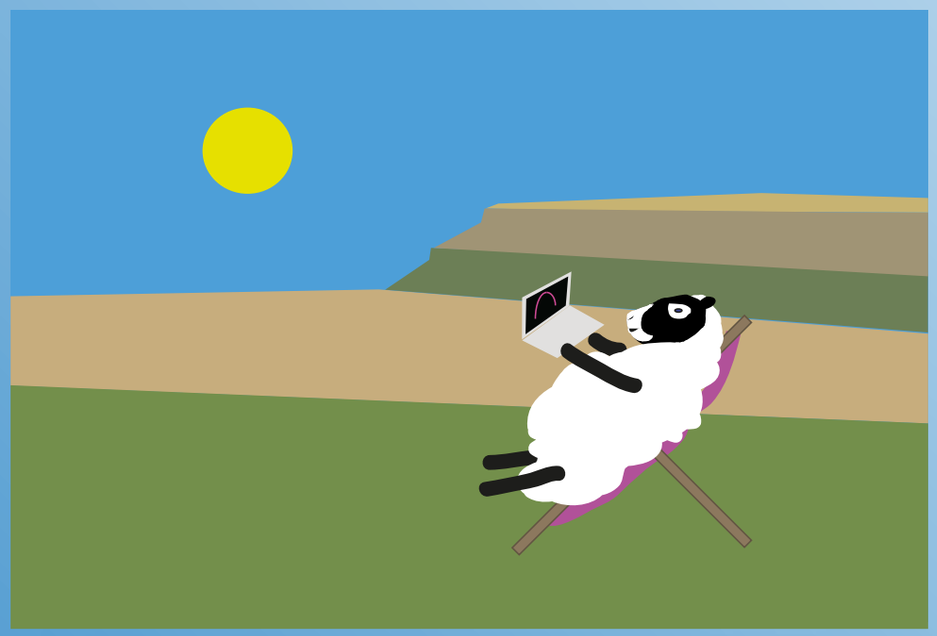
How cold was the LGM?

JD Annan, JC Hargreaves (Blue Skies Research)
&
T Mauritsen (MISU, Stockholm University)



BlueSkiesResearch.org.uk

Summary of recent analyses

of LGM global mean surface air temperature

Summary of recent analyses

of LGM global mean surface air temperature

- Annan and Hargreaves 2013 (AH2013) using MARGO (SST), Bartlein et al (SAT) data and PMIP2 models: -4.0 ± 0.8C

Summary of recent analyses

of LGM global mean surface air temperature

- Annan and Hargreaves 2013 (AH2013) using MARGO (SST), Bartlein et al (SAT) data and PMIP2 models: -4.0 ± 0.8C
- Tierney et al 2020 (TEA) using new ocean proxy data analysis and data assimilation with CESM: -6.1 ± 0.4C

Summary of recent analyses

of LGM global mean surface air temperature

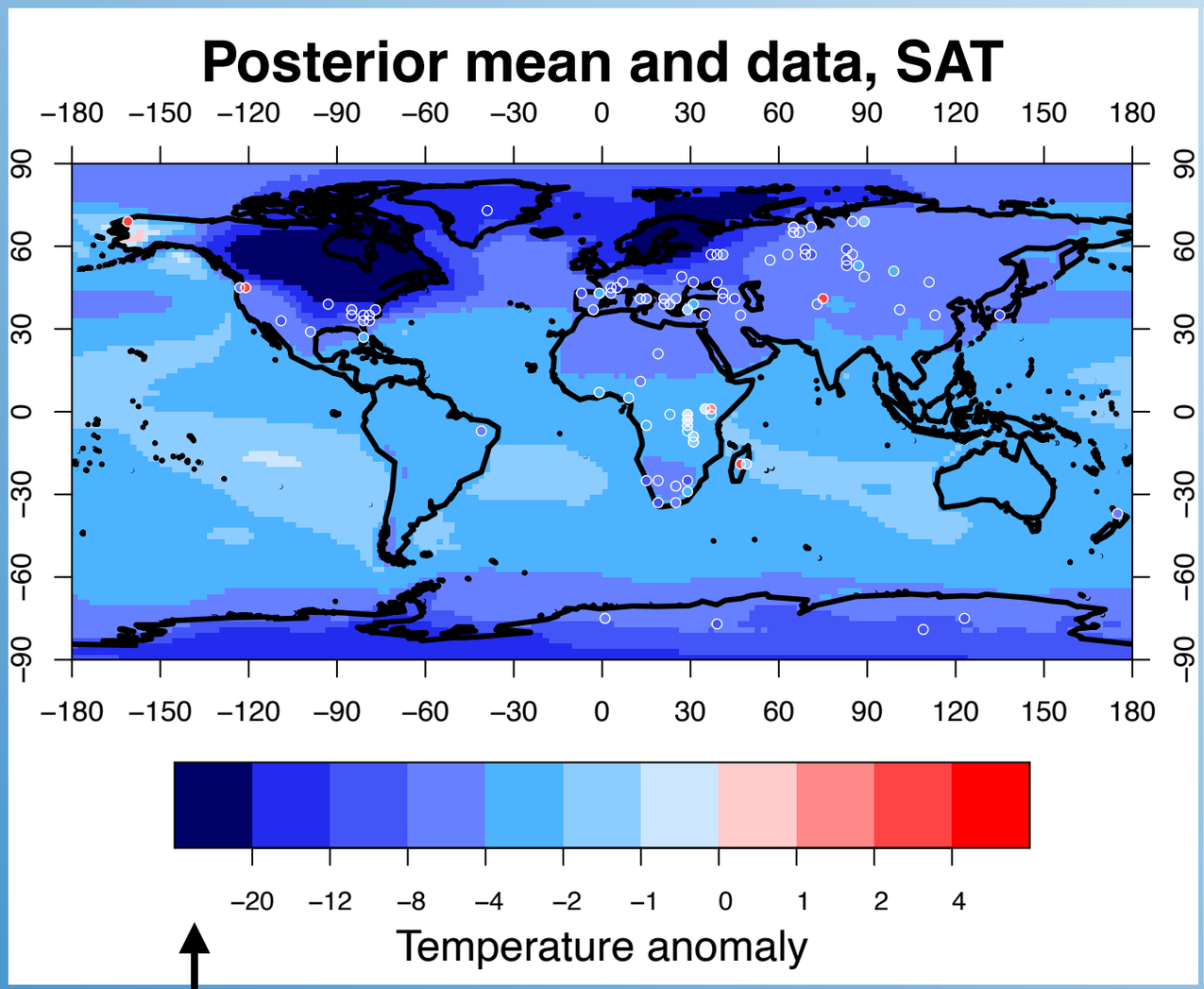
- Annan and Hargreaves 2013 (AH2013) using MARGO (SST), Bartlein et al (SAT) data and PMIP2 models: -4.0 ± 0.8C
- Tierney et al 2020 (TEA) using new ocean proxy data analysis and data assimilation with CESM: -6.1 ± 0.4C
- This work: update to AH2013 using all PMIP2/3/4 models, adding in TEA data, improved method. Result is -4.5±1.7C
  - In review at Climate of the Past

