Robustness and Behavior of Adjoint Calculations of Observation Impacts in Numerical Weather Prediction

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Questions of Interest

- How do observation impacts on forecast skill evolve over the early forecast period (up to 48 hours)?
    1. How well does the adjoint capture the total observation impact?
    2. Do impacts evolve differently for various data types and regions?
- How does the use of self-analysis verification affect the estimation of
    1. Forecast error
    2. Forecast error growth
    3. Observation impacts

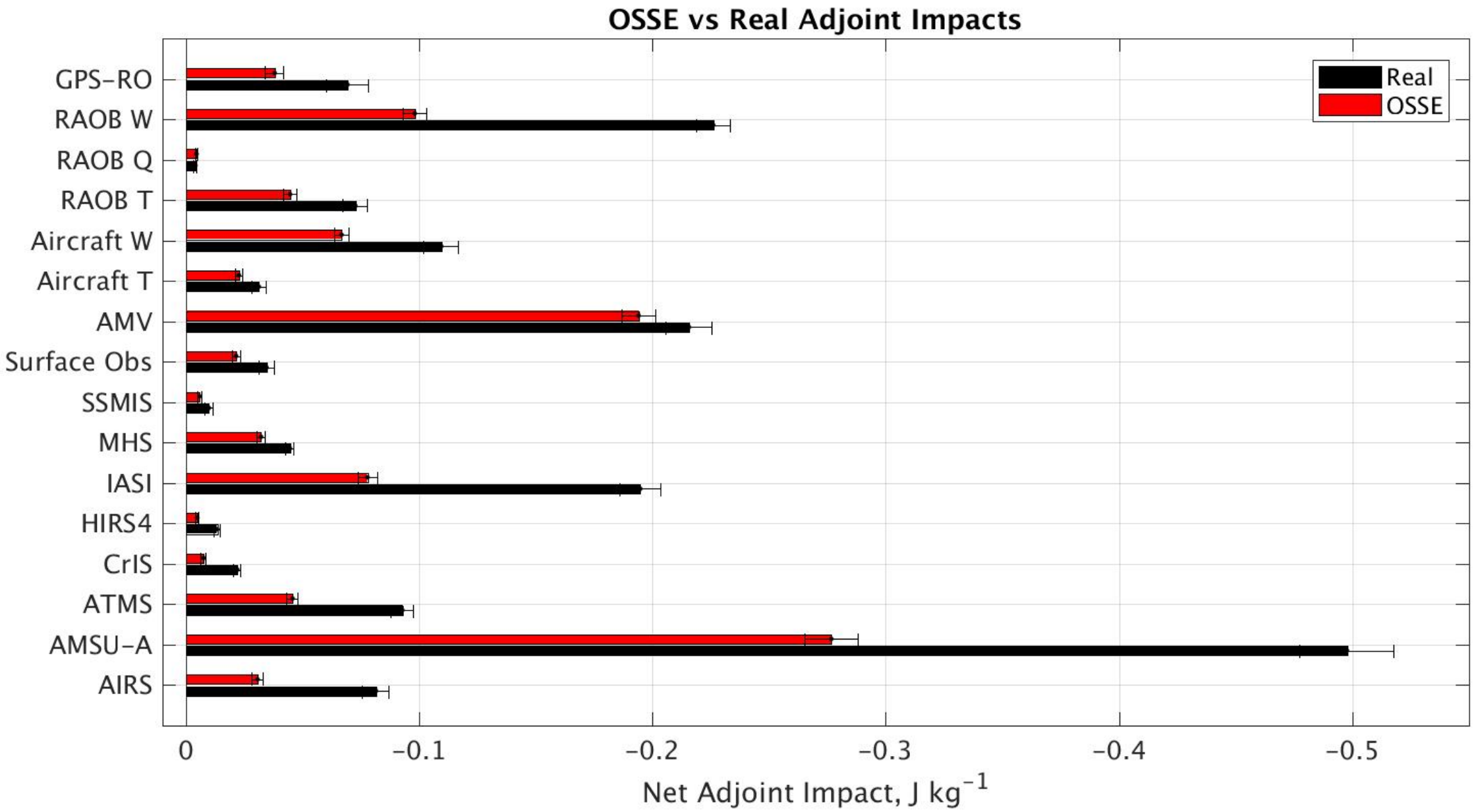
What is an OSSE?

