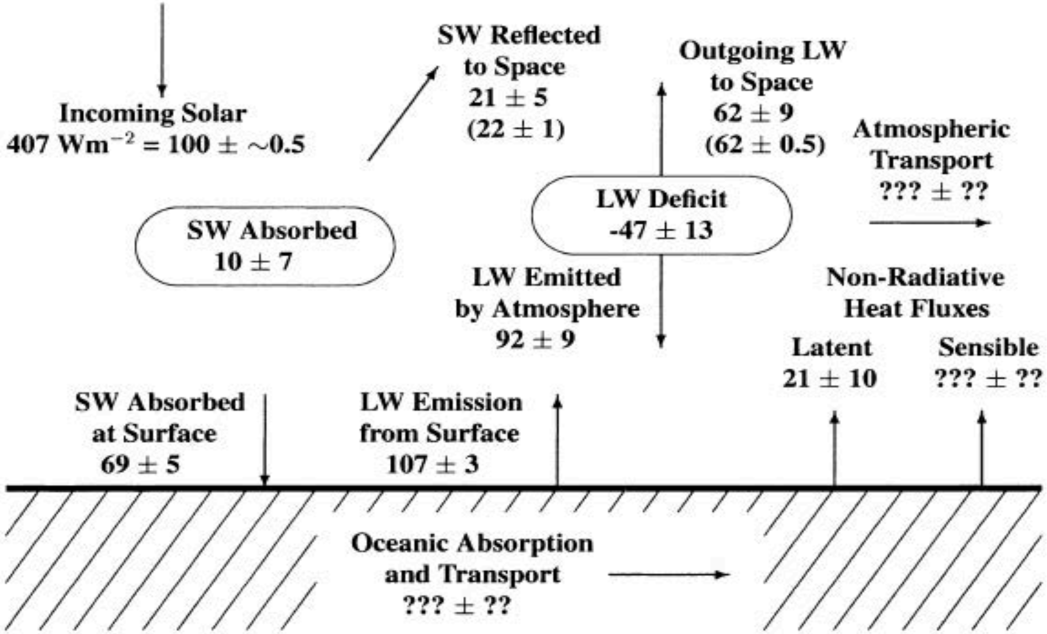
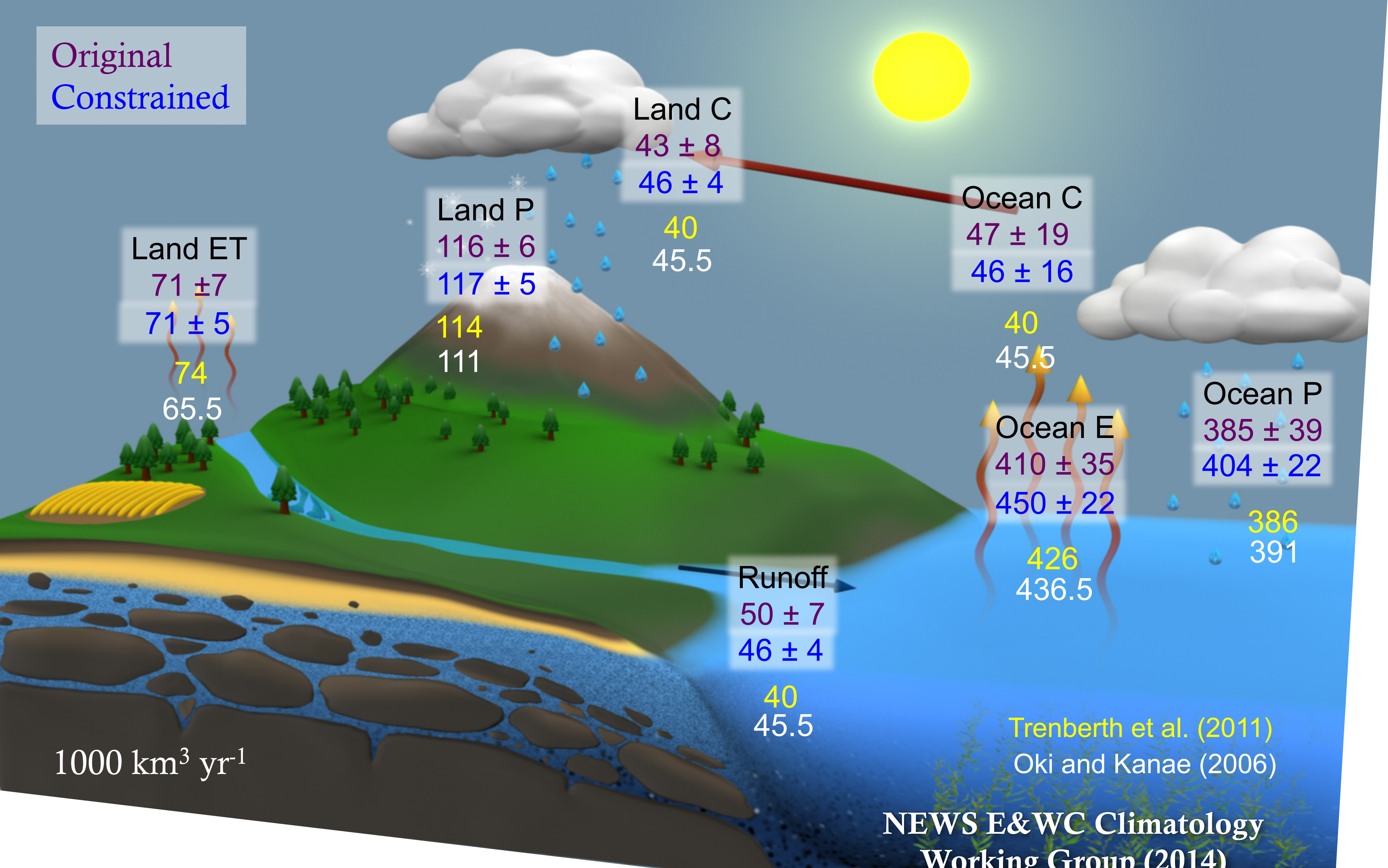
# Revisiting The Role of Clouds in the Global Energy Budget

## Energy Budget Over Oceans from 35∘N to 35∘S




L'Ecuyer and Stephens (2002)


