Intercomparison of the Arctic cloud cover climatologies from different observations and reanalyses

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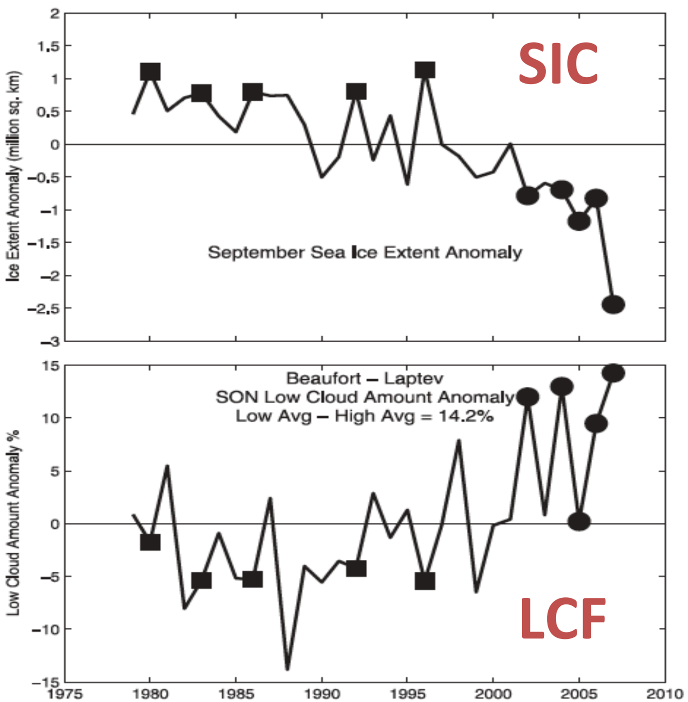
Motivation

- Clouds in the Arctic have a strong warming effect, especially in winter. Curry et al., 1996
- The sensitivity of cloud radiative forcing in the Arctic is about 1 W/m^2 per 1% of cloudiness. Shupe and Inrieri, 2004
- Sea ice extent and thickness may be affected by cloud changes, and sea ice changes may in turn influence on cloud cover. Eastman and Warren, 2010
- The largest cloud data discrepancies are noted over the polar regions. Chernokulsky and Mokhov, 2010



Data overview

Datasets for cloudiness

- **Observations**
  - Satellite-borne observations
  - Ground-based observations
  - Others (aircraft measurements, sky radiometers, radiosonde etc.)
- **Numerical simulations**
  - Reanalyses data
  - Global climate models

Ground-based dataset

EECRA (Extended Edited Cloud Reports Archive)

Hahn and Warren, 2003

Derived from synoptic weather reports based on visual four-time-a-day (**00, 06, 12, 18 UTC**) observations from ships and land meteorological stations

Spatial resolution: **5 degree**

Time period: **1972-1996 (for land)**

1954-2007 (for ocean)

Information for:

- Cloud amount (total and low)
- Occurrence of different cloud types

Satellite datasets

- **ISCCP** (International satellite cloud climatology project) Rossow and Schiffer, 1999
- **UW HIRS** (University of Wisconsin High-resolution Infrared Radiation Sounder) Wylie et al., 2005
- **PATMOS-x** (Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Atmospheres) Heidinger et al., 2011
- **APP-x** (AVHRR Polar Pathfinder) Wang and Key, 2005
- **MODIS** (Moderate Resolution Imaging Spectroradiometer) Ackerman et al., 2008
- **CERES** (Clouds and the Earth's Radiant Energy System) Minnis et al., 2008
- **AIRS-LMD** (Atmospheric Infrared Sounder - Laboratoire de Meteorologie Dynamique) Shtubenrauch et al., 2008
- **MISR** (Multi-angle Imaging Spectro-Radiometer) Di Girolamo et al., 2010
- **ATSR-GRAPE** (Global Retrieval of Along–Track Scanning Radiometer cloud Parameters and Evaluation project) Poulsen et al., 2010
- **CALIPSO** (Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations) Winker et al. 2009, Chepfer et al., 2010
- **CloudSat** (Cloud profile 94-GHz radar) Stephens et al., 2002

Dataset	Satellites	Spectral channels	Resolution / Swath (km)	Observational time (LT)	Period
ISCCP	GS + POS (NOAA)	1 VIS + 1 IR	4-7 / -	Every 3 hour	1983-2008
UW HIRS	NOAA	6 IR	19-35 / 2240	~ 02:00, 14:00	1979-2001
PATMOS-x APP-x	NOAA	1 VIS + 1 NIR + 3 IR	1-4 / ~3000	~ 02:00, 07:00, 14:00, 19:00	1982-2009
MODIS	Terra + Aqua	2 VIS + 4 NIR + 8 IR	0.25-1 / 2330	10:30, 22:30 (Terra) 01:30, 13:30 (Aqua)	2000-2011 (T) 2002-2011 (A)
CERES	Terra + Aqua	1 VIS + 1 NIR + 3 IR			2000-2010 (T) 2002-2010 (A)
AIRS-LMD	Aqua	6 IR	13.5 / 1600	01:30, 13:30	2003-2008
MISR	Terra	3 VIS + 1 NIR	0.275 / 380	10:30	2001-2009
ATSR-GRAPE	ERS-2 + ENVISAT	2 VIS + 1 NIR + 4 IR	1 / 512	10:30	1995-2010
CALIPSO-GOCCP	CALIPSO	1 VIS (lidar)	0.25-1 / -	01:30, 13:30	2006-2011

Satellite datasets

Satellite datasets provide information on:

- Cloud fraction (total, high, middle, low) – satellite view!
- Cloud water path
- Cloud albedo
- Cloud emissivity
- Cloud optical depth
- Effective radius for cloud particles
- Cloud top temperature and pressure
- Cloudiness types (derived from cloud top pressure and optical) – different from those from ground-based visual observations!
- Radiative fluxes

Data spatial resolution: 0.5° – 2.5°

Reanalyses and GCM data

Reanalyses data:

- ERA reanalyses**: ERA-40** + **ERA-Interim** Uppala et al, 2005; Dee et al., 2011
- NCEP reanalyses: **NCEP/NCAR** + **NCEP/DOE** + **NCEP-CFSR** Kistler et al., 2001; Kanamitsu et al., 2002; Saha et al., 2010
- **NOAA CIRES 20th century reanalysis** Compo et al., 2011
- **NASA-MERRA** Bosilovich, 2008
- **JRA-25** Onogi et al., 2007

GCM simulations:

- **CMIP3** project Meehl et al., 2007

CMIP5 will come soon…

Parameters:

Cloud fraction (on different layers), water path, radiative fluxes etc.

Data limitation

For ground-based observations:

- Nonuniformity of spatial coverage. Lack of observations over vast oceanic and desert regions.
- Temporal inhomogeneity. Poor quality of night observations

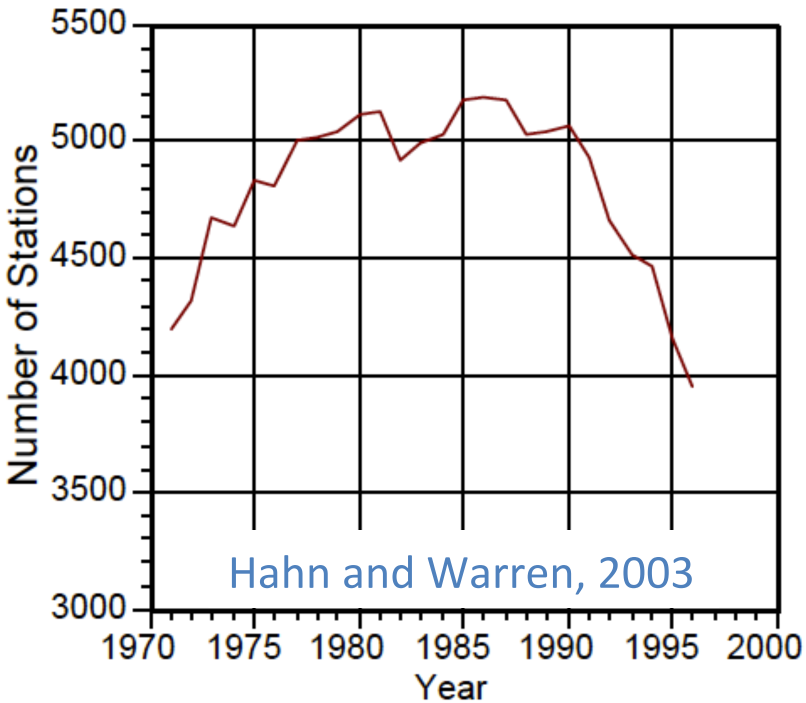
For satellite data:

- Inhomogeneity: spatial (e.g. different number of observations for different regions) and temporal (e.g. drifting orbit of NOAA satellites).
- Dependence on view angle.

