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# Quasi-Deterministic Cloud detection for Infrared Sea Surface Temperature Retrieval from Satellite Imager measurements


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**ESSIC/NOAA**



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**Computing Facility: Eileen Maturi, NOAA**

**Contribution from: Andy Harris, NOAA/ESSIC**

# Introduction

Prabhat K. Koner, Andy R. Harris & Eileen Maturi, Hybrid cloud and error masking to improve the quality of deterministic satellite sea surface temperature retrieval and data coverage, Remote Sensing Environment, vol. 174, p. 266-278, 2016.

A quasi-deterministic hybrid cloud and error mask (CEM) is demonstrated using both functional spectral differences (FSD) and RT calculations (DD) for GOES-13 imager IR measurement.

Prabhat K. Koner & Andy R. Harris, Improved quality of MODIS sea surface temperature retrieval and data coverage using physical deterministic methods, Remote Sens. 2016, 8(6), 454; doi:10.3390/rs8060454.

Improved CEM is proposed using same FSD with GOES-13 derived coefficients and RT based tests are altered due to more channels available in MODIS. SST is retrieved using same MTLS.

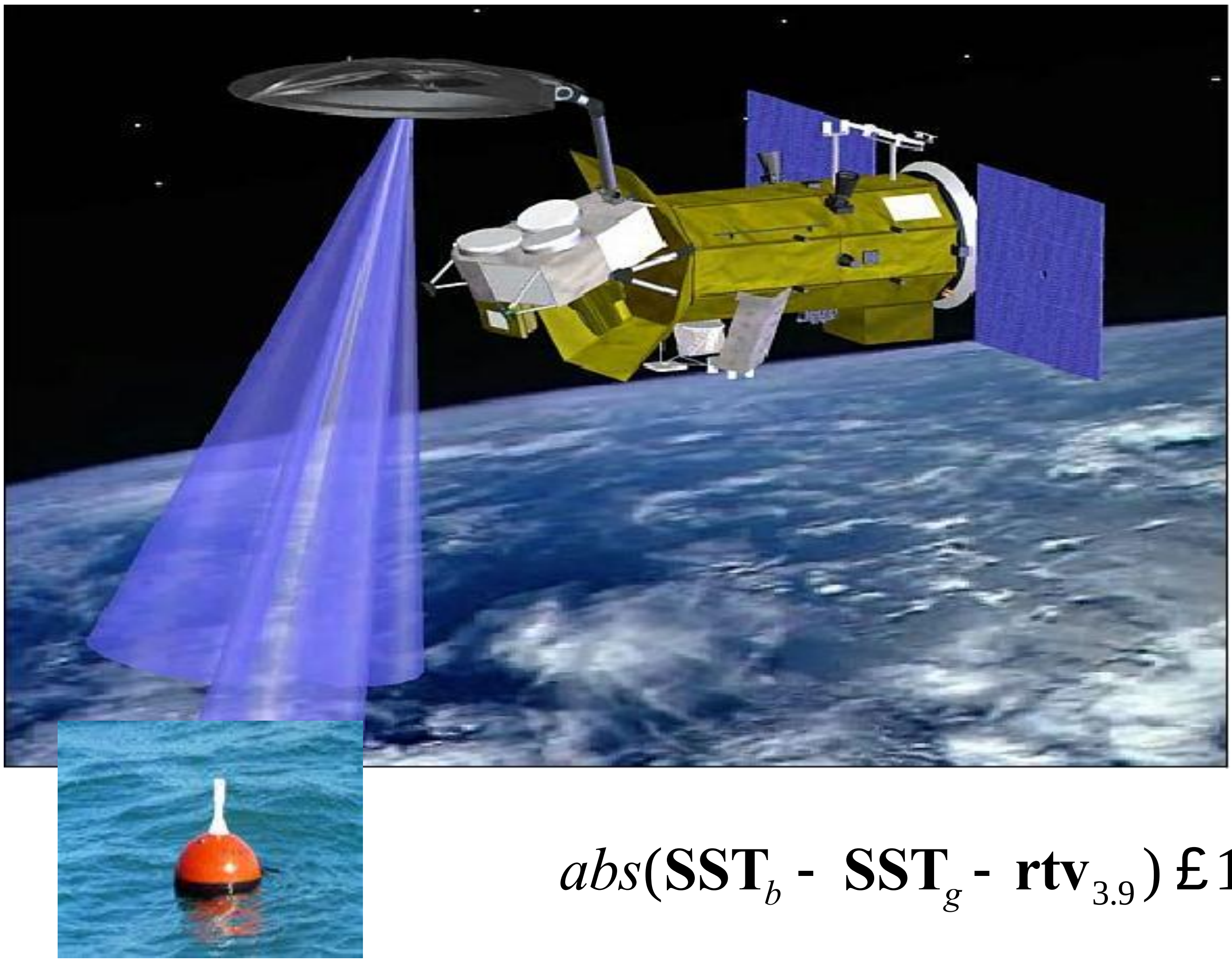
# Data and Software downloaded

- MODIS L2P SST: ftp://ftp.nodc.noaa.gov/pub/data.nodc/ghrsst/L2P/MODIS_A/JPL/
- MODIS L1b & Geo Loc: ftp://ladsweb.nascom.nasa.gov/allData/6/
