Moving AMSU-A to all-sky assimilation at ECMWF

David I. Duncan, Niels Bormann,

Peter Weston, Alan Geer

ITSC-23, June 2021

ECMWF

David.Duncan@ecmwf.int

Background

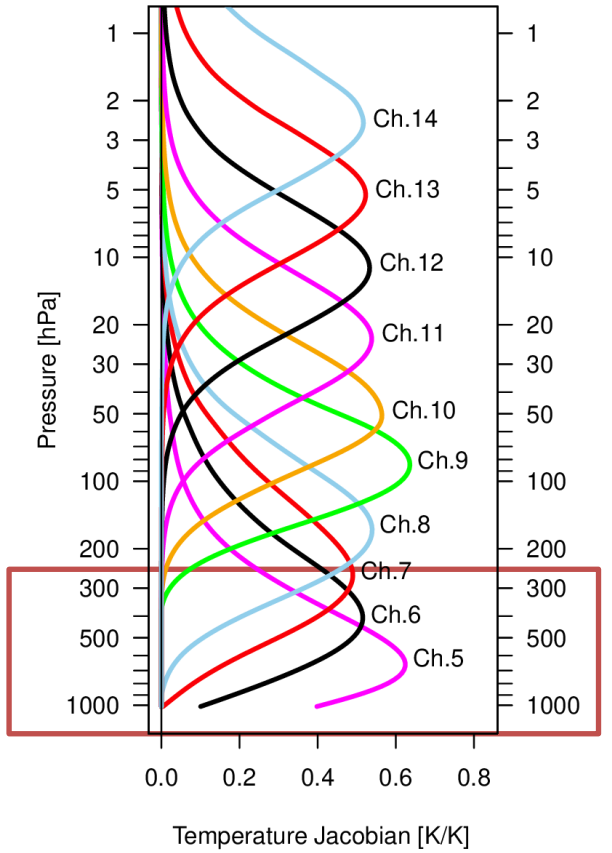
ECMWF assimilates AMSU-A channels 5-14 in clear-sky conditions

Data used through clear-sky (CS) assimilation; cloud screening only significant for a few tropospheric channels – 5, 6, 7

All-sky (AS) assimilation should provide better coverage of *persistently cloudy regions* and *high-impact weather*

It's a goal to transition to AS for AMSU-A, but several challenges exist:

- CS has been refined over 20 years – any sub-optimal settings for AS are magnified
- Observations added exclusively in cloudy conditions, requiring well-tuned error model
- Temperature signals are order ~0.1K, but AS errors can be 10K



ECMWF

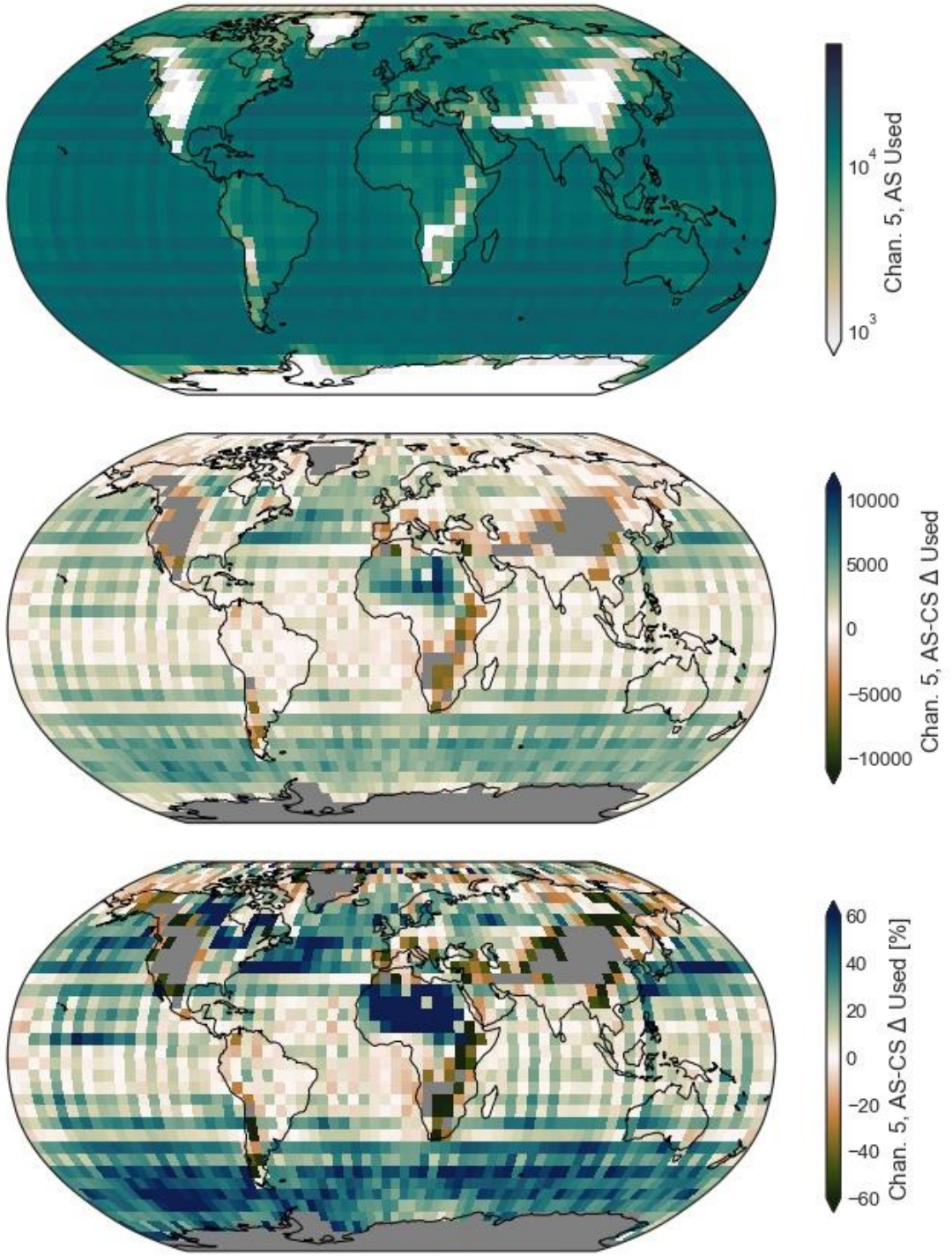
All-sky for T sounders

Data selection applies lessons from AS humidity sounders:

