Moist Processes

generalities

Plan of the lecture

- Definition of moist variables in the model
- Evolution by transport
  - ☐ Resolved and Parameterized
  - ☐ Treatment of negative values due to transport
- Evolution by processes
  - ☐ Resolved and Parameterized
  - ☐ Prognostic and diagnostic schemes: ascending operational compatibility
- Parallel and cascading approach: APLPAR structure
- Cloudiness (from here and there, for this and that)

Moist Variables (ALARO-0)

We consider air parcel with mass ratios of dry air and five water species:

q_d	Dry air
q_v	Water vapor ratio (spectral for the time-being)
q_l	Suspended liquid water
q_i	Suspended solid water
q_r	Falling liquid phase: rain
q_s	Falling solid phase: snow and other possible sub-types: hail, graupel, …

Ratios = mass-weighted framework, due to mass-type vertical coordinate
(unifying HPE, NH-EE and also deep atmosphere cases, see Catry et al. 2007)

Evolution by resolved transport: 3D advection by the dynamics

Semi-Lagrangian advection:

What kind of interpolators:
- high-order precision (32-point cubic polynomials);
- quasi-monotonous;
- other

Possibility to apply the SLHD diffusion scheme:
- currently done on water vapor and suspended species; not on falling species

Water vapor is still a spectral variable, which is not fully consistent with the other water species: need to go for RT as spectral variable (LSPRT option) and compute horizontal gradient of water vapor for convection closure.

Parametrized transport (1/2)

Divergence of diffusive fluxes: PDIFXV

Vertical diffusion (ACDIFUS); X='T' as for turbulence

thermodynamic variables V= 'Q' (vapor), 'T' and 'S' (enthalpy)

Transport of moist conservative variables (LDIFCONS):

$$q_t = q_v + q_l + q_i$$

-Transport of total water content and moist equivalent enthalpy

When no cloudiness (PNEBDIFF=0), then suspended water species are not transported: PDIFTQL=PDIFTQI=0

Parametrized transport (2/2)

Transport by convective up draught (ACCVUD);

Transport by convective down draught (ACMODO):

Fluxes PDIFCV

with ‘C’ standing for Convection

and thermodynamic variables V= ‘Q’, ‘QL’,’QI’, and ‘S’

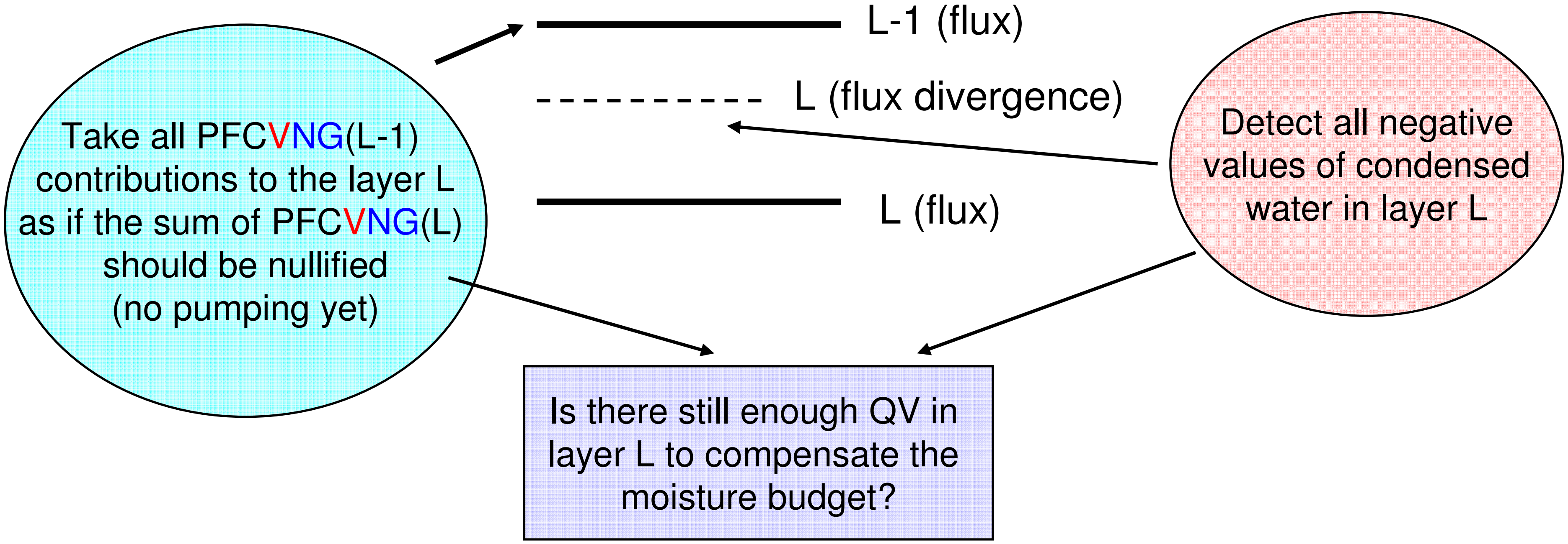
The ‘old’ convective parameterization ACCVIMP transports only ‘Q’ and ‘S’ (environment without condensates)

