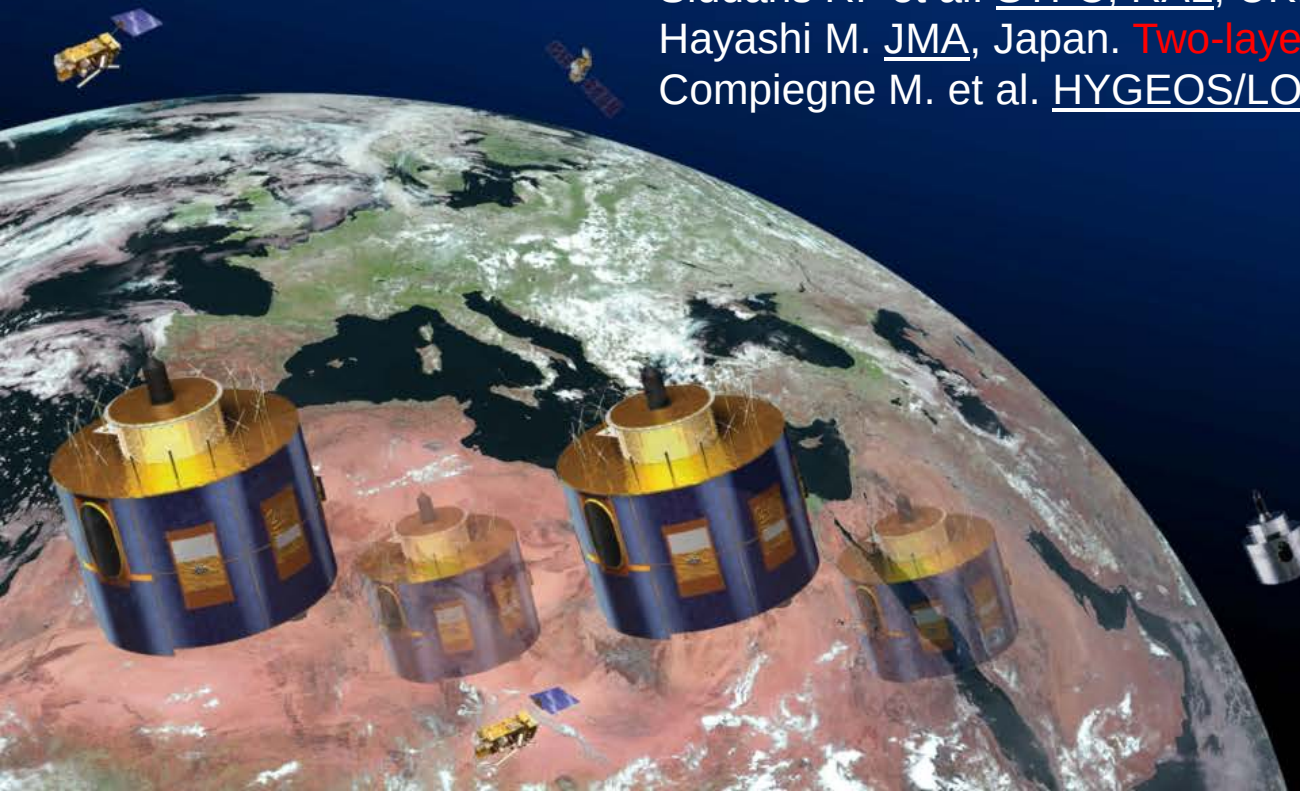
ICWG-II 29 Oct - 2 Nov 2018

Cloud property retrieval from SEVIRI, FCI and METimage at EUMETSAT

Philip Watts, Loredana Spezzi, John Jackson, EUMETSAT

Grateful Acknowledgments to:
Siddans R. et al. STFC, RAL, UK. Two-layer fast RT theory, code
Hayashi M. JMA, Japan. Two-layer coding and refinements
Compiegne M. et al. HYGEOS/LOA, France. Cloud models for O2 A-band



Contents

- VIS-IR Multi-layer retrieval: improving the Radiative Transfer
- Oxygen A-band retrieval: mandatory vertical inhomogeneity
- Inhomogeneity for the VIS-IR world
- Presentation for forecasters

Contents

- VIS-IR Multi-layer retrieval: improving the Radiative Transfer
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Reminder that the retrieval is:

Minimisation of:

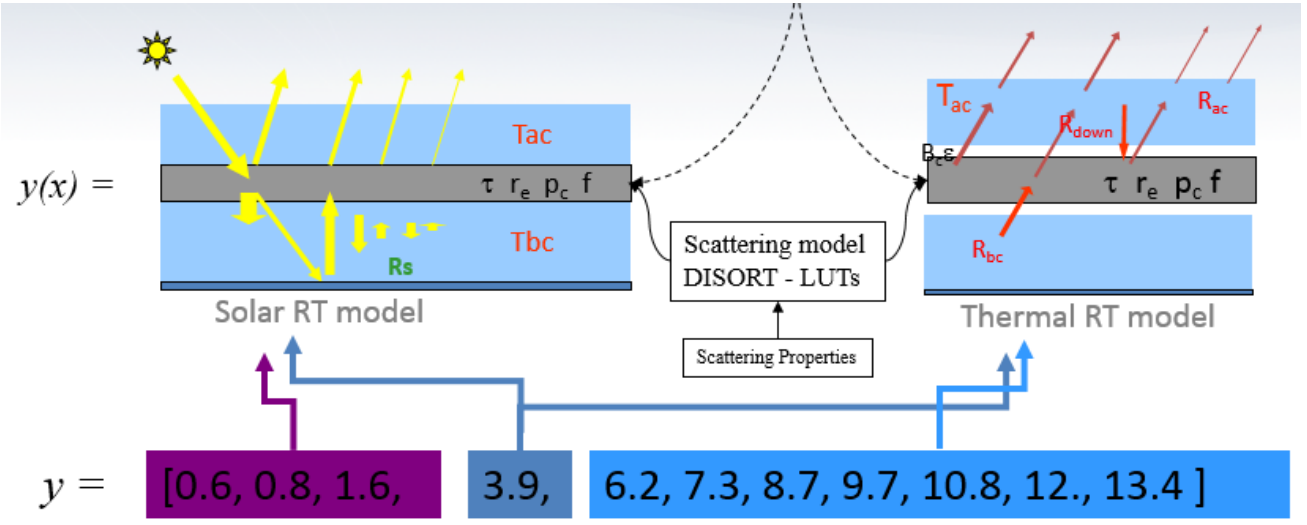
$$J = \left(y_m - y(x)\right) S_y^{-1} \left(y_m - y(x)\right)^T + \left(x - x_b\right) S_x^{-1} \left(x - x_b\right)^T$$

Cloud state

Fast RT model

Error estimates

Measurements



Two cloud states considered in this talk

$X_1 = [\ COT,\ r,\ CTP,\ T_{skin}\ ]$

$Y_1(X_1)$

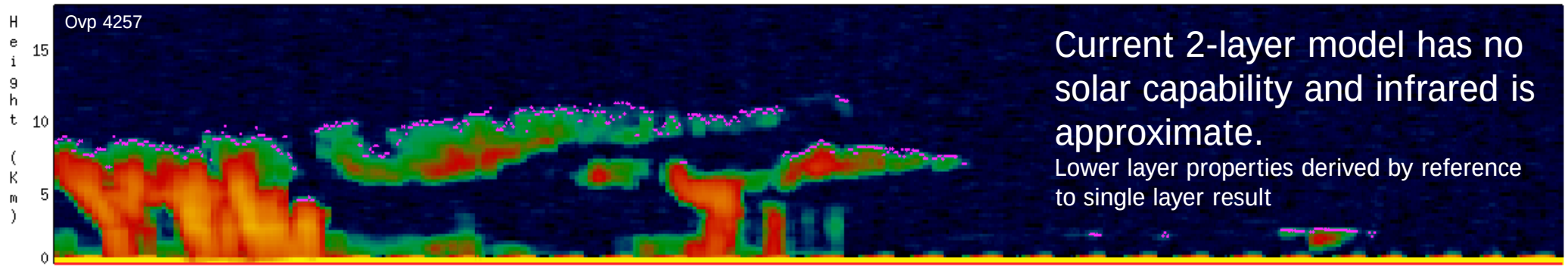
1- Layer cloud (ice or liquid) or
2- Layer cloud where T_{skin} acts as lower layer temperature

$X_2 = [\ COT_{upper},\ r_{upper},\ CTP_{upper},\ COT_{lower},\ r_{lower},\ CTP_{lower}\ ]$

$Y_2(X_2)$

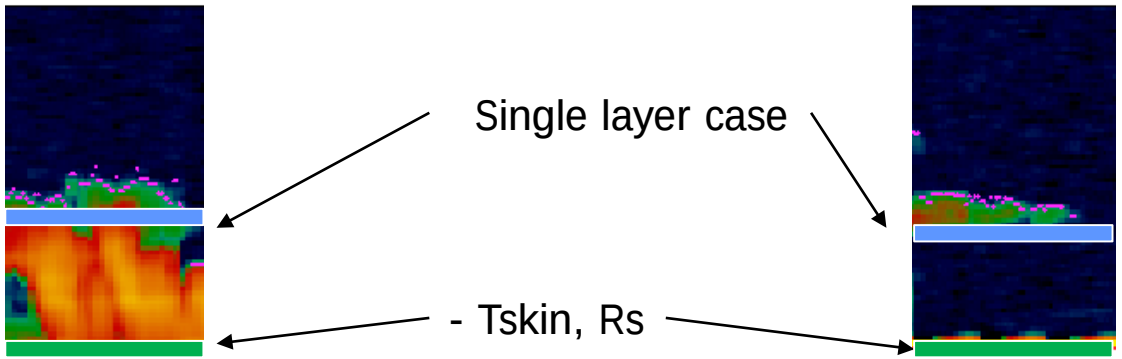
2- Layer cloud

VIS-IR Multi-layer : improving the Radiative Transfer



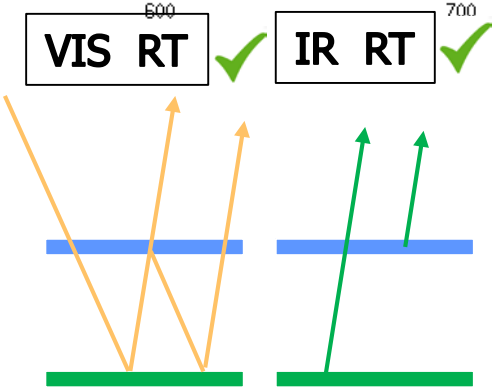
Current 2-layer model has no solar capability and infrared is approximate.

Lower layer properties derived by reference to single layer result



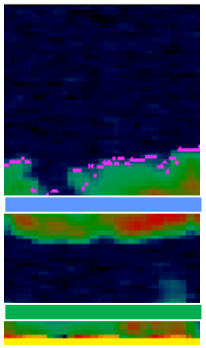
Single layer case

- Tskin, Rs



Current 2-Layer retrieval uses skin temperature proxy for the lower layer cloud temperature. Simple but quite effective.

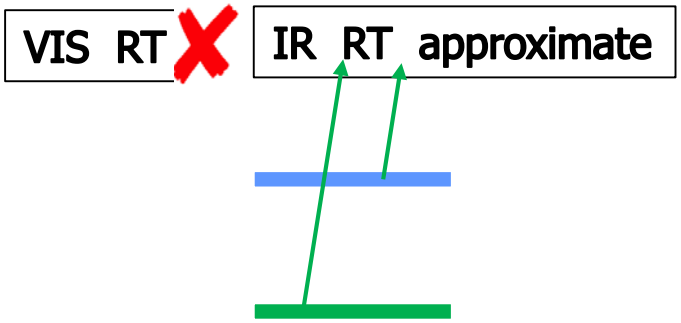
- IR RT is approximate
- Solar RT is not available



Multi-layer case

- Upper layer

- Tskin = lower cloud Temperature



EUMETSAT

Complete 2-layer fast RT (STFC, RAL)

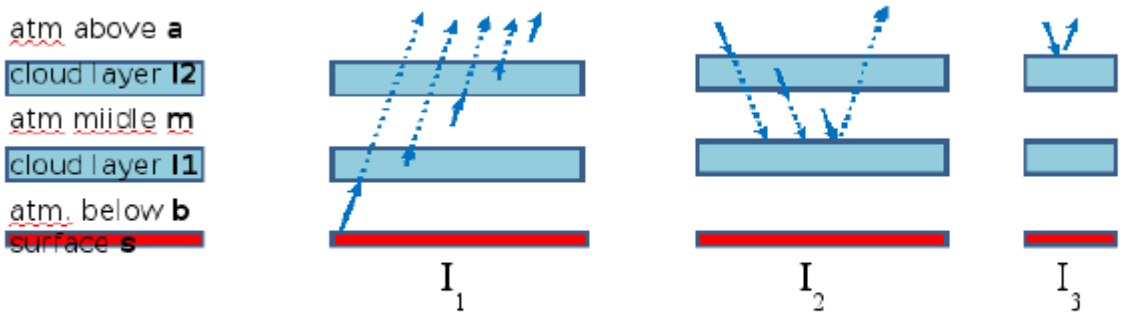


Figure 4.4: The first plot represents the IR notation for the 2

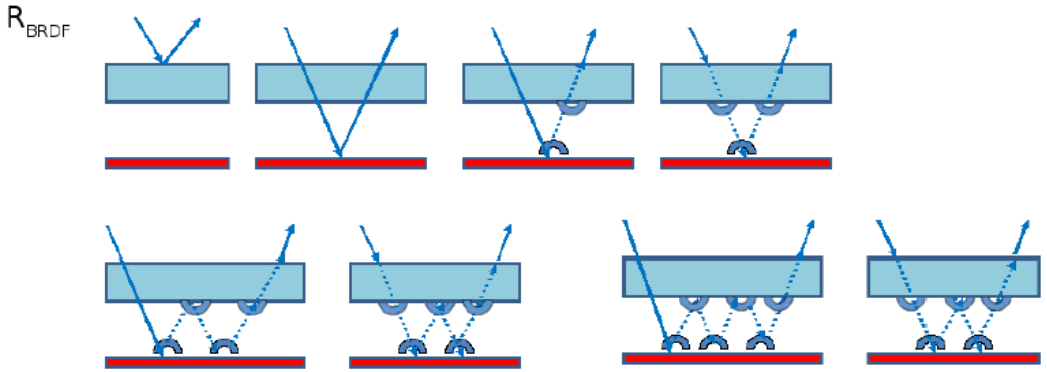
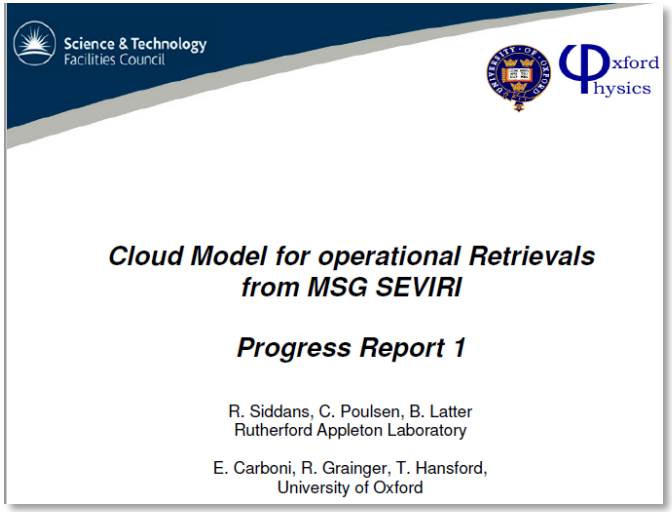
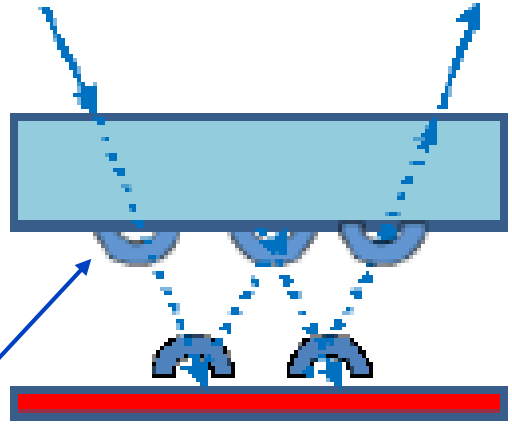


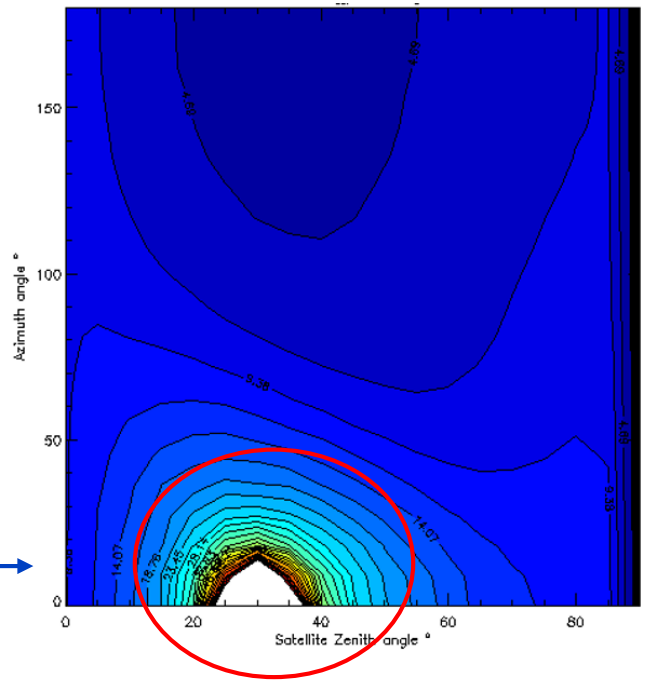
Figure 4.1: Scheme of the bidirectional reflectance for the surface-cloud layer system. The beam components are illustrated with arrows and continuous lines, the diffuse components with dotted lines and semicircles. This figure represents the first three orders of scattering between surface and cloud, the forward model takes into account all of them.

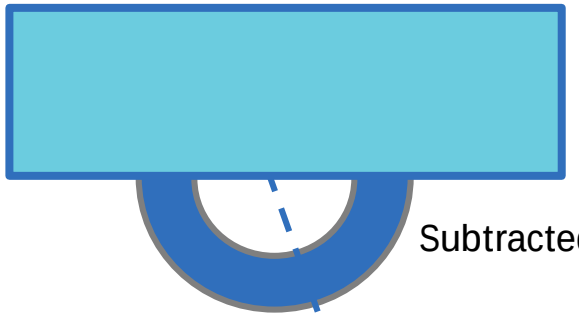


Problem: diffuse transmission is not isotropic
Solution: integrate forward peak and add to 'beam' component



