Dispersion simulations of inline HYSPLIT for Sagebrush tracer experiment

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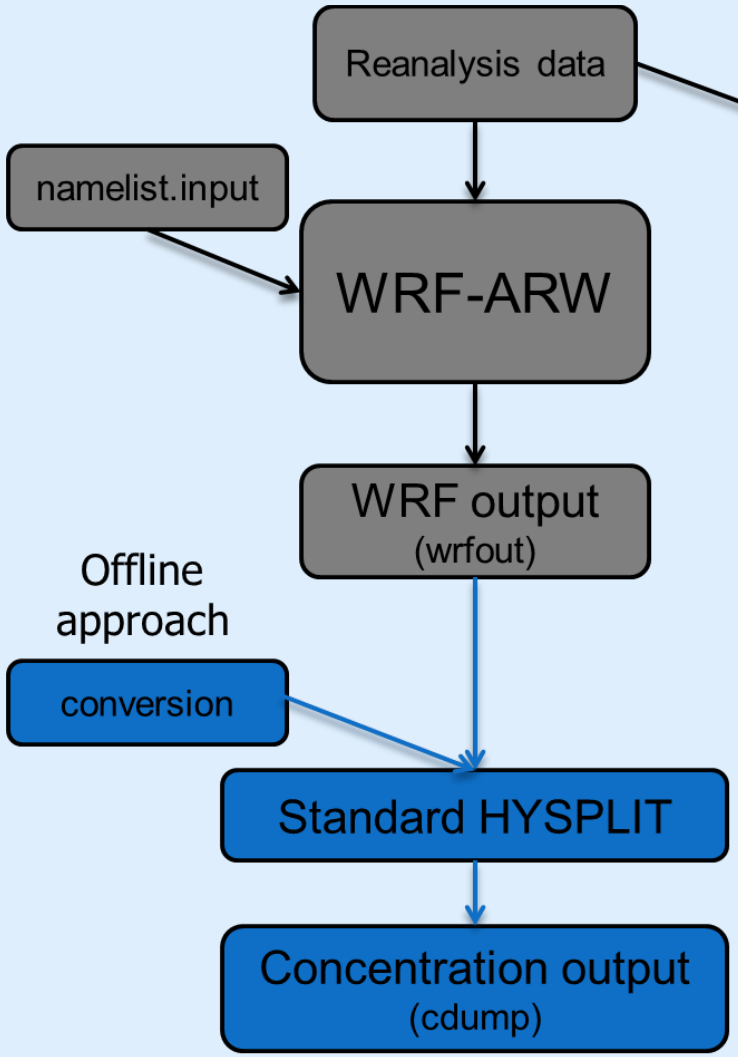
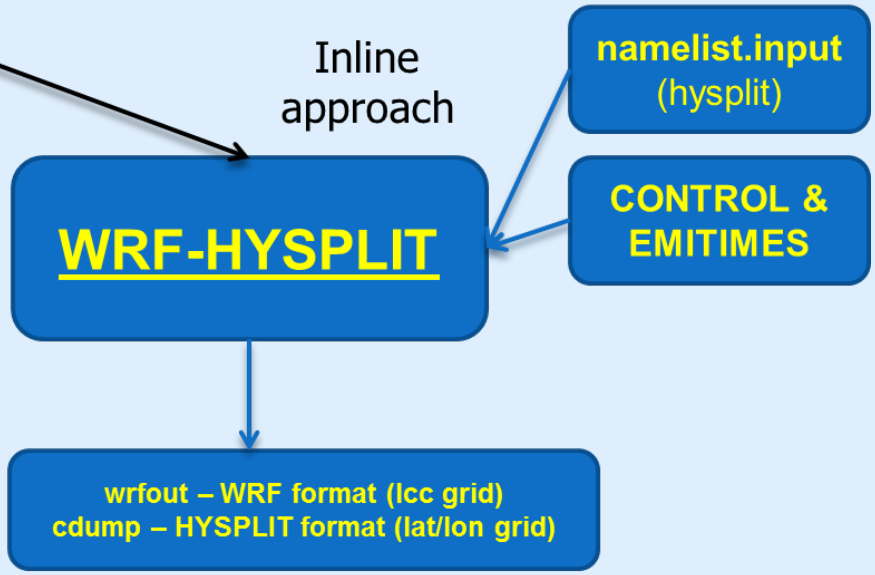
Diagram of inline and offline coupling





