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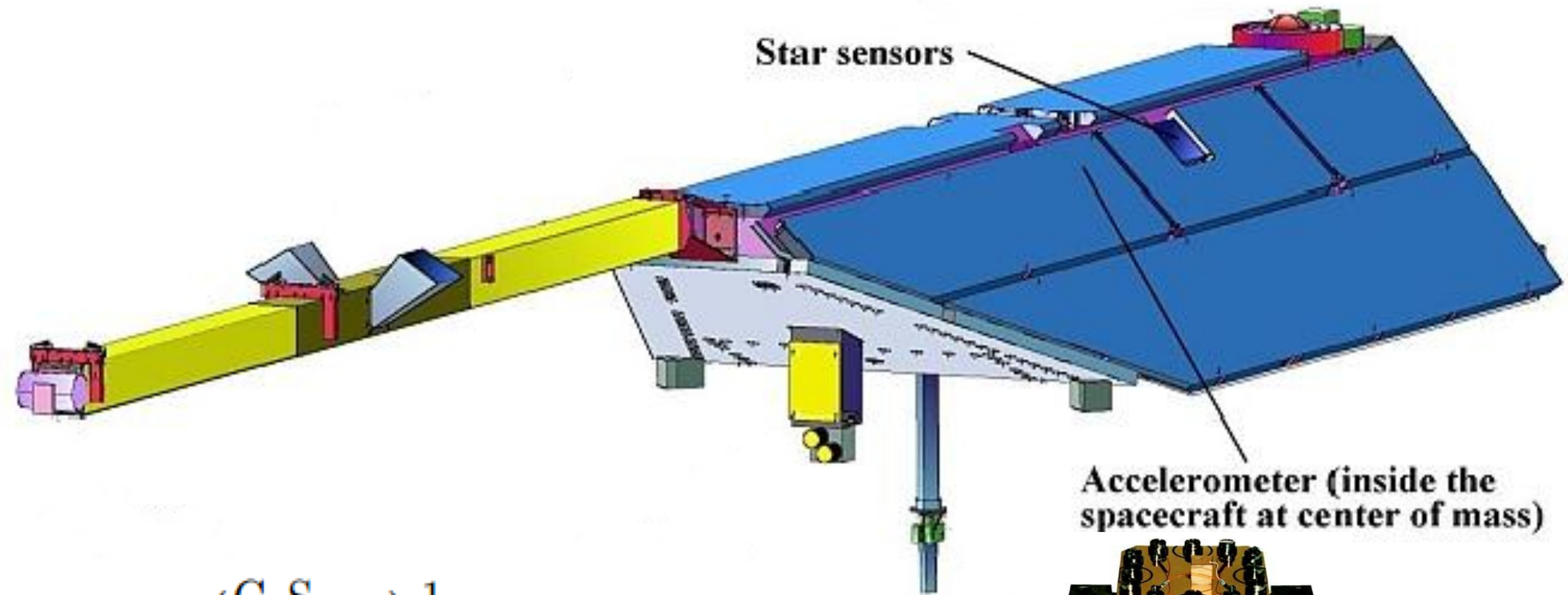
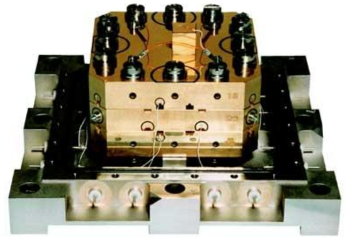
# Neutral mass density can be derived from accelerometer measurements onboard CHAMP




