CERES Cloud Properties: Update Spring 2017

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Thanks to Dave Doelling and his calibration team!

CERES Science Team Mtg., Hampton, VA, 16-18 October 2016

Topics

- Publications
- Status
- MODIS Collection 6 vs 5
- Ed4 Improvements vs Ed2
- GEO update
- Ed5 update

Update of CERES Cloud-related Papers since Oct 2016

Edition-4 related

Zhang, Z., X. Dong, B. Xi, H. Song, P.-L. Ma, S. Ghan, S. Platnick, and P. Minnis, 2017: Intercomparisons of marine boundary layer cloud properties from two MODIS products, ground-based retrievals, and a GCM over the ARM Azores site. *J. Geophys. Res.*, **122**, doi:10.1002/2016JD025763.

Painemal, D., C. Chiu, P. Minnis, M. Cadeddu, C. Yost, X. Zhou, E. Eloranta, E. Lewis, R. Ferrare, and P. Kollias, 2017: Aerosol and cloud microphysics co-variability in the northeast Pacific boundary layer estimated with ship-based and satellite remote sensing observations. *J. Geophys. Res.*, **122**, doi:10.1002/2016JD025771.

Shea, Y. L., B. A. Wielicki, S. Sun-Mack, and P. Minnis, 2017: Quantifying the dependence of satellite cloud retrievals on changes in instrument calibration. *J. Climate*, **30**, doi:10.1175/JCLI-D-16-0429.1.

Wu, P., X. Dong, B. Xi, Y. Liu, M. Thieman, and P. Minnis, 2017: Effects of environment forcing on marine boundary layer cloud-drizzle processes. *J. Geophys. Res.*, **122**, doi:10.1002/2016JD026326.

Foster, M. J., S. A. Ackerman, R. A. Frey, L. Di Girolamo, A. K. Heidinger, S. Sun-Mack, W. P. Menzel, P. Minnis, G. Zhao, 2017: Cloudiness [in “State of the Climate 2016”]. *Bull. Amer. Meteorol. Soc.*, submitted.

Sun-Mack, P. Minnis, Y. Chen, D. R. Doelling, and B. Scarino, 2016: Calibration changes to Terra MODIS Collection-5 radiances for CERES Edition 4 cloud retrievals. *IEEE Trans. Geosci. Remote Sens.*, in preparation.

Trepte, Q. Z., P. Minnis, C. R. Yost, S. Sun-Mack, and Y. Chen, 2017: Global cloud detection for CERES Edition 4 using Terra and Aqua MODIS data. *J. Atmos. Oceanic Technol.*, In preparation.

Minnis, P., S. Sun-Mack, C. R. Yost, Y. Chen, et al., 2017: Changes to CERES MODIS cloud product retrieval algorithms for Edition 4. *IEEE Trans. Geosci. Remote Sens.*, in preparation.

Edition-5 related

Scarino, B. R., P. Minnis, T. Chee, K. M. Bedka, C. R. Yost, and R. Palikonda, 2017: Global clear-sky surface skin temperature from multiple satellites using a single-channel algorithm with angular anisotropy corrections. *Atmos. Meas. Tech.*, **10**, 351-371, doi:10.5194/amt-10-351-2017.

Clouds - Processing Status

CERES MODIS Status (Coll 5 Data)

Ed4 processing

- *Aqua: Jul 2002 – Jan 2017 (~15 y)*
- *Terra: Feb 2000 – Jan 2017 (~17 y)*

CERES VIIRS Ed 1 Status

Ed1 delivered, 5 years completed

- *Jan 2012 – Dec 2016*

Switch to MODIS Collection 6

C6 radiances scaled to C5 to maintain continuity in CERES data record

- MODIS Collection 5 (C5) stopped on March 30, 2017. Need to migrate to C6 beginning in April 2017
- The MODIS C6 has the most updated calibration
  - Detector to detector, scan angle, stability and absolute calibration, some of which were not in the C5 calibration code
- To avoid creating a discontinutity in Ed4, we will scale the C6 channel radiances back to C5 absolute calibration
  - Scaling factors developed by regressing pixel-level C6 and C5 radiance pairs
  - The MODIS cloud code has been modified to read in scaling factors
  - Update annually unless large anomaly occurs
  - Use invariant deep convective clouds, desert, and polar ice to forecast any visible trends

Switch to MODIS Collection 6

C6 radiances scaled to C5 to maintain continuity in CERES data record

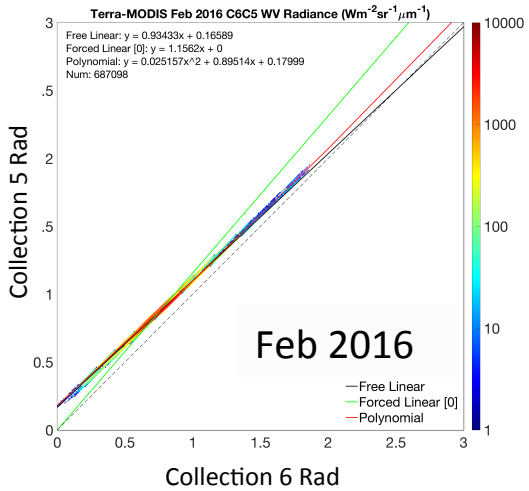
C5-C6 summary from last STM

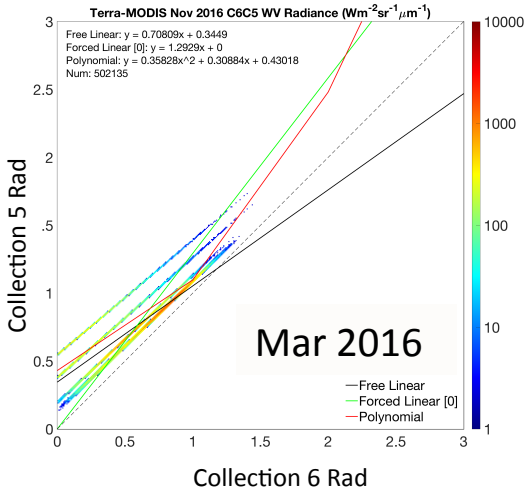
- Changes caused by C6 calibrations are small, but significant for some bands
- Most impactful problem is degradation of Aqua Vis calibration
  - induces artificial trends in C5 Aqua and Terra, continues in C6
- Unmaintained nocturnal 3.7 µm corrections introduce trends at night
- Strategy outlined for improvements in Ed5

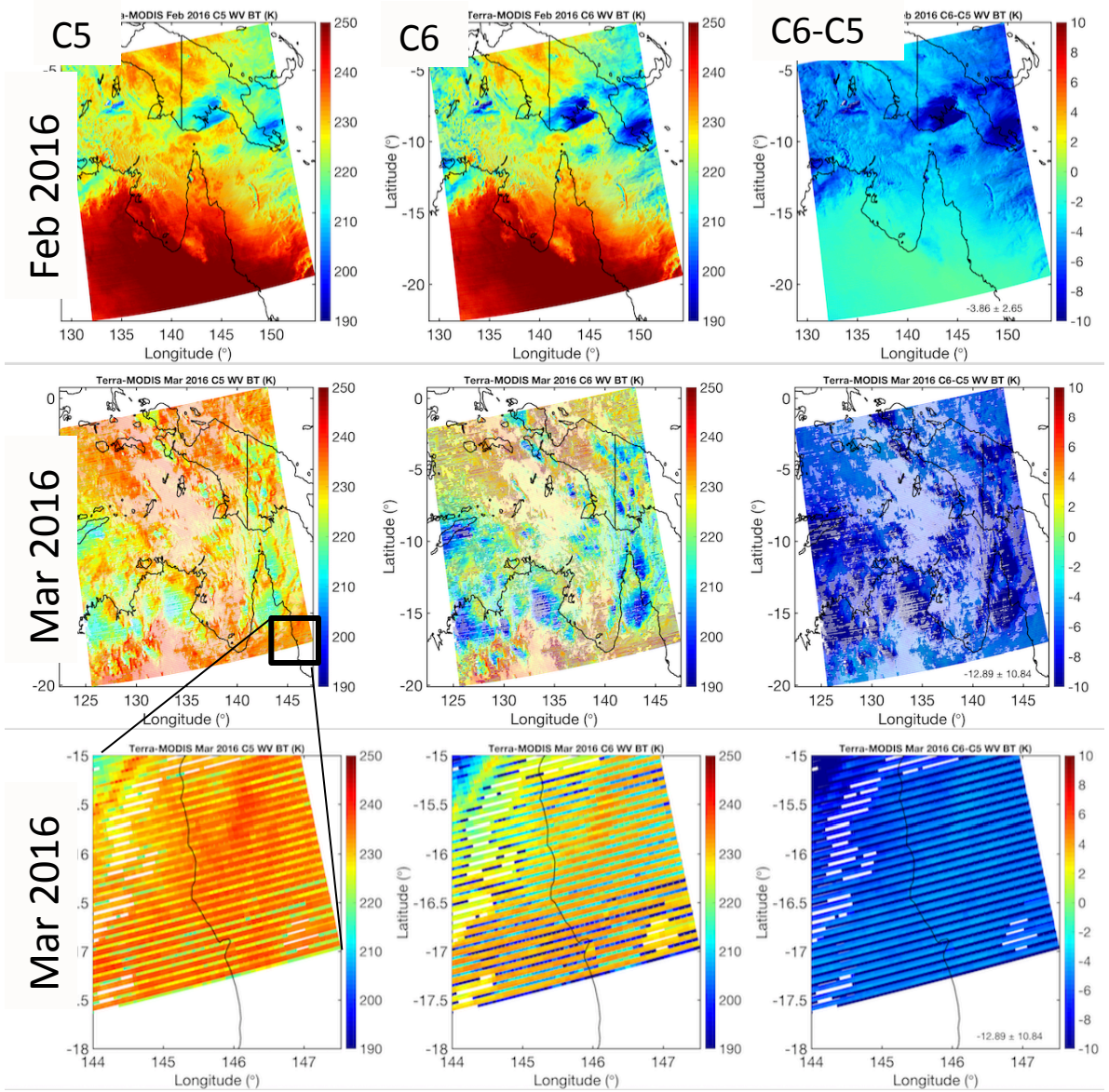
Recent developments

- Major anomaly in TERRA WV channel occurred in Feb 2016
  - TERRA WV channel degrading since 2008
- WV channel used in cloud mask
  - most critical over snow/ice during nighttime
- Discontinuity in cloud properties possible
  - Assessing the potential impact of removing WV channel from mask (in progress)

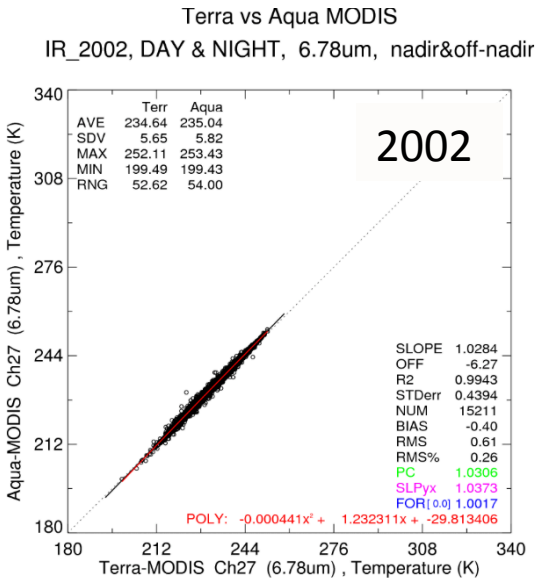
Terra-MODIS Water Vapor 6.7µm

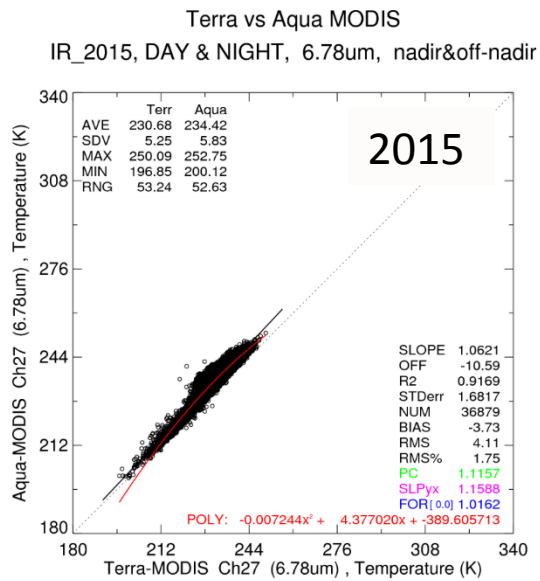


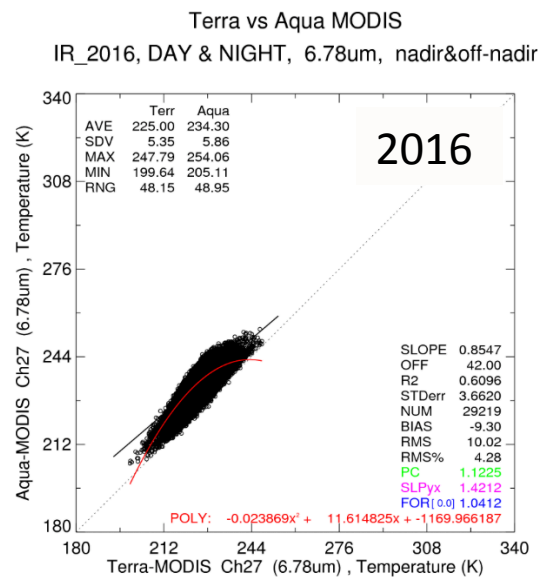


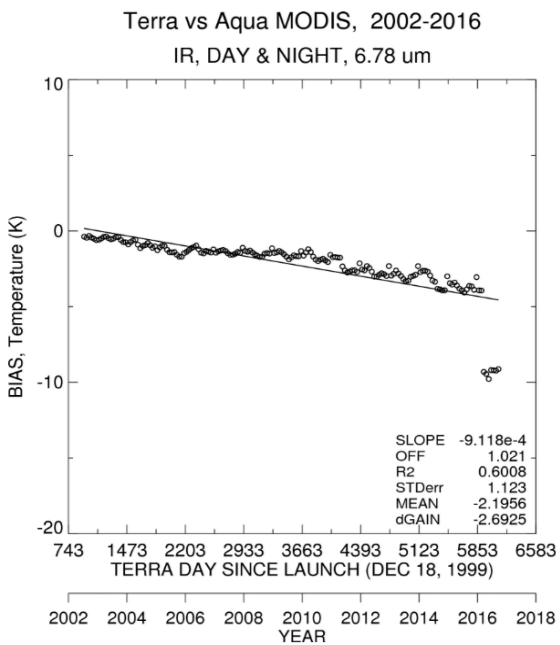


Terra and Aqua WV nadir matched BT





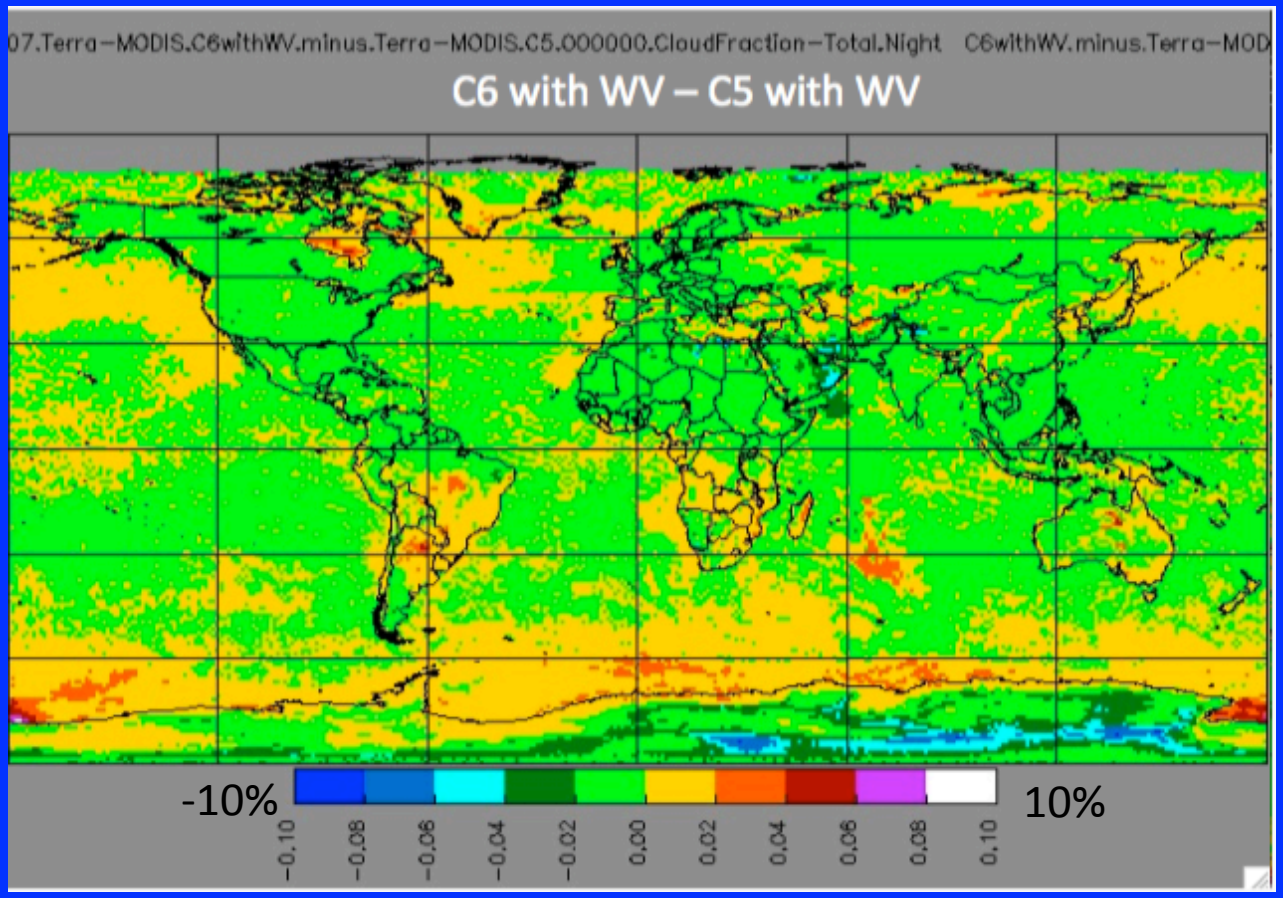




- Terra and Aqua orbits cross over the poles
- At the ground intersect the angles between Terra and Aqua match
- During 2002 the Terra and Aqua WV temperatures were very similar
- After 2010 the Terra WV started to degrade
- After the Terra satellite anomaly the Terra WV is rendered un-useable without correcting the detector to detector striping

TERRA WV Channel
Impact of C6/C5 scaling on Cloud Fraction

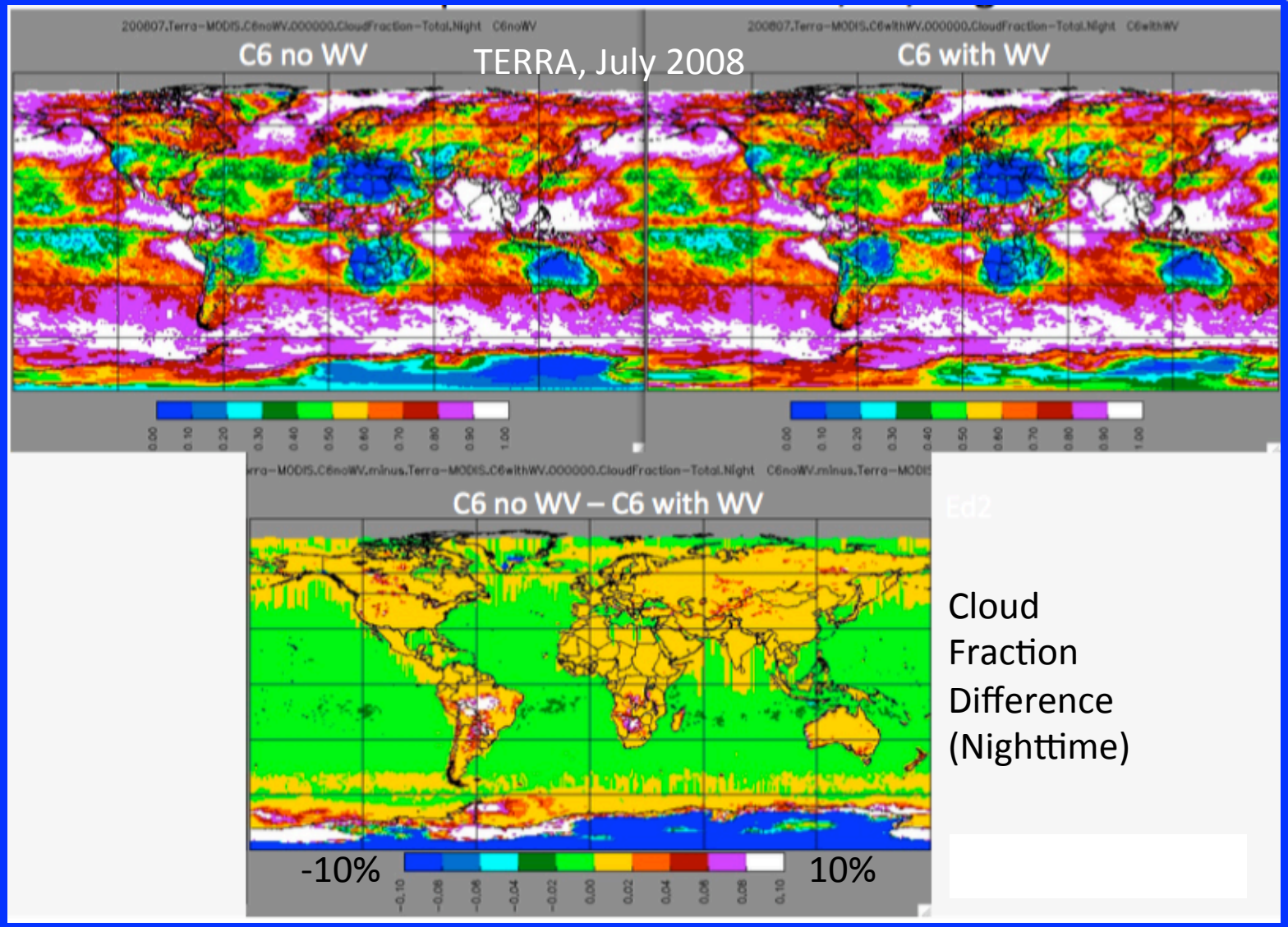
TERRA, July 2008



Cloud Fraction Difference (Nighttime)

