Cloudy-affected Infrared Brightness Temperature Assimilation by LETKF

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University of Reading

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Outline

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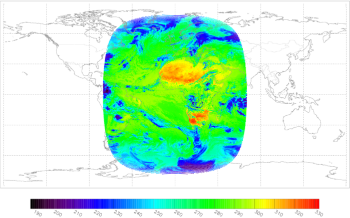
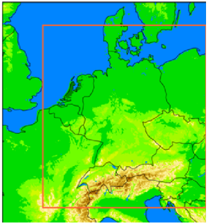
Challenge

- **Direct assimilation of SEVIRI radiances** (instead of retrievals)
- Spinning Enhanced Visible and Infrared Imager (SEVIRI)
- SEVIRI 12-channel instrument in MSG (Meteosat Second Generation).
- Produces images of the Earth every 15 minutes
- High horizontal resolution (3Km for IR channels, and 5Km for Europe)
- Assimilation of all-sky brightness temperatures (water vapor and window channels)
- Model: **COSMO-DE** both deterministic and EPS: 2.8km
  DA system: **LETKF** [a]
- simulated radiances through **RTTOV 10**

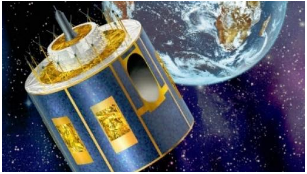




[a] Hunt et al. 2007

Why is it a Challenge?

- It is necessary:
  - to perform accurate radiative transfer simulations: more complex in cloudy cases
  - develop an adequate bias correction
  - to take into account or remove the effect of clouds
  - specify correctly observation error
  - to define an optimal horizontal and vertical localization length-scale



Why is it a Challenge?

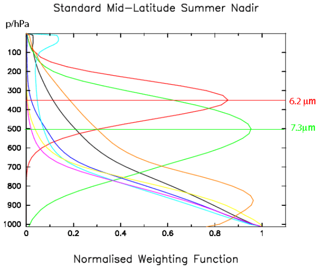
- Only few channels are assimilated in most of the operational regional models:
  - **WV** and **CO2** channels assimilated in the **HIRLAM**[a] (including cloud-affected radiances)
  - **WV** channels included in the **Met Office** regional UKV operational model and three **IR** channels over sea surfaces
  - **Météo France** regional ALADIN-model has five channels operationally assimilated (**WV6.2, WV7.3, IR8.7, IR10.8, and IR12.0**) mainly over sea and under clear-sky conditions
  - All these limited area models employ 4-DVar as Data Assimilation method
  - First attempt to assimilate cloudy-affected radiances with an LETKF in a high-resolution model

