Assimilation of tracer information from super-pressure balloons

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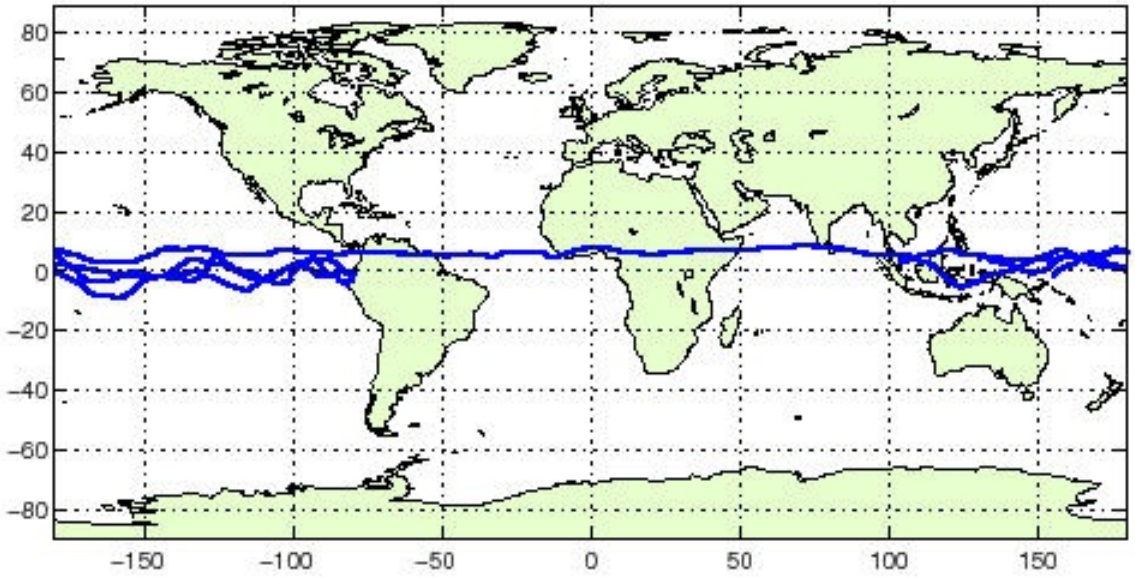
Historical background

- GEOS4 (the previous generation assimilation system) had difficulty to generate a reasonable QBO.

- Interest in improving stratospheric winds led to early attempts to assimilate data from the 1998 equatorial balloon campaign.

- Derived wind observations were assimilated every 6 hours into GEOS4, which used the PSAS assimilation algorithm.

Assimilation of Equatorial balloons



- 3 balloons launched from Ecuador in Sept 1998.
- Around 60 mb
- Maximum duration was 45 days.

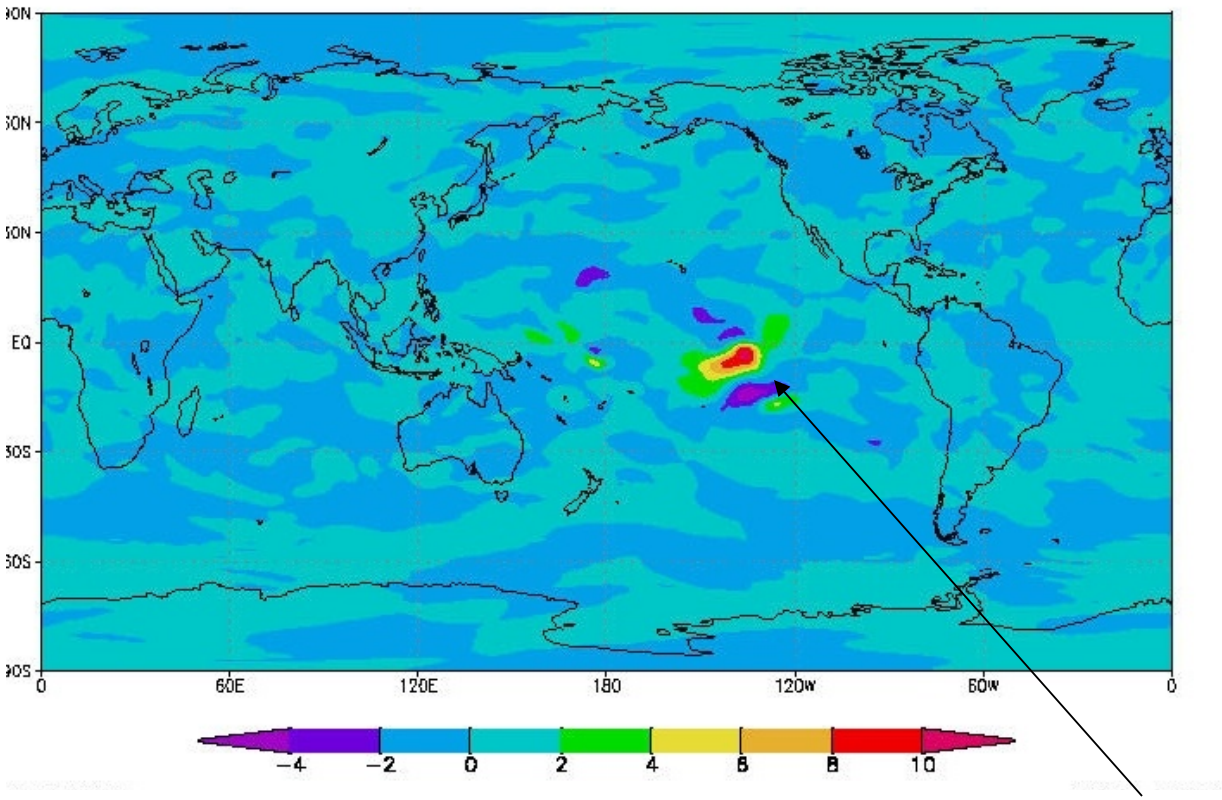
Can we improve the Stratospheric winds by assimilating wind vectors from these balloons?

