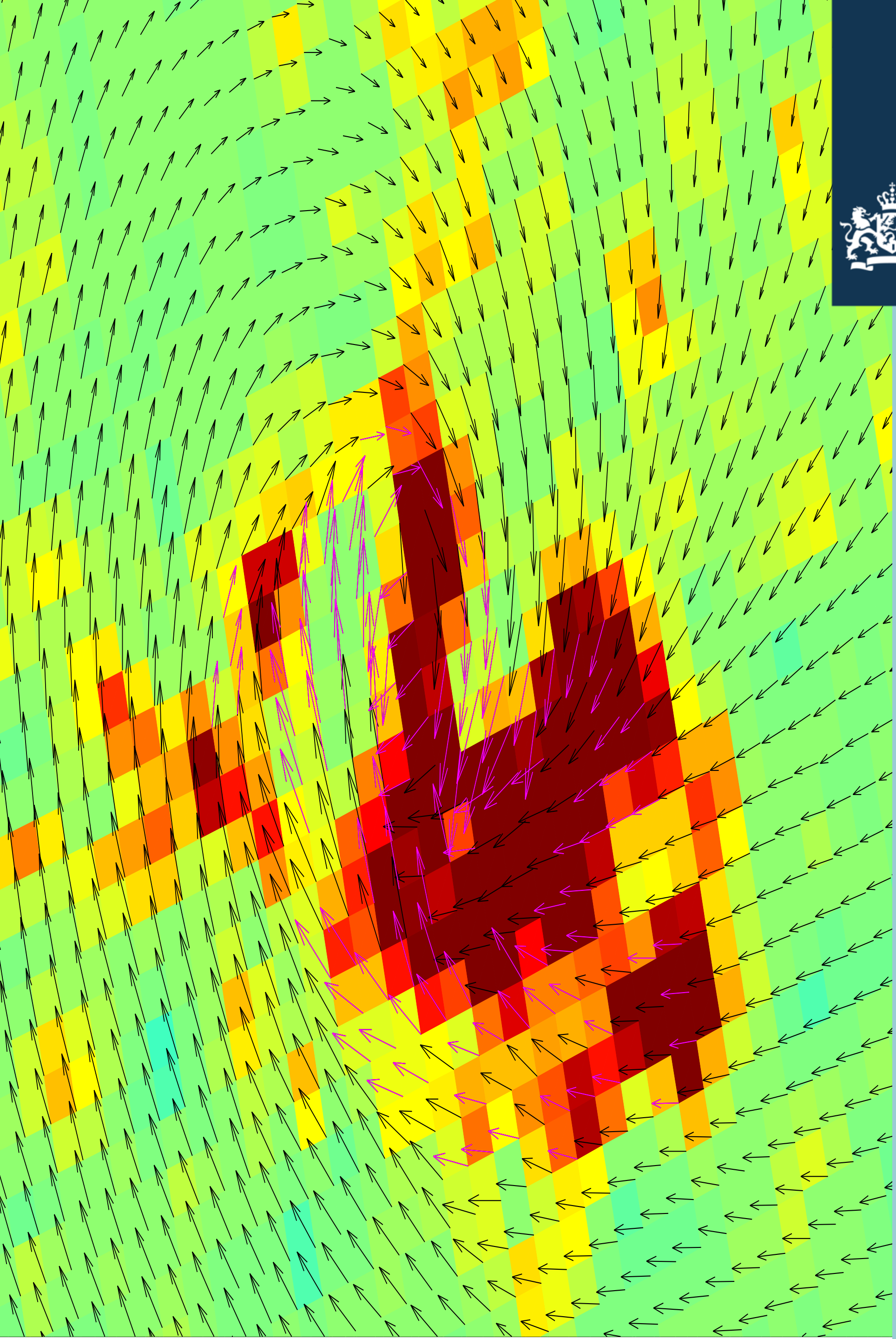


Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

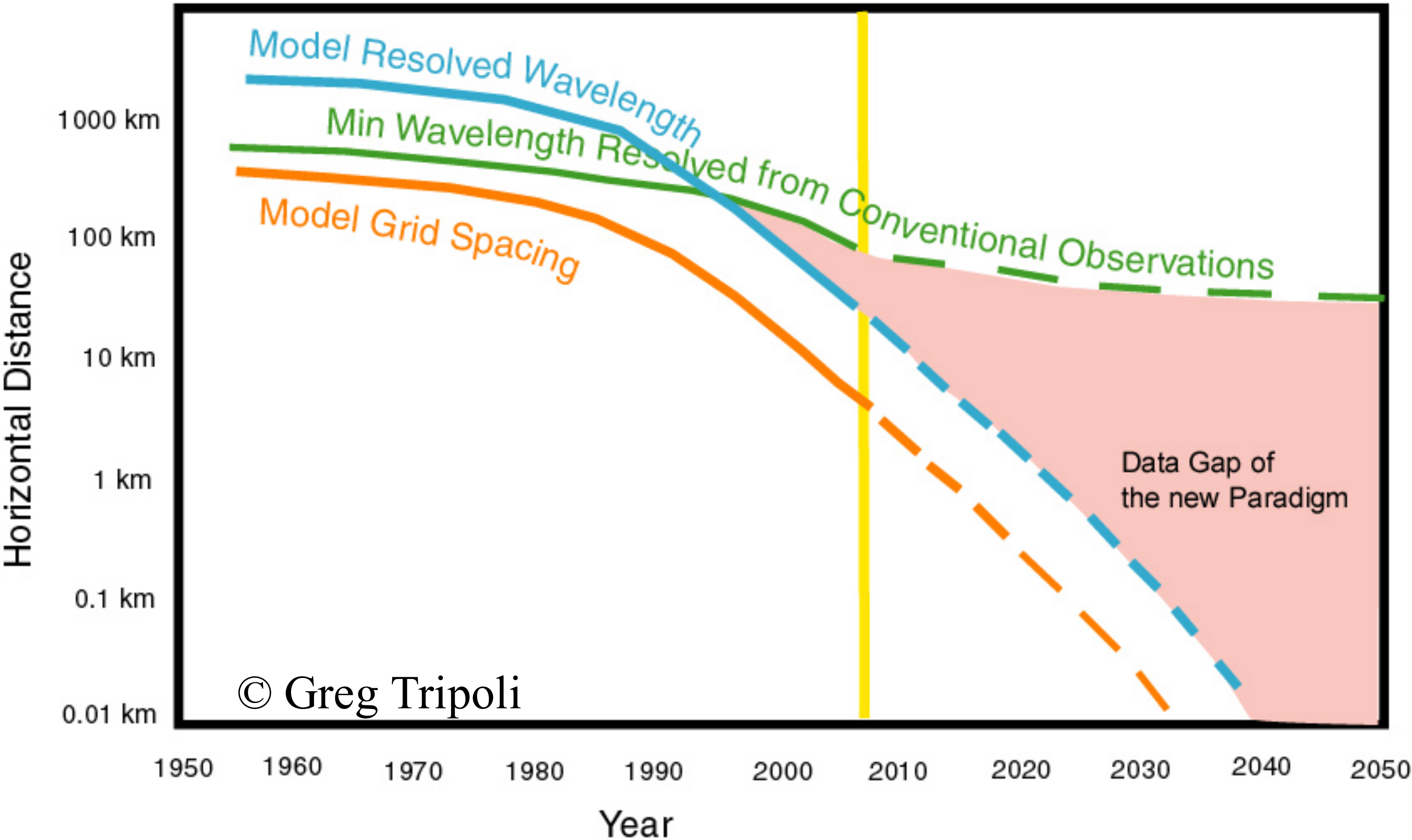
Mesoscale scatterometer assimilation

Ad.Stoffelen@knmi.nl

Leader Active Remote Sensing Group
Satellite Observations, KNMI

Gert-Jan Marseille
Jur Vogelzang
Wenming Lin (ICM)
Marcos Portabella (ICM)

Do we have enough data?



Does Dynamical Downscaling With Regional Climate Models add Value to Surface Marine Wind Speed From Reanalyses?

Jörg Winterfeldt[1*], Ralf Weisse[1], Matthias Zahn[1]

[1]Institute of Coastal Research, GKSS Research Centre, Geesthacht, Germany

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Simulations with RCMs REMO and CLM: *(available from* **coastDat** *Database)*

by GKSS Forschungszentrum Geesthacht

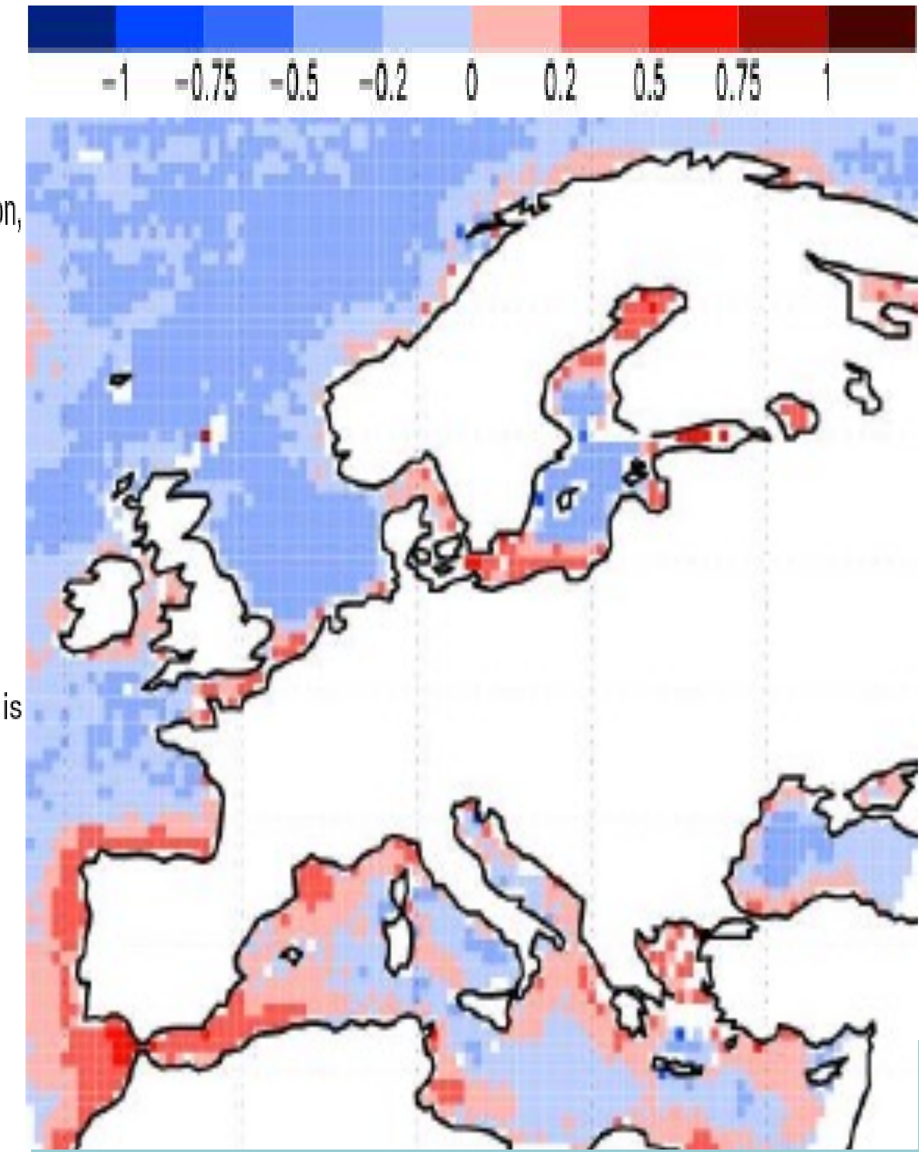
- Three hindcasts with RCMs REMO (Jakob and Podzun, 1997) and CLM (Böhm et al. 2006)
- Initialization and forcing at lateral boundaries: NCEP/NCAR-Reanalysis (NRA), ~1.875° resolution,
- SN-REMO & CLM hindcasts are additionally forced by spectral nudging (von Storch et al., 2000)

Hindcast	*STD-REMO (Standard)*	*SN-REMO*	*CLM*
Based on:	EM	EM	LM
	Hydrostatic	Hydrostatic	Non-hydrostatic
Forcing:	NRA	NRA	NRA
Spectral Nudging:	No	Yes	Yes
Resolution:	0.5°	0.5°	0.44°

- For that purpose a gridded QuikSCAT Level 2B 12.5 km swath (L2B12) data set is produced on SN-REMO grid (rain flagged L2B12 data discarded) co-location with SN-REMO: QuikSCAT wind speed retrieval max. 12.5 km and +/- 10 min from SN-REMO grid point / time step

- Modified BSS = $\begin{cases} 1 - \sigma_F^2 \sigma_R^{-2} & \text{if } \sigma_F^2 \leq \sigma_R^2 \\ \sigma_R^2 \sigma_F^{-2} - 1 & \text{if } \sigma_F^2 > \sigma_R^2 \end{cases}$

- "Forecast" F: SNREMO, reference "forecast" R: NRA, predictand/observation: gridded QuikSCAT L2B12 data



HARMONIE from ECMWF

- HSCAT scatterometer 50 km
- HARMONIE effective resolution 25 km, grid 2.5 km

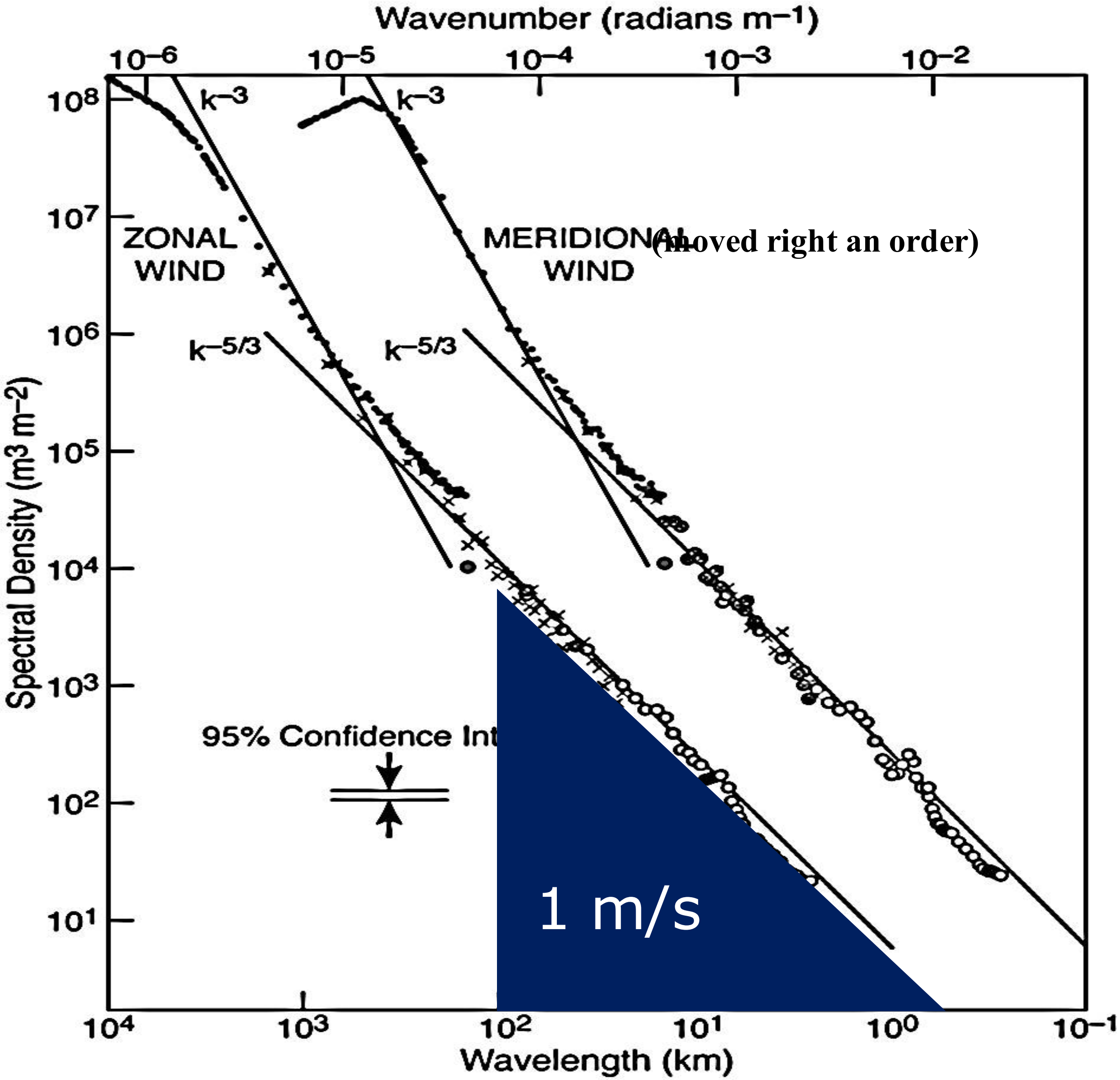
(m/s)	bias u_{10m}	stdev u_{10m}	bias v_{10m}	stdev v_{10m}
HSCAT	(23.961 collocations); $\overline{\Delta t} = -0.29$; $\overline{\lvert\Delta t\rvert} = 0.85$			
$(o-b)$	-0.46	1.61	-0.24	1.57
Temporal interpolation: $(o-b_t)$	-0.46	1.36	-0.22	1.29
+ spatial averaging: $(o-\bar{b}_t)$	-0.45	1.25	-0.22	1.18

- ECMWF:

	t_f	bias u_{10m}	stdev u_{10m}	bias v_{10m}	stdev v_{10m}
HSCAT	5.6	-0.11	1.09	0.05	1.15