[a]Stengel et al. 2010

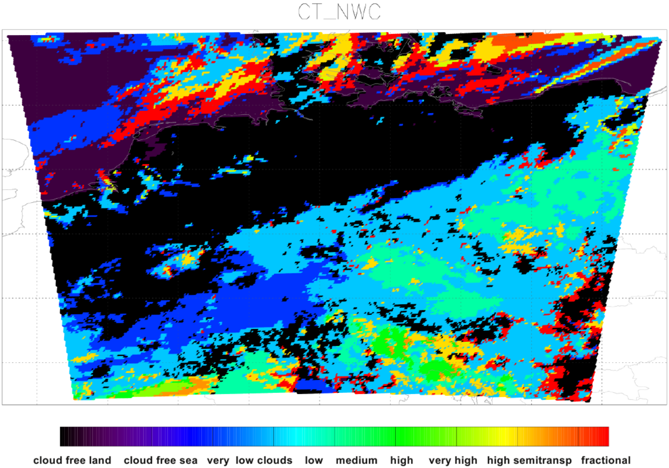
Outline

Bias Correction

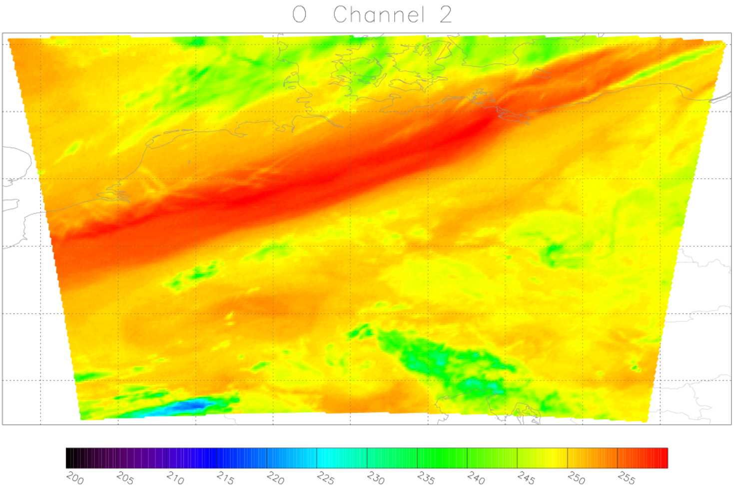
- **WV073** , WV062 and IR 8.7
- Test case from 2011-06-01 00:00 to 2011-06-06 12:00 UTC
- O-B and RMSE statistics at each assimilation update time
- clear sky, low, medium and high clouds
- low (surface to 2 km AGL), middle (2 to 6 km AGL), and upper troposphere (6 to 14 km AGL)
- model cloud top defined as the first model level from the model top with a total cloud mixing ratio greater than $1e^{-6} kgkg^{-1}$
- the observed and simulated cloud top heights were considered *matched* if their difference was less than 600 m
- **CTH** from NWC SAF used to classify SEVIRI radiances



