The stratosphere-troposphere connection in ensemble forecasting

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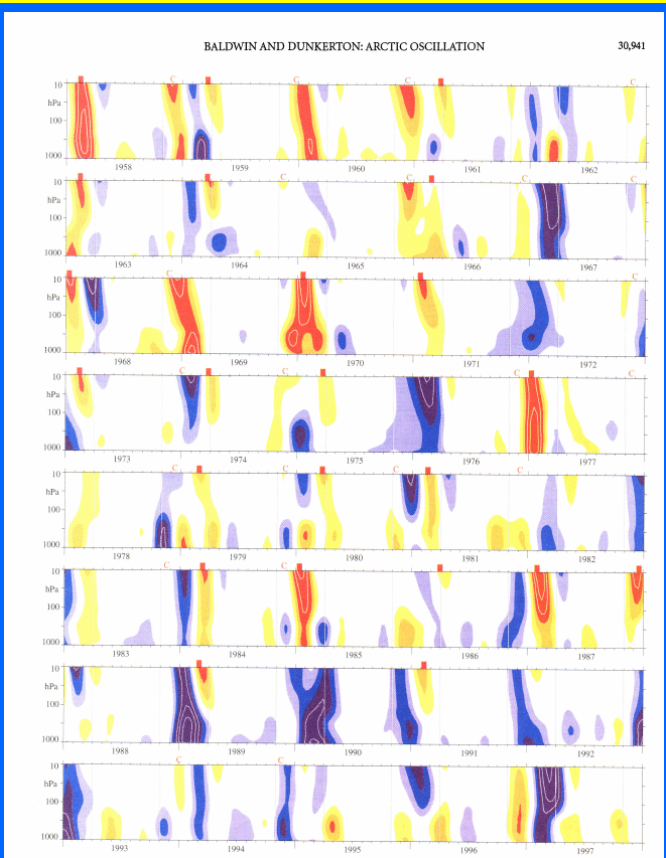
Overview

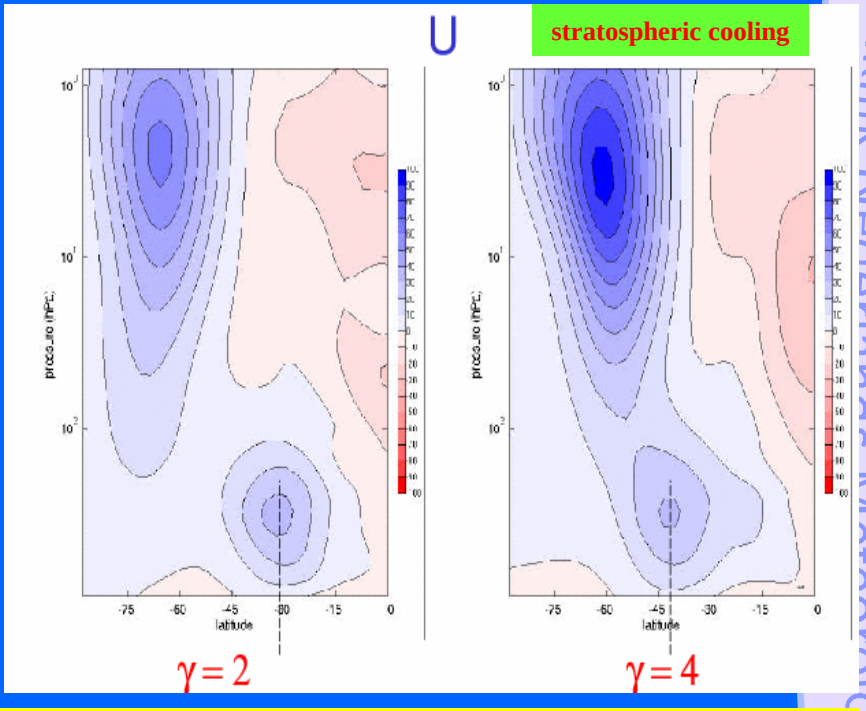
- Definition of stratospheric initial condition perturbations and some of their properties
- Experimental set-up of L62/L91 ensembles
- Evaluation of ensemble flavours (occurrence of Stratospheric Sudden Warming)
- Conclusions

Stratosphere-troposphere interaction?

Filtered AO signature during 1958-1997

Baldwin and Dunkerton (1999)





- Stratospheric polar vortex strengthens

- Tropospheric jet weakens and shifts polar wards

Polvani and Kushner (2002)

SPARC DynVar Project: Dynamics and Variability of the coupled Stratosphere-Troposphere system. www.sparcdynvar.org

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Stratospheric experiment with the ECMWF model

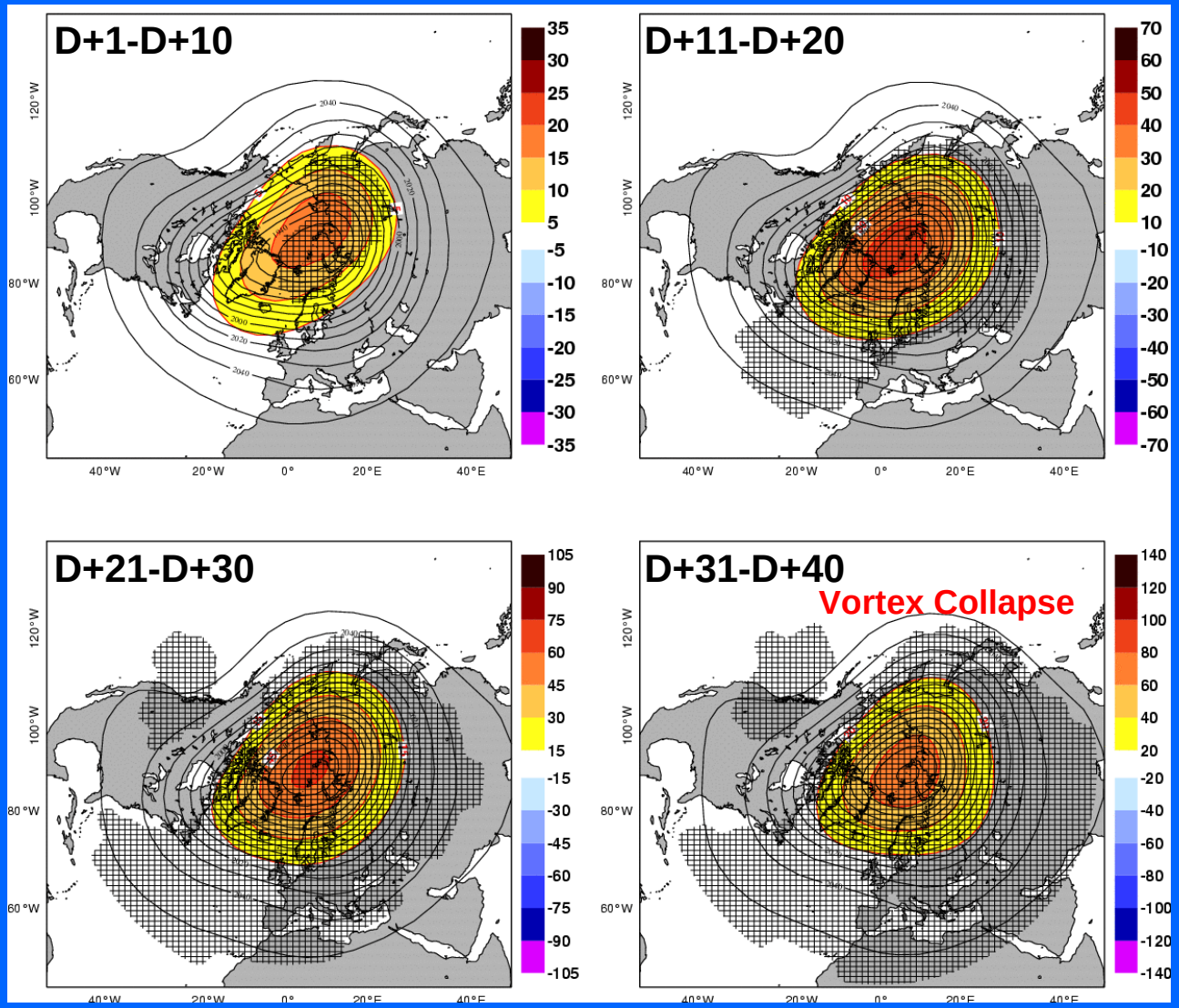
- Apply a forcing **F** to the model tendency
- Forcing **F** is constructed to change the strength of the stratospheric polar vortex (18 sensitivity calculations).
- Perform 60 forty-day T95L60 integrations during DJF 1982-2001 with

$$dx/dt=EC(x),\ dx/dt=EC(x) + \mathbf{F} \text{ and } dx/dt=EC(x) - \mathbf{F}$$

- Forcing **F** is small and zero below 150 hPa
- and **F** is kept constant during the integration

Jung and Barkmeijer (2006)

Stratospheric Response (50hPa) Weak-Ctl



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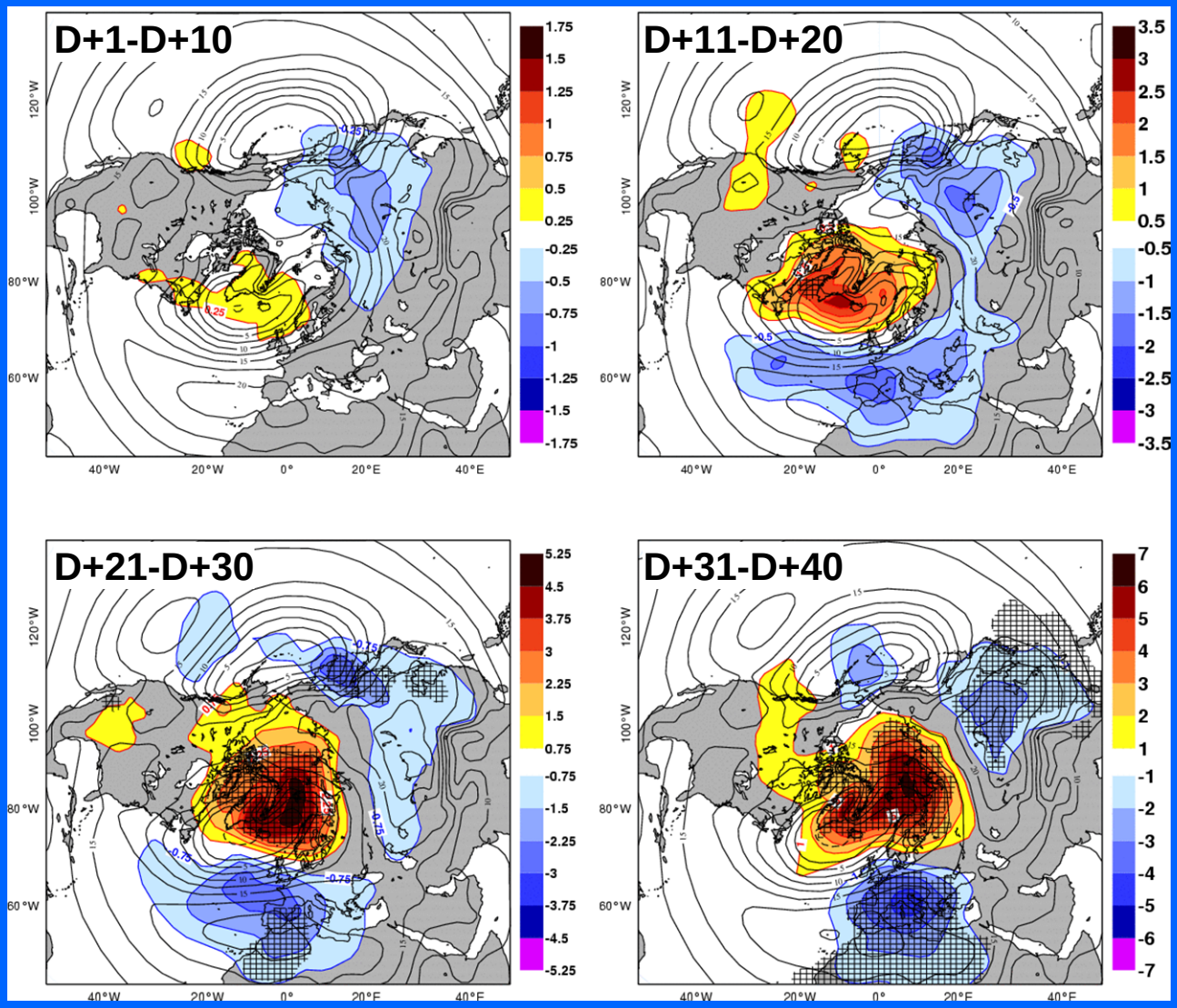
Z1000 Response (Weak-CTL)



