SMALL SATELLITES EXTRAORDINARY TRANSFORMATIVE POTENTIAL FOR KNOWLEDGE BASED DESIGN AND DECISIONS

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Small Satellites

Shorter Developmment Cycle

1.Catalyze Faster Evolution
Of both, Novel Ideas & Innovative Technologies

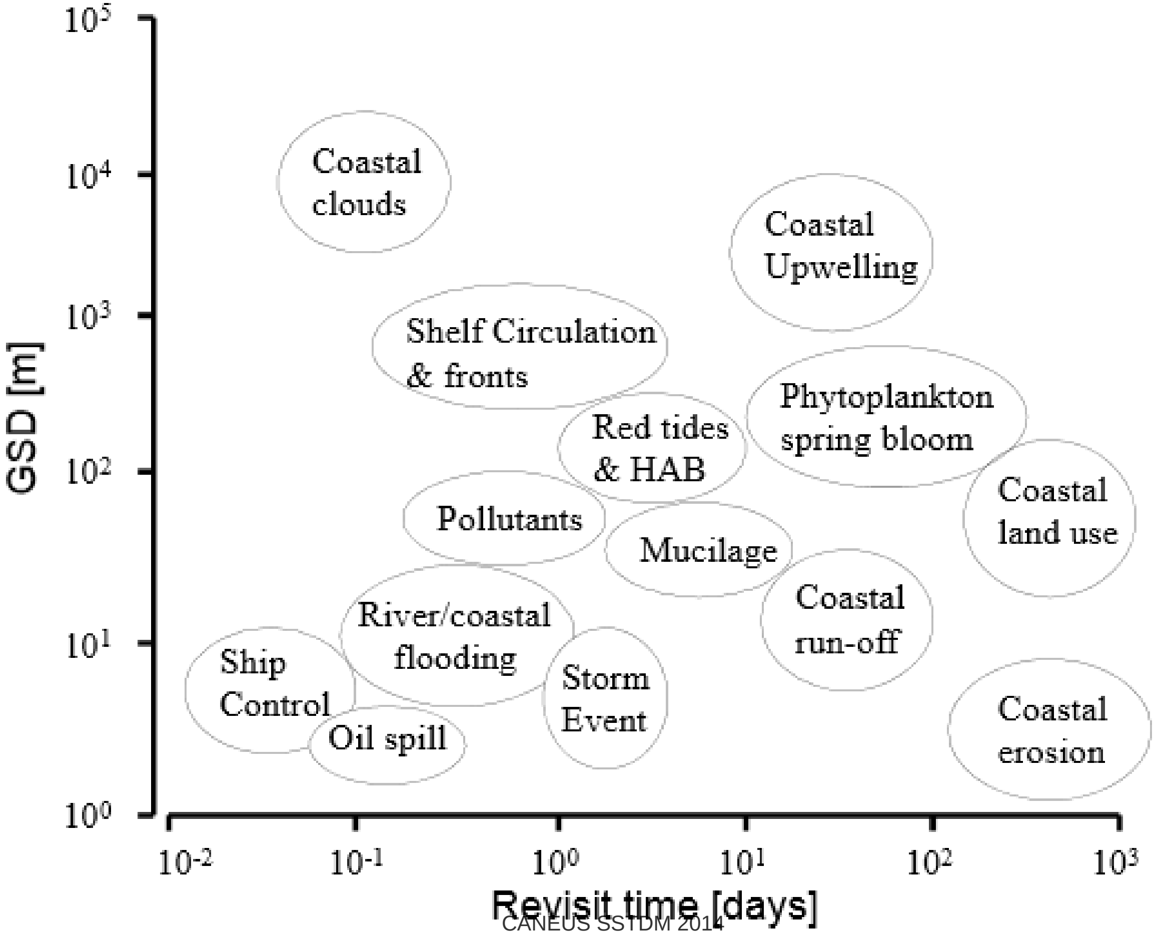
2. Responsive to New Opportunities and Insightful Ideas

3. Democratization of Science Initiatives:
Potentially Large Gene Pool of Curiosity Inspired Minds to engage in a Faster Realization of the Chain:

Concept to Creation

Small Satellites

Higher Reoccupation Frequency
Growing List of Applications



Small Satellites

Lower Orbit, Higher Reoccupation Frequency

1.Quicker Delivery of Information

2. Uncertainty Reduction in Inverse Estimations:

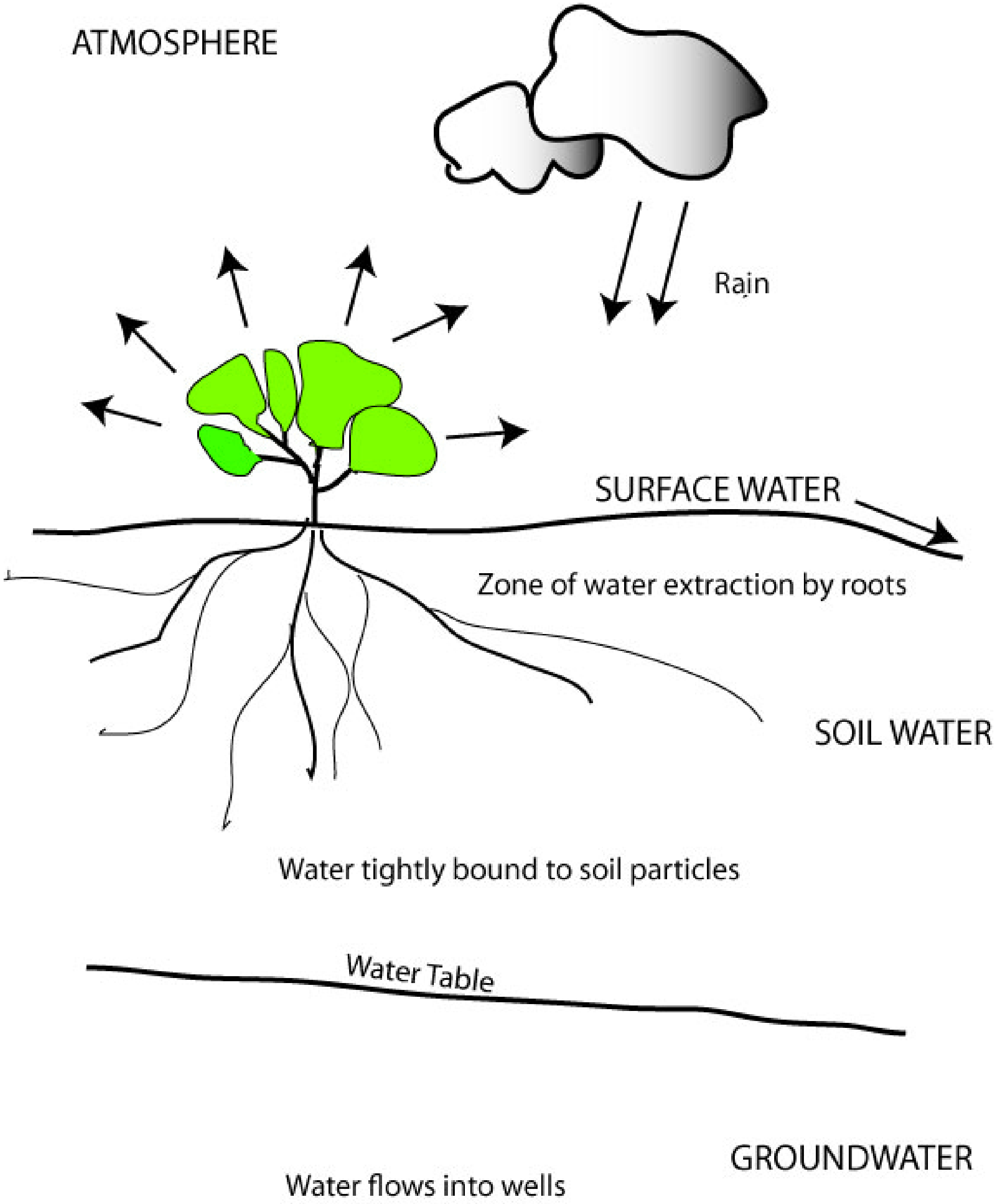
*Advance warning Systems (Landslides, Avalanches, Floods)

*Glacier Response Models

*Groundwater Storage State using Gravity data

*System State Vector (Soil Moisture, Ecosystem Health)

*Stream Flows (Component of the Annual Water Cycle)



