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A novel IR cloud detection technique for SST application

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NOAA

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

U.S. DEPARTMENT OF COMMERCE

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.

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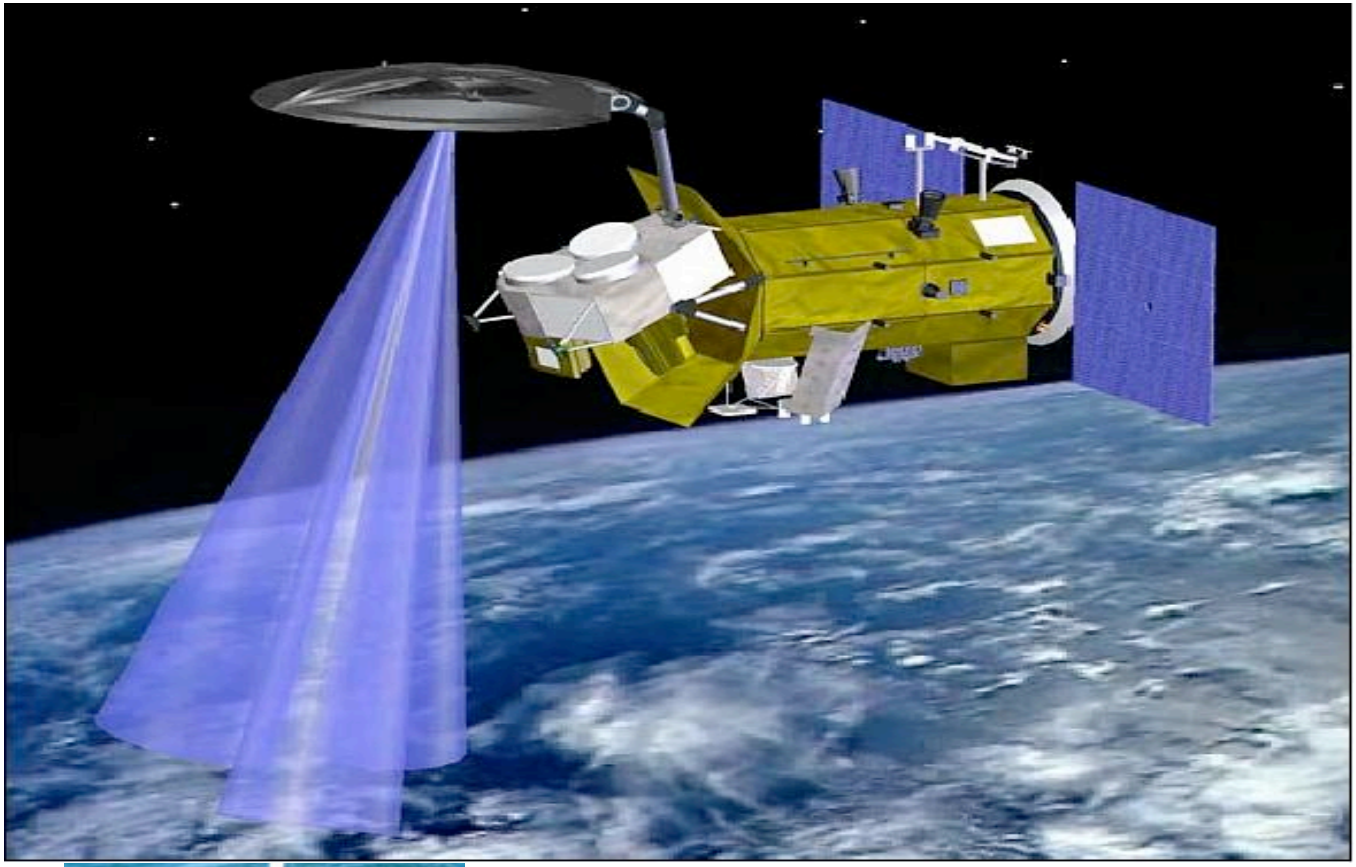
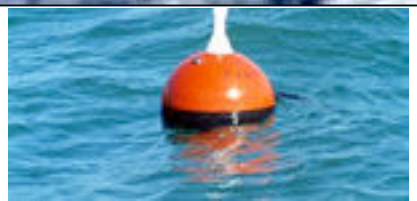
Cloud detection verification





Data and Software downloaded

- MODIS-A L2P SST: ftp://podaac-ftp.jpl.nasa.gov/allData/ghrsst/data/L2P/MODIS_A/JPL/
- MODIS-A L1b: ftp://ladsweb.nascom.nasa.gov/allData/6/MYD021KM/
- MODIS-A Geo-Loc: ftp://ladsweb.nascom.nasa.gov/allData/6/MYD03/
- 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/

