Anatomy of a Successful Parameterization from a Modeler's Point of View

Philip Cameron-Smith

Lawrence Livermore National Lab.

edited by W. Wiscombe to just focus on generic advice about parameterizations

Parameterizations take a long time to mature, and need to be simple

- GCM = Dynamics + parameterizations
- 10 years/day, 1 CPU, 1 Gflop, 100 km res.
  → only 3 operations/parameterization!
- Generally takes years for parameterization to become part of IPCC runs. Steps:
  - Observations
  - Box or column model
  - Off-line model
  - GCM
  - Battle with other parameterizations (bake-off)
- Parameterizations need an <u>advocate</u> to succeed

Good computer-science is required

- Important effect on GCM
- Fast
- Scalable
- Moderate data requirements
- Well coded and documented:
  - Fortran90
  - Comments in code
  - Formal documentation
  - Low-dimensional stand-alone code

Parameterizations must be valid for ALL possible inputs

- Applicable everywhere on Earth
- Applicable for altered climates
  - Physically based.
- Operates on many GCM scales
  - (10-1000 km; minutes to millenia)
- Uses available quantities
- Consistent with other parameterizations
- Well validated
  - Validatable inside GCM
- Few tunable parameters (zero is ideal)

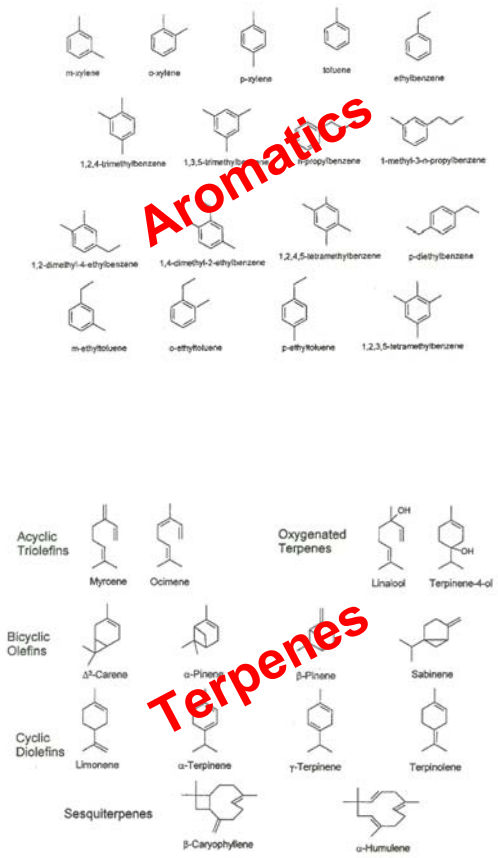
Tuning is like “the Force”: it has good and bad sides, and it holds GCMs together

Tuning

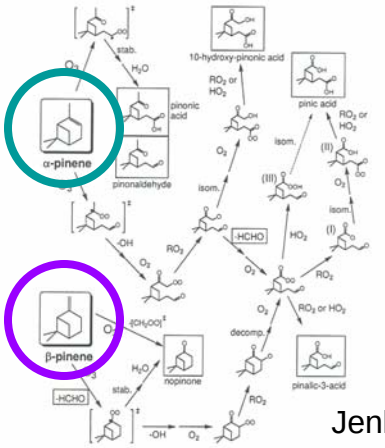
- Measurement in a high dimensional chaotic space
  - Single Pendulum = Elementary Physics
  - Double Pendulum = Chaos
- Implicit & explicit tuning
  - Explicit = Find parameter values to best fit obs.
  - Implicit = Choose parameterization that gives best GCM fit to obs. (ie, includes compensating errors)
  - Implicit = Stop looking for bugs when fit to obs. is good.
- Climateprediction.net
- Automatic differentiation

The formation of secondary organic aerosols (SOAs) in global models requires parameterization

Many precursors → Each can react with OH, NO_3, O_3 to form many products…. → Which can be represented by a set of two product reactions….



Seinfeld & Pankow



Jenkin

Fig. 1. Schematic representation of the formation routes of C_9 and C_{10} acid products and the major carbonyl products (HCHO, pinonaldehyde and nopinone), following the ozonolysis of α- and β-pinene, as applied in the present work. The stable products are shown in boxes.

O_3 + α-pinene,

O_3 + β-pinene

(1550 rxn; 520 species)

(1) VOC + O_3 →

$a_1P_1 + a_2P_2$ + HVP

(2) $P_1 + O_3$ →

$b_1P_3 + b_2P_4$ + HVP

…….

(n) ……..

