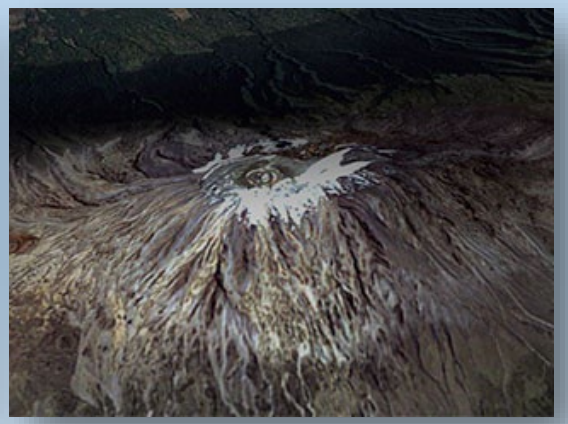
TRISHNA: AN INDO-FRENCH SPACE MISSION TO STUDY THE THERMOGRAPHY OF THE EARTH AT FINE SPATIO-TEMPORAL RESOLUTION

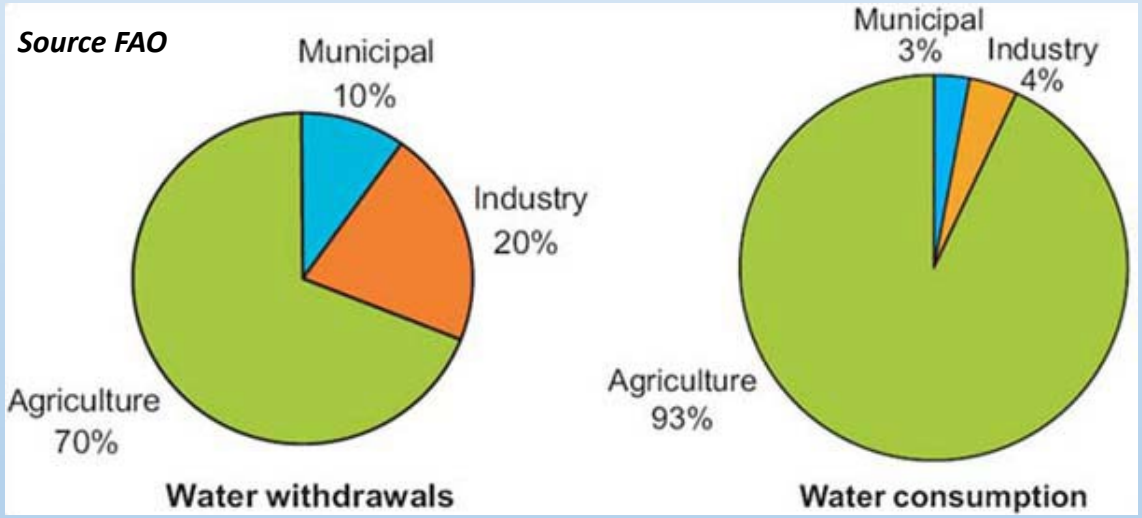
J.-L. Roujean [1], B. Bhattacharya [2], P. Gamet [1], M.R. Pandya [2], G. Boulet [1], A. Olioso [3], S.K. Singh[2], M. V. Shukla[2], M. Mishra[2], S. Babu[16], P. V. Raju[15], C.S. Murthy[15], X. Briottet [4], A.Rodler [5], E. Autret [6], I. Dadou [7], D. Adlakha[2], M. Sarkar[2], G. Picard [8], A. Kouraev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

... in line with global change

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

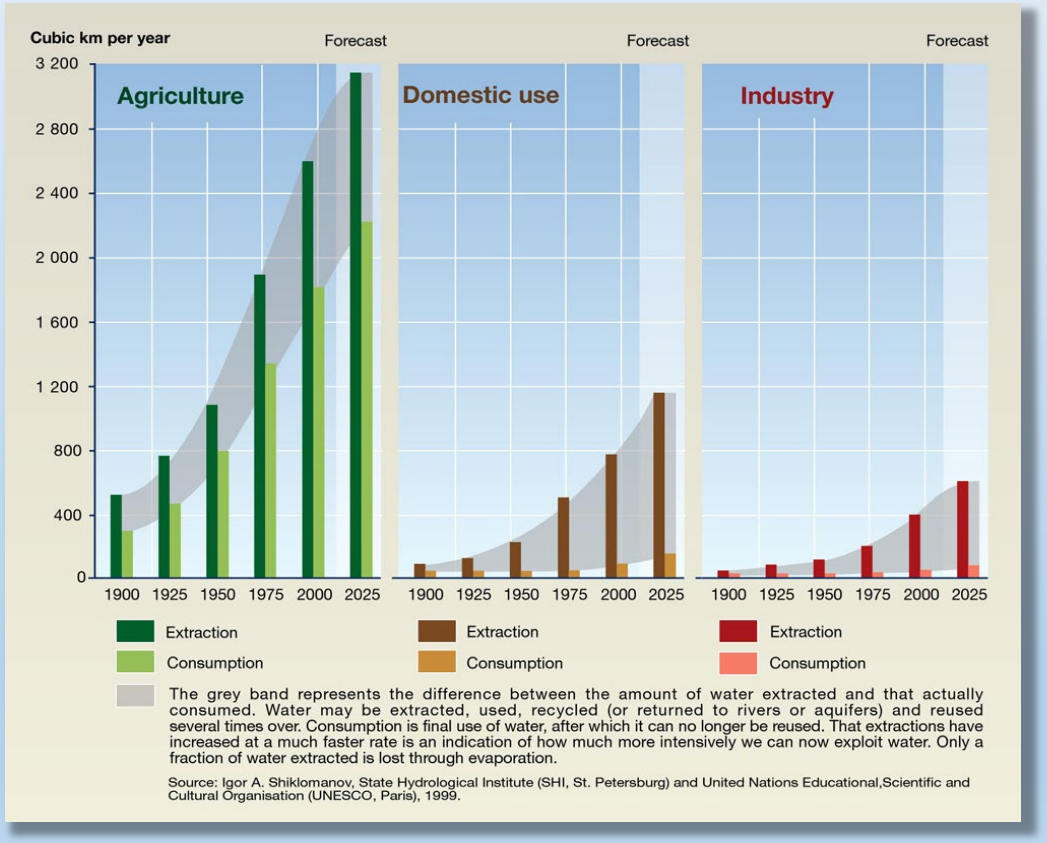
Pressure on water supply for irrigation !

