Using Data Assimilation to Understand the Systematic Errors of CHAMP Accelerometer-Derived Neutral Mass Density Data

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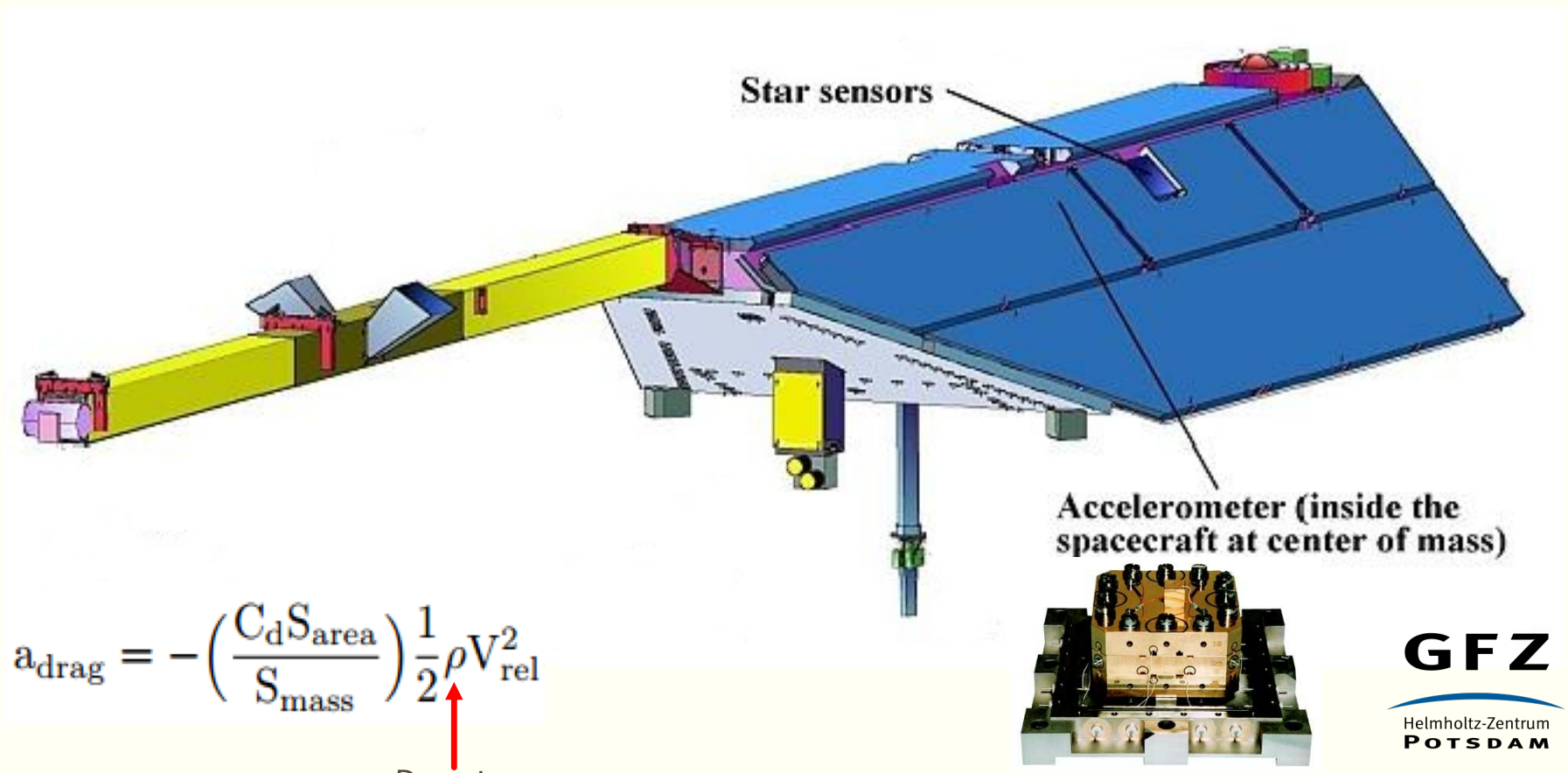
Neutral mass density can be derived from accelerometer measurements onboard CHAMP



