Optimizing parameterized GWD using Data Assimilation.

Reducing the SH winter vortex breakdown delay?

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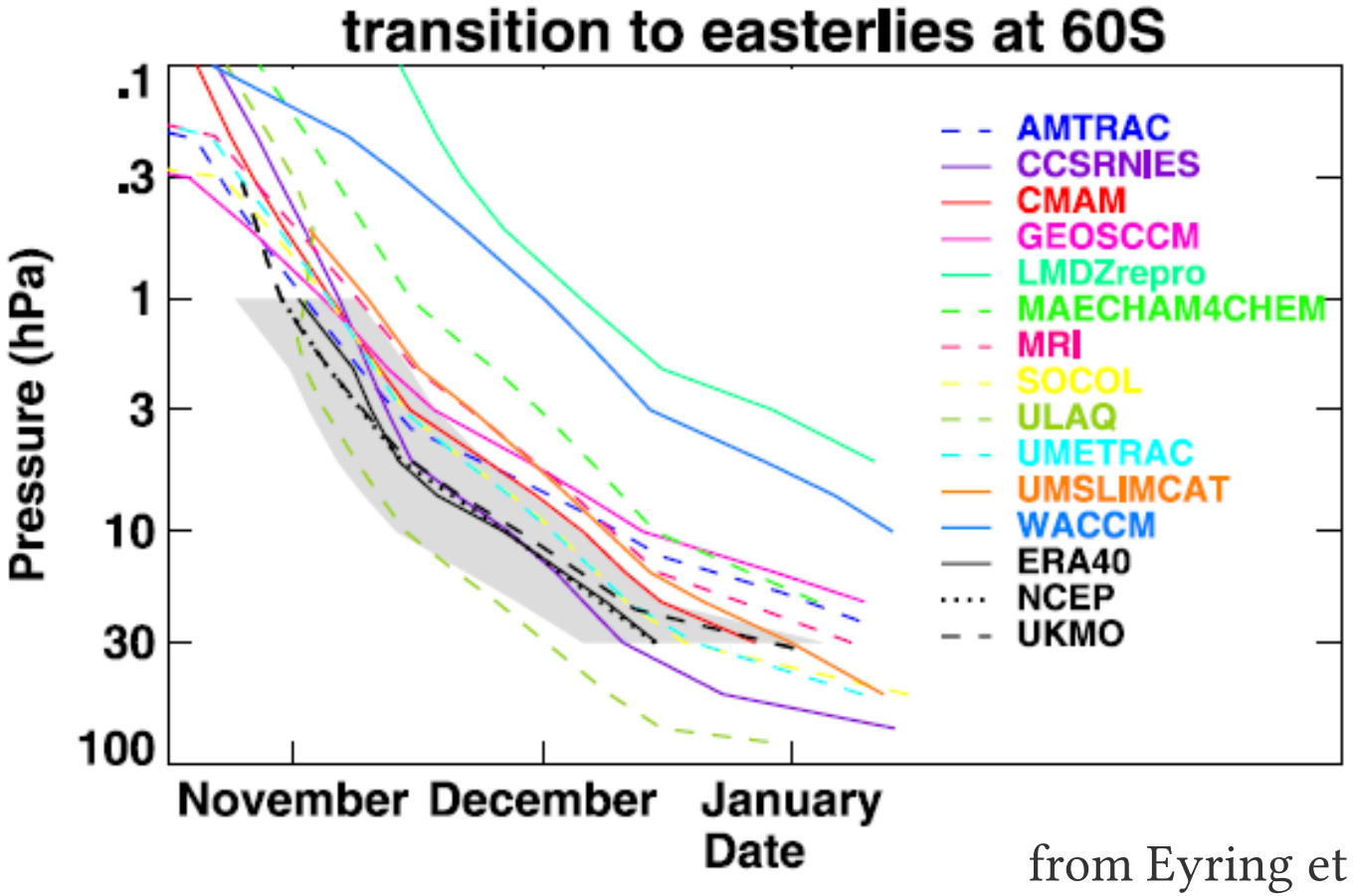
2016 SPARC GW Symposium – State College, PA. 20-may-2016

A known problem?



Zonal mean zonal zero-wind lines from different GCMs

from Eyring et al. (2006), J. Geophys. Res.

- Polar vortex breakdown is persistently delayed in most GCMs
- Also implications for tracking Antarctic ozone transport.

Objectives

- Understanding better the relationship between the delayed vortex breakdown, large scale waves and non-orographic GWD.

- Reducing the bias in the timing of the SH vortex breakdown through gravity waves parameterization (GWP) improvements/tunning.

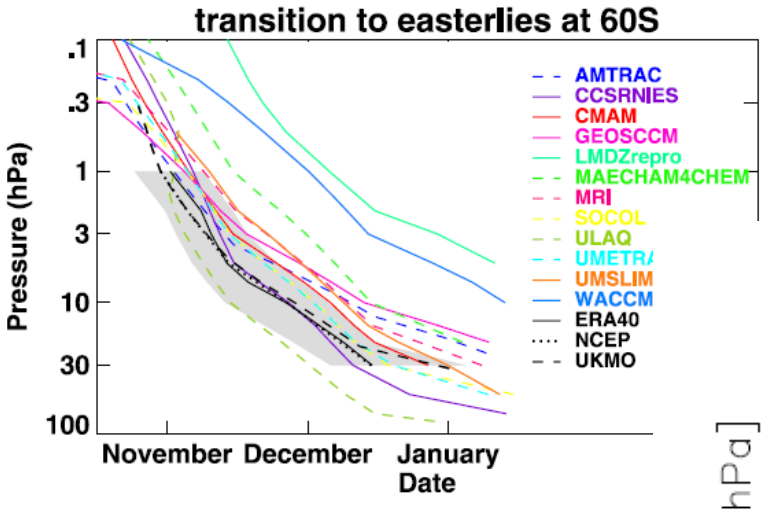
- Potential of data assimilation for GWP parameter estimation. Dealing with multi-scale interactions?

