Effective assimilation of TMPA precipitation: Results and plans for IMERG

Eugenia Kalnay[1], Guo-Yuan Lien[2,1],
Takemasa Miyoshi[2,1]
Students/Collaborators:
Tse-Chun Chen[1], Cheng Da[1],
Steve Penny[1,4], George Huffman[3], Daisuke Hotta[5]
[1] University of Maryland, [2]RIKEN Data Assimilation Team,
[3]NASA/GSFC, [4]NOAA/NCEP,[5]Japan Met. Agency

OUTLINE

- Introduction: Obstacles and Solutions for Effective Precipitation Assimilation. Main results.
- The Gaussian Transform of the GFS model and TMPA observations.
- Comparison of No Transform, Logarithm Transform and Gaussian Transform.
- Impact on the GFS forecasts verified against ERA Interim.
- New approach to improve IMERG with LETKF assimilation of precipitation (Miyoshi's suggestion)
- Plans

Obstacles/Solutions to Precipitation Assimilation

- Model forecasts "forget" assimilation changes/Use LETKF
- Precipitation is very non-Gaussian/Use Gaussian Transformation
- Adjoint model of precipitation/Not needed with LETKF

Obstacles/**Solutions** to Precipitation Assimilation

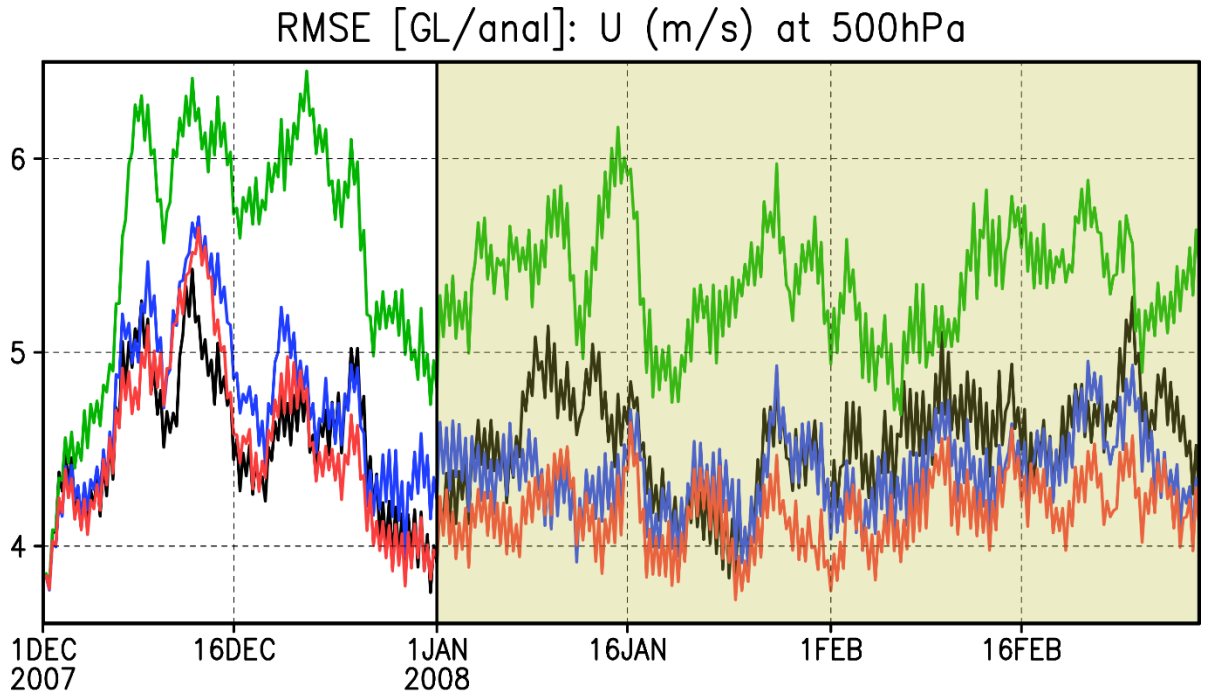
- Model forecasts "forgets" assimilation changes/Use LETKF
- Precipitation is very non-Gaussian/Use Gaussian Transformation
- Adjoint model of precipitation/Not needed with LETKF

These methods were **successfully** tested (under NASA support) in:

Lien et al., 2013, Tellus: Perfect model OSSE
Lien et al., 2015a, MWR (revision): TMPA and GFS statistics
Lien et al., 2015b, MWR (revision): Assimilation of TMPA
Hotta et al., 2015, in preparation: Application of EFSO

Kotsuki, **Miyoshi**, **Lien** et al. are experimenting with NICAM and GSMaP (JAXA support)

The main result: it works with TMPA/GFS



Improvement achieved with GFS-LETKF
(U-wind @ 500 hPa)

Radiosondes ONLY

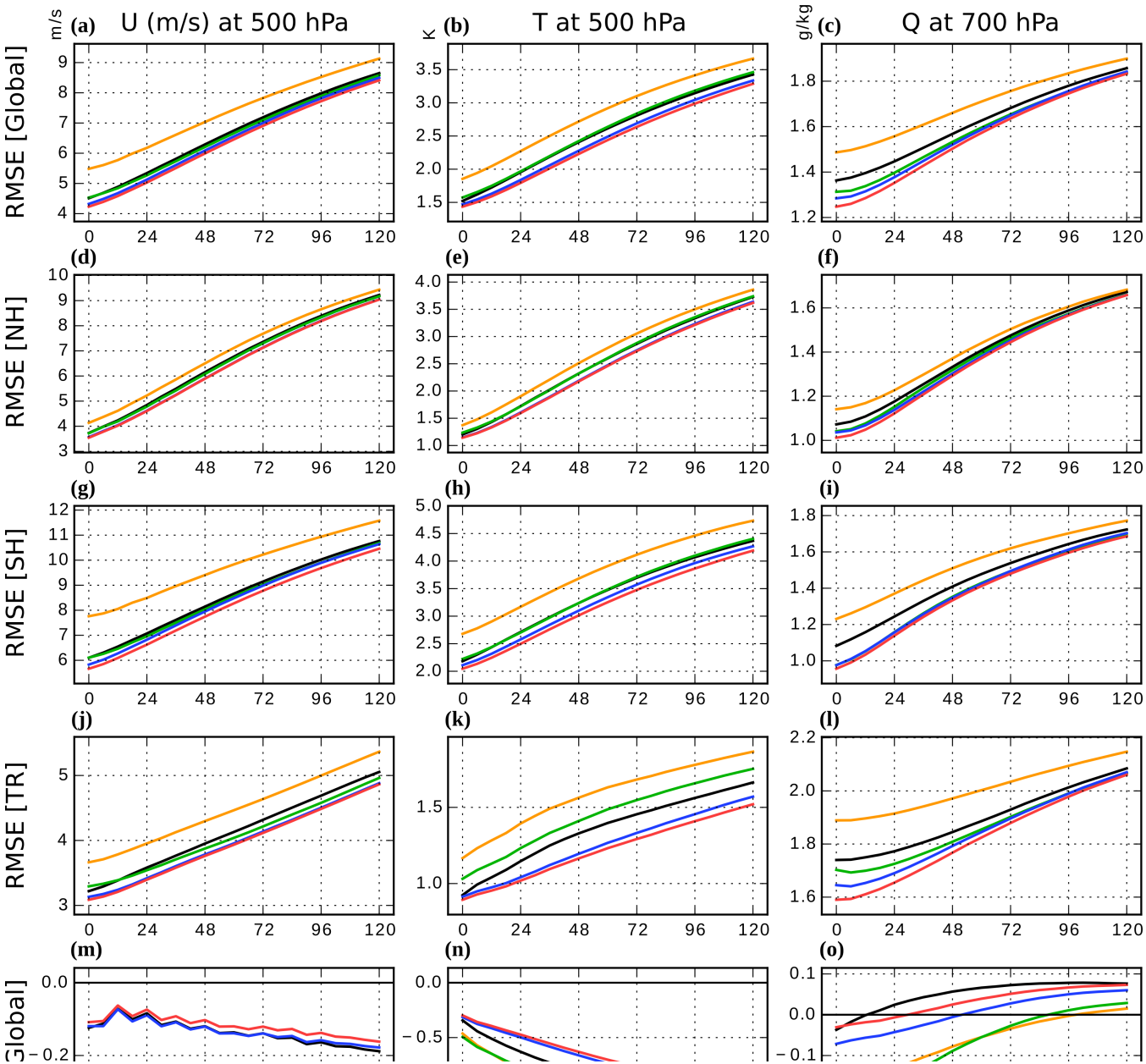
Radiosondes+Precip. (No-Transform)

Radiosondes+Precip. (Log-Transform)

Radiosondes+Precip. (Gaussian-Transform)

After a spin-up of 1-2 weeks, the assimilation of precipitation with Gaussian Transform is clearly the best. No-precipitation and Log Transform are similar. No Transform is much worse. 5-day forecasts maintain the advantage (they don't "forget")!

