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Some recent advances in middle atmosphere data assimilation

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SPARC General Assembly, Bologna, Italy, 31 August 2008

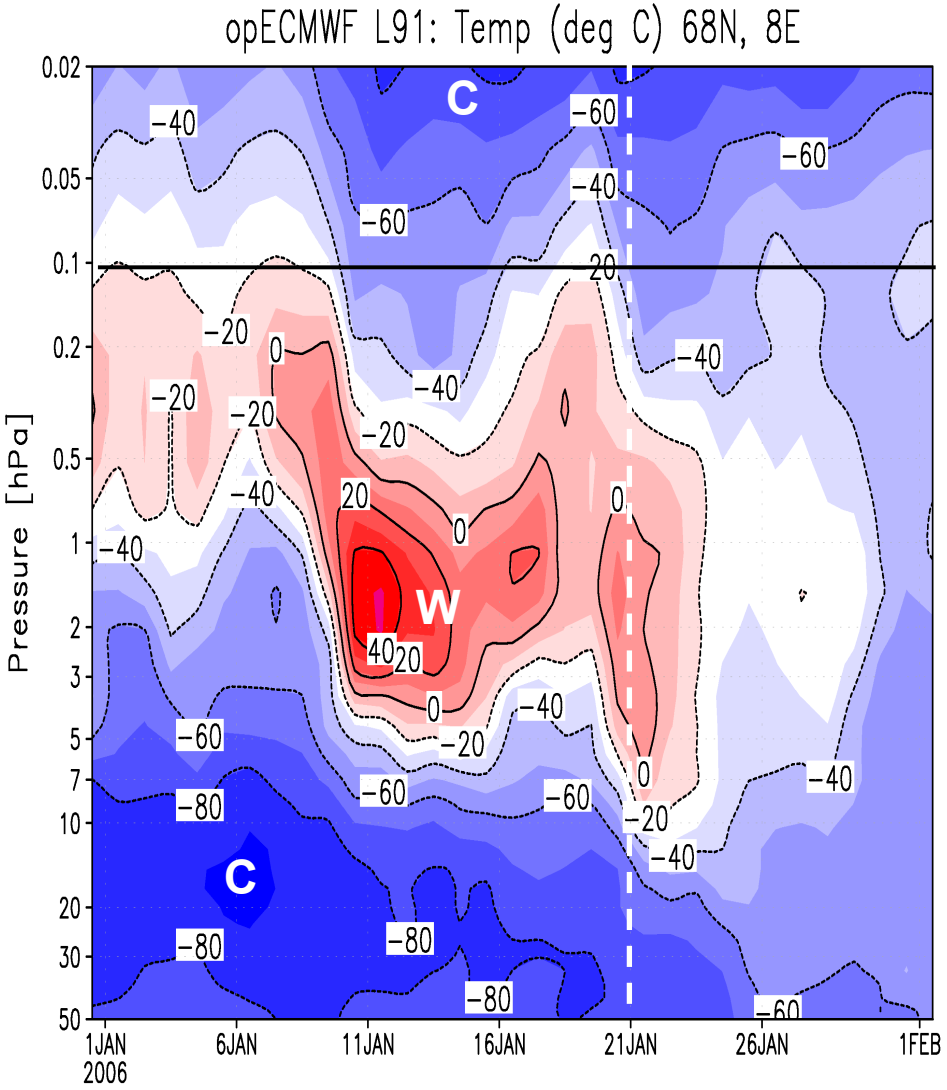
Advances in the past 5 years

- Operational weather centres raising model lids into the mesosphere
- Impact of latest improvements in assimilated fields on tracer transport
- Vertical propagation of information of observations into the mesosphere
- Holy grail: using obs to help improve model parameterizations

Advances at operational centers

NH winter 2005-6

Figure courtesy of Kirsten Krüger



- Operational model lids are moving to 0.01 hPa (80 km)
- ECMWF, Feb. 1/06
- Improved resolution, vertical extent, more obs, some limb
- Can now see meso-spheric coolings above SSWs
- Relevant for IPY, study of SSWs

