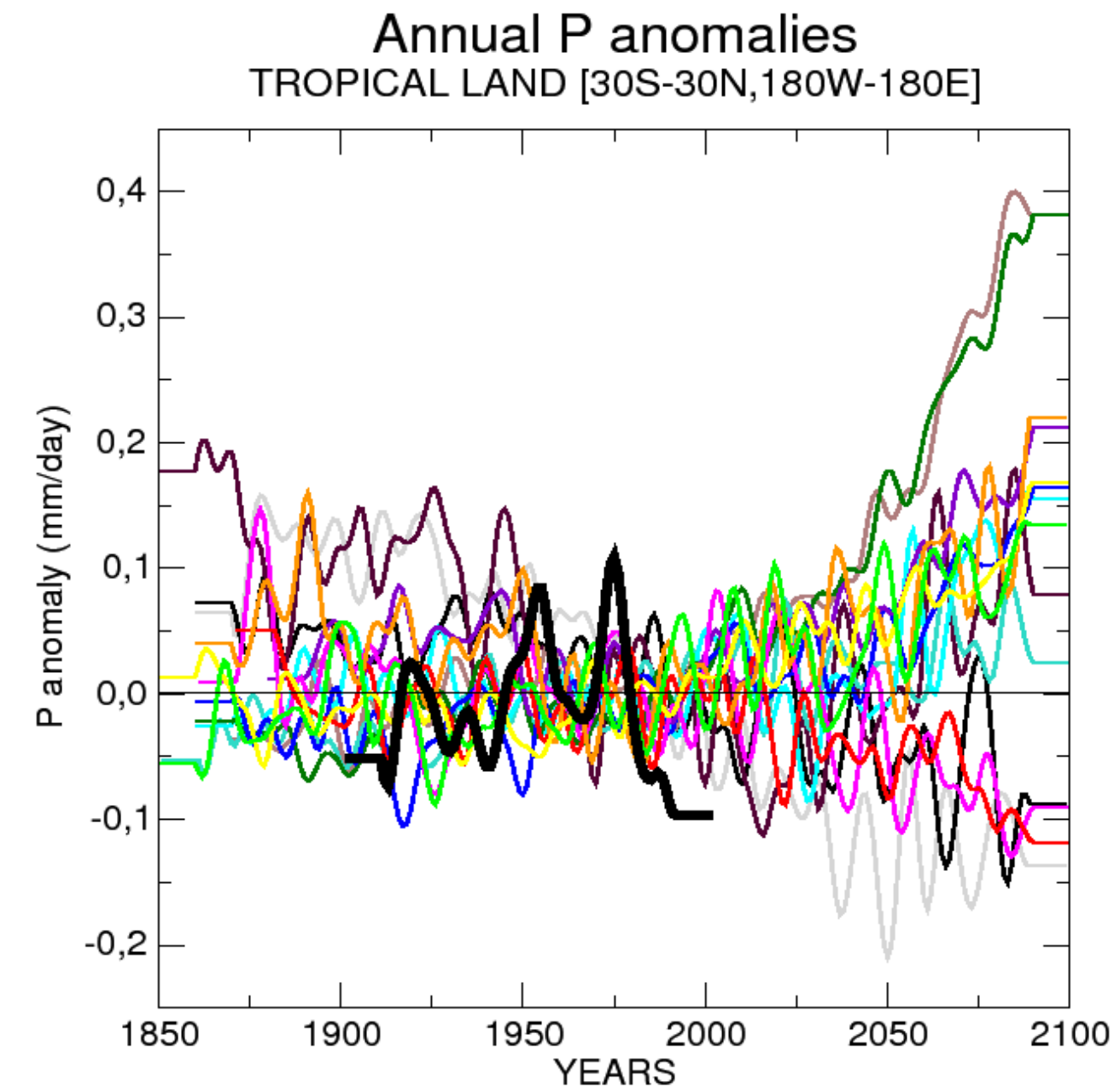
...in the context of climate change



- How to achieve resilient cities and mobility?
- Which strategies of reduction/adaptation to climate change?
- How to downscale climate scenarios to relevant scales?

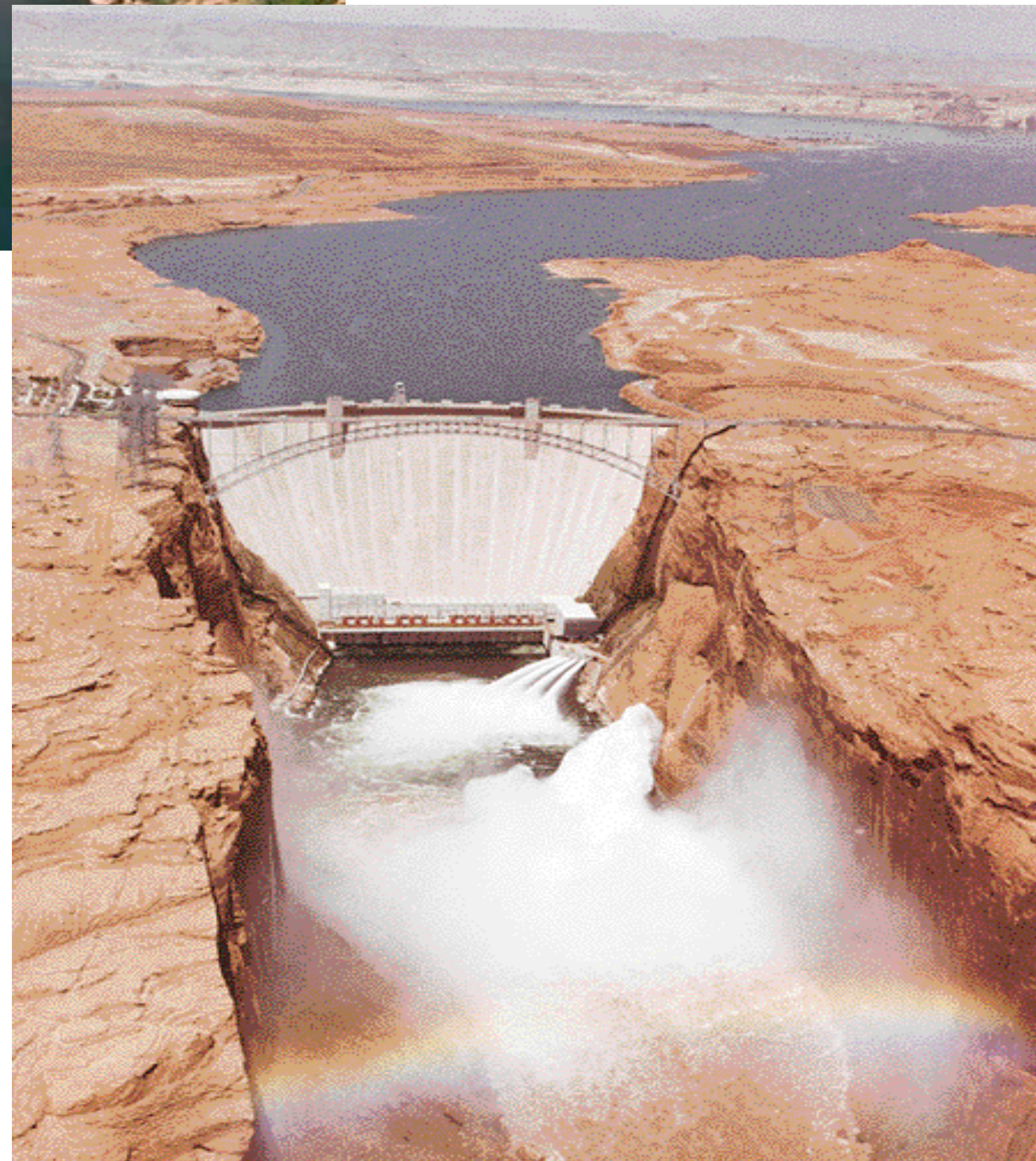


Strong agreement of models
on temperature increases...



but strong disagreement on the
evolution
of precipitation extremes

Glen Canyon Dam



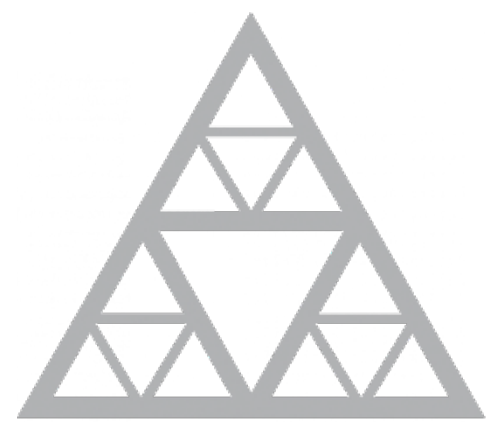
- Part of the Colorado River Storage Project:
 - Close to Page, Powell,
 - $L=1,560$ feet (475 m), $H=710$ feet (216 m), $W=300$ feet (91 m, at base)-25 feet (8 m, at crest) Arizona, USA,
 - construction: 1956-1966,
 - created Lake Powell,
 - ,901,000 cubic yards (3,747,000 m³) of concrete
 - run by US Bureau of Reclamation,
 - California, Arizona, Nevada, New Mexico: about 8.2 million acre-feet (10.1 km³) of water each year, 85 % for



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Glen Canyon Dam





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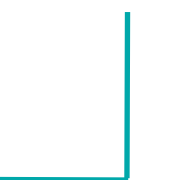
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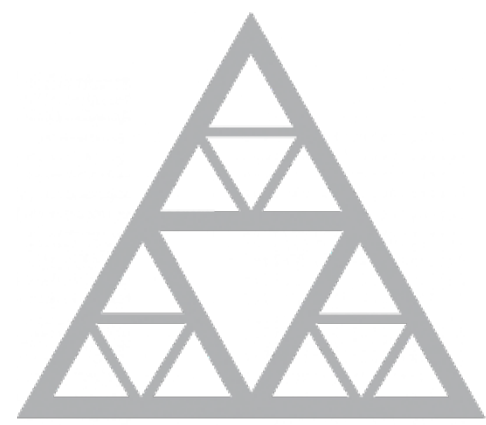
Glen Canyon Dam



- What about risks?
 - A dam failure (US-BR, 1990) :
 - 230 feet (70 m) high at Lake Mead,
 - overtopping Hoover Dam,
 - floodwave 500 feet (150 m) high through the Grand Canyon,
 - Might reach Parker Dam and Lake Havasu: the starting point of the Colorado River Aquaduct,
 - Shortages of water and energy
- A careful design to avoid this mega tsunami?

- US-BR movie on 1983 and 1984 floods...





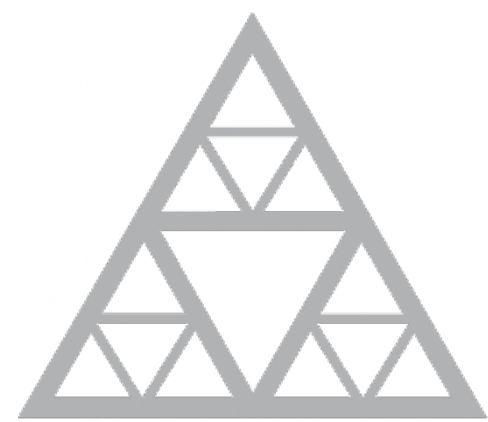
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Glen Canyon Dam



- But several failures:
 - false weather predictions: BR late to open spillways,
 - spillways
 - Constructed on former diversion tunnels: less capacity, 30% clearance,
 - Huge vibrations, debris ejections:
 - Cavitation at work:
 - huge damages !
 - Impossible to use spillways at full capacity!
 - Dam anchored in unstable Navajo sandstone ("solidified sand dunes").
- **Catastrophe avoided by wooden flashboards (8 Feet, 2.4 m) !**
- Researches needed to introduce air slots and cushions:immediately used for the 1984 flood !



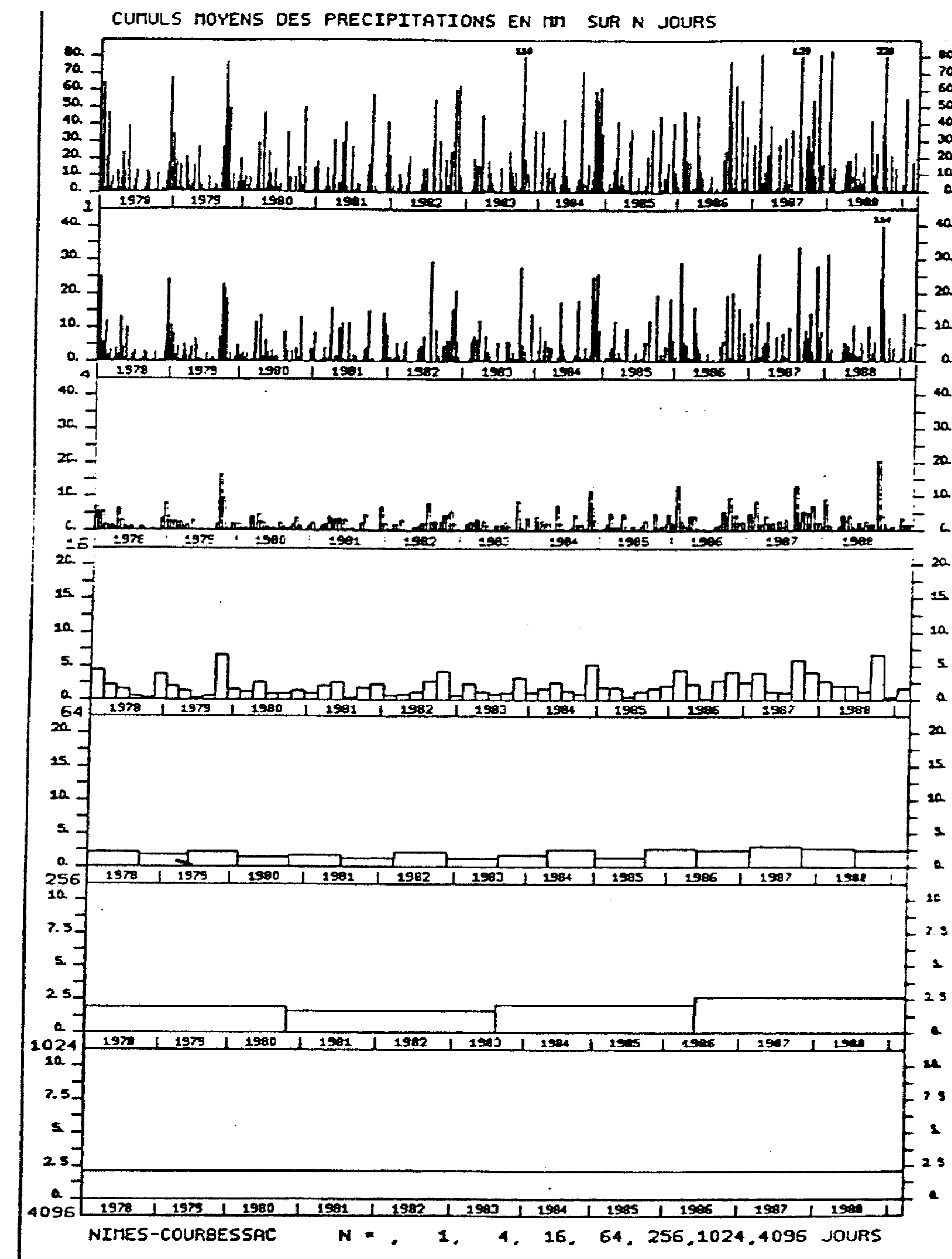
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Nîmes flood of 1978