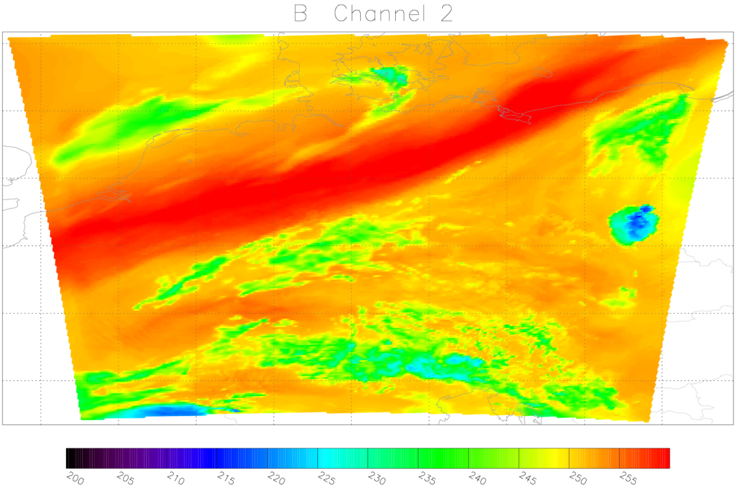
Cloud type 2011-06-02 00:00



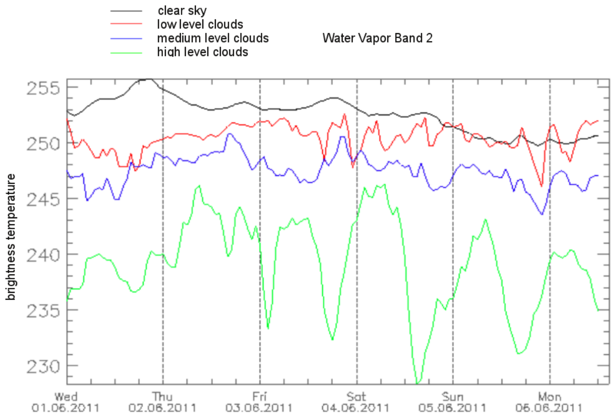
Observations WV 2011-06-02 00:00



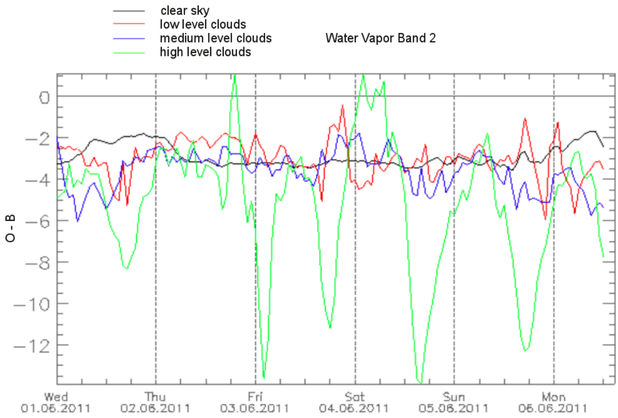
Background WV, 4 hour free forecast



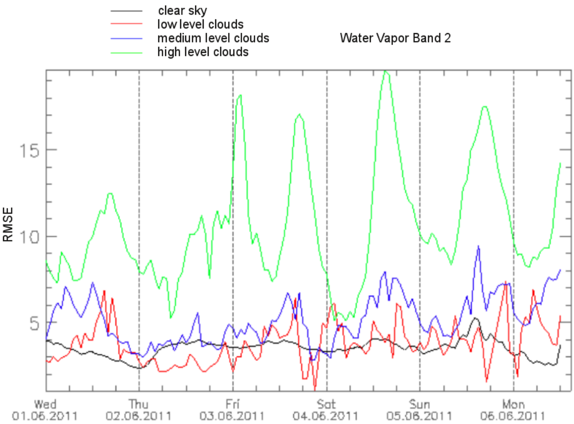
Averaged simulated brightness temperatures



Observation minus Background for matching grid points



O-B RMSE for matching grid points between observed and simulated T_B



Outline

WV073 Assimilation Experiments

- 12 hours assimilation from 2011-06-04 12:00 UTC to 2011-06-05 00:00 UTC
- **bias correction** value applied to the simulated observation (rather than to the real observations)

$$d_o = H(x^{(b)}) + y_{bc}^{(b)} - y^o$$

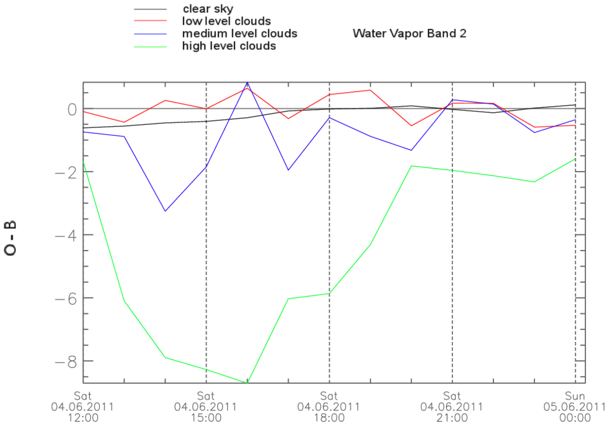
- model-simulated cloud field from a given ensemble member is used to determine the cloud top height
- bias statistics from the 3-day period

	Clear sky	Low-level clouds	Medium-level clouds	High-level clouds
y^{bc}	-2.9	-2.9	-3.1	-4.4

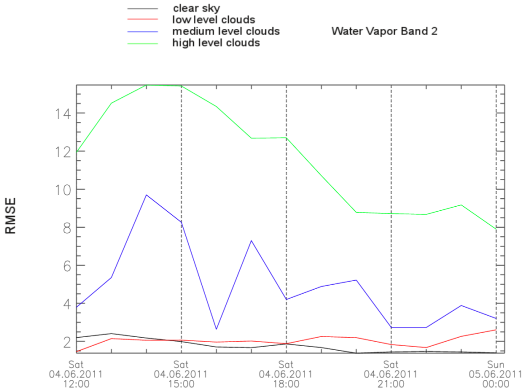
Table : Bias correction values in Kelvin [K], for assimilated WV 7.3 SEVIRI radiances in COSMO

- Optimal settings: Observation error 3.5 K, horizontal and vertical localization radii 35 km and 0.7 log pressure units