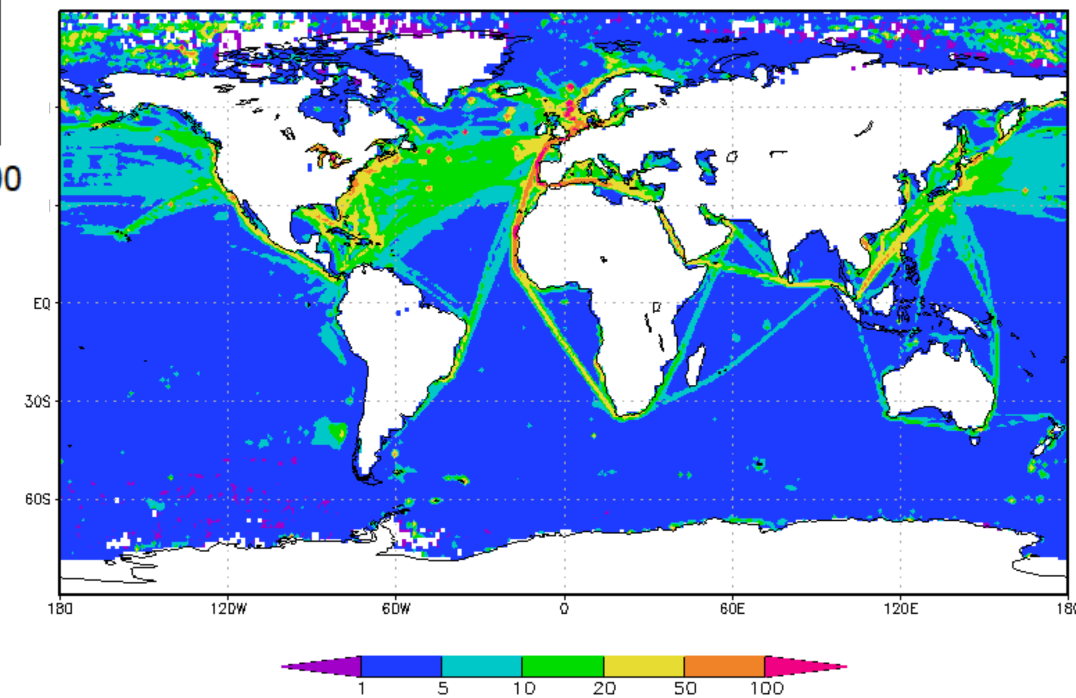
For reanalyses and GCMs data:

- Cloudiness characteristics strongly depend on cloud prediction schemes and cloud overlap assumptions. Reanalyses do not assimilate information on clouds!

Data limitation: ground-based observations



Number of land stations with 20 or more observations per month for Julys



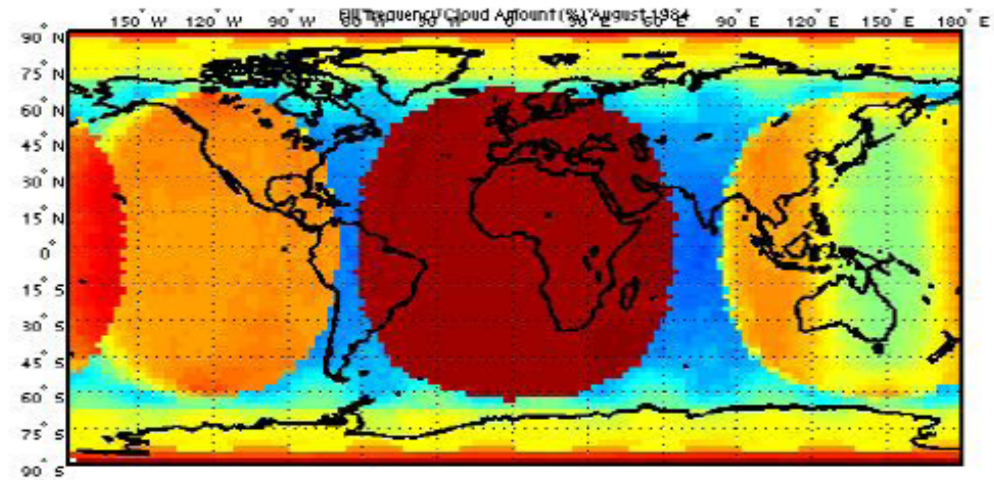
Monthly-mean number of observations (over the ocean)

