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

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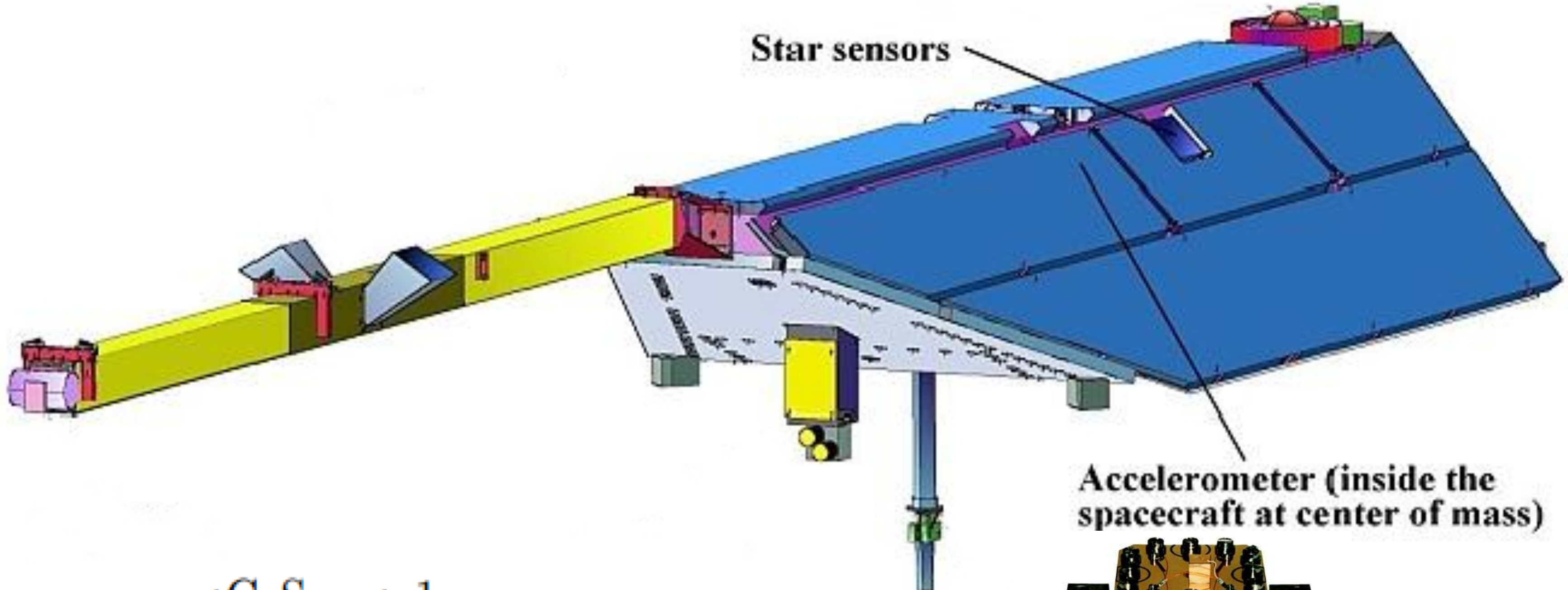
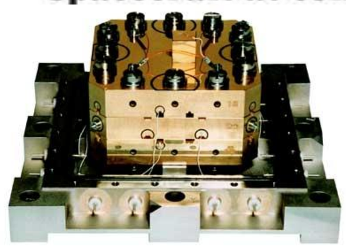
Neutral mass density can be derived from accelerometer measurements onboard CHAMP