Model and Data

- **Middle atmosphere model (Univ. of Reading model)**
  - **Hydrostatic equations**
  - **Hexagonal-icosahedral horizontal grid (~480km resolution)**
  - **16 isentropic vertical levels (from ~100mb to ~0.01mb)**
  - **Non-orographic spectral gravity wave drag parameterization (Scinocca 2003) launched at tropopause**

- **MERRA reanalyses**
  - **Analyzed fields and 6h forcings**

- **Scope: Years 2003-2009**



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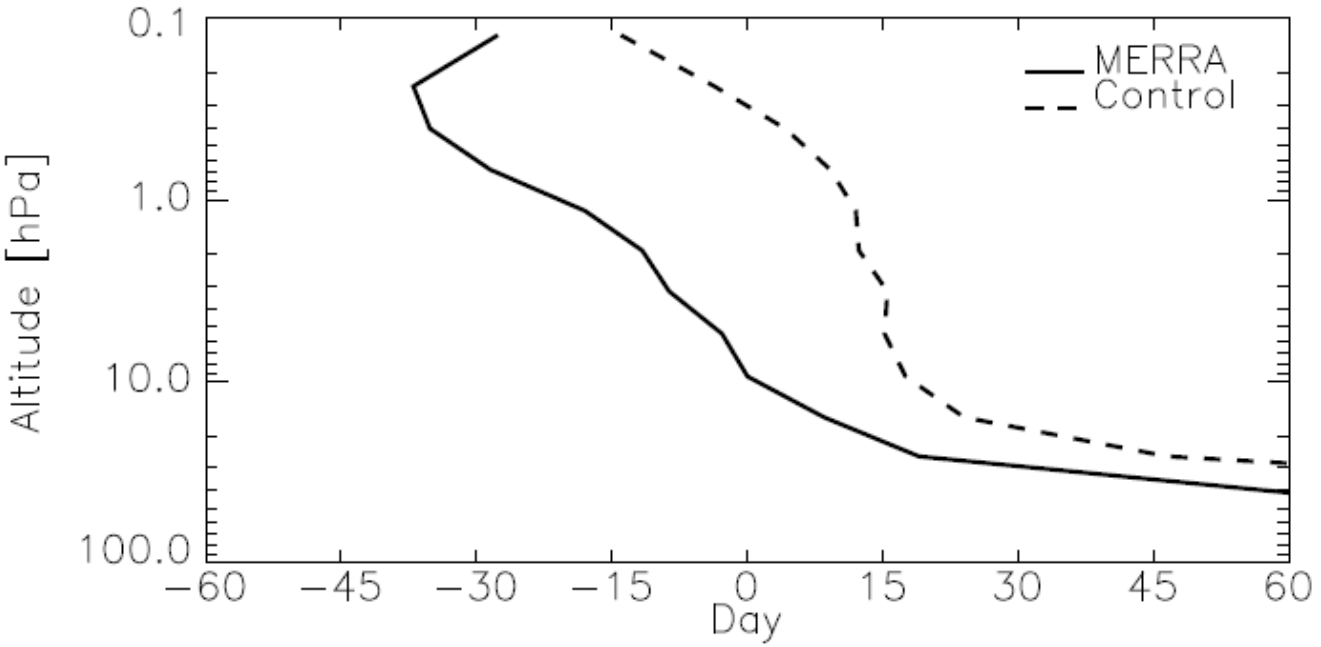
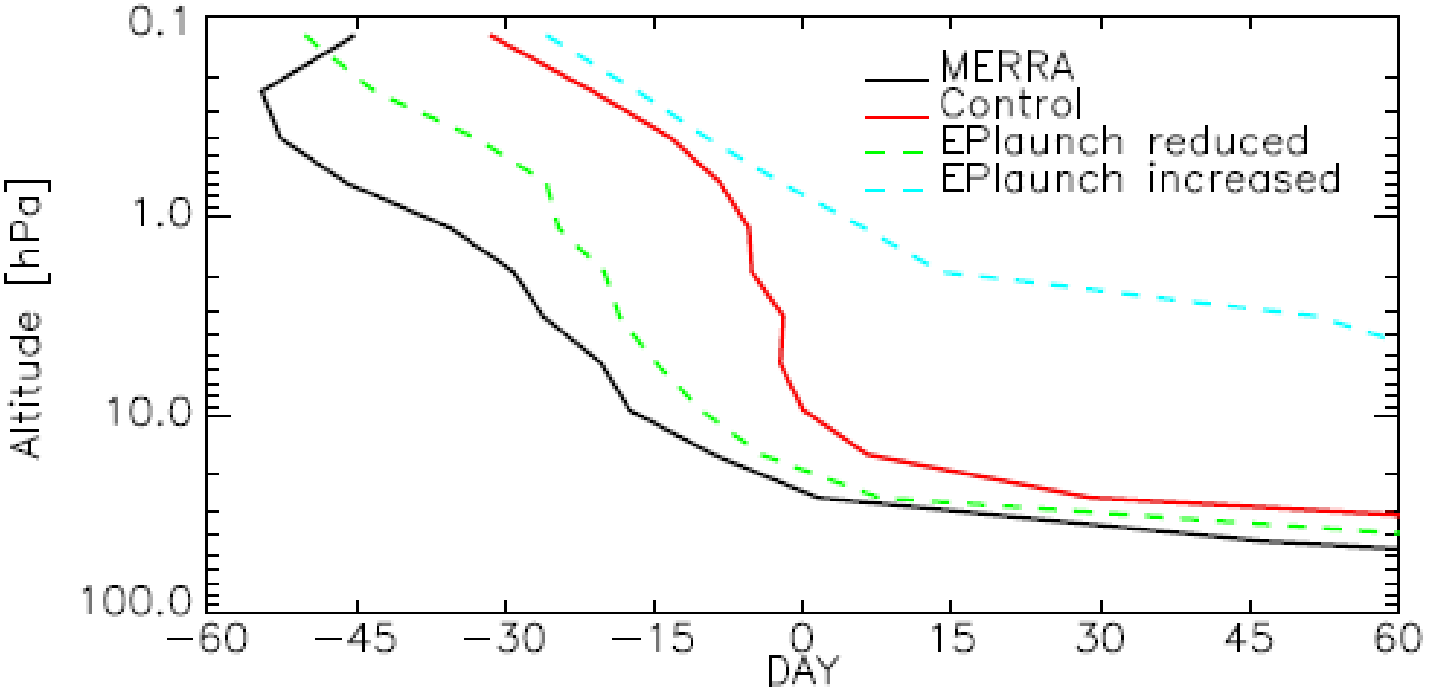


