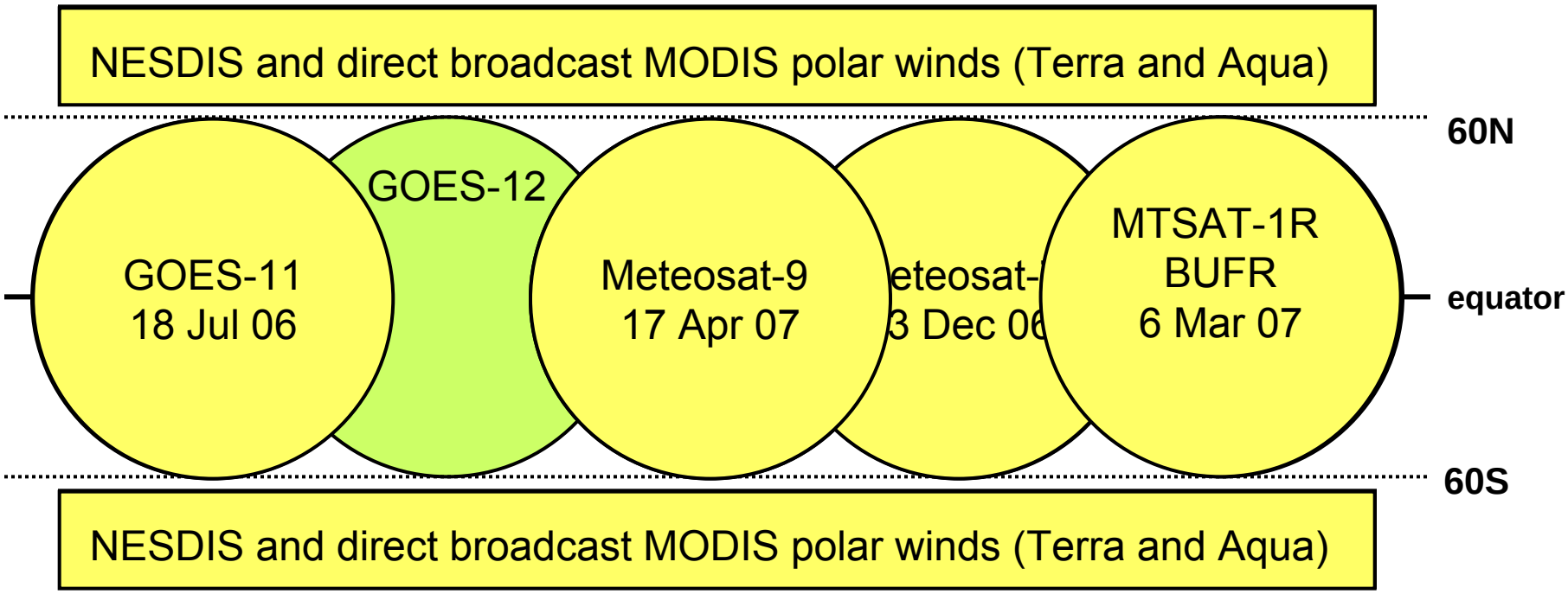
# AMV errors

## A new approach in NWP

Mary Forsythe and Roger Saunders, 9th International Winds Workshop, Annapolis, 15th April 2008

# AMV Satellite Status Update




In near future

- AVHRR polar winds from NOAA 15-18

Further ahead

- AVHRR polar winds from Metop-A
- Meteosat-8 rapid scan winds

We also plan to assess other AMV data sets

# AMV data denial trials

## Introduction

*Compare AMV denial results at several NWP centres using the same season.*

**Centres involved so far are:**

- Met Office
- JCSDA
- ECWMF
- Meteo-France
- DWD

**Season:** 12th Dec 2007 – 12th Jan 2008

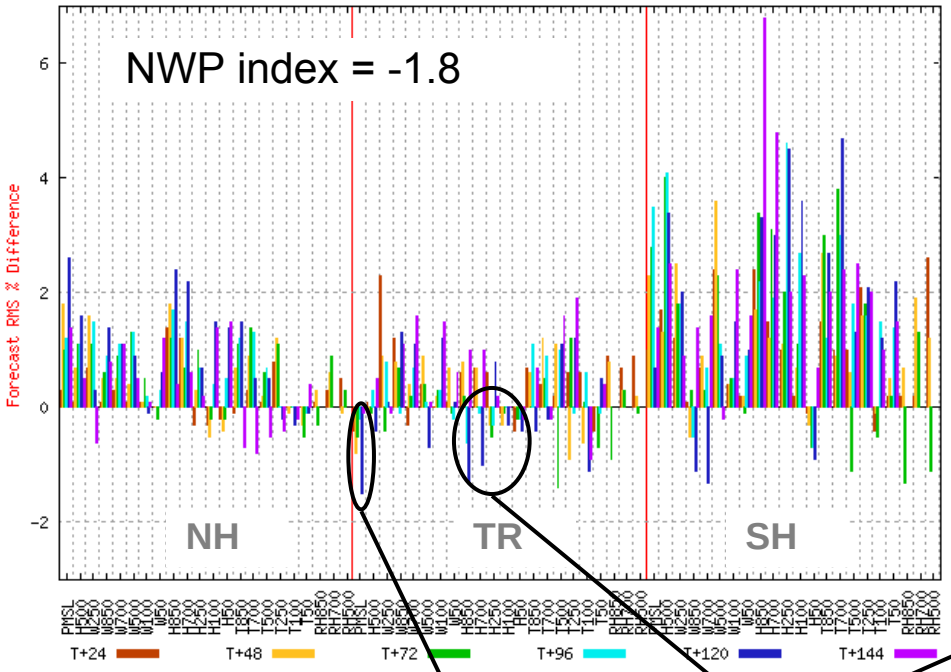
There are differences between the operational set-up, trial set-up and verification systems at different centres, but the results should give us some idea of whether we see similar impacts.

*Additionally at Met Office can compare results to previous AMV data denial and to other data denial experiments – some results shown here.*

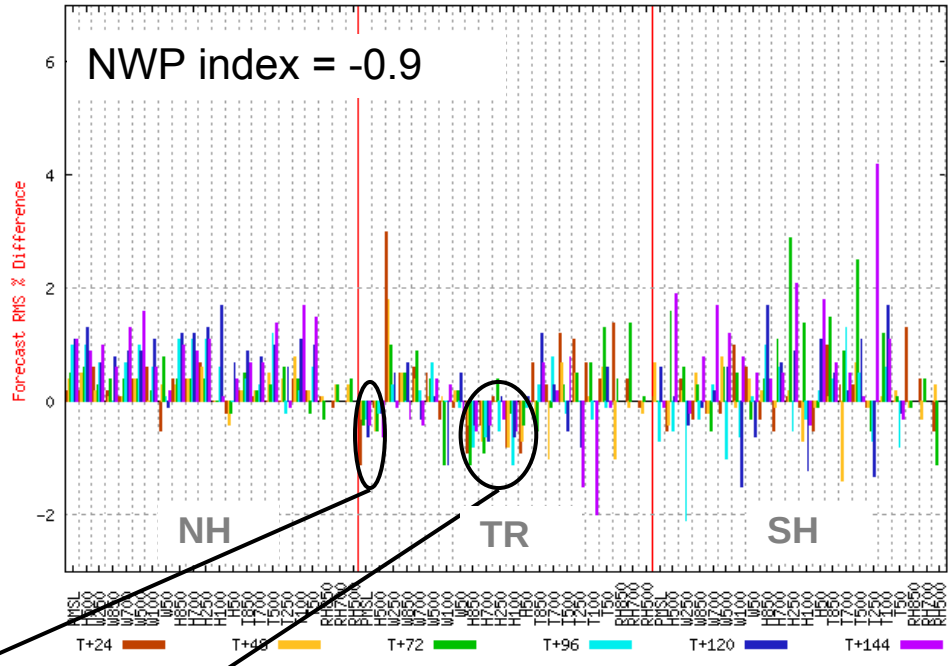
# AMV data denial trials

## Verification versus observations

12/12/05 – 11/01/06




12/12/07 – 12/01/08




Mostly positive impact from AMVs

Poor impact on TR PMSL

Poor impact on TR height fields

Overall similar pattern of impacts, but generally smaller in Dec 07 season. May be partly due to other improvements e.g. IASI, GPSRO and model changes.

# Contents

This presentation covers the following areas

- A new approach to setting AMV errors
- Assimilation trial results
- Where to go from here…
- Summary

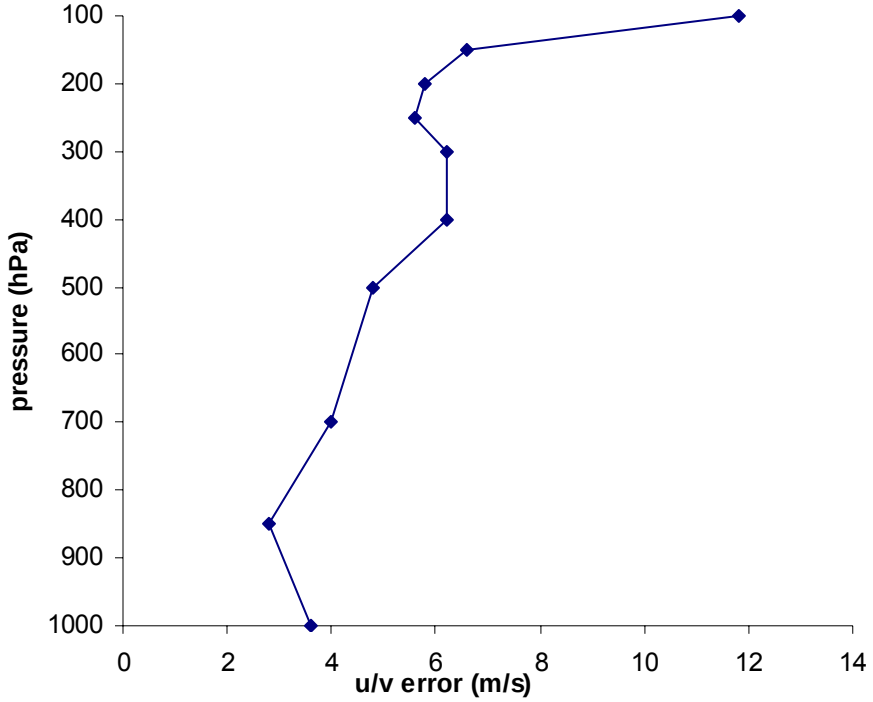

# A new approach

## to setting AMV errors

# Introduction

A good specification of the observation error is essential to assimilate in a near-optimal way

Currently observation errors vary only with pressure




Based on O-B statistics, but inflated to alleviate problems with spatially correlated error

# Two different approaches

## Statistical

*Identify factors that may affect the errors and use these as predictors*

e.g. wind speed

wind shear etc.

