Recent improvements in the all-sky assimilation of microwave radiances at the ECMWF

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clear sky assimilation
13 August 2016
GOES mid-infrared – 15UTC
Dundee receiving station / NOAA / EUMETSAT

Microwave - 9-21UTC
AMSR2 37 GHz, v-polarised, supperobbed

Very sensitive to clouds and rain

brightness temperature [K]
13 August 2016

GOES mid-infrared – 15UTC
Dundee receiving station / NOAA / EUMETSAT

Very sensitive to convective rain and surface

Microwave - 9-21UTC
AMSR2 10 GHz, v-polarised, superobbed
Impact of all-sky assimilation at ECMWF
Forecast sensitivity (FSOI) of major observing systems at ECMWF

100% = full observing system

**Summer 2006**
(from Cardinali, 2009)

Microwave WV 6.2%

August 2016
Microwave WV 20.4%

Increase in FSOI by 14% in last 10 years for MW WV

Geer et al., QJRMS, under review
What has happened recently?

All-sky assimilation of humidity sounding channels on SSMIS

GMI and AMSR2 added in all-sky

ATMS and Metop-B MHS added in clear skies

F18, all-sky over snow, MWHS-2

All-sky assimilation of all four MHS (transferred from clear-sky)

Geer et al., QJRMS, under review
Real improvements in medium-range synoptic forecasts

**Mechanism:** 4D-Var can infer dynamical initial conditions from observed WV, cloud and precipitation

Confidence range 95% with AR(2) inflation and Sidak correction for 4 independent tests

Z: SH –90° to –20°, 500hPa

Z: NH 20° to 90°, 500hPa

Improvements up to forecast day 5 by adding all-sky

All–sky GMI, AMSR2, MHS and SSMIS – No all-sky control
FSOI for different MW WV

- DMSP-F17 SSMIS
- SNPP ATMS
- NOAA-18 MHS
- FY-3C MWHS-2
- Metop-A MHS
- Metop-B MHS
- GCOM-W AMSR2
- NOAA-19 MHS
- DMSP-F18 SSMIS
- GPM GMI
- FY-3B MWHS-1

MW WV:
- 324934
- 201524
- 218021
- 475378
- 212727
- 212669
- 186306
- 133106
- 119373
- 112681
- 82237

FSO [%]

Geer et al., QJRMS, under review
Status all-sky assimilation of *microwave imager (MWI)* radiances at ECMWF
Microwave imager (MWI) radiances

• Instruments:
  ▪ SSMIS-F17, AMSR2, GMI

• Use of microwave imager observations:
  ▪ 19v/h GHz, ~24v GHz, 37v GHz, ~90v GHz
  ▪ over ocean only equatorward of 60°
  ▪ in some areas screening: cold air outbreak areas, low TCWV
  ▪ thinned to 100km separation
  ▪ superobbing: roughly 80 km x 80 km grid box
  ▪ corresponding model profile at the grid point closest to the observation
All-sky development for **microwave imager** (MWI) radiances at ECMWF

...started with the aim to assimilate 10 GHz
Histogram of over-ocean brightness temperatures from TMI 10 GHz vertically polarised channel covering August 2013

Limitations in current modelling in sub-grid variability?

Different scales?
Field of view (FOV) of GMI observation within superob

- Unify resolution between different frequencies
1. Scale matching
Field of view (FOV) of GMI observation within superob

- Unify resolution between different frequencies
- Match scales between observations and model

**EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS**

Katrin Lonitz – WMO DA Symposium 2017

Lean et al. (2017) ECMWF Tech Memo 799
Subgrid variability:
2. Beamfilling effect

Response function
**Subgrid variability:**

2. Beamfilling effect

**Example:** same cloud liquid water distributed differently within superob

- Convective cloud
- Stratiform cloud

lower brightness temperature than for stratiform case
Subgrid variability: 3. Projection effect

