TIRCALNet

TIR Top-of-Atmosphere Calibration Network

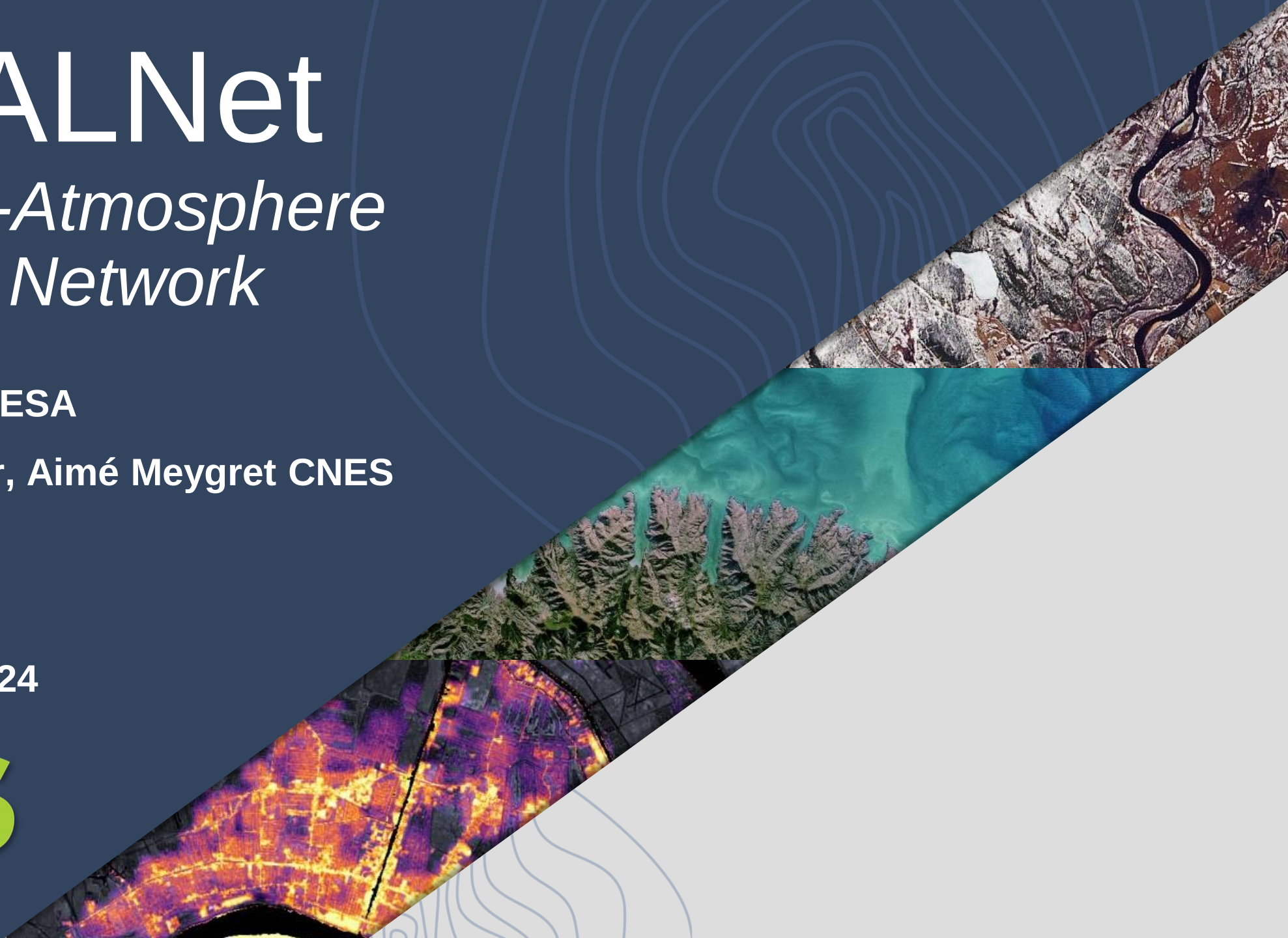
Steffen Dransfeld, ESA

Morgane Chapelier, Aimé Meygret CNES

ISFRN Workshop

Southampton, UK

22nd – 23rd April 2024



CEOS Committee on Earth Observation Satellites

TIRCALNet Context

As per CNES WGCV presentation last year:

- Several TIR missions operational: ECOSTRESS, ASTER, LANDSAT-8&9, MODIS, VIIRS, SLSTR, SEVIRI…
- TIR future missions with higher resolution: TRISHNA, LSTM, SBG
- More and more demanding LST accuracy requirements better than 0.1 K for climate studies
- Importance of vicarious calibration for the validation of on-board calibration systems (black bodies) or direct calibration
- L2 products (temperature & emissivity) validation need

In addition numerous new space TIR companies are about to be launched: ConstellR, Ororatech, Aistech,…