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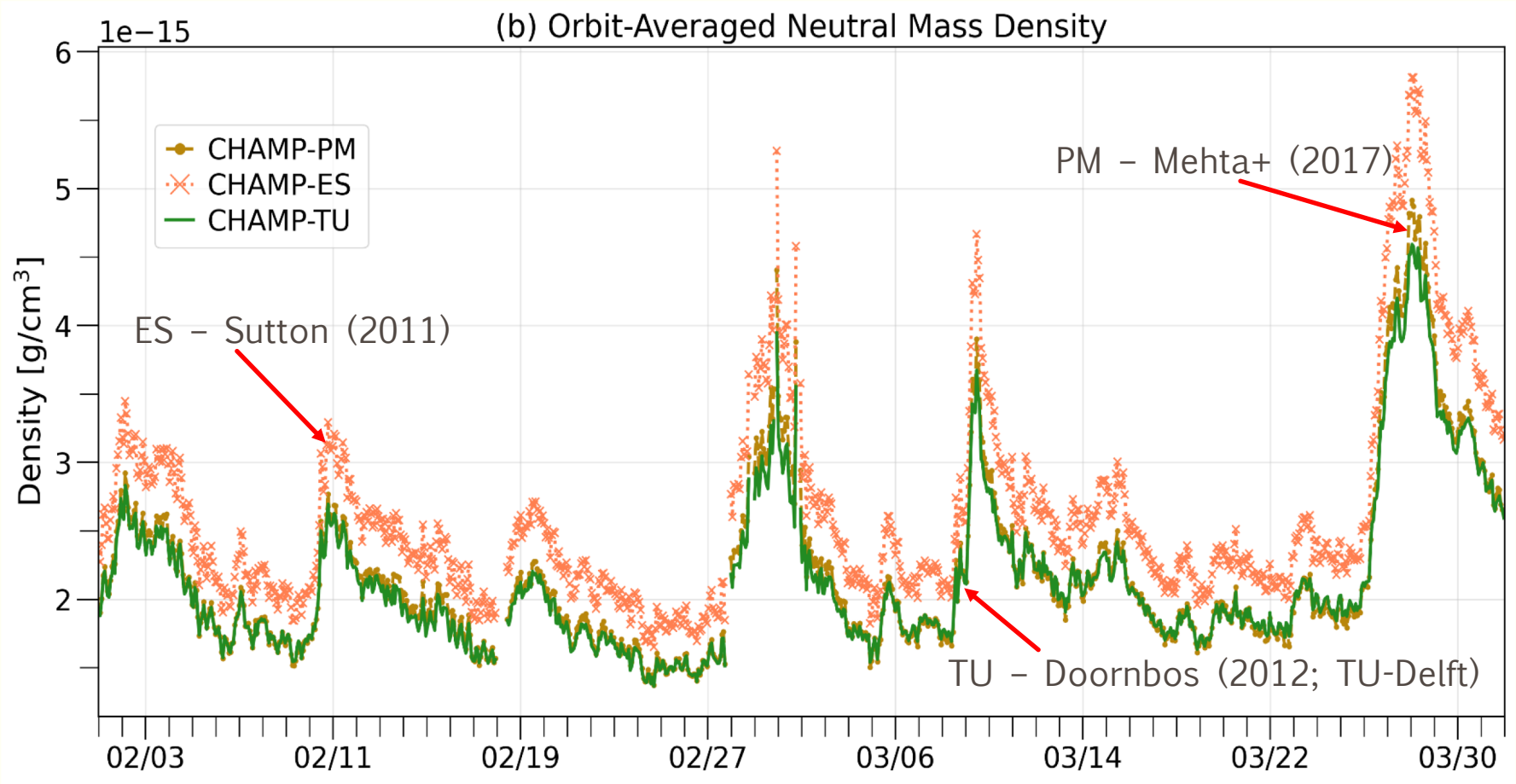
The uncertainties of accelerometer-derived NMD are not fully understood



