Single-Column Model

Introduction

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Modeling Basics

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

$$C' = ar{C} + c$$

$ar{C}$ \cdots part resolved by a model

$c$ \cdots the sub-grid component
Modeling Basics

Governing equations:

$$\frac{\partial \bar{X}}{\partial t} = D_{LS}(\bar{X}) + F_{SS}(\bar{X}) + S_i$$
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resolved  \hspace{1cm} \text{parametrized}
Modeling Basics

Governing equations:

\[ \frac{\partial \bar{X}}{\partial t} = D_{LS}(\bar{X}) + F_{SS}(\bar{X}) + S_i \]

resolved \quad \text{parametrized}

numerics \quad \text{physical processes}
Modeling Basics

numerics ⇄ physical processes

• Atmospheric models: $L_x >> L_z$

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

• Physics: Horizontal component usually neglected → treated like independent columns
Testing approaches

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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, Single-column models
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Simplistic approach: Small scale processes are fully determined by inter-process balance and large scale forcing:

numerics \rightarrow \text{physical processes}
SCM equation

\[ \frac{\partial \tilde{C}}{\partial t} = \mathcal{D}_{\tilde{C}} + \mathcal{P}_{\tilde{C}} - \frac{\tilde{C} - \tilde{C}_0}{\tau} \]

\(\mathcal{D}_{\tilde{C}}\) \hspace{1cm} \ldots \hspace{1cm} \text{LS / dynamics tendency}

\(\mathcal{P}_{\tilde{C}}\) \hspace{1cm} \ldots \hspace{1cm} \text{physics tendency}

\(\frac{\tilde{C} - \tilde{C}_0}{\tau}\) \hspace{1cm} \ldots \hspace{1cm} \text{relaxation term}

Evolution of \(\mathcal{D}_{\tilde{C}}\) and \(\tilde{C}_0\) being prescribed.
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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
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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,...).
Numerics of physics in IFS

- Sequential splitting of physical processes
- Dynamics →
  → Radiation →
  → Vertical diffusion + Sub-grid orography processes →
  → Cloud$_0$ →
  → Convection →
  → Cloud →
  → Non-orographic gravity wave →
  → Methane oxidation, Surface parametrization, ozone chemistry...
Specific limitations for IFS SCM

- Radiation is computed within the entire column (effect of interpolation cannot be studied).
- Vertical advection is diagnosed (horizontal homogeneity is assumed).
- No SL physics: $2^{nd}$ order accurate coupling of physics to dynamics through averaging of slow processes along the SL trajectory.
Conclusions

• SCM modeling is a 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.
• Comparing with observation is a delicate matter.
• Full 3D model gives best results.