Poster: A449 Long

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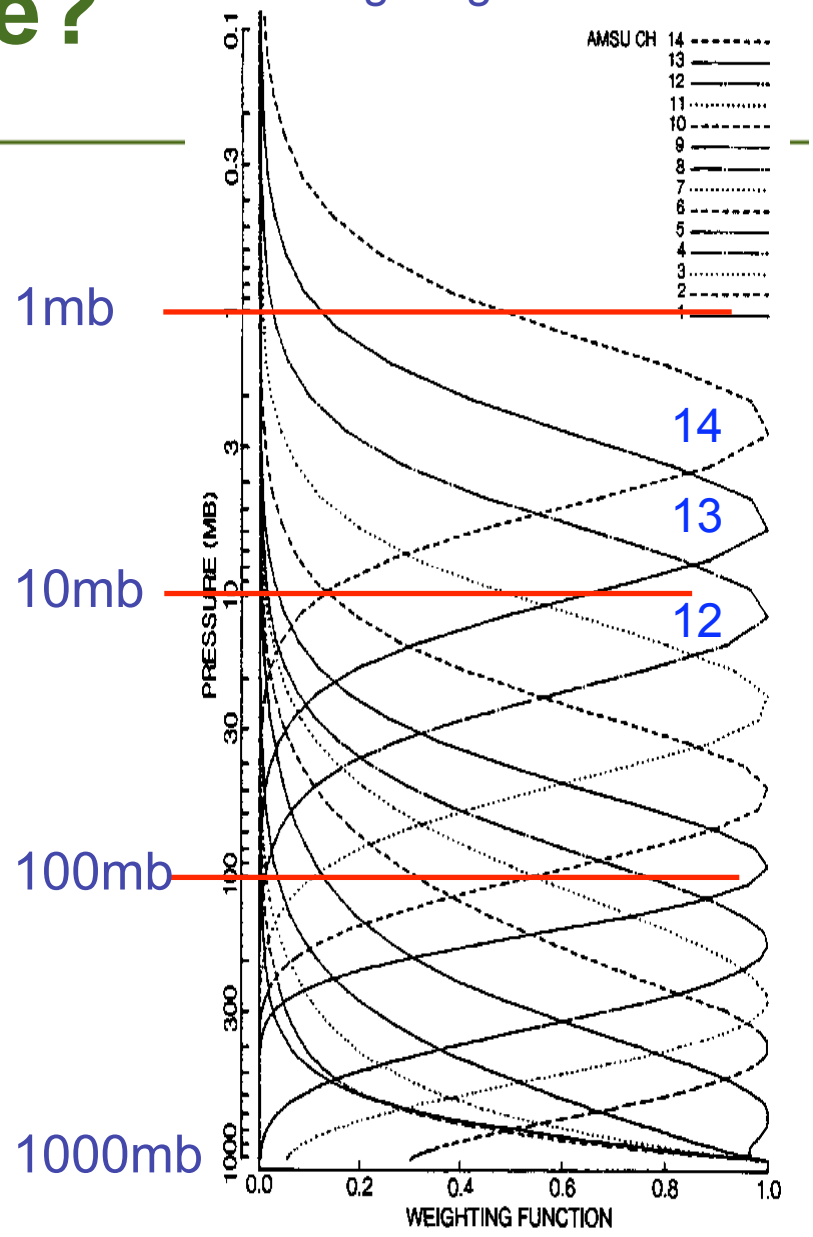
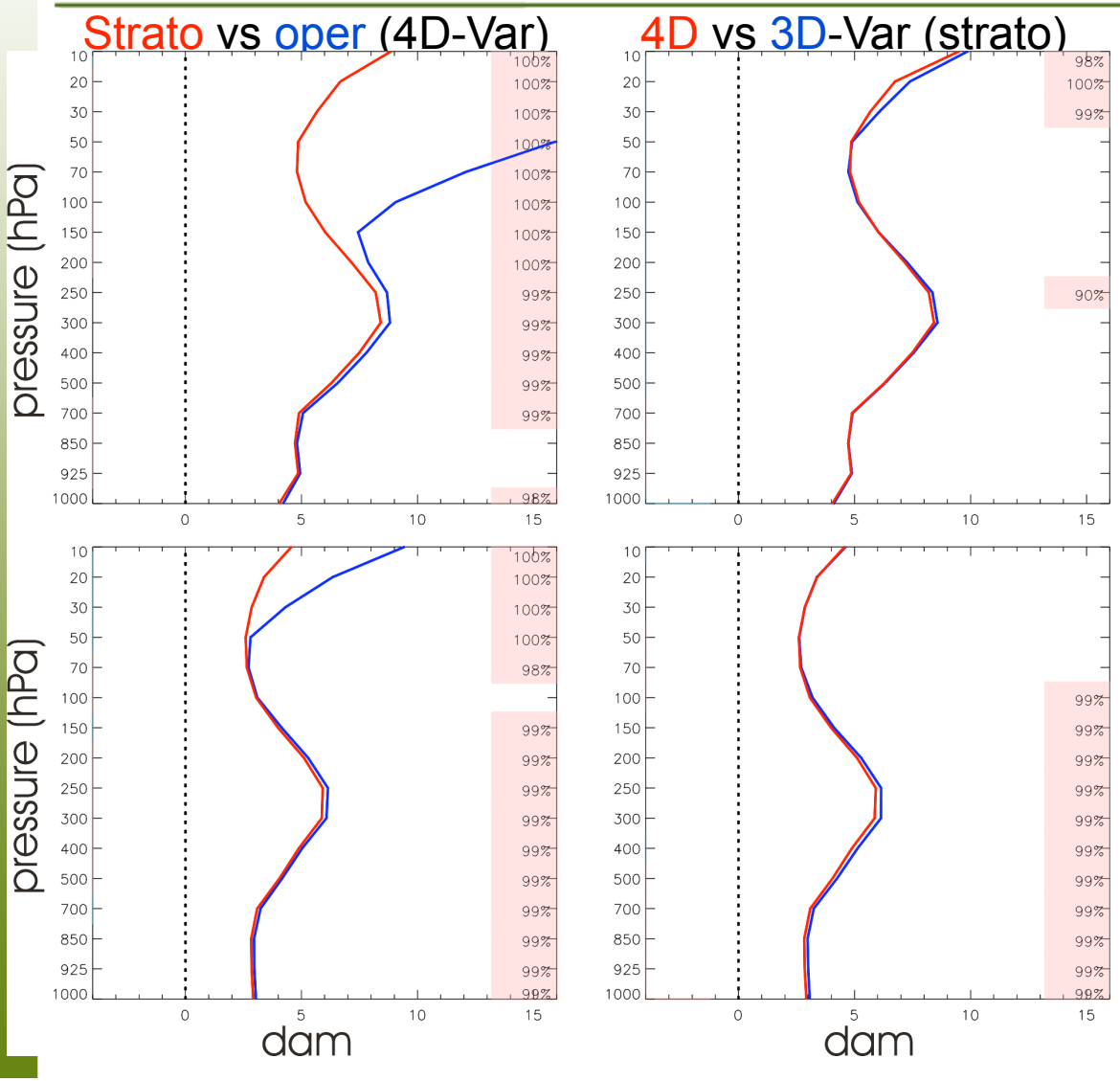
Why the mesosphere?

