EUMETSAT EPS-Second Generation
3rd User Consultation Meeting

# Benefits of a Microwave Imaging (MWI) Instrument

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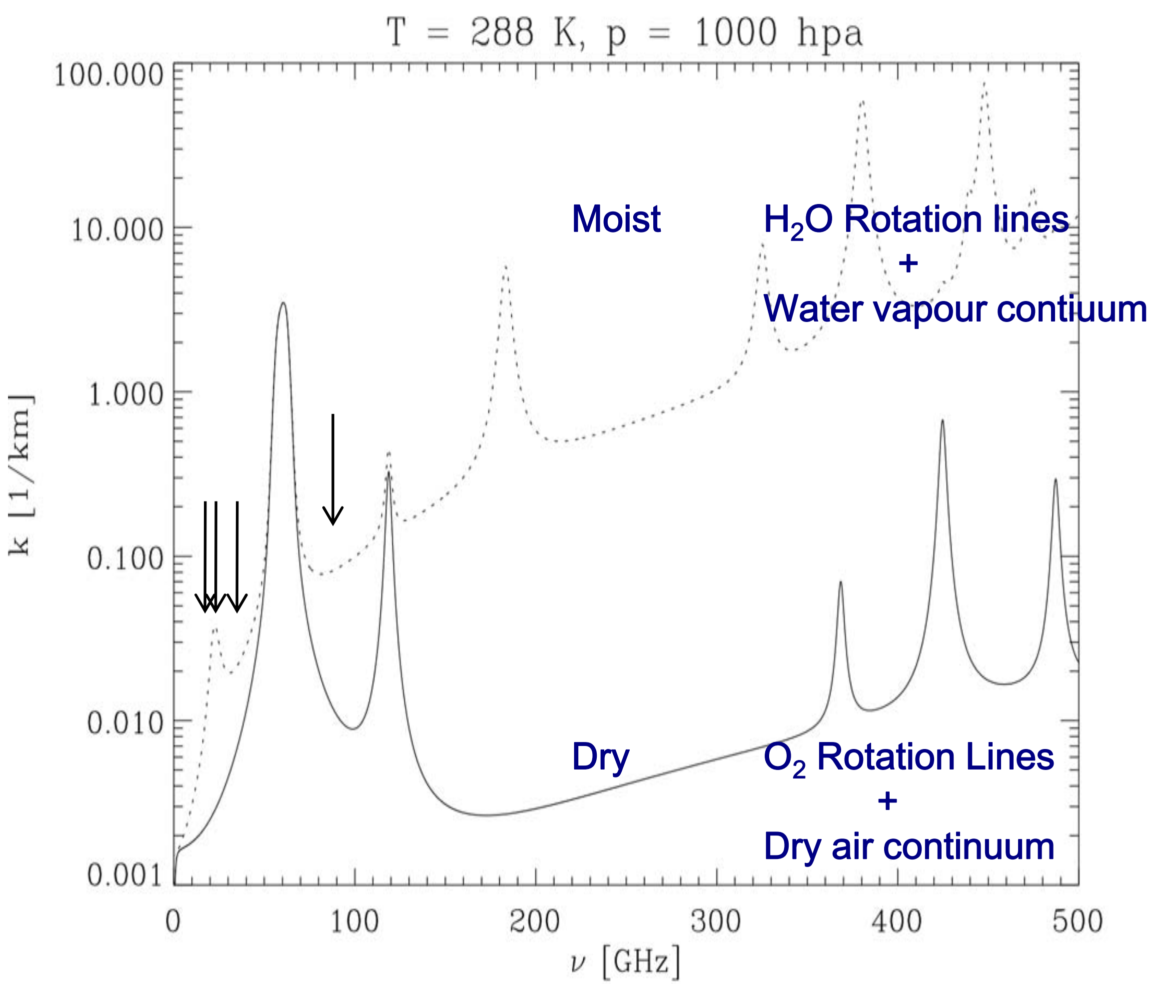
ECMWF

# Outline

- **Introduction**
  - Channels, sensitivities and instruments
  - Operational series (past, present and future)
- **Current Use at NWP Centres**
- **The Impact of MWI data in NWP**
  - Clear sky
  - All sky
  - JMA mesoscale DA
- **Other Applications**
  - Reanalysis (& **CM_SAF**)
  - Sea ice analysis (**OSI-SAF**)
  - Hydrology (**H-SAF**)
- **Future Directions**
- **Summary**

# Microwave Imager Data
# Channel locations




MWI instruments normally have channels at :

- 19, 22 , 37, 85 GHz as a minimum (*eg* SSMI) (↓)

Can be supplemented by :

- **lower frequency channels** at 6.8 GHz and 10.7 GHz (*eg* AMSR-E and Windsat)
- **sounding channels** at 50-60 GHz (T) and / or 183 GHz (Q) (*eg* SSMIS). 118 GHz is a candidate in MWI MRD.
- **additional window channels** 100, 166 GHz (candidates in current MWI MRD)



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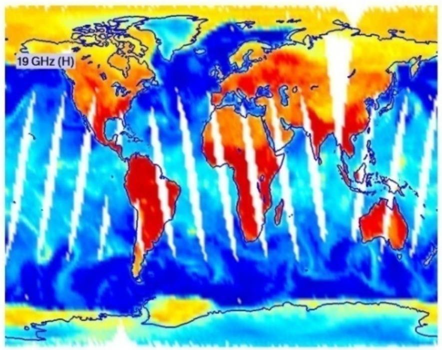
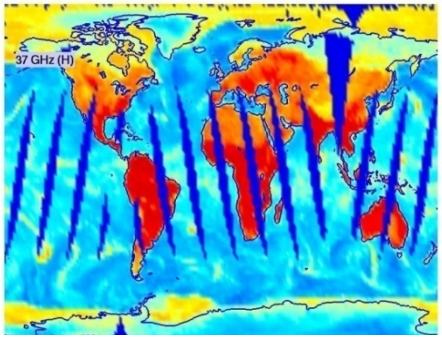
# Microwave Imager Data
# Measured brightness temperatures

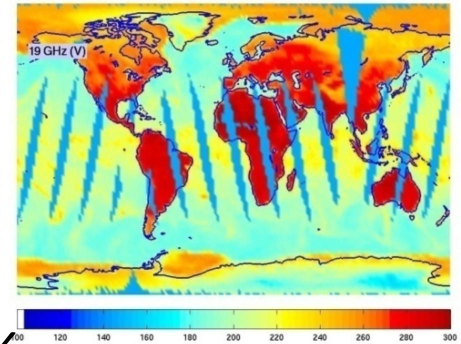
19 GHz (H pol)

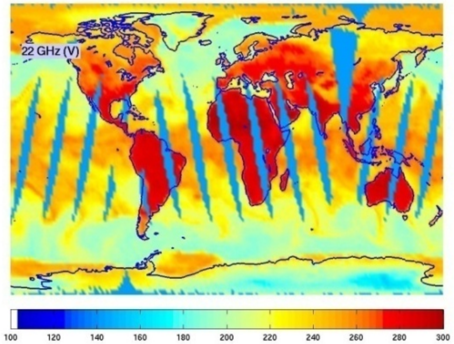


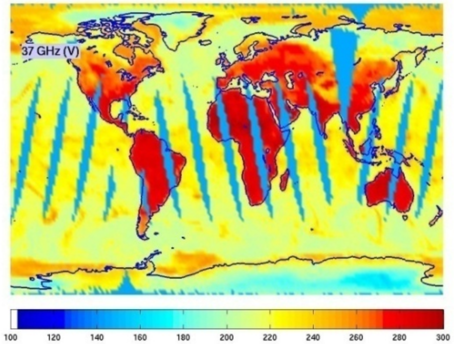

Measurements obtained over 12 hours by F-16 SSMIS

37 GHz (H pol)




100K 300K

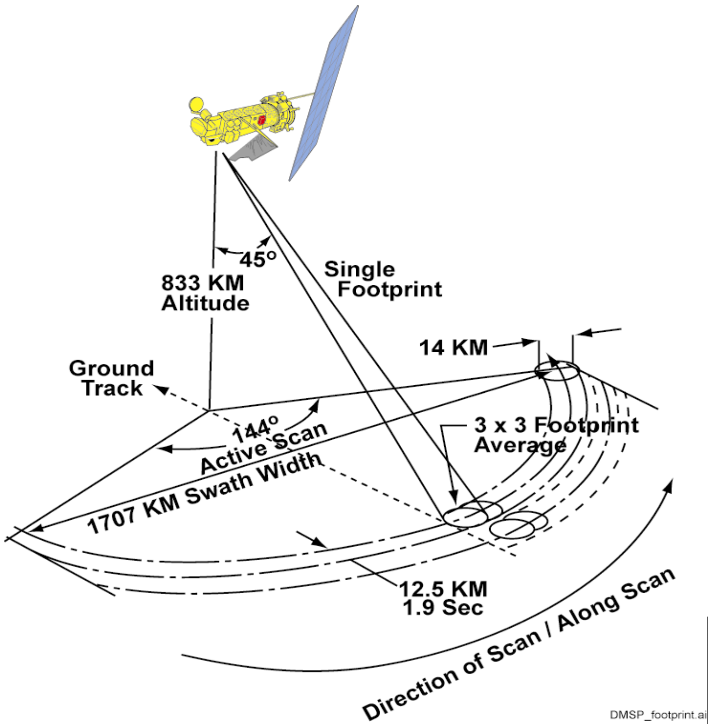
19 GHz (V pol) 22 GHz (V pol) 37 GHz (V pol)

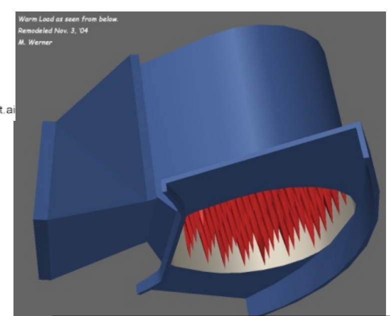
MWI radiances sensitive to:

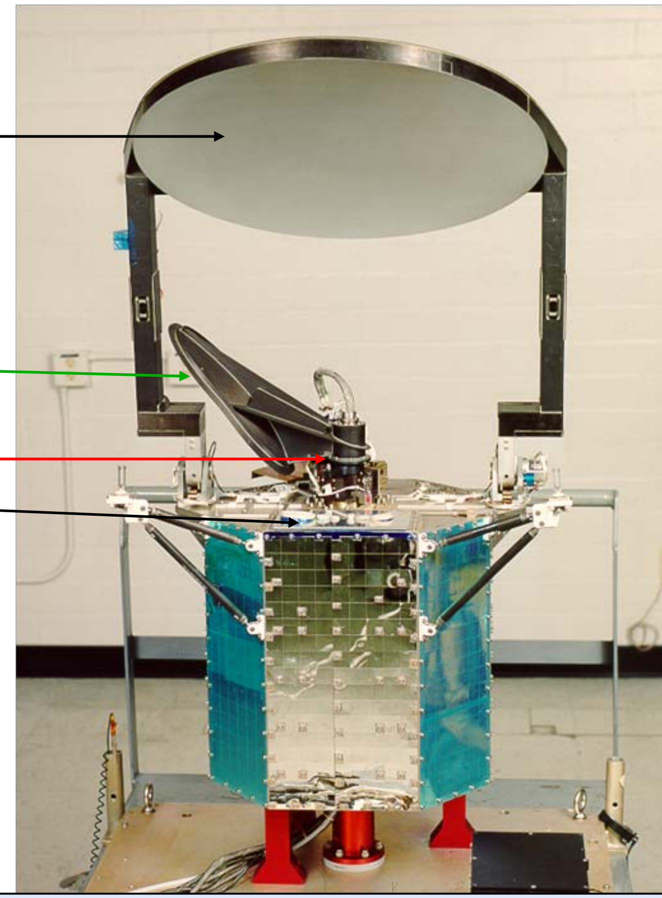
**Atmospheric humidity (TCWV)**
**Ocean surface WS**
**Liquid water path (cloud & precip)**
**Sea ice**

89 / 91GHz also used
In ECMWF all-sky system

# Microwave Imaging Instruments
# Conical Scanning Radiometers



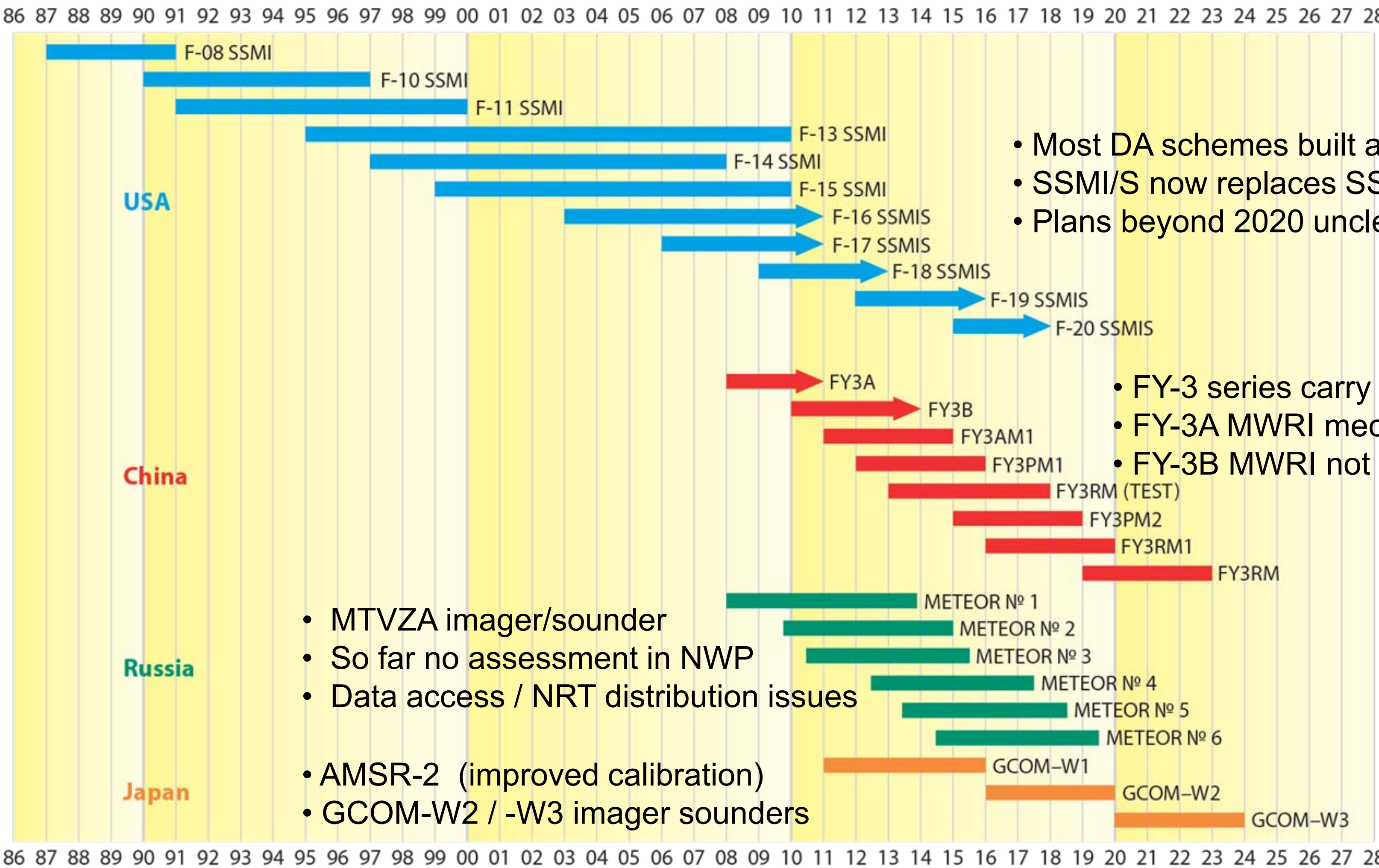




Special Sensor Microwave Imager/Sounder (SSMIS)

- SSMIS suffers from instrument biases:
  - Warm load shielding
  - Reflector emission
- All MWI instruments to date have suffered calibration problems

# Operational MWI instruments 1987-2024




- Most DA schemes built around SSMI
- SSMI/S now replaces SSMI
- Plans beyond 2020 unclear (DWSS?)

- FY-3 series carry MWRI
- FY-3A MWRI mech. instabilities
- FY-3B MWRI not yet assessed

- MTVZA imager/sounder
- So far no assessment in NWP
- Data access / NRT distribution issues

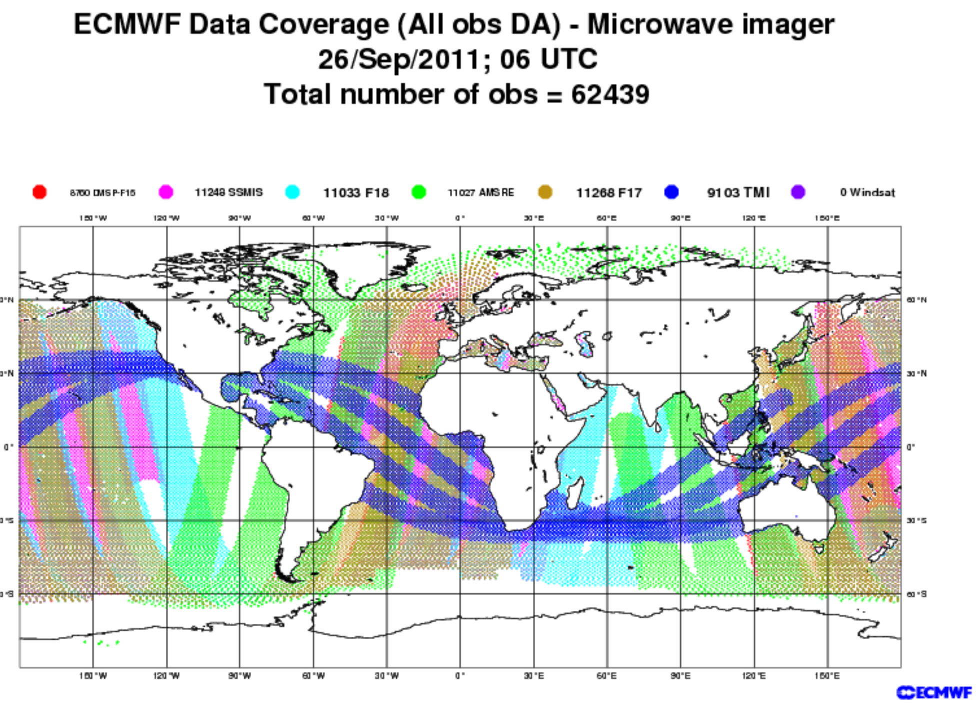
- AMSR-2 (improved calibration)
- GCOM-W2 / -W3 imager sounders

# Assimilation of MWI data at NWP Centres

| | SSMIS | AMSR-E | TMI | Windsat |
|---|---|---|---|---|
| ECMWF | F17<br>F16 / F18 | | | Radiances |
| Met Office | F16 / F17<br>F18 | | | (u,v) |
| Meteo-France | F16 / F17 / F18 | | | |
| JMA (Japan) | F16 / F17<br>F18 | | | (u,v)<br>Radiances |
| NRL (US) | WS / TCWV<br>F16 / F17 / F18 LAS ch rads | | | (u,v) |
| Canada | F16 / F17 / F18 | | | |

