The Indian-French TRISHNA mission
Monitoring our ecosystem health from space

J.-L. Roujean [1], B. Bhattacharya [2], P. Gamet [1], M.R. Pandya [2], G. Boulet [1], A. Olioso [3], S.K. Singh [2], M. V. Shukla [2], M. Mishra [2], S. Babu [16], P. V. Raju [15], C.S. Murthy [15], X. Briottet [4], A. Rodler [5], E. Autret [6], I. Dadou [7], D. Adlakha [2], M. Sarkar [2], G. Picard [8], A. Kouraev [7], C. Ferrari [9], B.M. Irvine [10], E. Delogu [11], T. Vidal [12], O. Hagolle [1], P. Maisongrande [11], M. Sekhar [14], K. Mallick [13]

The Indian-French TRISHNA mission
Monitoring our ecosystem health from space

TRISHNA

1. **Background**
2. Challenges
3. Mission

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Signs of warming

Ecosystem stress	Urban Heat Island	Flooding	Extreme Events
Drought	Sea Rise	Shrinking Ice Sheets	Retreat of Glaciers

TRISHNA

1. **Background**
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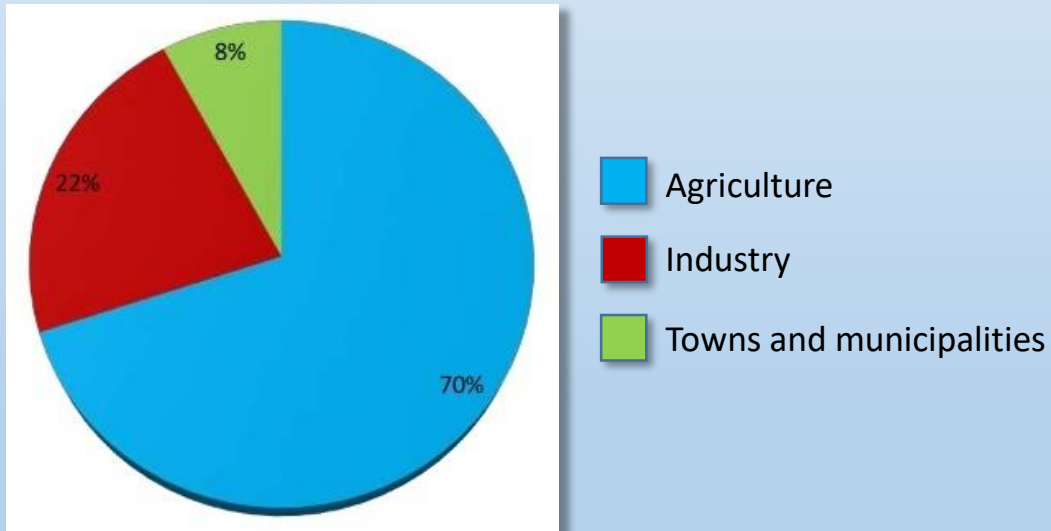
Increasing scarcity and deteriorating quality of the water resource

70% of World water use is for agriculture **!**

World water use

- Agriculture
- Industry
- Towns and municipalities

Source: World Bank, World Development Indicators, 2012

Rapid increase of water consumption

Cubic km per year

Agriculture — Forecast
Domestic use — Forecast
Industry — Forecast

Extraction
Consumption (Agriculture)

Extraction
Consumption (Domestic use)

Extraction
Consumption (Industry)

The grey band represents the difference between the amount of water extracted and that actually consumed. Water may be extracted, used, recycled (or returned to rivers or aquifers) and reused several times over. Consumption is final use of water, after which it can no longer be reused. That extractions have increased at a much faster rate is an indication of how much more intensively we can now exploit water. Only a fraction of water extracted is lost through evaporation.

Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

Trends in water use by sector (UNEP)

(http://www.unep.org/dewa/vitalwater/article43.html)
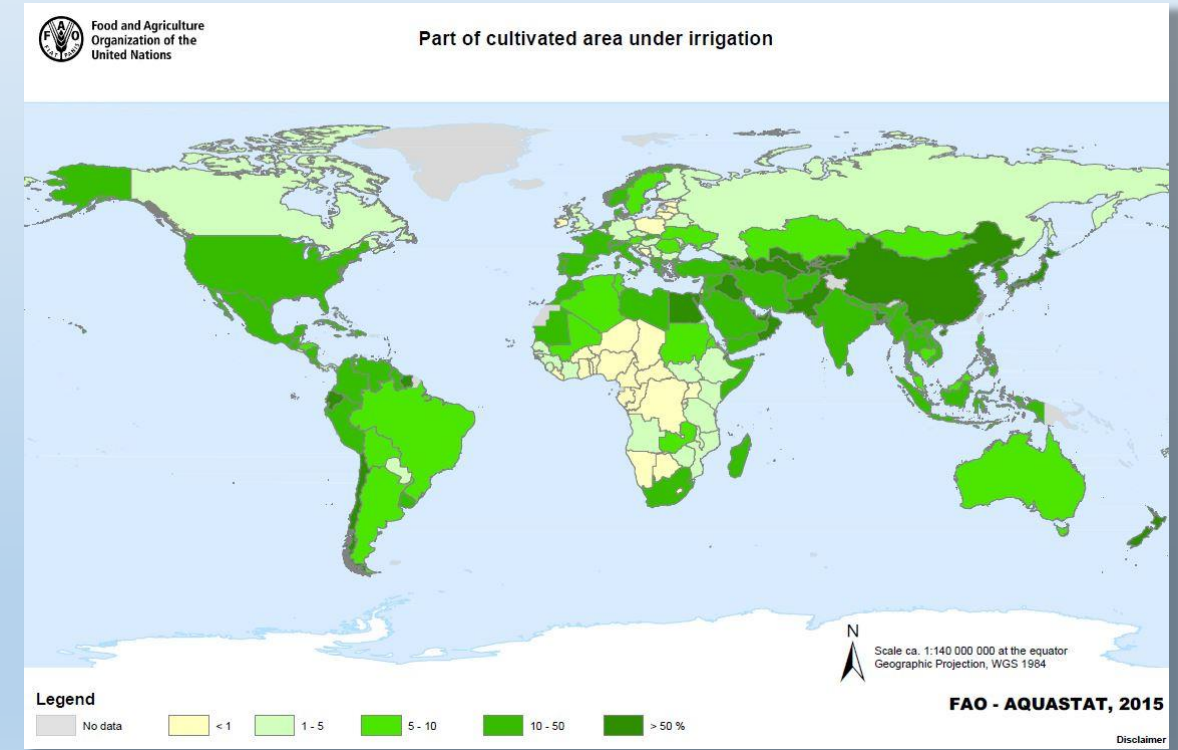
Increasing scarcity and deteriorating quality of the water resource