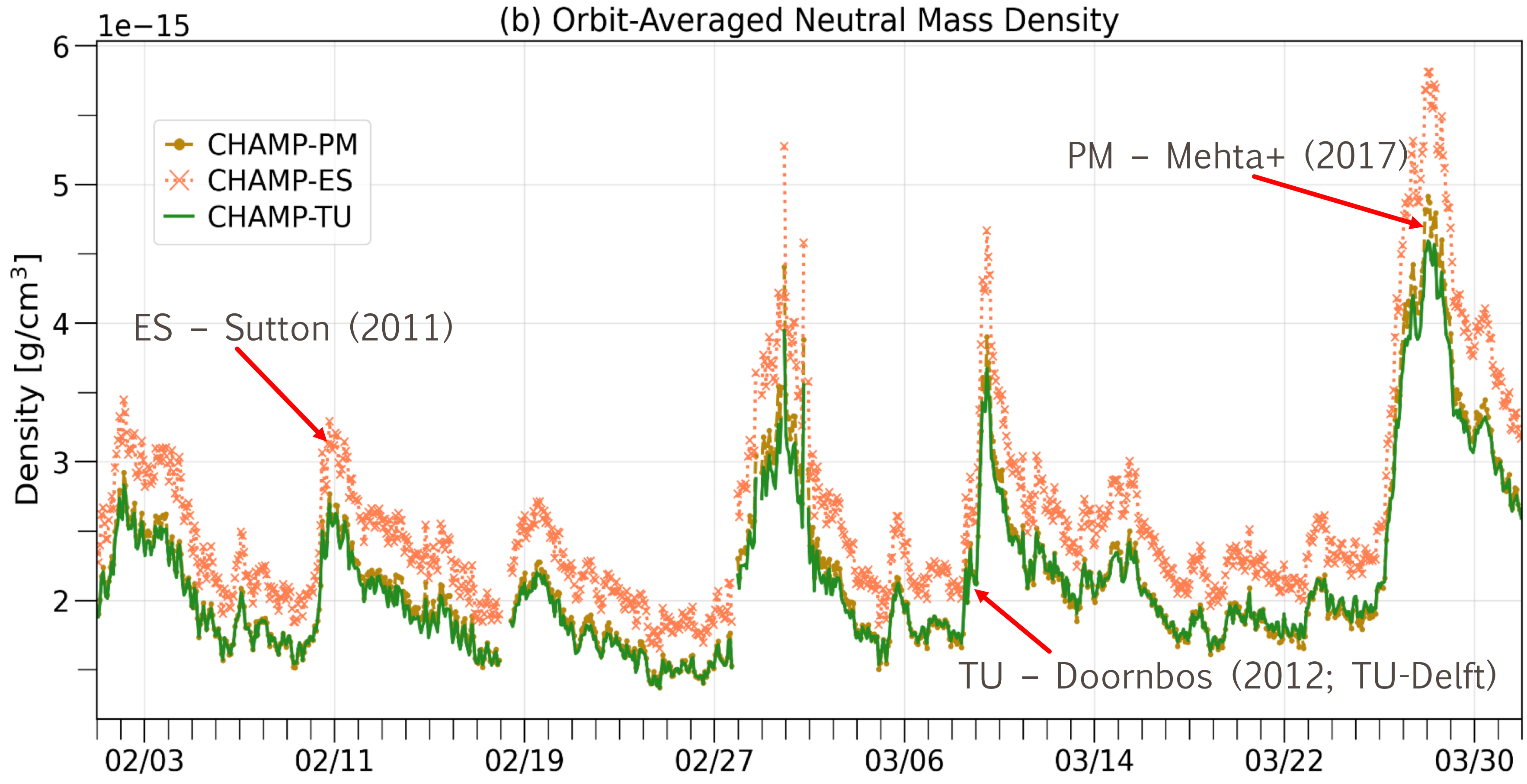


$$a_{drag} = -\left(\frac{C_d S_{area}}{S_{mass}}\right)\frac{1}{2}\rho V_{rel}^2$$

