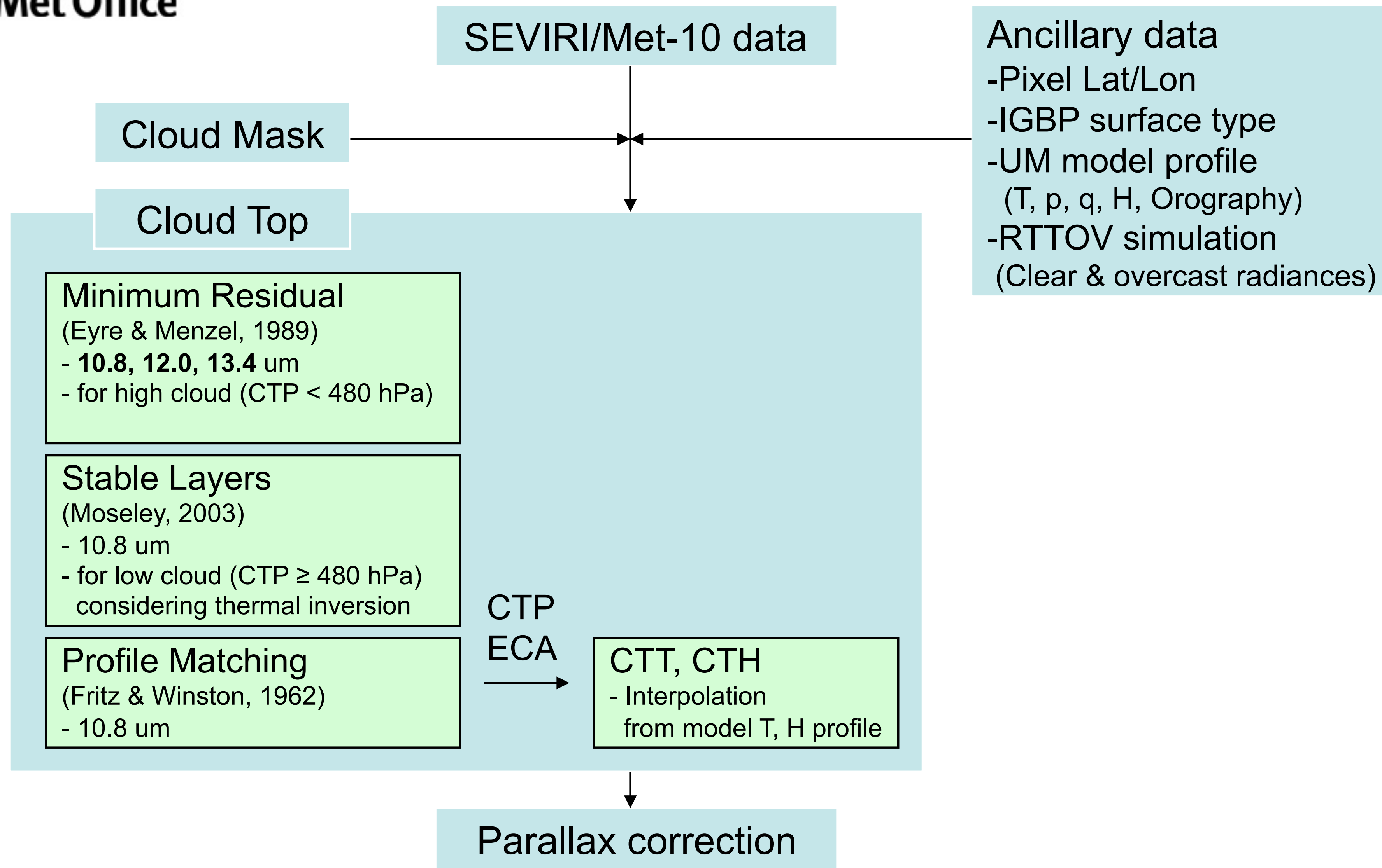
Validation of SEVIRI cloud-top height retrievals from A-Train data

Chu-Yong Chung, Pete N Francis, and Roger Saunders

Contents

MO GeoCloud Retrievals



AVAC-S

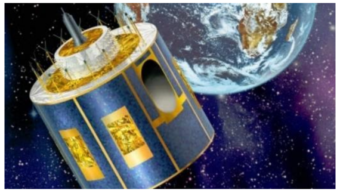
(A-Train Validation of Aerosol and Cloud properties from SEVIRI)

Met Office

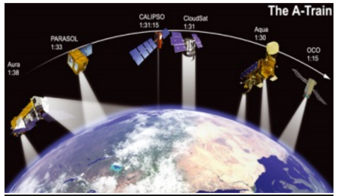
- Main purpose and functionalities (EUM-07-839-INF, 2013)
  - developed by EUMETSAT
  - To provide a framework for validating aerosols and cloud parameters derived from **MSG SEVIRI** (**OCA, CLA, and CMSAF**) with **A-Train** data
  - To map SEVIRI and A-Train derived products on a common grid
    - Reference : CPR observations
    - Spatial : ±10 pixels (possible to use parallax correction function)
    - Temporal : ±7.5 minutes window (for 15-min interval SEVIRI data)
  - To provide a number of tools for scene identification, sub-setting and data merging are provided to support validation scenarios, statistical analysis and visual inspection

AVAC-S

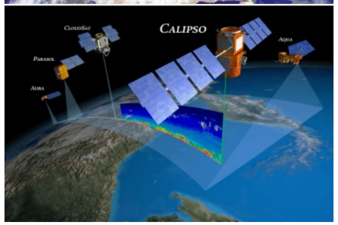
(A-Train Validation of Aerosol and Cloud properties from SEVIRI)



- ❑ SEVIRI/Met-10
  - 12 channels passive Vis-IR radiometer
  - The measured radiance and the retrieved CTH are radiatively effective ones



- ❑ CALIOP/CALIPSO
  - dual wavelength (532 and 1064 nm) lidar measuring profiles of total backscatter
  - the most sensitive to cloud particles and able to detect clouds with a very small optical depth (down to 0.01)



- ❑ CPR/CloudSat
  - 94GHz nadir-looking radar measuring the backscattered signal
  - The Cloud Profiling Radar (CPR) is very much sensitive to raindrop-sized particles,
  - but less sensitive to small ice particles than CALIOP

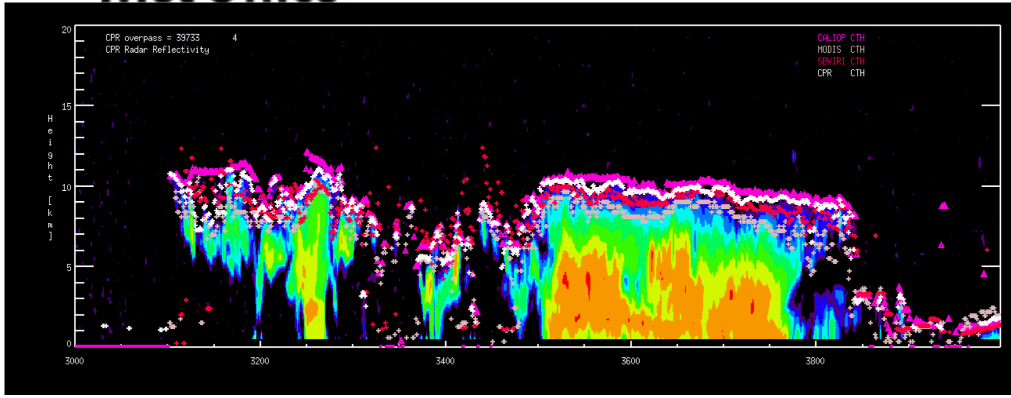
➔ Due to the different sensitivity to cloud particles, it is expected that

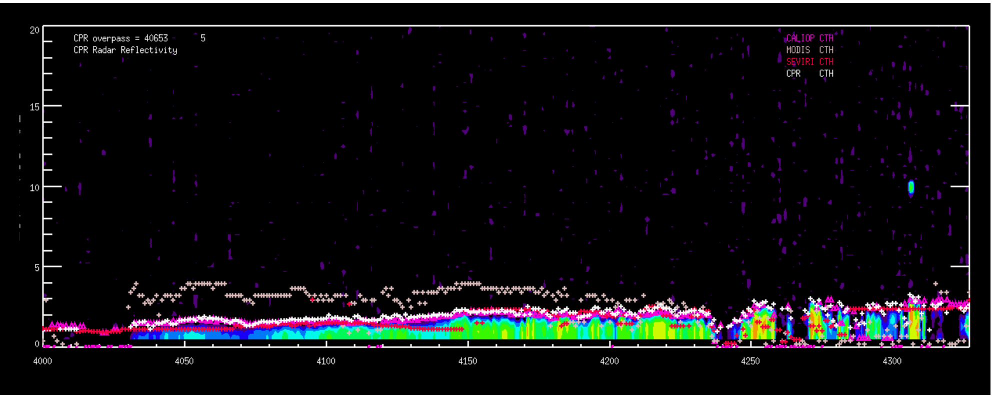
CTH of passive imager (SEVIRI) retrievals is lower than the CTH of CALIOP and is similar to the CTH of CPR

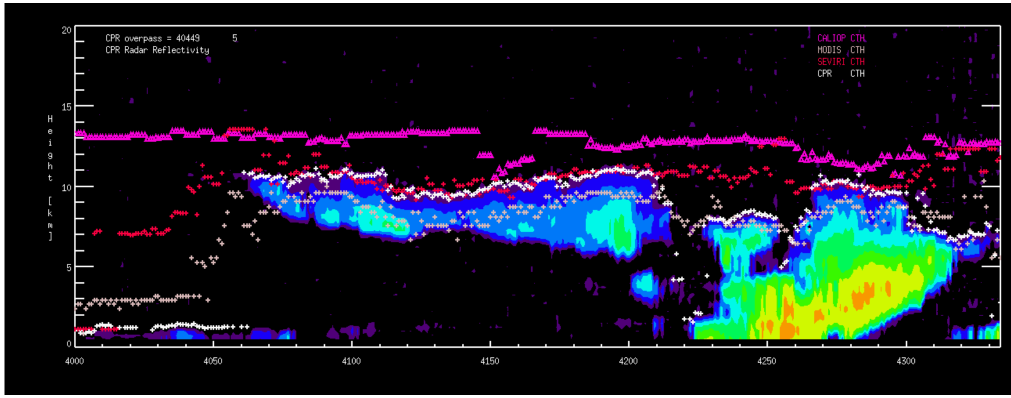
CALIOP CTH
CPR CTH
SEVIRI CTH
MODIS CTH

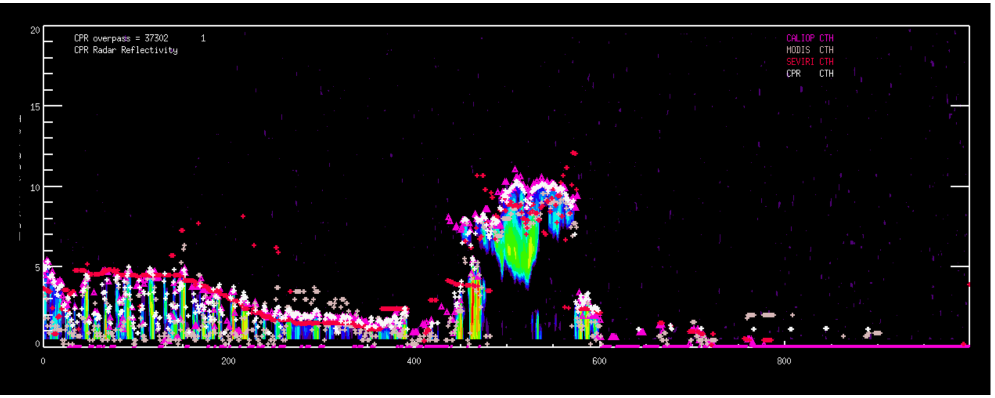
Examples

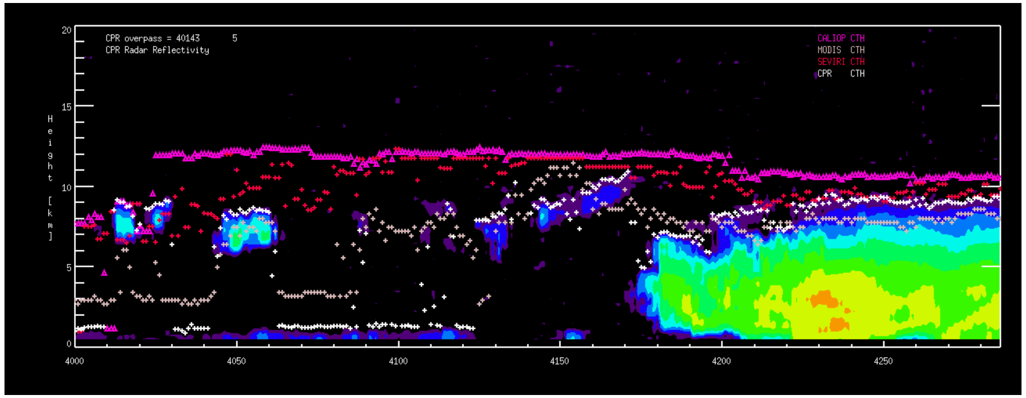
Met Office











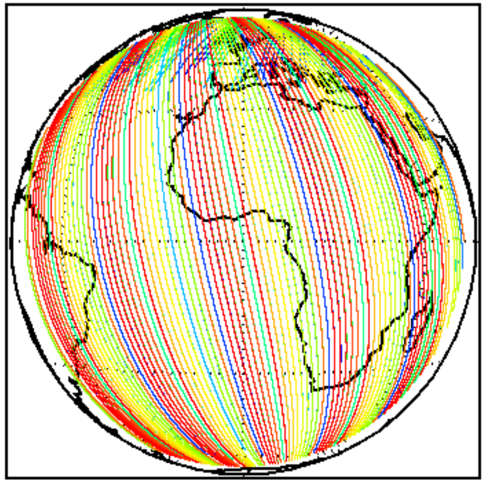
Long-term Monitoring

Long-term monitoring

Met Office

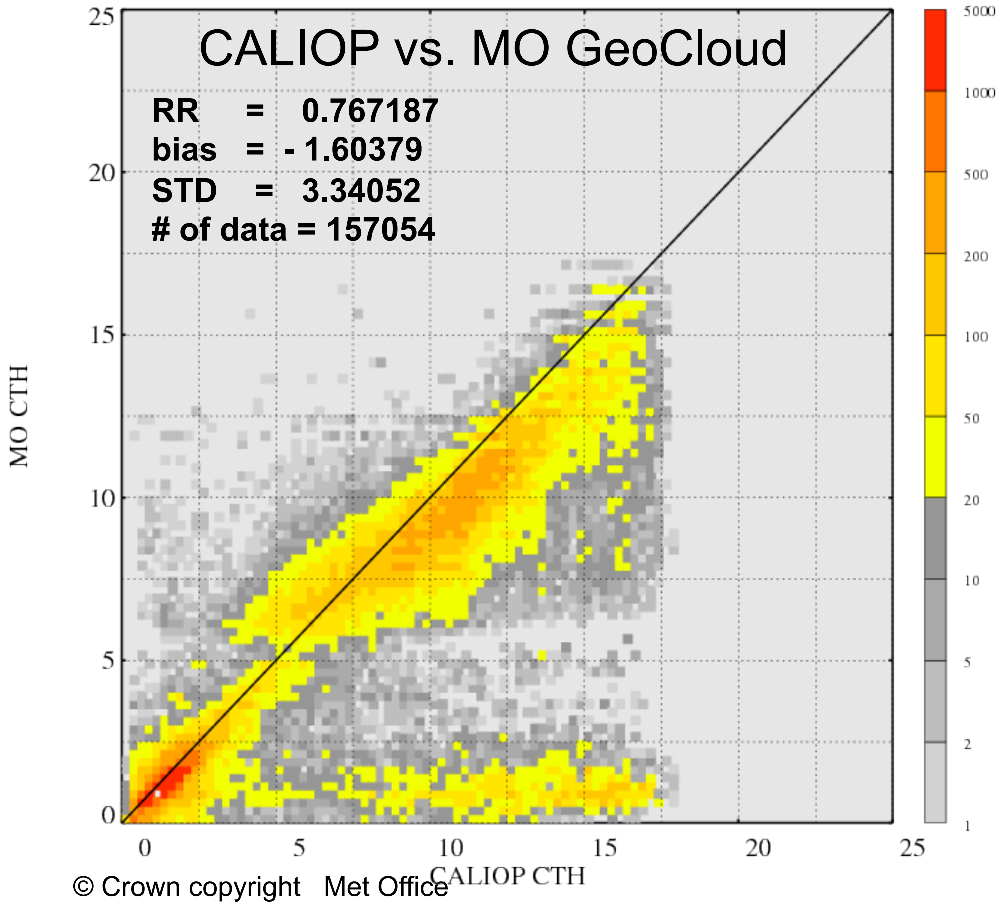
- Data :
  - SEVIRI : operational product
  - CPR : 2B-GEOPROF, 2B-CLDCLASS from CIRA
  - CALIOP : 2B-05kmClay from LARC/NASA
  - MODIS : MAC06S1.002 from GSFC/NASA
- Period :
  - May ~ Dec. 2013 (7daily data, 8 months)
- Filters
  - Quality Control : CTH_VAR < 5.0E4
  - Uniformity Check : SEVIRI CTH STD_{5x5} < 1.0 km