(< 1ary renewable and 2ary freshwater resources)



Agriculture : irrigation, livestock, aquaculture
Industry : drainage, wastewater, cooling, etc
Municipal : public distribution network, etc

Rapid increase of water consumption

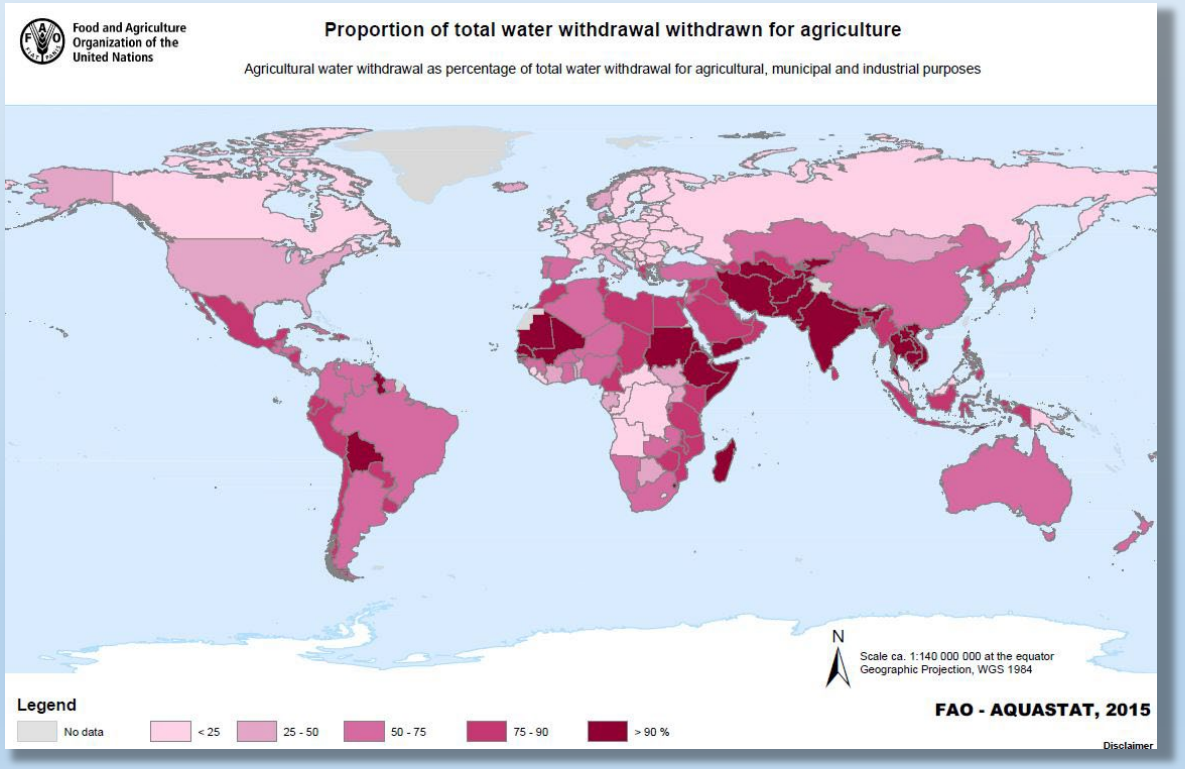


Trends in water use by sector (UNEP)

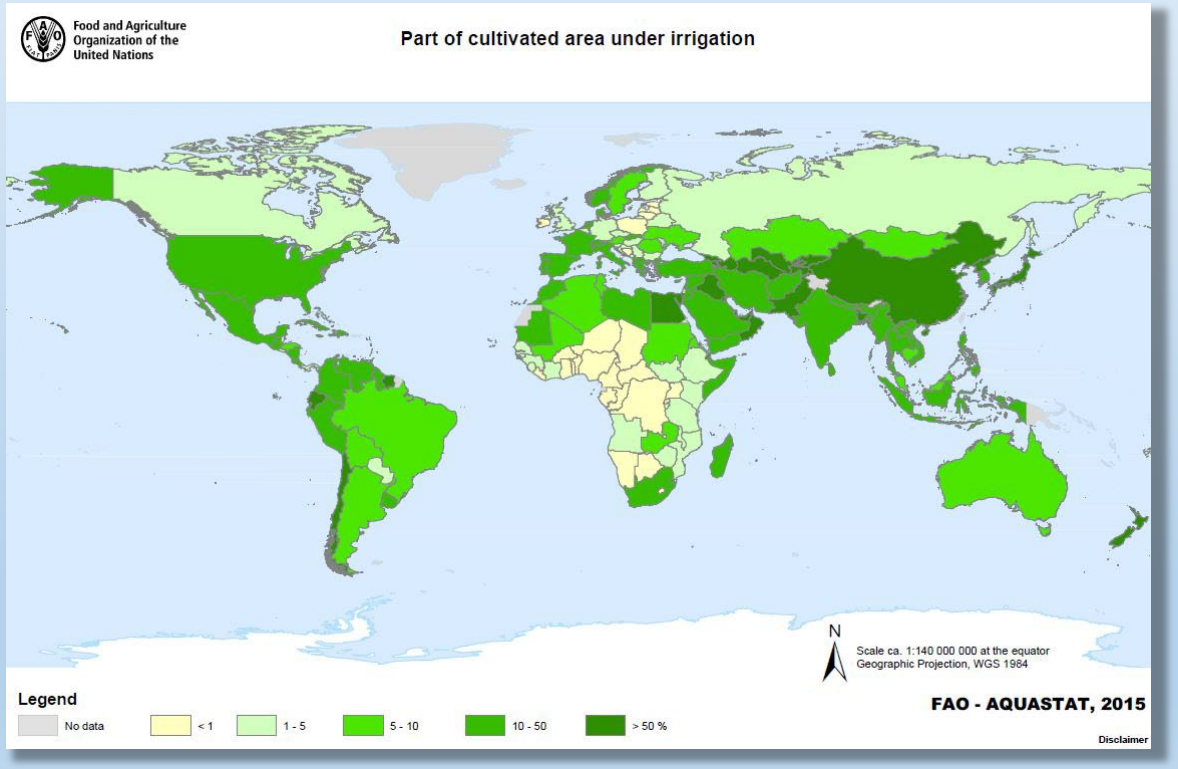
(http://www.unep.org/dewa/vitalwater/article43.html)

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Proportion of total water withdrawal withdrawn for agriculture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

Change in temperatures

Change in rainfall regimes

Global scale
Regional scale
Plot scale

Access to freshwater reserves

Optimized management of water

Surface temperature and its dynamics

TRISHNA !