The 5-day forecasts do not “forget” the advantage



OUTLINE

- Introduction: Obstacles and Solutions for Effective Precipitation Assimilation. Main results.
- The Gaussian Transform of the GFS model and TMPA observations.
- Comparison of No Transform, Logarithm Transform and Gaussian Transform.
- Impact on the GFS forecasts verified against ERA Interim.
- New approach to improve IMERG with LETKF assimilation of precipitation (Miyoshi's suggestion)
- Plans

Gaussian Transform: perfect model (Lien et al., 2013)

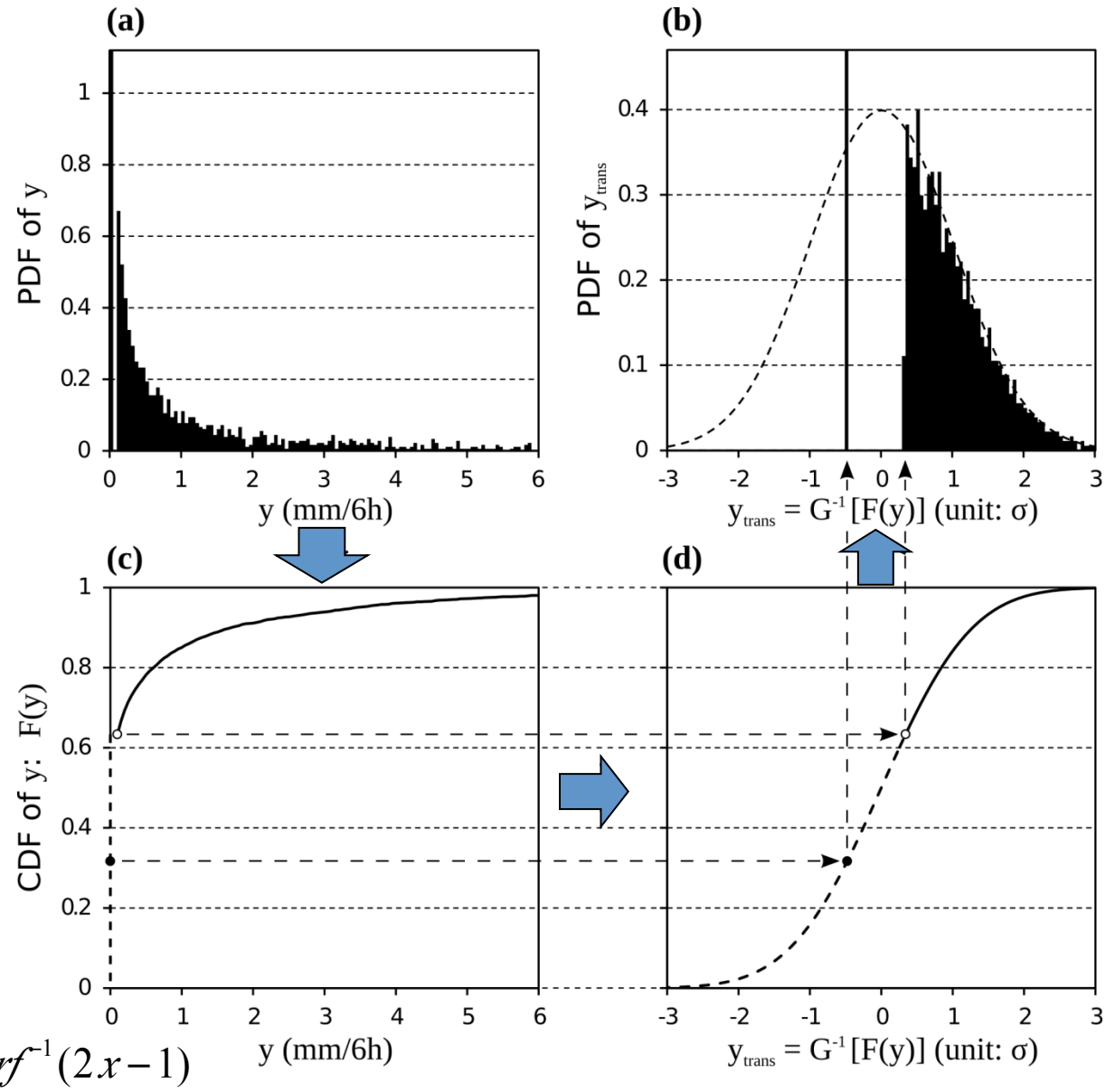
Start with pdf of *y*=rain at every grid point (mm/6hr).

Compute CDF of *y* (mm/6hr).

Convert CDF into a y^{transf} Gaussian CDF (sigma units) using the error function.

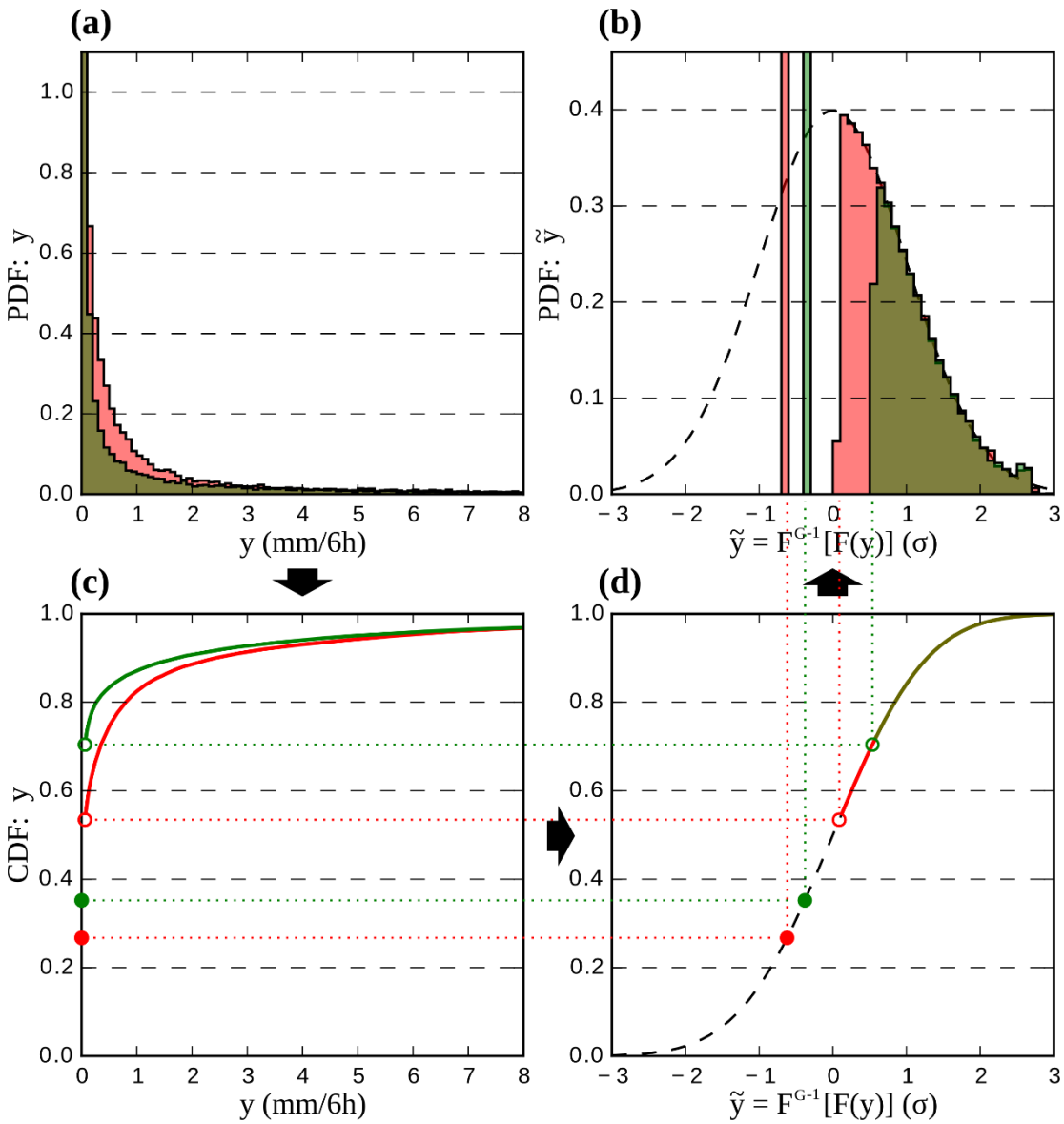
The PDF (y^{transf}) is now a Gaussian (sigma).

After the analysis in Gaussian variables we transform back the y^{transf} CDF from Gaussian to the model *y* (mm/6hr).



$$G^{-1}(x) = \sqrt{2}\,erf^{-1}(2x-1)$$

Gaussian Transform: TMPA, GFS model



—: Model
—: Obs.