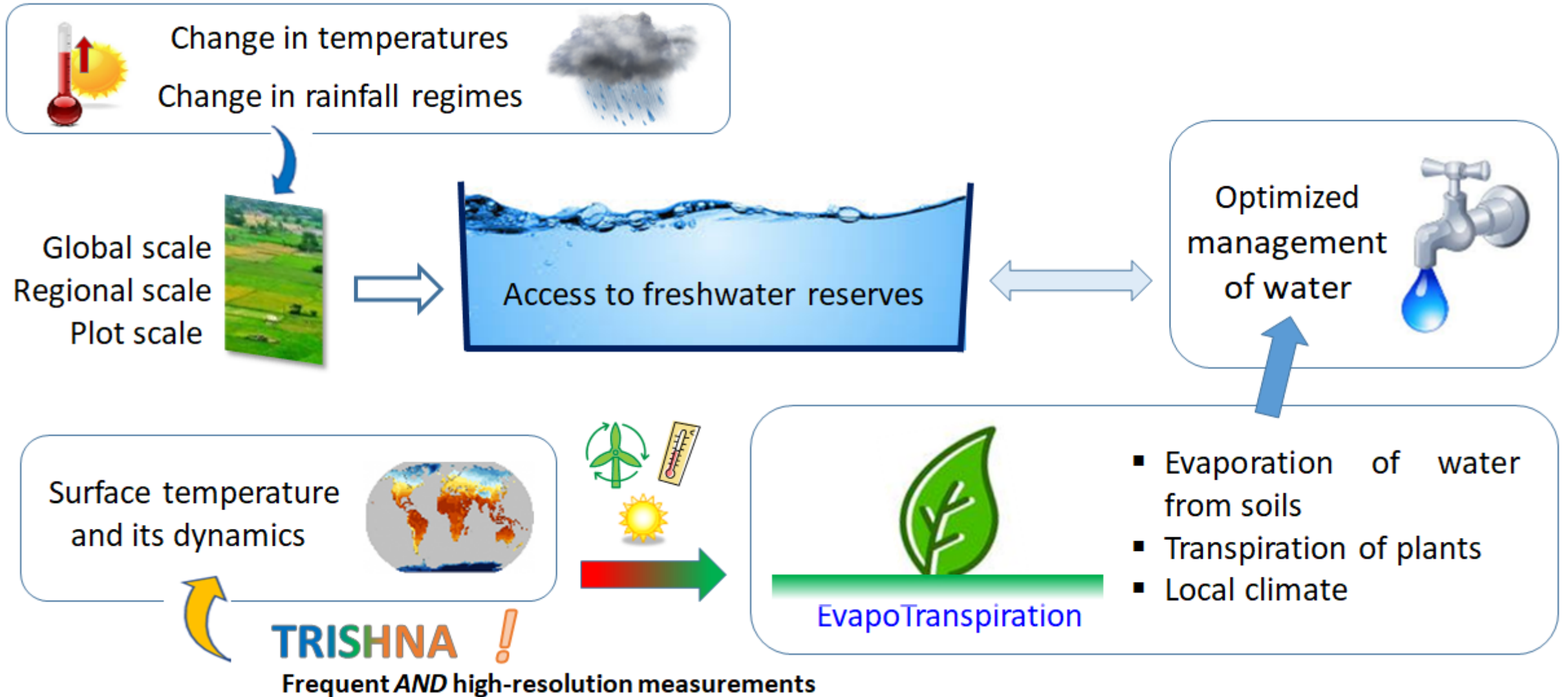**Proportion of total water withdrawal withdrawn for agriculture**
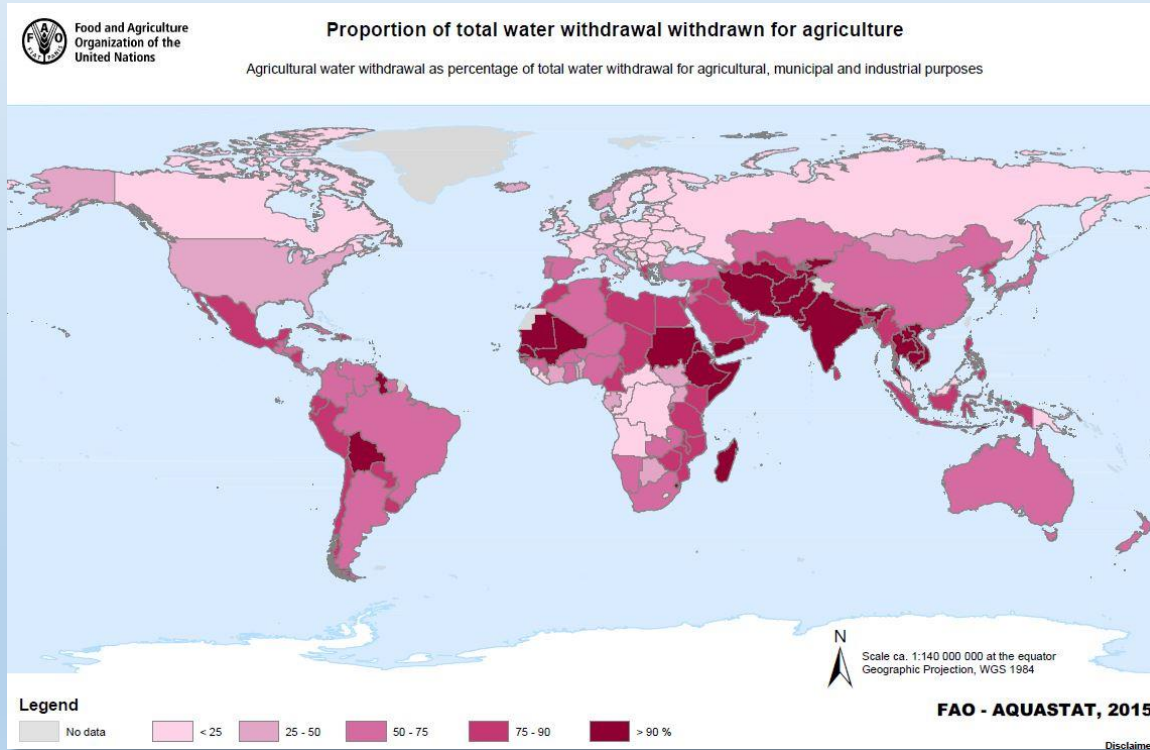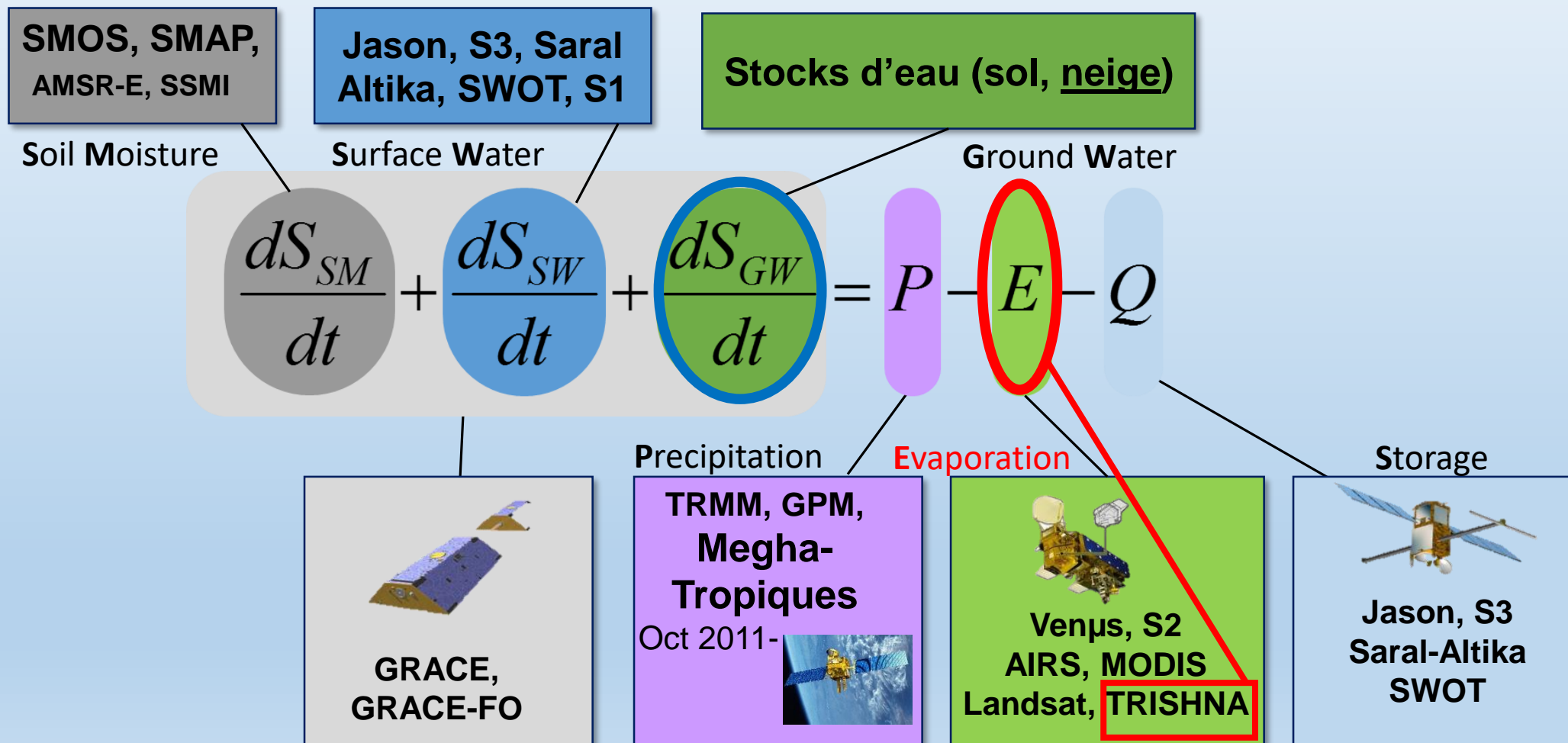
Part of cultivated area under irrigation