This assumed isotropic diffuse transmission actually looks like this





Subtracted from here

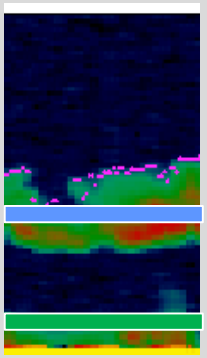
..and added to here

The transmission (energy) close to the beam direction is integrated

Developed by Masahiro Hayashi, JMA

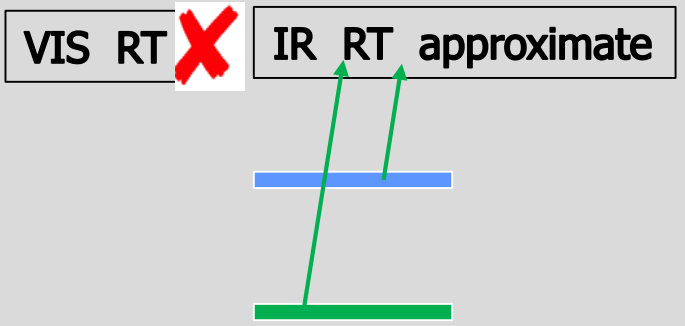
MM2L and F2L RT models

MM2L

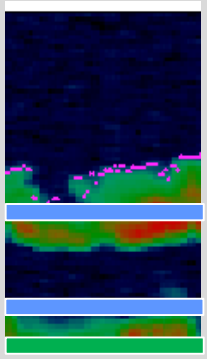


Multi-layer case

- Upper layer
- Tskin = lower cloud Temperature

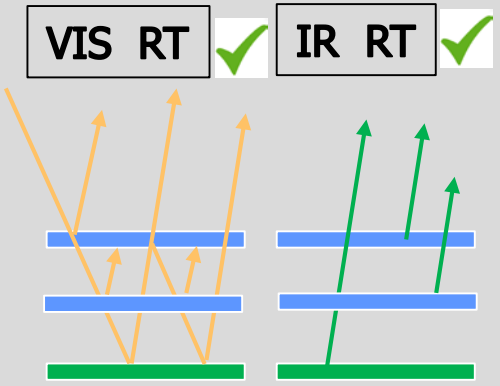


F2L



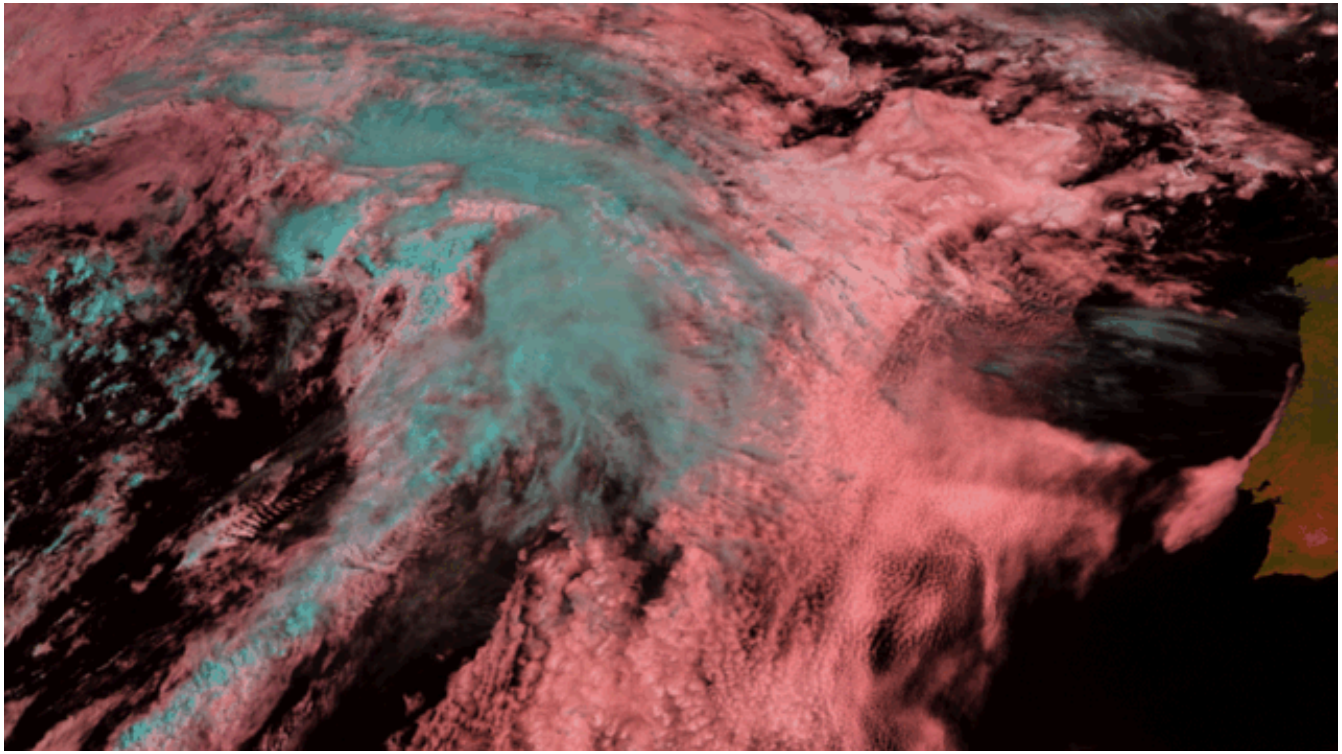
Multi-layer case

- Upper layer
- Lower layer
- Tskin = lower cloud Temperature



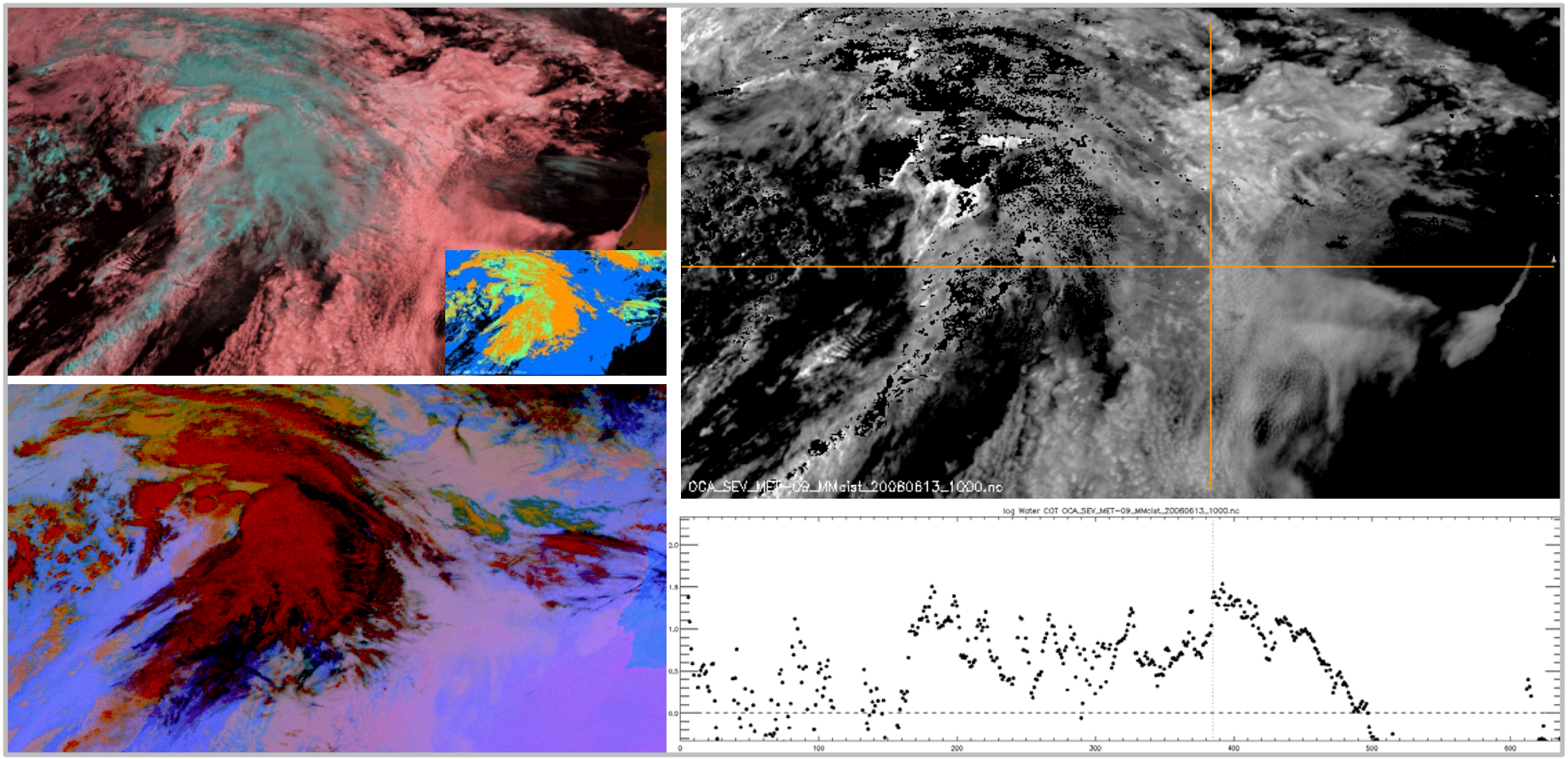
Validation (subjective): Lower layer COT

- Scene with stratocumulus field underlying cirrus



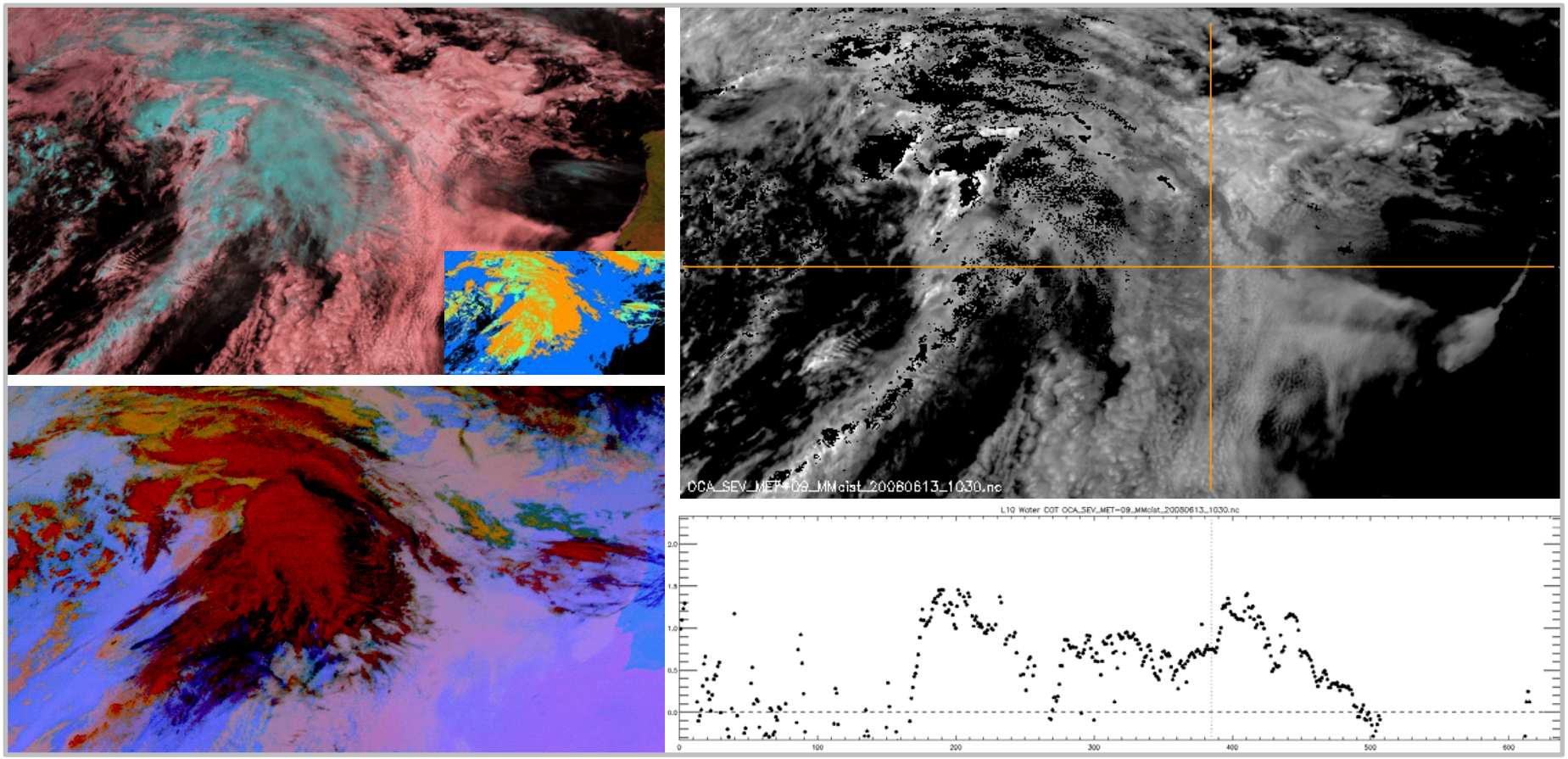
Lower layer COT: MM2L (Tskin as lower CTT+..)

MM2L 2008 June 13 1000Z



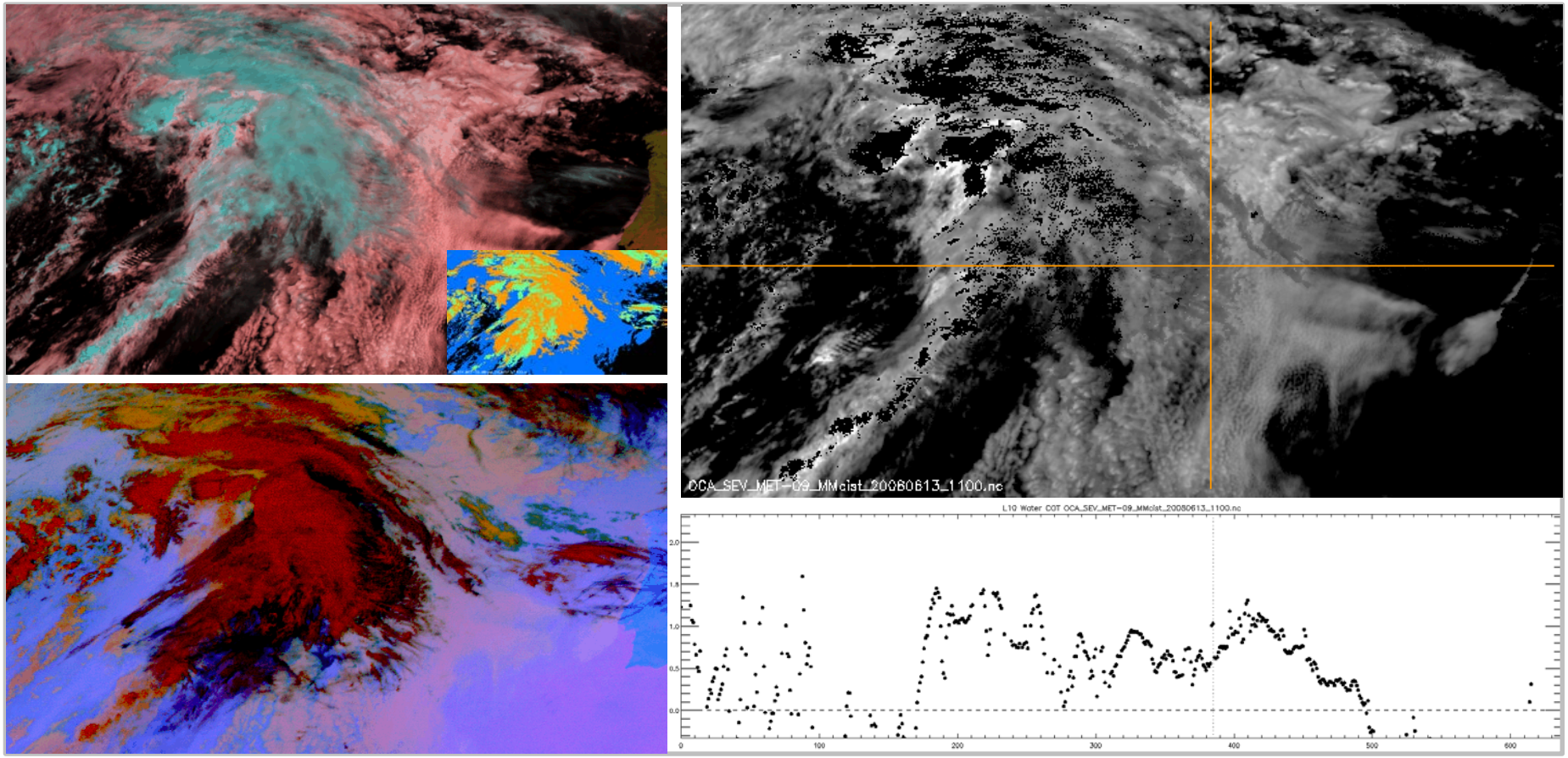
Lower layer COT: MM2L (Tskin as lower CTT+..)

MM2L 2008 June 13 1030Z



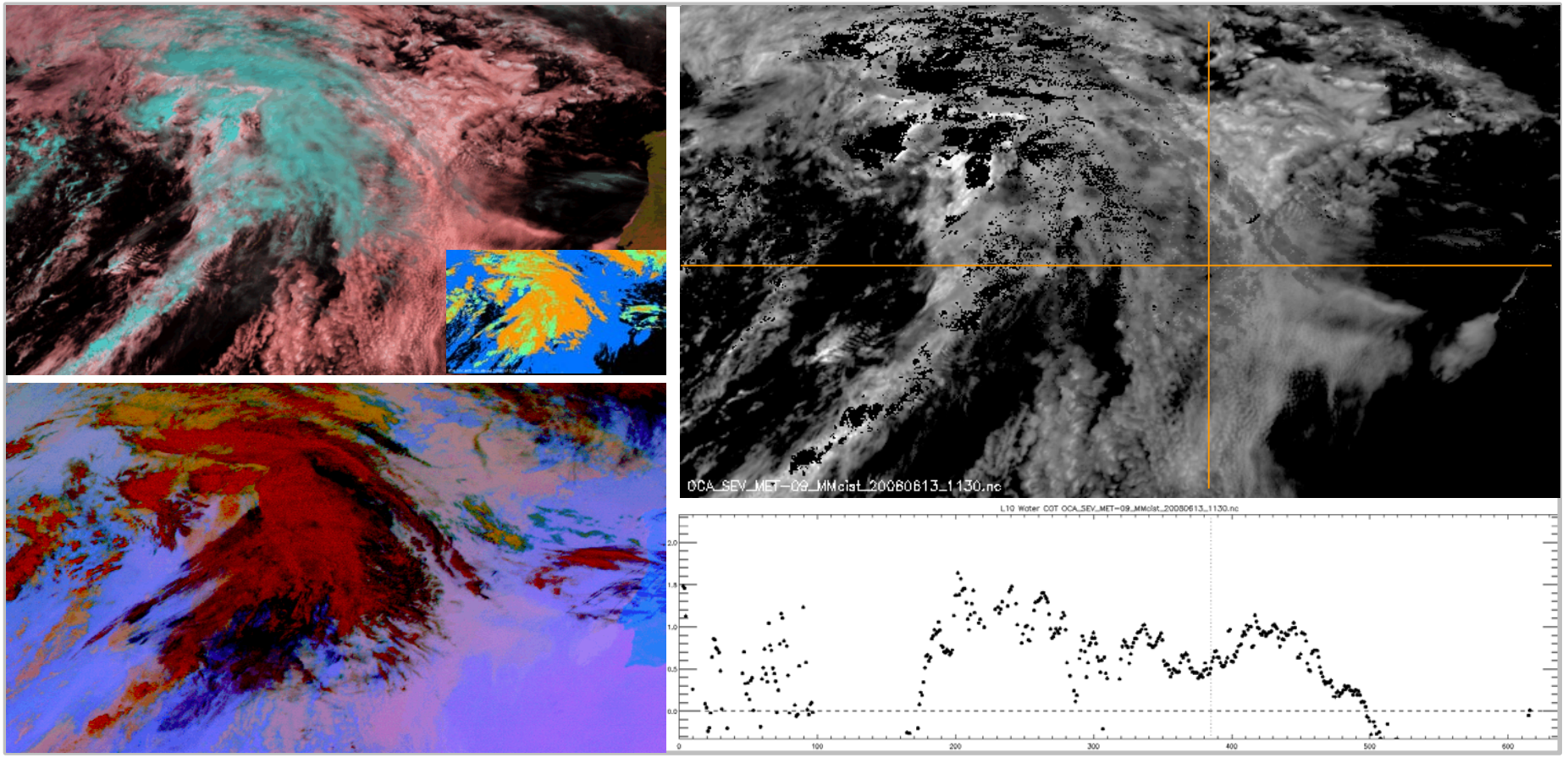
Lower layer COT: MM2L (Tskin as lower CTT+..)

MM2L 2008 June 13 1100Z



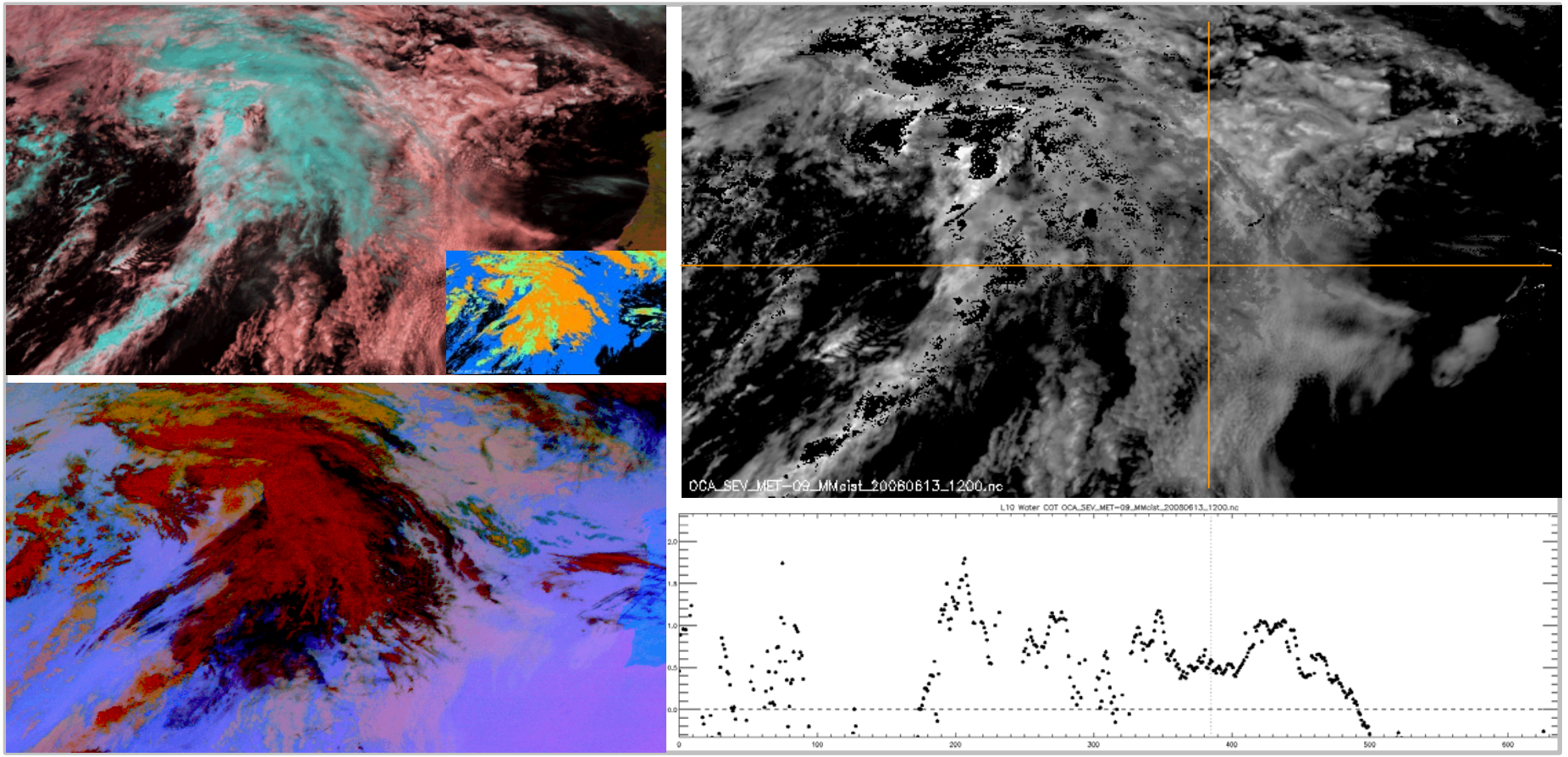
Lower layer COT: MM2L (Tskin as lower CTT+..)