Small differences due to scaling

TERRA WV Channel
Impact of no WV channel in Cloud Mask

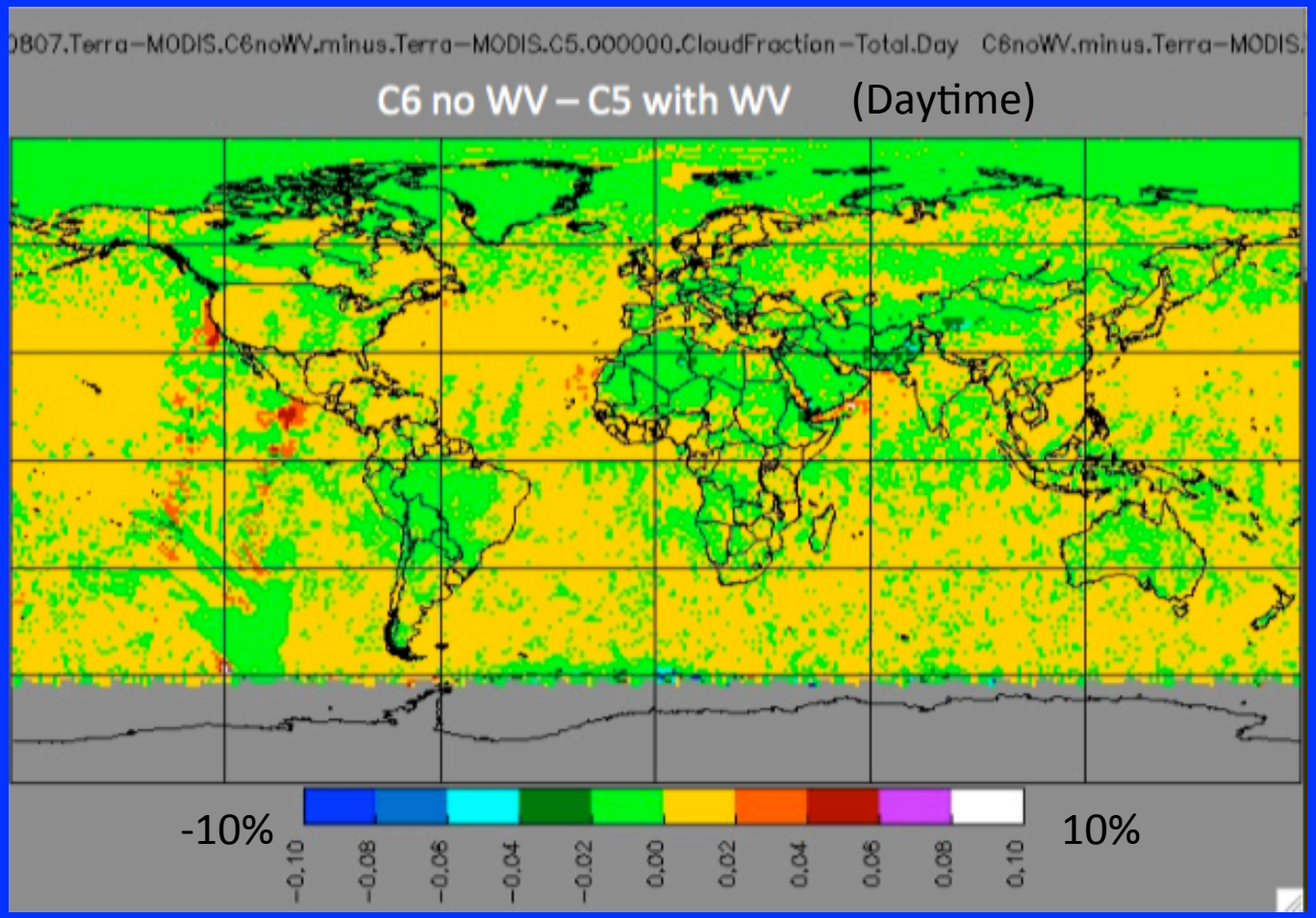


Cloud Fraction Difference (Nighttime)

Mostly impacts Polar regions

TERRA WV Channel: Impact of WV Removal

TERRA, July 2008



Daytime cloud fraction differences small

TERRA WV Channel: Impact of WV Removal

- Discontinuity in Ed4 Terra cloud properties possible in polar regions, minimal impact expected elsewhere
- Expect greatest impact on SFC fluxes
- Minimal impact on TOA flux (?) - ADM's similar over snow/ice, clouds
- No current solution to compensate for lost WV channel in Ed4
- Need to develop strategy for Ed5

Ed4 vs Ed2 Clouds

Primary changes to cloud mask

- Increased thin Ci detection over land and ocean
- Improved aerosol (heavy dust) and low cloud discrimination
- Improved polar cloud and snow/ice detection
- Smoother transitions into polar regions

Primary changes for optical depth

- Improved vis calibration (anchor Aqua) But, Aqua degrading
- New ice crystal models (roughened hexagonals)
- Improvements for cryosphere (1.24 μm Terra and Aqua, 1.24 μm snow model)

  But, thin cloud Tau too high

Primary changes for cloud height

- Regional lapse rates for B.L clouds (Sun-Mack et al., 2013, JAMC)
- Optically thick ice cloud correction (Minnis et al., 2008, GRL)
- Optically thin cirrus – many different factors
  - Aqua accuracies improved, Terra reduced

Coding improvements

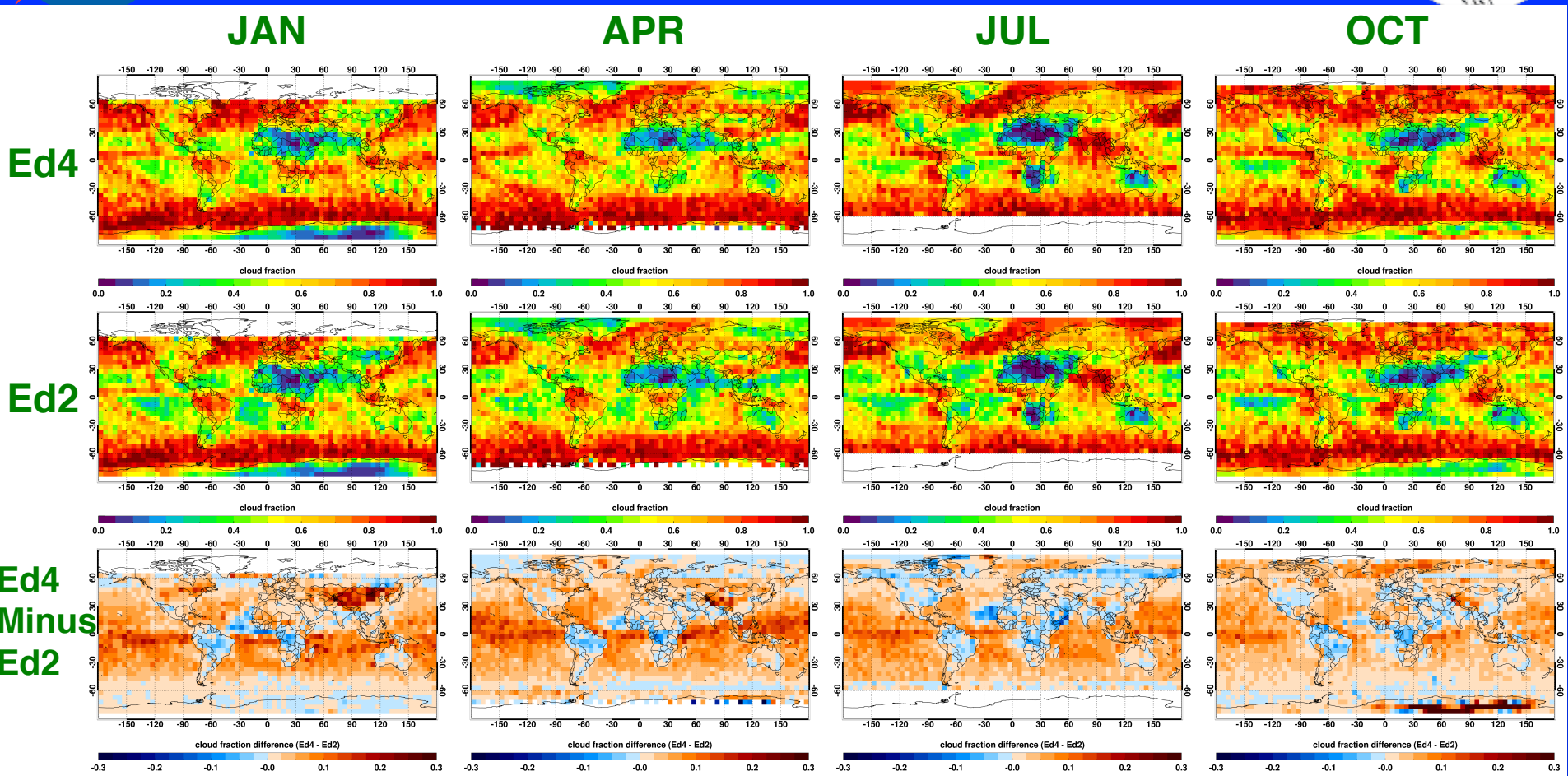
- Eliminated core dumps (3-4% data loss)
- Fewer no retrievals (from 5% to 1%)

Ed4 vs Ed2 Clouds
Cloud Fraction

MODIS comparisons with CALIPSO

- Spatially/temporally matched cloud properties for January, April, July, and October (JAJO) 2015-2016
- Aqua-MODIS Edition 4 and Edition 2
- CALIPSO products used:
  - Vertical Feature Mask (VFM) V4-1
- Compute Fraction Correct (FC), Hit Rates (HR), False Alarms (FAR), and Heidke Skil Scores (HSS)
- Additional notes:
  - No parallax correction. View angles are < 20 degrees

MODIS Ed4 – Ed2 Cloud Fraction
Daytime (2015-2016)



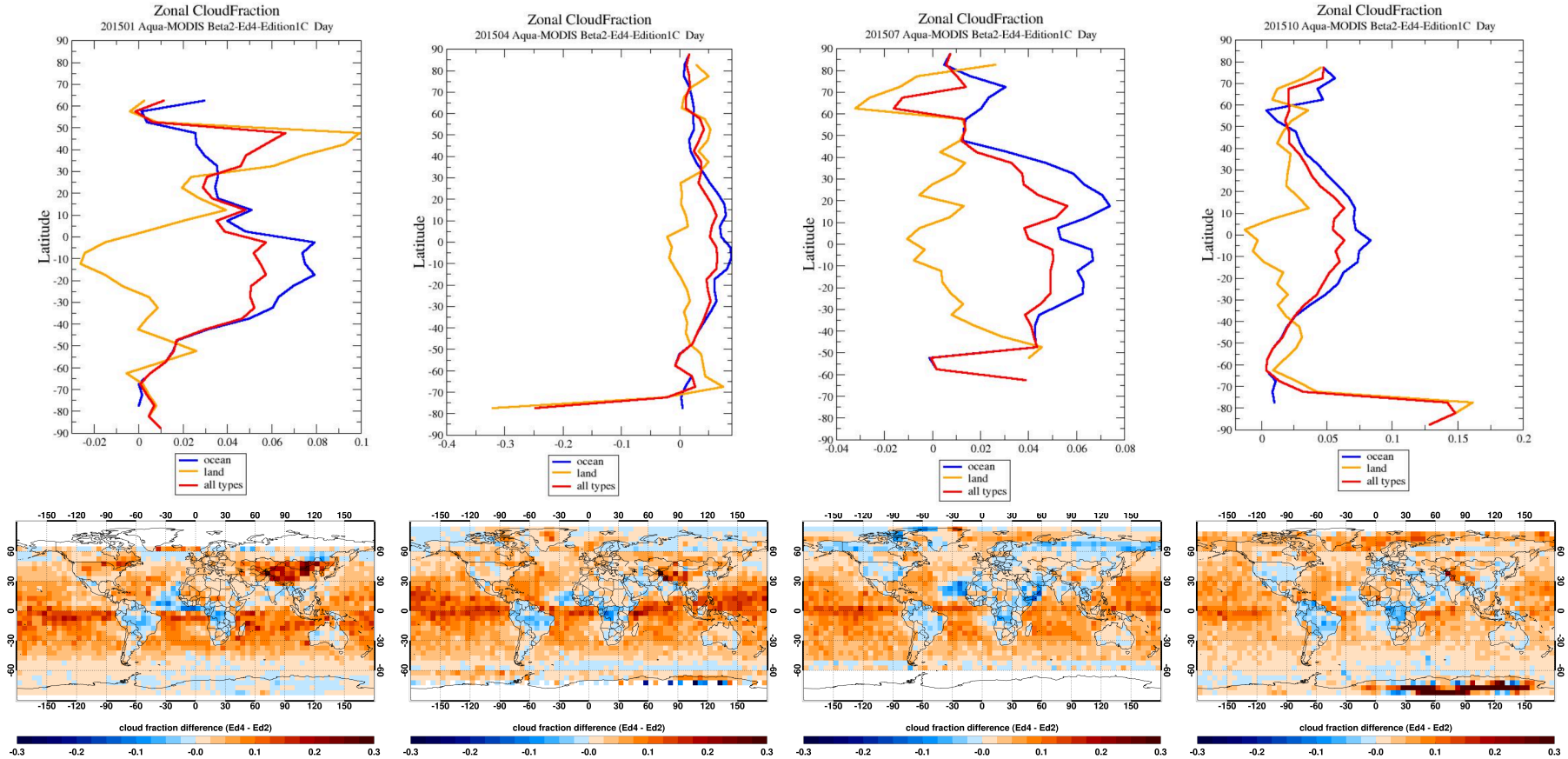
Daytime Ed4 cloud fraction 0.03 higher (global mean)

Global means

Cloud Fraction	JAN	APR	JUL	OCT
Edition 4	0.619	0.629	0.652	0.666
Edition 2	0.587	0.594	0.626	0.634

MODIS Ed4 – Ed2 Cloud Fraction
Daytime

JAN **APR** **JUL** **OCT**



Ed4 – Ed2

Zonal mean increases over low lat oceans. Land diffs mostly neutral exc. Antarctica

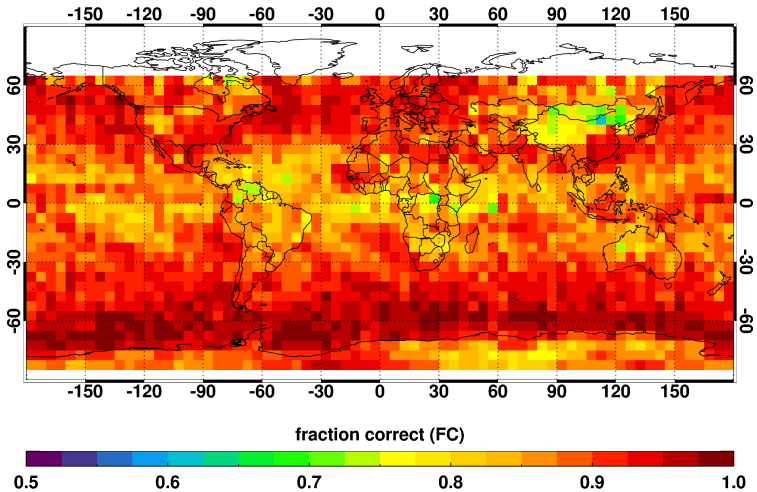
Global means

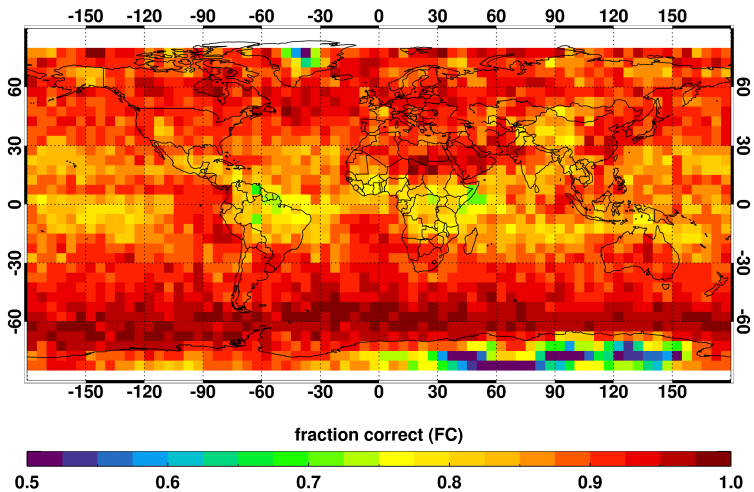
Cloud Fraction	JAN	APR	JUL	OCT
Edition 4	0.619	0.629	0.652	0.666
Edition 2	0.587	0.594	0.626	0.634

MODIS Ed4 – Ed2 Fraction Correct
Daytime

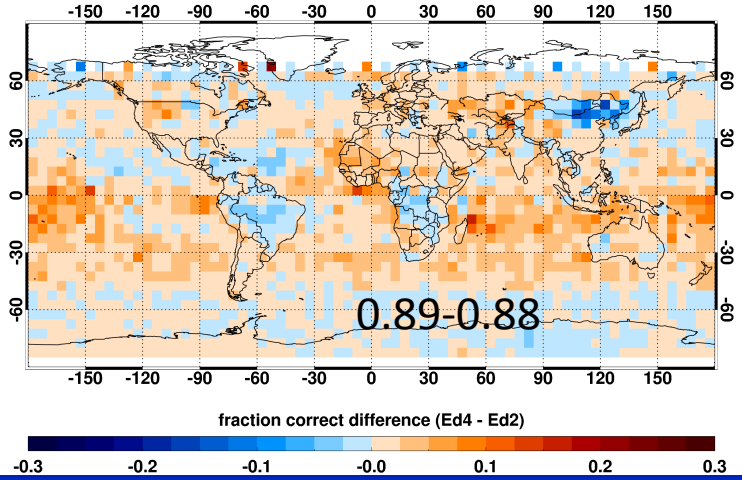
JAN | OCT

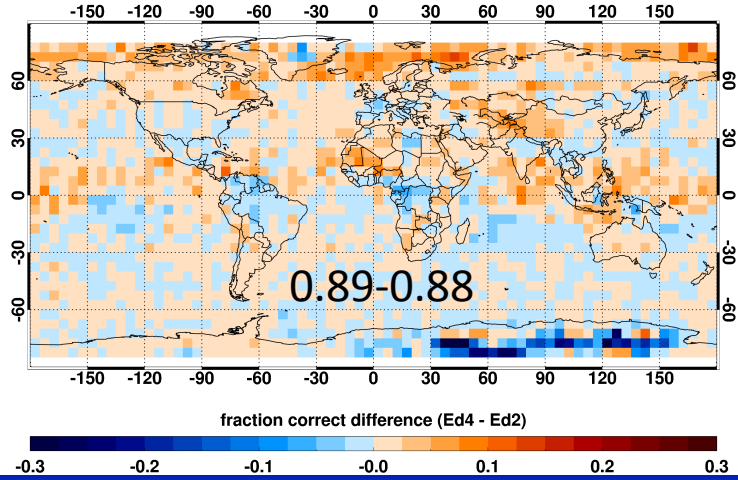
Ed4





Ed4 – Ed2





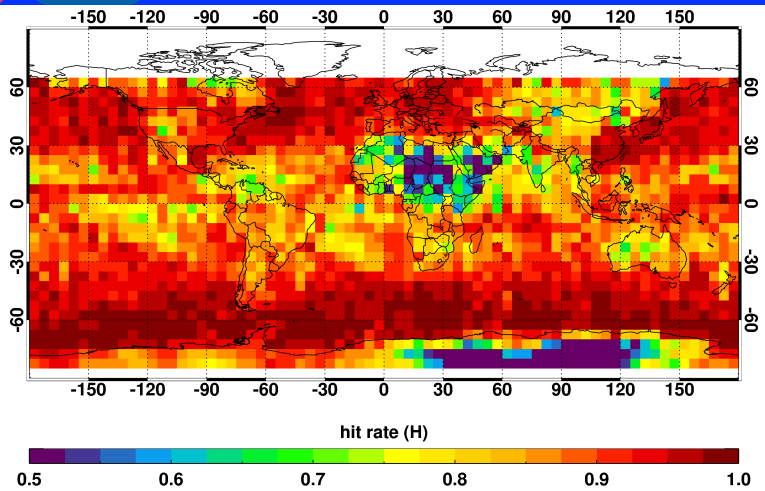
FC correct nearly the same overall.
Significant increases over lower latitude oceans, E. tropical Atlantic
Improved over Arctic but lower FC over E. Antarctica in Oct