Assimilation impact after 6 days

Difference between analyses with and without balloons

Zonal winds at 60 mb

GEOS-4 Assimilation



Previous corrections simply move with the balloons
So there is never more than one increment.

More effective to assimilate a stationary wind measurement!

Elongated Zonal Background error Correlations

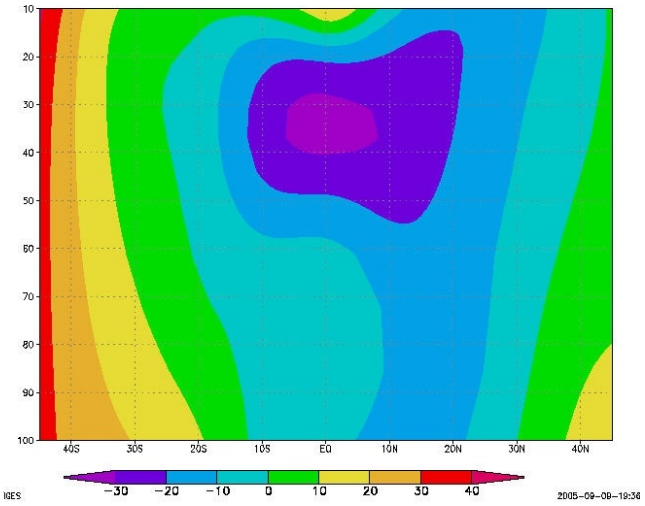
Gaspari, et al. 2006, QJRMS

- Zonal correlation length scale is increased in the Stratosphere from about 600 km to nearly 40,000 km at 10 mb.
- At 60 mb the zonal correlation length is about 3,000 km.
- What is the impact on the zonal flow with this new correlation?

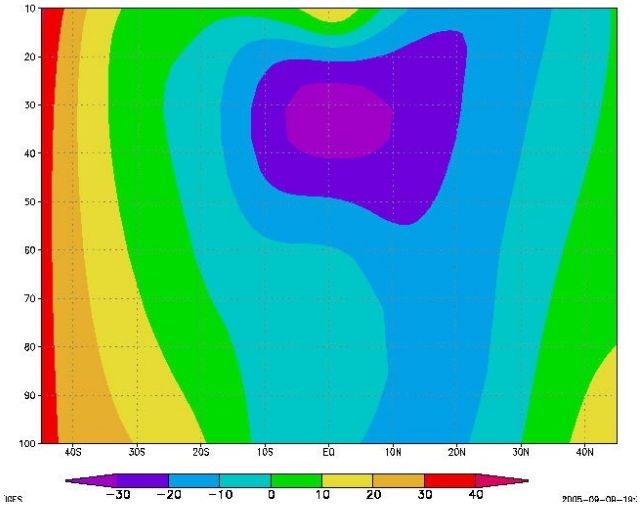
Zonal Mean velocity

averaged over last 30 days of assimilation

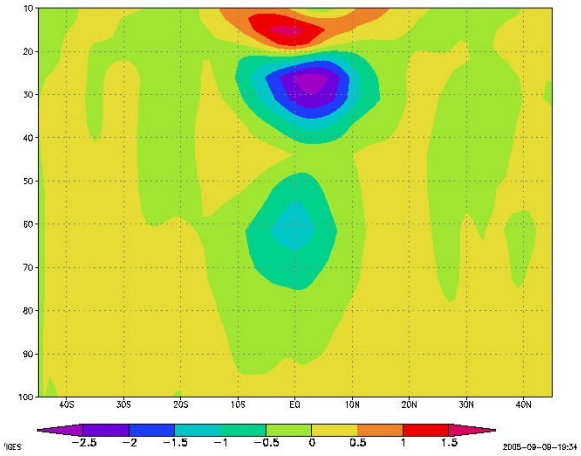
No balloons



Balloons assimilated



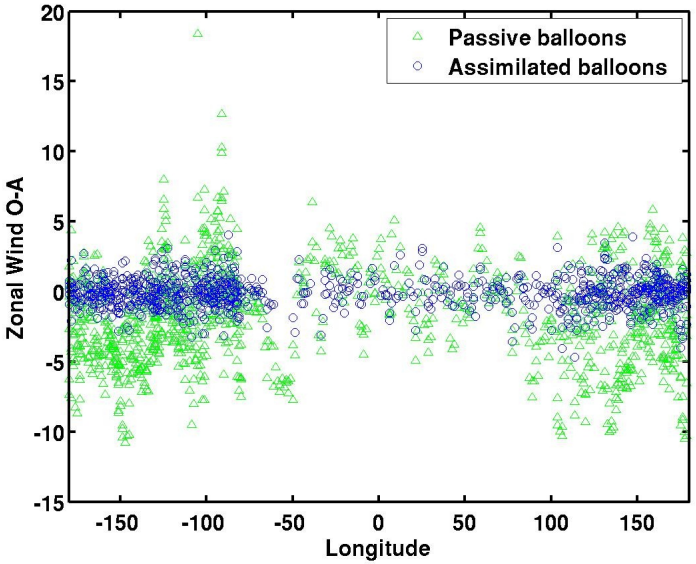
Difference



Zonal wind is strengthened well above Balloon location → stronger QBO.