- GOES-13: NOAA.
- VIIRS L2 NAVO SST: ftp://podaac-ftp.jpl.nasa.gov/allData/ghrsst/data/GDS2/L2P/VIIRS_NPP/NAVO/v1 or v2/
- VIIRS L2 OBPG SST: http://oceandata.sci.gsfc.nasa.gov/VIIRS/L2/
- VIIRS-A L1b & Geo-Loc: SCDR, NOAA.
- GFS ftp://nomads.ncdc.noaa.gov/GFS/Grid4/
- Buoy data: http://www.star.nesdis.noaa.gov/sod/sst/iquam/
- CRTM : http://ftp.emc.ncep.noaa.gov/jcsda/CRTM/REL-2.1/
- NGAC Aerosol data: Personal communication with Jun Wang, NCEP, NOAA.

# Data and Forward model specifications

- Forward model using ver. CRTM2.1
- Monthly point matchups
- Buoy (coastal, Moore & drifters)
- iQUAM quality control *in situ* data
- GFS profile data including surface
- NGAC aerosol profiles
- TTLS/MTLS inverse method

# Quantitative test for Cloud algorithm



***e.g.:***

Many validations are based on visually estimated cloud amounts reported by observers.
Kotarba, A. Z. (2009). Atmospheric Research, 92, 522–530

We proposed experimental filter (EXF) for cloud test:

$$abs(\mathbf{SST}_b - \mathbf{SST}_g - \mathbf{rtv}_{3.9}) \le 1;\ \mathbf{rtv}_{3.9} = \frac{\mathbf{T}^{\mathbf{m}}_{3.9} - \mathbf{T}^{\mathbf{s}}_{3.9}}{\mathbf{K}^{SST}_{3.9}}$$

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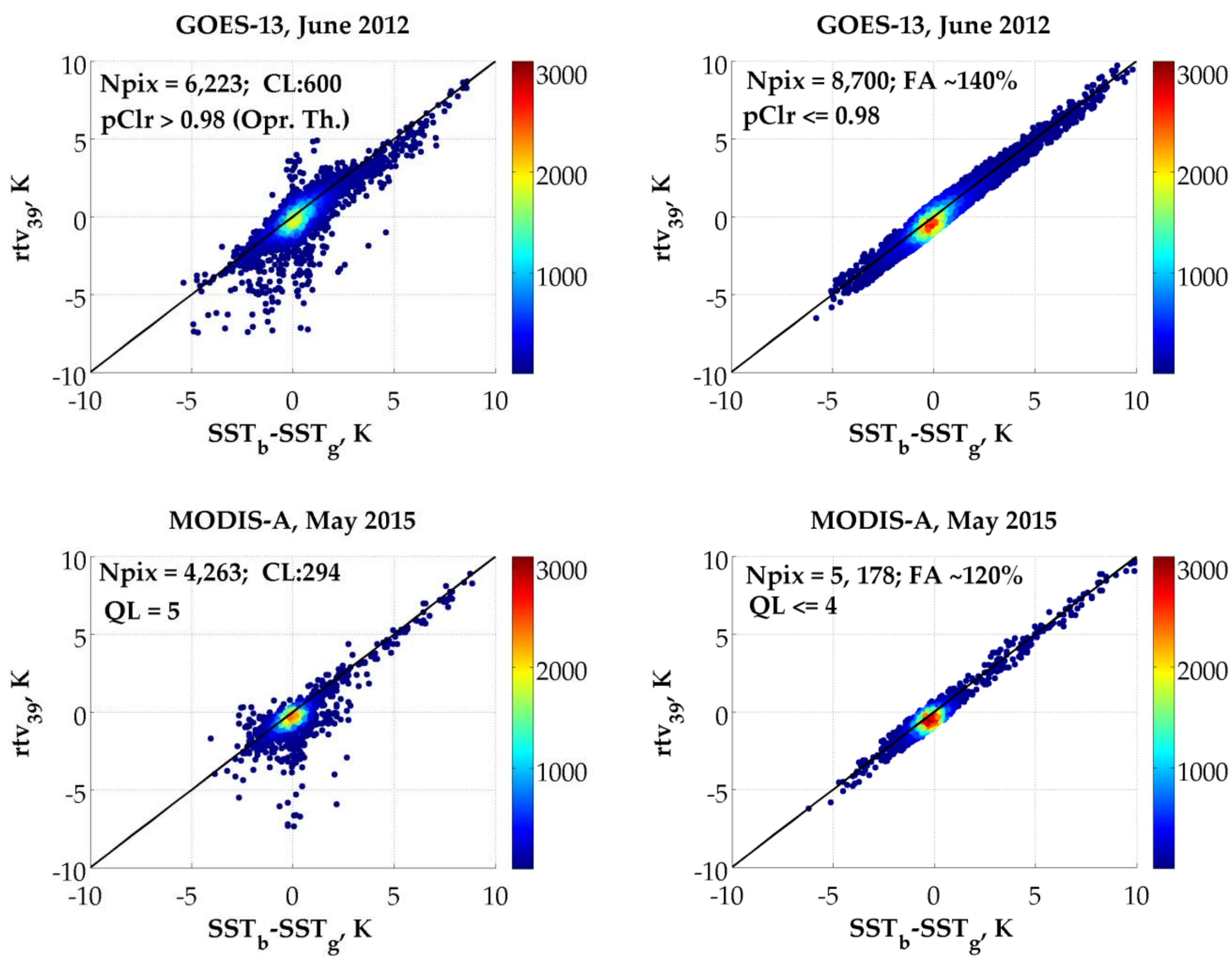
# Limitation of prevalent Cloud algorithms

**Left Panel**: Cloud leakages (CL); Several publications report that the CL is one of hurdles for improving SST quality.

