OSE and OSSE Studies to Evaluate the Impact of Real and Simulated Global Hawk Data on Winter Storm Forecasts over Alaska and the Arctic

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Global Observing Systems Analysis (GOSA) Group : http://www.esrl.noaa.gov/gsd/gosa/

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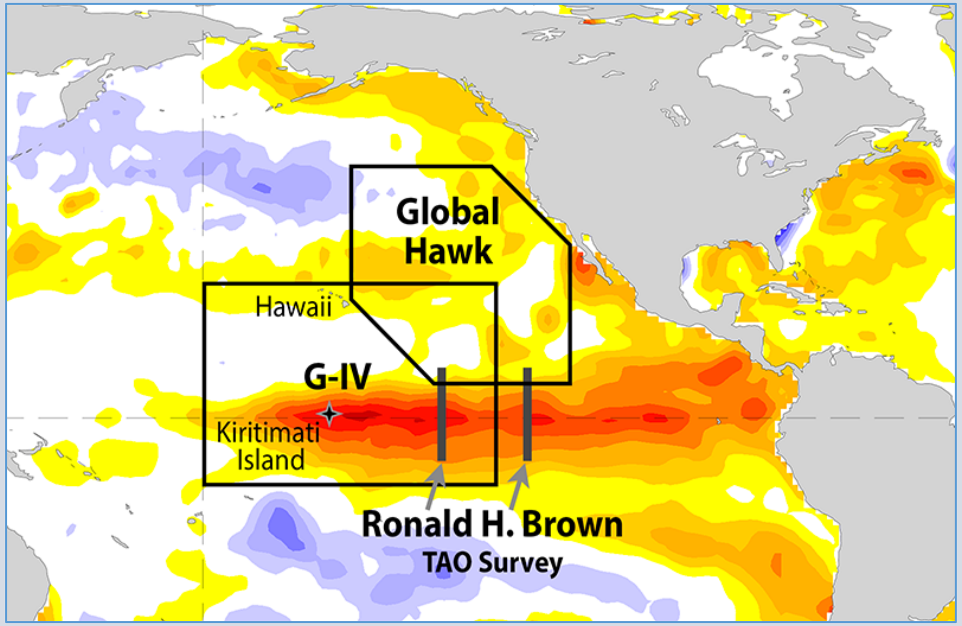
Connecting Models and Observations

Sensing Hazards with Operational Unmanned Technology (SHOUT) Project and Motivation

- Project within NOAA's Unmanned aircraft systems (UAS) program
- Test impact of real and simulated UAS data on forecasts using targeted observing with Global Hawk (GH)
  - Observing System Experiments (OSEs)
  - Observing System Simulation Experiments (OSSEs)
- Satellite gap mitigation (Soumi-NPP and JPSS-1/2)
- **SHOUT-El Nino Rapid Response (ENRR)**
  - Joint effort Feb 2016 with GH, G-IV, C-130's
  - Improve U.S. West Coast forecasts
  - GH sampled 3 storms
  - 3rd Storm – Feb 21st – strong Atmospheric River
    - 66 total dropsondes released

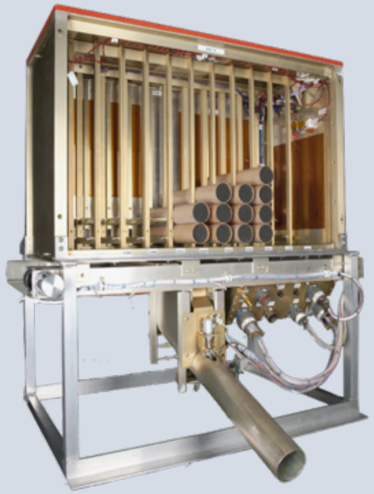
Global Observing Systems Analysis Group



http://www.esrl.noaa.gov/psd/enso/rapid_response/

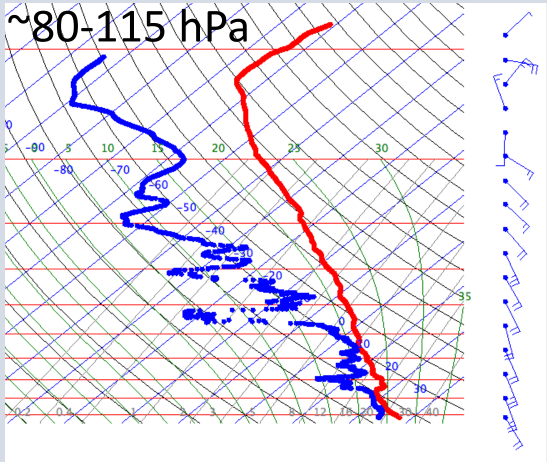
SHOUT Global Hawk Instrumentation Payload

Airborne Vertical Atmospheric Profiling System (AVAPS)

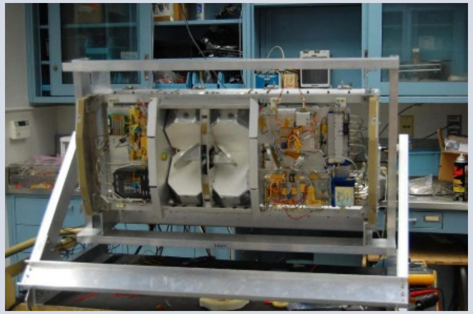


Temperature, wind, humidity

88 sondes

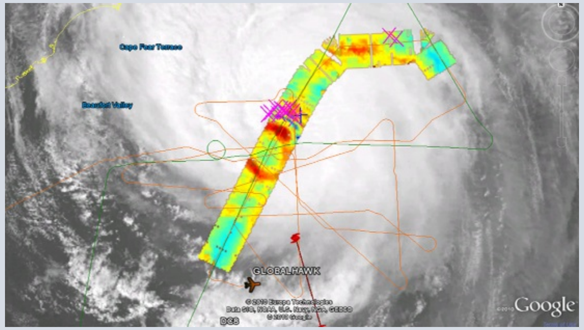


High Altitude Monolithic Microwave Integrated Circuit (MMIC) Sounding Radiometer (HAMSR)



Microwave radiometer operating at 25 spectral channels

3-D distribution of temperature, water vapor

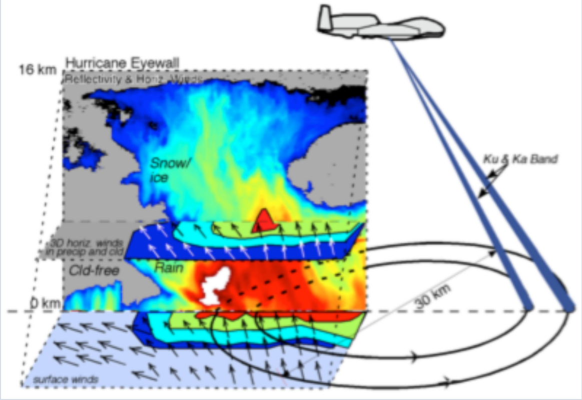


High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)