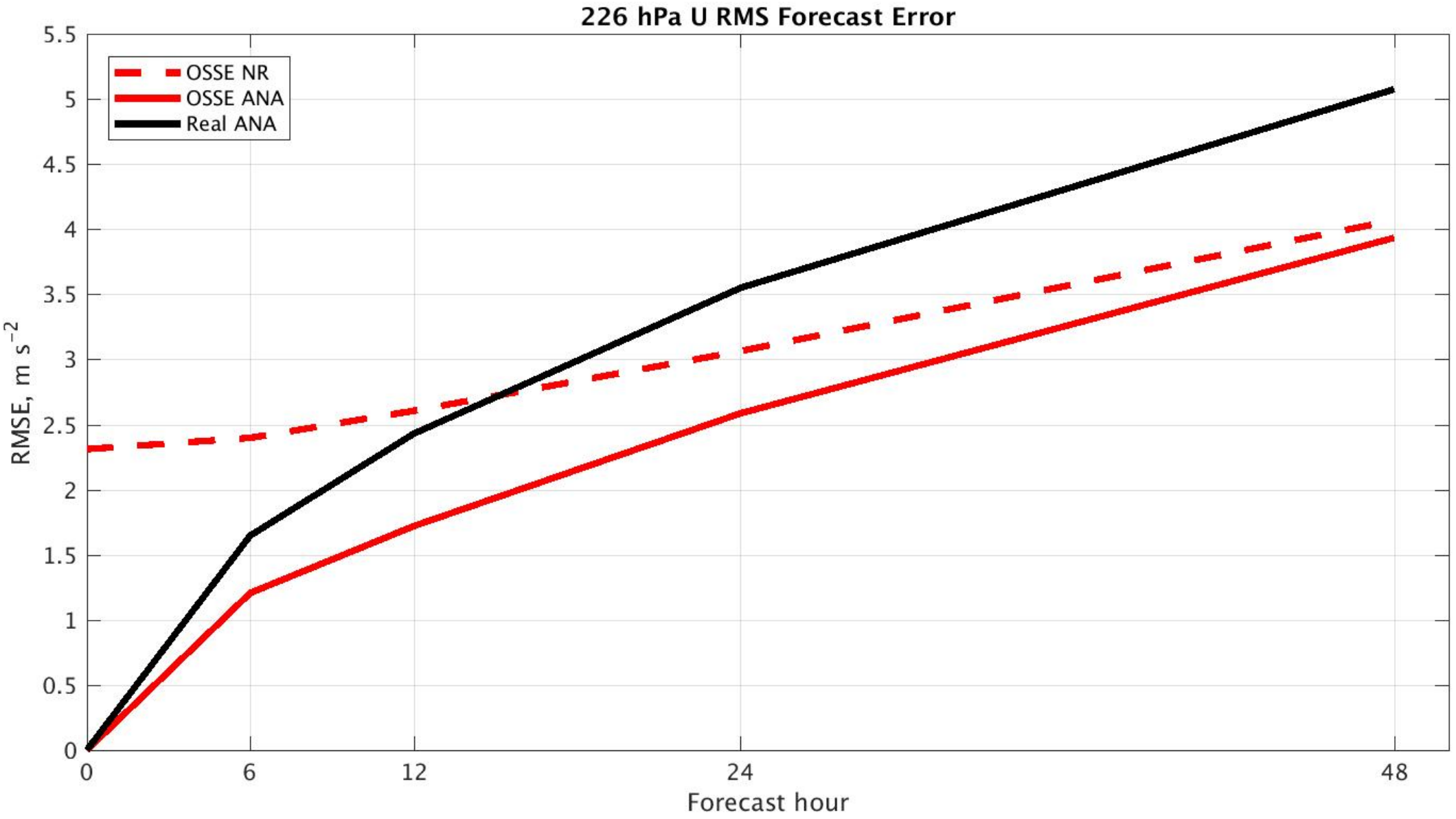
An OSSE is a modeling experiment used to evaluate the impact of new observing systems on operational forecasts when actual observational data is not available.

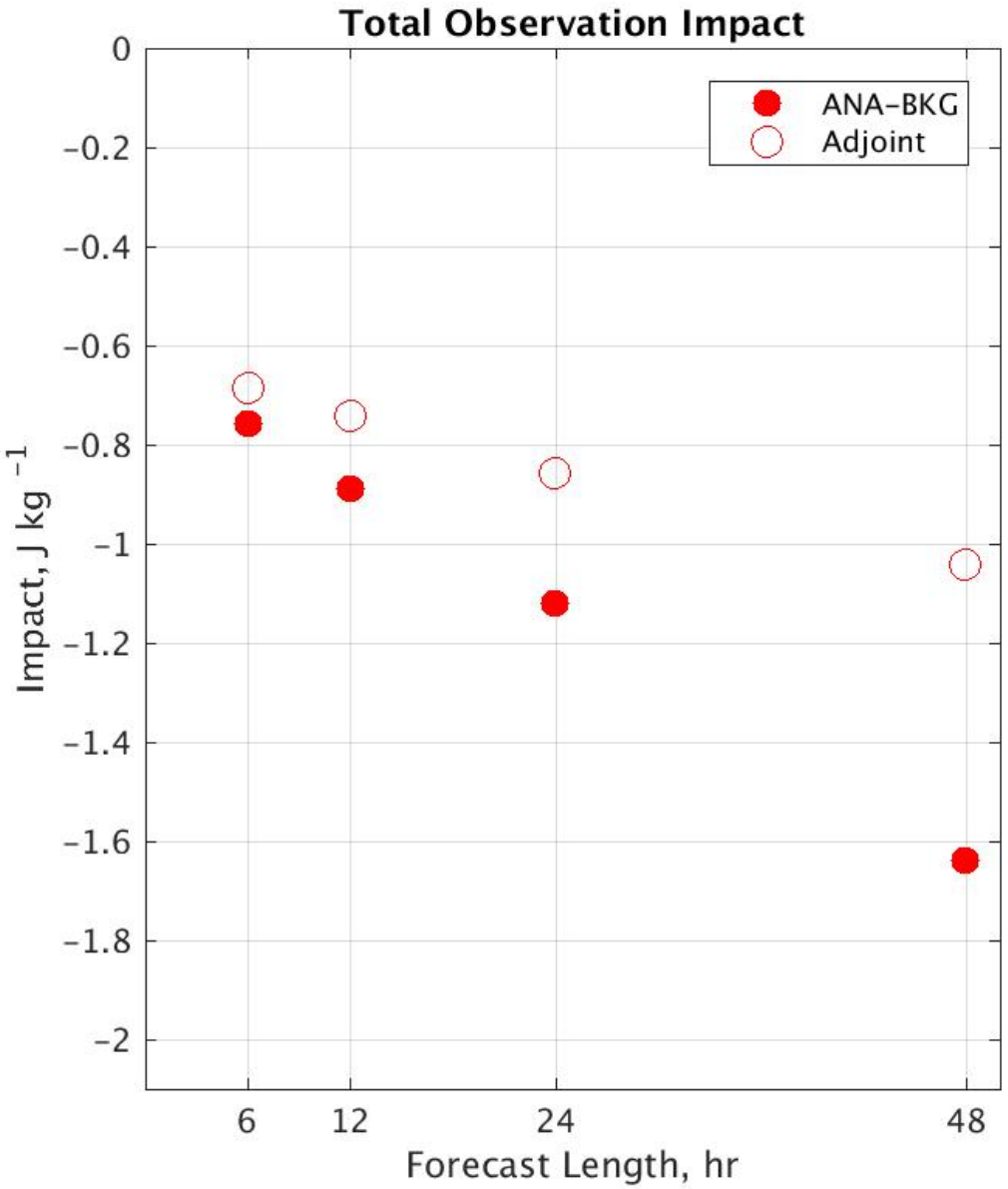
- A long free model run is used as the “truth” - the Nature Run
- The Nature Run fields are used to back out “synthetic observations” from all current and new observing systems.
- Suitable errors are added to the synthetic observations
- The synthetic observations are assimilated into a different operational model
- Forecasts are made with the second model and compared with the Nature Run to quantify improvements due to the new observing system