Data limitation: satellite observations

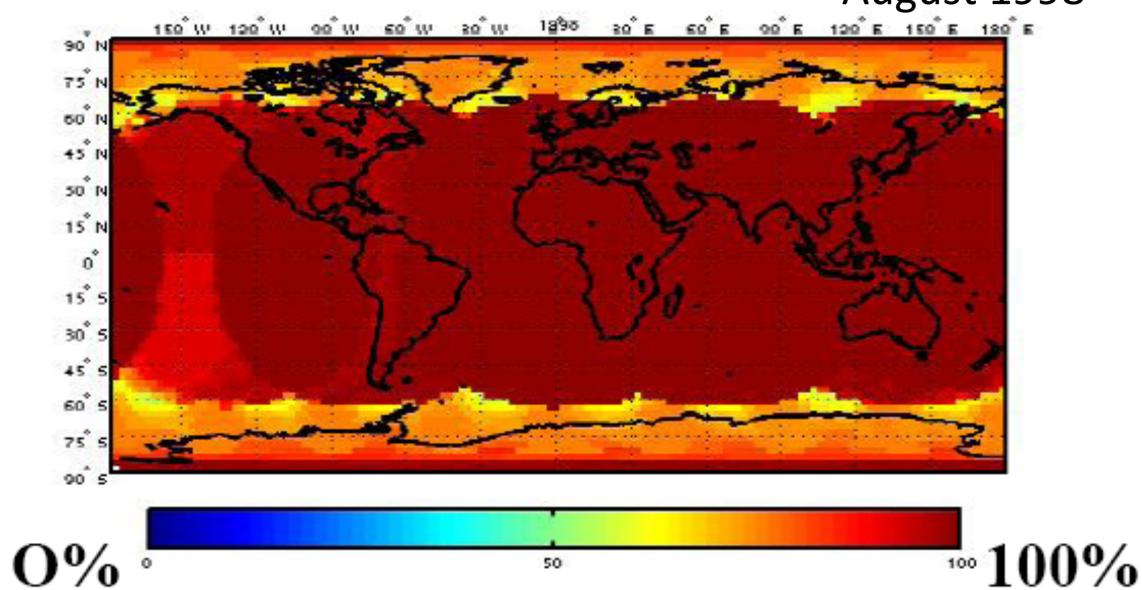
Spatial inhomogeneity

Number of observations per month in the **ISCCP** data
Rossow, 2010

August 1984



August 1998



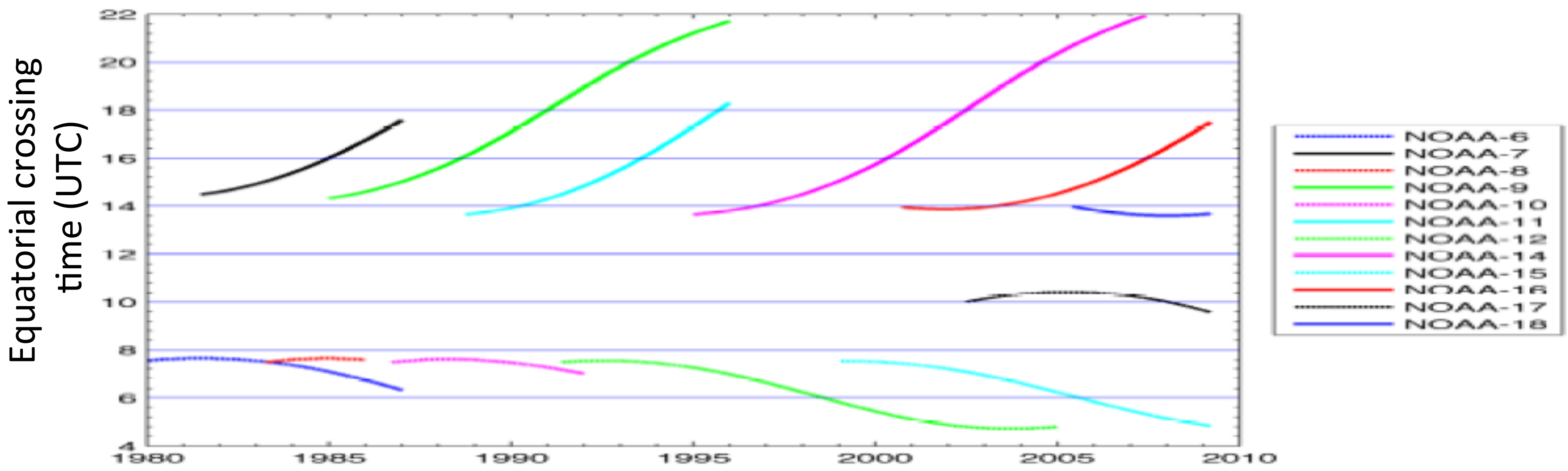
100% = 248 observations

Data limitation: satellite observations

Temporal inhomogeneity

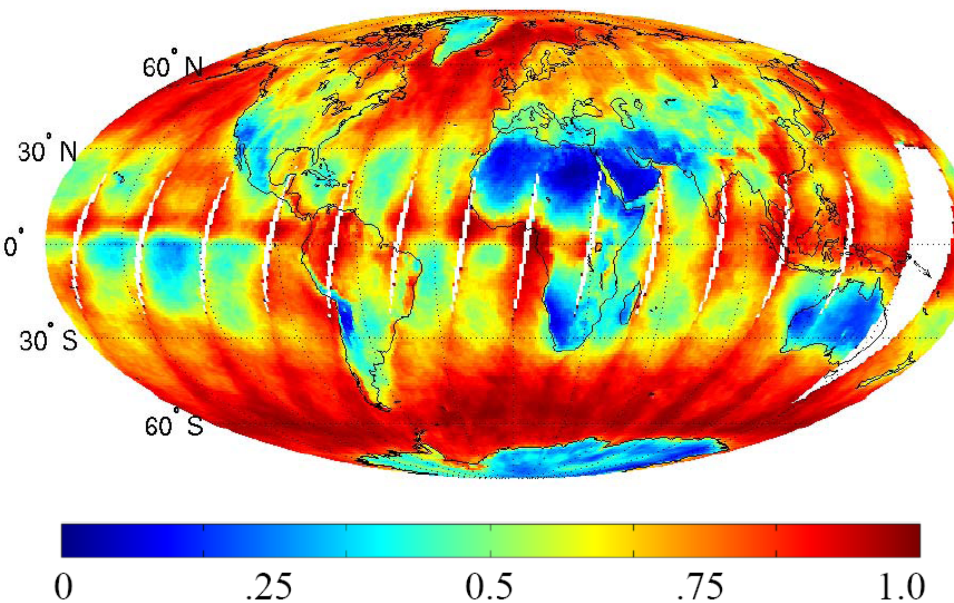
NOAA satellites equatorial crossing time changes

Menzel, 2010



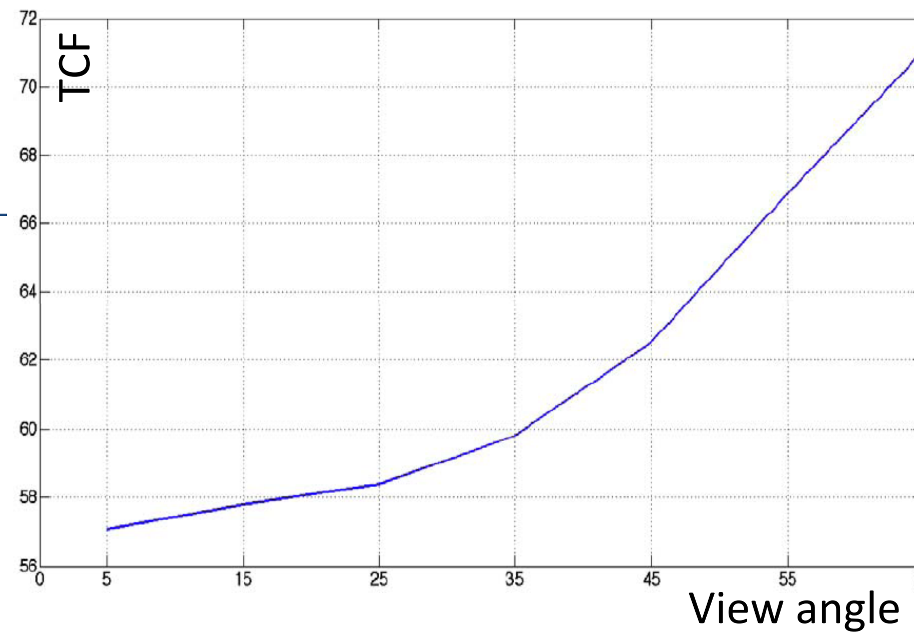
Data limitation: satellite observations

Dependence on view angle



Total cloud fraction: mean for every 16th day from MODIS data
(16 day orbit procession)
Maddux et al., 2010