- Satellite radiances sense up to 0.1 hPa
- A model lid at 0.1 hPa means a sponge layer below this so obs (e.g. ch. 12-14) not well assimilated due to sponge
- To resolve Brewer-Dobson circulation, and winter polar temperatures and ozone descent, need good stratopause simulation, so sponge above 0.1 hPa

AMSU normalized weighting functions



Improving the stratosphere improves forecasts even in the troposphere



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

Winter

Impact of strato is bigger than that of 4D-Var

Summer

Impact of 4D-var is bigger than that of strato

Charron, Vaillancourt, Roch

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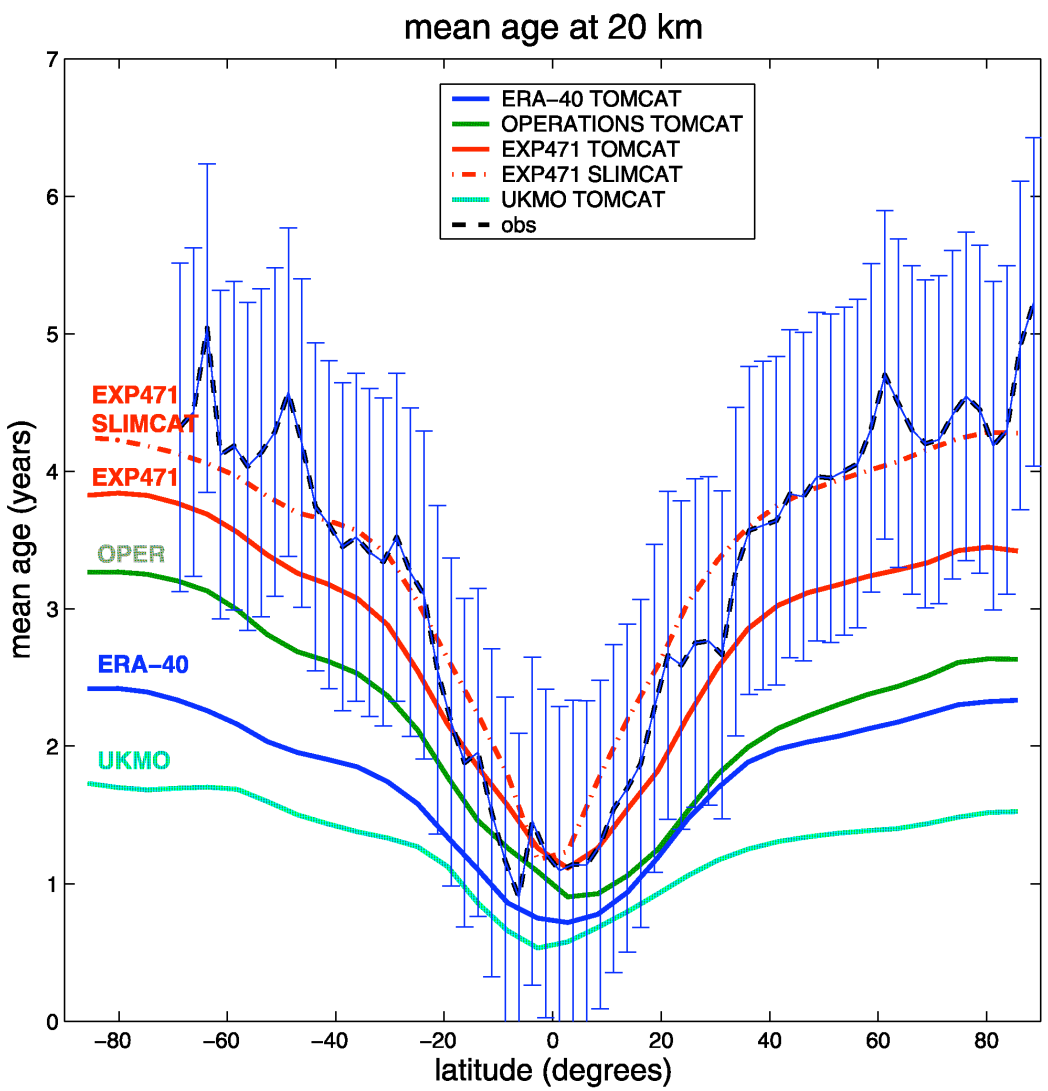
Improvements in assimilation techniques impact age-of-air



Monge-Sanz et al. (2007)

Poster: A162 Reszka

4D-Var (12h) + better balance + TOVS bias corr. + lower model bias +…

Operational 4D-Var (6h)

ERA40 3D-Var

Poster: C135 Monge-Sanz

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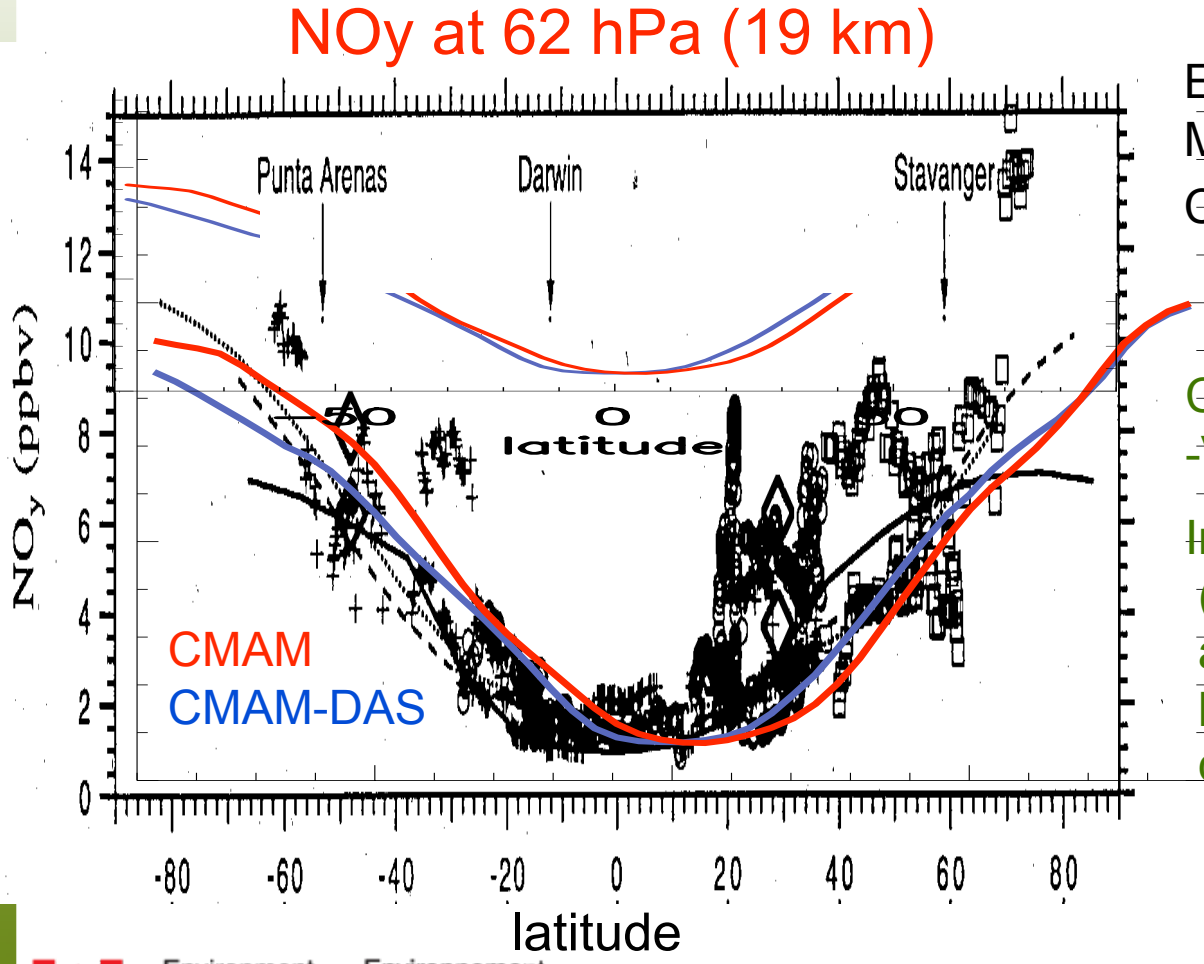
Latitudinal gradients can be well maintained even in 3D-Var analyses

