SIRTA
Site Instrumental de Recherche par Télédétection Atmosphérique

JSS2017

Evolution of fog and low stratus observed by satellite

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Summary

1. Introduction
2. Case study: two consecutive but divergent fog events
3. Method: definition of satellite indicators
4. Results: follow-up of fog evolution
5. Conclusion

1. Introduction

Objectives & applications

Objectives:

⇒ intraday predictability of

- fog and low stratus cover
- ground irradiance: solar panels

Applications:

⇒ transports:

- security
- reducing delays
- €,$: reducing financial losses due to delays & cancellations

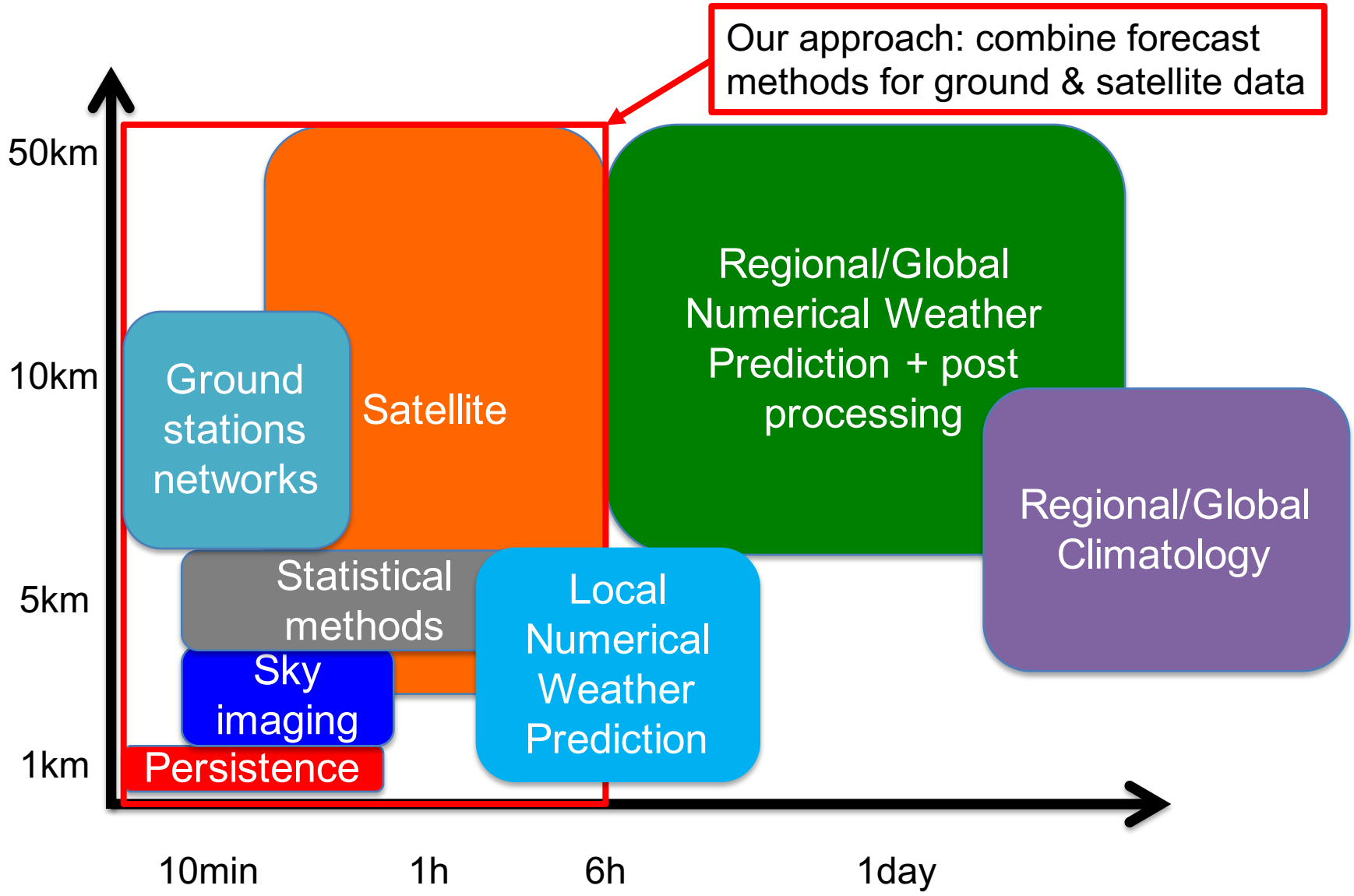
=> electricity production forecasts

- for a better distribution and transmission system management
- input parameters of storage strategy
- €,$: pricing & buy and sell opportunities on electricity market

TREN-D-X

What are the different forecasting methods for:

- **fog evolution ?**
- **solar electricity production ?**



Satellite & ground-based studies complementariness

in both cases, a model-to-prediction approach:

- identify key variables
- quantify order of magnitude and variability
- design conceptual models to transform observations to 0-6 hours forecasts

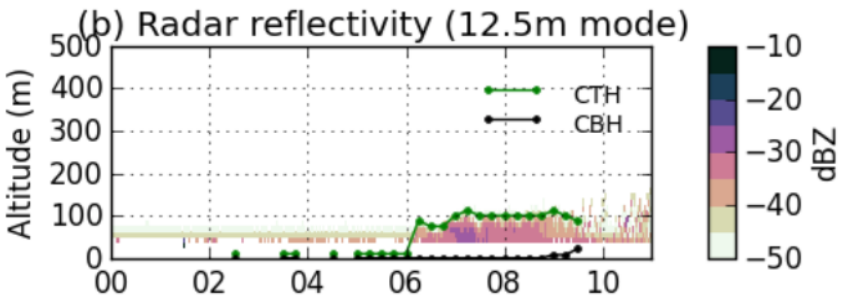
ground observations:
from below, local point of view

