SMART DROUGHT MANAGEMENT:

Going into the Internet of Things Era

AGRICULTURAL UNIVERSITY OF ATHENS, HELLAS

Christos A. Karavitis
Ass. Professor, Water Resources Management
Sector of Water Resources
Dean School of Environment and
Agricultural Engineering

SMART DROUGHT MANAGEMENT:
GOING INTO THE INTERNET OF THINGS ERA

THE TRANSFORMING ENVIRONMENT

TRENDS AND DEVELOPMENTS

PREPARING THE SYSTEM OF THE 21ST CENTURY

SHIFTING PARADIGMS IN THEORY & PRACTICE

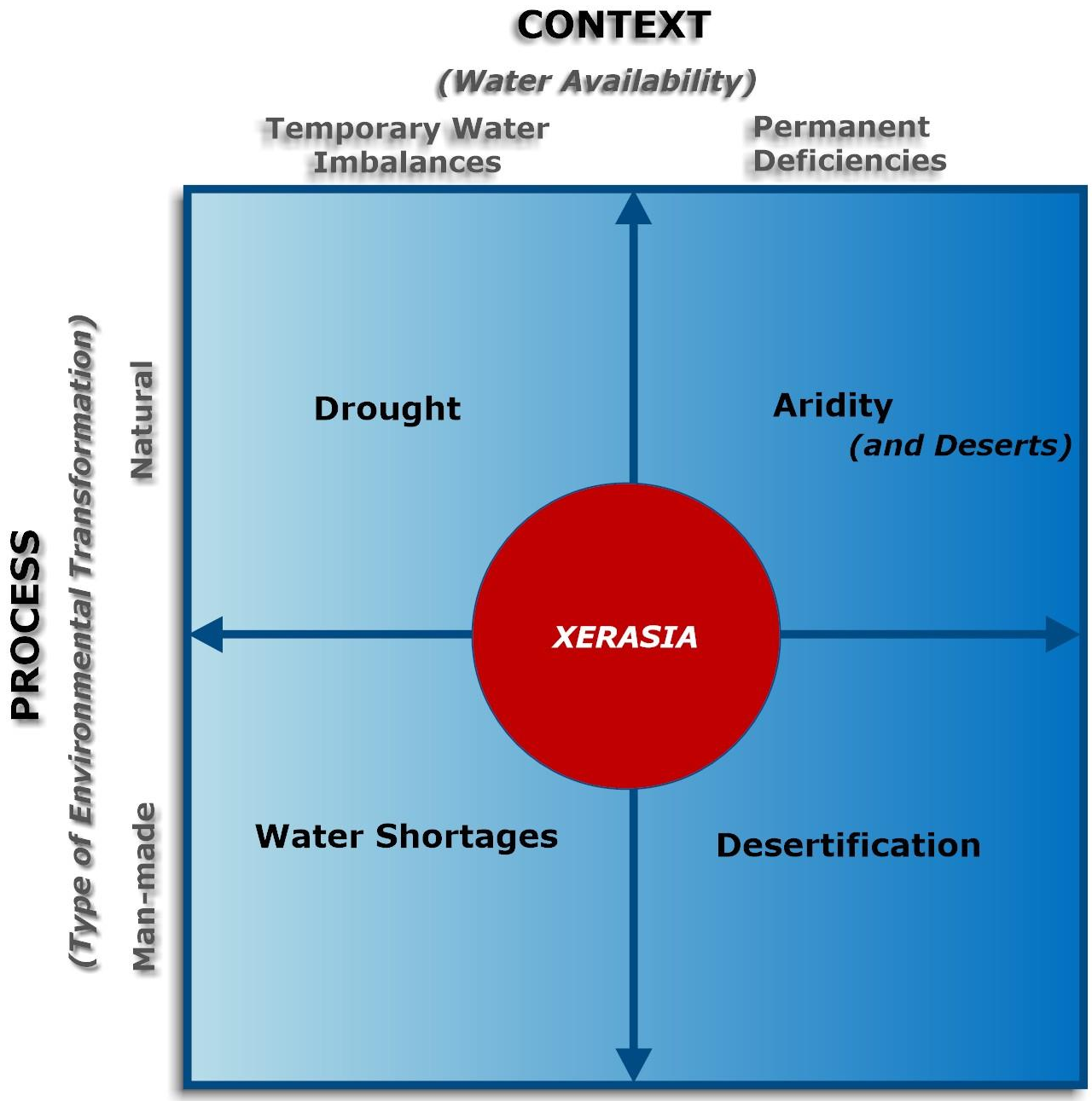
SPECULATING ABOUT THE FUTURE

Definitions of Drought

A **creeping phenomenon, a "non-event**"

A source of confusion in devising an objective definition may be that drought implies a variety of things to **various professionals** according to the specialized field of study (meteorology, hydrology, water resources, agriculture etc.).

- **Operational definitions** attempt to demarcate the severity, onset and termination point of droughts
- **Conceptual definitions** attempt to identify the boundaries of the drought event



Vlachos. E.C. 1983; Karavitis, C.A. 1992; Karavitis et al 2014

Drought

- a usually unexpected and unpredicted time period of abnormal dryness which affects water supply" (Grigg, N.S., 1988).

- The state of adverse and wide spread hydrological, environmental, social and economic impacts due to less than generally anticipated water quantities (Karavitis, 1992)

Social and Economic Drought / Water resources Engineering

- Gap between supply and demand of economic goods such as
  - water,
  - food,
  - raw materials,
  - hydroelectric power,
  - transportation

- depends on the time and space processes of supply and demand
- Social Stresses – Economic impacts

From Drought Management Strategies to Drought Management Policies

---

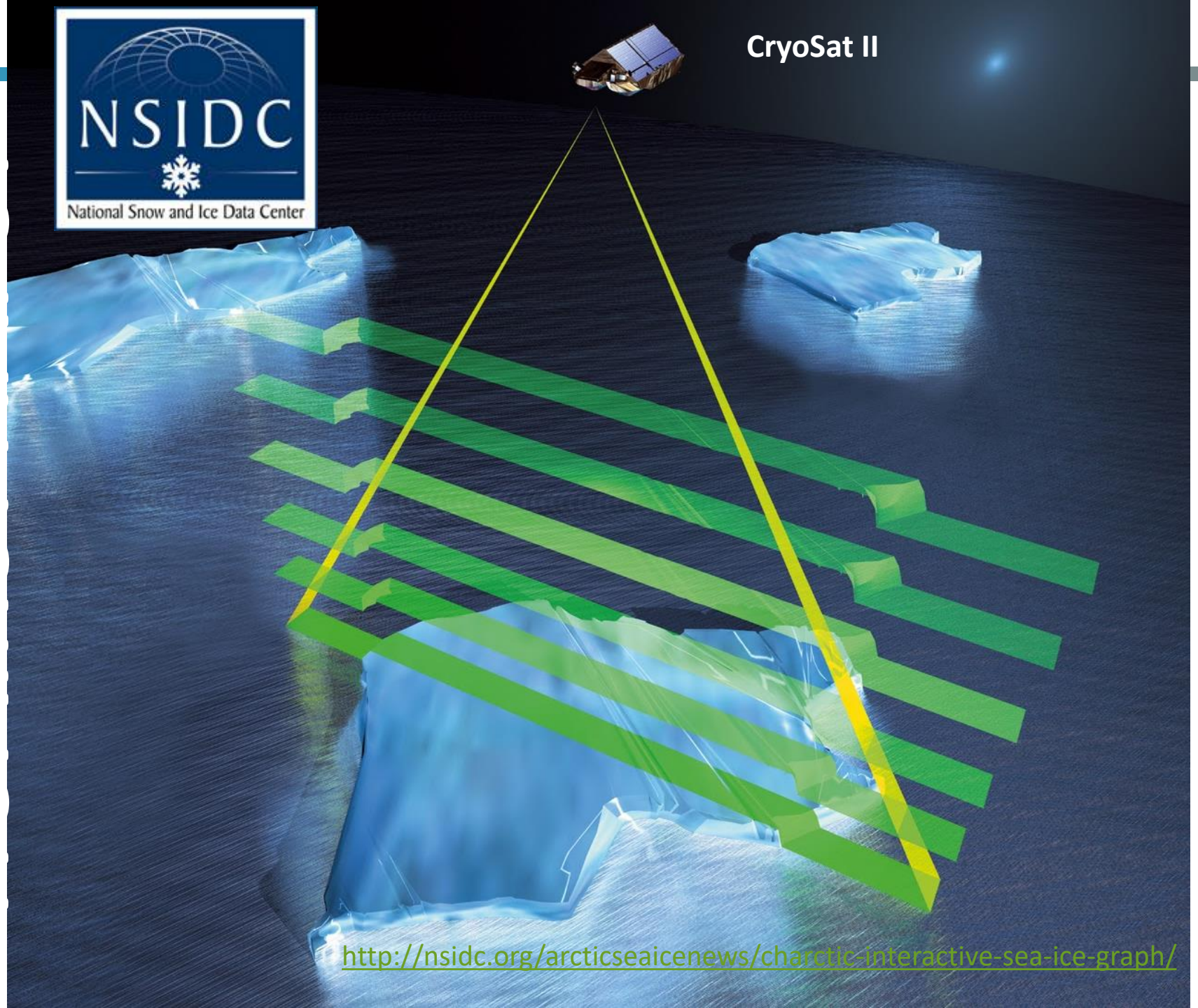
THE TRANSFORMING ENVIRONMENT

TRENDS AND DEVELOPMENTS

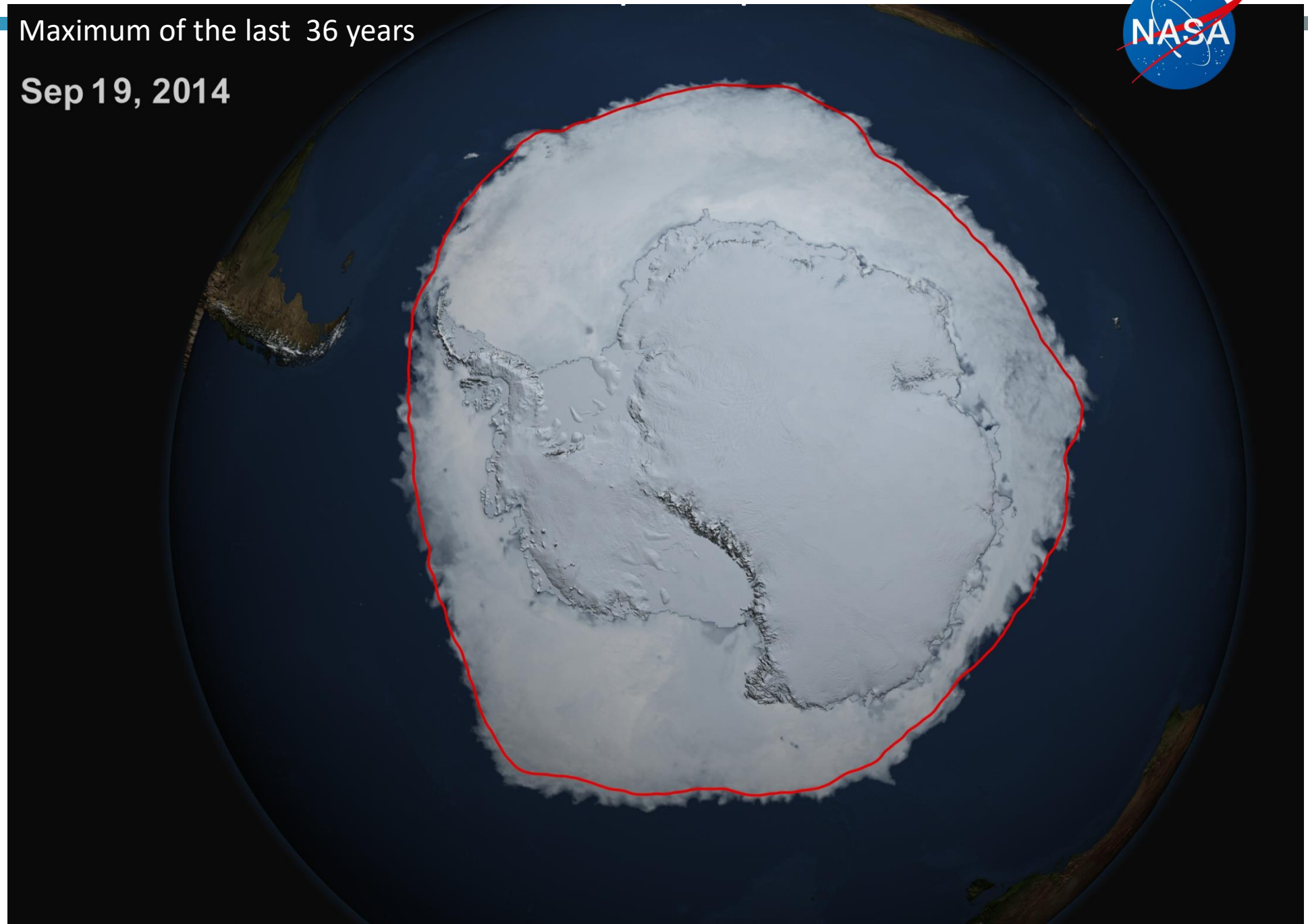
PREPARING THE SYSTEM OF THE 21ST CENTURY

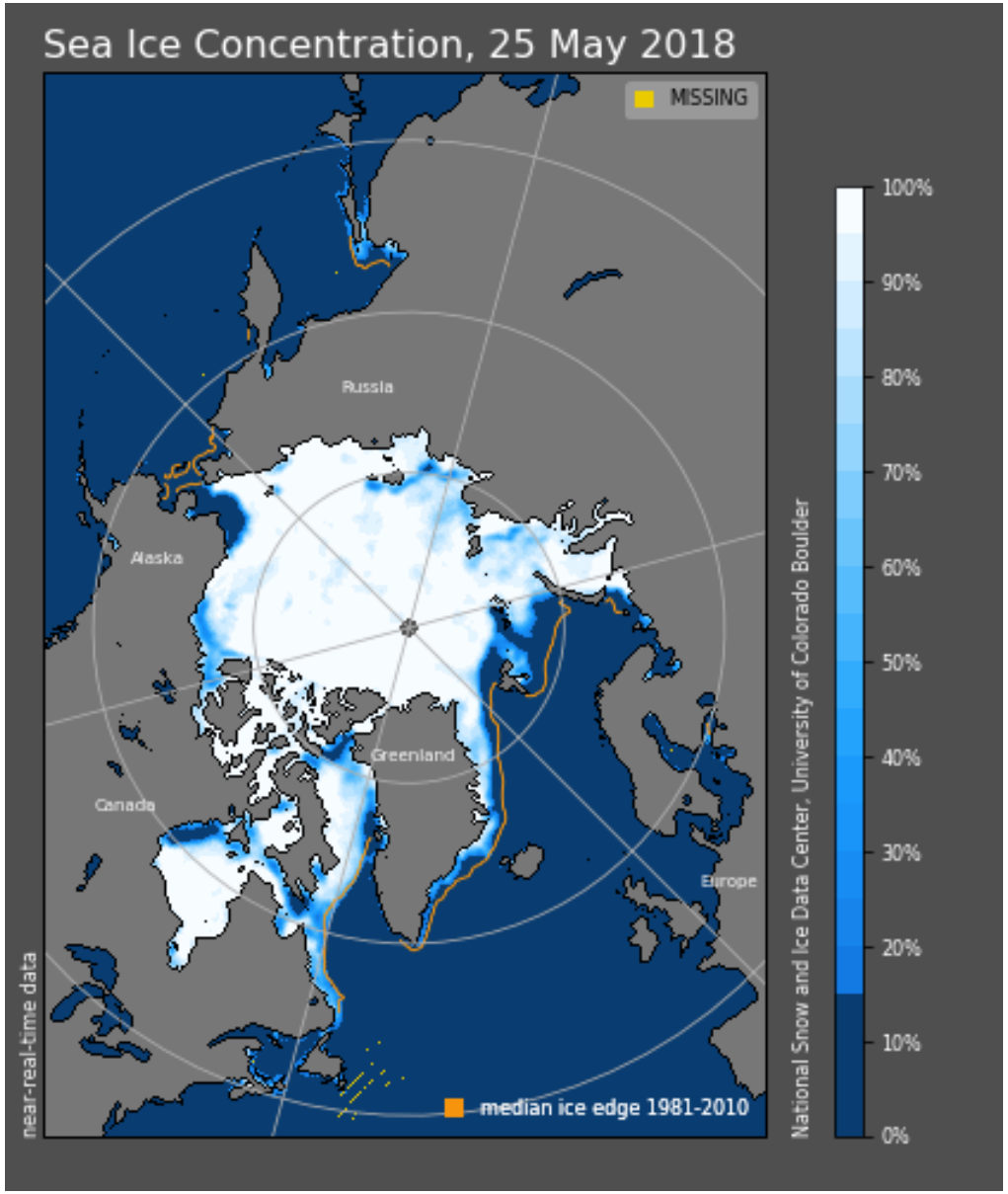
SHIFTING PARADIGMS IN THEORY & PRACTICE

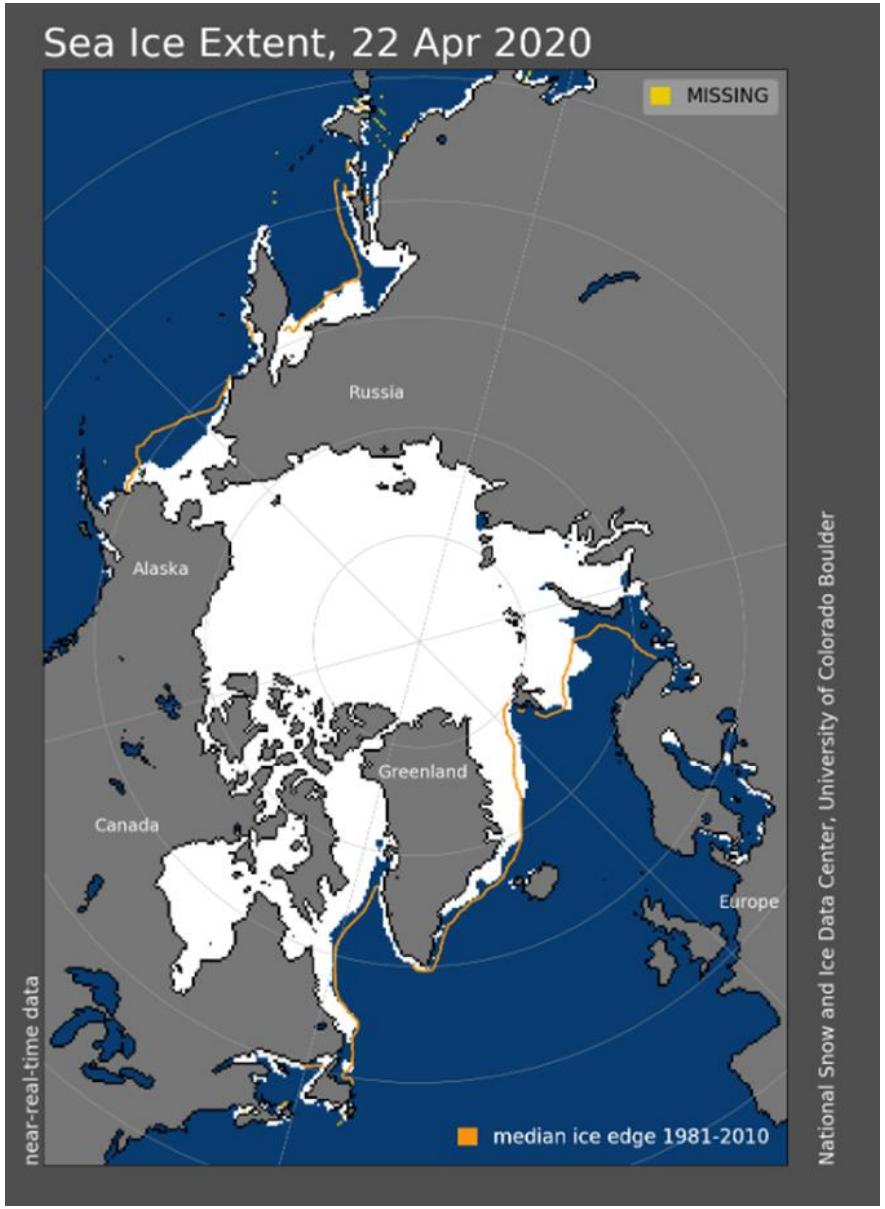
SPECULATING ABOUT THE FUTURE


NSIDC
National Snow and Ice Data Center
CryoSat II
http://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/

