Harmony-TIR: a tandem EE10 mission for Sentinel-1 for better understanding of Marine Boundary Layer Clouds and their interaction with the ocean surface: initial ECSIM-DALES simulations and retrievals using M2

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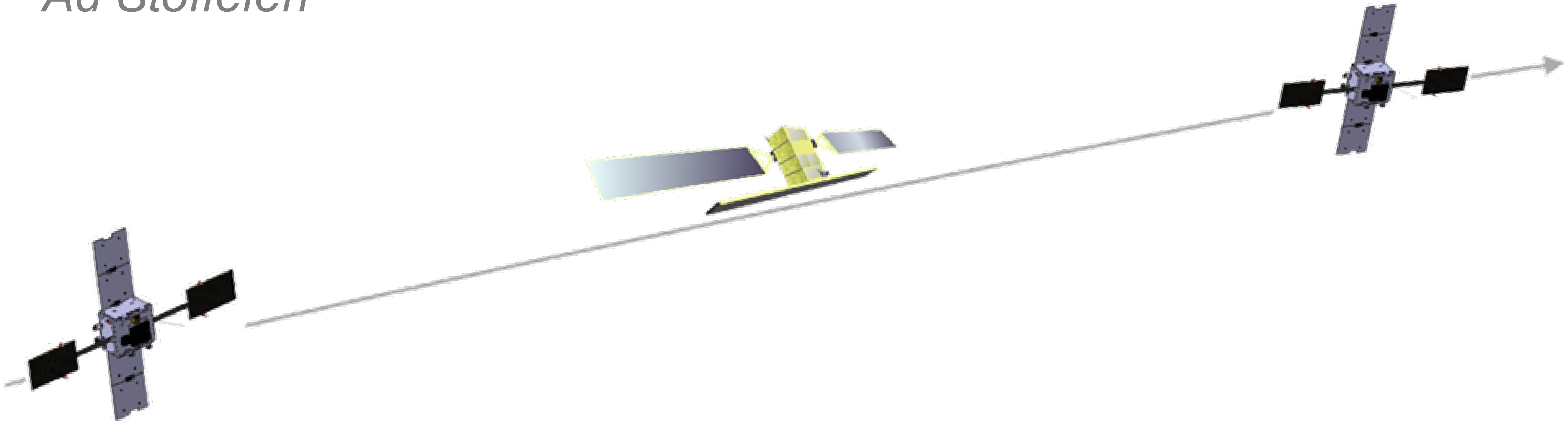
ESA EE10 Harmony Observations of Sea Surface Winds and Sea Surface Deformation

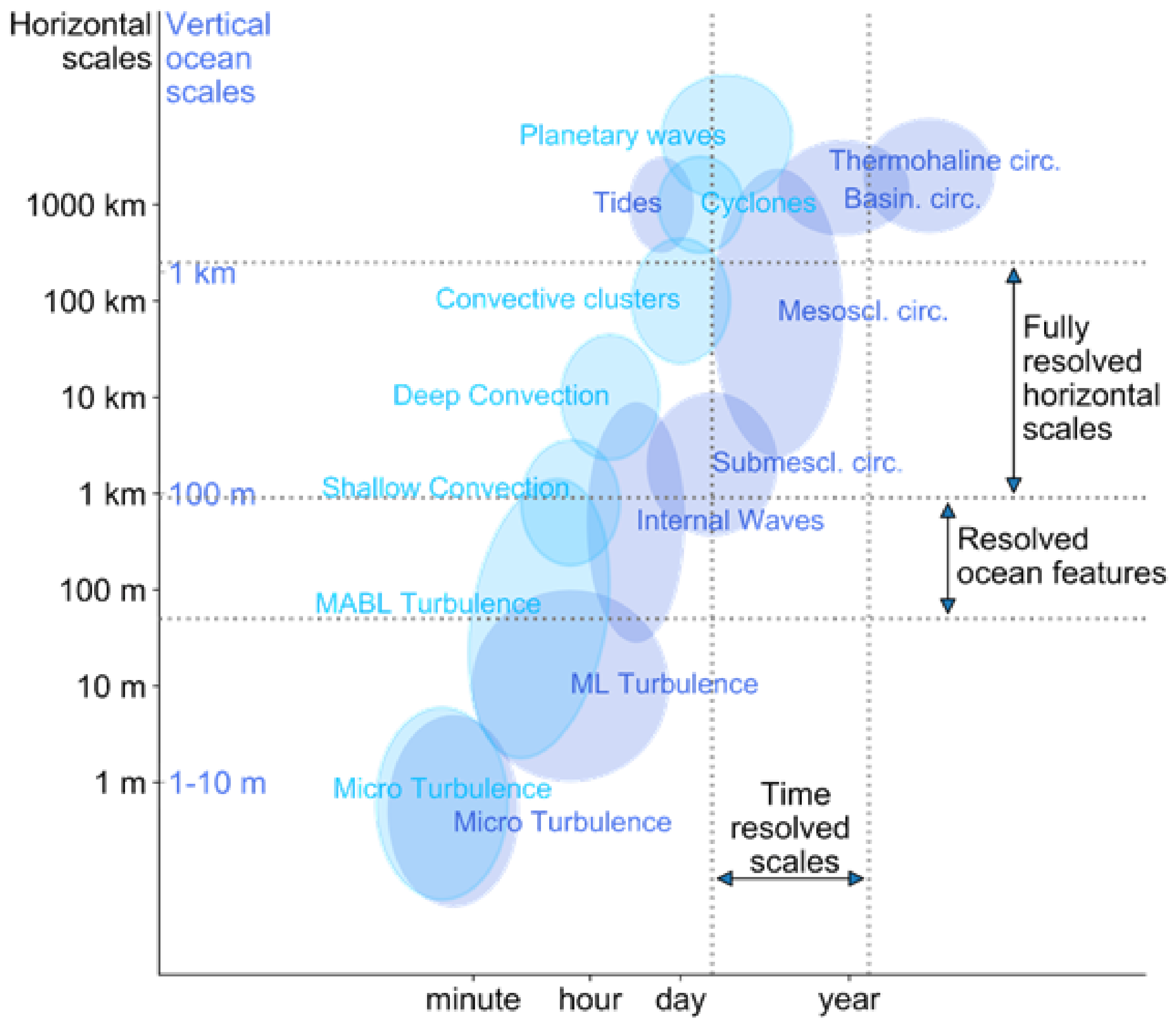
*Paco López-Dekker, Bruno Buongiorno Nardelli,
Bertrand Chapron, Claudia Pasquero, Jan-Peter Muller,
Ad Stoffelen*



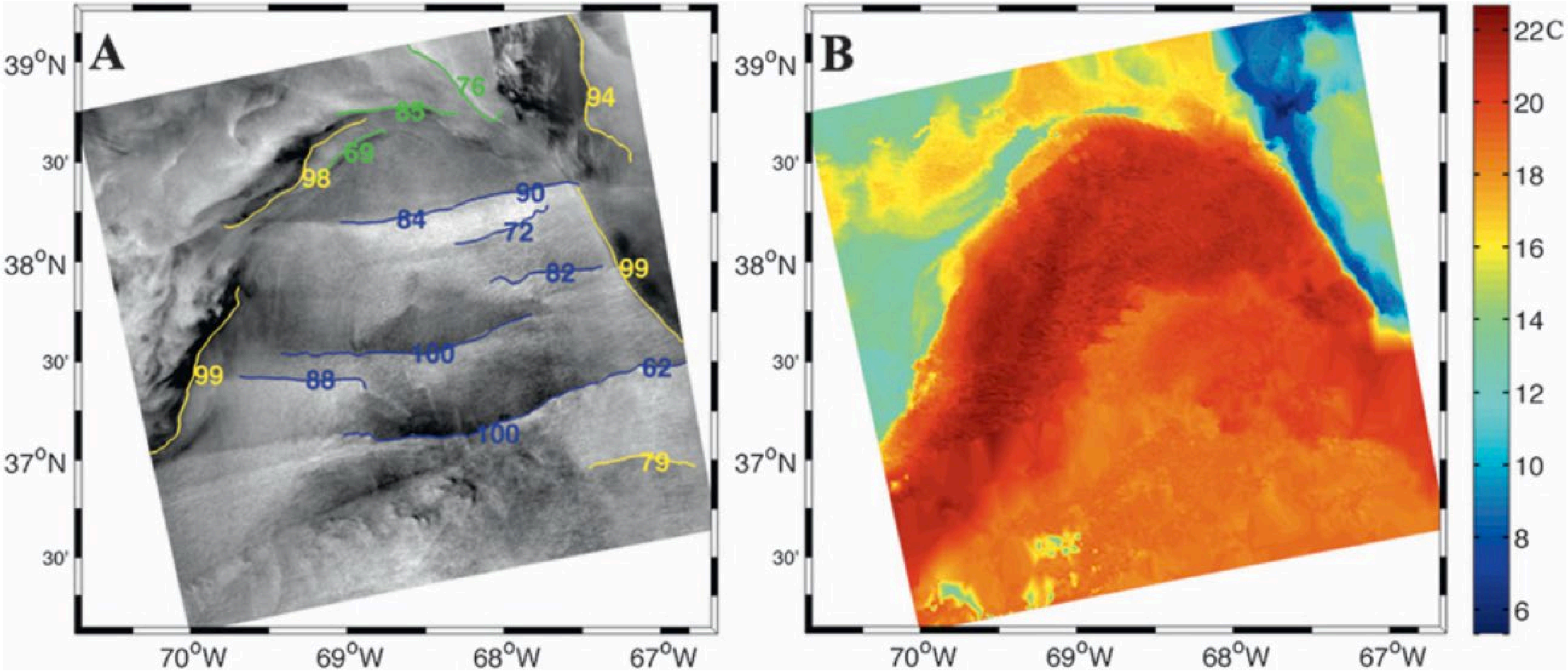
TU Delft

Peformance/Requirements overview

What	Requirement
Relative TSC (Total Surface Current)	0.1 m/s @2 km res.
Relative surface wind	min(7.5%, 1 m/s) @1 km res.
SST (NEdT)	0.1 K @ 1km res.



How are SAR backscatter & SST related?



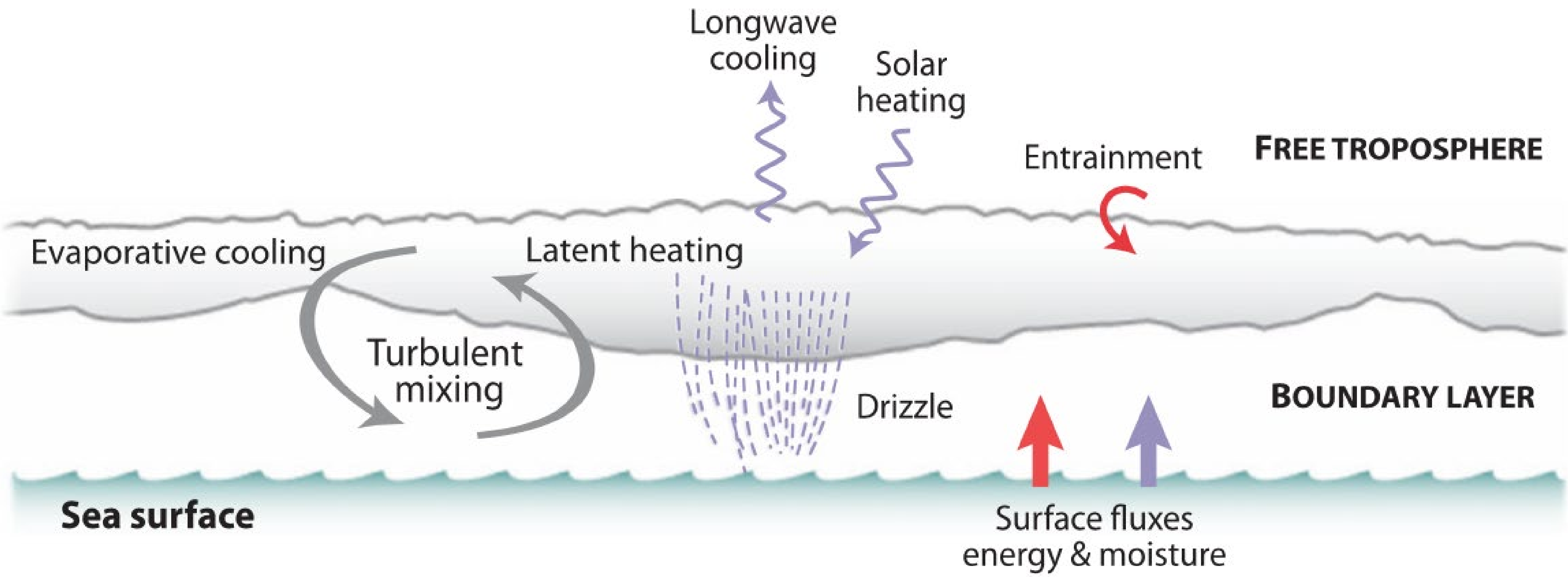
Jones, C. T.; Sikora, T. D.; Vachon, P. W.; Wolfe, J. (2012) Toward Automated Identification of Sea Surface Temperature Front Signatures in Radarsat-2 Images. Journal of Atmospheric and Oceanic Technology 29, 89–102.

