SPM (personal) review

COSMO General Meeting, 6 September 2016
Offenbach

Introduction:

- COSMO long-term scientific strategy consequently aims at convective-scale and probabilistic forecasting
- during the coming COSMO year we will decide how to implement our strategy into further concrete actions: future Priority Tasks and Projects
- we want also to check whether some aspects of the strategy, itself, need to be reconsidered
- here are some (personal) comments to note challenges related to the convection-permitting regime, as a background for our further discussions

Properties of the turbulent flow:

- we may define turbulence as a high-Raynolds number nonlinear disordered flow of many embedded scales
- with such definition, majority of atmospheric flows appear as turbulent with scales ranging from global to ‘micro’ (turbulence is not only a sub-grid-scale process!)
- some general properties of atmospheric flows can be deduced from properties of turbulence, e.g.:

  → 2-d turbulent flows are characterised by energy spectra proportional to k^{-3}

  → for 3-d turbulent flows the characteristic energy spectra are proportional to $k^{-5/3}$,

(k – turbulent eddy wave number)

An evidence: atmospheric spectra

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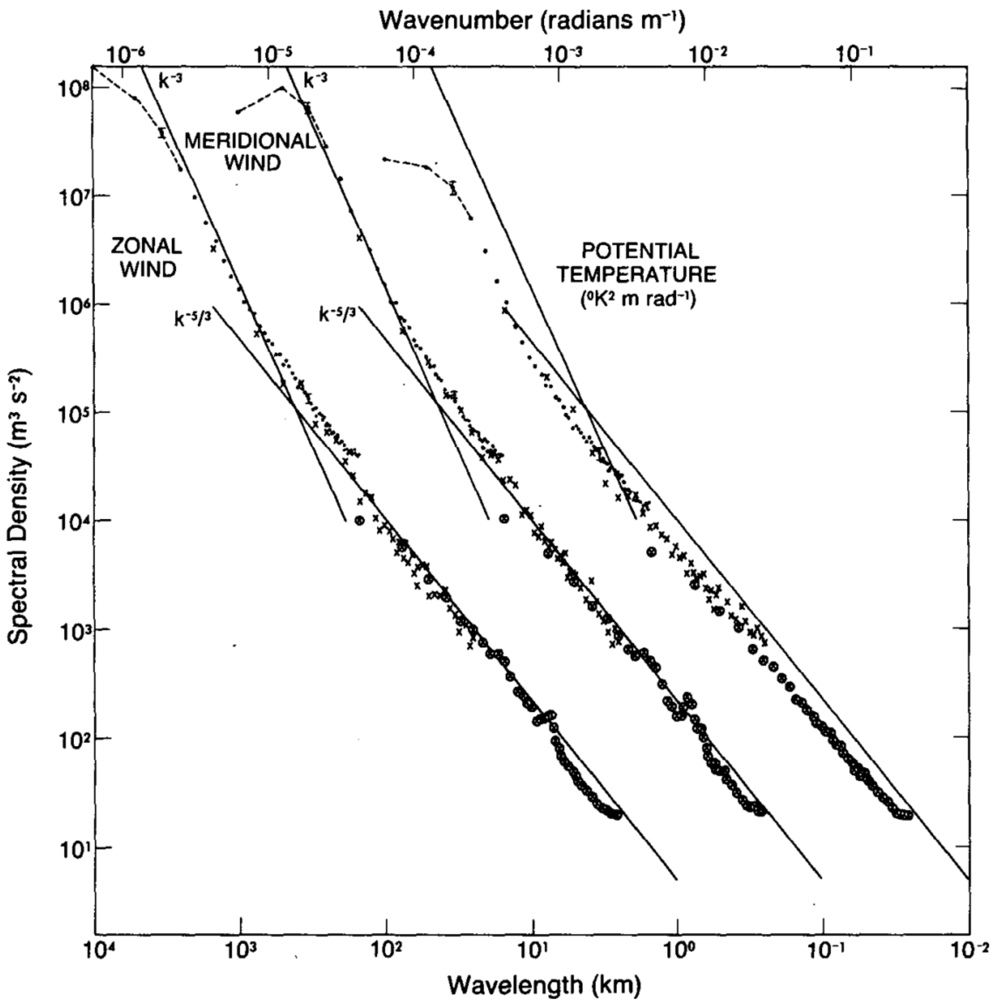