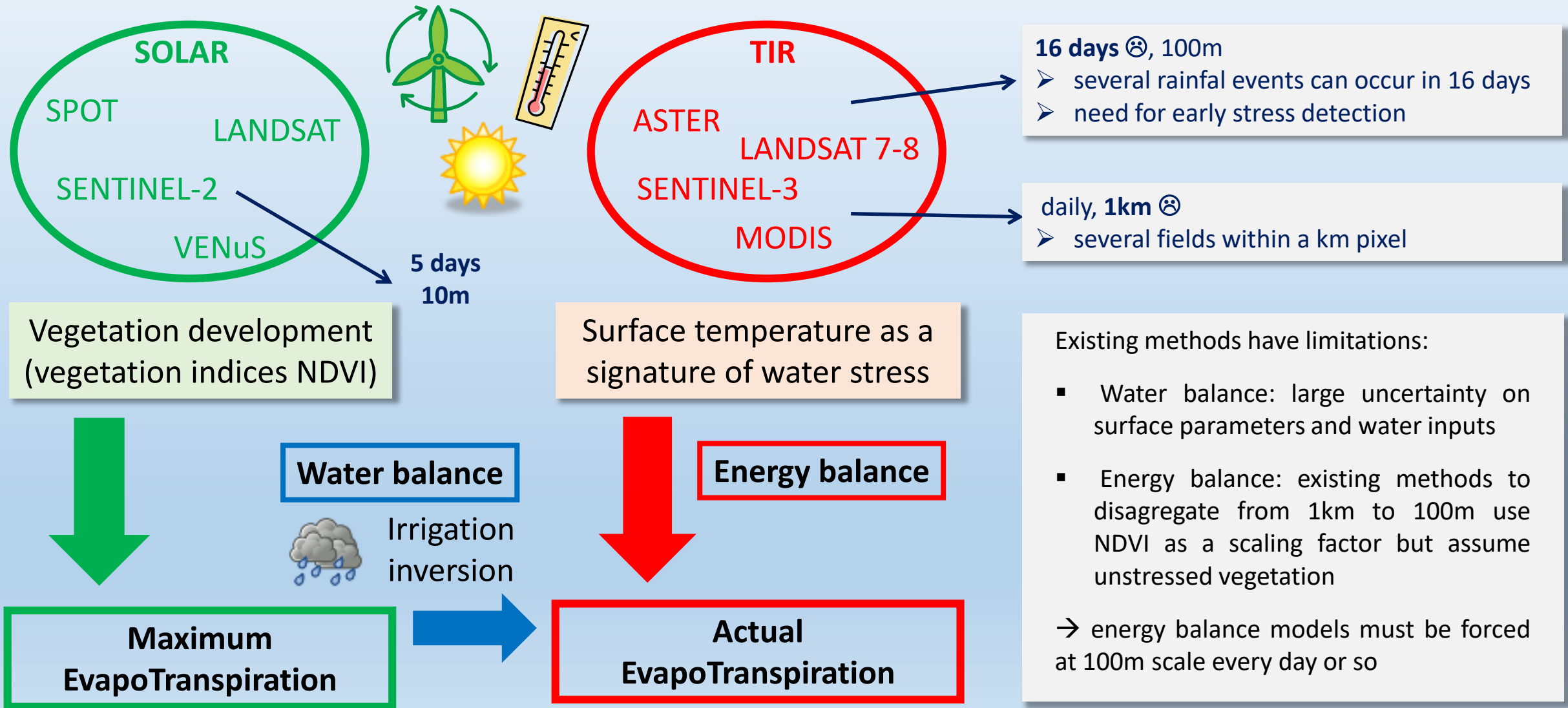**20% arable land irrigated → 45% food production (FAO)**
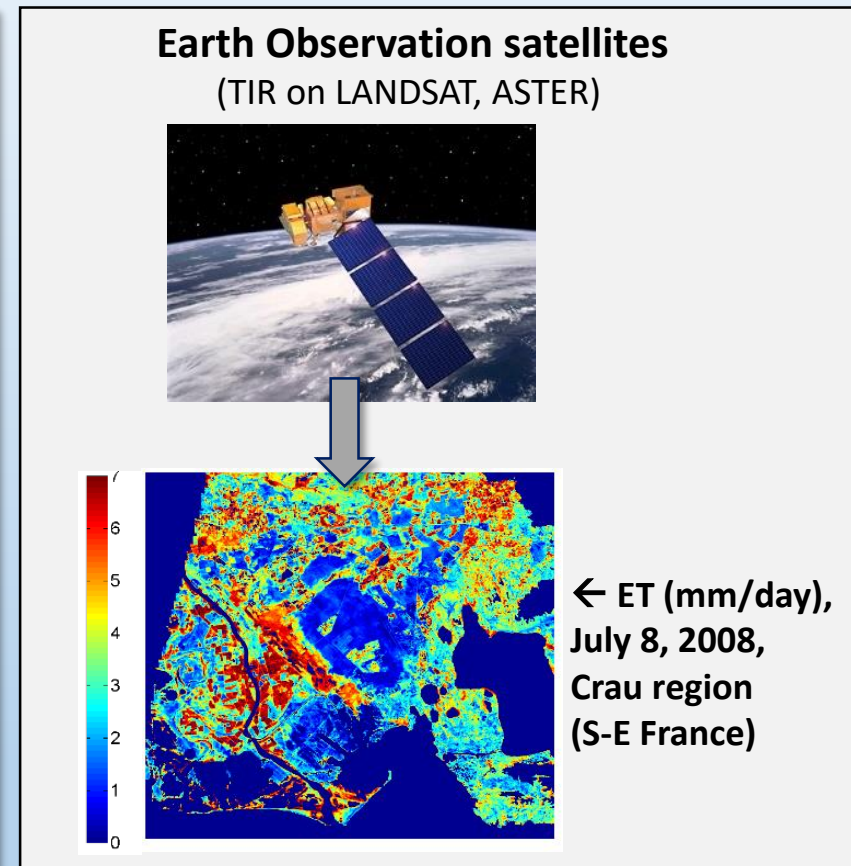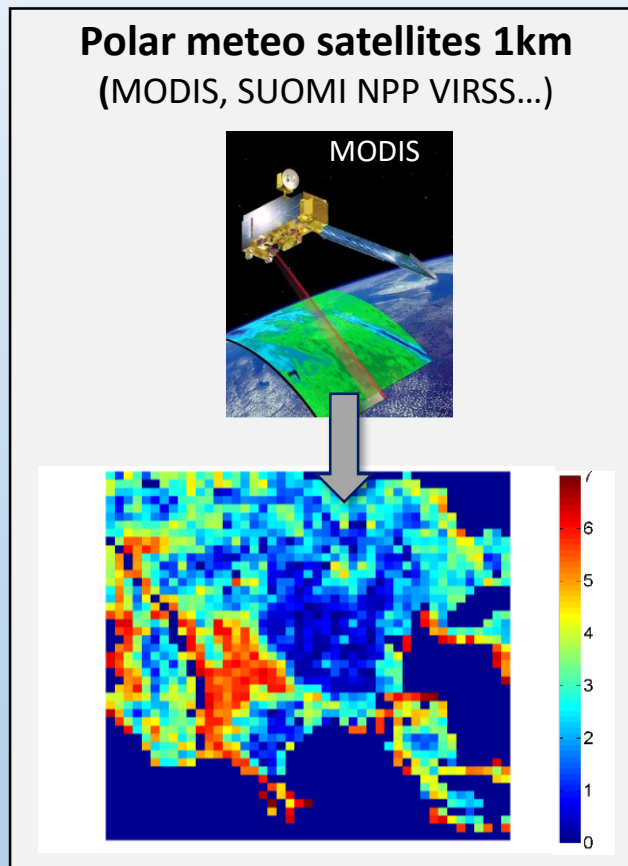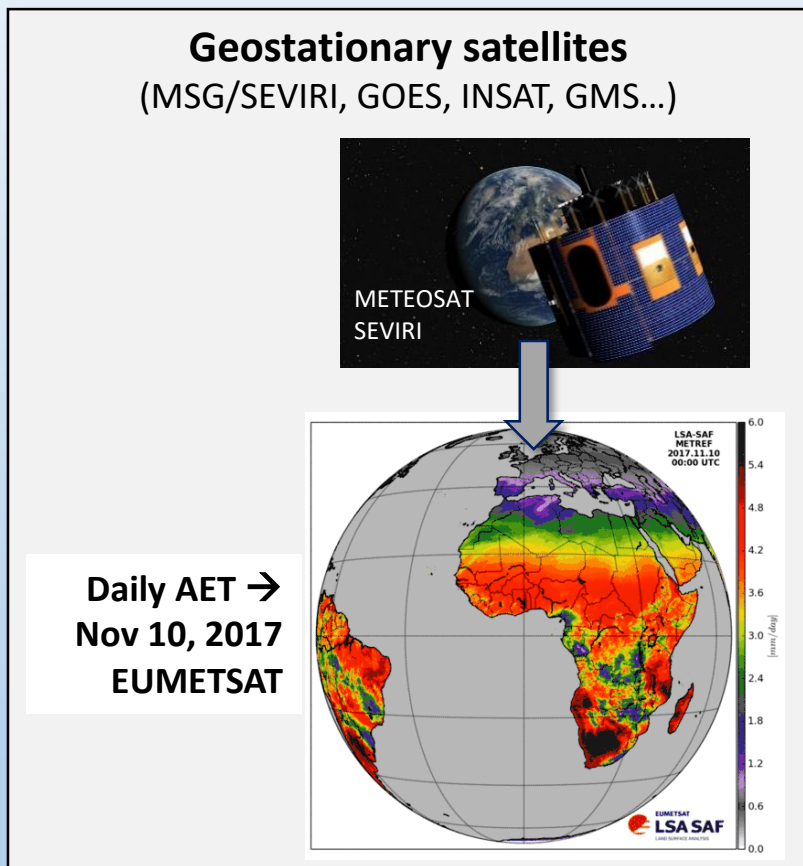
TRISHNA and the management of water resource

