Chemical data assimilation in CAM-chem/DART: an overview

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Outline

3 Items:

- **MOPITT and IASI CO** data assimilation and validation study

- MOPITT **CO reanalysis**

- **Geostationary Constellation** for atmospheric composition: DA simulation experiments

Setup: the CAM-chem/DART system

❖ **CESM CAM-Chem:**

- CAM-Chem tropospheric and/or stratospheric chemistry, BAM or MAM aerosols
- CAM5 or CAM4 physics
- Online meteorology or specified dynamics
- Resolution 2deg to 1deg, 26 to 56 levels
- Prescribed Ocean and Ice and Carbon Nitrogen (CN) for Land Model
- Emissions: RCP 8.5 (HTAP, MACCity) Anth, FINN Fires, MEGAN (online/offline) Biog

❖ **DART EnKF (Ensemble Kalman Filter):**

- Ensembles of perturbed simulation run in parallel to calculate model covariance statistics: increase number of ensembles for better results vs numerical cost
- 6hours cycling: ensemble of 30 members

- Meteorological Data assimilated (Ps,U,V,T,Q): NCEP standard bufr data, Radiosondes, Aircraft, Satellites, Surface sites, GPS data

- Chemical Data assimilated (CO, O3, NO2, AOD):
- Here we will focus on CO assimilation

MOPITT and IASI CO data assimilation

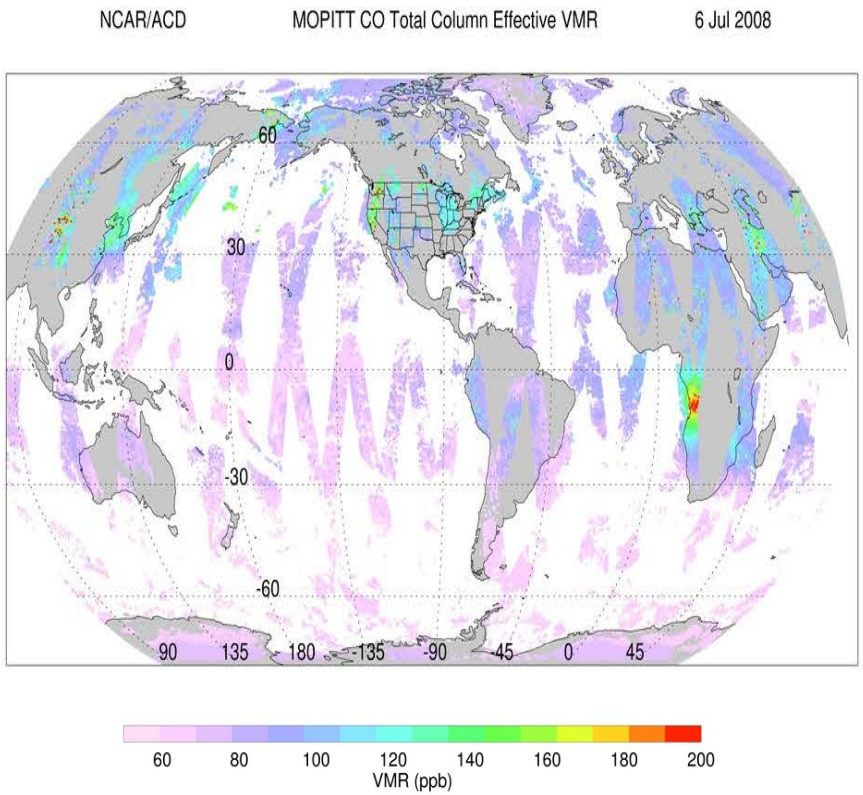
The sounders **MOPITT** and **IASI** are both measuring the tropospheric carbon monoxide using **nadir** geometries and **infrared** bands

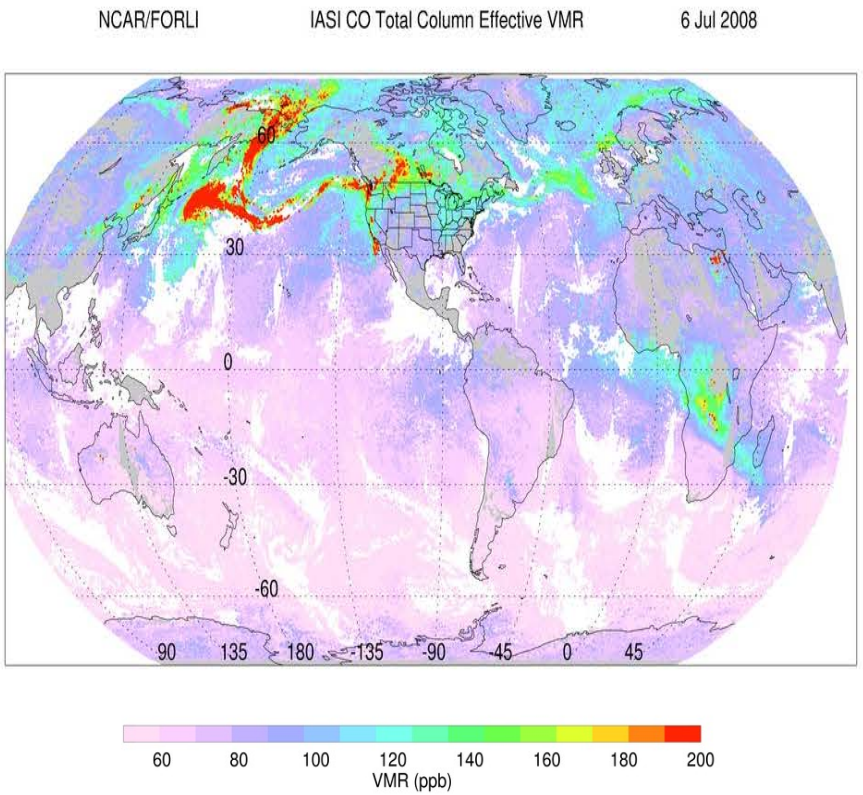
MOPITT:

- Covers the globe in 3 days (narrow swath)

IASI:

- Covers the globe in one day (large swath)





Averaging Kernels: Sensitivity Functions

MOPITT:

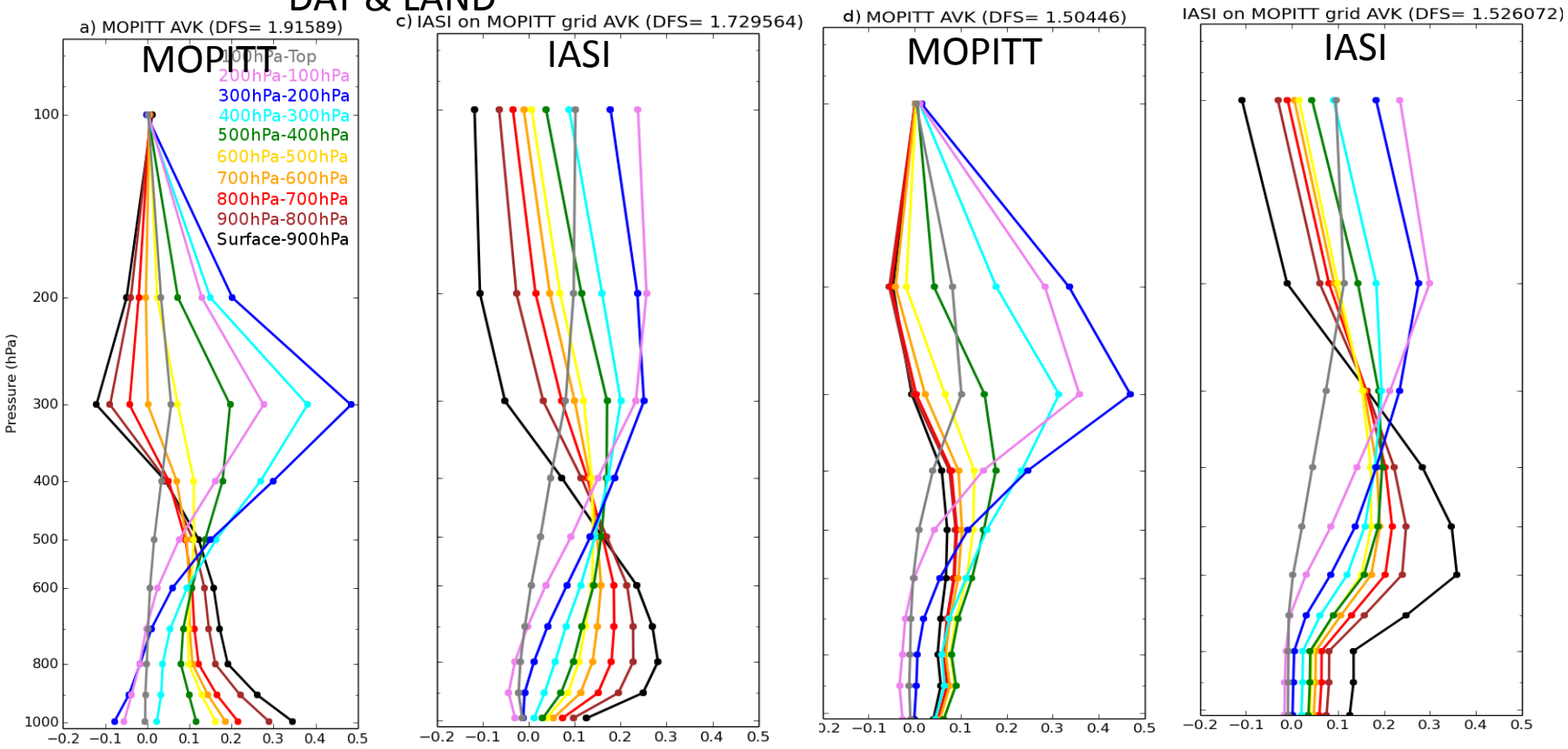
- Multi-spectral (NIR+TIR) allows **enhanced surface sensitivity at CO source regions**
- low sensitivity in night-ocean conditions.

