V Gorin and M Tsyrulnikov

Can model error be perceived from routine observations?

Motivation: all existing approaches in model-error modeling are largely *ad-hoc*. Any objective knowledge on real model errors is very welcome.

Model error: definition

The forecast equation:

$$\frac{dX}{dt} = F(X)$$

The truth substituted into the forecast equation:

$$\frac{dX^t}{dt} = F(X^t) - \varepsilon$$

Model error =
forecast tendency *minus* true tendency:

$$\varepsilon = F(X^t) - \frac{dX^t}{dt}$$

The goal: objectively estimate a model error model

Let us aim to estimate a mixed additive-multiplicative model:

$$\varepsilon = \mu \cdot F + \varepsilon_{add}$$

where *epsilon_add* and *mu* are spatio-temporal random fields, whose probability distributions are to be estimated.

Even in a parametrized Gaussian case, estimating model parameters (variances and length scales) requires a <u>proxy</u> to model error *epsilon*.

Assessing model error: approximations

$$\varepsilon = F(X^t) - \frac{dX^t}{dt}$$

1) In dX/dt, replace the truth by observations.
2) Replace instantaneous tendencies with finite-time ones.
3) In F(X), replace the truth by the analysis (and subsequent forecast).

$$\int \varepsilon dt \approx \int F(X^m)dt - \Delta X^o = \Delta X^m - \Delta X^o$$

The question: can we assess <u>epsilon</u> having the <u>r.h.s.</u> of this equation?

Numerical experiments: setup

Methodology: **OSSE.**

Model: **COSMO (LAM, 5000*5000 km, 40 levels, 14 km mesh).**

Observations: **T,u,v,q, all grid points observed, obs error covariance proportional to background error covariance.**

Analysis: **simplified: with R~B, the gain matrix is diagonal.**

Assimilation: **6-h cycle; 1-month long, interpolated global analyses as LBC.**

Model error: **univariate and *constant* in space and time for 6-h periods.**

Finite-time tendency lengths: **1, 3, and 6 h.**

Magnitudes of imposed model errors and obs errors

Obs errors std:

(1) realistic (1 K and 2 m/s)

(2) unrealistically low (0.1 K and 0.2 m/s)

(3) zero

Model errors std:

(1) realistic (1 K/day and 2 m/s per day)

(2) unrealistically high (5 K/day and 10 m/s per day)

Assessing model error: an approximation-error measure

If model error is observable, then $\int \varepsilon dt = \varepsilon_0 \cdot \Delta t$

should be close to data $d = \Delta X^m - \Delta X^o$

Both quantities are known from simulations, so we define the discrepancy (the model-error observability error) as

$$r = r.m.s. \frac{d - \varepsilon_0 \Delta t}{\varepsilon_0 \Delta t}$$

Results (1)

The model-error observability. R.m.s. statistics. Realistic error magnitudes

With realistic both obs error and model error, the model-error observability error *r* appears to be above 1 (not observable at all) for all 3 tendency lengths (not shown).

Results (2): obs error small or zero, model error normal.