Total cloud fraction: annual-mean for region 35°S – 35°N

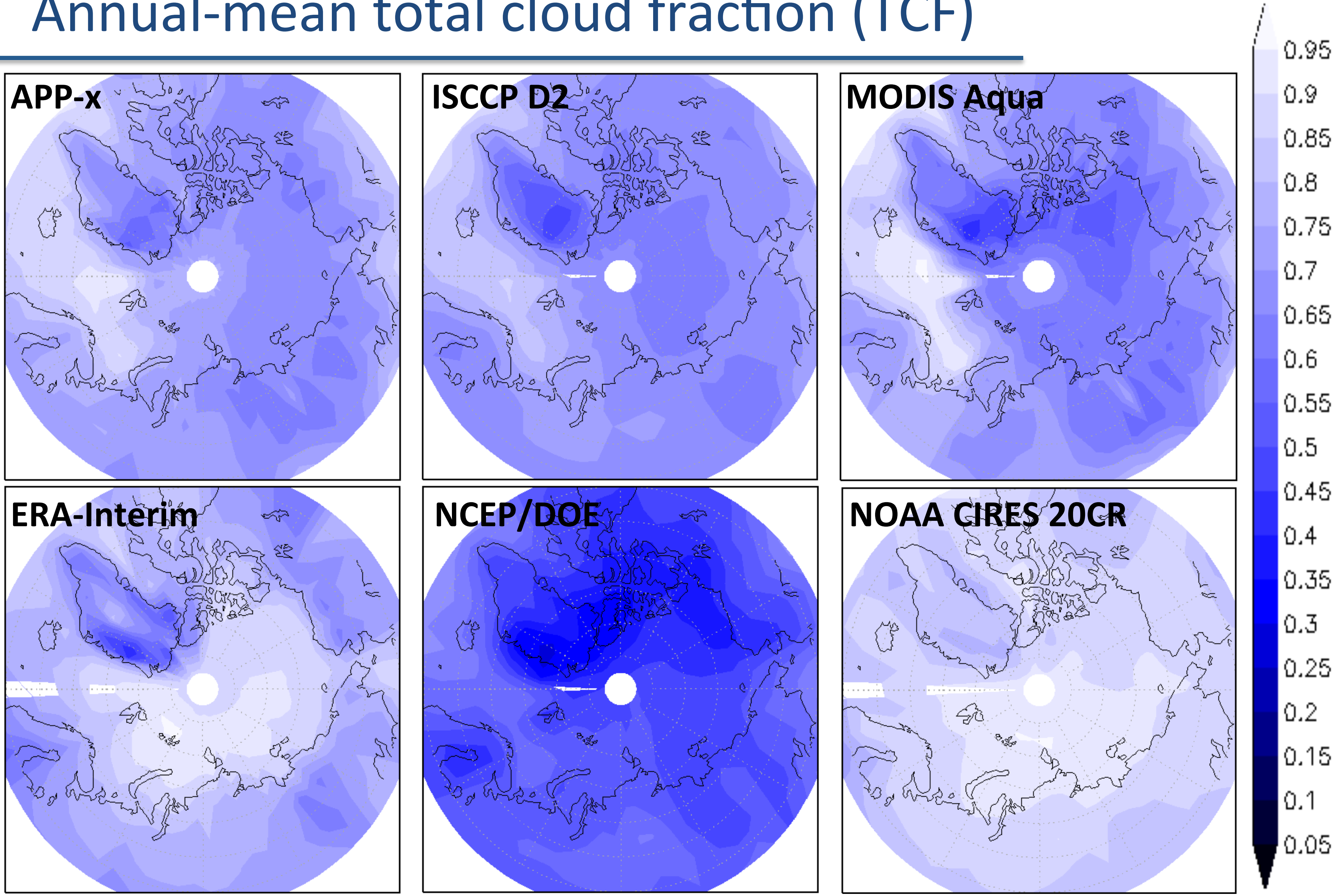


Objectives & Data

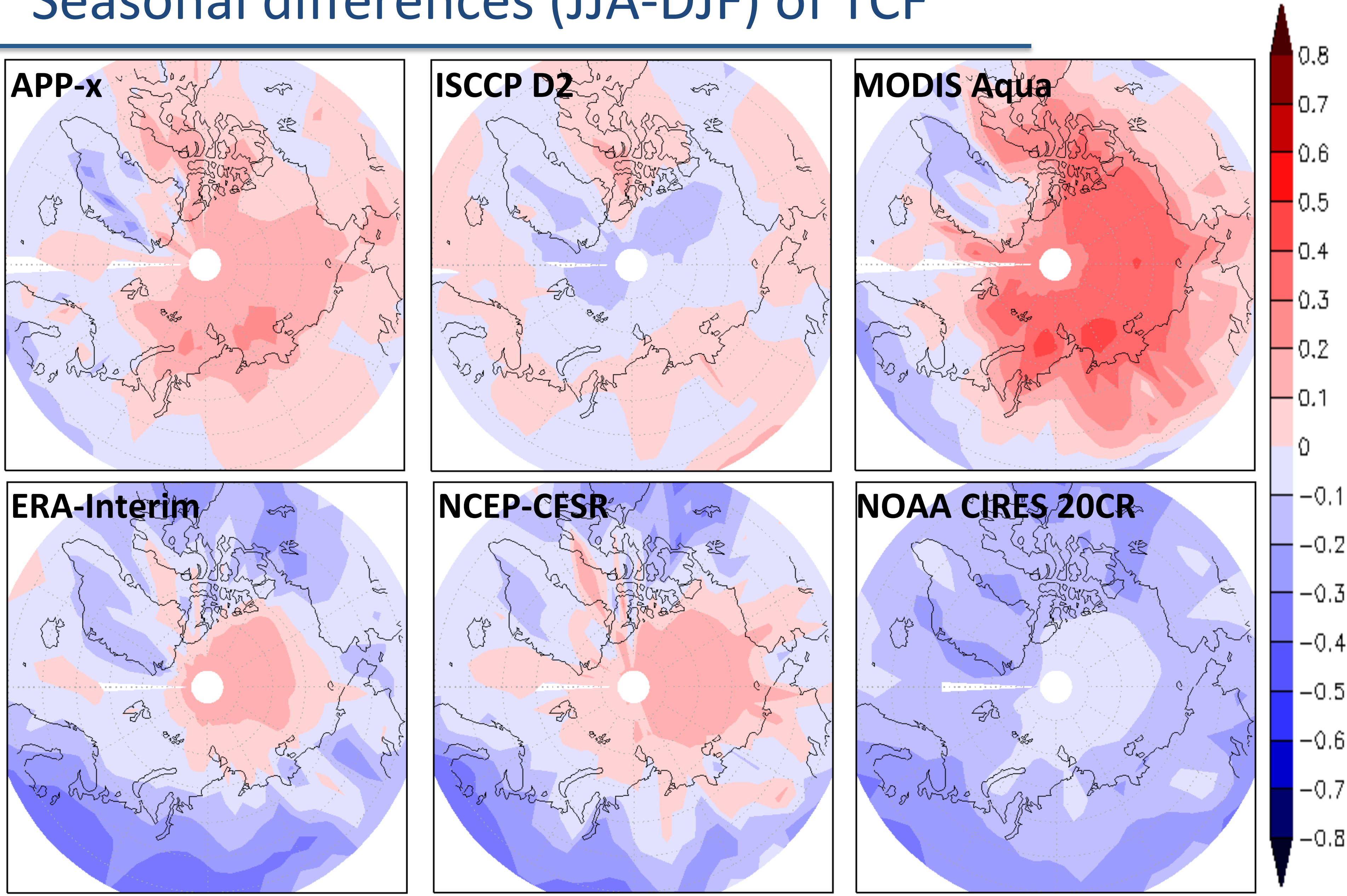
- Intercomparison of 16 cloud climatologies over the Arctic region north of 60°N was performed for different season, separately over the ocean and over land.

- The following data are used:
  - Satellite observations: APP-x, CERES SSF-product (on Aqua and Terra satellites), ISCCP D2, MODIS collection 5 (on Aqua and Terra satellites), PATMOS-x;
  - Ground-based visual observations: EECRA;
  - Reanalyses data: ERA-40, ERA-Interim, JRA-25, NCEP/NCAR, NCEP/DOE, NCEP-CFSR, NASA MERRA, NOAA CIRES 20CR.

