Views from the 6 aircraft campaigns: ACT-America, HIPPO, CONTRAIL, ATom, ORCAS, and ABoVE

Assimilation of airborne CO_2 measurements into GEOS and comparisons with satellite retrievals

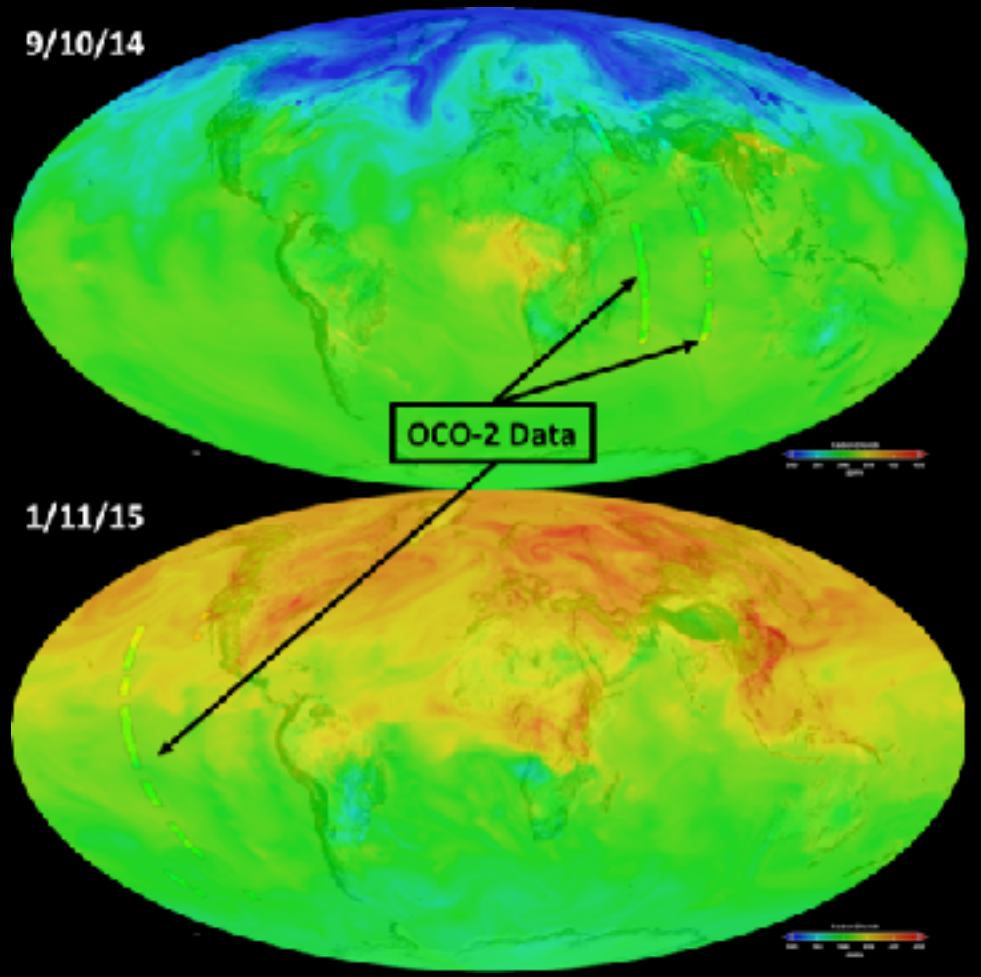
B. Weir[1,2], C. O'Dell[3], E. Bell[3], L. Ott[2], A. Chatterjee[1,2], and S. Pawson[2]

1) USRA, 2) NASA GMAO, 3) CSU

Our assimilation approach

- Traditionally, GMAO produces analyses of met vars (wind, temp, pres) and short-lifetime trace gases (water vapor, ozone), e.g. MERRA-2 and GEOS FP
- We've applied the same approach to analyze CO_2 based on OCO-2 (right) and GOSAT-ACOS retrievals

- Still, (like everyone) assim struggles to show skill over prior
- What can we learn from met/NWP analysis?



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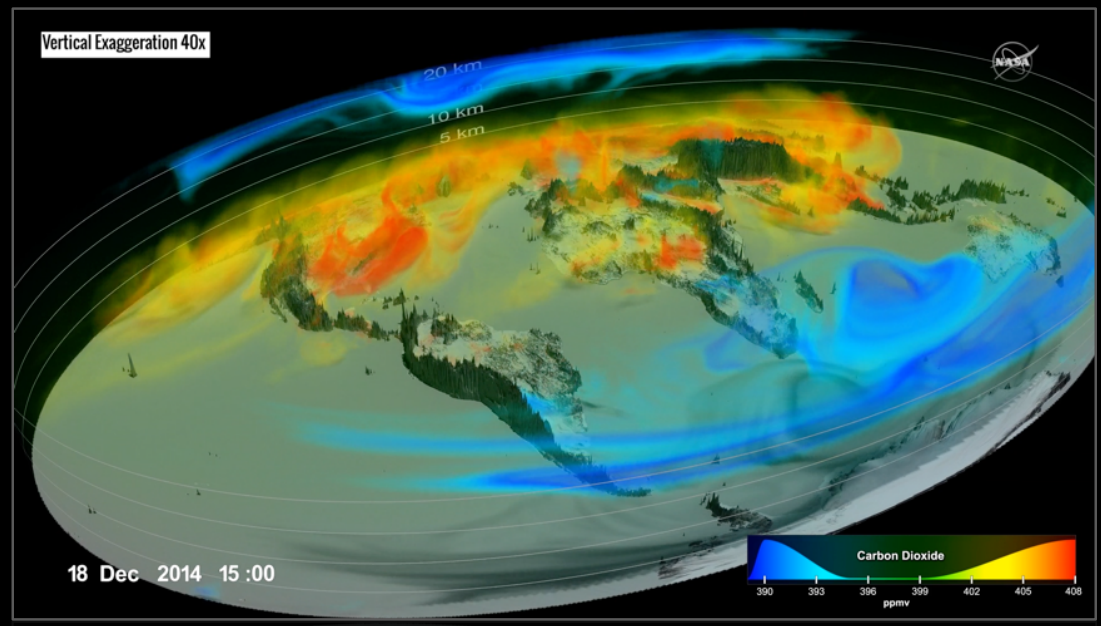