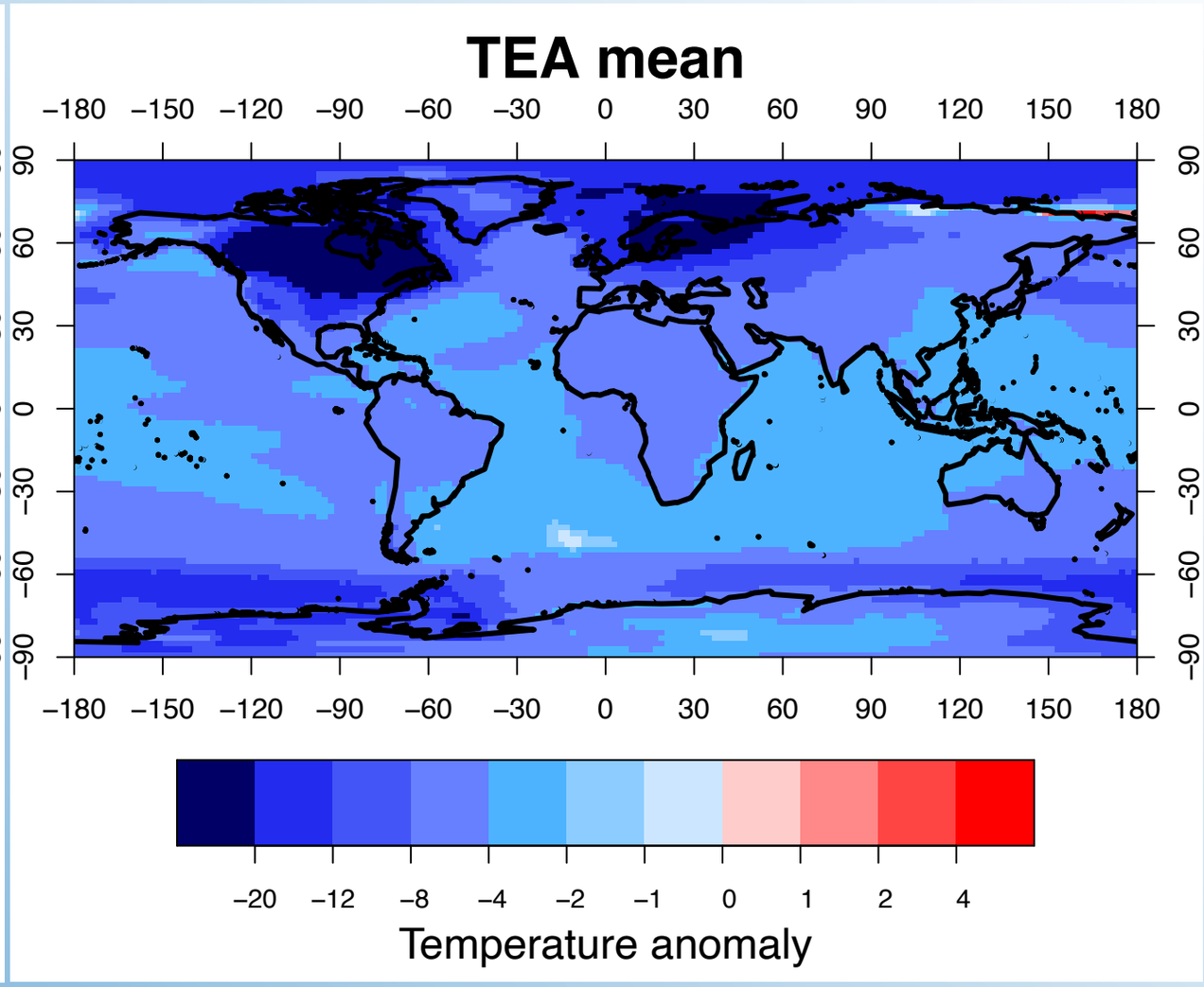
Summary of recent analyses

of LGM global mean surface air temperature

- Annan and Hargreaves 2013 (AH2013) using MARGO (SST), Bartlein et al (SAT) data and PMIP2 models: -4.0 ± 0.8C
- Tierney et al 2020 (TEA) using new ocean proxy data analysis and data assimilation with CESM: -6.1 ± 0.4C
- This work: update to AH2013 using all PMIP2/3/4 models, adding in TEA data, improved method. Result is -4.5±1.7C
  - In review at Climate of the Past
- (all quoted with ±95% probability intervals)