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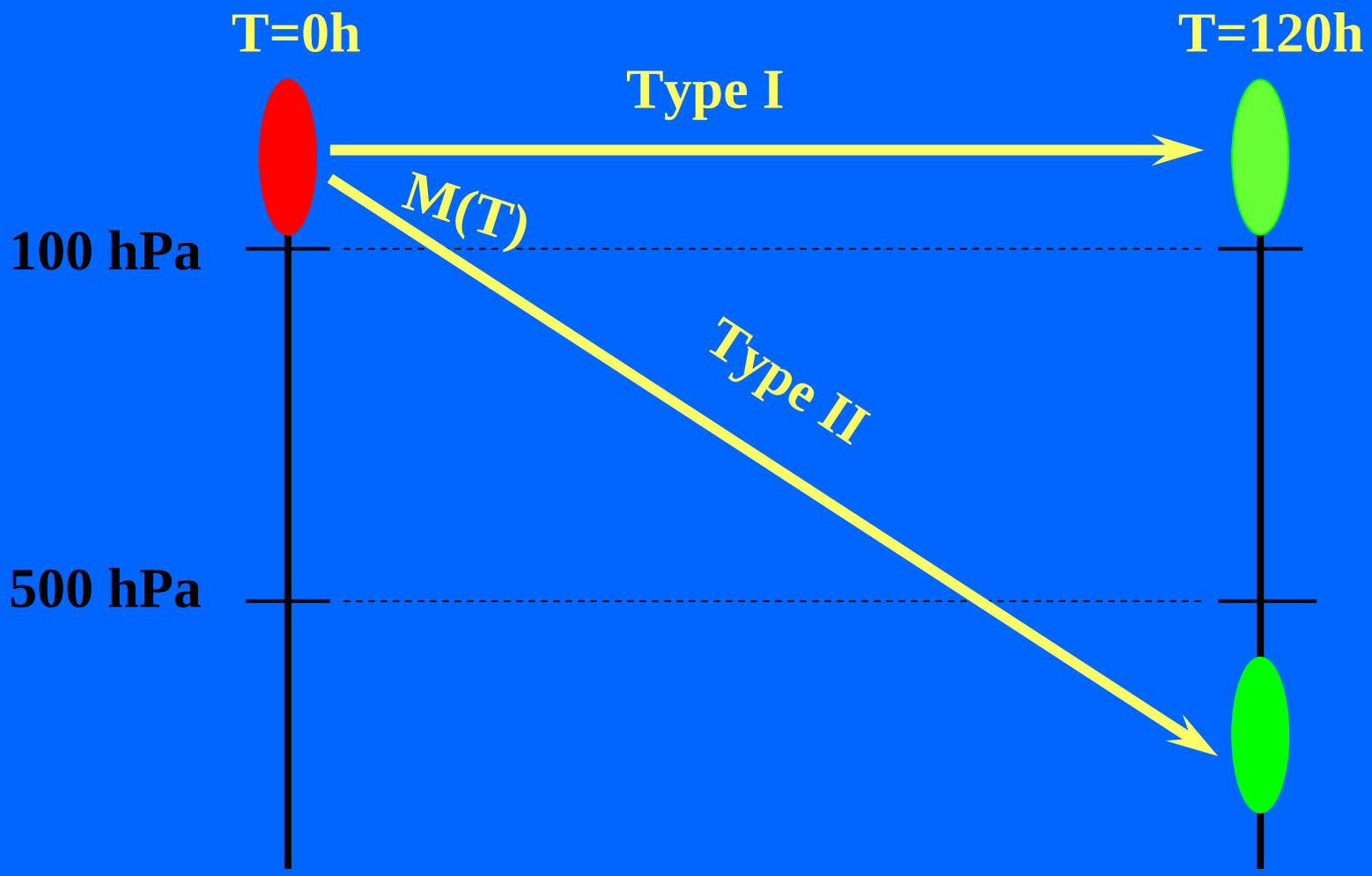
Analysis perturbations in the stratosphere



Why not use singular vectors ?

Evaluate an expression of the form:

$$\frac{< P_{evo} M(T) P_{ini} \varepsilon(0) \ , \ P_{evo} M(T) P_{ini} \varepsilon(0) >}{< P_{ini} \varepsilon(0) \ , \ P_{ini} \varepsilon(0) >}$$

Stratospheric SVs maximize this ratio and can be obtained by solving a standard eigenvalue problem

Experimental set-up

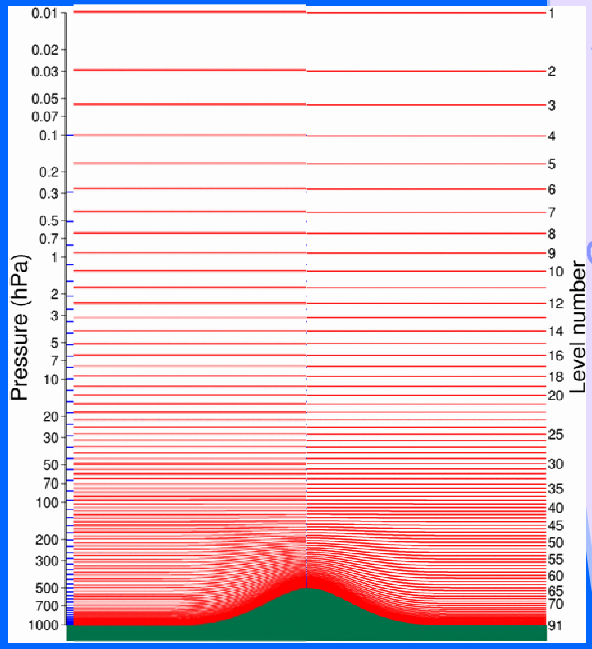
- 10 D+30 ensembles (50 members) during 22 Dec. 2005 -23 Feb. 2006 with a recent version of the ECMWF model (cy32r2)

VARIOUS FLAVOURS:

- T159L62 operational setting
- T159L62 operational with S-SVs added

- T159L91 operational setting
- T159L91 operational with S-SVs added
- T159L91, **only** S-SVs
- T159L91, **only** ST-SVs

L91



- Compared to L91, the vertical resolution of the L62 model is coarser above 150 hPa: 15 (45) levels up to 5 (0.01) hPa.

- Occurrence of a Stratospheric Sudden Warming during 23-27 January 2006.

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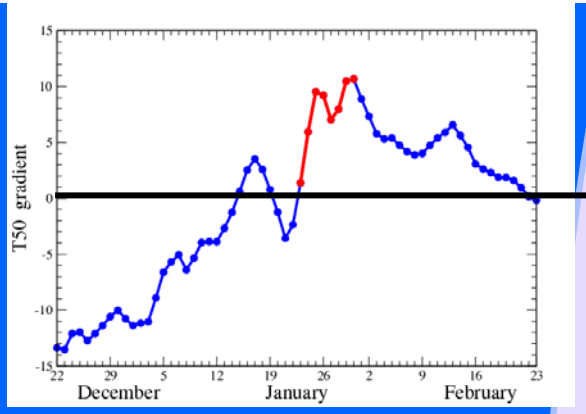
SSW during January 2006

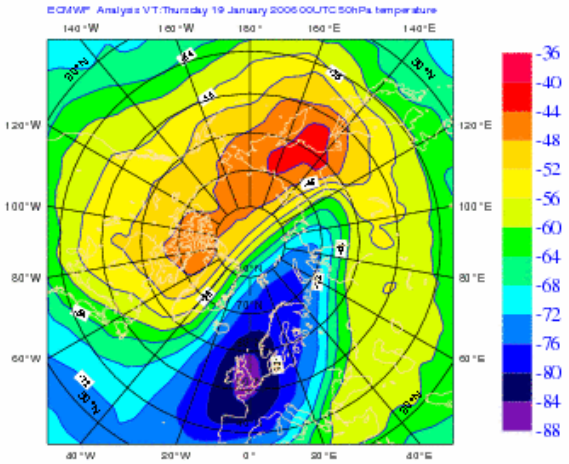
Presented by the 50 hPa temperature difference between 85º- 90º N and 55º- 60º N