BIAS for matching grid points WV 7.3 T_B assimilated

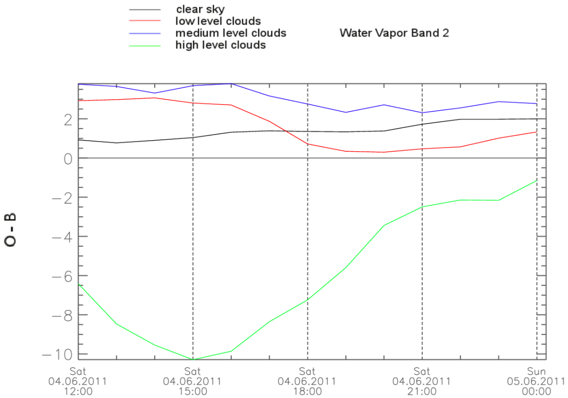


RMSE for matching grid points WV 7.3 T_B assimilated

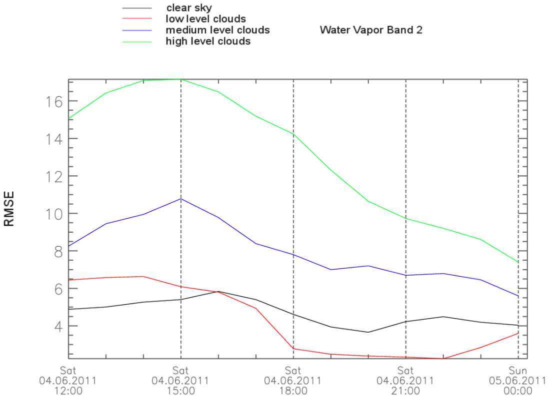


BIAS for all grid points WV 7.3 T_B assimilated

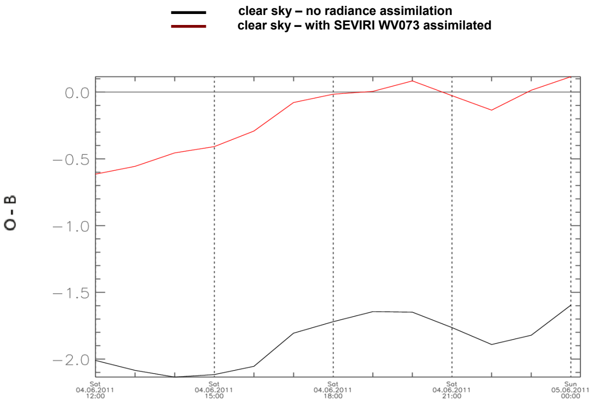
- Statistics based on **CTH retrievals** from NWC SAF to classify observations
- No attempt made to determine if the COSMO model has a similar cloud in the same location



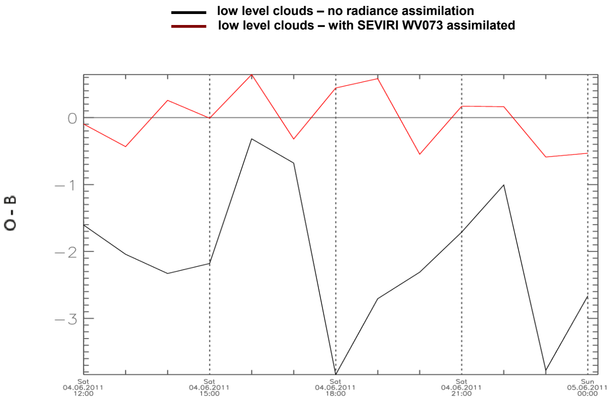
RMSE for all grid points WV 7.3 T_B assimilated



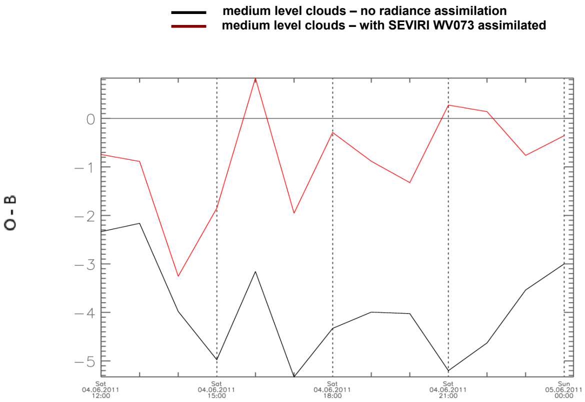
Bias clear sky - control and assimilation



