Comparison of EnOI data assimilation into two physical models of the thermosphere

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Background ATMOP (www.atmop.eu) is an FP7 project which aims to improve orbital predictions for satellites close to Earth, through improved predictions of space weather effects on the thermospheric density responsible for the drag on the LEO satellites.
This work A key part of ATMOP (WP5) is using a physics-based model, as a complement to the semi-empirical DTM model used operationally. Specifically, we have worked on building data assimilation (DA) systems, using in-situ density observations, such as those from the CHAMP satellite, to constrain the model density predictions, bringing them closer to the observed density values.
Here we compare the results of assimilating observations into two different physical models: UCL's CMAT2 model & NCAR's TIEGCM model.
Both simulate the thermosphere-ionosphere region, but differ in some details. The assimilation is performed using an ensemble optimal interpolation (EnOI) scheme, and the forecast results from both models are compared to observations not included in the assimilation.

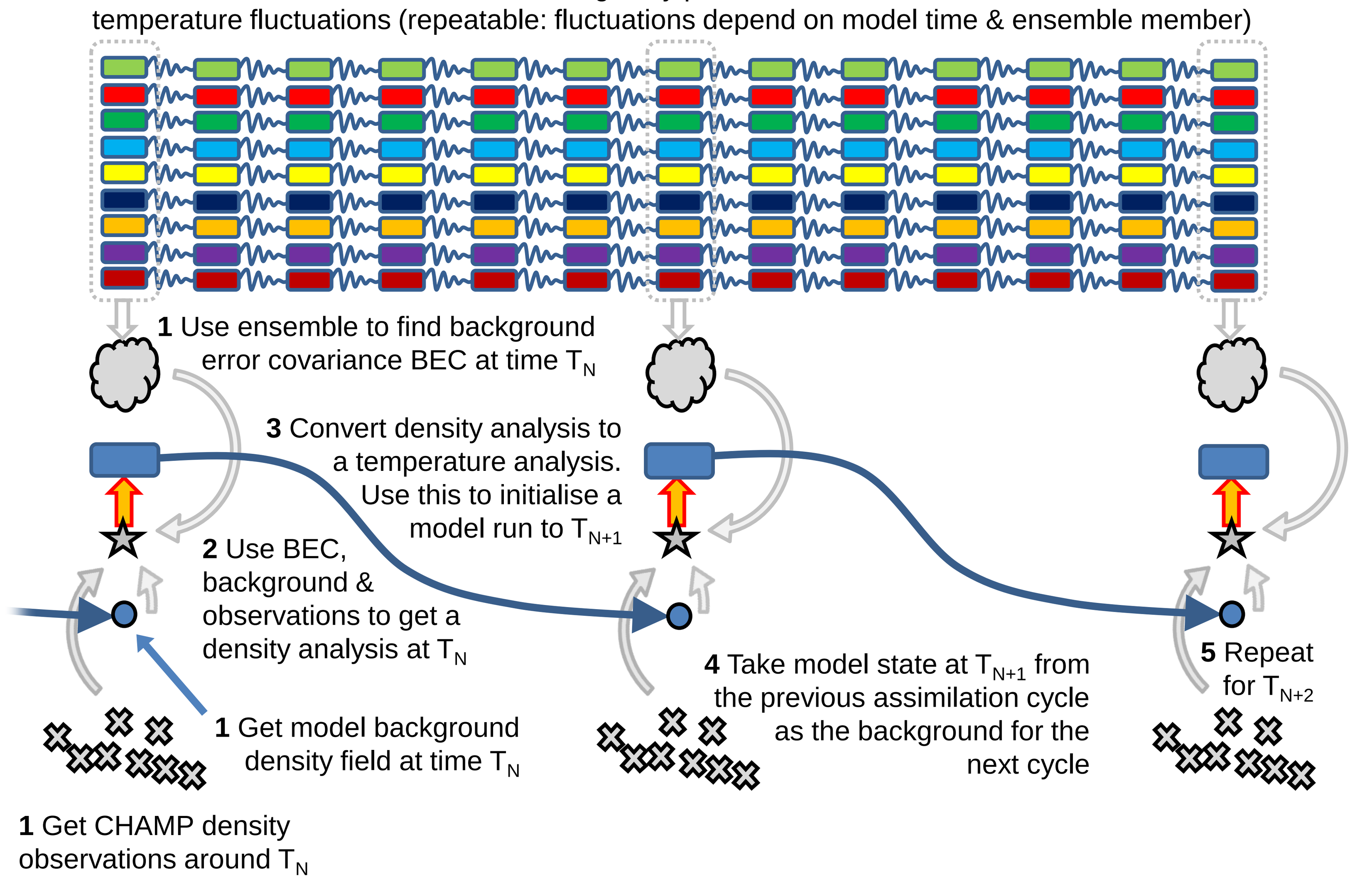
1. Observations & models used

CHAMP In-situ densities from accelerometer, 10 s cadence, at altitudes of ~450 km (2000) to ~300 km (2010). Near-polar, ~circular orbit (period ~90 mins) provides changes in local time coverage (but only slowly).