**Right Panel**: False Alarms (FA); This is new. The reports on enormous FA for operational cloud algorithm are seldom.



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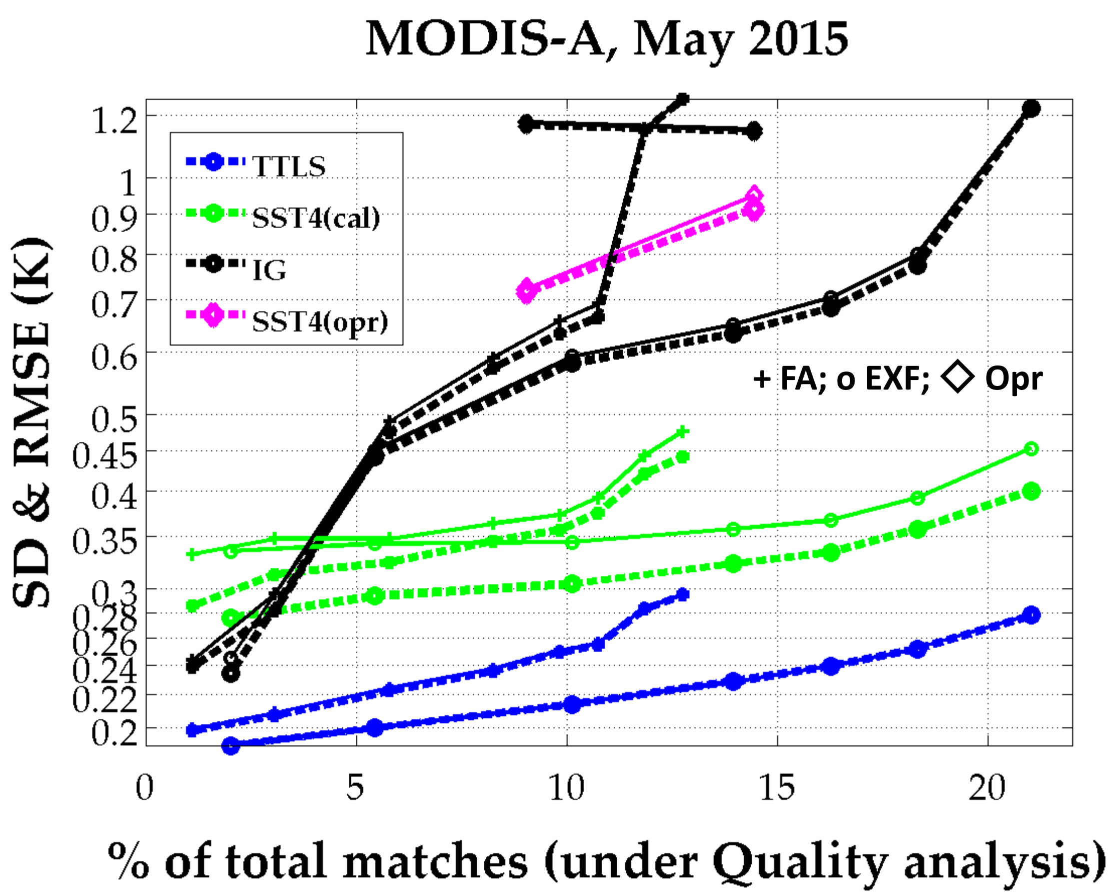
# Validation of EXF




- **Mutually inconsistence between EXF & TTLS is verified by cSST4**
- **Coefficients of cSST4: calculates using matches of Nov. 2013**
- **The RMSE for set of FA pixels:**
  - **< 0.3 K TTLS**
  - **< 0.5 K cSST4**
- **All RMSEs under EXF < 0.7 K SST4 (opr) Cloud Free (QL=5)**
- **IG error for all sets are ~ 1.2 K; confirms that EXF selection is independent of IG**
- **50% of TTLS SST < 0.22 K (~ buoy random error)**

# Some history of Cloud detection using Spectral differences

Saunders & Kriebel: APOLLO (1988)

Spectral Differences (11 & 12 µms)

Ackerman et al. : MODIS (~2000)