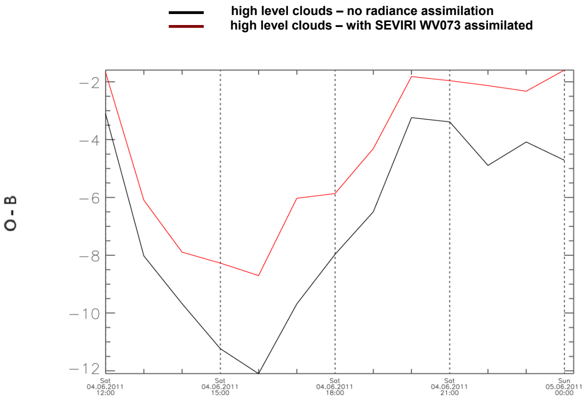
Bias low level clouds - control and assimilation



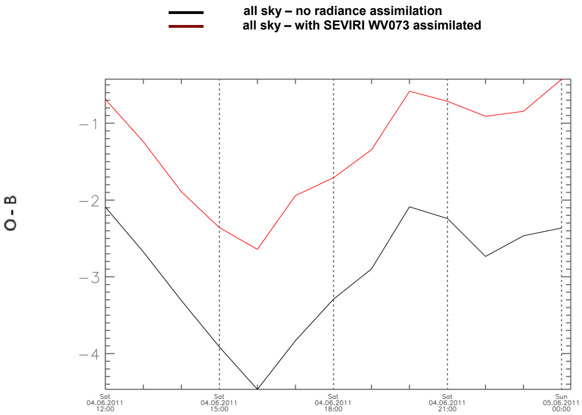
Bias medium level clouds - control and assimilation



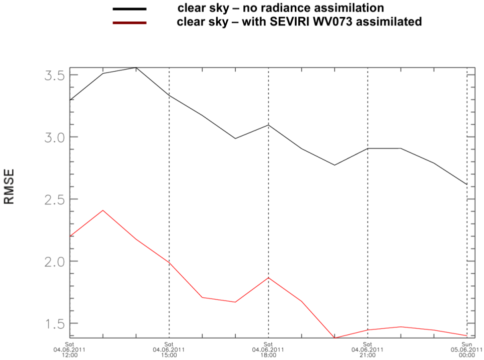
Bias high level clouds - control and assimilation



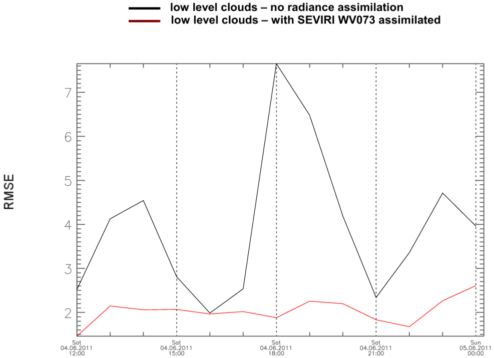
Bias all sky - control and assimilation



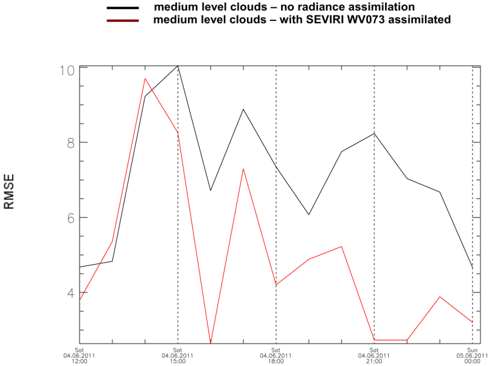
RMSE clear sky - control and assimilation