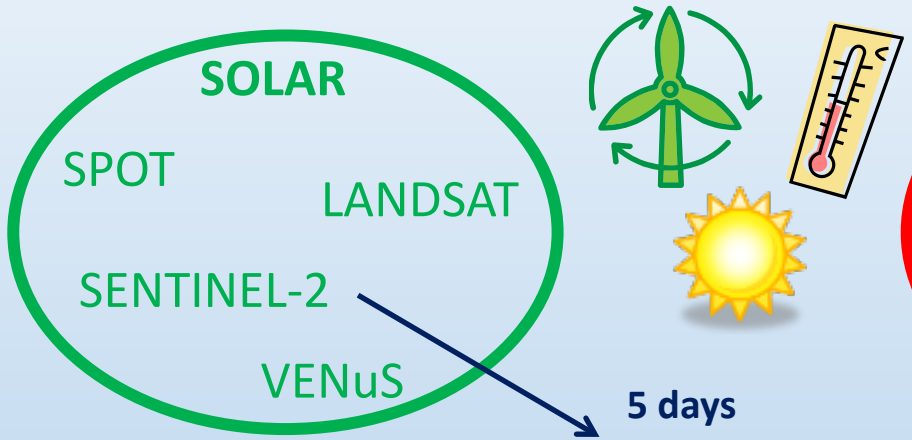
- Evaporation of water from soils
- Transpiration of plants
- Local climate

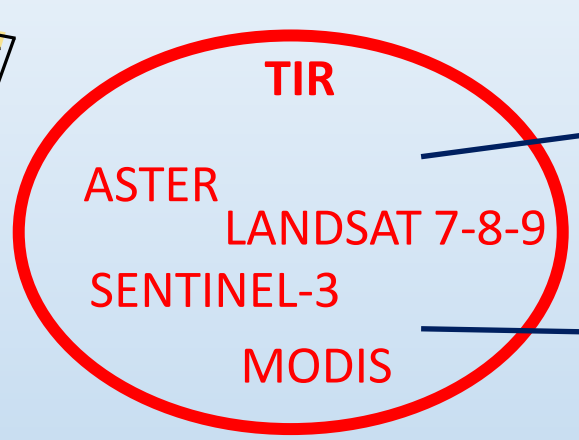
EvapoTranspiration

Frequent *AND* high-resolution measurements

TRISHNA

Computing EvapoTranspiration with remote sensing data





8-16 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 budget

Irrigation inversion

Energy budget

Maximum EvapoTranspiration

Actual EvapoTranspiration

Existing methods have some limitations:

- **Water budget large uncertainty on surface parameters and water inputs**
- **Energy budget: disagreggation from 1km to 100m with NDVI as scaling factor assumes unstressed vegetation**

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

TRISHNA

- ISRO/CNES cooperation, launch in 2025
- 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, 1030 km 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 and 1 AM (+/- 15 mins)
- 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

TRISHNA and Ecosystem stress

Gilles Boulet / CESBIO et al.

ISRO-IISC-IIT-Other Academia

Area

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

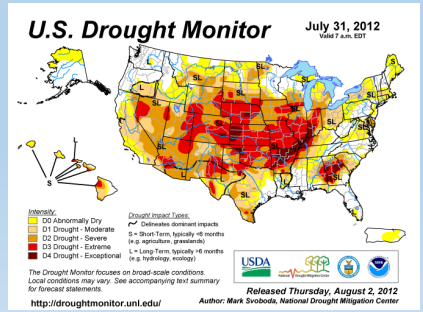
What is at stake

- Optimize irrigation
- Manage consumption of water
- Arbitrate water savings
- Additional irrigation
- Monitor droughts and their impact on yield
- Diagnose vulnerable areas (fire, drought, frost, etc)

What TRISHNA brings

- ETR
- STRESS
- TEMPERATURE

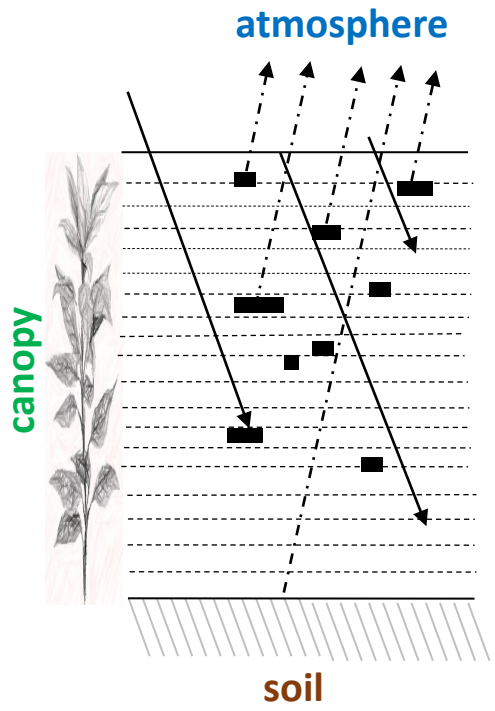
Evaporative Stress Index



TRISHNA

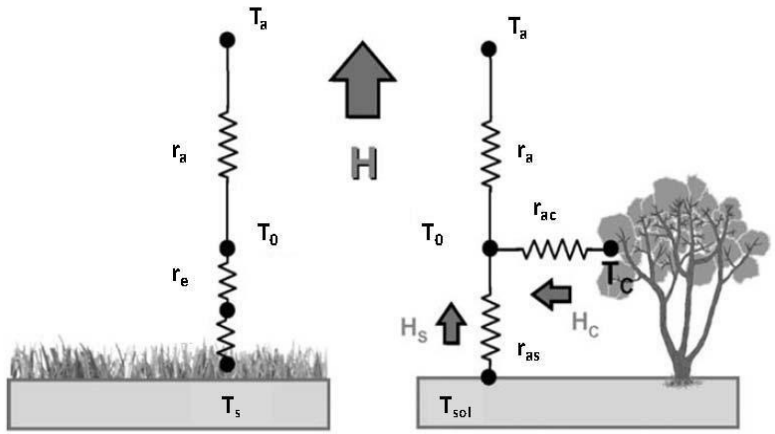
Multi-layer transfer Models

(MuSICA, SCOPE)
Ogée et al., 2003
Van der Tol et al., 2009



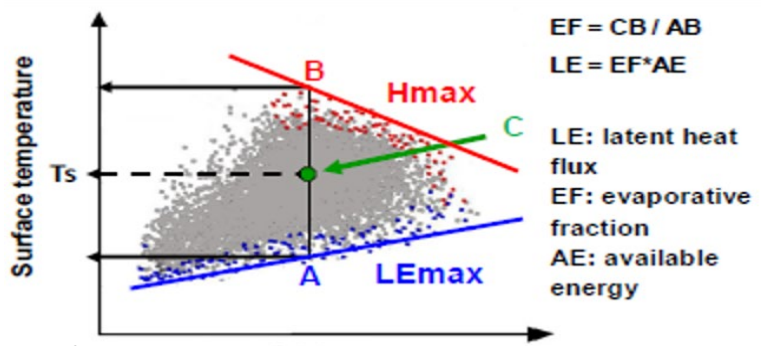
Single- and two-source resistance schemes

(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



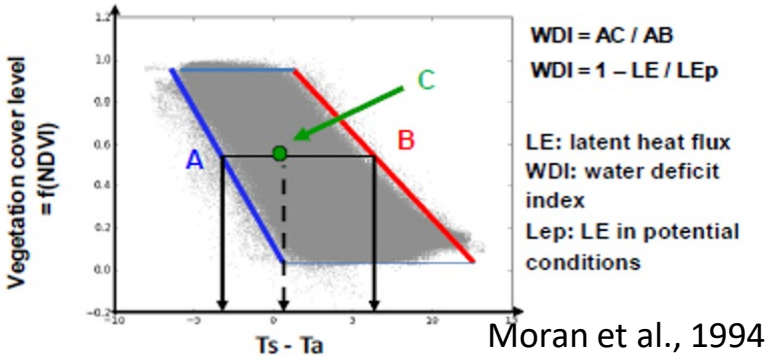
Contextual methods

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



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)