Use linear regression against AMV-RAOB vector differences to create regression coefficients, which are then used to estimate the AMV errors.

Method used for producing expected errors – see Le Marshall & Rea, 2004 (Aust Met Mag, 53, 123-131) and Howard Berger's talk.

This is a simpler approach, but is always going to be limited.

## Physical

*Try to understand what the error sources are and attempt to quantify them*

Requires understanding of errors in the radiance data and errors due to limitations of the AMV derivation approach.

A tougher problem, but there is information available during the derivation that can be used as a start.

Approach I would like to see pursued.

# Physical approach

## Error sources

Two independent sources

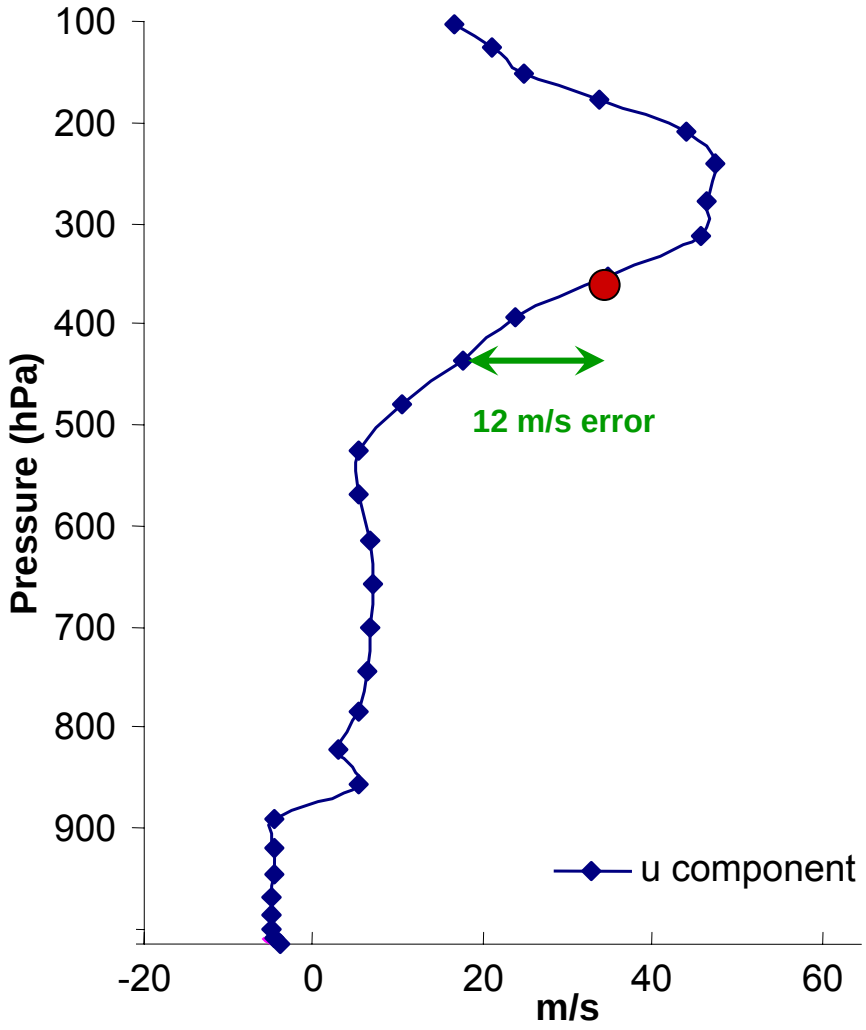
**Error in vector**

• Linked to accuracy of tracking step

**Error in height**

• Linked to accuracy of height assignment

• More problematic if large vertical wind shear

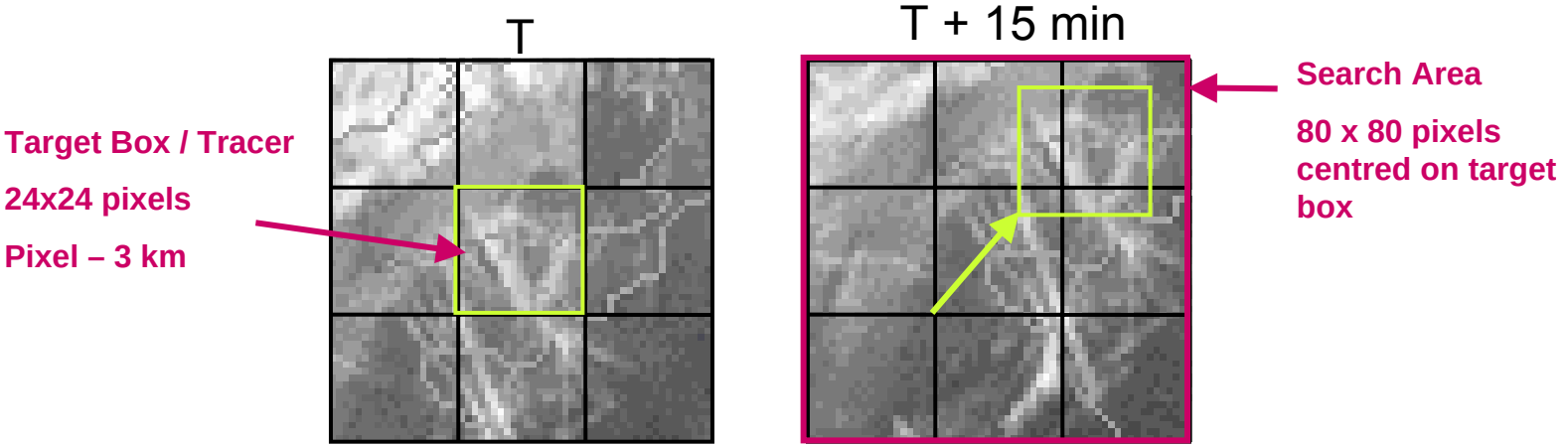


# Physical approach

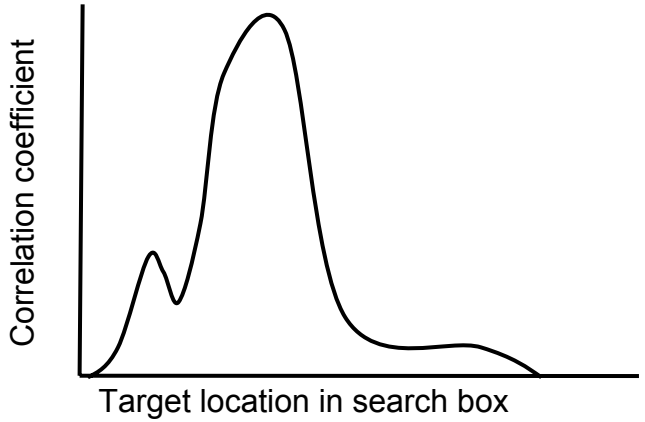
## Vector error

Vector derived from displacement of target between two images.

Location of target in search window found by best match of individual pixel counts with all possible locations of target in search area.




Have more confidence in tracking if correlation coefficient is large and only one distinct maxima (no ambiguity).



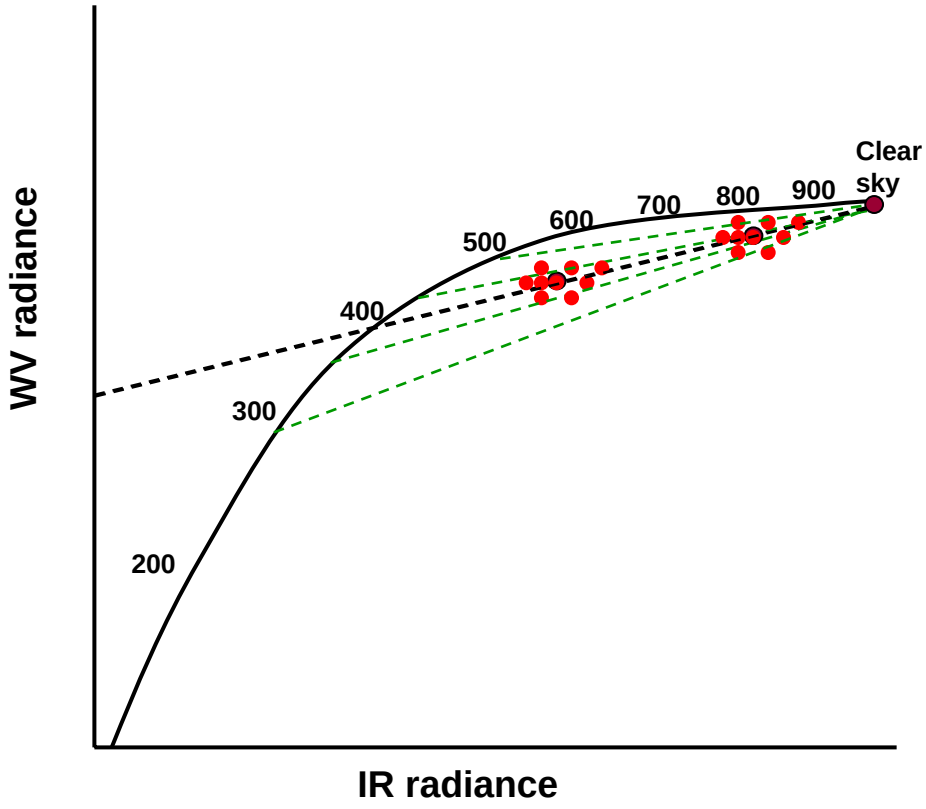
# Physical approach

## Height error

Several sources of height error

1. Identification of appropriate pixels to use for height assignment
2. Limitations of height assignment techniques
3. Errors in forecast model (used for temperature and moisture profiles)
4. Biases in the satellite radiance data
5. Errors in RT models

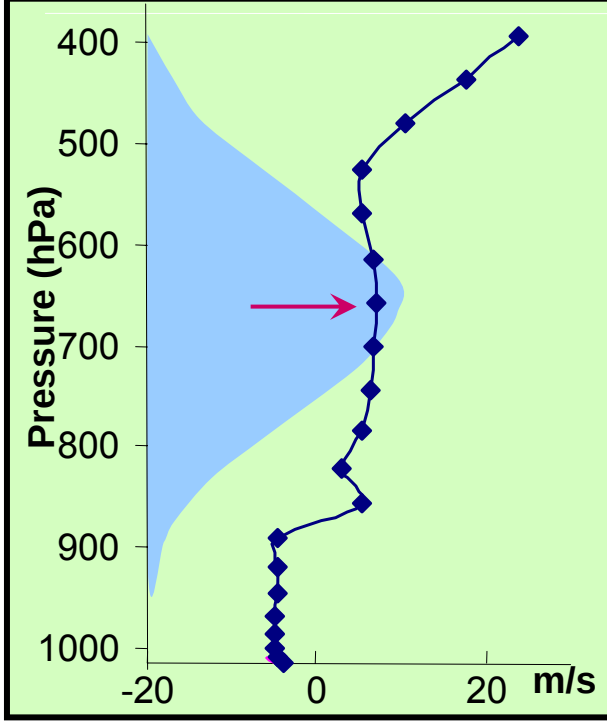
Etc.