Bauer et al., 1998; Bennartz and Greenwald, 2011
Take home messages
- Part 1 -

1. Superobbing
   → Match scales between observed and simulated brightness temperatures
     – consistent for all channels

2. Beamfilling effect

3. Projecting effect
   → Multi-independent column approach (O’Dell et al. (2007) in the observation operator,
     superseding the current two-column approach (Geer et al, 2009)
   
   → Additionally taking into account horizontal inhomogeneities using a slanted-path
4. land-sea mask

current land-sea mask based on inner and outer loop resolution

1st inner loop….

last inner loop

…. 

outer loop

Current land-sea mask filters out useful observations over ocean.
4. Land–sea mask

- use land-sea-mask of superob
- Halo outside superob area: especially seen for 10GHz
Current land-sea mask based on inner and outer loop resolution

Active GMI data
New land-sea mask using actual field of view (FOV) of observation

GMI data w/ lsm=0
Take home messages
- continued-

1. Superobbing
   - Match scales between observed and simulated brightness temperatures – consistent for all channels

2. Beamfilling effect

3. Projecting effect
   - Multi-independent column approach (O’Dell et al. 2007) in the observation operator, superseding the current two-column approach (Geer et al. 2009)
   - Additionally taking into account horizontal inhomogeneities using a slanted-path

   - Takes into account the “halo-effect”
   - Allows more observations over ocean to be assimilated
   - Under testing
Future plans for all-sky assimilation at ECMWF

- **Microwave imager radiances:**
  - Assimilation over land
  - 10 GHz work supports potential future assimilation of sea-ice, SST and snow cover
  - Assimilation of more frequencies (150-170GHz)

- **all-sky AMSU-A**
- **all-sky Infrared**
- **in 10 years: visible channels in all-sky**

- **development of direct assimilation of active observations in 4D-Var to support ingestion of EarthCARE (space-borne cloud radar and lidar)**
- **sub-mm microwave such as EUMETSAT Ice Cloud Imager (ICI)**
Take home messages

1. Superobbing
   → Match scales between observed and simulated brightness temperatures – consistent for all channels

2. Beamfilling effect (Kummerow, 1998; Geer et al 2009)

3. Projecting effect (Bauer et al., 1998; Bennartz and Greenwald, 2011)
   → Multi-independent column approach (O’Dell et al. (2007) in the observation operator, superseding the current two-column approach (Geer et al, 2009)
   → Additionally taking into account horizontal inhomogeneities using a slanted-path

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Backup slides
Terra/Aqua Modis Cloud coverage
First experiments at ECMWF assimilating cloud and rain retrievals, and rainy radiances

New linearised moist physics model with tangent-linear and adjoint

Observation operator for rain and cloud affected microwave radiances: RTTOV-SCATT

1D+4D-Var TCWV retrievals from cloud and rain-affected radiances

New microwave sensors activated in all-sky by default

Transfer existing MHS sensors to all-sky

Ability to model radiances affected by frozen hydrometeors (snow and hail) allows all-sky assimilation of WV sounders

Cloud-dependent observation error model

Direct all-sky radiance assimilation

Timeline of operational cloud and precipitation radiance assimilation

WV sounders

Imagers

GMI
SAPHIR
MWHS–2
SSMIS F–18
MHS Metop–B
MHS Metop–A
MHS NOAA–19
MHS NOAA–18
SSMIS F–17
SSMIS F–17
TMI / GMI
AMSR–E / AMSR–2
SSMI F–15
SSMI F–13
Subgrid imhomogeneities:
3. Inhomogeneity in field of view

FOV of one (left) and many (right) GMI observations within superop
Subgrid imhomogeneities:
3. Inhomogeneity in field of view

GMI swath

edge of swath

middle of swath

89 GHz
Current land-sea mask
based on inner and outer loop resolution

Land-sea mask of trajectory
New land-sea mask using actual field of view of observation

Active data

New land-sea mask using FOV