- Removal of thinning preference for clear-sky scenes
- Pick observation nearest T159 grid point (~120km spacing)
- No ‘sink variable’ for skin temperature

Otherwise, many CS elements retained:

- Replicate across-scan and latitudinal sampling
- No super-obbing
- Slant-path radiative transfer
- Screen out high orography and Antarctica for low-peaking channels
- Thin all satellites together
- AMSU-A continues to anchor the stratosphere



Less / More Ch 5 used in All-sky

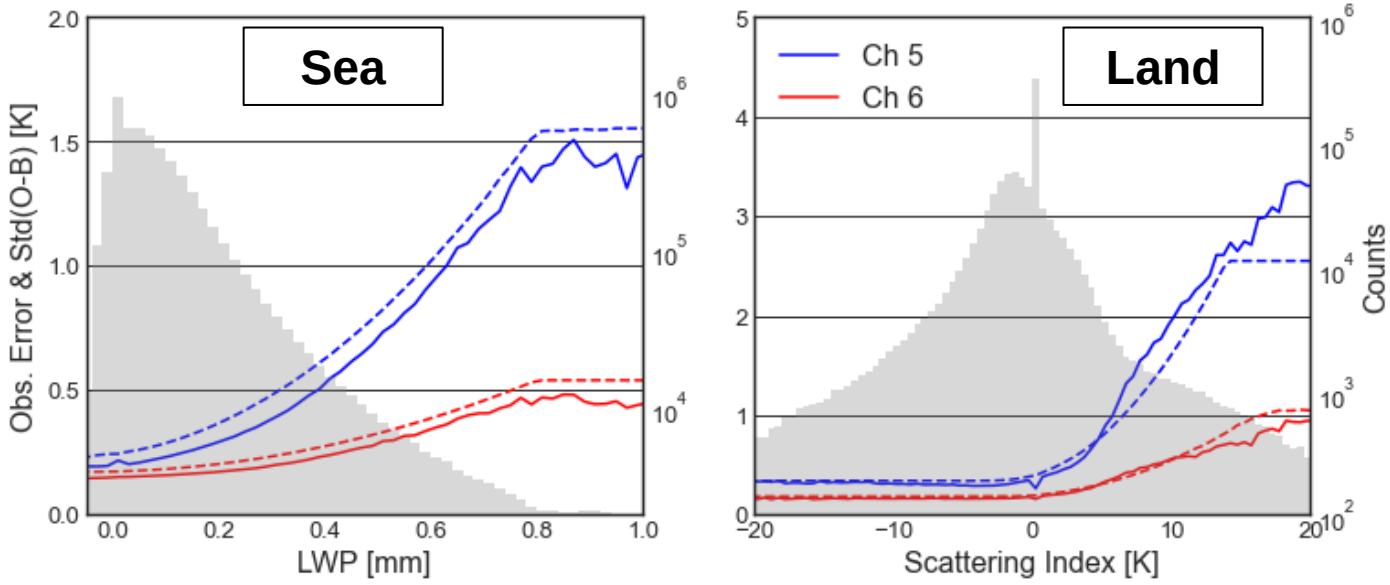
All-sky for T sounders

All-sky error model based on a ‘symmetric’ cloud predictor (Geer & Bauer, 2011)

- Linear or quadratic increase with predictor
- Symmetric predictor balances scattering signals from model and observation

For AMSU-A, we lack polarization information used by imagers and high frequency channels used by H sounders

- Liquid water path retrieval (sea)
- 23-89GHz scattering index (land)



ECMWF

All-sky for T sounders

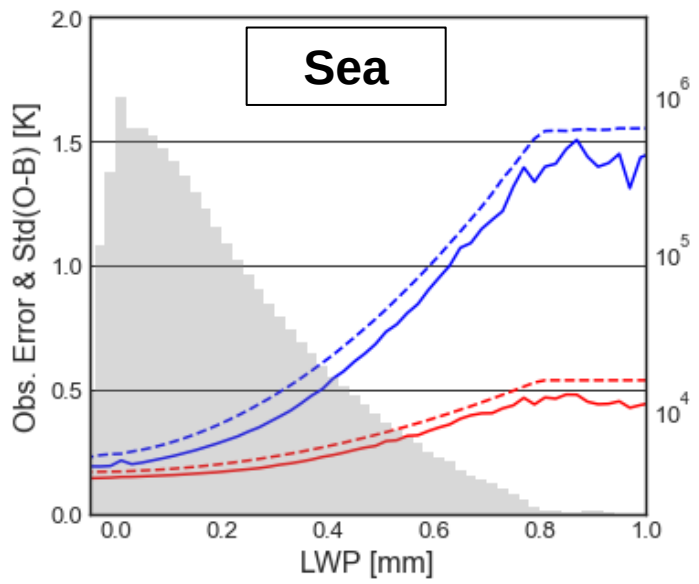
All-sky error model based on a ‘symmetric’ cloud predictor (Geer & Bauer, 2011)

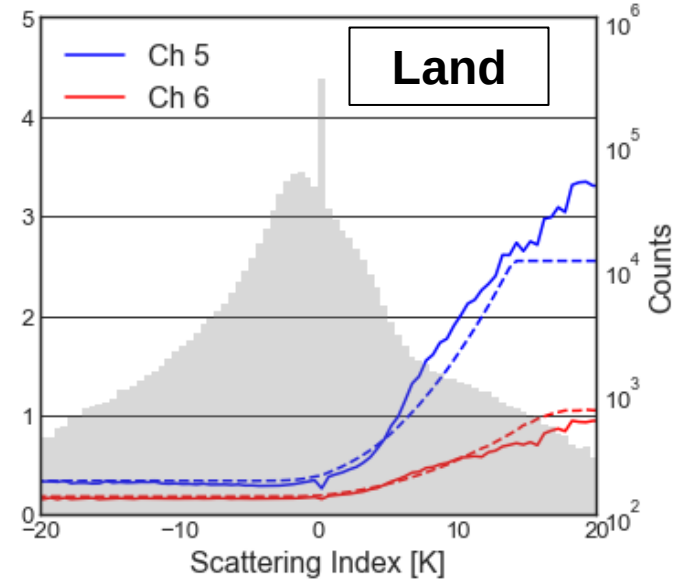
- Linear or quadratic increase with predictor
- Symmetric predictor balances scattering signals from model and observation

