Diagnostic of an anisotropic background error correlation function using an Ensemble method

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Outlook

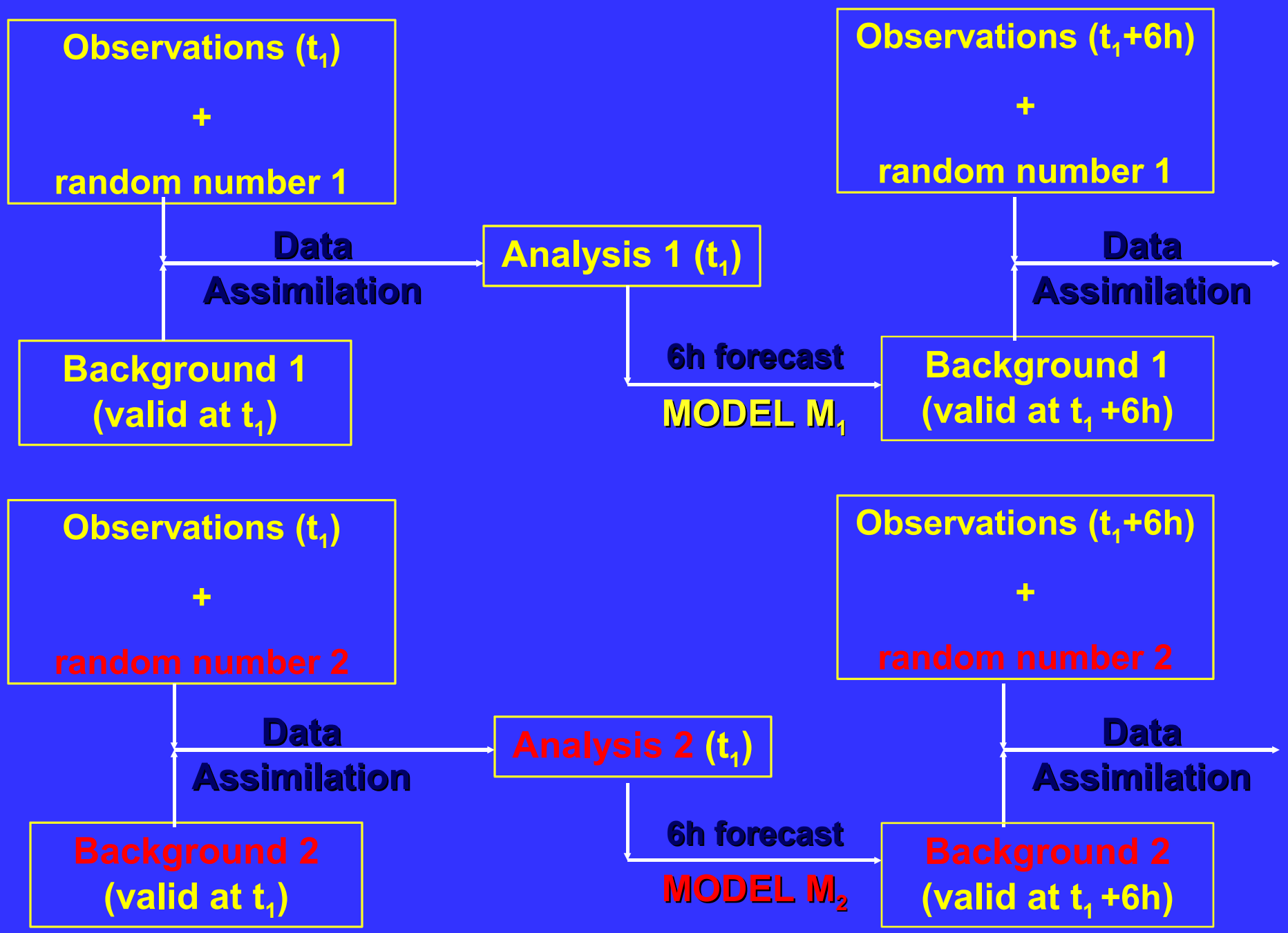
- Introduction
- Ensemble method
- Diagnostic of the correlation function in a perfect model framework
- The importance of model error

Introduction

- The analysis field results from a combination of observations and background (short range forecast)
- The weights given to the observations and to the background depend on error statistics
- The background errors statistics determines the way as the information from observations is spread spatially
- How to estimate the background error statistics?

Analysis ensemble method

Imagine an ensemble with 2 members


Observations (t_1)
+
random number 1
Data Assimilation
Analysis 1 (t_1)
Observations (t_1+6h)
+
random number 1
Data Assimilation
Background 1 (valid at t_1)
6h forecast
MODEL M_1
Background 1 (valid at t_1 +6h)
Observations (t_1)
+
random number 2
Data Assimilation
Analysis 2 (t_1)
Observations (t_1+6h)
+
random number 2
Data Assimilation
Background 2 (valid at t_1)
6h forecast
MODEL M_2
Background 2 (valid at t_1 +6h)

Ensemble experiments

Perfect model approach:

it is assumed that the model error does not contribute to the background error,

in other words,

$$M_1 = M_2$$

Experiments:

Five 4D-var assimilation cycles

with non-stretched ARPEGE

Period:

4th February to 24th March

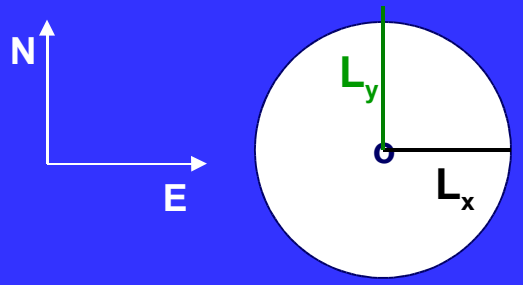
Autocorrelation function in gridpoint space

Daley definition of length scale: measure of the inverse curvature of the autocorrelation function at the origin

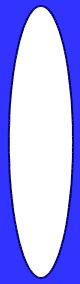
⇔

L gives an idea about how the autocorrelation function decays with distance, from its initial value.

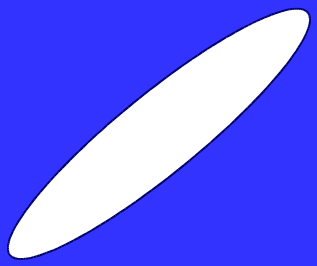
Isotropic: $L_x = L_y$



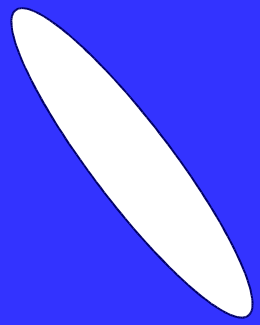
$L_x < L_y$



OR



$L_x > L_y$



Length scale of autocorrelation

Covariance of stream function =>

$$\langle \psi_1 \psi_2 \rangle = \sigma(\psi_1)\sigma(\psi_2)\rho$$

ρ: autocorrelation

$\sigma(\psi_1)$, $\sigma(\psi_2)$: standard deviation of background error

Helmholtz's theorem =>

$$v^{\psi} = \frac{\partial \psi}{\partial x}$$

Rotational component of meridional wind

Covariance of v between 2 points =>

$$\langle v_1^{\psi} v_2^{\psi} \rangle = \left\langle \frac{\partial \psi_1}{\partial x_1} \frac{\partial \psi_2}{\partial x_2} \right\rangle$$

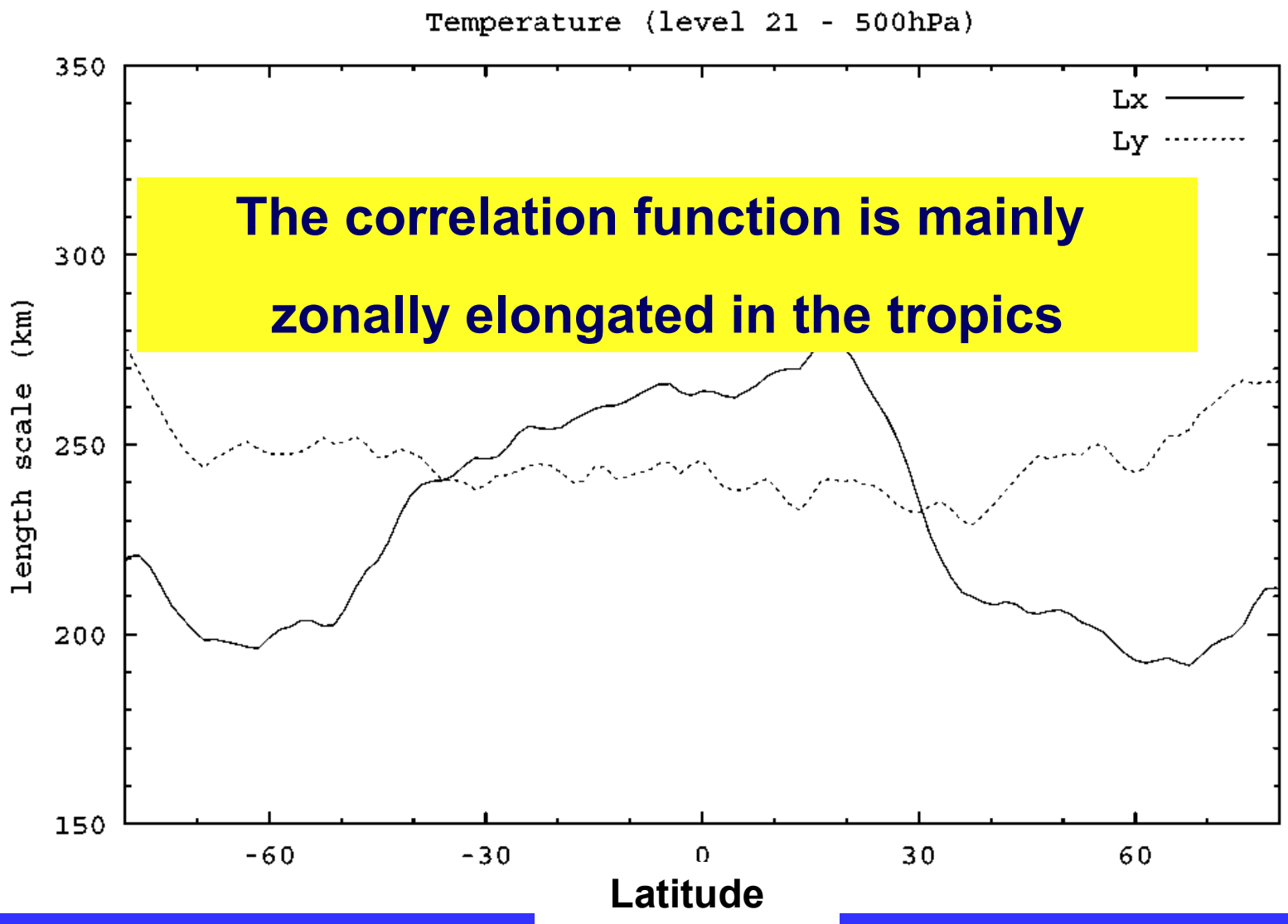
Zonal length scale of autocorrelation =>

