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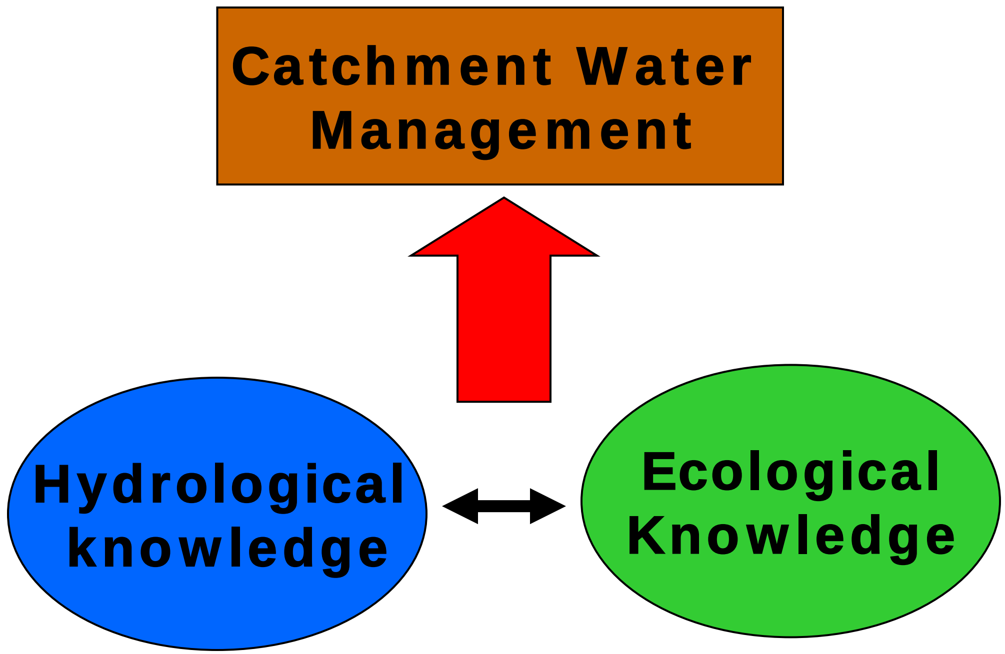
Chapter six

Future Trends in Hydrology

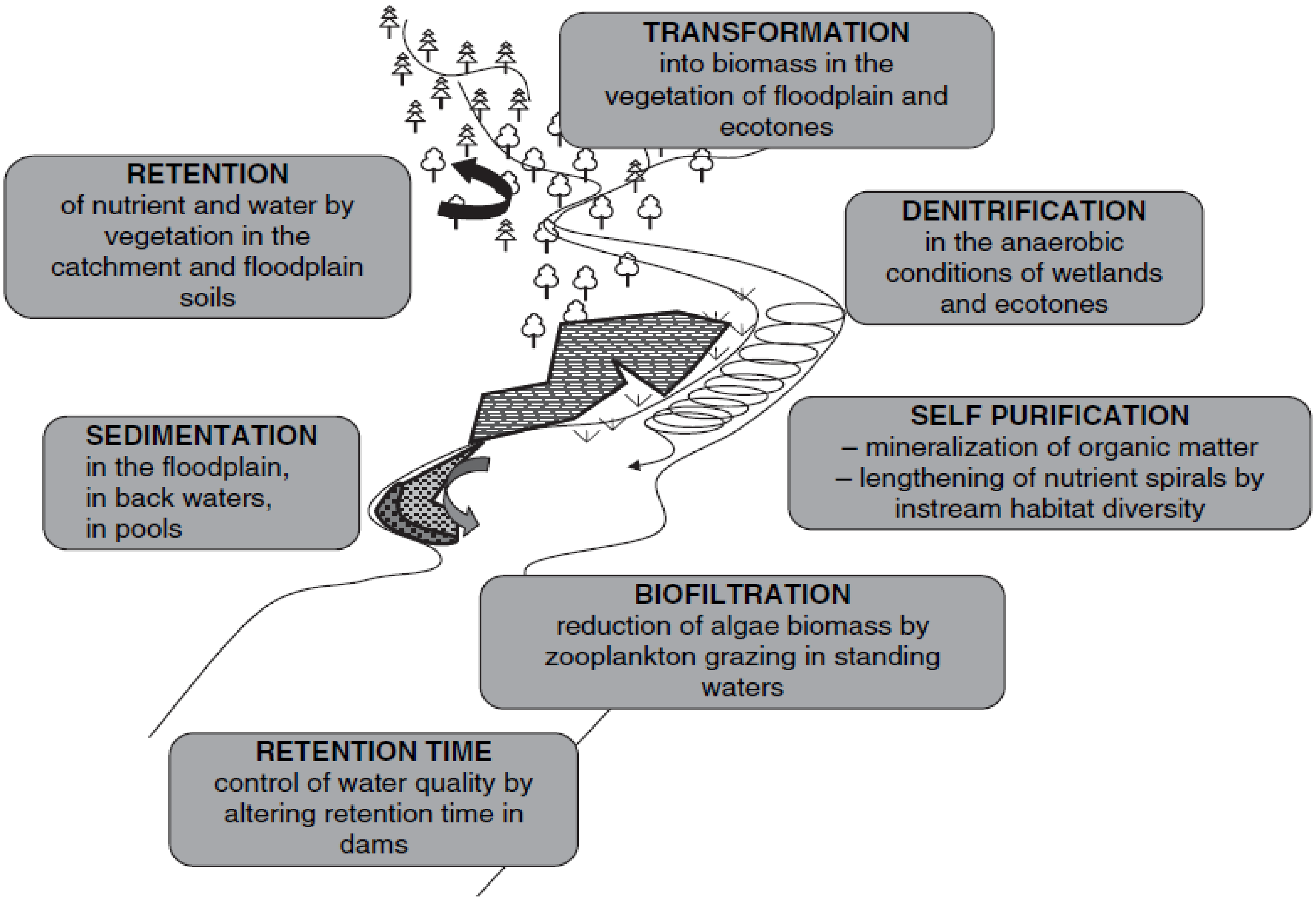
- Environmental Hydrology, Eco-hydrology, and Global Climate Change
- Radar and Remote sensing Hydrology
- Isotope Hydrology
- Hydrological Information System

Ecohydrology

- Ecohydrology is a sub-discipline shared by ecological and hydrological sciences that is concerned with the effects of hydrological processes on the distribution, structure and function of ecosystems, and on the effect of biological processes on the elements of the water cycle. It quantifies and explains the relationships between hydrological processes and biotic dynamics at a catchment scale.



Ecohydrological Processes



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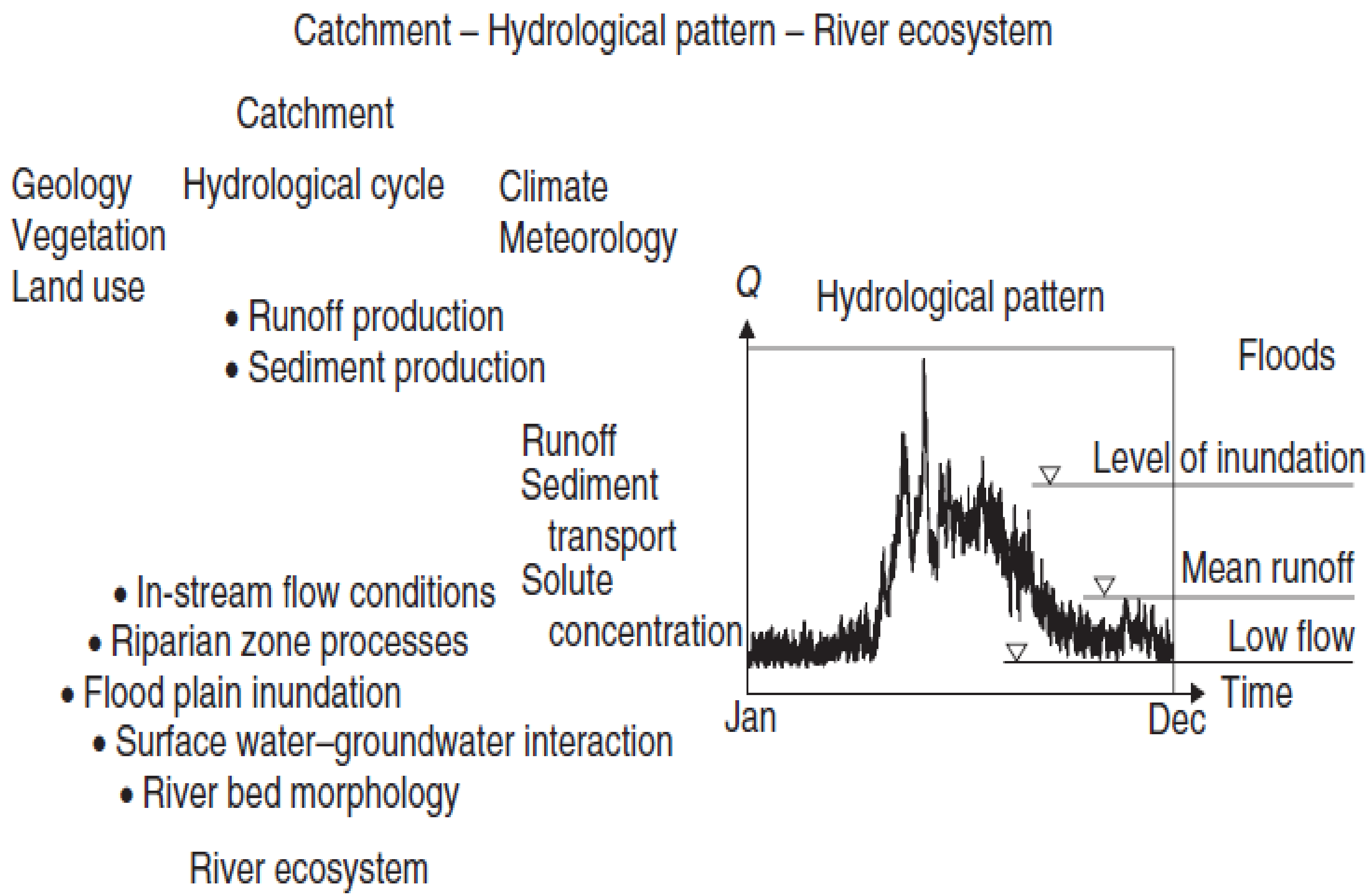
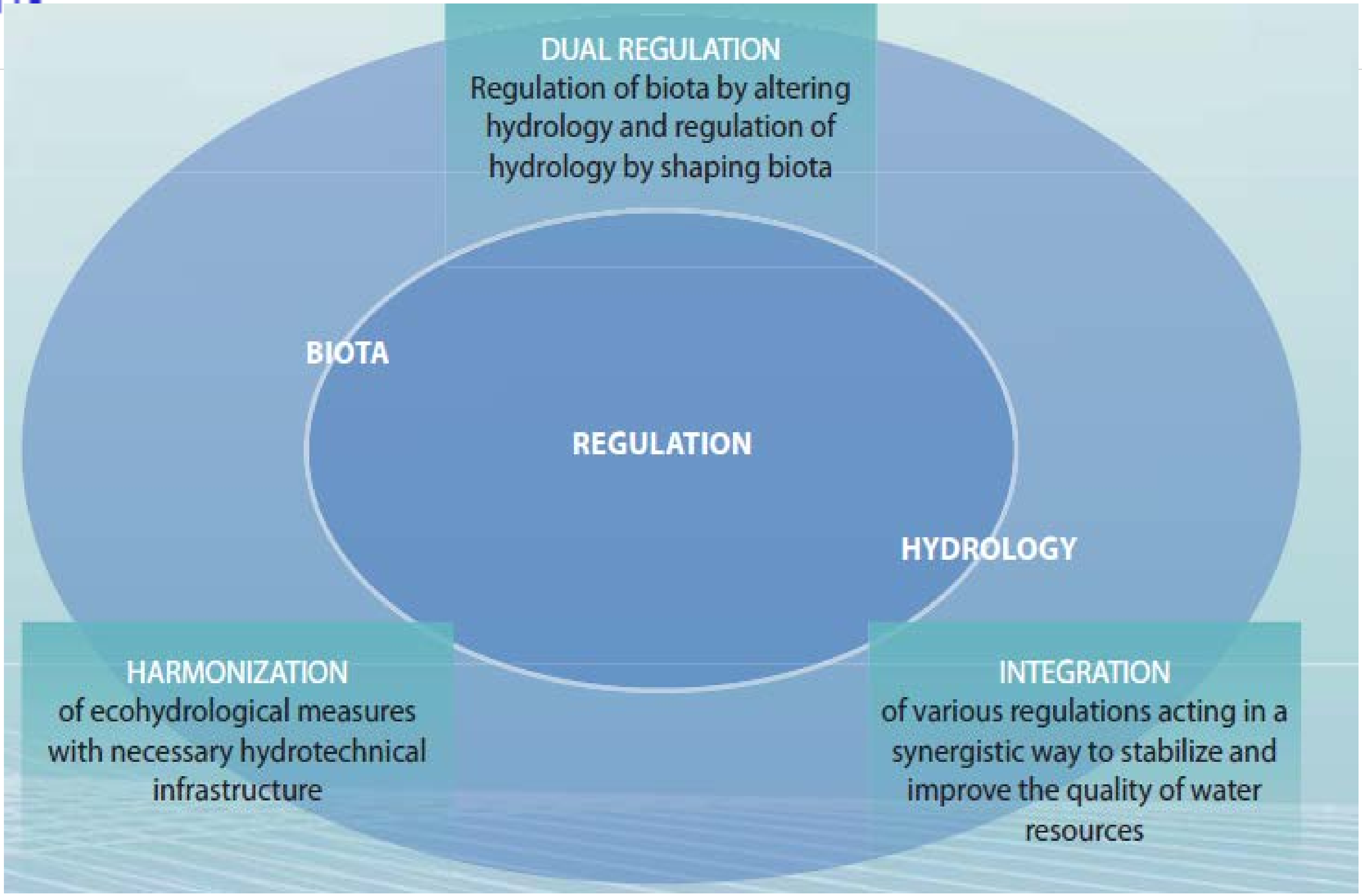
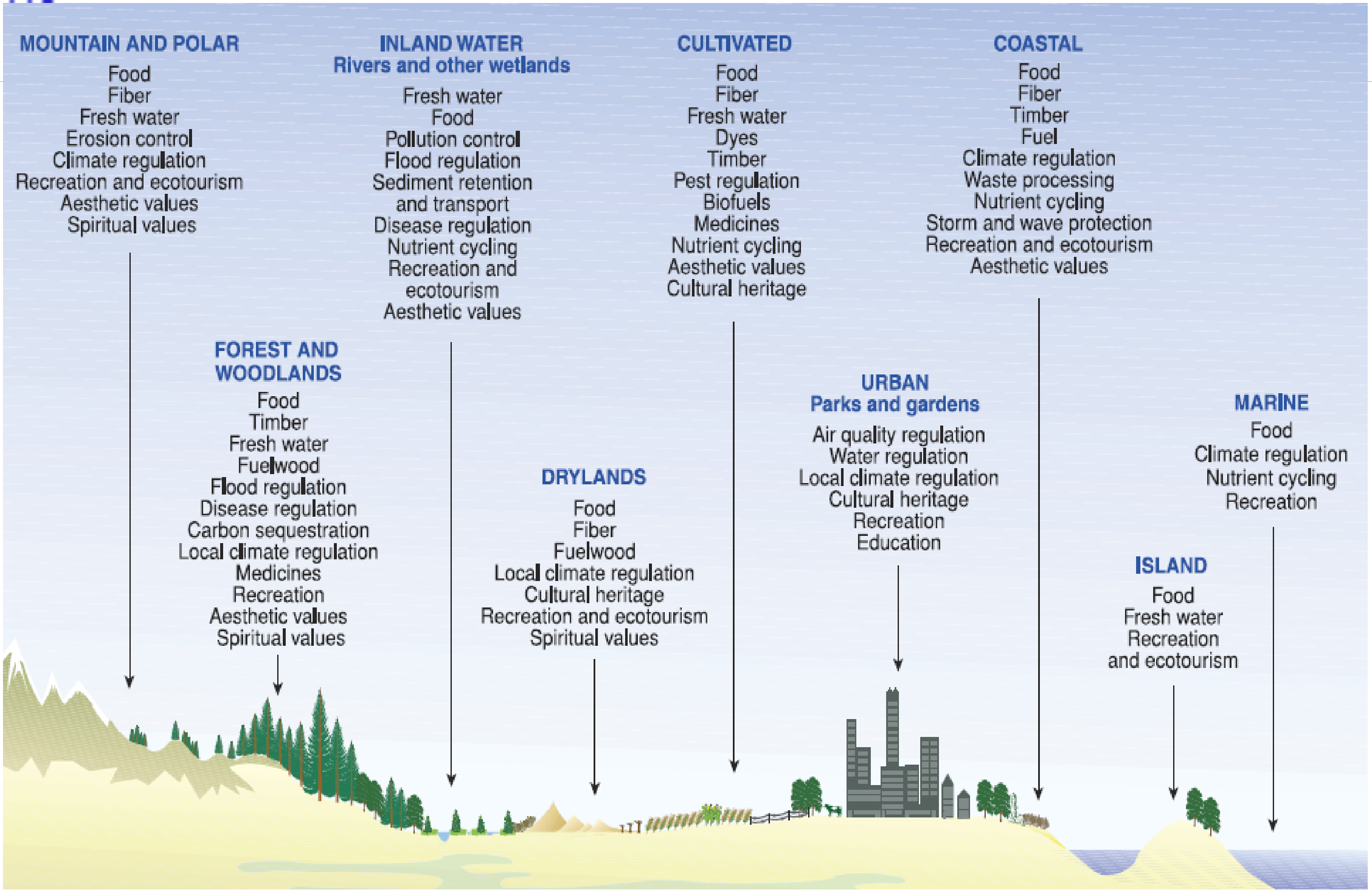
Ecohydrological Processes



