Recent developments in the data assimilation system for the Canadian Middle Atmosphere Model

S. Polavarapu[1,2], S. Ren[2], Y. Rochon[1], D. Sankey[2], D. Tarasick[1]

[1]Meteorological Service of Canada
[2]University of Toronto

OUTLINE

1. CMAM climate model
2. Data assimilation scheme
3. Background error statistics
4. Preliminary results
5. Recent work
6. Next

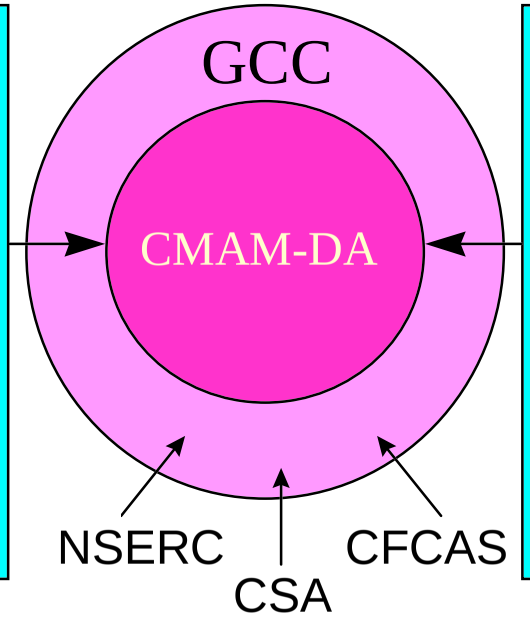
Middle atmosphere data assimilation for climate applications (CMAM-DA)

Canadian Middle Atmosphere Model (CMAM)

- **Improve understanding of middle atmosphere dynamics by confronting a climate model with observations.**
- **Create platform for assimilation of middle atmosphere measurements from Canadian and international instruments.**
- **Can produce assimilated data sets for climate studies.**

MSC (MAI)

Data assimilation:
Polavarapu, Steenbergen
Air quality:
Rochon, Tarasick
Climate modelling:
McFarlane



Universities

U. Toronto - Physics:
Ren, Sankey, Yang, Shepherd
York U. - Chemistry:
McConnell

Canadian Middle Atmosphere Model (CMAM)

CMAM is a complex GCM with interactive chemistry, radiation and dynamics

- T47 spectral model
- 65 levels (0-95 km)
- 5 min time step
- T, vort, div, ln Ps, q hybrid
- 44 species advected
- 127 gas-phase chemical reactions
- aerosols for chem but not phys/rad
- chemistry from 6 km to top

Data Assimilation - 3DVAR

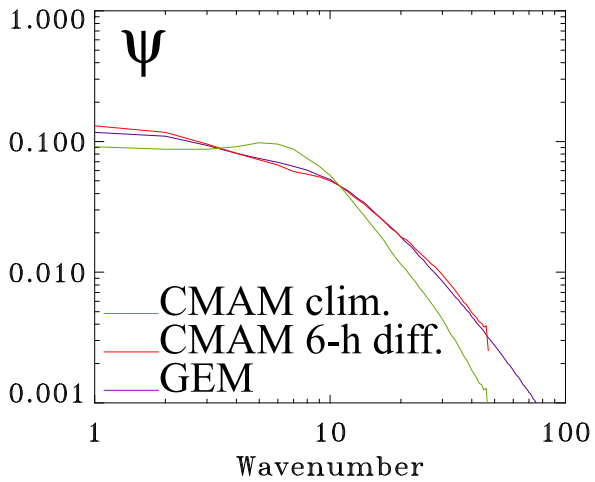
Start with CMC's operational 3DVAR designed for GEM NWP model 10 mb lid

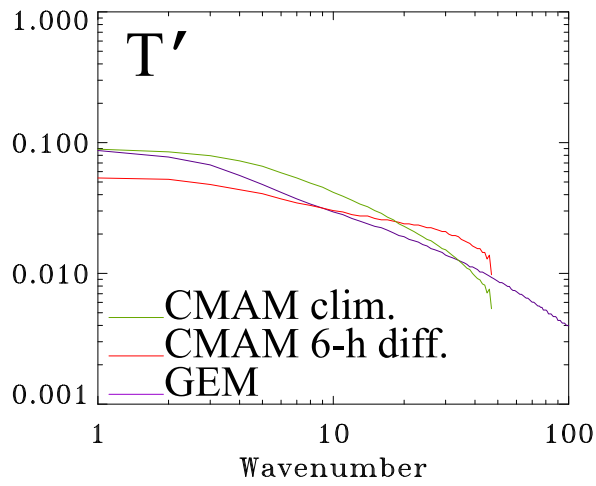
- anal. variables: T', Ψ, χ', ln q, Ps'
- analysis directly on model levels
- N1QN3 - quasi-Newton minimization
- NMC-based background covariances
- digital filter initialization