HARMONY-TIR Science Objectives

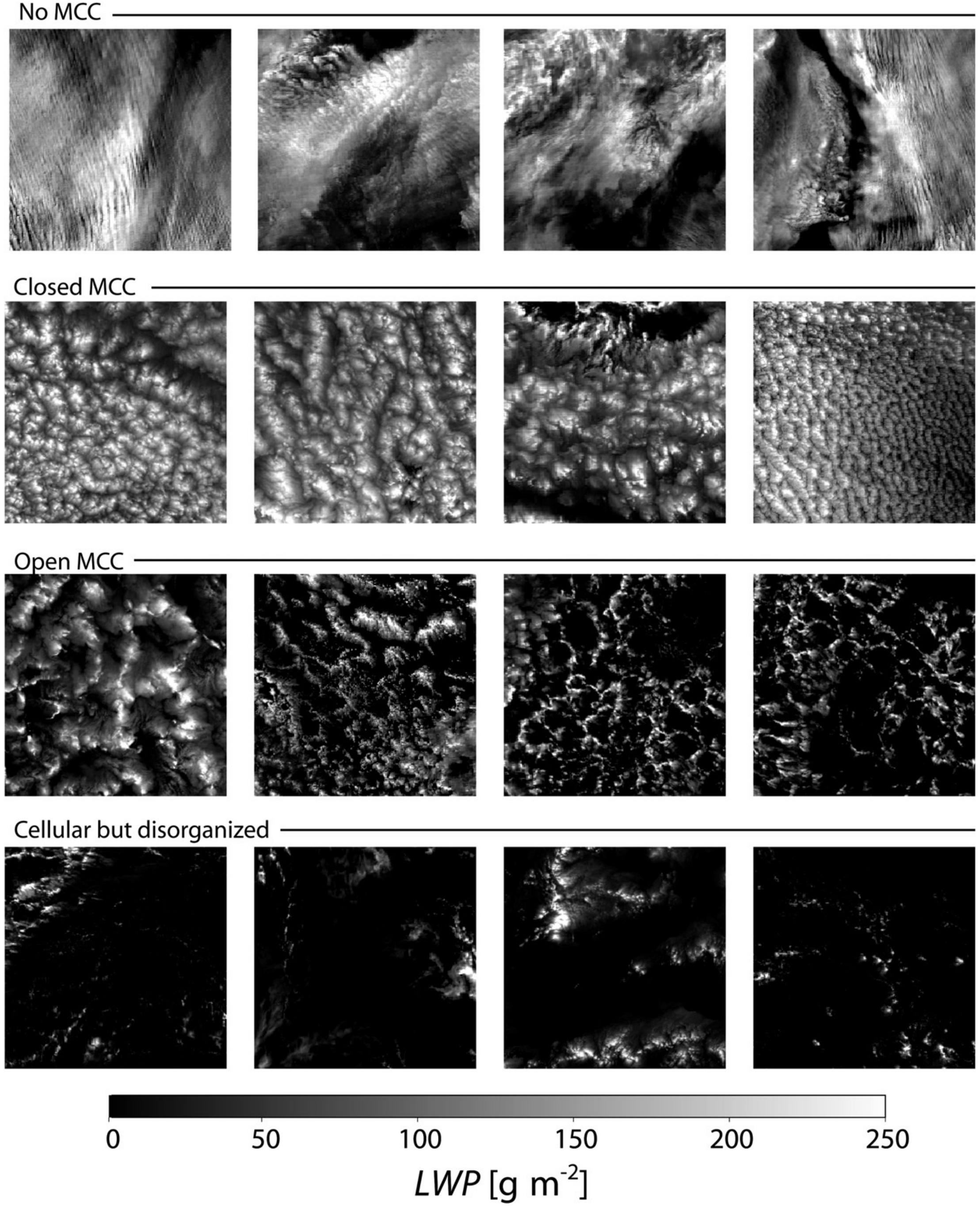
- Cloud-top heights of boundary layer clouds (MrStCu) are directly related to the height of the boundary layer (Bretherton, 2004). The impact of such Boundary Layer Clouds is significant for AR5+6 (IPCC). Their formation mechanism is poorly understood. They play a major role in global cooling.
- The largest uncertainty in climate forcing is the vertical velocity of cloud-scale updrafts*
- Need to understand the nature of the interactions in vertical convective updrafts between aerosols, cloud microphysics and dynamics at scales from individual clouds to whole systems
- Improve the current mass flux parameterisation of cloud and aerosol dynamic interactions and their radiative effects especially vertical updrafts
- Develop improved parameterisation of clouds within GCMs by quantifying the convective mass flux and mixing as a function of vertical winds, wind shear and precipitation forming processes.
- SST intimately linked to severe weather systems over the ocean, e.g. typhoons
- Relate SST, cloud characteristics and SAR-derived surface winds & currents

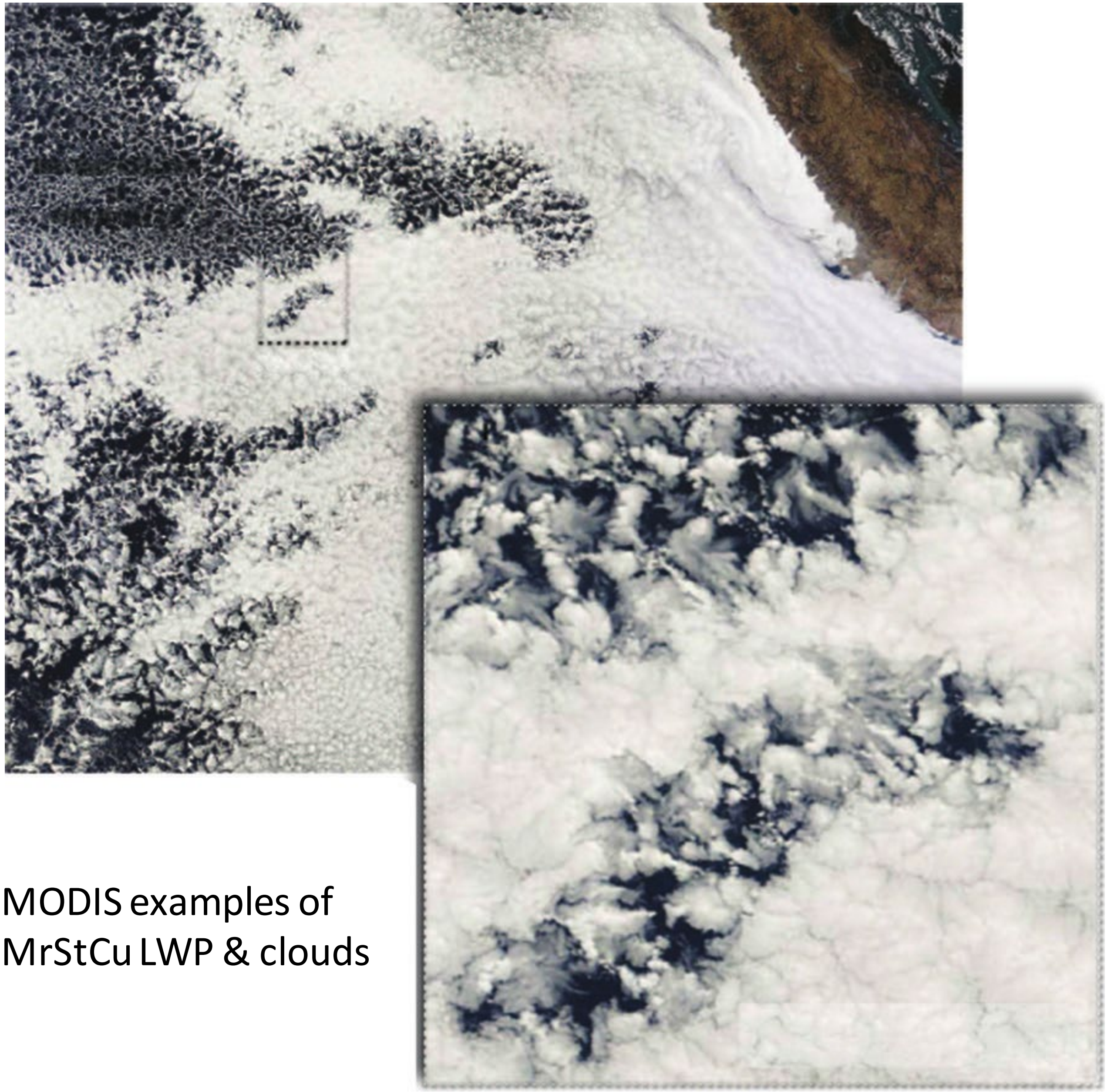
*Donner et al., 2016 DOI: 10.5194/acp-2016-400

Marine Boundary Layer clouds



Wood, R. Stratocumulus clouds. *Mon. Wea. Rev.* **2012**, *140*, 2373–2423.

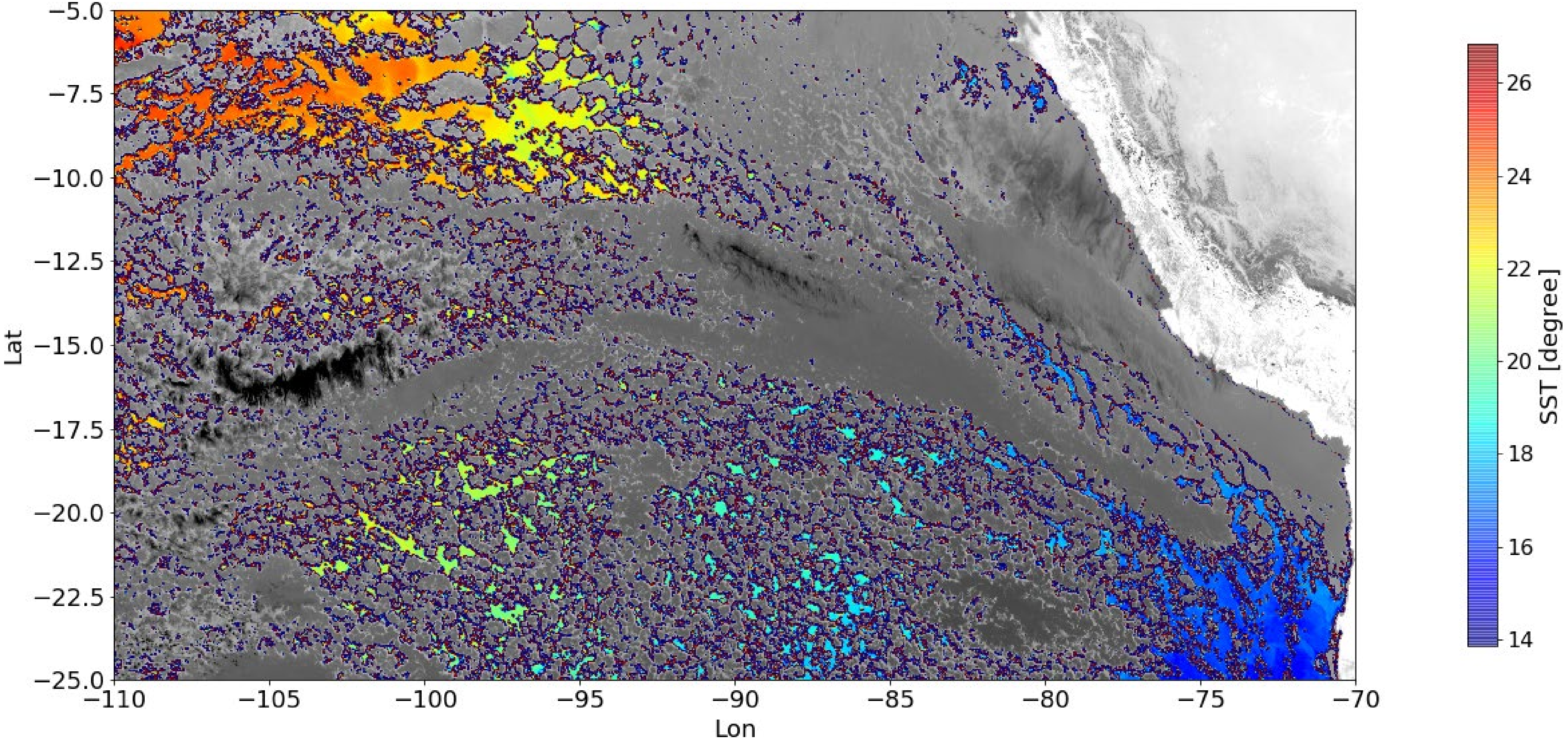




MODIS examples of MrStCu LWP & clouds

Wood, R. Stratocumulus clouds. *Mon. Wea. Rev.* **2012**, *140*, 2373–2423.

