Single versus dual component wind observations

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Overview

- Background
- 1. Single-level analysis framework and experimental result
- 2. Full-scale wind assimilation results

Background

- Main target application for Doppler Wind Lidar observations is data assimilation/numerical weather prediction
  - Observations are inherently Line of Sight (LOS)
- Question: How useful are observations of one vs. two wind components?
  1. Single-level analysis system
  2. Full, global 3-D data assimilation system

1. Single-level analysis system
(Riishojgaard et al., JAM, 2004)

- User-specified truth and background states taken as input
- Simulation of a set of observations of the true state with specified error characteristics
- Standard analysis equations solved on a single-level domain
- Same background error covariance model as GMAO GEOS-4 system
- Observations are judged by analysis error variance

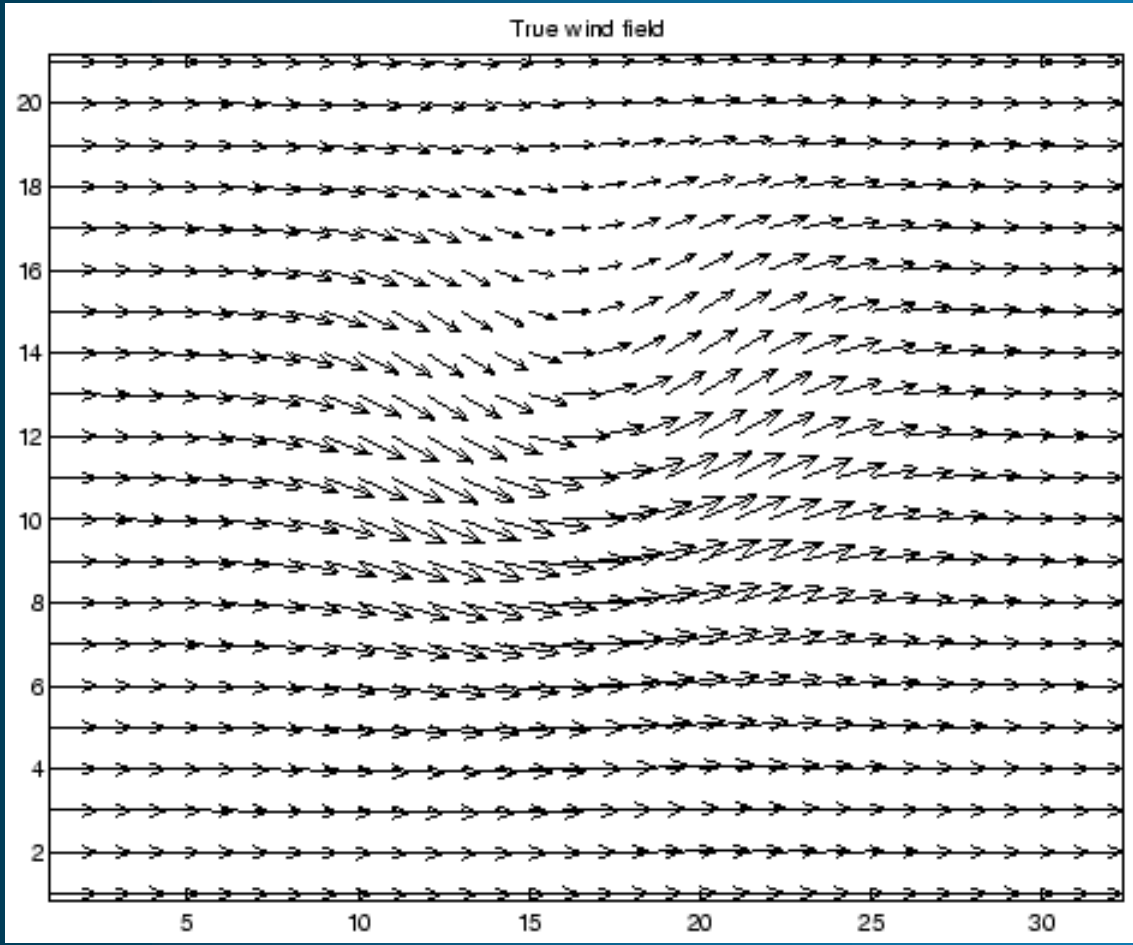
Single-level system (continued)

- Analysis domain is 21*31 grid points (2000 by 3000 km at a resolution of 100 km).
  - n=21*31*2=1382
- Background wind error covariance is derived from the assumed error of the underlying stream function and/or velocity potential

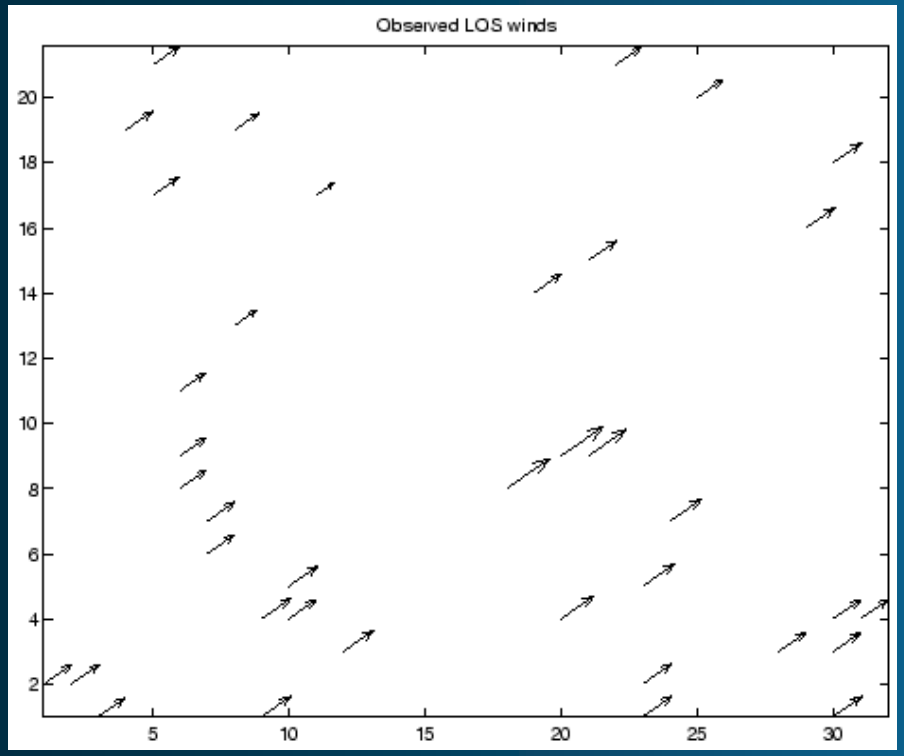
Single-level experiments

- Non-divergent “true” (zonal flow w./ eddy) and background (zonal flow) states
- Correctly specified non-divergent background error covariance matrix
- This setup favors the single-perspective observations: The number of degrees of freedom is reduced to one per grid point!
- Variable number of randomly located line-of-sight (LOS) wind observations with random orientations

