



# Comprehensive cloud evaluation in GCMs

Keith Williams & Alejandro Bodas-Salcedo

CFMIP, 08/06/15



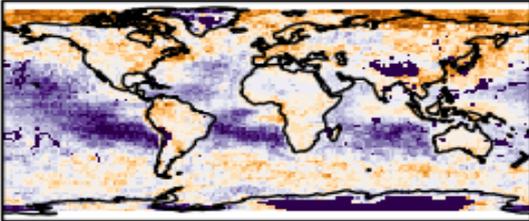
# Aims of the project

- Use a range of observational data and diagnostic techniques to provide a thorough evaluation of cloud.
- This is illustrated through the evaluation of:
  - The GA6 configuration of the Unified Model (currently operational at the Met Office).
  - Prototype GA7 configuration (#136.5), which contains numerous cloud changes. GA7 will be operational from spring 2016 & will underpin UKESM1 – the UK's submission to CMIP6.

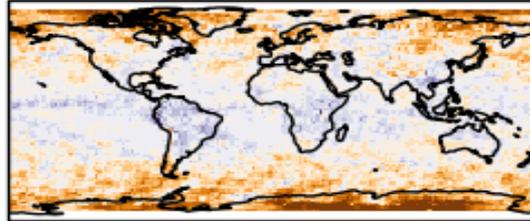
# Bias in cloud cover

(against CALIPSO)

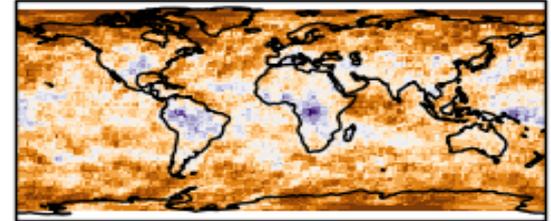
GA6-T+24  
Low-top cloud bias



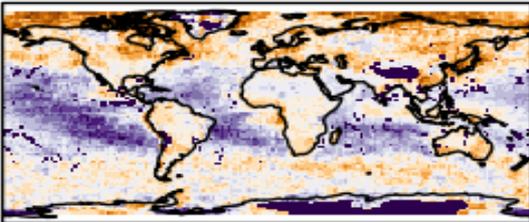
GA6-T+24  
Mid-top cloud bias



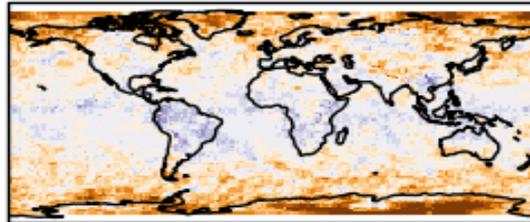
GA6-T+24  
High-top cloud bias



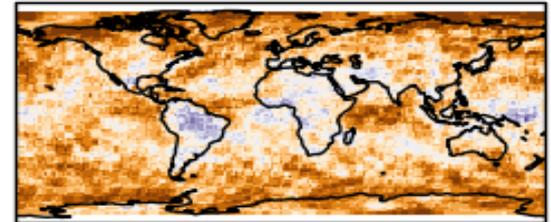
GA6-T+120  
Low-top cloud bias



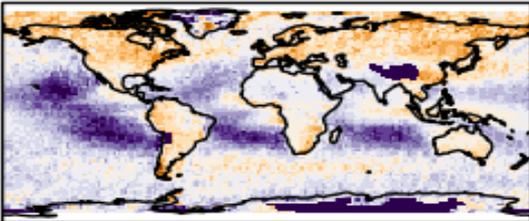
GA6-T+120  
Mid-top cloud bias



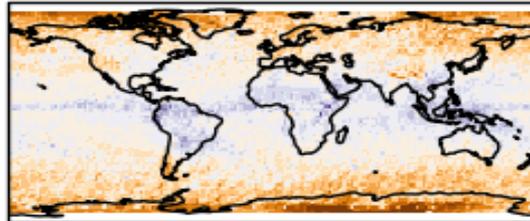
GA6-T+120  
High-top cloud bias



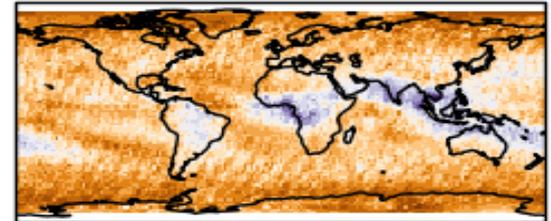
GA6-AMIP  
Low-top cloud bias



GA6-AMIP  
Mid-top cloud bias



GA6-AMIP  
High-top cloud bias





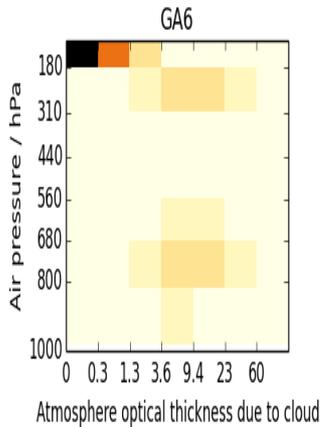
Met Office



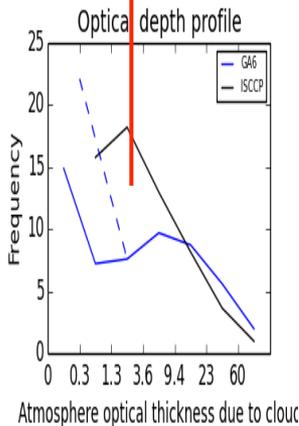
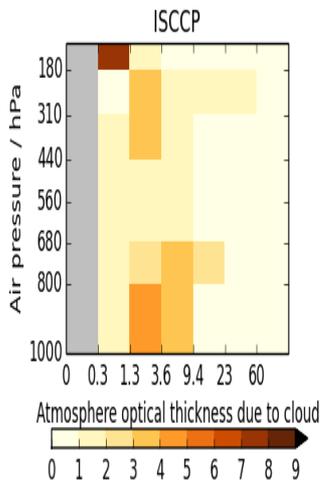
# Tropics

# Comparison against satellite data over the tropics

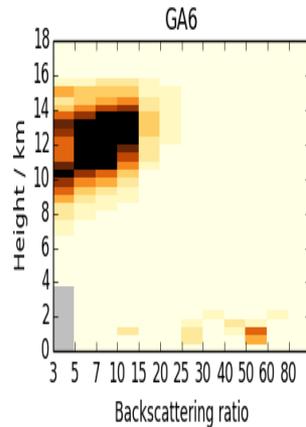
## ISCCP



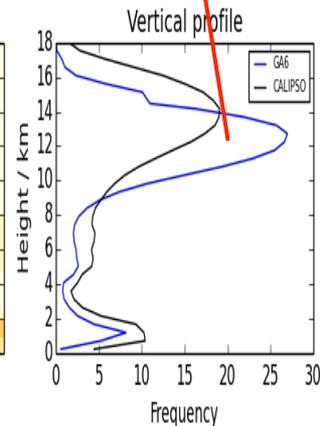
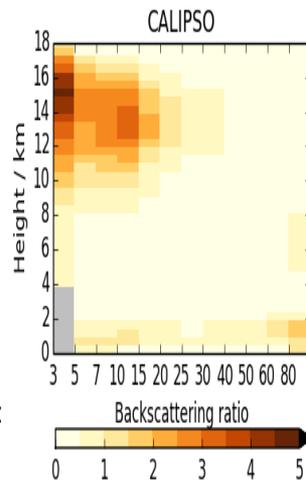
Too little medium brightness cloud



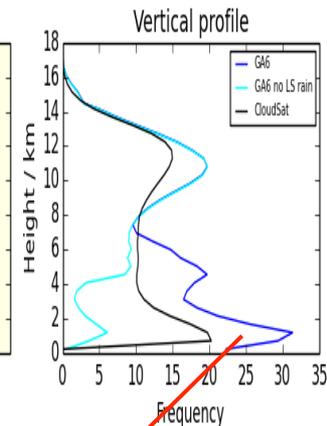
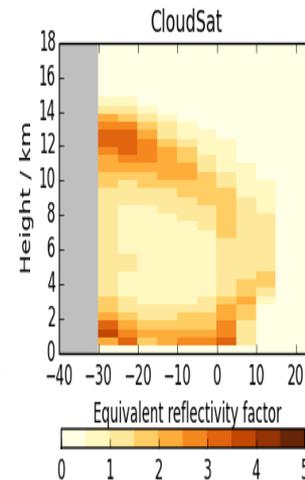
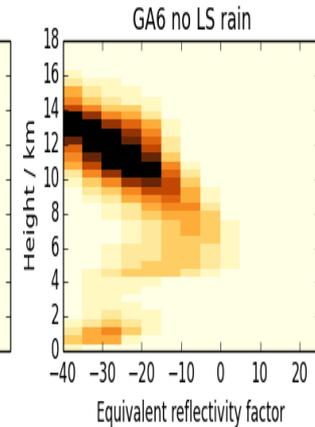
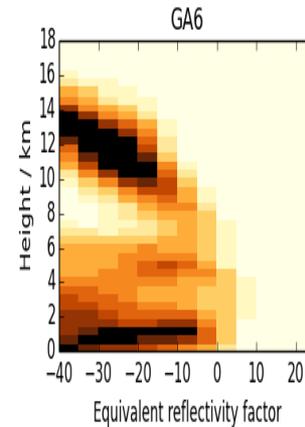
## CALIPSO



Excessive cirrus and too low



## CloudSat



Excess "drizzle" (<0.005mm/hr)

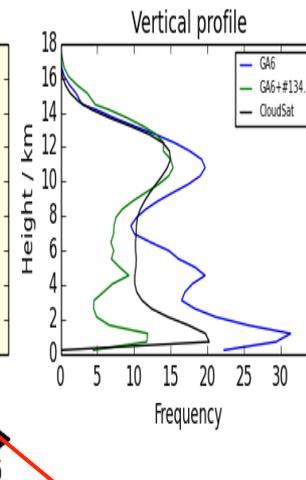
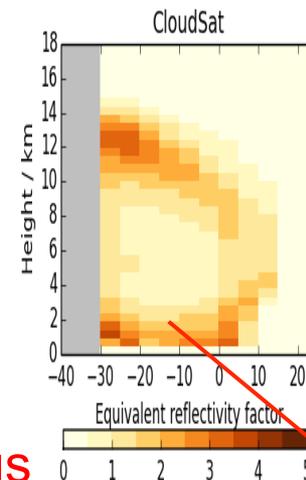
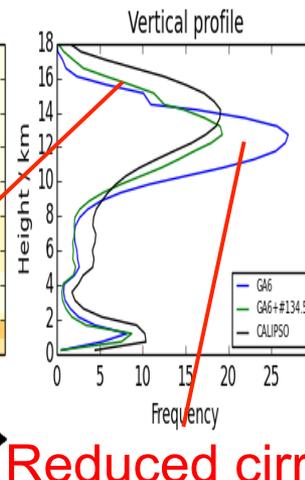
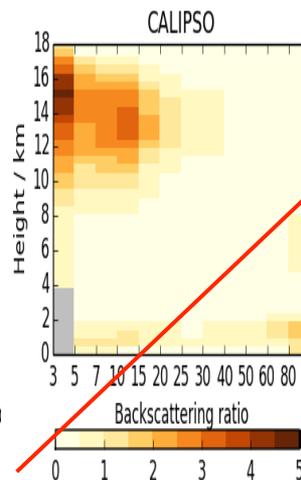
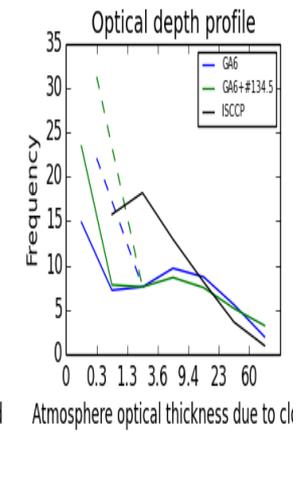
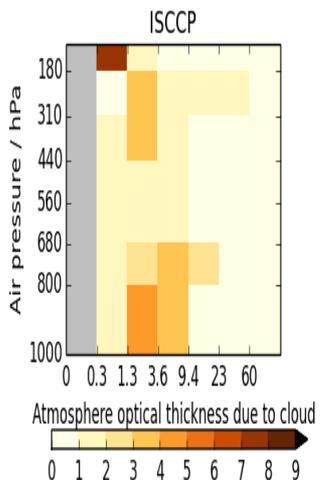
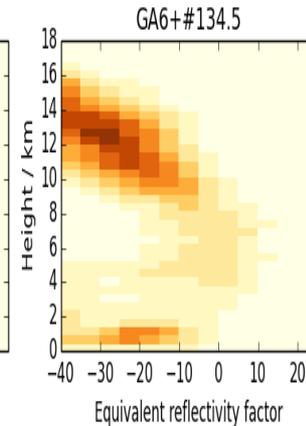
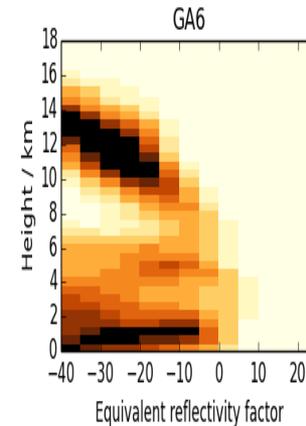
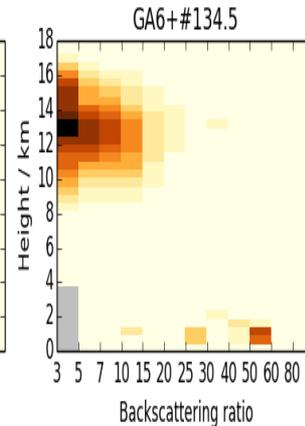
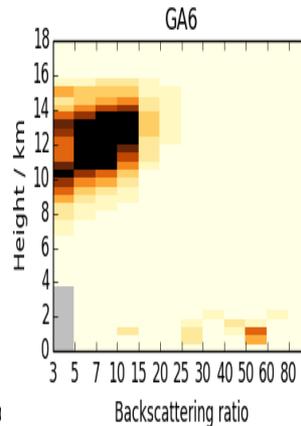
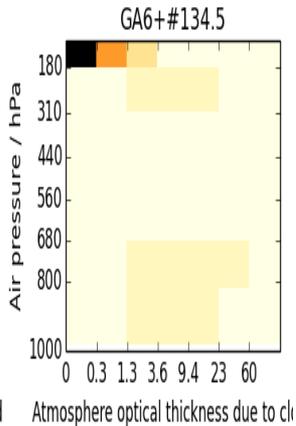
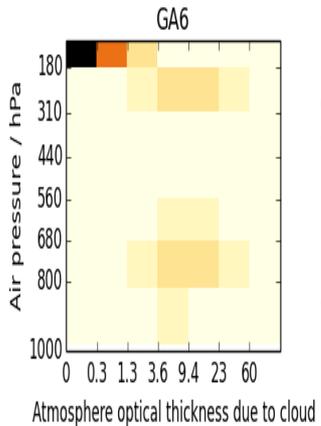


# Comparison against satellite data over the tropics

ISCCP

CALIPSO

CloudSat

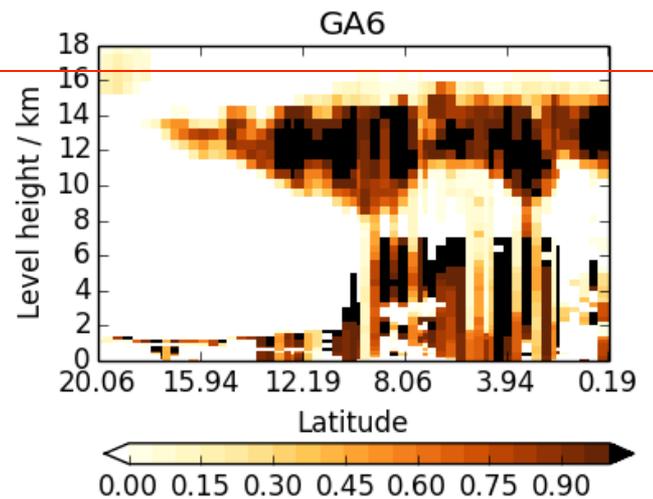
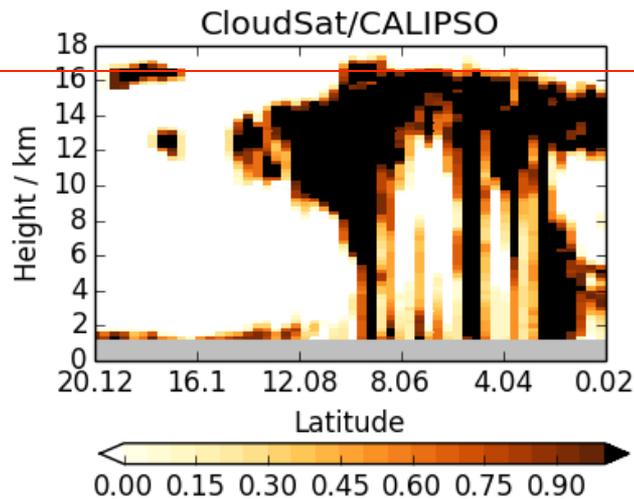
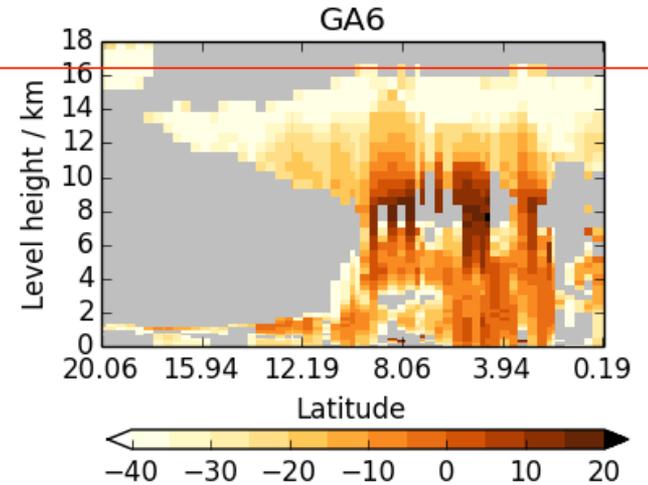
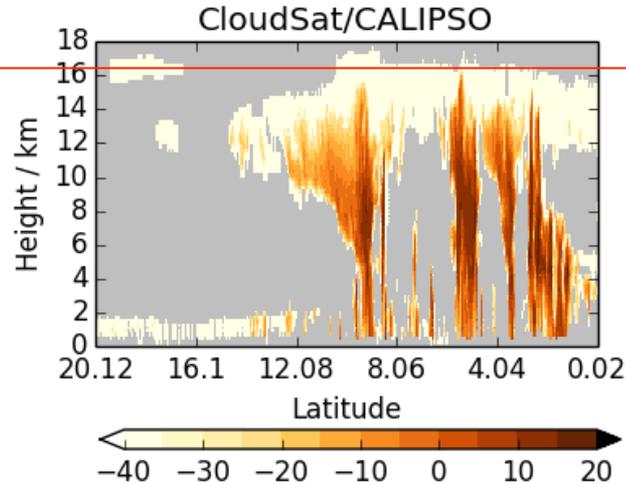
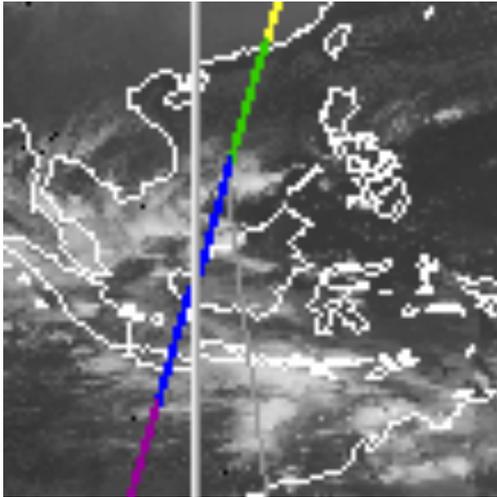