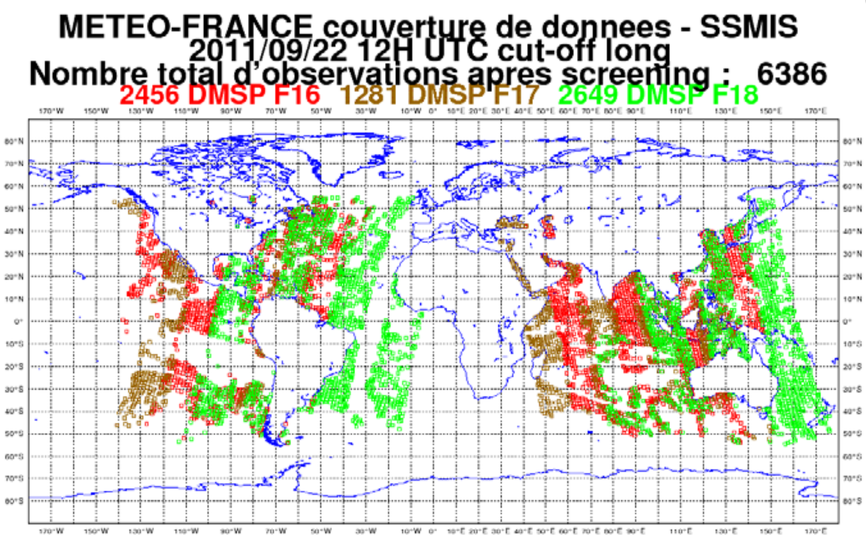
| Assimilated | Monitored | Planned in 2011/12 |
|---|---|---|

# Current Use of MWI Data at NWP Centres




**Météo-France.**
Actively assimilated clear sky MWI data from :

**F16 SSMIS**
**F17 SSMIS**
**F18 SSMIS**



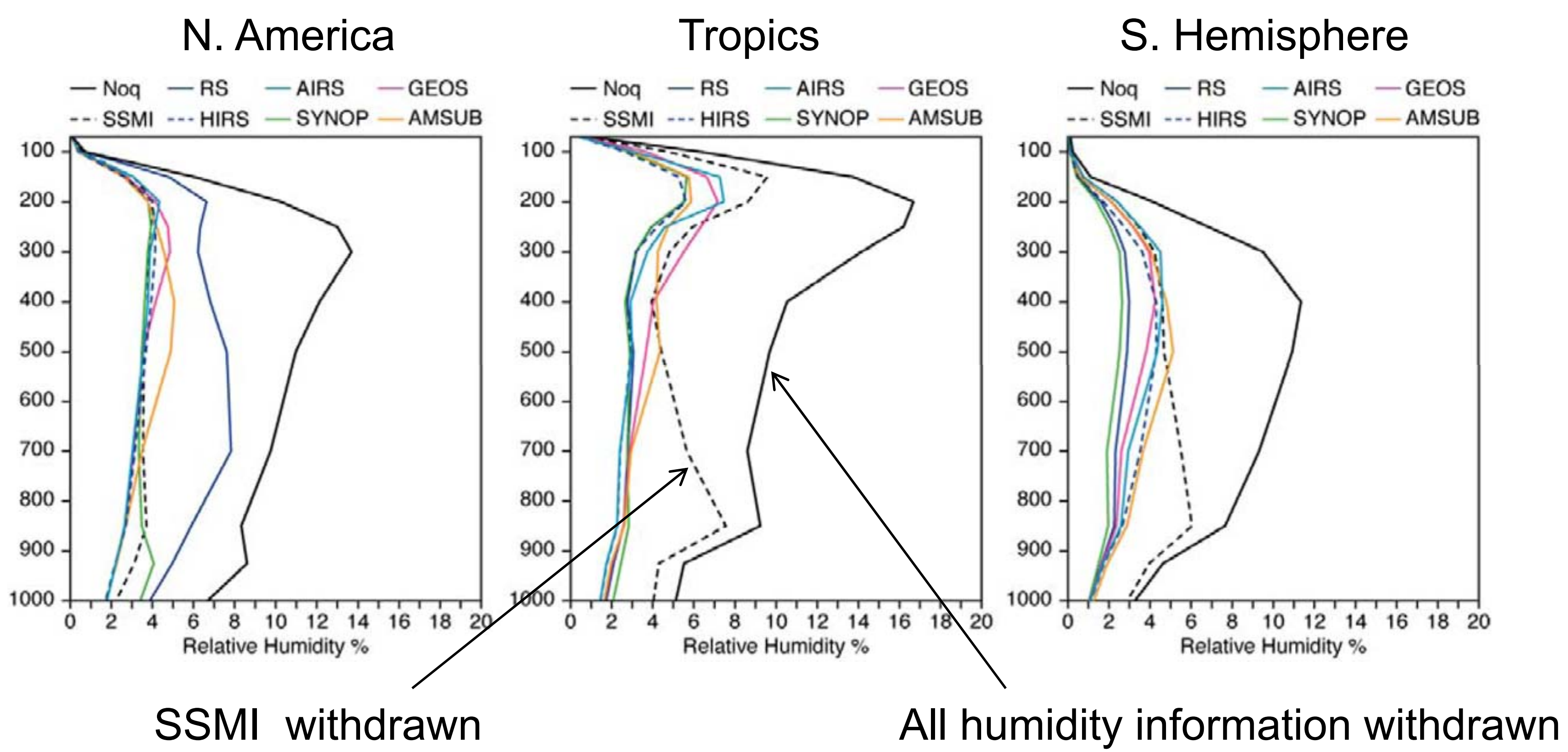

**ECMWF.**
Monitored MWI data from :

**F15 SSMI**
**F16 SSMIS**
**F17 SSMIS**
**F18 SSMIS**
**AMSRE**
**TMI**

**[F17, AMSRE and TMI actively assimilated]**

# The Impact of MWI Data on NWP analyses

RMS differences in analysis RH, relative to a *full system* experiment



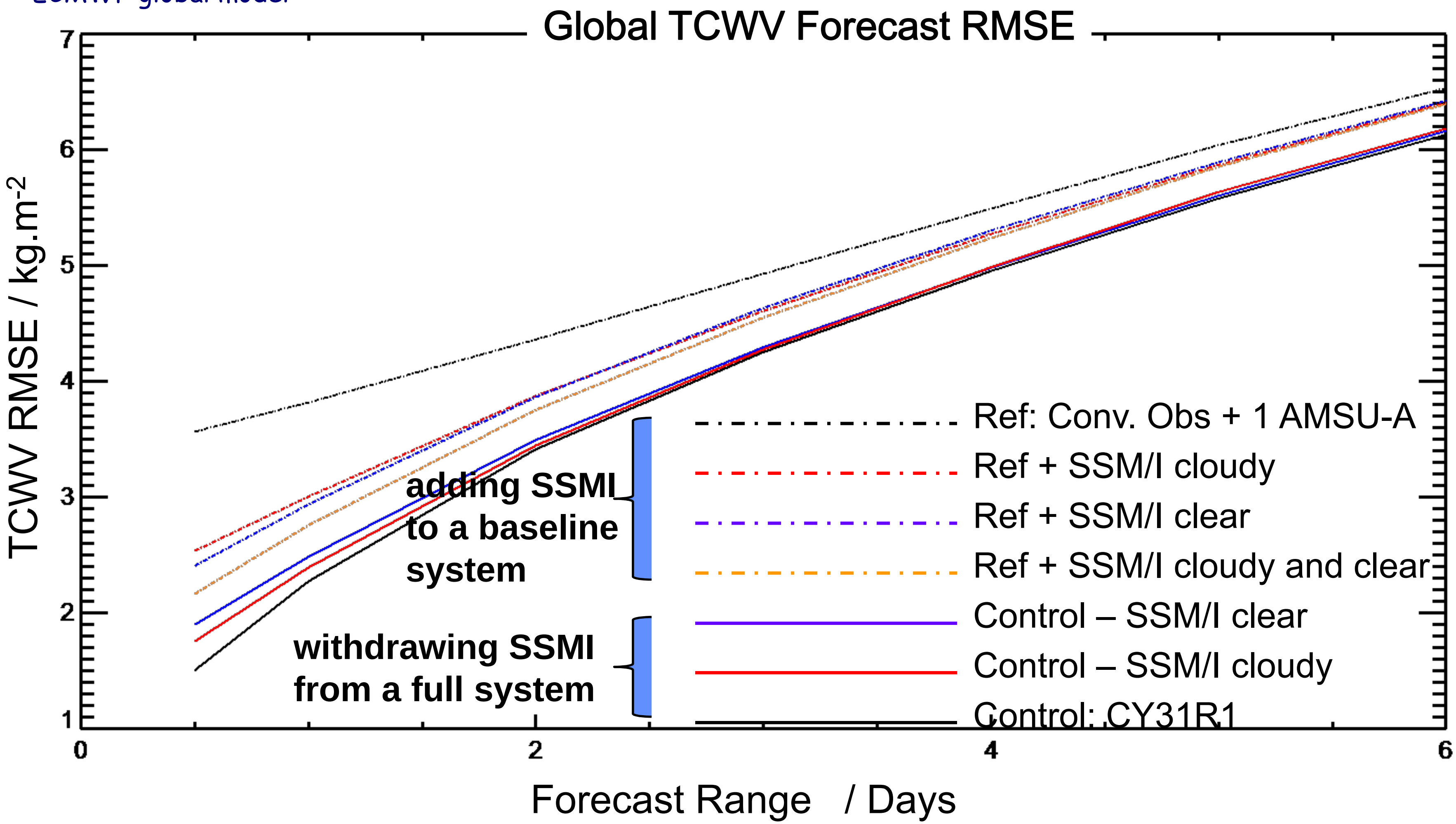

Below 600hPa (in the tropics and SH) SSMI provides the dominant constraint on the humidity analysis