GOES-16@2km 10.85µm SST visible: complex MABL clouds

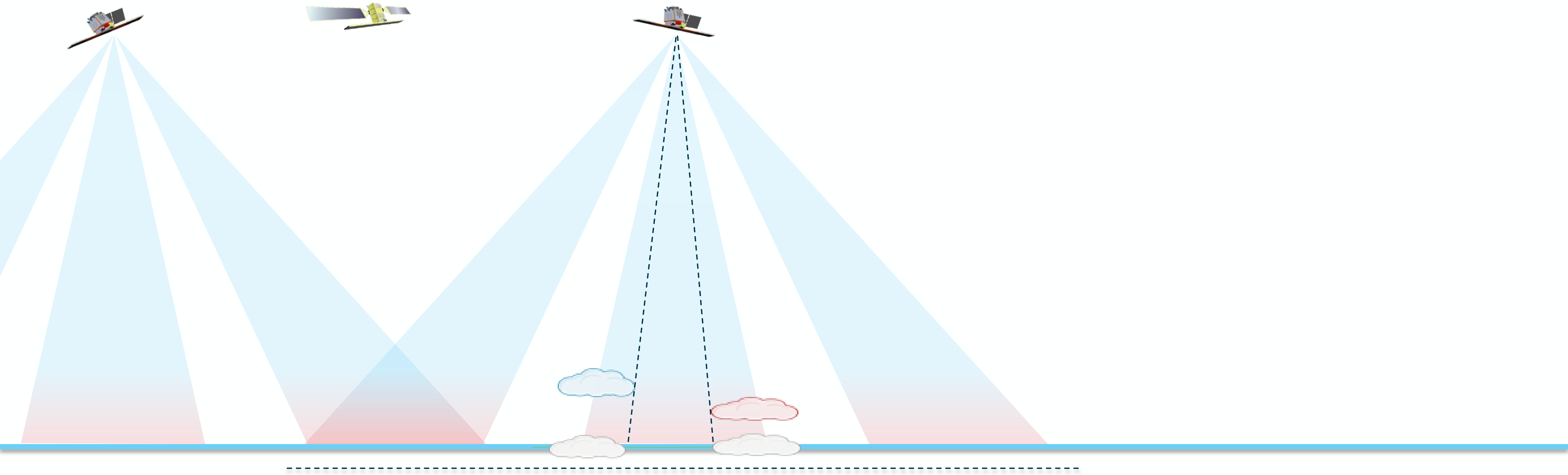


N.B. visibility of GOES L2 SST has much higher probability with nominal 333m HARMONY-TIR GSD

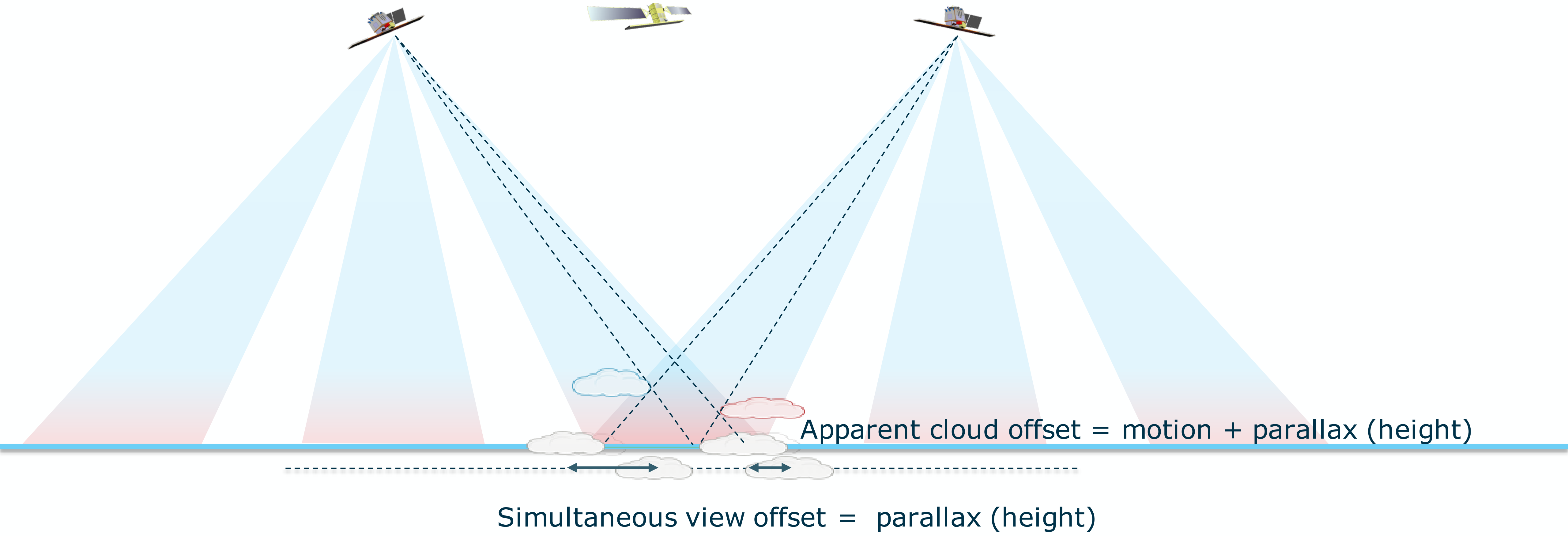
Thermal IR: key measurands: requirements

- Sea-surface temperature (SST) : 0.5K
- Macroscopic Cloud properties
  - Cloud detection/masking 1 pixel
  - Cloud-top height (CTH) ≈200m
  - Advective Cloud-top winds (CTW) <3m/s
  - Vertical Cloud-top winds ≤1m/s
  - Convective cloud-top divergence (CTd)
  - Cloud-top Mass flux (CMF)

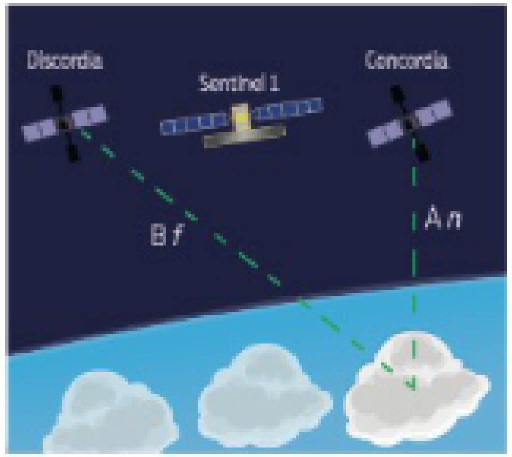
Cloud-top Motion Vectors



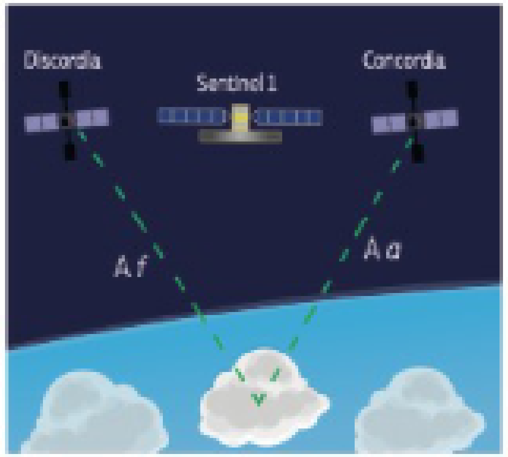
Cloud-top Motion Vectors



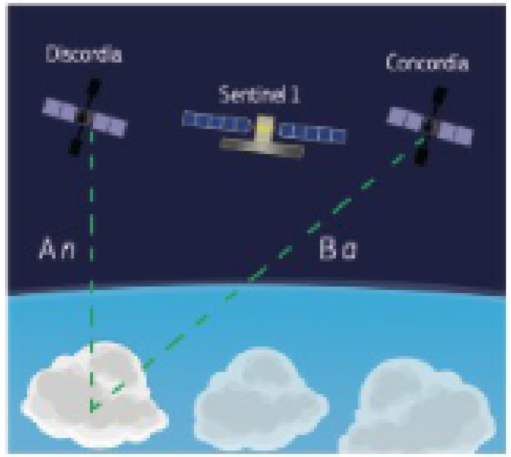
HARMONY-TIR measurement concept schematic