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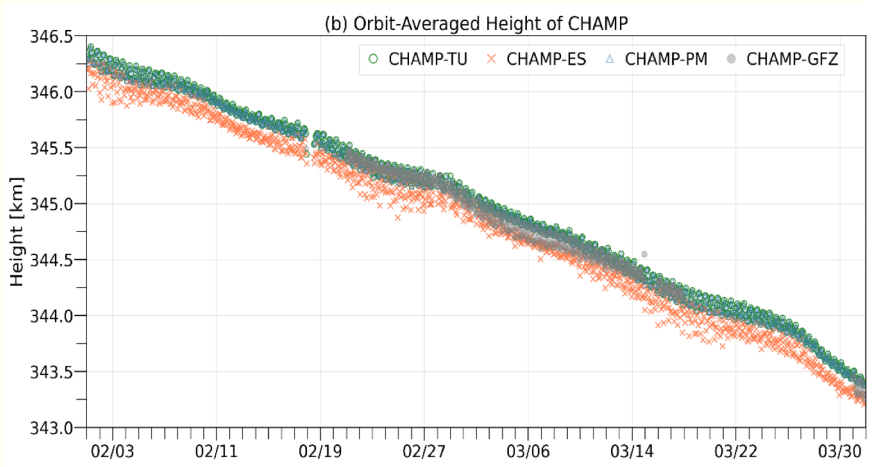
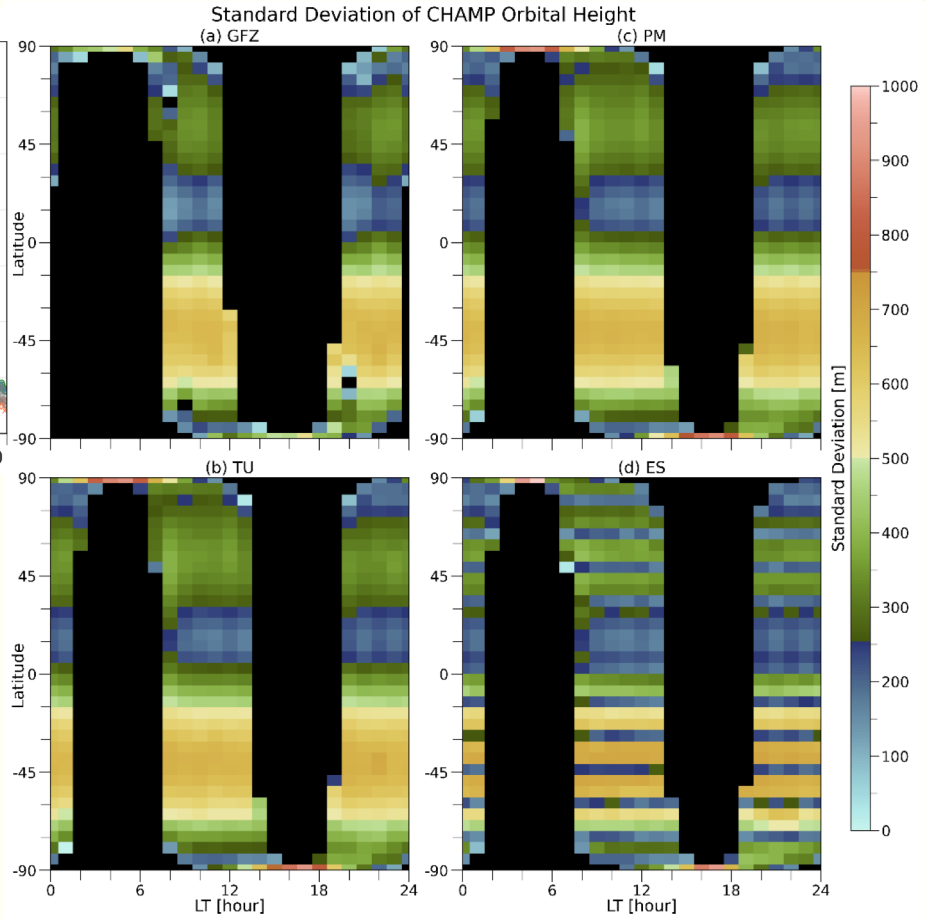
Some discrepancies exist in the published CHAMP height





GFZ - Rother and Michaelis (2019)

PM – Mehta+ (2017)

ES – Sutton (2011)