Tristan L'Ecuyer
Alex Matus, Yun Hang, Kristof van Tricht, and Elin McIlhattan

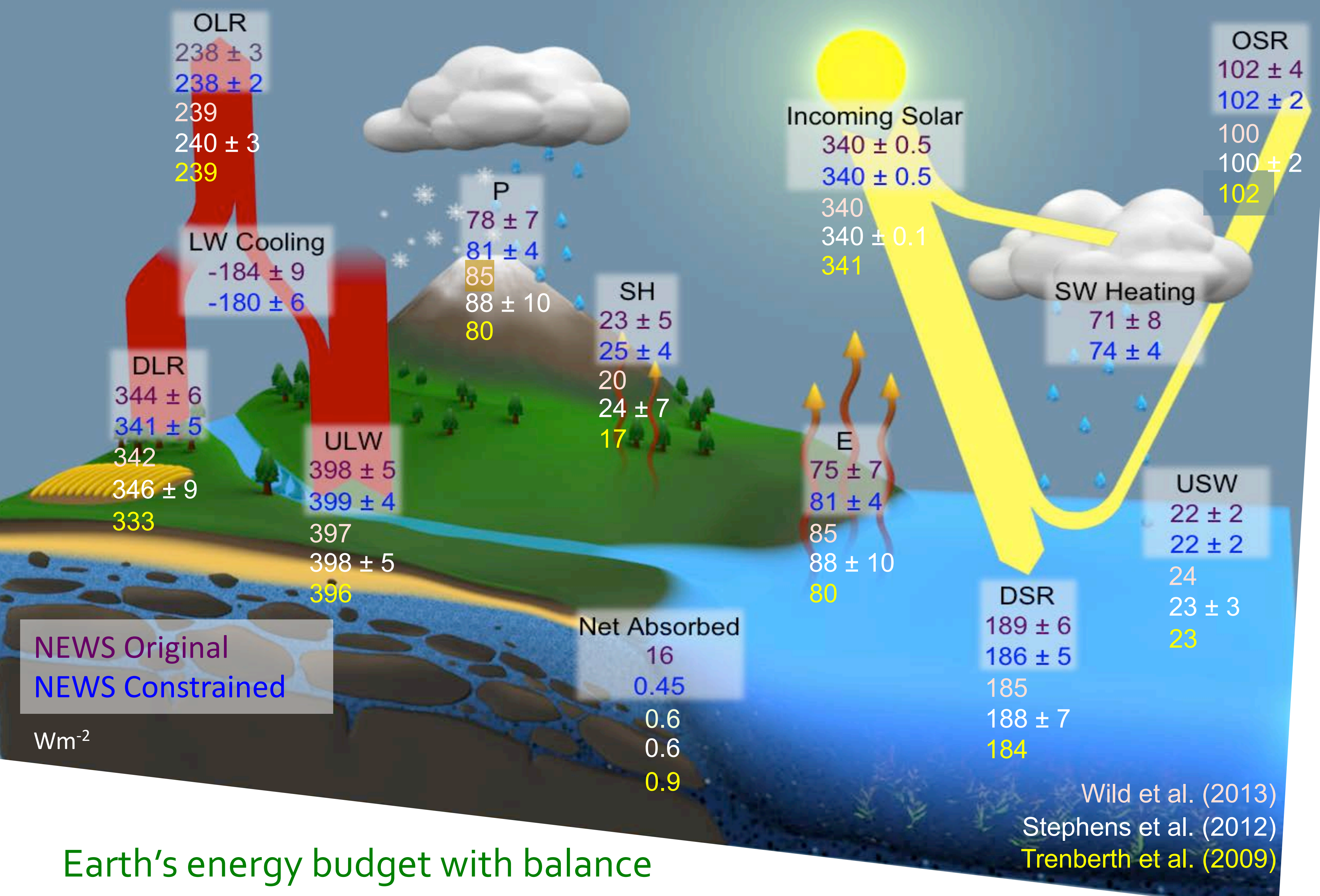



Earth's water cycle with balance constraints imposed.

Rodell et al. (2015)

https://disc.gsfc.nasa.gov/uui/datasets/NEWS_WEB_ACLIM_V1.0/summary

NASA ENERGY AND WATER CYCLE STUDY




Earth's energy budget with balance constraints imposed.

L'Ecuyer et al. (2015)

NASA ENERGY AND WATER CYCLE STUDY

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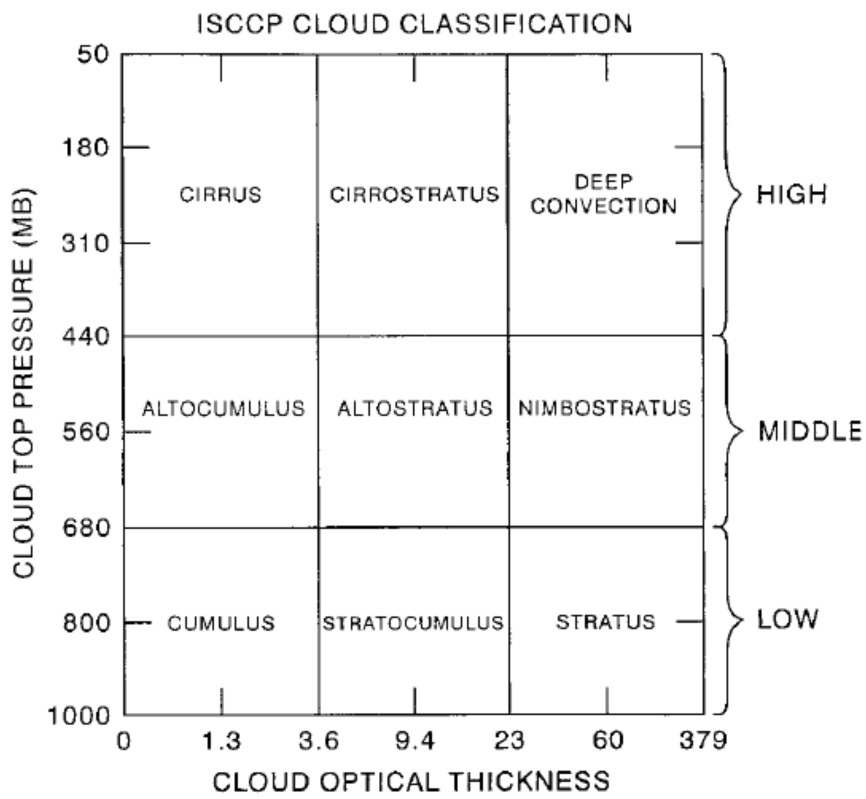
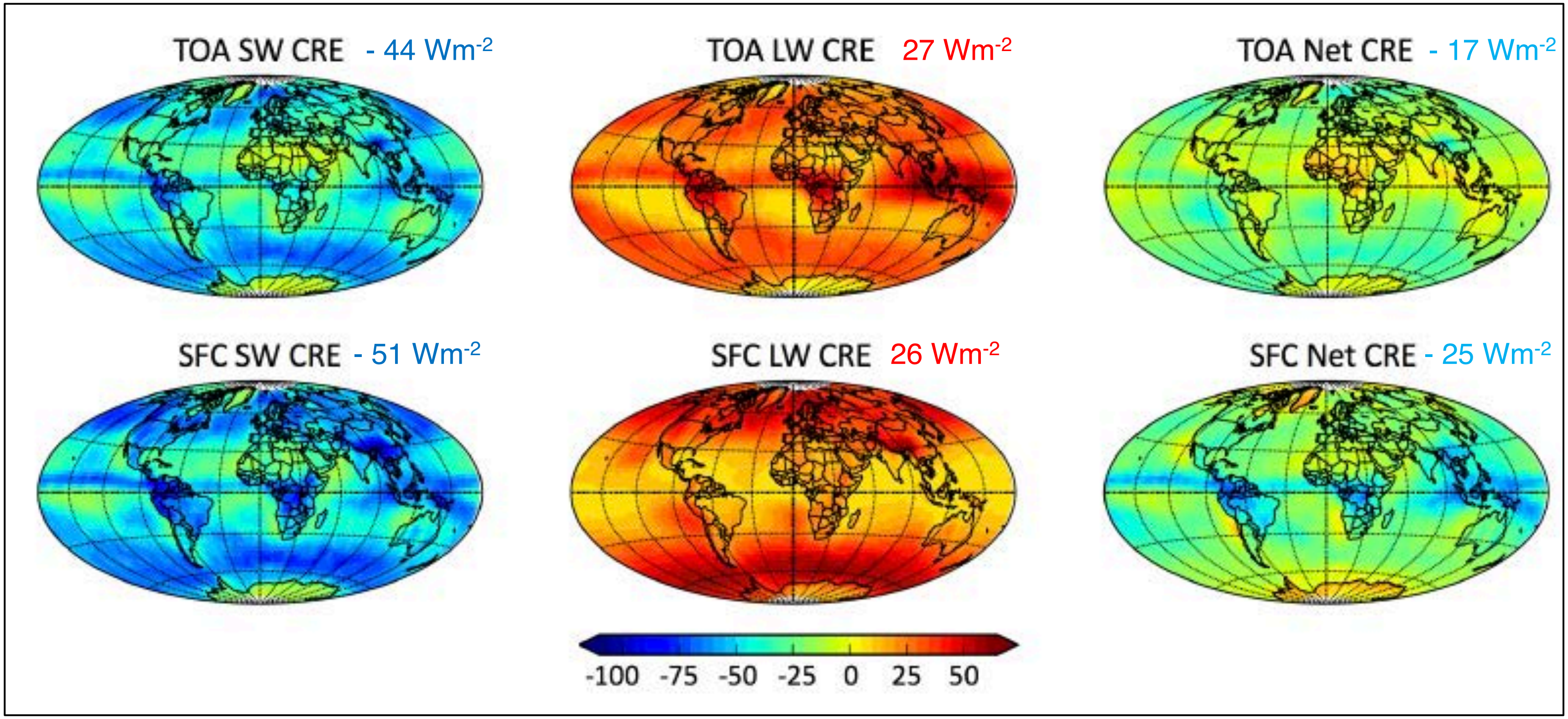
# Reassessing the Influence of Clouds on Earth's Radiation Budget



