Met Office

# Intercomparison of operational Stratosphere-resolving global NWP Systems

David Jackson

Thanks to Saroja Polavarapu (CMC), Florence Rabier (Meteo France), Chiashi Muroi (JMA), Mikhail Tolstykh (RusHMC)

SPARC DA Workshop, New Mexico, USA, 11-13/06/2012

# Background

- S Polavarapu initially proposed (to F Rabier) a summary of representation and impact of stratosphere in global NWP models – way of strengthening SPARC – WGNE links
- Proposed at 2011 SPARC DAWG – D Jackson to take forward
- Idea is to produce a SPARC report or even a review paper

# Overview

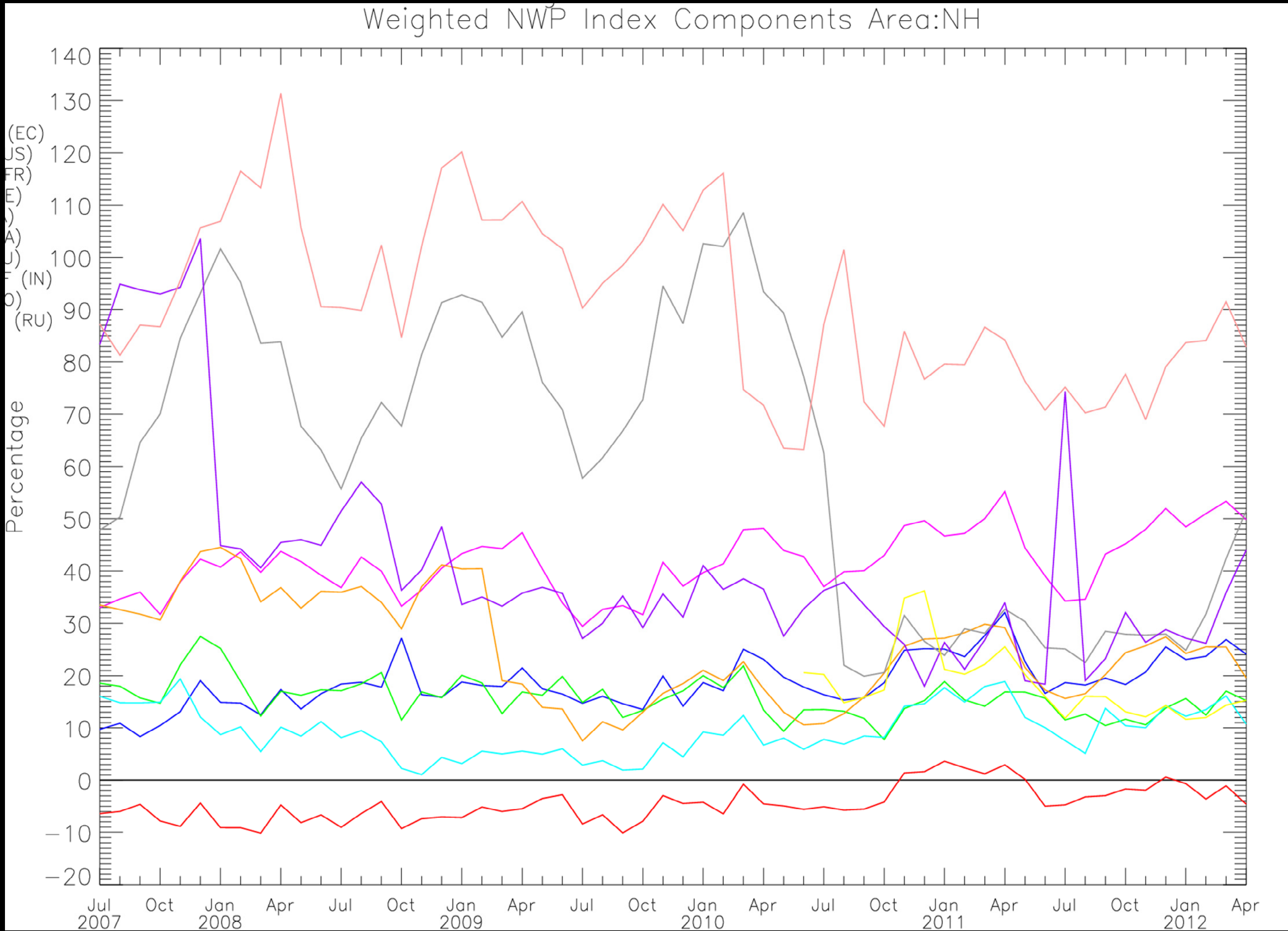
- Summary of global NWP model resolutions and domains
  - Performance in the stratosphere (and mesosphere)
  - Impact on tropospheric forecasts
- Summary of DA and GW parametrizations
- Next steps:
  - Study some way from completion
  - Intercomparison of impact of DA, GW, radiation not explicitly done (or even easy)
  - Scope?

# NH NWP scores relative to MetO

Met Office

Main question:

How much of this variation in NWP skill is due to the representation of the stratosphere?