Lien et al. (2015b)

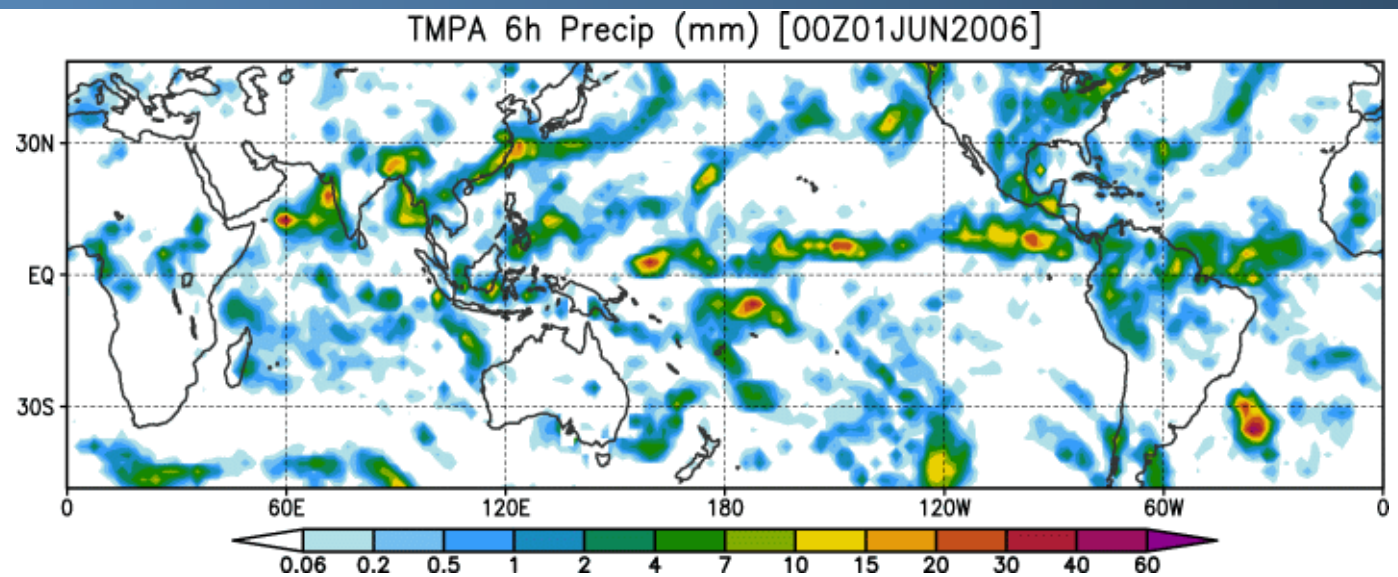
Note that the model at this point (Maryland) has a wet bias. This is typical for most of the globe.

The open circles correspond to the zero precipitation probability and the full circles correspond to the median of the zero precipitation probability

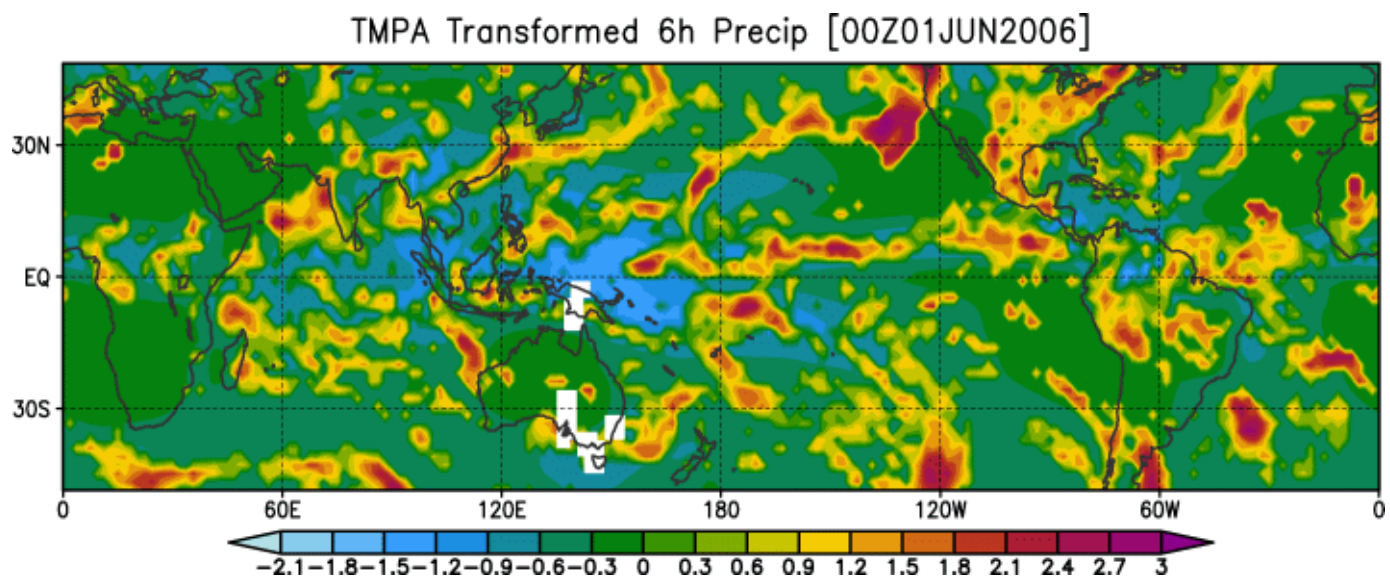
REAL OBSERVATIONS (TMPA)

Example of Gaussian precipitation transformation

Original variable *y* (mm)



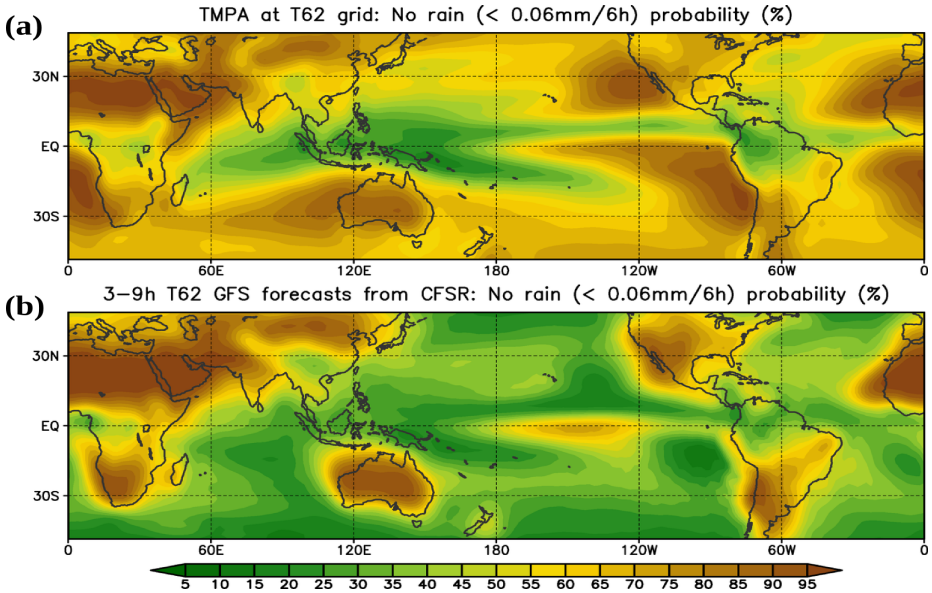
Transformed Variable y^{trans} (sigma)

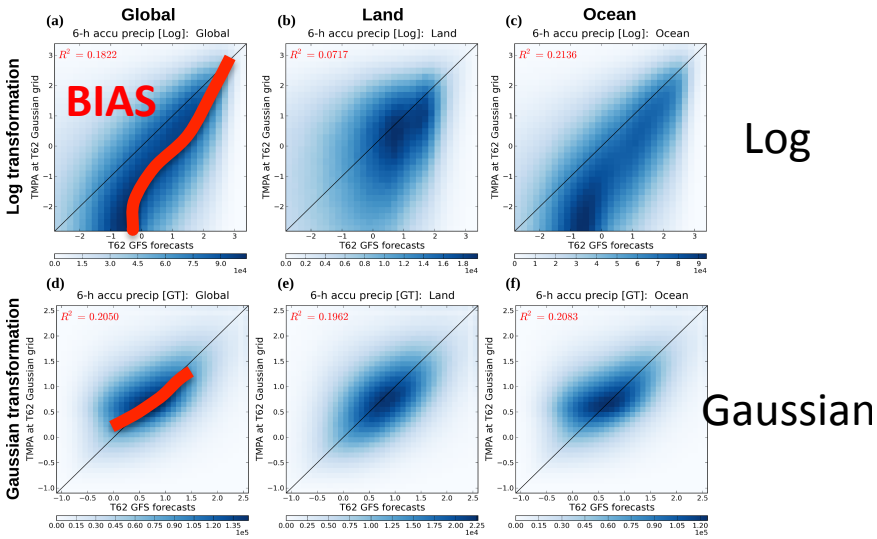


OUTLINE

- Introduction: Obstacles and Solutions for Effective Precipitation Assimilation. Main results.
- The Gaussian Transform of the GFS model and TMPA observations.
- Comparison of No Transform, Logarithm Transform and Gaussian Transform.
- Impact on the GFS forecasts verified against ERA Interim.
- New approach to improve IMERG with LETKF assimilation of precipitation (Miyoshi's suggestion)
- Plans

