

A large, white, fluffy cloud is shaped like a unicorn, complete with a single horn pointing upwards. The cloud is set against a clear blue sky. The text is overlaid on the image.

A Unified Convection Scheme : 'UNICON'

AMWG Meeting. NCAR. Boulder.
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Sungsu Park

AMP. CGD. NESL. NCAR. Boulder. CO.

*“ The **Unicorn** is the only fabulous beast that does not seem to have been conceived out of human fears. He is **fierce** yet **good** , **selfless** yet **solitary** , but always mysteriously **beautiful**. He could be captured only by unfair means, and his single horn was said to **neutralize poison** ”.* From the ‘*The Unicorn and the Lake*’ by Marianna Mayer.

Major Remaining Issues in the Parameterization of Convection

- I. Unified Treatment of *Shallow* and *Deep* Convection
- II. Unified Treatment of *Dry* and *Moist* Convection
- III. Unified Treatment of *Forced* and *Free* Convection
- IV. Treatment of *Downdraft Dynamics*
- V. Parameterization of *Lateral Mixing*
- VI. Formulation of *Self-Consistent Closure*
- VII. *Cloud Overlap* for Microphysics, Radiation, and Aerosol Wet Deposition
- VIII. *Microphysics* interacting with *Aerosols*
- IX. Convection across the *Scale Barrier*

- Some important 'features' (possibly) associated with convection scheme
 - Double ITCZ
 - Unrealistic timing and intensity of convective precipitation (e.g., diurnal cycle)
 - Too rapid transition from stratocumulus to cumulus along the subtropical transect
 - Biases of water vapor & clear sky LW radiation (?)
 - Too strong subtropical high in summer (?)
 - Too strong hydrological cycle (?)
 - Monsoon
 - Lack or weak MJO
 - Climate sensitivity of cirrus clouds
 - Many other features since 'convection' is the 'pump' of the atmospheric circulation

OUTLINE

I. Brief Description on the UNICON

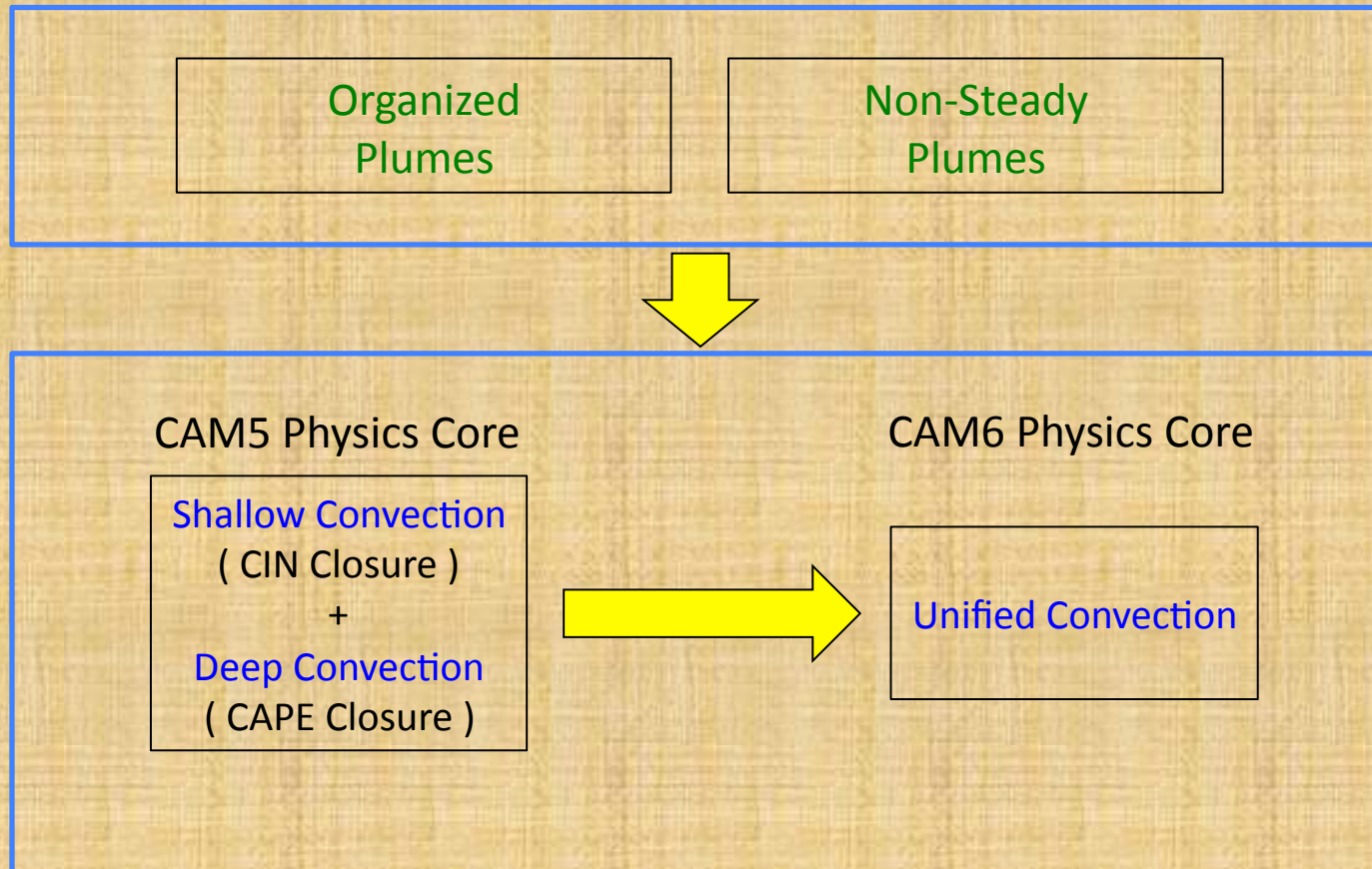
II. SCAM5 Simulation :

- Dry Convective PBL
- Stratocumulus-Topped PBL (DYCOMS-II)
- Shallow Convective Case (BOMEX)