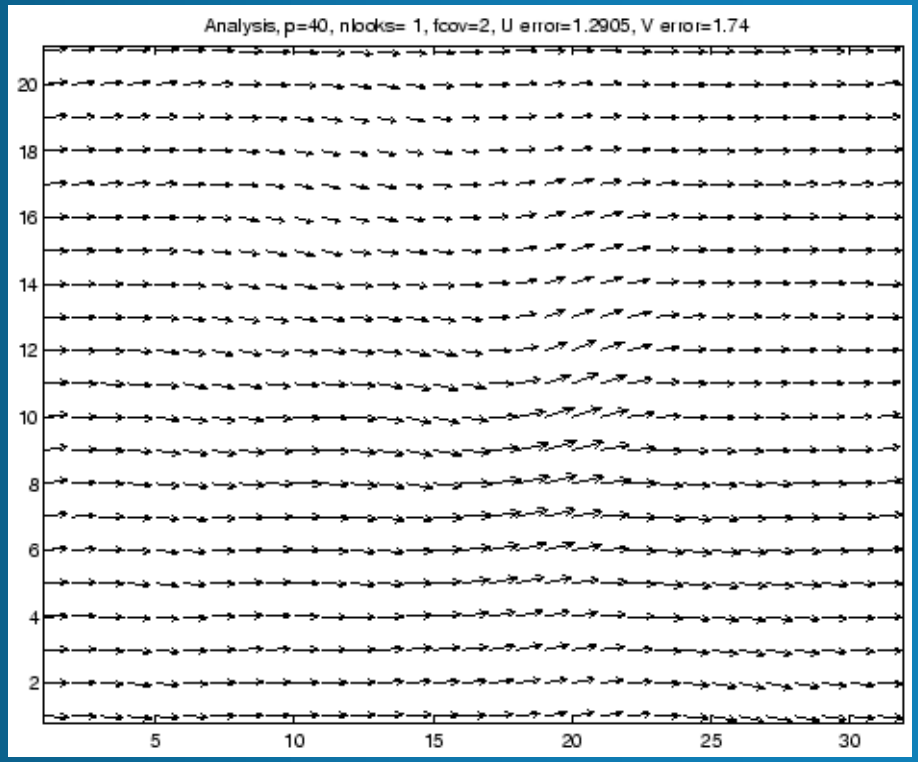
True state



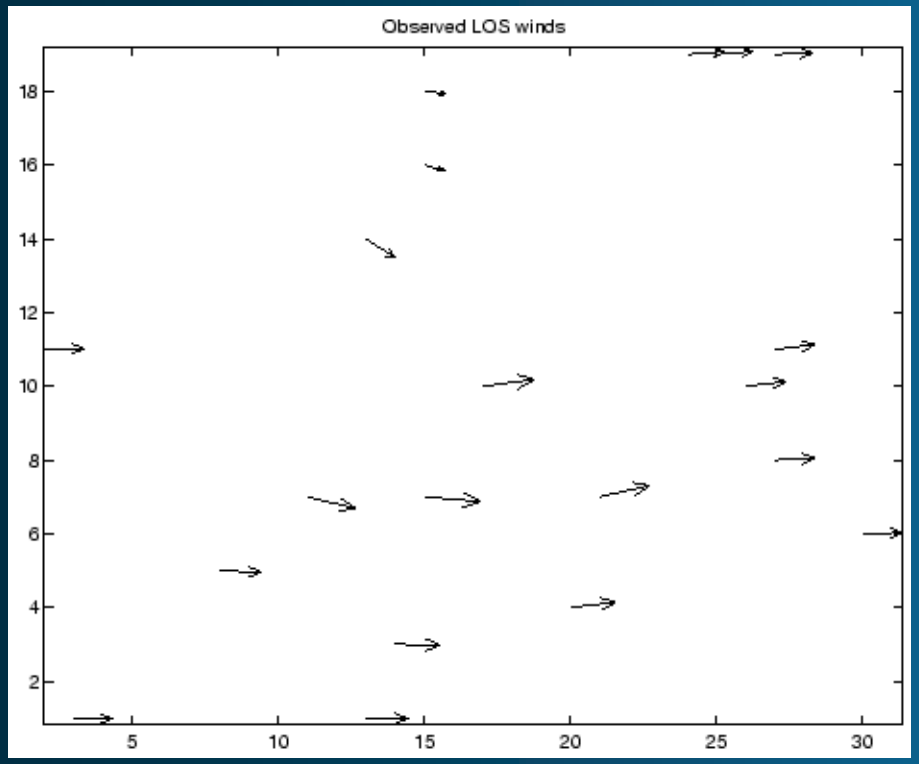
Single LOS winds, p=40



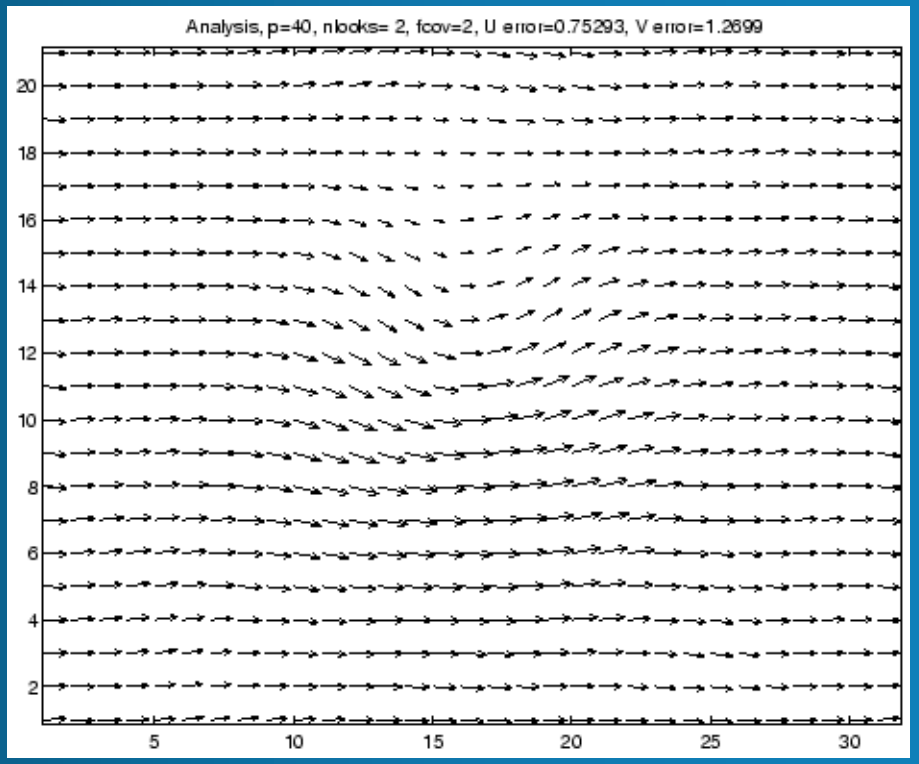
Single LOS analysis



Dual LOS winds; p=40

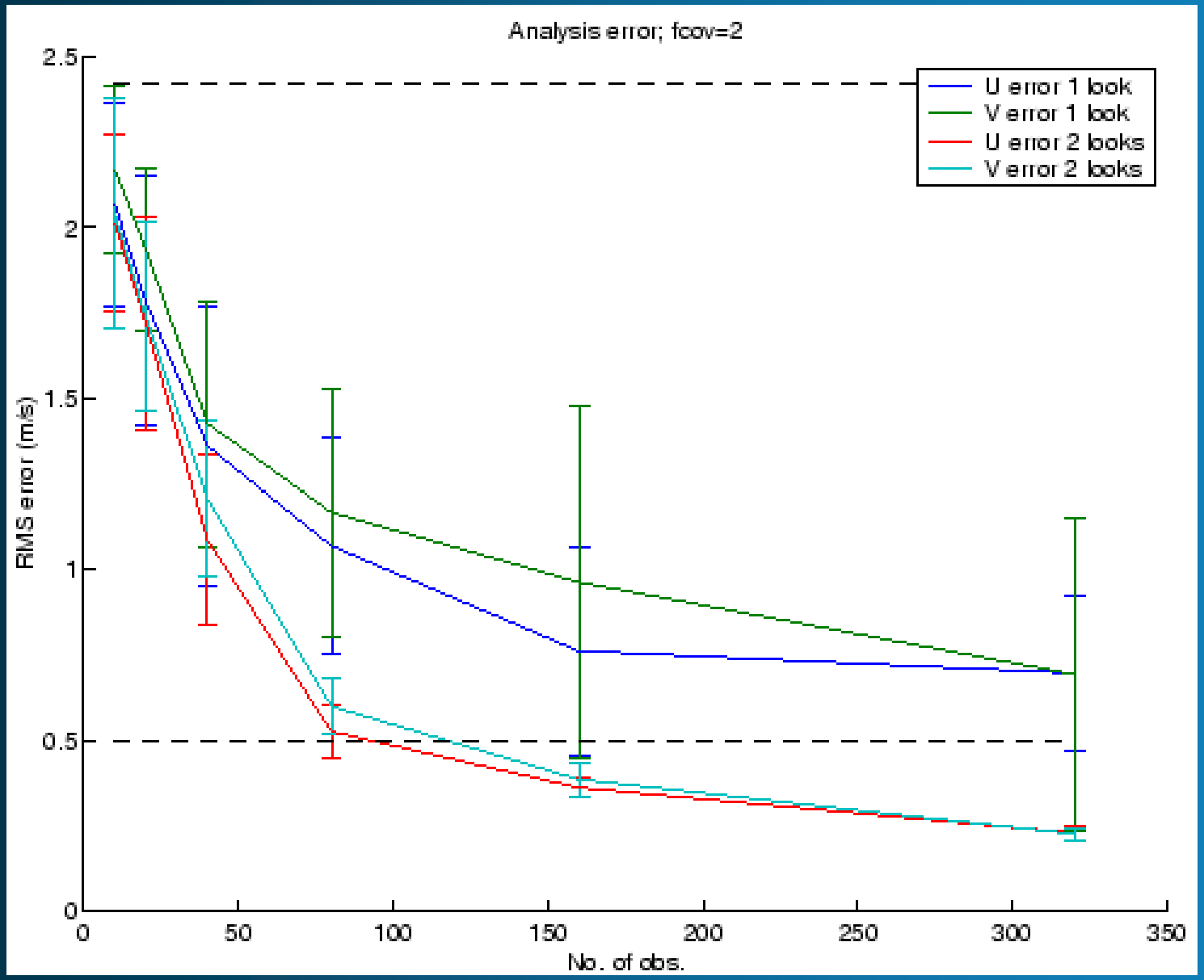


