

Oxygen A-band photon path length: Detecting the cloud layer information

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O2 A-band and photon path length distribution

- Photon path length distribution is very sensitive to 3D cloud structures.
- The first two moments of photon path length distribution have sufficient sensitivity to distinguish multiple layer clouds from single layer clouds.

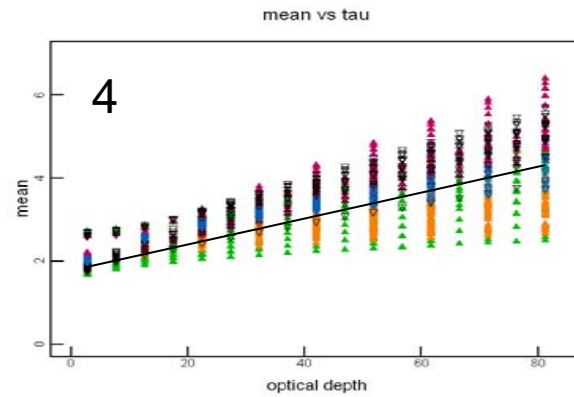
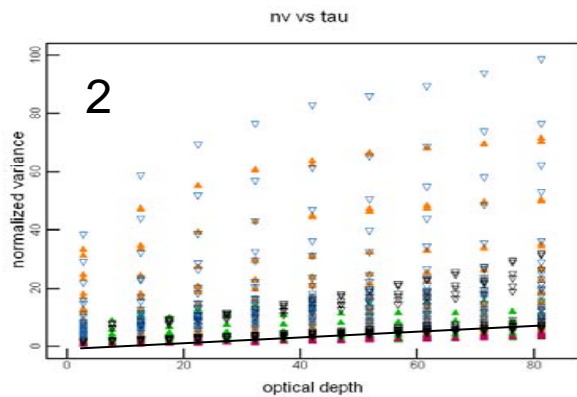
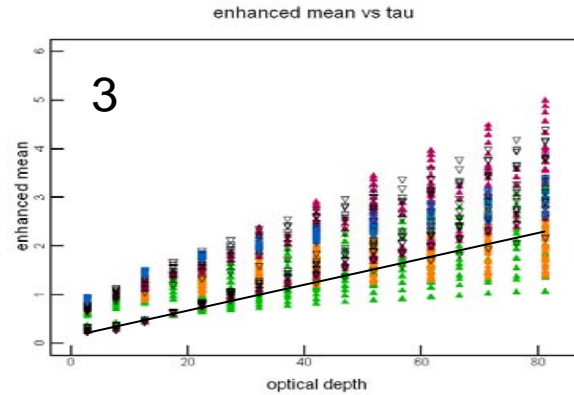
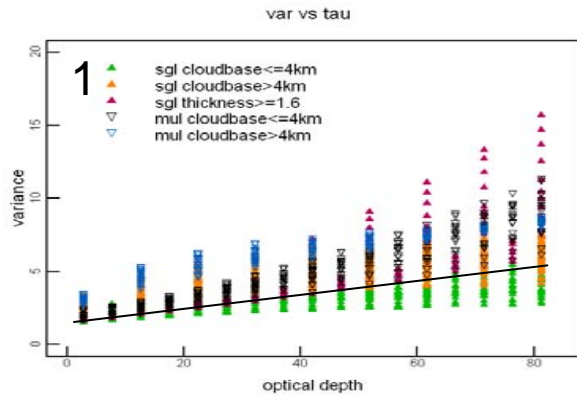
Using photon path length information from RSS, this study is to detect possible “missed” layers by cloud radar.

▪ Approach:

Monte Carlo simulations as “ground true” for cloud detection.

- Mean and Variance of photon pathlength distribution from RSS
- Cloud optical depth from MFRSR
- The lowest cloud layer information (cloud base and thickness) from cloud radar

MC simulations (thousand cases) :



Four step approach:

- Variance of PLD: relatively thin single-layer clouds
- Normalized Variance of PLD: Thick single-layer clouds using O2 depth of the lowest layer for normalization
- Enhanced mean pathlength: Single layer clouds with large solar zenith angles
- Mean Pathlength: High single layer clouds

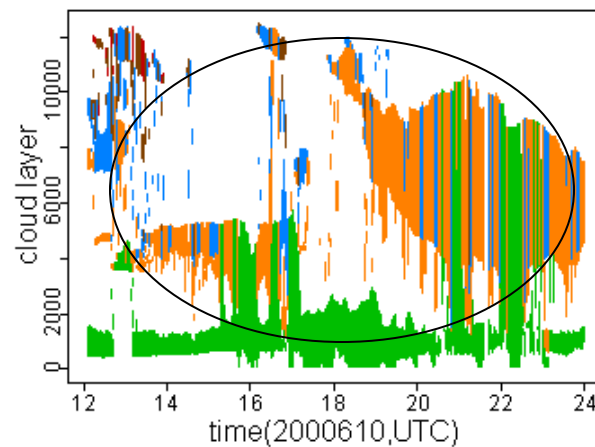
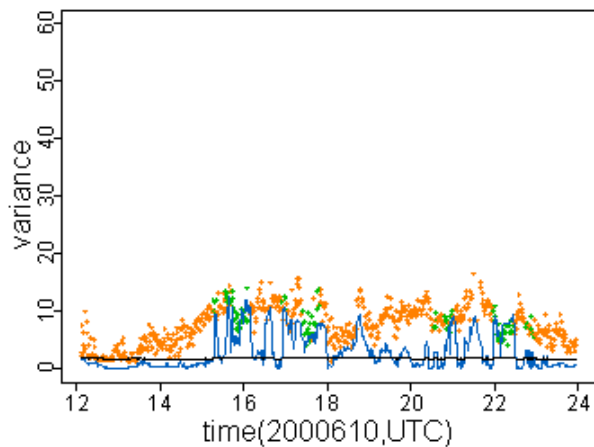
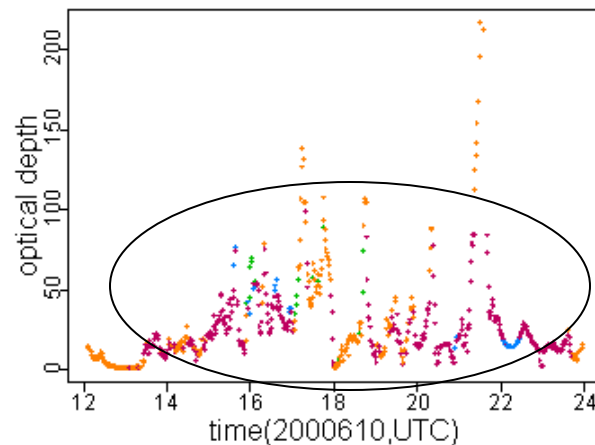
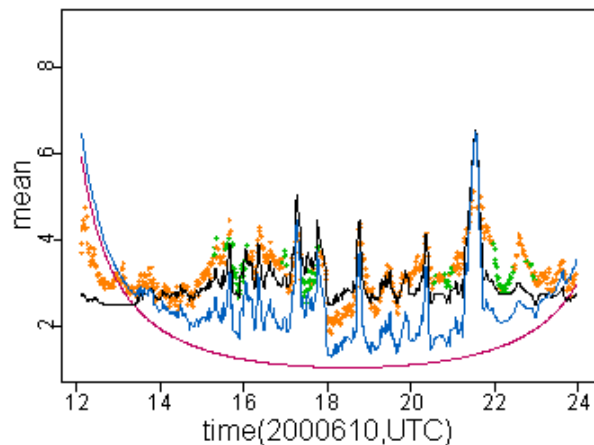
Normal conditions (MC simulation)