Andersson *et al*, QJRMS (2007)
Also available as
ECMWF Tech Memo 493

ECMWF

# The impact of SSMI radiance assimilation on ECMWF forecast fields of TCWV

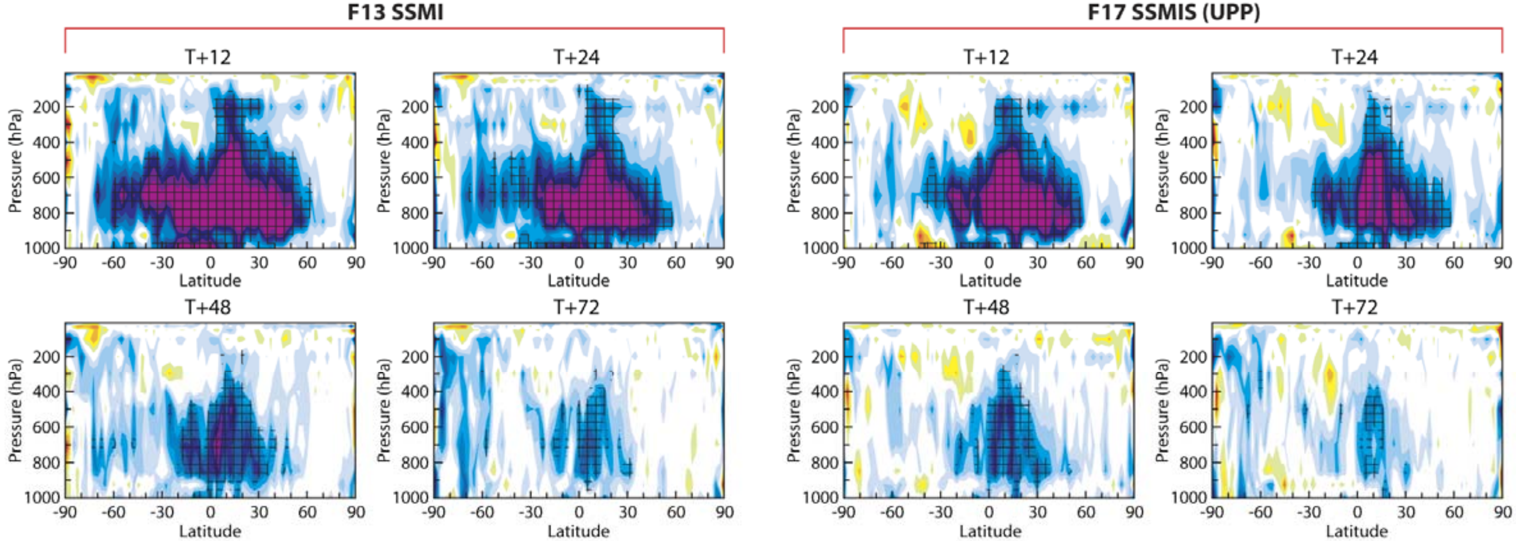
ECMWF global model

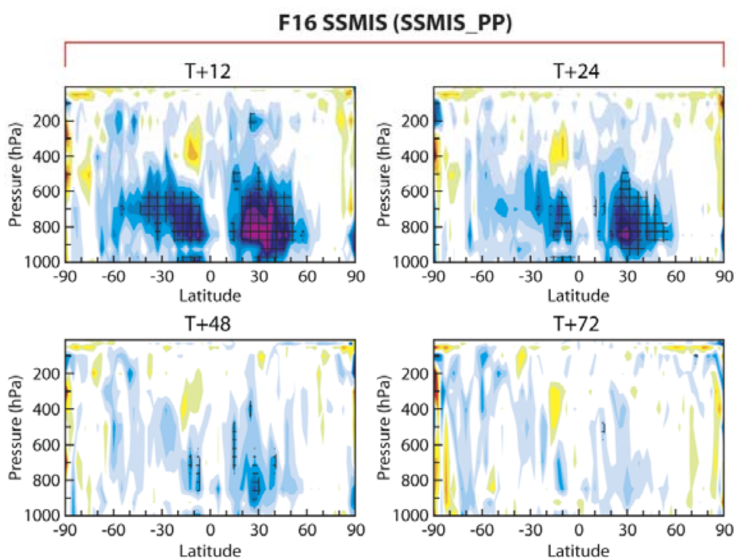





ECMWF

# The impact of MWI radiance assimilation





- Results for <u>clear sky</u> processing shown
- ΔRMSE for RH, relative to a NOSAT baseline
- Positive benefits to T+72 hours



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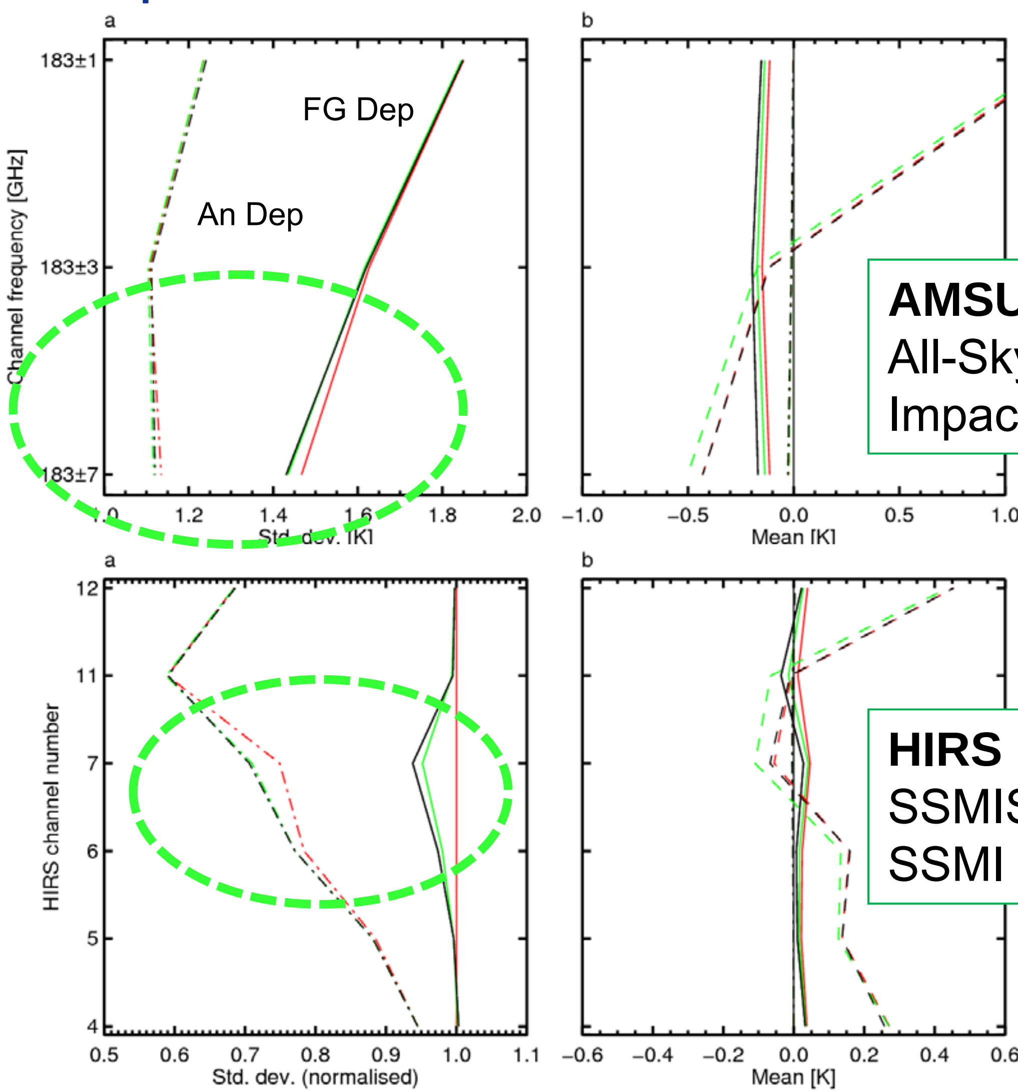
# Testing SSMIS in the ECMWF All-Sky System: Improved FG fit to other observations