Key Principles of Ecohydrology



Ecosystems and their Services



Water Resources-Ecosystem Services-Society

Increasing amount of scientific input

Beneficiaries
(e.g. communities, irrigators, fishers, tourists, etc.)

Benefits
(e.g. clean water, water for industry, protection from hazards, etc)

Ecosystem Services
(e.g. water purification services, flood mitigation, erosion control,)

Processes (Water regime + Ecosystem)
(e.g. water & nutrient cycling, ecological interaction, etc.)

Adapted from Plant et al, 2012

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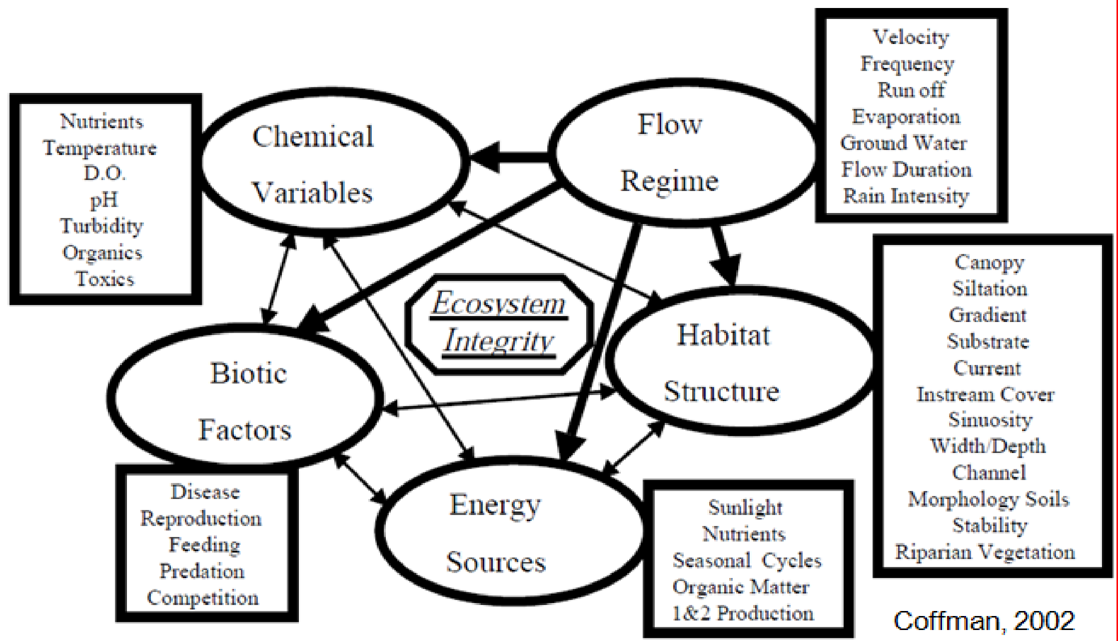
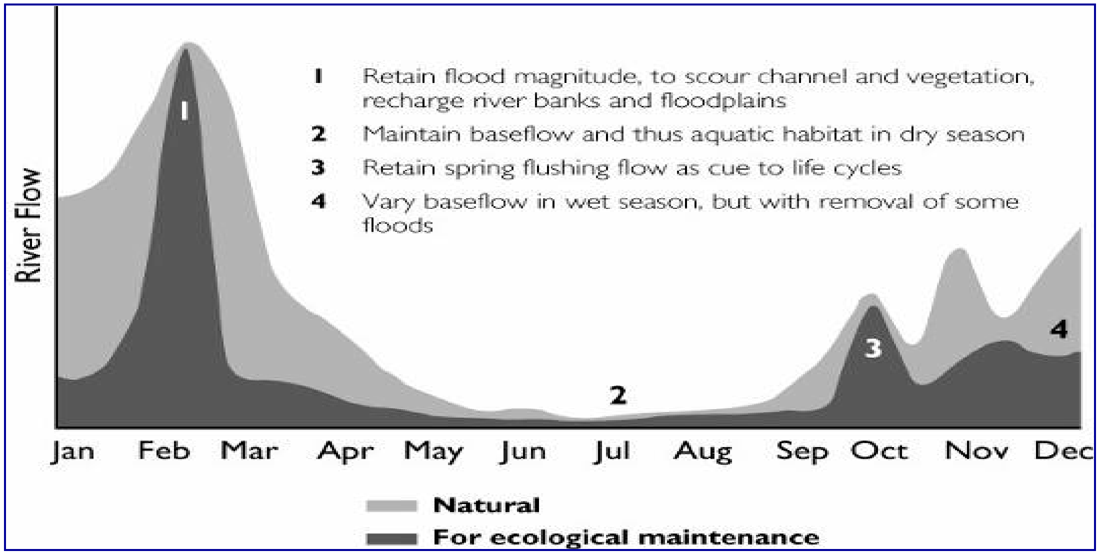
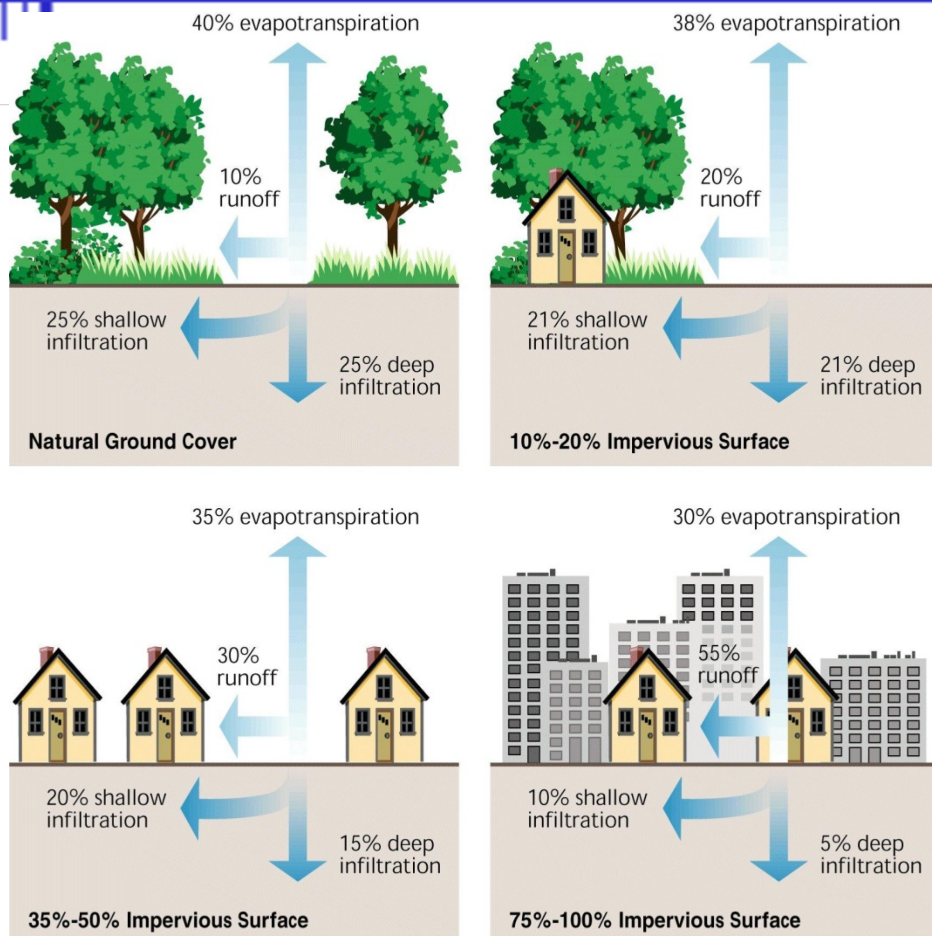
Flow Regime - Ecological Integrity