7year composite of zonal-mean zonal zero-wind lines at 60S from MERRA vs. middle atmosphere model.

- **About 16 days of delay at 10hPa in control integration**
- **Sharper transition in control integration**
- **Can be improved with parameter estimation??**

Sensitivity experiments

→ Globally changing the amount of MF launched in the GWD parameterization

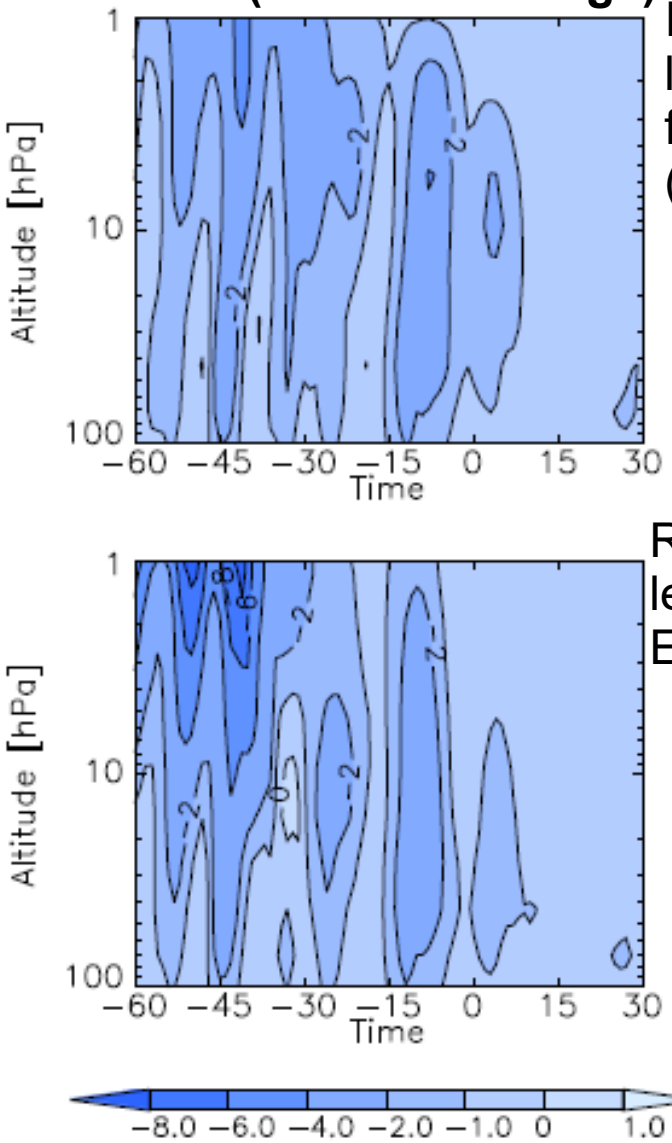


Zonal mean zonal zero-wind lines from different configurations

Results from: Scheffler G. and Pulido M., 2015, J. Atmos. Sci.

Compensation mechanisms?

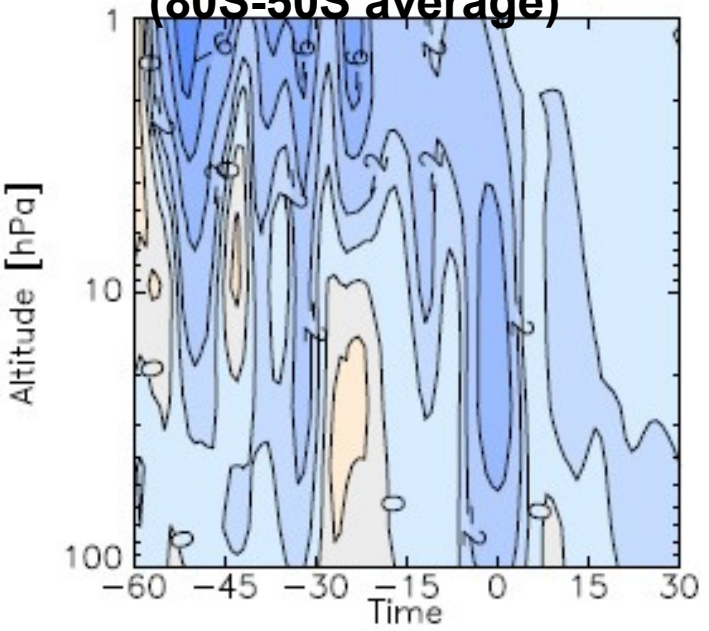
EPFD (80S-50S average)



Increase of GWD MF leads to reduced EP flux divergence (EPFD)

Reduction of GWD MF leads to an increased EPFD

EPFD derived from MERRA (80S-50S average)



Increased GW activity changes the mean flow, and in turn, the refraction index, reducing PW propagation (and its EPFD).