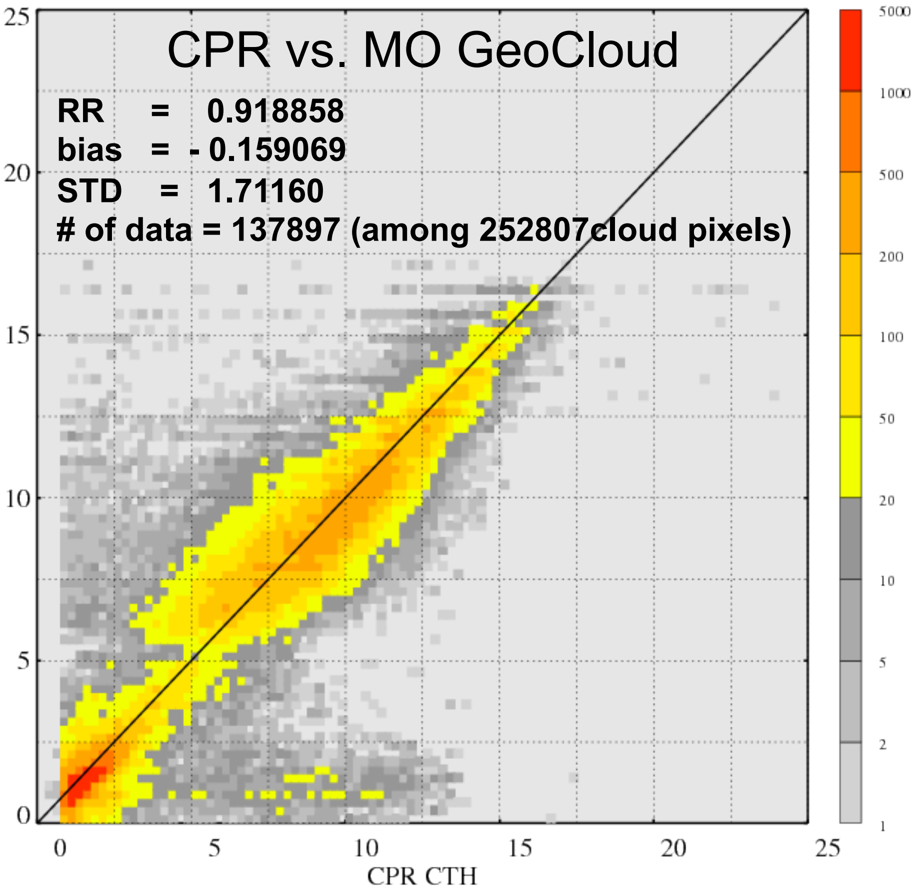
Met Office



Start Time : Wed May 01 01:26:32 2013

End Time : Tue Dec 31 17:10:57 2013



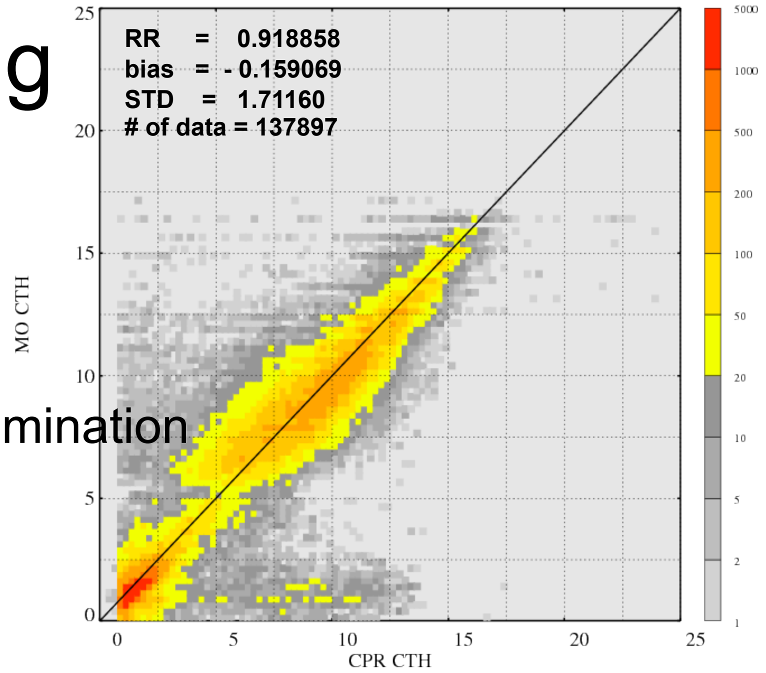


Long-term monitoring

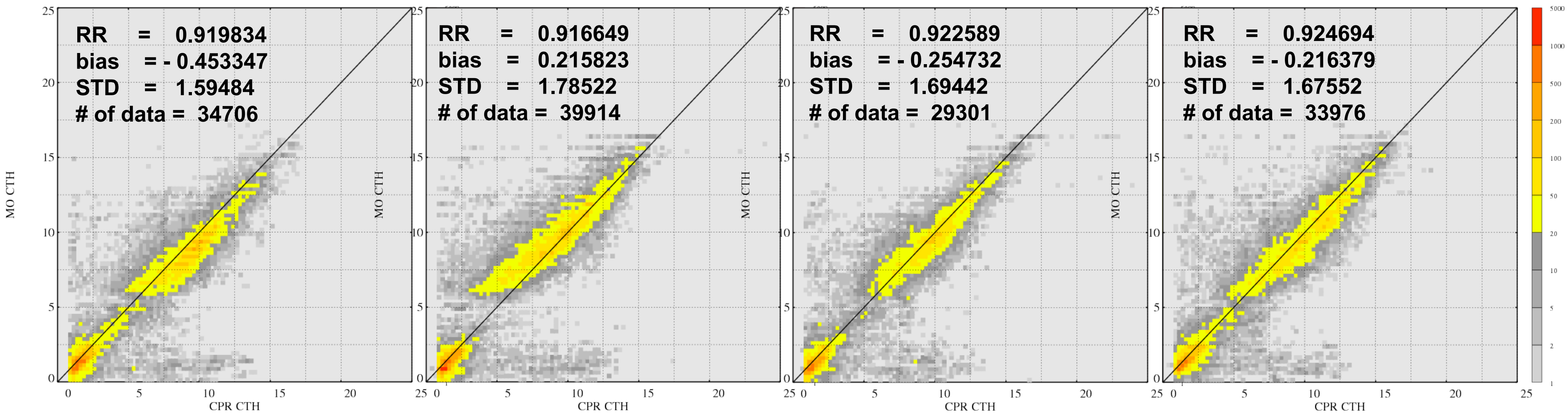
Met Office

- CO2 channel bias correction increment update
  - ~ 10/07 : -1.15
  - 10/07/13 10:43 : 0.85 after Met-10 decontamination
  - 24/09/23 09:45 : -0.15
  - 15/11/13 14:20 : -0.65

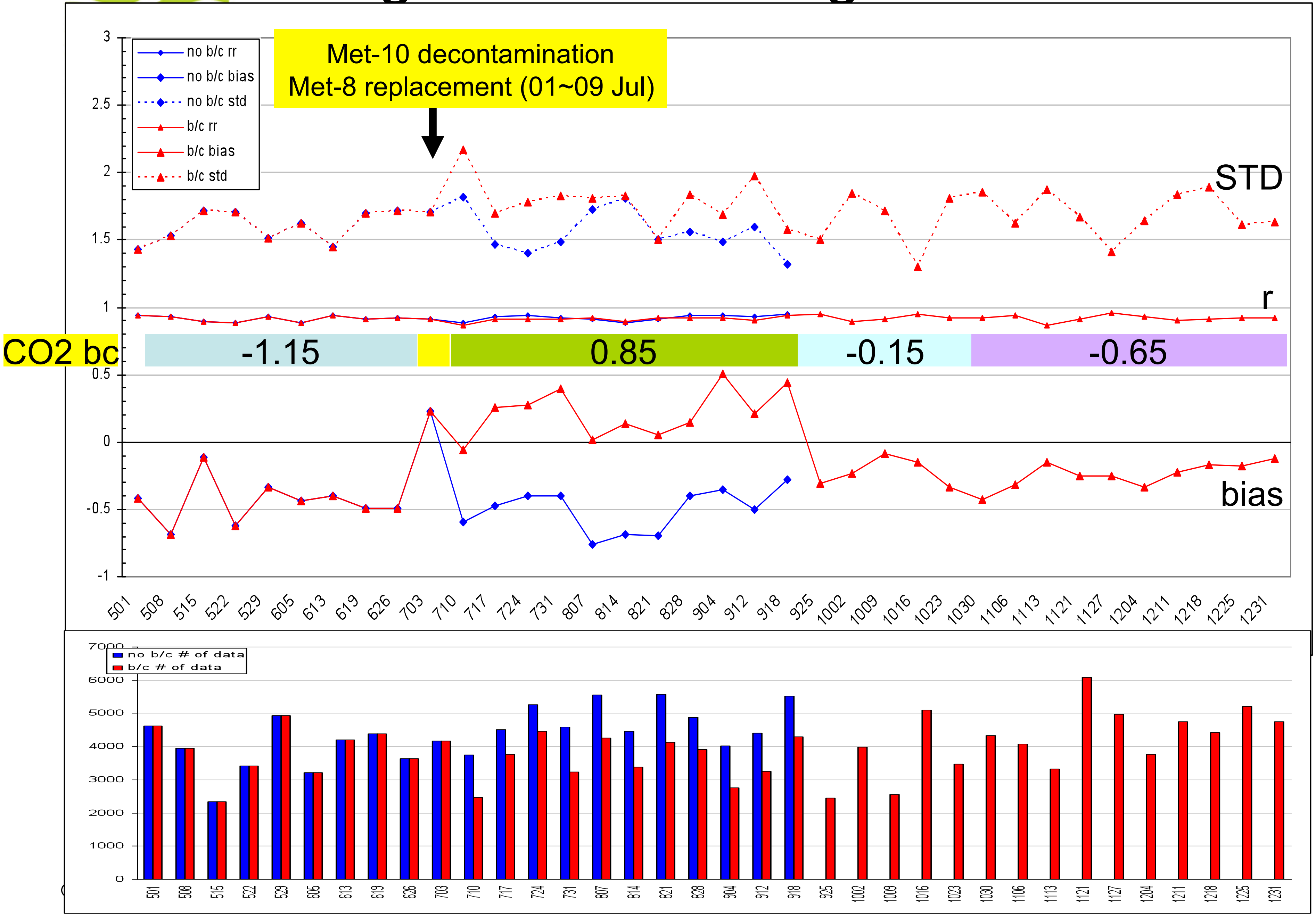
May ~ Dec., 2013

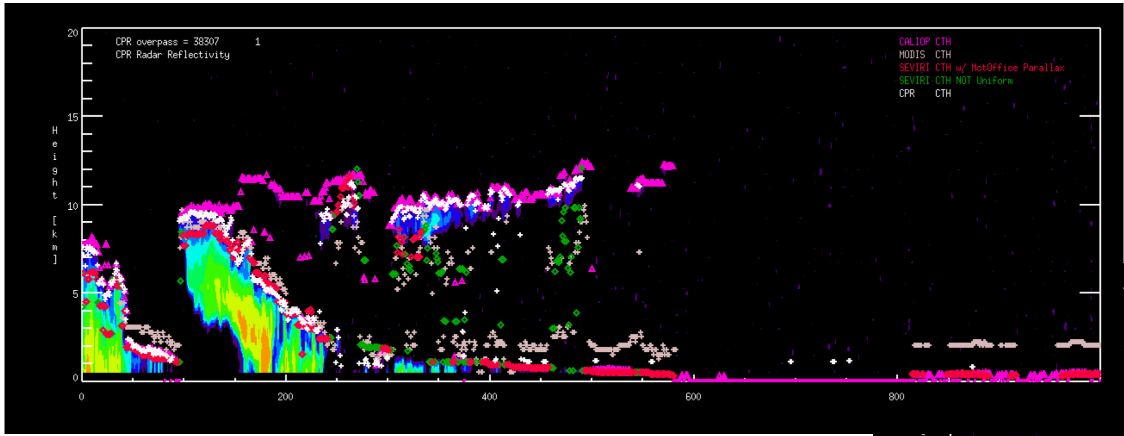


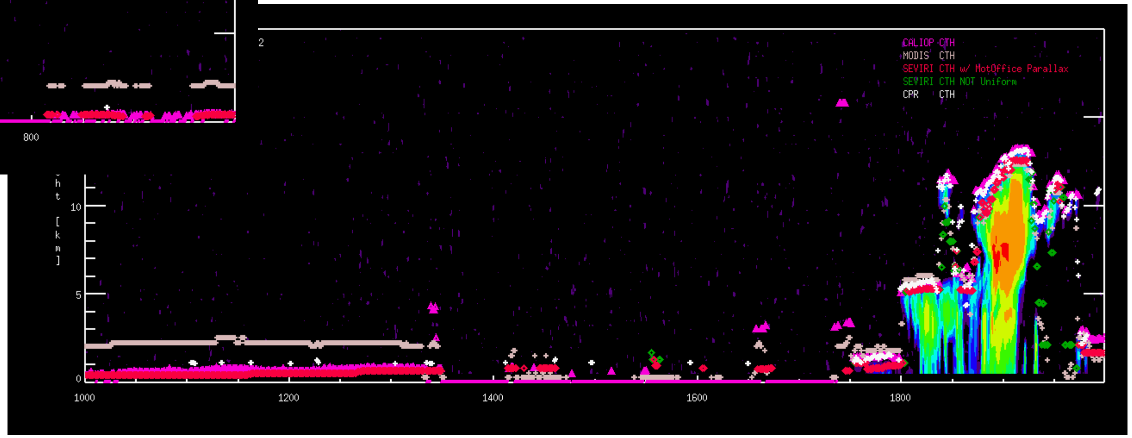
01/05 ~ 26/06	10/07 ~ 18/09	25/09 ~ 13/11	20/11 ~ 31/12
b/c : -1.15	b/c : 0.85	b/c : -0.15	b/c : -0.65



