



# Validation of MODIS Cloud products through an inter-comparison with MISR, GOES and ground-based radar/lidar

**Jan-Peter Muller and Catherine Naud**  
(University College London)

**Eugene Clothiaux** (Pennstate University)

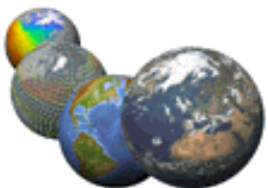
**Paul de Valk** (KNMI)





# MODIS vs MISR: objectives

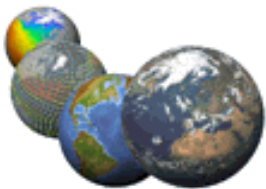
- Understand what biases and artefacts exist in the MODIS CO2 slicing CTP and MISR stereo CTH through inter-comparison
- understand differences between MODIS and MISR using ground-based mm-radar + lidar (in conjunction with Eugene Clothiaux, PSU) and GOES CTHs (in conjunction with Paul de Valk, KNMI and SAF/CMS, Lannion)





# MODIS vs MISR : Overview

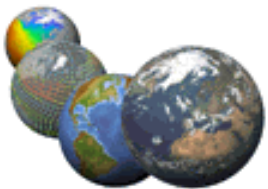
- Inter-comparison of MOD06 with MISR-2TC CTHs over the British Isles
- Comparison of Cloud-Top Heights vs radar at Chilbolton and ARM SGP sites
- Comparison of MODIS/MISR Cloud-Top Heights vs GOES at ARM SGP
- Conclusions
- Future plans for MODIS vs MISR cloud studies at UCL





# MODIS intercomparison with MISR: method

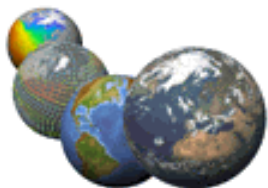
- MOD06 CO<sub>2</sub> slicing CTP product transformed into geopotential CTH using ECMWF objective analyses (*all pixels where CTP retrieved with IR channel removed*)
- MISR 2TC Stereo CTH product (above ellipsoid) includes correction of wind advection effects
- MODIS CTH at 5km resolution; MISR stereo CTH at 1.1km : MISR CTH reprojected onto MODIS latitude-longitude grid using weighted averages



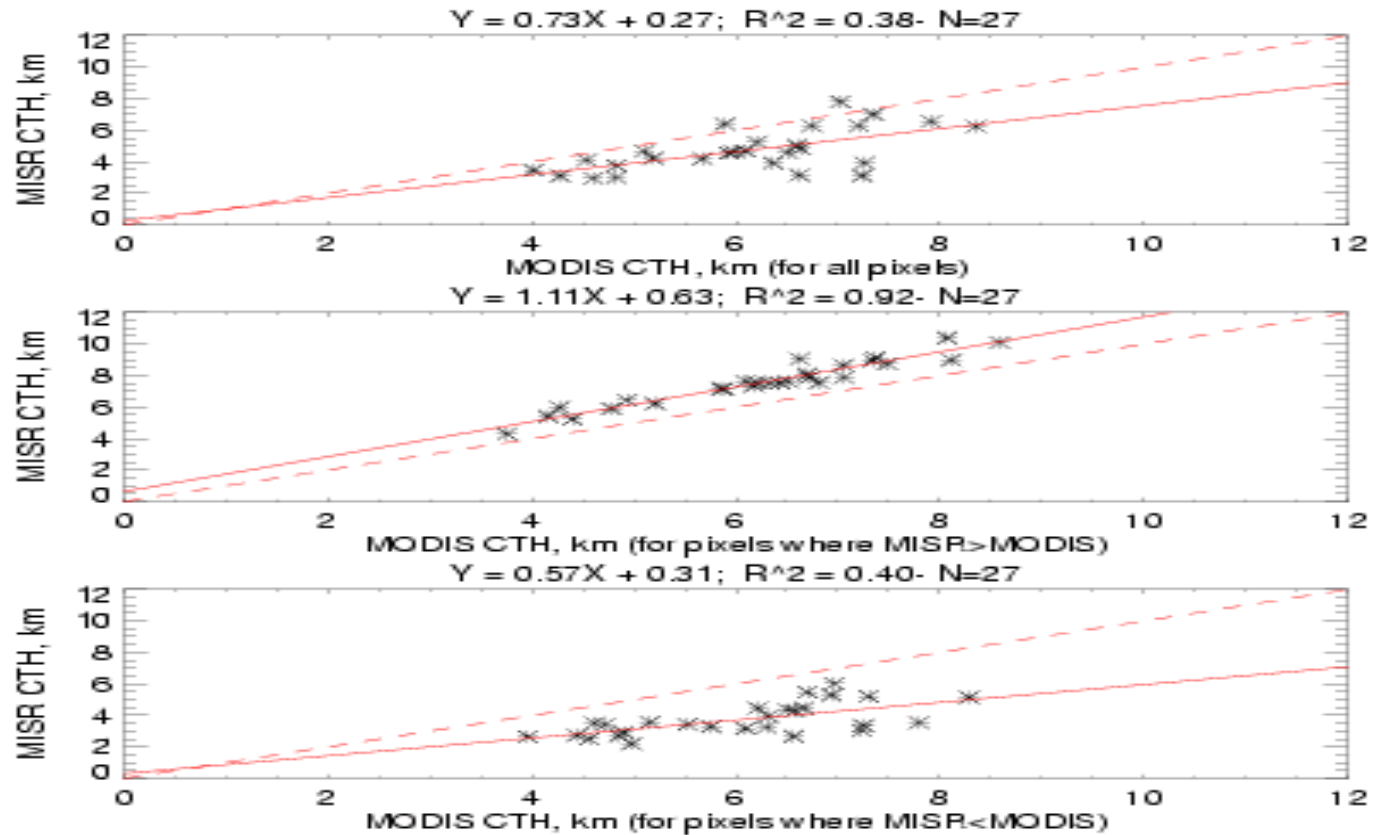


## MODIS vs. MISR CTH : over the British Isles (1)

- Over British Isles: 27 cases have been studied. 7 are from 25/8/00 until 26/11/00, then from 05/03/01 to 10/10/01, all using the latest MISR processing chain
- Pixel-by-pixel comparison for statistics and calculation of CTH differences per pixel
- Comparison of average CTH per scene for all 27 cases



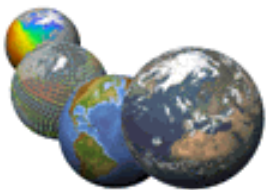
# MODIS vs. MISR CTH : over the British Isles (2)