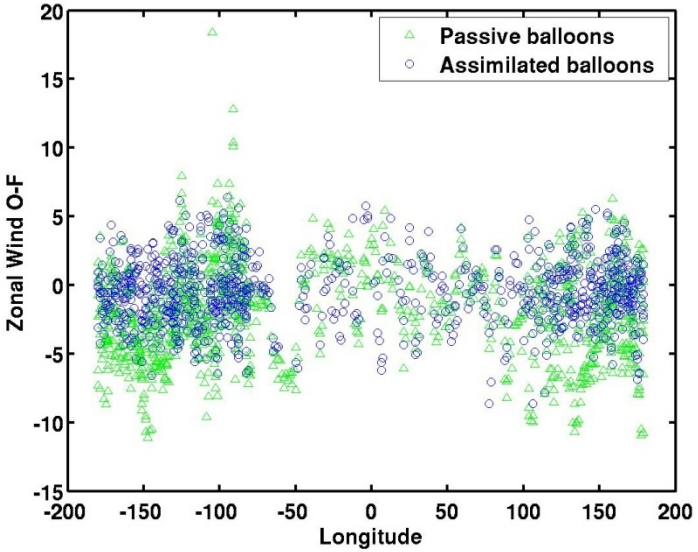
Forecasts of zonal velocity at balloon locations

Analyses



Larger reduction in analysis errors

6-hr Forecasts



Smaller reduction in forecast errors.

Why is there so little impact on the forecast?

- **Driftsonde provides velocity data only at one level. Flows above and below can drag the layer back.**

- **Sonde profiles don't have this problem because the entire profile is corrected by the observation.**

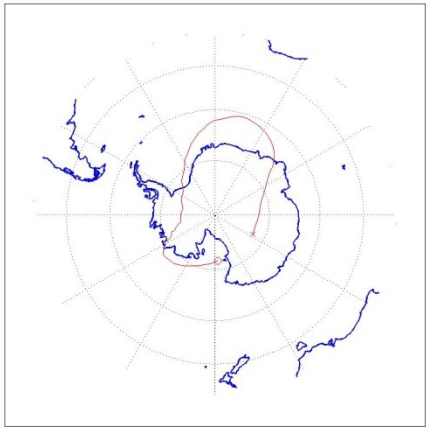
- **Is there a better way to assimilate driftsonde observations?**

Antarctic Winds

- A similar desire to improve stratospheric wind estimation during polar vortex breakdown over Antarctica
- What is the impact of improvements to polar winds on ozone assimilation and forecasts?
- We assimilated VORCORE observations from Sept 2005 to January 2006, also using GEOS4.
- Outside the tropics, it is not possible to extend zonal background error correlations.

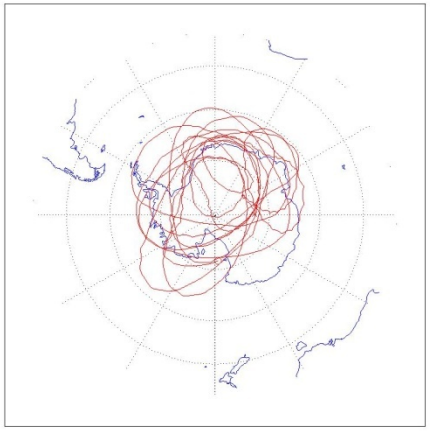
Characteristic Balloon Trajectories

Balloon 1



Sept 5 – 11, 2005

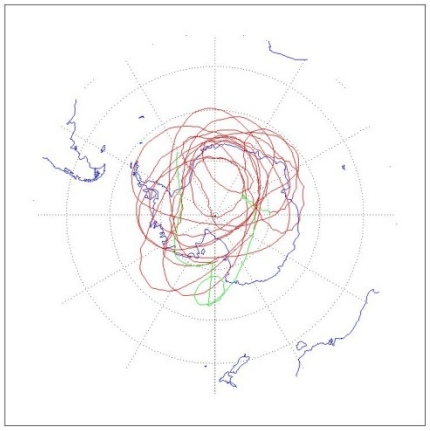
Balloon 2



Sept 6 – Dec 6, 2005

Passive balloon

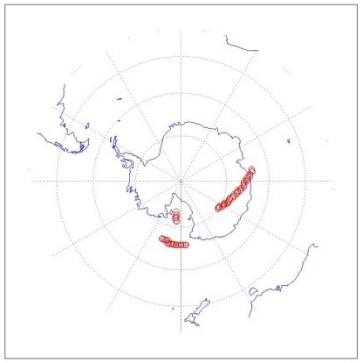
Balloon 27



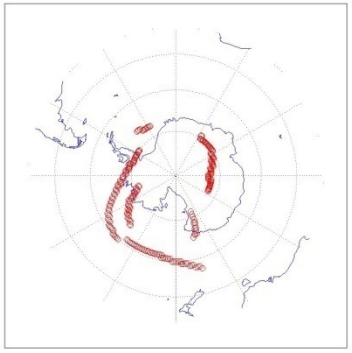
Oct 28, 2005 – Feb 1, 2006

Data Processing/superobbing

- Observations are superobbed to reduce data density.
- Balloon 2 is removed from for use as outside data set.