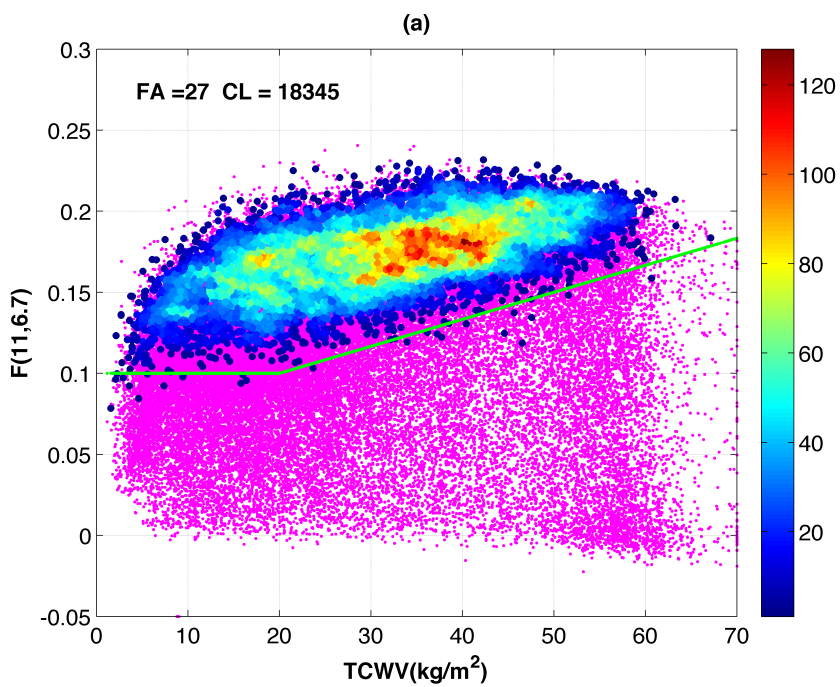
Data and Forward model specifications

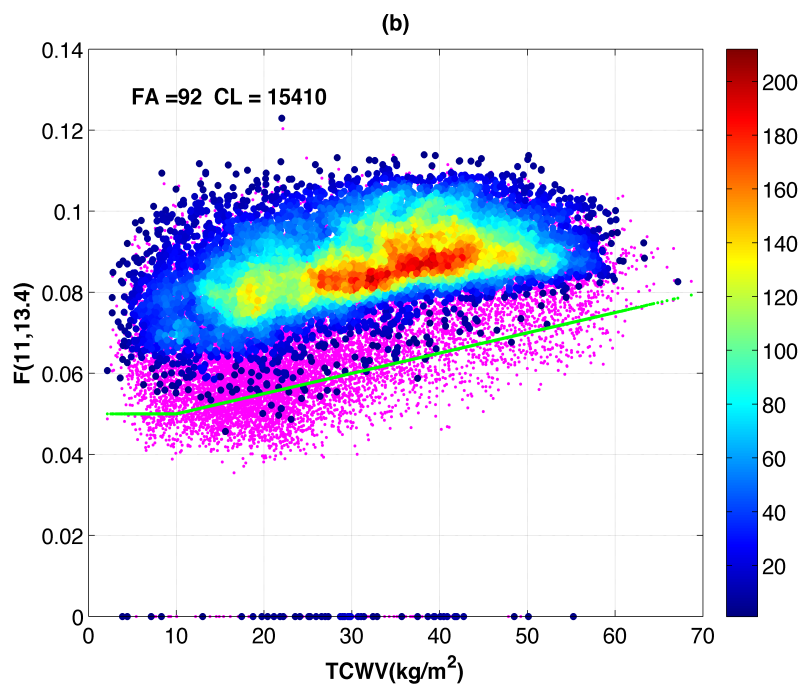
- Forward model using ver. CRTM2.1
- Monthly point matchups
- Buoy (coastal, Moore & drifters)
- iQUAM quality control *in situ* data
- GFS for profile data including surface
- NGAC aerosol profiles
- Night time scenarios
- MTLS and TTLS inverse method

Functional Spectral Differences

$$\frac{2(T_{11}^{m}-T_{6.7}^{m})}{(T_{11}^{m}+T_{6.7}^{m})} > a_1 + \max\left(\frac{TCWV-b_1}{C_1},0\right)$$

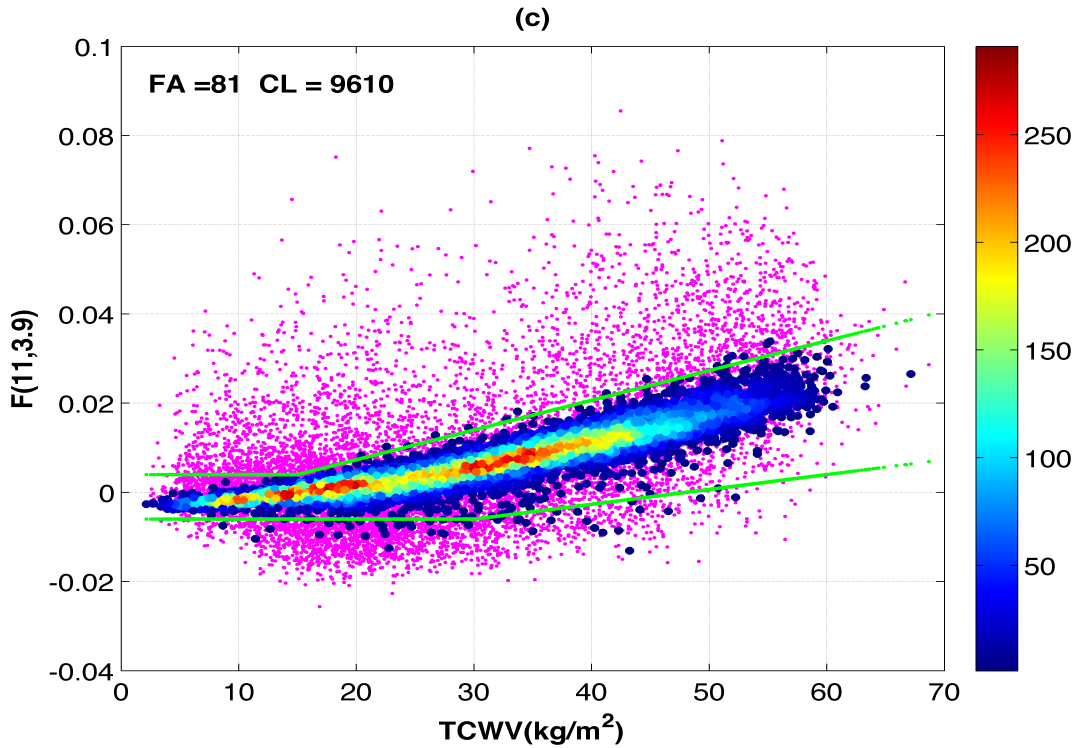
$$\frac{2(T_{11}^{m}-T_{13.4}^{m})}{(T_{11}^{m}+T_{13.4}^{m})} > a_2 + \max\left(\frac{TCWV-b_2}{C_2},0\right)$$