⇒ numerous instruments
⇒ in-situ & remote-sensing

geostationnary satellite:
from above, wide sightview from space

⇒ fixed point of view
⇒ uninterrupted temporal series of maps

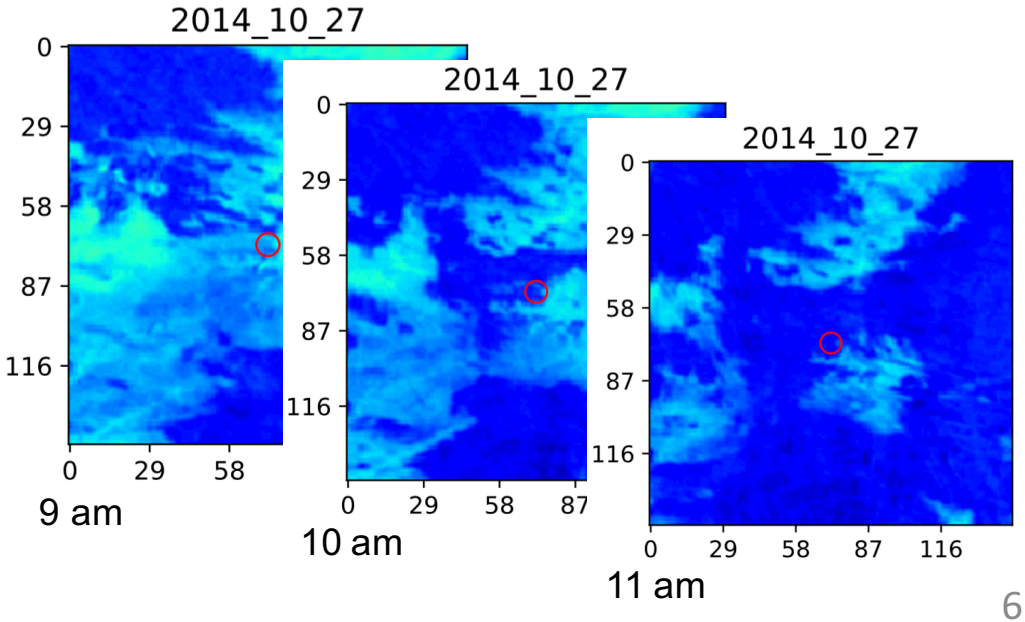
SIRTA, 2014/10/27



CBH: Cloud Base Height
CTH: Cloud Top Height

Key dissipation process: surface warming
Ref : Wærsted et al 2017

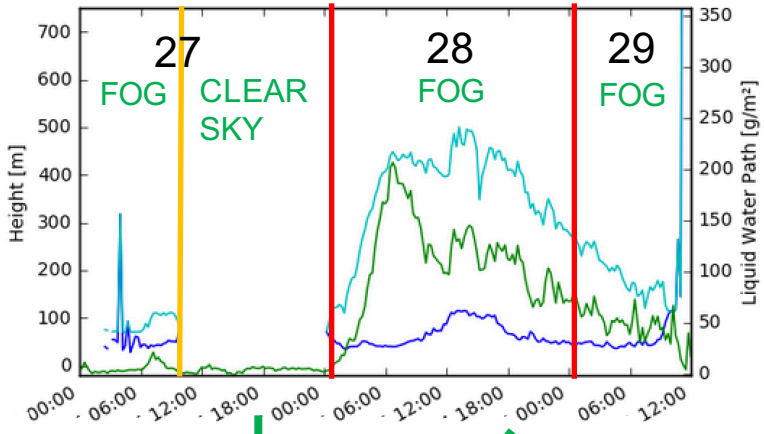
cloud albedo sequence:



2. Case study: two consecutive but divergent fog events

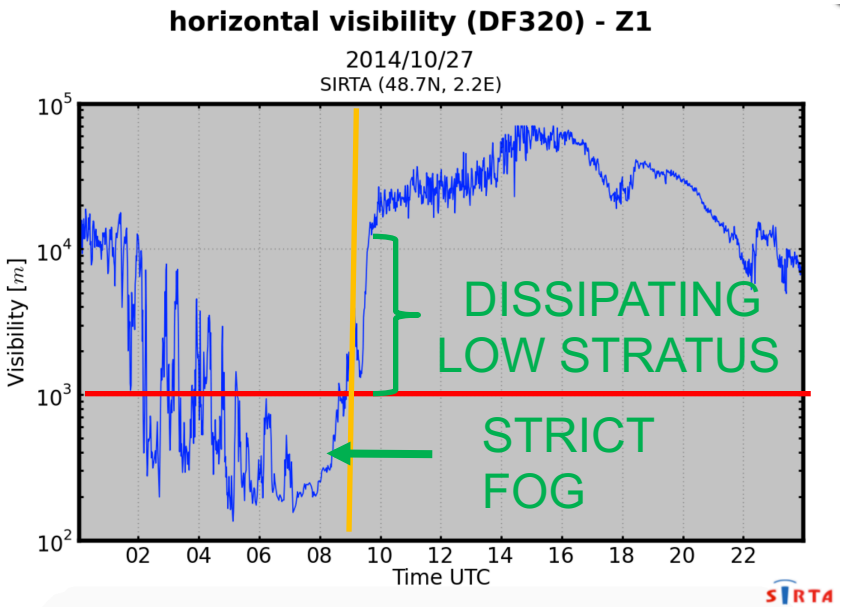
Consecutive but divergent fogs: a ground perspective 1/2