Observations on Sept 15, 2005
3 balloons

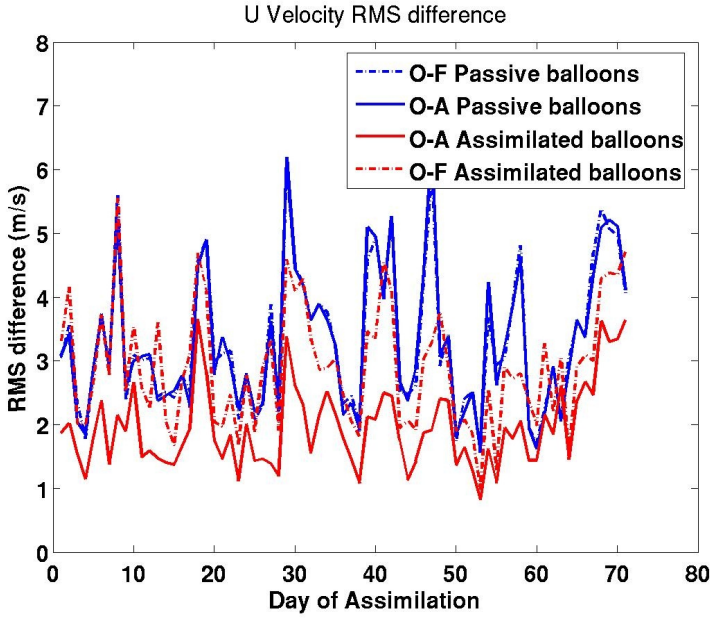


Observations on Oct 15, 2005
9 balloons

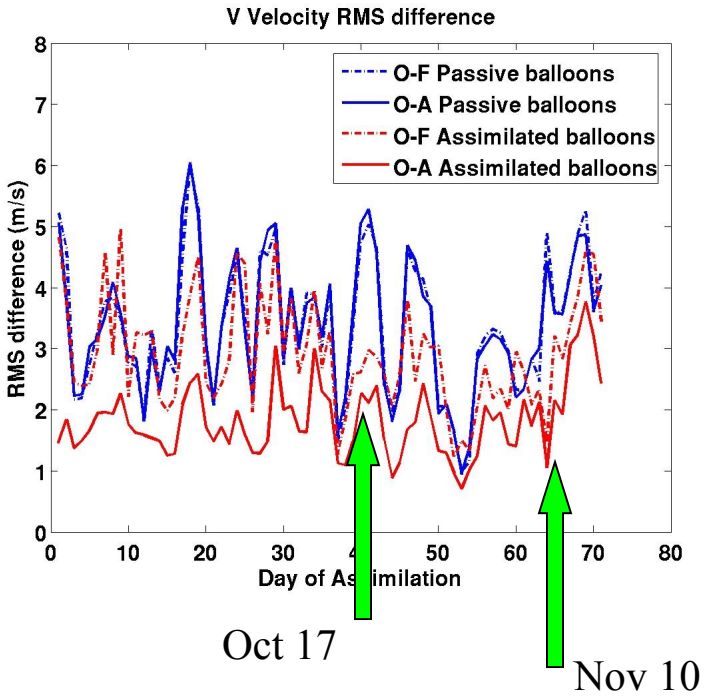
Impact of Assimilation on Meridional Winds

- Compare V-velocity with and without assimilated balloons.
- How do the forecast and analysis change due to the assimilation ?
- Where is the balloon located when the RMS difference is largest?

RMS of O-F and O-A for outside measurements (balloon 2)



Zonal



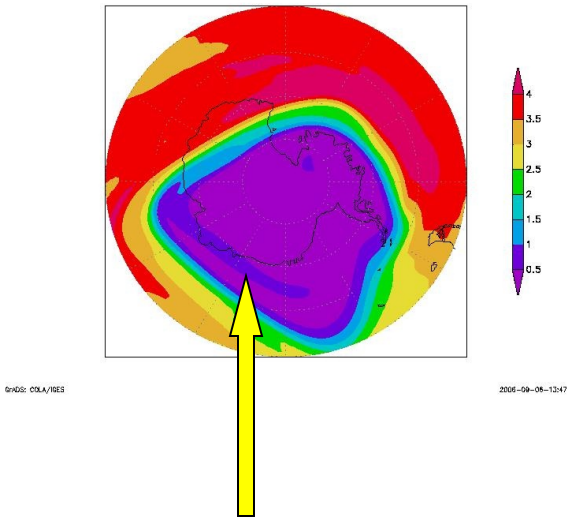
Meridional

Ozone Forecast

- Assimilation Run using MLS ozone obs.
- Mixing Ratio at 50 mb

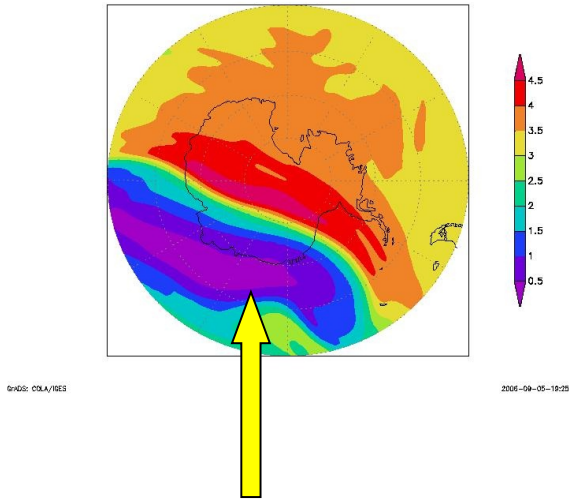
Ozone Forecast without assimilated balloons