Figure courtesy of Michaela Hegglin



ER2 aircraft data from Murphy et al. (1993)

CMAM-DAS - March 03

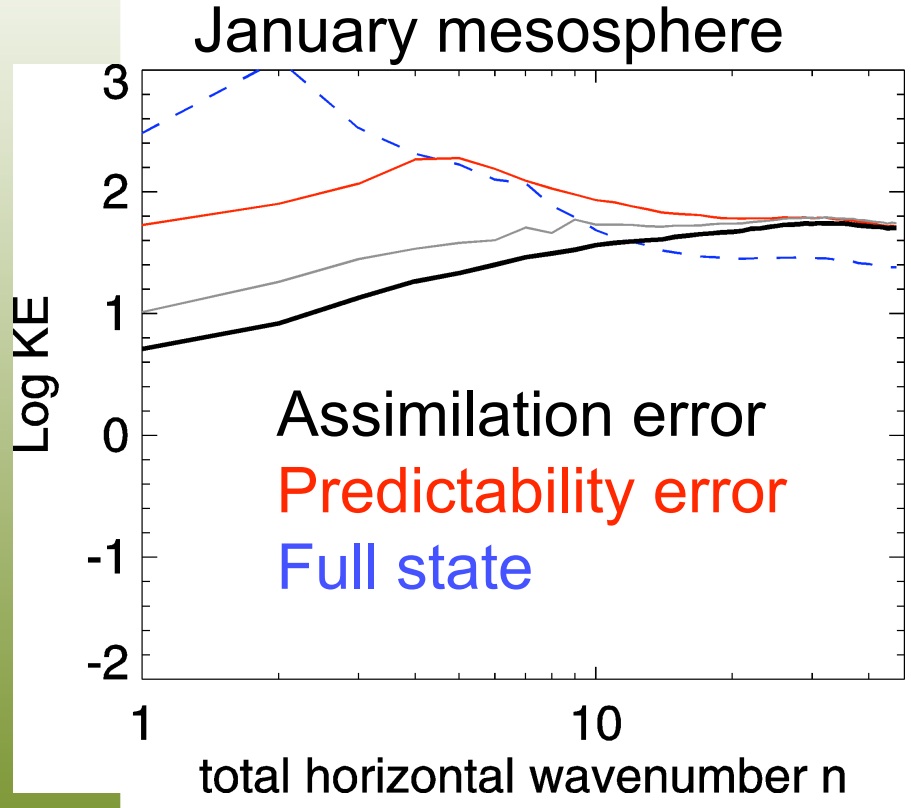
CMAM-DAS uses 3D -Var (not 4D-Var)!

Improvements due to: (1) online transport and/or (2) improved balance in increments due to IAU ?

Moving on up (to the mesosphere)

- A model lid near the mesopause helps improve simulation of stratosphere
- The mesosphere is now part of weather forecasting domain
- With observations in the troposphere and stratosphere only, what happens to the mesosphere? Is it improved?

Tropospheric and stratospheric obs help determine large scales in mesosphere



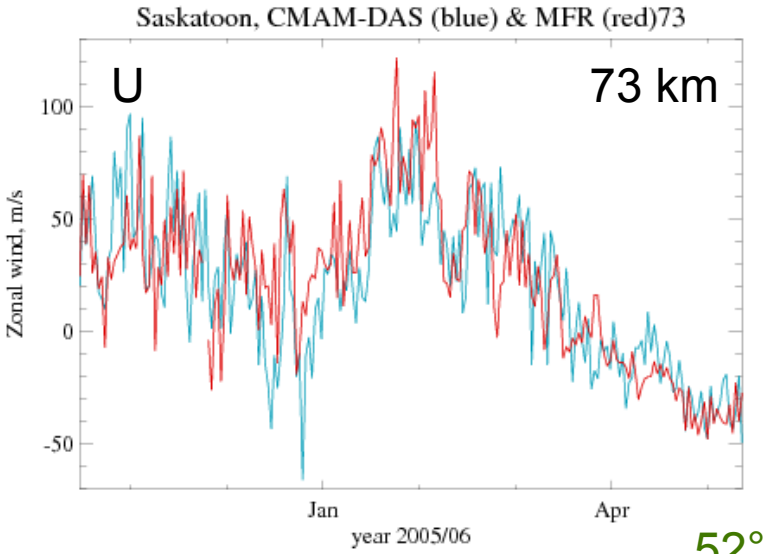
Nezlin et al. (2008)