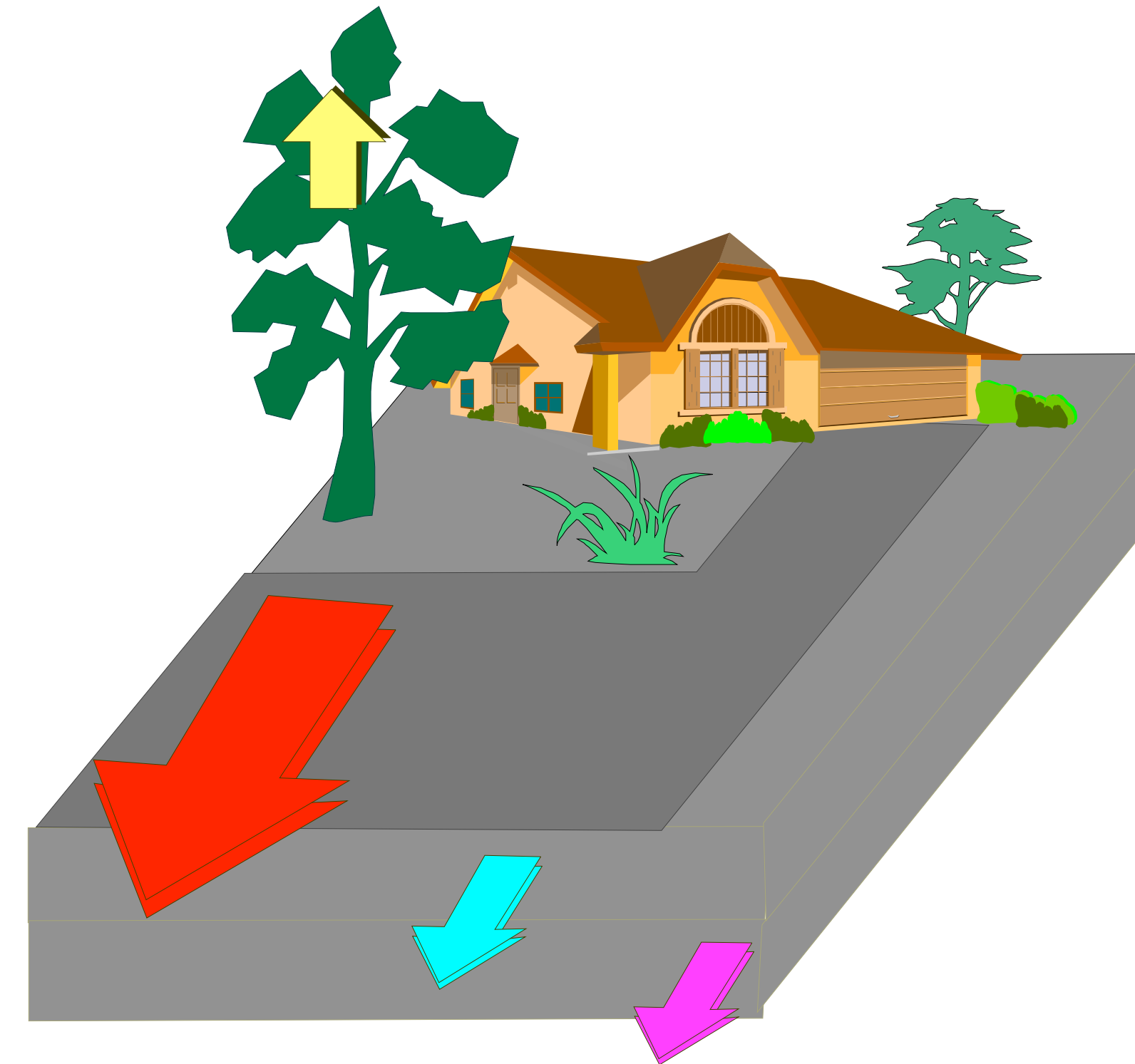
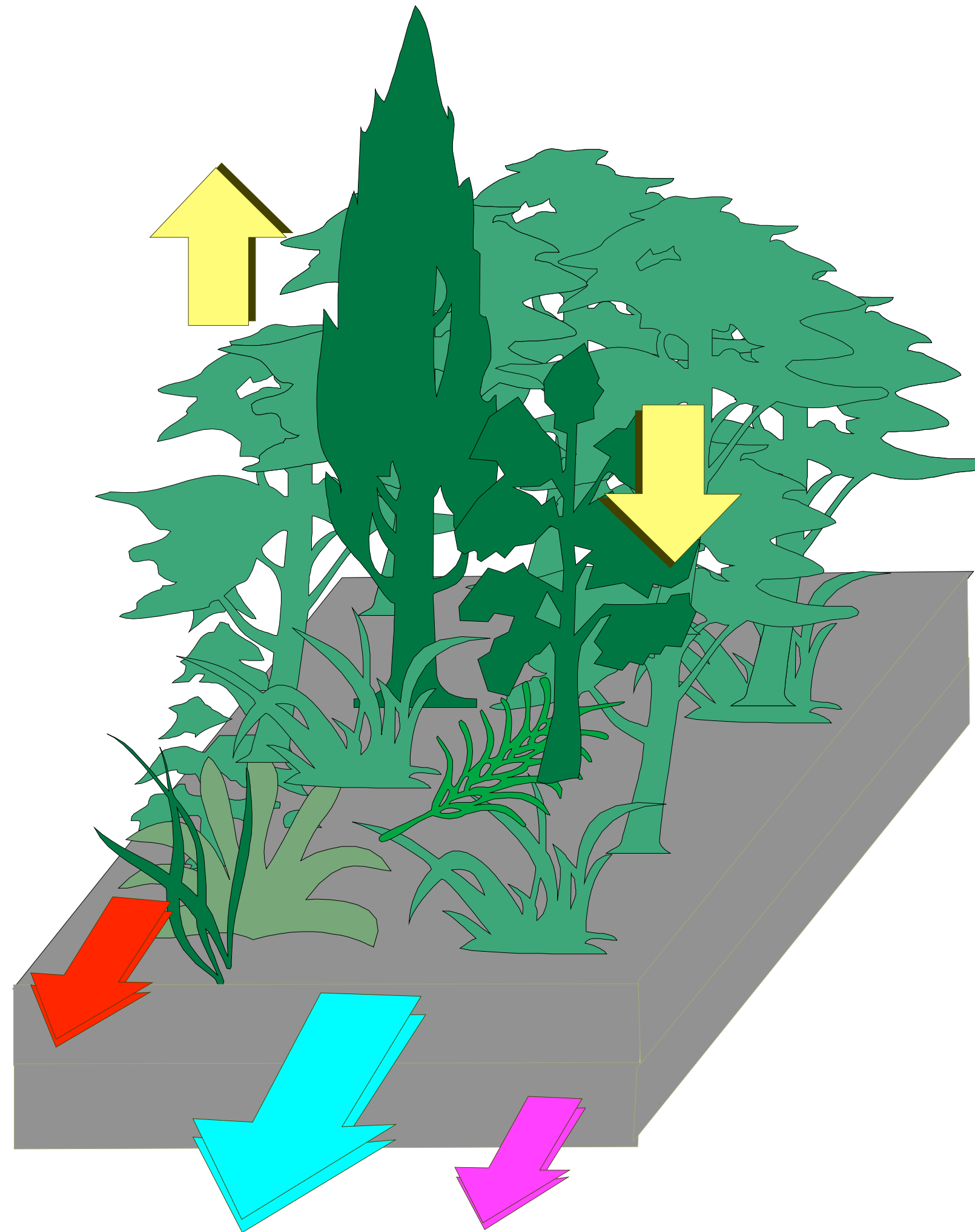
Les larmes du crocodile, SDIS30

Rain rates at Nîmes (France) 1978 - 1988 averaged over (from top to bottom): 1, 4, 16, 64, 256, 1024 and 4096 days. (Ladoy et al., 1993)



Effect of urbanization on the surface runoff

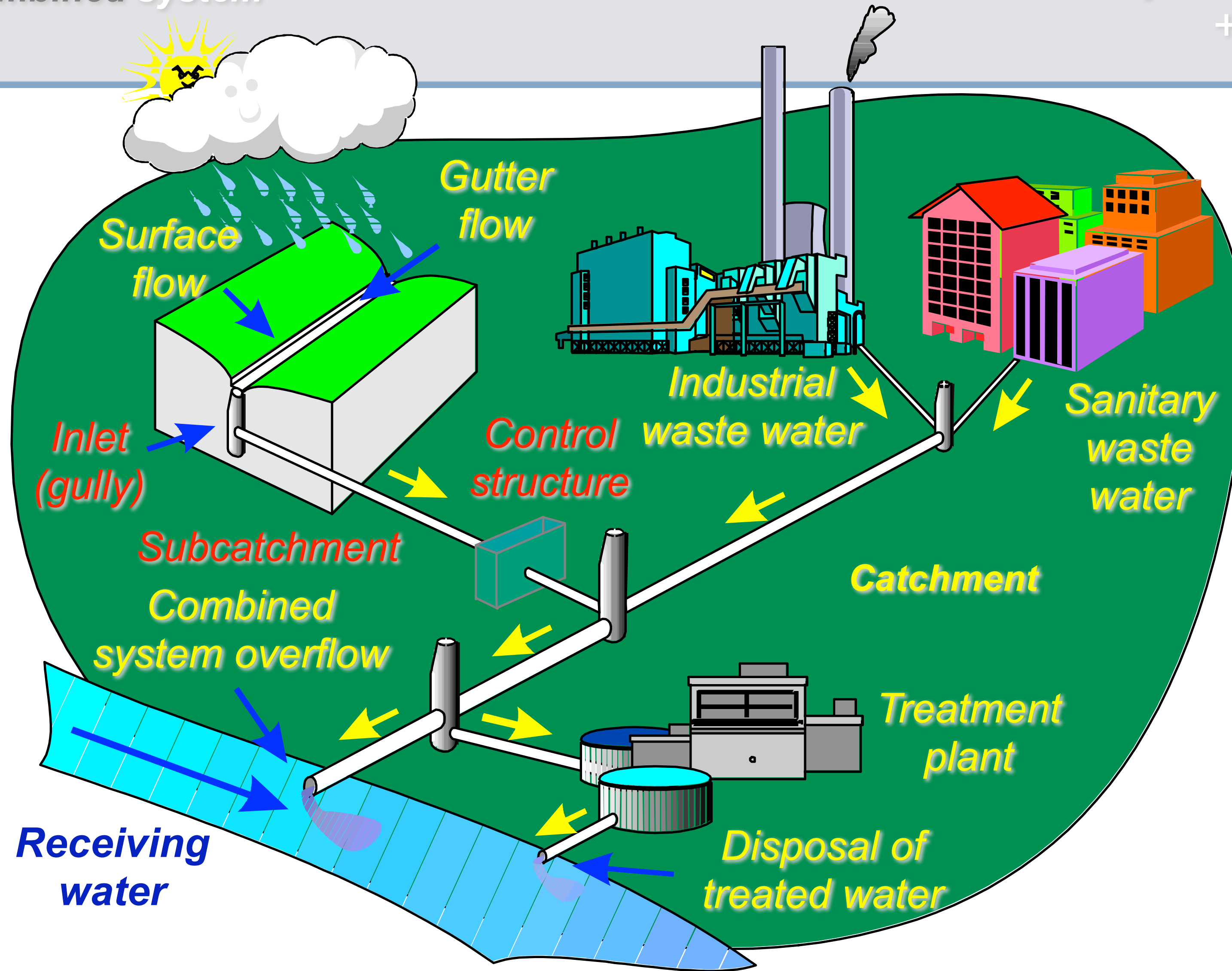
- **surface runoff**
- subsurface flow
- **groundwater flow**
- **evaporation**