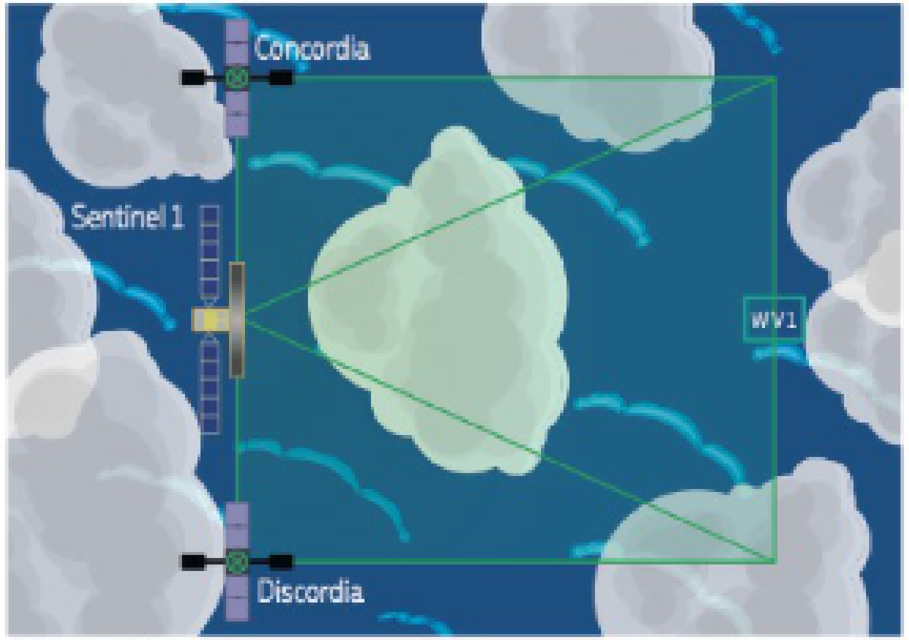
time t_0



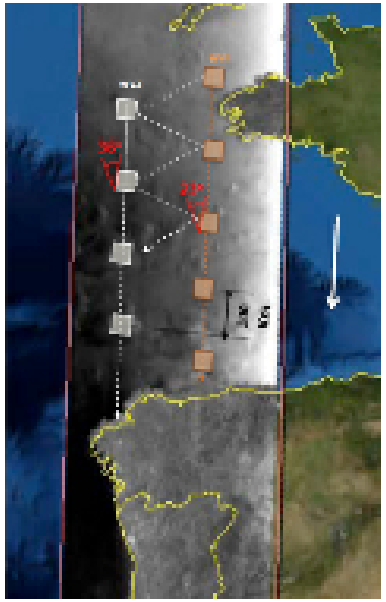
time t_1



time t_2

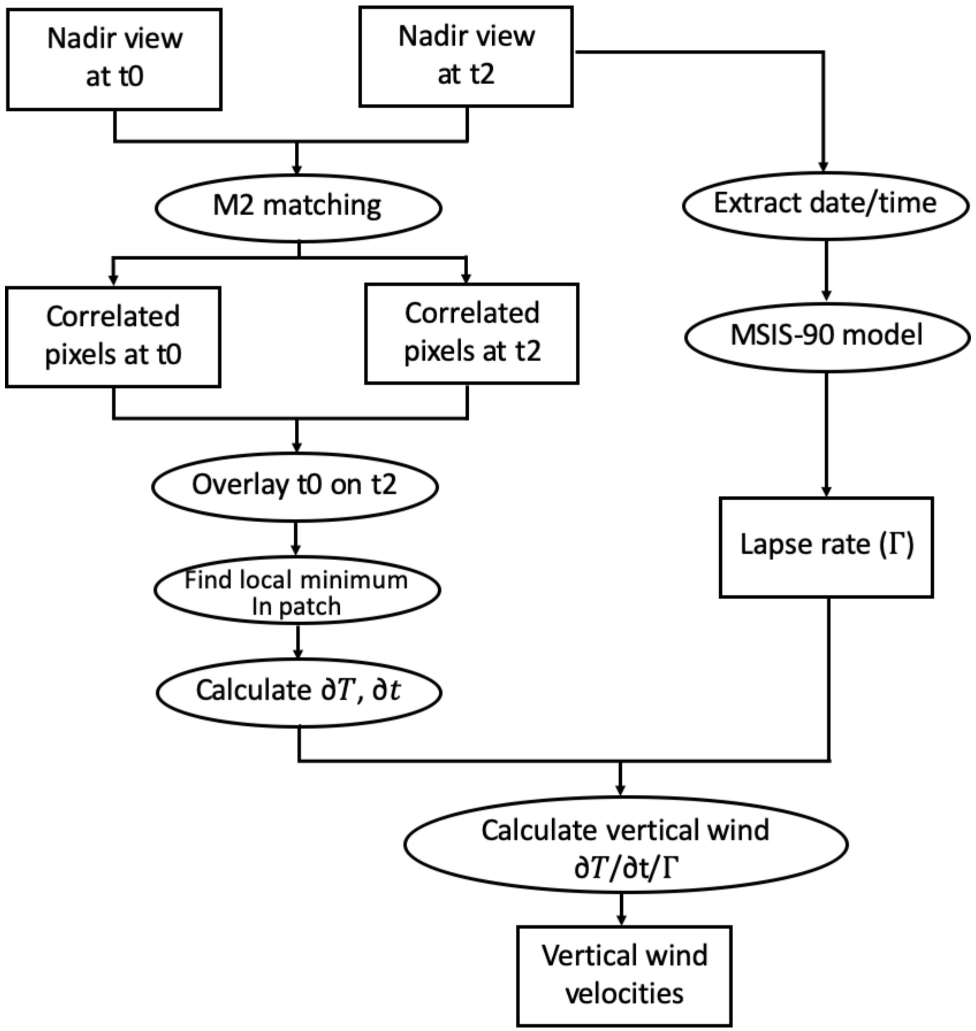


Above View



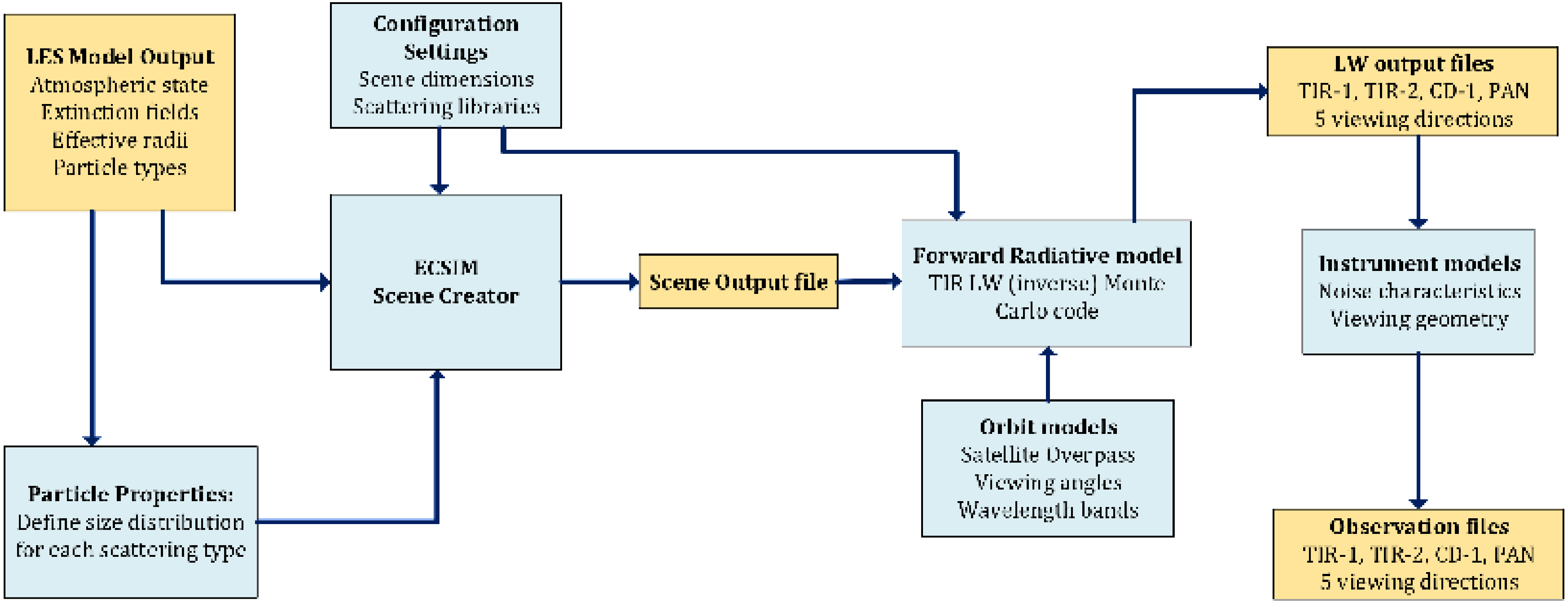
Steps for calculating CMV-W: simplified geometry

1. Method: Use t0 -> t2 BT difference to retrieve the vertical winds.
2. STEP 1: retrieve t0 -> t2 nadir view disparities, which was already done in the horizontal wind field retrieval.
3. STEP 2: calculate Δ"BT" for each pixel in t0 nadir view image. Δ"BT" at (i,j) is calculated from the difference in the minimum BT in patch at t0 minus the minimum BT in patch t2. Patch size (9,5)
4. STEP 3: calculate Δ"BT/" Δt = Δ"BT"/120s
5. STEP 4: extract lapse rate from MSIS-90 model (-5.77 K/km) for the local area at the date and time of the observation.
6. STEP 5: derive vertical wind speed = Δ"BT/" Δt / (-5.77 K/km)



[3] Hamada, A.; Takayabu, Y. N. Convective cloud top vertical velocity estimated from geostationary satellite rapid-scan measurements. Geophys. Res. Lett. 2016, 43, 5435–5441..doi:10.1002/2016gl068962

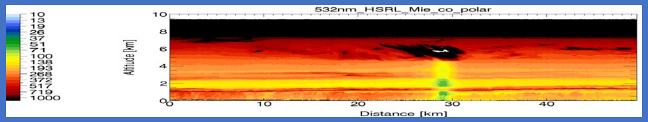
ECSIM – 4D clouds created from WRF-DALES and 3D radiative transfer modelling system

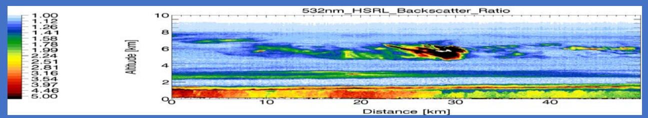


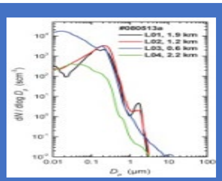
Gerd-Jan van Zadelhoff, Ad Stoffelen (KNMI: Royal Netherlands Meteorological Institute, NL). LES outputs from DALES created by Pier Siebesma (TU Delft, NL)

Creation of model or observational based scenes

Observed & Model Data



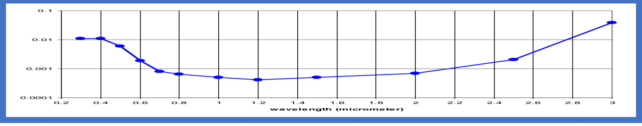


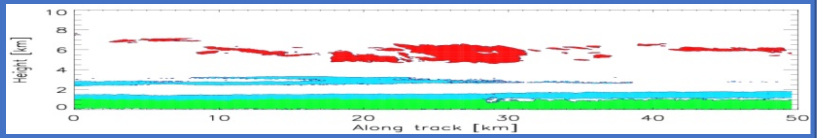


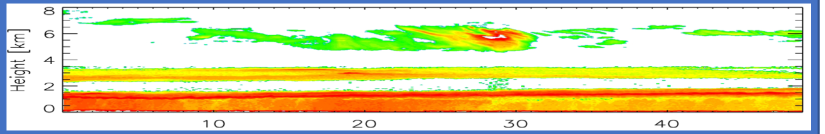
T, P, RH

Scene Creation

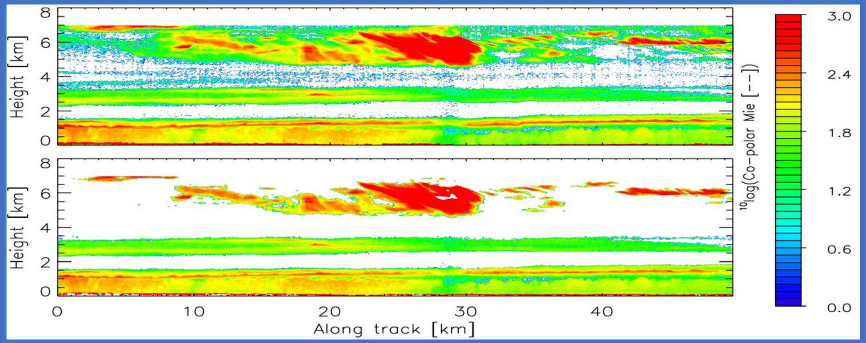
- **Scattering properties**
- **Particle type mask**
- **Extinction field**
- **Effective Radius field**



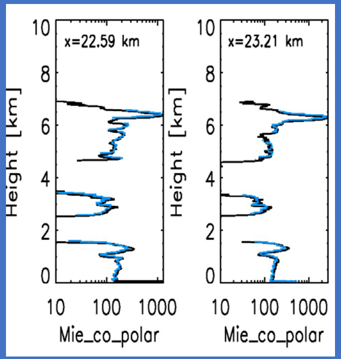


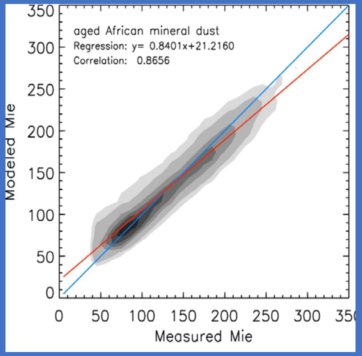


Forward modeling Radiative Transfer



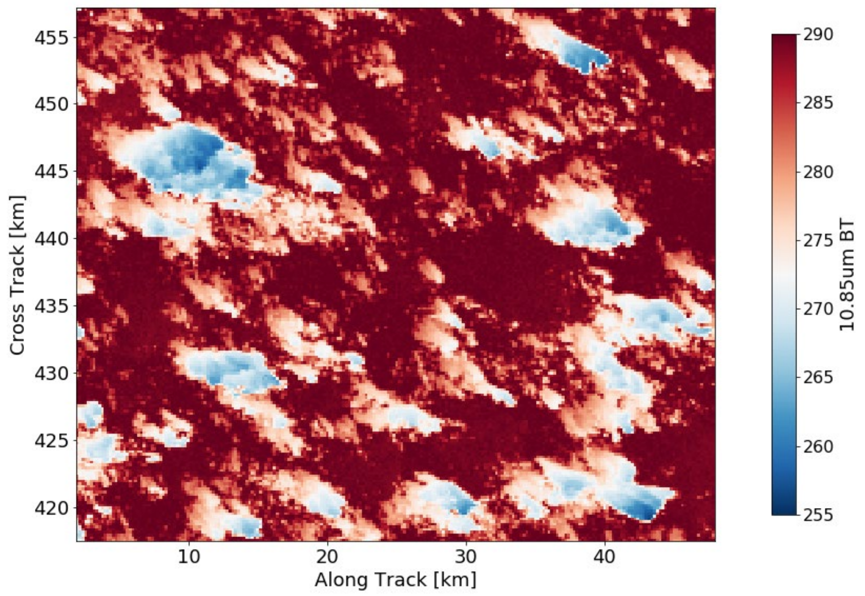
Evaluation

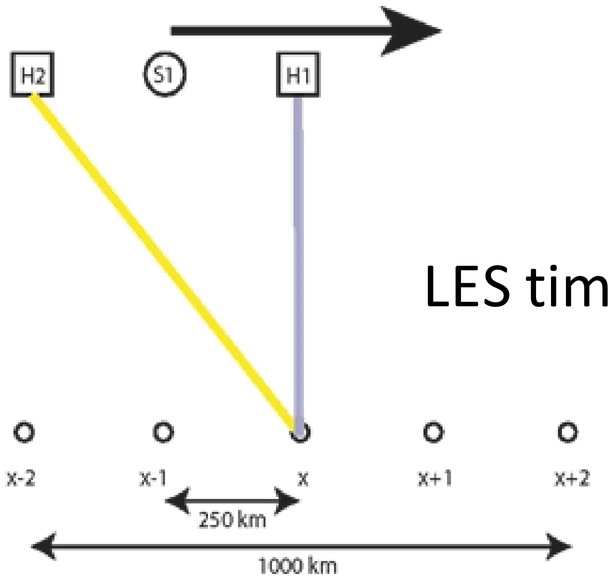




LES simulations t0

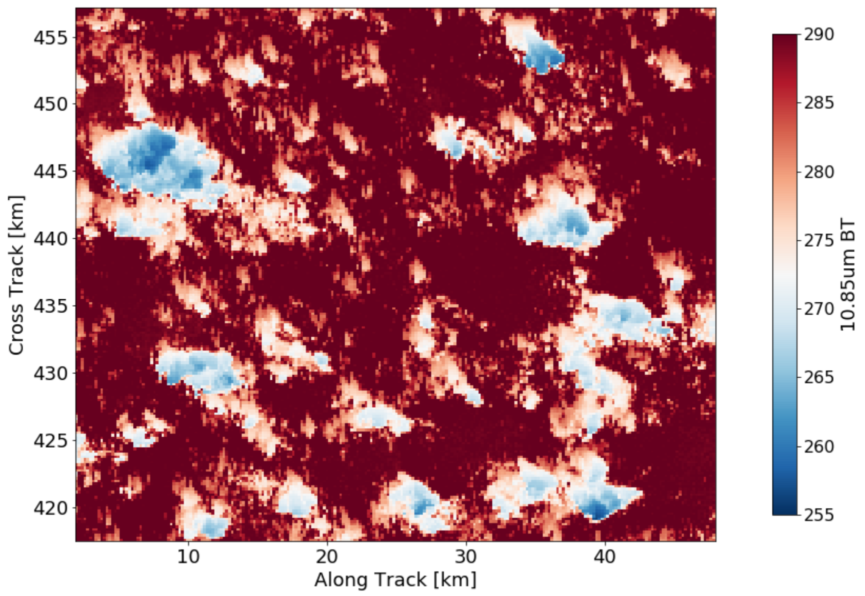
Discordia (H2)