Dual LOS analysis

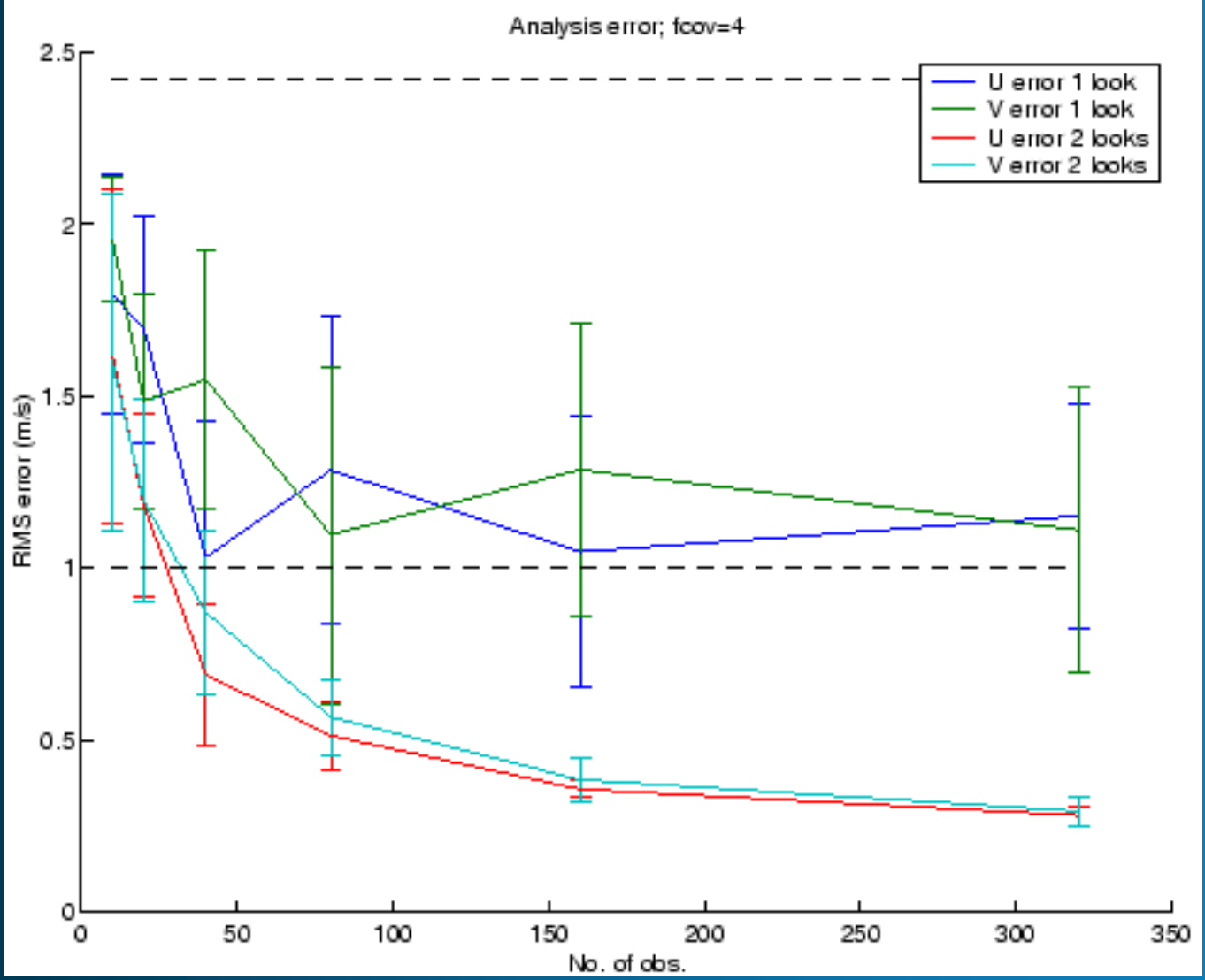


Ensemble of experiments

- No of obs. ranging from p=10 to p=320
- 15 experiments for each value of p, each with a randomly selected LOS orientation