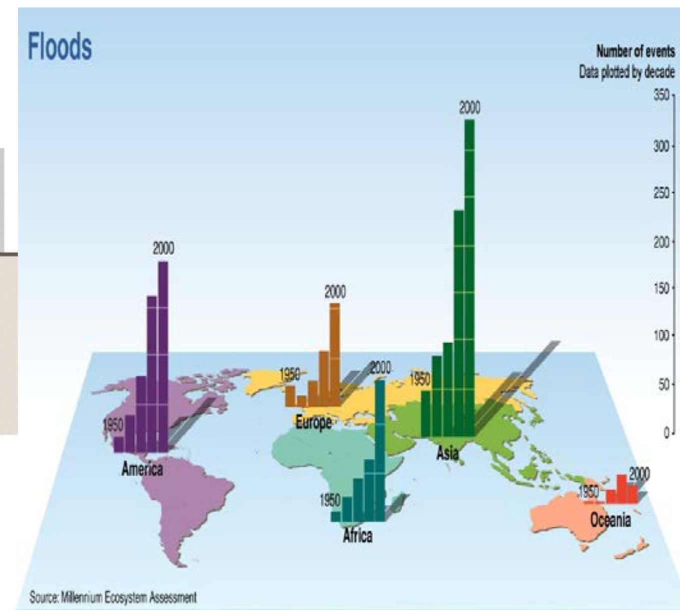


Coffman, 2002



Flood Hazard-Ecosystem Degradation





Environmental Hydrology

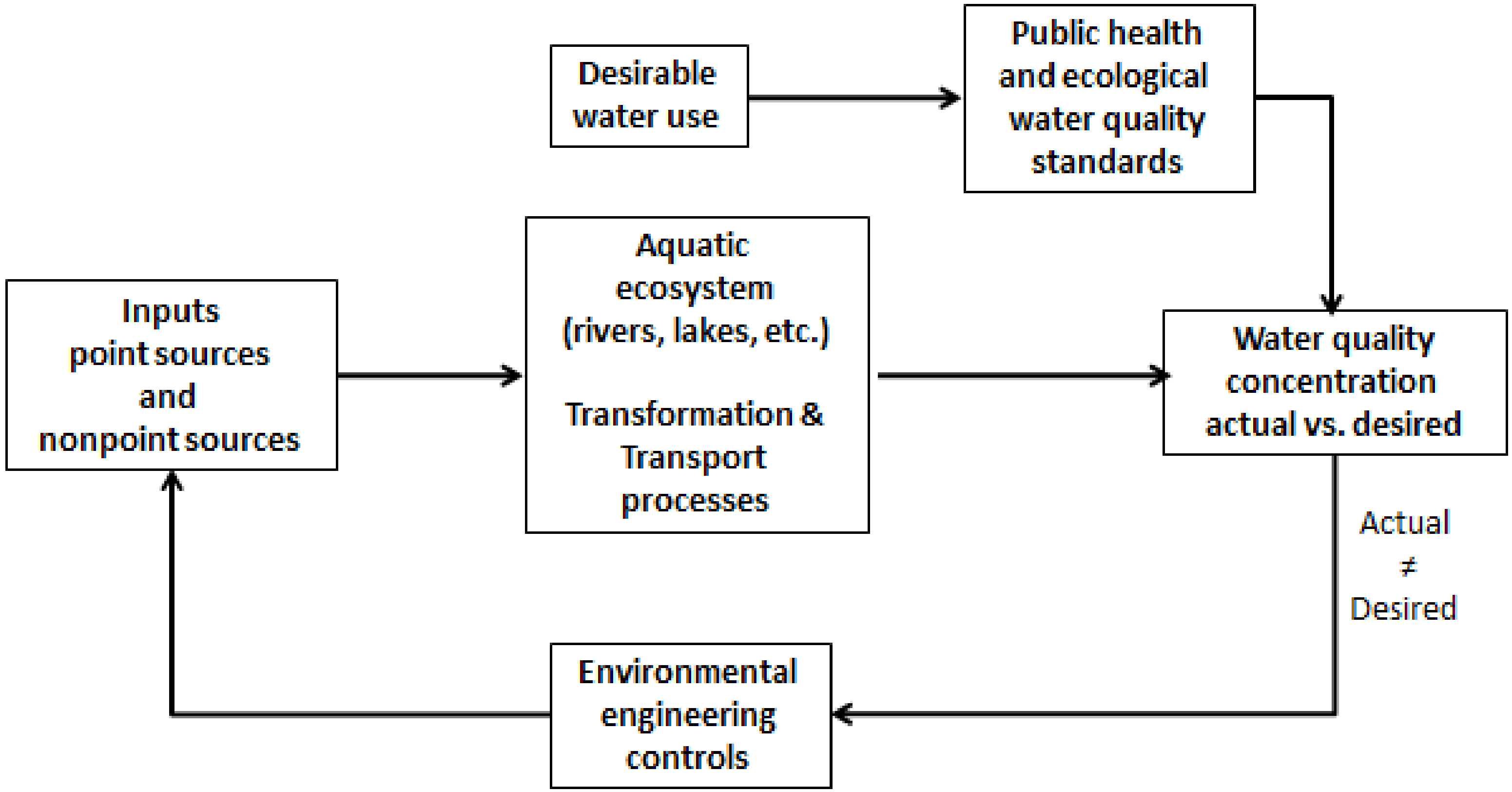
- Hydrology plays a fundamental role in environmental planning, management and restoration

- Environmental hydrology uses collection of hydrologic concepts that apply to solution of environmental problems

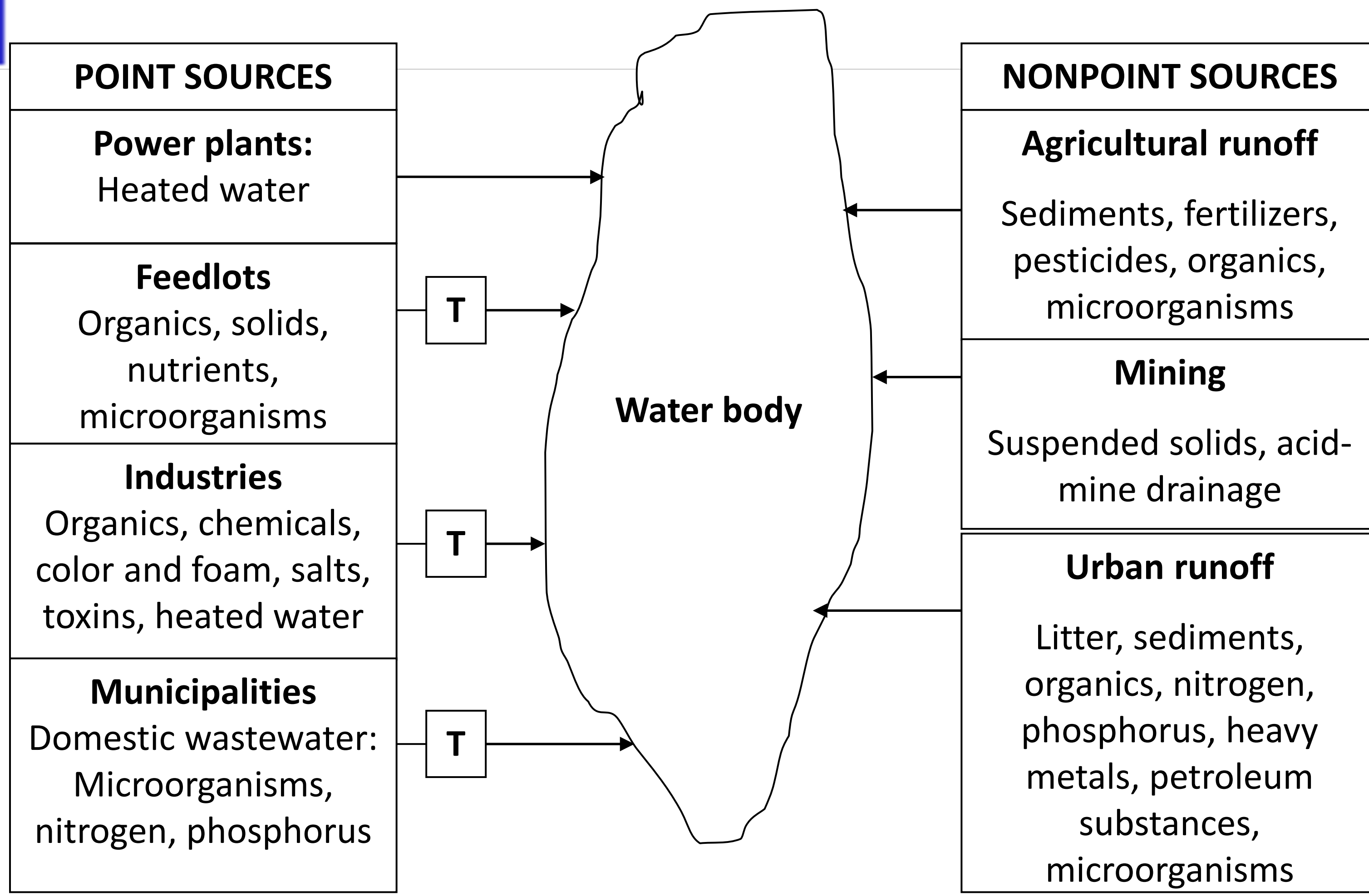
Environmental Flow

- Water that is allocated for maintaining aquatic habitats and ecological processes in a desirable state is referred to as instream flow requirement, Environmental flow or environmental water demand
- Hydrological Methods for determination of EFs:
  - Tennant method: linking average annual flow to different categories of instream habitat condition
  - Use of design low-flow range: Flow duration curve ranging between 70% and 99% with Q90% and Q95% widely used
  - 7Q10 method- 7-day low-flow event over a 10-year return period: if water quality is a primary concern
  - Range of hydrologic variability (RVA)- developed for situations when the conservation of native biota and ecosystem integrity are the prime objectives in sustaining riverine ecosystems,