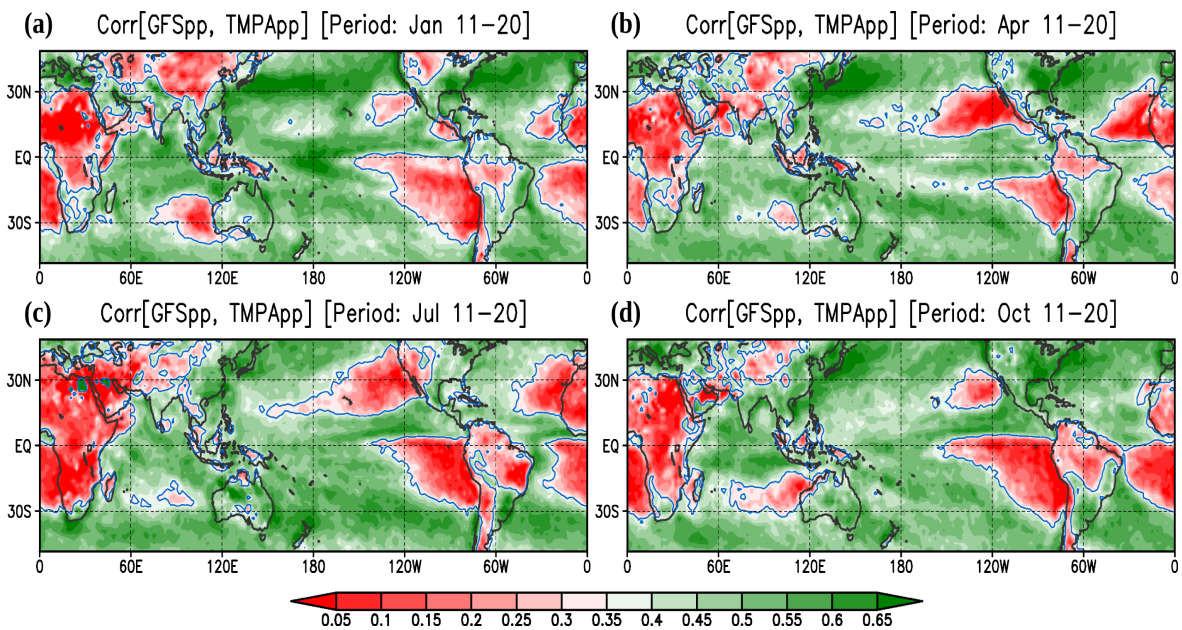
Probability of zero rain: GFS has a wet bias

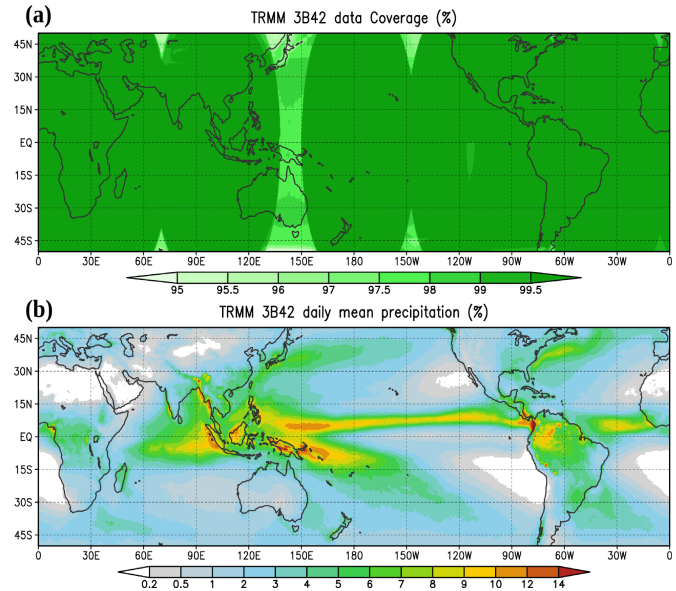




The Gaussian Transform is better able to deal with the bias than the Log Transform

Correlation of the TMPA/GFS time series over 10 years

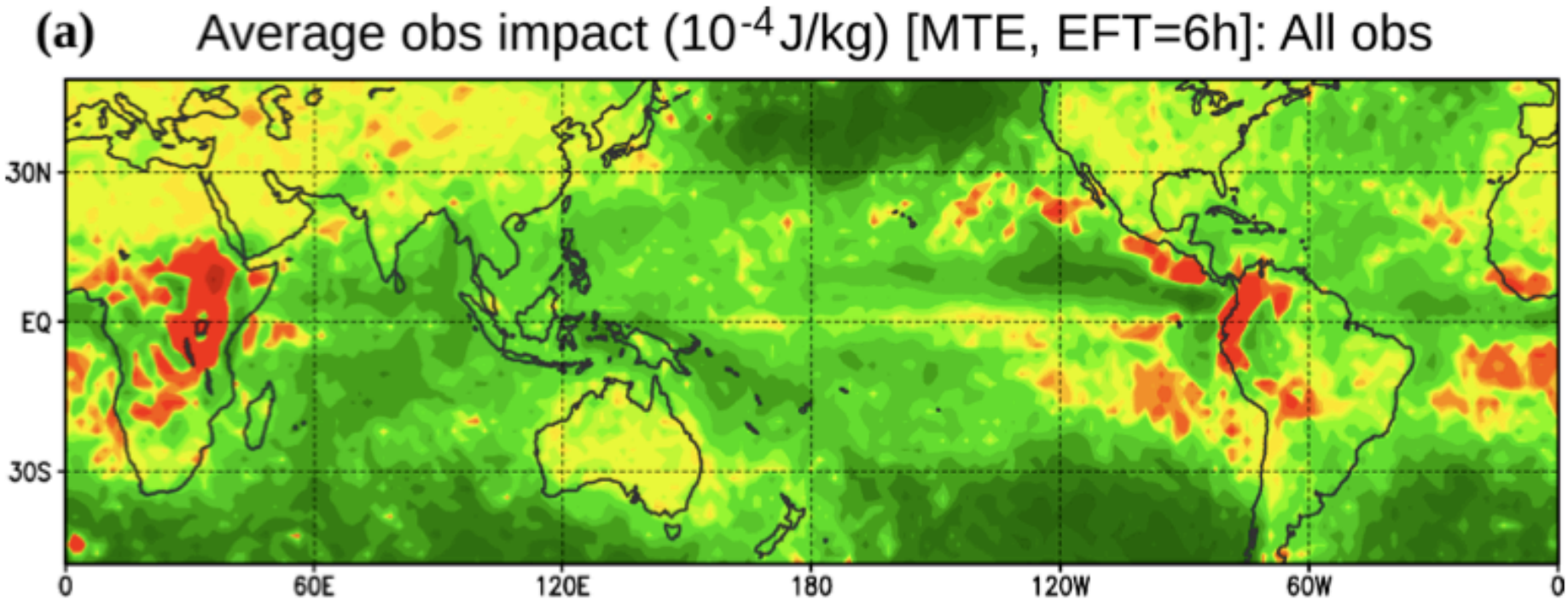




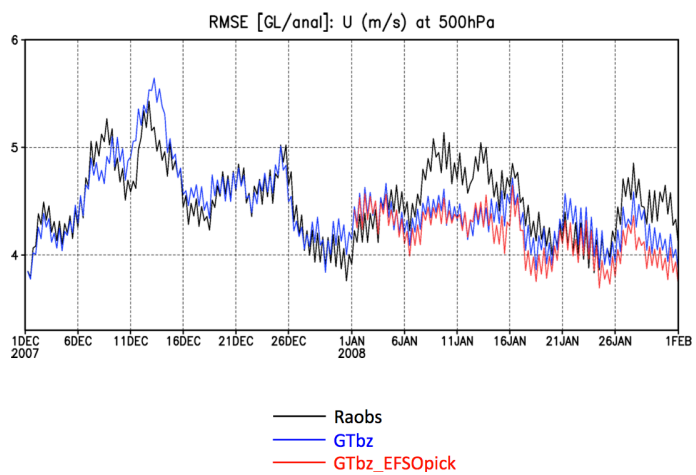
Oceans: correlation is high over over rainy oceans, low over marine stratus deserts.