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

Density



GFZ
Helmholtz-Zentrum
POTSDAM

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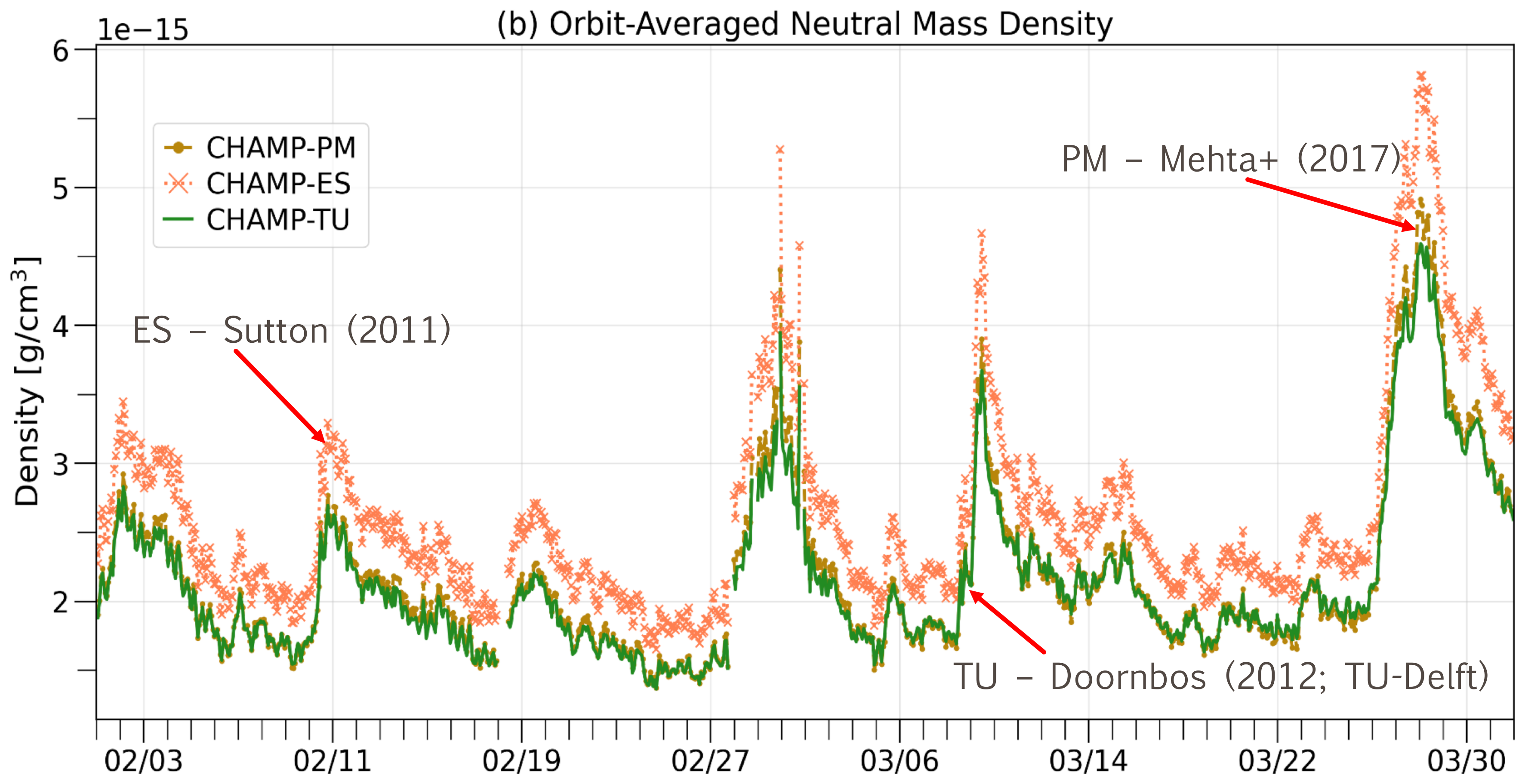
# The uncertainties of accelerometer-derived NMD are not fully understood

