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Polar winds from highly elliptical orbiting satellites: a new perspective

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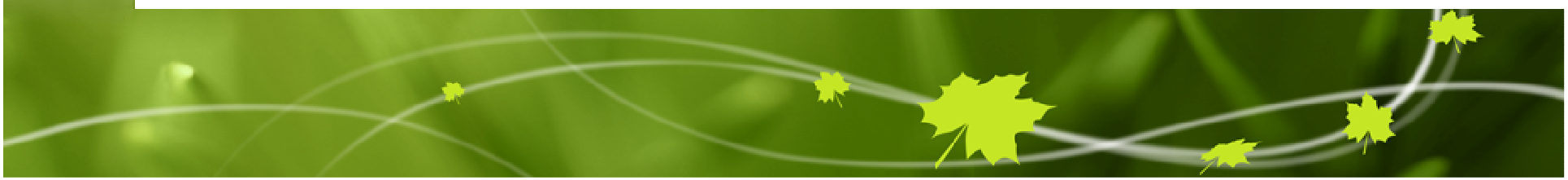
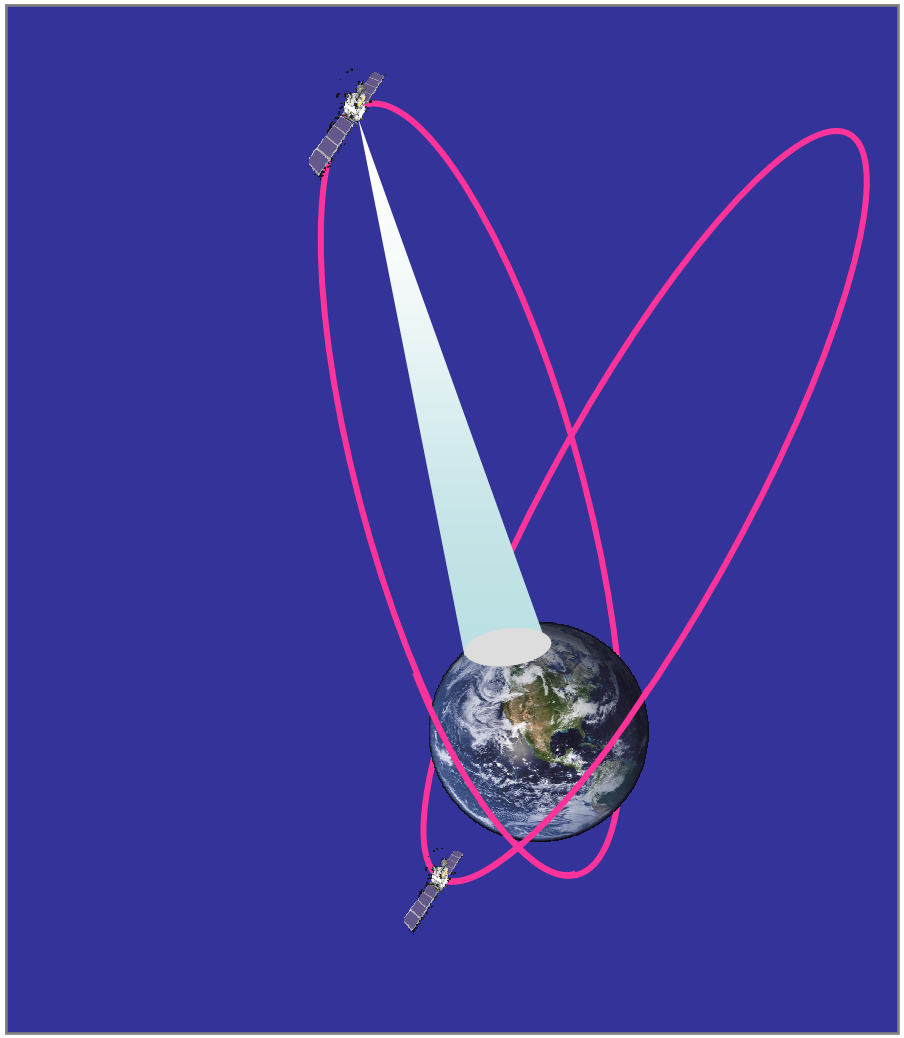