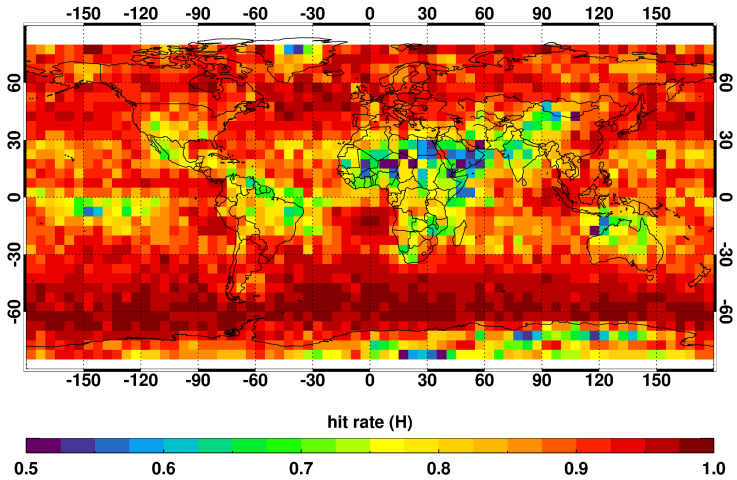
MODIS Ed4 – Ed2 Hit Rate
Daytime

JAN

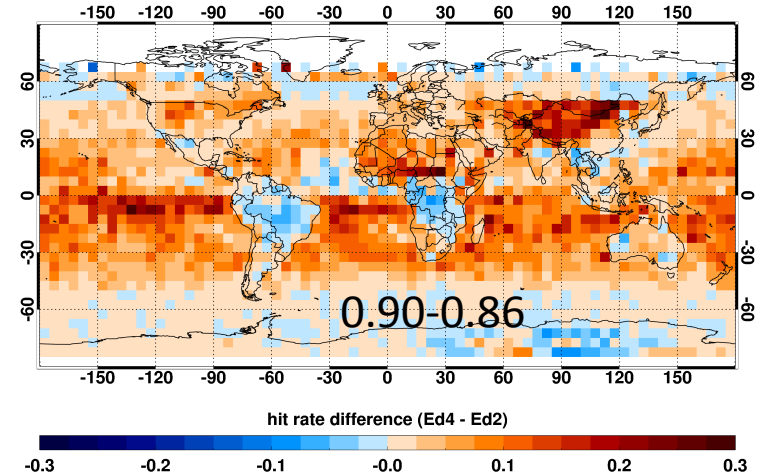
OCT

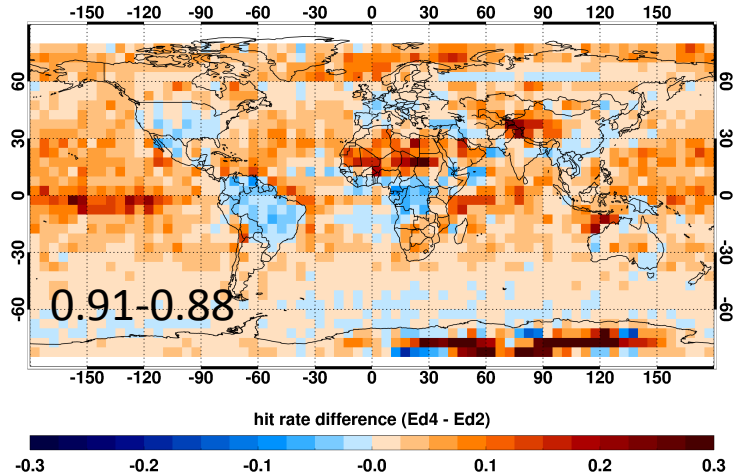
Ed4





Ed4 – Ed2





Higher hit rates overall, especially lower latitude oceans

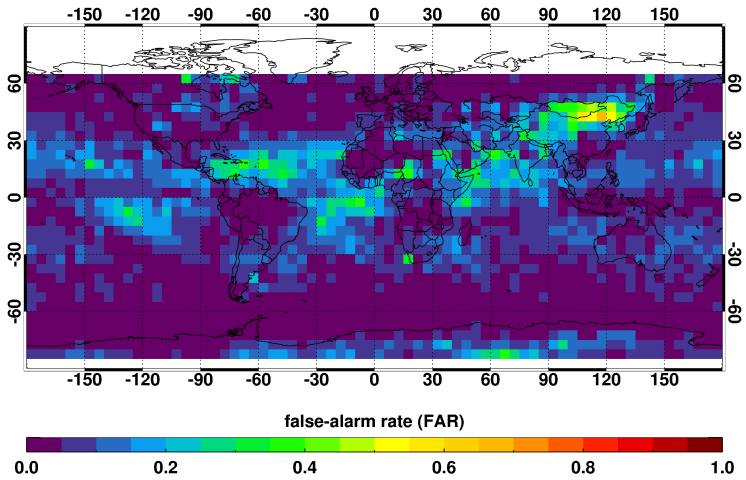
Small decrease over land (S. Amer, C. Africa)

Big improvement E. Antarctica (Oct), neutral or slight dec in Jan

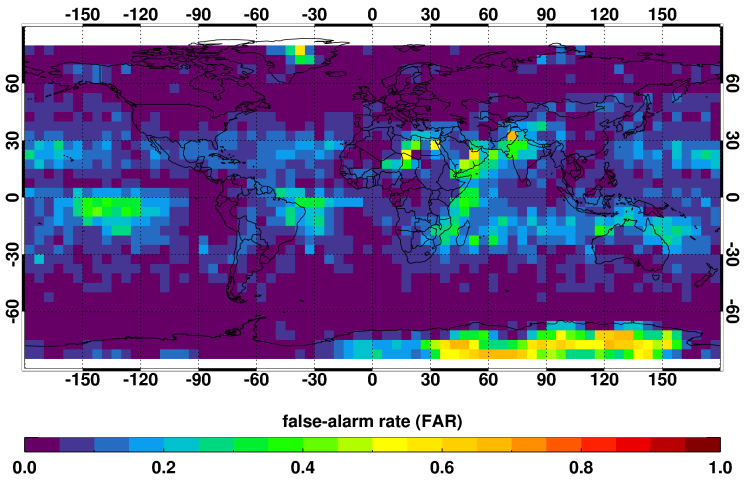
MODIS Ed4 – Ed2 False Alarm Rate
Daytime

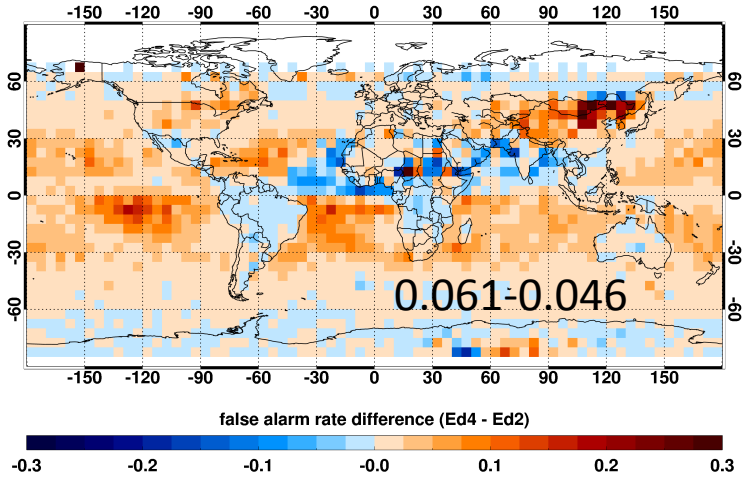
JAN

OCT

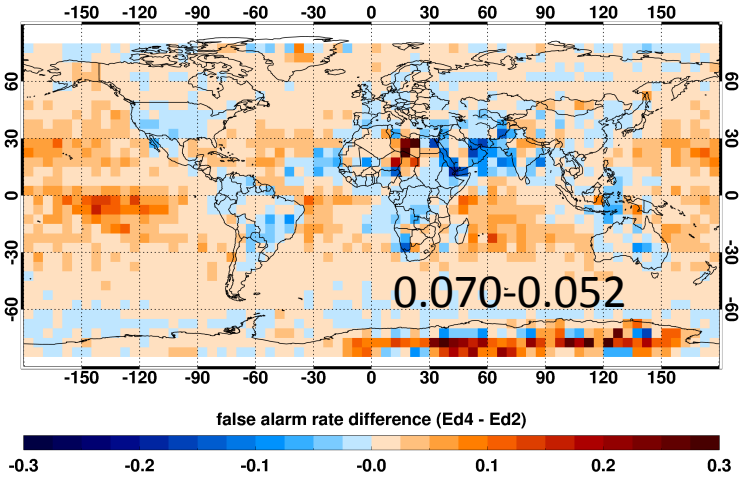


Ed4





Ed4 – Ed2



False Alarms mostly increase in Ed4

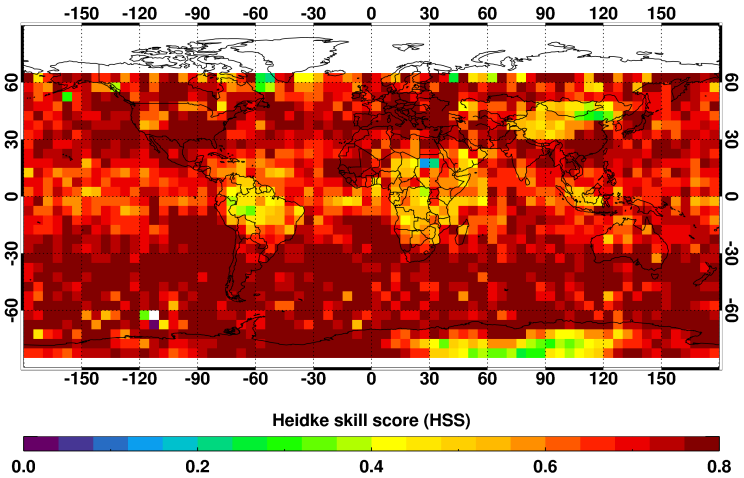
Largest differences in areas with lower cloud fractions

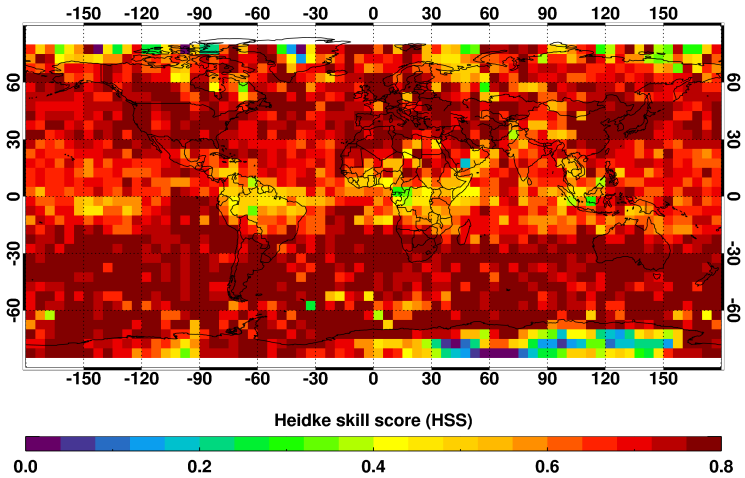
MODIS Ed4 – Ed2 Heidke Skill Score
Daytime

JAN

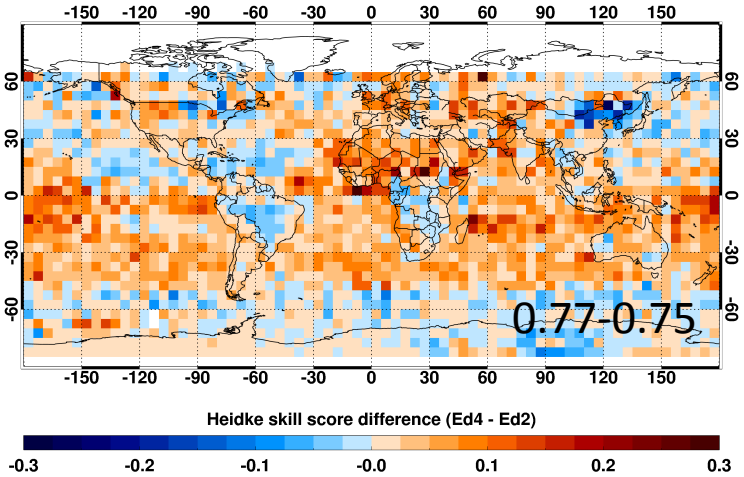
OCT

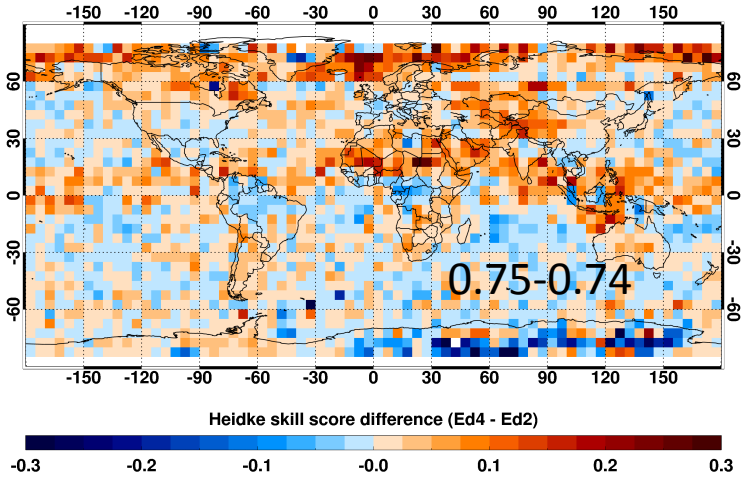
Ed4





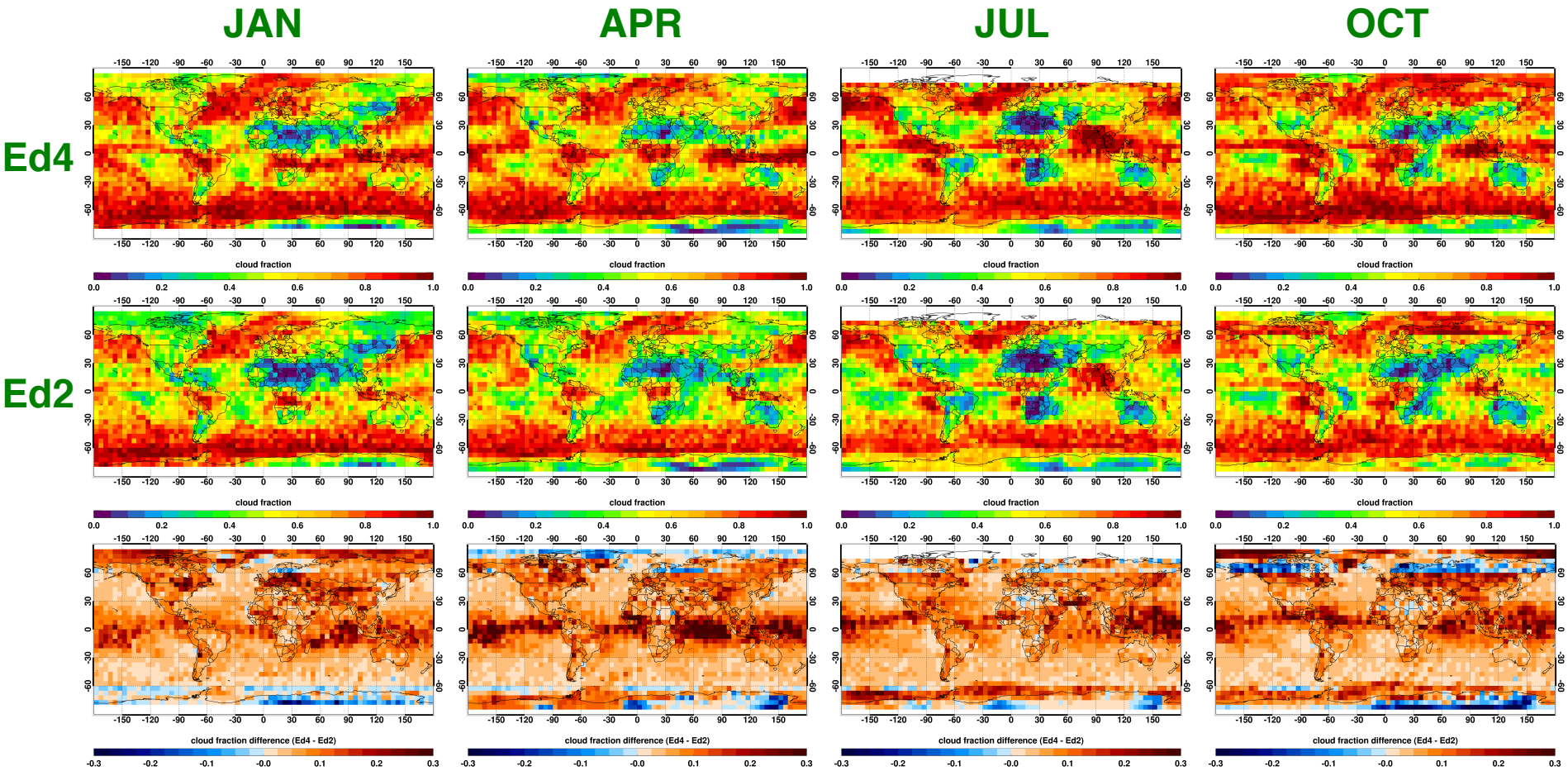
Ed4 – Ed2





Overall skill during daytime slightly better for Ed4 than Ed2

MODIS Ed4 – Ed2 Cloud Fraction
Nighttime

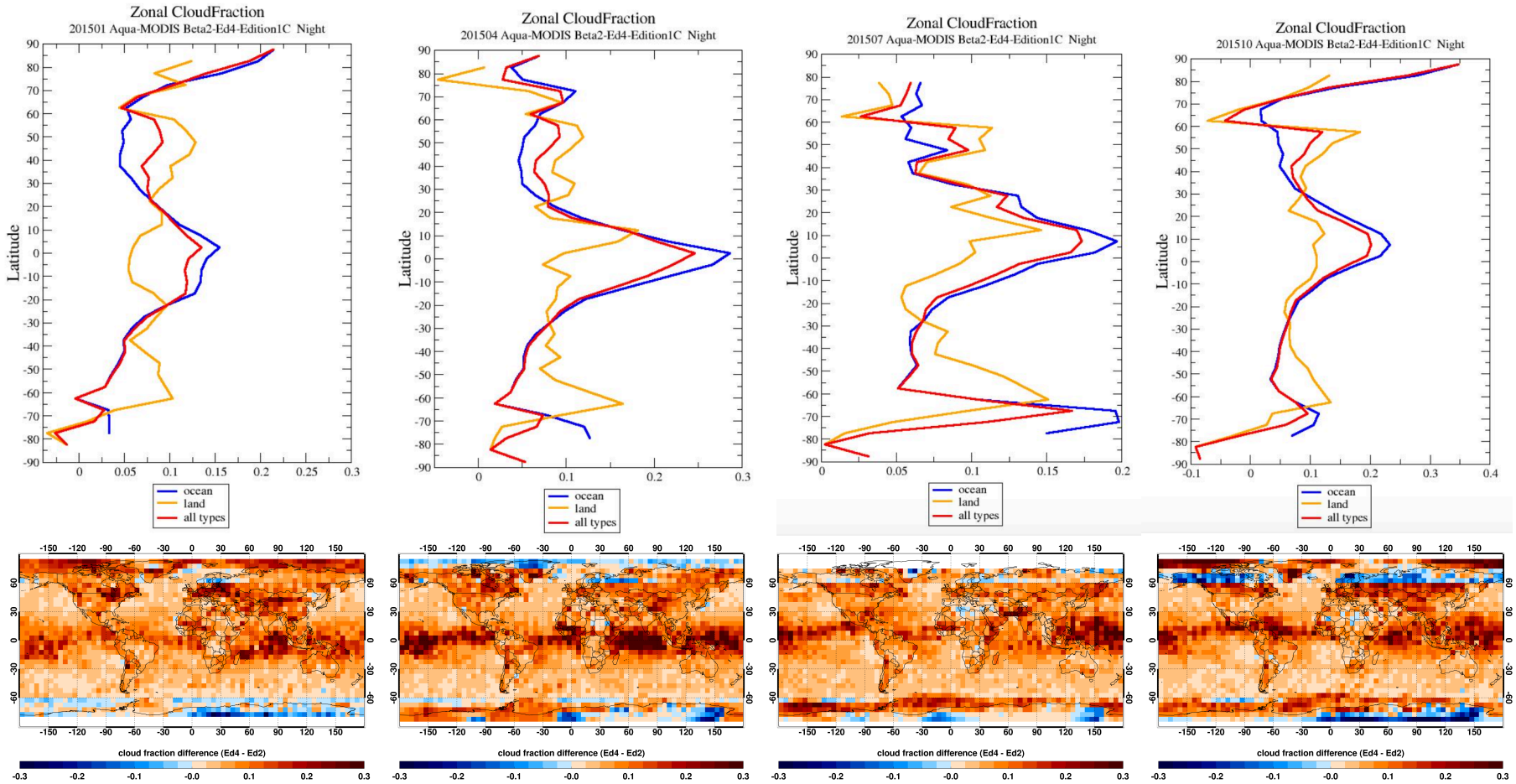


Daytime Ed4 cloud fraction 0.07 higher (global mean)

	Cloud Fraction	JAN	APR	JUL	OCT
Global means	Edition 4	0.657	0.631	0.646	0.688
	Edition 2	0.583	0.563	0.578	0.622