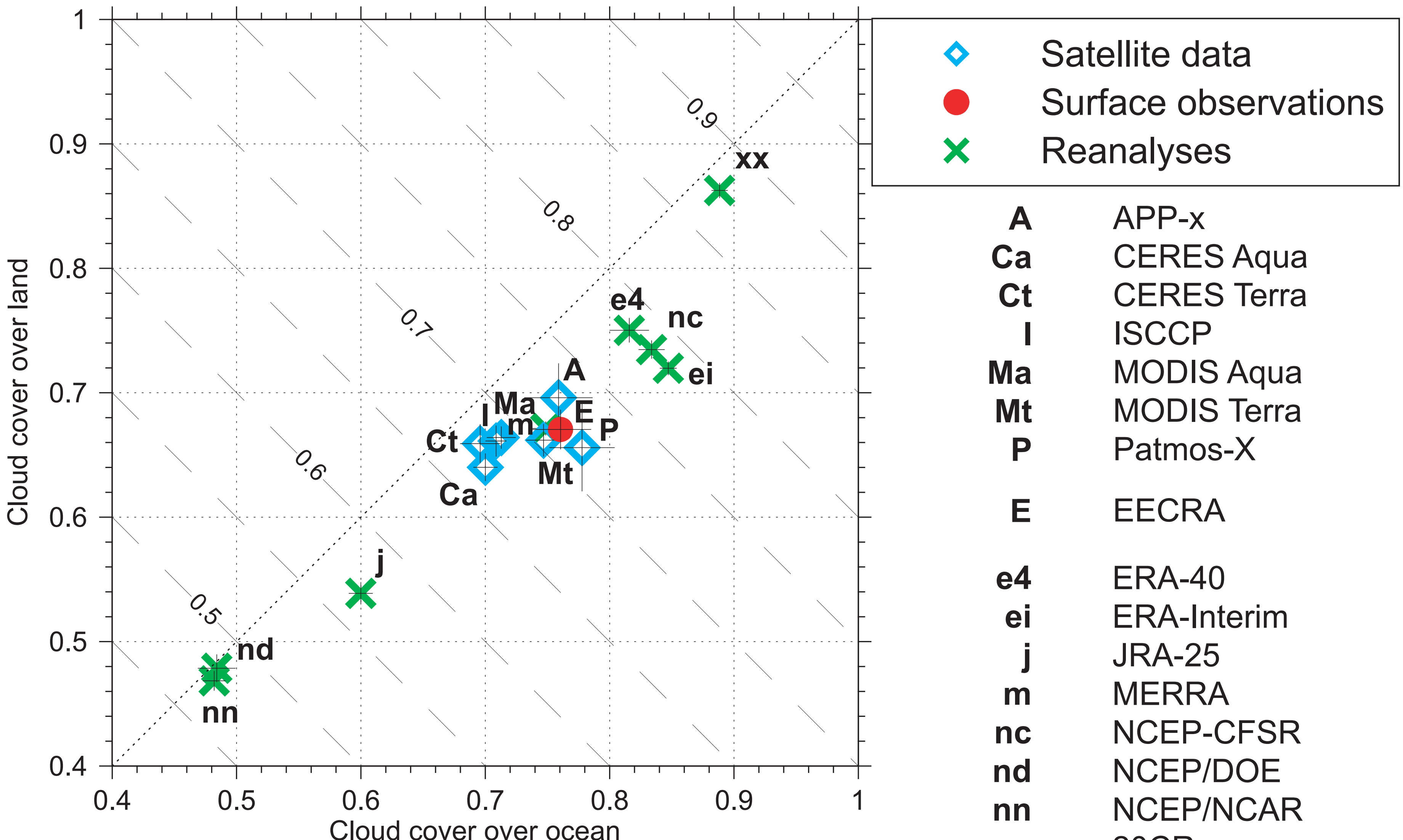
Annual-mean total cloud fraction (TCF)



Seasonal differences (JJA-DJF) of TCF

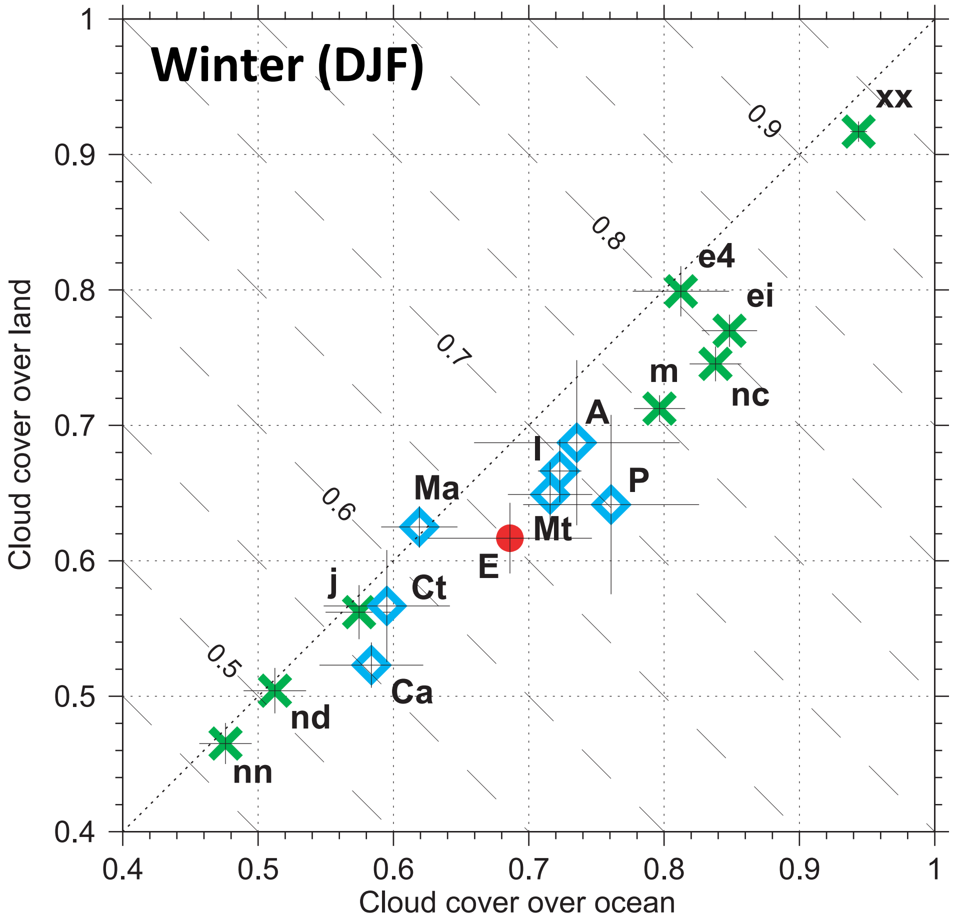


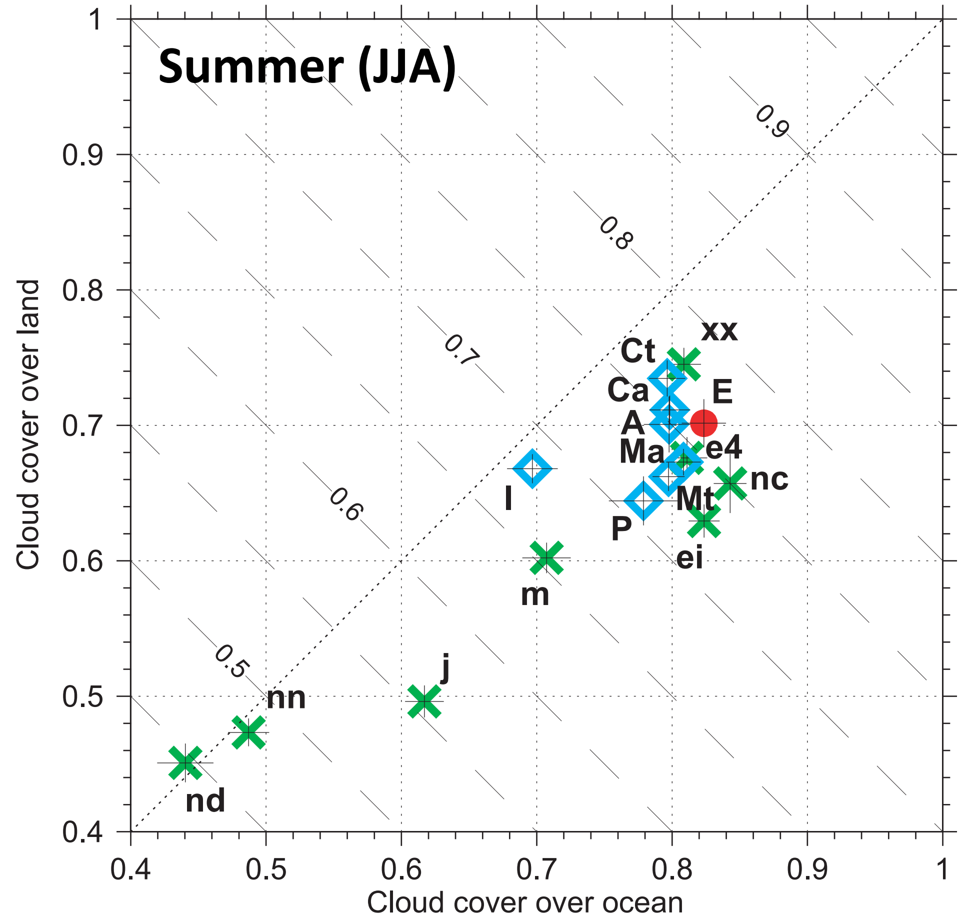
Annual-mean TCF over the Arctic (north of 60°N)