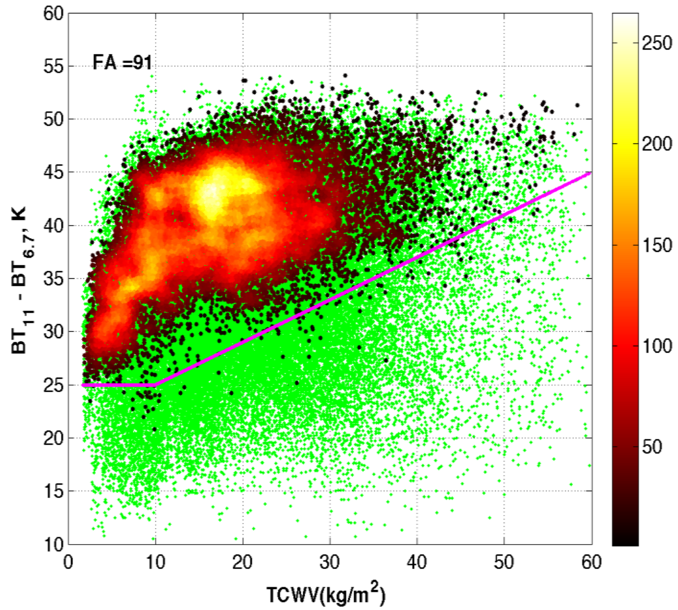
Spectral Differences (6.7 & 11 µms)

Jedlovec : GOES13 (2008)

Spectral Differences (3.9 & 11 µms)

Walker et al: GOES13 (2012)

Spectral Differences (11 & 13.4 µms)




Relaxed and TCWV dependent threshold are implemented in our cloud and error mask (CEM) algorithm. TCWV obtains from GFS data and it is unique from other operational cloud algorithms.

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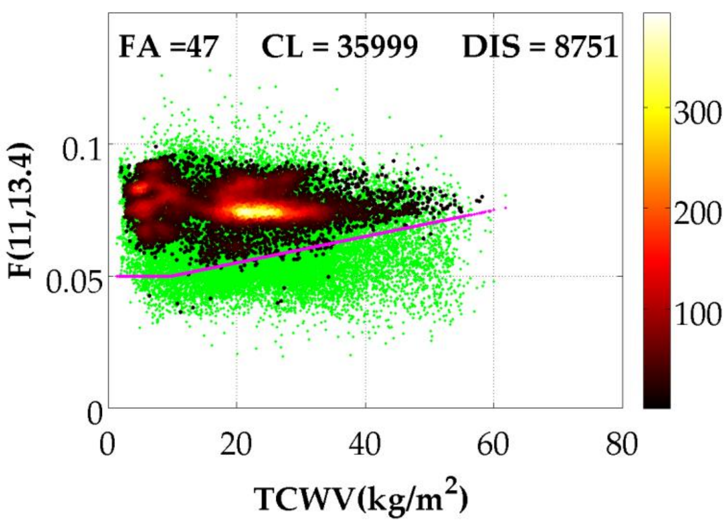
# Normalized spectral differences in CEM

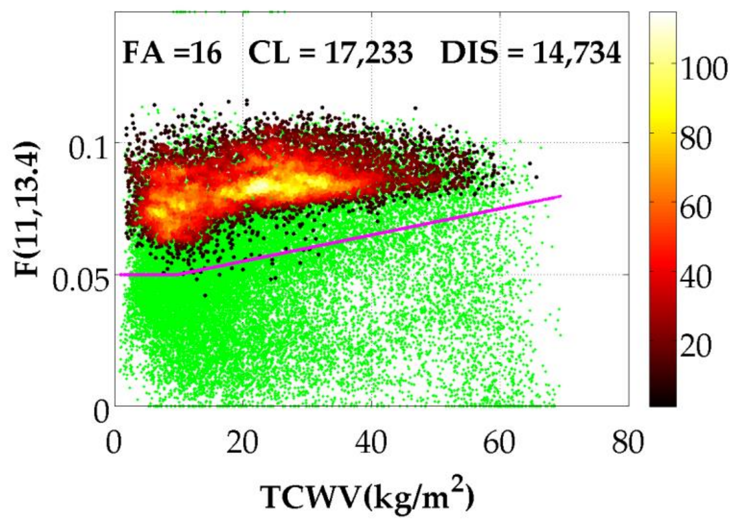
$$\frac{2(T_x^m - T_y^m)}{(T_x^m + T_y^m)} > a_{xy} + \max\left(\frac{TCWV - b_{xy})}{C_{xy}}, 0\right)$$