Land: Correlation is low over the tropics, both rainforests and deserts (e.g., Africa)

Ensemble Forecast Sensitivity to Observations (EFSO) average impact of **rain obs.**



Assimilating only the precip obs identified by EFSO as good improved the results



Assimilating TRMM rain with a GFS T62 model verified against ERA Interim (RMSE)

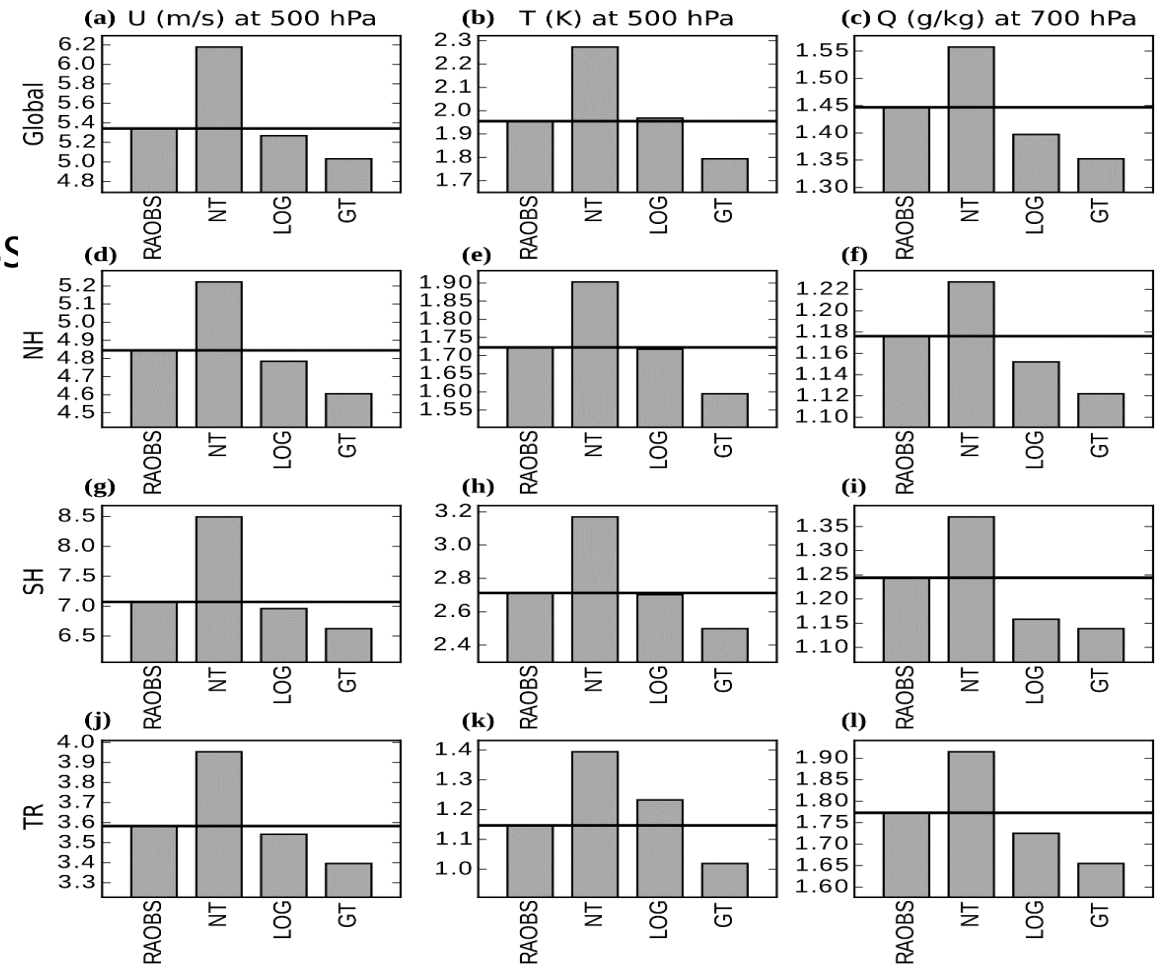
24hr forecast RMSE

Comparing RMSE of

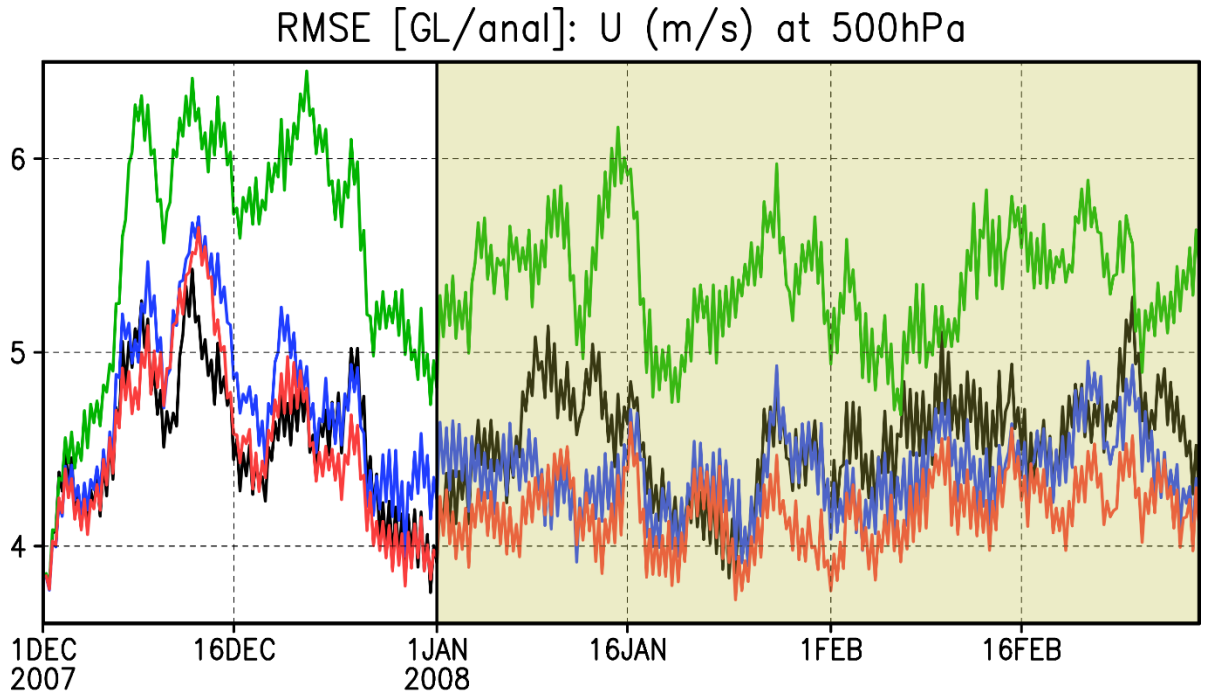
No assim. of precip	RAOBS
Assim. with No Transform	NT
Assim. with LOG Transform	LOG
Assim. w Gaussian Transform	GT

Gaussian Transform is the best in all areas, for all variables

Gaussian Transformation and EFSO/PQC can be used to accelerate the use of new observations in NWP.



The main result: it works with TMPA/GFS



Improvement achieved with GFS-LETKF
(U-wind @ 500 hPa)

Radiosondes ONLY

Radiosondes+Precip. (No-Transform)

Radiosondes+Precip. (Log-Transform)

Radiosondes+Precip. (Gaussian-Transform)

After a spin-up of 1-2 weeks, the assimilation of precipitation with Gaussian Transform is clearly the best.

5-day forecasts maintain the advantage (they don't "forget")!