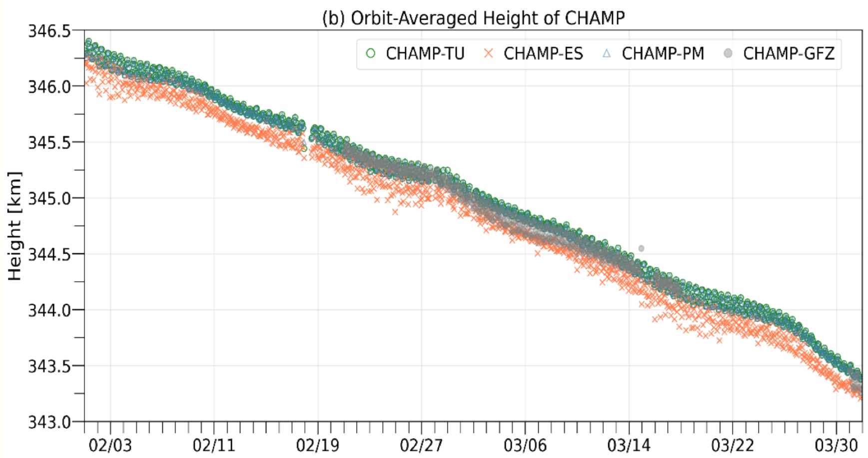
Density

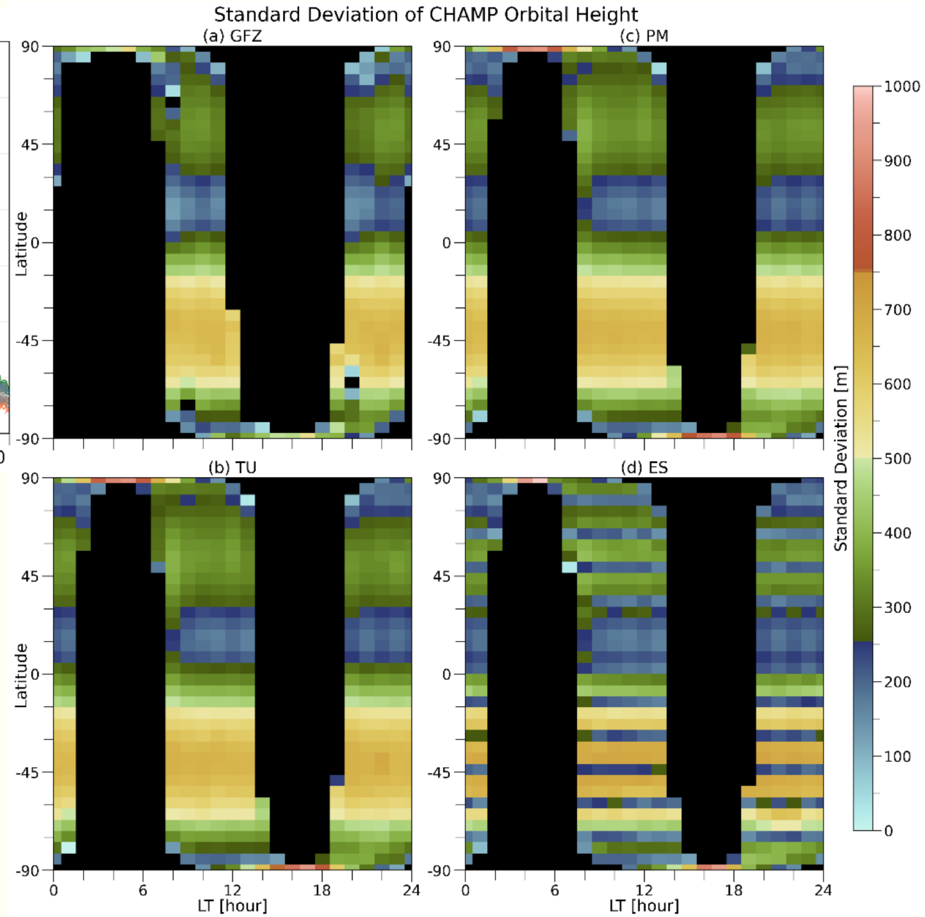


The uncertainties of accelerometer-derived NMD are not fully understood



Some discrepancies exist in the published CHAMP height





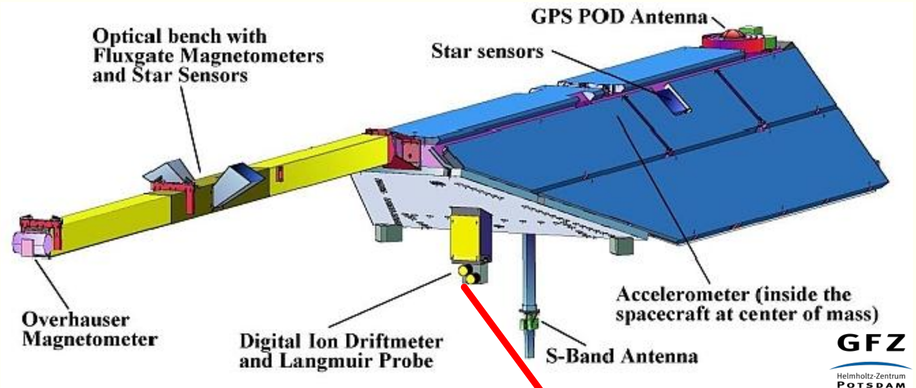
GFZ - Rother and Michaelis (2019)