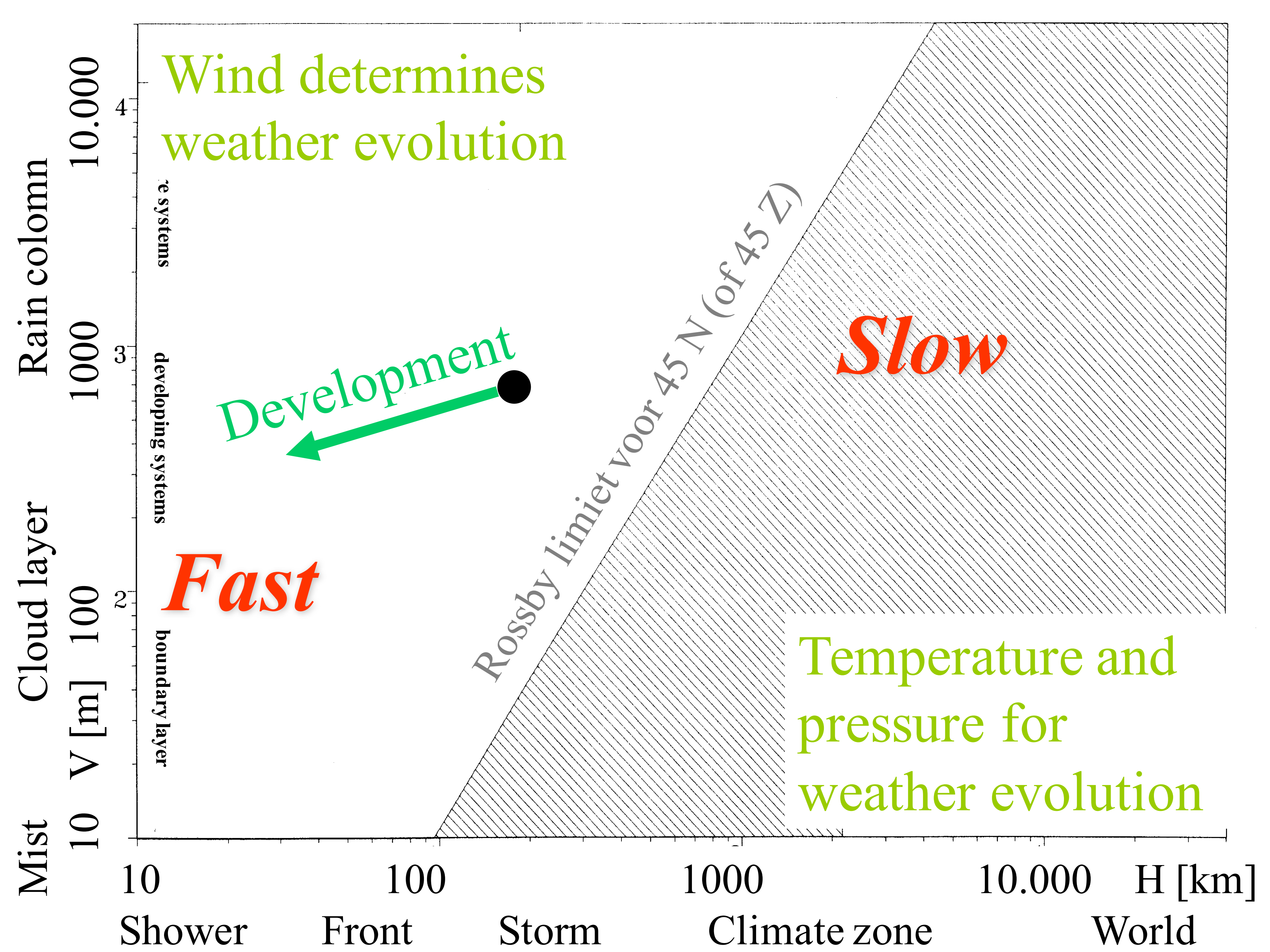
- ECMWF 6-hour forecast better than matched 50-km scale time-interpolated HARMONIE background
- ECMWF resolution is ~150 km over the open ocean
- Deterministic resolution

Nastrom & Gage Observed Spectrum



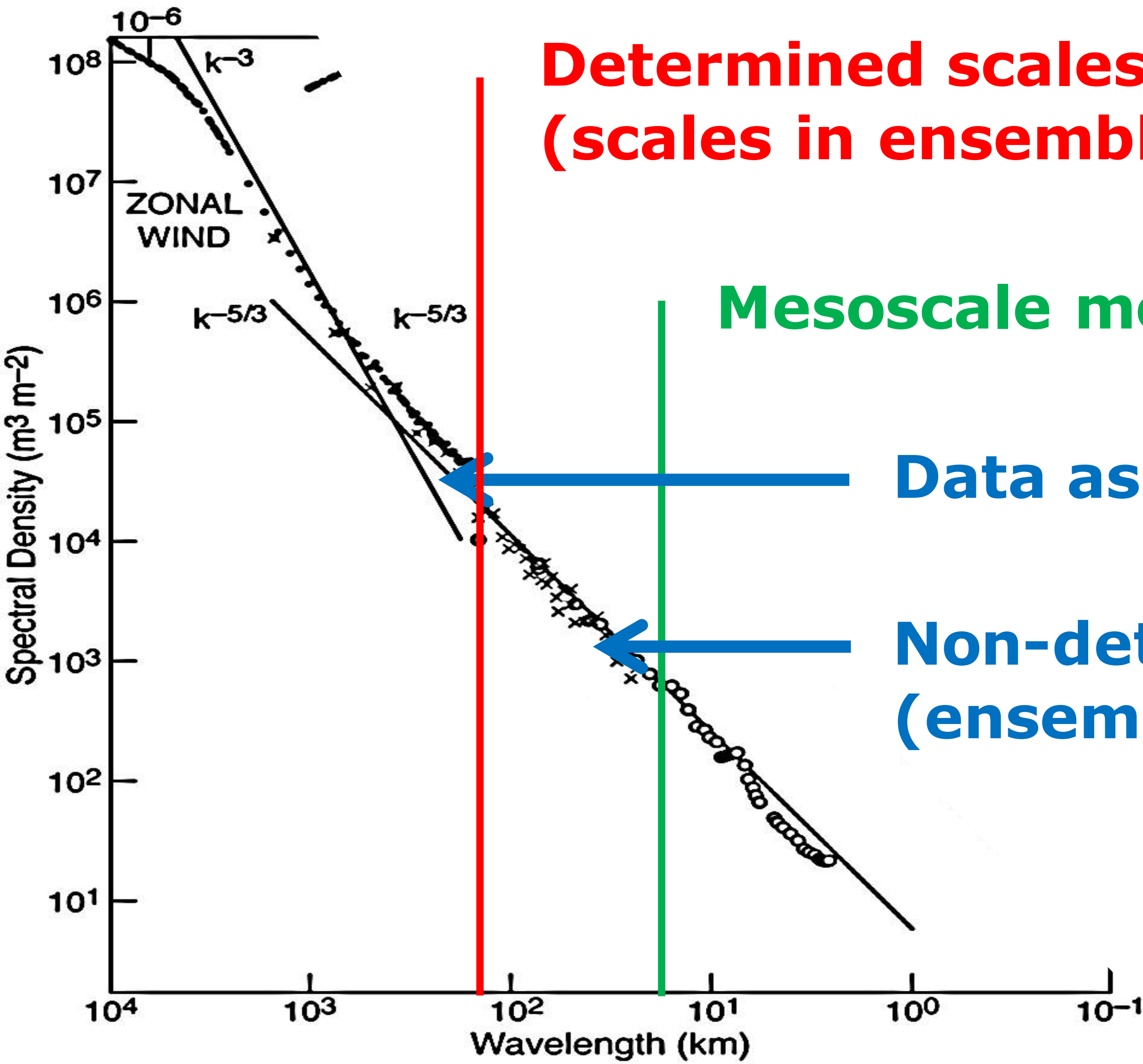
- Tropospheric spectra are close to $k^{-5/3}$
- 3D turbulence
- L/H ~ 100
- SD = 0.4 (log spectral density)

➢ Least variance/ detectability in small scales



Wind determines weather evolution
Development
Fast
Slow
Rossby limiet voor 45 N (of 45 Z)
Temperature and pressure for weather evolution
developing systems
boundary layer
Mist
Cloud layer
Rain colomn
V [m]
10
100
1000
10.000
H [km]
Shower
Front
Storm
Climate zone
World

Nastrom & Gage Observed Spectrum



Determined scales
(scales in ensemble mean)

Mesoscale model resolution

Data assimilation (B)

Non-determined scales
(ensemble spread)

Small-scale data assimilation

- The amplitude spectrum of small-scale atmospheric waves can be well simulated in NWP models, but the determination of the phases of these waves will be problematic in absence of well-determined forcing (orography) or observations
- Undetermined phases at high resolution cause
  - Increased NWP model error, B' > B
  - Model errors get more variable and uncertain since small scales tend to be coherent; coherence is of most interest
  - B error structures will be spatially more sharp
  - Increased O-B, while the observation (representativeness) errors will be reduced; observations (should) get more weight, O' < O
  - Increments would be larger
  - When O' > B, the analysis error will be larger too ! A' > A

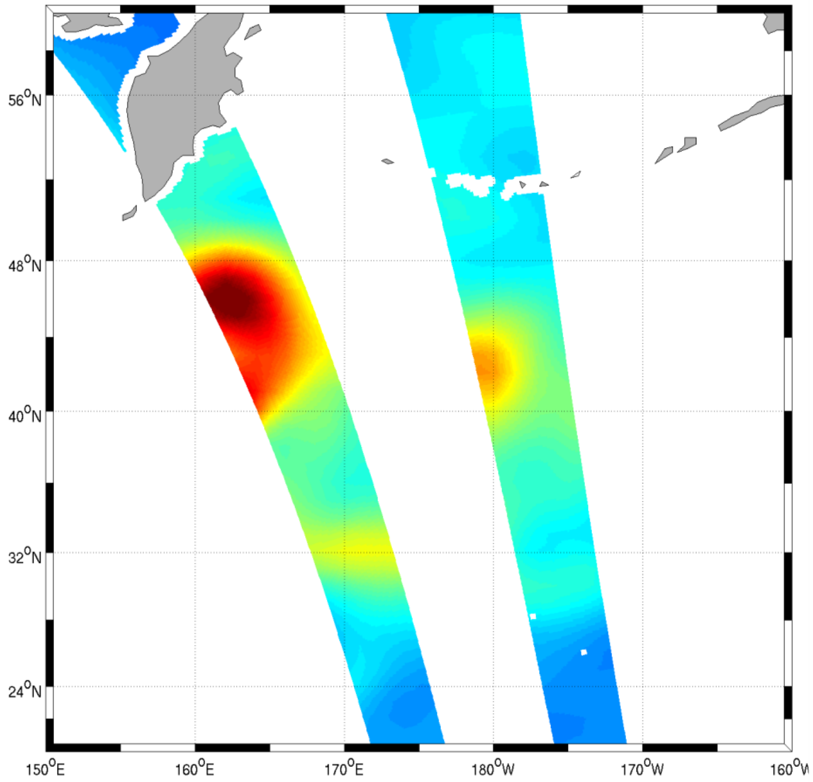
Challenges

- Adaptive B covariances are difficult to estimate
- More (wind) observations are needed to spatially sample small-scale B structures
- Observations need to be accurate, O < B
- How to prevent overfitting (uncertain B, small O) due to inaccurate and high innovation weights ?
- And spin-up due to more noisy analysis (statistical B) ?

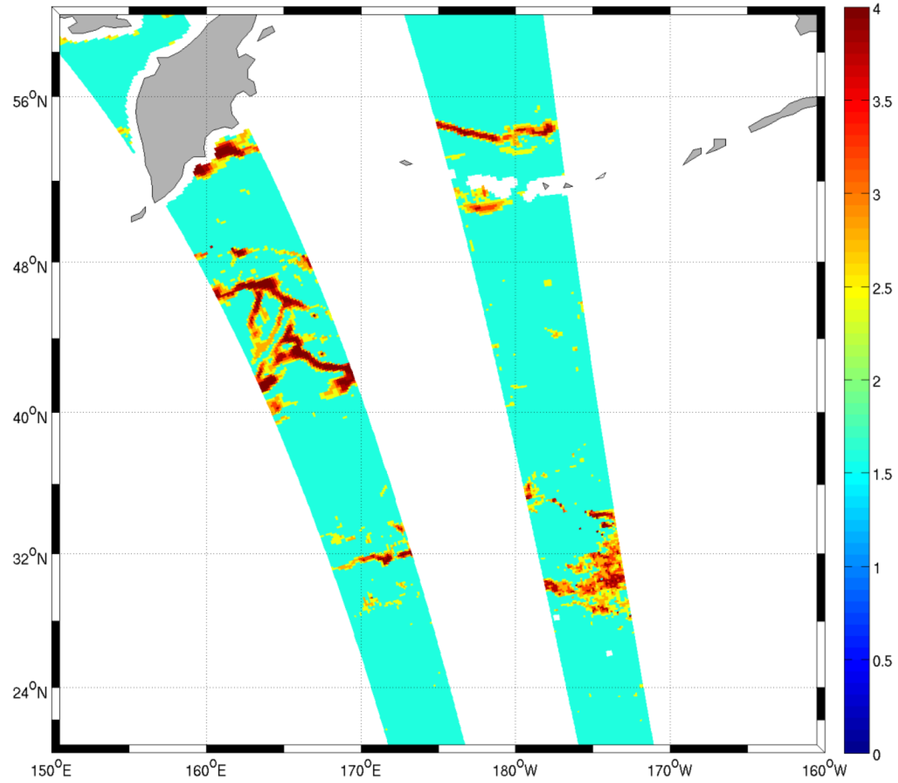
- Separate determined from undetermined scales in data assimilation, e.g.,
  - Data assimilation with ensemble mean ?
  - Maintain broad B ?
  - SuperMod up to determined scales ?

Examples

Estimated B error variances

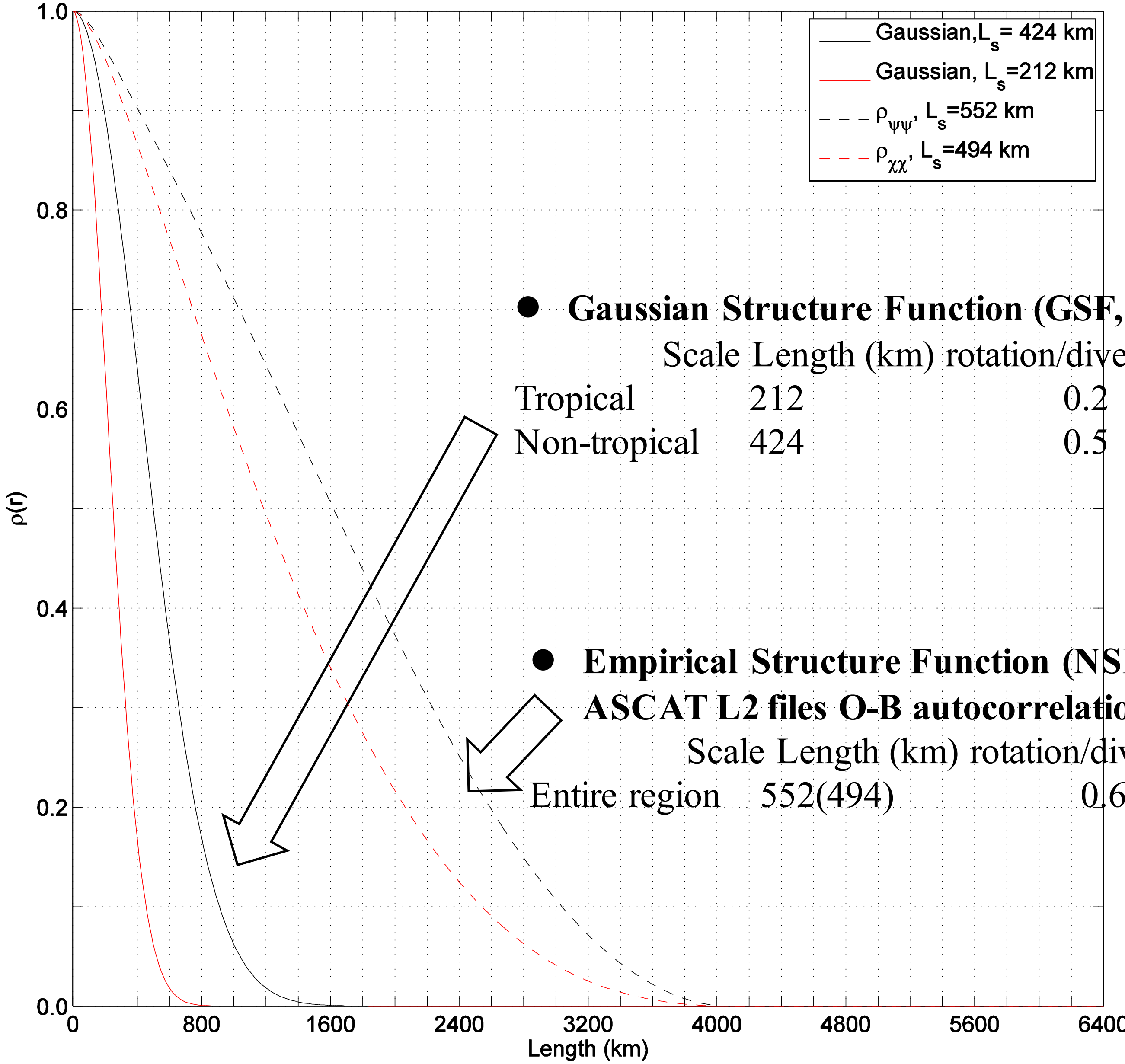


ECMWF Ensemble Data Assimilation (EDA background error)