OUTLINE

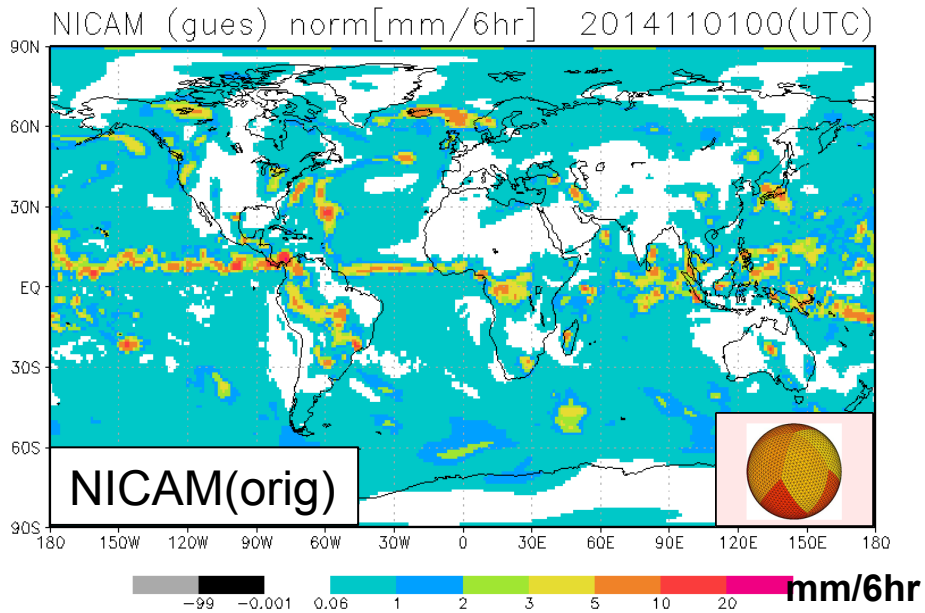
- Introduction: Obstacles and Solutions for Effective Precipitation Assimilation. Main results.
- The Gaussian Transform of the GFS model and TMPA observations.
- Comparison of No Transform, Logarithm Transform and Gaussian Transform.
- Impact on the GFS forecasts verified against ERA Interim.
- New approach to improve IMERG with LETKF assimilation of precipitation (Miyoshi's suggestion)
- Plans

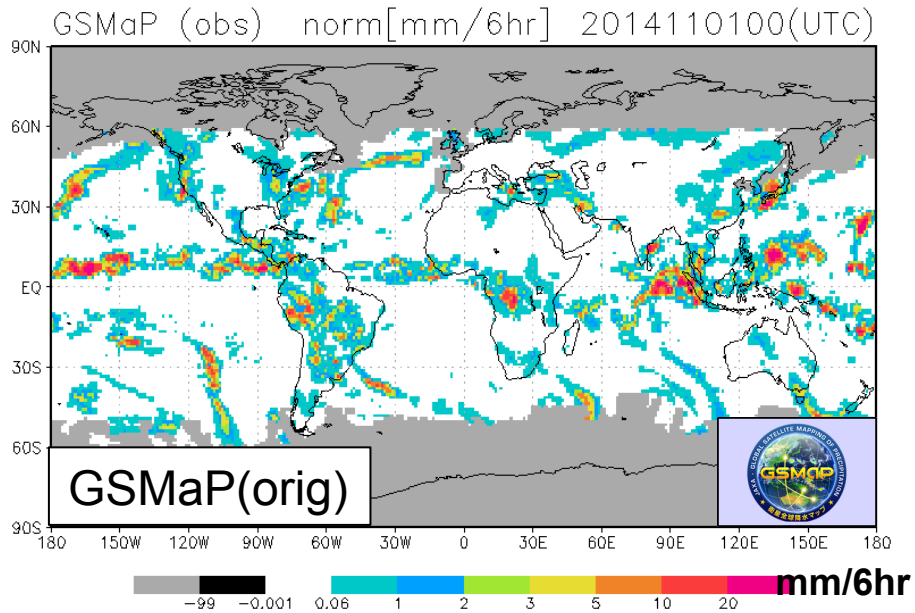
Idea from the RIKEN team (Miyoshi et al., 2015, JAXA)

- After the analysis in Gaussian space, transform back using the GSMaP CDF (observations) rather than the model CDF. This will create a GSMap-like version of the analysis.

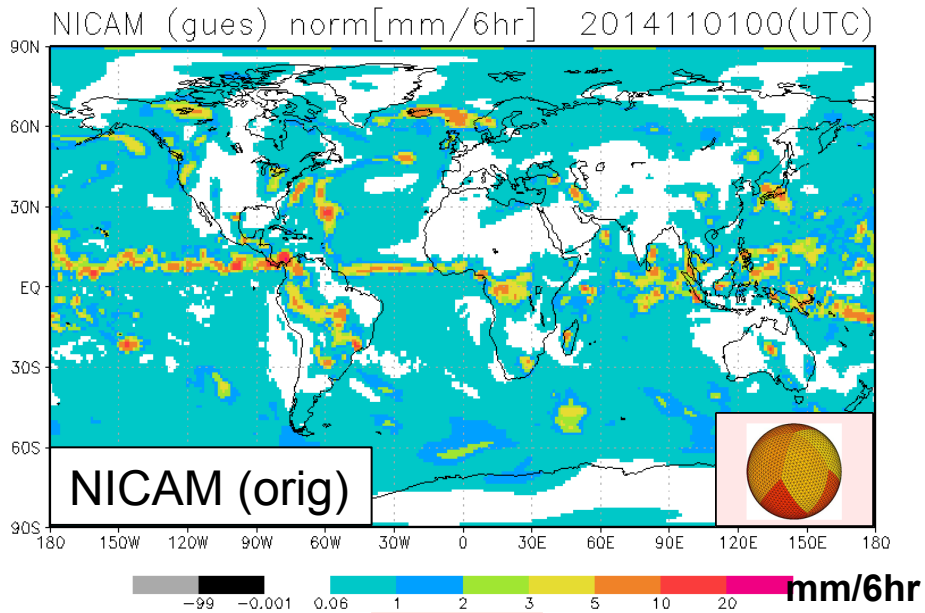
- The same can be done with the GFS analysis and create an IMERG-like analysis that benefits from the forecast information.