CMAT2 Model of middle atmosphere, thermosphere & ionosphere. Drivers: F10.7 (solar) & Kp (geomagnetic). Grid: 18°E x 2°N (-90 to 90N), 39 pressure levels, ~80 km to ~350 km (solar min).

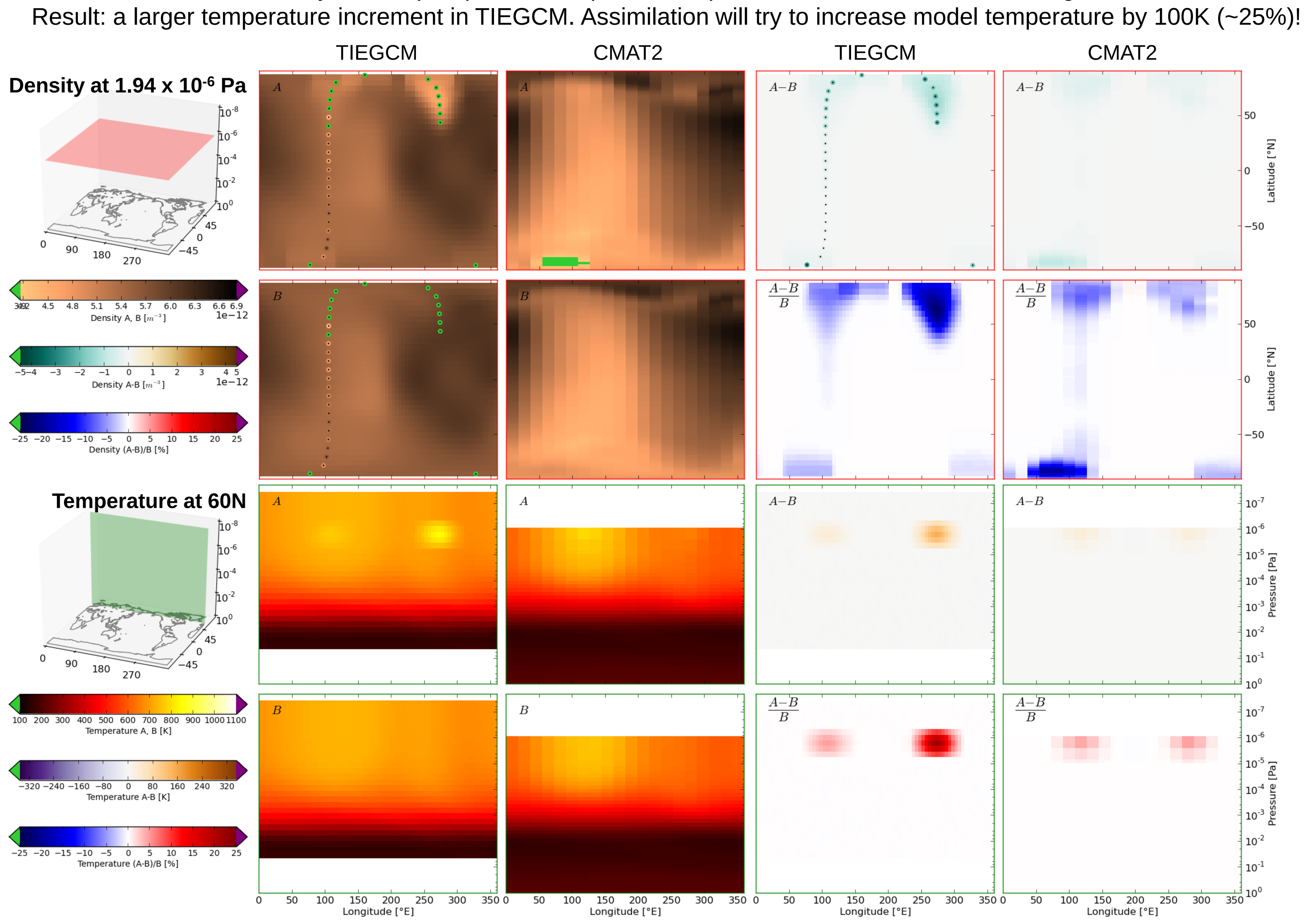
TIEGCM Middle atmosphere, thermosphere & ionosphere model. Using Heelis variant: same drivers as CMAT2. Grid: 5°E x 5°N (-87.5 to 87.5N), 29 pressure levels, ~97 km to ~500 km (solar min).