TIRCALNet Objectives

- To collect surface temperature and emissivity, and atmospheric data necessary for the simulation of observations by TIR optical sensors and thus verify their radiometric calibration
- To increase the number of matchups between in-situ measurements and space sensor observations and reduce the overall uncertainties, and reduce the efforts of individual agencies
- To ensure traceability of the space sensor radiometry to the “Système International” (SI)
- To support the establishment of the Global Earth Observation System of Systems by providing measurements to verify the radiometric consistency between EO space sensors
- The success and experience return from RadCalNet network dedicated to VNIR-SWIR optical sensors cal/val

Current Limitations of LST Sites

- Spatial representativeness of the in situ reference measurements
- Directional effects
- Lack of emissivity measurements
- Data access
- Data harmonization
- Do not provide TOA radiances
- Data quality assurance (error budget traceable to SI)
- In situ instruments calibration quality and traceability
- Needs for the development of denser ground-based reference Network

First activities for TIRCALNet

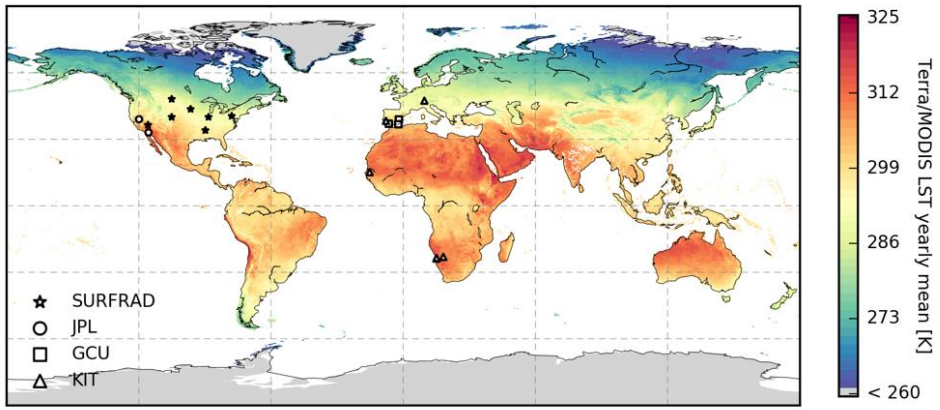
ESA and CNES defined after discussions with domain and agency (CNES, ESA & NASA) experts that TIRCALNet should be able to provide TOA Brightness Temperature signals propagated from BOA measurements of ~ 0.5K uncertainty and a set of tasks were identified :

- Task 1 → Identification of uncertainty contributors to TOA-derived BT
- Task 2 → Sensitivity analysis of uncertainties on TOA BT estimation
- Task 3 → Definition of best site characteristics, optimal instrumentation and forward propagation scheme
- Task 4 → Selection of potential candidate sites based on Task 3
- Task 5 → Interaction with Working Groups and network roadmap

Site Study Objectives

- TRISHNA, LSTM, SBG
- Existing network for LST
- Need for a denser network
  - that provides L_{TOA}
  - with evaluated uncertainty for each site
  - with a demanding requirement on TOA radiance (0.5K)

- Impact of uncertainty sources ?
  - Atmosphere
  - Emissivity
  - Temperature (retrieved from radiometer measurements)



⇒ **Study on La Crau, Gobabeb, Lake Tahoe and Lake Constance site**

Uncertainty budget (Tasks 1 & 2)

Radiative transfer equation

$$L_{TOA} = L^{\uparrow}_{atm} + \tau^{\uparrow} \left(\epsilon \, L_{BB}(T_S) + (1 - \epsilon) \, L^{\downarrow}_{atm} \right)$$

Assumptions:

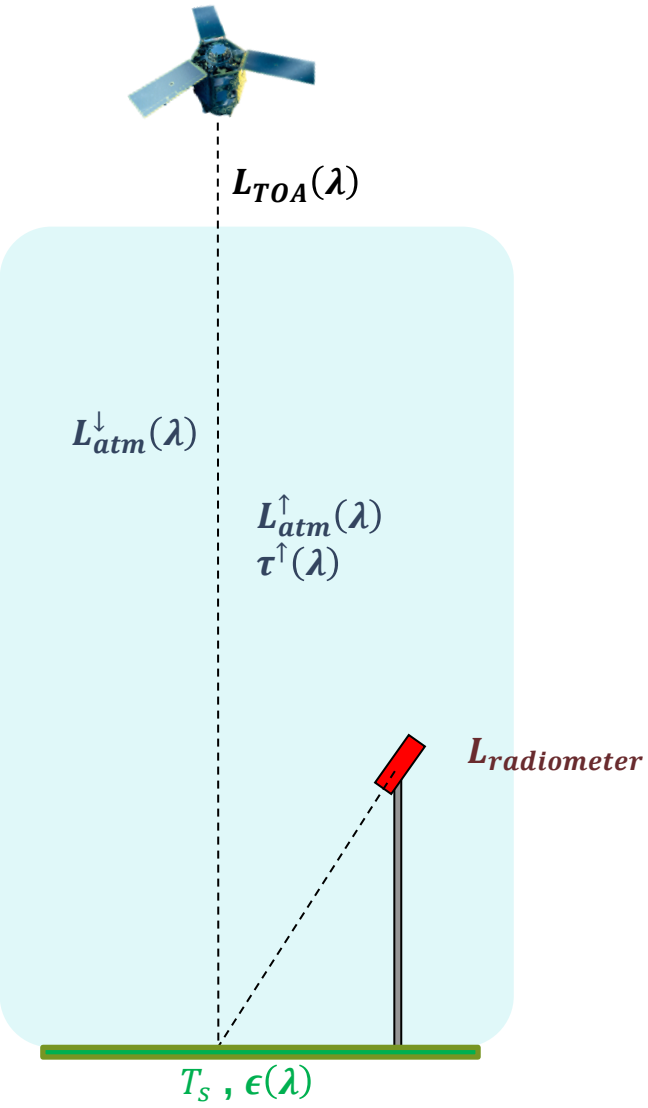
- **Lambertian surface**
- **Nadir satellite**