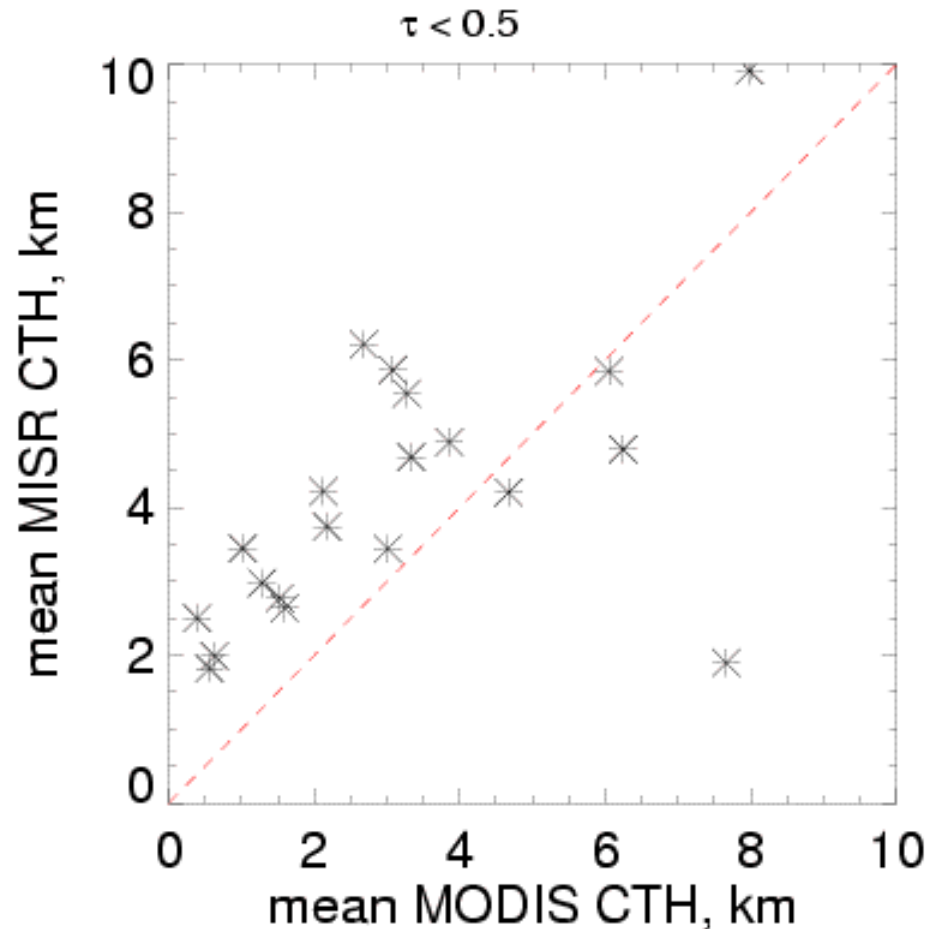
Average CTH for each date: MODIS CTH > MISR CTH on average per scene

MISR > MODIS: show systematic difference of 0.63km, good correlation between cases

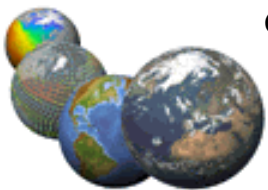
MISR < MODIS: MISR CTH around 2-4km for most cases



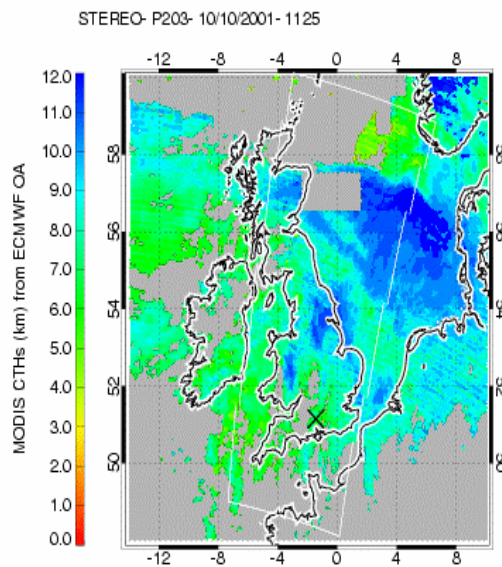
## MODIS vs. MISR CTH : over the British Isles (3)



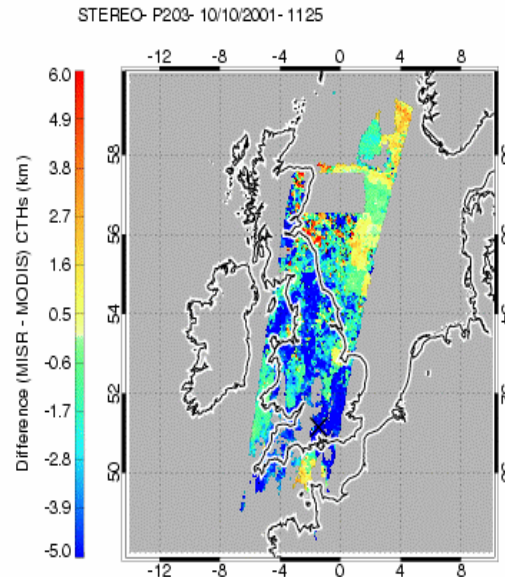
Pixels with MOD06 optical depth less than 0.5: MISR sensitive to small optical depth, and corresponding MISR stereo CTH usually higher than MODIS CTH



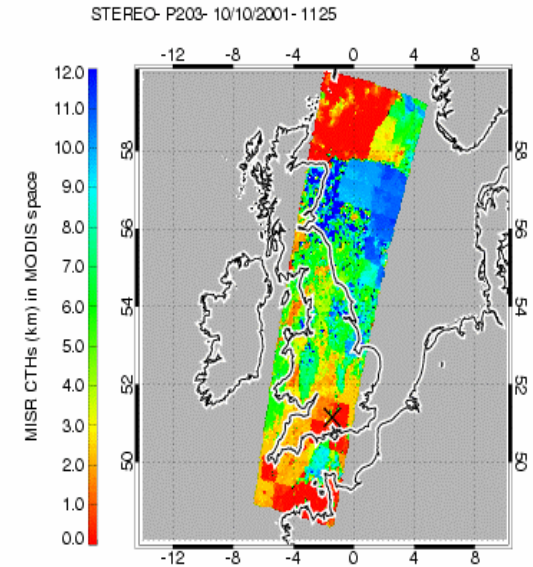
# MODIS vs. MISR CTH : over the British Isles (4) for 10 October 2001 (Path 203- O9642)