namelist.input – including new section for HYSPLIT parameters

CONTROL – same format as the standard HYSPLIT

EMITIMES – optional for HYSPLIT time varying emissions

Comparison of inline and offline approaches

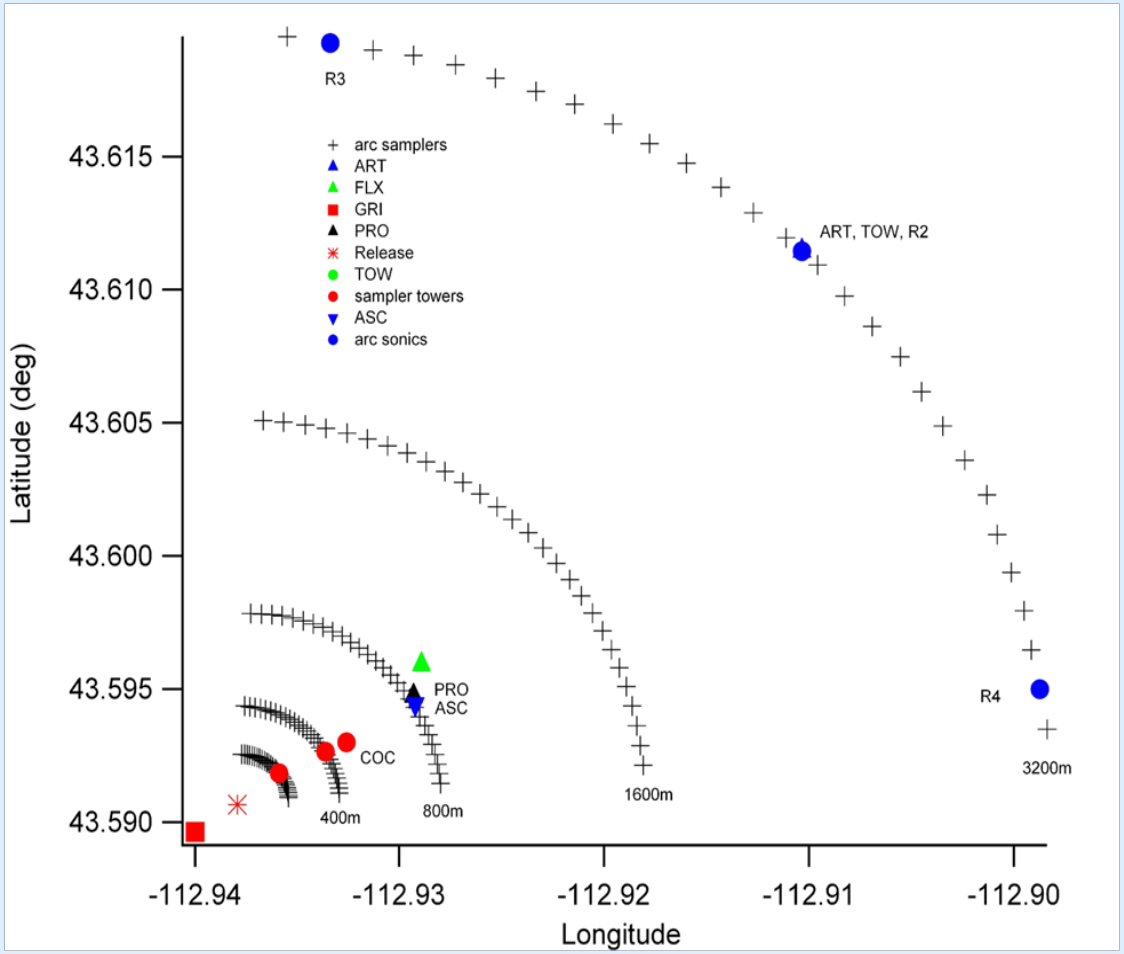
	Inline HYSPLIT	Offline HYSPLIT
Source of met. input	WRF-ARW **No conversion**	Varying met data (WRF, NARR, etc); Need conversion programs for each
Met. input frequency	At WRF's time step (minute or second) **No temporal interpolation**	WRF's output (every hour or minute) Need interpolation
Vertical grid	Using WRF's terrain-following hydrostatic vertical coordinate **No vertical interpolation**	HYSPLIT internal terrain-following coordinate Need interpolation
Horizontal grid	Following WRF's grid	Following the grid of met input
Disk usage	Dispersion output and WRF output based on users' request	Large cost of data storage if high temporal resolution data are needed
Multiple simulations	Requires repeating met simulation	Met simulation is run only once