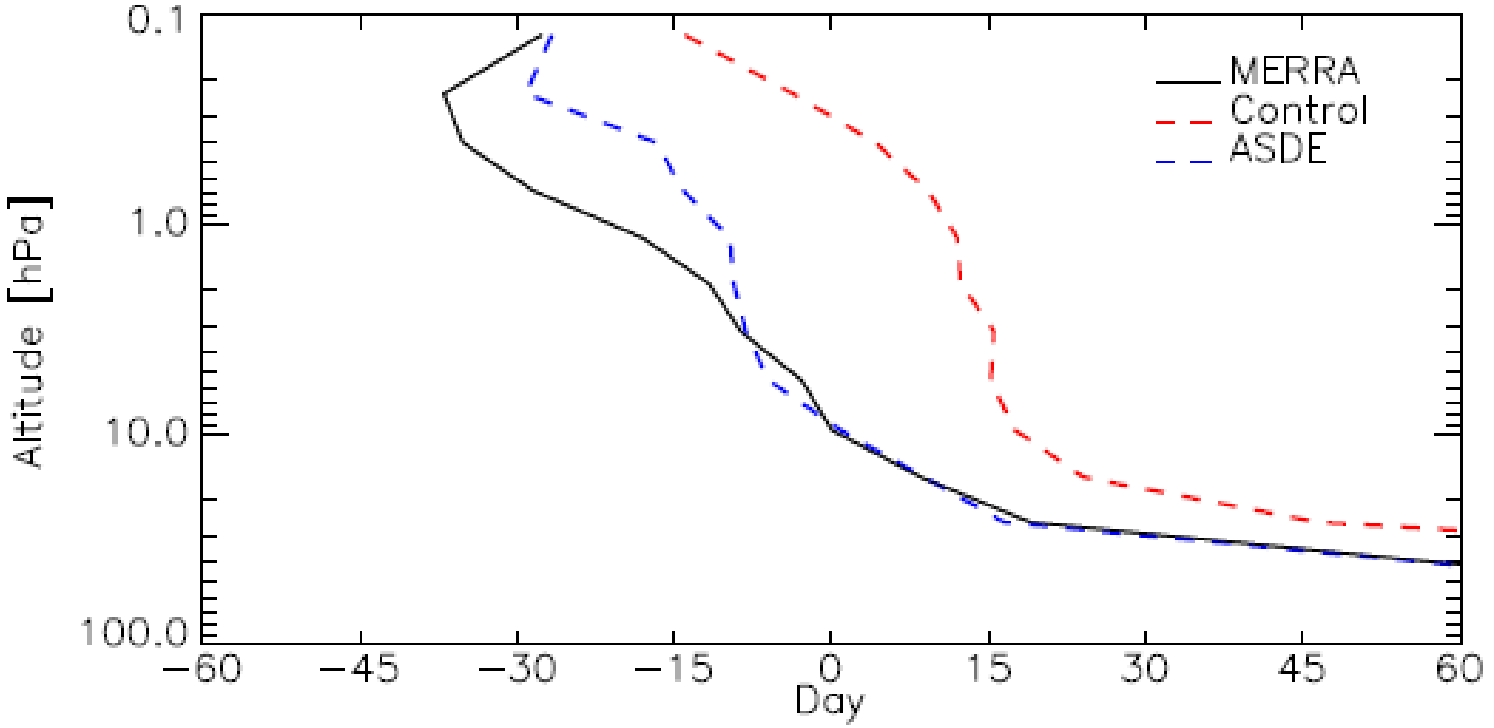
There are interactions between GWD and large scale drag . (Cohen et al. 2014, McLandress et al. 2012)

Data Assimilation

- Assimilation System for Drag Estimation (ASDE)
  - *Pulido and Thuburn (2005a; 2005b)* *Q. J. R. Meteorol. Soc.*
  - 4D-Var scheme
  - Estimates missing forcing term in the momentum equations that fits the model runs to a given set of observed variables.
  - With the GWP switched off -and for short time windows- the missing forcing is directly attributable to the missing gravity wave drag.
  - Missing GWD estimated for 2003-2009

