# An Introduction to Observing System Simulation Experiments

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# 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

# Types of OSSEs

- NWP OSSE
  - Global OSSE
  - Regional OSSE
- Ocean / Coupled OSSE
- Chemistry, carbon, aerosol, …. OSSE
- Climate OSSE
  - Plan design of climate observing network

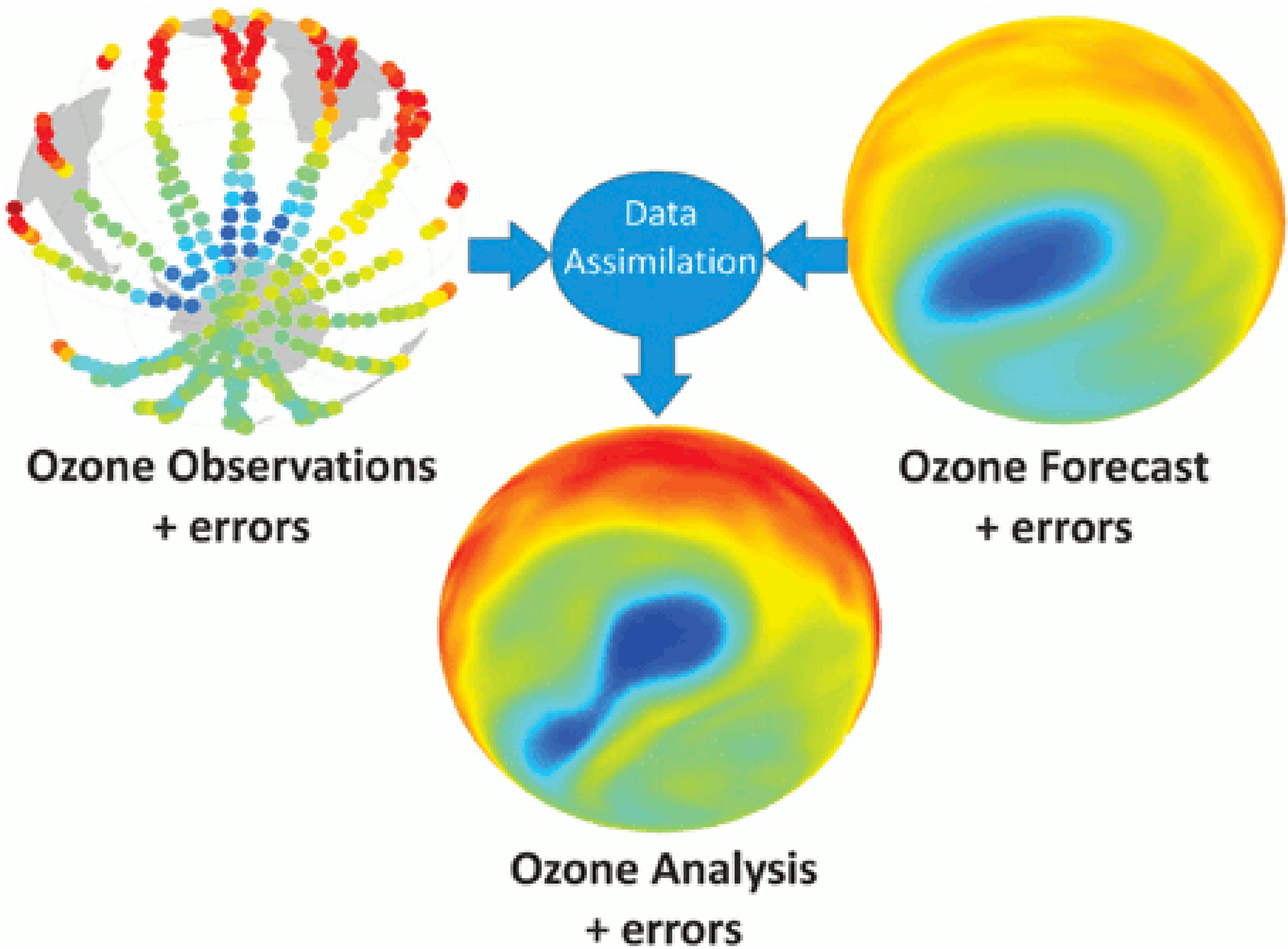
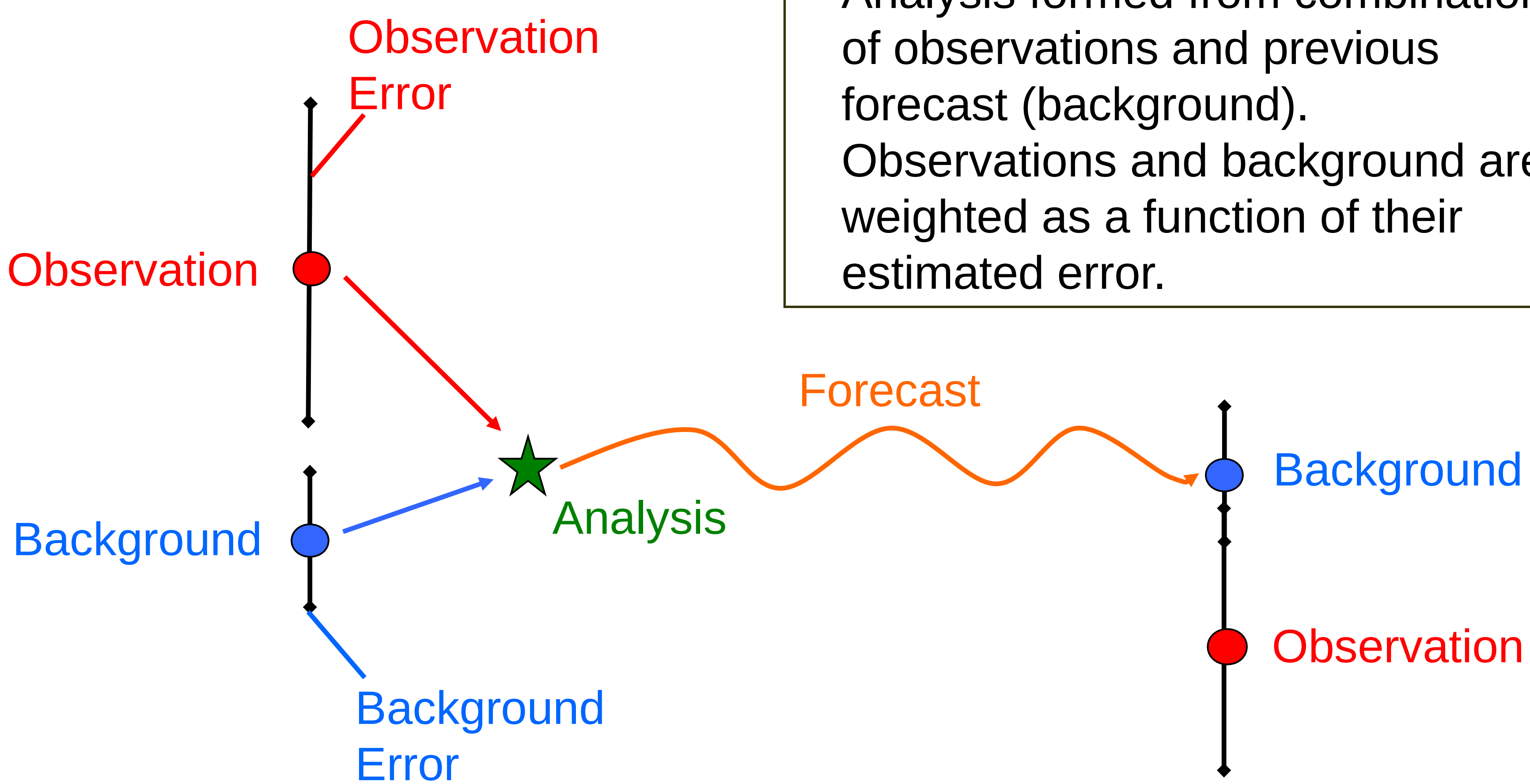