THE WATER CYCLE

Annual Renewing Agent of Fresh H_2O

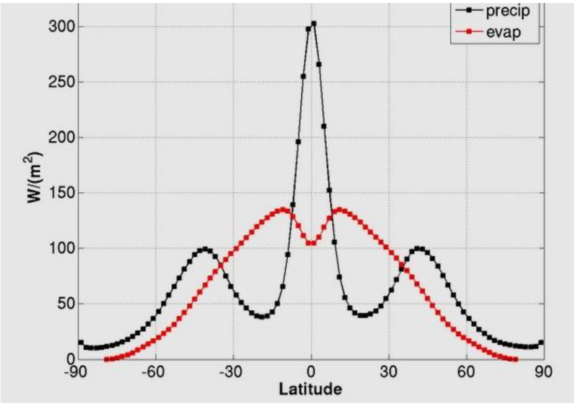
*ATMOSPHERE,
*SURFACE WATER,
*SOIL WATER &
*GROUNDWATER

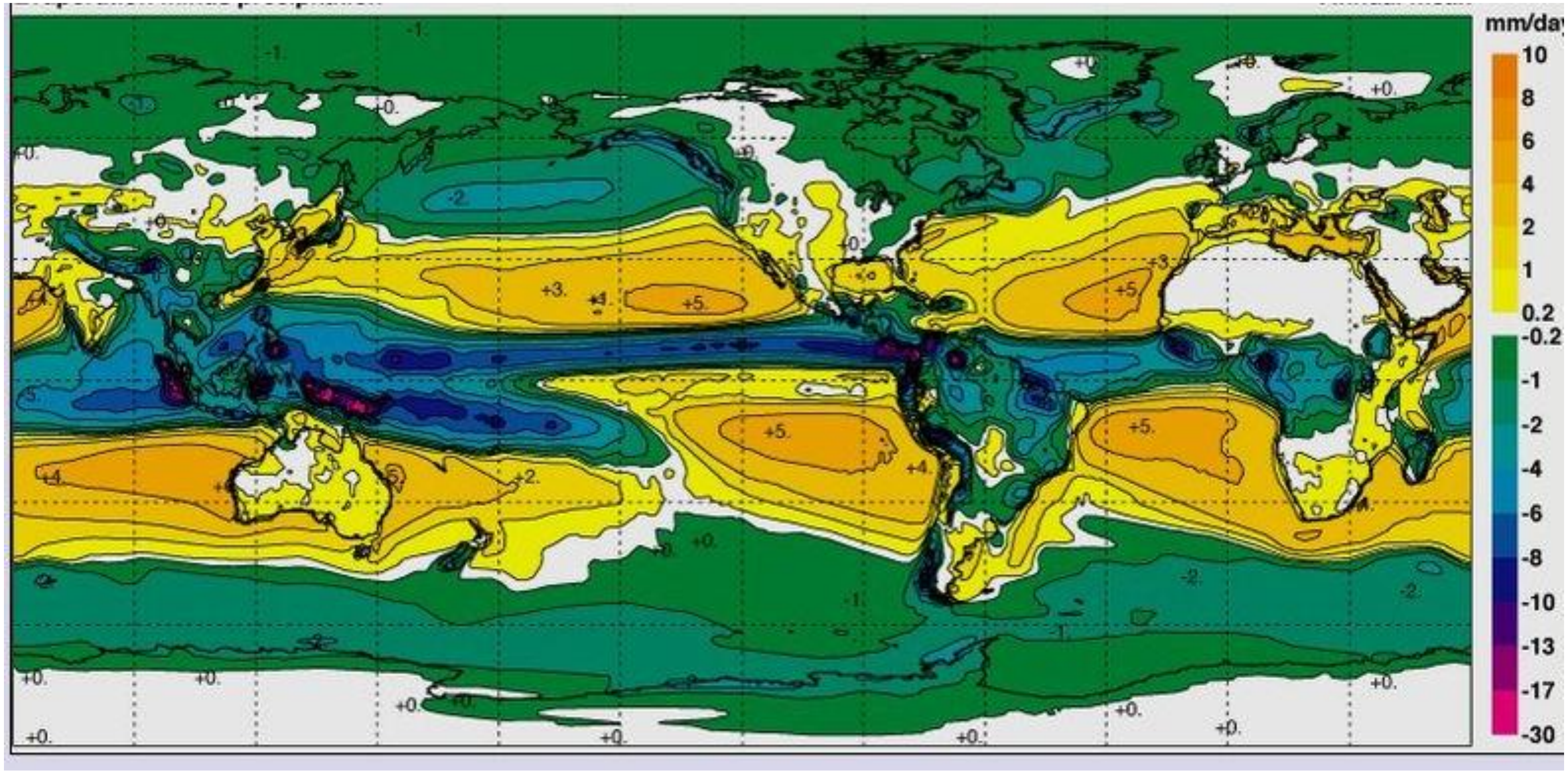
$P + In - ET = SF + \Delta St$

ΔSt (Surface, **Soil** & Ground)