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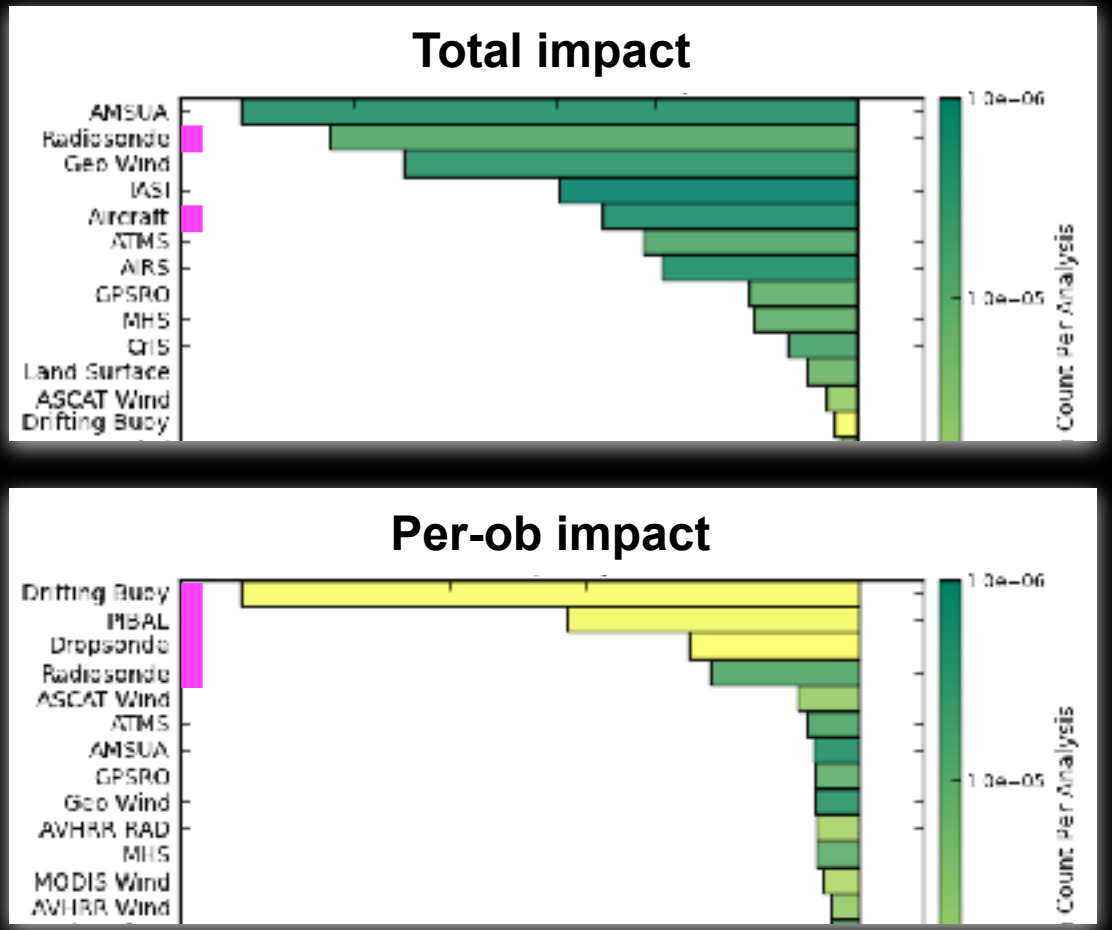
LESSONS FROM MET ANALYSIS

- **In situ met obs:** 2nd greatest total impact (top) and greatest (bottom) per-ob impact
- They are basis of VarBC bias correction:
  - Rough assumption that model + in situ analysis has little bias
  - Used as baseline to bias correct radiance assim
- **NWP based on satellites alone would likely struggle to show skill** (paraphrasing Kalnay)
- **For CO_2: Need to build an anchor for satellite assim based on in situ obs**



An idea from Chris

- Use assimilation machinery to ingest aircraft campaign data, then compare to satellite retrievals (similar to VarBC approach)

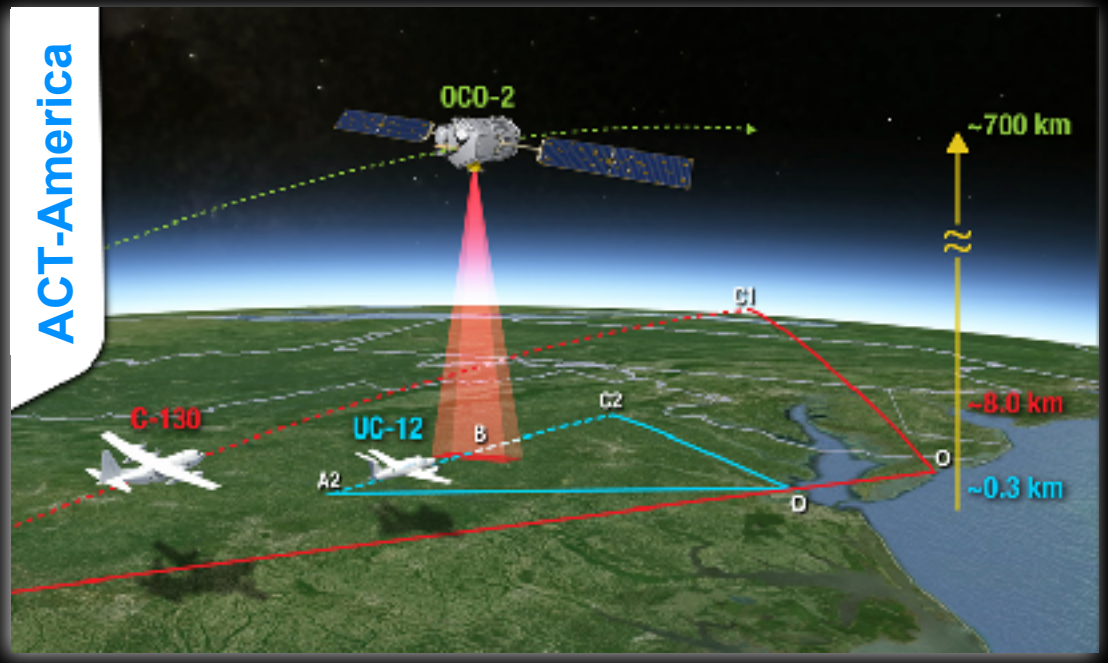
- Then …
  1. If aircraft improves model agreement w/ satellite data, suggests model errors
  2. If aircraft degrades model agreement w/ satellite data, suggests retrieval errors

AIRCRAFT CURTAINS OF CO_2

- Basic approach: 1) build 2D “curtains” of CO_2 by assimilating aircraft obs into GEOS and 2) compare to satellite overpasses

- Pros: no ad hoc coincidence criteria or stitching of stratosphere on top, no need for direct overpass (correlations)

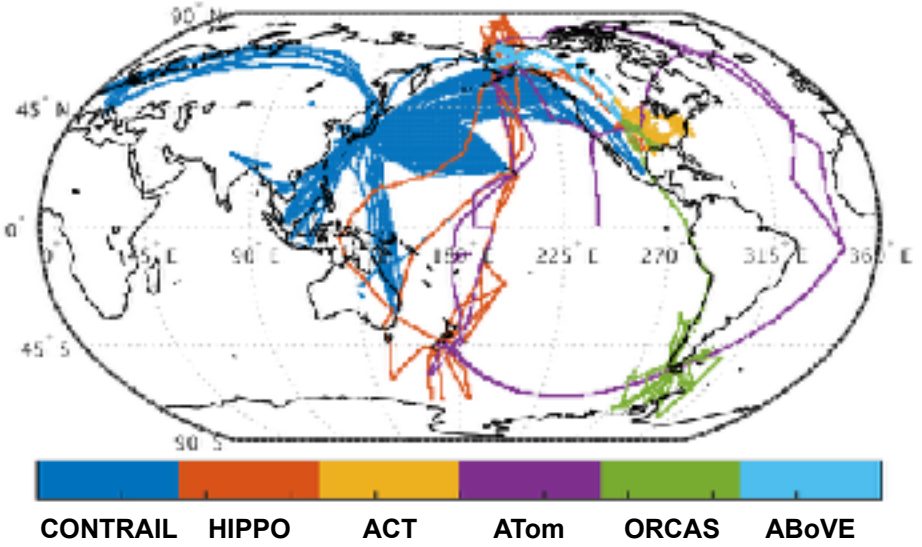
- Cons: reliance on model data



AIRCRAFT CURTAINS OF CO_2

- Coverage
  - Open ocean — HIPPO & ATom
  - Arctic — ABoVE
  - Mid-lat. land — ACT-America
  - S. Hem. — ORCAS
  - UTLS — CONTRAIL
- By no means an exhaustive: AirCore, CARVE, ASCENDS test flights, DISCOVER-AQ, SEAC4RS, AJAX, …