Image: Lahoz, W. and P. Schneider, Front. Environ. Sci., 2014

# Data Assimilation

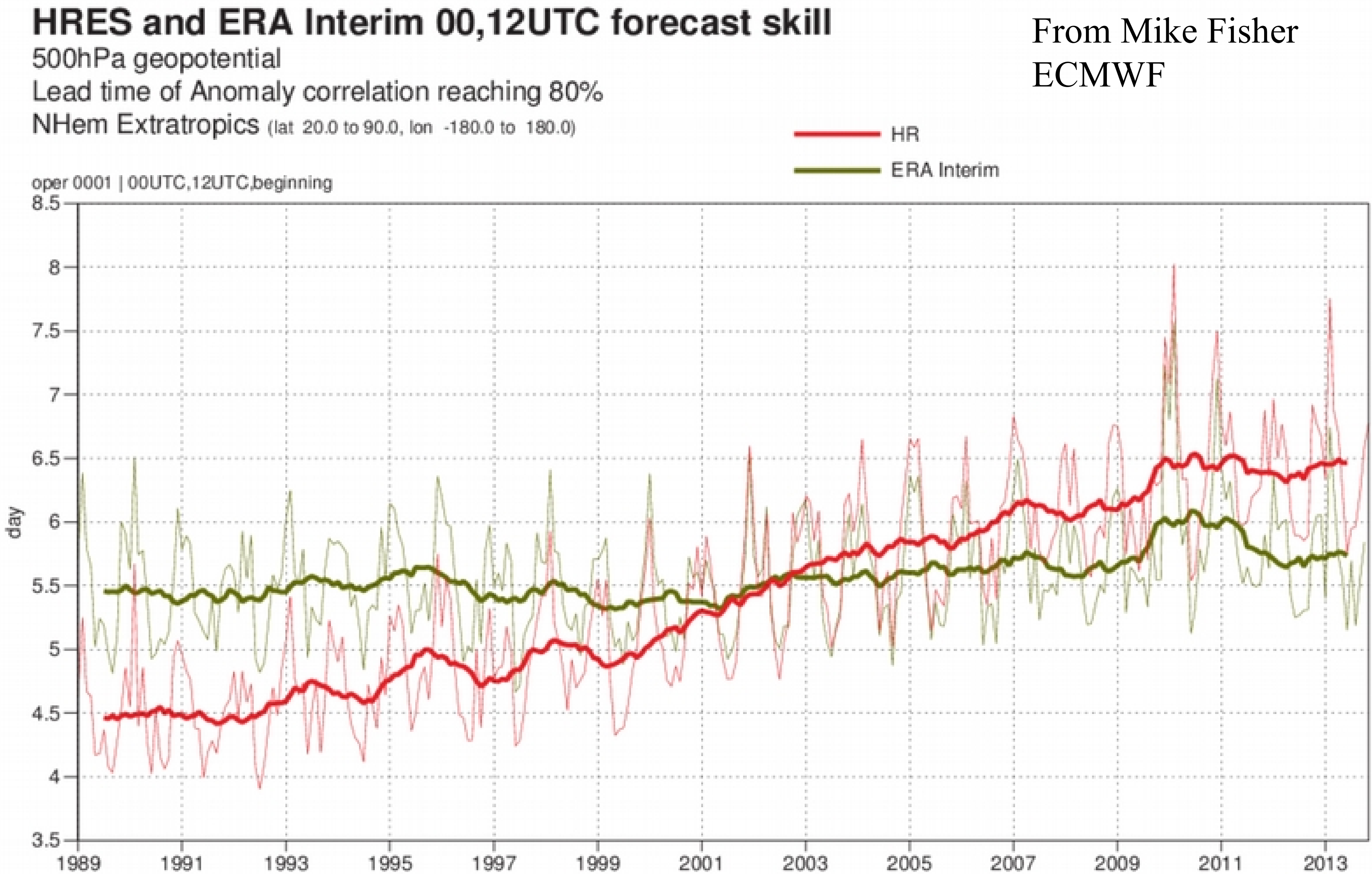
Analysis formed from combination of observations and previous forecast (background). Observations and background are weighted as a function of their estimated error.



# Data Assimilation

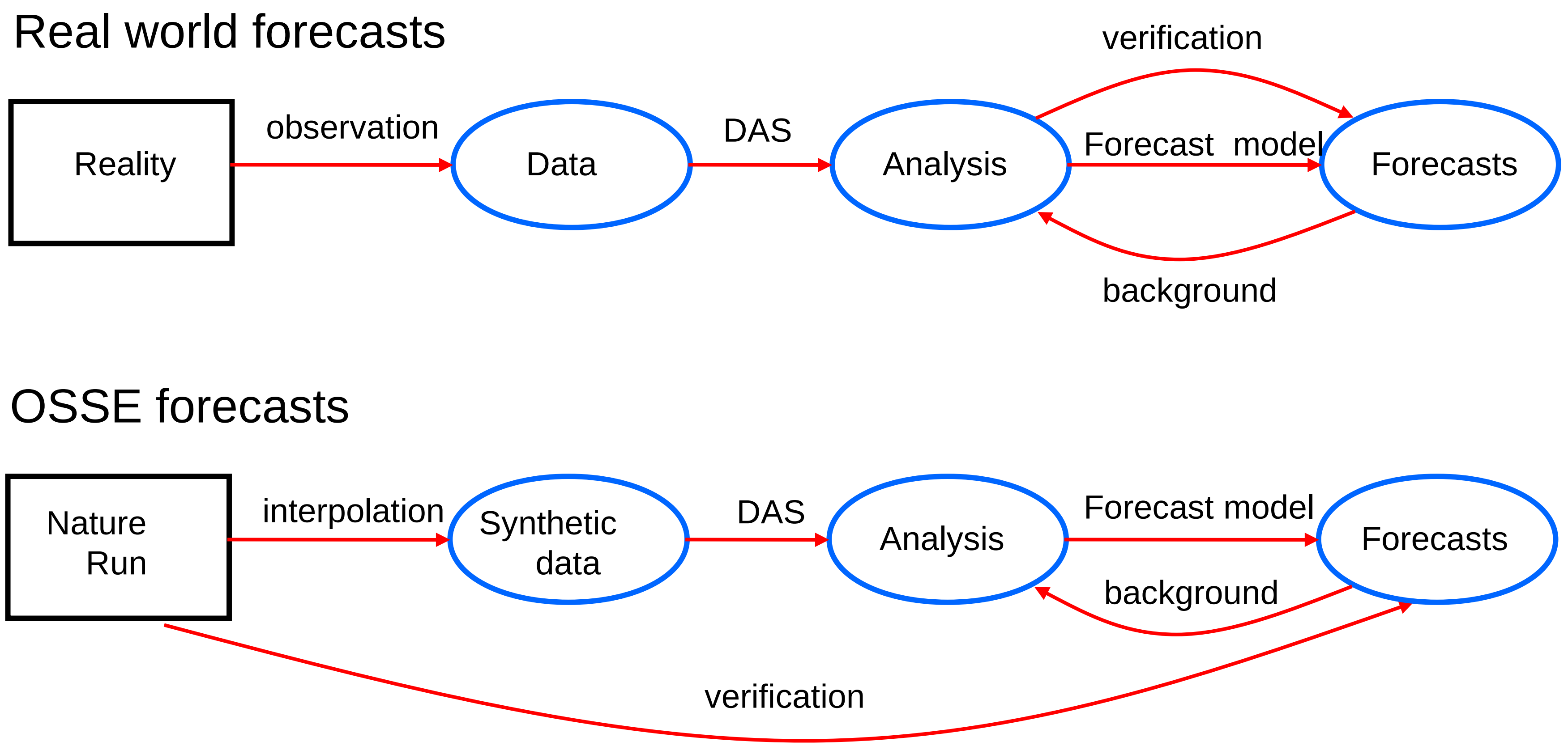
- Statistically based
- Limited by computational demands
- Filters particular kinds of observation error
- Spreads information spatially and dynamically
- A new observation set will likely provide little improvement when added to the present observation network