Dual-frequency conical scanning rada

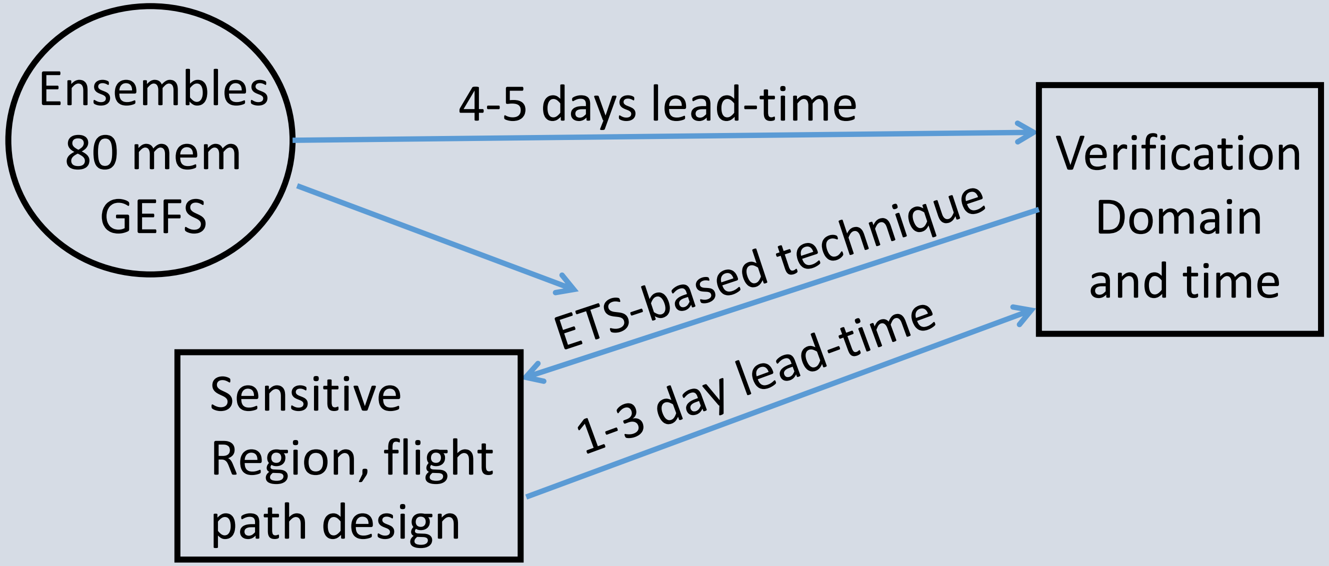
3-D winds, ocean vector winds, preci

Resolution: 60 m vertical, 1 km horiz



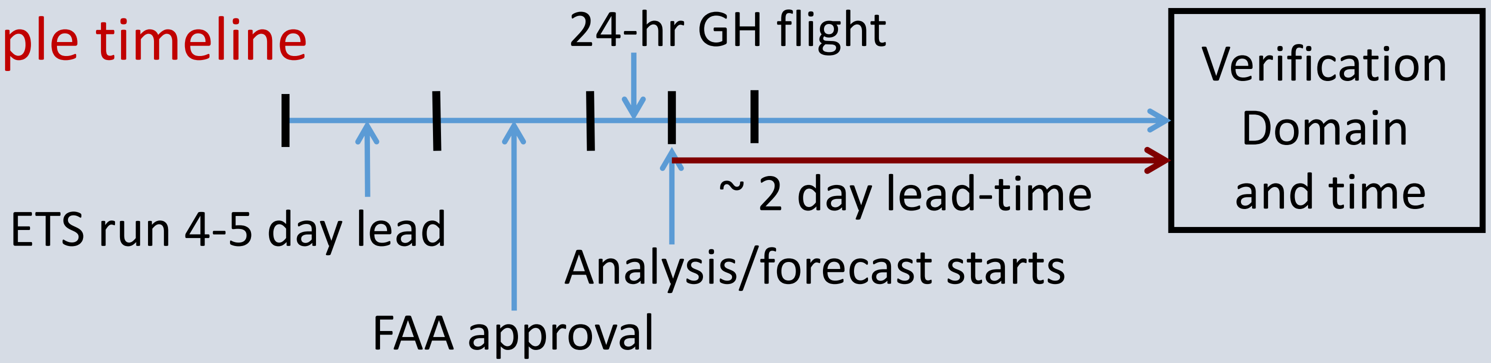
Ensemble Transform Sensitivity (ETS) Targeted Observing Technique

- Improve forecasts in verification region at selected *targeting and verification times*
- Calculates *gradient* of total forecast error variance to analysis error variance reduction



- Daily forecast briefings providing high-impact cases 4-5 days in advance
- ETS to identify areas of large error growth at 1-3 day lead time
- Subsequent flight path design

* Sample timeline

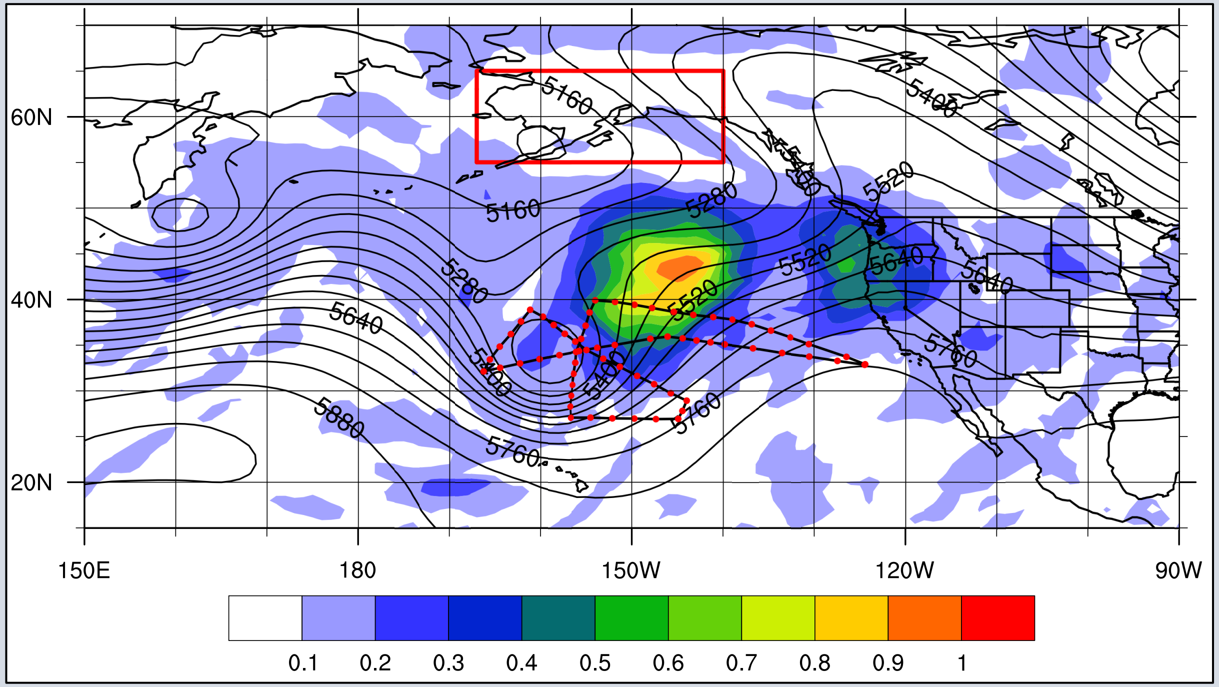


Zhang et al. (2016)

OSE Experiment Design during SHOUT-ENRR February 21 Storm
Cycling Global Forecast System (GFS) model 2/21 18z to 2/22/ 12z

Experiment Name	Description
CTL	All current operational observations
DROP	*CTL* + GH dropsondes
noNPP	*CTL* without Soumi-NPP satellite
DROP_noNPP	*noNPP* + GH dropsondes