27: 2014/10/27
28: 2014/10/28
29: 2014/10/29

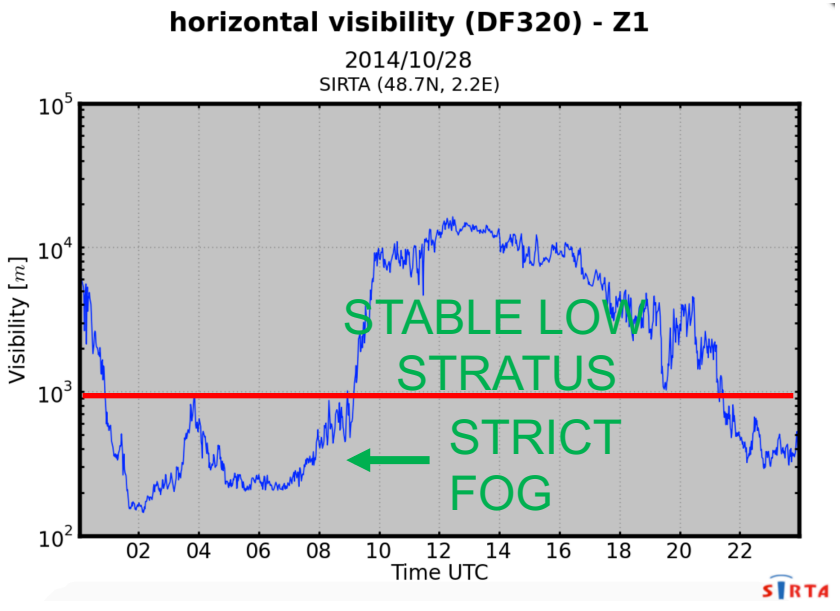


FOG HERE MEANS:
FOG & VERY LOW STRATUS

27: LIGHT FOG



28: HEAVY FOG

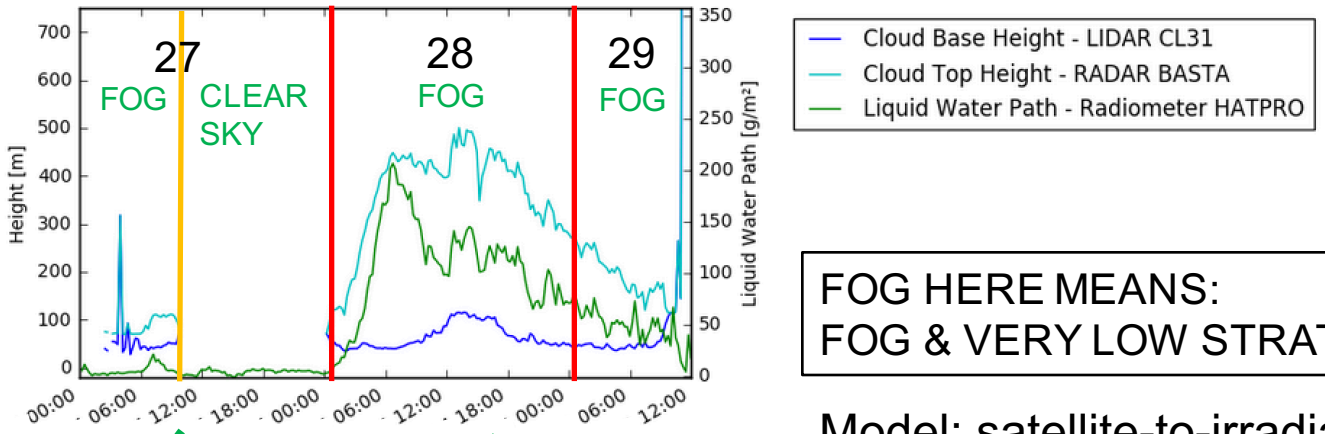


Strict definition of fog: horizontal visibility < 1km & water dropplets => fog

=> Fog on both 27 & 28th until 9am: same « experience » at ground level

Consecutive but divergent fogs: a ground perspective 2/2

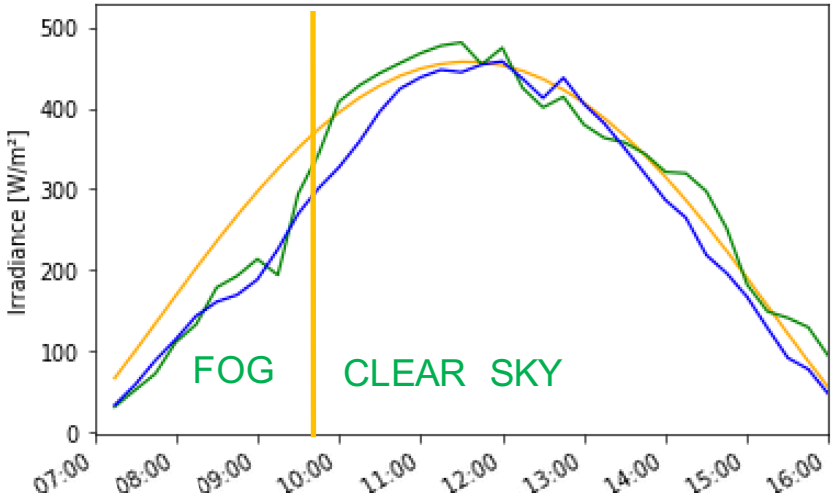
27: 2014/10/27
28: 2014/10/28
29: 2014/10/29