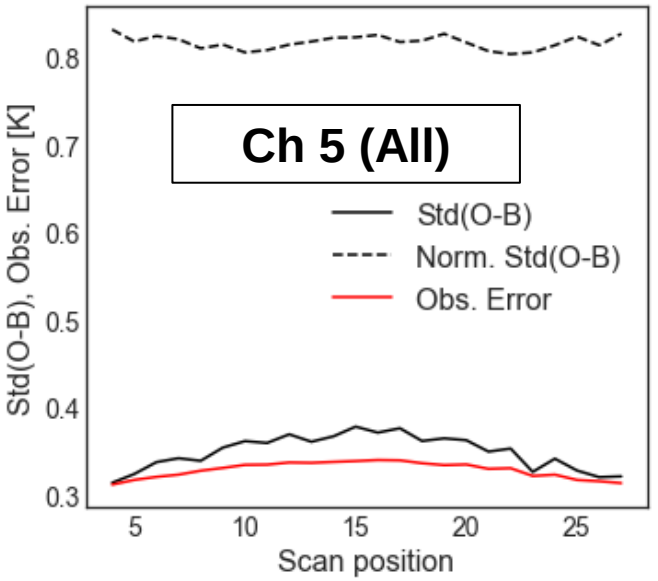
For AMSU-A, we lack polarization information used by imagers and high frequency channels used by H sounders

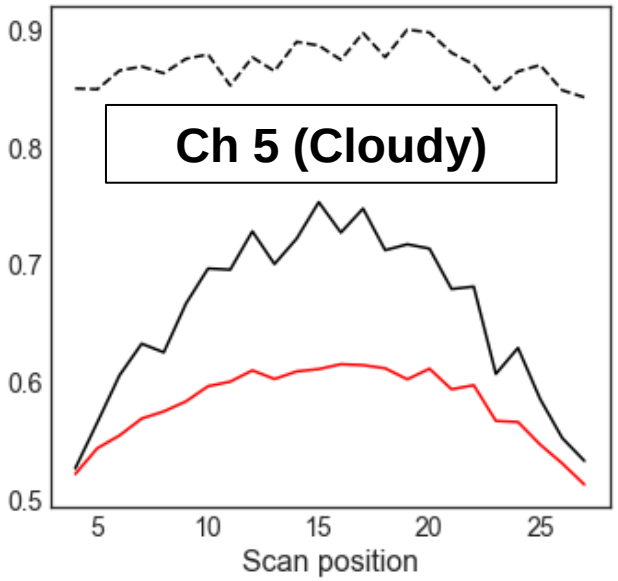
- Liquid water path retrieval (sea)
- 23-89GHz scattering index (land)