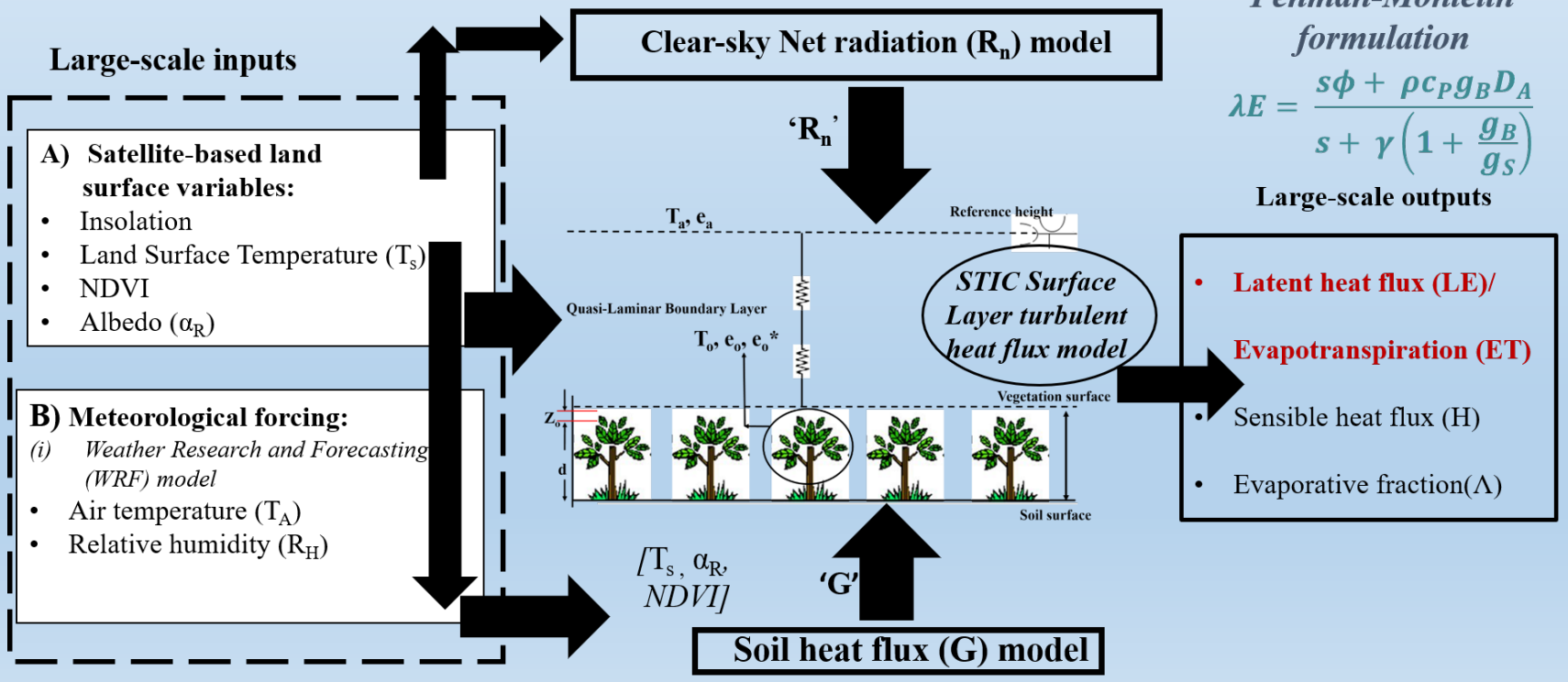
Moran et al., 1994

• **Surface Temperature Initiated Closure (STIC)** is an analytical model (Mallick et al, 2014) that introduced LST in Penman - Monteith Formulation to simulate latent heat fluxes (λE)

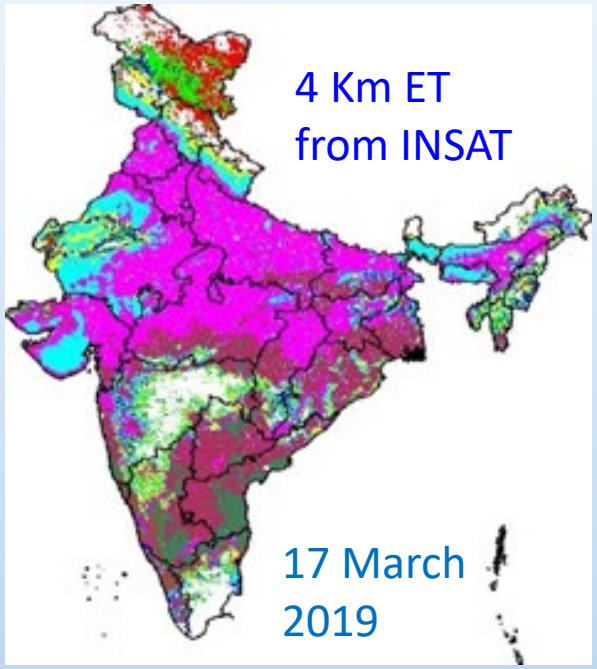
• Belongs to the family of remote sensing-based models of net radiation and heat fluxes. It uses as inputs LST, albedo, NDVI. It is eligible for large-scale application

Surface Energy balance

$R_n = H + \lambda E + G$

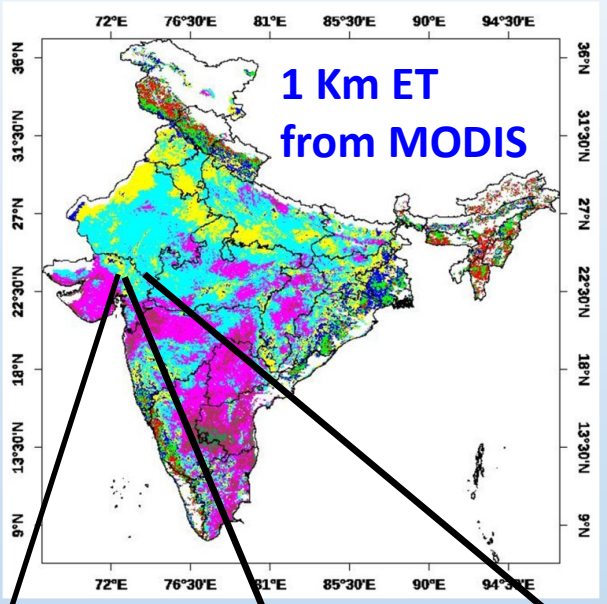


TRISHNA



Evapotranspiration (mm day^{-1})

- Mask/Cloud Cover
- 0.1-0.5
- 0.5-1.0
- 1.0-1.5
- 1.5-2.0
- 2.0-2.5
- 2.5-3.0
- 3.0-3.5
- 3.5-4.0
- 4.0-4.5
- 4.5-5.0
- 5.0-5.5
- 5.5-6.0
- 6.0-6.5
- 6.5-7.0



Evapotranspiration (mm day^{-1})