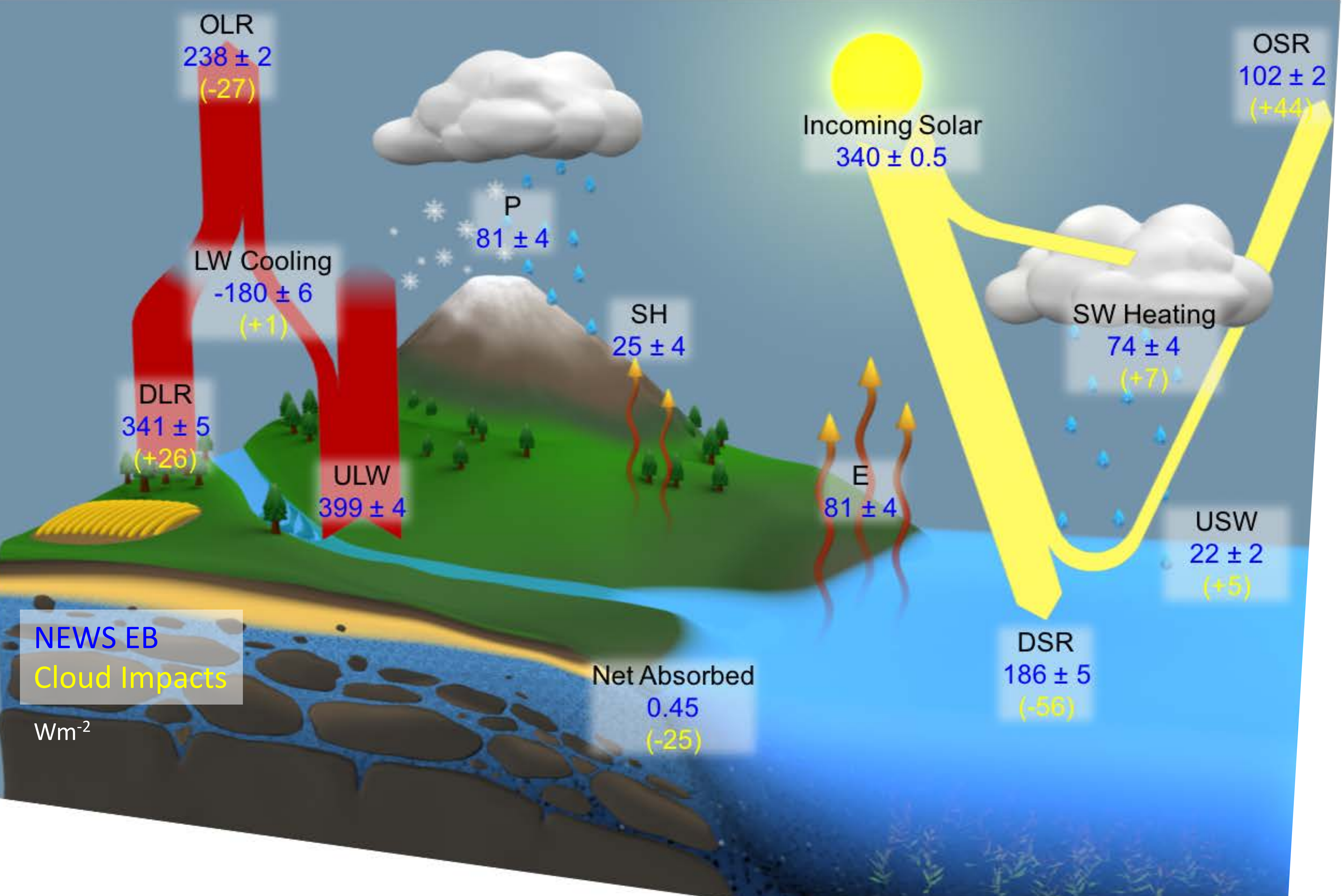

Rossow and Schiffer, *BAMS* (1999)

# CloudSat/CALIPSO Perspective

2007-2010 Mean




Hang et al, in preparation, 2017




## Cloud effects in the context of Earth's energy budget

# Rossow and Lacis, *J. Climate* (1990)

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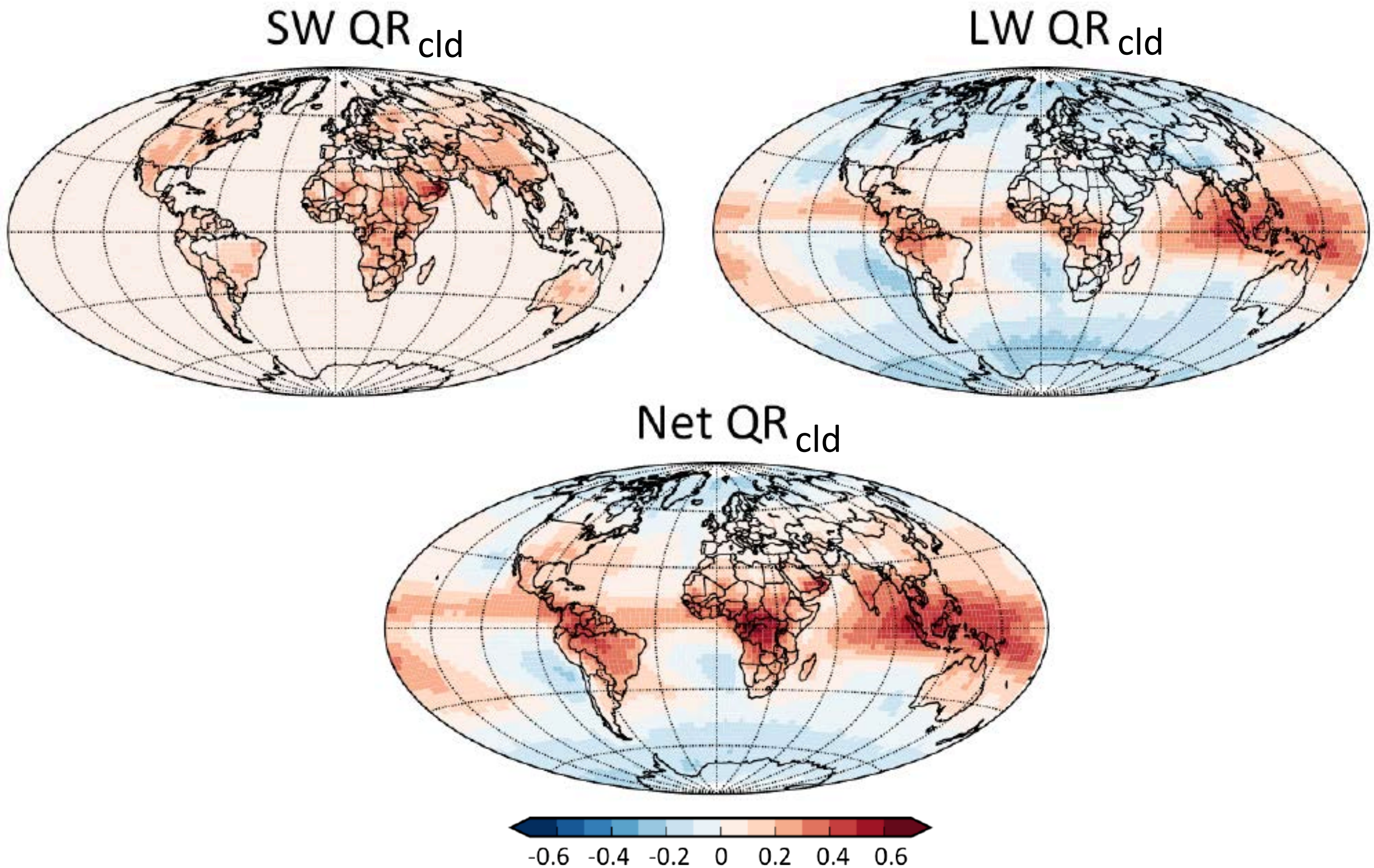
TABLE 9. Annual global mean ERB, SRB, net solar heating and net thermal cooling from NOAA-5 analysis and from the GISS GCM climatology (values in parenthesis). "Cloudy" and "clear" quantities represent global values estimated by assuming completely clear or completely cloud conditions.

| Quantity (w m$^{-2}$) | Total | Cloudy | Clear | Total − clear | | Cloudy − clear |
|---|---|---|---|---|---|---|
| ERB | 12 (17) | −23 (−2) | 51 (37) | −38 (−21) | -17 | −73 (−39) |
| SRB | 128 (105) | 95 (64) | 163 (150) | −35 (−45) | -25 | −68 (−86) |
| Net Sol TOA | 237 (222) | 187 (166) | 292 (284) | −55 (−63) | | −105 (−119) |
| Net Sol SRF | 169 (158) | 113 (100) | 231 (222) | −62 (−65) | | −118 (−123) |
| Net Therm TOA | 225 (205) | 210 (168) | 241 (247) | −16 (−42) | | −31 (−79) |
| Net Therm SRF | 41 (53) | 17 (36) | 67 (72) | −26 (−19) | | −50 (−37) |