Higher errors near nadir, so apply scan-dependent weighting to error model



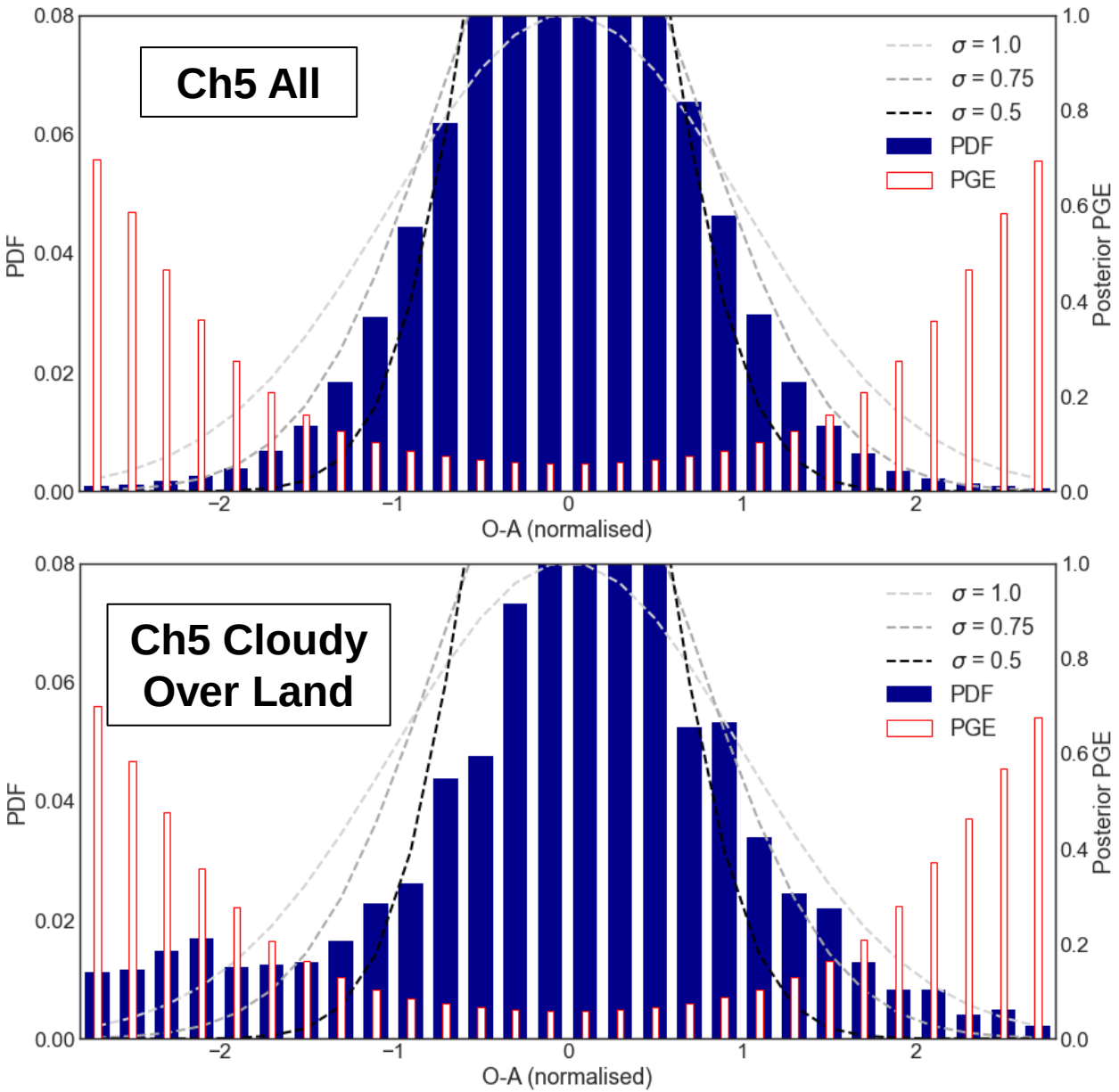






ECMWF

All-sky for T sounders



VarQC systematically down-weights observations far away from the analysis state

*We set a priori **probability of gross error (PGE)** by channel*

This has proven crucial for all-sky imager & H sounders before

VarQC was a critical element of driving forecast improvements for AS AMSU-A

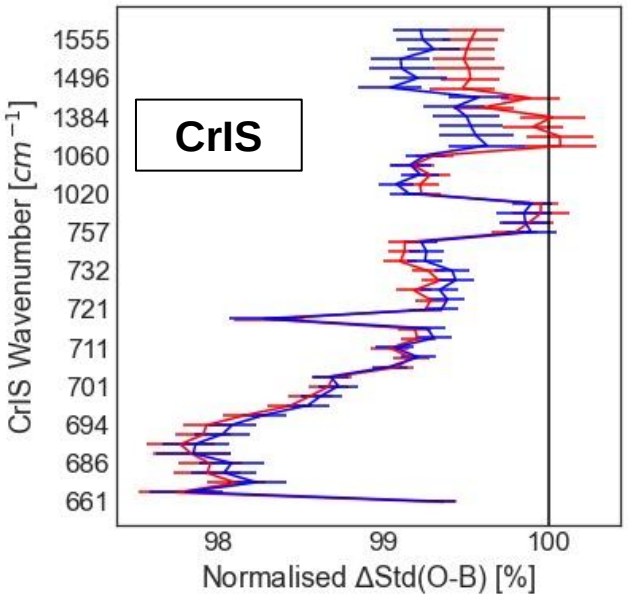
- Cloudy departures can yield more skewed / non-Gaussian PDFs, for channel 5 especially
- Channel 5 and 6 VarQC a priori increased relative to CS settings
- Surface sensitivity to emissivity errors is also dulled by VarQC
- Care needs to be taken that clear observations are not overly down-weighted by VarQC and that is reflected in error model

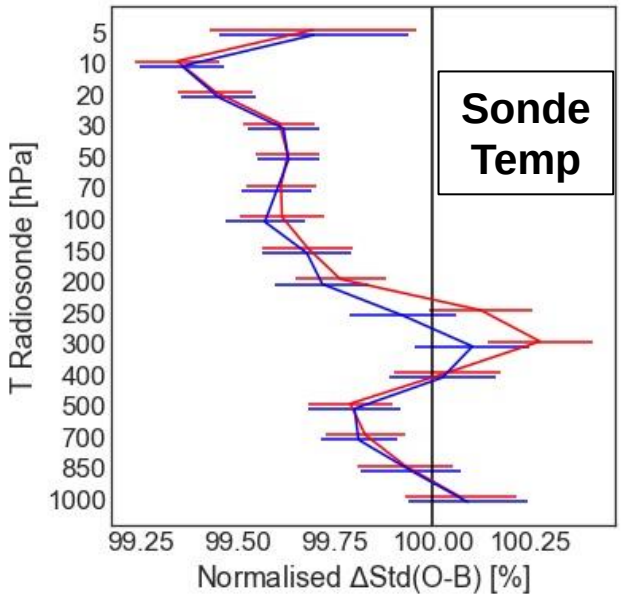
Results

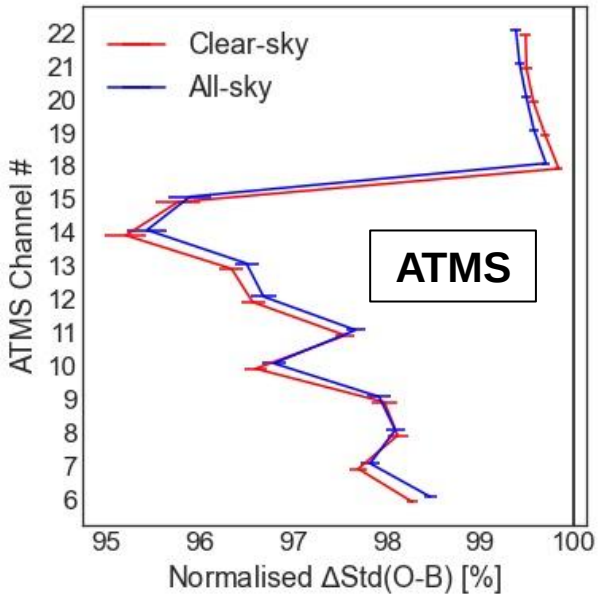
Compare AS & CS against an AMSU-A denial experiment (2 seasons, TCo399, Cycle 47R1)

- Overall impact is very similar between CS & AS
- True for medium-range scores and observation space
- Small differences exist for ATMS and humidity sensitive observations