About 30% multiple-layer clouds are removed with single-layer clouds

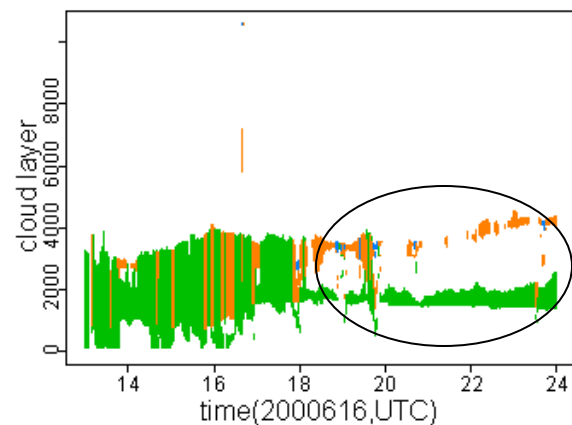
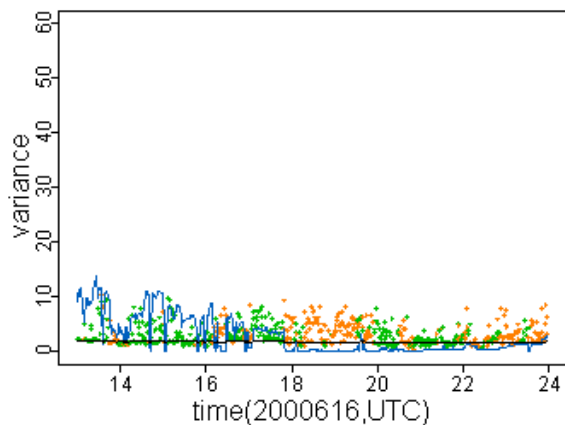
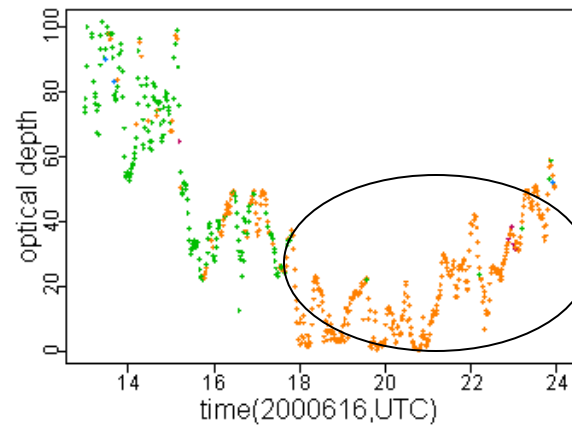
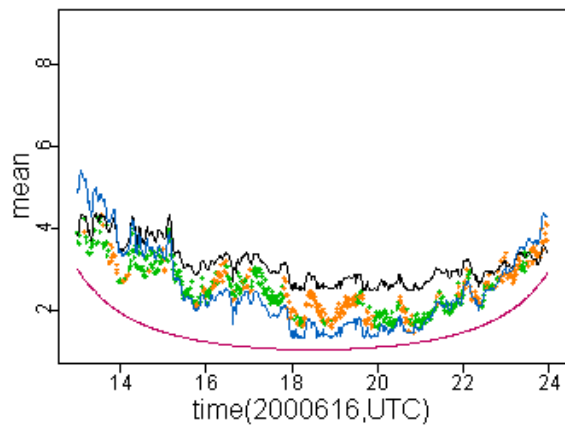
More strict conditions (MC simulation)

About 57% multiple-layer clouds are removed with single-layer clouds.

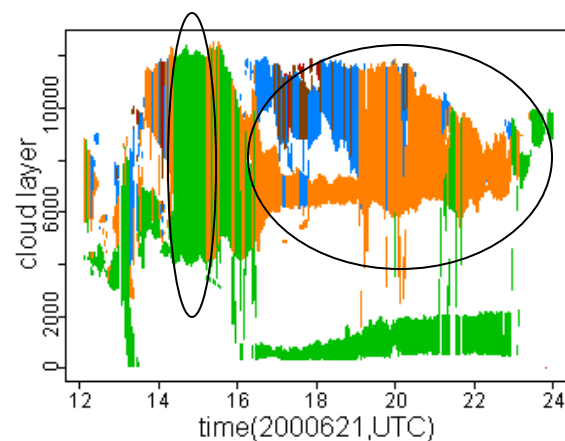
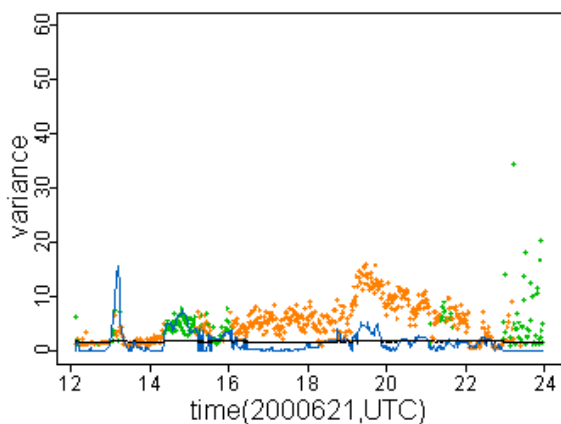
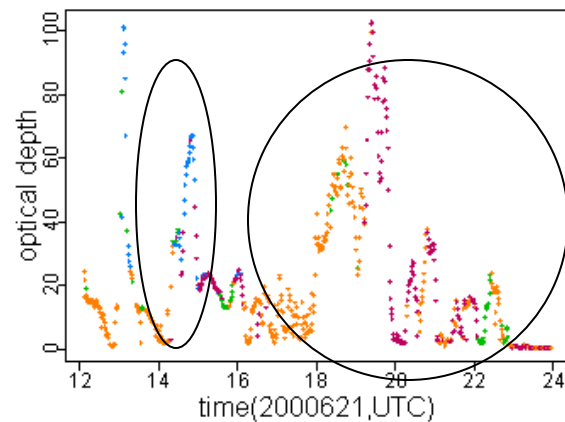
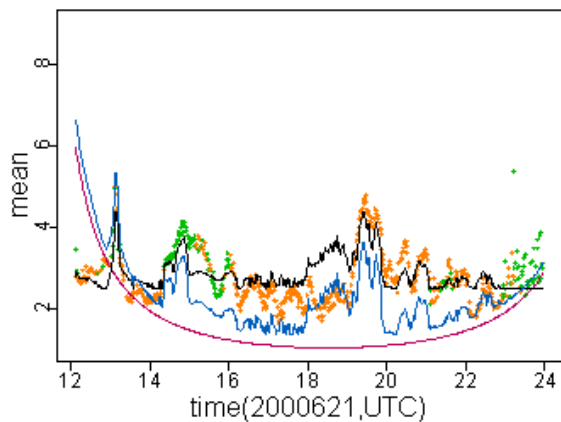
Case: Consistent with radar observation