Data in NOAA ObsPack from 2009 thru 2017



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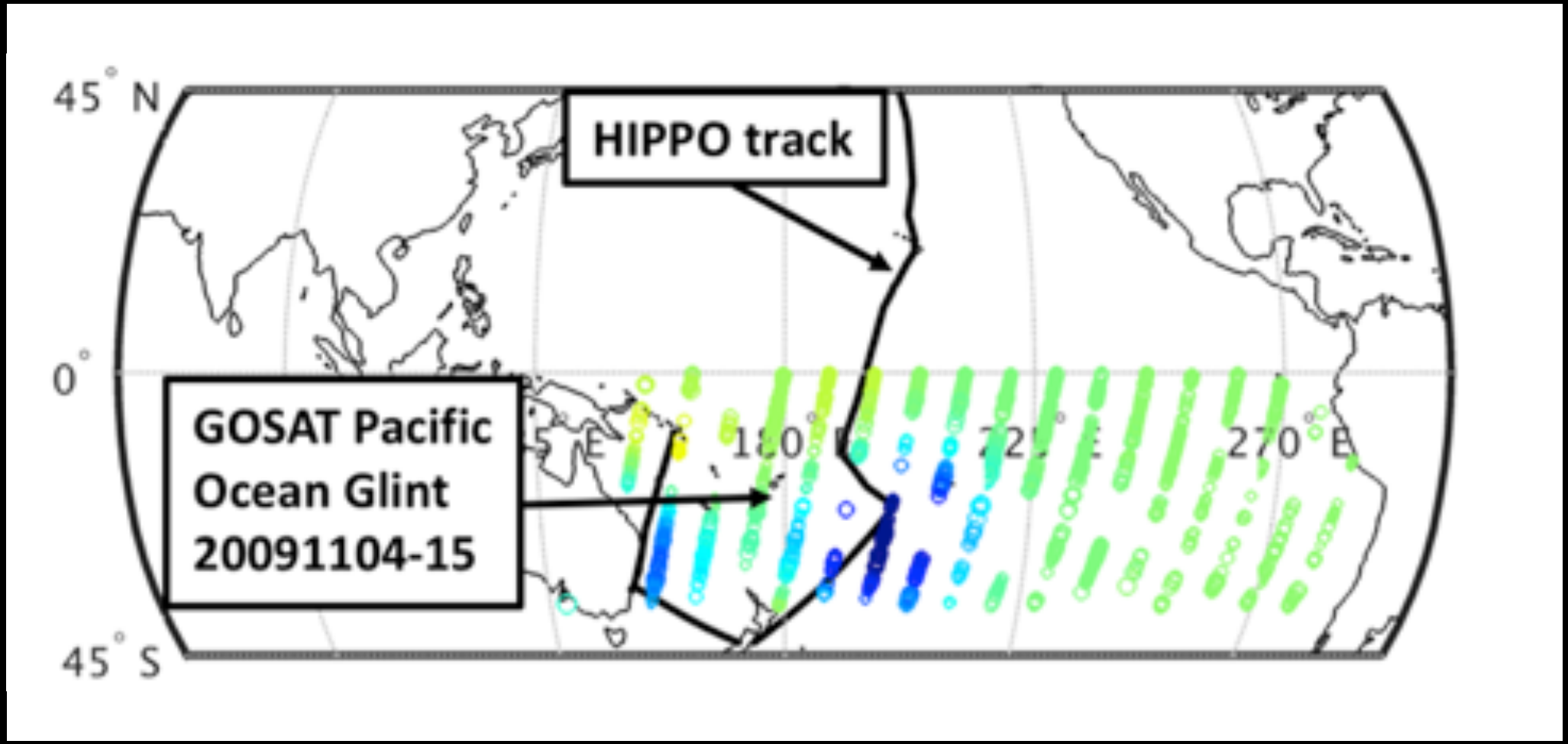

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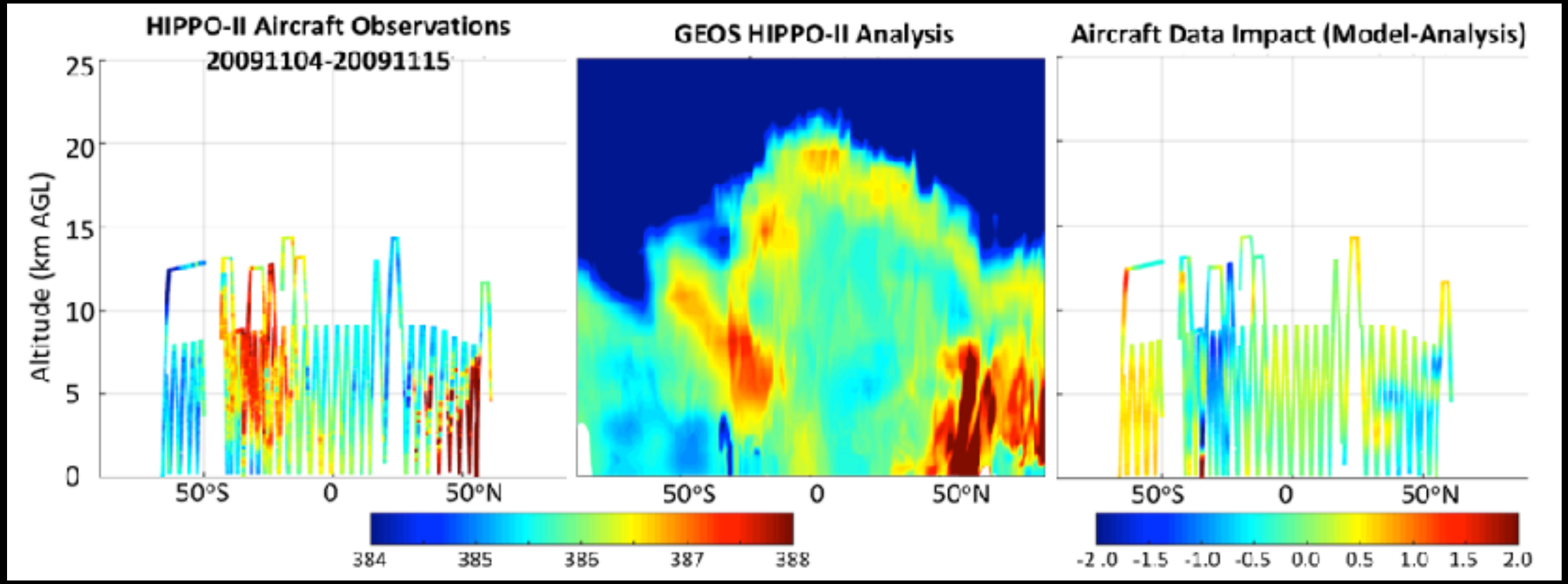

