Reanalysis requirements for satellite data

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Outline

- Reanalysis at JMA
  - Overview of JRA-55
  - JRA-55 family
- Challenges of future reanalyses regarding satellite data
  - Data rescue: Early meteorological satellites
  - Homogenisation through recalibration and reprocessing
  - Improvements in observation operators
- The next Japanese reanalysis: JRA-3Q
- Summary

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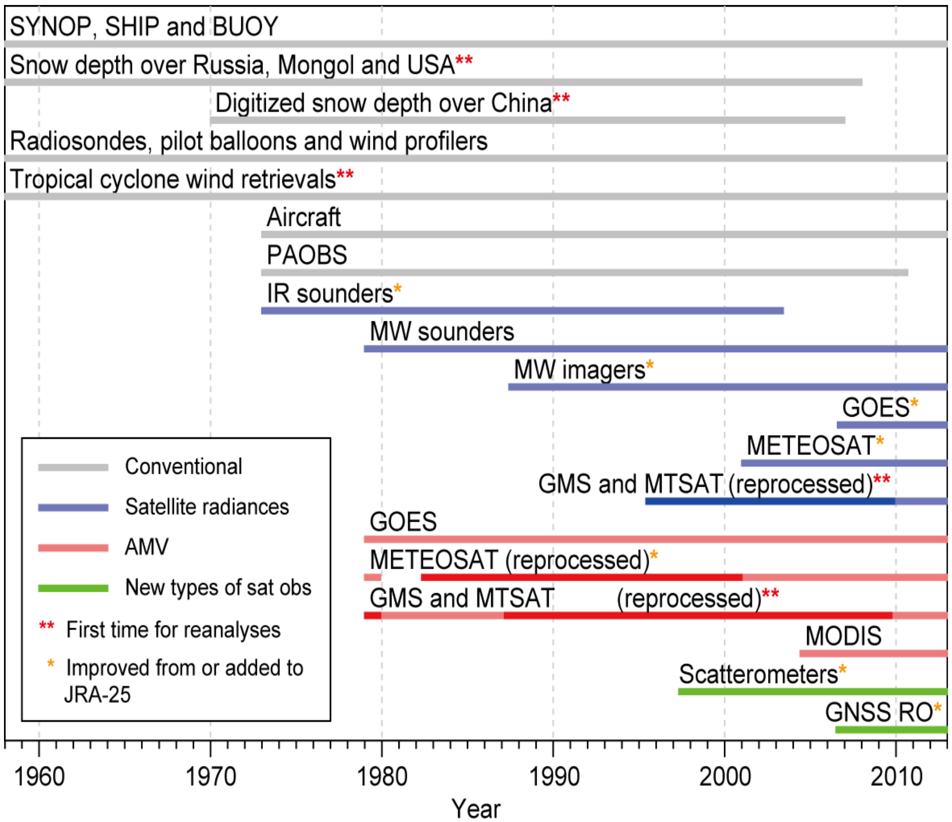
Reanalysis at JMA

- Reanalysis of past observations with a constant, state-of-the-art data assimilation system aims at producing a high-quality climate dataset.
- JRA-25 (1979-2004, JMA/CRIEPI) and JCDAS (2005-2014.1)
  - produced with JMA's NWP system as of 2004.3
- JRA-55 (1958-)
  - produced with JMA's NWP system as of 2009.12
- Reanalysis provides a basis for a wide range of climate research and application including
  - climate monitoring, verification of seasonal predictions, forcing for ocean models and CTMs, study of predictability etc.
- Continued improvement of reanalysis is crucial to advance climate research and improve climate services.

