Comparison of cloudiness from satellite, ground-based and reanalyses data and GCM simulations

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Datasets used:

- **Satellite Observations**
 (ISCCP, UW HIRS, Patmos-X, MODIS (Terra and Aqua), CERES (Terra and Aqua), PARASOL-POLDER, AIRS-LMD, CALIPSO-GOCCP, MISR, ATSR-GRAPE)

- **Surface Observations**
(EECRA, CRU, ICOADS, RIIHMI)

- **Reanalyses data**
(ERA-40, ERA-Interim, NCEP/NCAR, NCEP/DOE, JRA, MERRA)

- **GCM Simulations**
(22 Global Climate Models from CMIP3 Project, IAPRAS CM)

GROUND-BASED OBSERVATIONS

➔ EECRA
Hahn and Warren, 2007
01/1971-12/1996, 5°, 8 obs/day (land)
01/1954-12/1997, 5-10°, 4-8 obs/day (ocean)
Extended Edited Synoptic Cloud Reports Archive (visual observations from land stations and ships)

➔ CRU (for land)
Mitchell and Jones, JC, 2005
01/1971-12/2002, 0.5°
Climatic Research Unit (combined visual observations of clouds and sunshine durations for land)

➔ ICOADS (for ocean)
Worley et al., IJC, 2005
01/1960-05/2007, 1°, 4-8 obs/day
The International Comprehensive Ocean-Atmosphere data Set (visual observations from ships)

GCM

➔ CMIP
Meehl et al., BAMS, 2007
01/1971-12/1999, 1-5°, 6h (20c3m scenario)
The Coupled Model Intercomparison Project (22 Global Climate Models)

➔ IAP RAS CM
Mokhov et al., DAN, 2005
01/1971-12/1999, 4.5°x6°, 5d
A.M. Obukhov Institute of Atmospheric Physics global climate model of intermediate complexity

SATELLITE OBSERVATIONS

➔ ISCCP
Rossow and Schiffer, BAMS, 1999
07/1983-06/2008, 2.5°, 8 obs/day
instr. resol: 4-7 km, 1 VIS + 1 IR
The International Satellite Cloud Climatology Project, 3-5 geostationary and 2-4 NOAA polar-orbiting satellites (PS), DX-algorithm: spectral threshold test + spatial and temporal homogeneity test

➔ UW HIRS
Wylie et al., JC, 2005
01/1979-12/2001, 1°, 02:00 AM, PM
instr. resol: 19-35 km, 6 IR
Universite of Wisconsin High-resolution Infrared Radiation Sounder, 2 NOAA PS, CO_2-slicing algorithm: cloud height estimation by CO_2 profile measuring

➔ Patmos-X
Heidinger, 2004
01/1982-05/2008, 0.5°, 02:00+07:00 AM, PM
instr. resol: 1-4 km, 1 VIS + 1 NIR + 3 IR
Advanced Very High Resolution Radiometer Pathfinder Atmosphere - Extended, 2-4 NOAA PS, CLAVR-X algorithm: series of spectral threshold tests

➔ MODIS
Ackerman et al., JGR, 1998
02/2000-12/2009, 1°, 10:30 AM, PM (Terra)
07/2002-12/2009, 1°, 01:30 AM, PM (Aqua)
instr. resol: 0.25-1 km, 2 VIS + 4 NIR + 8 IR
The Moderate Resolution Imaging Spectroradiometer, EOS PS Terra and Aqua, series of spectral threshold tests + spatial and temporal homogeneity test

➔ CERES
Wielicki et al., BAMS, 1996
02/2000-08/2007, 1°, 10:30 AM, PM (Terra)
07/2002-08/2007, 1°, 01:30 AM, PM (Aqua)
instr. resol: 0.25-1 km, 1 VIS + 1 NIR + 1 IR
Clouds and the Earth's Radiant Energy System, MODIS instrument for clouds, series of spectral threshold tests

➔ PARASOL-POLDER
Buriez et al., IJRS, 1997
03/2005-10/2009, 10', 13:30 AM
instr. resol: 6.2 km, 2 VIS + 3 NIR
POLDER instrument on PS PARASOL (ERB & clouds algorithm: series of spectral multiangle and polarization threshold tests)

➔ AIRS-LMD
Stubenrauch et al., JGR, 2008
01/2003-12/2008, 1°, 01:30 AM, PM
instr. resol: 13.5 km, 6 IR
Atmospheric Infrared Sounder on PS Aqua, minimizing of χ^2 weighted error function + series of spectral threshold tests

➔ CALIPSO-GOCCP
Chepfer et al., JGR, 2010
01/2007-12/2008, 1°, 01:30 AM, PM
instr. resol: 0.33-1 km, 1 VIS (active rem. sens.)
GCM–Oriented CALIPSO Cloud Product, CALIOP lidar non PS CALIPSO, obtaining cloud profile from attenuated backscattered and molecular density profile

➔ MISR
Diner et al., Trans. Geosci., 1998
01/2001-12/2008, 1°, 10:30 AM
instr. resol: 0.275 km, 3 VIS + 1 NIR
Multi–angle Imaging Spectro–Radiometer on PS Terra, RLRA algotihm: cloud height estimation by stereoscopic measurements + series of spectral multiangle threshold tests

➔ ATSR-GRAPE
Sayer et al., 2009
06/1995-12/2000, 1°, 10:30 AM, PM
instr. resol: 1 km, 2 VIS + 1 NIR + 4 IR
Along–Track Scanning Radiometer on PS ERS-2, simultaneously retrieval cloud parameters using measurements and radiative transfer model

REANALYSES

➔ ERA
Uppala et al., QJRMS, 2005
07/1957-08/2002, 2.5°, 6h (ERA-40)
01/1989-12/2009, 1.5°, 6h (ERA-Interim)
European Center for Medium-Range Weather Foreacasts Reanalyses