IASI:

- TIR only. Good sensitivity but not as good as MOPITT in day-land conditions.
- Keeps a significant sensitivity in night-ocean conditions.

DAY & LAND

NIGHT or SEA



Assimilation experiments

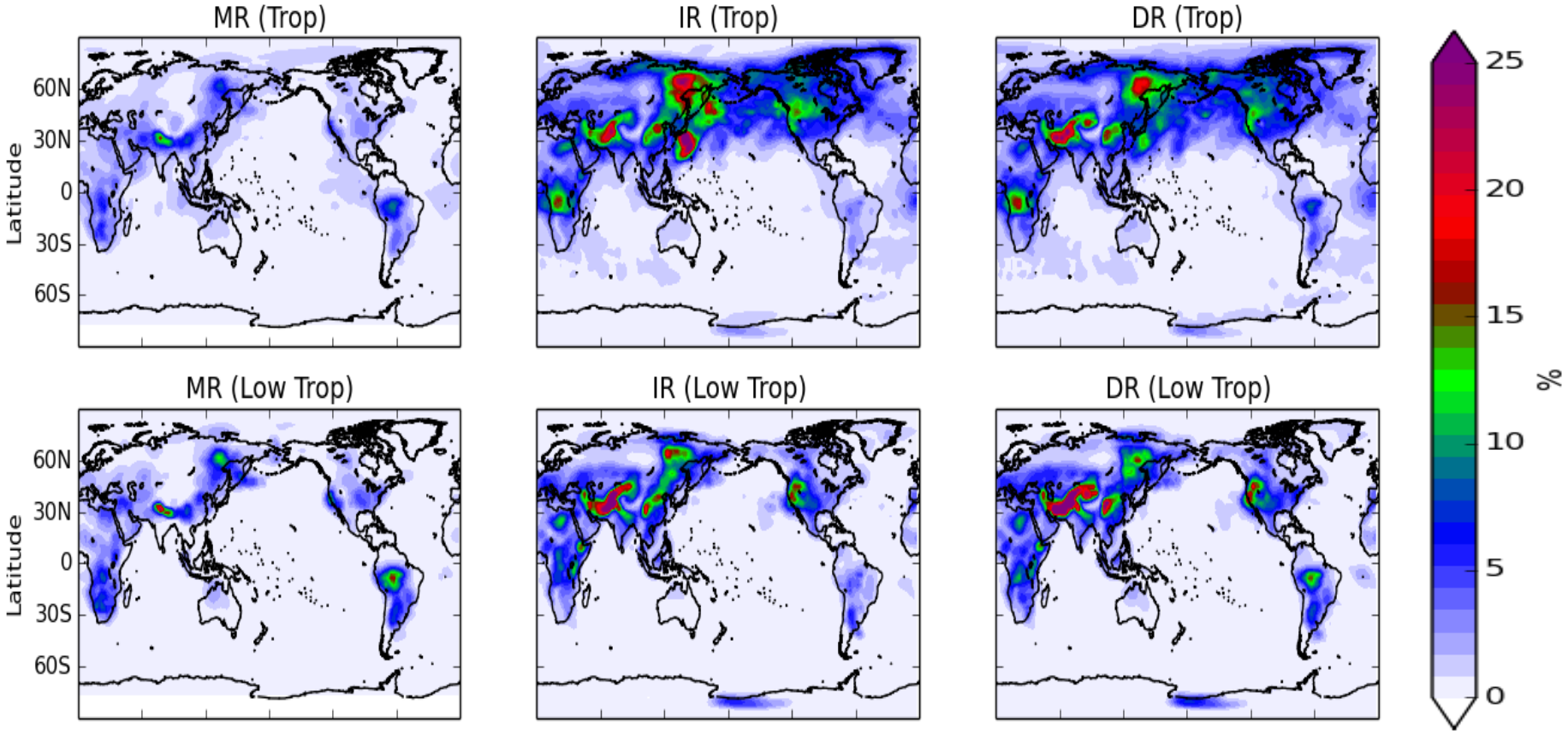
Experiments are performed over June-July 2008

Using CAM5, Tropospheric MOZART, RCP8.5 emissions, FINN and MEGAN offline

Experiment	Meteorology Assimilation	MOPITT CO Assimilation	IASI CO assimilation
CR: Control Run	Yes	No	No
MR: MOPITT Run	Yes	Yes	No
IR: IASI Run	Yes	No	Yes
DR: Double Run	Yes	Yes	Yes

Data assimilation increments (July 2008)

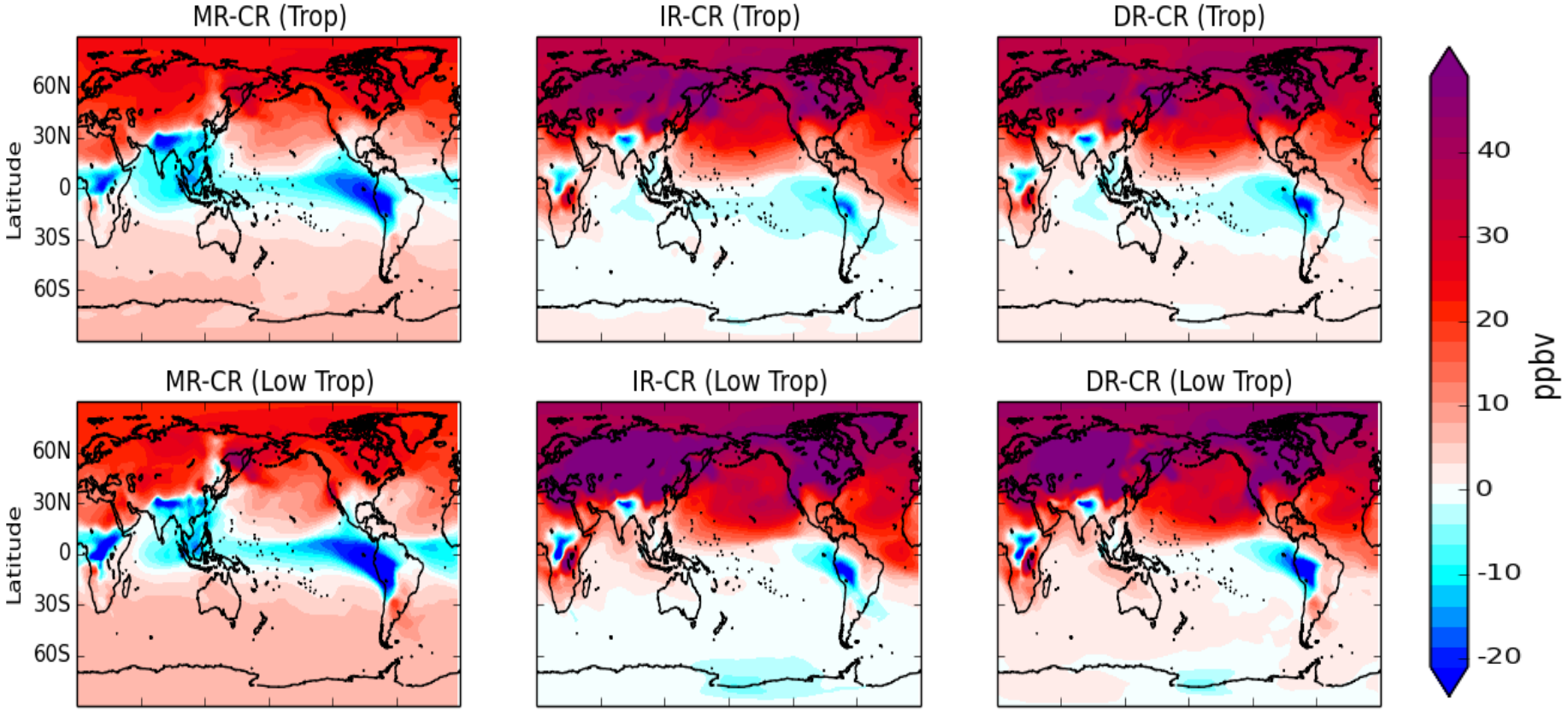
RMS(Posterior-Prior)



- RMS generally stronger for IR because of coverage
- Compared to IR, MR give a good constrain close to emissions because of sensitivity
- DR shows a combination of IR and MR increments, less DR increments over transpacific transport

Data assimilation impacts (July 2008)