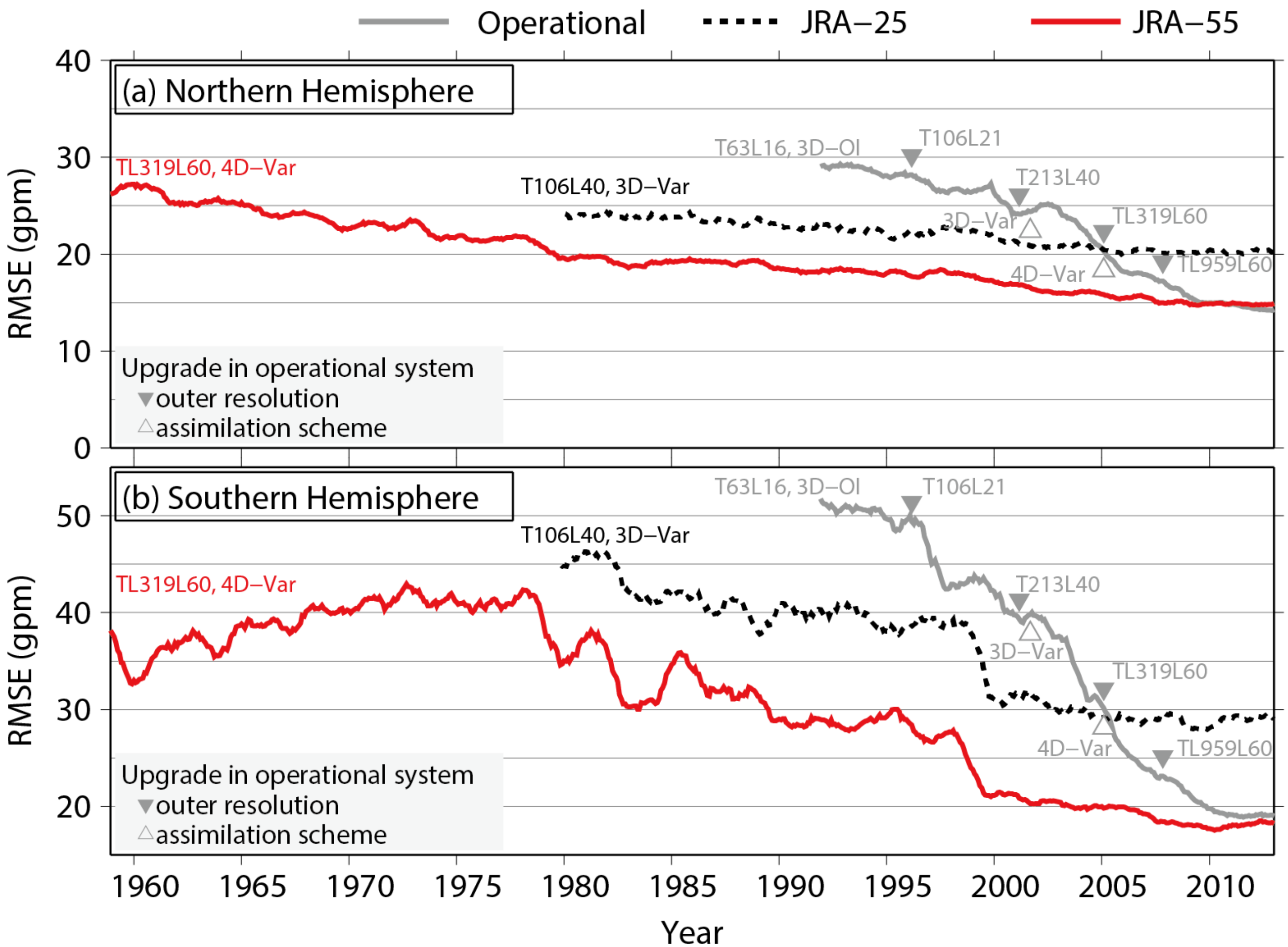
Observational data used for JRA-55



Chronology of types of observational data assimilated in JRA-55

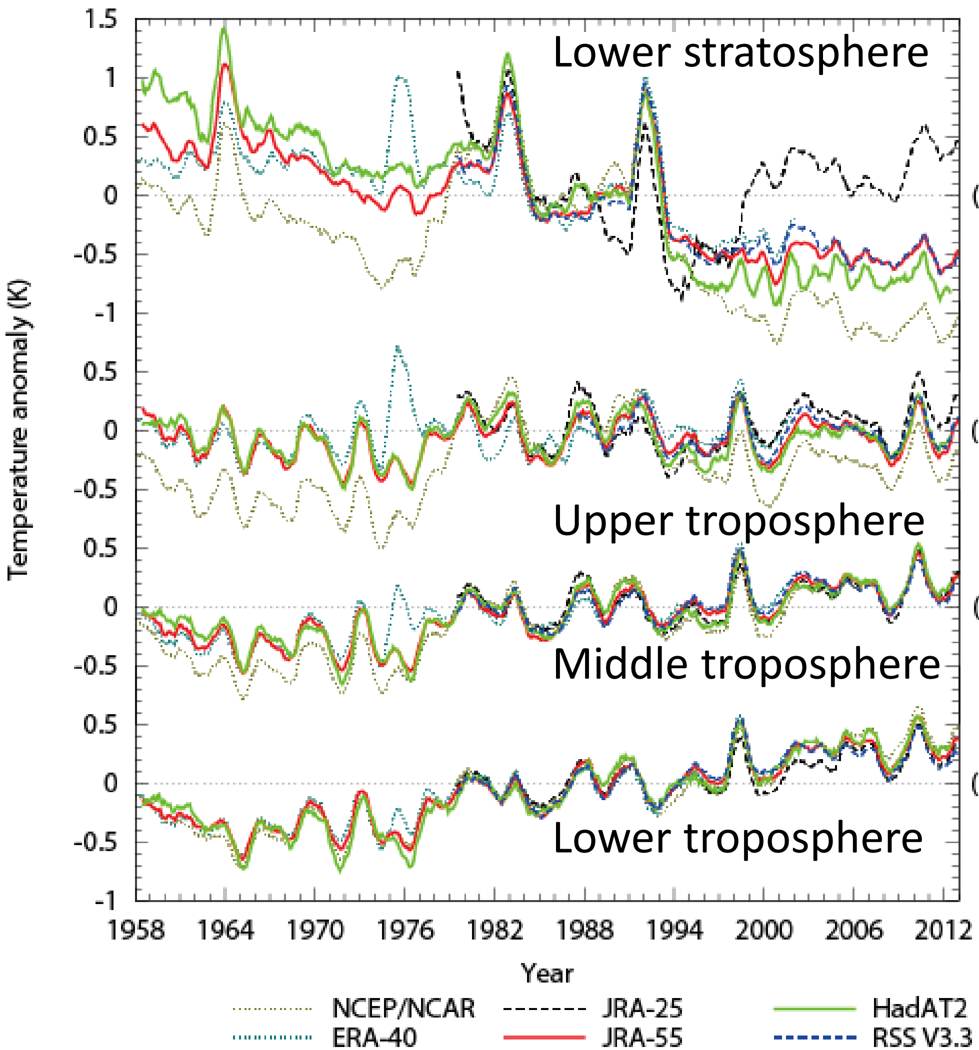
- The major data source
  - The ERA-40 observational dataset supplied by ECMWF
- Homogenization
  - Radiosonde Observation Correction using Reanalyses (RAOBCORE) v1.4 (Haimberger 2008)
- Reprocessed satellite observations
  - GMS, GOES-9 and MTSAT-1R (MSC/JMA)
    - Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring SCOPE•CM
  - METEOSAT (EUMETSAT), TMI (NASA and JAXA), AMSR-E (JAXA), QuikSCAT (NASA/PO.DAAC), AMI (ESA), GNSS/RO (UCAR)