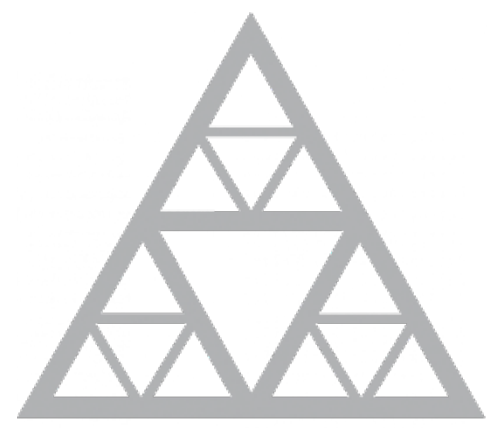


Components of a "conventional" urban drainage catchment

B. Combined system

Combined system overflow
+ treatment





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Two floods in France



Spring 2001

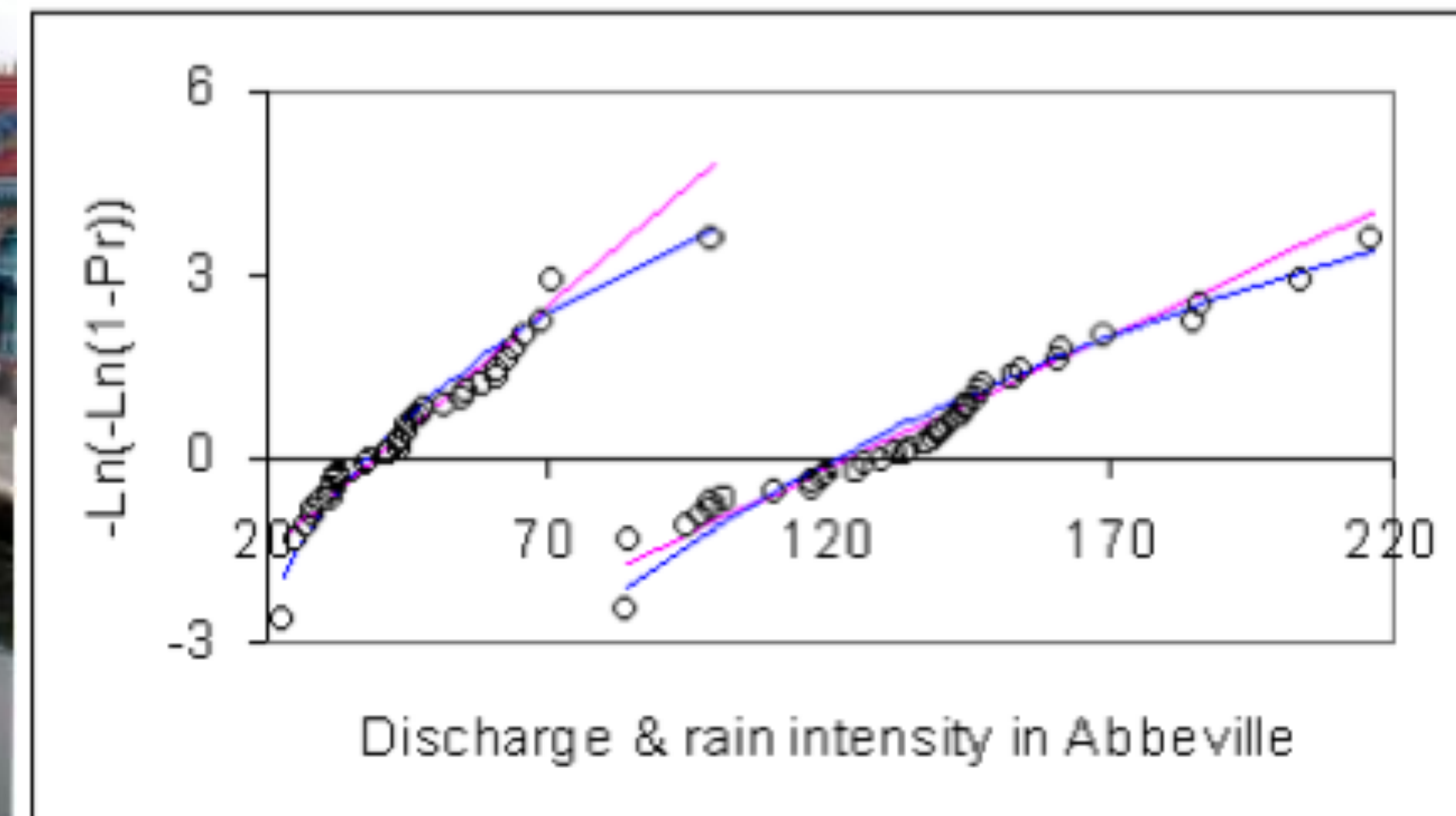
“Floods in Abbeville: two years of rainfall fell in three months.

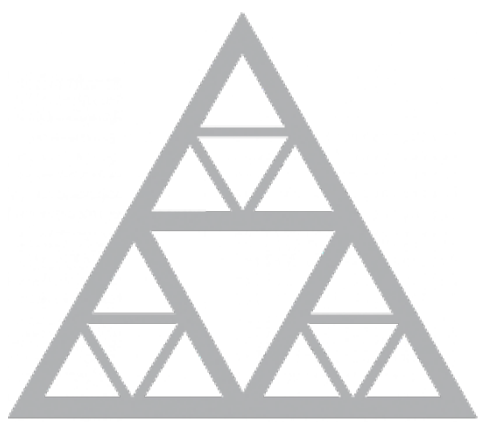
Water gushed from forgotten springs which had dried up many years before...”

From press



Abbeville station





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Extremes

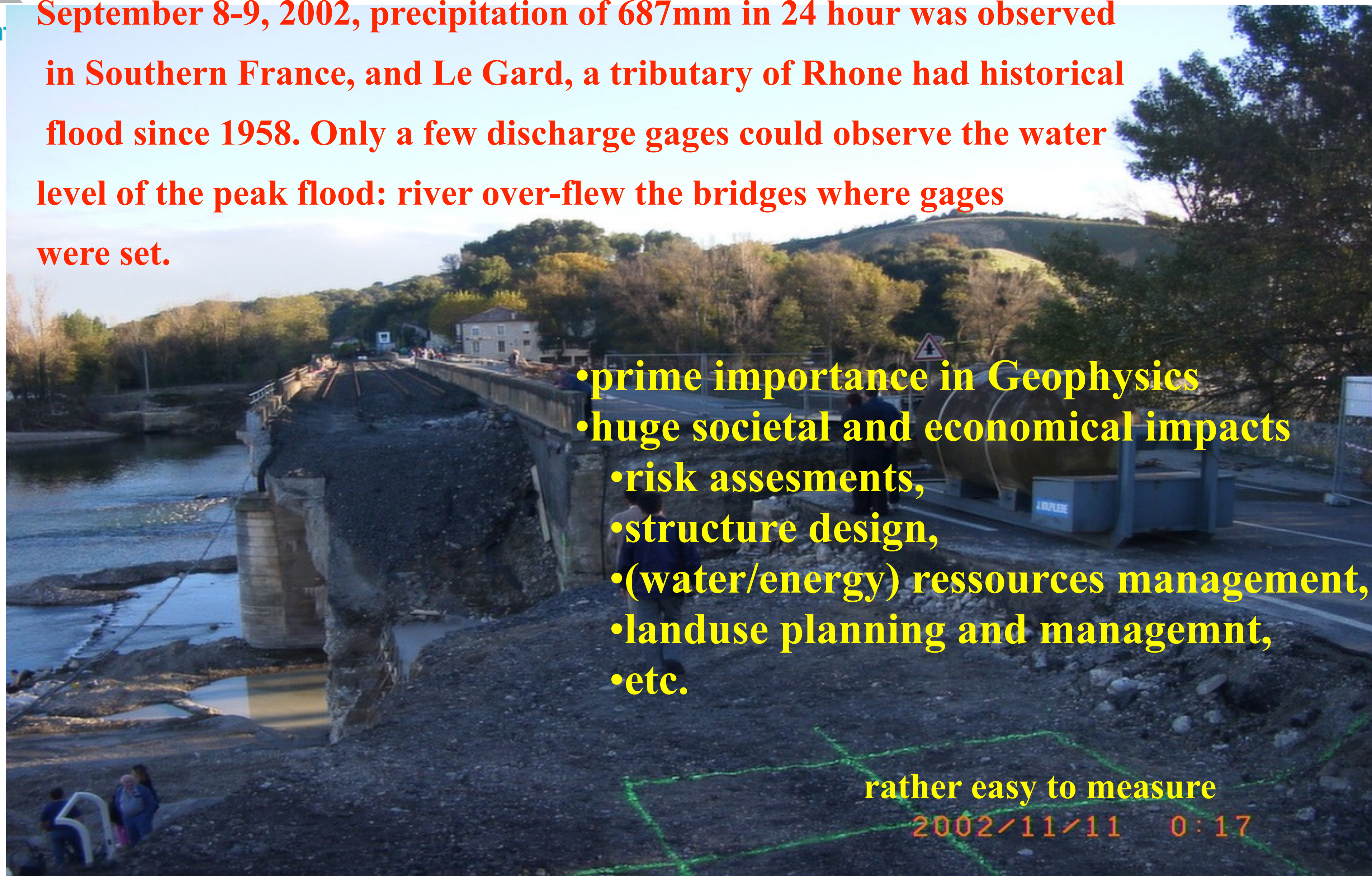


September 8-9, 2002, precipitation of 687mm in 24 hour was observed in Southern France, and Le Gard, a tributary of Rhone had historical flood since 1958. Only a few discharge gages could observe the water level of the peak flood: river over-flew the bridges where gages were set.

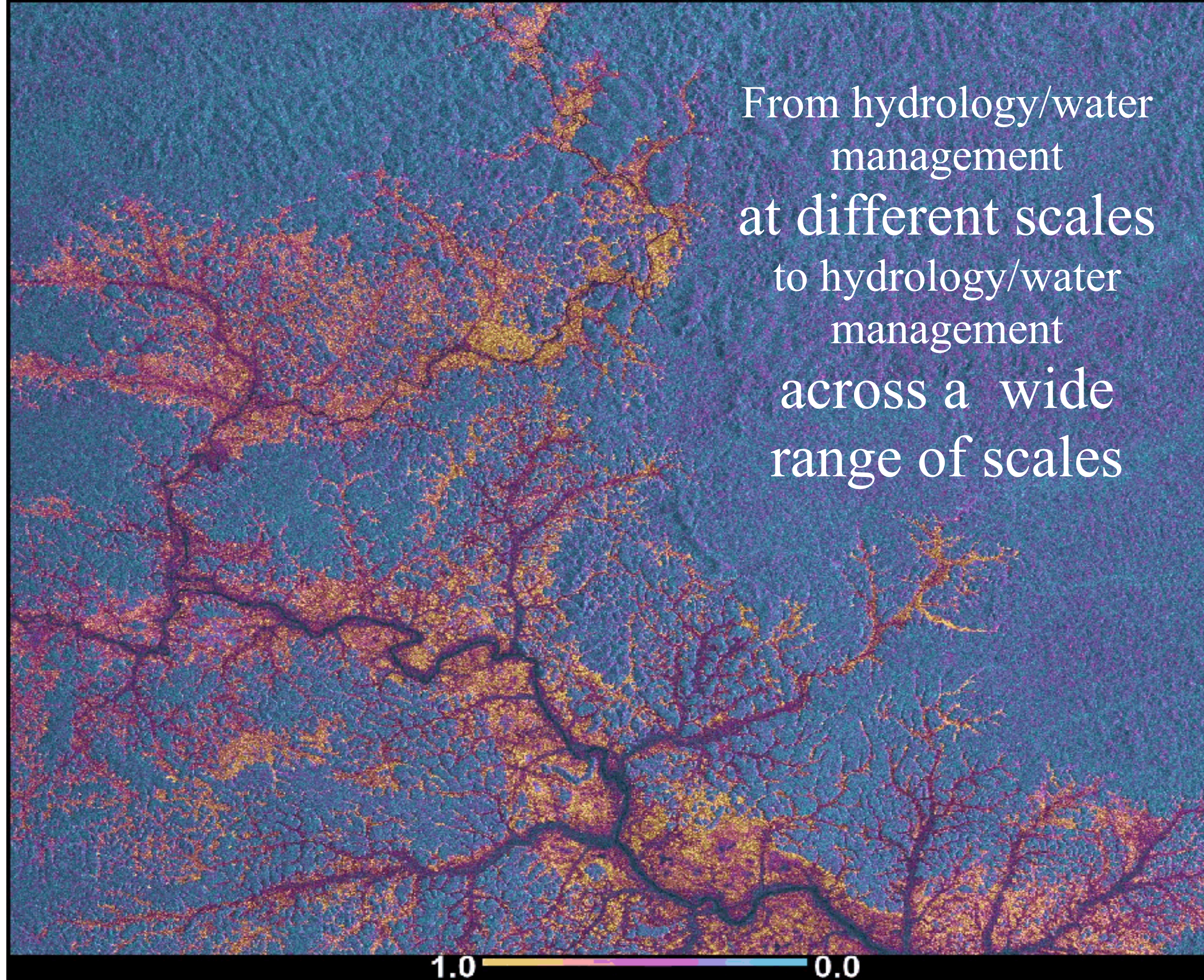
- prime importance in Geophysics
- huge societal and economical impacts
 - risk assessments,
 - structure design,
 - (water/energy) resources management,
 - landuse planning and managemnt,
 - etc.

rather easy to measure

2002/11/11 0:17

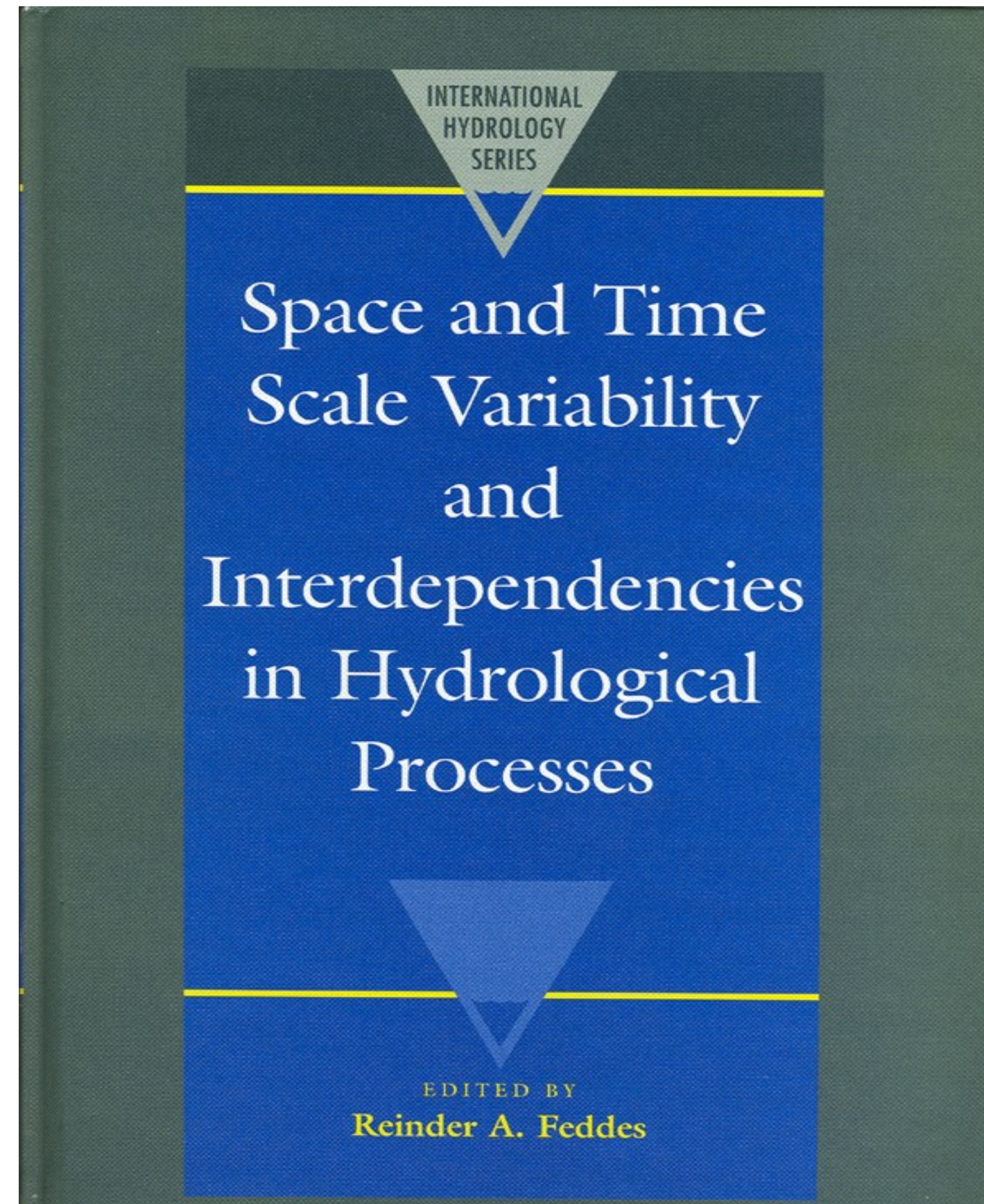


From hydrology/water
management
at different scales
to hydrology/water
management
across a wide
range of scales