MODIS CTH



MISR-MODIS CTH difference



MISR CTH

Large areas with MODIS CTH greater than MISR CTH, MISR misses high clouds

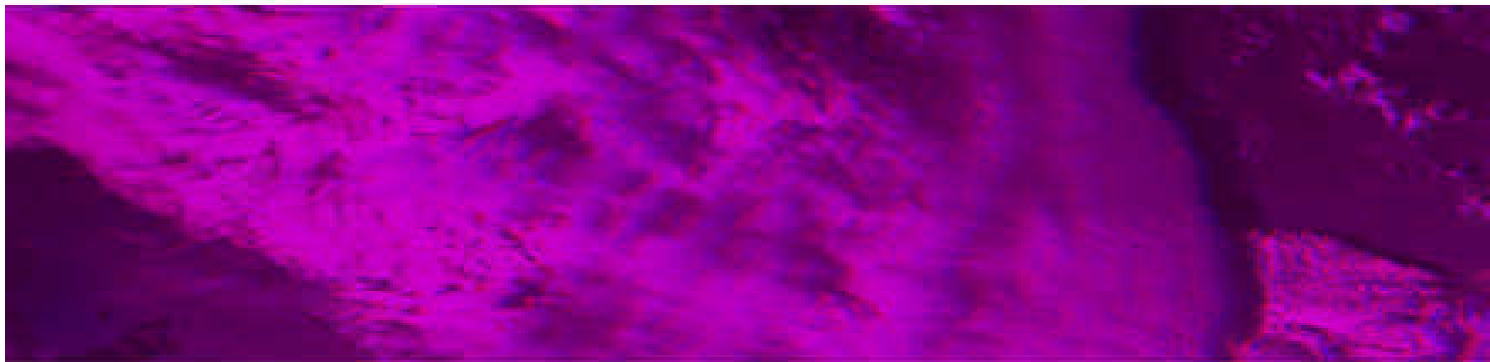
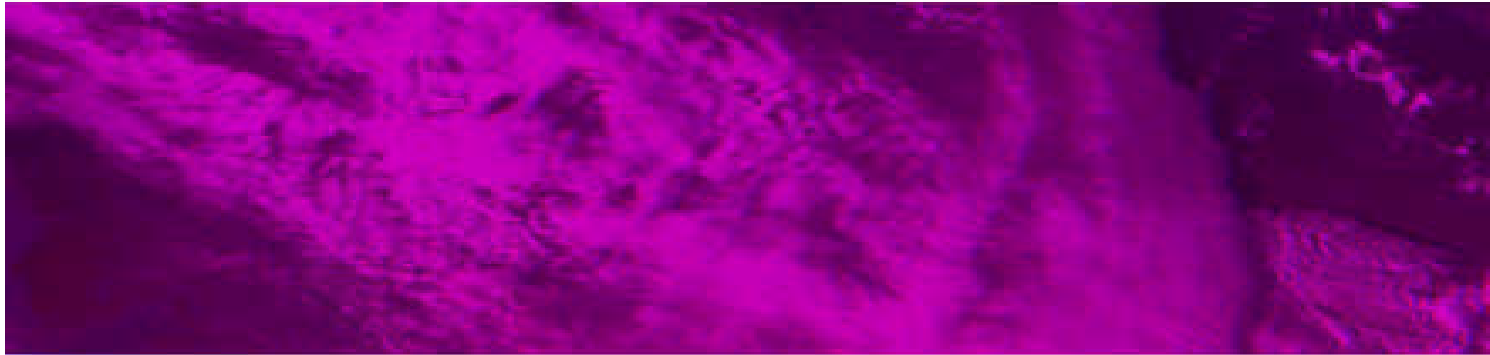
NB : missing data for MODIS for CTH < 3km (IR retrieval) – grey areas: no data





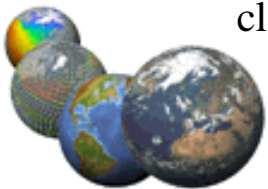


## MODIS vs. MISR CTH : over the British Isles (5) for 10 October 2001 (Path 203- O9642)



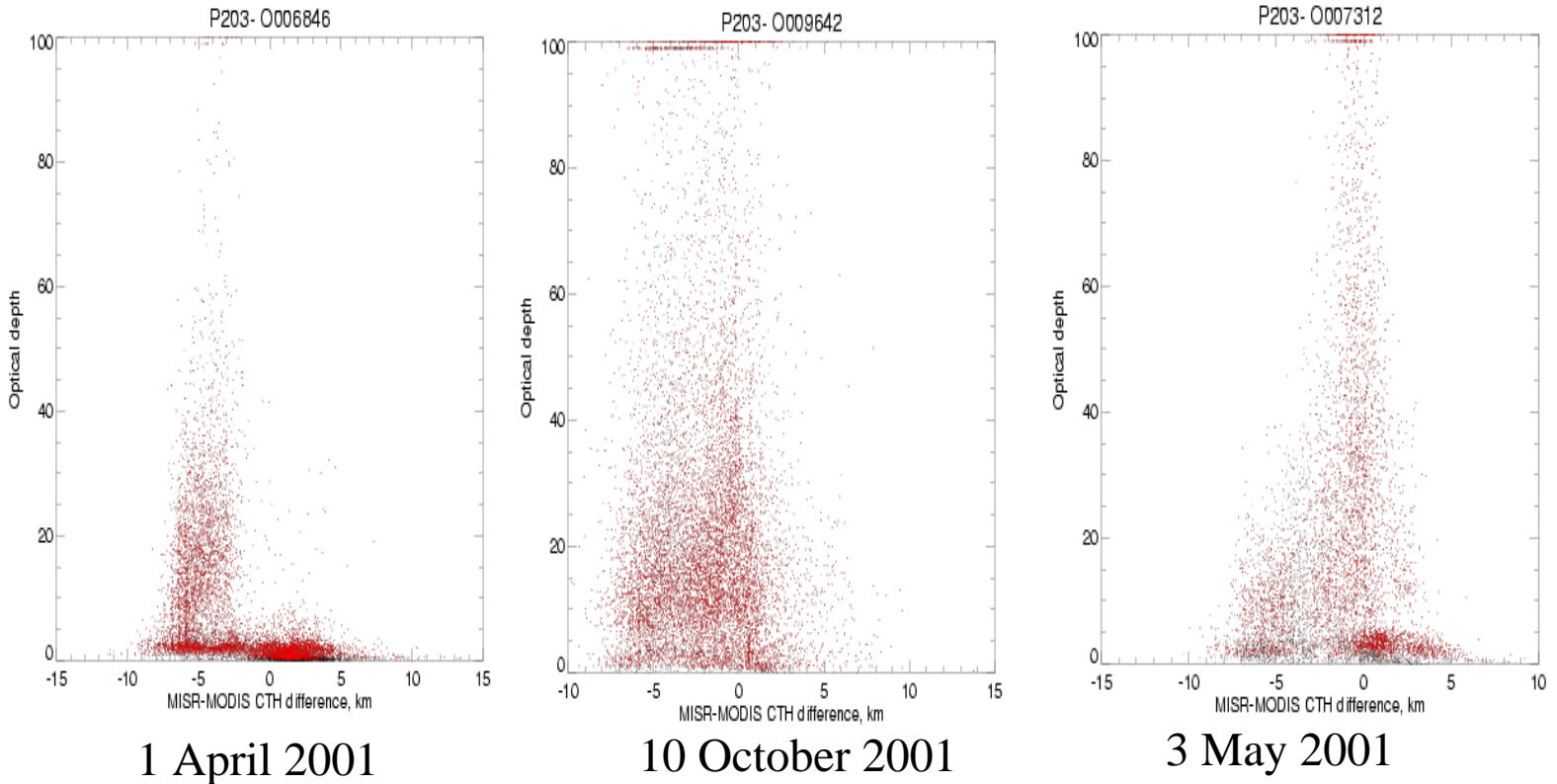
Top panel: AN-AF ; lower panel: CF-DF shown as Red/Blue anaglyphs

