Zhao and Carr Microphysics Scheme

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Background

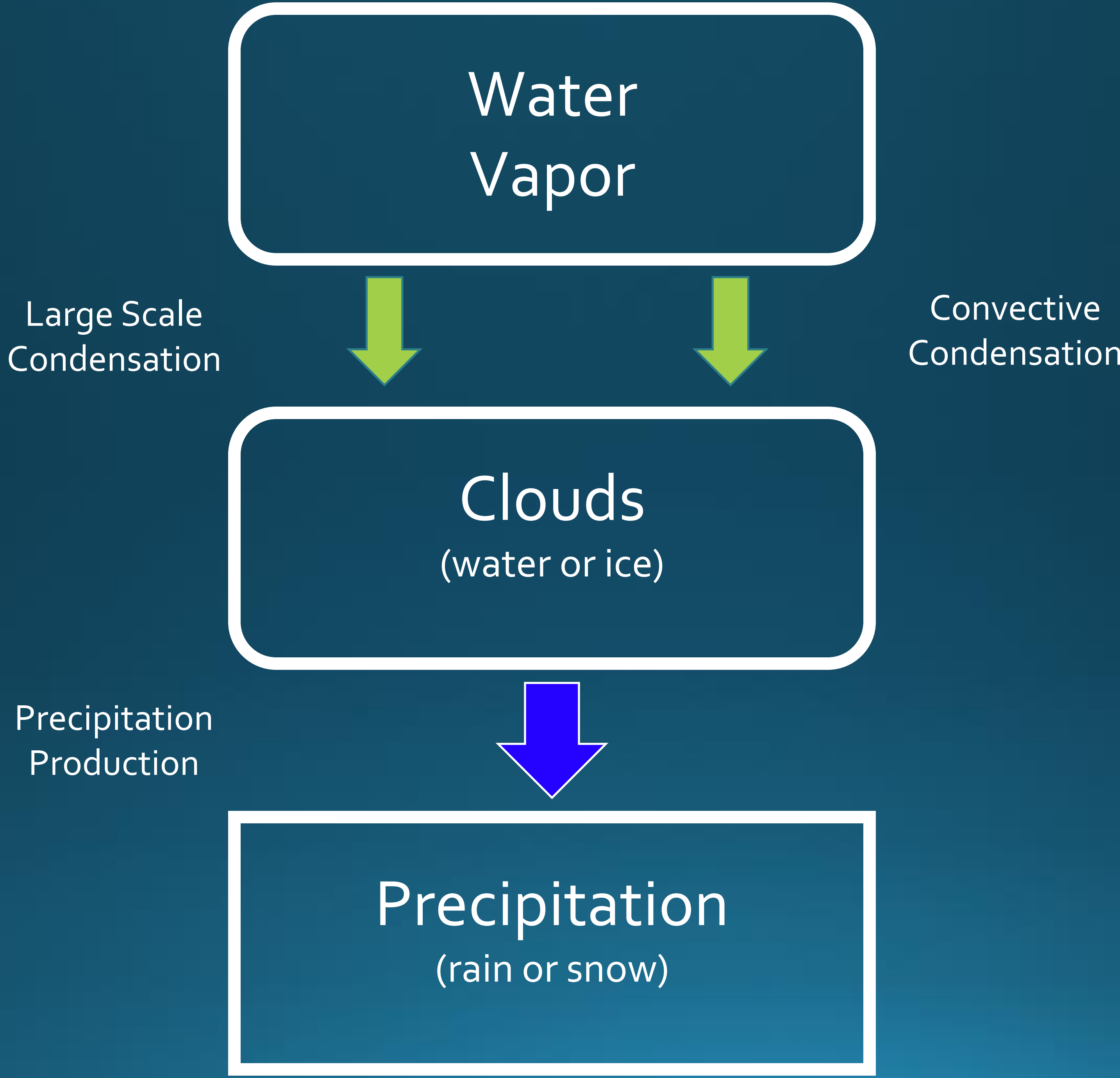
- Study was released in 1997.
- Many operational and research models until then *ignored* cloud ice and water processes.
  - Lead to several issues, including underestimates of latent heat release.
- Other models included cloud ice/water calculations, however these took much more computing power.
  - Included one or more additional prognostic variables.
  - However, they better represented thermodynamic effects.