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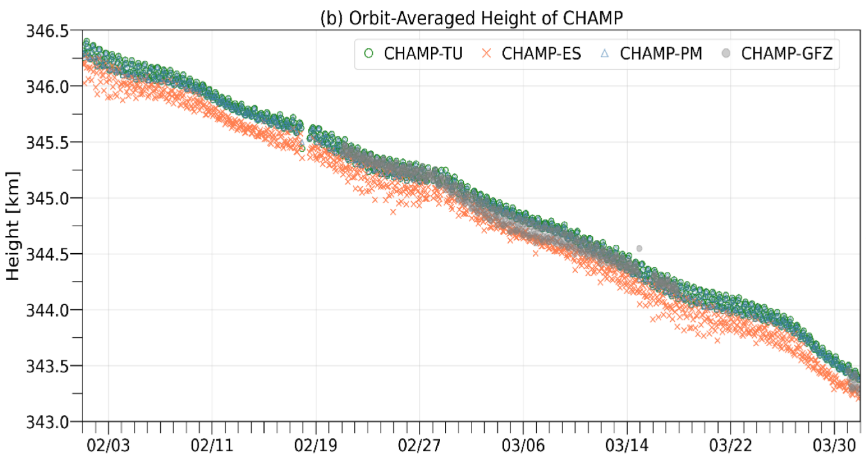
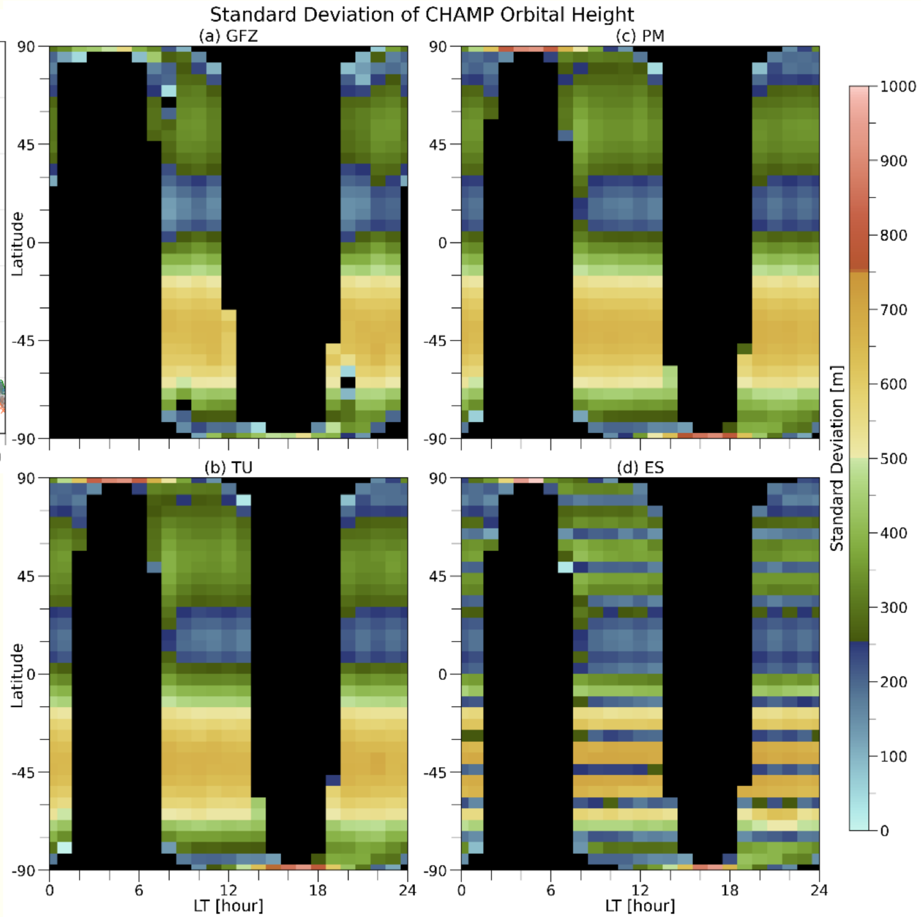
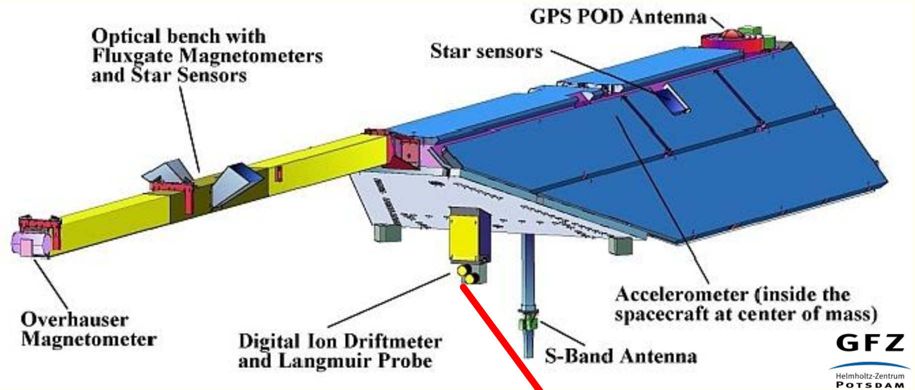
# Some discrepancies exist in the published CHAMP height