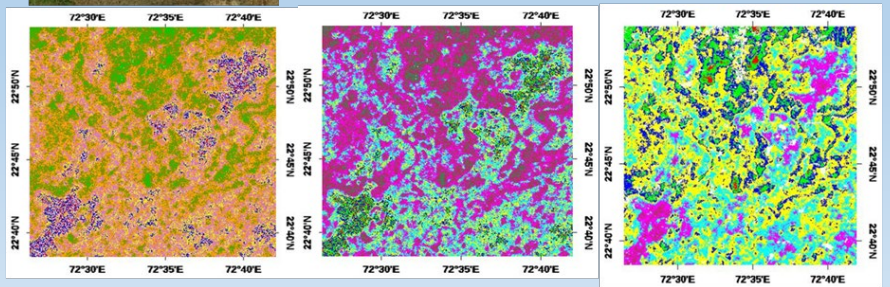
- Mask/Cloud Cover
- 0.1-0.5
- 0.5-1.0
- 1.0-1.5
- 1.5-2.0
- 2.0-2.5
- 2.5-3.0
- 3.0-3.5
- 3.5-4.0
- 4.0-4.5
- 4.5-5.0
- 5.0-5.5
- 5.5-6.0

TIR resolution	% RMSE vs in situ flux measurements	
8 Km (Kalpana-1)	*Indian geo. satellites*	35%
4 Km (INSAT 3D)		25%
1 Km (MODIS)		20%
65m (ECOSTRESS)		12%

17th June

27th August

12th March

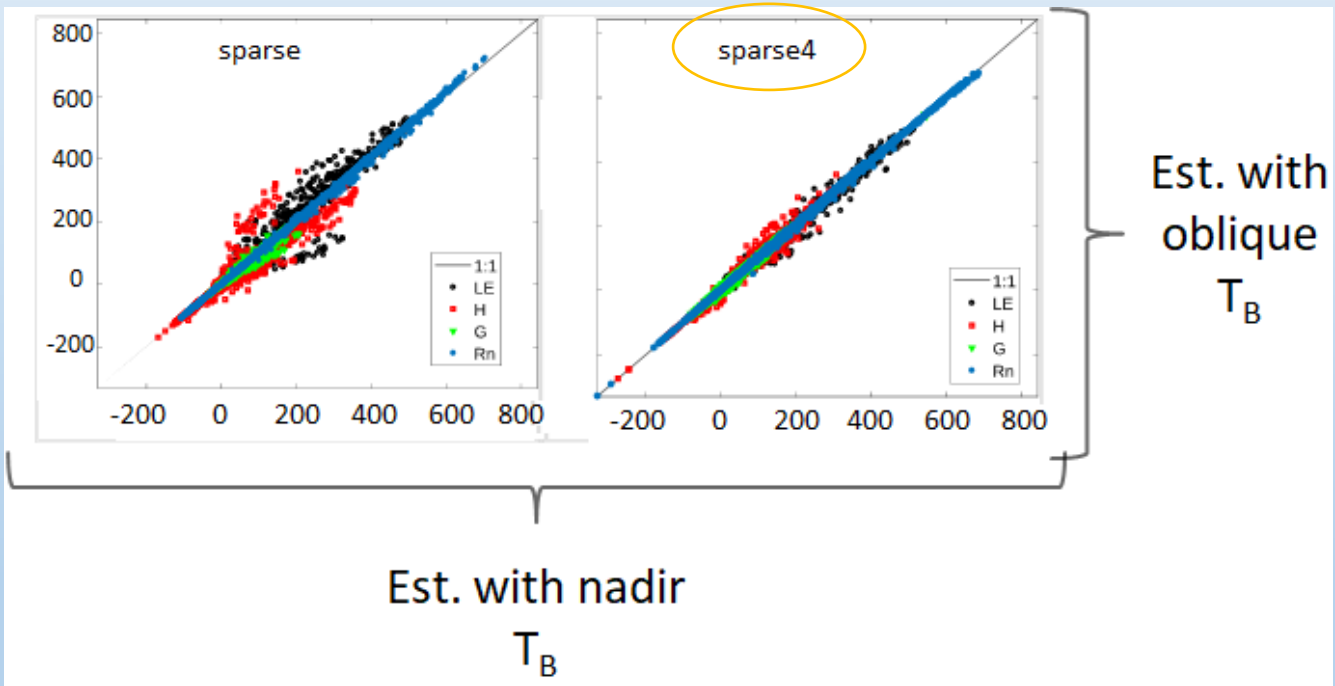


- 1.9-2.0
- 2.0-2.2
- 2.2-2.3
- 2.3-2.4
- 2.4-2.5
- 2.5-2.6
- 2.6-2.7
- 2.8-2.9
- 2.9-3.0
- 3.1-3.2
- 3.2-3.3
- 3.3-3.4
- 3.4-3.5
- 3.5-3.6
- 3.7-3.8
- 3.8-3.9
- 3.9-4.0

TRISHNA

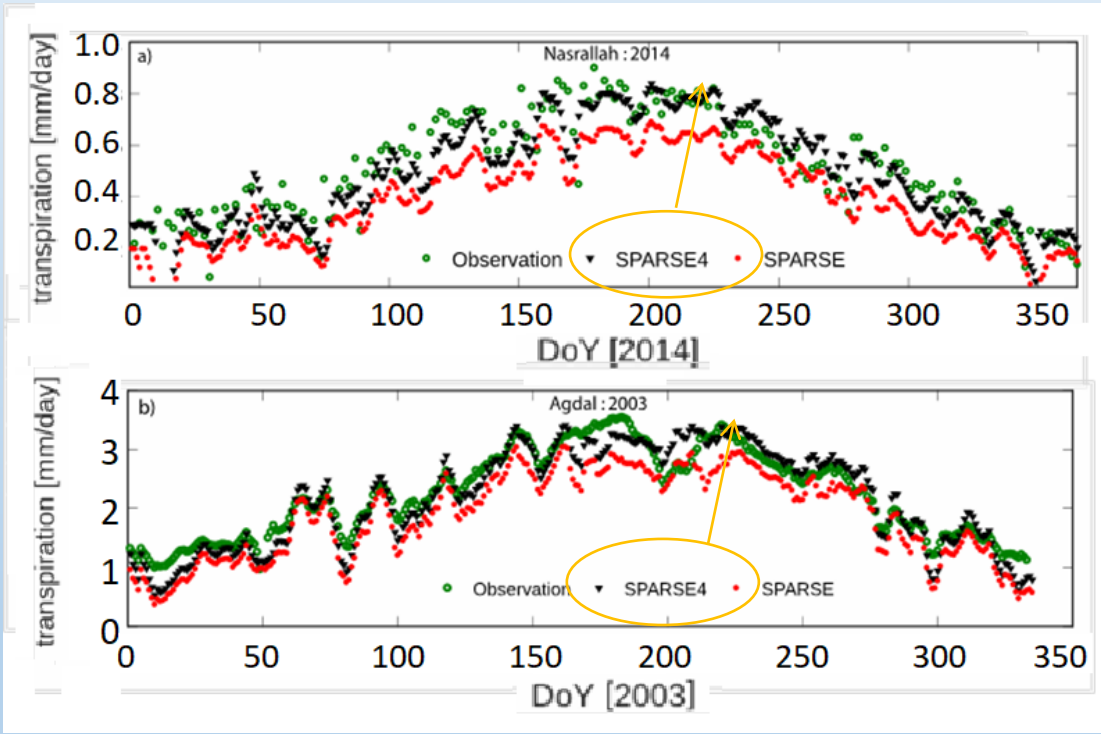
Sensitivity of flux retrievals to direction of view is reduced