ECMWF JMA NCEP Met-France CMC DWD NCMRWF BOM RHMetC KMA

# Summary of global NWP model resolutions and domains

| Centre | Current | Planned |
|---|---|---|
| ECMWF (Euro) | T1279L91, ~-0.01 hPa | T1279L137, ~0.01 hPa (late 2012) |
| Met Office (UK) | ~25km L70, ~0.01 hPa | ~17km L70 or L85, ~0.01 hPa |
| Meteo France | T798L70, 0.05 hPa | No change |
| DWD (Germany) | 20km, L60, 5 hPa | 20-40km, L60, 5 hPa, Icosahedral Nonh/static (2013) |
| RusHMC (Russia) | 0.72x0.9,L28, ~ 5 hPa (T169 L31, ~10 hPa) | ~0.2x0.225, L51, ~5 hPa (later 0.5-1 hPa) (T339L31, ~10 hPa) |
| NCEP (USA) | T574L64, 0.266 hPa | T878L64, 0.266 hPa (2012?) |
| Navy / NRL (USA) | T319L42, 0.04 hPa | T479L60, |
| CMC (Canada) | 0.45x0.3 L80, 0.1 hPa | 0.35x0.23, L80, 0.1 hPa |
| CPTEC/INPE (Brazil) | T299L64 | T666L96 |
| JMA (Japan) | T959L60, 0.1 hPa | T959L100, 0.01 hPa (2013?) |
| CMA (China) | T639L60, 0.1 hPa | 50km L36, 10 hPa |
| KMA (Korea) | ~25km L70, ~0.01 hPa | Follows Met Office |
| NCMRWF (India) | ~25km L70, ~0.01 hPa | Follows Met Office |
| BOM (Australia) | ~40km L70, ~0.01 hPa | ~25km L70, ~0.01 hPa (follows Met Office) |

# Summary of global NWP models - comments

Met Office

- Only Germany and Russia have models with UB below 1 hPa level
- New China UB will drop to 10 hPa – why?
  - Own model - Non-hydrostatic core
  - Current poorer results fixed by 3D-Var resn, orog GW, new BCs
- India, Korea and Australia use same model as Met Office
- Russia use two models:
  - SL-AV – semi Lagrangian with upper boundary currently at ~5 hPa
  - Spectral model with upper boundary currently at 10 hPa

# Impact of Stratosphere on Tropospheric Forecasts

Met Office

Where is there a benefit?

Well known:

- Better initial conditions (eg better assimilation of satellite radiances)

- Better extended range (> 10 day) forecasts (SNAP)

- But what about for shorter forecasts?

# Raised model lid improves tropospheric forecasts

Met Office system. L50 (L38) = 63 km (38 km) upper boundary

Numbers show change in skill score from N216L38 control run

| | Vs. Observations | Vs. Analyses |
|---|---|---|
| N216 L50 | +0.8 | +0.7 |
| N320 L38 | +0.3 | -0.2 |
| N320 L50 | +1.0 | +0.8 |