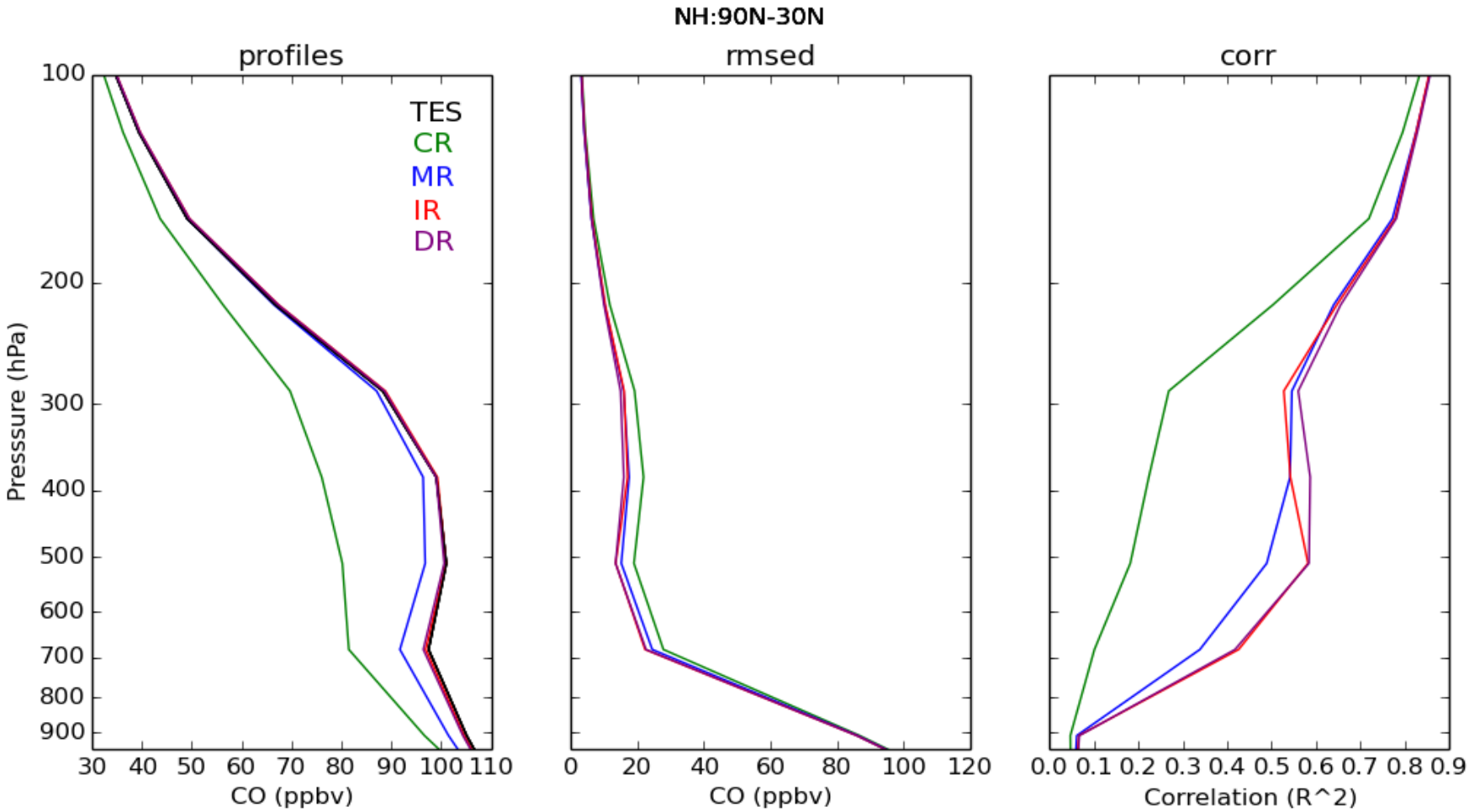
Assimilation Run – Control Run



- Assimilation corrects a negative CO bias (attributed to emissions, CO lifetime ?)
- Stronger global constraint of IR due to IASI coverage and sensitivity
- Comparatively MR constraint is located at the sources
- MR decrease CO at the tropics due to transport of errors.

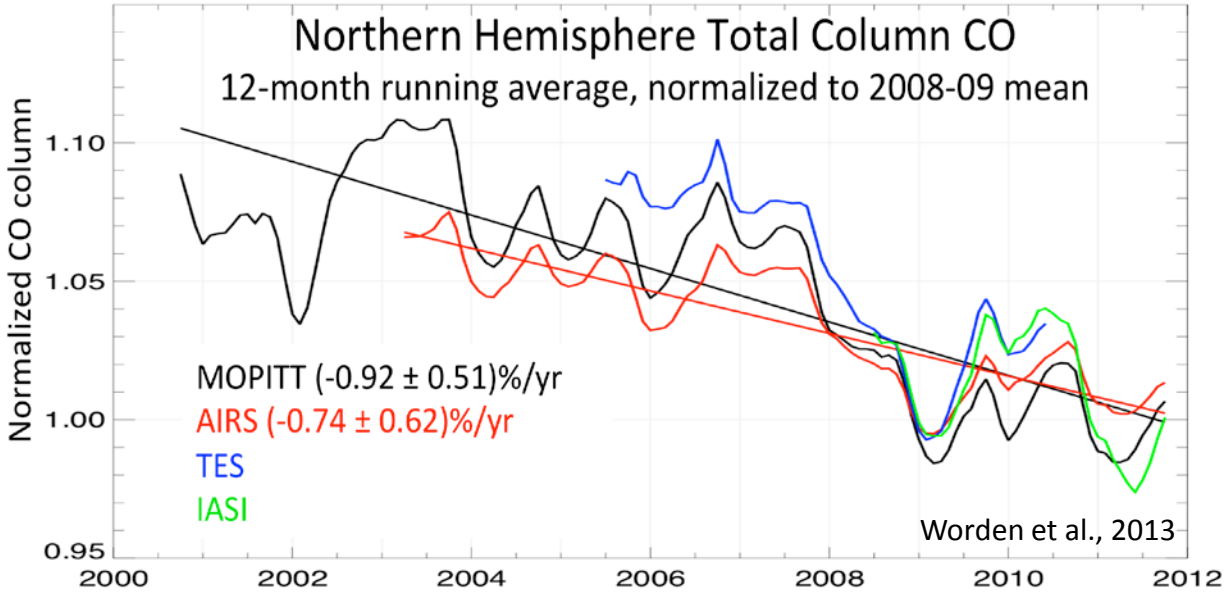
Evaluation against TES CO: Northern Hemisphere July 2008

TES CR MR IR DR



- Bias correction, stronger with IR, DR than with MR but variability is similar
- Variability improved in all experiments

MOPITT CO Reanalysis (B. Gaubert)



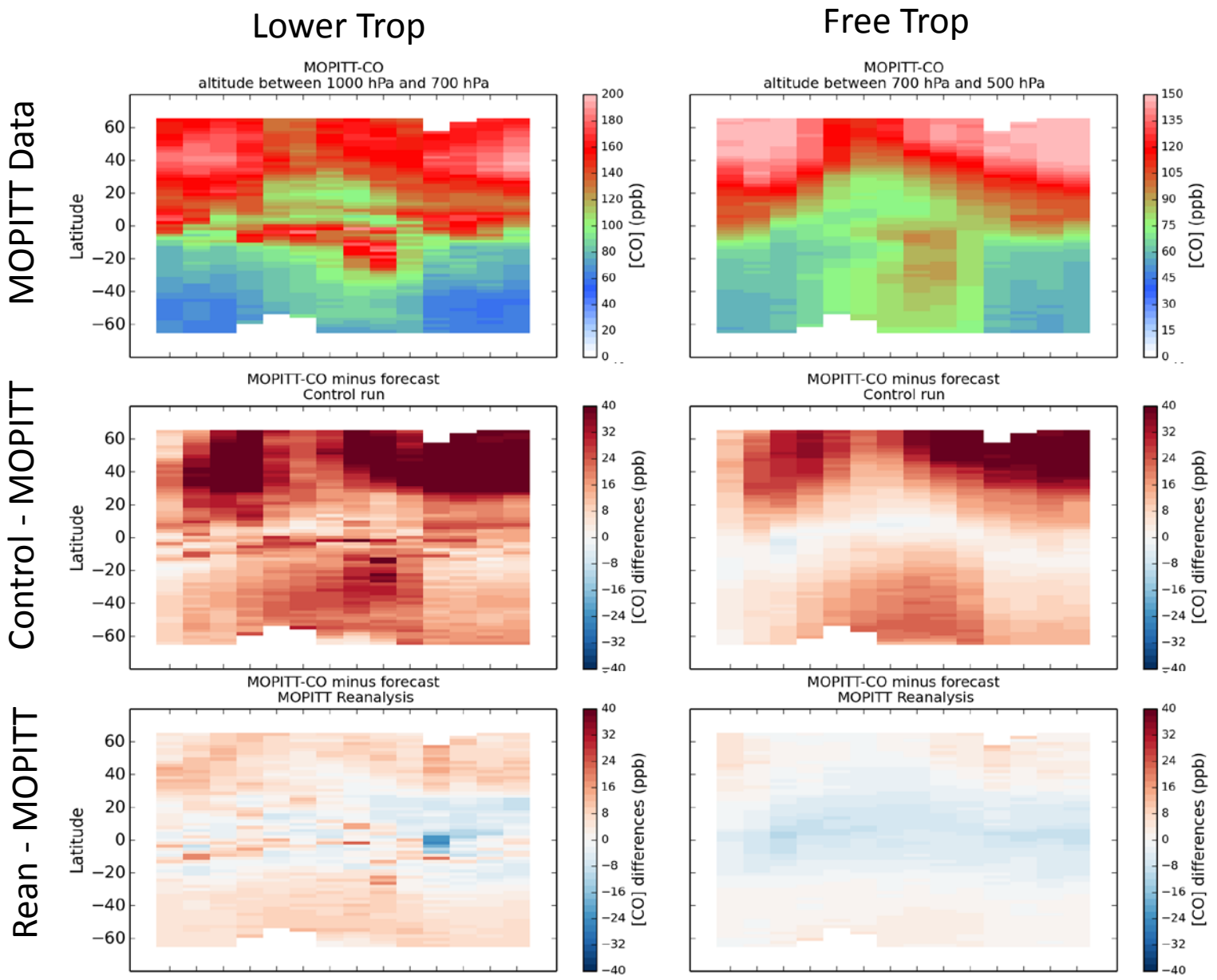
MOPITT has now **14 years** of data: global monitoring of tropospheric CO.

Explain **interannual variability** and **trend** of CO?

Performing **a reanalysis of the full MOPITT record** will give insight about variability and trend. For now 4 years have been performed.