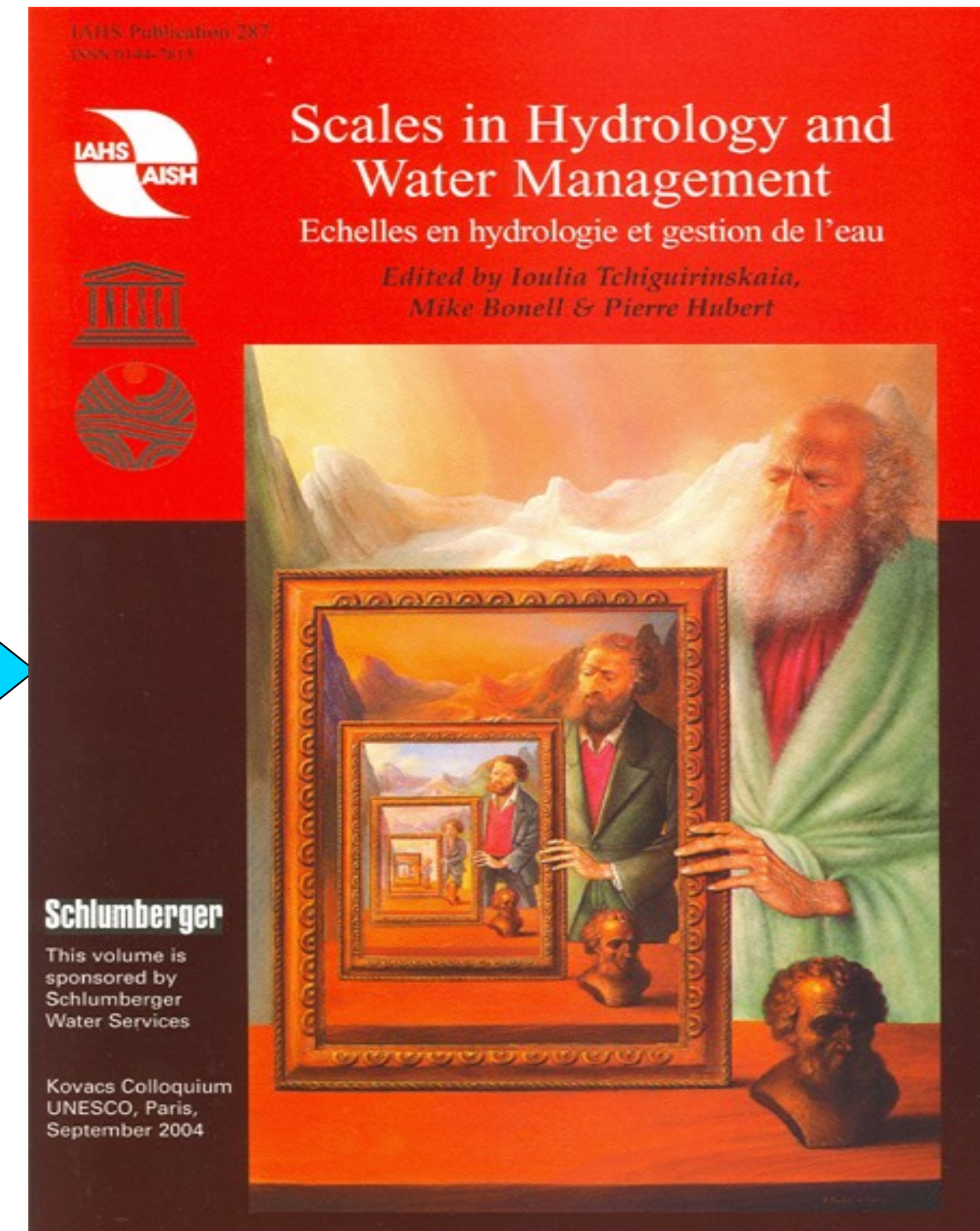
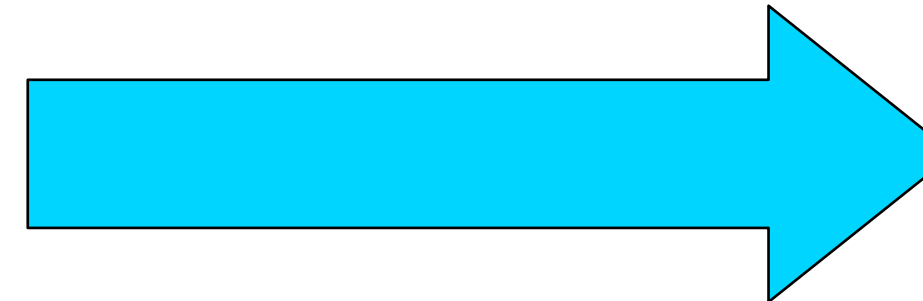


**JERS-1 Coherency Image (14 Feb 97 to 30 Mar 97 = 44 days)
Balbina Reservoir (north of Manaus)**

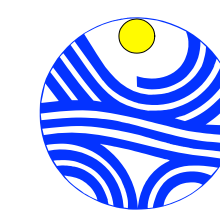
and water resource management ?

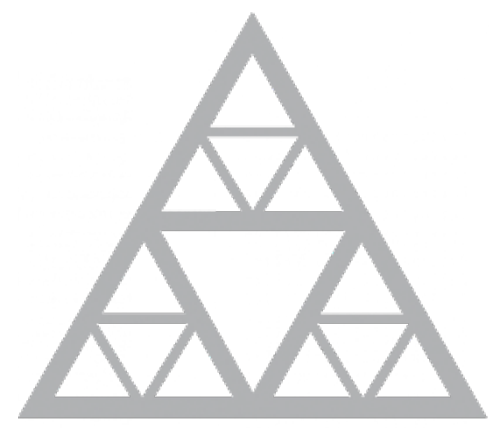


12 years later



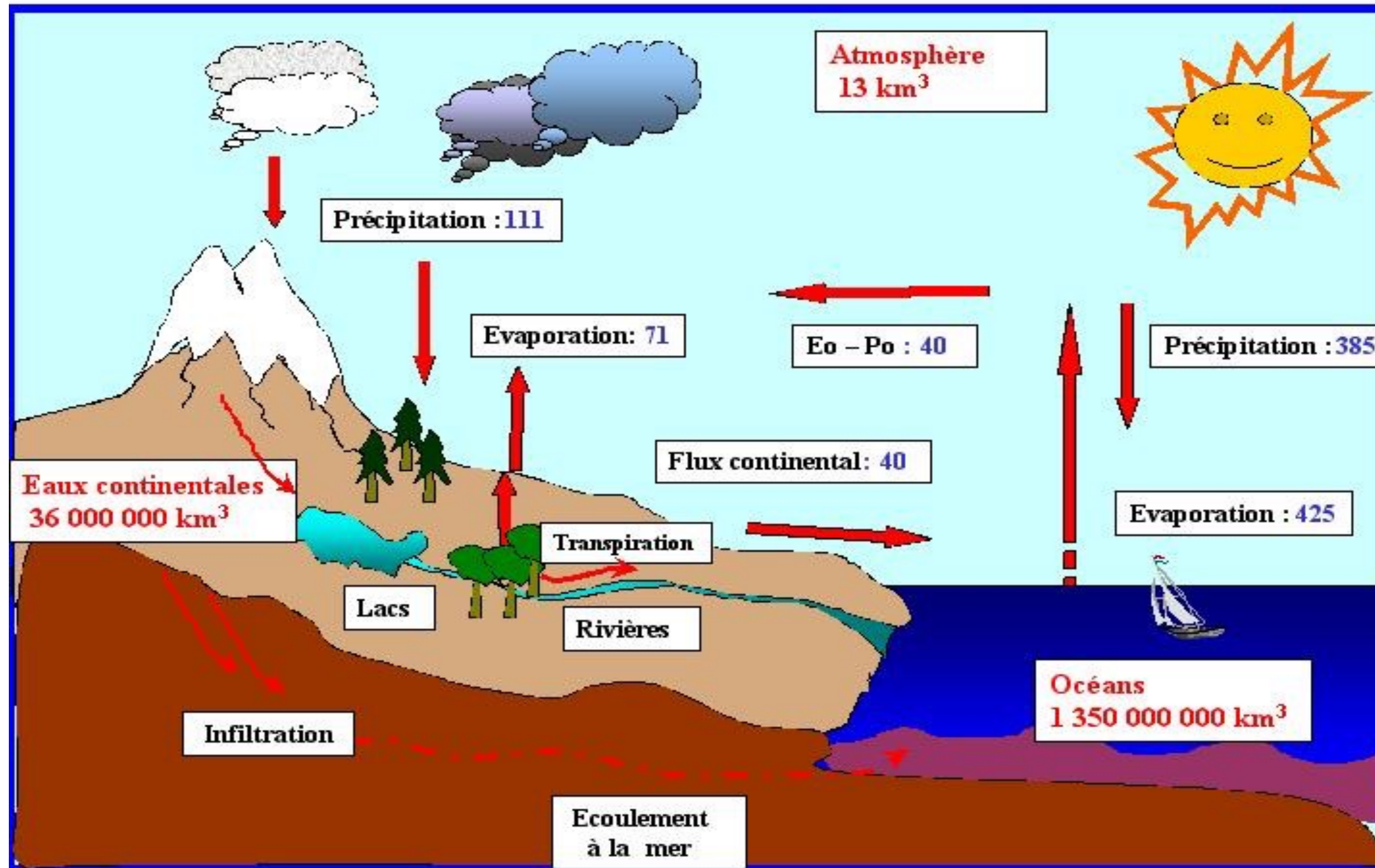
to *also* manage across scales
... and not only over a few scales?





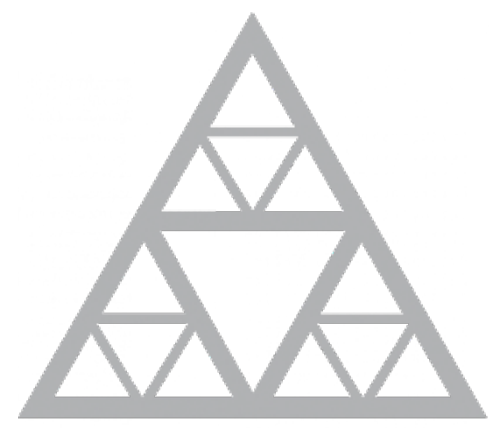
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How diverse is the water cycle?



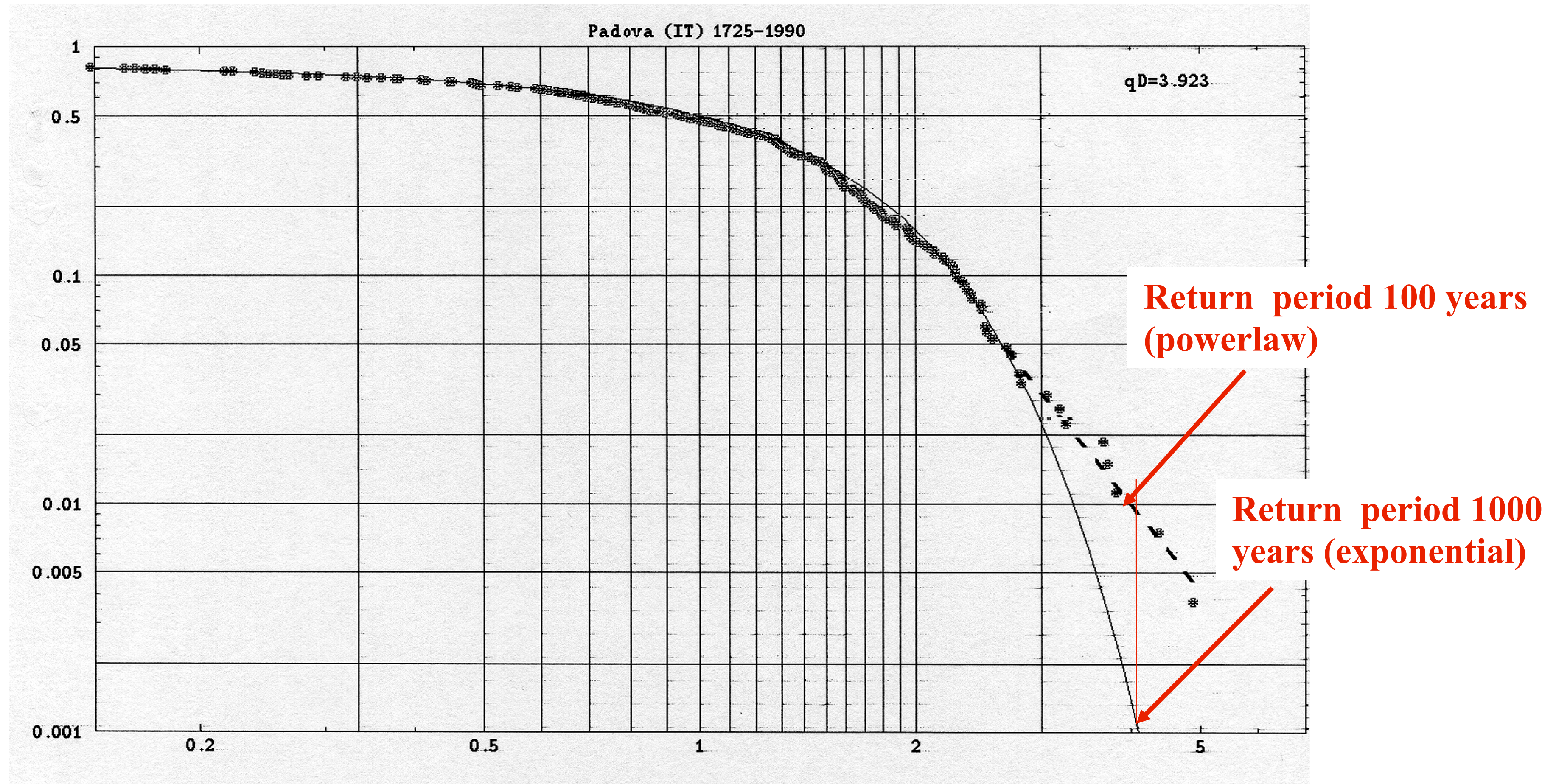
Usual comments:
fluxes are not so easy to
evaluate, because of
their variability

This variability is
related to the
embedded multiplicity
of time-space scales
(see Rodriguez-Iturbe and
Rinaldo, 1997).