- **Atmospheric profiles (ECMWF) + RTTOV with IASI high resolution spectral bands:** $L^{\uparrow}_{atm}(\lambda)$, $L^{\downarrow}_{atm}(\lambda)$, $\tau^{\uparrow}(\lambda)$
- **Surface emissivity** $\epsilon(\lambda)$**:**
  - **La Crau: Labed 91 for soil**
  - **Gobabeb:** MAST2 (ONERA measurement, FICE campaign)
  - **Lake Constance:** Tap Water (JHU)
  - **Lake Tahoe:** Tap Water (JHU)

- **Radiometer measurement** $L_{radiometer}$ **simulated for surface temperature retrieval**

⇒ **Derived quantities: surface temperature** $\widetilde{T}_S$ **+ uncertainty**

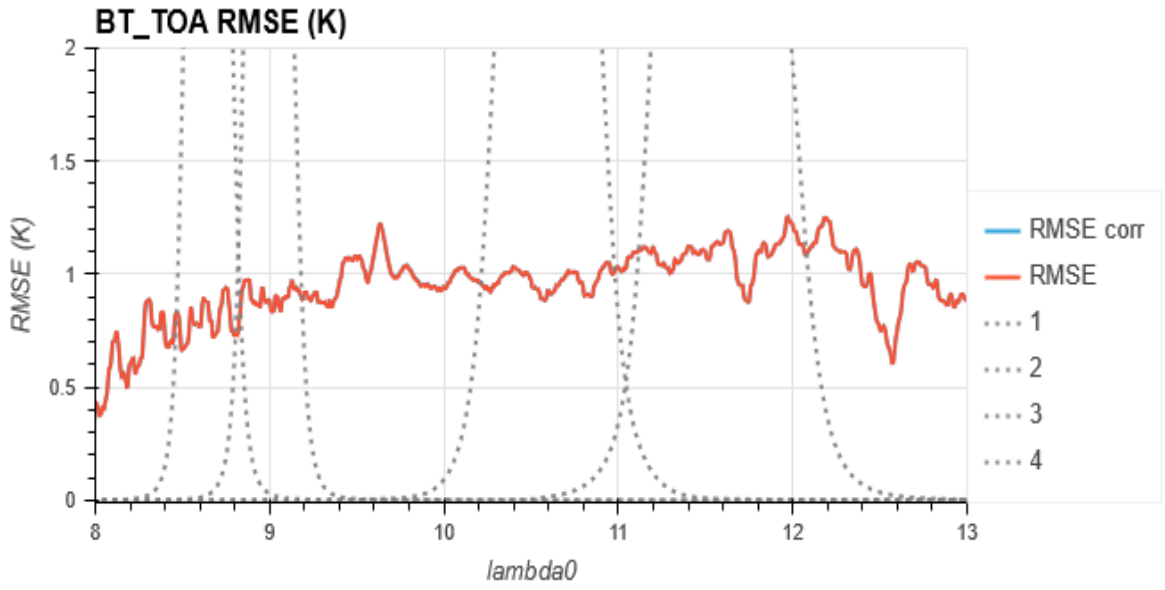
⇒ **Emissivity uncertainties drive the overall TOA uncertainty.**