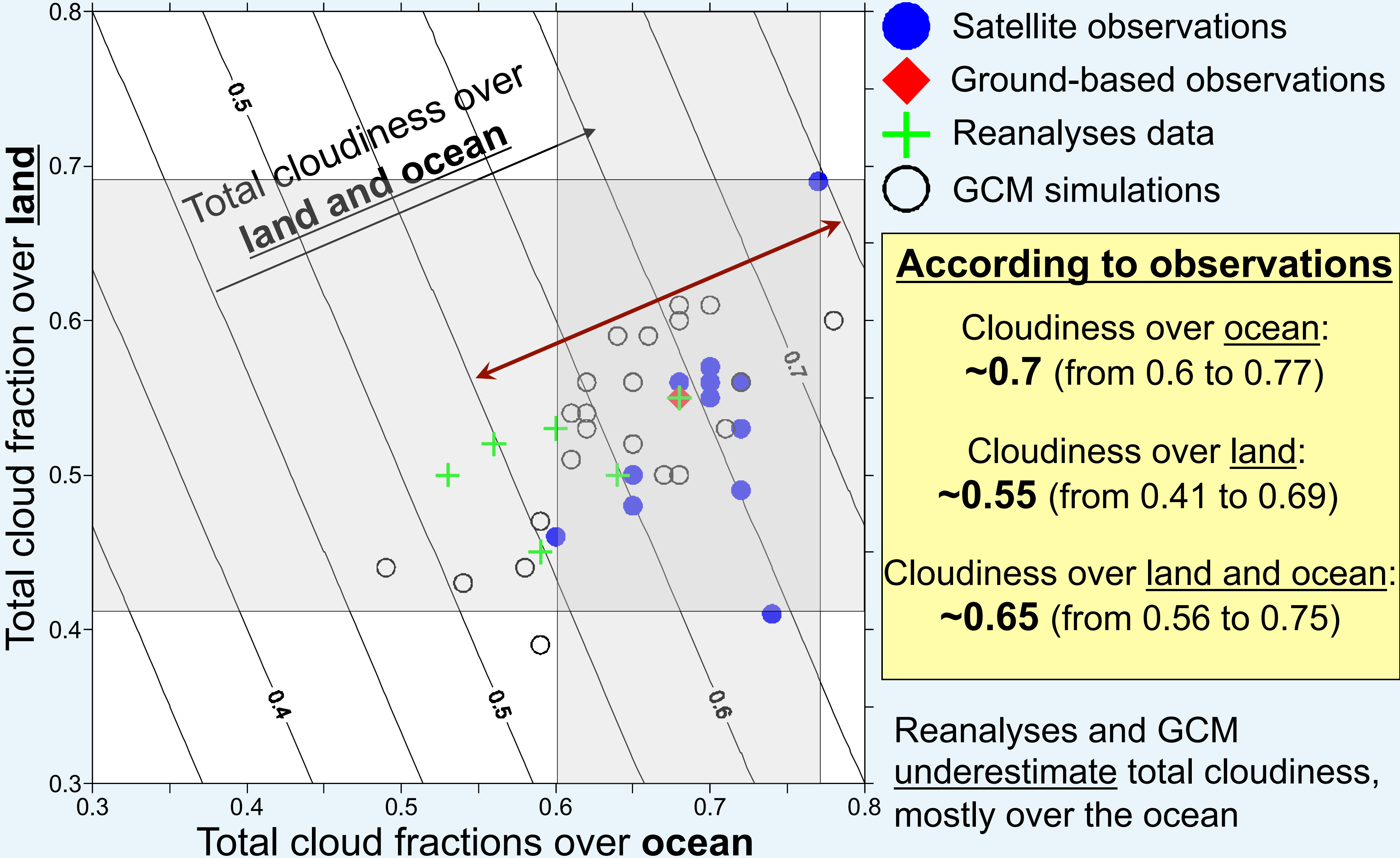
➔ NCEP
Kistler et al., BAMS, 2001
Kanamitsu et al., BAMS, 2002
01/1948-12/2008, ~2°, 6h (NCEP/NCAR)
01/1979-01/2008,~2°, 6h (NCEP/DOE)
National Centers for Enviromental Prediction Reanalyses

➔ JRA
Onogi et al., JMS, 2007
01/1979-12/2009, 2.5°, 6h
Japan Meteorological Agency Reanalysis

➔ MERRA
Bosilovich, E-Zine, 2008
01/1979-03/2009, 0.5°x0.67°, 3h
NASA Modern Era Reanalysis for Research and Applications

Annual-mean cloud fraction (CF)

Global annual-mean CF



According to observations

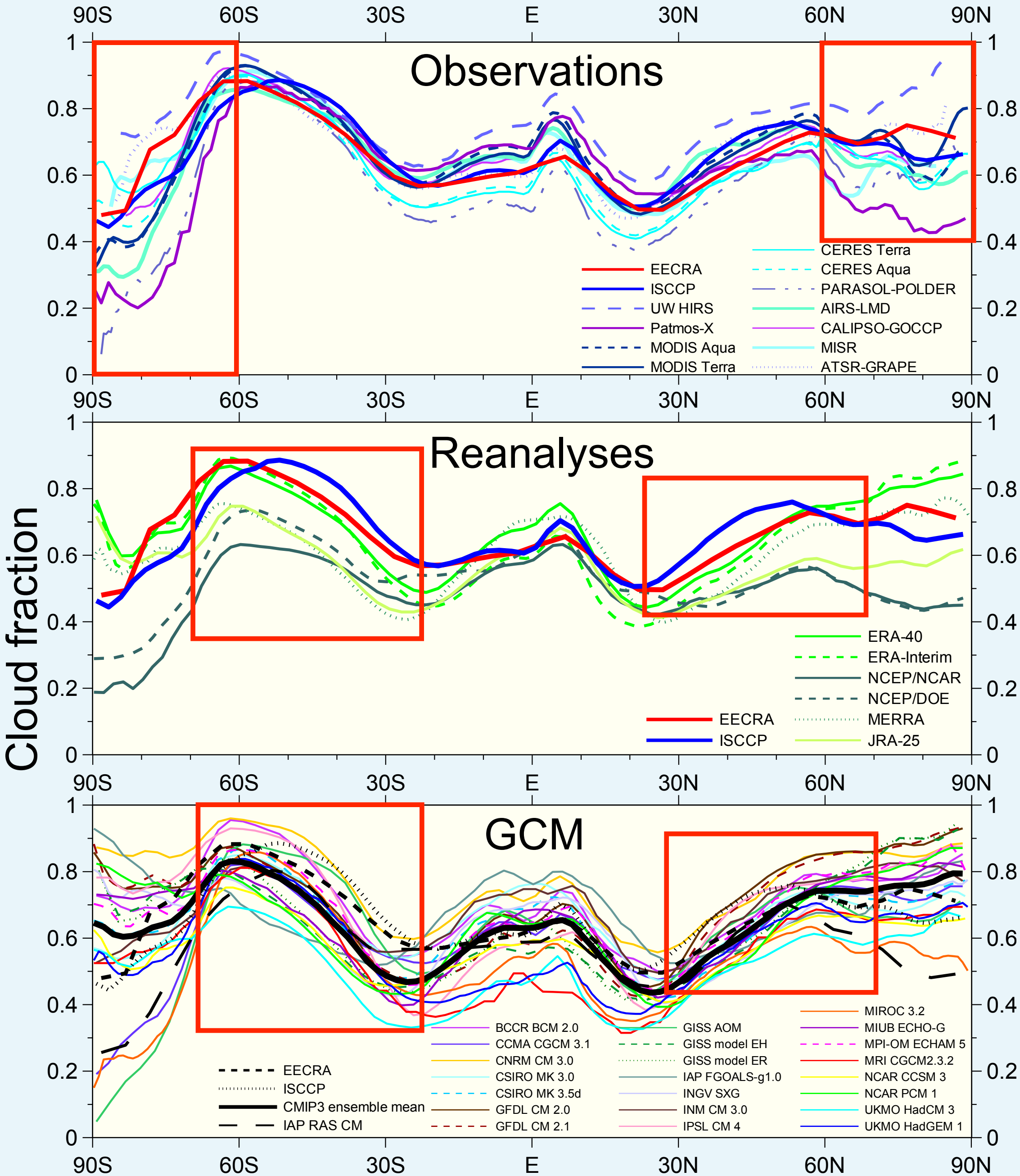
Cloudiness over ocean:
~0.7 (from 0.6 to 0.77)