**No imagers**

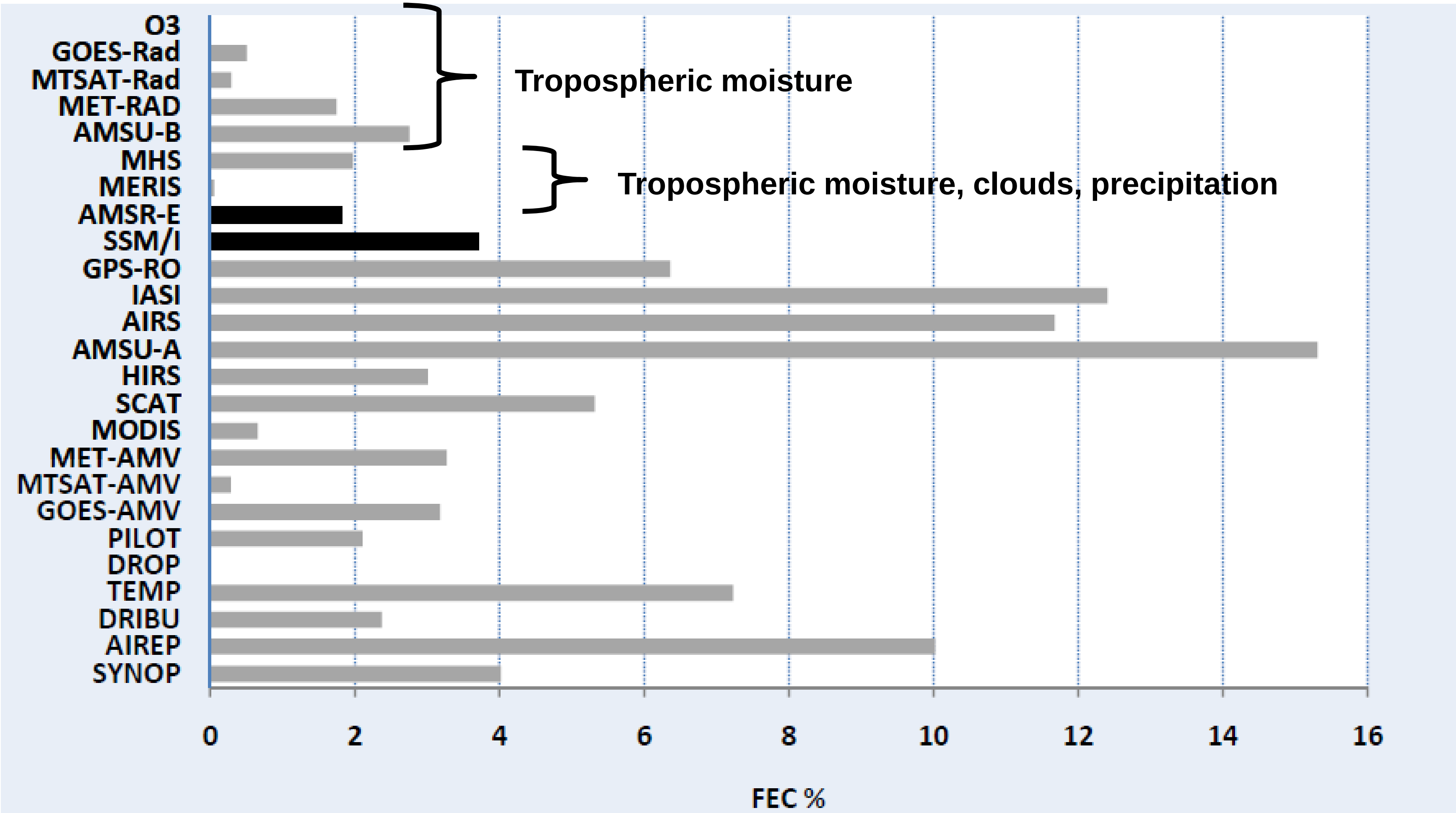
**All-Sky-New (SSMI + AMSRE)**

**All-Sky-New (SSMIS)**

**AMSU-B / MHS**
All-Sky-New with SSMIS matches Impact of SSMI+AMSR-E

**HIRS**
SSMIS shows improvement over SSMI and AMSR-E

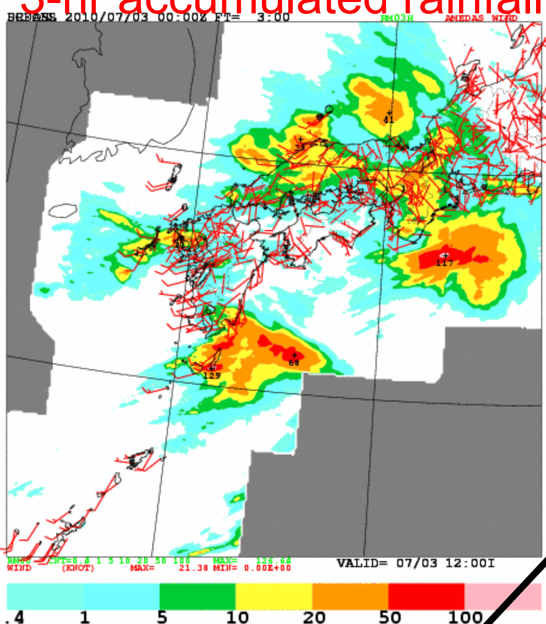
# Forecast impact of cloud / precipitation observations



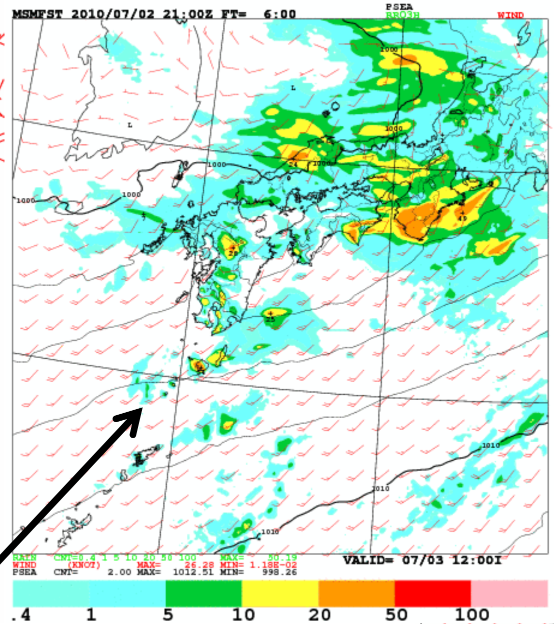

**FEC** = <u>24-hour</u> Forecast Error Contribution = Forecast error reduction due to observations

# JMA Mesoscale DA
# Radar obs. vs. MSM precipitation forecasts

3-hr accumulated rainfall



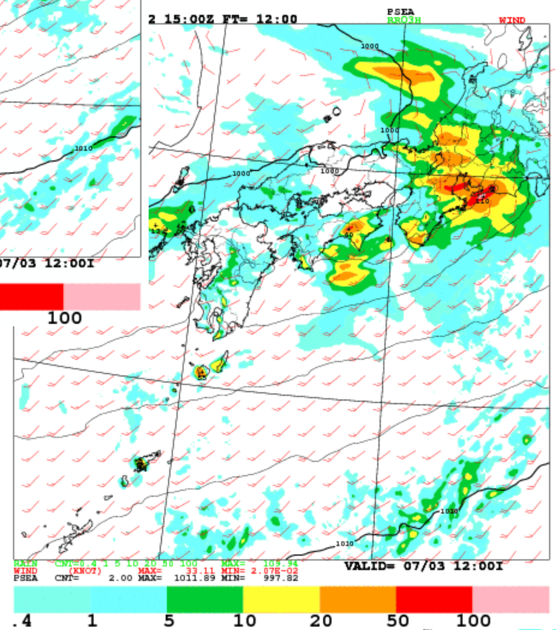

RA observation



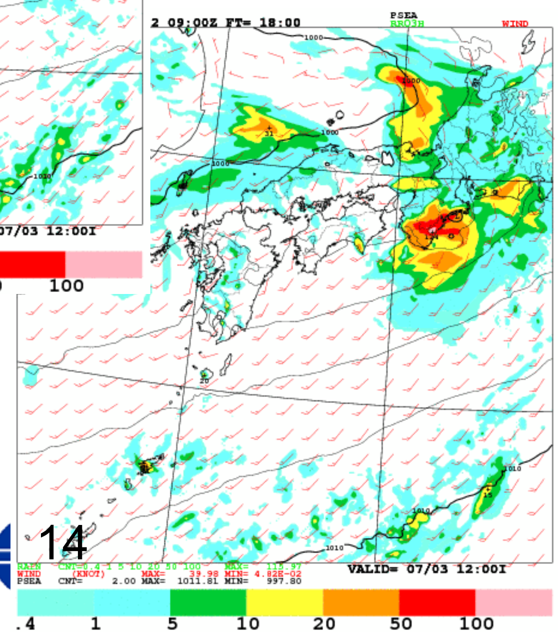

6-hr forecast

**Retrieval assimilation (Control)**

**Valid time: 12JST 03 July, 2010**




12-hr forecast



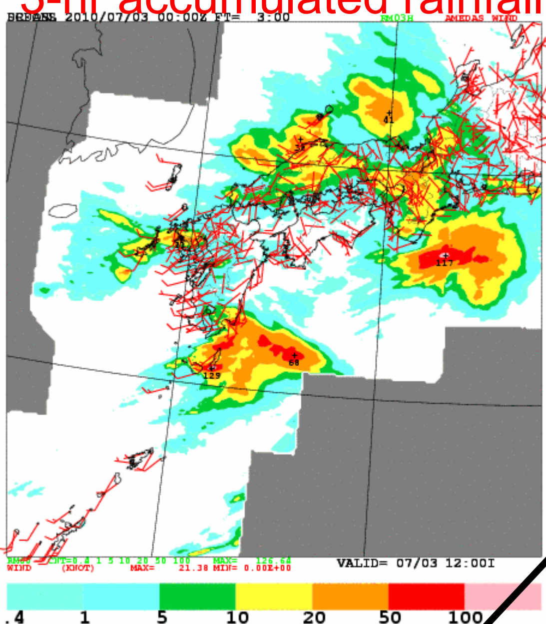

18-hr forecast

Weak rain in forecasts

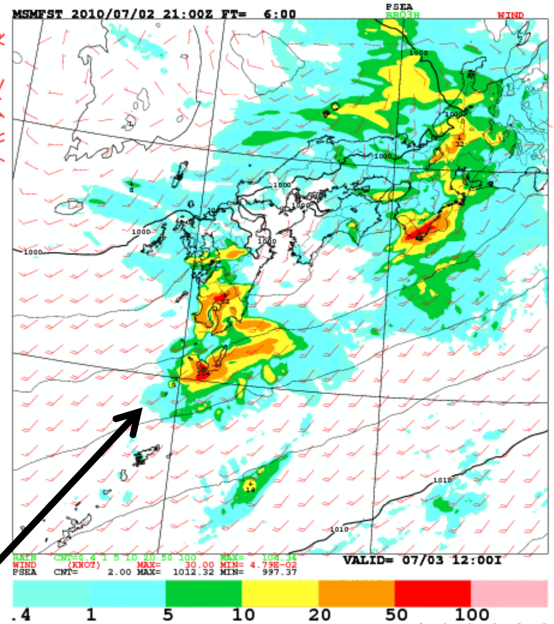
(Masahiro Kazumori, JMA)