2. Ensemble optimal interpolation (EnOI) data assimilation



3. TIEGCM vs CMAT2 analyses: 06Z 5th Mar 2009, cold start

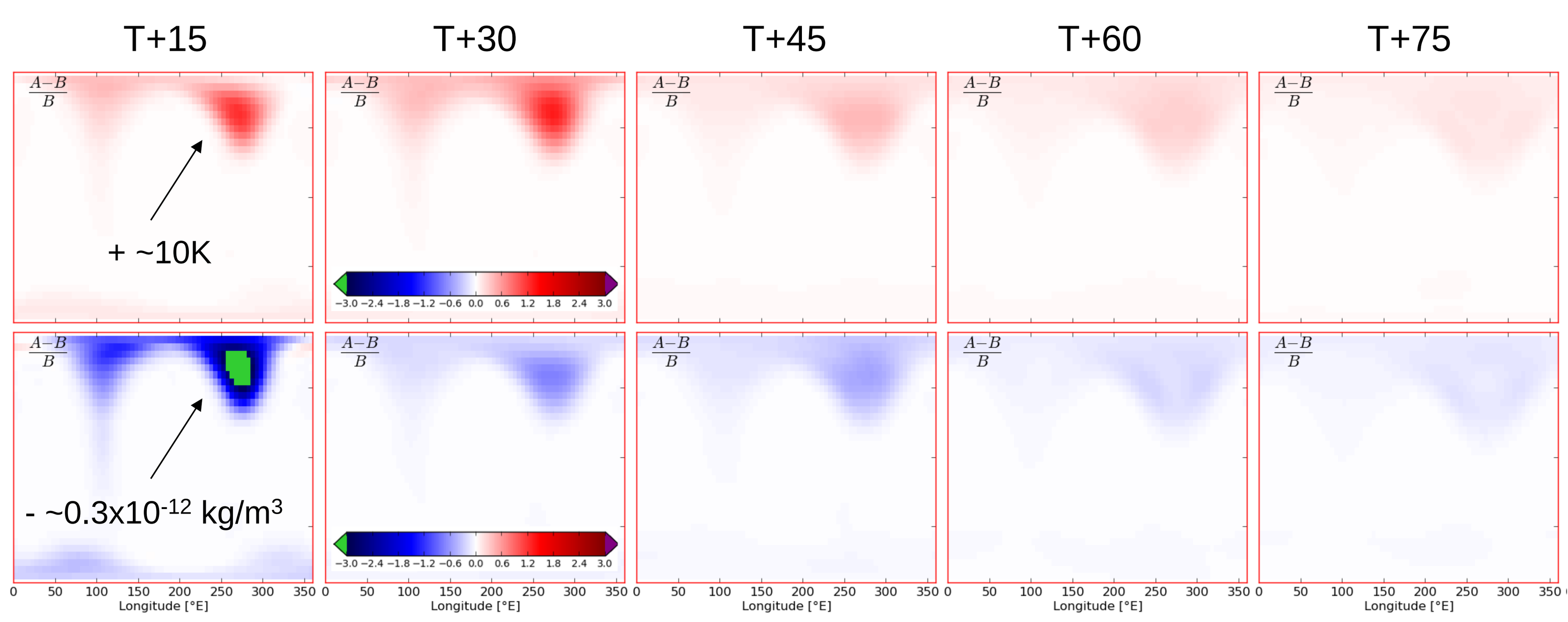
Cold start: analysis **A** from background **B** with no prior data assimilation (DA).
Assimilated CHAMP density values (dots) are lower (less dense) than both models. Difference is greater for TIEGCM.
Result: a larger temperature increment in TIEGCM. Assimilation will try to increase model temperature by 100K (~25%)!



4. The need for incremental analysis updates (IAU)

Problem increments disappear quickly as model adjusts. See below (A & B: model data with & without DA). Initial ~100K TIEGCM increment becomes ~10K ~15 minutes after assimilation, & becomes negligible ~105 minutes after assimilation. Makes intended 6 hour assimilation cycle difficult – improvements from one cycle do not persist long enough for following cycle to build upon them.

Potential solution incremental analysis updates (IAU): add the increment in small "increments", rather than all at once at cycle start: the model is less likely to damp the smaller resulting imbalance. To be continued…



5. Assimilative model performance: 5th Mar, after 5 days of DA

A Compare free-running & assimilative models – does DA help? NB assimilating into TIEGCM only – CMAT2 still TBD.
B How does a forecast perform? Once assimilation stops, how quickly does the model return to free-running state?