Cloudiness over land:
~0.55 (from 0.41 to 0.69)

Cloudiness over land and ocean:
~0.65 (from 0.56 to 0.75)

Reanalyses and GCM underestimate total cloudiness, mostly over the ocean

A.V. Chernokulsky and I.I. Mokhov Comparison of cloudiness from satellite, ground-based and reanalyses data and GCM simulations
ENVIROMIS-2010, 5-11 July 2010, Tomsk, Russia



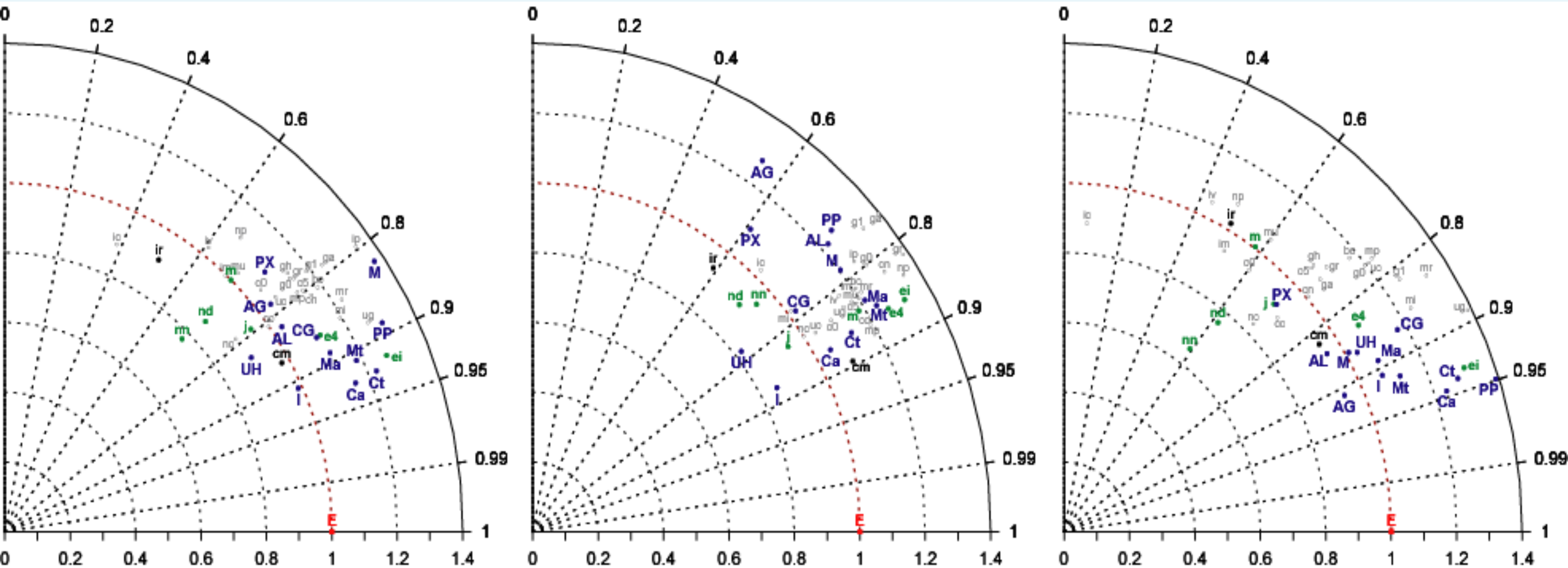
Zonal annual-mean CF

Largest distinctions among observations are noted
<u>In polar latitudes</u>

In general, GCM and reanalyses underestimate cloud fraction
<u>in midlatitudes</u>