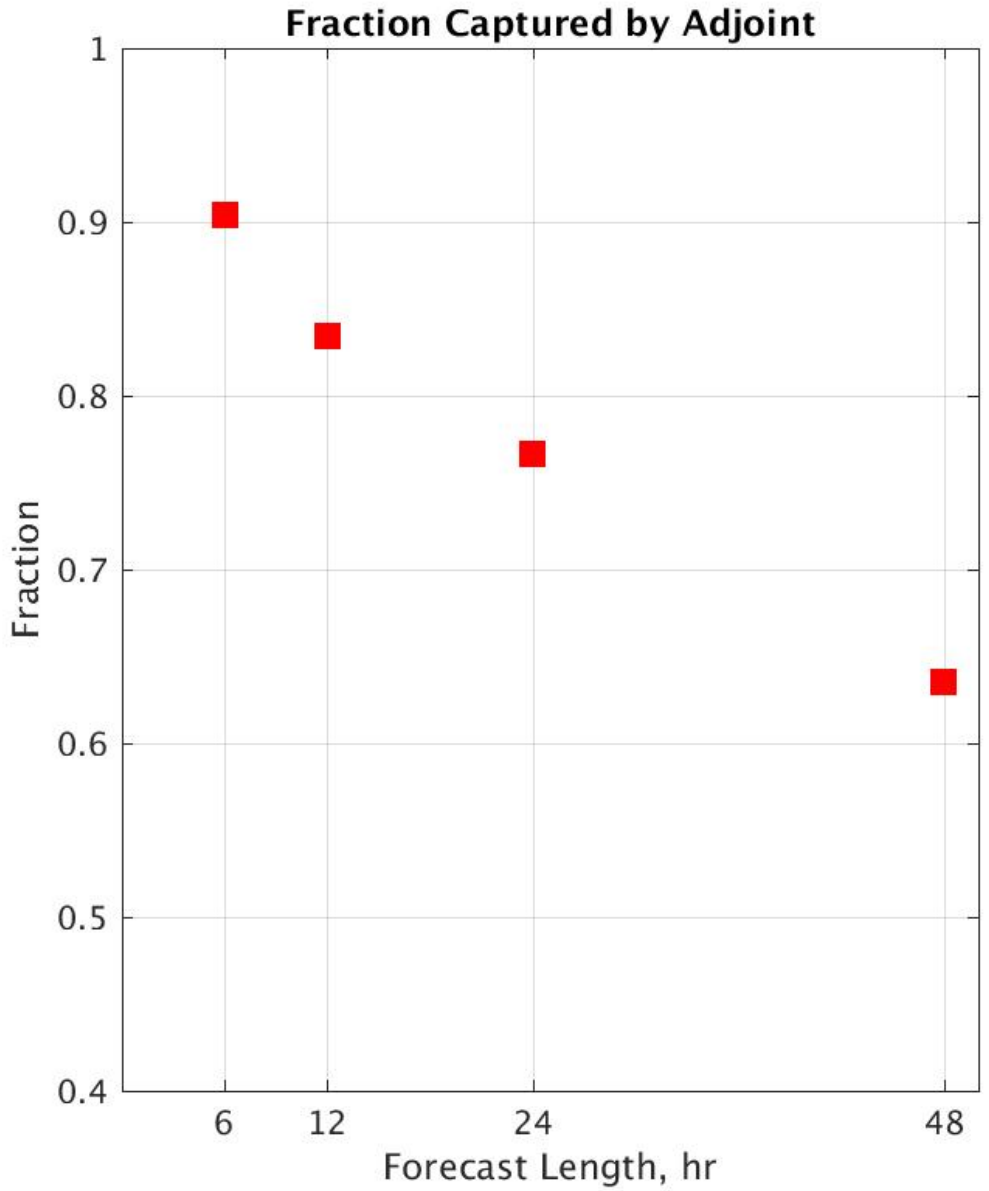
GMAO OSSE Framework

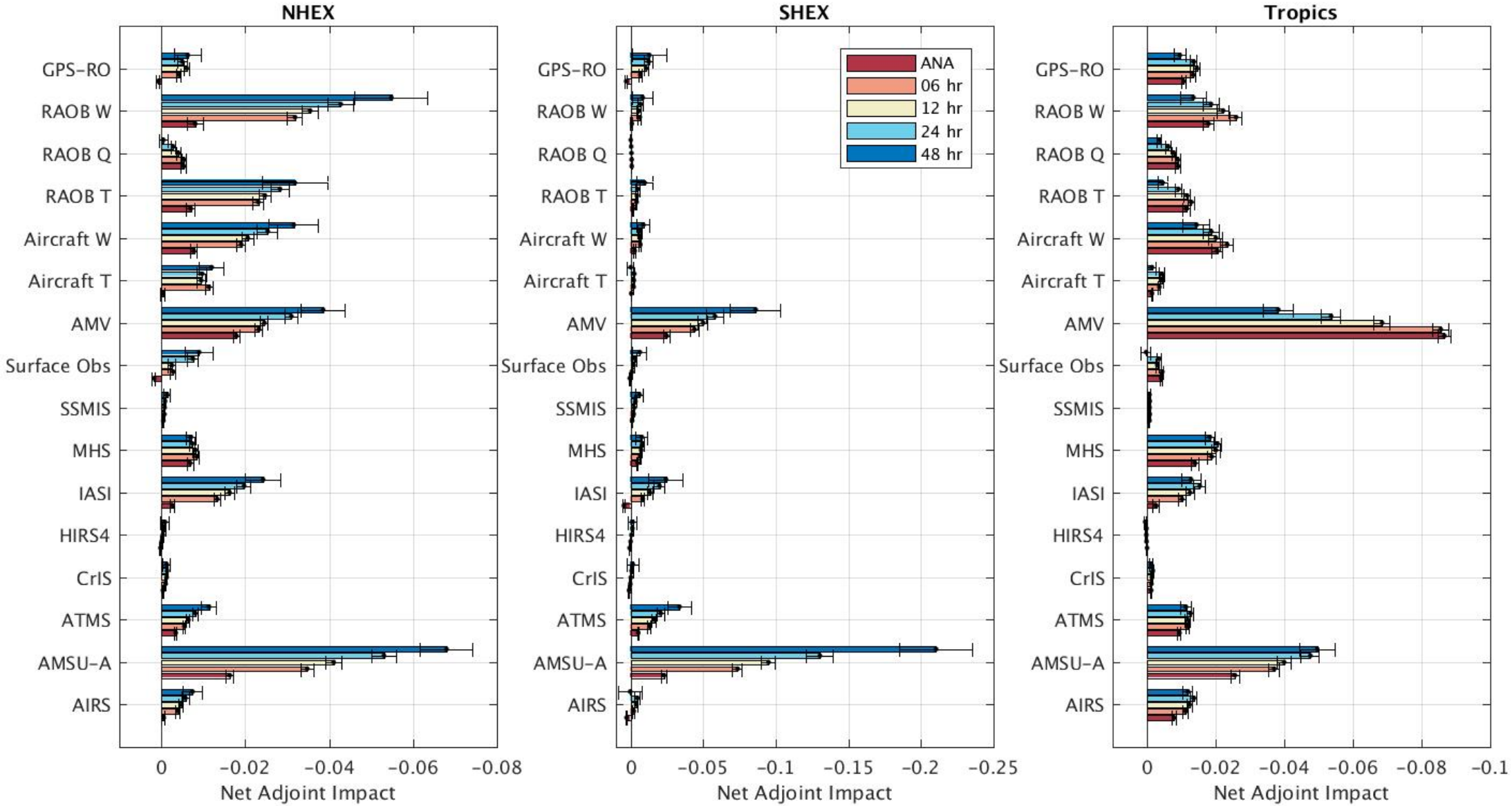
- **Nature Run**
  - ❖ 2 years free forecast of the GEOS-5 model (G5NR)
  - ❖ 7 km horizontal resolution, 72L
  - ❖ 30 min output, 13 aerosols
- **Synthetic observations**
  - ❖ Generated from G5NR output fields
  - ❖ Include G5NR cloud effects
  - ❖ Conventional, GPSRO, AIRS, IASI, CRIS, AMSUA, MHS, ATMS, SSMIS, HIRS4
- **Correlated and uncorrelated observation errors**