III. CAM5 Simulation

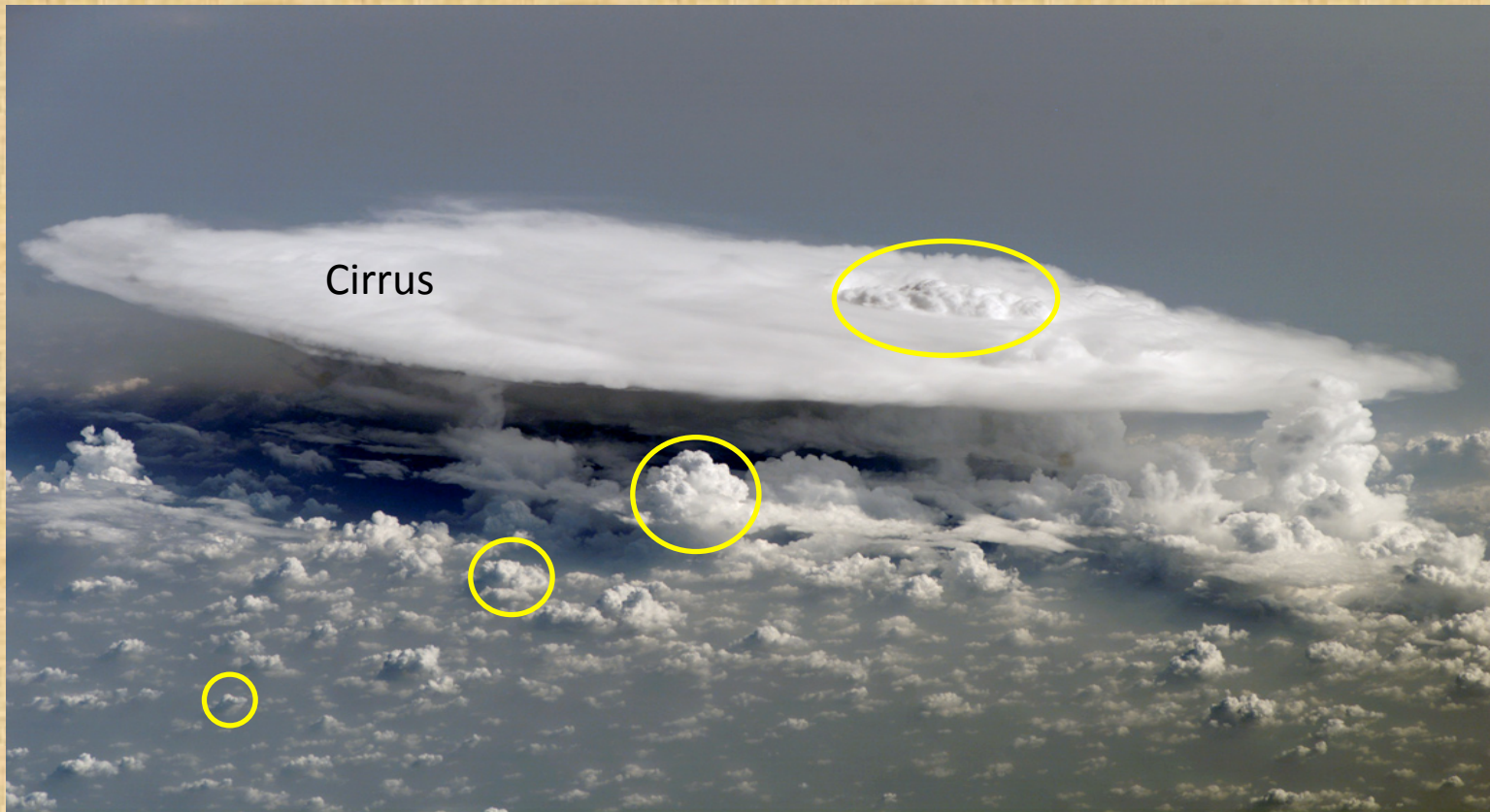
IV. SUMMARY

A Strategic Plan for Next Generation CAM6



- I. CAM5 **Shallow Convection** + **Organized Plume** : C. Hohenegger and C. Bretherton (& S. Park)
B. Mape and R. Neale (& S. Park)
- II. **UNICON** : S. Park

Image of Tropical Deep Convective System



- Various cross-sectional sizes of convective updraft plumes
- Roughly speaking, larger plume grows deeper.

Overview of UNICON

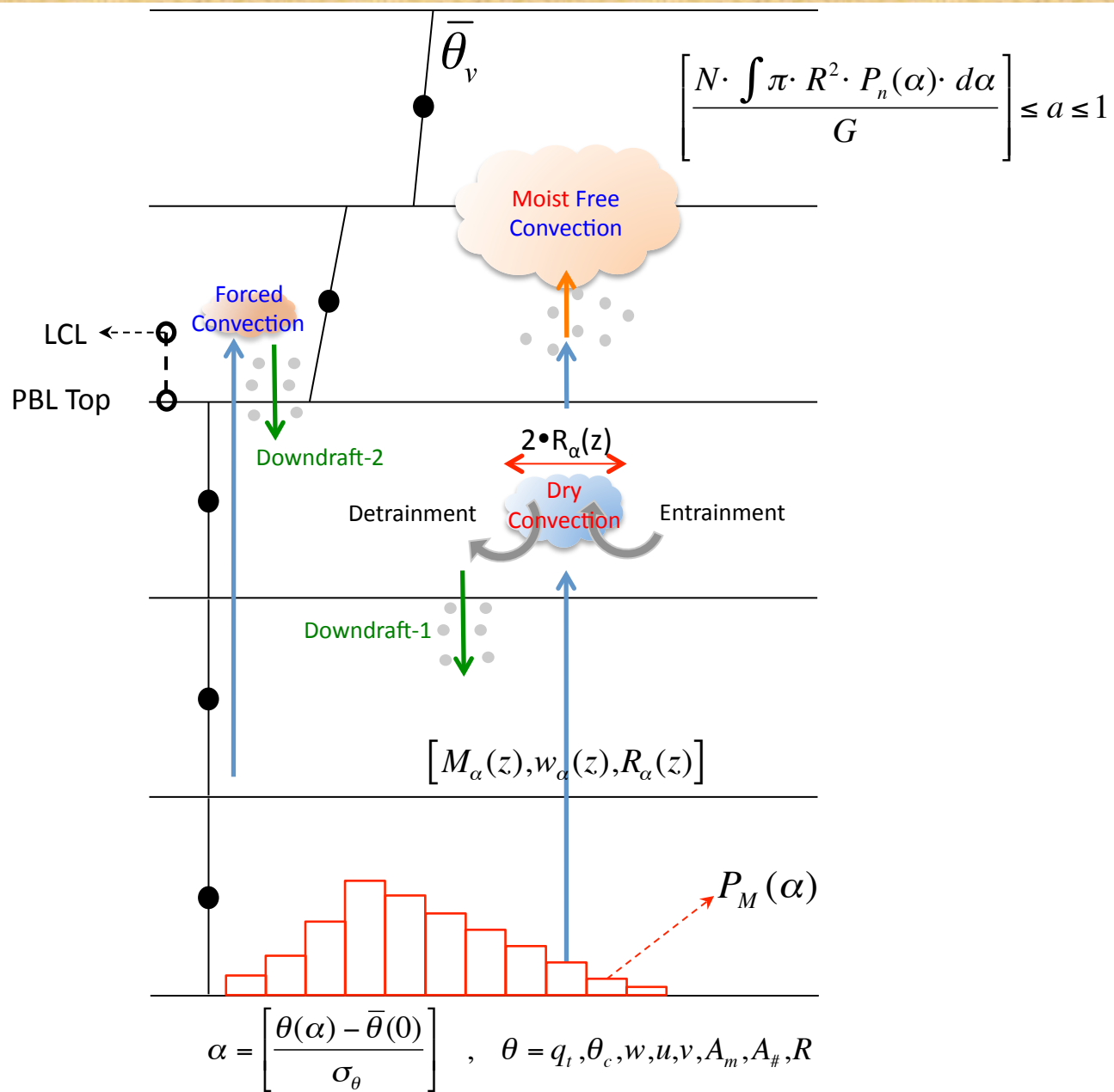
I. *A completely new vertical transport scheme by asymmetric turbulences designed to address the major issues associated with the parameterization of convection :*