MM2L 2008 June 13 1130Z



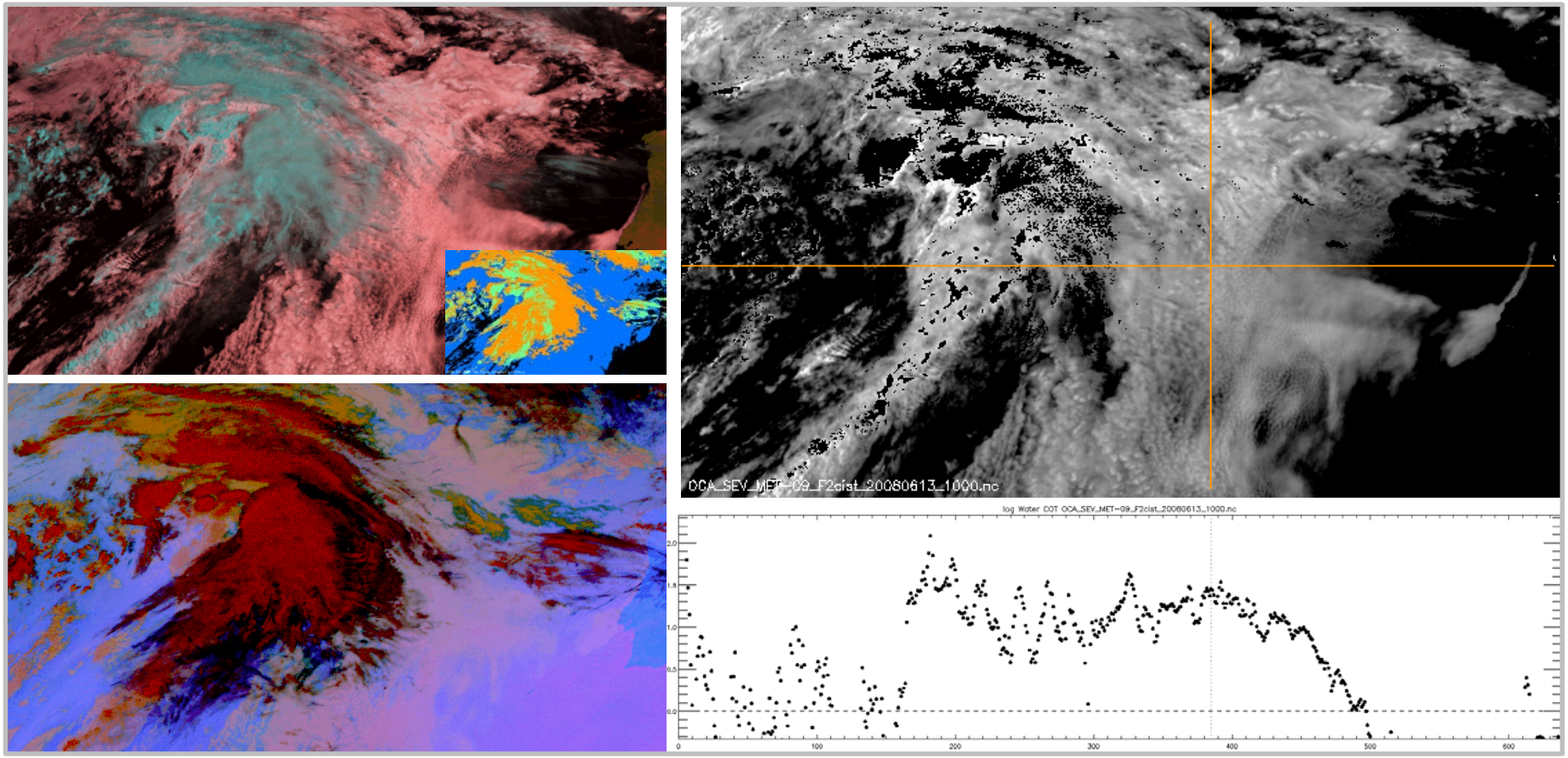
Lower layer COT: MM2L (Tskin as lower CTT+..)

MM2L 2008 June 13 1200Z



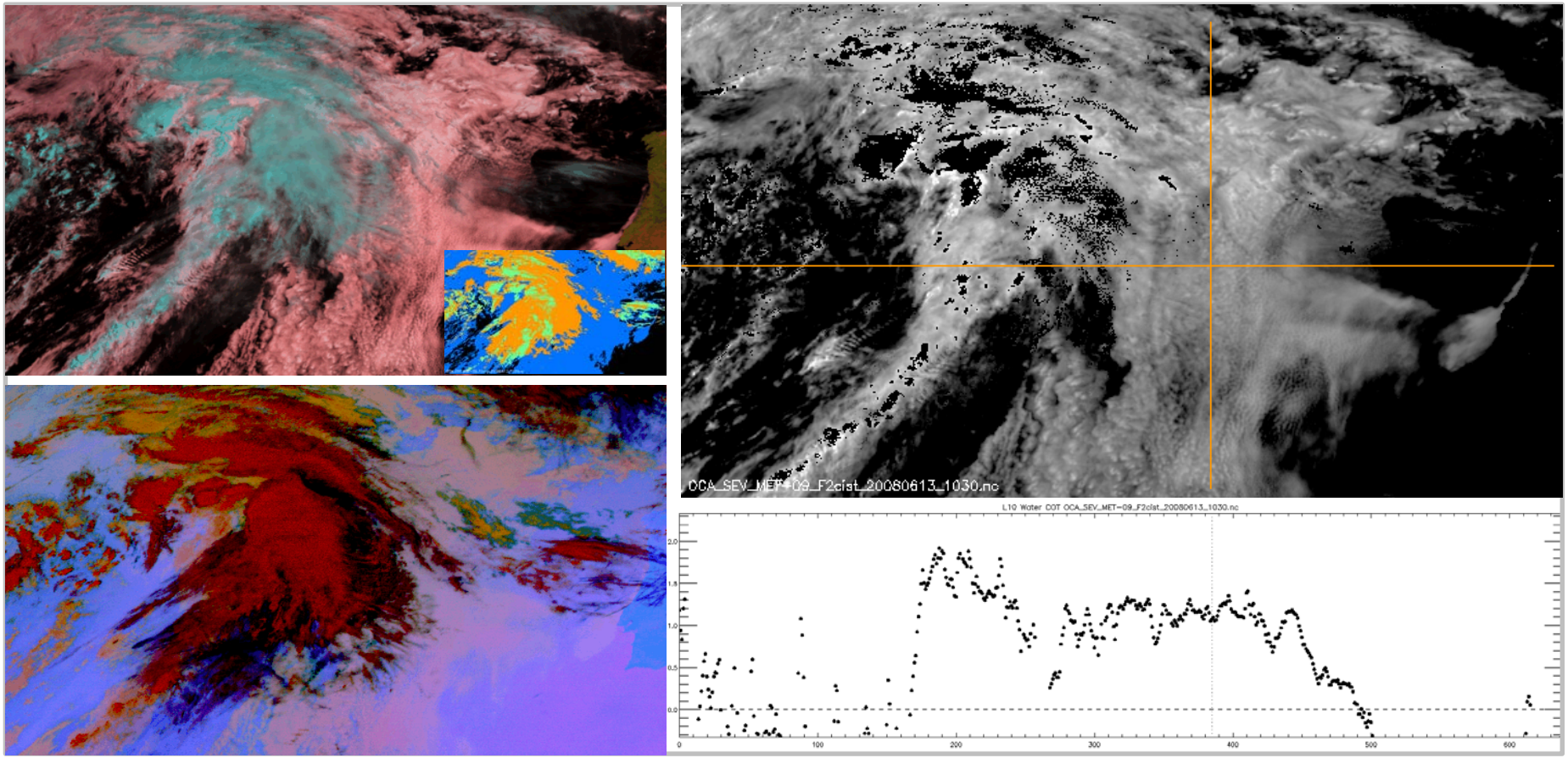
Lower layer COT: F2L (Full 2-Layer RT)

F2L June 13 1000Z



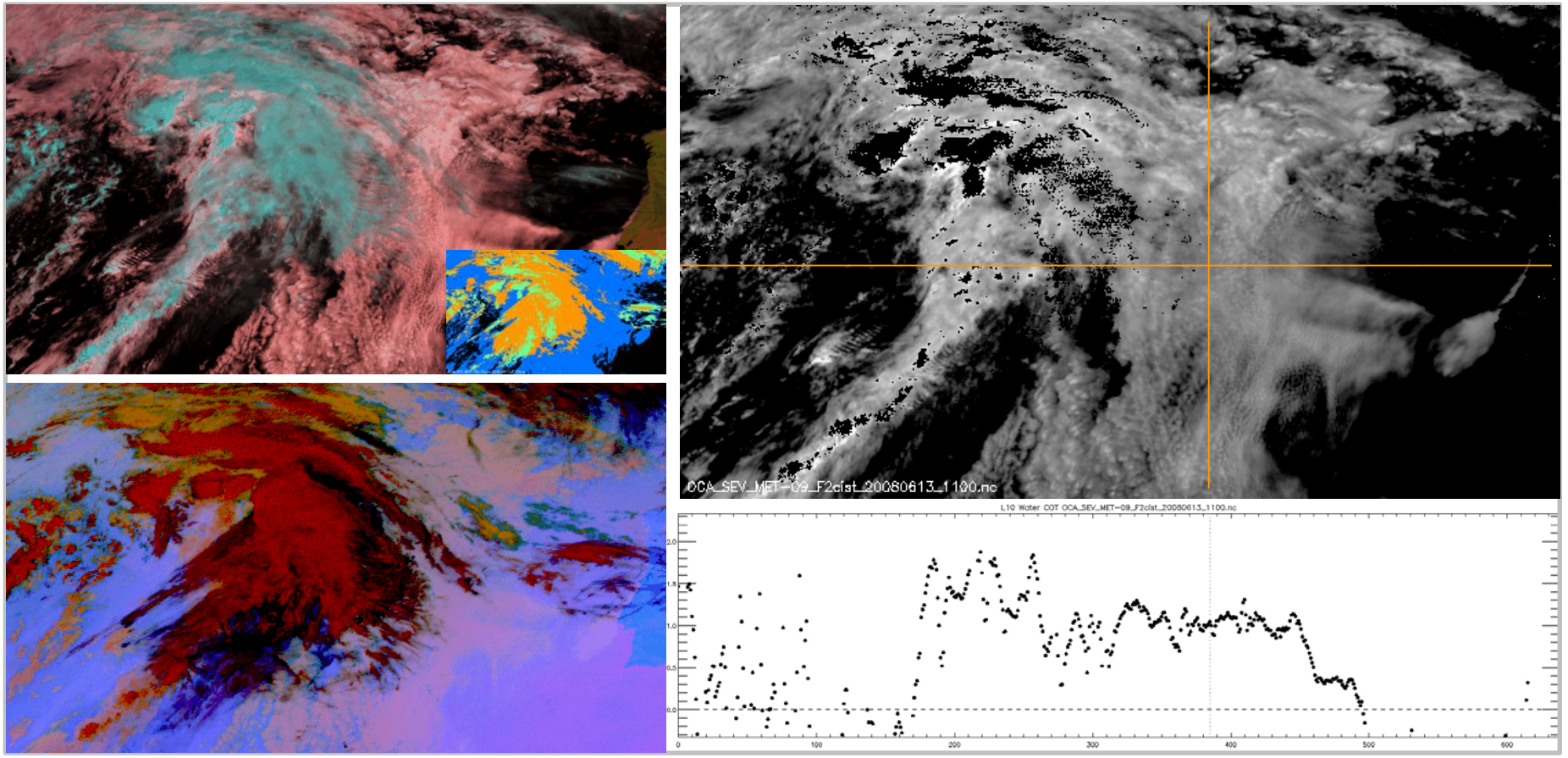
Lower layer COT: F2L (Full 2-Layer RT)

F2L June 13 1030Z



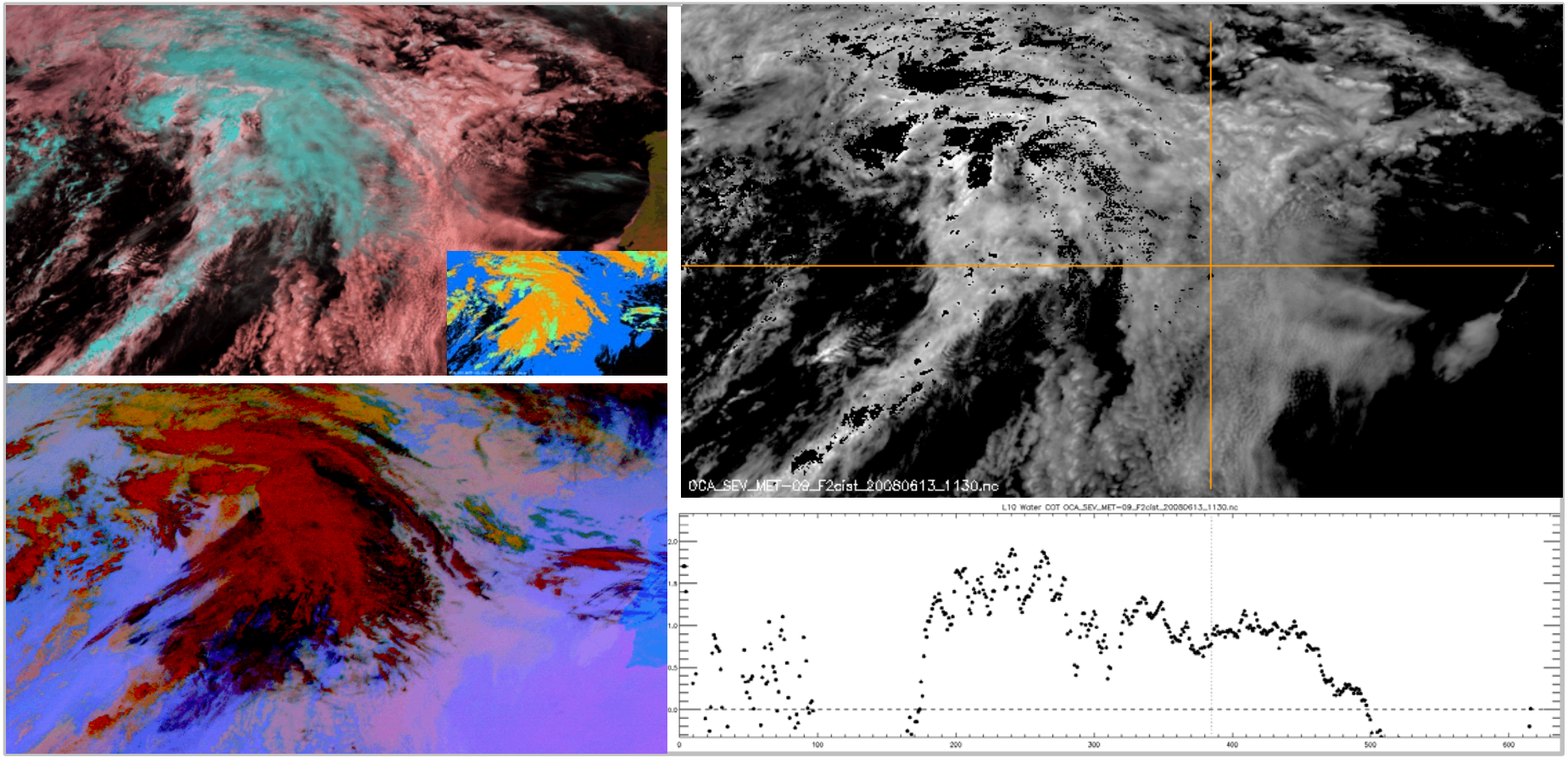
Lower layer COT: F2L (Full 2-Layer RT)

F2L June 13 1100Z



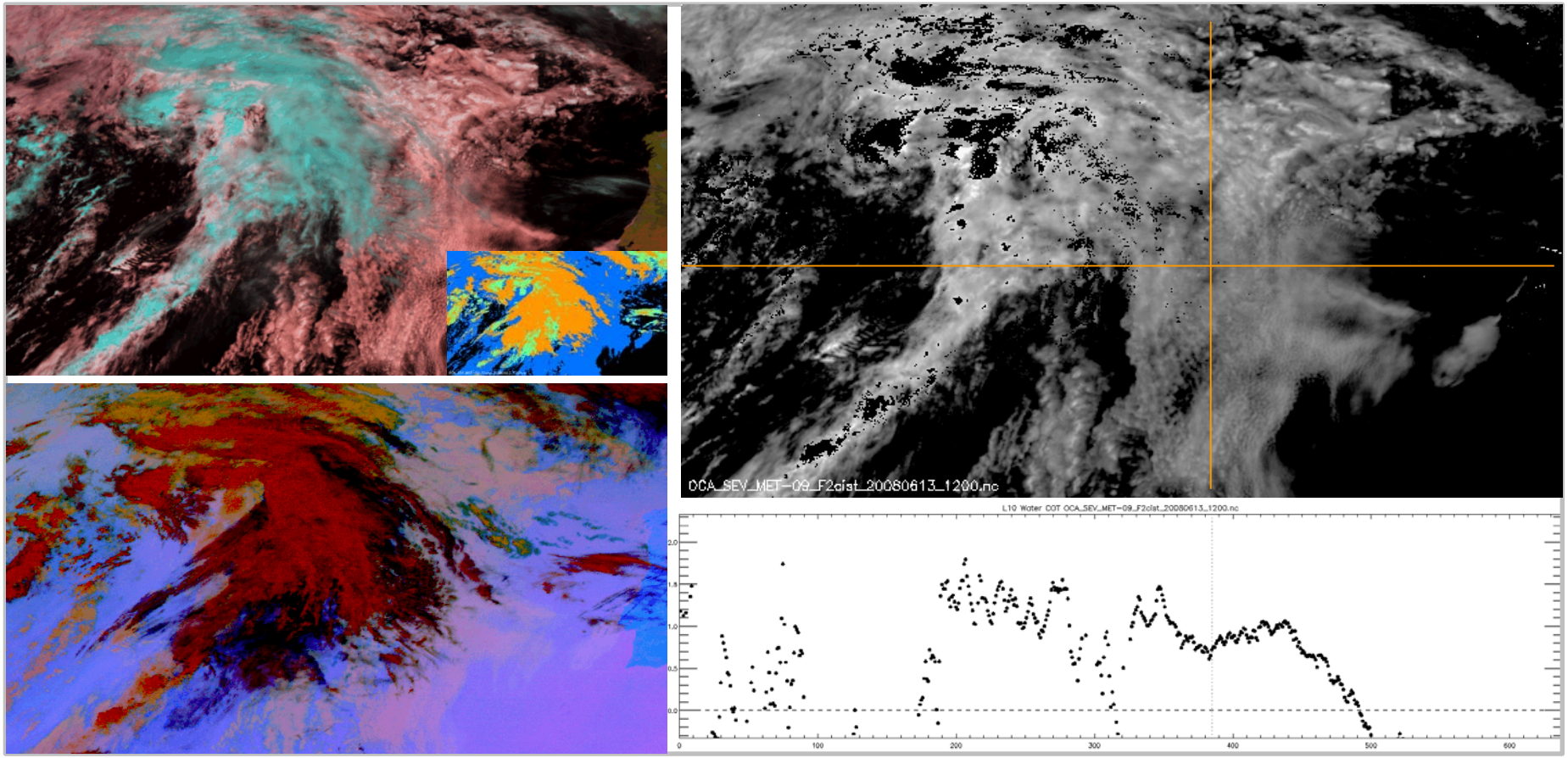
Lower layer COT: F2L (Full 2-Layer RT)

F2L June 13 1130Z



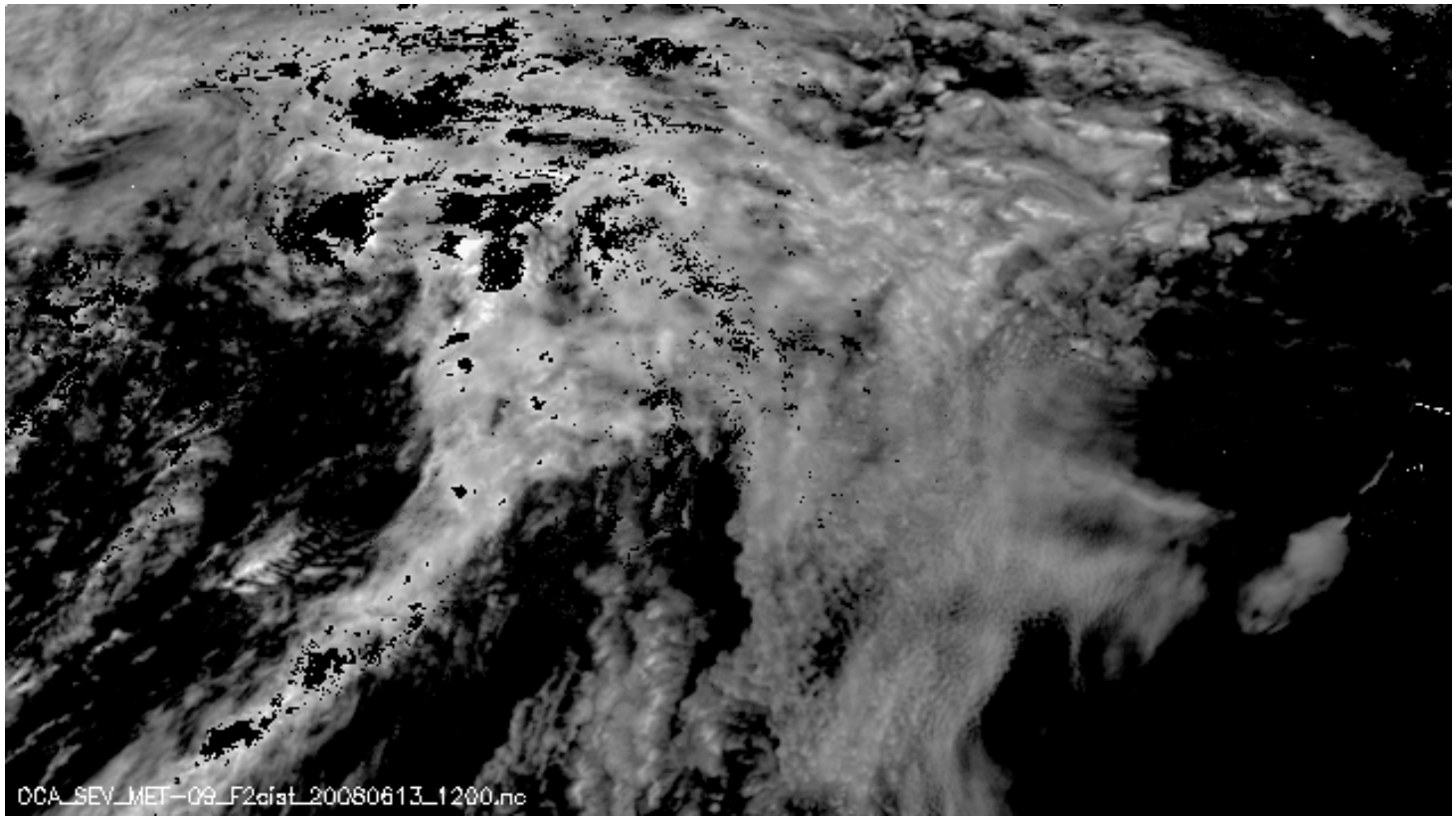
Lower layer COT: F2L (Full 2-Layer RT)

