# Stratospheric Data Assimilation at the Met Office - progress and plans

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# Stratospheric Data Assimilation

- Historical Background
- Reducing model errors - USSP GWD
- Variational assimilation: 3D-VAR
- Ozone assimilation
- New Dynamics
- Future plans

 

# Stratospheric Analysis – History

- “SSU Analysis” - 1978
  - Original stratospheric analysis, based on gridded retrievals of thickness; T and winds derived
- Analysis Correction Scheme - 1991
  - First Met Office stratospheric data assimilation system; asynoptic, repeated insertion
- Variational Assimilation - 2000
  - 3D-VAR assimilation; 6 hour cycle

 

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# Model errors

- Many troposphere-stratosphere General Circulation Models have large errors:
  - Cold winter poles; biases of 40K or more in southern winter.
  - Westerly winds in the upper stratosphere are commonly double the observed strength.
  - Almost constant winds in the tropical lower stratosphere, while observations show Quasi-Biennial Oscillations between -30 and +20 m/s.

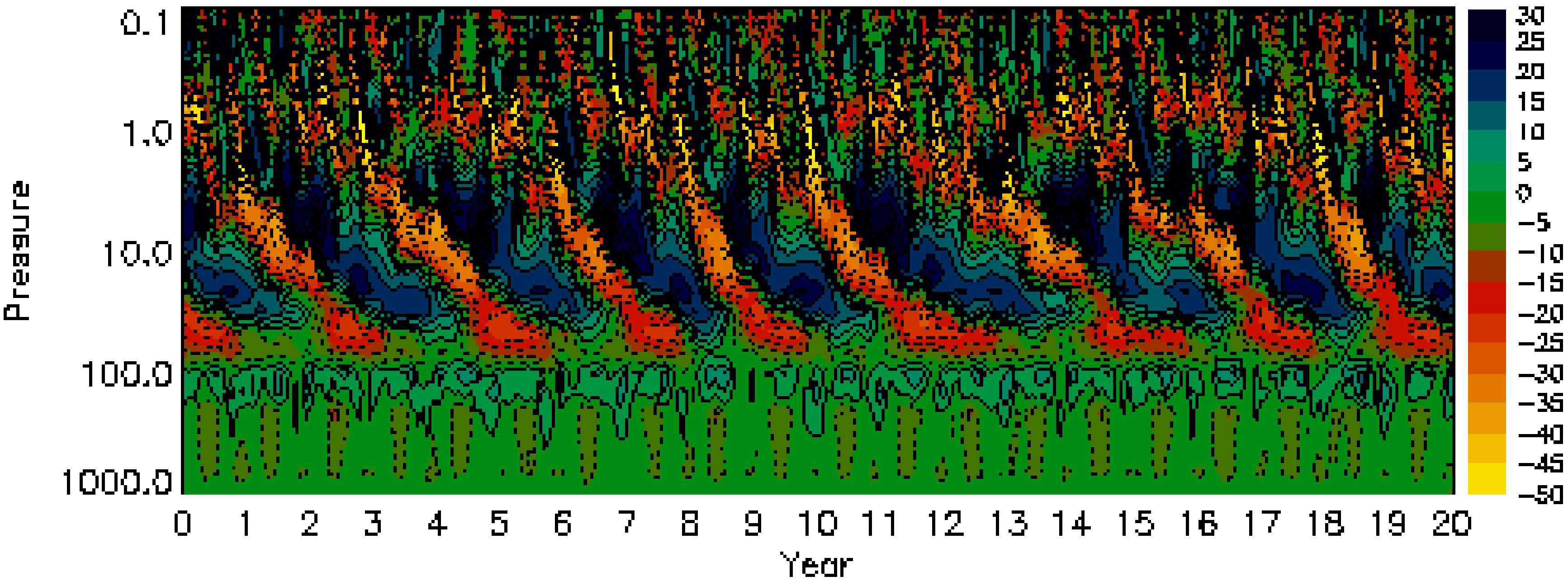
 

# Gravity wave drag

- Typical model errors are alleviated using a parametrization of drag due to breaking gravity waves
- We have implemented the USSP scheme (Warner and McIntyre, 2000) in the UM
  - Isotropic and homogeneous source of gravity waves in the lower atmosphere
  - Launch spectrum proportional to $m^{-3}$ at large $m$
  - Hydrostatic, non-rotating dispersion relation: $\omega/k=N/m$
  - “Transparent” upper boundary