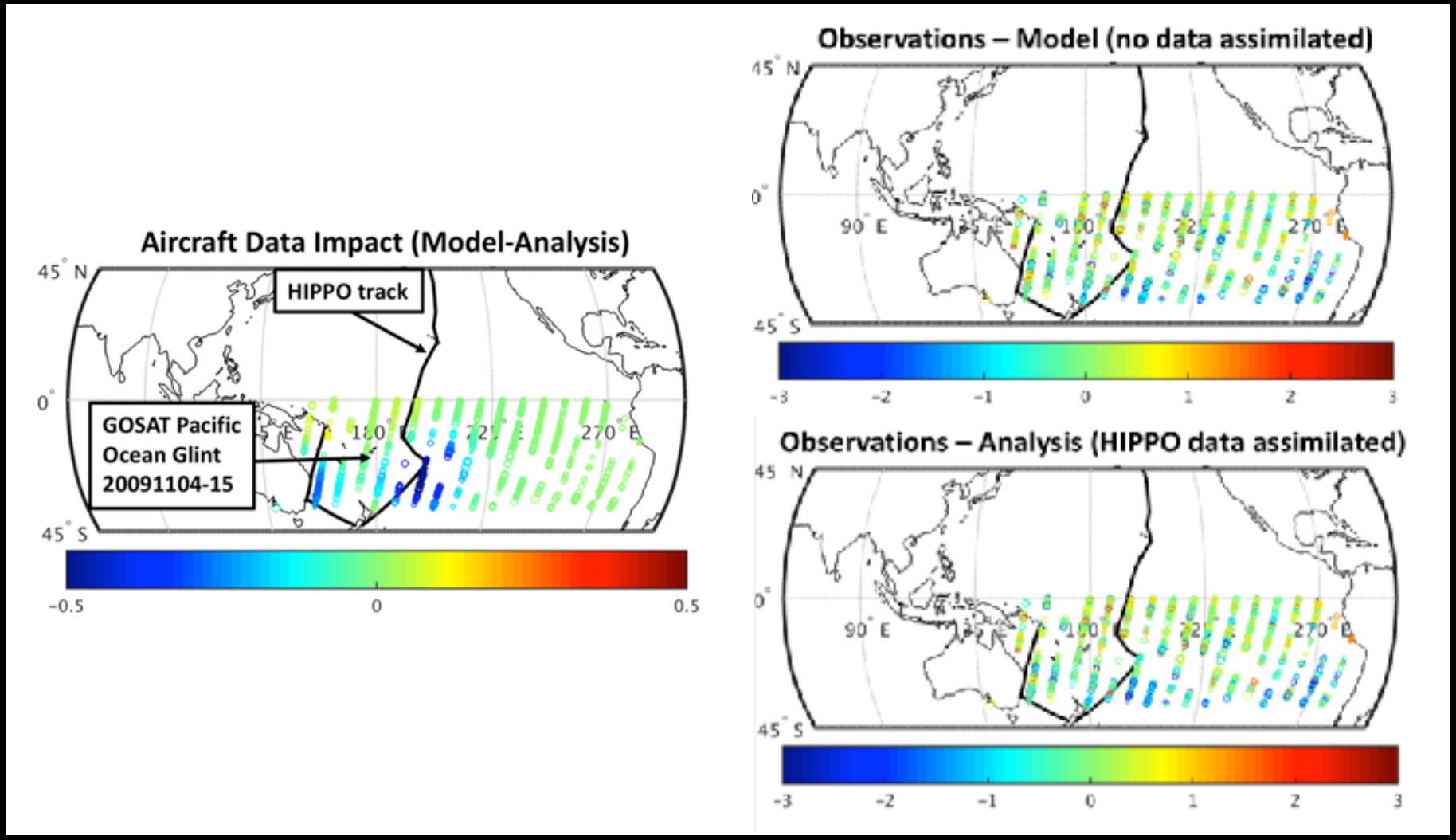
Aircraft Data Impact (Model-Analysis)
45° N
0°
45° S
HIPPO track
GOSAT Pacific
Ocean Glint
20091104-15
90° E
180°
270° E
-0.5
0
0.5
Observations – Model (no data assimilated)
45° N
0°
45° S
90° E
180°
270° E
-3
-2
-1
0
1
2
3
Observations – Analysis (HIPPO data assimilated)
45° N
0°
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-2
-1
0
1
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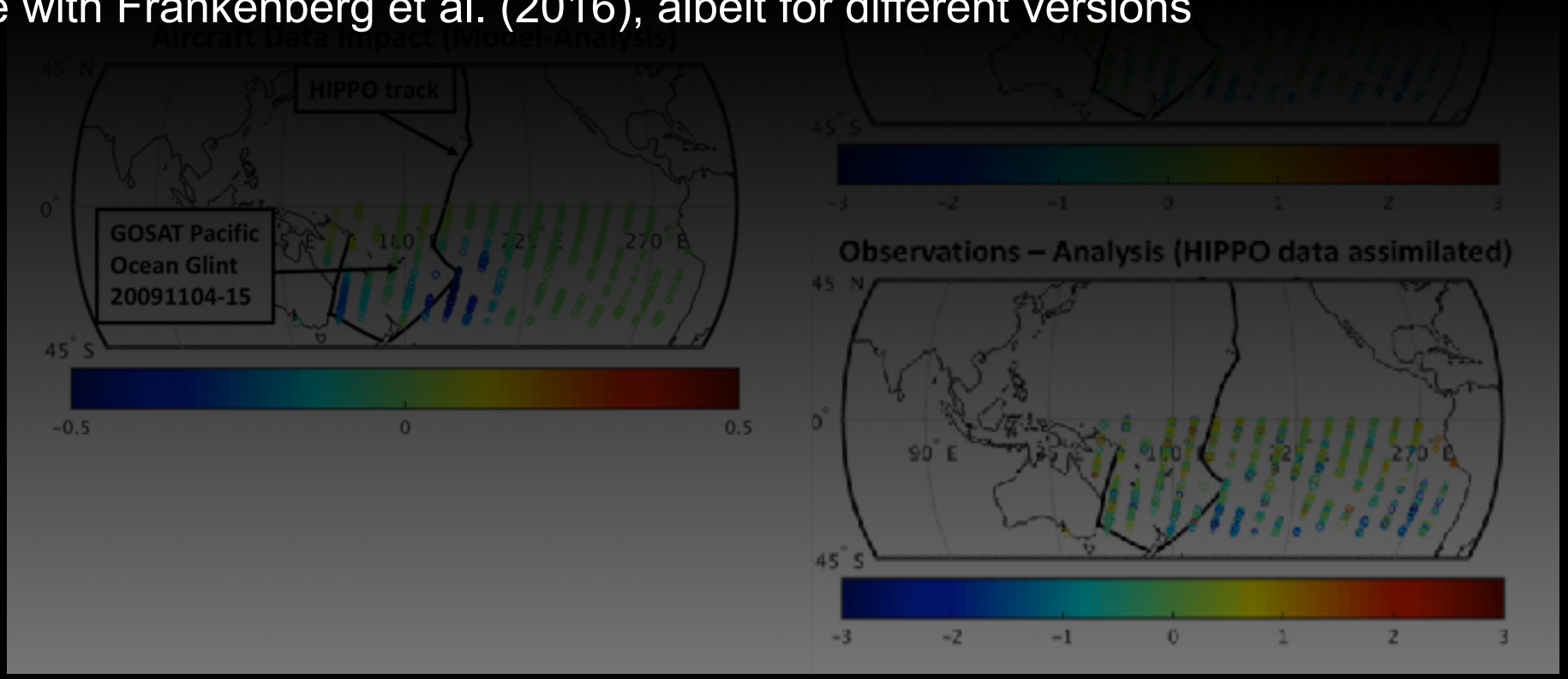
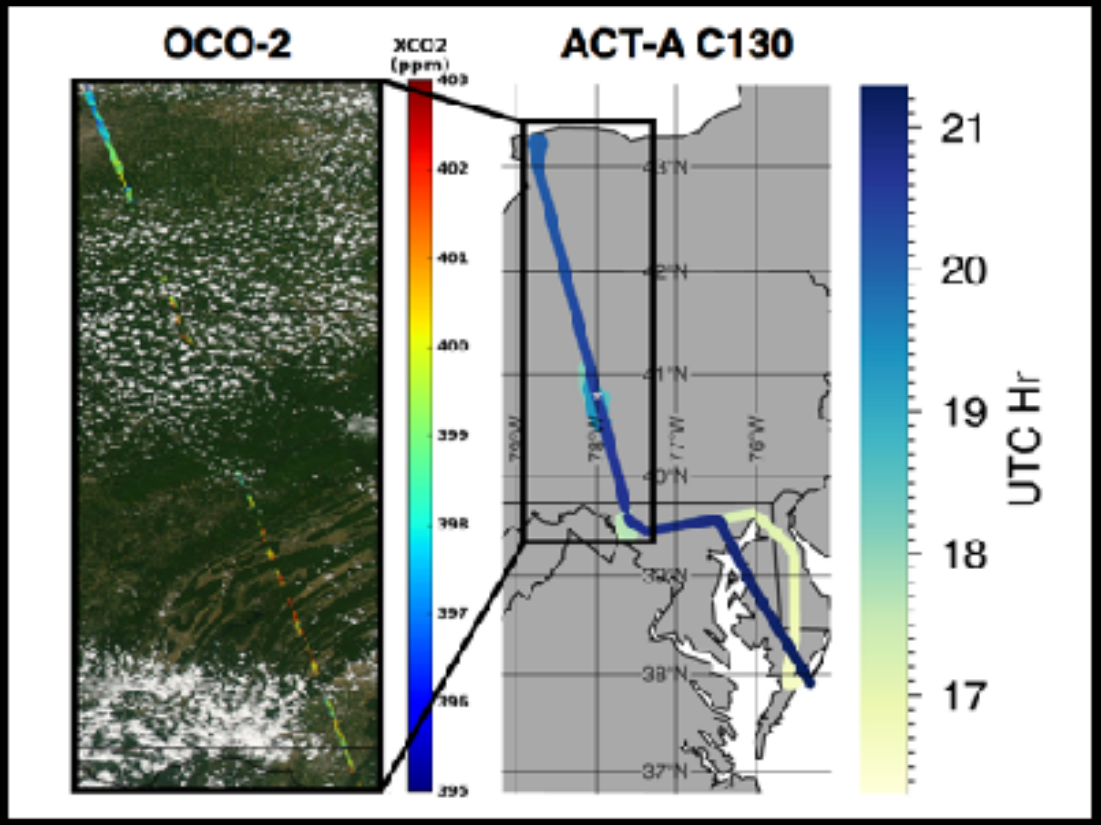
1) HIPPO II: Nov 2009