Water cycle

SMOS, SMAP, AMSR-E, SSMI

Jason, S3, Saral Altika, SWOT, S1

Stocks d'eau (sol, neige)

Soil **M**oisture

Surface **W**ater

Ground **W**ater

$$\frac{dS_{SM}}{dt} + \frac{dS_{SW}}{dt} + \frac{dS_{GW}}{dt} = P - E - Q$$

Precipitation

Evaporation

Storage

TRMM, GPM, Megha-Tropiques
Oct 2011-

GRACE, GRACE-FO

Venμs, S2 AIRS, MODIS Landsat, TRISHNA

Jason, S3 Saral-Altika SWOT

Computing EvapoTranspiration with remote sensing data

SOLAR

SPOT

LANDSAT

SENTINEL-2

VENuS

5 days 10m

TIR

ASTER

LANDSAT 7-8

SENTINEL-3

MODIS

16 days ☹, 100m
➢ several rainfal events can occur in 16 days
➢ need for early stress detection

daily, **1km** ☹
➢ several fields within a km pixel

Vegetation development (vegetation indices NDVI)

Surface temperature as a signature of water stress

Water balance

Energy balance

Irrigation inversion

Maximum EvapoTranspiration

Actual EvapoTranspiration

Existing methods have limitations:

- Water balance: large uncertainty on surface parameters and water inputs

- Energy balance: existing methods to disagregate from 1km to 100m use NDVI as a scaling factor but assume unstressed vegetation

→ energy balance models must be forced at 100m scale every day or so

TRISHNA

Thermal Infrared remote sensing data without TRISHNA: a resolution/revisit dilemna

Geostationary satellites
(MSG/SEVIRI, GOES, INSAT, GMS…)

METEOSAT SEVIRI

Daily AET →
Nov 10, 2017
EUMETSAT

Polar meteo satellites 1km
(MODIS, SUOMI NPP VIRSS…)

MODIS

Earth Observation satellites
(TIR on LANDSAT, ASTER)

← ET (mm/day),
July 8, 2008,
Crau region
(S-E France)

Resolution	> 3 km	1 km	60 - 120m
Revisit	15 min	1 day	18 days

TRISHNA

TRISHNA Thermal Infrared Instrument

600 pixels x 15845 scan samples
= 1 strip

Developed by	**AIRBUS DEFENCE AND SPACE**
Acquisition	Across track scanner
Mass	195 kg
Spectral bands	4 TIR
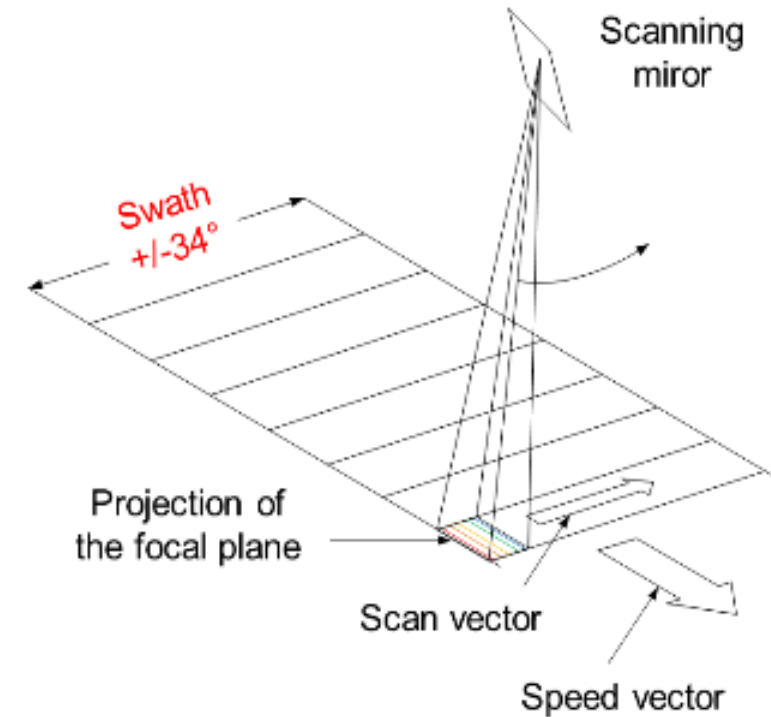
TRISHNA VIS – NIR – SWIR instrument
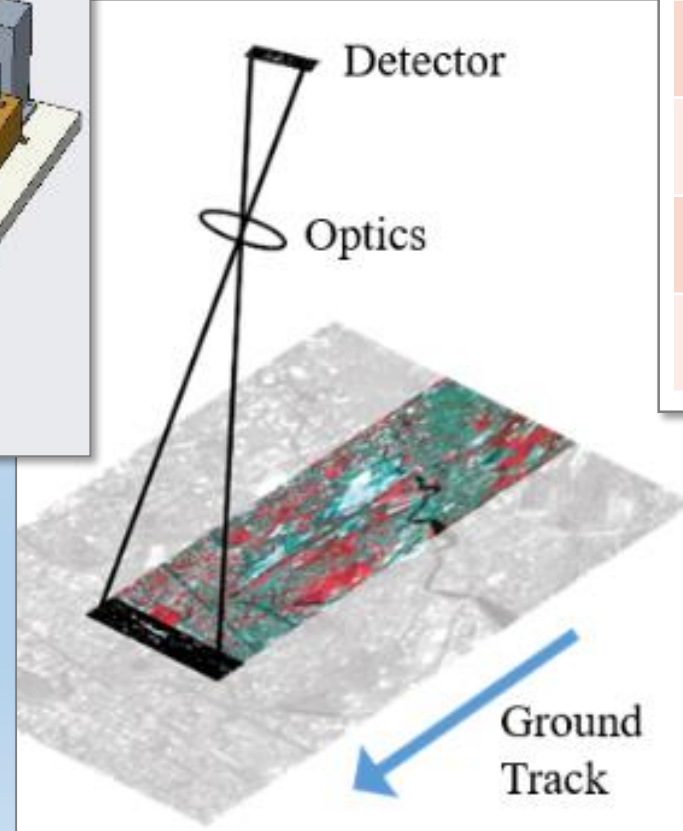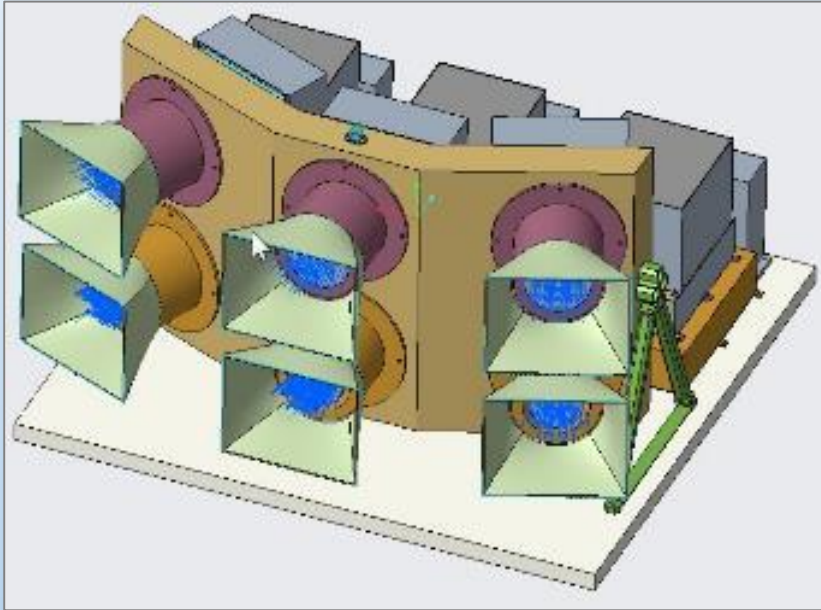
Developed by	**ISRO**
Optical Heads	6
Acquisition	Pushbroom
Mass	90 kg
VIS & NIR bands	5
SWIR bands	2