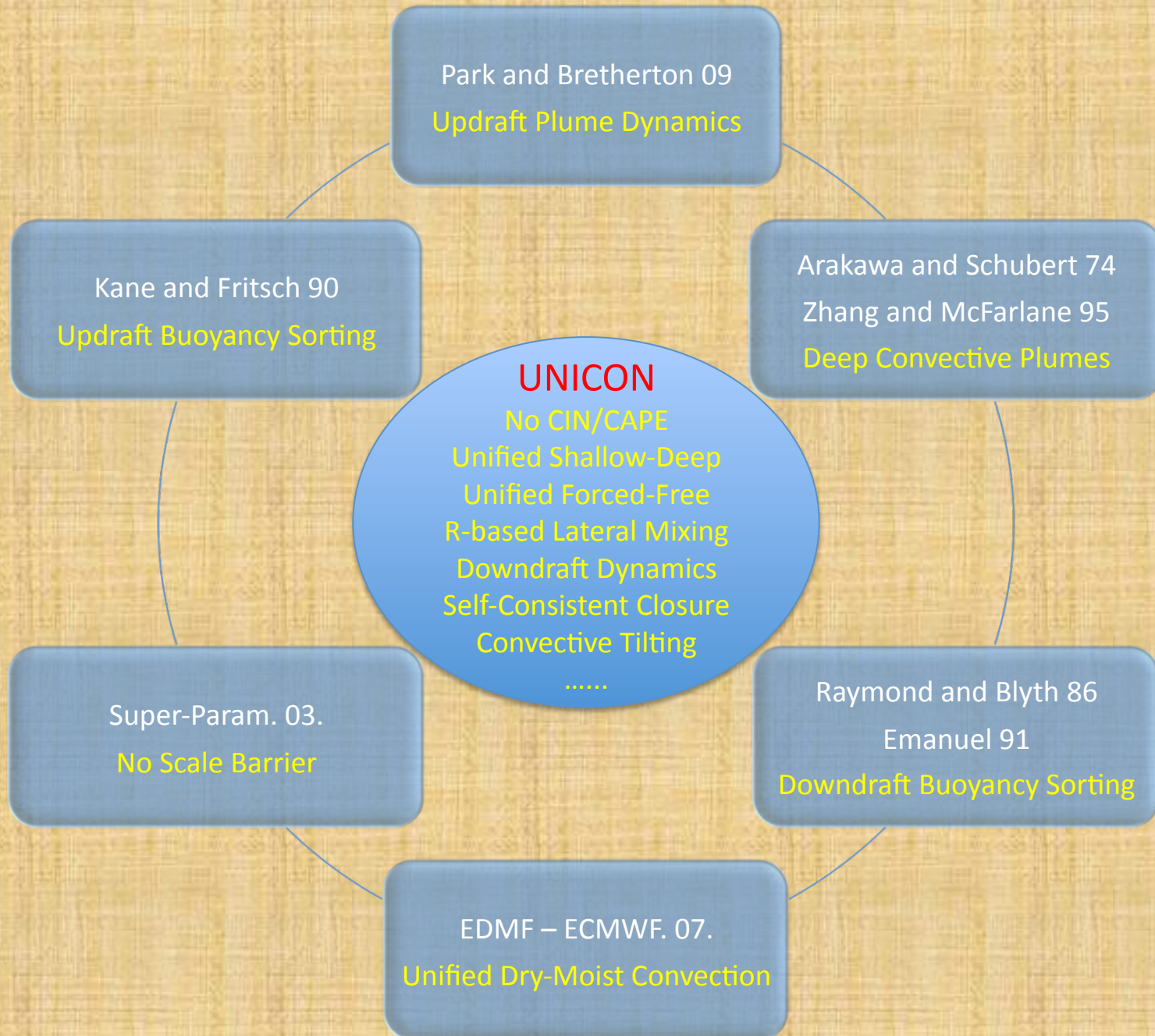
- Developing a conceptual framework : July. 2006 ~ Jan. 2009.
- Mathematical formulation and coding : Jan.2009 ~ Nov. 2009.
- Intensive debugging : Nov. 2009 ~ Nov. 2010.
- Testing : Nov.2010 ~ Present.
- Code : ~ 10,000 Lines, Computation time : ~ CAM5 shallow convection scheme when n=1.

II. *Some of unique aspects of UNICON are*

- Consistent closure for all scalars ($q_t, \theta_c, u, v, w, A_m, A_{\#}$) controlled by the surface fluxes
- Updraft plume mixing rate as a function of plume radius R
- Launch correlated multiple plumes with different thermodynamic properties and R
- Generic treatments of 'convective downdraft' and 'detrainment'
- Treatment of vertical tilting of updraft plume : 'cumulus-precipitation overlap' and associated 'evaporation of convective precipitation'
- No CIN/CAPE closures : Fully dynamic plume model without any priori assumption
- Unified treatment of 'shallow/deep', 'dry/moist', and 'forced/free' convections
- Capability to handle convective organization by setting ' $R = fcn(M_d/M_u)$ ' at surface
- Well-harmonized with the CAM5 symmetric turbulence scheme (i.e., moist PBL scheme)

UNICON (S. Park 2011)





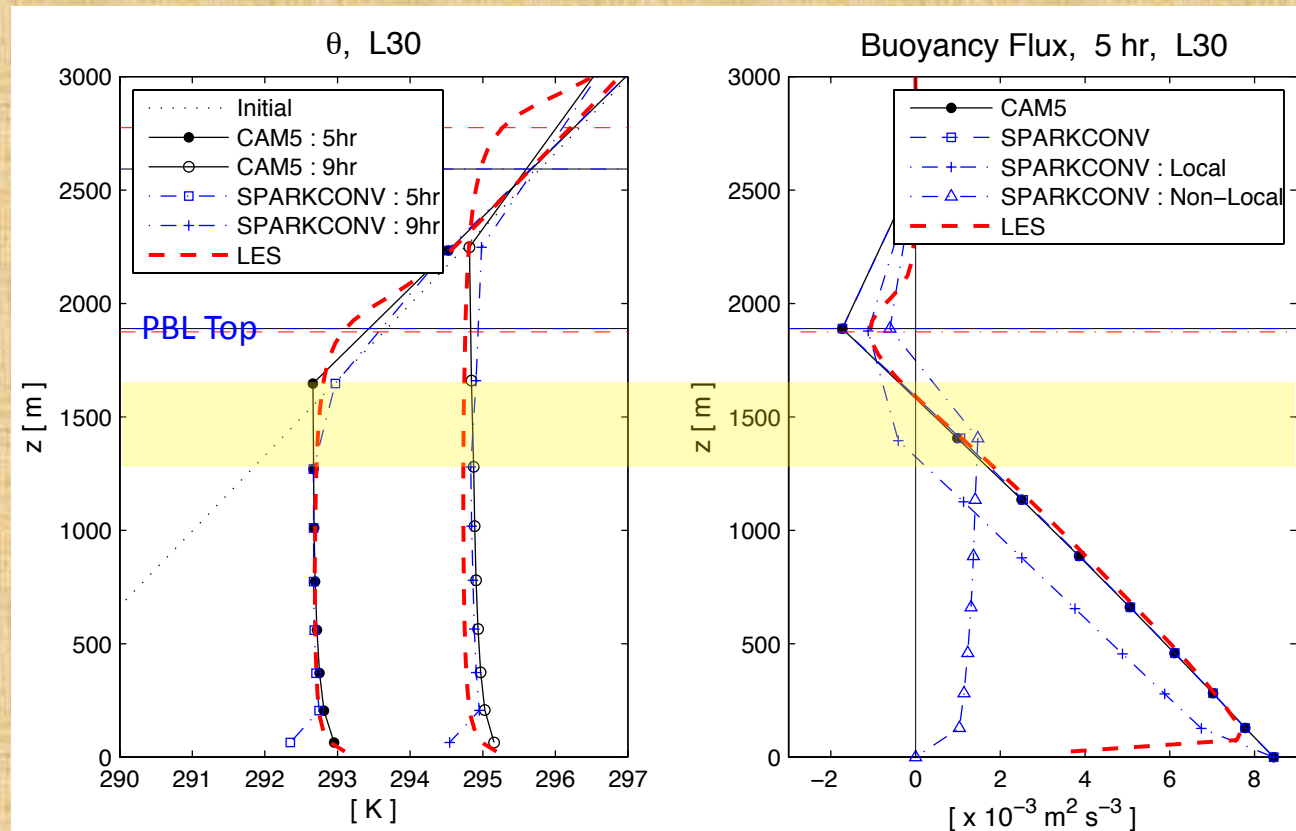
SCAM5 Simulation :