Modify 3DVAR to run with CMAM

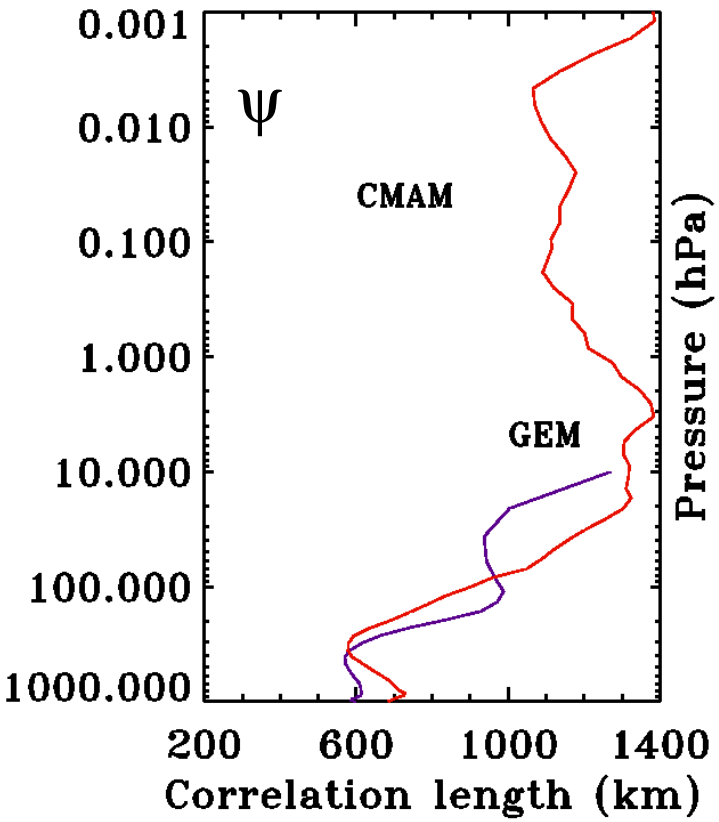
- create interfaces for CMAM state I/O
- generalize vertical coordinate
- extend lid to 0.001 mb (95 km)
- derive covariances based on CMAM climate runs only

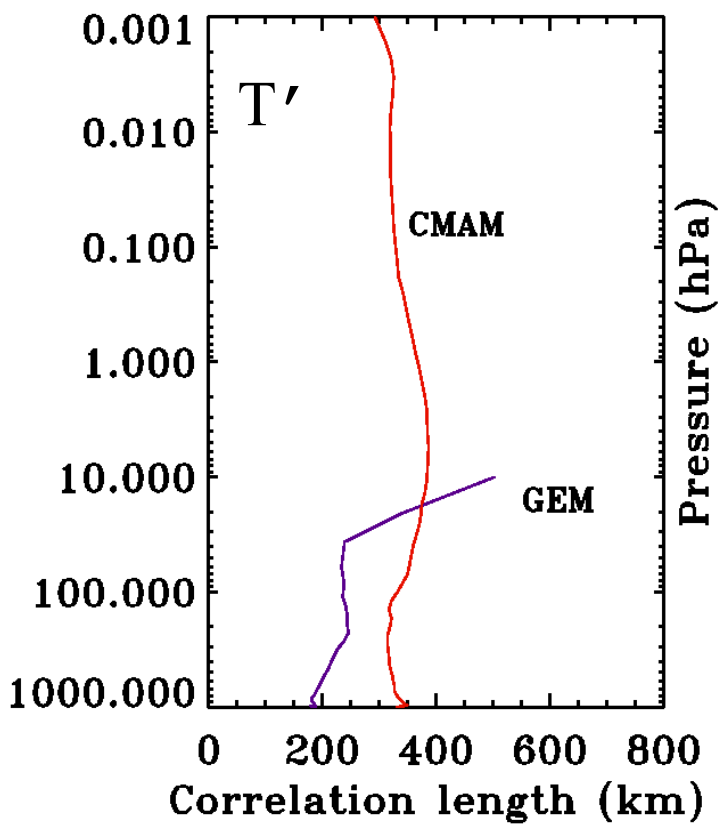
Spectra of hor. autocorrelation functions near 500 hPa