**Coefficients are calculated using GOES-13 match ups of June 2010**

GOES-13, Jan 2013



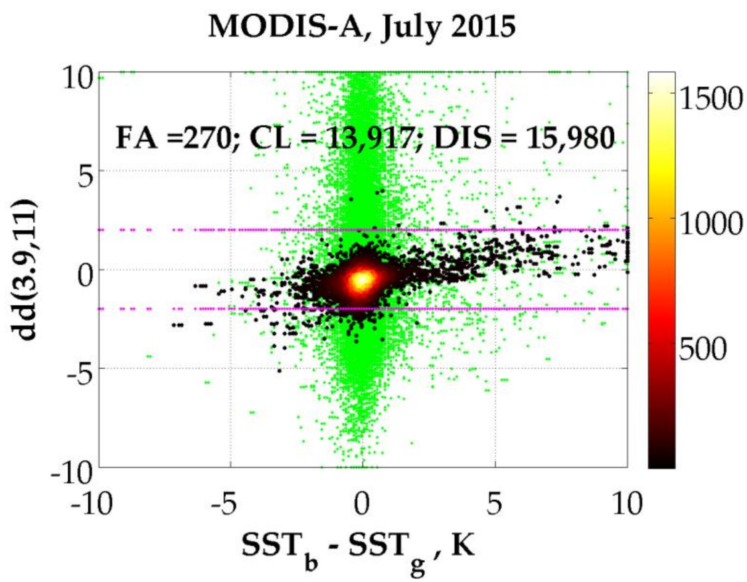

MODIS-A, Jan 2015

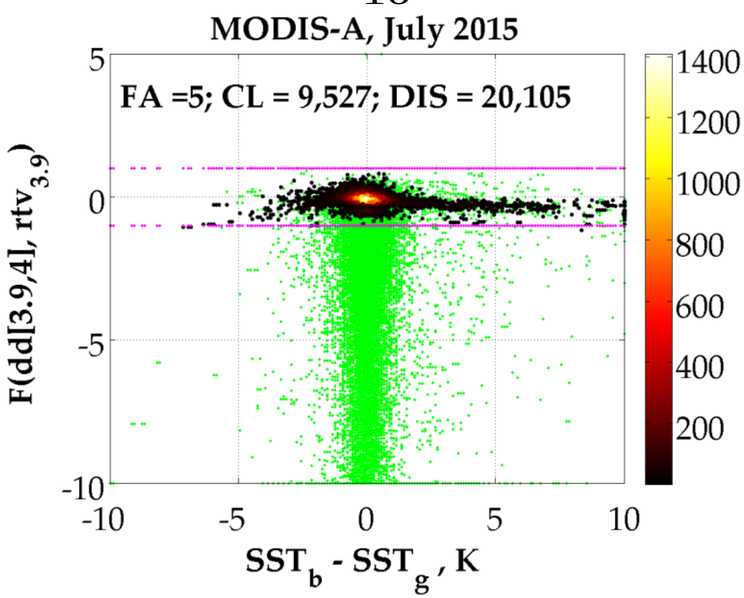



Spec. Diff. between 13.4 and 11 µm of MODIS is interesting and not explore extensively.

# RT based Double differences Tests

$$abs\left(\left(T^{m}_{3.9} - T^{m}_{4}\right) - \left(T^{s}_{3.9} - T^{s}_{4}\right)\right) \leq 0.8*\left(0.1 + \frac{\max(rtv_{3.9}, 2)}{10} + \frac{\min(rtv_{3.9}, -1)}{3}\right)$$



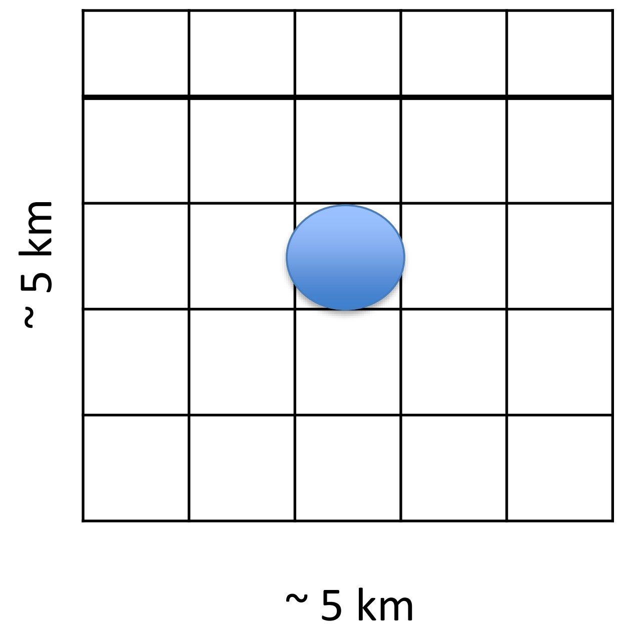




- ❖ **DD test is unique and new addition in cloud detection literature.**
- ❖ **DD (3.9 & 11) µm first applied to GOES-13, where no. of channels is limited.**
- ❖ **Functional DD(3.9 & 4) µm is further improvement for MODIS; reduces FA of 265 and CL of 4,390, and increases detection of 4, 125.**

# Spatial Coherence test

5x5 grid box:

Max – Cpix < 0.6 K




Problem:

more the 0.3 K/km temperature gradient will be screened out.

Need improvement of this test.