Dry Convective PBL

Stratocumulus-Topped PBL

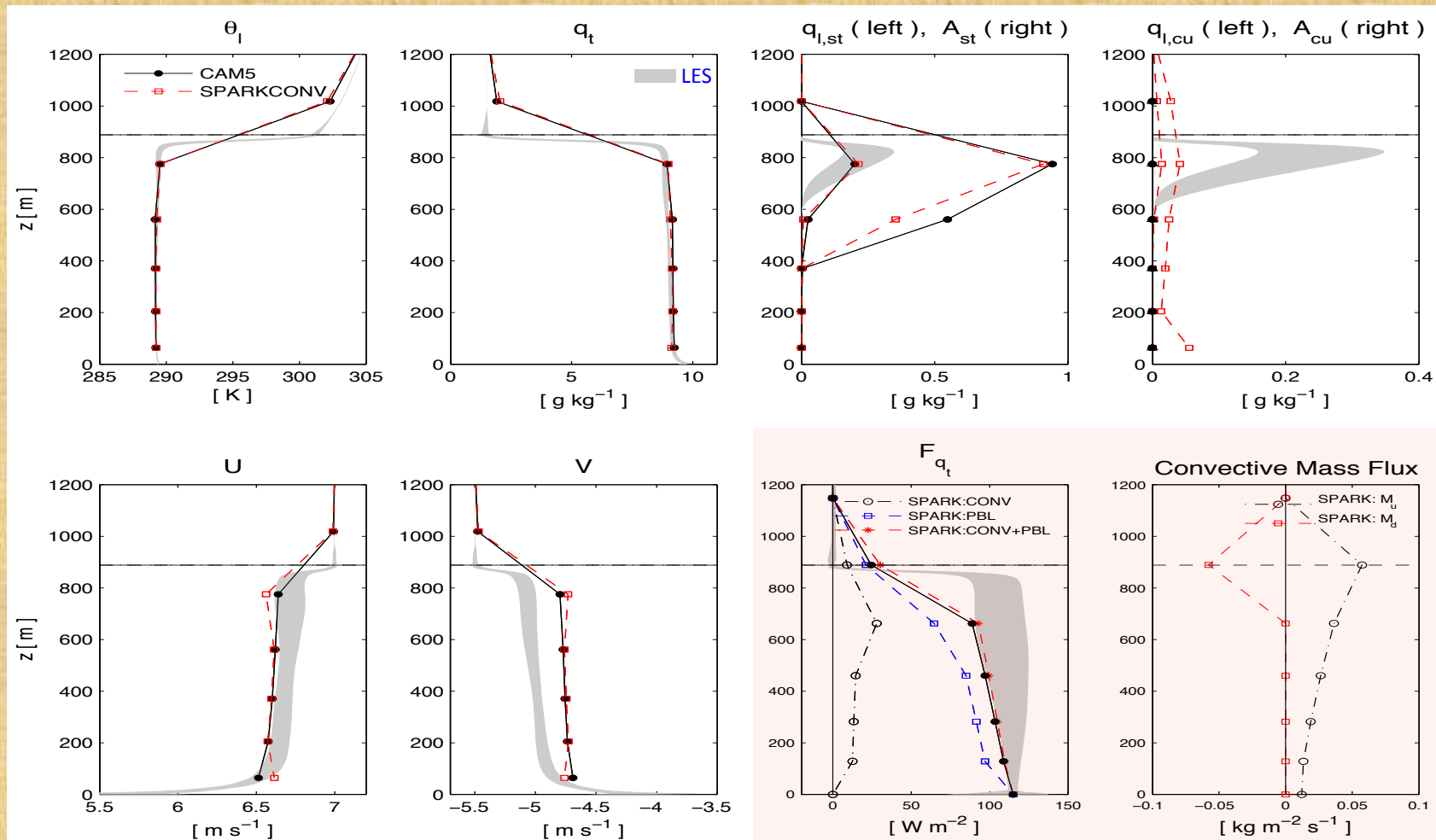
Shallow Cumulus Case

Dry Convective PBL. L30.



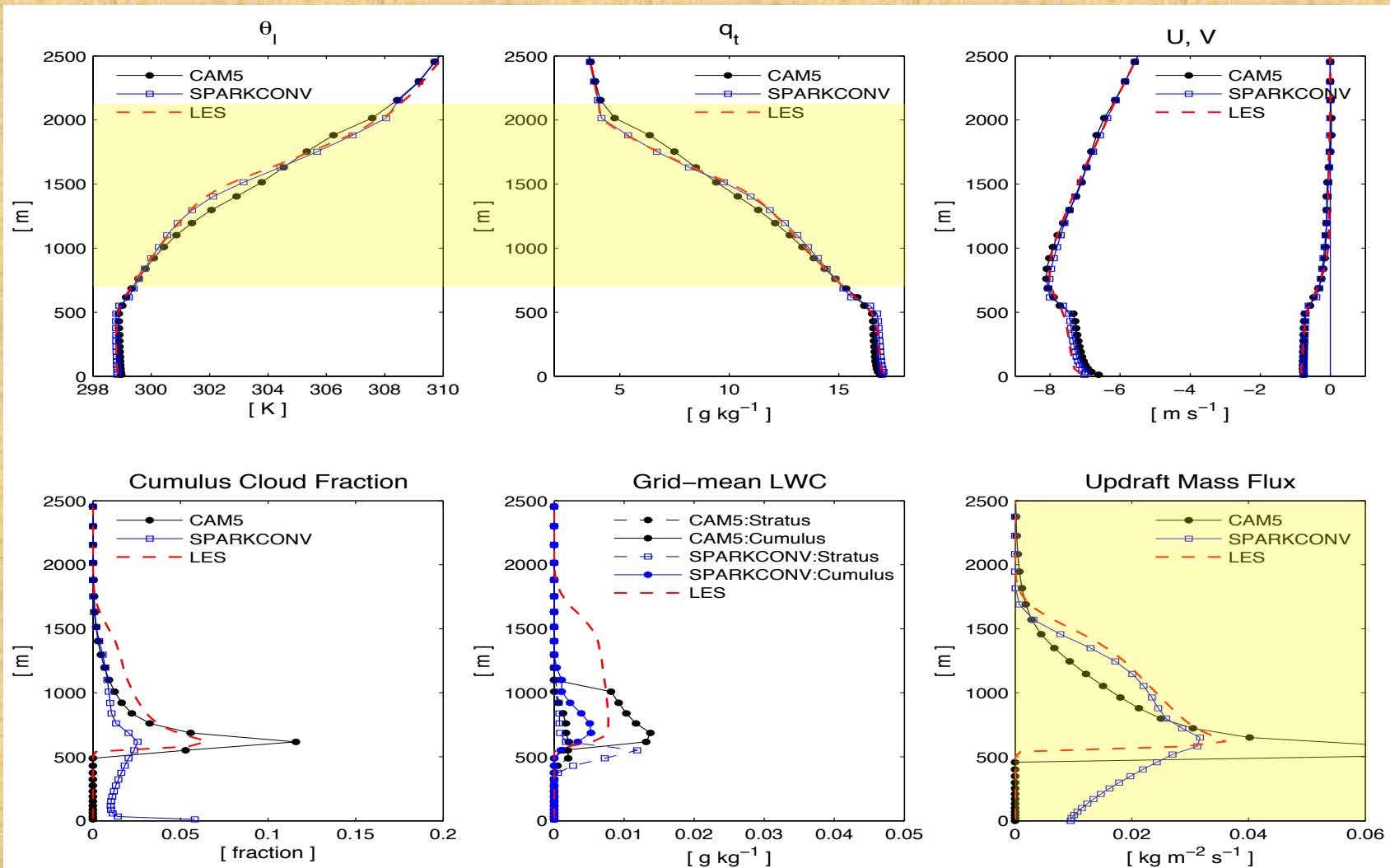
- The non-local transport by the **UNICON** improves the simulation of temperature in the lower and upper PBL.
- The sum of buoyancy fluxes from the **UNICON** and CAM5 PBL scheme is almost identical to the buoyancy flux from the CAM5 PBL scheme alone.