TRISHNA

Coverage and revisit
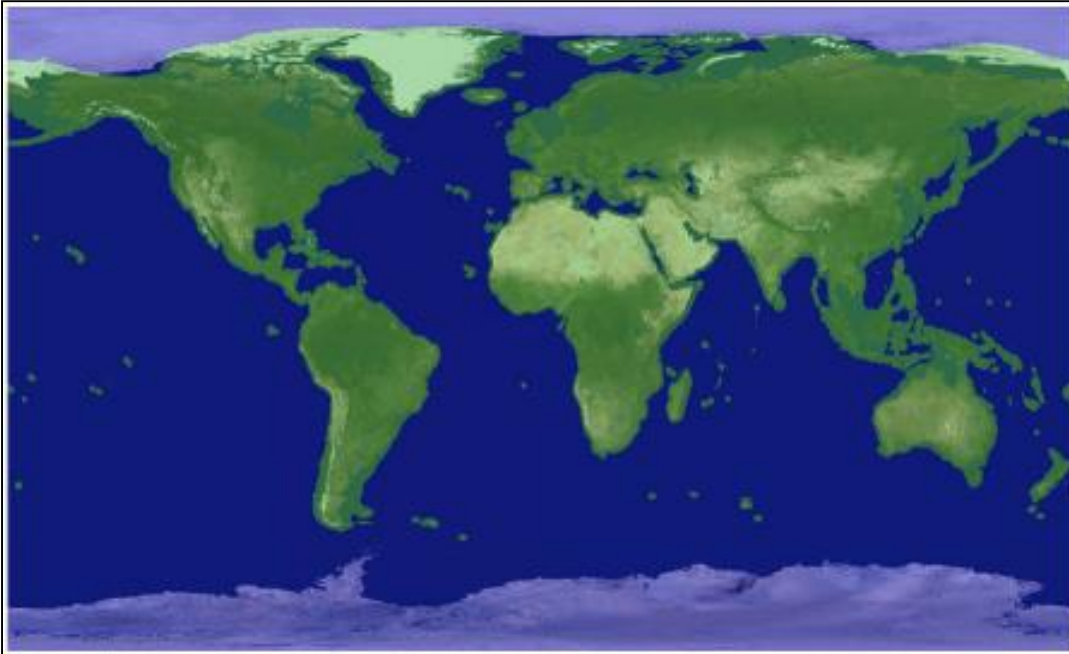
TRISHNA full resolution data coverage (in green)

All continental land surfaces (including inland waters)
All coastal waters up to 100km from the shore

Number of accesses in 8 days
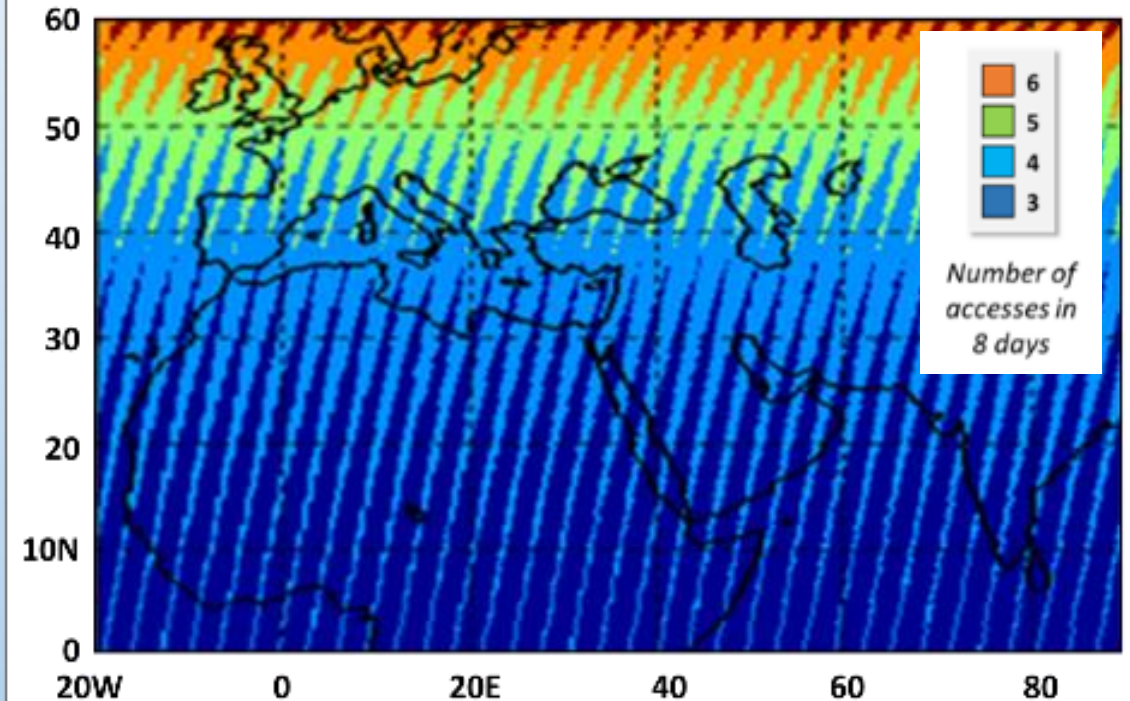
TRISHNA geometric revisit frequency due
to the overlap between adjacent orbits

TRISHNA

Spectral bands

Band name	Wavelength Center (nm)	FWHM (nm)	Purpose
Blue	485	70	Detection of low clouds
Green	555	70	Coastal, sediments, snow
Red	670	60	Vegetation (LAI, fCOVER, NDVI, …)
NIR	860	40	Vegetation (LAI, fCOVER, NDVI, …)
WV	910	20	Water vapour content estimation
Cirrus	1380	30	Detection of thin cirrus clouds
SWIR	1610	100	AOD, snow/cloud discrimination, vgt stress, burnt areas

Band name	Wavelength Center (µm)	FWHM (µm)	Purpose
TIR 1	8.65	0.35	Temperature/emissivity separation
TIR 2	9.0	0.35	Temperature/emissivity separation
TIR 3	10.6	0.7	Split-window
TIR 4	11.6	1.0	Split-window

Source: TRISHNA SMRD V3.0

- ❑ ISRO/CNES cooperation, launch end of 2024
- ❑ Scientific & operational applications
- ❑ Focus on **ecosystem stress and water use**
- ❑ Global coverage
- ❑ 4 TIR bands + 5 VNIR bands + 2 SWIR bands
- ❑ Revisit : 3 acquisitions at equator per 8 days period
   761km-8day orbit reducing hot spot constraints in intertropical zone
- ❑ ± 34° scan angle, 1030km swath
- ❑ Nadir spatial resolution (VIS-NIR-SWIR-TIR):
   57 m for continental and coastal areas, binned at 1 km over open ocean
- ❑ Overpass time : 1 PM
- ❑ NeDT 0.2K
- ❑ Indo-French[*] Joint Science Team, synergies with ECOSTRESS, SBG, LSTM science & application teams
   (*) with other contributors
- ❑ Free and open data policy for worldwide scientific community

Learn more about TRISHNA !
https://labo.obs-mip.fr/multitemp/trishna
https://trishna.cnes.fr/en

TRISHNA science teams organization

Joint Science Team :

❑ Joint Science Advisory group

❑ Ecosystem stress and water use
❑ Coastal and inland waters
❑ Urban microclimate monitoring
❑ Solid Earth
❑ Cryosphere
❑ Atmosphere

❑ CAL/VAL
❑ Definition of the products

Organization :

❑ French / Indian mirror organization involving local research entities

❑ Objectives: definition of the expected variables and associated precision, products, algorithms, cal/val strategy
→ joint Indo-french ATBDs

❑ Synergies with ECOSTRESS, SBG, LSTM science teams

TRISHNA

TRISHNA and Ecosystem stress
Gilles Boulet / CESBIO et al.

