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The price of hyper-resolved modelling

- Price: resources (human and technical)
- Uncertainty/Sensitivity analysis becomes more complex/impossible?
- Is the value in a single executed hydro-resolved model?
- Complexity increases by working in a coupled mode
- Can we improve a forecast by using uncertain hydrology (in contrast to increasing resolution)

Small scale processes, large scale prediction

- Land surface schemes: sophisticated in representation of mass & energy flux in surface and subsurface.
- Soil moisture is important for representing the climate system especially in summer seasons.
- Uncertainty in the atmosphere can be dealt with through the implementation of ensemble forecasts generated with perturbed initial conditions and stochastic physics.
- Uncertainty in the parameterisation of soil moisture (and other land surface) equations is not typically represented in these schemes.
- Parameterisation of soil moisture physics in land surface schemes is not straightforward. The land surface is extremely heterogeneous and difficult to parameterise. Many realistic parameter sets.

- **Land surface uncertainty could be represented by stochastic parameterisation**

Land surface hydrology parameterisation

ECMWF soils from FAO database

Within class heterogeneity – effects throughout forecast.
Soil physics uncertainty experiment: ECMWF seasonal forecasts

- 25 member ensembles
- Variations on Cycle 36R4 which is used in the operational model versions of the recently implemented System 4 (S4)
- Varying resolutions T159 / T255
- 4 month MJJA 1989-2008
- Perturbed soil physics in HITESSEL
- Also atmospheric stochastic physics turned on/off
- Comparison to GPCP corrected ERA interim
- Sensitive parameters are those which determine how active the soil hydrology is:
  - $K$ Hydraulic Conductivity
  - $\alpha$ van Genuchten parameter
  - Select from known distributions

<table>
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<th>Experiment label</th>
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<th>Atmospheric stochastic physics (SPE) and/or Soil Physics Perturbation (soil)</th>
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<td>Atmospheric stochastic physics and Soil Physics Perturbation (strong perturbation)</td>
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</table>

**Source Data:**
- **ERA40**
- **ERA-Interim**
- **GPCP corrected ERA-Interim (offline HITESSEL)**
Global land points, climatology of top layer soil moisture anomalies for JJA over the period 1989-2008.
Global land points, climatology of top layer soil moisture anomalies for JJA over the period 1989-2008.

T255 all off (yellow)

T155 all off (blue dash)

‘Control experiments’
Global land points, climatology of top layer soil moisture anomalies for JJA over the period 1989-2008.
Global land points, climatology of top layer soil moisture anomalies for JJA over the period 1989-2008.

T159 soil only

T159 soil only – moderate (blue)

‘Soil perturbation only’

T159 soil only - strong (yellow dash)
Global land points, climatology of top layer soil moisture anomalies for JJA over the period 1989-2008.

‘Combined atmospheric stochastic physics and soil perturbation’

- Higher resolution better
- Combined uncertainty experiment best
Time series correlation – 2m temperature (not anomaly)
Precipitation time series
### Brier Skill Score of seasonal forecast

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**BSS (∞) for the first season using 1991-2005 as the hindcast period**
Sobol sensitivities to soil parameter perturbations for global regions

2m temperature

Evaporation

Soil Moisture

Precipitation

Z500
Sobol Sensitivities (Main Effect) - Top Left Box: Stochastic Physics, bottom right: Parameter Uncertainty - Param: Temperature
Hyper resolved modelling: calibration of river parameters (example from N. America)

Bank Height
\[ B = M_b \times R^{EB} \]

Channel width
\[ W = M_w \times R^{EW} \]

River section
\[ (M_b + M_w) \times R^{(Eb + Ew)} \]

Original parameters
New parameters
Best simulations (correlation, MAE, NSE)

New parameters set:
Bootstrapping of the linear regression.

7 sets of parameters selected for each continent:
From the bootstrap: Mean Eb, Ew (exponential coefficients)
From the bootstrap: Mean Mb Mw +/- (25%, 50%, 75%) standard deviation of bootstrap

\[ R = \text{calculated from the river network map and climatology of daily runoff from the land surface model} \]
Hyper resolved modelling: Global forecasting

Forecasting example:
29/07/2010 - Pakistan
Hyper resolved modelling: HTESSEL

• Already set-up for multiple regions e.g. AMMA
• 1km/5km within next 5 years (not just scientific reasons e.g. representation of land sea and dynamic tiling)
• Coarse scale set-up will be retained
Conclusions

- Showed effects of soil physics parameter perturbations on forecasted summer surface variables using recent versions of the ECMWF seasonal ensemble forecasting system.

- Seasonal forecast variables are significantly sensitive to perturbations in soil moisture parameters.
  - Variability in 2 metre temperature, precipitation, soil moisture, (also evaporation, total column water vapour and Z500).

- Some evidence of improvement in seasonal forecasting skill:
  - Warm events in summer 2m temperature – global land points
  - Wet events in summer precipitation – global land points

- Climate behaviour of forecasts is maintained

- Not clear: increase resolution or increase uncertain representation

- ... despite this ECMWF will run a 1km land surface scheme within the next 5 years