As a first step could combine the errors from the height assignment method with some measure of the spread of cloud heights within the target. Build in complexity with time.

# Estimating the total error

Total u/v error = $\sqrt{}$ (u/v Error$^2$ + Error in u/v due to error in height$^2$)




Error in vector due to error in height $= \frac{\sqrt{\Sigma\, W_i(v_i-v_n)^2}}{\Sigma\, W_i}$

where $W_i = e^{-((p_i-p_n)^2/2\mathbf{Ep}^2)} * dP_i$

Summation over levels with a significant $W_i$

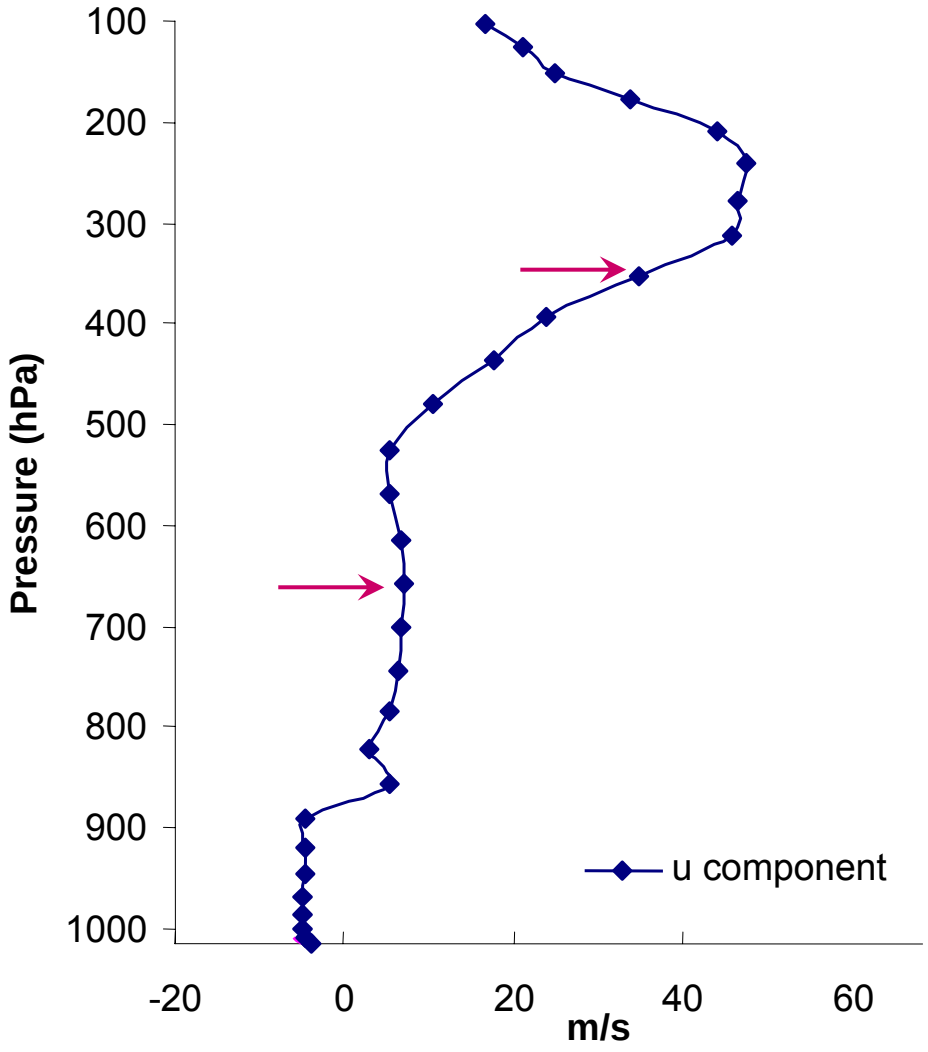
- i = model level
- $v_i$ = wind component on model level
- $v_n$ = wind component at observation location
- $p_i$ = pressure on model level
- $p_n$ = pressure at observation location
- $dP_i$ = layer thickness

For this we need an estimate of:

1. **u and v error (Eu and Ev)**
2. **height error (Ep)**

Ideally from data producers

# Examples




| P hPa | Eu m/s | Ep hPa | Total u error m/s |
|---|---|---|---|
| 350 | 2 | 60 | 11.1 |
| | 2 | 80 | 12.9 |
| | 2 | 100 | 14.3 |
| 660 | 2 | 60 | 2.2 |
| | 2 | 80 | 2.6 |
| | 2 | 100 | 3.6 |

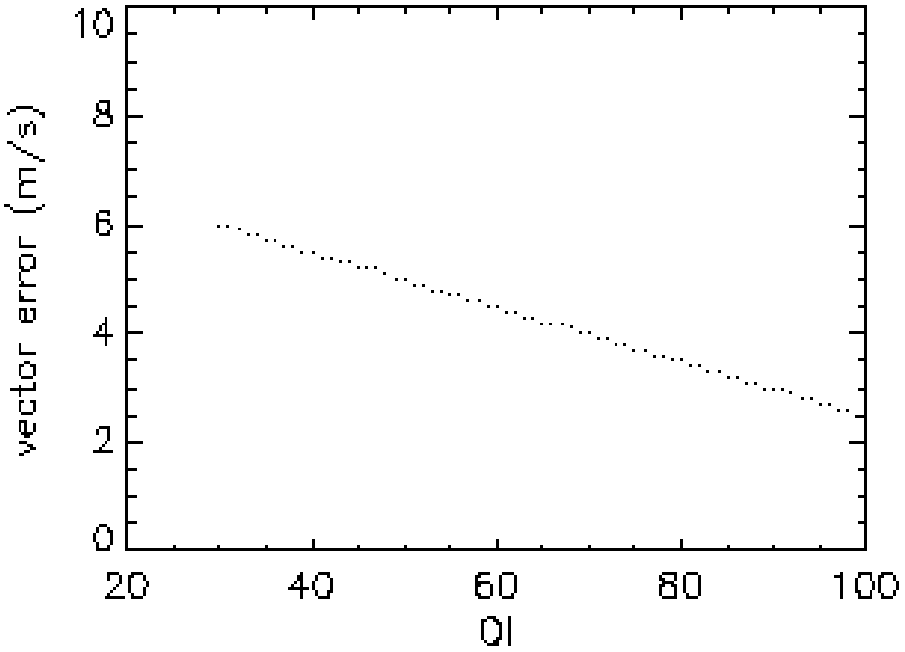
Height assignment error is not a problem in regions of low wind shear.

# Inputs

## What to use for Eu and Ev?

Eu, Ev and Ep are not yet available from AMV producers. Can we estimate sensible values in interim?

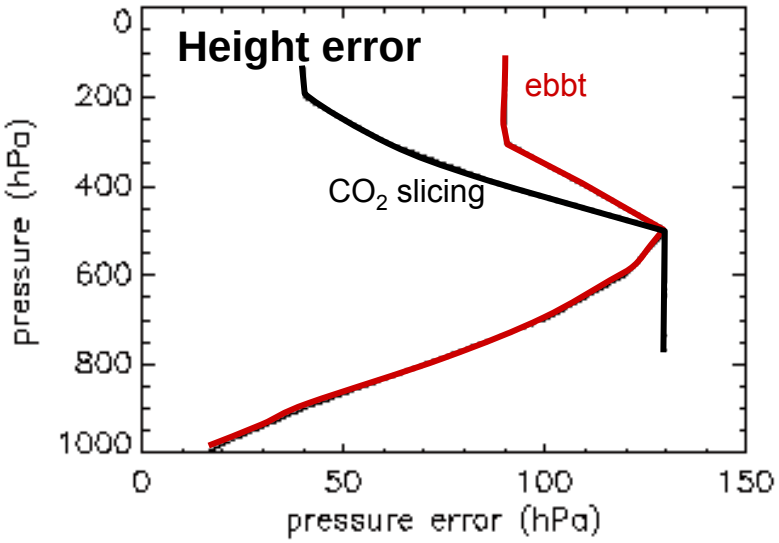
Eu and Ev – function of model-independent QI