Maximum of the last 36 years

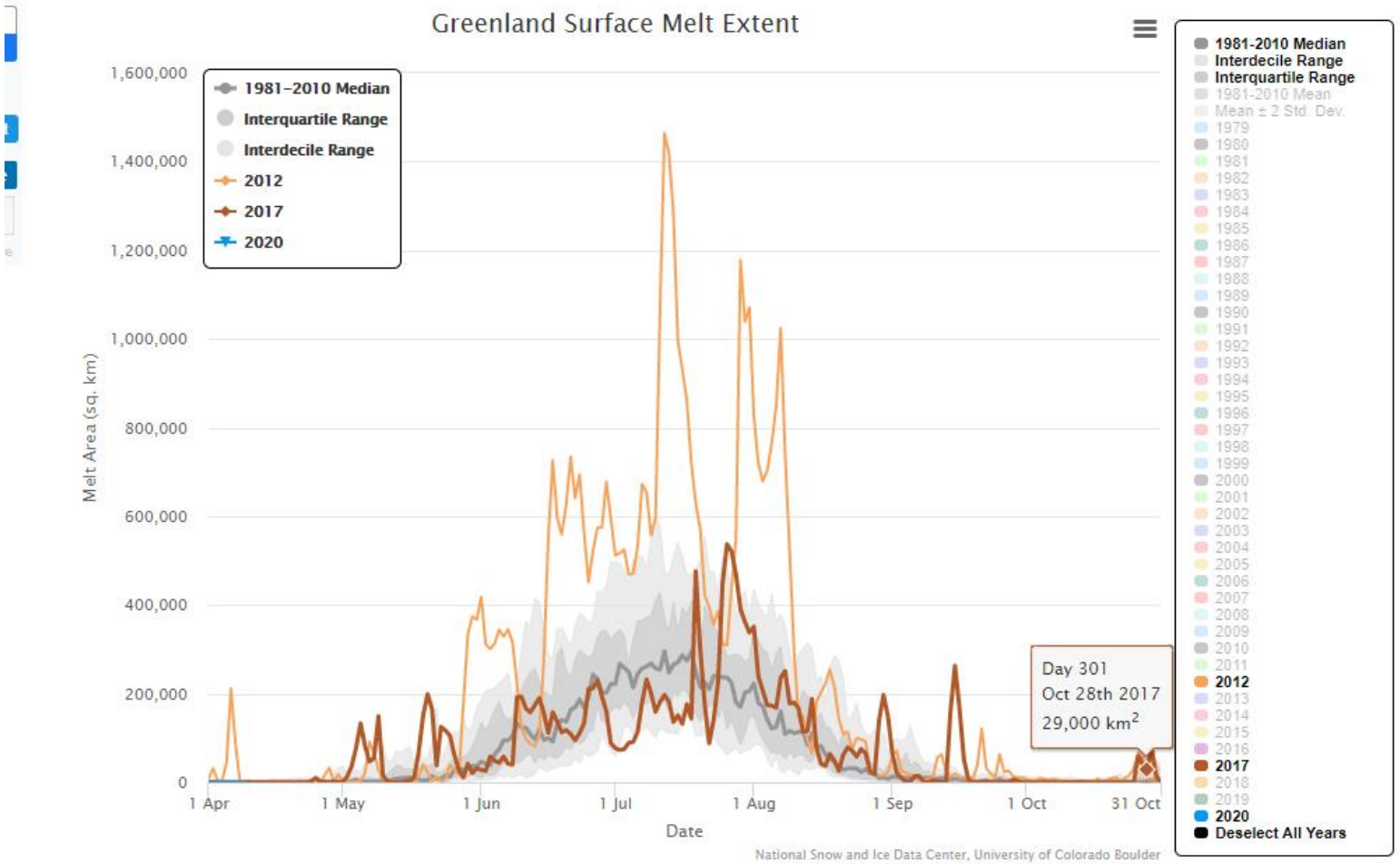



Sea Ice Concentration, 25 May 2018
MISSING
Russia
Alaska
Greenland
Canada
Europe
median ice edge 1981-2010
near-real-time data
National Snow and Ice Data Center, University of Colorado Boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%


Sea Ice Extent, 22 Apr 2020
MISSING
Russia
Alaska
Greenland
Canada
Europe
median ice edge 1981-2010
near-real-time data
National Snow and Ice Data Center, University of Colorado Boulder

https://nsidc.org/greenland-today/greenland-surface-melt-extent-interactive-chart/

Greenland Surface Melt Extent Interactive Chart

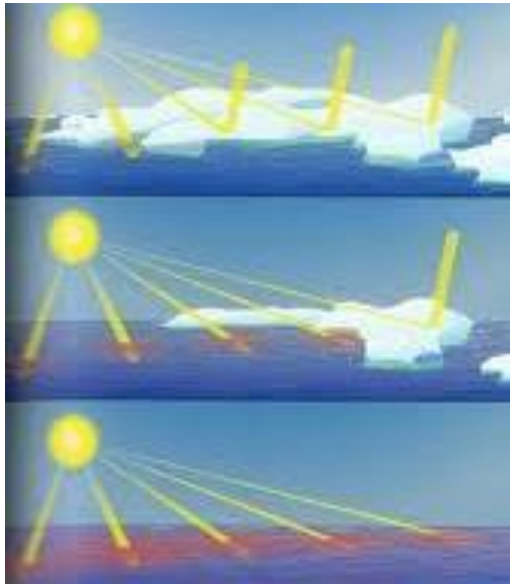


The Cryosphere: Why do we care?

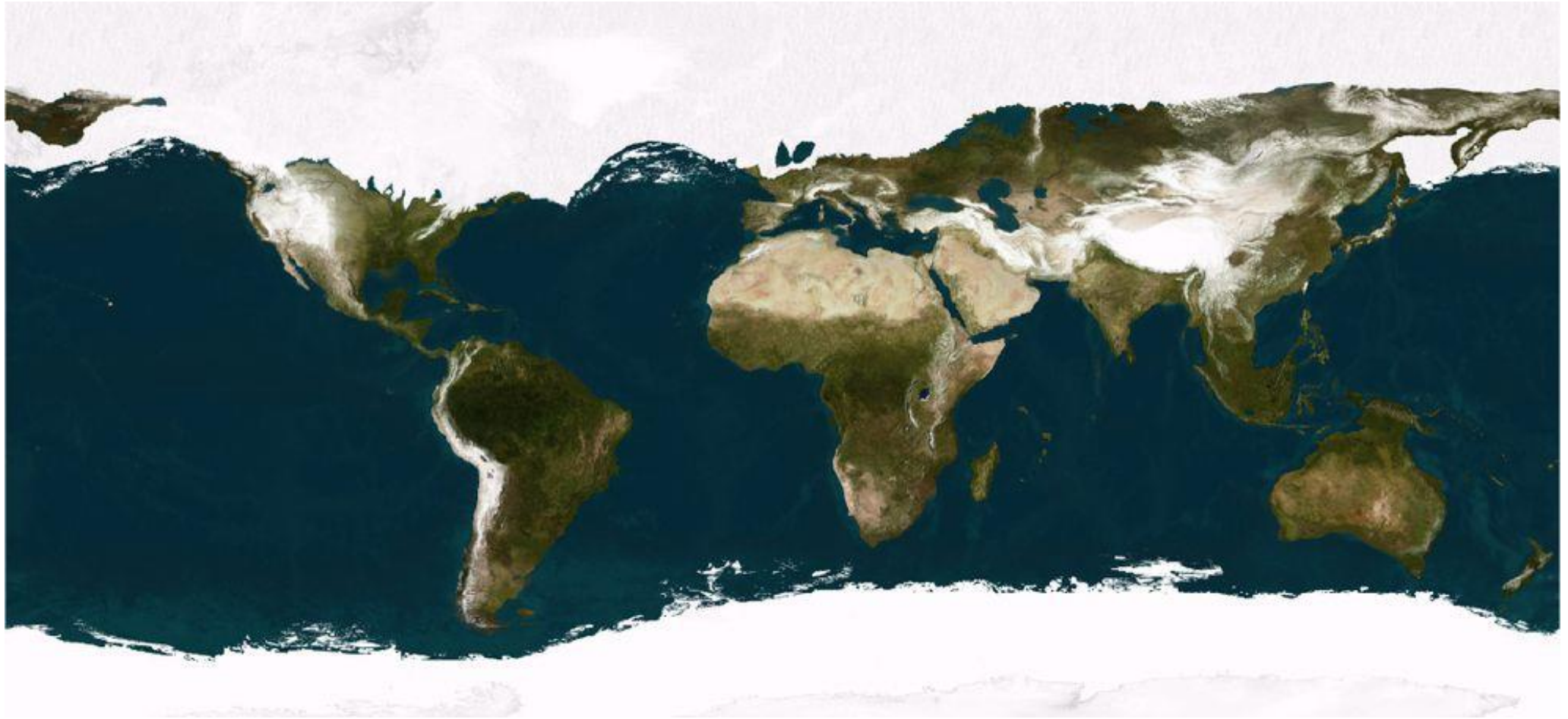
Some major impacts of melting cryosphere on the Earth system:

- Feedbacks on climate system e.g. albedo, release of methane/CO_2
- Changes in ocean and atmospheric circulation
- Changes in ecosystems that depend on snow and ice

Ice sheets also contain a record of our climate for the past 800,000 yrs



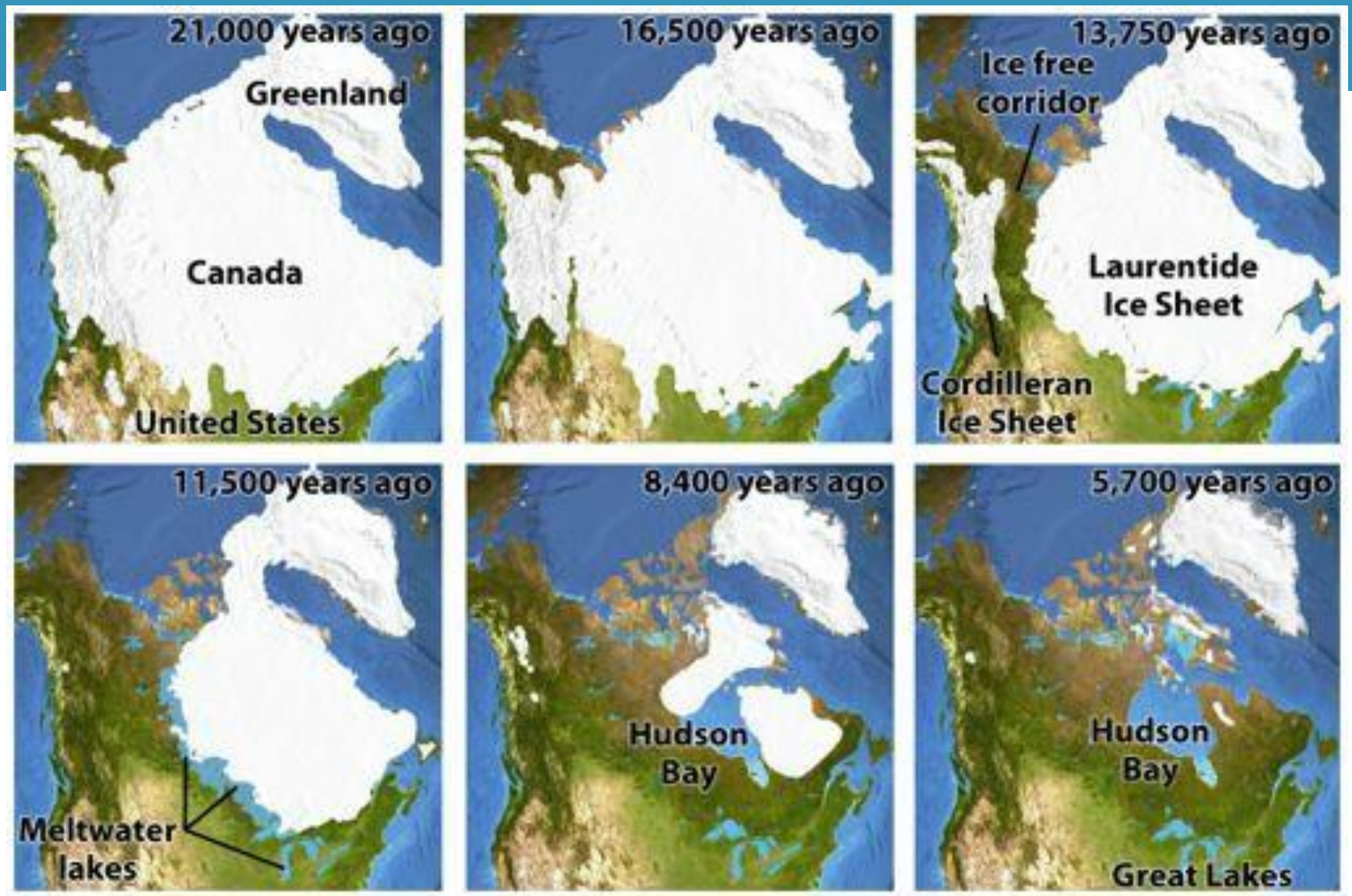
The Last Ice Age (20,000 years ago)



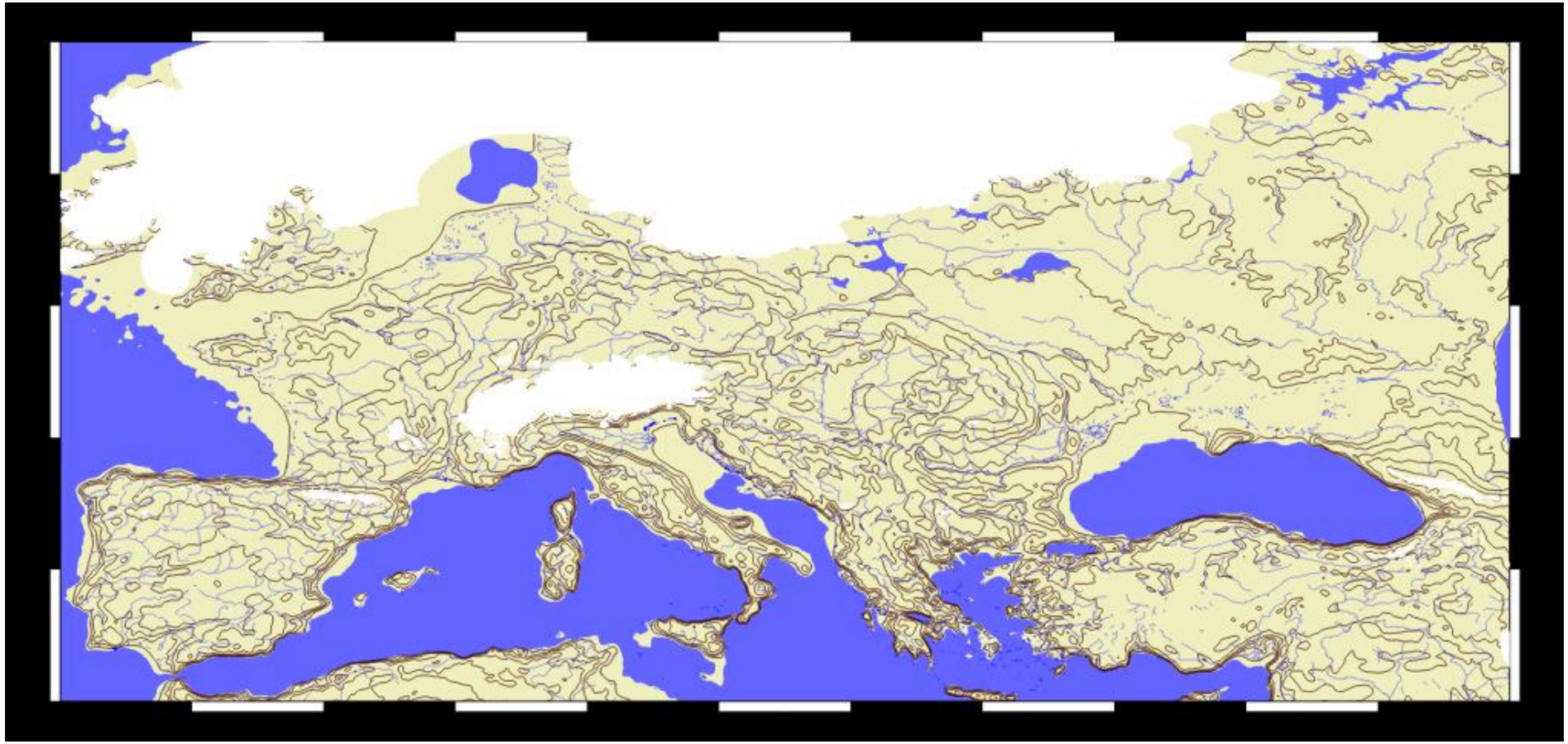
→ Ice sheets covered much of North America & Europe

→ Sea level was 130 m lower than today, exposing land that is covered by ocean today.

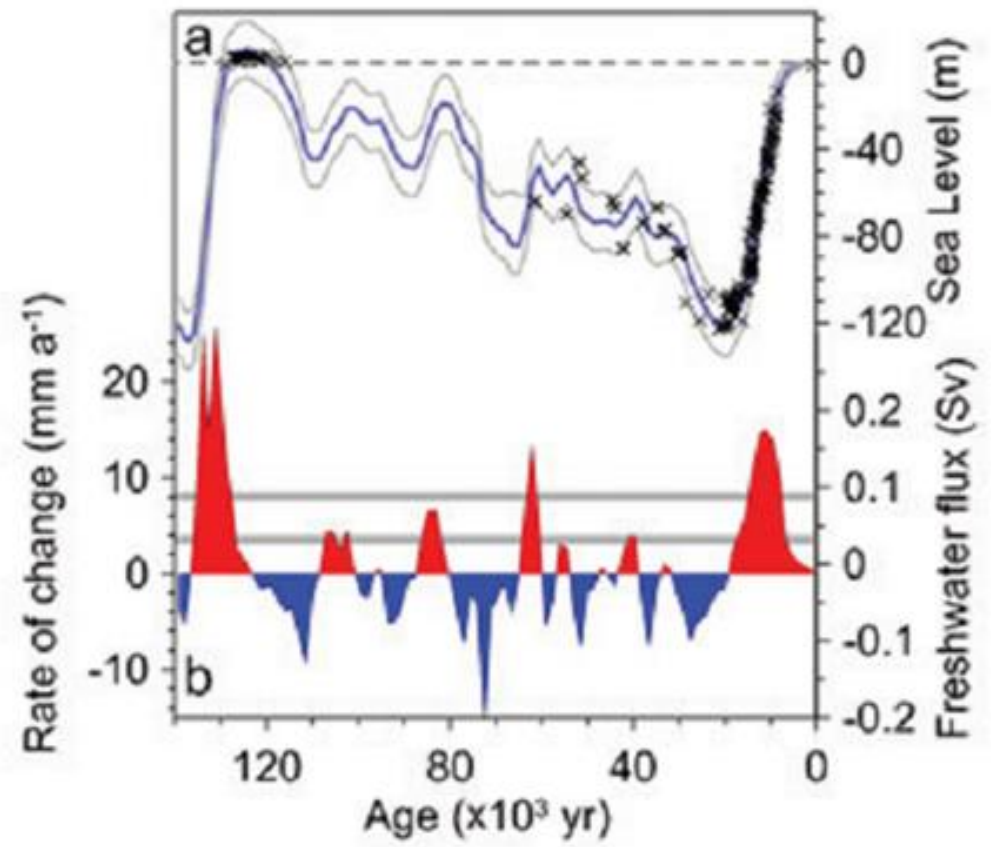
THE HISTORY OF THE NORTH AMERICAN ICE SHEETS



LAST ICE AGE IN EUROPE 20,000 YEARS AGO

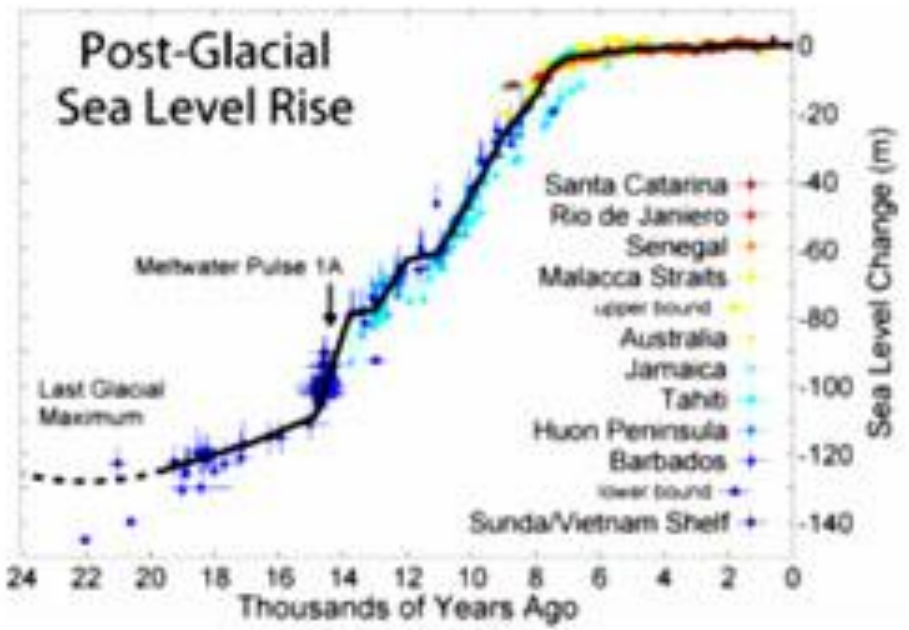


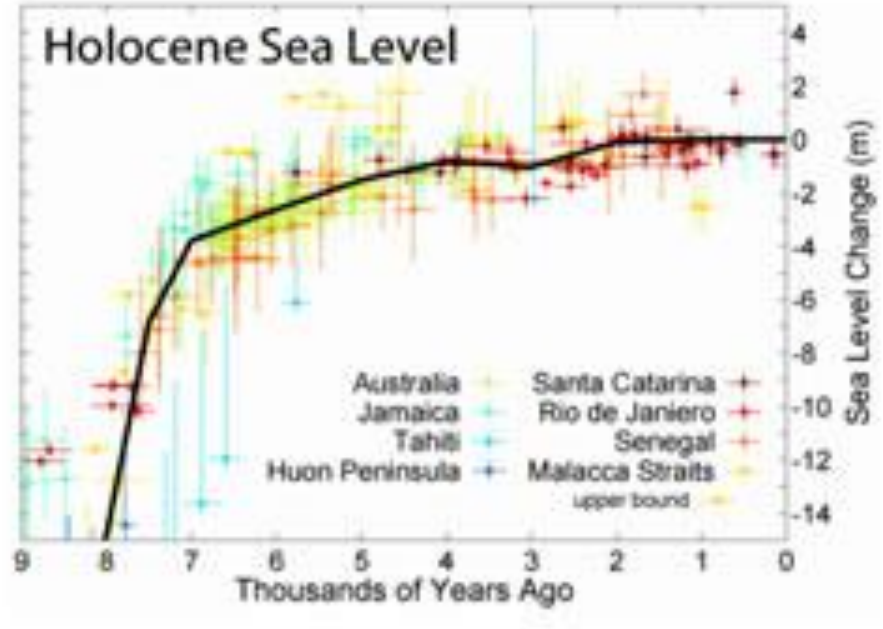
SEA LEVEL (130.000 YEARS AGO)