Basic performance of the data assimilation system

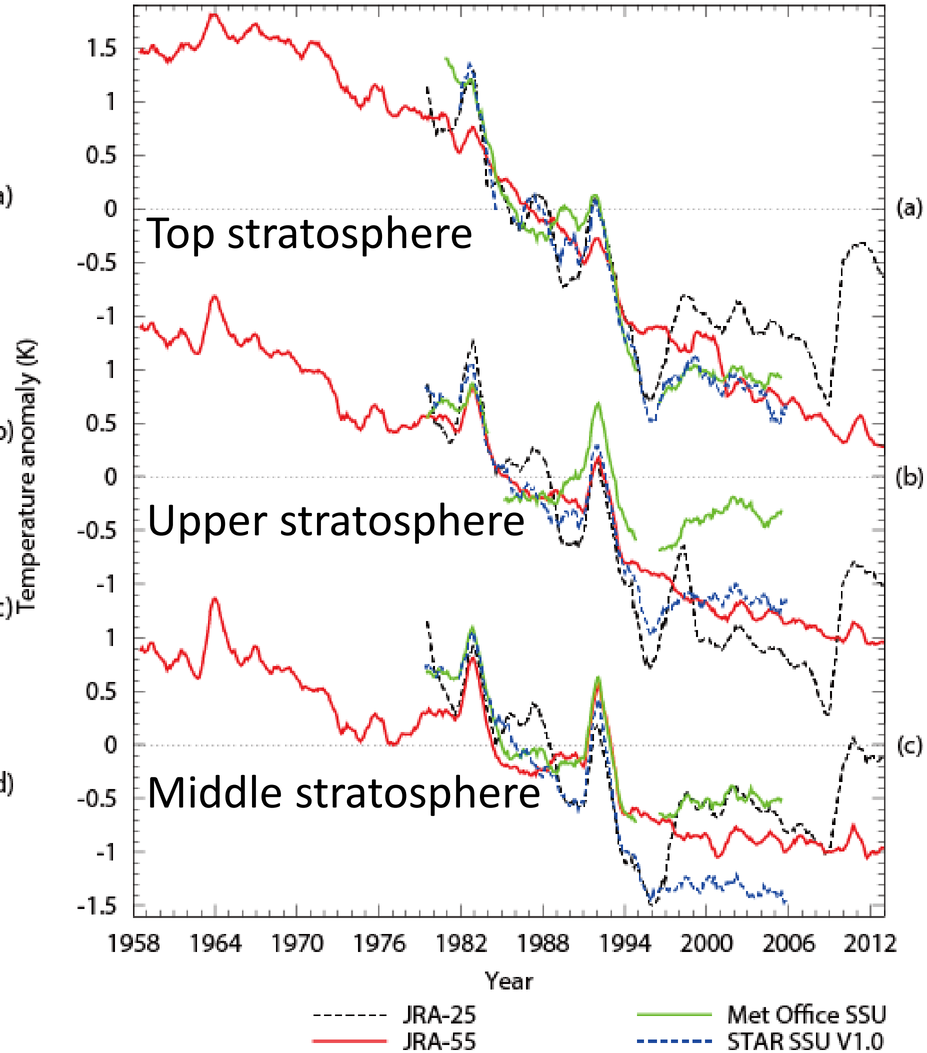


RMS errors of 2-day forecasts of geopotential height (gpm) at 500hPa verified against their own analysis