AF-AN shows low contrast for multi-layer clouds, causing MISR CTH retrieval to miss high clouds. Better contrast with CF-DF

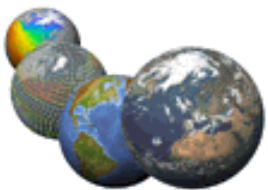




# MODIS vs. MISR CTH : over the British isles (6) sensitivity to cloud optical depth (MOD06)



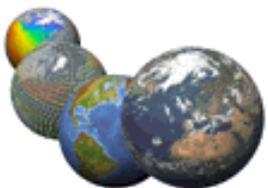
N.B. Clusters for zero difference (all optical depths), where MISR misses highest cloud layer, and when MISR CTH > MODIS CTH, small values of optical depth.



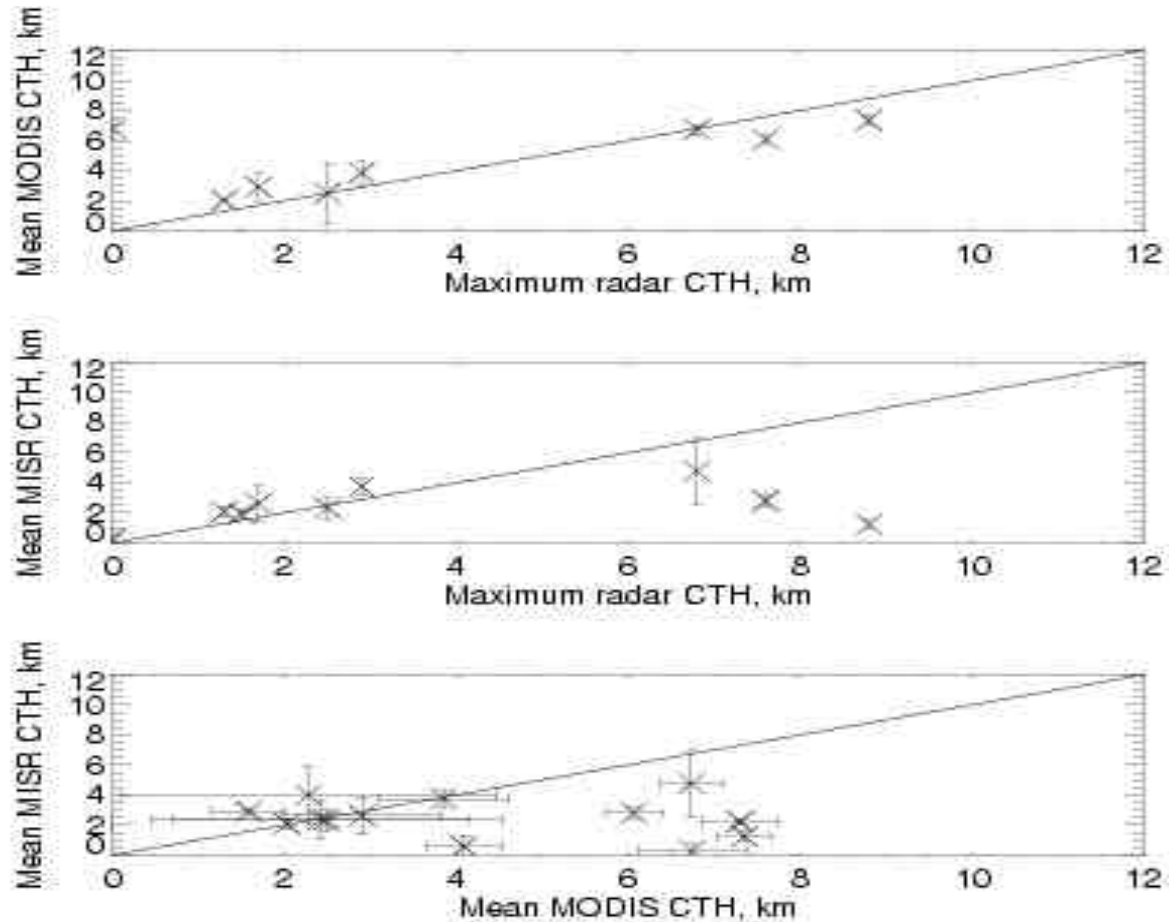


# Comparison of MODIS and MISR 2TC stereo CTHs vs radar

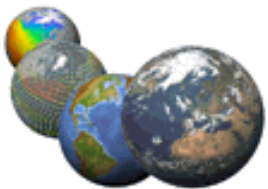
- 2 sites: Chilbolton (UK) and SGP ARM site (US)
- A small window  $\pm 0.1^\circ$  was used to calculate the MISR and MODIS CTHs statistics over Chilbolton and SGP.
- 5min sampling of radar profiles, median CTH for SGP (from reflectivity clutter flag processed by E. Clothiaux), maximum visually retrieved CTH for Chilbolton
- Chilbolton: 8 dates with MODIS, MISR and radar, 8 dates with radar and MODIS, 9 with radar and MISR and 13 with MISR and MODIS.
- SGP: 6 cases with MODIS, MISR and SGP, 10 dates with MISR and radar and MODIS and radar