Water Cycle to Intensify with Global Warming

The 2007 IPCC Report



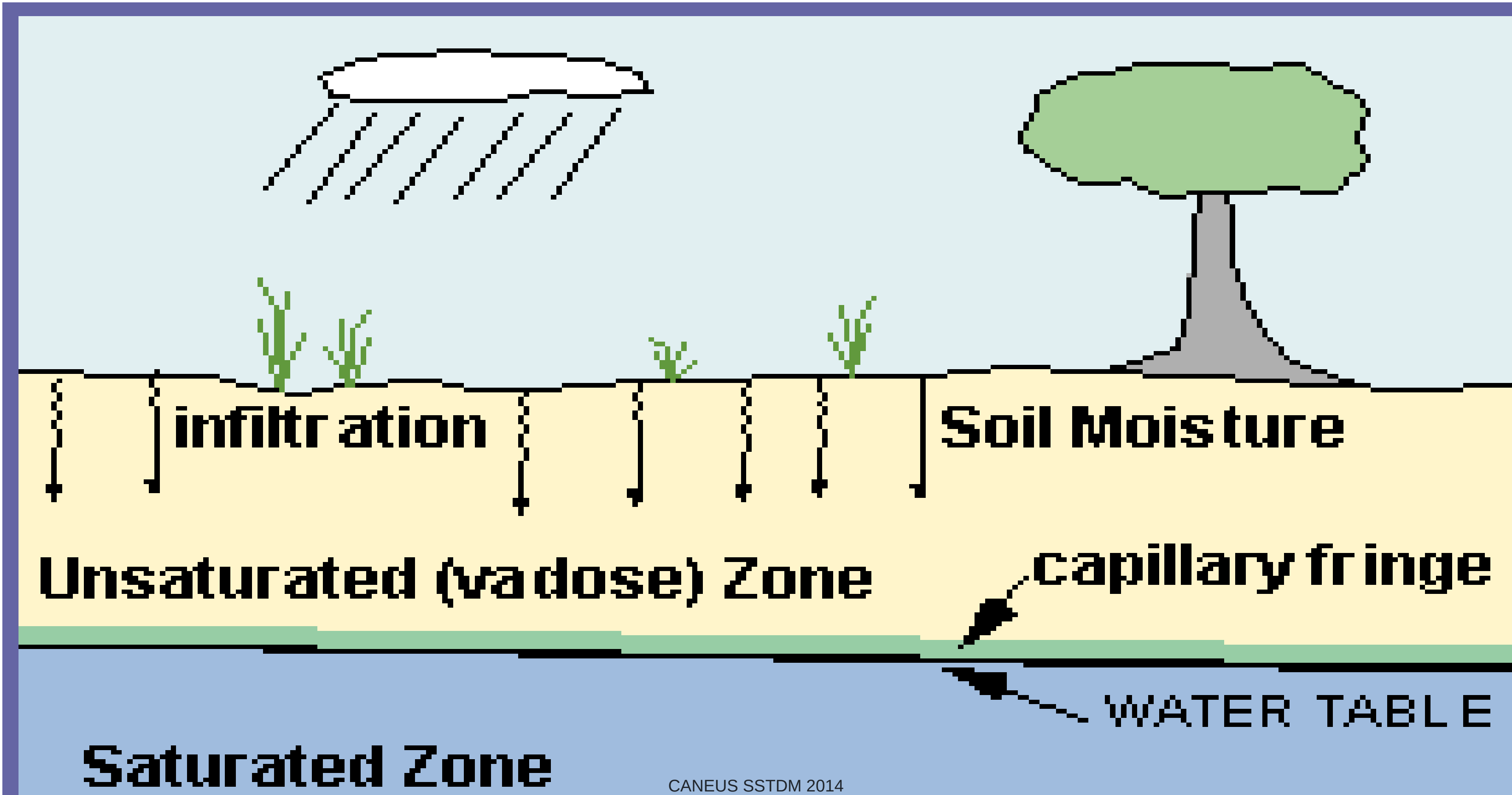


Annual Mean Evaporation– Precipitation

SOIL MOISTURE

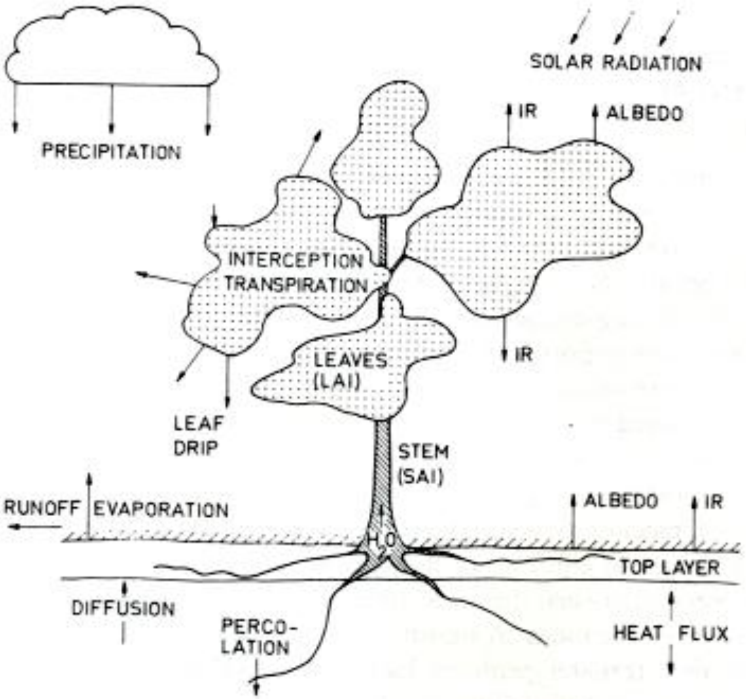
THE INHOMOGENEOUS ECOSYSTEM BOUNDARY LAYER

POTENTIALLY TRANSFORMATIVE KNOWLEDGE FOR FARMERS, MODELERS



SOIL MOISTURE VARIATIONS AFFECT THE EVOLUTION OF WEATHER & CLIMATE

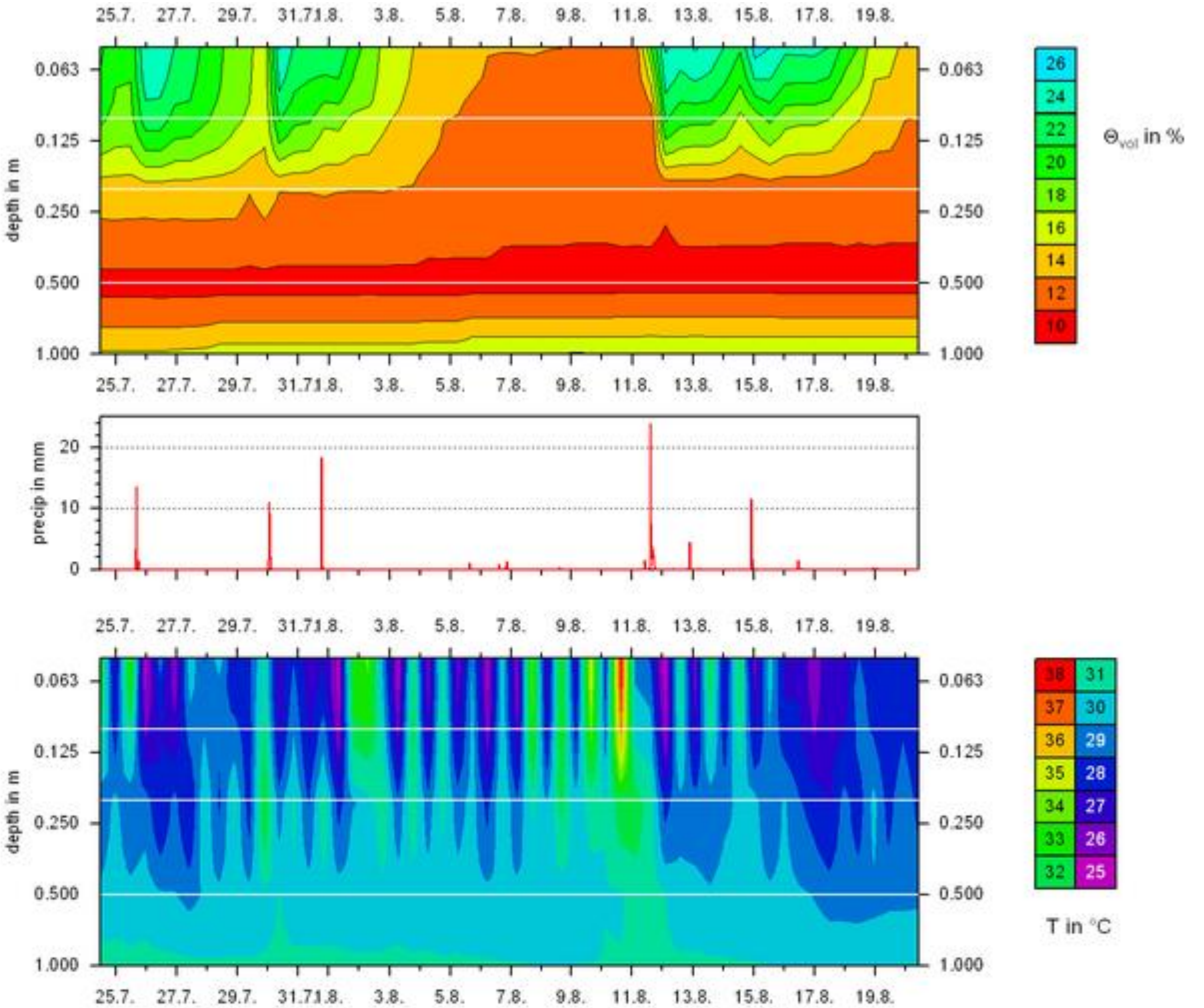
BECAUSE SOIL MOISTURE DETERMINES EVAPORATION & TRANSPIRATION RATES AT THE LAND-ATMOSPHERE BOUNDARY, AND THE HIGH LATENT HEAT OF WATER, IT EFFECTIVELY CONTROLS THE SURFACE ENERGY FLUX.



$$P - E = R_w + S_w - G_w \quad ; \quad R_h = S_h + L_h + TS_h - G_h$$

Volumetric soil moisture content, Θ_{VOL}, at different depth (top), precipitation (middle) and soil temperature, T, at different levels (bottom) 2006. The measurements were performed during the AMMA campaign 2006 at Bontioli, Burkina Faso (3°W , 11°N)

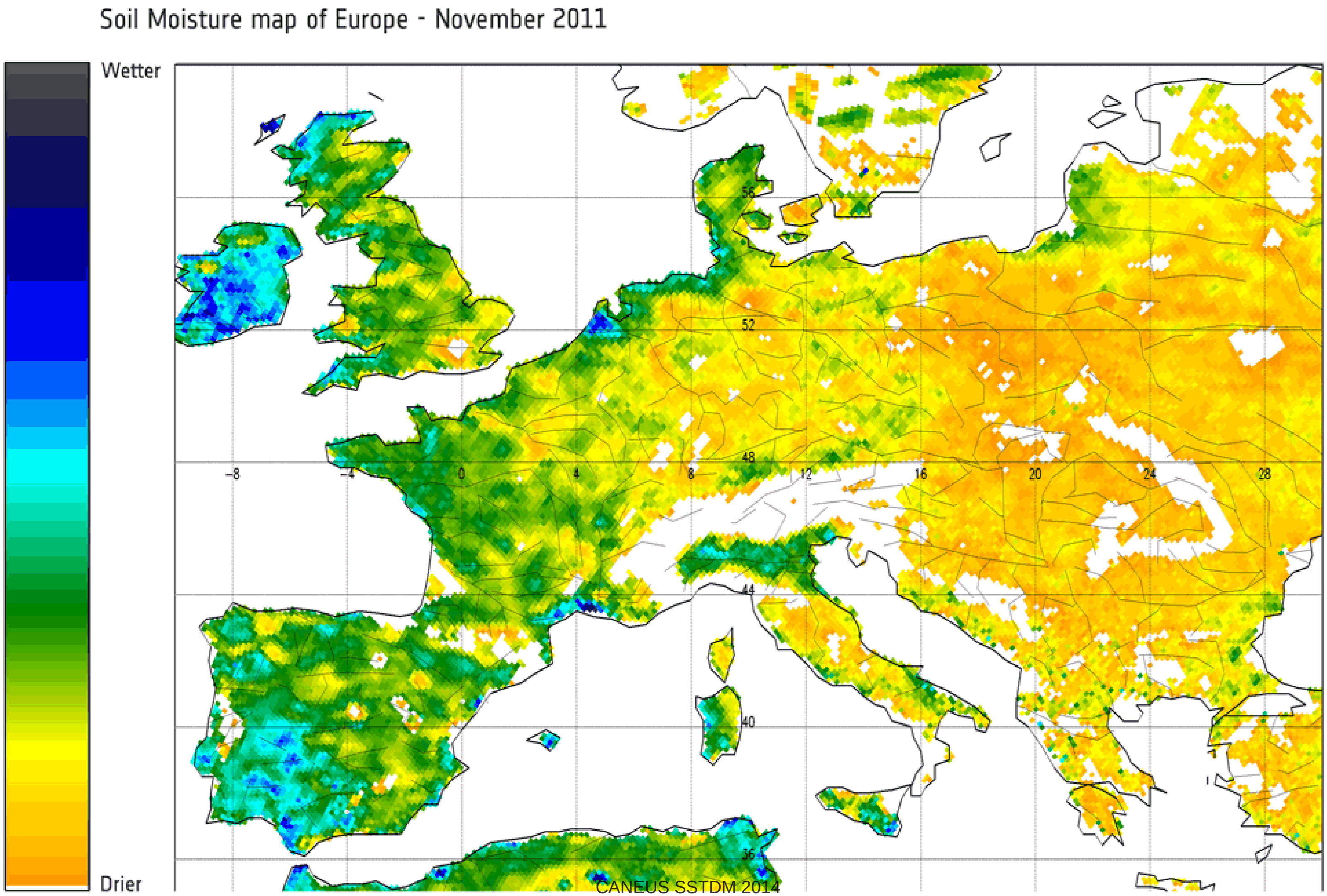
Koher et al. 2010

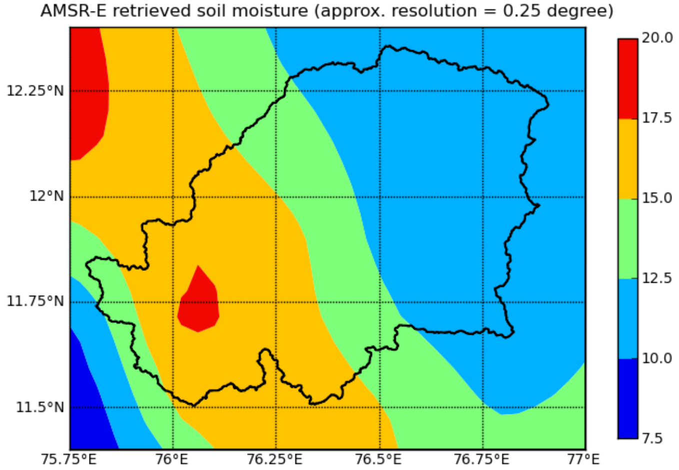


Soil Moisture Map of Europe from Space

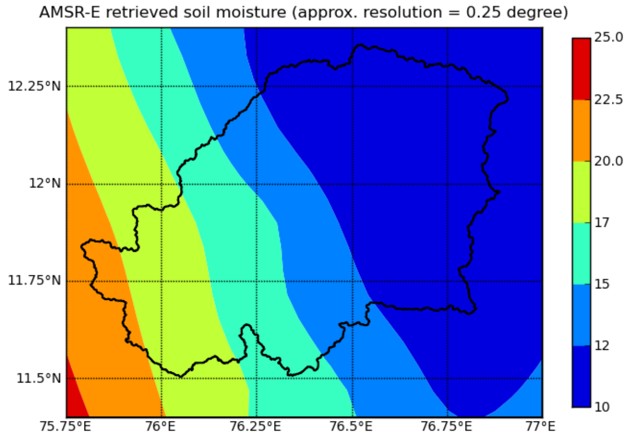
Possible because of the high Dielectric of Water