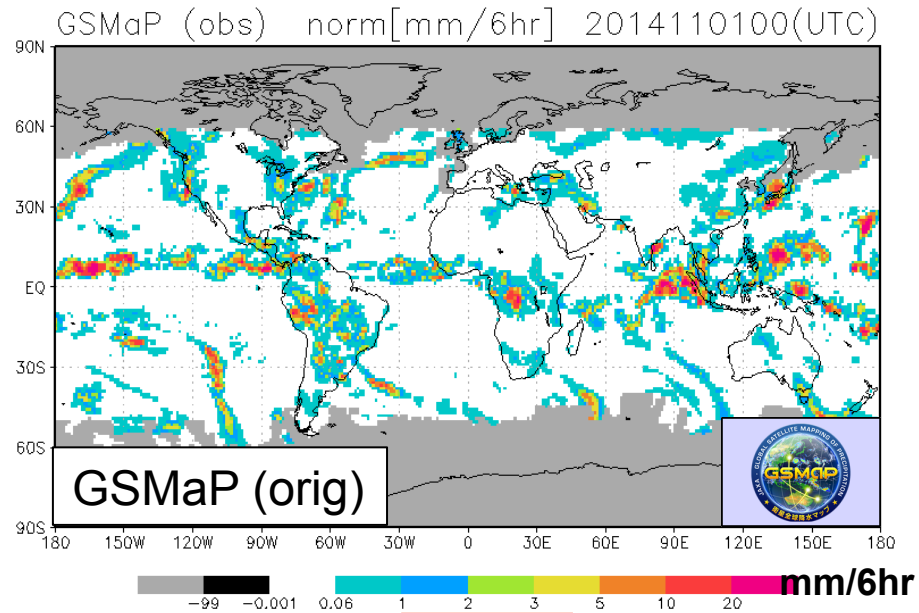
Gaussian Transformation





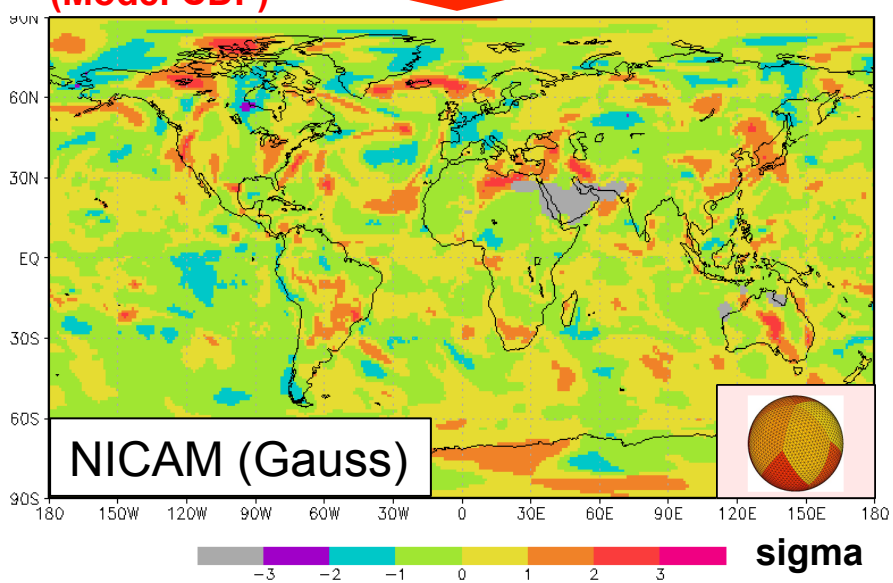
Gaussian Transformation

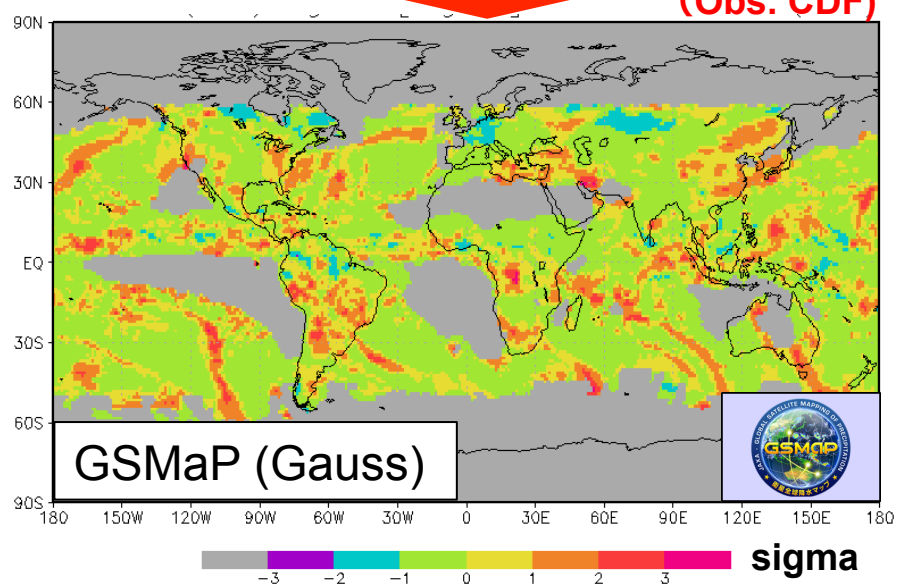




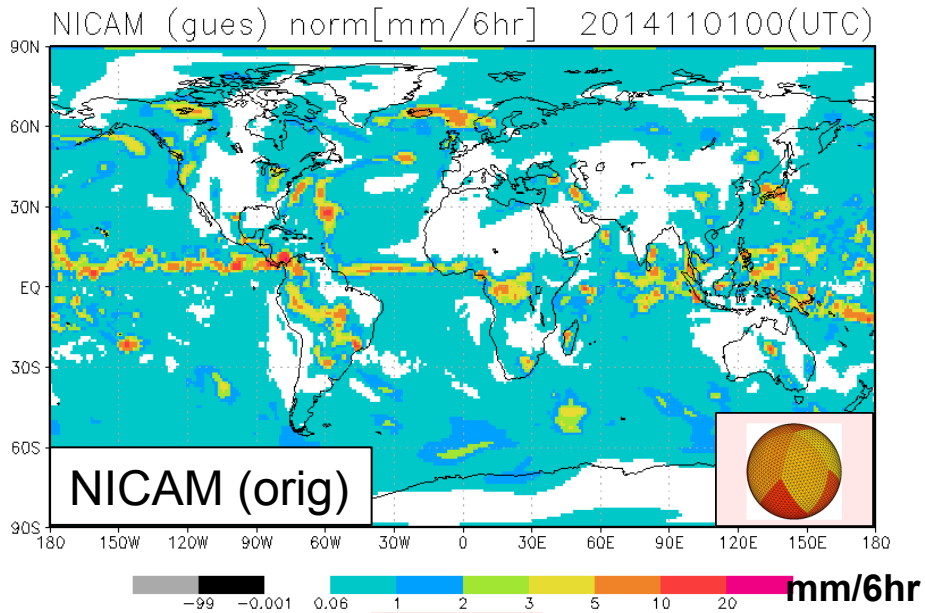
Transformation (Model CDF)

Transformation (Obs. CDF)