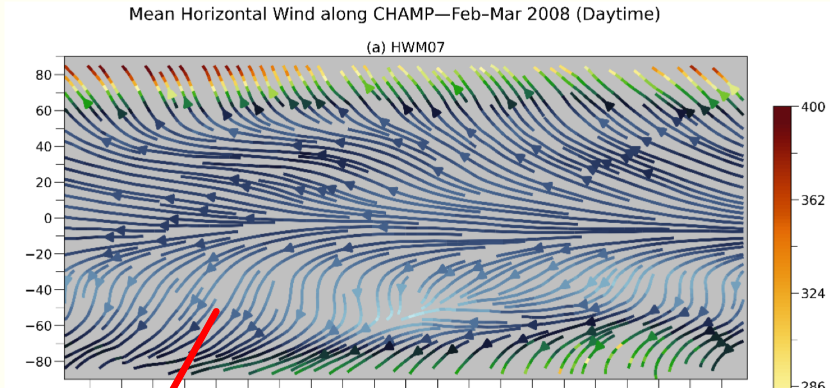
PM – Mehta+ (2017)

ES – Sutton (2011)

TU – Doornbos (2012; TU-Delft)

Assimilate observations along CHAMP to understand the impact on NMD





electron density +
electron temperature
Rother and Michaelis (2019)

Horizontal wind model 2007
Drob+ (2008)

TIE-GCM
+
DART

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

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

H7-10%: HWM07
with 10% uncertainty

HWM07 was partly used to derive CHAMP-TU

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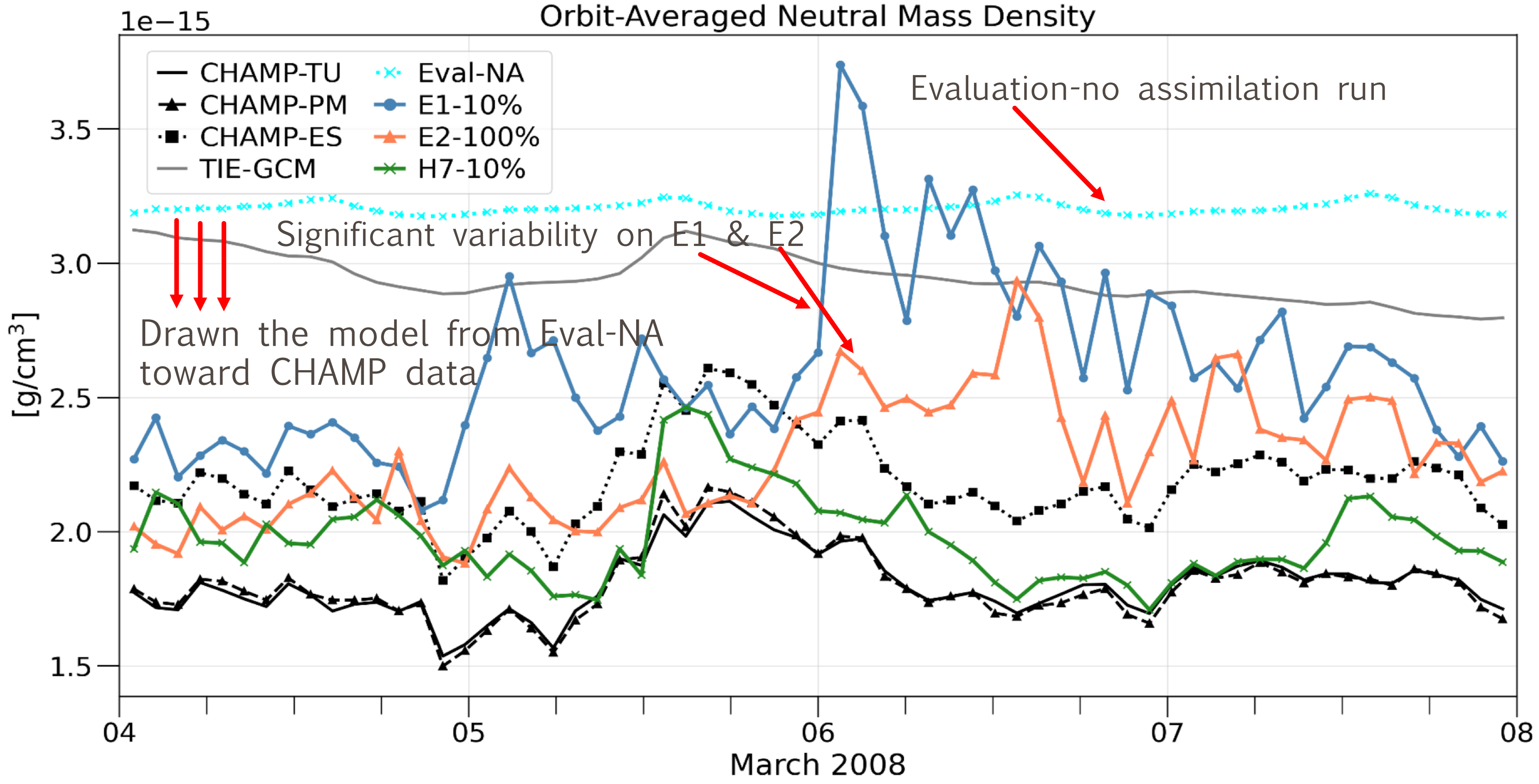
NCAR | National Center for
UCAR | Atmospheric Research

