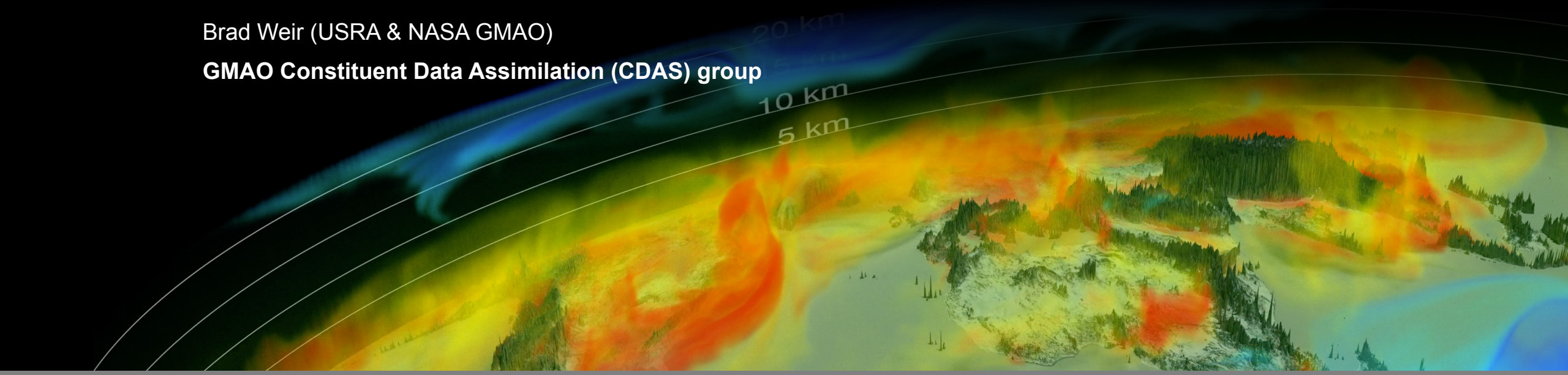
Multispecies trace gas assimilation: Current state of the GMAO system and plans for inclusion in the JEDI framework

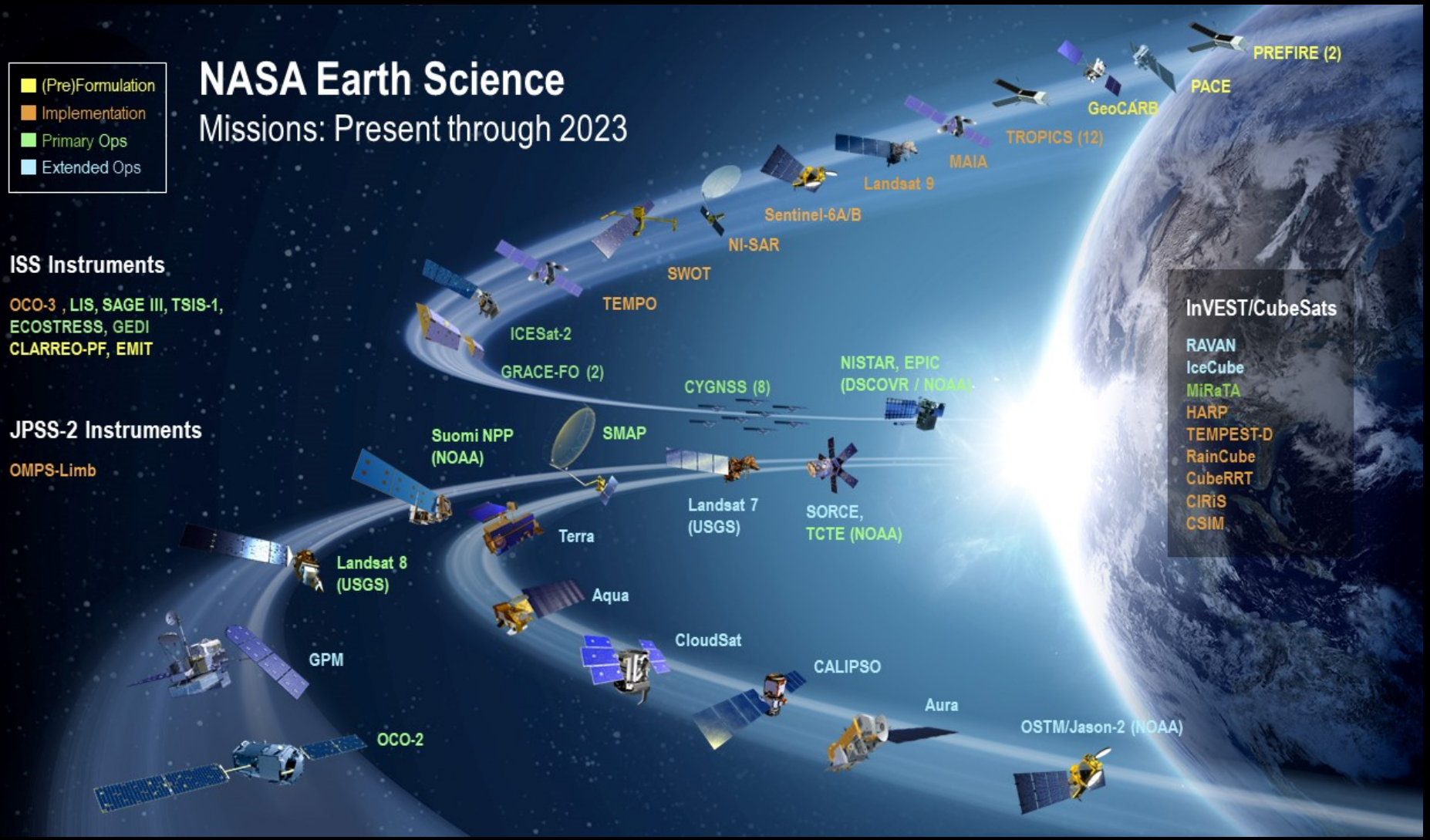
Brad Weir (USRA & NASA GMAO)