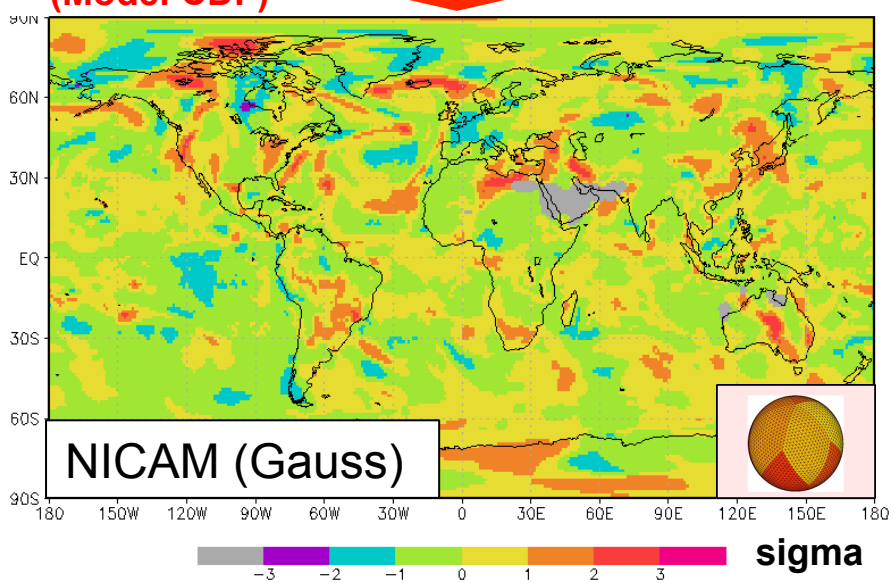




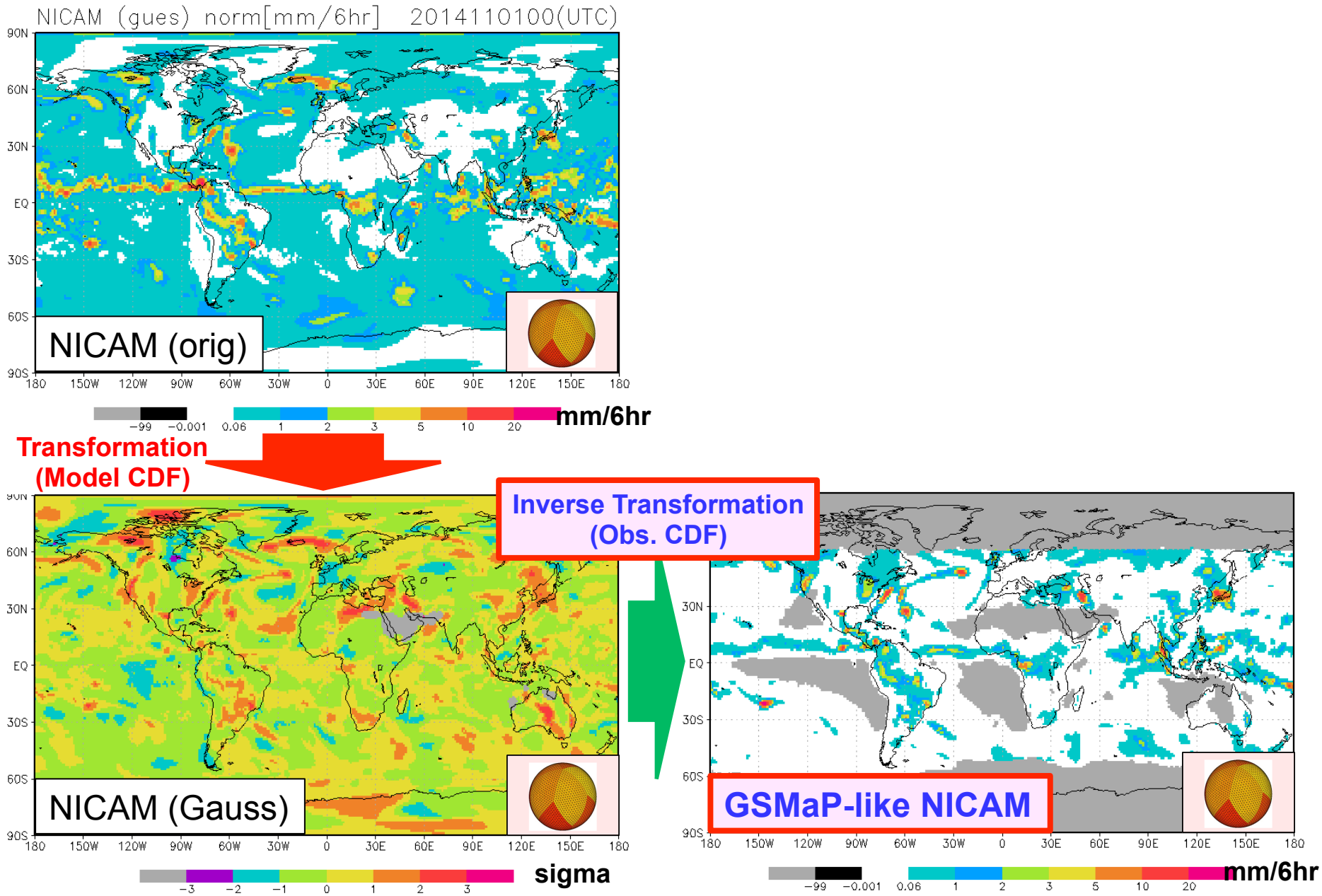
Forward/Inverse Transformations



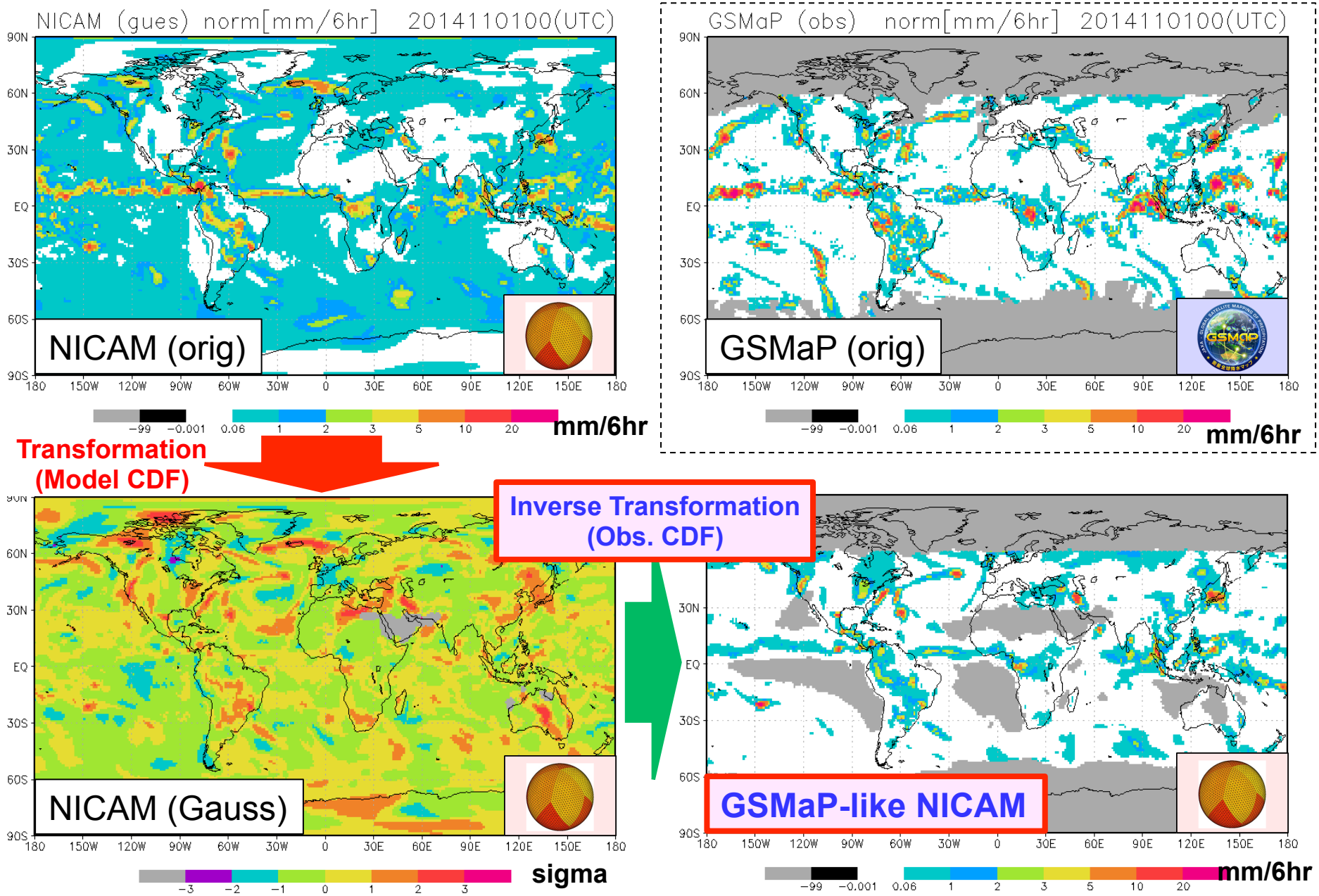
Transformation (Model CDF)



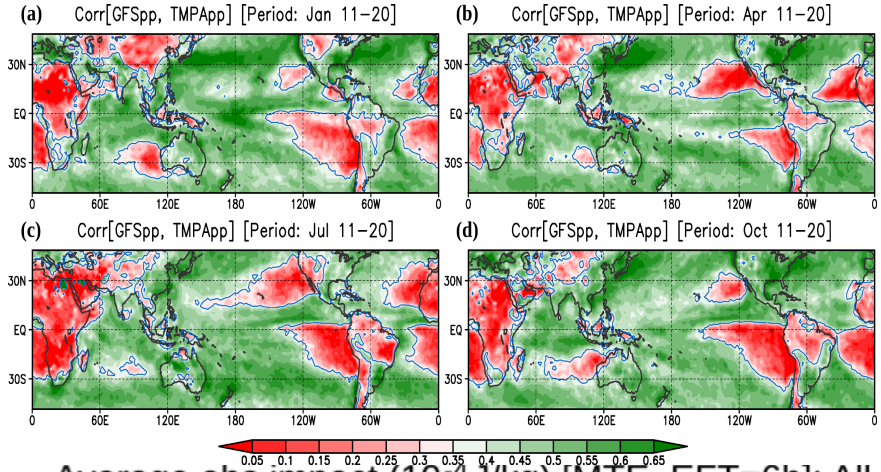
Forward/Inverse Transformations



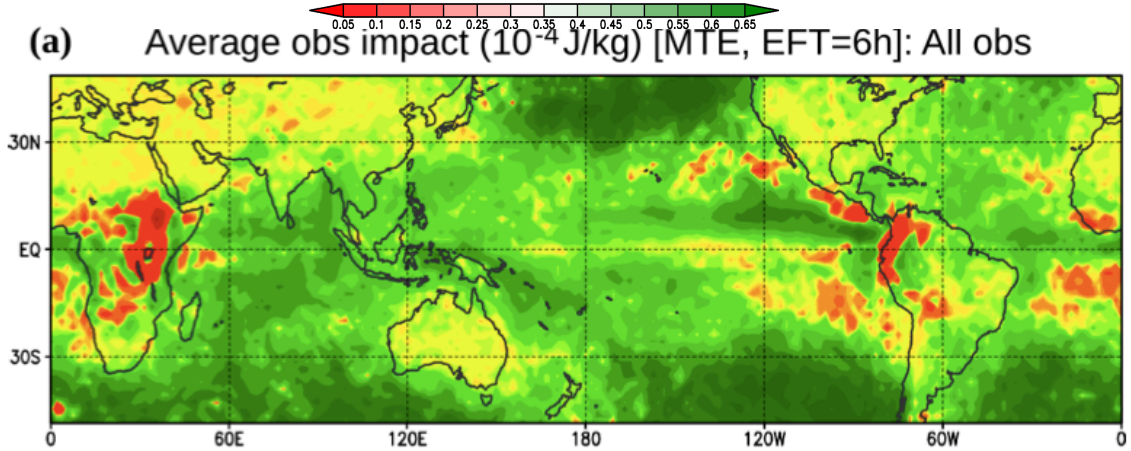
Forward/Inverse Transformations



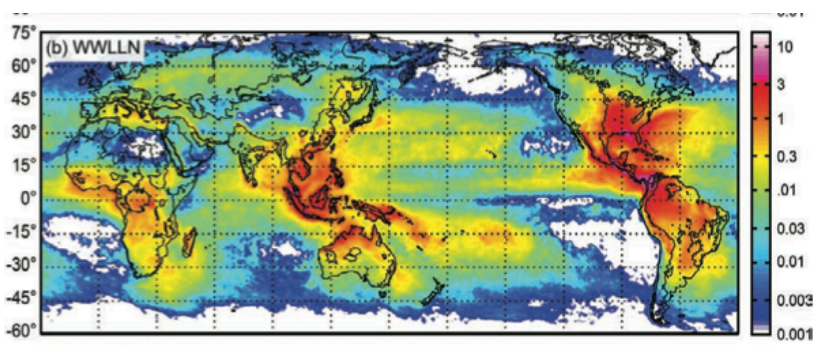
Combining IMERG/EFSO with lightning



Correlation between TMPA observed and GFS model precipitation



EFSO gives us the 6 hr impact of each observation. We can estimate the impact of IMERG in the presence or absence of lightning.



WWLLN Lightning Climatology

Plans

- Add satellite radiances to the control analysis.
- Use IMERG and compare with TMPA.
- Assimilate IMERG to improve typhoon prediction.
- Estimate **IMERG errors** using **EFSR** (Hotta, 2014).
- Combine EFSO-IMERG with lightning to improve assimilation of convective precipitation.
- Transform back the GFS analysis using IMERG CDF (suggested by Miyoshi et al., RIKEN, JAXA support). This will give an analysis/forecast that looks like IMERG but has additional model information (e.g., orography).
- Work with NOAA and NASA to make assimilation of precipitation operational.
- This could be applied to other non-Gaussian variables…