$$\left(L_x^{\psi}\right)^2 = \frac{\sigma^2(\psi)}{\sigma^2\left(\frac{\partial \psi}{\partial x}\right) - \left(\frac{\partial \sigma(\psi)}{\partial x}\right)^2}$$

Meridional length scale of autocorrelation =>

$$\left(L_y^{\psi}\right)^2 = \frac{\sigma^2(\psi)}{\sigma^2\left(\frac{\partial \psi}{\partial y}\right) - \left(\frac{\partial \sigma(\psi)}{\partial y}\right)^2}$$

Zonal and meridional length scales



The correlation function is mainly zonally elongated in the tropics

Inertia matrix of correlation function

$$\begin{pmatrix} 1/N_{xx} & 1/N_{xy} \\ 1/N_{xy} & 1/N_{yy} \end{pmatrix}$$

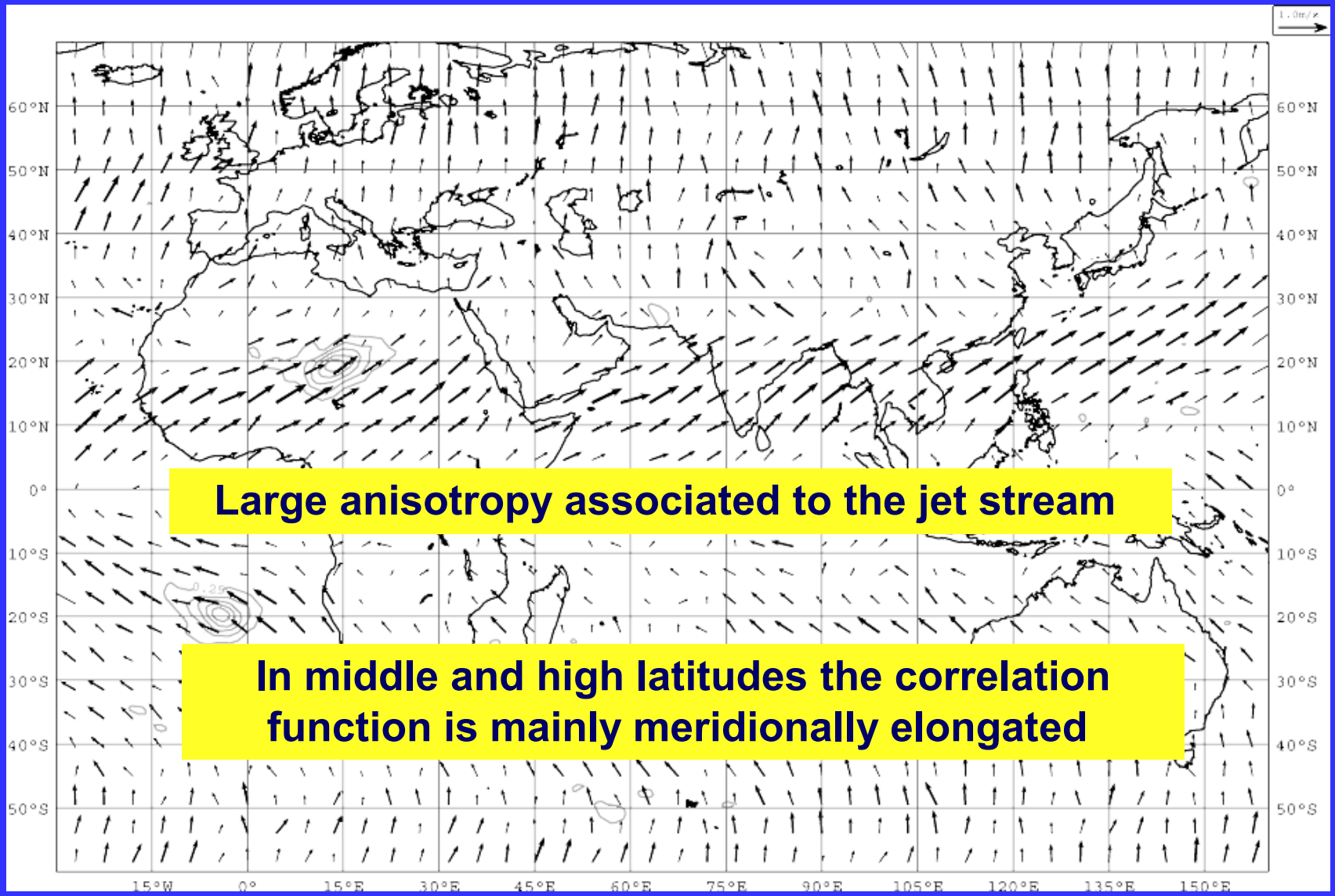
$$N_{xx} = L_x^2 \qquad N_{yy} = L_y^2$$

$$N_{xy} = \frac{\sigma^2(\psi)}{\left\langle \frac{\partial\psi}{\partial x}\frac{\partial\psi}{\partial y} \right\rangle - \frac{\partial\sigma(\psi)}{\partial x}\frac{\partial\sigma(\psi)}{\partial y}}$$

Tilting term – covariance term

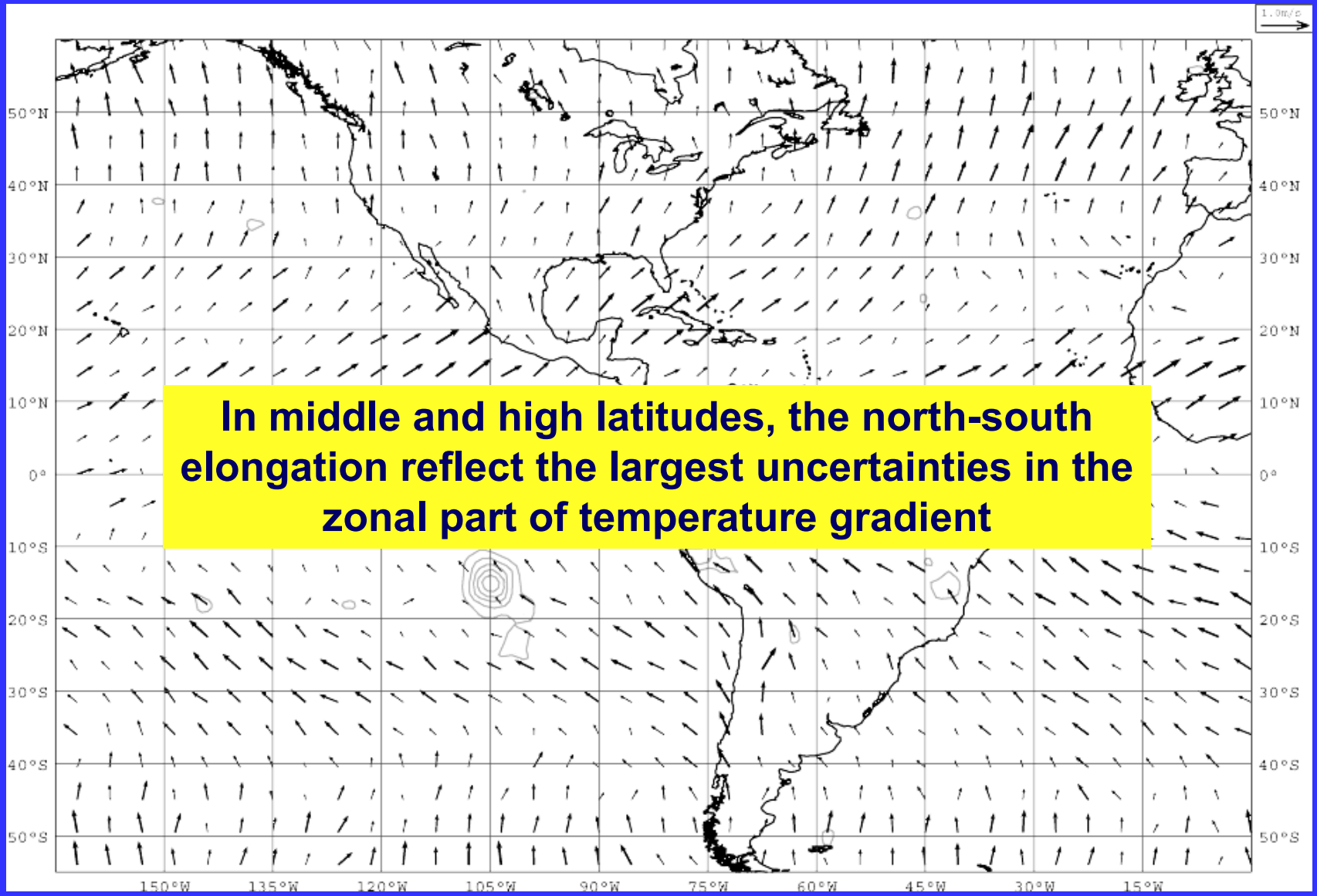
The main anisotropy axis identifies the direction of the largest elongation of the correlation function