Biggest impact on RMS errors from L50

- Improved fit to observations and reduced model errors

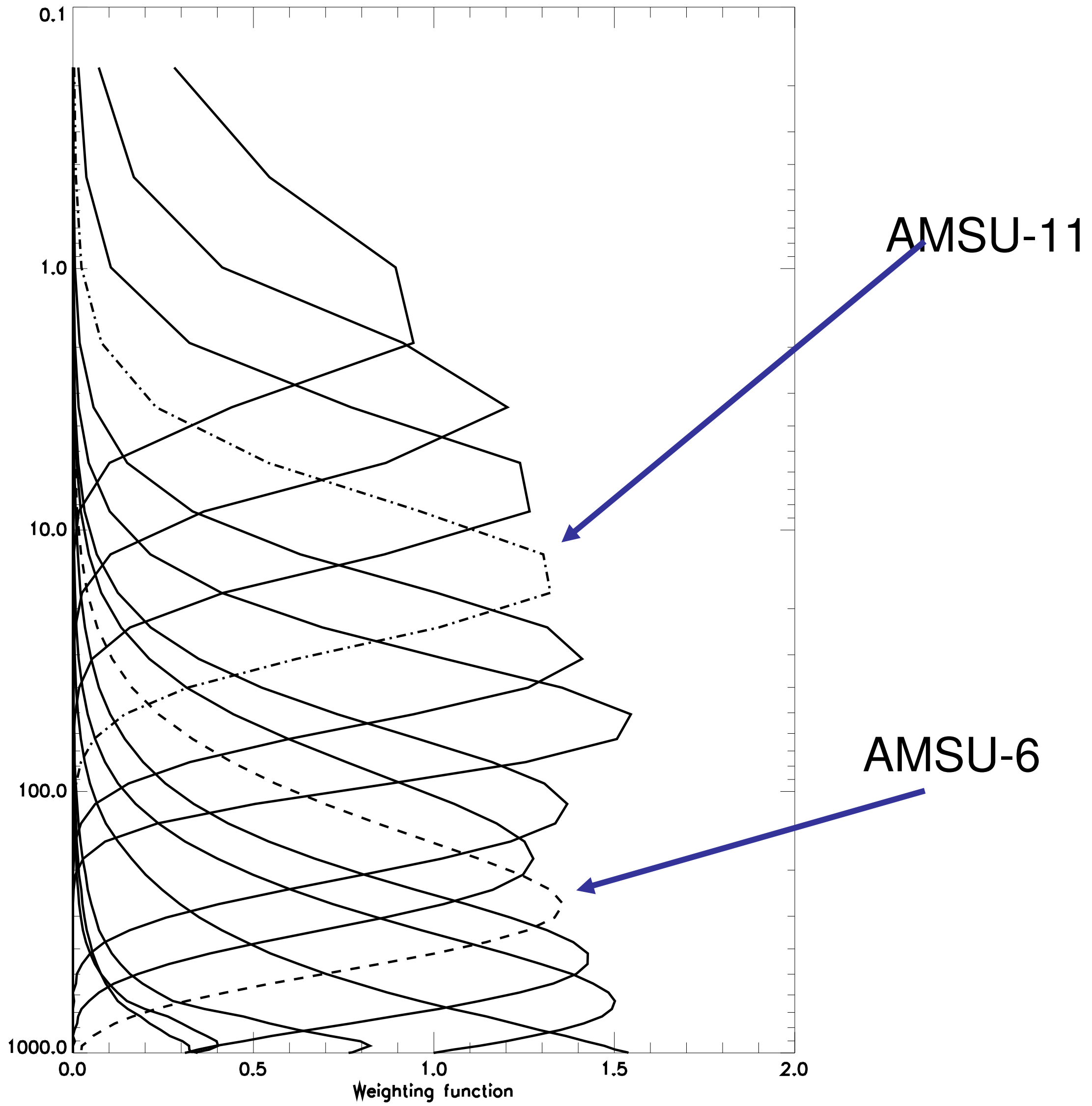
However, little impact if same ICs were used to run forecasts with L38 and L50 models

Figures above are NWP skill scores (RMS errors for tropospheric forecast fields)
>~0.2-0.4 increase is stat. sig.

# AMSU-A weighting functions

Benefit comes from:

- Better representation of the stratosphere in the model
- Extra stratospheric satellite channels
- Improved analysis throughout the depth of the atmosphere through improved use of satellite data.



## The stratospheric influence on the troposphere in the context of operational medium-range weather forecasts

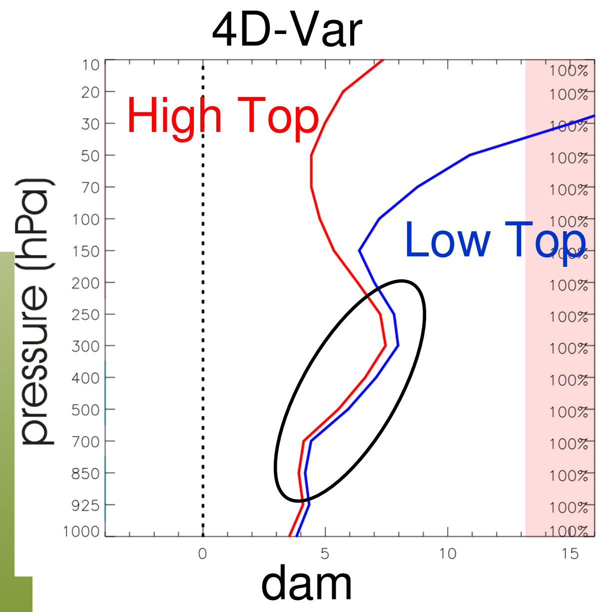
Polavarapu et al, SPARC Data assimilation workshop, Exeter, 22 June 2010