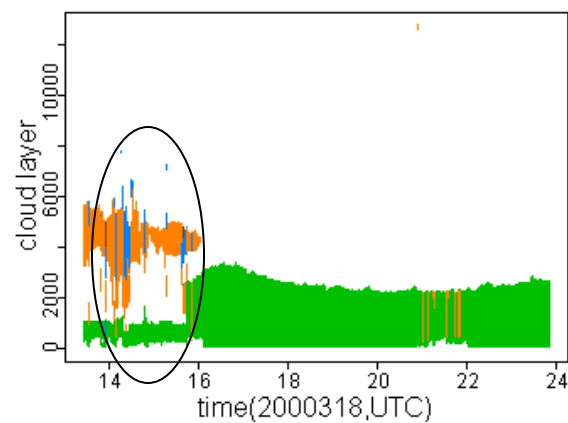
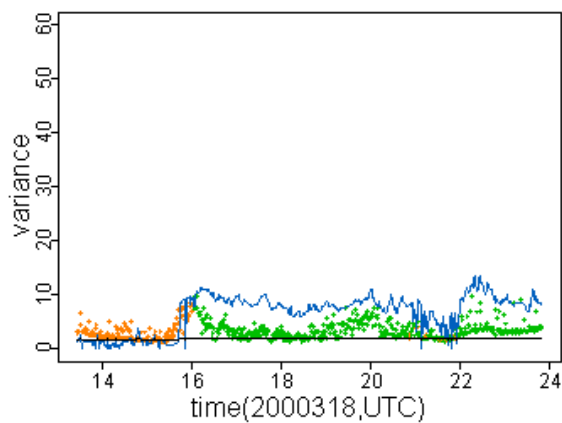
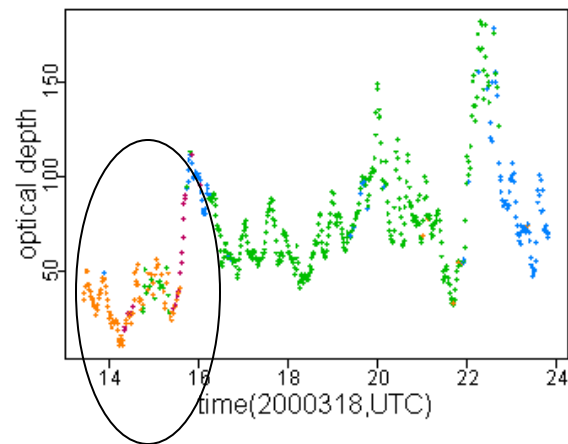
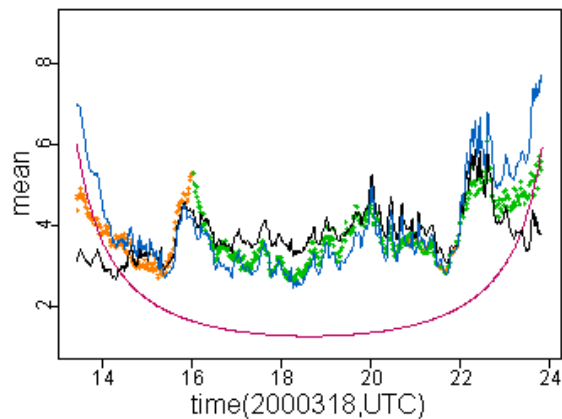
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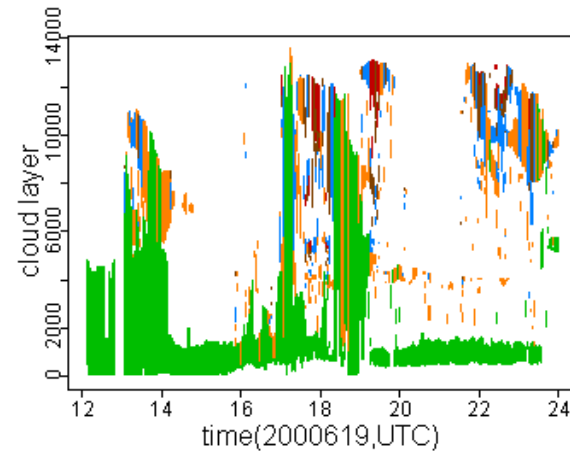
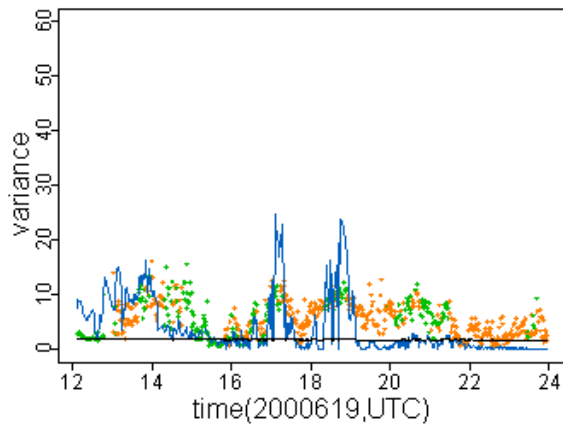
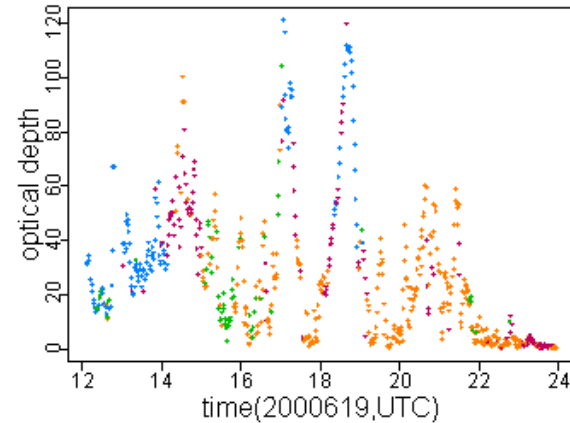
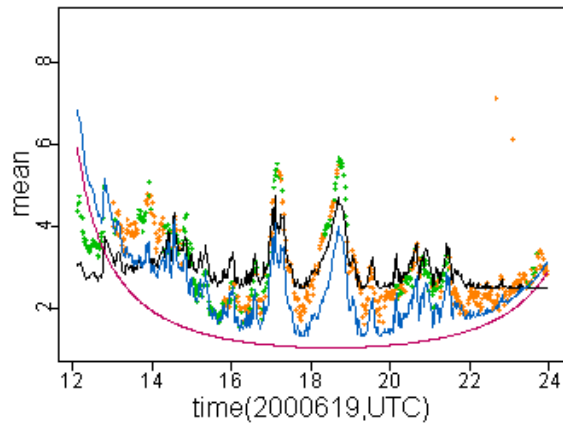
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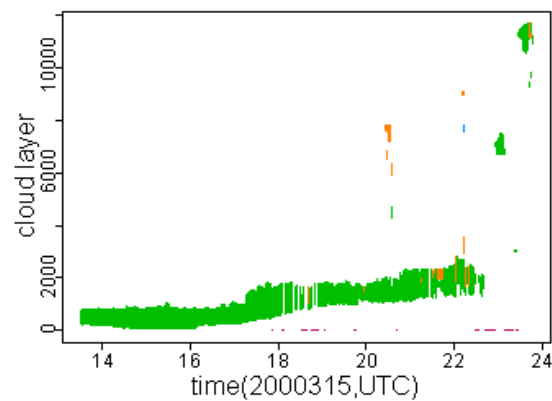
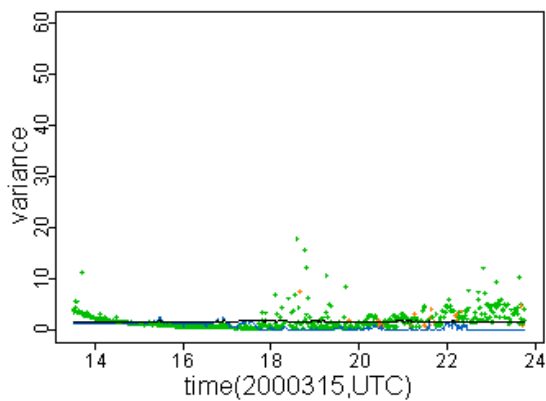
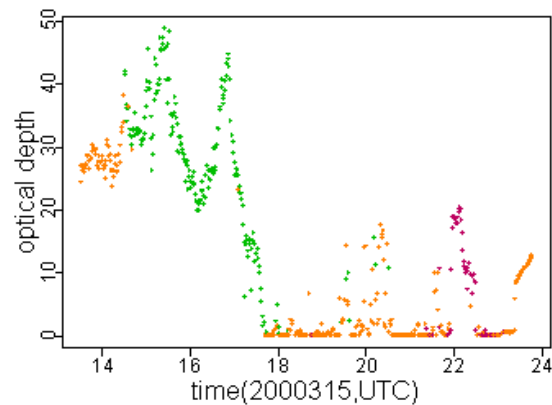
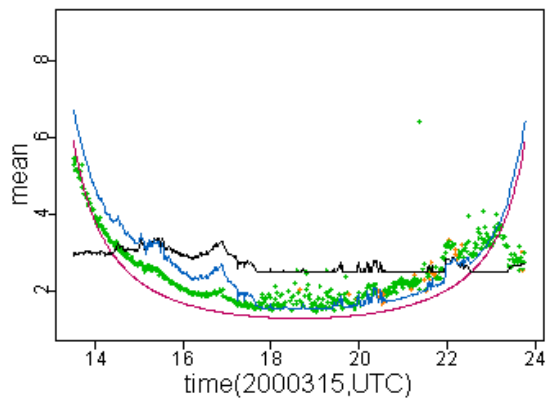
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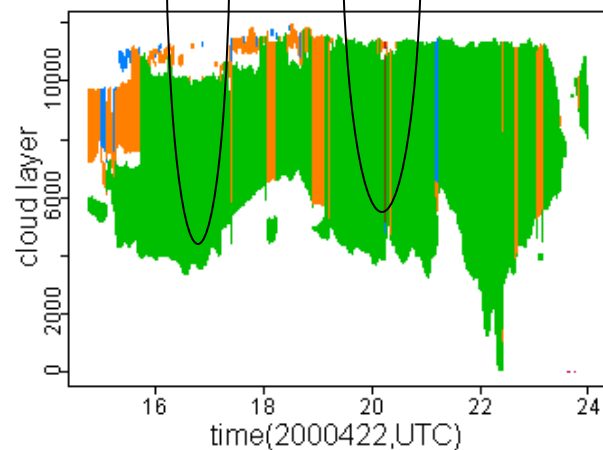
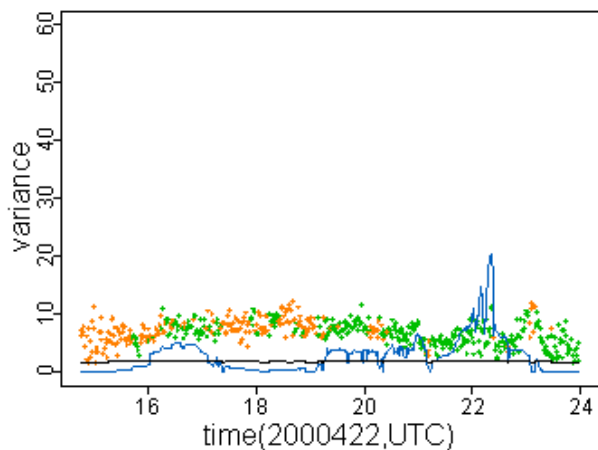
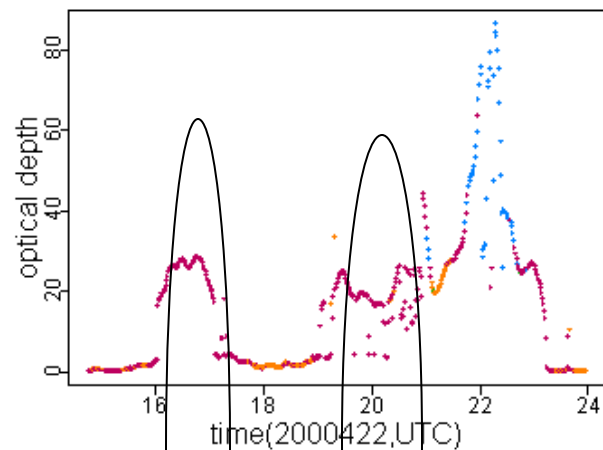
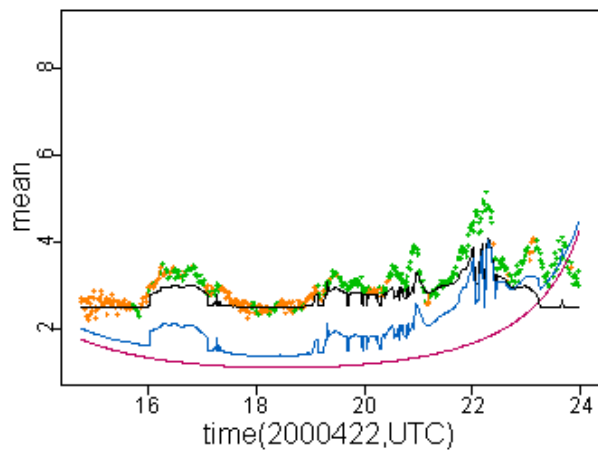
Case: Possible “missed” multiple-layer clouds by cloud radar