Impact of observing system changes
Global mean temperature anomaly

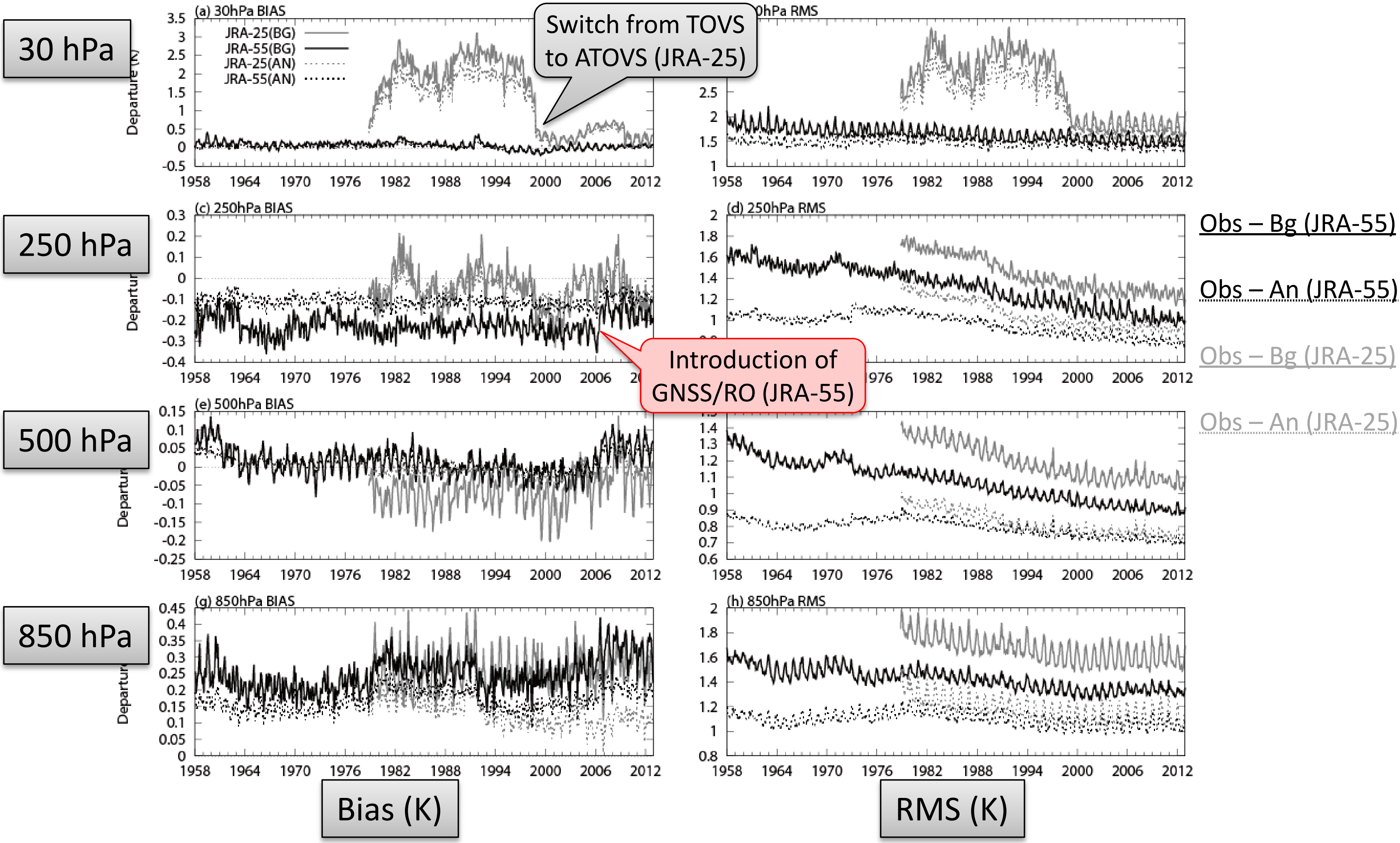


Twelve-month running mean temperature anomalies averaged over 82.5N to 82.5S

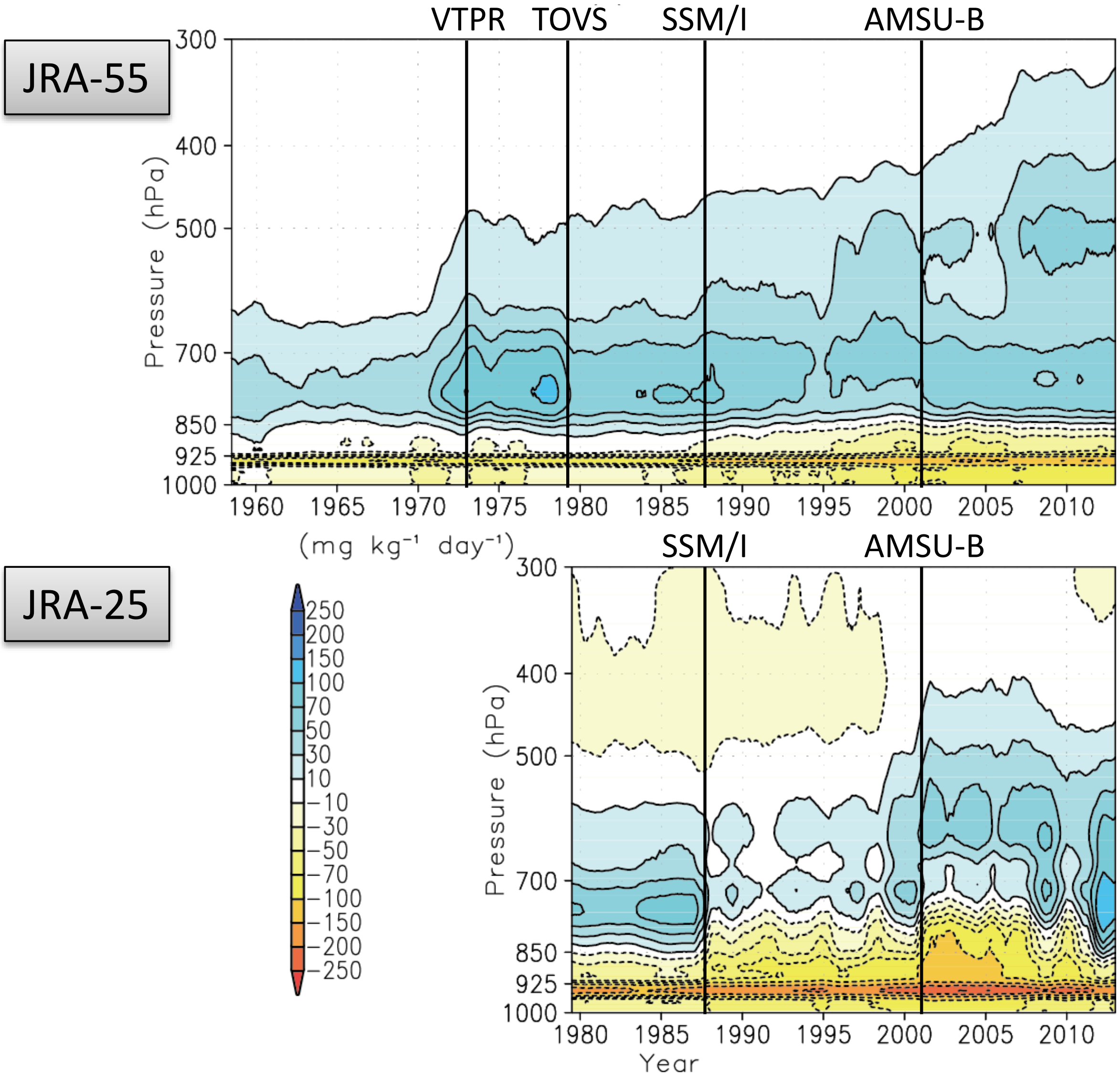


Twelve-month running mean temperature anomalies average over 75N to 75S

Impact of observing system changes
Departures of radiosonde temperatures



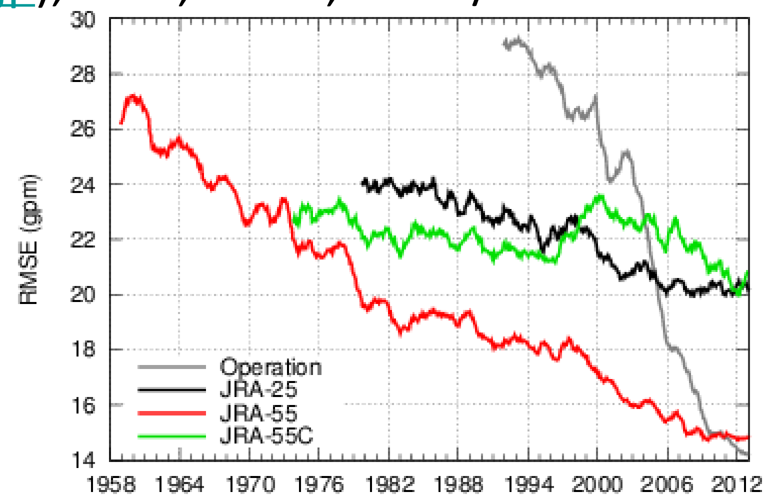
Impact of observing system changes
Global mean specific humidity increments



- JRA-55 has significant moistening increments above 850 hPa and drying increments below it.
- The moistening increments in the upper and middle troposphere tend to slightly increase as the number of observations from satellite humidity channels increases.

JRA-55 family

- To aid further study of the representation of low-frequency variability and trends in JRA-55, different types of product have been produced with the common base NWP system.
- JRA-55 (JMA)
  - Full observing system reanalysis
  - Available from JMA (http://jra.kishou.go.jp), DIAS, NCAR, NASA/ESGF
  - S. Kobayashi et al. (2015)
- JRA-55C (MRI/JMA)
  - Using conventional observations only
  - Available from DIAS, NCAR (coming soon)
  - C. Kobayashi et al. (2014)
- JRA-55AMIP (MRI/JMA)
  - AMIP type run
  - Available from DIAS, NCAR (coming soon)



RMS errors of 2-day forecasts of geopotential height (gpm) at 500hPa averaged over the northern hemisphere

Figure updated from C. Kobayashi (2014)

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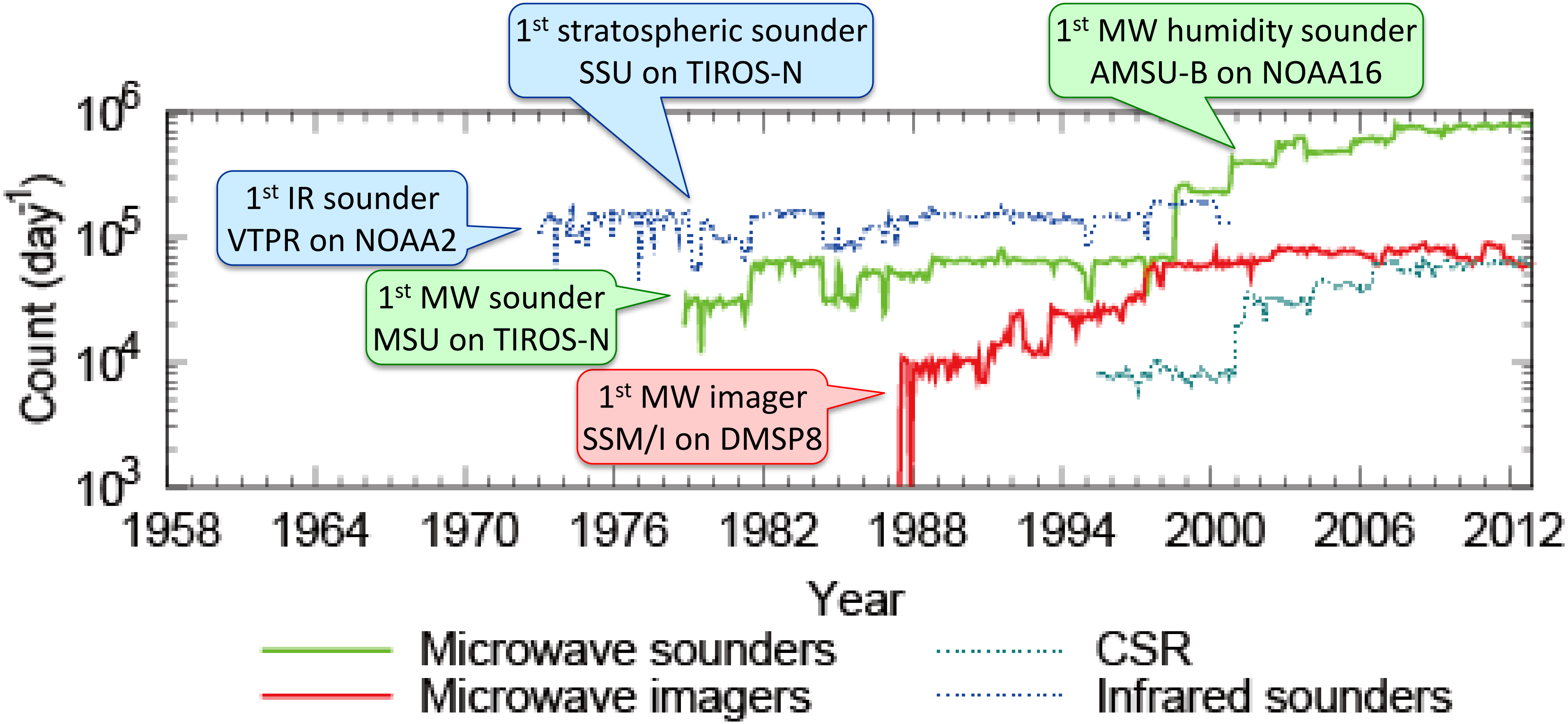
Challenges of future reanalyses regarding satellite data