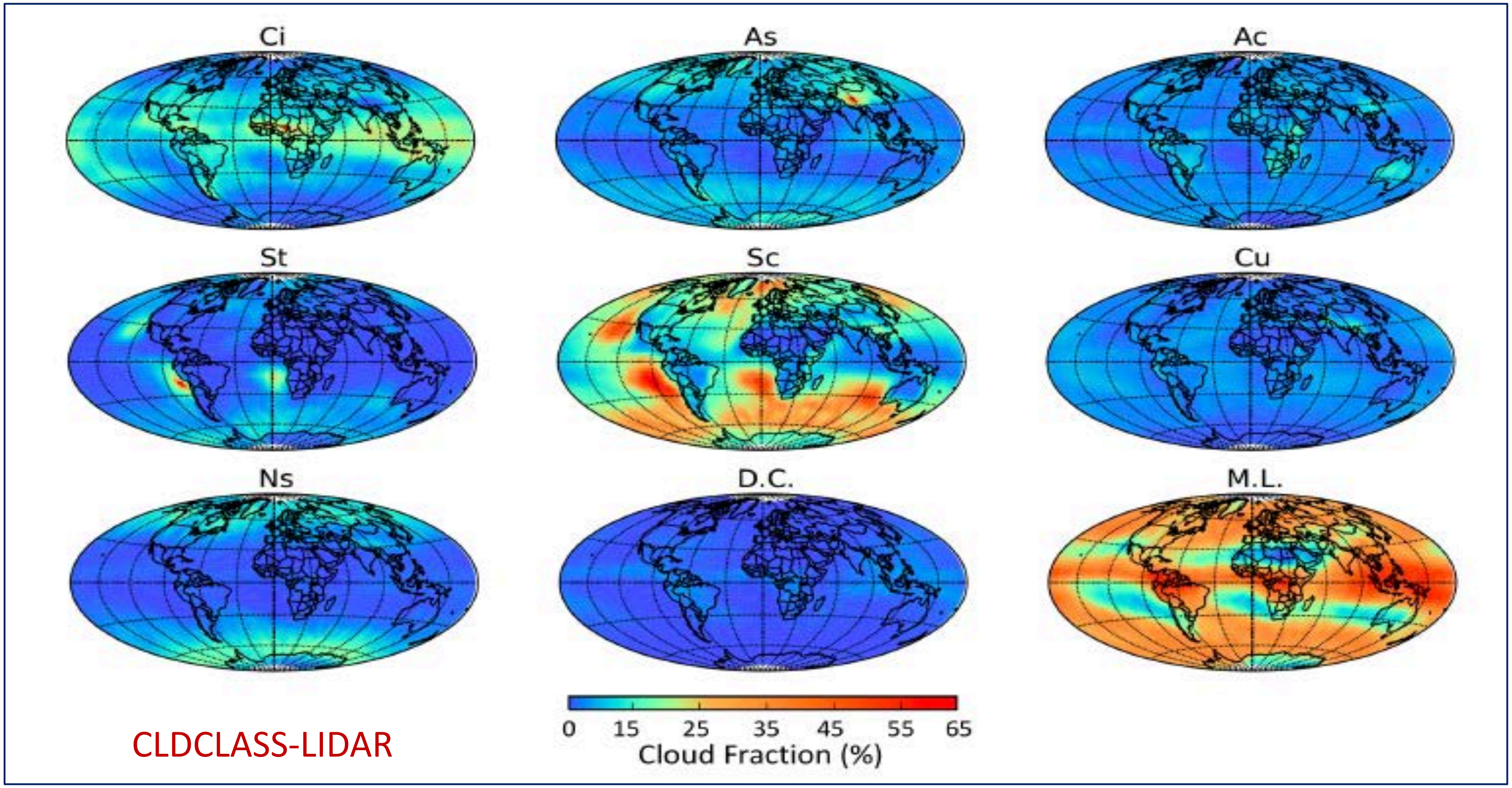
# Cloud Impact on Radiative Heating




$$Q = \frac{dT}{dt} = -\frac{g}{c_p}\frac{\Delta F_{NET}}{\Delta p}$$

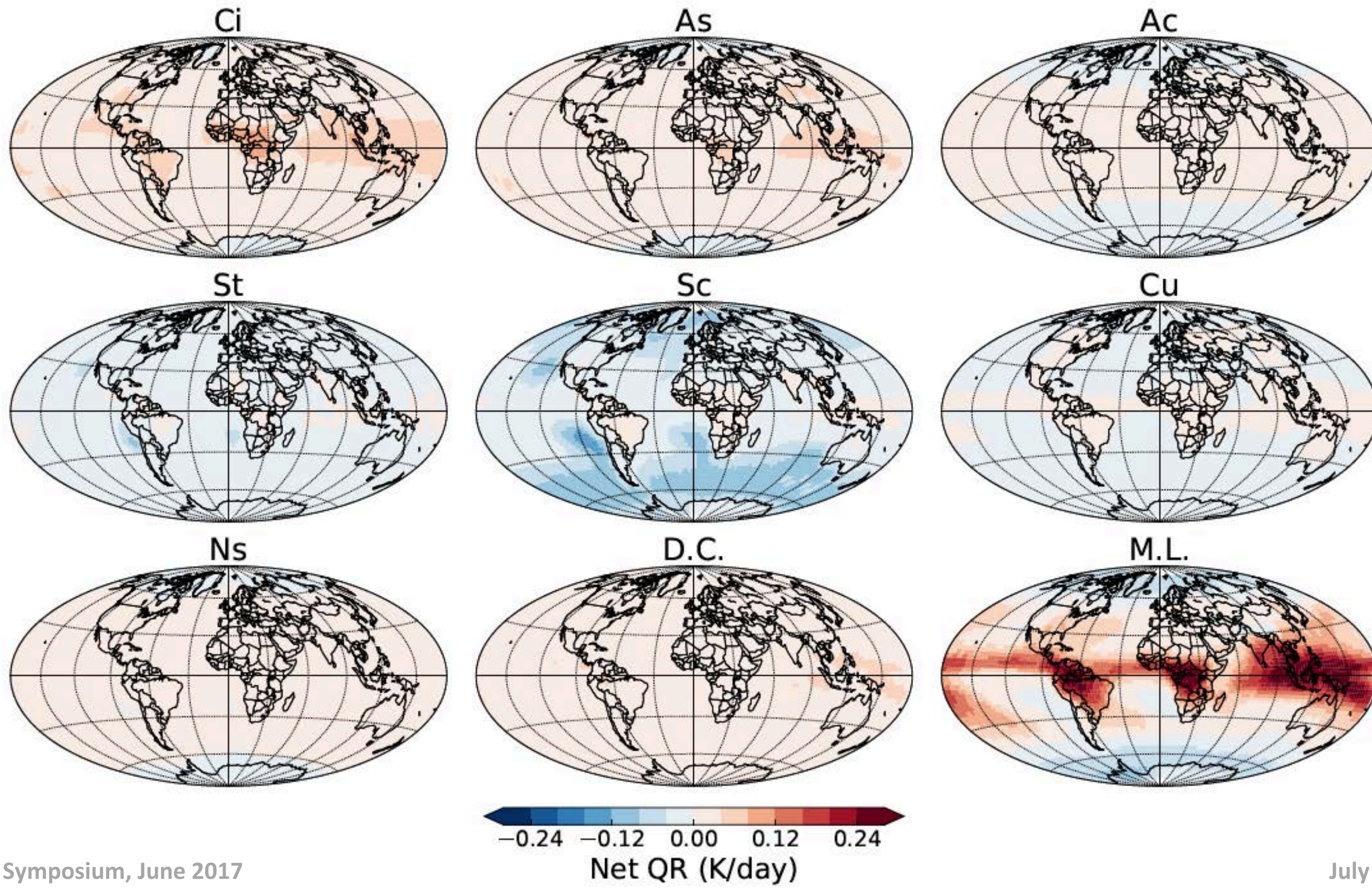
Cloud Impact = $Q_{all\text{-}sky} - Q_{clr\text{-}sky} \propto CF_{TOA} - CF_{SFC}$