Predictability

- the predictability limit for a turbulent flow:

  „the time needed for an error confined to a small scale (k_0) to contaminate a larger scale eddy of interest (k)”:

  → for 2-d turbulence (atmospheric large scale) it is proportional to $\ln (k_0 / k)$: there is no ‘principal’ limit of predictability (we just need k_0 large, enough)

  → for 3-d turbulence (atmospheric small-scale) it is proportional to $k^{-2/3}$ (no dependence on k_0!): strong inherent predictability limit proportional to the eddy turnover time and diminishing with its diminishing size (decreasing of the scale of initial error will not help!)

Lorenz 1969 study estimating predictability of different atmospheric scales (including convective ones)

PREDICTABILITY OF FLOW POSSESSING MANY SCALES OF MOTION 303

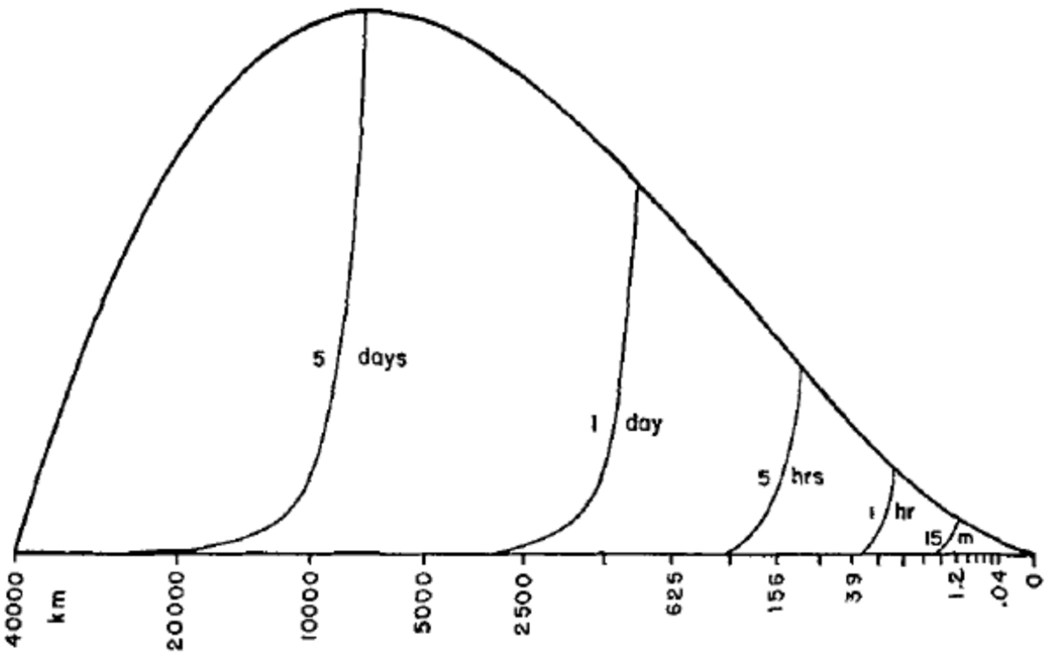

Fig. 2. Basic energy spectrum (heavy curve), and error-energy spectra (thin curves) at 15 minutes, 1 hour, 5 hours, 1 day, and 5 days, as interpolated from numerical solution in Experiment A. Thin curves coincide with heavy curve, to the right of their intersections with heavy curve. Horizontal coordinate is fourth root of wave length, labeled according to wave length. Resolution intervals are separated by vertical marks at base of diagram. Vertical coordinate is energy per unit logarithm of wave length, divided by fourth root of wave length. Areas are proportional to energy.