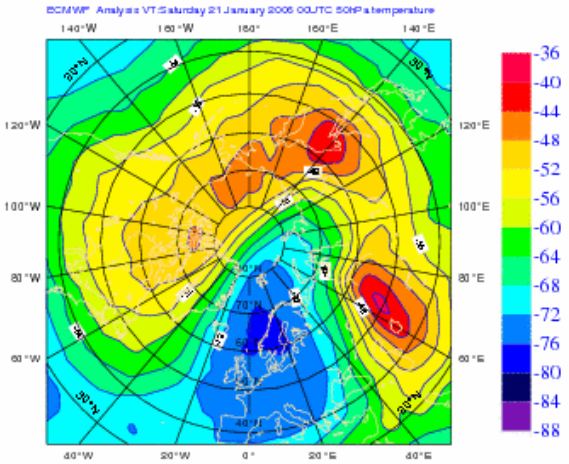


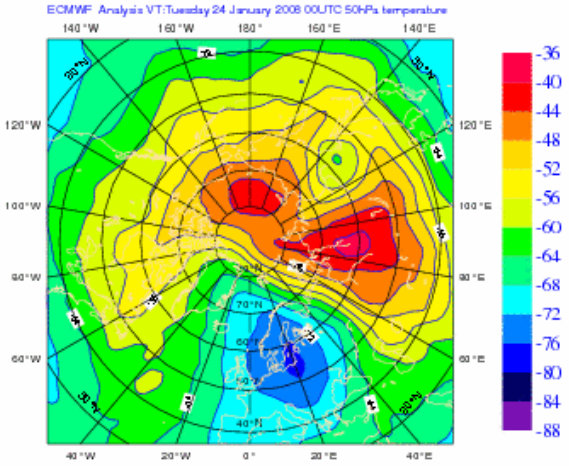
T50

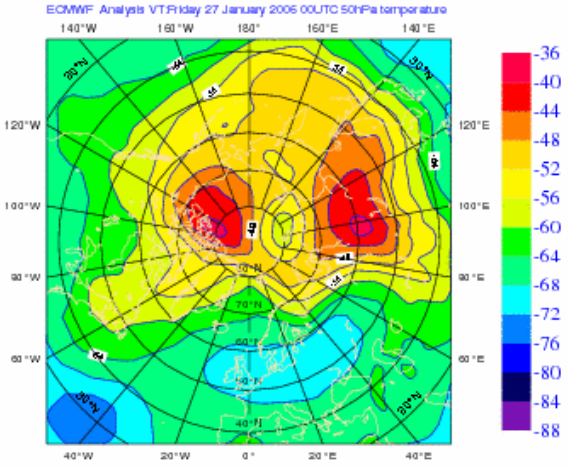
19 21

24 27

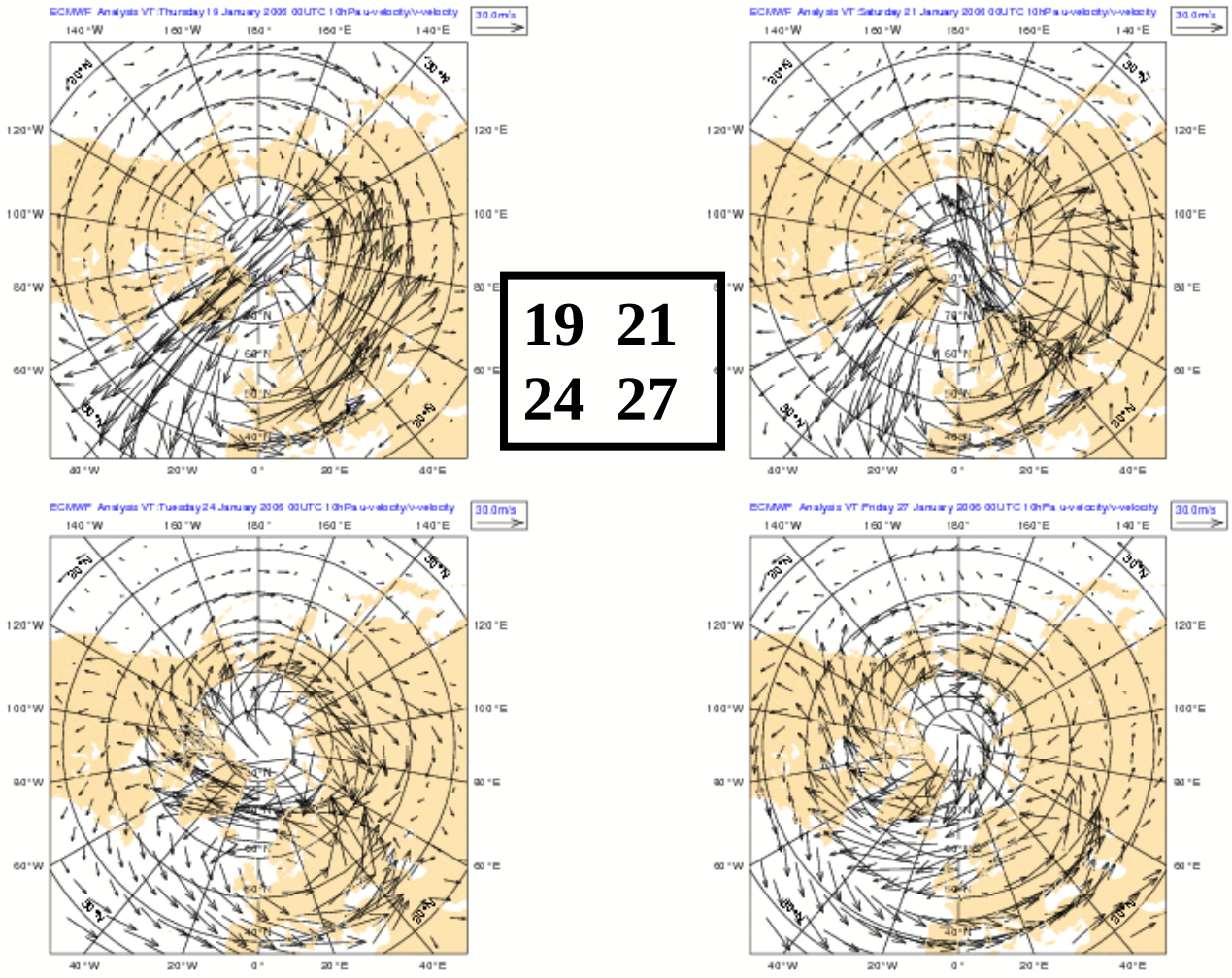








Wind field at 30 hPa



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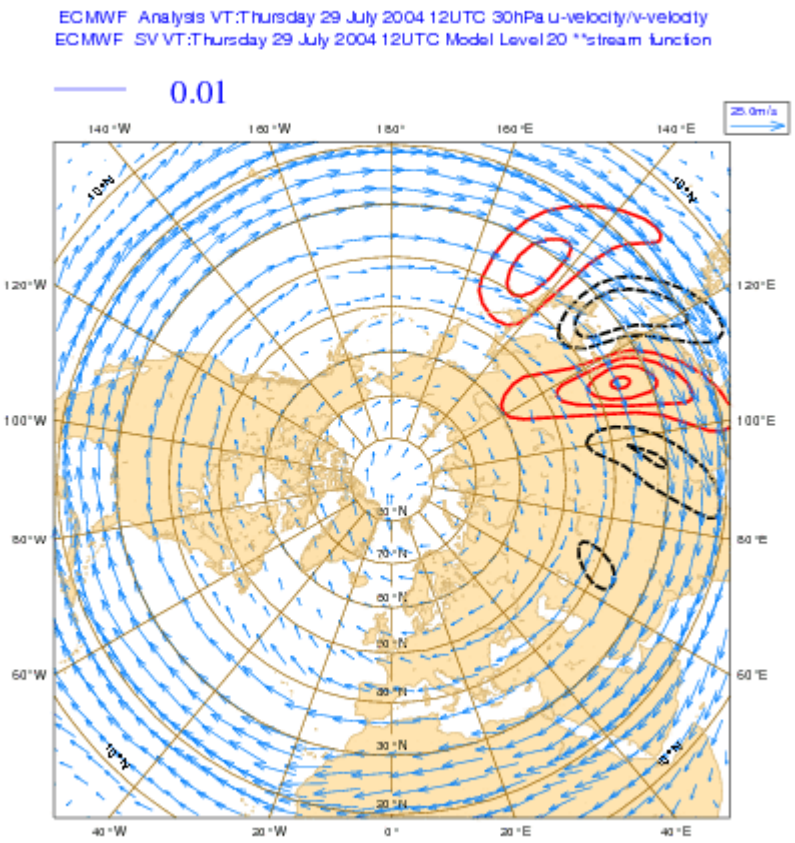
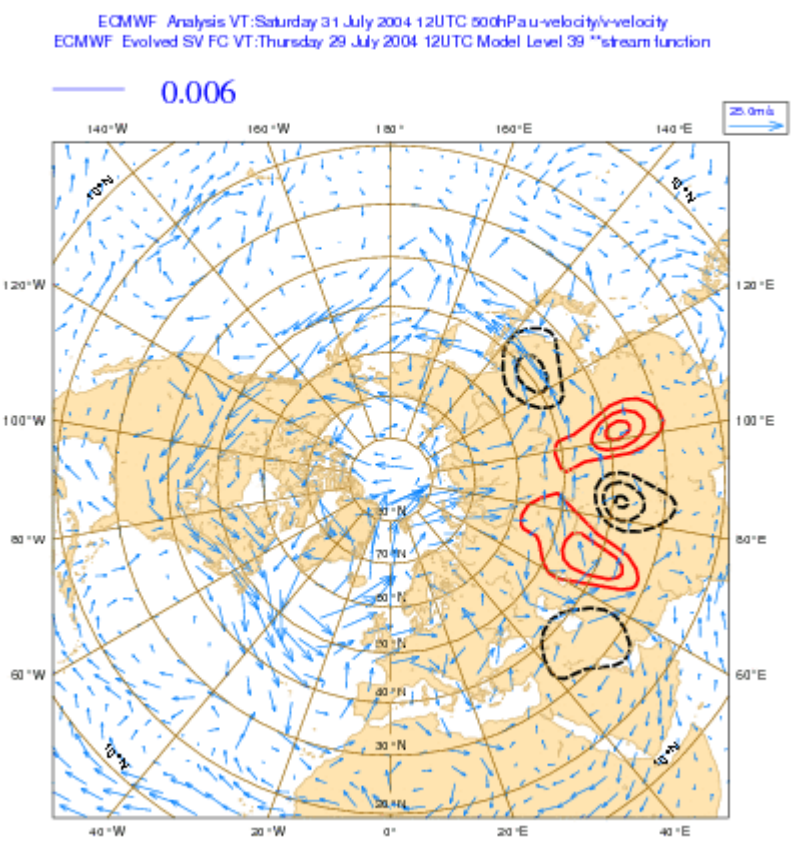
Example of an ST-SV for a summer case

t=0h at 35 hPa **t=48 h at 500 hPa**





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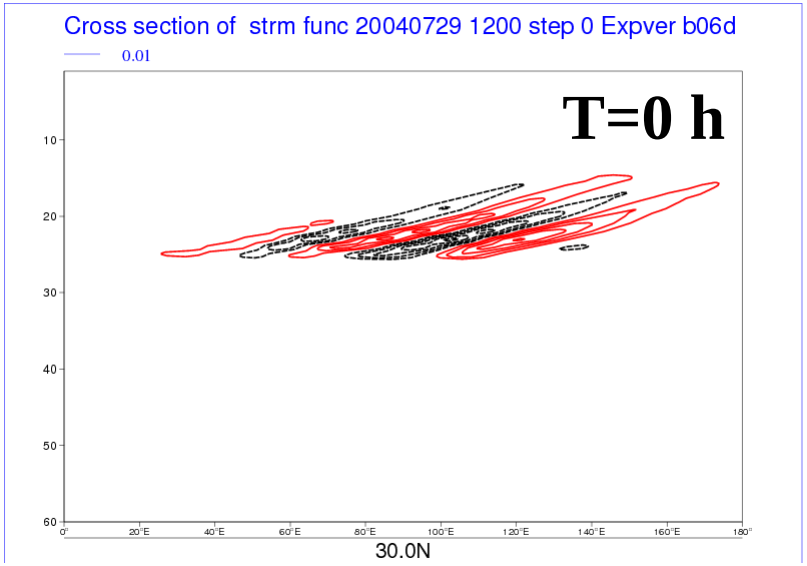
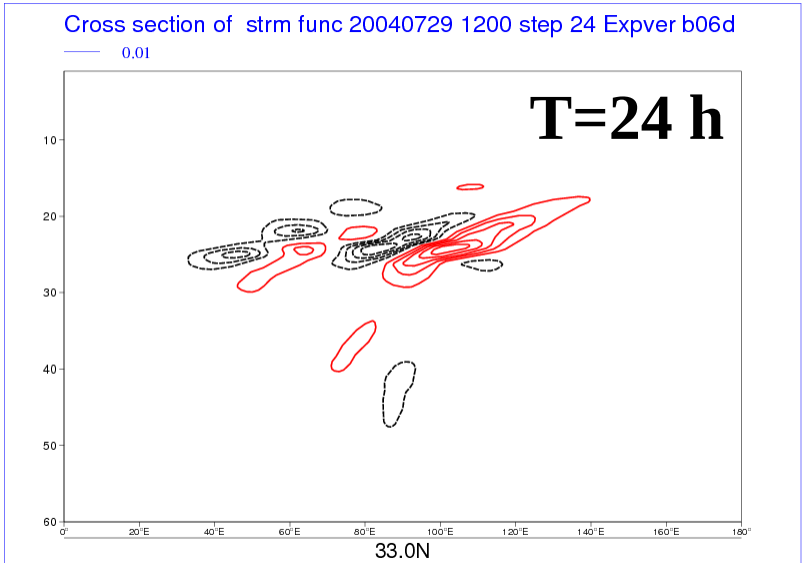
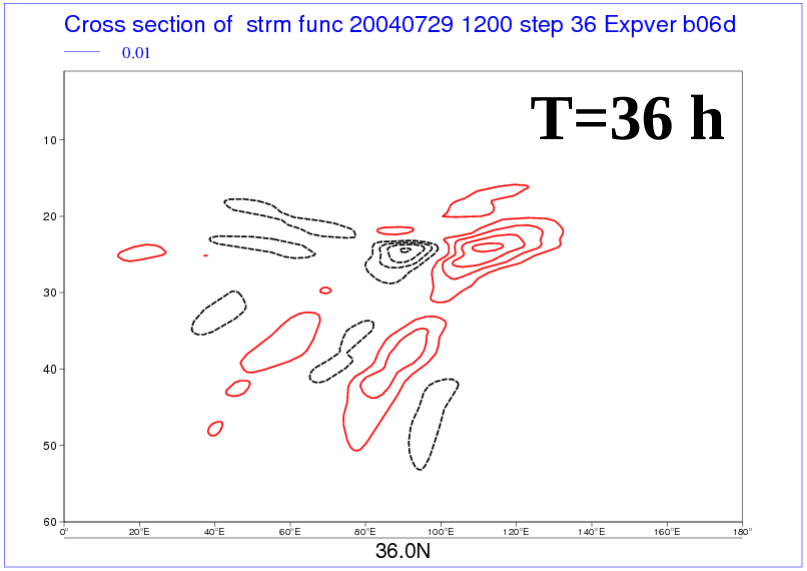
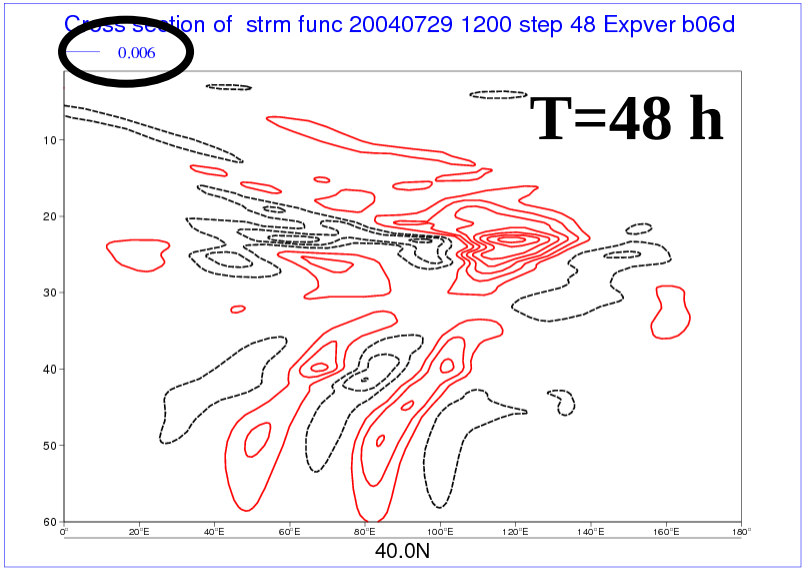