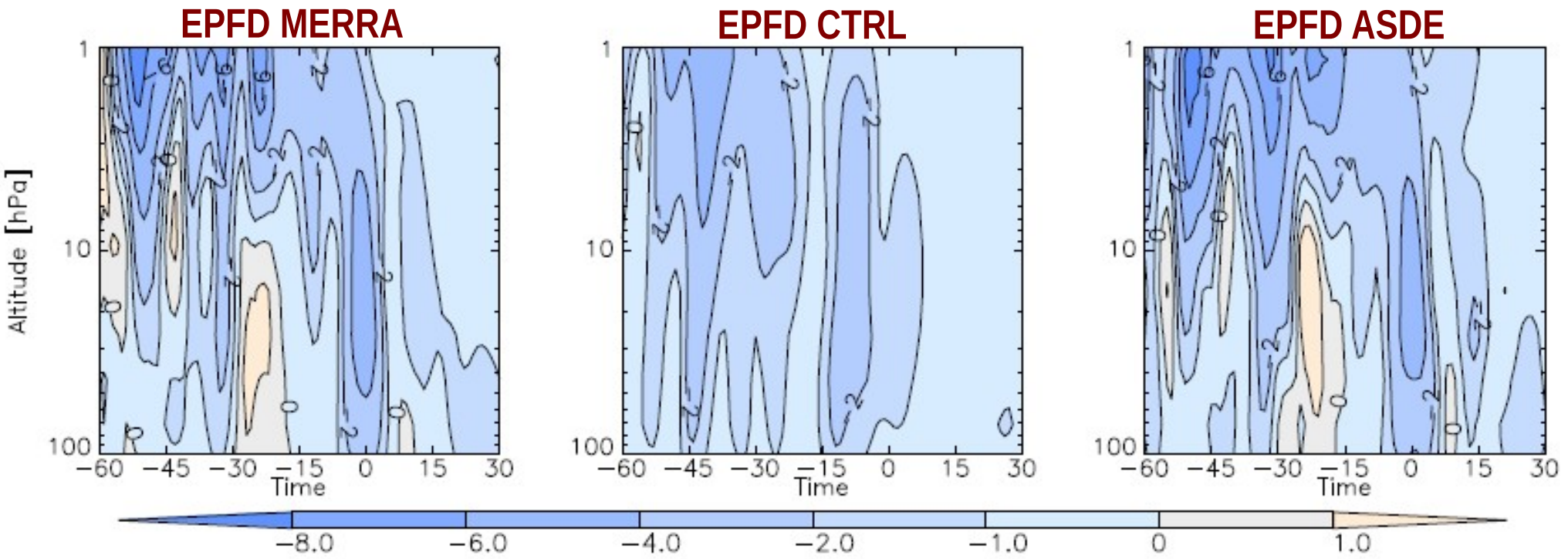
Data Assimilation

- Assimilation System for Drag Estimation (ASDE)



Zonal mean zonal zero-wind lines from different configurations at 60S

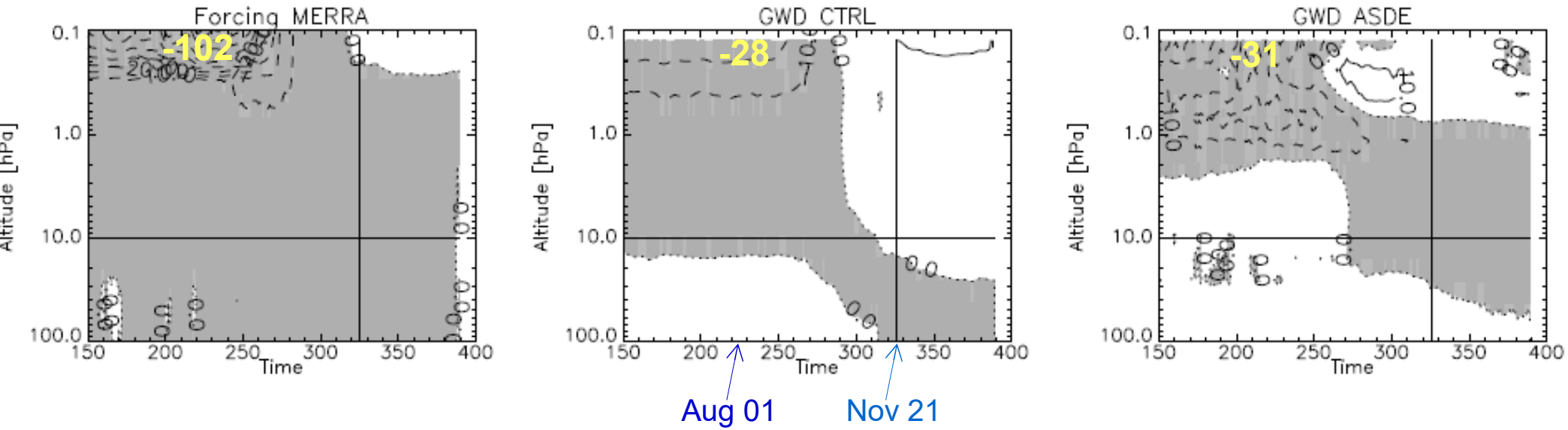
Biases largely corrected when adding missing forcing from ASDE to the forward integration



- EPFD from MERRA is reproduced accurately when using missing drag from ASDE
- It's desirable that optimal parameters improve also the EPFD in the model

GWD [m/s/d] profiles

(80S-50S averages)



- Similiarties in GWD profiles between ASDE and the control integration in the lower mesosphere in winter. Not so much in the stratosphere
- GWD vertical structure from the parameterization needs to be adjusted!

Parameter Estimation

- Parameter estimation steps

  1- Estimate GWD profiles with ASDE for 2003-2009.