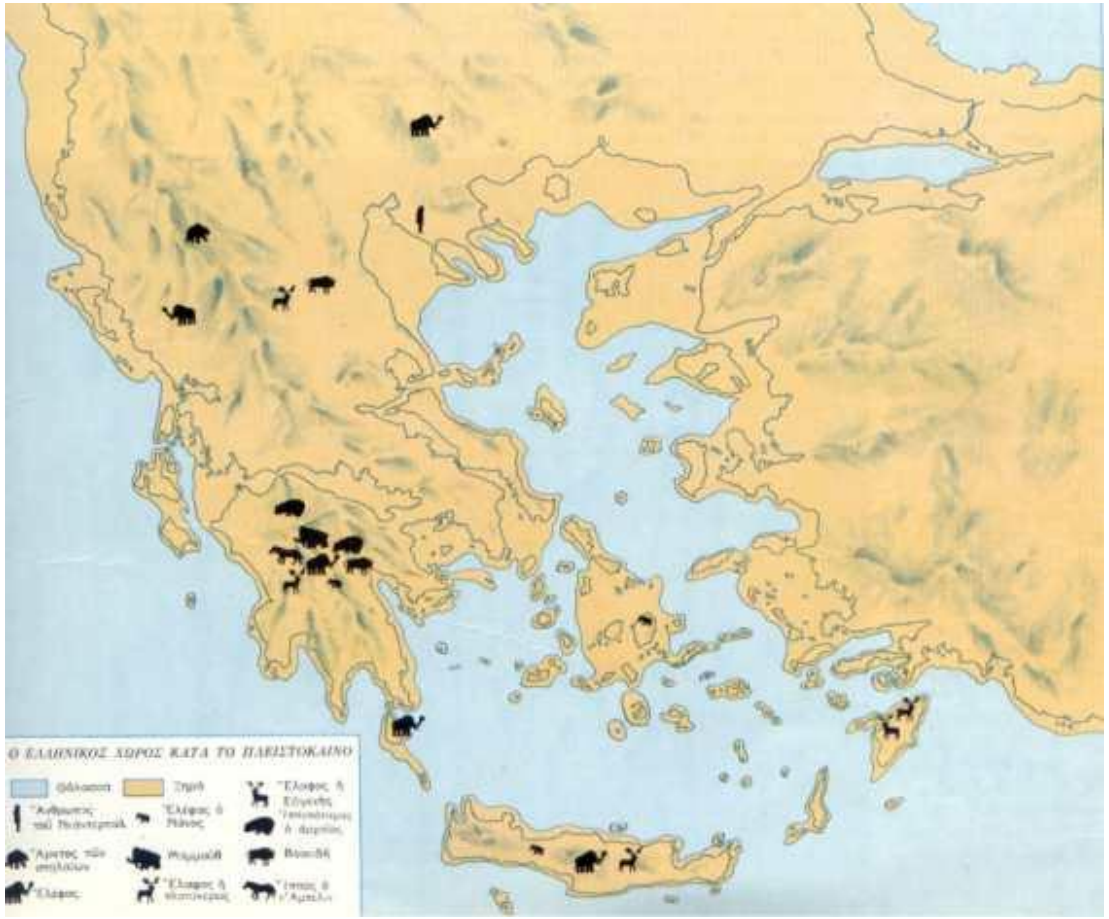
Rahmstorf, 2007

SEA LEVEL RISE IN THE LAST MILLENNIA

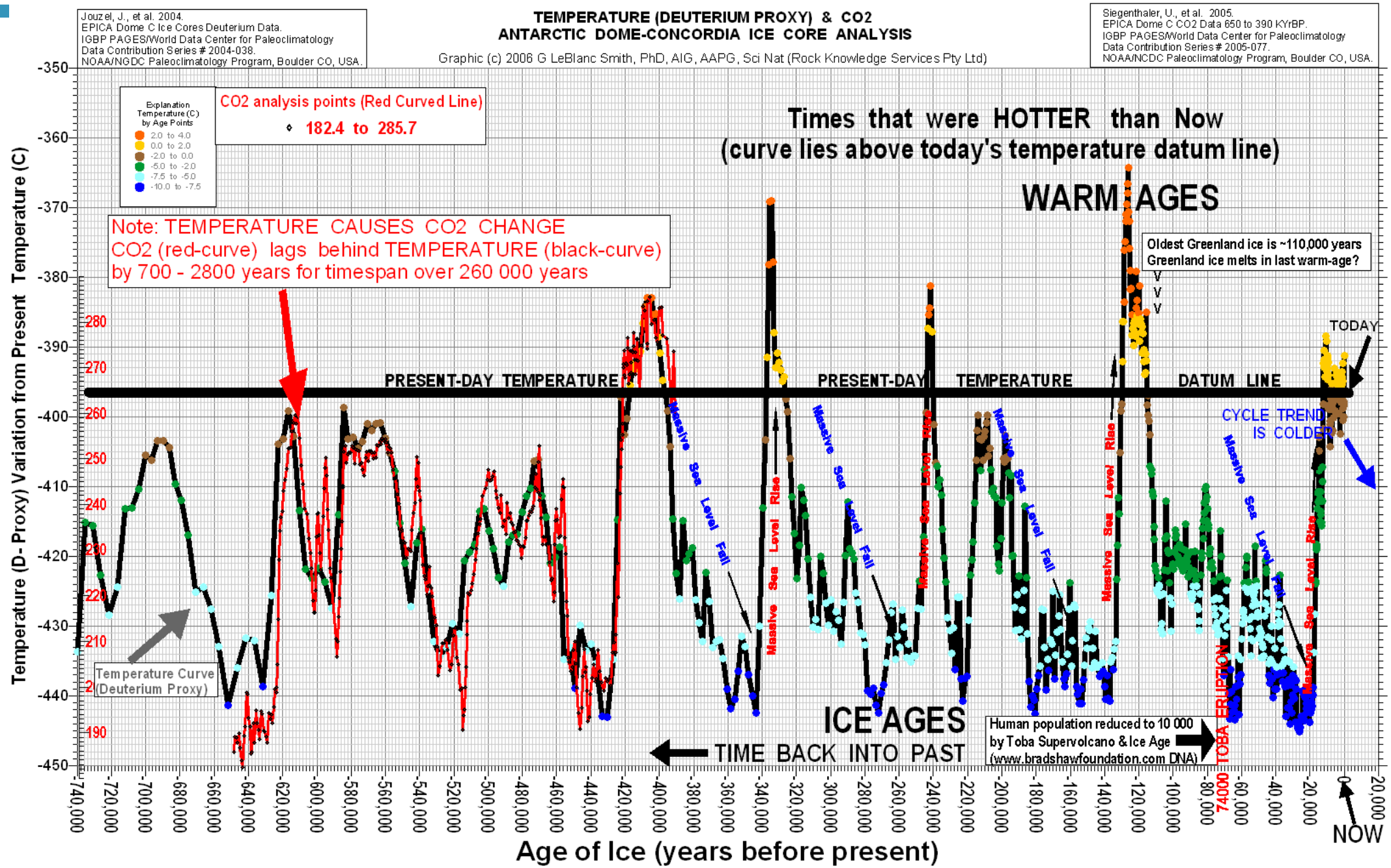


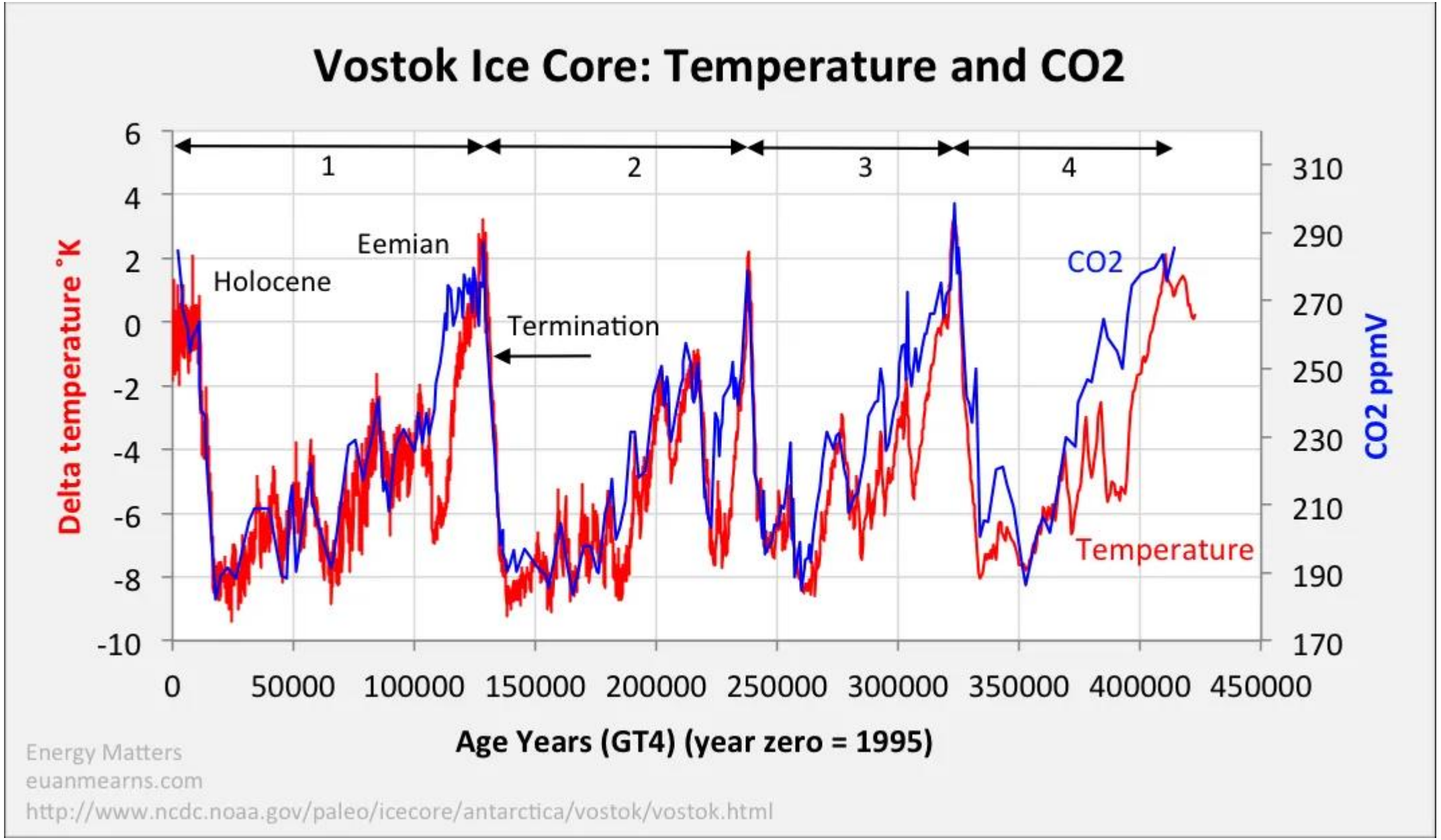


PLEISTOCENE : 2.000.000-20.000 YEARS SHORE LINES DURING THE RECURRING ICE AGES

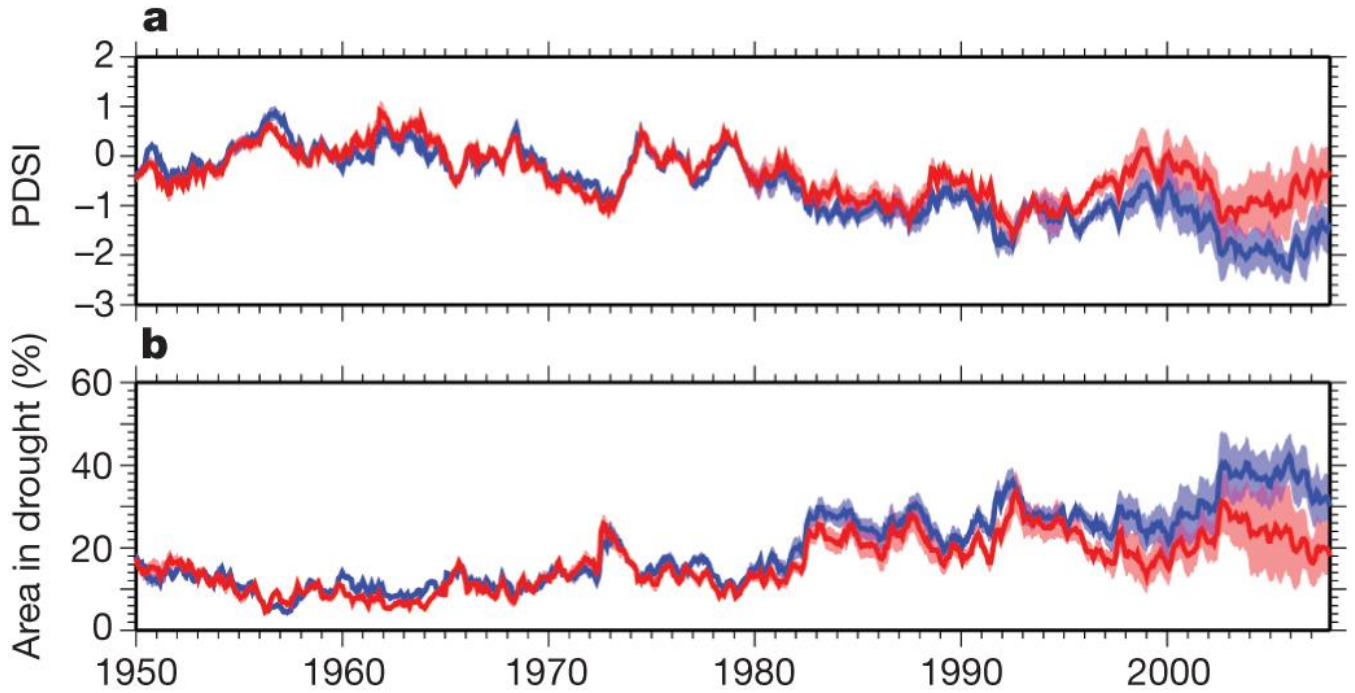


GRAPH SHOWING MAJOR GLOBAL HOT-COLD CYCLES & LAG OF CO2 BEHIND TEMPERATURE




Vostok Ice Core: Temperature and CO2
6
4
2
0
-2
-4
-6
-8
-10
Delta temperature °K
1
2
3
4
Eemian
Holocene
Termination
CO2
Temperature
310
290
270
250
230
210
190
170
CO2 ppmV
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
Age Years (GT4) (year zero = 1995)
Energy Matters
euanmearns.com
http://www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok.html

Global average time series of the PDSI and area in drought.
Little change in global drought over the past 60 years



a, PDSI_Th (blue line) and PDSI_PM (red line). **b**, Area in drought (PDSI <−3.0) for the PDSI_Th (blue line) and PDSI_PM (red line). The shading represents the range derived from uncertainties in precipitation (PDSI_Th and PDSI_PM) and net radiation (PDSI_PM only). Uncertainty in precipitation is estimated by forcing the PDSI_Th and PDSI_PM by four alternative global precipitation data sets. Uncertainty from net radiation is estimated by forcing the PDSI_PM with a hybrid empirical–satellite data set and an empirical estimate. The other near-surface meteorological data are from a hybrid reanalysis–observational data set. The thick lines are the mean values of the different PDSI data sets. The time series are averaged over global land areas excluding Greenland, Antarctica and desert regions with a mean annual precipitation of less than 0.5 mm d^{-1}

J Sheffield et al. Nature **491**, 435-438 (2012) doi:10.1038/nature11575

nature

SMART DROUGHT MANAGEMENT:
GOING INTO THE INTERNET OF THINGS ERA

THE TRANSFORMING ENVIRONMENT

TRENDS AND DEVELOPMENTS

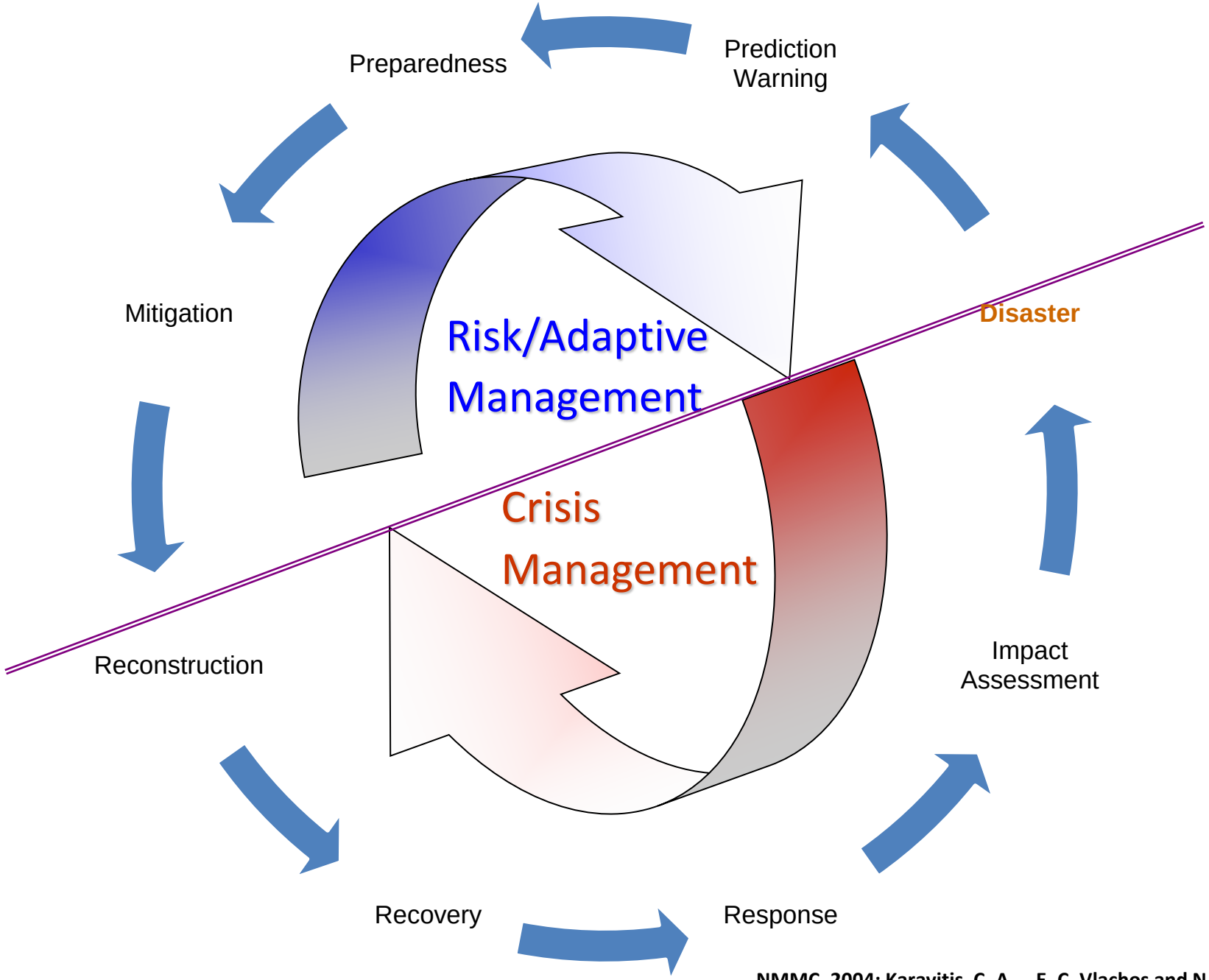
PREPARING THE SYSTEM OF THE 21ST CENTURY

SHIFTING PARADIGMS IN THEORY & PRACTICE

SPECULATING ABOUT THE FUTURE

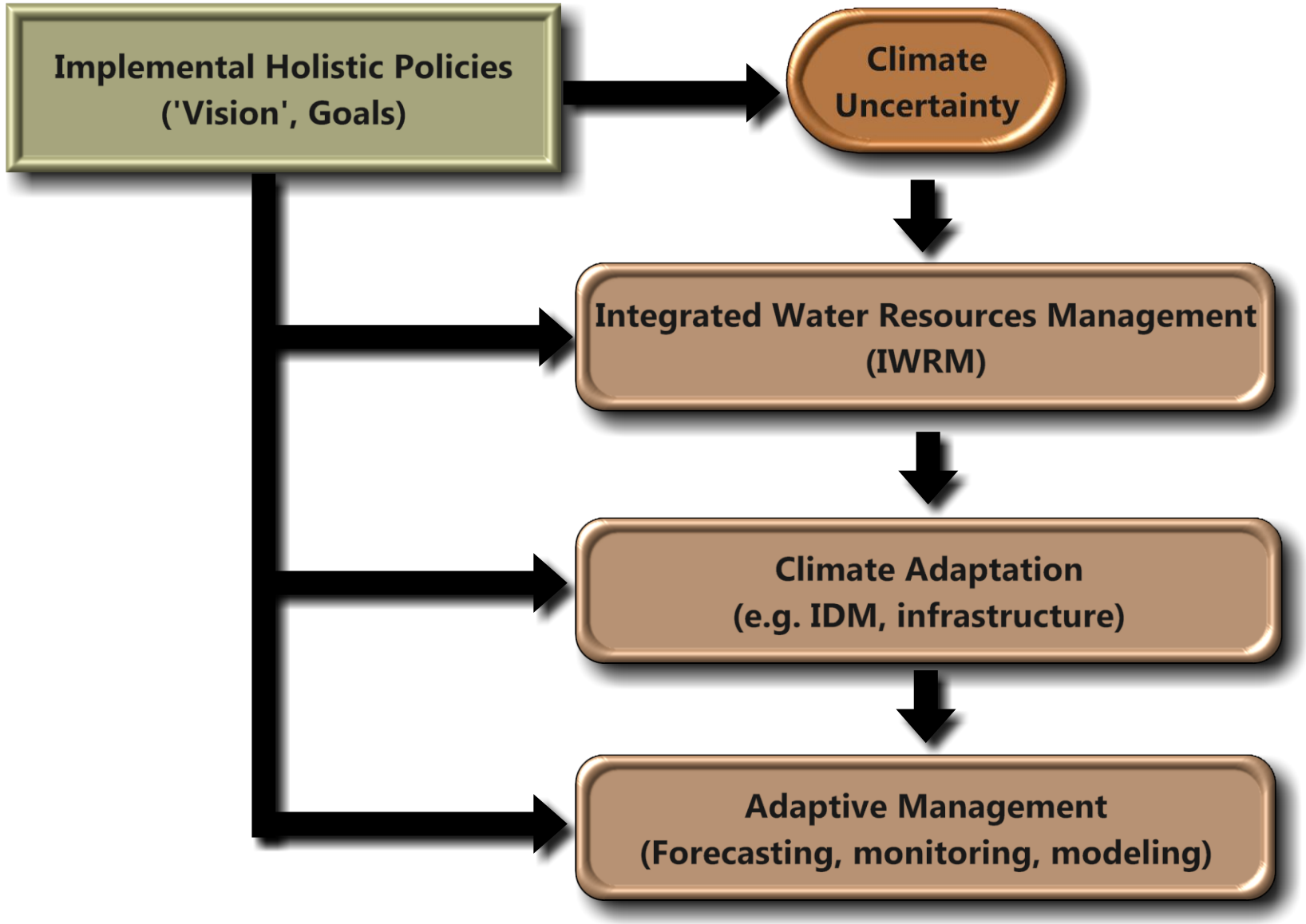
Why are Drought Contingency Policies Needed?