GMAO Constituent Data Assimilation (CDAS) group



Constituent (trace gas) assimilation

Produce assimilated fields of trace gases beyond just Q and O_3 …


(Pre)Formulation
Implementation
Primary Ops
Extended Ops
NASA Earth Science
Missions: Present through 2023
ISS Instruments
OCO-3 , LIS, SAGE III, TSIS-1,
ECOSTRESS, GEDI
CLARREO-PF, EMIT
JPSS-2 Instruments
OMPS-Limb
PREFIRE (2)
PACE
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TROPICS (12)
MAIA
Landsat 9
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NI-SAR
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NISTAR, EPIC
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Suomi NPP
(NOAA)
SMAP
Landsat 7
(USGS)
SORCE,
TCTE (NOAA)
Terra
Landsat 8
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Aqua
CloudSat
GPM
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OSTM/Jason-2 (NOAA)
InVEST/CubeSats
RAVAN
IceCube
MiRaTA
HARP
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CubeRRT
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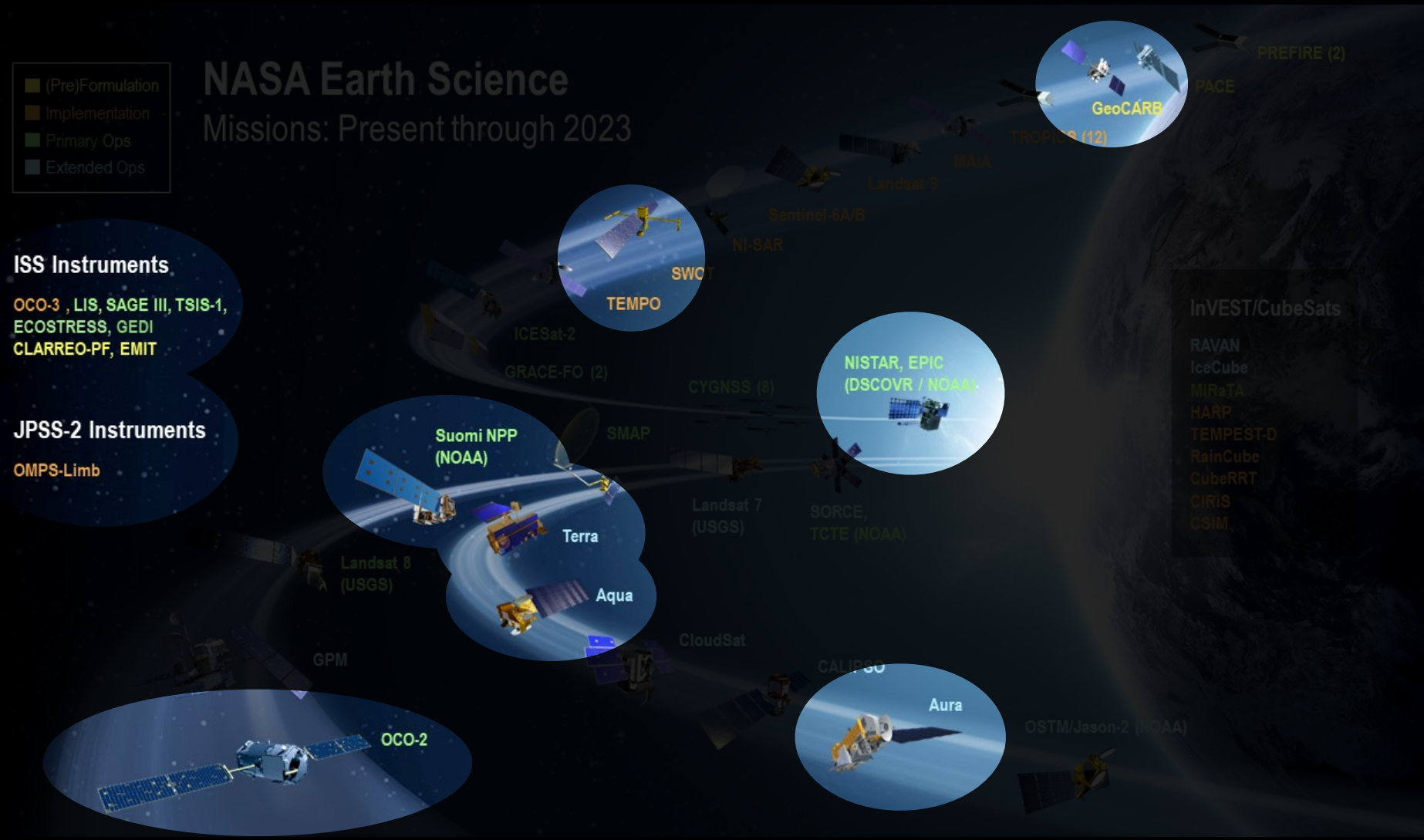
CSIM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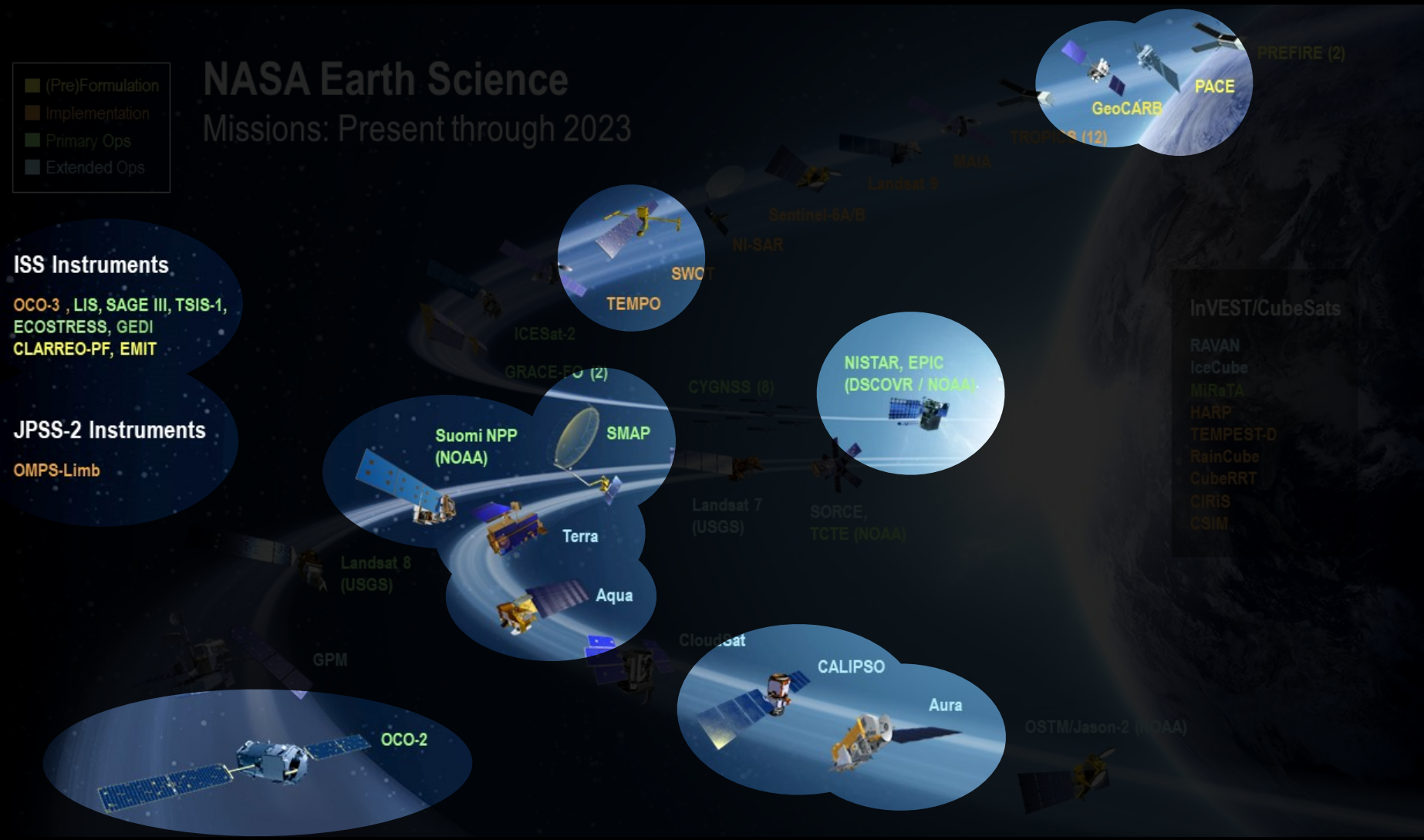
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GMAO CDAS Applications

- Greater utilization of multi-agency fleet of satellites
- Tie-ins to NWP/S2S:
  - Stratospheric chemistry => radiation budget => improvements in predictability
  - CO_2 as a transport tracer?