- How to improve time-consistency of reanalysis while using changing observing systems?
- Availability of “anchoring observations” that constrain model biases is a key.
  - Data rescue of early meteorological satellites
  - Homogenisation through recalibration and reprocessing
  - More effective use of satellite data through improvements in observation operators such as RT models
    - Rain-affected radiances
    - Tropospheric channel radiances over land
    - Better characterization of spectral response functions (SRFs)

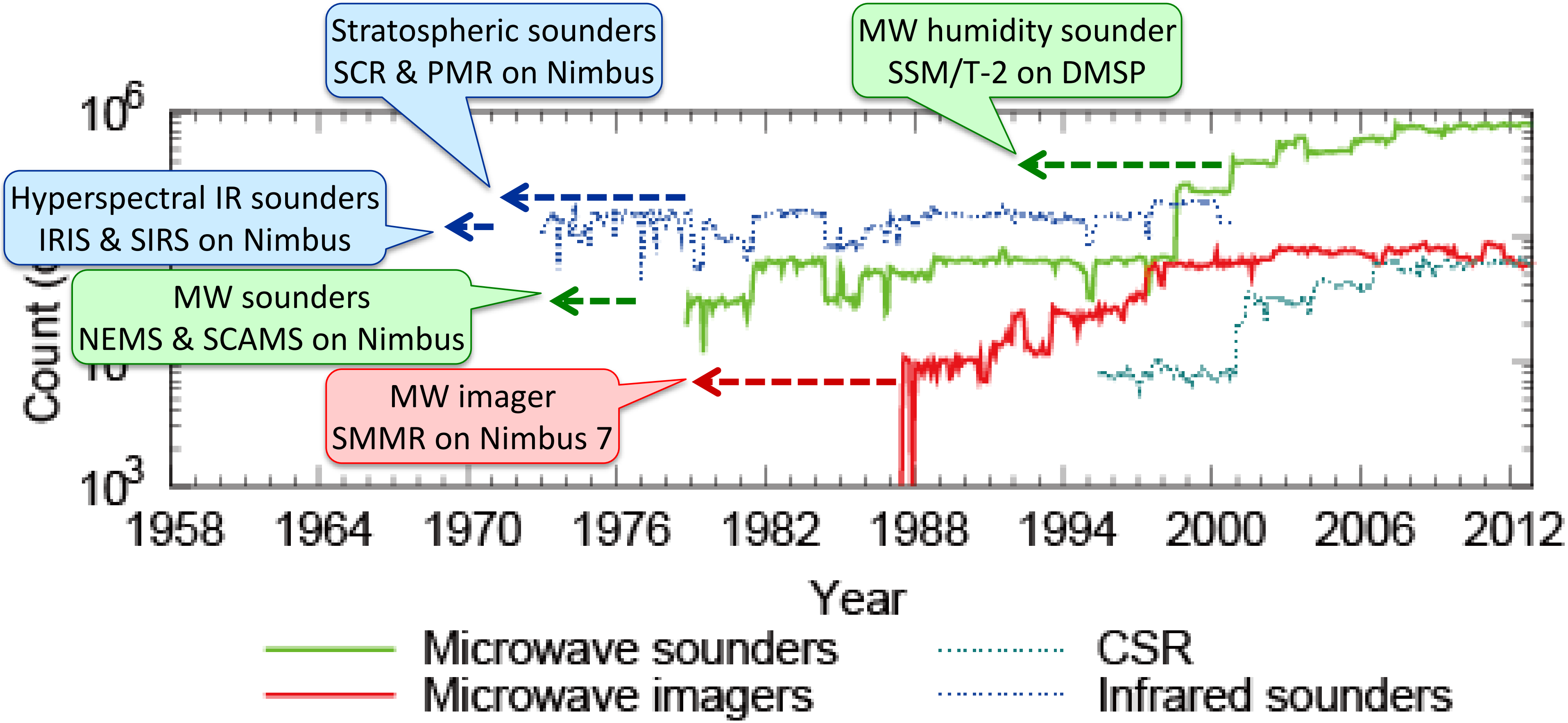
Data rescue: Early meteorological satellites