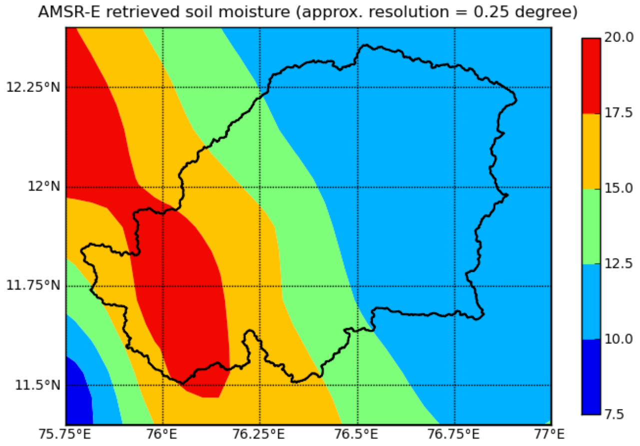
(~50 km, 4%)



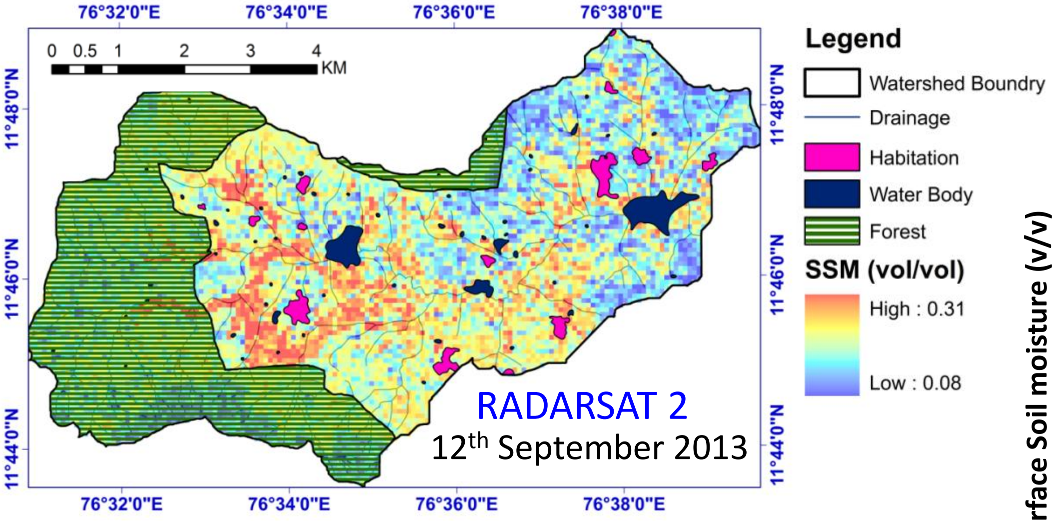


Soil Moisture from AMSR-E , caliberated and validated using the field measured surface soil moisture in a watershed of the Kabini basin in South India.



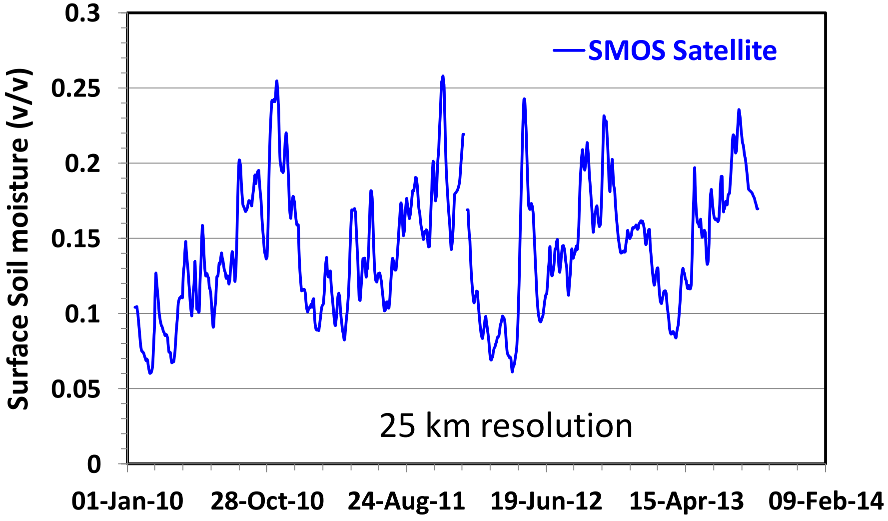


Retrieval of Surface Soil Moisture – RADARSAT 2 & SMOS



RADARSAT 2
12th September 2013

Disaggregation of SMOS soil moisture using RADARSAT 2 at AMBHAS site is evaluated.



25 km resolution

CAL/VAL of RADARSAT 2 at a spatial resolution of 100mx100m using 50 field plots in AMBHAS site (www.ambhas.com)

- time series of backscatter coefficients using CDF matching approach.
- water cloud model

SSM = WP + (FC-WP)*CDF(BC)

Where, SSM is surface soil moisture

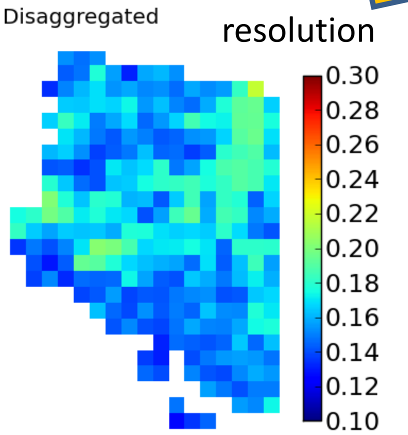
WP is wilting point; FC is field capacity

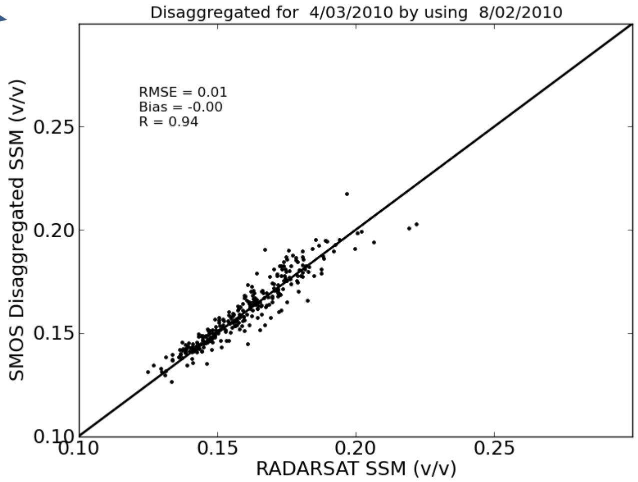
CDF is cumulative density function

BC is backscatter coefficient

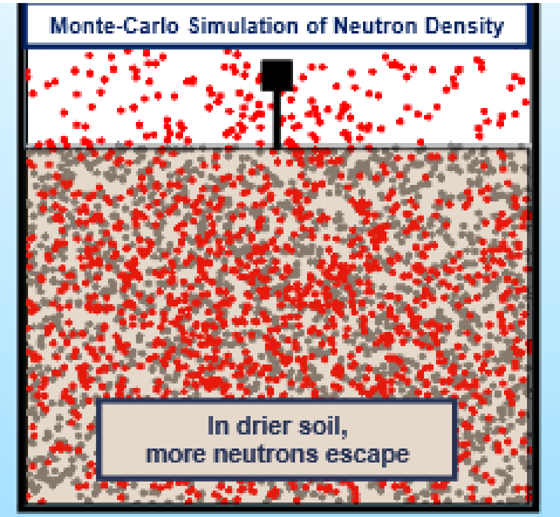
Tomer , Kerr, Sekhar et al. (2014). ***Microrad****, JPL, March 25-27, 2014*