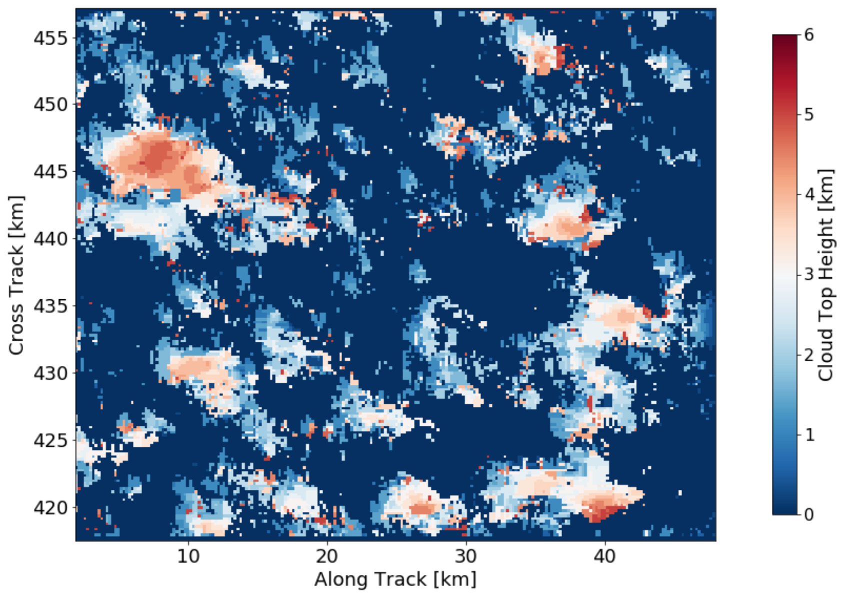




LES time 09:32:00

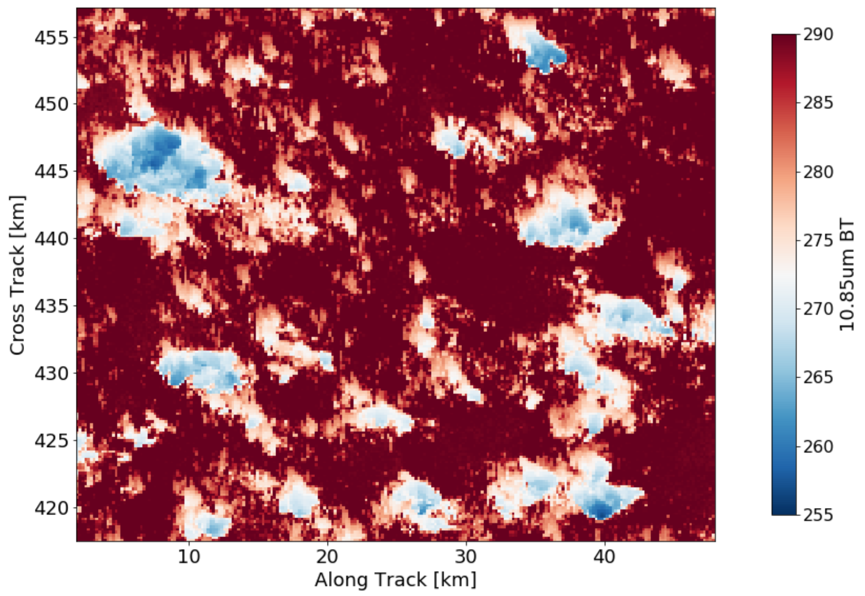
Concordia (H1)



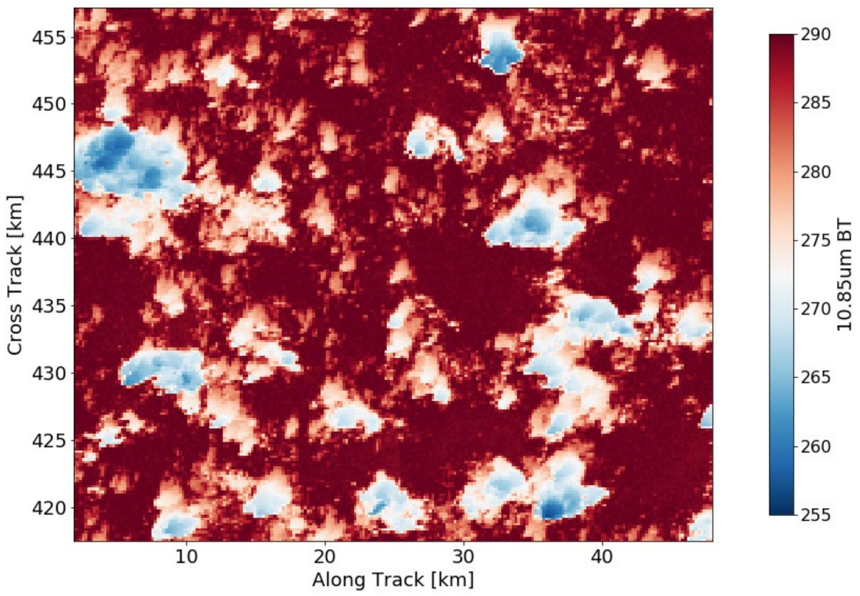


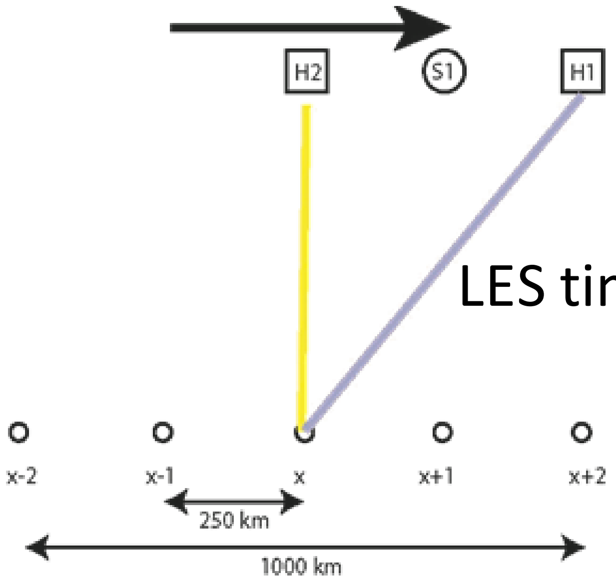
LES simulations t2

Discordia (H2)



Concordia (H1)





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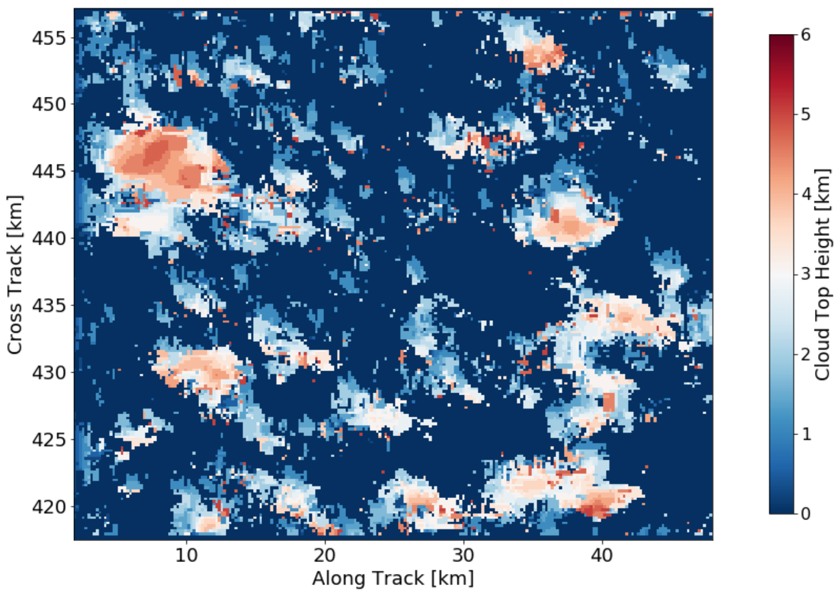
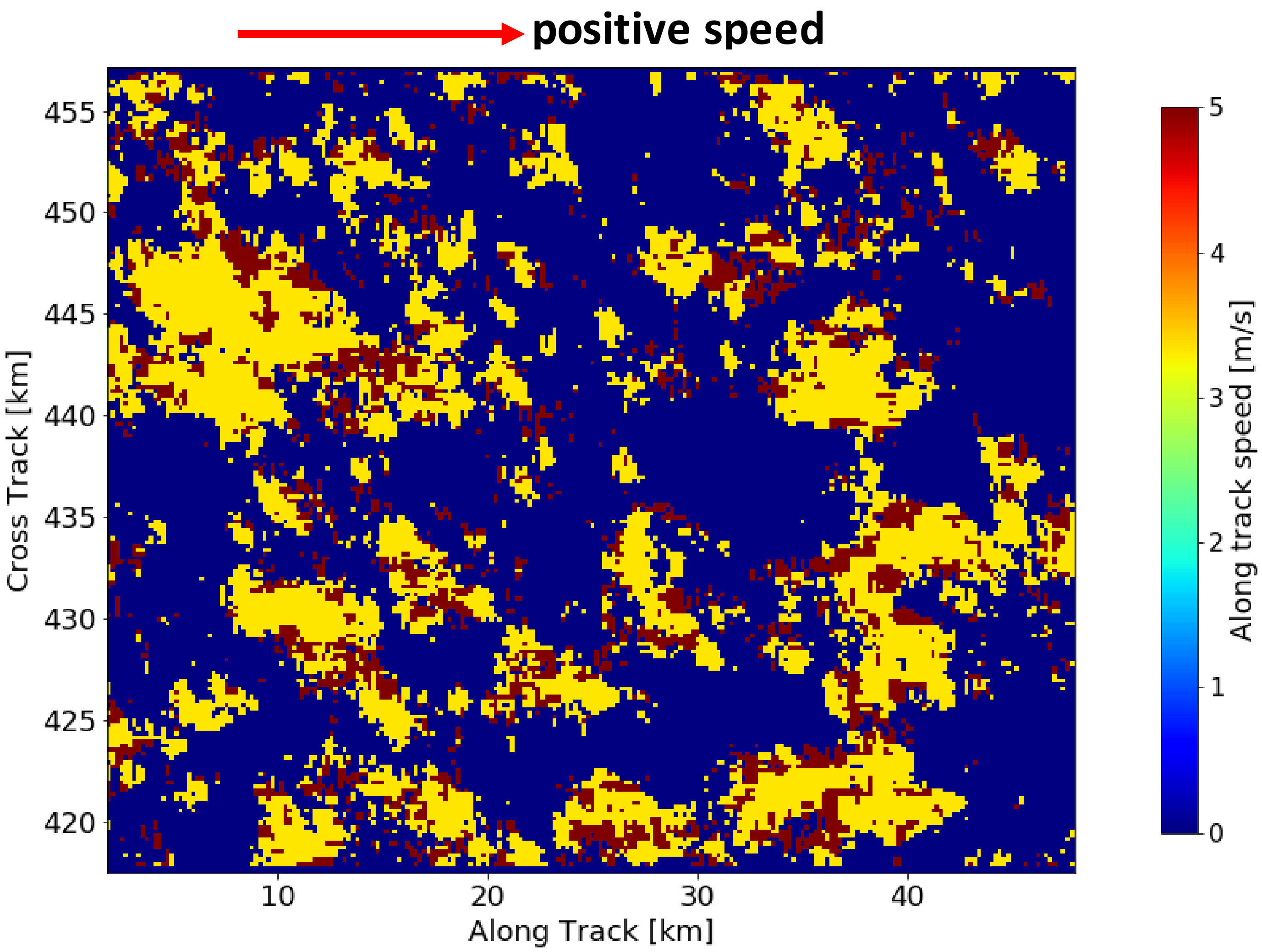
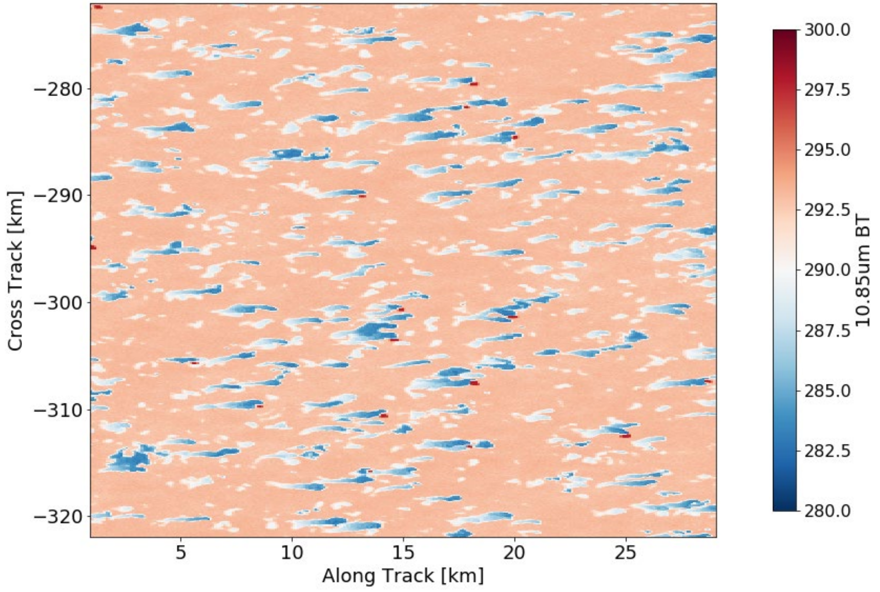