Results

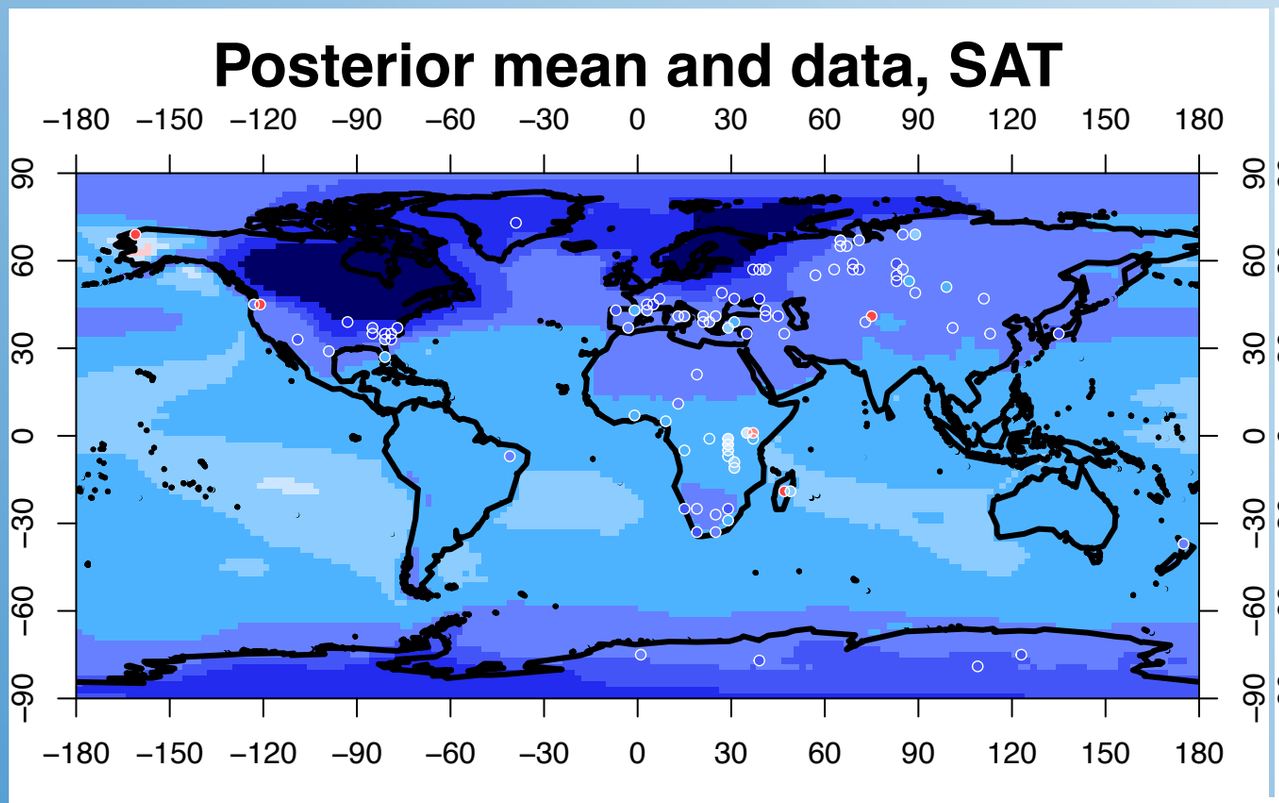


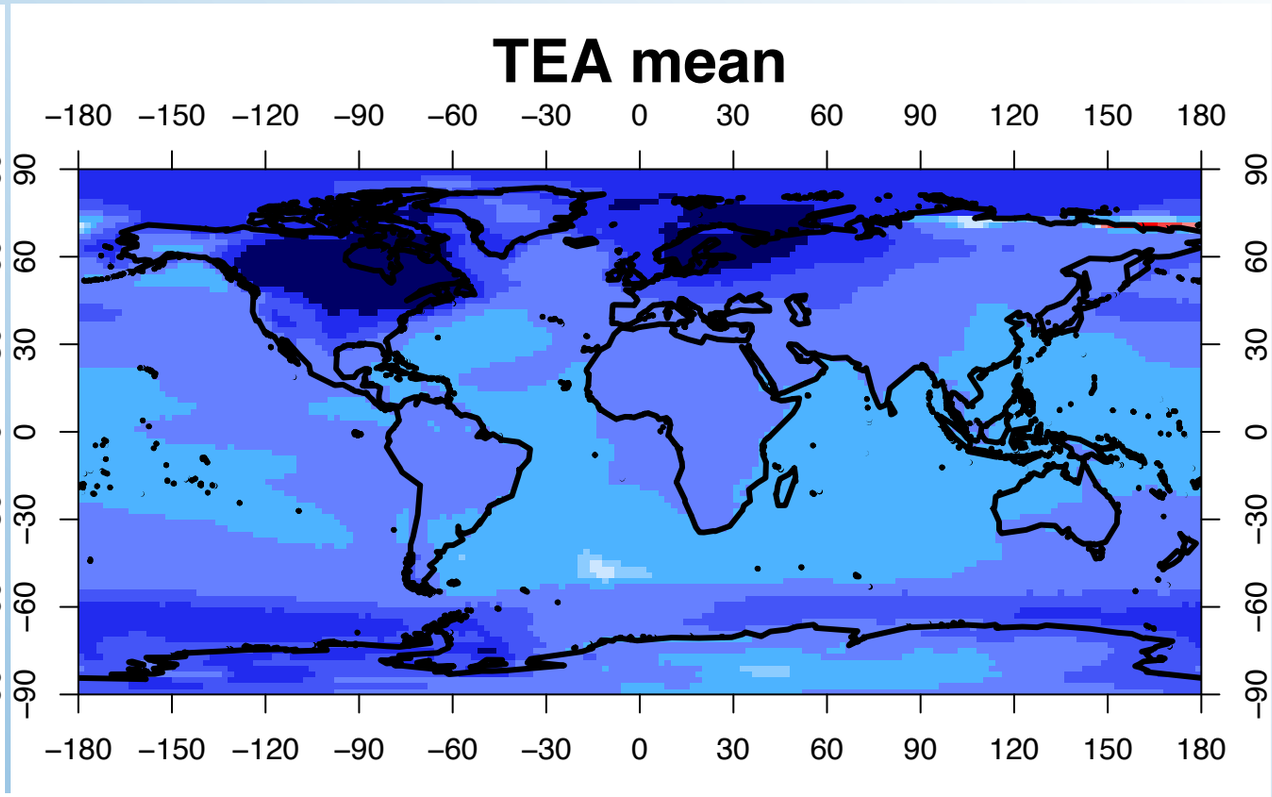


Our new work

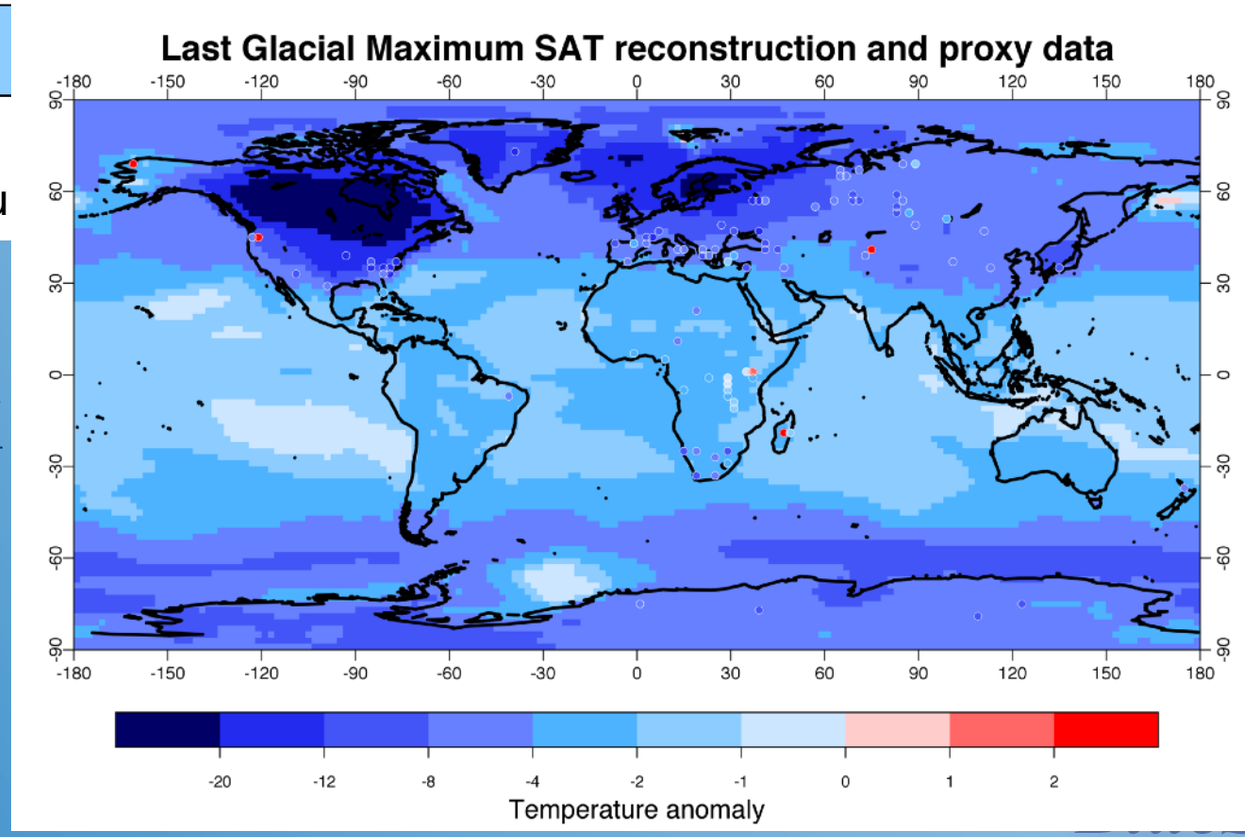
BlueSkiesResearch.org.uk

Results





Our new work



←AH2013

kiesResearch.org.uk

Why is our new result so different from TEA?

Why is our new result so different from TEA?

- TEA data seems quite similar to MARGO at coincident locations (mean difference -0.3C).

Why is our new result so different from TEA?