# Inputs

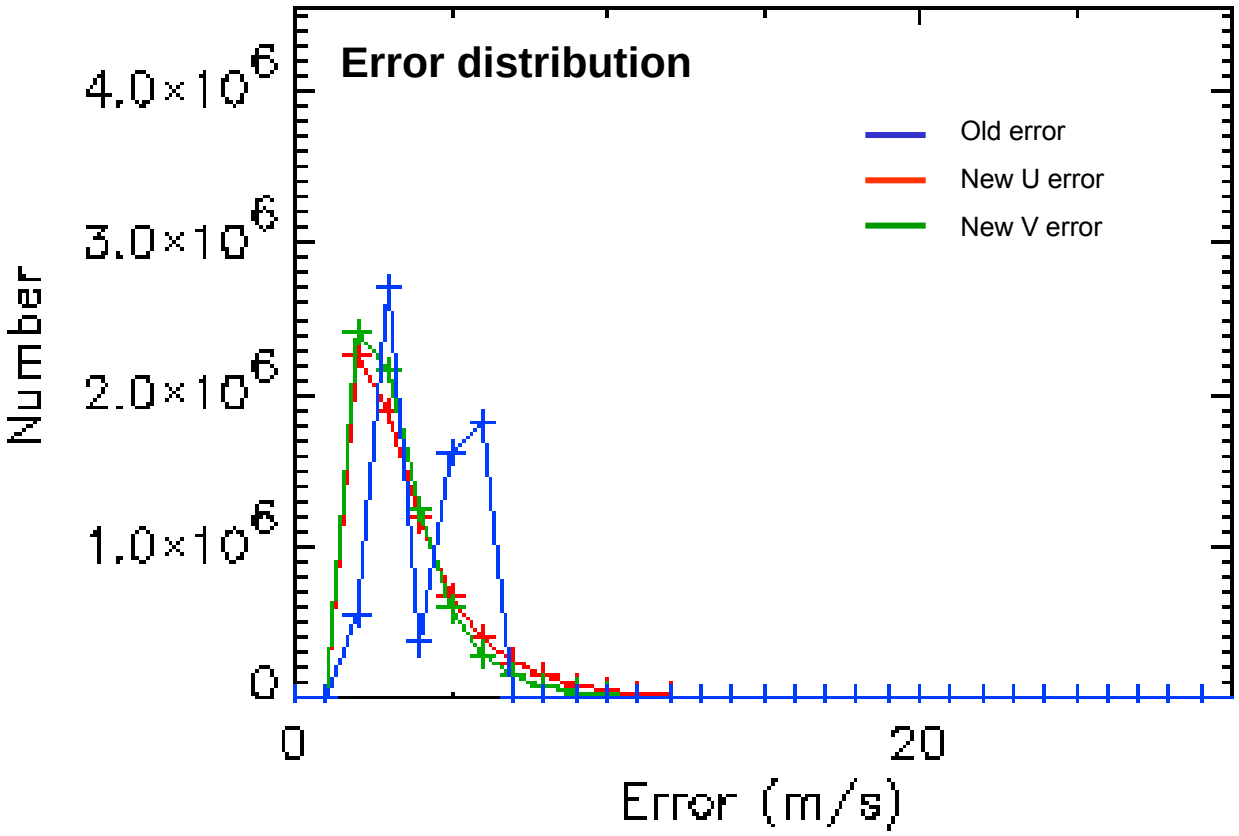
## What to use for Ep?

Use best-fit pressure stats as a guide to generate Ep as a function of satellite / channel / height assignment method / surface type / latitude band and pressure level.

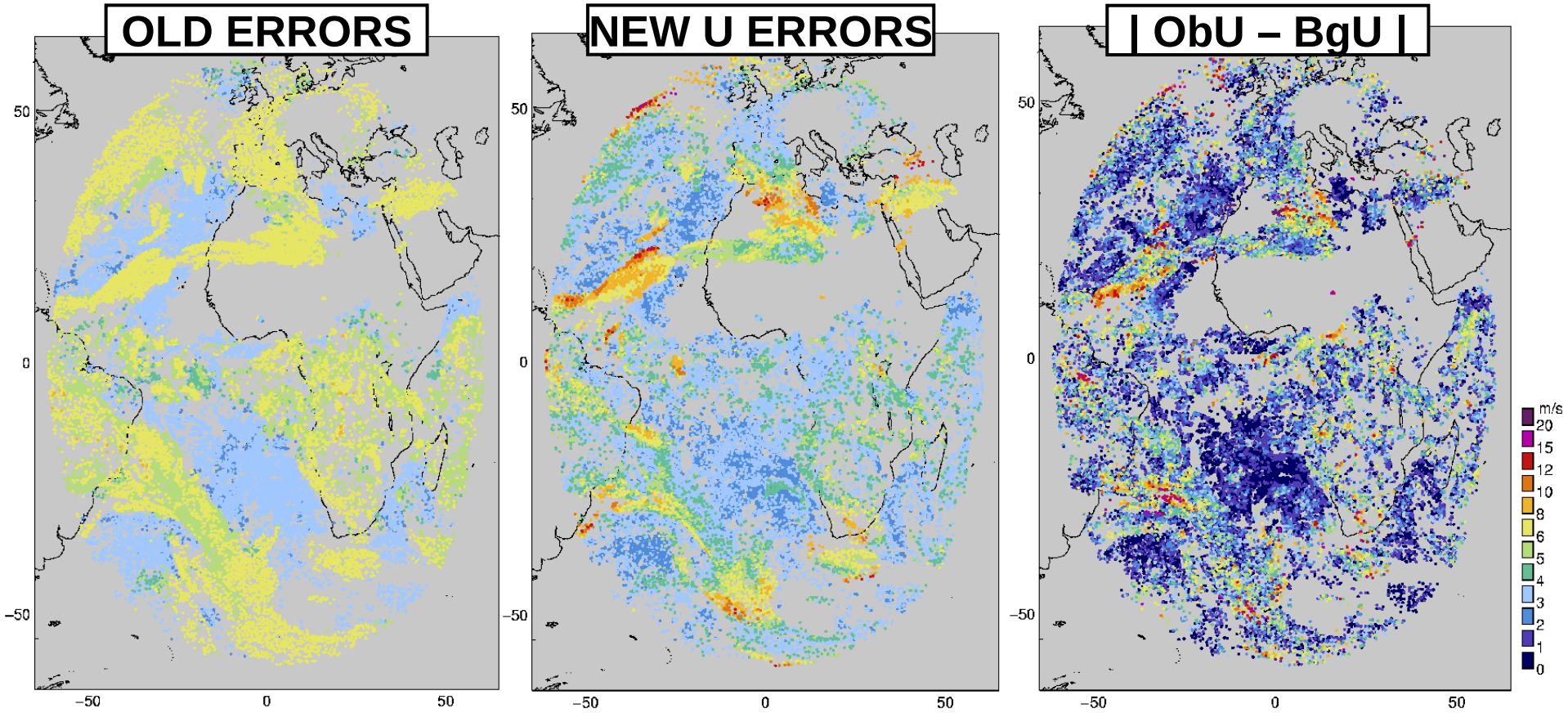


# Old versus new

Two weeks of data (after blacklisting)



# Old versus new

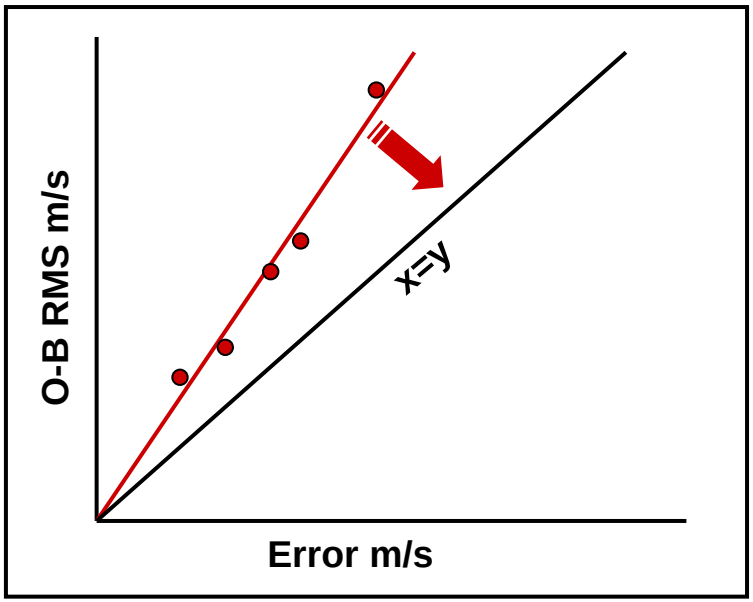



Meteosat-9 IR 10.8 AMVs on 24th Feb 08, QU18

# How good are the new errors?

Should see a positive correlation with O-B rms

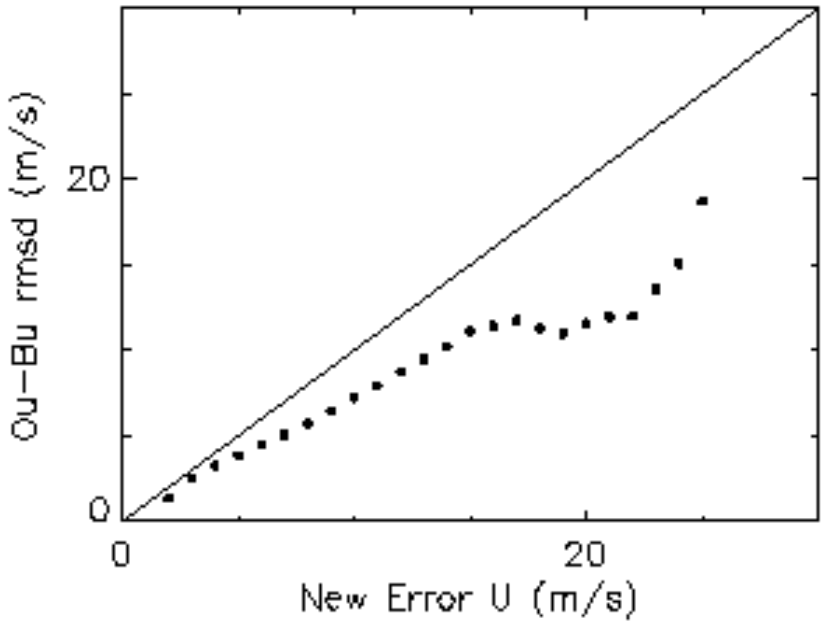
O-B rms will contain a contribution from background error

