Single-Column Model *Introduction*

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Modeling Basics

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

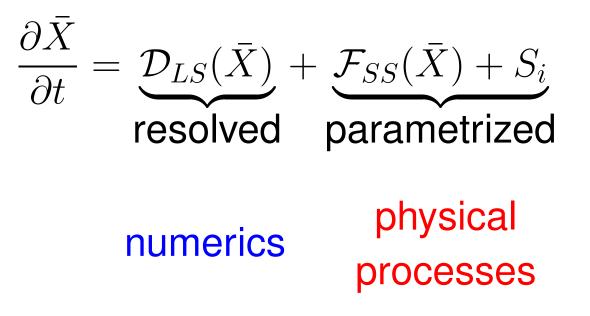


- $\bar{C} \cdots$ part resolved by a model
- $c \cdots$ the sub-grid component



Modeling Basics

Governing equations:





Modeling Basics

numerics \rightleftharpoons physical processes

- Atmospheric models: $L_x >> L_z$
- 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.



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

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

- $\begin{array}{lll} \mathcal{D}_{\bar{C}} & \cdots & \mathsf{LS} \, / \, \mathsf{dynamics tendency} \\ \alpha \frac{\bar{C} \bar{C}_0}{\tau} & \cdots & \mathsf{relaxation term} \\ \mathcal{P}_{\bar{C}} & \cdots & \mathsf{physics tendency} \end{array}$

Evolution of $[\mathcal{D}_{\bar{C}}]_{hor}$ and C_0 being prescribed.



Numerics of physics in IFS

- Sequential splitting of physical processes
- Dynamics (prescribed+resolved) ightarrow
 - $\rightarrow \text{Radiation} \rightarrow$
 - \rightarrow Vertical diffusion + Sub-grid orography processes \rightarrow
 - $\rightarrow \text{Cloud}_0 \rightarrow$
 - ightarrow Convection ightarrow
 - $\rightarrow \text{Cloud} \rightarrow$
 - \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.



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.

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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.