- Extension of a reanalysis like MERRA-2 to trace gases
- Air quality forecasts and analyses
- Forecasting support for field campaigns
- Special products for fields campaigns
  (e.g. “curtains” from ACT-America flights for OCO-2 validation)
- OSSE support for future missions
- Synergistic activities w/ other instruments: AVHRR, MODIS, SMAP, GEDI, ECOSTRESS, etc.

GMAO's Constituent Data Assimilation System (CDAS)

- Generalization & extension of GSI/ADAS O_3 analysis to handle ***<u>at run time</u>***:
  - Any choice of species
  - Any choice of chemistry models
  - Generic *point sample* and *averaging kernel retrieval* obs types
- Ability to use "replay" mode to avoid repeating met analysis
- It actually works!
- Some setbacks getting into main GSI development stream, looking forward to JEDI development paradigm

CDAS Observation types

- Point sample
  - Any obs at a given lat/lon/pressure (or altitude)
  - Examples: in situ data from NOAA GMD, MLS soundings, some older retrievals

- Averaging kernel retrieval
  - $H(x) = x_a + h^T A(x - x_a)$
  - You provide x_a and $h^T A$ for each sounding, we do the rest
  - Examples: OMI retrievals, most modern satellite retrievals

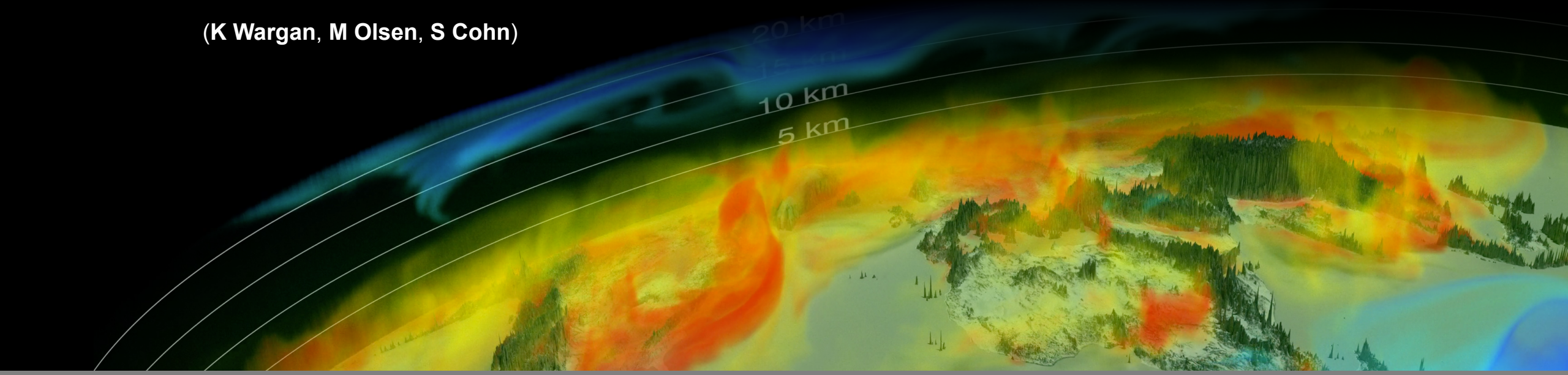
- Run time portability perfect fit for JEDI system

GMAO CDAS Examples

1. ***Stratospheric chemistry***
   - Limb sounding O_3, H_2O, HNO_3, HCl, N_2O data
   - Family-based stratospheric chemistry model (StratChem)
2. ***Climate / Carbon cycle***
   - Retrievals of CO, CO_2, and CH_4 from MOPITT, GOSAT, OCO-2
   - Upcoming data from TROPOMI, OCO-3, GeoCarb
   - Offline OH chemistry for CO and CH_4
3. ***Air quality***
   - CO from MOPITT; NO_2 & BrO from OMI & TROPOMI; traditional O_3 & H_2O measurements
   - GEOS-Chem chemistry module

Multi-species stratospheric chemistry assimilation

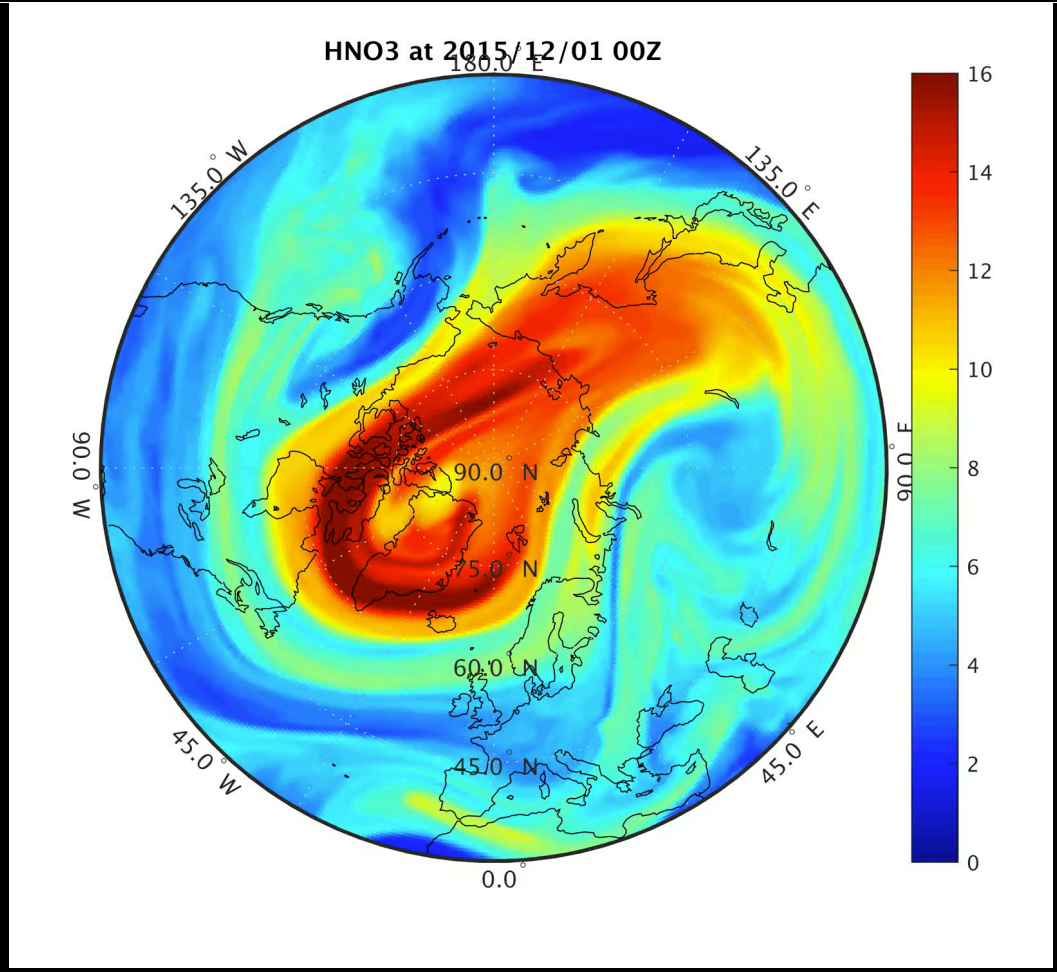
(**K Wargan**, **M Olsen**, **S Cohn**)