# Operational System versus Reanalysis




From Mike Fisher
ECMWF

# OSSEs vs. the Real World



# Why do an OSSE?

1. You want to find out if a new observing system will add value to NWP analyses and forecasts
2. You want to make design decisions for a new observing system
3. You want to investigate the behavior of data assimilation systems in an environment where the truth is known

# When not to run an OSSE

- When you can't model the phenomena you are interested in
- When you can't simulate your new observations
- When you can't assimilate your new observations

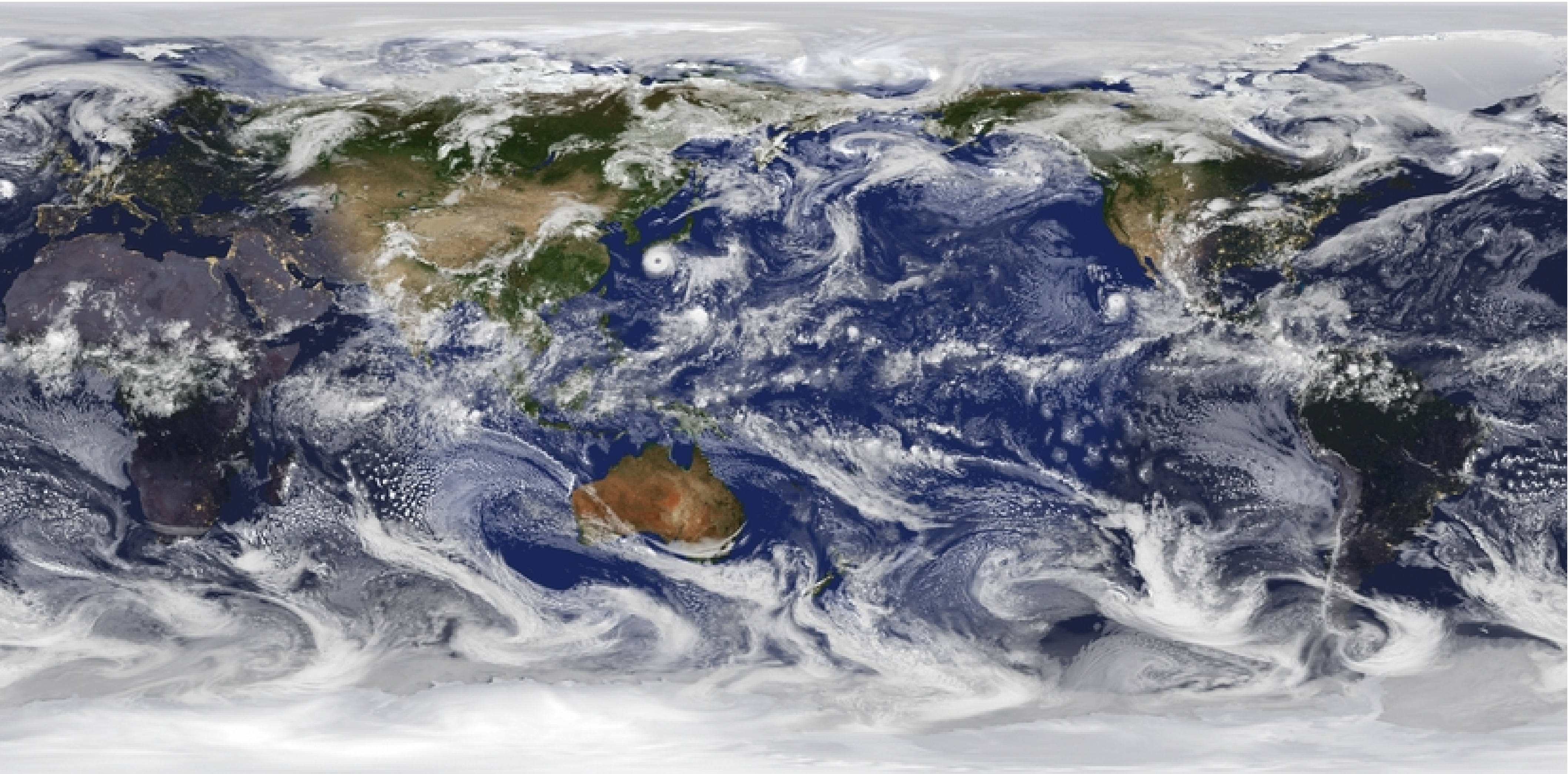
# Construction of an OSSE

- Nature Run (“truth”)
- Synthetic observations with errors
- Forecast model with data assimilation system
- Calibration and validation of the OSSE
- Experiment design