MODIS Ed4 – Ed2 Cloud Fraction Nighttime

JAN APR Jul OCT



Ed4 – Ed2

Daytime Ed4 cloud fraction 0.07 higher (global mean)

Global means

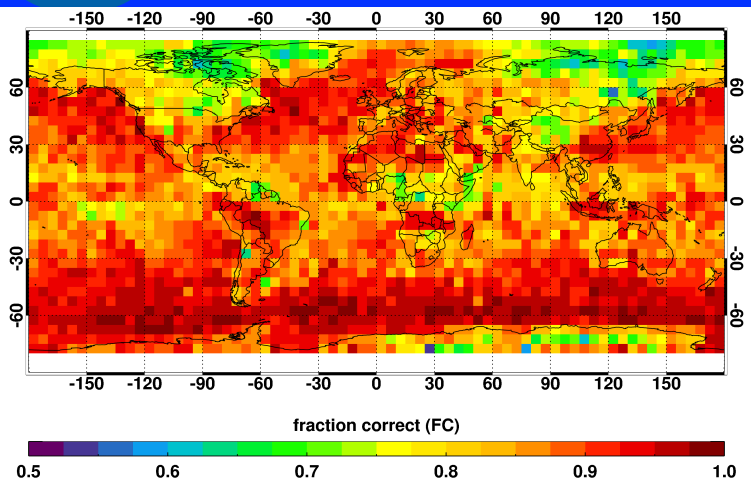
Cloud Fraction	JAN	APR	JUL	OCT
Edition 4	0.657	0.631	0.646	0.688
Edition 2	0.583	0.563	0.578	0.622

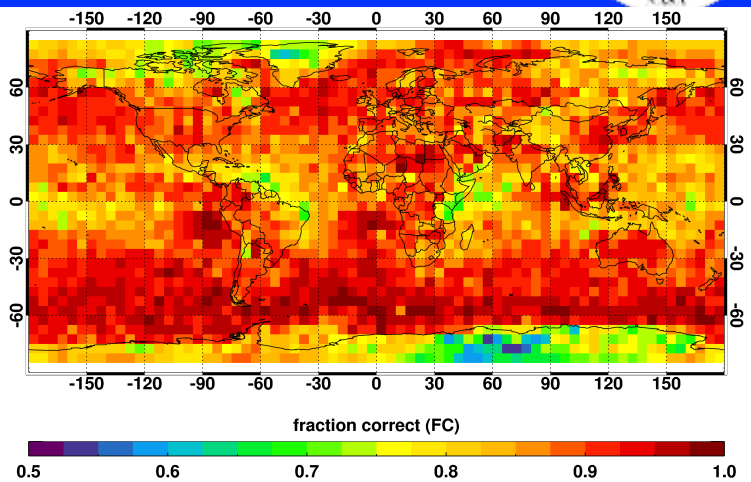
MODIS Ed4 – Ed2 Fraction Correct
Nighttime

JAN

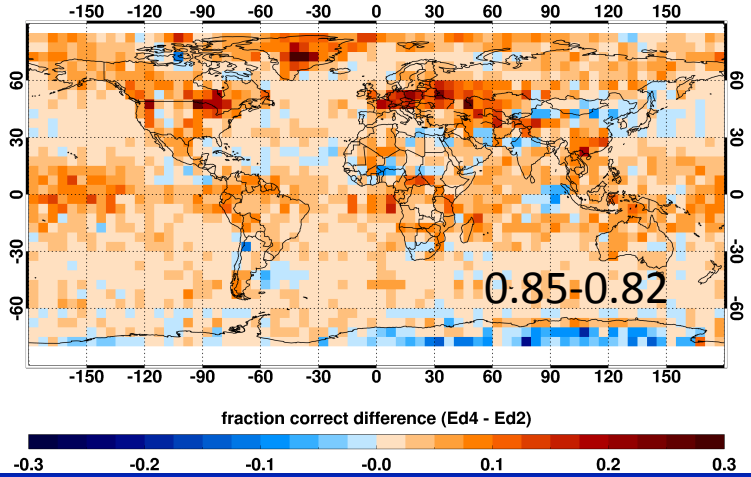
OCT

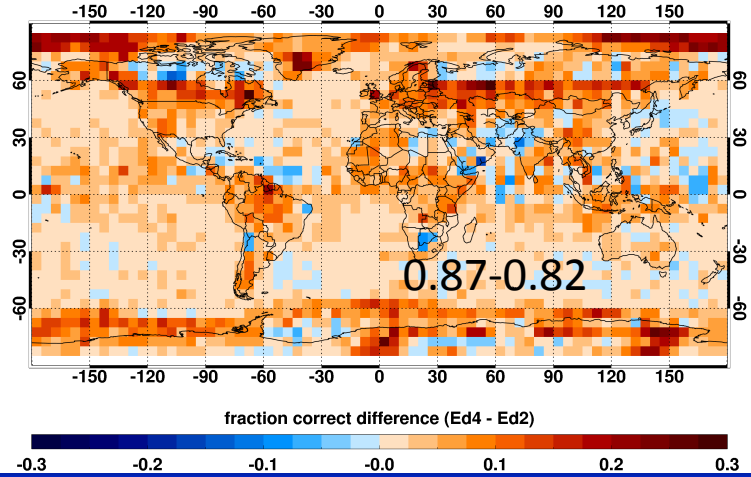
Ed4





Ed4 – Ed2





FC correct 3-5% higher than Ed2.

Significant increases over land, tropical and southern polar ocean

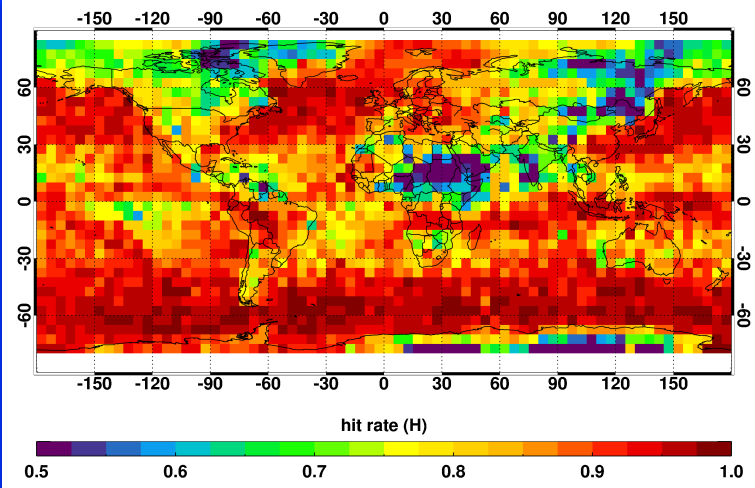
FC decreases over E Antarctica in Jan

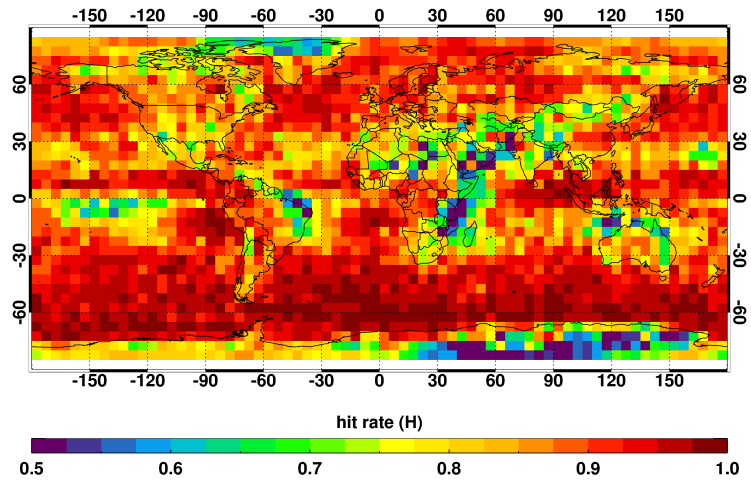
MODIS Ed4 – Ed2 Hit Rate
Nighttime

JAN

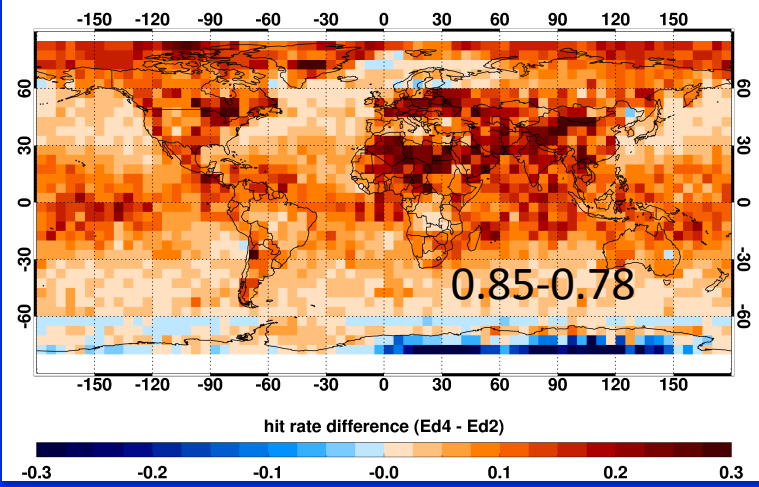
OCT

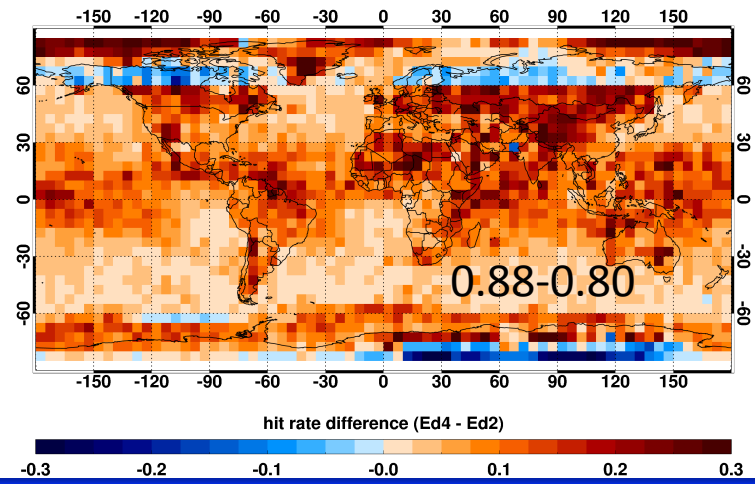
Ed4





Ed4 – Ed2





Hit rates increase 7-8% in Ed4, especially lower latitude oceans and land areas

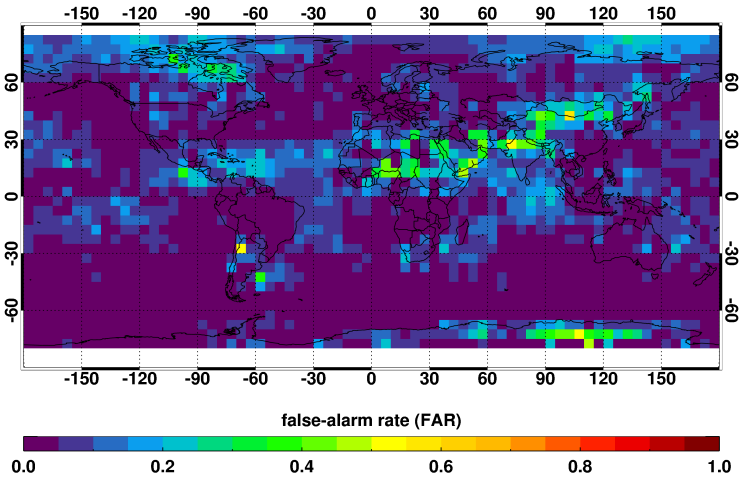
Nice improvement oerall in the Arctic

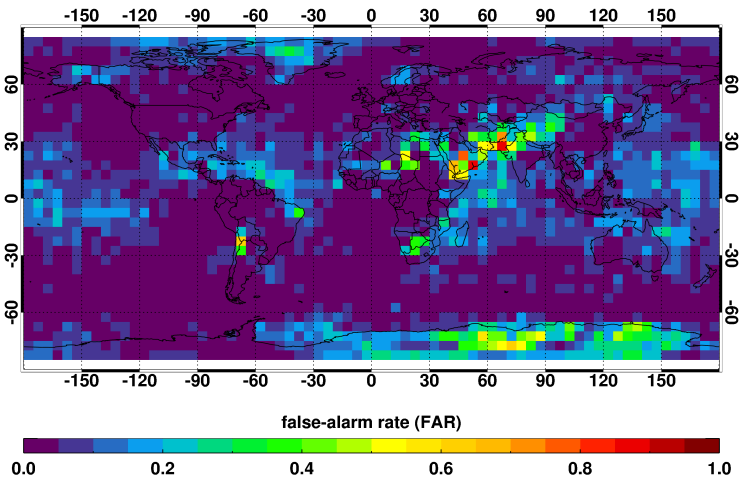
Lower hit rates E Antarctica

MODIS Ed4 – Ed2 False Alarm Rate
Nighttime

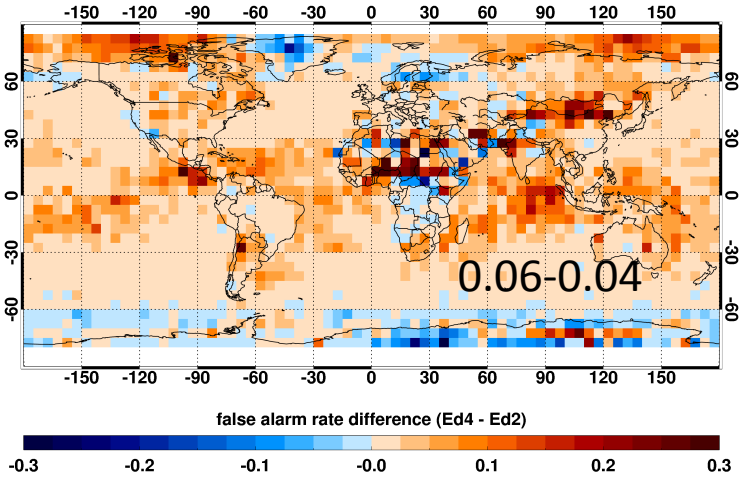
JAN | OCT

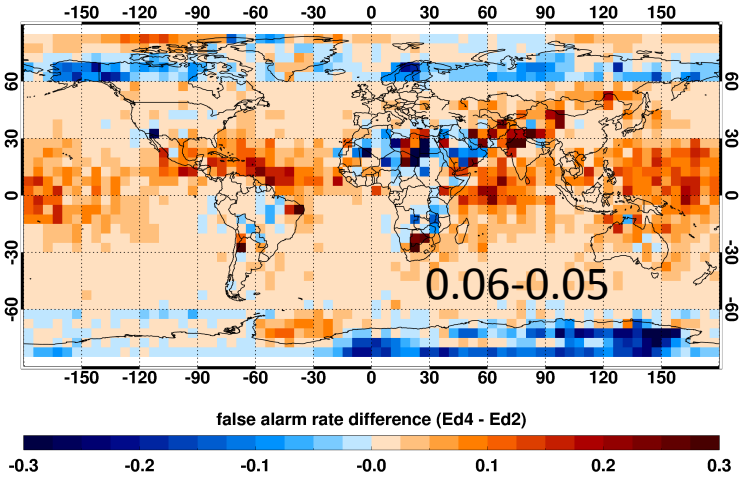
Ed4





Ed4 – Ed2





False Alarms similar overall

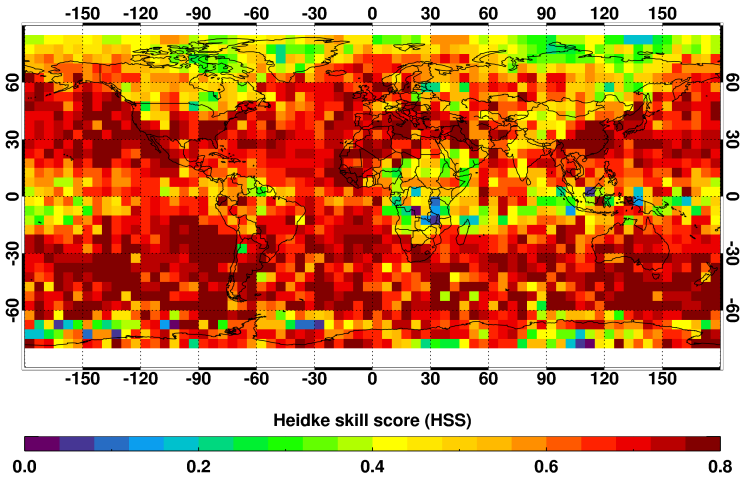
Reduction over E Antarctica, seasonal dependence over N.polar regions

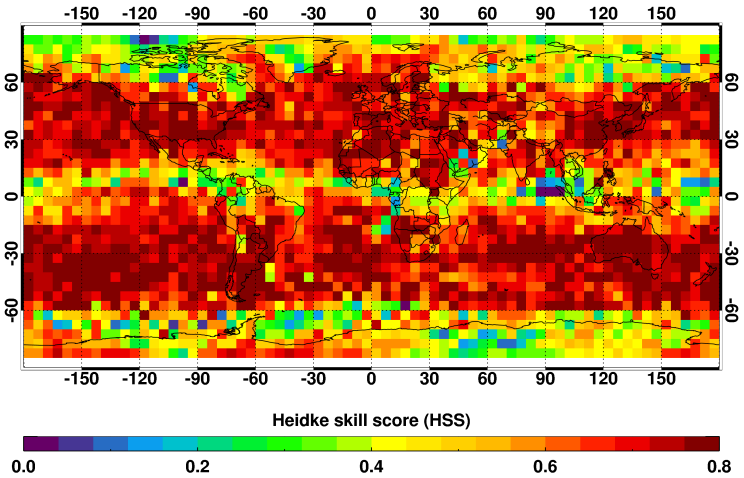
MODIS Ed4 – Ed2 Heidke Skill Score
Nighttime