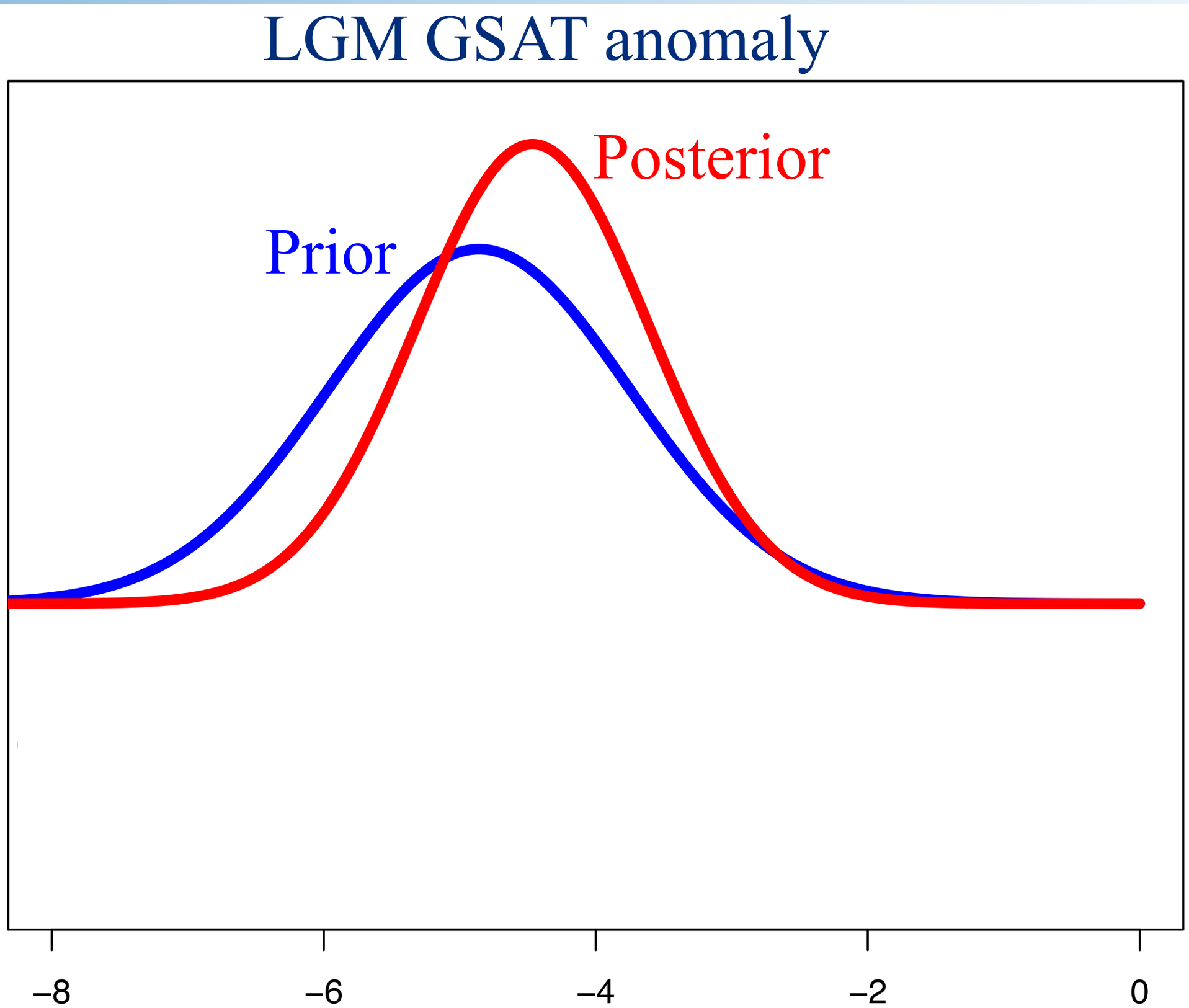
- TEA data seems quite similar to MARGO at coincident locations (mean difference -0.3C).
- In our current research, we get similar results using either TEA, or MARGO, or both together.

Why is our new result so different from TEA?

- TEA data seems quite similar to MARGO at coincident locations (mean difference -0.3C).
- In our current research, we get similar results using either TEA, or MARGO, or both together.
- →We don't think it's the data

The assimilation update

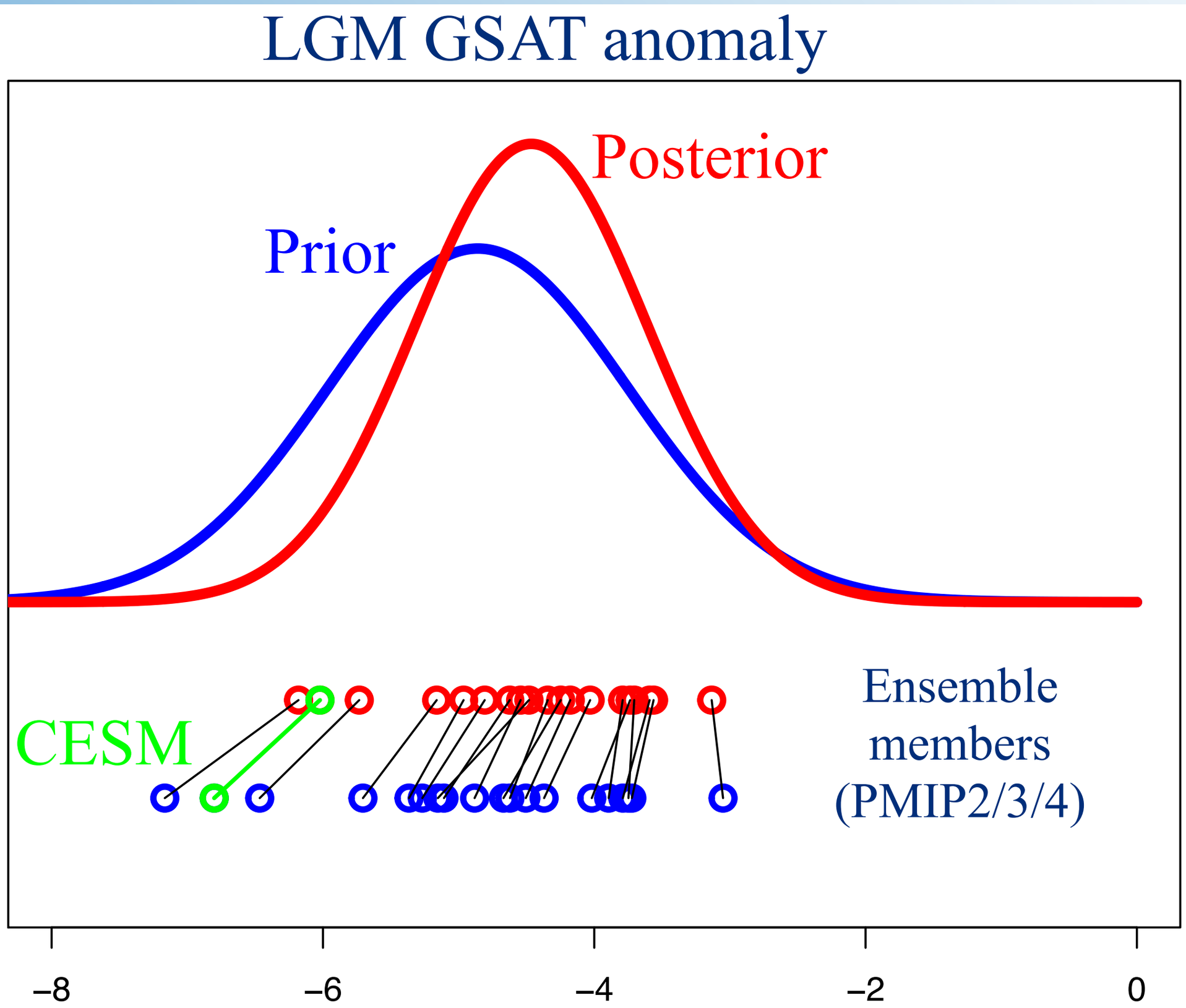
(based on EnKF method)