Long-term monitoring

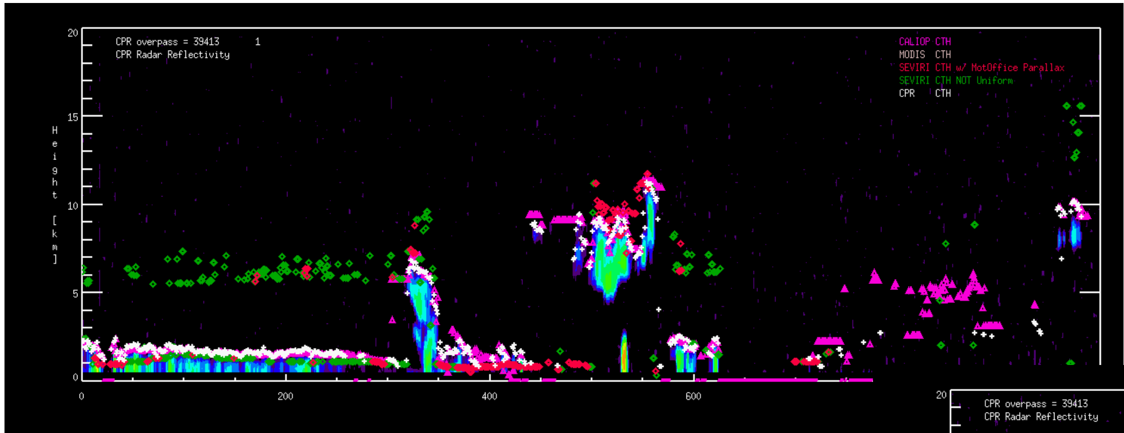






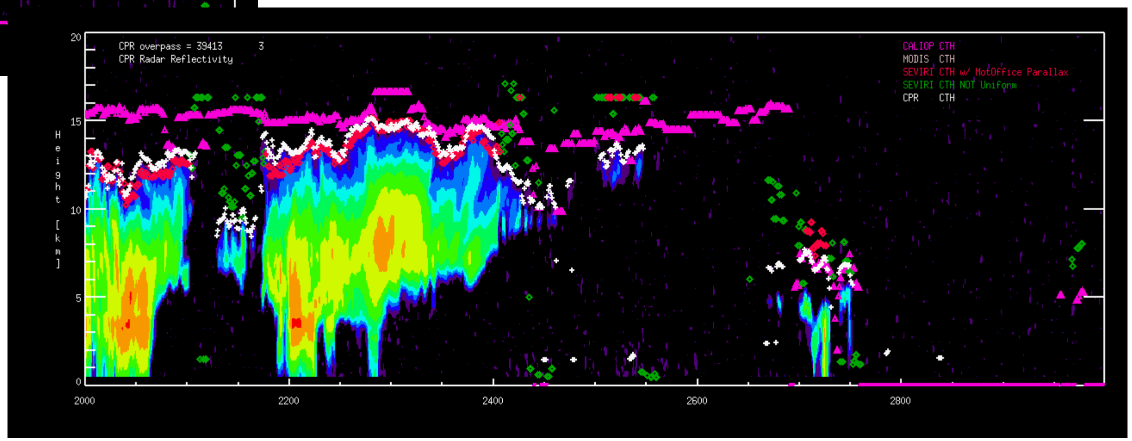
10/07/2013 Overpass 38307

CO_2 bias_corr : -1.15

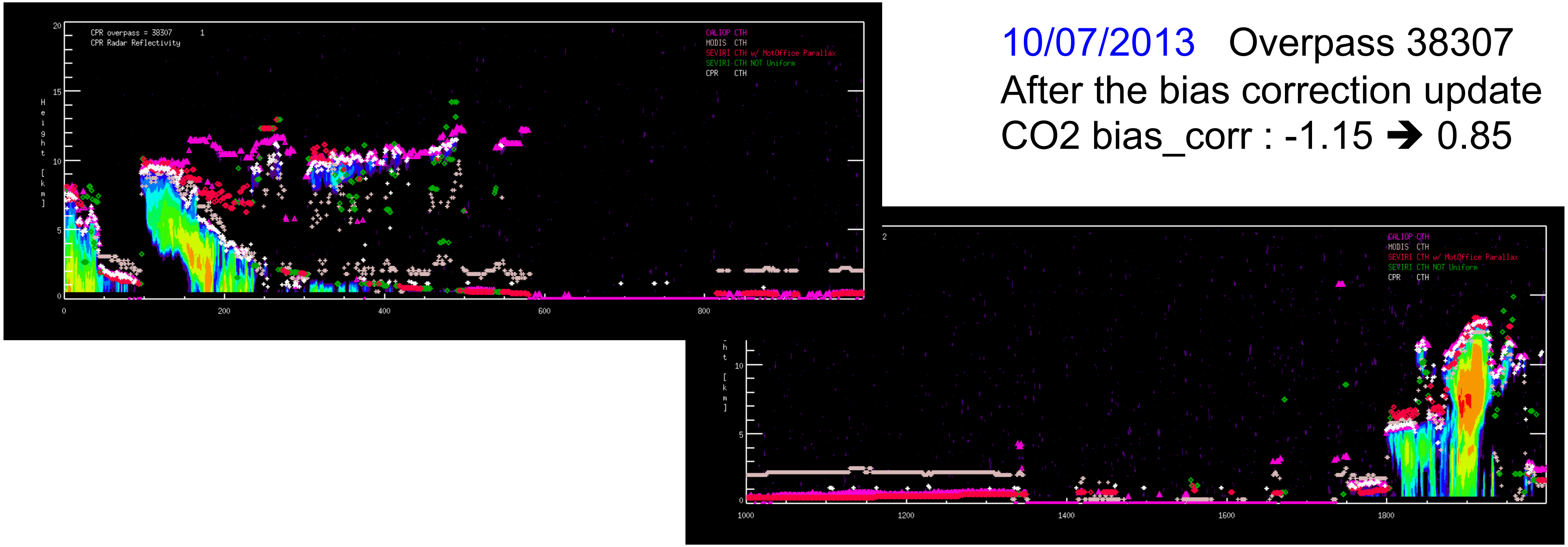


24/09/2013 Overpass 39413

CO_2 bias_corr : 0.85



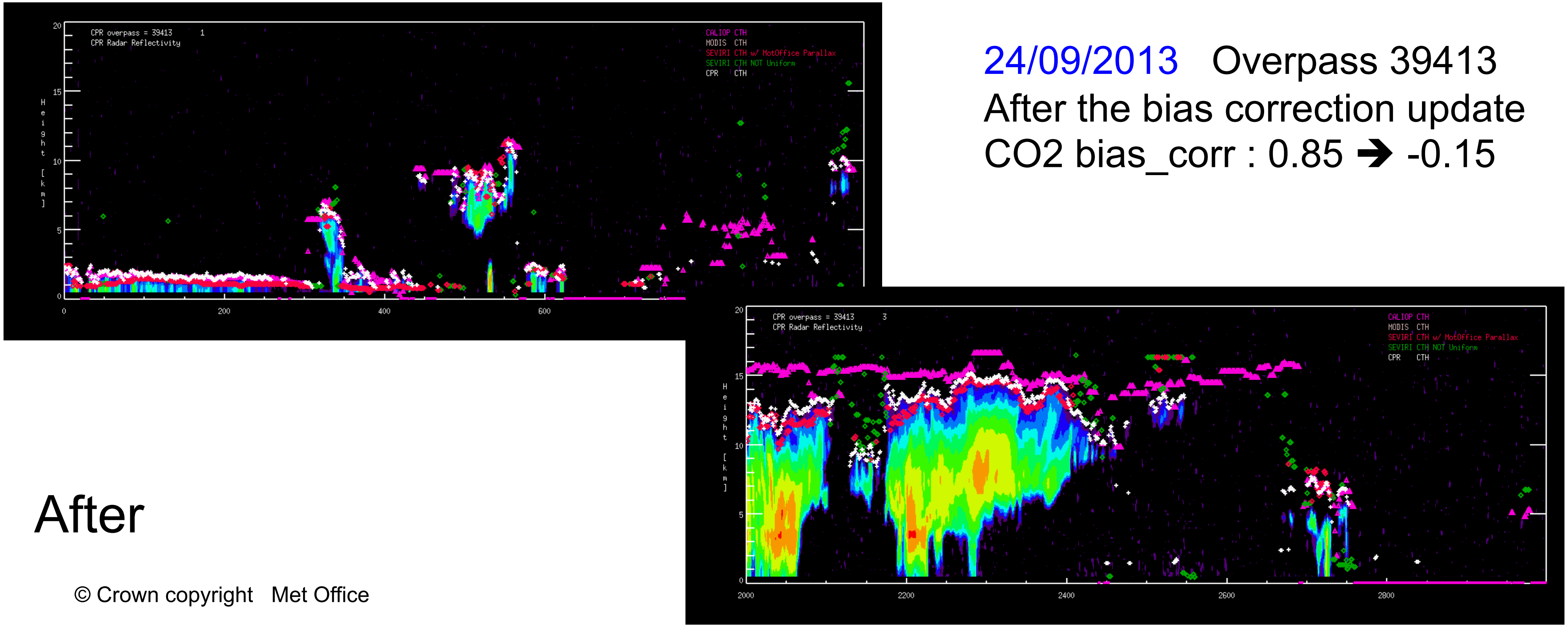
Before



10/07/2013 Overpass 38307

After the bias correction update

CO_2 bias_corr : -1.15 ➔ 0.85



24/09/2013 Overpass 39413

After the bias correction update

CO_2 bias_corr : 0.85 ➔ -0.15

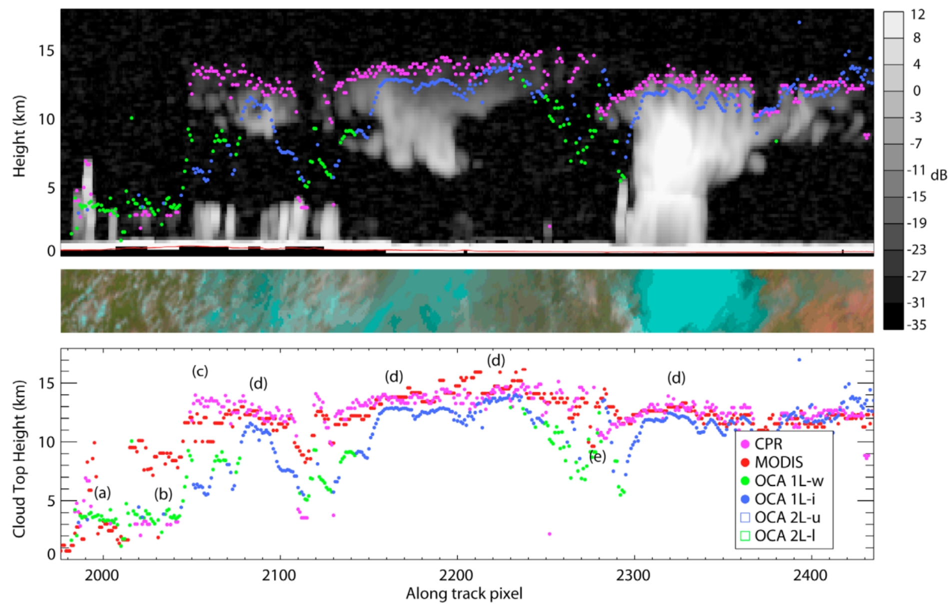
After

Comparison with OCA

Comparison with OCA

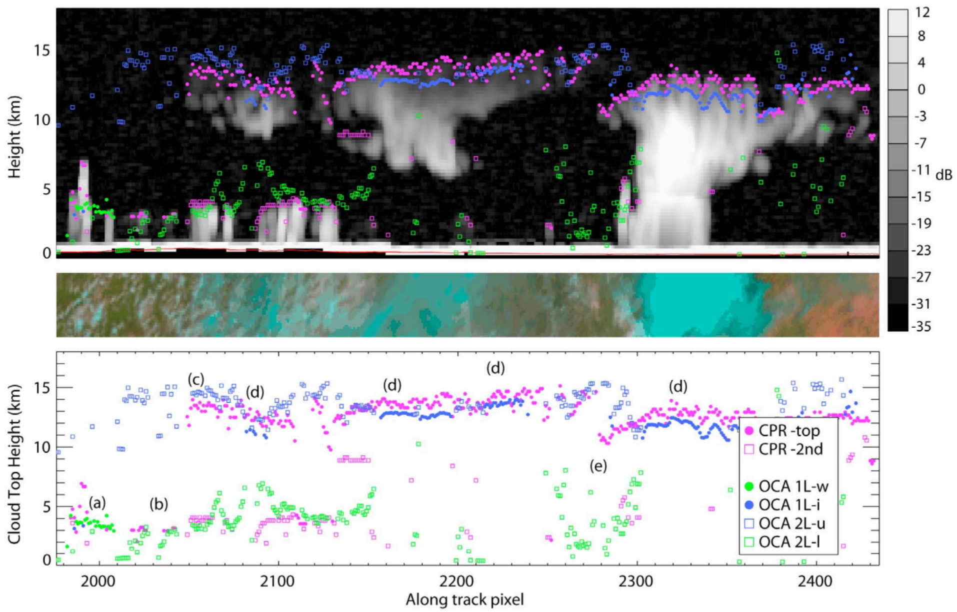
Single layer OCA

- CPR
- OCA1 – ice
- OCA1 – water

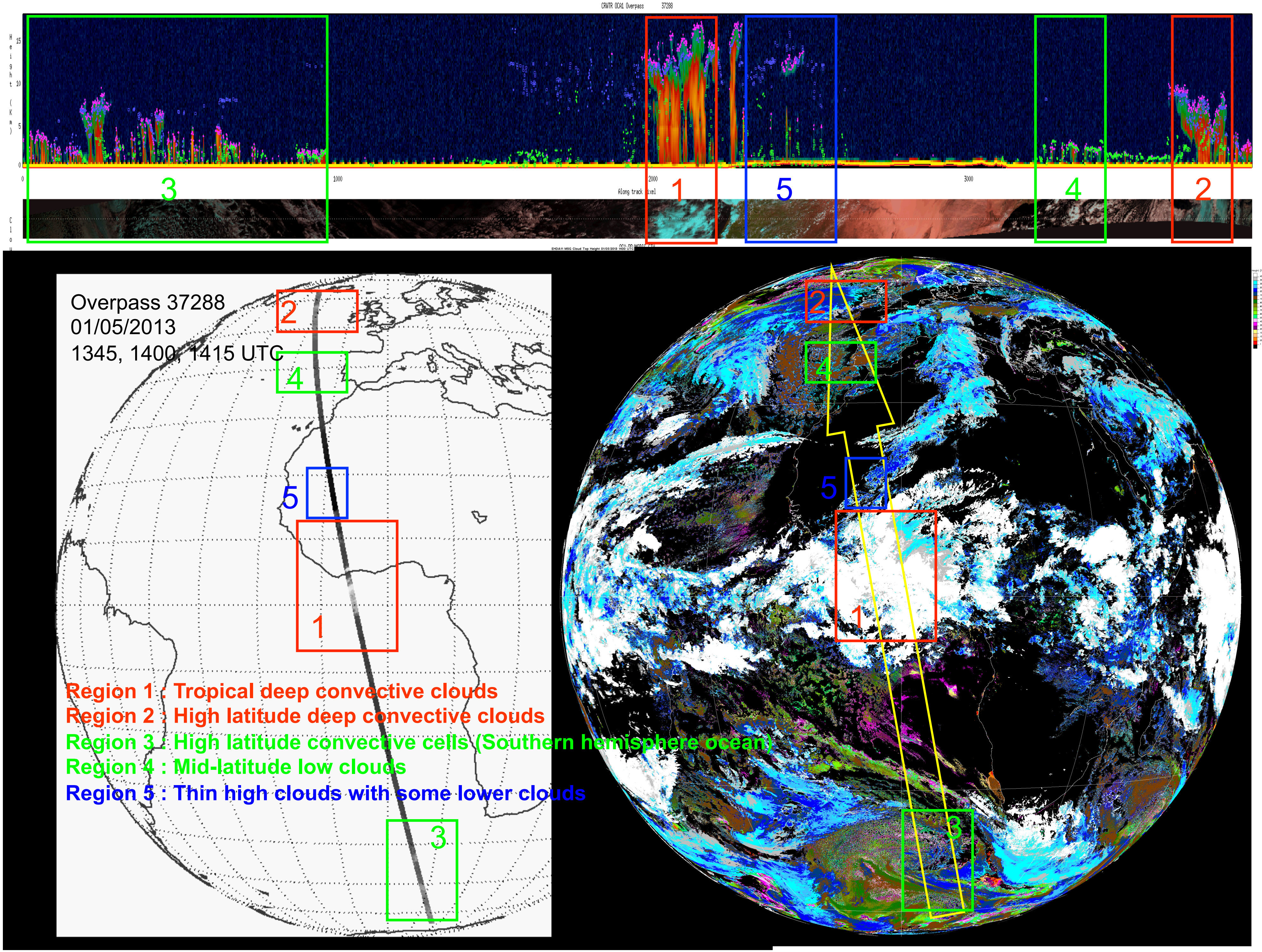


2-layer OCA

- CPR
- OCA 1L – ice
- OCA 1L – water
- ▫ OCA 2L – upper
- ▫ OCA 2L - lower

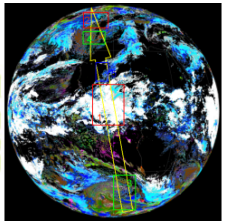


From Watts et al. (2011)