Reduced cirrus spreading rate

Warm rain microphysics

# Case study

## VT: 18Z 17/12/2010 (T+6)

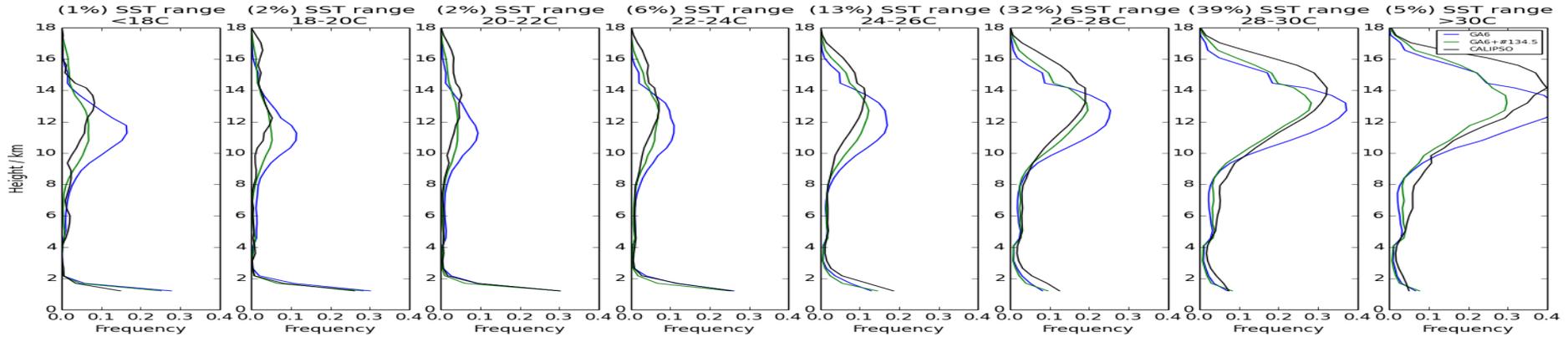




Met Office

By SST:

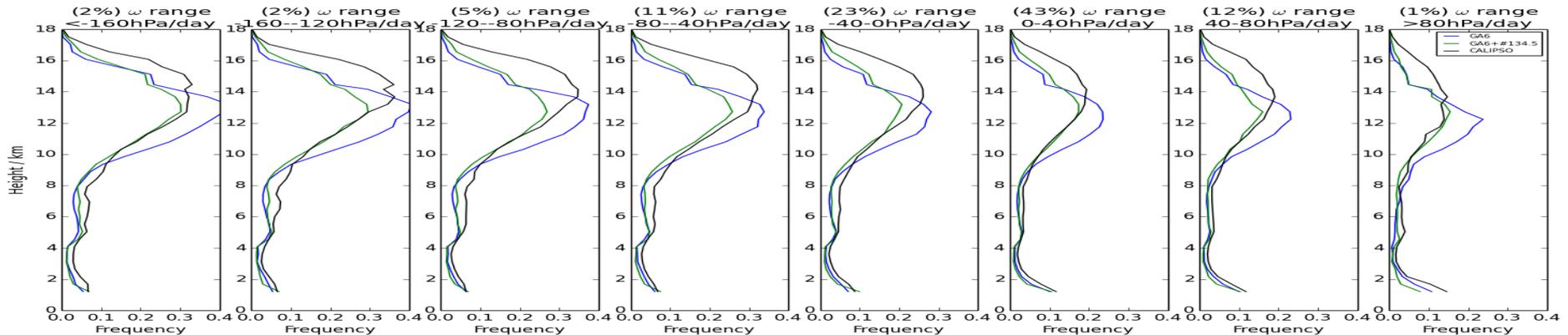
# CALIPSO composites (mean over tropics)



← Cool

Warm →

By vertical velocity:



← Strong ascent

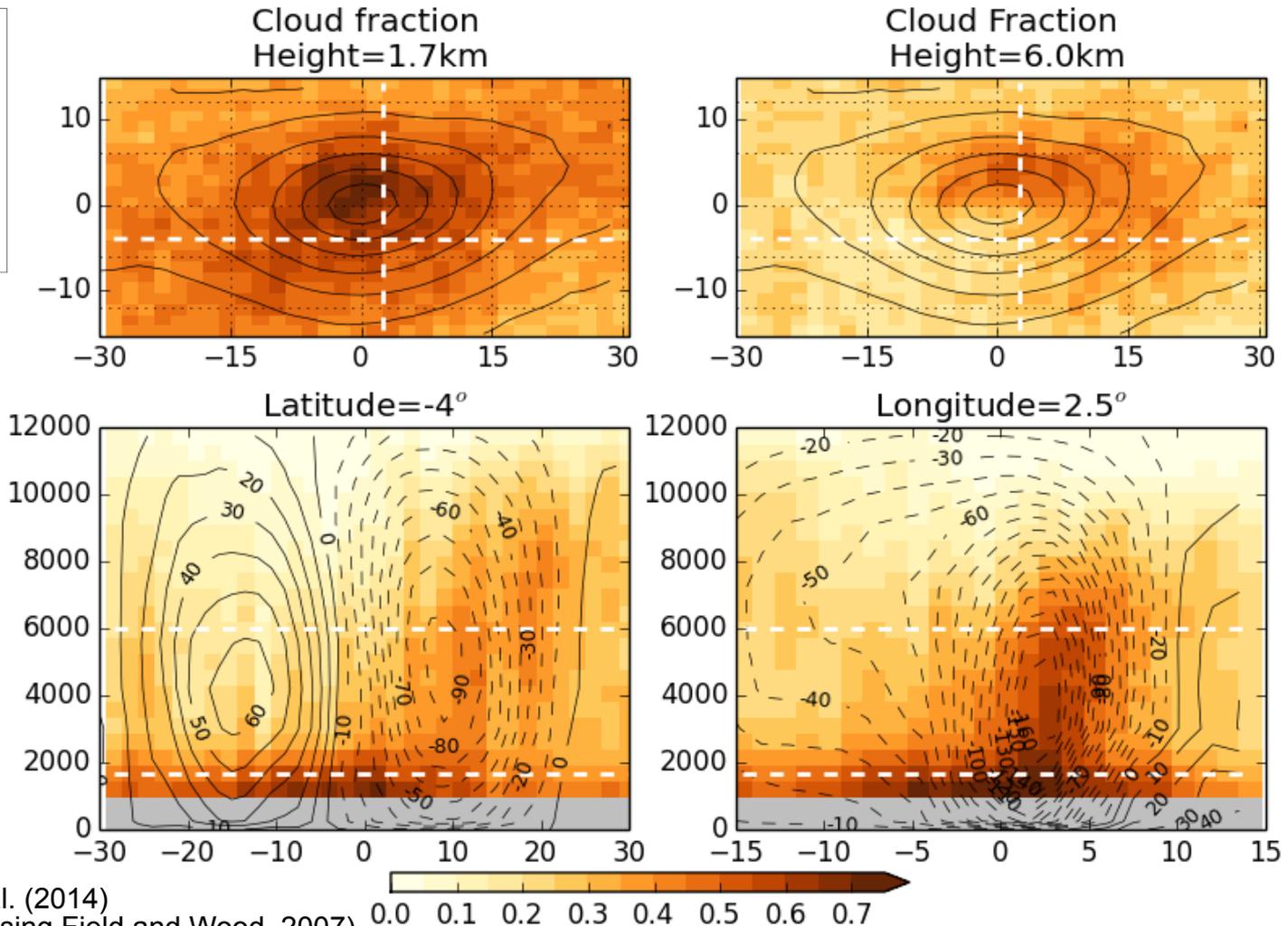
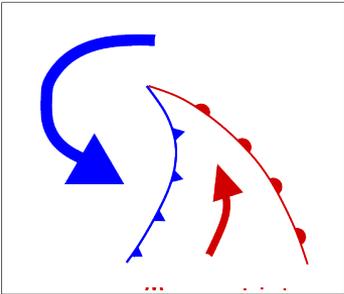
Strong subsidence →



# Mid-latitude storm tracks



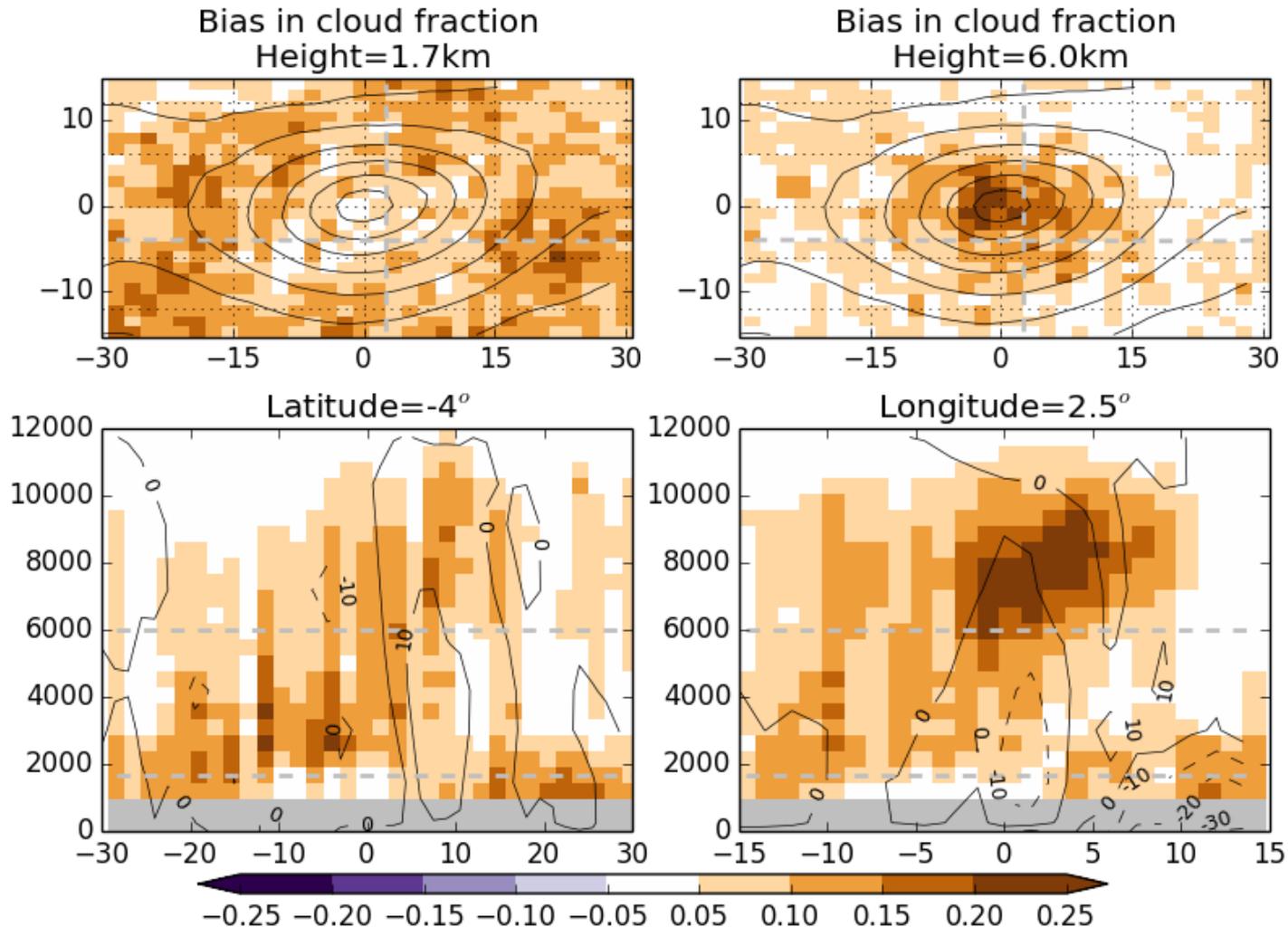
# Composite cyclone: RL-GEOPROF hydrometeor frac. Northern hemisphere winter



Following Govekar et al. (2014)  
(cyclone compositing using Field and Wood, 2007)

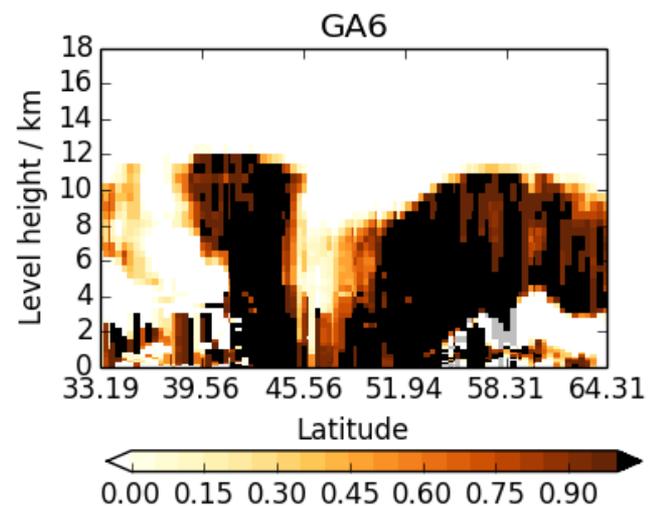
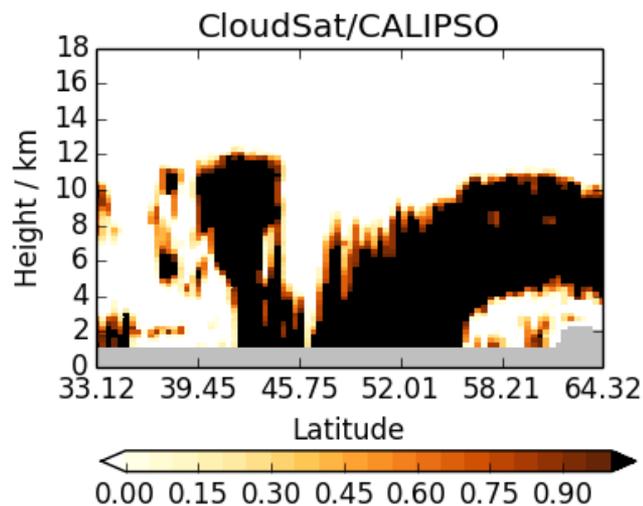
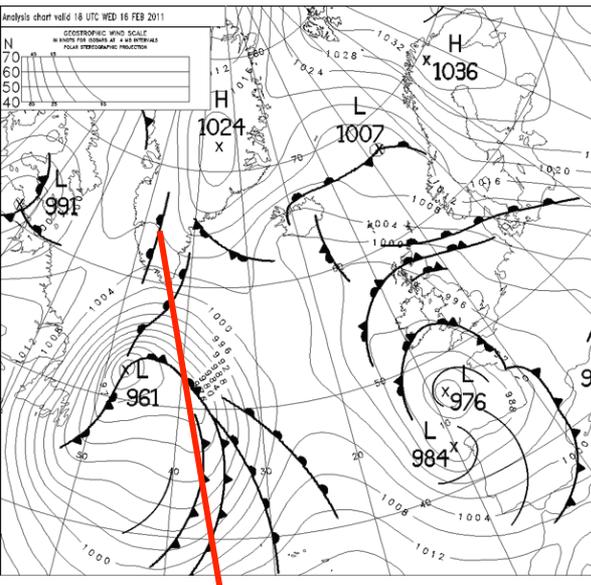
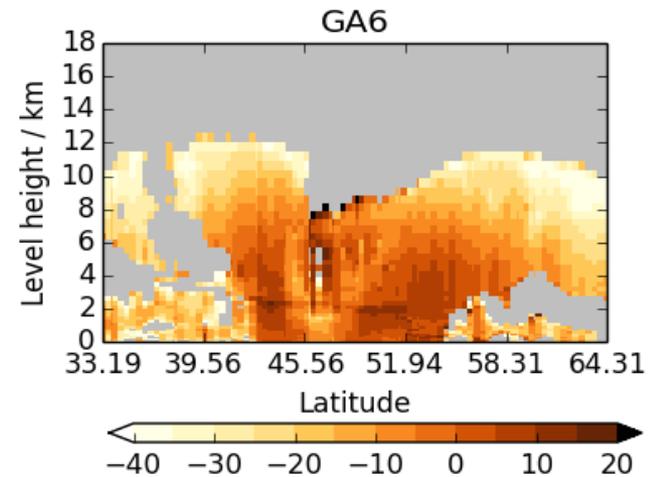
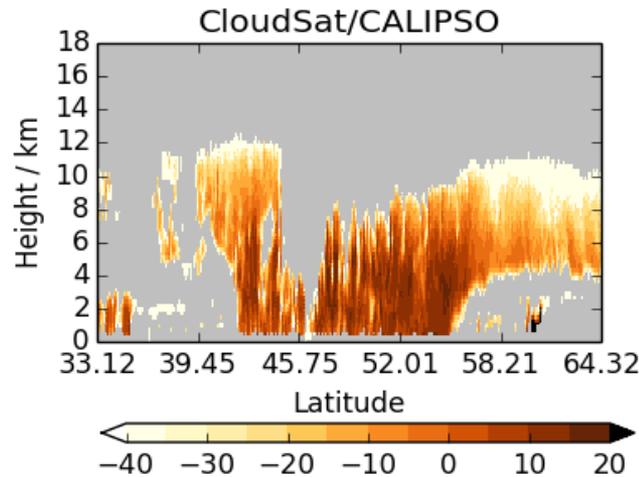
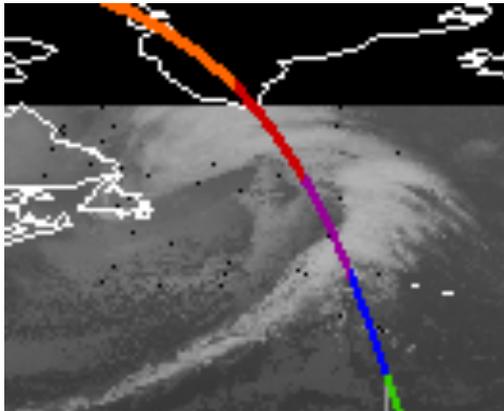