Overall Scheme Goal

- To properly model all important precipitation processes while remaining simple enough that no additional computational resources are needed.
    - Simplicity achieved through the use of only one additional variable, cloud mixing ratio.

So how does it work?

- Much of this scheme could be referred to a “top-down” method.
  - Starts at the top of a cloud and works its way down.
- Similar to the explicit methods we talked about earlier.
  - Example: Determining precip type
- Uses *one* predictive variable to represent cloud ice and water instead of two.
  - Cloud ice/water mixing ratio


Water
Vapor
Large Scale
Condensation
Convective
Condensation
Clouds
(water or ice)
Precipitation
Production
Precipitation
(rain or snow)

Assumptions

- There is an approximate balance between the fall speed of cloud particles and the model's large scale upward motion.
  - This means that vertical advection of the mixing ration is ignored.
  - Vertical motion is relatively weak in large scale models.
  - Reduces computational time and need for computational resources.

4 Main Processes

- Large scale condensation
- Convective condensation
- Cloud evaporation
- Precipitation production

Large Scale Condensation

- Large scale condensation is achieved through calculation of relative humidity.
- Equations split RH, allowing part to contribute to condensation in cloudy parts of a grid square and the other part to continue increasing RH in cloud-free areas of the square.
- If RH is below the critical value, condensation does not occur and cloudiness (referred to as *b* in the scheme) equals zero.
- If RH is above the critical level at a given grid square, cloudiness begins to increase.

Large Scale Condensation

- RH Critical levels vary depending on land type and particle type (water or ice)
- While these values are known, we need to know where each particle type exists in the cloud.

TABLE 2. The IW values in different temperature regions.

Temperature	Large-scale condensation	Convective condensation
$T > 0°C$	IW = 0	IW = 0
$-15°C < T < 0°C$	IW = 1, if there is cloud ice at or above this point at current or the previous time step;	
	IW = 0, otherwise.	IW = 1
$T < -15°C$	IW = 1	IW = 1

Assumptions

- Temperature as a cloud content indicator
- T > 0°C
  - All clouds contain liquid water particles
- T < -15°C
  - All clouds contain frozen ice particles
- 0°C > T > -15°C
  - Clouds may contain either ice or water
  - Depends on conditions at level immediately above and conditions at previous time steps

Convective Condensation

- Adaptation of Betts-Miller (1986) convective parameterization scheme
  - Adapted to include cloud water and ice
- Model temperature (T) and specific humidity (q) profiles are adjusted toward reference profiles
  - Occurs in areas of deep convection