Area

- **Irrigated** Agriculture
- **Rain-fed** Agriculture
- Ecosystems

What is at stake

- Optimize irrigation
- Manage consumption of water
- arbitrate water savings
- additional irrigation
- follow the droughts and their impact on yield
- Better diagnosis of vulnerable areas (fire, drought, frost impact)

What TRISHNA brings

ETR

STRESS

TEMPERATURE
EMISSIVITY
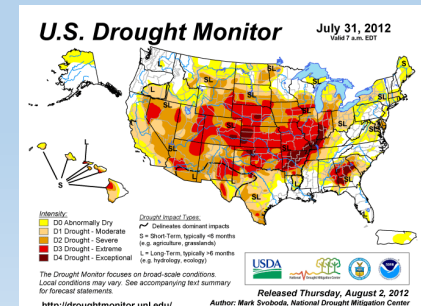
Biogeophysical and Biogeochemical processes

Multi-layer transfer Models

(MuSICA, SCOPE)
Ogée et al., 2003
Van der Tol et al., 2009
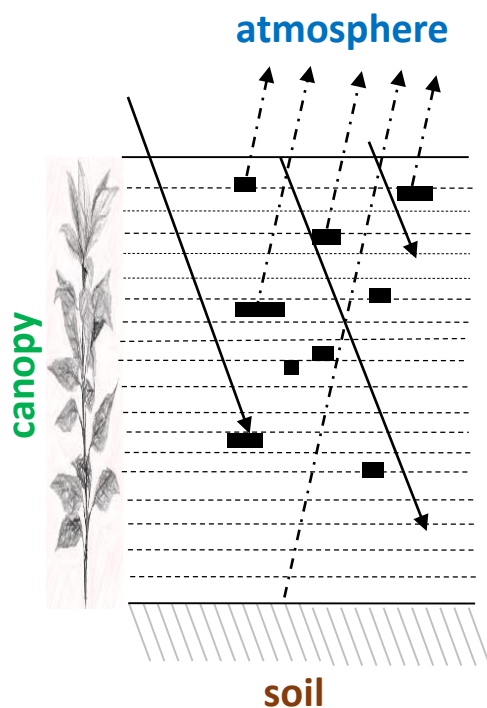
Single- and two-source resistance schemes

(Kustas et al., 2009)
Ras : soil-air aerodynamic resistance
Rac : vegetation-air aerodynamic resistance
Tsol : ground temperature
TC   : canopy temperature
Hs   : Sensible heat flux from the ground
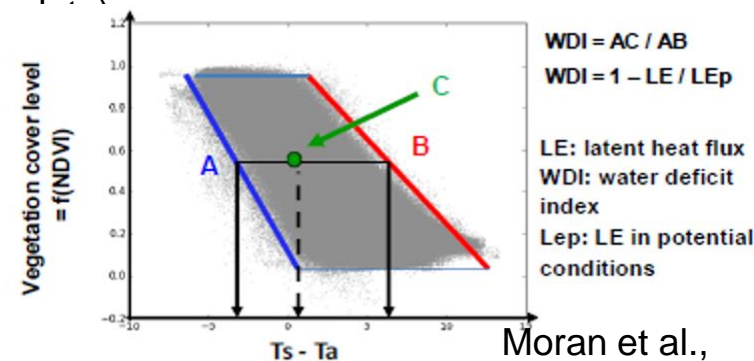Hc   : Sensible heat flux from the canopy
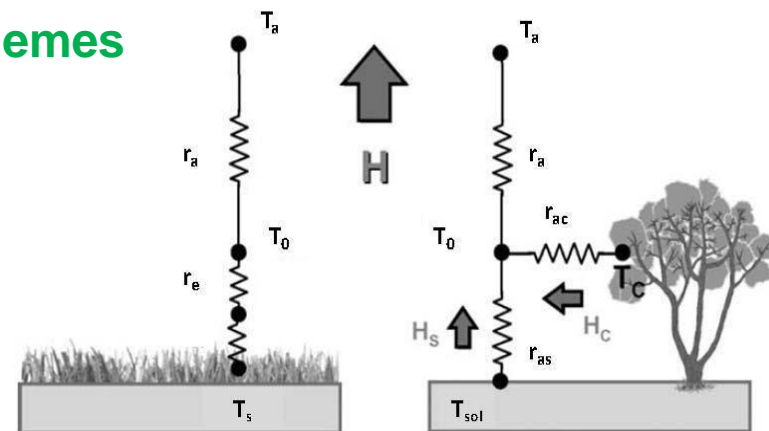
Contextual methods

S-SEBI calculates an evaporative fraction at any point C from temperature limits for each albedo class A and B

EF = CB / AB
LE = EF*AE

LE: latent heat flux
EF: evaporative fraction
AE: available energy
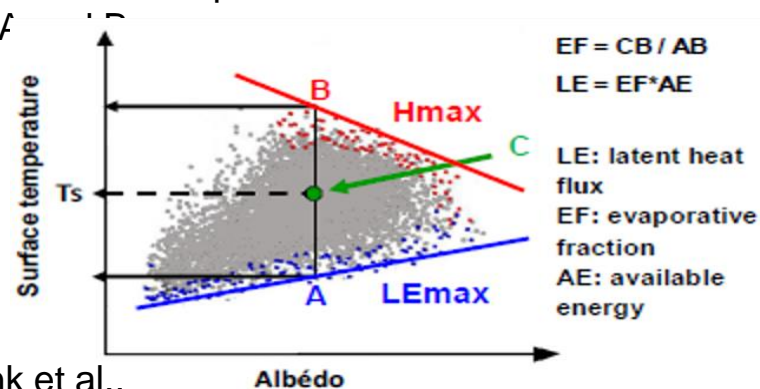
Roerink et al., 2000

Water Deficit Index model estimates a stress factor for a given point C according to temp. limits A and B (identified by range of vgt coverage deduced from solar domain data)

WDI = AC / AB
WDI = 1 – LE / LEp

LE: latent heat flux
WDI: water deficit index
Lep: LE in potential conditions

Moran et al., 1994

impact of accounting for the directional signature of T_{surf} in energy budget components retrieval
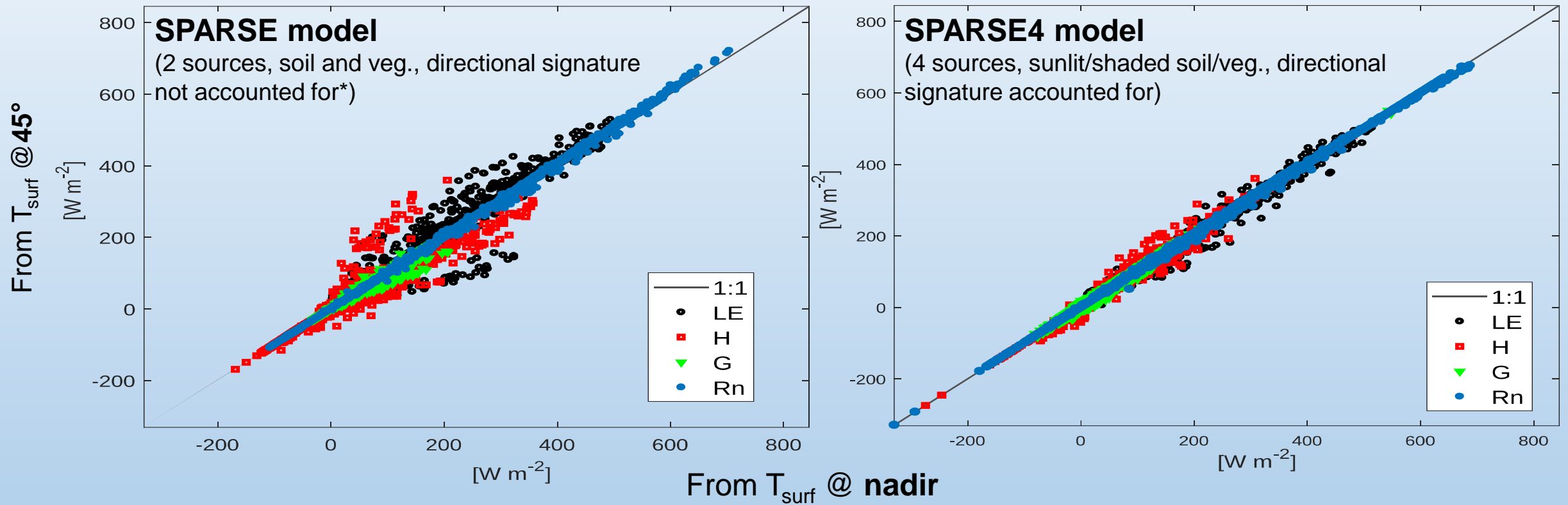
* Like TSEB, only the effect of view angle on the amount of soil and vegetation viewed

R3 2004 irrigated wheat site, Marrakech, Morocco
Retrival from 2 incident angles (2 IRTs)

TRISHNA

Need for an EvapoTranspiration (ET) product at <100m (plot size < 1ha) from day-to-day data (rapid moisture change between two successive rainfalls)
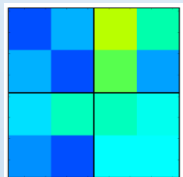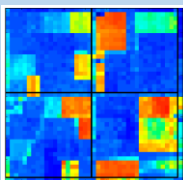
For the moment, MODIS and S3 temperature products are available
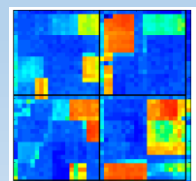➢ daily ET at 1km with energy budget model with little unknown inputs
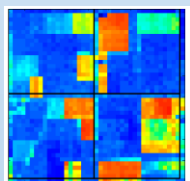
ET values that can also be obtained with NDVI data and water budget models at S2 pixel size
➢ But they rely on many unknown inputs including water inputs (irrigation) and model parameters
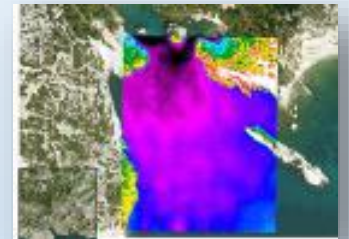
SEN4ET products use S3 ET data disagregated to S2
➢ But the method assumes that the vegetation is unstressed

TRISHNA will provide ET estimates every 2-3 days (depending on clear sky conditions) at <100 m

TRISHNA

Coastal & Inland waters   Emmanuelle Autret / LOPS et al.