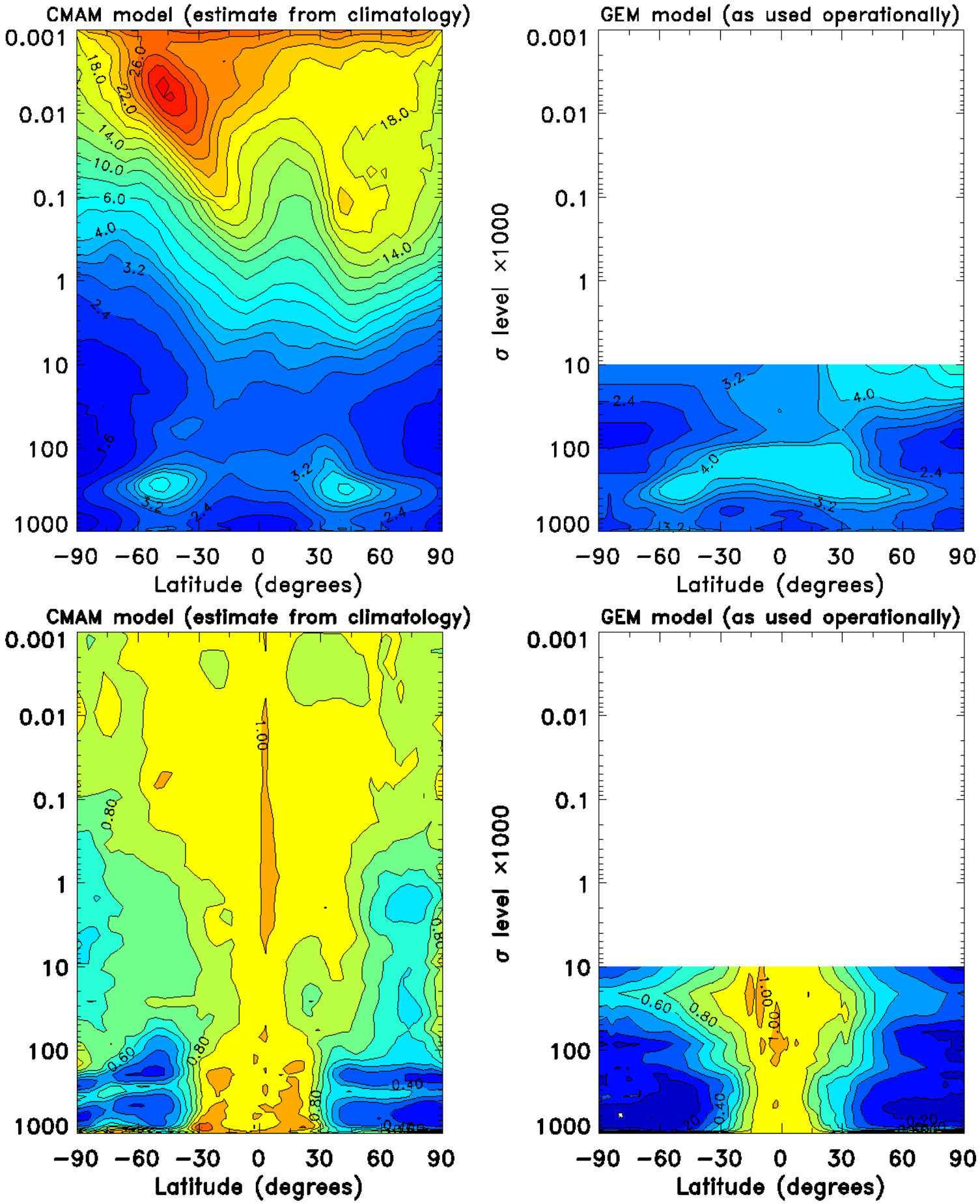




Horizontal correlation length scales





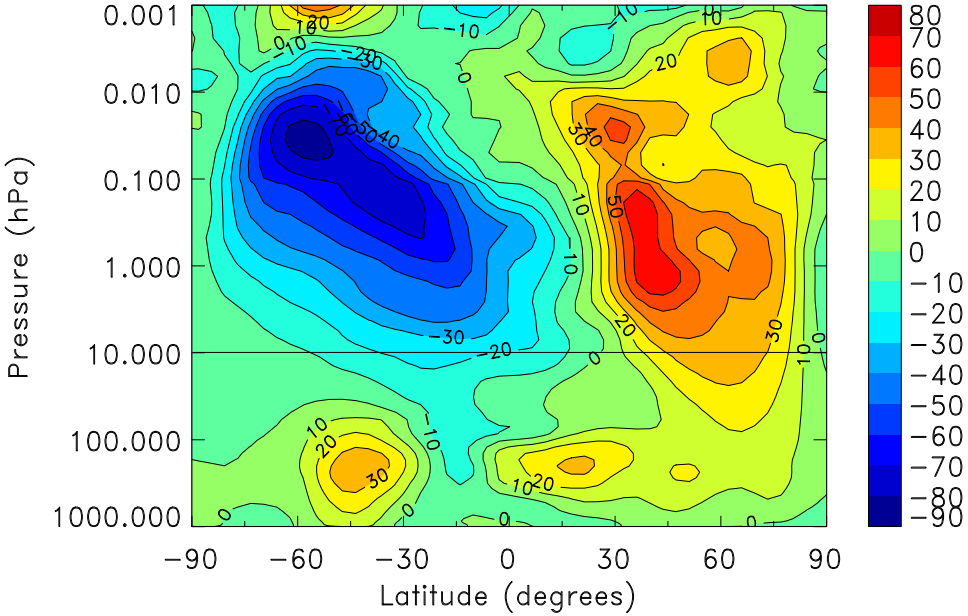

CMAM model (estimate from climatology)
GEM model (as used operationally)
CMAM model (estimate from climatology)
GEM model (as used operationally)
σ level ×1000
Latitude (degrees)
0.001
0.01
0.1
1
10
100
1000
−90 −60 −30 0 30 60 90
26.0
22.0
18.0
14.0
10.0