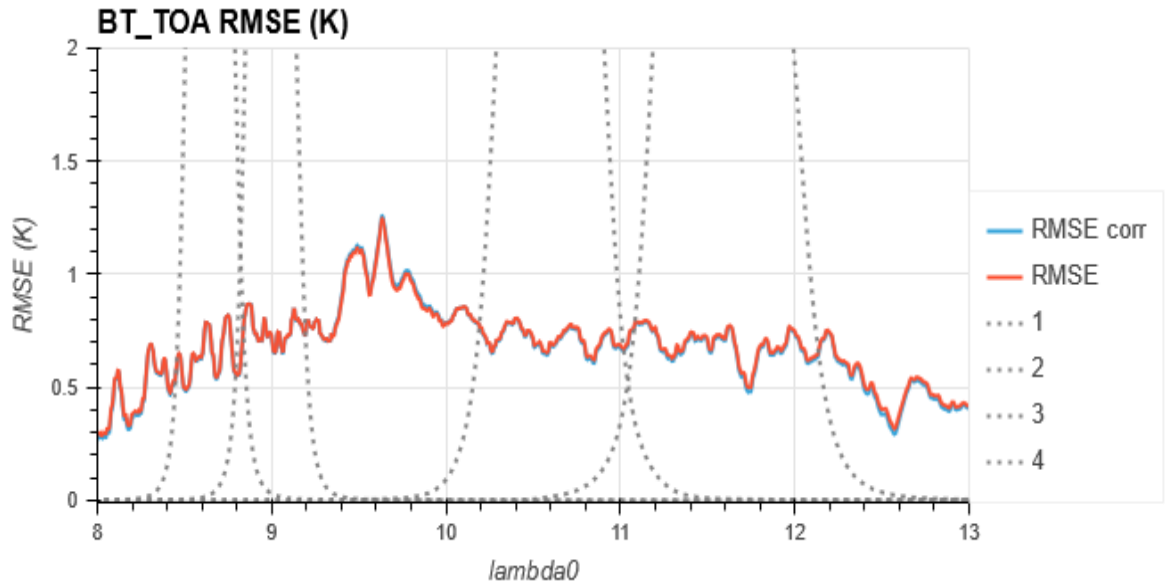
Uncertainty budget : La Crau

- **Uncertainty on emissivity at IASI spectral resolution : std 0.02 (+ std 0.01 on mean emissivity)**
- **Emissivity spectrum : Labed&Stoll91**
- **JPL radiometer**

Driest month : January



Wettest month : November

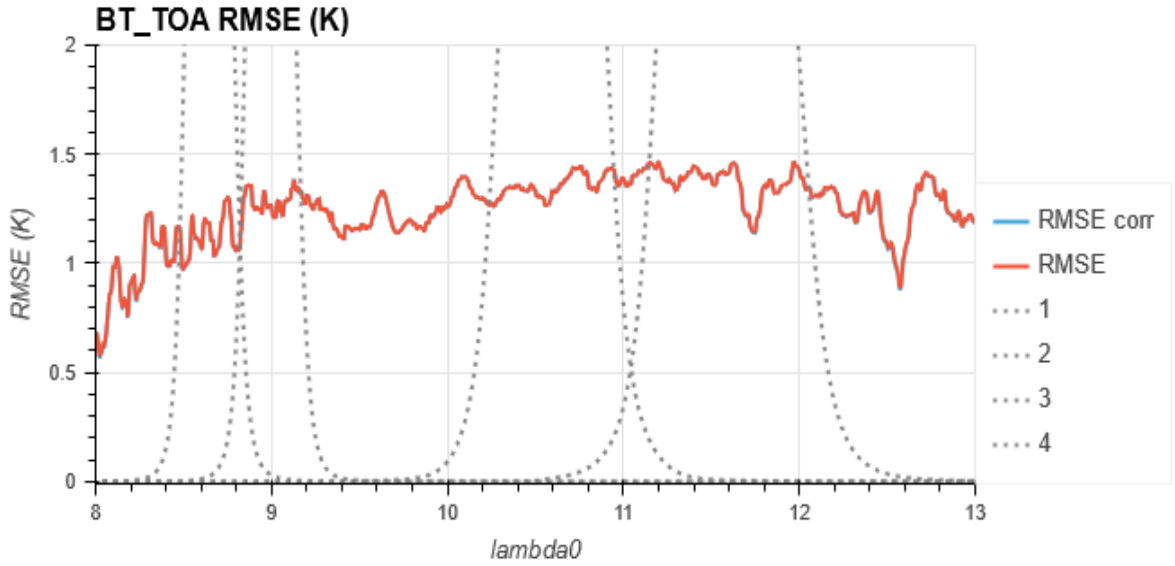


- **Better performance for wet months because of the higher atmosphere contribution (reduce the impact of the emissivity errors on TOA radiance)**