# Composite cyclone: GA6 hydrometeor frac bias Northern hemisphere winter



# Case study

## VT: 15Z 16/02/2011 (T+27)

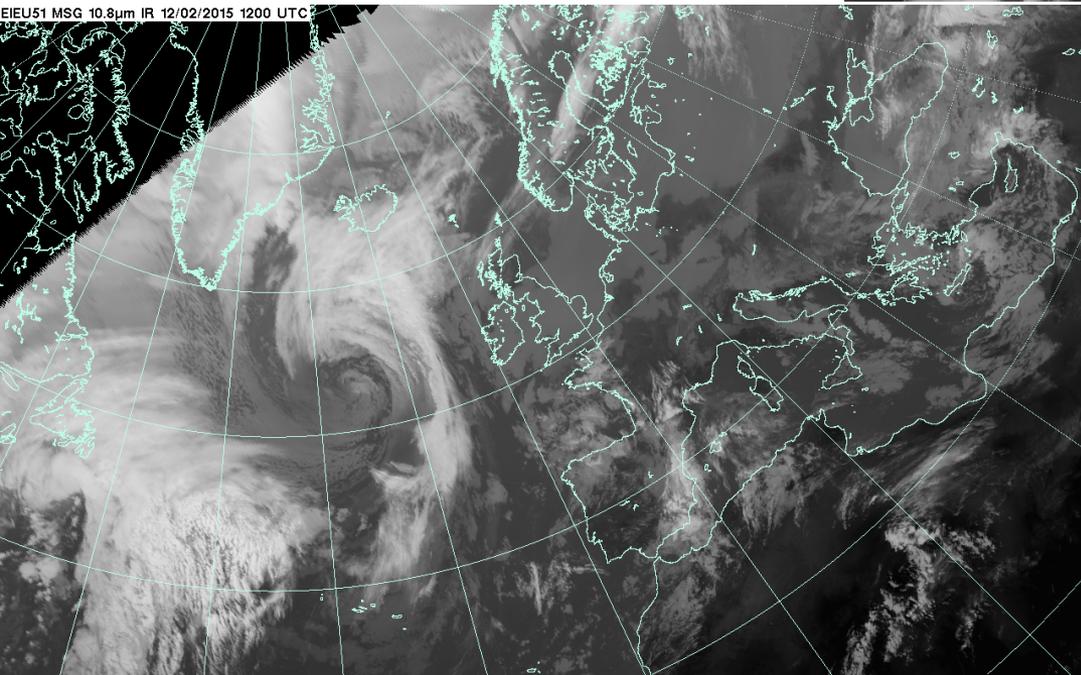
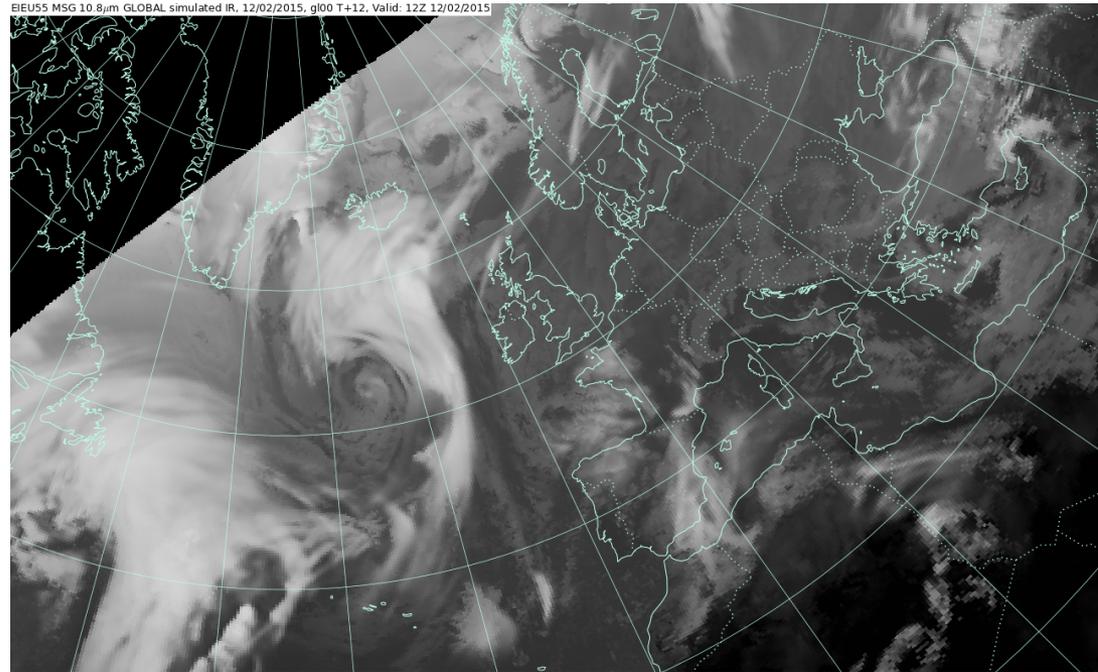




GA6

# Simulated imagery

VT: 12Z 12/02/15 (T+12)

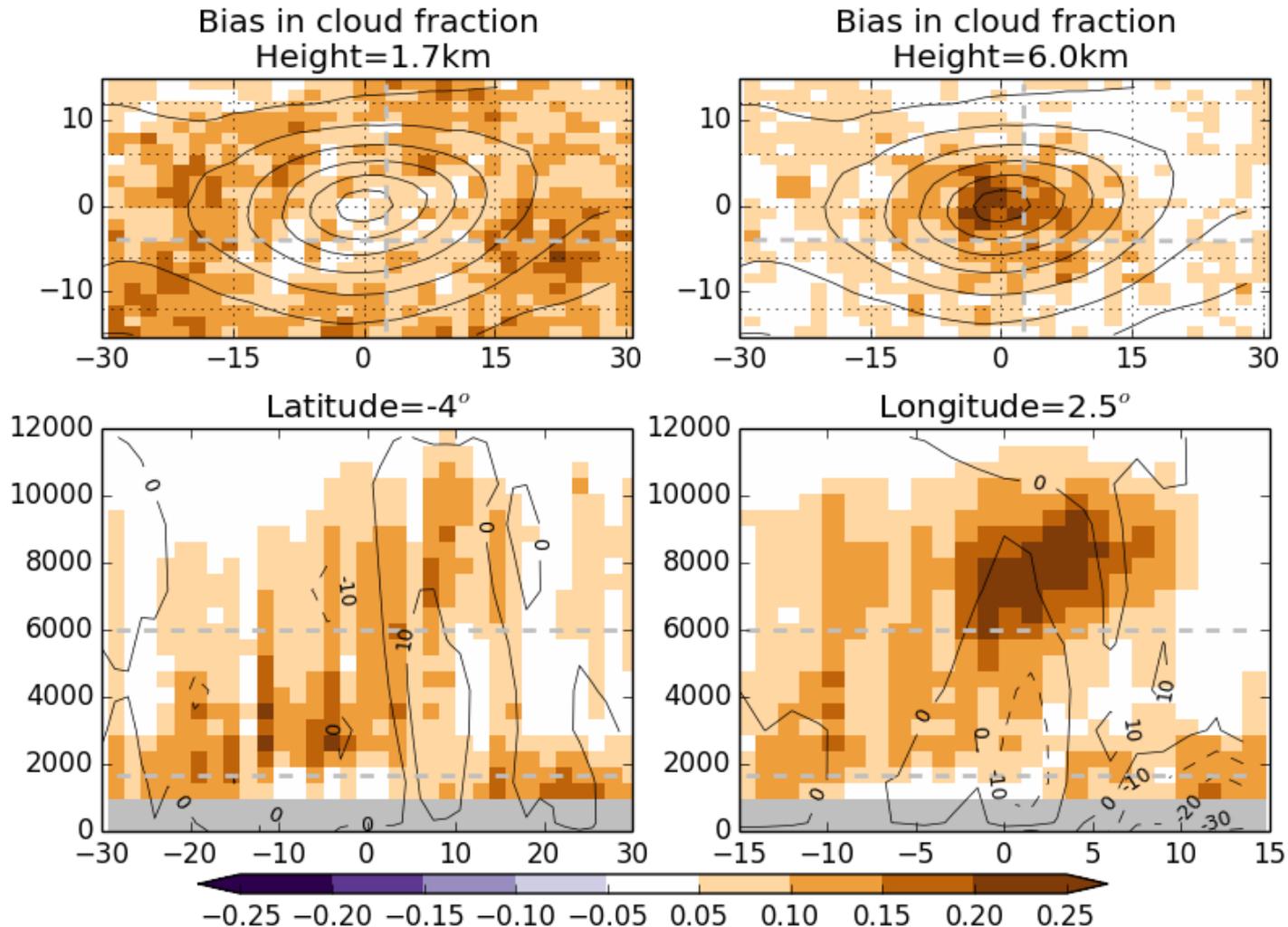


Satellite

*Tom Blackmore*

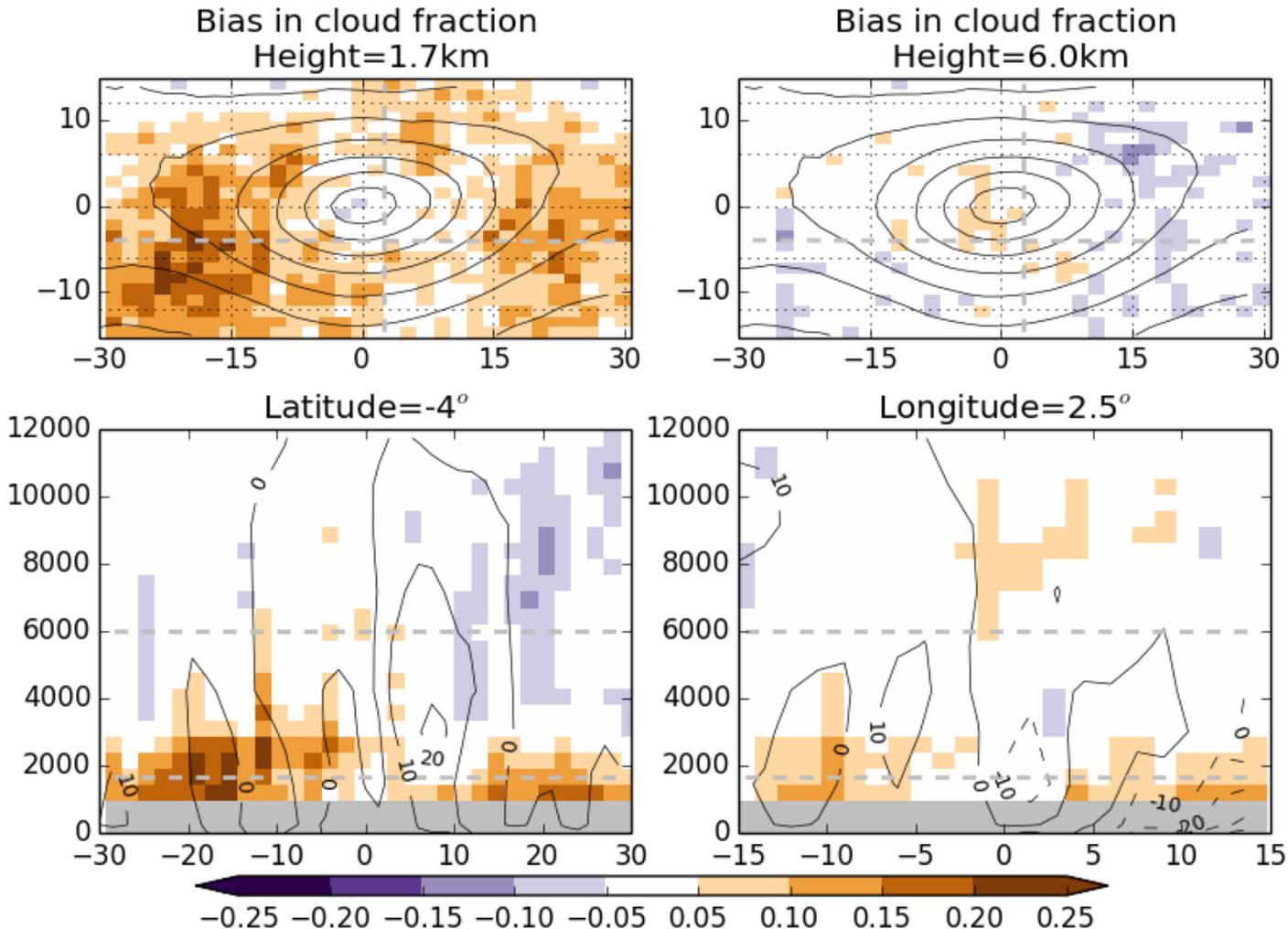


# Composite cyclone: GA6 hydrometeor frac bias Northern hemisphere winter





# Composite cyclone: #134.5 hydrometeor frac bias Northern hemisphere winter

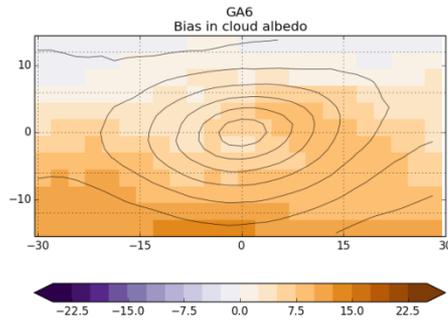




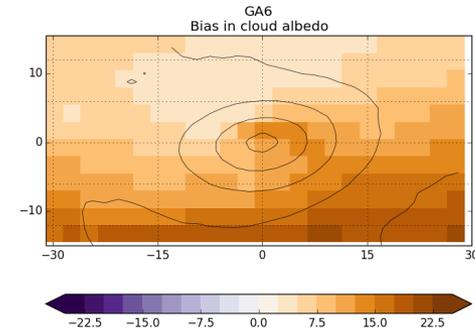
# Composite cyclone: GA6 cloud albedo bias

## Winter

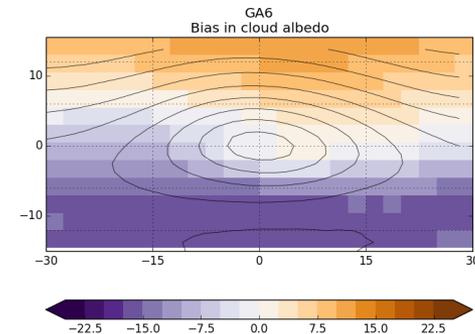
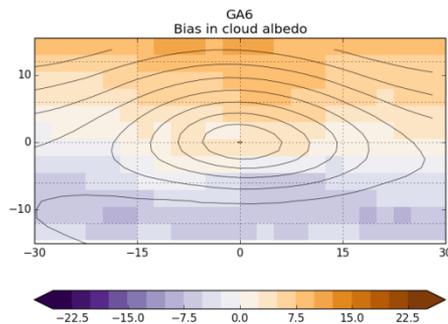
### Northern hemisphere:



## Summer

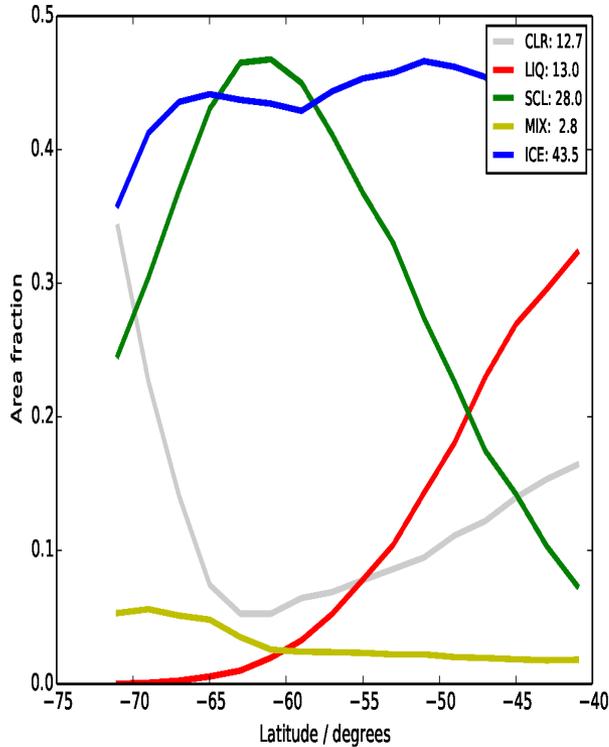


### Southern hemisphere:



# Possible causes of albedo bias

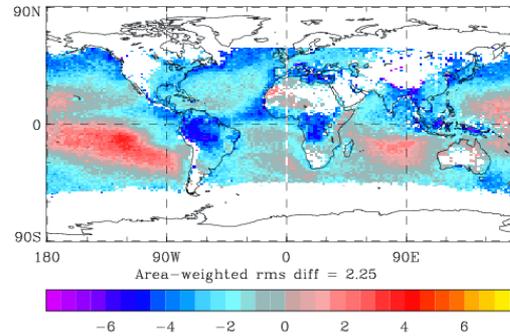
## Cloud phase:



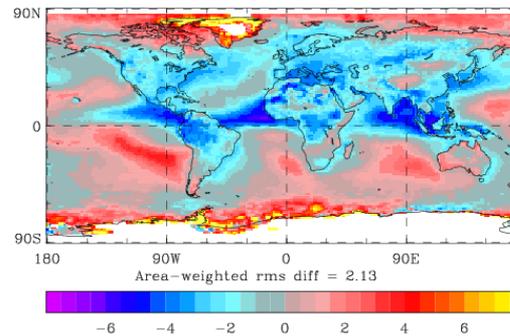
c/o Alejandro Bodas-Salcedo

## Aerosol interaction:

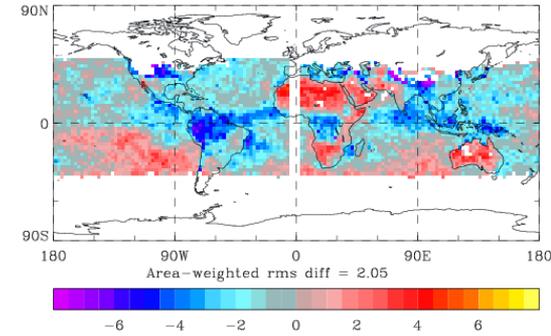
re bias vs Kawamoto



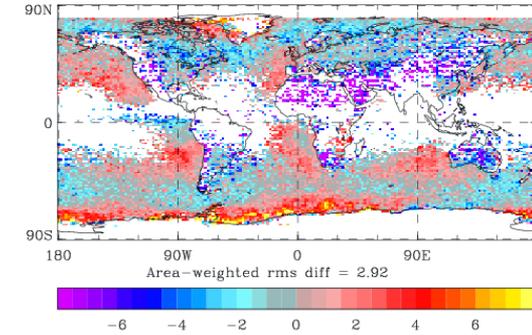
re bias vs ATSR



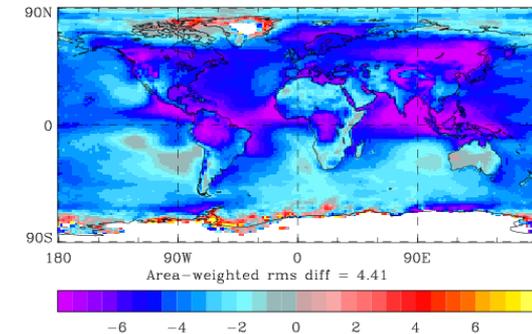
re bias vs Han



re bias vs POLDER



re bias vs CERES-MODIS





# Comparison with ground-based observations



# Comparison with ground-based (CloudNet) sites

(Chilbolton, Lindenberg, Darwin, SGP and Murgtal)

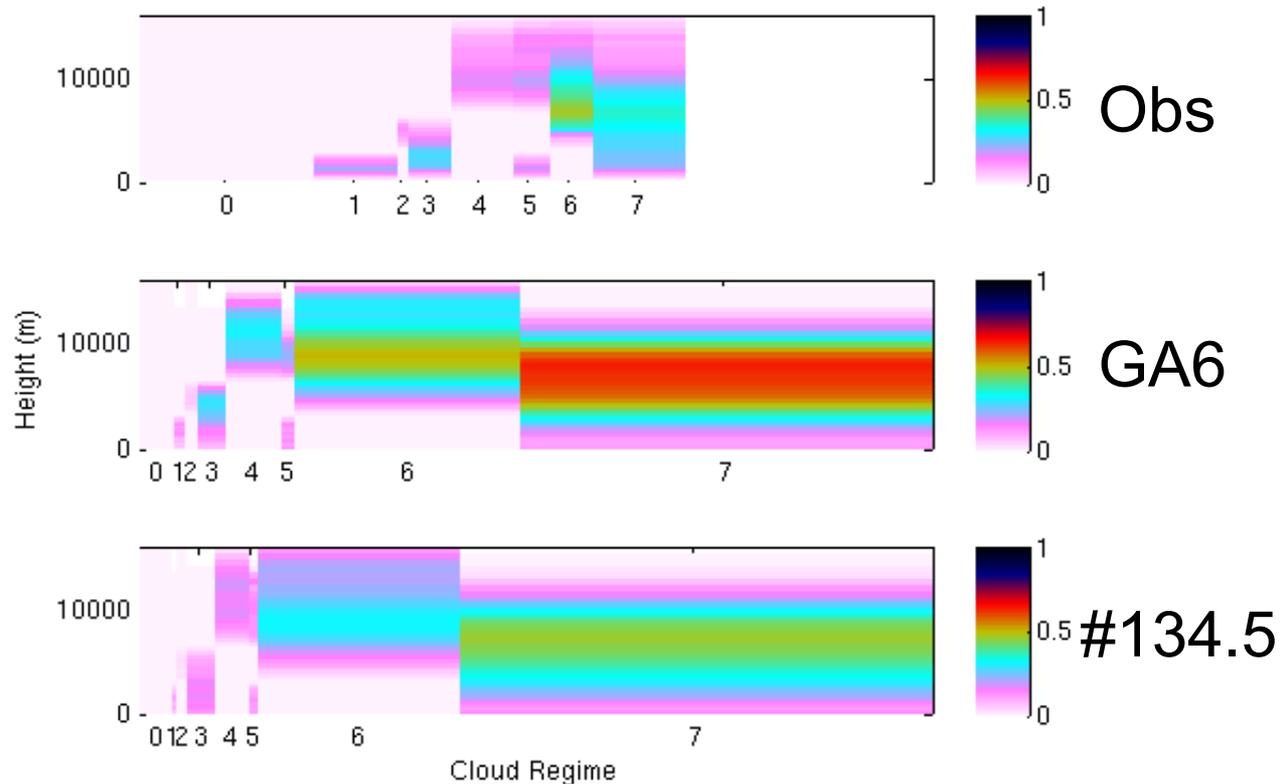
• Excess high cloud in GA6 improved in #134.5

• Low cloud too infrequent (not seen in satellite comparisons)

- 0 clear sky
- 1 low cloud
- 2 mid-level
- 3 low and mid
- 4 high
- 5 high and low
- 6 high and mid
- 7 low and mid and high

Width = frequency of occurrence  
Shading = cloud cover profile

c/o Cyril Morcrette and Kwinten Van Weverberg



CAUSES - <http://portal.nersc.gov/project/capt/CAUSES/>

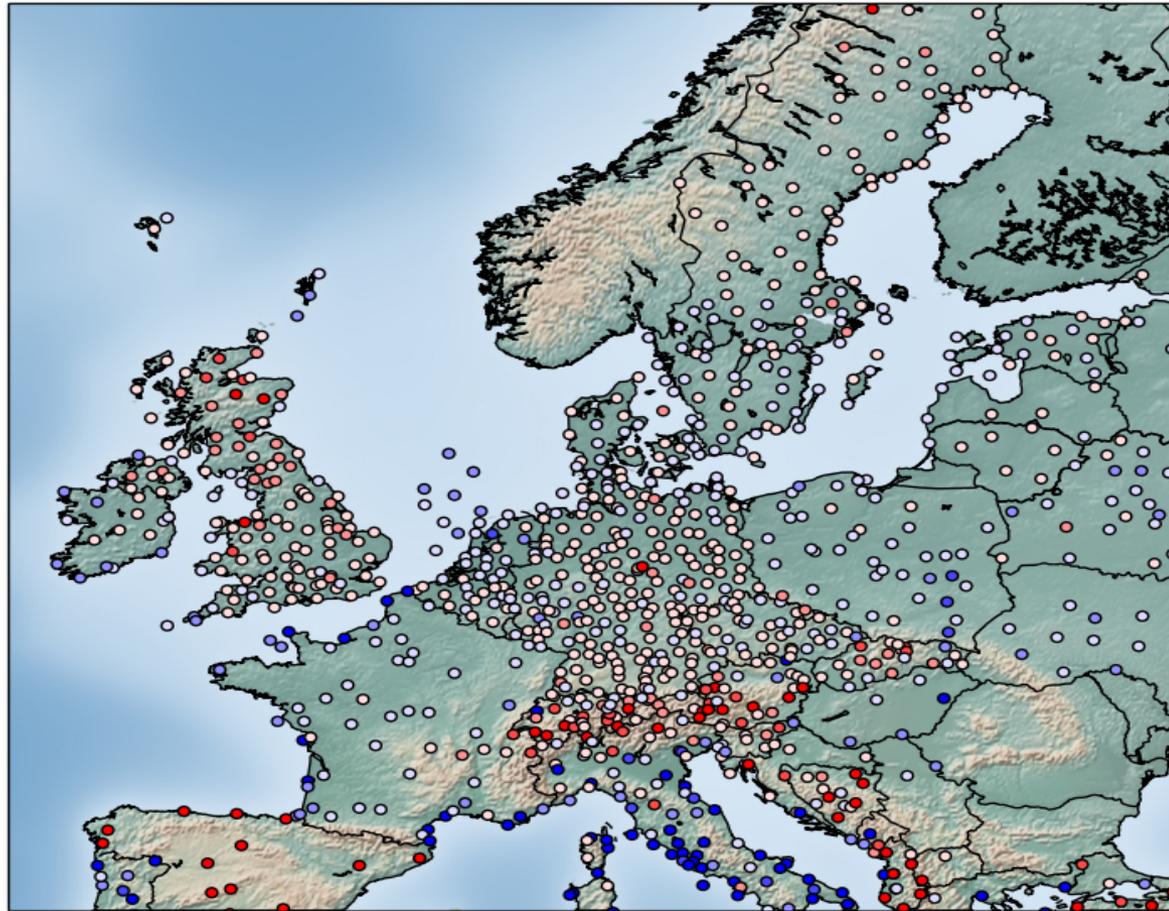


# Bias in freq. CBH<1km (T+24)

(when amount >2.5okta)

Cloud Base Height (given 2.5 Oktas Cloud Cover), Frequency Bias, category 1, T+24,  
20140715 to 20150529, Surface Obs, UK-GM

<=1000.m



0.50 0.57 0.67 0.80 1.00 1.25 1.50 1.75 2.00



# Mean radiation bias

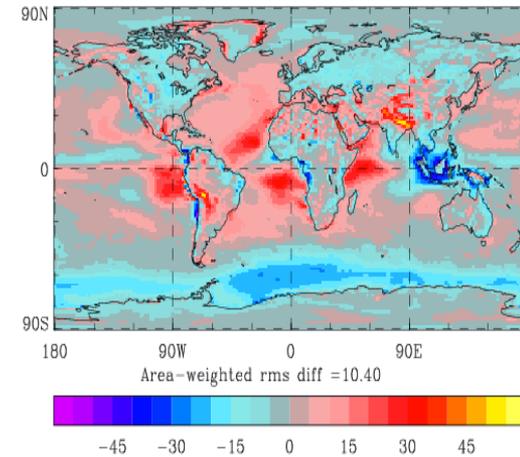
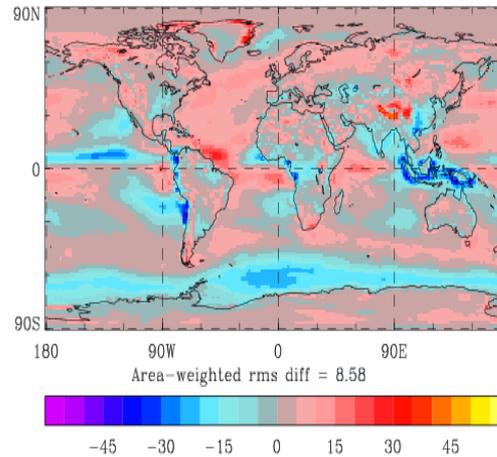
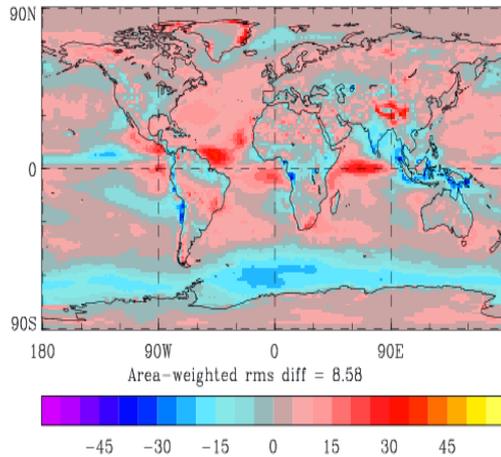
# TOA radiation bias

GA6

#134.5

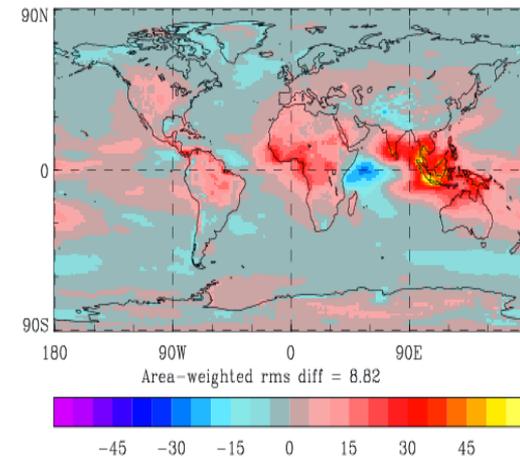
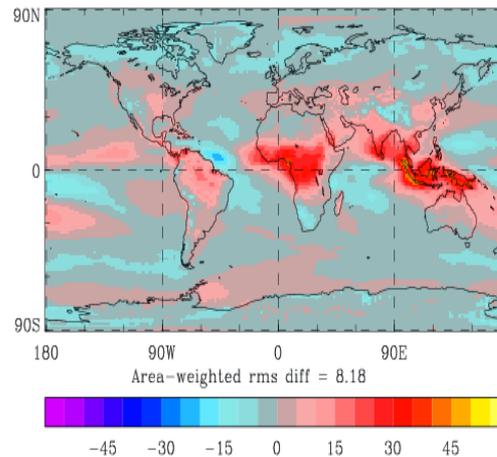
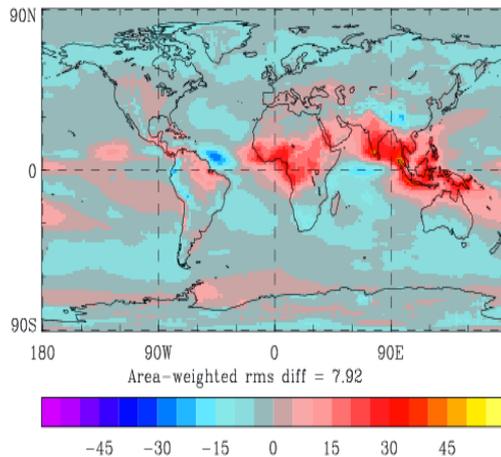
HadGEM2