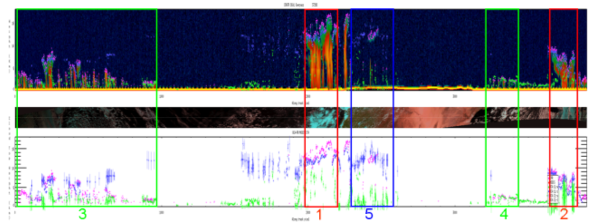


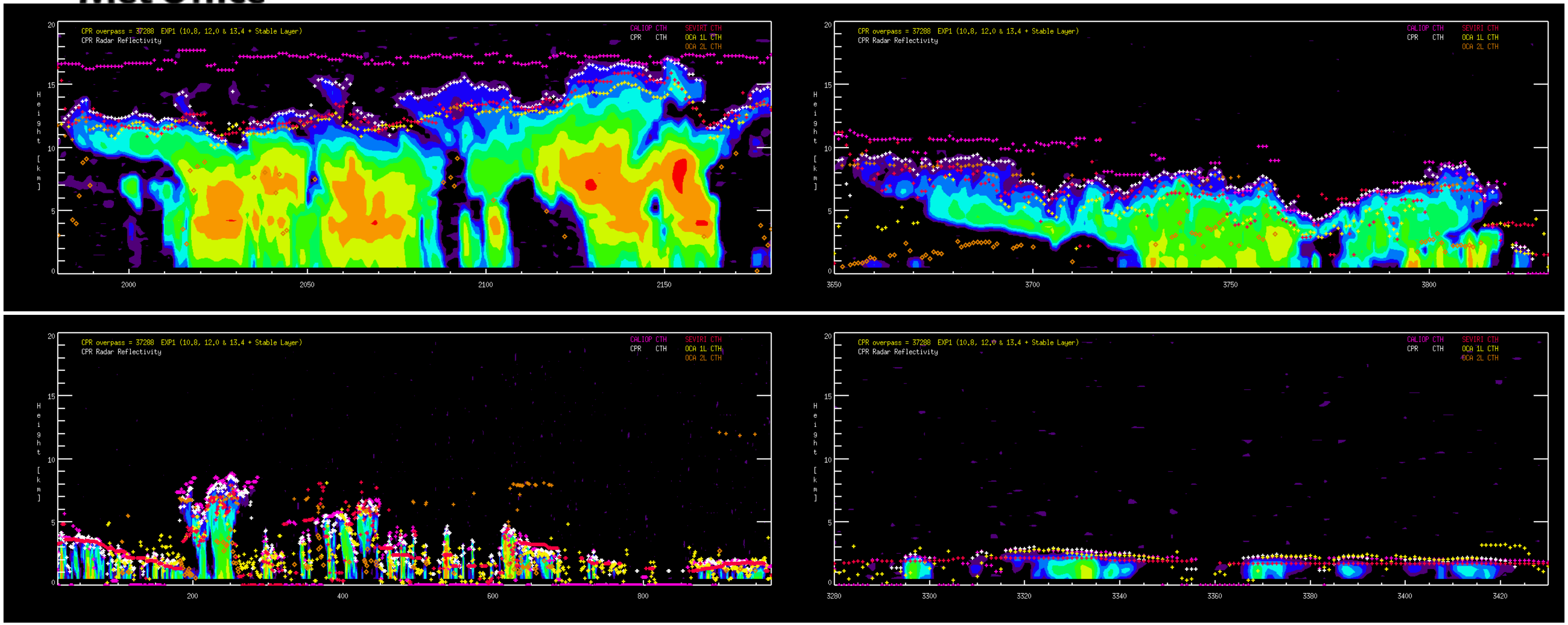
CRWTR OCA1 Overpass 37288
Height (Km)
Along track pixel
3
1
5
4
2
Overpass 37288
01/05/2013
1345, 1400, 1415 UTC
Region 1 : Tropical deep convective clouds
Region 2 : High latitude deep convective clouds
Region 3 : High latitude convective cells (Southern hemisphere ocean)
Region 4 : Mid-latitude low clouds
Region 5 : Thin high clouds with some lower clouds

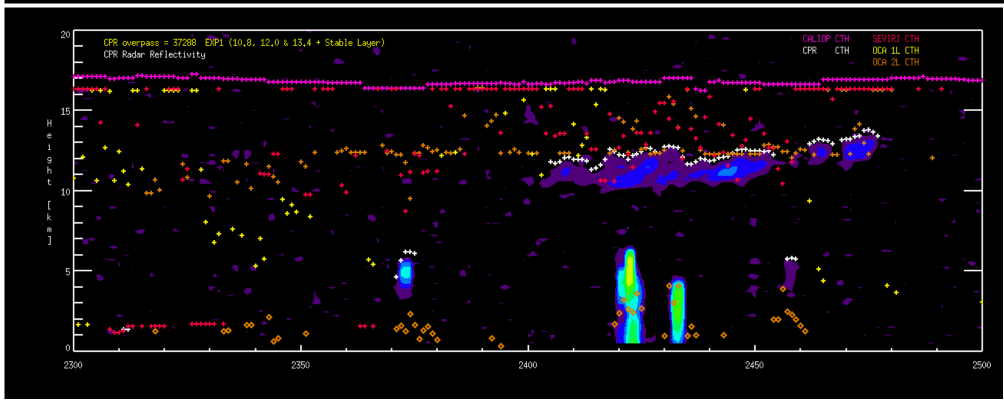
CALIOP CTH
CPR CTH
SEVIRI CTH
OCA (OCA-2L)



Met Office

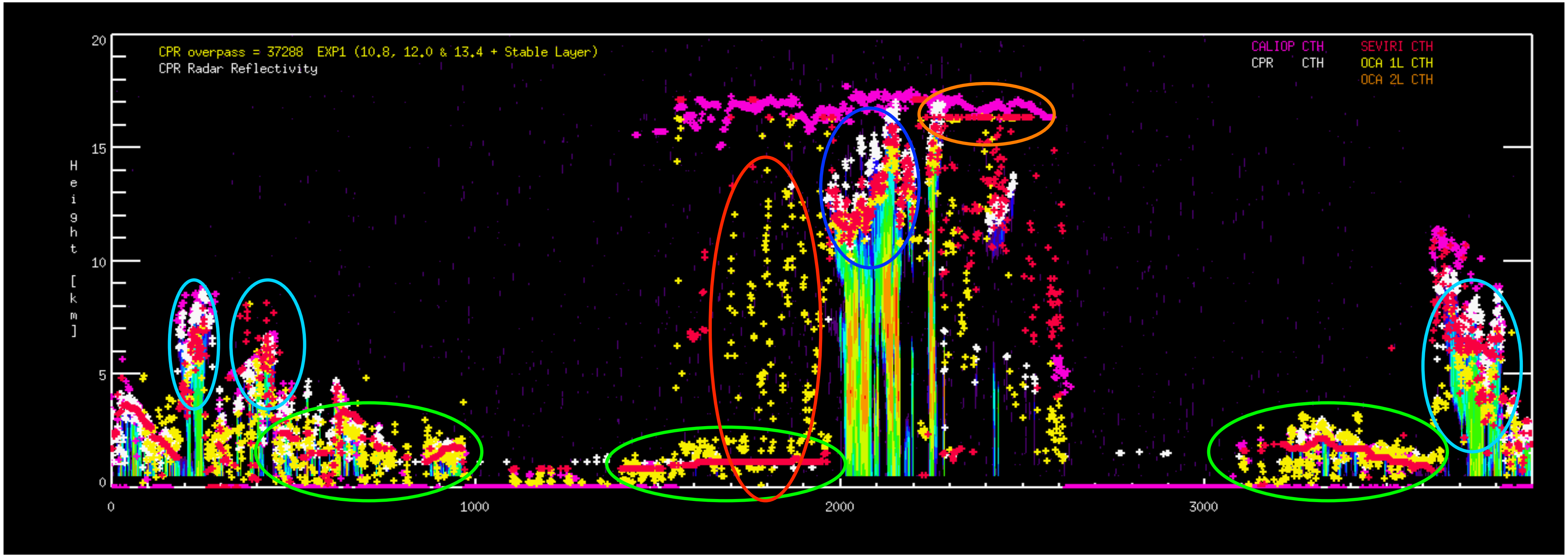


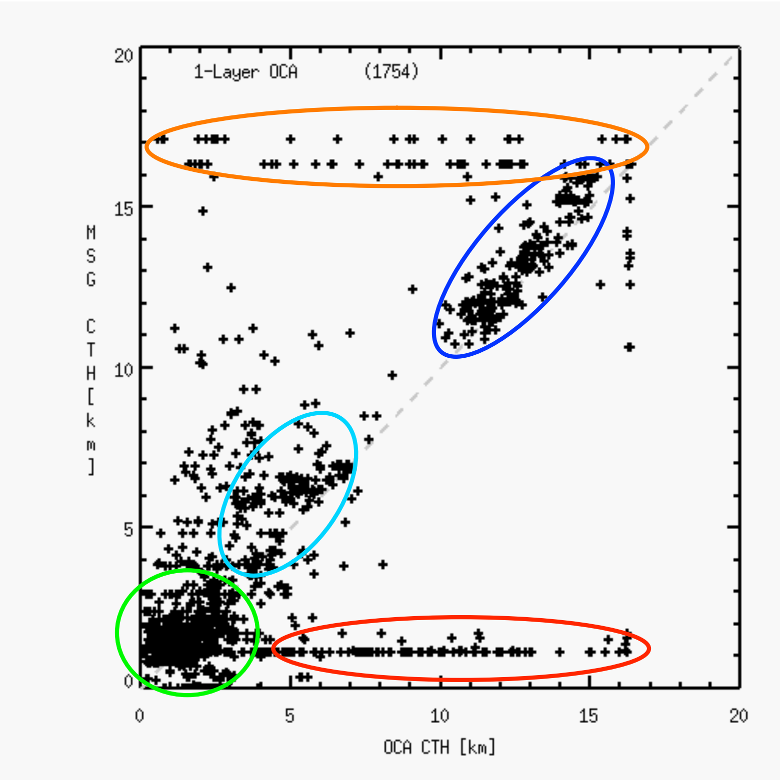


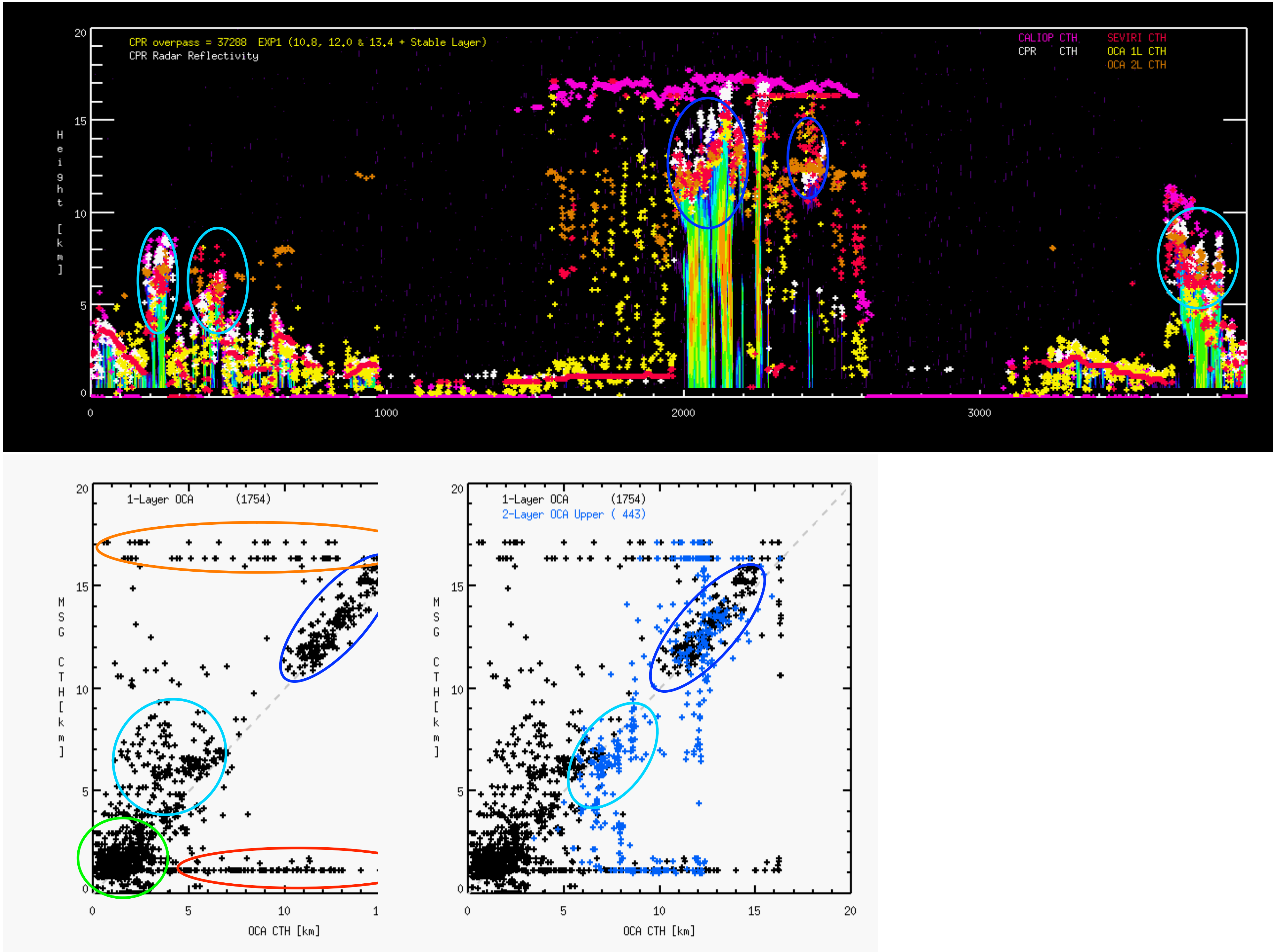


OCA produces a more realistic variation in CTH than GeoCloud for low-level clouds