Clear-sky AMSU-A
All-sky AMSU-A
AMSU-A Denial



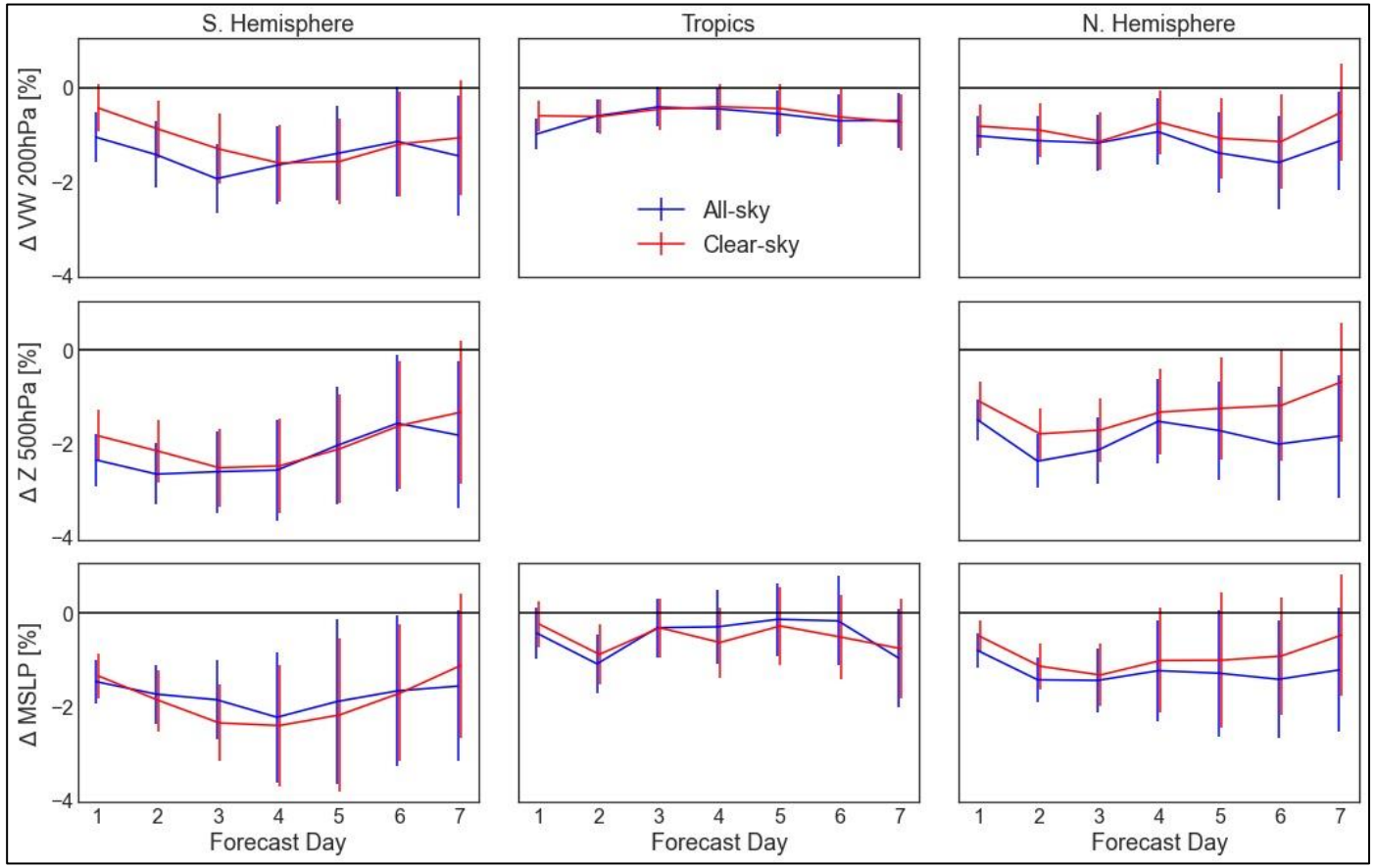




Results

Compare AS & CS against an AMSU-A denial experiment (2 seasons, TCo399, Cycle 47R1)

- Overall impact is very similar between CS & AS
- True for medium-range scores and observation space
- Small differences exist for ATMS and humidity sensitive observations



Clear-sky AMSU-A
All-sky AMSU-A
AMSU-A Denial

Conclusion: AS **replicates** overall forecast impact of CS AMSU-A, with some small benefits visible too