Satellite gap mitigation

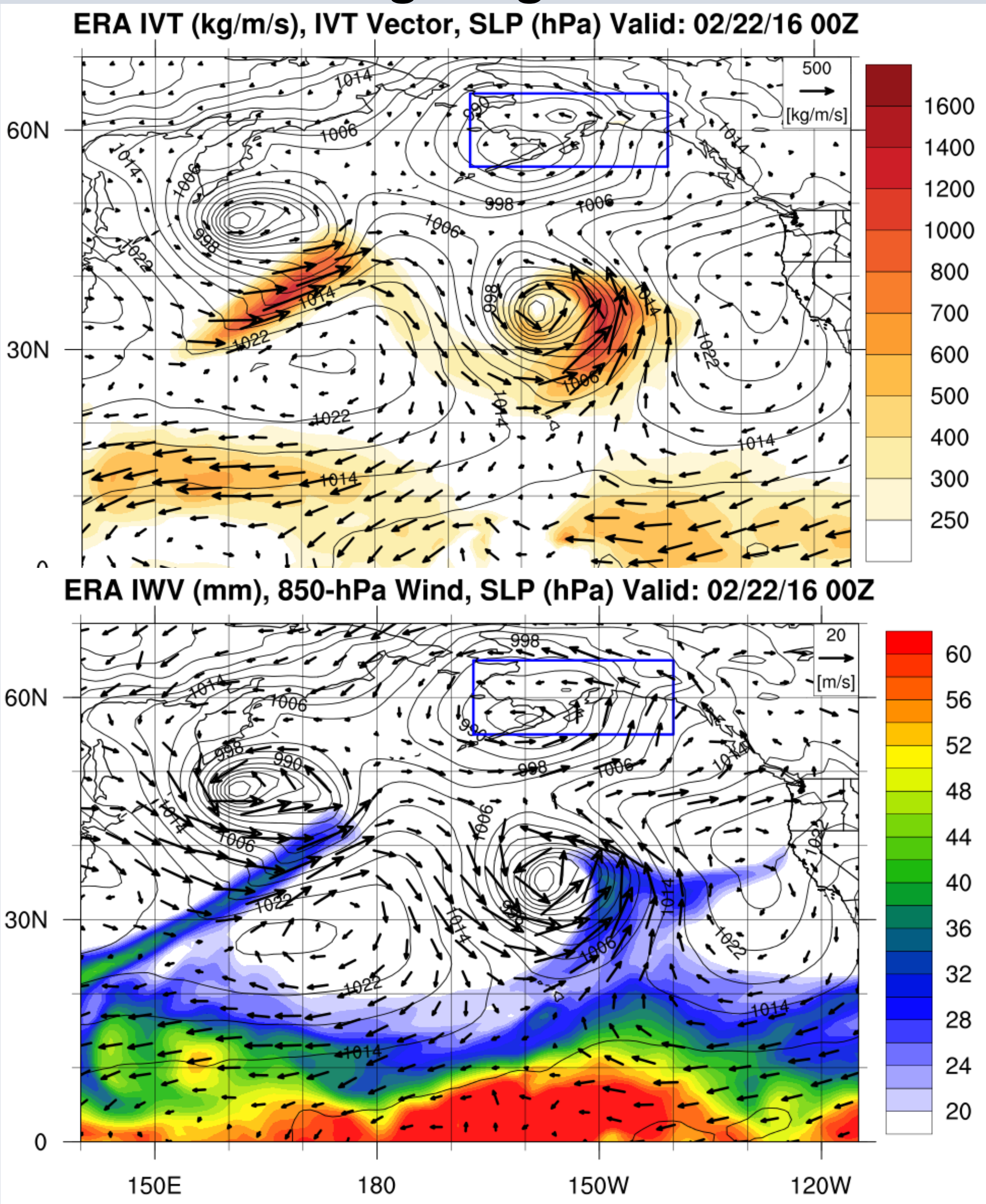


ETS sensitivity at GH flight time (00z Feb 22nd) for verification time (00z Feb 24th) over AK verification domain

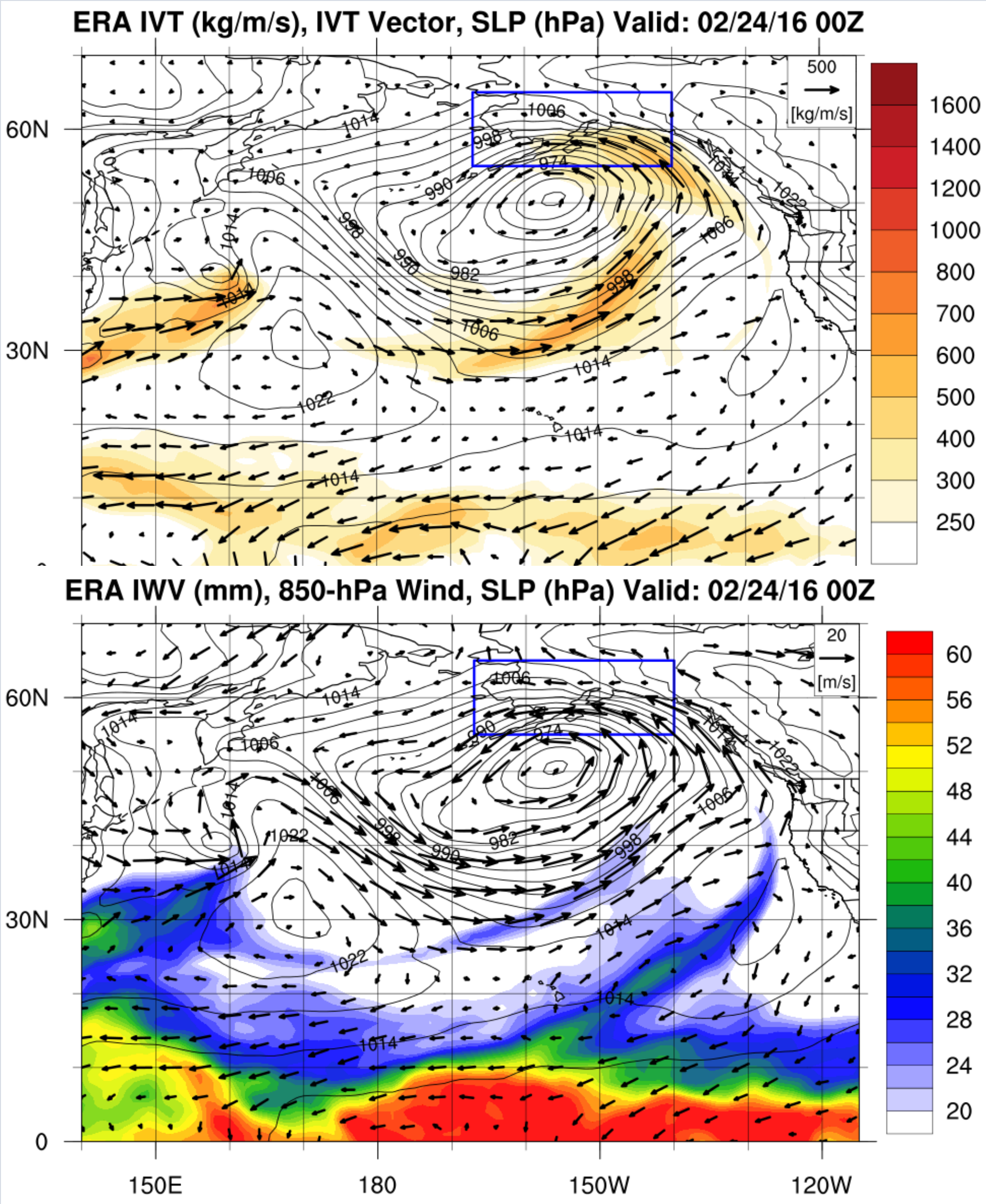
Results verified against ECMWF analysis using Anomaly Correlation and RMSE