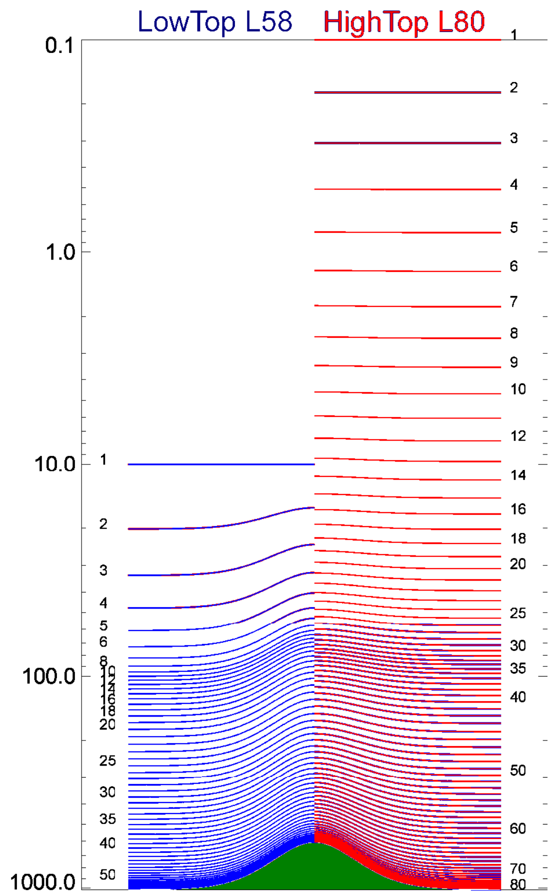
| | Low Top | High Top |
|---|---|---|
| **Vertical coordinate** | Normalized sigma | Hybrid |
| **No. of vertical levels** | 58 | 80 |
| **Lid height** | 10 hPa | 0.1 hPa |
| **Sponge layer at lid (Del2)** | 4 levels<br>Acts on full fields | 6 levels<br>Acts on departures from zonal mean |
| **Tropical sponge near lid** | 4 levels (coef=450)<br>Down to 50 hPa | 8 levels (coef=50)<br>Down to 3 hPa |
| **Radiation scheme** | Fouquart/Bonnel + Garand | Li and Barker |
| **Non-orographic GWD scheme** | No | Hines |
| **Methane oxidation** | No | Yes |
| **Ozone climatology** | Kita and Suma (1986) | Fortuin et Kelder (1998) below 0.3 hPa, HALOE above 0.3hPa, Transition between 2 to 0.3 hPa |

# Improving the stratosphere improves 5-day forecasts in the troposphere

On June 22, 2009 Canadian Meteorological Centre implemented operationally a global stratospheric model (0.1 hPa) for medium range weather forecasts

O-F(5 day) against NH sondes for GZ




A good stratosphere impacts troposphere forecasts as much as 4D-Var

Winter

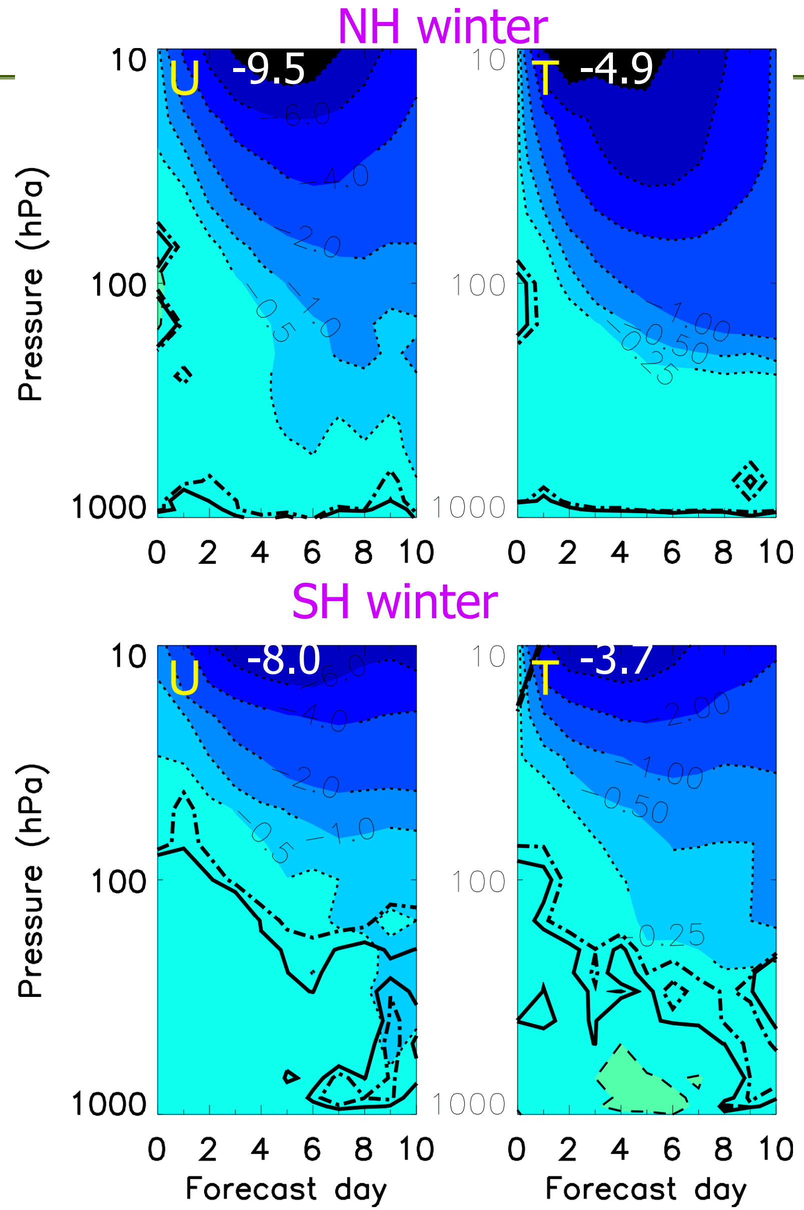
Dec. 20 – Jan. 26, 2006 (75 cases)

# Are other forecasts improved?

- Compare forecast errors (cf sondes) of High Top with old Low Top
- Diff = Error stddev (High Top) – Error stddev (Low Top)
- Negative (blue) means High Top errors are lower