Taylor diagrams for spatial distributions of annual-mean CF

Land+Ocean **Only Land** **Only Ocean**



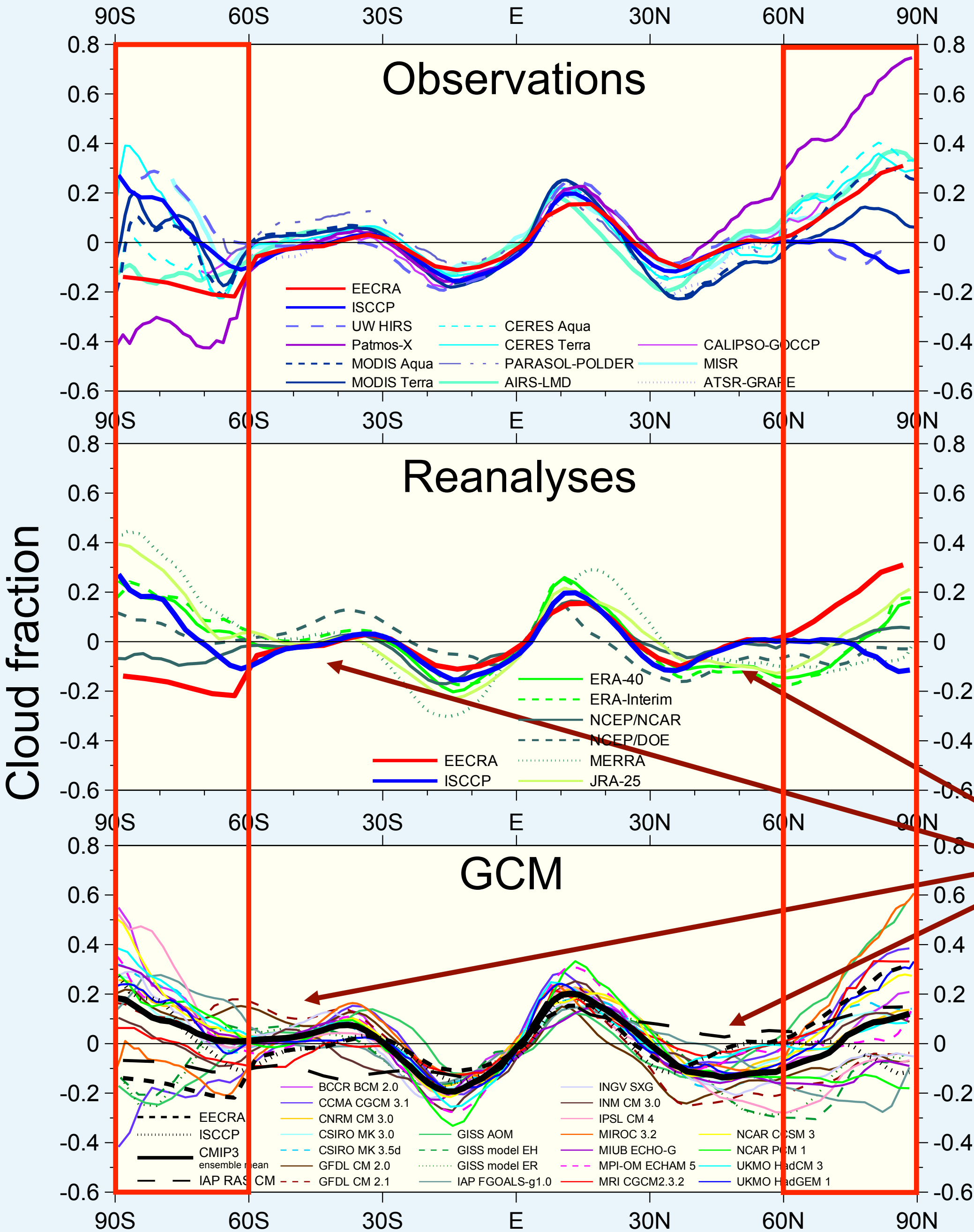
Reference dataset is EECRA (surface observations)

Angle axis corresponds to coefficient of spatial correlation between cloudiness field from reference and other data

Radial axis corresponds to spatial standard deviations of cloudiness field from different data normalized by reference data spatial standard deviations

Seasonal differences in CF

(June-July-August (JJA) mean – December-January-February (DJF) mean)



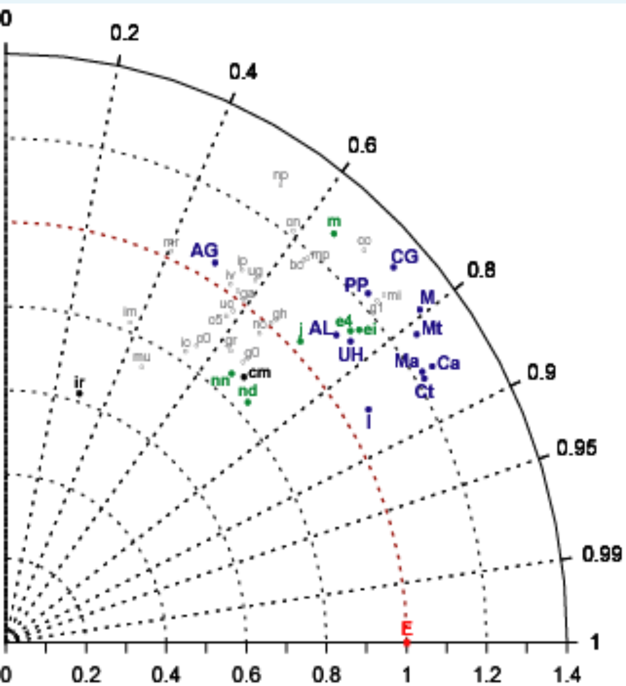
Seasonal differences in zonal-mean CF

Largest distinctions among different datasets are noted in polar regions (even in sign on seasonal difference)

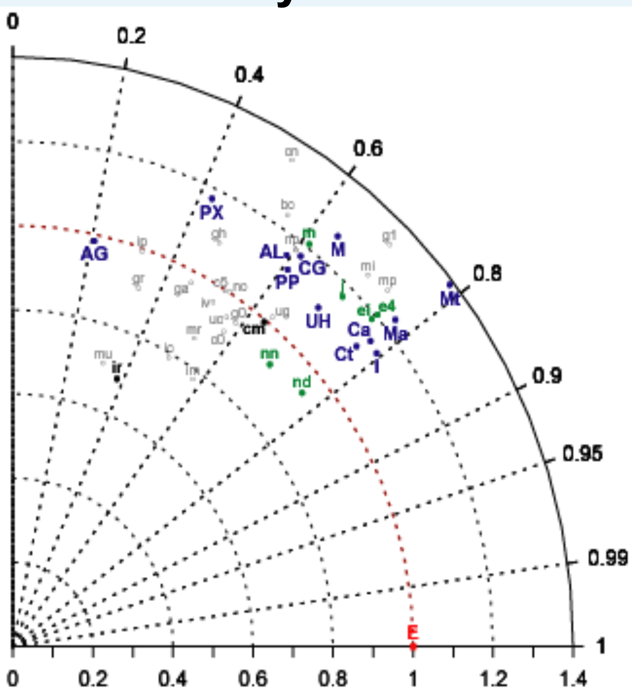
In general, reanalyses and GCM overestimate seasonal difference In midlatitude

Taylor diagrams for spatial distributions of seasonal differences in CF (JJA-DJF)