500hPa



Large anisotropy associated to the jet stream

In middle and high latitudes the correlation function is mainly meridionally elongated



In middle and high latitudes, the north-south elongation reflect the largest uncertainties in the zonal part of temperature gradient

The impact of the model error

Ensembles		Error sources
PO		Observations at T299 (M_1 = M_2)
POR		Observations and Resolution (T299-T449)
PORP		Observations, Resolution and Physics
Sensitivity experiments	POH	Observations at High resolution (T449)
	POPH	Observations and Physics at High resolution (T449)

Perturbations in physics

- Turbulent fluxes (USURIC, USURICL, USURID, USURIDE)
- Cloudiness scheme (HUCOE, QSSC, QSSUSC)
- Closure of deep convection (LSRCONT, LSRCON, REFLKUO)

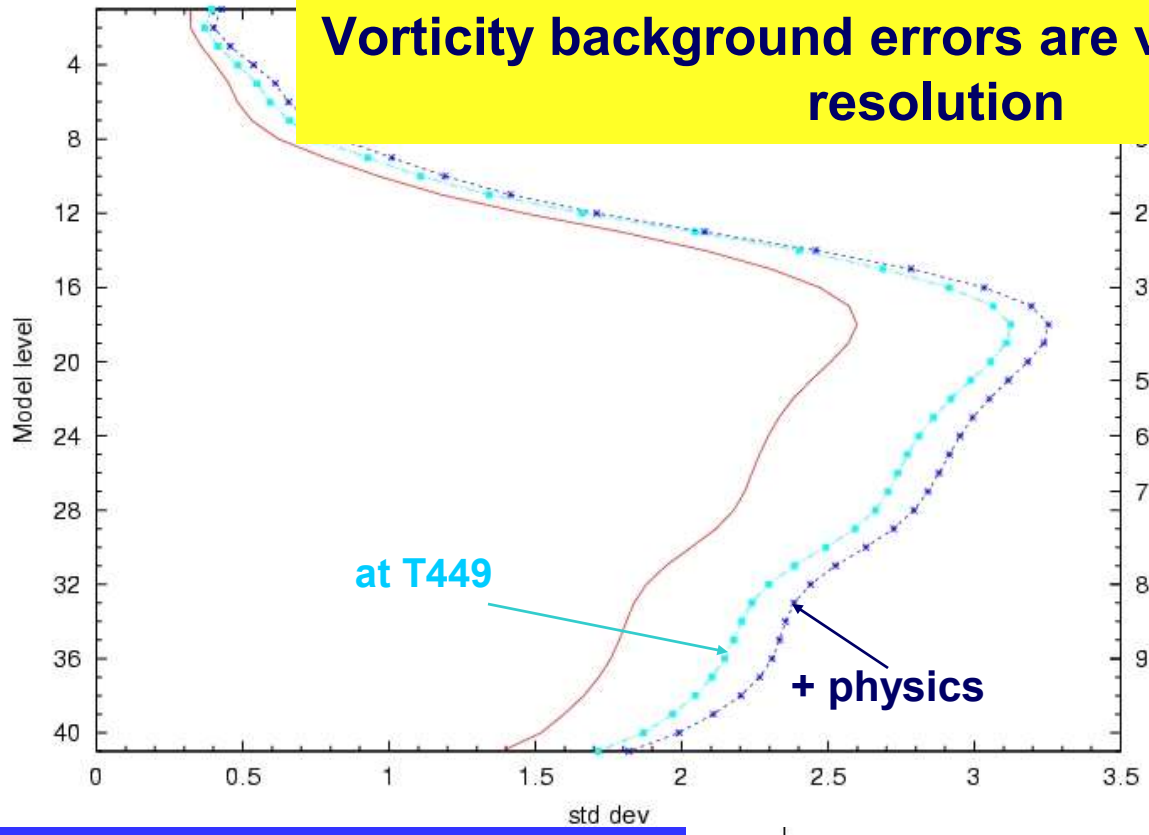
HUCOE - controls the triggering of stratiform clouds

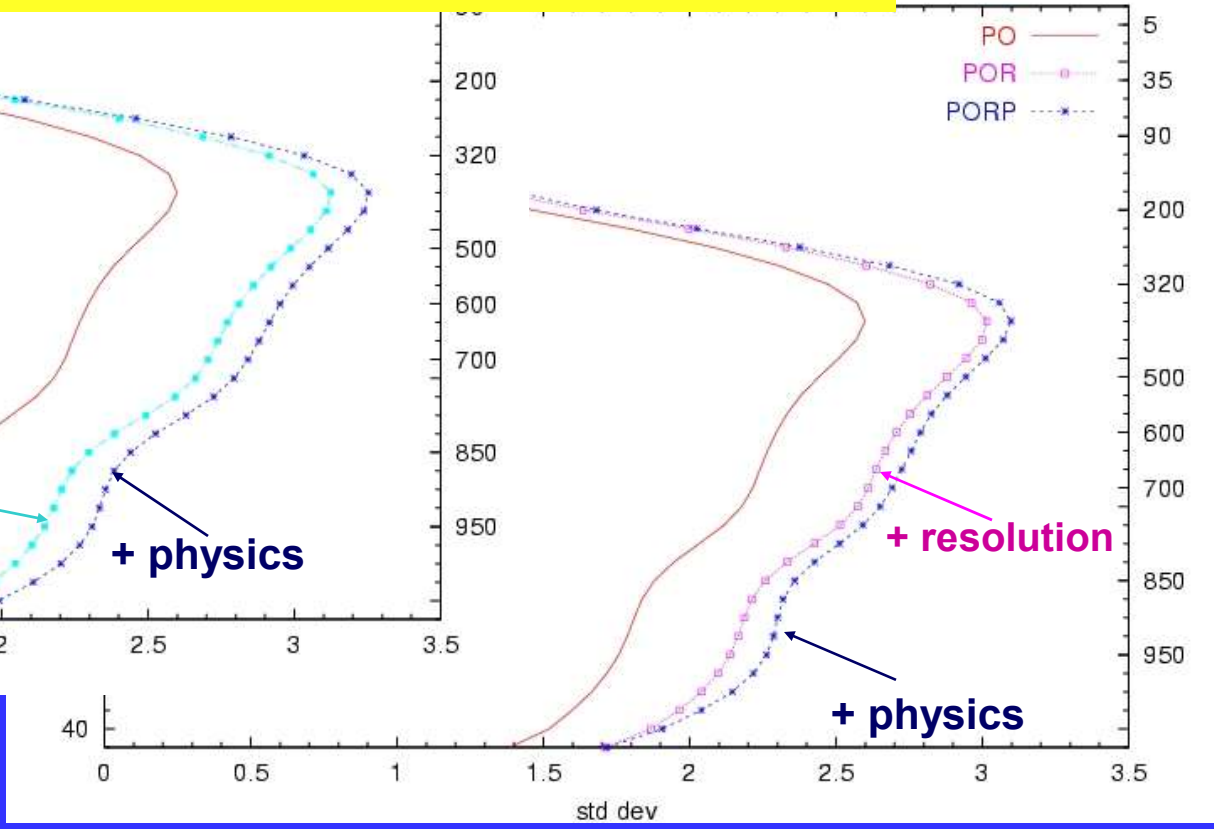
QSSC – influences the shallow convection