- Prevailing crisis management attitude
- Natural Hazards Emergency Response Procedures
- Protocols for Processes and Procedures
- Create a wider menu of options and alternatives

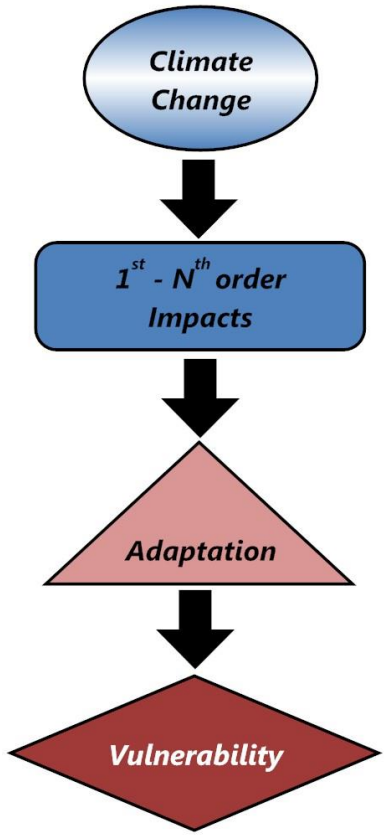


NMMC, 2004; Karavitis, C. A., . E. C. Vlachos and N. S. Grigg, 2005

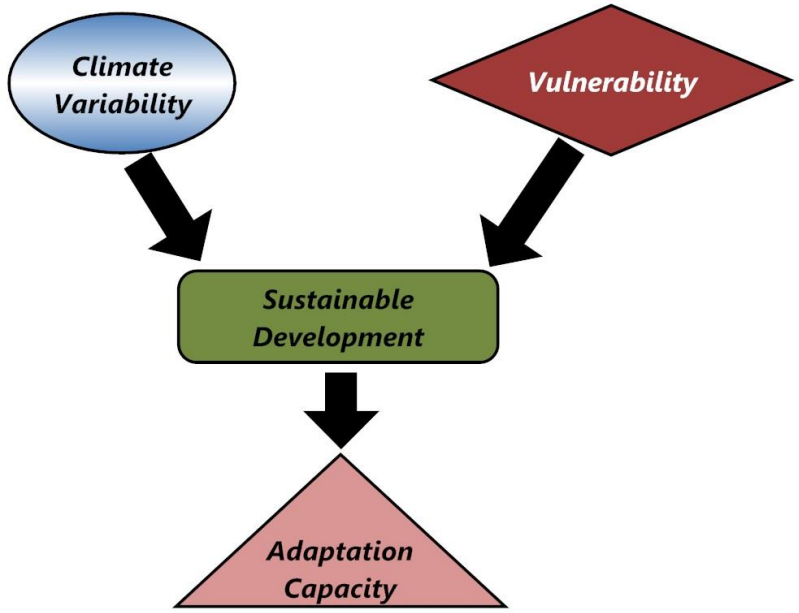
Analysis for a Risk Management Framework



Adaptation Planning



Scenario - led



Vulnerability-first

Source: IPCC Dr. Thomas E. Downing (SEI) 2009

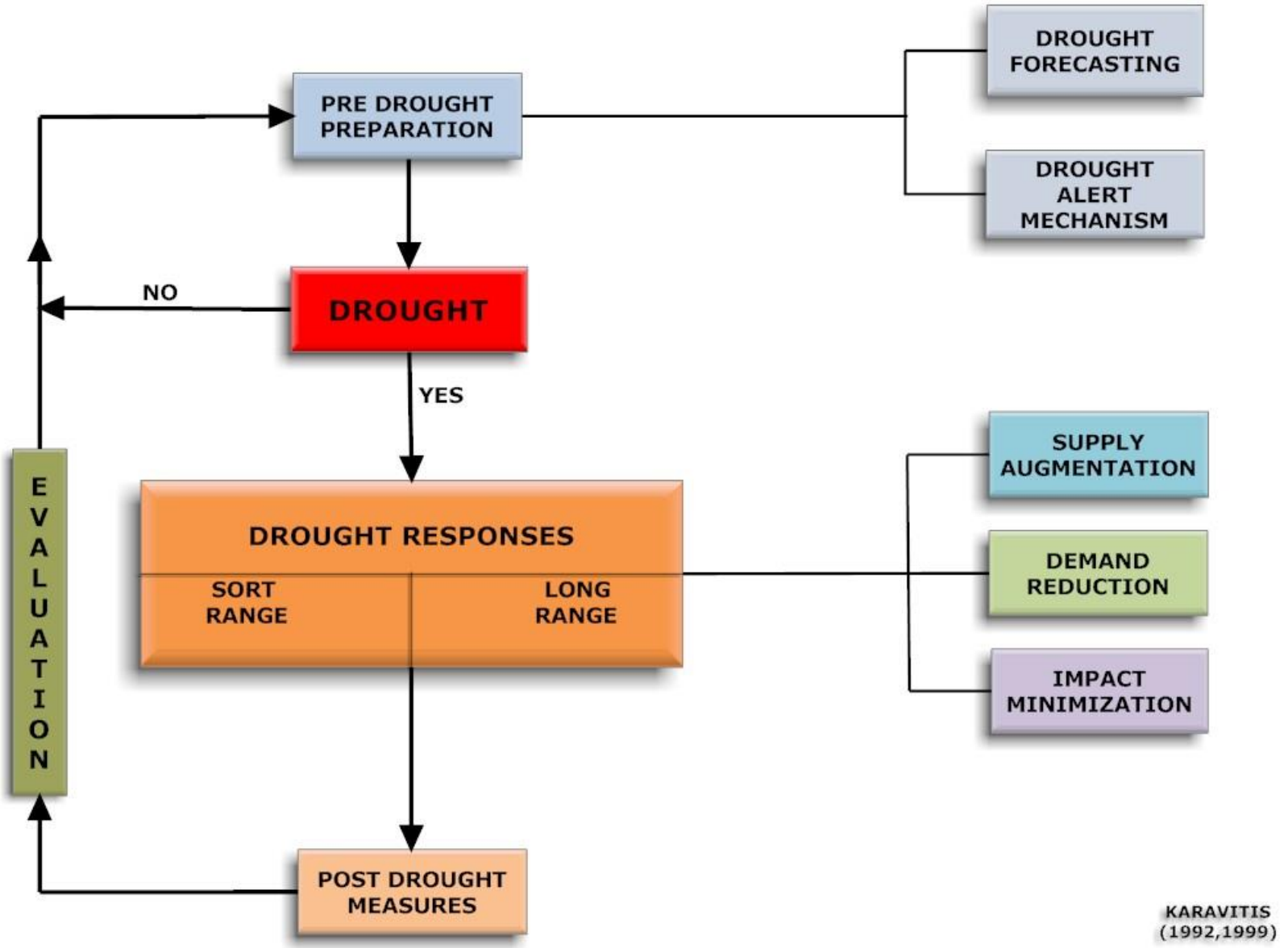
Vulnerability

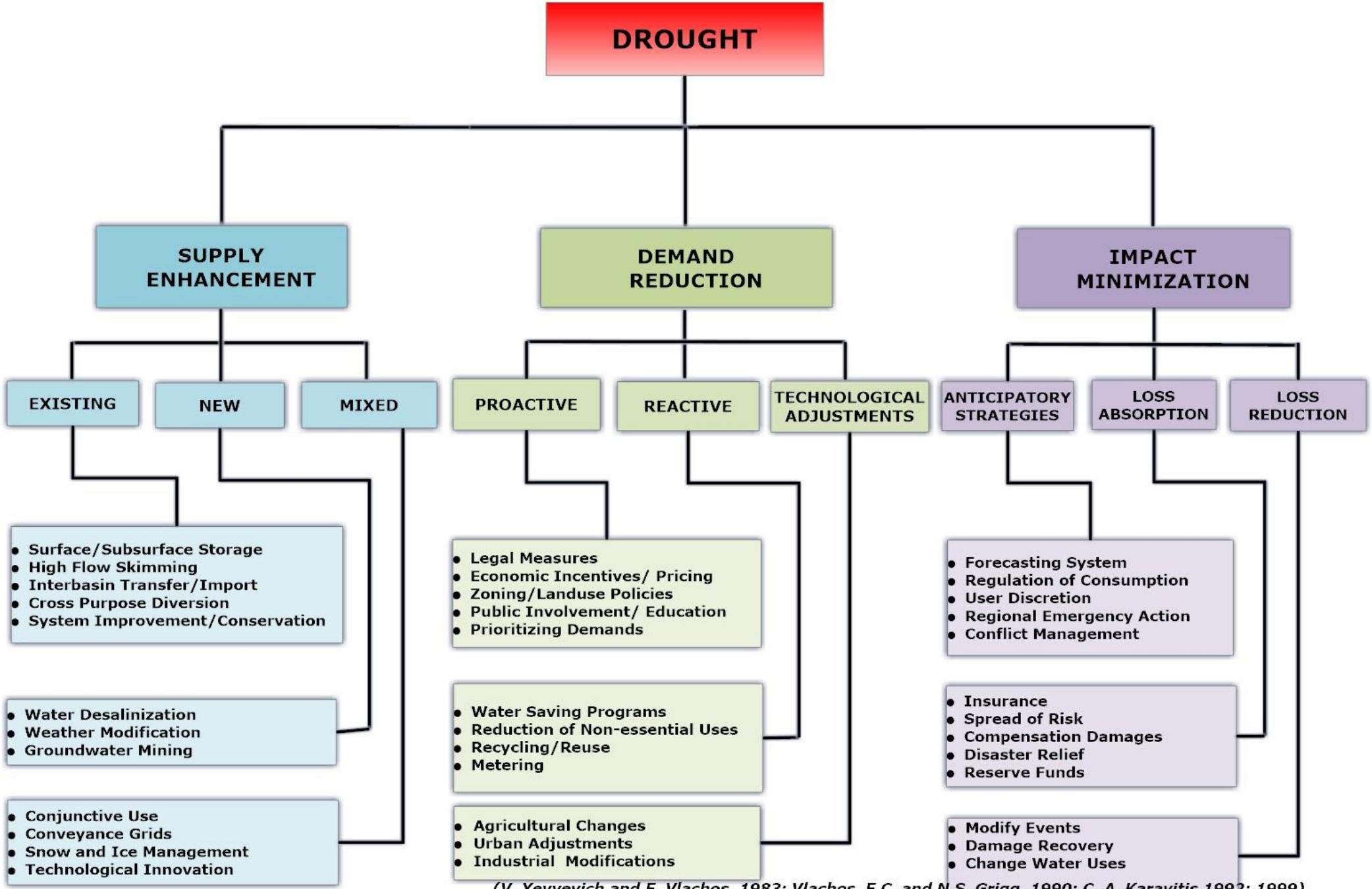
The degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor (Turner et.al, 2003)

Vulnerability = F(Hazard , Impacts)

UN-ISDR, 2004

Drought contingency Plan





(V. Yevyevich and E. Vlachos, 1983; Vlachos, E.C. and N.S. Grigg, 1990; C. A. Karavitis 1992; 1999)

SMART DROUGHT MANAGEMENT: GOING INTO THE INTERNET OF THINGS ERA

THE TRANSFORMING ENVIRONMENT

TRENDS AND DEVELOPMENTS

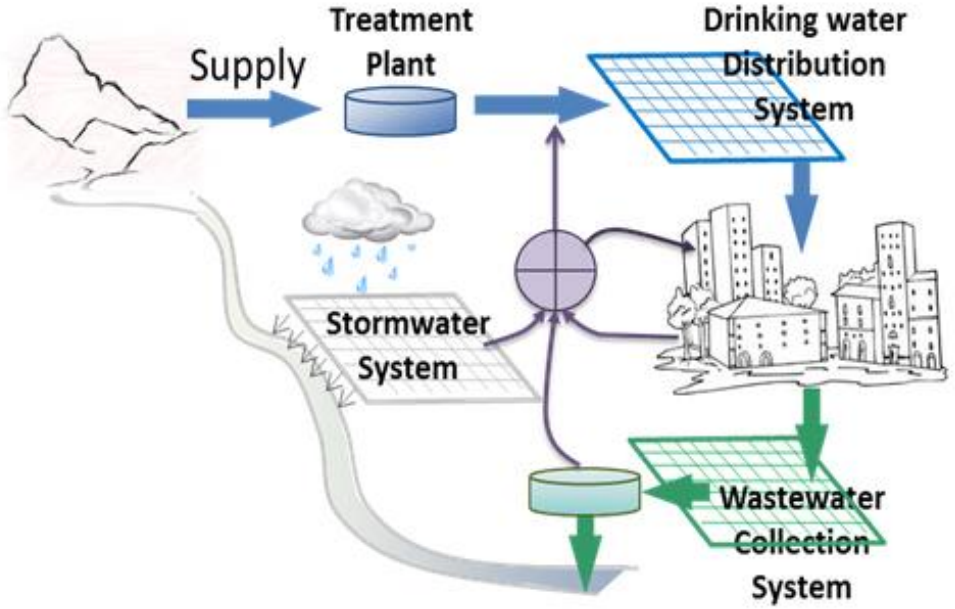
PREPARING THE SYSTEM OF THE 21ST CENTURY

SHIFTING PARADIGMS IN THEORY & PRACTICE

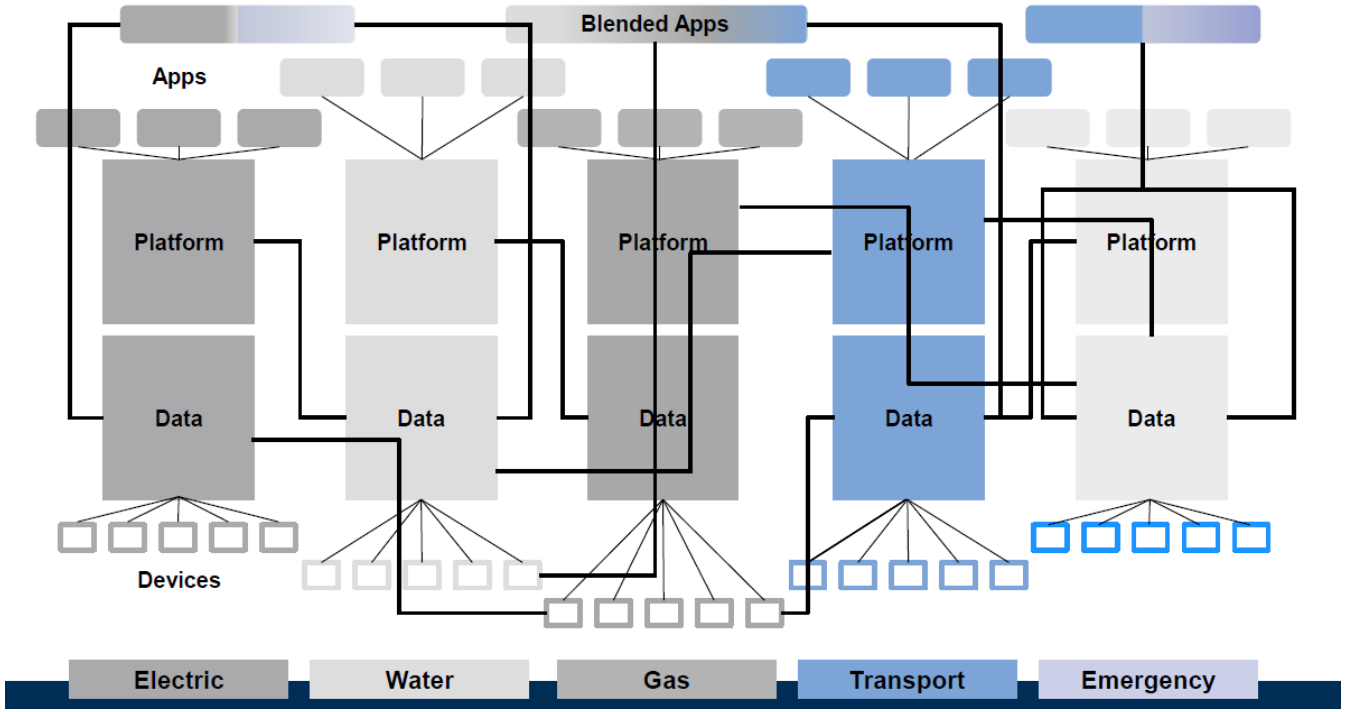
SPECULATING ABOUT THE FUTURE

What is Smart Water Management

Use of computing devices, information technologies, and communication systems (ICTs) to manage different types of water systems



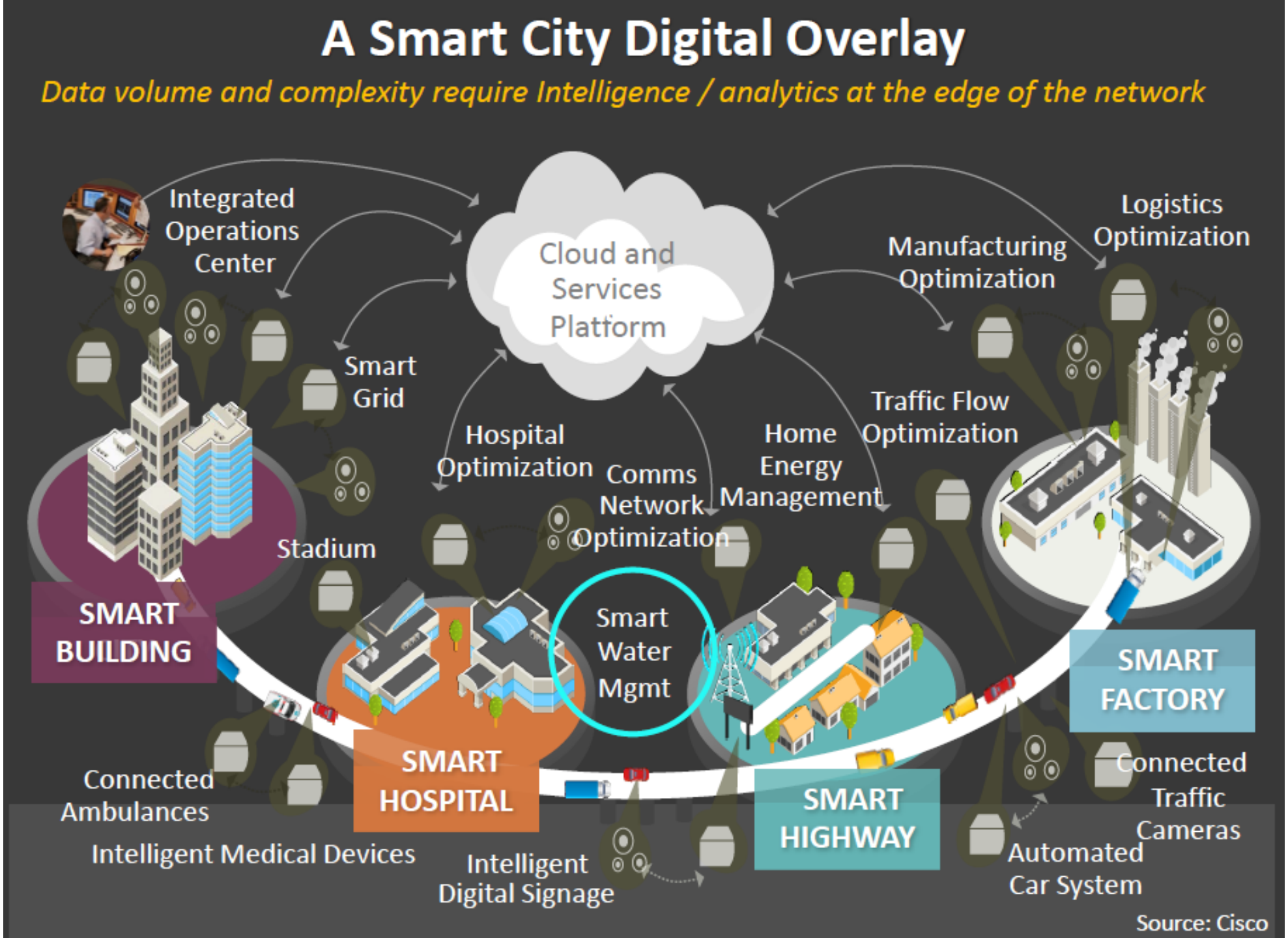
Big picture
Smart cities



Credit: Smart Cities Council

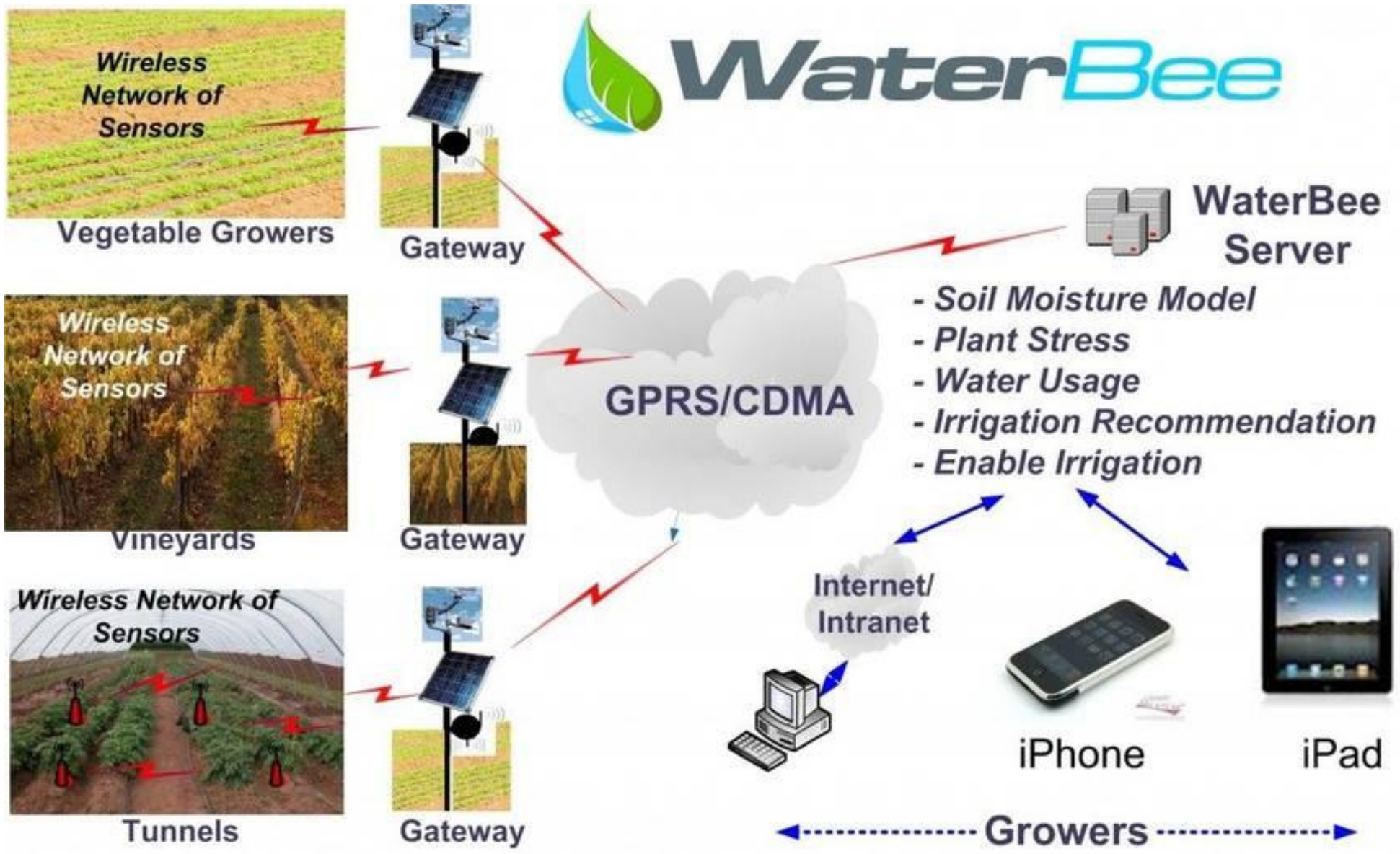
A Smart City Digital Overlay

Data volume and complexity require Intelligence / analytics at the edge of the network