ASCAT-derived ECMWF background error by triple collocation in QC classes

NWP Background spatial error correlation structure



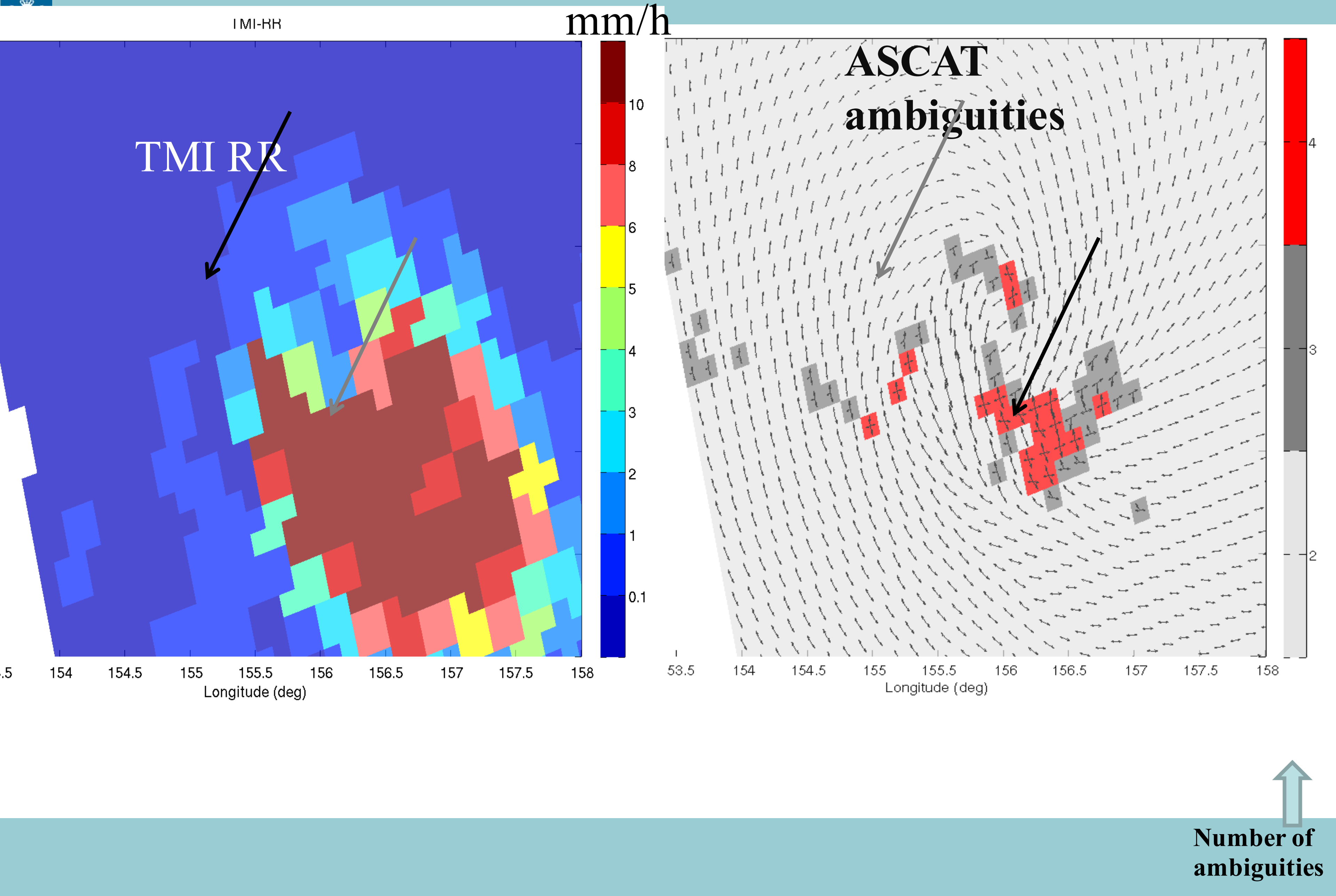
- **Gaussian Structure Function (GSF, default setting)**

	Scale Length (km)	rotation/divergence ratio
Tropical	212	0.2
Non-tropical	424	0.5

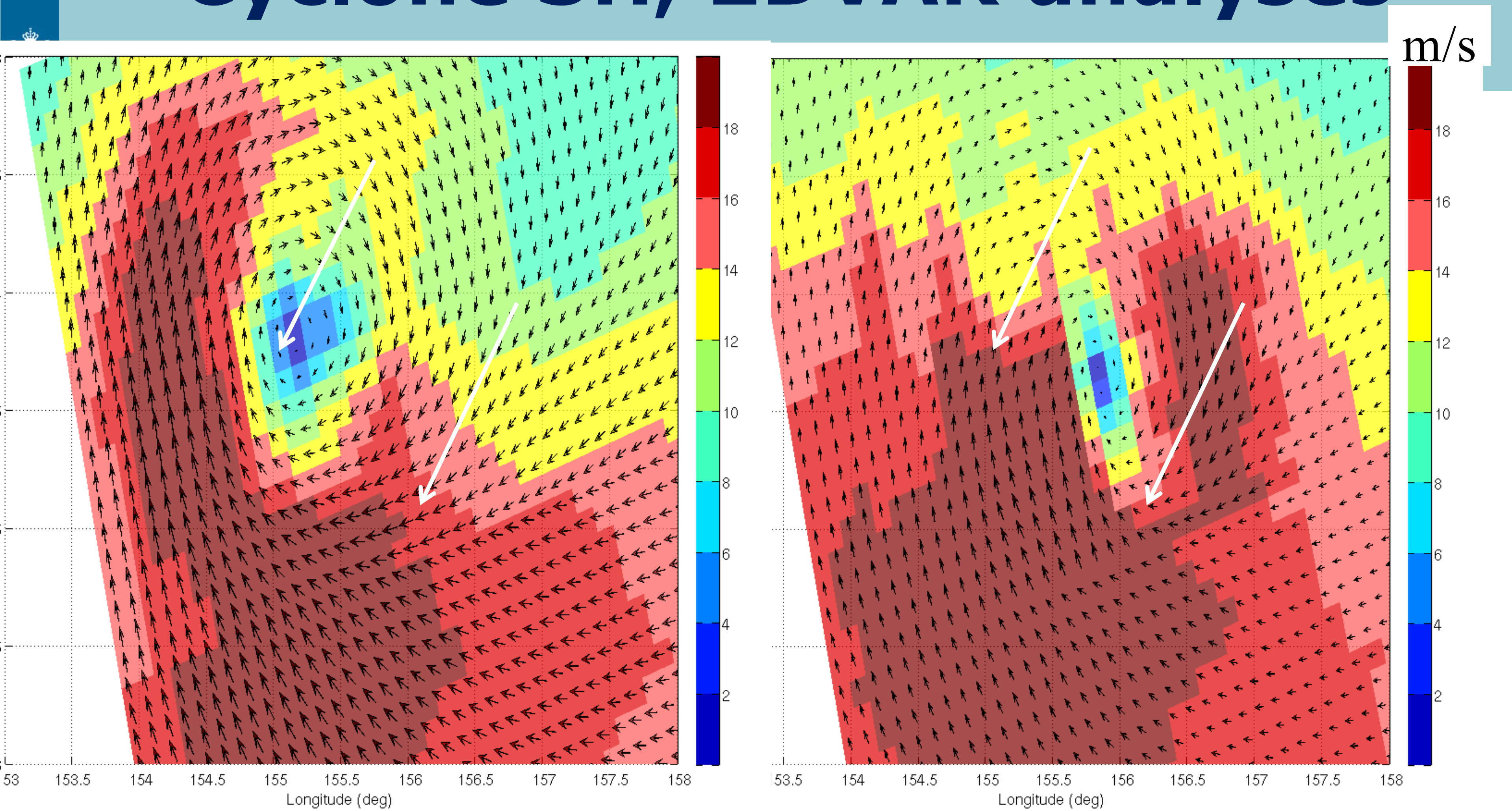
- **Empirical Structure Function (NSF, derived from ASCAT L2 files O-B autocorrelation, new setting)**

	Scale Length (km)	rotation/divergence ratio
Entire region	552(494)	0.62

Cyclone SH


TMI-RR
mm/h
TMI RR
10
8
6
5
4
3
2
1
0.1
154
154.5
155
155.5
156
156.5
157
157.5
158
Longitude (deg)
ASCAT
ambiguities
4
3
2
53.5
154
154.5
155
155.5
156
156.5
157
157.5
158
Longitude (deg)
Number of
ambiguities

Cyclone SH, 2DVAR analyses

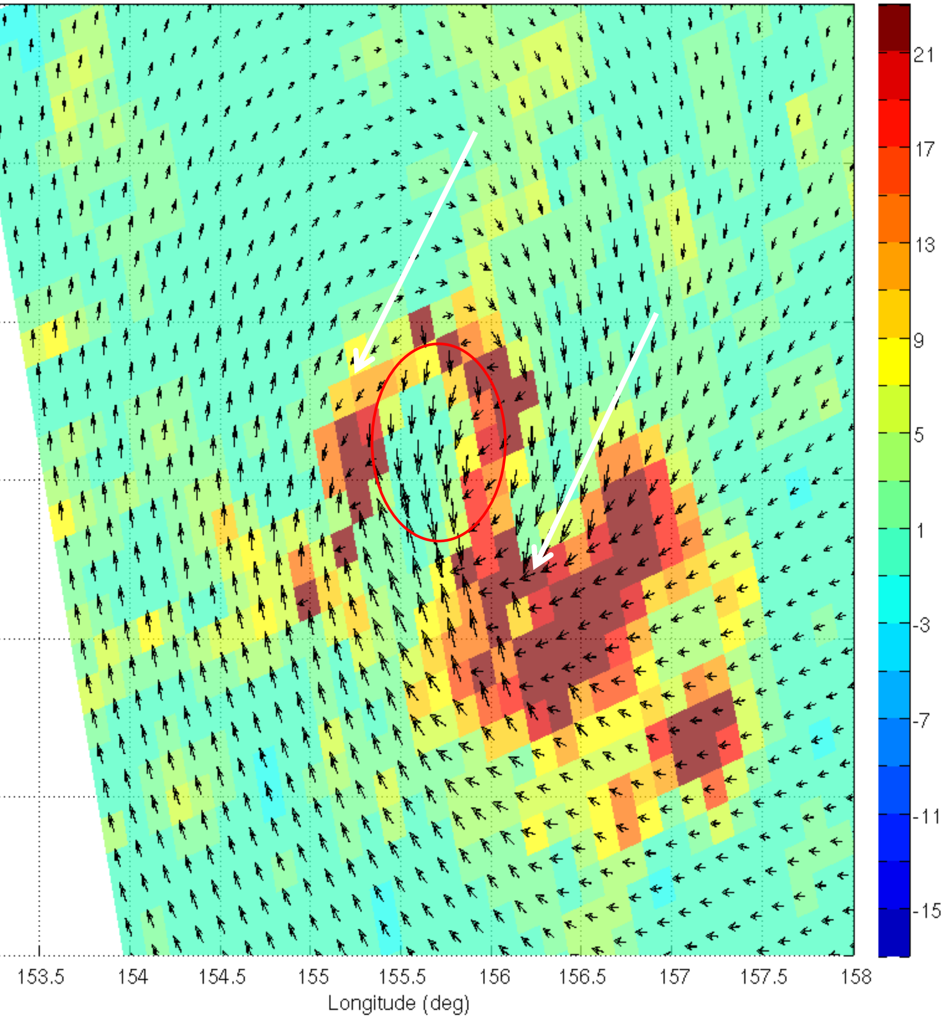


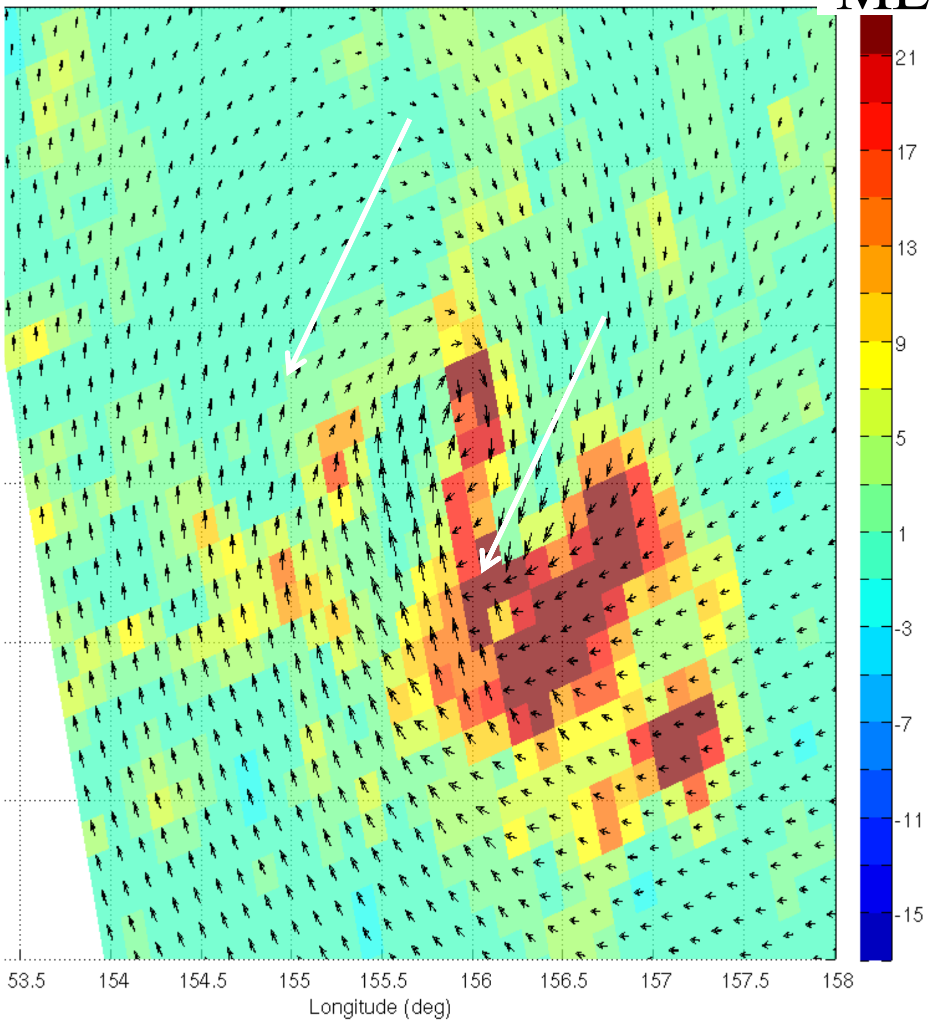
Default setting:
- Gaussian structure function
- Fixed O/B errors

New setting:
- Empirical structure function
- Flexible O/B errors

Cyclone SH, selected solutions

MLI





Default setting:

- Gaussian structure function
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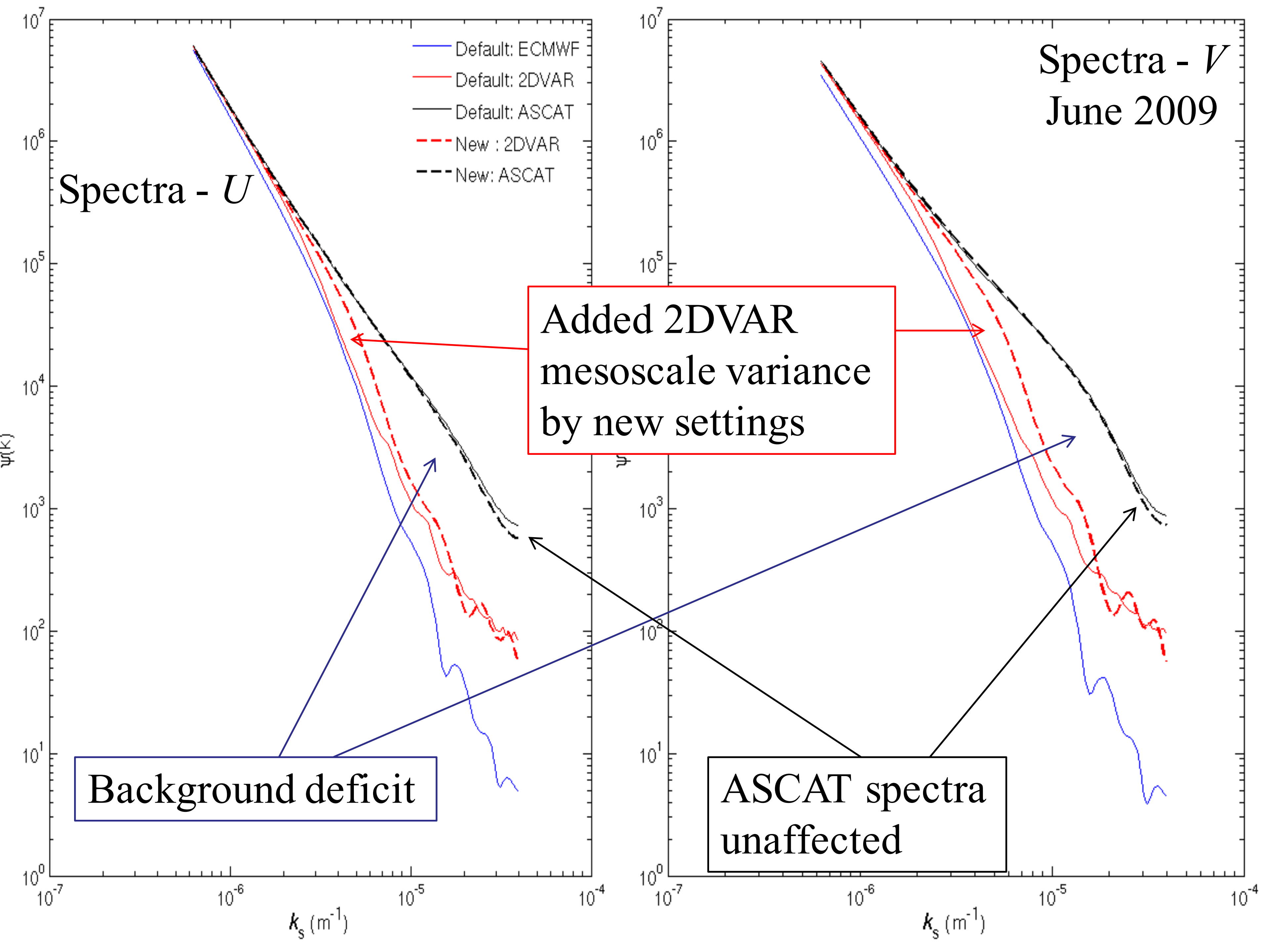
New setting:

- Empirical structure function
- Flexible O/B errors



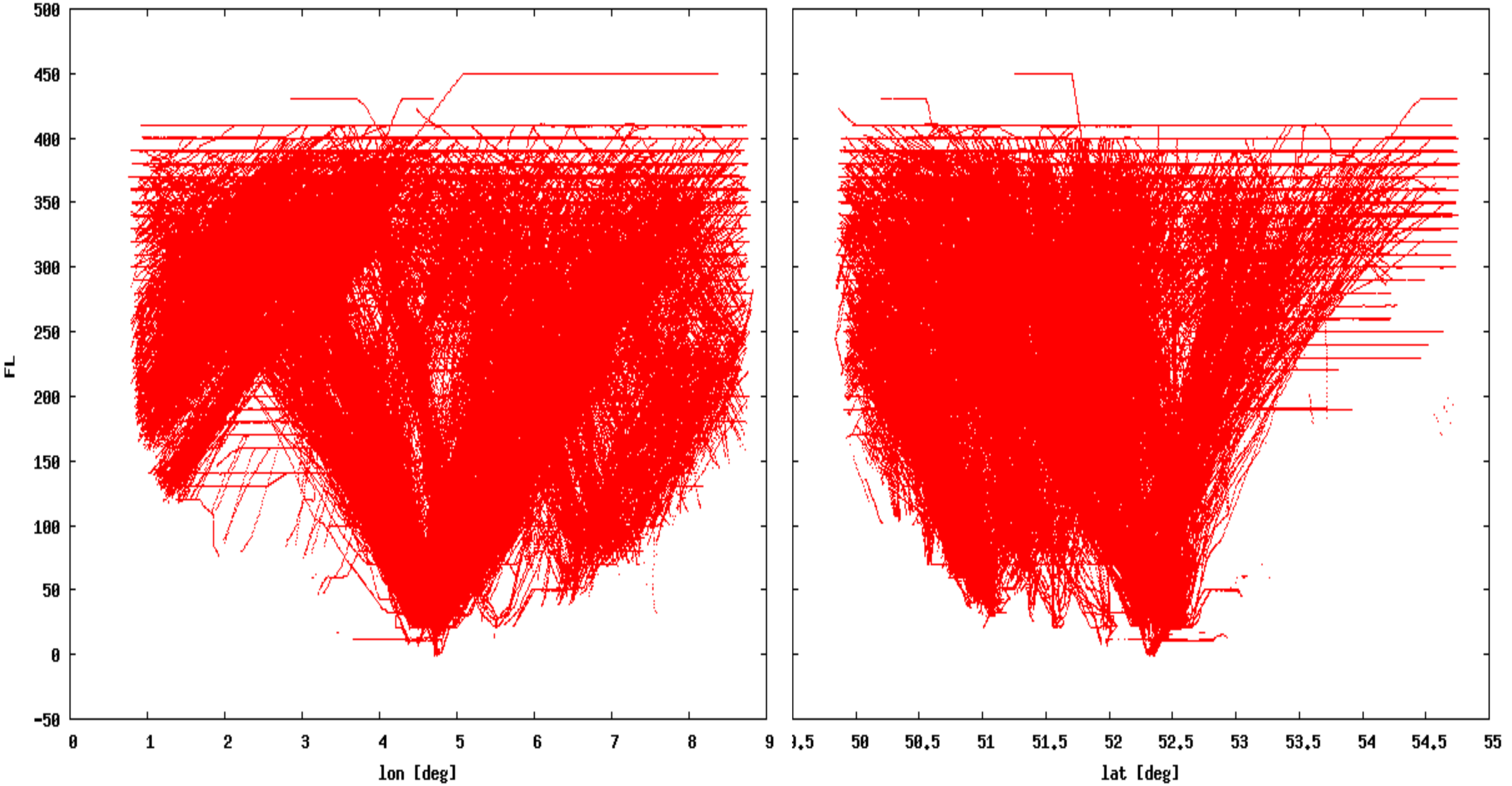
Spectra - U
Spectra - V
June 2009
Default: ECMWF
Default: 2DVAR
Default: ASCAT
New : 2DVAR
New: ASCAT
Added 2DVAR mesoscale variance by new settings
Background deficit
ASCAT spectra unaffected
ψ(k)
k_s (m^{-1})

All the QC-accepted data (March-August 2009)

	ASCAT-ECMWF-buoy comparison (mean buoy winds)		
	ASCAT vs ECMWF	ASCAT vs buoy point wind	N
Default	2.27	1.86	6908
New	2.26	1.83	

	ASCAT-ECMWF-buoy comparison (mean buoy winds)			
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs ASCAT	N
Default	1.91	2.01	1.22	6908
New	2.06	1.85	0.81	

Data volume 15-03-2008



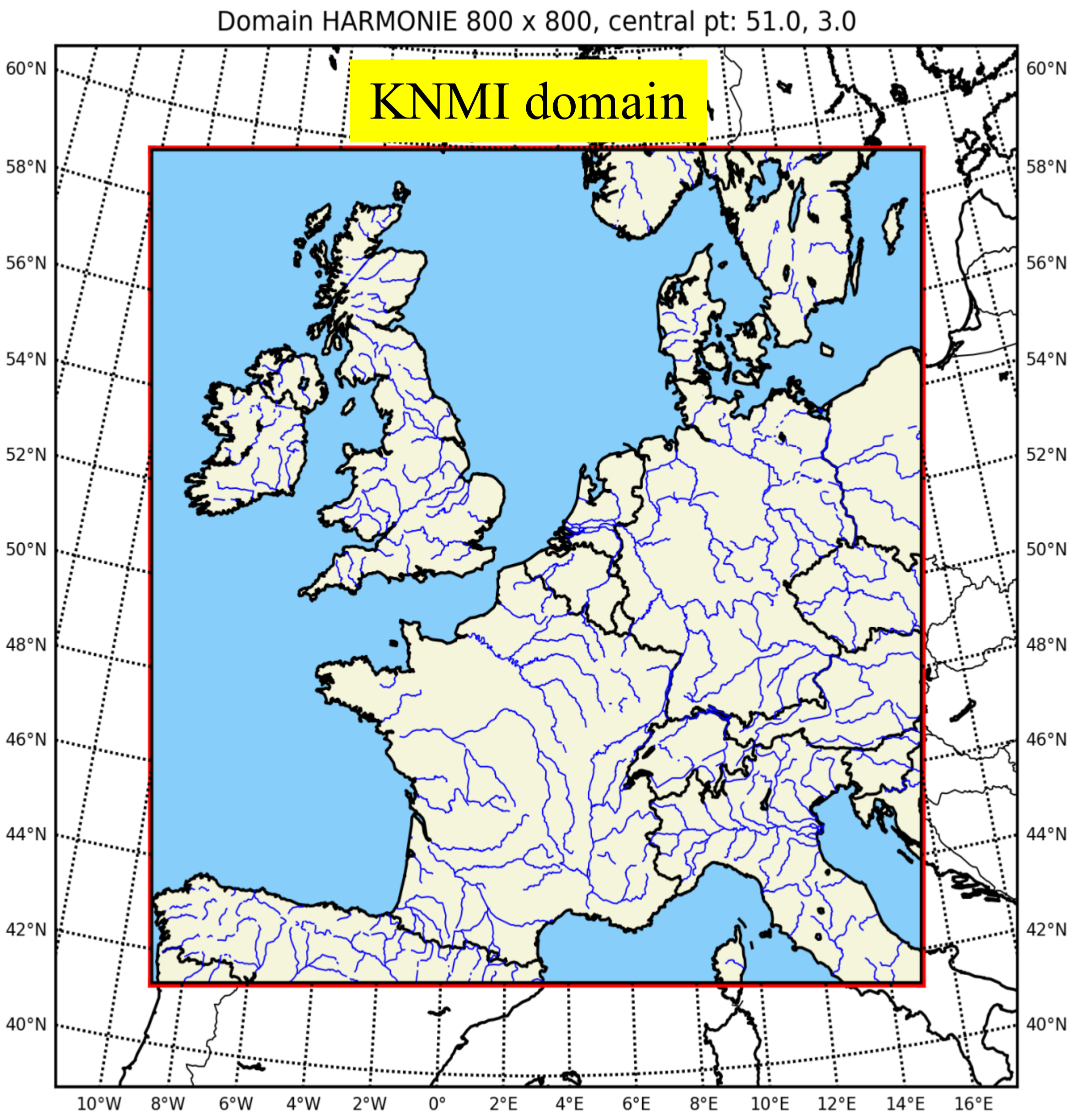
- 1 424 147 observations

Improved prediction of landing times by ModeS aircraft winds

Case\ Parameter	Minimum (s)	Maximum (s)	Mean (s)	St.Dev. (s)
No Wind	-293	169	2,3	79,9
KNMI 1.0	-80	70	-3,8	20,5
D11	-64	56	-3,2	17,7
H11	-58	46	-3,3	17,6
M11(3)	-69	55	-3,4	17,7
M11(1)	-61	50	-4,9	17,4

- ModeS winds have impact in HIRLAM, but not in HARMONIE ?

HARMONIE model
(Hirlam ALADIN Research on Meso-scale Operational NWP in Euromed)



- Non-hydrostatic
- 800x800 grid
- 2.5 km grid size
- 65 vertical levels
- 3D-Var assimilation
  - 8 times per day
  - 48-hour forecast
- ECMWF boundaries
- Available since 2012

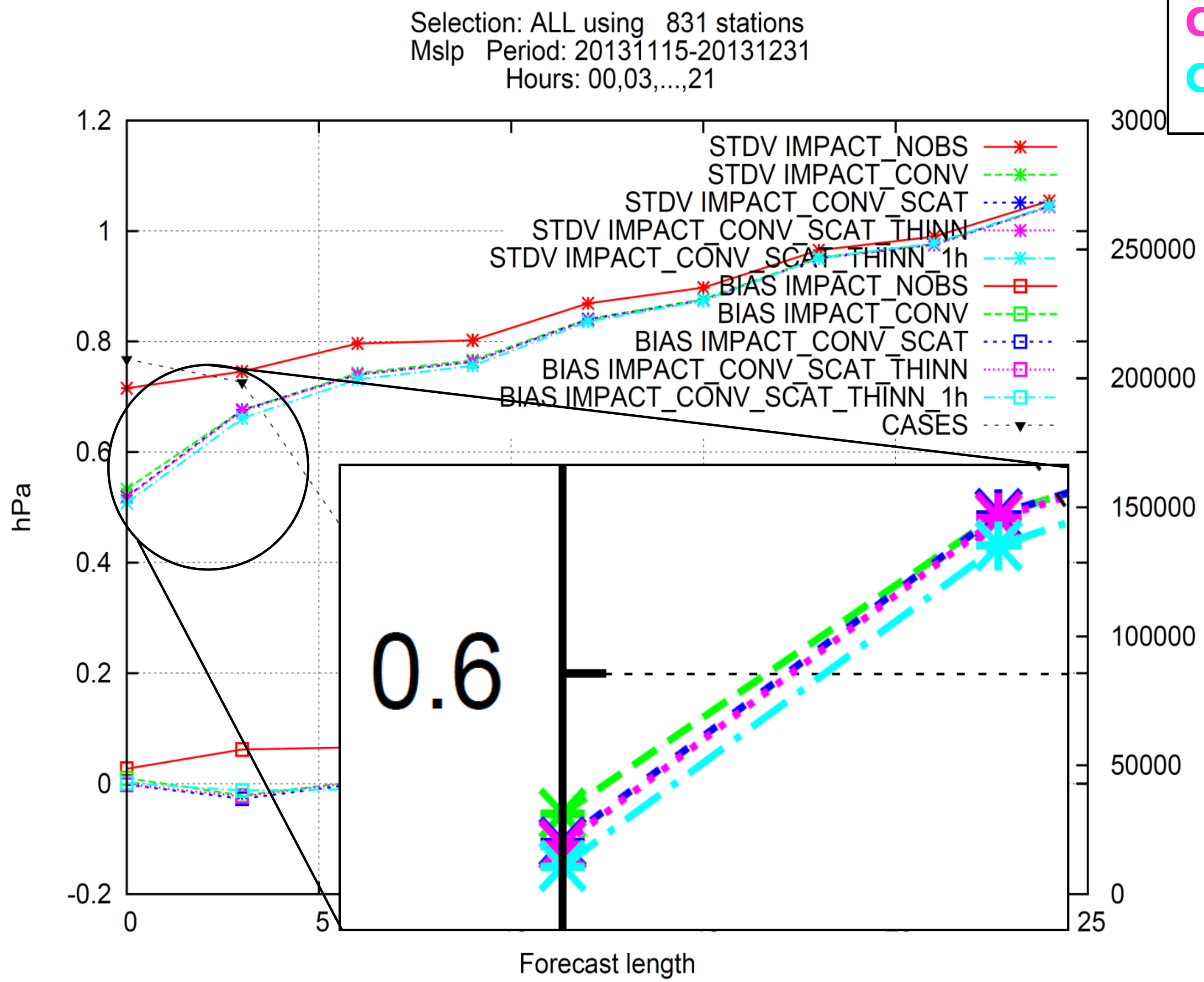
HARMONIE impact experiments

- 6-week period 15/11/2013 – 31/12/2013
  - Including 5/6 December “Mandela storm”
- 3D-Var data assimilation
- Conventional observing systems:
  - radiosonde, aircraft, SYNOP (ground stations), buoys
- Available scatterometers: ASCAT A/B (12.5 km coastal), OSCAT (50 km), HSCAT (so far used for verification only)
- Experimental model version; cycle Cy38h1.2

NO OBS	; no observations
CONV-3h	; conventional observations – 3-h cycling
CONV+SCAT-3h	; **CONV-3h** + scat observations - no thinning
CONV+SCAT-THINN-3h	; **CONV+SCAT-3h** but ASCAT thinning (100 km)
CONV+SCAT-THINN-1h	; **CONV+SCAT-THINN-3h** but 1-h cycling

MSLP verification over land

NO OBS
CONV-3h
CONV+SCAT-3h
CONV+SCAT-THINN-3h
CONV+SCAT-THINN-1h



First time improved forecast skill from DA!!

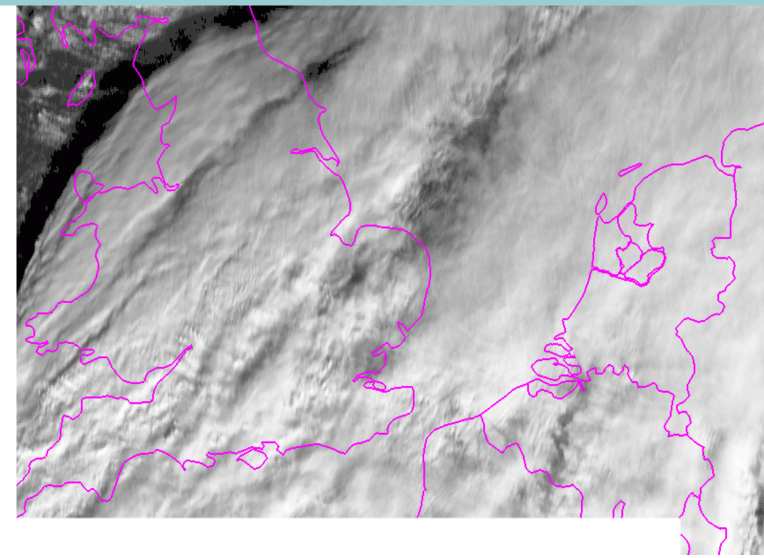
- Scatterometer improves analyses of mean sea level pressure over land
- SCAT impact gone after 3 hours (in 3-h cycle)
- Impact maintained for 1-h cycling; SCAT or additional SYNOPS??