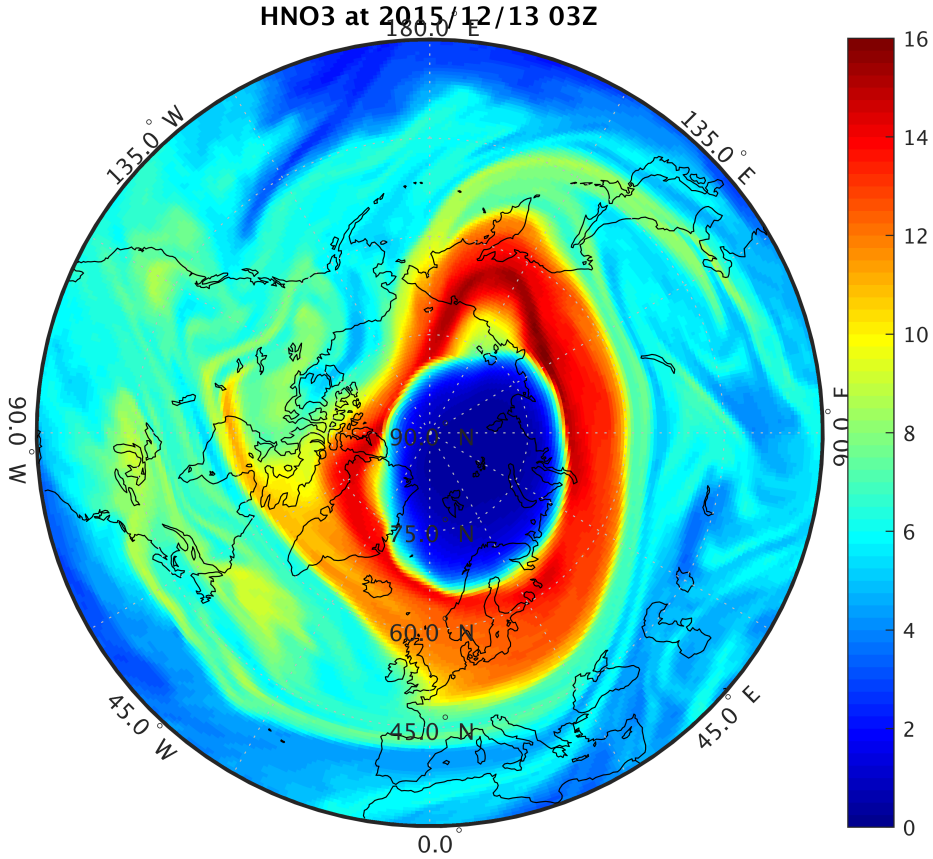
Multi-species stratospheric chemistry assimilation

- Stratospheric O_3 and H_2O = major controls on Earth's energy balance
- Improved estimates have potential to improve short to seasonal forecasts
- Concentrations determined by N and Cl chemistry
- Here: ***Preliminary*** demonstration of CDAS assimilation of O_3, H_2O, HNO_3, & HCl from MLS into stratospheric chemistry model

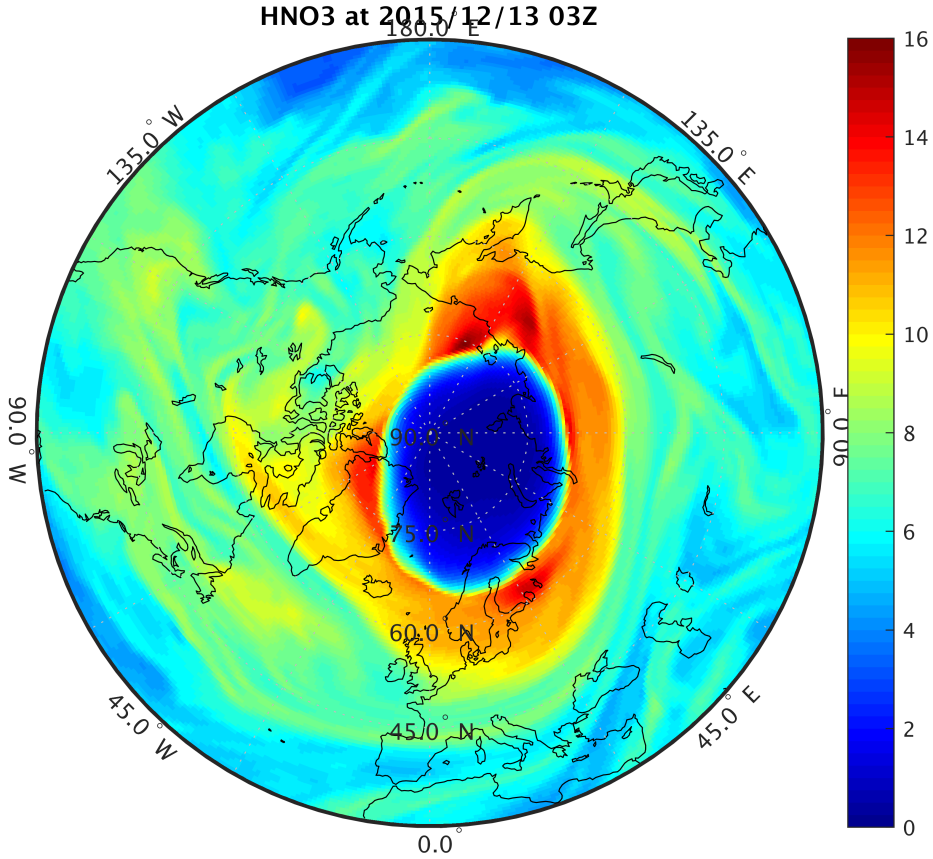
- Left: HNO_3 at 500 K theta level during formation of polar stratospheric cloud