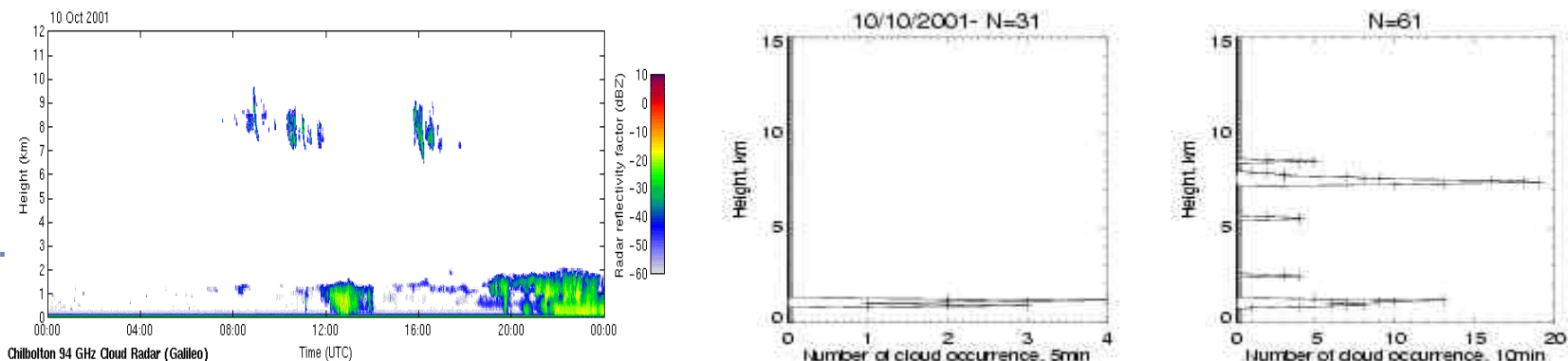
# Chilbolton: MODIS vs MISR vs 94GHz Radar (1)



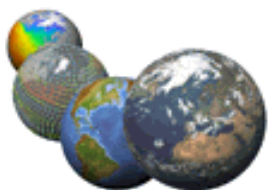
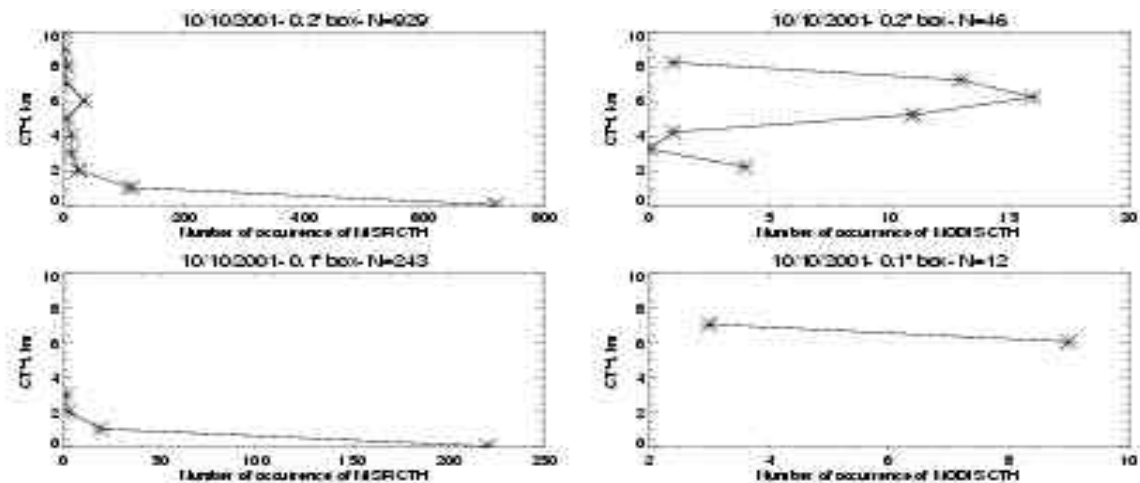
N.B. MISR does not detect high clouds above 6km for multi-layer or broken clouds



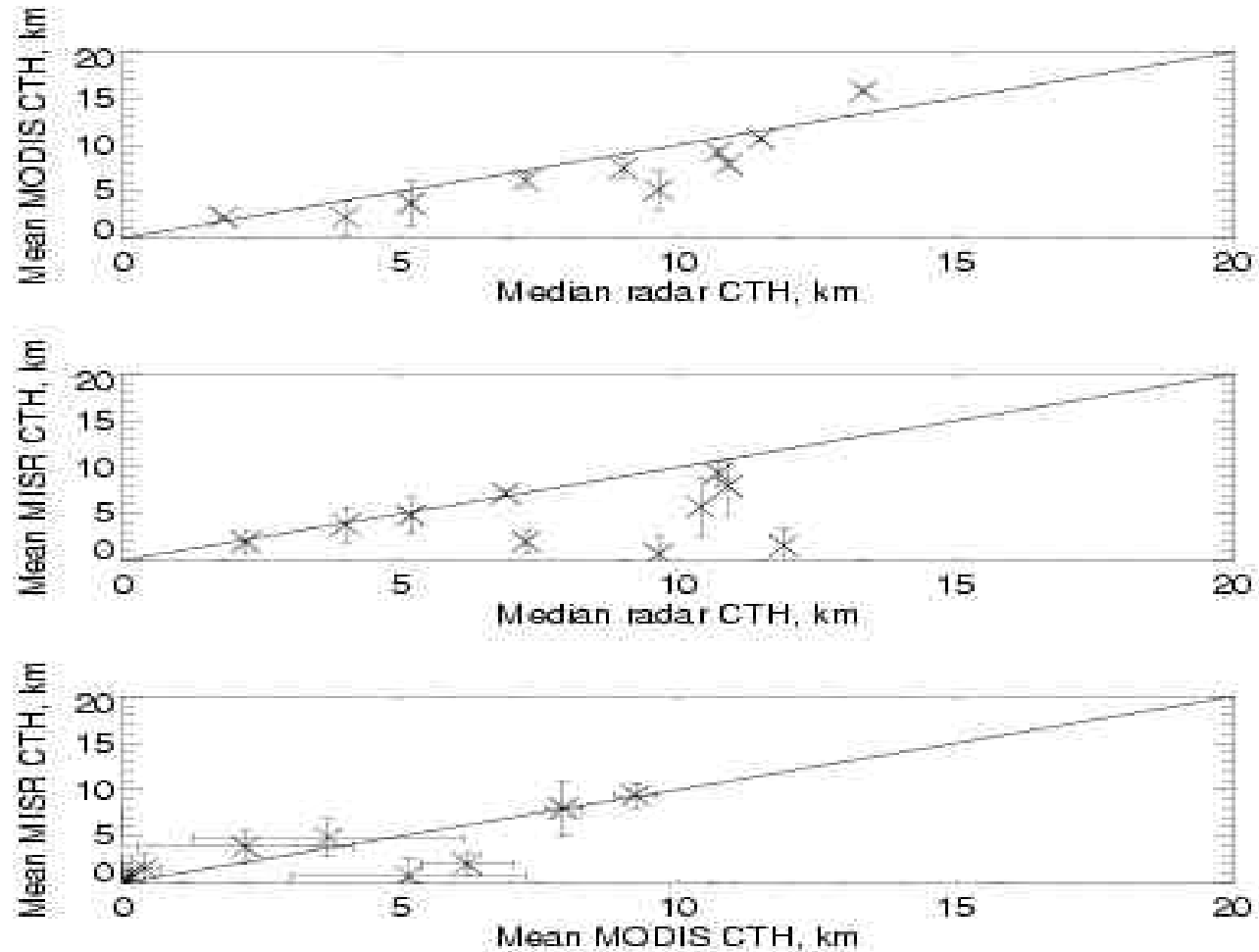
# Chilbolton: MODIS vs MISR vs 94GHz Radar (2): 10 October 2001 (Path 203, O9642)