Results

- Forecast error standard deviations are improved at all forecast ranges in winter
- Improvement is much greater in winter than summer
  (improvement depends on season, not hemisphere)
- Improvement in skill spreads downward with forecast range in winter
- Improvement in troposphere is comparable to that seen when upgrading from 3D to 4D-Var in winter

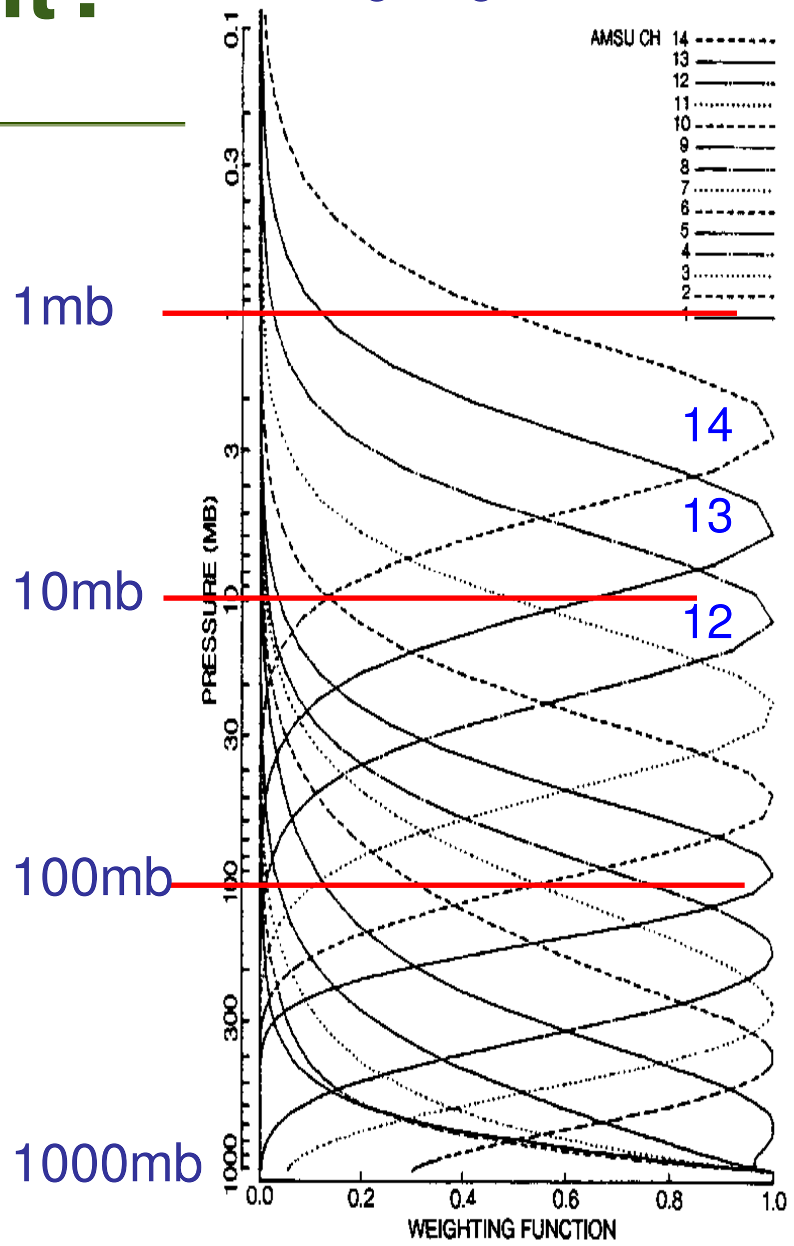



Environment Canada Environnement Canada

# Why the improvement?

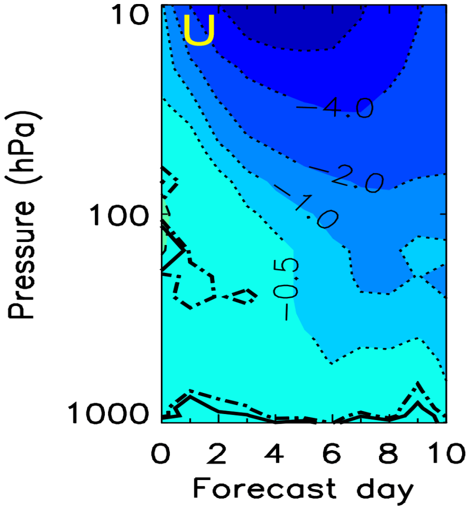
- Changes to the model
  - raised lid height, new radiation, raised and weakened sponge layers, GWD scheme, etc.
- Differences in observation sets
  - extra obs: AMSU 11-14, GPSRO
- Changes in way obs are assimilated
  - AMSU 9-10 obs errors were reduced