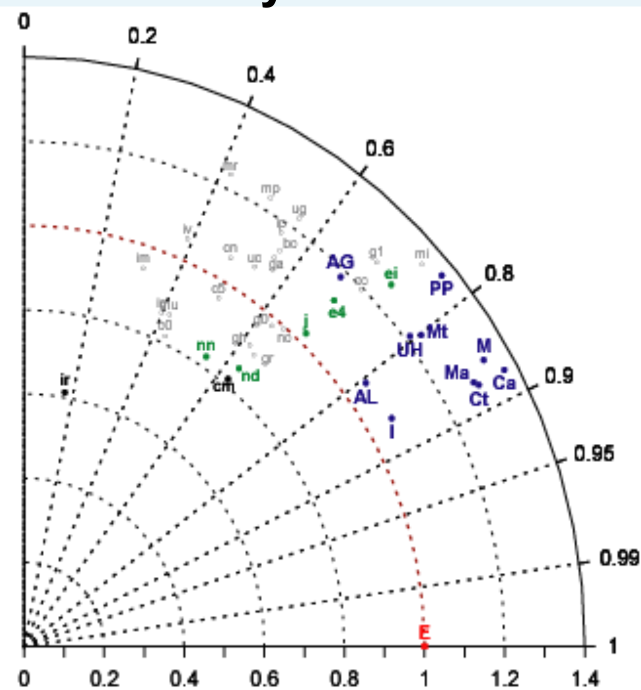
Land+Ocean



Only Land



Only Ocean



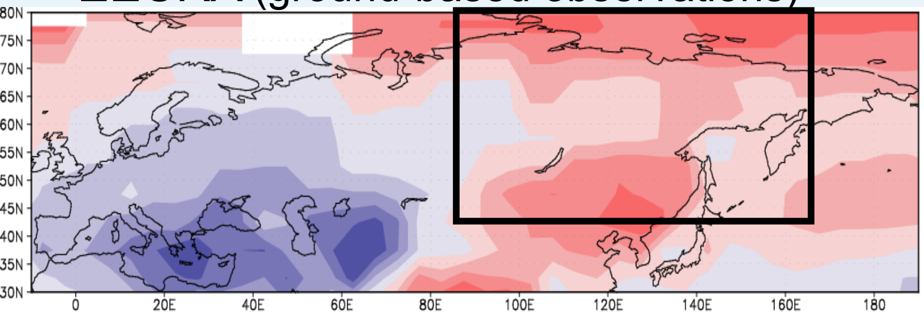
Reference dataset is EECRA (surface observations)

Angle axis corresponds to coefficient of spatial correlation between cloudiness field from reference and other data

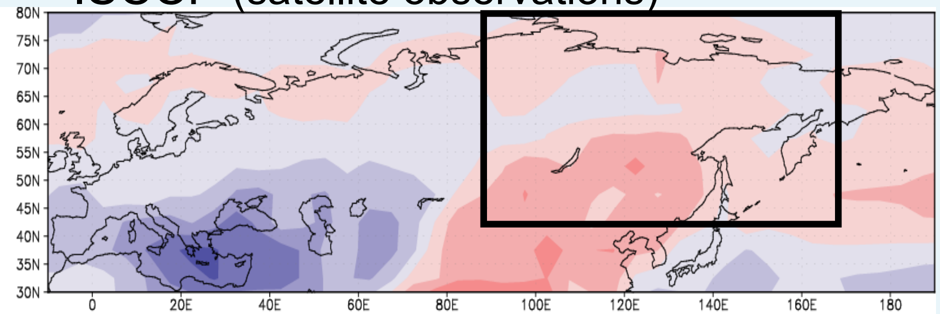
Radial axis corresponds to spatial standard deviations of cloudiness field from different data normalized by reference data spatial standard deviations

Seasonal differences in CF over Northern Eurasia (JJA-DJF)

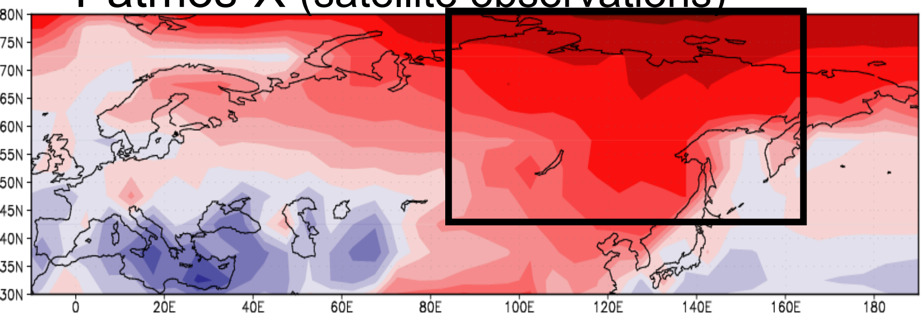
EECRA (ground-based observations)



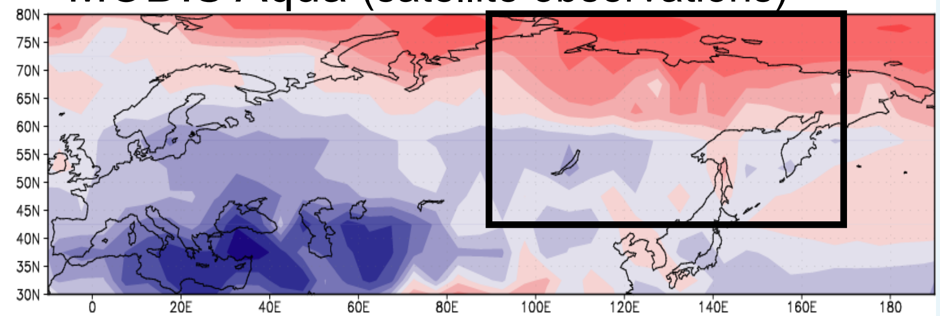
ISCCP (satellite observations)