6.0
4.0
3.2
2.4
1.6
1.00
0.80
0.60
0.40
0.20

Preliminary Results

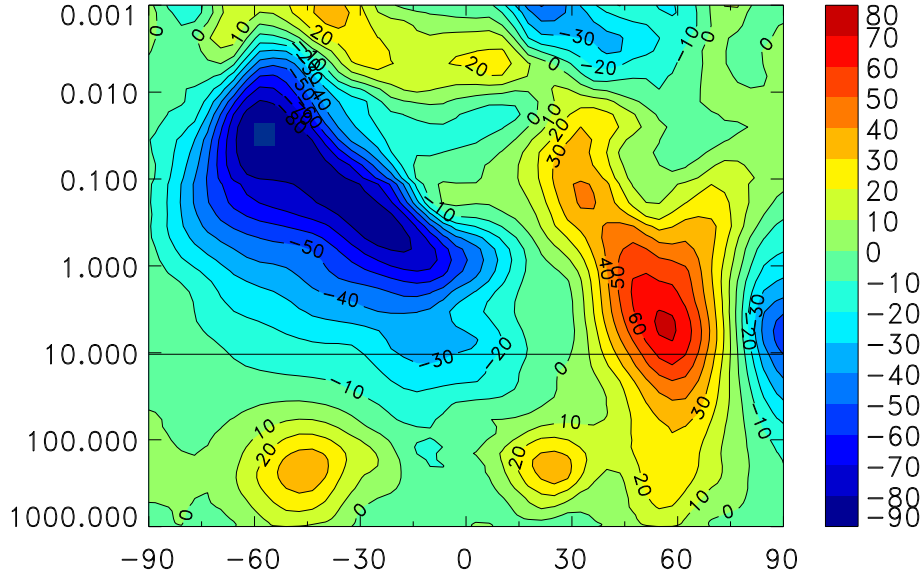
CMAM + 3DVAR assimilation system

- CMAM v5 T47L65 full chemistry
- 3DVAR on CMAM coord., 95 km lid
- stats = CMAM climatology or
  = CMAM 6-h diff. climatology
- Jan 1994
- Background from Jan. CMAM climate run snapshot
- obs = sondes, SATEM, AIREP, sfc, humsat below 10 mb only