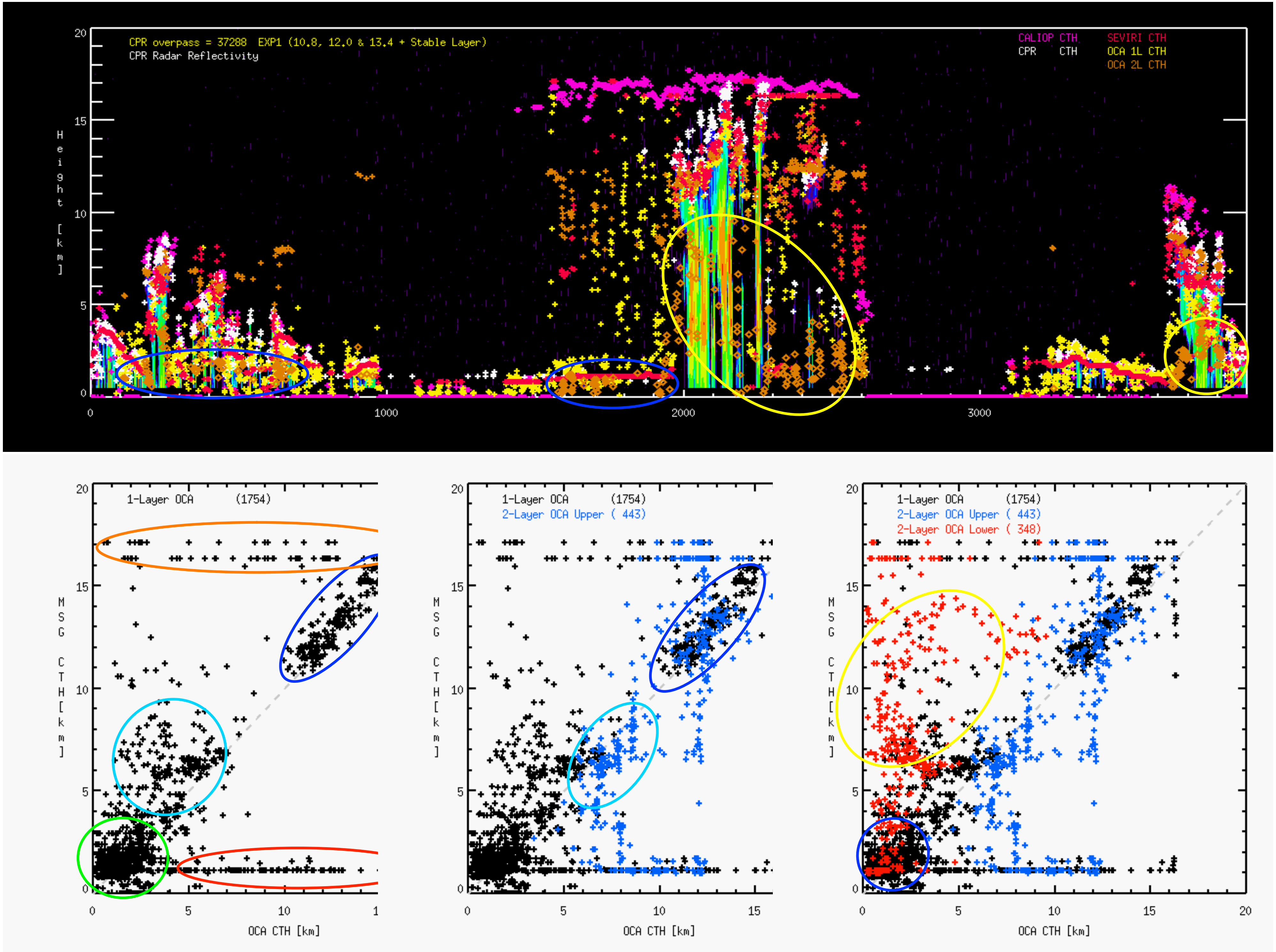
OCA is less good than GeoCloud at detecting very thin high-altitude cloud in this particular case
OCA can produce CTH better for multi-layered cloud-top information below the thin cirrus


CPR overpass = 37288 EXP1 (10.8, 12.0 & 13.4 + Stable Layer)
CPR Radar Reflectivity
CALIOP CTH
CPR CTH
SEVIRI CTH
OCA 1L CTH
OCA 2L CTH
Height [km]
20
15
10
5
0
0
1000
2000
3000


1-Layer OCA (1754)
MSG CTH [km]
OCA CTH [km]
20
15
10
5
0
0
5
10
15
20



CPR overpass = 37288 EXP1 (10.8, 12.0 & 13.4 + Stable Layer)
CPR Radar Reflectivity
CALIOP CTH
CPR CTH
SEVIRI CTH
OCA 1L CTH
OCA 2L CTH
Height [km]
1-Layer OCA (1754)
2-Layer OCA Upper (443)
MSG CTH [km]
OCA CTH [km]


CPR overpass = 37288 EXP1 (10.8, 12.0 & 13.4 + Stable Layer)
CPR Radar Reflectivity
CALIOP CTH
CPR CTH
SEVIRI CTH
OCA 1L CTH
OCA 2L CTH
Height [km]
1-Layer OCA (1754)
2-Layer OCA Upper (443)
2-Layer OCA Lower (348)
MSG CTH [km]
OCA CTH [km]

Summary and Future plans

Met Office

- GeoCloud CTH are investigated comparing with A-Train products using AVAC-S
  - 10.8, 12.0 and 13.4 um Minimum Residual thought to be the best choice for MR CTH approach through the MR sensitivity tests with various channel combinations
  - GeoCloud CTH found to be very sensitive to CO_2 channel bias correction changes
  - Continue to monitor the GeoCloud CTHs vs. CPR and CALIOP
- Comparison with OCA have shown similarities and differences!
  - Would like to continue to explore reasons for the differences
- Introduce OCA's 2-Layer approach into MO 1DVAR-Cloud

Met Office

Thank you !

MR Sensitivity Tests

MR sensitivity tests

OPS : Original operating algorithm : processes every 2 pixel steps

EXP1 : Full pixel resolution

EXP2 : EXP1 + increased CO2 channel R_Matrix (0.57K → 1.5K)

EXP3 : EXP1 + 5 channels algorithm (6.2, 7.3, 10.8, 12.0, 13.4)

EXP4 : EXP1 + Minimum Residual Only

EXP5 : EXP2 + Minimum Residual Only

EXP6 : EXP3 + Minimum Residual Only

EXP7 : MR only with 10.8, 12.0 and 6.2 um

EXP8 : MR only with 10.8, 12.0 and 7.3 um

EXP9 : MR only with 10.8, 12.0, and 6.2, 7.3 um

EXP10-11 : 5-ch MR + Stable Layer (EXP3) but with different R_Matrix and bias correction increments

EXP12 : MR with 6.2 + SL

EXP13 : MR with 6.2, 7.3 um + SL

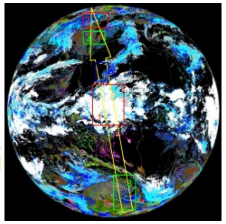
		R_Matrix	Bias_corr_incr
OPS & EXP3, EXP6-9 12-13	WV6.2	3.40	0.05
	WV7.3	2.19	-0.40
	IR13.4	0.57	-1.15
EXP2 & EXP5	WV6.2	3.40	0.05
	WV7.3	2.19	-0.40
	IR13.4	1.50	-1.15
EXP10	WV6.2	1.60	0.65
	WV7.3	1.13	0.20
	IR13.4	0.89	-0.90
EXP11	WV6.2	1.60	0.65
	WV7.3	1.13	0.20
	IR13.4	1.69	-0.90

With or Without Stable Layer method

MR using different channel combinations

Different R_Matrix and/or BC increments

CALIOP
CPR
SEVIRI – Uniform
SEVIRI – Not Uni.
OCA



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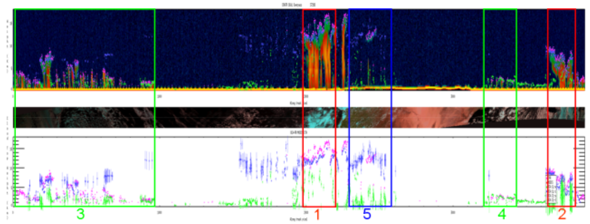
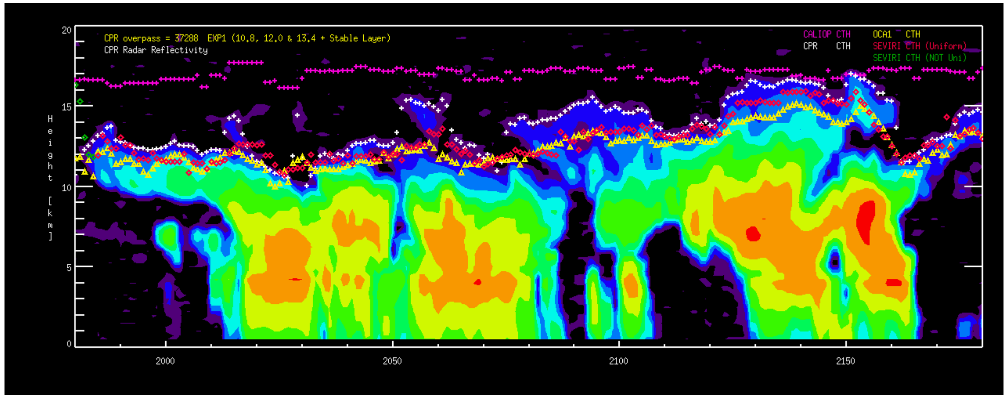
EXP1 ~ OPS

MR with 10.8, 12.0 and 13.4 + SL



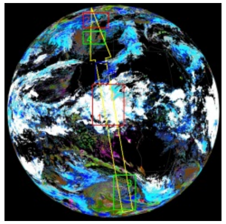
Region 1 : Tropical Deep convective clouds



No large sensitivity on MR tests, regardless of SL on/off.

WV7.3 MR (EXP8) derives CTH slightly lower

CALIOP
CPR
SEVIRI – Uniform
SEVIRI – Not Uni.
OCA



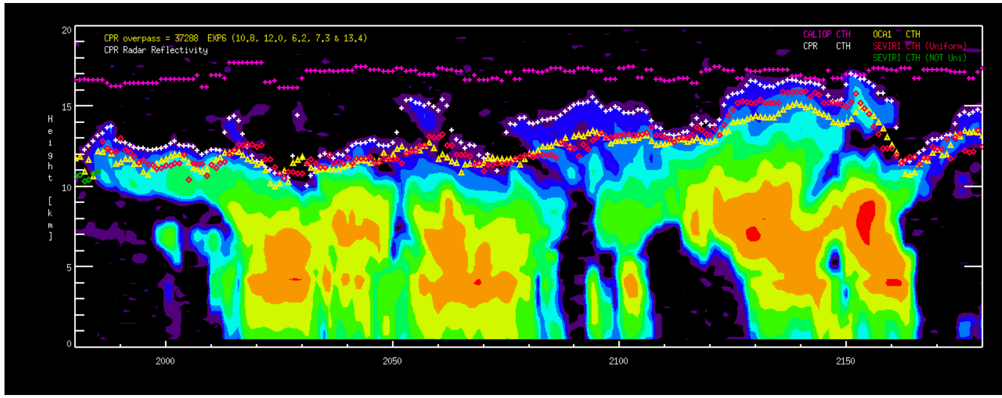
EXP6

MR only with 5 channels

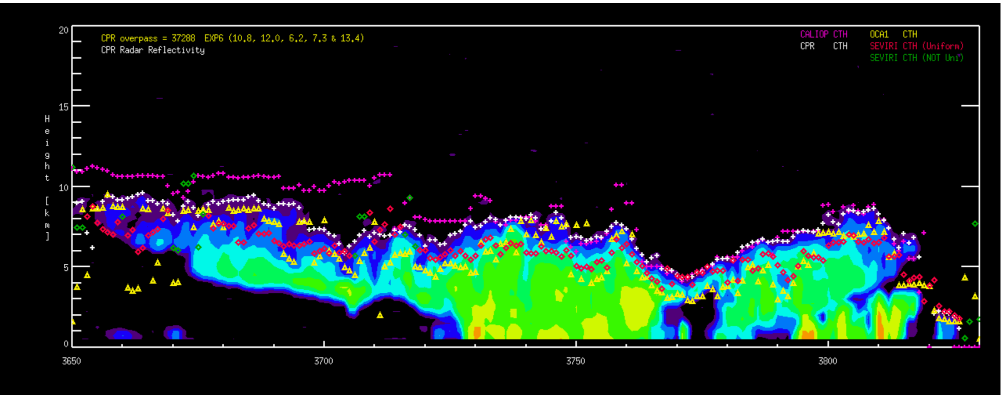
		R_Matrix	BC_incr
EXP3 & EXP6	WV6.2	3.40	0.05
	WV7.3	2.19	-0.40
	IR13.4	0.57	-1.15
EXP10	WV6.2	1.60	0.65
	WV7.3	1.13	0.20
	IR13.4	0.89	-0.90

Met Office

Region 1 : Tropical Deep convective clouds

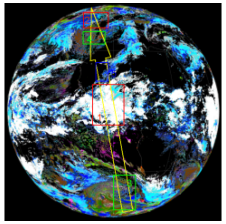


Region 2 : High latitude convective clouds



WV6.2 MR (EXP7) derives CTH much higher

CALIOP
CPR
SEVIRI – Uniform
SEVIRI – Not Uni.
OCA



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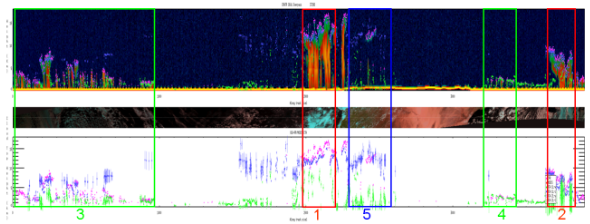
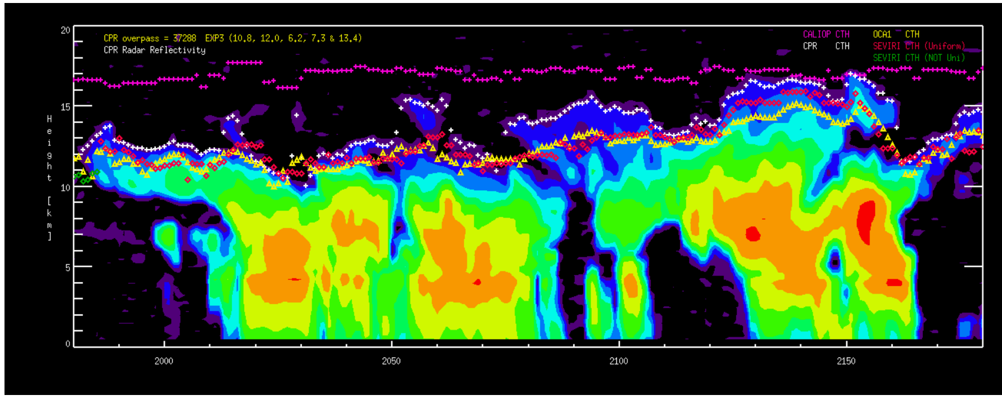
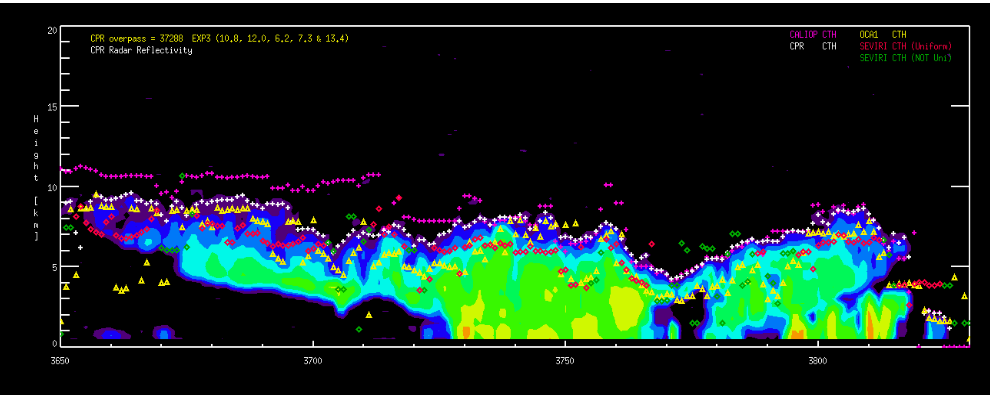
EXP3
MR with 5 channels + SL