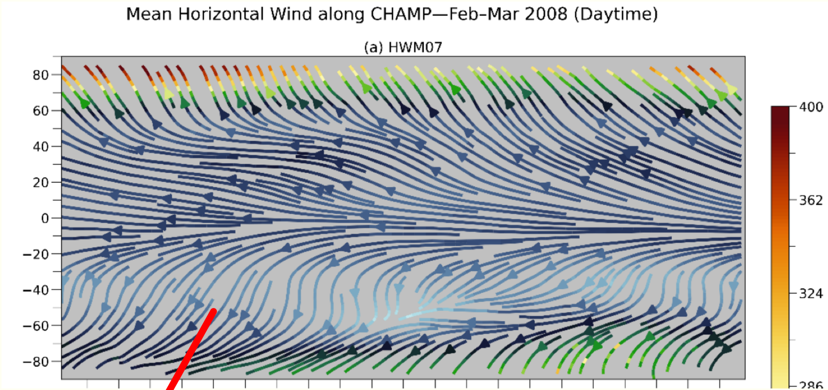



GFZ - Rother and Michaelis (2019)
PM – Mehta+ (2017)
ES – Sutton (2011)
TU – Doornbos (2012; TU-Delft)

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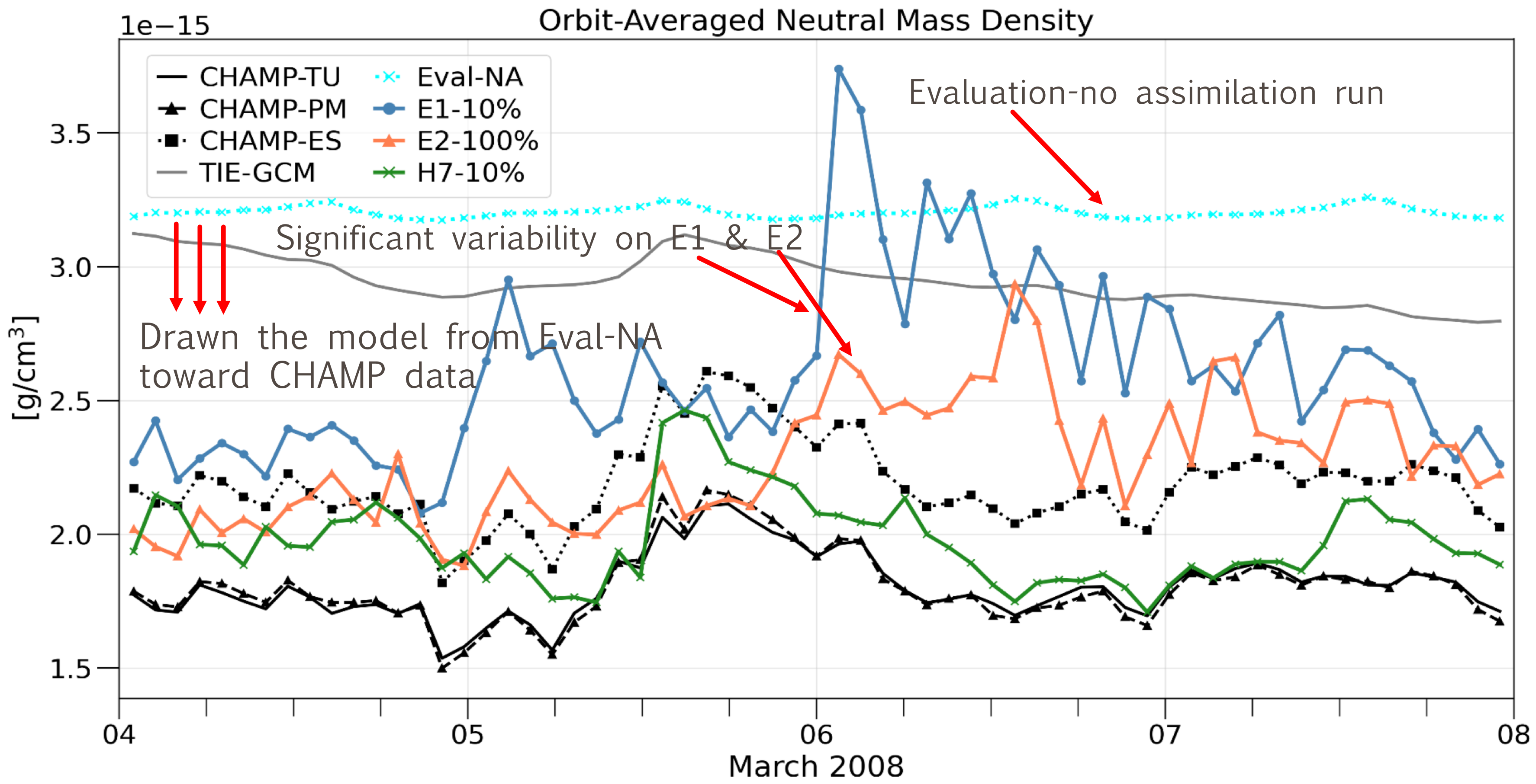
# Assimilation of HWM07 neutral winds greatly improves TIE-GCM's agreement with CHAMP neutral mass density