A validation and evaluation is presented for the first year (See also B. Gaubert poster)

1st Year evaluation: Feb 2002- March 2003

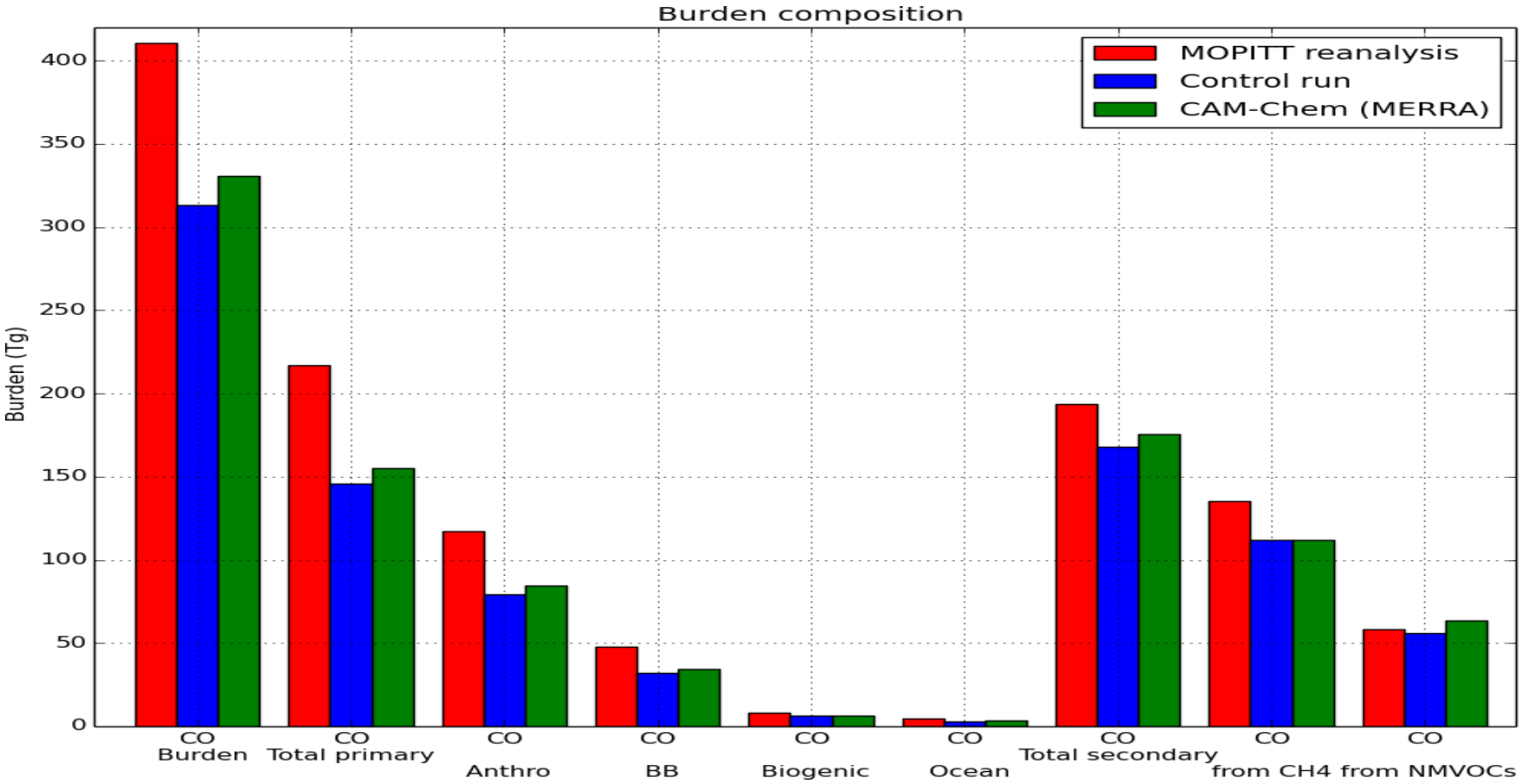


CO budget: Feb 2002- March 2003

Variable	MOPITT-reanalysis	Control-run	CAM-Chem (MERRA)
CH4 burden (Tg)	4106.8	4107.9	4099.3
CH4 lifetime (y)	9.58	8.95	8.78
CO burden (Tg)	401.5	299.2	316.12
CO emissions (Tg)	961.9	961.9	963.7
CO deposition (Tg/y)	153.5	116.4	127.5
CO chemical loss(Tg/y)	2432.9	2020.7	2124.2
CO lifetime (y)	0.155	0.14	0.14

- Increase in CO leads to reduce OH availability
  - Increase methane lifetime (from 8.95 to 9.58 years)
  - It reduces the effective CO chemical production
- Increase in CO depositions

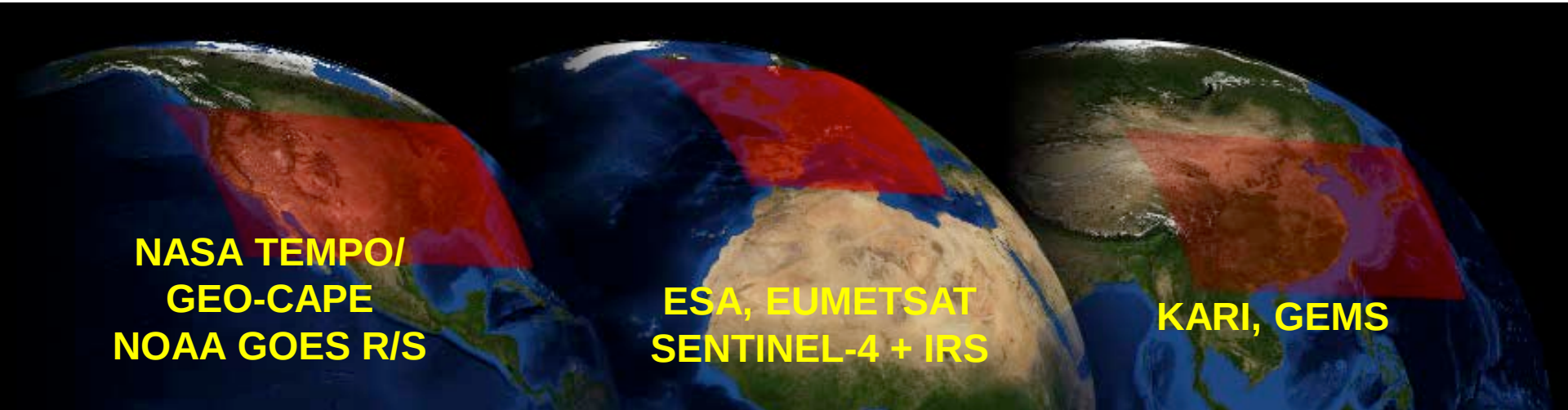
CO budget with TAGS: Feb 2002- March 2003



- Emissions sources and Methane oxidations have been tagged
- Tags are updated after the analysis in order to close the budget (relative proportion is unchanged)
- Means that a change in the burden is due to an error corrected by MOPITT
- Despite a lower chemical production due to a reduced OH (model feedback), suggest a lack of primary & secondary production

OSSEs & the GEO constellation

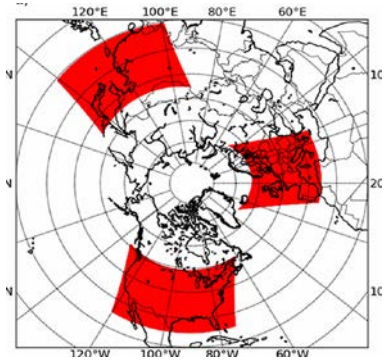
- **The CEOS Atmospheric Composition Constellation activity identified joint OSSEs as a way to promote collaboration between the planned and proposed geostationary Earth orbit (GEO) missions from NASA GEO-CAPE/TEMPO, ESA Sentinel 4 & KARI GEMS**
- **OSSEs are extensively used by the NWP community to develop and optimize contemporary meteorological satellite instruments; now increasingly used in other fields of earth observation**
- **OSSEs assess the *impact of hypothetical observations on a model analysis/forecast/inversion* and provide a means to generalize on the conclusions of limited case-studies**

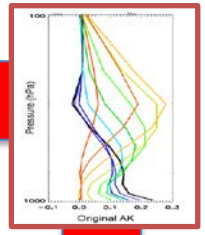


What is an Observing System Simulation Experiment: OSSE

Science question: What will the new data add?

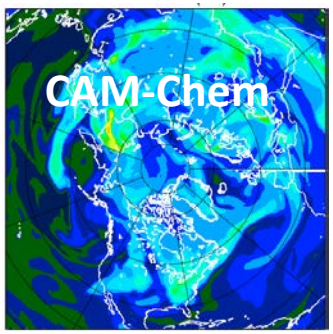
Synthetic Observations

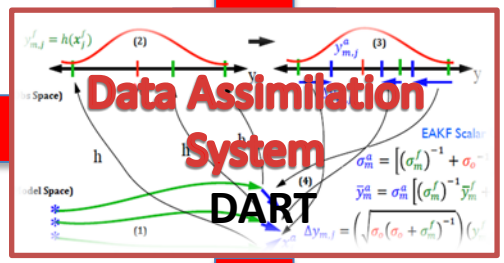




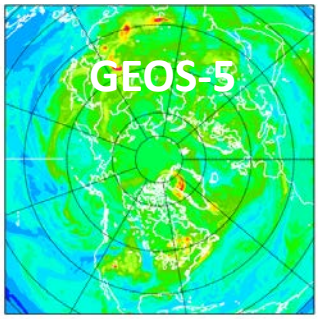
Observation Simulator

Control Run

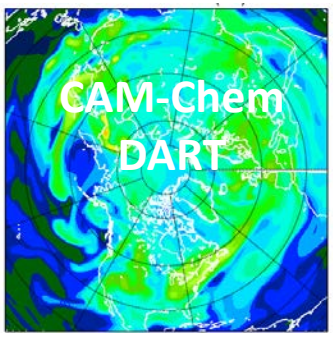




Nature Run



Assimilation Run



Evaluation & Assessment

Evaluation & Assessment

Models setups

GMAO GEOS-5 Nature Run

Emissions:
Anth: merge of several scaled inventories: EDGAR, EPA/NEI, CAC, BRAVO, EMEP.
Fires: QFED v2.2.
Biog: MEGAN