  - ❖Calibrated and validated to match statistics of real data
- **Experimental model**:
  - ❖GEOS-5 v. 5.17, 25 km horizontal resolution, 72L
  - ❖3DVar and 4DEnVar GSI available
- **FSOI:**
  - ❖ adjoint tool with moist physics option, total wet energy norm (TWE)

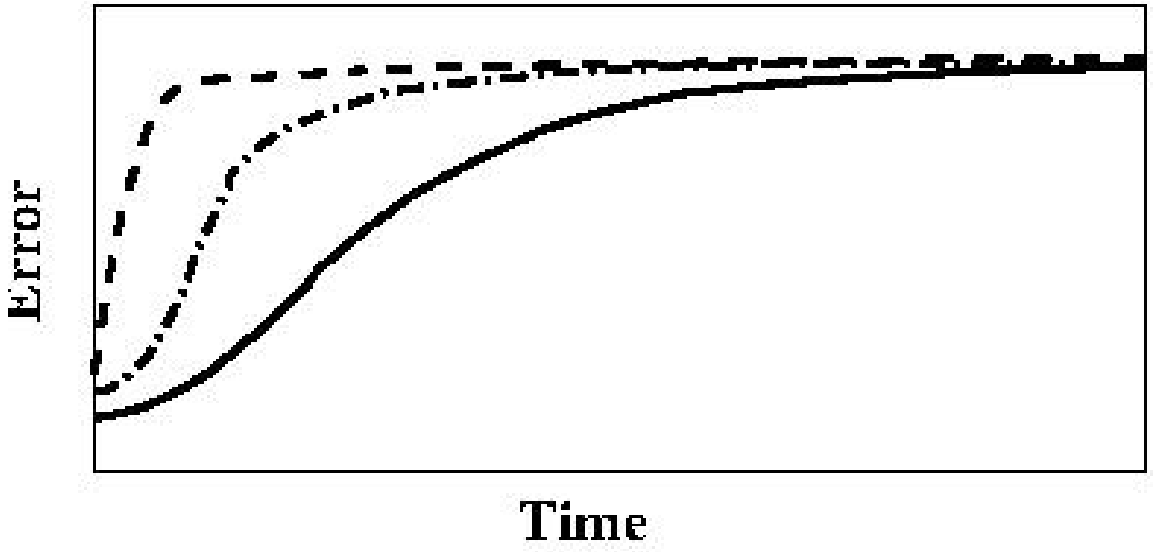

OSSE vs Real Adjoint Impacts
GPS-RO
RAOB W
RAOB Q
RAOB T
Aircraft W
Aircraft T
AMV
Surface Obs
SSMIS
MHS
IASI
HIRS4
CrIS
ATMS
AMSU-A
AIRS
Real
OSSE
0
-0.1
-0.2
-0.3
-0.4
-0.5
Net Adjoint Impact, J kg^{-1}