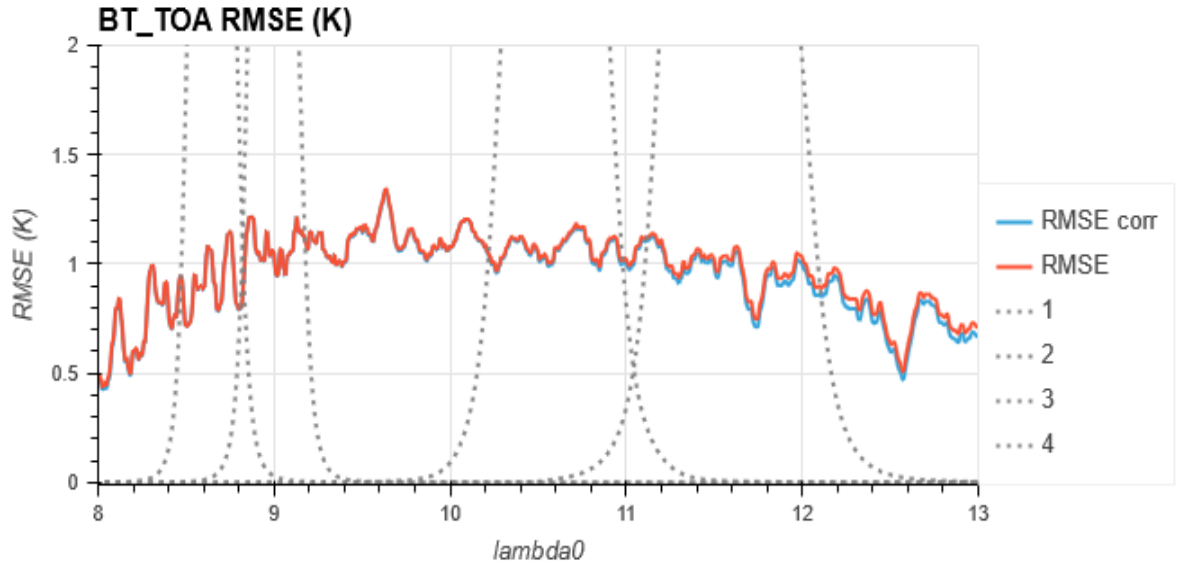
Uncertainty budget : Gobabeb

- **Uncertainty on emissivity at IASI spectral resolution : std 0.02 (+ std 0.01 on mean emissivity)**
- **Emissivity spectrum : MAST2 (ONERA measurement, FICE campaign)**
- **KT15 radiometer**