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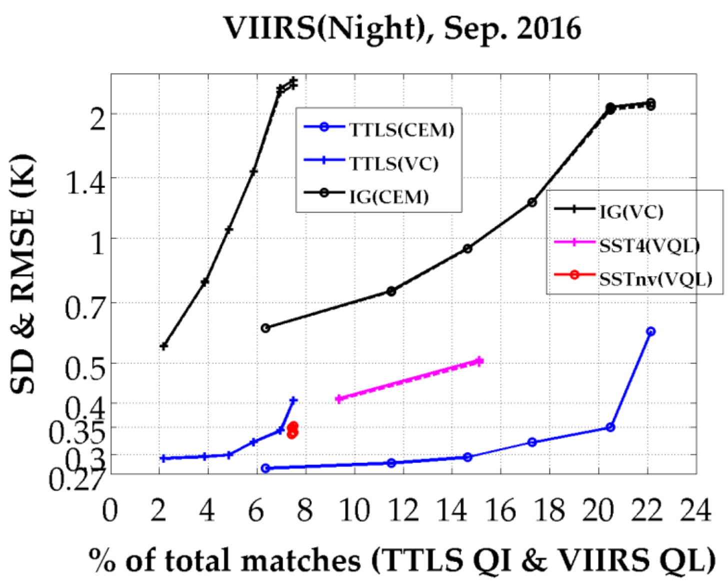
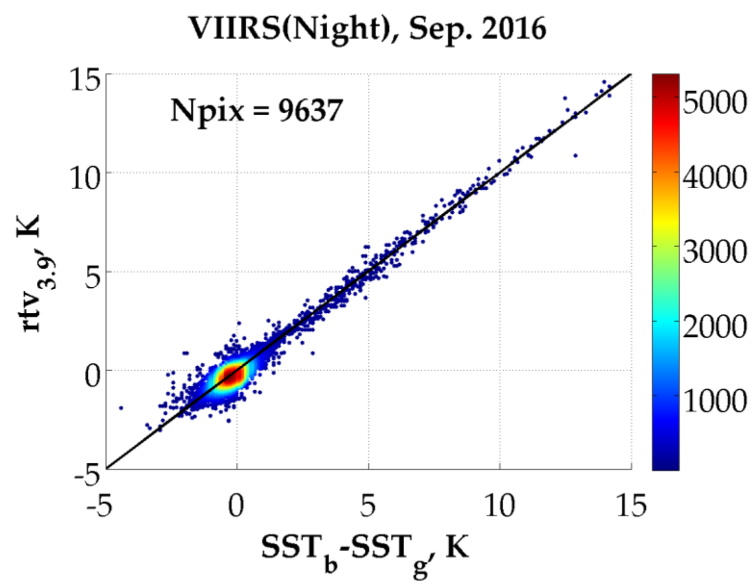
# Additional Cloud detection using PDSST scheme

- **TTLS** developed for 3-parameter retrieval

$|\Delta \boldsymbol{y}| \le 1$: $\lambda = (\sigma_{end\text{-}1})^2$ $|\Delta \boldsymbol{y}| > 1$: $\lambda = (\sigma_{end\text{-}1}/\log(|\Delta \boldsymbol{y}|))^2$




- ❖ **Absence of 6.7 & 13.4 µm channel, VIIRS cloud detection is challenging.**
- ❖ **data coverage CEM: 20.5%, OBPG: 9.4% (QL=5), NAVO: 7.4%(QL=5)**
- ❖ **Reduction of RMSE from 0.6 to 0.35 K discarding 1.5% matches.**
- ❖ **Right panel: single channel retrieval & distance from IG is ~ 1:1**