# Nature Runs

- Nature Runs act as the 'truth' in the OSSE, replacing the real atmosphere.
- Usually, a long free (non-cycling) forecast from the best available model is used as the NR
- Must be able to realistically model phenomena of interest
- Preferably a different model base is used for the NR and the experimental forecast model to reduce incestuousness

# GEOS-5 Nature Run



2 year, 7 km/72L, 30 minute resolution
15 aerosols, ozone, CO, $CO_2$

Image courtesy: William Putman

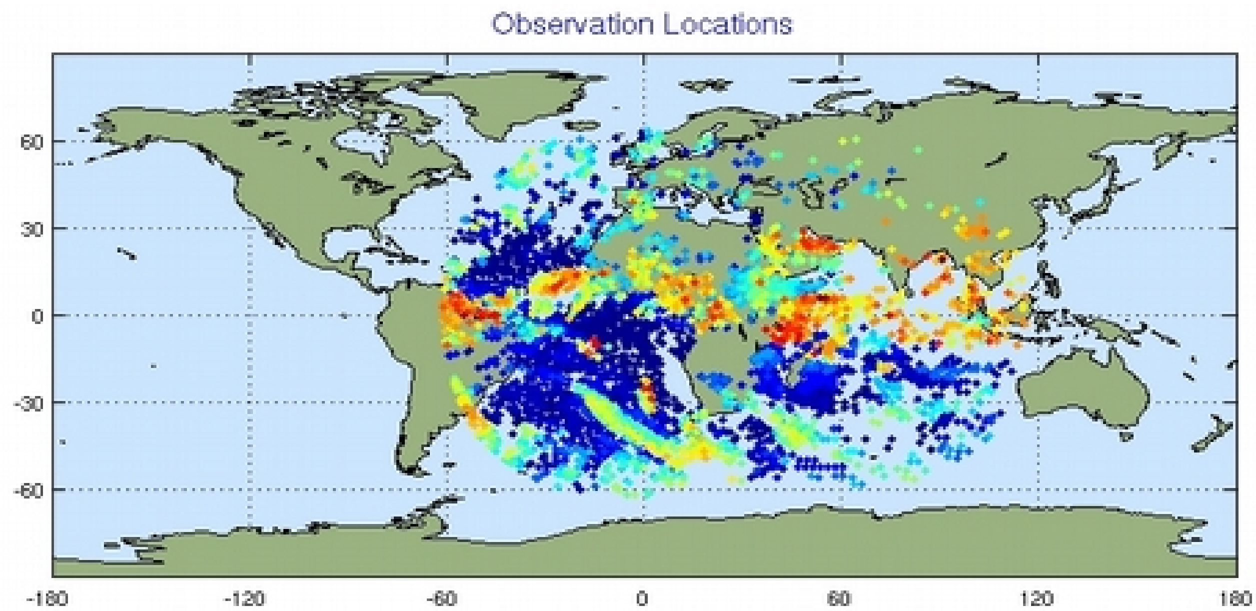
# Nature Run Validation

- Evaluate if NR is sufficiently realistic to yield meaningful results
- In addition to the phenomena of interest, the NR should realistically replicate fields needed to generate synthetic observations
- Can't validate everything; corollary – don't expect a NR to come pre-validated for your needs