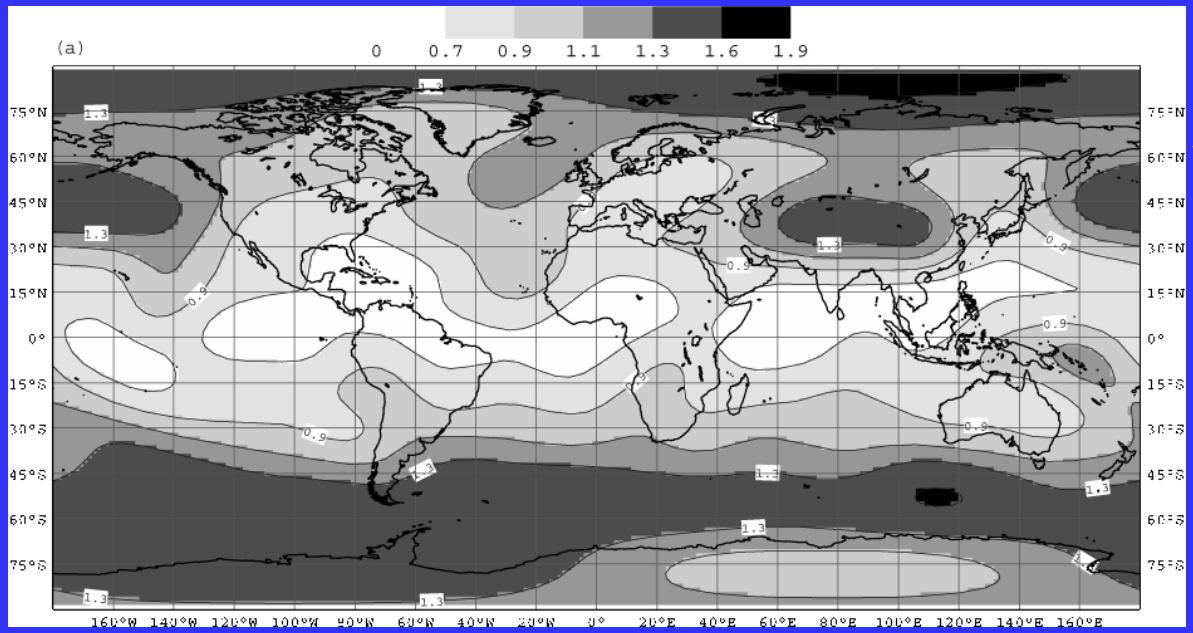
QSSUSC – controls the amount of condensated water from convective clouds

Vorticity background error

Vorticity background errors are very sensitive to resolution



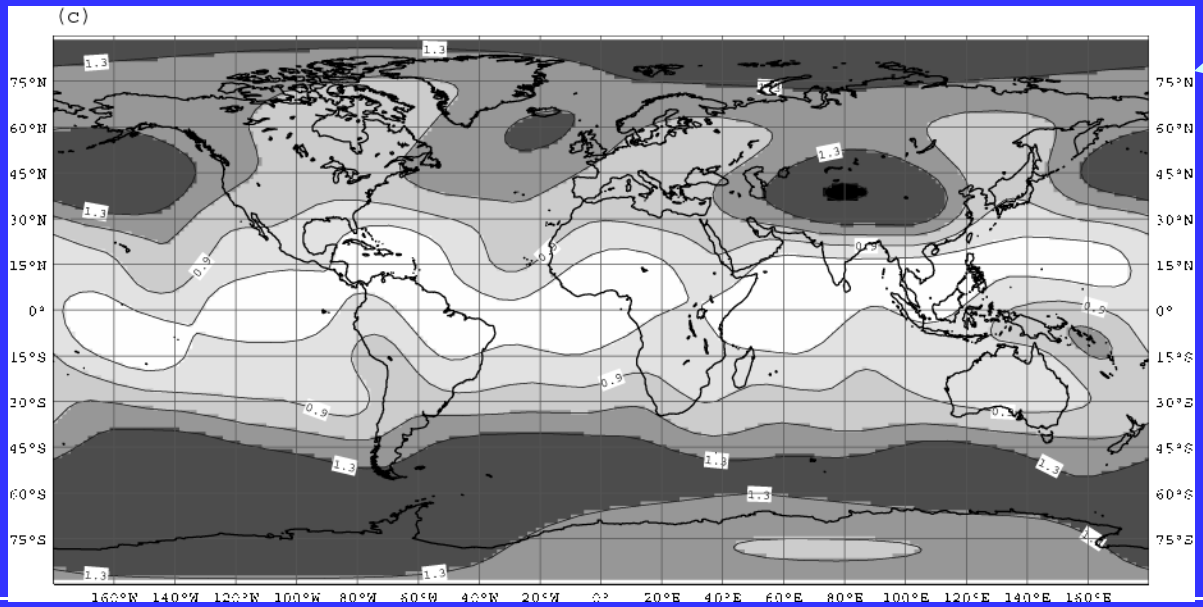




PO

Error sources:

Observations



PORP

Error sources:

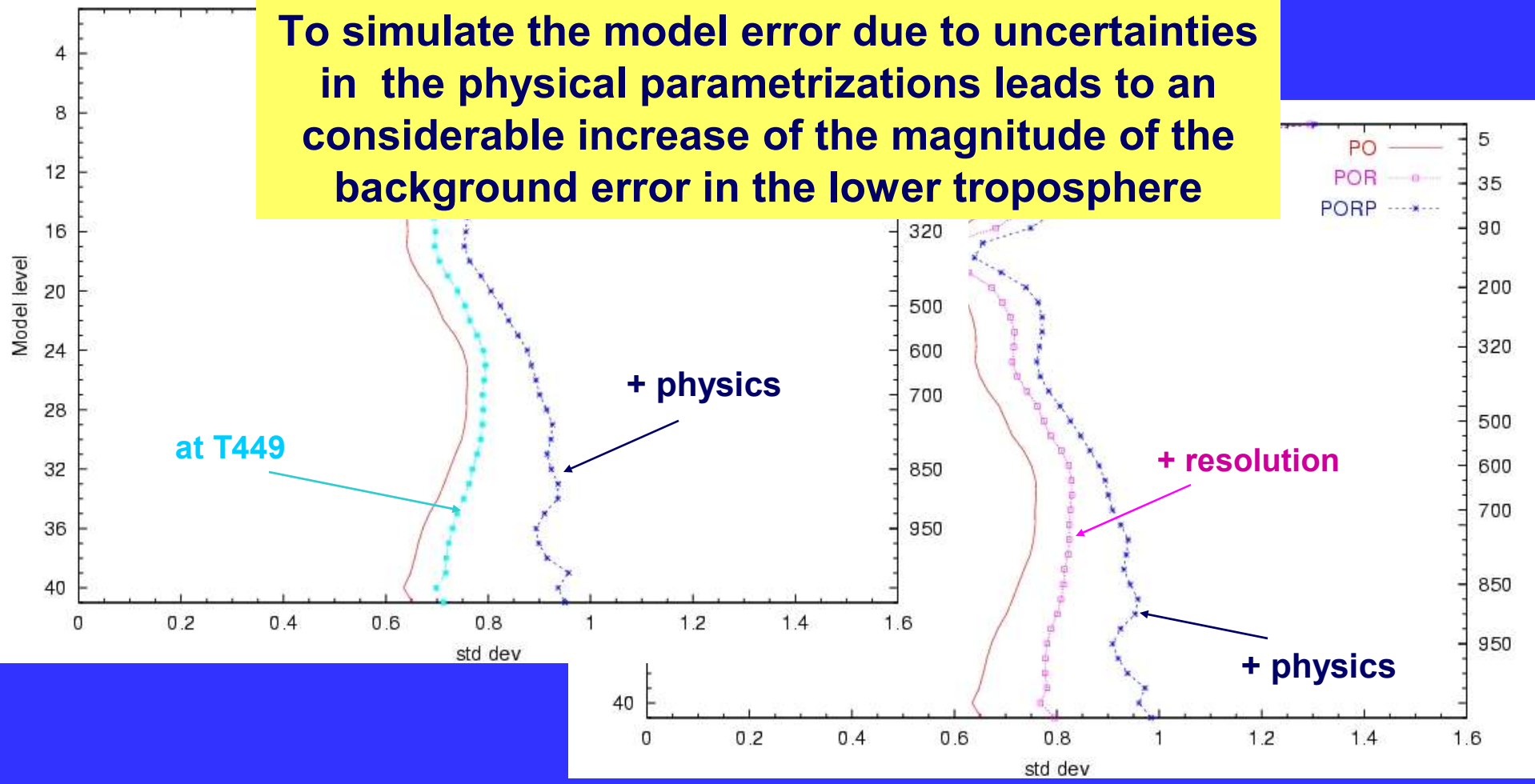
Observations

Resolution

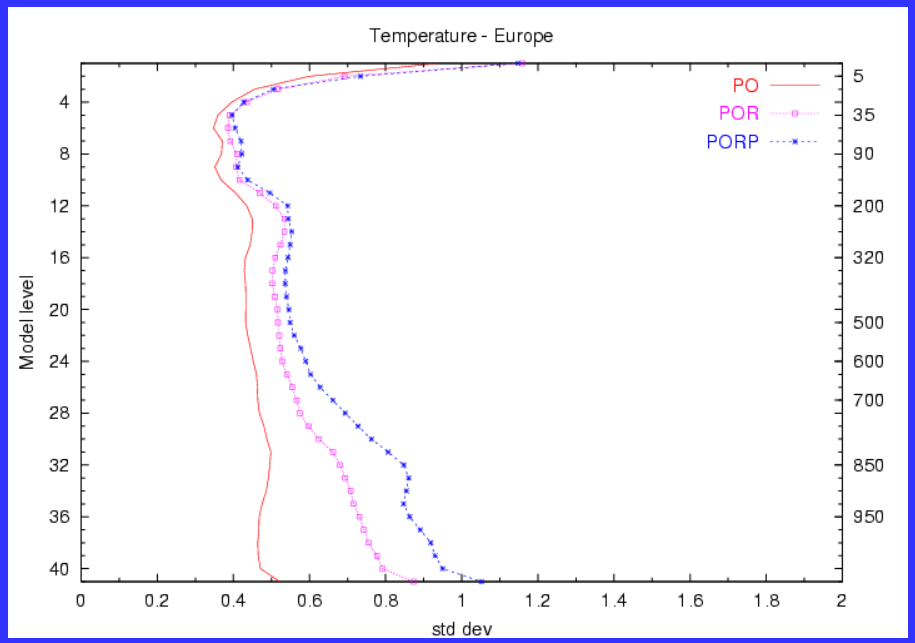
Physics

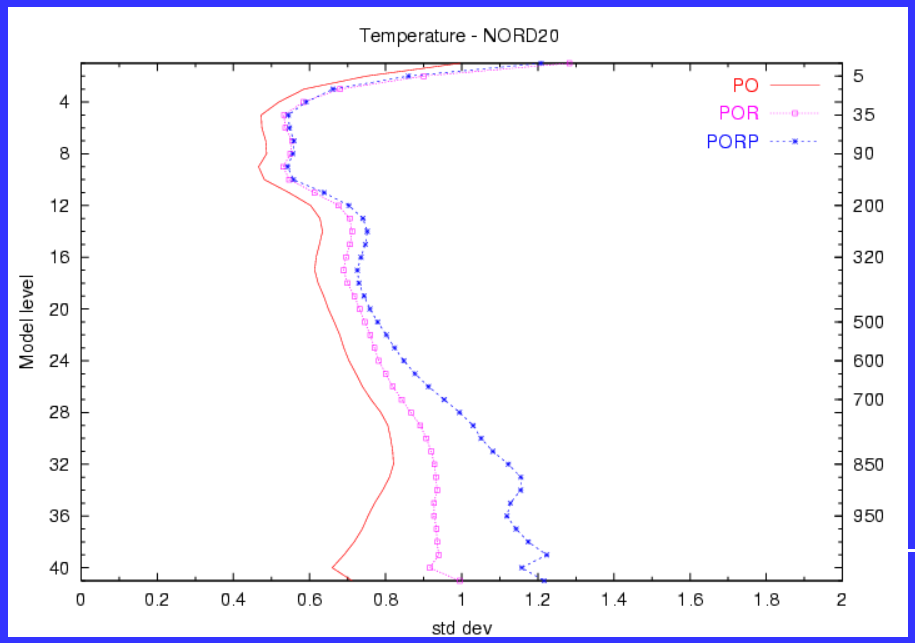
Temperature background error

To simulate the model error due to uncertainties in the physical parametrizations leads to an considerable increase of the magnitude of the background error in the lower troposphere

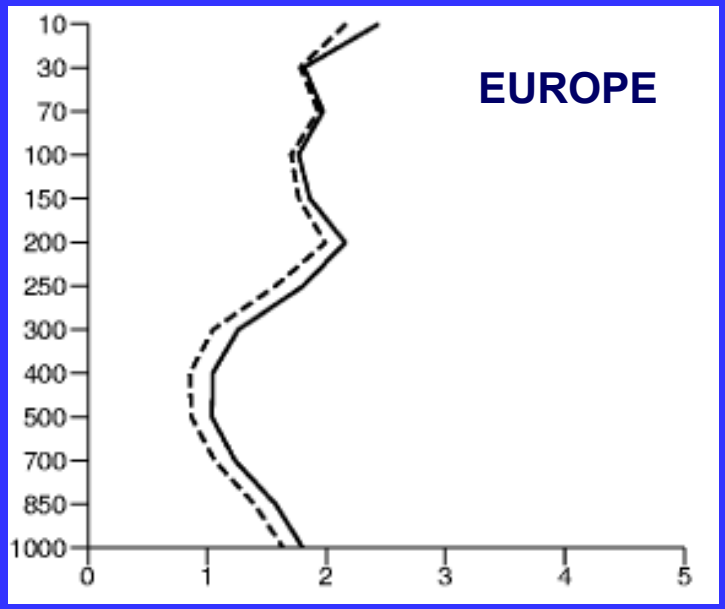


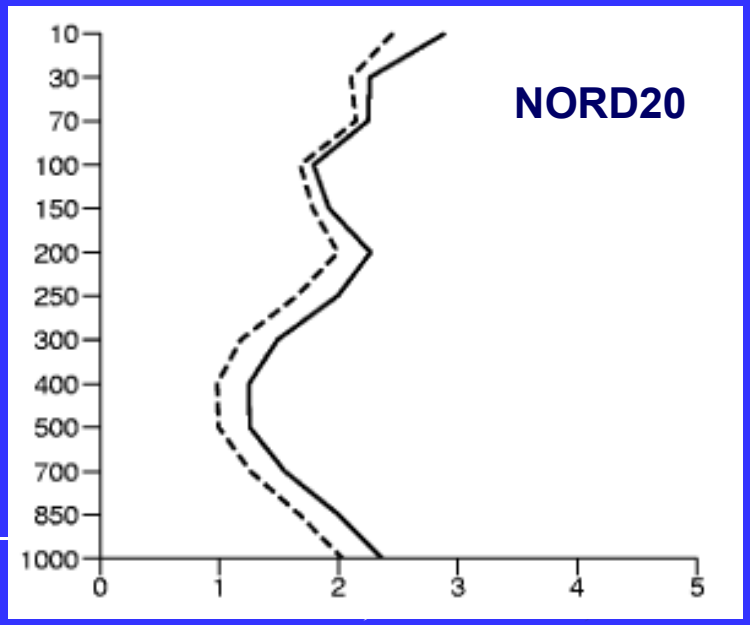
background error (ensemble)