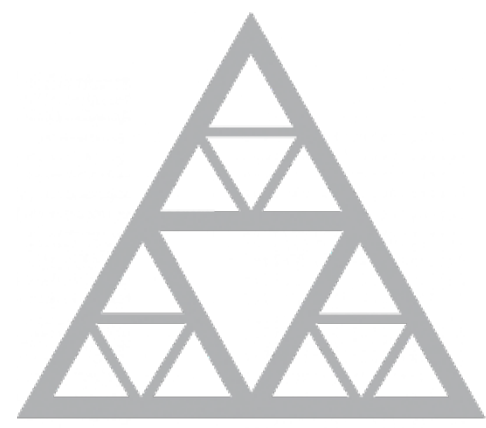


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Long time series (≈ 2.5 centuries)



Padova series (Italy): empirical probability distribution (dots), normal fit (continuous line) and asymptotic power-law (dashed line).

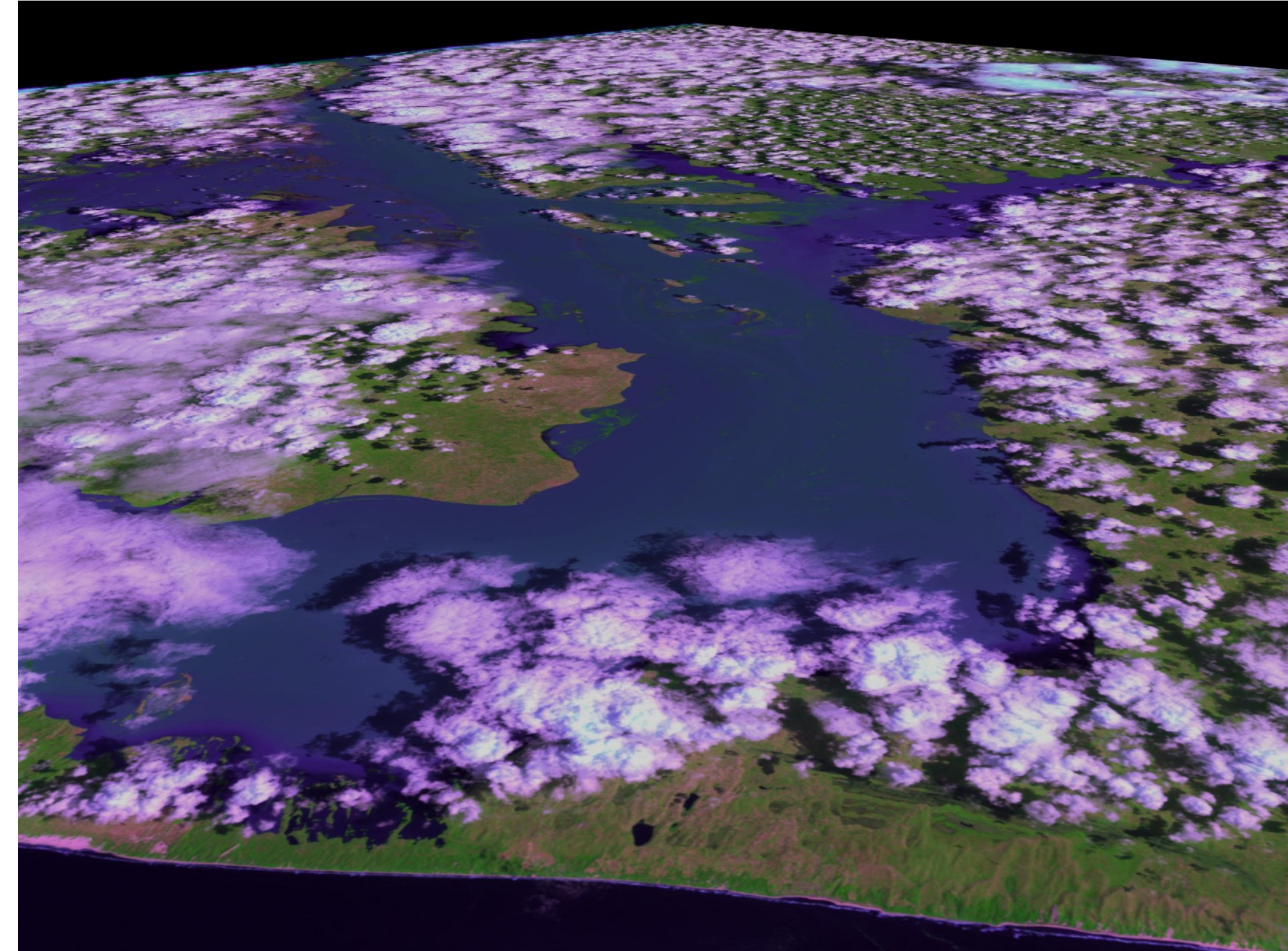
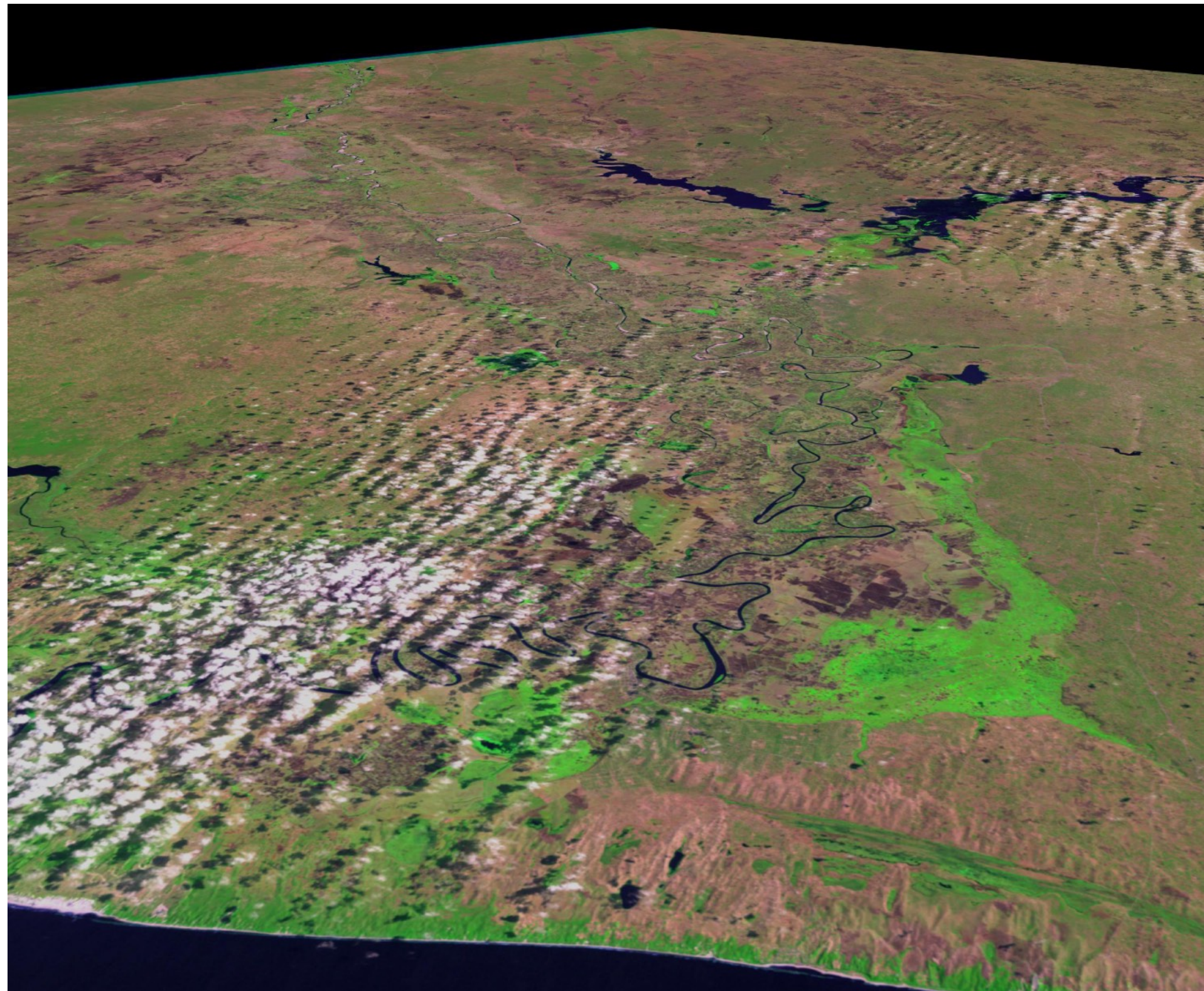


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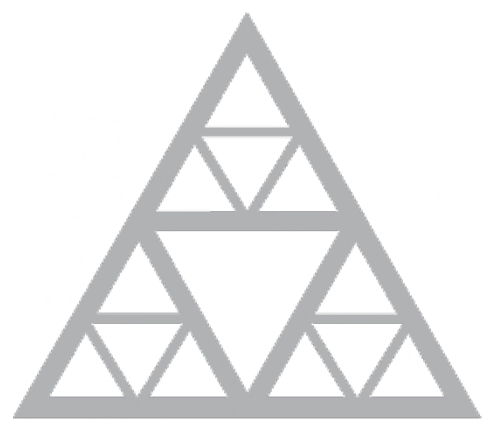
2000 Mozambique Flood



The Marico River and the Crocodile River join into the Limpopo River: drainage area \approx 415 000 km², In dry years, the upper parts of the river flow for 40 days or less



- Approximately 800 people were killed. 1,400 km² of arable land was affected and 20,000 head of cattle were lost. It was the worst flood in the Mozambique in 50 years

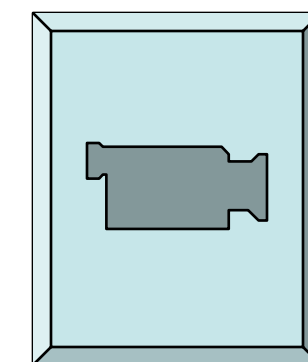
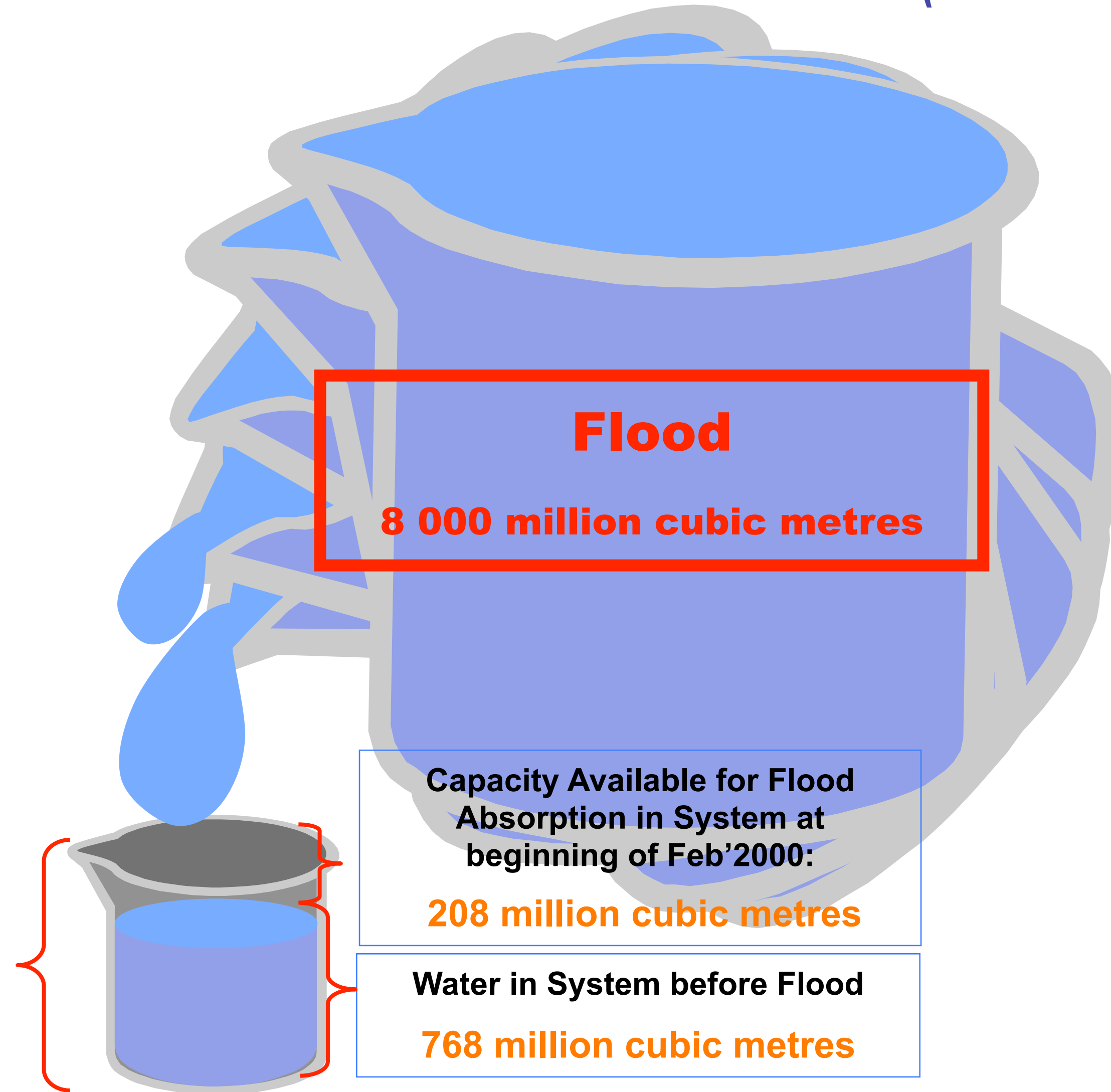