Functional Spectral Differences

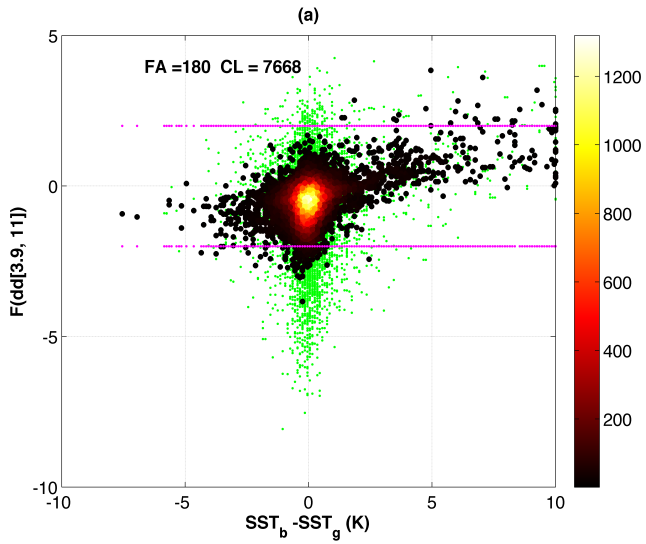
$$\frac{2(T_{3.9}^{m}-T_{11}^{m})}{(T_{3.9}^{m}+T_{11}^{m})} > a_3 + \max\left(\frac{TCWV-b_3}{C_3},0\right) \qquad \frac{2(T_{3.9}^{m}-T_{11}^{m})}{(T_{3.9}^{m}+T_{11}^{m})} < a_4 + \max\left(\frac{TCWV-b_4}{C_4},0\right)$$



RT based Tests for cloud detection

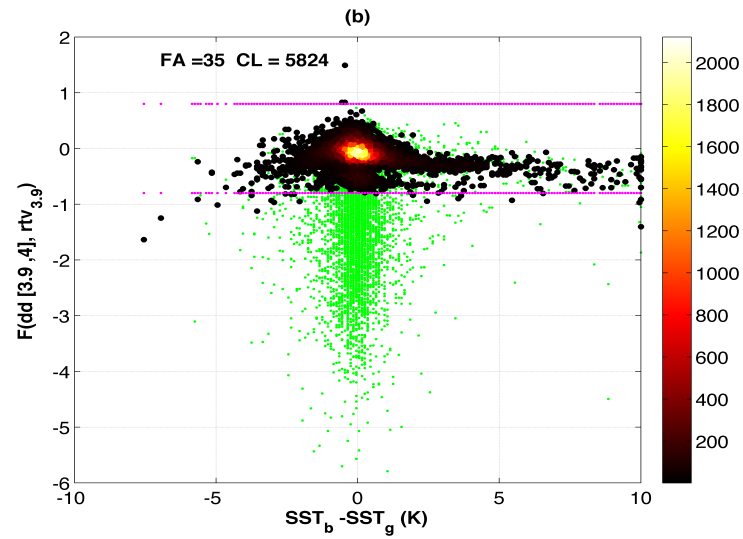
DDF double difference filter

$$abs((T^m_{3.9} - T^m_{11}) - (T^s_{3.9} - T^s_{11})) \le 2$$



$$abs((T^m_{3.9} - T^m_4) - (T^s_{3.9} - T^s_4))$$

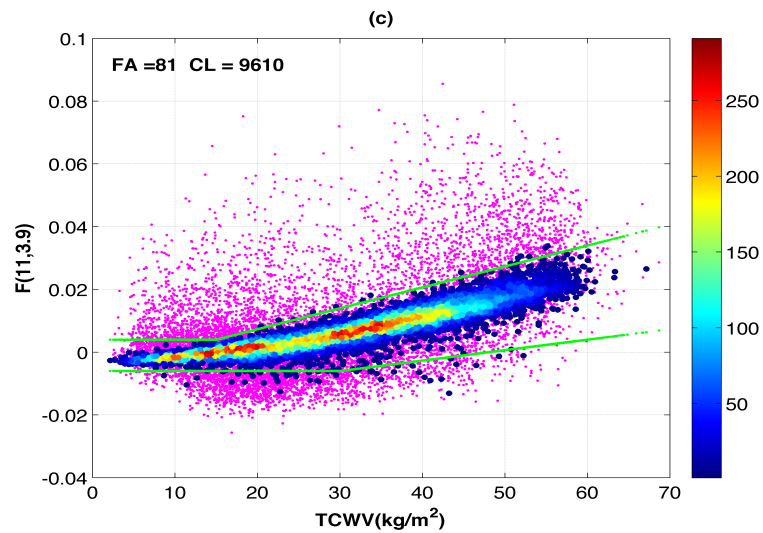
$$\le 0.8*(0.1 + \frac{\max(S_{3.9}, 2)}{10} + \frac{\min(S_{3.9}, -1)}{3})$$



WVTF Water Vapor Threshold filter is also modified for MODIS from GOES13 implementation.

