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Coupling WRF with a Lagrangian particle dispersion model that includes a scale-aware cumulus parameterization

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Introduction

- Greenhouse gas emissions can be inferred by combining atmospheric receptor measurements with a Lagrangian particle dispersion model (LPDM), e.g., the Stochastic Time-Inverted Lagrangian Transport model (STILT; Lin et al. 2003). See also companion poster P40 (Henderson et al. 2016)
- STILT requires several meteorological variables from an NWP model, the most important being the horizontal and vertical wind components. Moist convective mass fluxes provide additional realism to the NWP-based meteorological depiction supplied to STILT, leading to a reduction in LPDM transport errors over models that use simple advection
- Moist convective mass fluxes from earlier versions of WRF (v2.1.2, and more recently v2.2 and v3.0) using the Grell and Devenyi 2002 (GD2002) cumulus parameterization were provided to STILT through an interface described by Nehrkorn et al. 2010. However, GD2002 will soon be deprecated in WRF v3.5, thus requiring an update to the WRF-STILT coupling in order to accommodate a new cumulus parameterization
- This poster describes WRF model changes being implemented to couple STILT with the scale-aware convective parameterization described in Grell and Freitas 2014 (GF2014) and outlines a plan to demonstrate the performance of the updated WRF-STILT model

Process

- The procedure to develop, test, and evaluate the updated WRF-STILT coupling between WRF-ARW v3.8 and GF2014 is analogous to that described in Nehrkorn et al. 2010
  - ➢ Identify convective mass flux terms in GF2014 required by STILT
  - ➢ Compute time-averaged terms, as required
  - ➢ Modify **module_cu_gf.F** to store and write out required mass flux terms (example in accompanying panel)
  - ➢ Other functions of the interface, such as time-averaging and I/O remain unchanged from the earlier modifications of Nehrkorn et al. 2010
- Inspect convective mass flux quantities for proper mass conservation (see Performance Verification)
- Test the WRF convective mass fluxes in STILT on a sample case
  - ➢ Case selected for use with this work (Fig. 1), centered over South America (outer domain), with inner nest centered over Brazil