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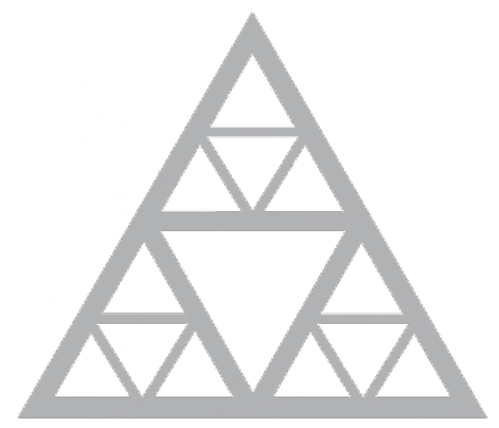
Storage Capacity vs Flood Volumes for Limpopo and Crocodile-West / Marico WMA (Feb.-Ma. 2000)



Total System
Storage Capacity
**976 million
cubic metres**



Credit to Stefan Van Biljon (SA)

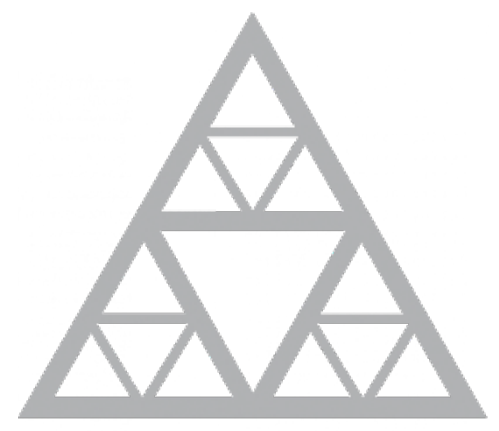


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PPRI RATP

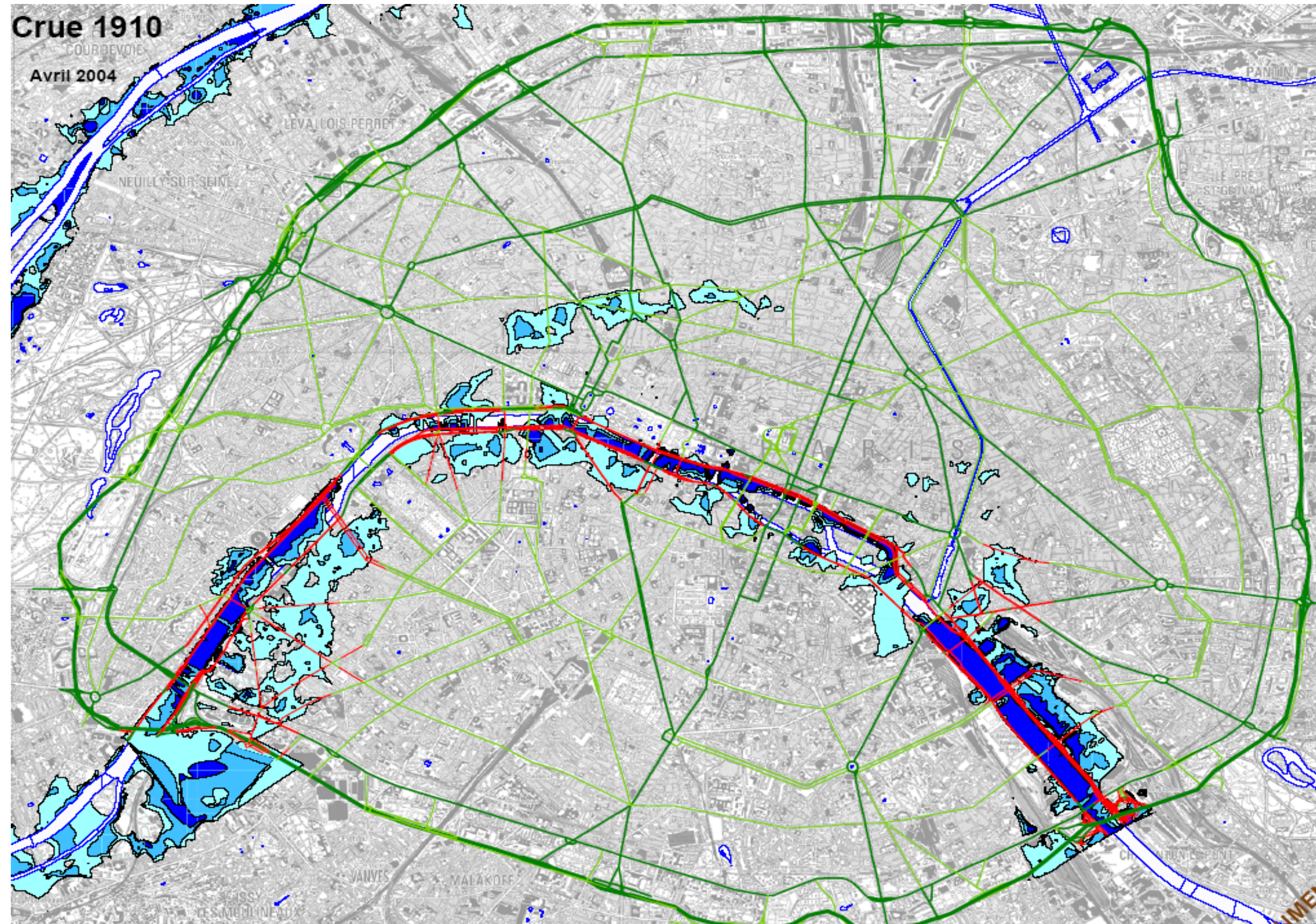


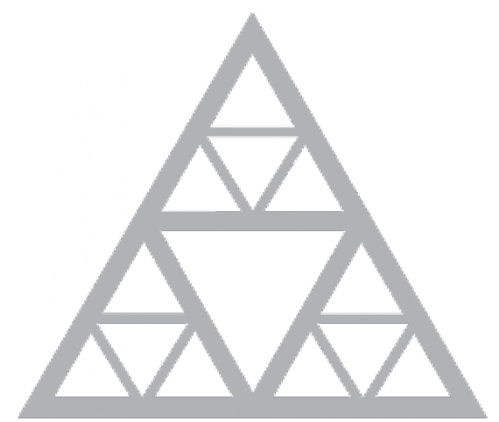
(remerciements à J. Brochet, RATP)



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Risques encourus



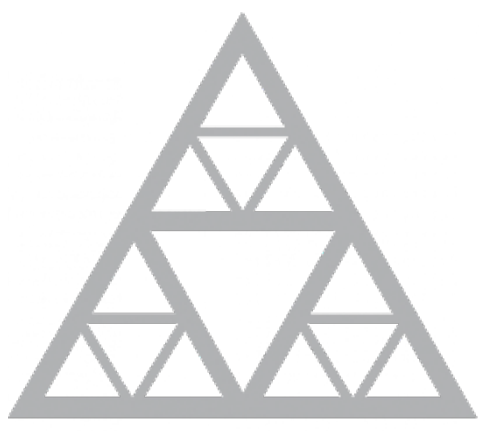


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Risques encourus



1910 : Réseau RATP = 60km Lignes inondées = 30 km



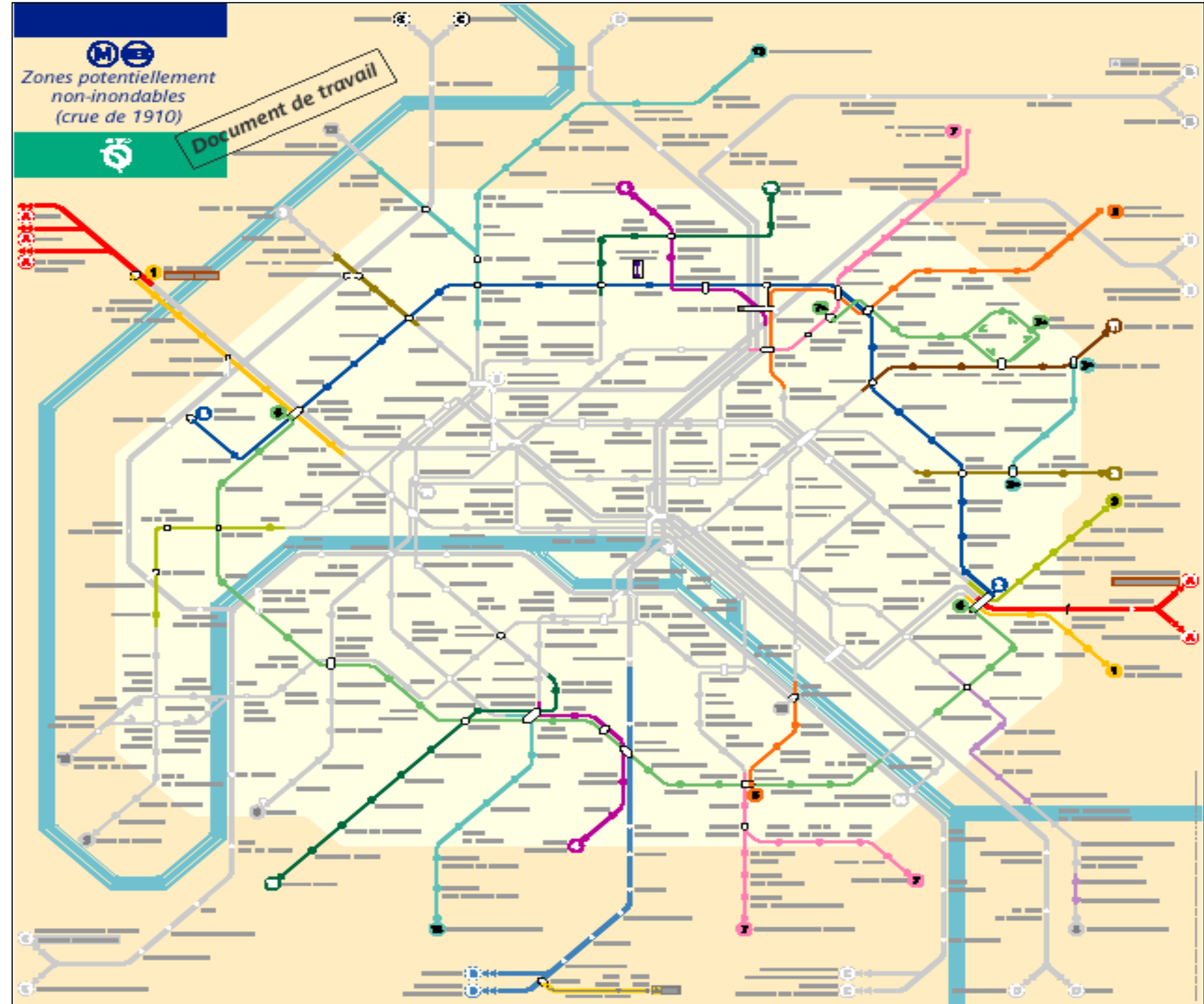
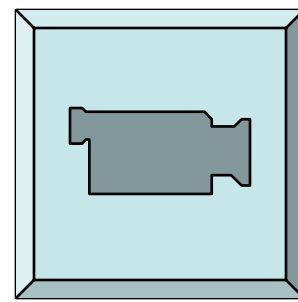
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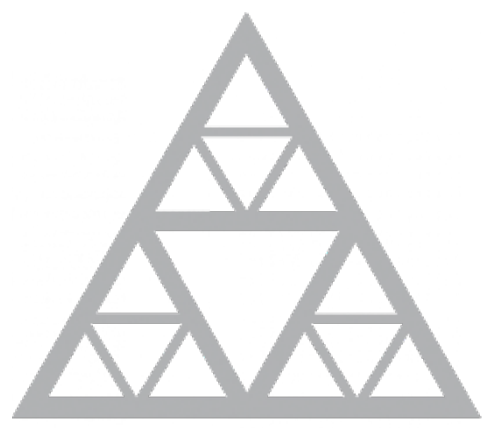
Risques encourus

Aujourd'hui:

Réseau = 212 km

Estimation des lignes
inondées = 140 km

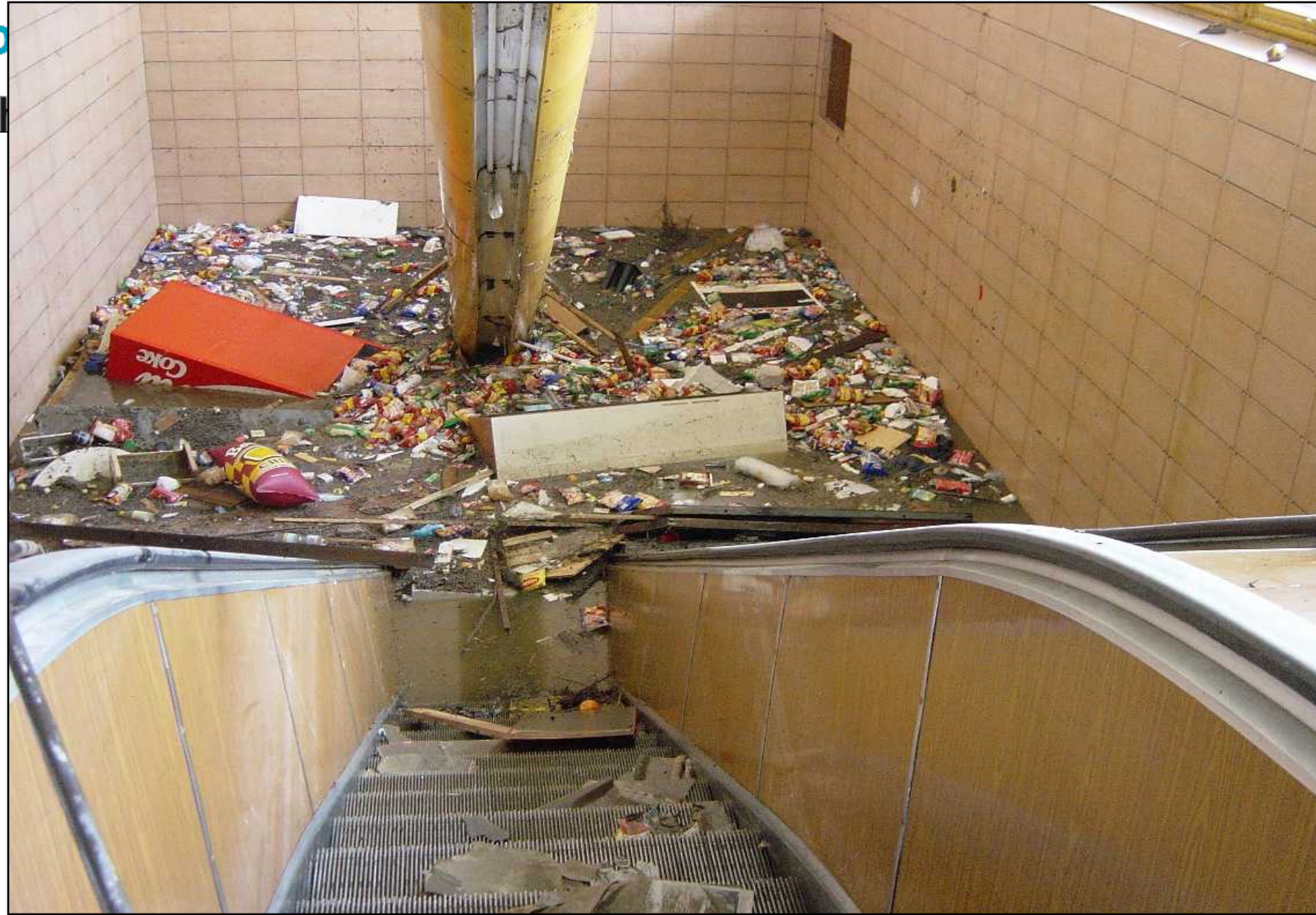




Risques encourus



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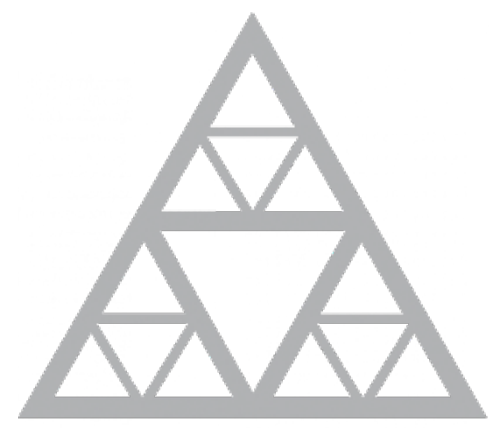