Publication: Ngan et al. (2015) http://dx.doi.org/10.1175/JAMC-D-14-0247.1

The inline WRF-HYSPLIT website: http://www.arl.noaa.gov/WRF_inline.php

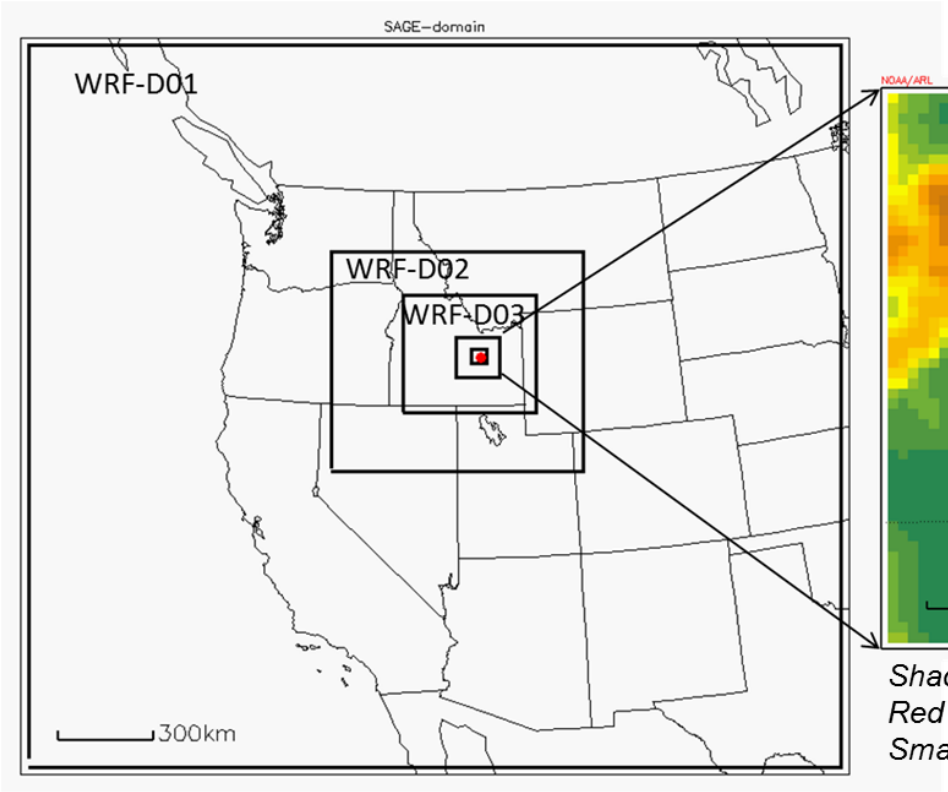
Sagebrush tracer experiment

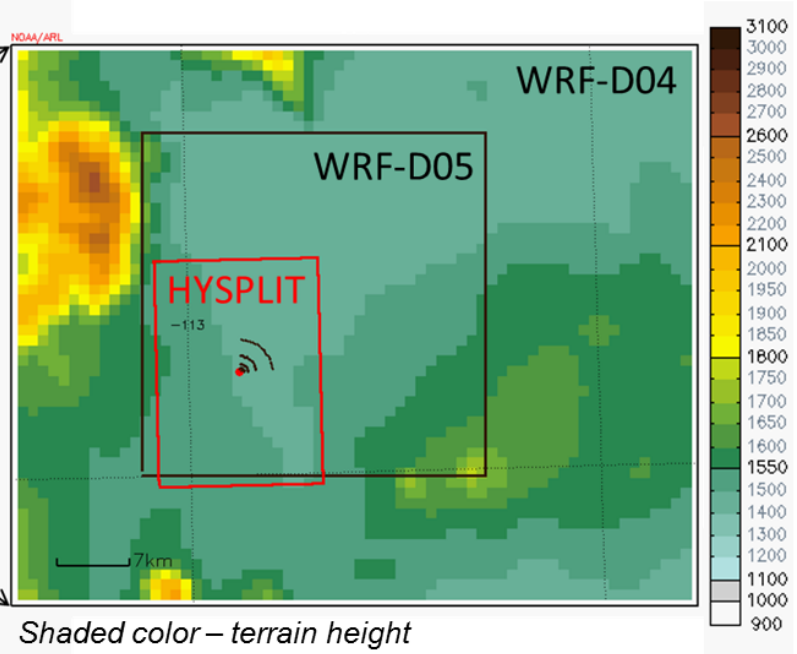
Conducted by ARL's Field Research Division



from NOAA Technical Memorandum OAR ARL-268

Domain configuration





Shaded color – terrain height
Red dot – release location
Small black dots – sampling network

- Horizontal grid: 27km, 9km, 3km, 1km and 333m
- Vertical coordinate: 33 layers with the 1st mid-layer at around 8m and 20 layers included below 850 hPa.
- Simulation period: 2013/10/07 00UTC – 10/08 00UTC

WRF model configuration

	D01	D02	D03	D04	D05
Grid spacing (km)	27	9	3	1	0.333
IC/BC	3-hrly NARR			D03 nestdown	
Nesting	2-way nesting			2-way nesting	
Microphysics	WSM3			WSM3	
Cloud	Grell & Devenyi			---	
Radiation	RRTMG			RRTMG	
PBL	MYJ			MYJ	
Surface scheme	MO similarity theory			Similarity	
LSM	Noah			Noah	
Nudging	3D nudging (nudge PBL wind)		3D nudging (no PBL wind)	--	
time step (sec)	90	30	10	3	1

HYSPLIT model configuration

- Tracer: SF_6
- Sampling network: 10-minute interval for 2 hours
- Release location: Idaho National Laboratory
- Release time: 1930 UTC on 7th October 2013
- Release duration: 2.5 hours
- Release rate: 35748 g/hr with 250,000 particles
- HYSPLIT grid: ~11 m (horizontal)
  50 m (vertical)
- WRF data frequency: 5-minute for offline
  using WRF time-step for inline

Statistical metrics

$$Rank = R^2 + 1 - \left|\frac{FB}{2}\right| + \frac{FMS}{100} + \left(1 - \frac{KSP}{100}\right)$$ (Draxler 2006)

Correlation coefficient (R)

$$R = \frac{\sum(M_i - \overline{M})(P_i - \overline{P})}{\sqrt{\sum(M_i - \overline{M})^2 \sum(P_i - \overline{P})^2}}$$

Fractional bias (FB)

$$FB = 2\frac{(\overline{P} - \overline{M})}{(\overline{P} + \overline{M})}$$

Figure of merit in space (FMS; %)