# Distinguishing Cloud Regimes



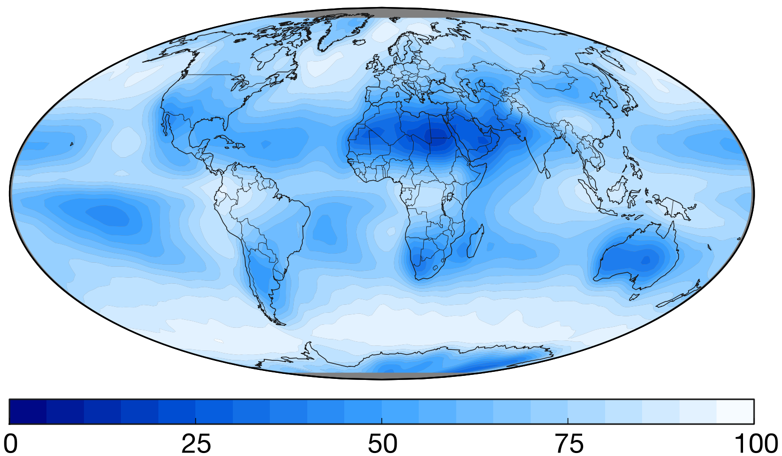

Hang et al, in preparation, 2017

# Influence on Column Heating

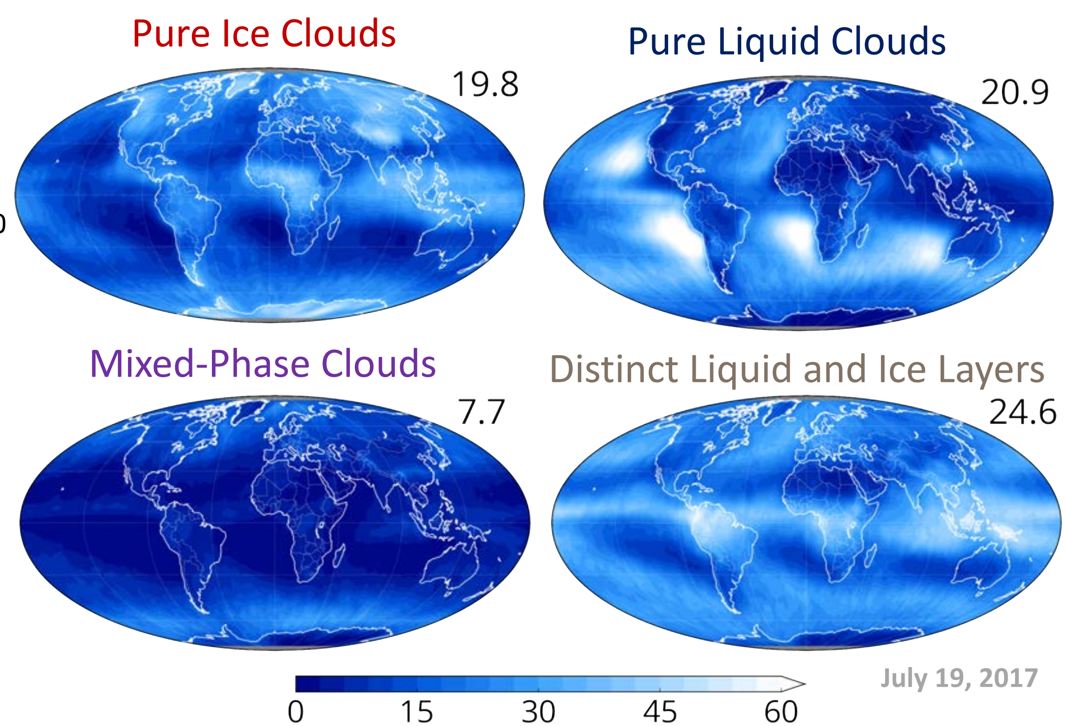


# A "Simple" Cloud Phase Classification

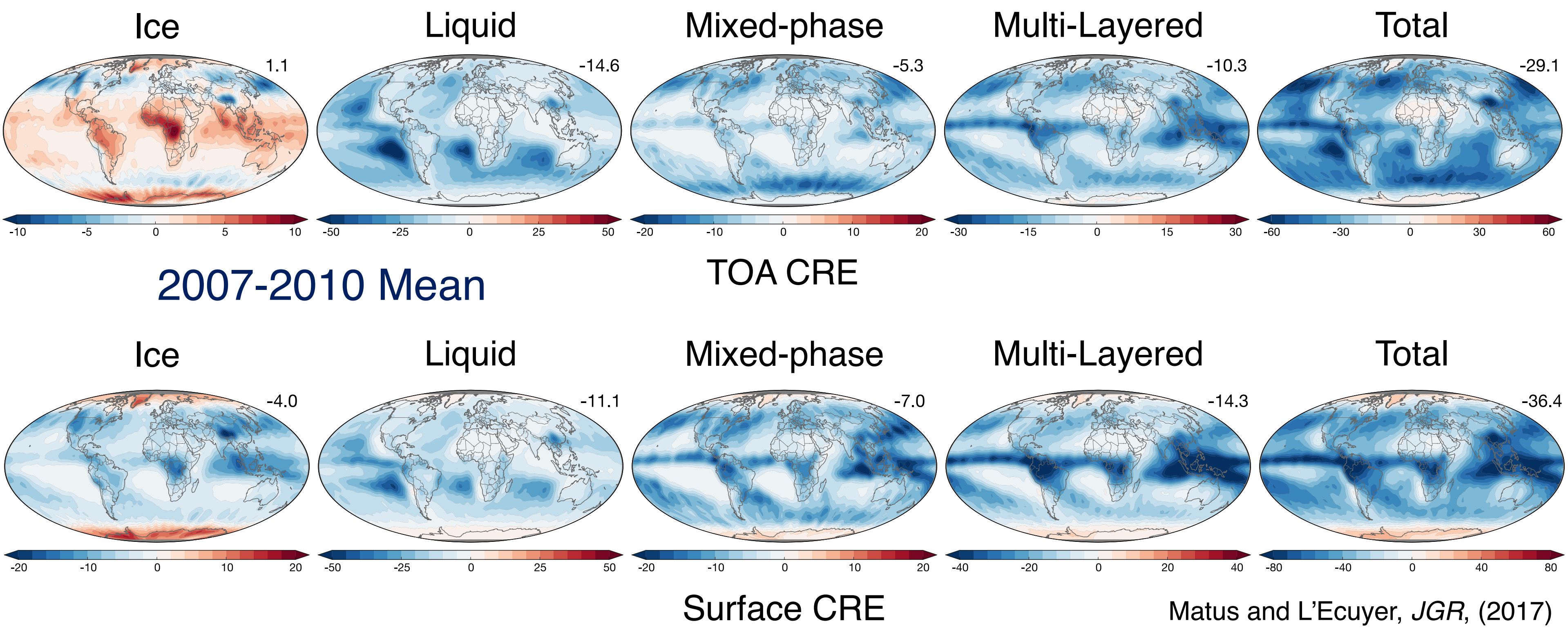
Total Cloud Fraction




Matus and L'Ecuyer, *JGR*, (2017)