- Assimilation of HIPPO II indicates low bias of GOSAT-ACOS v7 retrievals
- In line with Frankenberg et al. (2016), albeit for different versions



2) ACT-America: 27 July 2016

- ACT-America campaign has a number of coordinated underflights of OCO-2



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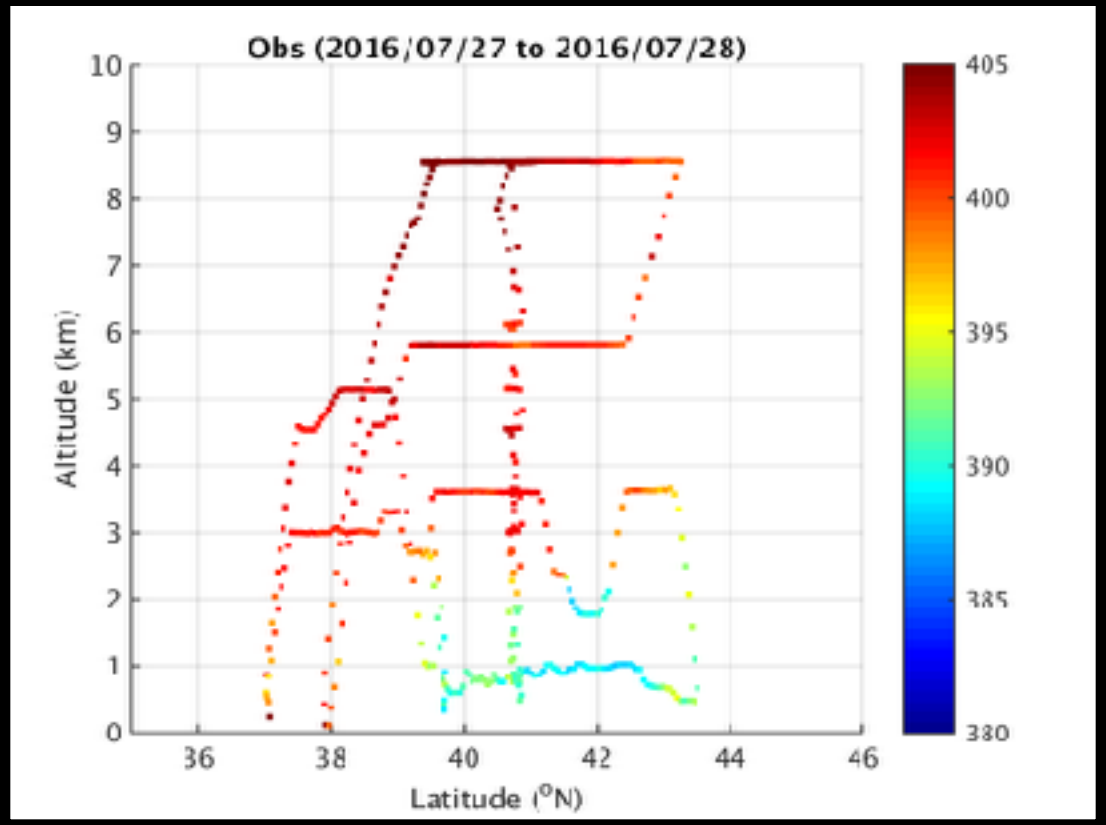

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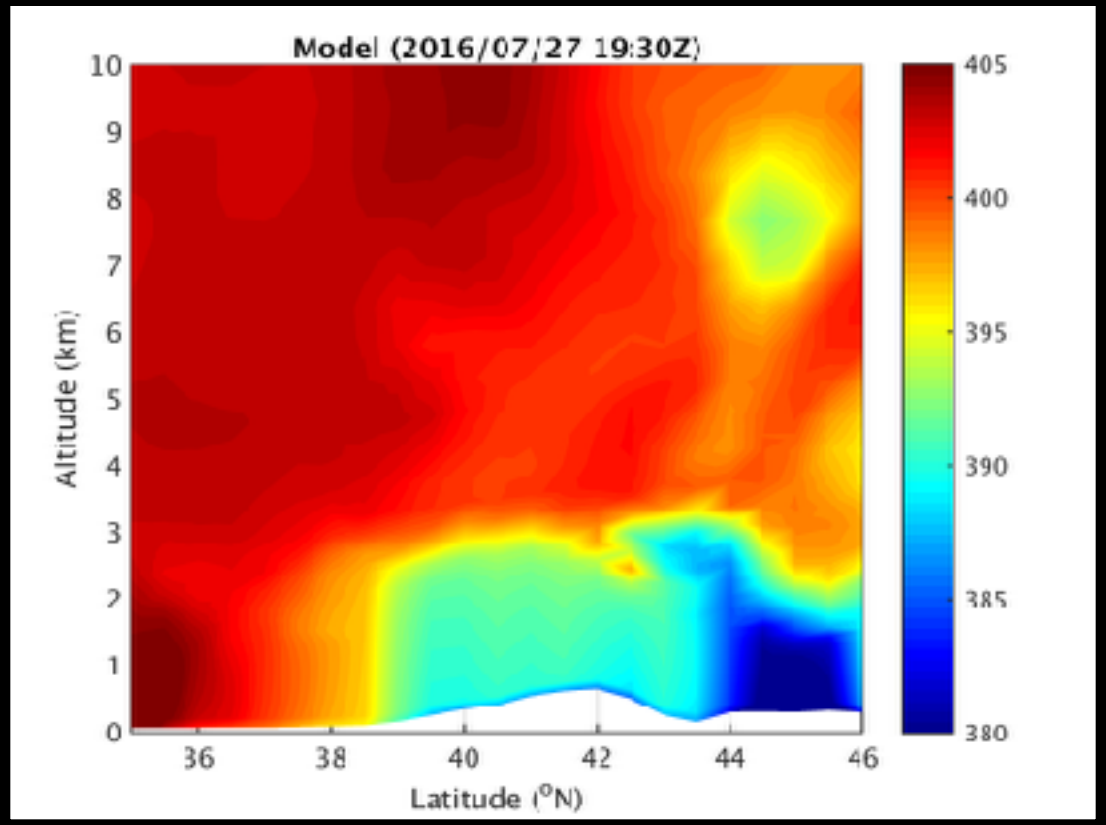