Current availability of satellite radiances



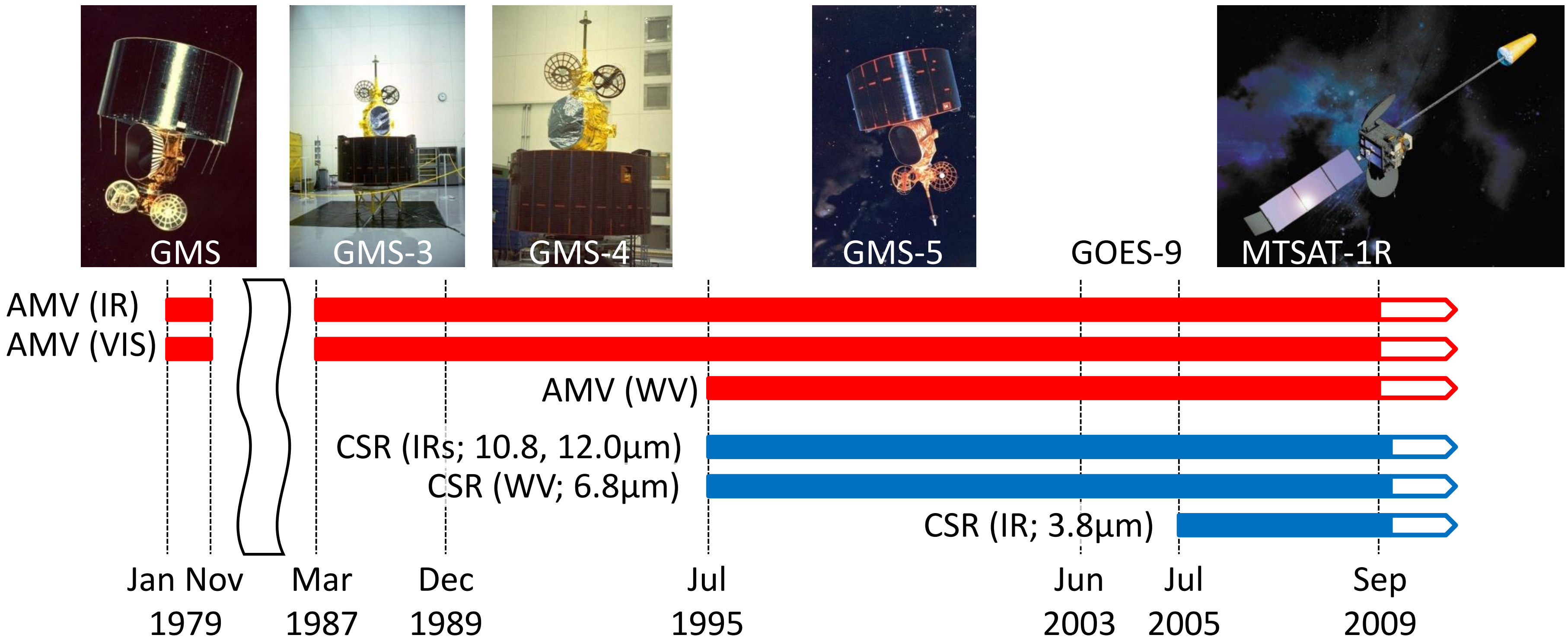
Data rescue: Early meteorological satellites

Possible extension through data rescue by ERA-CLIM, CM SAF and elsewhere



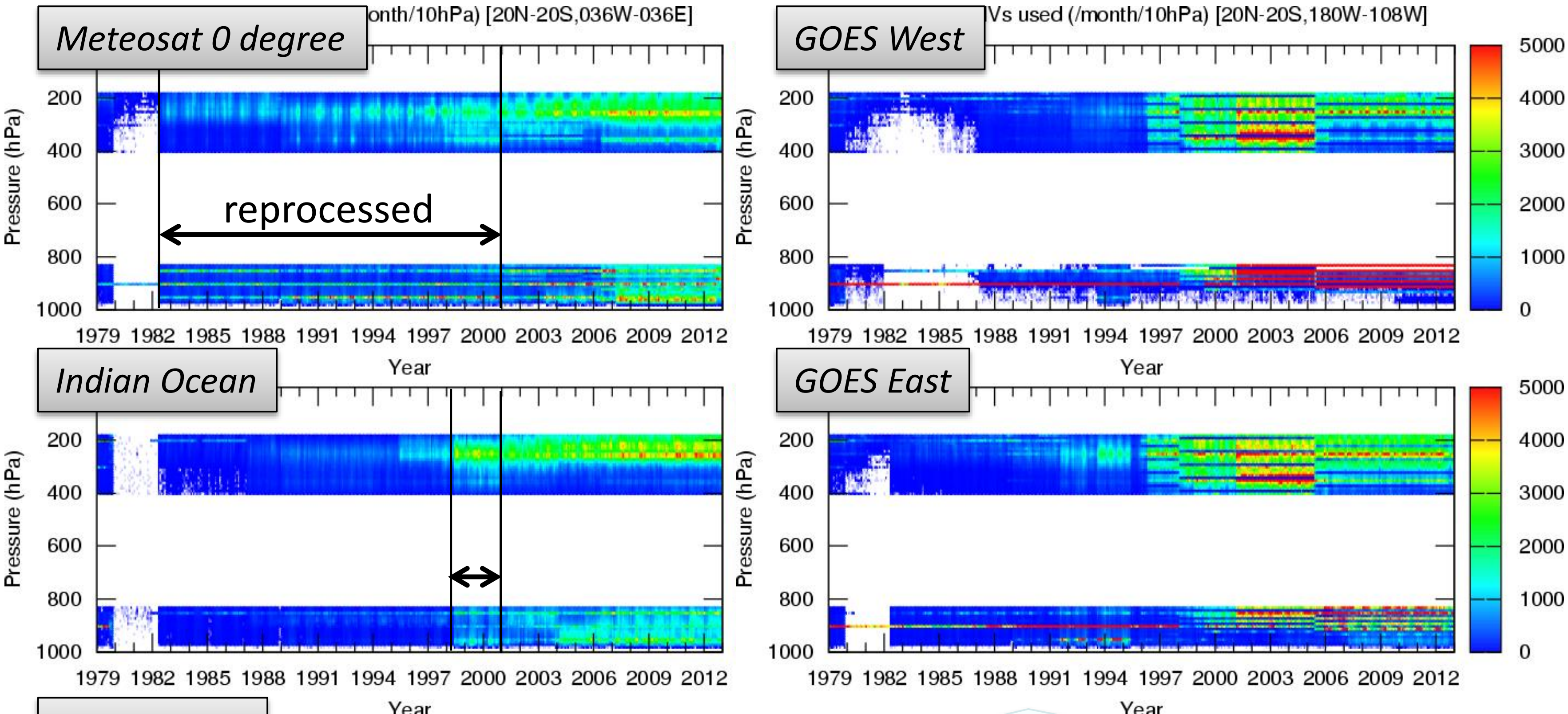
GMS/MTSAT reprocessing at JMA/MSC

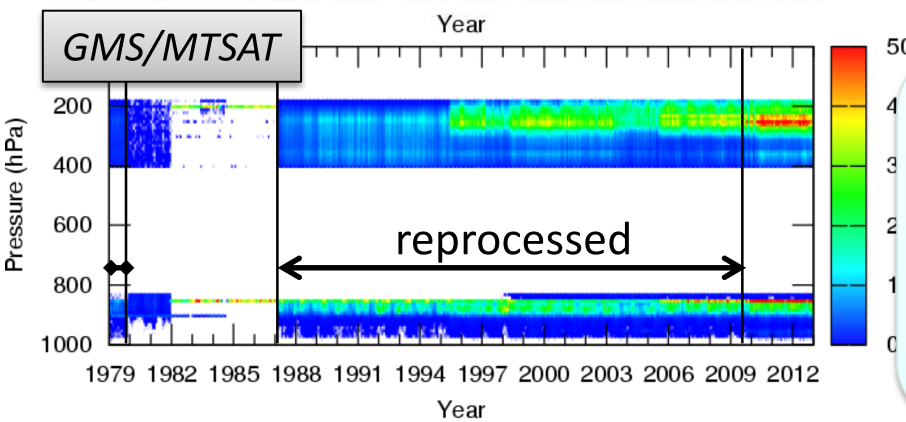
- JMA’s contribution to SCOPE-CM and reanalysis
  - **SCOPE-CM**: Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring



- The reprocessed AMVs and CSRs are provided to the Japanese 55-year Reanalysis (JRA-55)

The number of AMVs assimilated in JRA-55





"New" reprocessed data will be available for future reanalyses.