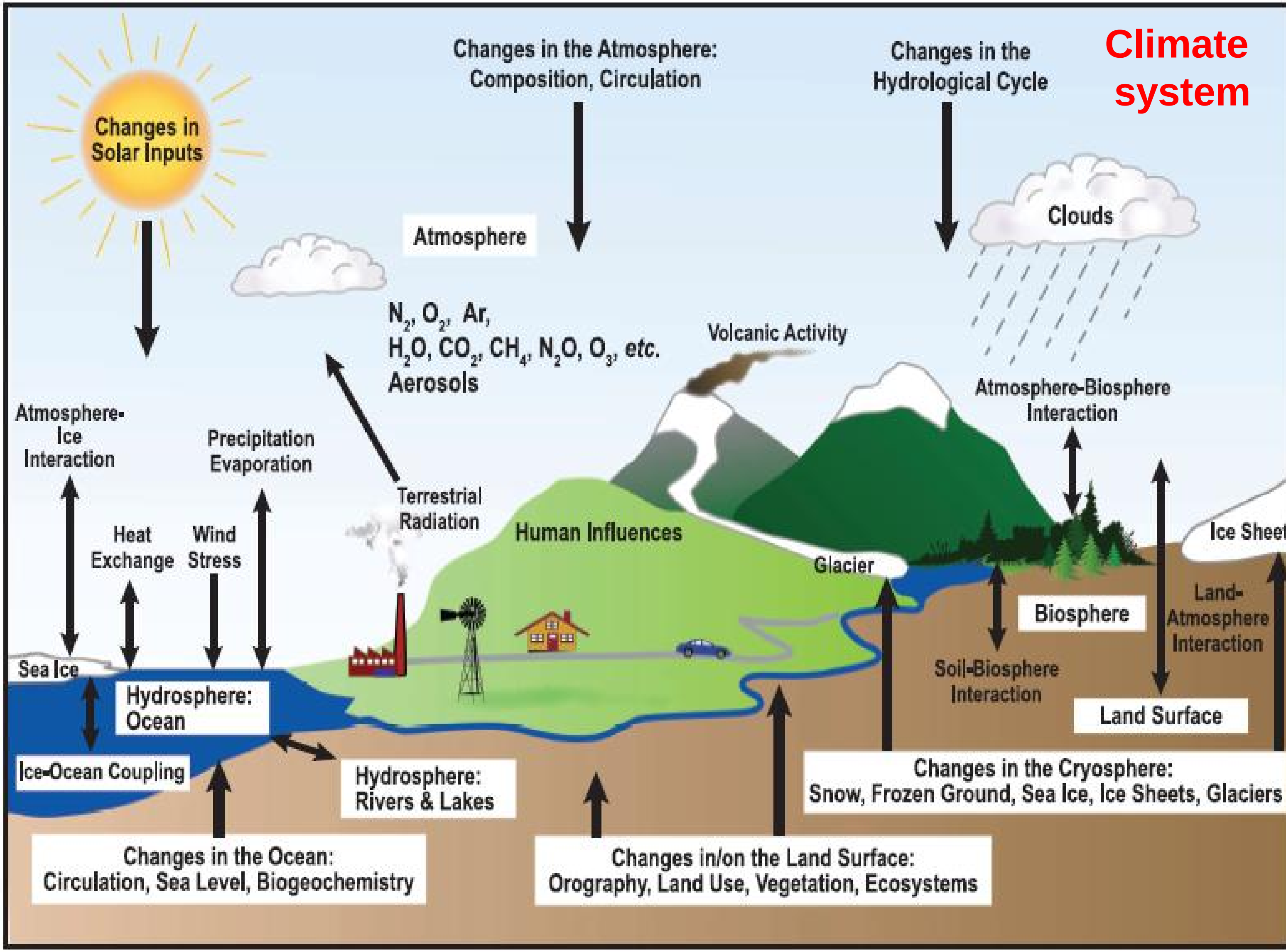
Water Pollution and Control



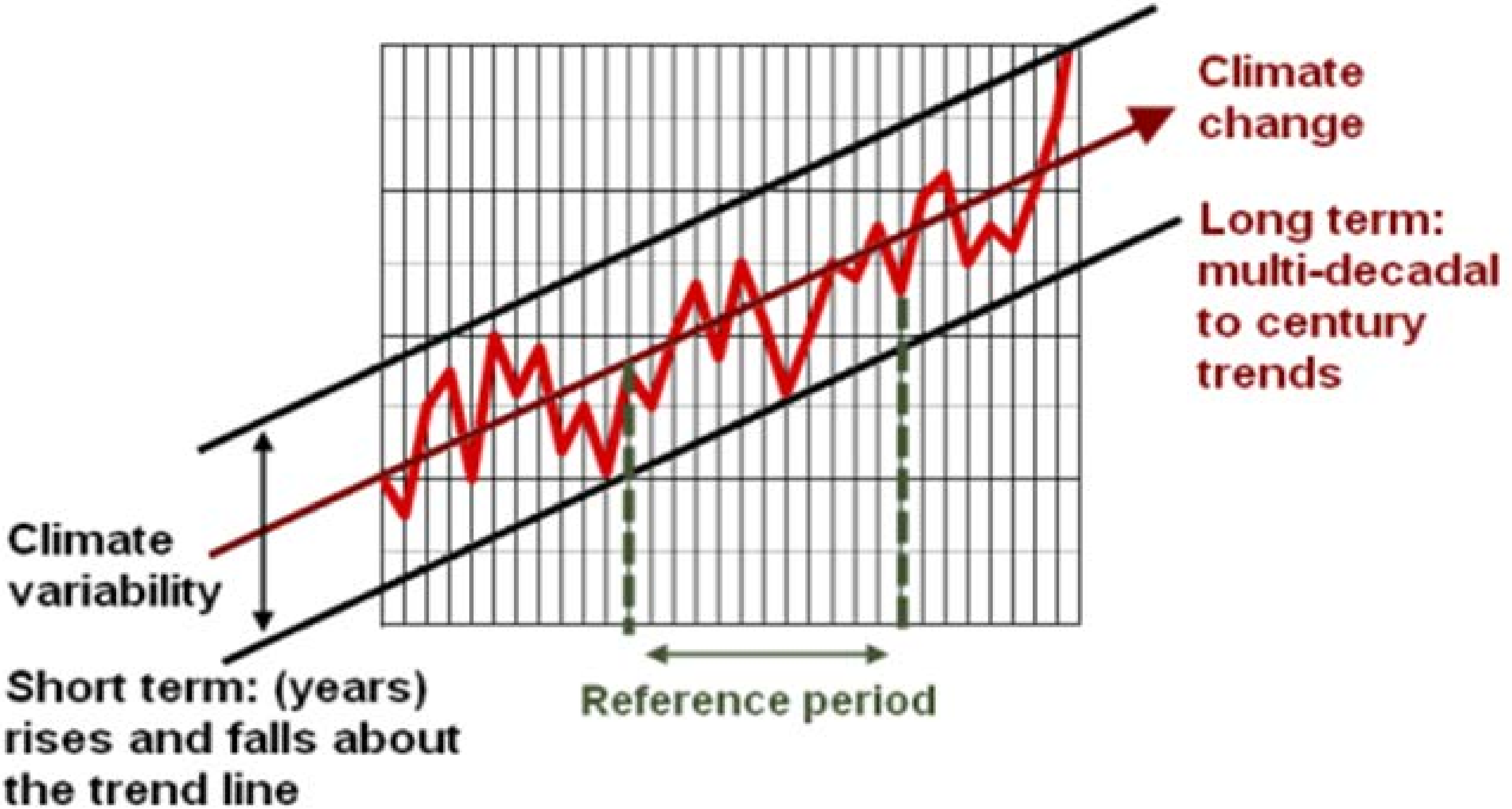
Sources of water pollution



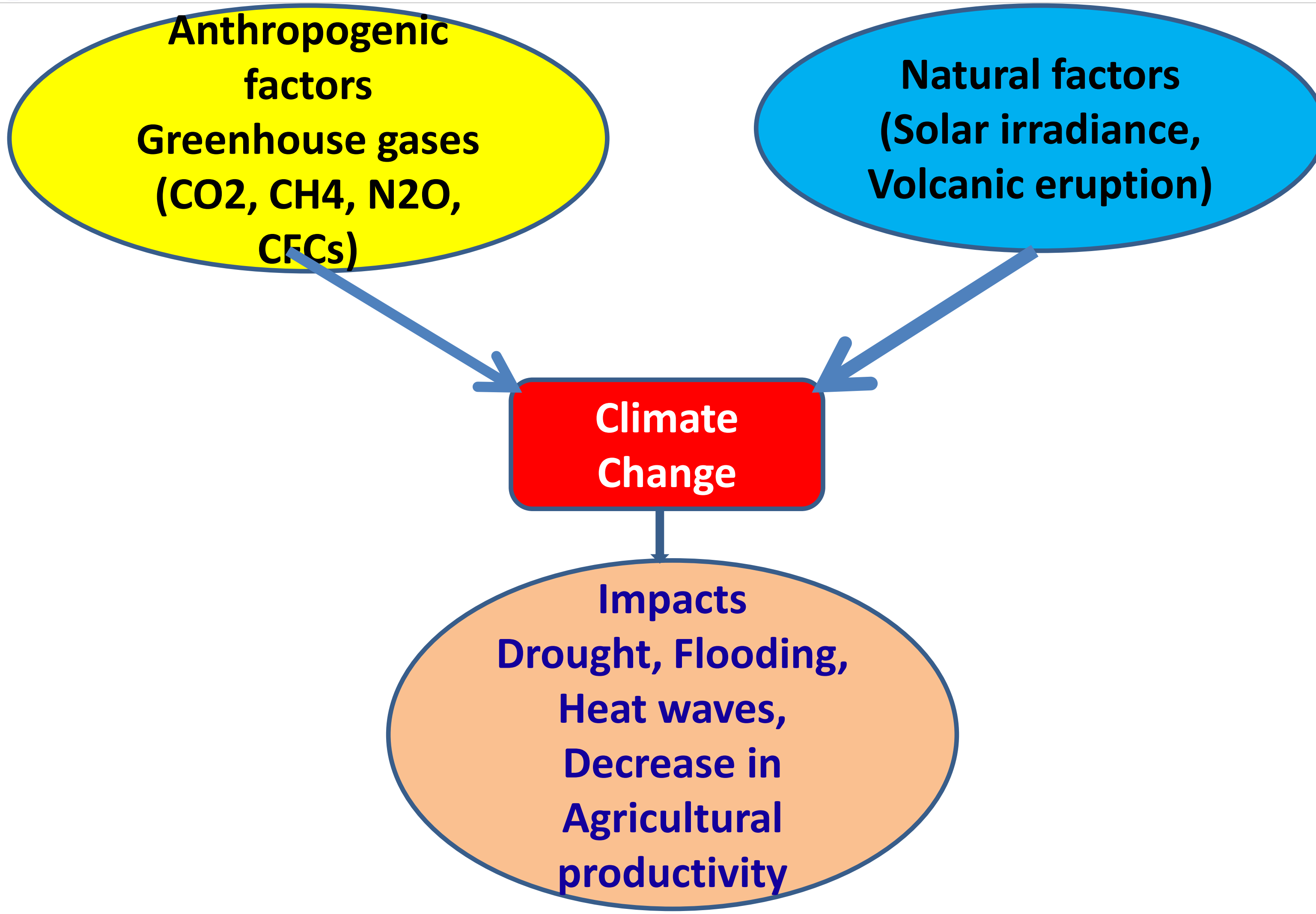
Climate Change and Water Resources



Climate Variability & Climate Change

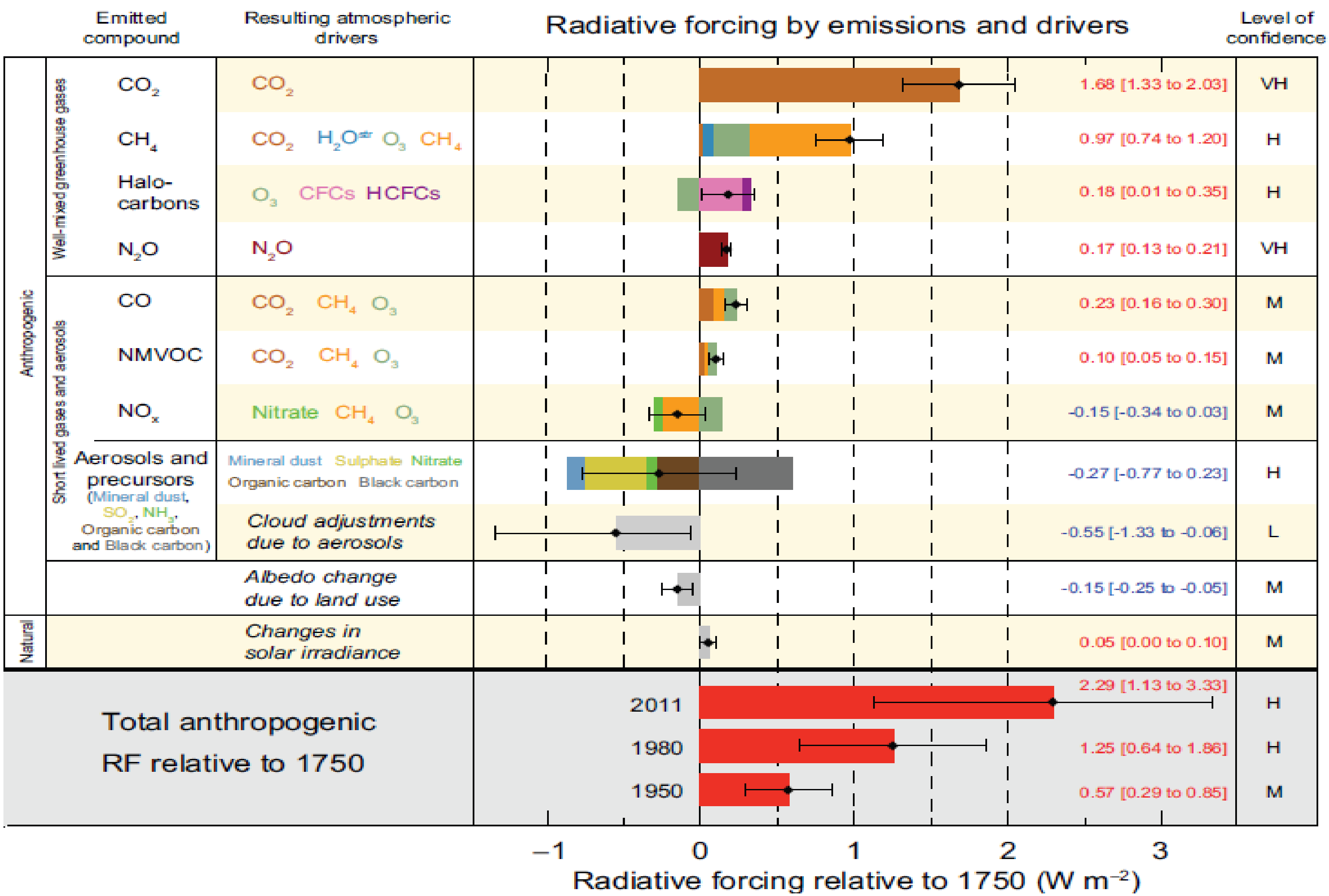


Drivers and Impacts of Climate Change

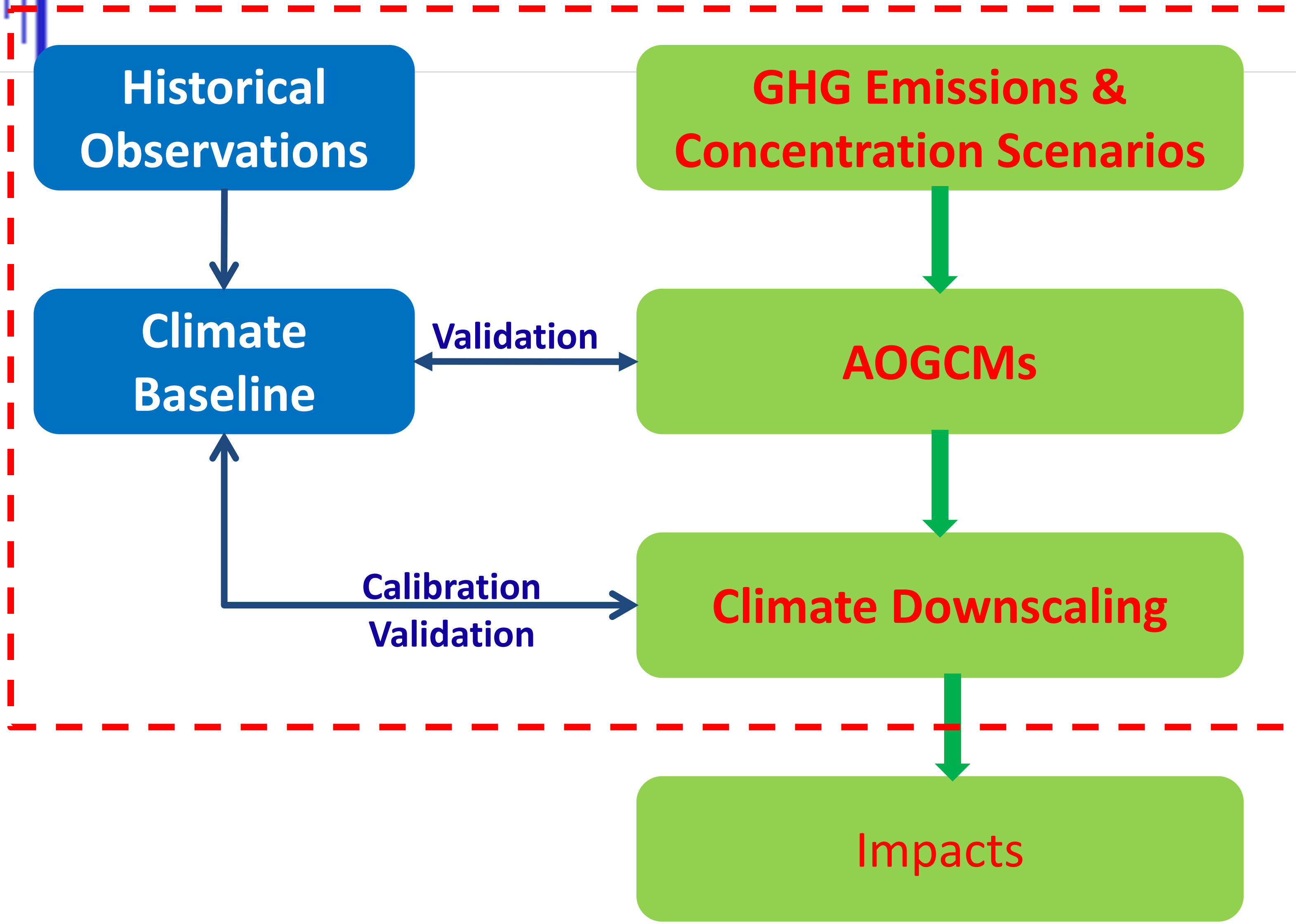


Radioactive Forcing

Definition: A change in the net radiation at the top of the atmosphere due to some external factor.