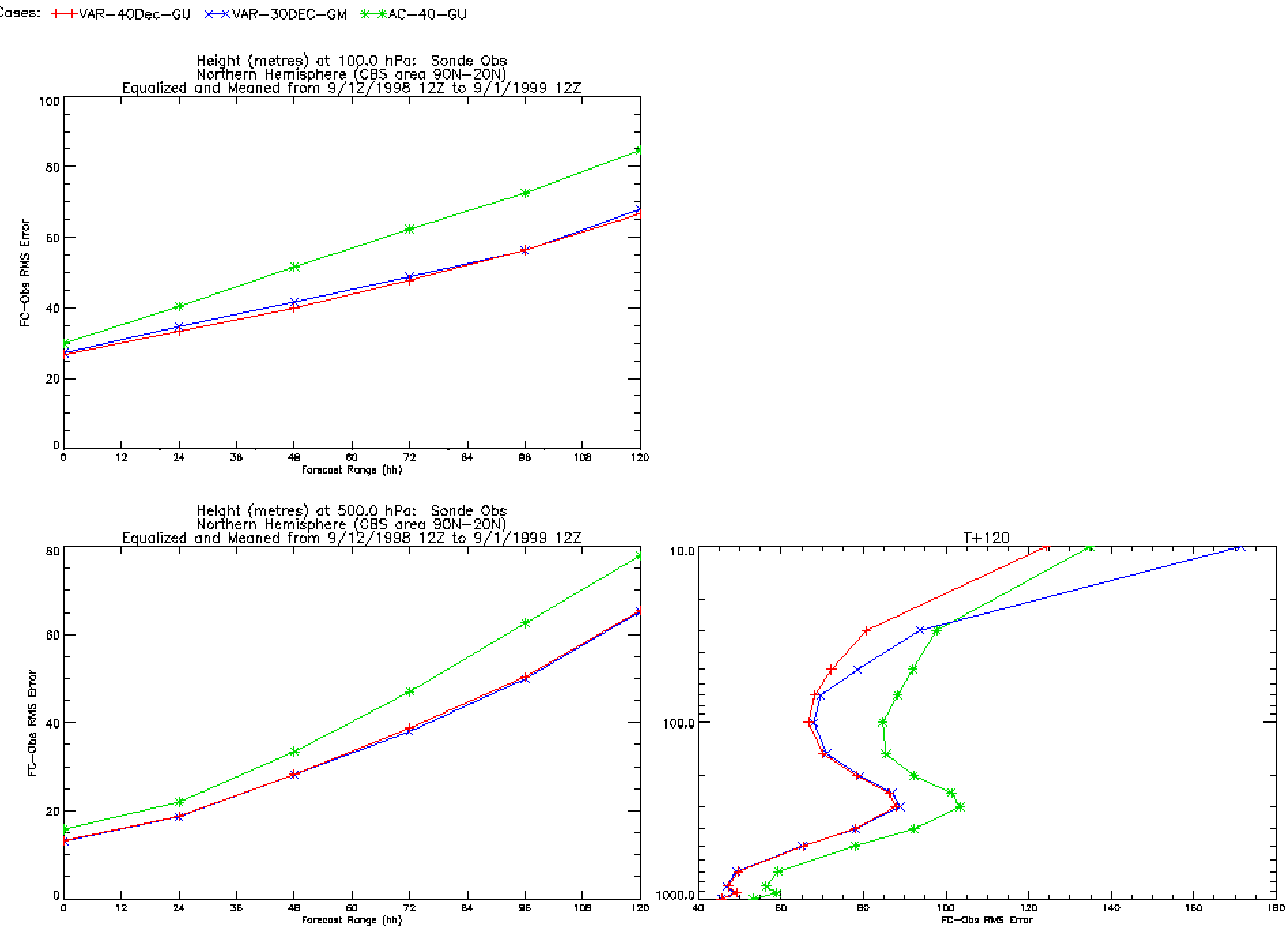
 

# Simulated QBO



# Features of 3D-VAR for the stratosphere

- Direct assimilation of ATOVS & TOVS radiances
  - radiance bias correction, except uppermost channels
- Background error covariances using “NMC method”
  - use rotated vertical modes in stratosphere
- Prototype for future extended global forecast system, spanning stratosphere
  - 40-level model, based on current global 30-L model
  - most testing done at medium resolution (0.83°x1.25°), rather than usual stratospheric low resolution (2.5°x3.75°)


Cases: VAR−40Dec−GU VAR−30DEC−GM AC−40−GU
Height (metres) at 100.0 hPa: Sonde Obs
Northern Hemisphere (CBS area 90N−20N)
Equalized and Meaned from 9/12/1998 12Z to 9/1/1999 12Z
FC−Obs RMS Error
Forecast Range (hh)
Height (metres) at 500.0 hPa: Sonde Obs
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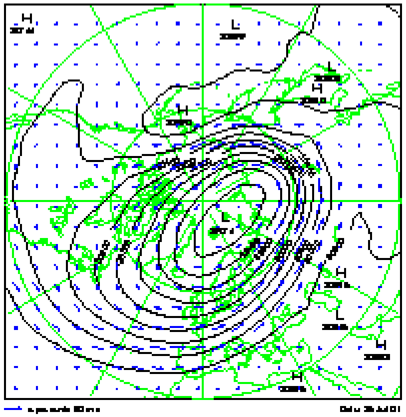
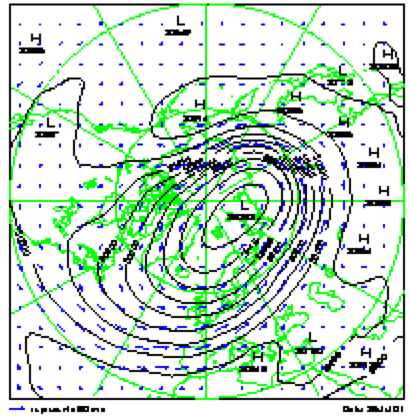
Forecast Range (hh)
T+120
FC−Obs RMS Error

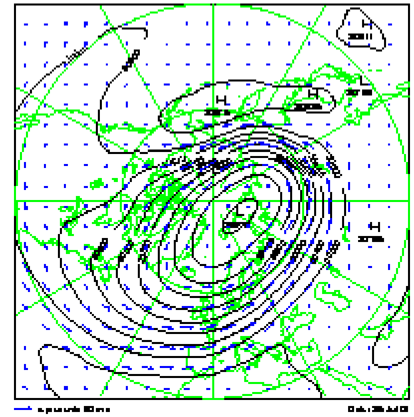
Old operational (AC)
Geopotential height and wind vectors
Valid at 12 GMT Nov 10 2000 day 316
Level: 10.0 hPa Analysis



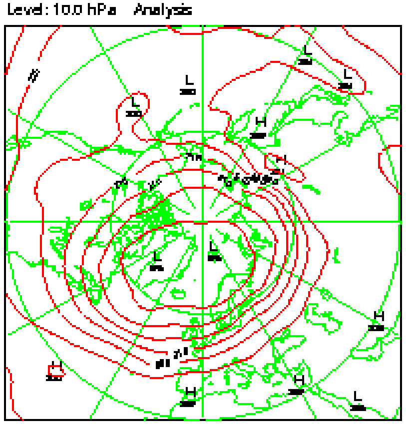
ECMWF
Geopotential height and wind vectors
Valid at 12 GMT Nov 10 2000 day 310
Level: 10.0 hPa Analysis