LES simulations

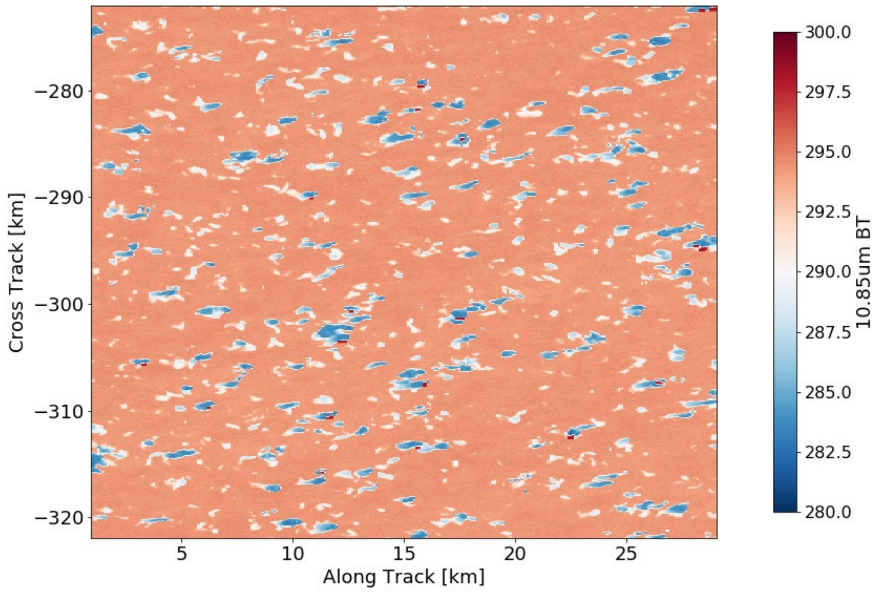


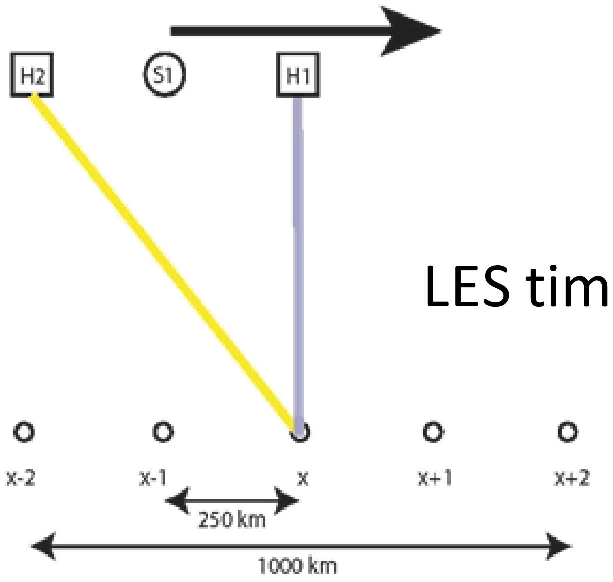
EUREC4A simulations t0

Discordia (H2)

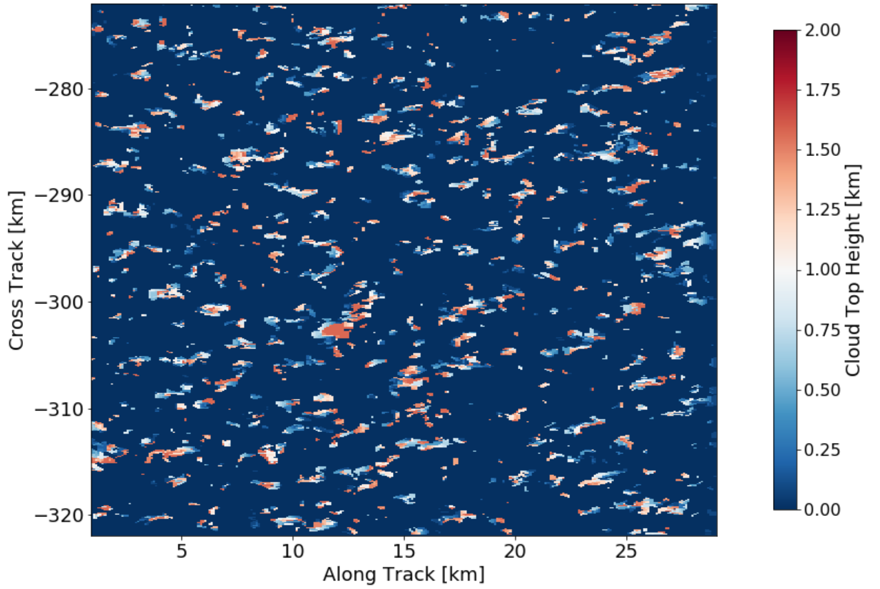


Concordia (H1)





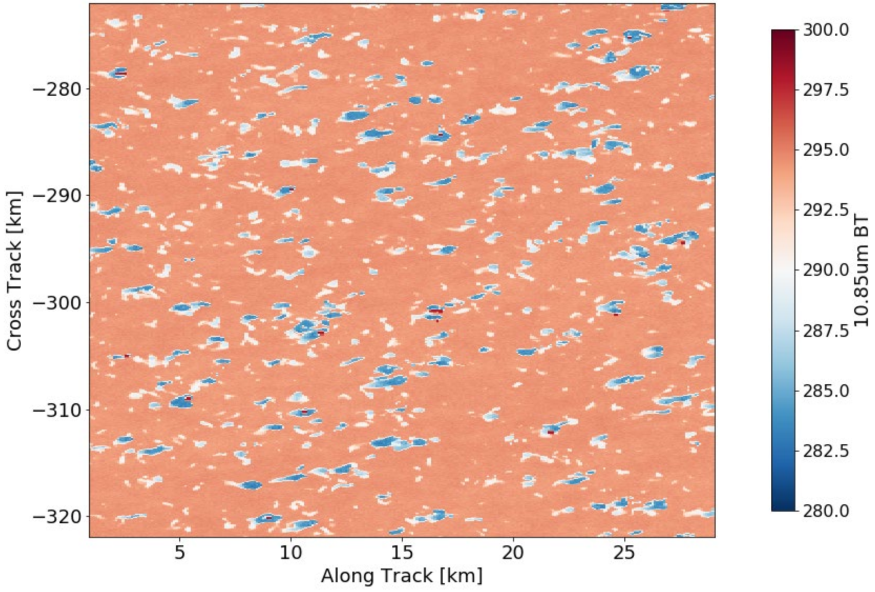
LES time 36:02:30



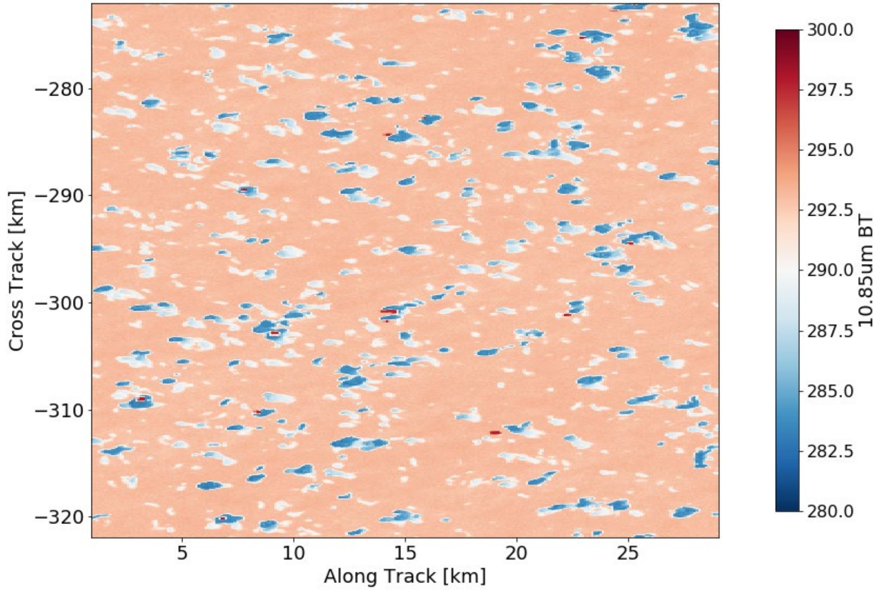
DALES simulations Courtesy of Pier Siebsema, TU Delft

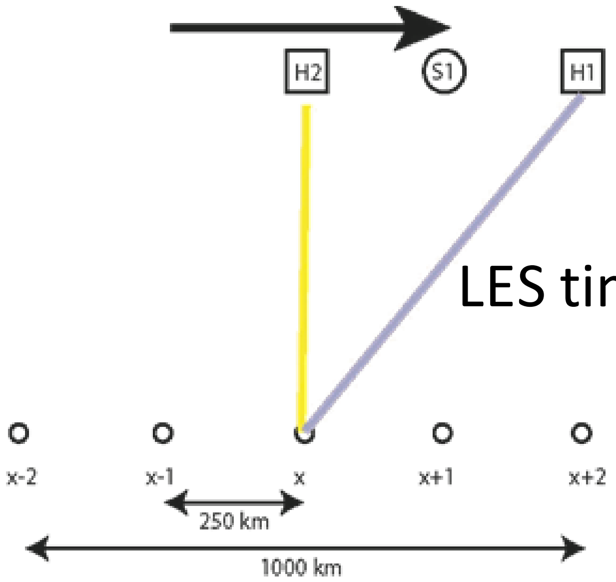
EUREC4A simulations t2

Discordia (H2)



Concordia (H1)