Treatment of negative values (1/3)

Each transport process can cause negative values of QV, QL, QI, QR, QS

Corrections are taken into the budget via the fluxes PFCVNG

The first correction: at the beginning of APLPAR
(after previous dynamical advection step)



L-1 (flux)

L (flux divergence)

L (flux)

Take all PFCVNG(L-1) contributions to the layer L as if the sum of PFCVNG(L) should be nullified (no pumping yet)

Detect all negative values of condensed water in layer L

Is there still enough QV in layer L to compensate the moisture budget?

Treatment of negative values (2/3)

Is there still enough QV in layer L to compensate the moisture budget?

YES

Update QV, QL, QI, QR, QS: if there was some negative value, QV diminishes and the negative species ratios are set to zero. The corrections update the PFCVNG (L) at the bottom of the layer. The sum of PFCVNG(L) is zero

No

QV is set to zero. Other negative species are also set to zero. Fluxes PFCVNG (L) at the bottom of the layer are updated, but their sum remains negative: QV of the layer could not compensate and the difference is pumped from the layer L+1 below.

Treatment of negative values (3/3)

After turbulent transport (ACDIFUS):

- Divergence of PDIFTV fluxes gives the contribution to the evolution. This can lead to negative values for QV but also for QL and QI when these are transported. But the update of PFCVNG fluxes is coded for all three of them: QV, QL and QI in an incremental way.

- Caution: in the current code the update of variables after turbulence (3MT case) is coded in the same loop like the correction of negative values: these are two distinct issues!

After up draught (ACCVUD; 3MT only):
-Update of T, QV, QI, QL
and correction of negative values and fluxes is done for QV, QL, QI.

After down-draught (ACMODO; 3MT only):
Just negative correction fluxes are updated, values not any more (last process).

Evolution by thermodynamics

- So-called resolved processes (microphysics):
  - In cloud condensation/evaporation.
  - Auto-conversion from suspended condensates to precipitating condensates.
  - Collection of suspended water by falling species.
  - Evaporation/melting-freezing of precipitating condensates.
  - Sedimentation of precipitating condensates (interaction with auto-conversion, collection, evaporation/melting-freezing)
- Convective processes:
  - Condensation by up-draught.
  - Evaporation/melting of precipitating condensates by down-draught. But what about the ‘convective’ sedimentation?

Definition of pseudo-fluxes for interfacing

- Processes with pseudo-fluxes:
    - Condensation/evaporation in cloud: PFCSQL/N, PFCCQL/N
    - Auto-conversion & collection: PFPFPSL/N, PFPFPCL/N
    - Evaporation/melting of precipitating species: PFPEVPSL/N, PFPEVPCL/N
- Divided into ‘resolved’ and ‘convective’ and to ‘liquid’ and ‘solid’ phase for all categories

What are pseudo-fluxes

- Pseudo-fluxes are the flux-dimensioned vertical integrals of the various moisture rate of changes (twelve of them).
- Together with the ‘real’ precipitation fluxes, they offer a simple and homogeneous writing for the budget equations of moisture species and enthalpy (see Catry et al., 2007)