Chemistry:
AeroChem: Global CO "tracer" with prescribed OH and CH4
GOCART aerosols

Resolution:
Vertical: 72 levels (Surface - 0.01hPa),
Horizontal: 0.5°(0.06°)

NCAR CAM5-Chem Control Run

Emissions:
Anth: RCP8.5
Fires: FINN
Biog: MEGAN

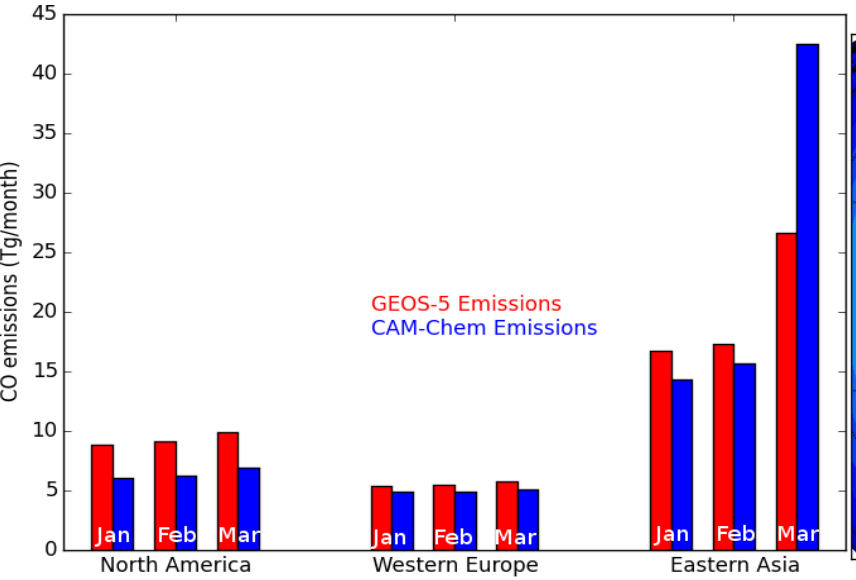
Chemistry:
MOZART "full" tropospheric chemistry
Aerosols (MAM) and chemistry
(87 species + 16 bulk aerosols)

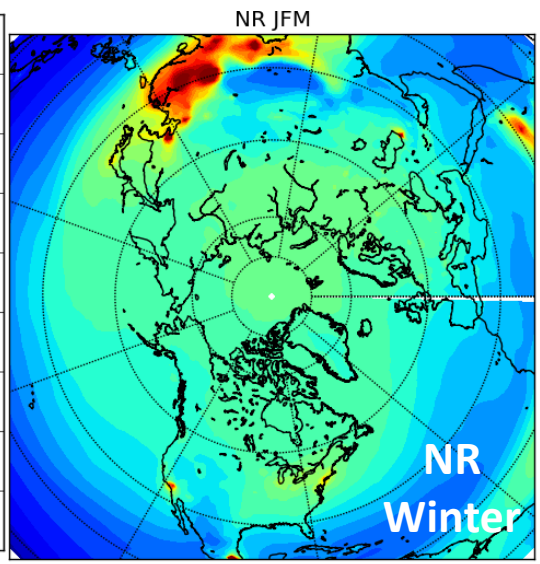
Resolution:
Vertical: 30 levels (Surface - 3hPa)
Horizontal: 1°

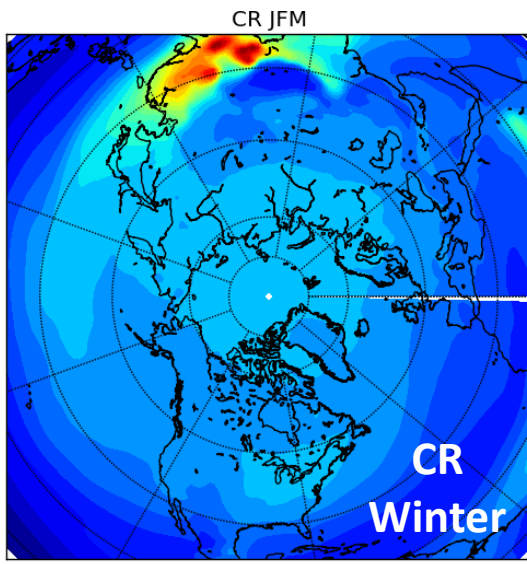
Assimilation run over Winter (JFM) & Summer (JJA) 2006.
Reduced NR resolution (0.5°) used.

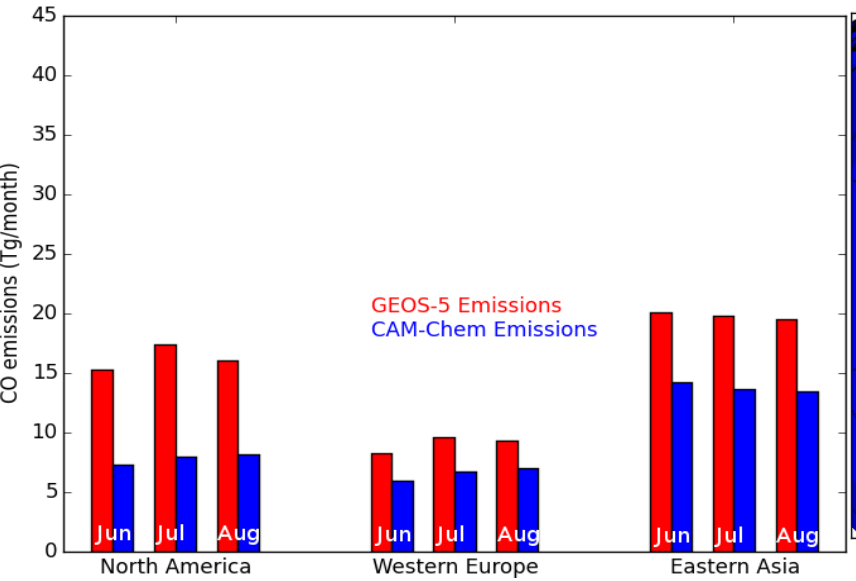
Nature Run (NR) and Control Run (CR) comparisons