RSW



04c

OLR

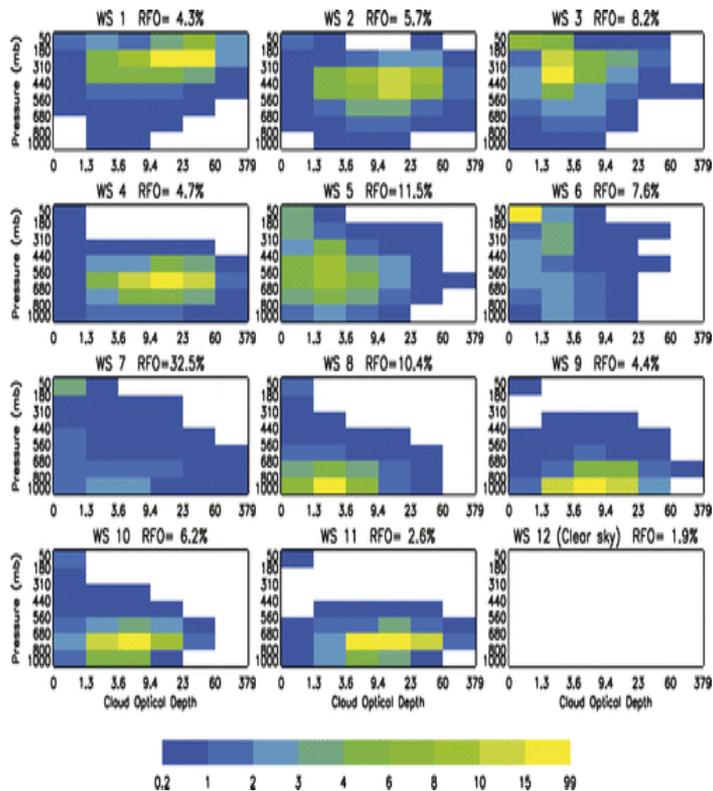


03f

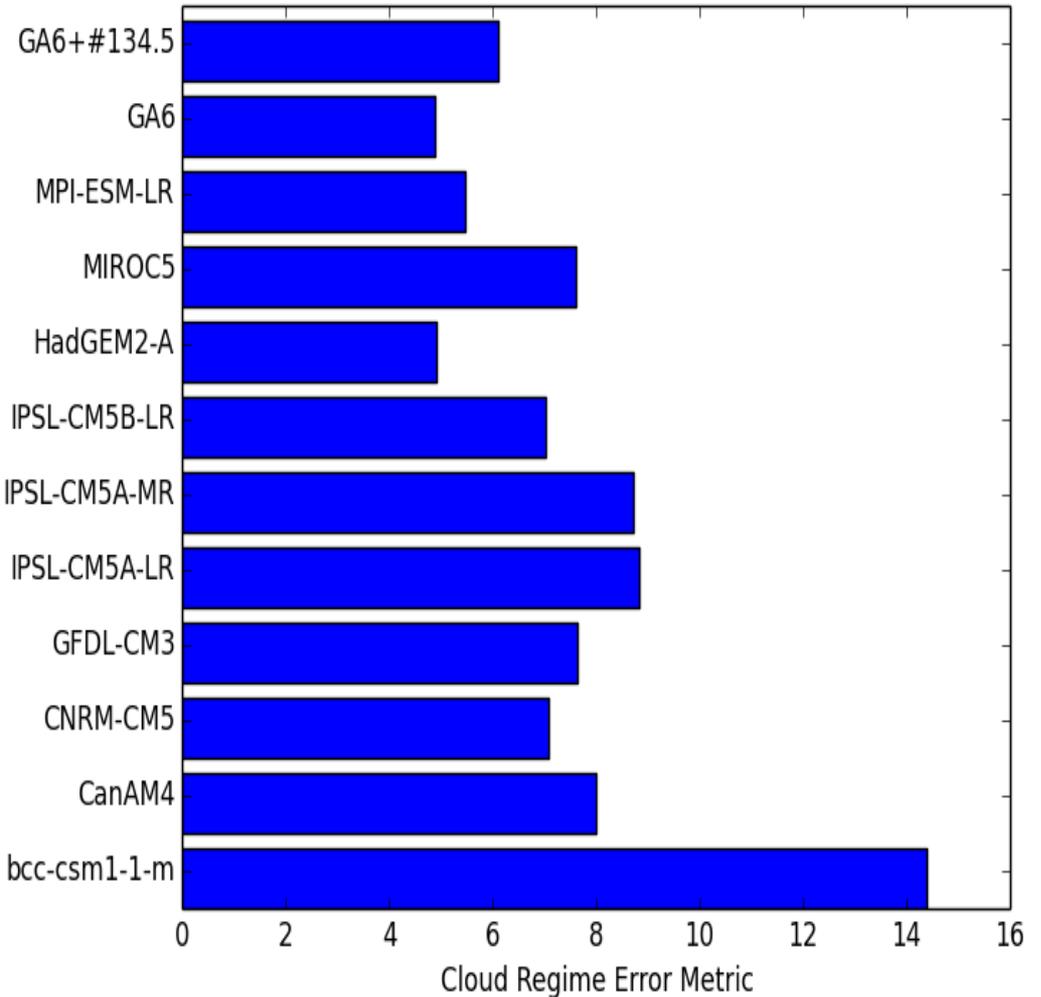


# Cloud regime error metric

(Williams and Webb, 2009)



ISCCP cluster centroids from Tselioudis et al. (2013)





# Conclusions

- It is easy to draw the wrong conclusion on model performance when just using one dataset/diagnostic technique/timescale.
- Use of a range of observational data (each to its own strengths) and various diagnostic techniques has permitted a comprehensive evaluation of cloud in the model.
- Overall cloud amount reasonably well simulated in the global UM although:
  - GA6 has excessive amounts of sub-visual cirrus which is corrected in proto-GA7.
  - Indications of slightly too much boundary layer cloud and/or drizzle in northern mid-latitudes.
- Main outstanding error is the cloud is too reflective in the northern hemisphere (esp. equatorward side of cyclones), and not reflective enough in the southern hemisphere (esp. poleward side of cyclones).



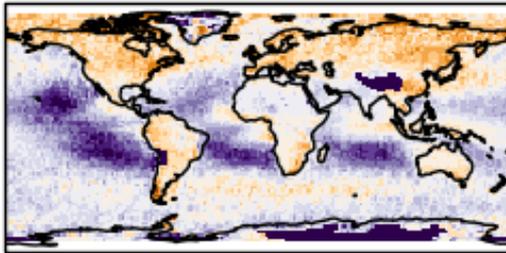
**Met Office**



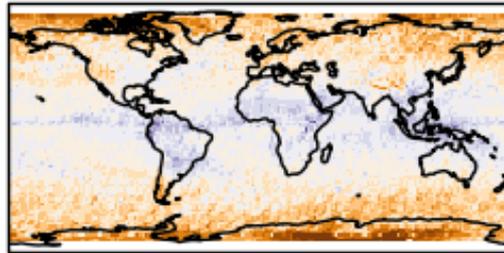
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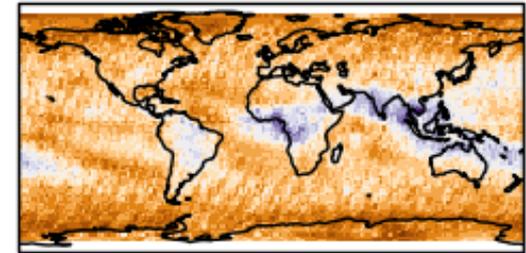
GA6  
Low-top cloud bias



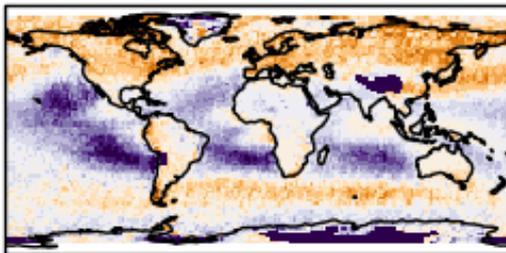
GA6  
Mid-top cloud bias



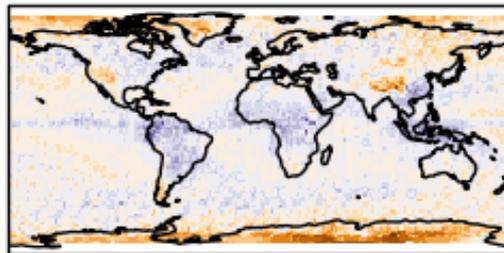
GA6  
High-top cloud bias



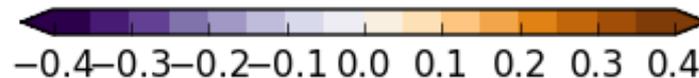
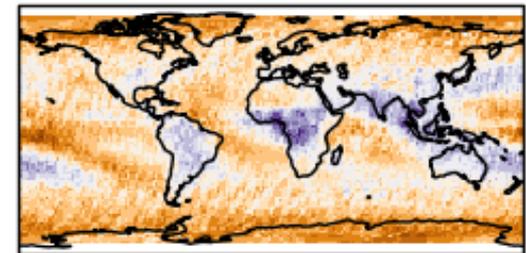
GA6+#134.5  
Low-top cloud bias



GA6+#134.5  
Mid-top cloud bias



GA6+#134.5  
High-top cloud bias



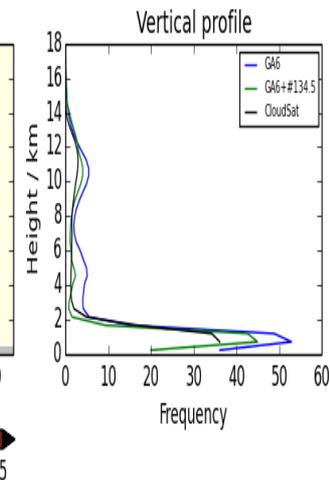
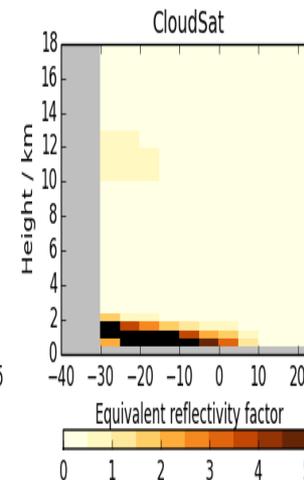
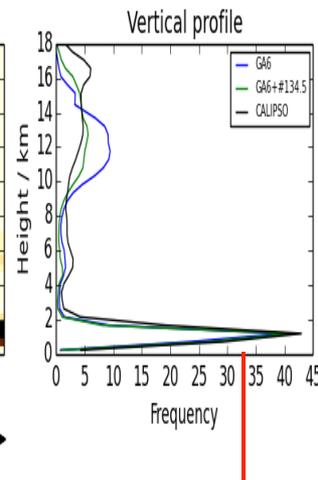
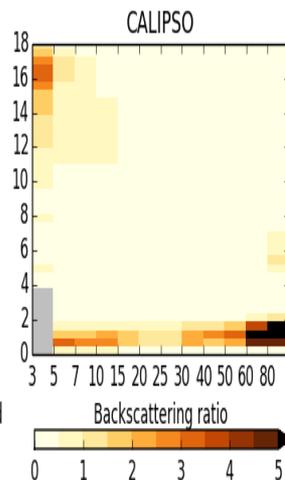
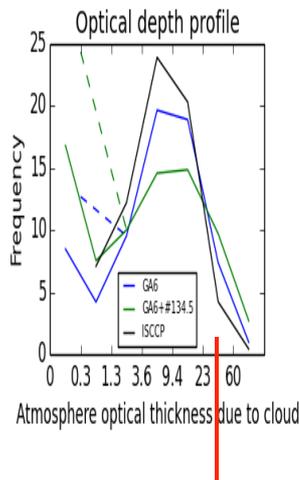
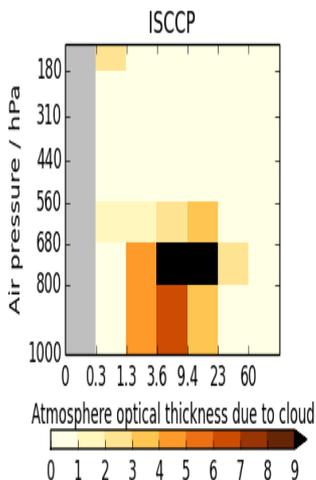
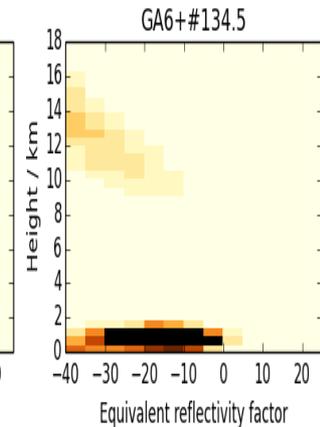
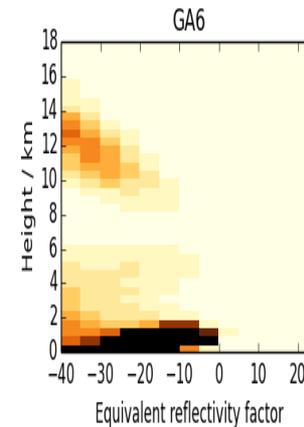
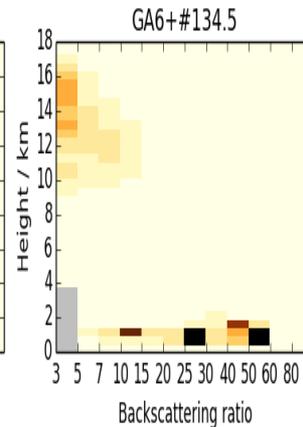
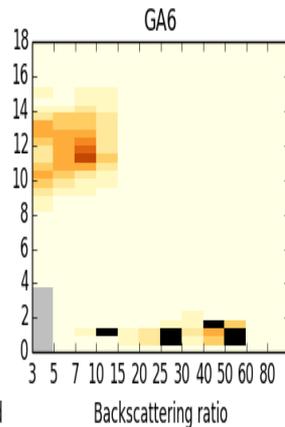
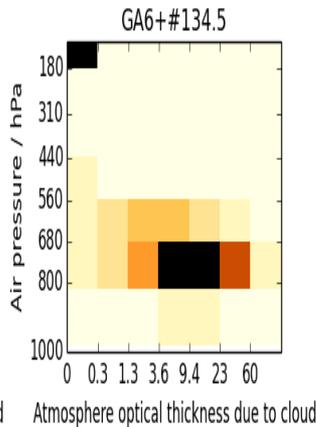
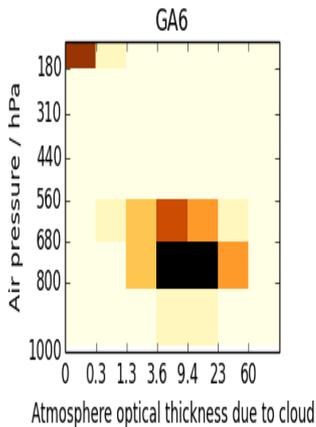


# Comparison against satellite data over sub-trop stratocu

ISCCP

CALIPSO

CloudSat



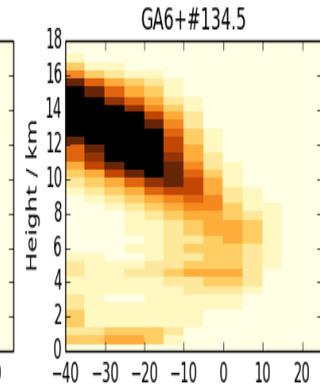
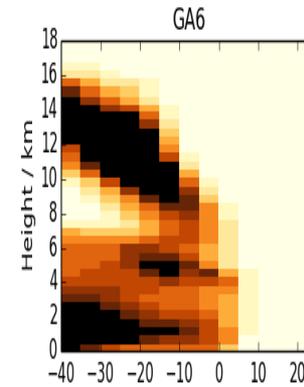
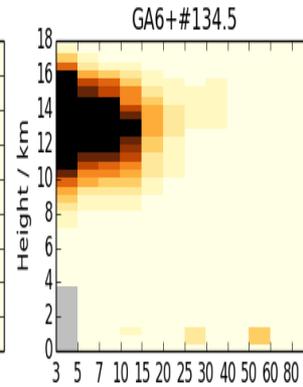
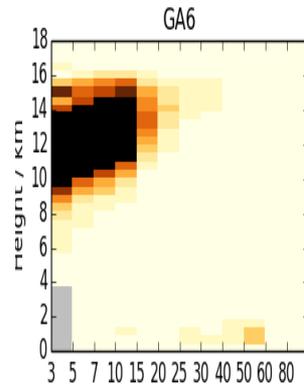
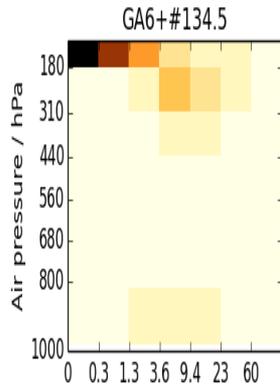
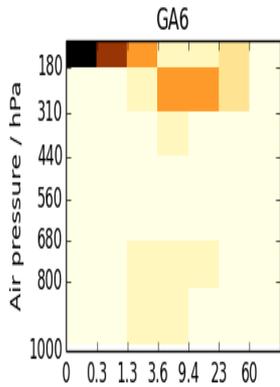


# Comparison against satellite data over the warm pool

ISCCP

CALIPSO

CloudSat



Atmosphere optical thickness due to cloud

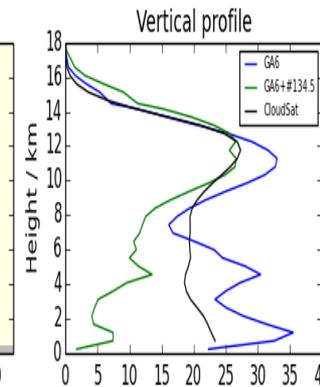
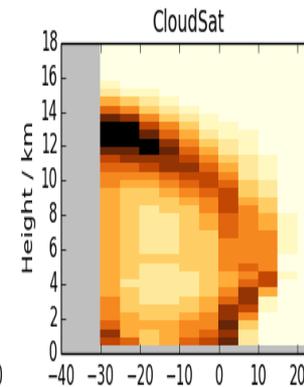
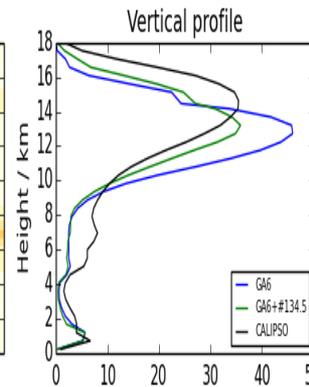
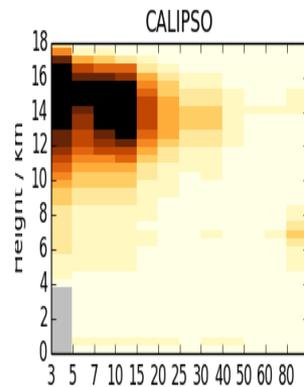
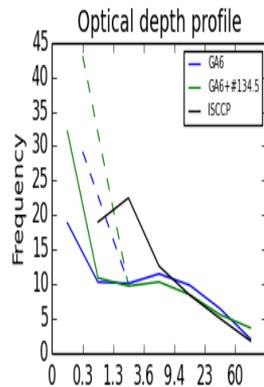
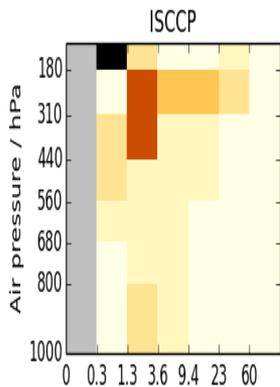
Atmosphere optical thickness due to cloud

Backscattering ratio

Backscattering ratio

Equivalent reflectivity factor

Equivalent reflectivity factor



Atmosphere optical thickness due to cloud

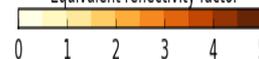
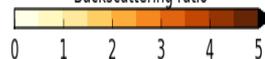
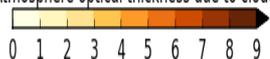
Atmosphere optical thickness due to cloud