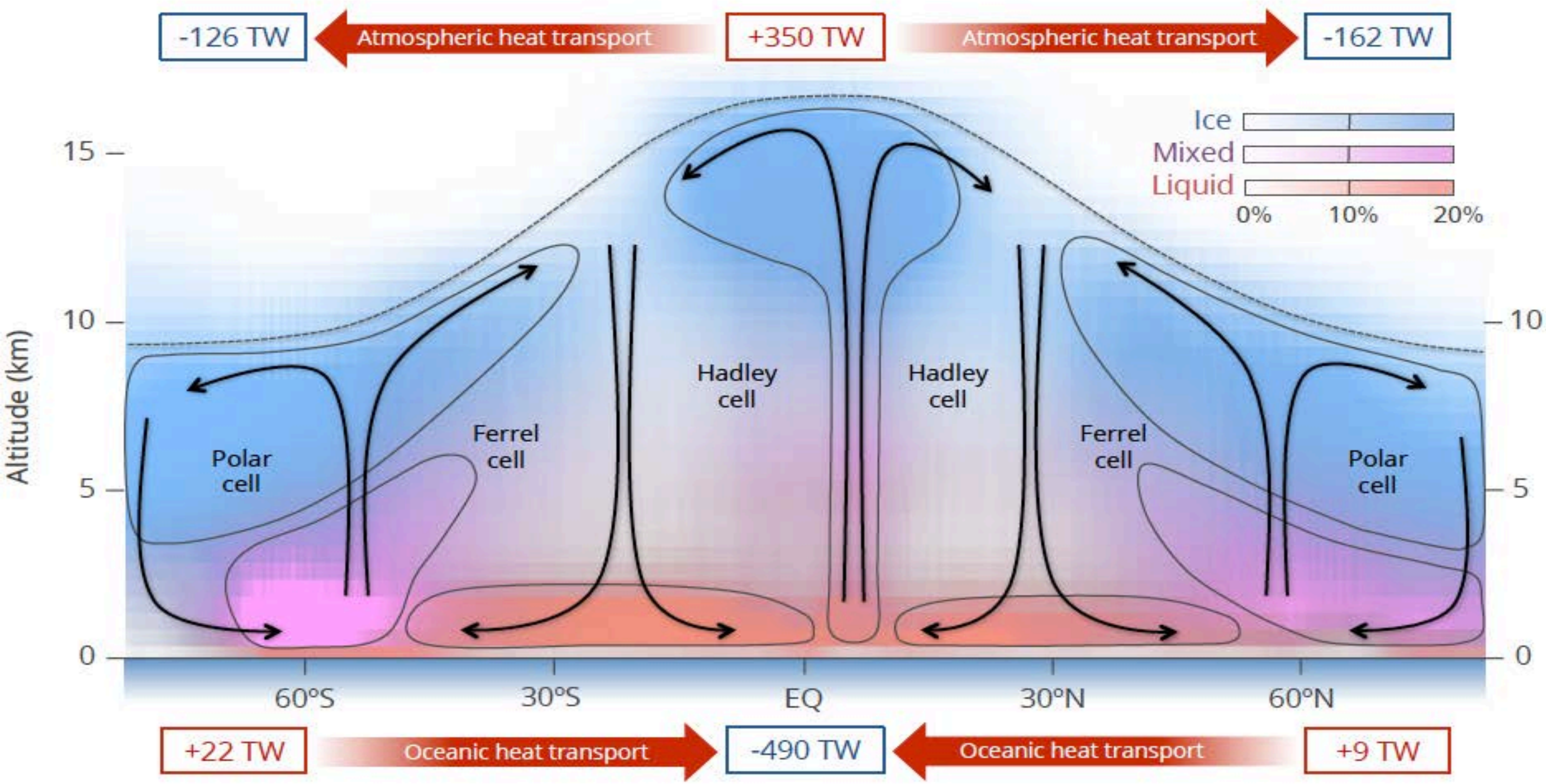
# Net Radiative Effects




Matus and L'Ecuyer, *JGR*, (2017)

Despite making up only **8%** of total cloud cover, mixed-phase clouds contribute about **20%** to the NET CRE at both TOA and surface

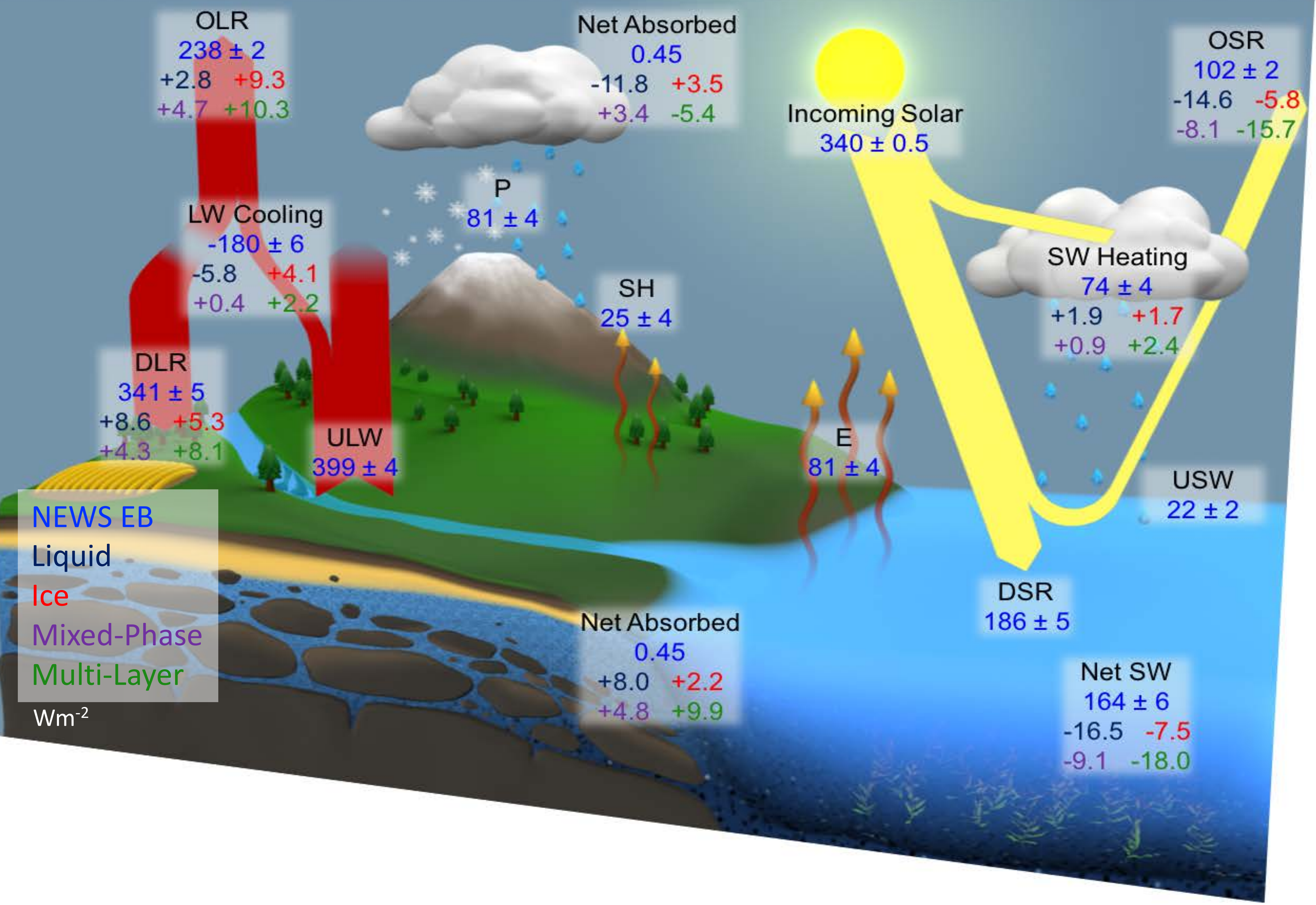
# Vertical Distribution




Matus and L'Ecuyer, *JGR*, (2017)

# Key Points

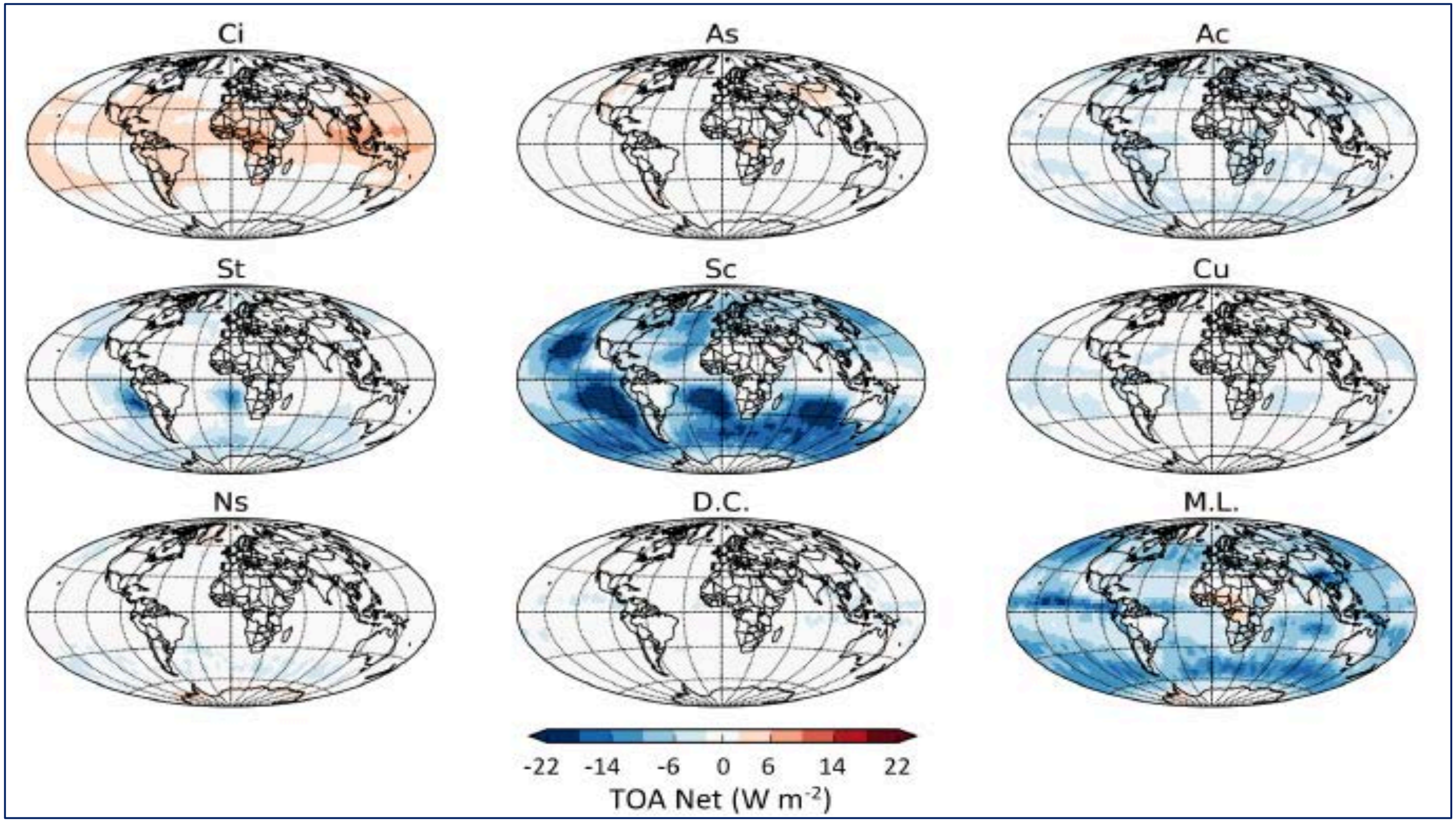
- The new dimension provided by active sensors enable cloud states to be redefined to explicitly include vertical structure information, including a more robust separation of single- and multi-layer cloud systems and mixed-phase clouds.
- On the annual mean, clouds are found to exert a net cooling of -17 $Wm^{-2}$ (±6 $Wm^{-2}$) globally.
- Multi-layered clouds are prevalent in many of the classical cloud regimes, accounting for 42% of global cloud cover and contributing nearly 30% of the total net global cloud radiative effect at TOA.
- Mixed-phase clouds comprise less than 10% of total cloud cover but account for about 20% of the net cloud radiative effect at TOA and surface.