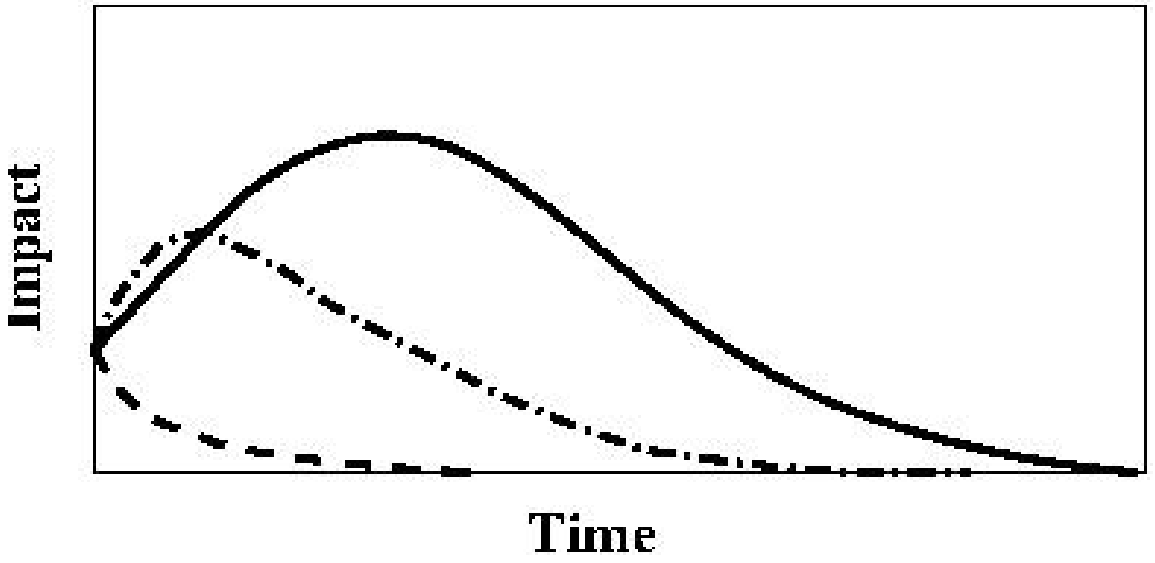

226 hPa U RMS Forecast Error
OSSE NR
OSSE ANA
Real ANA
RMSE, m s^{-2}
Forecast hour
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
0
6
12
24
48

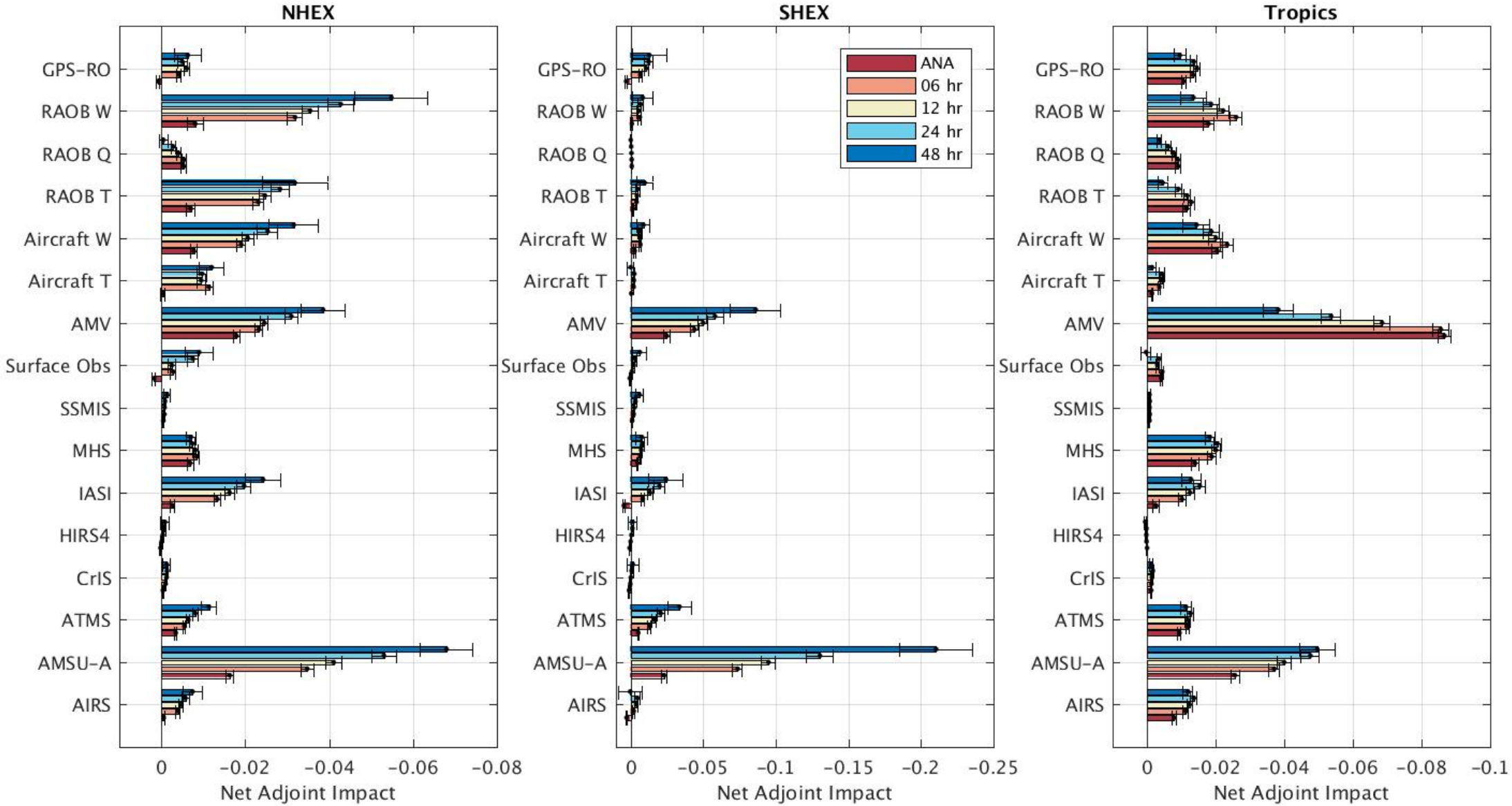

Total Observation Impact
ANA-BKG
Adjoint
Impact, J kg -1
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
6
12
24
48
Forecast Length, hr