F2L June 13 1200Z



Lower layer COT: MM2L - F2L comparisons

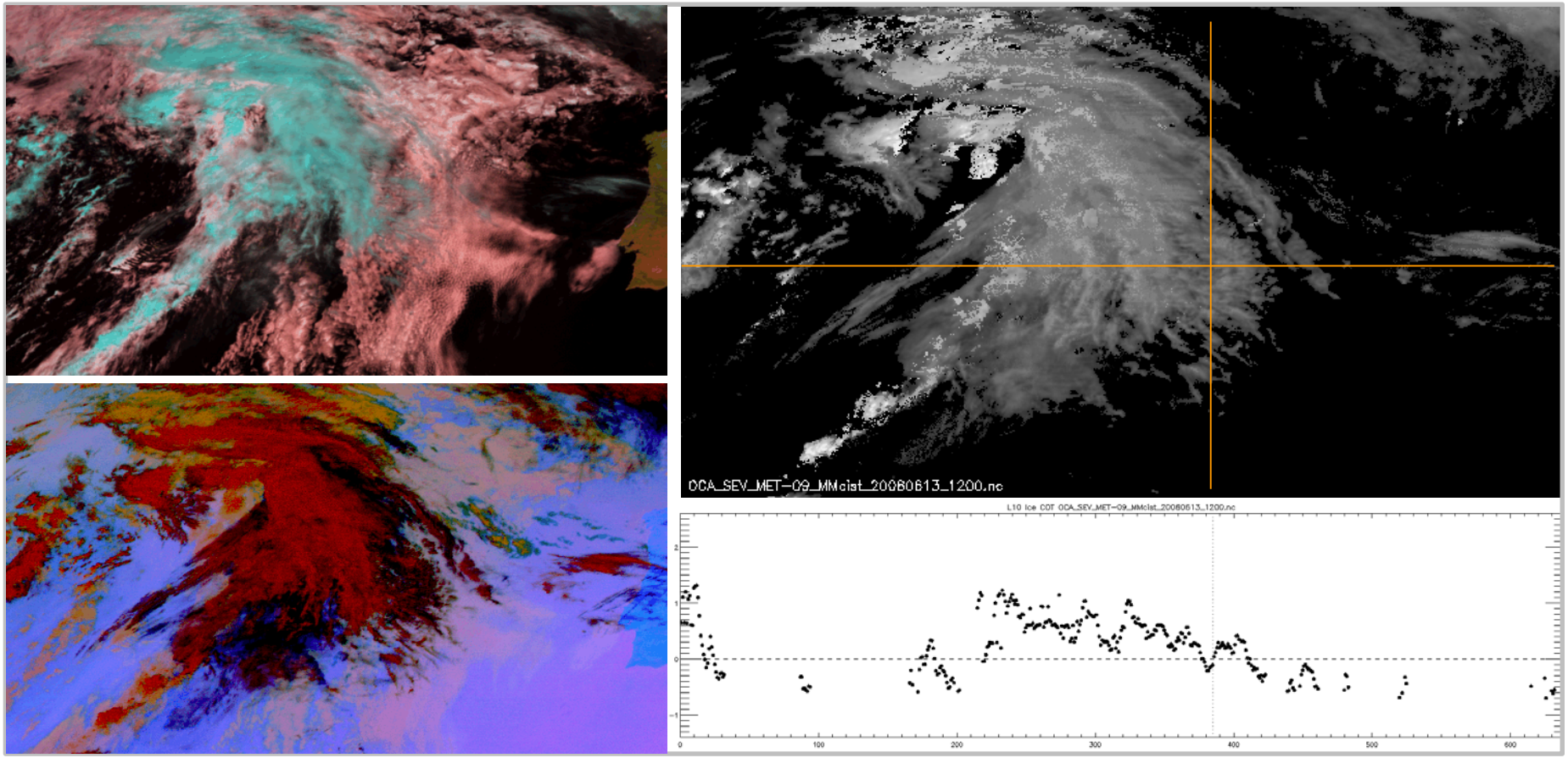
Frame by frame comparisons MM2L – F2L



Use of full 2-Layer RT significantly improves the visual coherency of the lower layer COTs

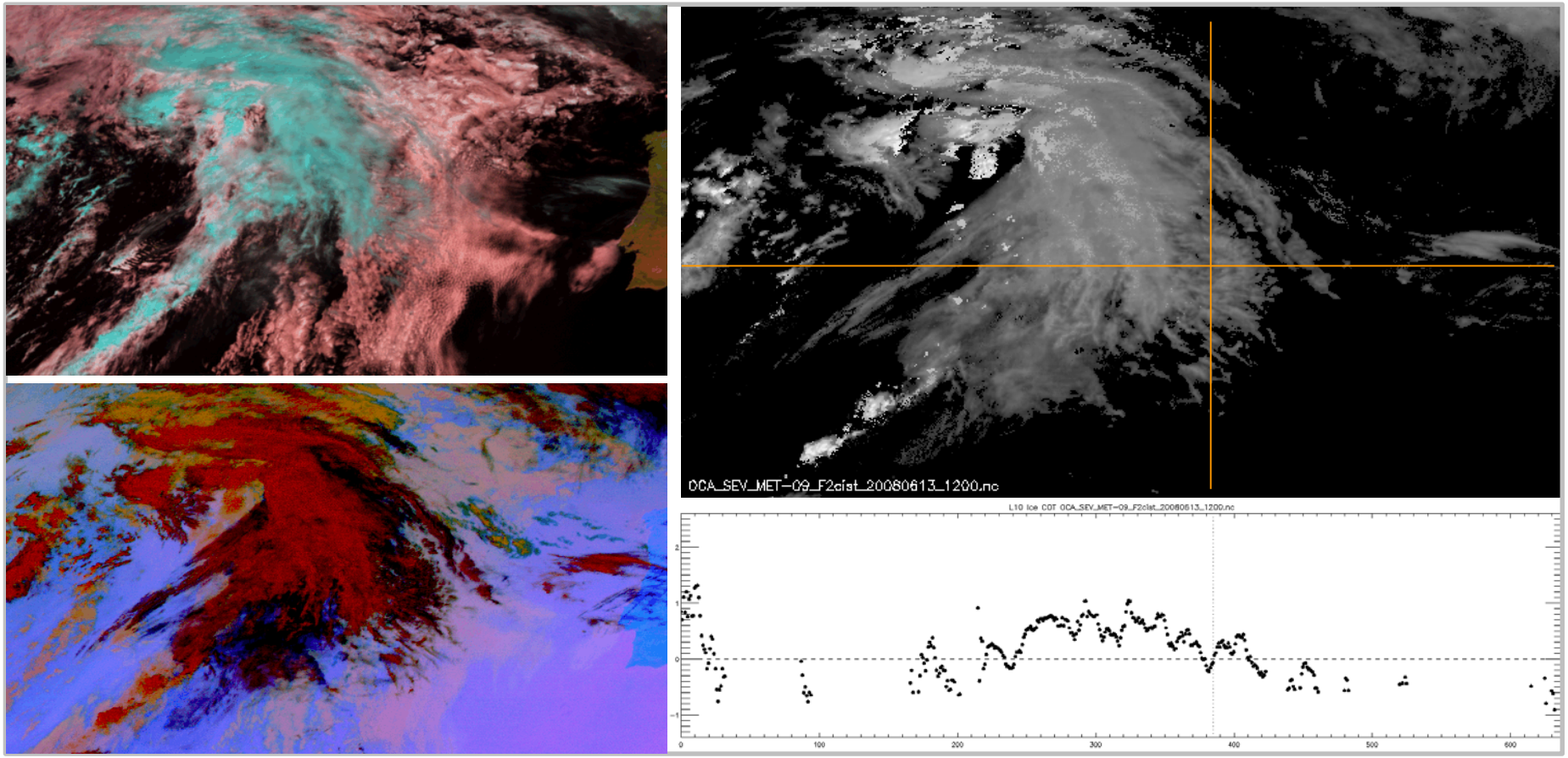
Upper Layer COT: MM2L

MM2L June 13 1200Z

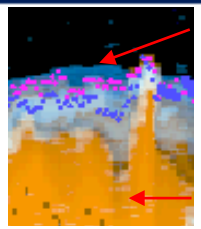


Upper Layer COT: F2L

F2L June 13 1200Z



Validation: .v. CPR CTP ovp4111



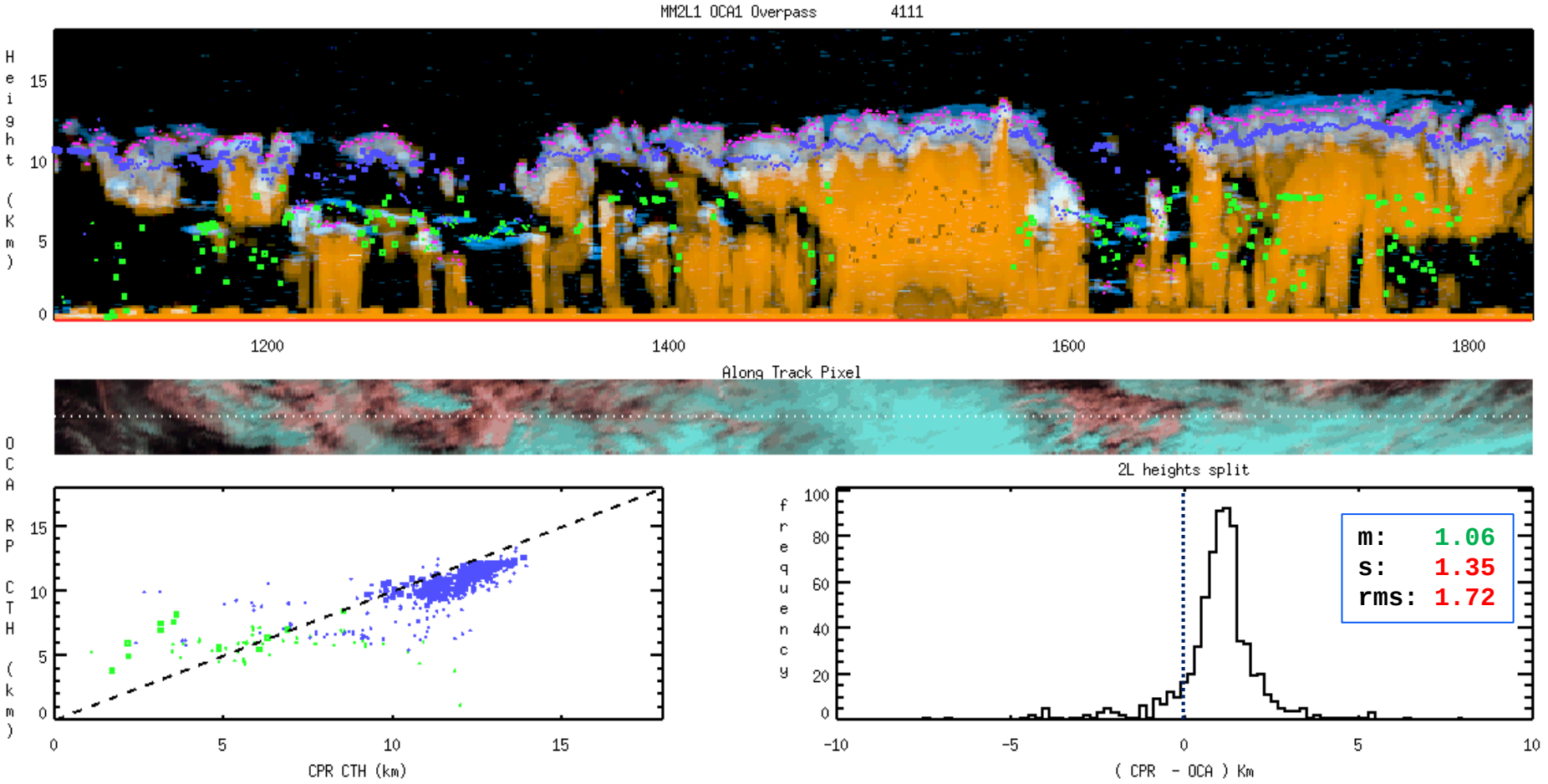
Lidar backscatter only

*Radar CTH

*MOCA CTH

Radar backscatter only

MM2L - Standard Cloud
Radiative properties:
Geometrically Thin



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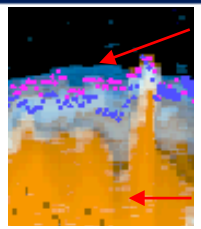


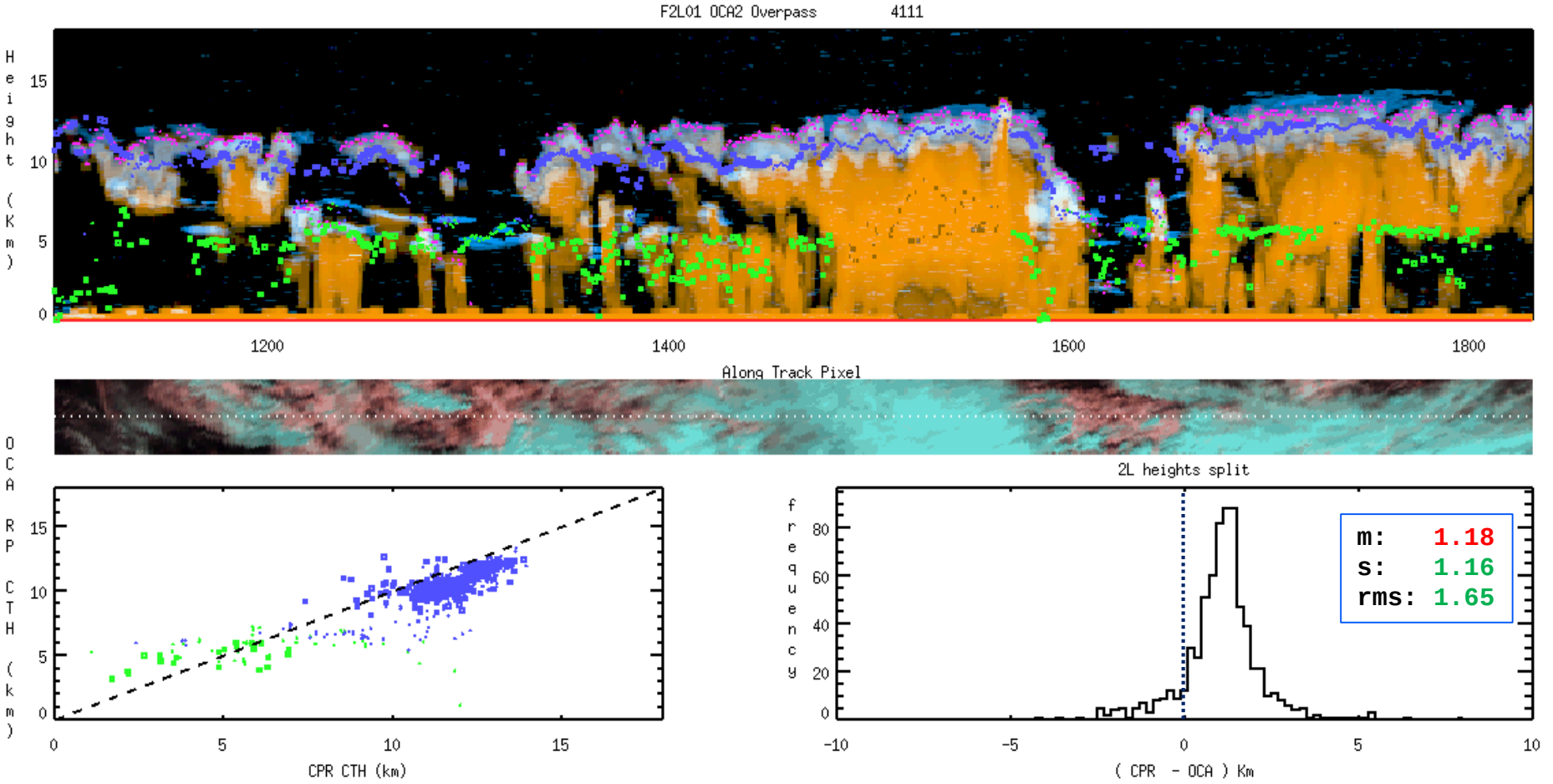
Lidar backscatter only

*Radar CTH

*MOCA CTH

Radar backscatter only

F2L – Full 2-layer
Radiative properties:
Geometrically Thin



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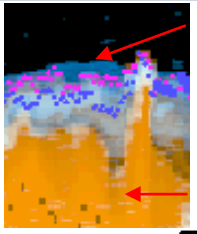


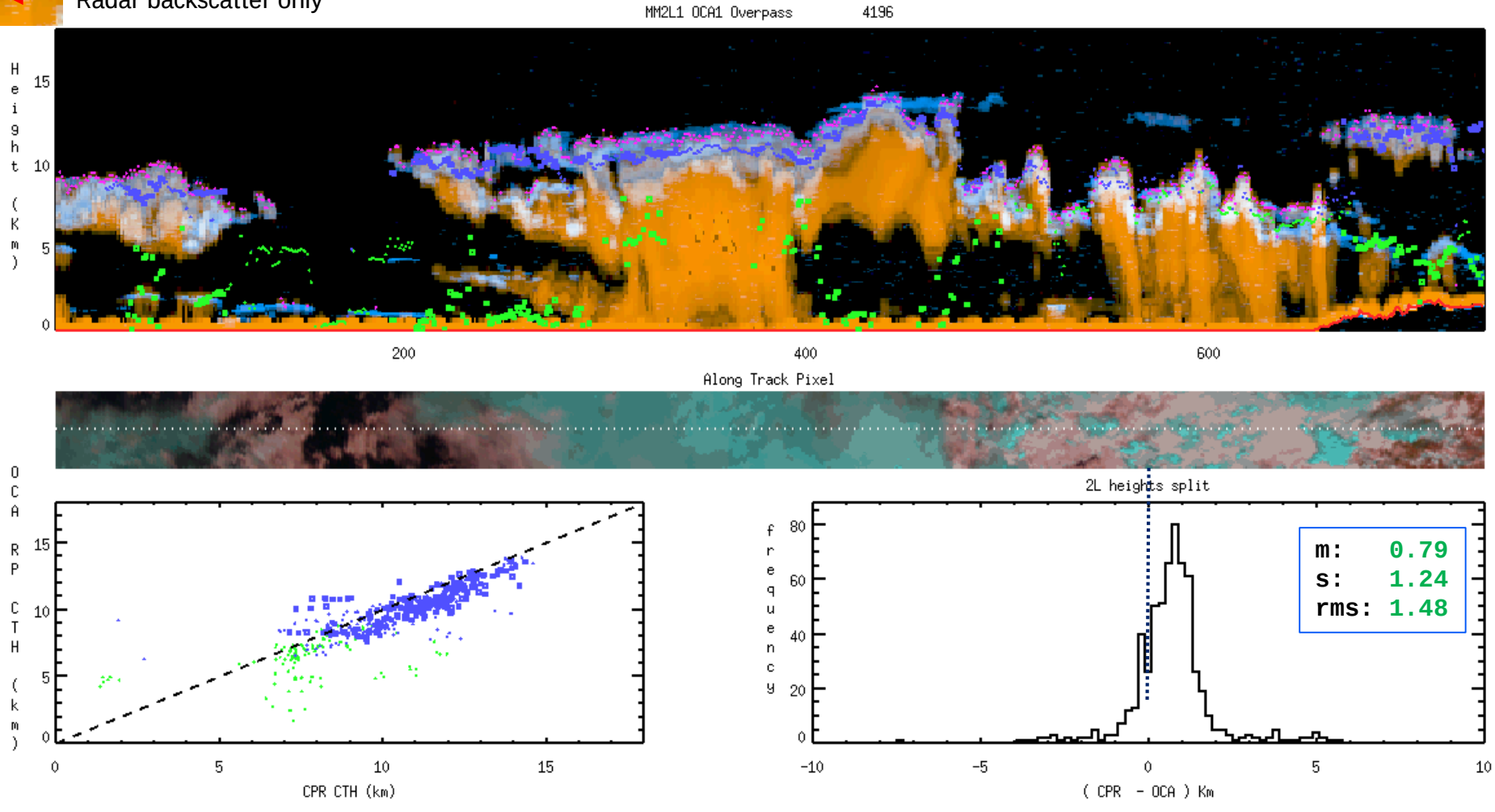
Lidar backscatter only

*Radar CTH

*MOCA CTH

Radar backscatter only

MM2L - Standard Cloud
Radiative properties:
Geometrically Thin



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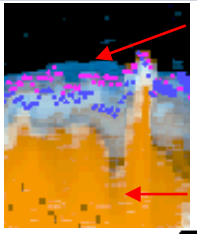