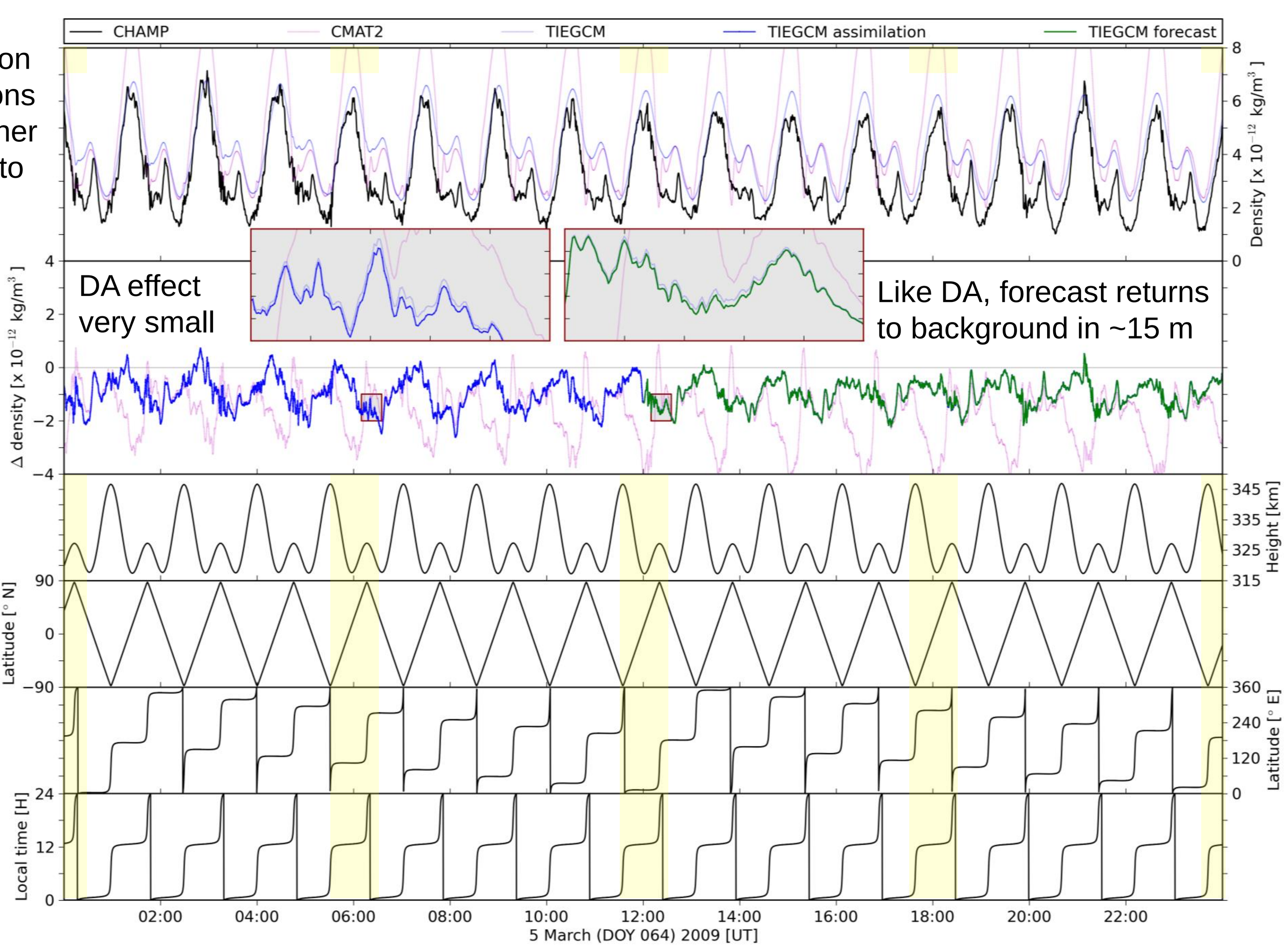
6 hour assimilation cycle, observations from 30 mins either side, decimated to 120 s cadence.

Very small effect of increment does not persist between assimilation cycles. Would a shorter cycle (~ 1 hr) help?

Driver values: Kp ~ 1, F10.7 ~ 68 sfu

Note current data comes largely from ~12Z local time.

A shorter assimilation cycle should help with ~00Z coverage too.



Conclusions

We have demonstrated an EnOI data assimilation system for the thermosphere, which assimilates in-situ density data into two different models, CMAT2 & TIEGCM. When the outstanding issues are resolved, this should bring model forecasts closer to observations.

Future work

Overall assimilation into CMAT2; incremental analysis updates (IAU); use of in-situ density data from GRACE & GOCE satellites.
DA proper vertical localisation & quality control; use of super-observations; multiple observation sources (e.g. CHAMP & GOCE).
Long-term verification against independent thermospheric & ionospheric data (e.g. UCL's FPI wind measurements, TEC maps); assimilation of these data: good ionospheric data coverage may help.

ATMOP FP7 project

European Space Weather Week 10
Antwerp – Nov 2013

SEVENTH FRAMEWORK PROGRAMME

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