Stratocumulus-Topped PBL (DYCOMS). L30.



- The **UNICON** is active even in the well-mixed Sc-topped PBL.
- The simulation with **UNICON + CAM5 PBL** is quite similar to the one with **CAM5 PBL** alone.
- The generic convective downdraft in **UNICON** simulates the penetrative entrainment at the PBL top.

Shallow Cumulus Case (BOMEX). L80.



- The **UNICON** very well reproduces the LES.
- The **UNICON** is active both above and below the cloud base, i.e., **unified treatment of dry and moist convection** similar to EDMF.

CAM5 Simulation :

CAM5 (DpCu + ShCu)

ShCu

ShCu-MNP

ShCu-HBP

UNICON

OBSERVATION

*Thanks to Brian **M**apes and Rich **N**eale for providing ShCu-**MNP** simulation figures.*

*Thanks to Cathy **H**. and Chris **B**. for providing ShCu-**HBP** simulation figures.*

**PRECT
ANN**

CAM5

**ShCu-
MNP**

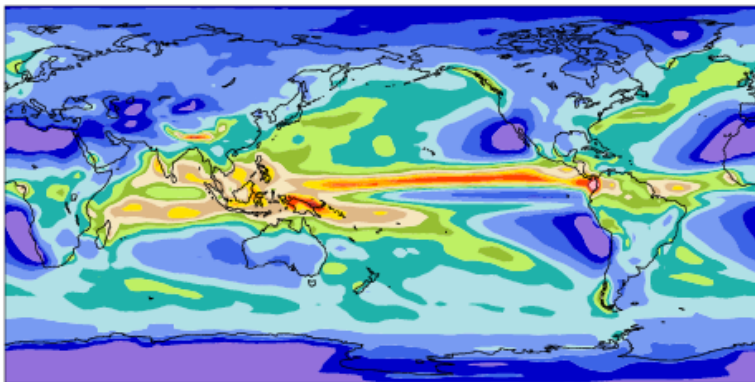
UNICON

cam5_bem_ctrl (yrs 1-2)

Precipitation rate

mean= 2.95

mm/day

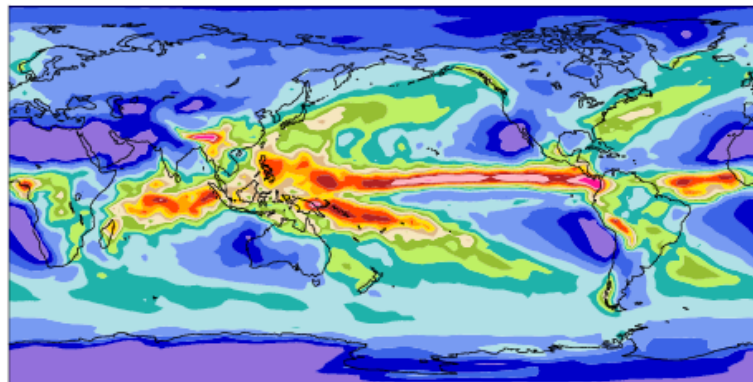


cam5_bem_rkm0 (yrs 1-2)

Precipitation rate

mean= 3.18

mm/day

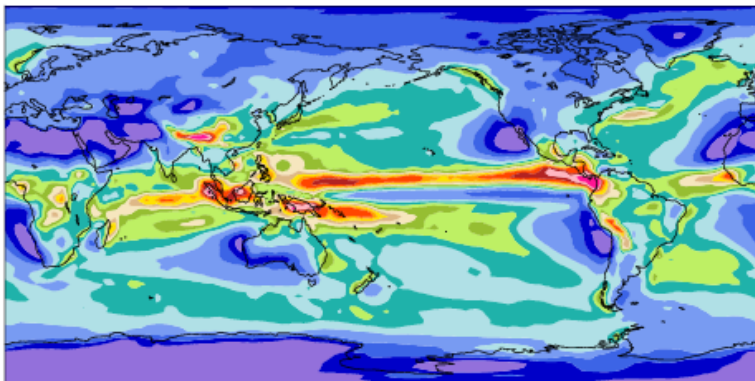


cam5_bem_rkm10 (yrs 1-2)

Precipitation rate

mean= 3.11

mm/day

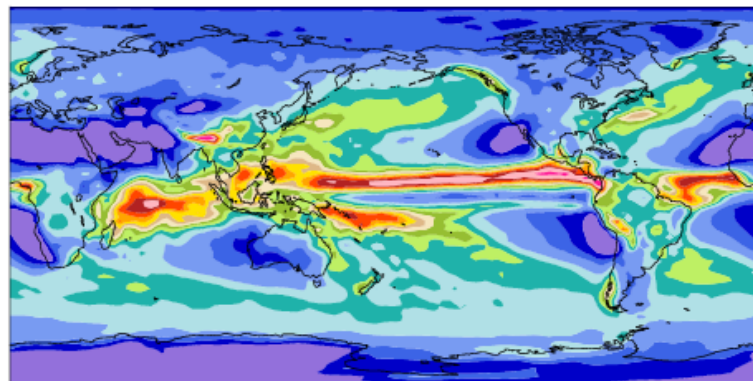


scamcpt_cam5_0_12_006 (yrs 2-3)

Precipitation rate

mean= 3.02

mm/day

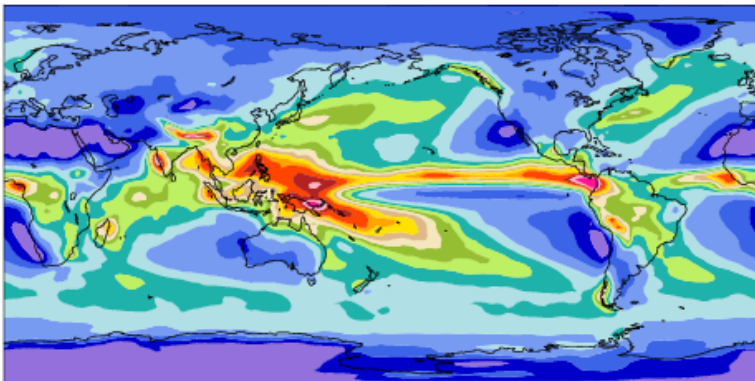


scamcpt_cam5_0_12_008a (yrs 1-9)