Functional Spectral Differences

- 1. $$\frac{2(T_{11}^{m}-T_{6.7}^{m})}{(T_{11}^{m}+T_{6.7}^{m})} > a_1+\max\left(\frac{TCWV-b_1)}{C_1},0\right)$$
- 2. $$\frac{2(T_{11}^{m}-T_{13.4}^{m})}{(T_{11}^{m}+T_{13.4}^{m})} > a_2+\max\left(\frac{TCWV-b_2)}{C_2}\right.$$
- 3. $$\frac{2(T_{3.9}^{m}-T_{11}^{m})}{(T_{3.9}^{m}+T_{11}^{m})} > a_3+\max\left(\frac{TCWV-b_3)}{C_3}\right.$$
- 4. $$\frac{2(T_{3.9}^{m}-T_{11}^{m})}{(T_{3.9}^{m}+T_{11}^{m})} < a_4+\max\left(\frac{TCWV-b_4)}{C_4}\right.$$

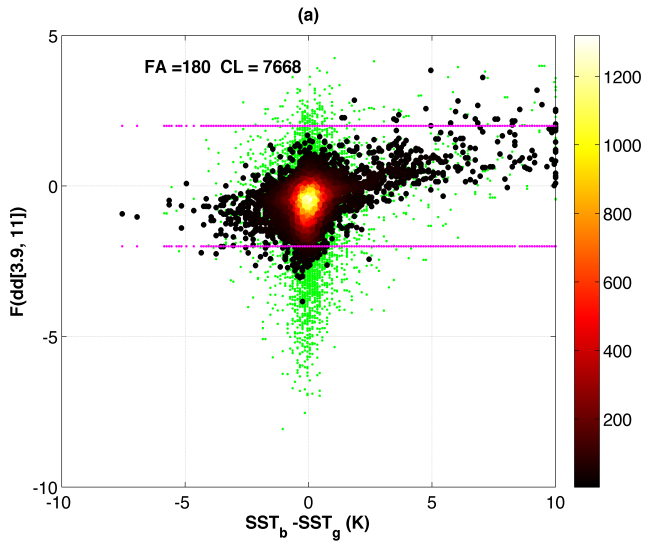


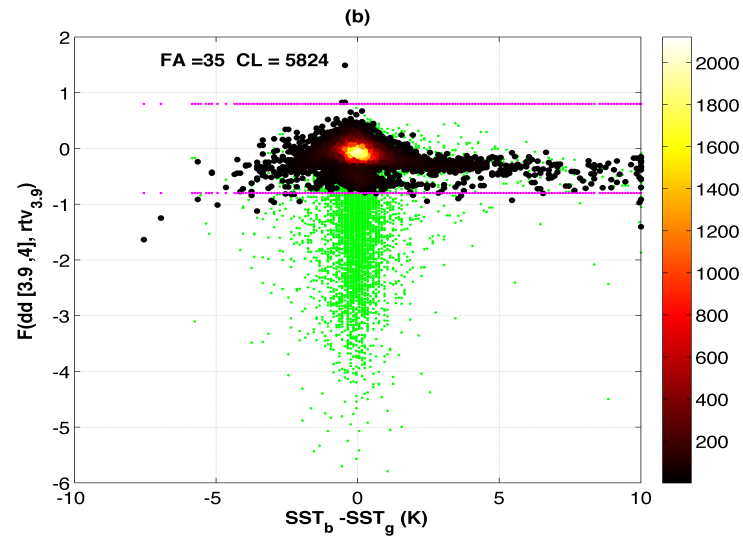
RT based Tests for cloud detection

DDF double difference filter

$$abs((\mathbf{T}^m_{3.9} - \mathbf{T}^m_{11}) - (\mathbf{T}^s_{3.9} - \mathbf{T}^s_{11})) \le 2$$

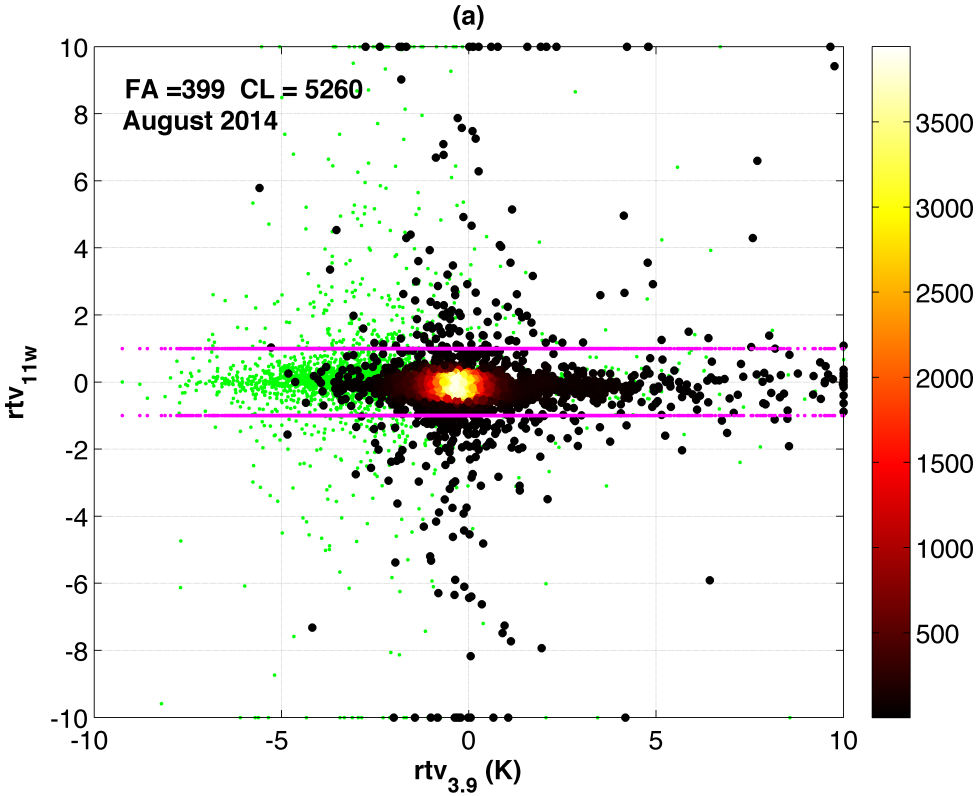
$$abs((\mathbf{T}^m_{3.9} - \mathbf{T}^m_{4}) - (\mathbf{T}^s_{3.9} - \mathbf{T}^s_{4})) \le 0.8*(0.1 + \frac{\max(S_{3.9}, 2)}{10} + \frac{\min(S_{3.9}, -1)}{3})$$





WVTF Water Vapor Threshold filter is also modified for MODIS from GOES13 implementation.