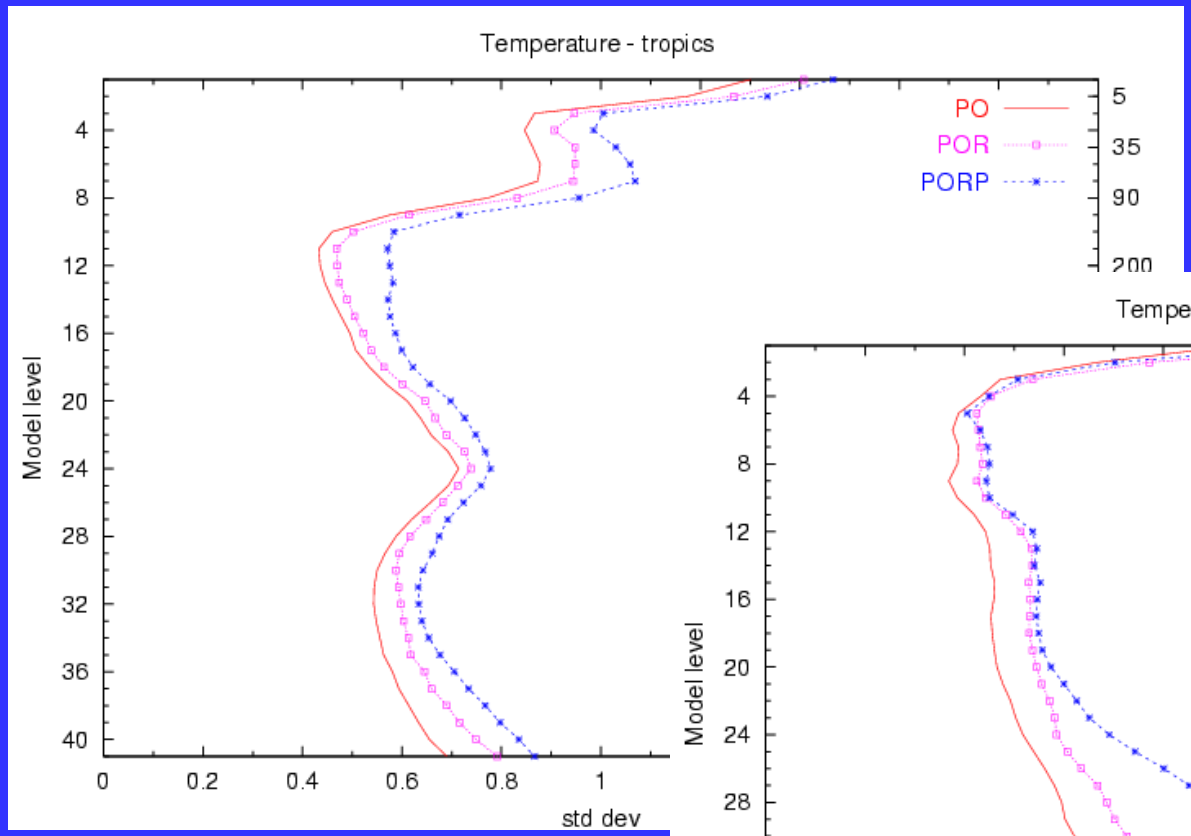


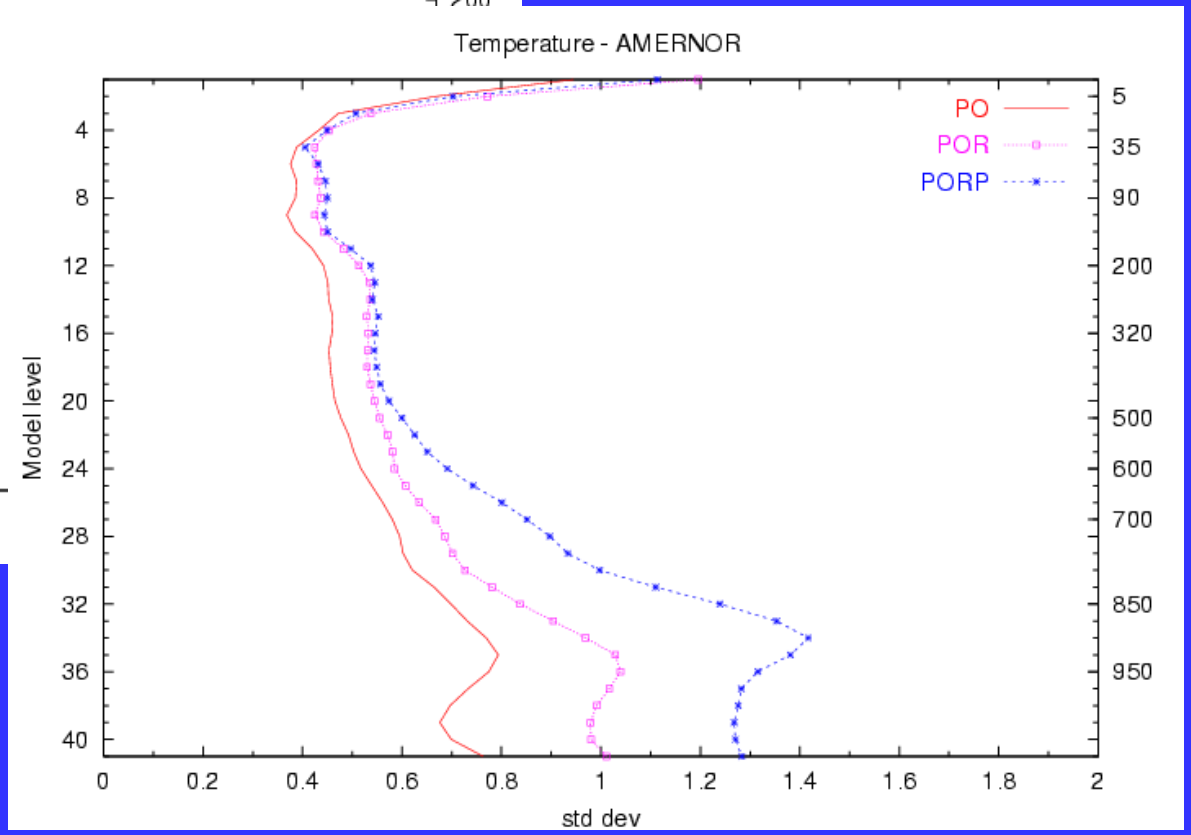
Innovation vector

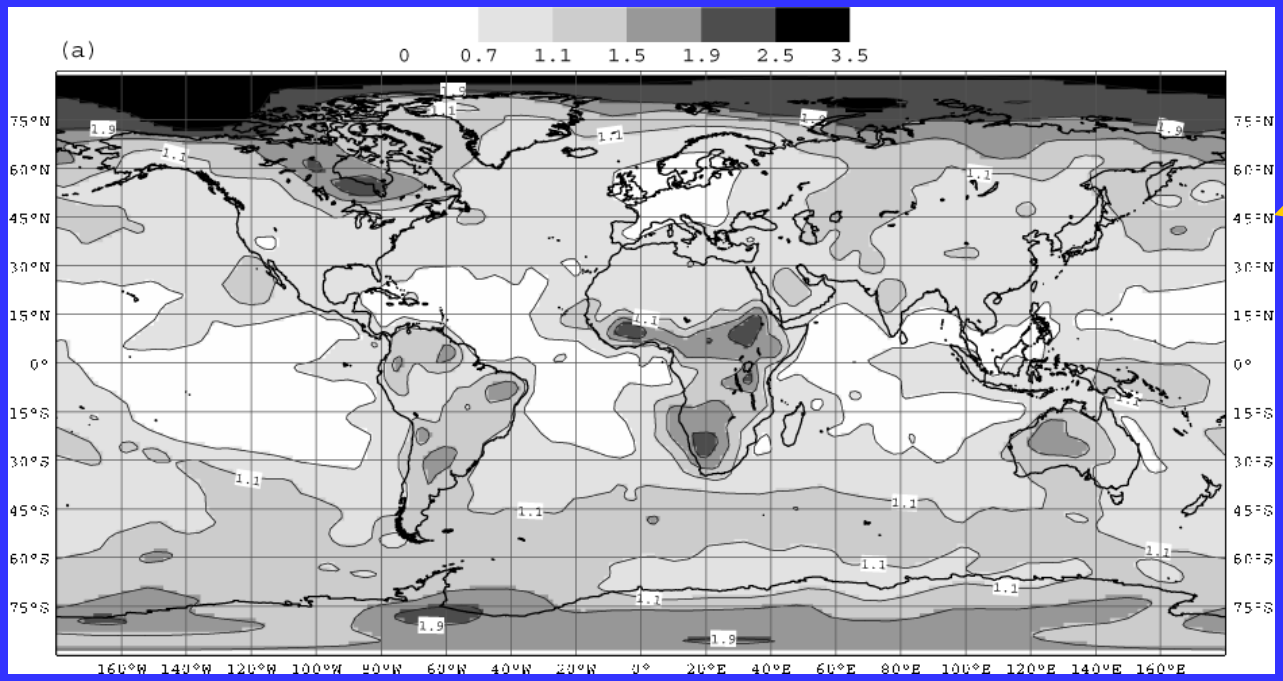




Temperature background error



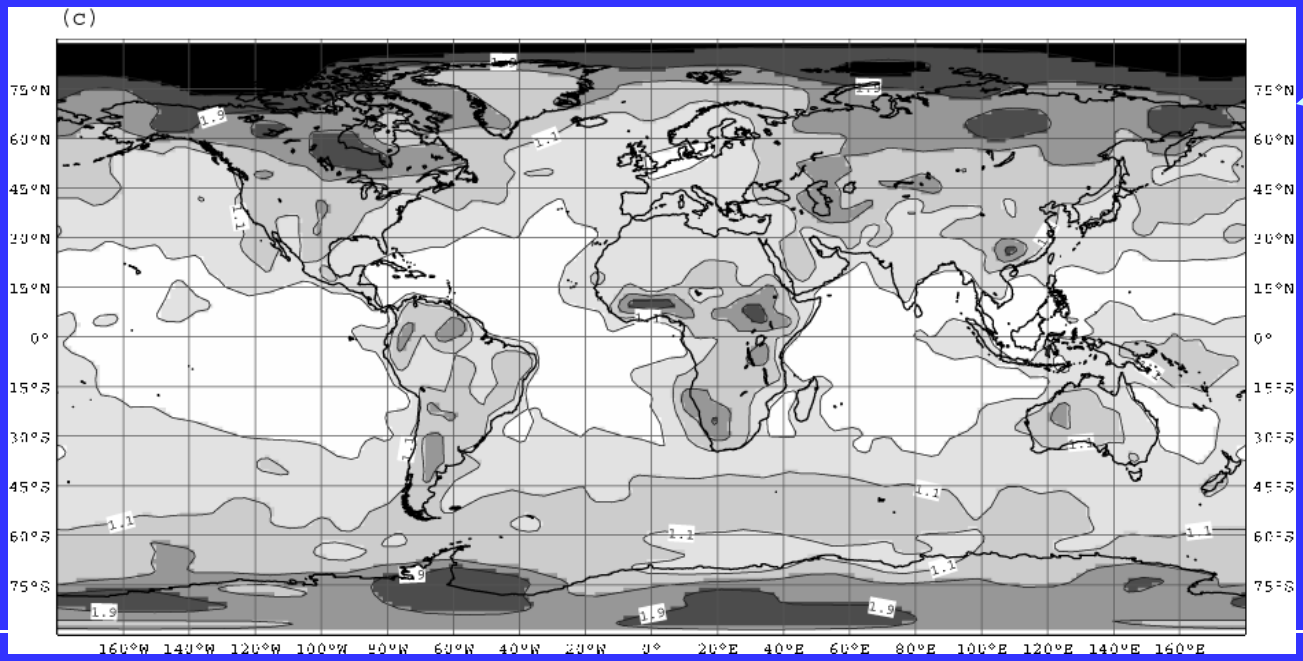




PO

Error sources:

Observations



PORP

Error sources:

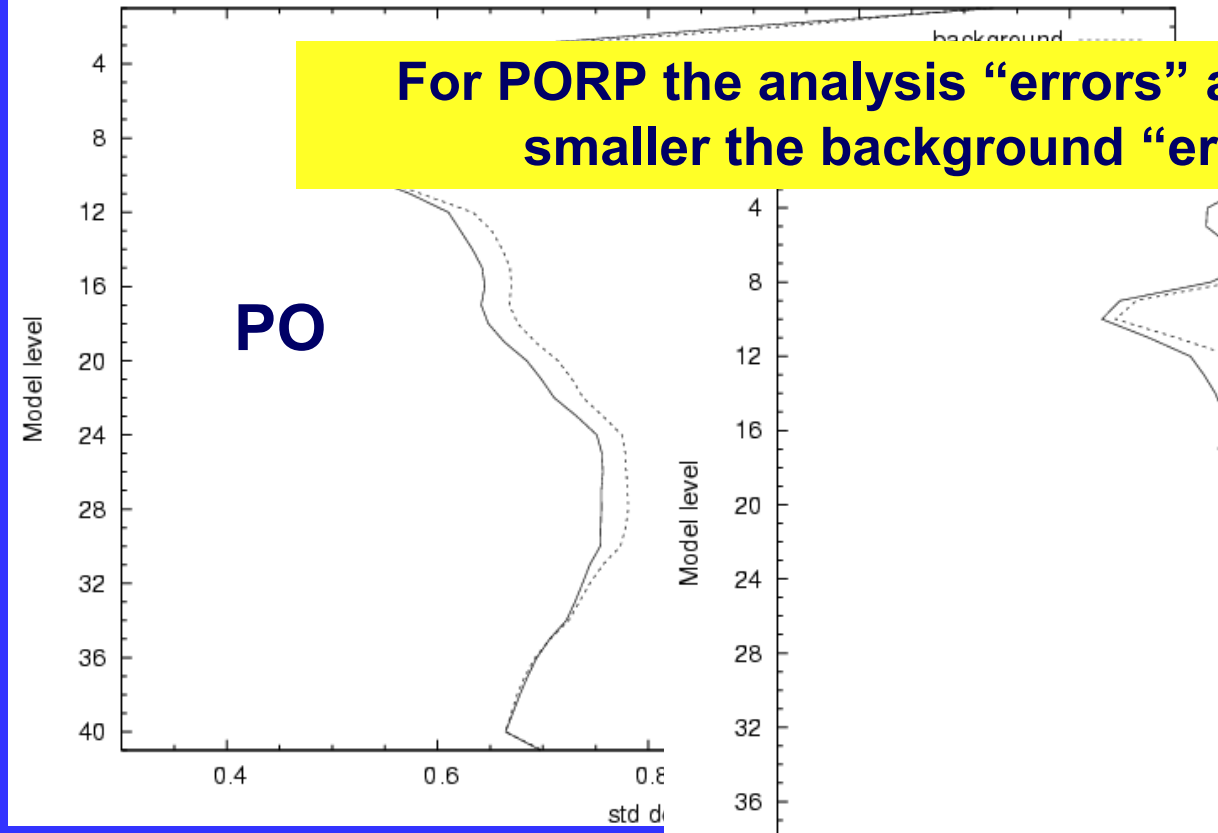
Observations

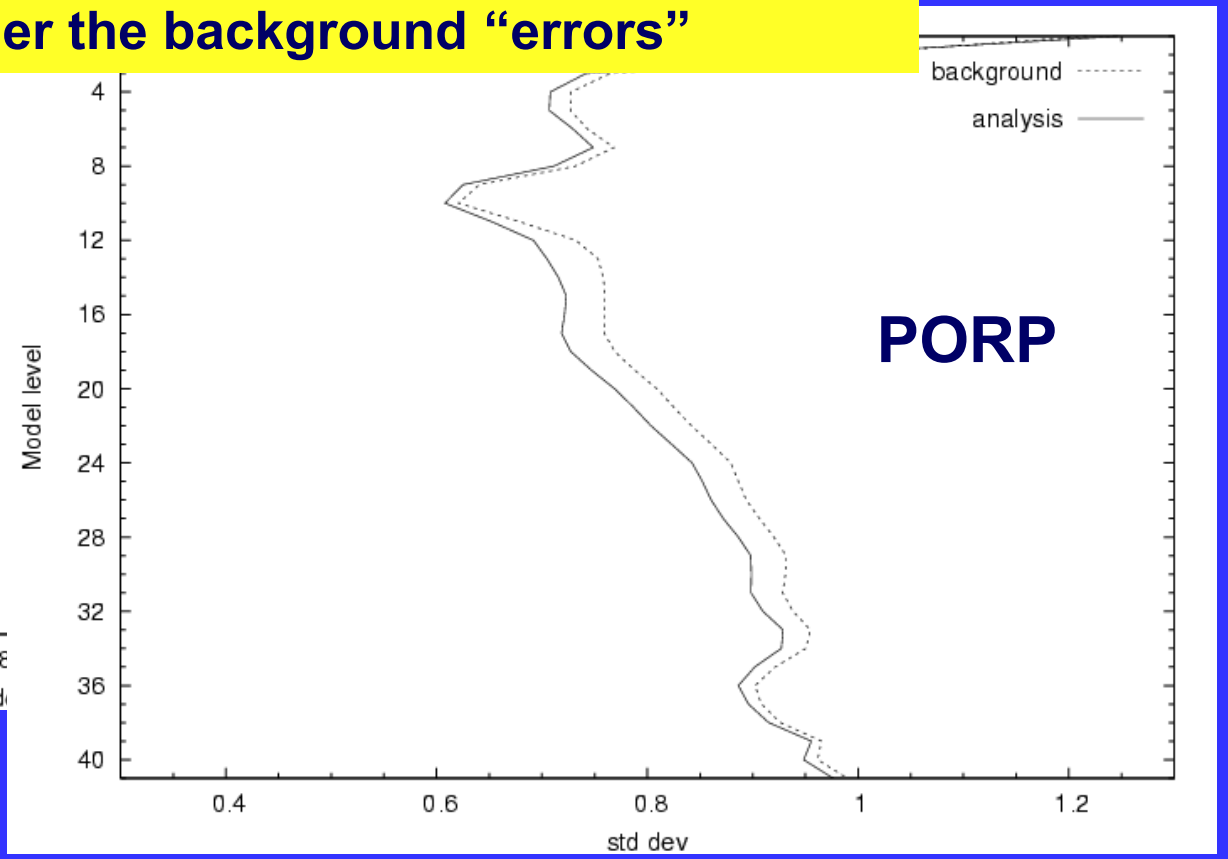
Resolution

Physics

Analysis versus background error

For PORP the analysis "errors" are always smaller the background "errors"