Oct 17, 2005



Mixing within ozone hole

Nov 15, 2005

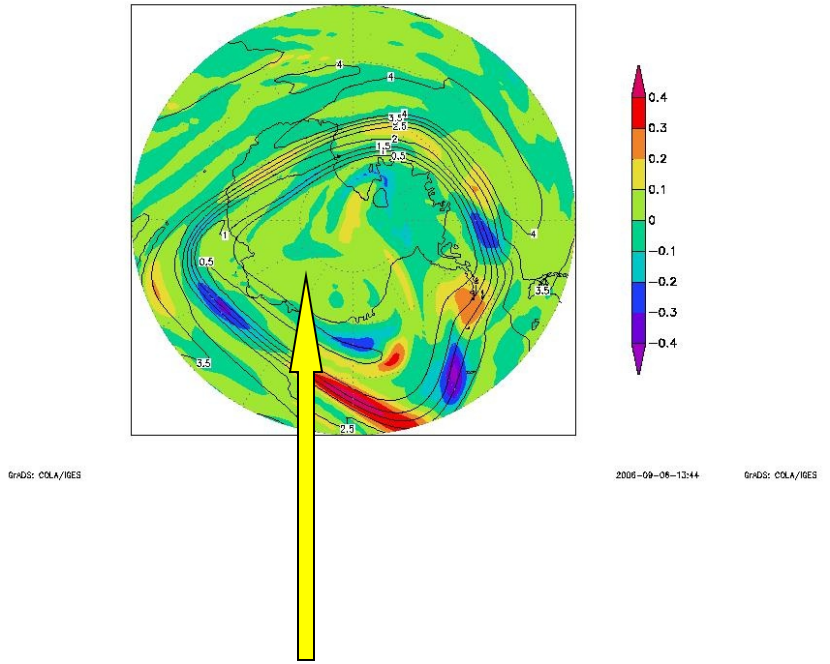


Ozone hole broken down

Corrections to Ozone Field

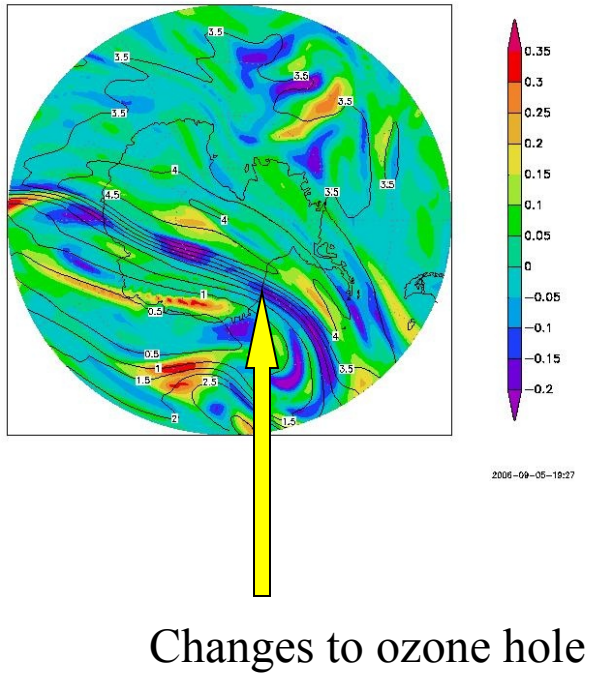
Color: Assimilated – Passive
Contours: Passive balloons