Influence of cloud phase on Earth's energy budget

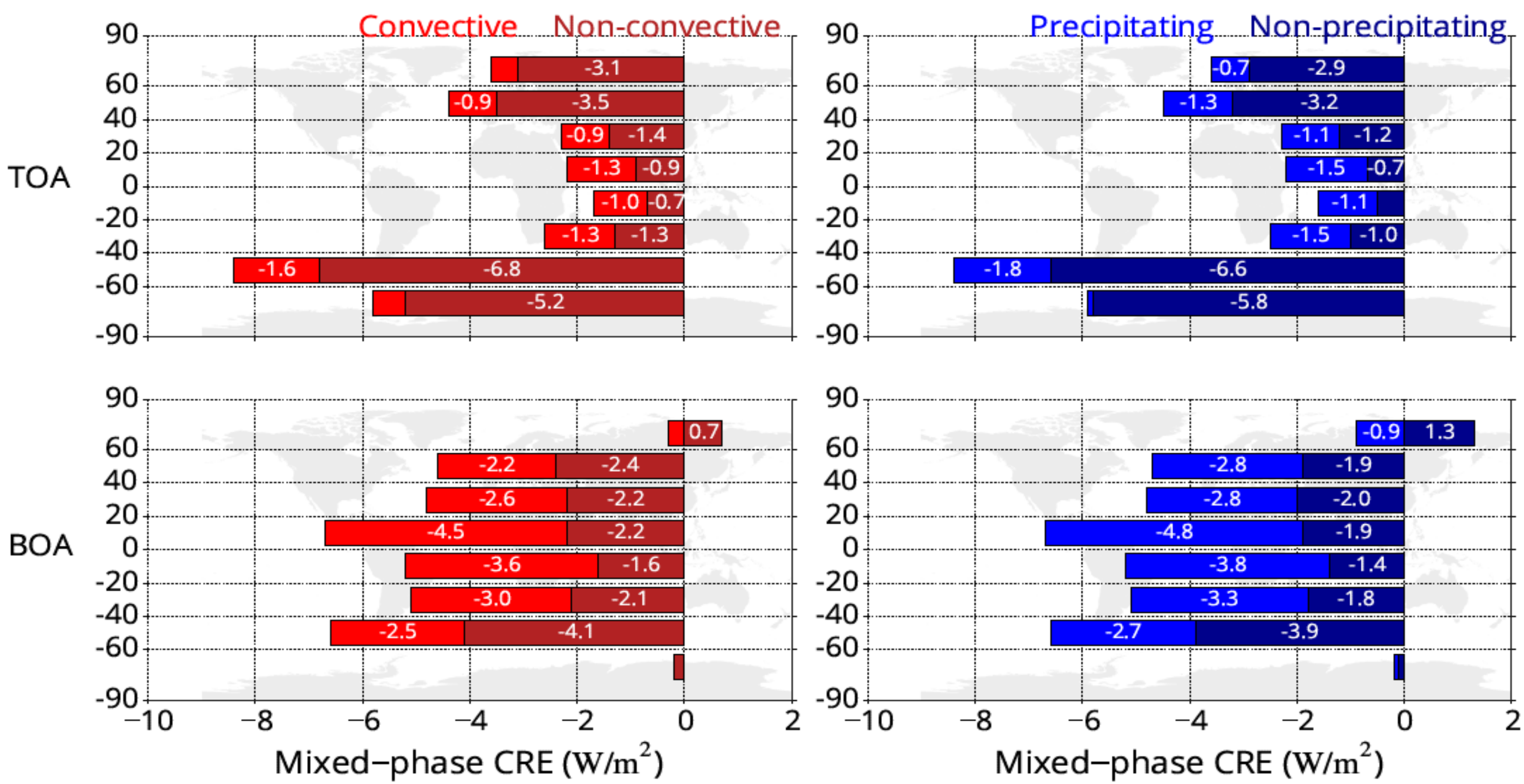
# 2016 GDAP Meeting

# Influence on TOA CRE



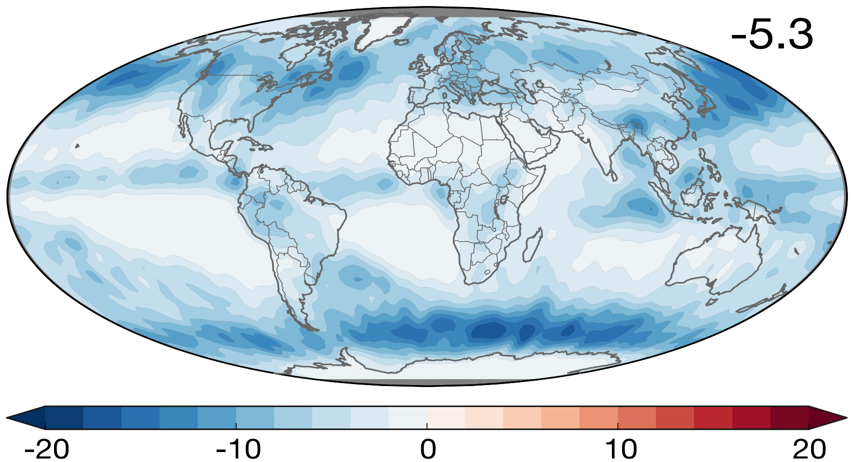

Hang et al, in preparation, 2017

# Distinguishing Mixed-Phase Regimes

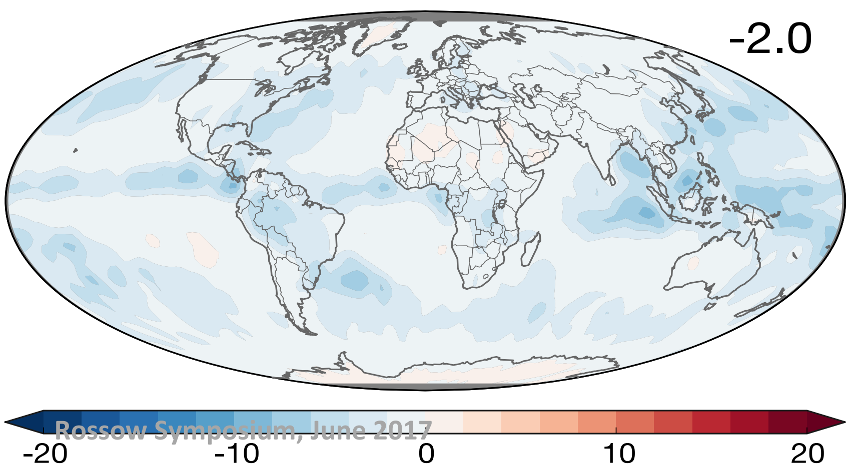


# Regional Distribution of Regimes

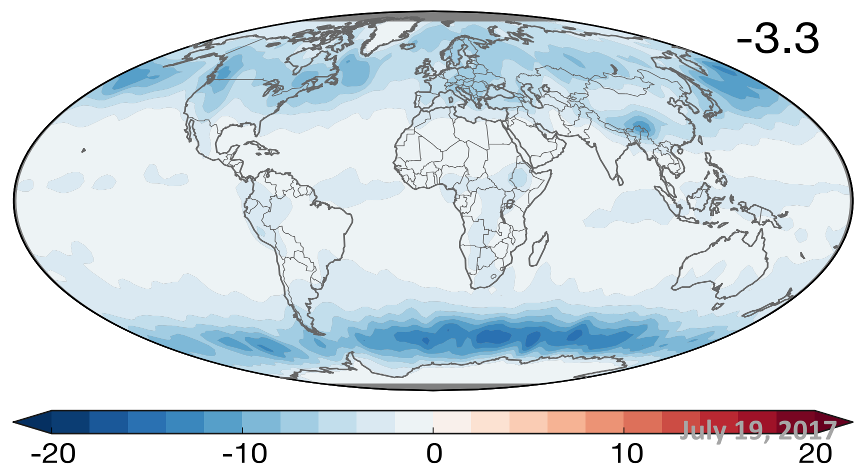