Example of evolution of rain

Auto-conversion and collection pseudo-flux

$$\frac{d\,q_r}{dt} = g\frac{\partial}{\partial p}\left[PFPFPSL + PFPFPCL\right]$$

Evaporation (melting/freezing) pseudo-flux

$$-g\frac{\partial}{\partial p}\left[PFPEVPSL + PFPEVPCL\right]$$

Precipitation flux

$$-g\frac{\partial}{\partial p}\left[PFPLSL + PFPLCL\right]$$

There is also flux of corrections due to negative values

Prognostic and diagnostic schemes

- Not all ‘precipitation’ routines compute the pseudo-fluxes (ACPLUIE, ACCVIMP)
- With prognostic condensates and falling precipitations we have a mixed situation: resolved pseudo-fluxes are computed by the microphysics, while convective pseudo-fluxes are either not (ACCVIMP), or partly only (3MT routines or ACVIMPGY – one scheme of climate model)
- Messy situation in APLPAR -> now all routines should compute the pseudo-fluxes (since last phasing)

Ascending compatibility

ACPLUIE (diagnostic scheme): PFCSQL/N = PFPFPSL/N = PFPLSL/N
condensation=auto-conversion=precipitation
Evaporation of precipitating species counted in PFPLSL/N: PFPEVPSL/N=0.

ACCVIMP (diagnostic scheme): PFCCQL/N = PFPFPCL/N = PFPLCL/N
condensation=auto-conversion=precipitation
No explicit evaporation of precipitating species: PFPEVPCL/N=0.

ACCDEV (prognostic scheme): PFCSQL/N is computed

APLMPHYS (prognostic scheme): PFCSQL/N, PFPFPSL/N, PFPEVPSL/N
are computed

L3MT (prognostic scheme): PFCCQL/N computed in ACCVUD (up draught)
PFPFPCL/N=0: all auto-conversion & collection
is computed in APLMPHYS
PFPEVPCL/N in ACMODO (down draught)

Parallel and cascading approach

- APLPAR (standard): processes are called in parallel (each called process works with T, QV, QL, QI, QR and QS)
- In 3MT scheme we introduced cascade:

  There are local variables ZT, ZQV, ZQL, ZQI, ZQR, ZQS : they are updated after transport and/or processes.

  But T, QV, QL, QI, QR and QS are updated by the sum of all fluxes afterwards, as usual (CPTEND_NEW)
- This amounts to something intermediate between parallel and sequential

Cloudiness: the use

- For radiative computations: cloud cover and cloud water content, liquid and solid. It is also ZQL and ZQI but not necessarily the same as computed by the microphysics; it has to account also for convective cloudiness.
- For turbulent diffusion scheme (LDIFCONS; ZNEBDIFF).
- For the resolved condensation rates
- For the microphysical computations, when cloud geometry is taken into account

Cloudiness: way of computations

- Resolved cloudiness: concept of ‘critical relative humidity’
  - ACNEBCOND => input to (ACDIFUS), ACCDEV, APLMPHYS. It has options of Xu-Randall type or Smith type
  - ACNEBN => input to ACRANEB. It combines the resolved and convective cloudiness computations
- Convective cloudiness:
  - ACCVIMP => diagnosed from precipitation divergence
  - 3MT => computed in ACCVUD

Cloudiness – some rationalization?

- In APLPAR: many ZNEBxxx; need to do something
- First steps:
  - routine ACNEBCOND unifying the cloudiness computation for the condensation scheme used in 3MT or LSTRAPRO; input for ACDIFUS
  - Externalization of computations of partial cloudiness in to a separate routine ACNPART (previously part of ACNEBN)
- Next steps:
  - verify what lo leave in ACNEBN (ideally just the computation of the total cloudiness cover and its water content to be used in radiation)
  - Unified framework for convective cloudiness?

Conclusions

- Arrival of new prognostic schemes complicates the code
- Effort is needed
  - To offer at the same time the test-bed to try various ideas of the schemes (modularity)
  - To obey to a general set of equations determining the interface to the dynamical core (not to go either to a completely uncontrolled situation with lot of potential bugs or to kill any other/new approach)
- This is partly done, but continuation of this strategy is absolutely necessary