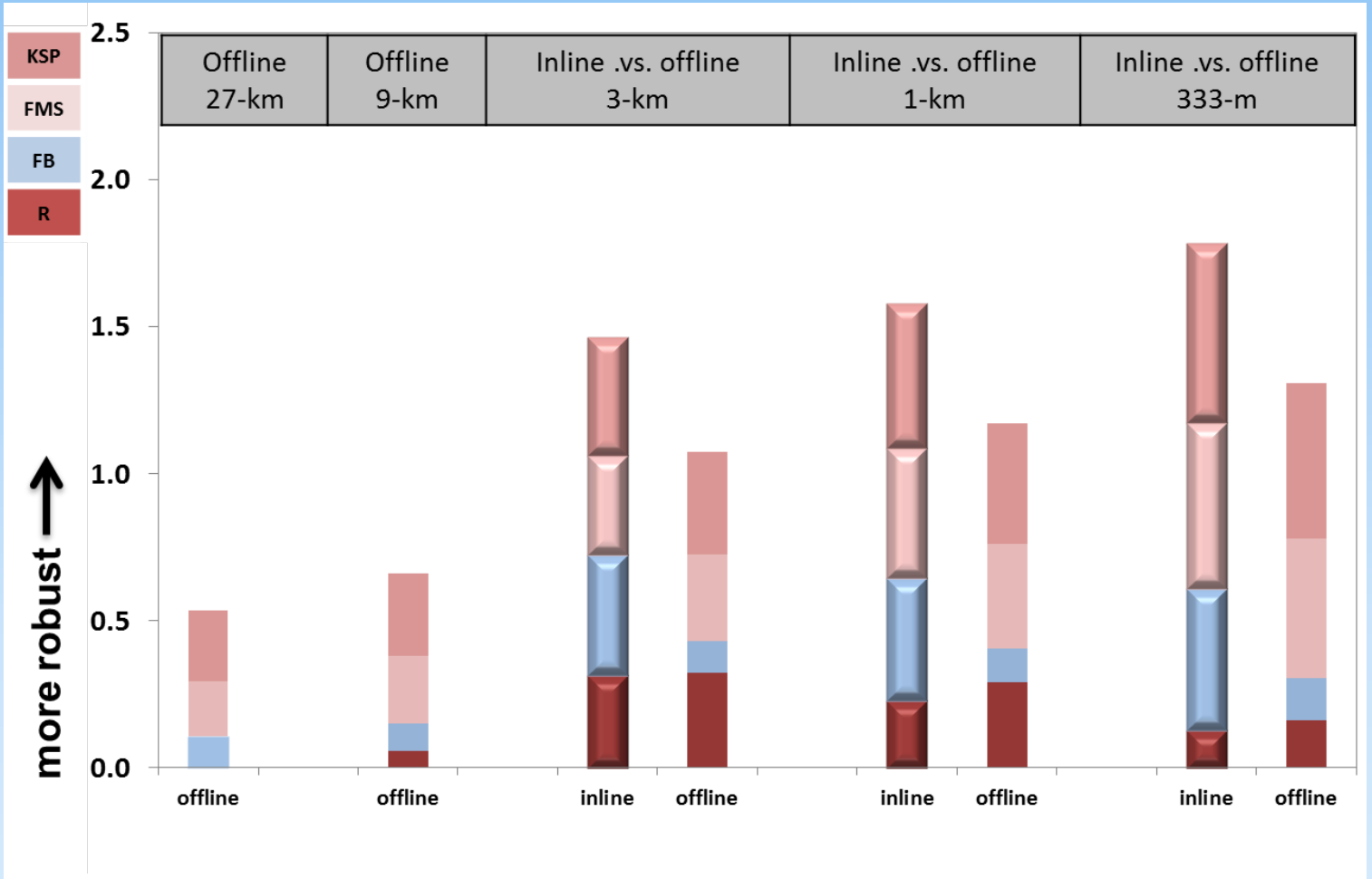
$$FMS = 100\frac{N_p \cap N_m}{N_p \cup N_m}$$

Kolmogorov-Smirnov parameter (KSP; %)