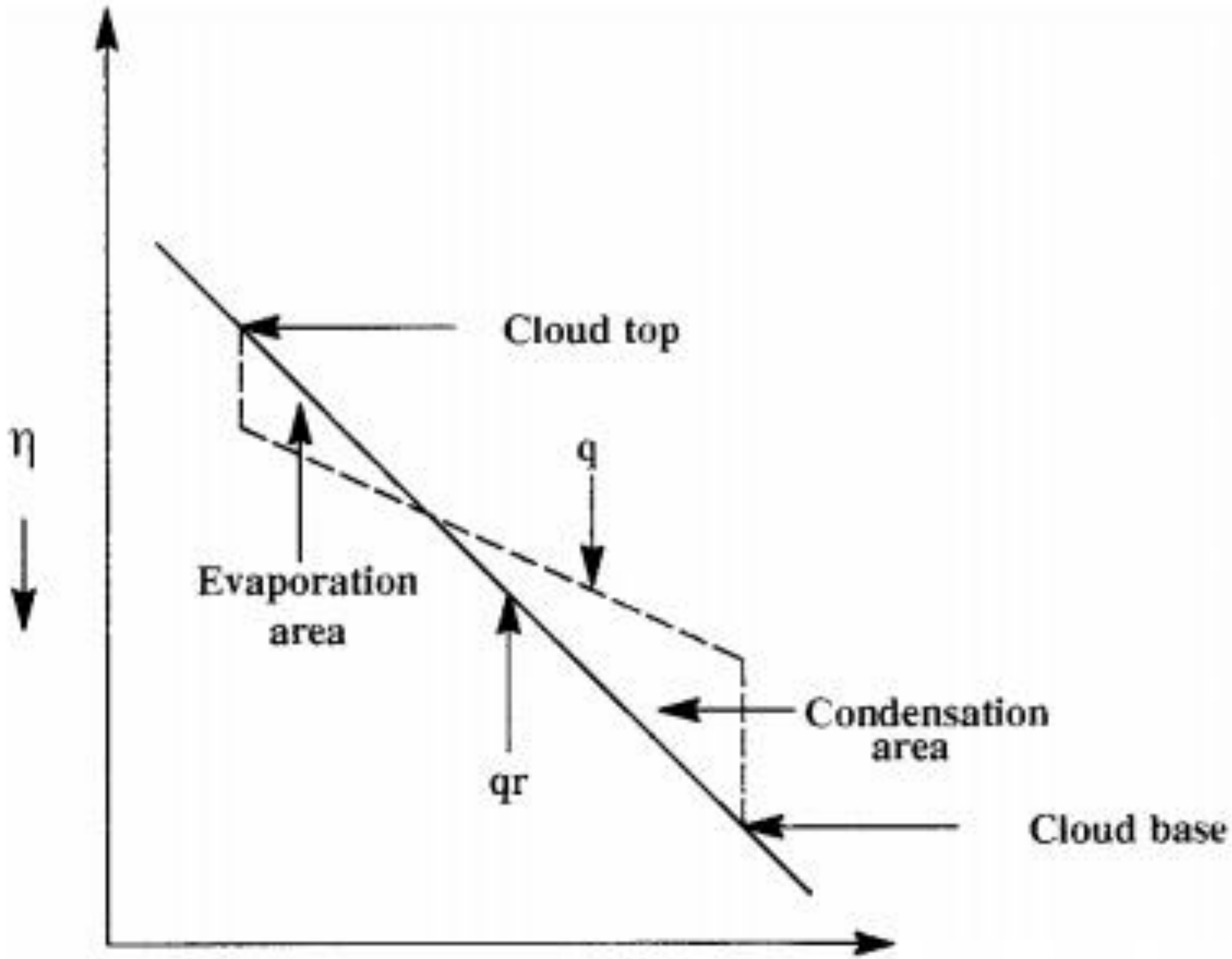


FIG. 2. Schematic representation of condensation and evaporation in the Betts–Miller convective adjustment scheme. (q—model's profile of specific humidity; q_r—reference profile.)

Convective Condensation

- This modified scheme does not produce convective precipitation by itself
  - Combines convective clouds with large scale condensation clouds, then calculates total precipitation
- Allows microphysical processes to influence convective precipitation

Assumptions

- When completing the convective adjustment process, vertical motions are assumed to *immediately* transfer condensed water from condensation points to evaporation points for evaporation.
- All non-transferred condensed water is assumed to stay at the condensation points.
- Cloud particle type is assumed to be ice when T is between 0°C and -15°C