New Operational (3DVAR)
Geopotential height and wind vectors
Valid at 12 GMT Nov 10 2000 day 316
Level: 10.0 hPa Analysis



Old operational (AC)
Temperature
Valid at 12 GMT Nov 10 2000 day 316
Level: 10.0 hPa Analysis



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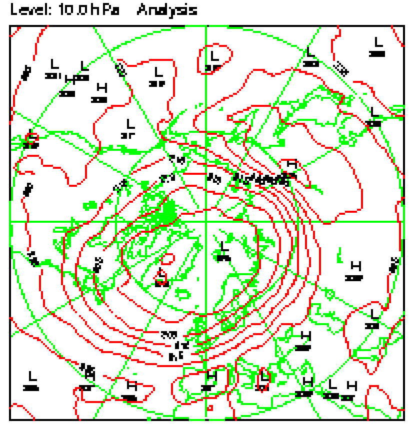

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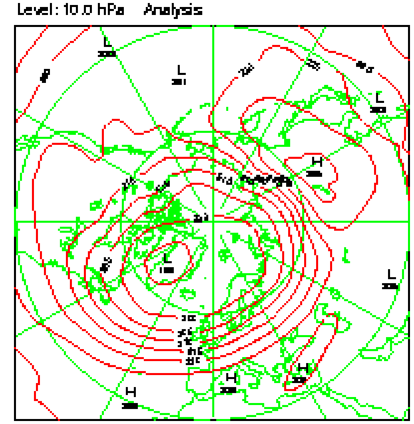

Old operational (AC)
Geopotential height and wind vectors
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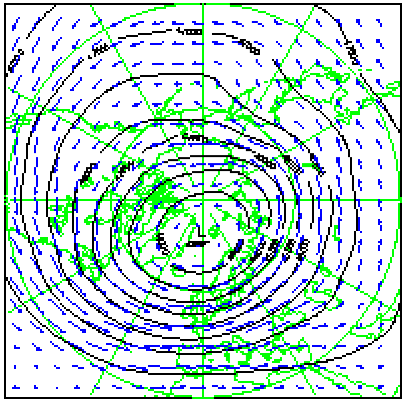
Level: 1.00 hPa Analysis



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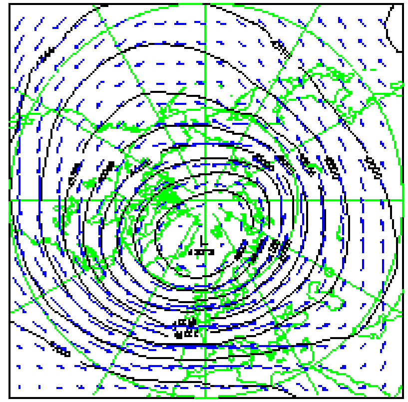
Level: 1.00 hPa Analysis



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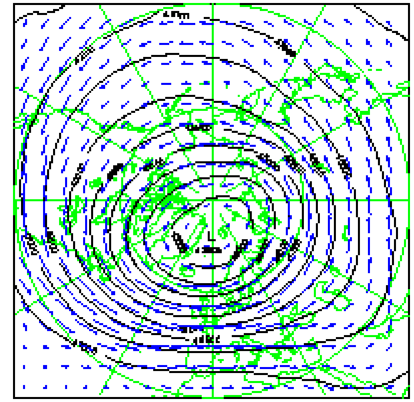

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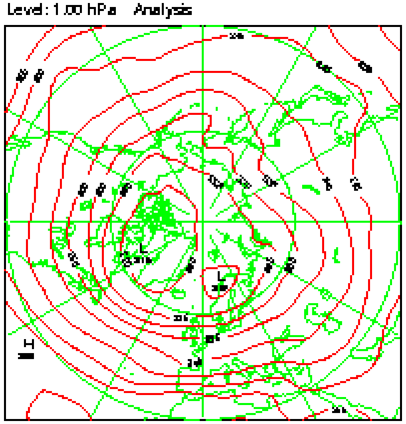

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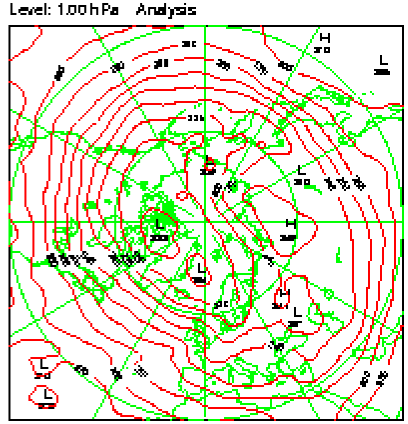

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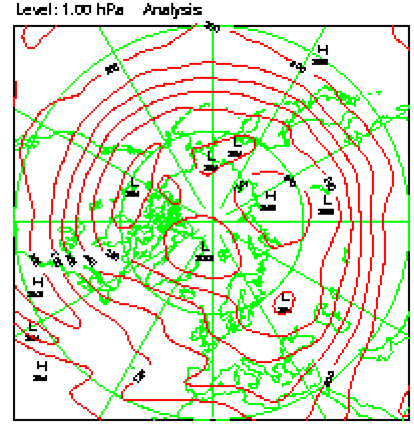
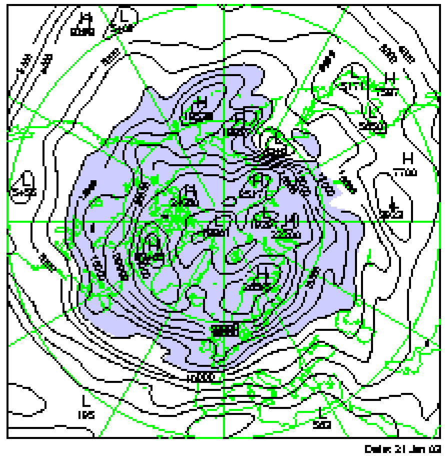