Irrigated wheat (Morocco)



Improved LE partitioning

Orchard



SPARSE model
(2 sources, soil and veg)

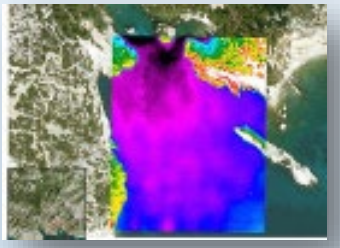
SPARSE4 model
(4 sources, sunlit/shaded soil/veg.)

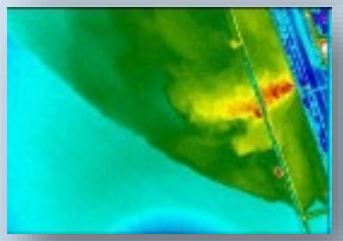
TRISHNA

Coastal & Inland waters

Emmanuelle Autret / LOBS et al.

ISRO-Academia





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

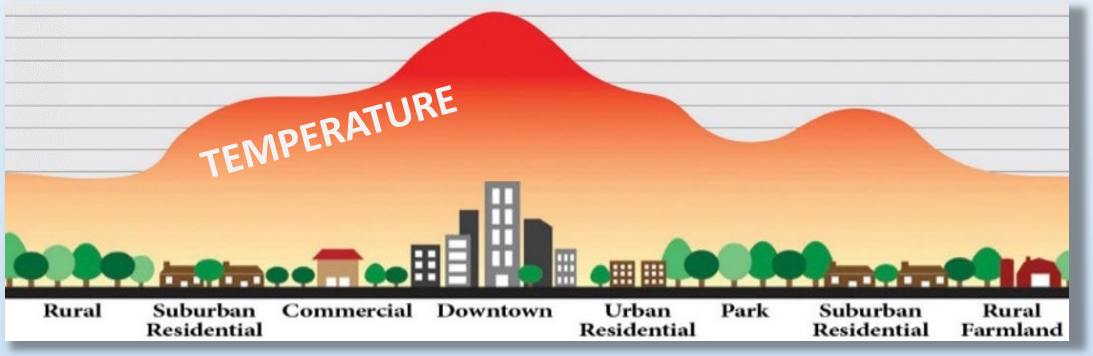
INDICES

TRISHNA

Urban microclimate monitoring

Xavier Briottet / ONERA et al.

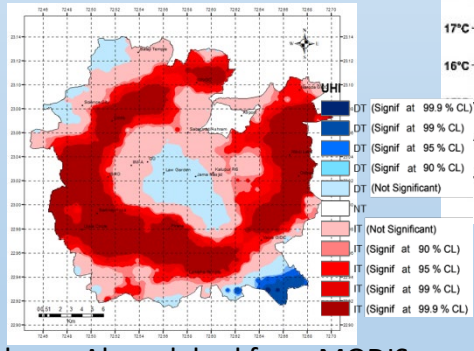
ISRO-Academia



Urban Heat Island (UHI)

Air Temperature
Rugosity, Wind
Radiative trapping
Impermeability of the soils

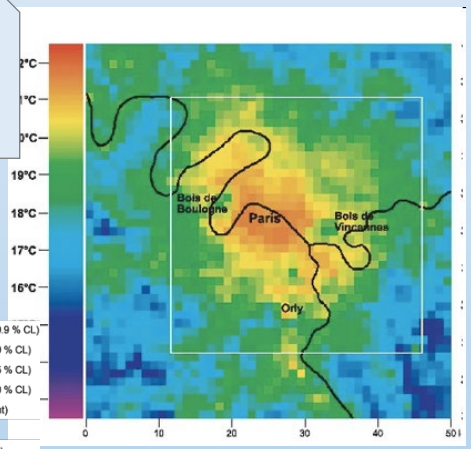
Themes:
Hydrology, building heat model, urban climatology



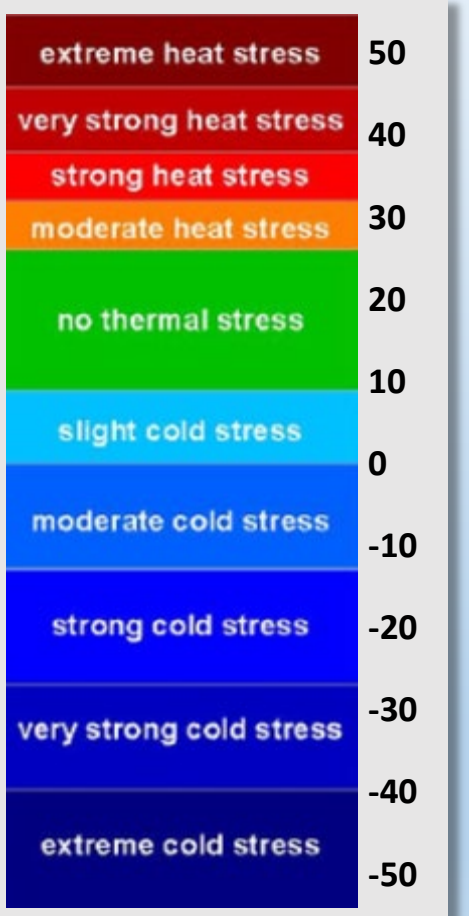
UHI trend over Ahmedabad from MODIS (*Chhabra et al, 2019*)

Connection with population health, comfort and safety

Urban population:
2008: 3.3 Billions
2050: 5 Billions



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



UTCI : Universal thermal confort index
www.utci.org

What TRISHNA brings:

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

Exogenous data
+ Remote Sensing data
+ urban microclimatology model

Air Temperature

TRISHNA

Cryosphere

Ghislain Picard IGE

ISRO-Academia

Area

- Sea ice, ice sheets, ice caps
- Snow & Glaciers
- Permafrost & Seasonally frozen ground
- River & lake ice

What is at stake

- Snow-melt runoff and debris thickness estimation
- Snow cover change & metamorphism at sub-watershed scale
- Modelling snow energy fluxes
- Snow mass, Snow Water Equivalent (SWE), Snow depth

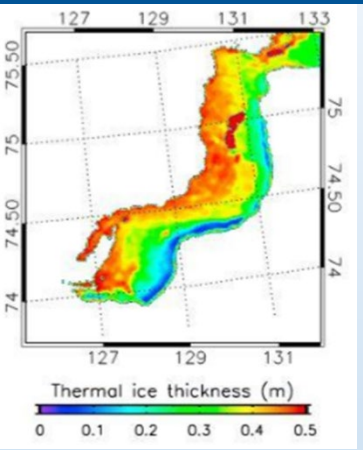
What TRISHNA brings

TEMPERATURE (Noon-night)

