ESSENCE

DEISA and the creation of a large ensemble of climate model runs

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• The project
• The conduction of the project
• Some results
Ensemble Simulations of Extreme weather events under Nonlinear Climate change (ESSENCE)

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- Steering Group: Michiel vd Broeke, Gerrit Burgers, Peter Jan van Leeuwen, Peter van Velthoven, Bart vd Hurk, Geert Jan van Oldenborgh & PI’s

Center for Climate Research
The Project

• A DECI/DEISA project

• Conducted jointly by KNMI and IMAU (Univ. Utrecht) within Centre for Climate Research

• Large model ensemble
  • Reduce weather noise
  • Better sampling of extremes

• Basic ensemble (1950-2100, SRES A1b) + 3 experiments
• ECHAM5/MPI-OM
Background

• greenhouse gases => climate change
• global-mean impact: simple
• local: partly obscured by noise (“weather”)
• large ensemble:
  • better signal-to-noise ratio
  • better sampling of extremes
The Task

**ECHAM5 (atmosphere model)**
- about 96 x 192 x 31 grid-points
- \((u,v,w), T, q\) + a lot of physics
- 6 cpu's

**MPI-OM (ocean model)**
- 254 x 220 x 41 grid-points
- \((u,v,w), T, S\)
- 1 cpu

**Coupler**
- 1 cpu

5-6 model years per day per run
~ 6000 model years performed
Technical organization

170,000 cpu hours on Stuttgart SX-8
(\(\sim 90\% \text{ finally used}\))
Data storage (\(\sim 50\) TB) at SARA (Amsterdam)
\((\text{distributed?})\)

model runs => output
output => postprocessing (I/O intensive)
postprocessed data => SARA
at SARA: data reorganization (I/O intensive)
=> final storage
Conducting the runs (1)

model runs => output
- SX-8
- 20 runs in parallel

output => postprocessing
- Itanium cpu
- limit: 4 (sometimes 8) jobs in parallel
- bottleneck

reduction to 8 parallel runs

human intervention necessary
Conducting the runs (2)

postprocessed data => SARA
no problem
at SARA: data reorganization
again I/O limitation
Experience

Short time between notification and start
  • a lot of time was lost for preparation
  • testing during project time
We were lucky: model was developed for SX-6
  (this played no role in assigning SX-8!)
I/O was the bottleneck,
sometimes disk storage, too
Recommendations

- have everything ready when “go” comes
- have a good picture of cpu usage and I/O
- application should be tested on different platforms before assigning computing centre
- don’t underestimate the extra effort of a “large” project
Some Results
Temperatures

(a) Essence ensemble vs. world averaged observations

(b) Essence ensemble vs. De Bilt observations
Do observed and modelled trends differ?

\[ t_{\text{obs}} / t_{\text{mod}} - \text{observed / modelled trend} \]

\[ \sigma_{\text{obs}} / \sigma_{\text{mod}} - \text{uncertainty in trend estimates} \]

\[ z = \frac{|t_{\text{mod}} - t_{\text{obs}}|}{\sqrt{\frac{\sigma^2_{\text{mod}}}{n_{\text{mod}}} + \frac{\sigma^2_{\text{obs}}}{n_{\text{obs}}}}} > 2.12 \]

\[ = 17 \quad = 1 \]

=> Sampling uncertainty from model negligible
z-val trend $T_{2m}$ (HadCruT3)
z-val trend $T_{2m}$ (ERA-40)
Significance of trends

time series: \( x(t_i), \quad i = 1, \ldots, n_t \)

regression line: \( \hat{x}(t_i) = a + bt_i \) (ens. average)

regression residuals: \( e(t_i) = x(t_i) - \hat{x}(t_i) \)

standard error of \( b \): \( s_b = \frac{s_e}{\sqrt{\sum (t_i - \bar{t})^2}} \)

variance of residuals: \( s_e^2 = \frac{1}{n_{\text{eff}} - 2} \sum e(t_i)^2 \) (ens. members)

t-value: \( t_b = \frac{b}{s_b} = b \sqrt{\frac{\sum (t_i - \bar{t})^2}{\sum e(t_i)^2 (n_{\text{eff}} - 2)}} > 1.96 \)

effective dof: \( n_{\text{eff}} = n_t \frac{1 - r}{1 + r} \cdot 17 \)
trend precip 1950–2100
Trend > noise, $T_{2m}$ (starting 1980)
Trend > noise, sea ice (starting 1980)
Increase in $T_{100}$ as multiple of increase in $T_{\text{mean}}$. 

Diagram showing map of the world with color gradients indicating the increase in $T_{100}$.
a) GEV-fit at 2°E, 42°N (Southern France)

- 2090–2099
- 2040–2049
- 1990–1999
- 1950–1959
- era40

Return Time / years
Conclusions

- large ensemble => noise reduced
- **local** temperature trend already detectable at some places
- temperature extremes increase harder than means
- temperature extremes may reach dangerous levels within this century
- model has problems with extreme temperatures

Andreas Sterl, DEISA course, Stuttgart, 07.03.2008