Climate Scenarios & Modelling



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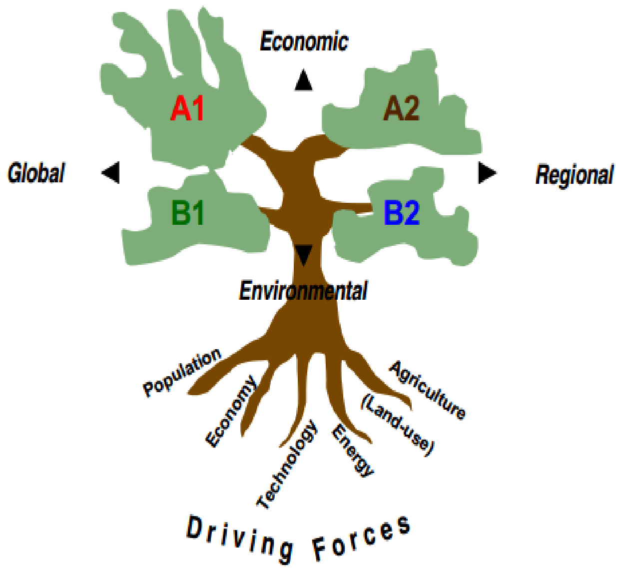
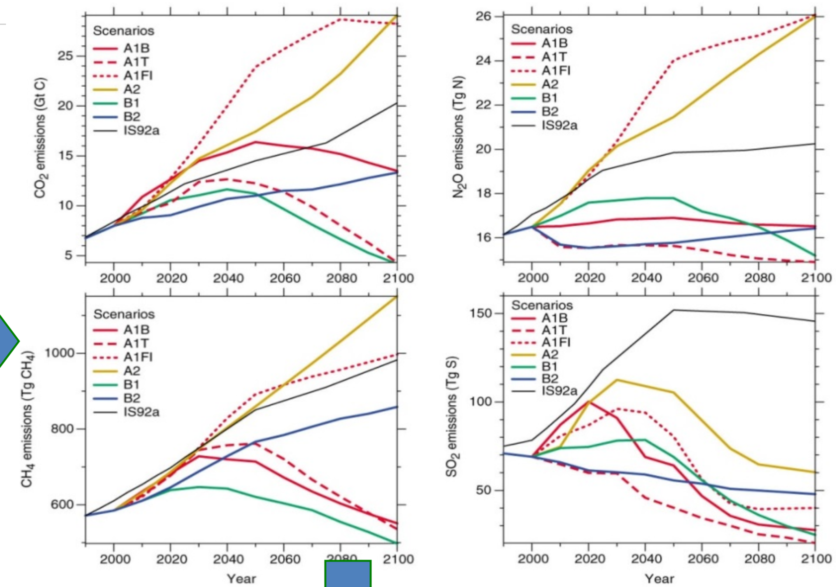
Scenarios-SRES