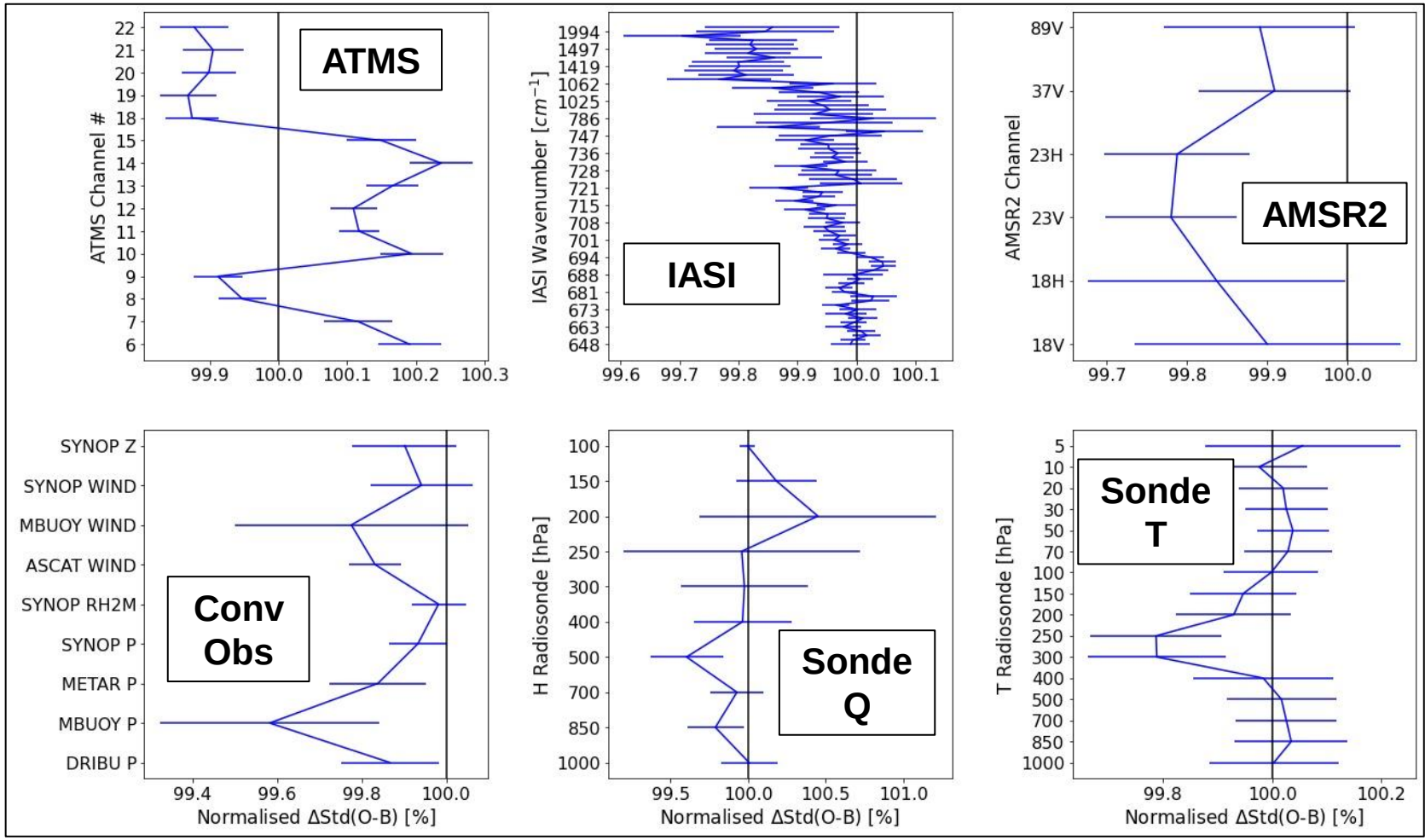
ECMWF

Results

Now we compare directly to current operational assimilation system (clear-sky AMSU-A)

- Improved representation of humidity is clear in MW, IR, and conventional obs
- Despite Ch5 peaking around 600hPa, improvements seen for surface pressure and ASCAT 10m winds particularly in tropics
- Around 0.5% decrease in Z500 RMSE, significant out to day 2

All-sky AMSU-A
Clear-sky AMSU-A



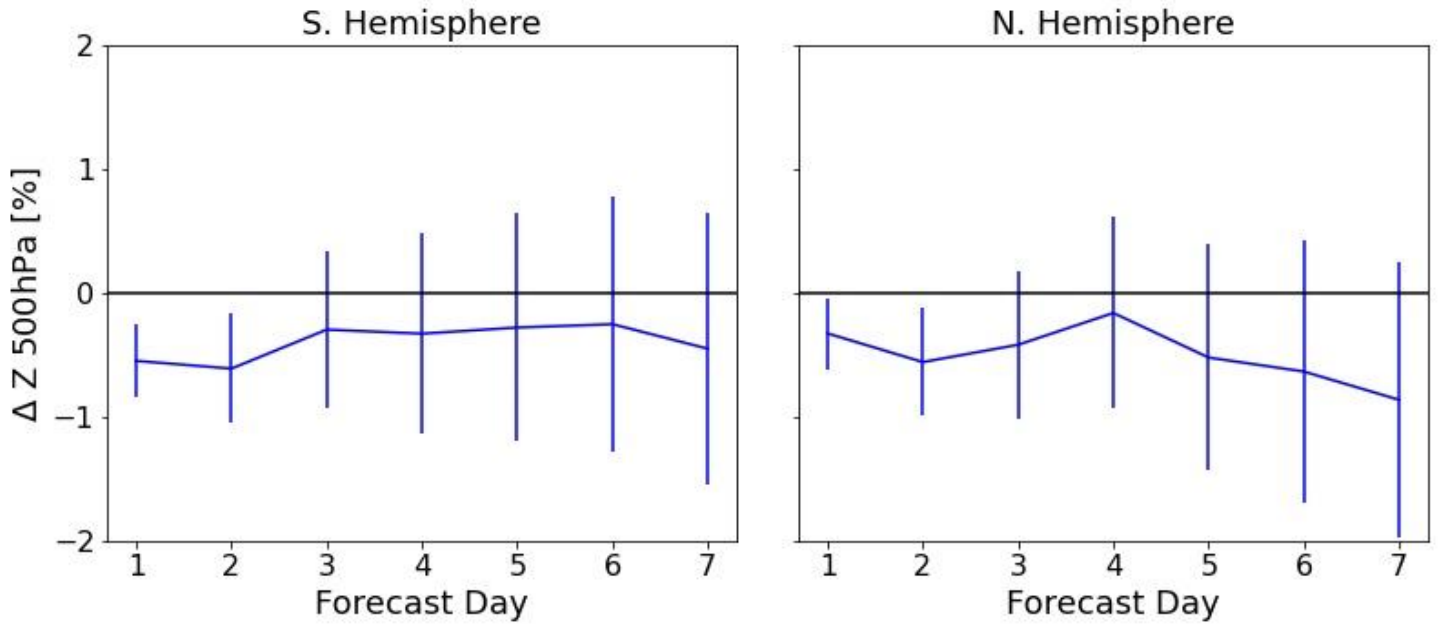
Conclusion: all-sky now **exceeds** overall forecast impact of clear-sky AMSU-A assimilation

ECMWF

Results

Now we compare directly to current operational assimilation system (clear-sky AMSU-A)

- Improved representation of humidity is clear in MW, IR, and conventional obs
- Despite Ch5 peaking around 600hPa, improvements seen for surface pressure and ASCAT 10m winds particularly in tropics
- Around 0.5% decrease in Z500 RMSE, significant out to day 2