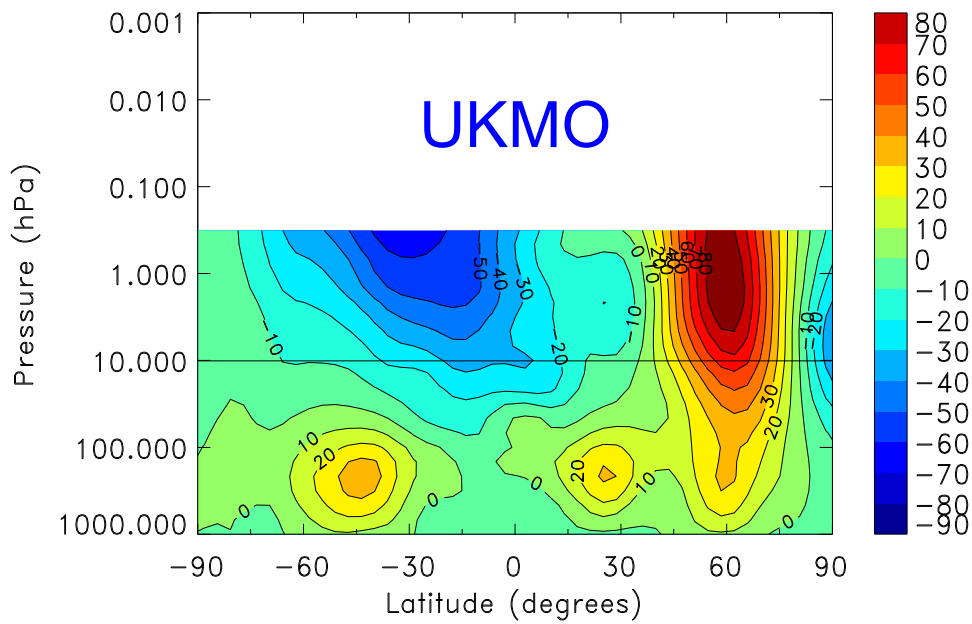
CMAM climate run



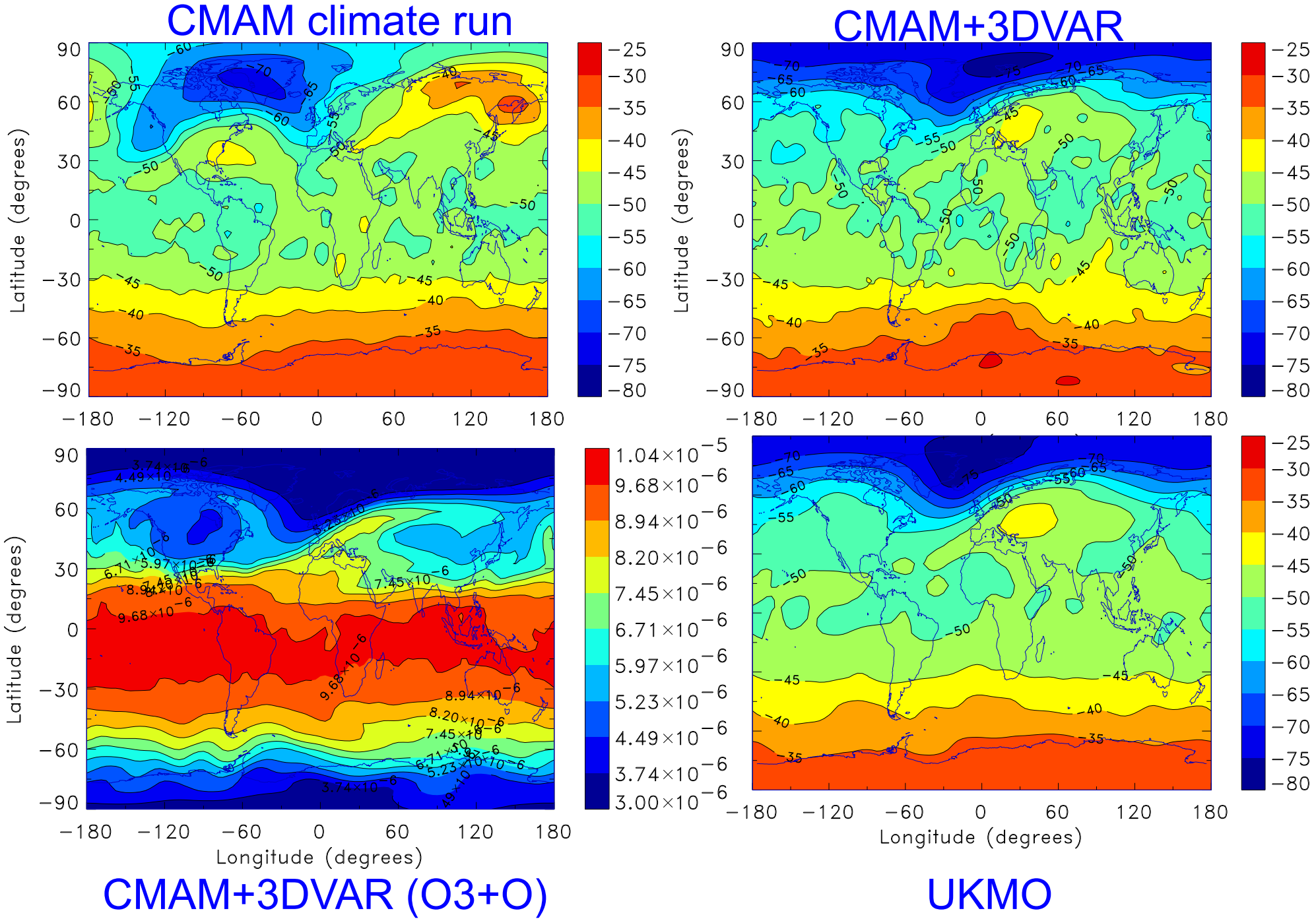
CMAM+3DVAR



U (m/s) zonal average
11-30 Jan 1994



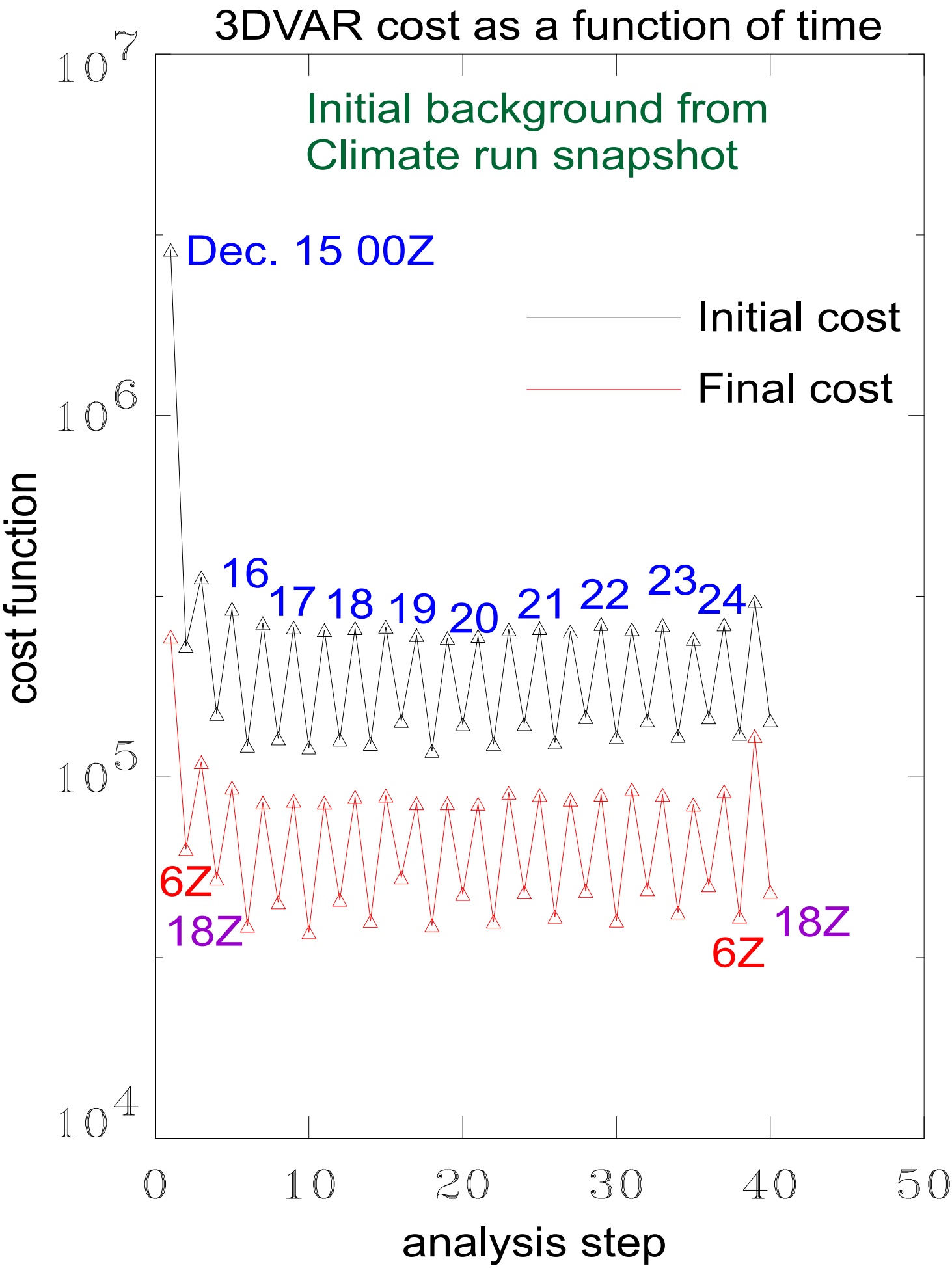
T in °C at 14 hPa, Jan. 30, 1994 12 Z



Current Experiment

Changes from preliminary experiment