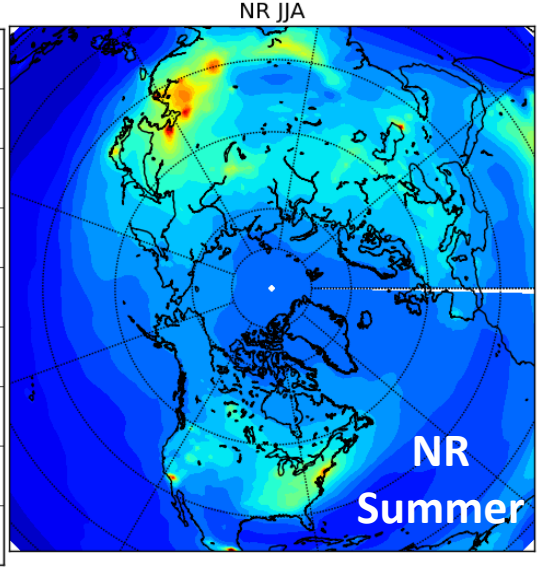
CO Emissions & CO Lifetime

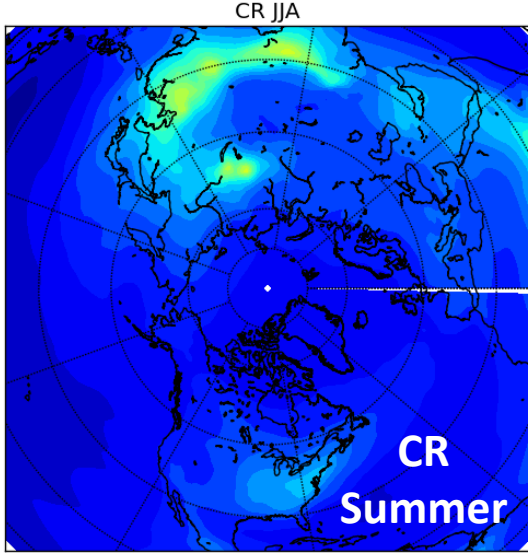


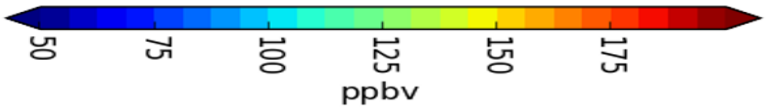






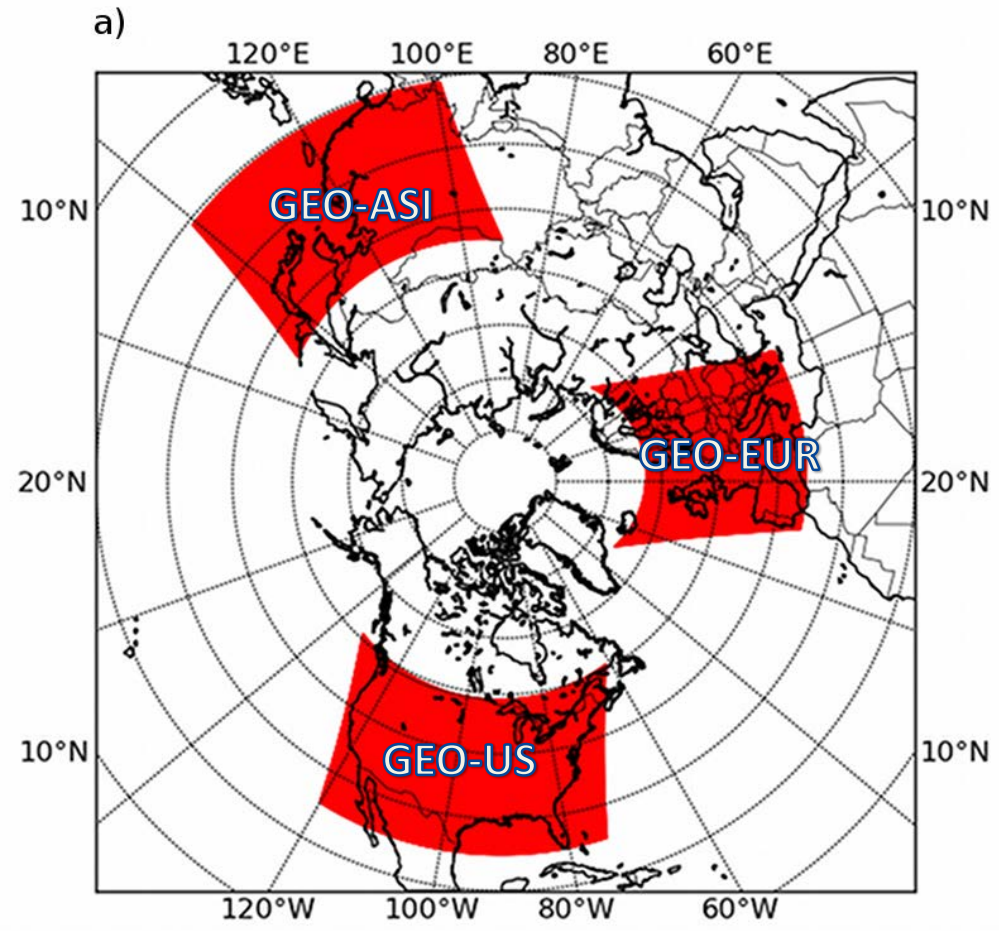






Experimental design: data assimilation experiments

Instruments designs: 3 MOPITT like instruments



Nature Run (NR)

Assimilation Runs (AR):

AR0: All

AR1: US

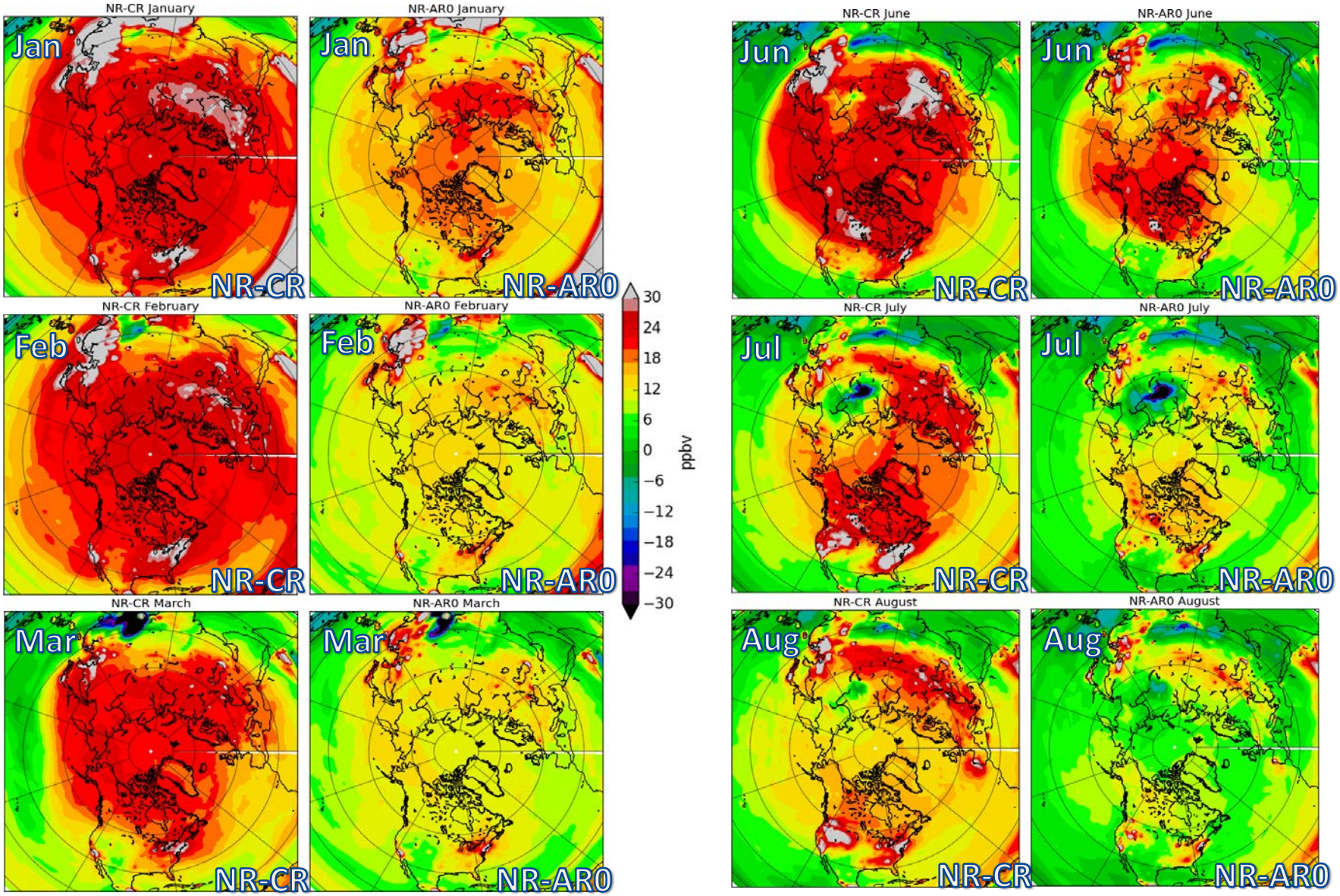
AR2: EUR

AR3: ASI

Control Run (CR)

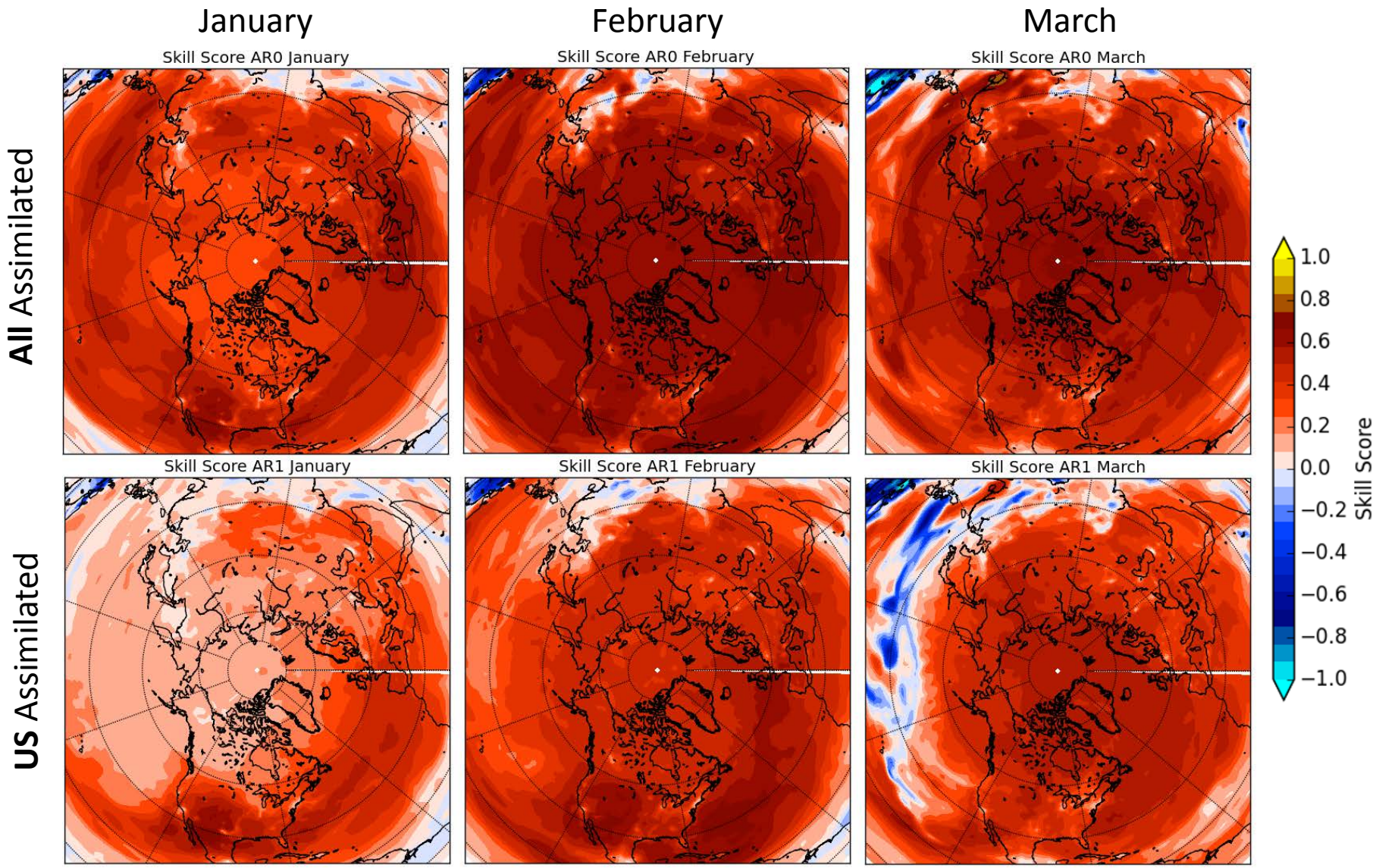
Monthly Mean Comparisons (NR-CR, NR-AR)