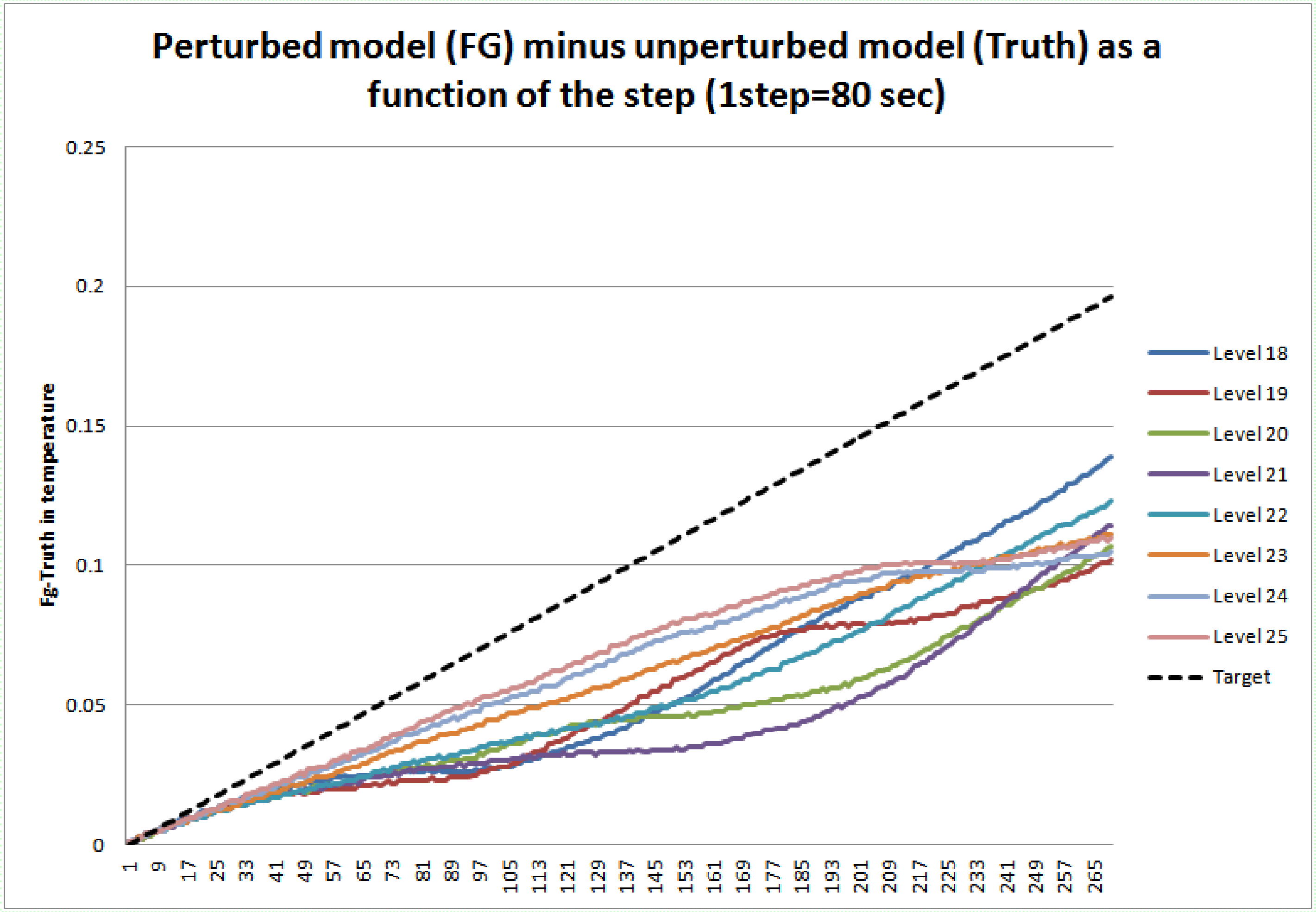
The model-error observability error "r"

OE	Field	$\Delta t = 1$ h	$\Delta t = 3$ h	$\Delta t = 6$ h
OE small	T	> 1		0.68
	u	> 1		2.7
	v	> 1		3.4
OE=0	T	1.0	0.58	0.46
	u	1.2	1.8	1.6
	v	1.4	1.5	2.0
Fc starts	T	0.28	0.30	0.33
from	u	0.33	0.75	0.99
truth	v	0.35	0.69	1.20

Results (3): an example of finite-time forecast tendency error.

Dashed – expected model error eps*(Delta t), colored – perceived model error d.

