Turbulent Scales in the Boundary Layer: A Year-Long Large-Eddy Simulation

Jerôme Schalkwijk, Harm Jonker, Pier Siebesma
YOGA: A Year-Long Large-Eddy Simulation

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Topics

- Year of GALES (YOGA)
  - Set-up
    *Driven by regional model*
  - Computational aspects
    *Continuous year-long simulation using GPU Acceleration*
- Turbulence Spectra
  *Do we see a spectral gap?*
YOGA set-up (1)

Embedment in Large-Scale Weather model

Roel Neggers, Pier Siebesma and T. Heus, BAMS, sept 2012

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RACMO

SCM

LES

supersite

CESAR observational supersite

Horizontal advection

LS subsidence
YOGA set-up (2)
Continuous (un-interrupted) LES run

Jan 1 – Dec 31; 2012, Cabauw, the Netherlands.
YOGA runs
Model grid

Webcam

YOGA-HR
~(5 km)$^2$ x 3 km
25m x 25m x ~10m

YOGA
~(25 km)$^2$ x 25 km
100m x 100m x ~30m

Turbulence

Large scales

YOGA: A Continuous Year Of GALES
YOGA : Computational Numbers
Year of GALES & Year of GALES - HR

- 2 Non-stop year-long runs

<table>
<thead>
<tr>
<th></th>
<th>YOGA</th>
<th>YOGA-HR</th>
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<tbody>
<tr>
<td>Grid cells</td>
<td>$256^3$ (16M)</td>
<td>$194^3$ (7M)</td>
</tr>
<tr>
<td>Time steps</td>
<td>7M</td>
<td>16M</td>
</tr>
<tr>
<td>3D fields (if stored)</td>
<td>~2.5 PetaByte</td>
<td></td>
</tr>
<tr>
<td>Wall clock time</td>
<td>????</td>
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- How?
YOGA: A Continuous Year Of GALES

GALES

GPU-resident Atmospheric Large-Eddy Simulation

Acceleration

CPU

GPU

Advection

Surface

Routine 3

Routine 5

Routine 6

Routine 4
GALES

GPU-resident Atmospheric Large-Eddy Simulation

CPU

GPU

Residency

- Advection
- Surface
- Routine 3
- Routine 4
- Routine 5
- Routine 6

YOGA: A Continuous Year Of GALES
High-Performance Simulations of Turbulent Clouds on a Desktop PC: Exploiting the GPU

Schalkwijk, Griffith, Post & Jonker

March 2012

Result:
Time per time-step at $256^3$
24 CPUs: 2.6s
48 CPUs: 1.9s
1 GPU: 0.8s
YOGA : Computational Numbers
Year of GALES & Year of GALES - HR

- 2 Non-stop runs of
  *GPU-resident Atmospheric Large-Eddy Simulation*

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YOGA
Year of GALES & Year of GALES - HR
YOGA
Year-averaged time-series

- Good agreement
- YOGA-HR better resolves diurnal cycle of $u$

$z = 140m$
Van der Hoven Energy Spectrum

Power spectrum of variance in 100m wind

- Qualitative correspondence
- Spectral gap is visible!
  *But less pronounced and narrower*

Van der Hoven (1957)
Power Co-Spectra
Energy spectrum of turbulent transport

$q_t$

$\theta_l$

Gap Scale: 3-4hr

$\omega$ (Hz)

$E_{\text{avg}}(\omega)$

$z$ (m)
Concluding remarks

- It is now computationally feasible to perform >year LES runs. Statistics vs case studies.

- LES is capable of handling extremely diverse situations. From stable boundary layer to deep convection in 1 run.

- Qualitative spectrum of van der Hoven (1957) can be reproduced including presence of “spectral gap“.

- Spectral gap is also present in temperature/humidity co-spectra but is very large (~4hrs).

- YOGA dataset will be made available.
Thank you for your attention
Questions?