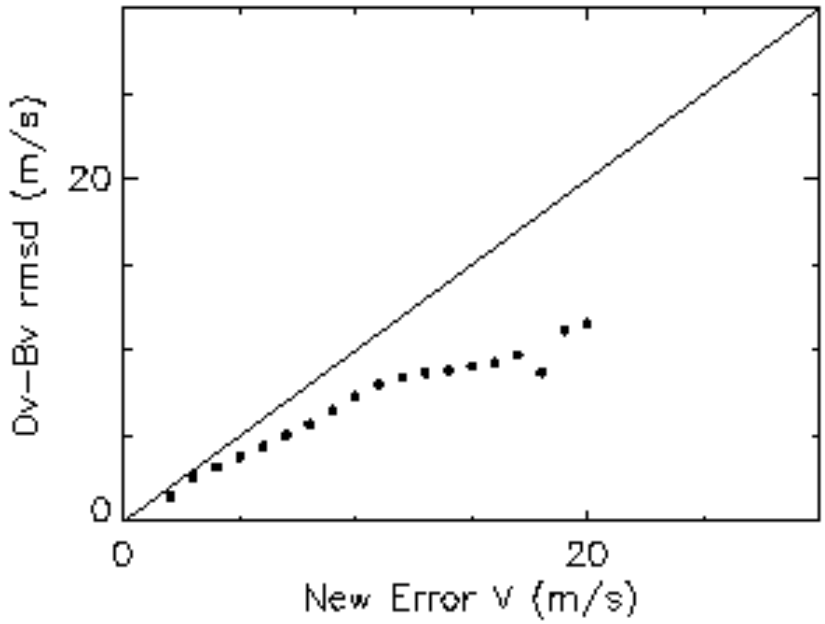



BUT we also know that it is better to use inflated errors for AMVs

# How good are the new errors?

Two weeks of data (after blacklisting)




Fairly encouraging result

Tendency to over-estimate at larger errors

# Impact on other AMV QC

## Background check

Amongst other things the background check is dependent on:
1.observation error
2.background error (typically 2.2-7 m/s – set to 3 m/s in example)

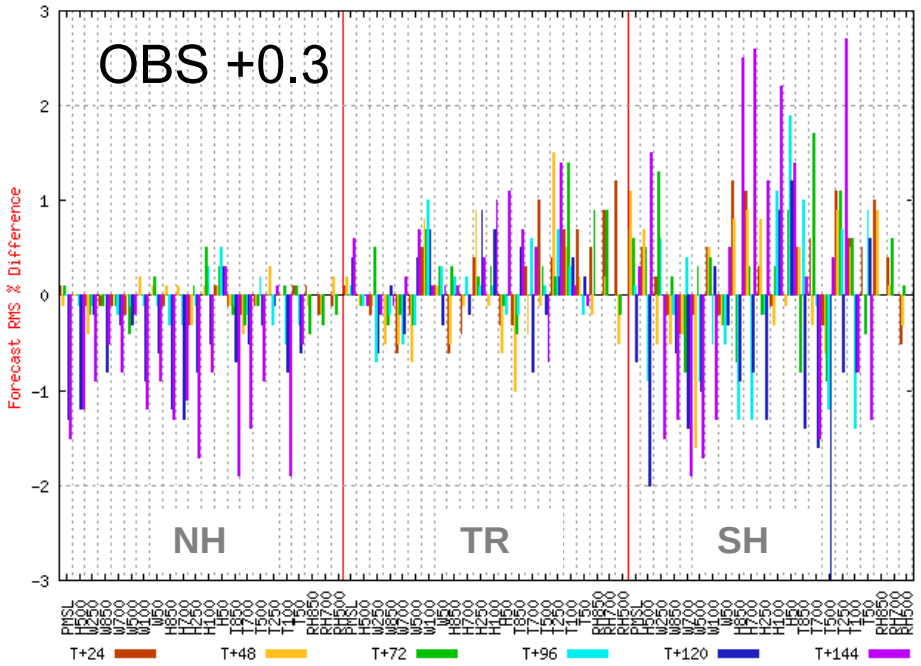
| Ob Err (m/s) | O-B threshold for rejection (m/s) |
|---|---|
| 2 | 9 |
| 6 | 14.5 |
| 10 | 20.5 |
| 15 | 27 |
| 20 | 32 |

If the AMV error is big it is more likely to pass the background check, but will be down-weighted in VAR. One outcome of the new error scheme is very few observations fail the background check.

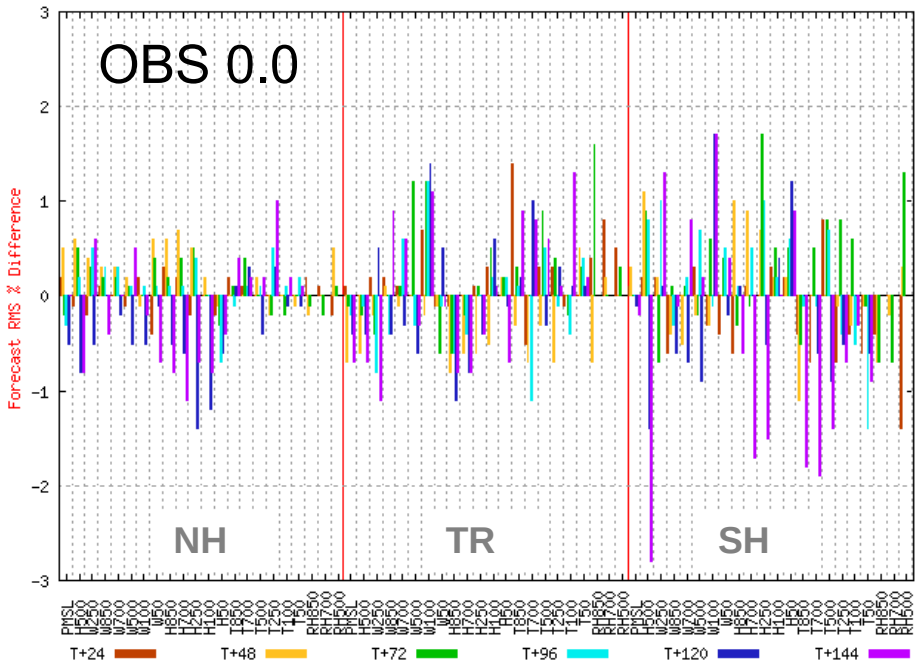
# Assimilation trial results

# NWP Index

May-Jun 07




Dec 07 – Jan 08



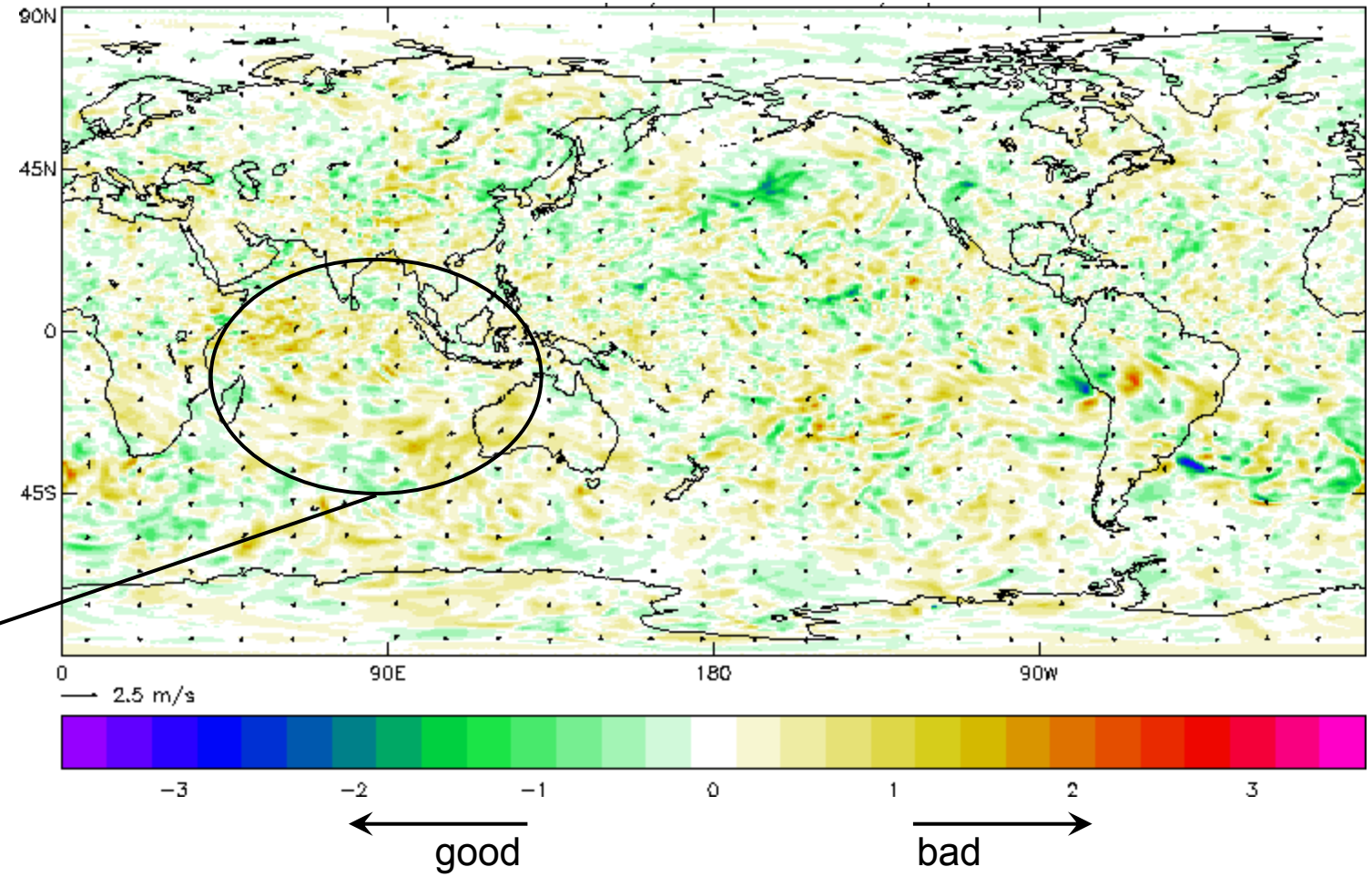

Below the line indicates a positive impact

Long range generally improved. Results more mixed in Tropics and SH.

# 250 hPa wind verification

## T+48 forecast error

T+48 250 hPa wind forecast error difference between control and trial over the course of the Summer trial




Indian Ocean slightly larger errors

# Where to go from here …

# Where to go from here …..

## Individual errors

New scheme likely to be included in the next parallel suite (operational July 2008).

Plan to review height errors using latest best-fit statistics generated with 6 months of data.

BUT we are currently estimating our own u/v/height errors

We should see an improvement when we have access to estimates from the producers based on limitations in the derivation.

*EXAMPLE:*

*All height errors for AMVs using the $CO_2$ slicing height assignment at 200 hPa currently set to 40 hPa. This will be bigger than the true error for some and less for others due to limitations of using a statistical approach*

# Summary

# Summary

New AMV error scheme takes into account…..