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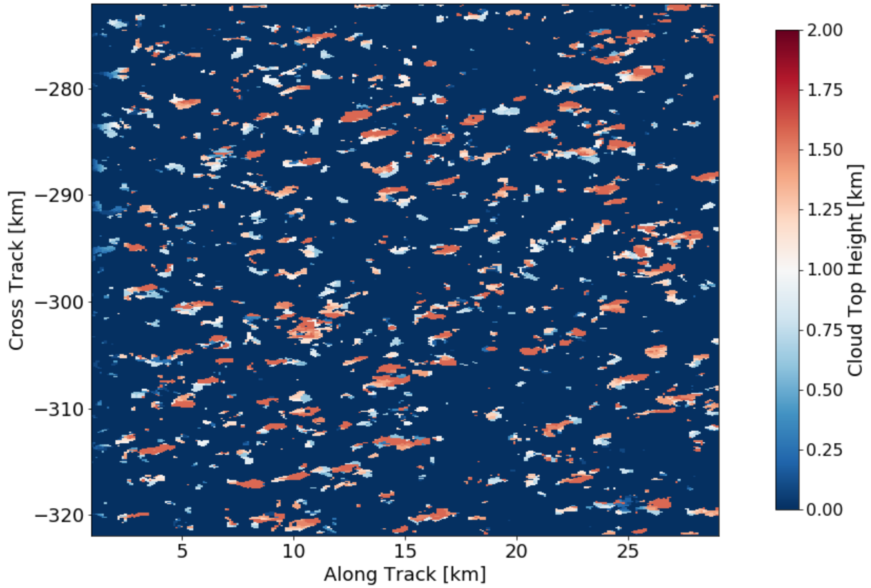
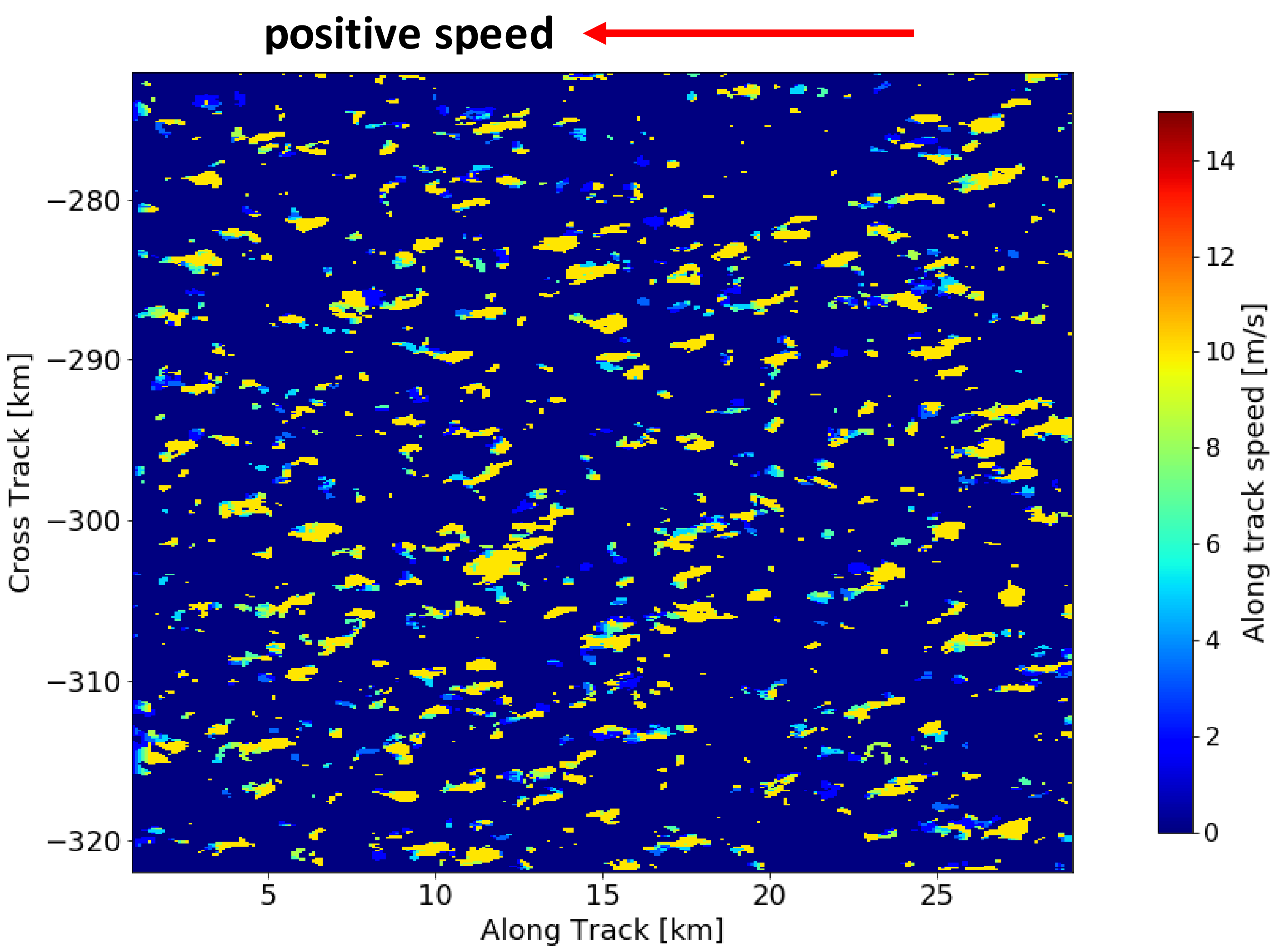
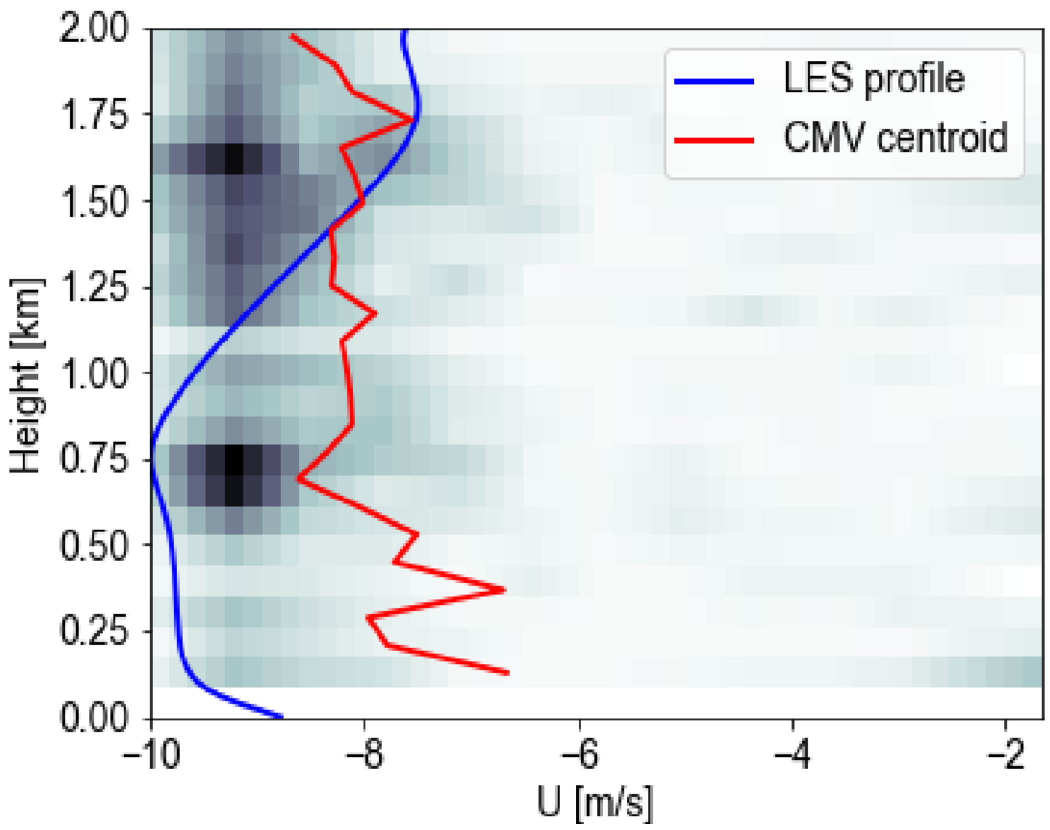


DALES simulations Courtesy of Pier Siebsema, TU Delft

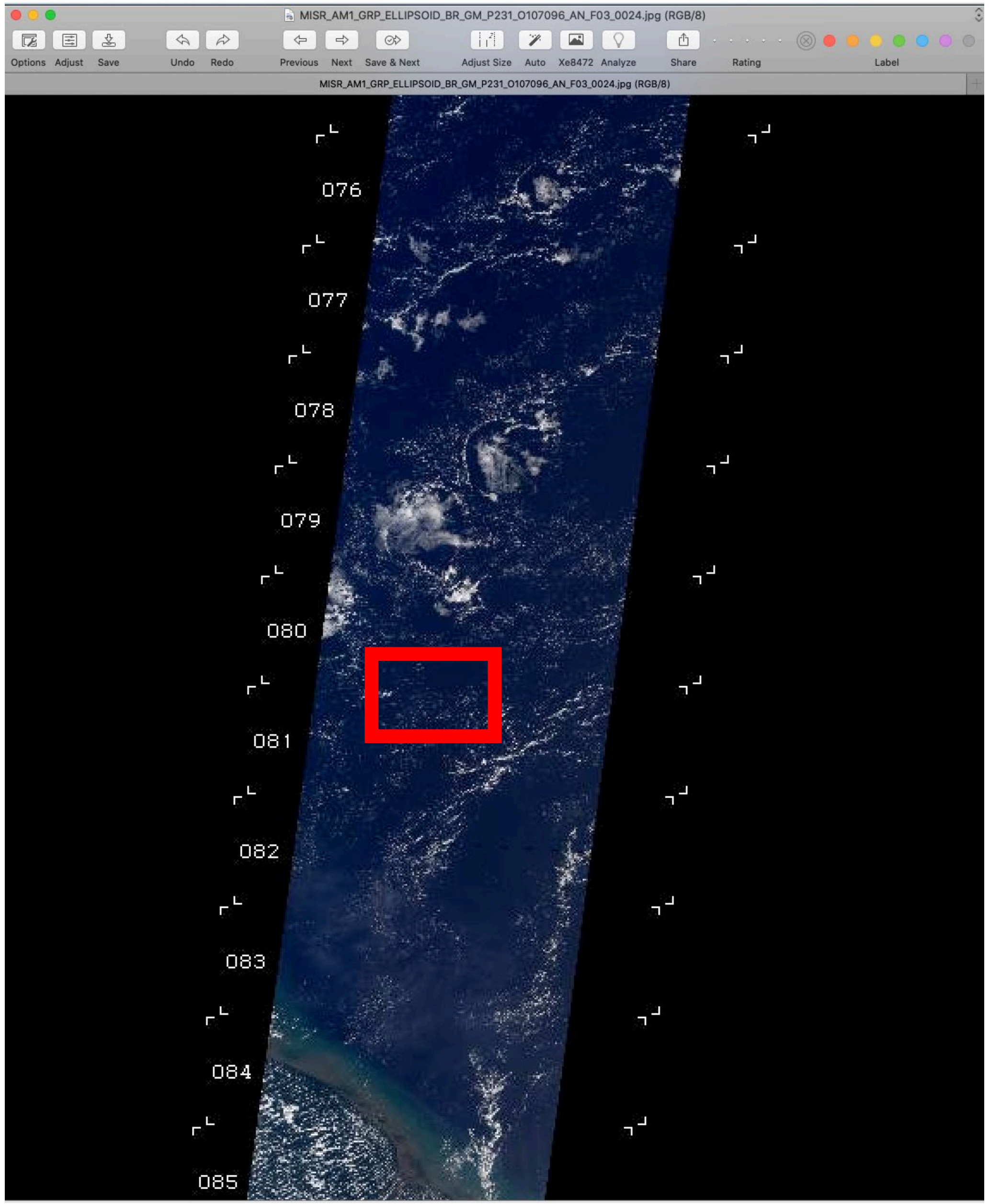
EUREC4A simulations cf input wind-field

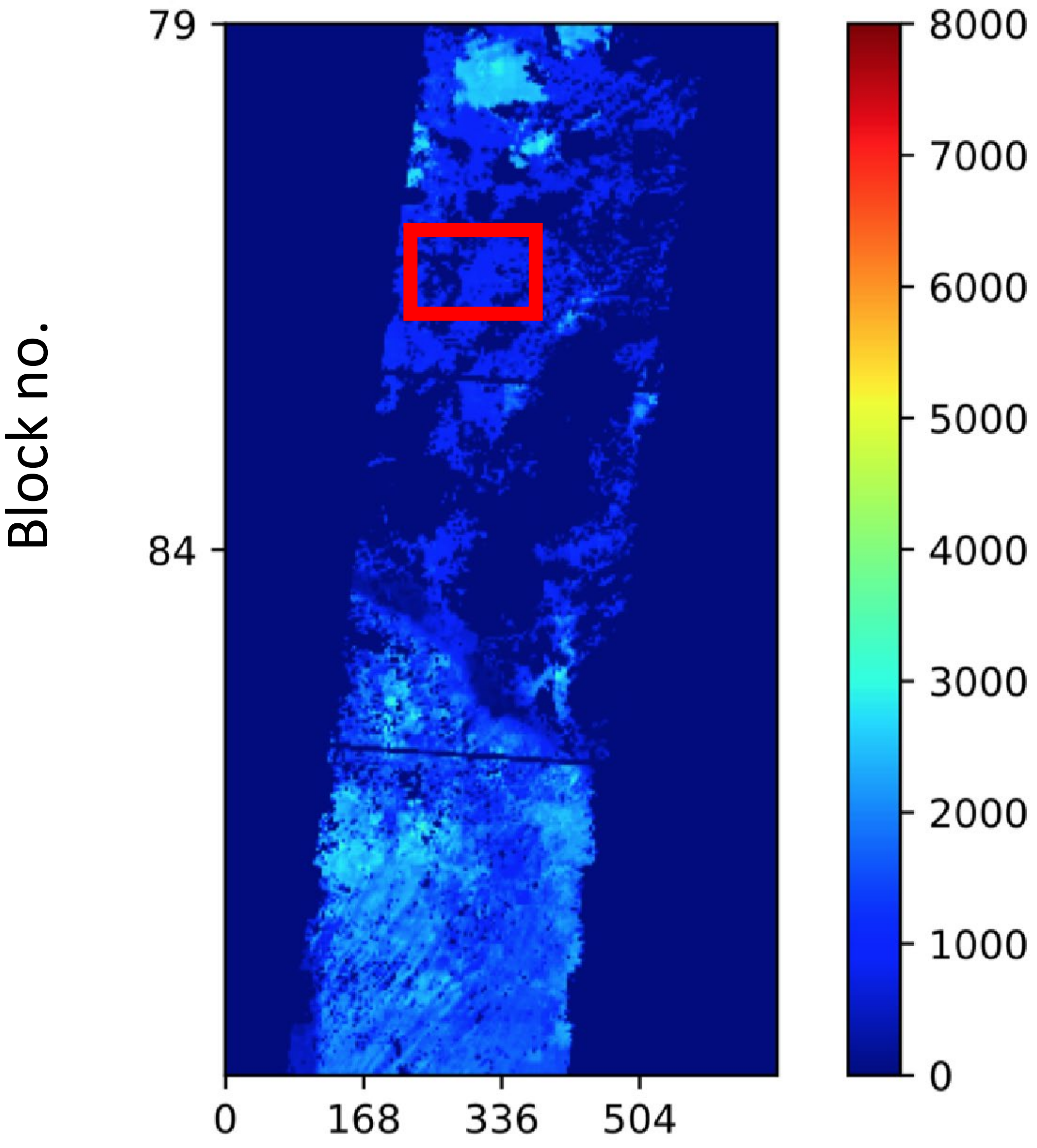




Courtesy of Paco Lopez Dekker, TU Delft, HARMONY-PI

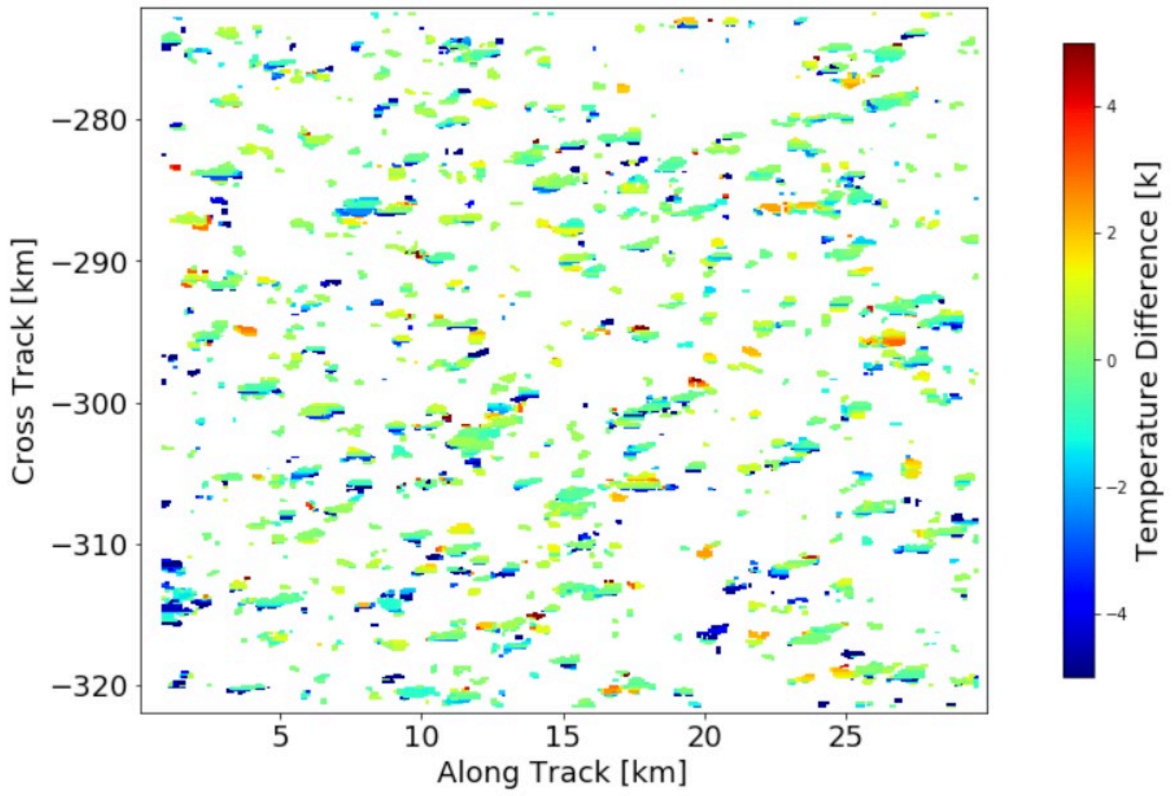
Results from MISR for EUREC4A for same day.