$$KSP = Max|D(M_k) - D(P_k)|$$

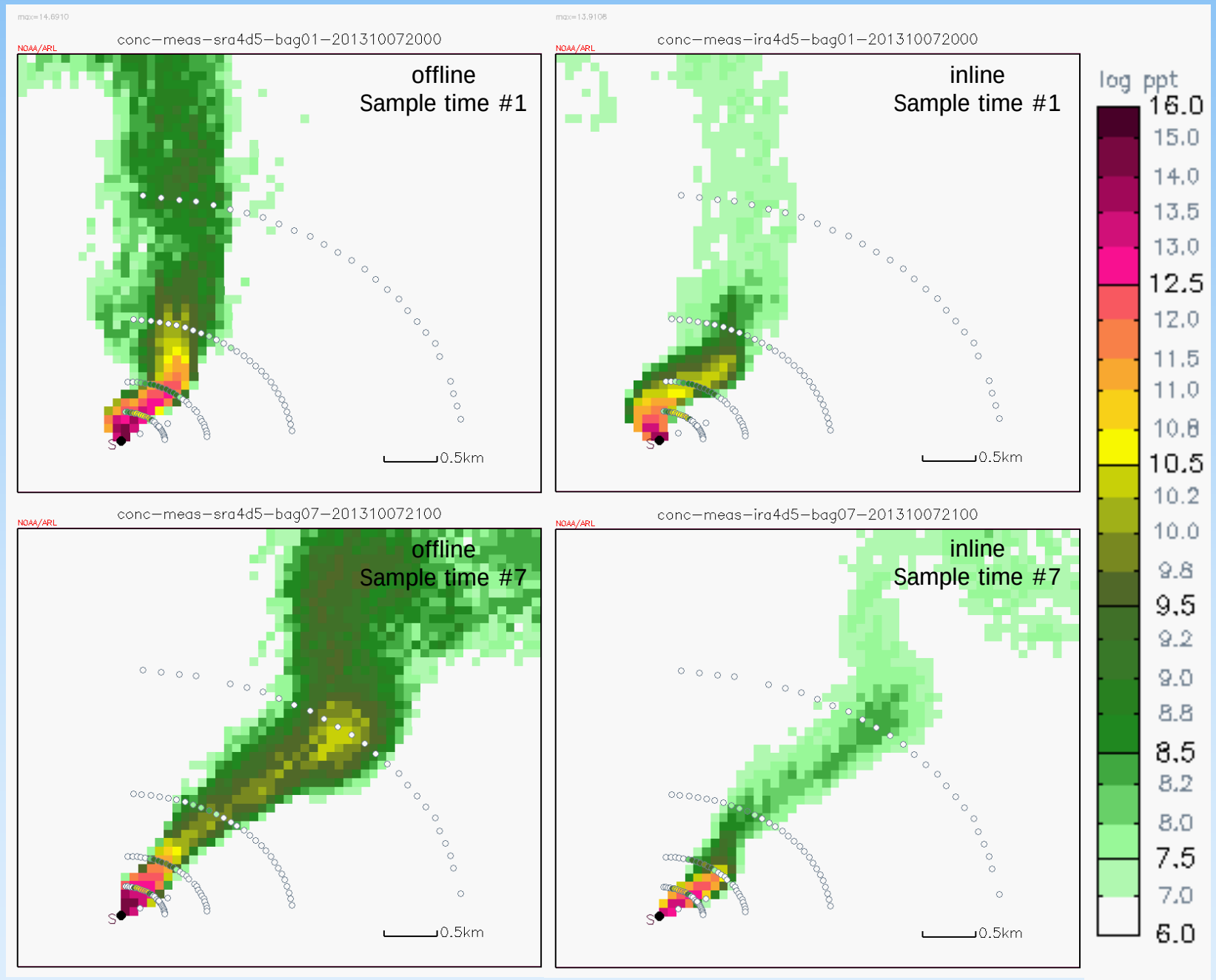
NOTE: "M" – measured tracer concentrations
"P" – predicted tracer concentrations
N is number of samples and "D" is the cumulative distribution

Dispersion results using different grid spacing (3-km, 1-km & 333-m) and coupling approaches (inline and offline)

