Single-Column Model

Introduction

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Modeling Basics

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

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

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

$c$  ... the sub-grid component
Modeling Basics

Governing equations:

\[
\frac{\partial \bar{X}}{\partial t} = \mathcal{D}_{LS}(\bar{X}) + \mathcal{F}_{SS}(\bar{X}) + S_i
\]

- resolved
- parametrized

numerics

physical processes
Modeling Basics

numerics ⇔ physical processes

• Atmospheric models: $L_x \gg L_z$

• Numerics: 3D problem (frequently separated to horizontal and vertical parts)

• Physics: Horizontal component usually neglected → treated like independent columns (1D)
Testing approaches

- Atmospherics model is a complex non-linear environment (numerical methods ↔ large scale processes ↔ 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.
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Simplistic approach: Small scale processes are fully determined by inter-process balance and large scale forcing:

numerics $\rightarrow$ physical processes
SCM equation

\[ \frac{\partial \bar{C}}{\partial t} = D \bar{C} - \alpha \frac{\bar{C} - \bar{C}_0}{\tau} + P \bar{C} \]

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

Evolution of \([D \bar{C}]_{\text{hor}}\) and \(\bar{C}_0\) being prescribed.
Numerics of physics in IFS

- Sequential splitting of physical processes

- Dynamics (prescribed+resolved) →
  → Radiation →
  → Vertical diffusion + Sub-grid orography processes →
  → Cloud$_0$ →
  → Convection →
  → Cloud →
  → Non-orographic gravity wave →
  → 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.
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Cons

• SCM balance 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.