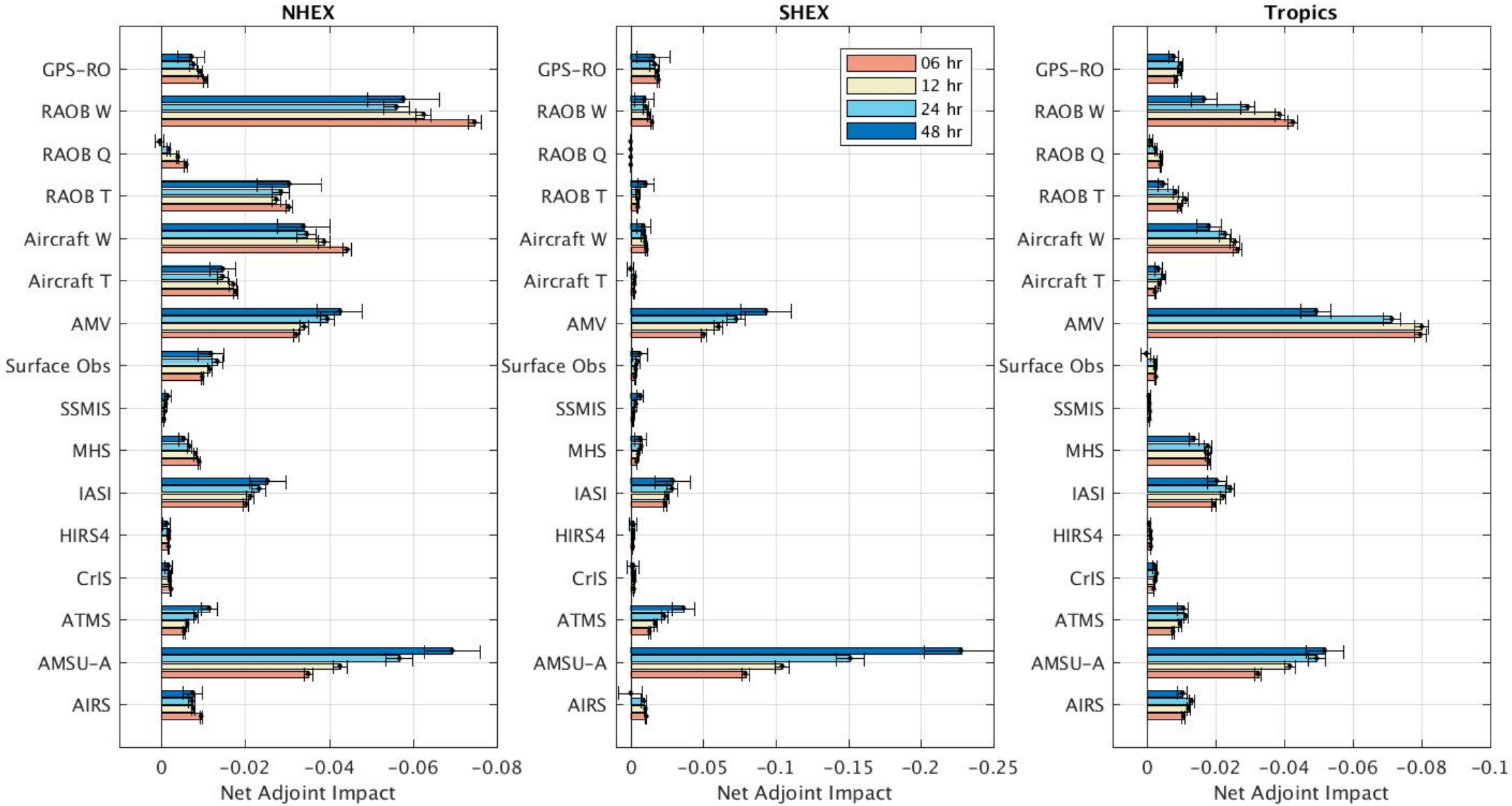

Fraction Captured by Adjoint
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
6
12
24
48
Forecast Length, hr