AMSU normalized weighting functions

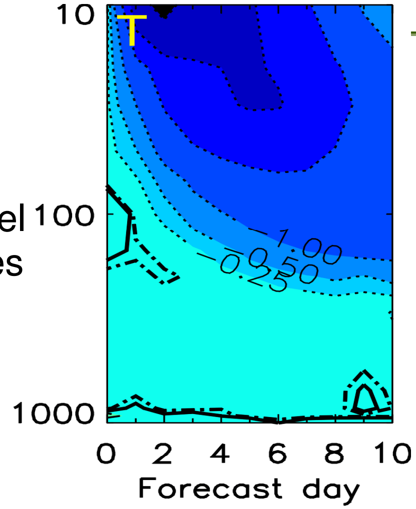


# Winter NH stddev obs vs model

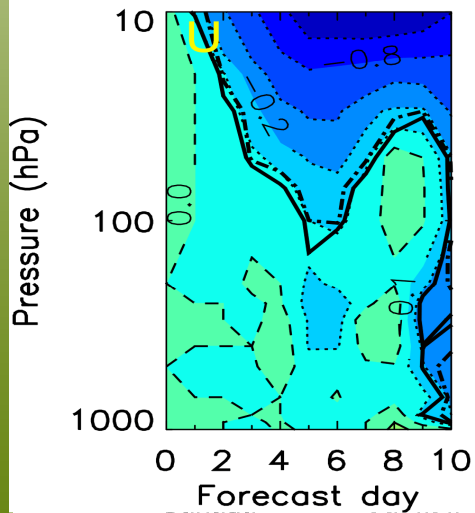
Most of the improvement is due to changes in model



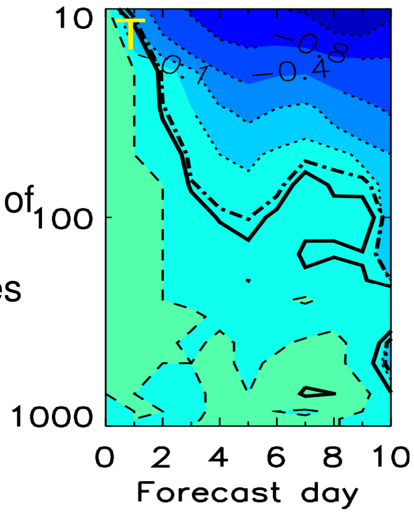

Impact of model changes




Contour intervals not the same!




Impact of obs changes




## Which model changes explain improvement?

- New radiation scheme explains some (~25%) of the impact in the troposphere.
- The lid height explains almost all of the improvement in the stratosphere

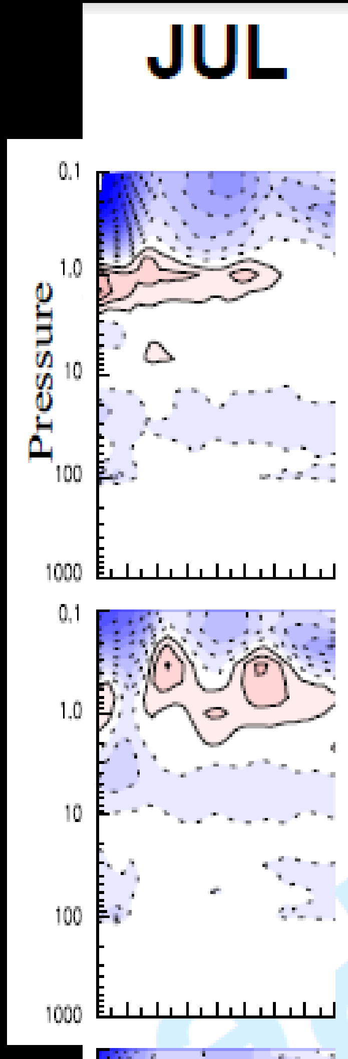
Canada

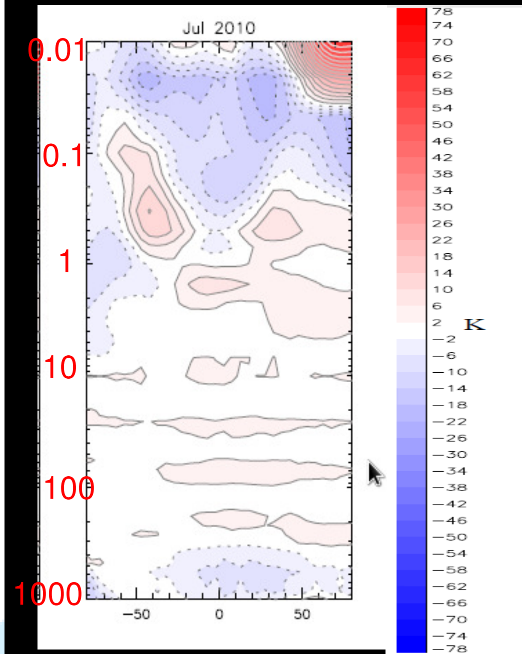
Met Office

# Benefits of raising upper boundary even higher

## Rationale

- Move upper boundary away from upper stratospheric channel weighting fn peaks
- Better resolution of B-D circn / mesospheric MMC
- Better representation of downward moving stratopause after major SSWs