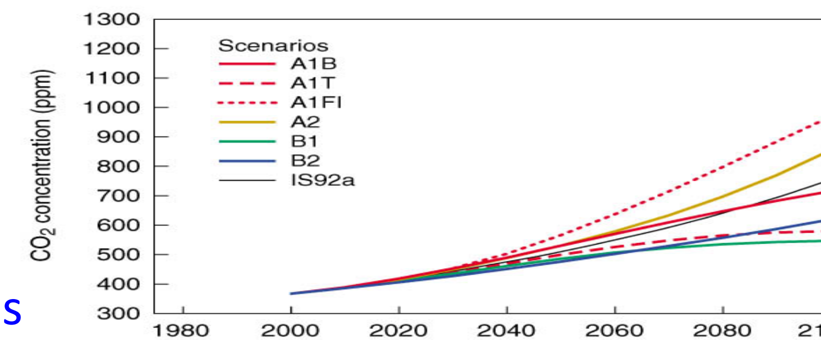
Socio-economic scenarios



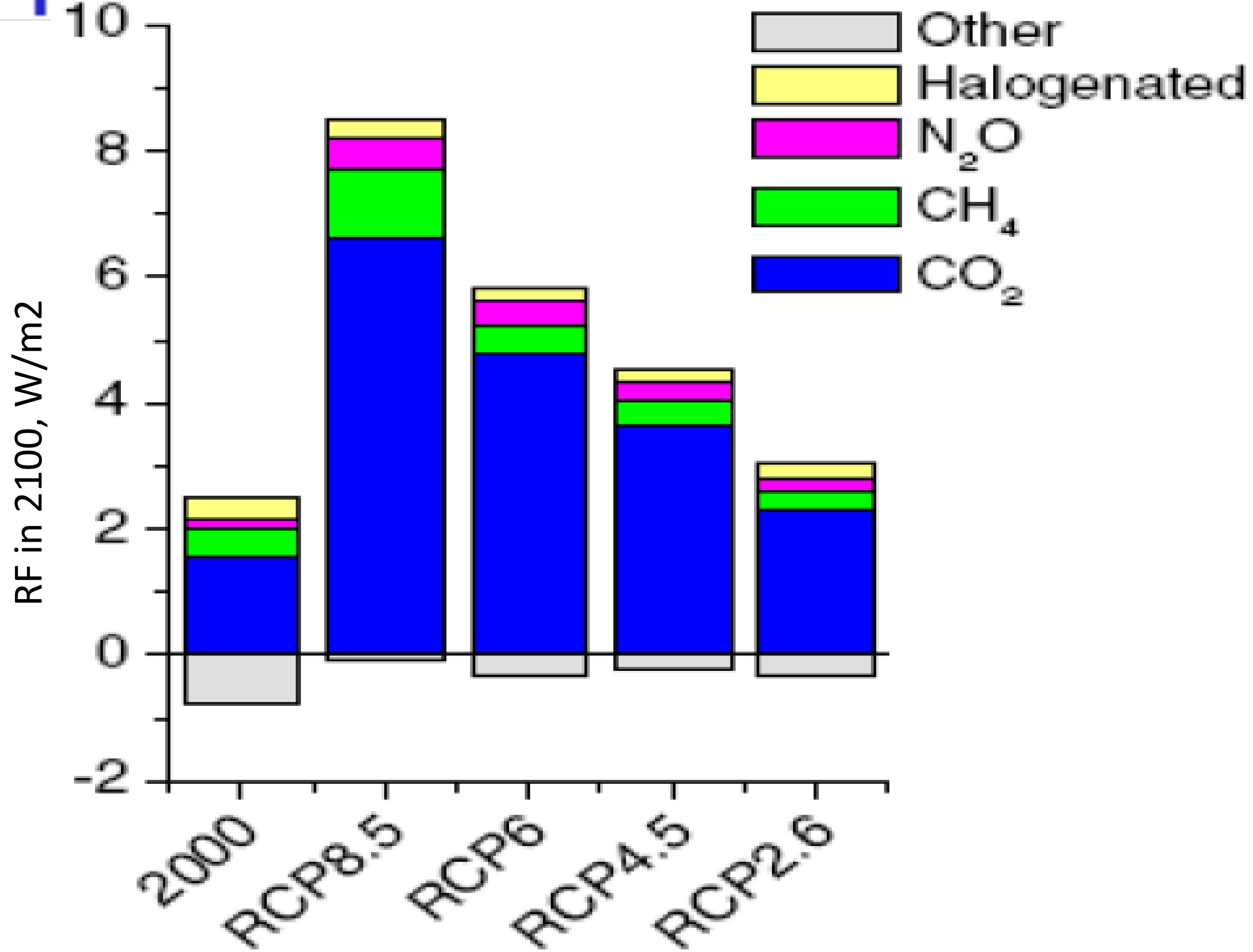
Emissions scenarios



Atmospheric concentrations

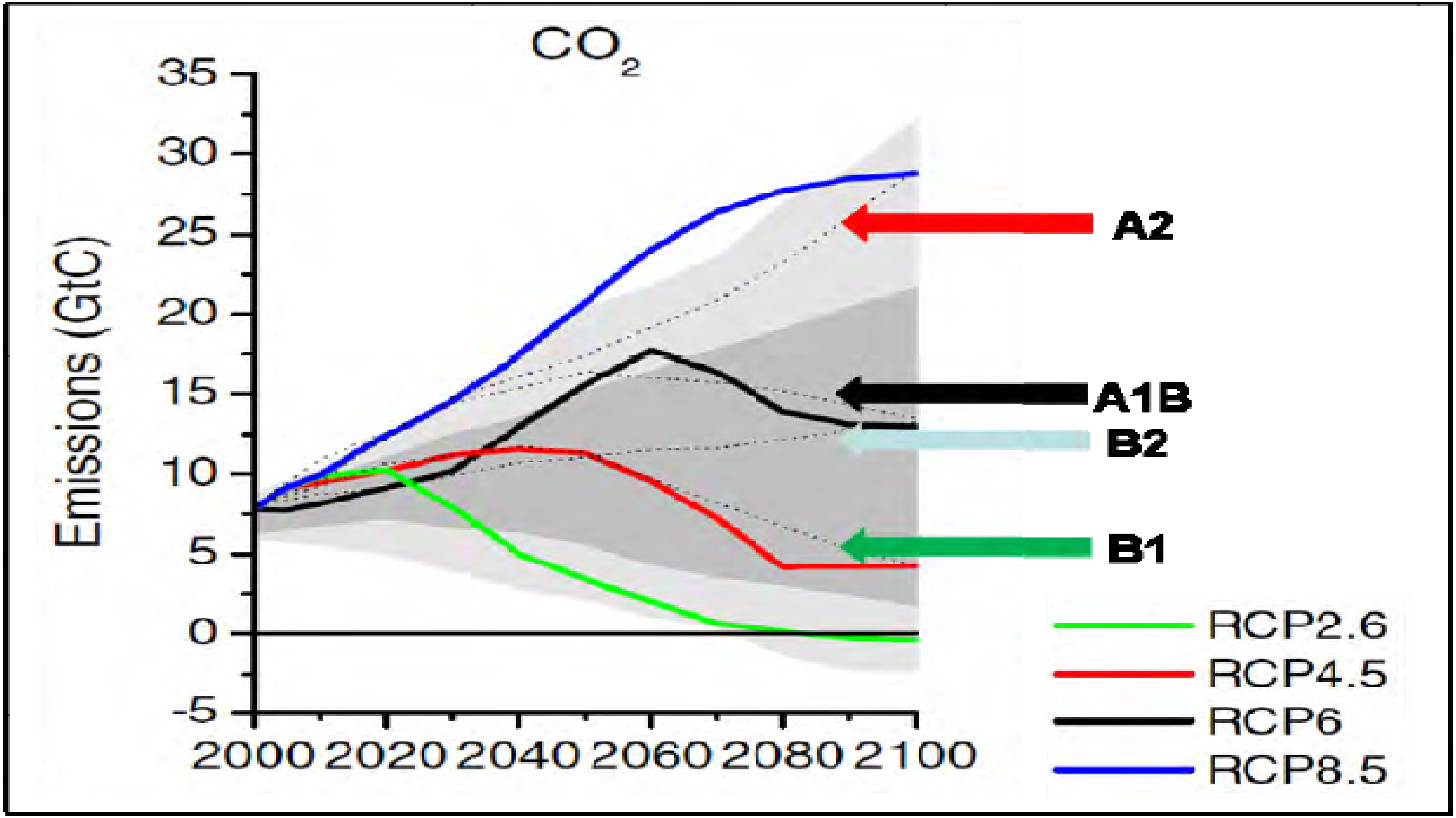


Scenarios- RCPs



Wayne, 2013

SRES vs. RCPs



Based on van Vuuren et al, 2011

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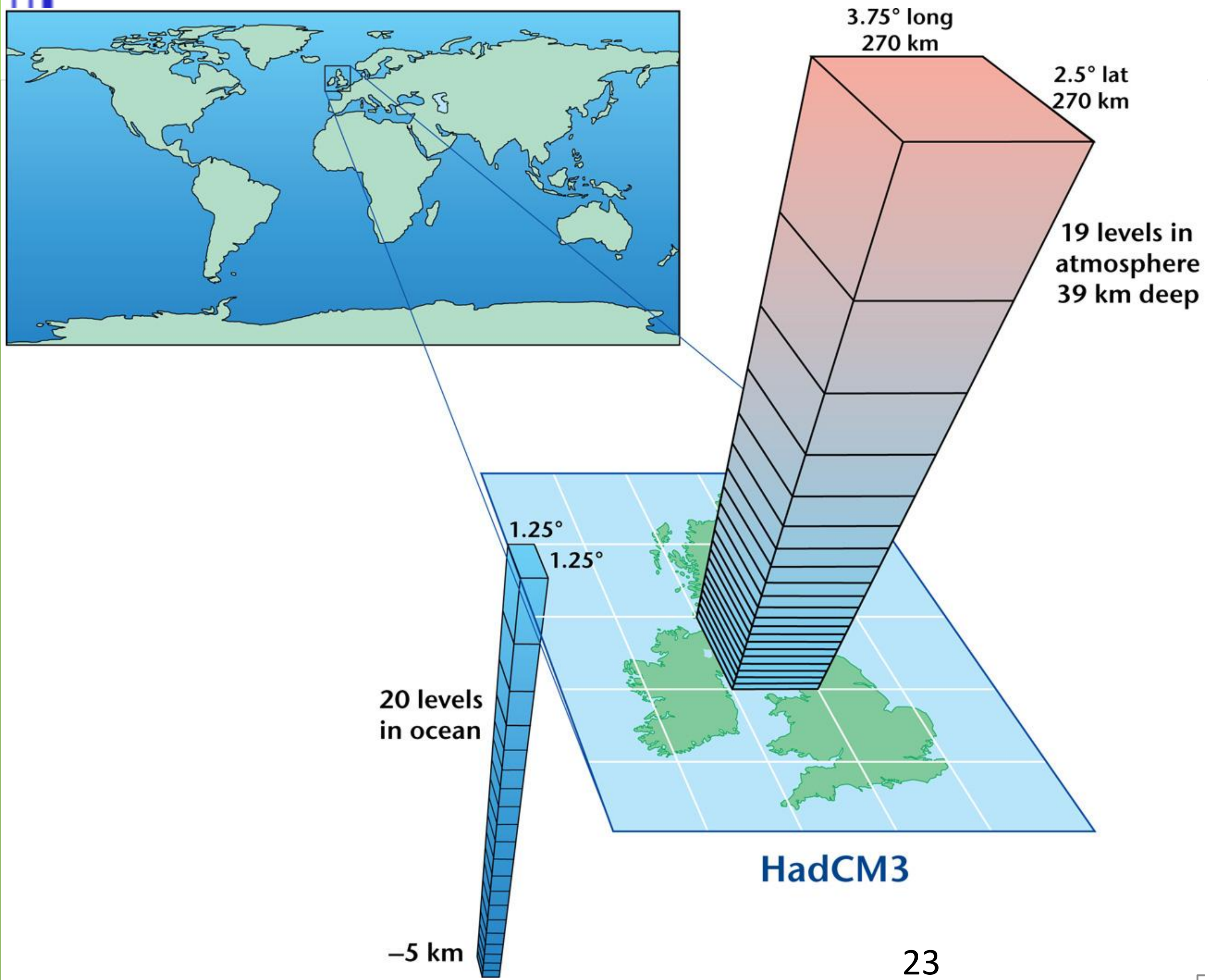
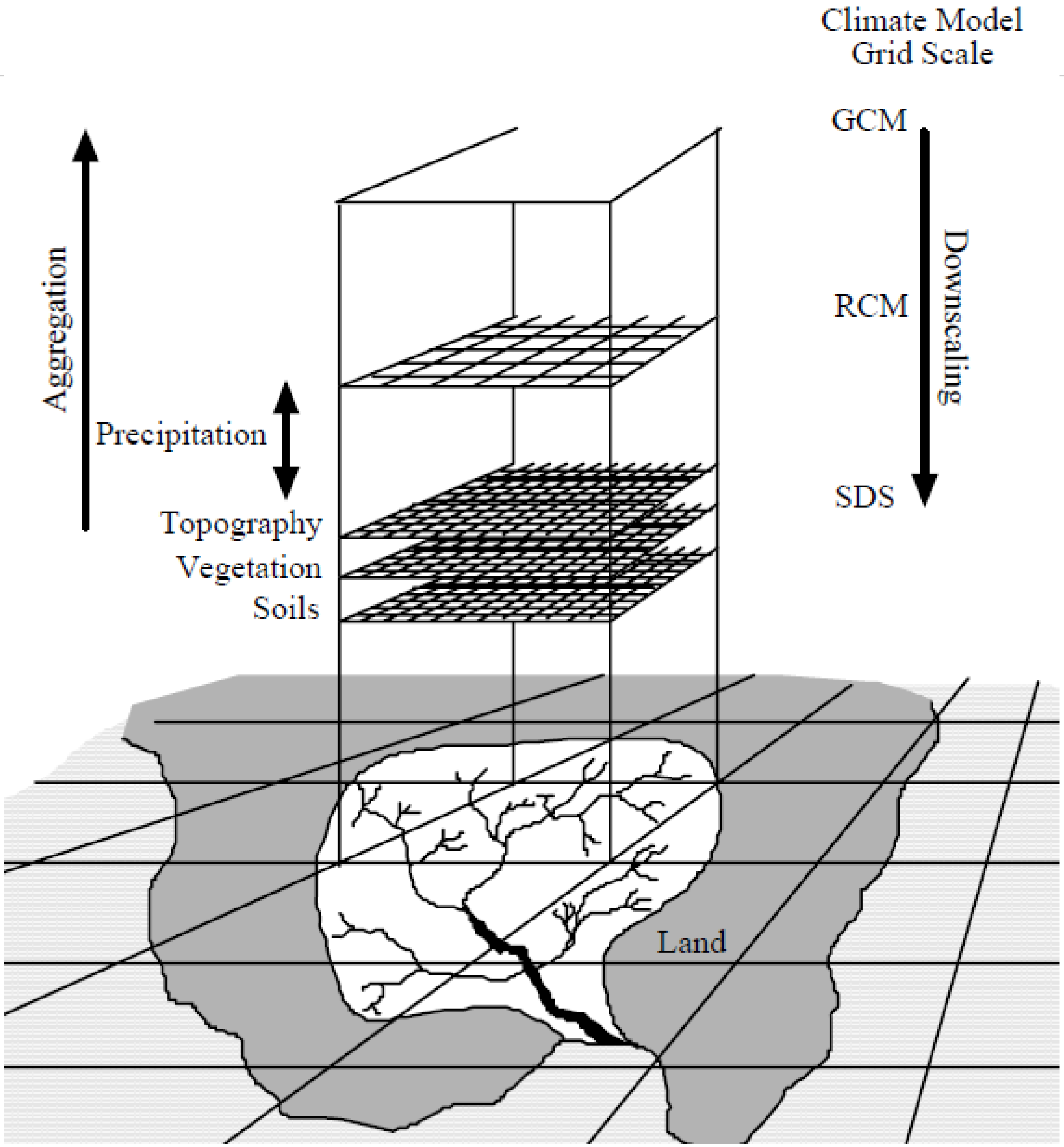
Global Circulation Models (AOGCMs)

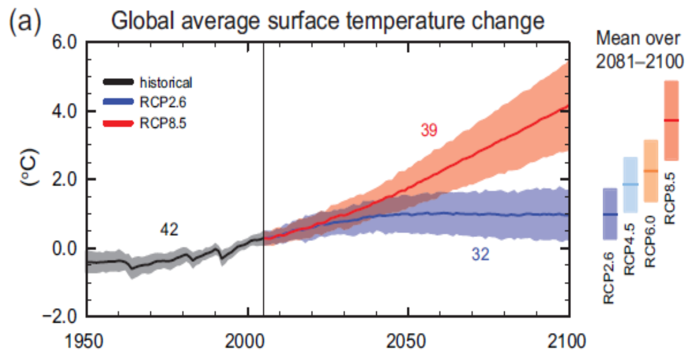


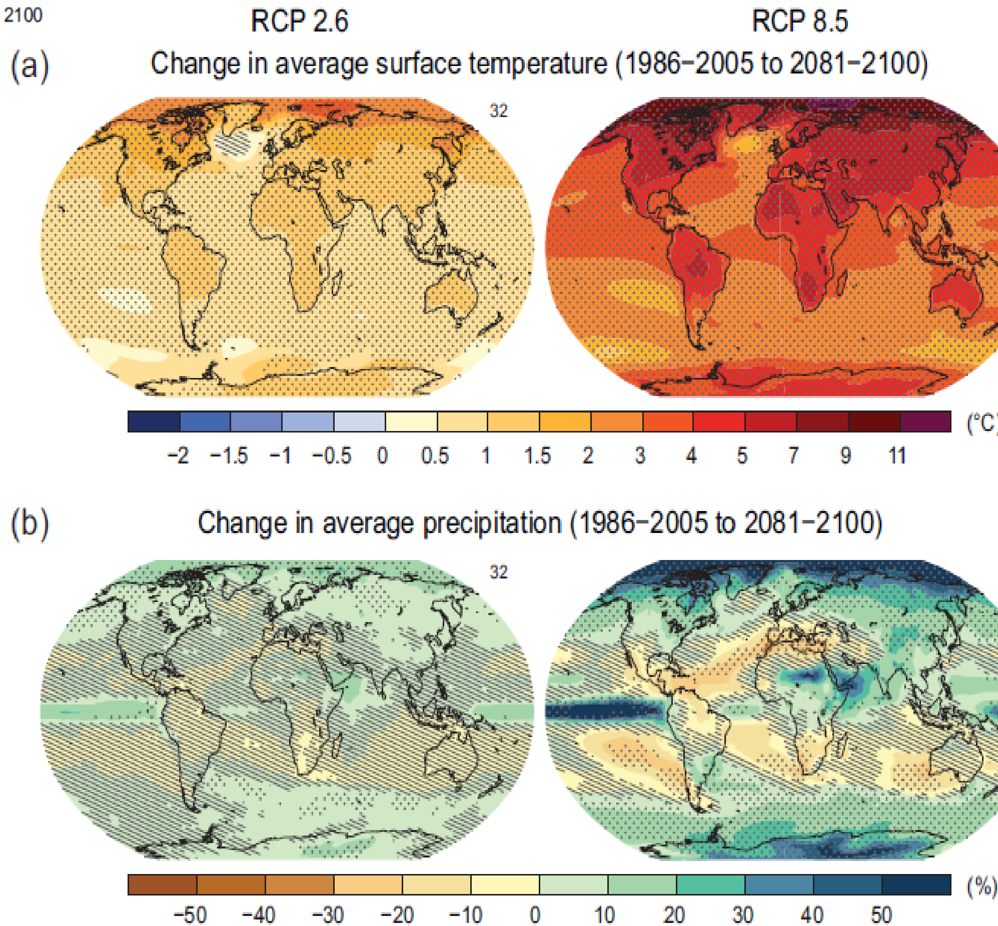
Climate Downscaling

- Dynamical
- Statistical



Projections of Temperature and Precipitation- CMIP5 multi-model mean results





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Potential Impacts of CC on the Hydrologic Cycle/process

Surface temperature ↑ Evaporation ↑

↓

Water holding capacity

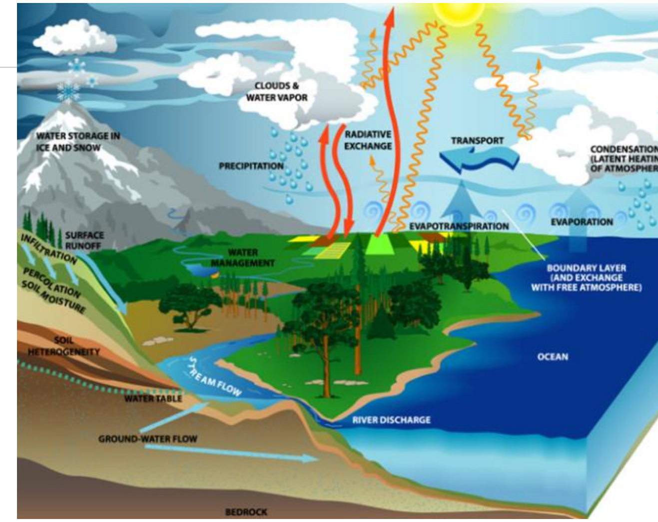
Atmospheric moisture

Enhanced Greenhouse

Rain intensity ↑

Rain frequency ?