Lidar backscatter only

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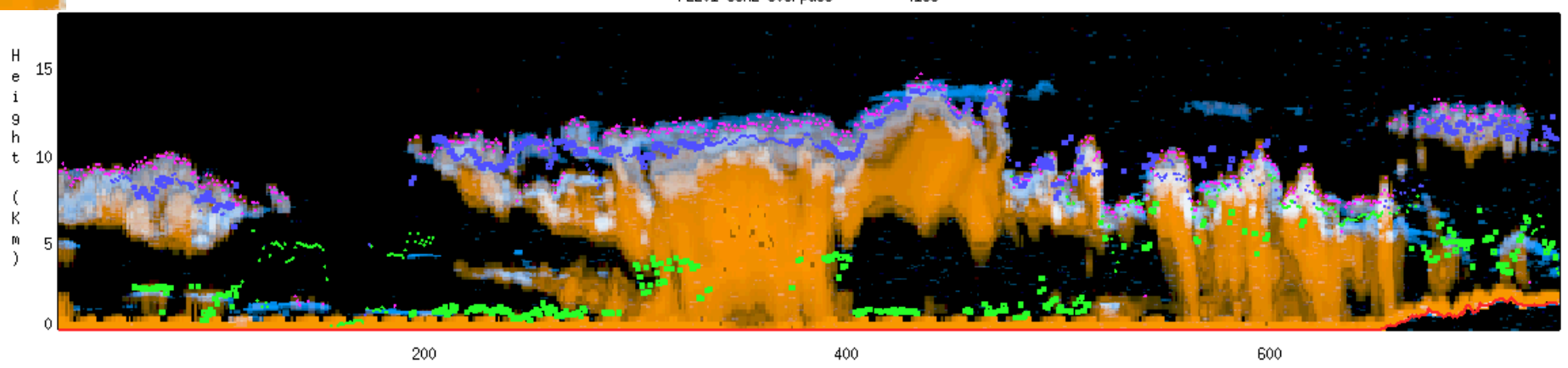
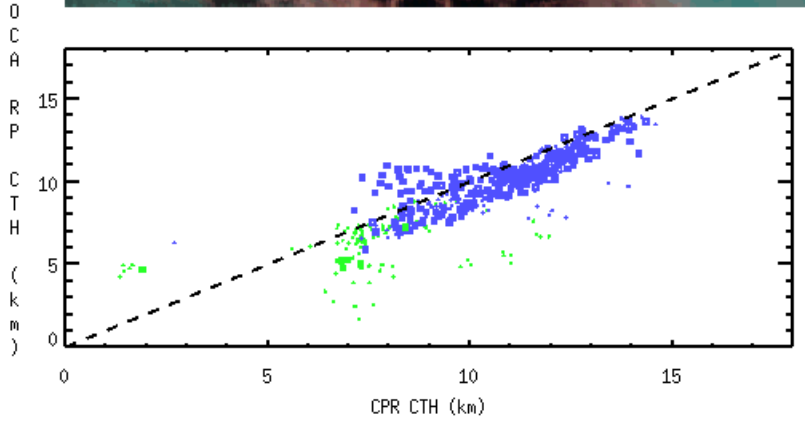
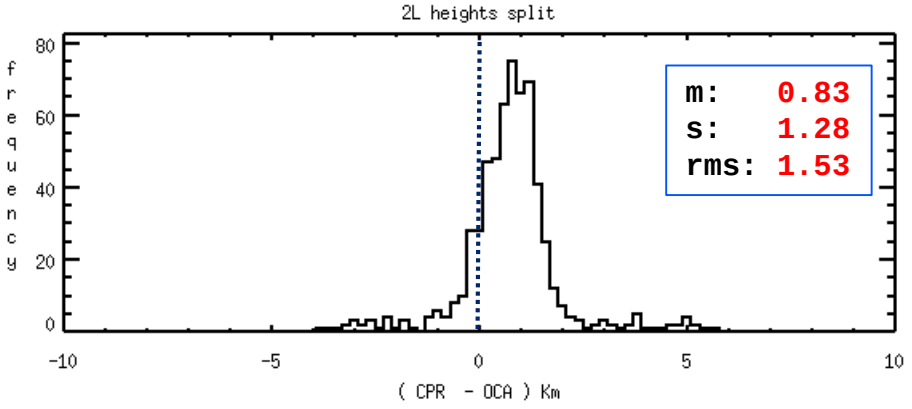
Radar backscatter only

F2L – Full 2-layer
Radiative properties:
Geometrically Thin







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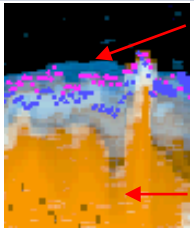


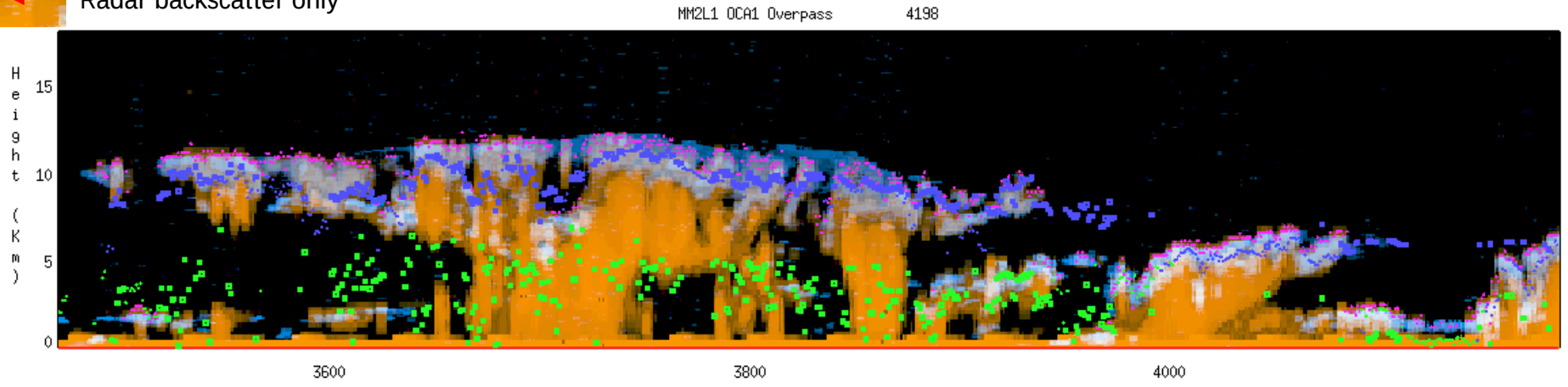
Lidar backscatter only

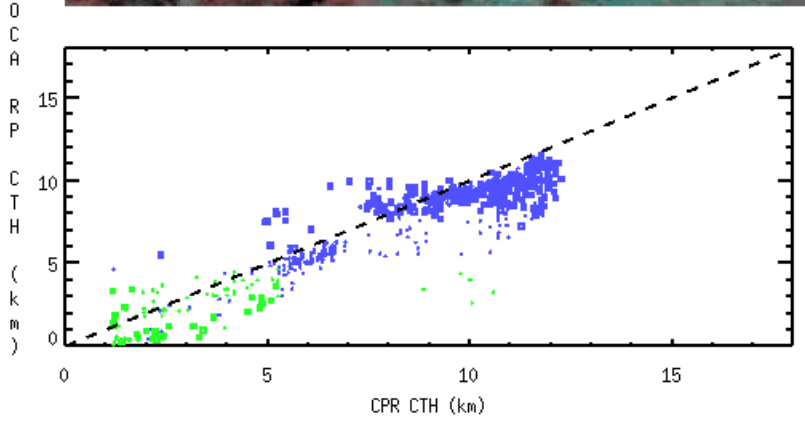
*Radar CTH

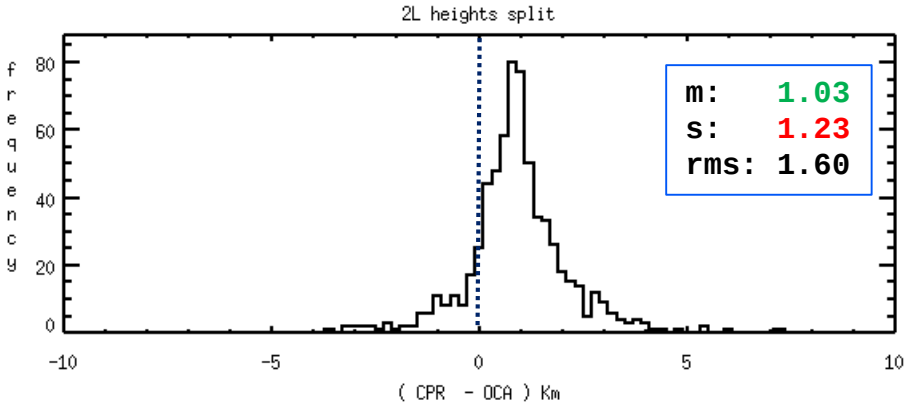
*MOCA CTH

Radar backscatter only

MM2L - Standard Cloud
Radiative properties:
Geometrically Thin







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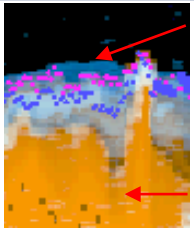

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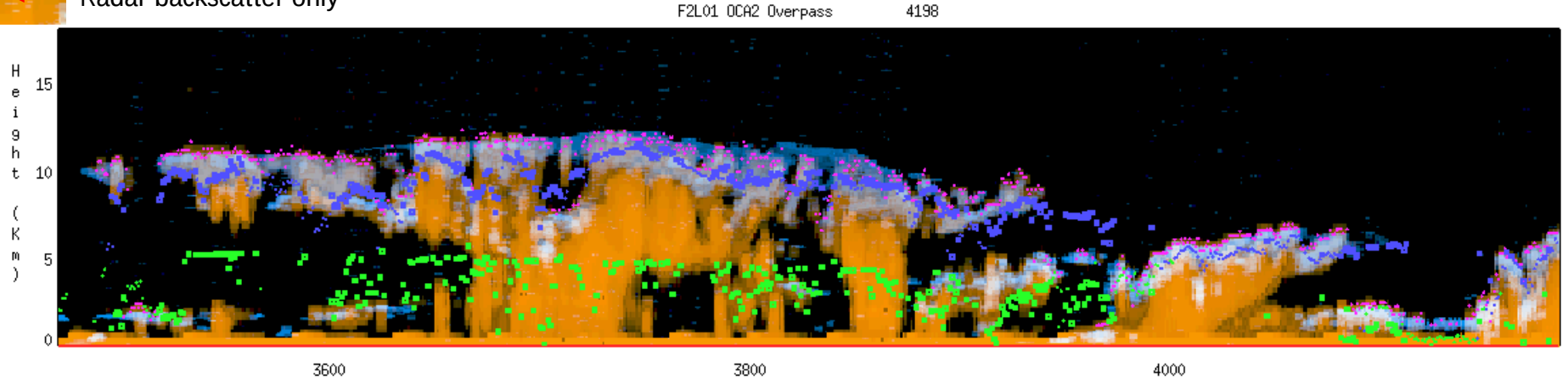
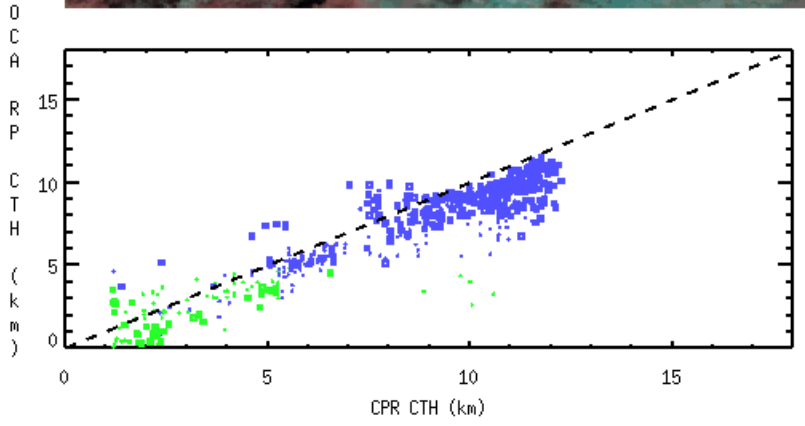
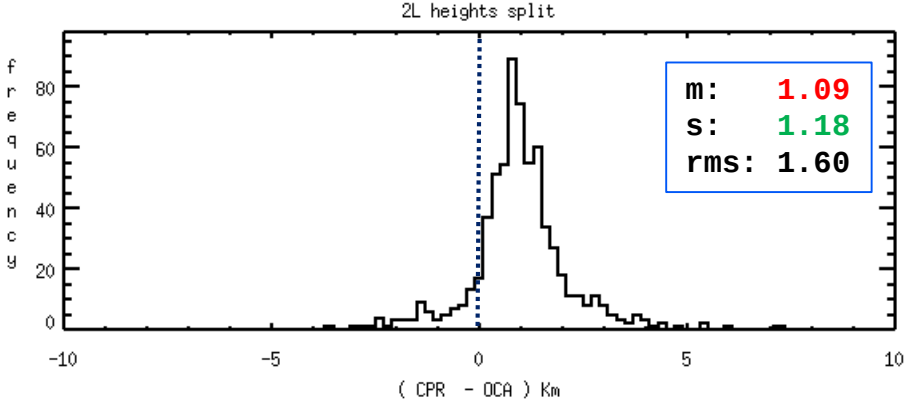
F2L – Full 2-layer
Radiative properties:
Geometrically Thin







Full 2-Layer RT model: conclusions to date

- COT: Subjective evidence that layer optical properties are significantly improved with full 2-layer model (very small sample)
- CTP: Impact rather neutral, evidence of increased variance
- Data samples presented very small - 80 A-train orbits have been processed, analysis ongoing..

- VIS-IR Multi-layer retrieval: improving the Radiative Transfer

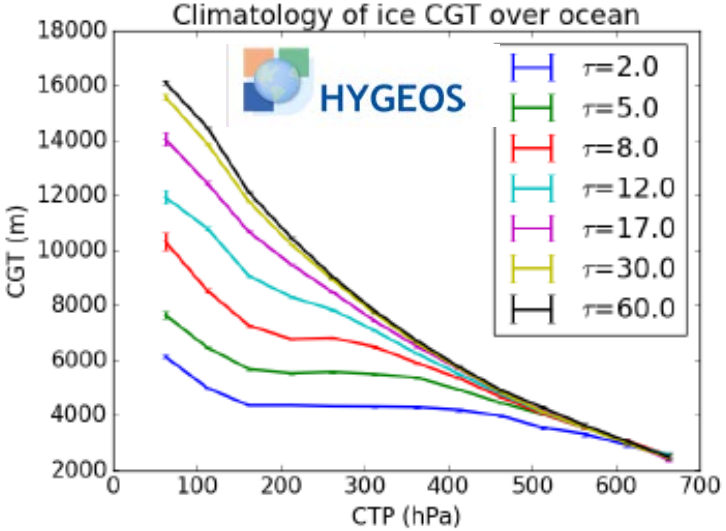
- Oxygen A-band retrieval: mandatory vertical inhomogeneity

- Inhomogeneity for the VIS-IR world

- Presentation for forecasters

Oxygen A-band retrieval: mandatory vertical inhomogeneity

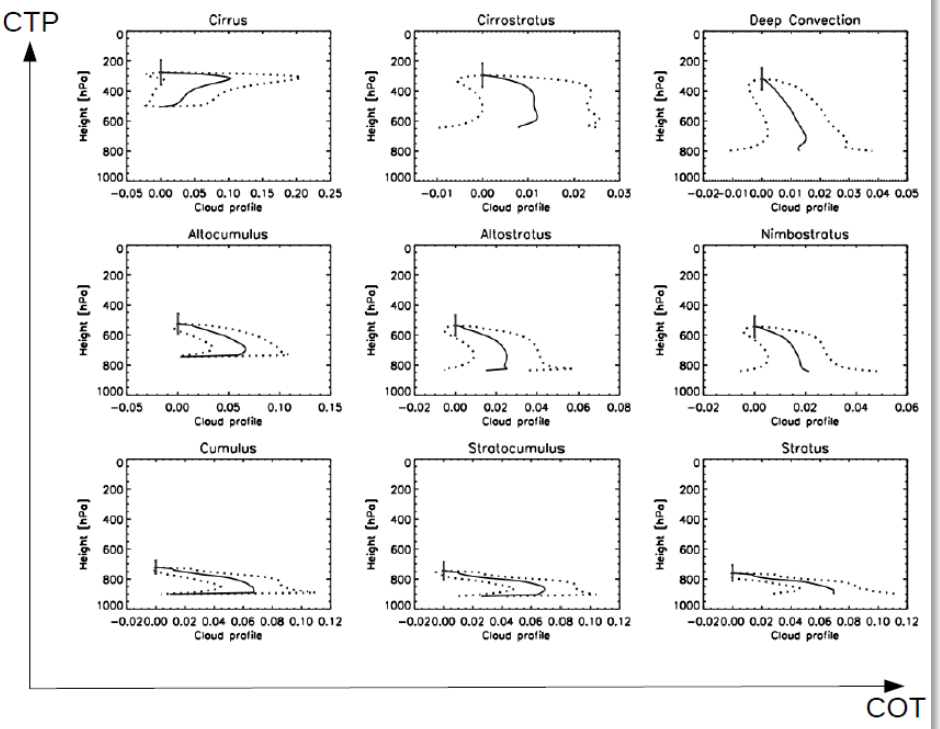
- CTP product from METimage O2-band (EPS-SG)
- Significant errors result from poor assumptions of extinction profile and cloud geometrical thickness
- CGT and profile parameterized in terms of COT, CTP:



HYGEOS

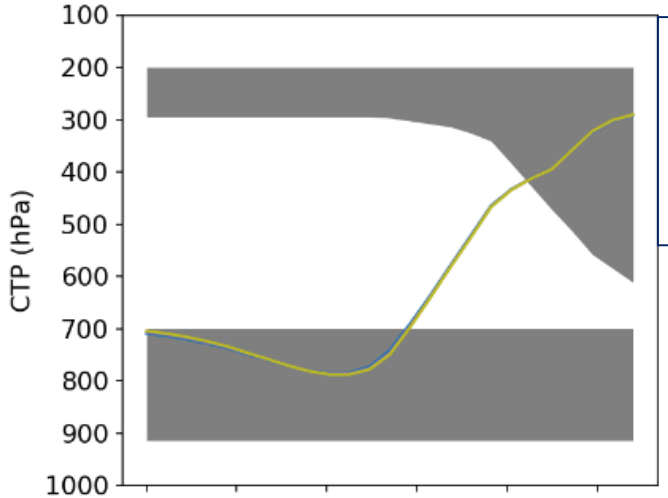
Vertical profile climatology

- Climatology profile for 9 ISCCP types built with 1 year (2010) of CloudSat data (Carbajal-Henken et al., 2013)
- When building the LUT, we interpolate in (COT, CTP) the profile and adjust its CGT according to the CGT climatology



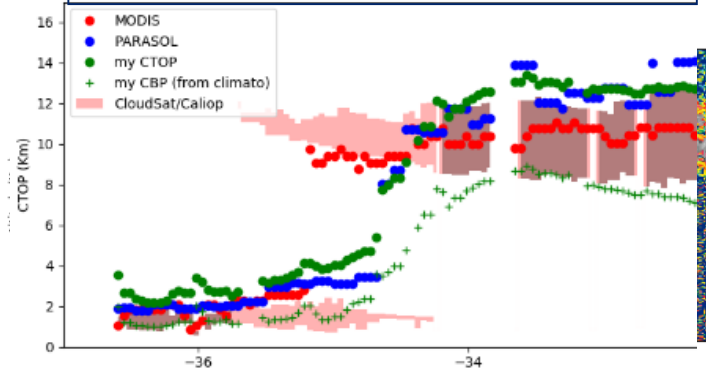
Oxygen A-band retrieval: characteristics in multi-layer