(Long et al, QJRMS in review)

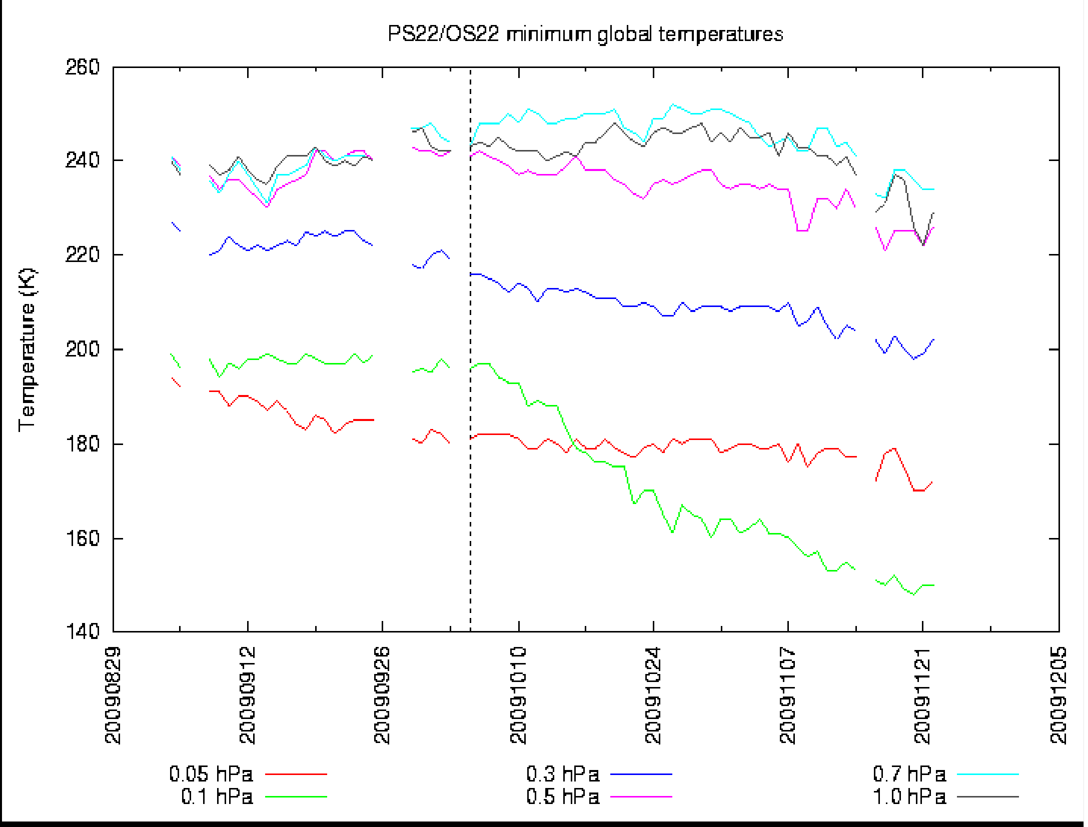
## Benefits

- UM 63km -> 80 km
- Errors v EOS MLS
- Reduced error in 1-0.1 hPa region – especially winter
- High errors in 0.1-0.01 region – radiation + GWD

# Issues with raising the lid in mesosphere – lack of observations

- MetO – switch from 63 km to 80km lid
- No obs above ~1 hPa
- Cold drift near 0.1 hPa seen after operational implementation (Oct 2009) but not before
- Related to **B** correlation structure and lack of mesospheric obs
- Controlled by assimilating SSMIS (minus Zeeman effect in forward model)

Mike Thurlow (Met Office)



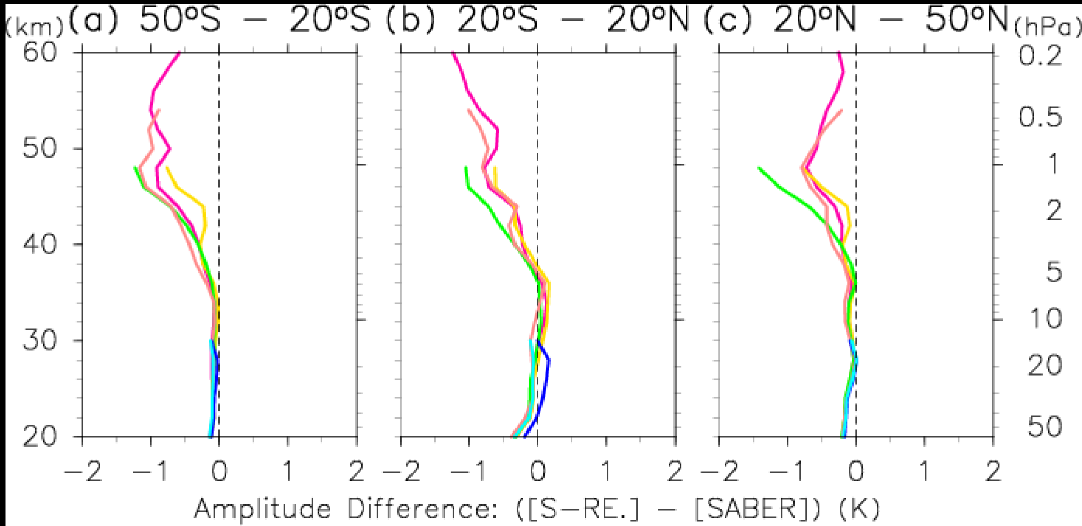
# Diurnal tides: Mean* difference between "SABER" and "Reanalysis"