Prague 2002 :

17 km inondés

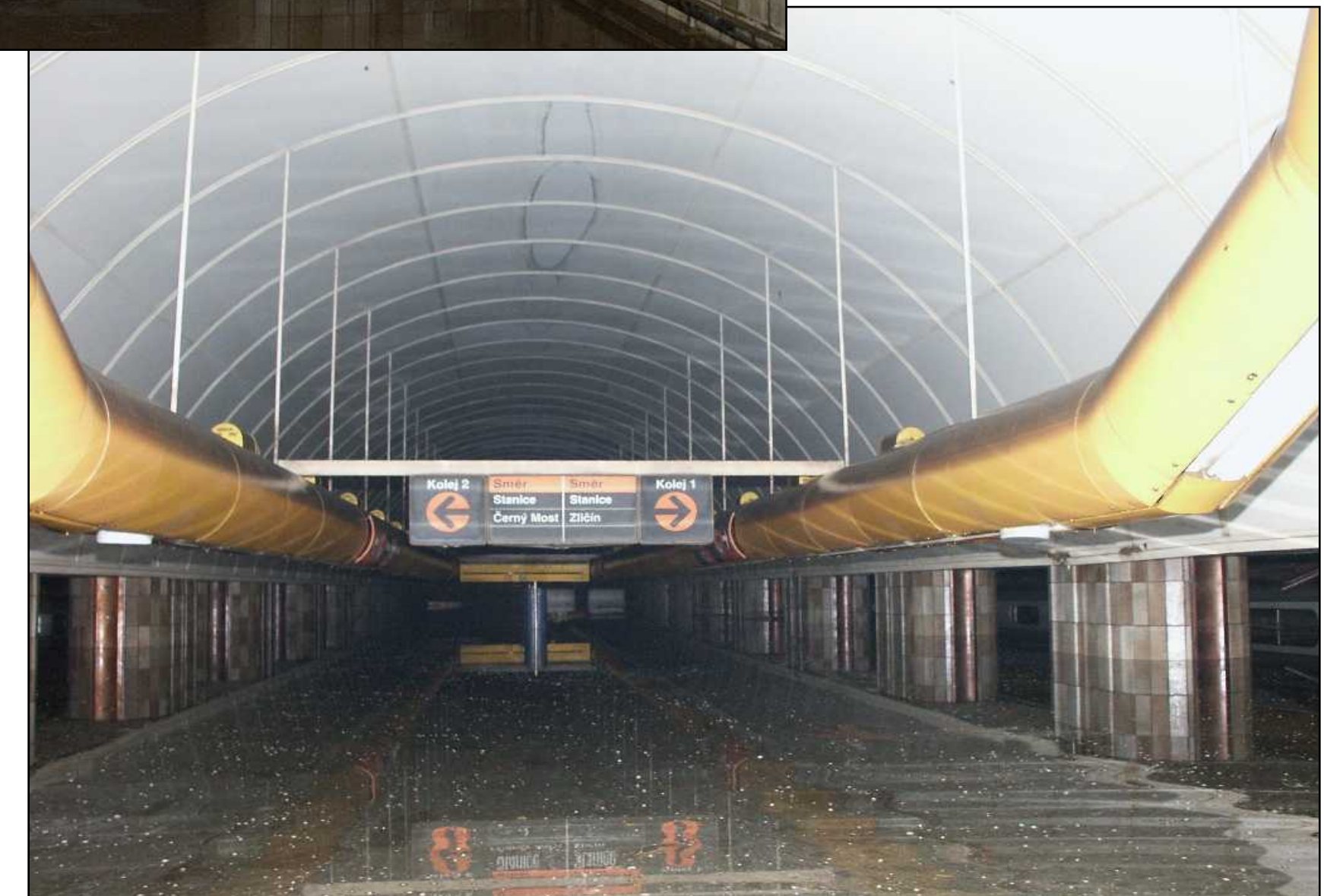
300 M€ dégâts

6 mois de remise en état

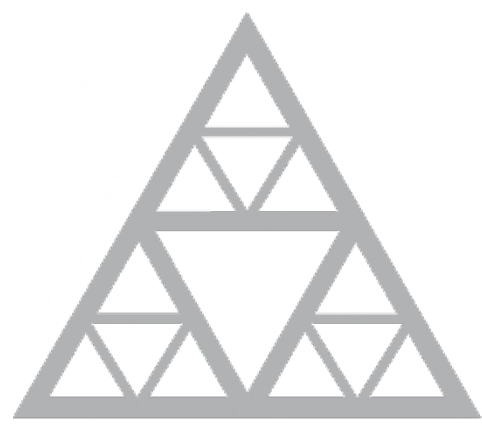


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Risques encourus





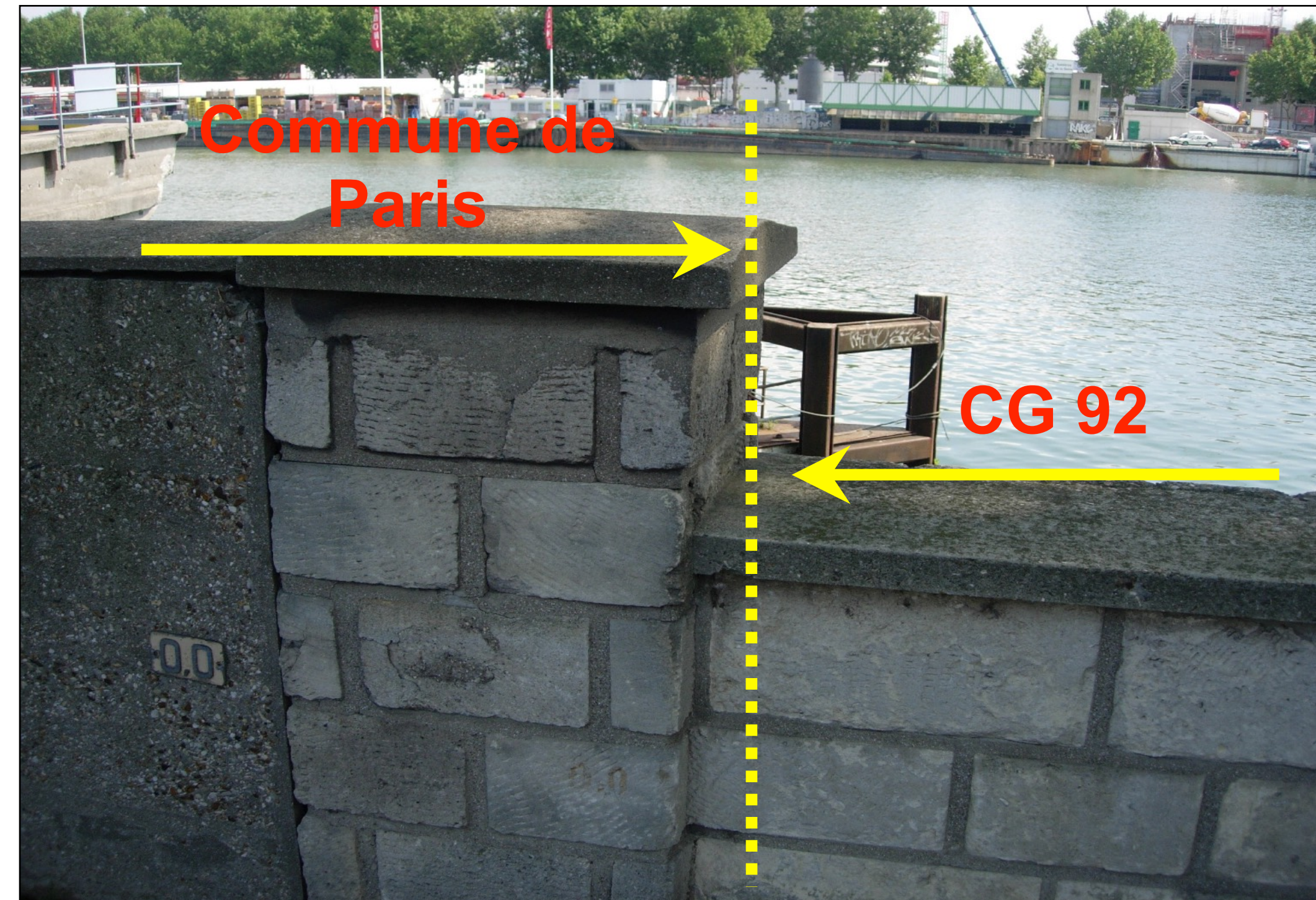


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Problème de stabilité des ouvrages en sable.



Efficacité théorique des ouvrages jusqu'à une crue cinquantennale (de type 1924)



(remerciements A. Guillon, CG92)

Dysfonctionnement des ouvrages existants en raison de nombreuses brèches



Brèche effectuée par un riverain

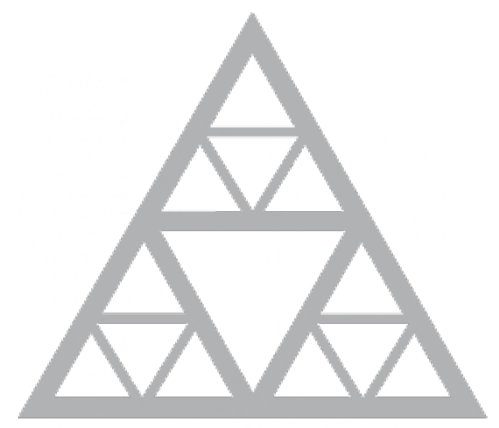


Difficulté de pose des batardeaux



Murettes = support EDF ?





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19 - 20 November 2013 in Sardinia (Italy)



Urban heavy rainfall disaster – Toga-Gawa, Kobe 2008; Zosigaya, Tokyo, 2008

Geographical Map of Japan

Characteristic

- Both accidents occurred **within one hour after the rain began to start.**

Togagawa:

- Sudden increase of water level of Toga-river i(1.3 m during 10 min).
- 20 people playing at a river side park were swept and 5 kids were killed

Zoshigaya:

- Sudden increase of water level in the sewage pipe.
- Five workers were swept downstream and drawn.



午後2時15分頃、現場から約150メートル上流の増水する前の都賀川。子供らが川遊びをしていた。



午後2時50分、急激に増水した都賀川。10分間で1.3mの水位上昇。5名が流されて犠牲。



現場付近のマンホールを開け、中に入って捜索する東京消防庁の隊員=5
日午後2時、東京都豊島区雑司が谷(植村光貴撮影)