Old operational (AC)
PV at 1900K 12Z 10 Nov 00

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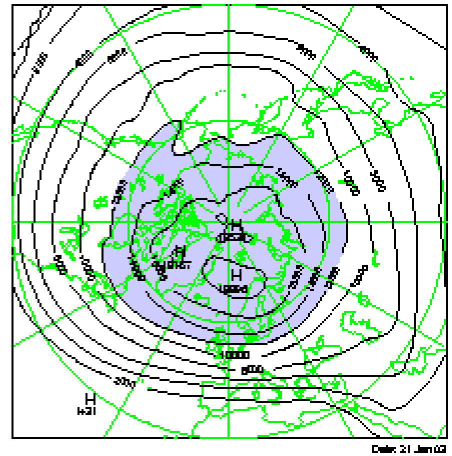
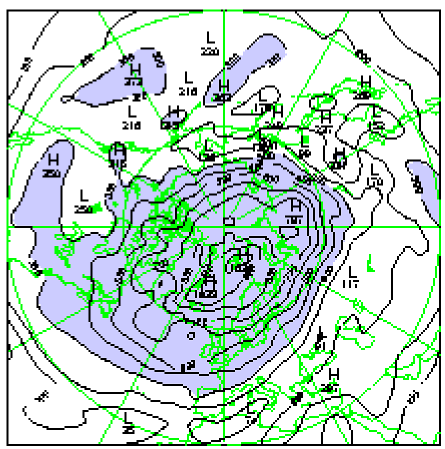
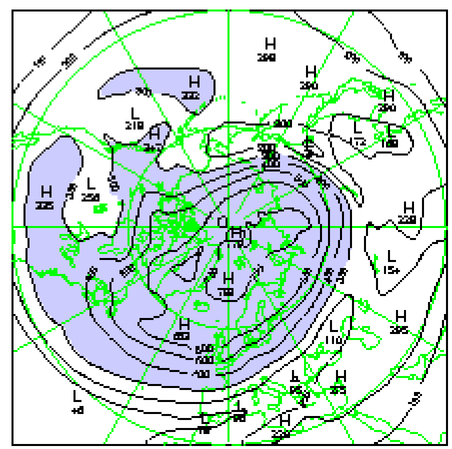



Old operational (AC)
PV at 840K 12Z 10 Nov 00




New Operational (3DVAR)
PV at 840K 12Z 10 Nov 00



# Ozone Assimilation

- Potential benefits for NWP
  - Improved radiance assimilation (HIRS, AIRS, IASI)
  - Improved radiative heating rates
  - Possible impact on UTLS wind fields
  - Improved forecasts of surface UV
- Exploitation of research satellite data (eg Envisat)

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# Ozone in 3D-Var - Current system

- Univariate ozone assimilation using 3D-Var.
- Background ozone via tracer transport equation. Option of parametrized chemistry (not used here).
- Background error covariances from ECMWF (later with increased variances at upper levels).

# HIRS-9 and SBUV data

## SBUV Data

- Ozone retrievals for 6 layers:

1013-16 hPa

16-8 hPa

8-4 hPa

4-2 hPa

2-1 hPa

1-0.1 hPa

## HIRS-9 ozone Jacobian

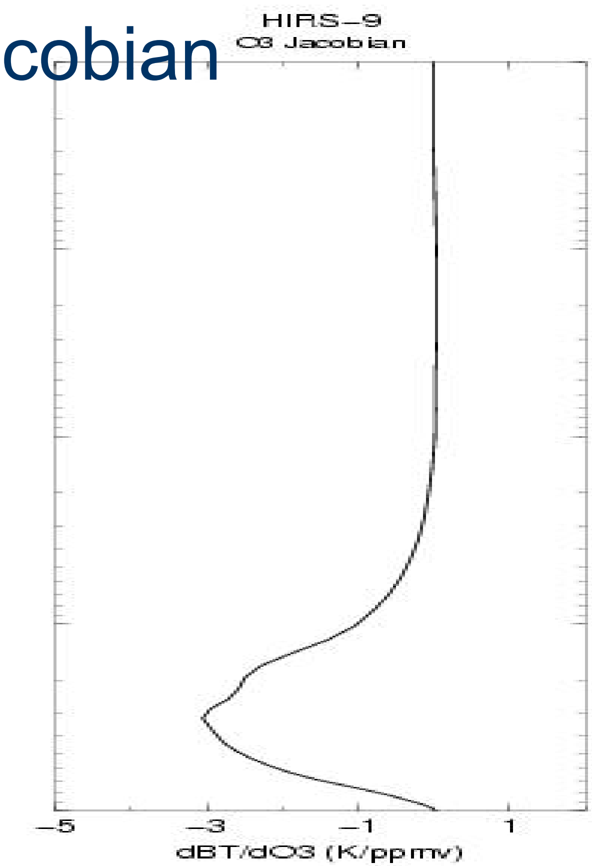
0

1

10

100

1000



# Ozone analysis increments

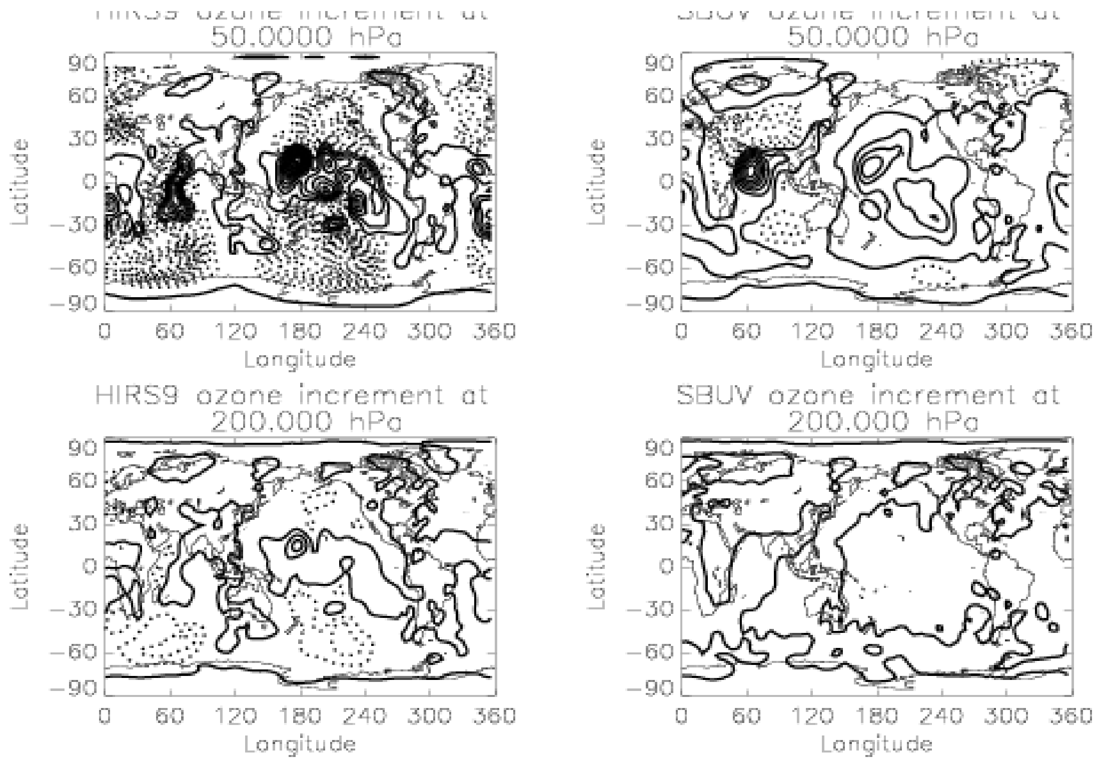
HIRS-9 (left) SBUV (right)

50 hPa (top)

cont. int.

0.004 ppmm

200 hPa



# HIRS-9+SBUV test: O-A (GOME)

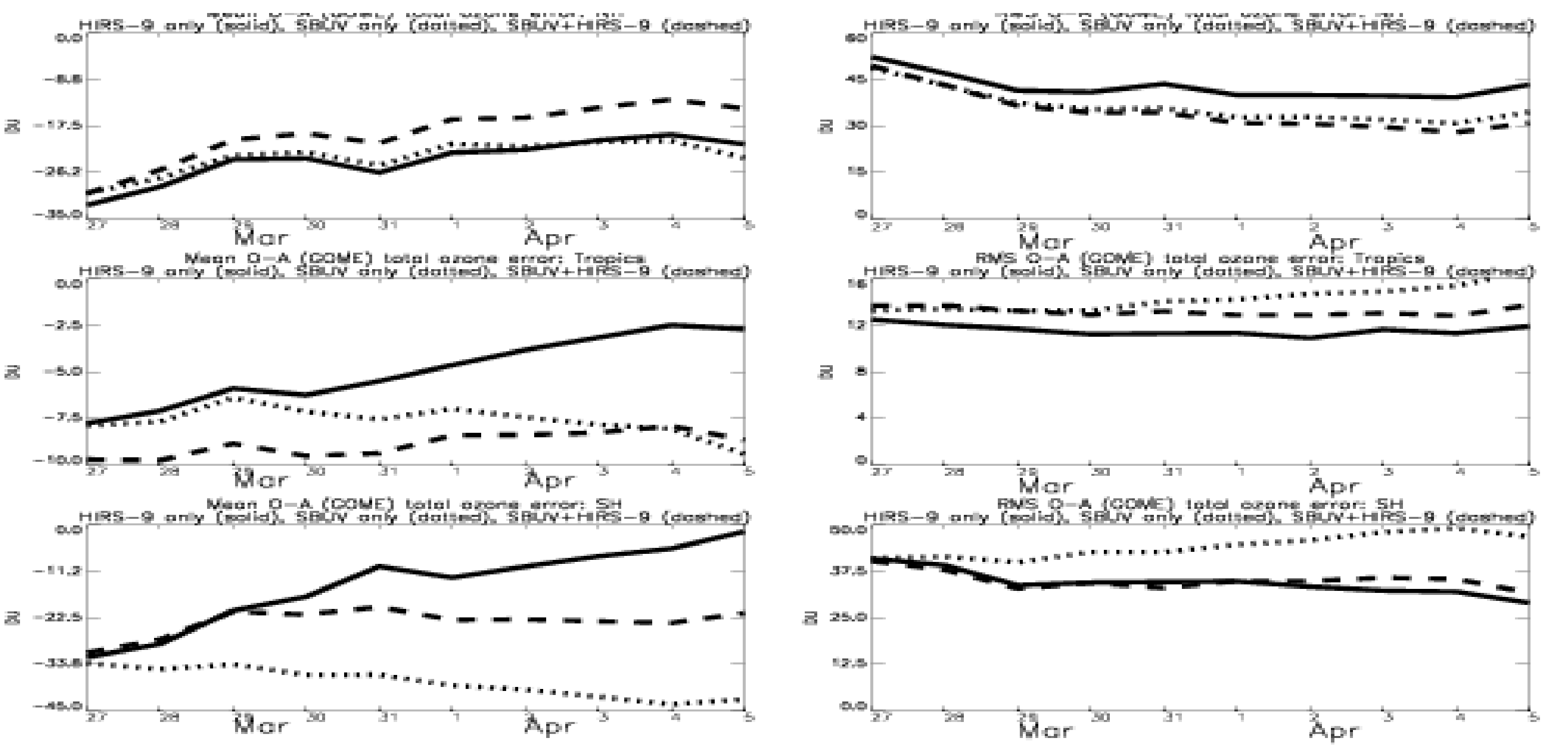
Mean error | RMS error

NH

Tr.

