Comparing OCA and DARDAR upper layer COT in multi-layer situations

Phil Watts

EUMETSAT

Plan

- OCA method overview
- The “problem” with VIS + IR in multi-layer
- OCA 2-layer method overview
- DARDAR-OCA comparisons

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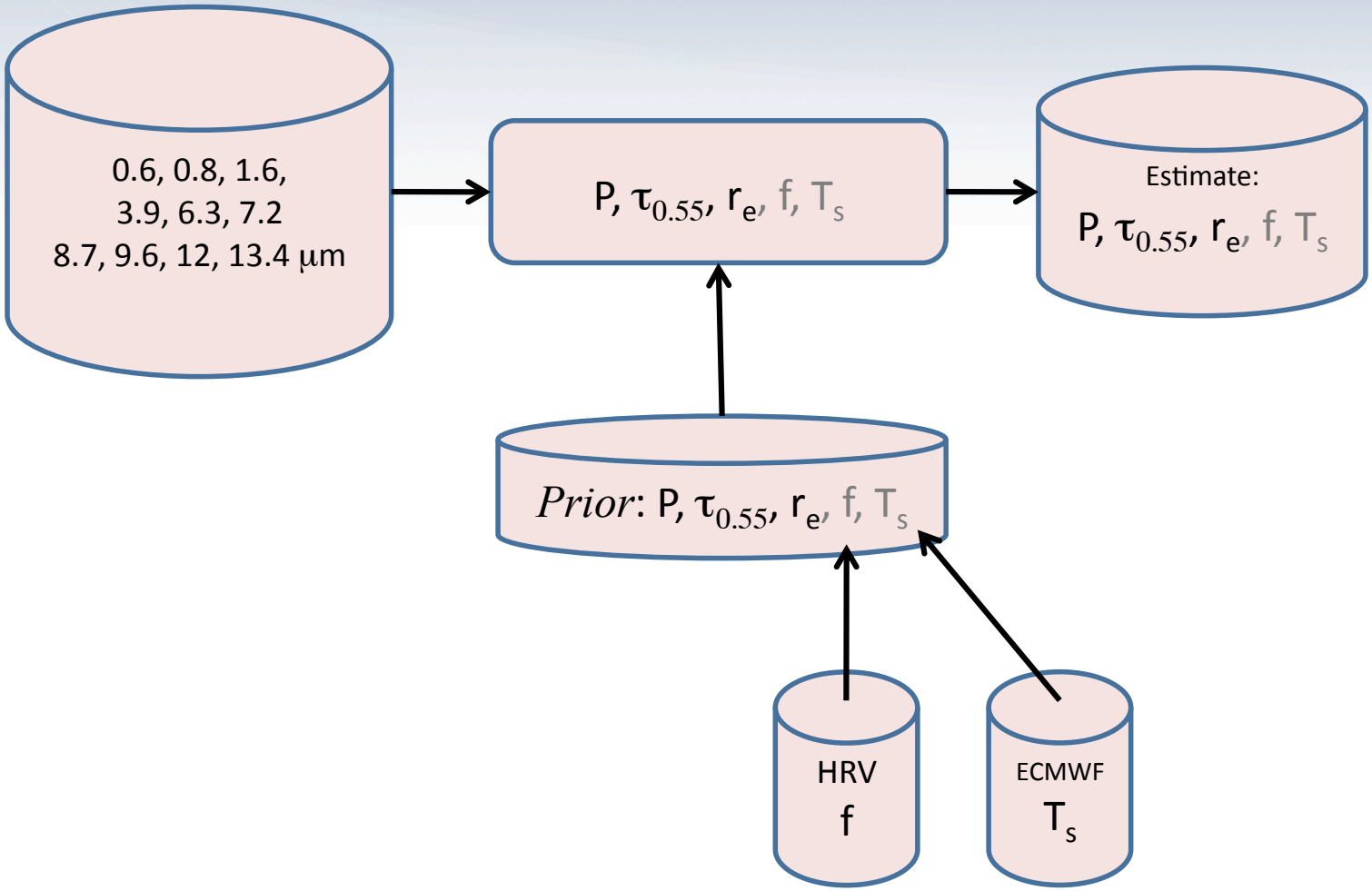
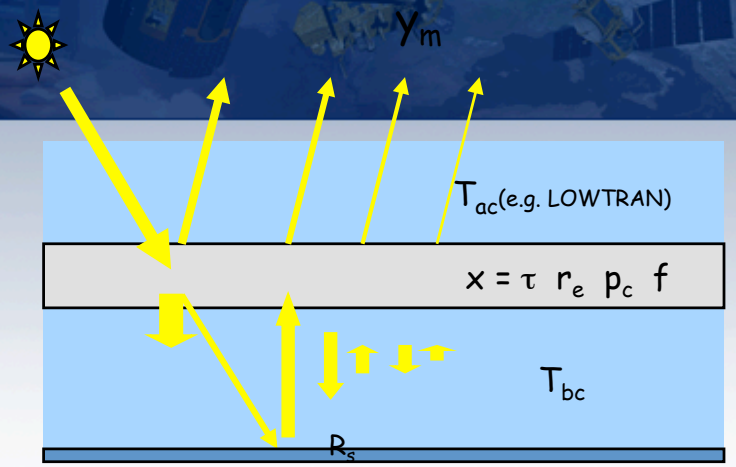
EUMETSAT OCA cloud retrieval



Optimal Estimation:

1. Relate measurements, y_m, to a 'realistic' model of the cloud, x, with a radiative transfer model, $y(x)$

2. Find state x that maximises $P(x|y)$



Use Bayes Theorem: $P(x|y) \sim P(y|x).P(x)$

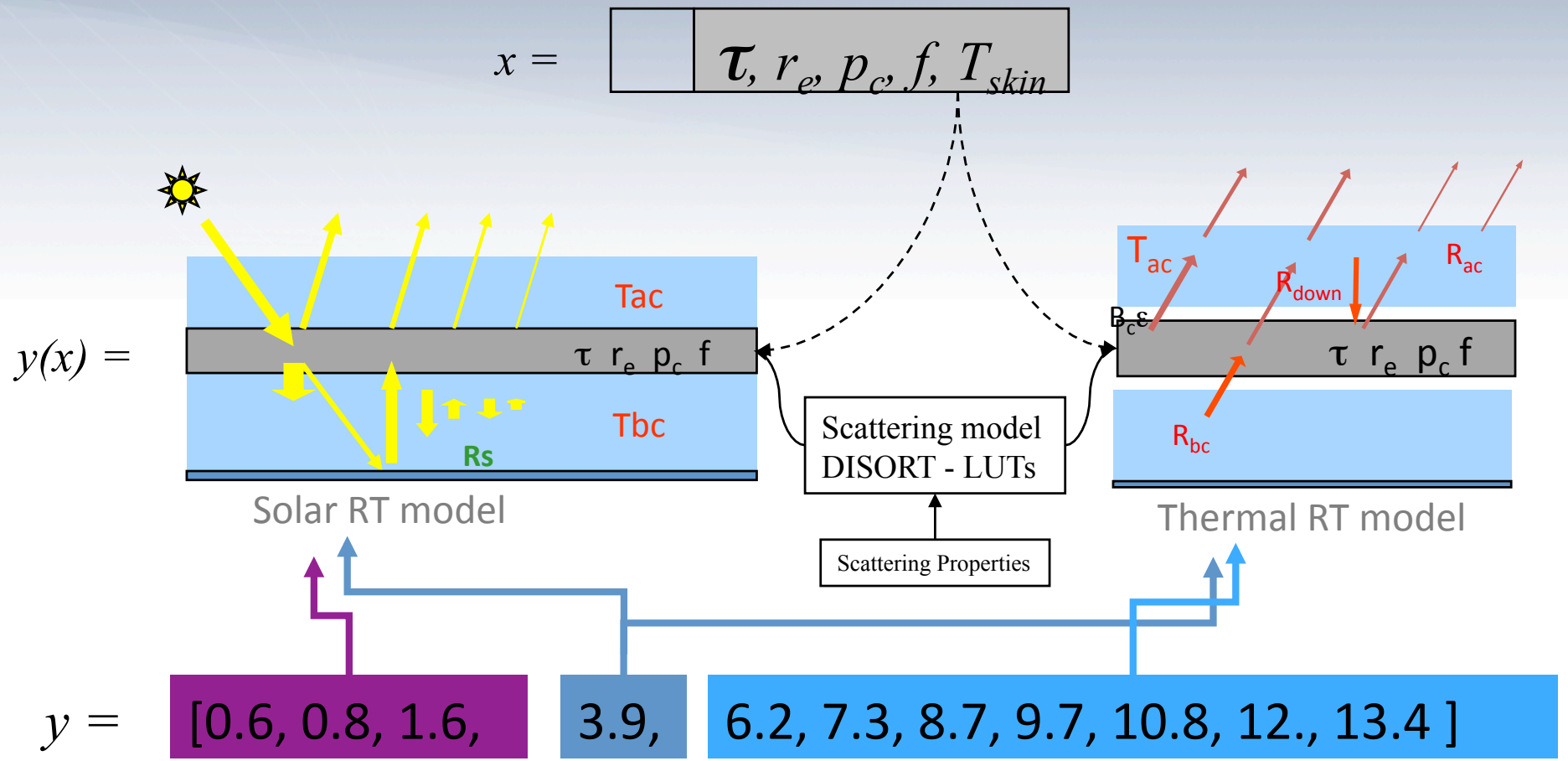
Radiance information **Prior information**

$$P(x \mid y) = \exp^{-(y_m - y(x))S_y^{-1}(y_m - y(x))^T} .\exp^{-(x - x_b)S_x^{-1}(x - x_b)^T}$$

Minimise w.r.t. x:

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

$y(x)$ – forward model



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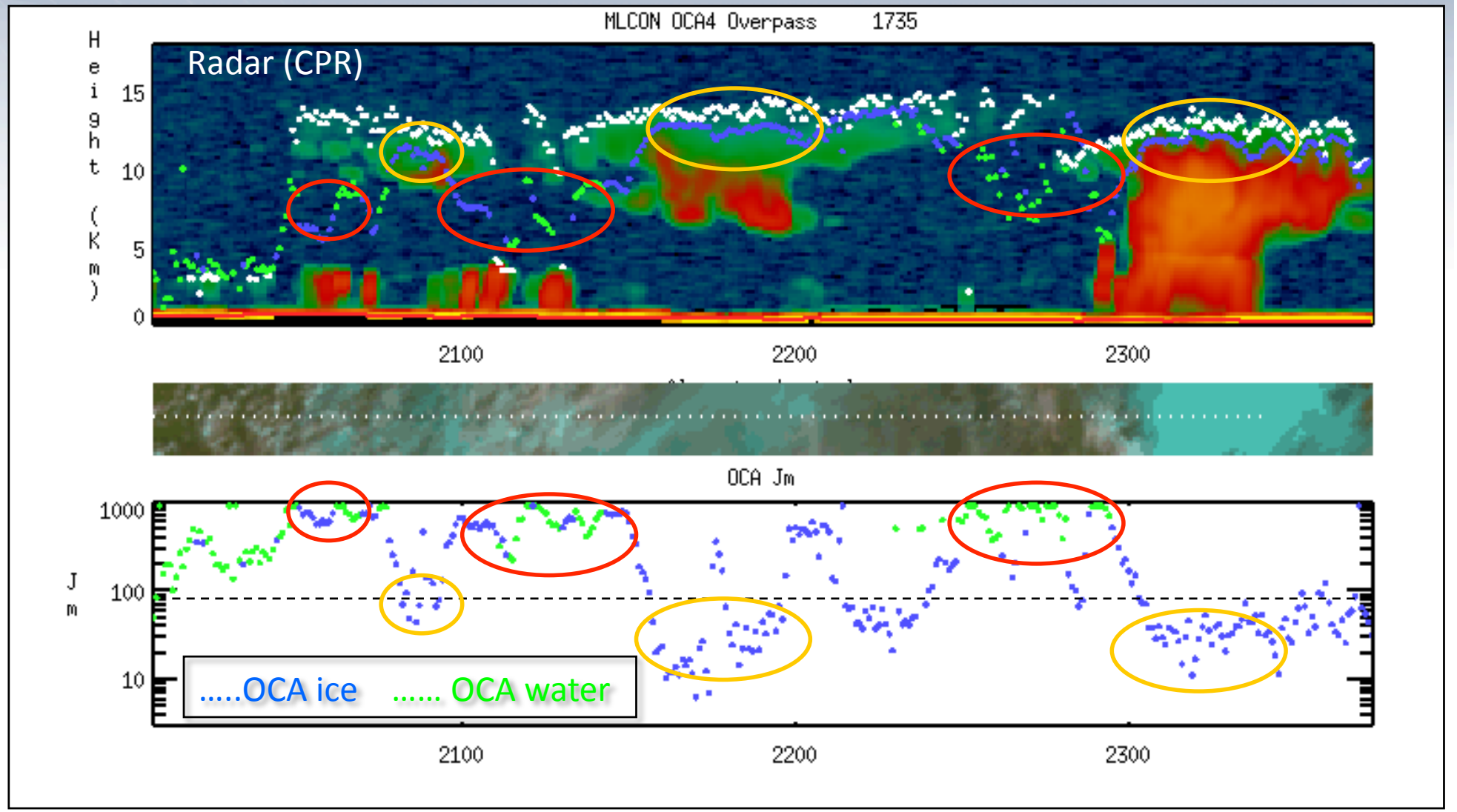
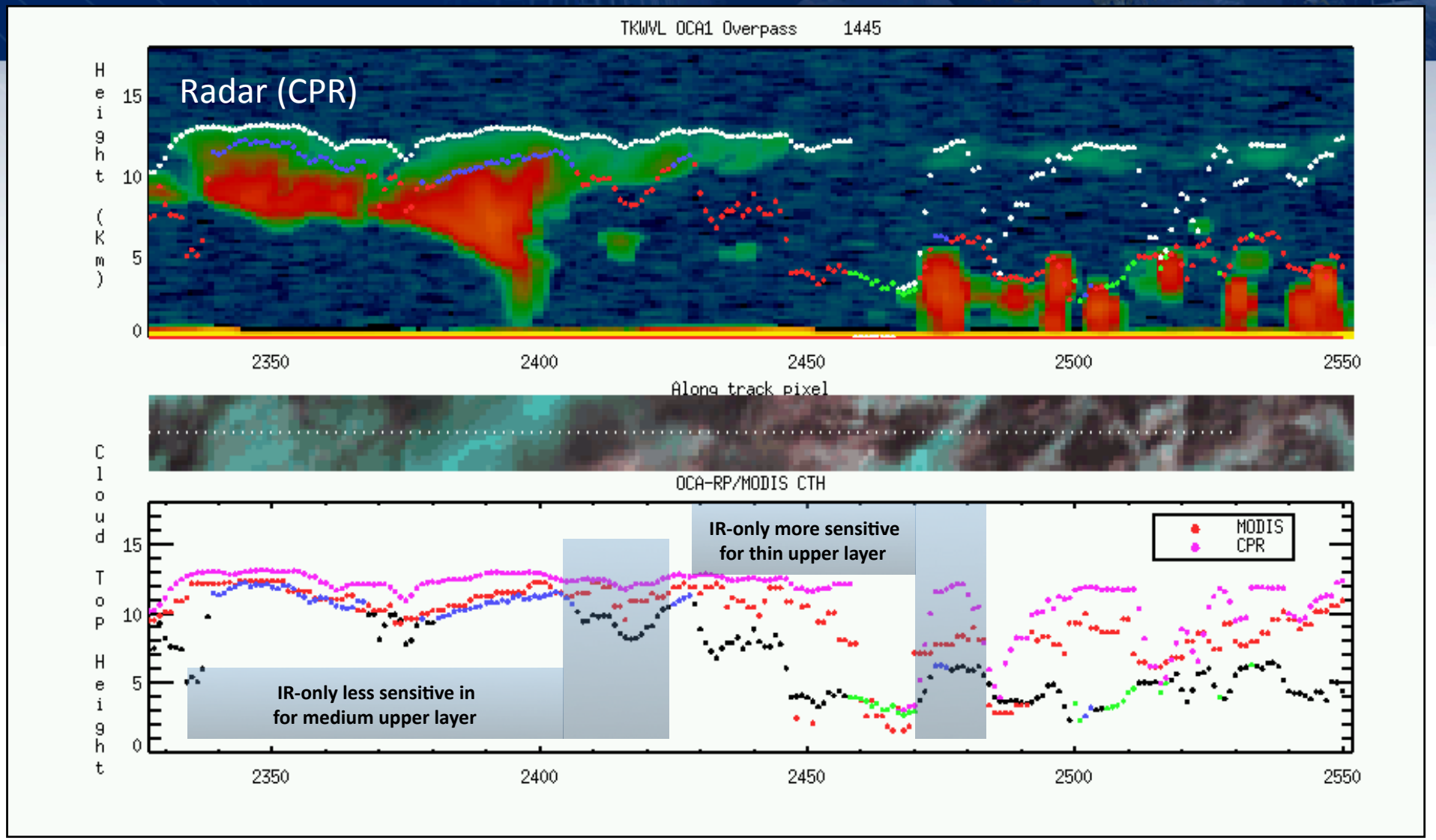
The “problem” with VIS+IR in Multi-layer Cloud



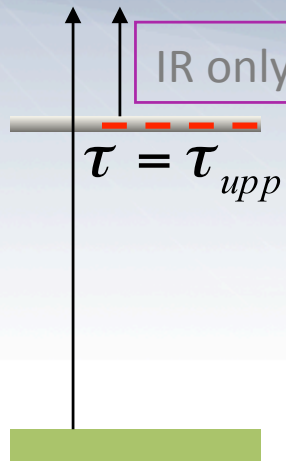
Multi-layer Cloud



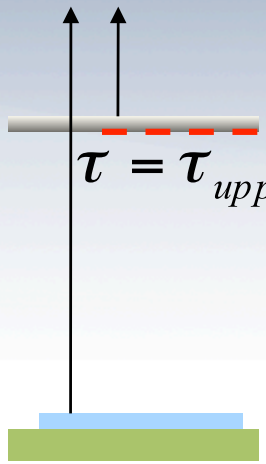
... Radar (CPR) ... MODIS .....OCA ice ..... OCA water .... OCA Jm reject