# JMA Mesoscale DA
# Radar obs. vs. MSM precipitation forecasts

3-hr accumulated rainfall



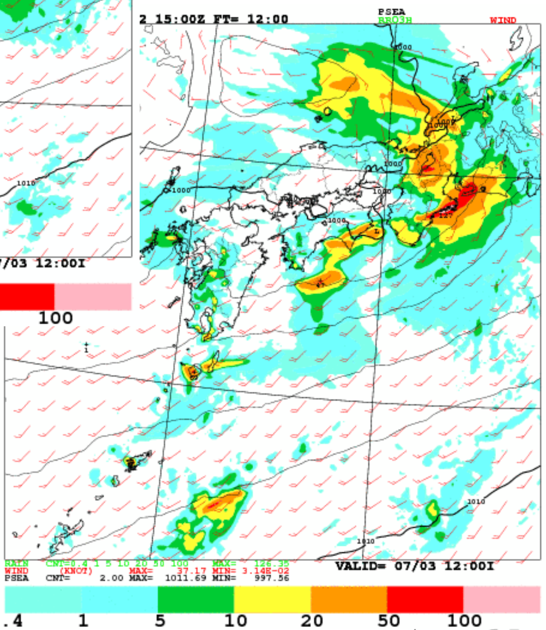

RA observation



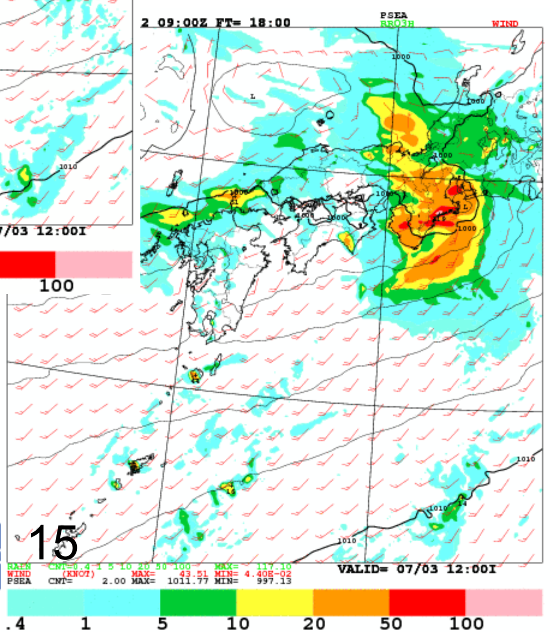

6-hr forecast

**Radiance assimilation (Addition of F-16,17 SSMIS Imagers)**

**Valid time: 12JST 03 July, 2010**




12-hr forecast



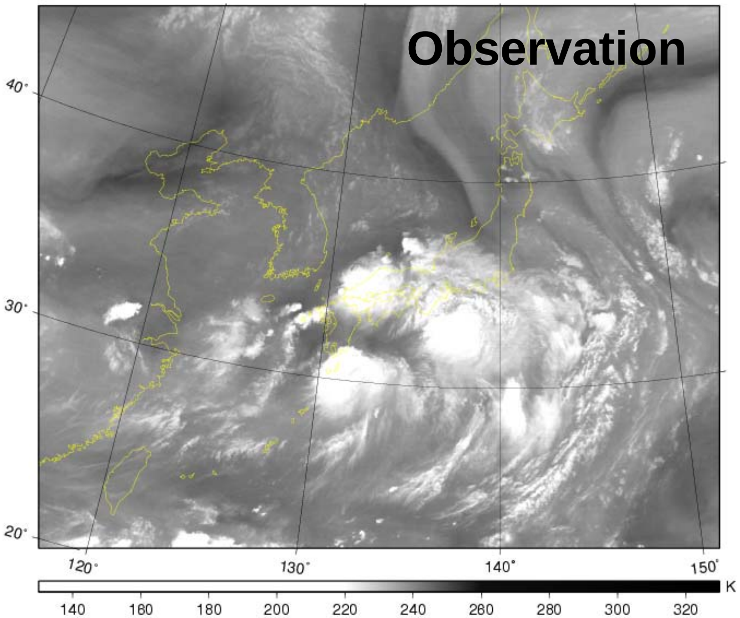

18-hr forecast

**Improvement in short-range precipitation forecast**

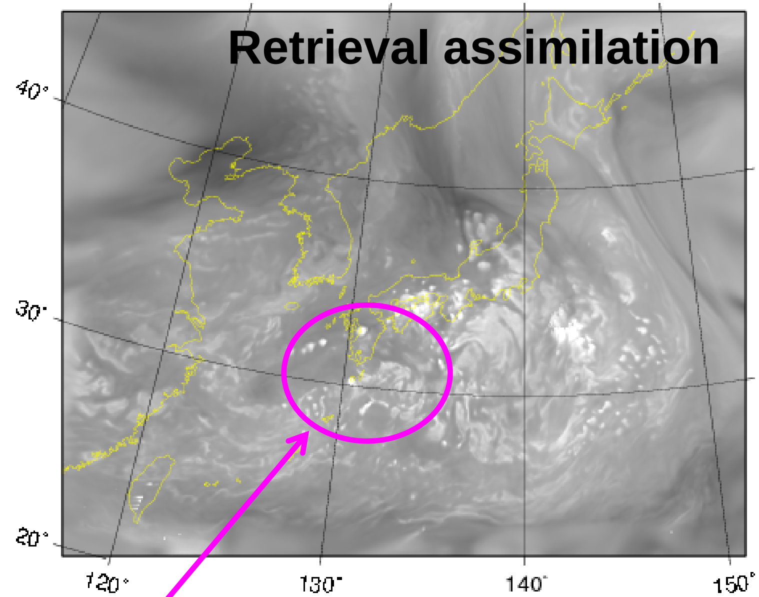
(Masahiro Kazumori, JMA)

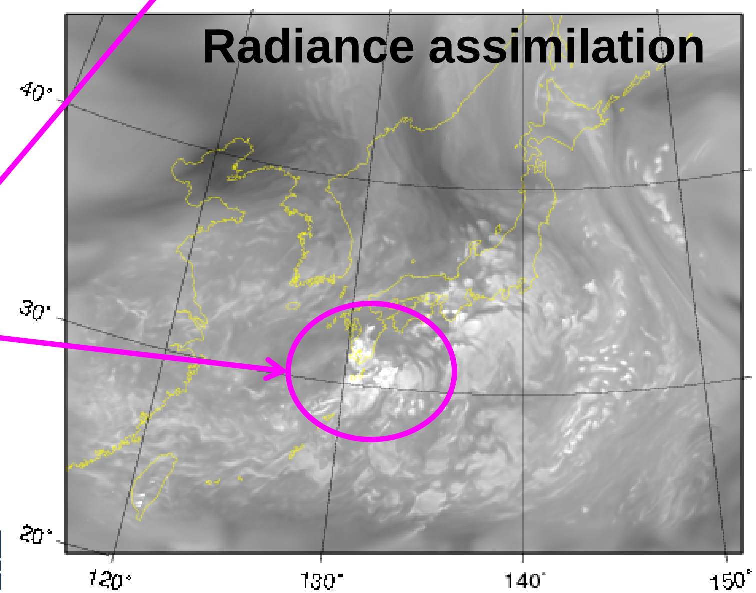
# JMA Mesoscale DA
# Verification with MTSAT cloud image

Observed MTSAT image (WV)




Simulated MTSAT image (WV)



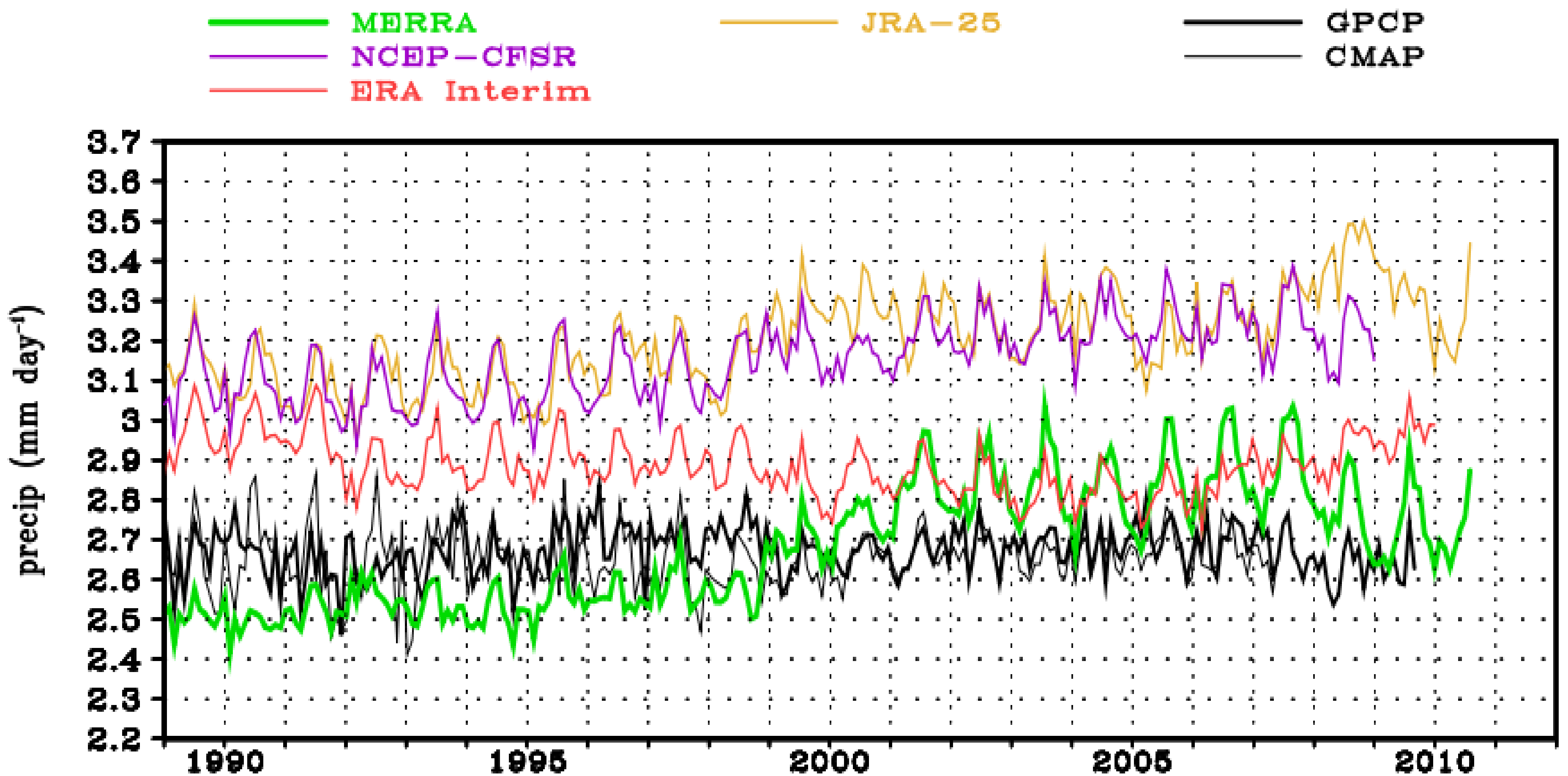




MTSAT WV image contains moisture information in the upper troposphere.