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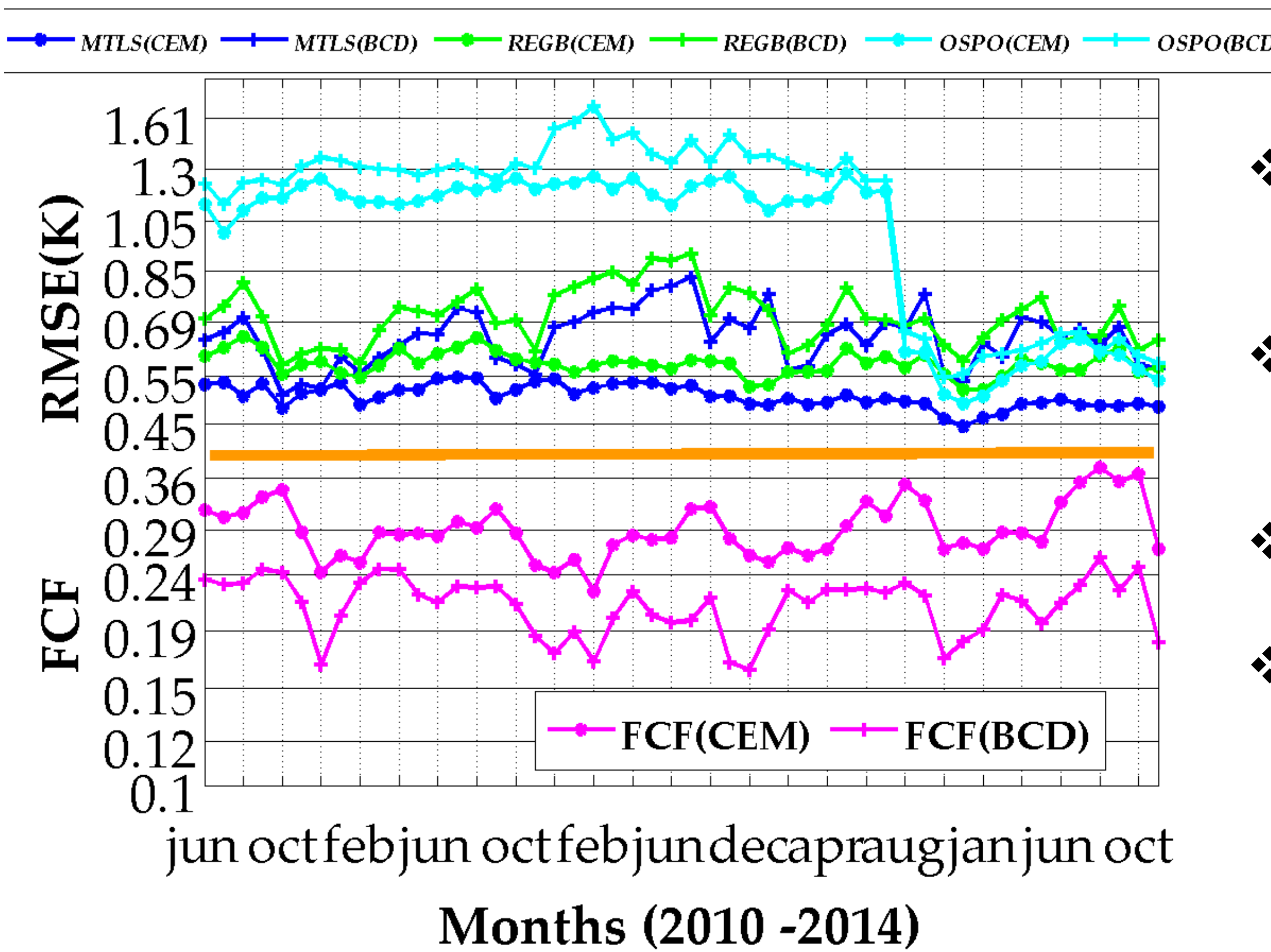
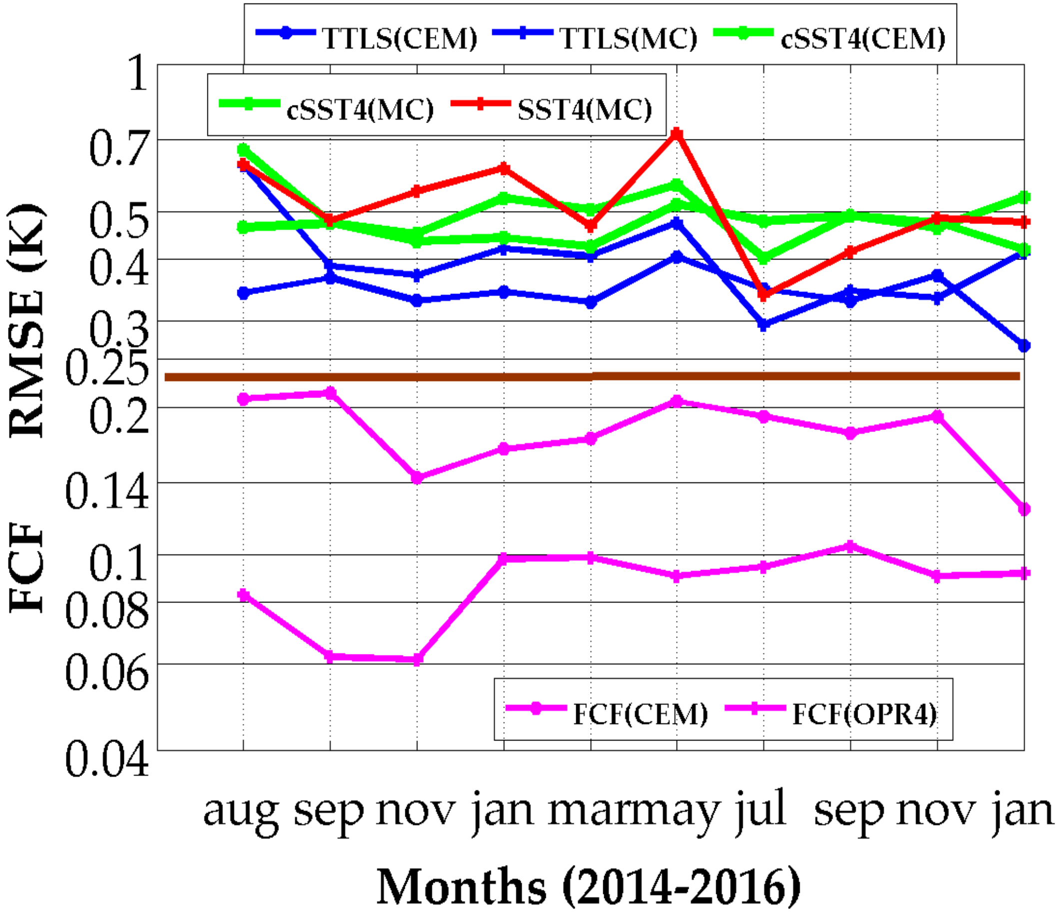
# GOES-13 Time series (50 months)




- Above 5 millions of matchups (day & night composite)
- Avr. MTLS RMSE reduction 22 % (0.67 to 0.5 K).
- Avr. data coverage increased of 38 %.
- Mutually inconsistence between MTLS & CEM.