Multi-species stratospheric chemistry assimilation



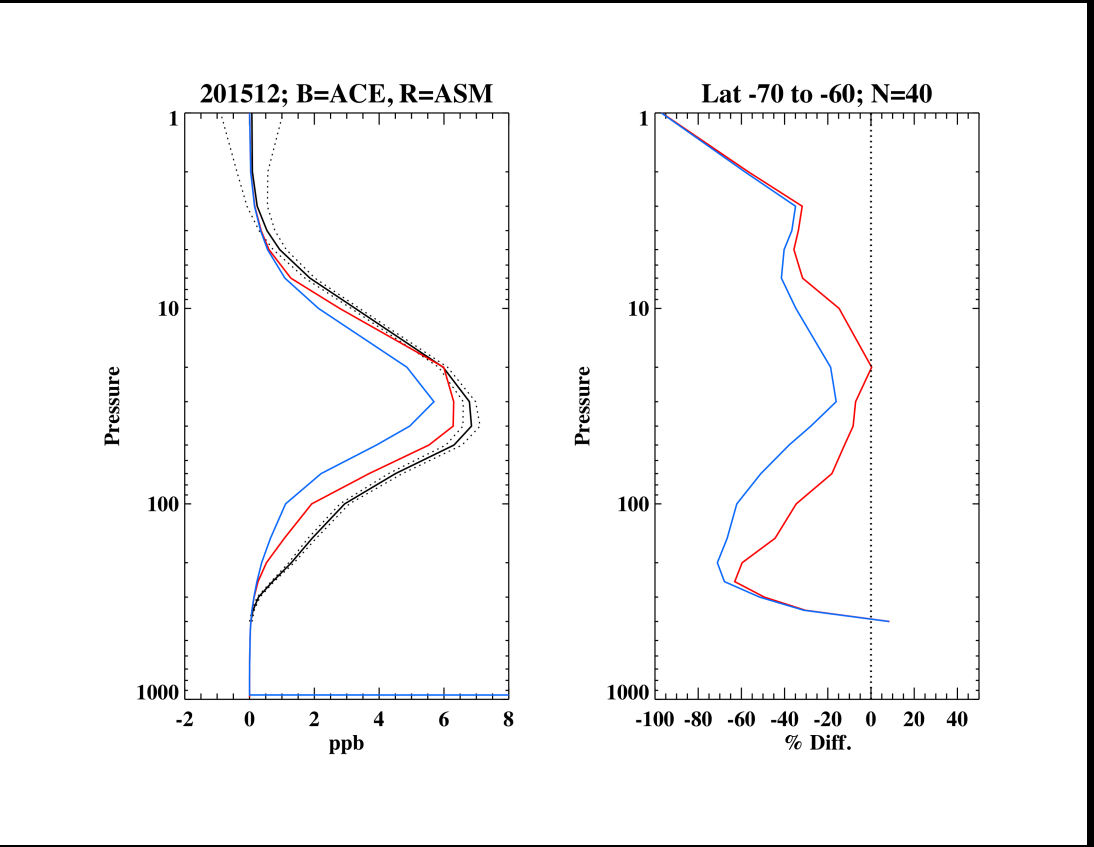
Free/control



Assimilated

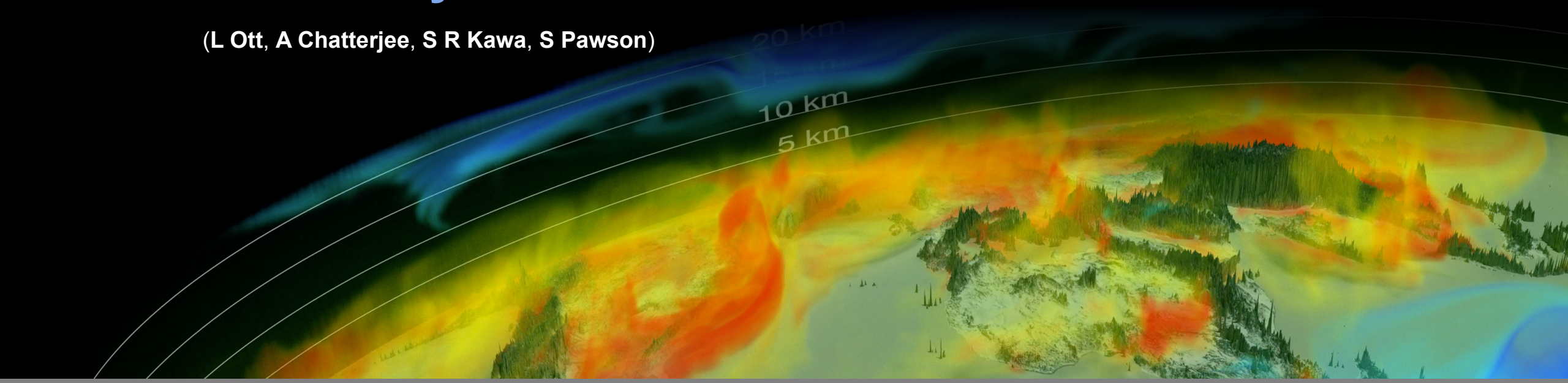
Multi-species stratospheric chemistry assimilation

- Can compare results to ACE-FTS solar occultation measurements (black)
- Free/control run (blue) and assimilation (red)
- Profiles are HNO_3 in 10 deg latitude bins averaged over the month
- Preliminary results look encouraging



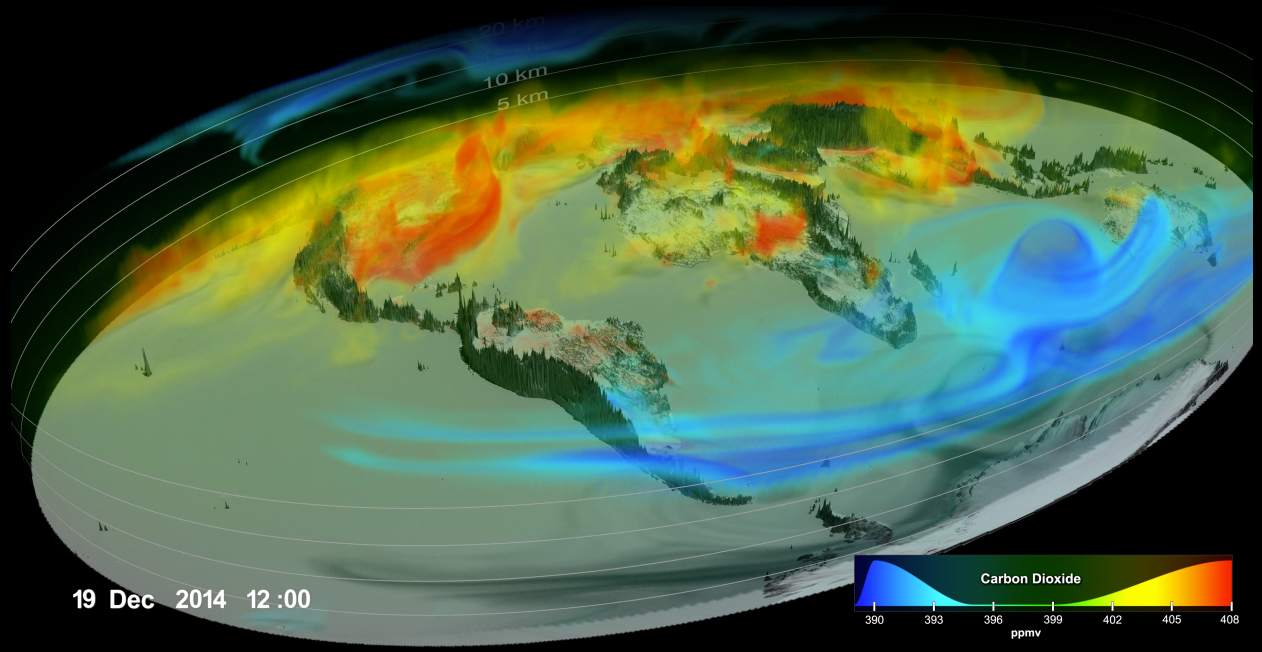
Carbon cycle data assimilation

(L Ott, A Chatterjee, S R Kawa, S Pawson)