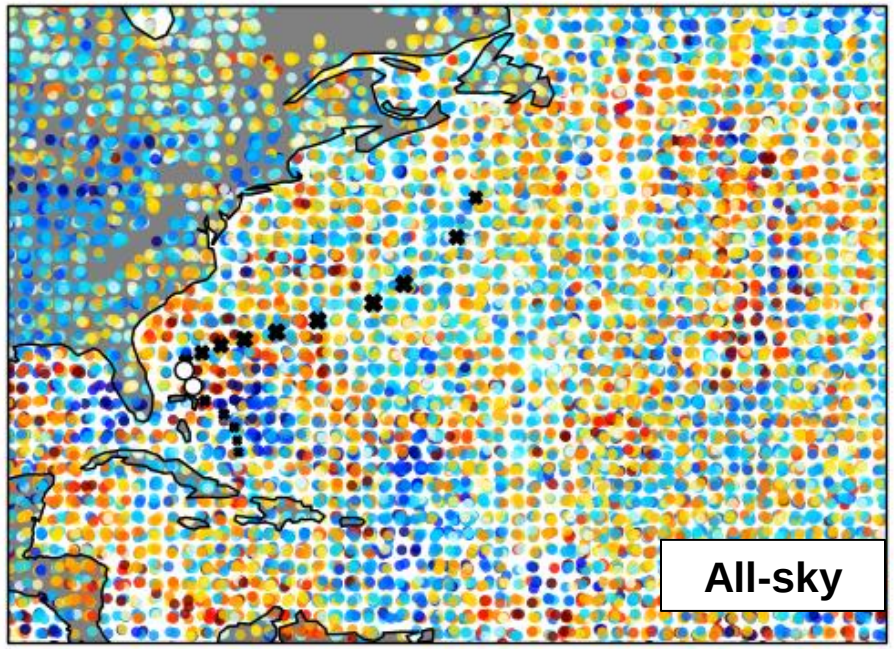


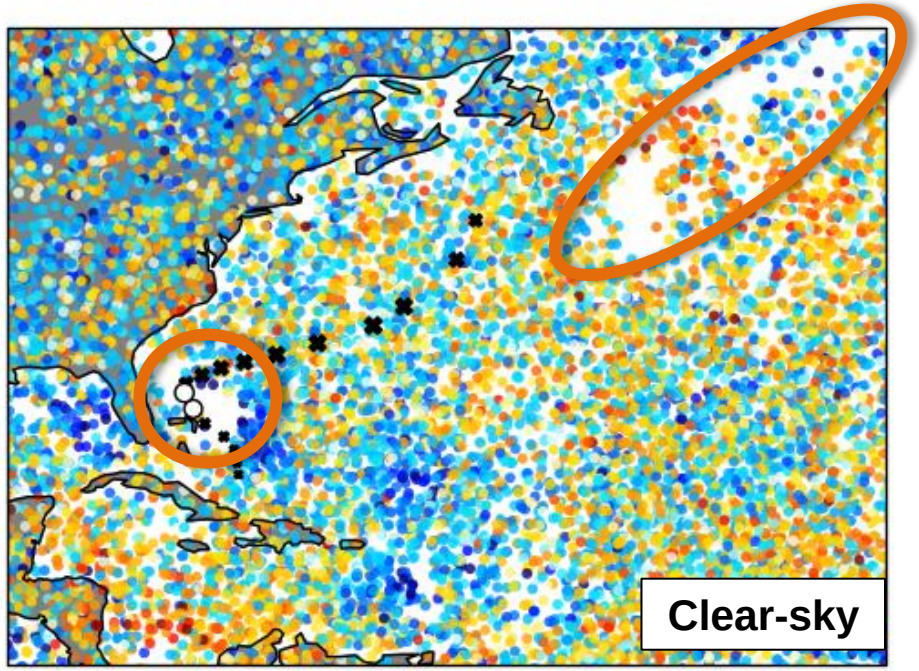
All-sky AMSU-A
Clear-sky AMSU-A

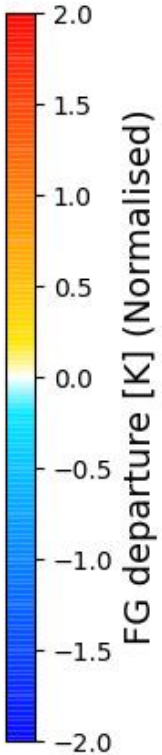
Conclusion: all-sky now **exceeds** overall forecast impact of clear-sky AMSU-A assimilation

ECMWF

High-impact sampling







Tropical cyclones provide excellent example of the increase in sampling from all-sky

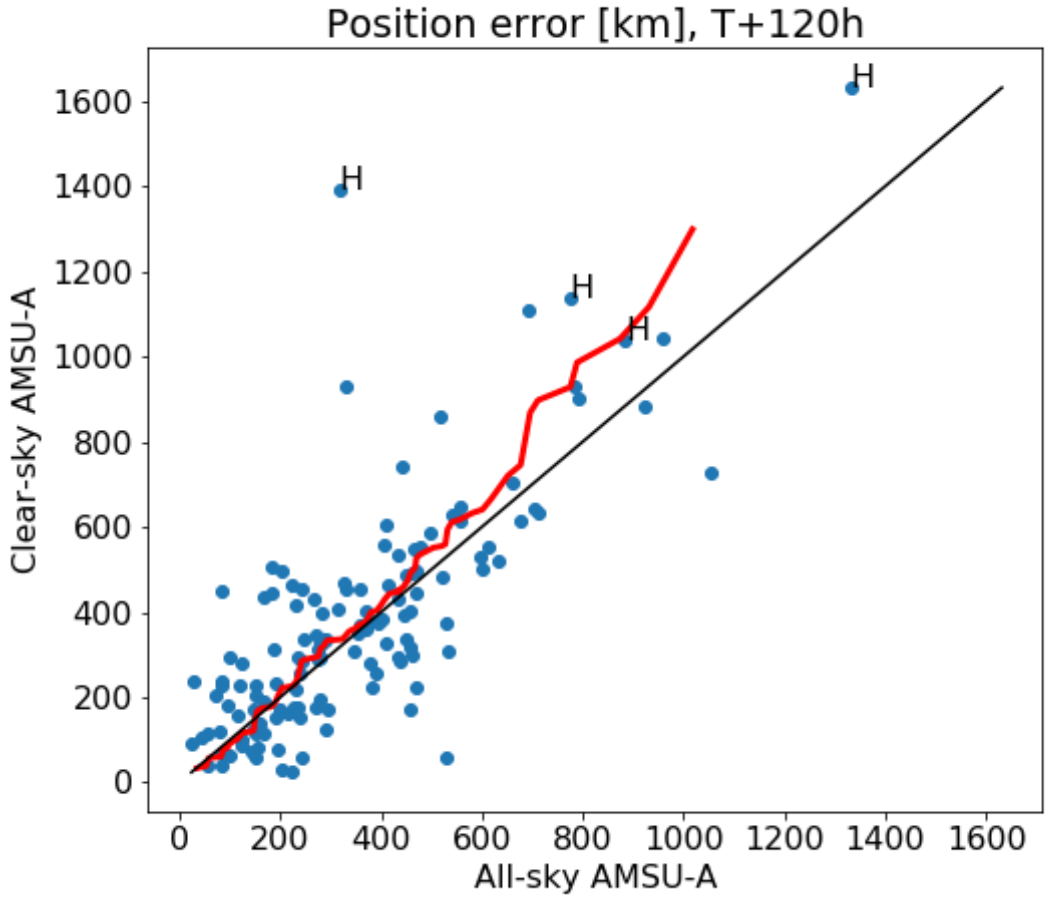
Here Hurricane Humberto makes a sharp turn to north Atlantic, better observed by AMSU-A