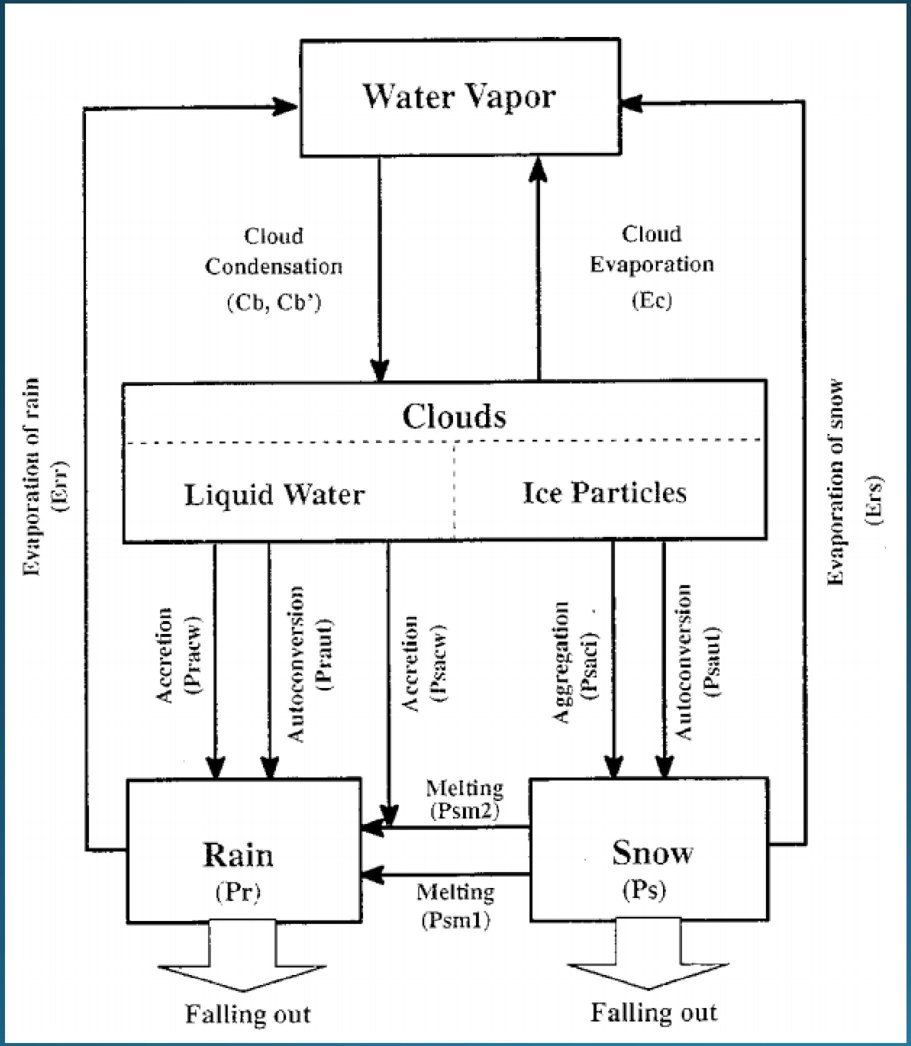
Cloud Evaporation

- Only takes place where RH is less than the determined critical level.
- Cloud evaporation may be stopped if this critical level is reached during evaporation
- This is achieved through a few assumptions

Assumptions

- During cloud evaporation, only part of the cloud evaporates and all evaporated water is used to increase the relative humidity until the critical value is reached.
- Additionally, all evaporation is assumed to occur in one time step.
- This ensures that evaporation only takes place where no condensation is occurring.