Cross section of strm func 20040729 1200 step 0 Expver b06d
0.01
T=0 h
30.0N

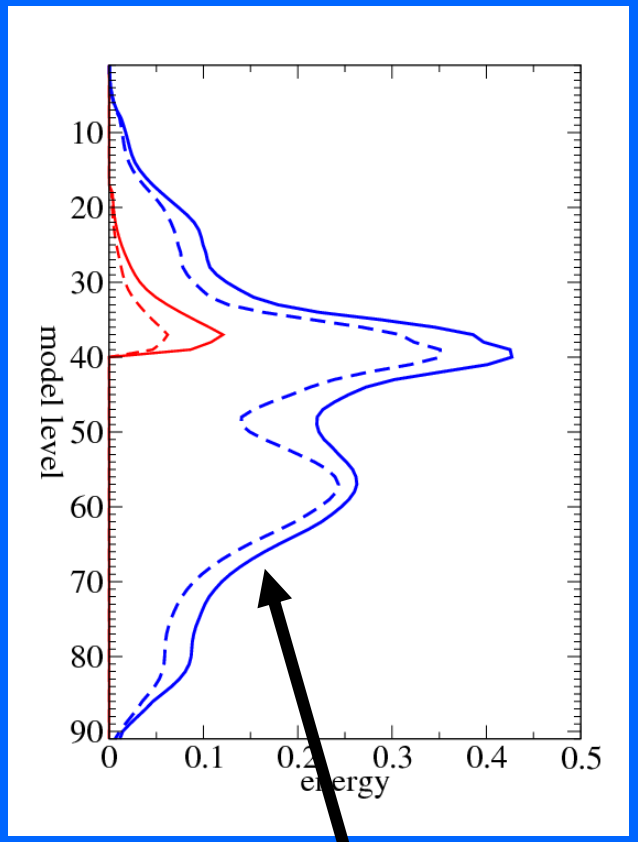

Cross section of strm func 20040729 1200 step 24 Expver b06d
0.01
T=24 h
33.0N


Cross section of strm func 20040729 1200 step 36 Expver b06d
0.01
T=36 h
36.0N


Cross section of strm func 20040729 1200 step 48 Expver b06d
0.006
T=48 h
40.0N

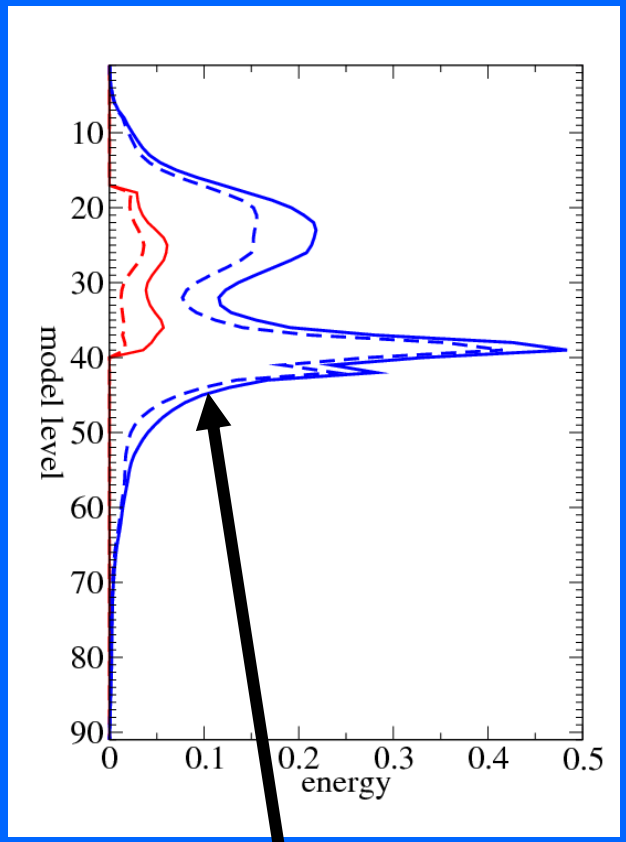
Vertical energy distribution of stratospheric SVs

ST-SV



* 0.2

S-SV



* 0.05

total t=0h
kinetic t=0h

total t=120h
kinetic t=120h

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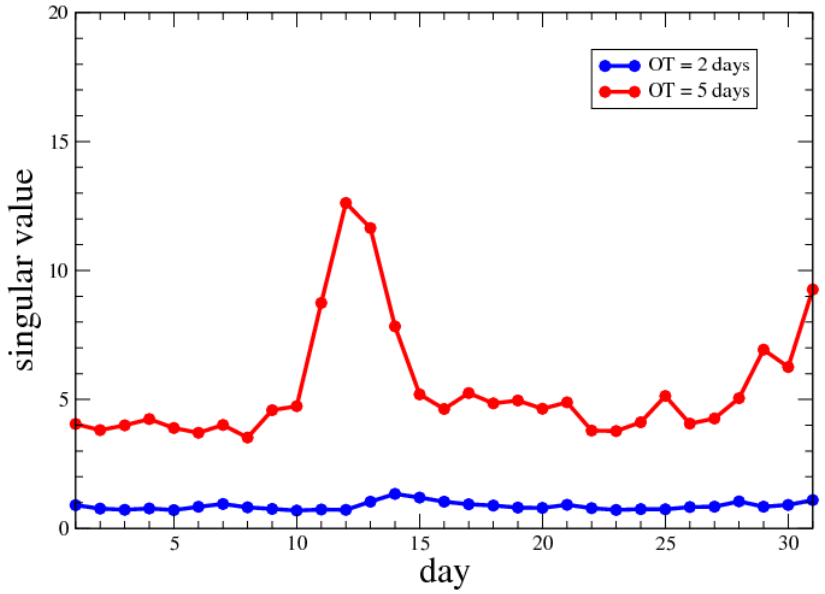
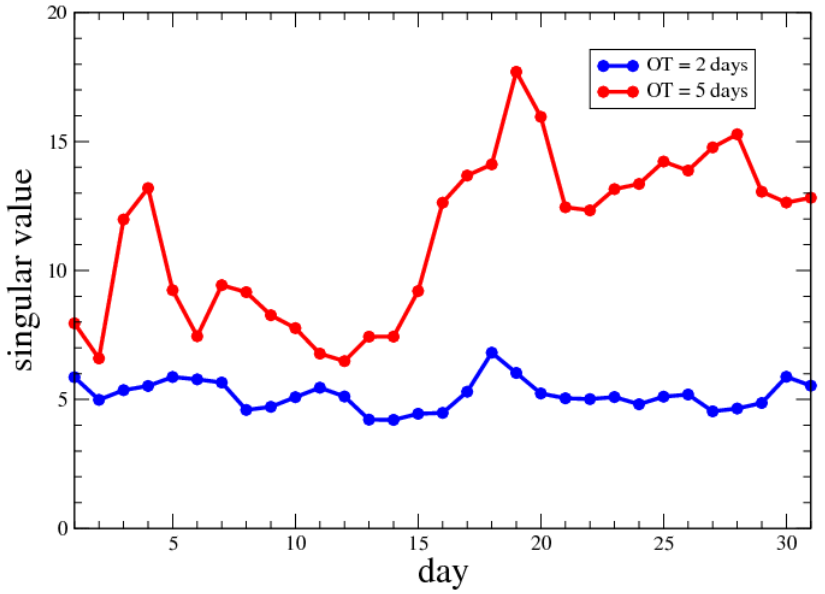
Amplification of stratospheric SVs

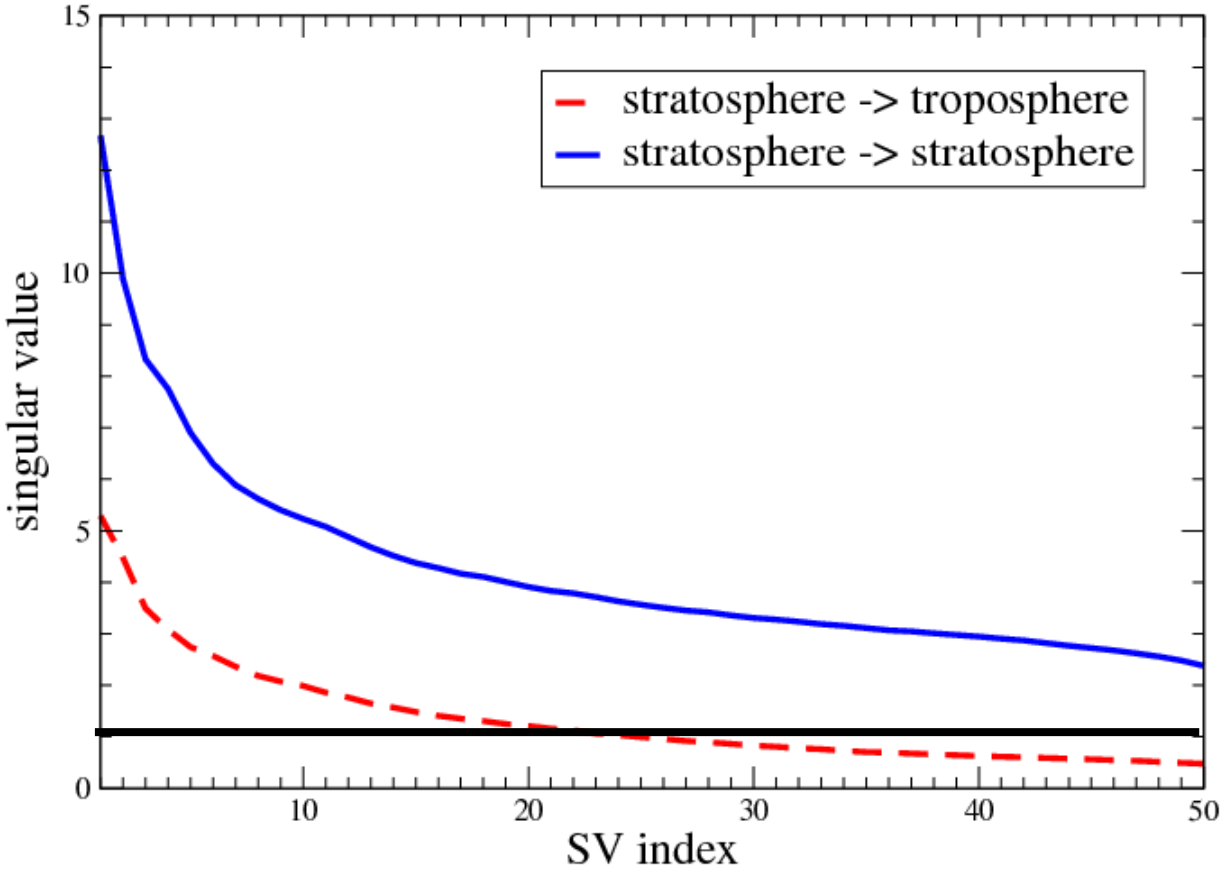
ST-SVs



S-SVs

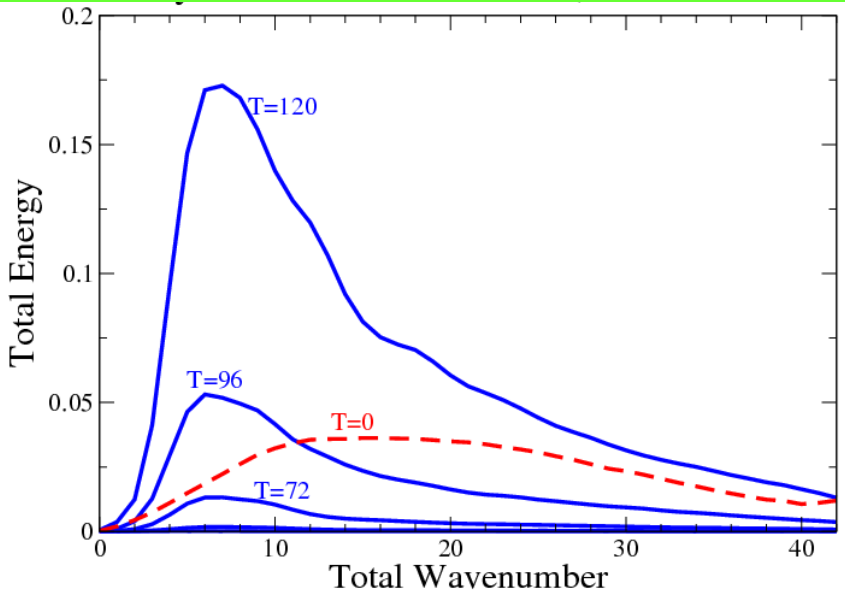


Averaged eigenvalue spectrum (OT=5d)

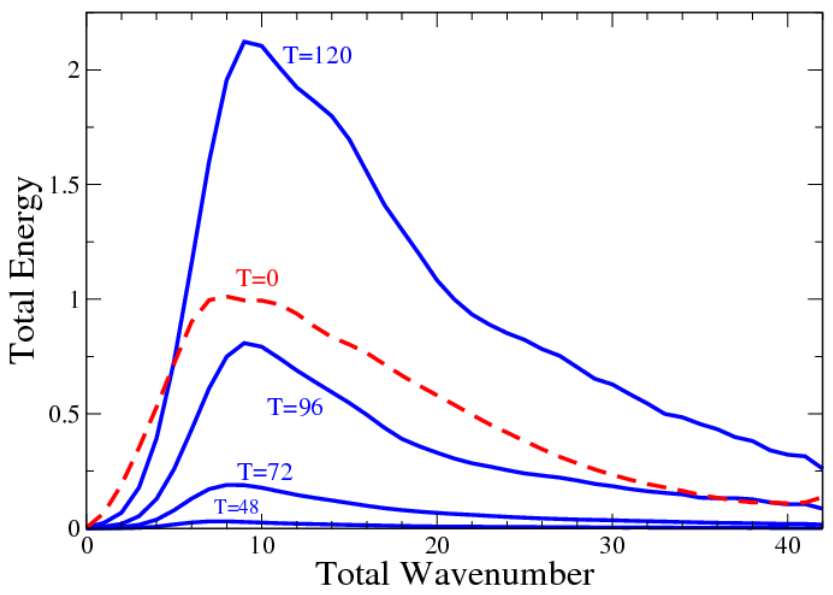


Evolution of total energy for S-SVs and ST-SVs and measured below 500 hPa (blue lines).