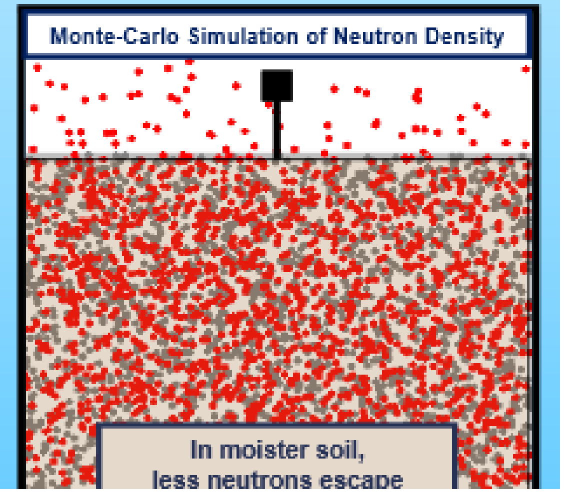
100 m resolution

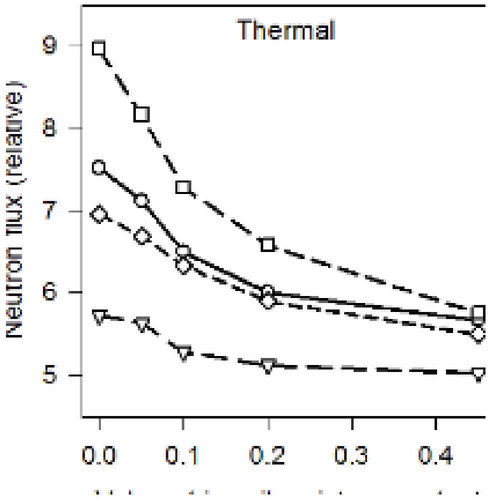


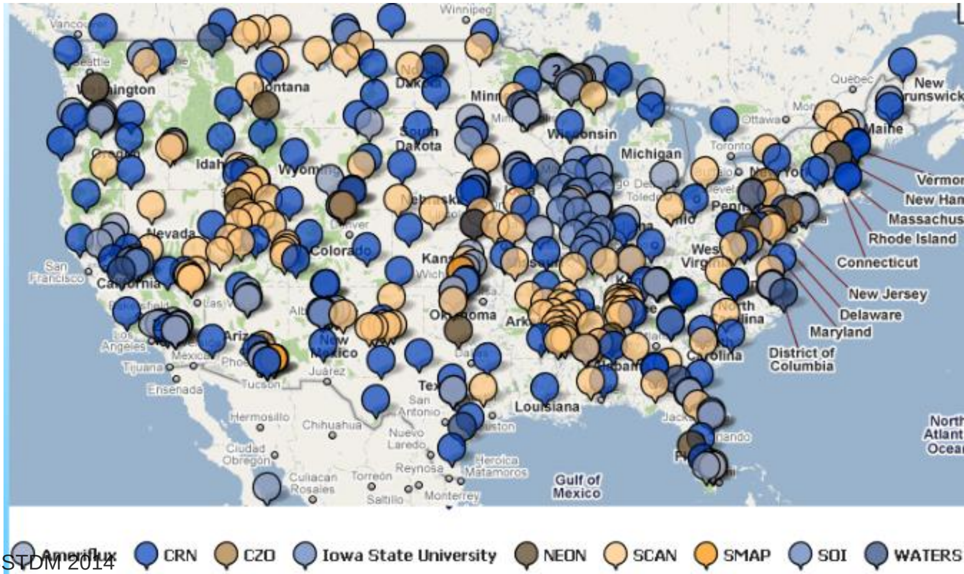


Fruitful Possibility of Bayesian Estimation of Soil Moisture Determined from the density of Cosmic Ray Induced Neutrons + That from Satellites

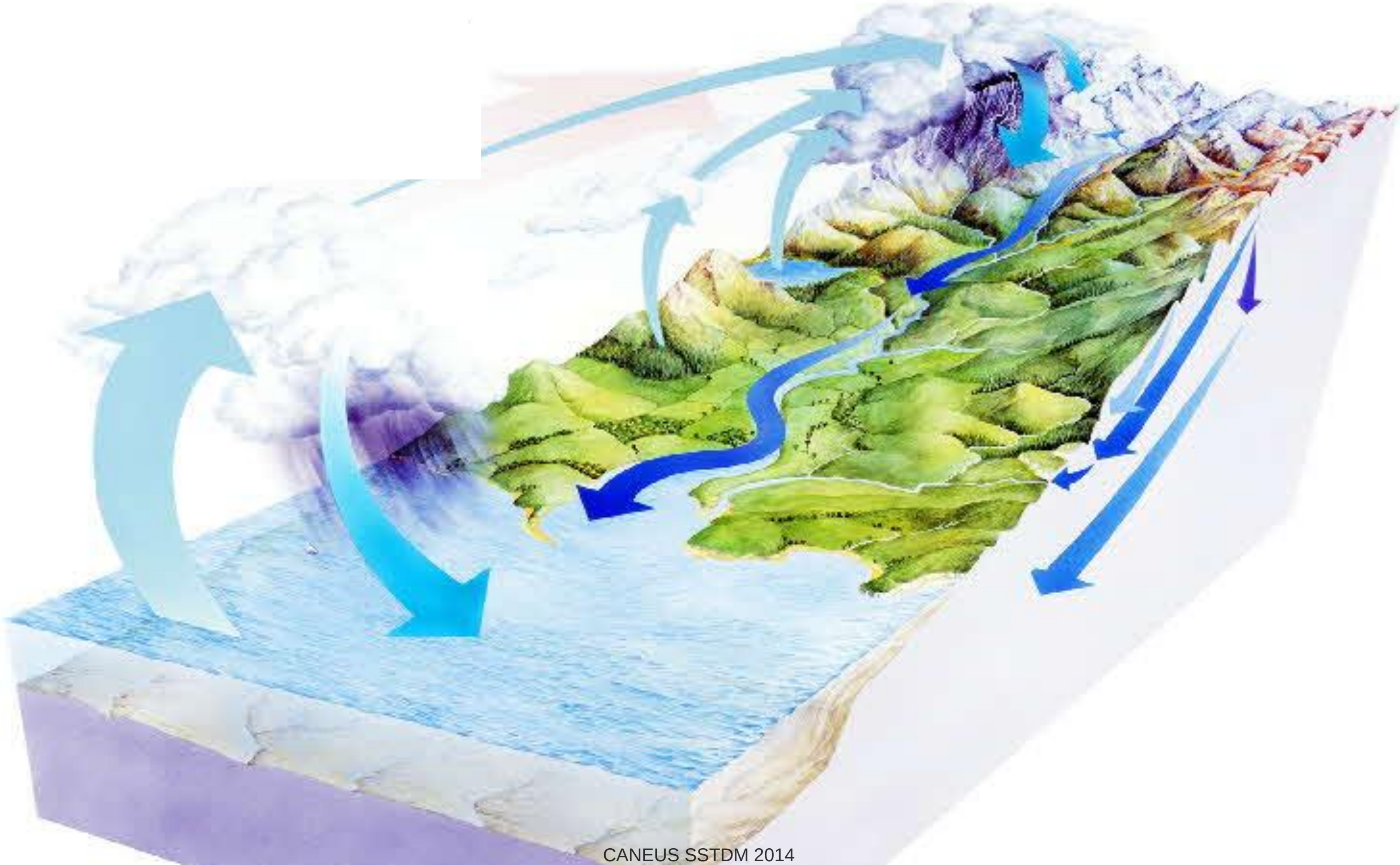


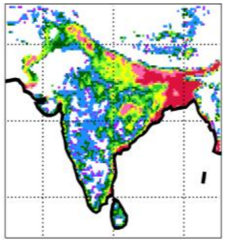






PRECIPITATION – ET – STREAM RUN OFF IS ALL THE WATER AVAILABLE FOR CONSUMPTION

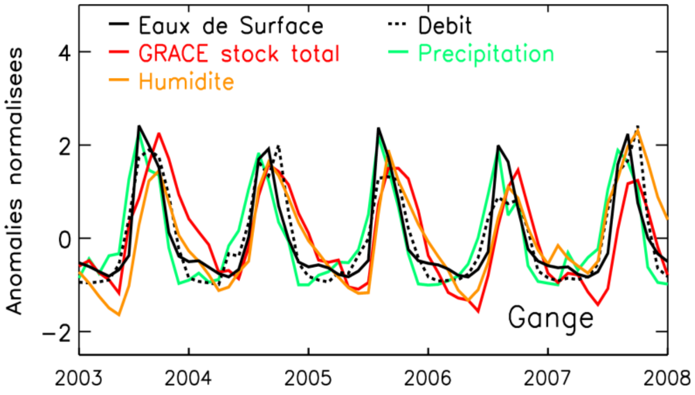




Variations of continental water storage components over the Indian subcontinent

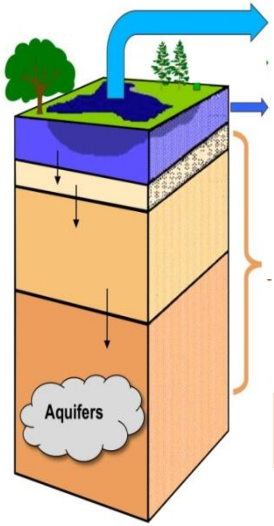
Now

Near-future



Papa et al., 2006, 2008, 2010ab

Total water storage (GRACE)



Surface water → **Storage** = flood extent + altimetry.+ DEM

Soil moisture RZ → **Storage**= AMSR-E, SMOS, modeling

To **isolate the "Groundwater" components:**

Ground-water → **Storage**= GRACE TWS (Surface water+soil moisture)

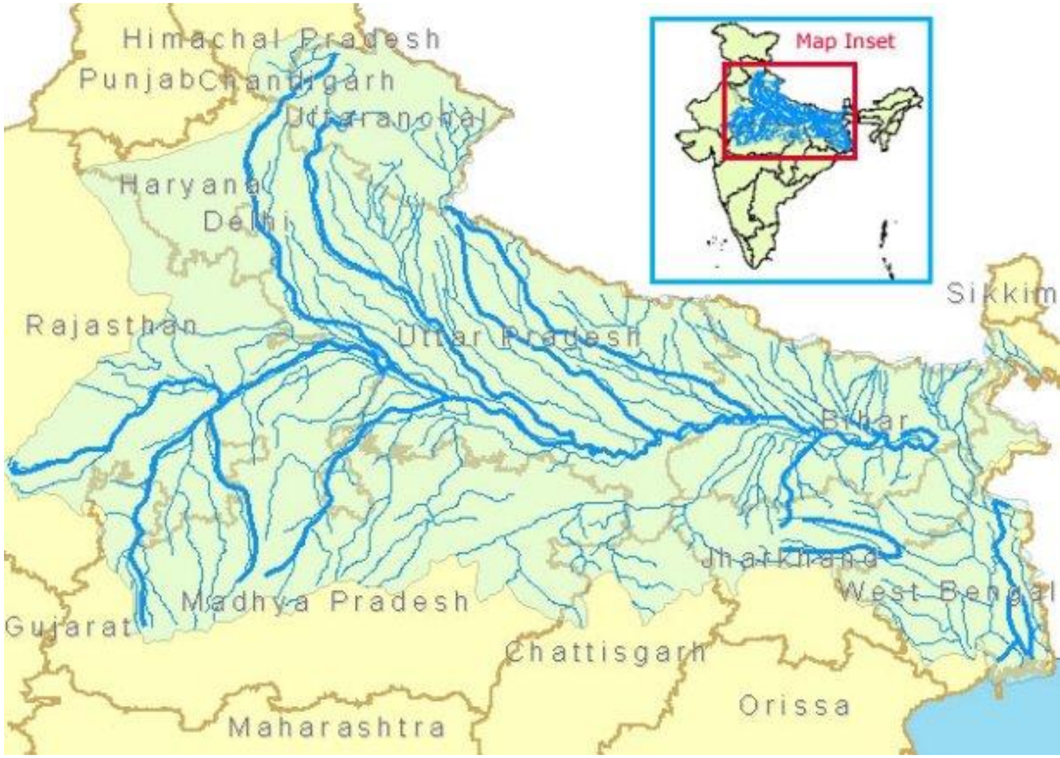
Understanding processes/ Variability/ Trend; Better closure of the terrestrial water budget.