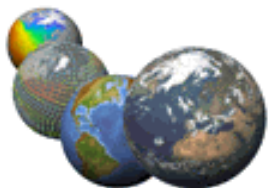
10-Oct-01: for  $0.1^\circ$  box, MISR averaged CTH=0.28km and MODIS CTH=6.75km;



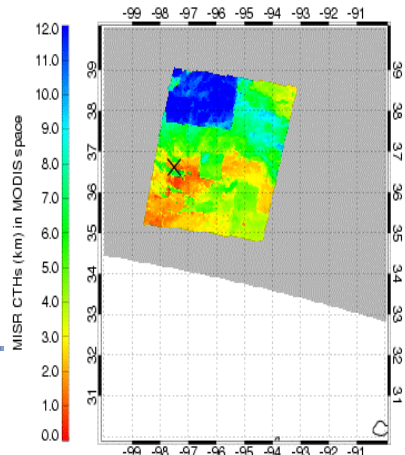
# SGP: MODIS vs MISR vs 35GHz Radar (1)



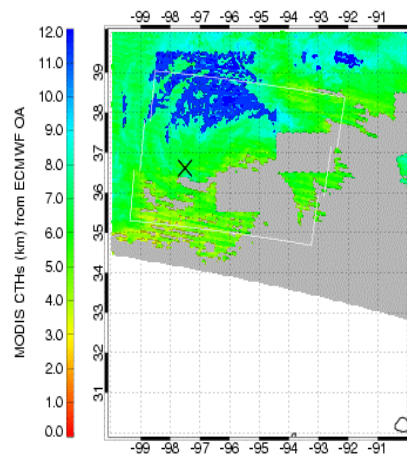
N.B. MISR misses clouds above 7km- MODIS CTH generally lower than Radar CTH



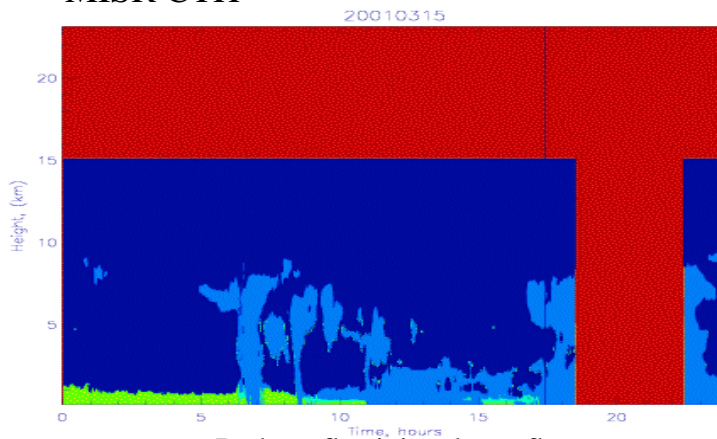
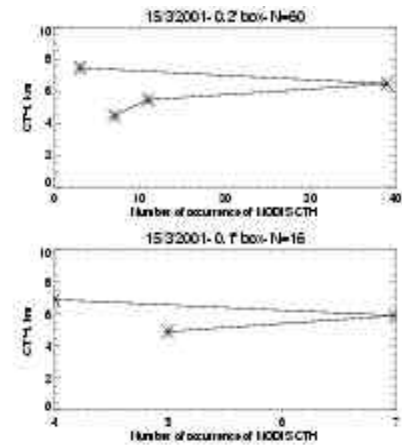
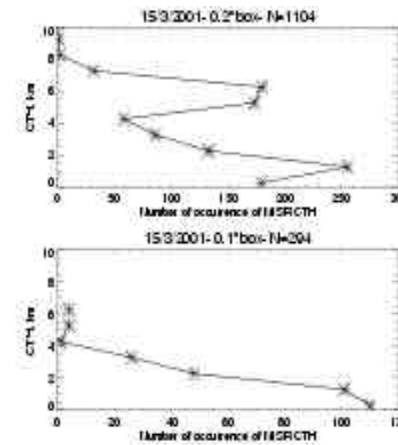
# SGP: MODIS vs MISR vs 35GHz Radar (2): 15 March 2001 (Path 27, O6602)



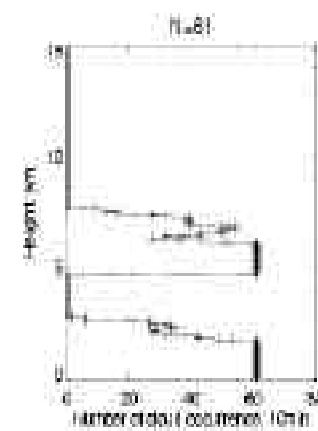
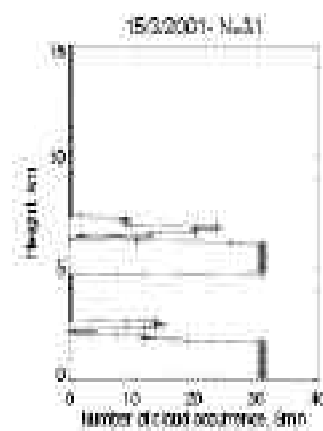
MISR CTH