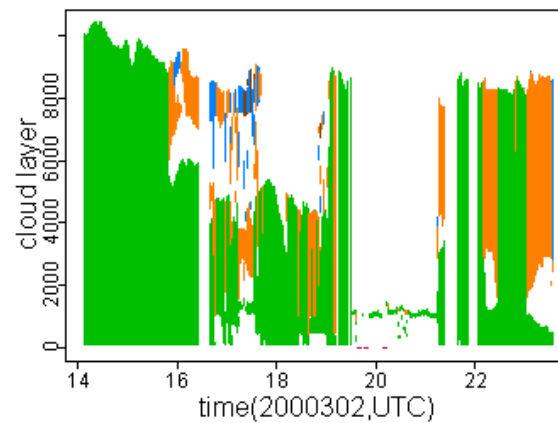
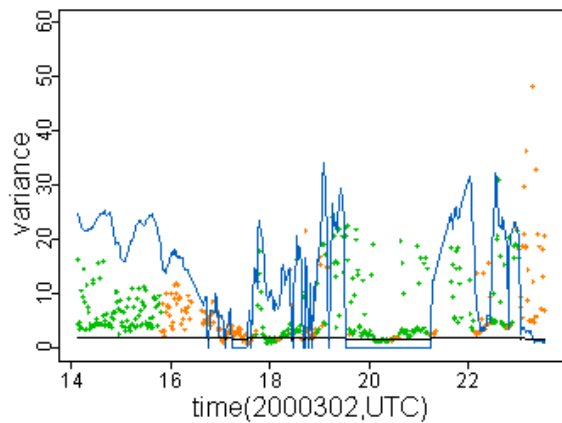
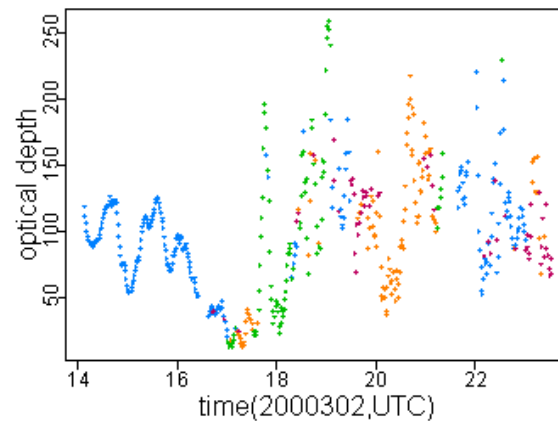
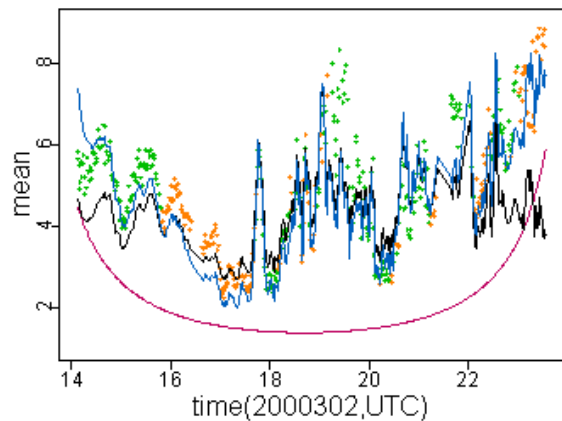
Case: Possible “missed” multiple-layer clouds by cloud radar