S-SVs

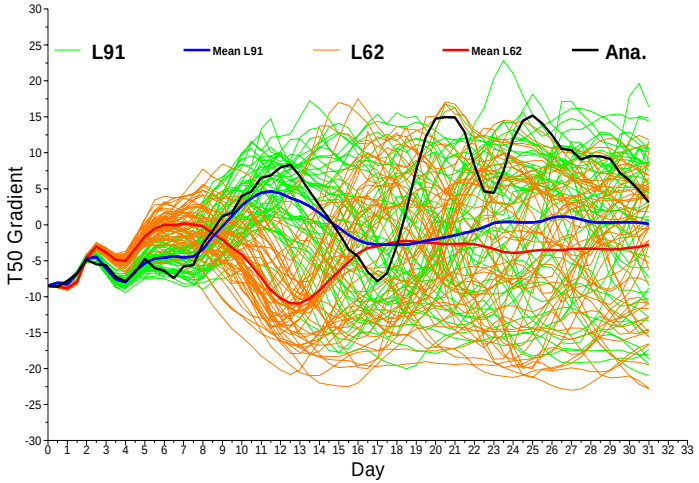


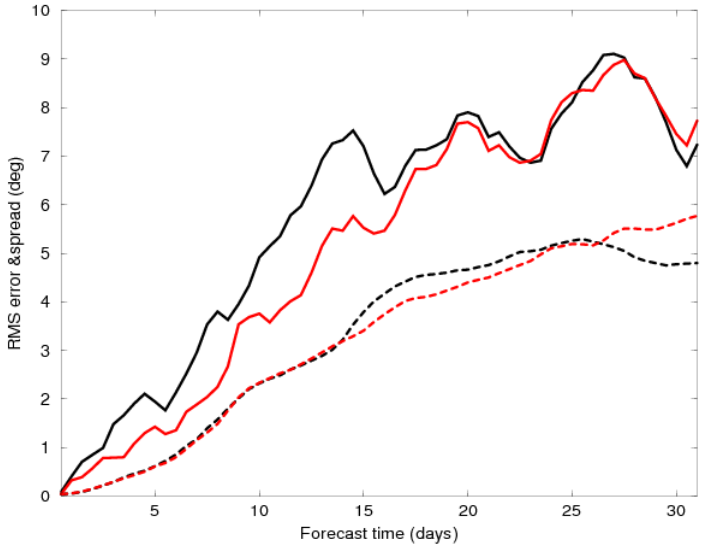
ST-SVs



Impact of vertical resolution

Forecast starting on 5/1/06





L91 **L62**

RMS error L62
RMS error L91
Spread L62
Spread L91

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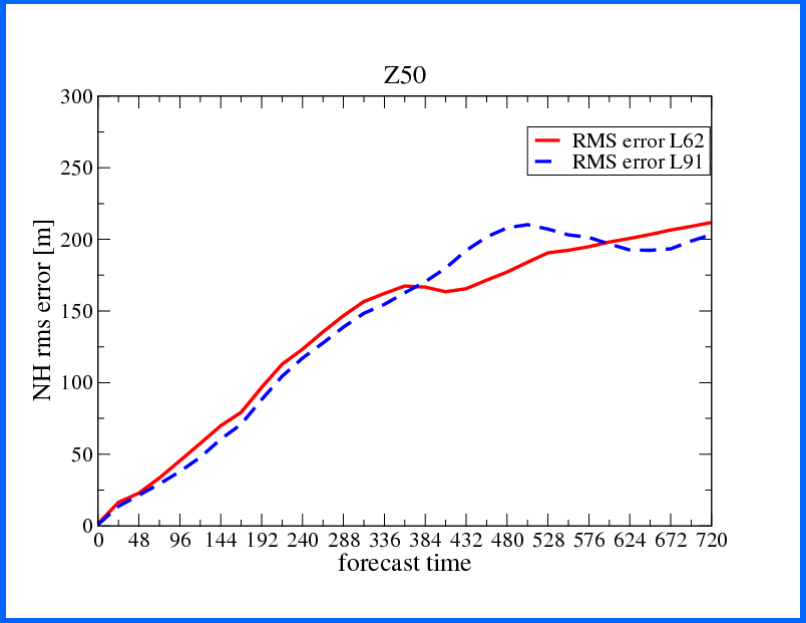
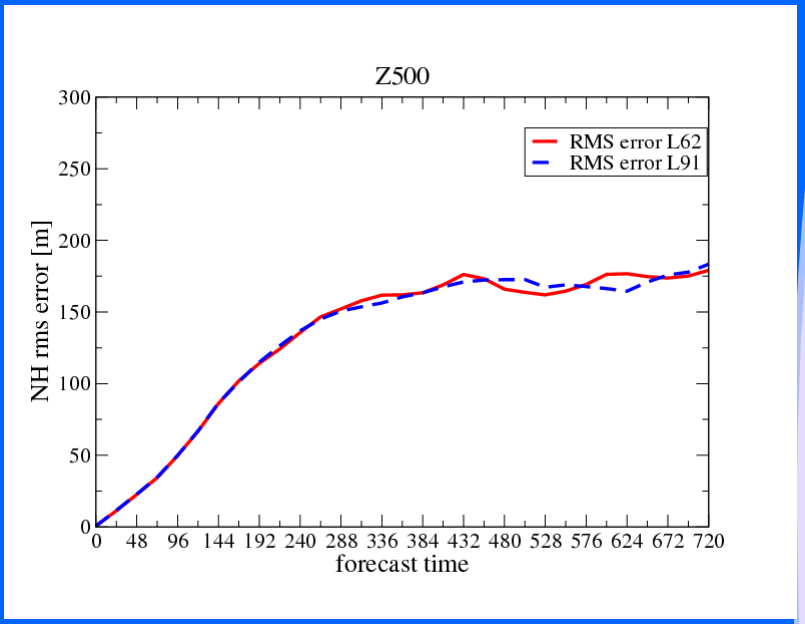
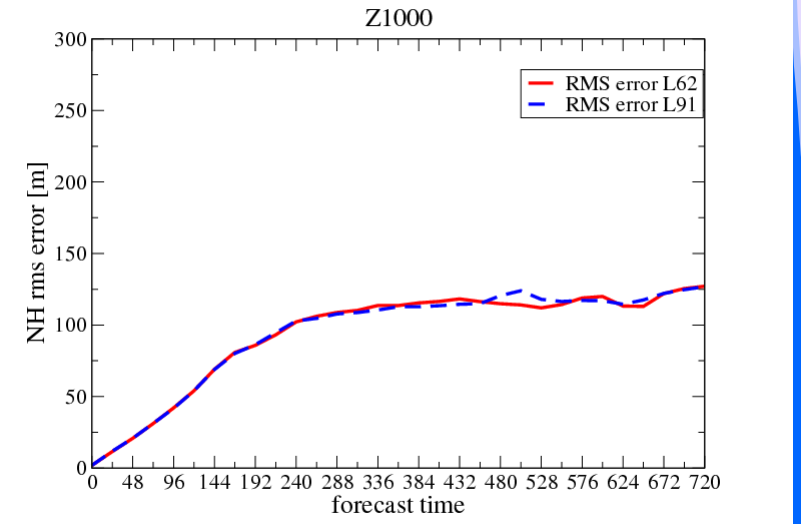
RMS error of the unperturbed T159 forecast







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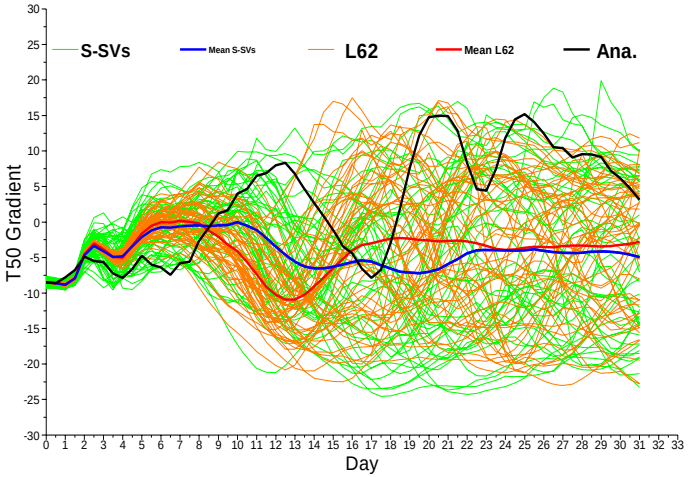
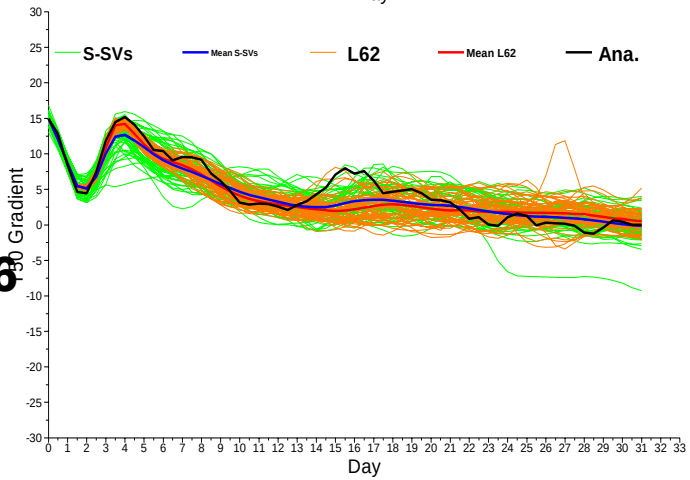
Impact of S-SVs

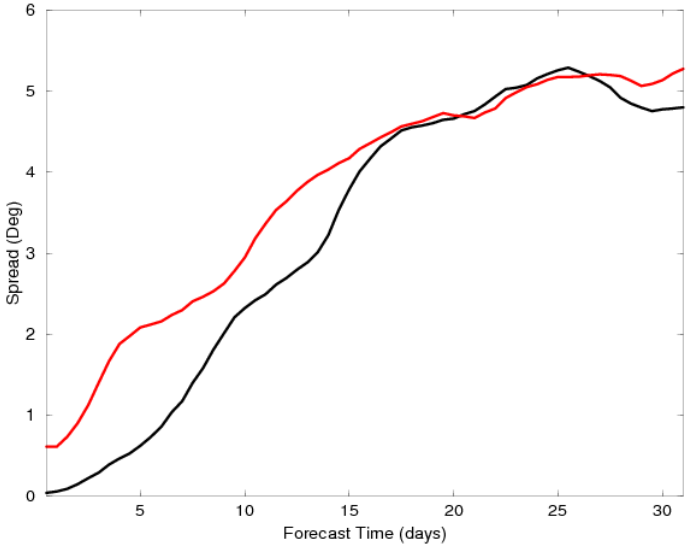
Forecast 5/01/06



Forecast 26/01/06



Ensemble spread



OPS

OPS + (S-SV)

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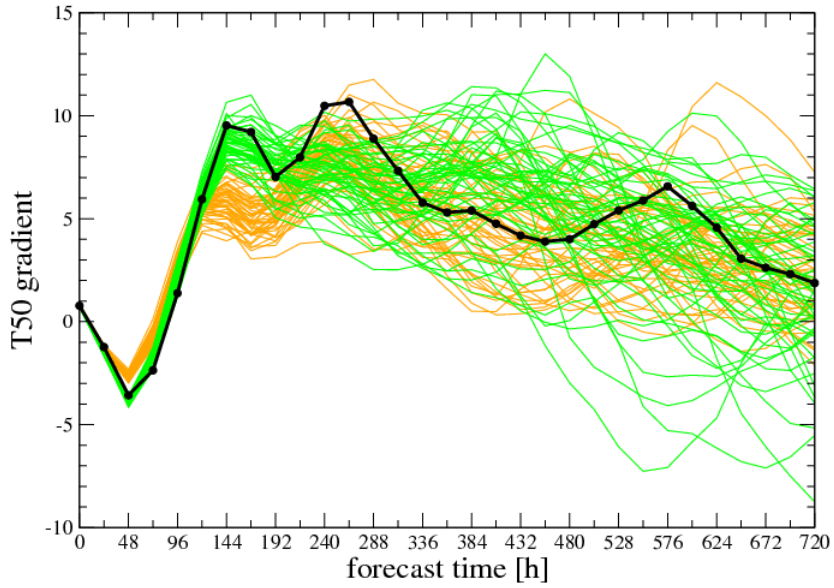
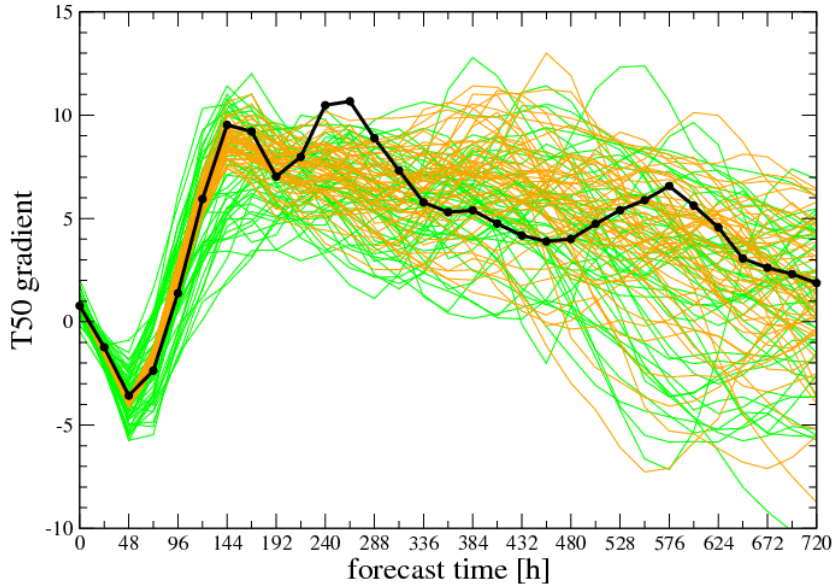
Ensembles + Stratospheric Sudden Warming