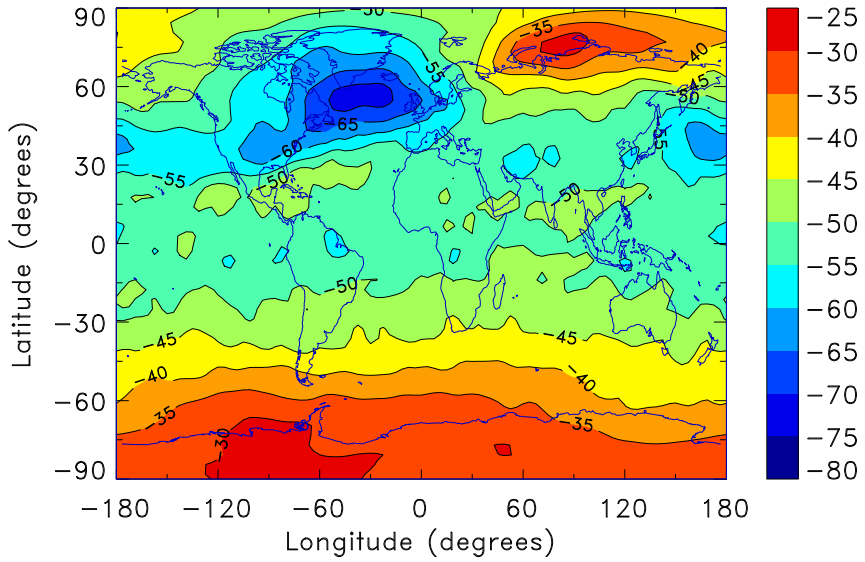
- New 3DVAR version from CMC: uses T, Ps obs; QC-var
- New obs types: ACARS, AMSU, sonde sig. levels, dropsondes
  2-3X more obs than in 1994
- Focus: Jan. 2002, start: 15 Dec 2001
- stats = CMAM 6-h diff. climatology
- same background state used in 1994 expt (a Jan. CMAM state)
- code preparation for O3 assim.


3DVAR cost as a function of time
Initial background from
Climate run snapshot
Dec. 15 00Z
Initial cost
Final cost
16
17
18
19
20
21
22
23
24
6Z
18Z
6Z
18Z
cost function
analysis step
10^7
10^6
10^5
10^4
0
10
20
30
40
50