Driest month : September



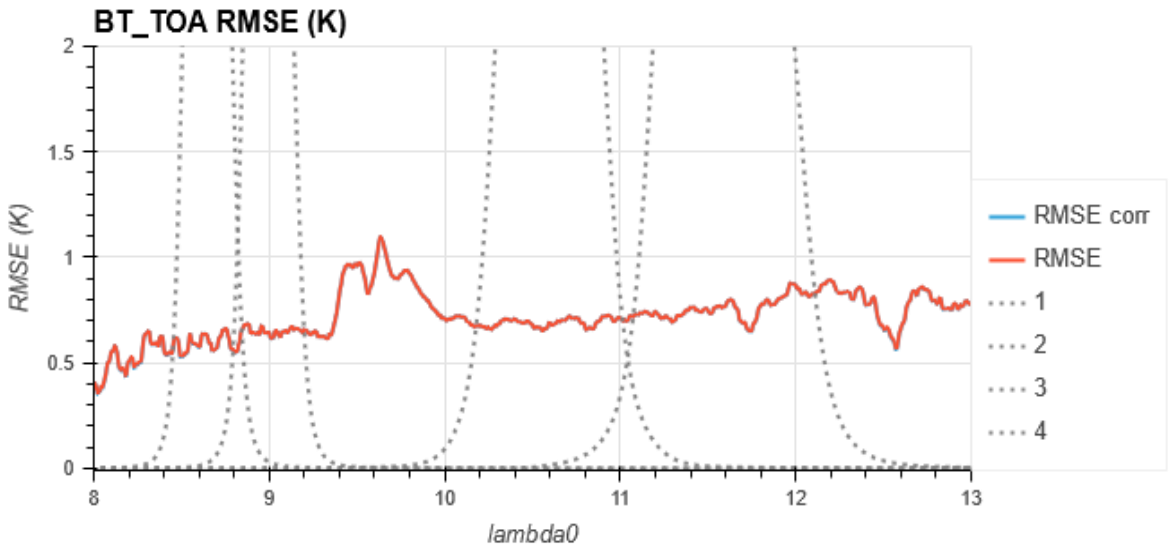
Wettest month : February



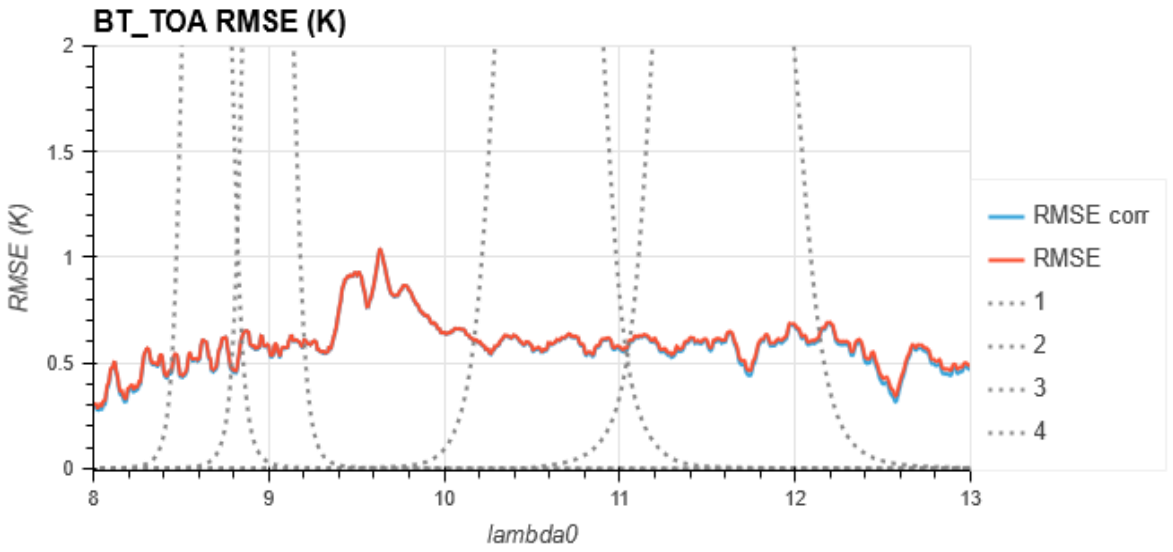
Uncertainty budget : Lake Constance

- **Uncertainty on emissivity at IASI spectral resolution : std 0.015 (+ std 0.01 on mean emissivity)**
- **Emissivity spectrum : Tap Water (JHU)**
- **KT15 radiometer**

Driest month : March



Wettest month : June

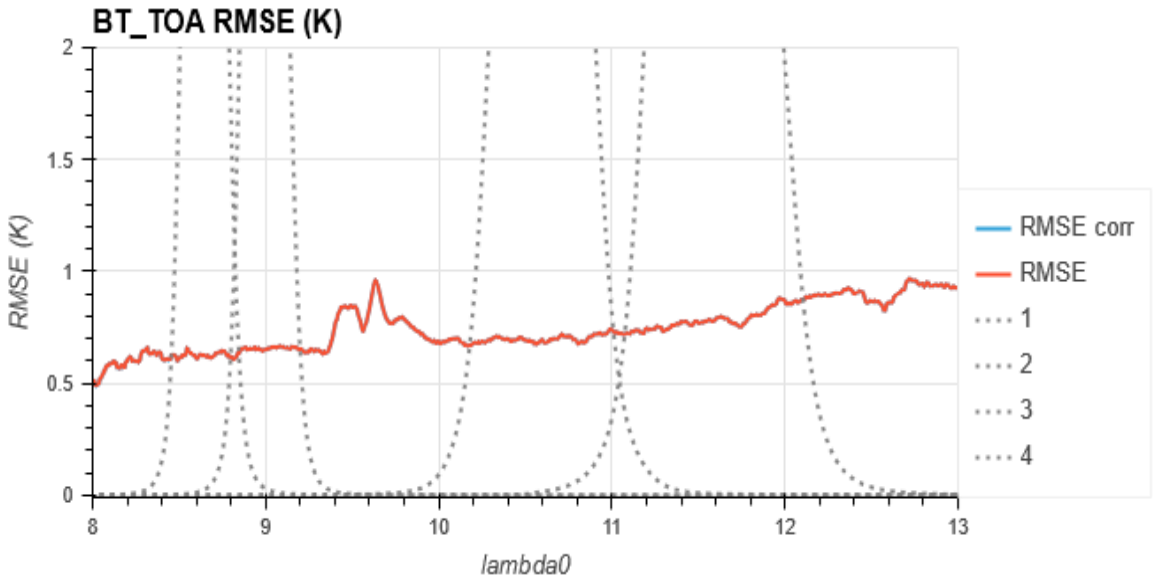


- **0.5 K objective marginally reached for Lake Constance**

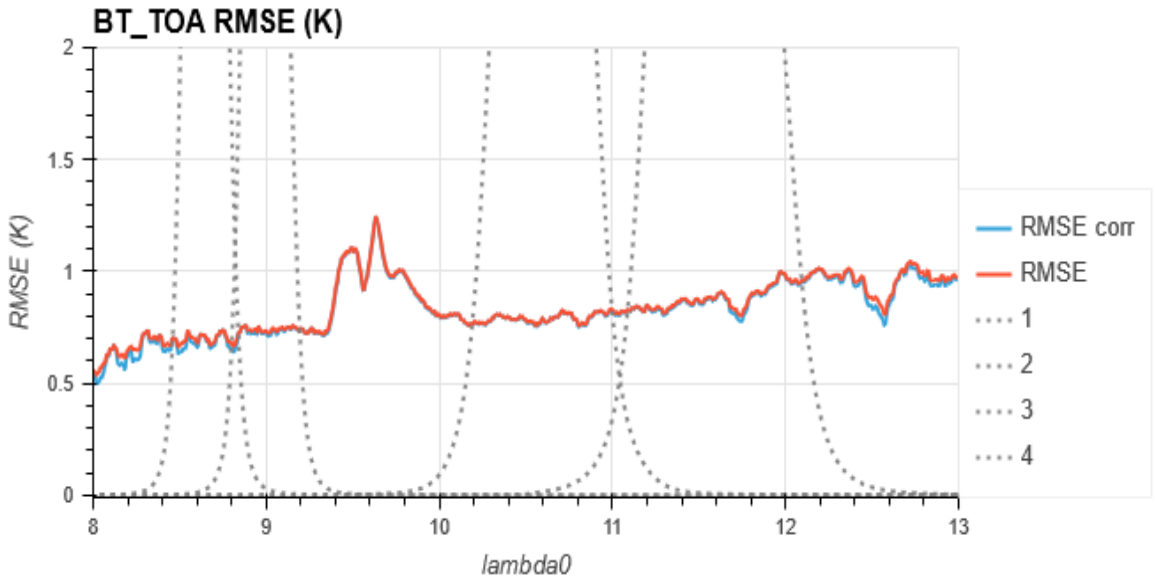
Uncertainty budget : Lake Tahoe

- **Uncertainty on emissivity at IASI spectral resolution : std 0.015 (+ std 0.01 on mean emissivity)**
- **Emissivity spectrum : Tap Water (JHU)**
- **JPL radiometer**