L62 OPS

L91 OPS

analysis



L91 OPS

L91 OPS + (S-SV)

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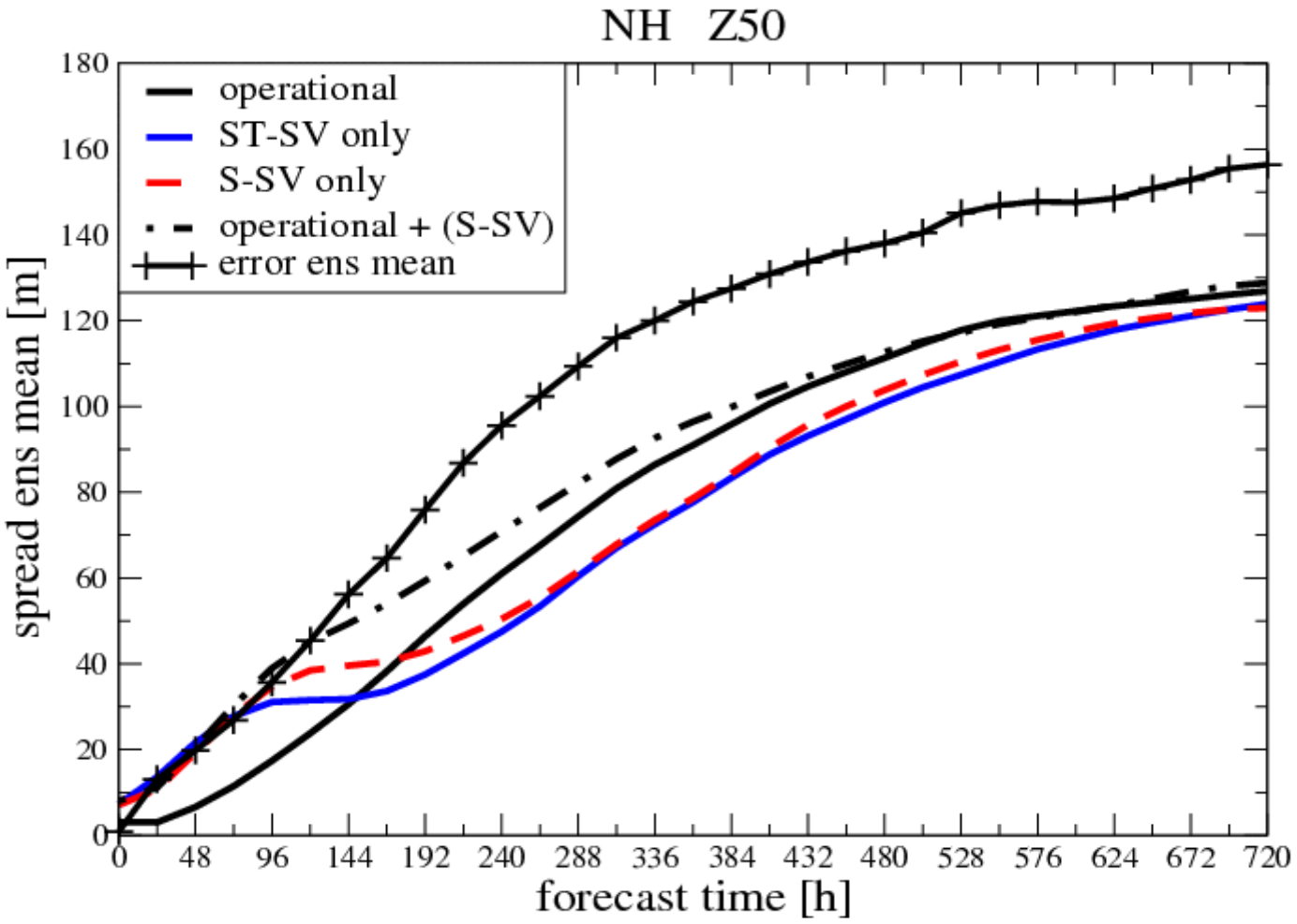
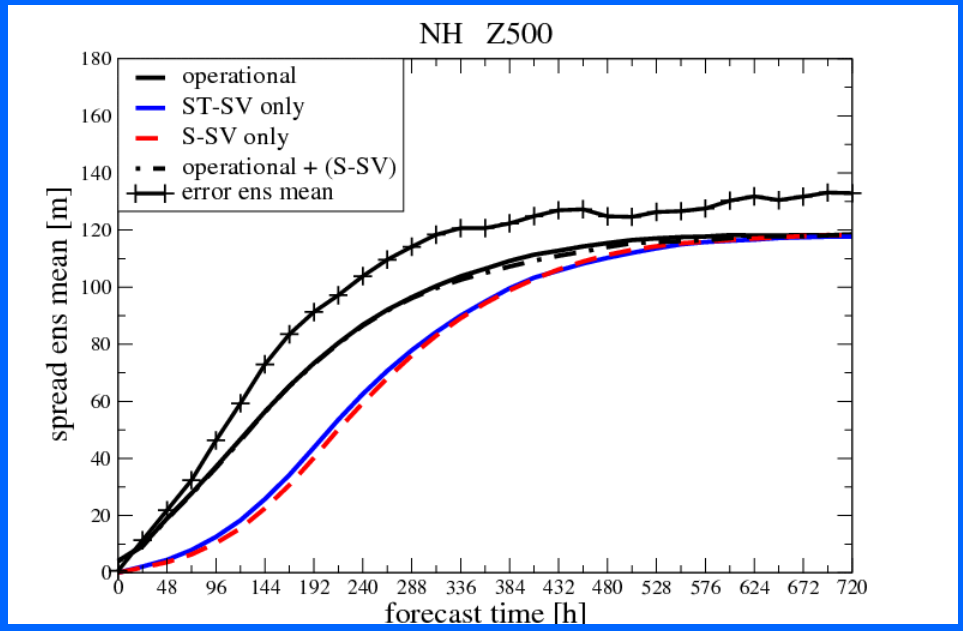
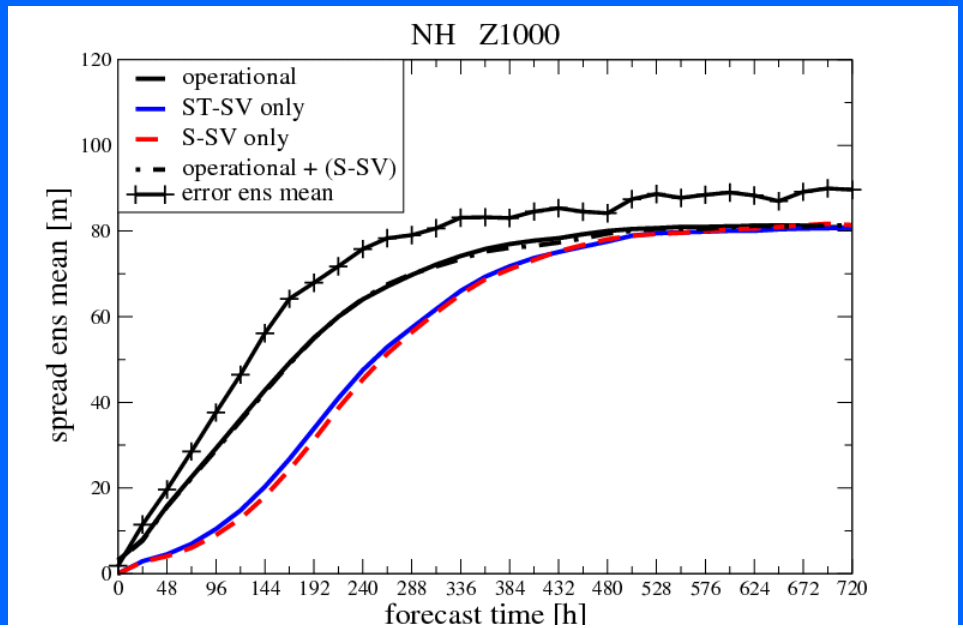
OPS < ST-SV < S-SV < OPS + (S-SV)



S-SV < ST-SV < OPS = OPS + (S-SV)





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Z500 spread around ensemble mean (10 cases)

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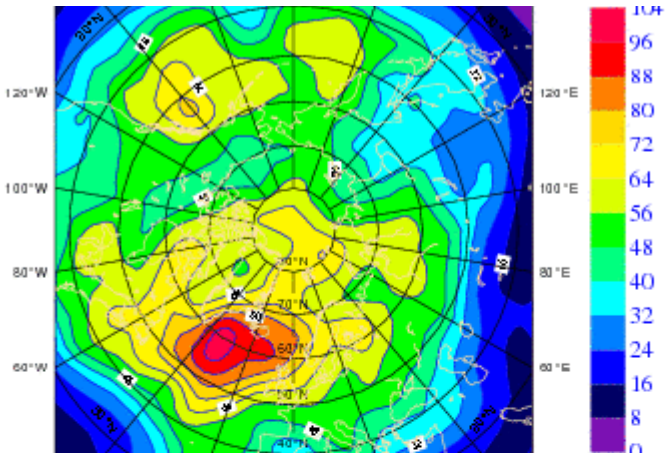
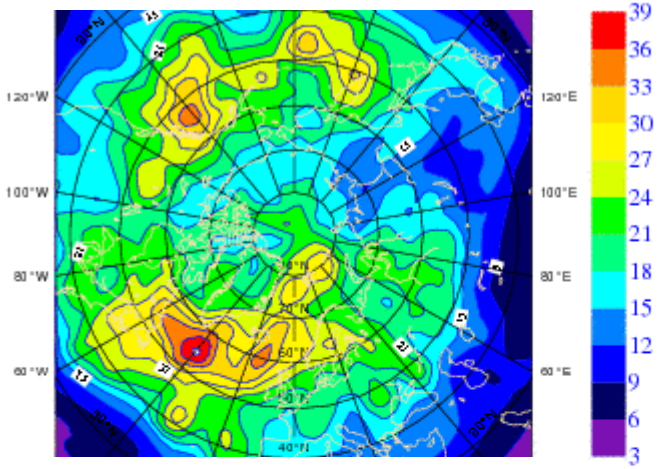
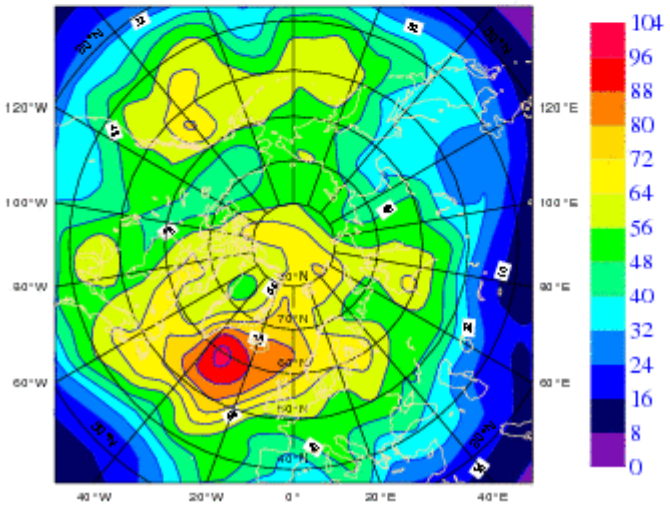
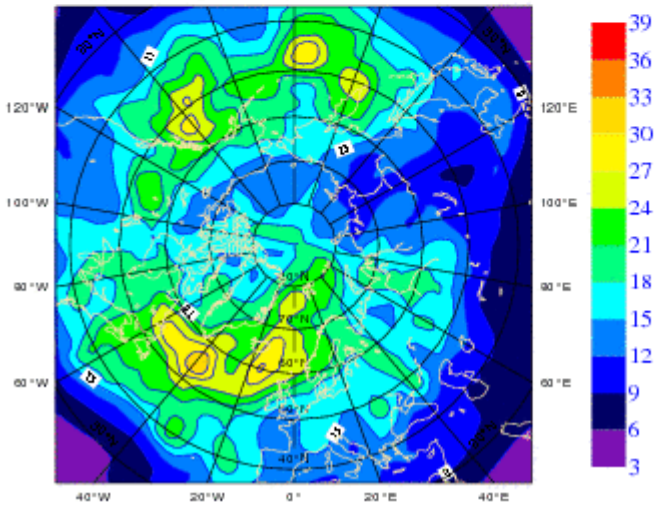
OPS **day 5** **ST-SV**