Implications for the (convective-scale) NWP:

- we may (roughly) say that it is mainly stratification and rotation which is responsible for reduction of large scale flow into 2-d (geostrophic) turbulence
- if so, it is only with convection-permitting models where the effects of atmospheric 3-d turbulent regime are explicitly represented (partially, but still strongly)

  (other NWPs explicitly represent stratified flows with the rest being parameterised)

- so: due to absolute and very short predictability limits (~1 hour for 10 km, Lorenz 1969) convection-permitting NWPs need very different assimilation/ensemble strategies comparing to convection-parameterised ones

Analysis/ensemble problem for large scales (Kalnay, 2002)

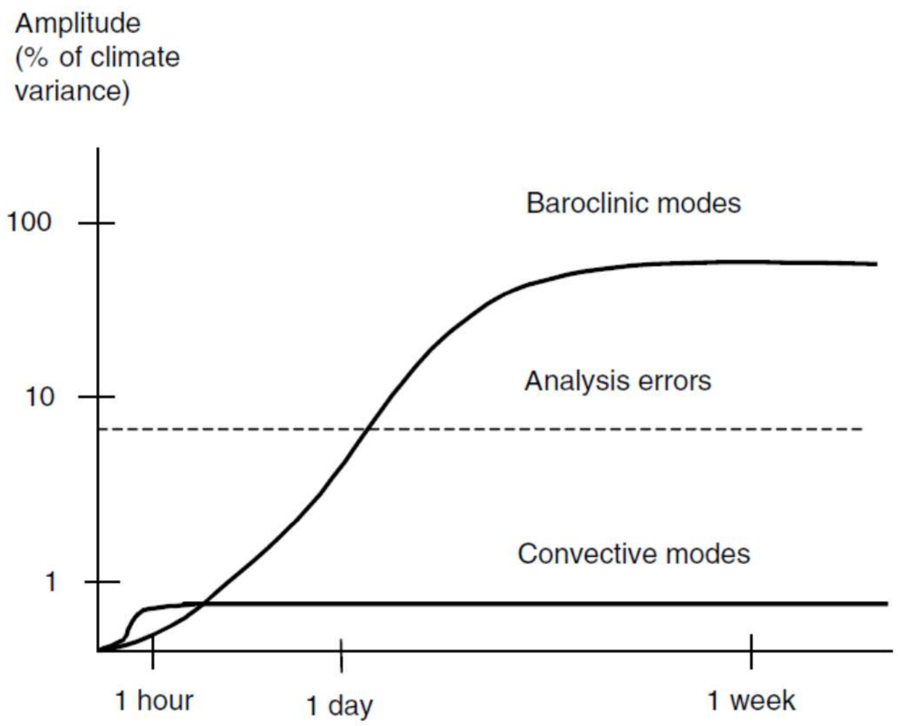

Figure 6.5.6: Schematic of the time evolution of the rms amplitude of high-energy baroclinic modes and low-energy convective modes. Note that although initially growing much faster than the baroclinic modes, convective modes saturate at a substantially lower level. These modes are therefore insignificant in the analysis/ensemble perturbation problem, since the errors in the analysis (dashed line) are much larger than the convective saturation level. (Adapted from Toth and Kalnay, 1993.)

Some problems we face …

- for actual atmospheric flows, the predictability limits are flow dependent and we need to know them better (the estimates vary, some time significantly)

- what should be the DA strategy (e.g. methodology) when we expect that effects of very small assimilated scales will influence forecast for very short time, at least in a deterministic sense?
- also: what should be the related (and doable) observation strategies for assimilated time- and spatial scales: where to invest?(e.g. should we demand from EUMETSAT 100-200m resolution data in 10-20 year?)

Some problems we face …

- how to design probabilistic methods for reliable representation of statistical properties of the convective flow?

- Uboldi and Trevisan (2015) suggest that representation of probabilistic characteristics of ‘unstable convective space’, itself, is more complicated than for larger-scales:

  → the space has a flat spectrum of very large number of bred vectors with competitive growth rates

  → an attempt to strongly decrease the analysis error via increase of the number of members in an ensemble-based forecast (or assimilation scheme) may become very computationally demanding (if possible)

Some problems we face …

- With convection-permitting NWP we also aim for better representation of the interplay of convection with larger scales, beyond the limits of predictability of ‘smallest’-scale convection (as represented by a model)

- So, in principle we need a reliable probabilistic represention of the process of up- and downward energy (and error) cascade especially between smallest and largest model-represented scales, and especially of:

  → the process of convection organization

  → the process of downward propagation of relatively small larger scale errors and their feedback with convection

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Theoretical and practical aspects …

- More, we know very well that our ability for reliable data assimilation crucially depends on ability to represent probabilistic aspects of the flow

  → the two aspects (DA/EPS) are actually very strongly entangled, especially in the context of ensemble or hybrid data assimilation systems (COSMO LETKF!)