RT based Cloud detection



$$\mathbf{rtv}_{\mathbf{TCWV}} = \frac{\mathbf{T}_{11}^{\mathbf{m}} - \mathbf{T}_{11}^{\mathbf{s}} - \mathbf{K}_{11}^{\mathbf{sst}}\mathbf{rtv}_{3.9}}{\mathbf{K}_{11}^{\mathbf{TCWV}}}$$

3x3 spatial test: **Unchanged**

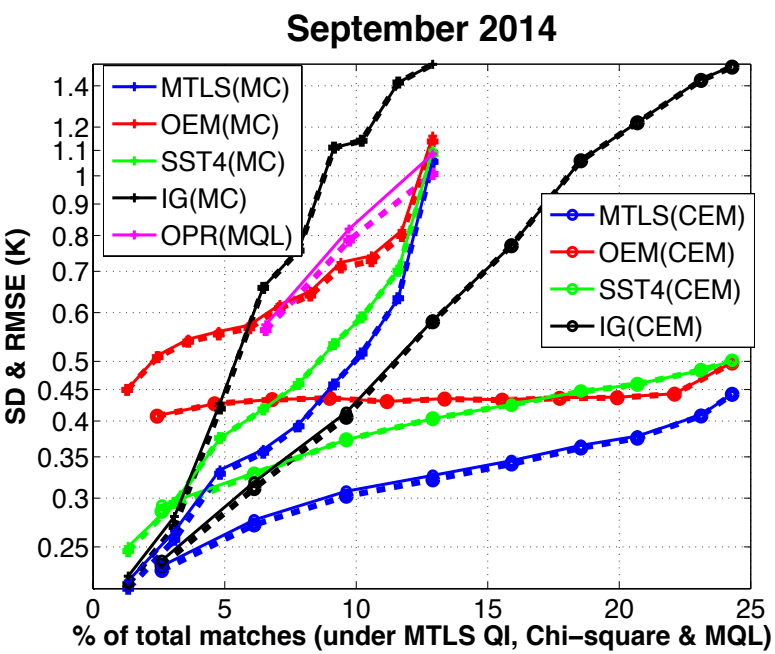
Max – Min < 5 K

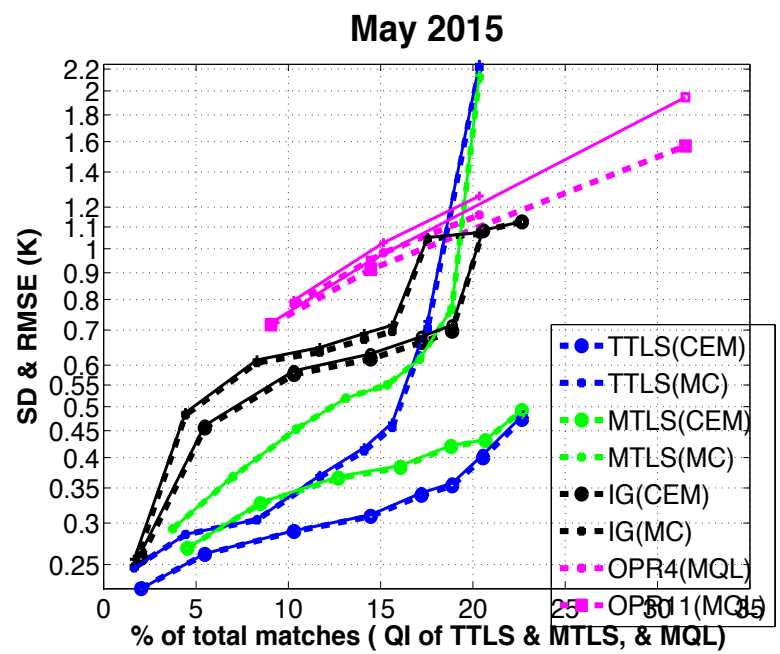
Max – Cpix < 0.5 K

Results for different SST retrievals

Left Panel: OPR11 (QL 3:5) vs. MTLS, OEM and IG, and SST4 (offline) for CEM and MC