- CIMSS has recently reprocessed GOES AMVs from 1995 to mid 2013.
- Reprocessing of AMV/CSR/ASR is underway in the framework of SCOPE-CM phase 2 project (2014-2018)

Radiative transfer models used for JRA

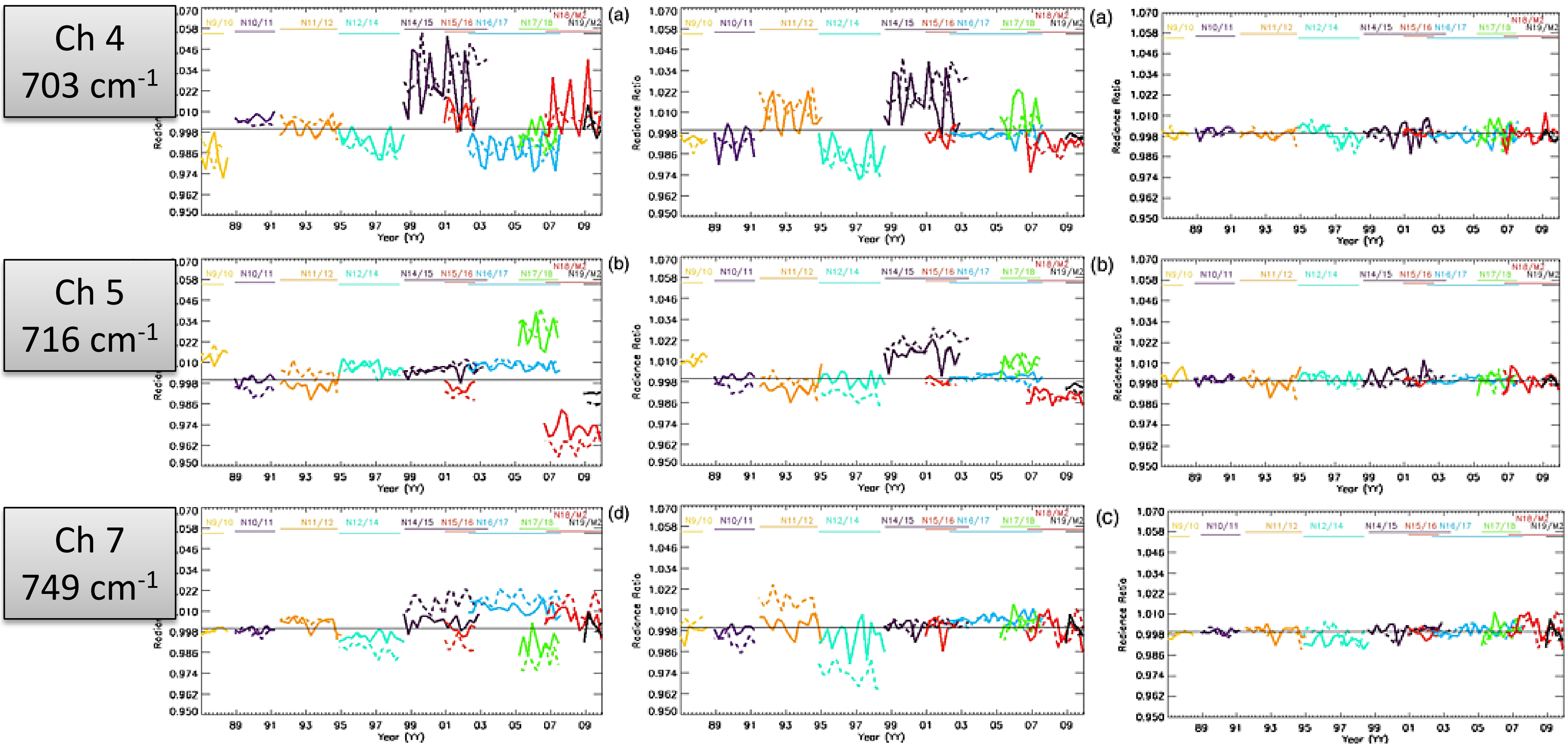
	RT model	Emissivity model (ocean)	Improvements from previous RT models
JRA-25	(TOVS) RTTOV-6	IR: ISEM MW: FASTEM-1	*RTTOV-6* • Addition of IR emissivity model for ocean *RTTOV-7* • Change to transmittance computations (RTTOV-7 predictors) • Inclusion of cosmic background radiation
	(ATOVS) RTTOV-7	IR: ISEM MW: FASTEM-2	*RTTOV-8* • Change to transmittance computations (RTTOV-8 predictors) • Microwave scattering code (not activated for JRA yet)
JRA-55	RTTOV-9	IR: ISEM MW: FASTEM-3	*RTTOV-9* • Change to transmittance computations (RTTOV-9 predictors) • Improvements to the atmospheric path length computation *RTTOV-10* • Land surface emissivity atlases
			• Inclusion of Zeeman effect • Refinements in LBL and layering for coefficient generation *RTTOV-11* • Variable GHG • HIRS shifted spectral response • SSU with variable cell pressure • etc.

From https://nwpsaf.eu/deliverables/rtm/

Spectral-response uncertainty

- Spectral response functions (SRFs) determine the altitudes where the instruments have their sensitivity.
- There is considerable uncertainty in SRFs for various instrument-specific reasons;
  - IR filter radiometers
    - Uncertainties and errors in the prelaunch SRF measurements
    - e.g. Chen et al. (2013) for HIRS
  - MW radiometers
    - Shifts, drifts and uncertainties in pass band center frequencies
    - e.g. Lu and Bell (2014) for MSU and AMSU-A
  - Gas correlation spectroscopy
    - Changes in gas cell pressures
    - e.g. Kobayashi et al. (2009); Nash and Saunders (2015) for SSU
- Better characterisation of SRFs is essential for accurate radiative transfer simulations.