Oct 17, 2005



Corrections to ozone hole mixing

Nov 15, 2005

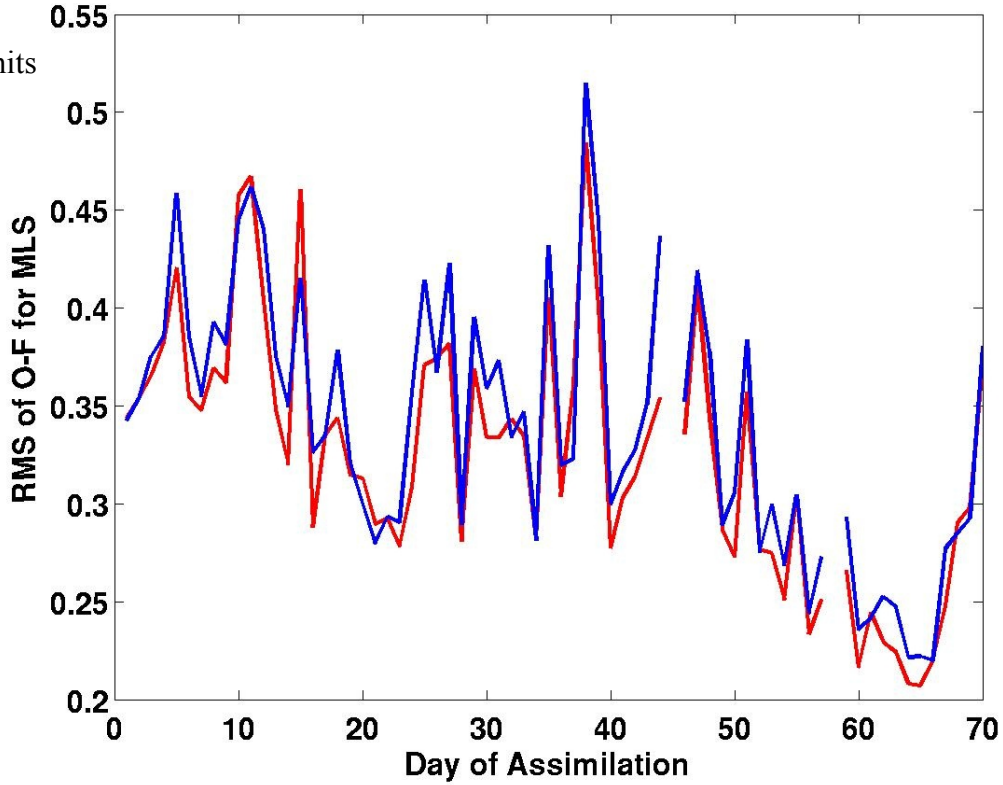


Changes to ozone hole shape

Ozone O-F

using MLS observations and 6-hour forecasts

Dobson Units



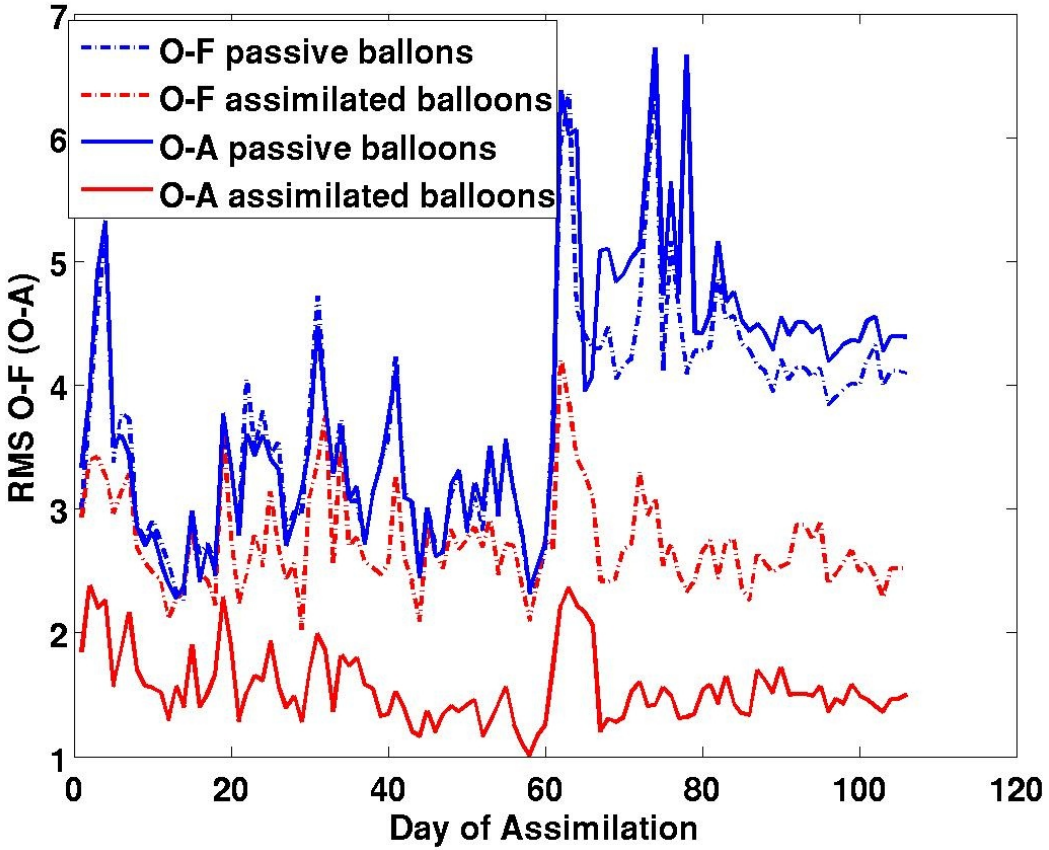
Without balloons

With balloons

6-hour forecast O-F for ozone show a modest, but consistent improvement from the assimilation of balloon wind velocities, starting around the 25th day.

Assimilation into GEOS-5

- Uses the 3DVAR Gridspace Statistical Interpolation (GSI) analysis system.



Sept 5 Nov 8

Lagrangian Assimilation of Tracers

- Basic Idea: Assimilate position of tracer rather than wind vector derived from tracer movement.

- This requires a forecast of the balloon position in the model so that the O-F becomes the difference between the observed and forecast balloon positions.

- Previous work done on Ocean drifters (Salman et al., 2006; Nodet, 2006) showed improvements to estimating ocean circulation using Lagrangian assimilation rather than derived velocity vectors.

Why should Lagrangian Assimilation work better?