JAN

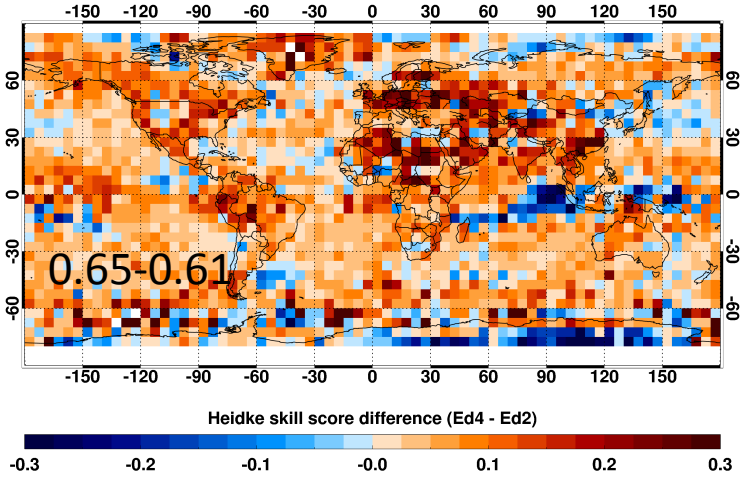
OCT

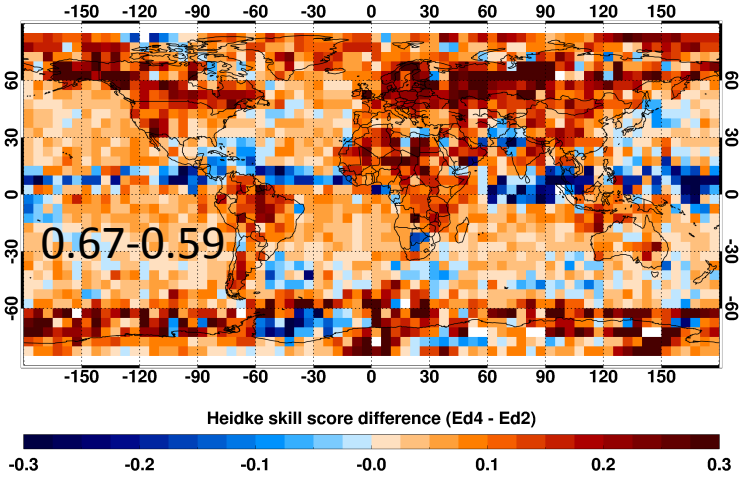
Ed4





Ed4 – Ed2

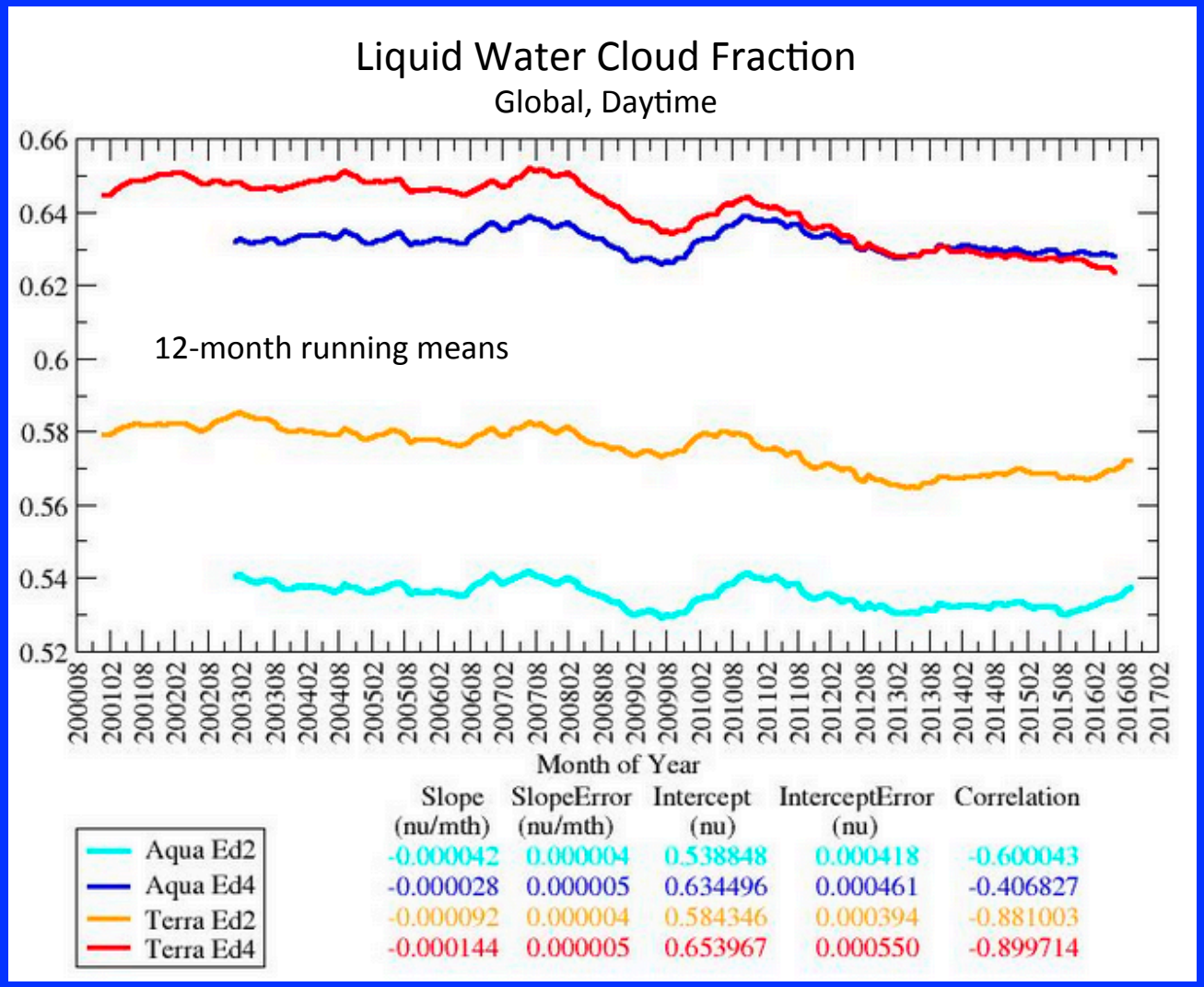




Much improved overall skill in Nighttime Ed4

Ed4 vs Ed2 Clouds

Cloud Phase



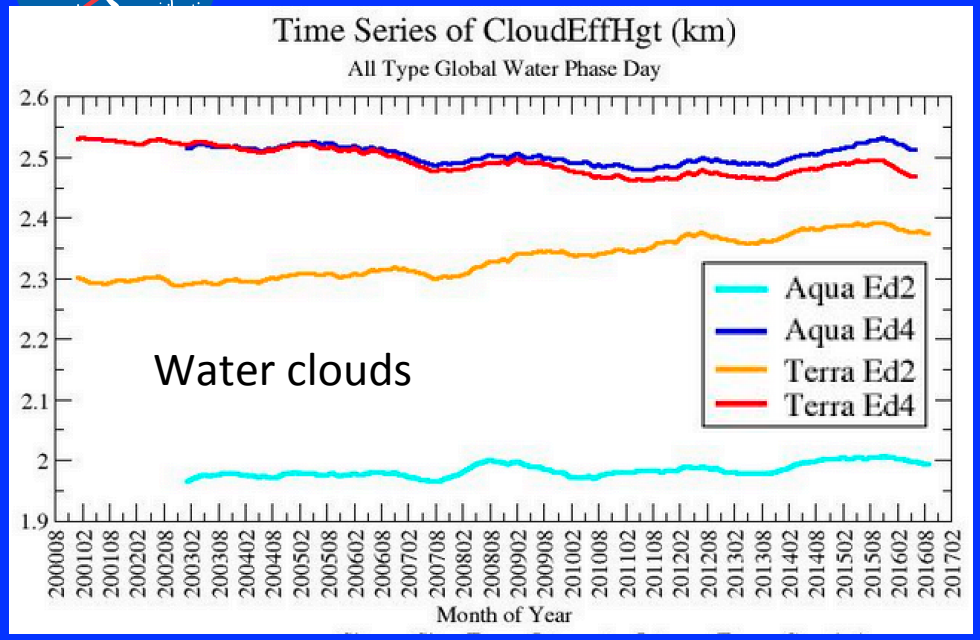
	Slope (nu/mth)	SlopeError (nu/mth)	Intercept (nu)	InterceptError (nu)	Correlation
Aqua Ed2	-0.000042	0.000004	0.538848	0.000418	-0.600043
Aqua Ed4	-0.000028	0.000005	0.634496	0.000461	-0.406827
Terra Ed2	-0.000092	0.000004	0.584346	0.000394	-0.881003
Terra Ed4	-0.000144	0.000005	0.653967	0.000550	-0.899714

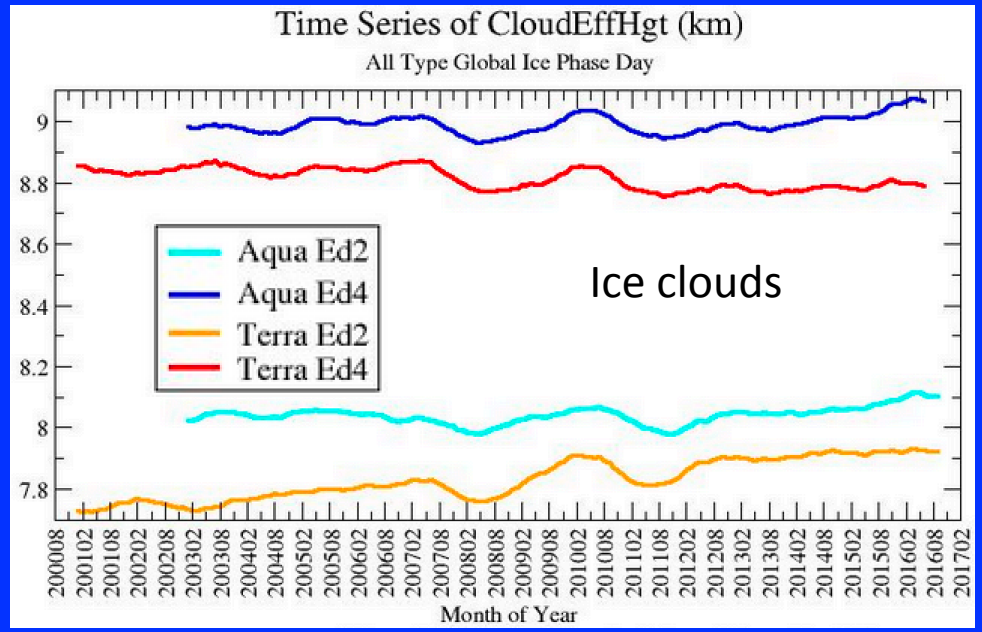
Increased water clouds (Too much SLW identified as ice in Ed2)

Improved consistency between Terra and Aqua

Ed4 vs Ed2 Clouds

Cloud Top Height





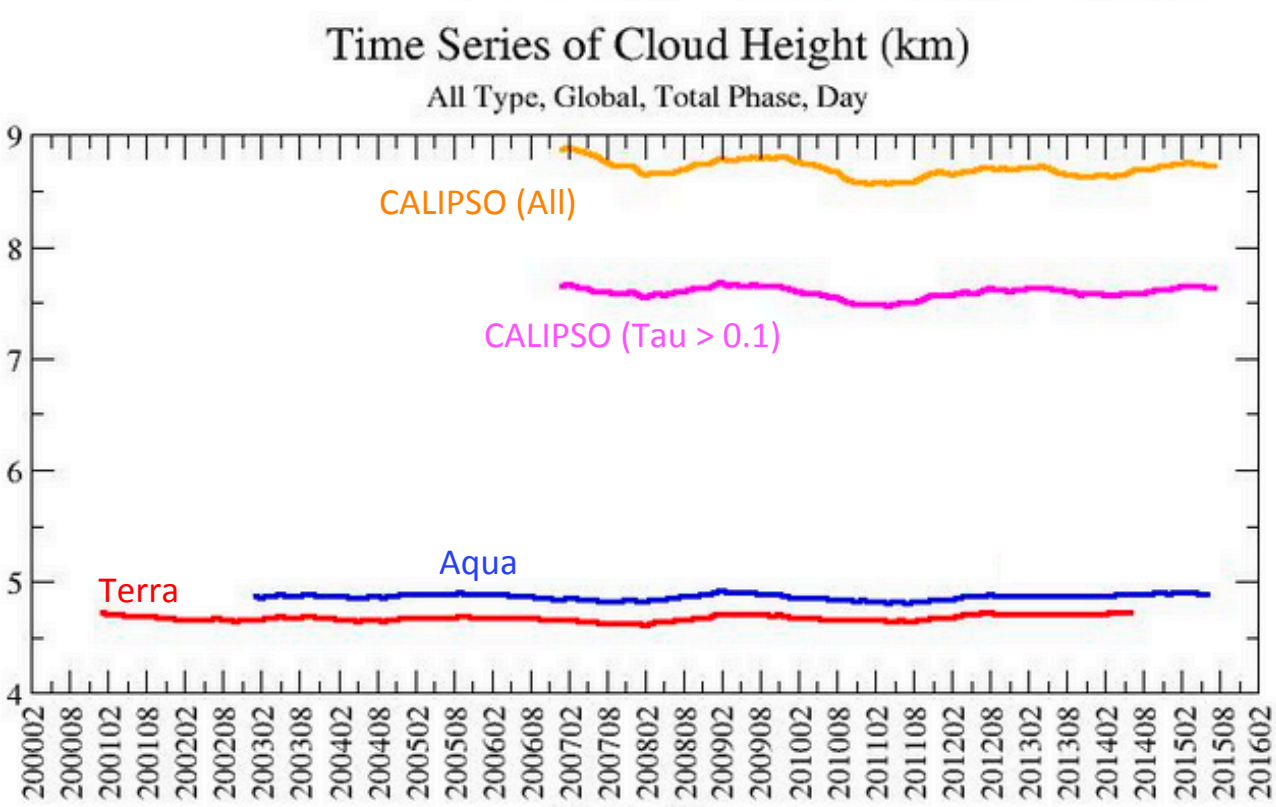
CTH's increase (closer to CALIOP)

Water cloud heights more consistent between Terra and Aqua

Ed4-Ed2 differences due to different inputs for part of record and algorithm differences as noted earlier (e.g. regional lapse rates, etc)

Ed4 vs Ed2 Clouds

Cloud Top Height

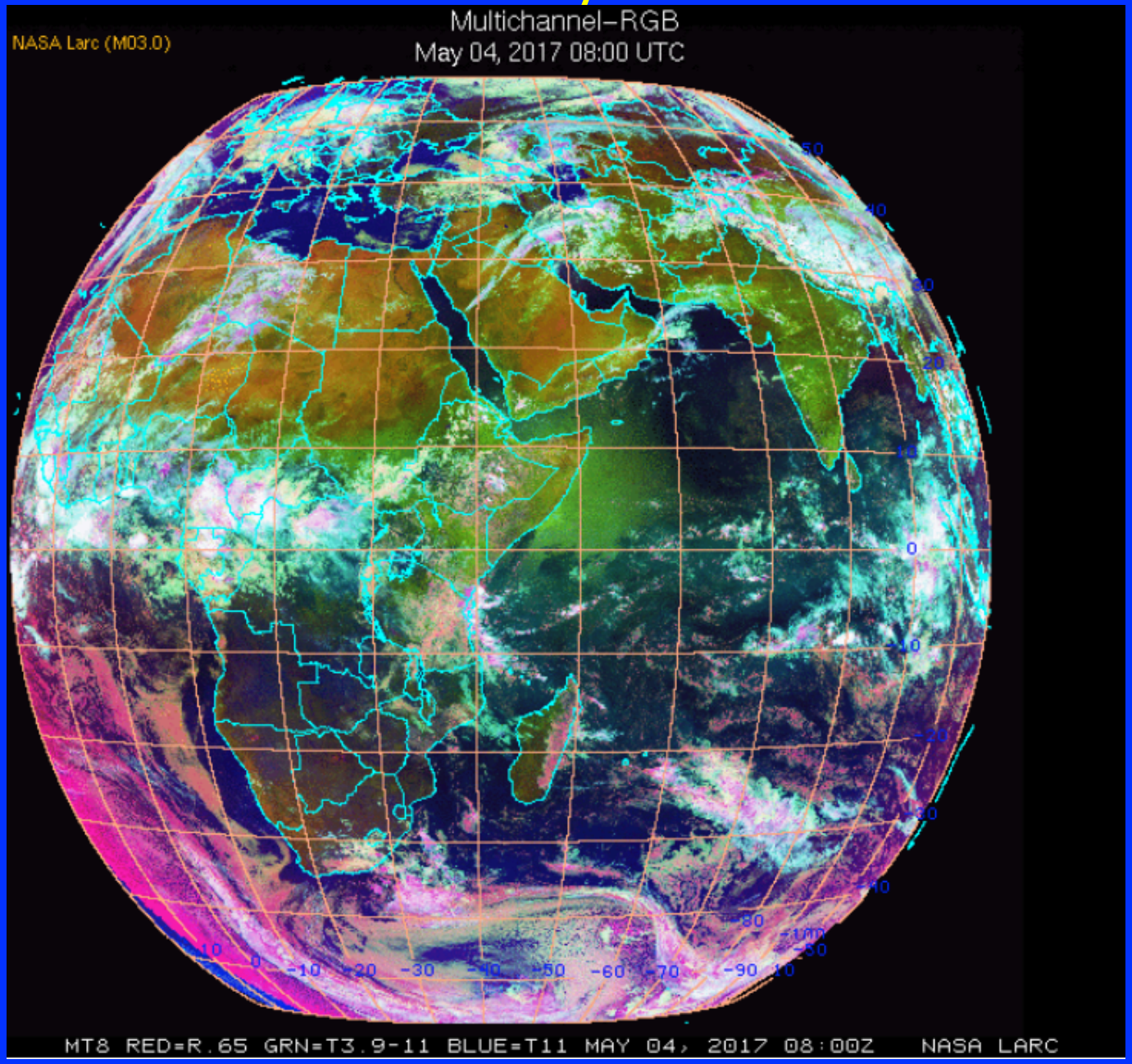


	Slope (km/mth)	SlopeError (km/mth)	Intercept (km)	InterceptError (km)	Correlation
AquaEffHgt	0.000011	0.000047	4.867630	0.004008	0.020261
TerraEffHgt	0.000166	0.000041	4.664776	0.003819	0.305332
NPPEffHgt	0.000470	0.000088	5.085880	0.001492	0.708812
ClayAllTauAllRes	-0.000937	0.000223	8.754184	0.013189	-0.385052
ClayGT01TauAllRes	-0.000076	0.000162	7.600684	0.009534	-0.046549

Ed-4 Aqua and Terra CTH lower than CALIPSO but higher than Ed-3 which implies that Ed4 ismore accurate

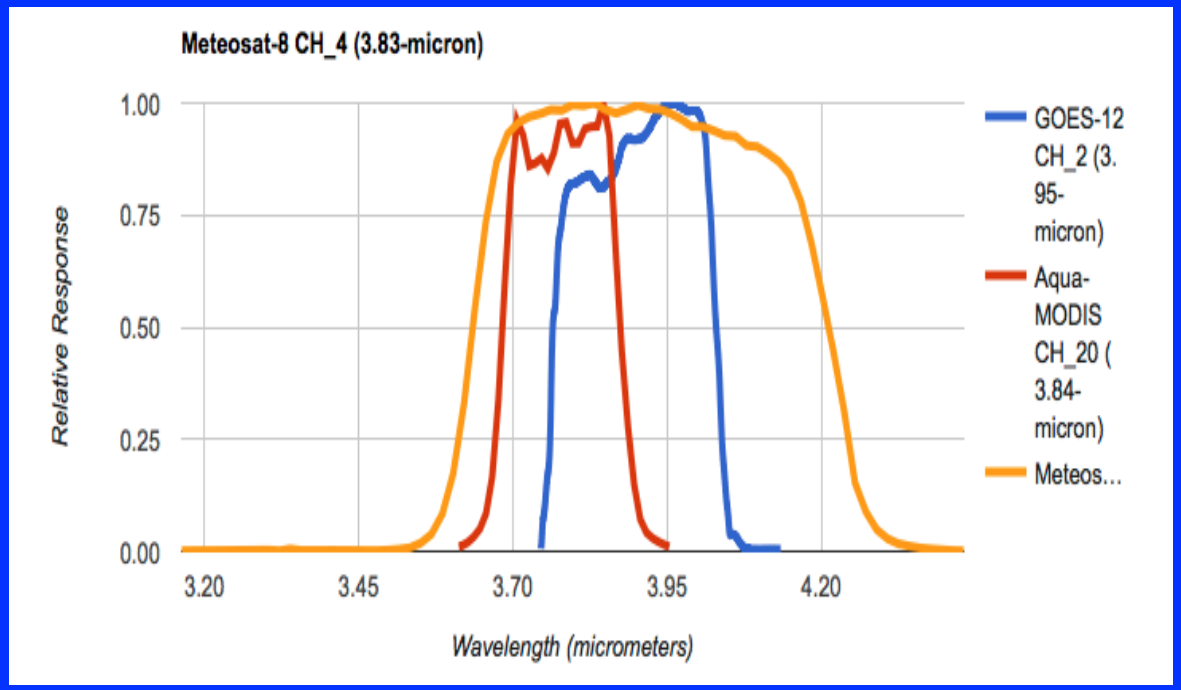
GEO UPDATE

Met-8 recently moved - Indian Ocean



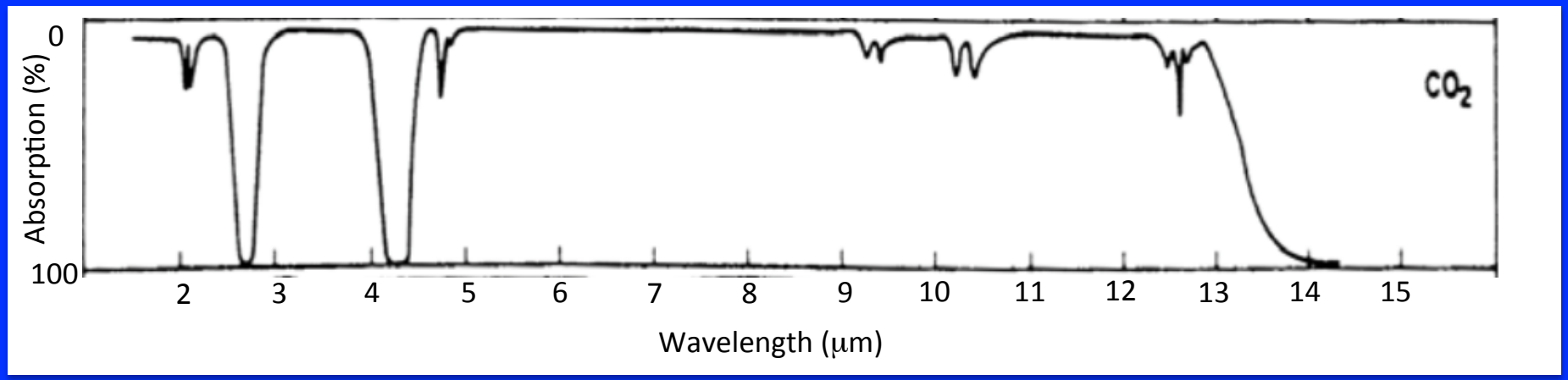
2nd gen
SEVIRI
Imager

MSG SEVIRI 3.9 μm Band



SEVIRI SRF well into 4.3 um CO2 absorption band

For 300 K scene, the BT depression due to CO2 absorption is 5 K!



Met-8 Cloud Mask Improvements and Challenges

Challenges:

- Major CO2 absorption band in MSG 3.9 μm channel. Cloud mask not employing theoretical atmospheric correction (cross-calibrated with GOES-12). Significant tuning to cloud mask needed in order to use existing clear sky maps.
- Met-8 regions are very inhomogeneous, including deserts, land, ocean and narrow seas. The 1-deg resolution clear sky maps introduced chunky cloud mask results along coasts.