Case: Possible “missed” multiple-layer clouds by cloud radar



Cases: Possible “missed” multiple-layer clouds by cloud radar



Aggregate statistic

One-year (year 2000) observations at ARM SGP site for the statistics

Normal conditions (Observation)

Cloud base	SGL	SGL-	MUL-	MUL	MS
	PLD (RD)	PLD (RD)	PLD (RD)	PLD (RD)	
0-1km(67%)	28% (71%)	35% (60%)	21% (65%)	16% (75%)	8%
Above 1km(33%)	9% (75%)	18% (69%)	45% (45%)	28% (40%)	28%
total	22% (72%)	29% (63%)	29% (58%)	20% (63%)	15%

SGL: Single-layer cloud

SGL-: Possible single-layer cloud

MUL-: Possible multiple-layer cloud

MUL: Multiple-layer cloud

MS: Missed multiple cloud by Radar in terms of single layer clouds

PLD: Photon pathlength distribution method.

(RD): Coincident rate with Radar

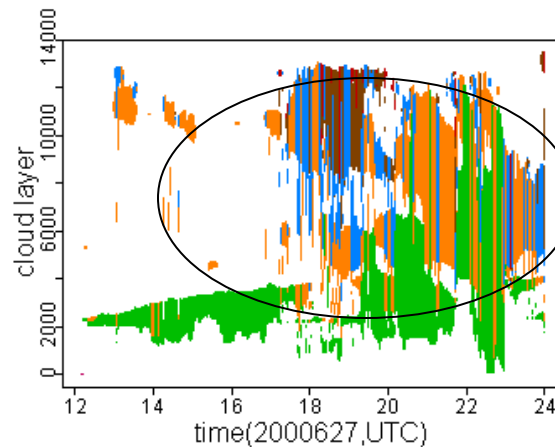
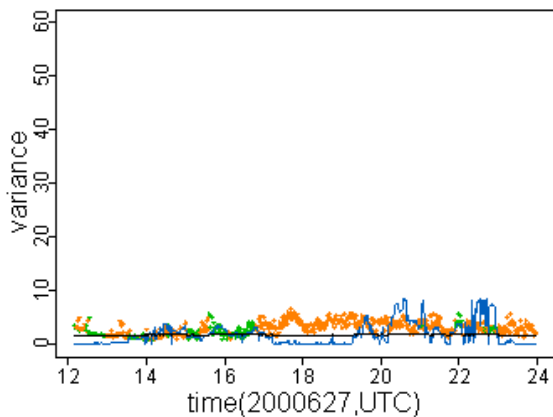
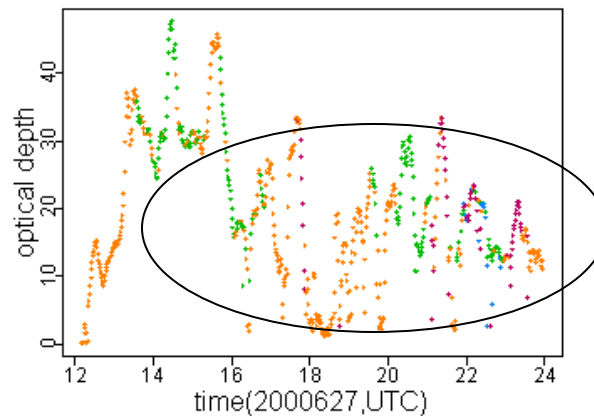
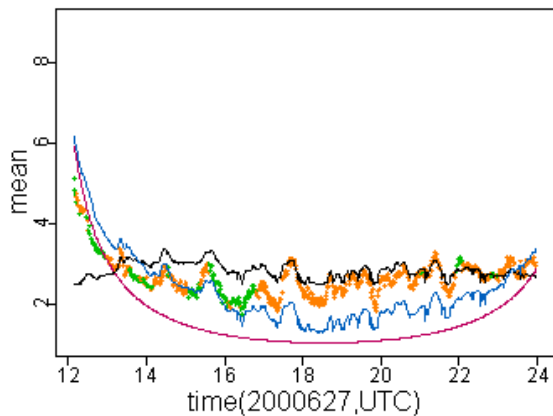
Strict conditions (Observation)

Cloud base	SGL	SGL-	MUL-	MUL	MS
	PLD (RD)	PLD (RD)	PLD (RD)	PLD (RD)	
0-1km(67%)	33% (71%)	30% (60%)	25% (66%)	12% (75%)	6%
Above 1km(33%)	13% (71%)	15% (73%)	51% (46%)	21% (37%)	22%
total	26% (71%)	25% (64%)	34% (59%)	15% (62%)	11%