Analysis error; fcov=2
U error 1 look
V error 1 look
U error 2 looks
V error 2 looks
RMS error (m/s)
No. of obs.
0
0.5
1
1.5
2
2.5
0
50
100
150
200
250
300
350

Single vs. dual perspectives for mixed error covariance



Conclusions, single-level study

- Single-perspective observations lead to analysis errors that are more than twice as large as dual-perspective observations in this framework
- Even idealized non-divergent flow with non-divergent error covariances not observable along a single direction
- For more realistic background error covariances, the analysis error in the single-perspective experiments is about 4 times that of the corresponding dual-perspective experiments
- Caveats
  - Simplistic analysis framework (no mass observations)
  - Length scale of analyzed wave different from error correlation length
  - Poor background field

2. Global assimilation/forecast study

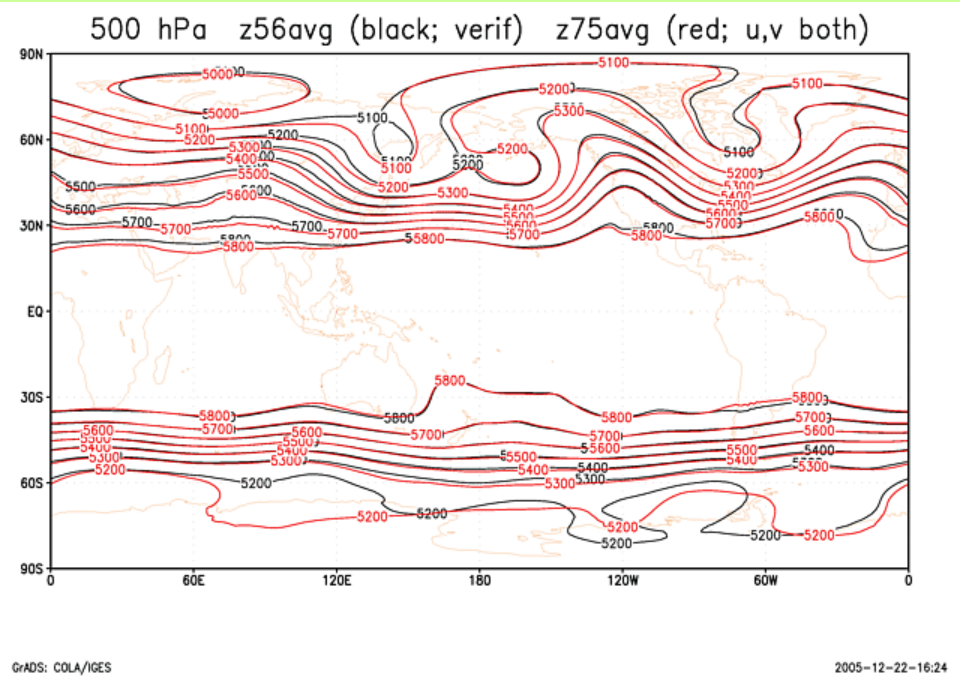
- Single-level study generated considerable interest in ADM mission team
  - KNMI/ECMWF study funded by ESA: For a given number of observations, two single-perspective (ADM) satellites have a larger impact on bad forecasts than a single satellite providing vector information
- Classical data impact experiments carried out with GMAO GEOS-4 system to assess the information content in one vs. two components
  - Control (fv56): All normal operational data
  - Exp. 1 (fv75): Only wind observations (RAOB, SAT, Aircraft)
  - Exp. 2 (fv76) : Only U-component wind observations
  - Exp. 3 (fv77): Only V-component wind observation
- Experiments evaluated on assimilation and forecast skill

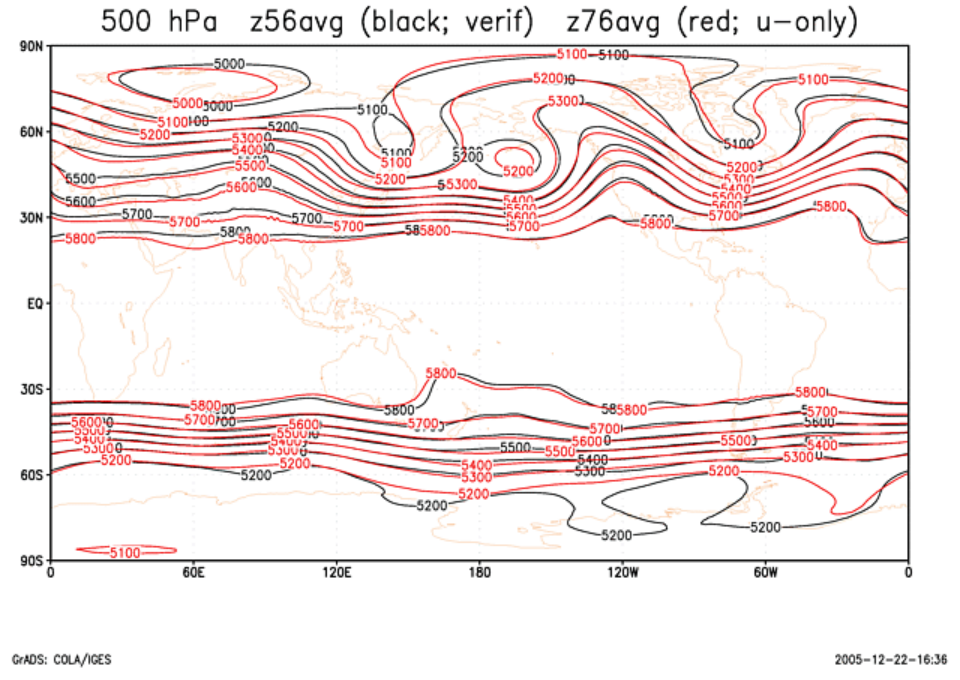
Monthly mean 500 hPa analysis, control in black, perturbation in red

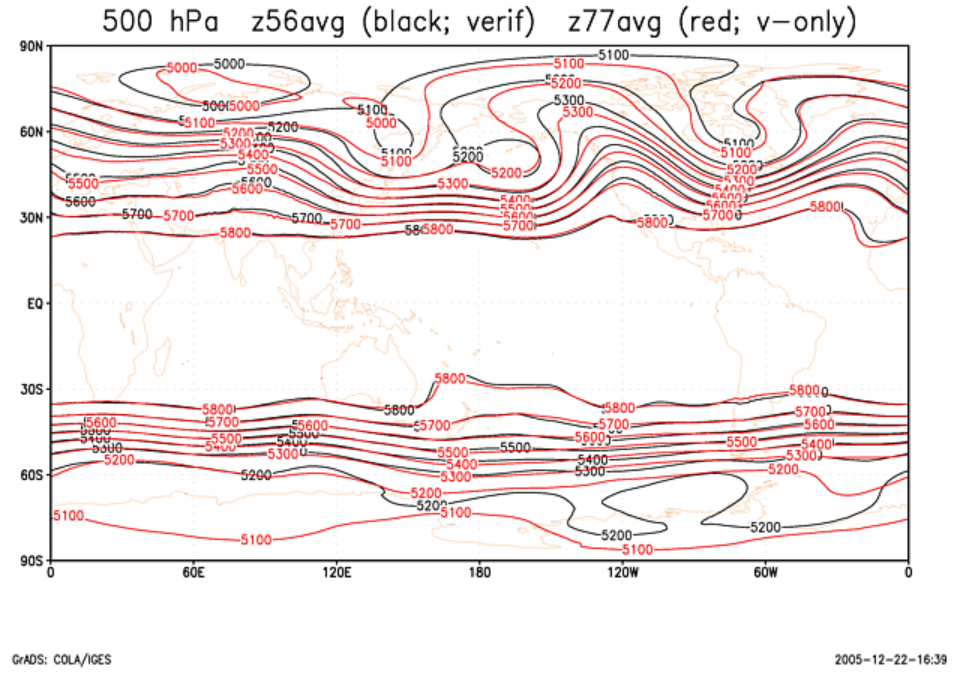
All winds (fv075)