Right Panel: OPR11 & OPR4 vs, TTLS, MTLS and IG for CEM and MC





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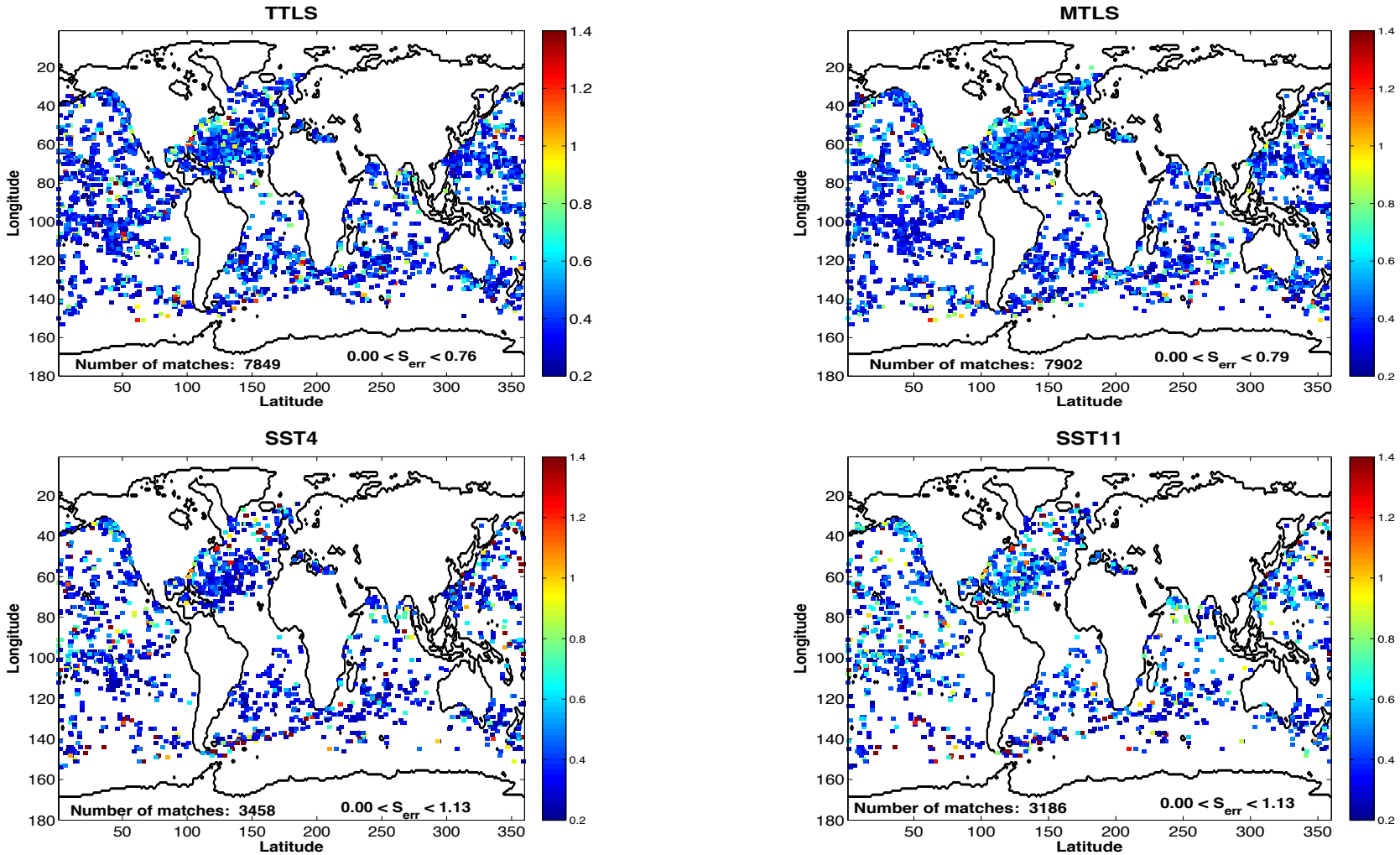
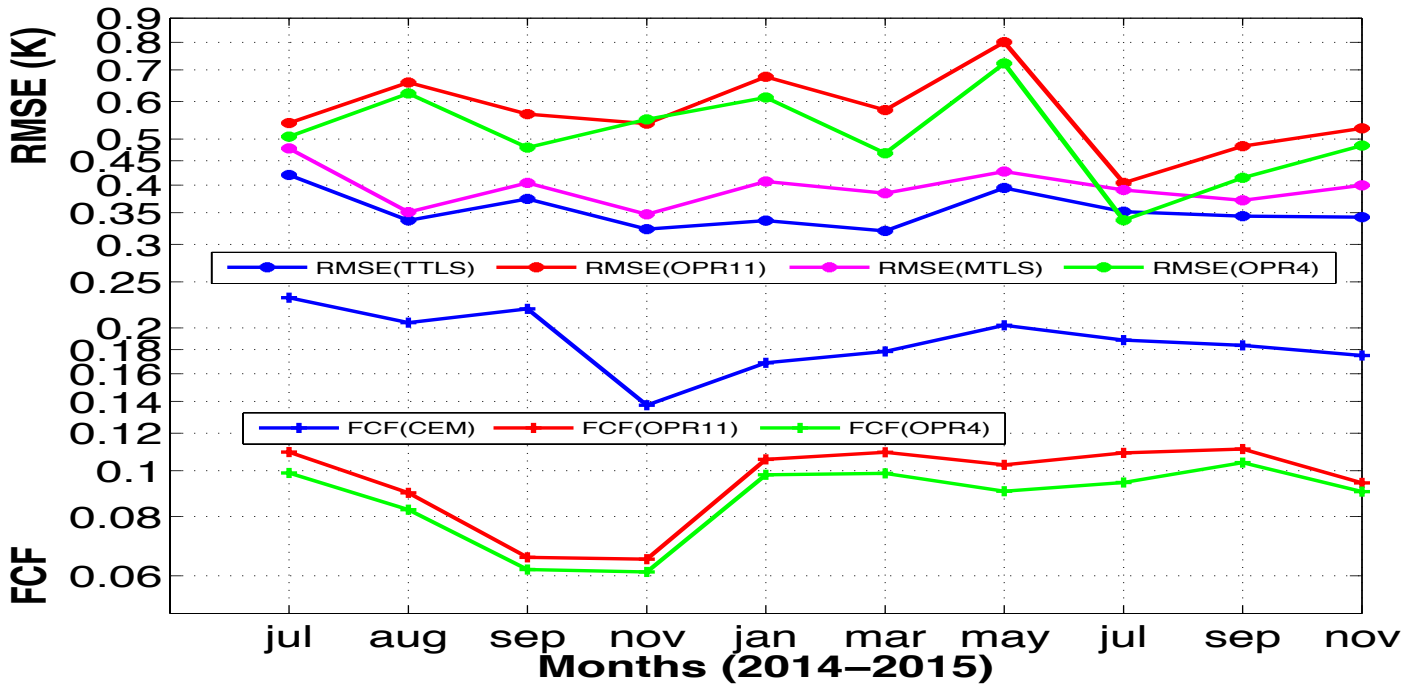
Spatial 0.05°×0.05° distribution of RMSE



Time Series of retrieval error and data coverage

- Error (RMSE) reduction ~ 50%; Data coverage (FCF) improves ~50%
- TTLS error fairly constant; Operational error is wide variation

  FCF = Fraction of cloud free.