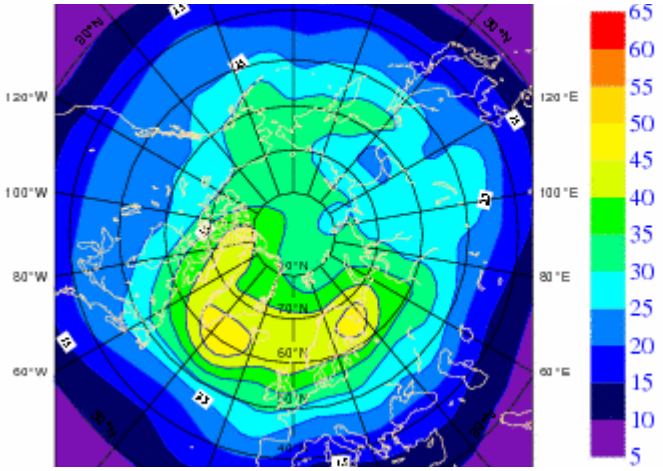
OPS+(S-SV) **S-SV**

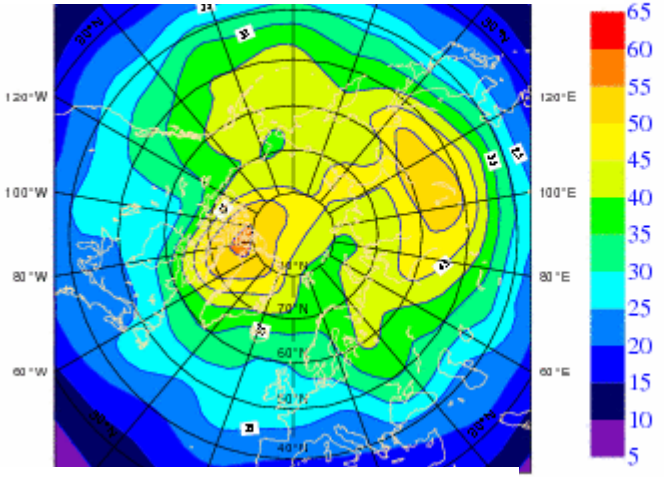




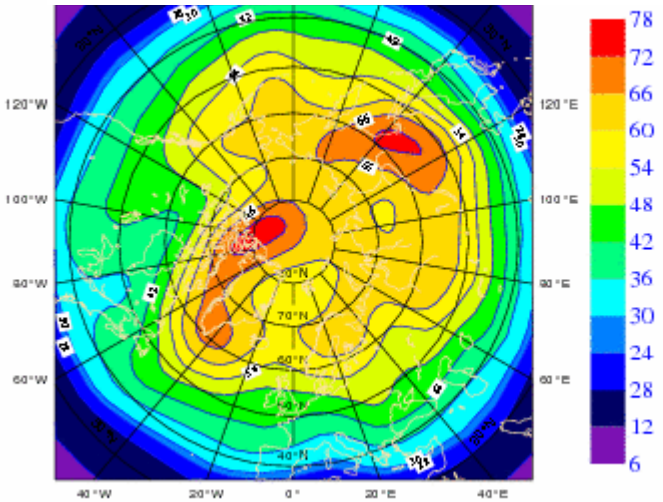
Z50 spread around ensemble mean (10 cases)

OPS **day 5** **ST-SV**

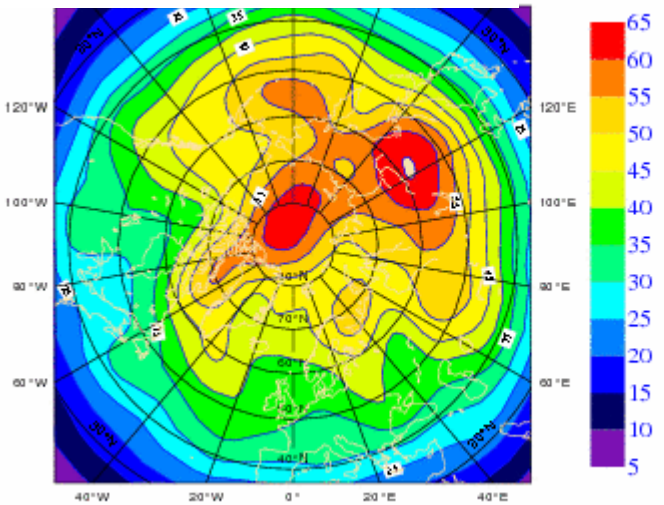




OPS+(S-SV)



S-SV



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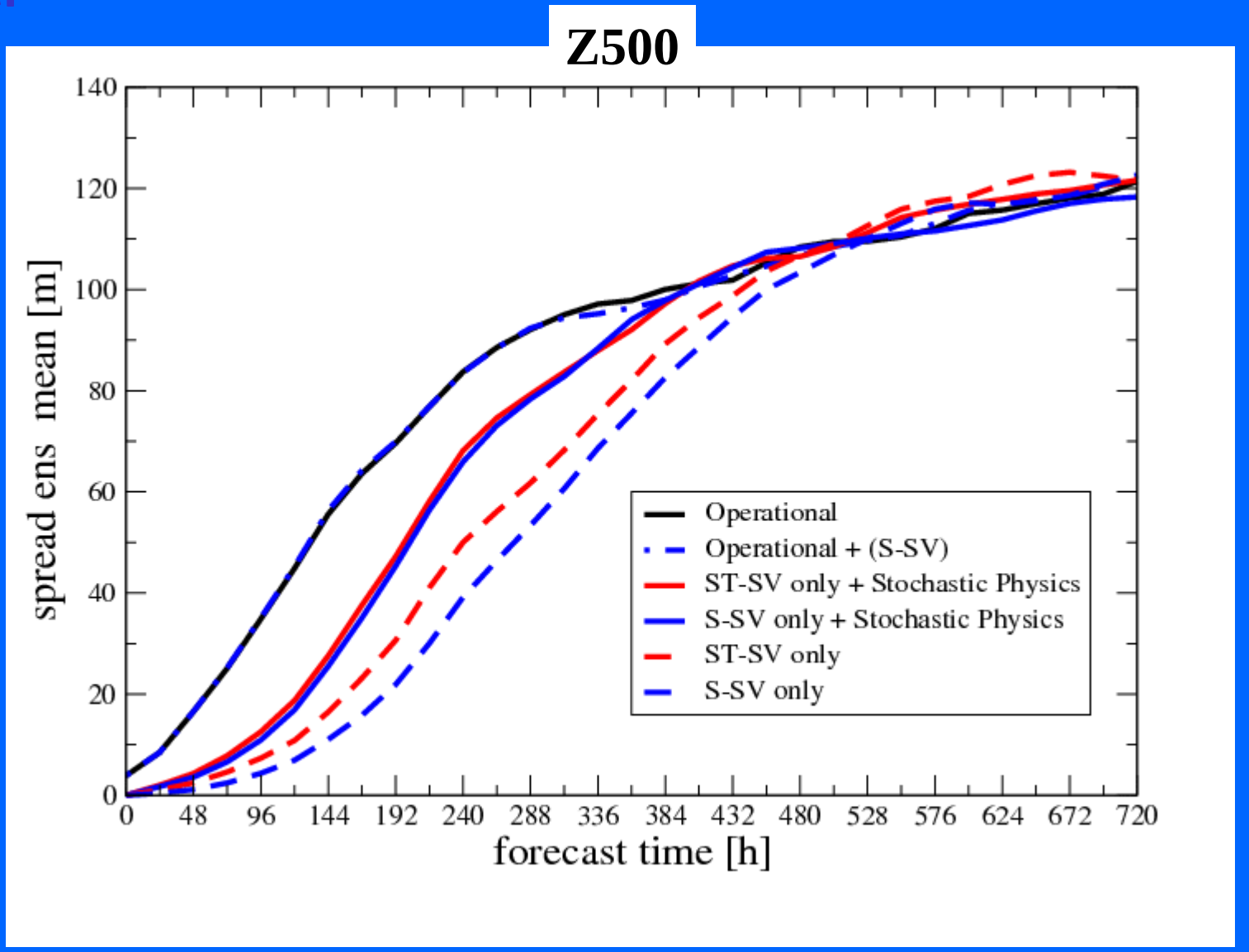
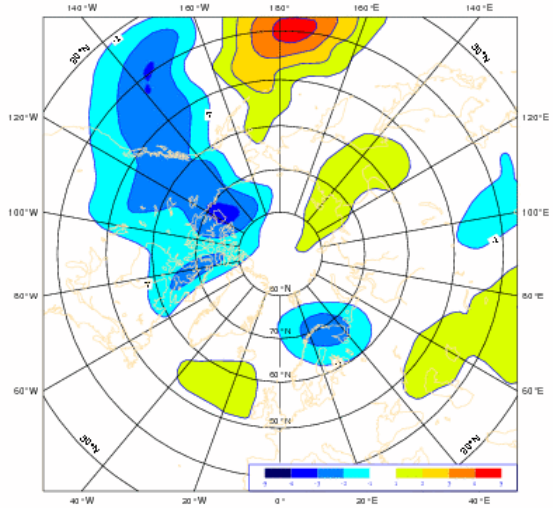
Analysis perturbations vs. stochastic physics

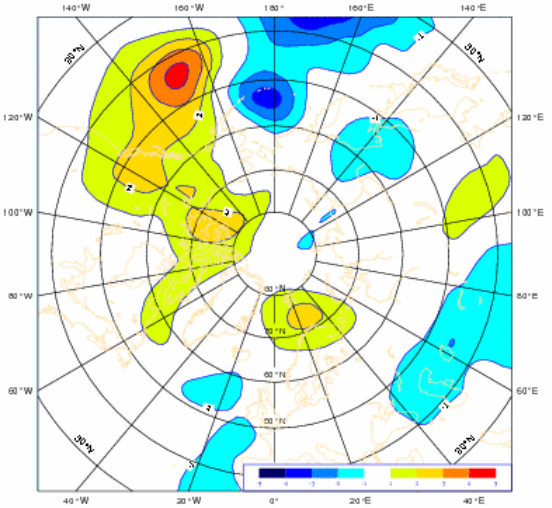


Linearity check of ST-SV ensemble (t = 5d)

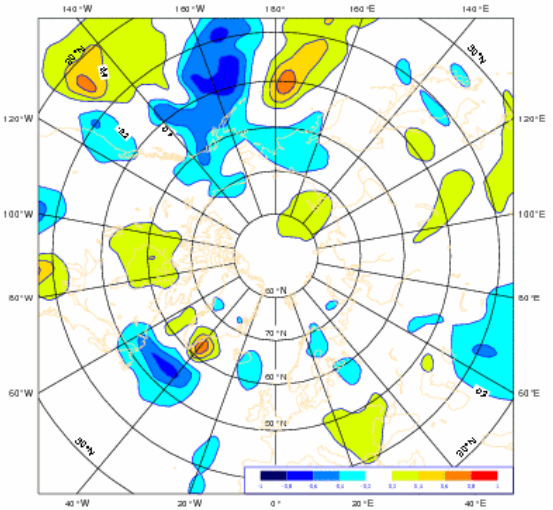
‘+’ runs-control

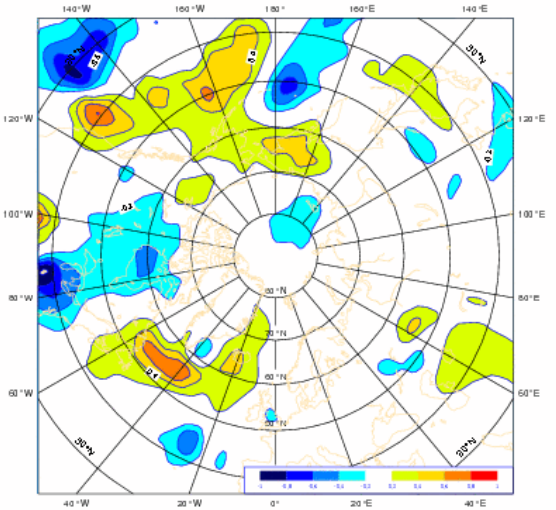


‘-’ runs-control



Z50 (c.i.= 1 m)





Z500 (c.i.= 0.3 m)