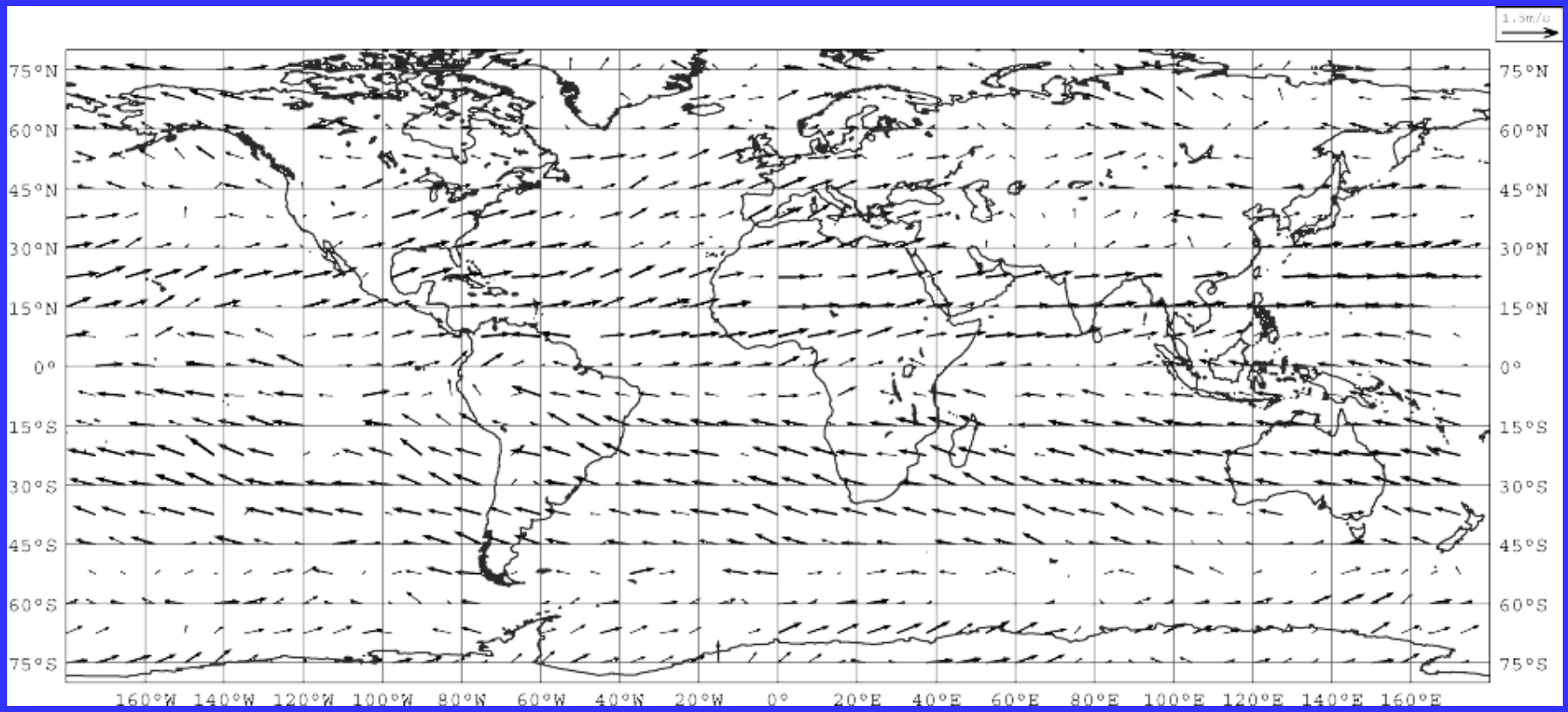


Conclusions

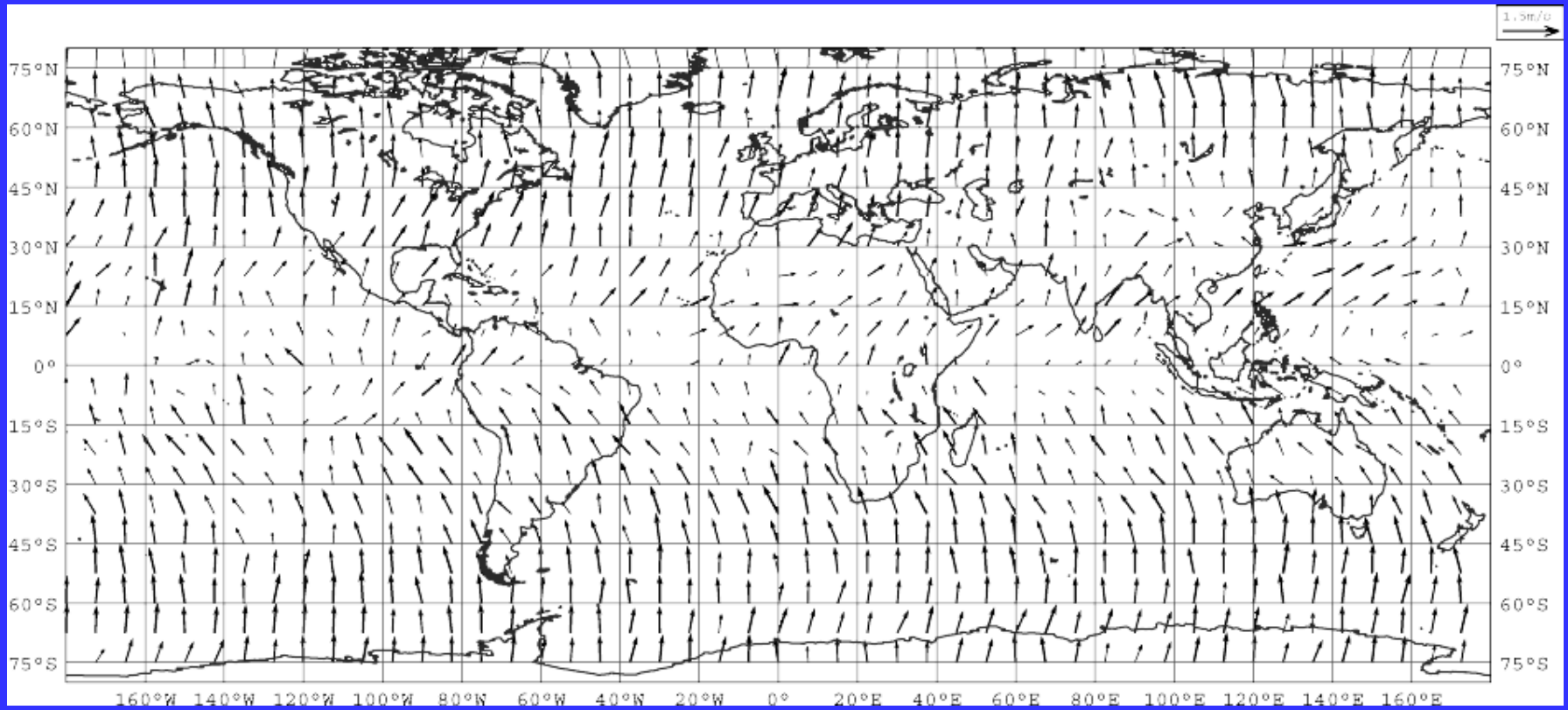
- In the middle and high latitudes the temperature background error correlation is mainly north-south elongated
- In jet stream areas, the anisotropy is quite large
- In the tropics, the correlation function is mainly zonally elongated, with a SW-NE tilt in the Northern Hemisphere
- The vorticity background errors are very sensitive to resolution
- For the temperature, the model error due to uncertainties in physics seems to be not negligible

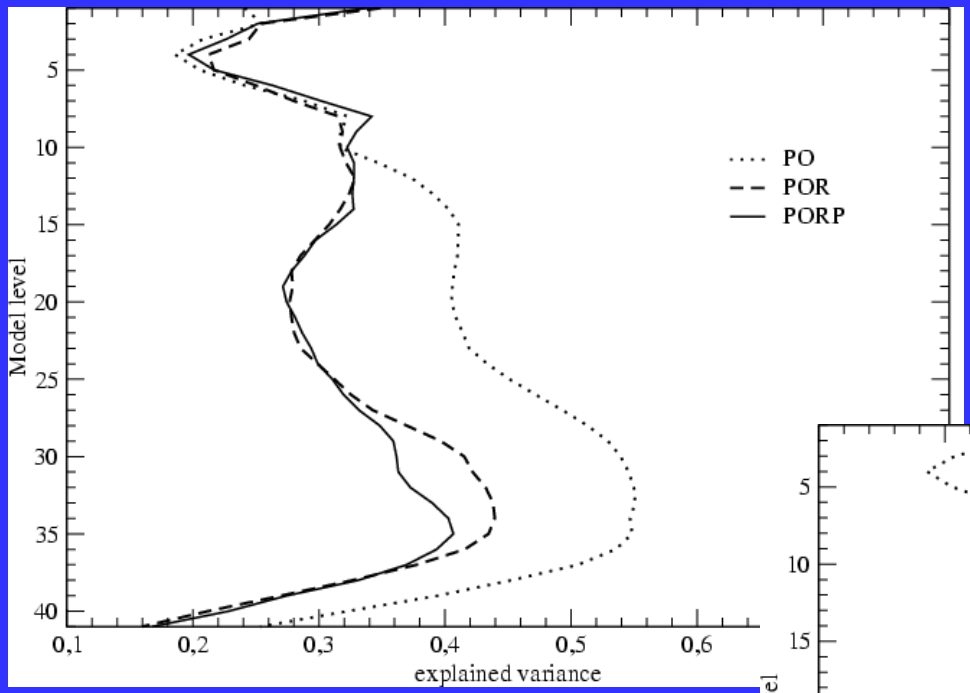
Thank's for your attention

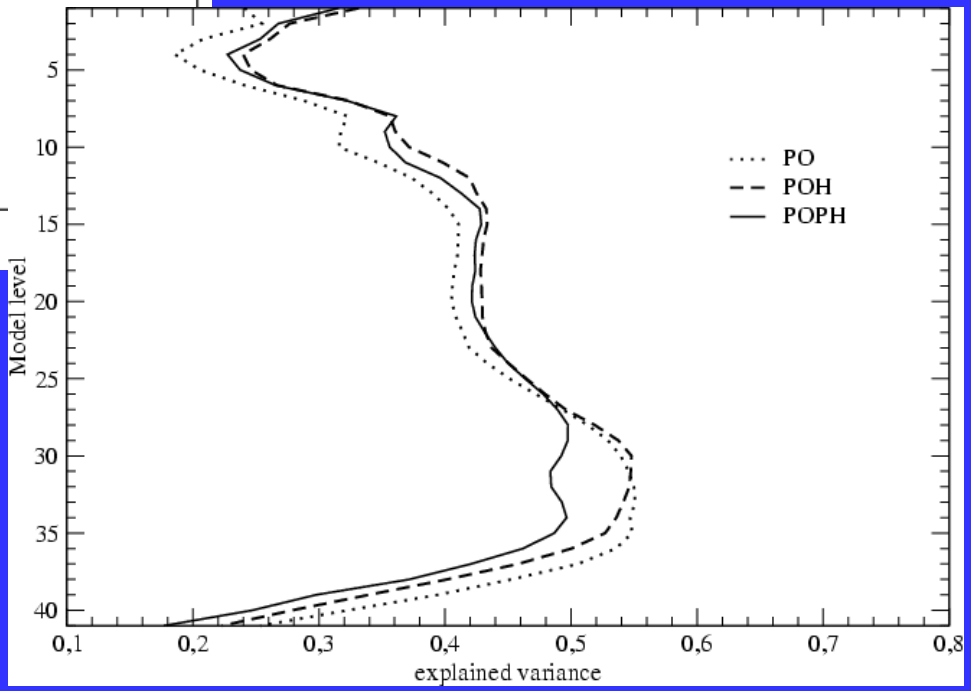
Zonal wind (300hPa)



Meridional wind (300hPa)




Model level
5
10
15
20
25
30
35
40
0,1
0,2
0,3
0,4
0,5
0,6
explained variance
PO
POR
PORP


Model level
5
10
15
20
25
30
35
40
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
explained variance
PO
POH
POPH