Precipitation Production



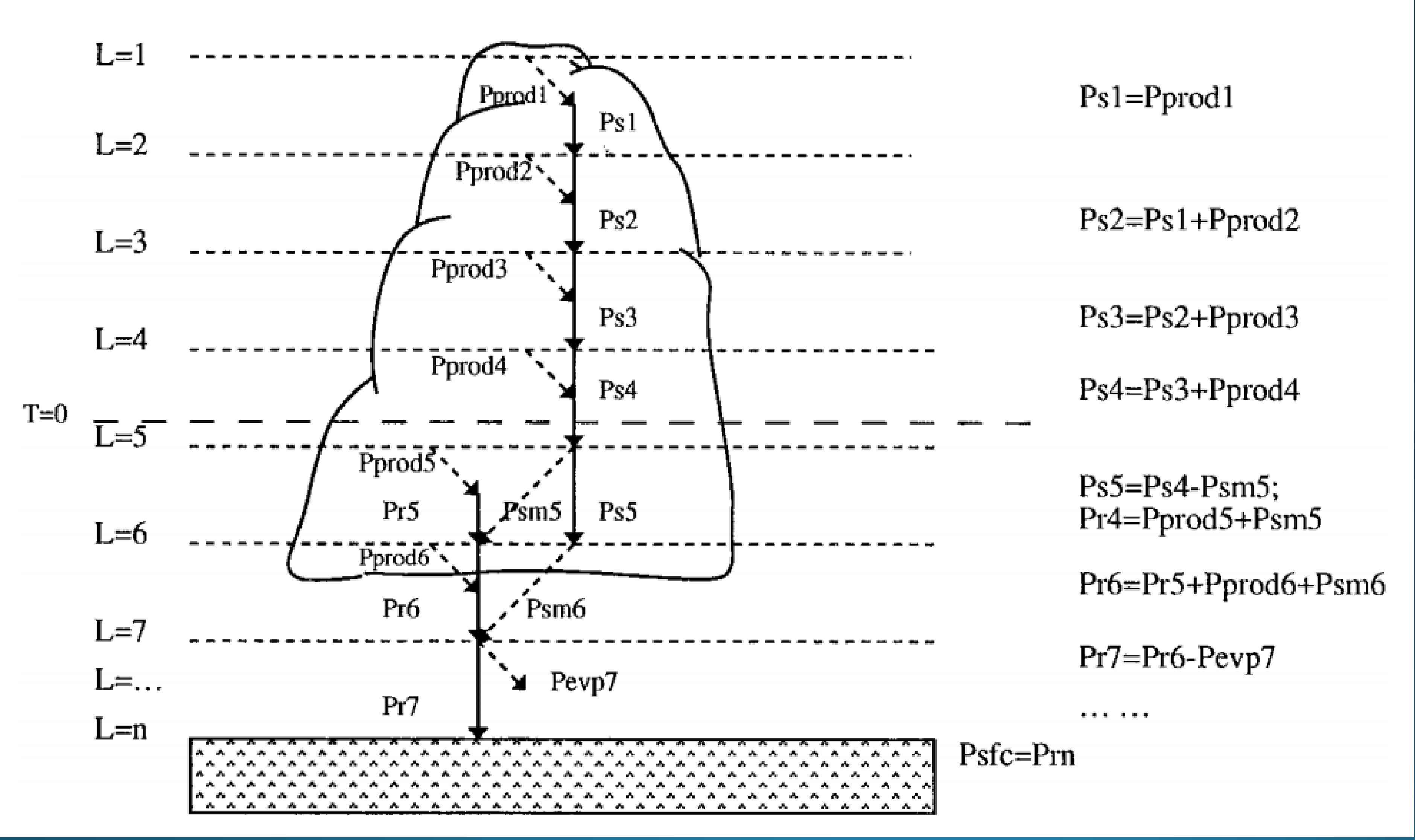
Assumptions

- Only two types of hydrometeors are considered in the scheme (rain and snow).
  - Does not include things like ice pellets, graupel, etc.
  - Thus, only microphysics processes involved with rain and snow are included in the scheme.
- Freezing of raindrops and interaction of raindrops with ice particles are ignored due to relatively weak synoptic vertical motion.
- Precipitation is calculated *directly* from the mixing ratio.
  - Eliminates the need to calculate fall velocities of raindrops, reducing computational time and need for resources.
  - Also eliminates the need for several more rainfall predictive equations.

Assumptions

- Below the freezing level, all melted snow is assumed to become raindrops.
- For snow melting due to collection of liquid water below the freezing level, the scheme assumes collected droplets to be between 0°C and 4°C, while the melting snow temperature is assumed to be 0°C.
  - This allows for a simpler calculation of the overall melt rate of snow.
- Evaporation of melting snow below the freezing layer is ignored, simply due to the difficulty of modeling latent heat in this case.