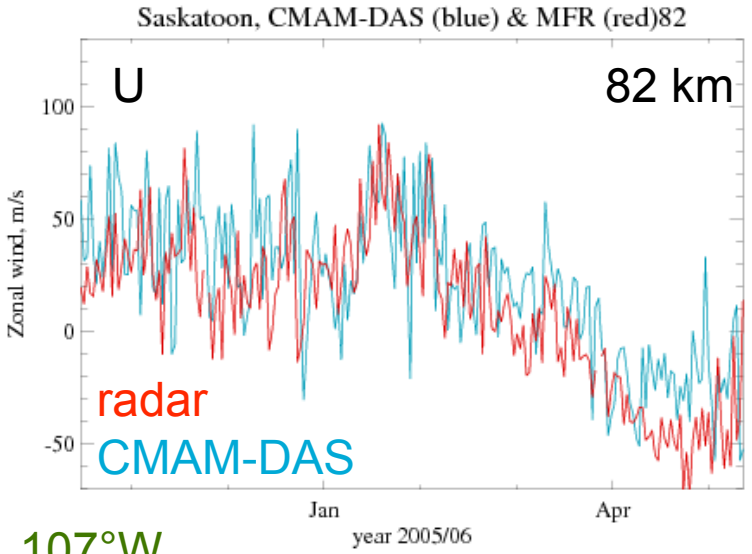
- "Reference" is model generated, so known
- Obs below mesosphere only in CMAM-DAS
- Model forecast propagates information from troposphere and stratosphere to mesosphere

Poster: A72 Nezlin

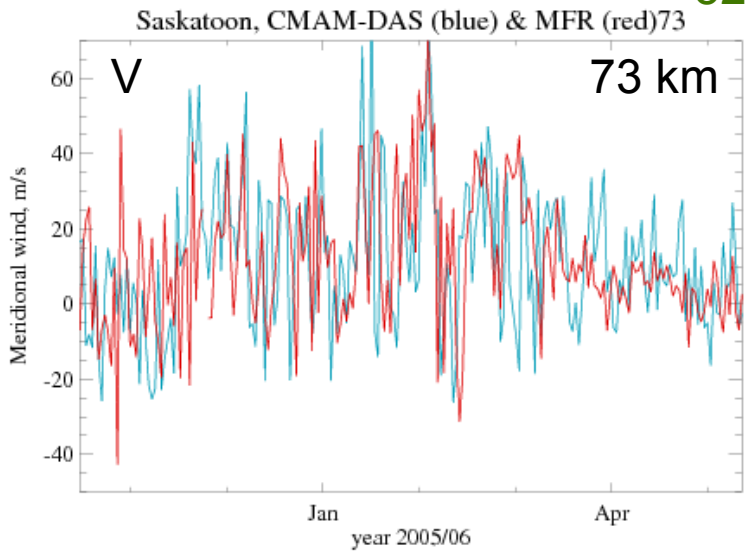
Mesospheric analyses have some value even when obs only below 45 km

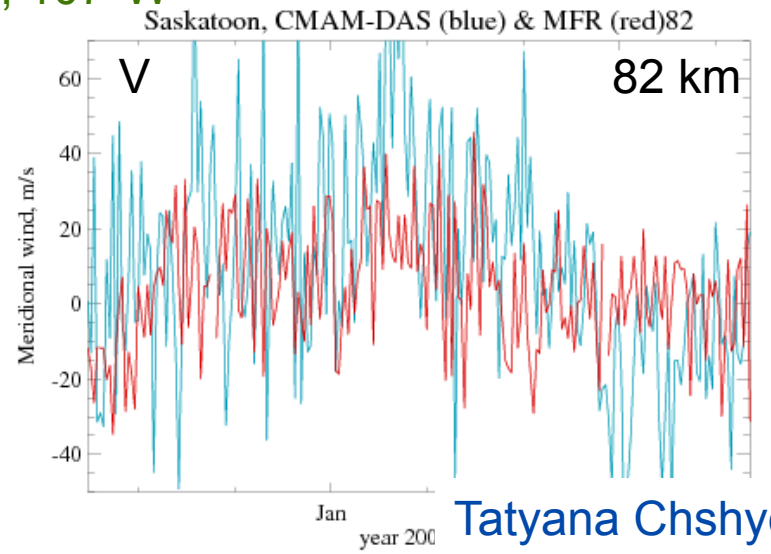
Compare CMAM-DAS to Saskatoon radar winds at noon