A	APP-x
Ca	CERES Aqua
Ct	CERES Terra
I	ISCCP
Ma	MODIS Aqua
Mt	MODIS Terra
P	Patmos-X
E	EECRA
e4	ERA-40
ei	ERA-Interim
j	JRA-25
m	MERRA
nc	NCEP-CFSR
nd	NCEP/DOE
nn	NCEP/NCAR
xx	20CR

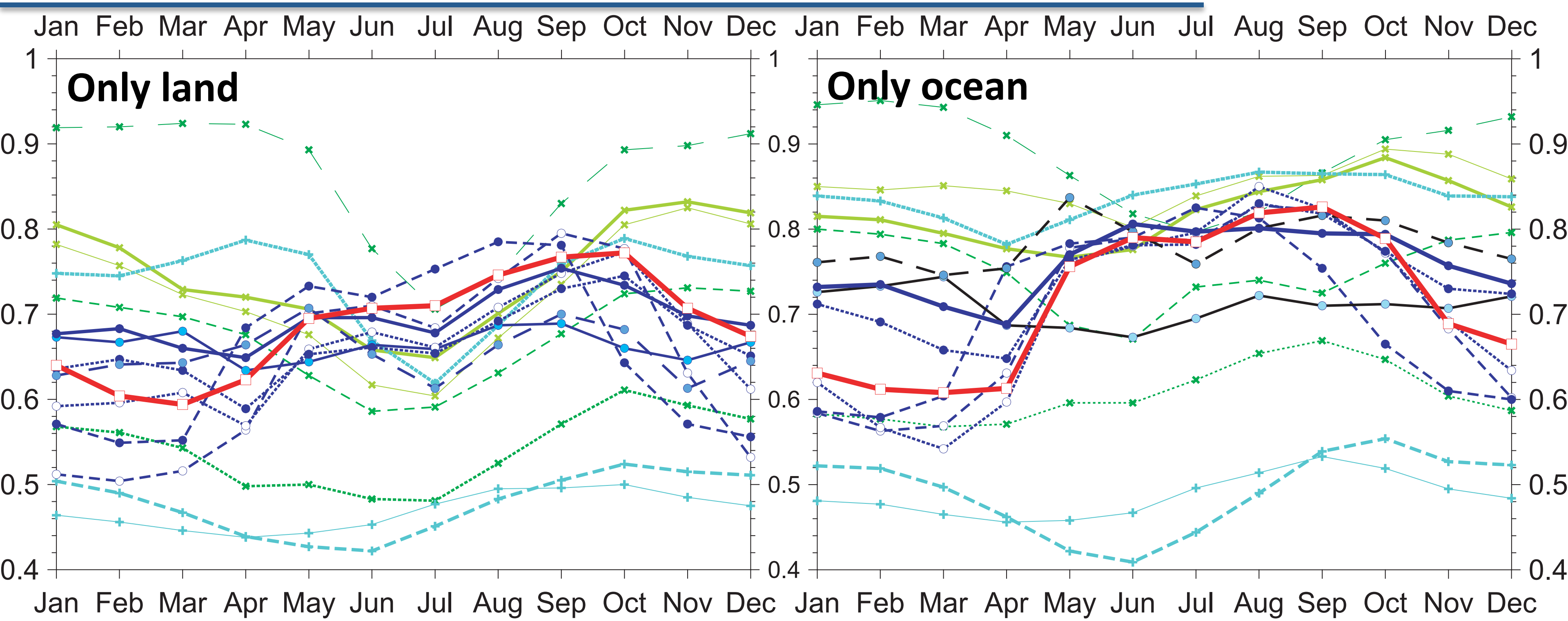
DJF- and JJA-mean TCF over the Arctic





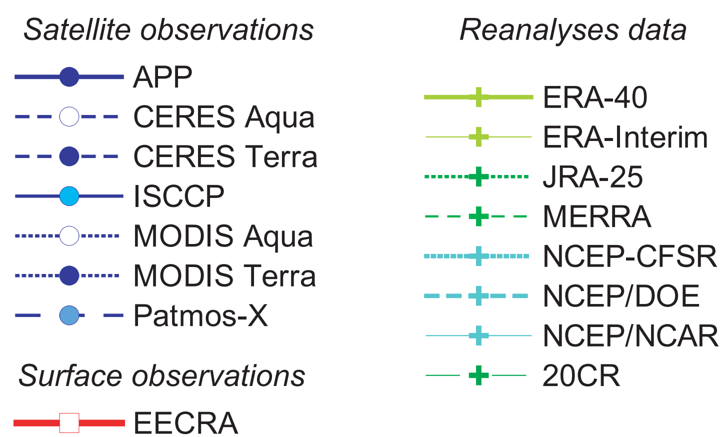
Different observations for TCF are in better agreement in summer than in winter and over the ocean than over land

Annual cycle of TCF over the Arctic



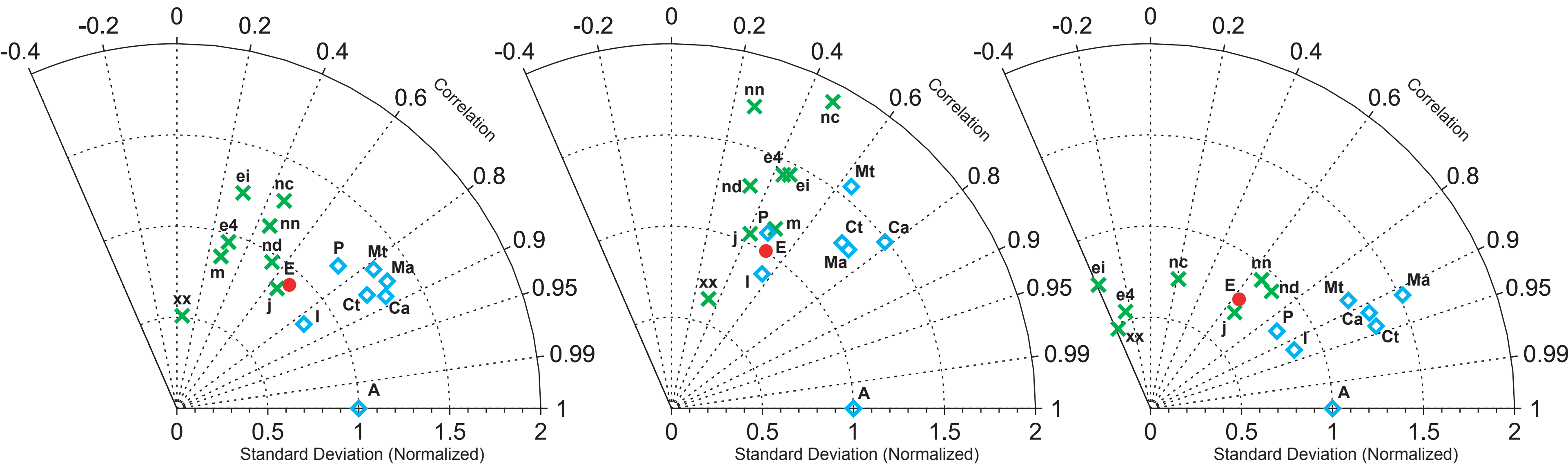
The TCF annual cycle is reverse to the sea-ice extent annual cycle according to the most of observations