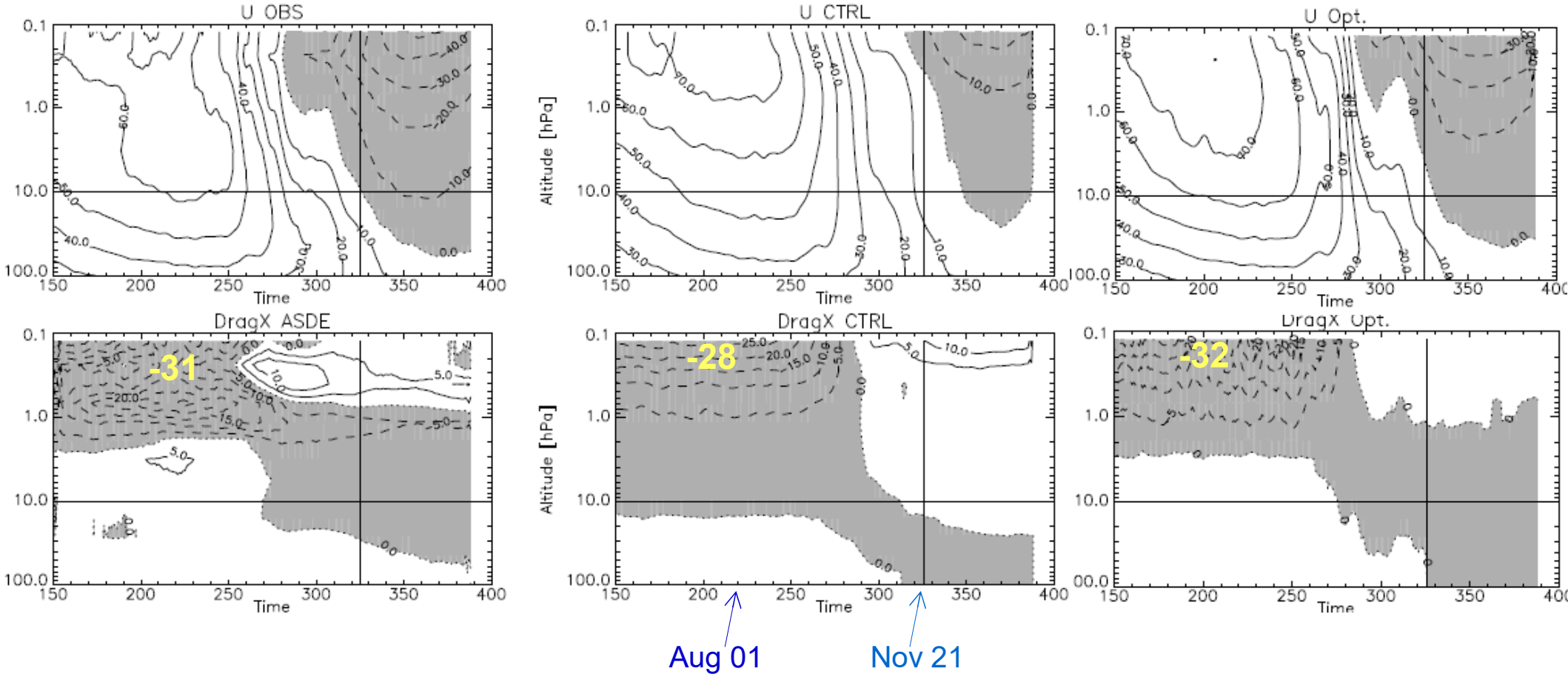
  2- Use GWD profiles as observations to tune parameters in an offline implementation of the parameterization (with a genetic algorithm)

  3- Integrate the model with optimal parameters

  - **Can we alleviate late warming biases with optimal parameters??**

Results -Paramter estimation

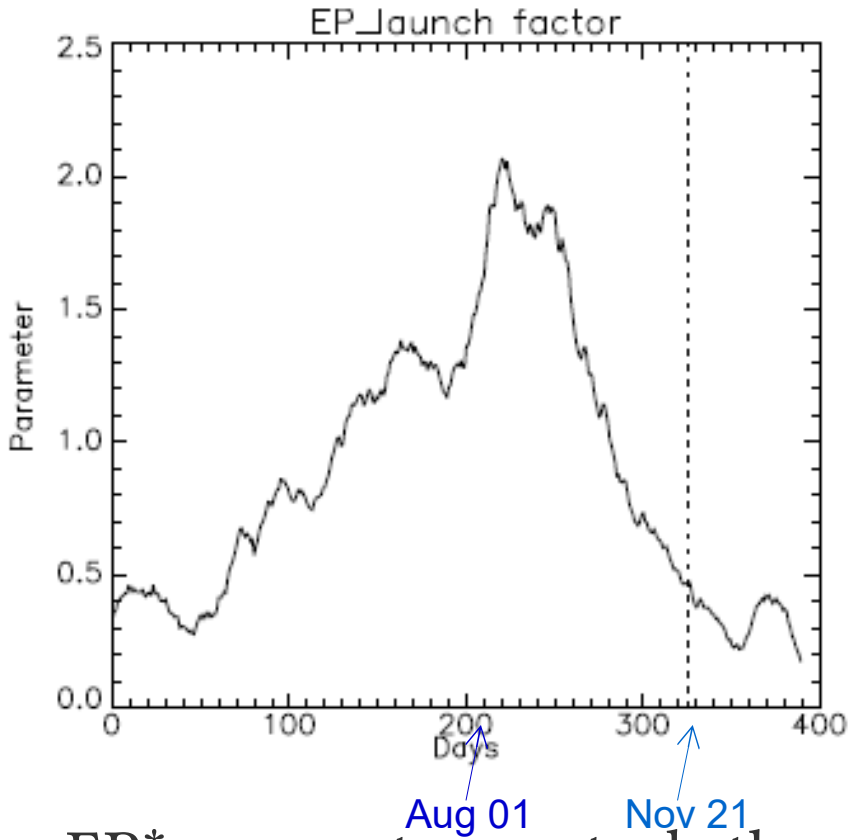
(80S-50S averages)