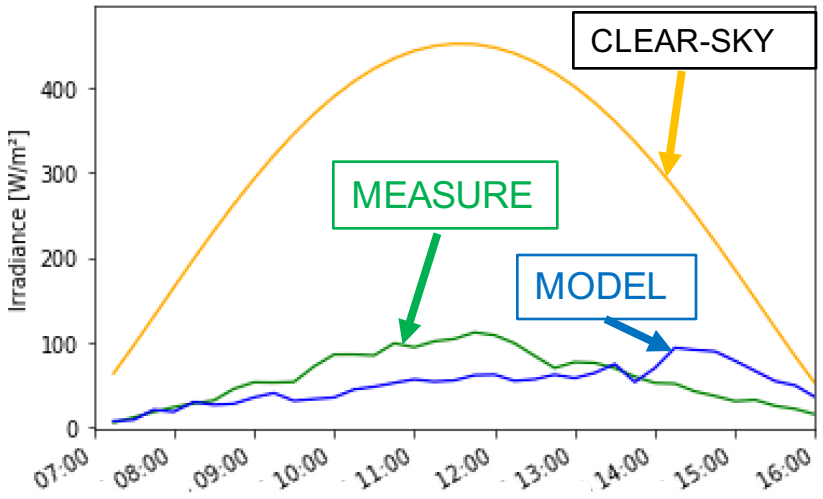
FOG HERE MEANS:
FOG & VERY LOW STRATUS

Model: satellite-to-irradiance
ref Mueller et al 2012

27: LIGHT FOG



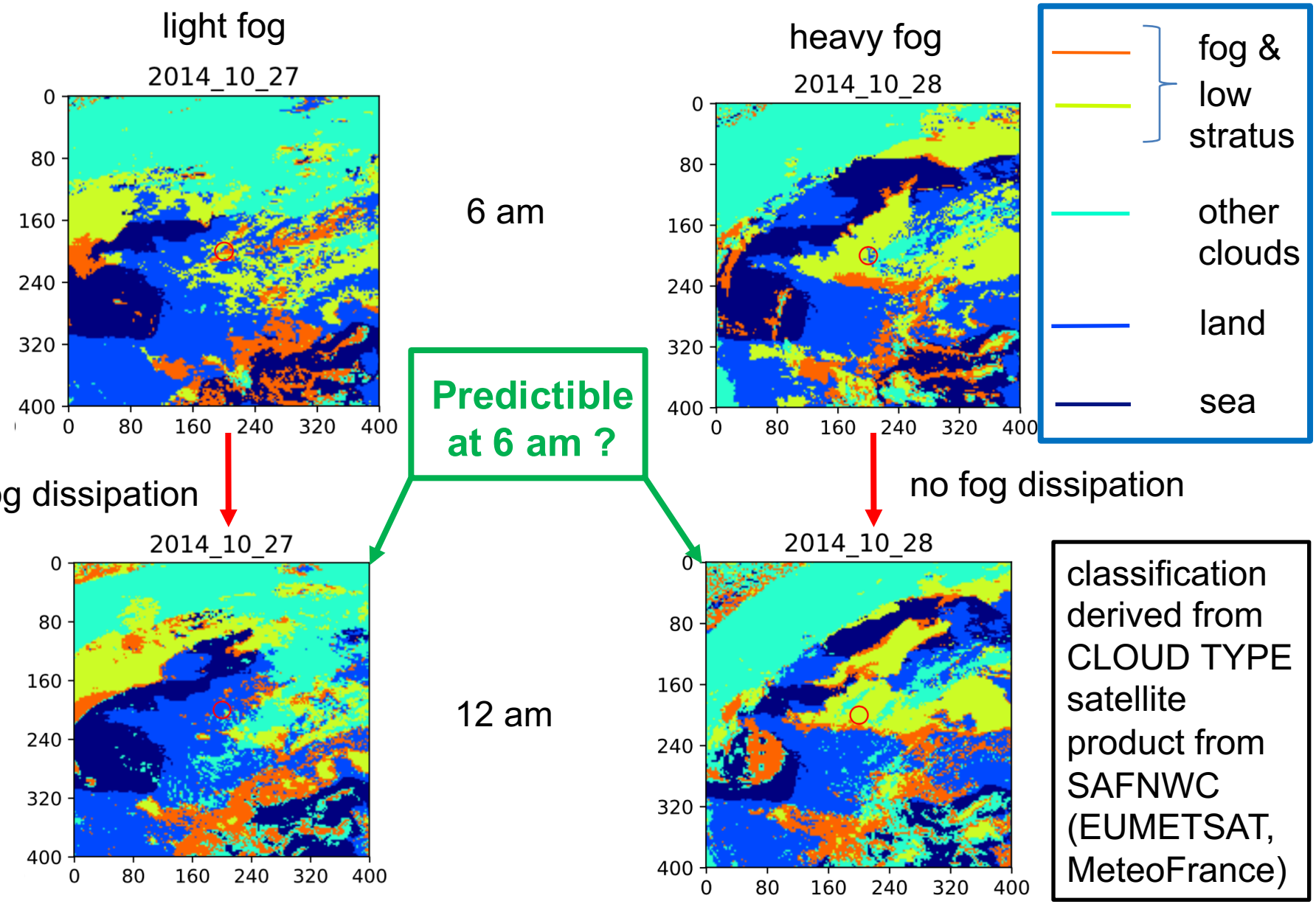
28: HEAVY FOG



Ground Horizontal Irradiance [W.m^{-2}]

=> GHI max is 4,5 times less by heavy fog compared to clear sky

Consecutive but divergent fogs: a satellite perspective



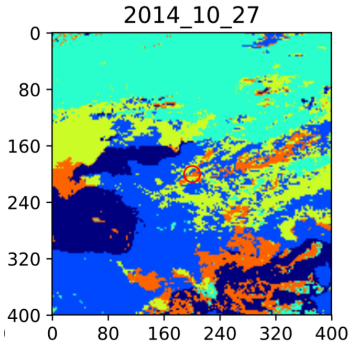
=> What would be the variables that would enable anticipating fog dissipation ?

3. Method: definition of satellite indicators

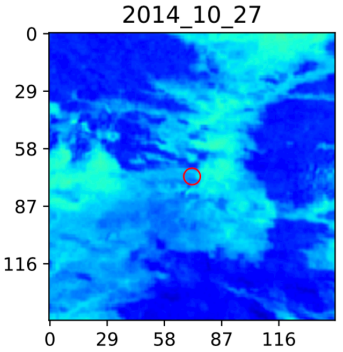
Selection of three satellite indicators

1. Cloud Type:
   - clusters of pixels: classification of meteorological situations
   - enables monitoring subsets of images with close physical properties

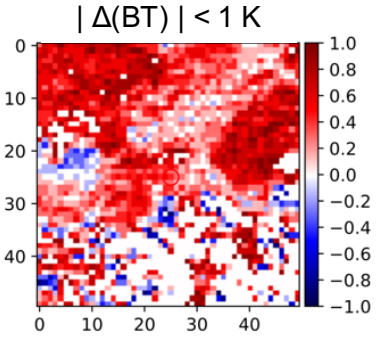
   [satellite product from SAFNWC: EUMETSAT, MeteoFrance…]



2. Cloud Albedo based on visible high resolution channel:
   - ref: Mueller et al 2012
   - contrasted key figure growing with cloud optical depth
   - intermediate key figure for estimating ground irradiance using satellite-to-irradiance models: basis for solar panels applications

