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Uncertainty Quantification for GPM-era Precipitation Measurements

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Outline

What we learned from TRMM-era measurements -"The Error Structure"
1. concepts and procedures
2. error composition
3. systematic & random errors

Applications of the Error Structure

- 4. scaling of errors
- 5. sources of errors

What error structure to expect with GPM-era measurements

Procedure to quantify uncertainty Step 1: Get a reference dataset



It is all uncertain if we know no truth



If truth is available ...



Measurements can be validated

Procedure to quantify uncertainty

Step 2: Error decomposition (Tian et al., 2009)



(total error) (hit error) (missed) (false) E = H - D + F Procedure to quantify uncertainty

Step 3: Separate systematic and random error

E = H - D + F



The Error Structure unifies uncertainty definition and quantification



Uncertainty quantification = (-D, F, , \tilde{A})

Total Error E $E = R - R_{ref}$



Error Decomposition Scheme(total error)(hit error)(missed)(false)

E = H - D +



(Tian et al., 2009)

F



90 -60 -30 0 30 60 90 120 150

-150-120-90 -60 -30 0 30 60 90 120 150

-150 -120 -90 -60 -30 0

0 30 60 90 120 150

Determining the Error Structure – next step, hits error



Hit error (H) is multiplicative (Tian et al., 2014)

Additive error model

 $X_i = a + bT_i + \varepsilon$





Two parameters quantify systematic error

$$X_i = a T_i^{\beta} e^{\varepsilon} \qquad \sigma = stdev(\varepsilon)$$

±: scale error (ideal: 1)

²: shape error (ideal: 1)

systematic error

2







-0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1



-0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

One parameter quantifies random error

$$X_i = a T_i^{\beta} e^{\varepsilon}$$
 $\sigma = stdev(\varepsilon)$

Random error \tilde{A} (ideal: 0)



Procedure of uncertainty quantification – 3 steps to the Error Structure



Uncertainty quantification = (-D, F, \pm , ², \tilde{A})

Scaling of errors: how Error Structure changes with space/time scales



Systematic error (α , β)

False (F)

Random error (σ)

Missed (-D)





How systematic and random errors vary with space/time scales





GPM Constellation of Satellites

NPP (NASA/IPO)

MetOp B & C (EUMETSAT)

JPSS-1 (NASA/NOAA) GPM Core Observatory (NASA/JAXA)

> Megha-Tropiques (CNES/ISRO)

> > NOAA 19 (NOAA)

DMSP F19/F20 (DOD)



GCOM-W1 (JAXA)

Errors can be traced back to Level-2 retrievals (Tang, Tian & Lin, 2013; Poster #Z42 today)

AMSR-E SSM/I(DMSP F13) TMI SSM/I(DMSP F13) AMSR-E(Aqua) TMI(TRMM) a) b) - · - Corrected Q2 m. AMSR-E - · - Corrected Q2 m. SSMI-F13 - · - Corrected Q2 m. TMI AMSR-E/TMI/SSMI 16 32 64 128 0.25 0.5 32 0.25 0.5 1 2 4 8 2 4 8 16 64 128 0.25 0.5 8 16 32 64 128 2 4 SSMIS(DMSP-F18) SSMIS(DMSP-F16) Precipitation amount / Total GV amount (%) SSMIS(DMSP-F17) SSMIS(DMSP-F16) SSMIS(DMSP-F17) SSMIS(DMSP-F18) - Corrected Q2 m. F16-Ð g) e) Corrected Q2 m. F17 --- Corrected Q2 m. F18 **SSMIS** 0.25 0.5 2 4 8 16 32 64 128 0.25 0.5 1 1 32 64 128 32 2 4 8 16 0.25 0.5 1 2 4 8 16 64 128 AMSU-B(NOAA-15) AMSU-B (NOAA-16) AMSU-B (NOAA-17) AMSU-B(NOAA-15) AMSU-B(NOAA-17) AMSU-B(NOAA-16) - · - Corrected Q2 m. N15 --- Corrected Q2 m. N16 - Corrected Q2 m. N17 AMSU-B 0.25 0.5 1 16 32 64 128 0.25 0.5 1 0.25 0.5 16 32 64 128 2 8 32 64 128 4 2 4 8 16 1 2 4 8 MHS(NOAA-18) MHS (NOAA-19) MHS(METOP-A) ▲ MHS(NOAA-18) MHS(NOAA-19) → MHS(METOP-A) m) 7ŀ n) 0) - · - Corrected Q2 m. N18 - · - Corrected Q2 m. N19 --- Corrected Q2 m. MetOp-A MHS 16 32 64 128 0.25 0.5 2 4 8 0.25 0.5 16 32 64 128 0.25 0.5 2 4 8 16 32 64 128 1 1 2 4 8 1 Precipitation rate (mm/hr) Precipitation rate (mm/hr) Precipitation rate (mm/hr)

Summary

What we learned from TRMM-era measurements:

- The Error Structure and procedures to determine it
 - 1. concepts and procedures
 - 2. error composition
 - 3. separation of systematic
 - & random errors



4. scaling of errors
 5. sources of errors

Summary

What uncertainty do we expect from GPM-era measurements

- 1. Missed precipitation (-D): reduced
- 2. False precipitation (F): reduced
- 3. systematic errors (α , β): slight to moderate improvement
- 4. random errors (σ): ~same, but higher at higher resolution



References

Tang, L, Y. Tian, and X. Lin, 2014: Validation of precipitation retrievals from satellite-based passive microwave sensors, J. Geophys. Res., 119, doi:10.1002/2013JD020933.

Tian, Y., C. Peters-Lidard, J. Eylander, R. Joyce, G. Huffman, R. Adler, K.-L. Hsu, F. J. Turk, M. Garcia, and J. Zeng (2009), Component analysis of errors in satellitebased precipitation estimates, J. Geophys. Res., 114, D24101, doi:10.1029/2009JD011949.

Tian, Y., G. Huffman, R. Adler, L. Tang, M. Sapiano, V. Maggioni, and H. Wu, 2014: Modeling errors in daily precipitation measurements: additive or multiplicative? Geophys. Rev. Lett., 40, doi:10.1002/grl.50320.