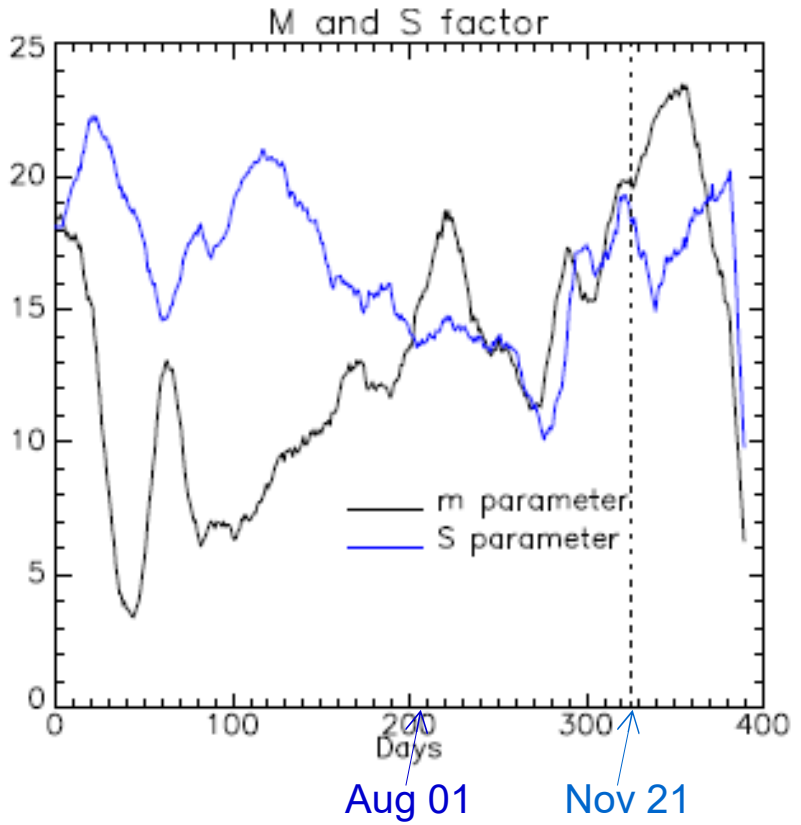


- Wind transition largely improved
- Parameterized GWD vertical profiles show more ressemblance with ASDE

Optimal parameters

(80S-50S averages; normalized)

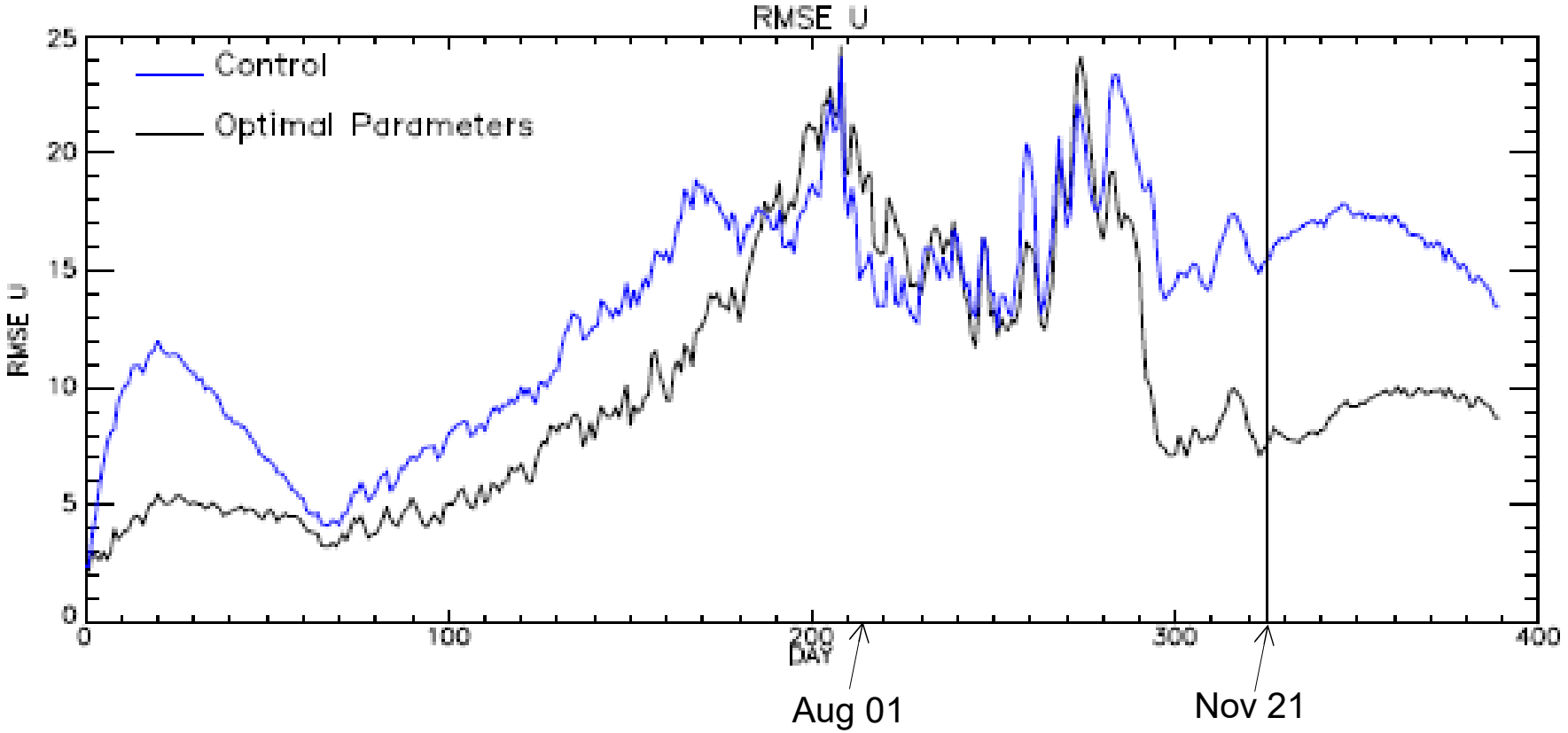




- EP* parameter controls the amount of GW momentum launched
- M* and S* parameters are related with filtering and saturation (highly related with each other)