TU – Doornbos (2012; TU-Delft)

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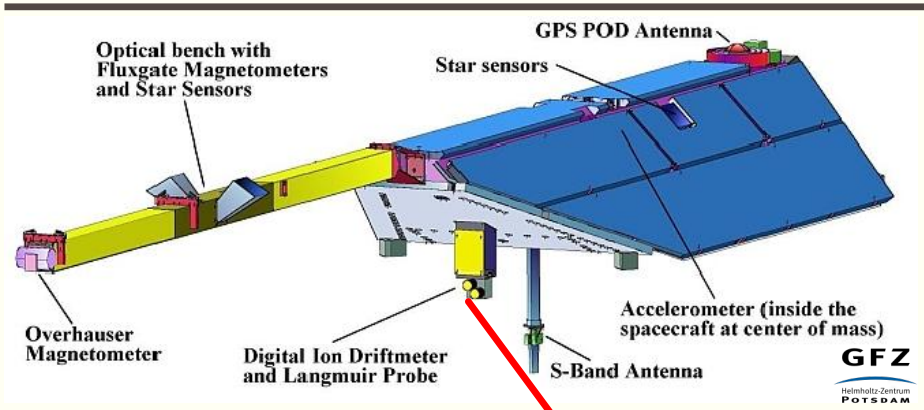
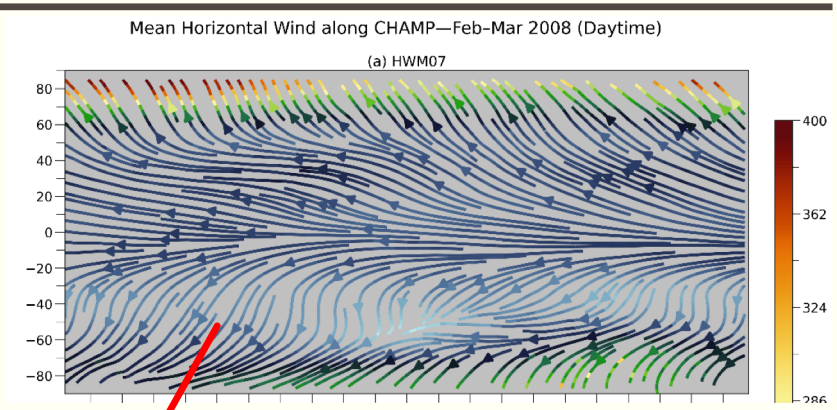
Assimilate observations along CHAMP to understand the impact on NMD





electron density +
electron temperature
Rother and Michaelis (2019)

E1-10%: CHAMP-Ne-Te
with 10% uncertainty

E2-100%: CHAMP-Ne-Te
with 100% uncertainty

TIE-GCM + DART

Horizontal wind model 2007
Drob+ (2008)