Driest month : February



Wettest month : September



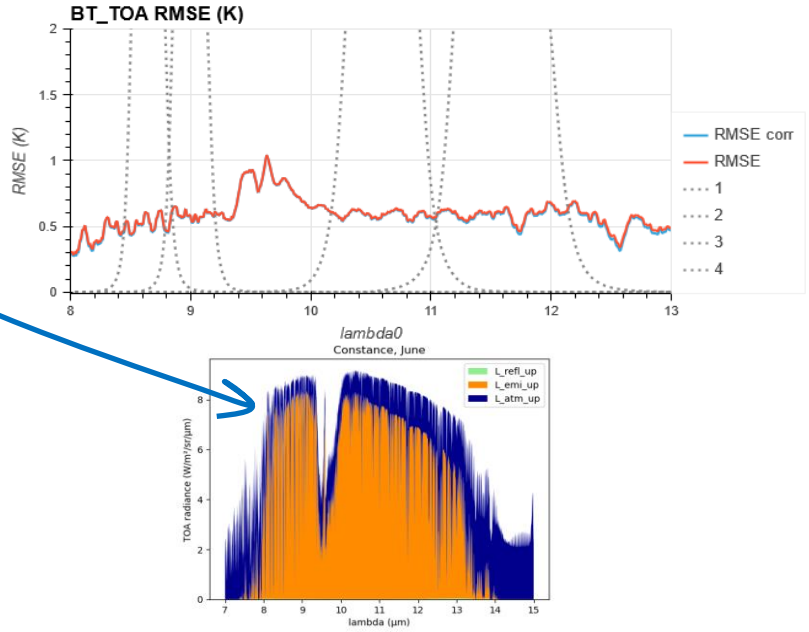
- **ECMWF surface temperature for Lake Tahoe to be consolidated for this case (higher than expected)**

⇒ A better performance is expected…

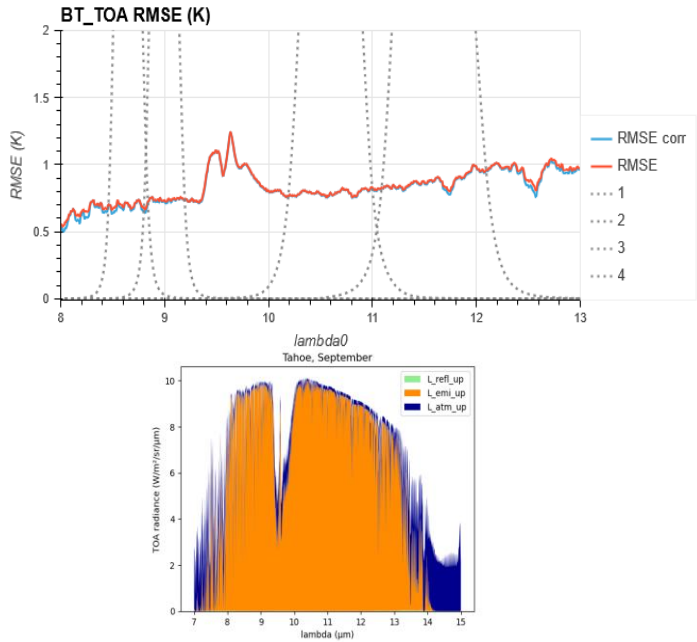
CNES study - synthesis

- **Confirmation that the main impact on TOA Brightness Temperature is the uncertainty on the ground emissivity. Uncertainties on the atmospheric profiles is an issue but of lesser impact.**
- **Atmosphere (L_atm_up) tends to compensate errors on surface emissivity: lower errors for Lake Constance than Lake Tahoe**
- **Emissivity and atmosphere errors hypothesis have to be consolidated**

Wettest month : June



Lake Tahoe, wettest month : September



CNES study – next steps

- **To improve the surface emissivity caracterization :**

  - Deploying and comparing dedicated instrumentation for Temperature/Emissivity separation:

    - CIMEL CE312 (6 spectral bands)

    - 4 KT 15 (with TRISHNA like bands)

  - Emissivity box under construction

- **Assess the performances of a radiance based method (that is pushing TOA the BOA surface radiance measured by in situ radiometers without retrieving Temperature and Emissivity)**
- **Delivery: Error budget technical note + code (beginning of march)**

Next steps towards other sites

ESA have started a TIRCALNet Preparation Study end of 2023:

- Transfer of CNES La Crau uncertainty budget template to other sites (e.g. from ESA LAW project) and perform similar simulations to gain an understanding how site environment may influence the uncertainty.
- Develop a full site uncertainty budget template inclusive of atmospheric, forward propagation, instrumentation and site environment uncertainties
- Development of a site measurement and forward propagation protocol to minimise uncertainties at TOA
- Analysis of site characteristics (surface, cloud cover, etc.) to find possible candidate sites (e.g. Lake Tahoe, Acqua Alta platform, Russel Ranch
- Develop a roadmap to equip and operate sites
- Discussions with partnering agencies on how to collaborate and set up and operate networks (funding for instrumentation, site operation, data analysis, supporting studies, etc.)