52°N, 107°W





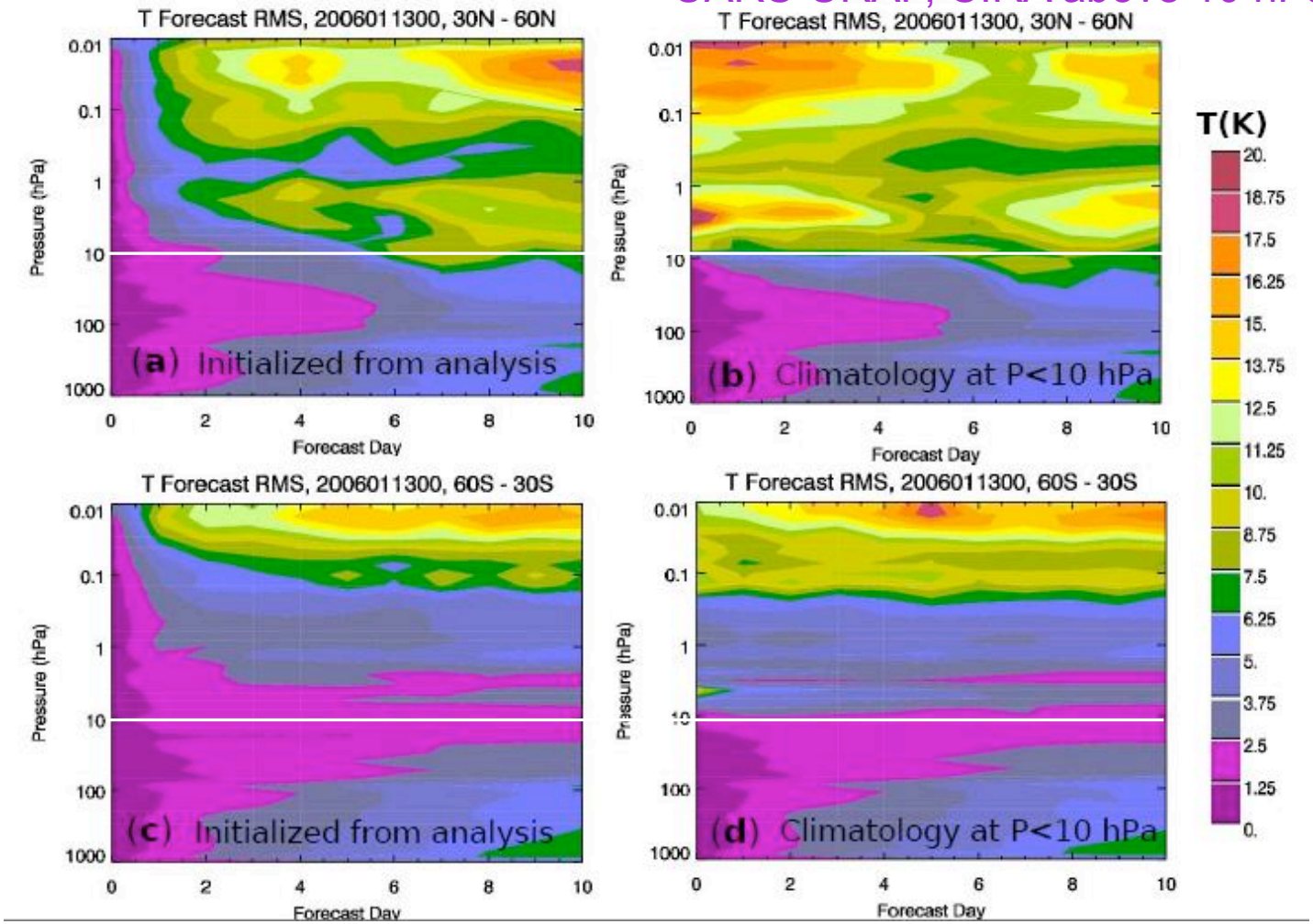
Tatyana Chshyolkova

Assimilating mesospheric obs is useful esp in winter

Hoppel et al. (2008, SPARC Newsletter no. 30, p.30)

Forecasts from analyses

Forecasts from climatology
UARS-URAP, CIRA above 10 hPa



- NRL's model NOGAPS-ALPHA T79L68, lid at 96 km
- SABER, MLS temperature assimilated 32-0.01 hPa
- 12 forecasts during Jan-Feb 2007

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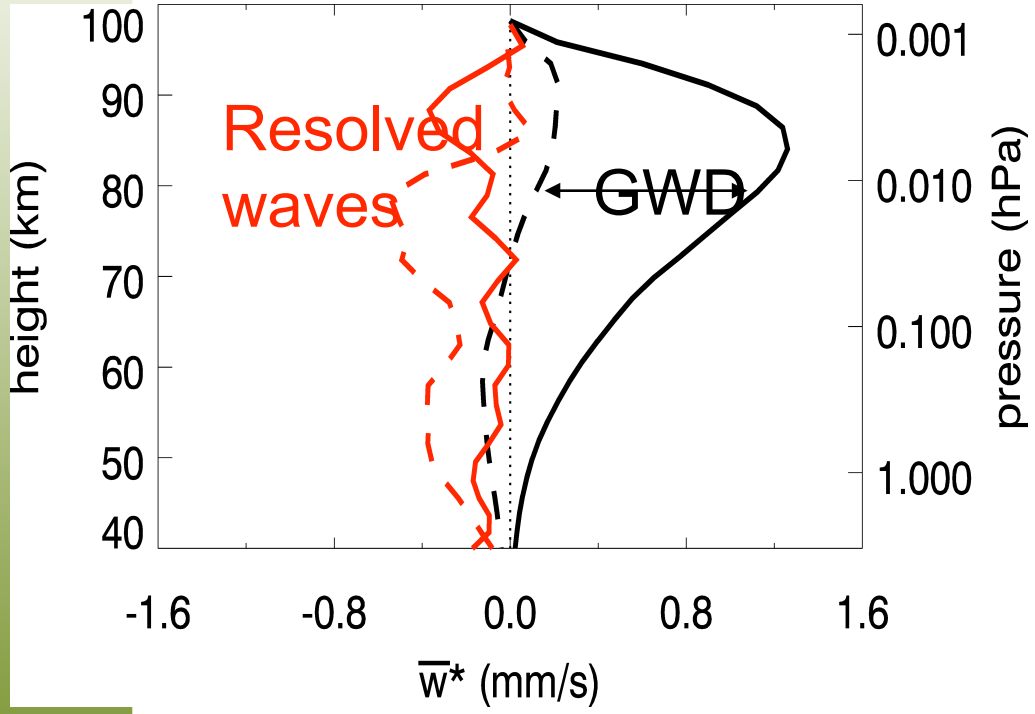
Information propagation through a Gravity Wave Drag (GWD) scheme

- GWD scheme has a big impact on (at least) some simulated phenomena. Here we look at the 2002 SH SSW.
- Information inserted in the lower atmosphere adjusts the planetary waves, whose EP flux divergence influences zonal mean wind, which filters GWs

Upwelling or cooling during 2002 SSW

Ren et al. (2008)



Profiles are ensemble and time (28 Sept. to 1 Oct. 2002) avg.