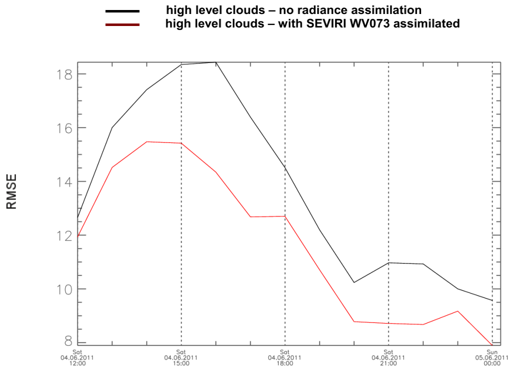
RMSE low level clouds - control and assmilation



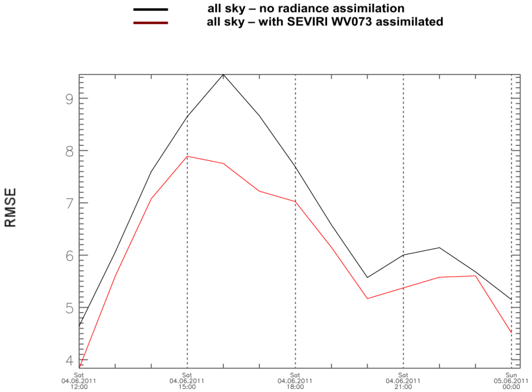
RMSE medium level clouds - control and assimilation



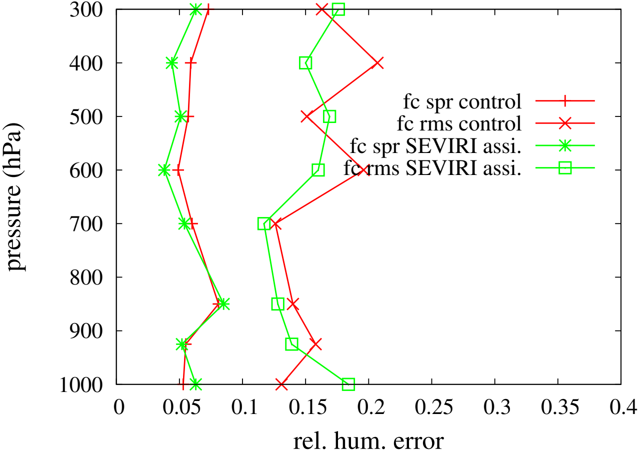
RMSE high level clouds - control and assmilation