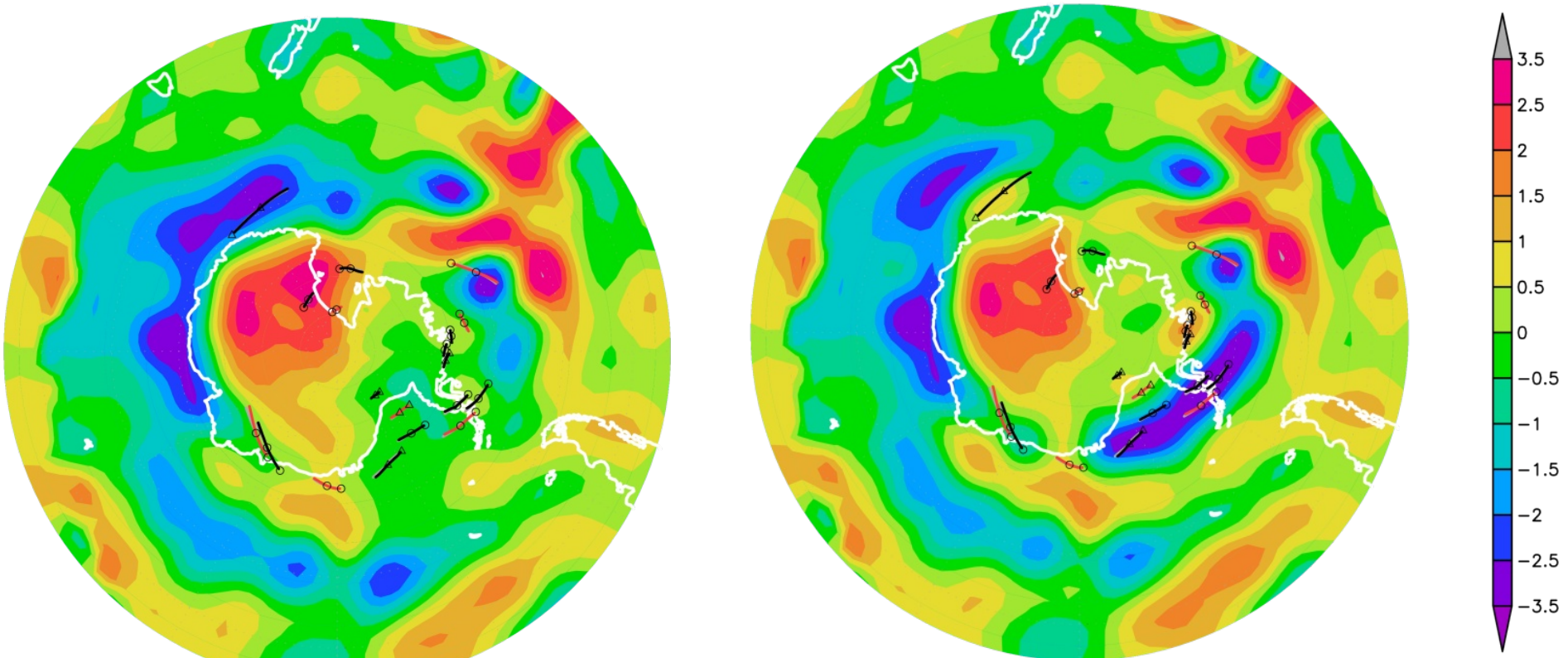
- Using direct measurements rather than derived velocities
- Can use more of the data (all measurements in 4DVAR)
- Does position data contain more information than velocity?

Development work done in GSI analysis system:

Louis-François Meunier – Météo-France

- Non-linear forward model for balloon trajectory
- Tangent linear and adjoint models needed for 3d and 4dVar assimilation.
- Addition of balloon position observations to cost function.
- Tests carried out using 3DVAR.

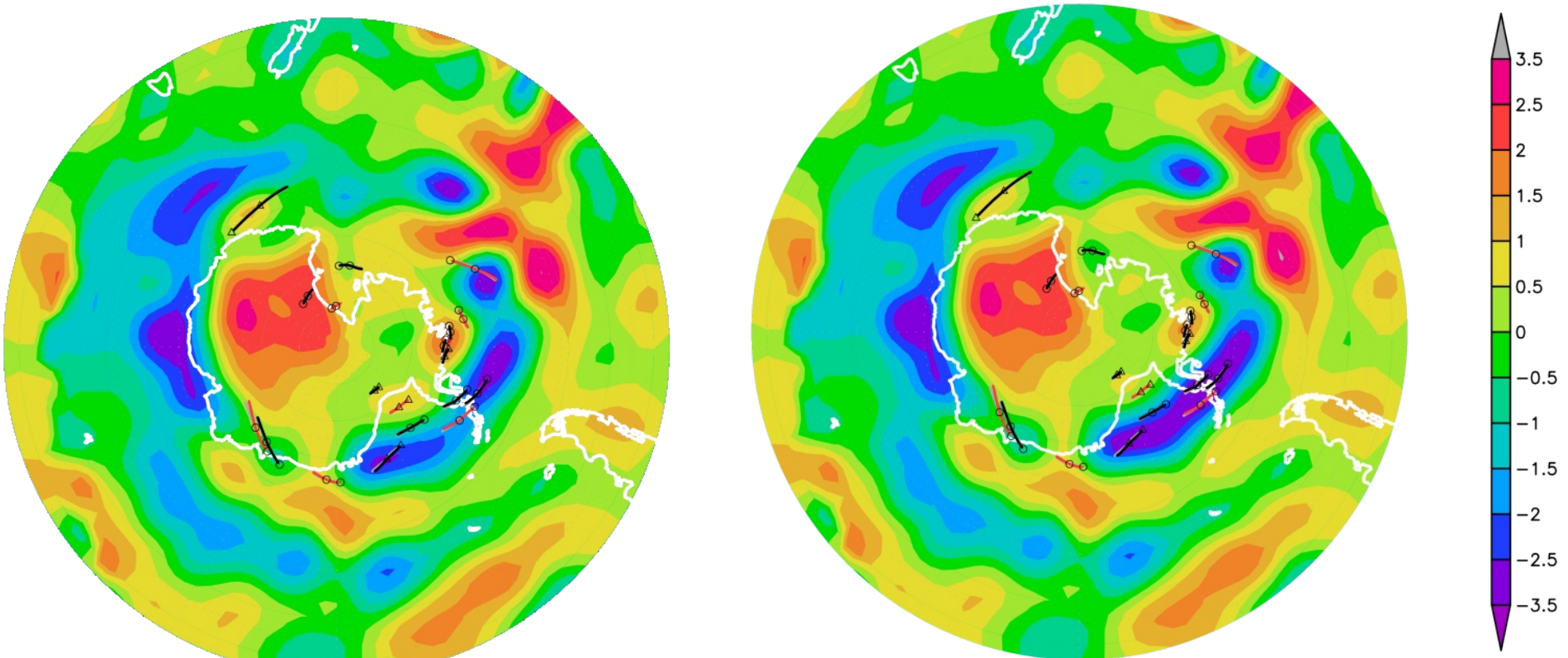
Impact of Assimilation: Analysis Increments