Outline

- Canada's plan for an HEO constellation: PCW mission
- Polar winds: unique capabilities from HEO
- Recent OSE study on polar winds
- OSSE for PCW: a challenge
- Simulated radiances: improving AMV product
- AMV from simulated data over Arctic: a first look
- Conclusion and perspectives

Polar Communications and Weather mission (PCW, also called Polarsat)



2 satellites to provide continuous GEO-like imagery 50-90 N

0.5-1 km VIS
2 km IR

12-h period
63.4 deg. inclination

Apogee: ~39,500 km
Perigee: ~600 km

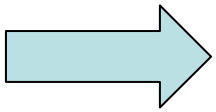
Status: Phase A
Launch: 2016

Background on Molniya concept

- **Russia:**
  - Used extensively for communications and classified missions
  - Mission including Earth observation planned: "Arctica"
- **United States**
  - Concept for Earth observation first proposed by Kidder and Vonder Haar (1990)
  - NASA/Goddard proposed a mission in 2004-2005 under Earth Science Pathfinder Program. Main focus was on high latitude winds. Main payload was a 6-channel imager. Stopped at Phase A level.
- **Canada**
  - CSA initiated a satcom/EO mission concept study in 2005
  - Saw the opportunity to take relay from NASA in 2006
  - Completed a Phase 0 in November 2008
  - Phase A started July 2009

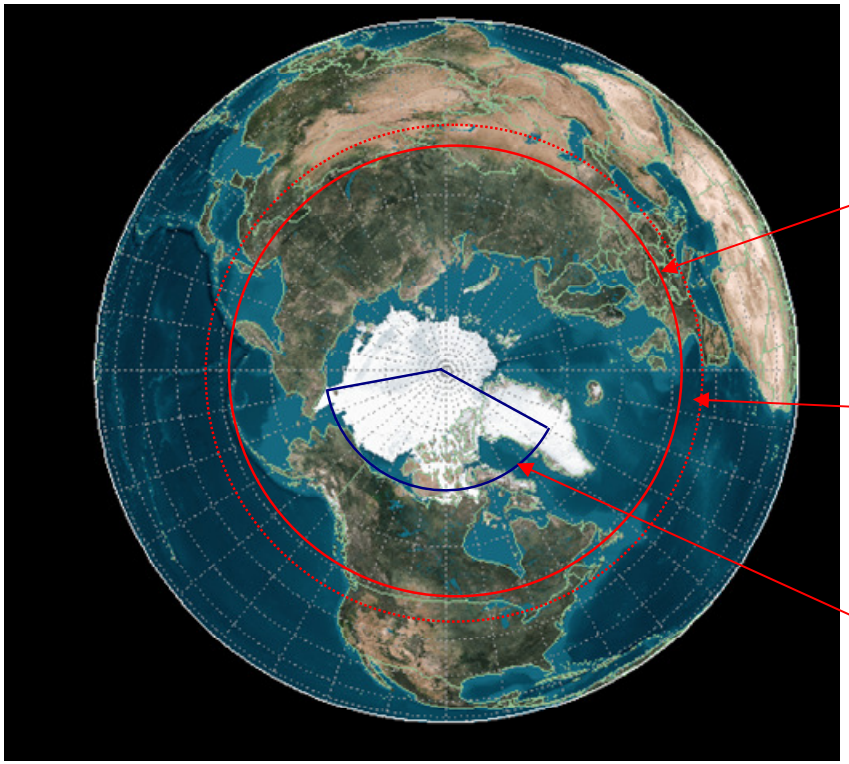
Specific Objectives

- To provide continuous meteorological services and information for the entire circumpolar region, with the imagery data "*refreshed*" as frequently as practical. GOAL 15 min.
- To improve weather prediction accuracy by providing high quality data currently not available or available with insufficient spatial / temporal resolution
- To improve the monitoring and prediction of air quality variables
- To improve the modeling of physical processes in the Arctic environment
- To develop measures of climate change through high quality monitoring of key atmospheric and surface variables
- To have the observing system with 2 satellites in place by 2016. Lifetime of 5 years (goal 7 years).