org.uk

The assimilation update

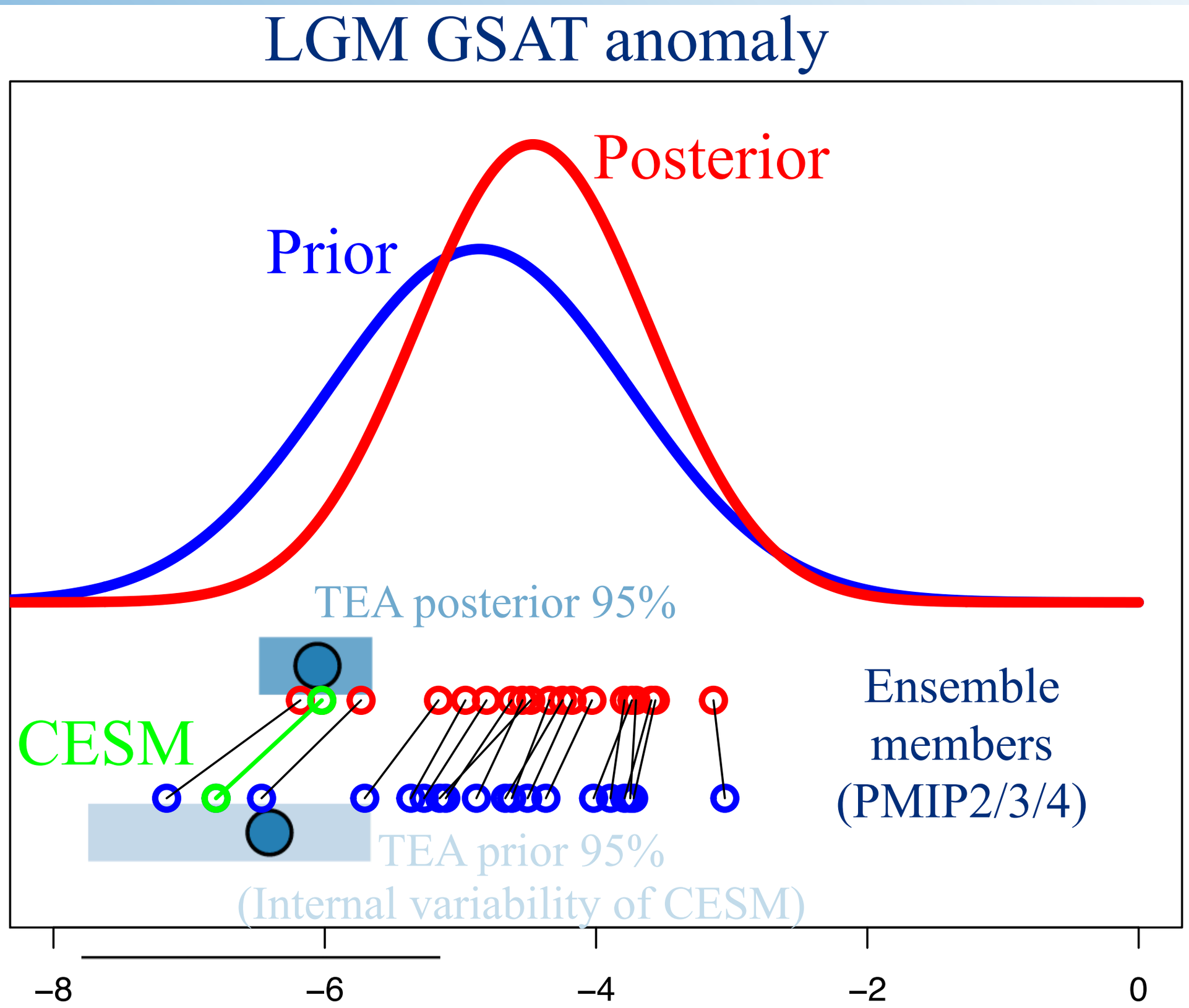
(based on EnKF method)