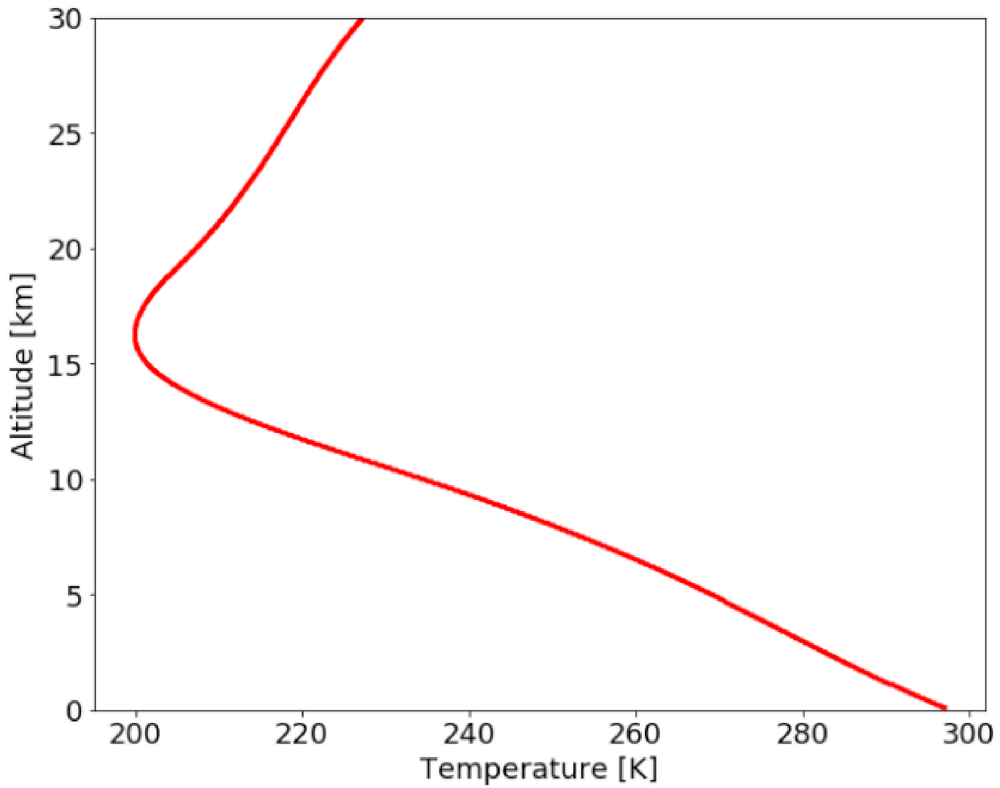


CTH field from MISR_AM1_TC_CLOUD_P231_O107096_F01_0001

BT difference from t0 and t2 after co-registration

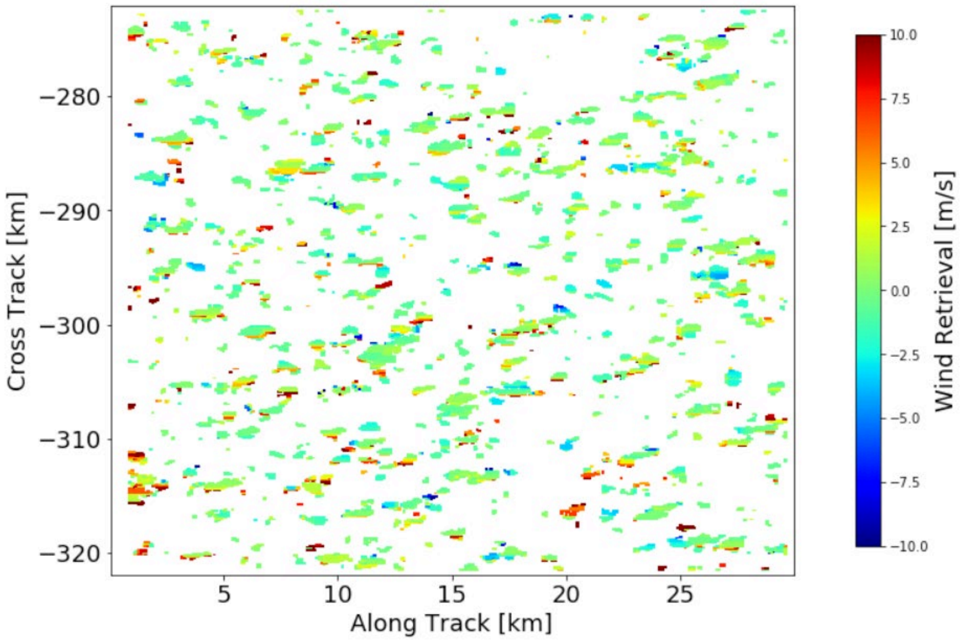


Vertical temperature profile for the simulated area.
The lapse rate between 0-3 km is -5.77 K/km

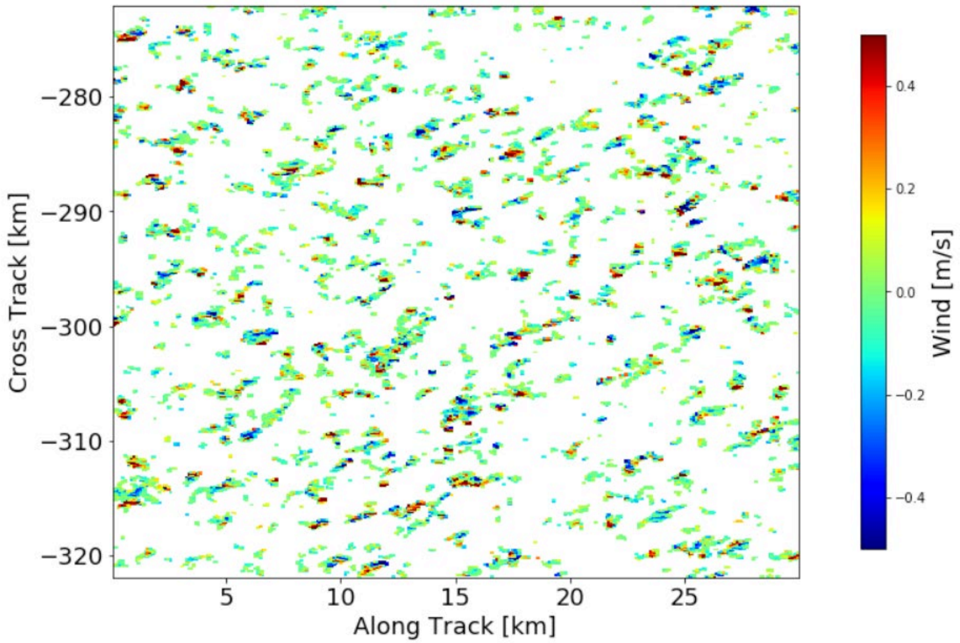


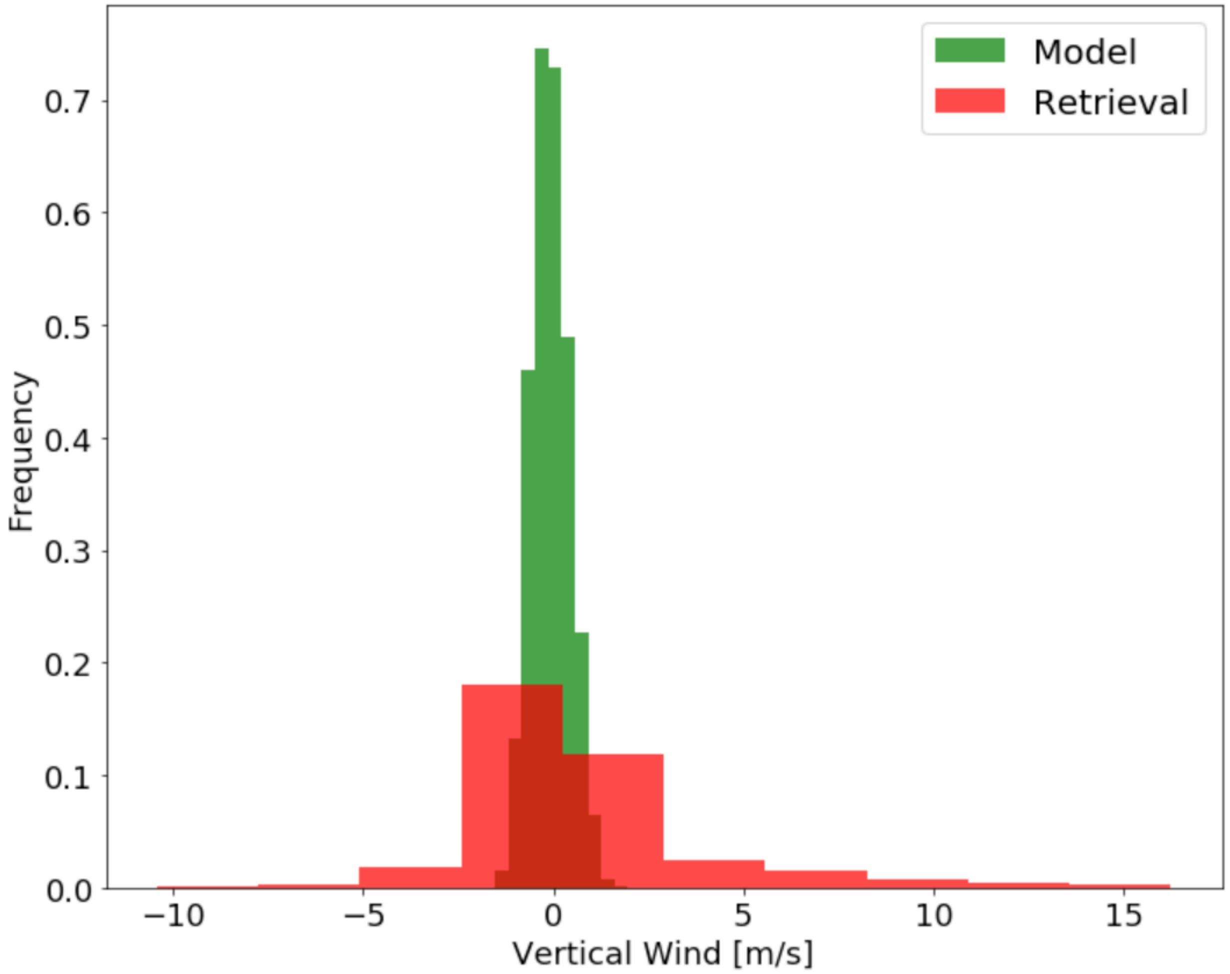
MSIS-90 model

Vertical wind retrievals from simulations



Vertical wind used in simulations





Vertical wind histogram from retrievals and simulations

N.B. cloud patterns similar but retrieved magnitudes very different

Summary and proposed Phase A work

- ESA awarded Earth Explorer 10 Phase A study to Harmony in February 2021
- There will be an ESA User Consultation meeting (UCM) in the summer 2022
- Depending on the outcome of this UCM, ESA may award Phases B-D starting in 2023
- Planned ESA-Harmony launch in 2028/9
- In the meantime, we now have the exciting possibility of simulating very realistic 4D cloud-fields in a computer and using this to test various measurement hypotheses as well as looking at error propagation and traceability in a way that has never been done before
- Harmony-TIR tandem concept ripe for exploitation with EarthWatch as well as future operational missions interested in better parameterisation of convective processes