Only V (fv076)

Only U (fv077)





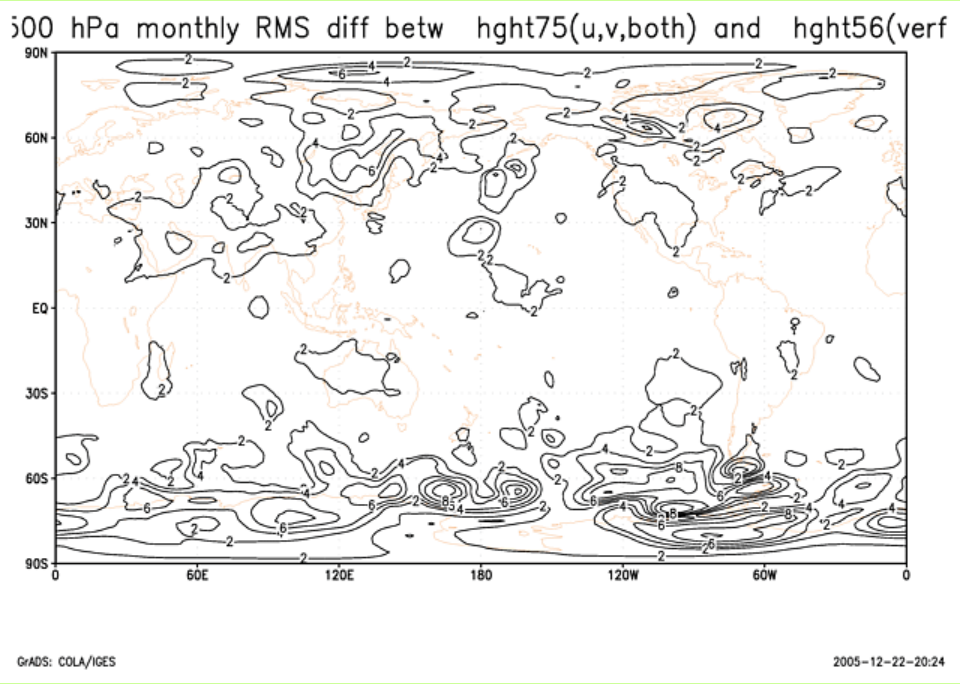


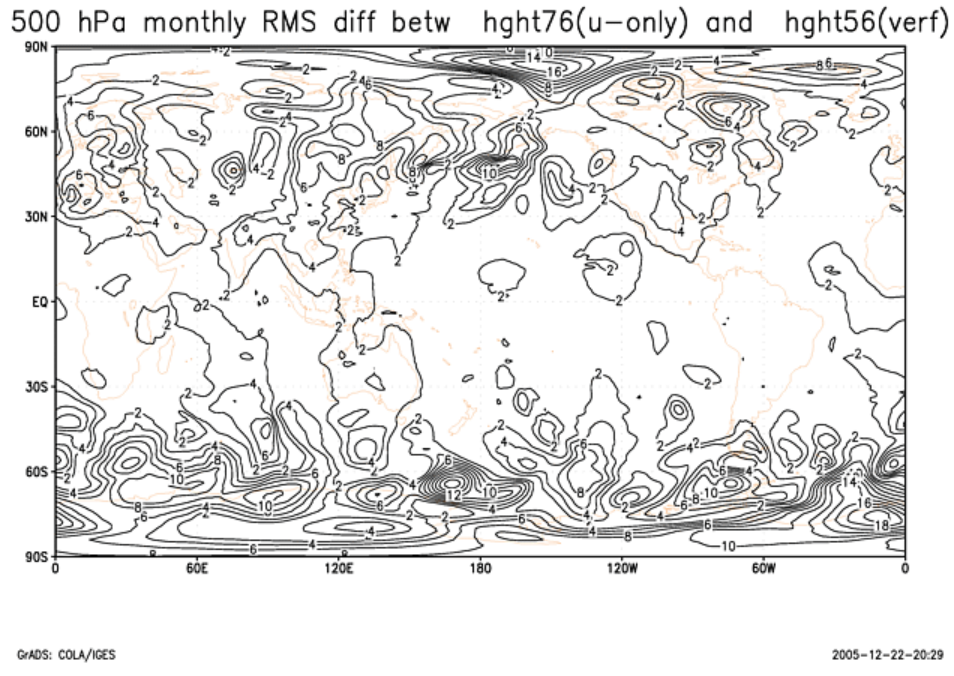
Monthly RMS errors in 500 hPa analysis

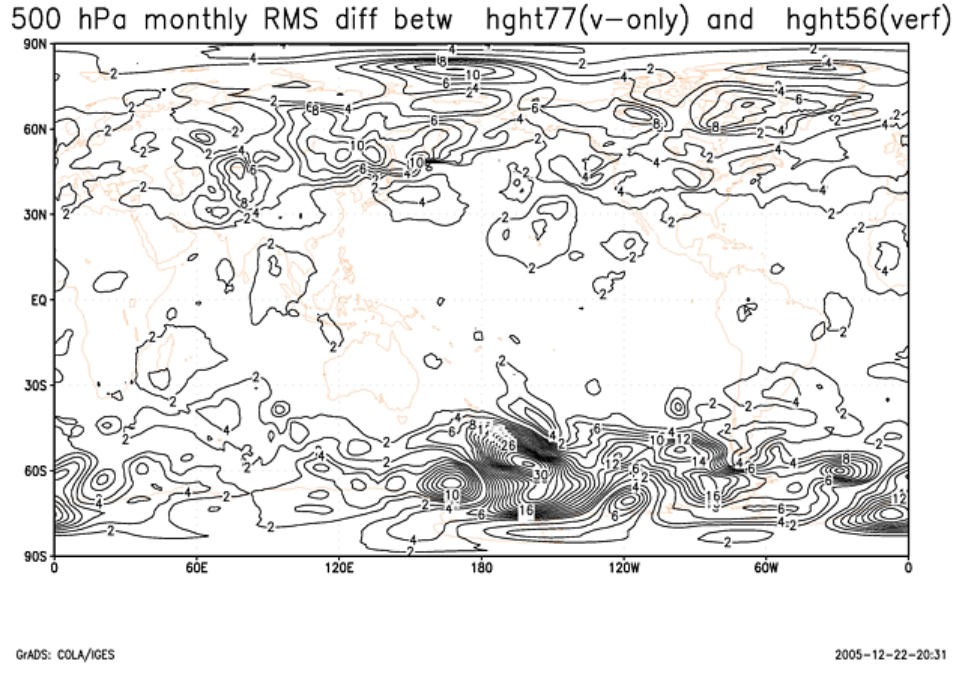
All winds (fv075)