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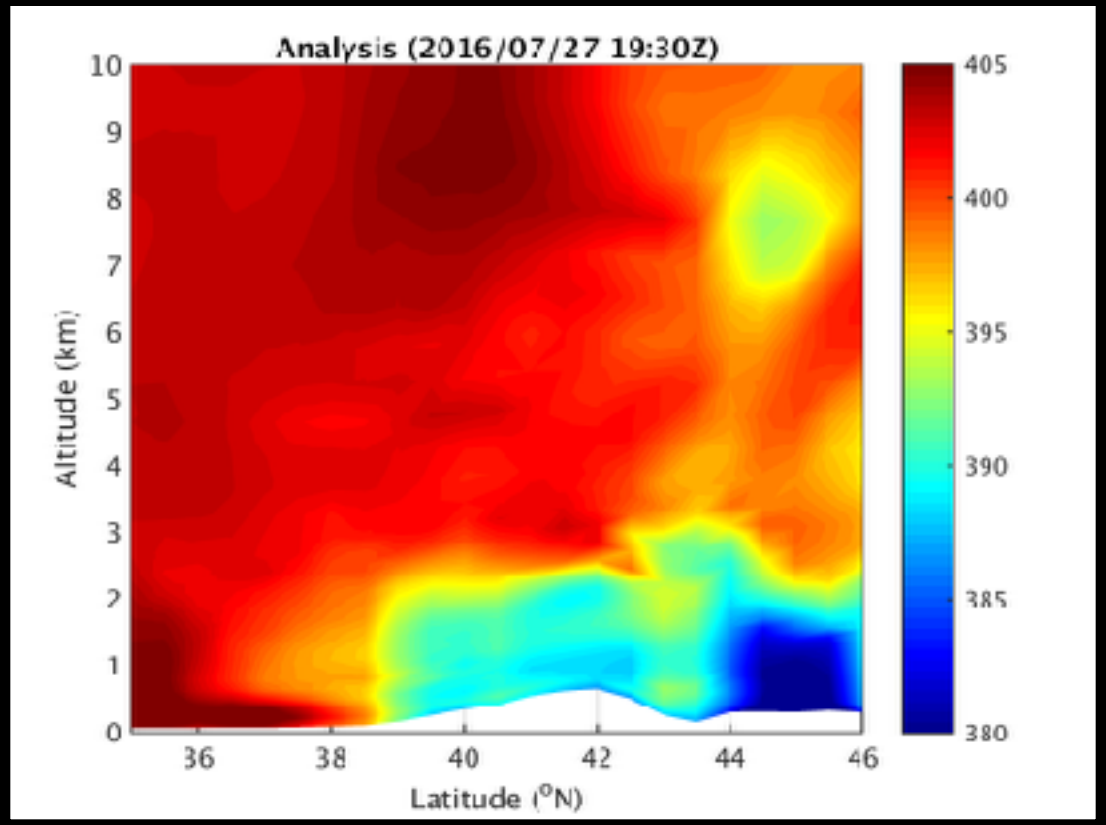

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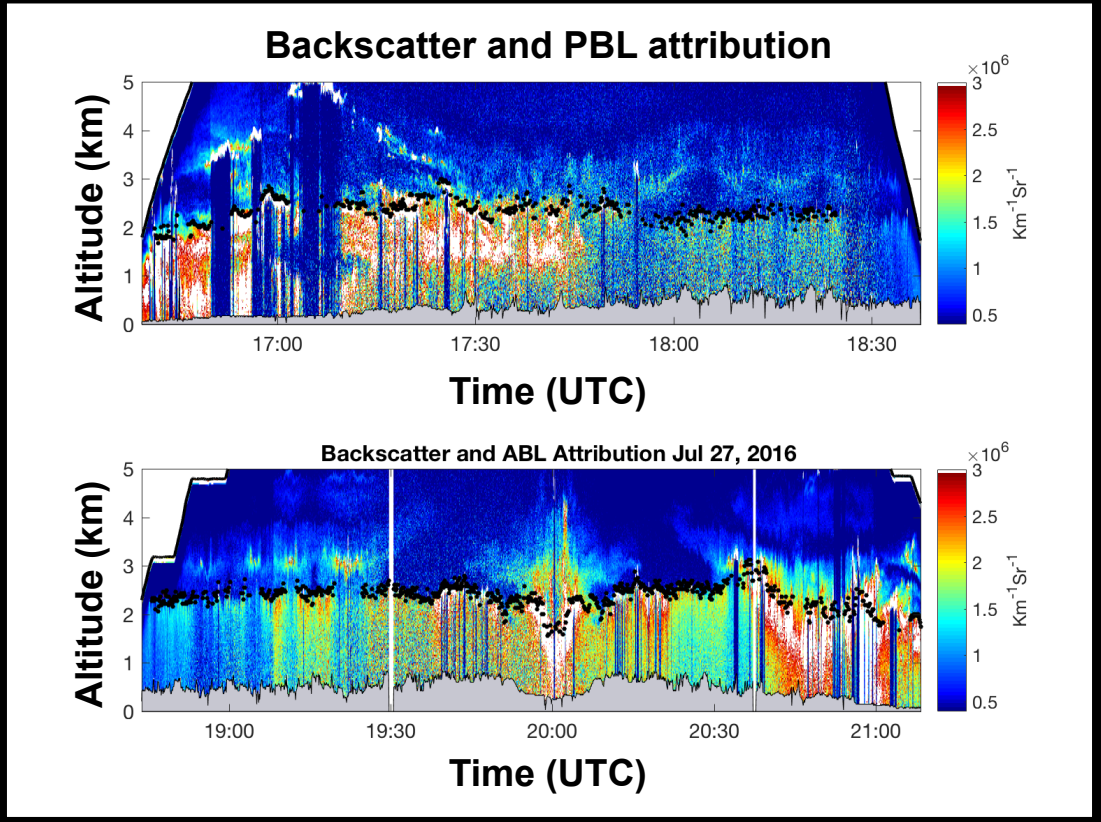

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- Assimilation of aircraft obs indicates that model PBL was too high
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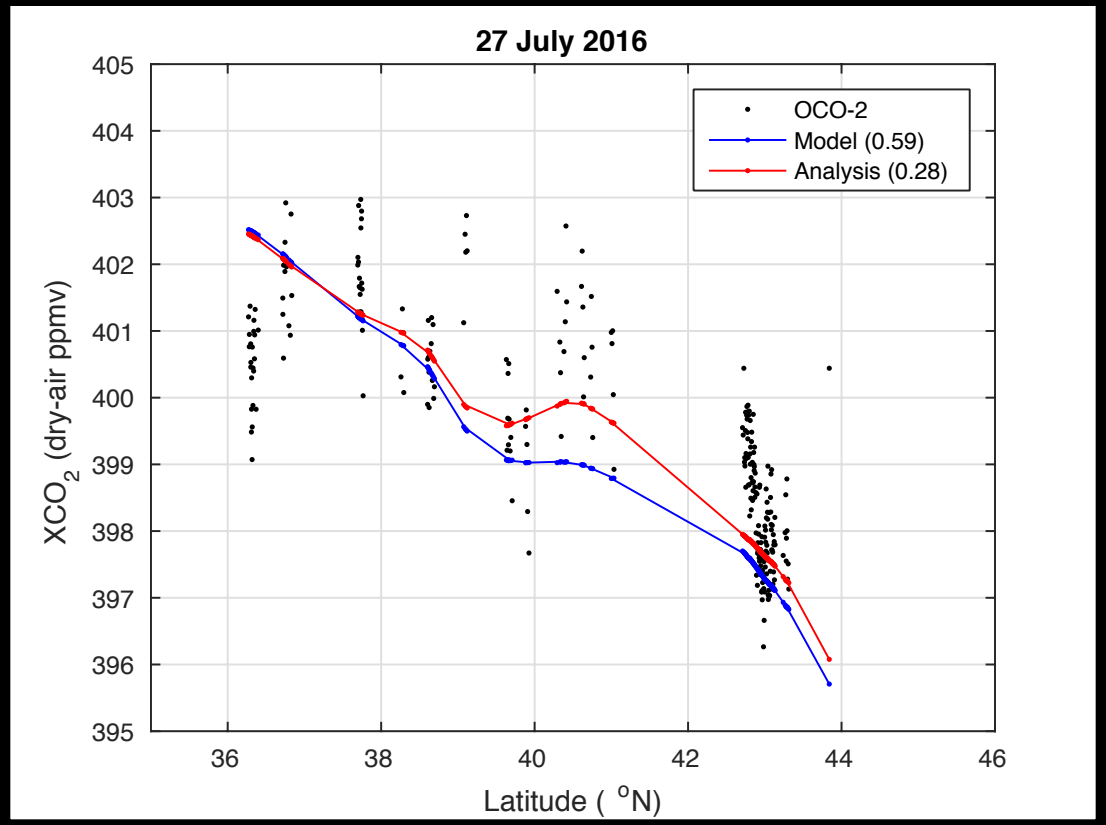
- Fixing the PBL height improves model agreement w/ OCO-2