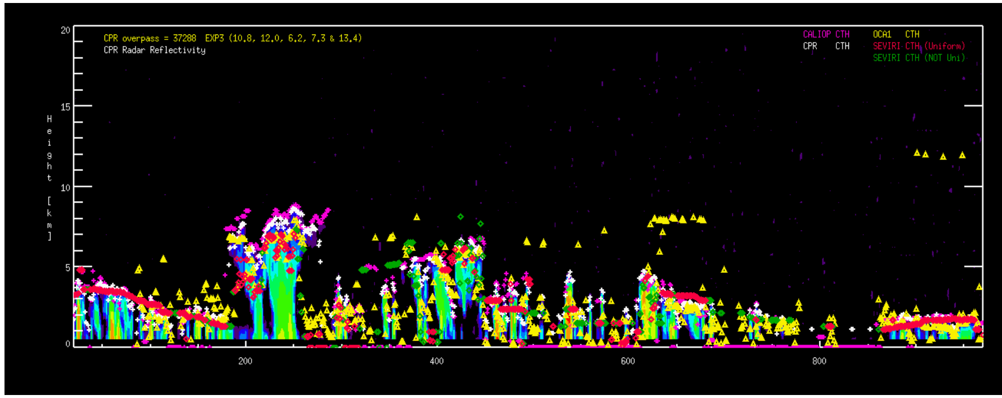
Region 1 : Tropical Deep convective clouds



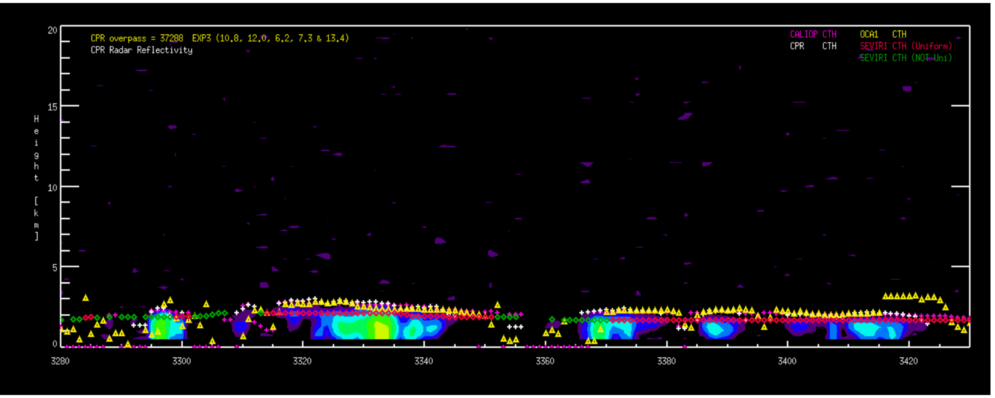
Region 2 : High latitude convective clouds



Region 3 : High latitude convective cells (SH ocean)



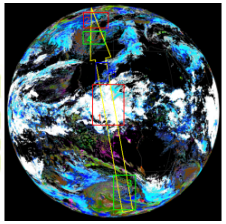
Region 4 : Mid-latitude low clouds



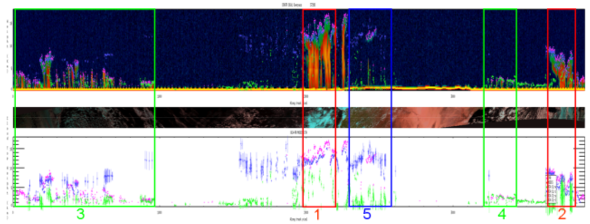
WV7.3 using MR shows good impact for lower CTH retrieval

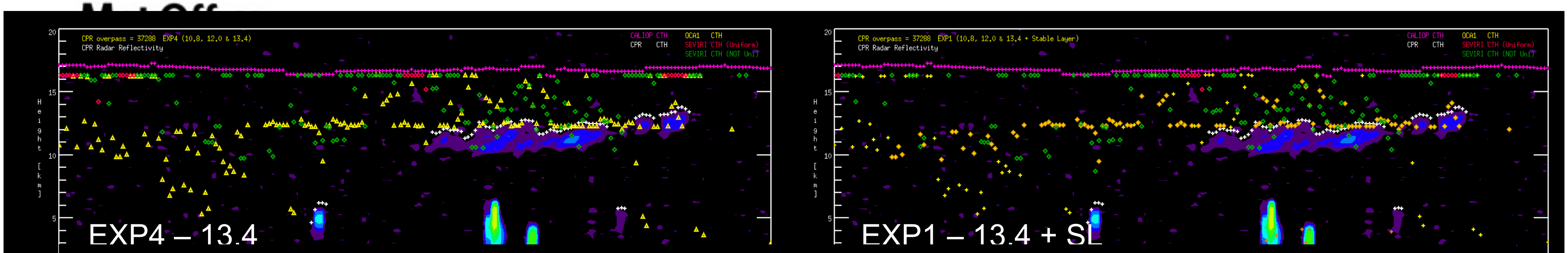
SL method looks more effective and powerful, however not produces pixel-resolution features

CALIOP
CPR
SEVIRI – Uniform
SEVIRI – Not Uni.
OCA (OCA-2)



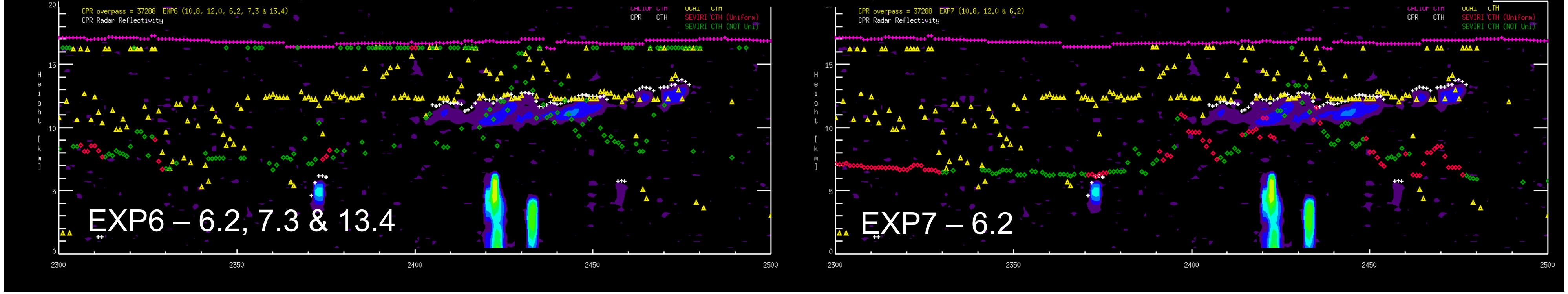
Region 5
Thin high clouds with lower clouds

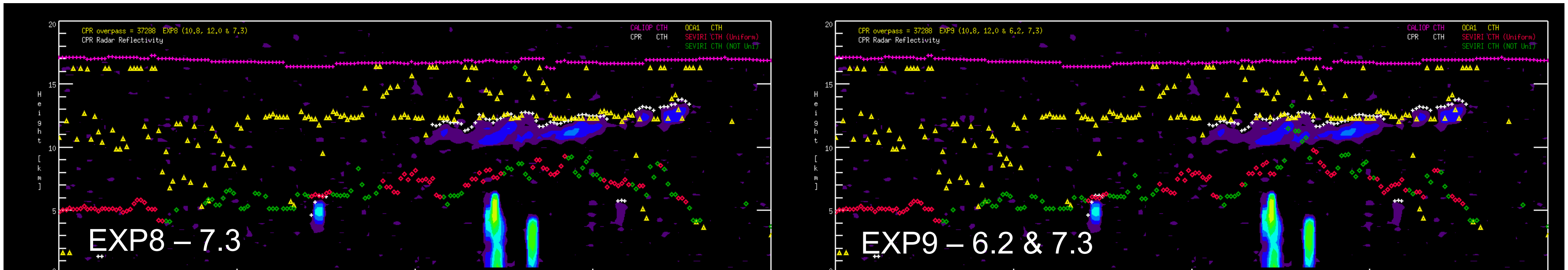




CO2 MR seems to be able to detect high level thin cloud around tropopause level

Can not assign multi layered cloud top properly, which OCA does better





WV channel using MR is a lot weaker to resolve it.

Overpass 37288

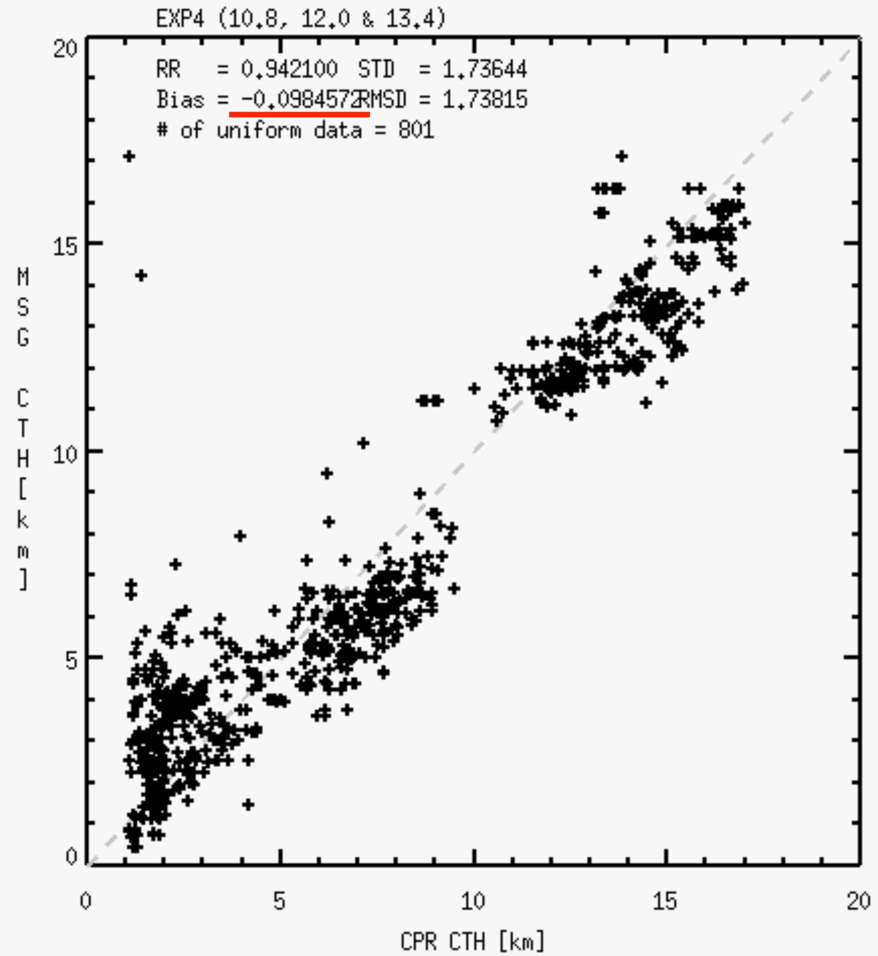
MO CLD vs CPR for full CPR overpass 37288

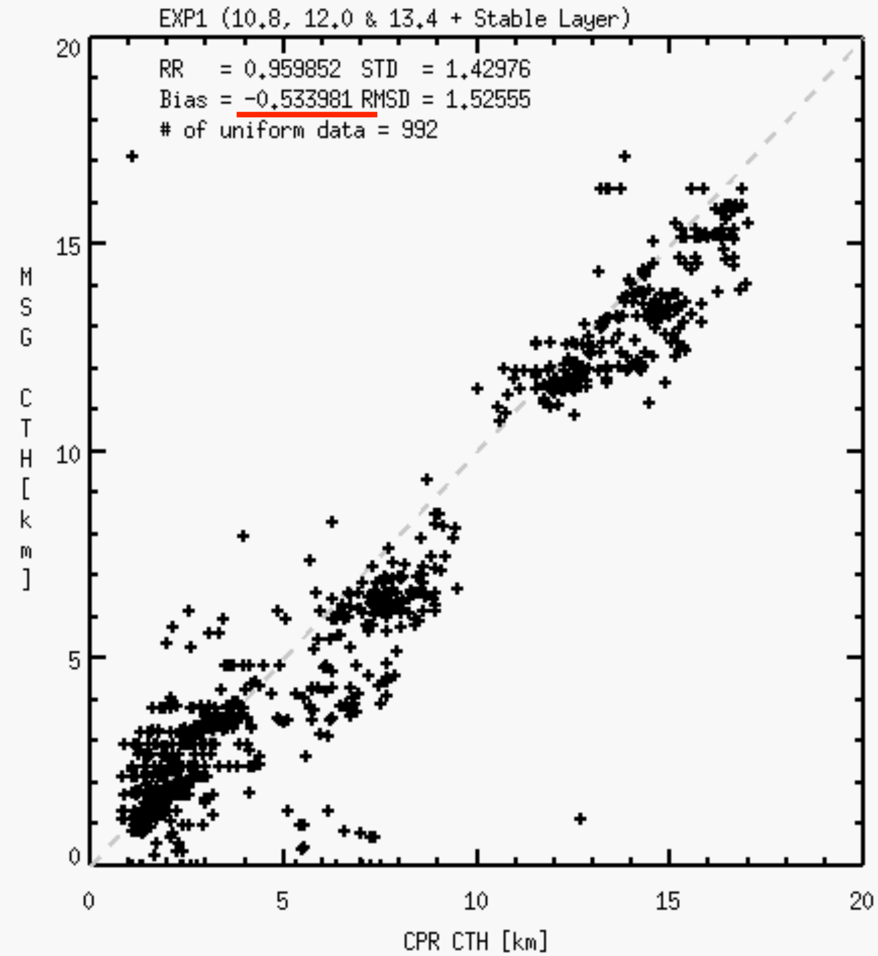
EXP ID	R	bias	STD	N(3900)	Contents
EXP4 **(WINs + 13.4)**	0.942	-0.098	1.74	801	**EXP4 & 5 have good R and small biases. Small biases are regarded that arise from weakness to assign low-level cloud. Also produce smaller number of homogeneous CTH data.**
EXP5 **(WINs + 13.4')**	0.943	-0.086	1.72	813	
EXP6 **(WINs + 6.2, 7.3, 13.4)**	0.941	-0.243	1.68	1007	**More homogeneous**
EXP7 **(WINs + 6.2)**	0.921	0.057	2.03	952	**EXP7 retrieves the mid- and lower-cloud higher than CPR**
EXP8 **(WINs + 7.3)**	0.929	-0.734	1.82	1188	**WV without CO2 (EXP7-9) MR tests show the weakness to assign the CTH for cirrus clouds that derive larger negative bias**
EXP9 **(WINs + 6.2, 7.3)**	0.933	-0.682	1.81	1150	
EXP1 **(WINs + 13.4 + SL)**	0.960	-0.534	1.43	992	**SL derives lower level CTH more stable, though it describes pixel resolution texture less** **CO2 and 5 channel MR make better R and STD results. GeoCloud CTH is about 5-600m lower than CPR CTH** **CO2 MR shows better performance to detect tropopause level high thin cloud than 5 channel MR**
EXP3 **(5 channels + SL)**	0.958	-0.625	1.42	1009	
EXP10 **(5 channels' + SL)**	0.960	-0.564	1.41	993	
EXP11 **(5 channels" + SL)**	0.958	-0.681	1.48	1015	
EXP12 **(WINs + 6.2 + SL)**	0.954	-0.529	1.53	1013	
EXP13 **(WINs + 6.2, 7.3 + SL)**	0.960	-0.705	1.45	982	

Overpass 37288

MO CLD vs CPR for full CPR overpass 37288

Met Office





1DVAR Cloud

Met Office

SEVIRI channel data

Cloud Mask

First guess CTP determination

Minimum Residual | Stable Layer | Profile Matching

1DVAR (Francis et. al., 2012)

x = [Pc, LWC, Re, N]
y = [6.2, 7.3, 8.7, 10.8, 12.0, 13.4]