- CMAM-DAS has no obs above 1 hPa (45 km)
- Ensemble of forecast "hits" (solid)
- Ensemble of forecast "misses" (dashed)
- "hits" have much more cooling due to GWD at 80 km
- "hits" have more cooling due to resolved waves below 80 km

Poster: A102 Ren

Gravity Wave Drag (GWD) scheme couples information in troposphere and mesosphere

- In a model simulation (forecasts), GWD is driving amplitude and vertical extent of mesospheric cooling above stratospheric warmings
- With the lower atmosphere constrained by obs, zonal mean mesosphere is slaved to it and is predictable through GWD
- If model forecast does not match observations, GWD scheme needs adjusting
- Can use assimilation tools to identify gravity wave drag force

Using 4D-Var to estimate forcing due to gravity wave drag

Pulido and Thuburn (2005,2006,2008)

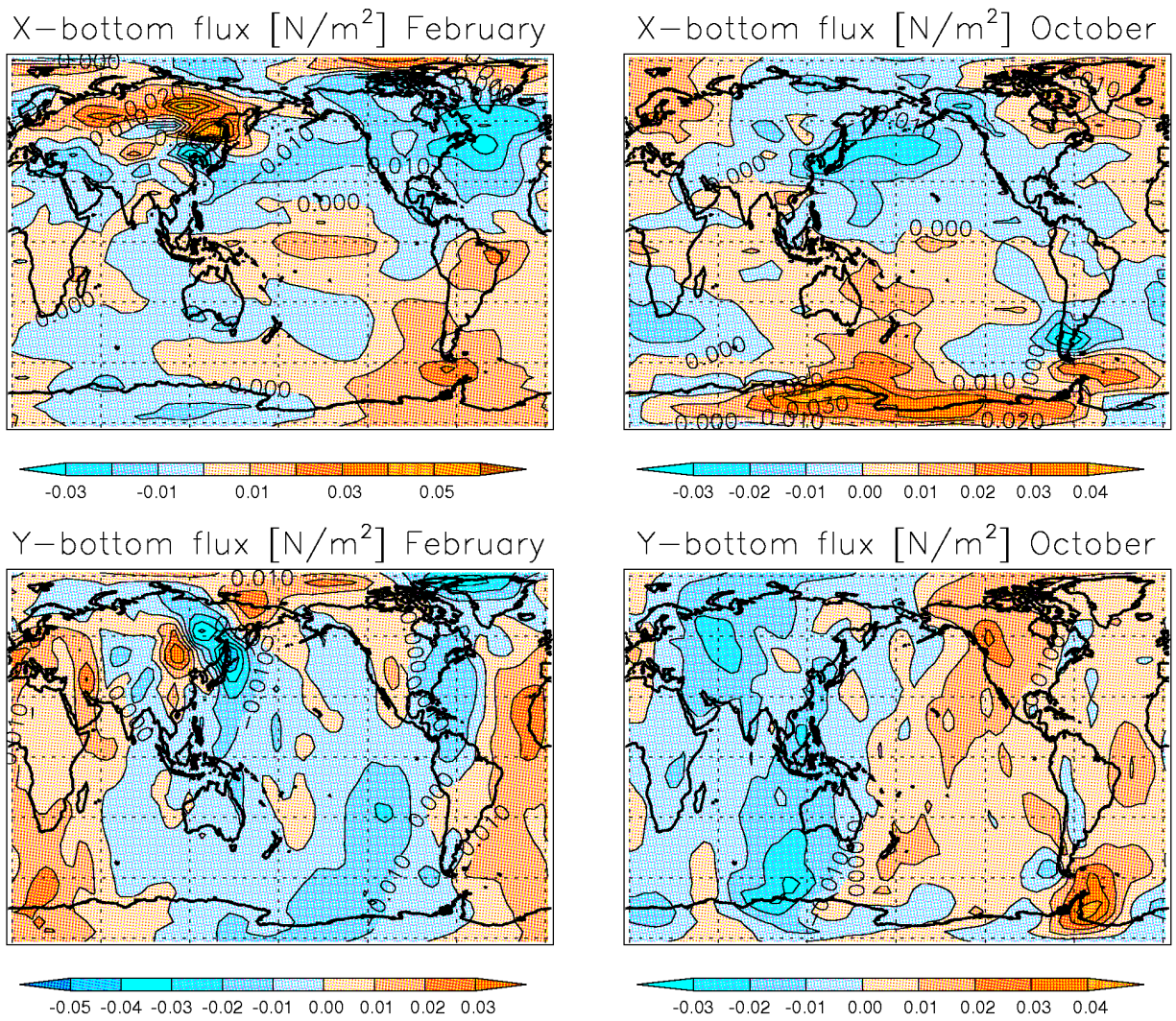
- Instead of using mismatch between observations and forecast to determine initial conditions (ICs), assume ICs correct and determine drag on u and v
- Knowns: u,v,T (Met Office analyses)
- Observed divergence not reliable, so not used. Thus only rotational part of drag is estimated (one 3D field)
- Can estimate 3D daily drag field. Drag assumed constant over 24 h.
- Resulting drag field consistent with previous estimates
  - Strength and location of winter deceleration centres
  - Descent of drag with QBO, SAO in tropics

GW sources? vertically integrate estimated drag

Pulido and Thuburn (2008)