Precipitation rate

mean= 3.12

mm/day

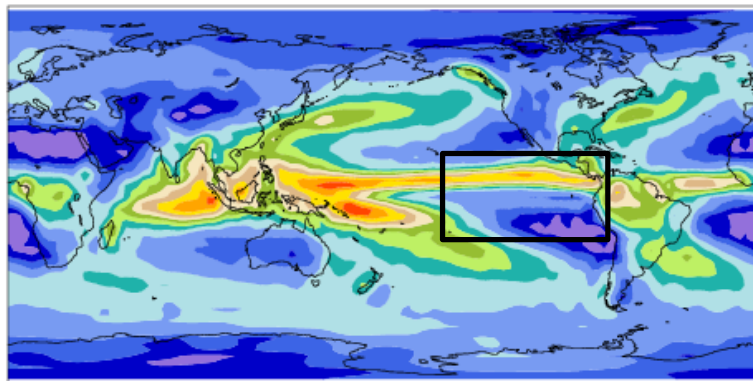


XIE-ARKIN

Precipitation rate

mean= 2.69

mm/day



ShCu

**ShCu-
HBP**

OBS

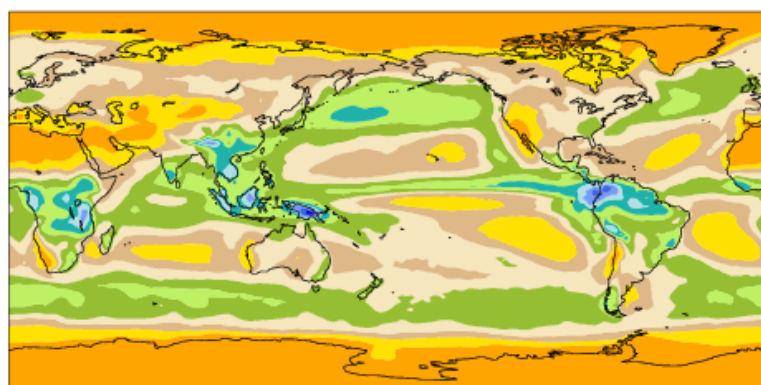
**SWCF
ANN**

CAM5

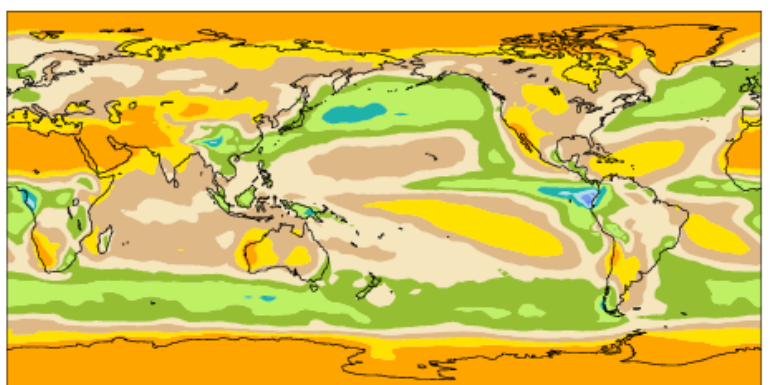
**ShCu-
MNP**

UNICON

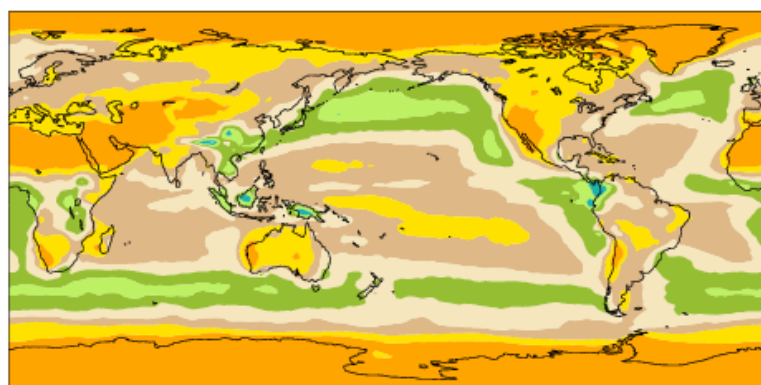
cam5_bem_ctrl (yrs 1-2)
TOM SW cloud forcing mean= -50.05 W/m²



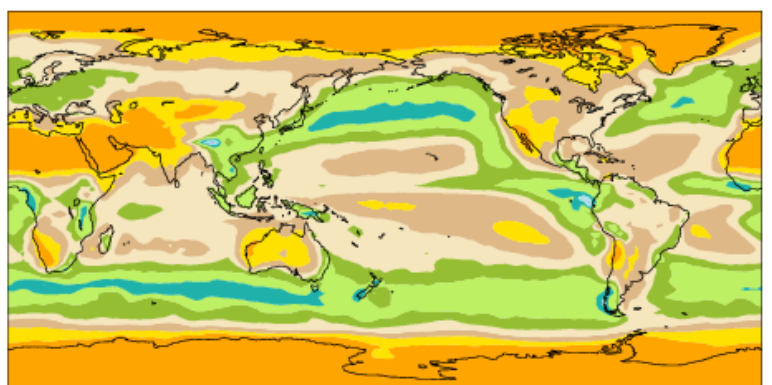
cam5_bem_rkm0 (yrs 1-2)
TOM SW cloud forcing mean= -45.73 W/m²



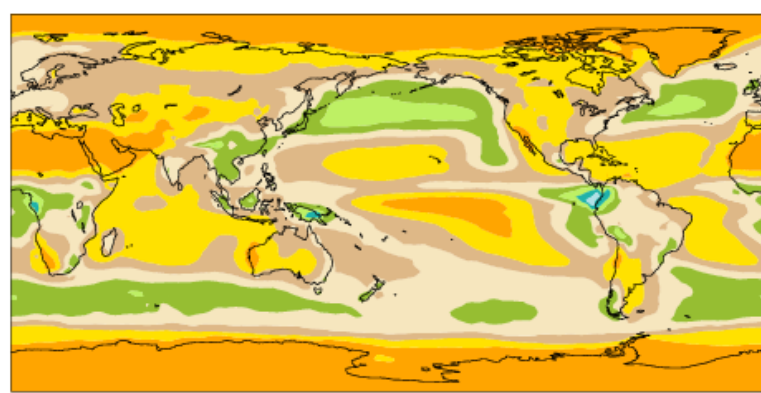
cam5_bem_rkm10 (yrs 1-2)
TOM SW cloud forcing mean= -41.37 W/m²



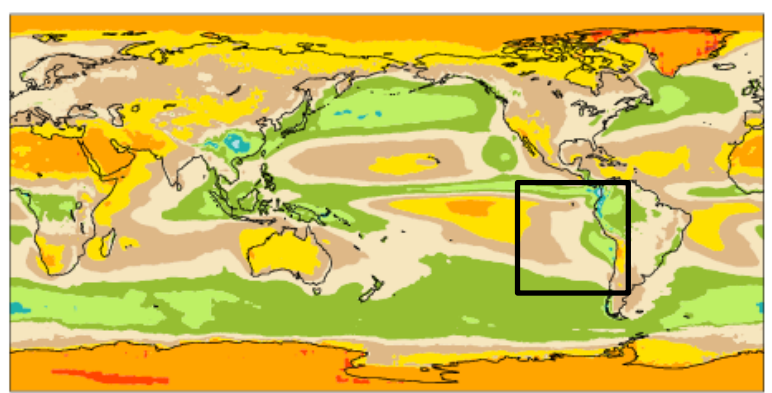
scamcpt_cam5_0_12_006 (yrs 2-3)
TOA SW cloud forcing mean= -50.31 W/m²