Floods & Droughts



Water Resource Impacts

Most likely:

- Global precipitation ↑~ 1- 2% per 1°C
- Snow season shorter→ earlier peak flow
- Glacial wastage → summer flow ↑ near-term, but ↓ long-term
- Sea level rise → saltwater intrusion, coastal flooding
- Intense precipitation → water quality impacts

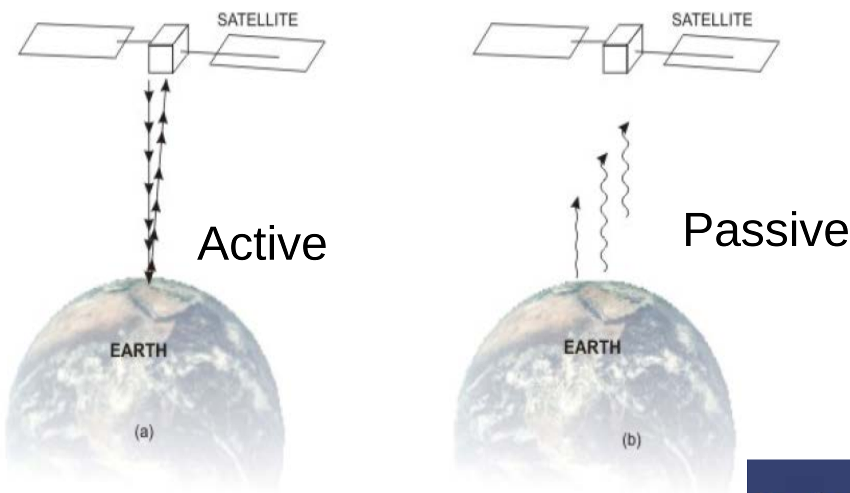
Climate Change in Ethiopia

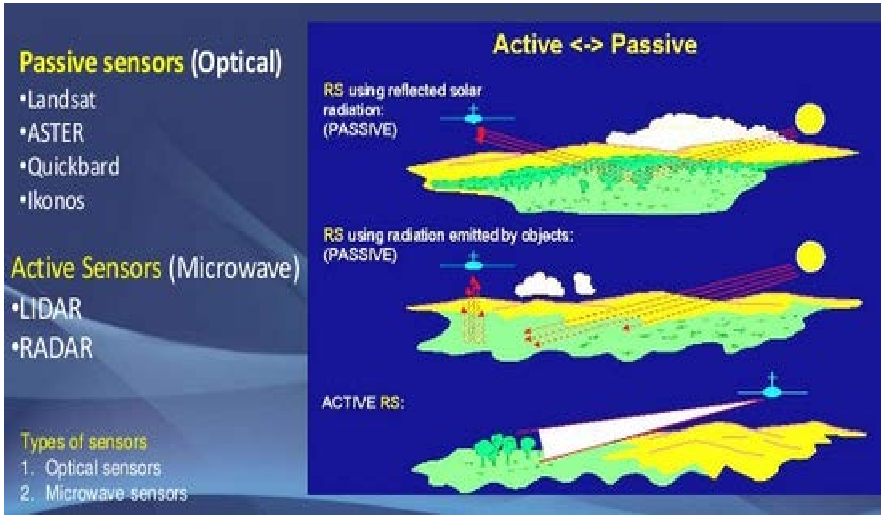
(CRGE Vision, 2010 *)*

Period	Temperature	Rainfall	Extremes
Historical	+1.3°C(1960-2006) More hot days and nights	No trend but highly variable	Regular severe floods and droughts
2020s	+1.2 °C (0.7-2.3 °C)	+0.4% increase in rainfall	Greater increases in rainfall in October to December especially in the south and east
2050s	+2.2 °C (1.4-2.9 °C)	+1.1% increase in rainfall	Heavier rainfall events, uncertain El Nino behaviors bring large uncertainties
2090s	+3.3 °C (1.5-5.1 °C)	Wetter conditions	Flood and droughts likely to increase, heat waves and higher evaporation

Remote Sensing in Hydrology

- Remote sensing is the process of inferring surface parameters from measurements of the upwelling electromagnetic radiation from the land surface.



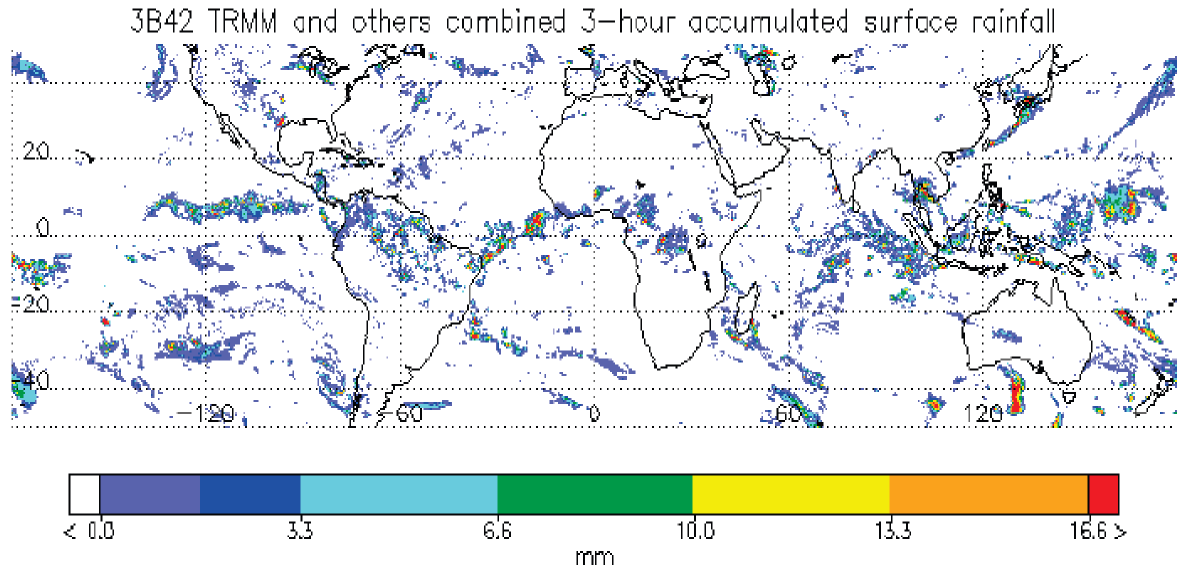


Common types of Remote Sensing' s Data Source

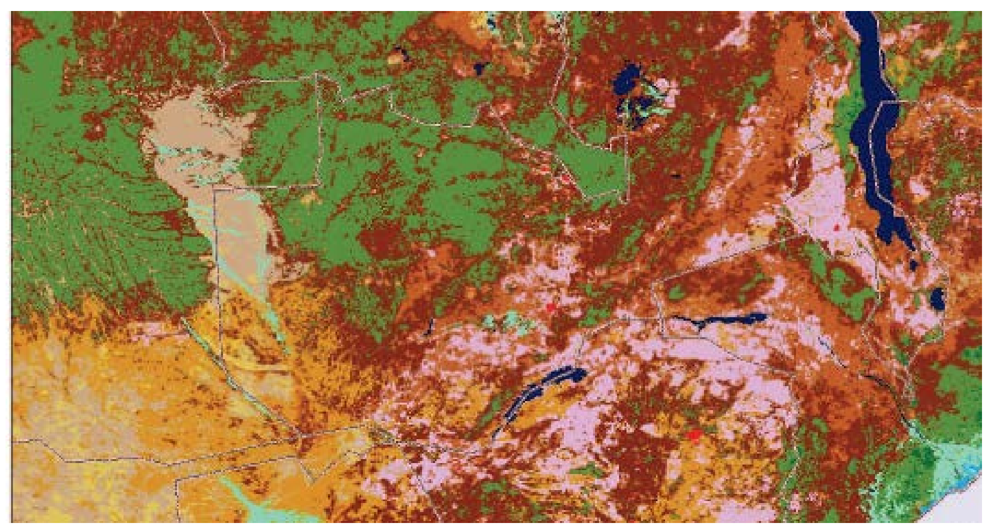
- Active system
  - Radar
  - Lidar
  - Sonar
- Passive system
  - Aerial photo
  - Satellite image

RS Applications

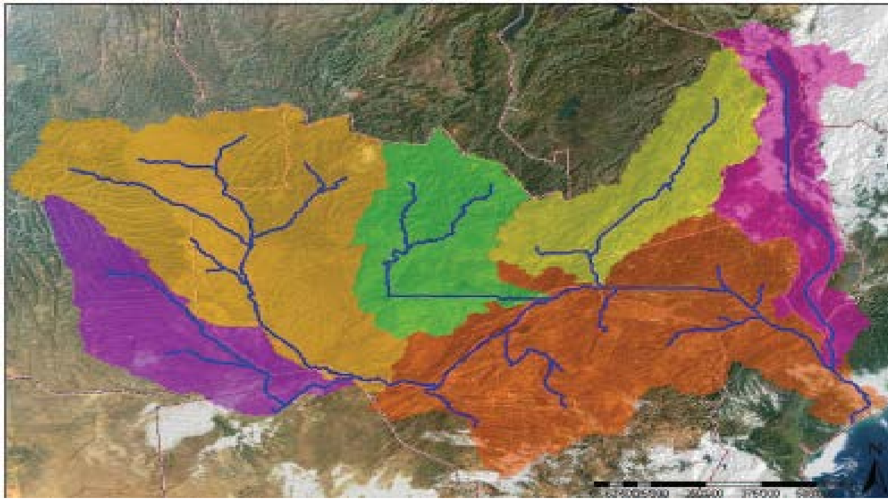
Precipitation Estimates
(from microwave/infrared Measurements)