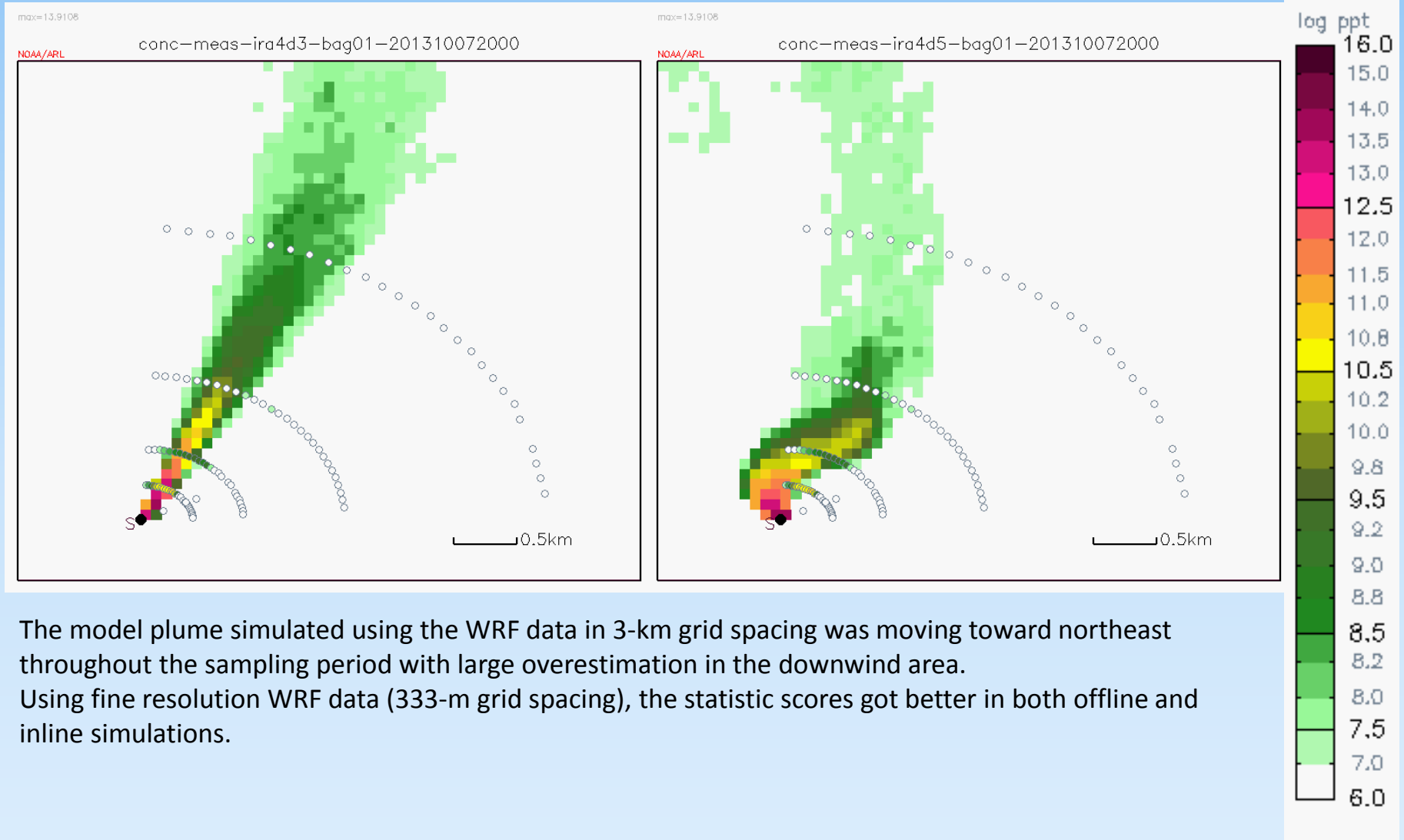


Inline HYSPLIT showed significant improvement compared to the offline approach for the Sagebrush case. The fractional bias of the inline plume was much lower than that of the offline plume calculated with different meteorological model resolutions.

Spatial plots of tracer concentrations, color dots: measured concentrations, unit: log ppt