Cartoon comparison IR .v. VIS+IR and 2-layer Cloud

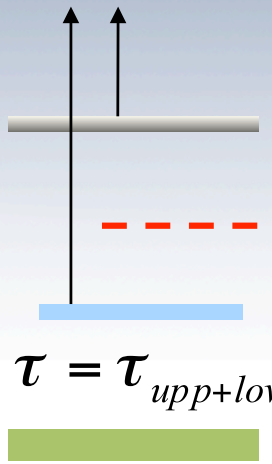
IR only e.g. MODIS



Single layer ice cloud:
IR-only:- upper

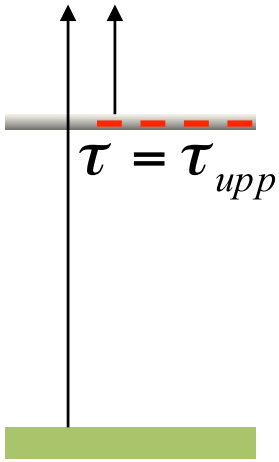


V.Low underlying water cloud:
IR-only:- upper

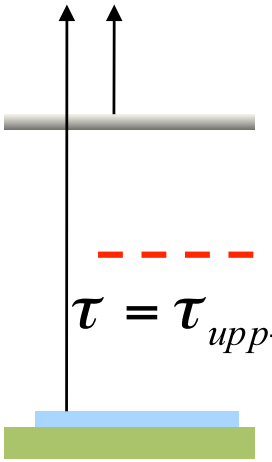


Mid-L underlying water cloud:
IR-only:- intermediate

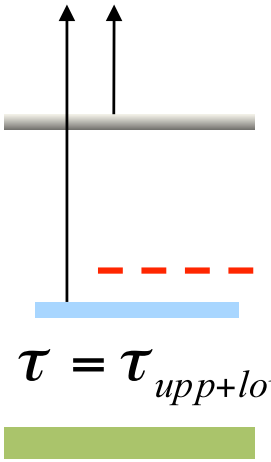
VIS+IR combined e.g. OCA



Single layer ice cloud:
IR/VIS:- upper



V.Low underlying IR+VIS:- intermediate



Mid-L underlying IR+VIS:- intermediate

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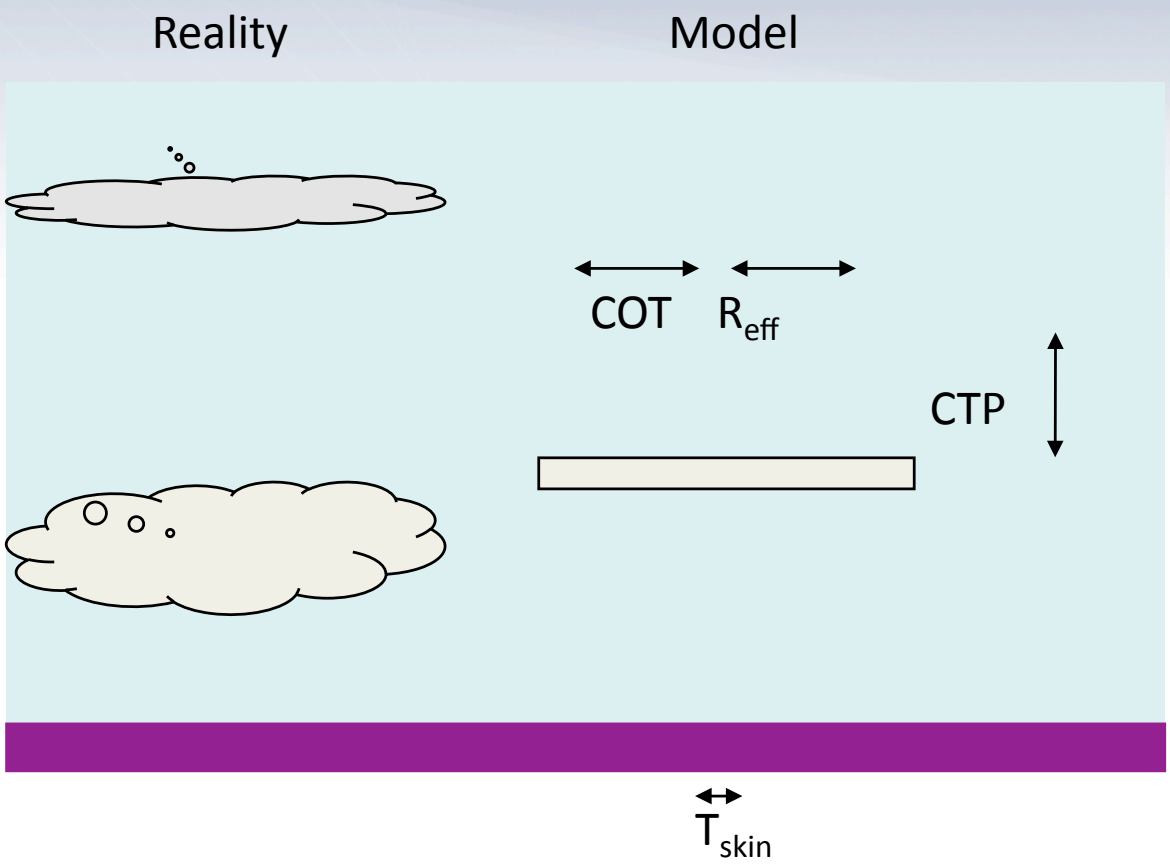
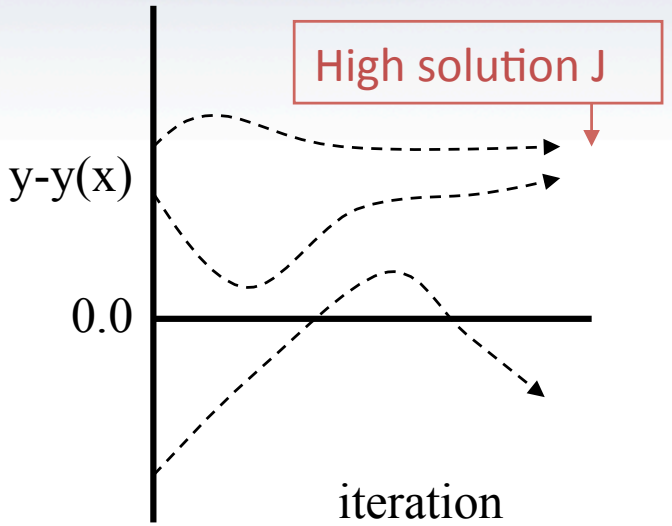
Two layer cloud – single layer model



VIS + IR

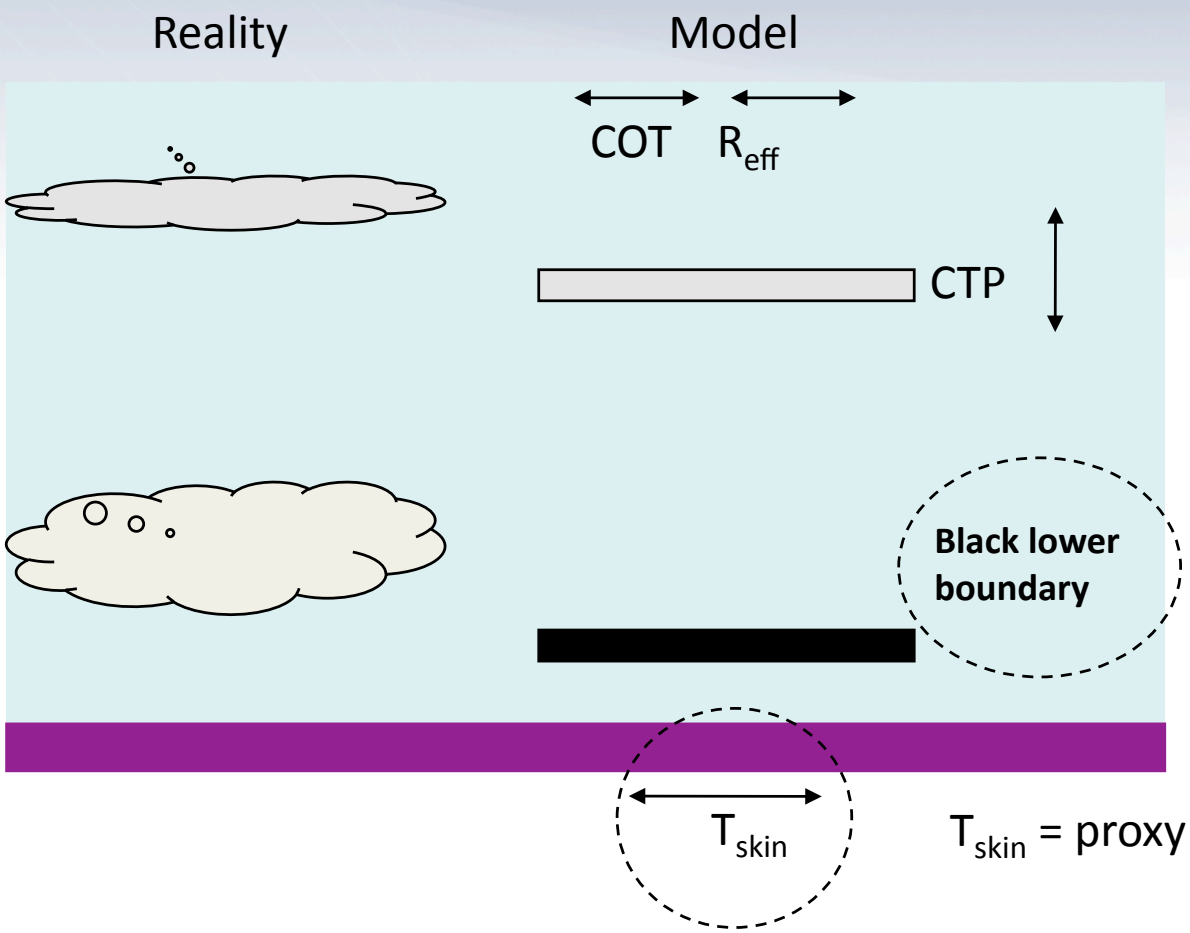
Measurement residuals (9)



Try again using 2-layer model >>

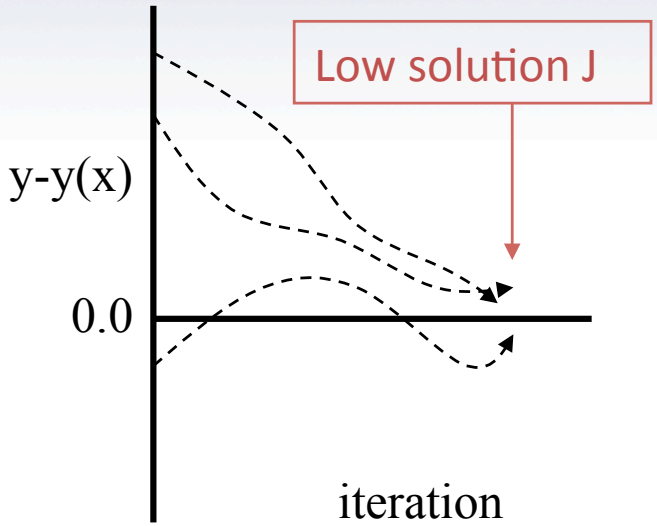
$X = [\ \tau, r_{eff}, p_c, f, T_{skin}\ ]$

Two layer cloud – T_{skin} as proxy lower CTT



IR only

Measurement residuals (9)



T_{skin} = proxy black cloud $CTT_{\_L}$

Two layer cloud – Done properly (CREW-V?)

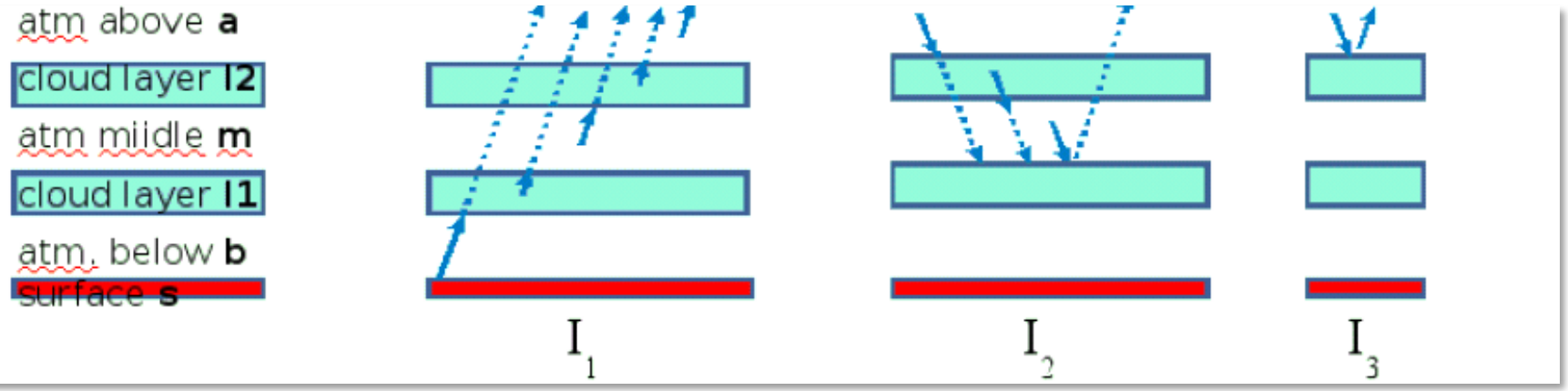
The Mickey-Mouse approach works – but is not very satisfactory:

- Cannot use the solar channels
- Treats IR only approximately

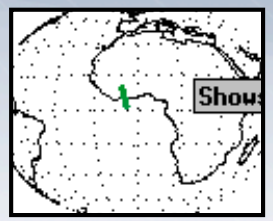
Plan to be done properly
(ref. Cloud model study by Oxford Uni. / RAL)