In general, reanalyses are failed to reproduce this annual cycle



Taylor diagrams for annual-mean TCF

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

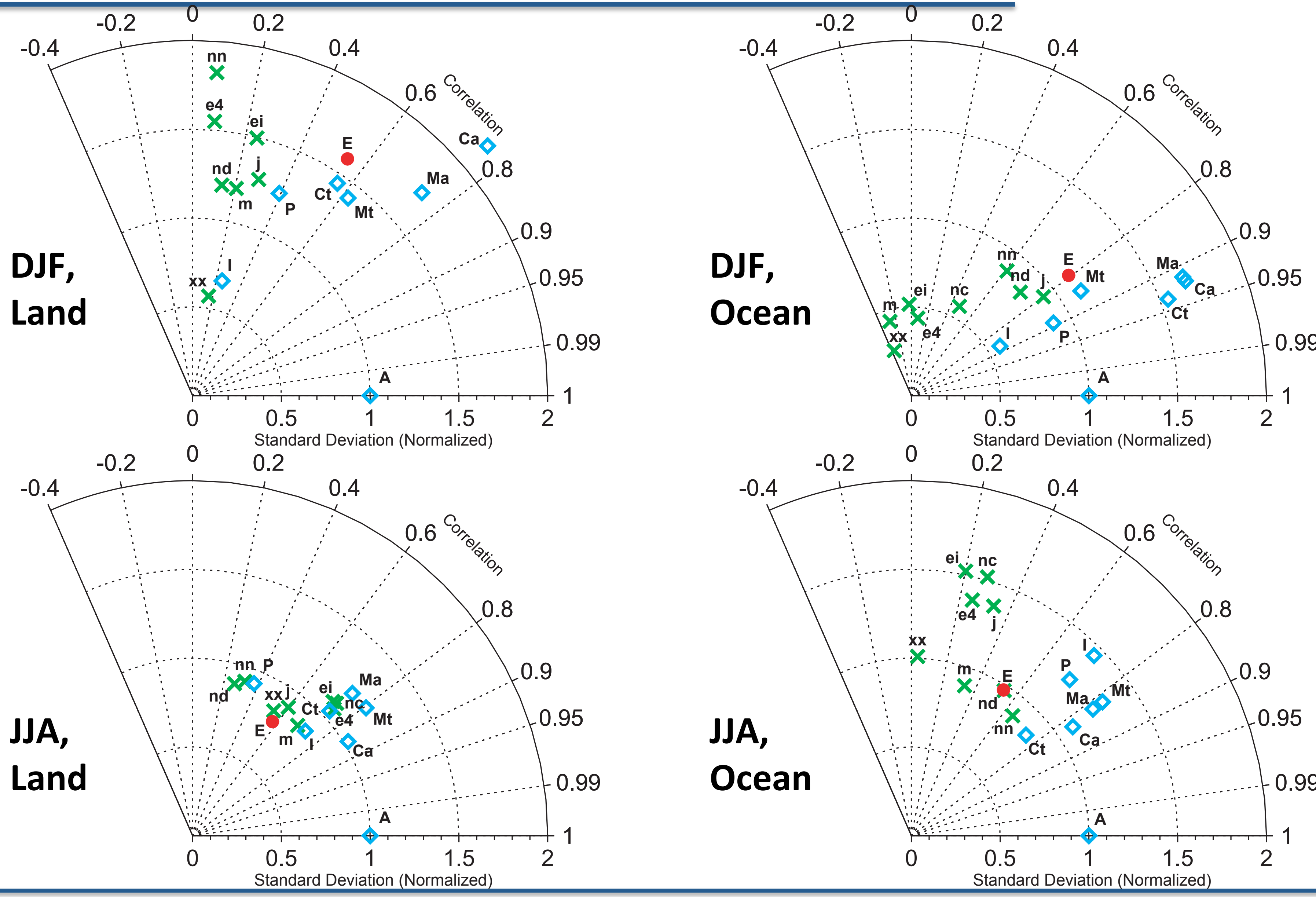


The reference dataset is APP-x

<u>Angle axis</u> corresponds to the coefficient of spatial correlation between cloudiness field from the reference and other data

<u>Radial axis</u> corresponds to the spatial standard deviations of cloudiness field from different data normalized by the reference spatial standard deviations

Taylor diagrams for DJF and JJA TCF



Causes of data discrepancies

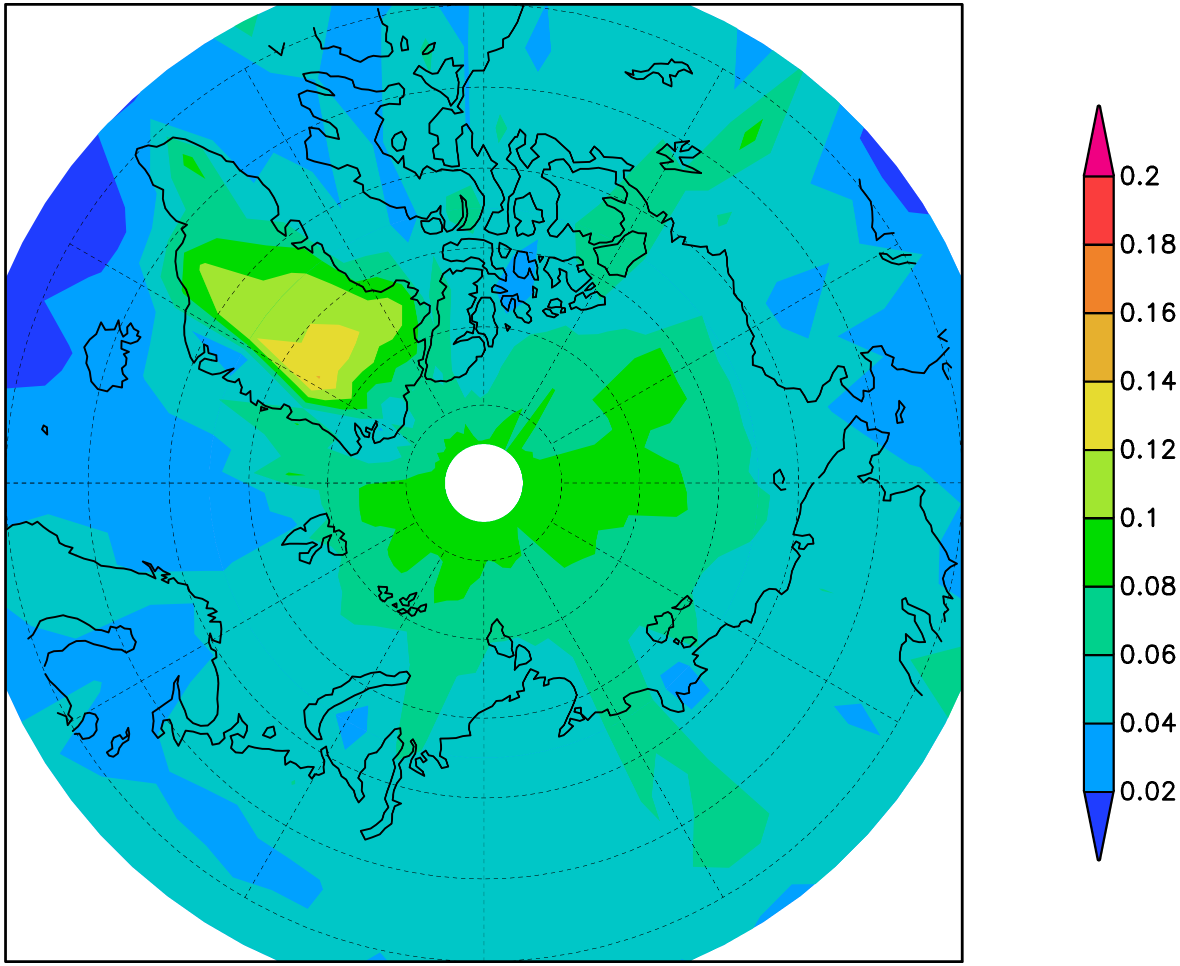
- Differences among cloud detection algorithms in different data