SH

Sol

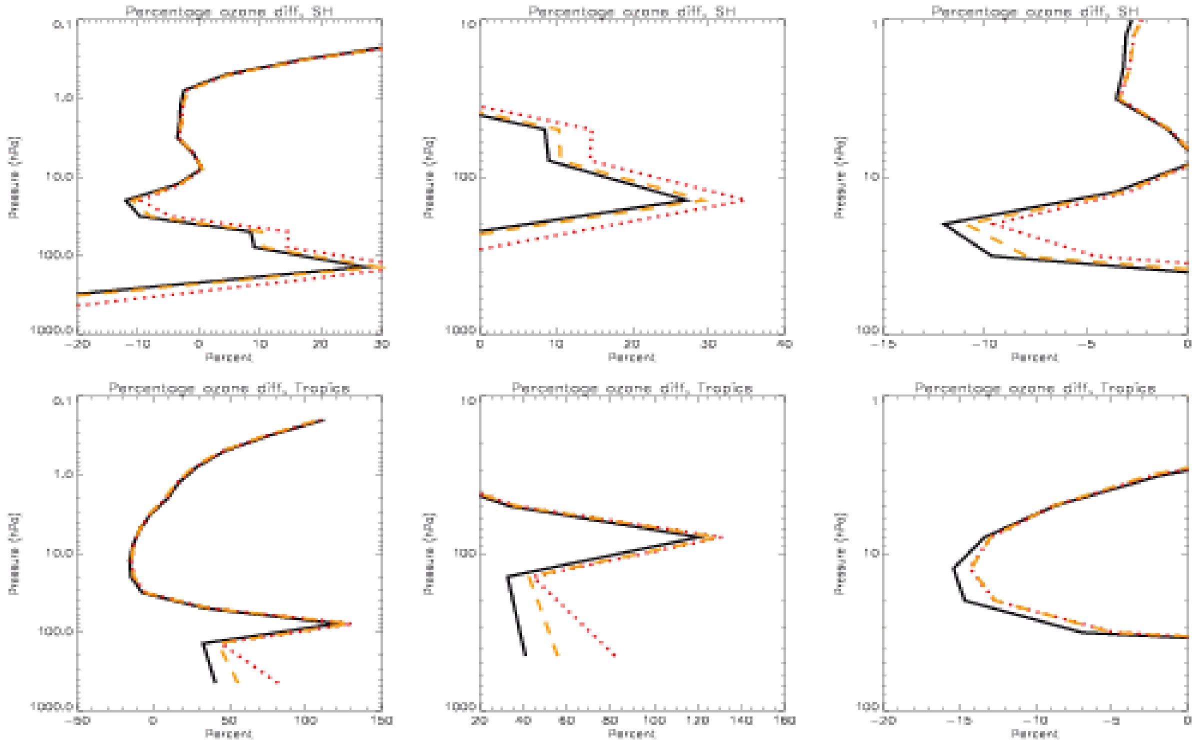


# Percentage difference from HALOE data

1000-0.1 hPa 1000-10 hPa 100-1 hPa

SH

Tropics




Solid: HIRS-9; dotted: SBUV; dashed: HIRS-9+SBUV

# New Dynamics

- The 3D-VAR assimilation has been adapted to use the new dynamical core of the UM
  - Semi- Lagrangian
  - Height coordinate
  - 50 levels at 2.5 by 3.75 degrees
- Pre-operational trials have been completed successfully.
- Operational implementation scheduled for October 2003 (after Met Office relocation).

# New Dynamics trials

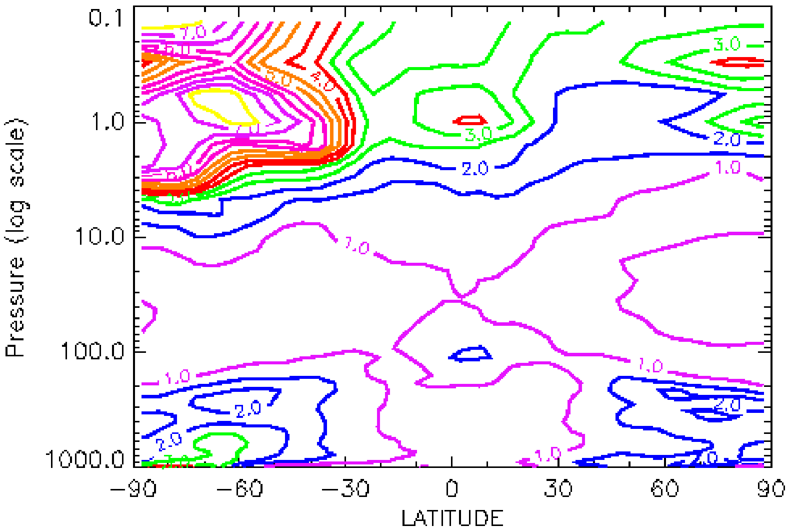
- The New Dynamics was tested by running pairs of one-month trials, for June 2001 and Dec 2002 (Dec 2001 was used for early trials)
- A range of technical problems were encountered in trials of the ND stratospheric data assimilation system.
- A particular problem was the specification of background error covariances (especially at upper levels).

# Error covariances

- Initial error covariances were produced by interpolating old dynamics model fields to ND grid, and applying NMC method (T+48-T+24 differences)
- High error variances led to very large increments at top and trial failure.

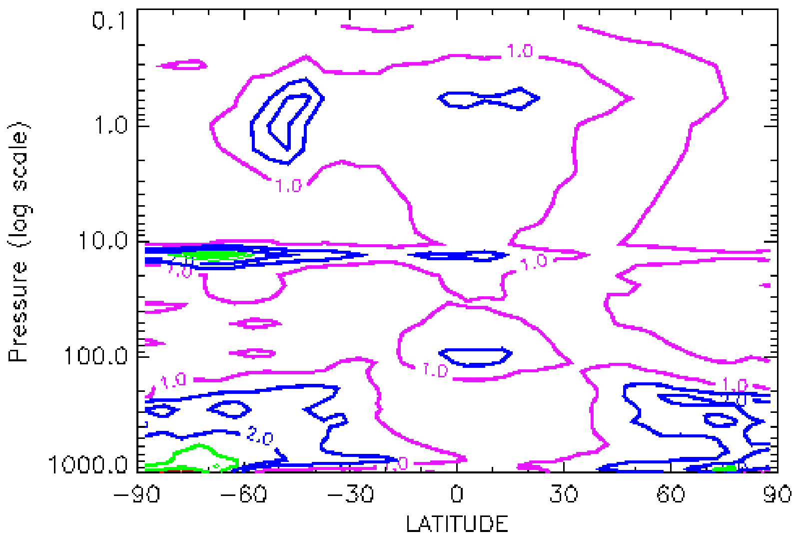
Temperature error SD (K)