$$x = [\ \tau_1,\ r_{eff1},\ p_{c1},\ \tau_2,\ r_{eff2},\ p_{c2}\ ]$$

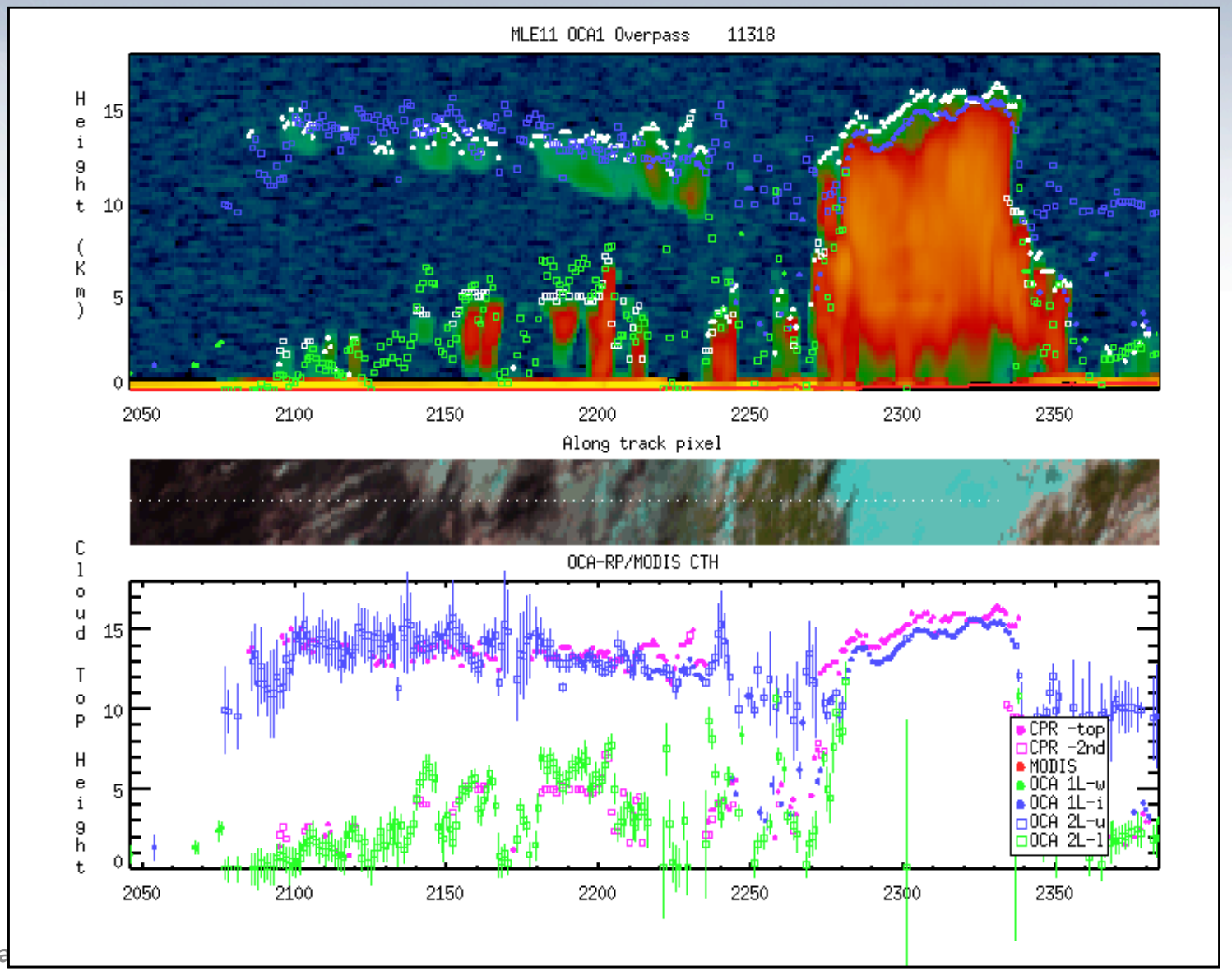
with
$y(x)$, $K(x)$



Two layer cloud – T_{skin} as proxy lower CTT



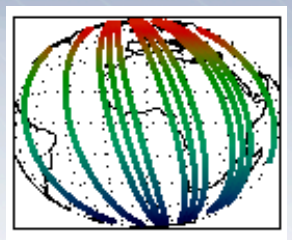
2-Layer CTP : CPR orbit 11318



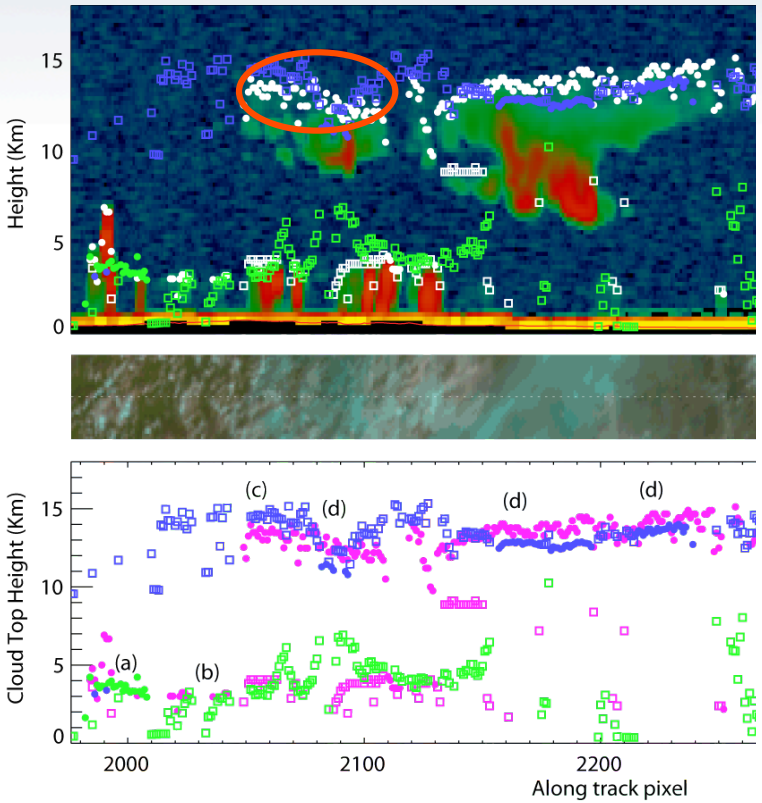
All cases

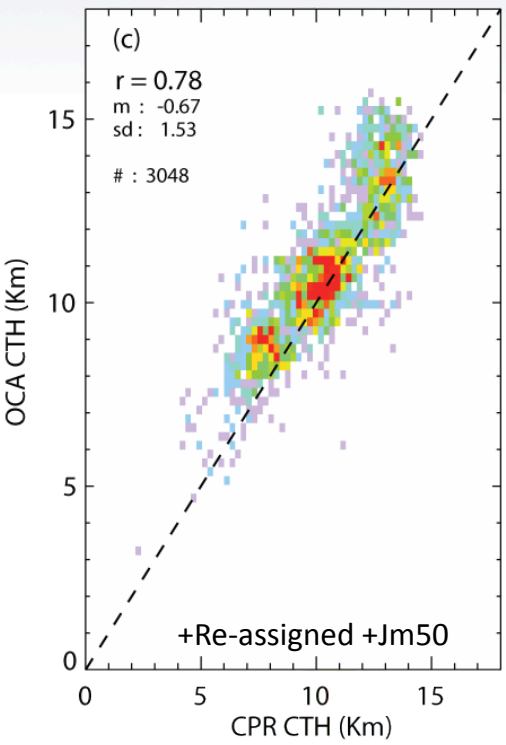
+Re-assigned

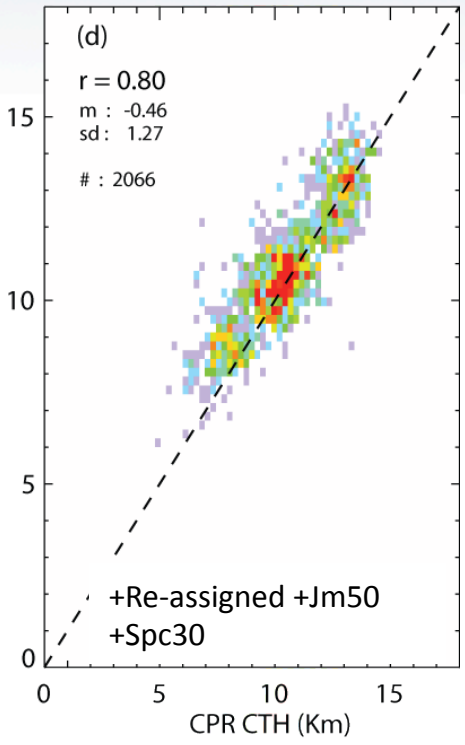
2-Layer CTP validation



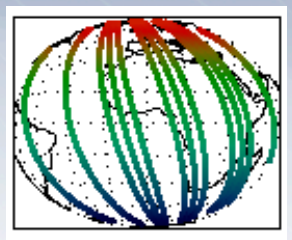
2L Upper layer only



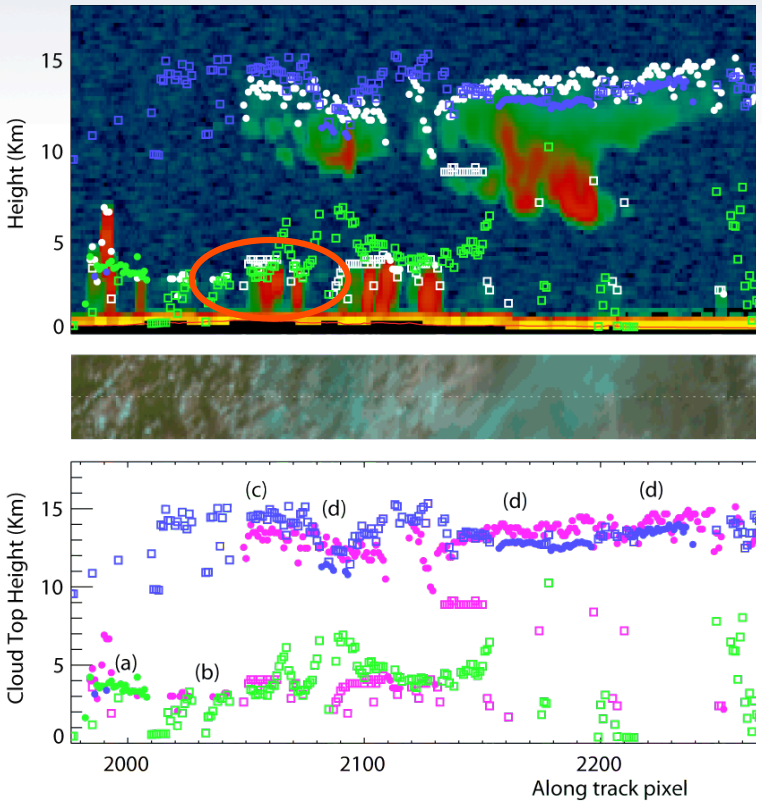