H7-10%: HWM07
with 10% uncertainty

HWM07 was partly used to derive CHAMP-TU

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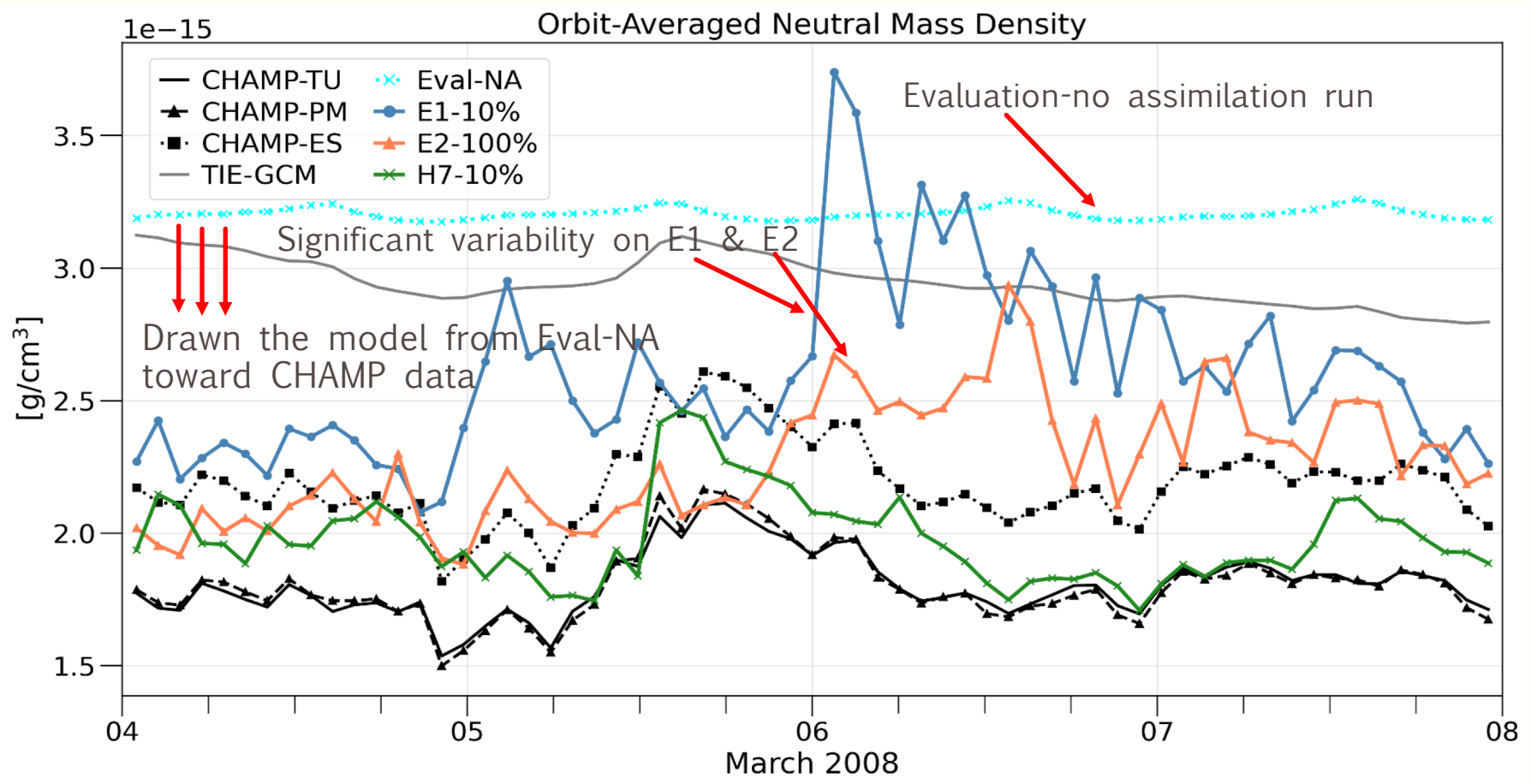
Assimilation of HWM07 neutral winds greatly improves TIE-GCM's agreement with CHAMP neutral mass density



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Estimating the Error Variance using the Grubbs' method

Grubbs (1948) "On Estimating Precision of Measuring Instruments and Product Variability", Journal of the American Statistical Association

Four instruments A, B, C, D measuring the same physical qty

$A = T + E_A$

$B = T + E_B$

$C = T + E_C$

$D = T + E_D$

$$\mathrm{Var}(A-B) = \frac{1}{n}\sum_{i=1}^{n}(A_i - B_i)^2 - \langle A-B\rangle^2,$$

Error variance can be estimated independent of true value T

$$\sigma(E_A) = \sqrt{\mathrm{Var}(E_A)} = \left\{\frac{1}{3}\Big(\mathrm{Var}(A-B) + \mathrm{Var}(A-C) + \mathrm{Var}(A-D)\Big) - \frac{1}{6}\Big(\mathrm{Var}(B-C) + \mathrm{Var}(B-D) + \mathrm{Var}(C-D)\Big)\right\}^{\frac{1}{2}}.$$