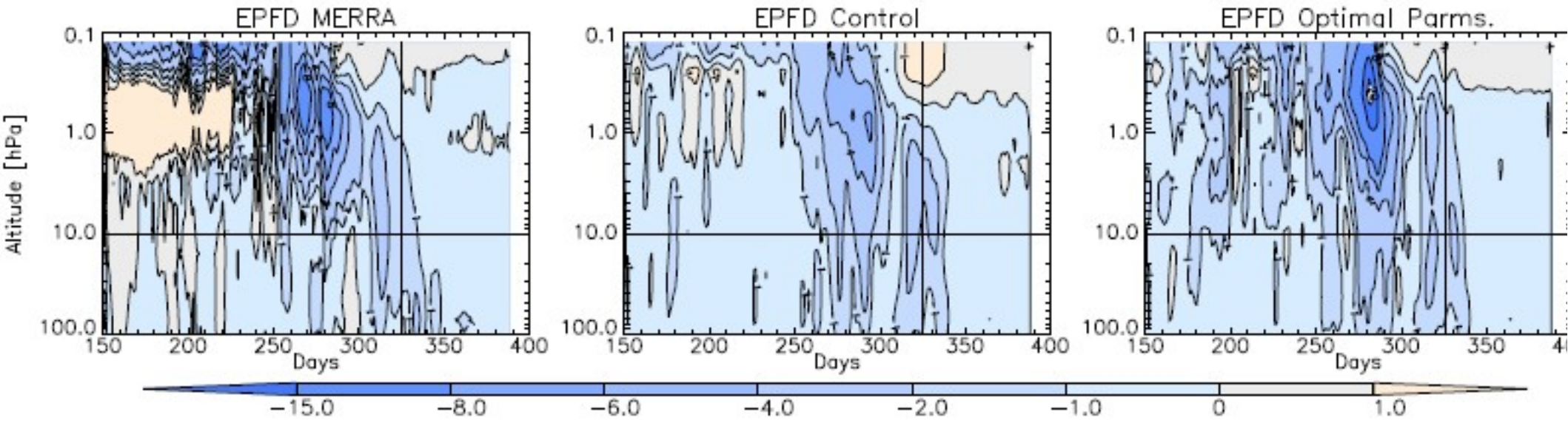
Zonal mean zonal wind RMSE

(80S-50S)



- Large improvements during late spring
- The jet formation is improved
- Detereoration during winter (mostly in lower mesosphere)

Results Parameter Estimation- EP flux divergence

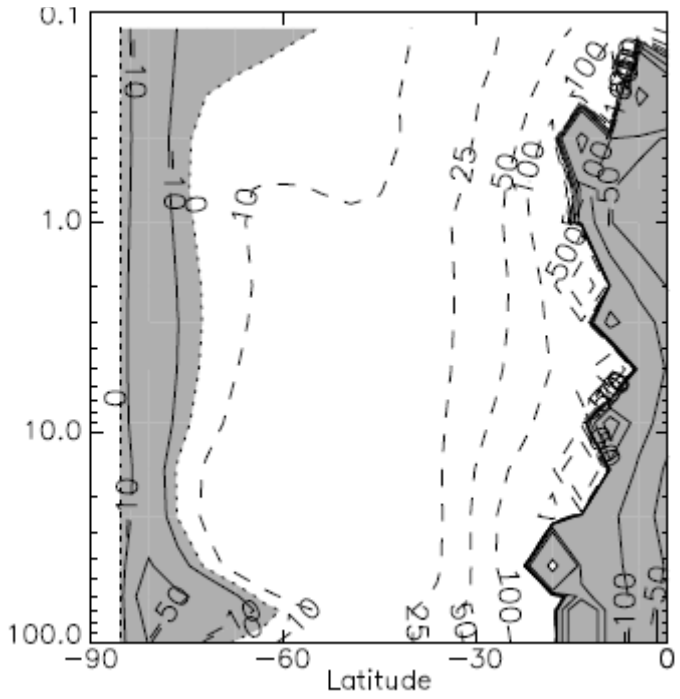


Large negative EPFD in lower mesosphere 30-40 days before the final warming when using optimal parameters

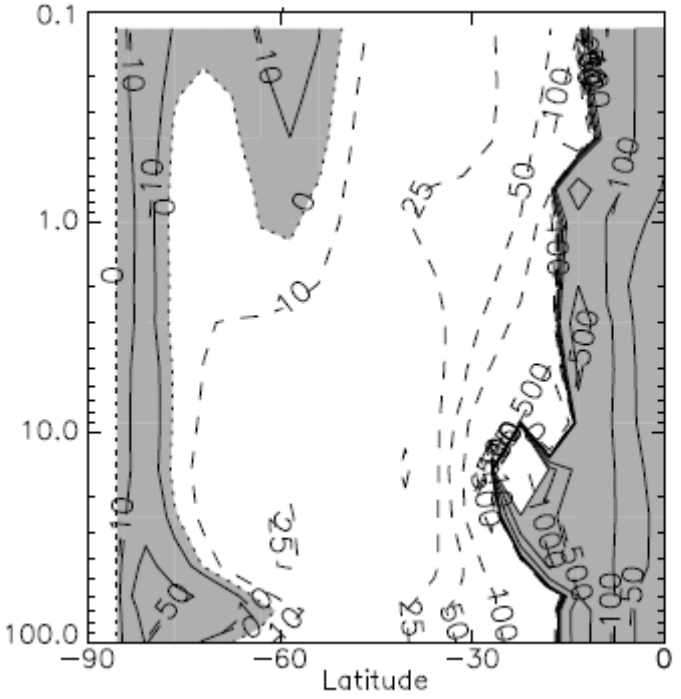
Changes in index of refraction?

Averages between days 240-280 (Aug 28-Oct 6)

Control Integration



With Optimal Parameters



Scaled quasi-geostrophic index of refraction for k=1

Negative values are shaded (No propagation!)

- Narrower waveguide which enhances PW breaking at high latitudes

Summary

- The delay in the vortex breakdown can be alleviated indirectly by modifying the amount of GWMF launched in non-orgraphic GWP. (Scheffler & Pulido 2015, JAS)

- Estimation of optimal parameters is not trivial. An annual cycle is suggested at least for the EP* parameter
- Parameter estimation should not aim exclusively to produce more/less GWD, but instead, take into account interaction mechanisms with large scale waves

(Scheffler & Pulido, in preparation)