Reference (balloons passive)

With balloon positions assimilated

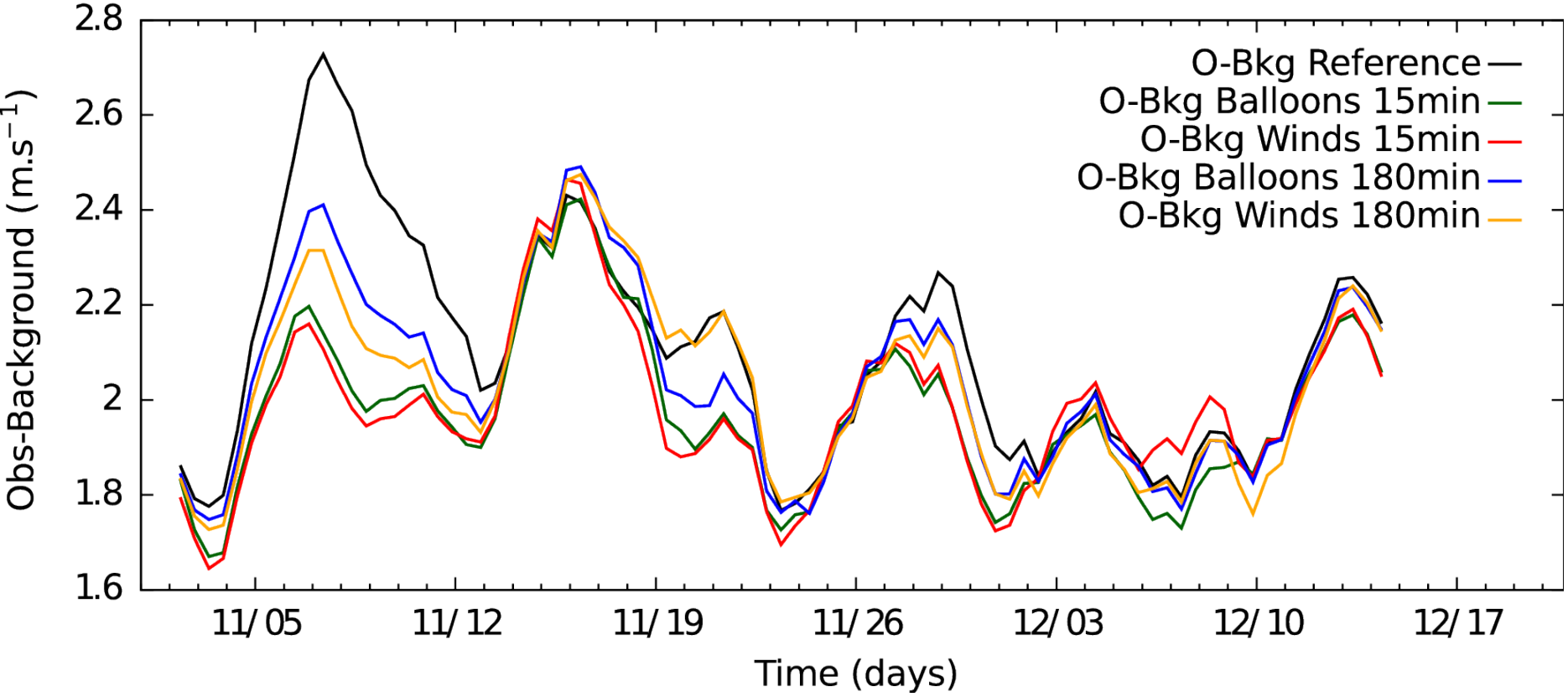
Impact of Assimilating Balloon position Instead of derived winds



With derived winds assimilated

With balloon positions assimilated

Innovations for passive balloons



Discussion

- An evolving approach to assimilating drift balloon observations has been presented.
- Potential to improve estimation of stratospheric winds during the polar vortex breakdown.
- Initial tests of a Lagrangian approach show no improvement in 3DVAR, but testing with 4DVAR is needed.
- Concordiasi dropsondes provide opportunity to assimilation entire profile, possibly eliminating the drag on adjacent layers.