Climate vs anthropogenic, Interactions

KNOWLEDGE OF STREAM FLOWS
CRITICAL USES BUT RARE AVAILABILITY

1. Calculating the Available Water Budget
2. Planning, designing, operating multipurpose water systems.
3. Flood Plains Management and Advance Warnings
4. Monitoring environmental conditions and aquatic habitats
5. Managing Water Rights and Trans-boundary Water Issues
6. River basin Systems Analysis

Creative Opportunities for Research & Development



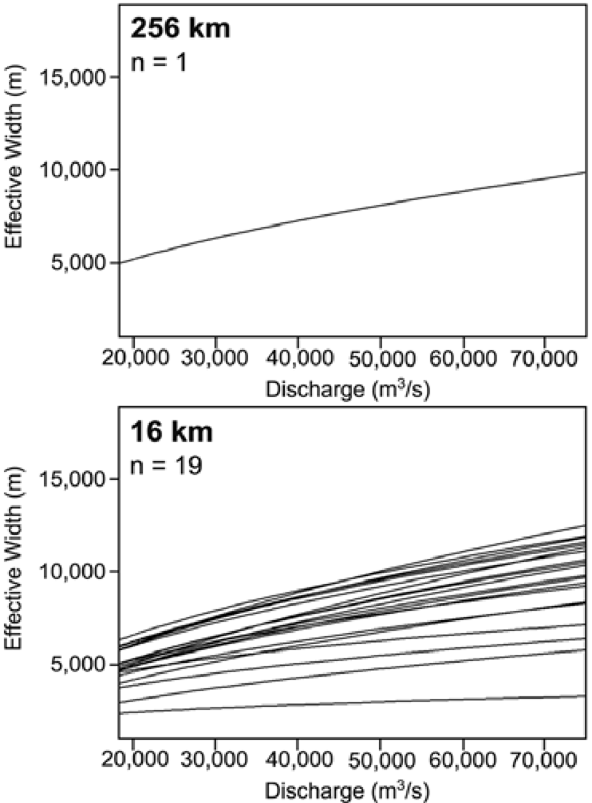
Traditional Stream Discharge Measuremets use:

$$Q = v\ w\ d$$

$$w = a\,Q^{k},\ v = b\,Q^{l},\ d = cQ^{m}$$

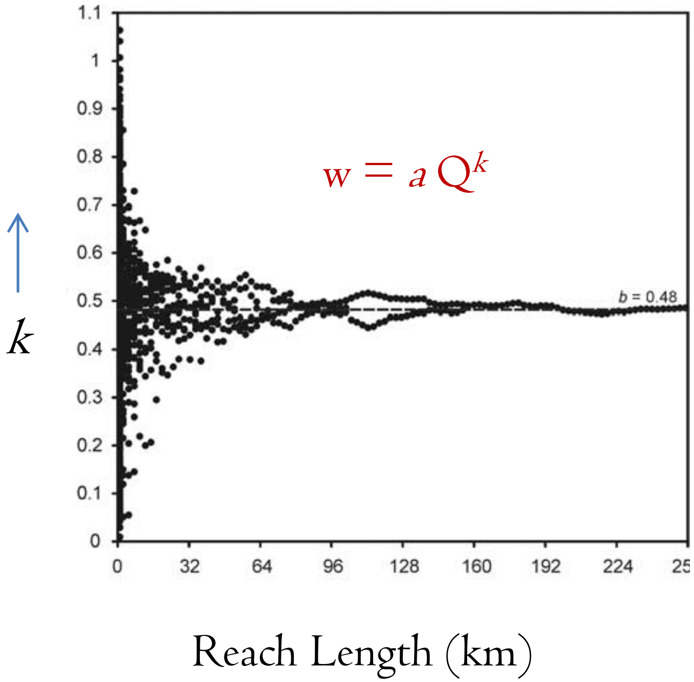
Where, $a \times b \times c = 1$, and $k + l + m = 1$, k a Diagnostic of the River's Form

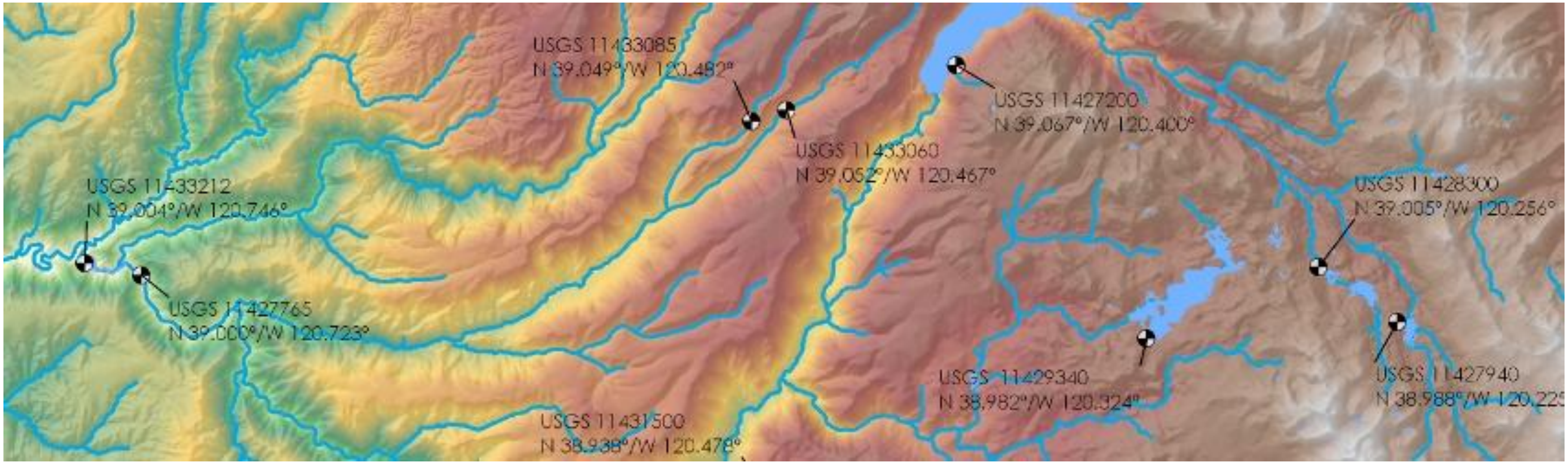
Figure Below left: Rating Curve's for different River Reaches, show Increasing Similarity with Reach length', making $Q \propto w$



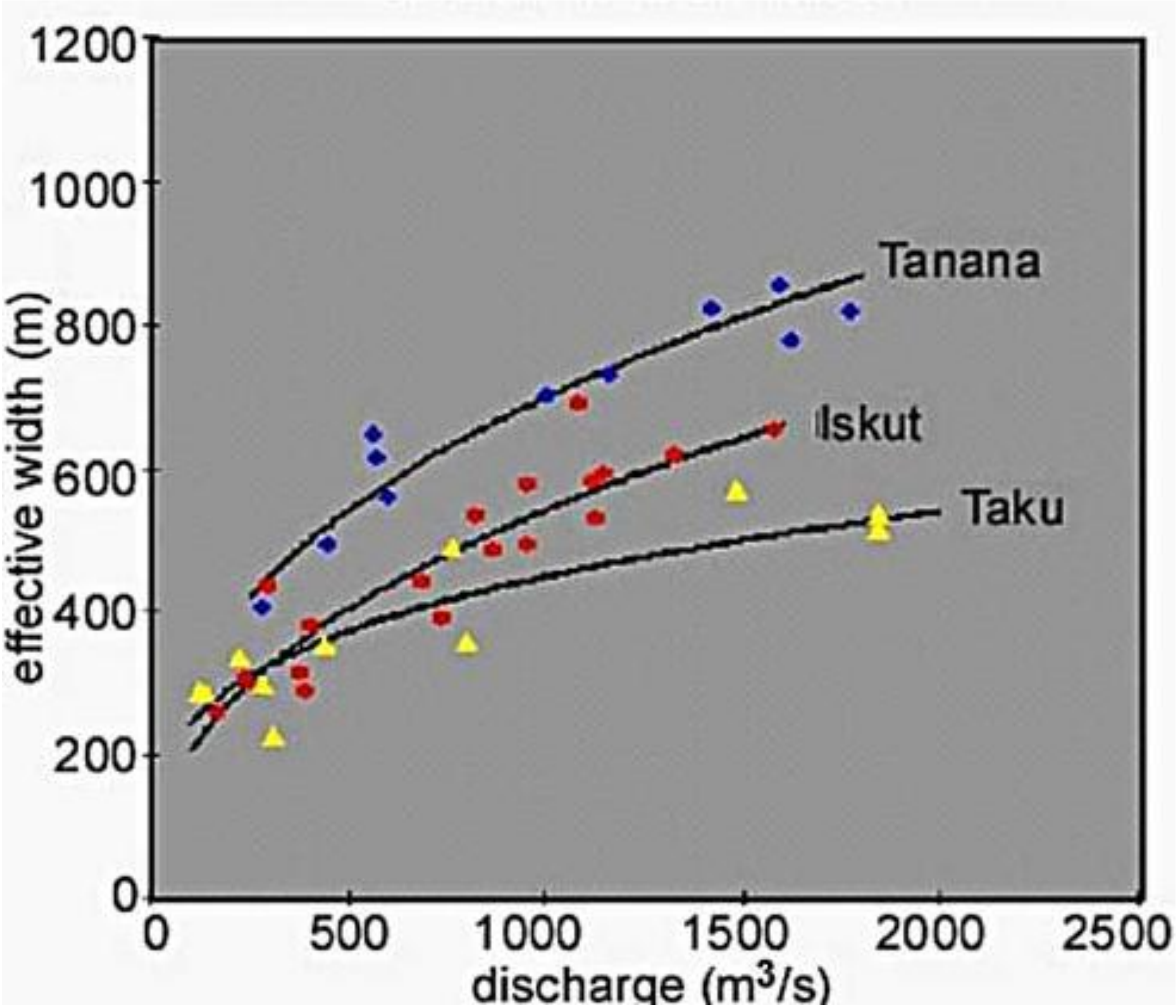
SPACE BASED DETERMINATION OF STREAM FLOW DATA