SCAT impact largely gone after 3 hours

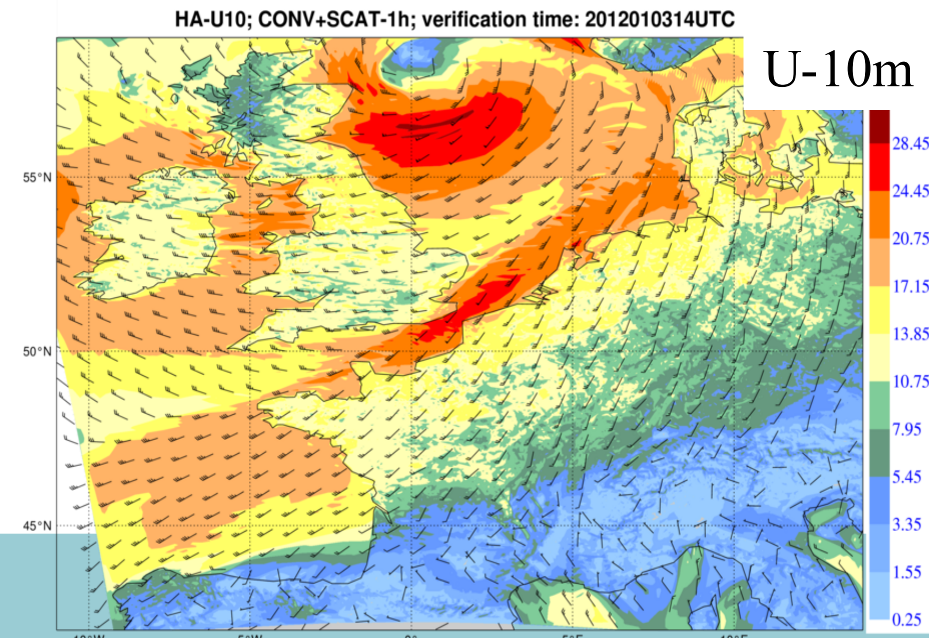
- Possible explanations
  - Incorrect weight given to observations in the analysis; this was verified and indeed too much weight is currently given to observations.
  - For ASCAT: 1.39/1.55 stddev, ignoring “footprint error”
  - Timing issue in 3D-Var for e.g. aircraft, all satellite data.
  - But scores do not take into account coarse temporal data coverage
    - Most forecast initial states had no SCAT data
    - Probably better to limit verification to forecasts initiated with SCAT
  - Model bias (next slides)

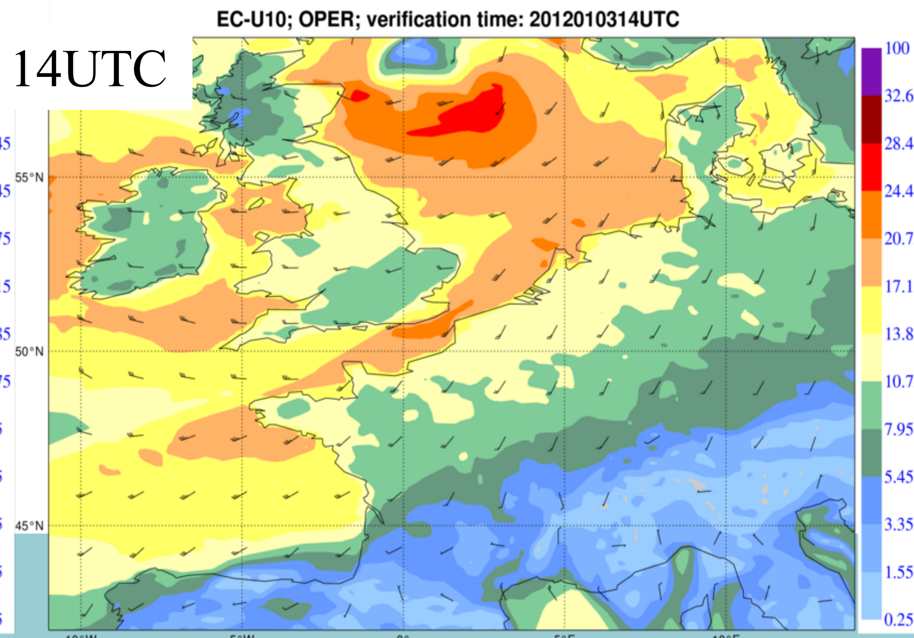
Model bias example: Storm Ulli , 3 January 2012

3 Jan. 2012 ~ 13UTC. In the strong westerly flow, a cold front rapidly moved across the North Sea, passing the Dutch coast. The front was accompanied with a squall line. The Dutch coastguard reported a so called meteo-tsunami at the coast of Ijmuiden, with a sea level change (rise and fall) of over 1.5 meters in 30 minutes.

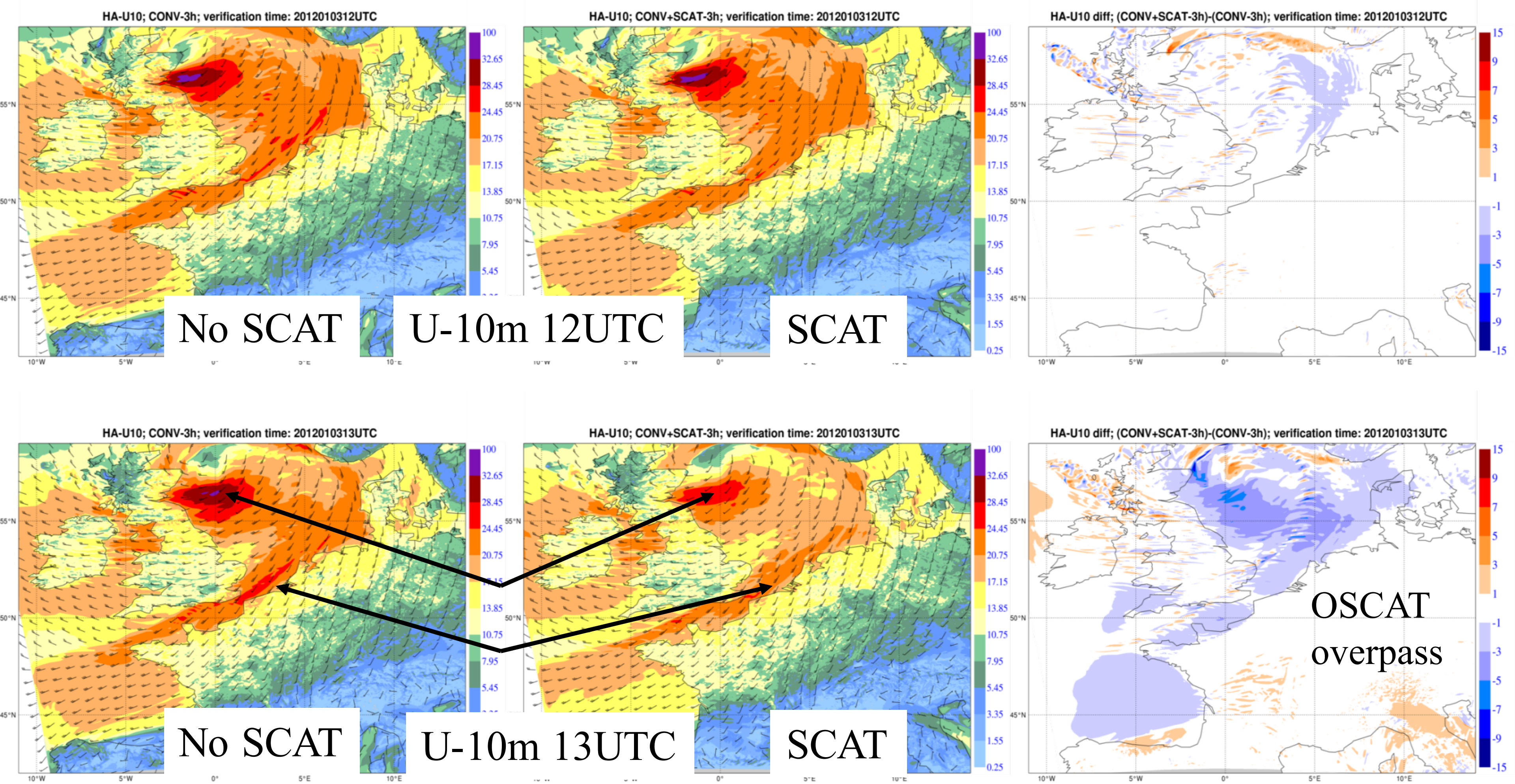


U-10m 14UTC

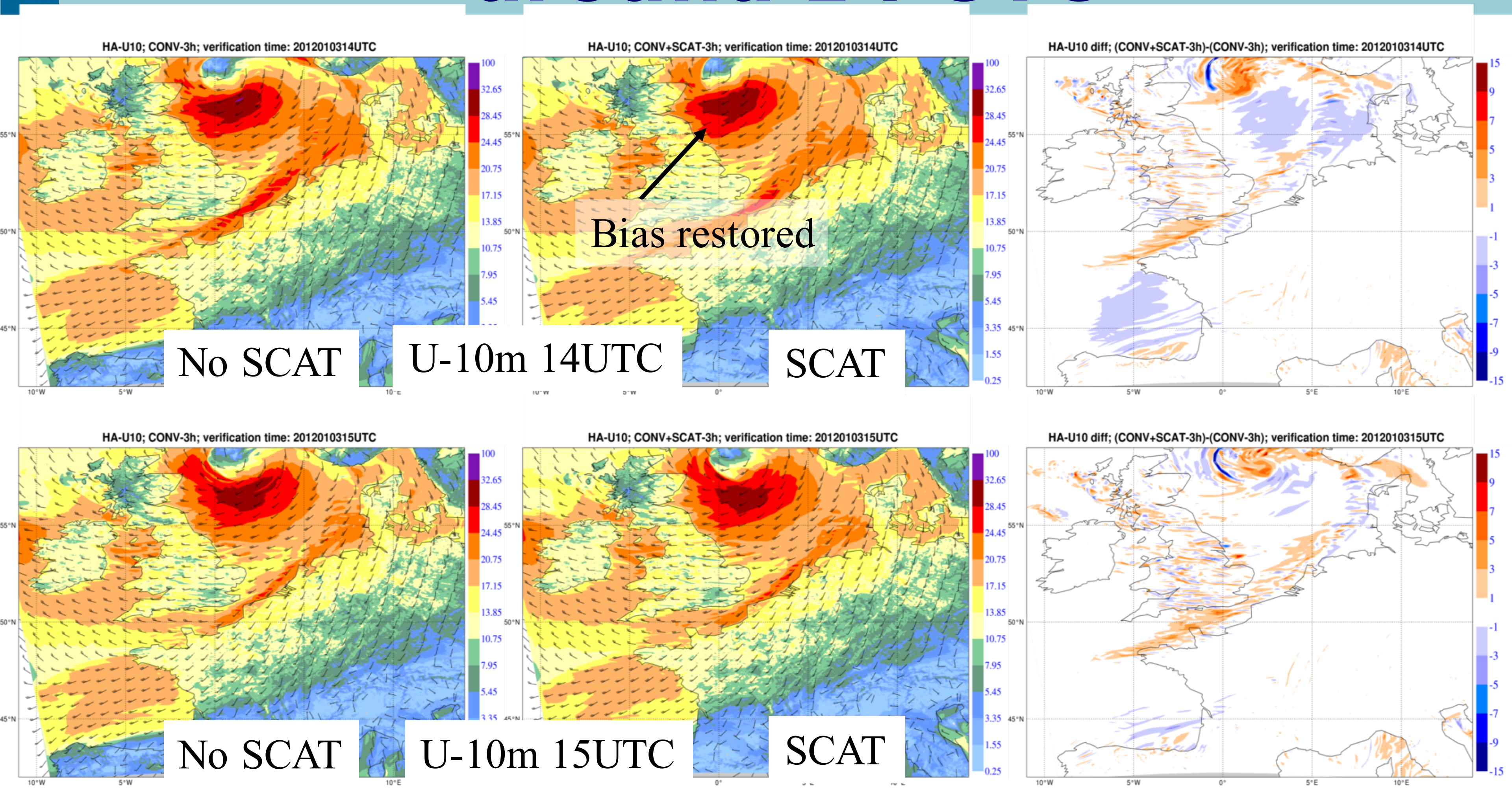




Harmonie 3 January around 13 UTC



Harmonie 3 January around 14 UTC



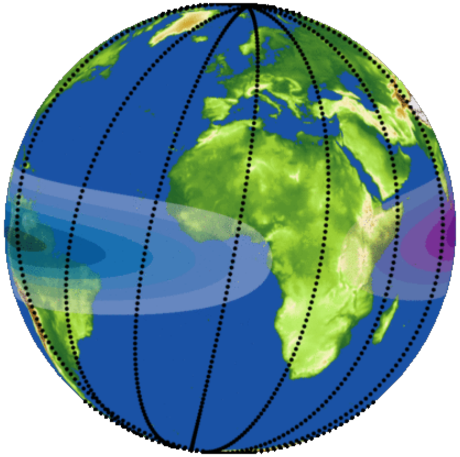
Large impact SCAT on analyses but not maintained in a biased model

Conclusions

- Mesoscale data assimilation is a new paradigm
- Many accurate 4D wind observations are needed to initialize 3D turbulence and convection in the atmosphere
- Undetermined scales cause headaches and destroy the analysis of the larger scales potentially
- It is possible to determine small observed scales in the analysis, if they did not exist yet (2DVAR)
- Weather models return to their climatological balance very quickly though
- Seek ways to avoid analyzing non-deterministic scales and their detriment as model noise
- Accurate treatment of time and space aspects, balance

Workshop

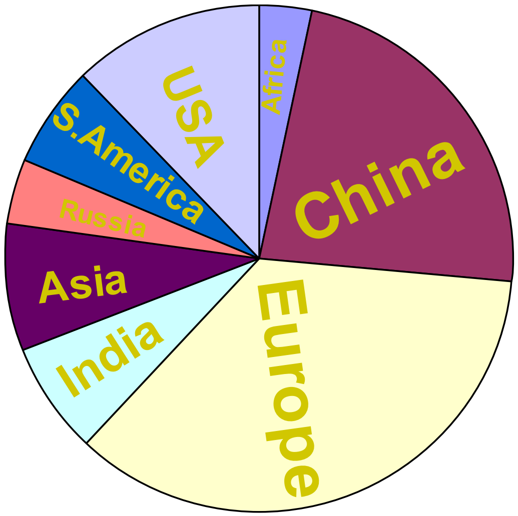
Wind Profiles and Mesoscale Data Assimilation