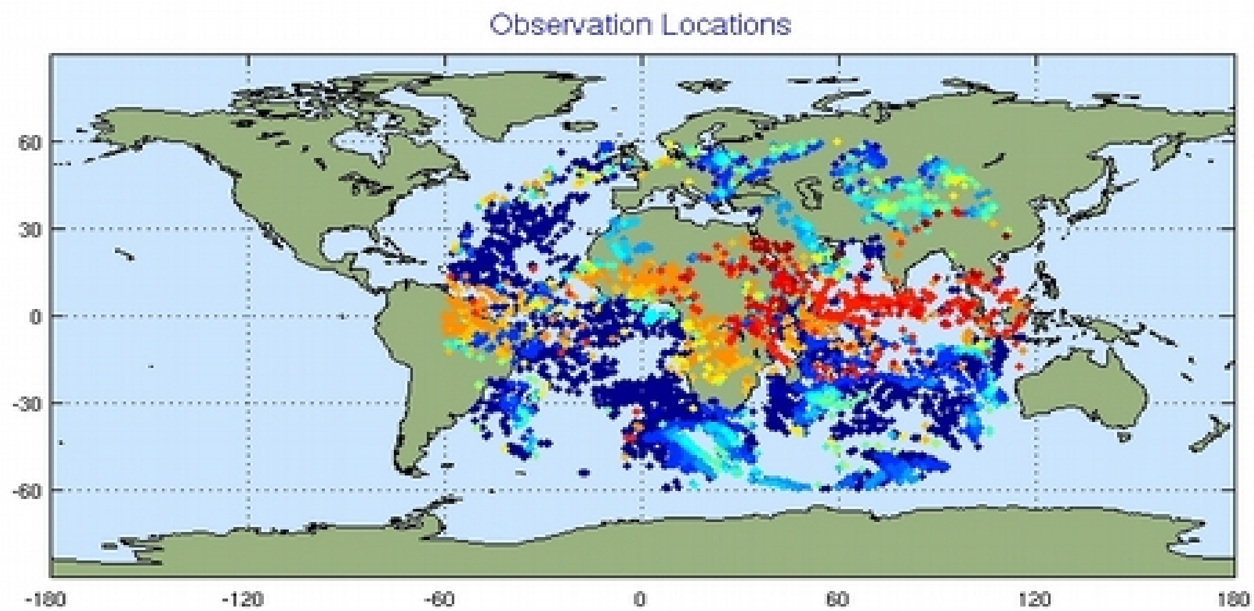
# Synthetic Observations

Example of METEOSAT AMV observations at 0000 UTC 10 July

Real




Simulated



# Synthetic Observations

- Most conventional types interpolated from NR fields using spatio-temporal distribution of real observations as a basis
- Radiance observations similarly generated using radiative transfer model with NR fields as input
- Atmospheric motion vectors should be based on clouds and water vapor in NR
- New observing types need an observation operator both to create and to assimilate the synthetic data

# Observation Errors

- Synthetic observations contain some intrinsic interpolation/operator errors, but less than real observations (usually)
- Synthetic errors are created and added to the synthetic observations to compensate
- Error is complex and poorly understood
  - Error magnitude
  - Biases
  - Correlated errors

# Forecast Model Requirements

- Data Assimilation System must be able to ingest both current and new data types
- Forecast model ideally similar to an operational model
- Forecast model should be distinctly different from the model used to make the Nature Run
  - ‘identical twin’ cases use the same model
  - ‘fraternal twin’ cases use similar models