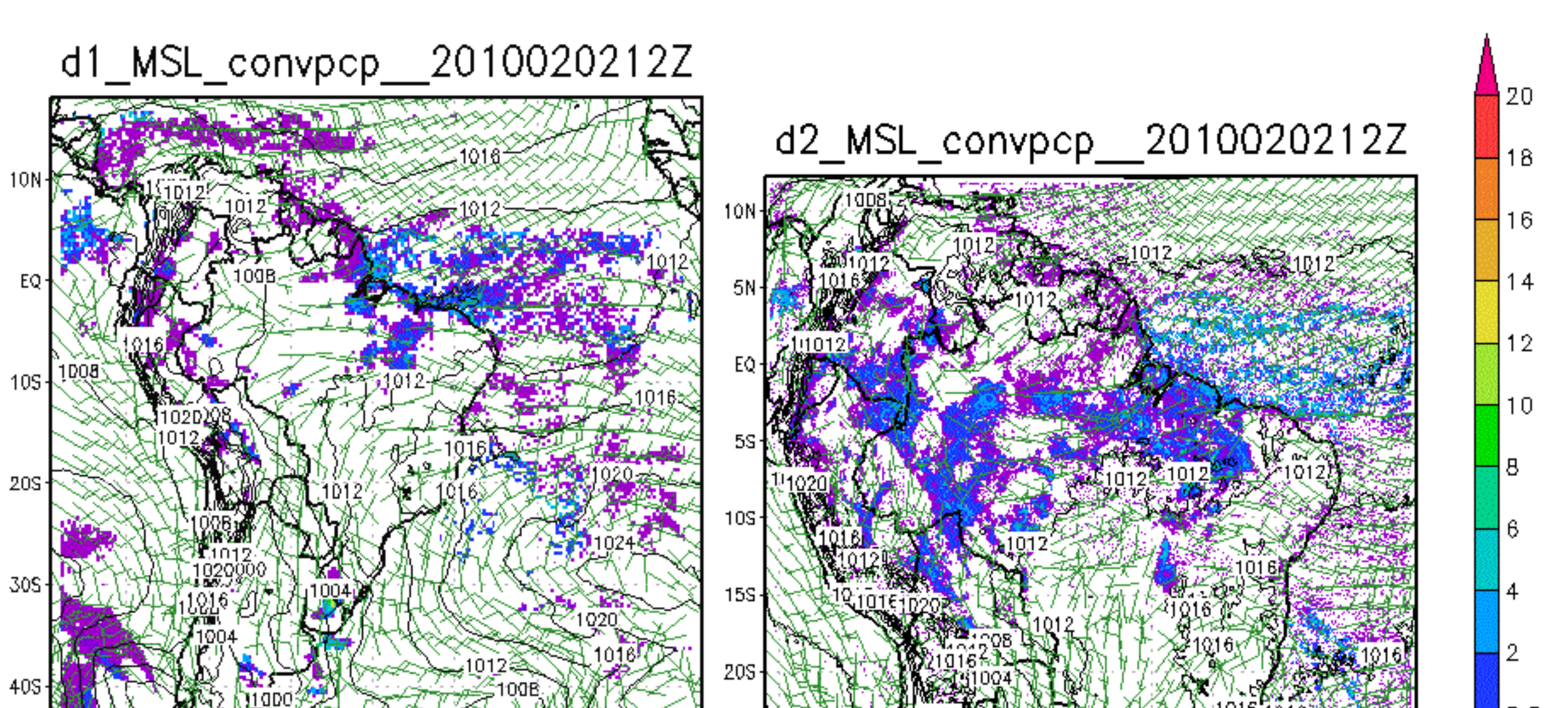

Fig. 1 – 12-hr forecast mean sea-level pressure (hPa), convective precipitation rate (mm/hr, shaded), and 10-m winds (full barb = 10 kts) valid 12 UTC 02 February 2010 in the outer (left) and inner (right) domains. Grid spacing is 36 and 12 km for domains 1, and 2, respectively.

WRF-STILT Interface

- GF2014 computes the mass fluxes in Fig. 2 as part of the of convectively induced tendencies of the environment; the fluxes, in turn, are provided to STILT through the interface:
  - ➢ vertical mass flux within the convective up/downdrafts (provided at full η levels)
  - ➢ entrainment/detrainment of mass between environment and up/downdrafts (provided at half η levels)