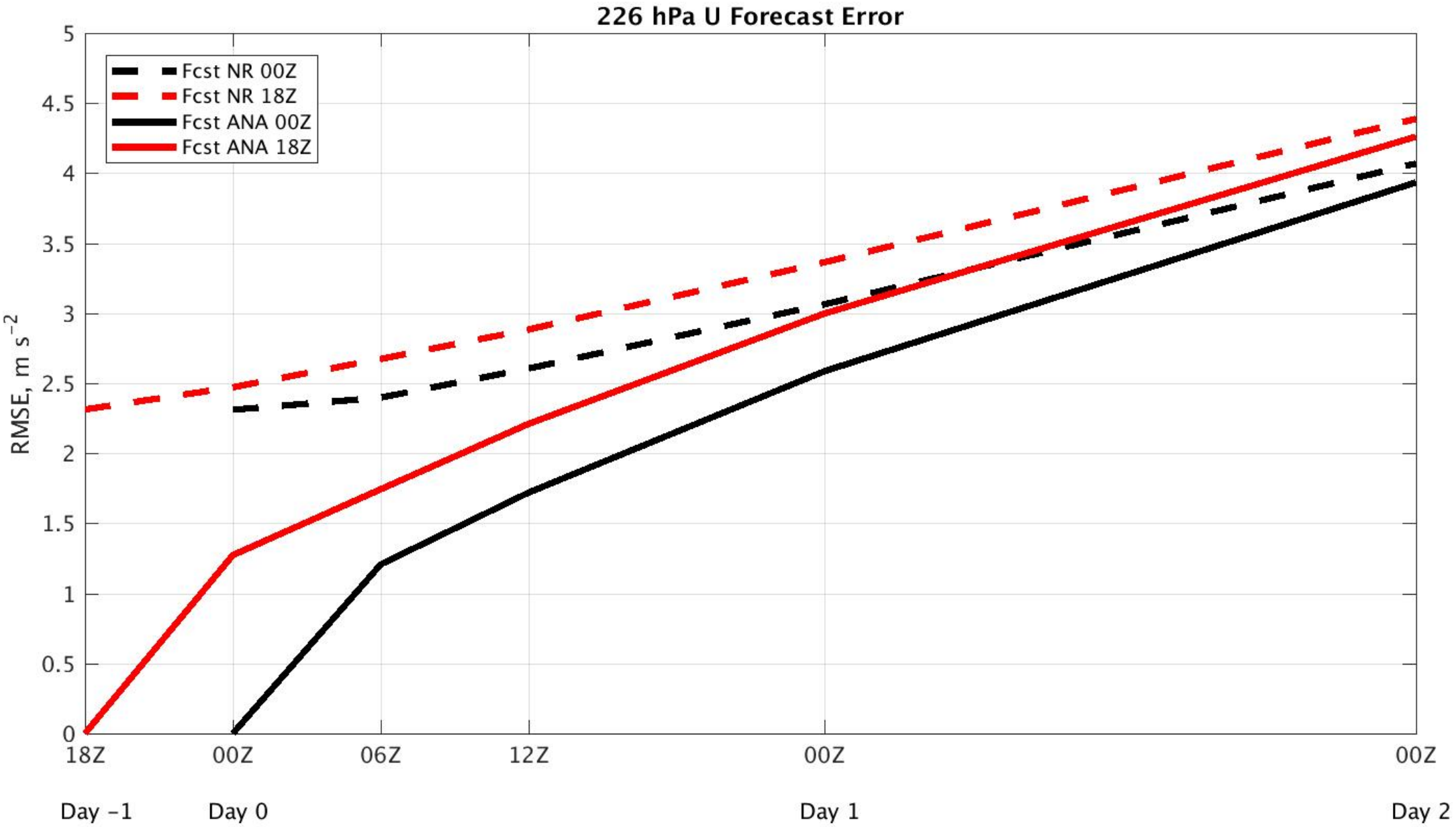

NHEX
SHEX
Tropics
GPS-RO
RAOB W
RAOB Q
RAOB T
Aircraft W
Aircraft T
AMV
Surface Obs
SSMIS
MHS
IASI
HIRS4
CrIS
ATMS
AMSU-A
AIRS
ANA
06 hr
12 hr
24 hr
48 hr
0
-0.02
-0.04
-0.06
-0.08
-0.05
-0.1
-0.15
-0.2
-0.25
Net Adjoint Impact