ERA-Interim Moisture transport (IVT and IWV) at Targeting and Verification times

Targeting time

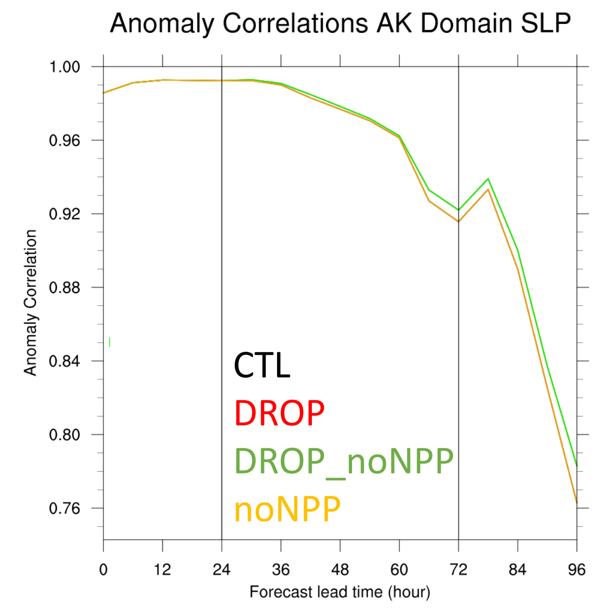


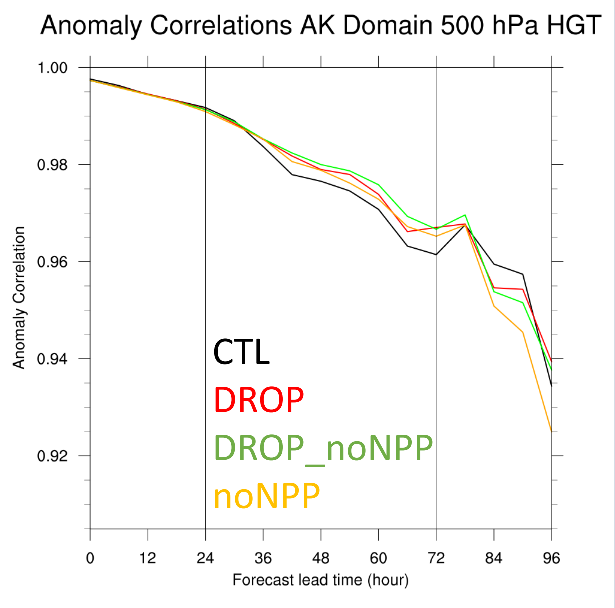
Verification Time



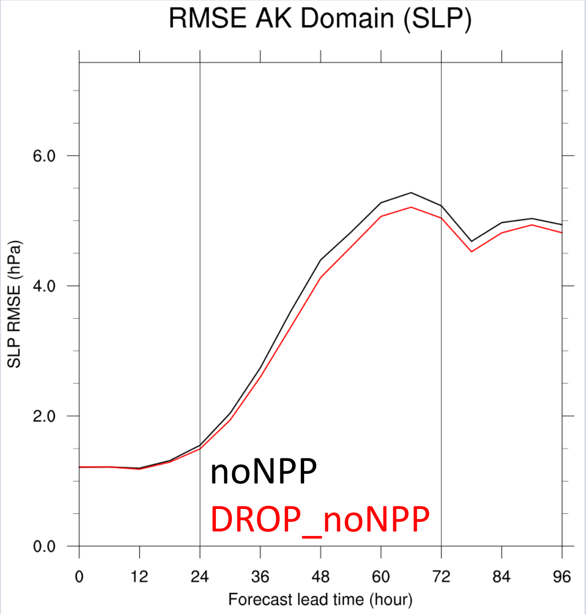
Assimilating dropsondes increases forecast skill and reduces error