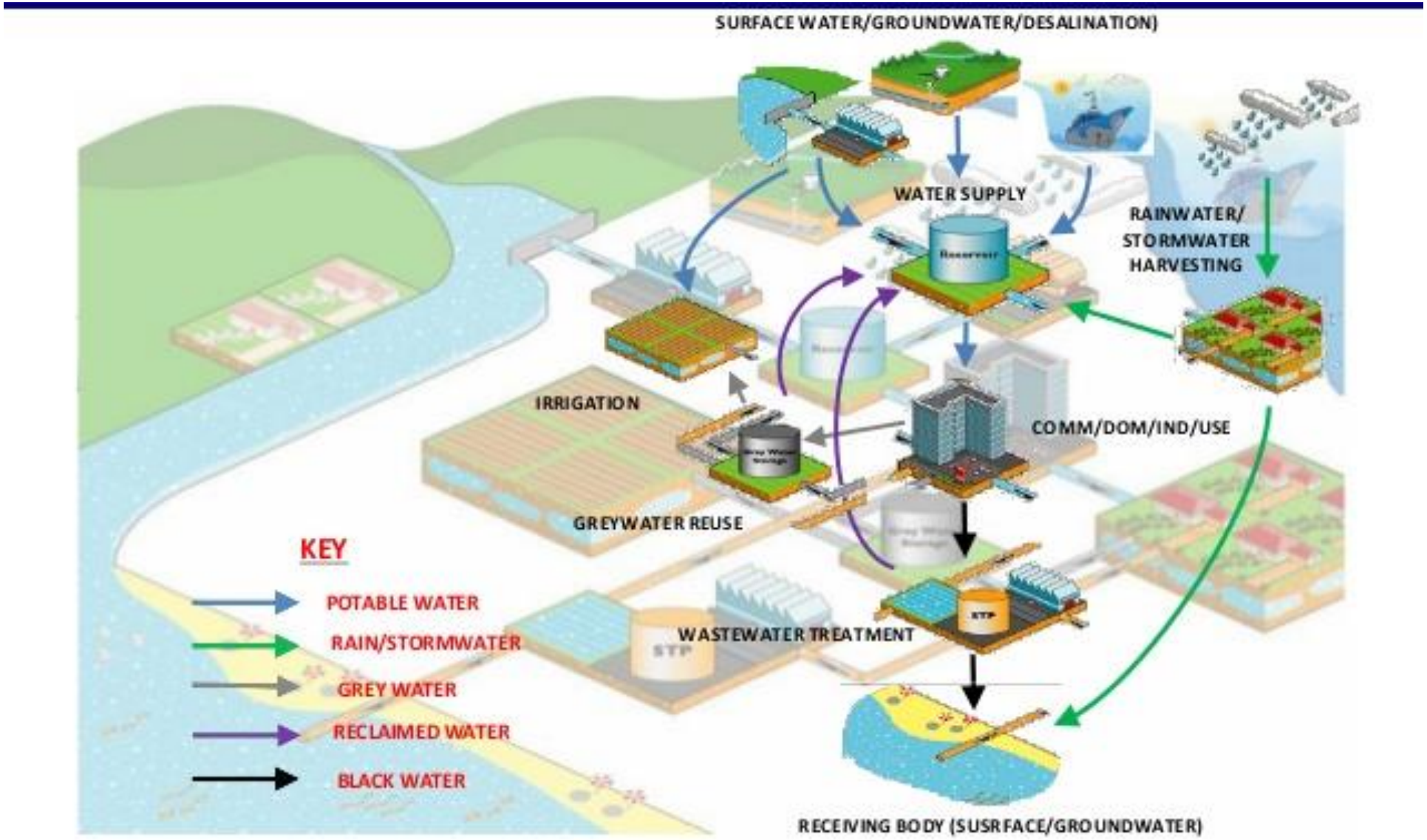
Source: Cisco

Smart irrigation example



https://www.treehugger.com/gadgets/smart-irrigation-and-water-management-system-controlled-app.html

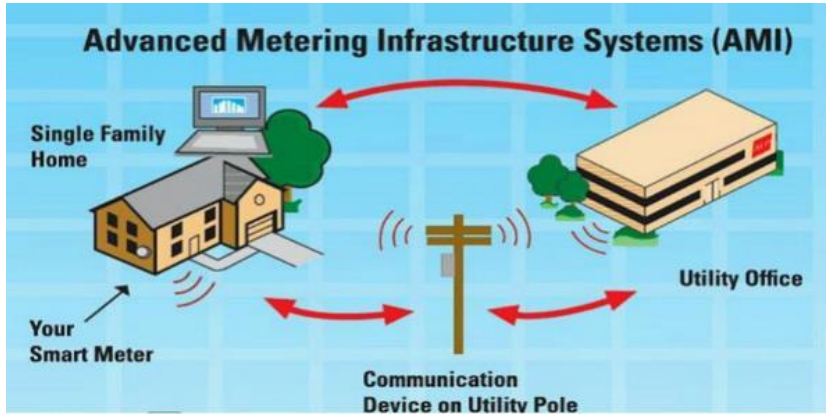
One Water



https://www.slideshare.net/globalwaterpartnership/integrated-urban-water-management

Smart Water Technologies

- SCADA
- Sensors
- Smart Pumps
- Automated Meter Reading
- Advanced Metering Infrastructure (AMI)
- Smart Valves
- Data Analysis Platforms
- IoT (Internet of Things) platforms
- Real to near real time visualization

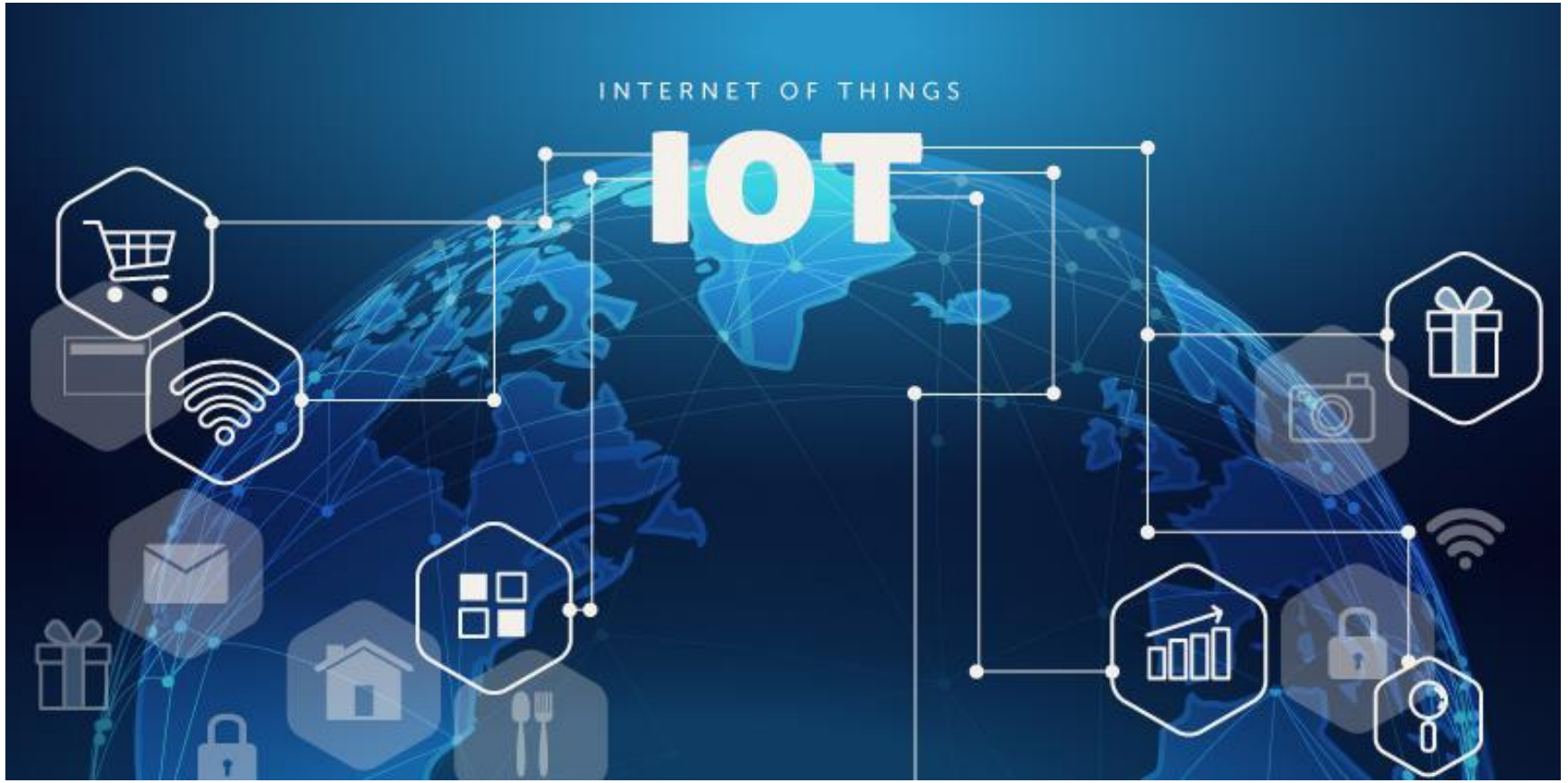


http://www.coherentchronicle.com/advanced-metering-infrastructure-market-headed-for-growth-and-global-expansion-by-2025/#prettyPhoto

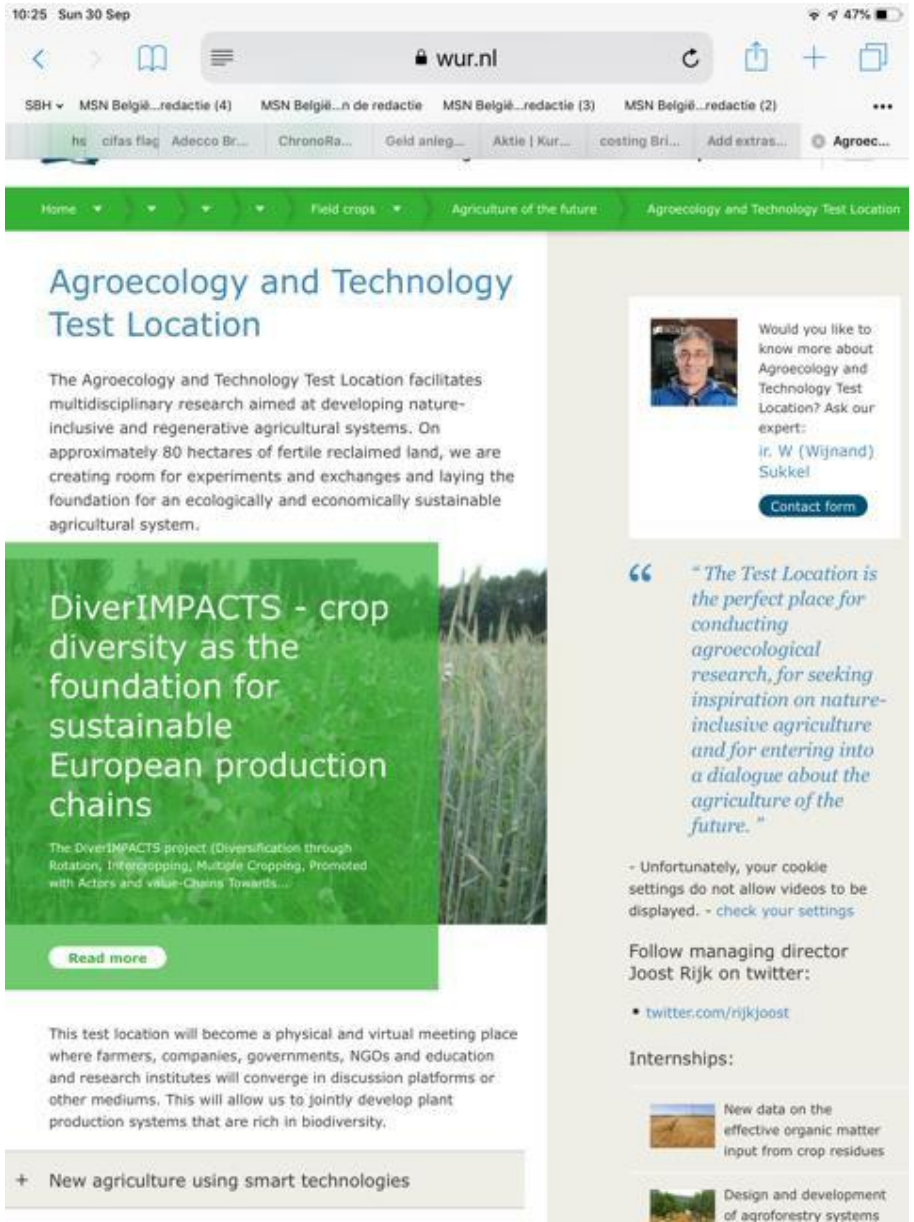
ECHOLOGICS

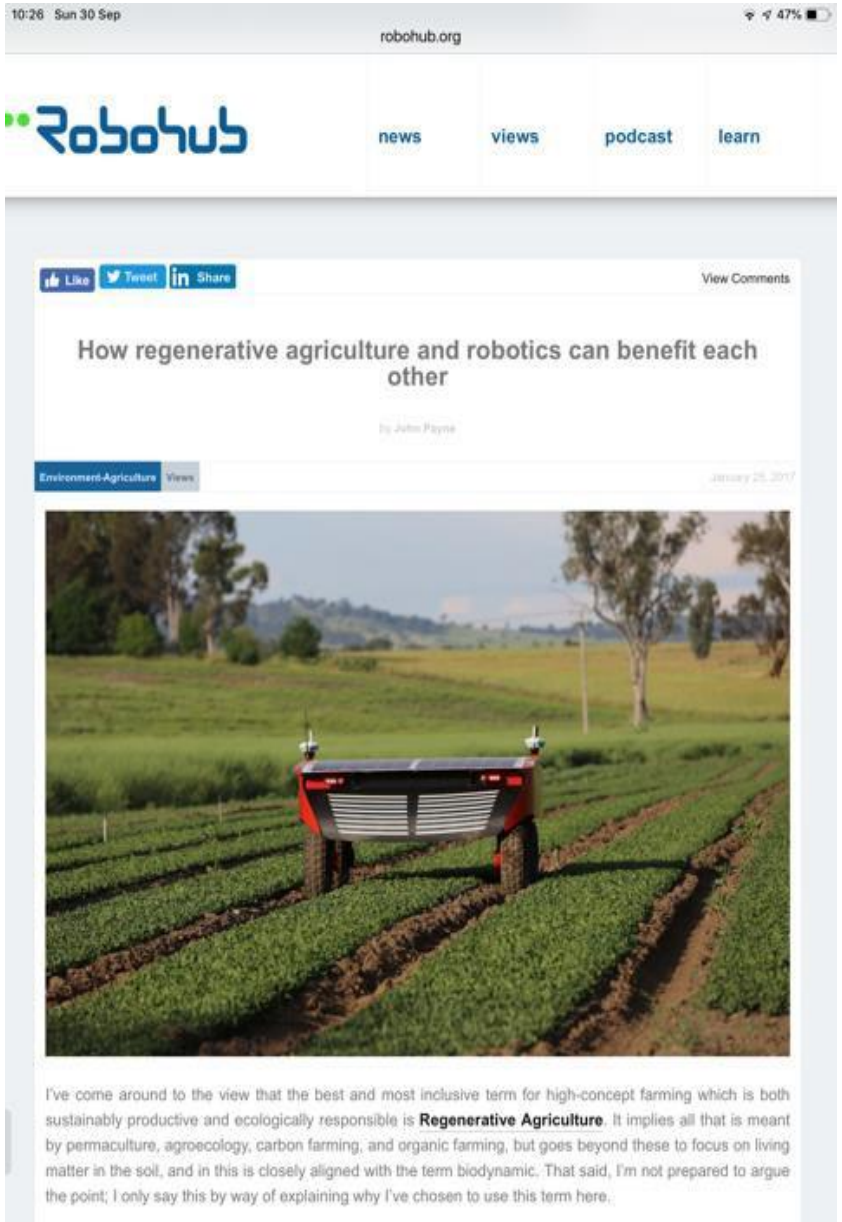
IoT (Internet of Things)

The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.



Robotics and AI to manage complexity





Drought Vulnerability Index

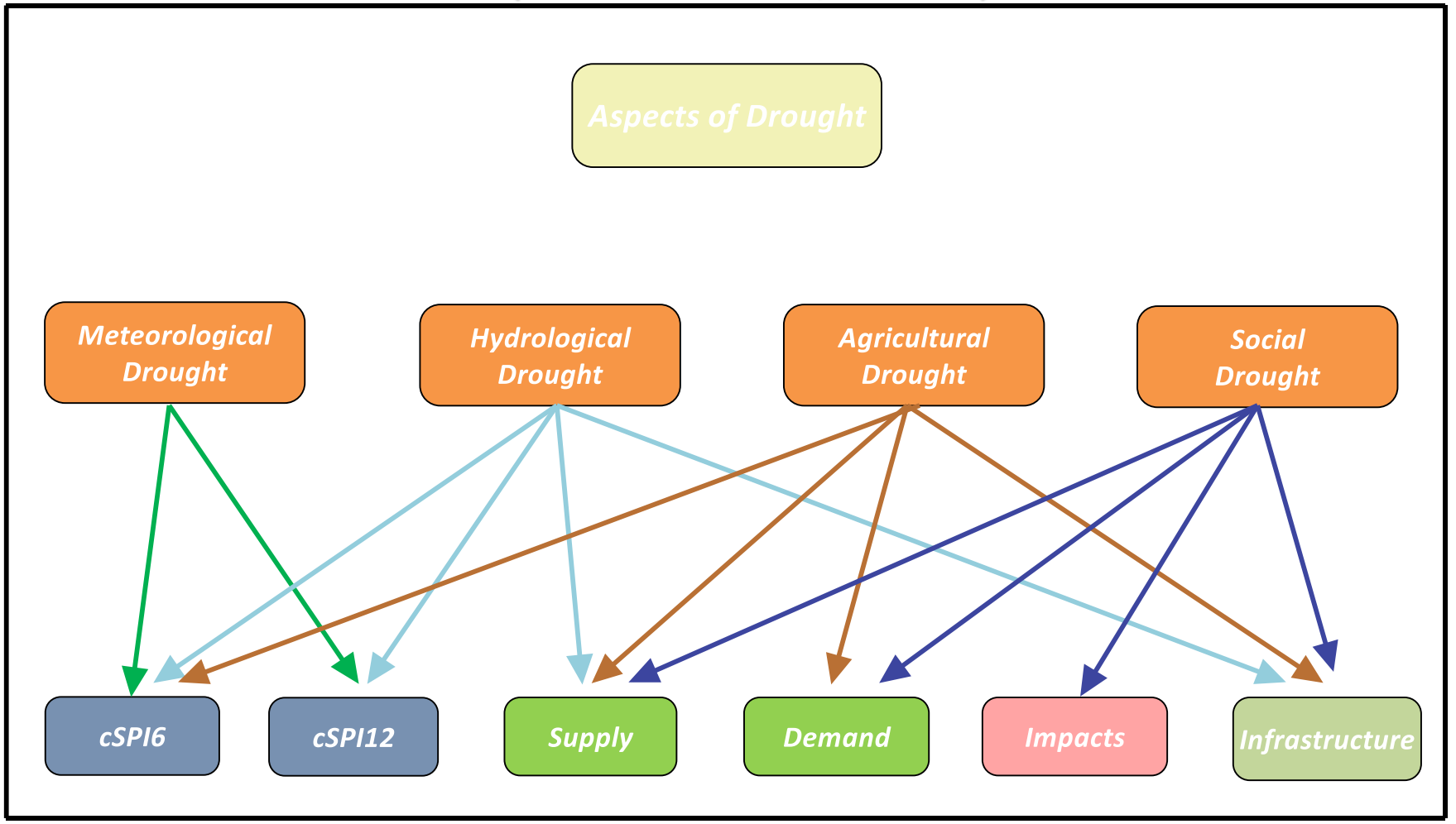
The assessment is based on a synthetic SPI-based Drought Vulnerability Index (SDVI) that was developed by Agricultural University of Athens, in the context of Drought Management Centre in South-eastern Europe (DMCSEE Project , 2011).