- Errors are variable and becoming better understood.
- Height assignment error often dominates, but is not a problem in regions of low wind shear.

The new errors are more variable than the old errors and appear to better reflect the O-B differences.

The impact trial results are slightly disappointing, but they are overall slightly positive and the change is recommended for operations.

Setting observation errors is not trivial. More benefit may be seen from refinement of the existing scheme and, in particular, provision of u/v/height errors by the producers.

Lots more work to do. Other strategies to improve the assimilation include:

- Updated blacklisting and background check
- More use in time window
- Observation operator changes to treat as layer

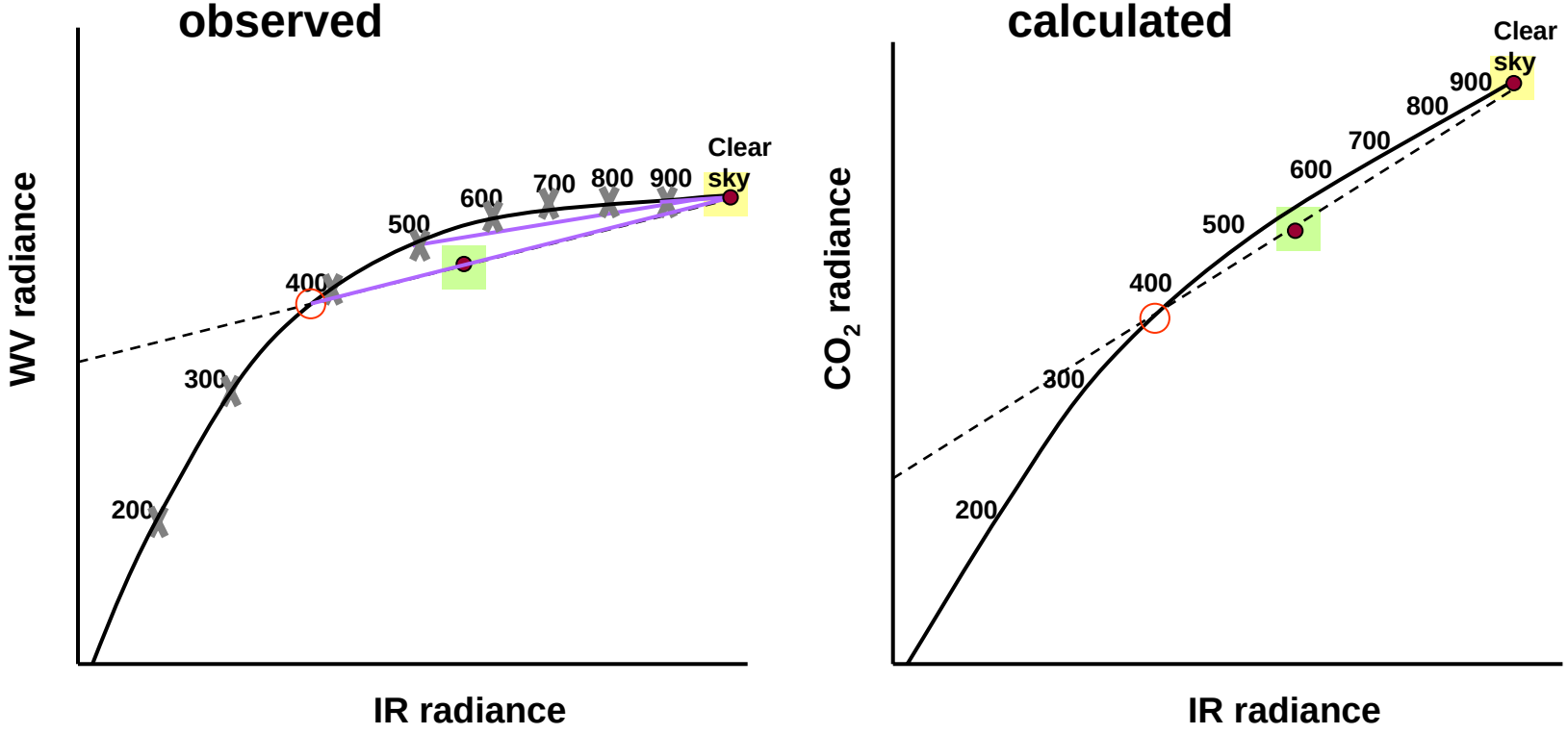
# Questions and answers

# Height Assignment #2

**Multi-channel – $CO_2$ slicing and WV intercept techniques**

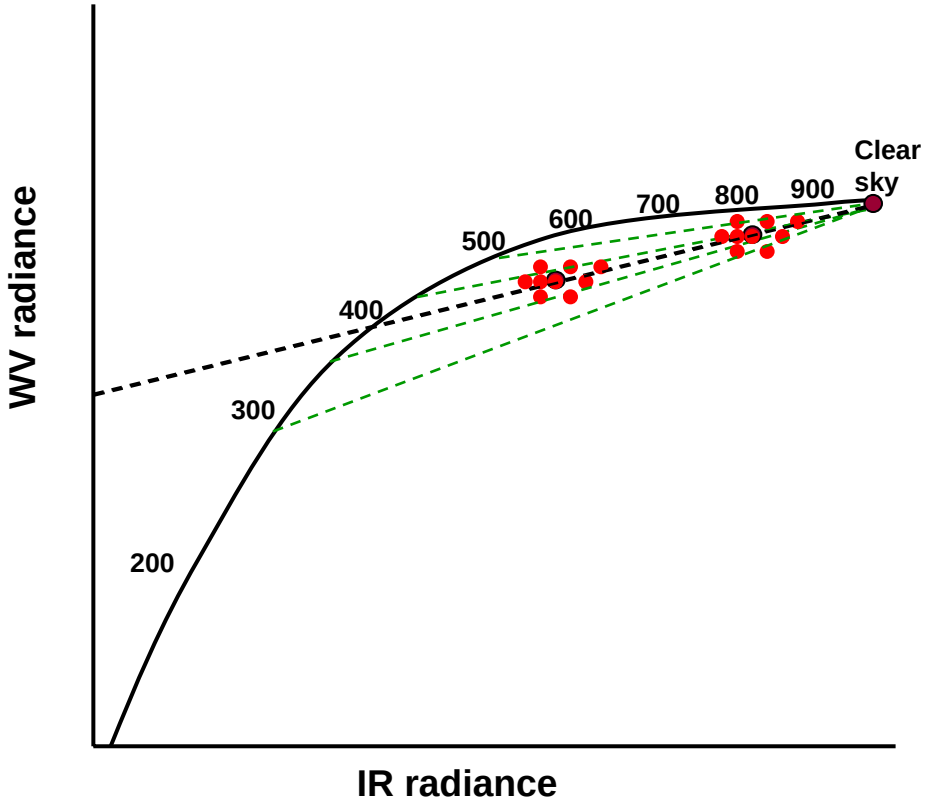
$$\frac{R_{CO2/wv} - R^{cs}_{CO2/wv}}{R_{IR} - R^{cs}_{IR}} = \frac{\cancel{\varepsilon} E_{CO2/wv}\left[R^{bcd}_{CO2/wv}(P_c) - R^{cs}_{CO2/wv}\right]}{\cancel{\varepsilon} E_{IR}\left[R^{bcd}_{IR}(P_c) - R^{cs}_{IR}\right]}$$

observed | calculated



# Height Assignment

$$\frac{R_{CO2/wv} - R^{cs}_{CO2/wv}}{R_{IR} - R^{cs}_{IR}} = \frac{nE_{CO2/wv}\left[R^{bcd}_{CO2/wv}(P_c) - R^{cs}_{CO2/wv}\right]}{nE_{IR}\left[R^{bcd}_{IR}(P_c) - R^{cs}_{IR}\right]}$$

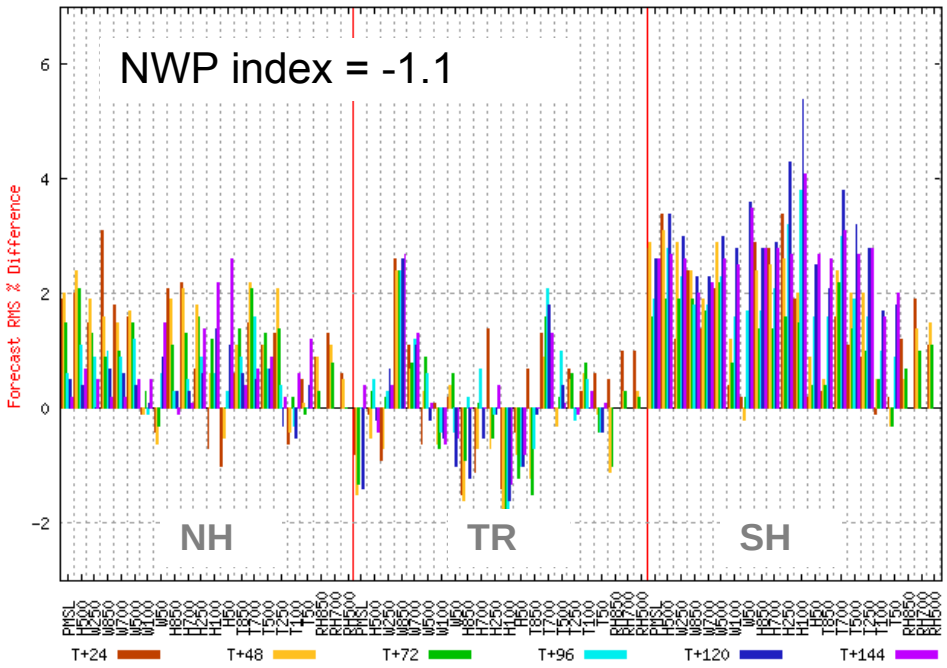



1. Assume one layer of cloud. If second cloud layer beneath will tend to put cloud too low.
2. Emissivity assumption not as true for IR/WV as IR/CO2 and less good for very thin cloud.
3. Observed radiances may have calibration error.
4. Cloudy pixels likely to show some spread – will effect accuracy of best-fit line.
5. Calculated clear sky radiance dependent on accuracy of surface temperature and surface emissivity.
6. Calculated curve dependent on profile of moisture and temperature and accuracy of RT model. Calculated WV radiances likely to have biggest errors due to uncertainties in moisture profile (CO2 profile less variable).
7. Both WV and CO2 methods lose sensitivity below about 600 hPa in atmosphere.
8. Cloud top pressure less well constrained for very thin cloud – best-fit line less well-constrained