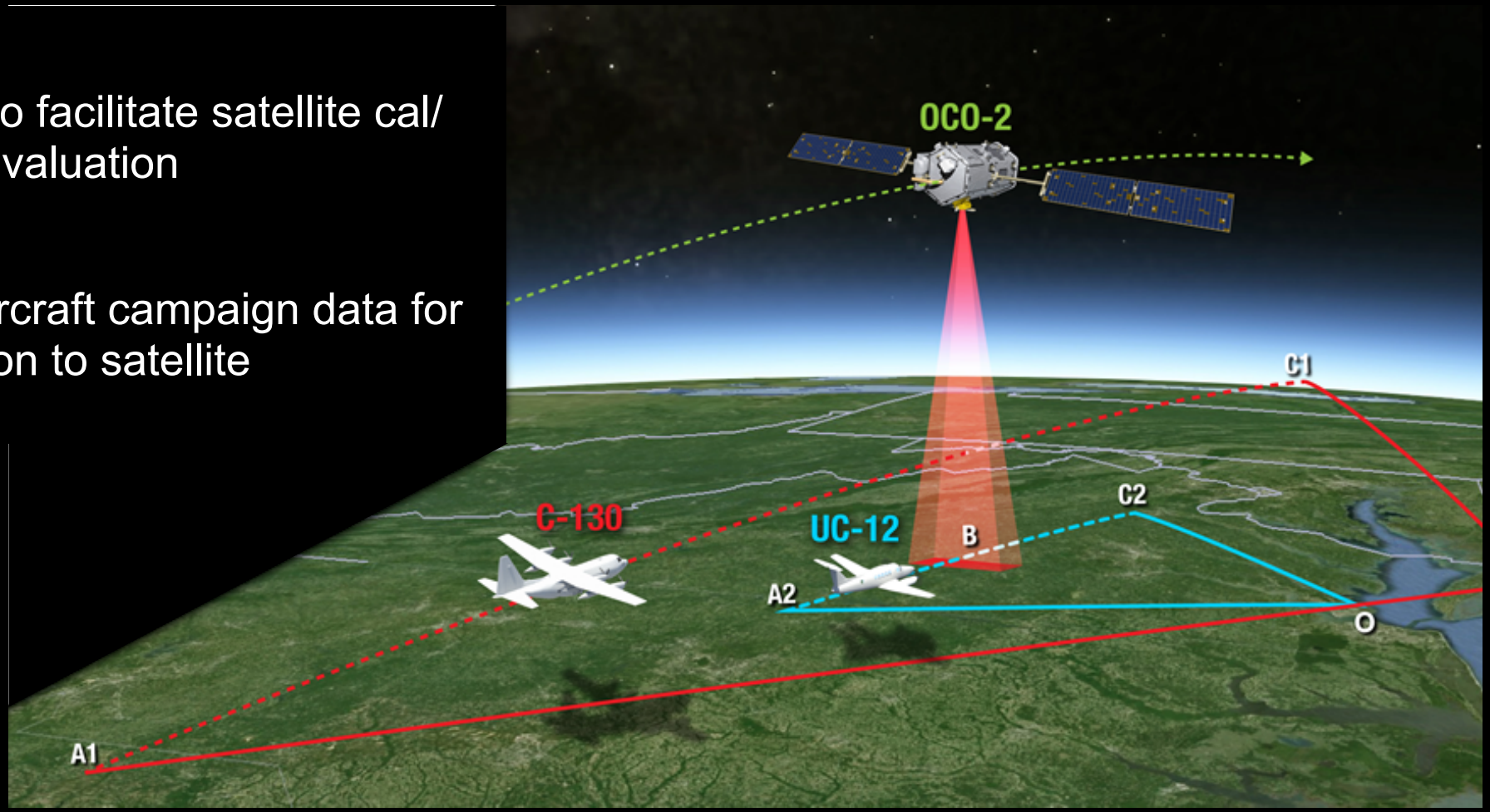
Carbon analyses & forecasts

- Refining two products: a CO, CO_2, CH_4 reanalysis and an FP product for CO_2 only.
- Already used in support of multiple aircraft campaigns
- Including forecasting support for ACT America via GEOS CF and specialized products for their OCO cal/val efforts