THE W_e – Q RATING CURVES FAIRLY CONSTANT FOR RL > 60 KM





EFFECTIVE WIDTH VS. DISCHARGE: ISKUT, TANANA AND TAKU RIVERS (3 BRAIDED RIVERS OF THE ARCTIC)

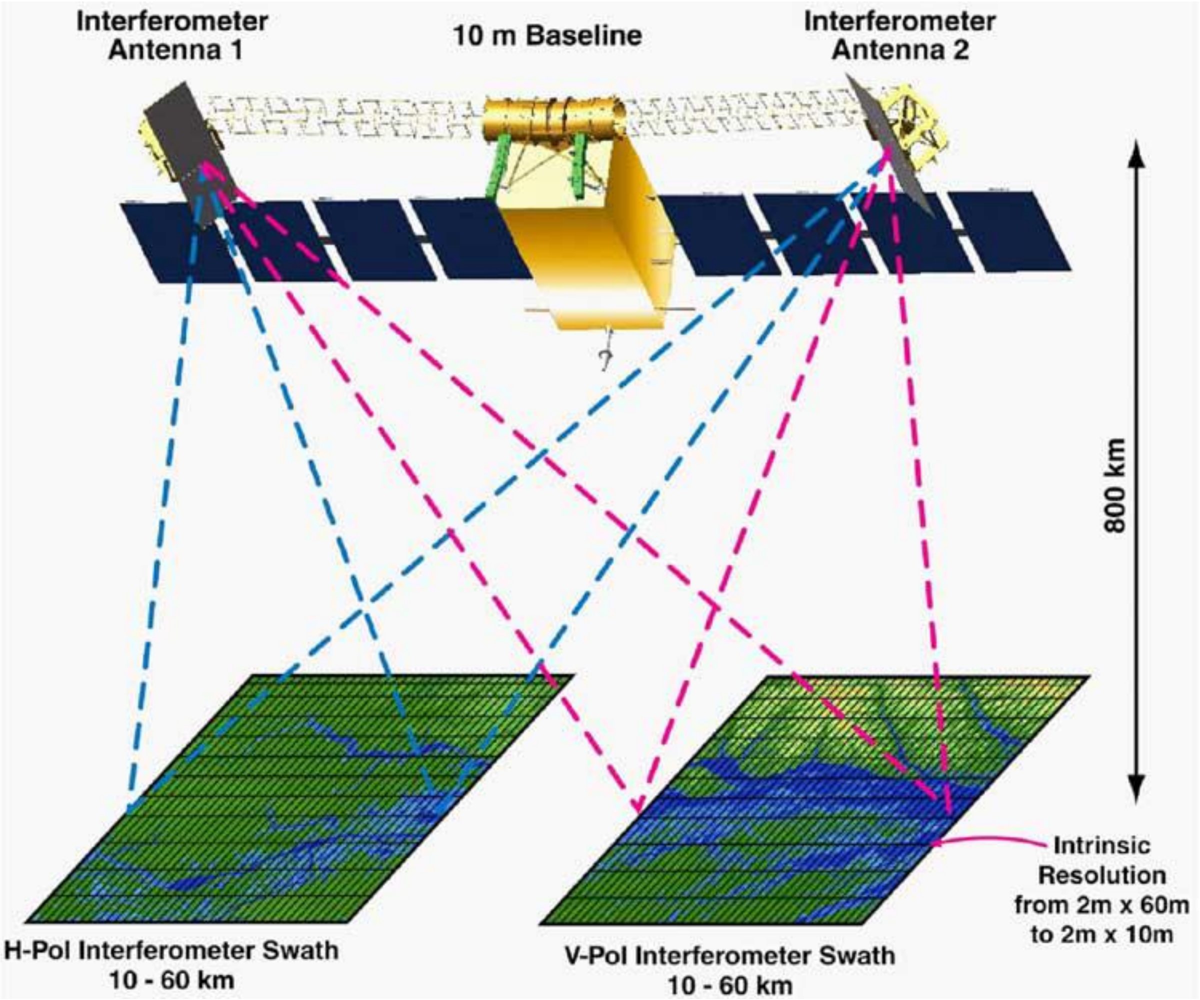


STABLE SCALING LAWS ALLOW CREDIBLE ESTIMATES OF FLOWS FROM SATELLITE MEASUREMENTS OF EFFECTIVE STREAM WIDTH, We

THE KA BAND RADAR INTERFEROMETRIC ALTIMETER OPERATES VERY NEAR NADIR RECEIVING STRONG RADAR RETURNS.

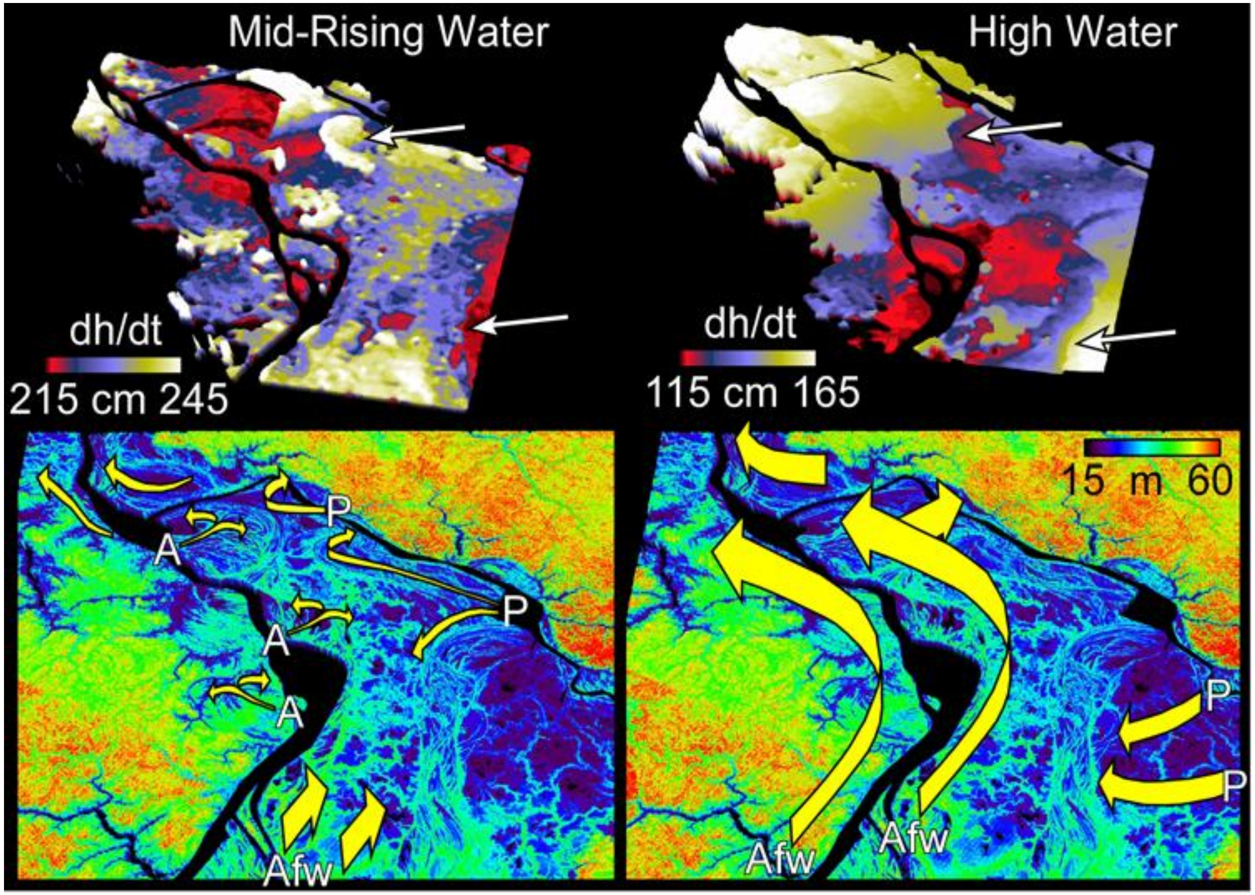
AT KA BAND THE INTERFEROMETER PENETRATES CLOUDS. IT RELIES ON SUBTLE CANOPY OPENINGS (~ 20 %) TO ACCESS UNDERLYING WATER SURFACES

A CONCEPTUAL VIEW OF KARIN.