org.uk

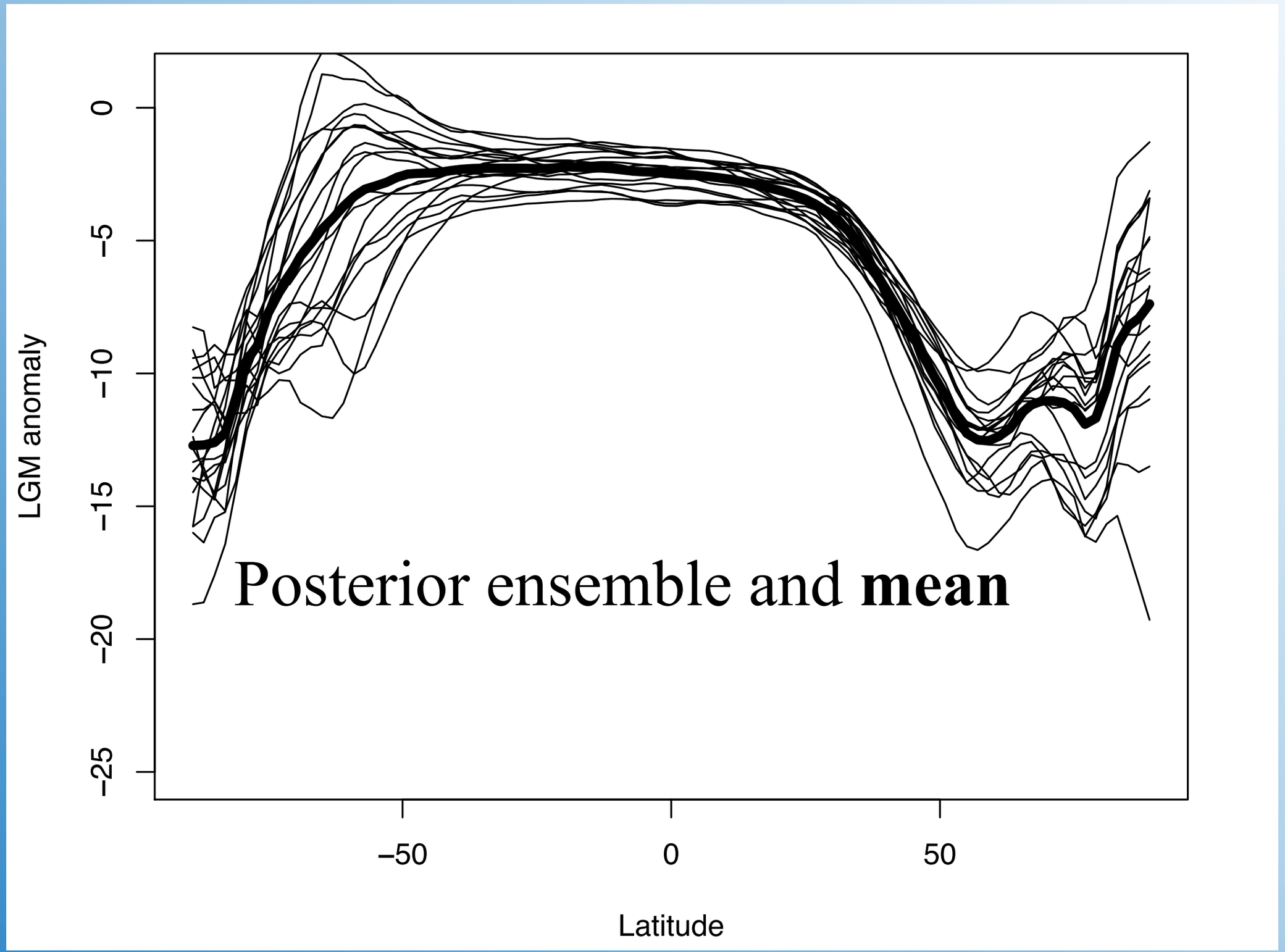
The assimilation update

(based on EnKF method)