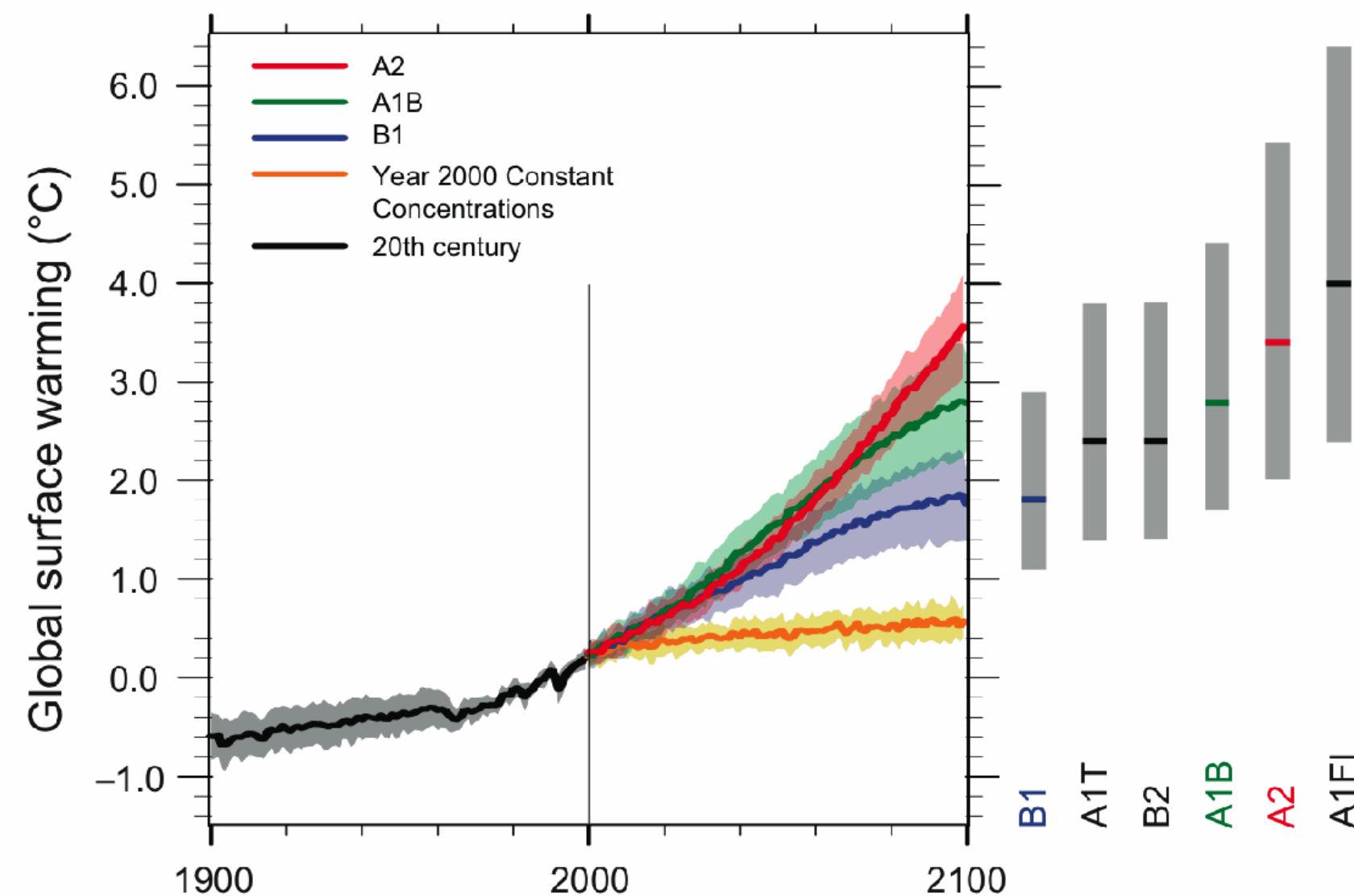


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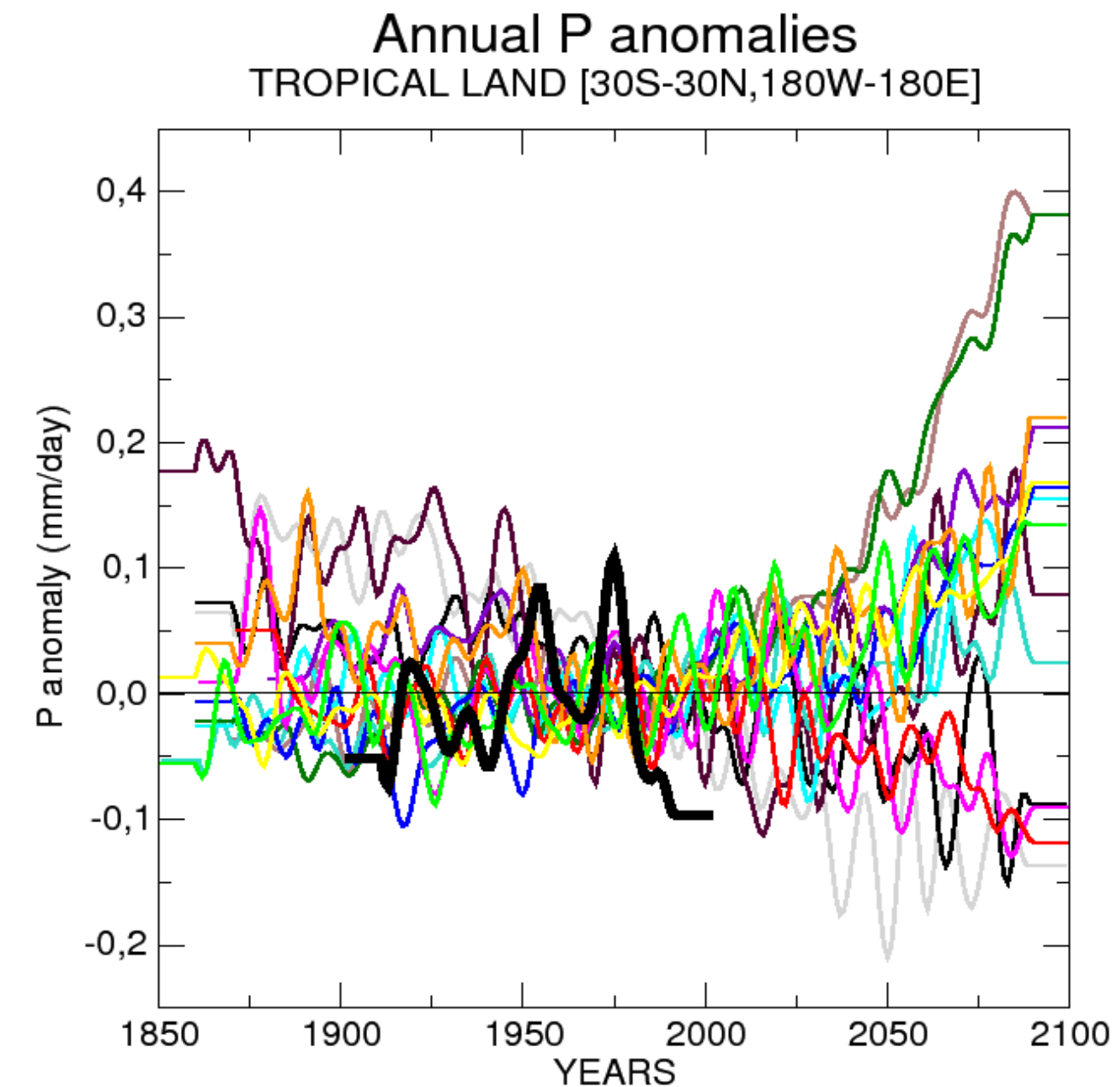
...in the context of climate change



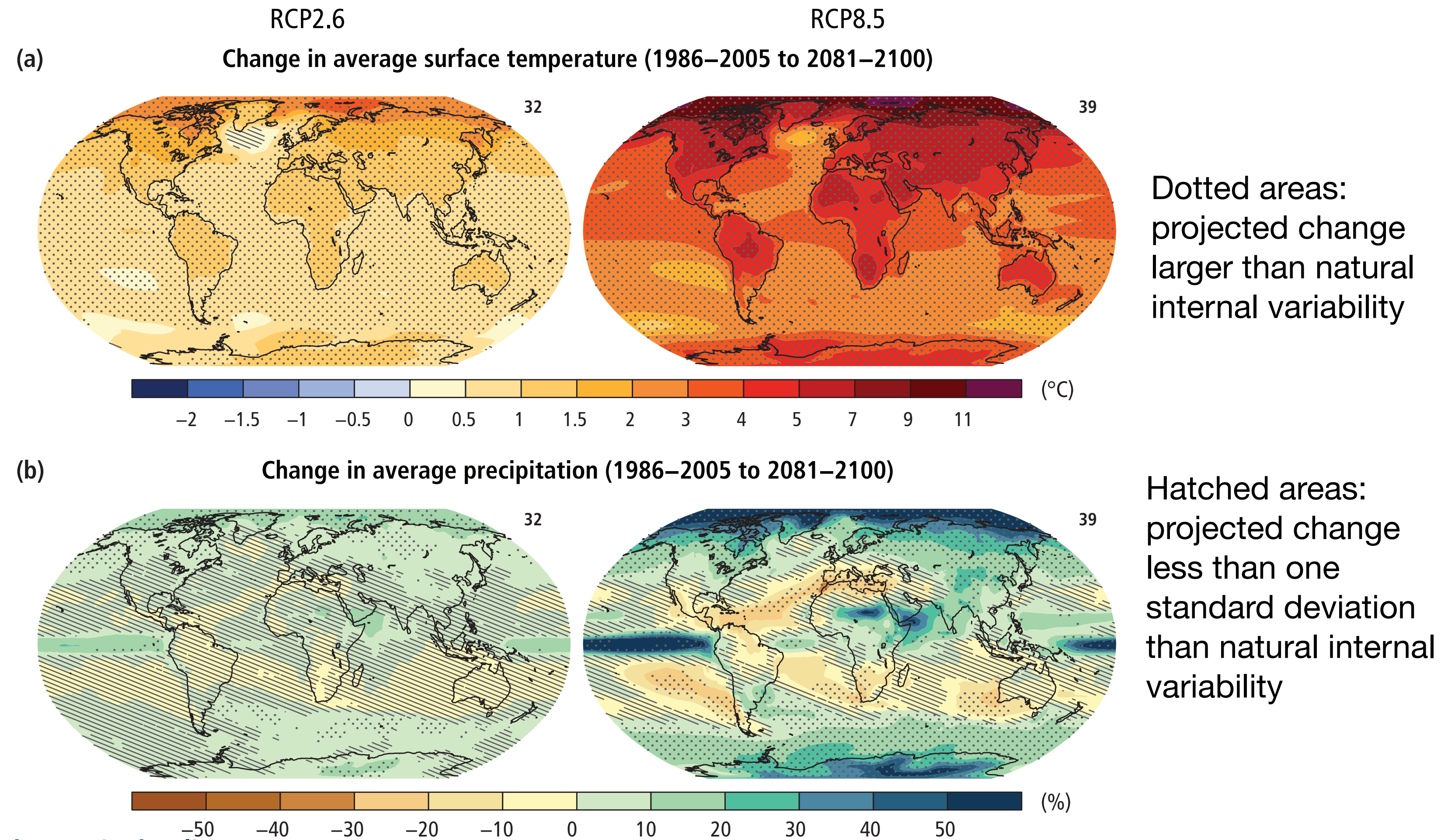
- How to achieve resilient cities and mobility?
- Which strategies of reduction/adaptation to climate change?
- How to downscale climate scenarios to relevant scales?



Strong agreement of models
on temperature increases...



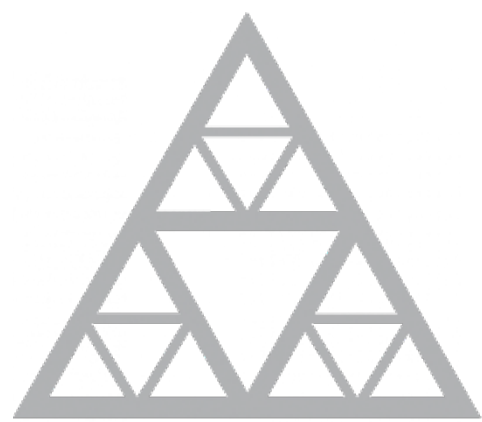
but strong disagreement on the
evolution
of precipitation extremes



SPM 2.2 Projected changes in the climate system

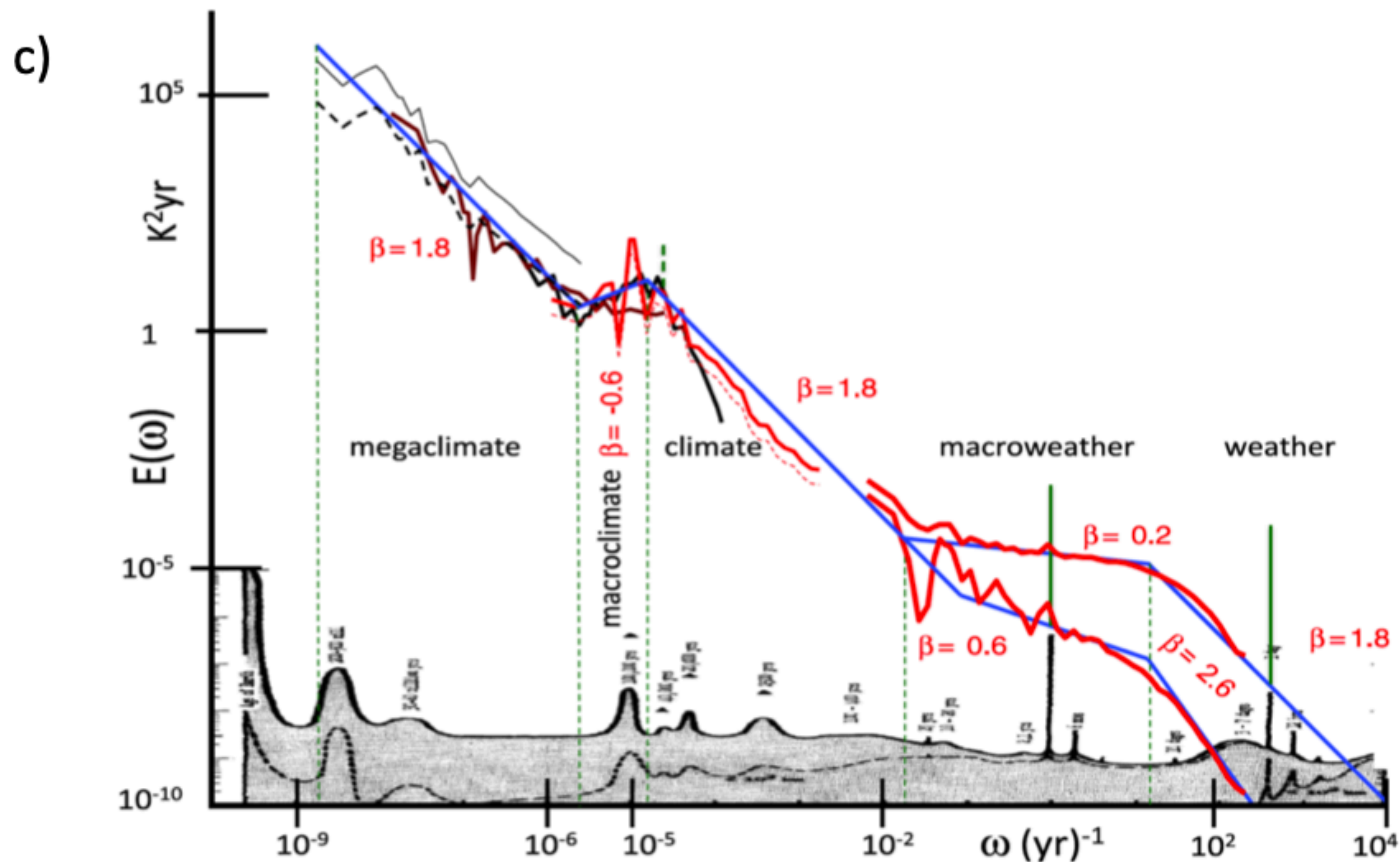
Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is *very likely* that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise. {2.2}

Figure SPM.7 | Change in average surface temperature (a) and change in average precipitation (b) based on multi-model mean projections for 2081–2100 relative to 1986–2005 under the RCP2.6 (left) and RCP8.5 (right) scenarios.



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Multiscale variability



Scaling regimes in atmospheric spectrum, Lovejoy and Schertzer (2013)

A long quest...
since antiquity,
Renaissance...