Inline dispersion results using WRF 3-km and 333-m grid spacing

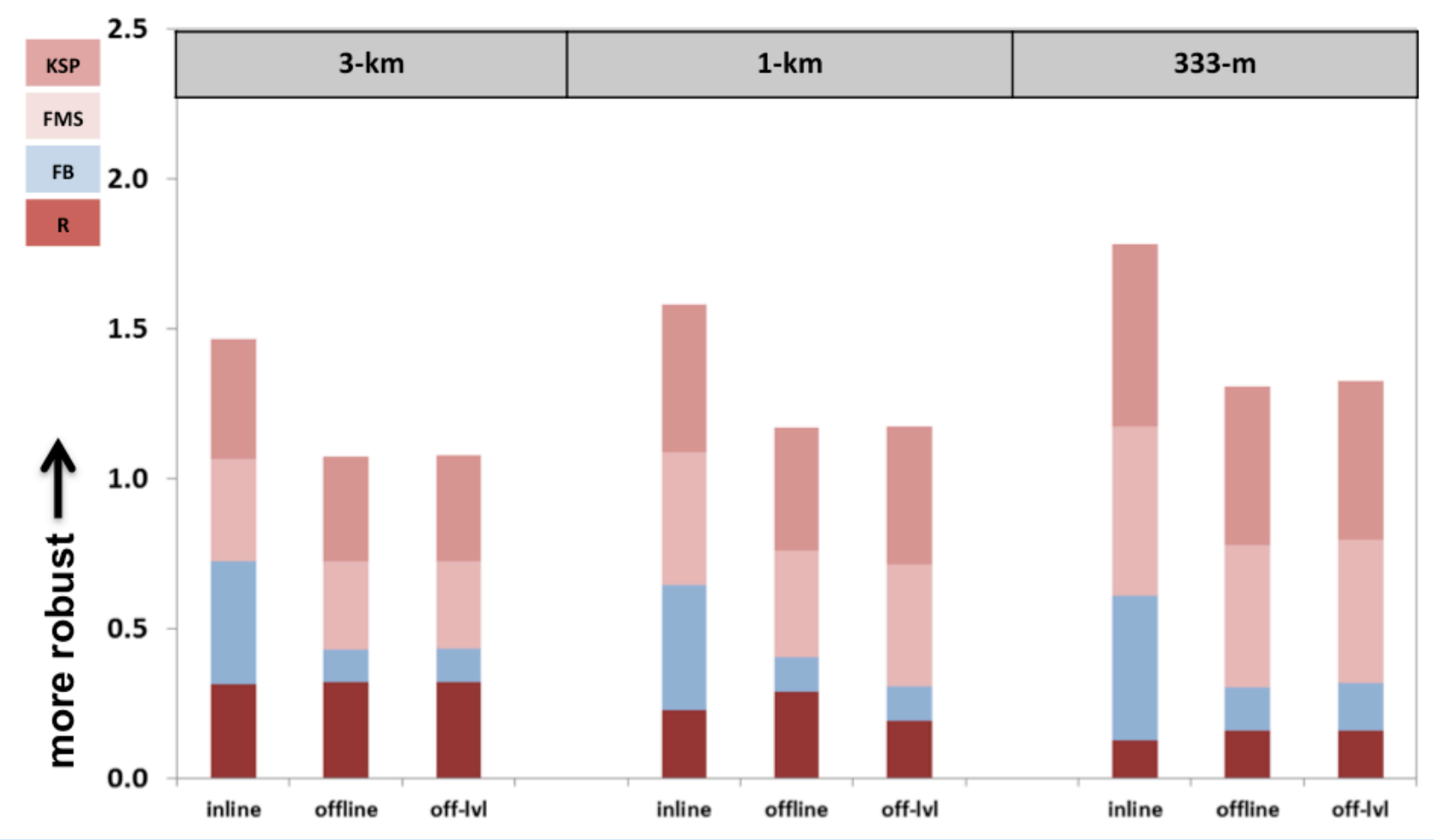


The model plume simulated using the WRF data in 3-km grid spacing was moving toward northeast throughout the sampling period with large overestimation in the downwind area.
Using fine resolution WRF data (333-m grid spacing), the statistic scores got better in both offline and inline simulations.

Impact of vertical layers on dispersion results

Layer	Inline layer height (m) Sagebrush	Offline (default) layer height (m)	Offline (enhanced) layer height (m)
1	7.8	10	5
2	23.7	30	16
3	43.4	70	33
4	67.1	130	56
5	98.8	210	86
	"inline"	"offline"	"off-lvl"

Dispersion results using different grid spacing (3-km, 1-km & 333-m) and coupling approaches (inline, offline and offline with more layers)



Summary

- Dispersion simulations for Sagebrush tracer experiment were conducted using the inline coupling of WRF-HYSPLIT and evaluated against measured tracer concentrations.
- The inline results outperformed the offline simulations. The inline coupling system is especially beneficial for a scenario that requires the use of fine spatial and temporal resolution to resolve the main dispersion features.
- The improvement of the inline over the offline method is attributed to the elimination of temporal and vertical interpolation of the WRF data, as well as using the WRF's vertical coordinate.

Future Work

- Dispersion simulations using the inline approach will be run for other tracer experiments in fine scale for the urban environment and other complex terrain studies.
- The inline HYSPLIT will also be tested using different parameters from the WRF model most relevant to plume mixing, stability, and convection.

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