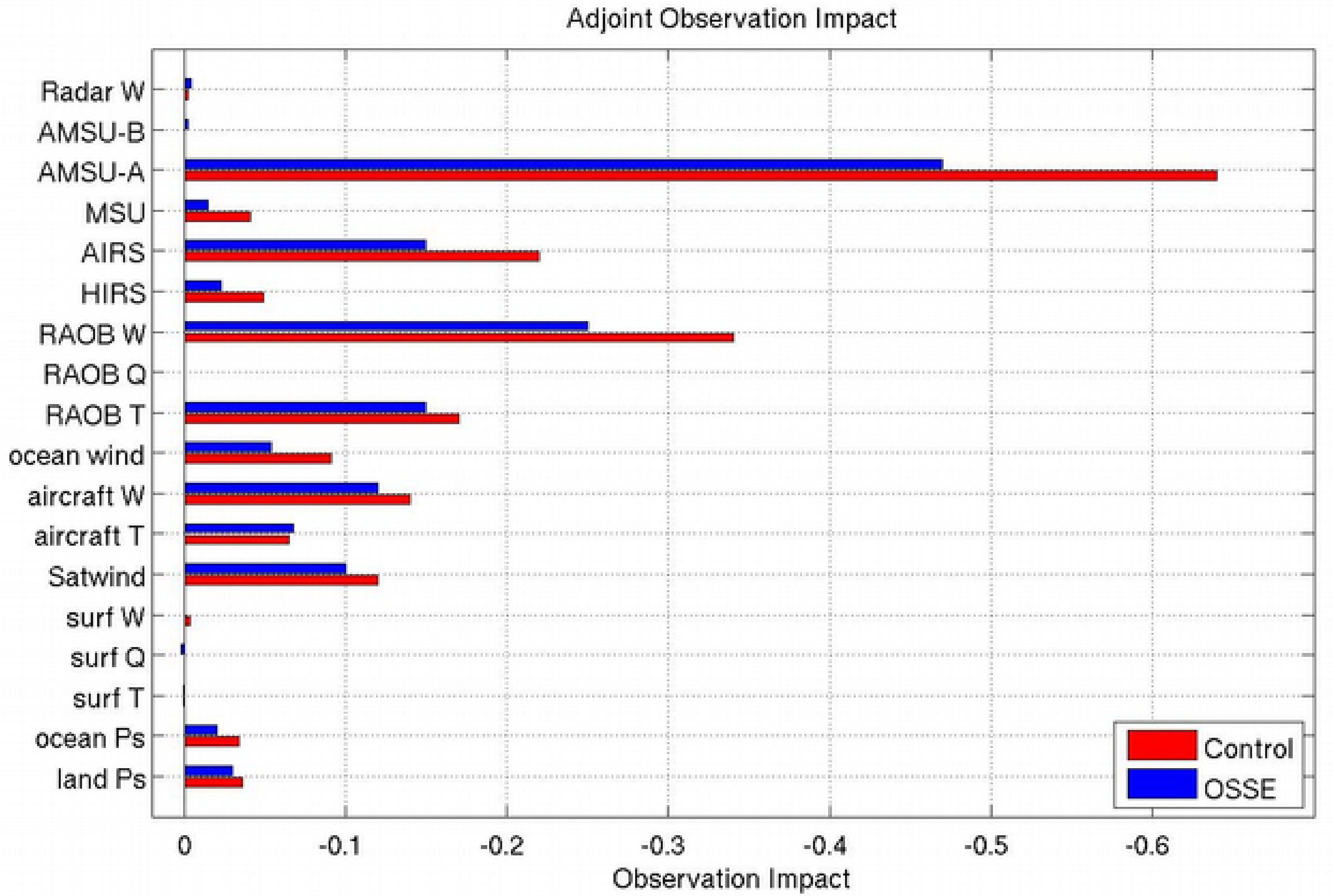
# Calibration

- Adjust synthetic observations and their errors to increase realism of the OSSE in a statistical sense
    - Compare OSSE statistics to statistics using real data in the same DAS/forecast system
- Need to decide what statistical metrics to use for the calibration, depending on your needs
- Calibrating new observation types?
    - Find an analogous data type if possible

# Criticisms of OSSEs

- Results only apply within the OSSE system – no concrete connection to the real world