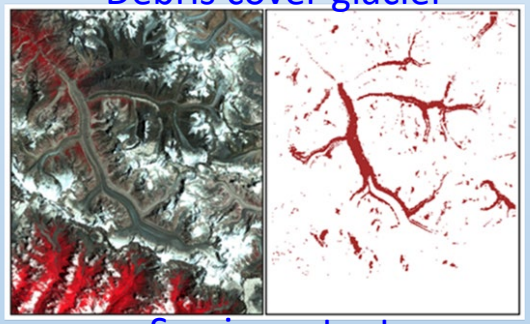
EMISSIVITY

Snow and Ice Albedo

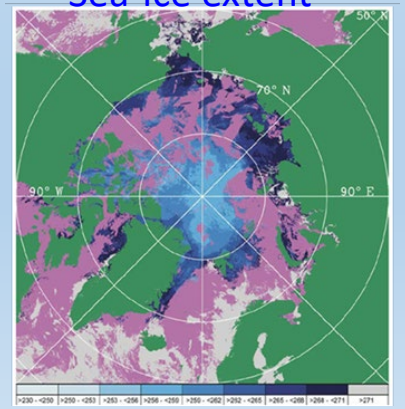
Snow cover



Debris cover glacier



Sea-ice extent



Solid Earth

ISRO-Academia

Area

- **Mineral exploration**
- **Vocanology**
- **Soil**

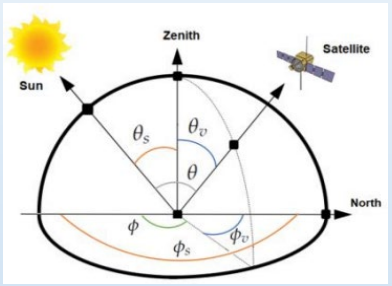
What is at stake

- Thermal anomaly detection of coal & peat fire (location & direction), volcanic eruption
- Estimating Lava effusion rate
- Emissivity-based detection of granitoids, RE etc.
- Geothermalenergy assessment
- Soil properties retrieval

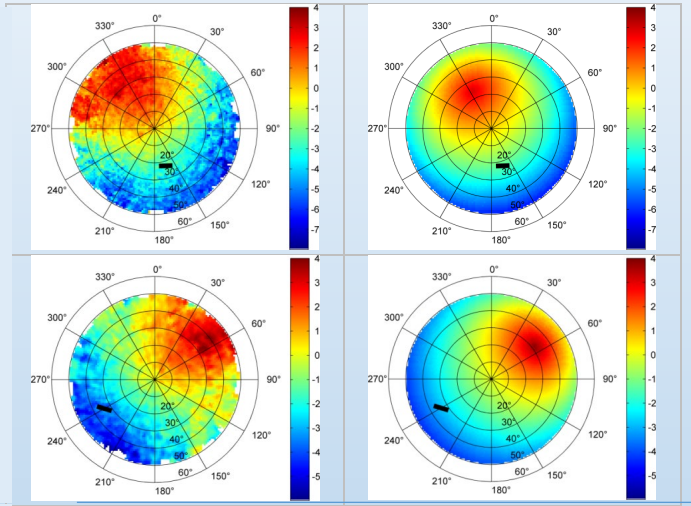
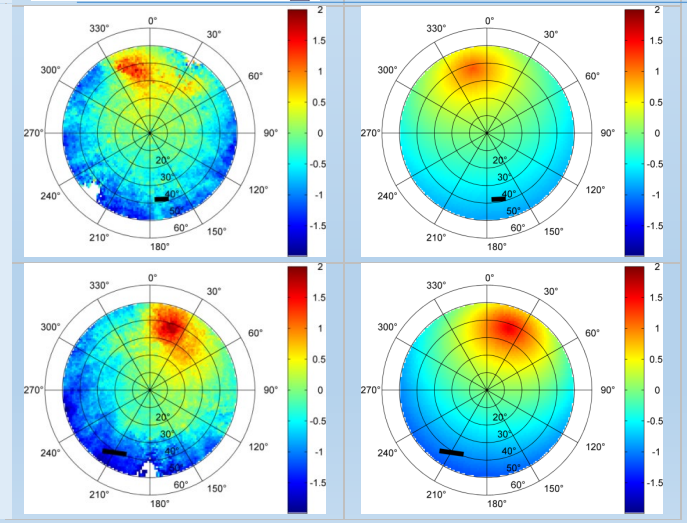
What TRISHNA brings

- **TEMPERATURE (noon-night)**
- **SPECTRAL EMISSIVITY**
- **ALBEDO**

TRISHNA



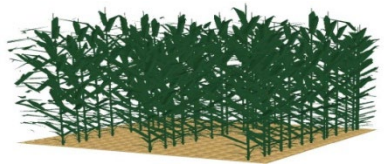
hot spot

	Measures	RL model
Urban		
Maritime Pines		

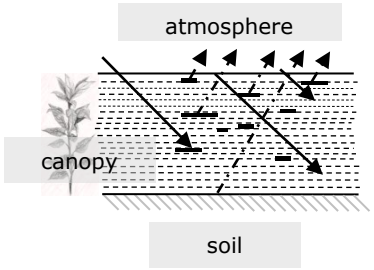
(crédit J.P. Lagouarde & M. Irvine)

3 categories of hot spot model:

- ❑ **3D (urban, vegetation, ex: DART)**
  [Lagouarde et al., RSE 2010 and 2012]



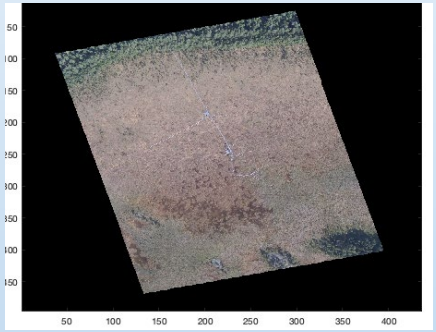
- ❑ **SCOPE 1D (multilayers)**
  [Duffour et al., 2015 and 2016a]