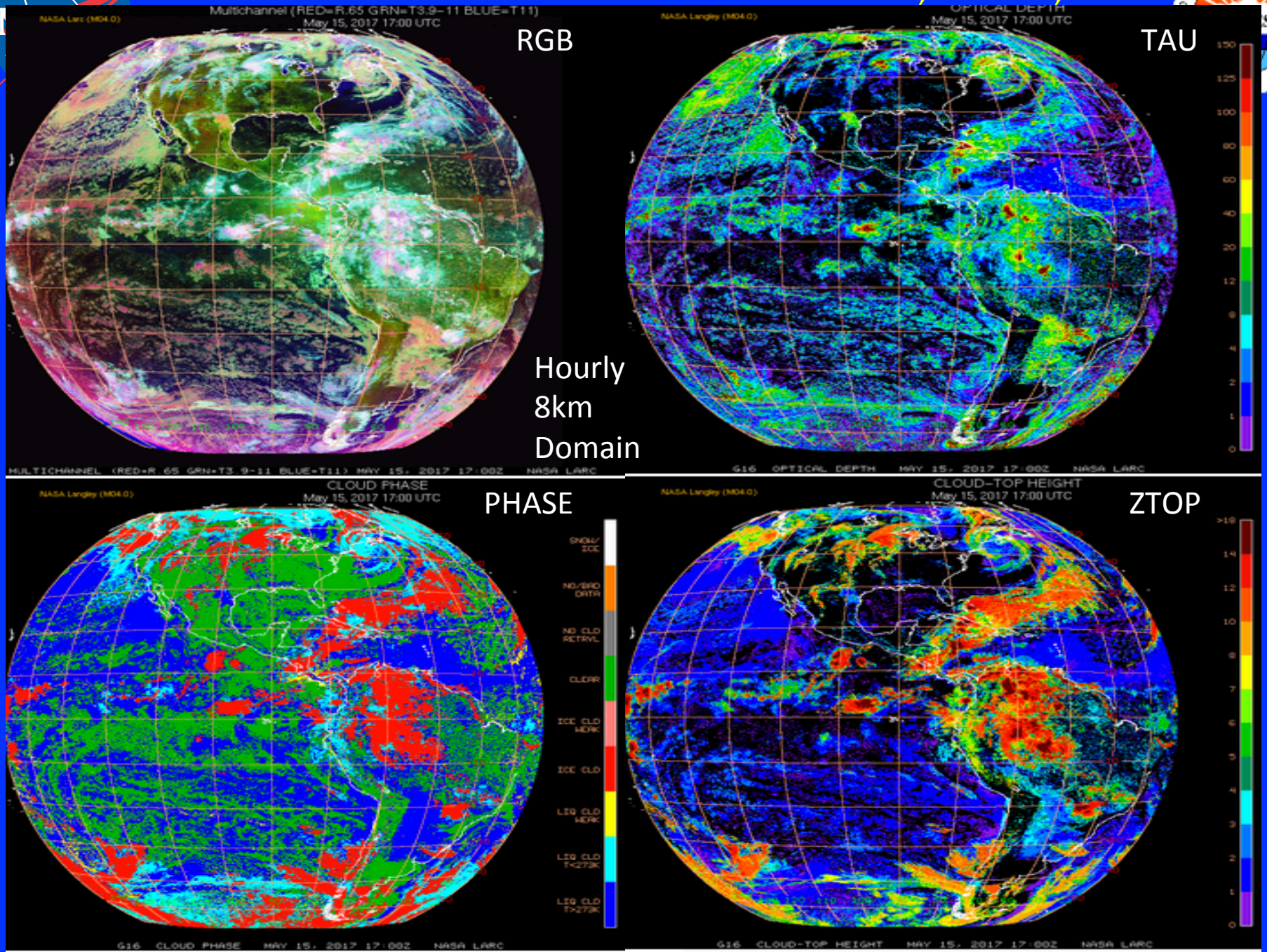
Improvements:

- Detected more daytime low clouds over ocean
- Increased nighttime tropical ocean thin Cirrus and low clouds detection.
- Increased thin Cirrus detection over nighttime desert

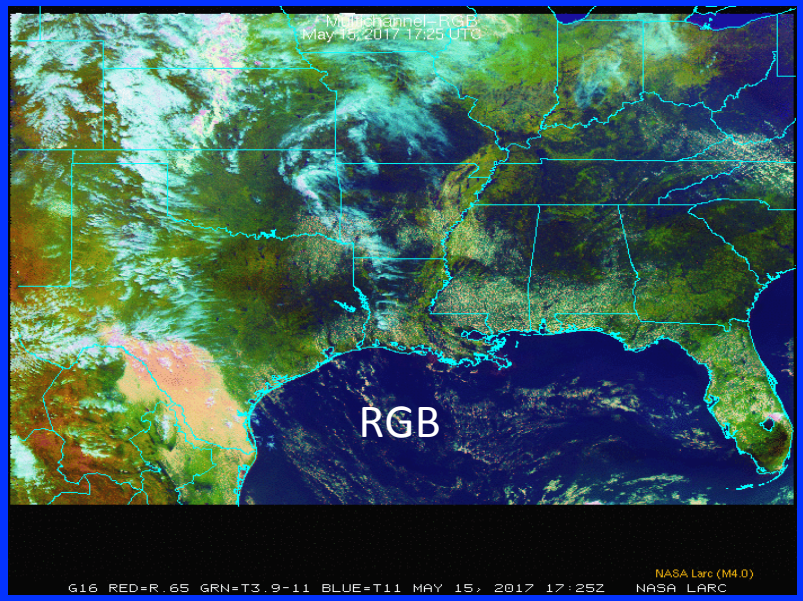
Met-8 results reasonably consistent with Met-10

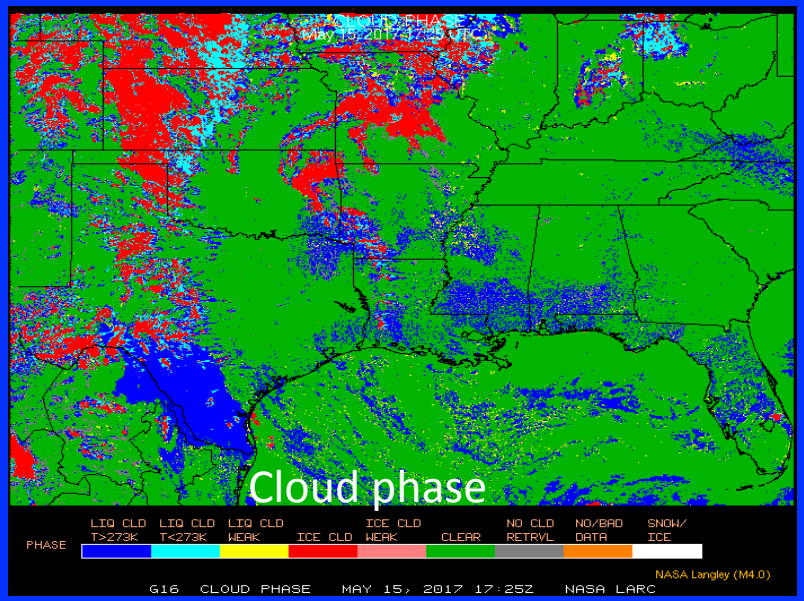
Ready to deliver Met-8 cloud code but not stopping work until we get a hard deadline

GOES-16 SATCORPS CLOUD PRODUCT 17:00 UTC, MAY 15, 2017

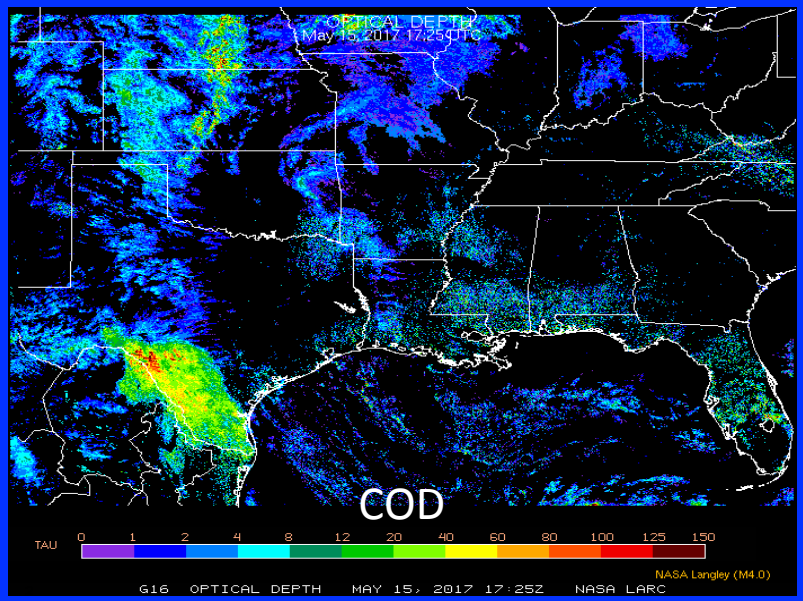


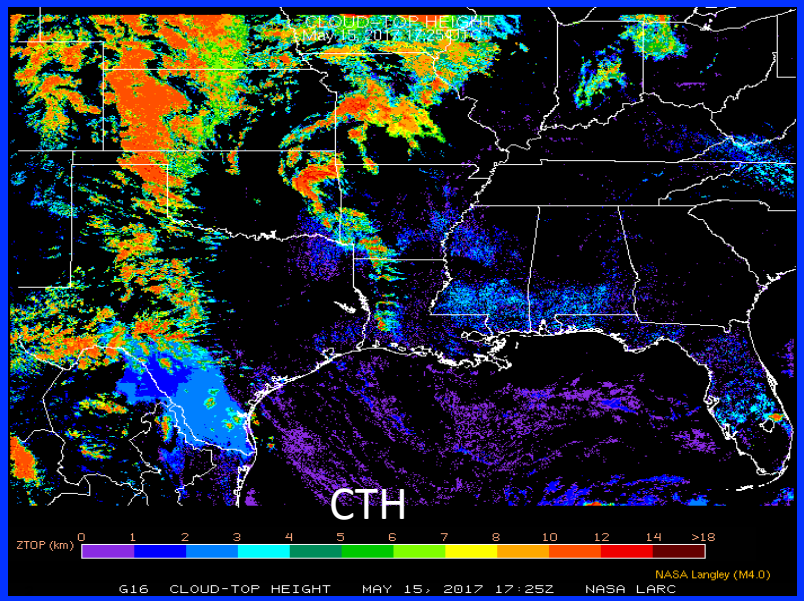
GOES-16 SATCORPS CLOUD PRODUCT 17:25 UTC, MAY 15, 2017





15-min 4-km Domain for NSSL Severe weather forecasting experiment





Initial results with AHI cloud code look good. Some nominal calibration problems

CERES ERB Diurnally Complete

GEO data critical – make up 85% of SYN1 clouds

- SYN1 TOA Flux calculation too cold and bright
- Suggests cloud fractions are too high

GEO vs MODIS Cloud Fraction

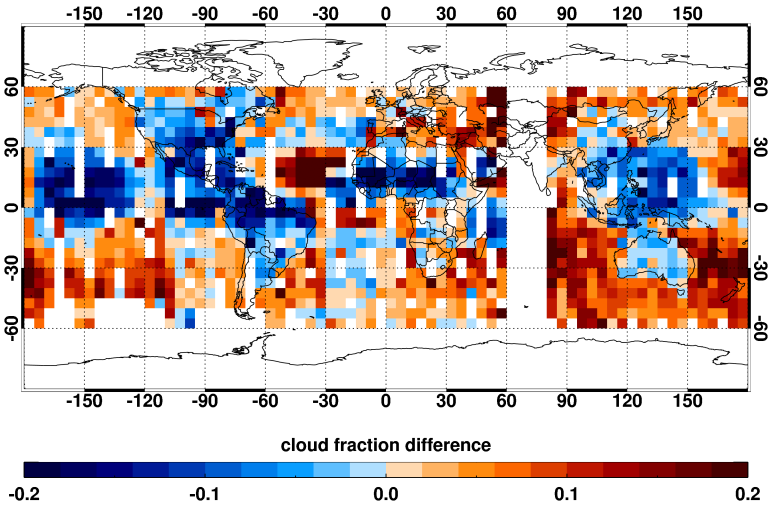
Differences relative to CALIPSO

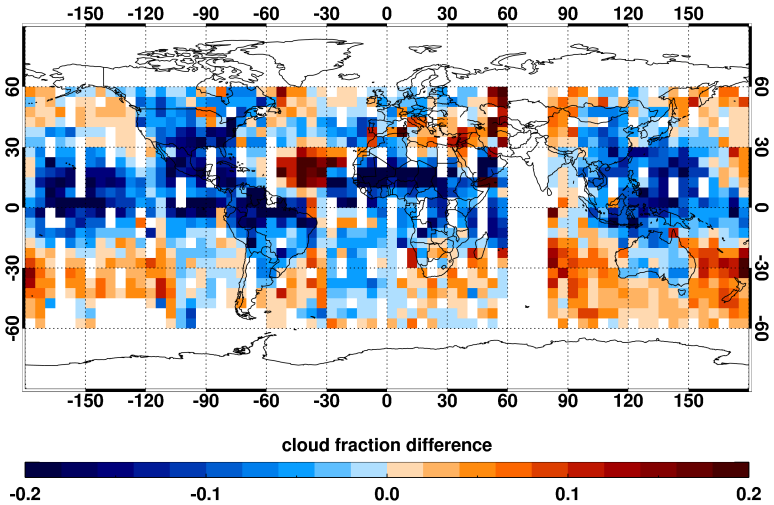
July 2010-2016
Daytime

Includes PC CALIPSO, No 80-km

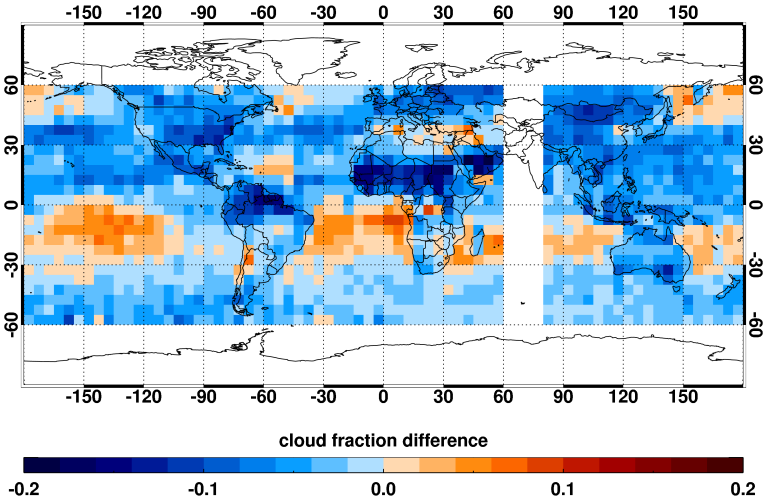
OVC CALIPSO, No 80-km

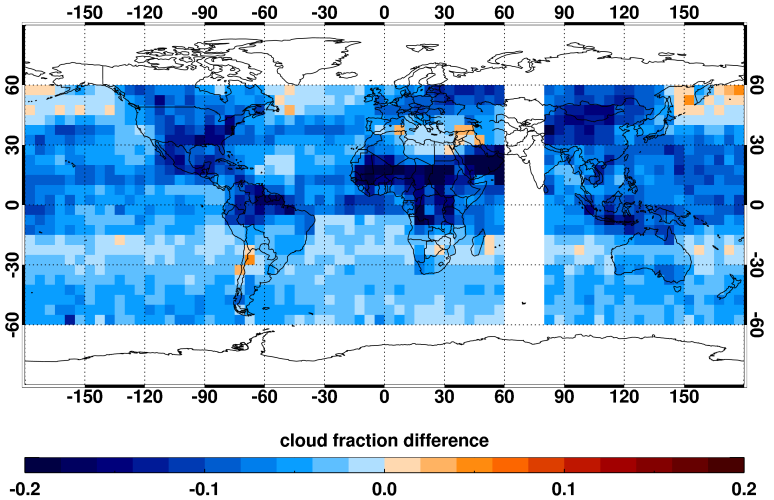
GEO minus CALIPSO





MODIS minus CALIPSO





GEO vs MODIS Cloud Fraction

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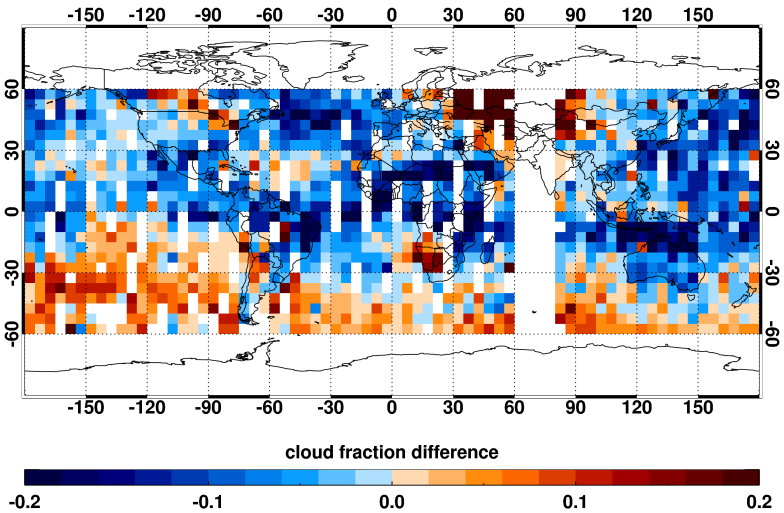
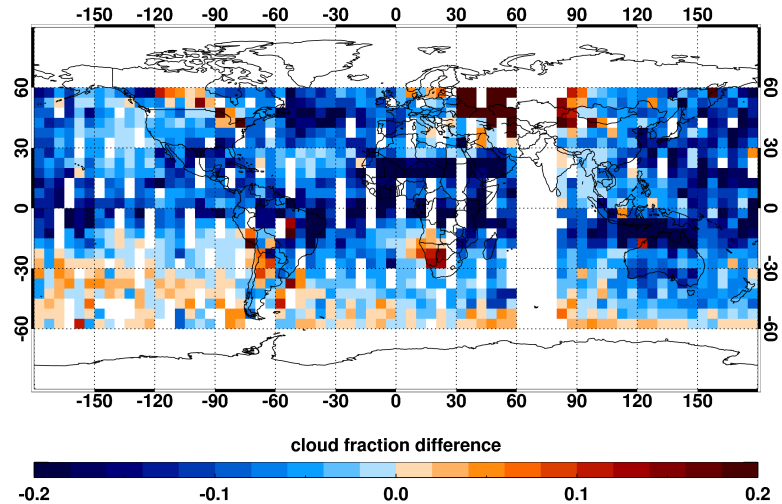
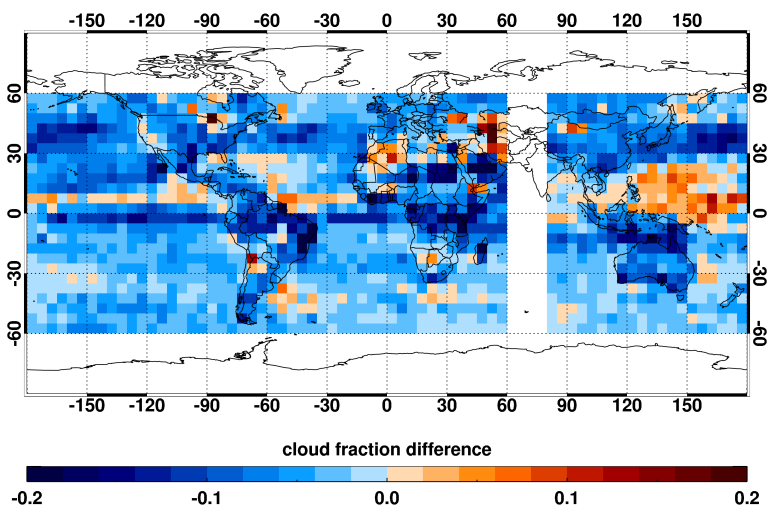
OVC CALIPSO, No 80-km

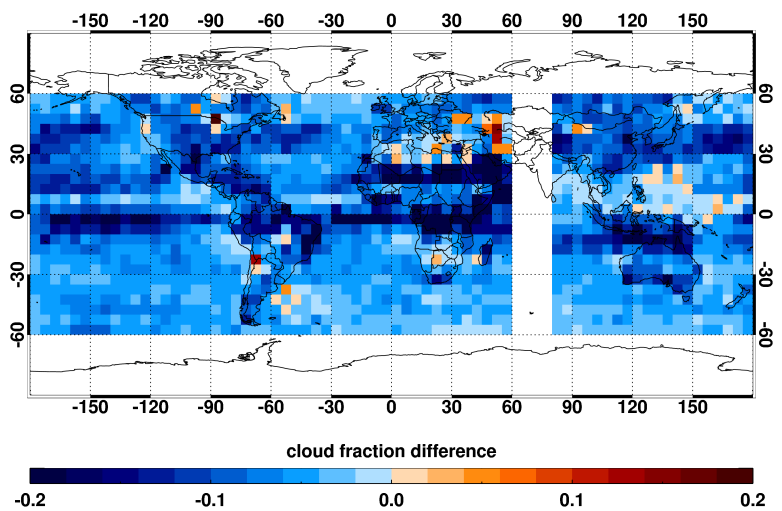
GEO minus CALIPSO

MODIS minus CALIPSO









GEO vs MODIS Ed4 Cloud Fraction

Differences relative to CALIPSO

Performance metrics July 2011-2016

Day

Satellite	FC	HR	FAR	HSS
GEO	0.84	0.88	0.13	0.65
MODIS	0.89	0.89	0.07	0.75

Night

Satellite	FC	HR	FAR	HSS
GEO	0.84	0.86	0.09	0.65
MODIS	0.88	0.89	0.05	0.73

Ed5 Ongoing Activities

- Use latest MODIS collection and next-generation GMAO reanalysis system.
- Cloud mask improvements
- Implement the new two-habit ice crystal models, to improve thin cirrus retrievals
- Update water droplet models
- Implement new nighttime thick ice cloud optical depth retrieval method
- Improve neural network multilayer detection
- Develop cloud property retrieval algorithm using neural network for top layer clouds.
- Use radiative transfer models to retrieval cloud properties for lower layer clouds
- Update and implement the new emittance parameterizations
- Clean up bugs in Ed4
- Improve cloud retrievals over snow
    - variable-band retrieval method
    - Use 1.24 um two-habit ice crystal models
- Develop revised clear-sky code to incorporate variable aerosol loading
- Re-write old Fortran code to improve efficiency and documentation

Ed5 Ongoing Activities

- Revise VIIRS code for future edition to make consistent with Ed5

  Merge and test CrIS (WV & CO2 broadband) with VIIRS to improve consistency and accuracy in MODIS & VIIRS retrieval algorithms.