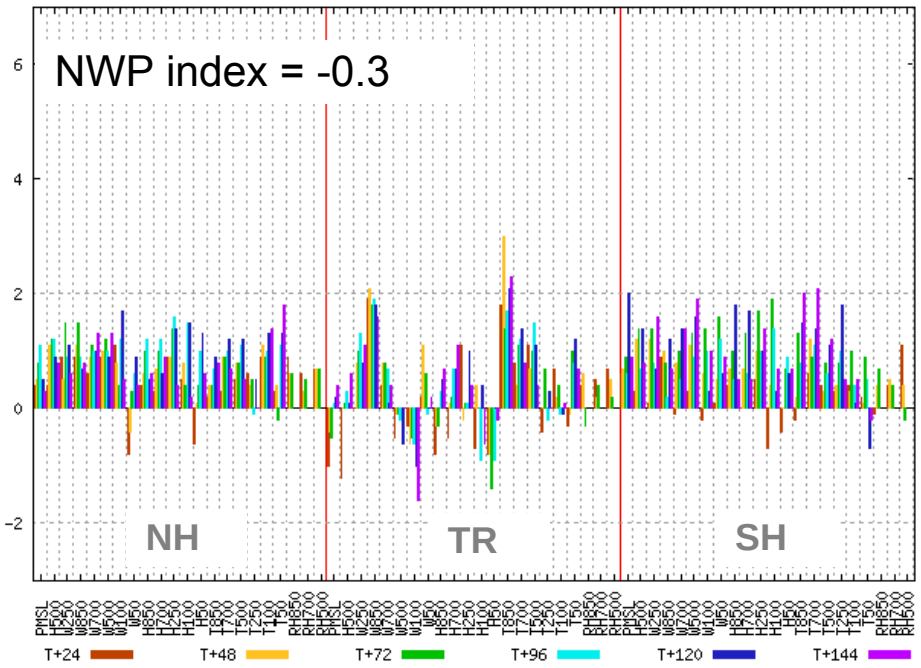
# AMV data denial trials

## Verification versus analyses

12/12/05 – 11/01/06




12/12/07 – 12/01/08




Mostly positive impact.

Similar pattern, but bigger impact in 2005 than 2007.

Main negative impacts on TR PMSL, 50 hPa and 100 hPa fields and TR height fields

# Impact on other AMV QC

## Thinning

**AIM:** to reduce data density to alleviate problems with spatially correlated error

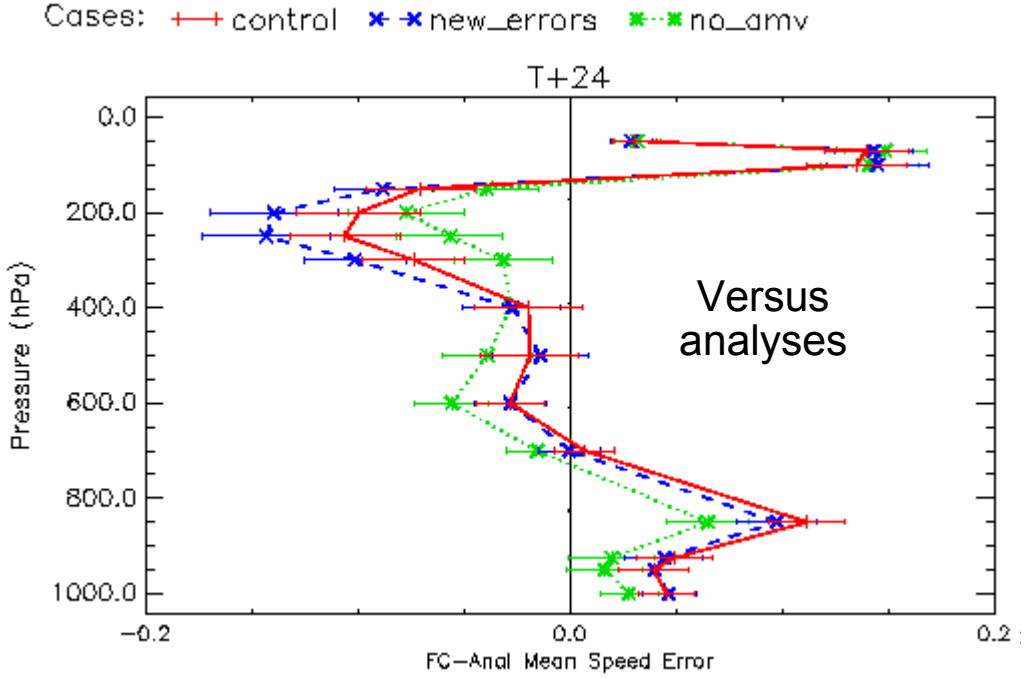
One decision involved is how to select which observation to use.

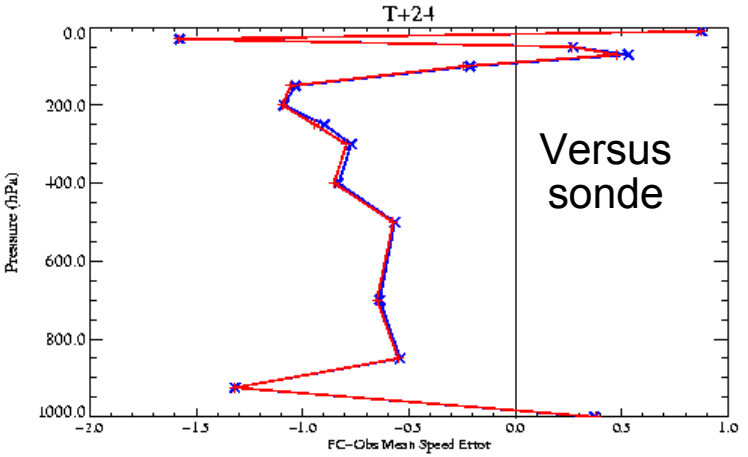
With the new individual errors, this was updated to select by lowest observation error replacing the current choice by highest quality indicator.