Simulated image from Test’s forecast field is closer to real observation.

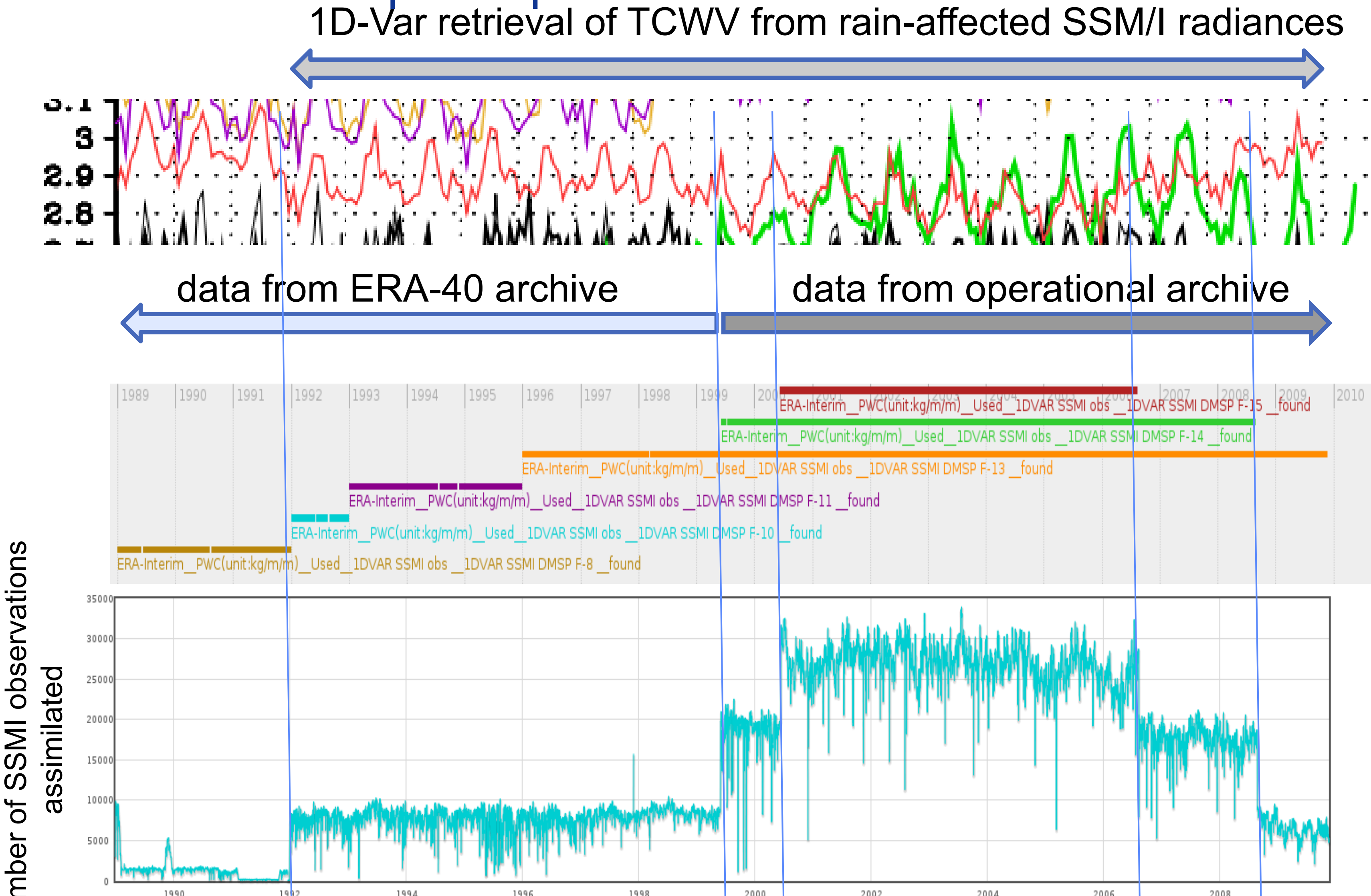
**Valid time: 03UTC 3 July, 2010, 6-hour forecast from 21UTC 2 July, 2010 initial time.**

# MWI Data in Reanalysis
# Global mean precipitation




K. Trenberth

# MWI Data in Reanalysis
# Global mean precipitation



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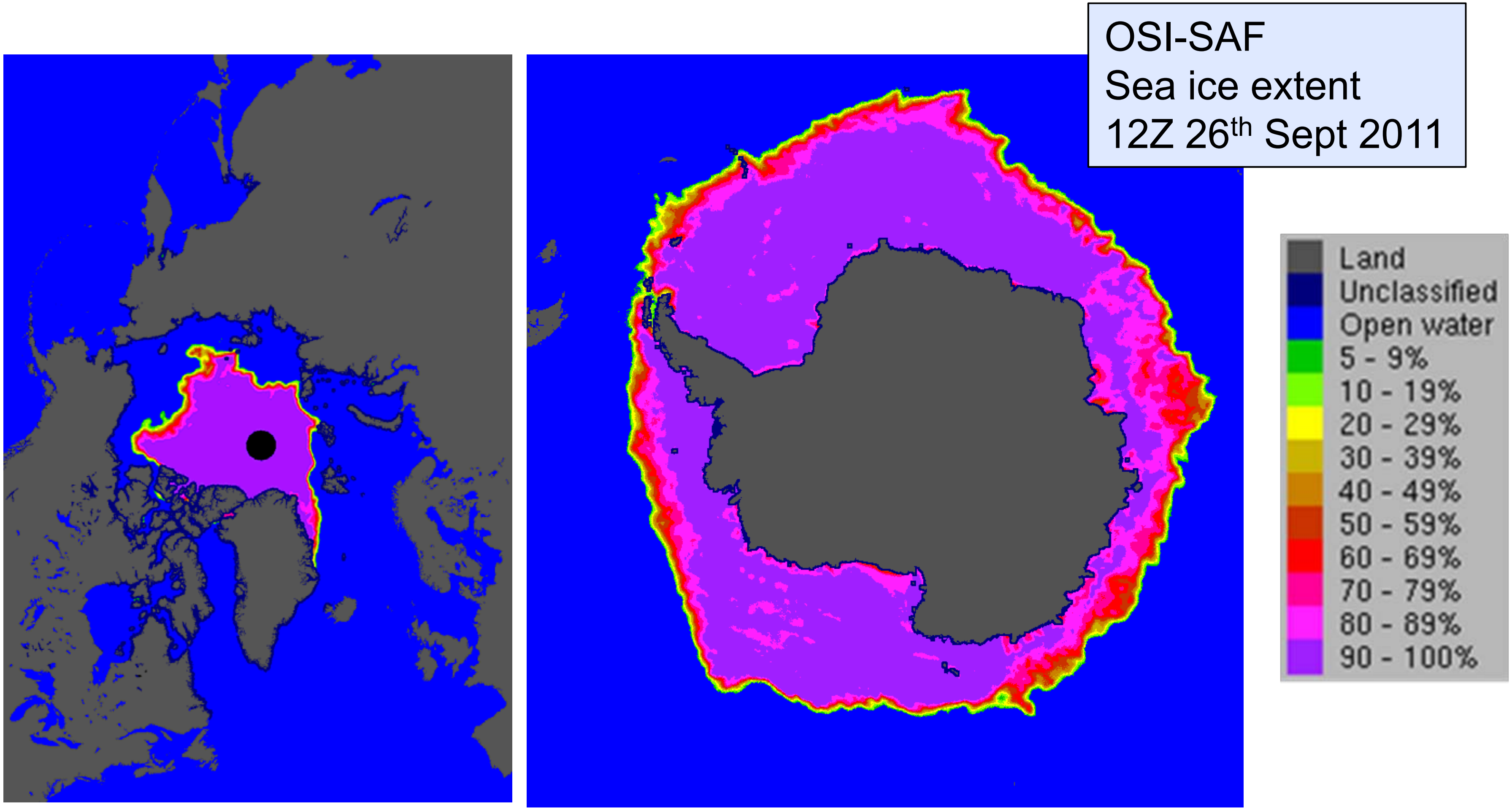
# MWI Data Supports (OSI-SAF) Sea Ice Analysis




(Lars-Anders Breivik)

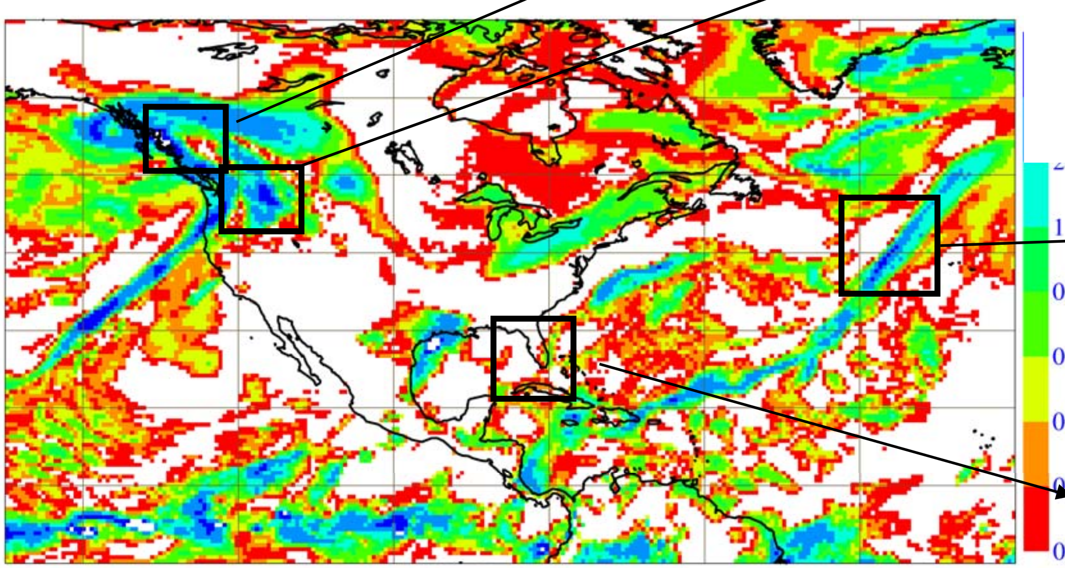
- Sea ice fraction derived from SSM/I & AMSR/E (19, 37, 85 GHz)
- Plans to use SSMI/S & GCOM-W