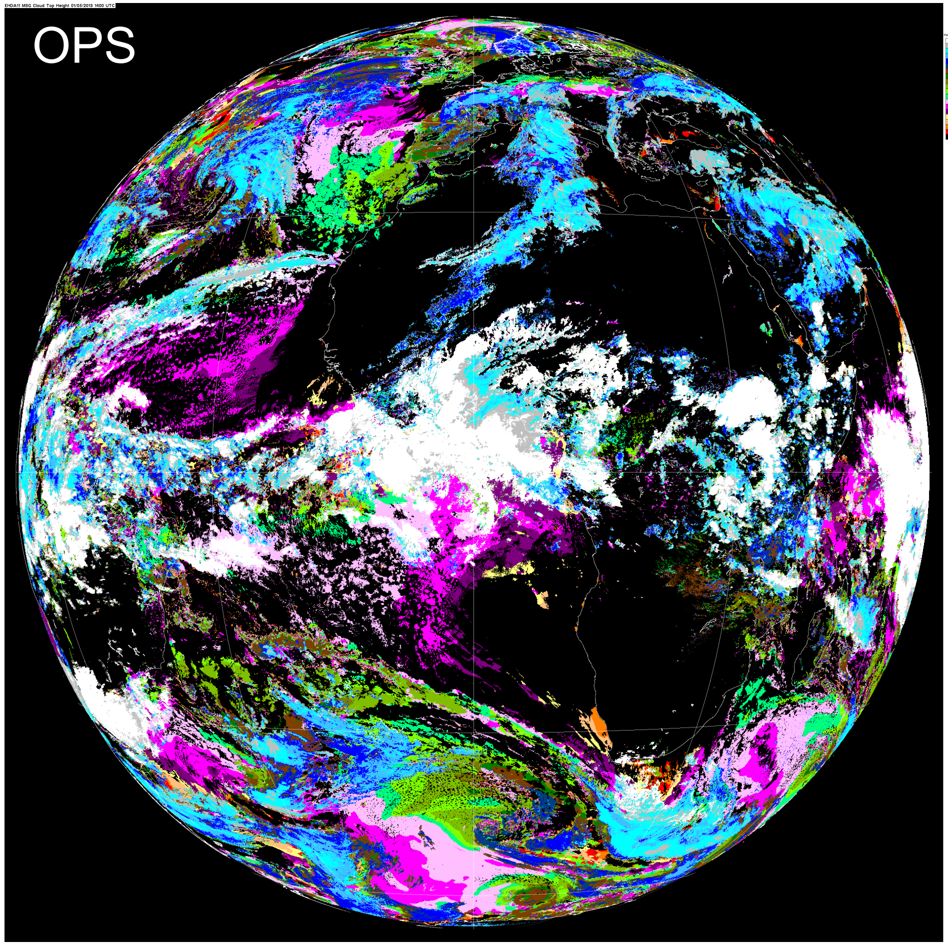
- phase dependent first guess, background state vectors and their constraints
- phase change check during minimization

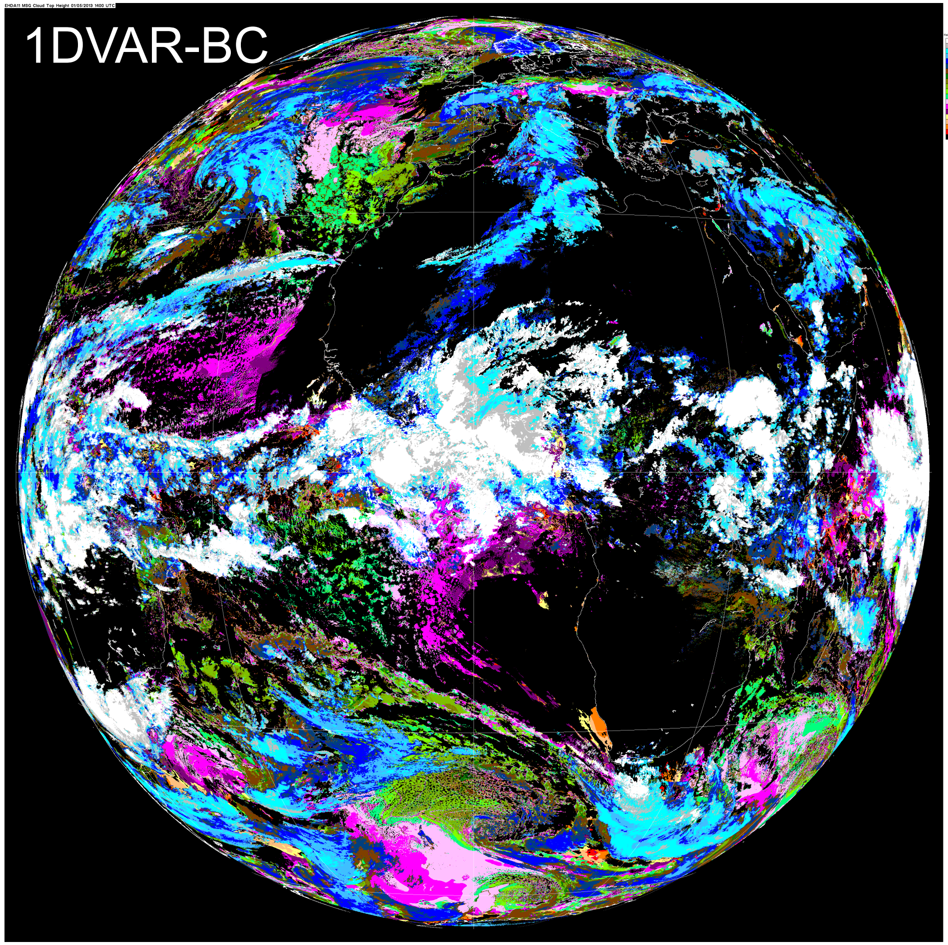
Auxiliary data
-Pixel Lat/Lon
-IGBP surface type
-UM model profile
(T, p, q, H, Orography)
-RTTOV simulation
(Clear & overcast radiances)
-Channel extinction coeff. wrt. Re and Phase

State variables	First guess	Background	
CTP	From MR/SL/PM	700 hPa (water) 400 hPa (ice)	
LWC	30 gm^{-2} (water) 10 gm^{-2} (ice)	30 gm^{-2} (water) 10 gm^{-2} (ice)	
Effective radius	8 um (water) 30 um (ice)	8 um (water) 30 um (ice)	
Cloud fraction	1	1	1.0E-5

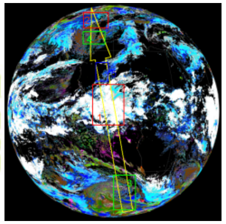
1DVAR-Cloud

1400 UTC, 01/05/2013





CALIOP
CPR
SEVIRI – Uniform
SEVIRI – Not Uni.
OCA



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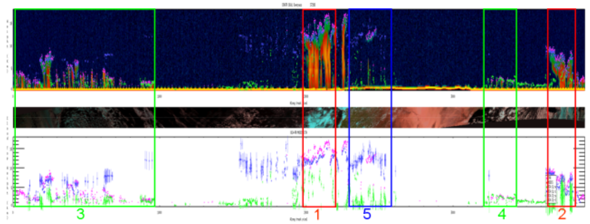
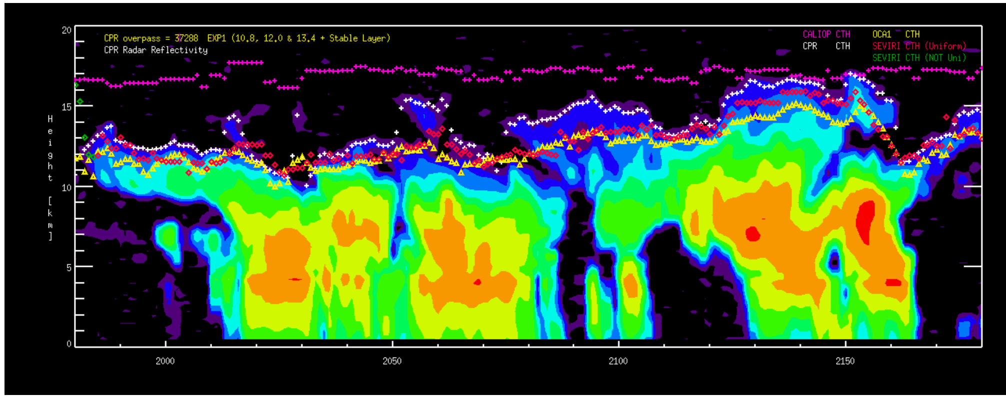
EXP1

MR with 10.8, 12.0 and 13.4 + SL

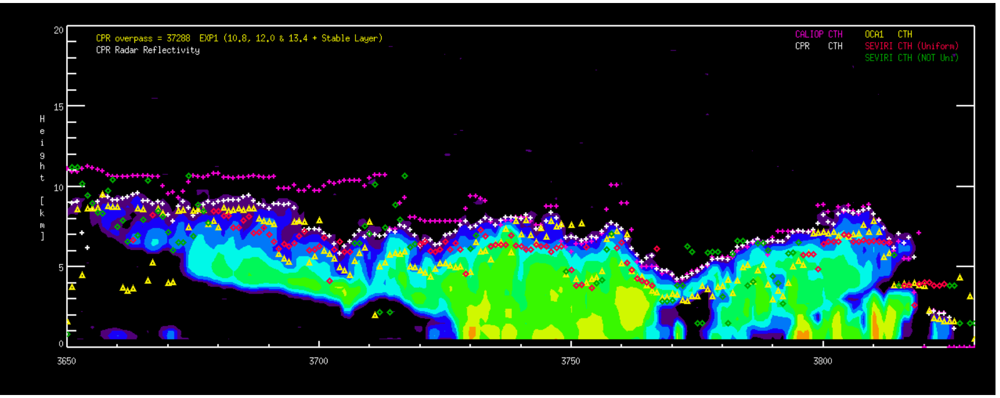


CO2 channel R_Matrix : 0.57

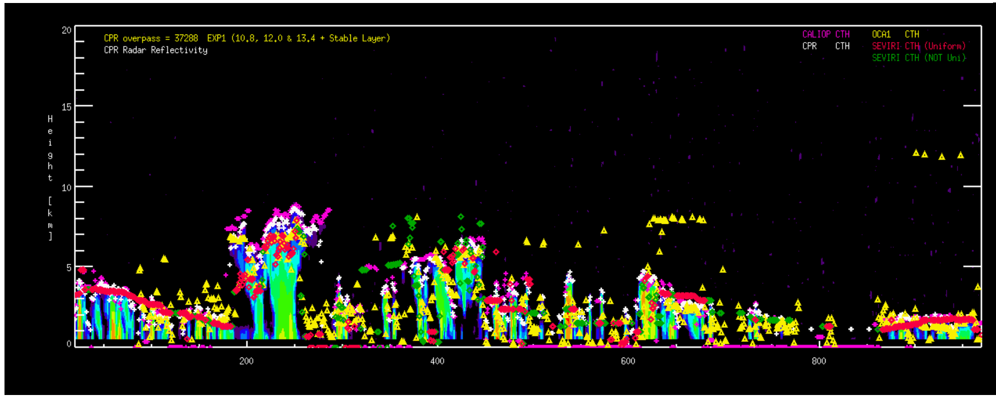
Region 1 : Tropical Deep convective clouds



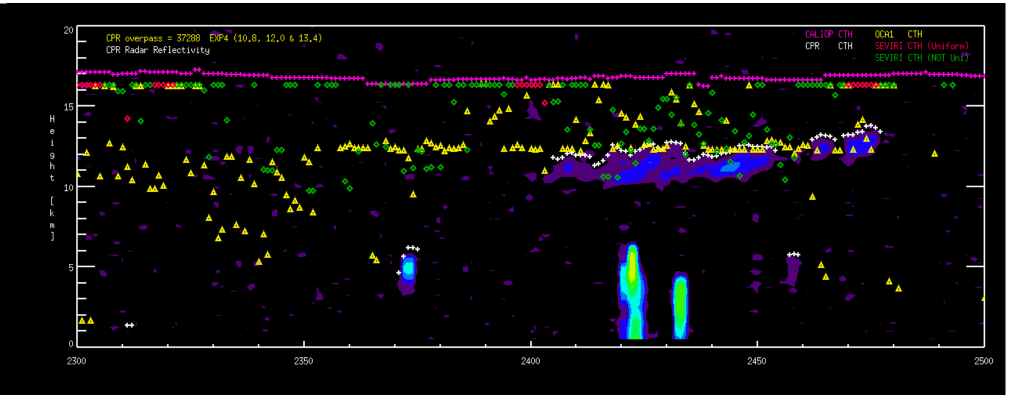
Region 2 : High latitude convective clouds



Region 3 : High latitude convective cells (SH ocean)