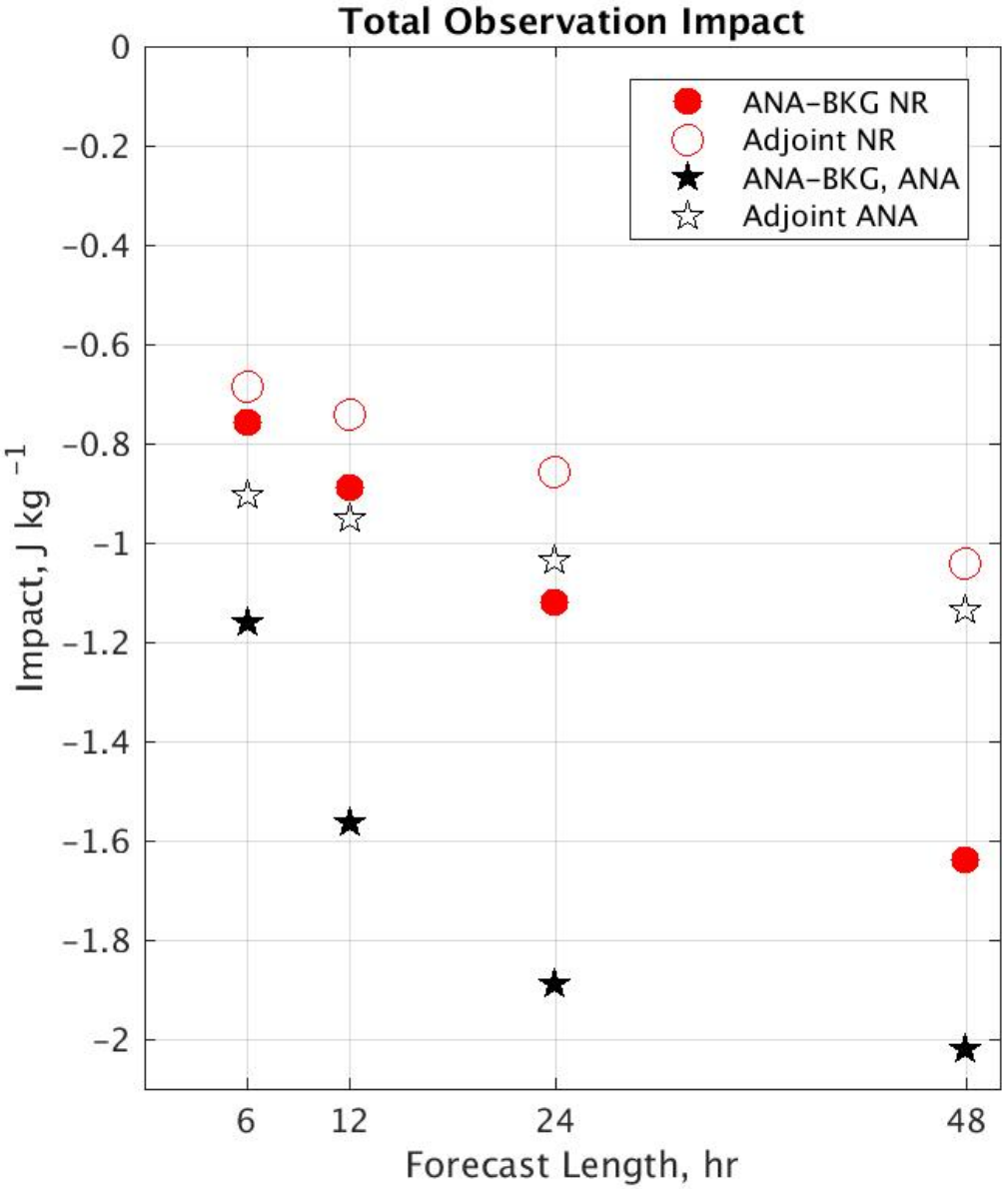

Error
Time

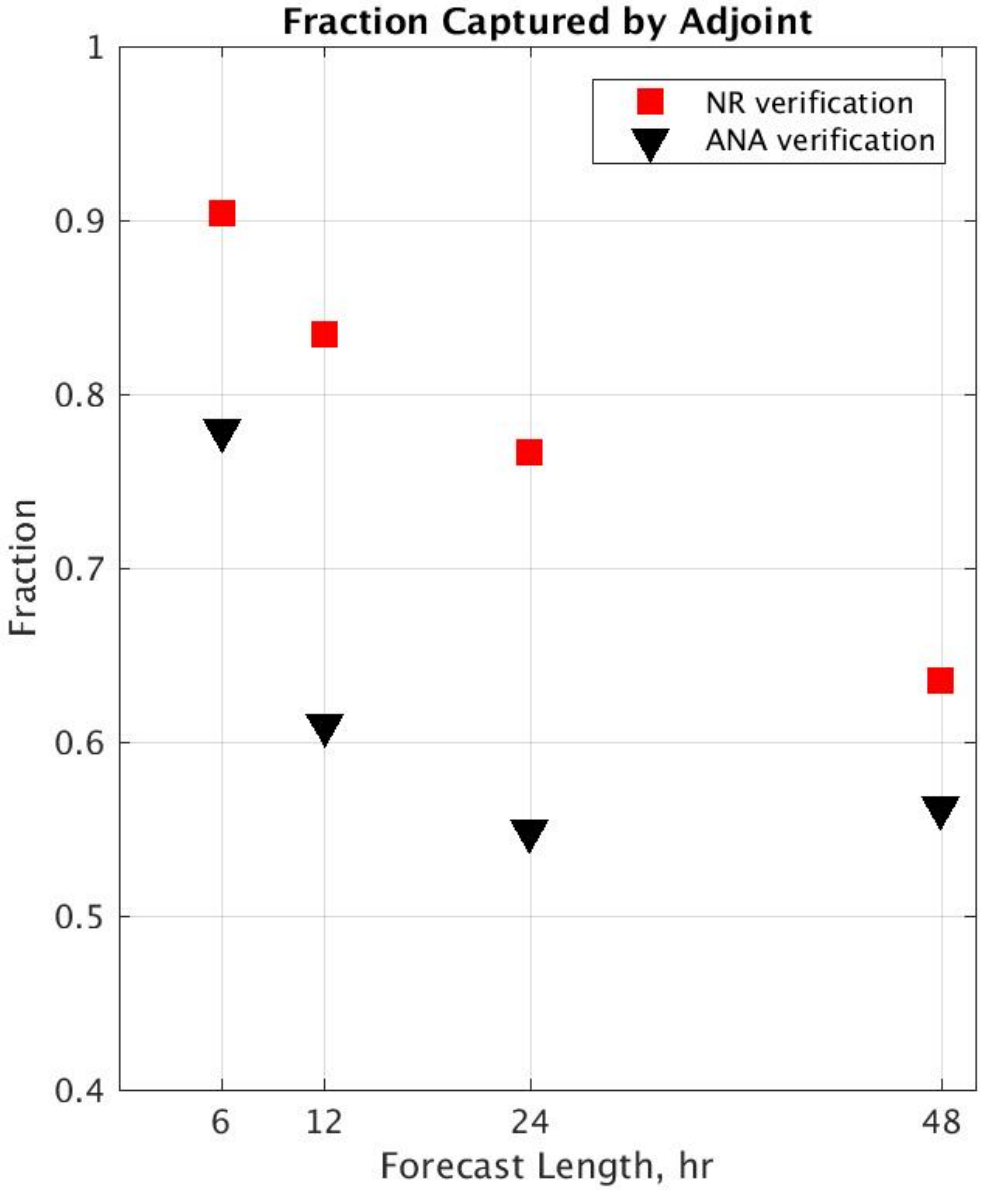

Impact
Time


NHEX
SHEX
Tropics
GPS-RO
RAOB W
RAOB Q
RAOB T
Aircraft W
Aircraft T
AMV
Surface Obs
SSMIS
MHS
IASI
HIRS4
CrIS
ATMS
AMSU-A
AIRS
ANA
06 hr
12 hr
24 hr
48 hr
0
-0.02
-0.04
-0.06
-0.08
-0.05
-0.1
-0.15
-0.2
-0.25
Net Adjoint Impact


NHEX
SHEX
Tropics
06 hr
12 hr
24 hr
48 hr
GPS-RO
RAOB W
RAOB Q
RAOB T
Aircraft W
Aircraft T
AMV
Surface Obs
SSMIS
MHS
IASI
HIRS4
CrIS
ATMS
AMSU-A
AIRS
0
-0.02
-0.04
-0.06
-0.08
-0.05
-0.1
-0.15
-0.2
-0.25
Net Adjoint Impact


226 hPa U Forecast Error
Fcst NR 00Z
Fcst NR 18Z
Fcst ANA 00Z
Fcst ANA 18Z
RMSE, m s^{-2}
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
18Z
00Z
06Z
12Z
00Z
00Z
Day -1
Day 0
Day 1
Day 2


Total Observation Impact
ANA−BKG NR
Adjoint NR
ANA−BKG, ANA
Adjoint ANA
Impact, J kg −1
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2
6
12
24
48
Forecast Length, hr


Fraction Captured by Adjoint
NR verification
ANA verification
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
6
12
24
48
Forecast Length, hr

Conclusions

- Observation impacts may grow or decay in time depending on the error growth behavior of the errors onto which the observation information projects
- Self-analysis verification grossly inflates error growth during the early forecast period while underestimating the actual forecast error
- Certain observing types are more strongly affected by self-analysis verification uncertainty, particularly RAOB and aircraft winds