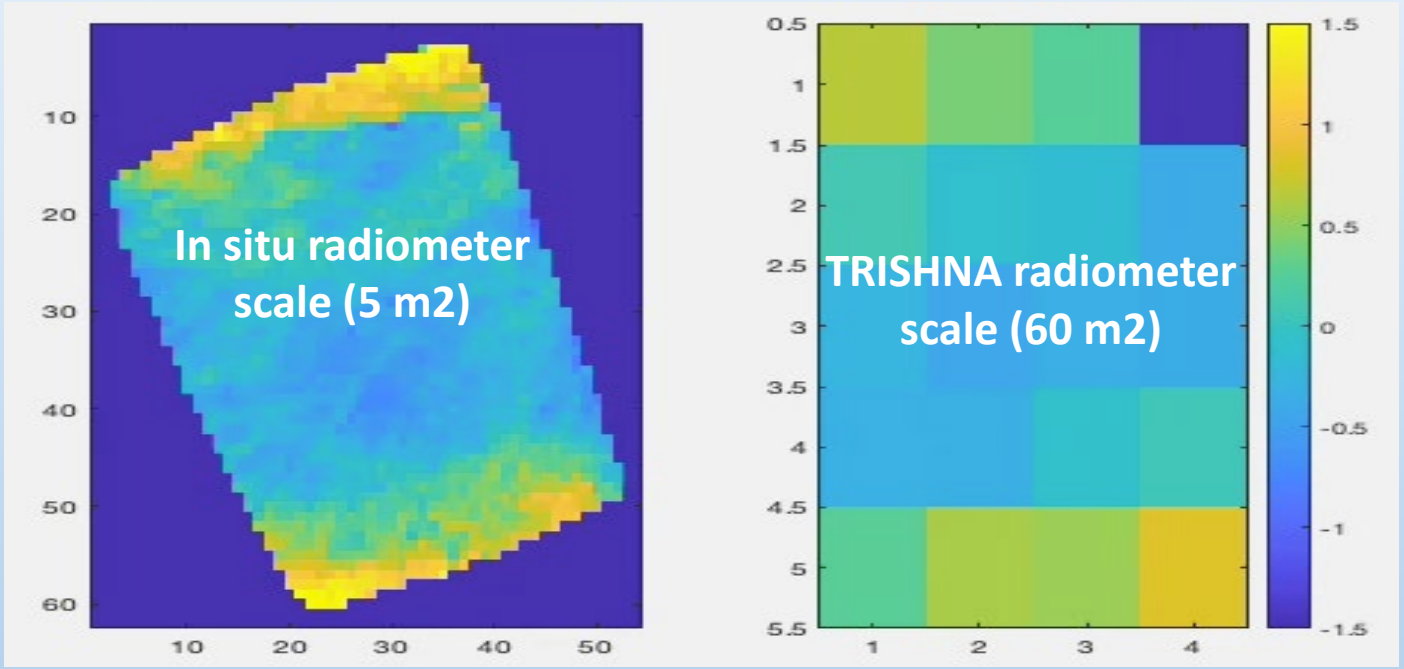


- ❑ **Parametric (Roujean-Lagouarde)**
  [Duffour et al., 2016b]

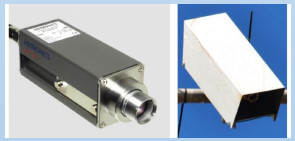
TRISHNA

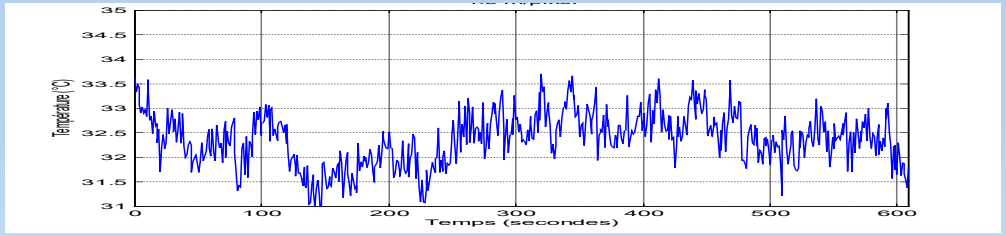
TRISHNA validation sites – Spatial/Temporal Variability (1/2)

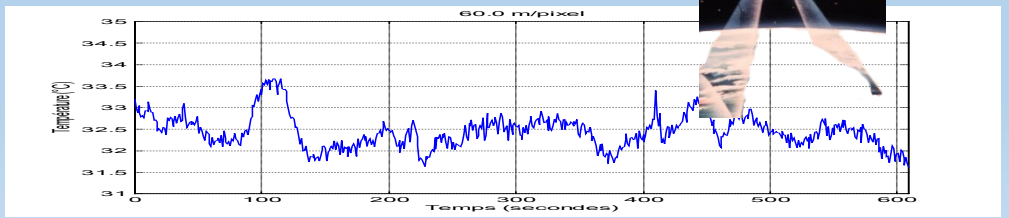


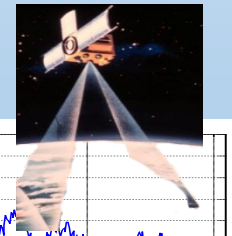


Spatial/ Temporal differences can be of several degrees K !



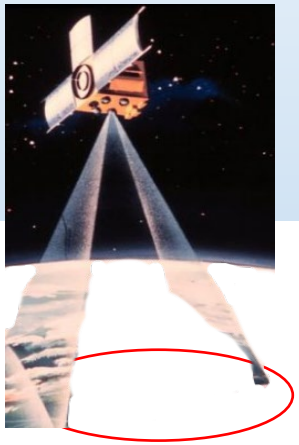


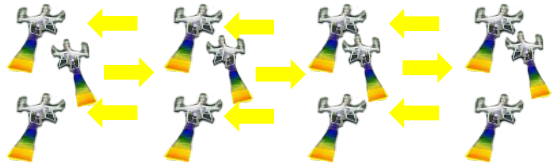




Instantaneous satellite images must be compared to in situ small footprint field measurements

TRISHNA validation sites – Spatial/Temporal Variability (2/2)





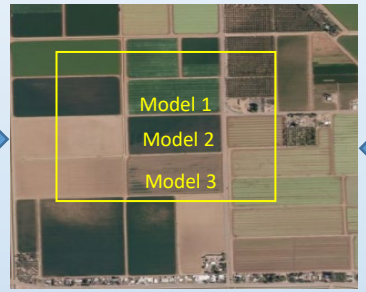
Compare the TRISHNA Pixel with several *in situ radiometer pixels*

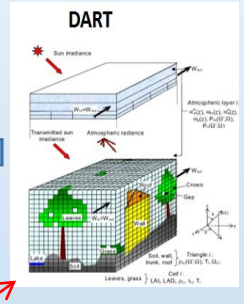
Test Spatial/Temporal integration with several radiometers or using a UAV integrating radiometer

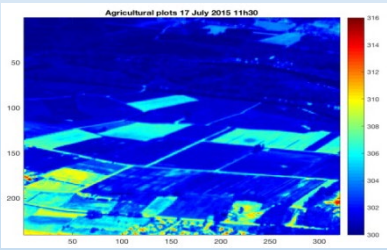
Initial results indicate that the UAV solution is extremely efficient at reducing in situ measurement variability related to turbulence

TRISHNA

Cal-Val activities







Simplified Directionel, Evapotranspiration Models

3D Directionel, Turbulence Model Upscaling

Upscaling Atmosphéric transfer ..

Research Quality data

Calibration data

Targeted Research Quality data

LST Validation Sites

Bias
RMSE
Correlation
Nash criteria
Consistency

LST Super-Sites

Downscaling

Signal integration

LST Field Campaigns

Landscape scale

TRISHNA footprint

Coll. : NASA/JPL, ESA, etc

TRISHNA

University of Zurich[UZH]