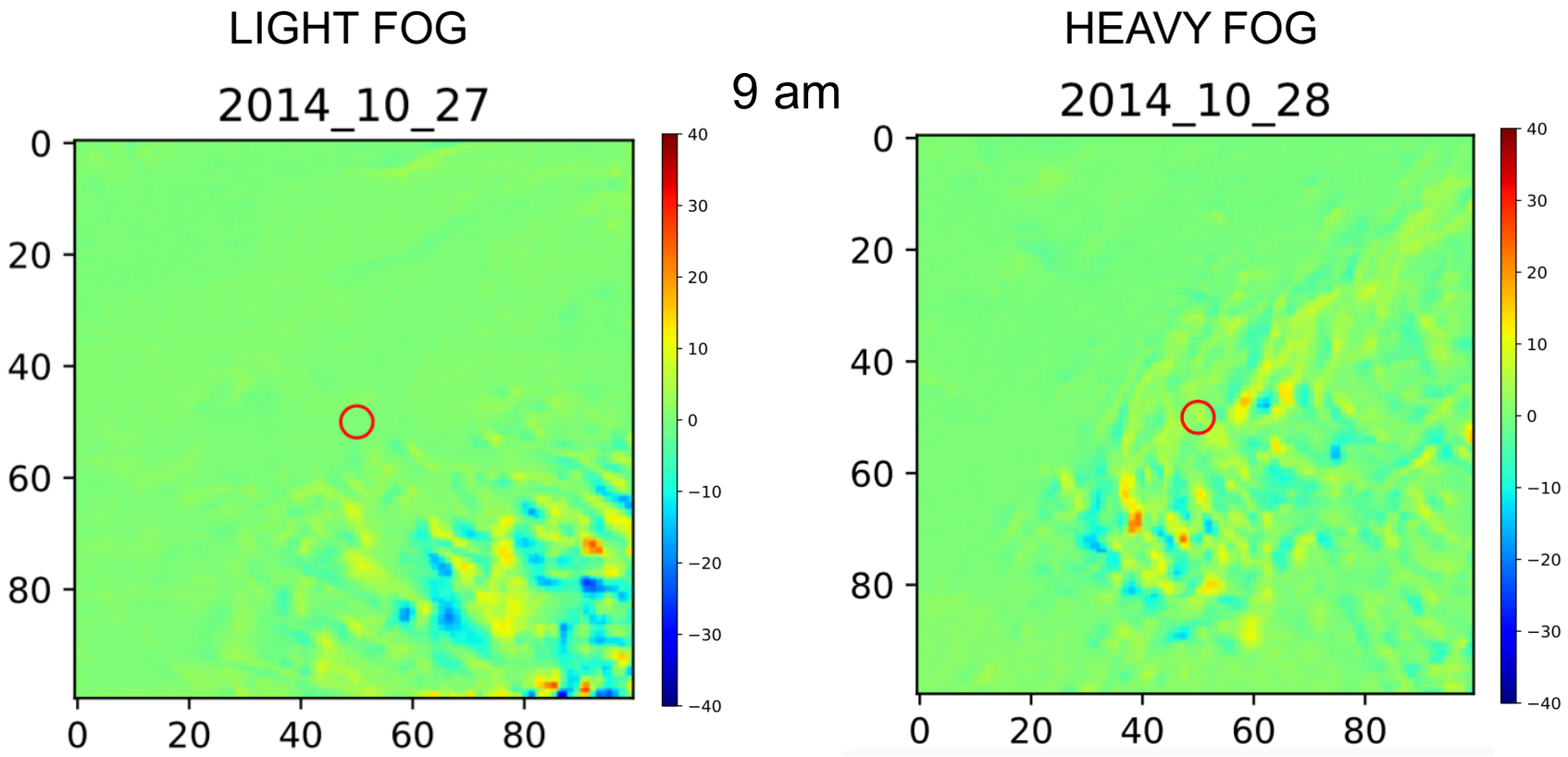


3. A new key figure at pixel level:
   - new proxy indicator for surface warming
   - based on variations of 10.8 µm IR channel for two consecutive images
   - notation: Δ(BT) 10.8 µm (K)



A new proxy indicator for surface warming 1/2

SIRTA-centered images of Δ(BT) 10.8 µm (K)