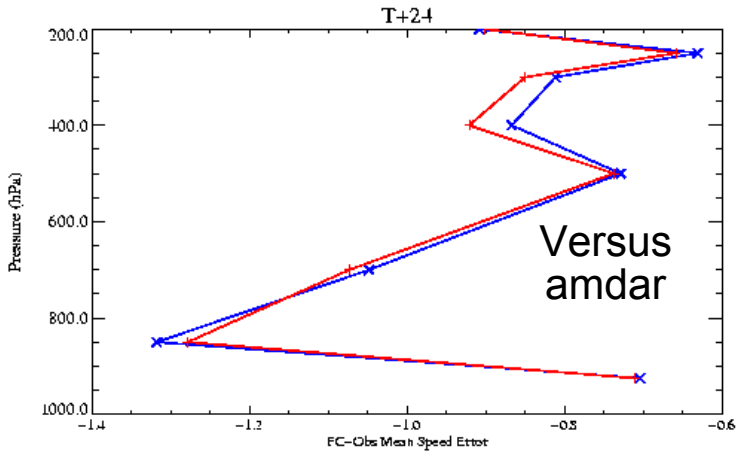
# Wind verification

## Mean speed error profile

**Mean speed error profiles for Winter season for T+24 forecast range in Tropics**

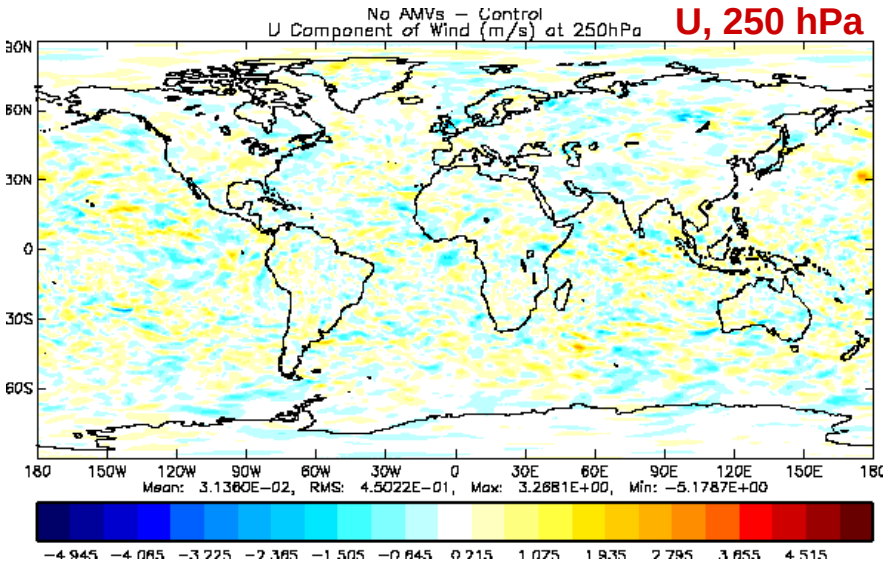


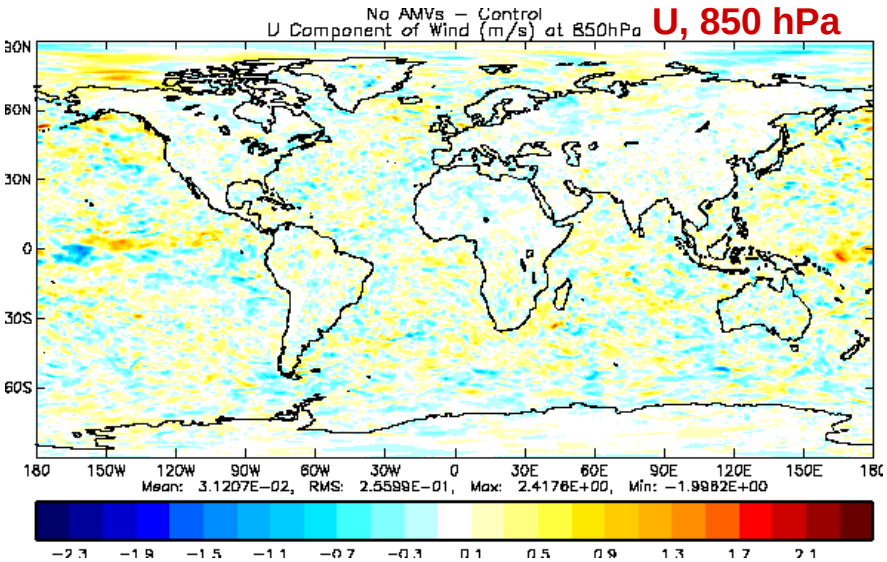



# AMV data denial trials

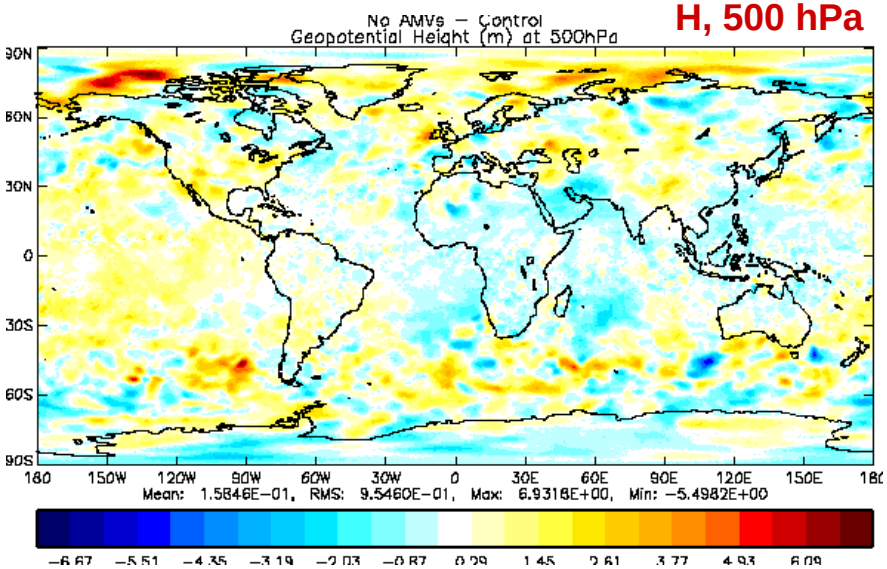
## T+48 forecast error




U, 250 hPa




U, 850 hPa




H, 500 hPa

bad ← → good

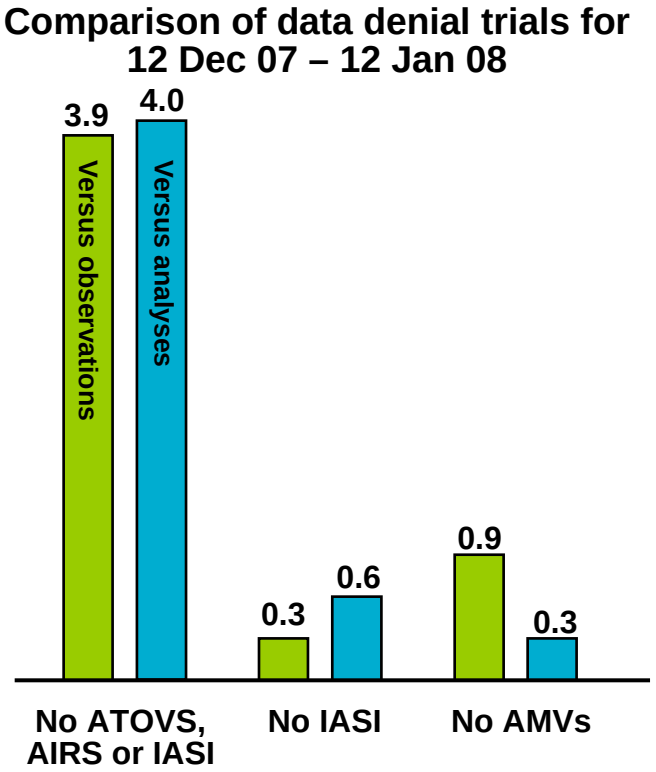
Impacts generally small, mixed and spread. Some localised benefit to H500 particularly in NH high latitudes (probably from polar winds).

# AMV data denial trials

## Summary

AMVs have a positive impact. Dec 07 shows less impact than the Dec 05.

This may be partly due to other improvements e.g. IASI, GPSRO and model changes.




Results from Fiona Hilton

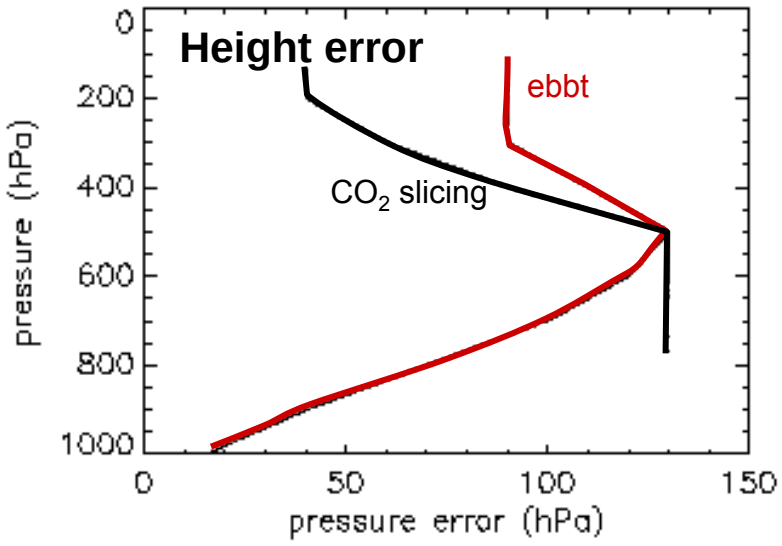
The impact of AMVs is much less than all the sounding data (as expected), but similar to IASI.

IASI experiment shows less impact than seen in Summer 07 season (where it was close to 1 point).

# Inputs

## What to use for Ep?

Use best-fit pressure stats as a guide to generate Ep as a function of satellite / channel / height assignment method / surface type / latitude band and pressure level.



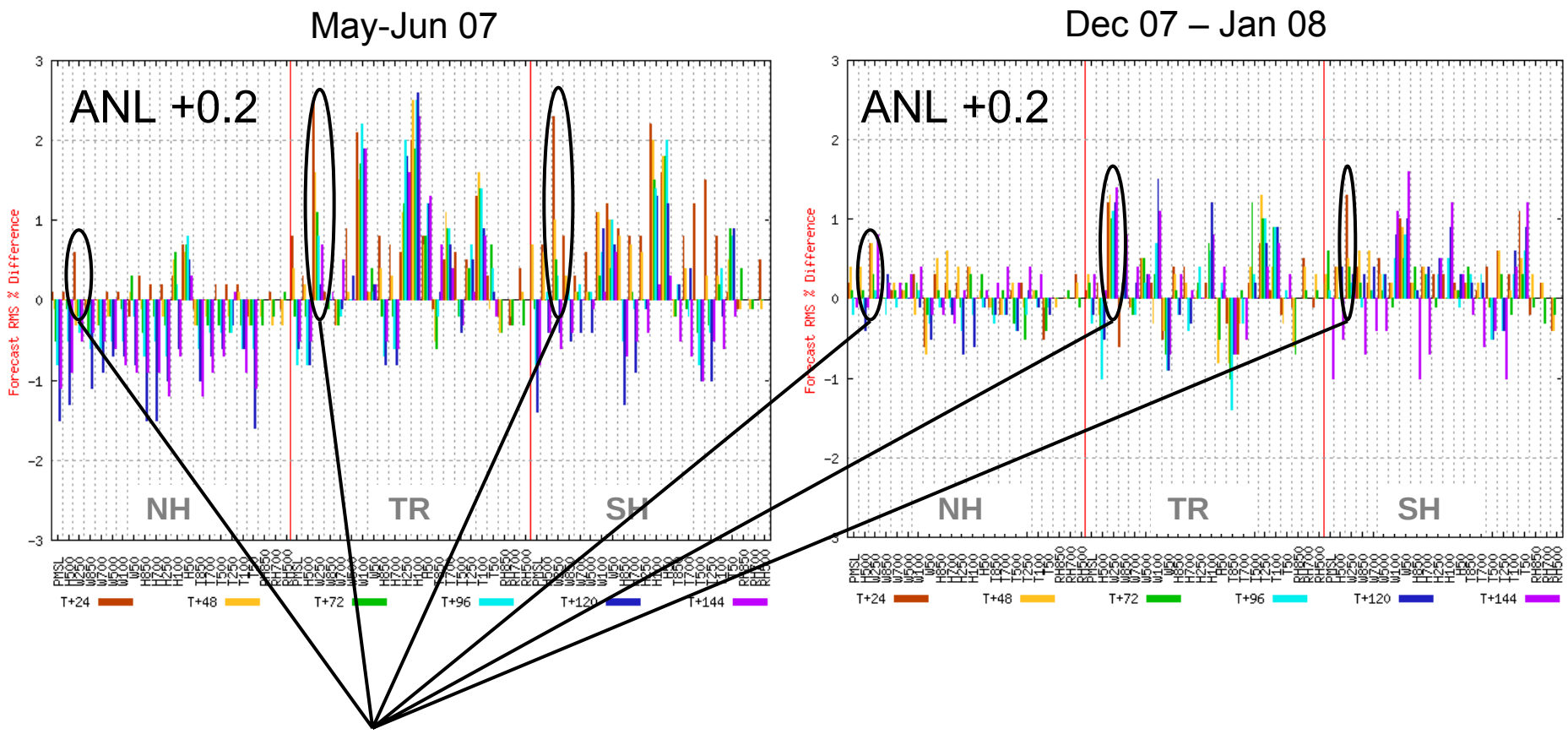

Observed - model best-fit pressure distributions (black curves)

1. Fairly Gaussian
2. Mostly unbiased

In cases with larger height bias can consider spatial blacklisting.

Elsewhere use rms of distribution as proxy for the height error (this will contain a contribution from the error in best-fit).

# NWP Index




250 hPa wind fields verify worse against analyses

# Where to go from here …..

## Other quality control changes

Also testing

1. Updates to spatial blacklisting
2. Removal of temporal constraints
3. Application of temporal thinning (3 hour)
4. Removal of asymmetric element of background check
5. Switch to unedited NESDIS winds
6. Switch to forecast-independent QI and review of QI threshold values
7. Application of minimum speed threshold
8. Changes to observation operator