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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 + $E_D$

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

Error variance can be estimated independent of true value T

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

# Estimating the Error Variance using the Grubbs' method

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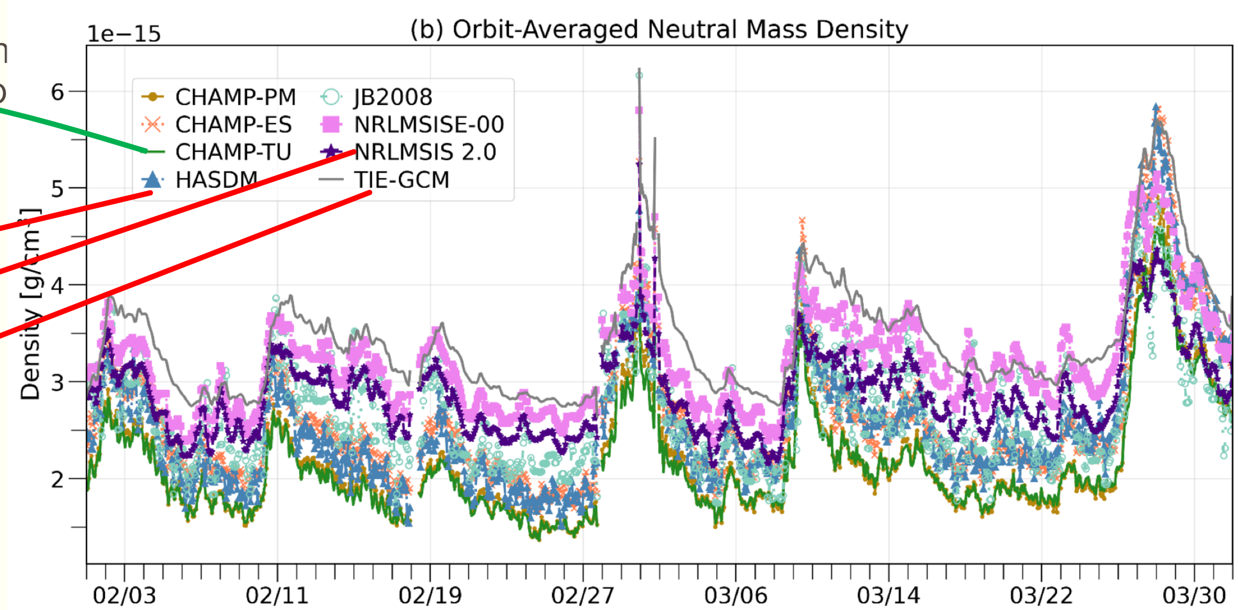
Four instruments A, B, C, D
qty

$A = T + E_A$

$B = T + E_B$

$C = T + E_C$

$D = T + E_D$

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# Grubbs' method provide reliable estimates of the error