Backscattering ratio

Frequency

Equivalent reflectivity factor

Frequency



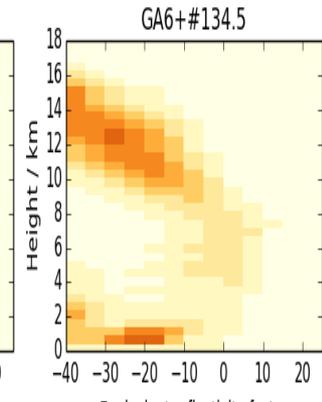
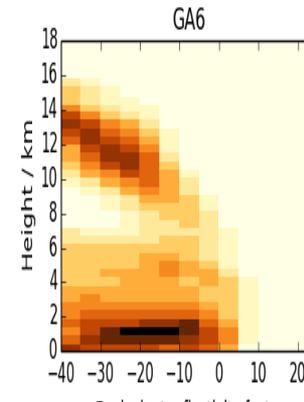
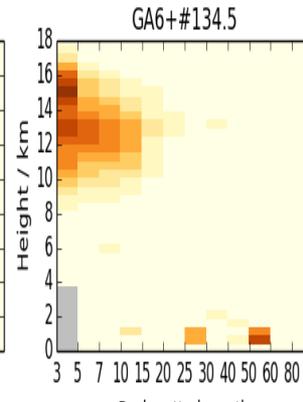
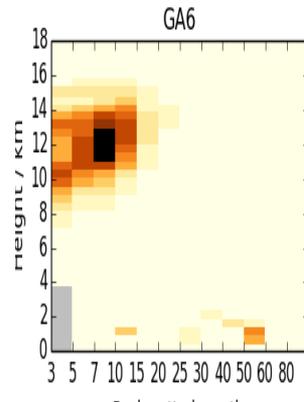
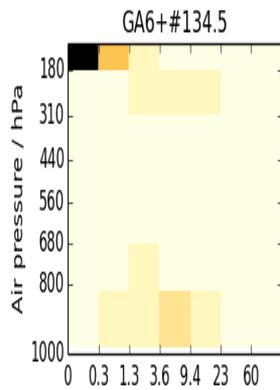
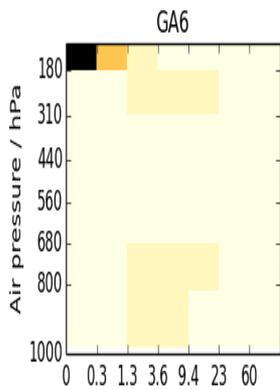


# Comparison against satellite data over the trade region

ISCCP

CALIPSO

CloudSat



Atmosphere optical thickness due to cloud

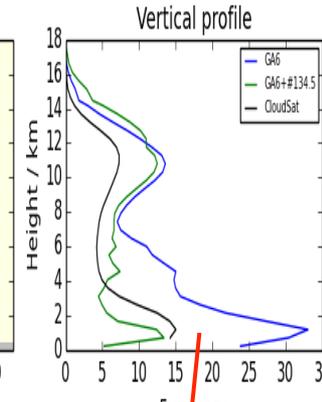
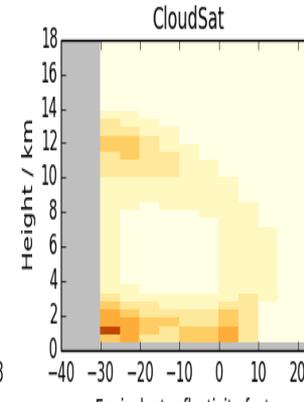
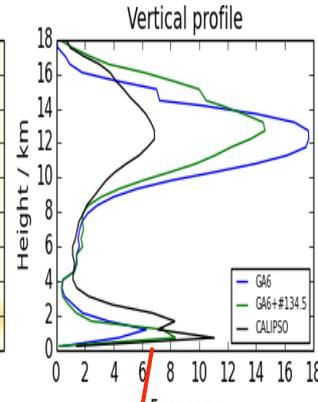
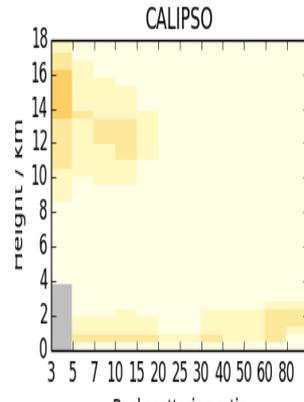
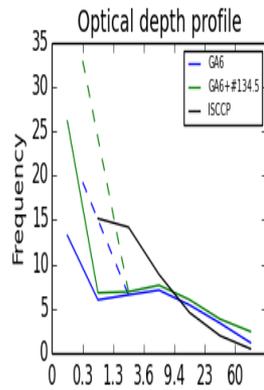
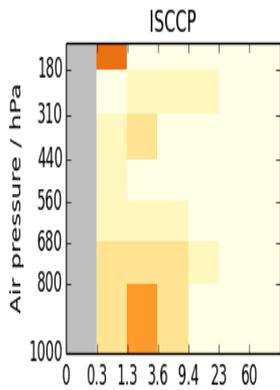
Atmosphere optical thickness due to cloud

Backscattering ratio

Backscattering ratio

Equivalent reflectivity factor

Equivalent reflectivity factor



Atmosphere optical thickness due to cloud

Atmosphere optical thickness due to cloud

Backscattering ratio

Frequency

Equivalent reflectivity factor

Frequency

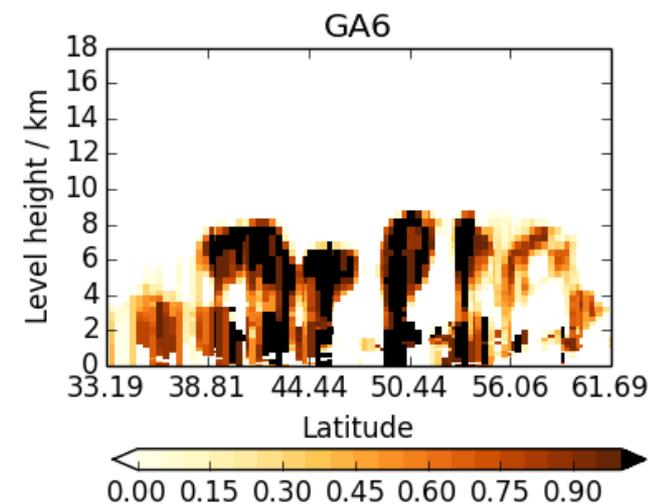
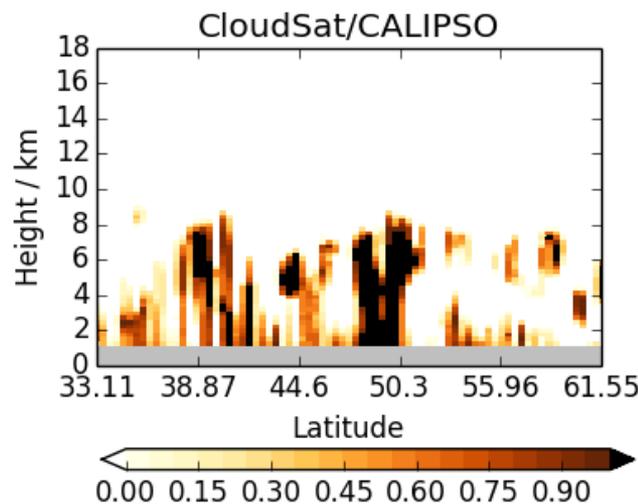
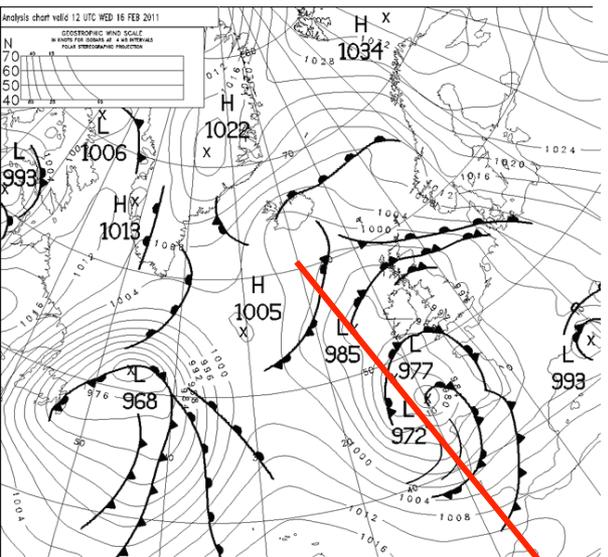
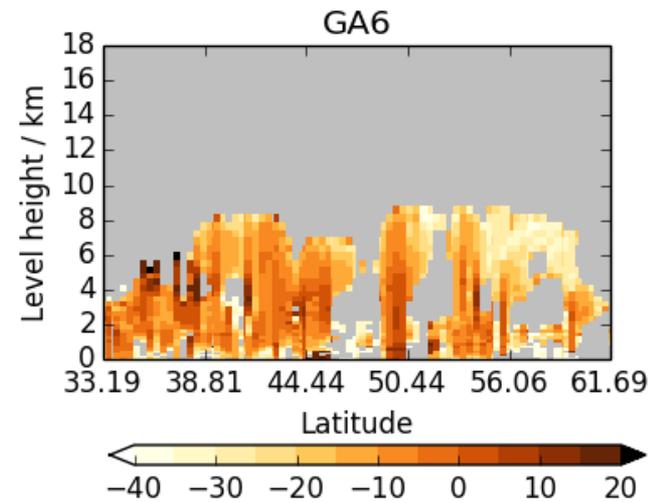
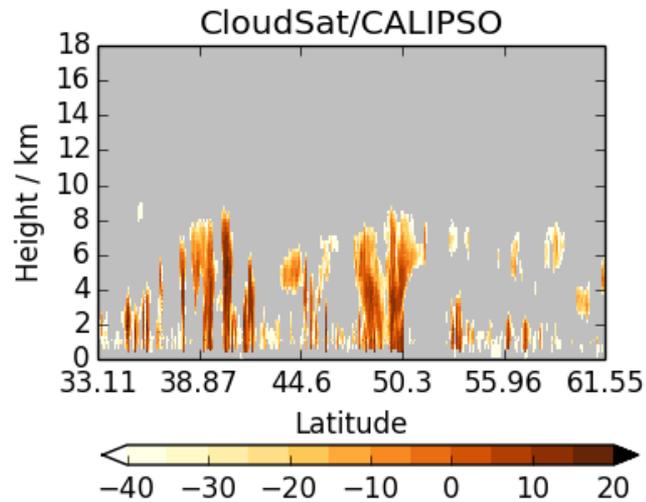
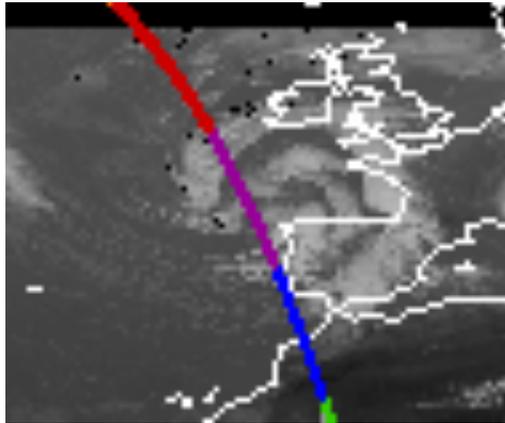


Forced shallow cu improves BL cloud amount

Excess "drizzle" particularly improved

# Case study

## VT: 12Z 16/02/2011 (T+24)



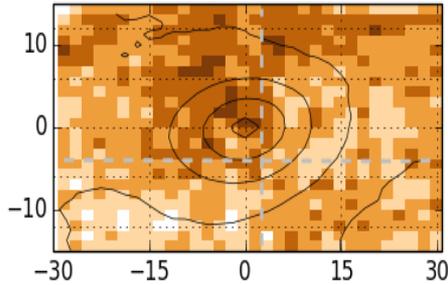


# Composite cyclone: Hydrometeor frac bias Northern hemisphere summer

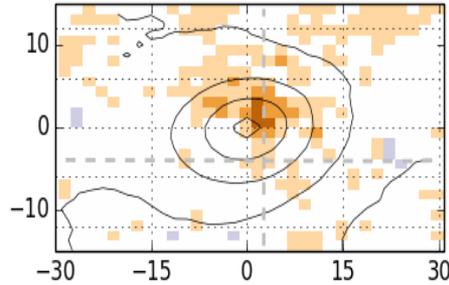
GA6

#134.5

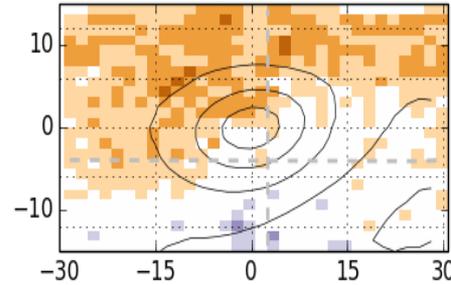
Bias in cloud fraction  
Height=1.7km



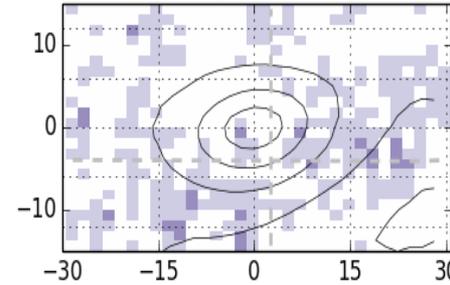
Bias in cloud fraction  
Height=6.0km



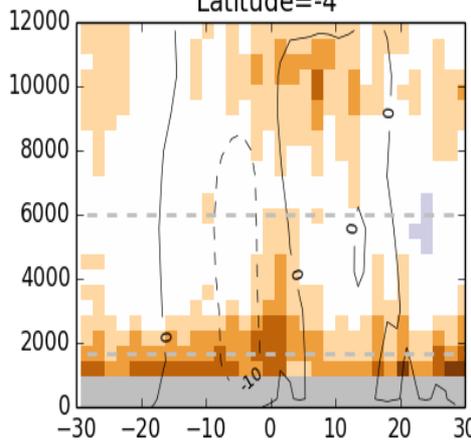
Bias in cloud fraction  
Height=1.7km



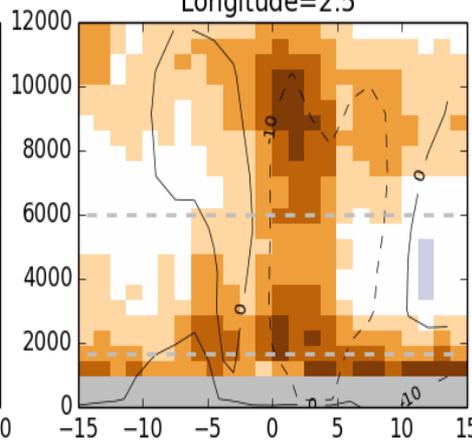
Bias in cloud fraction  
Height=6.0km



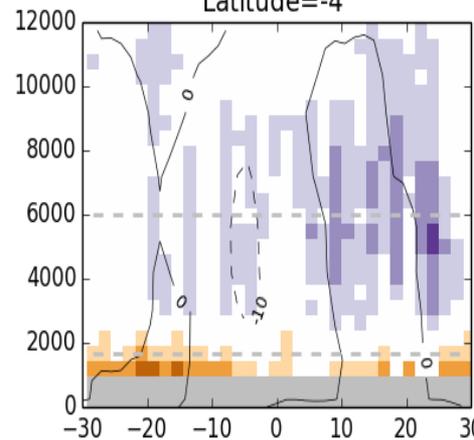
Latitude=-4°



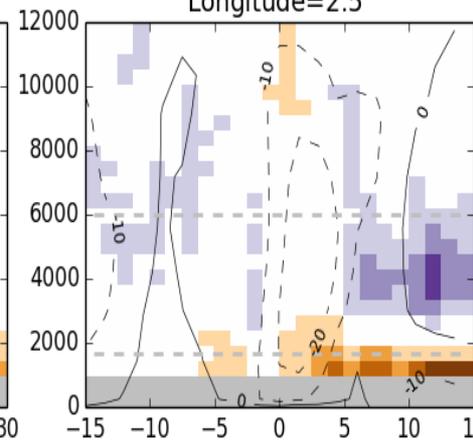
Longitude=2.5°



Latitude=-4°



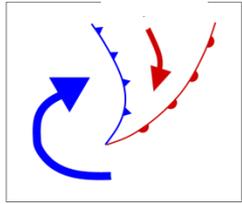
Longitude=2.5°



-0.25 -0.20 -0.15 -0.10 -0.05 0.05 0.10 0.15 0.20 0.25

-0.25 -0.20 -0.15 -0.10 -0.05 0.05 0.10 0.15 0.20 0.25

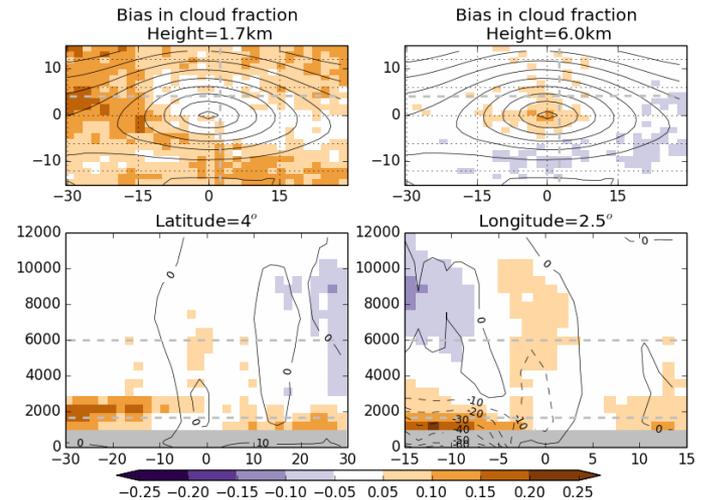
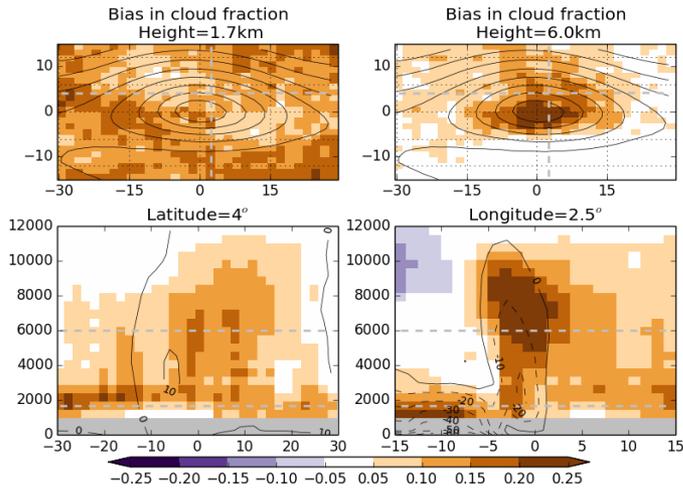
# Composite cyclone: Hydrometeor frac bias Southern hemisphere