Like IR-CTP, O2-band CTP reacts to overlying cloud - but less than IR

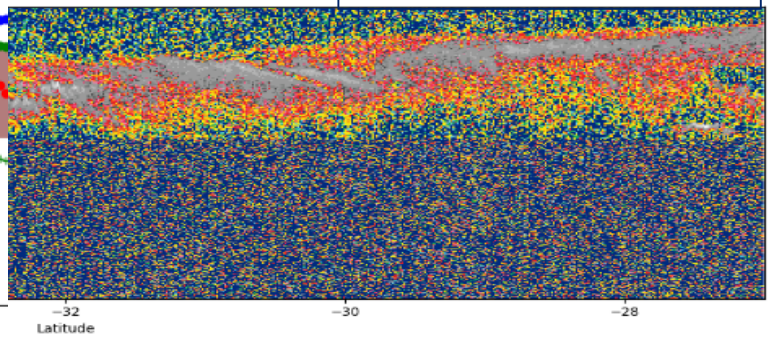


Simulated effect on CTP of gradually thickening cirrus over stratus

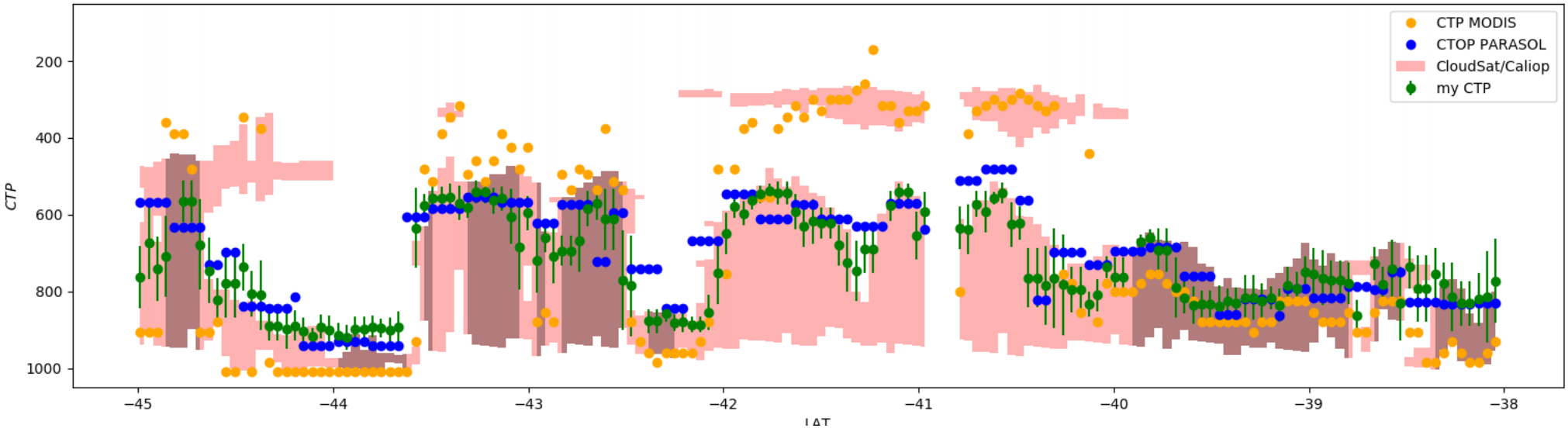
‘O2 band CTP’ ‘IR CTP’



CALIOP reflectance



Oxygen A-band retrieval: characteristics in multi-layer



The tendency of O2 band CTP to stay closer to lower (thicker) cloud layer can be used to:

- Constrain lower layer CTP in (OCA) VIS-IR scheme
- Provide reference height for co-registration of multiple 3MI views

- VIS-IR Multi-layer retrieval: improving the Radiative Transfer
- Oxygen A-band retrieval: mandatory vertical inhomogeneity

- Inhomogeneity for the VIS-IR world

- Presentation for forecasters

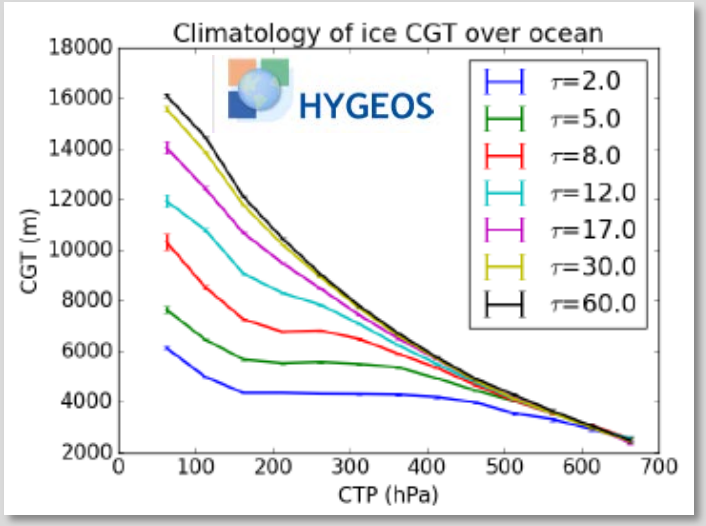
Vertical inhomogeneity: Preparatory work In house

Emissivity of the Vertically inhomogeneous cloud

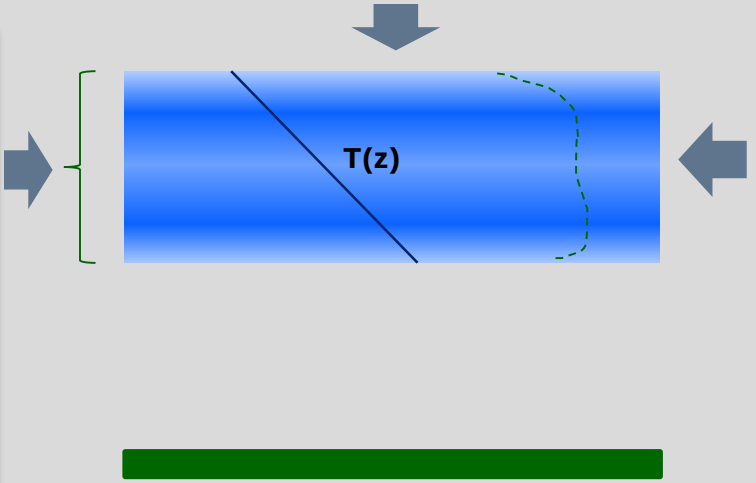
- Leveraged work for METimage O2-band CTP algorithm development (EXT(z)=Func(COT,CTP))
- Preliminary work done in-house:
  - Vertical Inhomogeneity for Infrared channels / emissivity only
  - Cloud CGT, EXT(z) = Functions of (COT,CTP) taken (roughly) from Cirrostratus parameterization
  - ! In-cloud gaseous absorption so far neglected ! (6.3, 7.2!)

Components of the vertically inhomogeneous IR cloud model:

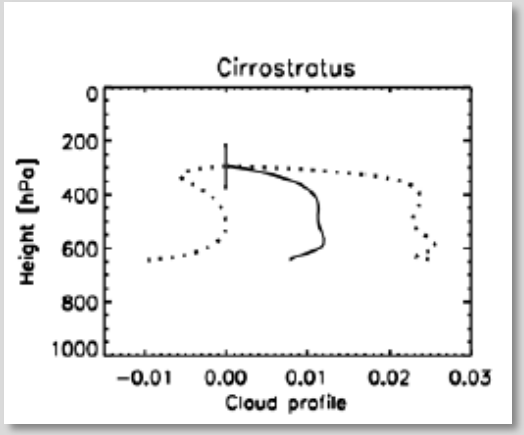
CGT(COT, CTP)



Fixed dT/dz



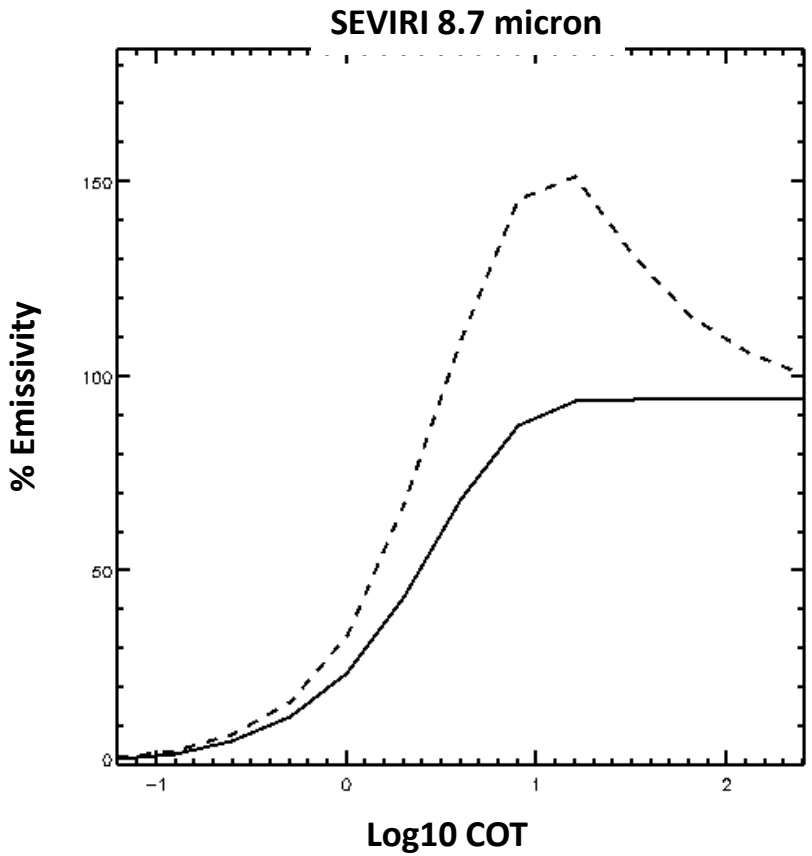
EXT(z) (COT, CTP)

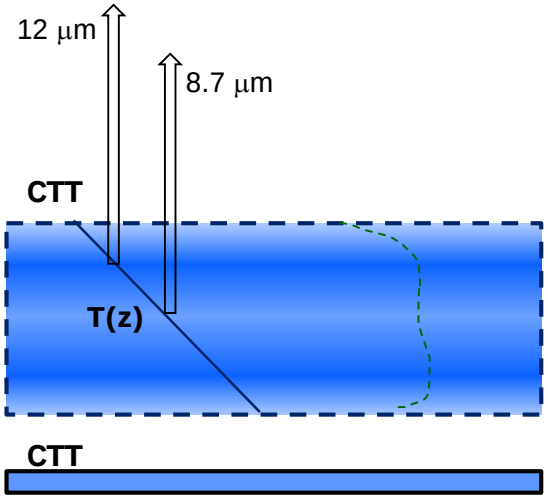


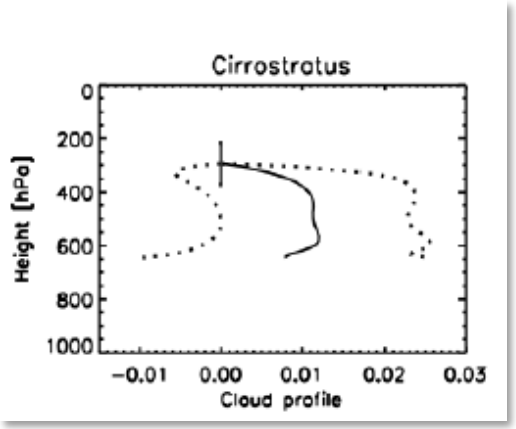
Vertical inhomogeneity: Preparatory work In house

Cloud Emissivity defined as: ratio of emitted radiance to black body emission at cloud top temperature

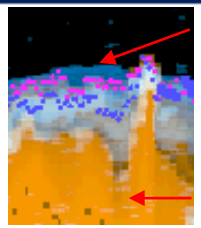
$$E_{cloud} = \frac{L_{cloud}}{B(CTT)}$$







Vertical IH Validation: .v. CPR CTP ovp4111



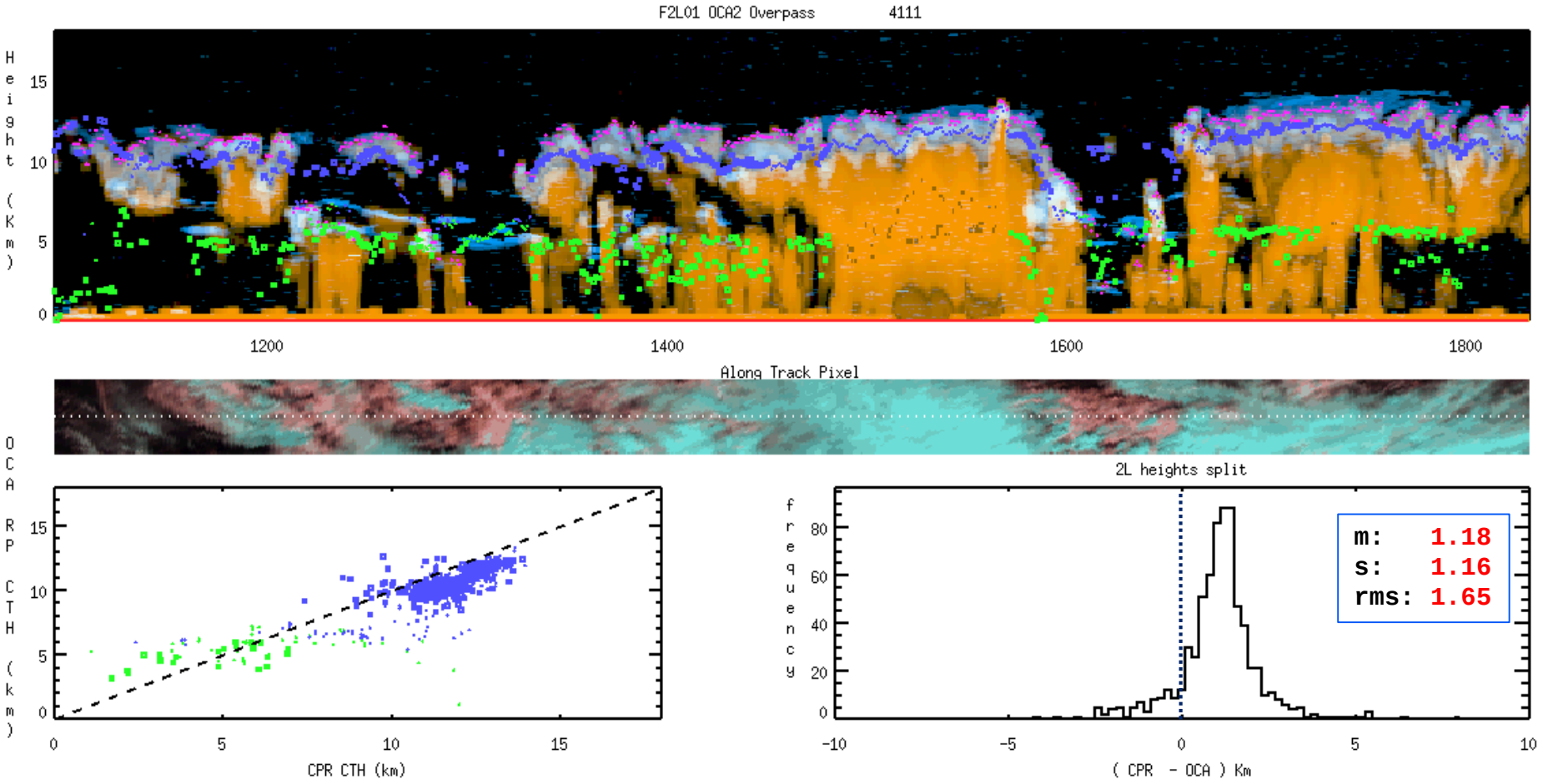
Lidar backscatter only

*Radar CTH

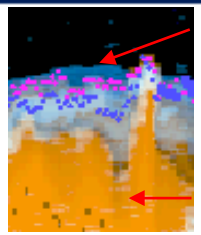
*MOCA CTH

Radar backscatter only

F2L – Full 2-layer
Radiative properties:
Geometrically Thin



Vertical IH Validation: .v. CPR CTP ovp4111



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Radar backscatter only

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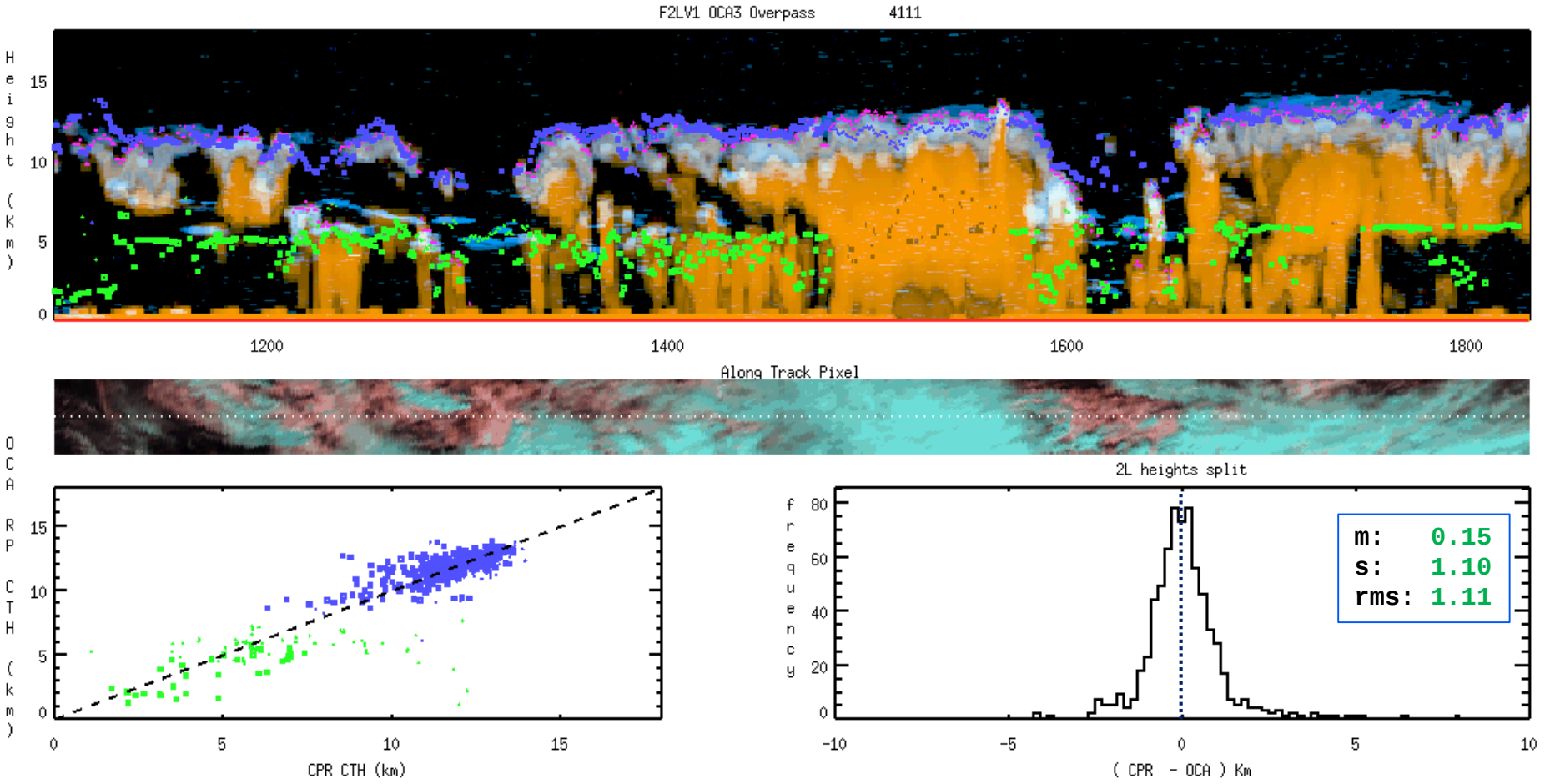
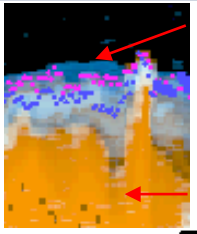
Radiative properties:
Vertically IH



Vertical IH Validation: .v. CPR CTP ovp4196



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*MOCA CTH

Radar backscatter only

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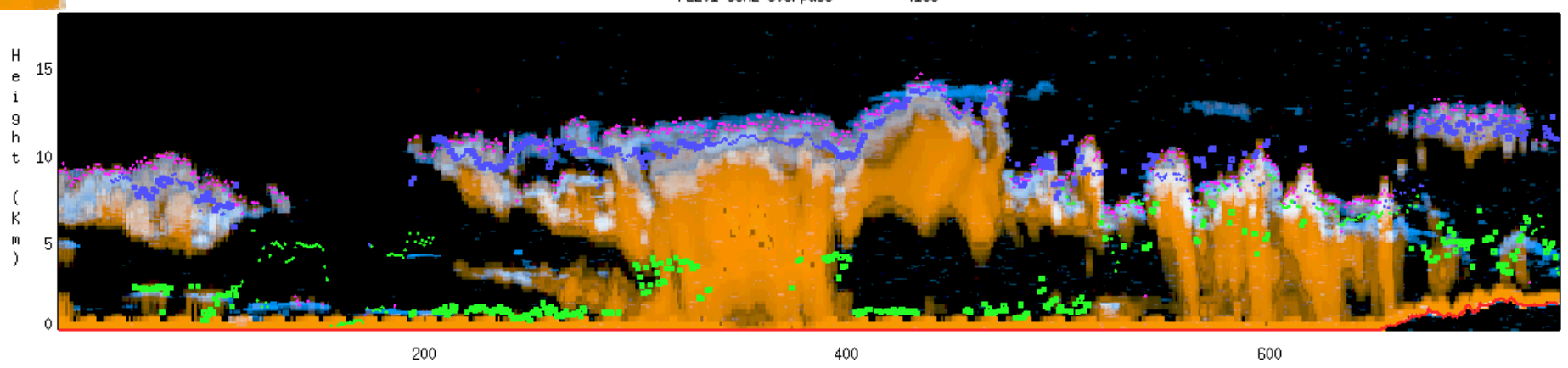
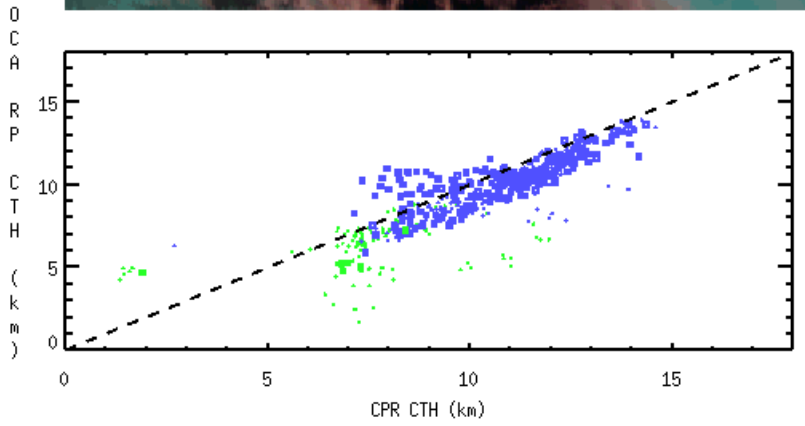
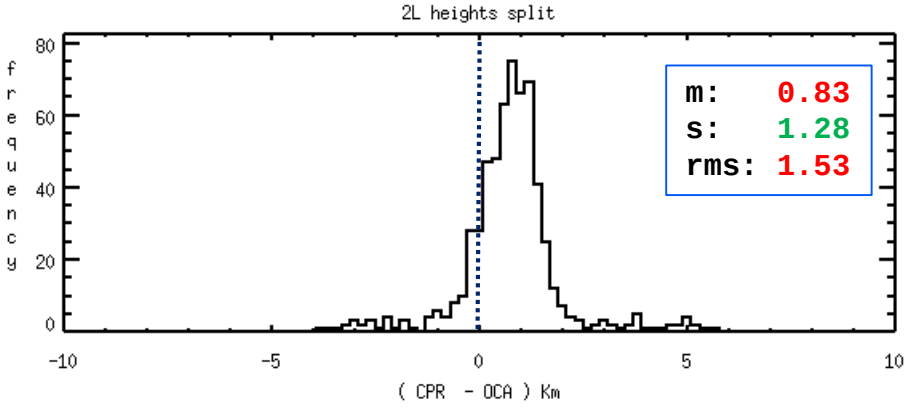
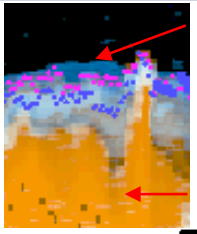
Radiative properties:
Geometrically Thin