# Error covariances

- New error covariances produced by only adding assimilation increments up to level 40 (~10 hPa)
- Used for first set of trials

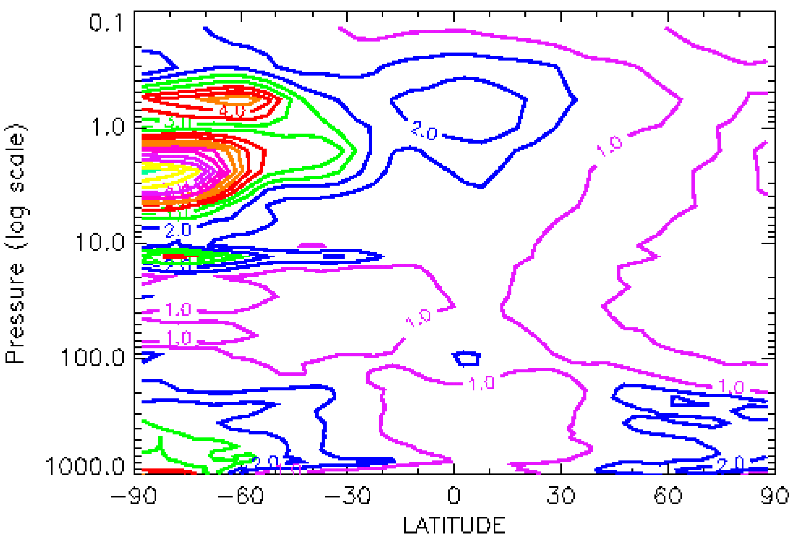
Temperature error SD (K)



# Error covariances

- Second generation covariances obtained by applying NMC method to forecasts from 1st set of trials
- Used for 2nd set of trials

Temperature error SD (K)



# Summary of verification against sondes for summer & winter trials

(percentage where each trial was better)

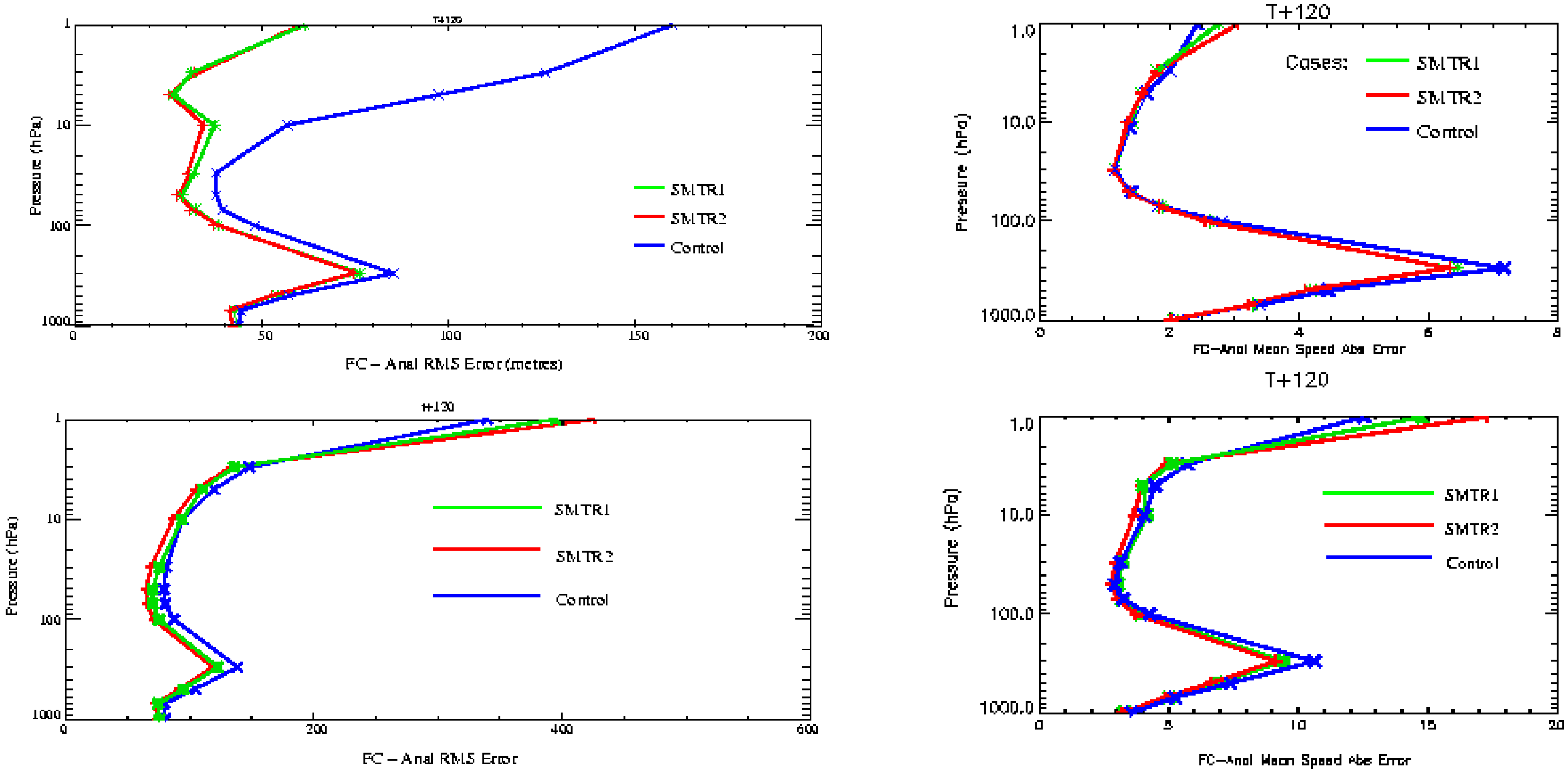
| Level (hPa) | SMTR1 | Control | Neutral |
|---|---|---|---|
| All | 81% | 6% | 12% |
| 100-10 | 72% | 7% | 20% |
| 1000-100 | 91% | 5% | 4% |

| | WNTR1 | Control | Neutral |
|---|---|---|---|
| All | 67% | 15% | 18% |
| 100-10 | 56% | 22% | 22% |
| 1000-100 | 78% | 7% | 15% |