- Even the best OSSEs are far from perfect: incestuousness, difficulty in generating observations and errors, deficiencies of the Nature Run
- By the time the new instrument is deployed, both the global observing network and the forecast models/DAS will be different
- Examples of sloppy or unsuccessful OSSEs

# Why believe OSSE results?



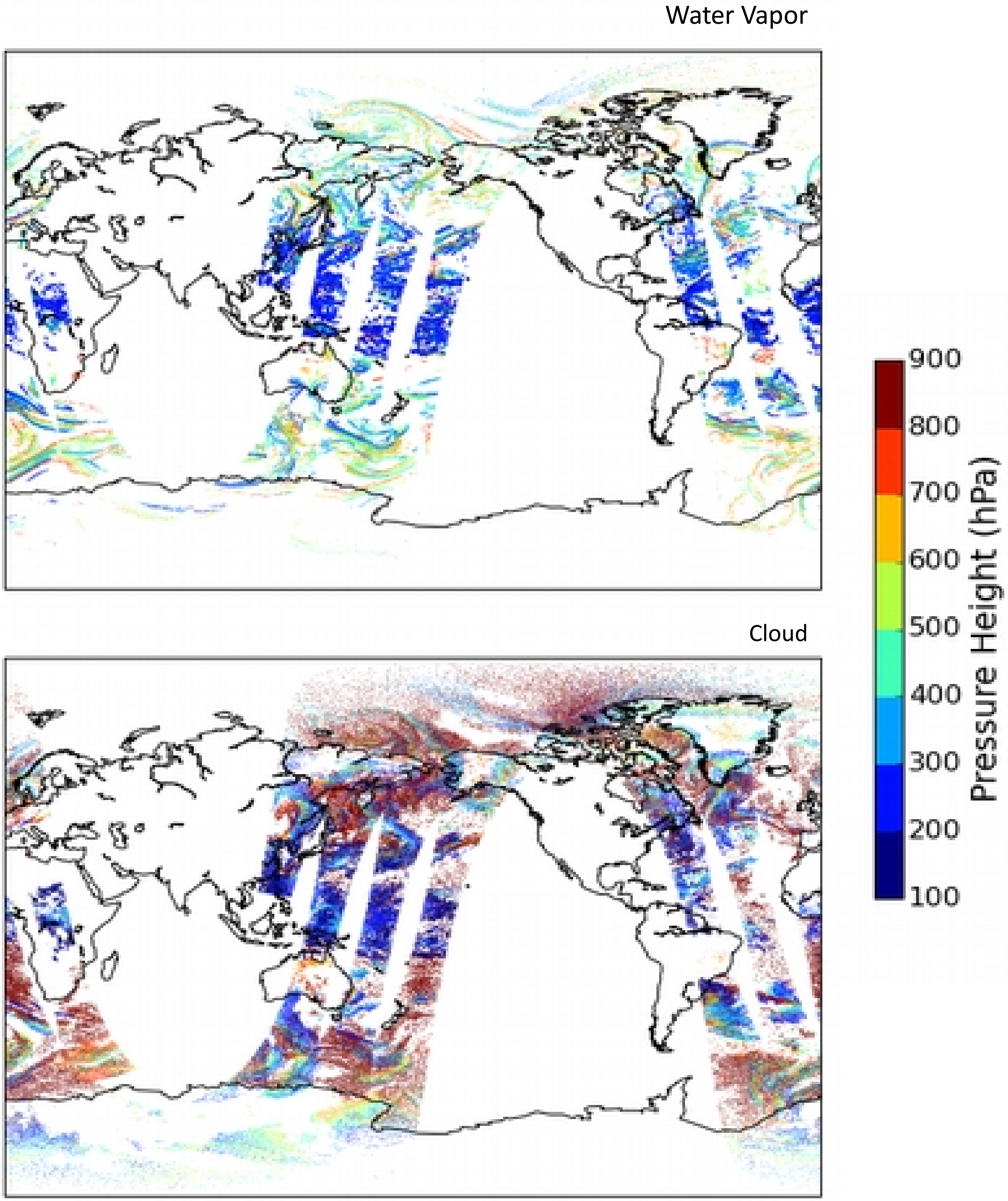

New observations can be put into context relative to existing observation impacts

# MiSTIC Wind OSSE

Constellation of satellites of the CubeSat class carrying a MWIR spectrometer operating in the range 4.08-5.8 µm for frequent measurement of temperature and humidity profiles.