Putting It All Together

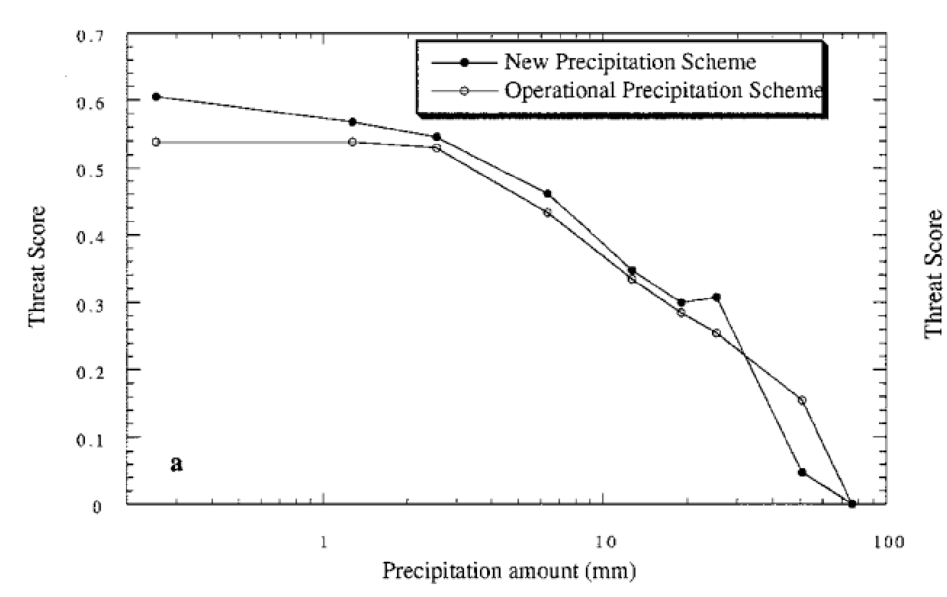


How Does It Compare?

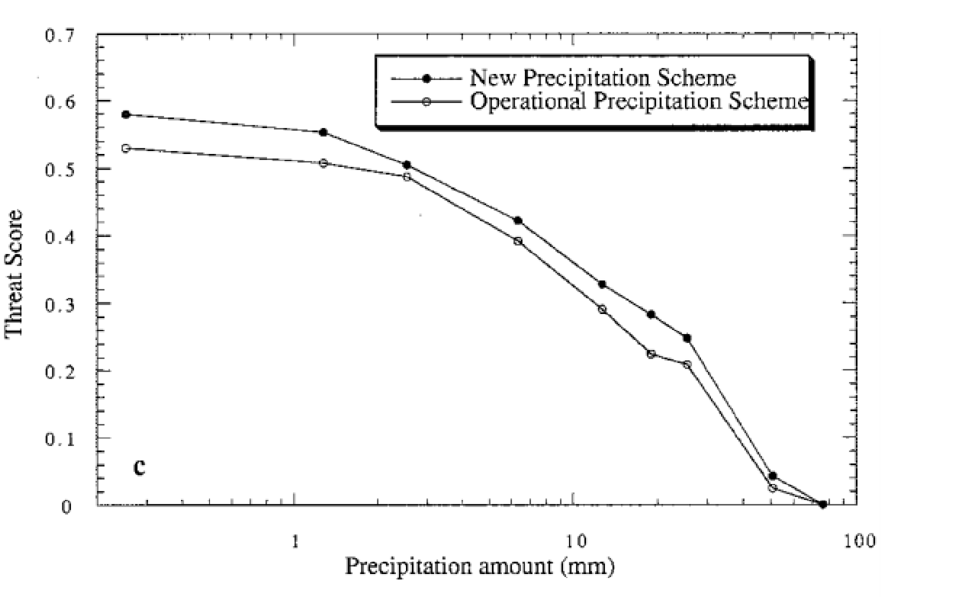
- Original 1997 study compared this scheme to the scheme being used in the operational NCEP Eta model at the time.
- Overall, found that this scheme predicted rainfall coverage and intensity better than the Eta model did.
- Forecasts were still poor in areas of large rainfall amounts.

How Does It Compare?

0-24 hr



24-48 hr



Reference

- Zhao, Q., and F. H. Carr, 1997: A Prognostic Cloud Scheme for Operational NWP Models. *Mon. Wea. Rev.*, **125**, 1931-1953

Questions?