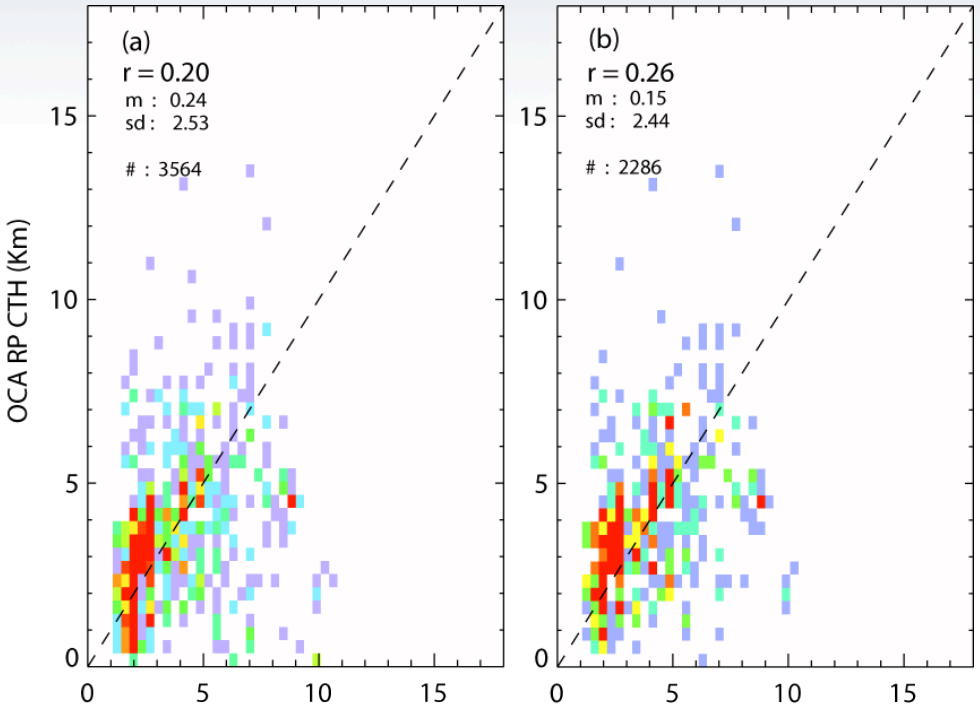


2-Layer CTP validation
2L Lower layer –

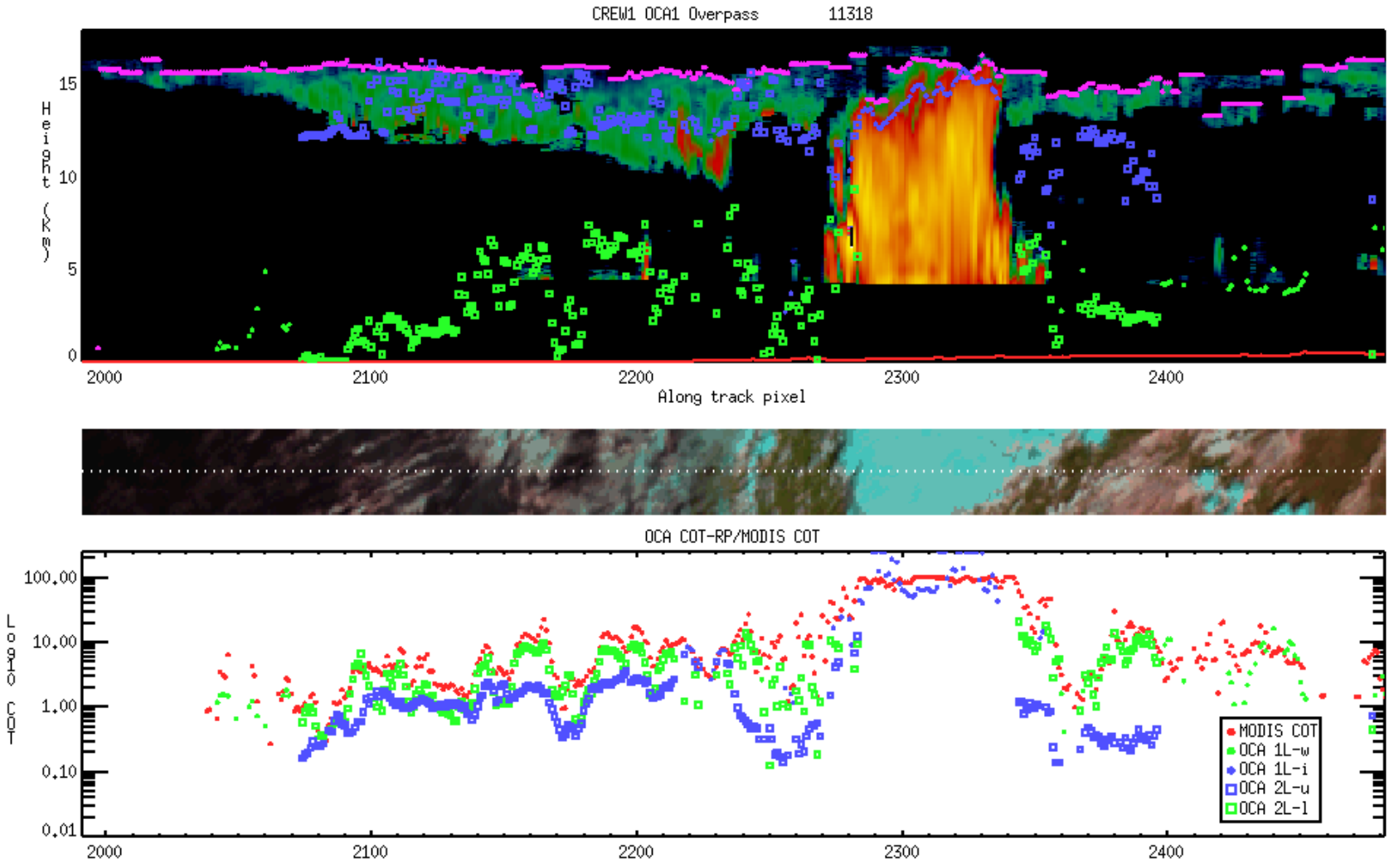


CPR 2nd layer heights





2-Layer COT validation MODIS



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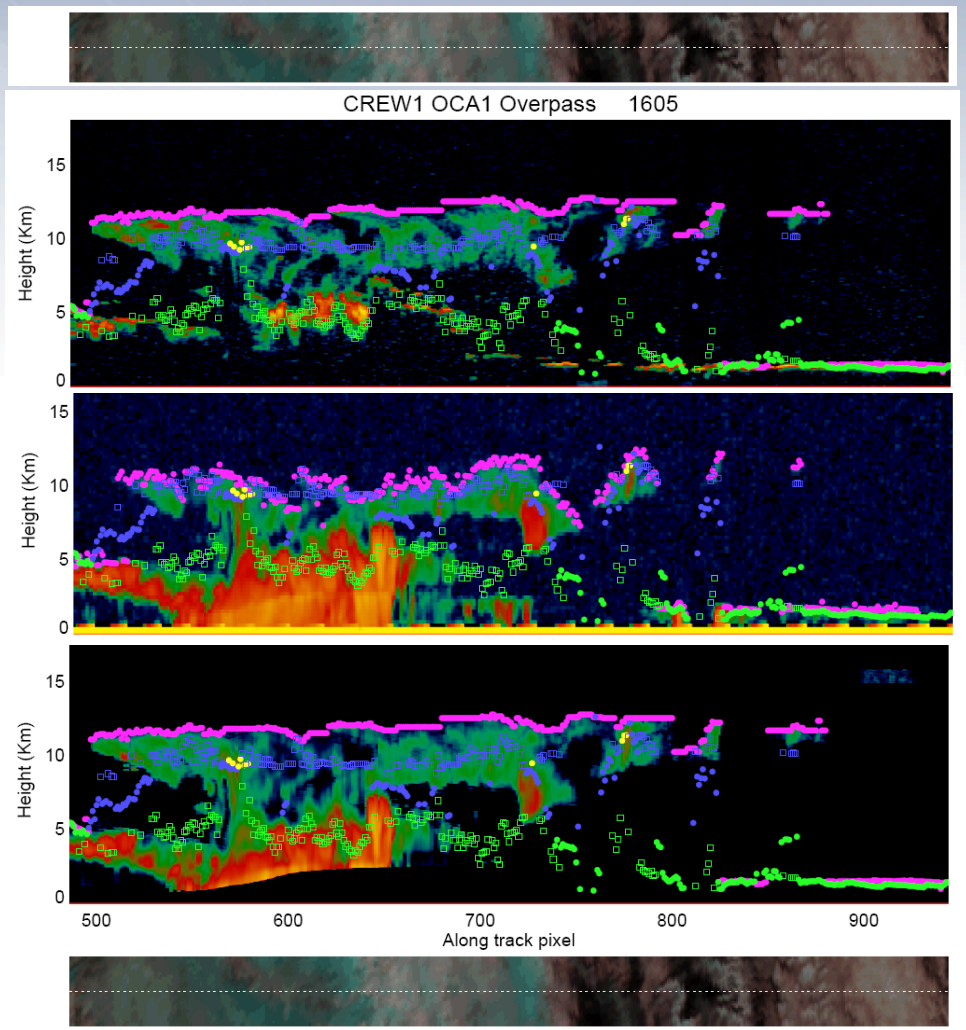
Validation using DARDAR ice COT



CALIOP backscatter:

Sensitive to highest and smallest particles but attenuates in thicker cloud.

CPR Reflectivity:

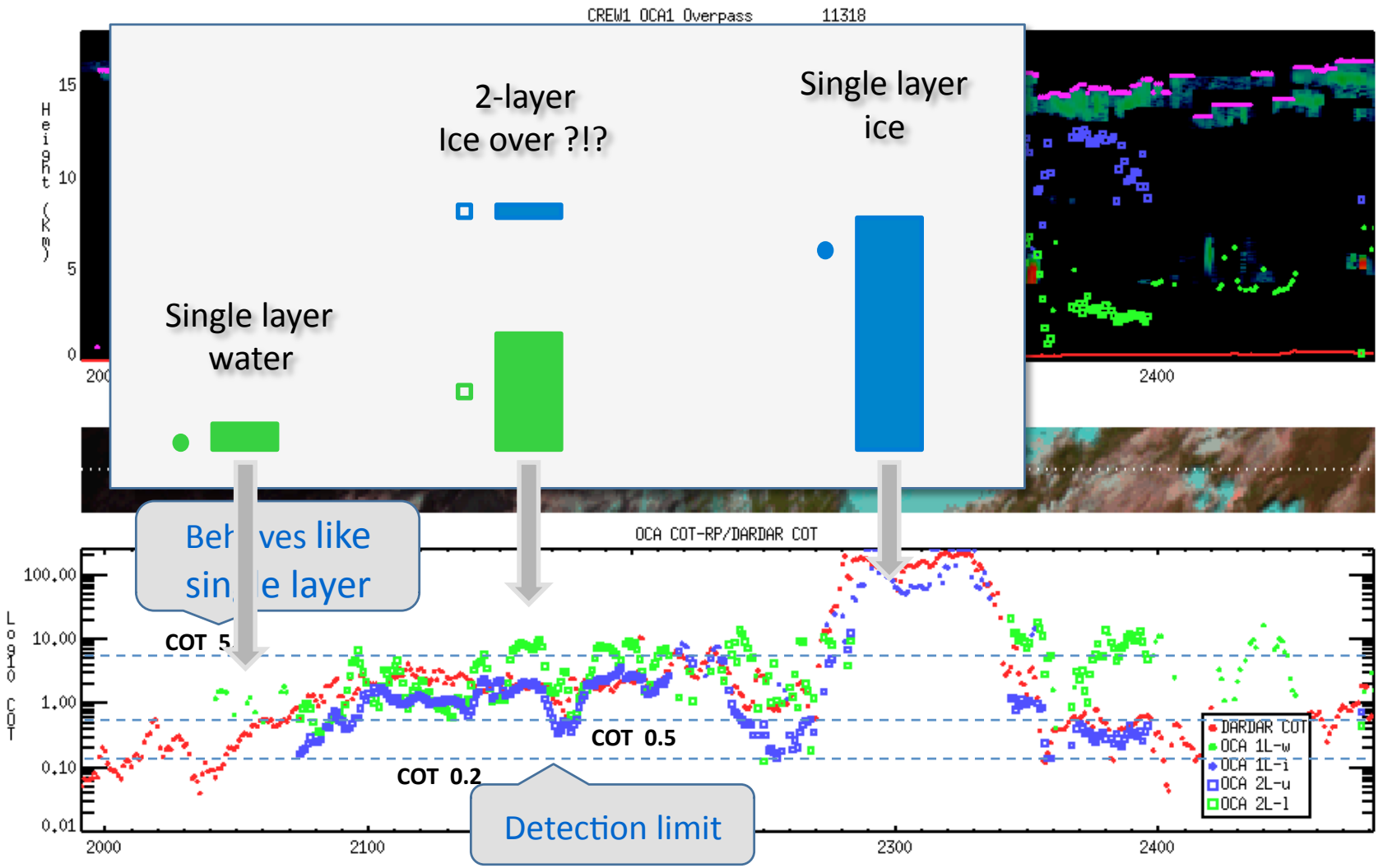
Less sensitive to high thin cloud but retains signal through to surface