scamcpt_cam5_0_12_008a (yrs 1-9)
TOA SW cloud forcing mean= -38.50 W/m²



CERES2
TOA SW cloud forcing mean= -47.07 W/m²



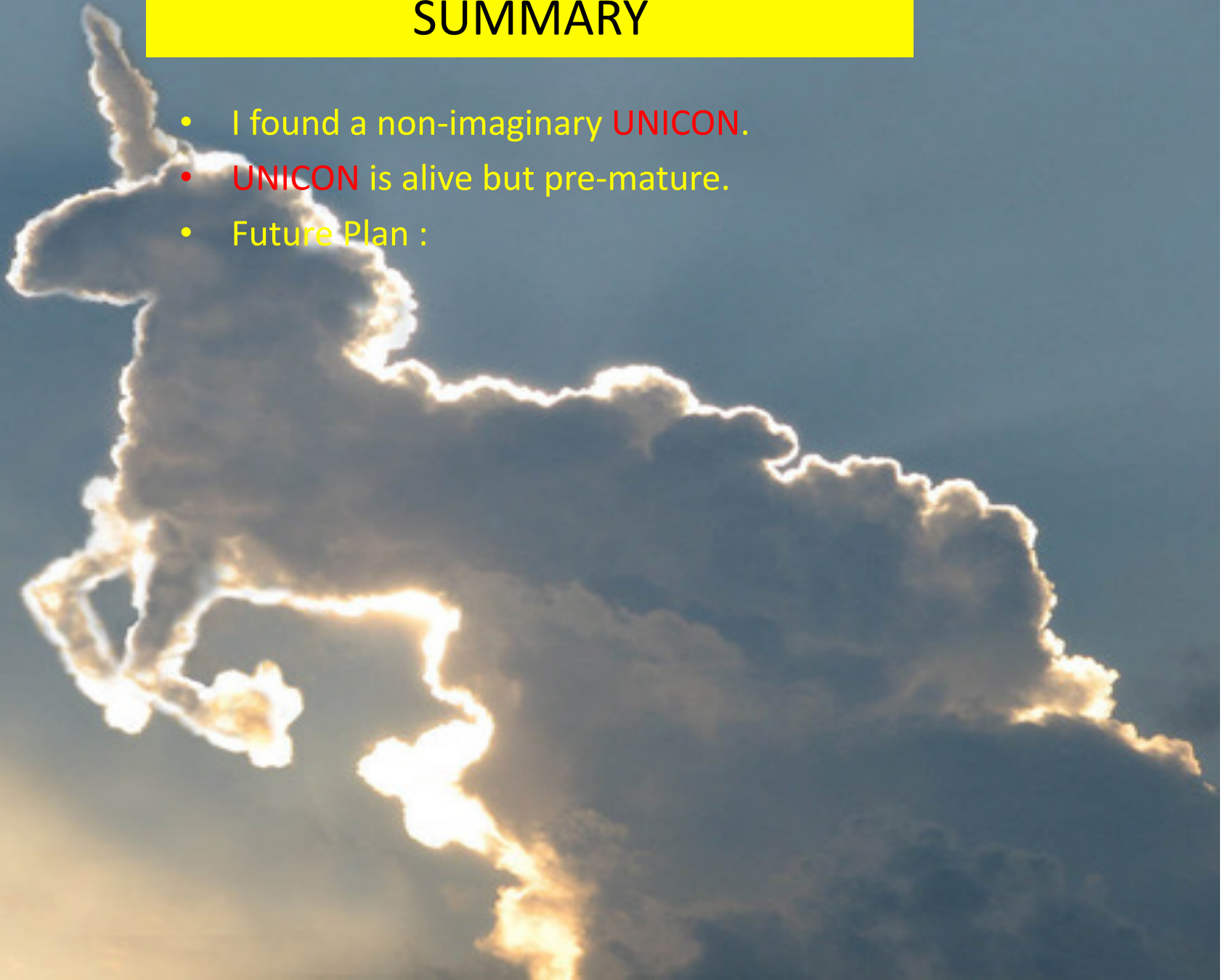
ShCu

**ShCu-
HBP**

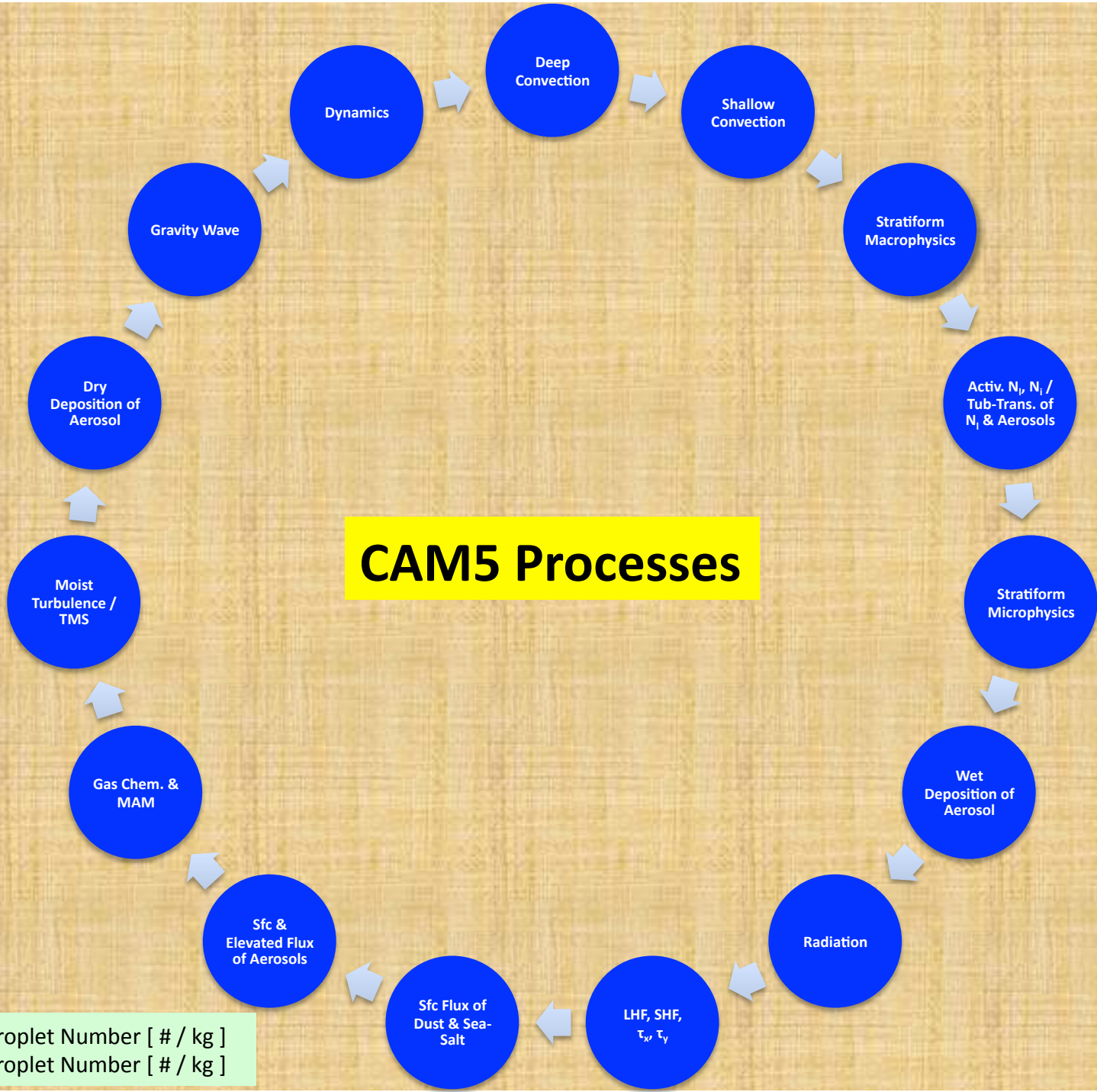
OBS

SUMMARY

- I found a non-imaginary UNICON.
- UNICON is alive but pre-mature.
- Future Plan :