Regional data assimilated, Global constrain, CO lifetime effect



Skill Score= 1 – MSE(AR-NR)/MSE(CR-NR) Improved Degraded

Winter case: CO lifetime is longer



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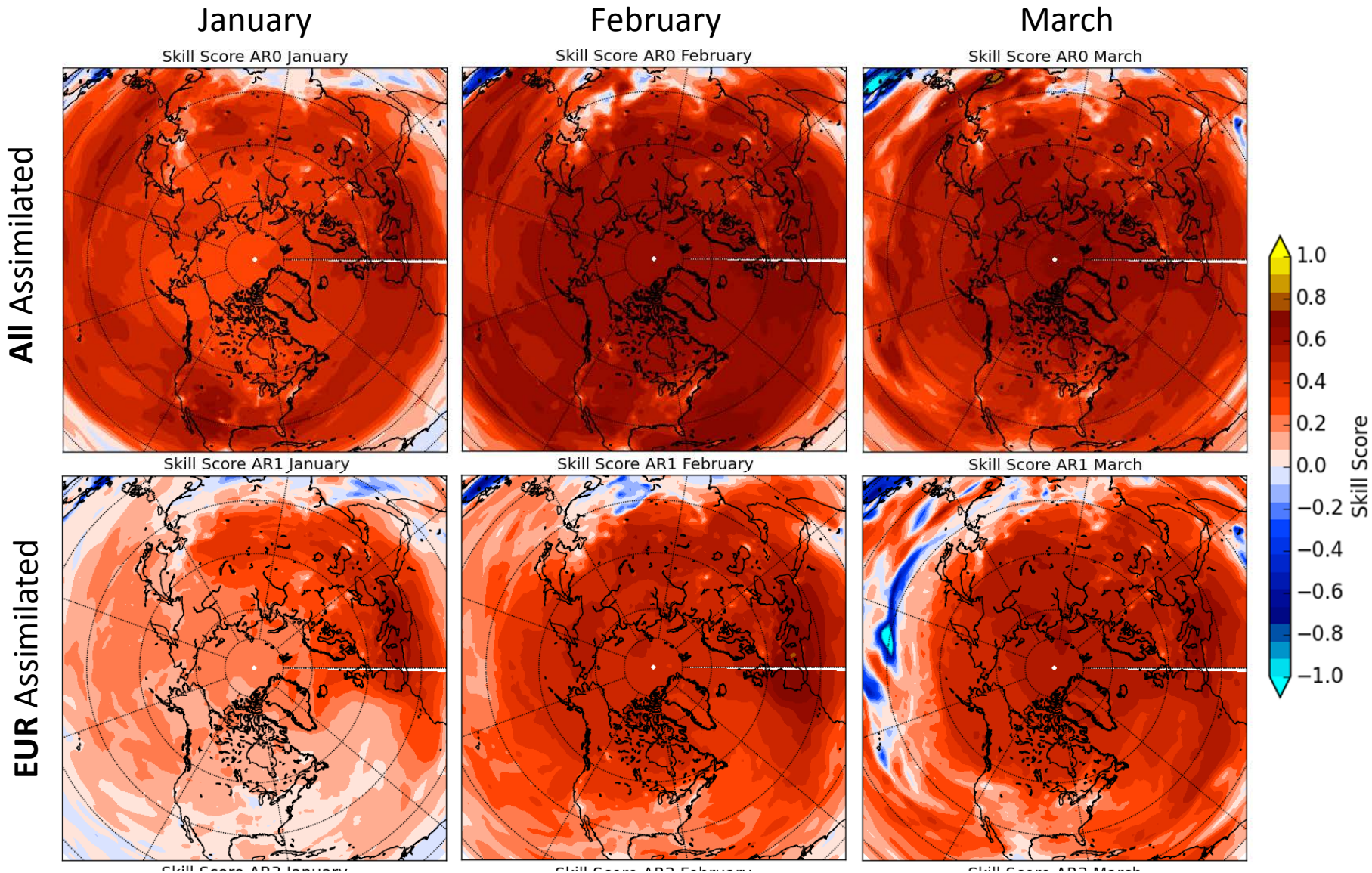

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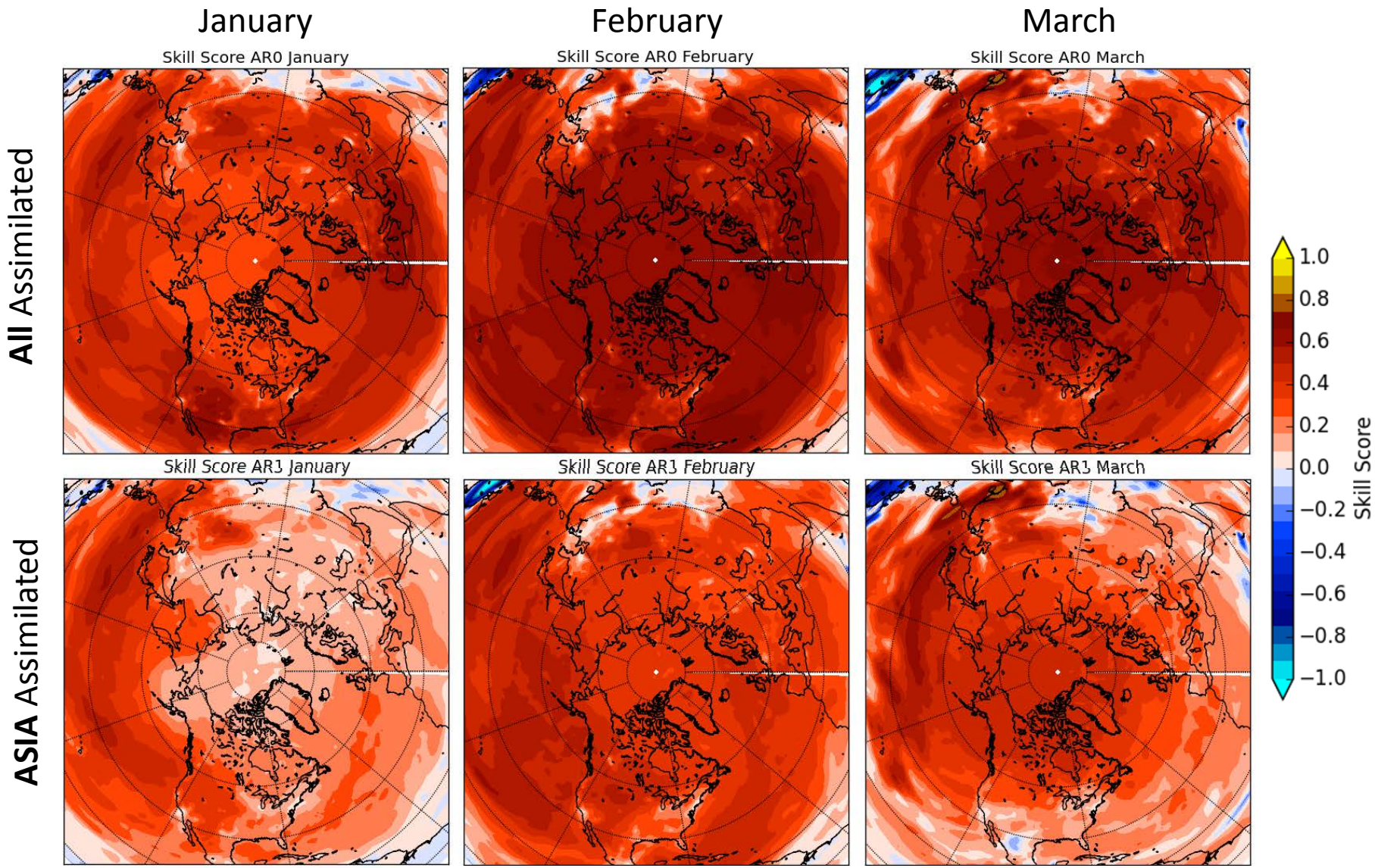

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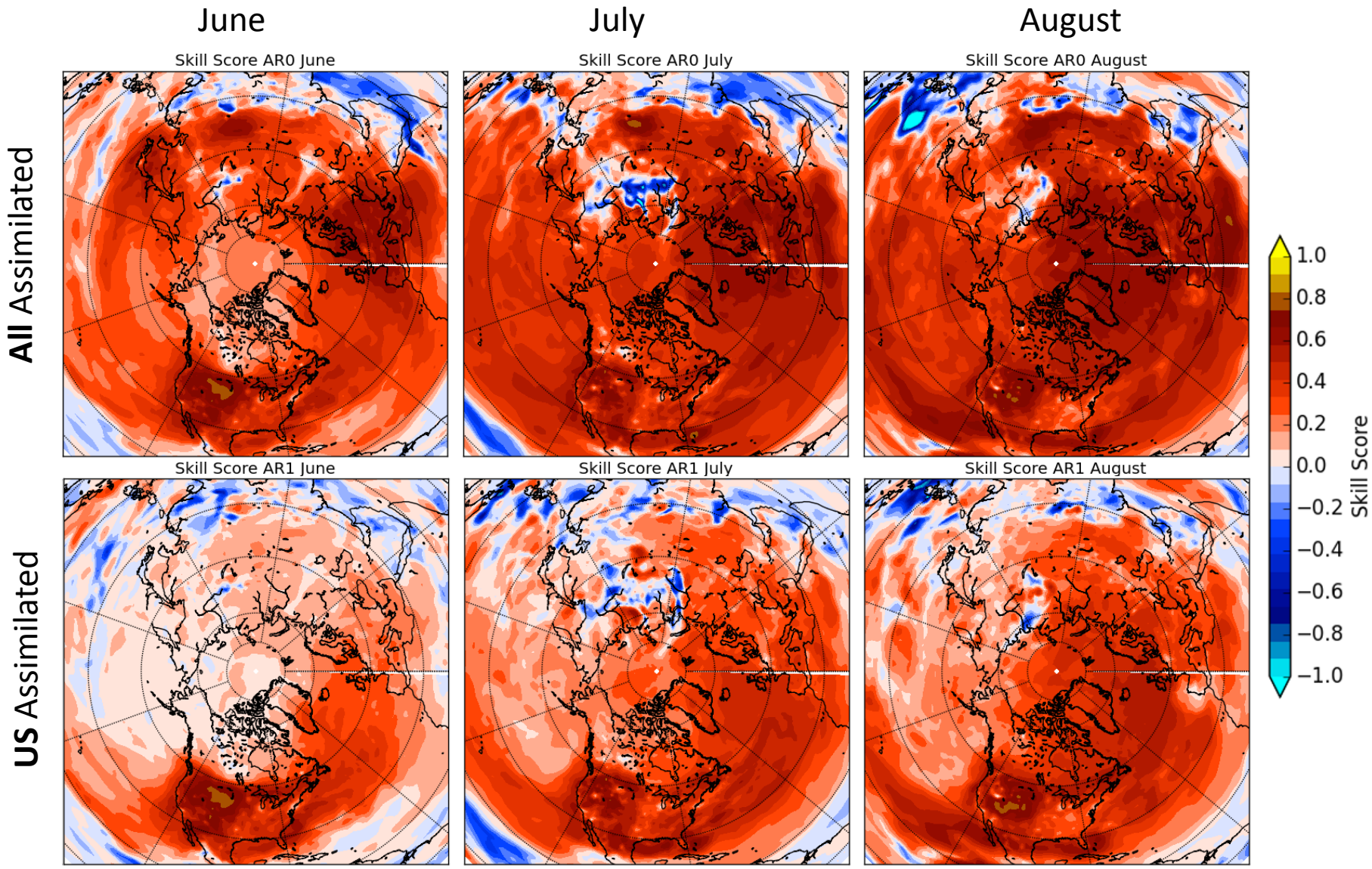
Summer case: CO lifetime is shorter