# Future Developments: Increased use of MWI over land, precipitation and cloud ice

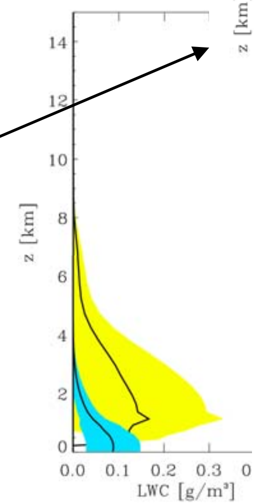
Canadian Snowstorm

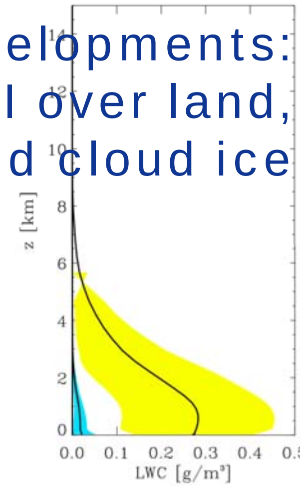
North Atlantic Front

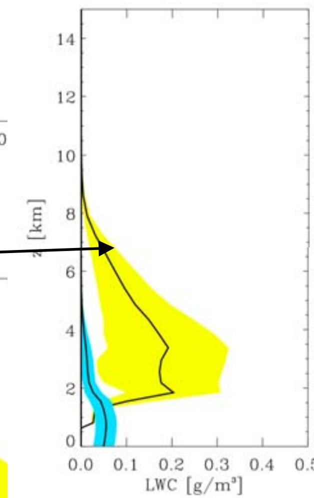
Florida Convection

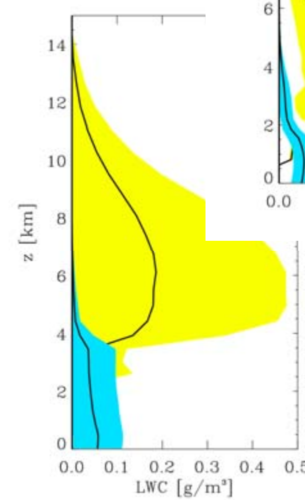



**ECMWF 6h-3h Precipitation Forecast on 26/01/2003**

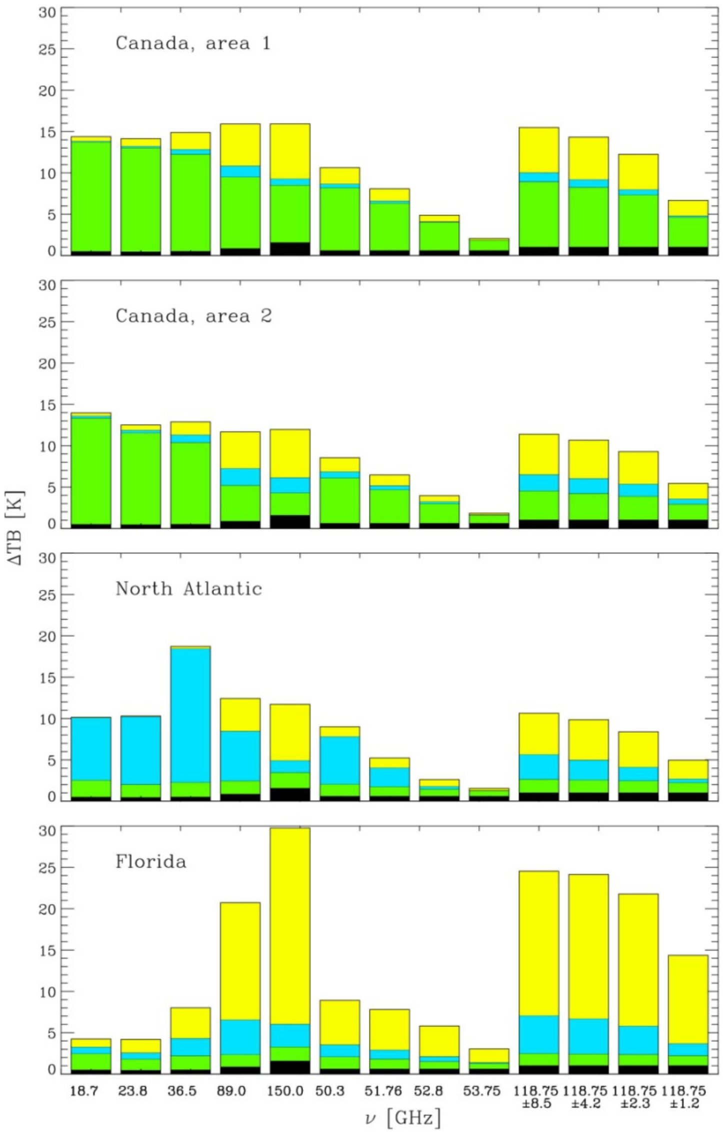


# Future Developments: Increased use of MWI over land, precipitation and cloud ice




NEΔT small; surface emissivity dominating window channels

NEΔT small; liquid precipitation dominating at lower frequencies; surface emissivity negligible

NEΔT small; solid precipitation dominates; surface emissivity small

**Contributions:**
NEΔT ■, surface emissivity ■, liquid precipitation ■, solid precipitation ■

# MRD MWI Precipitation

Precipitation

| Channel name | Frequency (GHz) | Bandwidth (MHz) | Stability (MHz) All TBC | Utilisation | Priority |
|---|---|---|---|---|---|
| MWI-4 | 10.65 | 100 | 50 | Heavy precipitation over sea | 2 |
| **MWI-5** | **18.7** | **200** | **50** | **Precipitation over sea** | **1** |
| MWI-6 | **23.8** | **400** | **50** | **Total column water vapour over sea** | **1** |
| **MWI-7** | **31.4** | **200** | **50** | **Precipitation over sea and (marginally) land** | **1** |
| **MWI-8** | **50.3** | **400** | ±1/±5.0/±10 | **Precipitation over sea and land includingdrizzle, snowfall, height and depth of the melting layer** | **1** |
| **MWI-9** | **52.610** | **400** | ±1/± 3.0/±5.0 | | **1** |
| **MWI-10** | **53.24** | **400** | ±1/±2.0/±5.0 | | **1** |
| **MWI-11** | **53.750** | **400** | ±1/±2.0/±5.0 | | **1** |
| **MWI-12** | **89.0** | **4000** | **100** | **Precipitation (sea & land) & snowfall** | **1** |
| MWI-13 | 100.49 | 4000 (TBC) | 100 (TBC) | Precipitation over sea and land | 2 |
| **MWI-14** | **118.7503±4.00 (TBC)** | **2x1000** | **15** | **Precipitation over sea and land including light precipitation and snowfall, height and depth of the melting layer** | **1** |
| **MWI-15** | **118.7503±2.10** | **2x400** | **15** | | **1** |
| **MWI-16** | **118.7503±1.4** | **2x400** | **15** | | **1** |
| **MWI-17** | **118.7503±1.200** | **2x400** | **15** | | **1** |
| **MWI-18** | **166.9** | **1425** | **100** | **Quasi-window, water-vapour profile, precipitation over land, snowfall** | **1** |
| **MWI-19** | **183.31±8.4** | **2x3000** | **100** | **Water vapour profile and snowfall** | **1** |
| **MWI-20** | **183.31±6.1** | **2x1500** | ±10/±30/±70 | | **1** |
| MWI-21 | 183.31±4.9 | 2x1500 | ±10/± 30/±70 | | 2 |
| **MWI-22** | **183.31±3.4** | **2x1500** | ±10/± 30/±70 | | **1** |
| MWI-23 | 183.31±2.0 | 2x1500 | ±10/± 30 | | 3 |

# Likely Developments in 2011-2020 and beyond

- Increased use of MWI data over land
- Increased use of MWI to constrain light precipitation, frozen precipitation and cloud ice
- Wider and more comprehensive use of MWI in NWP (significant moist physics parametrisation and DA developments expected)
- Wider use of sounding capabilities of some imagers (hampered so far by calibration issues)
- Exploitation of GPM constellation data
- Developing expertise in the use of polarimetric data for ocean surface wind vector analysis
- Increased use of SSMIS mesospheric sounding channels
- Increased awareness of instrument and RT modelling biases

# Summary and future prospects

- MWI data (19, 22, 37, 85 GHz) has been actively assimilated by many NWP centres for more than a decade, and continues to be a key part of NWP systems (by providing the strongest influence on lower tropospheric humidity).

- The SSMI series has provided the 'backbone' of the MWI constellation, and DA schemes have been developed based on SSMI. An SSMI-class instrument represents the minimum requirement for future missions.

- Scenarios for *post-2020* are uncertain and range from *bleak* (no operational imagers by the major agencies) to *promising* (US, China, Europe and Japan launching operational MWI's).

- Recent developments include the development of an *all-sky* system for MWI data at ECMWF – extending accurate moisture analysis into cloudy & rainy areas.

- Over the next decade we expect significant developments in the moist physics of forecast models and associated DA schemes, leading to a requirements for more comprehensive measurements of the hydrological cycle .