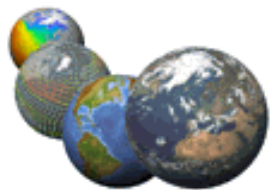
MODIS CTH



Radar reflectivity clutter flag



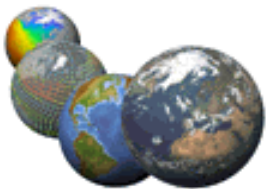
N.B. Multi-layer cloud case. Radar median CTH: 7.26km



# MODIS vs. MISR vs. Radar

## Summary of results to date

- Mean and standard deviation of differences for ALL 15 (8 CRF & 7 SGP) cases:
  - $\langle \text{Radar} - \text{MISR} \rangle = 2.26\text{km}$  ; std=3.25km
  - $\langle \text{Radar} - \text{MODIS} \rangle = 0.69\text{km}$  ; std=2.61km
- Best case scenario for 6 cases when highest layer detected by both MODIS and MISR:
  - $\langle \text{Radar} - \text{MISR} \rangle = 0.34\text{km}$  ; std=1.60km
  - $\langle \text{Radar} - \text{MODIS} \rangle = 0.50\text{km}$  ; std=1.50km
- It should be noted that this inter-comparison does not include any error budget for CTH detection by radar+lidar





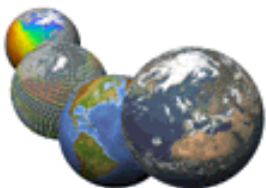
# MODIS vs. MISR vs. Radar Performance Assessment

- Performance assessed as follows:
  - $\text{CTH detection efficiency} = 100 * \text{TP} / (\text{TP} + \text{FP})$
  - $\text{Quality} = 100 * \text{TP} / (\text{TP} + \text{FP} + \text{FN})$
  - where
    - TP=Total Positives = occasions when MODIS or MISR detects a cloud layer which is also detected by radar
    - FP=False Positives = occasions when MODIS or MISR detects a cloud layer whereas radar does NOT
    - FN=False Negatives = occasions when MODIS or MISR does NOT detect a cloud layer whereas radar does
- Performance for MODIS:
  - CTH detection=86.67%
  - quality=73.3%
- Performance for MISR:
  - CTH detection=57.14%
  - quality=53.33%



# MODIS vs. MISR : conclusions

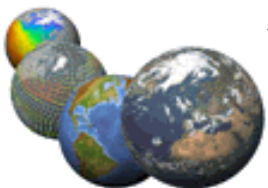
- MISR CTH higher than MODIS CTH when MISR detects high clouds: is MODIS less sensitive to thin clouds?
- MISR misses high clouds in multi-layer cloud conditions: contrast problem for AF-AN
- Confirmed by Anaglyph and Comparison with radar data for SGP and Chilbolton: AN/AF combination lacks contrast
- Propose modified processing chain to include off-nadir cameras using new UCL stereo matcher, M4, to match successive views





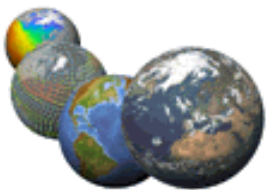
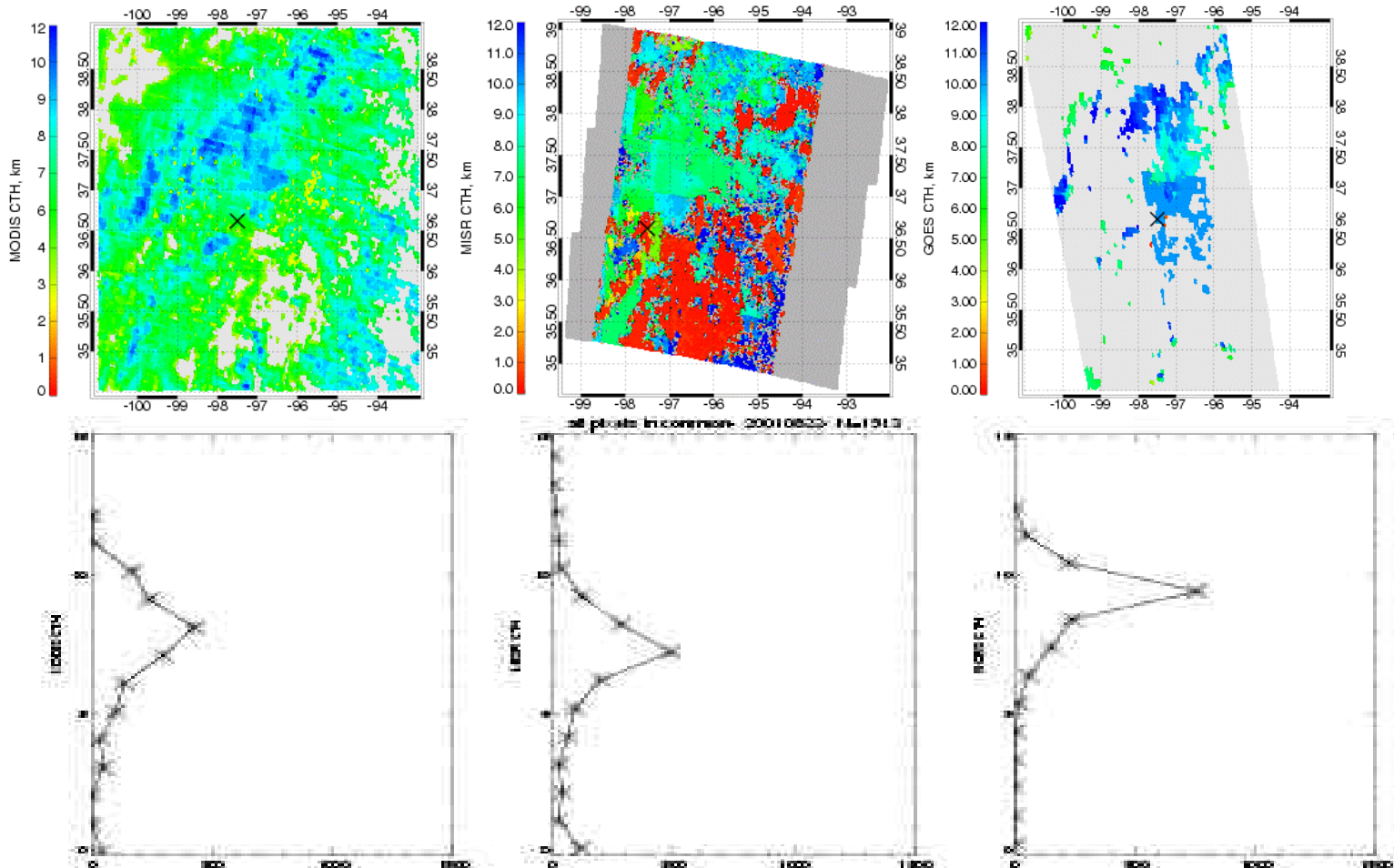
# MODIS vs. MISR vs GOES: SGP