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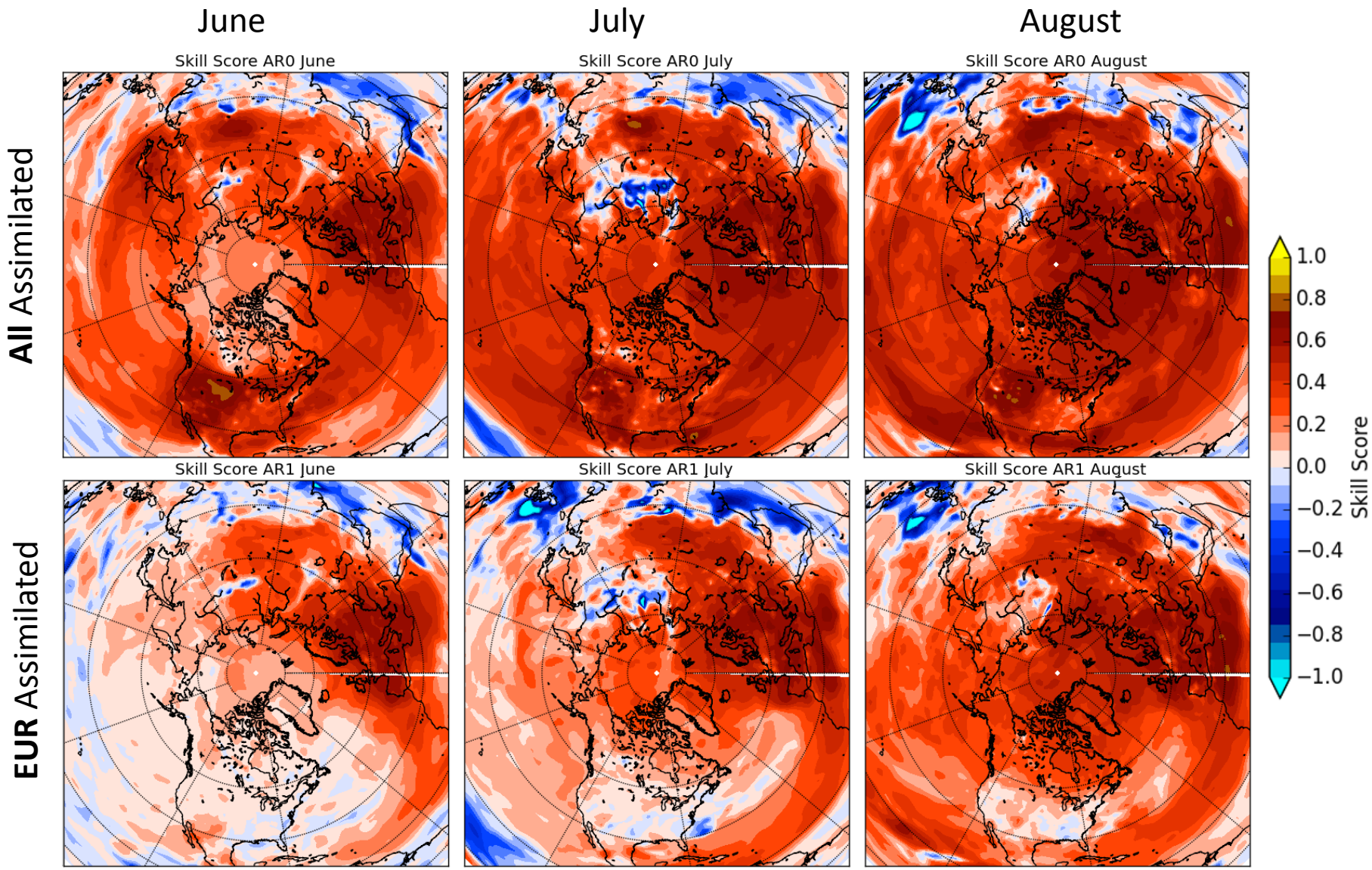

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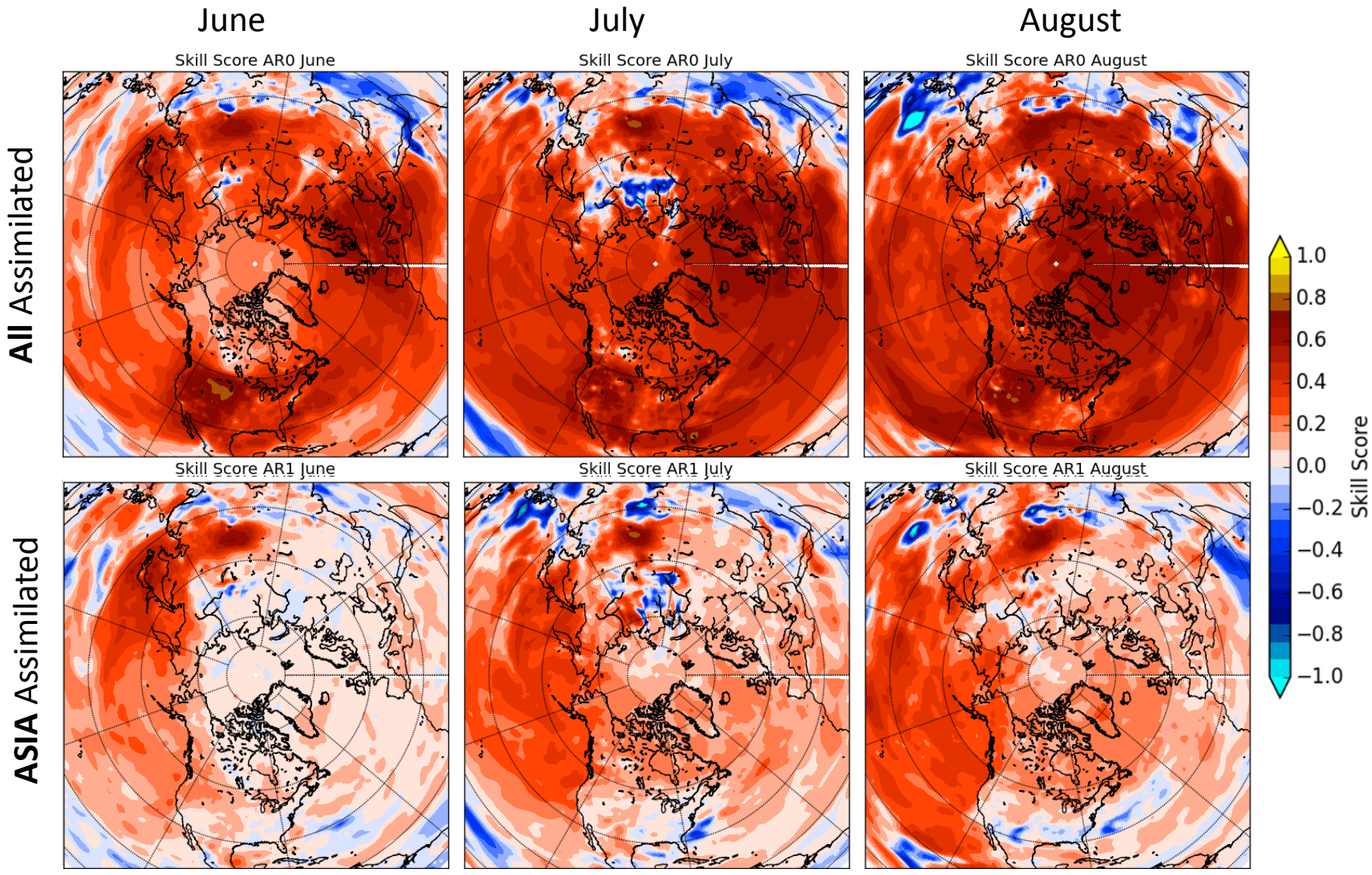

Summary & Ongoing work

- **MOPITT & IASI** study: validation of the DA system, multi platform chemical DA
- MOPITT **CO reanalysis**: now 4 years completed
- CAM-Chem/DART MOPITT **CO forecasting system** for field campaign and ACOM webpage
- **Global OSSE**, global constrain
- **CO emissions**, OSSE a good framework for algorithm/method validation
- **Multispecies**: strat-trop ozone, NO2, AOD
- Chemical ensemble **correlations**

Thank You!

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