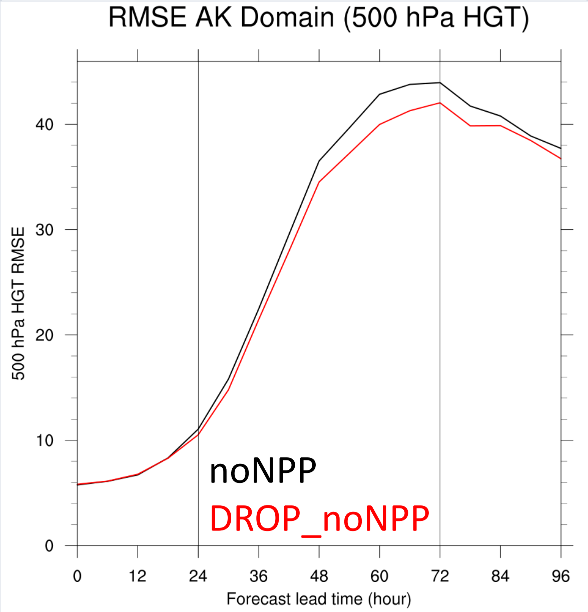
Anomaly Correlation



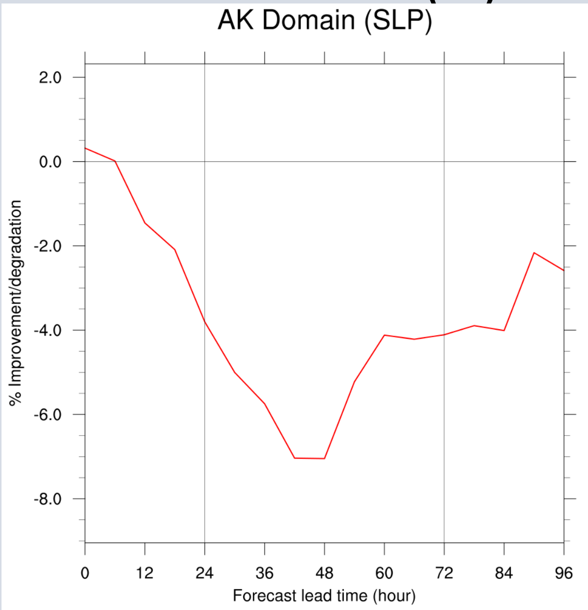


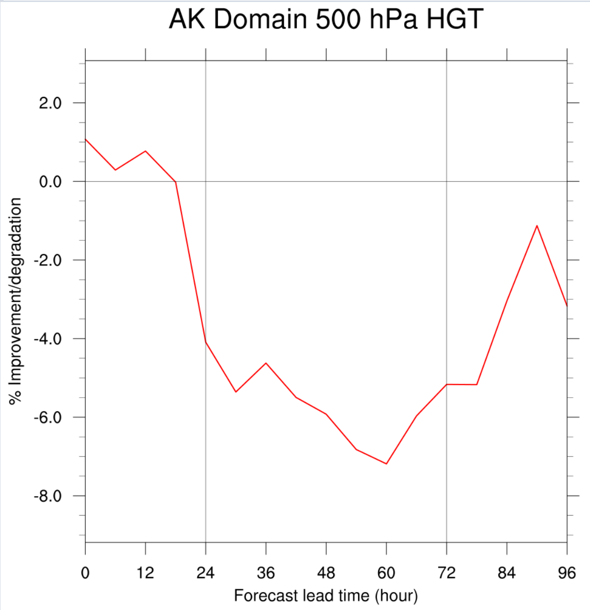
RMSE



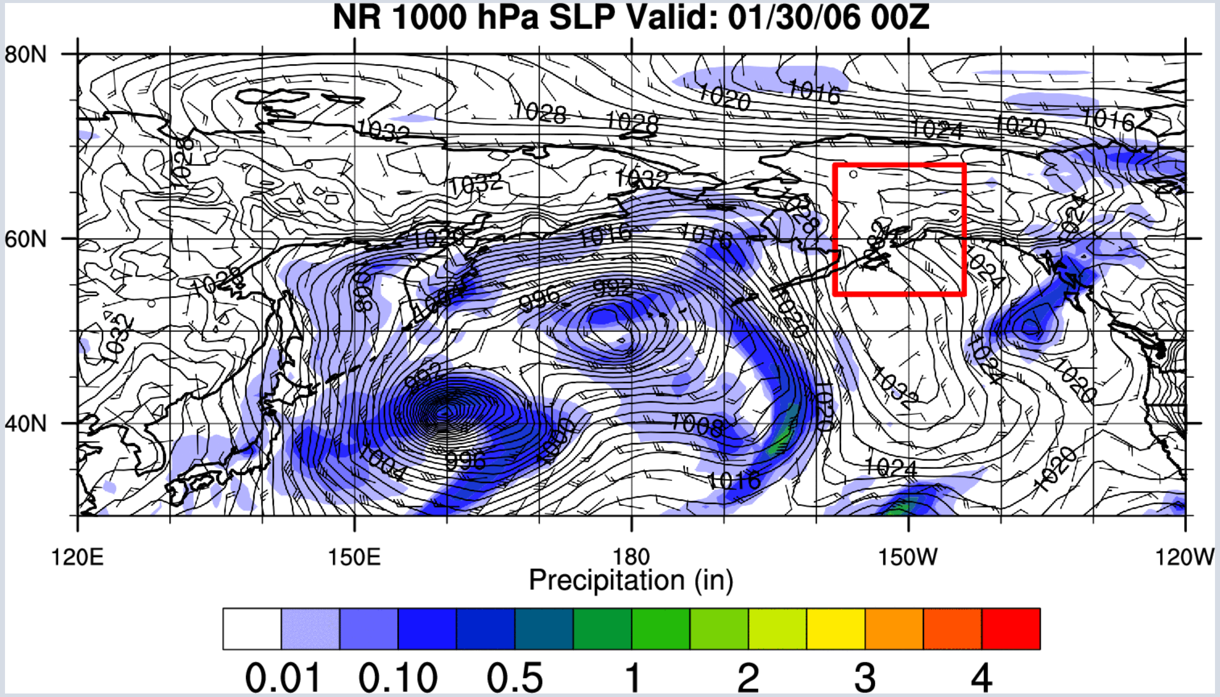


Relative RMSE (%)





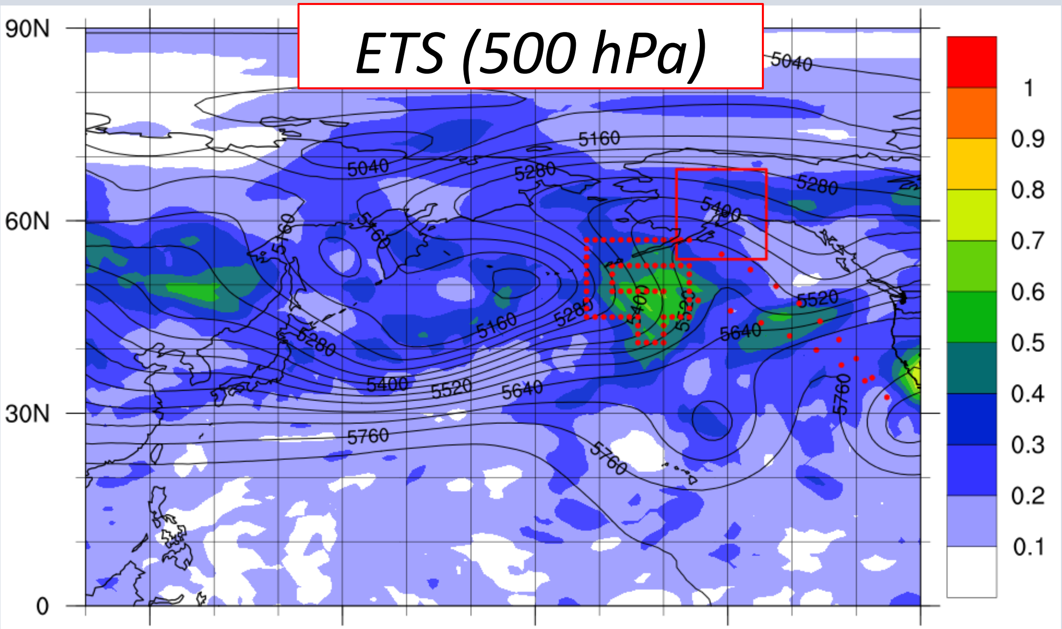
OSSE Experiment Design February Alaska Storm
Cycling GFS model 2-3 days in advance of Verification Time of 00 UTC Feb 2