SRF shifts for HIRS



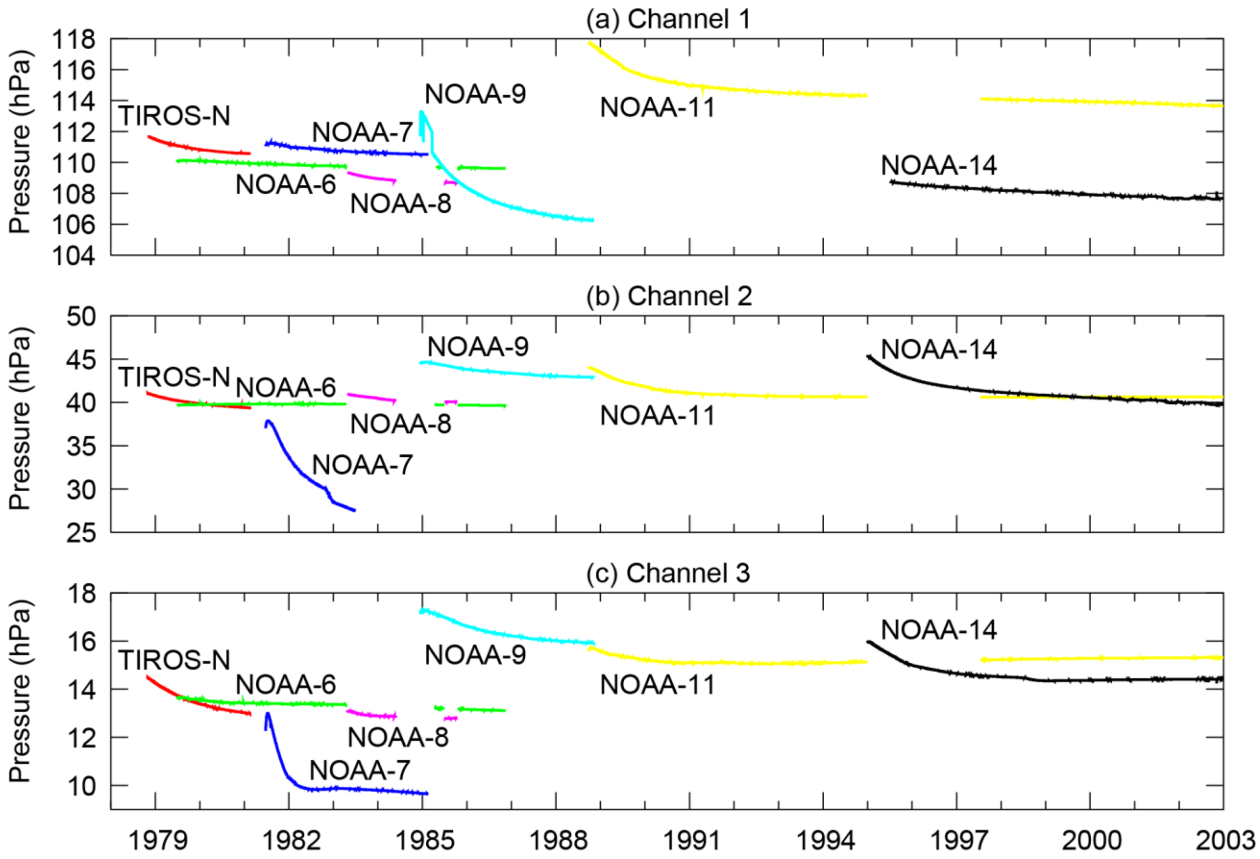
Inter-satellite biases → After accounting for the differences of prelaunch measured SRFs → After shifting the SRFs

Solid lines: SNO comparisons in the south polar region

Dashed lines: SNO comparisons in the north polar region

Chen et al., 2013: *J. Geophys. Res.*, **118**, 5190-5203.

SSU
Sealing problem of pressure modulator cell



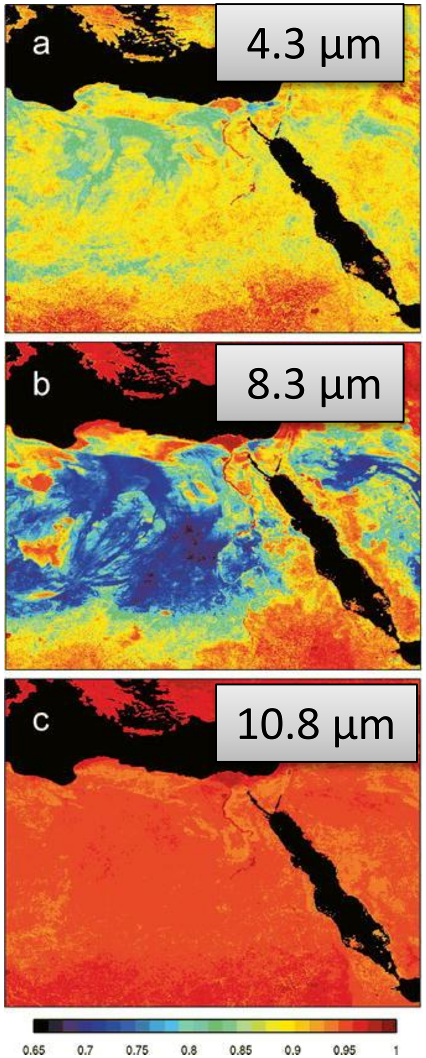
Time series for "effective" cell pressures deduced from the frequency of oscillation of the modulator cell

Values are adjusted to best fit to the Met Office's 6-monthly estimates.

A sealing problem caused cell pressures to increase during storage on the ground and then to decrease after launch.

Assimilation of tropospheric channels over Land

- In JRA-55, tropospheric channels are underused over land due to less accurate RT simulations, which stems from use of the constant emissivity (0.9) for both IR and MW.
- Land surface emissivity atlases are now available in the latest RTTOV, which paves the way for assimilating more tropospheric channels.
- Use of these atlases for early satellites might pose a challenge because they are based on recent observations (MODIS for IR and SSM/I for MW), but should be explored.



Emissivities for Aug 2003

Seemann et al., 2008: *J. Appl. Meteor. Climatol.*, **47**, 108-123.

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The next Japanese reanalysis

- **JRA-3Q** (pronounced as "Thank you!" in Japanese)
  - Japanese Reanalysis for Three Quarters of a century
- Provisional specifications
  - Atmospheric reanalysis from 1948? to present
  - Resolution: TL479L100, top level at 0.01 hPa
  - New boundary conditions and forcing fields
    - COBE-SST2 (from the beginning to 1981)
    - MGDSST (satellite-based SST from 1982 onward)
  - New observations
    - Observations newly rescued and digitised by ERA-CLIM et al.
    - Various reprocessed satellite observations
    - Improved tropical cyclone retrieval winds
- Aiming at starting production by FY2018

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Summary

- A significant progress has been made in time-consistency of reanalysis, but there are still considerable uncertainties that stem from model biases.
- “Families” of reanalyses could provide a useful means of assessing the time-consistency.
- A key to improve the time-consistency is availability of “anchoring observations” that constrain model biases.
  - Data rescue of early meteorological satellites
  - Homogenisation through recalibration and reprocessing
  - More effective use of satellite data through improvements in observation operators such as RT models
- Continuation of these efforts is essential for further improving quality of future reanalyses.