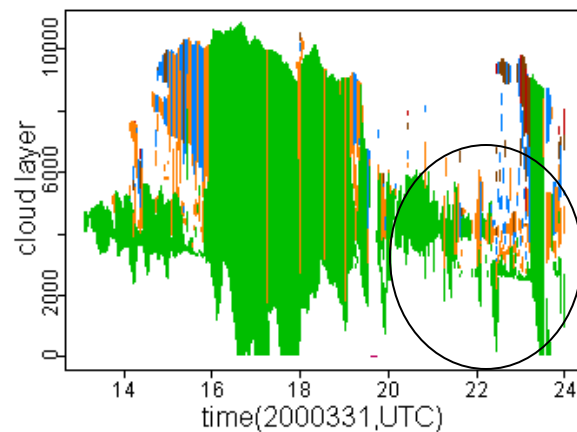
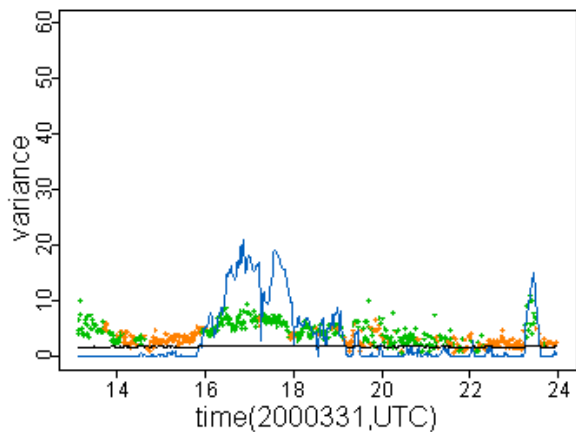
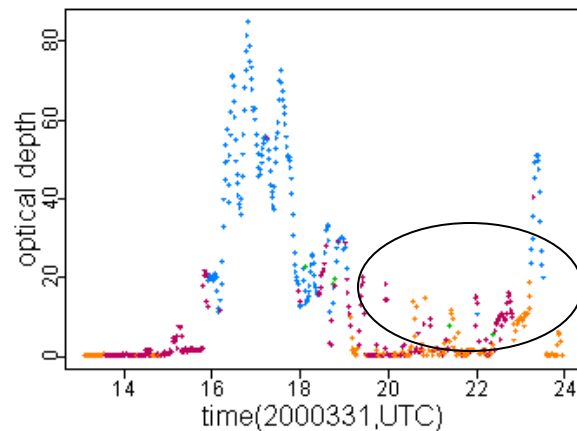
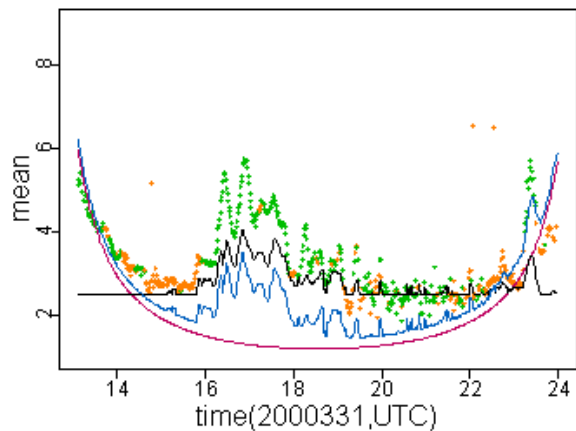
Conclusion

- With normal thresholds, at least 15% of single-layer clouds detected by radar could be multiple-layer clouds (11% for more strict conditions)
- Consequences of “missed” cloud layers on radiation and BBHRP remains to be determined.
- Needs a high-resolution O₂ A-band spectrometer with high moments to further detect cloud layer information.

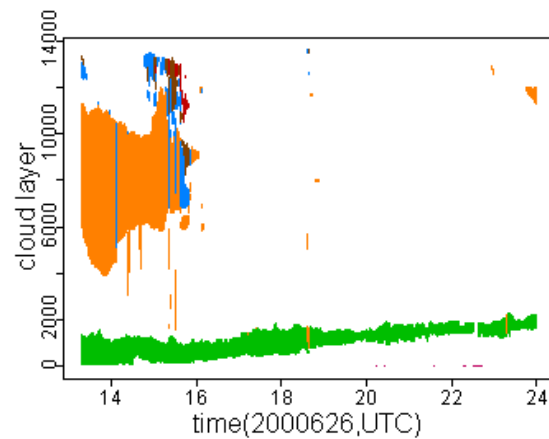
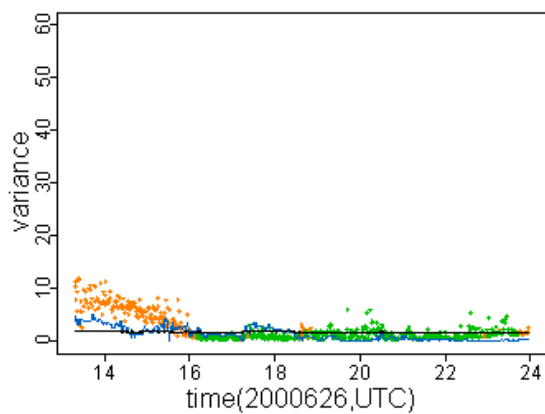
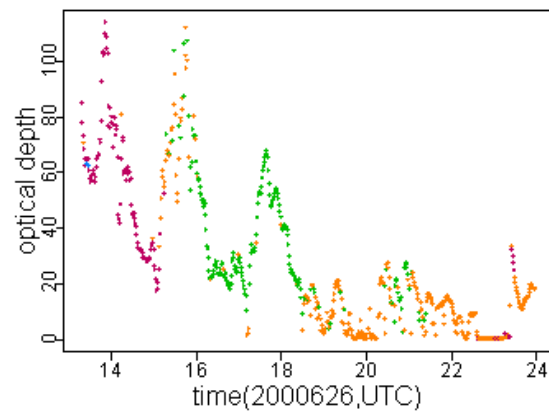
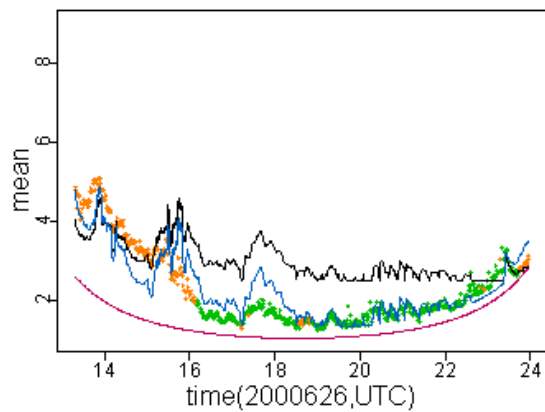
Case: Consistent with radar observation