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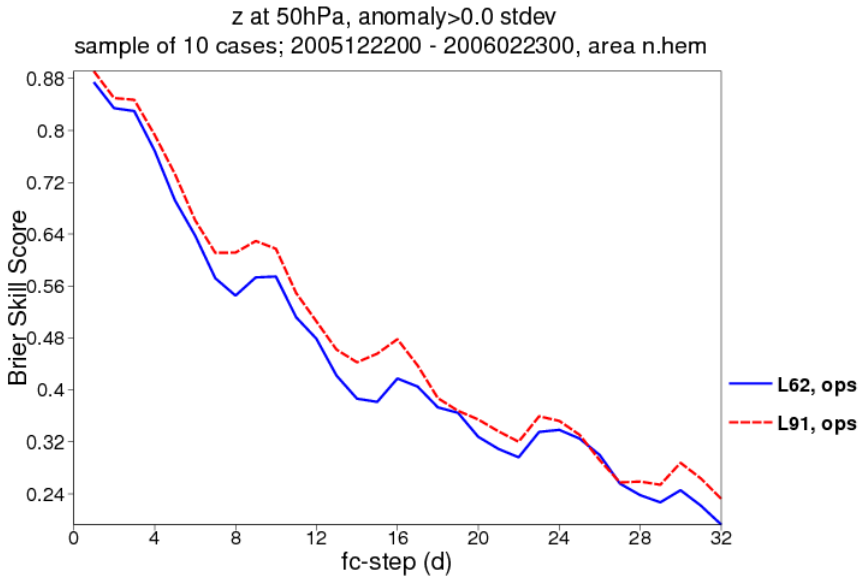
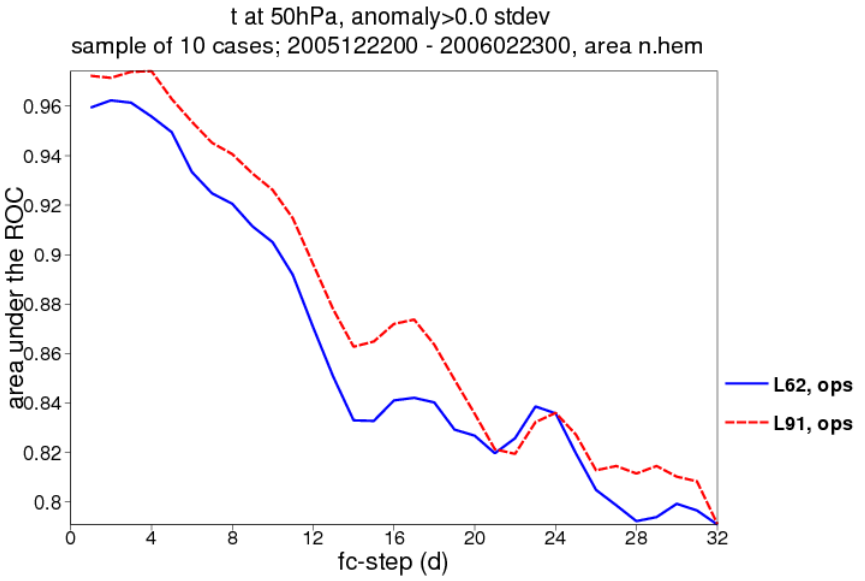
L91 > L62

Z50

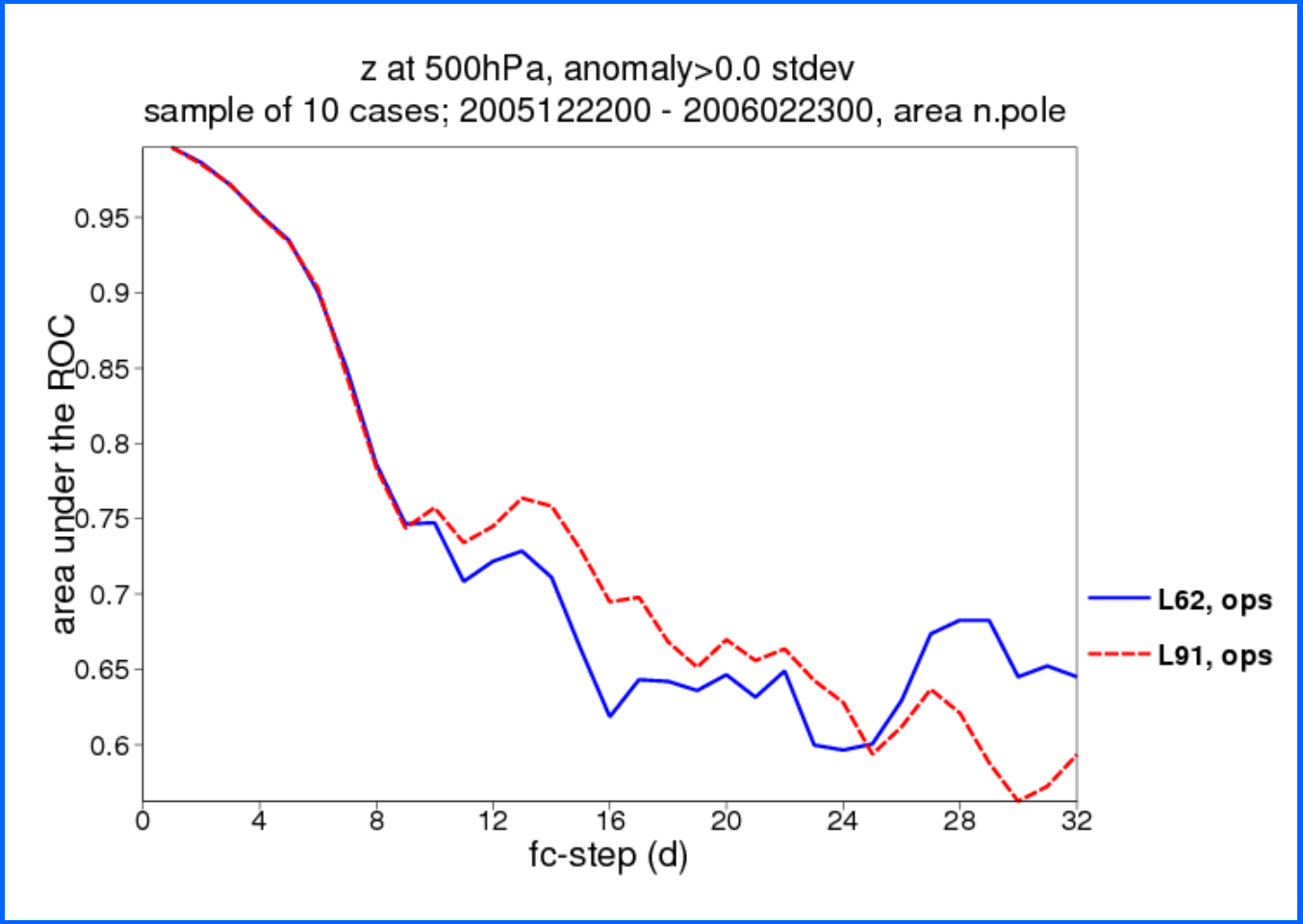


T50



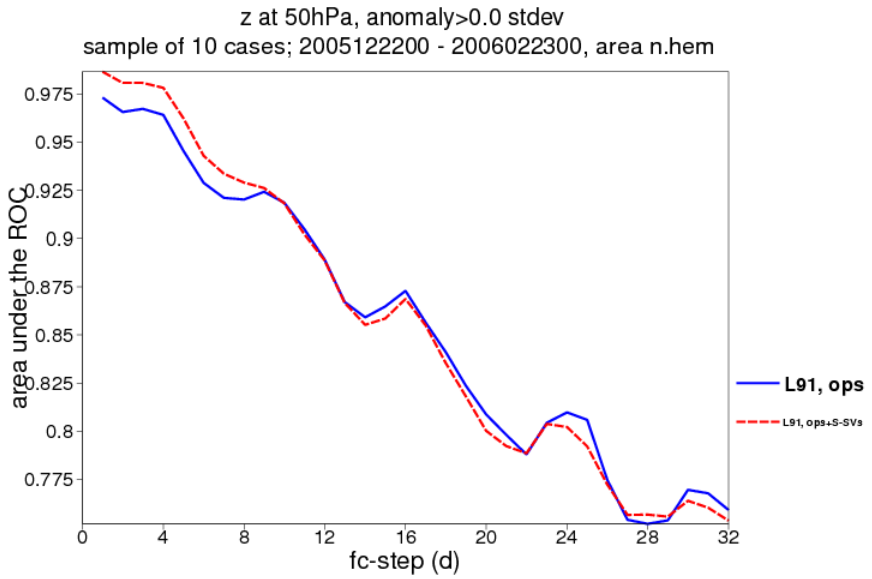
L91 vs. L62 (2)

Neutral tropospheric impact, apart from the 65^0-90^0 area:

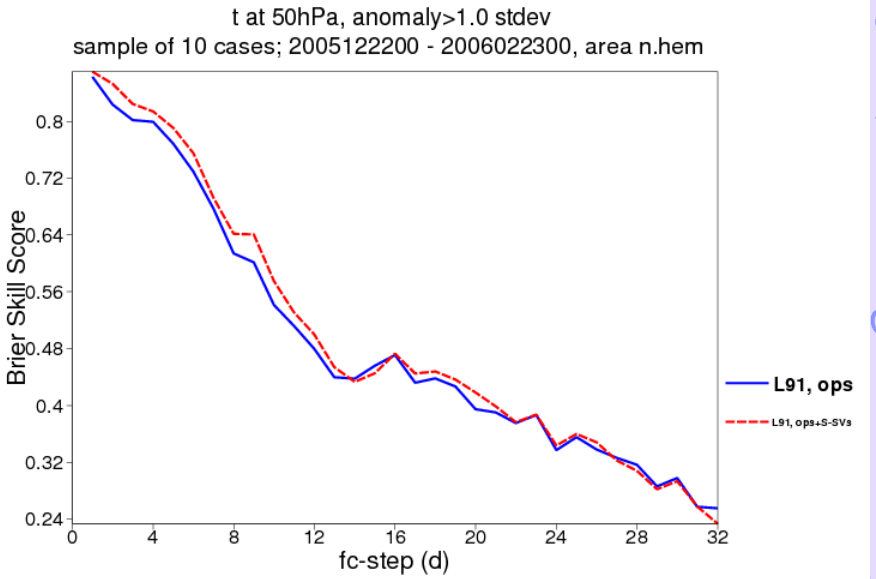


L91 vs. L91 + (S-SV)

Z50



T50



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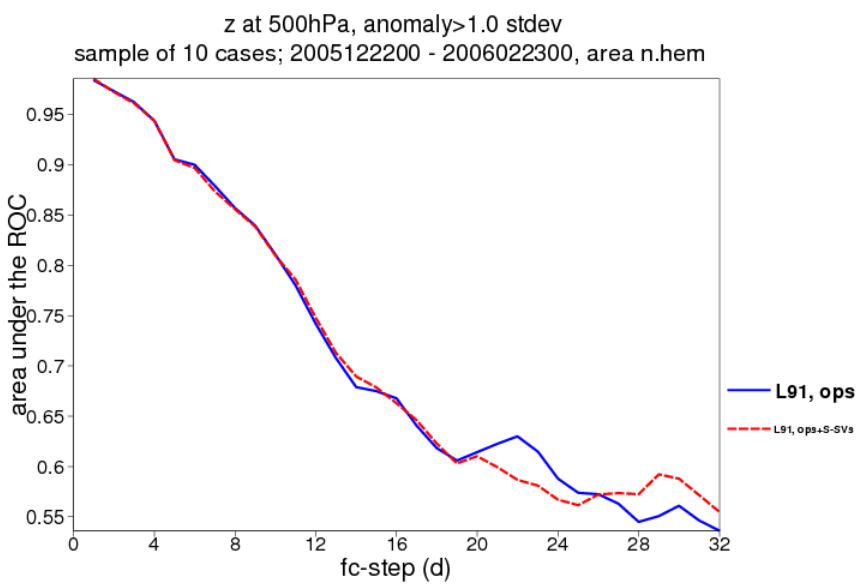
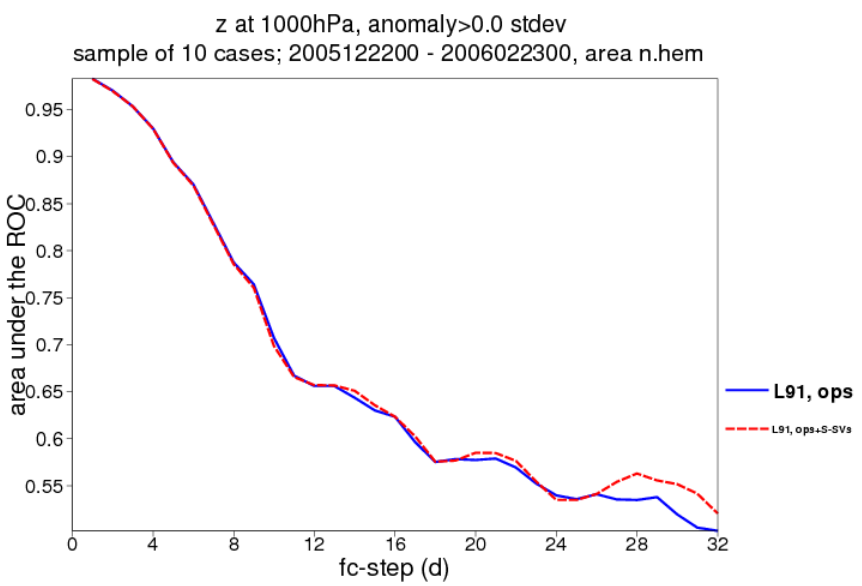
L91 vs. L91 + (S-SV)

Z500



Z1000



Conclusions

- Adjoint techniques are useful in exploring stratosphere-troposphere interaction.

  - amplification for ST-SVs also during summer

- Increase of vertical resolution (L91 vs. L62) improves ensemble performance in the stratosphere.

- Using stratospheric analysis perturbations results in

  - better ensemble performance in the stratosphere;
  - substantial ensemble spread in the troposphere.

  (ST-SV only experiment)

- Combining stratospheric and tropospheric analysis perturbations does not simply produce more ensemble spread in the troposphere.