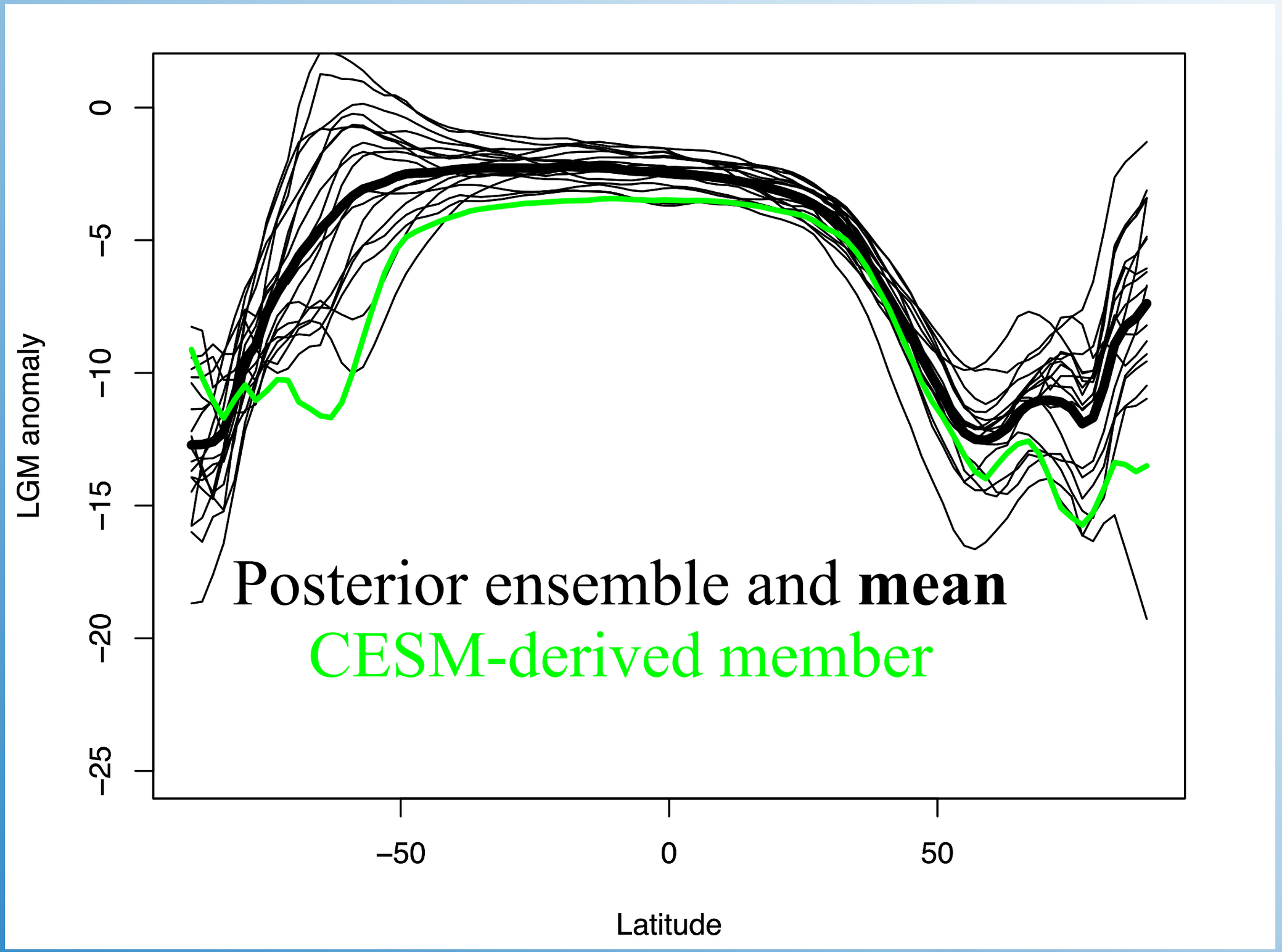
org.uk

Latitudinal variation



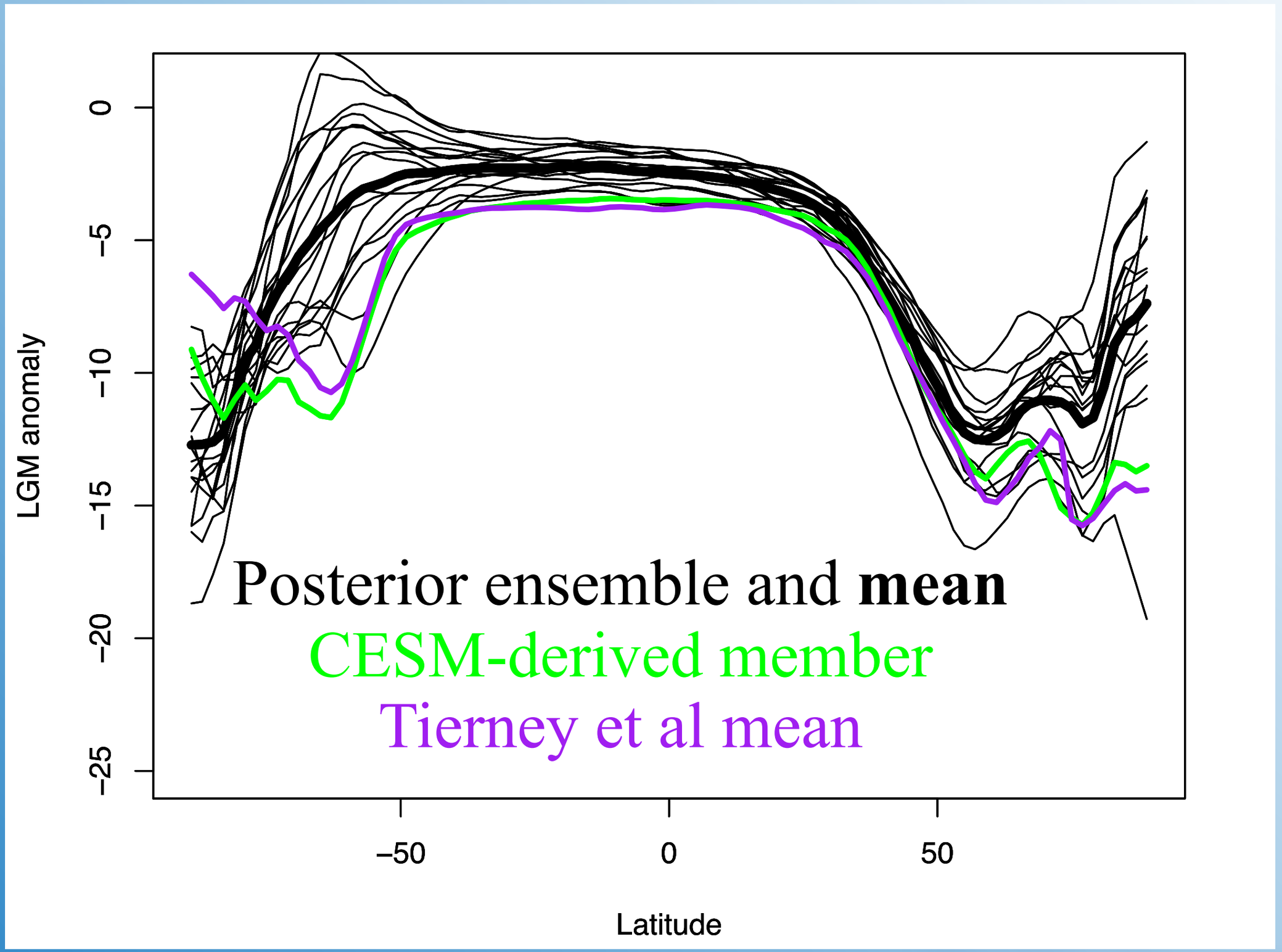
BlueSkiesResearch.org.uk

Latitudinal variation



BlueSkiesResearch.org.uk

Latitudinal variation



BlueSkiesResearch.org.uk

Conclusions

Conclusions

- Our LGM temperature estimate is milder than TEA but quite uncertain
  - Our posterior ensemble contains an estimate very similar to Tierney et al's mean (based on CESM)
  - We also contain a diverse set of warmer reconstructions

Conclusions

- Our LGM temperature estimate is milder than TEA but quite uncertain
  - Our posterior ensemble contains an estimate very similar to Tierney et al's mean (based on CESM)
  - We also contain a diverse set of warmer reconstructions
- These all agree well with the proxy data!
  - Data voids in regions of significant disagreement

Conclusions

- Our LGM temperature estimate is milder than TEA but quite uncertain
  - Our posterior ensemble contains an estimate very similar to Tierney et al's mean (based on CESM)
  - We also contain a diverse set of warmer reconstructions
- These all agree well with the proxy data!
  - Data voids in regions of significant disagreement
- Tierney et al have a cold and extremely (over)confident LGM estimate because their prior excluded the possibility of milder climate states

Conclusions

- Our LGM temperature estimate is milder than TEA but quite uncertain
  - Our posterior ensemble contains an estimate very similar to Tierney et al's mean (based on CESM)
  - We also contain a diverse set of warmer reconstructions
- These all agree well with the proxy data!
  - Data voids in regions of significant disagreement
- Tierney et al have a cold and extremely (over)confident LGM estimate because their prior excluded the possibility of milder climate states
- Single model ensemble fails to include uncertainty in feedbacks and model structure, not a good prior for this problem. Multi model ensemble represents a wider range of uncertainties
  - Yokohata et al 2012, 2013, Parsons et al 2021