- GOES CTH processed by SAF/CMS Lannion, France, with CO<sub>2</sub> slicing method developed for METEOSAT Second Generation SEVIRI
- 3 dates selected for July-August 2001: 5<sup>th</sup> July, 12<sup>th</sup> July and 22<sup>nd</sup> August with clouds in SGP area+ GOES (17:30), MISR and MODIS
- 5<sup>th</sup> July and 22<sup>nd</sup> August= clouds above SGP station + radar data available+ RS data for 22<sup>nd</sup> August (launch within 20min of acquisition)
- GOES (4km) and MISR(1.1km) reprojected onto MODIS 5km grid



# MODIS vs. MISR vs GOES: SGP

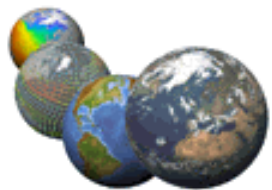
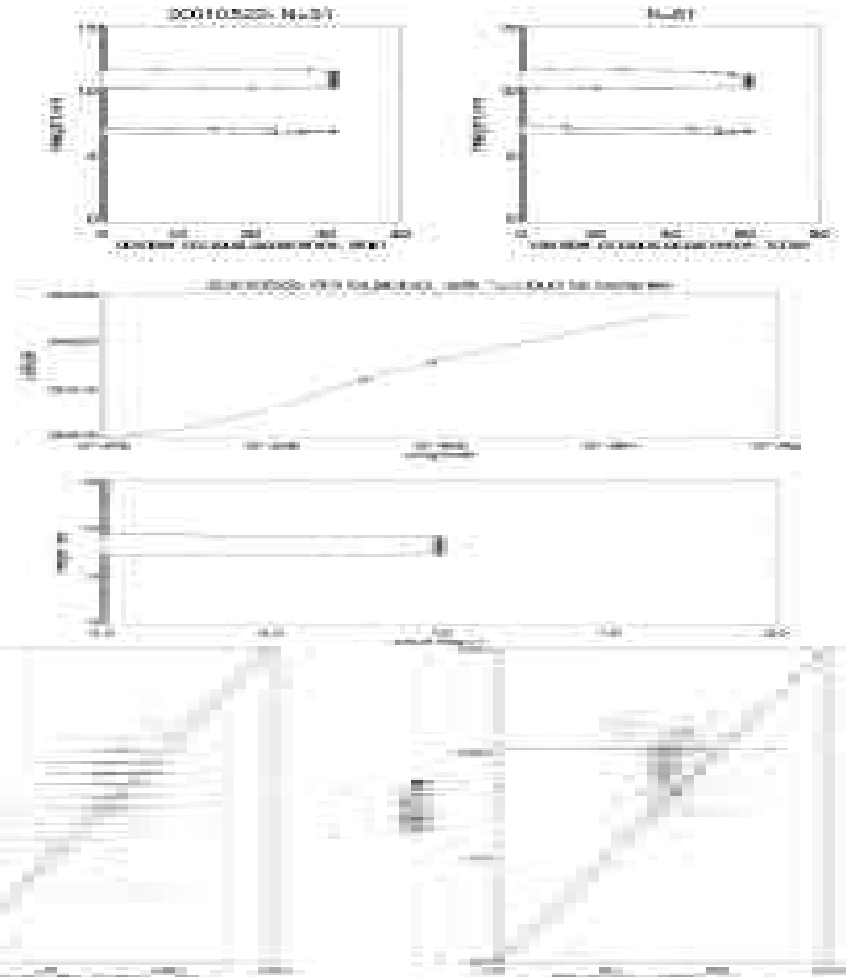
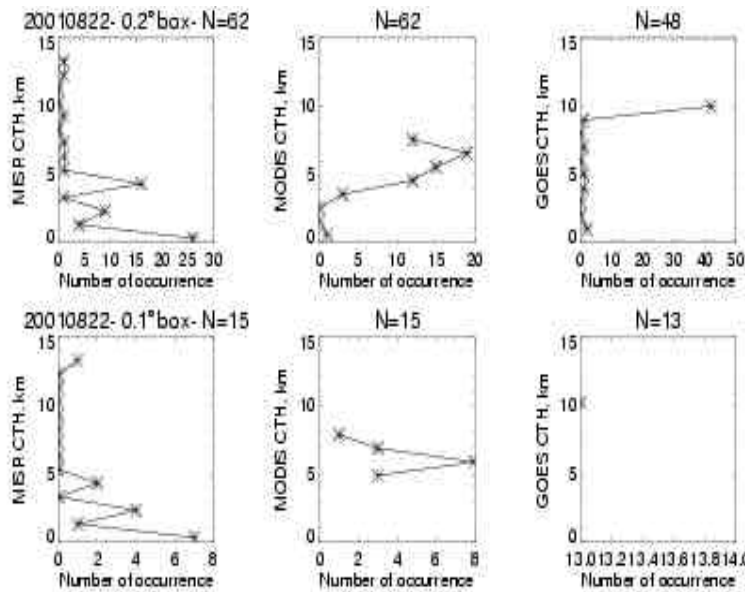
## 22-Aug-2001, 17:25, P027, O8932





# MODIS vs. MISR vs GOES: SGP

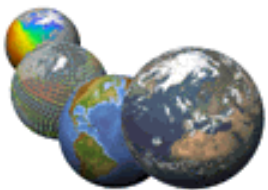
## 22-Aug-2001, 17:25, P027, O8932





# MODIS vs MISR vs GOES: SGP Conclusions

- Preliminary study: shows overall agreement for spatial distribution
- GOES assigns CTH higher than MODIS and MISR
- MISR problem when multilayer clouds very obvious on 22-August-01
- More dates over SGP to be examined after August 2001
- In addition ATSR2 stereo CTH and CTP to be compared over SGP and North Atlantic
- Various locations over North Atlantic, within C2 area to be studied, to check contrast land/ocean





# MISR vs MODIS: future work

- Will assess (with Catherine Moroney, JPL) whether M4 and/or CF/DF cameras improve MISR CTH retrieval for multi-layer conditions
- Need to understand MODIS CTH low bias (joint work with Richard Frey/Paul Menzel at SSEC)
- Ongoing comparison with radar at Chilbolton and SGP, to be extended to TWP and NSA
- Will use radiosonde data where launch available during overpass
- Extend MISR-MODIS CTH inter-comparison to the whole CLOUDMAP2 area (60W-40E, 20-80N) and will employ radiosondes for “CTH truth”