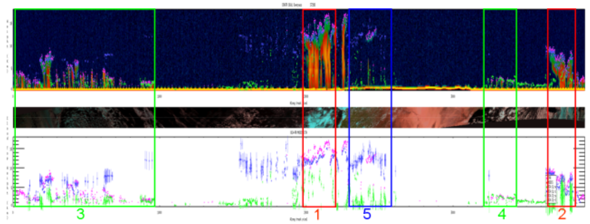


Region 5 : Thin high clouds with lower clouds



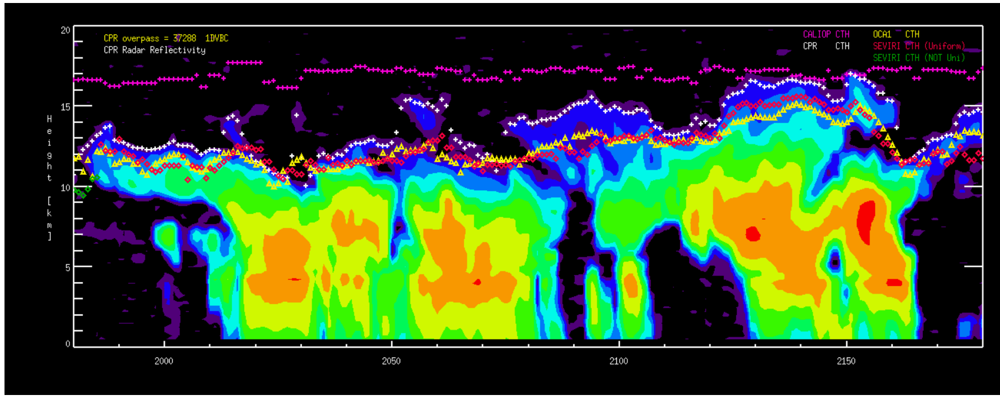
Met Office

1DVAR

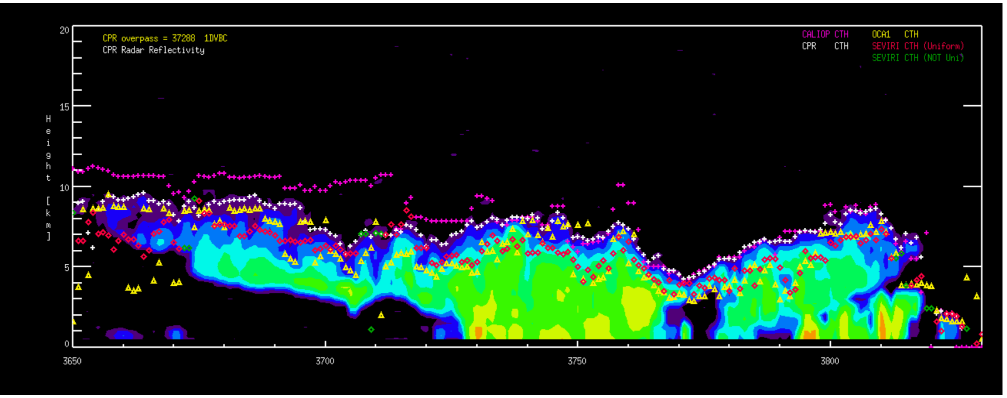


CO2 channel R_Matrix : 1.50

Region 1 : Tropical Deep convective clouds

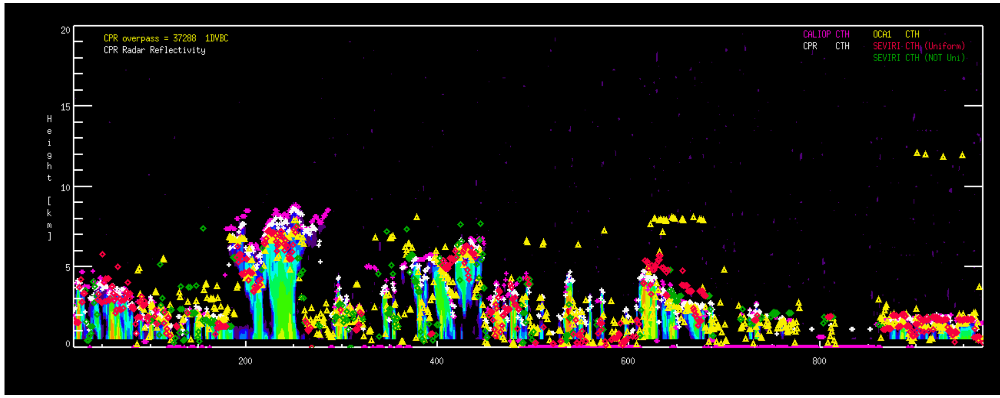


Region 2 : High latitude convective clouds

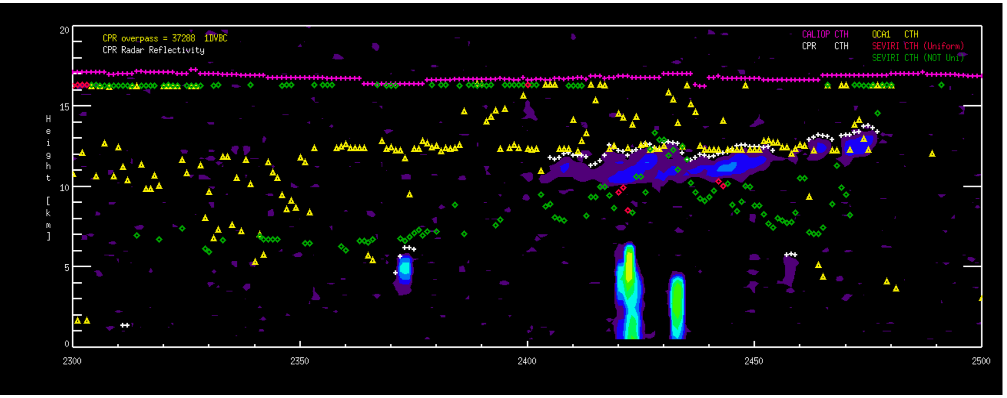


1DVAR-Cloud assigns deep convective cloud top heights slightly lower than MR, and makes them more similar to OCA1 results
1DVAR-Cloud shows the similar trend (lower) over high latitude deep convective cloud region, but makes them more homogenous.

Region 3 : High latitude convective cells (SH ocean)



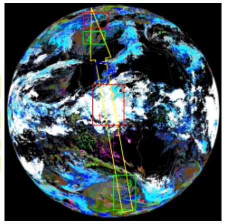
Region 5 : Thin high clouds with lower clouds

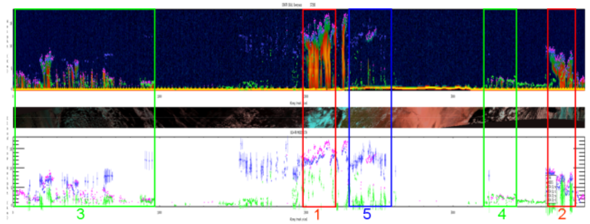


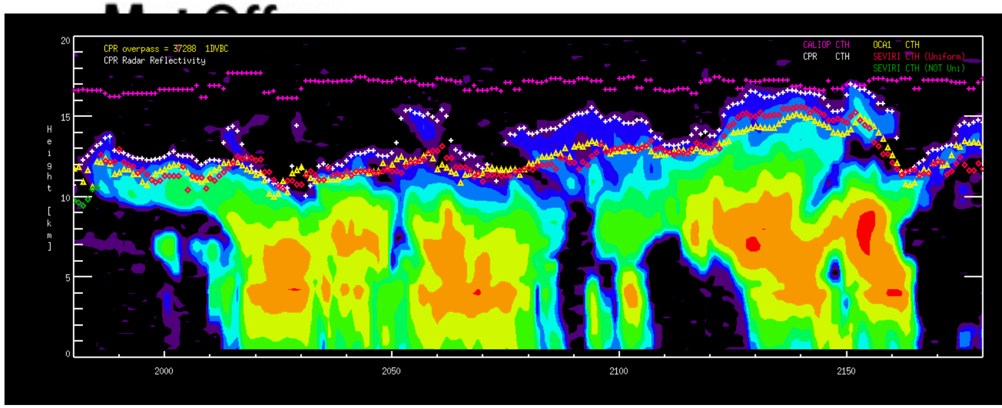
1DVAR-Cloud CTHs over low level convective cells show pixel-resolution feature, whereas SL does not.
In cirrus cloud case, GEO clouds has limitation to assign CTHs when they are very thin.
WV channel using tests (1DVAR as well as MR) show higher weakness

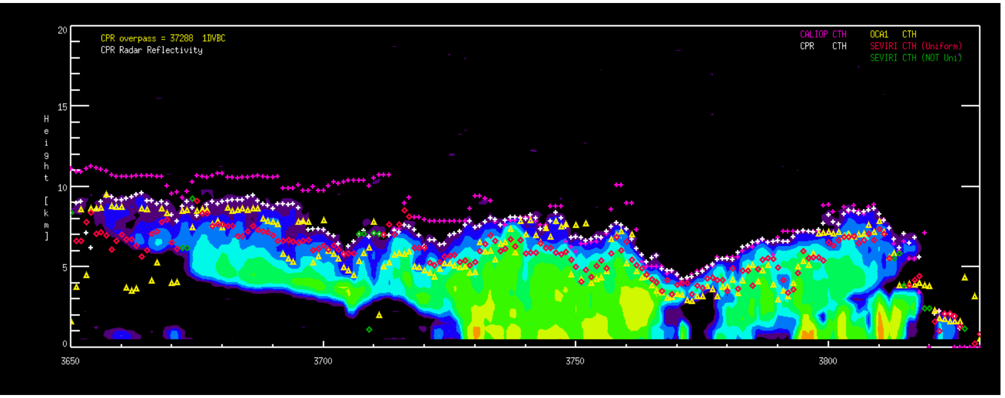
1DVAR

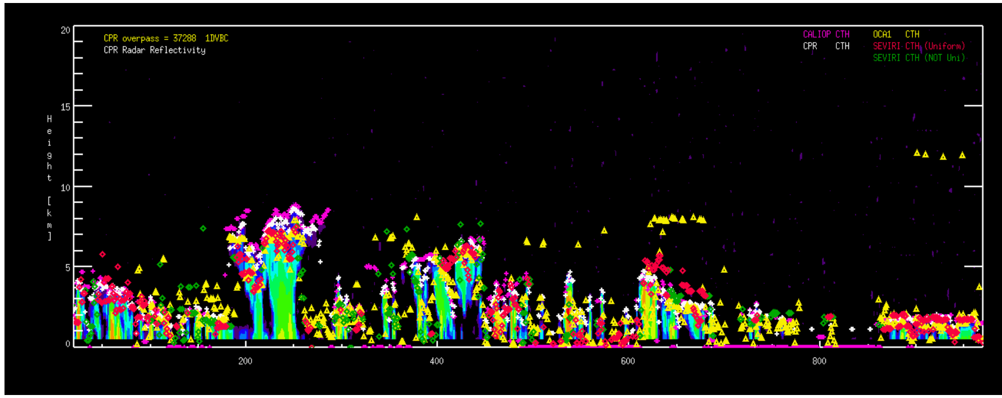
CALIOP
CPR
SEVIRI – Uniform
SEVIRI – Not Uni.
OCA

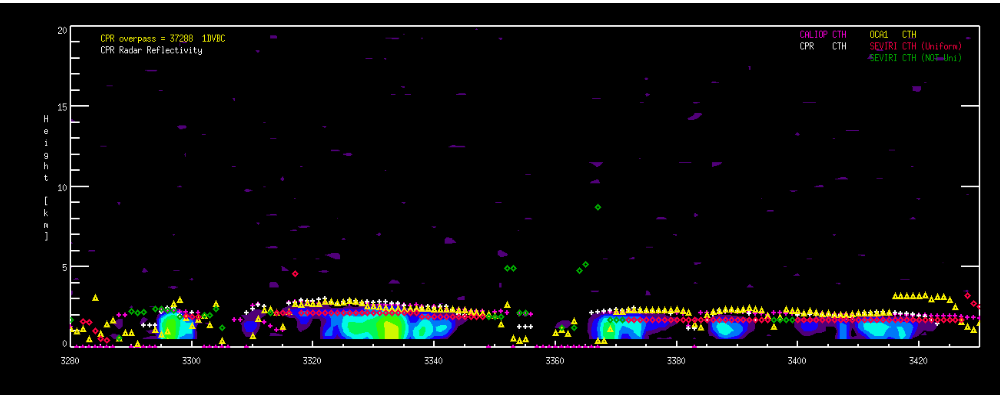


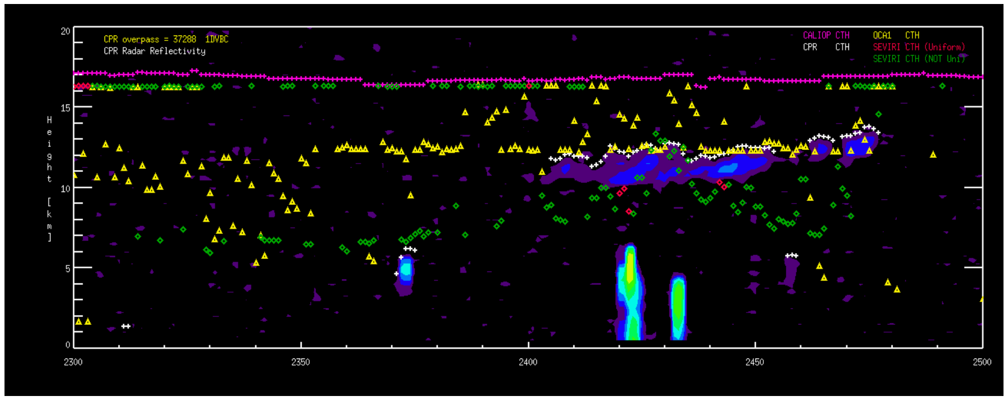






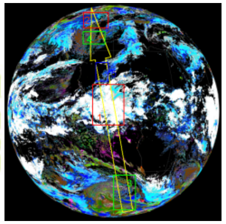


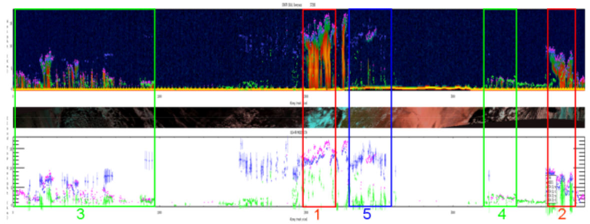


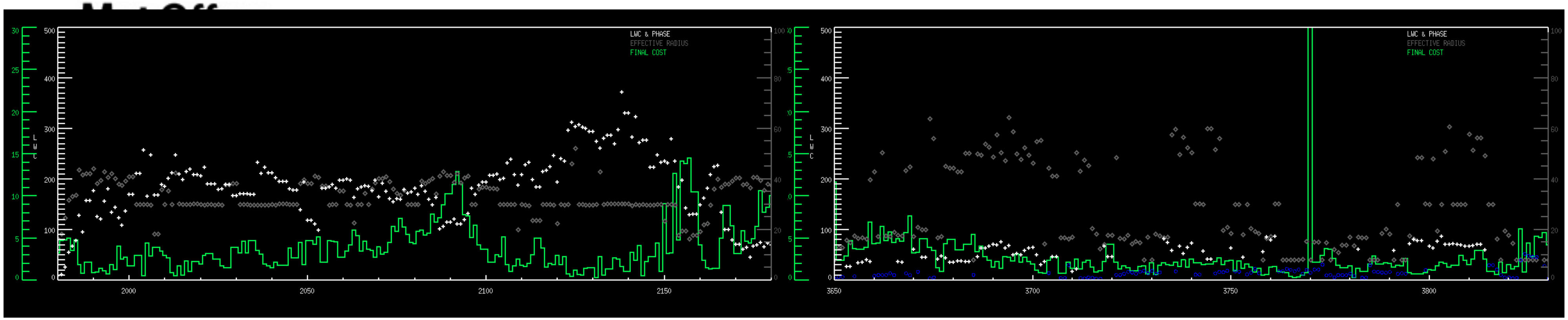


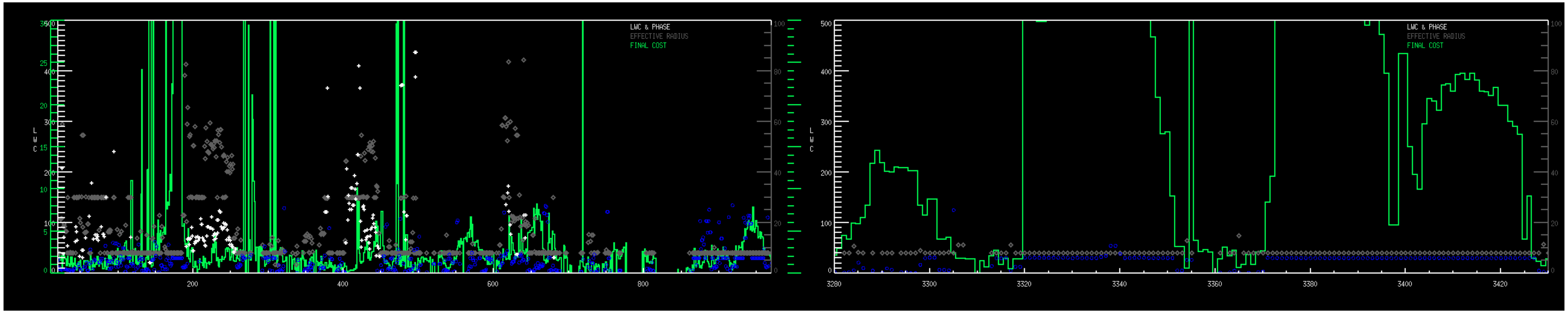
1DVAR

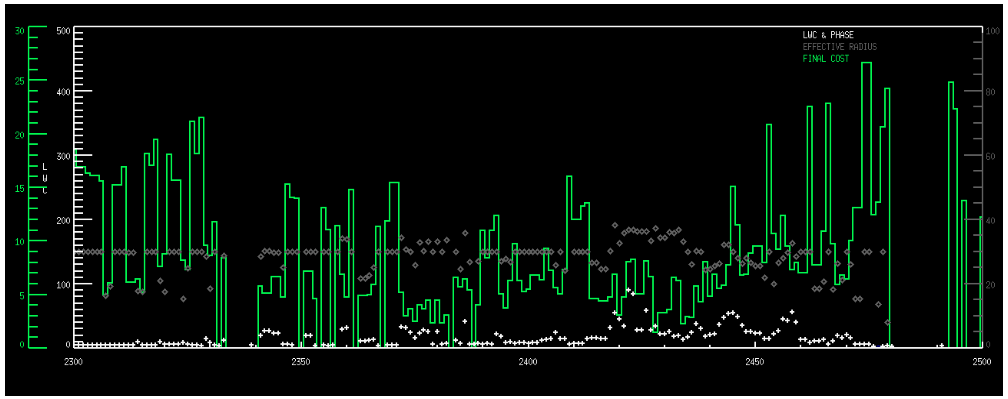
LWC & Phase
(ice, water)
Effective Radius
Final Cost











First guess

Phase	water	ice
Pc (hPa)	Pressure_fg (from MR/SL/PM)	
LWC (g/m2)	**30.0**	**10.0**
Re (um)	**8.0**	**30.0**
N	1.0	1.0