Summary and conclusions

- CEM is an original and innovative Quasi-deterministic superior cloud detection Algorithm.
- TTLS is physical deterministic method and the best choice when more measurement available like MODIS.
- TTLS and MTLS can additional cloud detection at solution time.
- MODIS SST is widely used for many application and ~3 times information gain will open up new frontier.
- We are adapting this understanding to improve the VIIRS Cloud mask and retrieval.

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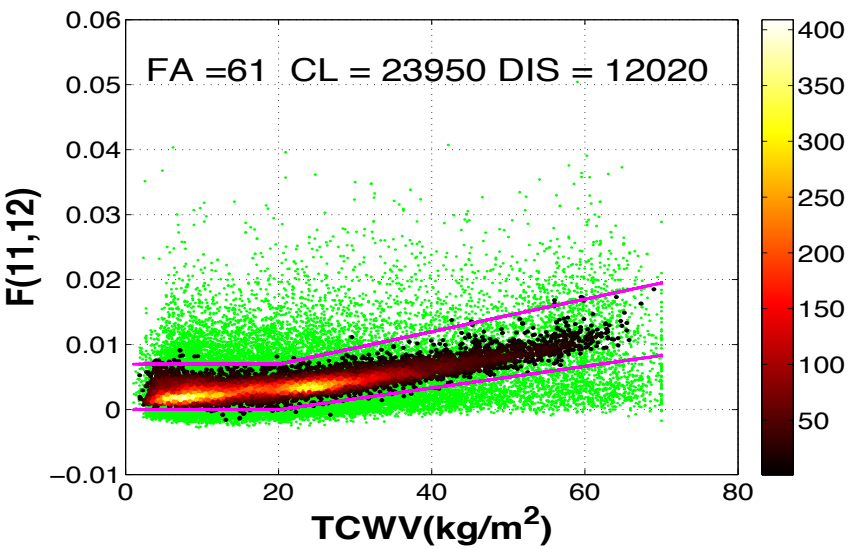
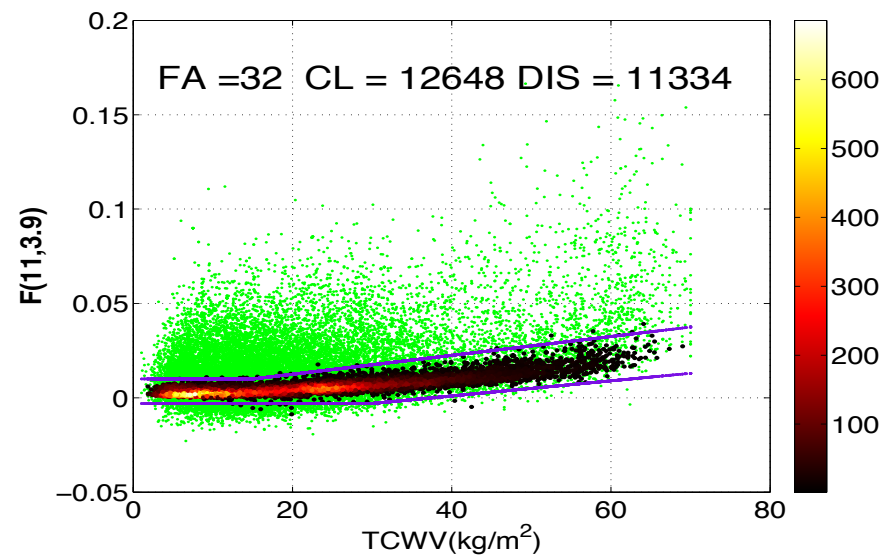
Thank You.