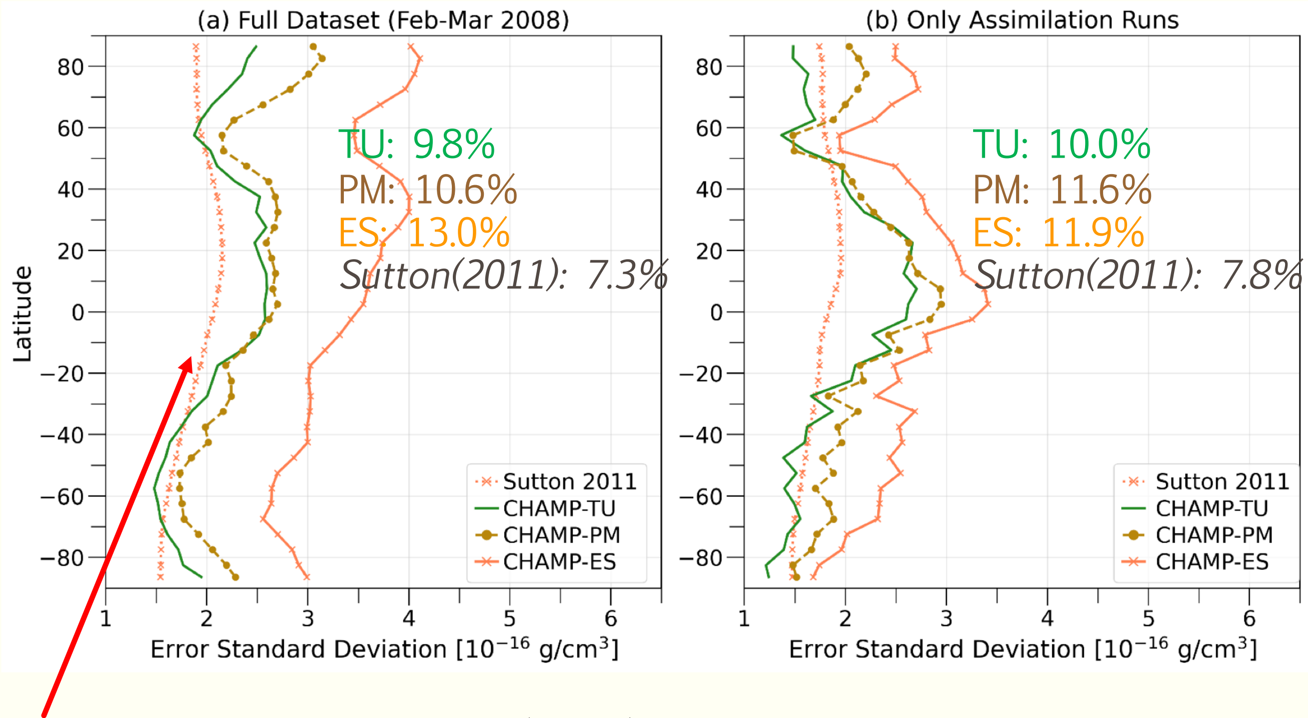
**(b)** uses only assim runs to estimate error (E1, E2, H7 as B, C, D instruments)

General agreement with previous estimates:

Bruinsma+(2004): 10-15%

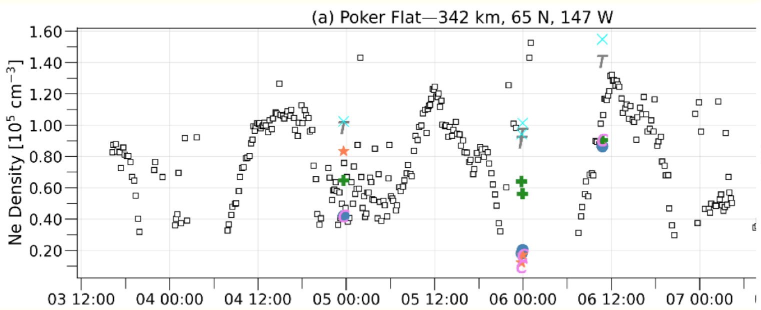
Sutton+(2007): 6-15.6%

Reveals latitudinal characteristics of error

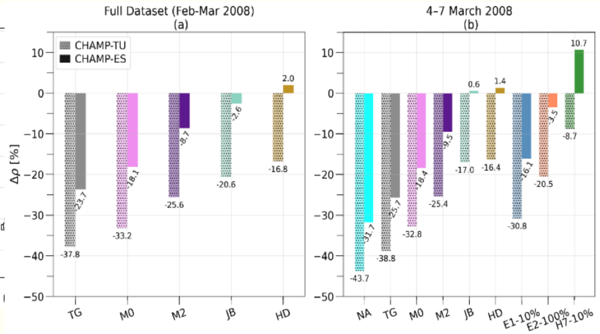



Error estimated by Sutton (2011) for CHAMP-ES data set

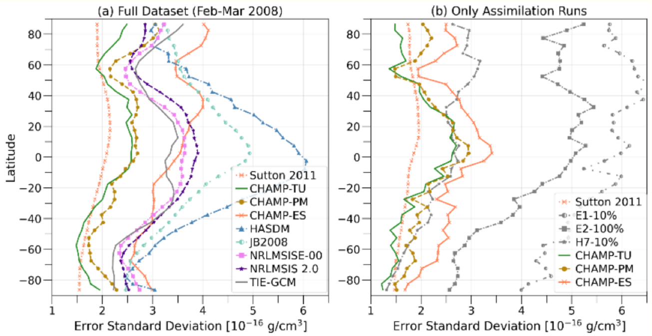
## Validation with ISR data




## Model Performance




## Error Estimates

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