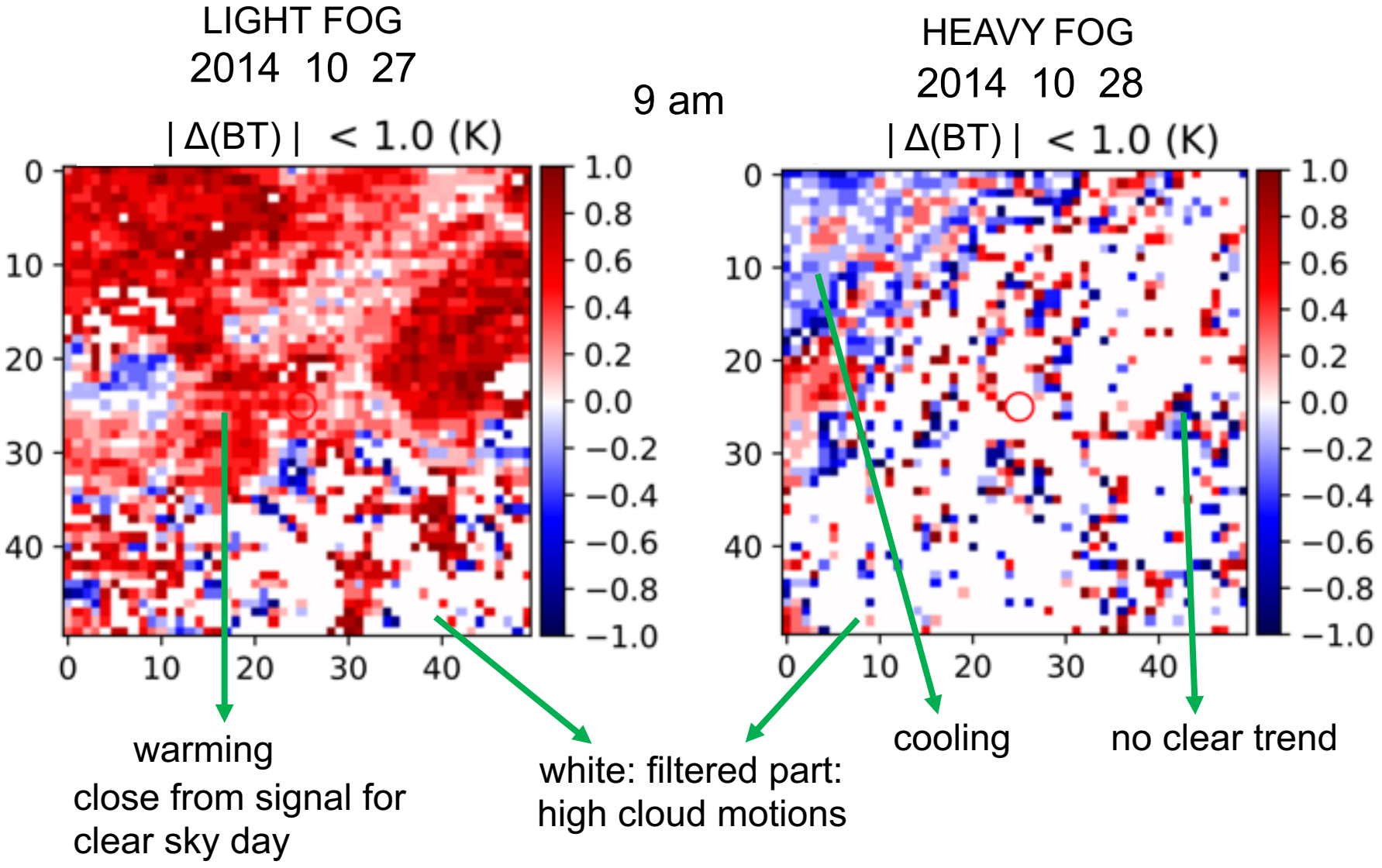


- most of the image (green color): uniform signal, variation close to 0
- kind of waves (blue,red,yellow): very strong variations due to high cloud motion

=> seems there is no information about fog based on this Δ(BT) maps
=> is there a « hidden signal » below these high variations ?

A new proxy indicator for surface warming 2/2

SIRTA-centered images of Δ(BT) 10.8 µm (K)

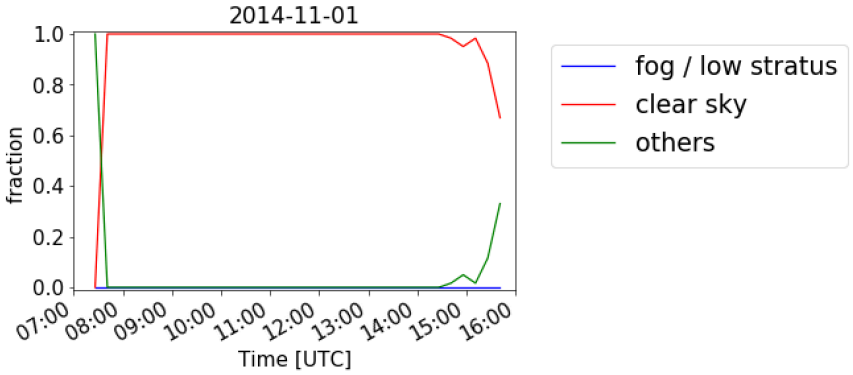


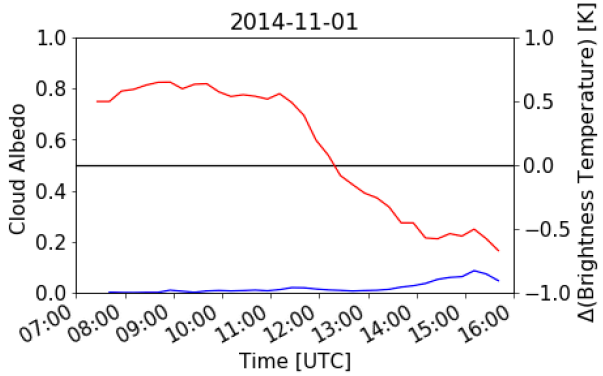
=> A warming signal for light fog at 9 am indicates pixel or subpixel clear sky areas

4. Results: follow-up of fog evolution

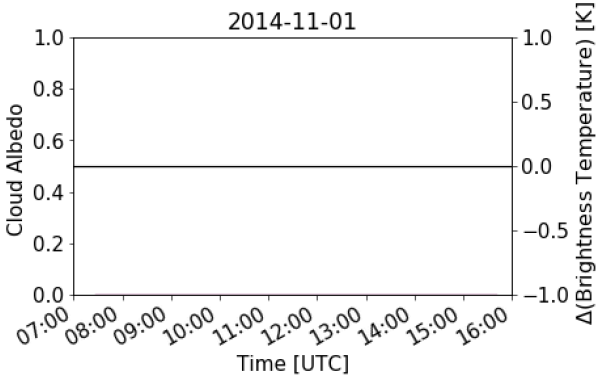
Evolution of satellite key figures: clear sky

- source: sequence of 11*11 pixels SIRTA-centered maps
- evolution of average of (changing) clear-sky and fog/low stratus clusters/subsets





clear sky pixels

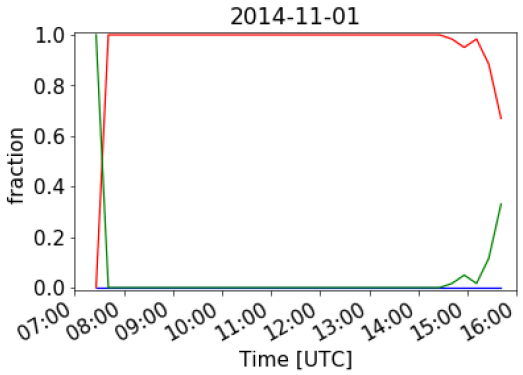


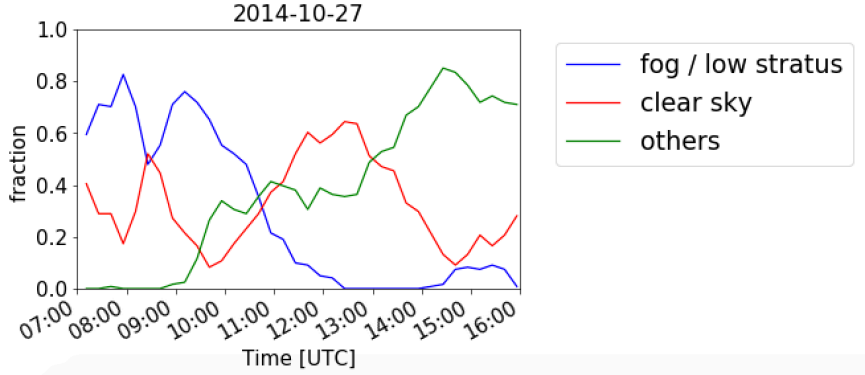
fog pixels

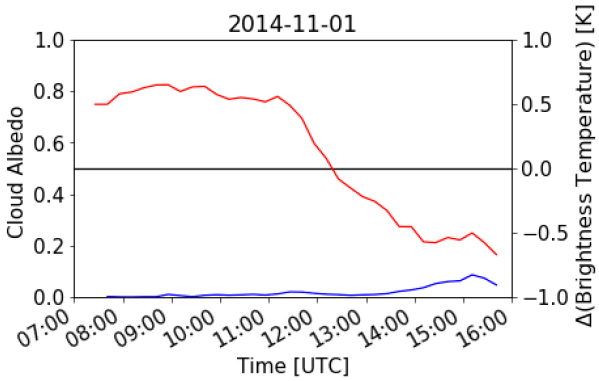
=> clear sky situations:

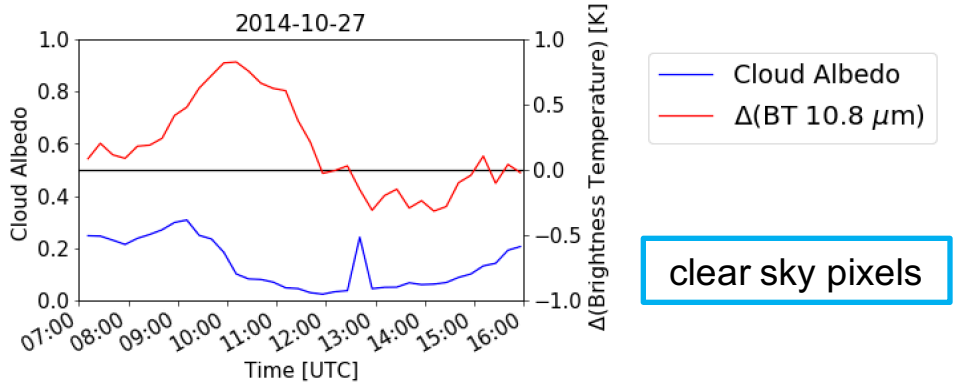
- very low cloud albedo
- solar-zenith-angle-like Δ(BT)