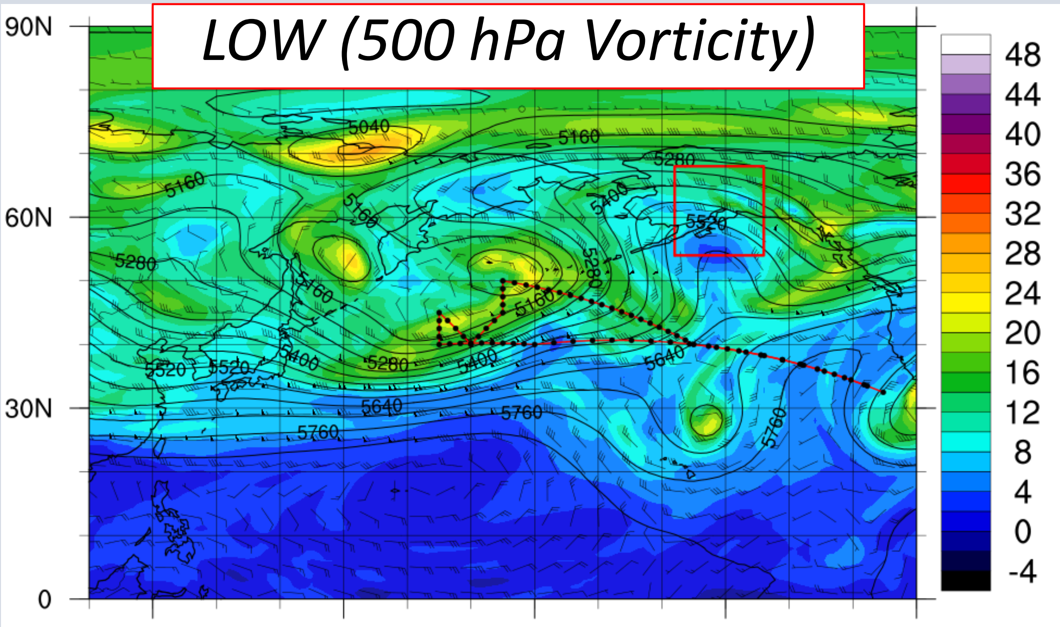


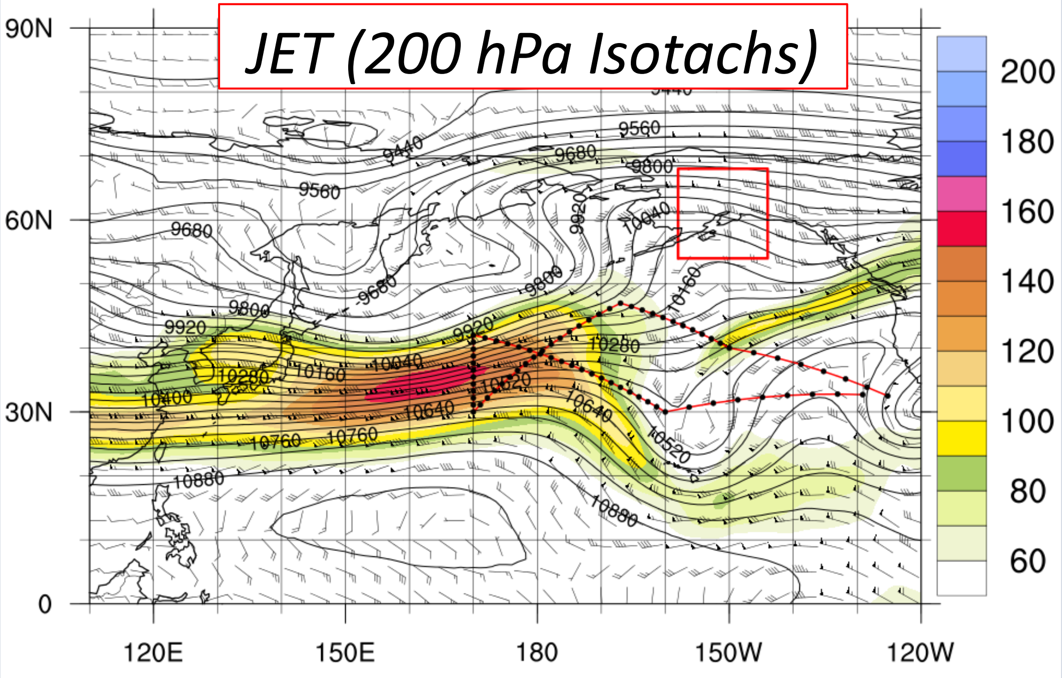
Experiment Name	Description
CTL	Operational obs. only
ETS	Automated ETS flight path design
LOW	Sample rapidly developing Low-pressure
JET	Sample jet exit region
MOIST	Sample Atmospheric river

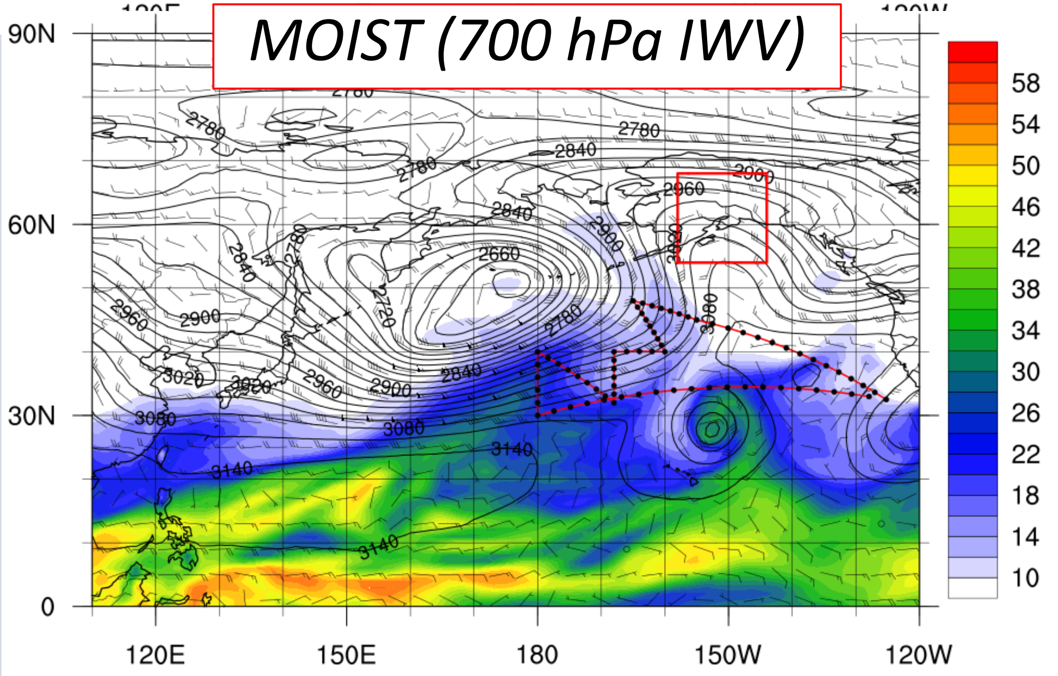
- 70-80 dropsondes per simulated GH flight
- *ETS* flight based on average 2-3 day ETS sensitivity
- Results verified against ECMWF T511 Nature Run