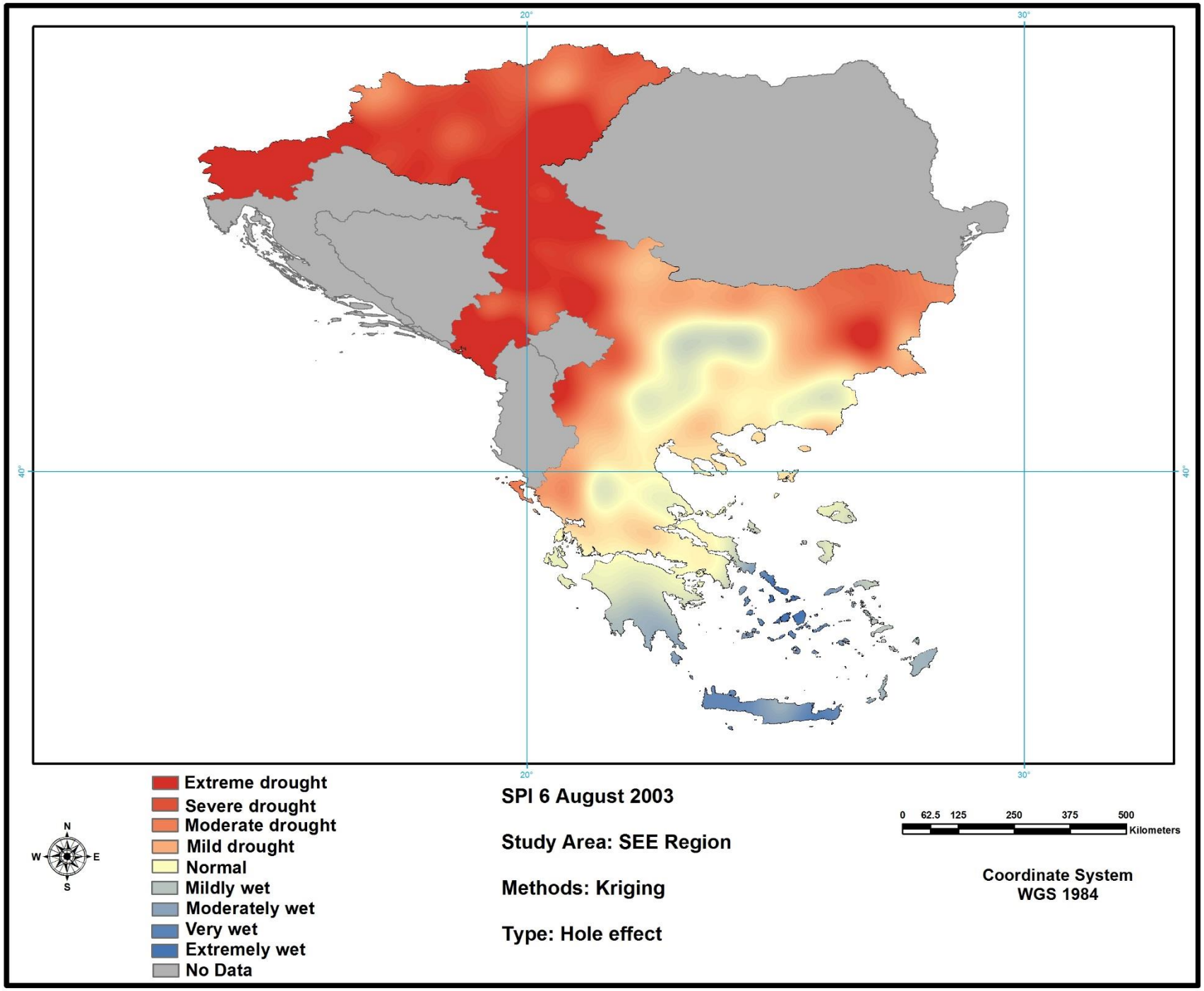
.

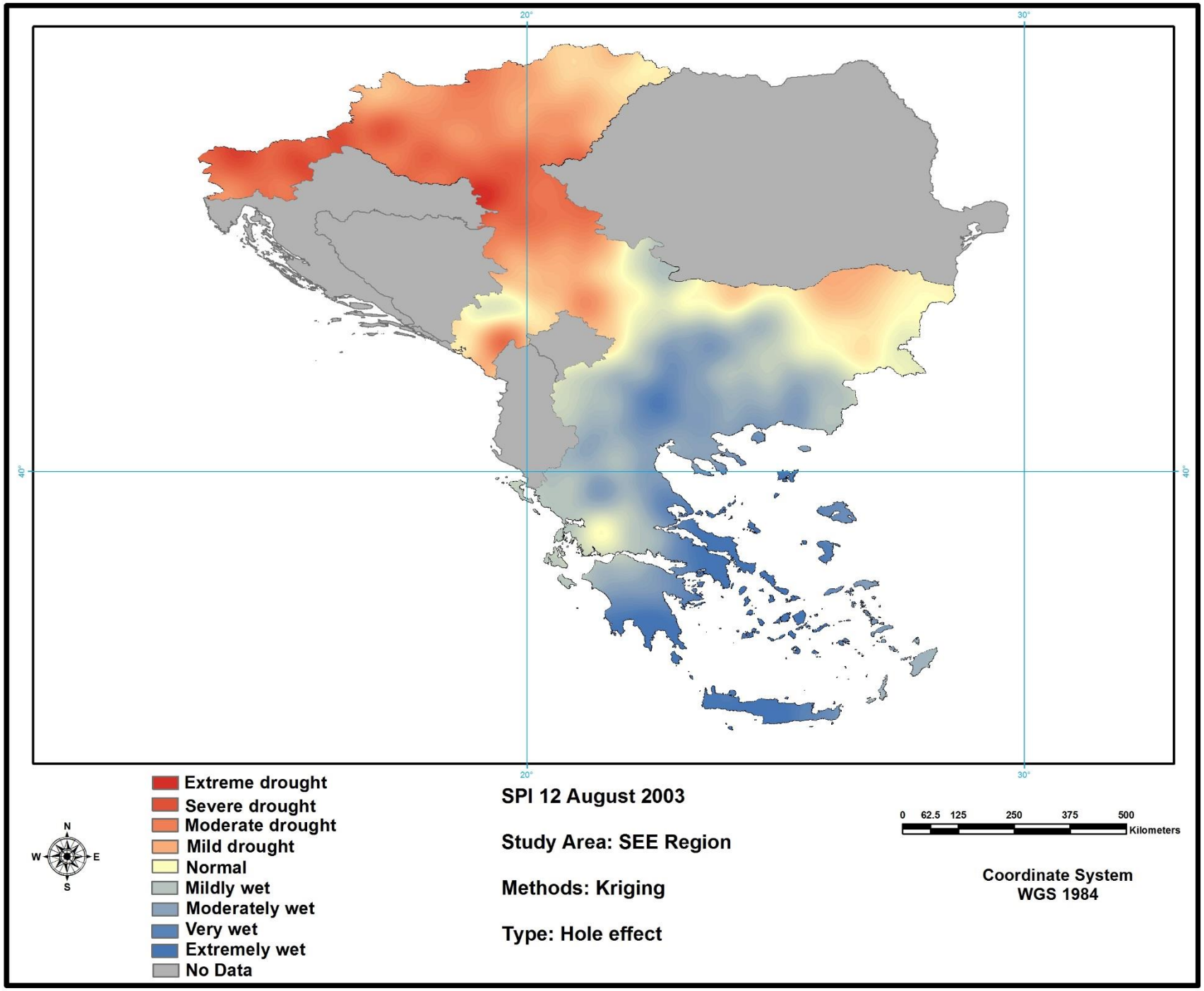
$$SDVI = \sum_{i=1}^{N} \frac{Scaled\ Value\ of\ the\ Components}{N}$$

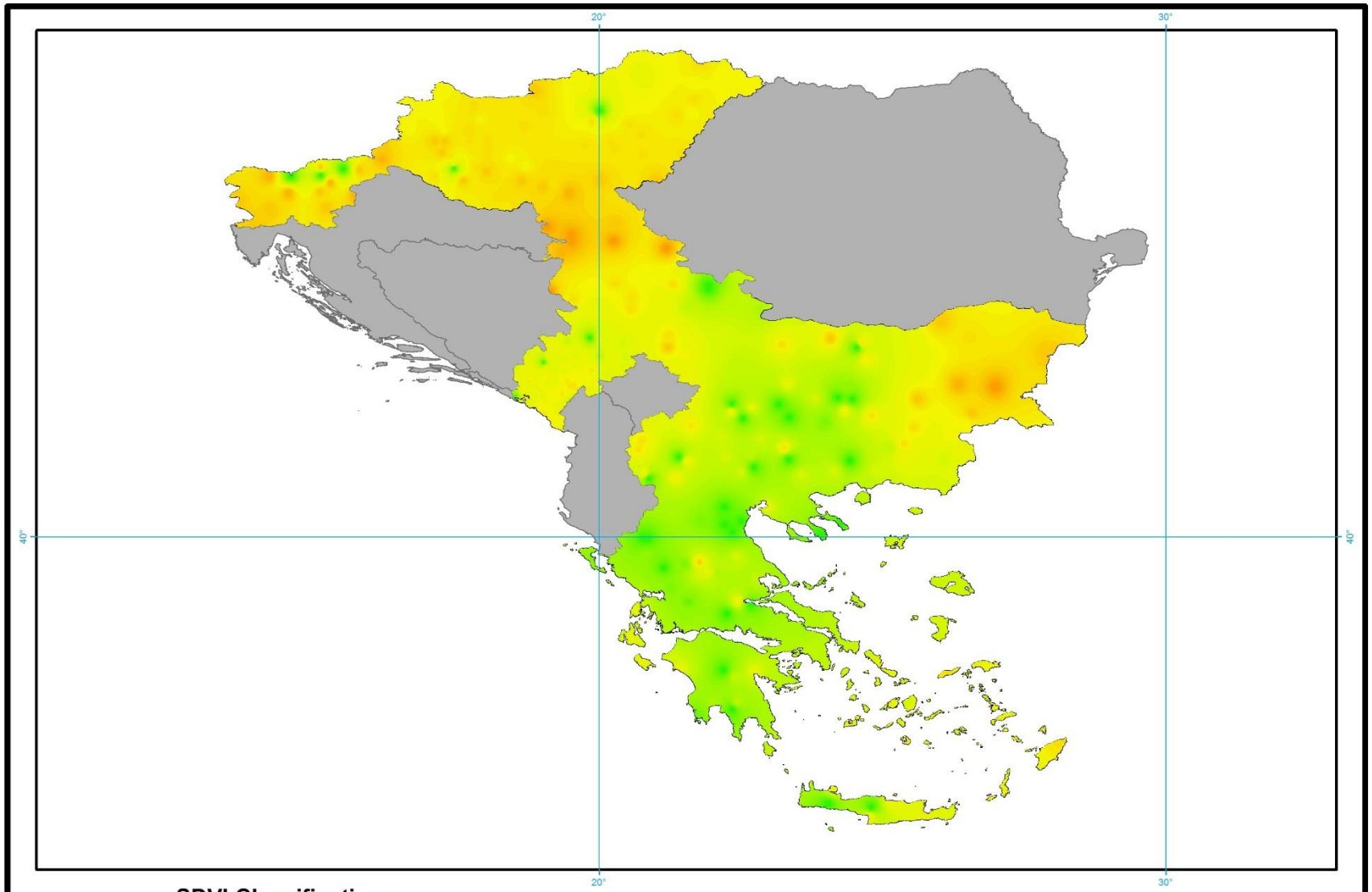
The equation implies that all the components are equally weighted.

Relation between SDVI & drought aspects (DMCSEE, 2011)




20°
30°
40°
Extreme drought
Severe drought
Moderate drought
Mild drought
Normal
Mildly wet
Moderately wet
Very wet
Extremely wet
No Data
N
W
E
S
SPI 6 August 2003
Study Area: SEE Region
Methods: Kriging
Type: Hole effect
0 62.5 125 250 375 500
Kilometers
Coordinate System
WGS 1984


20°
30°
40°
Extreme drought
Severe drought
Moderate drought
Mild drought
Normal
Mildly wet
Moderately wet
Very wet
Extremely wet
No Data
N
W
E
S
SPI 12 August 2003
Study Area: SEE Region
Methods: Kriging
Type: Hole effect
0 62.5 125 250 375 500
Kilometers
Coordinate System
WGS 1984



SDVI Classification

- Non Vulnerable
- Low Vulnerable
- Medium Vulnerable
- High Vulnerable
- Very High Vulnerable
- Extreme Vulnerable
- No Data

N
W
E
S

SDVI August 2003

Study Area: SEE Region

Methods: IDW
Inverse Distance Weighting

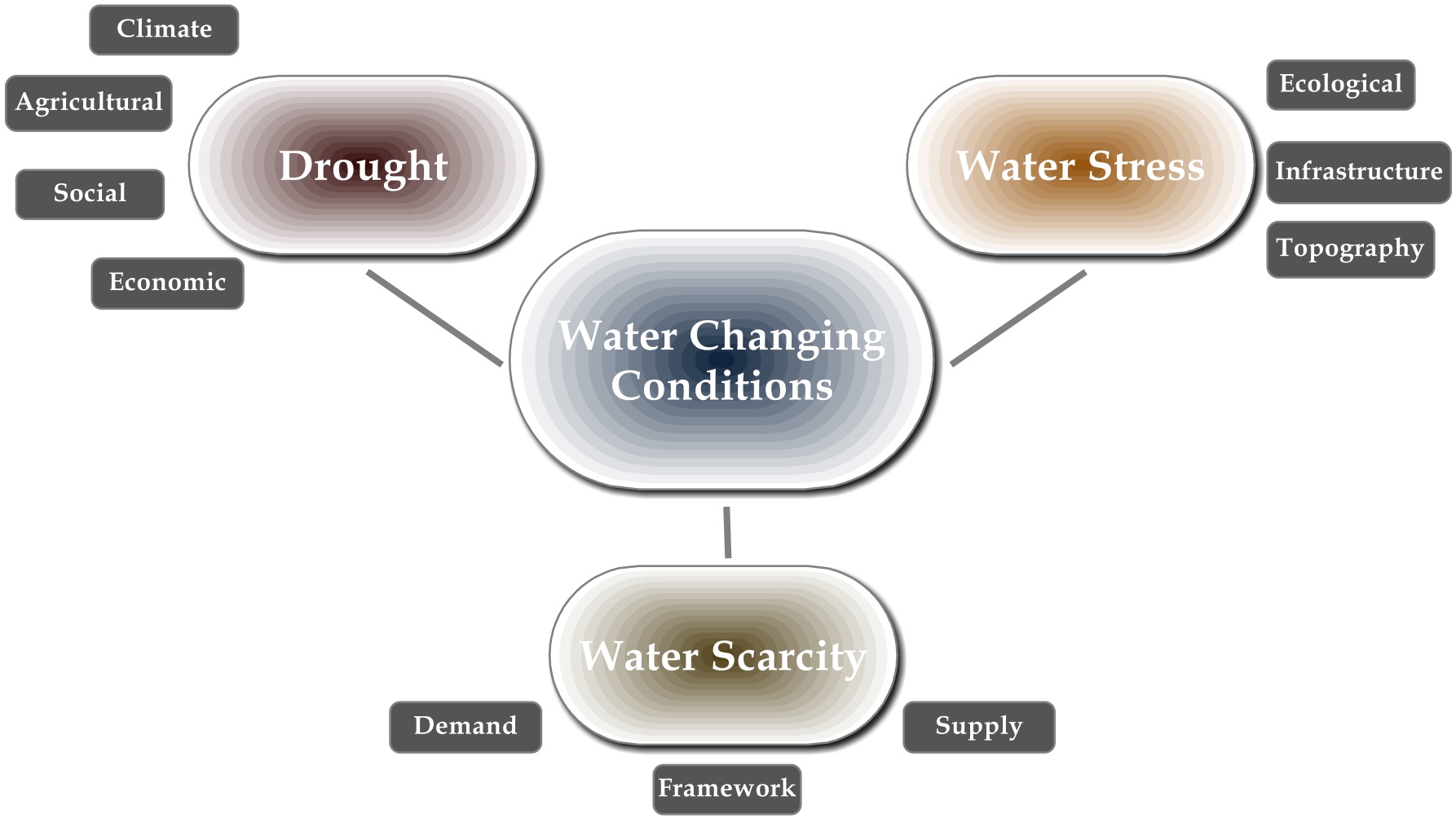
SPI-based Drought Vulnerability Index

0 62.5 125 250 375 500
Kilometers

Coordinate System
WGS 1984


University of Sao Paulo
USP
PROJECT
Coroado
Technologies for Water Recycling and Reuse in Latin American Context
2nd Plenary meeting in São Paulo & Itaipu Dam
May 7th-11th 2012
Assessment Decision Tools and Implementable Strategies under an Uncertain Future
Venue São Paulo Iguaçu Brazil
Project Coordinator: Agricultural University of Athens Greece
http://www.coroado-project.eu
Project Coordinator: AUA
UNC
National University of Cordoba
400 ANOS
November 25th - 29th
PROJECT
Coroado
3rd Plenary meeting Cordoba 2013
Technologies for Water Recycling and Reuse in Latin American Context
Assessment Decision Tools and Implementable Strategies under an Uncertain Future
Venue Cordoba Argentina
http://www.coroado-project.eu

Water Changing Conditions

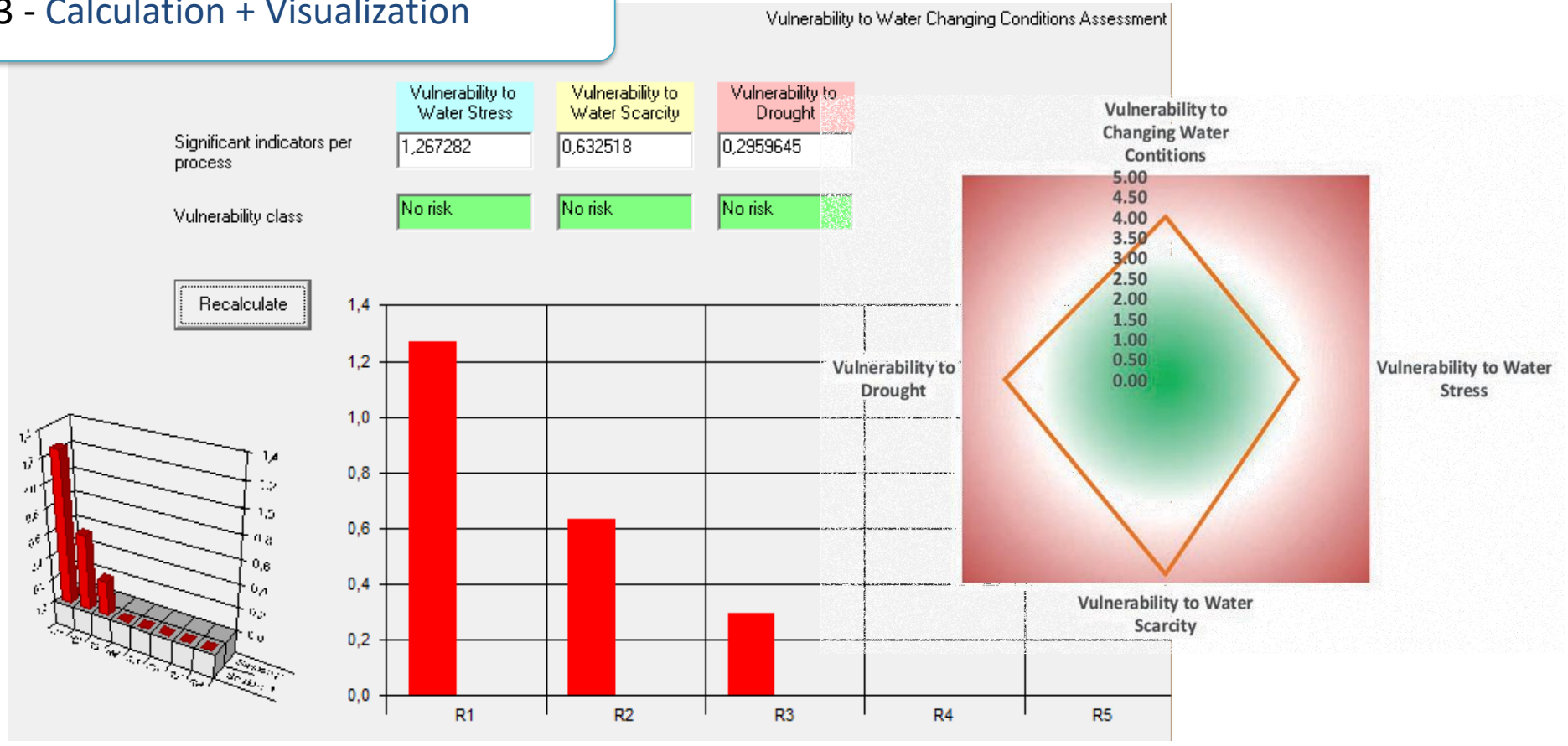


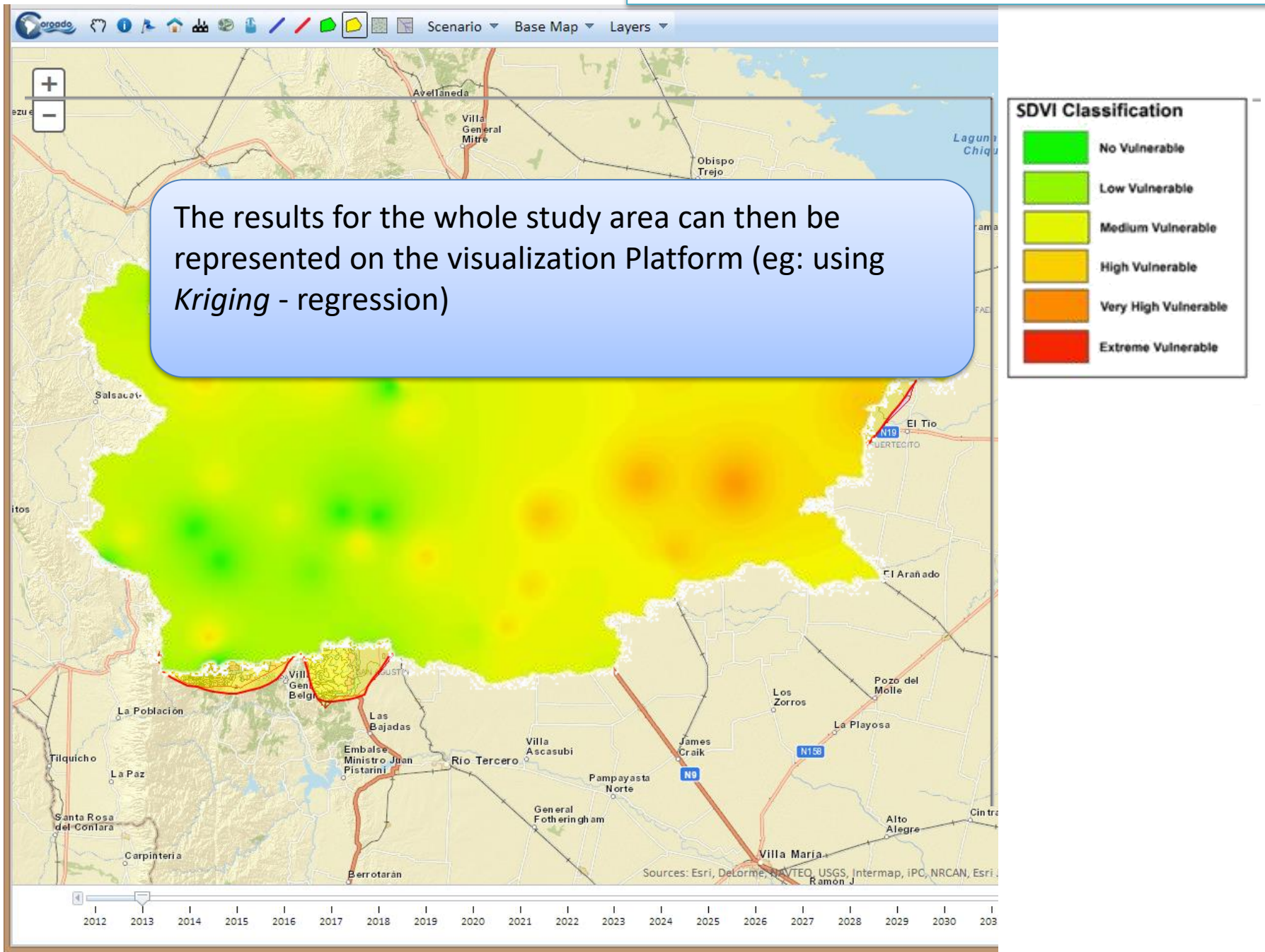
For each point (sub-area), the web tool can automatically calculate:

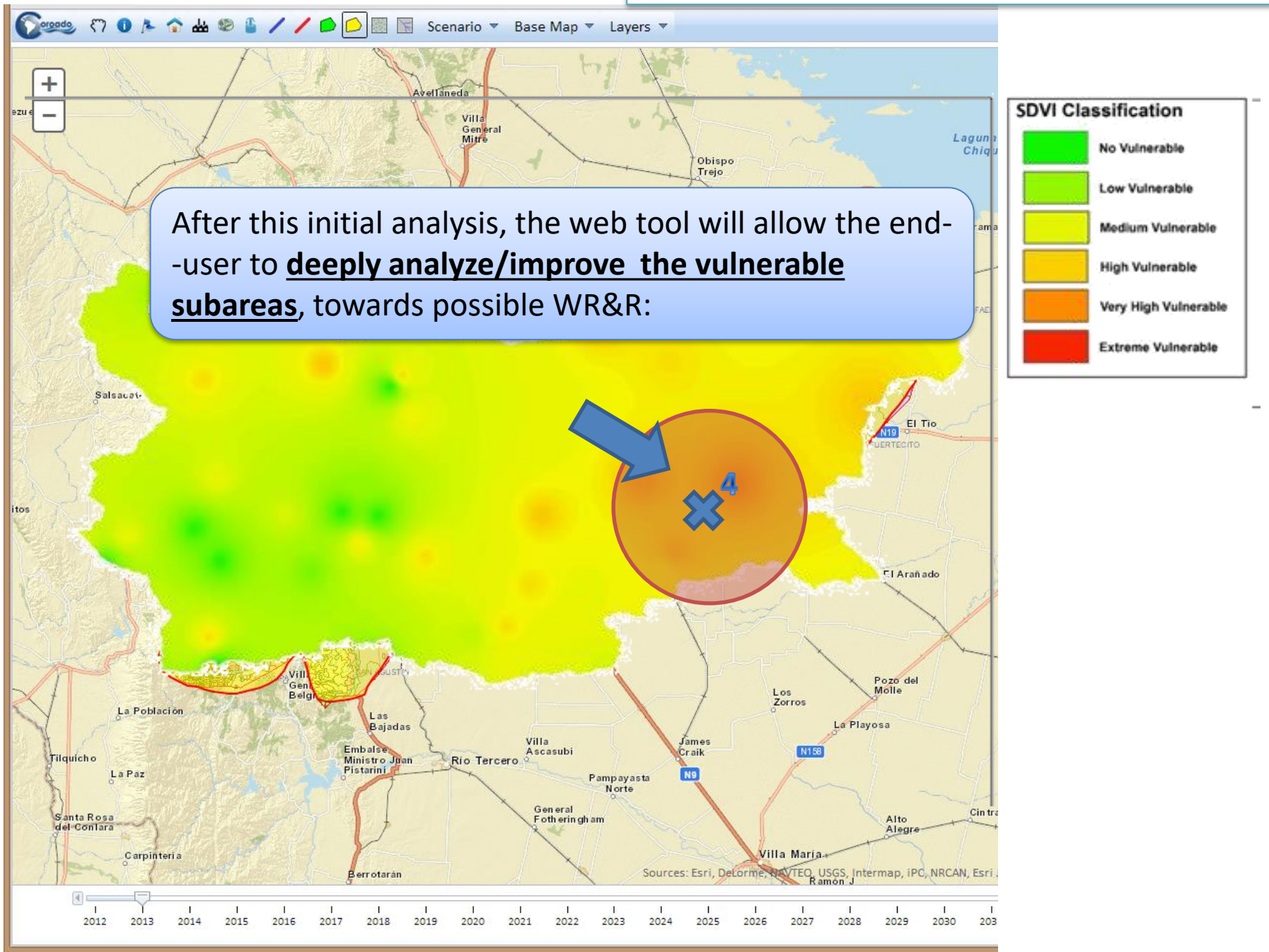
- **Water Stress Vulnerability Index (WStVI)**
- **Water Scarcity Vulnerability Index (WScVI)**
- **Drought Vulnerability Index (DVI)**

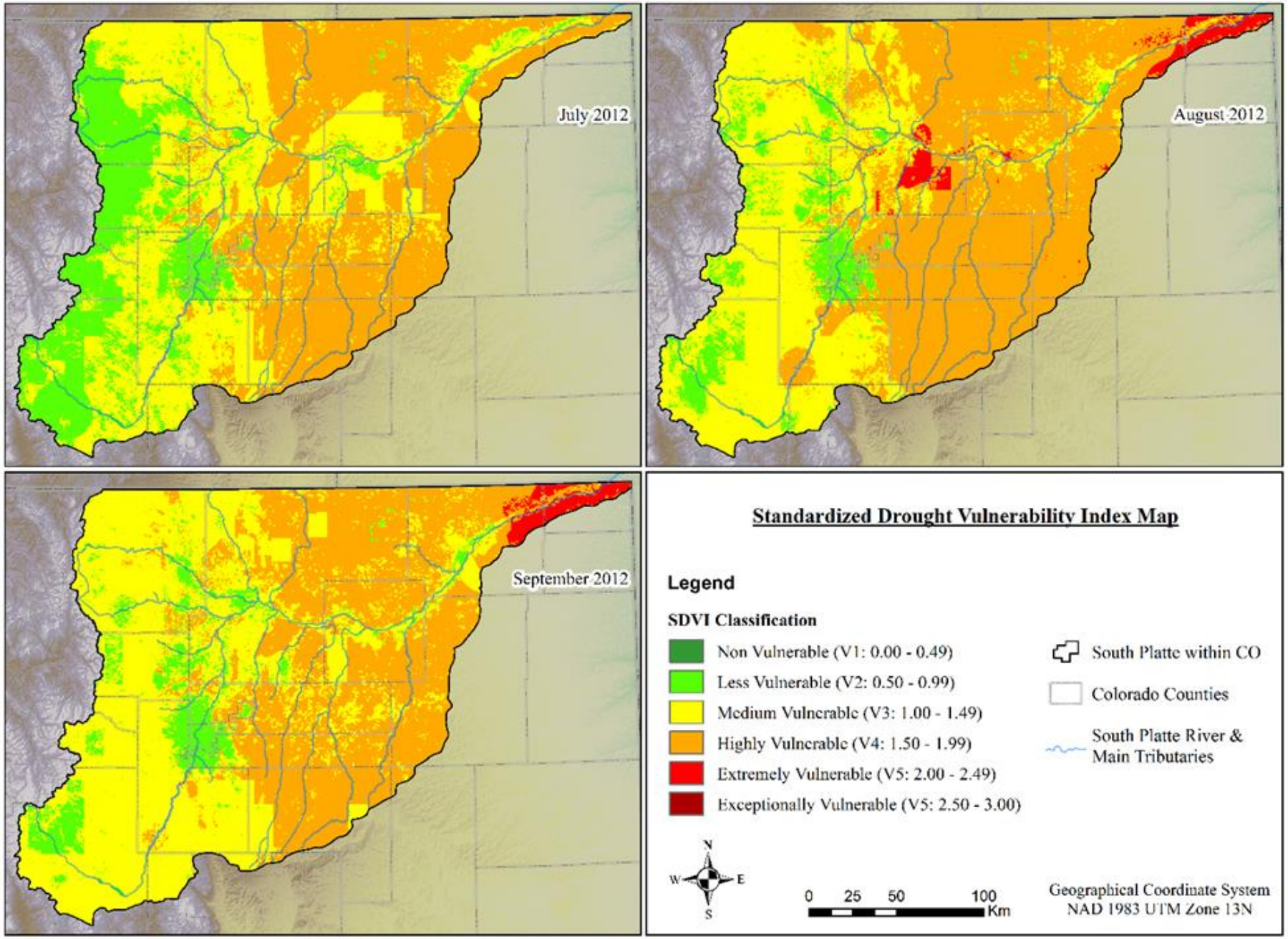
Point	Vulnerability to Water Changing Conditions	Vulnerability to Water Stress	Vulnerability to Water Scarcity	Vulnerability to Drought
Position 1	2.30	2.42	4.15	2.85
Position 2	1.78	2.55	3.78	3.33
Position 3	4.67	4.88	3.98	4.67

1.3 - Calculation + Visualization



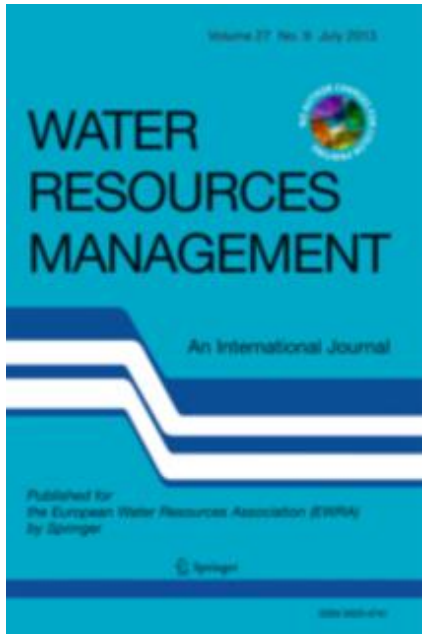

Scenario
Base Map
Layers
The results for the whole study area can then be represented on the visualization Platform (eg: using *Kriging* - regression)
SDVI Classification
No Vulnerable
Low Vulnerable
Medium Vulnerable
High Vulnerable
Very High Vulnerable
Extreme Vulnerable
Avellaneda
Villa General Mitre
Obispo Trejo
Salsacate
El Tio
El Arañado
La Población
Las Bajadas
Villa Ascasubi
Rio Tercero
Embalse Ministro Juan Pistarini
Tilquicho
La Paz
Santa Rosa del Conlara
Carpintería
Berrotarán
Pampayasta Norte
General Fotheringham
James Craik
Los Zorros
Pozo del Molle
La Playosa
Alto Alegre
Villa Maria
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030


Scenario
Base Map
Layers
After this initial analysis, the web tool will allow the end--user to deeply analyze/improve the vulnerable subareas, towards possible WR&R:
SDVI Classification
No Vulnerable
Low Vulnerable
Medium Vulnerable
High Vulnerable
Very High Vulnerable
Extreme Vulnerable
Avellaneda
Villa General Mitre
Obispo Trejo
Salsacate
El Tio
El Arañado
La Población
Las Bajadas
Embalse Ministro Juan Pistarini
Río Tercero
Villa Ascasubi
Pampayasta Norte
General Fotheringham
James Craik
Los Zorros
Pozo del Molle
La Playosa
Alto Alegre
Villa María
Tilquicho
La Paz
Santa Rosa del Conlara
Carpintería
Berrotarán
N19
N9
N158
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030



South Platte, Colorado, USA, Oikonomou, P.D., Tsesmelis, D.E., Waskom, R.M., Grigg, N.S., Karavitis, C.A. (2019),

Drought characteristics assessment in Europe over the past 50 years



Water Resources Management
https://doi.org/10.1007/s11269-020-02688-0

Check for updates

Drought Characteristics Assessment in Europe over the Past 50 Years

Panagiotis D. Oikonomou[1,2] · Christos A. Karavitis[3] · Demetrios E. Tsesmelis[3] · Elpida Kolokytha[4] · Rodrigo Maia[5]

Received: 9 March 2020 / Accepted: 30 September 2020/Published online: 06 October 2020

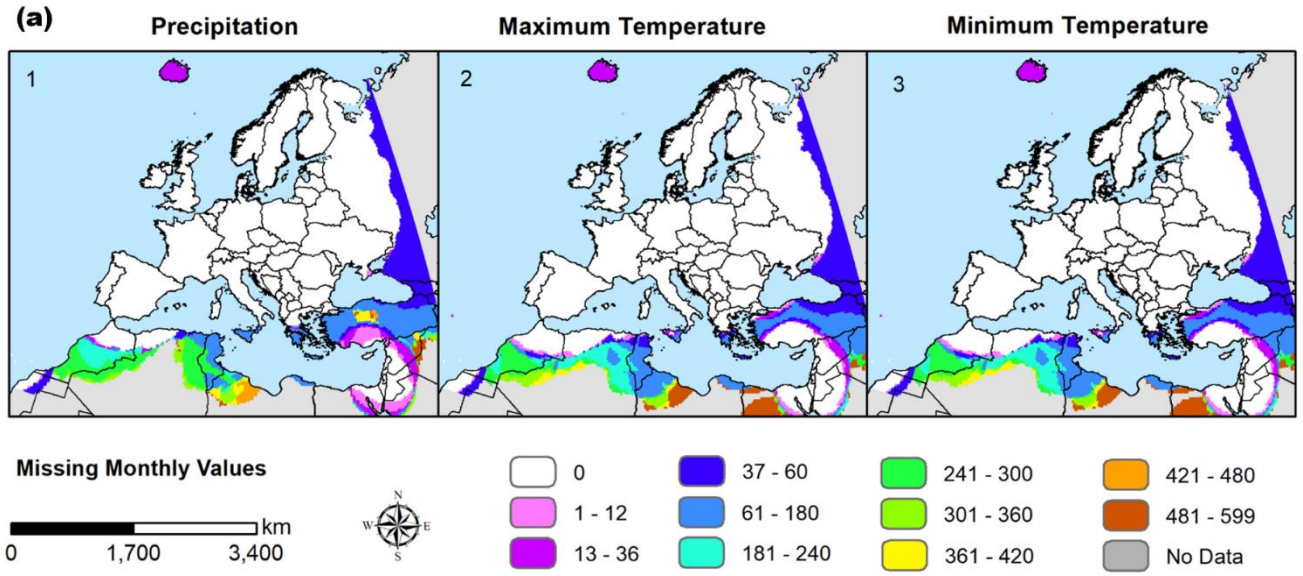
Drought in Europe over the past 50 years

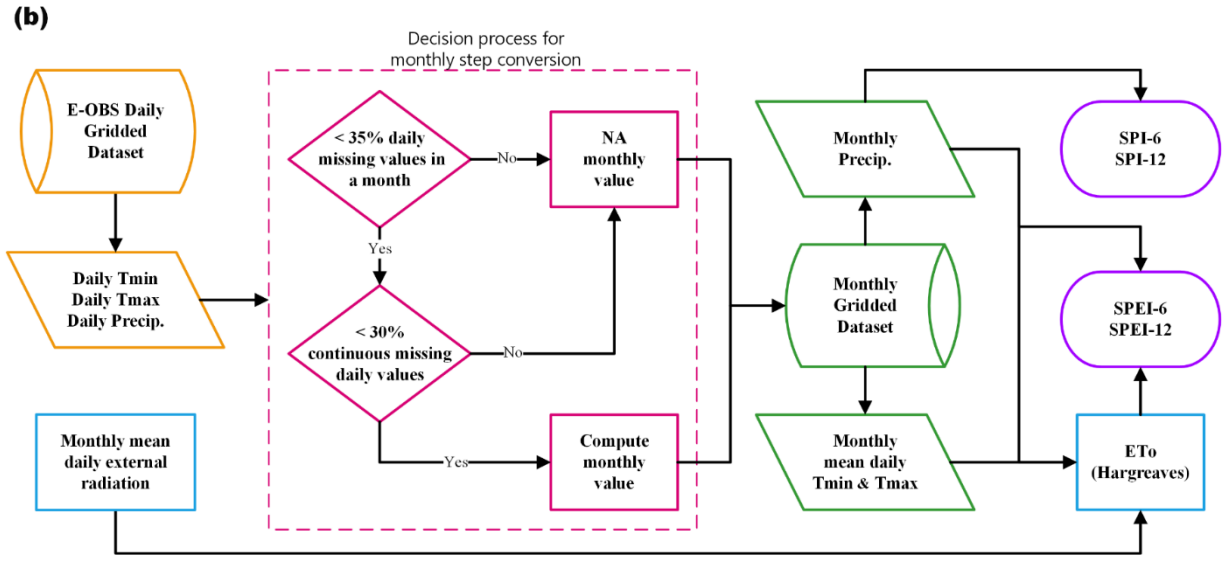
Scope

- Assess and visualize drought frequency, duration, and severity in Europe over the last 50 years (1969-2018) using SPI and SPEI for the 6 and 12-month scales
- Distinctly portray this representation on a 5-year time step, hence visualizing droughts in detail with ten quinquennia.
- Assess results against the already described droughts in the literature over the last half-century, an approach not performed in a Pan European scale

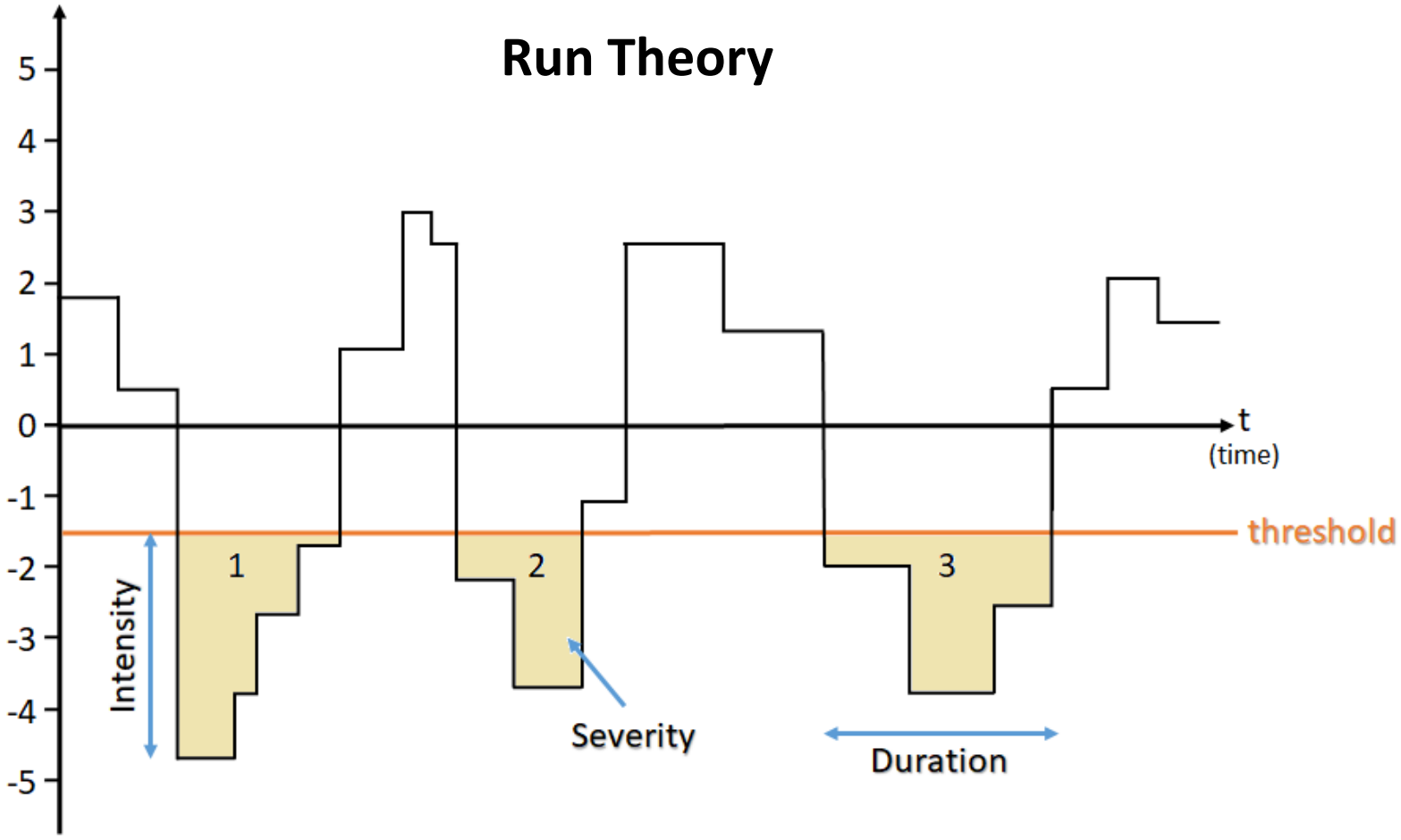
Drought in Europe over the past 50 years

- Daily E-OBS gridded dataset covers the area of 25 N–71.5 N × 25 W–45 E in a 0.25-degree regular latitude-longitude grid resolution
- E-OBS daily gridded dataset is considered as the best