Evolution of satellite key figures: clear sky versus light fog

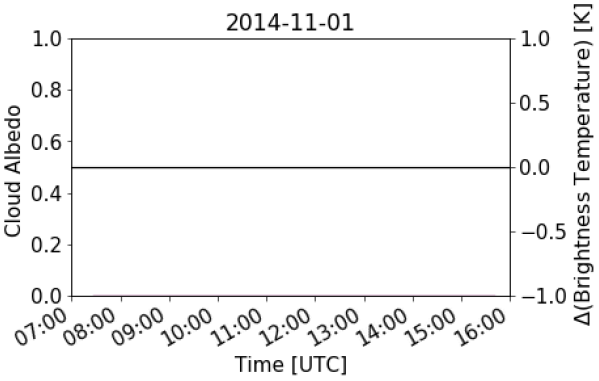


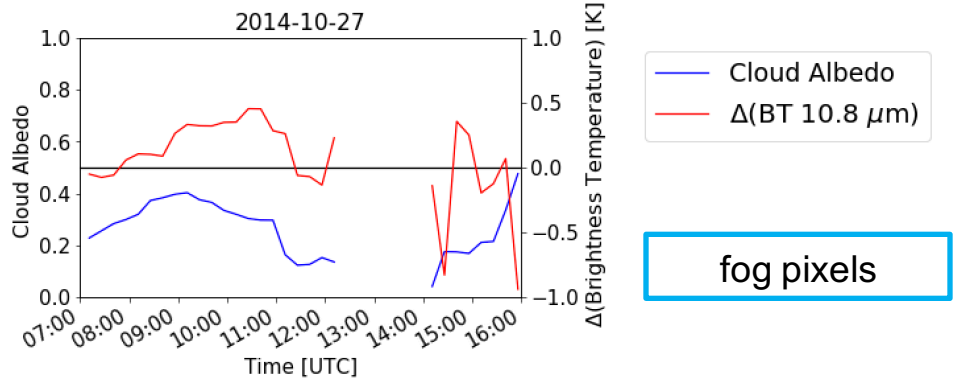






clear sky pixels

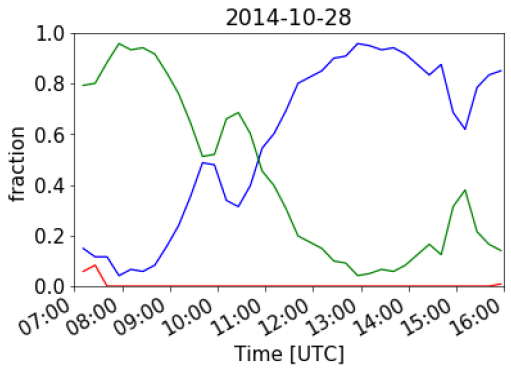


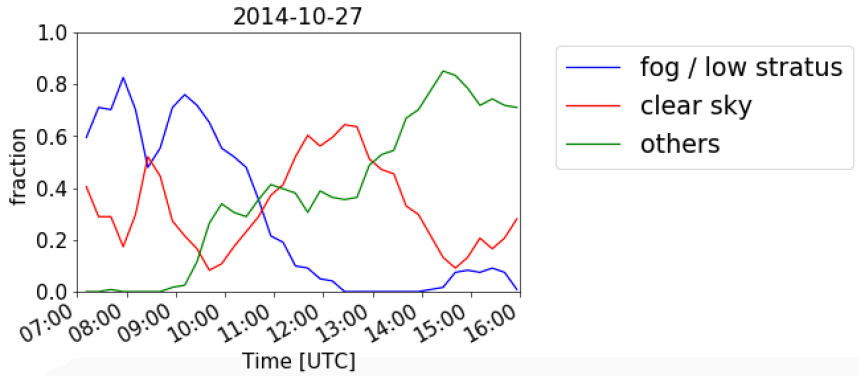


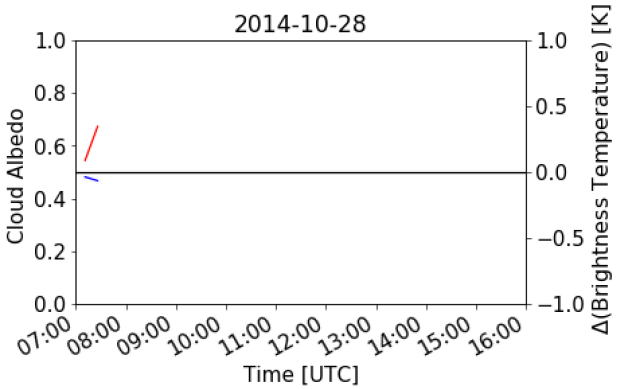
fog pixels

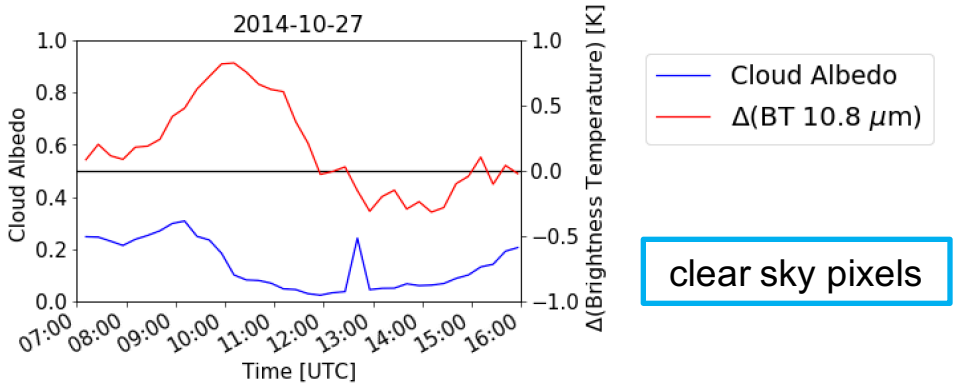
=> dissipating light fog: 1. decreasing cloud albedo 2. increasing clear sky pixels #
3. Δ(BT) close from clear-sky pattern

Evolution of satellite key figures: heavy fog versus light fog

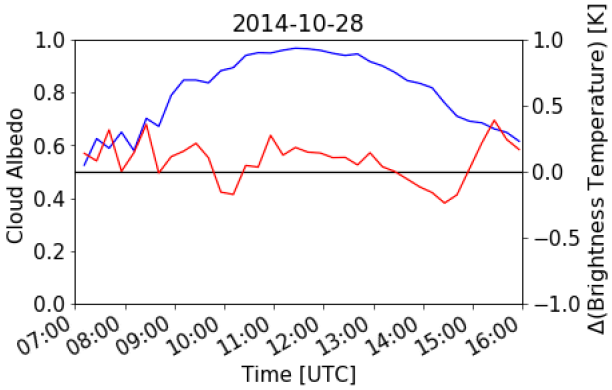


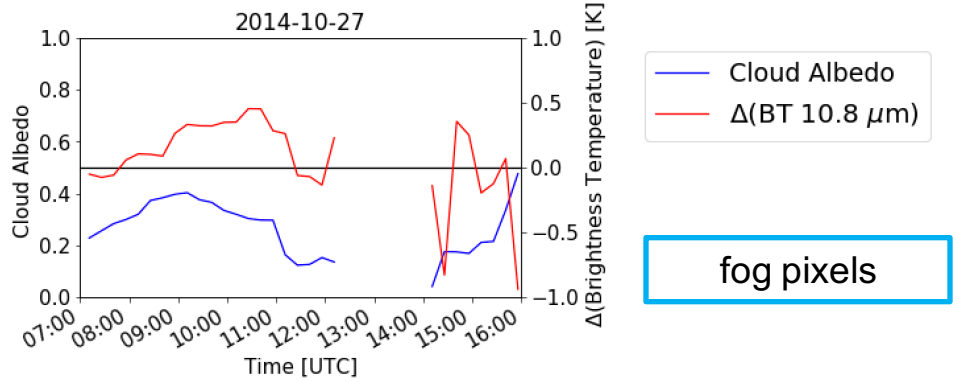






clear sky pixels





fog pixels

⇒ characterisation of heavy fog: 1. high cloud albedo 2. no clear sky pixels # 3. Δ(BT) without trend

5. Conclusion

Main results

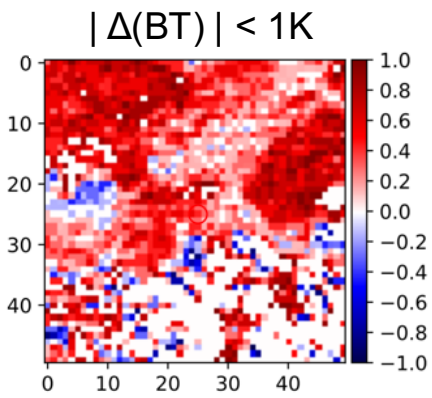
We tested a new approach combining 3 satellite indicators on a case study:

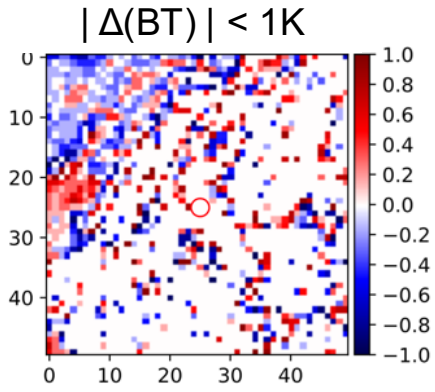
- « cloud type » satellite product
- cloud albedo
- a new satellite key figure based on 10.8 µm channel

New satellite key figure has following properties:

- physical meaning: related to warming/cooling of the surface which is a key variable of fog evolution
- clear contrast for light fog / heavy fog / clear sky
- enables identification of fog dissipation for the case study

LIGHT FOG
9 am
[+ HIGH CLOUDS]





HEAVY FOG
9 am
[+ HIGH CLOUDS]

Perspectives

Generalization study:

- check application to hybrid/multilayer situations
- check the results over a larger period of time
- study new key figures

Modeling:

- quantify orders of magnitudes of variables
- quantify variability
- characterize scenarios of evolution for intraday forecast

Thanks for your attention !

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Questions ?

Bibliography

- *Wærsted et al 2017 - Radiation in fog - Quantification of the impact on fog liquid water based on ground-based remote sensing*
- *Mueller et al 2012 - A new algorithm for the satellite-based retrieval of solar surface irradiance in spectral bands*
- *Tardif & Rasmussen 2007 - Event-based climatology and typology of fog in the New York City Region*