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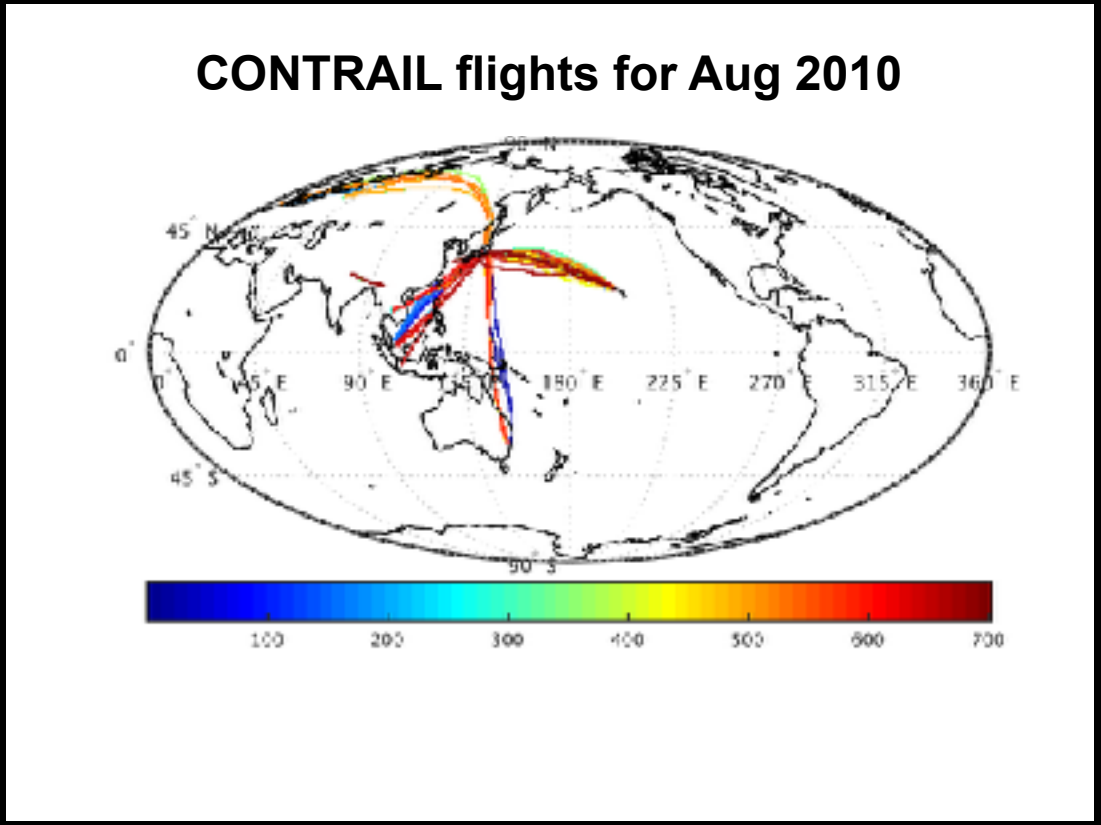
- How good is our model at high altitude?



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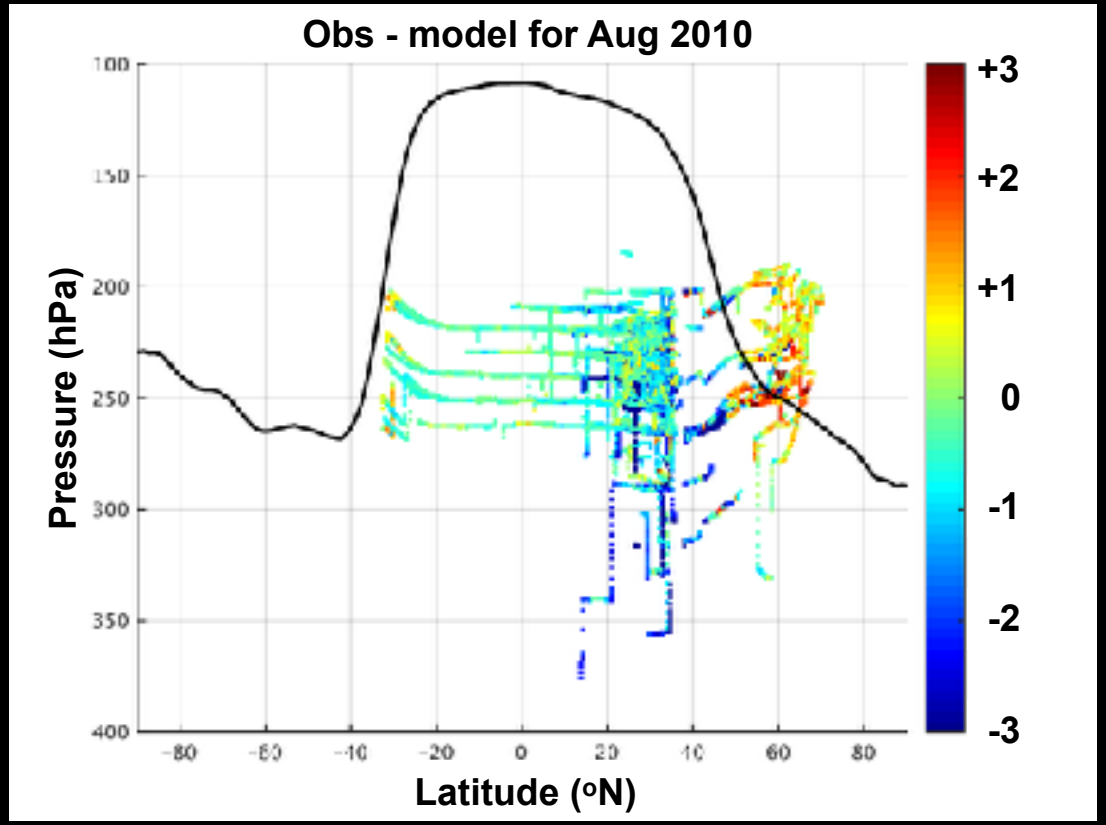
- Some indication model is too low in NH lower strat and too high in upper trop



CONCLUSIONS, FUTURE DIRECTIONS & PROBLEMS

- Model is wrong sometimes, satellite is wrong others
- Where we started, but starting to attribute blame: HIPPO II — retrieval bias, ACT-America — model PBL too high, CONTRAIL — not enough model STE?