Drought in Europe over the past 50 years

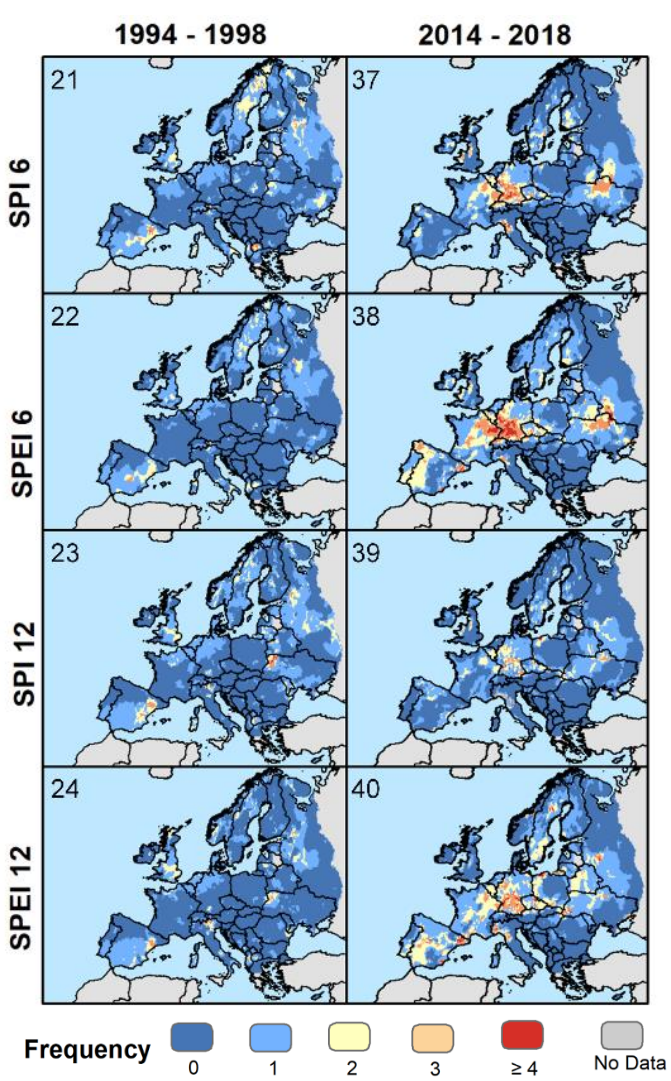


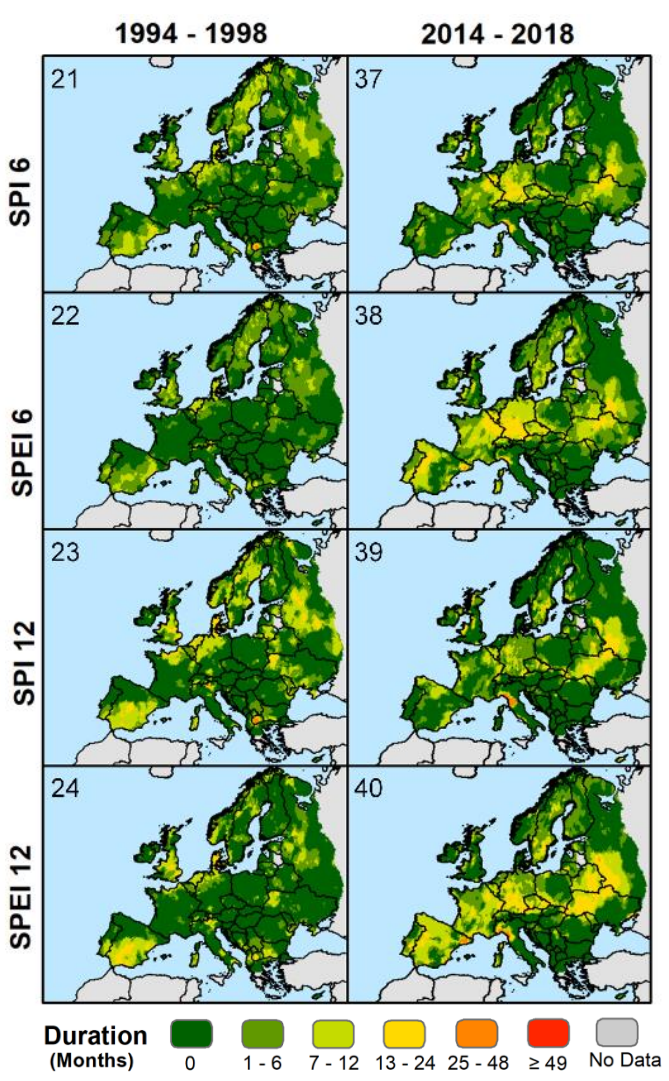
<u>Reference Drought</u>

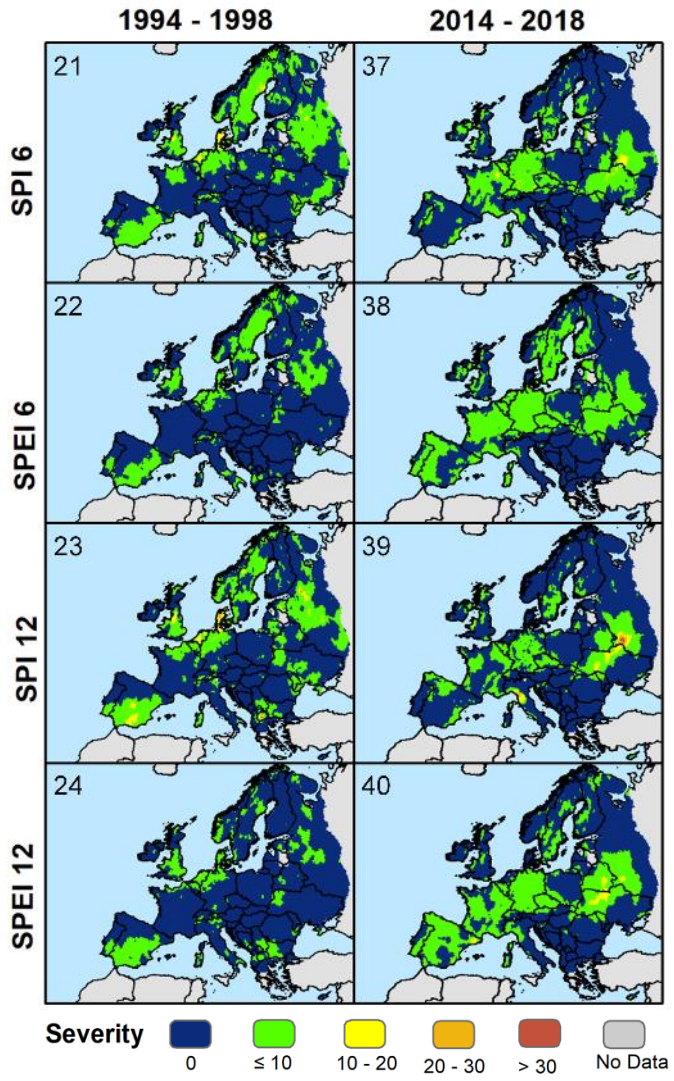
- Index < -1.5
- > 3 months

Investigating major drought events

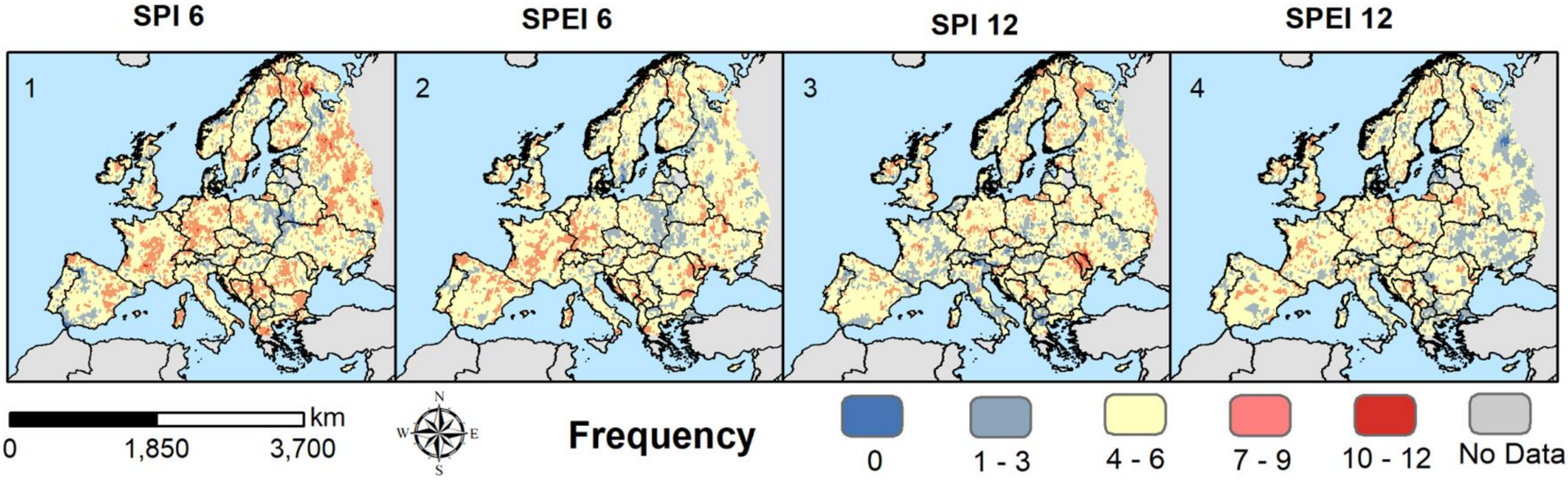
Drought in Europe over the past 50 years







Drought frequency for the 50 year period from 1969-2018



No particular tendencies for more or less frequent droughts in the two major geographical domains (north/south) of Europe are present

SMART DROUGHT MANAGEMENT: GOING INTO THE INTERNET OF THINGS ERA

THE TRANSFORMING ENVIRONMENT

TRENDS AND DEVELOPMENTS

PREPARING THE SYSTEM OF THE 21ST CENTURY

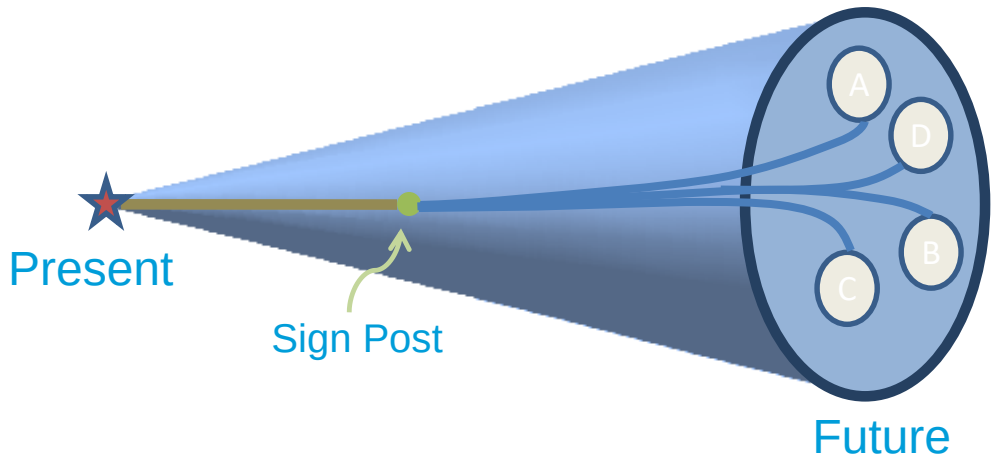
SHIFTING PARADIGMS IN THEORY & PRACTICE

SPECULATING ABOUT THE FUTURE

Nevertheless, the major challenge for any drought related research may be the development of comprehensive and effective drought management and decision making schemes. In such quests, forecasting may provide some help…

Scenario Planning

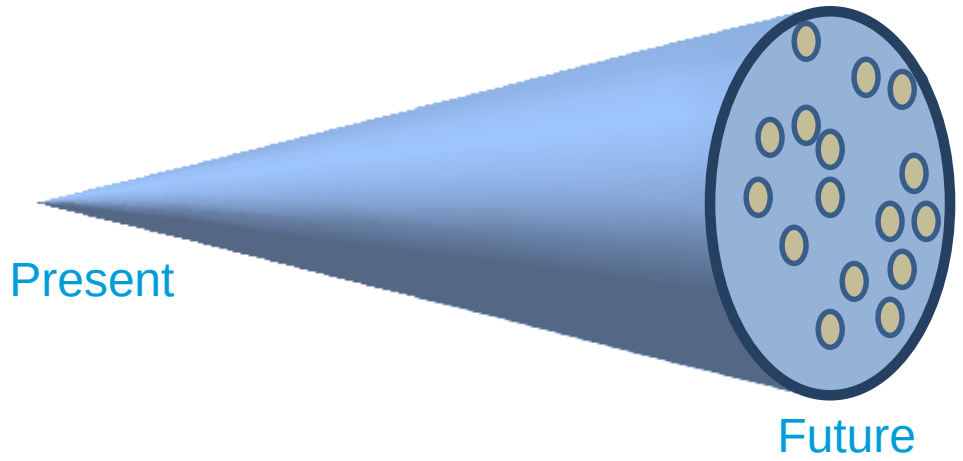
- Small number of equally likely scenarios [A, B, C, D]
- Common strategies (no regrets)
- Sign posts



Adapted from Malcolm Pirnie,2009

Robust Decision Making

- CIS analysis of many plausible likely scenarios
- Iteration and hedging



Adapted from Malcolm Pirnie,2009

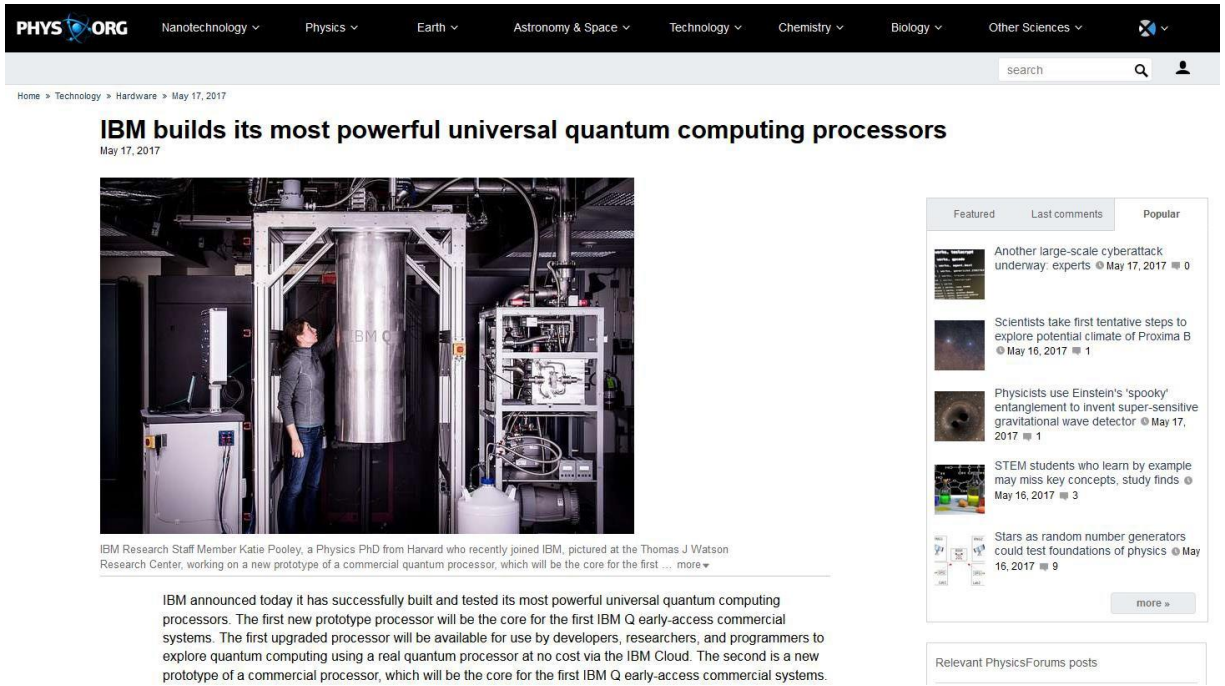
IBM Q

press anouncement on 6th of March 2017:

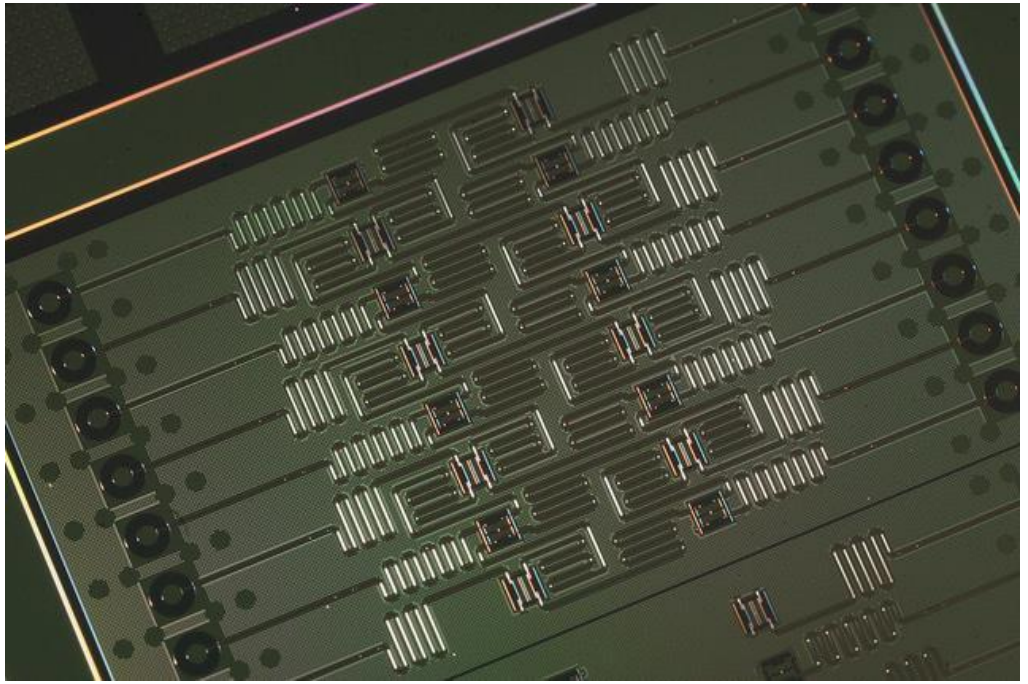
„The First Universal Quantum Computers for Business and Science”

press anouncement on 17th of May 2017:

16- and 17-qubit processors



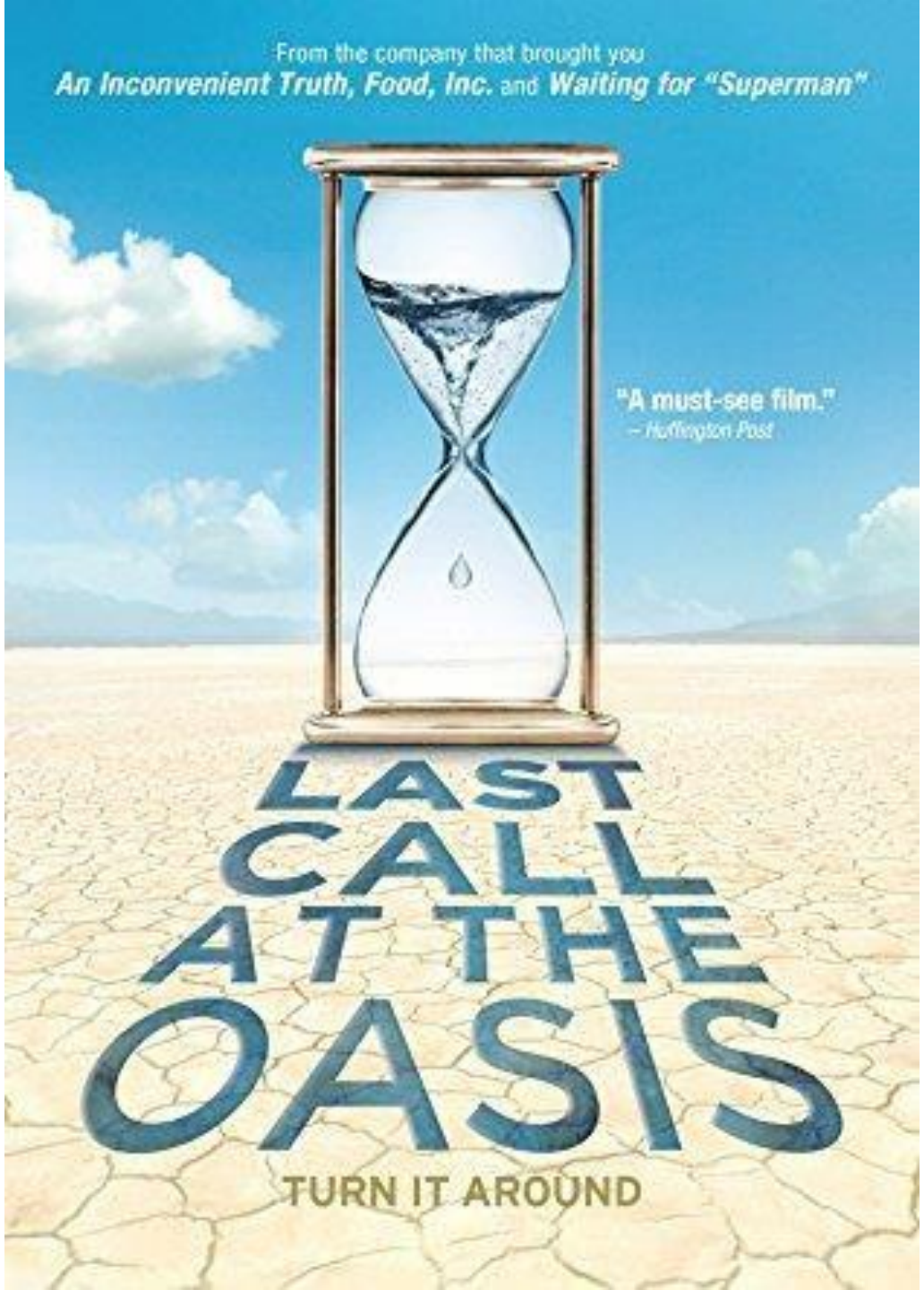
IBM 16-qubit processor



IBM aims at constructing commercial IBM Q systems with **~50 qubits in the next few years** to demonstrate capabilities beyond today’s classical systems

➡ **quantum advantage**

THANK YOU


From the company that brought you
An Inconvenient Truth, Food, Inc. and Waiting for "Superman"
"A must-see film."
– Huffington Post
LAST CALL AT THE OASIS
TURN IT AROUND

To be continued …

I’ll be back…