Internation Working Group

The study aims to create and provide input to an International Working Group aiming to set up TIRCALNet

JPL-NASA
- Operating Lake Tahoe and Salton Sea Calibration sites
- Long data record since 1998
- Providing operational Cal/Val for several TIR missions and preparing for SBG-TIR

CNES
- Operating La Crau calibration site
- Ramping up Cal/Val facility for TRISHNA mission

ESA
- Sentinel-3 LST operator, CCI-LST, FRM4STS
- LSTM Cal/Val preparation
- Support to new space companies

CSIRO
- Interest to assess and set up a site at Pinnacles Desert

INGV
- Operating a radiometer at Acqua-Alta platform in Venice lagoon
- Preparations for SBG-TIR mission Cal/Val

Link to other Projects & Networks

ASTeRN: Advanced Surface Temperature Radiometer and global Network

- Network consisting of 6 new sites for LST led by RAL SPACE
- Deployments starting in 2024

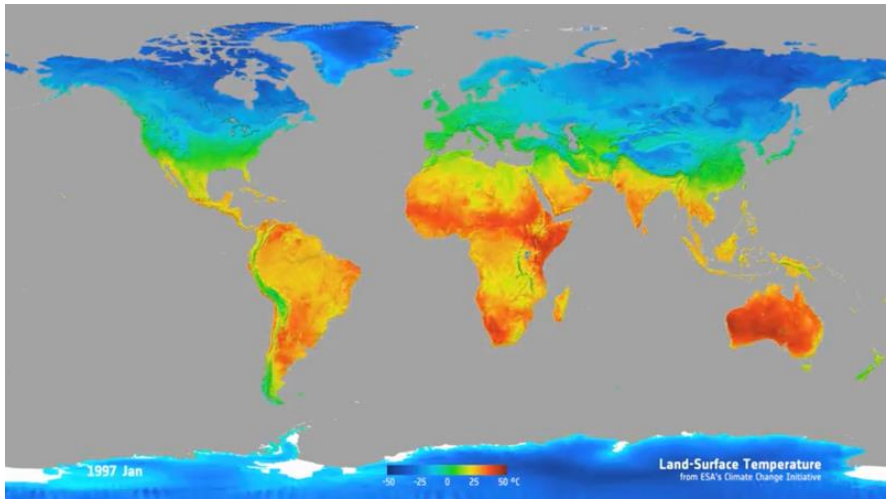
SLSTR and LSTM L2 Processor Development and associated Cal/Val expertise at University of Leicester

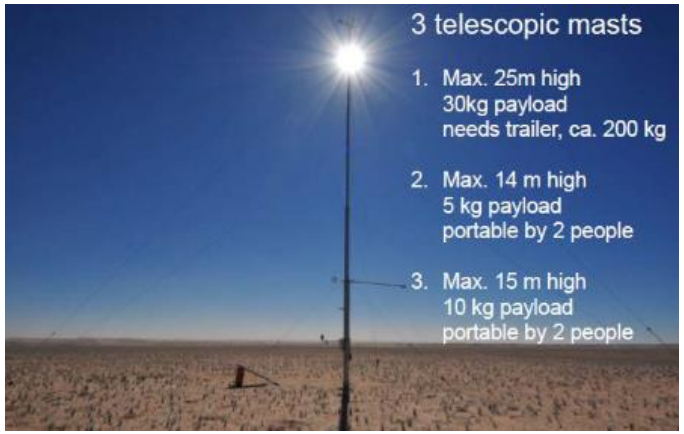
LST-CCI involving both University of Leicester and KIT

- Provides the needs for stability criteria at L1 for climate datasets
- Strong driver for a network and longterm operation scheme

FRM4STS project led by KIT

- Field radiometer intercomparison exercises (FICE)
- In situ and lab-based emissivity characterisations





Outlook for TIRCALNet

- Current ESA preparatory study started and going on for 18 Months
- Main project output will be a site prototype design and a roadmap towards an operational network that provides much needed TIR ToA anchoring points for radiometry cal/val
- The Working Group will then have to establish similar to Radcalnet a framework to equip sites as needed and start operating them.
- Still early to say when but at some stage beta-users from TIR mission operating entities will need to be included in the data uptake and assessment as this is **ultimately a support to ensuring well calibrated thermal data** !

Thank you very much for your attention !