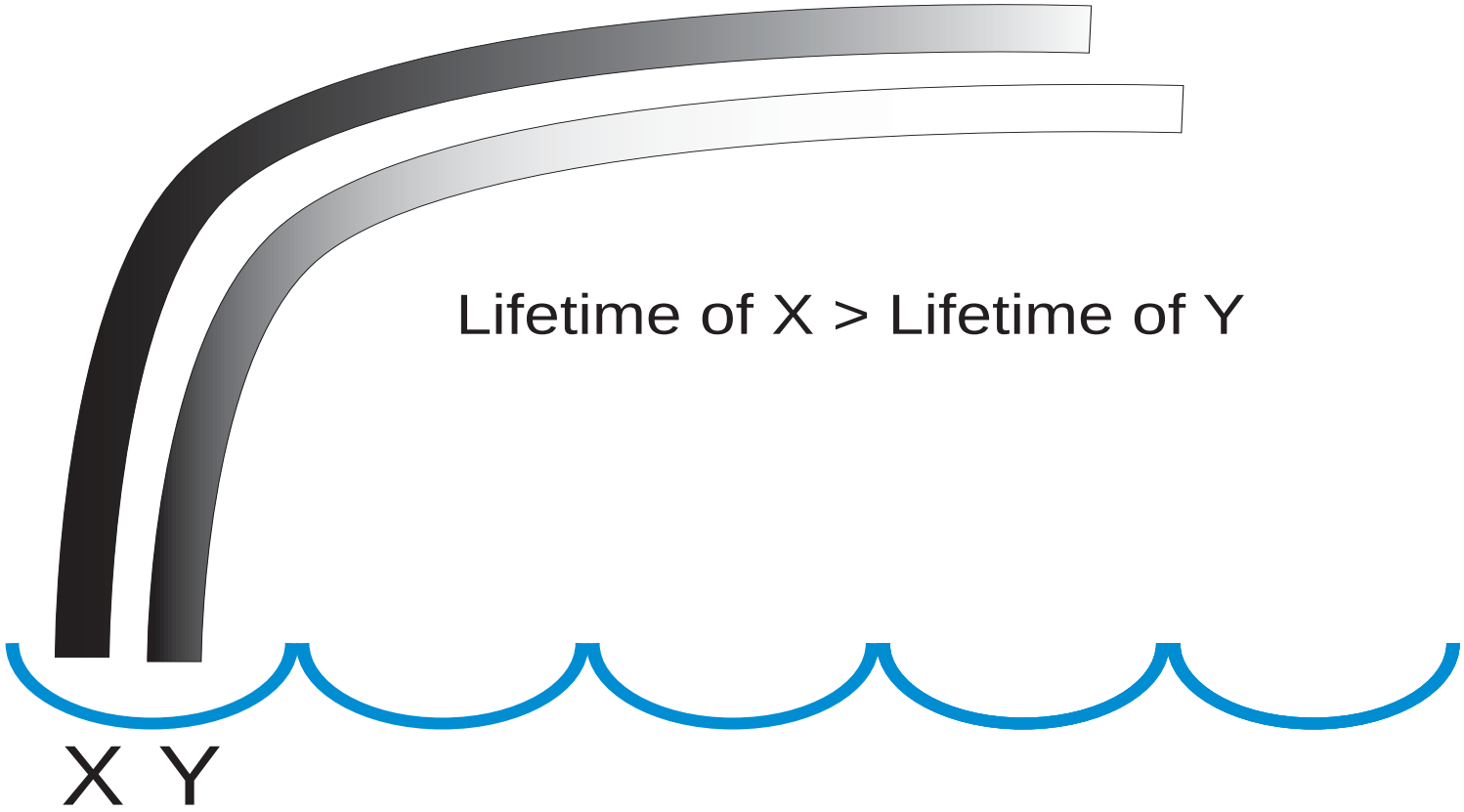
P_n = low vol. product

HVP = highly vol. product

Tracers offer alternative constraints on physical processes

- Physical processes move physical quantities,
  - Heat, momentum, vorticity, and moisture.
- Physical processes move tracer quantities,
  - Chemicals and aerosols.
- Some processes affect physical quantities and tracers similarly (*e.g.* advection), and some processes do not (*e.g.* photo-chemical reactions).
- Hence, tracers can offer new insights and constraints on physical processes, especially emergent properties.
- Ideally a tracer will isolate a single process, but unfortunately this is rare.
- Tracers can be run with feedback on or off.

Species with different lifetimes can provide clock giving “time since emission”



Summary

Anatomy of good parameterization:

- Important for climate,
- Widely applicable, (all regions, epochs, time scales and space scales)
- Fast (scalable),
- Documentation (in-code and formal),
- Standalone test-case,
- Validated (including inside GCM).
- Few tunable parameters (idealy zero).

Good parameterizations still need an advocate.

Current parameterizations pack a lot into small packages.

I believe tracers will have a tough but crucial role validating GCMs, especially emergent properties.