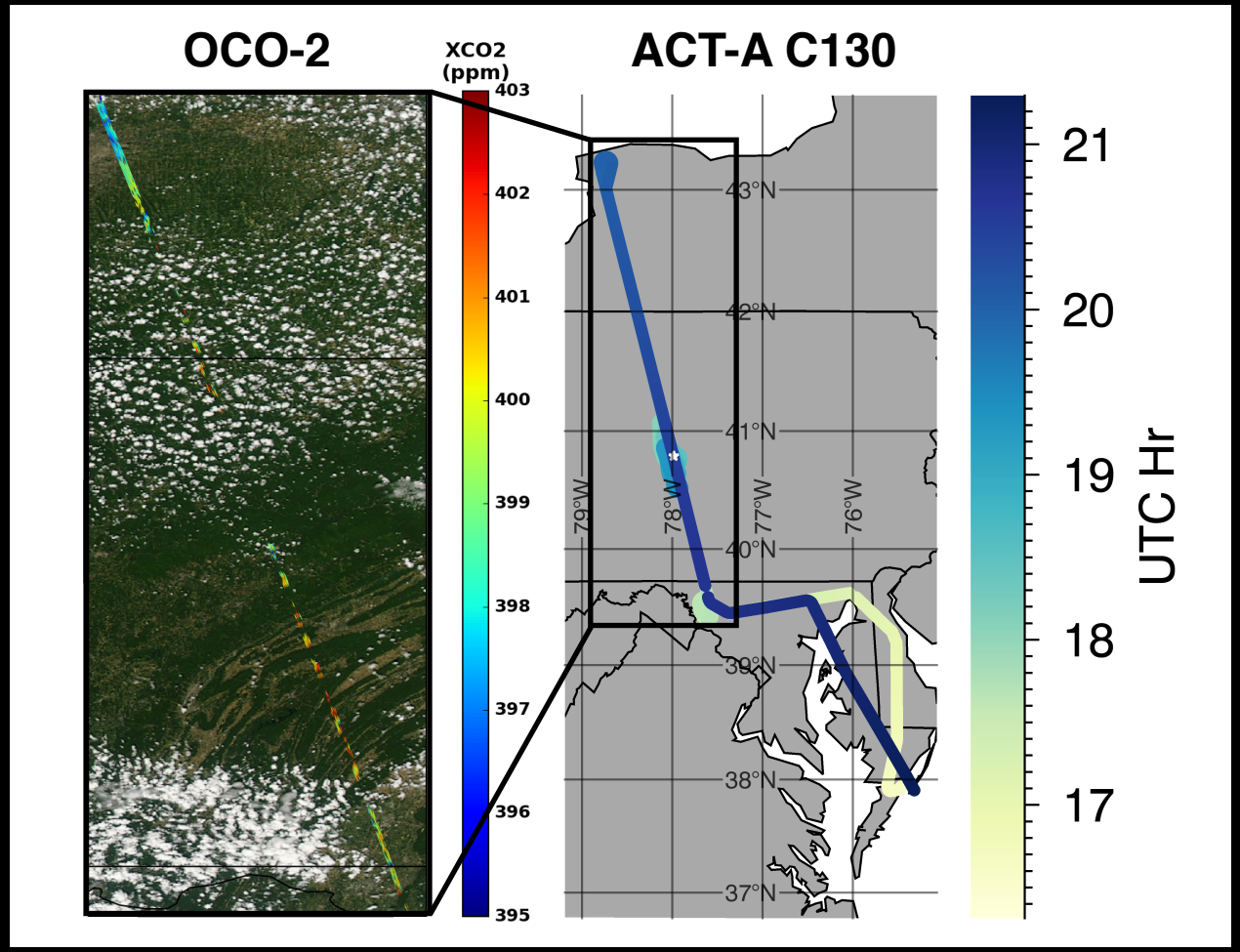


Aircraft curtains

- Use the model to facilitate satellite cal/val and model evaluation
- Fill in gaps in aircraft campaign data for direct comparison to satellite



ACT-America 27 July 2016 campaign



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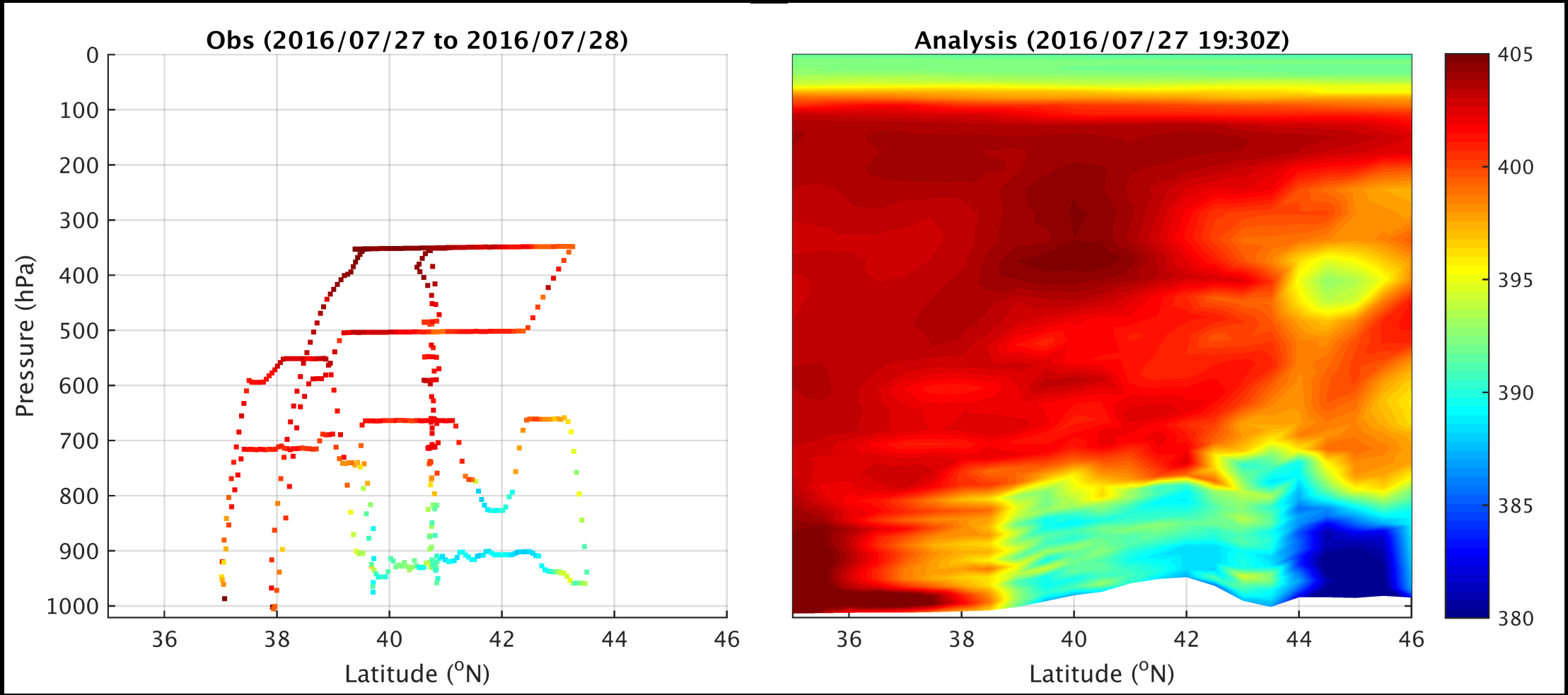