# MODIS-A time series (10 months)



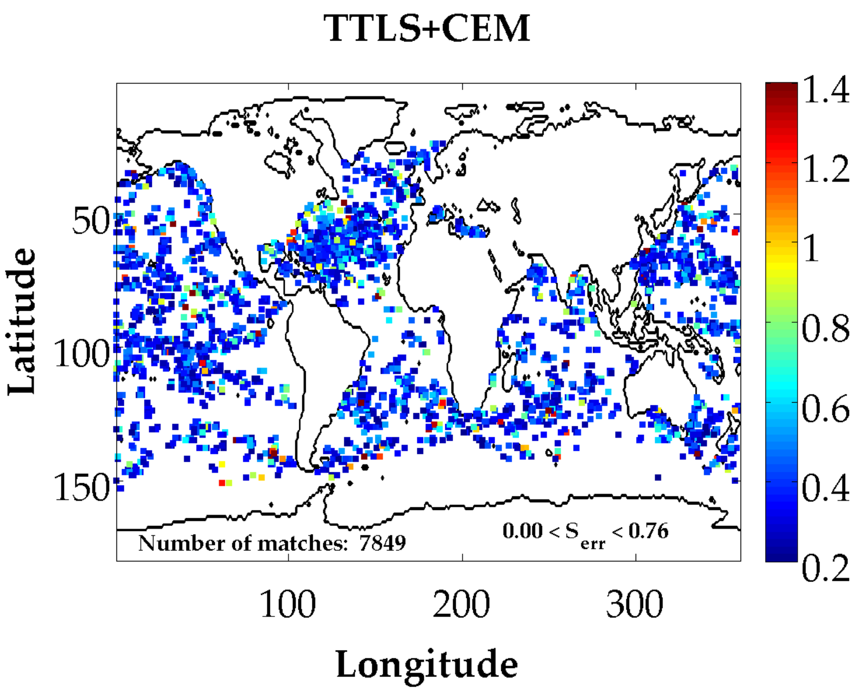

- PD SST suite increases Avr. data coverage from ~9% to 18% & simultaneously reduction of RMSE from 0.51 to 0.34 K.
- Focus of the talk is CEM.
- As operational SST data is inconsistence, offline cSST4 & TTLS are considered.
- Except one month of TTLS, the RMSE of both are low under CEM

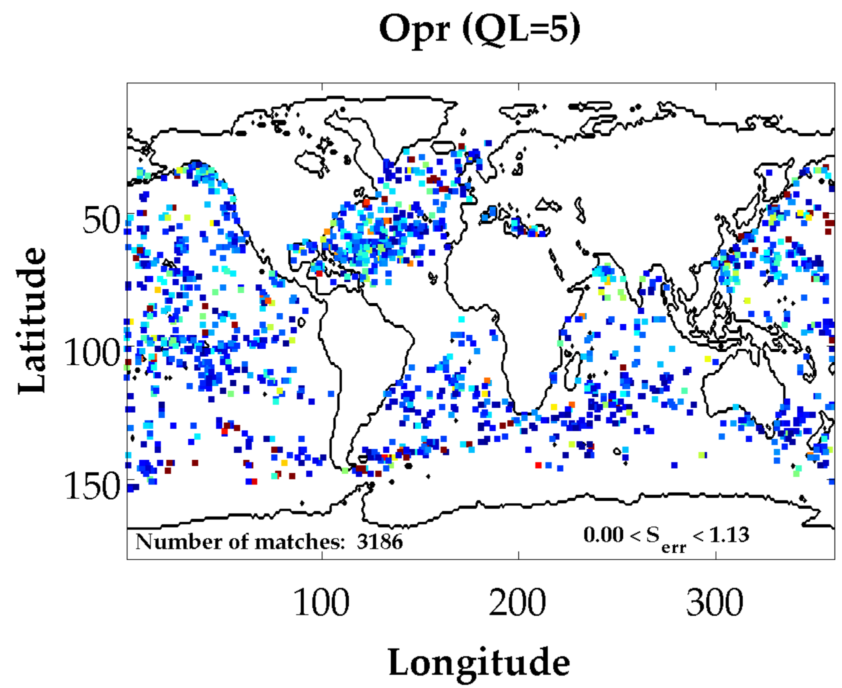
# Summary and conclusions

- CEM is a novel and innovative Quasi-deterministic cloud detection Algorithm.
- CEM is independent of locations (Ocean), seasons and sensors.
- TTLS and MTLS can perform additional cloud detection at solution time.
- CEM is not yet fully optimized and it can be improved further.
- Although CEM performed on match ups only, the substantial amount verification data serve as a ready point for operational use.

# Thank you

# Maps


TTLS+CEM
Latitude
50
100
150
Number of matches: 7849
0.00 < S err < 0.76
100
200
300
Longitude
1.4
1.2
1
0.8
0.6
0.4
0.2


Opr (QL=5)
Latitude
50
100
150
Number of matches: 3186
0.00 < S err < 1.13
100
200
300
Longitude