A practical example: the ‘right’ perturbation strategy?

- In practice, we are interested in using convection-permitting NWP for different time- (and space-) scales, e.g. for nowcasting and longer-term applications (like a day or even more)
- do the earlier considerations suggest strong scale-dependence of the perturbation strategies?

  → should the strategies be different for different applications (e.g. focusing on smaller scales for nowcasting and larger for longer-terms: note e.g. MeteoSwiss SPPT COSMO-E perturbations with scales of ~6h, ~300km)?

  → or, should the strategies be rather ‘unified’ and multi-scale?

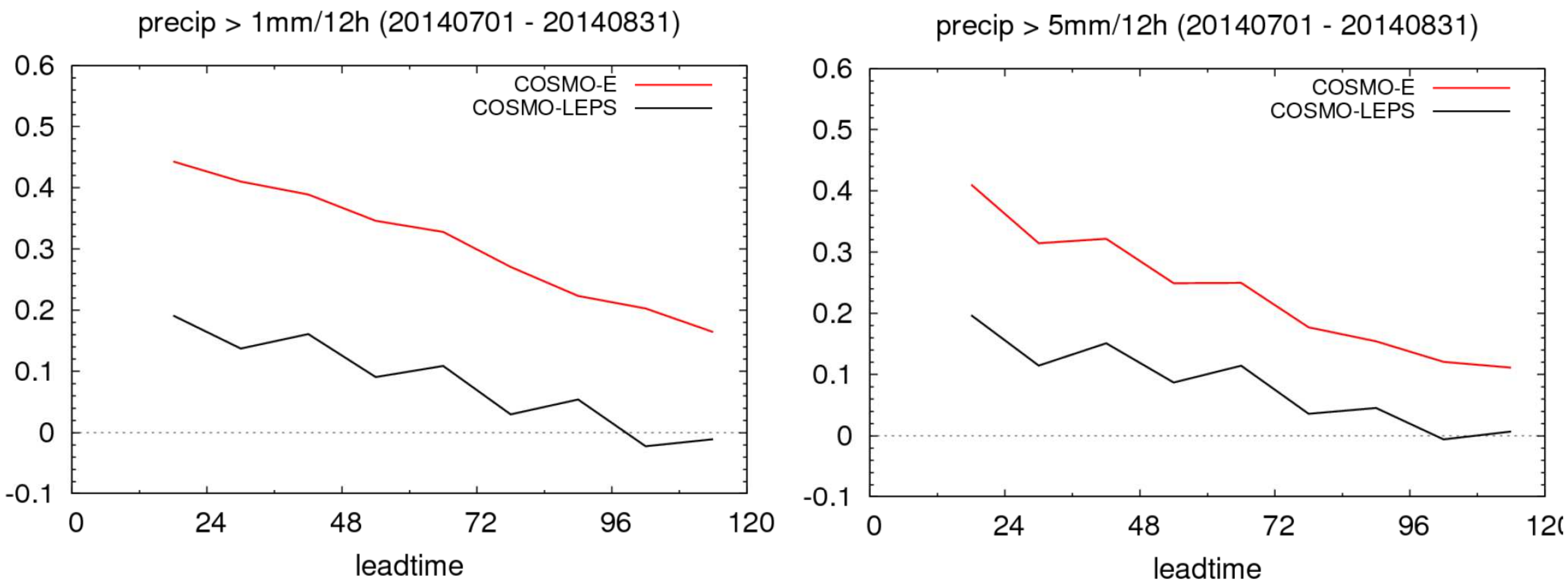
  → or, we need something very different …

We already have significant achievements in the area, as a good base for further developments:

Brier Skill Score (BSS)

skill wrt climatology (2001-2010) based on 300 stations

COSMO-E
COSMO-LEPS



- COSMO-E shows significant skill until end of forecast range
- clearly better than COSMO-LEPS, even though 9 grid-points averages used for both

Conclusions:

→ we are facing very interesting scientific challange of great importance for our community

→ within the consortium, we need a very good cooperation of practically all WGs to achieve a good progress

→ we need to communicate well and support ourselves

→ the scientific challanges call also for a wider cooperation, with Academia and with other partners

→ science is basically the dialog …

Thank you for attention!

Have a fruitful General Meeting

and every success in your work on development and improvement of COSMO modelling system!