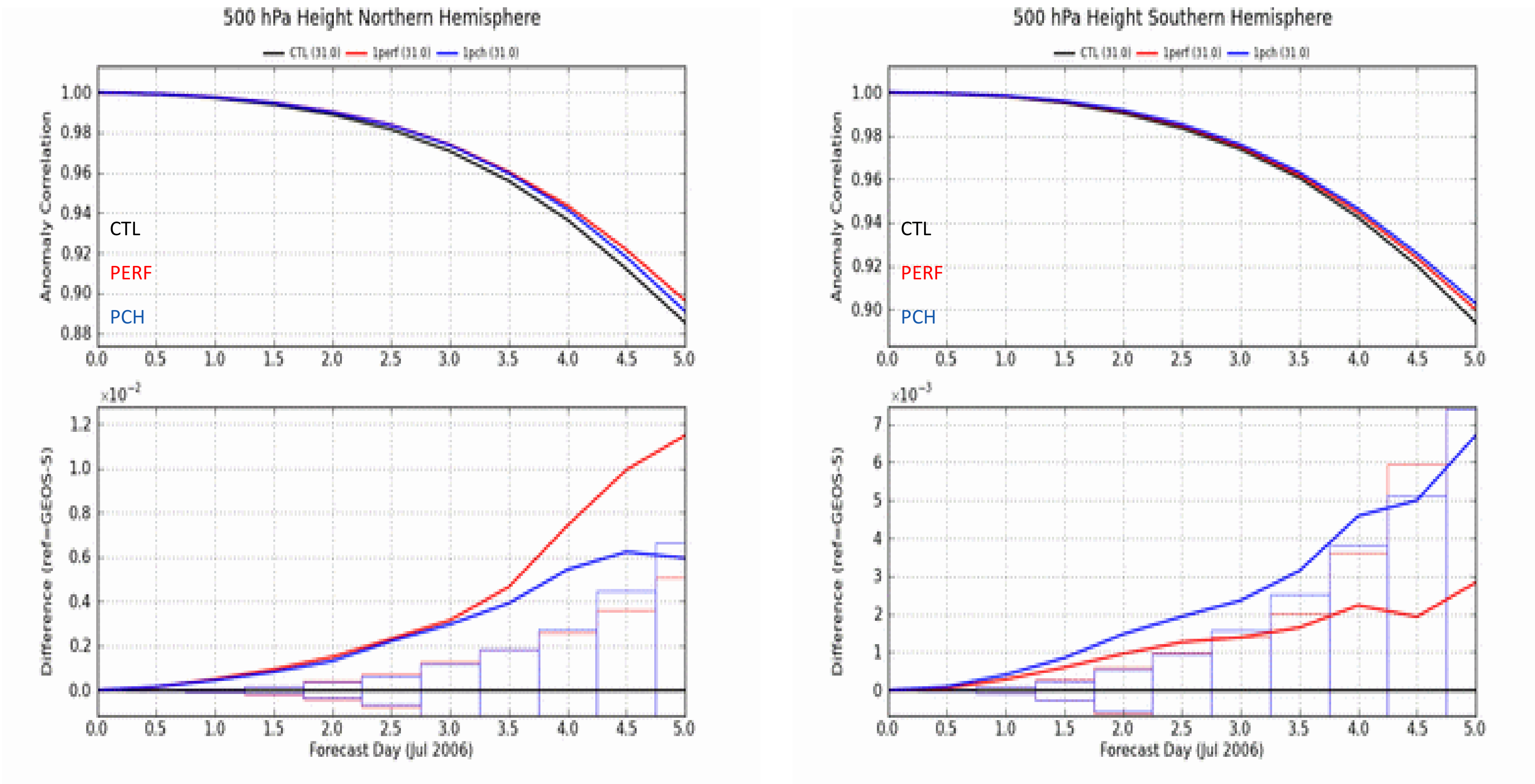
The wind profile is retrieved by assimilation of these frequent profiles.

The target spatial resolution is 2 to 4 km, and the frequency of sampling 1 to 2 h.




Slide courtesy of Will McCarty

# Forecast Skill – 500hPa Z Anomaly Correlation




Forecast skill improvement apparent – noted that improvement start within first day and remains

- Results consistently show improvement through the troposphere in midlatitudes
- Largest near surface in NH, consistent through column in SH



Slide courtesy of Will McCarty

# Takeaways

- OSSEs can provide useful information about new observational types and the workings of data assimilation systems
- Careful consideration of research goals should guide each step of the OSSE process
- OSSEs are hard, good OSSEs are harder