## Mixed-Phase Clouds



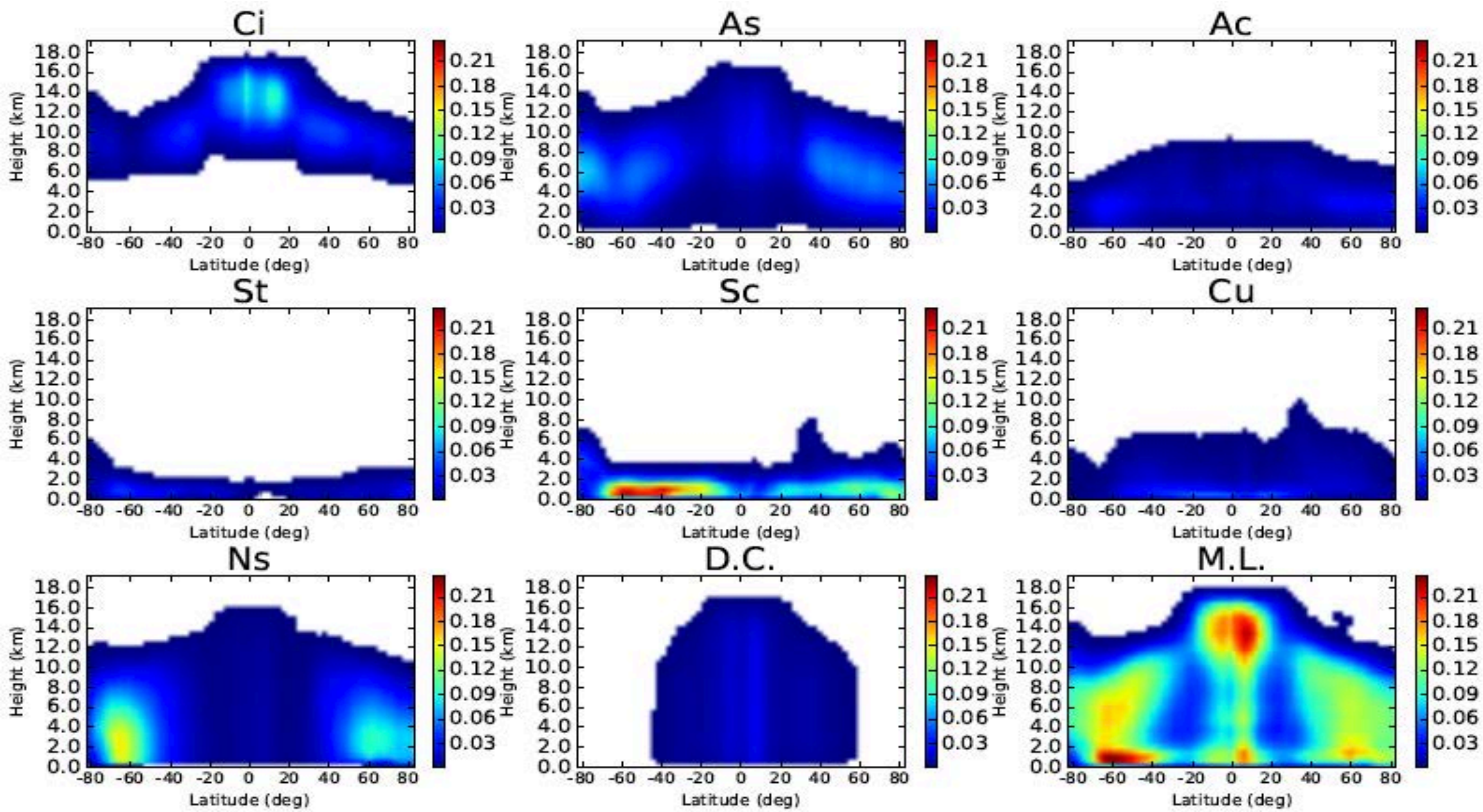

## Convective




## Non-convective

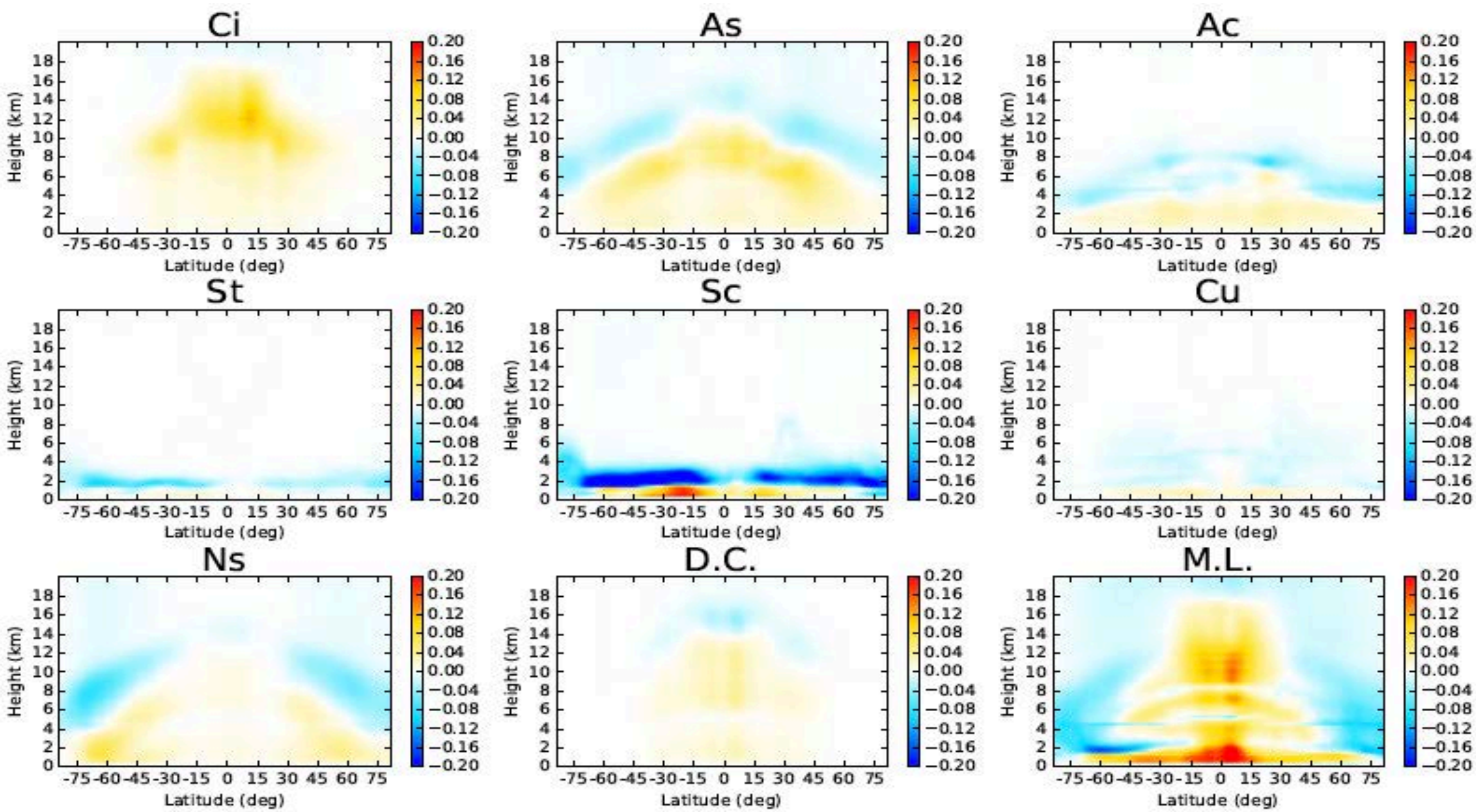


# Adding the Vertical Dimension




L'Ecuyer and Hang 2017, *in preparation*

# Influence on Net $Q_R(z)$




L'Ecuyer and Hang 2017, *in preparation*