DARDAR IWC:

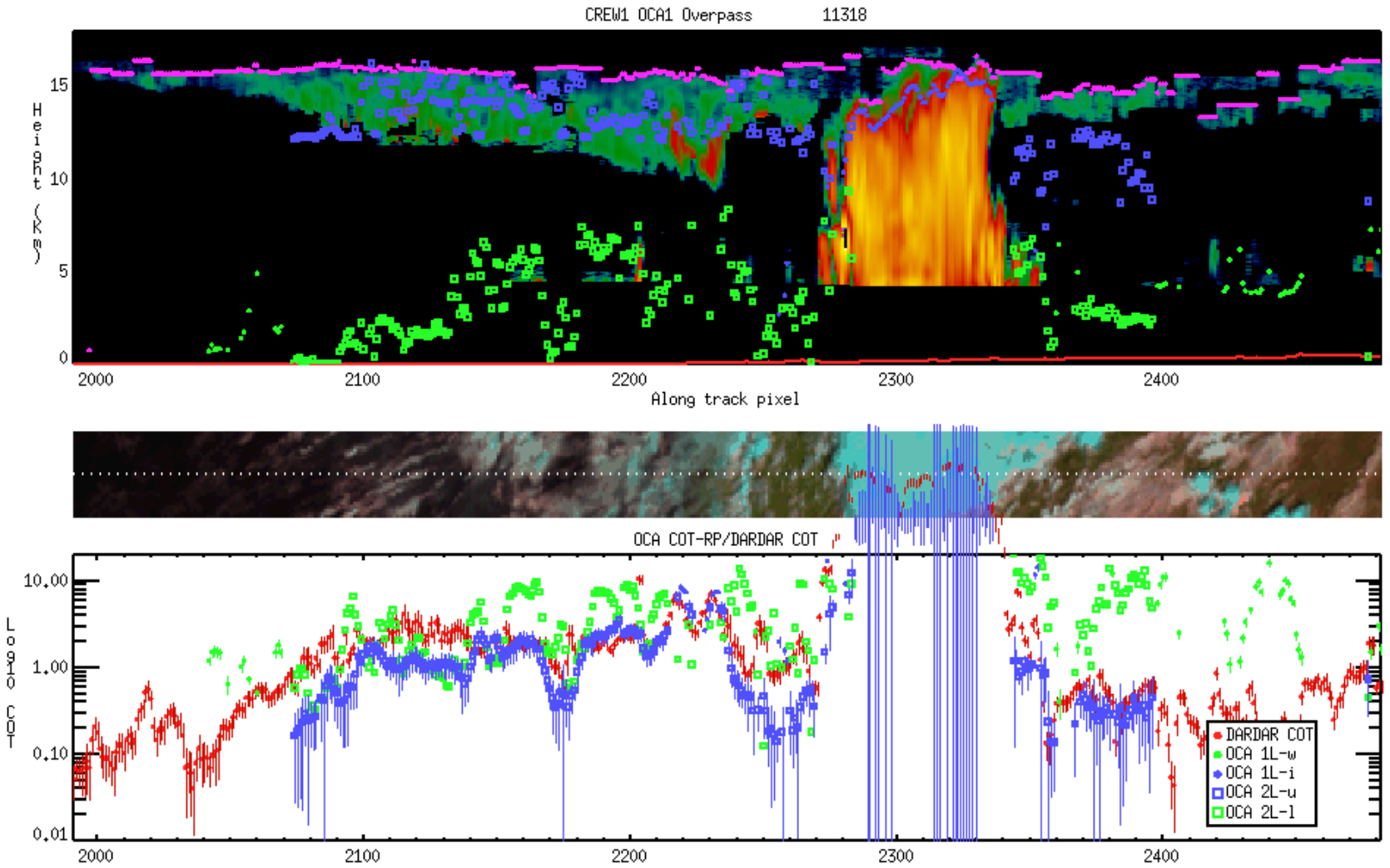
Combines optimally the signals of the radar and lidar to produce a complete profile of ice water content, IWC.

For direct comparison with OCA - DARDAR COT: visible optical depth, the integral of the ice cloud visible extinction along a vertical path through the entire atmosphere.