  Need method to deal with high VZA VIIRS areas unsampled by CrIS

  Convert VIIRS code to X86 from P6

- Revise GEO code for future editions to:

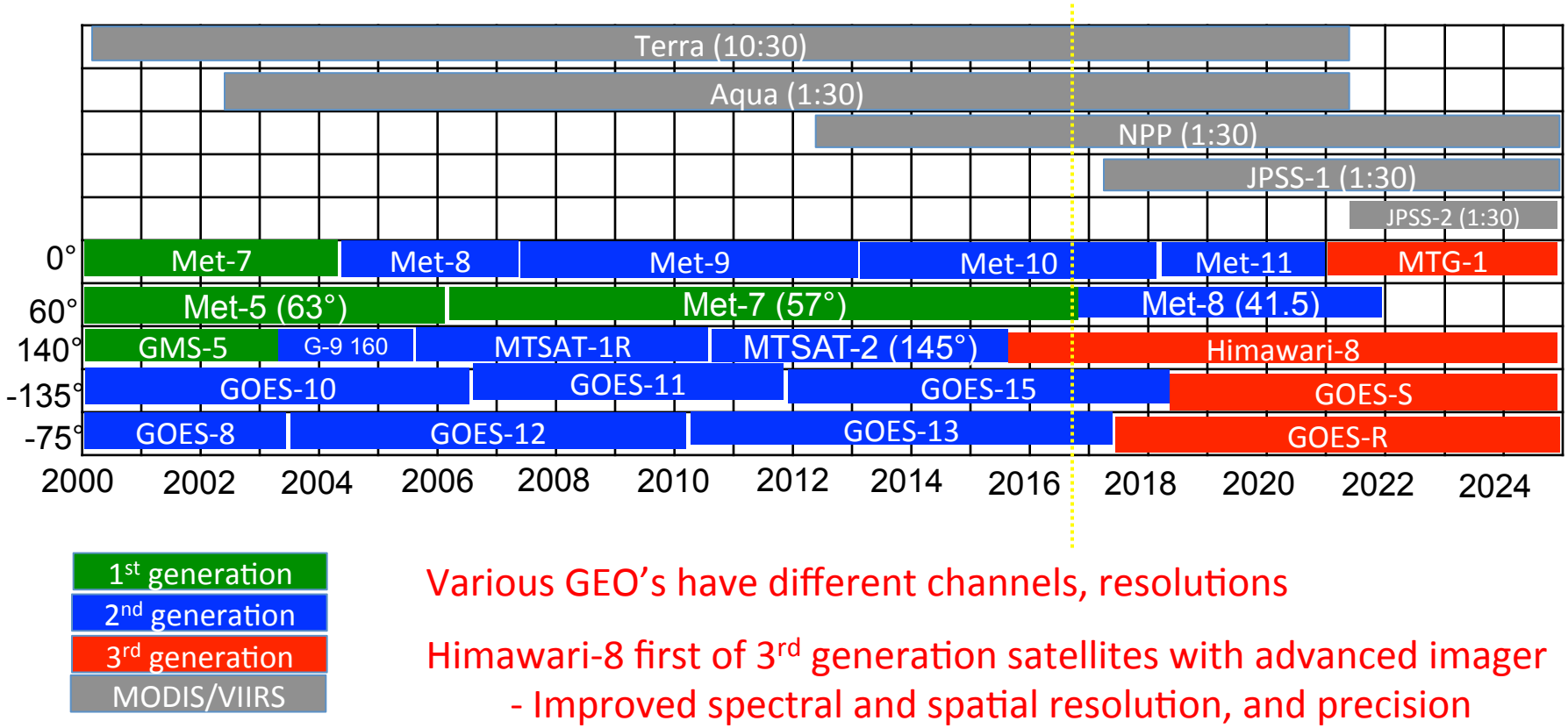
  - Employ imager-specific, spectral cloud reflectance and emittance models
  - Update calibrations and clear-sky maps for all channels
  - Improved atmospheric corrections
  - Test and implement new nighttime and multi-layer cloud algorithms
  - Perform validations
  - Improve consistency with MODIS/VIIRS

- Revise and publish submitted papers and submit additional papers on VIIRS and GEOs

- Complete Ed4 GEOsat processing through 2016 (on Science Computing Facility-SCF).

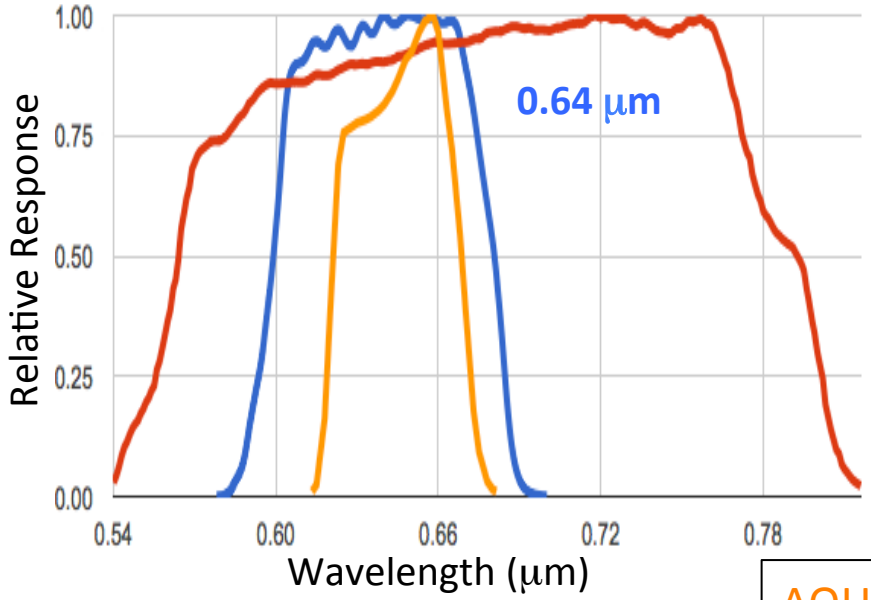
SPARES

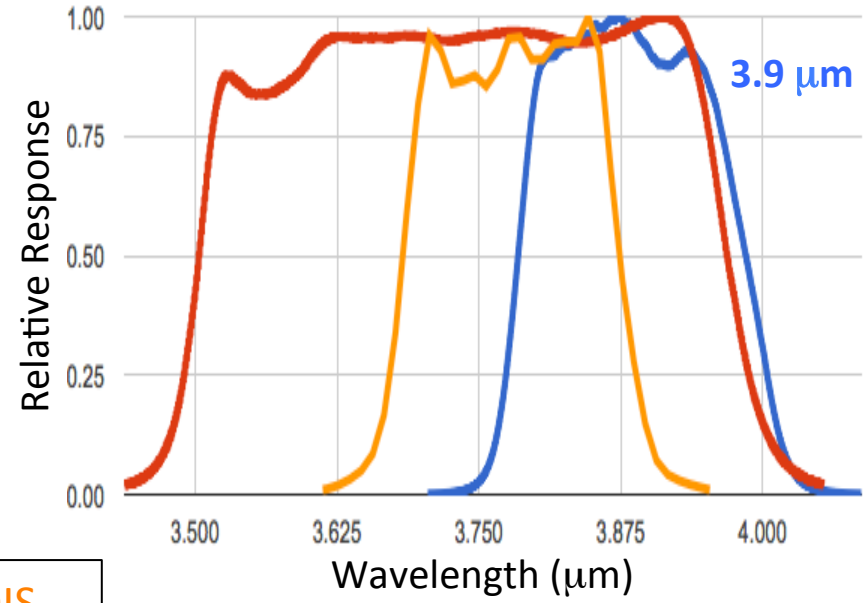
CERES record Geostationary Time Series



Various GEO's have different channels, resolutions

Himawari-8 first of 3rd generation satellites with advanced imager
- Improved spectral and spatial resolution, and precision

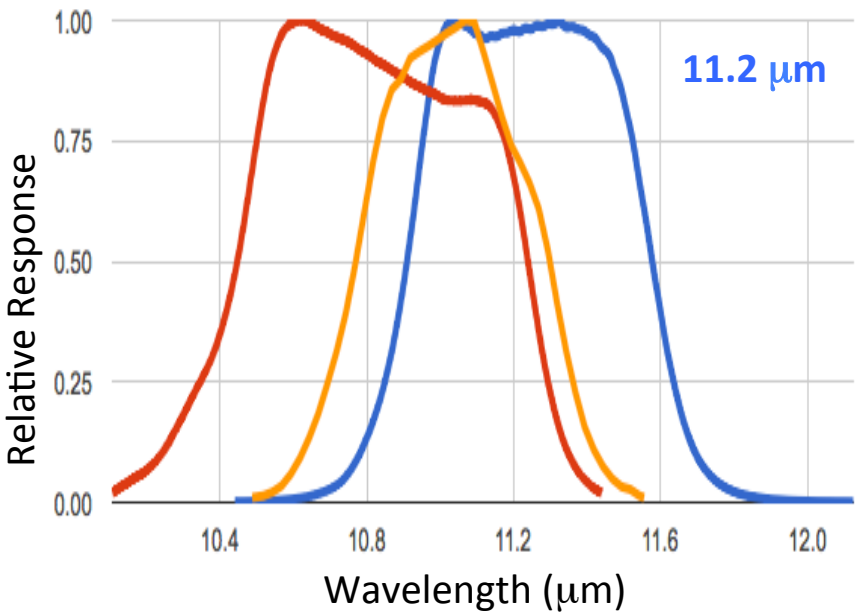


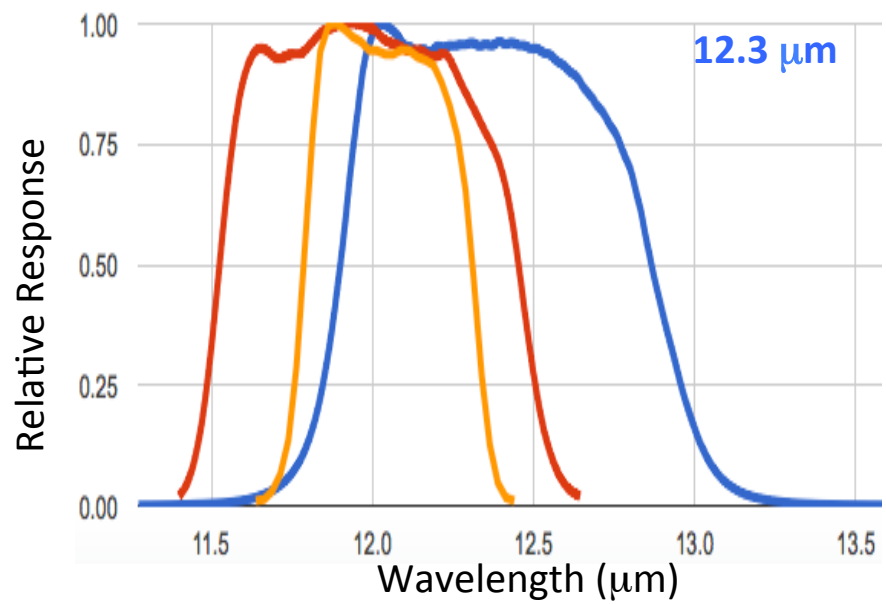


Original Himawari cloud analyses treated radiances like MTSAT

AQUA-MODIS
MTSAT
Himawari

New version incorporates Himawari specific SRF's in transmittance and emittance models





CrIS WV/CO2 Channel Merge with VIIRS

CrIS to VIIRS mapping package:

Completed:

- Used CERES-subsetted resolution VIIRS (netCDF4 product VNP0203IMD)
- Required two NOAA CrIS products: GCRSO_npp (Geolocation) and SCRIS_npp (SDR).
- Merged CrIS to VIIRS for channels: 6.7, 7.3, 13.3, 13.6, 13.9, 14.2 um
- Appended above 6 merged channels to the same VIIRS product: VNP0203IMD

Future:

- Bring the merged channels to CERES clouds production code with VNP0203IMD, including the 6 merged CrIS channels, as input.
- Check and calibrate the merged channels with corresponding MODIS channels.
- Test and validate CO2 retrieval with the merged CO2 channels
- Test and validate Neural Network Multilayer retrieval with water vapor channel
- Test and validate Neural Network Thick Optical Depth retrieval with water vapor channel
- Bring water vapor channel to cloud detection, especially over polar regions during night time.

Challenges:

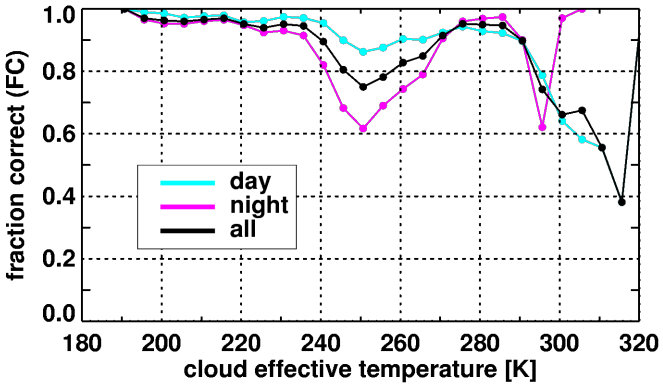
- CrIS does not cover full VIIRS swath width —- covering about 1800 km out of 2400 km VIIRS swath with about 300 km un-covered on each side of the swath.
- CrIS resolution is 19 x VIIRS