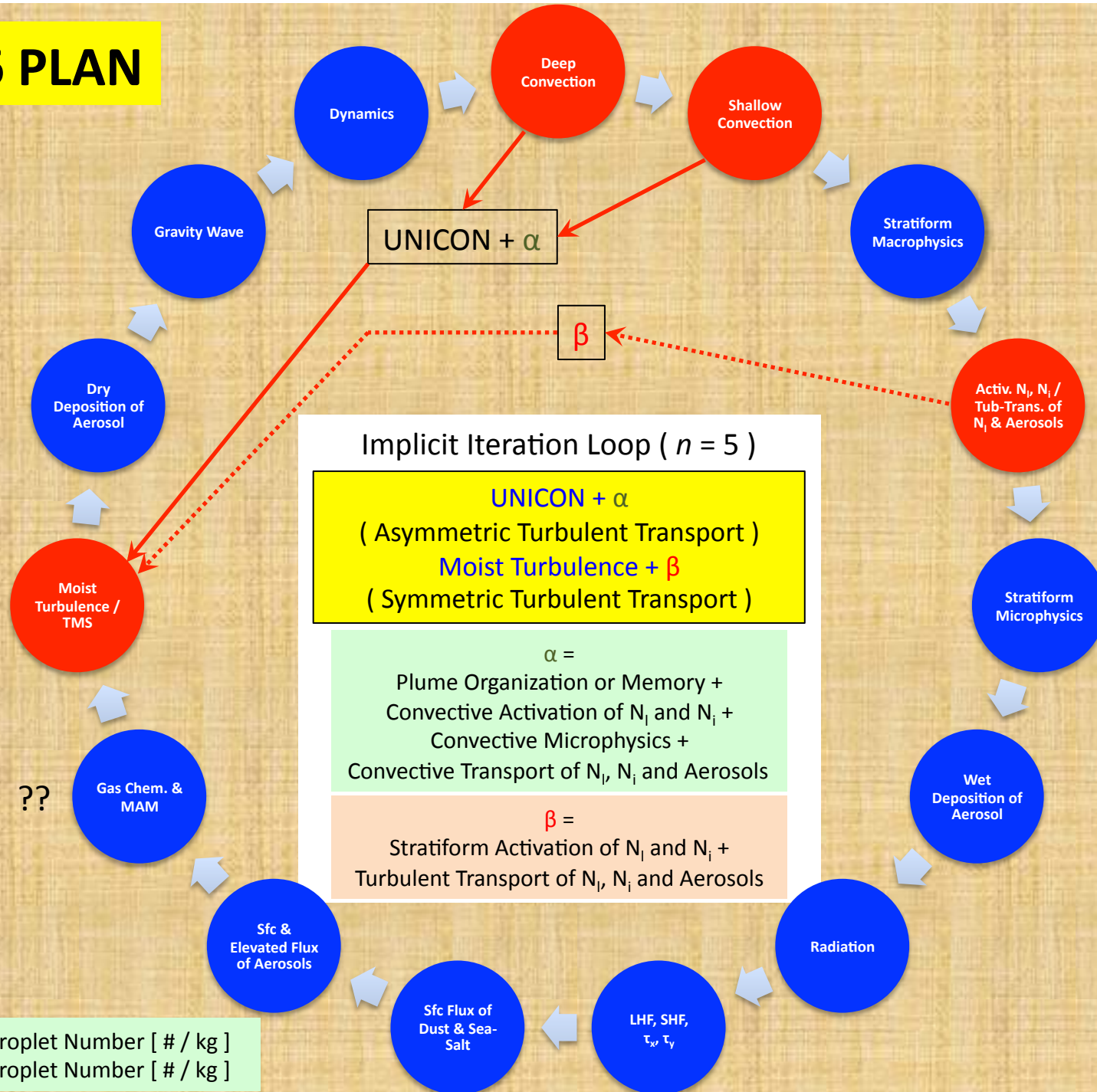


CAM5 Processes

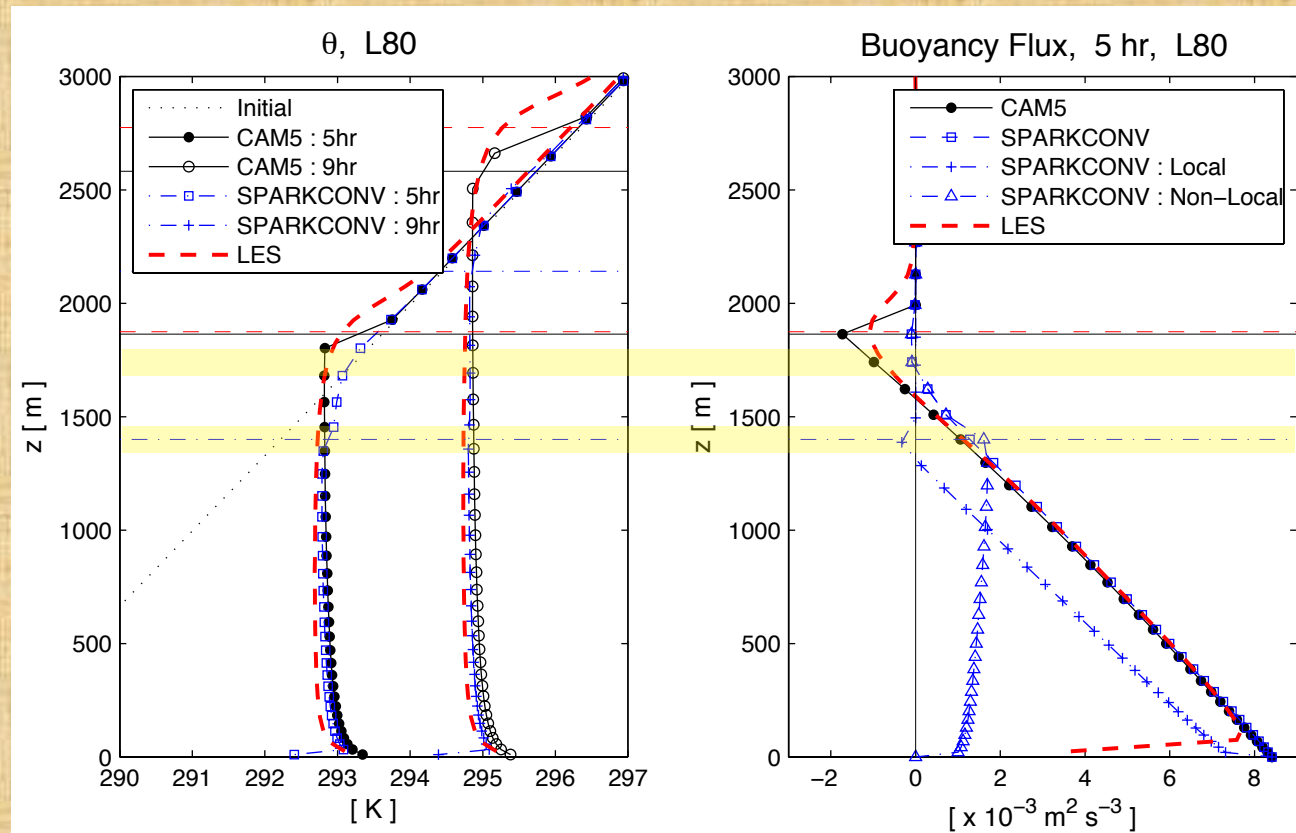


N_l : Liq Cloud Droplet Number [# / kg]
 N_i : Ice Cloud Droplet Number [# / kg]

CAM6 PLAN



Dry Convective PBL. L80.



- Due to the enhanced stability in the upper PBL by convective non-local transport, CAM5 PBL scheme underestimates the PBL top height : **mismatch between the PBL top height** identified from the **CAM5 PBL scheme** and **the base of overshooting zone** identified from the **UNICON**.
- It is necessary to refine (1) the '**merging criteria**' in CAM5 PBL scheme or (2) incorporate the **UNICON** into the **implicit iteration loop** used for CAM5 PBL scheme.