Forecast starts from <u>truth</u>, model error normal. ***Temperature***

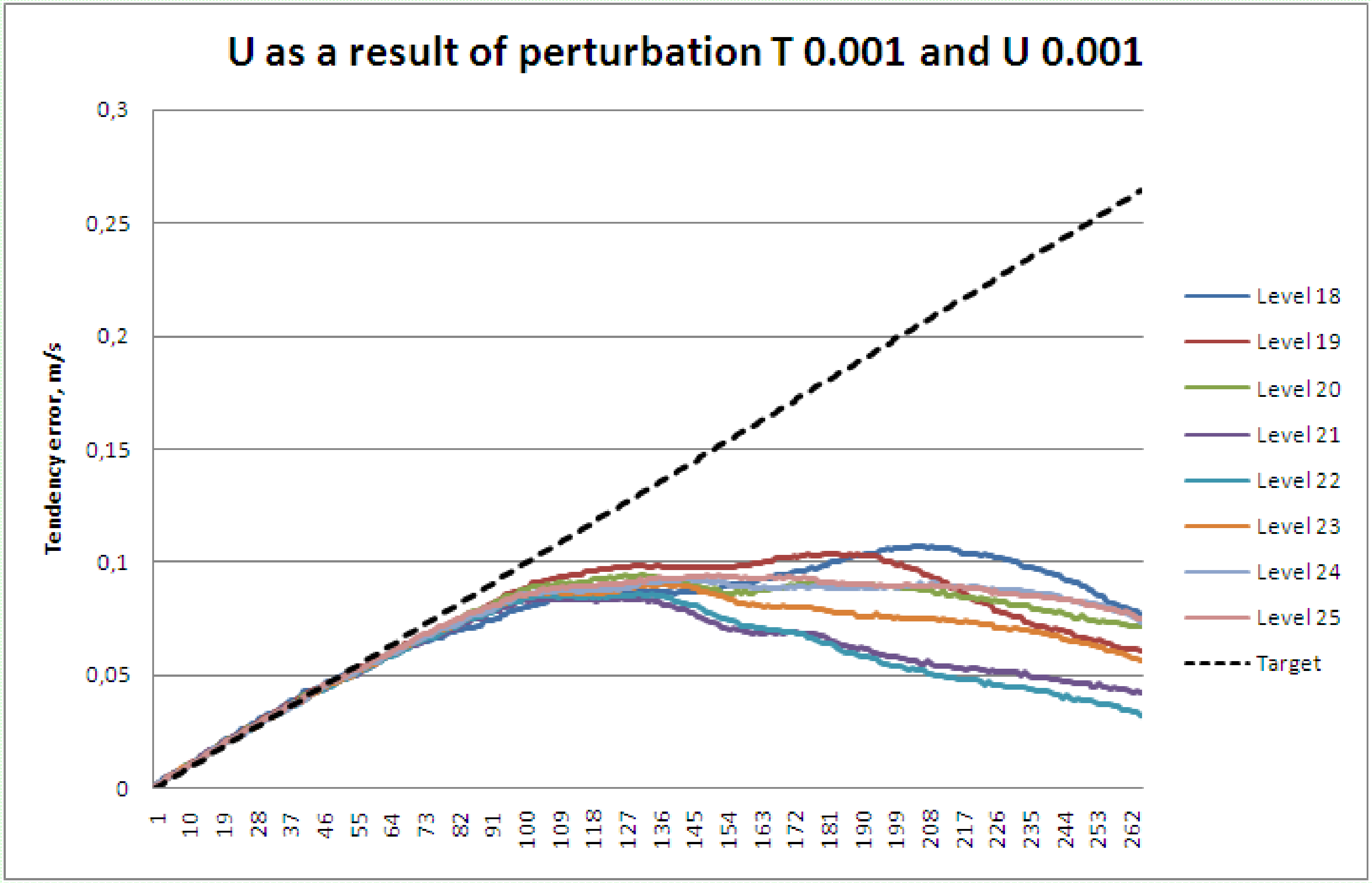


Model error is observable within 6 hours (albeit imperfectly)

Results (4): an example of finite-time forecast tendency error.

Dashed – expected model error eps*(Delta t), colored – perceived model error d.