OSSE Simulated Flight Tracks

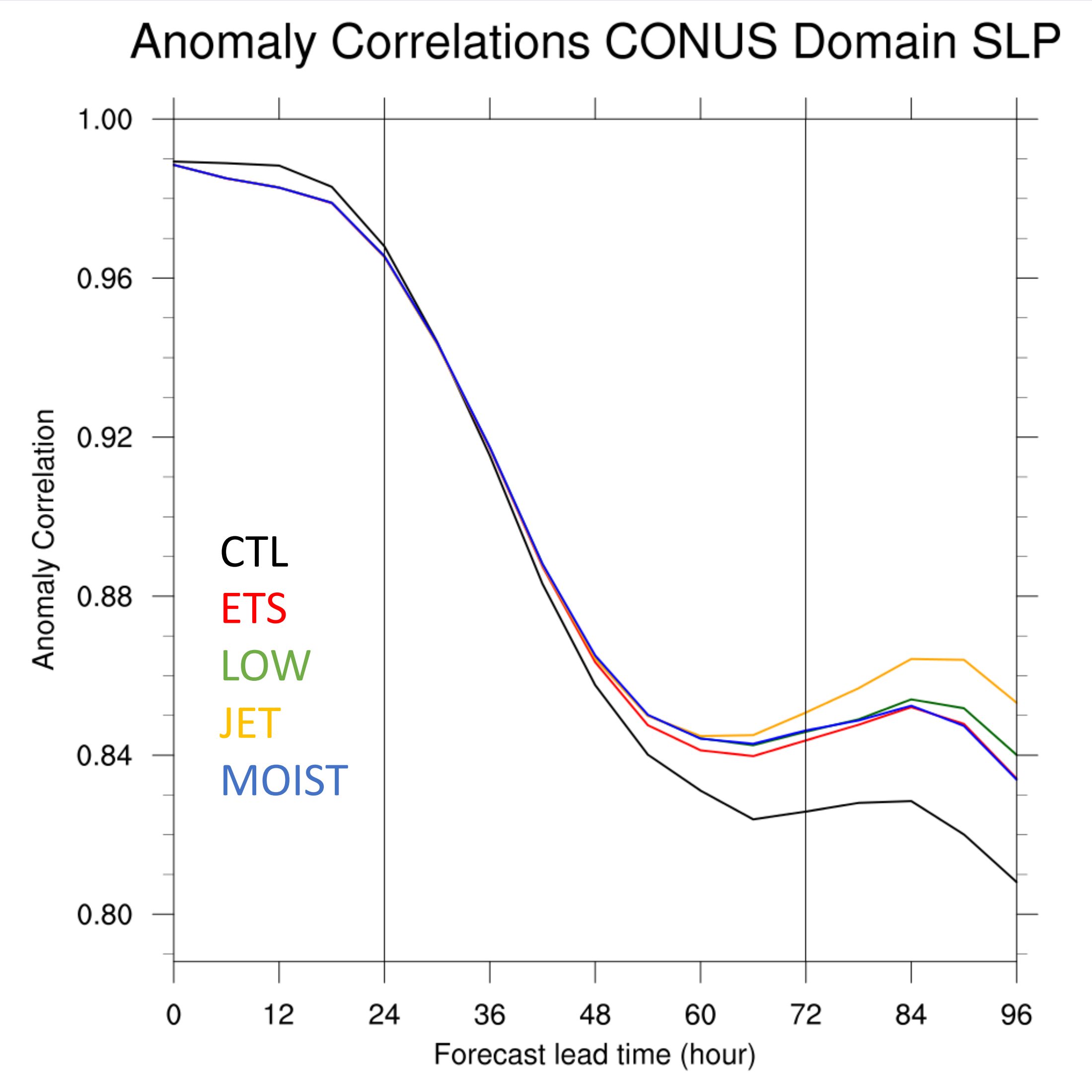


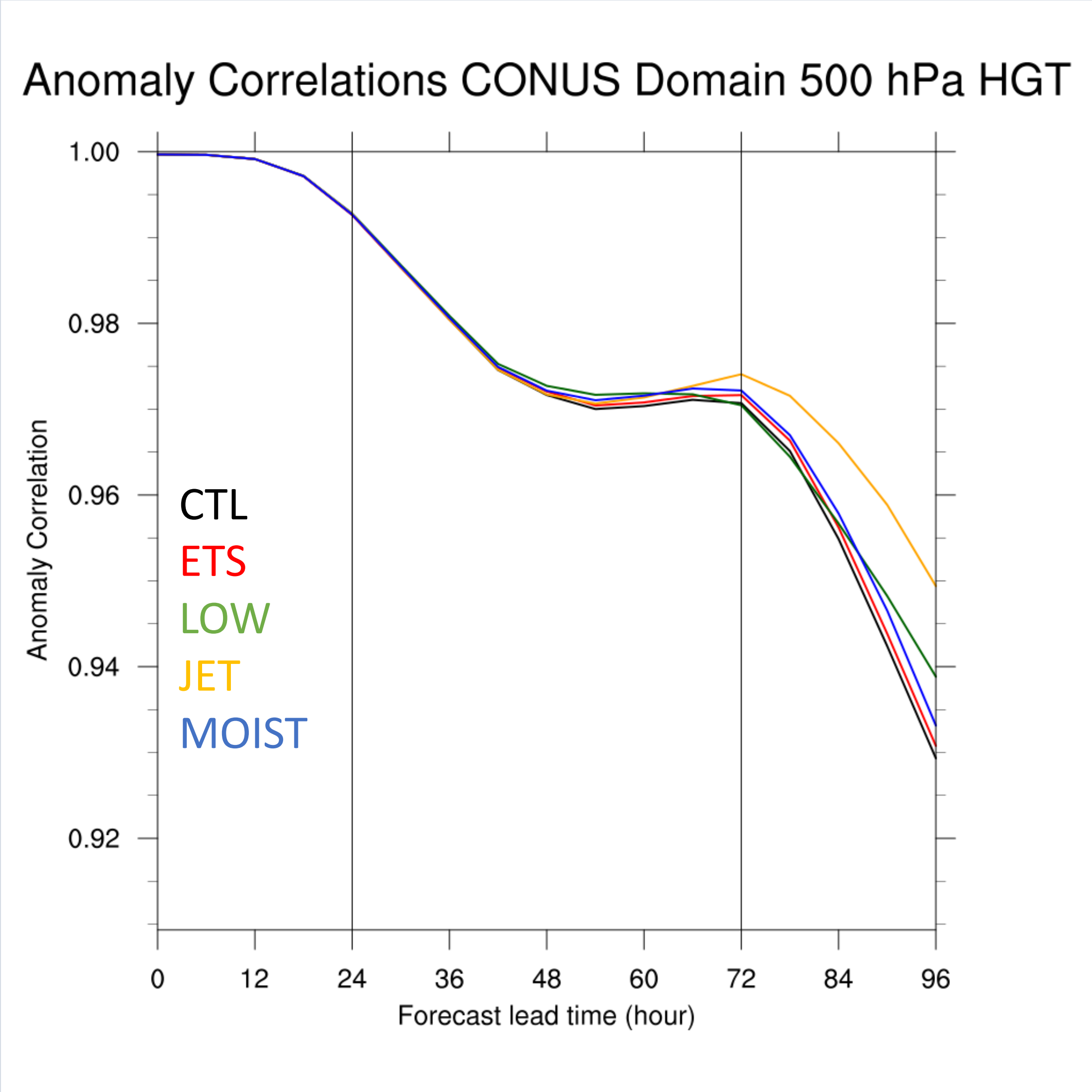






Simulated dropsondes increase forecast skill among all flight tracks





Summary

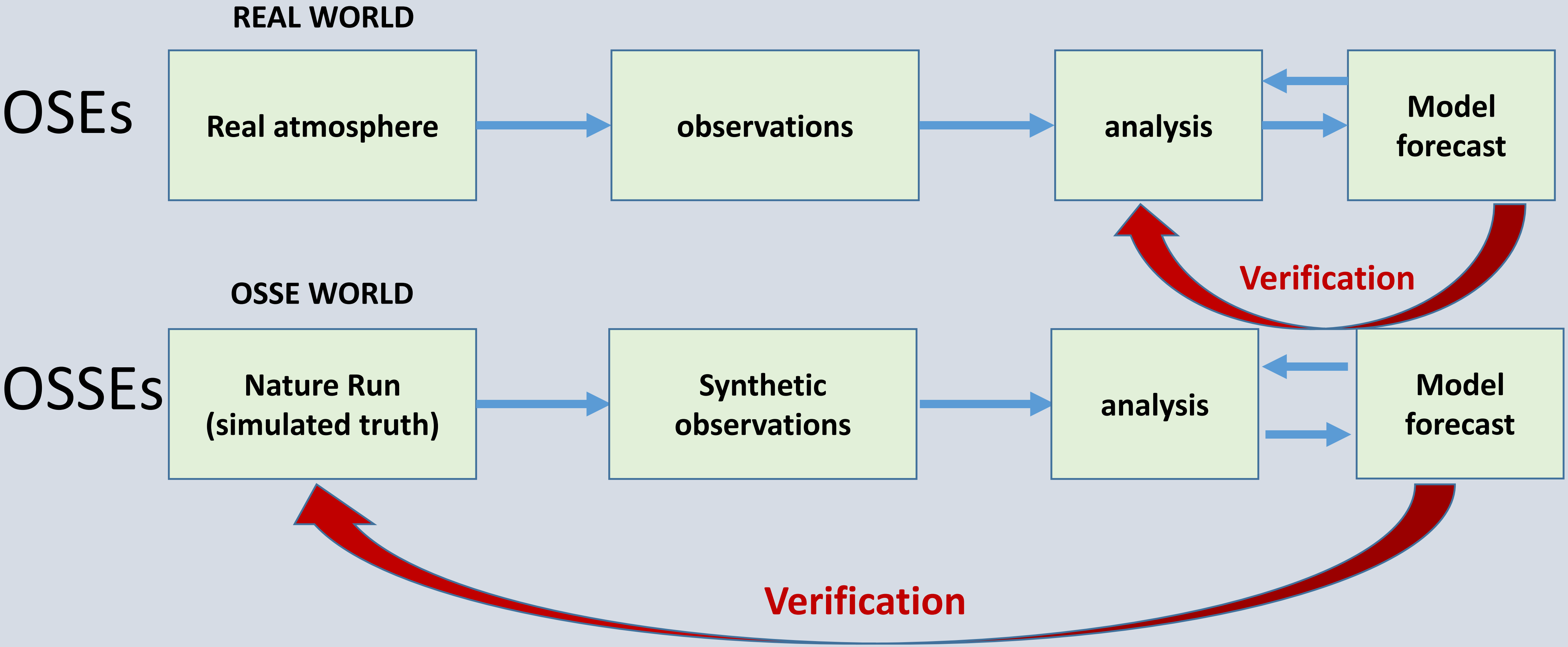
- SHOUT-ENRR OSE impact results
  - Increased forecast skill and reduced error when using targeted GH dropsondes during current observing and potential future satellite data gaps