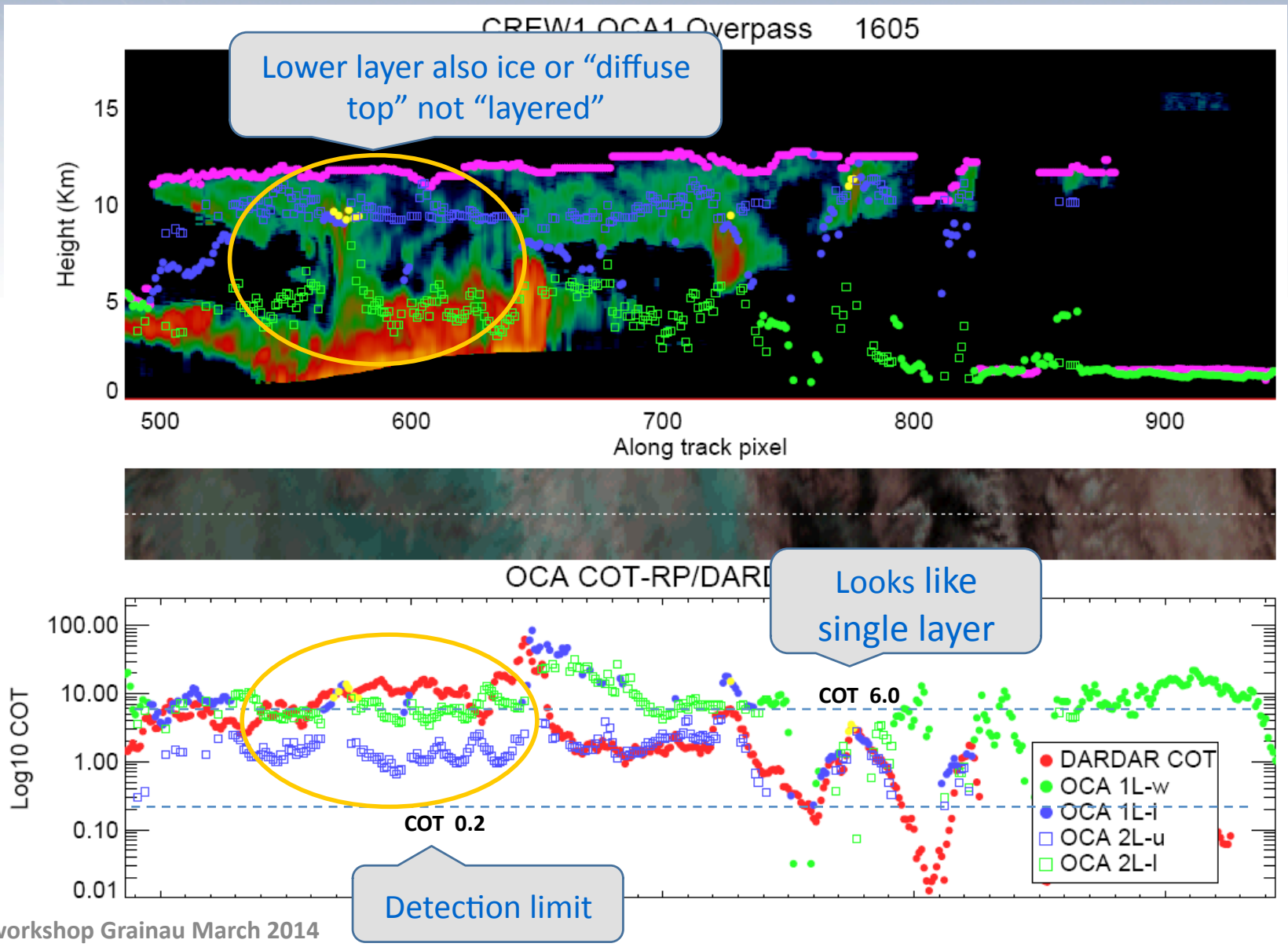
2-Layer COT validation DARDAR

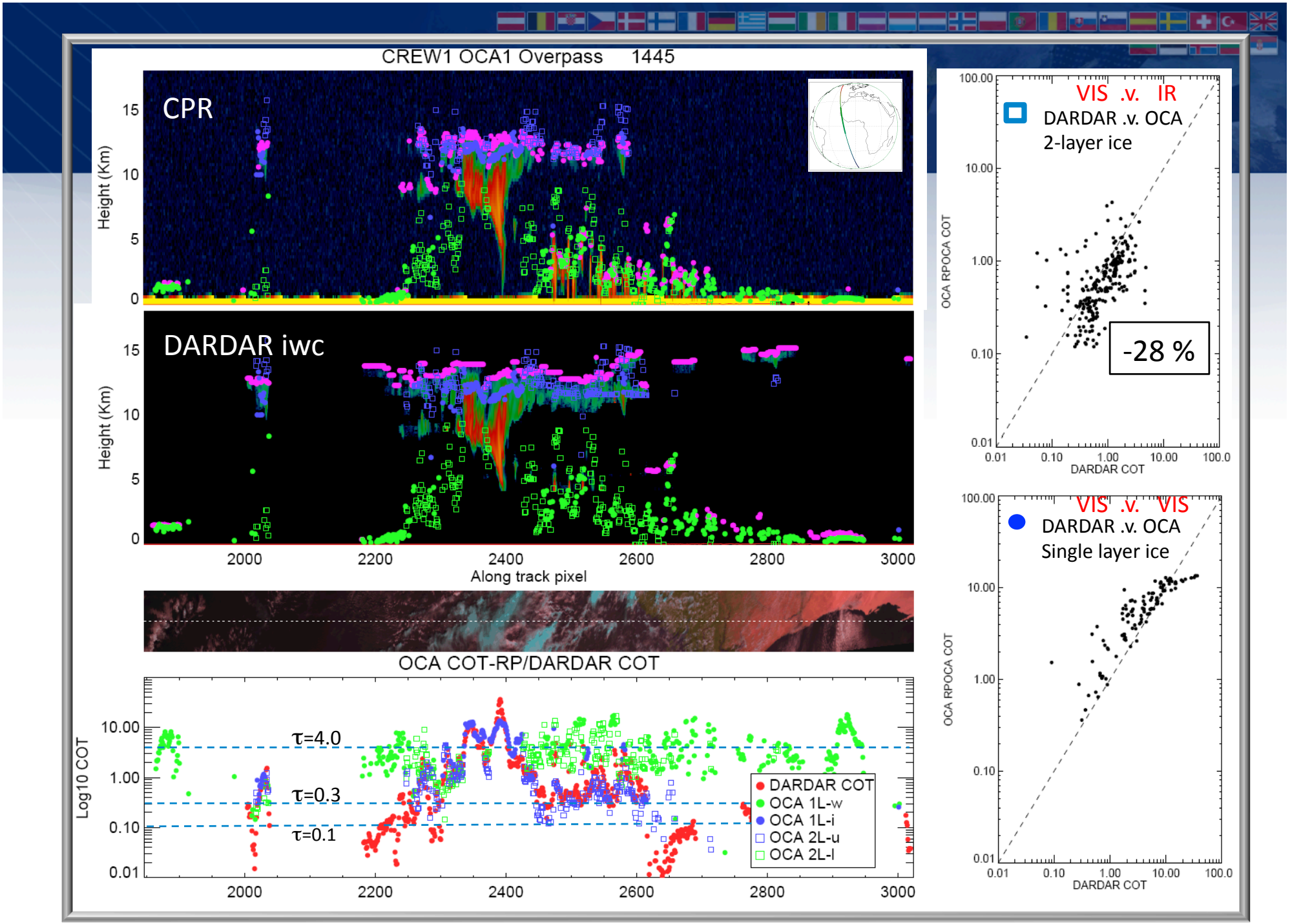


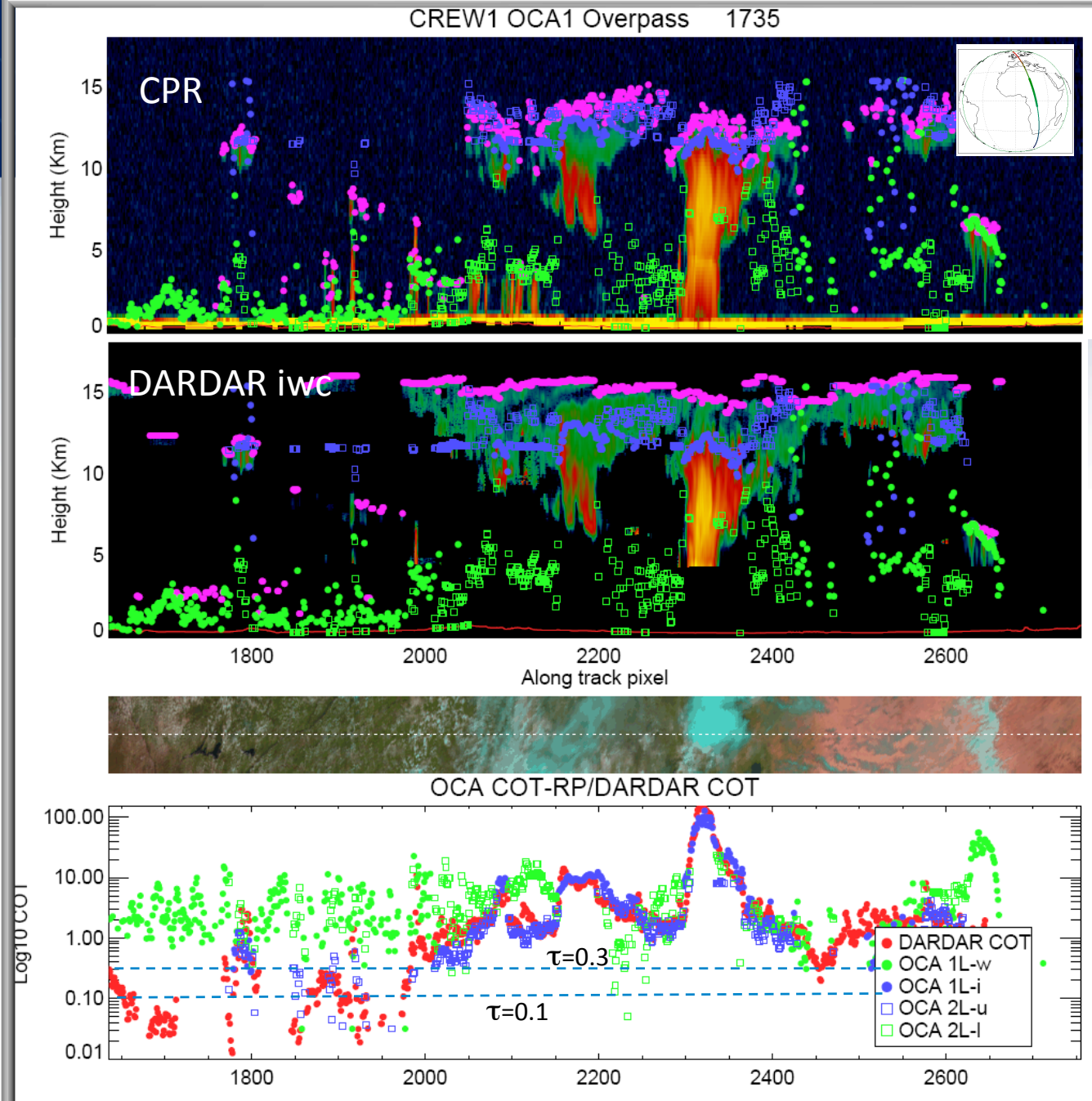
2-Layer COT validation DARDAR – 3σ
Error estimates

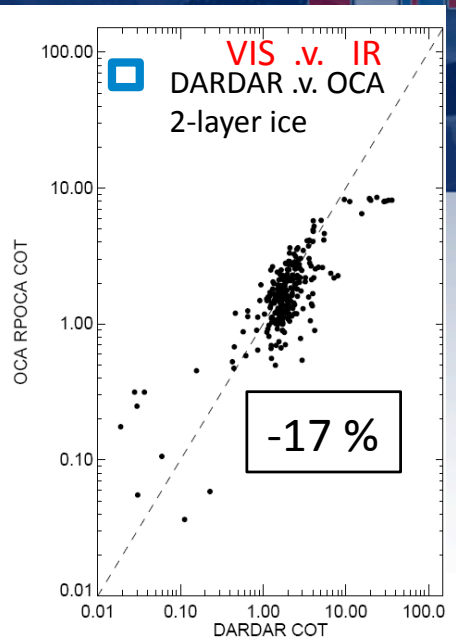


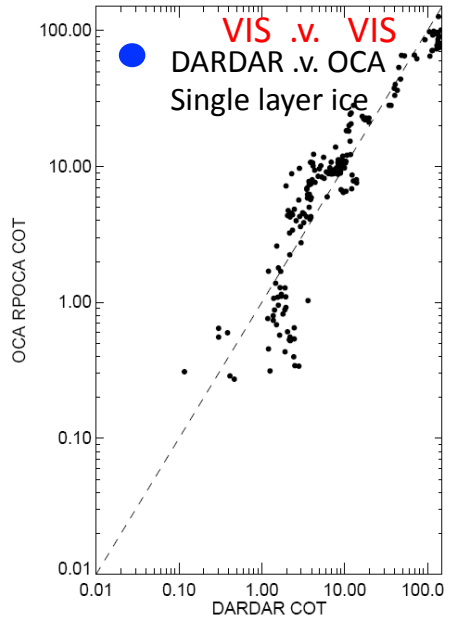
Using DARDAR ice COT..

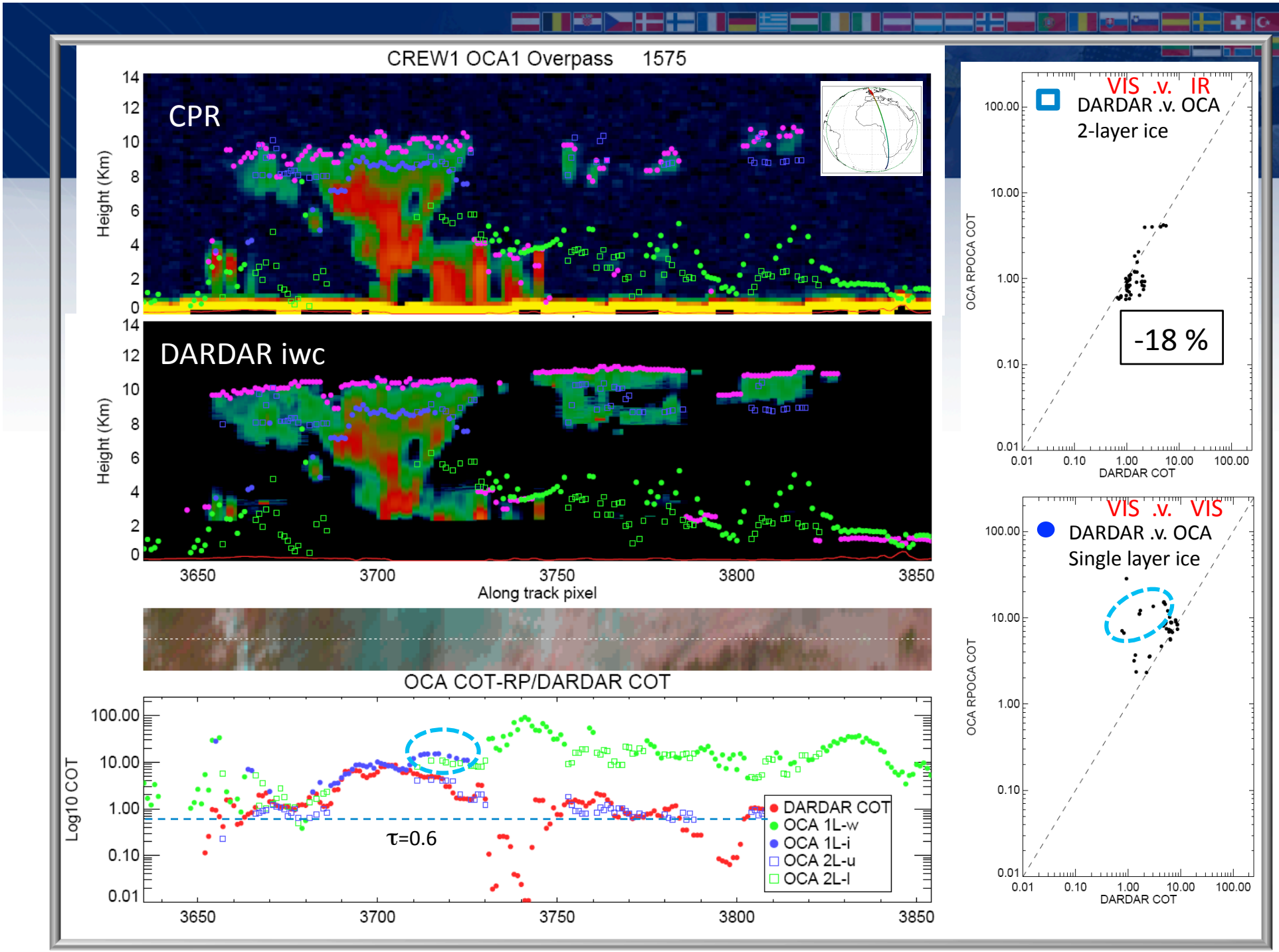



CREW1 OCA1 Overpass 1445
CPR
DARDAR iwc
Height (Km)
Along track pixel
OCA COT-RP/DARDAR COT
Log10 COT
τ=4.0
τ=0.3
τ=0.1
DARDAR COT
OCA 1L-w
OCA 1L-i
OCA 2L-u
OCA 2L-l
VIS .v. IR
DARDAR .v. OCA
2-layer ice
-28 %
OCA RPOCA COT
DARDAR COT
VIS .v. VIS
DARDAR .v. OCA
Single layer ice


CREW1 OCA1 Overpass 1735
CPR
DARDAR iwc
Height (Km)
Along track pixel
OCA COT-RP/DARDAR COT
Log10 COT
τ=0.3
τ=0.1
DARDAR COT
OCA 1L-w
OCA 1L-i
OCA 2L-u
OCA 2L-l