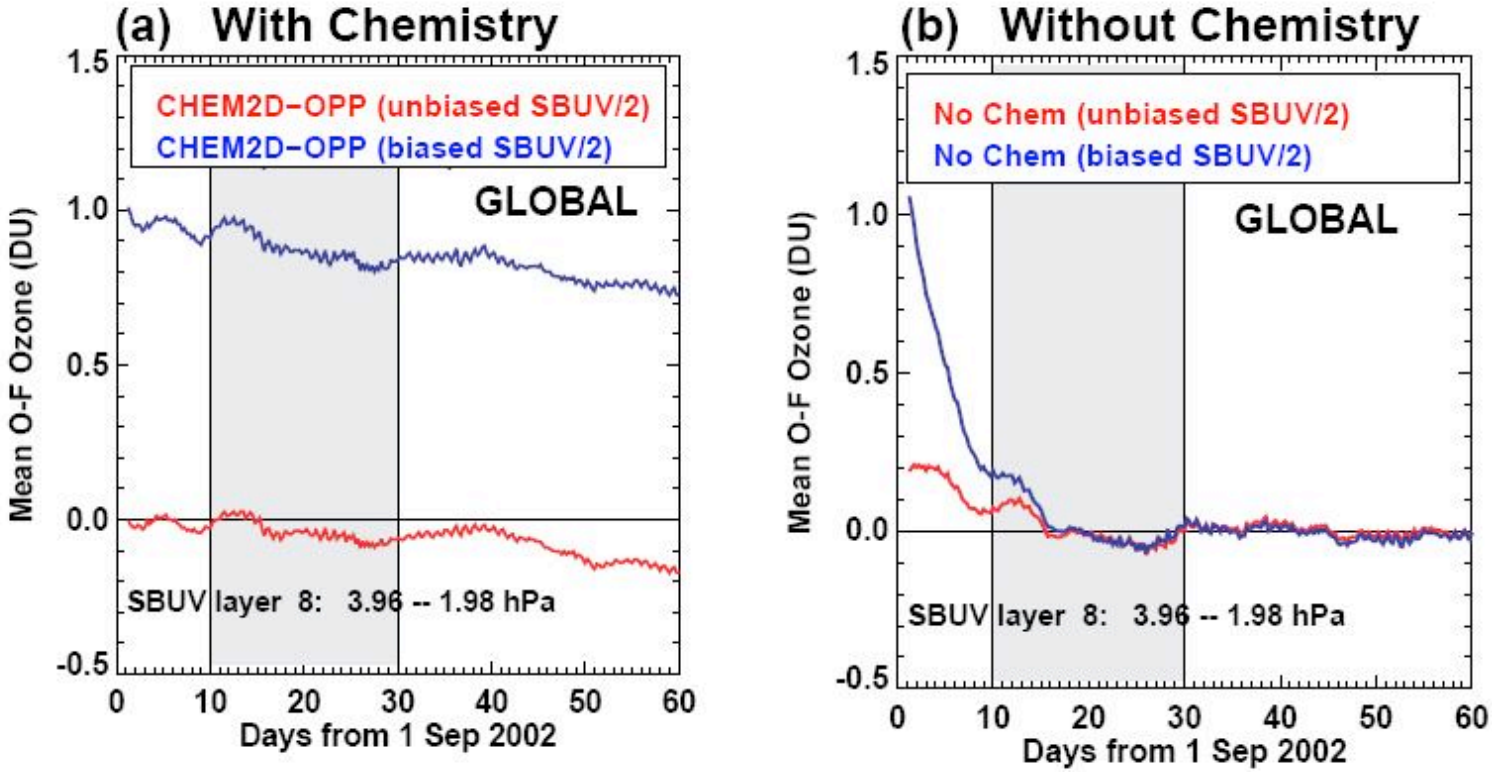
- Drag at a given level reflects GW sources and filtering by wind
- Contribution mainly from stratosphere where estimates are noisy
- Does this reflect GW sources? Need to compare to obs
- Could be used to estimate parameters in GWD schemes

Poster: A167 Pulido



Impact of chemistry in upper stratosphere on assimilation

Coy et al. (2007)



- t(ozone) ~ 1 day for SBUV layer 8 (2-4 hPa)
- Obs bias → Analysis bias → Forecast bias, if no chemistry.
  So O-F bias → zero
- Obs bias → Analysis bias → 0 if chemistry damps ozone.
  So O-F bias → O bias Can detect obs bias!

State of the art ~5 years ago
Problem areas for assimilated fields

- Tropical tropopause bias (Randel et al. 2004)
  - Low vertical resolution, sub-optimal use of satellite temperature retrieval data
- Tropical variability (QBO) under estimated (Randel)
  - Reliance on TOVS data
- Stratopause temperature and sharpness (Randel)
  - Close to model lid, low resolution satellite observations
- Polar vortex strength, structure and evolution in upper stratosphere (Manney 2005)
  - Close to model lid, low resolution satellite observations

- *Problematic Regions:* tropics, polar regions, upper stratosphere
- *Why?* Sub optimal resolution, vertical extent, data usage, model representation of GWD

More to do

- How do recent improvements in resolution, vertical extent, assimilation techniques and observation usage affect conclusions of SPARC report of 2004?
  - SPARC community provides feedback to assimilation community by using and assessing analyses/reanalyses

Poster: B315 Krueger

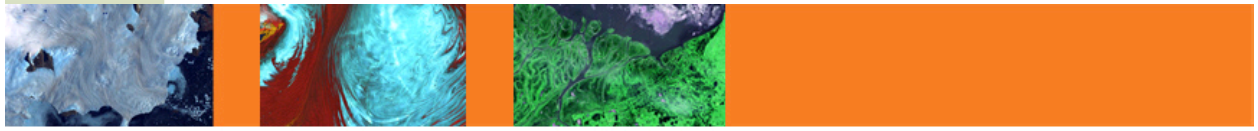
- Why is age-of-air now better with analysed winds?
- Have polar analyses improved? Exploit SPARC IPY archive of analyses.

Poster: A440 Farahani

- Separate model (forecast) and obs bias
- Use assimilation to help determine model parameters
  - How do we connect GW drag field to GW source parameters?

SPARC Data Assimilation Working Group

- Annual workshops: 2002 – Baltimore, 2003 – Florence, 2005 – Banff, 2006 – Noordwijk, 2007 – Toronto
- Mix of data assimilators, users of assimilation products, and experts in measurements, modeling, dynamics and chemistry



- SPARC IPY archive (Mar/07 – Mar/09)

http://www.moca-09.org

Montreal, 19-29 July 2009

SPARC-DAWG sessions:

J21: Adv in data assim

M01: Middle atm science

EXTRA SLIDES

Still more…

- Forcing of model by obs may lead to inconsistencies in derived products
  - Ozone loss rates — Poster: A294 Baier
  - Potential vorticity — Poster: A369 Yudin
- Improve constituent assimilation

  talk: A14 Mathison | Poster: A123 Errera | Poster: A151 Lahoz

  Poster: A405 Sekiyama
- Inferring ozone loss rates

  Poster: B27 Jackson | Poster: B297 Murtagh