Forecast starts from <u>truth</u>, model error normal. ***Zonal wind***

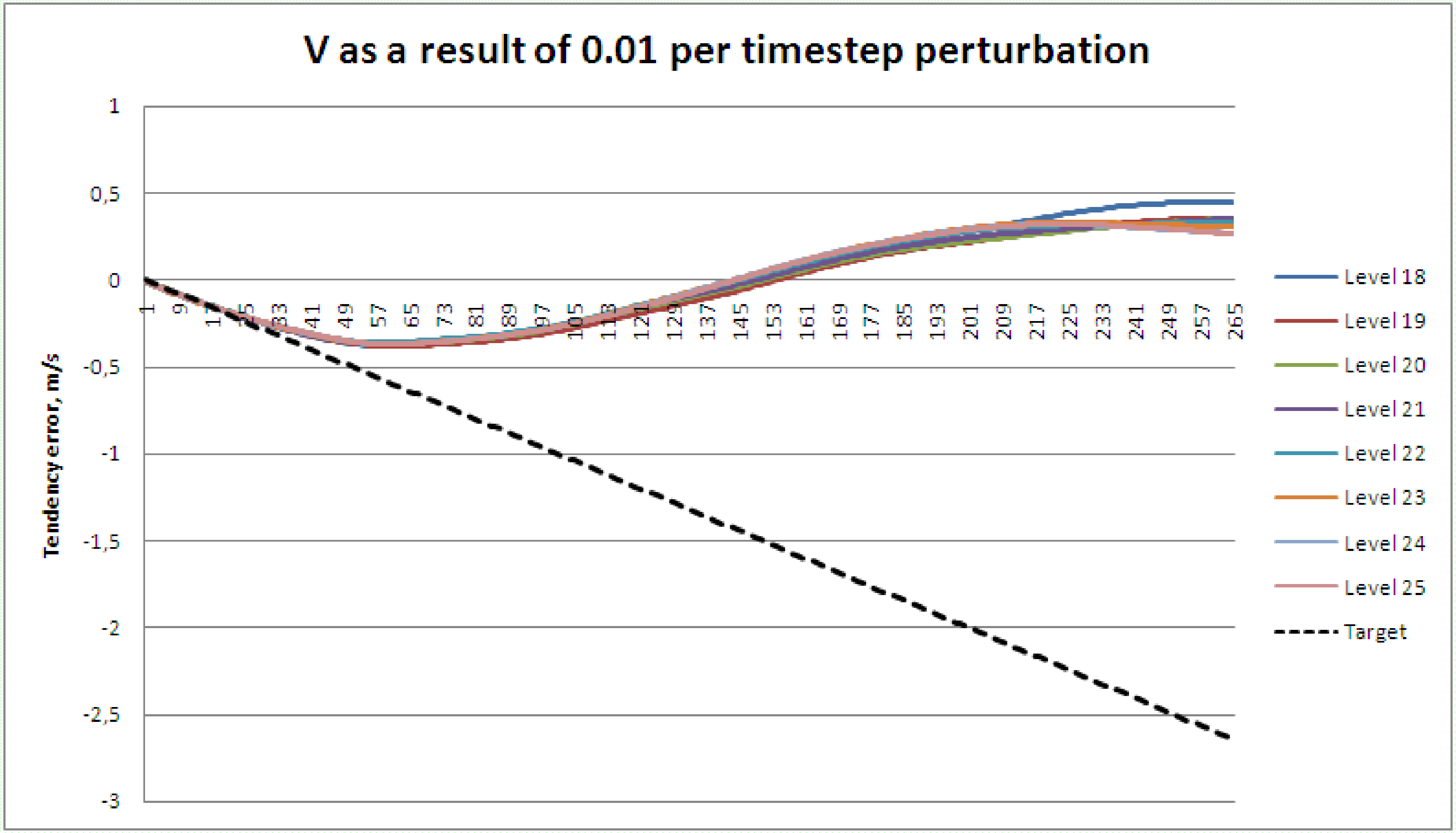


Model error is observable within 2 hours

Results (5): an example of finite-time forecast tendency error.

Dashed – expected model error eps*(Delta t), colored – perceived model error d.

Forecast starts from <u>truth</u>, model error normal. ***Meridional wind***



Model error is observable within just 1 hour

Conclusions

= Existing routine observations are far too scarse and far too inaccurate to allow a reliable assessment of realistic-magnitude model errors.

= A field experiment could, in principle, be imagined to assess model errors.

= Comparisons of tendencies from *operational* parametrizations vs. *most sophisticated* ones (both tendencies start from the same state) can be used as proxies to model errors.

The END

Results (6): obs error small or zero, model error large.

The model-error observability error "r"

OE	Field	$\Delta t = 1$ h	$\Delta t = 3$ h	$\Delta t = 6$ h
OE small	T	0.80	0.41	0.35
	u	1.75	0.98	1.09
	v	2.26	1.38	1.42
OE=0	T			0.34
	u			1.02
	v			1.30
Fc starts	T	0.27		0.34
from	u	0.26		0.98
truth	v	0.34		1.26