PCW to have an operational status linked to NRT meteorology
Not a demonstration mission: new mandate for Canada

Area of Interest



Meteorological Coverage Requirement (50ºN)

Meteorological Coverage Goal (45ºN)

Communications Coverage Requirement

Meteo requirement pertains to the entire circumpolar domain

PCW Channels

Band No.	Subgroup	Wavelength (microns)	Heritage	GSD (km)	Main applications
1	VNIR	0.45-0.49	ABI-01	1	Surface, clouds, aerosols
2		0.59-0.69	ABI-02	0.5	Wind, clouds, ice mapping
3		0.85-0.89	ABI-03	0.5	Wind, aerosols, vegetation
4	SWIR	1.04-1.06	SGLI SW1	1	Snow grain, clouds
5		1.37-1.39	ABI-04	2	Cirrus detection
6		1.58-1.64	ABI-05	1	Snow-cloud distinction, ice Mapping
7		2.22-2.28	ABI-06	2	Cloud phase, size
8	MWIR	3.80-4.00	ABI-07	2	fog/ fire detection, ice/cloud separation, wind, phase. Fire Radiation Power (FRP)
9		5.77-6.60	ABI-08	2	Wind, humidity
10		6.75-7.15	ABI-09	2	Wind, humidity
11		7.24-7.44	ABI-10	2	Wind, humidity
12	LWIR	8.30-8.70	ABI-11	2	Total water, cloud phase
13		9.42-9.80	ABI-12	2	Total ozone
14		10.1-10.6	ABI-13	2	Cloud, surface, cirrus
15		10.8-11.6	ABI-14	2	Cloud, SST, ash
16		11.8-12.8	ABI-15	2	Ash, SST
17	LIRCO2	13.0-13.6	ABI-16	2	Cloud height
18		13.5-13.8	MODIS-34	2	Cloud height, low level temperature
19		13.8-14.1	MODIS-35	2	Cloud height, mid level temperature
20		14.1-14.4	MODIS-36	2	Cloud height, high level temperature