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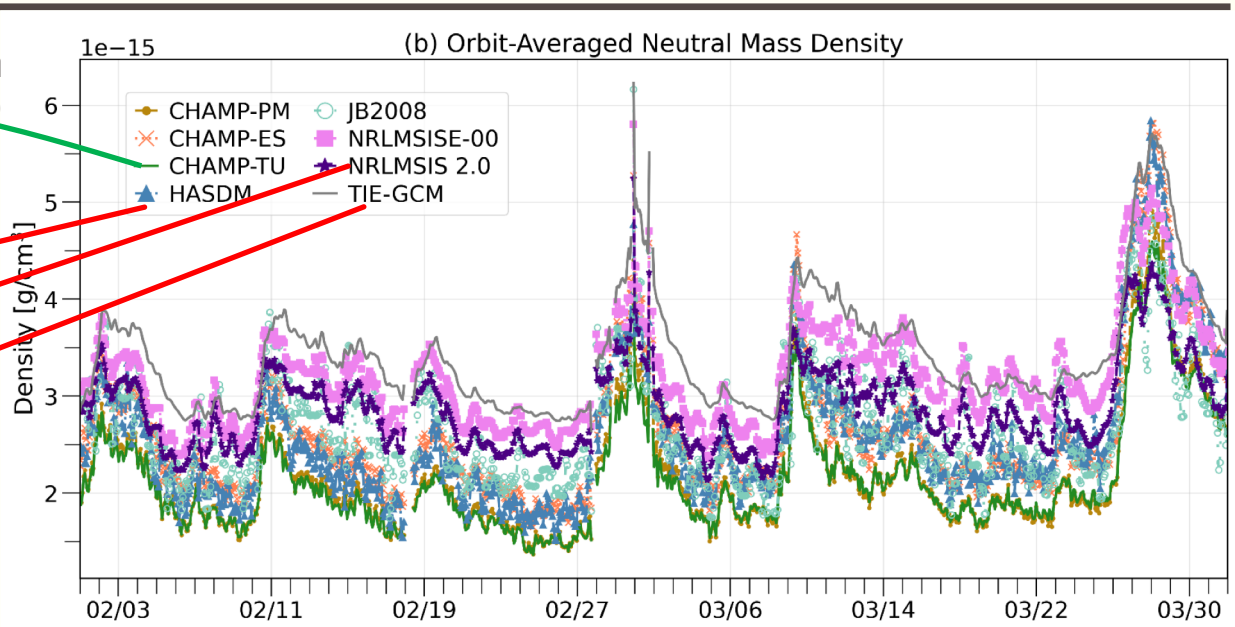


Error variance can be estimated independent of true value T

$$\sigma(\mathrm{E_A}) = \sqrt{\mathrm{Var(E_A)}} = \left\{ \frac{1}{3}\Big(\mathrm{Var(A-B) + Var(A-C) + Var(A-D)}\Big) - \frac{1}{6}\Big(\mathrm{Var(B-C) + Var(B-D) + Var(C-D)}\Big) \right\}^{\frac{1}{2}}.$$