- In our experimentation, all-sky AMSU-A improved representation of Humberto's extratropical transition
- This helped mitigate a multi-day forecast bust over Europe

High-impact sampling

Over the active 2019 hurricane season (Jun-Nov), the all-sky experiments outperformed CS

- TC track errors reduced (D+5 shown)
- Biggest improvement was for Humberto (H in figure)
- Absolute central pressure errors also reduced
- Hypothesis: combined impact of AMSU-A *near cyclone and downstream* improves cyclone circulation and the steering flow

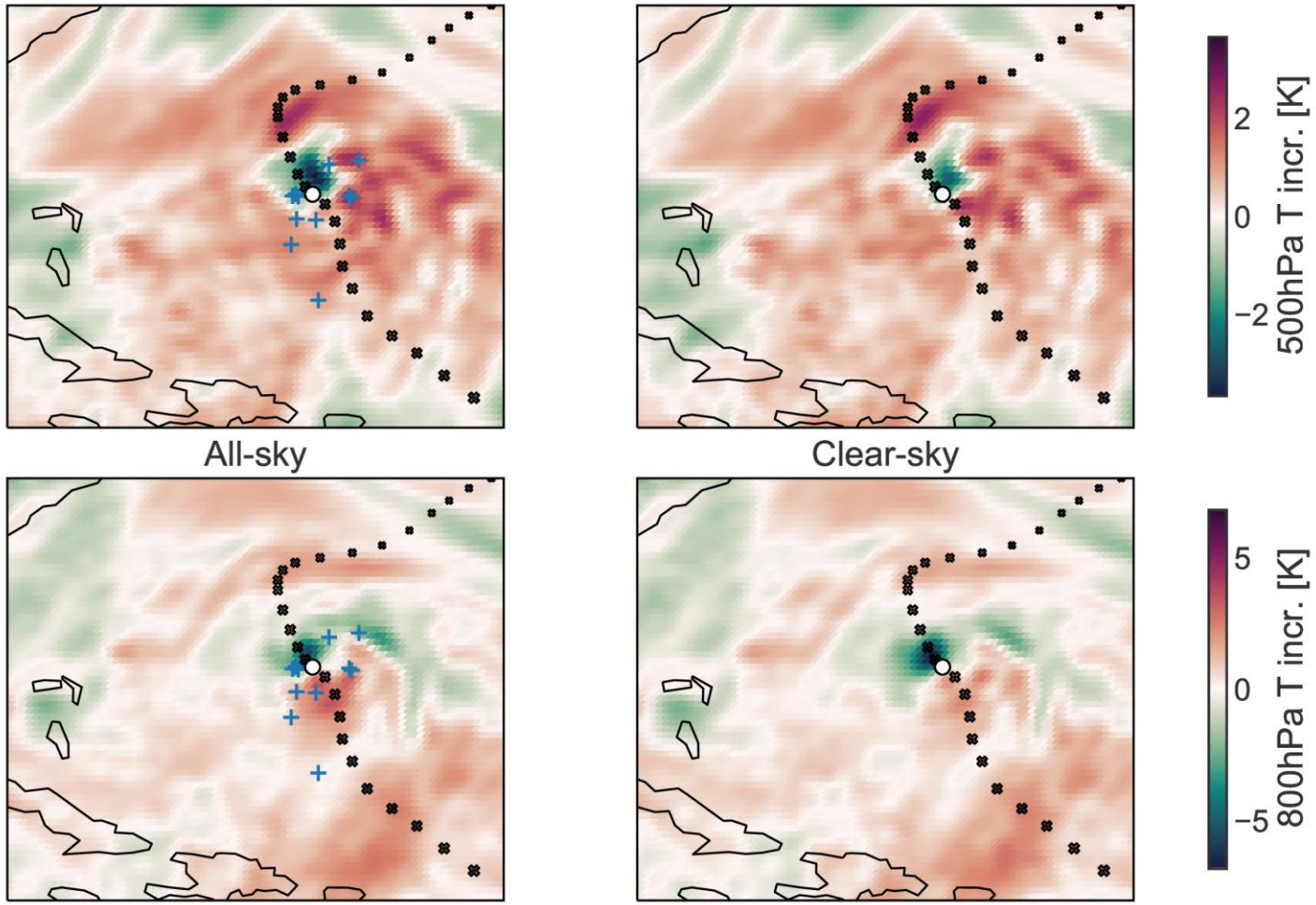


ECMWF

High-impact sampling

An extreme example of all-sky temperature sounder impact was for Tropical Storm Jerry

- Shown are analysis increments for temperature, begun from same background state
- Several very large FSOI values indicate a large impact (**+**) near the eye itself
- *Sharper increments are evident in the all-sky experiment*, nearby AMSU-A obs
- Impact from all-sky T sounding reaches lower tropospheric levels of circulation
- This case showed the *power of multiple AMSU-A sensors*, with NOAA-15/18/19 and Metop-A/B/C all sampling near the cyclone with very impactful observations



ECMWF

Conclusions

After years of development, all-sky temperature sounding *matches and exceeds* clear-sky impact

Compared to CS, several benefits:

- Humidity fits (IR & MW)
- Surface observations (pressure, winds)
- Improved mass distribution in stratocumulus regions
- Increase data usage:
  - +13% for Ch. 5
  - +6% for Ch. 6
- 0.5% improvement in Z500 through at least day 2

All-sky AMSU-A will be active as of October 2021, part of IFS upgrade to Cycle 47R3

Except for ATMS, all MW sensors will then be assimilated in all-sky at ECMWF

Future development: ATMS all-sky, AMSU-A Ch. 4

ECMWF