Area

- Coastal Waters
- Inland waters
- Sea Ice

What is at stake

- ▪ **Mixing processes**

- • **Water Quality,** algal bloom, halieutic resource, spring discharge (resurgence), discharge of water, pollutants

- • **Ecosystem Productivity** (phytoplankton)

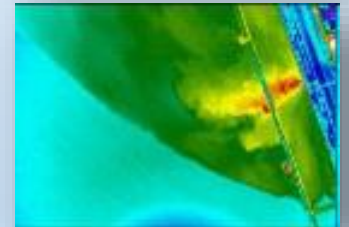- • Halieutic resource

- • **Melting and frost Processes**

What TRISHNA brings

TEMPERATURE

REFLECTANCES

COLOR

INDICES

Coastal & Inland waters
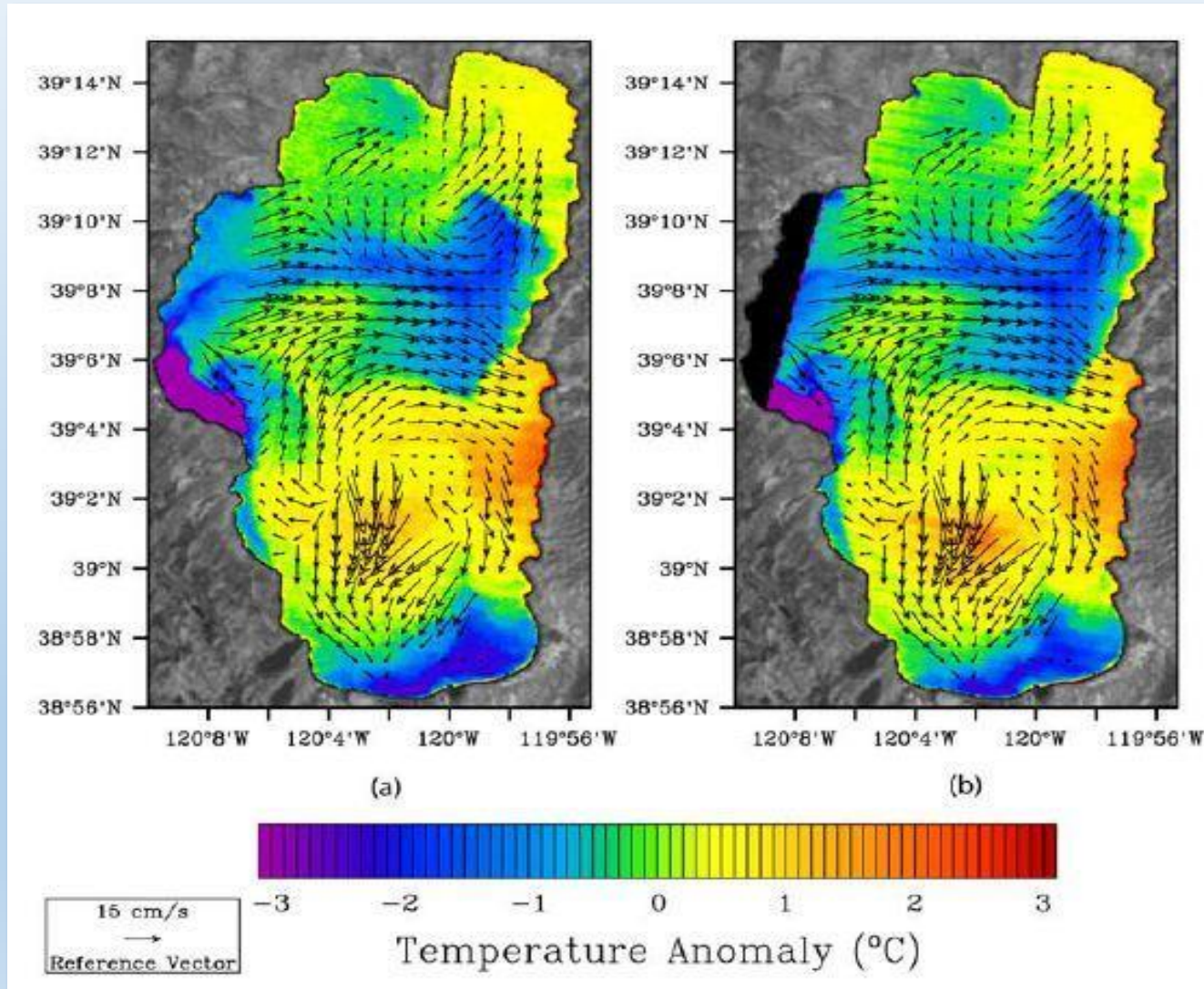Emmanuelle Autret / LOBS et al.

Lake Tahoe

(a) ETM+ Band 6 (high gain) temperature anomaly, June 3, 2001 18:28 UTC

(b) ASTER Band 13 temperature anomaly, June 3, 2001 19:06 UTC.

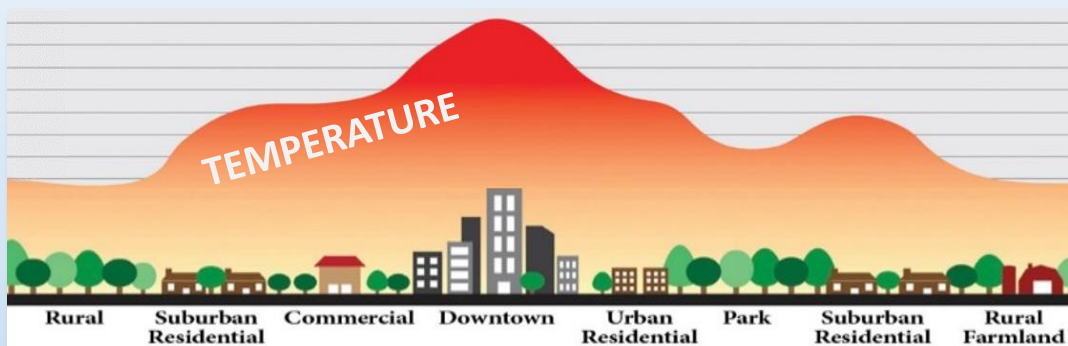The ETM+ image was interpolated to a 90m grid using bilinear interpolation.

The satellite image-derived surface current vector field is overlaid on both images.

(after Steissberg et al., 2005)

TRISHNA

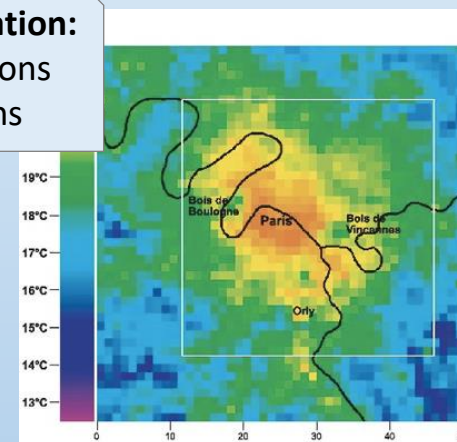## Urban microclimate monitoring · Xavier Briottet / ONERA et al.

Urban Heat Island (UHI)

Connection with population health, comfort and safety

Urban population:
2008: 3.3 Billions
2050: 5 Billions

Air Temperature
Rugosity, Wind
Radiative trapping
Impermeability of the soils

Themes:
Hydrology, building heat model, urban climatology

AVHRR Aug. 9, 2003 UHI over Paris (Do usset, 2007)

What TRISHNA brings:

- High revisit, global coverage
- LST, LSE
- Type of soil
- Rugosity

Exogenous data
+ Remote Sensing data
+ urban microclimatology model

Air Temperature
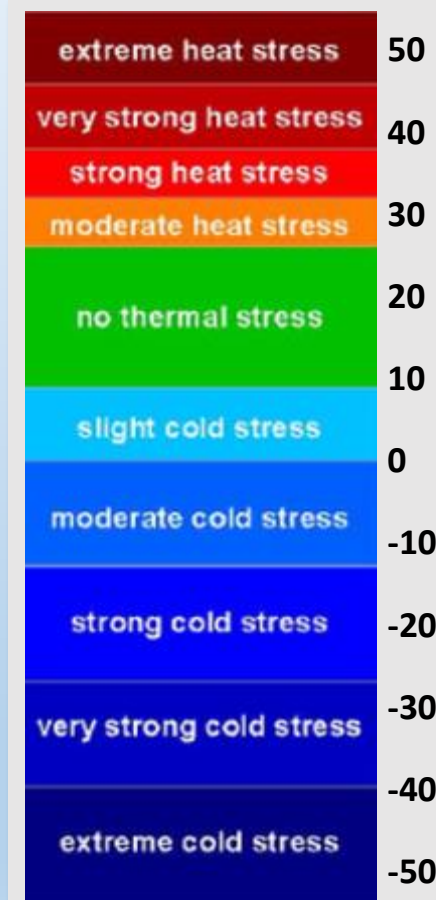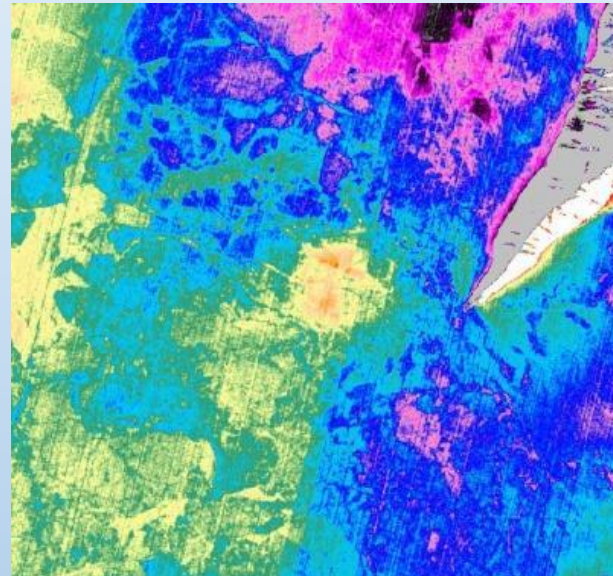

UTCI : Universal thermal confort index
www.utci.org

TRISHNA

Cryosphere

Band 5 NIR
(greyscale)

Band 11 TIR
(false colors)

Multiple ice types on the surface of Lake Baikal
Landsat-8 image, March 2, 2018
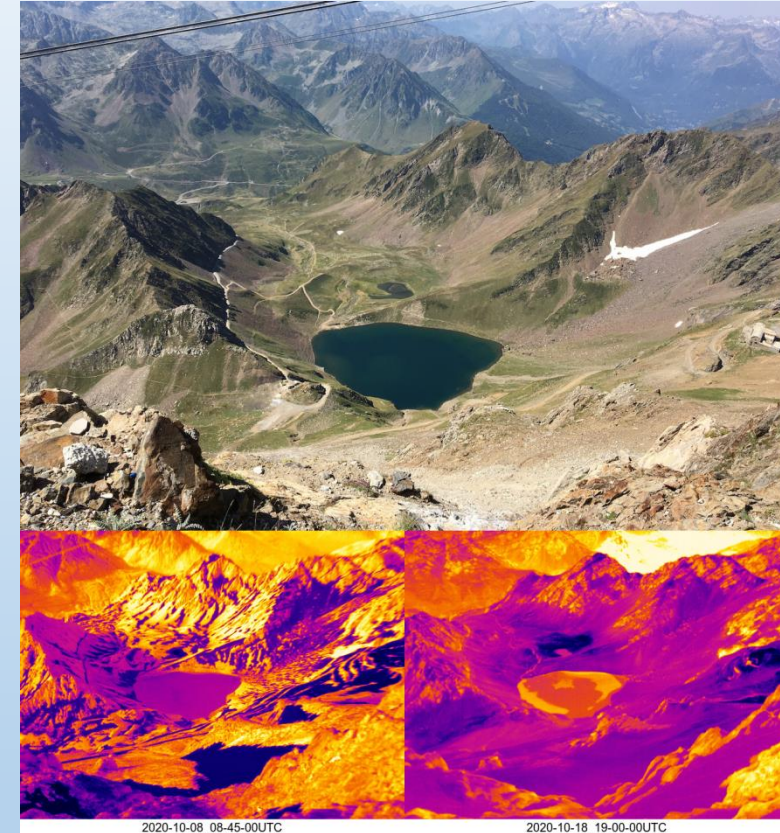
Pic du Midi study site in French Pyrenees
Viewpoint from TIR camera, October 2020
Snow-free and morning (left hand)

Snow covered and evening (right hand)

CalVal for TIR HR products : the TRISHNA approach

Chichaoua (Morocco)

Taous (Tunisia)

Nashik (India)

Estampes (France)

SCOPE

Model 1
Model 2
Model 3

DART

Agricultural plots 17 July 2015 11h30
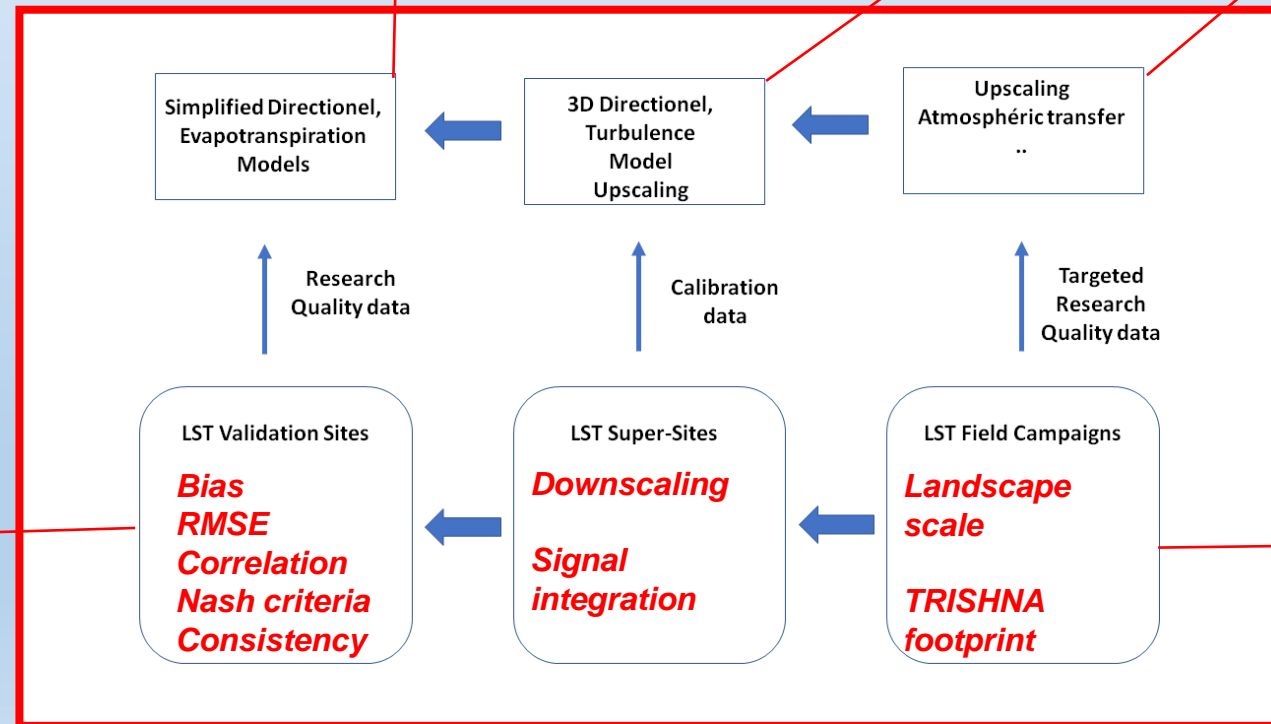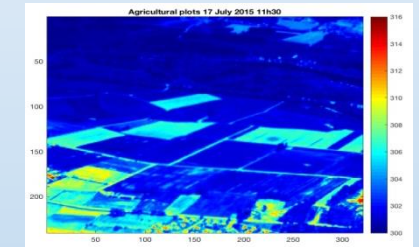
TELOPS

FLIR

Simplified Directionel, Evapotranspiration Models	3D Directionel, Turbulence Model Upscaling	Upscaling Atmosphéric transfer ..

Research Quality data

Calibration data

Targeted Research Quality data

LST Validation Sites	LST Super-Sites	LST Field Campaigns
Bias RMSE Correlation Nash criteria Consistency	*Downscaling Signal integration*	*Landscape scale TRISHNA footprint*

TRISHNA

TRISHNA Project Organization

Joint Project Team

Launch

Satellite

Bus

TIR instrument

VSWIR instrument

Payload Ground Segment

Technical Expertise
VSWIR

Payload Data Processing
TIR+VSWIR

Data Distribution   TIR+VSWIR

Prog.

Exogenous services

HK TM   HK TC   PL TM

S-band network   **X-band network**

PL TM   PL TM

Tracking   HK TM   HK TC   Report   Tracking

Payload Ground Segment

Technical Expertise
TIR

Payload Data Processing
TIR+VSWIR

Data Distribution   TIR+VSWIR

Prog.

Control Ground Segment

Users

25