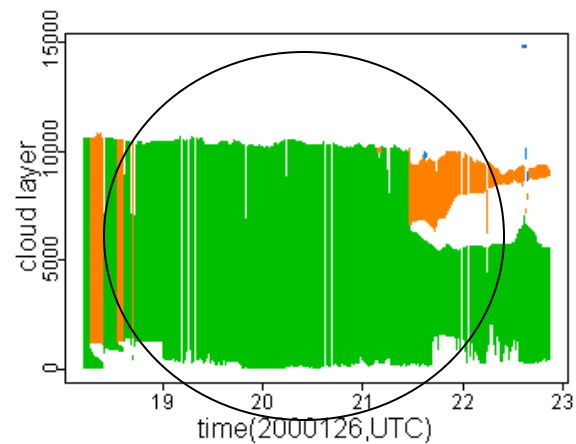
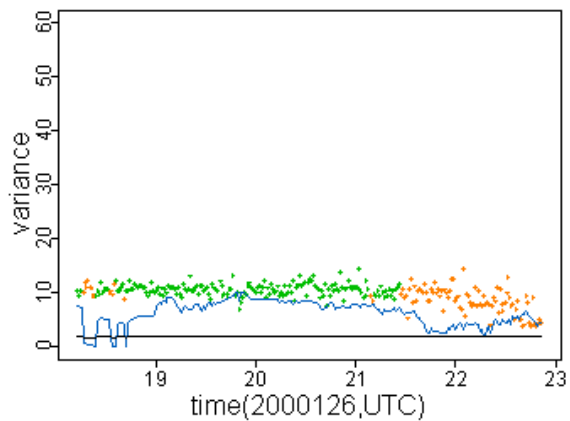
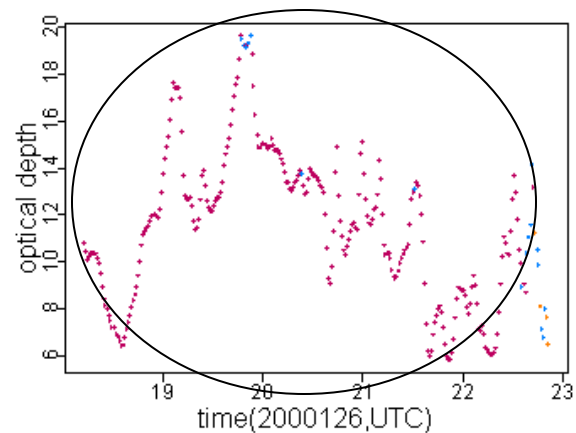
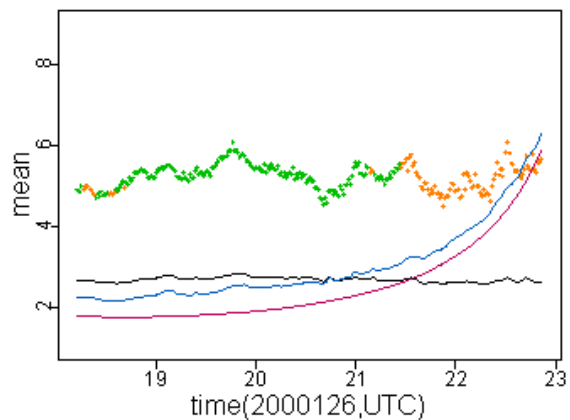
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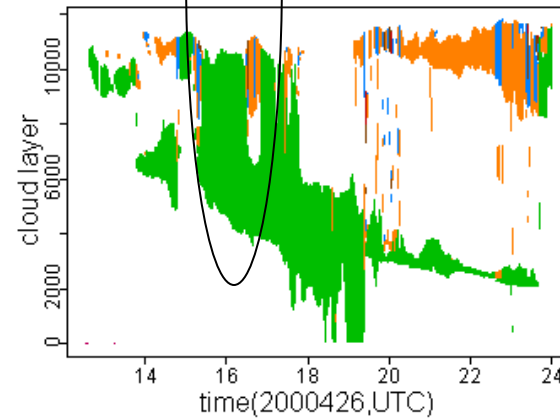
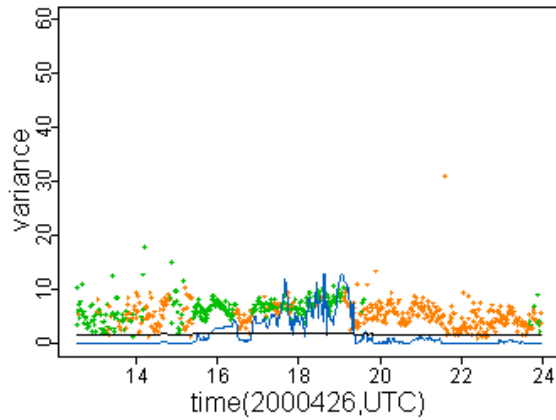
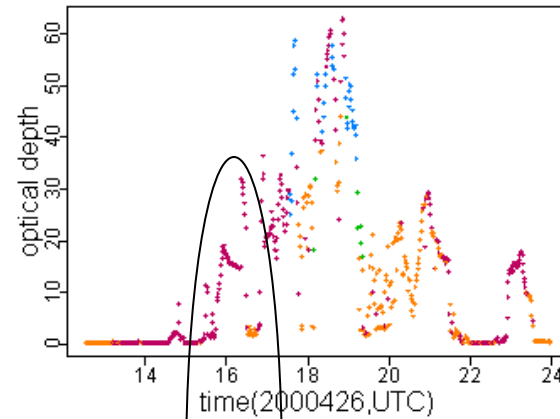
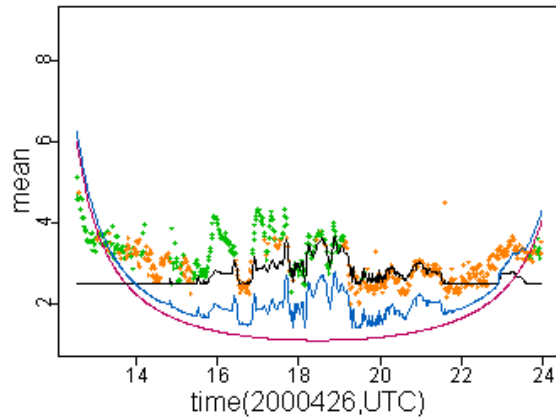
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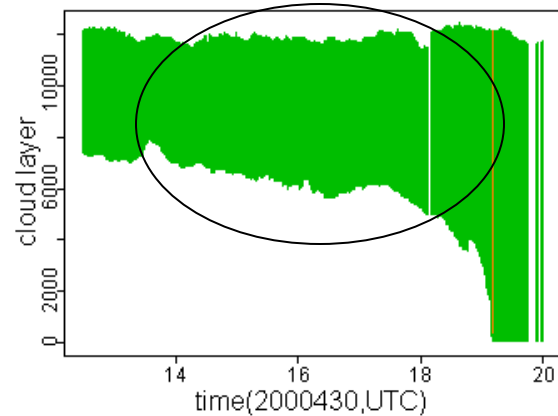
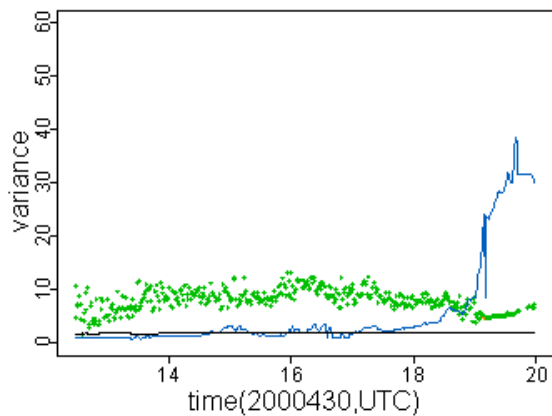
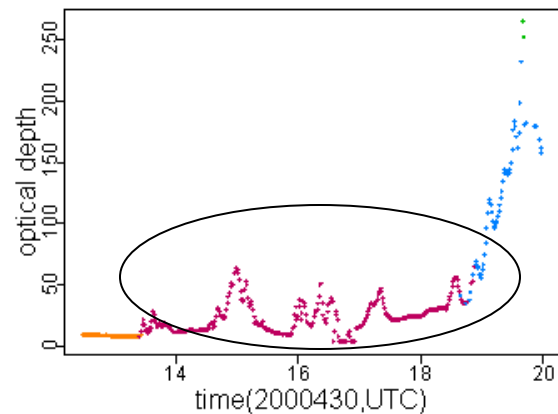
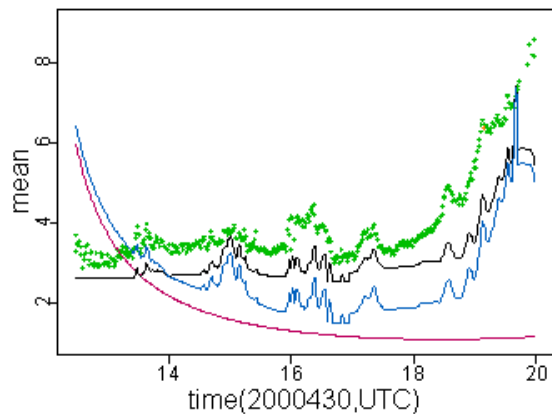
Case: Possible “missed” multiple-layer clouds by cloud radar