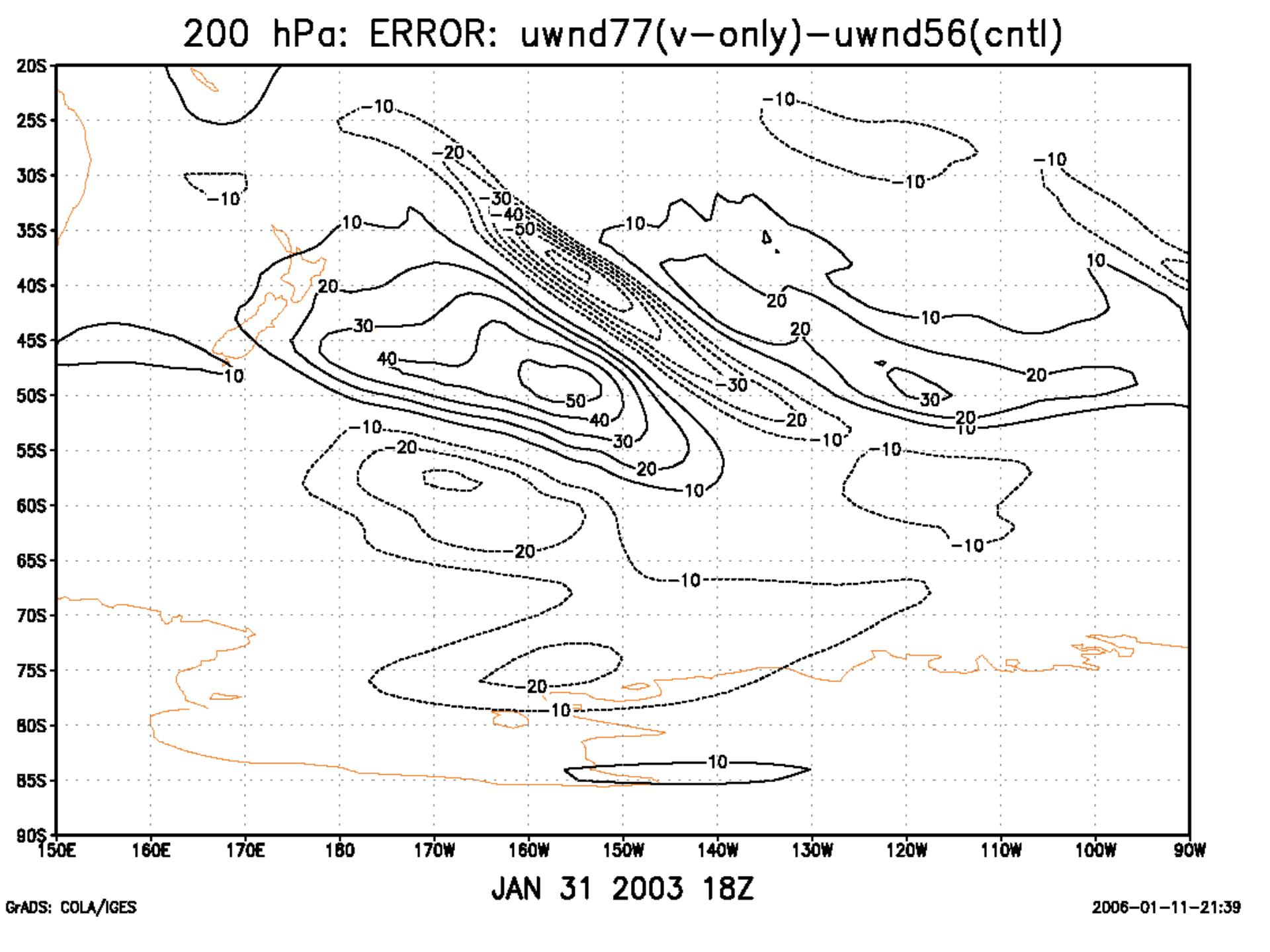
Only V (fv076)

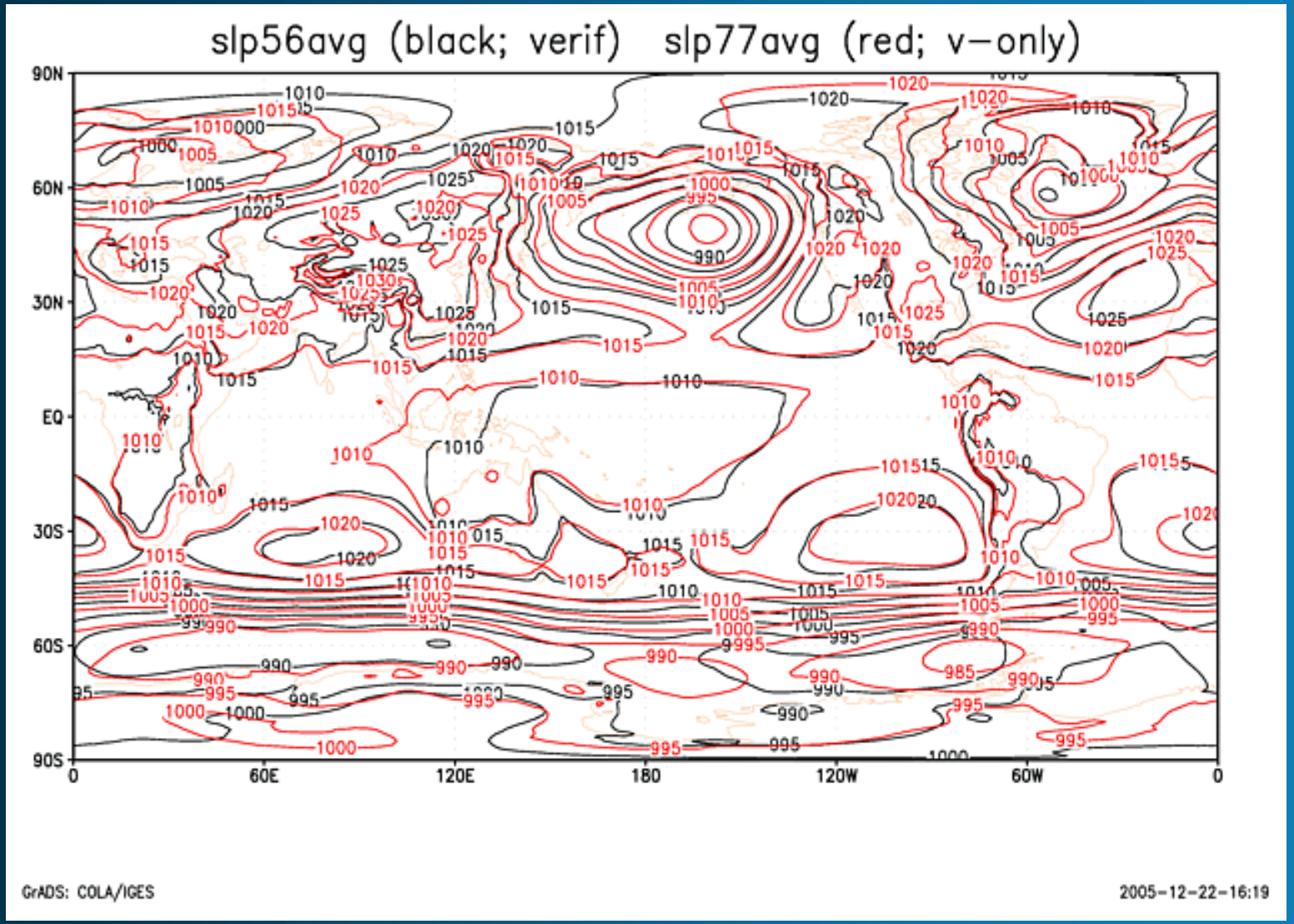
Only U (fv077)