Land cover of a basin

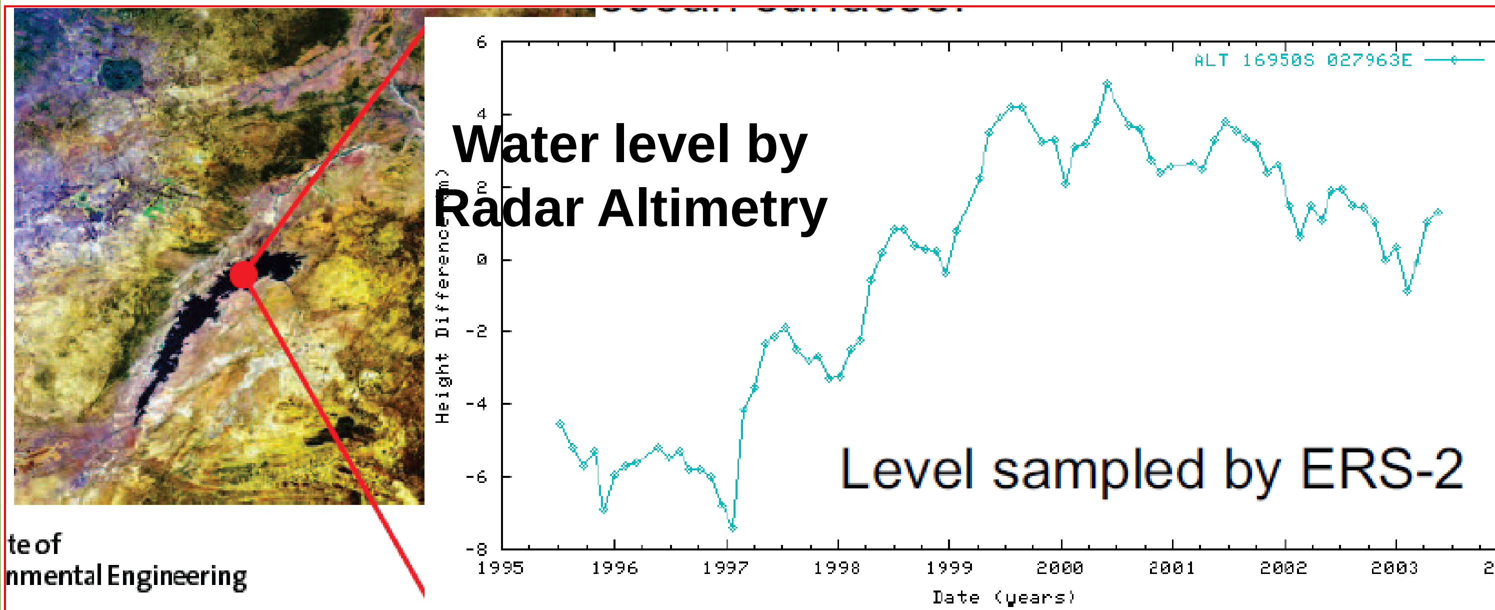


RS Applications

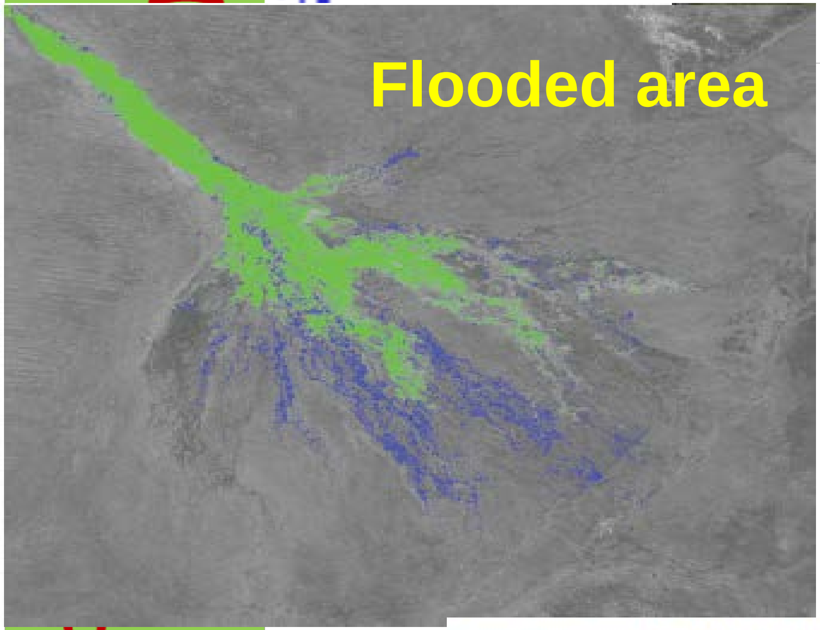


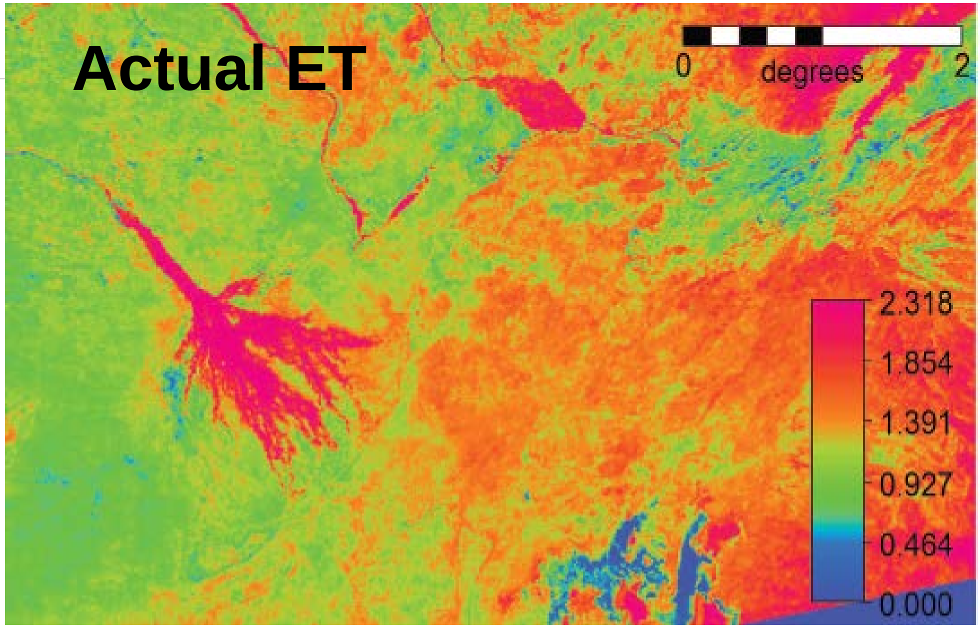
DEM from SRTM

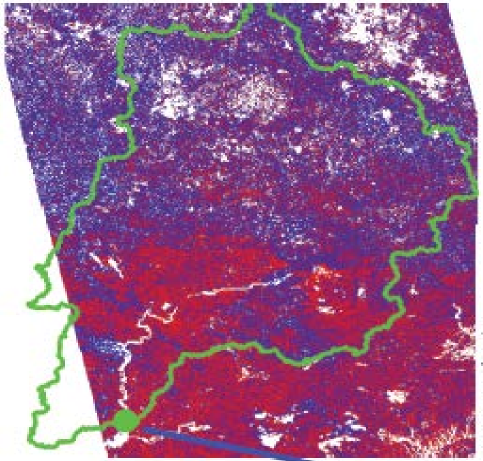
(can be used for watershed delineation)



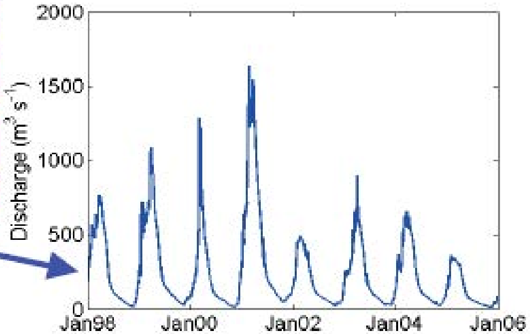
RS Applications







Correlation between soil moisture and runoff?



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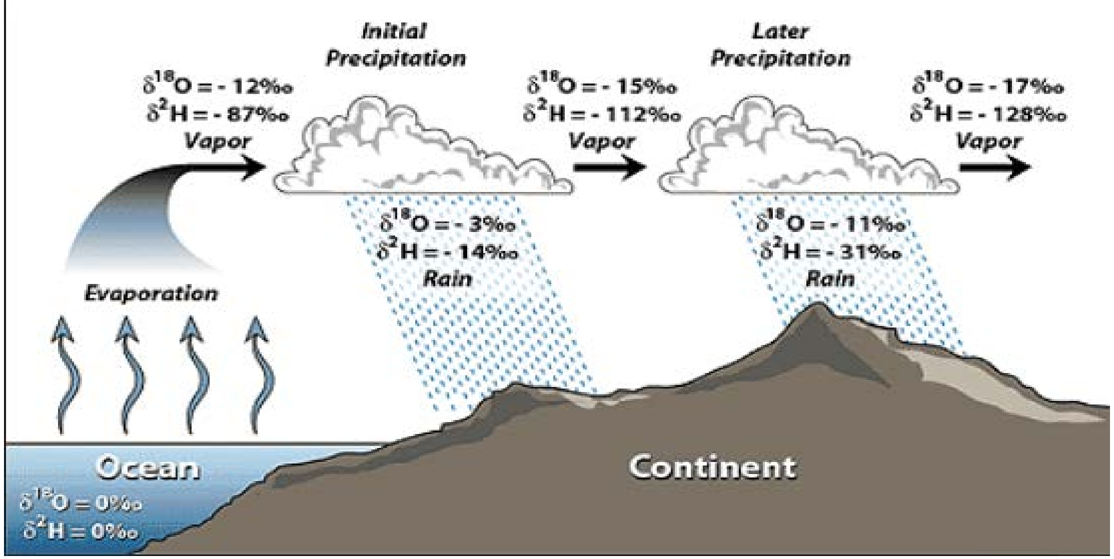
Isotope Hydrology

- Isotopes are atoms of the same element that have different numbers of neutrons; they can be stable or radioactive
- Isotopes in hydrology give a direct insight into the movement and distribution of processes within the hydrological system
- Partitioning of isotopes is governed by the principle that lighter isotopes, or those with a lower molecular weight, will be favored in evaporation processes and biological uptake, leaving the source material "heavier," or with the heavier isotope more abundant



$$\delta_{S/R} = \frac{R_{Sample}}{R_{Reference}} - 1$$

where R_{Sample} and $R_{Reference}$ stands for the isotope ratio (2H/1H and 18O/16O) in the sample and the reference material (ocean), respectively

Isotopes Commonly used in Hydrology

Environmental Stable Isotopes

Isotope	Ratio	%natural abundance	Reference (ppm)	Commonly measured phases	Application in hydrology
^{2}H	$^{2}H/^{1}H$	0.015	VSMOW (155)	H_2O,CH_4	Origin of water
^{13}C	$^{13}C/^{12}C$	1.11	VPDB	CO_2, Carbonates	Carbonates source, Groundwater Dating
^{15}N	$^{15}N/^{14}N$	0.366	Air N2 (3677)	N_2, NH_4NO_3,	Source of pollution
^{18}O	$^{18}O/^{16}O$	0.204	VSMOW (2005)	H_2O,CO_2, SO_4^{-2}, NO_3^-	Origin of water
^{34}S	$^{34}S/^{32}S$	4.21	CDT	SO_4^{-2},Sulphides, H_2S	Origin of salinity, Redox condition of aquifer
^{37}Cl	$^{37}Cl/^{35}Cl$	24.23	SMOC (0.324)	Saline waters	Source of pollution
^{87}Sr	$^{87}Sr/^{86}Sr$	07.00	USGS Tridacna,	Solution	Provenance of water
^{11}B	$^{11}B/^{10}B$	80.1	NISTRM 951 – (Sodium borate)	Solution	Source of pollution

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Isotopes Commonly used in Hydrology

Environmental Radioisotopes

Isotope	Half life (years)	Type	Energy(MeV)	Applications in hydrology
Tritium (^{3}H)	12.3	β	0.019	Young groundwater dating
Carbon (^{14}C)	5730	β	0.156	Old groundwater dating
Chlorine-36 (^{36}Cl)	3.1×10^{5}	β	0.714	Very old groundwater dating
*Cesium-137 (^{137}Cs)	30	γ	0.661	Sediment dating

Artificial Radioisotopes

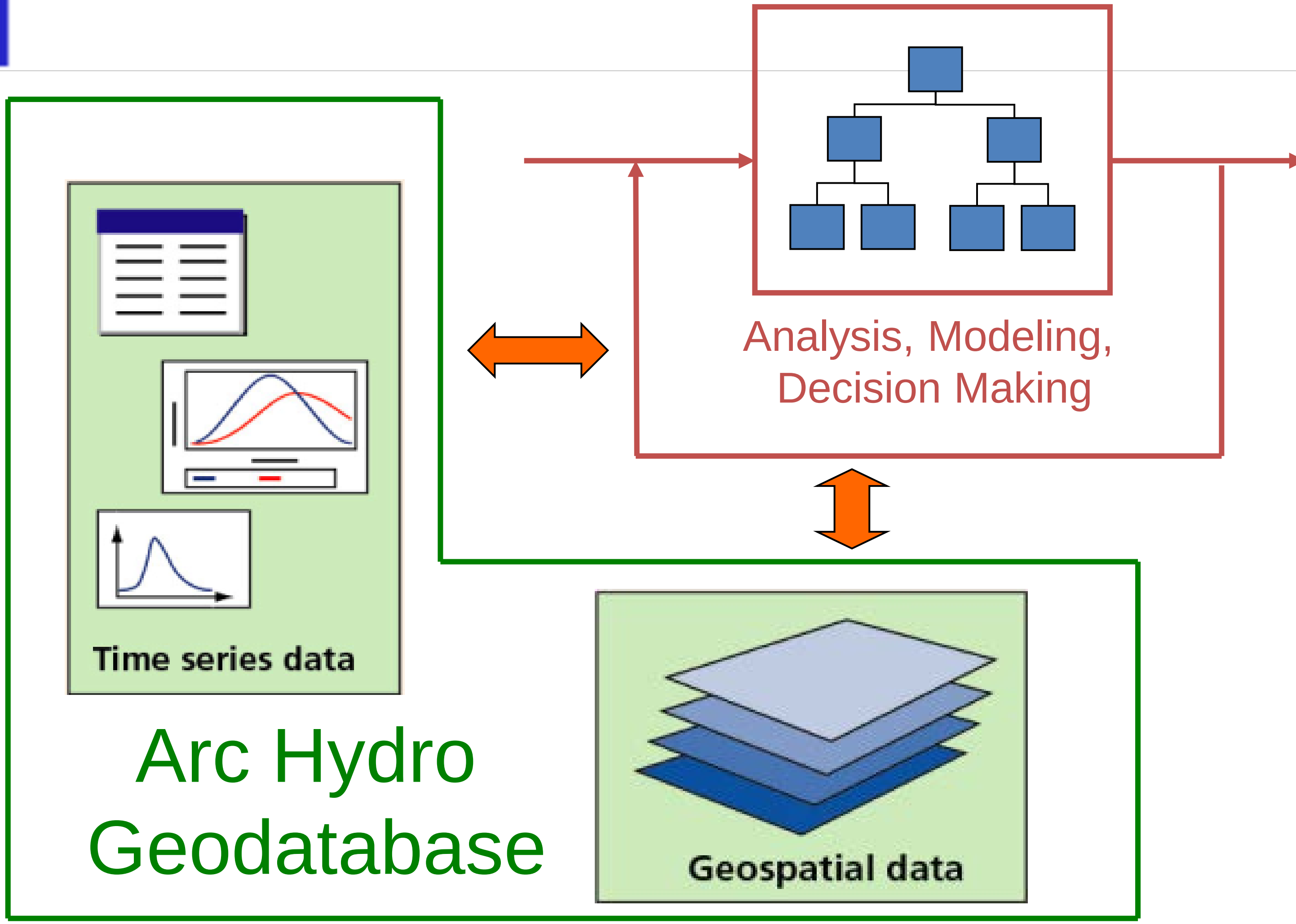
Isotope	Half life	Chemical form	Applications in hydrology
Tritium (^{3}H)	12.43 y	HTO	Groundwater recharge rate and flow direction
Cobalt-60(^{60}Co)	5.3 y	$K_3[Co(CN)_6]$	Groundwater recharge rate
Bromine-82(^{82}Br)	36 h	NH_4Br	Groundwater velocity, effluent dispersion
Gold-198(^{198}Au)	2.7 d	$HAuCl_3$	Seepage entry and exit points in dams

Applications of Isotopes in Hydrology

- Determination of the origin of water masses and the conditions during formation
  - Identification and separation of water components
  - Determination of groundwater recharge areas, flow paths, mixing
  - Determination of the origin of contaminant
  - Reconstruction of recharge temperatures for palaeoclimate studies

- Determination of the residence time of water in the system ("water age")
  - Calculation of flow velocities, assessing mixing and dispersion
  - Determination of water fluxes, recharge rates, and exchange rates
  - Study of transport and degradation of contaminants

Hydrologic Information System



A synthesis of geospatial and temporal data supporting hydrologic analysis & modeling