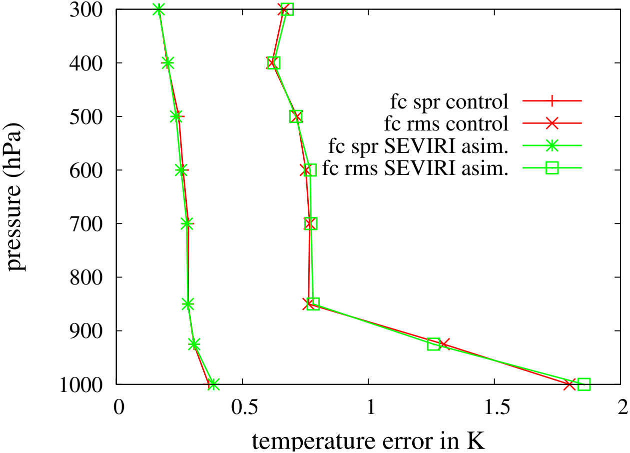
RMSE all sky - control and assimilation



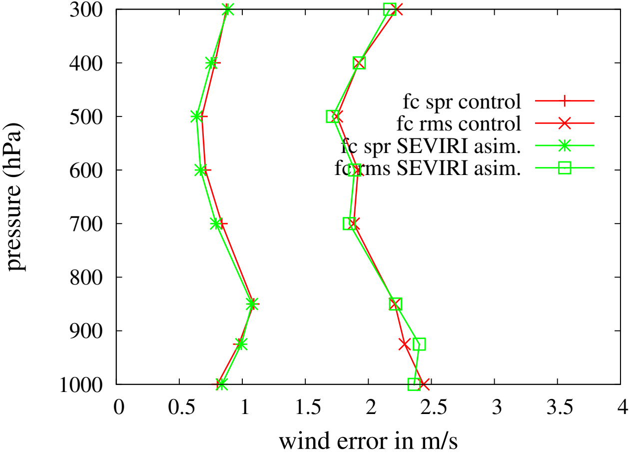
Vertical Profiles - RH



Vertical Profiles - T



Vertical Profiles - Wind



Outline

Next Steps

- Assimilation of WV067 and IR8.7 Brightness Temperatures
- Develop a time-dependent bias correction values for each cloud type (i.e. use of predictors)

$$d = H(x^b) + \sum_{i=1}^{N} \beta_i p_i(x_b)$$

with p_i one of the N predictors and β the bias parameters

- Vertical localization sensitivity studies
- Remove impact of high semi-transparent clouds

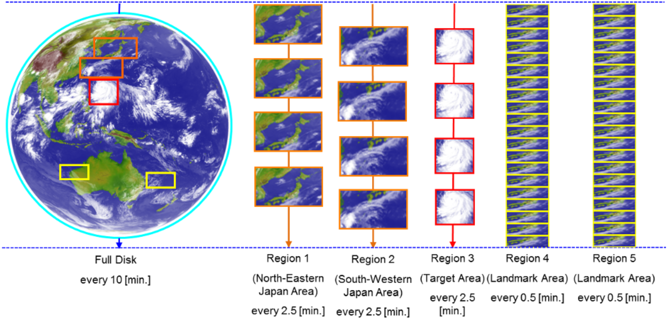
Outline

Collaboration with RIKEN/MRI: Assimilation of AHI radiances

- Models:
  - JMA NHM-LETKF [a]MSM
  - SCALE-LES
- Assimilation of cloud-affected **water vapor** brightness temperatures:
  - Study the impact of real satellite observations at convection-resolving scales
  - high-resolution model with high-resolution observations
  - improve forecasts of high impact weather events

[a]Kunii 2013

Assimilation of AHI radiances



- Advanced Himawari Imager on-board Himawari-8 - Operational 2015
- Provides 2.5-minute-interval images of Japan and 2Km-resolution images in infrared bands
- Improvement of current satellite products - AMV, CSR, CGI and SST
- New products development - Instability indices: severe events forecast

- Thanks for everything!! And see you in Kobe!

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Channels

Table 1. Spectral channel characteristics of SEVIRI providing central, minimum, and maximum wavelength of the channels and whether the channel is an absorption or a window channel. A concise summary of the use of the spectral channels is given in the section titled "SEVERI spectral channels."

Channel no.		Characteristics of spectral band (μm)			Main gaseous absorber or window
		λ_{cen}	λ_{min}	λ_{max}	
1	VIS0.6	0.635	0.56	0.71	Window
2	VIS0.8	0.81	0.74	0.88	Window
3	NIR1.6	1.64	1.50	1.78	Window
4	IR3.9	3.90	3.48	4.36	Window
5	WV6.2	6.25	5.35	7.15	Water vapor
6	WV7.3	7.35	6.85	7.85	Water vapor
7	IR8.7	8.70	8.30	9.10	Window
8	IR9.7	9.66	9.38	9.94	Ozone
9	IR10.8	10.80	9.80	11.80	Window
10	IR12.0	12.00	11.00	13.00	Window
11	IR13.4	13.40	12.40	14.40	Carbon dioxide
12	HRV	Broadband (about 0.4 – 1.1)			Window/water vapor

LETKF basics

- Implementation following *Hunt et al., 2007* from maryland group
- basic idea: do analysis in the space of the ensemble perturbations
- computational efficient, but also restricts corrections to subspace spanned by the ensemble
- explicit localization (doing separate analysis at every grid point, select only certain obs)
- analysis ensemble members are locally linear combination of first guess ensemble members