VIIRS Functional Spectral differences

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

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



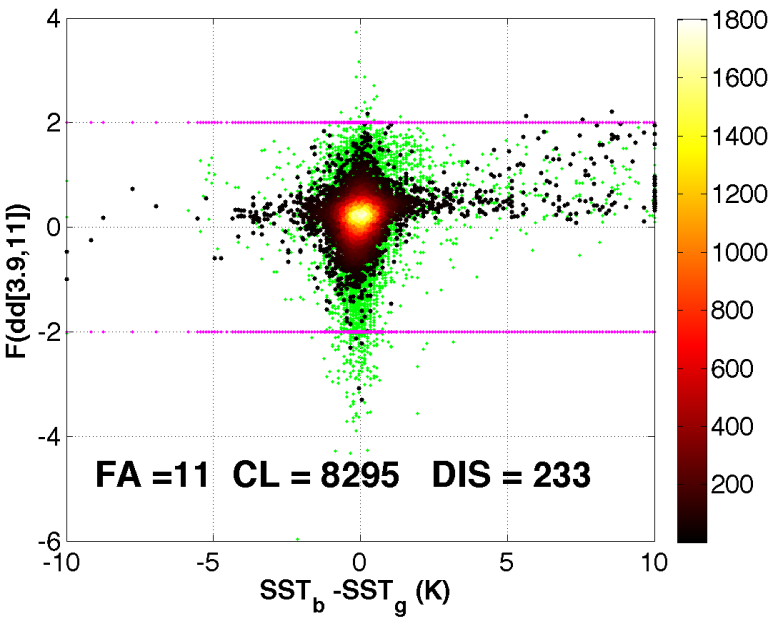


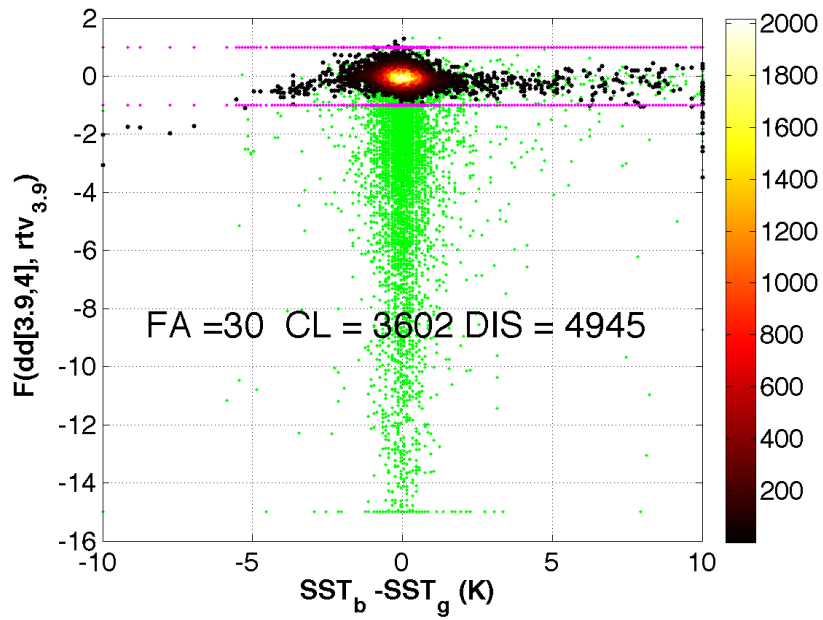
Difficulties: VIIRS does not have 13.4 and 6.7 µm Channels

RT based Double differences Tests

$$abs((T^m_{3.9} - T^m_{11}) - (T^s_{3.9} - T^s_{11})) \le 2$$

$$abs((T^m_{3.9} - T^m_4) - (T^s_{3.9} - T^s_4)) \le 0.8*(0.1 + \frac{\max(S_{3.9}, 2)}{10} + \frac{\min(S_{3.9}, -1)}{3})$$

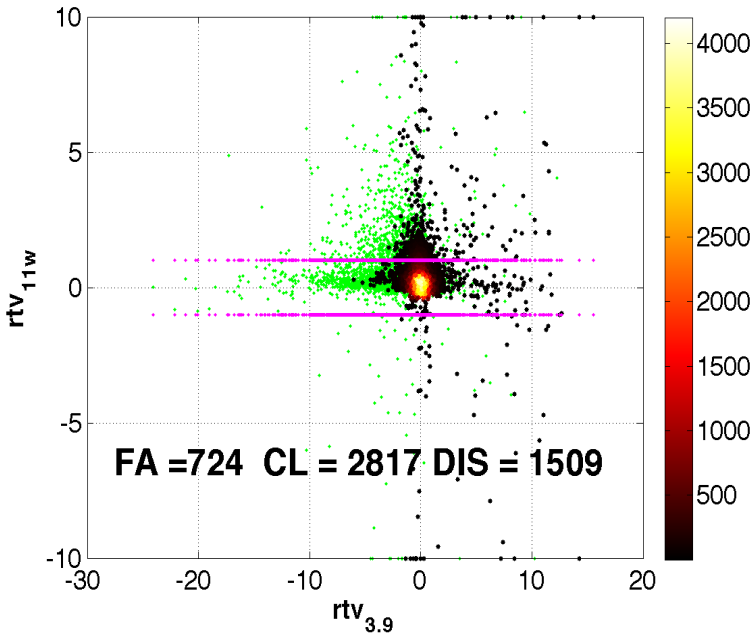


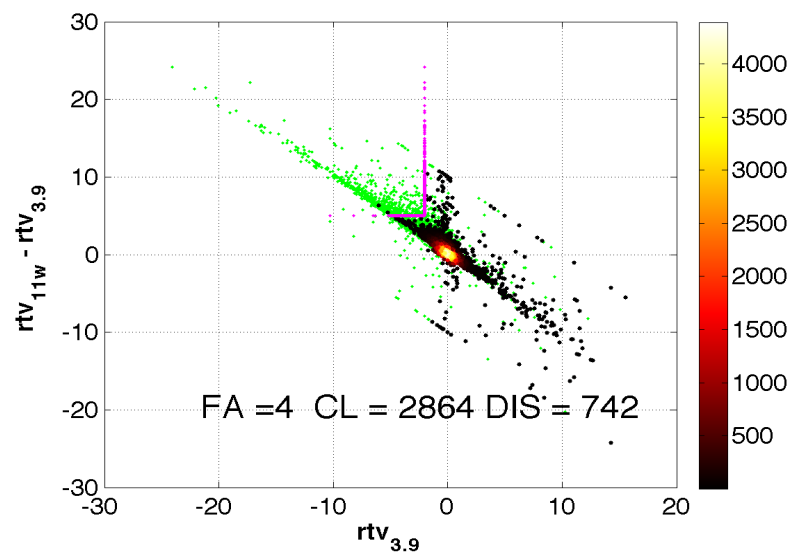


RT based Water vapor threshold Test

$$\mathbf{rtv_{TCWV}} = \frac{\mathbf{T_{11}^{m} - T_{11}^{s} - K_{11}^{sst} rtv_{3.9}}}{\mathbf{K_{11}^{TCWV}}}$$

$$rtv_{11w} - rtv_{39} <= 5 \text{ or } rtv_{39} > -2$$





Homogeneity (Spatial) Test