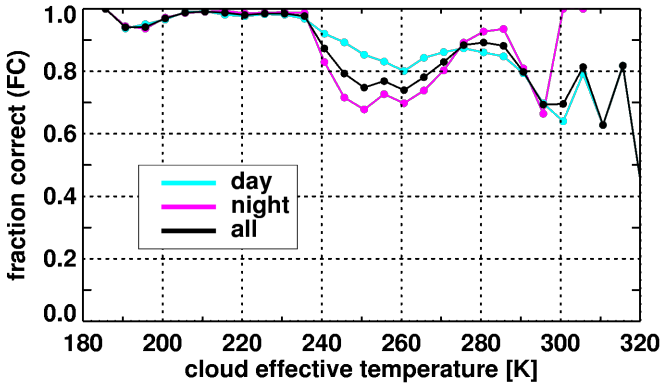
cloud phase

fraction correct as function of cloud effective temperature

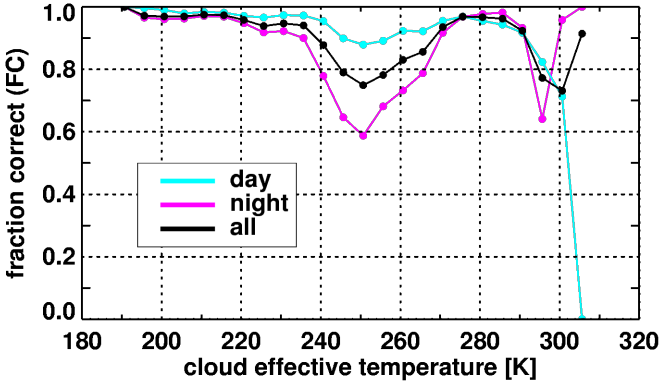
MODIS | **Him-8**

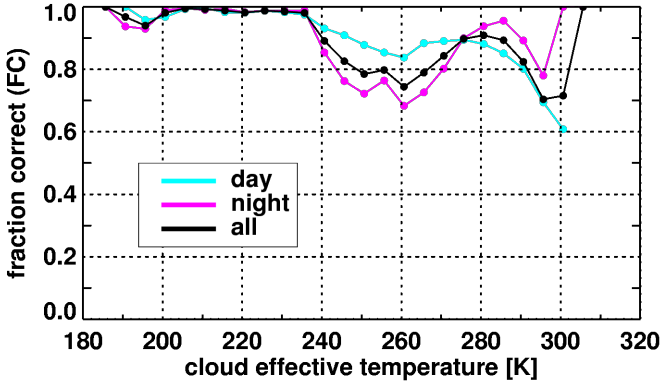
Full-disk, snow/ice free



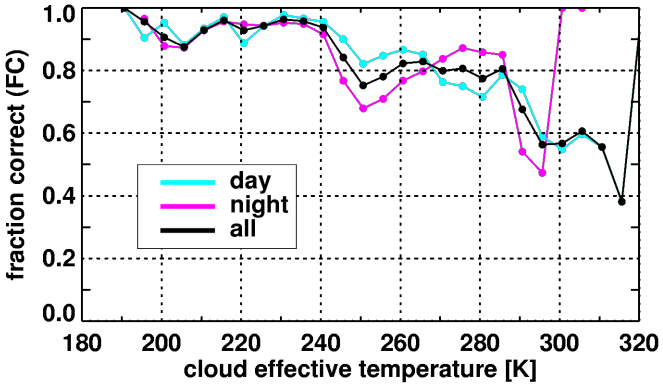


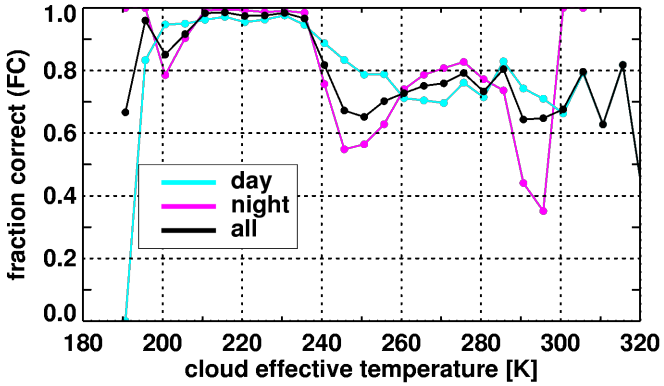
Full-disk, snow/ice free, ocean



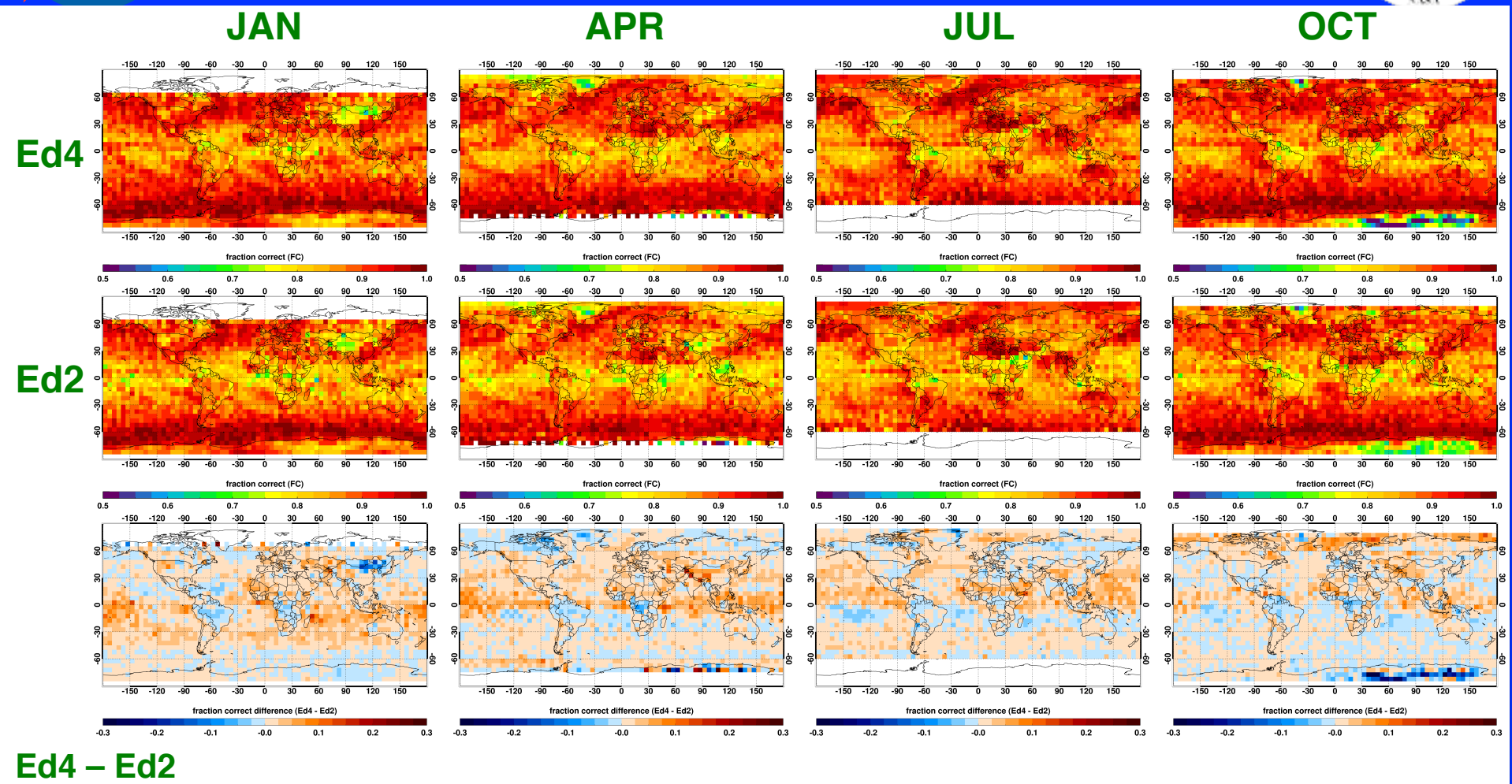


Full-disk, snow/ice free, land



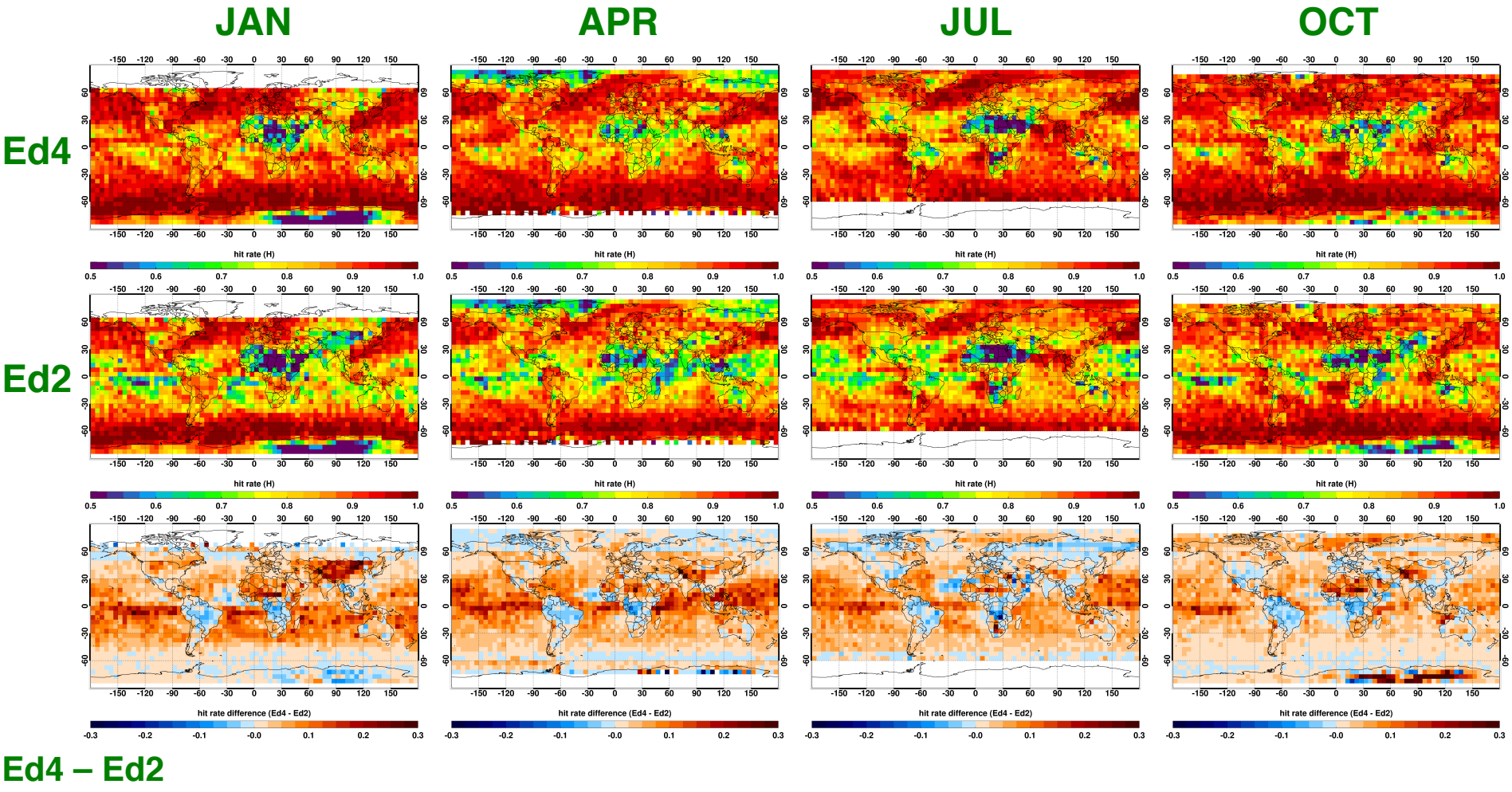


MODIS Ed4 – Ed2 Fraction Correct
Daytime



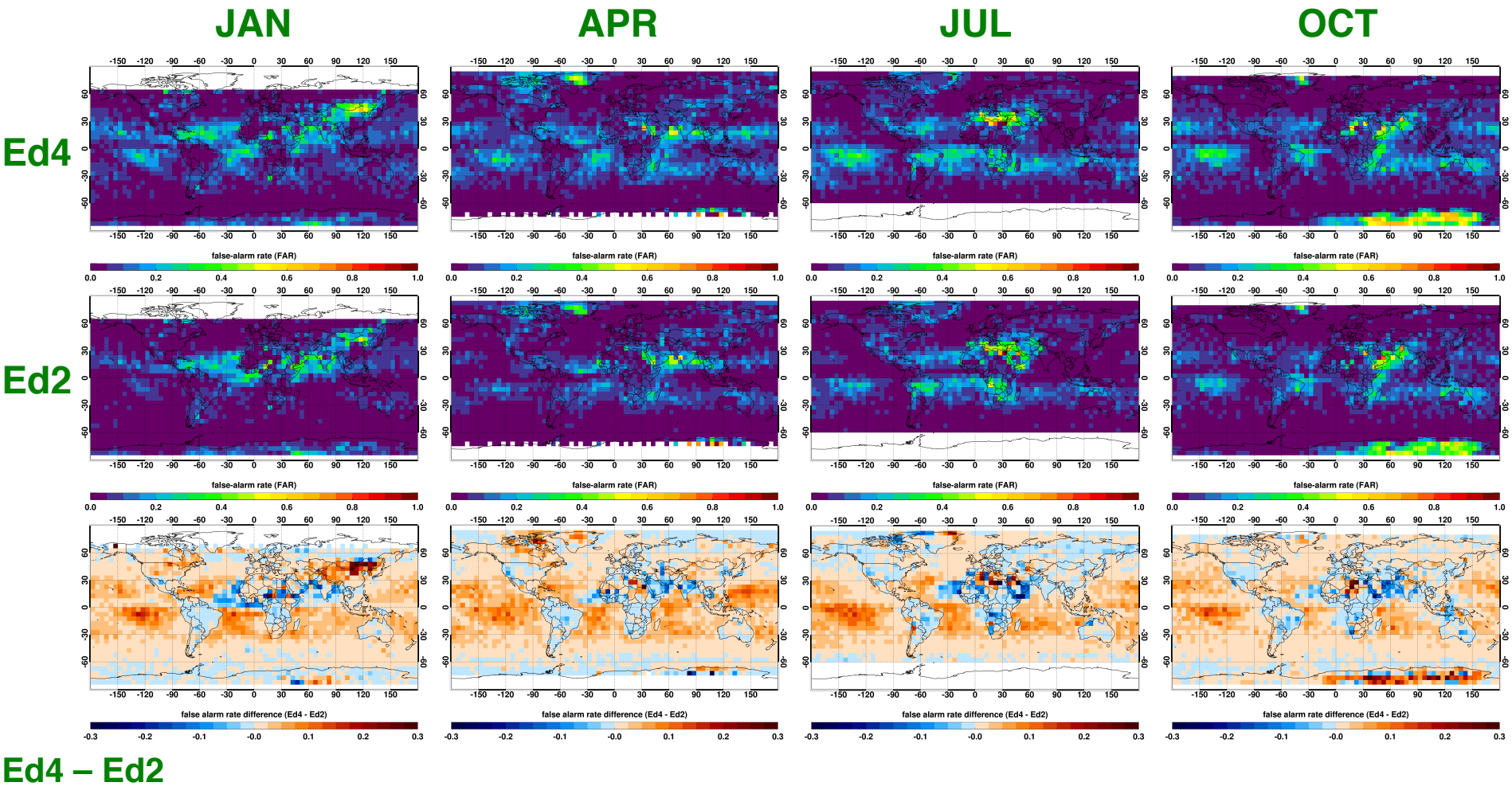
Fraction Correct	JAN	APR	JUL	OCT
Global means: Edition 4	0.894	0.878	0.889	0.889
Global means: Edition 2	0.882	0.867	0.878	0.884

MODIS Ed4 – Ed2 Hit Rate
Daytime



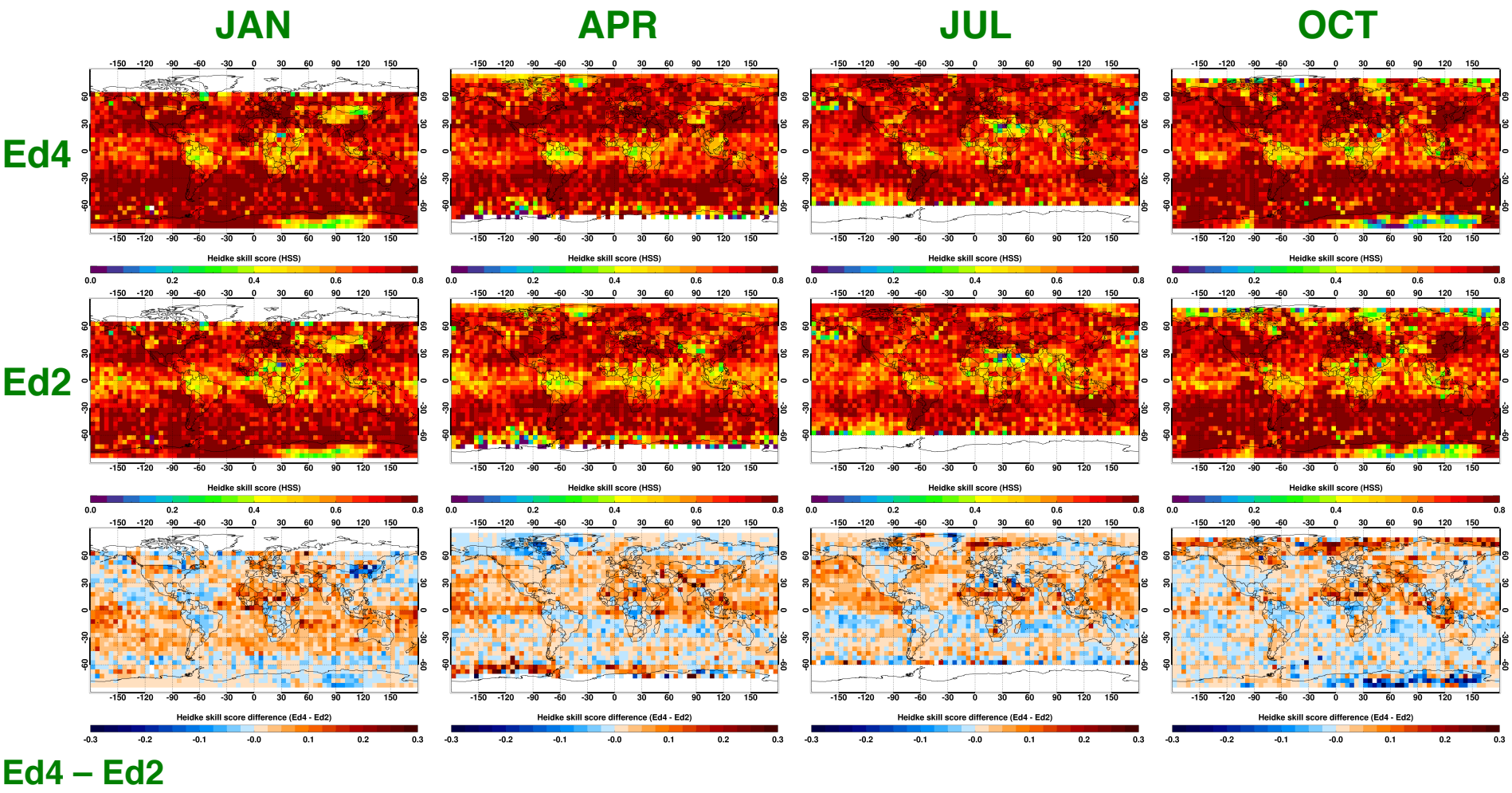
	HIT RATE	JAN	APR	JUL	OCT
Global means	Edition 4	0.895	0.880	0.896	0.906
	Edition 2	0.861	0.845	0.868	0.879

MODIS Ed4 – Ed2 False Alarm Rate
Daytime



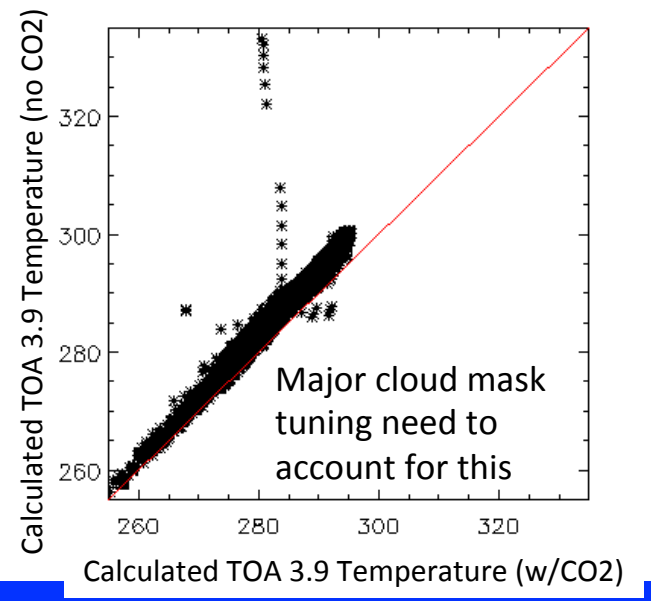
	False Alarm Rate	JAN	APR	JUL	OCT
Global means	Edition 4	0.061	0.065	0.061	0.070
	Edition 2	0.046	0.050	0.051	0.052

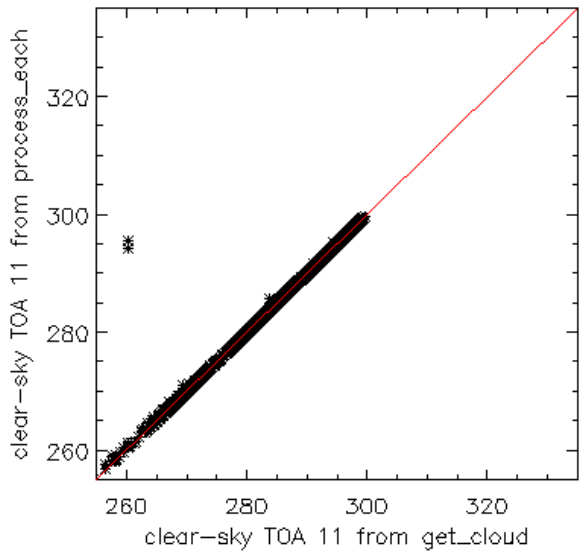
MODIS Ed4 – Ed2 Heidke Skill Score
Daytime

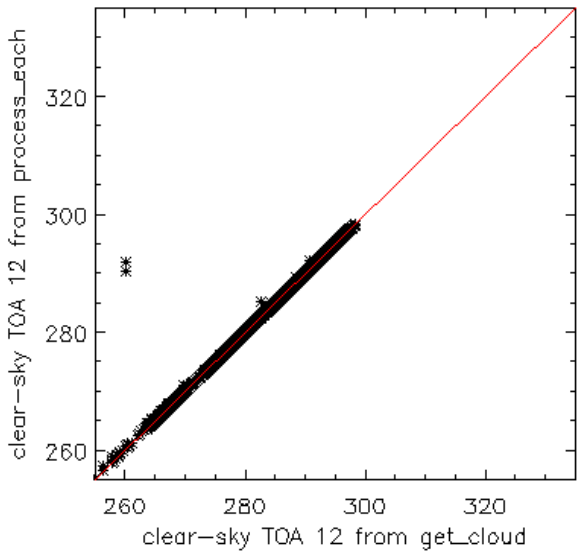


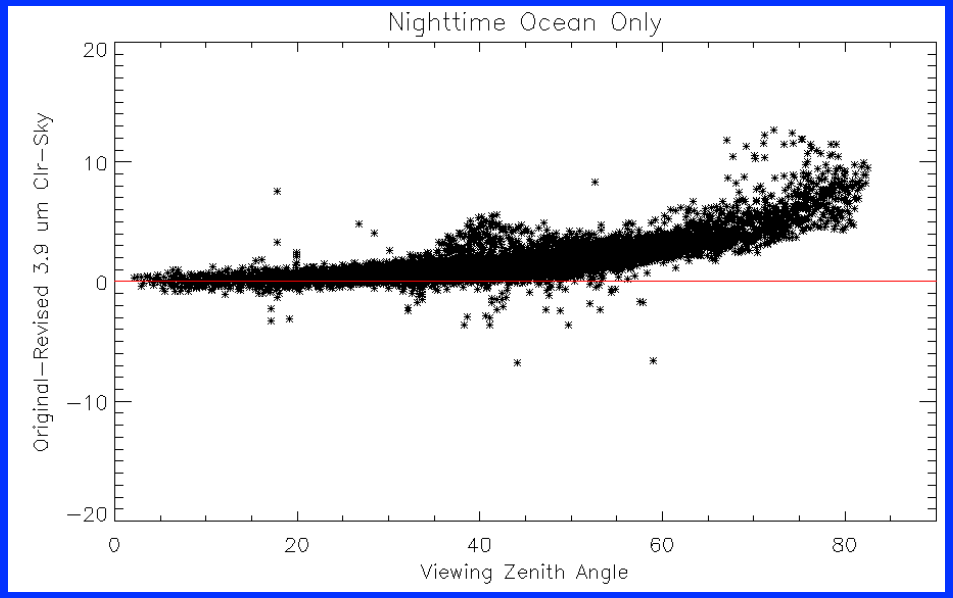
	Heidke Skill Score	JAN	APR	JUL	OCT
Global means	Edition 4	0.77	0.73	0.75	0.75
	Edition 2	0.75	0.72	0.73	0.74

Cloud mask and retrieval code using two different atmospheric correction procedures







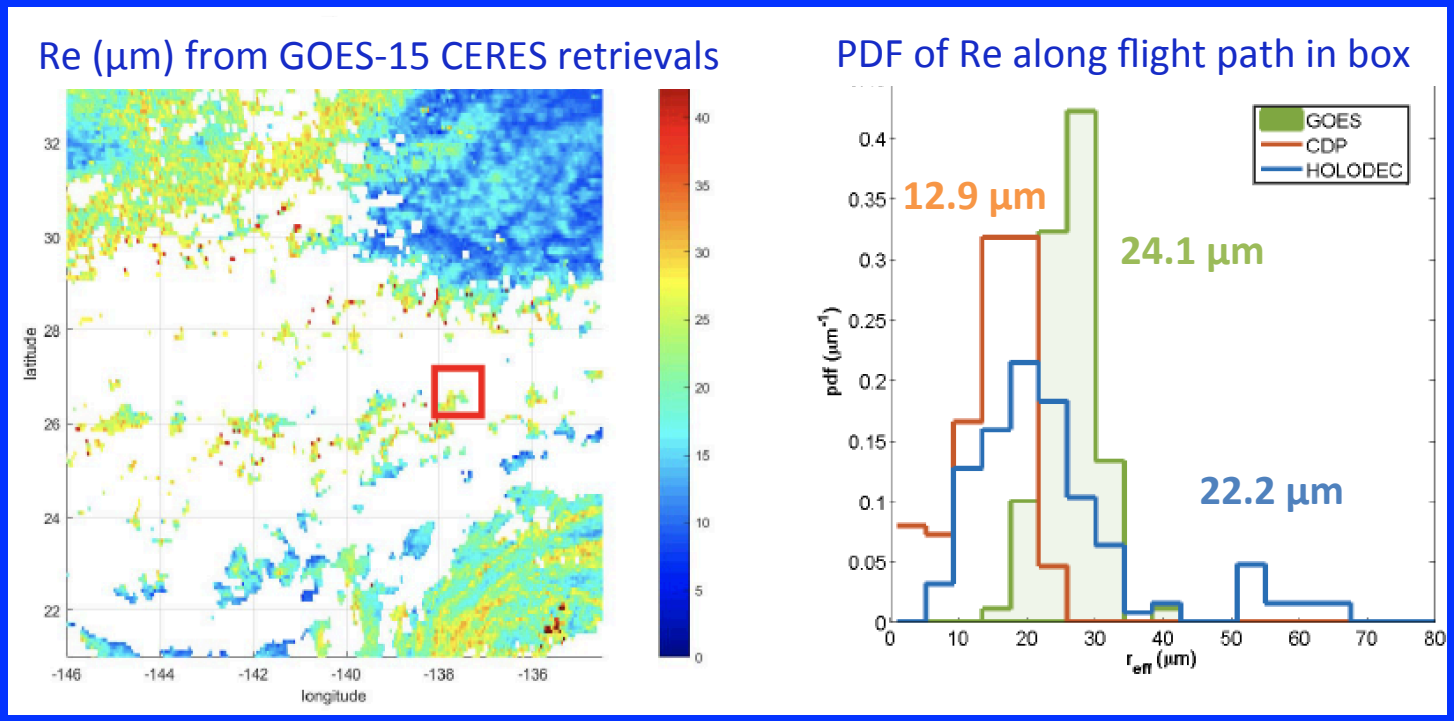


3-segment corrk with CO2 warmer than observations and VZA dependence

Large Effective Radii from MODIS/GOES Realistic

20:50 UTC, 19 July 2015 Northeast Pacific Ocean

Area of in situ measurements



- Large values of droplet effective radius (Re > 20 µm) often suspect: a retrieval artifact

- Recent comparisons with in situ data indicate that such values result from large drizzle drops within the clouds

- HOLODEC measures a wider spectrum of droplets than CDP and yields larger Re than CDP because of drizzlets (beginning of coalescence, 40-80 µm)

From *Glienke et al.* GRL submitted