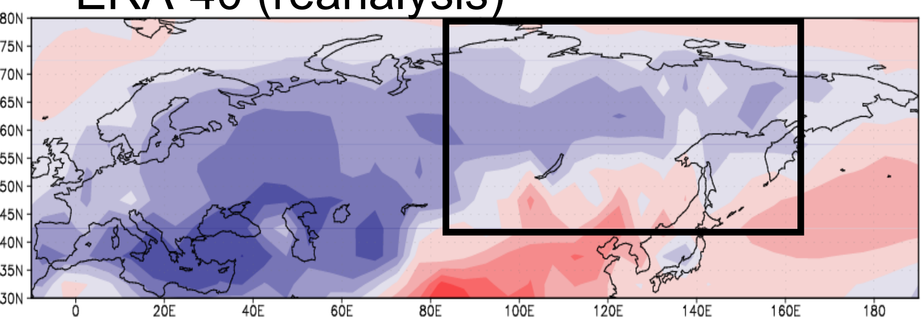
Patmos-X (satellite observations)



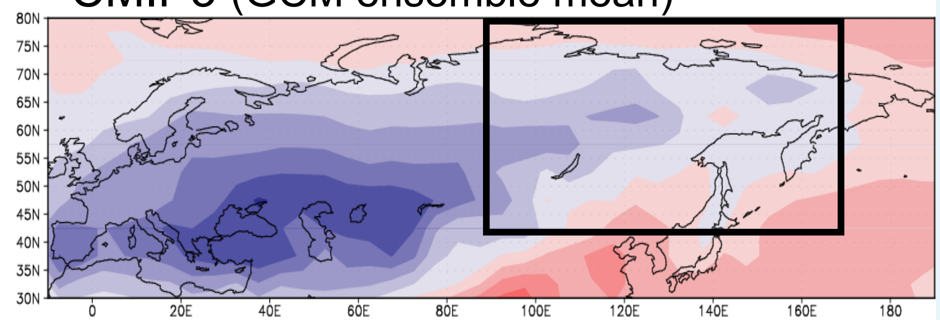
MODIS Aqua (satellite observations)

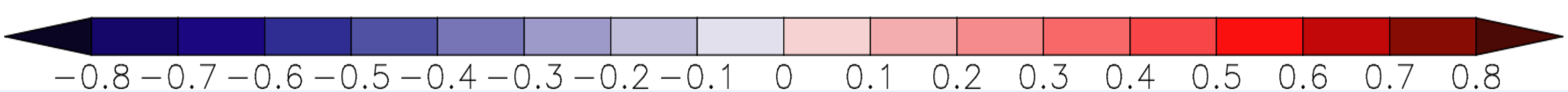


ERA-40 (reanalysis)



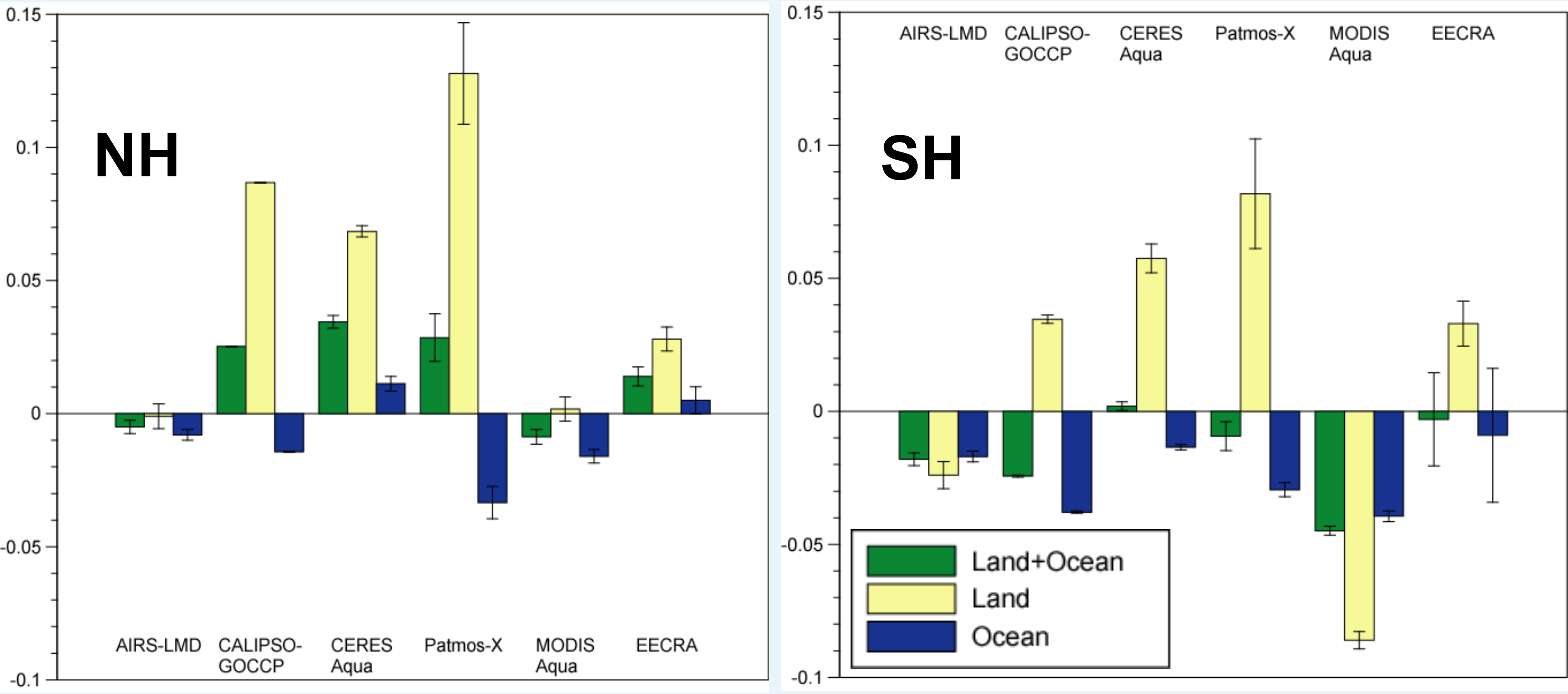
CMIP3 (GCM ensemble mean)





Diurnal cycle of CF

Day/night differences of hemisphere-mean CF (day – night)



Land: day CF > night CF in NH, uncertainty in SH

Ocean: night CF > day CF in SH, uncertainty in NH

Land+Ocean: day CF > night CF in NH, reverse in SH

Causes of data discrepancy:

- Differences among cloud detection algorithms in different data

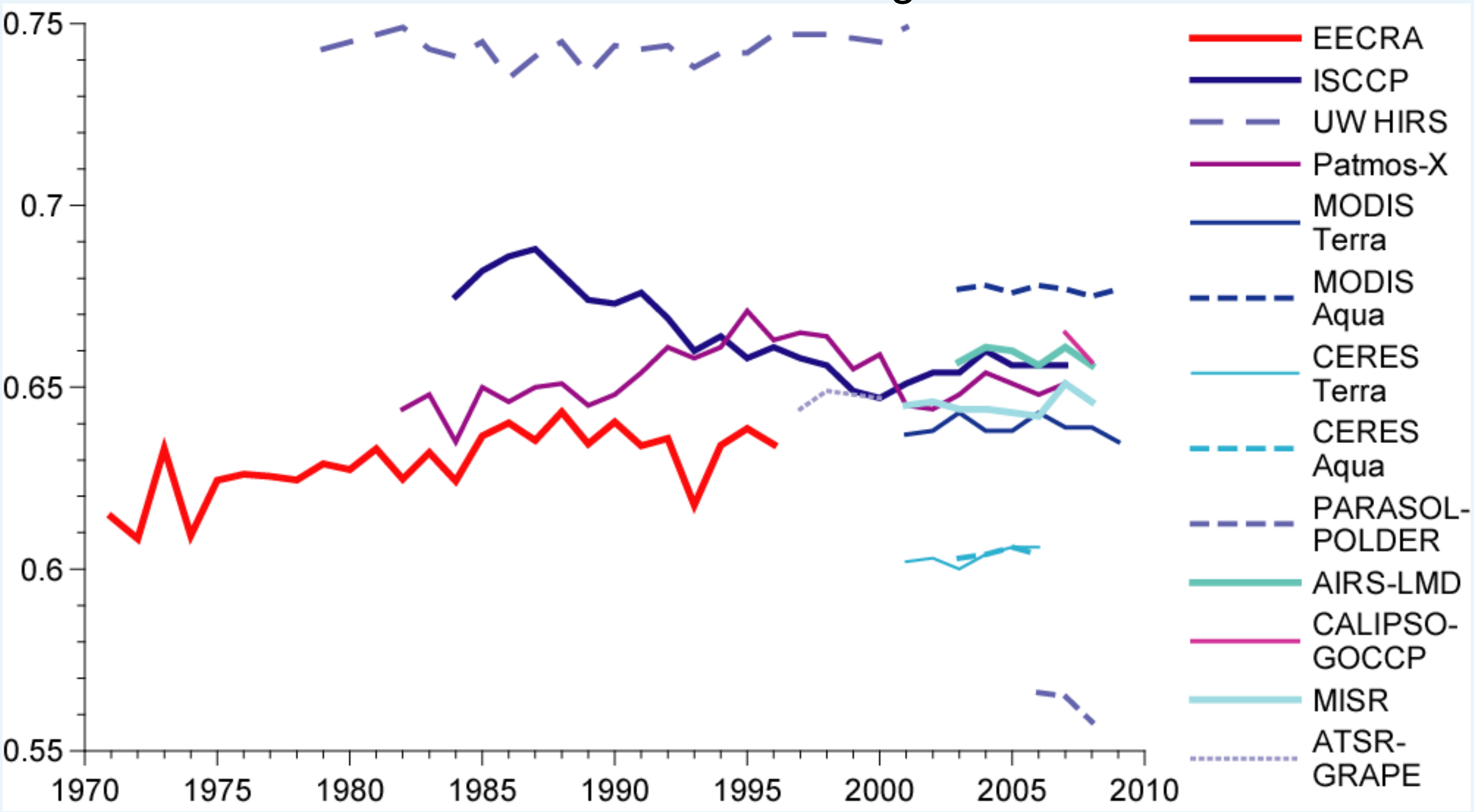
- Data inhomogeneity and accuracy (5-10%)

- The selection of averaging period (1-3% global CF, up to 30% regional CF)

- CF diurnal cycle (up to 15% over land and up to 7% over ocean)

The problem of selection of the unified averaging period

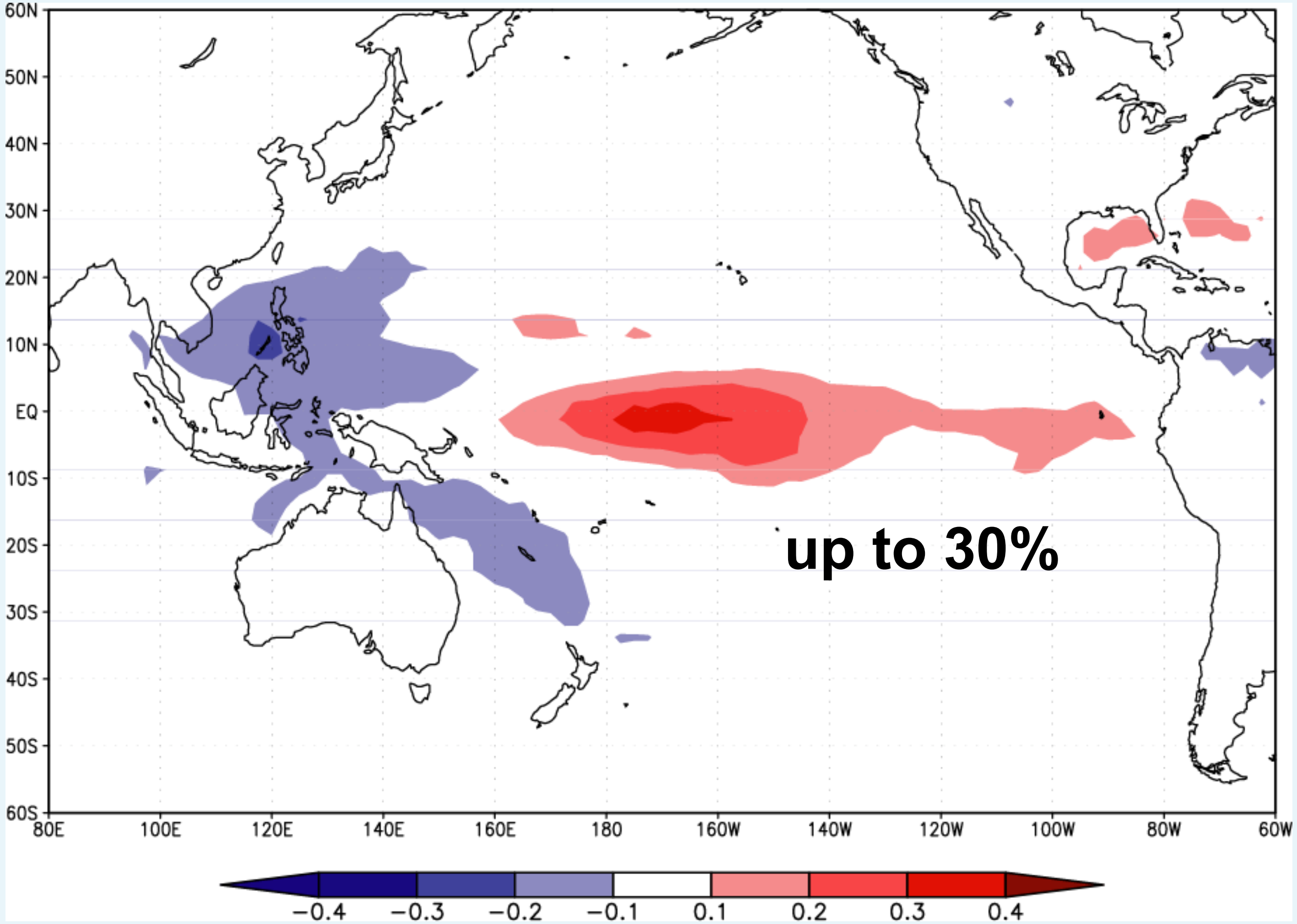
Global annual-mean CF from satellite and ground-based observations