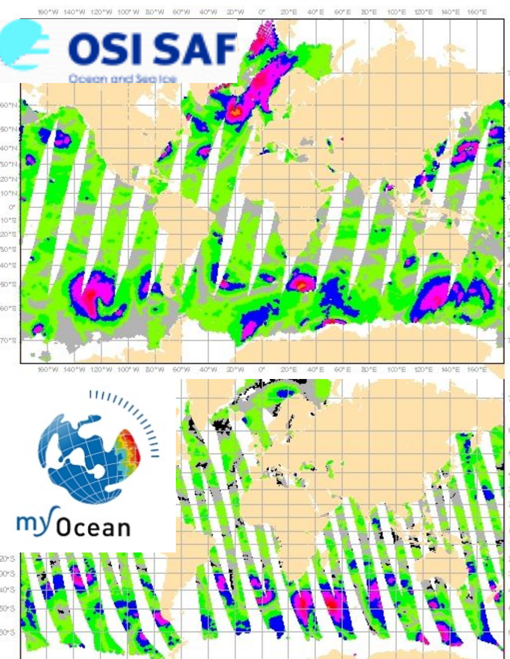


Ljubljana, 19-20 September 2016

meteo.fmf.uni-lj.si/en/workshop

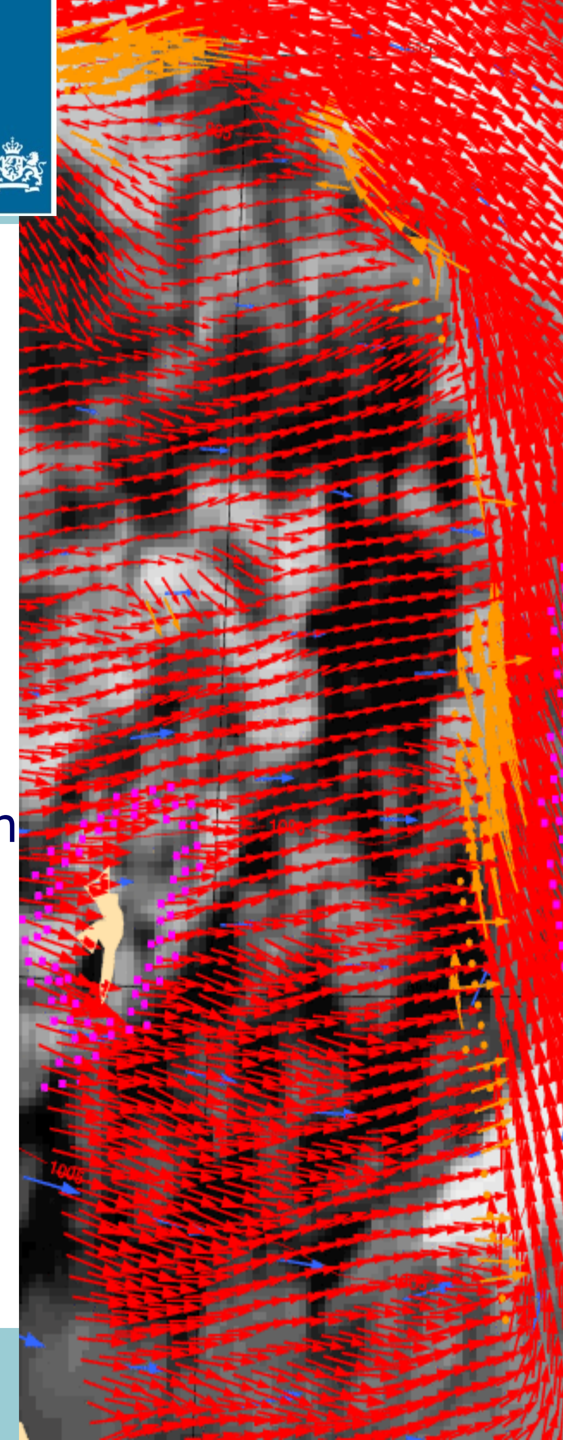
Satellite Wind Services at Sea



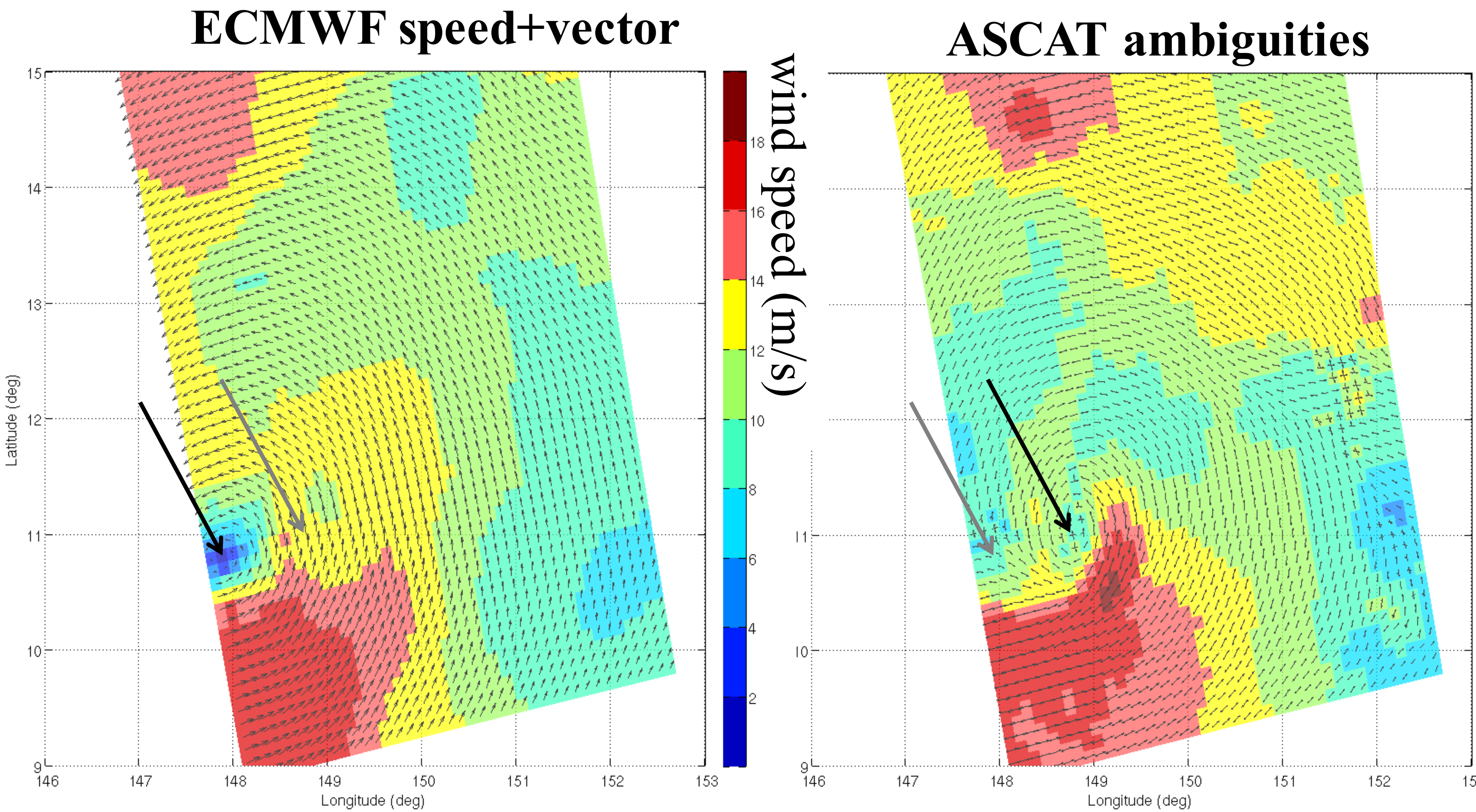


- 24/7 Wind product services (OSI SAF)
  - Constellation of satellites
  - High quality winds, QC
  - Timeliness 30 min. – 2 hours
  - Service messages
  - QA, monitoring
- Software services (NWP SAF)
  - Portable Wind Processors
  - Weather model comparison
- Organisations involved: KNMI, EUMETSAT, EU, ESA, NASA, NOAA, ISRO, SOA, WMO, CEOS, ..
- Users: NHC, JTWC, ECMWF, NOAA, NASA, NRL, BoM, UK MetO, M.France, DWD, CMA, JMA, CPTEC, NCAR, NL, . . .

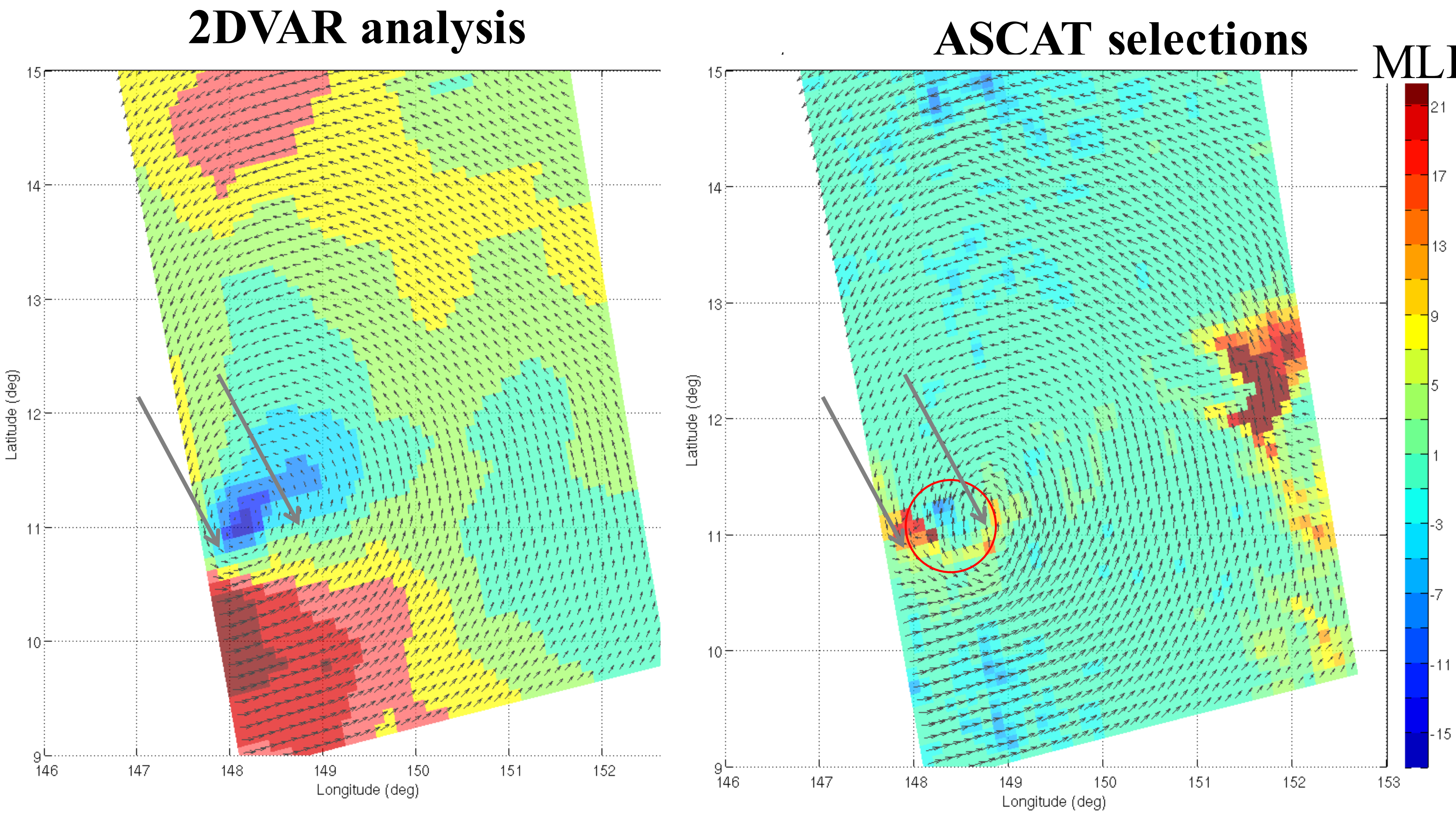
More information:
www.knmi.nl/scatterometer



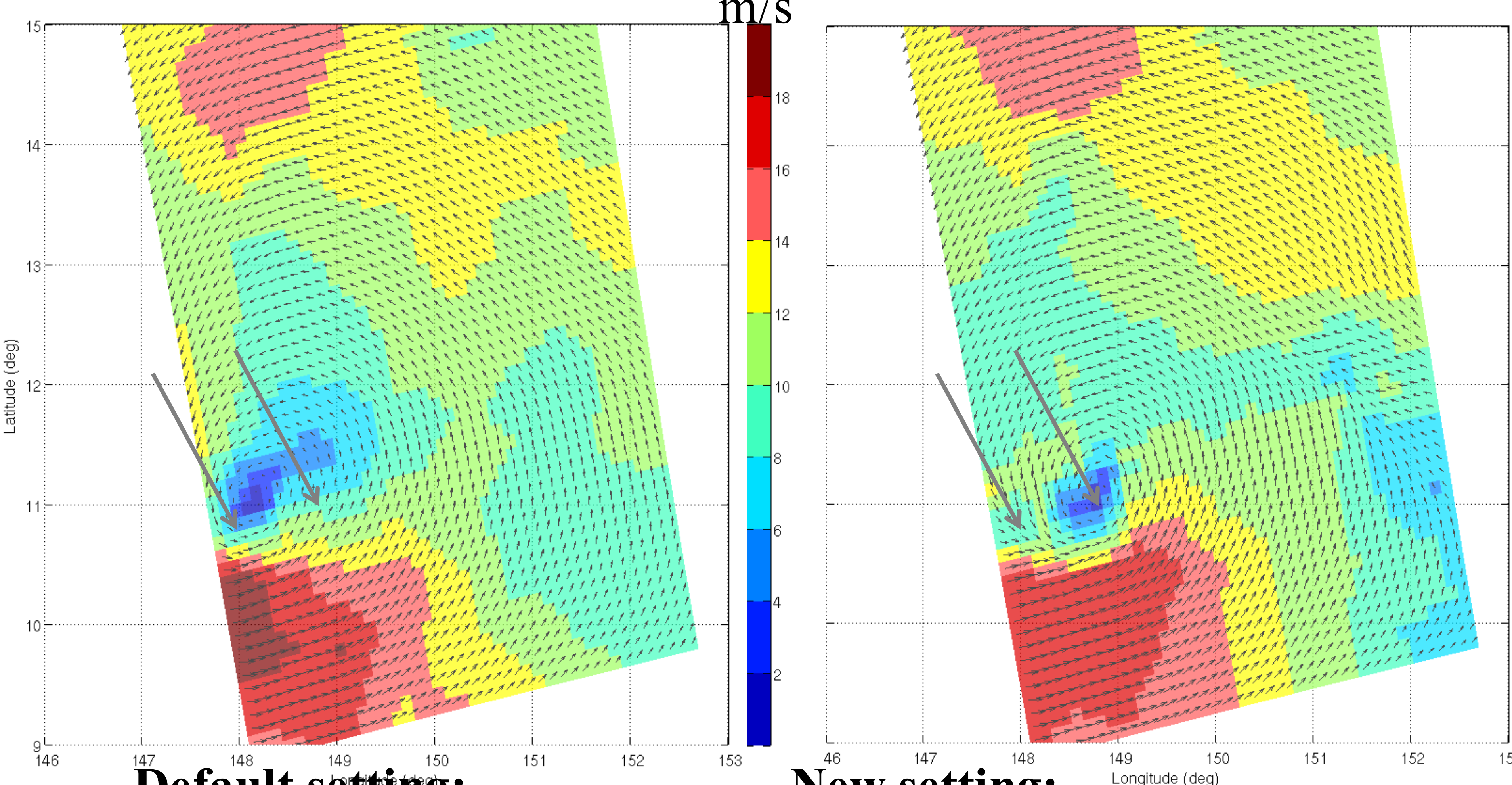
Typhoon Chan-hom, July 3, 2015 (early stage)



Typhoon Chan-hom, July 3, 2015 (early stage)



Typhoon Chan-hom, 2DVAR analyses



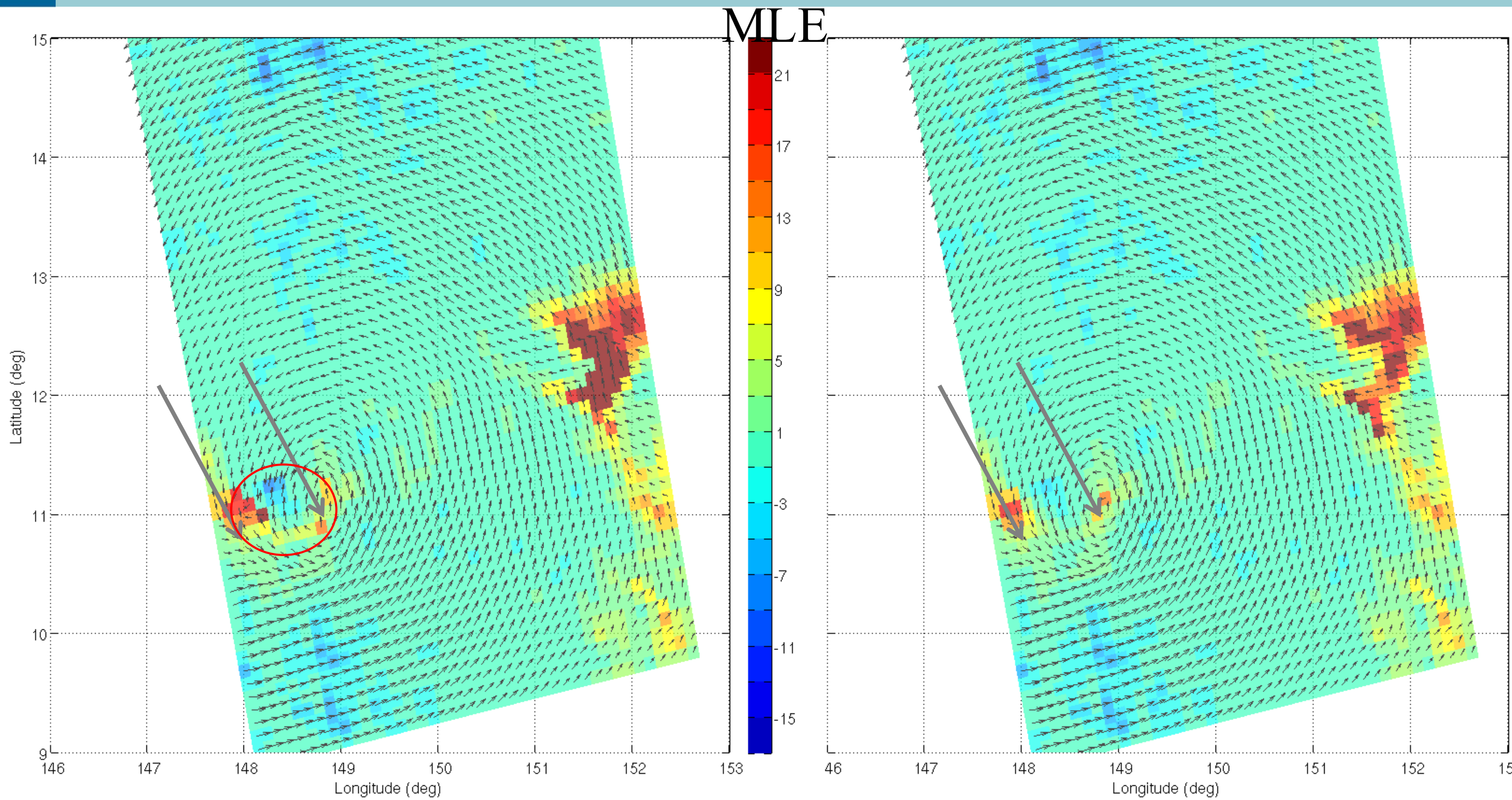
Default setting:

- ➢ Gaussian structure function
- ➢ Fixed O/B errors

New setting:

- ➢ Empirical structure function
- ➢ Flexible O/B errors

Typhoon Chan-hom selections



Default setting:

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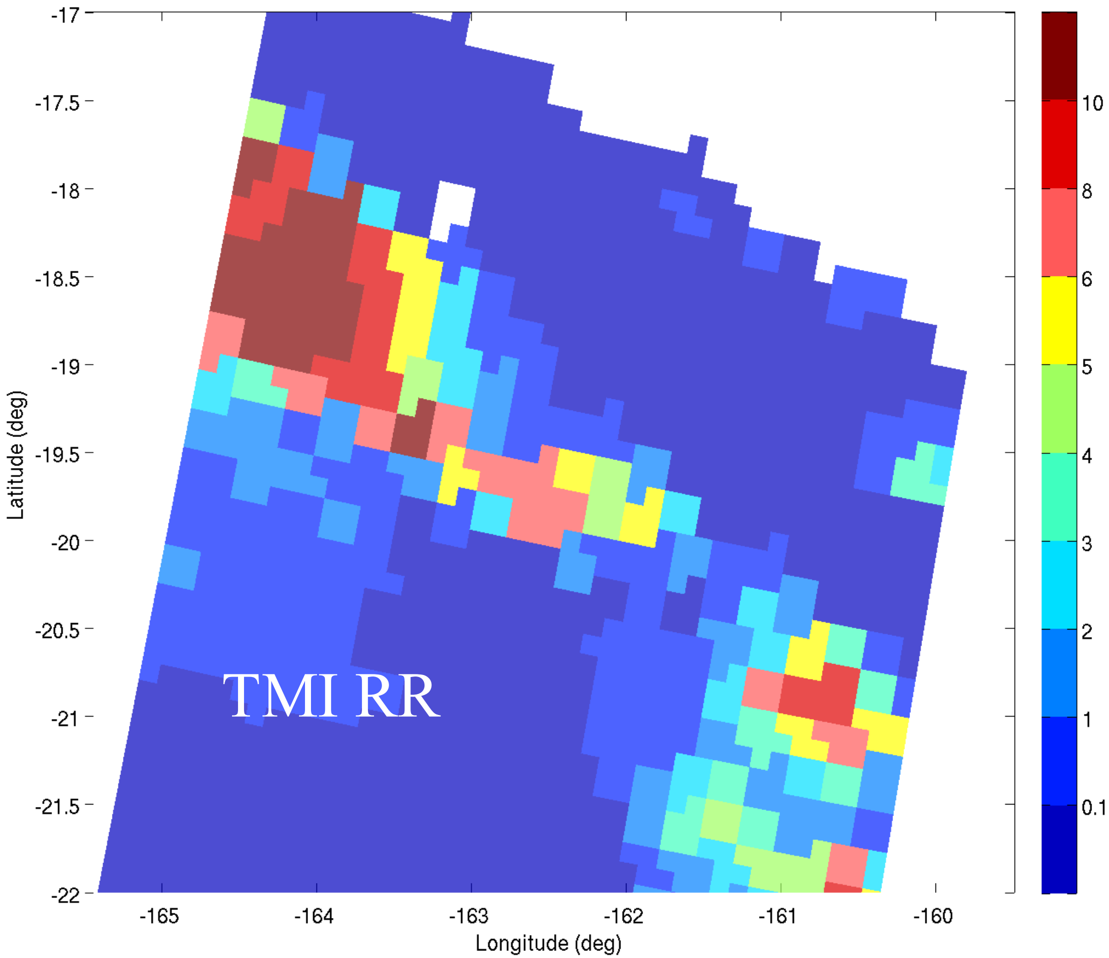
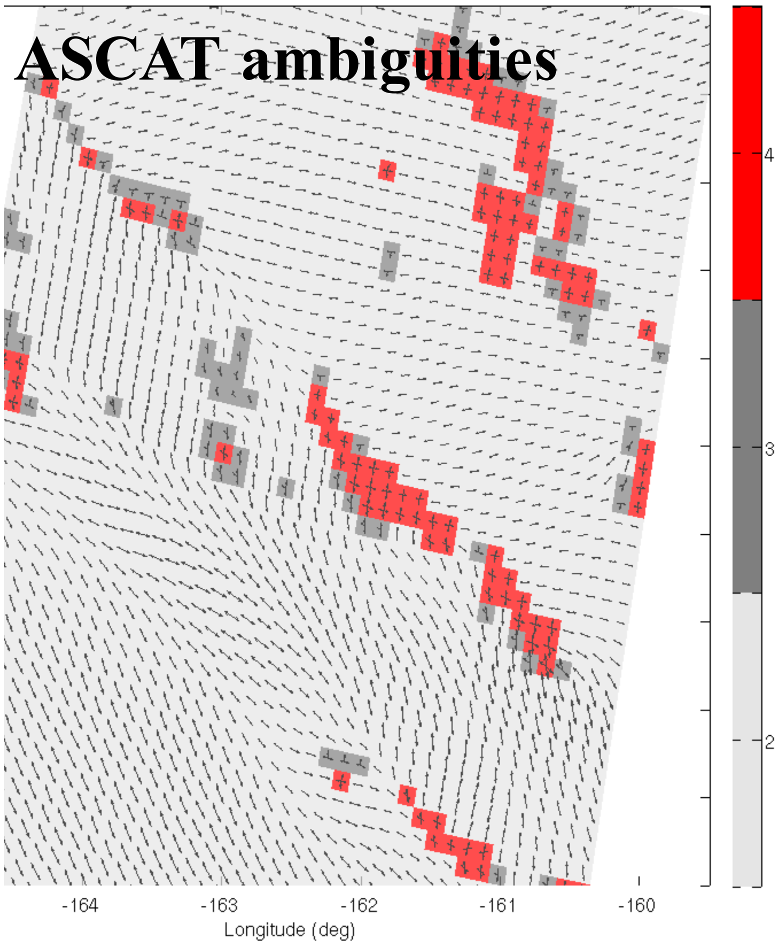
New setting:

- ➢ Empirical structure function
- ➢ Flexible O/B errors

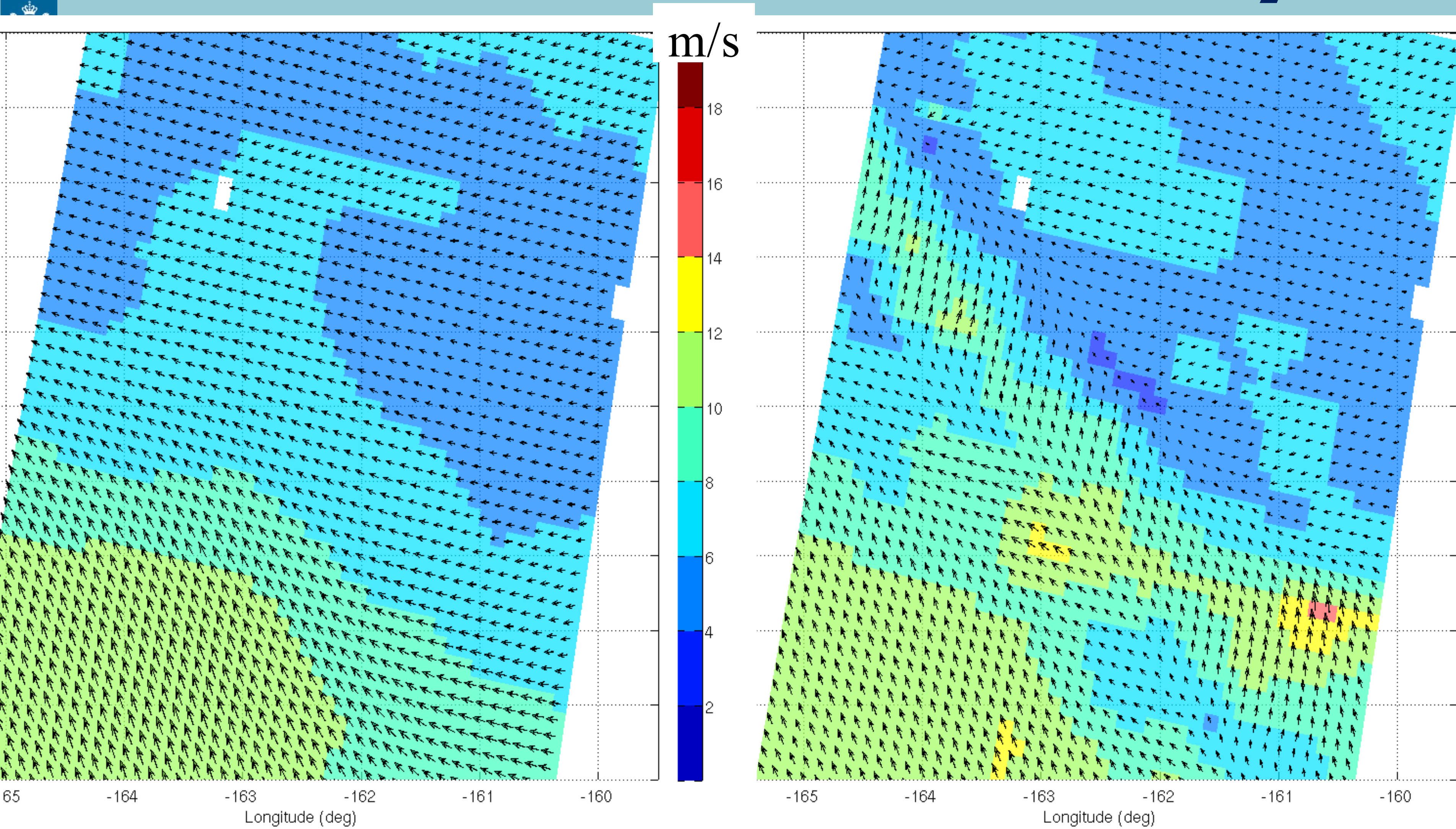
Wind front





Number of ambiguities

Wind front 2DVAR analysis



Default setting:

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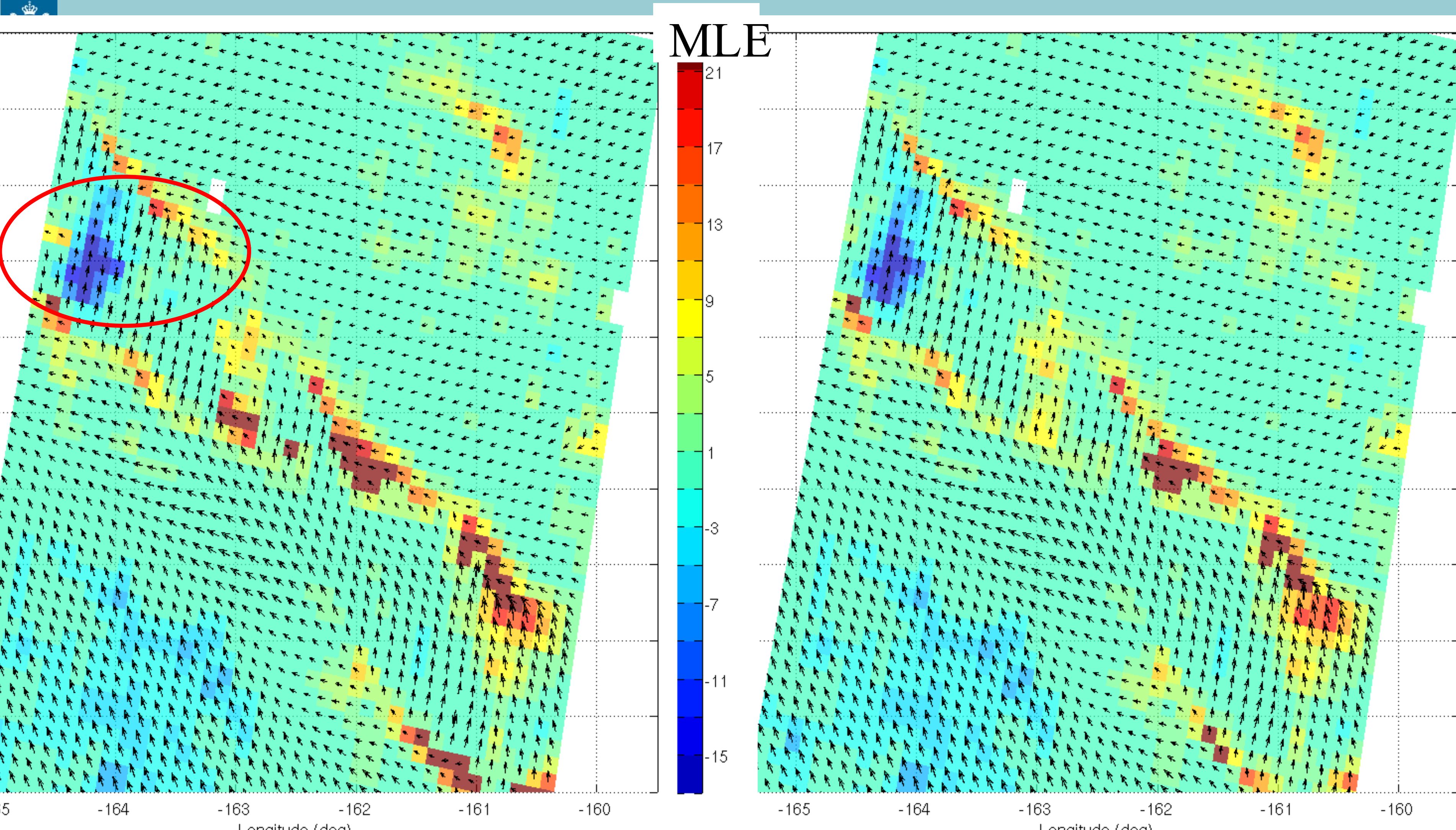
New setting:

- ➢ Empirical structure func
- ➢ Flexible O/B errors

Wind front selections



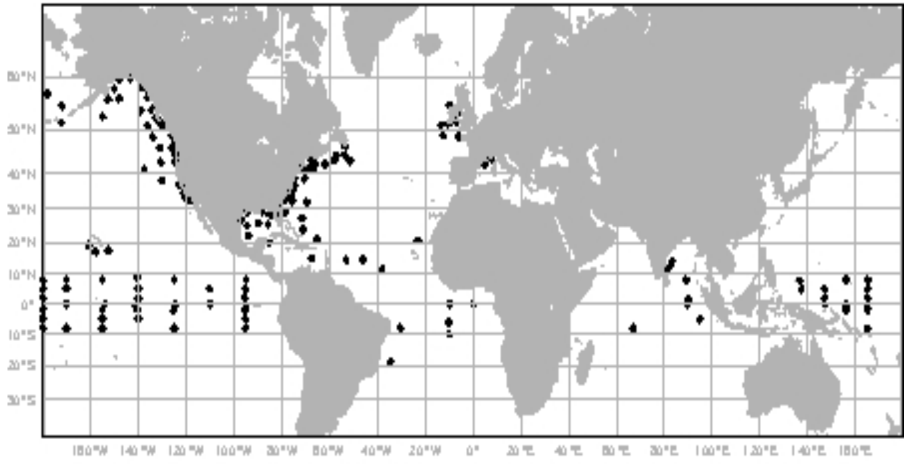
Default setting:

- Gaussian structure function
- Fixed O/B errors

New setting:

- Empirical structure function
- Flexible O/B errors

Triple collocation



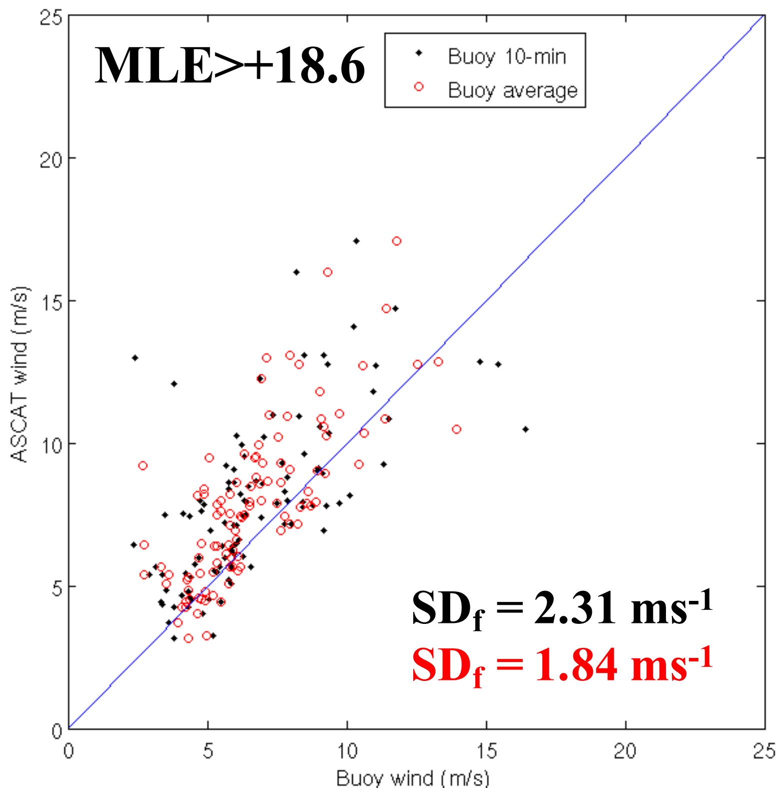
Data from November 2012 to January 2013

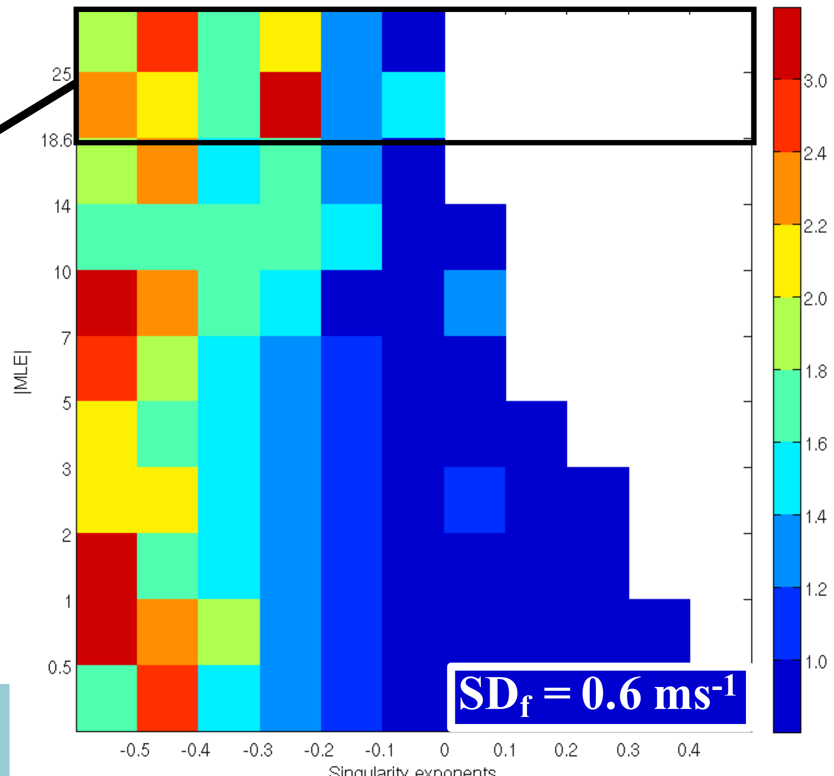
- Errors on scatterometer scale
- A and B very similar

m/s	Scatterometer σ_u	Scatterometer σ_v	Buoys σ_u	Buoys σ_v	ECMWF σ_u	ECMWF σ_v
ASCAT-A 25-km	0.63	0.71	1.21	1.35	1.39	1.44
ASCAT-B 25-km	0.63	0.66	1.26	1.39	1.38	1.42
ASCAT-A Coastal	0.76	0.84	1.18	1.34	1.54	1.57
ASCAT-B Coastal	0.81	0.79	1.24	1.35	1.53	1.57