- Data inhomogeneity and accuracy

- The selection of averaging period

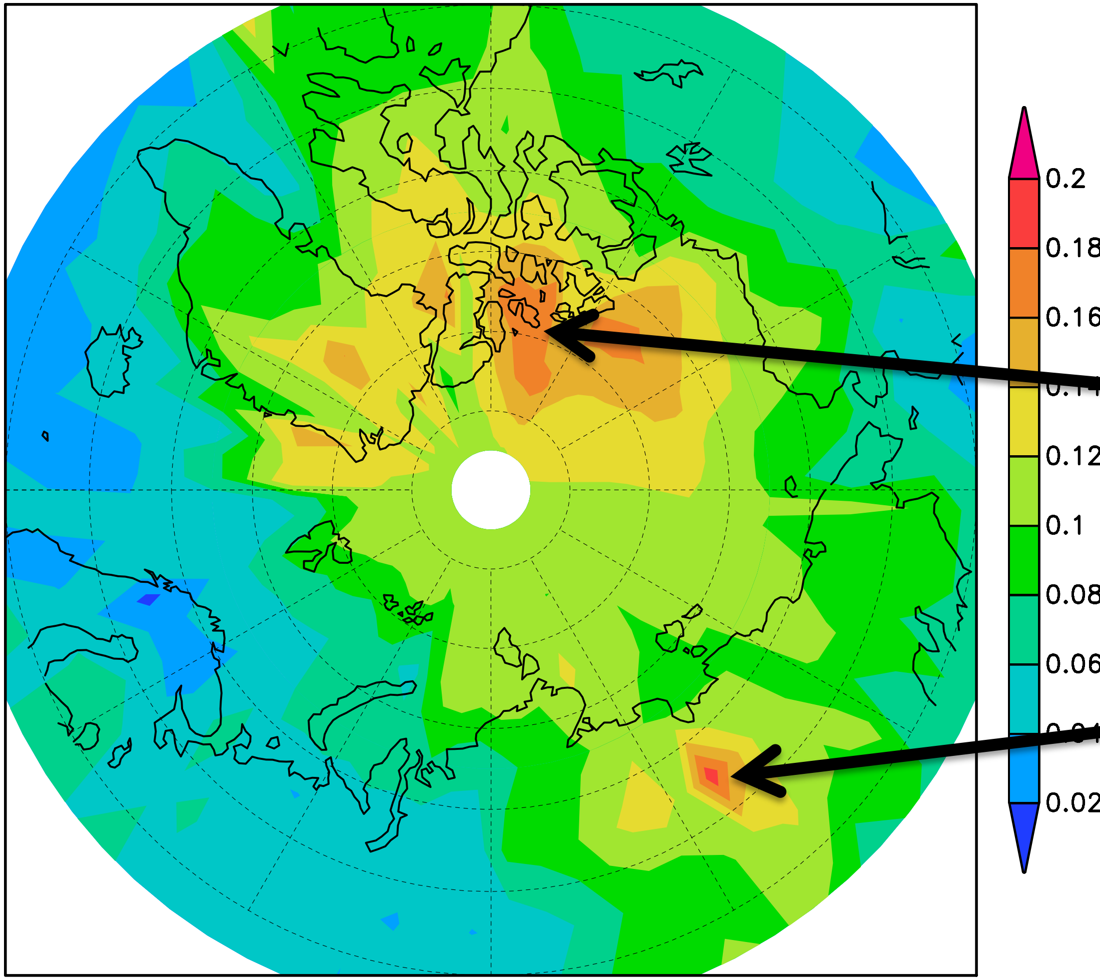
- Diurnal cycle of cloudiness

Inter-data standard deviation: summer

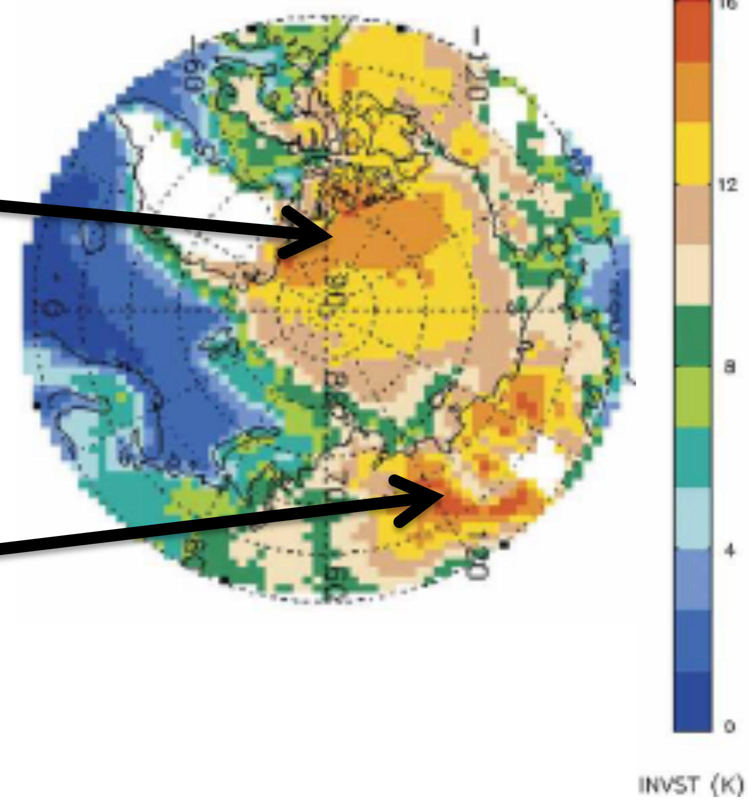


High inter-data standard deviation in summer is associated with high surface albedo

Inter-data standard deviation: winter



Winter temperature inversion strength (K)
Liu et al., 2006



High inter-data standard deviation in winter is associated with strong temperature inversions

Conclusions & Acknowledgements

- The Arctic annual-mean TCF is about 0.70±0.03 from different observational data. It is higher over the ocean (0.74±0.04) and less over land (0.67±0.03).
- Different observations for TCF are in better agreement in summer than in winter and over the ocean than over land.
- The TCF annual cycle is reverse to the sea-ice extent annual cycle according to the most of observations (with the maximum in August-October and the minimum in February-April).
- The main reason for observations discrepancies is differences in cloud-detection algorithms, especially when clouds are detected over an ice/snow surface (during the whole year) or over regions with the presence of strong low-tropospheric temperature inversions (mostly in winter).
- In general, reanalyses do not produce the arctic cloudiness well.

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