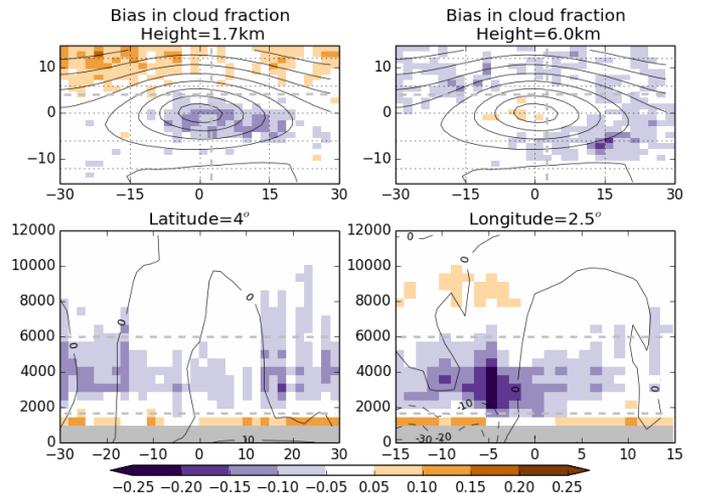
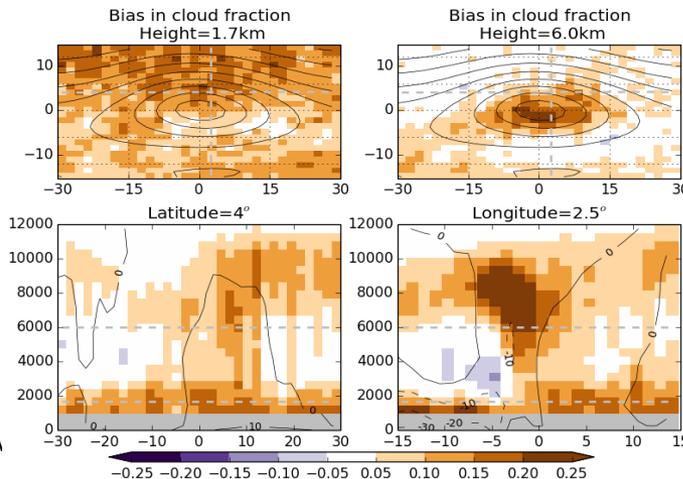
Winter

GA6

#134.5



Summer



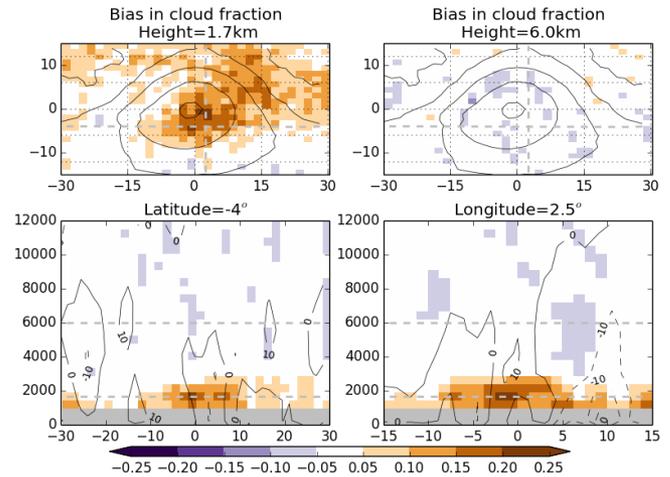
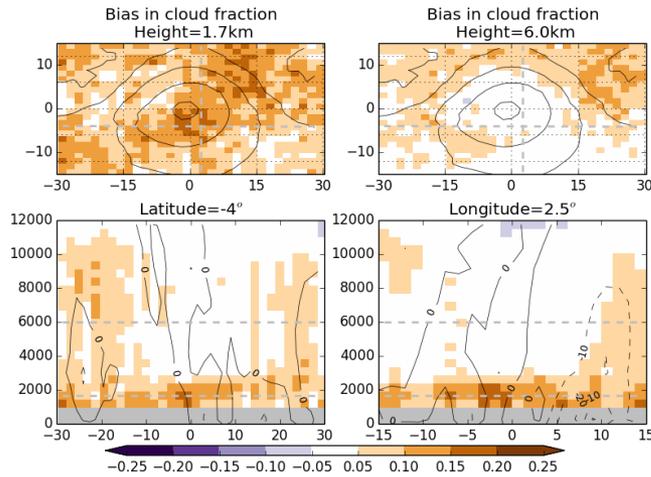


# Composite anti-cyclone: Hydrometeor frac bias Northern hemisphere

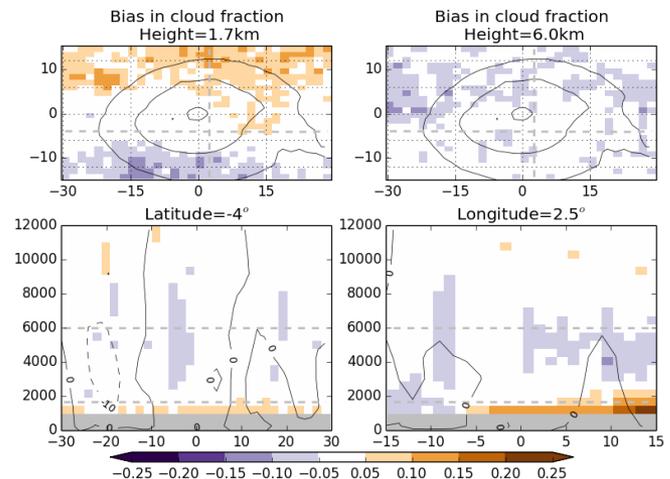
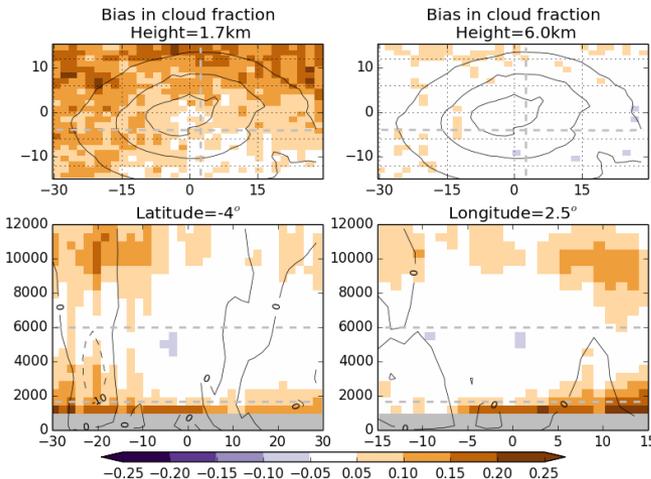
GA6

#134.5

Winter



Summer

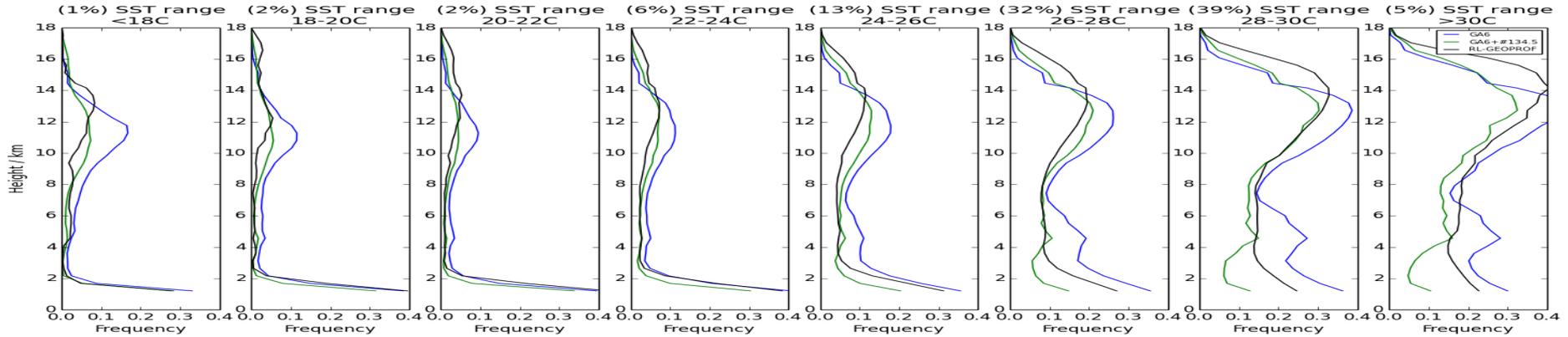




Met Office

By SST:

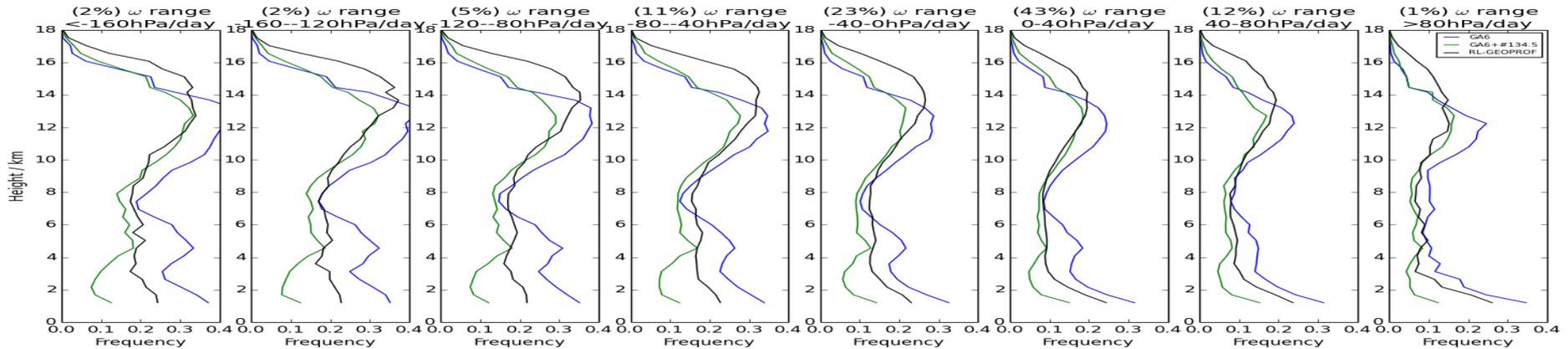
# RL-hydrometeor composites (mean over tropics)



← Cool

Warm →

By vertical velocity:



← Strong ascent

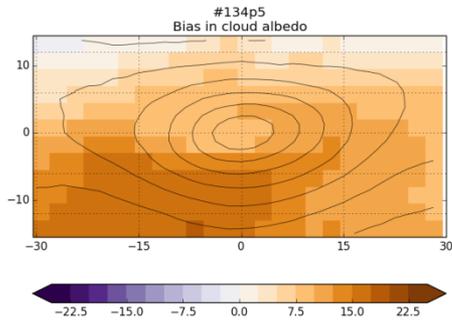
Strong subsidence →



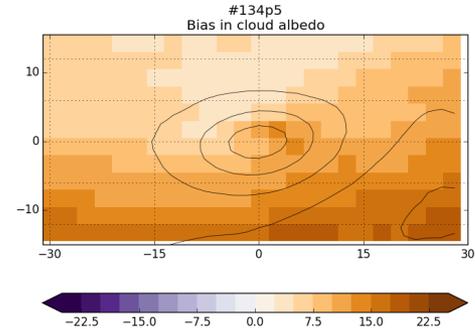
# Composite cyclone: #134.5 cloud albedo bias

Winter

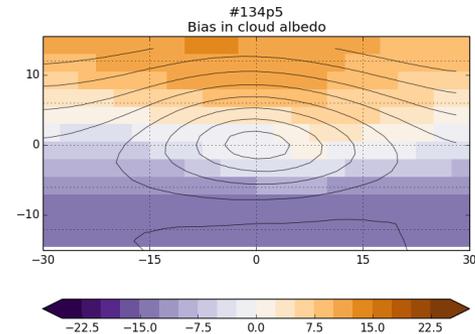
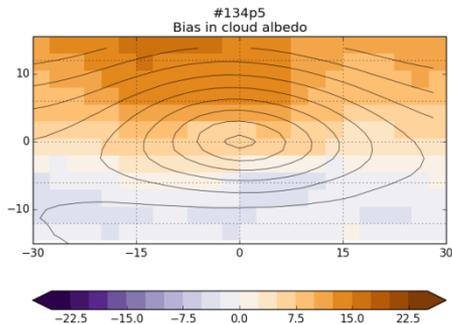
Northern hemisphere:



Summer



Southern hemisphere:



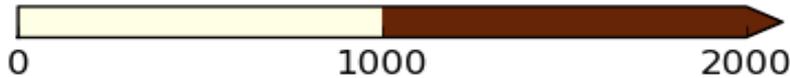
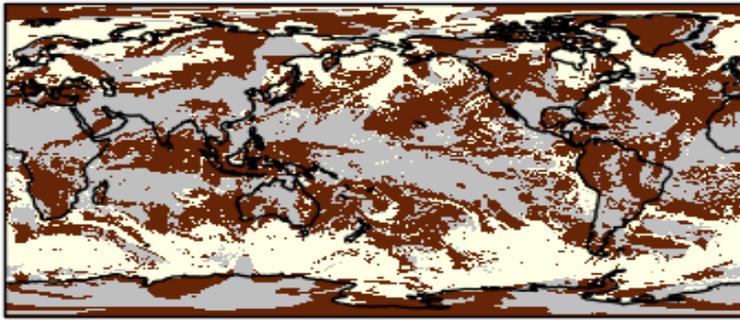


Met Office

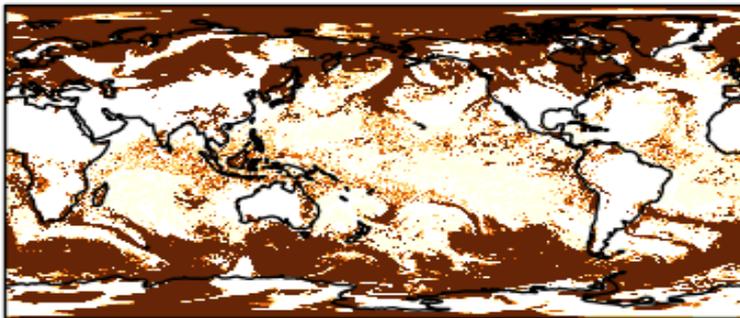
# Case study

VT: 12Z 02/12/2010 (T+24)

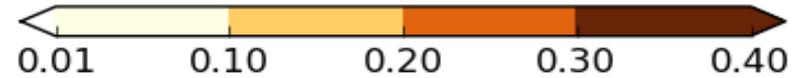
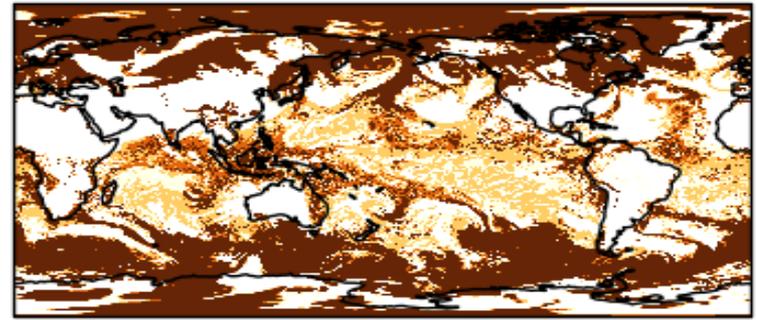
Cloud base height above ground  
(for cf > 2.5oktas)



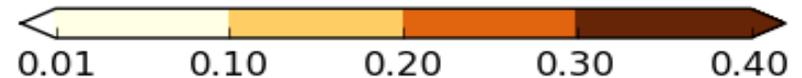
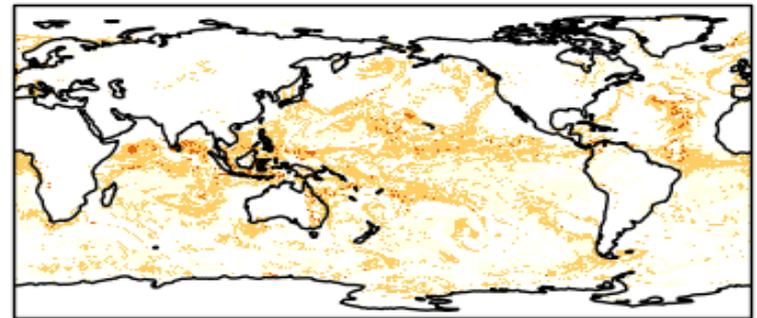
Max bulk cf <1000m  
(as seen by radiation)



Max total cf <1000m  
(as used by cbh diag)



