Single-Column Model

Introduction

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Modeling Basics

Prognostic quantity C described by an atmospheric model can be formally written as:

$$C = \bar{C} + c$$

$\bar{C}$ $\cdots$ part resolved by a model

c $\cdots$ the sub-grid component

Modeling Basics

Governing equations:

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numerics

physical processes

Modeling Basics

numerics $\rightleftarrows$ physical processes

- Atmospheric models: $L_x >> L_z$
- Numerics (3D): frequently separated to horizontal and vertical parts
- Physics: Horizontal component usually neglected
  $\rightarrow$ treated like independent columns

Testing approaches

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- Atmospherics model is a complex non-linear environment (numerical methods $\leftrightarrow$ large scale processes $\leftrightarrow$ diabatic processes,...)
- It is difficult to evaluate the impact of a single process of interest.
- A need to define alternative approaches to give more straightforward response: Academic simulations, LAM, 2D simulations, Single-column models
- Ideally testing environments offer faster response compared to the full environment.

Single-Column Model

Simplistic approach: Small scale processes are fully determined by inter-process ballance and large scale forcing:

numerics $\rightarrow$ physical processes

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$$\underbrace{\text{numerics}}_{\text{prescribed}} \rightarrow \underbrace{\begin{array}{c}\text{physical}\\ \text{processes}\end{array}}_{\text{evaluated}}$$

SCM equation

$$\frac{\partial \bar{C}}{\partial t} = \mathcal{D}_{\bar{C}} + \mathcal{P}_{\bar{C}} - \frac{\bar{C} - \bar{C}_0}{\tau}$$

$\mathcal{D}_{\bar{C}}$	$\cdots$	LS / dynamics tendency
$\mathcal{P}_{\bar{C}}$	$\cdots$	physics tendency
$\frac{\bar{C}-\bar{C}_0}{\tau}$	$\cdots$	relaxation term

Evolution of $\mathcal{D}_{\bar{C}}$ and $\bar{C}_0$ being prescribed.

Single-Column Model

Pros

- Stability is fully imposed by large scale forcing.
  - Easier to study physical processes interaction.
  - Allows to study subset of processes or single process only.
  - Allows to compare processes regardless the numerics (makes it easier to compare different physics packages).
- Computationally cheap.
- Substantial reduction of a problem size: Full data access is no longer an issue.

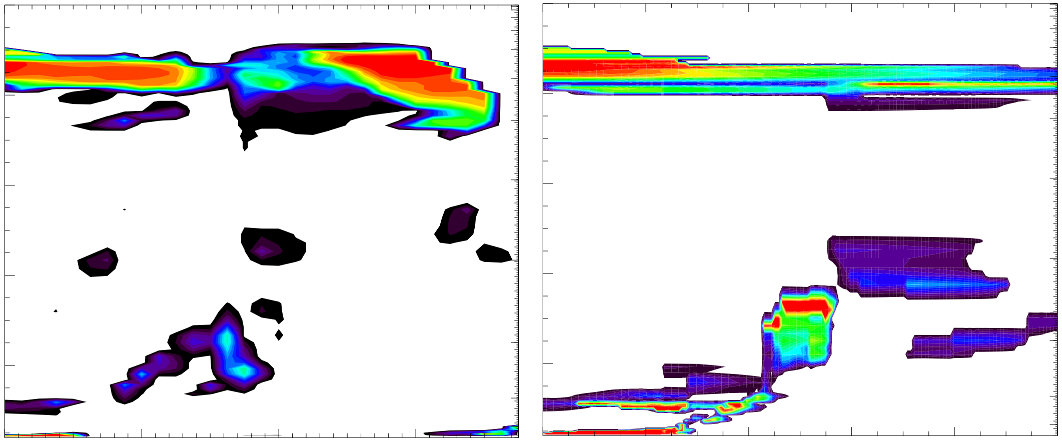
Single-Column Model

Cons

- SCM ballance can easily drift away from reality (missing SS $\rightarrow$ LS feedback), often leads to biased results.
- Results are very much related to the quality and setting of the LS forcing.
- Doesn't represent the direct 3D effect of some parameterizations (convection, flow interaction with orography,...).

Setting up new SCM experiment

- Create/extract initial and forcing profiles.
- Get/think about some reference.
- Tune the SCM forcing to get close to the desired performance.
- Only then explore the physics.



IFS SCM

SCM

- Developed originally as an independent tool using some routines from IFS (1994).
- Partially integrated to the IFS to share physics (2006) $\rightarrow$ phasing.
- Full integration: only minimal part remains specific to SCM, the rest (including modules) shares code with the full model (started 2012).

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Extraction tools

- Profiles created from archived files (ECMWF only, limitations).
- New tool to generate/store profiles during model integration.

Numerics of physics in IFS

- Sequential splitting of physical processes
- Dynamics $\rightarrow$

  $\rightarrow$ Radiation $\rightarrow$

  $\rightarrow$ Vertical diffusion + Sub-grid orography processes $\rightarrow$

  $\rightarrow$ Cloud_0 $\rightarrow$

  $\rightarrow$ Convection $\rightarrow$

  $\rightarrow$ Cloud $\rightarrow$

  $\rightarrow$ Non-orographic gravity wave $\rightarrow$

  $\rightarrow$ Methane oxidation, Surface parameterization, ozone chemistry...

Specific limitations for IFS SCM

- Radiation is computed within the entire column (effect of interpolation cannot be studied).
- Large scale tendencies diagnosed (FD) from one time step with minimum interval given by file storage frequency (1 hour).
- Vertical advection based on diagnosed quantity assuming horizontal homogeneity.
- No SL physics: 2^{nd} order accurate coupling of physics to dynamics through averaging of slow processes along the SL trajectory.

SCM-IFS versus (Open)IFS

- Specific library *scmec* is required to be linked with a sub-set of the IFS code.
- I/O file format is NetCDF.
- Building done by FCM.
- User interface and visualisation through MetView.
- Only available from CY38R2 (OpenIFS is related to CY38R1).

Conclusions

- SCM modeling is an efficient and simplistic tool to study model physics.
- Very useful for comparing different models or different versions of the same model.
- Quality strongly depends on large-scale forcing and SCM settings.
- Using SCM for tuning of physics is a delicate matter.
- Full 3D model gives best results.