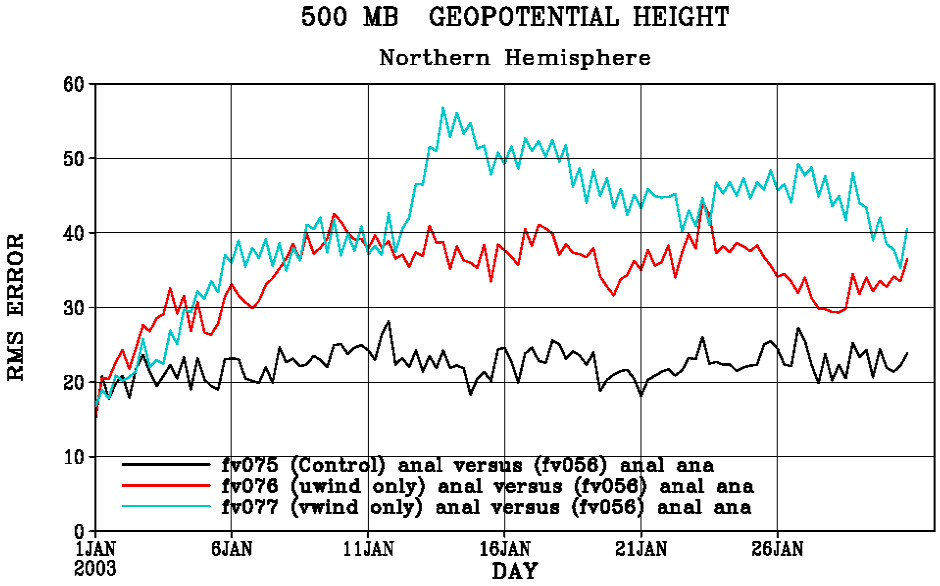


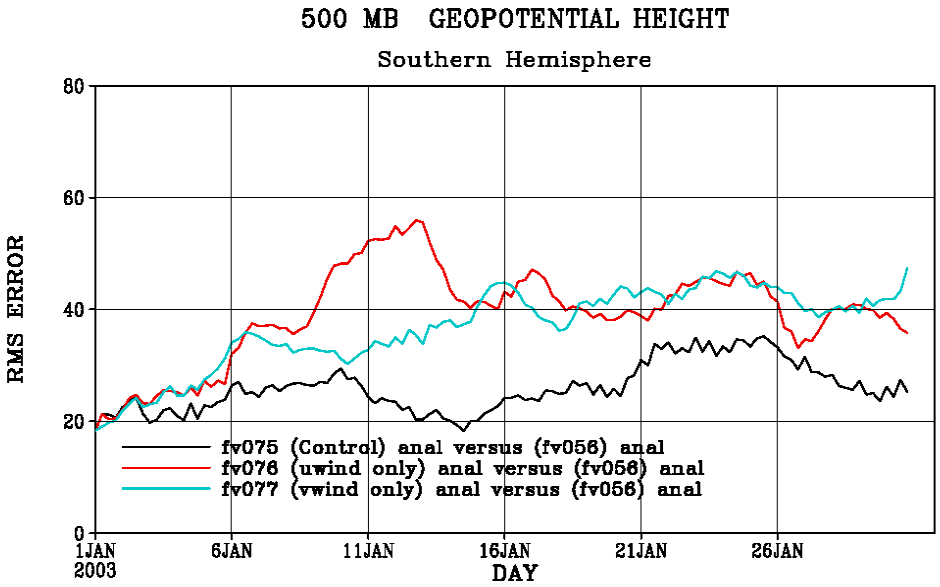




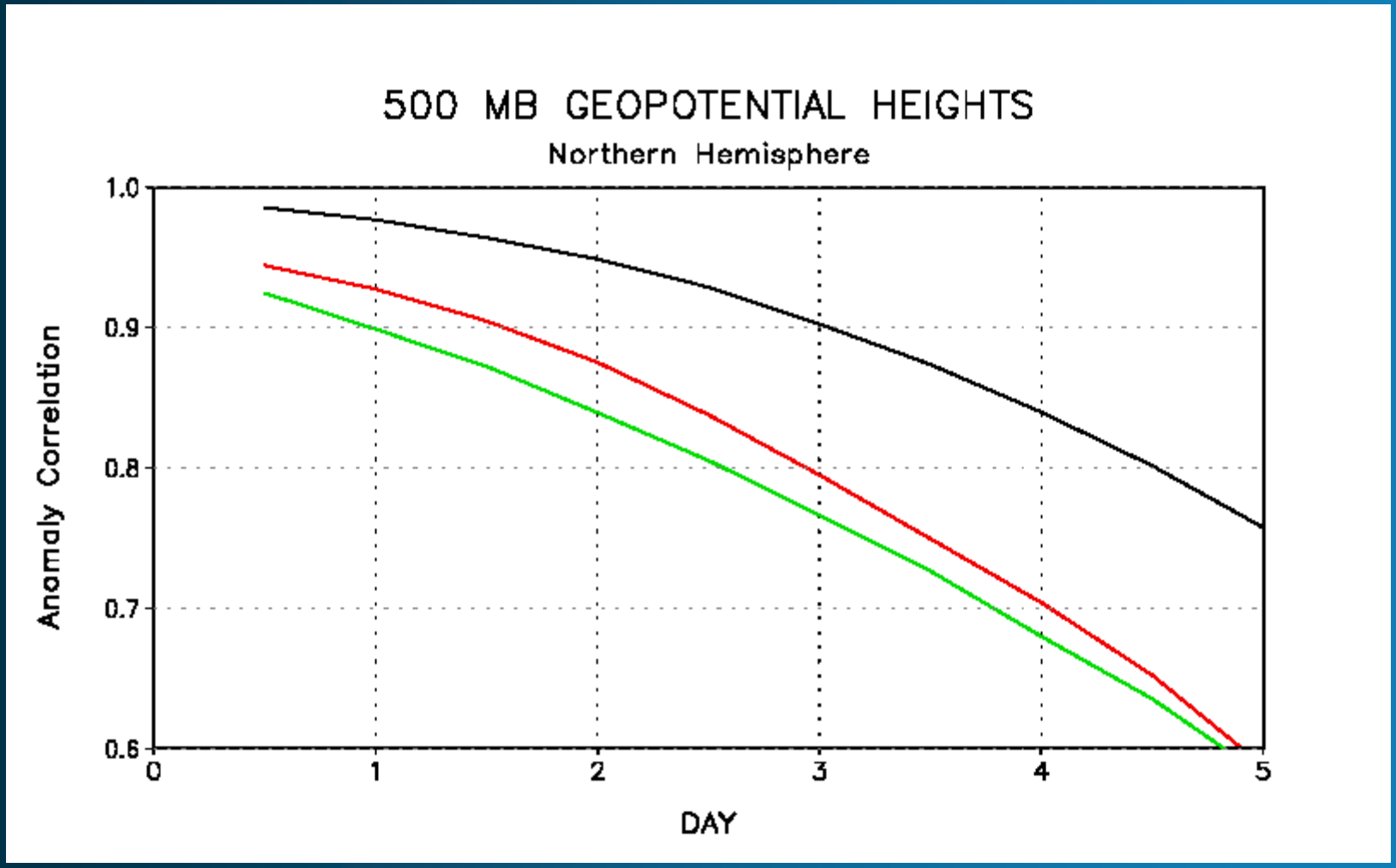

200 hPa: ERROR: uwnd77(v-only)-uwnd56(cntl)
20S
25S
30S
35S
40S
45S
50S
55S
60S
65S
70S
75S
80S
85S
90S
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W
JAN 31 2003 18Z
GrADS: COLA/IGES
2006-01-11-21:39


slp56avg (black; verif) slp77avg (red; v-only)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
GrADS: COLA/IGES
2005-12-22-16:19

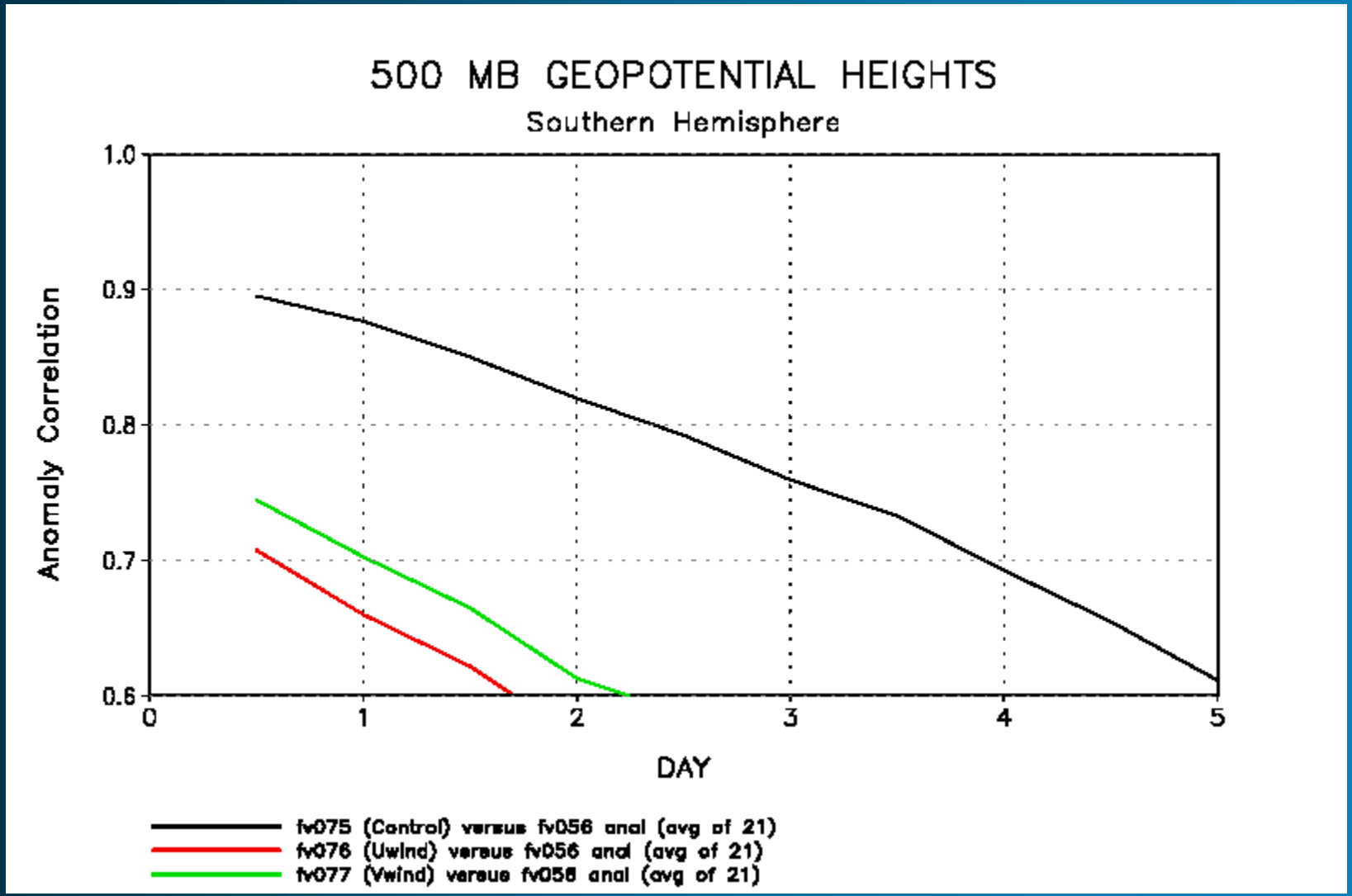

500 MB GEOPOTENTIAL HEIGHT
Northern Hemisphere
RMS ERROR
60
50
40
30
20
10
0
fv075 (Control) anal versus (fv056) anal ana
fv076 (uwind only) anal versus (fv056) anal ana
fv077 (vwind only) anal versus (fv056) anal ana
1JAN
2003
6JAN
11JAN
16JAN
21JAN
26JAN
DAY


500 MB GEOPOTENTIAL HEIGHT
Southern Hemisphere
RMS ERROR
80
60
40
20
0
fv075 (Control) anal versus (fv056) anal
fv076 (uwind only) anal versus (fv056) anal
fv077 (vwind only) anal versus (fv056) anal
1JAN
2003
6JAN
11JAN
16JAN
21JAN
26JAN
DAY

NH anomaly correlation coefficients against control, Both wind components (black), U only (red), V only (green)



SH anomaly correlation coefficients against control, Both wind components (black), U only (red), V only (green)



Conclusions, global assimilation/forecast study:

- Assimilation of wind observations only
  - Analysis provides good depiction of instantaneous flow field; reasonable initial conditions for forecast
- Assimilation of U- or V-component observations only
  - Analysis with some resemblance of instantaneous flow field; poor initial conditions for forecast
- Caveats:
  - “Extreme” experiments, presence of mass data will influence results (TBD)
  - GEOS-4; should be redone with state of the art system