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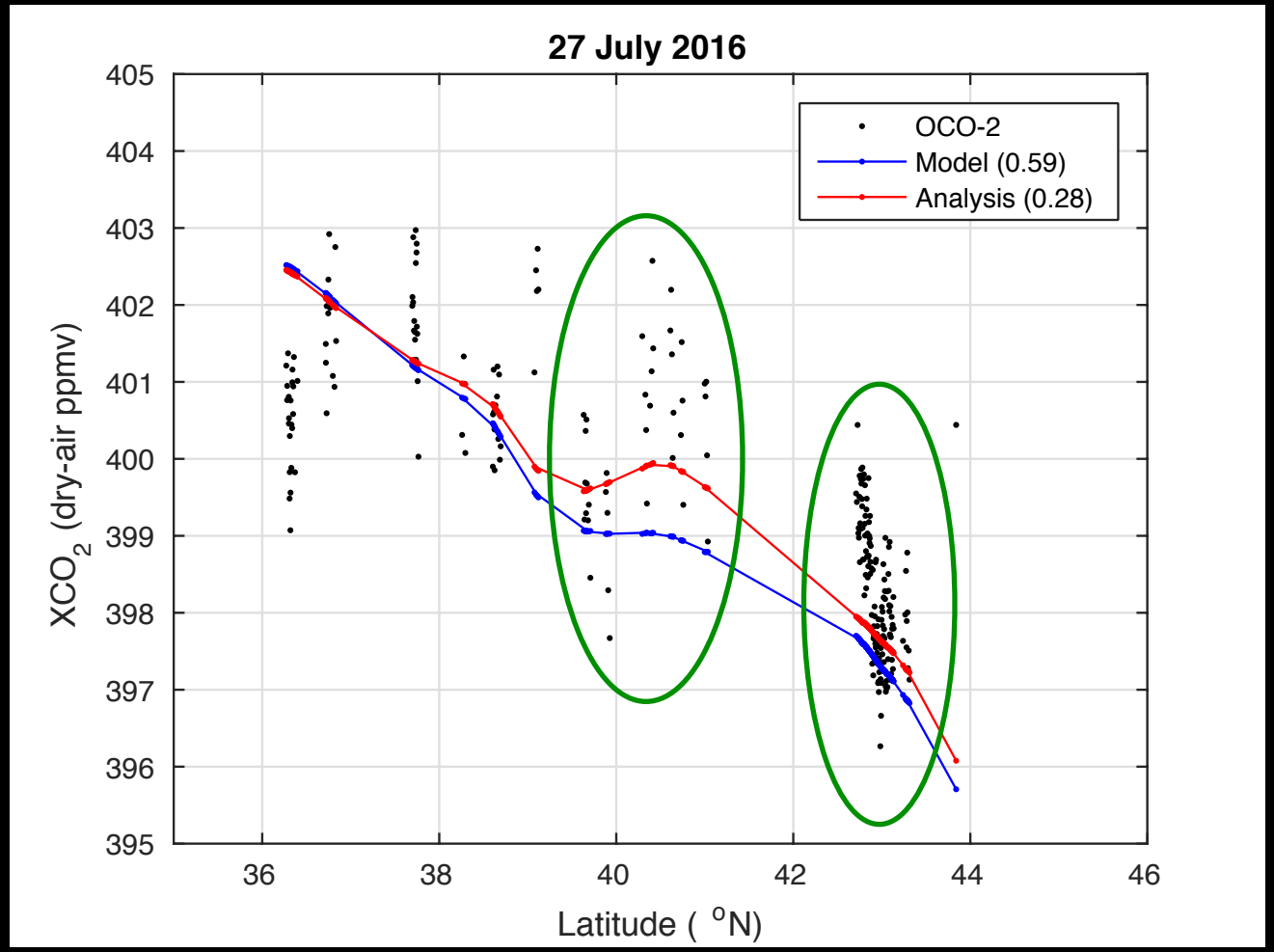
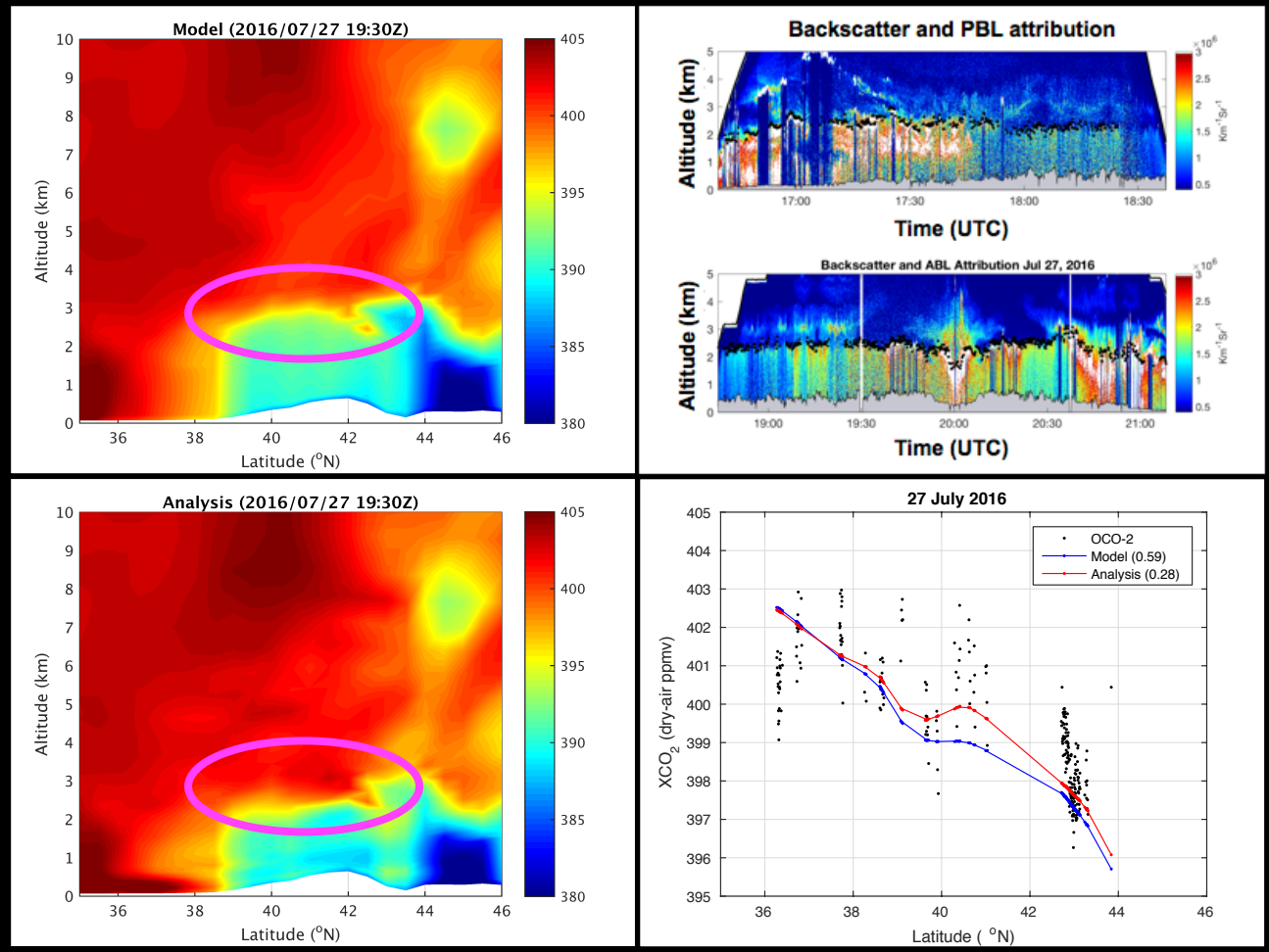


Curtains for OCO-2 overpass — 27 July 2016

- Assimilation of aircraft obs indicates that model PBL was too high
- Conclusion is consistent with CPL backscatter measurements
- Fixing the PBL height improves model agreement w/ OCO-2



Summary

- The GMAO has developed a constituent data assimilation system (CDAS) that allows for run-time configuration of chemistry modules, observed species, and observation types
- System has proven successful in a variety of applications
- Even potential impacts on NWP/S2S
- Its extensibility and portability fit well into the JEDI paradigm

The end — thank you!

Acknowledgements: the OCO-2 project at JPL, CalTech, the ACT-America project, NOAA/ESRL, NASA GSFC Science Visualization Studio, NASA CMS project & everyone I forgot