Met Office

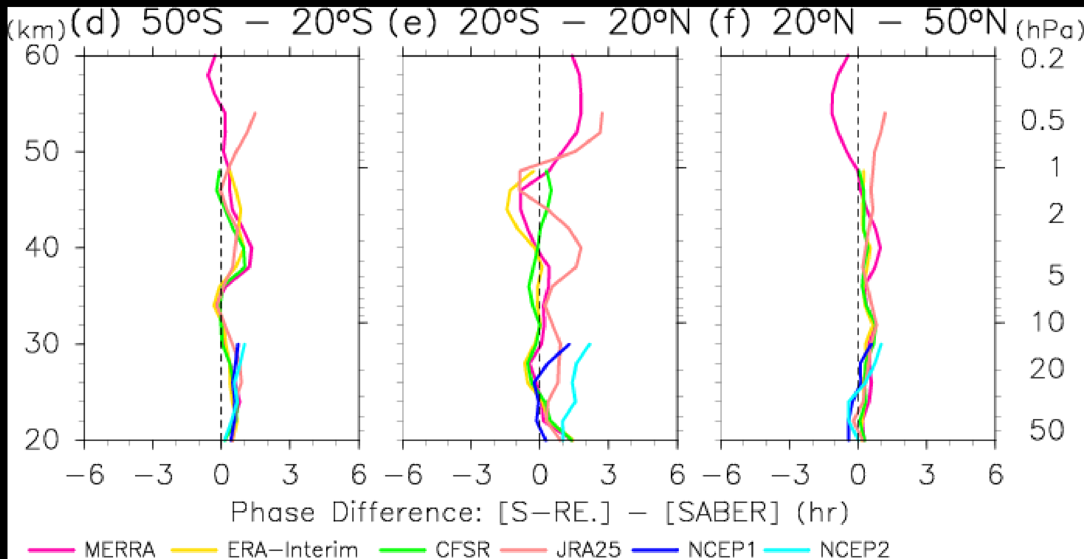
**Masatomo Fujiwara & Takatoshi Sakazaki et al. (Hokkaido Univ.)**

*Mean:
50S--20S: from October to March
20S--20N: All months
20N--50N: from April to September

Amplitude




Phase




- All reanalyses quite similar
- Difference with SABER large in the middle-upper stratosphere.
  - -**Amplitude**:
    - <20% below ~40km
    - 30-50% at 50-60 km.
  - -**Phase**:
    - <2 hr for almost all levels

- Why?
  - sponge layer?
  - model v assimilated obs bias?
  - DA initialisation and update cycle

# Summary of DA approaches

Met Office

| Method | Current | Future / Planned |
|---|---|---|
| 4D-Var | ECMWF (weak constraint), Canada, Japan, Korea, Australia, France, NRL, India | |
| Hybrid Ens/Var | UK (ETKF), France (Ensemble DA) | UK (upgraded ensemble), NCEP (May 2012), NRL, Canada, Australia, ECMWF, France (both Ensemble DA), India, Korea, Australia (ETKF) |
| LETKF | | Germany, Japan, Brazil |
| Other | Russia (OI), NCEP (SI), China (SI), Brazil (PSAS), Germany (3D-Var) | Russia (3D-Var) China (3D-Var) |

# Summary of GW approaches

| Method | Current | Planned |
|---|---|---|
| Spectral + orog | UK, ECMWF, Canada, India, Korea, Australia, France(?), NRL | UK, ECMWF, Canada, Japan, India, Korea, Australia, France, NRL |
| Orog only | NCEP, Japan (+RF), China | NCEP, China |
| RF | Russia | |
| Other / not known | Brazil, Germany | Russia (convective), Germany, Brazil |

# Summary So Far

Met Office

- All global NWP models include the stratosphere or plan to (except China)
- Benefit to troposphere analysis shown.
- Forecast impacts in 1-5 day range:
  - Not shown (UK) – if only model lid changes
  - Shown (Canada) – if model physics + lid changes
- Further vertical extension to mesosphere leads to improved stratosphere (higher lid), but problems from lack of obs, under-resolved tides
- Most DA systems are switching to a hybrid approach
- Spectral + orog GW schemes most popular

# Next steps

- Initial steps only – by no means complete
- More extensive summary of GW, radiation schemes, numerics, etc, and their impacts?
- Above may not be easy without explicit new experiments
- No definitive model description docs, so task much harder than initially thought
- Seek volunteers to form a team to complete this task?