VIS AMV

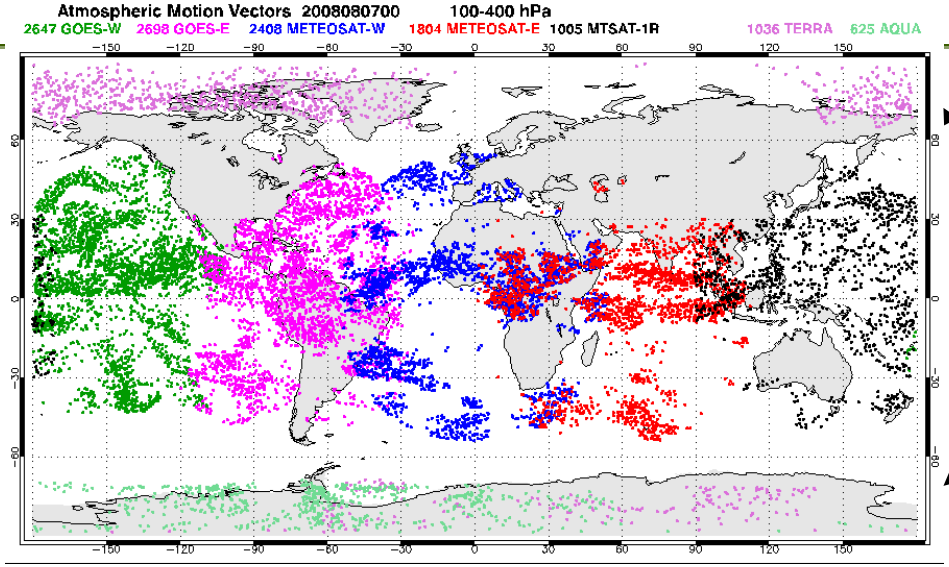
WV AMV

IR AMV

Height assignment

Typical AMV coverage

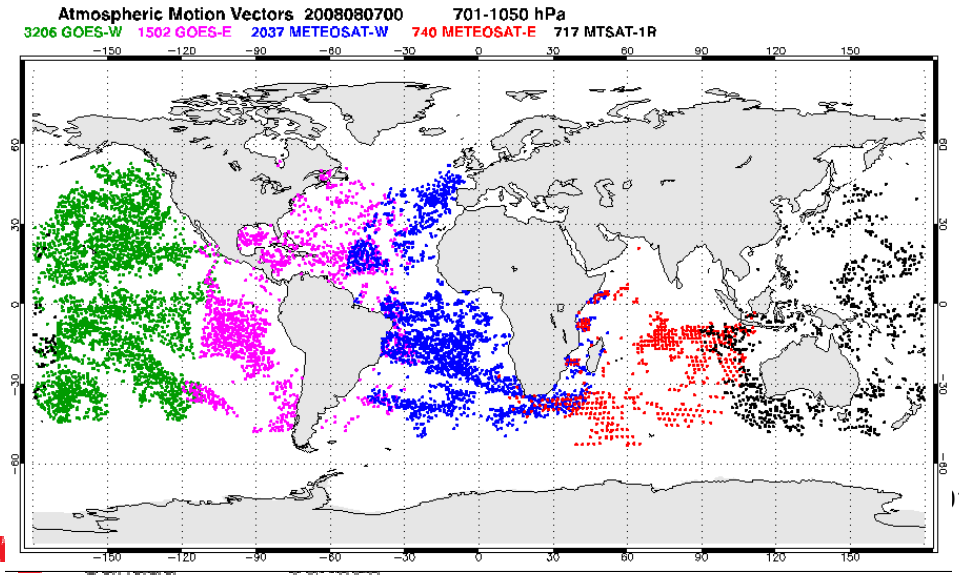
Example of 07 Aug 2008 00 UTC AMV availability