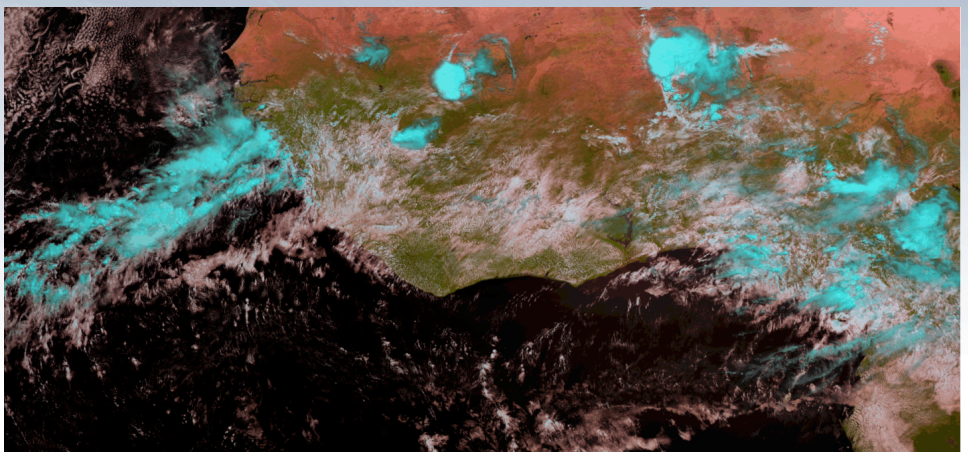

VIS .v. IR
DARDAR .v. OCA
2-layer ice
-17 %
OCA RPOCA COT
DARDAR COT

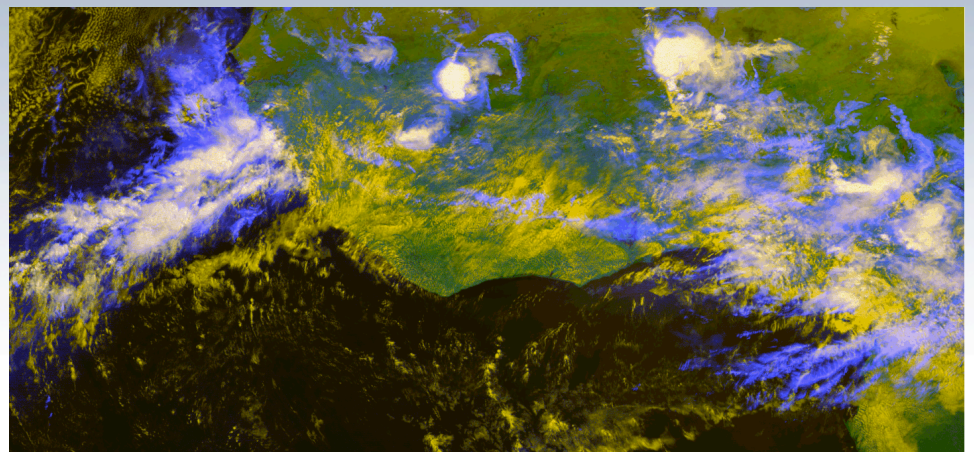

VIS .v. VIS
DARDAR .v. OCA
Single layer ice
OCA RPOCA COT
DARDAR COT

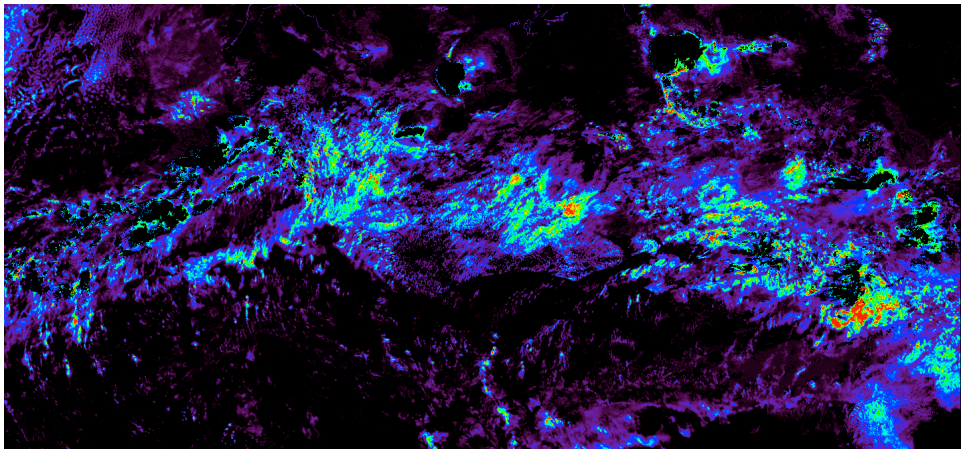

CREW1 OCA1 Overpass 1575
CPR
DARDAR iwc
Height (Km)
Along track pixel
OCA COT-RP/DARDAR COT
Log10 COT
τ=0.6
DARDAR COT
OCA 1L-w
OCA 1L-i
OCA 2L-u
OCA 2L-l
VIS .v. IR
DARDAR .v. OCA
2-layer ice
-18 %
VIS .v. VIS
DARDAR .v. OCA
Single layer ice
OCA RPOCA COT
DARDAR COT

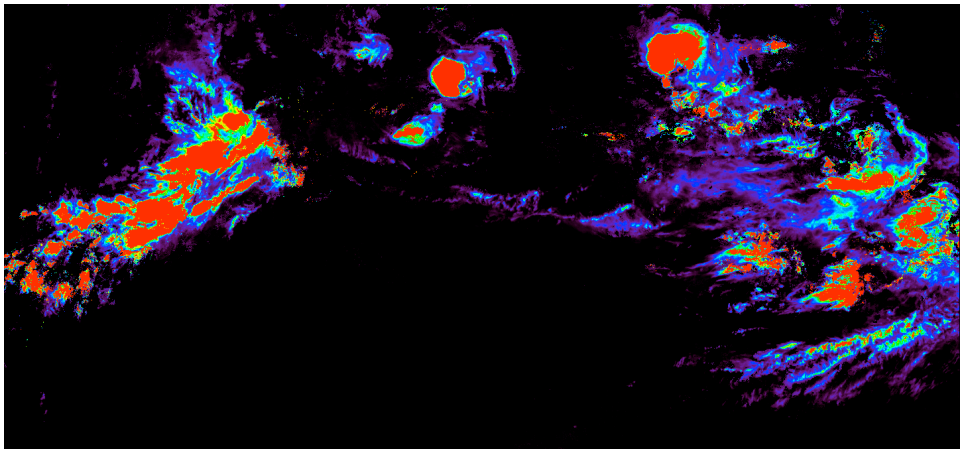
Summary

- Combined VIS + IR retrievals very sensitive to multi-layer
- Can detect by poor measurement fit
- Very simple (crude) adjustment to scheme -> 2 layers
- Upper layer COTs in comparison to DARDAR:
  - Detection for UL COT > 0.1 to 0.3 in tropics, > ~0.5 at high latitudes
  - When UL COT > ~4-6 cloud appears (IR) as single layer
  - UL OCA COTS possibly ~20-30% lower than DARDAR (first look)
  - Disagreement outside estimated (random) 3σ errors
  - SL OCA COTS possibly ‘a little high’ compared to DARDAR (“)





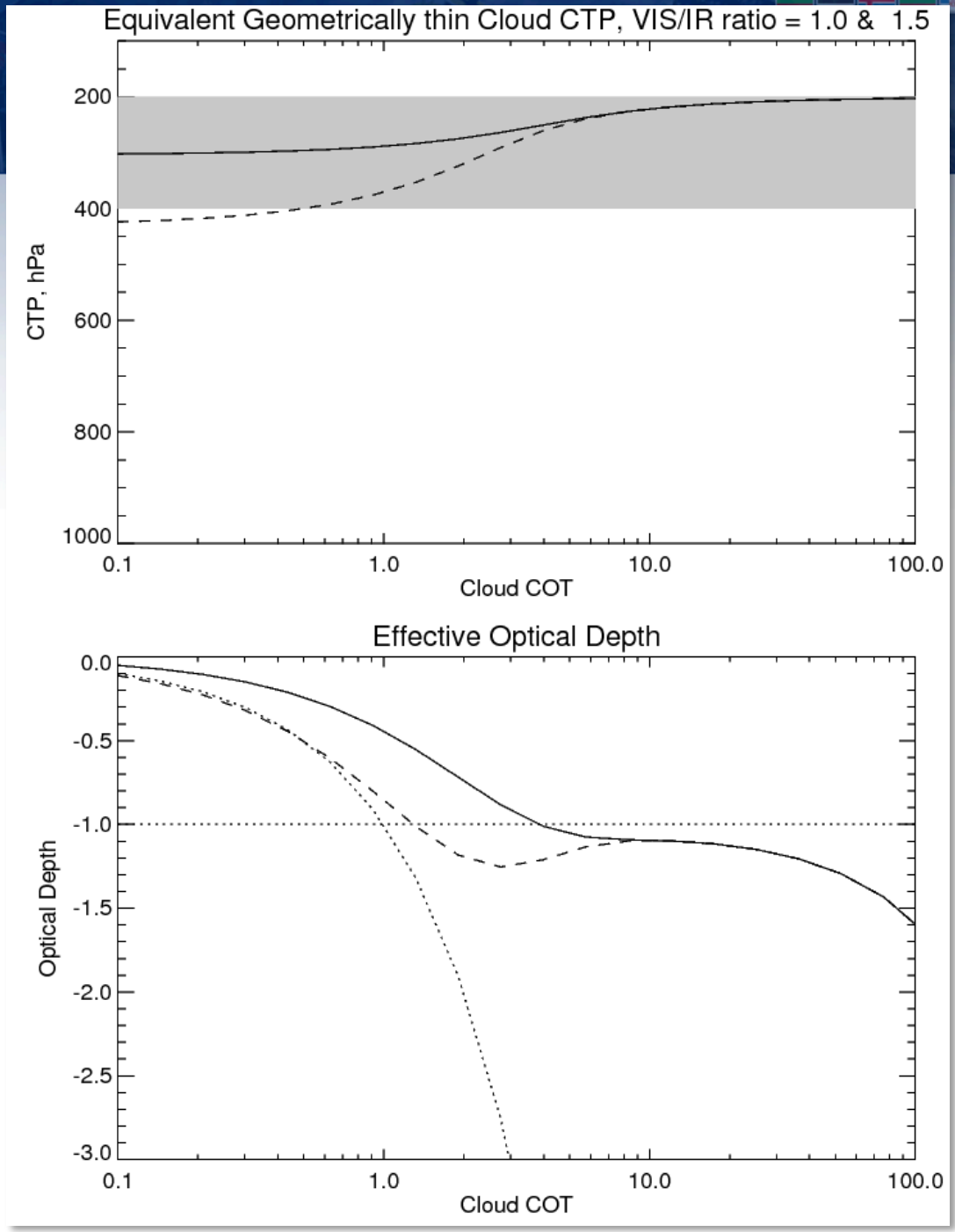




Lower Layer (water) COT scaled 0-42

Upper Layer (ice) COT scaled 0-11

2011 July 25 11:30-12:30


Equivalent Geometrically thin Cloud CTP, VIS/IR ratio = 1.0 & 1.5
CTP, hPa
200
400
600
800
1000
0.1
1.0
10.0
100.0
Cloud COT
Effective Optical Depth
Optical Depth
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
0.1
1.0
10.0
100.0
Cloud COT