Vertical IH Validation: .v. CPR CTP ovp4196



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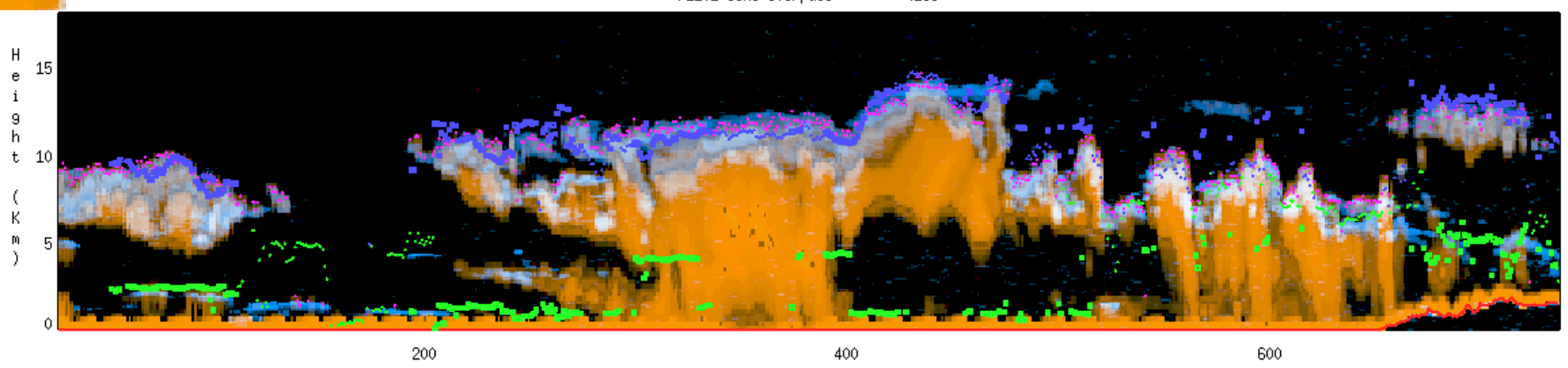
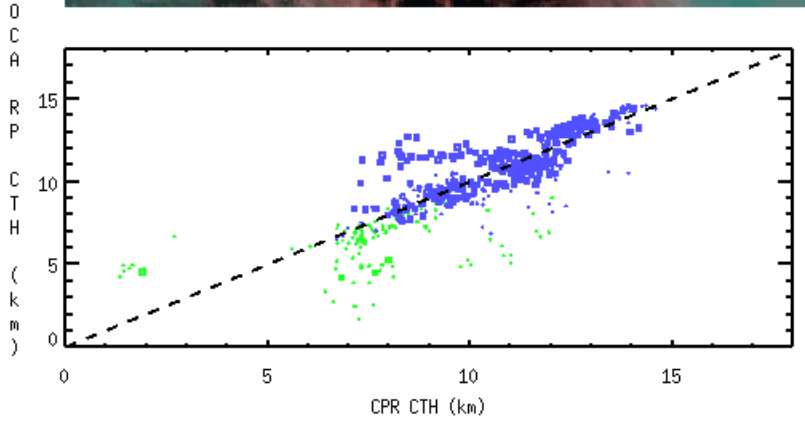
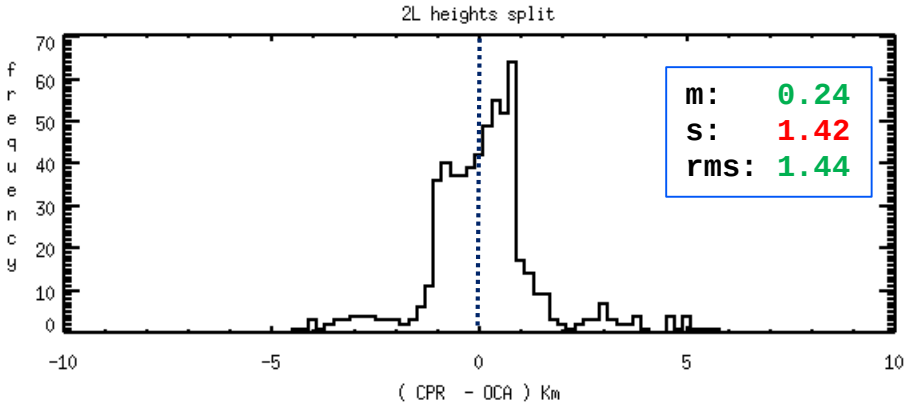
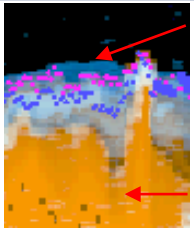
Vertically IH







Vertical IH Validation: .v. CPR CTP ovp4198



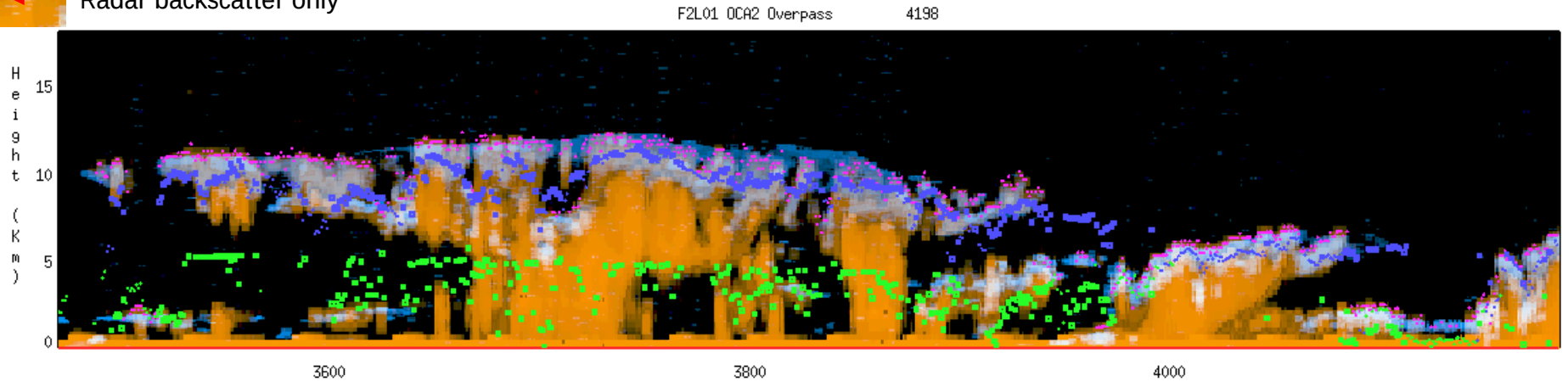
Lidar backscatter only

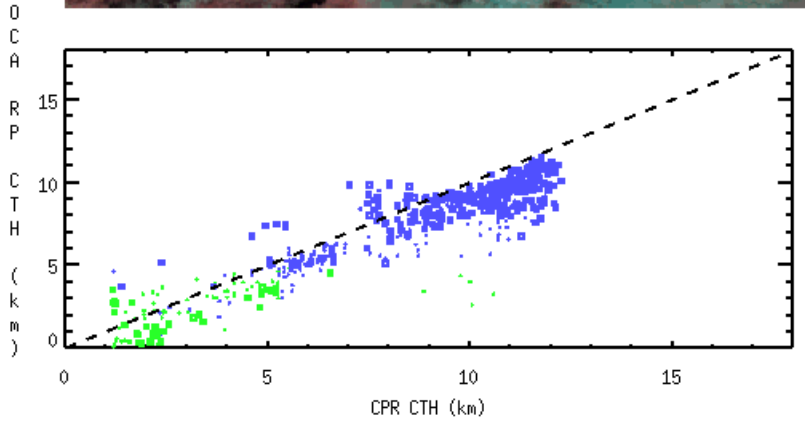
*Radar CTH

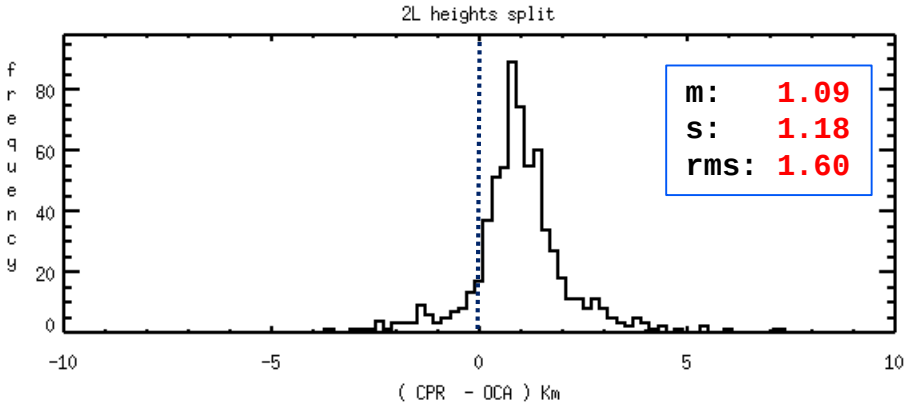
*MOCA CTH

Radar backscatter only

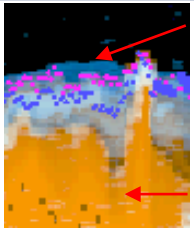
F2L – Full 2-layer
Radiative properties:
Geometrically Thin







Vertical IH Validation: .v. CPR CTP ovp4198



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Radar backscatter only

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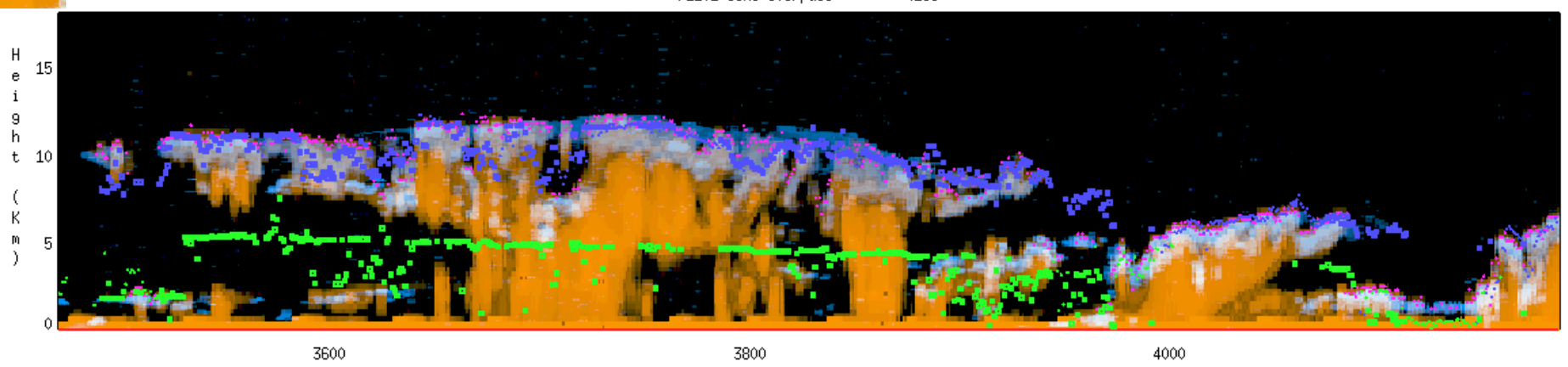
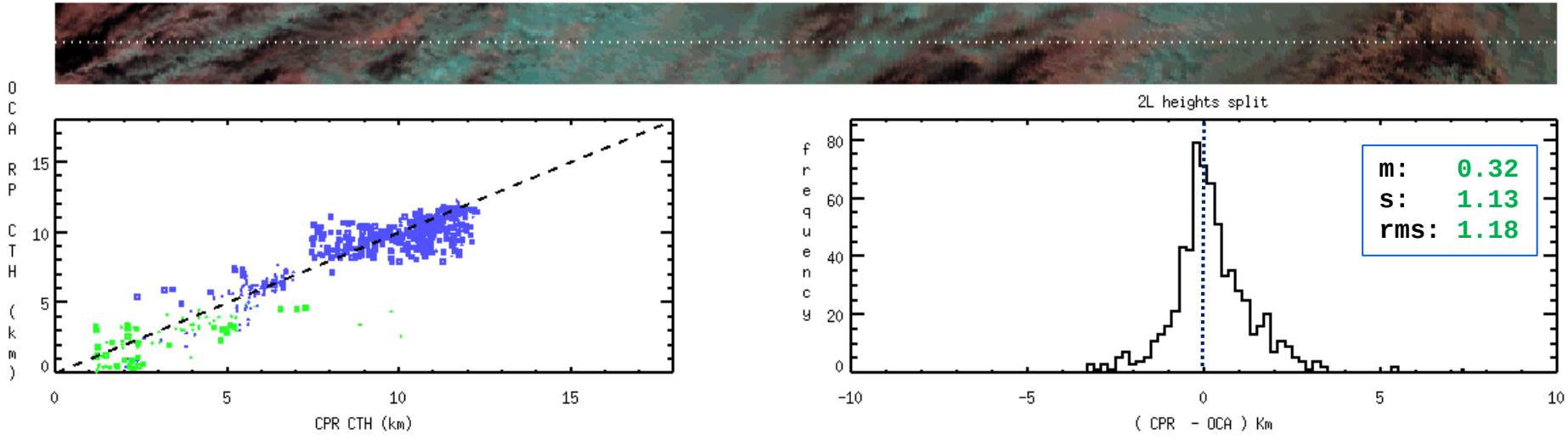
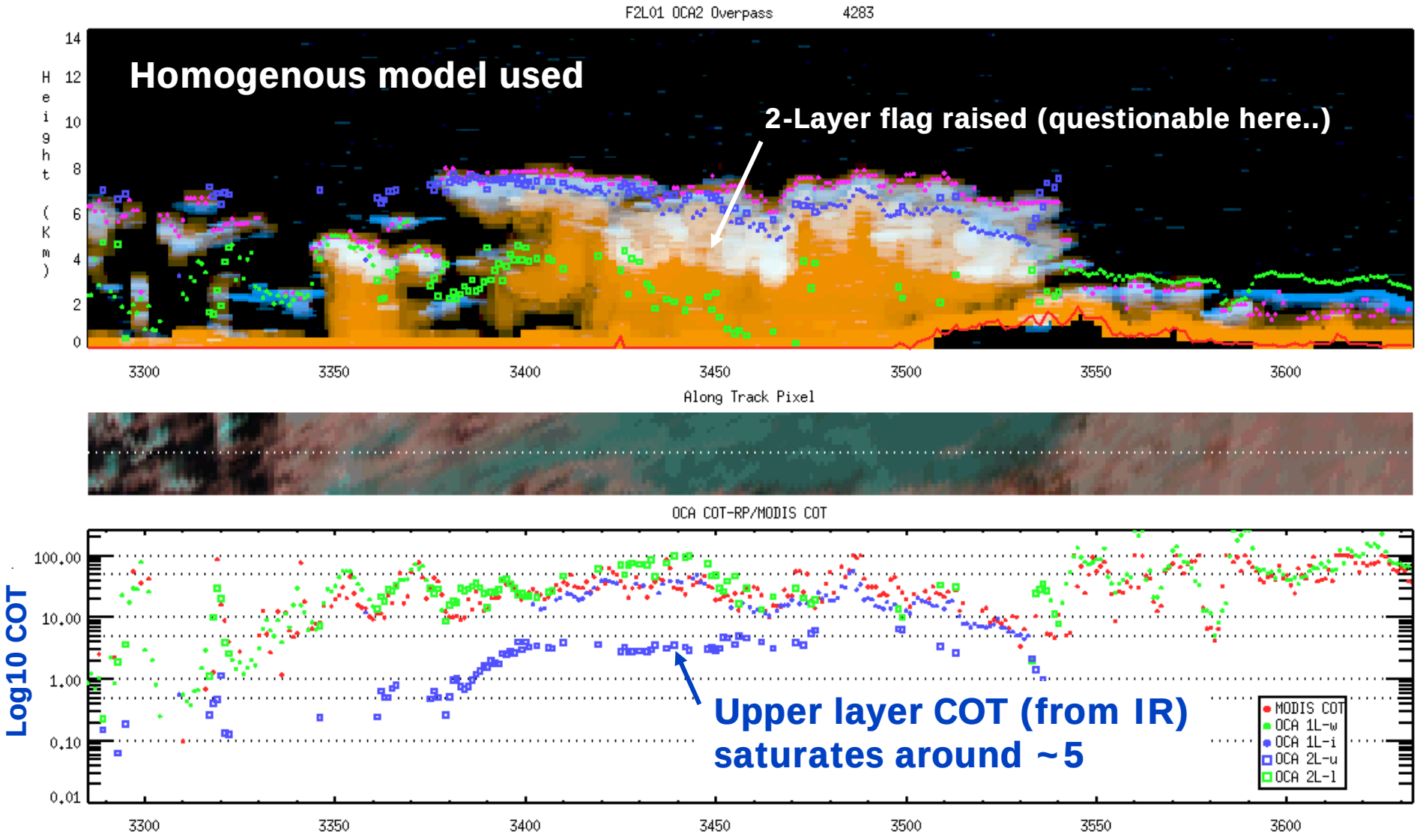
Radiative properties:
Vertically IH





Inhomogeneous clouds: IR COT sensitivity higher?