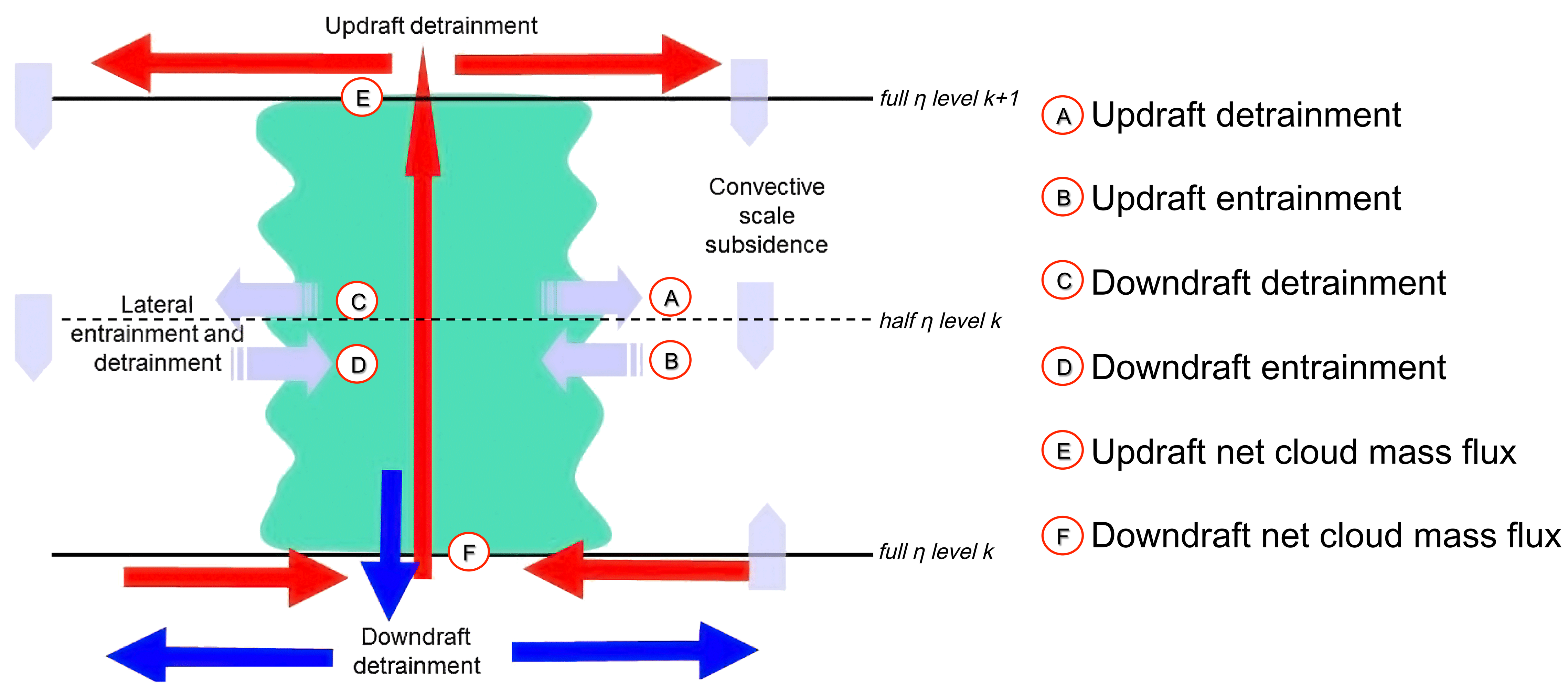

Fig. 2 – Conceptual picture of convective cloud and related fluxes from GF2014 that are passed to STILT. (After Grell and Freitas 2014)

```
        do k=kts+1,ktop(i)
! these three are only used at or near mass detrainment and/or entrainment levels
          entupk=0.
          detupk=0.
          entdoj=0.
! detrainment and entrainment for fowndrafts
          detdo=edto(i)*dd_massdetro(i,k)
          entdo=edto(i)*dd_massentro(i,k)
! entrainment/detrainment for updraft
          entup=up_massentro(i,k)
          detup=up_massdetro(i,k)
! subsidence by downdrafts only
          subin=-zdo(i,k+1)*edto(i)
          subdown=-zdo(i,k)*edto(i)
!
!       SPECIAL LEVELS
!
          if(k.eq.jmin(i))then
            entdoj=edto(i)*zdo(i,k)
          endif
          if(k.eq.ktop(i))then
            detupk=zuo(i,ktop(i))
            subin=0.
            subdown=0.
            detdo=0.
            entdo=0.
            entup=0.
            detup=0.
          endif
          if (l_flux) then
! z_cup(k+1):     zuo(k+1), -zdo(k+1) ==> subin   ==> cf[du]1   (k+1)  (full-eta level k+1)
!
! z(k)      :     detup, detdo, entup, entdo    ==> [de]f[du]1 (k)  (half-eta level  k )
!
! z_cup(k) :      zuo(k), -zdo(k)     ==> subdown ==> cf[du]1    (k)  (full-eta level  k )

! Store downdraft/updraft mass fluxes at full eta level k (z_cup(k)) in cf[ud]1(k):
     O  cfu1(i,k+1)  = zuo(i,k+1)
        cfd1(i,k+1)  = -edto(i)*zdo(i,k+1) O
! Store detrainment/entrainment mass fluxes at half eta level k (z(k)) in [de]f[du]1(k):
     O  dfu1(i,k) =  detup+detupk
        efu1(i,k) = -(entup+entupk) O
     O  dfd1(i,k) =  detdo
        efd1(i,k) = -(entdo+entdoj) O
          endif
```

Fig. 3 – Excerpted code from subroutine CUP_gf showing highlighted modifications used to store convective fluxes computed by GF2014 and their relation to Fig. 2

Performance Verification

- *Mass conservation*
  - ➢ In GF2014 the vertical profiles of the normalized up/downdraft mass fluxes are controlled by the fractional entrainment and detrainment
  - ➢ Any net gain (loss) of parameterized cloud mass through the up/downdraft not balanced by lateral entrainment/detrainment must also be accompanied by compensating convective-scale subsidence (uplift)
  - ➢ Therefore, the following terms represented in Fig. 2 (also highlighted in the code excerpt in Fig. 3) should sum very close to zero, indicating mass conservation:

$$\text{totmas} \equiv Ⓔ - Ⓕ + Ⓐ + Ⓒ - Ⓑ - Ⓓ \leq 1\times10^{-6}$$

  - ➢ Also verify mass conservation of time-averaged values of the convective fluxes
- *STILT performance*
  - ➢ Sensitivity of WRF-STILT results to selection of GD2002 vs. GF2014
  - ➢ Sensitivity of WRF-STILT results to changes in horizontal spatial resolution in terms of differences between results provided by outer vs. inner WRF model grids (Fig. 1)

References

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