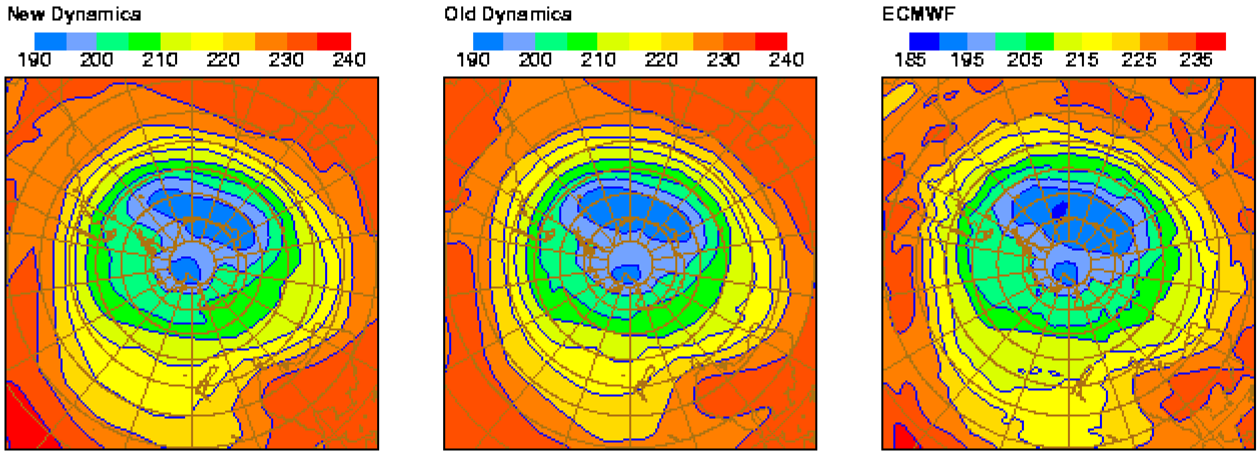
# Verification against analyses

T+120 forecasts for June trials
Top: NH, bottom: SH

Left: RMS height error (m), right: wind speed error (m/s)

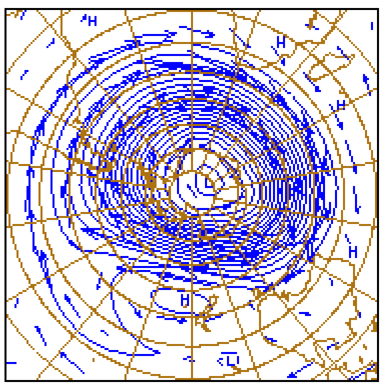


# Comparison of 10 hPa temperature (Southern hemisphere)

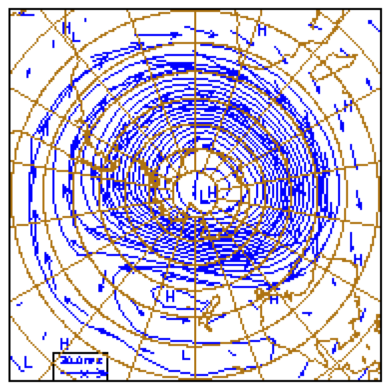


# Comparison of 10 hPa height and winds

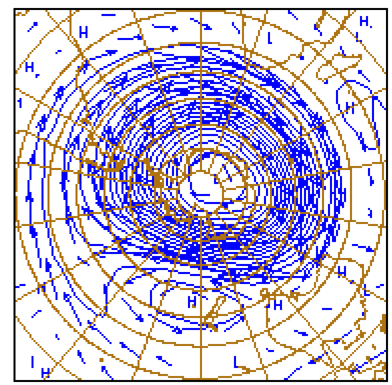
New Dynamics



Old Dynamics



ECMWF



# New Dynamics - summary

- Problems were encountered specifying background error covariances. These have been solved, but further work should be done to scale back error variances at upper levels.
- The pre-operational trials show encouraging improvements over old dynamics results.
- ND stratospheric assimilation system to be implemented in October.

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# Other work in progress

- Collaborations with DARC:
  - Ozone assimilation project (David Jackson)
  - Evaluation of proposed SWIFT instrument
  - Assimilation of Envisat Data (ASSET)
- Extend standard global assimilation system to span stratosphere

 

# Enhanced Resolution -
## Development of an Extended Global Assimilation System (DEGAS)

- Develop and trial extended global system spanning the stratosphere.
- Based on 50-L stratospheric model, but same, higher, horizontal resolution as global model.
- Anticipated benefit to processing of satellite soundings.

# Future Plans

- Introduction of 4D-VAR
- Further improvements to both vertical and horizontal resolution
- Improvements to assimilation of ozone and water vapour, particularly in UTLS (ASSET)

 

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# Summary

- Stratospheric data assimilation has developed significantly since the original Met Office system.
- In Nov 2000, 3D-VAR was adopted in the Met Office stratospheric data assimilation system.
- After relocation (October 2003), the stratospheric system will be migrating to the new semi-Lagrangian dynamical core.
- In 2004, we plan to extend the standard global forecast model to span the stratosphere.
- We will continue to develop the assimilation of ozone and water vapour observations.

 

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