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:

$$\frac{\partial \bar{X}}{\partial t} = \underbrace{\mathcal{D}_{LS}(\bar{X})}_{\text{resolved}} + \underbrace{\mathcal{F}_{SS}(\bar{X}) + S_i}_{\text{parametrized}}$$

numerics

physical processes

Modeling Basics

numerics $\rightleftarrows$ physical processes

- Atmospheric models: $L_x >> L_z$
- Numerics: 3D problem (frequently separated to horizontal and vertical parts)
- Physics: Horizontal component usually neglected
  $\rightarrow$ treated like independent columns (1D)

Testing approaches

- 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, linear analyses, Single-column models,...
- Ideally testing environment offers faster response compared to the full model.

Single-Column Model

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

numerics $\rightarrow$ physical processes

SCM equation

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

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

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

Numerics of physics in IFS

- Sequential splitting of physical processes
- Dynamics (prescribed+resolved) $\rightarrow$
  $\rightarrow$ 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 parametrization, ozone chemistry...

Setting up new SCM experiment

- Create/extract initial and forcing profiles.
- Get/think about some reference.
- Tune the SCM forcing to give satisfactory results.
- Only then explore the physics.

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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 of LS forcing.
- Doesn't represent the direct 3D effect of some parametrizations (convection, flow interaction with orography,...).

Specific limitations for IFS SCM

- Currently only u, v, T and q_v could be updated by LS forcing.
- Radiation is computed within the entire column (effect of interpolation cannot be studied).
- Only vertical advection is computed, horizontal advection is being prescribed.
- Second order accurate coupling of physics to dynamics through averaging of slow processes along the SL trajectory only applied through the available 1D trajectory.

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 setting.
- Comparing with observation is a delicate matter.
- Full 3D model gives best results.