CF differences between short period and whole period in one data < 1-3%

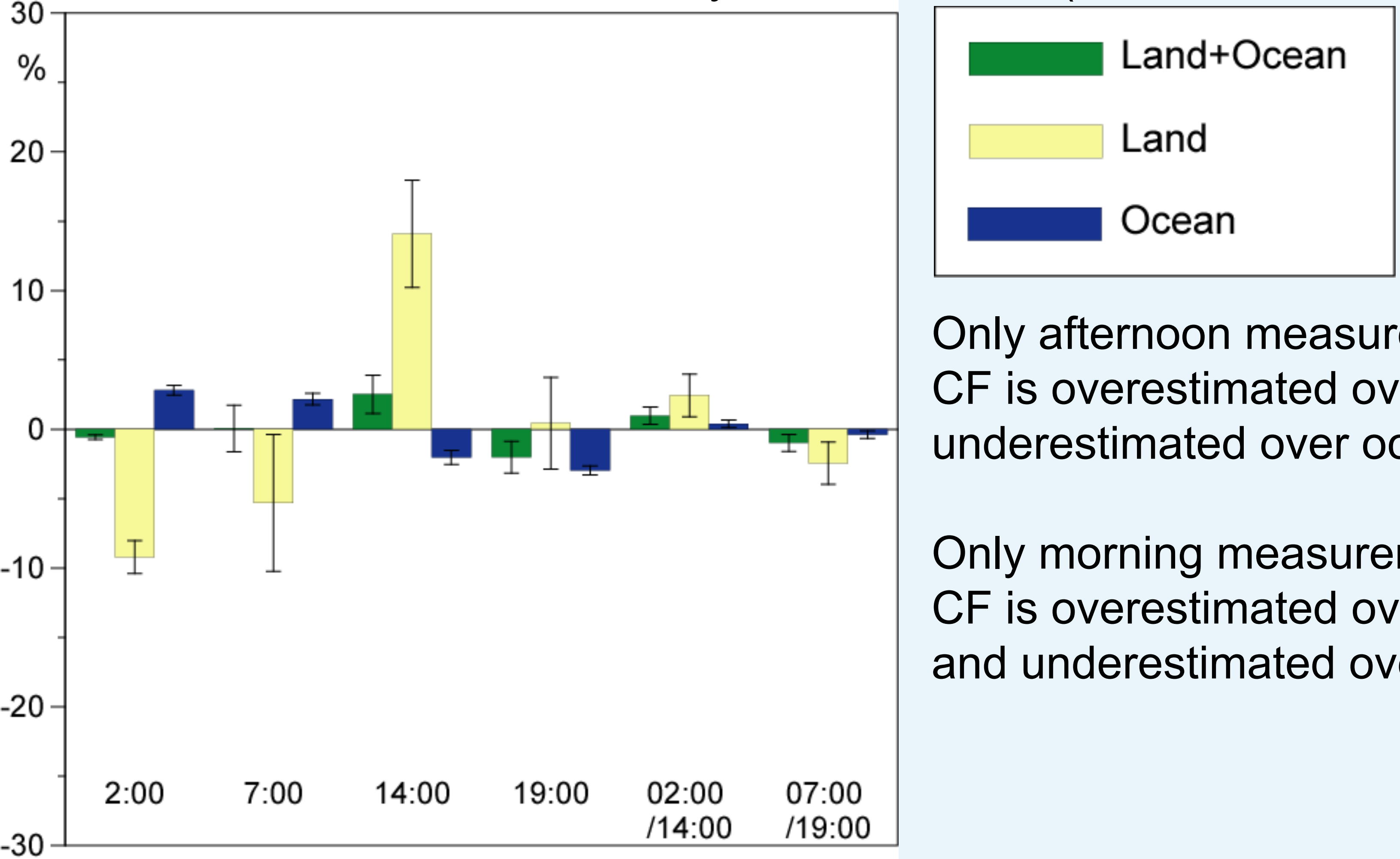
Regional features of averaging period selection: El Nino / La Nina

Differences in DJF CF between 5 El Nino and 5 La Nina years (from ISCCP data)



Influence of cloud diurnal cycle on CF detection

Global-mean CF: Differences between once-a-day / twice-a-day measurements and four-time-a-day measurements (from Patmos-X data)



Only afternoon measurements: CF is overestimated over land and underestimated over ocean

Only morning measurements: CF is overestimated over ocean and underestimated over land

CONCLUSIONS

• Global annual-mean CF is about 65% over land and ocean, it is about 55% over land and about 70% over ocean according to up-to-date satellite and surface observations.

• The largest distinctions of among different observations are noted over polar regions (for annual-mean CF as well as for CF seasonal difference).

• As a whole reanalyses and model simulations show less CF than observations mostly because of an underestimation in midlatitudes in both hemispheres. In general, model simulations and reanalyses has better agreement with observations in terms of annual mean CF and worse agreement in terms of seasonal difference.

• The main distinctions between observations are connected with time of observations and with algorithms of cloud detection

Acknowledgements to all science team who prepared cloudiness datasets