Max convective cf <1000m



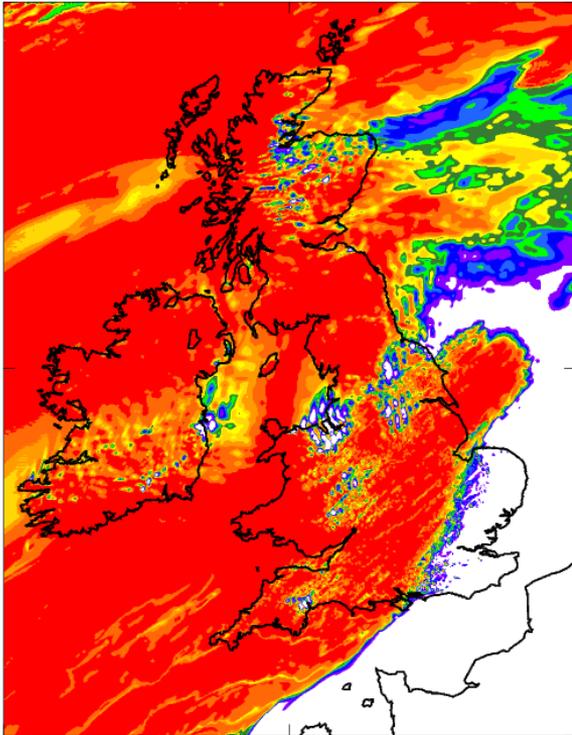


# Case study – low cloud amount

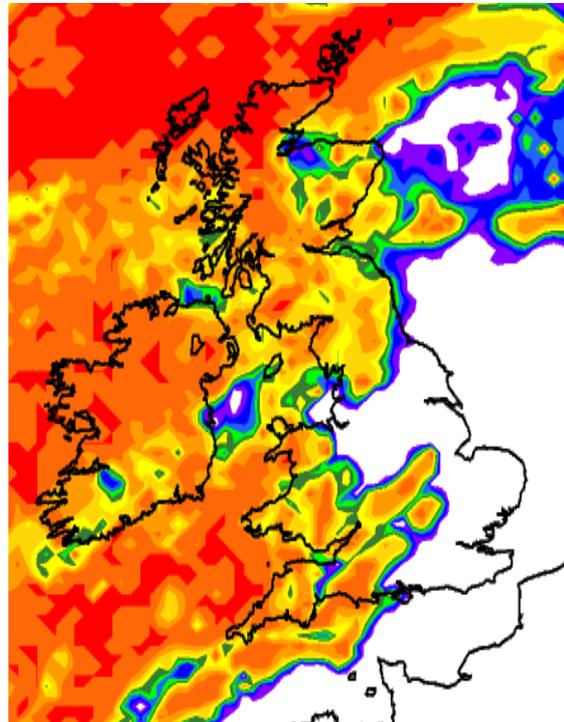
VT: 12Z 07/03/15 (T+12)

UKV

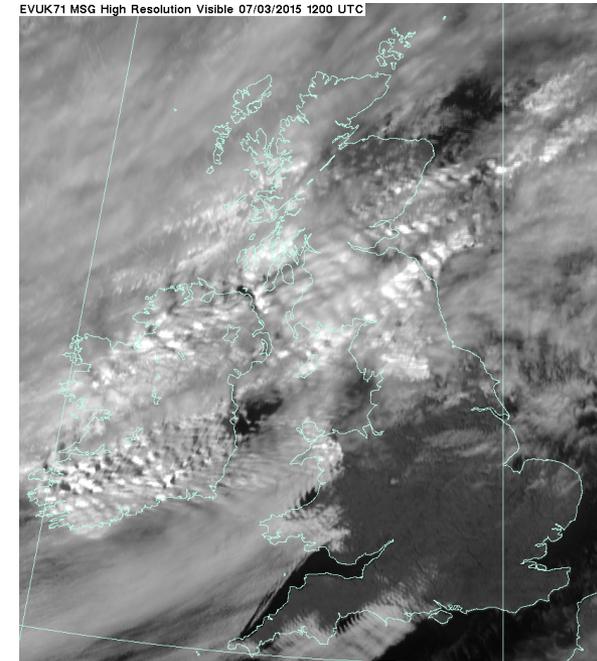
UKV op Low cloud amount  
Saturday 1200Z 07/03/2015 (t+9h)



Global



Satellite





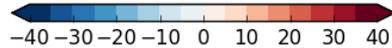
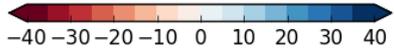
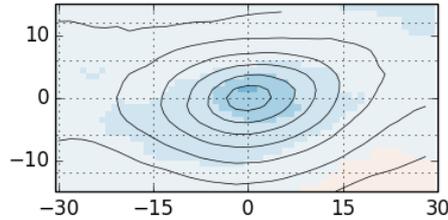
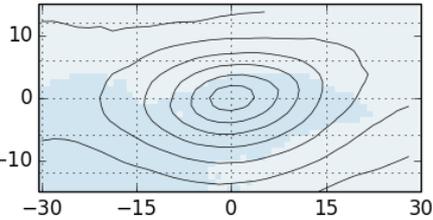
# Composite cyclone: GA6 radiation bias

## Winter

### Northern hemisphere:

GA6  
Bias in RSW

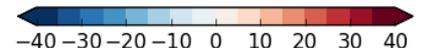
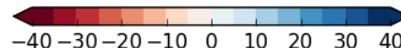
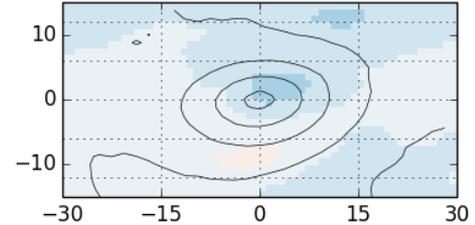
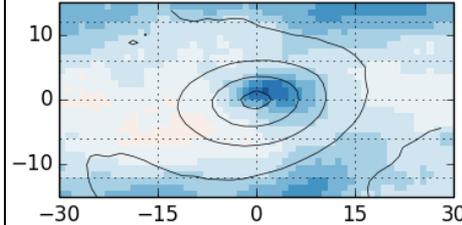
GA6  
Bias in OLR



## Summer

GA6  
Bias in RSW

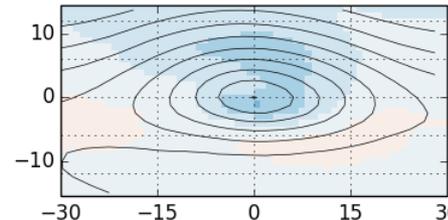
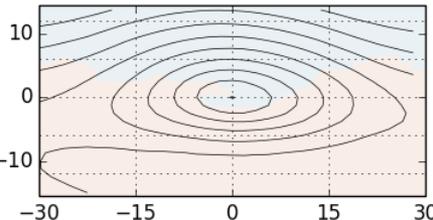
GA6  
Bias in OLR



### Southern hemisphere:

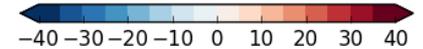
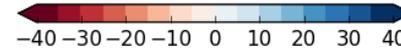
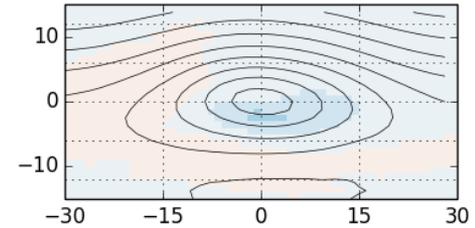
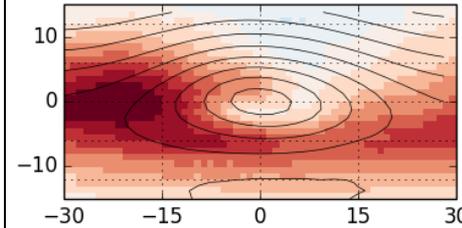
GA6  
Bias in RSW

GA6  
Bias in OLR



GA6  
Bias in RSW

GA6  
Bias in OLR

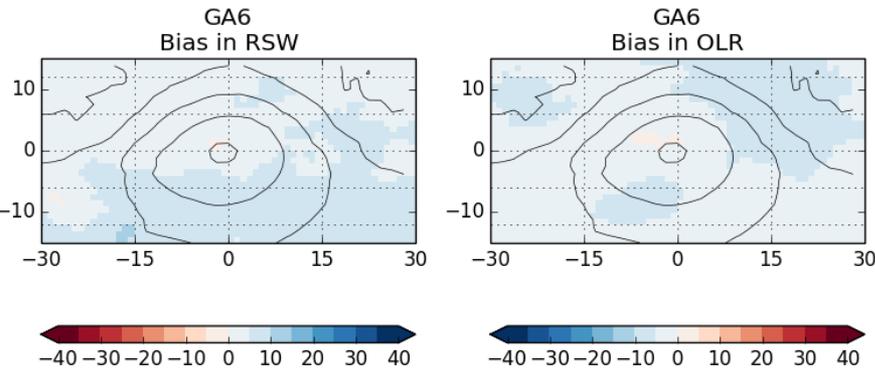




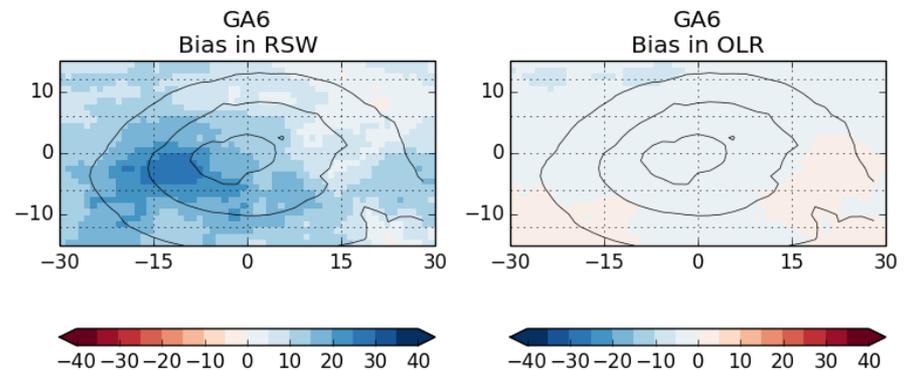
# Composite anti-cyclone: GA6 radiation bias

## Winter

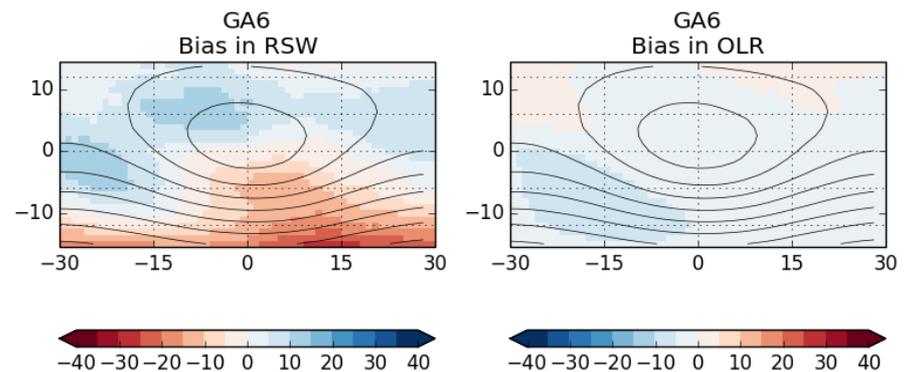
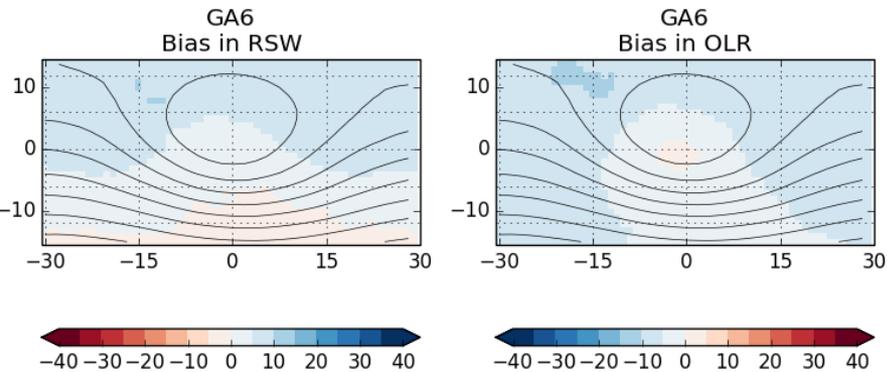
### Northern hemisphere:



## Summer



### Southern hemisphere:



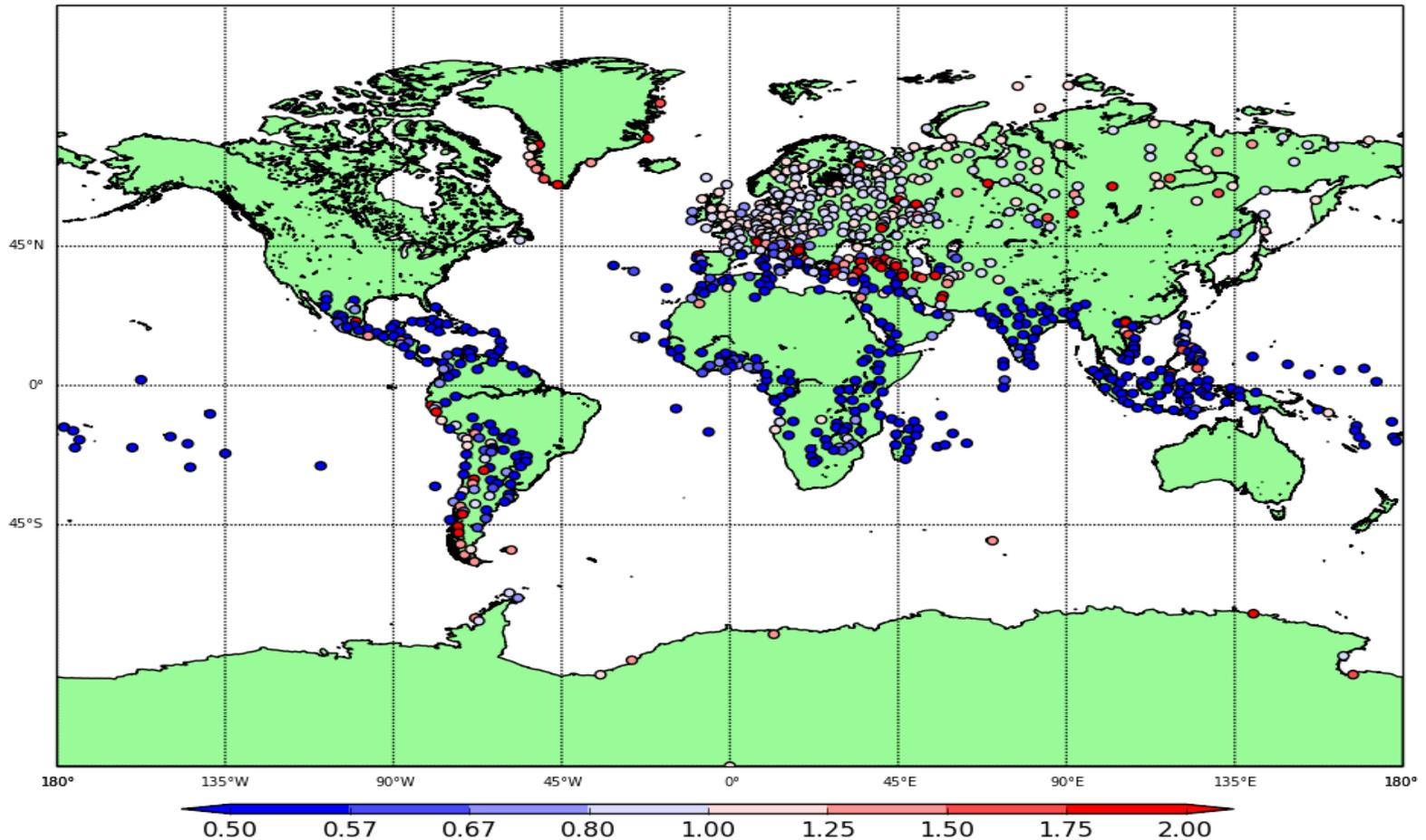


# Bias in freq. CBH<1km (T+24)

(when amount >2.5okta)

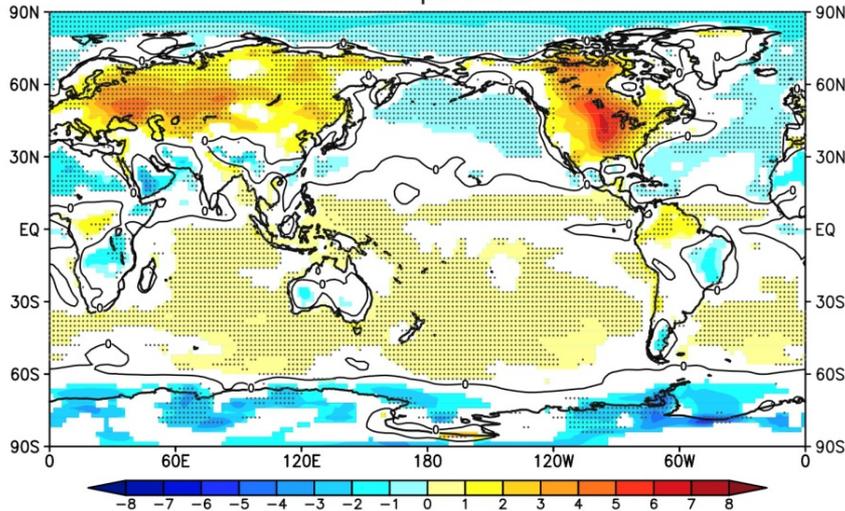
Cloud Base Height (given 2.5 Oktas Cloud Cover), Frequency Bias, category 1, T+24,  
20140715 to 20150228, Surface Obs, UK-GM

<=1000.



# CAUSES

2 Meter Temperature Bias



The warm bias over the US in summer is common to many GCMs.

It is seen in several climate models' long-term climate mean and it also shows up as a bias within a *few days* when running climate models from analysis in NWP mode.

## Aims:

A joint GASS/ASR comparison project aiming to evaluate clouds, radiation and precipitation in several weather and climate models using ground-based observations to better understand the reasons for the surface temperature error.

diagnostics required is available from CAUSES website:

<http://portal.nersc.gov/project/capt/CAUSES/>