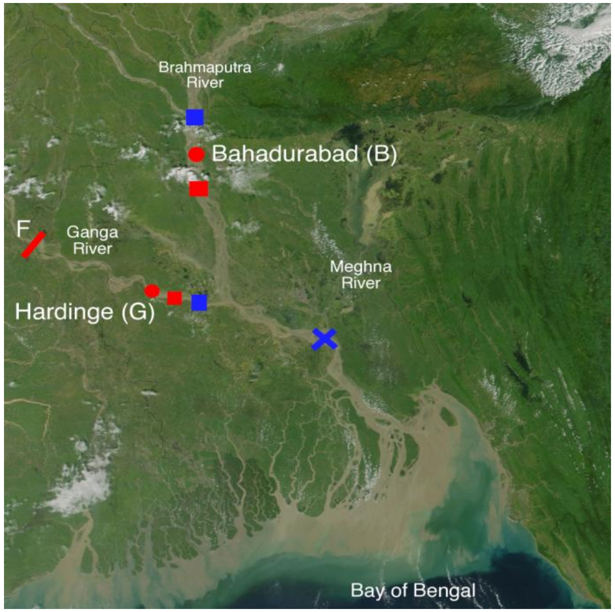
SATELLITES AFFORD A VANTAGE POINT TO MEASURE:

h, $\partial h/\partial t$, and $\partial h/\partial x$



(top) Changes in water levels $\partial h/\partial t$ and (bottom) perspective views of central Amazon

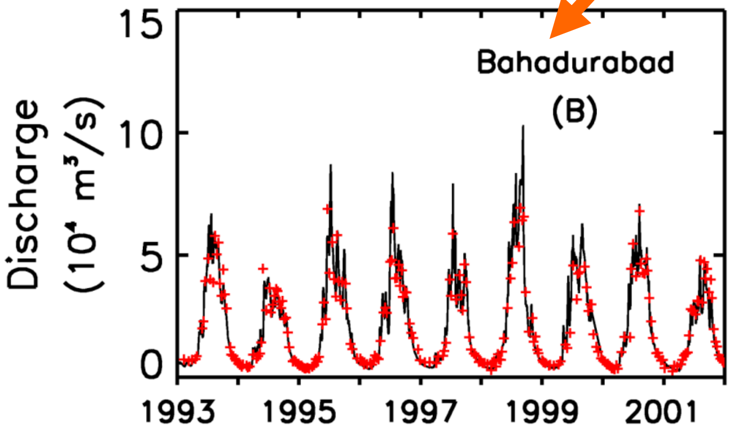
Radar altimetry to estimate river discharge.



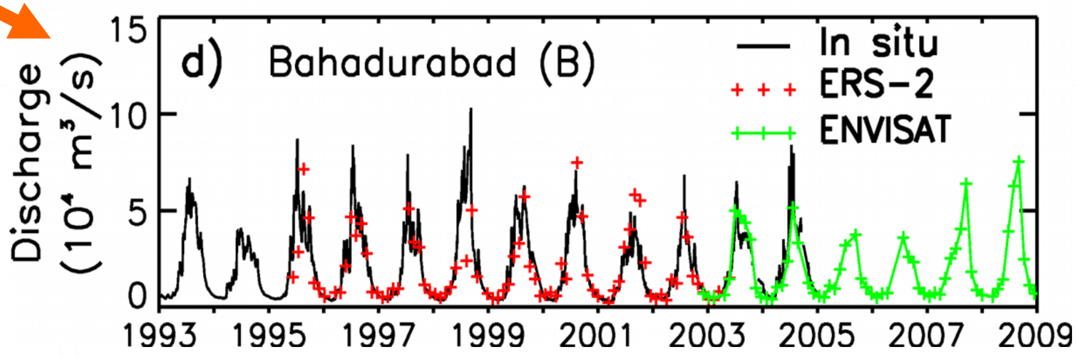
Relationship between altimeter river height and in situ river discharge for Bahadurabad.
Ex: Every 10/35 days (TOPEX, ERS-2, ENVISAT) and when the discharge is available, we compare the two observations and construct the "rating curve".

Discharge=f(Height), with f a polynomial function

Missing Q and Q time series can be extended using H from altimetry and the rating curve.



The same methodology is applied for both stations and all altimeters to estimate monthly G+B discharge



Ganges+Brahmaputra estimate over 1993-2008:
Annual mean = 32350 m^3/s
Typical error = 2700 m^3/s

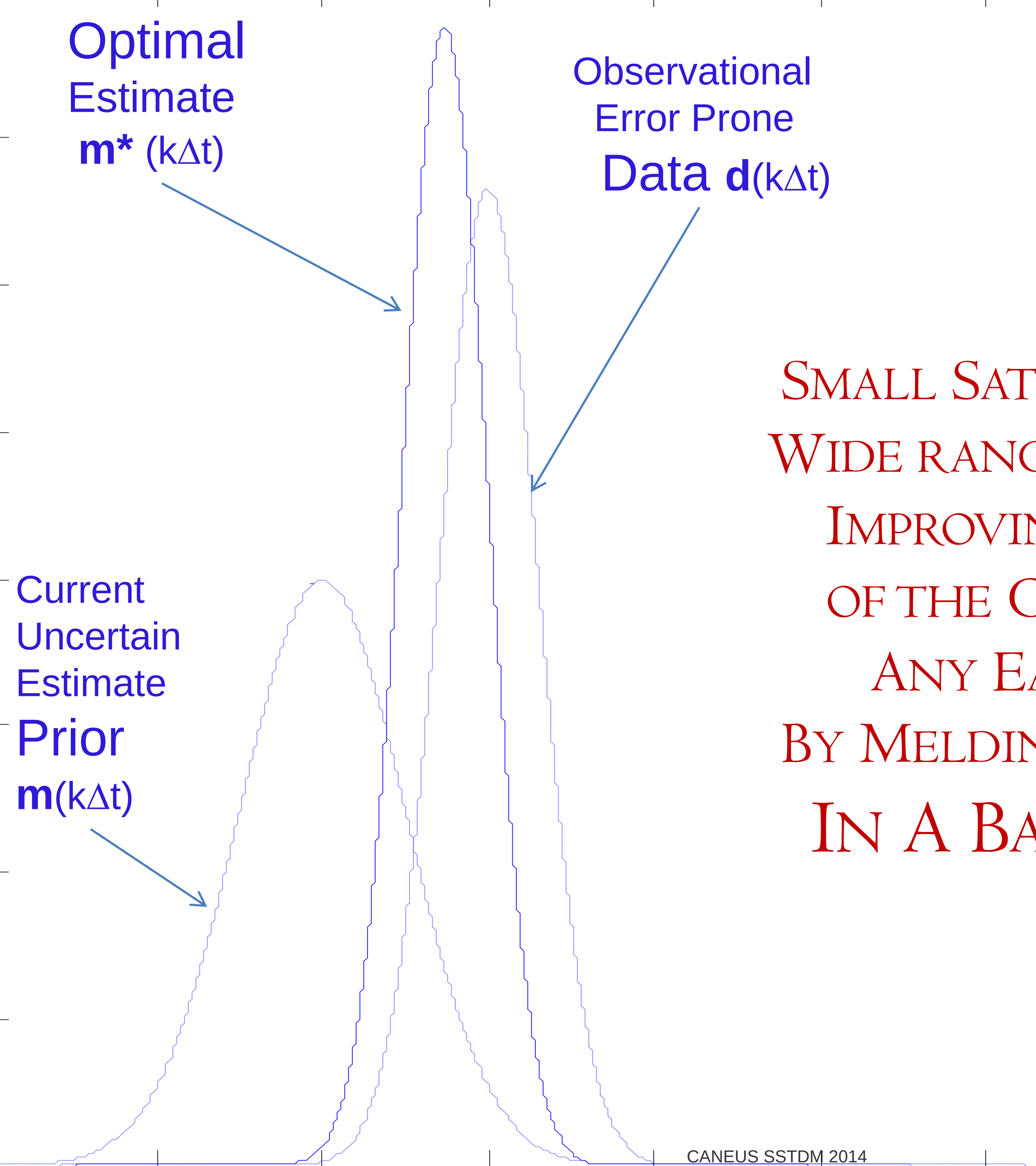
Comparisons between altimeter and *in situ* river heights for 2008-2011:
seasonal range = 7 meters, error = 17 cm

Papa et al., 2010b, 2012 JGR

Small Satellites with Frequent Passes Encourage the Possibility of using innovative approaches

e.g.,

Temporal variability of the 3-Dimensional Water Volume over a defined Control Area



SMALL SATELLITES OFFER THE WIDE RANGING POSSIBILITY OF IMPROVING KNOWLEDGE OF THE CURRENT STATE OF ANY EARTH SYSTEM BY MELDING DIVERSE DATA SETS IN A BAYESIAN FUSION

CHALLENGES

1. DEVELOPMENT OF COMPACT, LOW POWER SENSORS TO MATCH THE MINIATURIZATION OF SATELLITE SUPPORT HARDWARE

EXAMPLE: CIRCULARLY POLARIZED SYNTHETIC APERTURE RADAR

2. INCISIVE SIGNAL PROCESSING AND SIGNAL DESIGN TO ACCOMPLISH THE CONTRASTING REQUIREMENTS OF WIDE SWATH AND HIGH RESOLUTION