Dec. 31, 2001 12Z

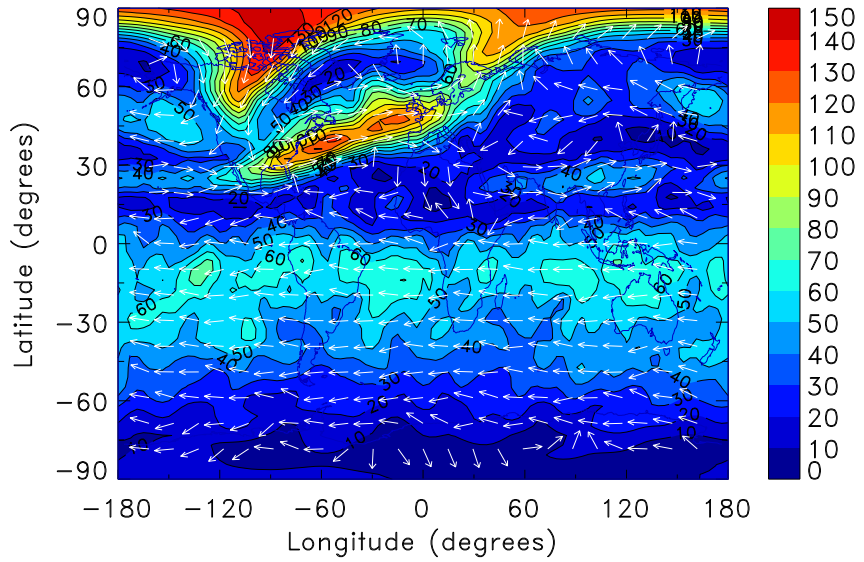
T in C at 14 hPa

CMAM

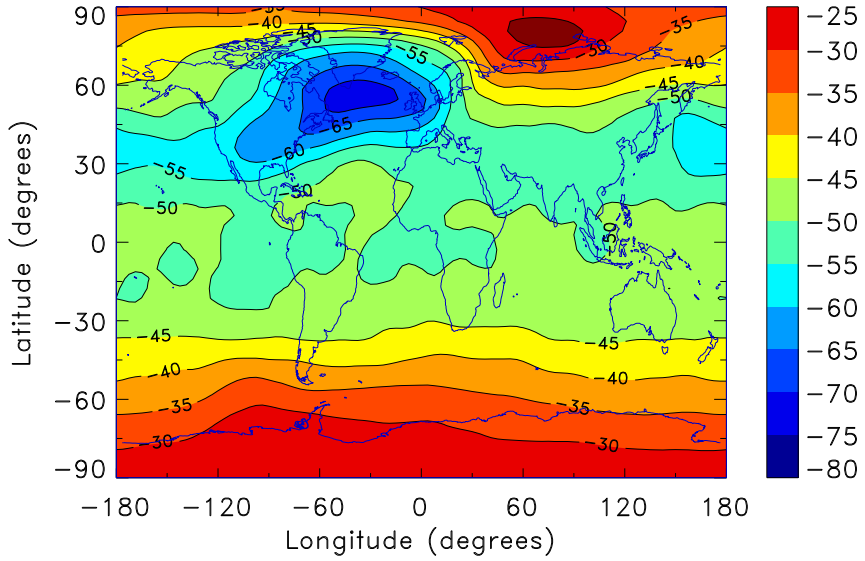


U (m/s) at 7 hPa

CMAM



UKMO



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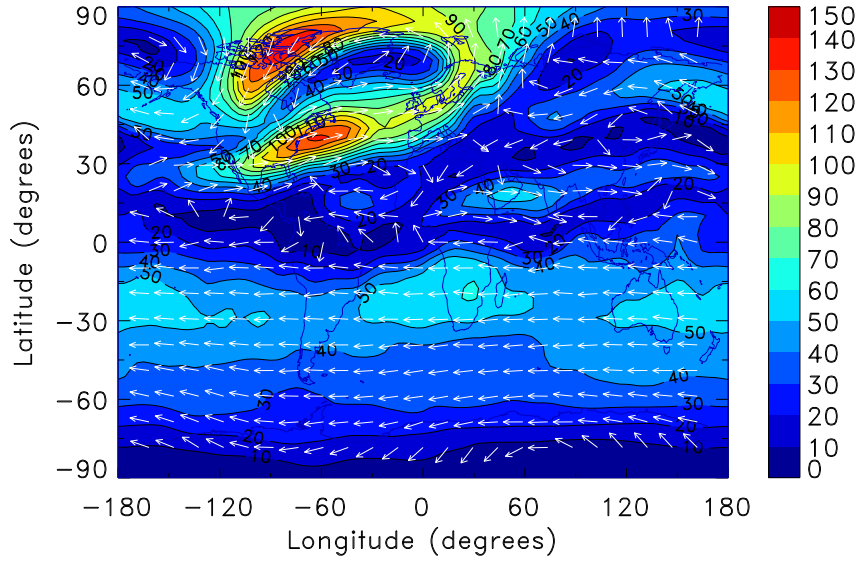

Data assimilation improvements

- add AMSU ch. 3-10, 11-14
- add univariate ozone assimilation
- replace DF with IDF or IAU
- implement forecast bias correction
- assimilate AMSU-B humidity data
- recalculate background stats using assimilation cycles
- get better correlations allowing longer length scales in tropics

CMAM-DA plans

- validate stratospheric analyses
- univariate ozone analysis
- mesospheric data assimilation?
- multivariate stratospheric chemistry analysis?

Stratospheric (T or wind) data sources:
AMSU, AIRS, SSMIS, SWIFT

Ozone data sources being considered:
SBUV, ODIN, ENVISAT, TOMS?, GOME?

Ozone data sources for verification:
ozone sondes, HALOE, ACE, SAGE?

Validation period: 2002

data sources in red

SCIENCE (to come)

Upward propagation of information: to what extent is the variability of the atmosphere being driven from below?

Do analyses capture individual stratospheric sudden warmings?

Is the model biased comapred to obs? If so, what kind of GWD parameterization is needed to correct this?

Why do GCMs alone usually not capture QBO while analyses do? i.e. type of model error?

Compare ozone analyses with obs to learn about model behaviour and observations