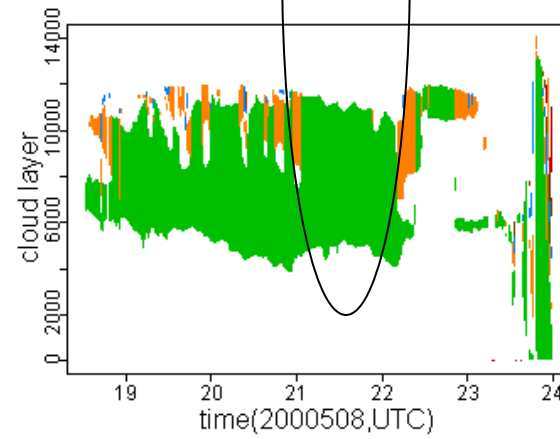
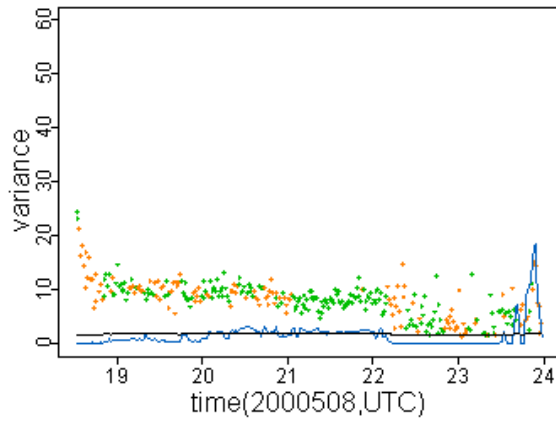
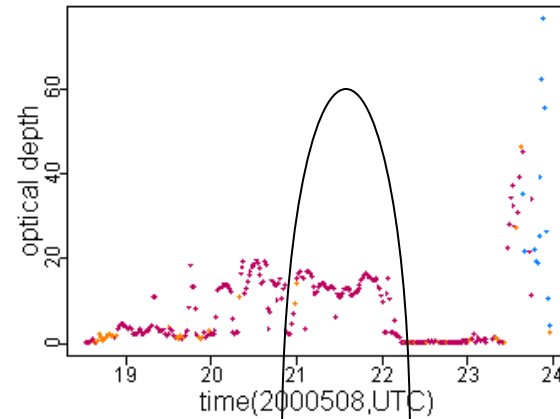
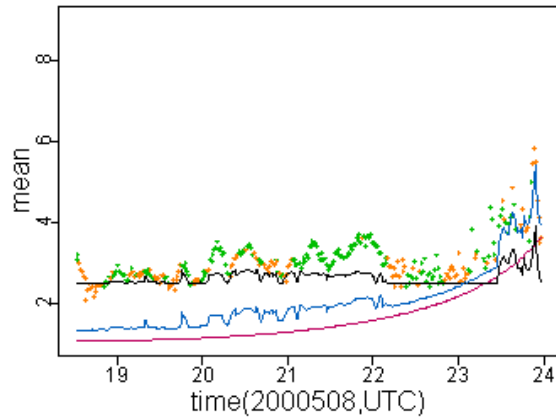
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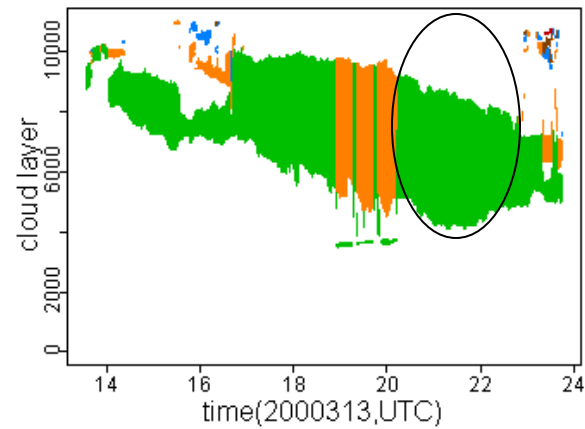
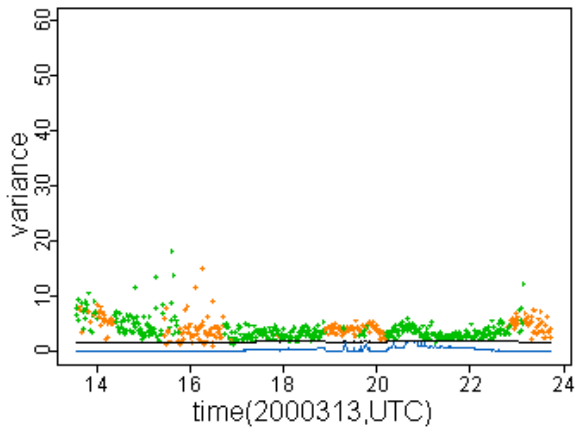
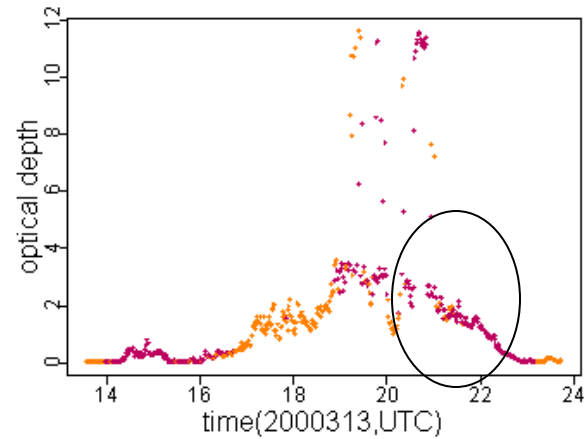
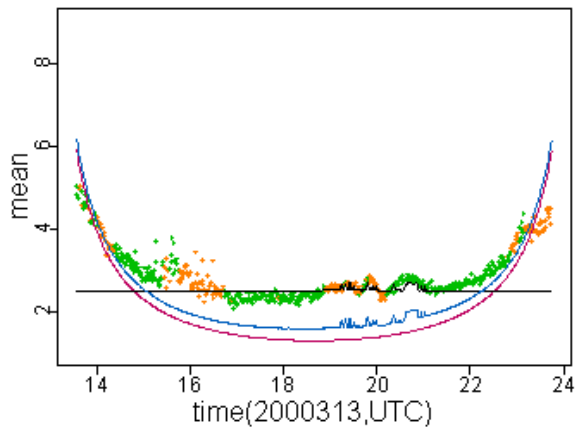
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