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



Using Data Assimilation to Understand the Systematic Errors of CHAMP Accelerometer-Derived Neutral Mass Density Data, Kodikara et al., AGU Fall Meeting 2021

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

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

Error variance can be estimated independent of true value T

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

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Grubbs (1948) "On Estimatin
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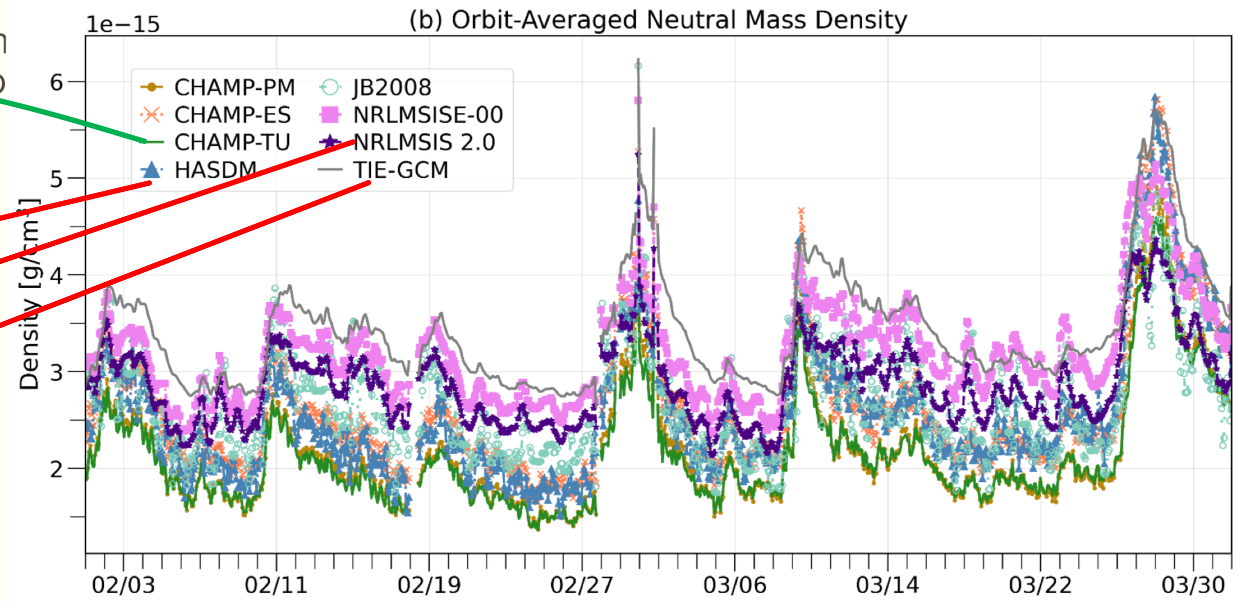
Four instruments A, B, C, D
qty



$A = T + E_A$

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$D = T + E_D$

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Grubbs' method provide reliable estimates of the error