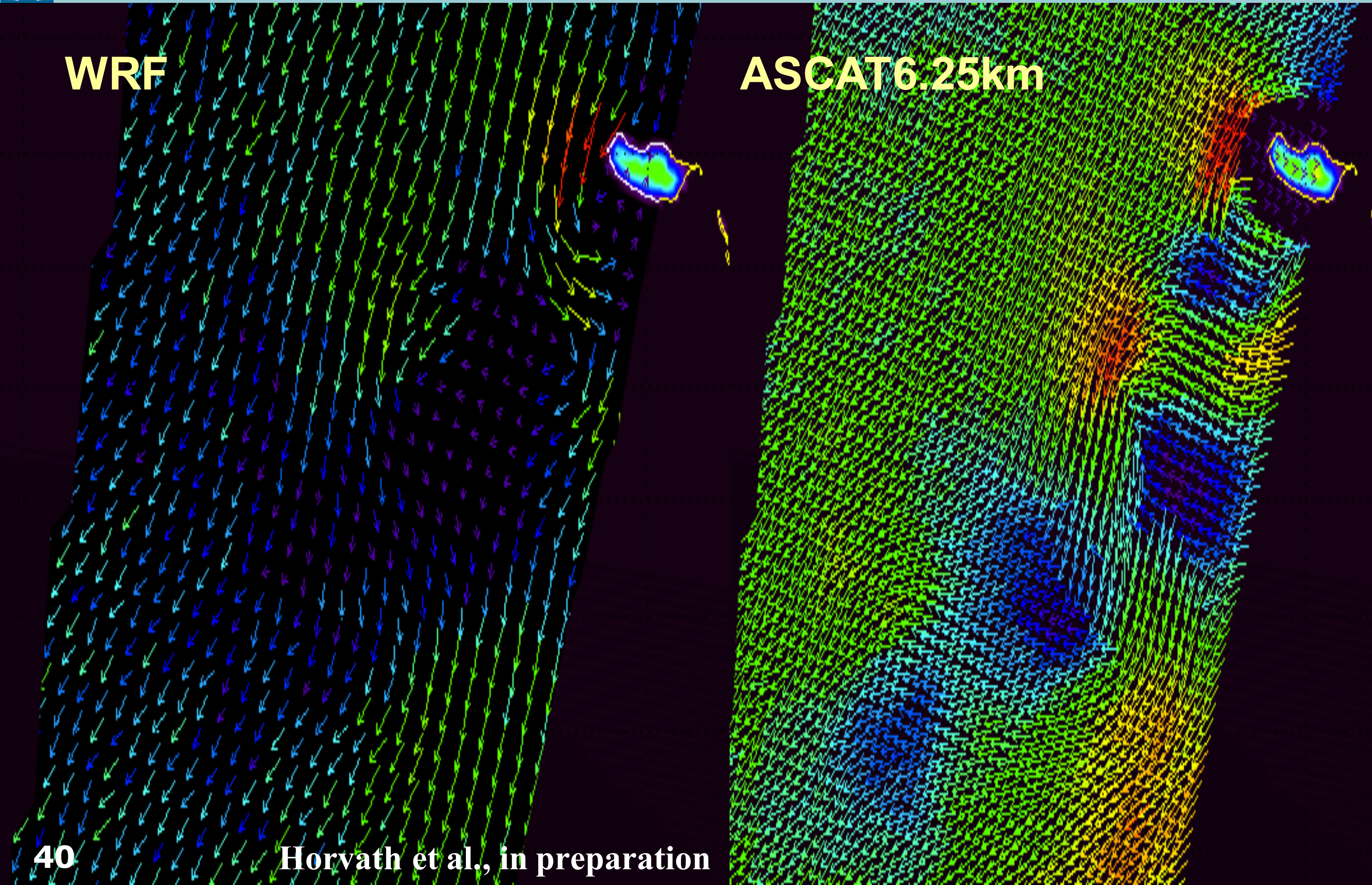
QC: Which error is acceptable?

- We can produce winds with SD of buoy-scatterometer difference of 0.6 m/s, but would exclude all high-wind and dynamic air-sea interaction areas
- The winds that we reject right now in convective tropical areas are noisy (SD=1.84 m/s), but generally not outliers!
- What metric makes sense for QC trade-off?



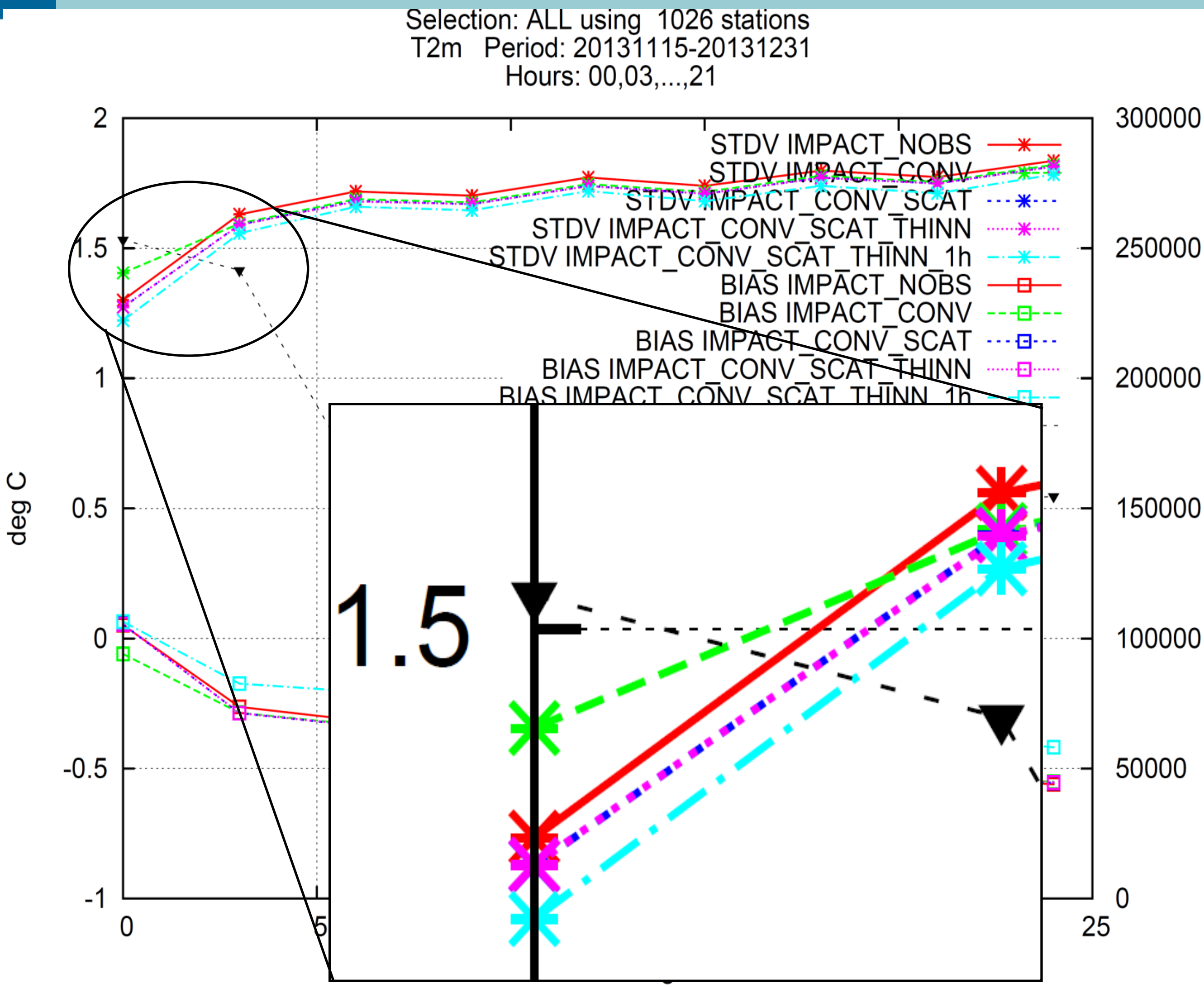


Observations and Models



Horvath et al., in preparation

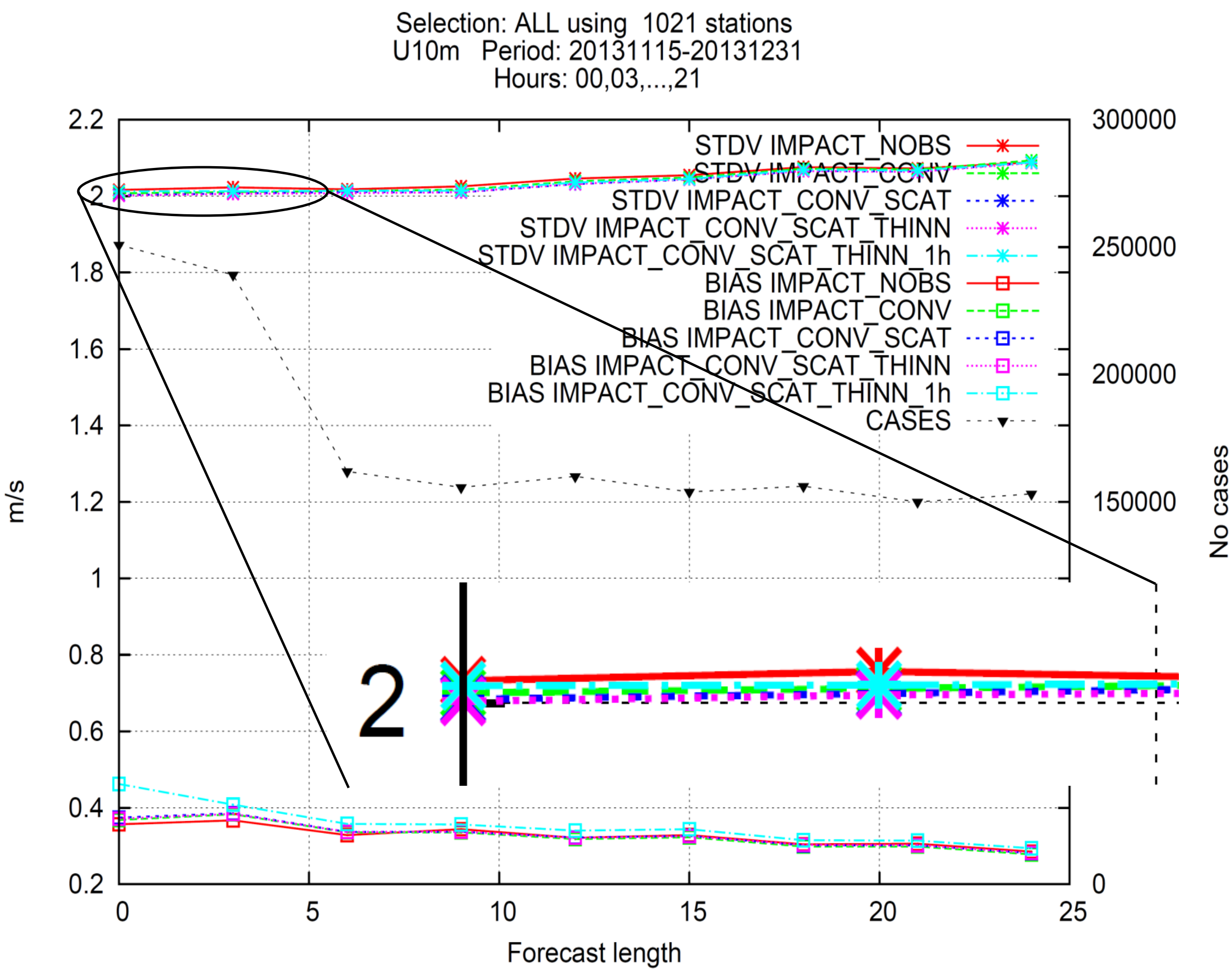
T2m verification over land



NO OBS
CONV-3h
CONV+SCAT-3h
CONV+SCAT-THINN-3h
CONV+SCAT-THINN-1h

- Scatterometer improves analyses of 2-m temperature over land
- SCAT impact gone after 3 hrs (3-h cycle)
- Impact maintained for 1-h cycling; SCAT or additional SYNOPS??

U-10m verification over



NO OBS
CONV-3h
CONV+SCAT-3h
CONV+SCAT-THINN-3h
CONV+SCAT-THINN-1h

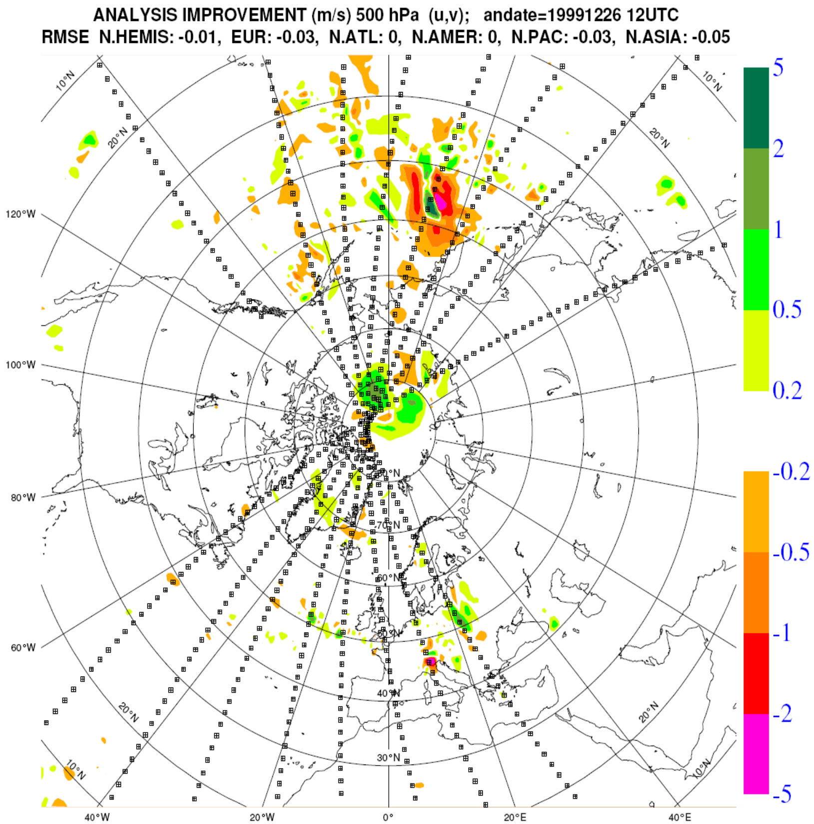
Scatterometer slightly positive for 10-m wind over land

Similar sores for SCAT thinning/no-thinning

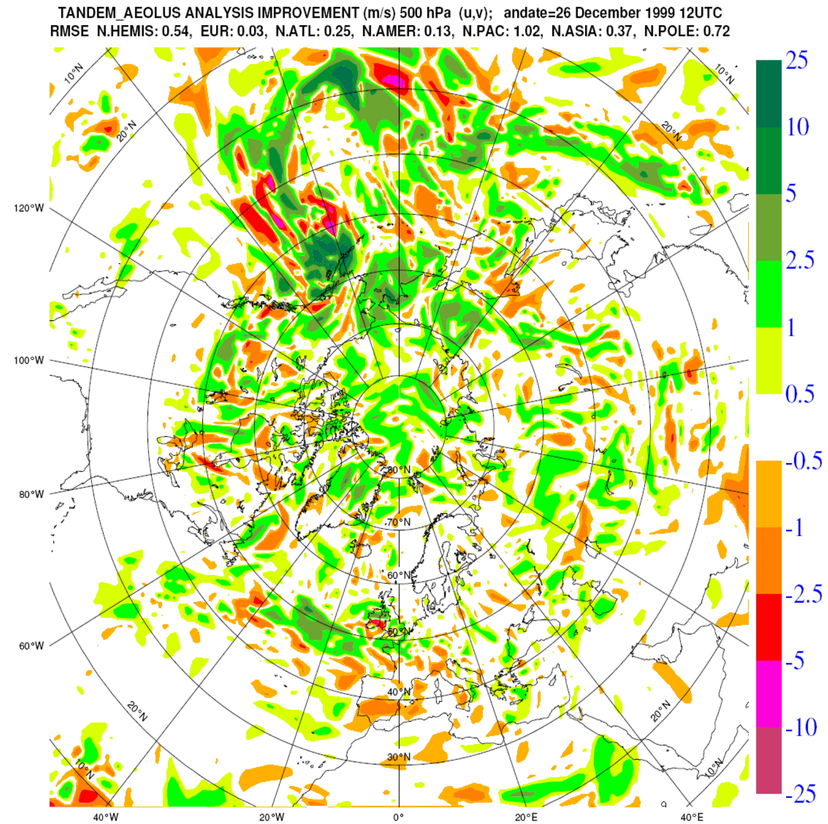
Tandem-Aeolus impact on analyses

Analysis improvement at forecast initial time of ’99 Christmas storm Martin (26 Dec 1999 12:00 UTC) for the Tandem-Aeolus scenario

Single-time SOSE; 6 hours DWL obs.



SOSE – cycling; 84 hours DWL obs.



- Positive interference of subsequent cycles

All the QC-accepted and 2-solution ($|MLE_1|<1$)

	ASCAT-ECMWF-buoy comparison (mean buoy winds)		
	ASCAT vs ECMWF	ASCAT vs buoy point wind	N
Default	2.19	1.74	5034
New	2.17	1.71	

	ASCAT-ECMWF-buoy comparison (mean buoy winds)			
	2DVAR vs ECMWF	2DVAR vs buoy point wind	2DVAR vs ASCAT	N
Default	1.85	1.94	1.17	5034
New	2.00	1.76	0.74	