Grubbs' method provide reliable estimates of the error

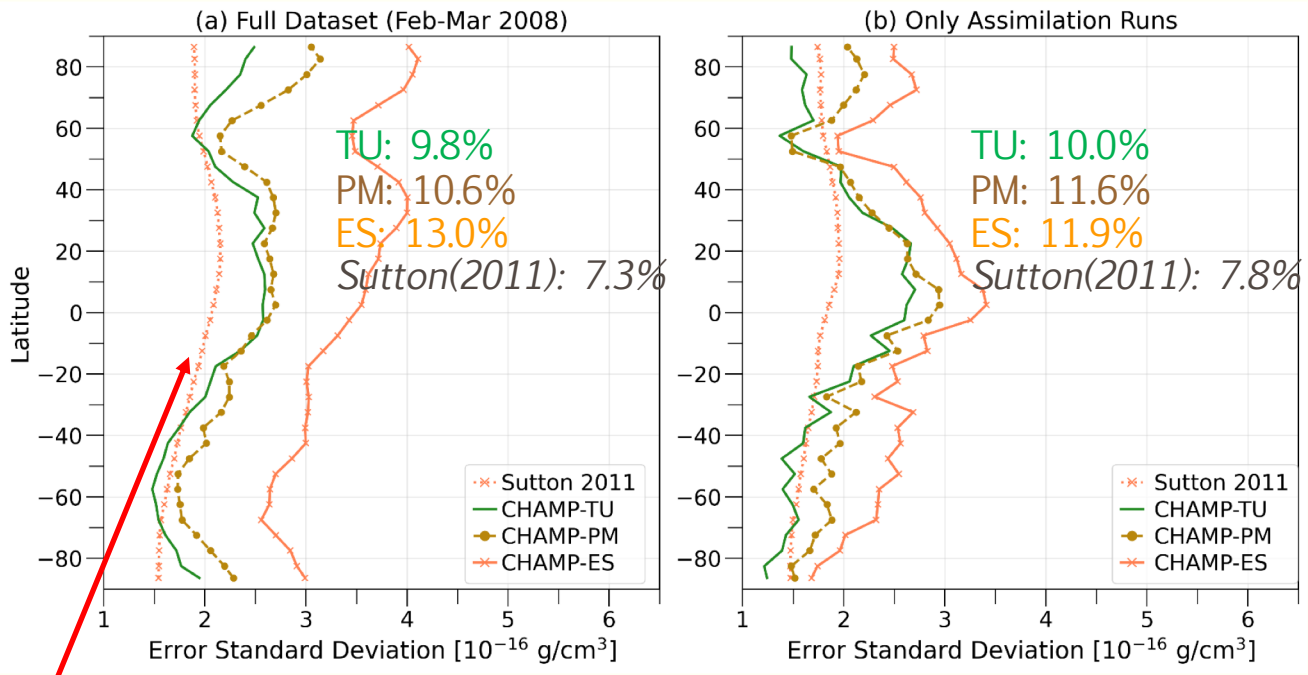
(b) uses only assim runs to estimate error (E1, E2, H7 as B, C, D instruments)

General agreement with previous estimates:

Bruinsma+(2004): 10-15%

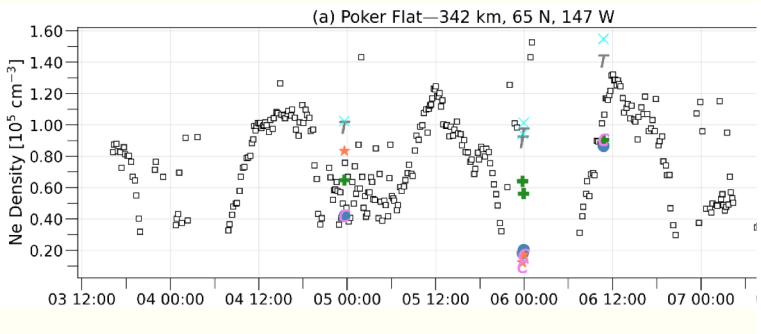
Sutton+(2007): 6-15.6%

Reveals latitudinal characteristics of error

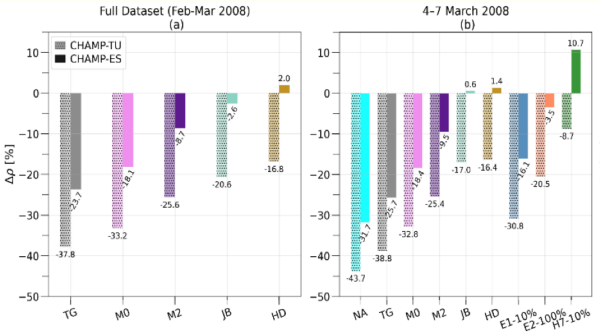


Error estimated by Sutton (2011) for CHAMP-ES data set

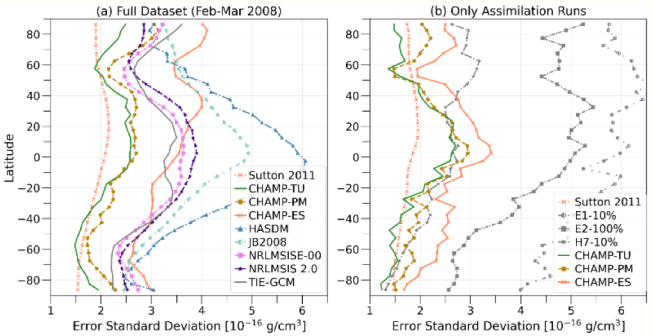
Validation with ISR data



Model Performance



Error Estimates



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