- OSSE studies
  - Validation of ETS technique shows it accurately identifies regions of increased error growth with higher forecast skill in *AUTO* path compared to *CTL*
  - Sampling upper-level jet streak and developing low show largest improvement over *CTL* forecasts in 1-3 day forecast lead times
  - Importance of both sensitive regions and key meteorological features

- Future Research needs
  - Further UAS campaigns to examine statistical significance of targeting
  - Dropsondes, microwave instruments, radar, and SST fluxes using UAS platforms

Backup slides

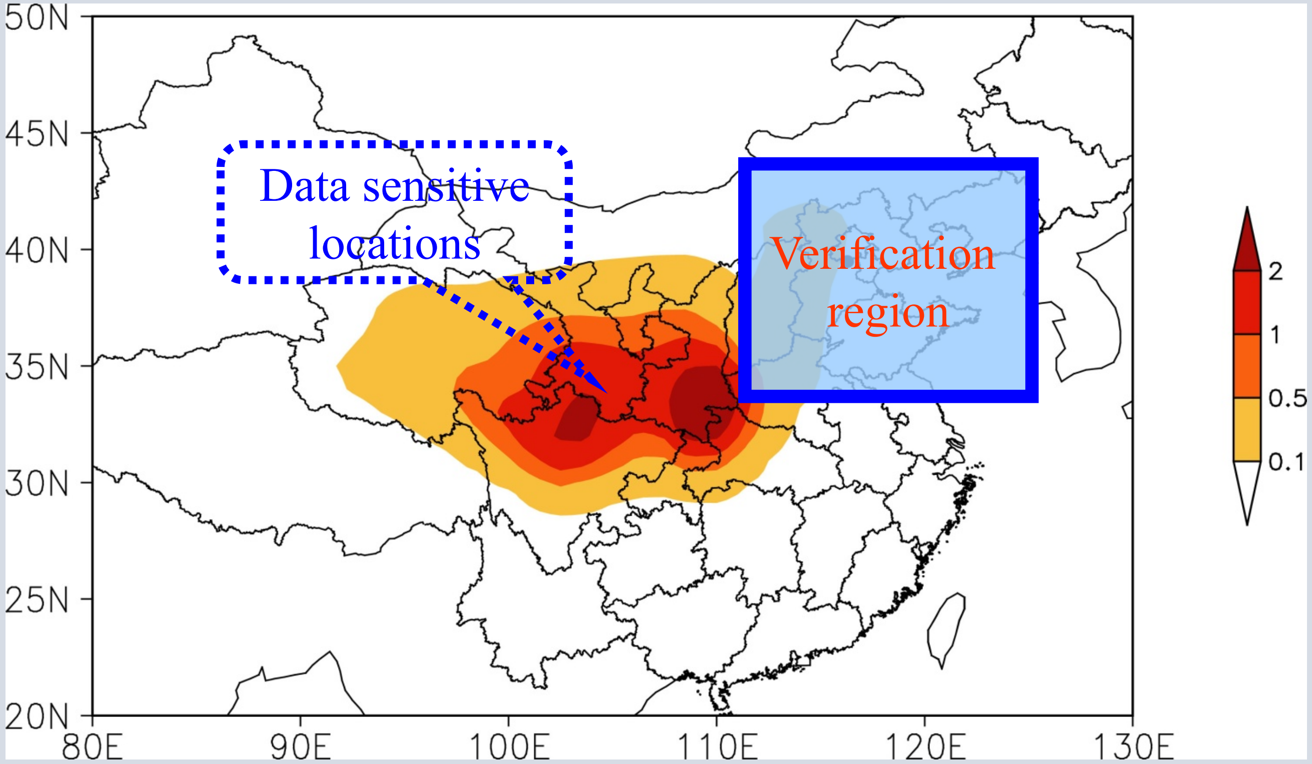
Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs)



Courtesy: Lidia Cucurull

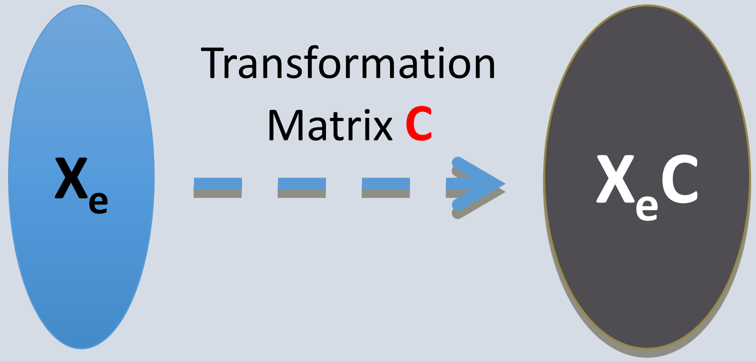
Ensemble Transform Sensitivity technique

(a) Calculate Ensemble transform matrix
(b) Predict forecast error covariance (analysis and forecast error)
(c) Estimate prediction error variance reduction



The locations of sensitive regions is dependent on the area in which a forecast improvement is wanted, the verification area, but also the forecast length and the atmospheric flow between the targeting and verification times.

Zhang et al. (2016)



Ensemble perturbations 80 GEFS members

Perturbations transformed to represent effect of adaptive observations

specify regions for possible adaptive observations

ETS based on Total Energy Norm
Temp, wind at 200, 500, 700 hPa

Atmospheric Variable	*DROP vs. CTL*	*DROP_noNPP vs. noNPP*
200 Height	-3.46	-3.05
300 Height	-1.12	-2.99
500 Height	-3.03	-4.22
700 Height	-3.66	-4.79
850 Height	-3.74	-4.44
925 Height	-3.68	-4.19
Sea-Level Pressure	-3.13	-3.7
200 Temperature	0	-1.53
300 Temperature	-0.5	-2.46
500 Temperature	0.62	-0.62
700 Temperature	-0.91	-0.91
850 Temperature	-1.61	-0.81
925 Temperature	-0.5	-1
200 u-wind	-1.98	-2.01
300 u-wind	-0.61	-3.59
500 u-wind	-2.08	-1.34
700 u-wind	-2.11	-1.89
850 u-wind	-2.72	-1.84
925 u-wind	-2.18	-1.48
200 v-wind	-3.11	-2.11
300 v-wind	0.3	-1.48
500 v-wind	-0.78	-1.95
700 v-wind	-1.65	-1.42
850 v-wind	-1.81	-2.03
925 v-wind	-1.81	-2.55
200 RH	-2.29	0
300 RH	1.87	-1.11
500 RH	-0.81	-0.45
700 RH	-0.75	-0.84
850 RH	-1.63	-1.33
925 RH	-0.92	-0.31

Comprehensive Evaluation of Relative RMSE in current and potential future observing systems

Reduction in forecast error of 1-5% across several variables