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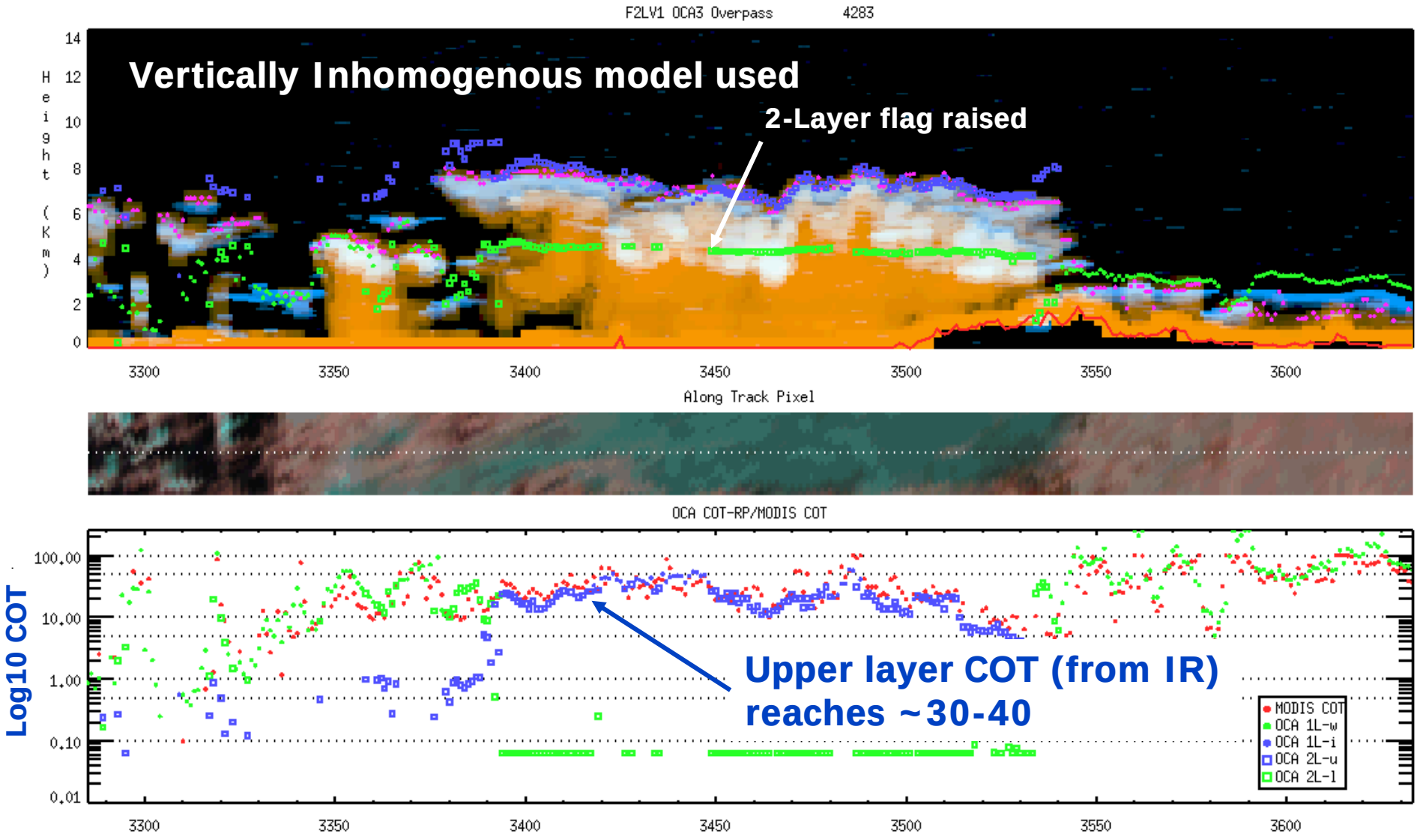
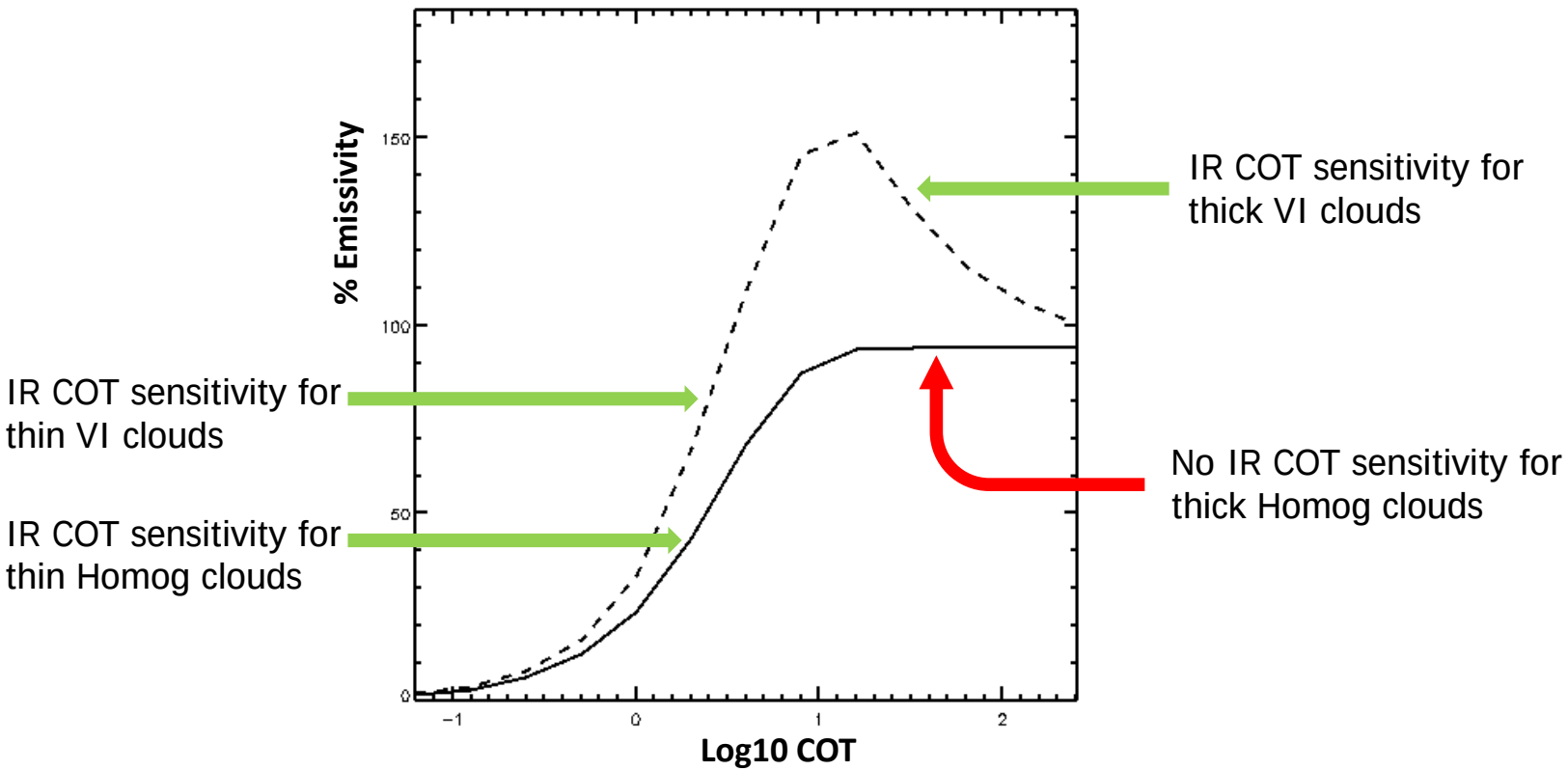


Inhomogeneous clouds: IR COT sensitivity higher?
How can that be?

- Vertically inhomogeneous Clouds COT > 5
  - Still do not transmit in IR..
  - But emission continues to depends on COT through Ext(z) and CGT



Summary: Vertical Inhomogeneity experiment

- Limited analysis so far: preliminary conclusions
- No cloud type (except liq/ice) discrimination

- Effective removal of bias with respect to CloudSat CTH with indications:
  - Optically thick clouds still low (under-corrected from homogeneous case)
  - Optically thin clouds too high (over-corrected from homogeneous case)

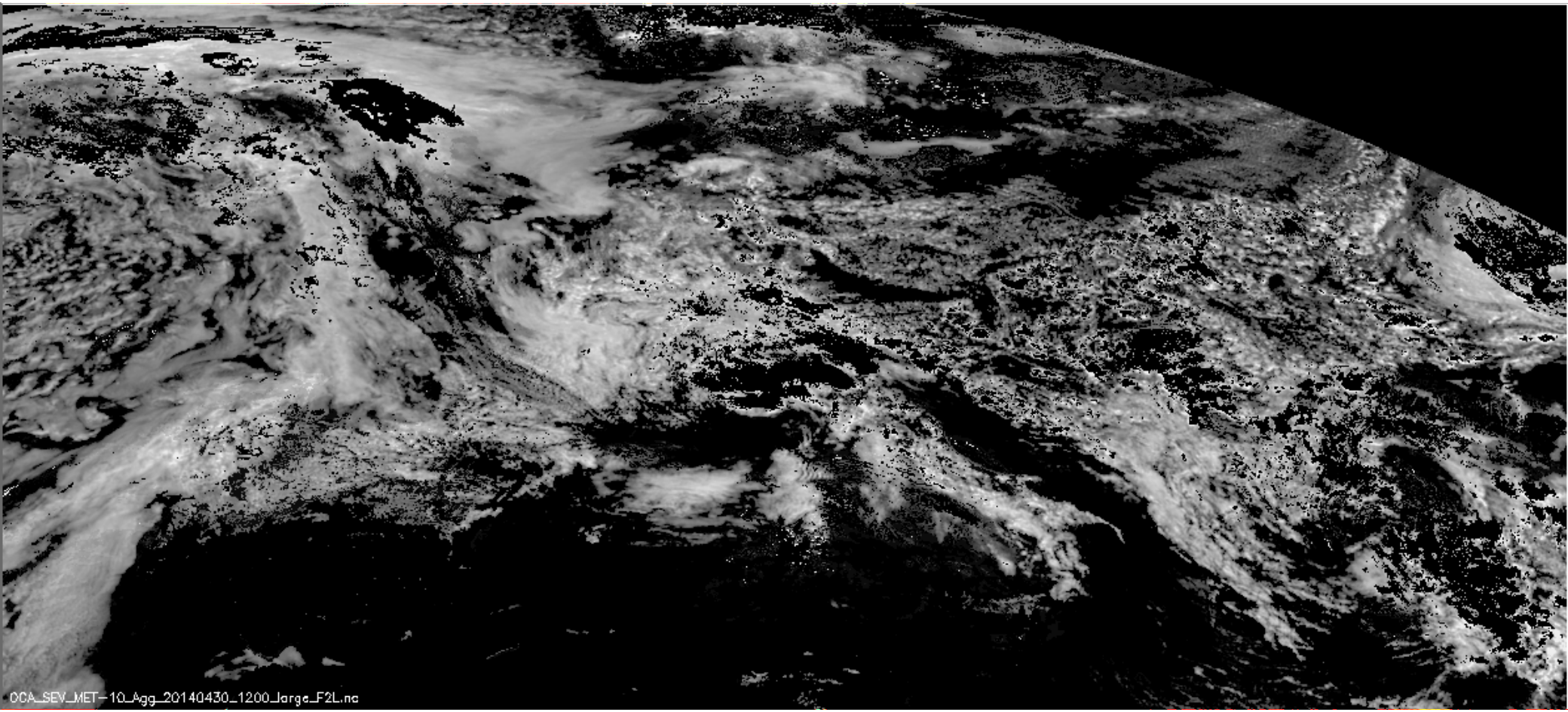
- Some indication of increase variance

- Results with more complete type discrimination of cloud type will be interesting!

- Sensitivity to COT in the IR extends to higher values (~30-50) with an Inhomogeneous cloud than (~4-5) with a homogeneous cloud – unexpected, unconfirmed but plausible and welcome!

- VIS-IR Multi-layer retrieval: improving the Radiative Transfer
- Oxygen A-band retrieval: mandatory vertical inhomogeneity
- Inhomogeneity for the VIS-IR world
- Presentation for forecasters

Product presentation to forecasters

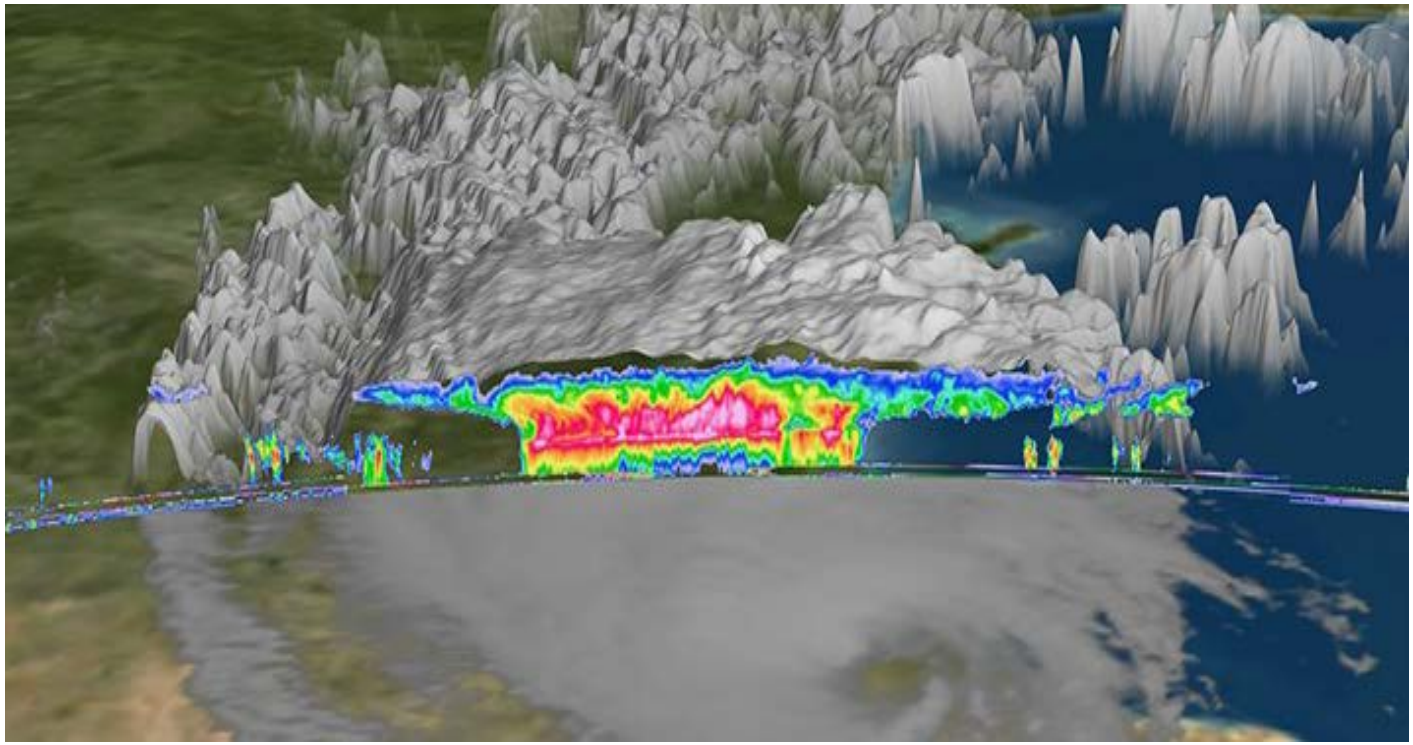


Presentation as sequence of images of product components is possibly:
CONFUSING (esp. with 2 layer clouds)
UNINTERESTING (compared to RGBs)
DEVALUED by inversion artifacts

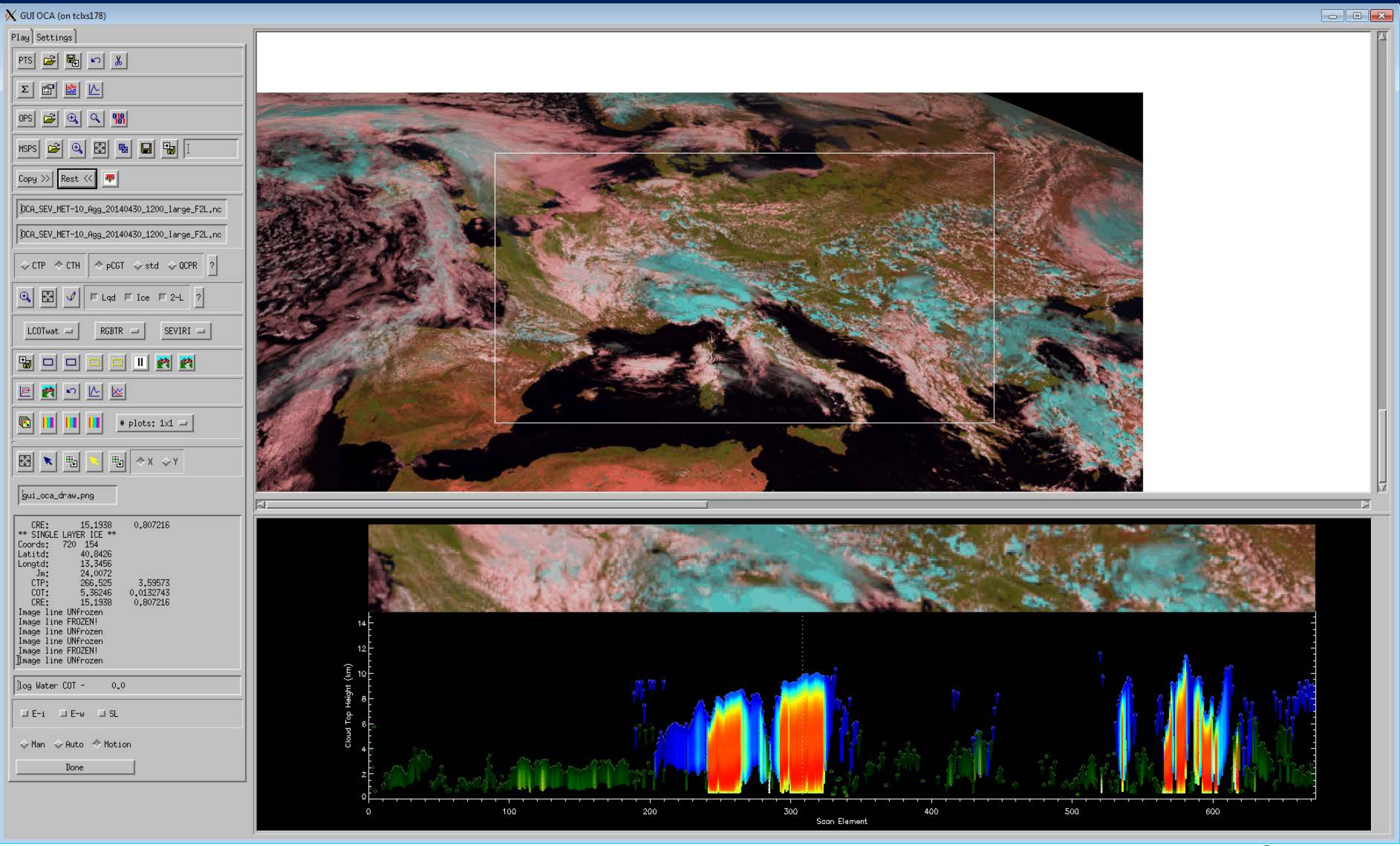
CTP upper layer ; **CTP** lower layer ; **COT** upper ; **COT** lower
Reff upper ; **Reff** lower
Error estimates

Product presentation to forecasters

- We do not have a great record of getting our cloud products used
- We think we have a good useful product
- ‘Inspiration’ from CPR..

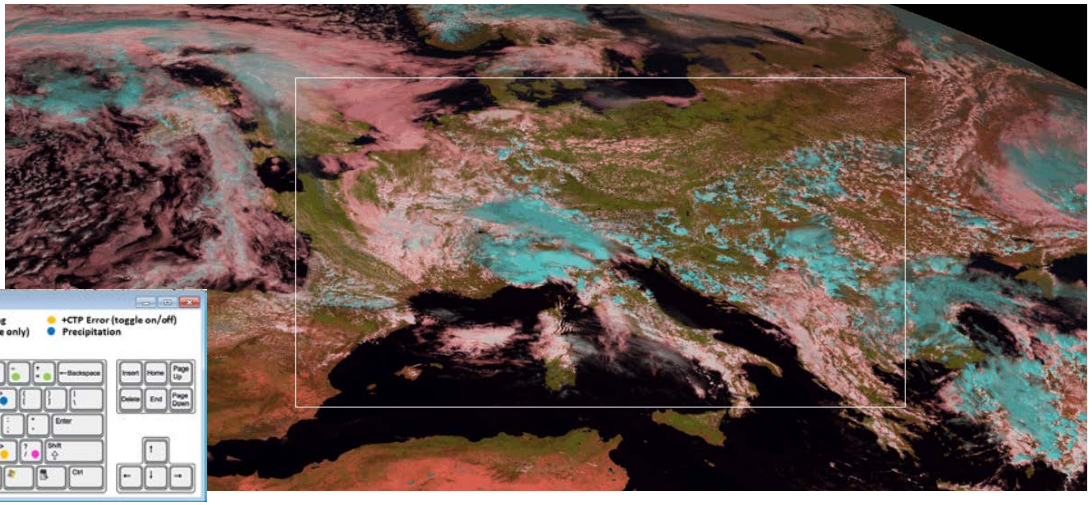


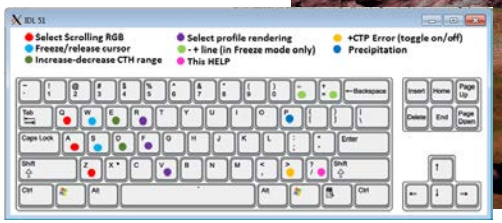
Development of tailored Product Visualisation

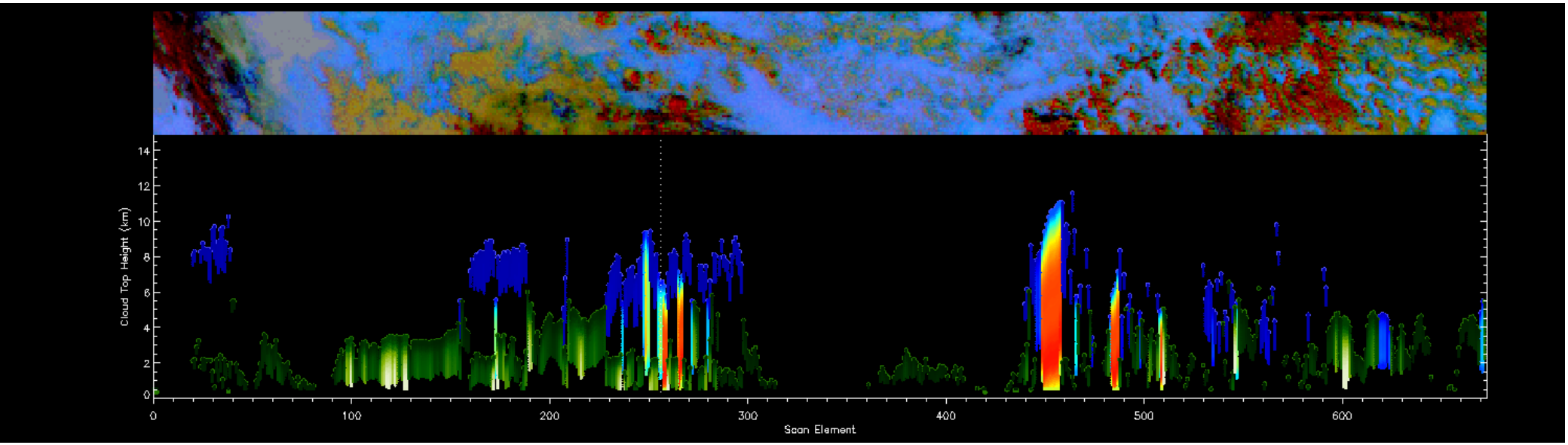


Development of tailored Product Visualisation

- Stay close to image/RGB
- Use 3D only moderately if at all
- Develop ideas with feedback
- Prioritise keyboard/mouse control
- Python based?
- Community effort?
- Models exist?
- How not to ‘oversell’ product?
- How to show microphysics?
- How to present errors?







30 YEARS 1986-2016

EUMETSAT

Thankyou