- More data: other campaigns, profiles from aircraift and AirCore
- Curtains can be cylinders too — potential to estimate fluxes using mass balance? e.g. using SEAC4RS + AJAX for Yosemite Rim Fire

- No **obvious** way to evaluate curtains — we've assimilated all available data
- Background error covariances: ¯_(ツ)_/¯

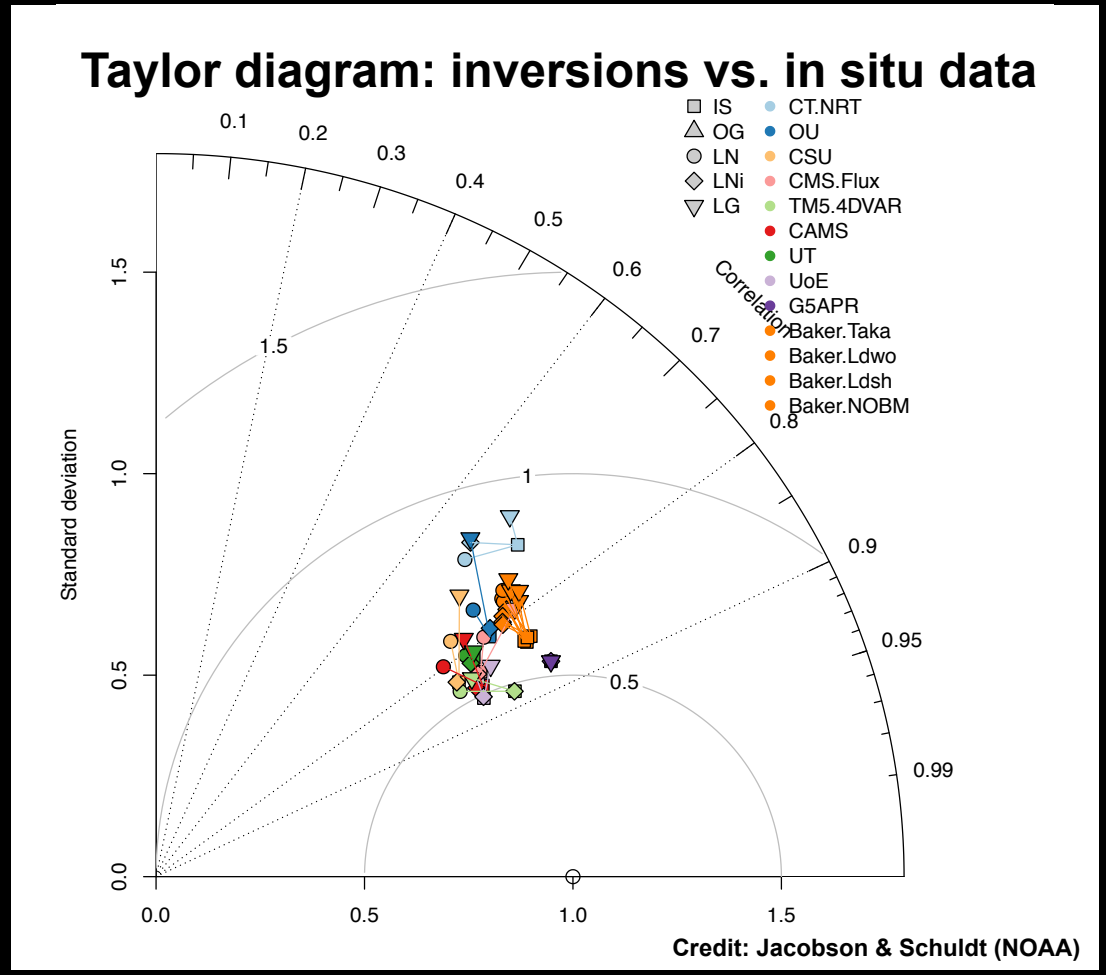
Thank you!

Acknowledgements: the OCO-2 project at JPL, CalTech, NOAA ESRL, HIPPO, ACT-America, CONTRAIL, and NASA CMS projects, & everyone I forgot

Backup slides

SLIDE TO MAKE (~~ALMOST~~) EVERYONE ANGRY

- Flux inversions are no better than a high-res simulation w/ a well-made prior



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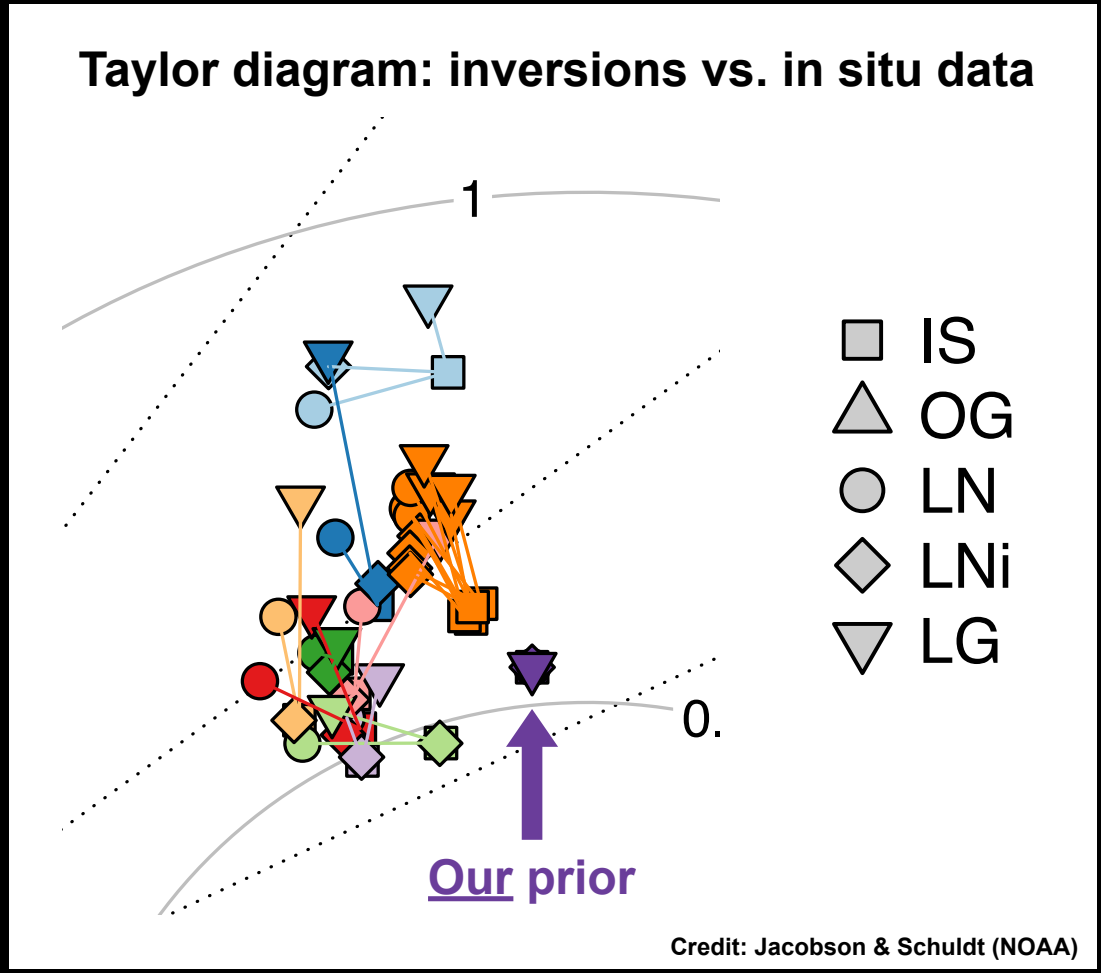
- Maybe Taylor diagram not the best metric



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- Land fluxes based on "poor man's inversion" of Chevallier
- Ocean fluxes based on suggestions from Jacobson
- Input from Baker, Collatz, Poulter, Kawa, many others …

Our prior

Background

- Can we construct a consistent picture of CO_2?
- Notably, 4D fields in space and time that agree with:
  1. Surface in situ measurements
  2. Aircraft in situ measurements
  3. Column retrievals (TCCON & satellites)
  4. A model based on reasonable scientific assumptions

- For me at least: answer is no, but yes is if #3 is excluded
- How do we attribute blame? … Most people trust #1 & #2, but not #3 & #4
- Basic idea: assimilate #1 & #2 into #3 and compare to #4