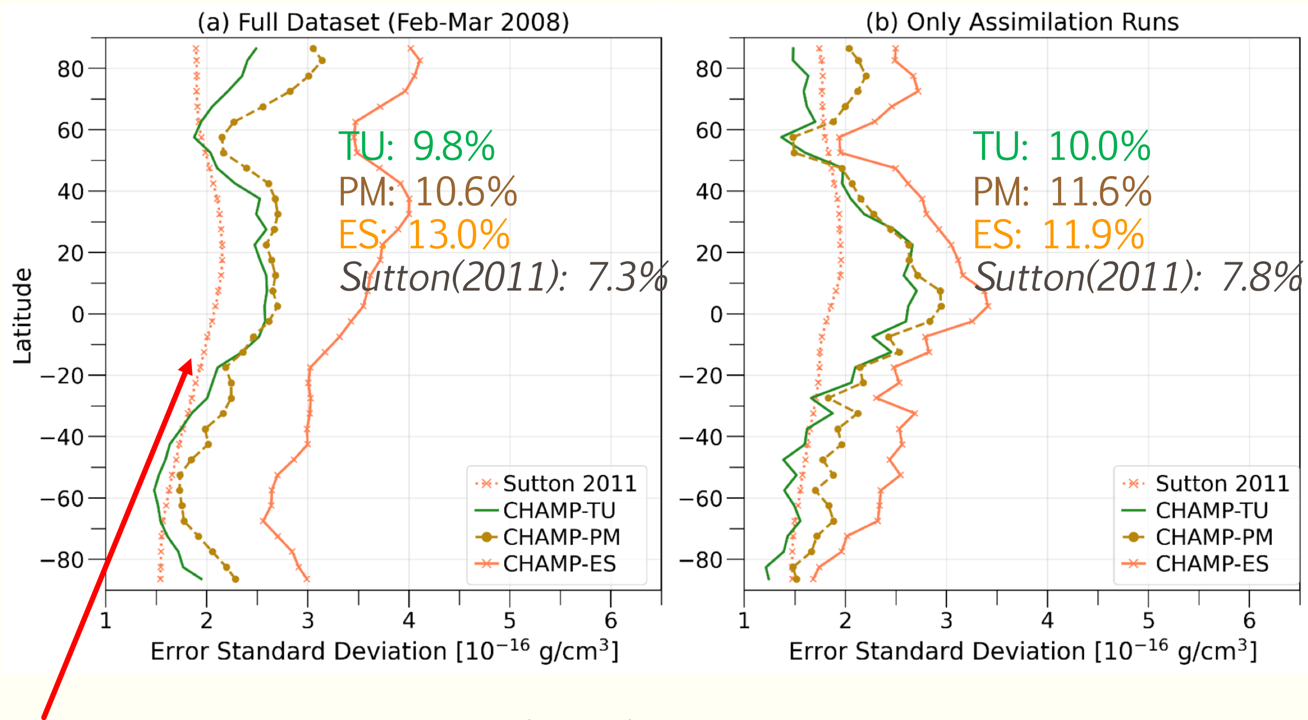
(b) uses only assim runs to estimate error (E1, E2, H7 as B, C, D instruments)

General agreement with previous estimates:

Bruinsma+(2004): 10-15%

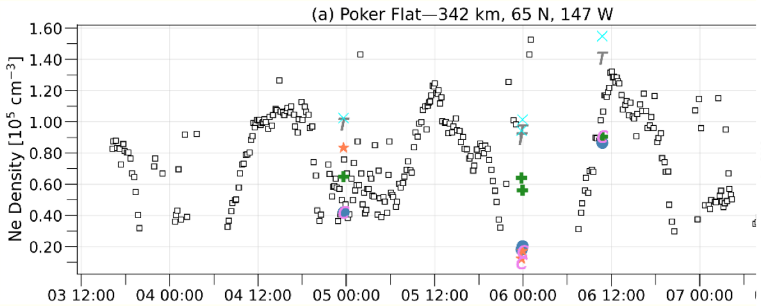
Sutton+(2007): 6-15.6%

Reveals latitudinal characteristics of error

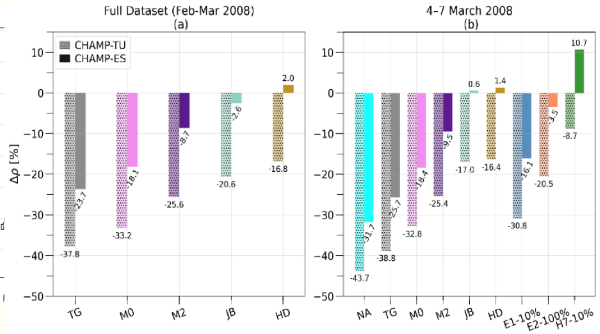


Error estimated by Sutton (2011) for CHAMP-ES data set

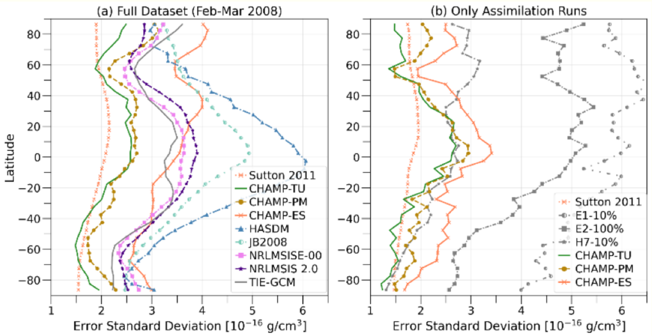
Validation with ISR data



Model Performance



Error Estimates



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