100-400 hPa

Recognized availability gap 55-65 N/S

Terra/Aqua AMVs



700 hPa to surface

No AMVs above 55 N/S

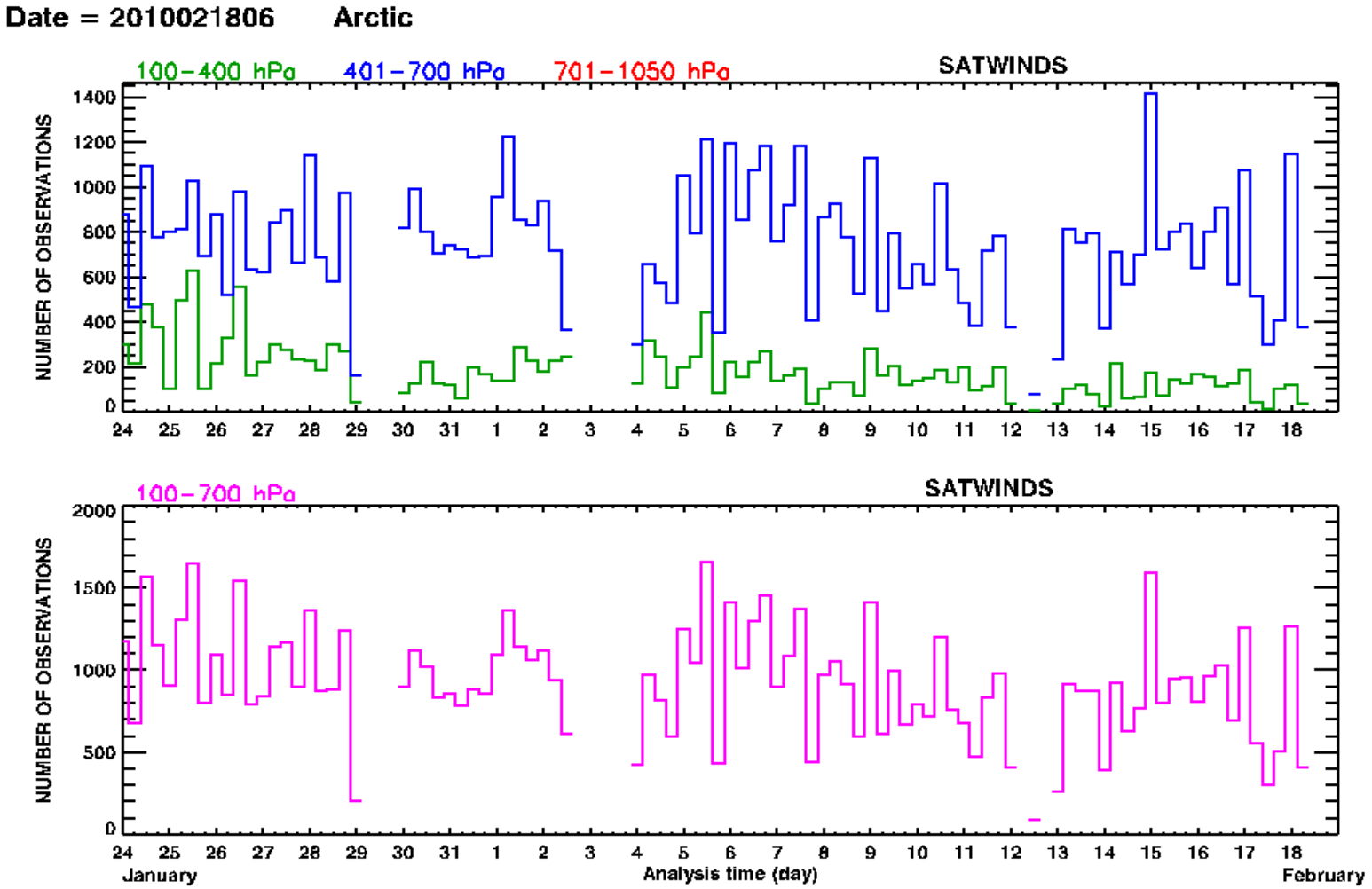
PCW features to serve this application:

- High temporal sequences
- Simultaneous retrievals
- Stereo views

Canada

Current number of Arctic AMVs assimilated

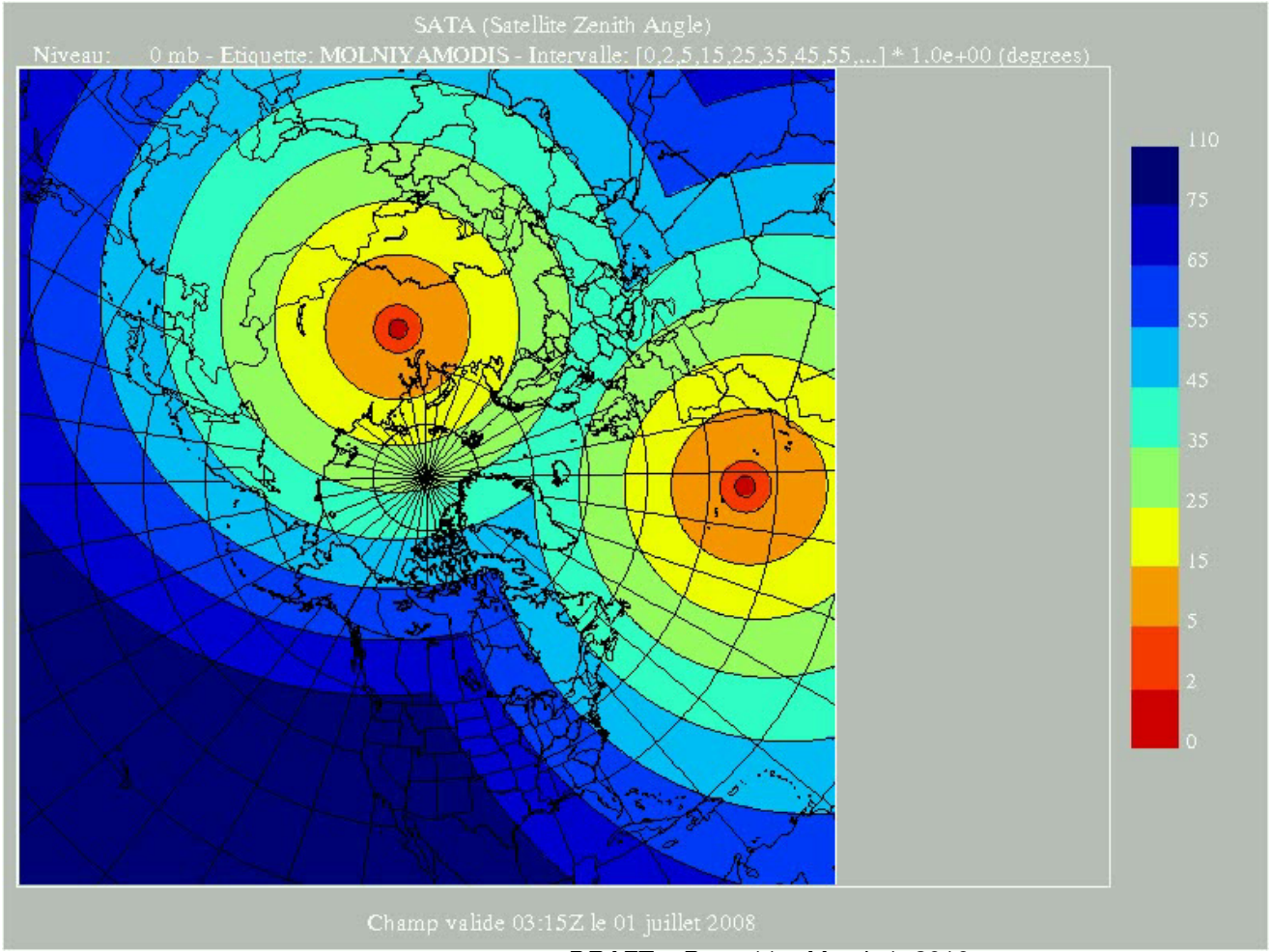
24 jan to 18 Feb 2010



Polar winds: unique and enhanced capabilities from PCW

- No spatial gap entire domain 55-90 N
- High temporal resolution: 15 min imagery
- CO2-slicing capability
- Stereo viewing

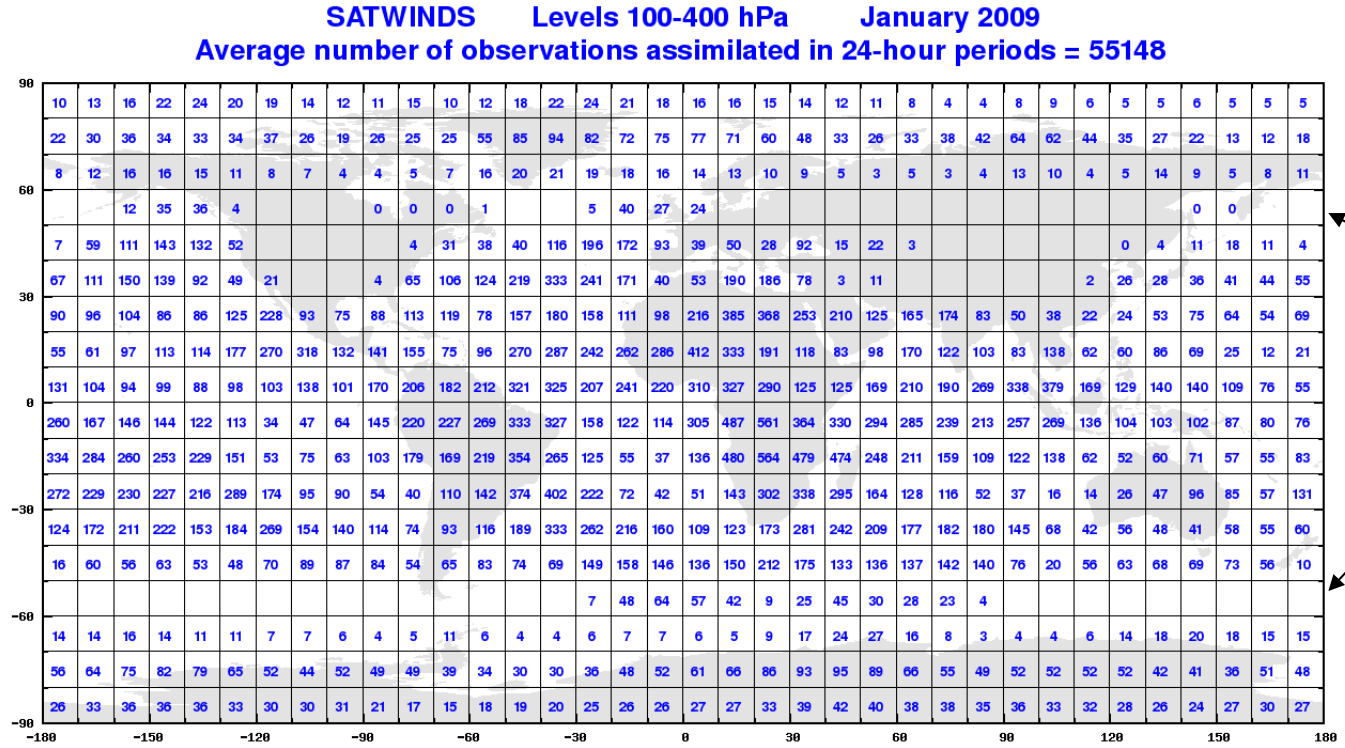
PCW: Coverage and stereo



RECENT OSE ON POLAR WINDS

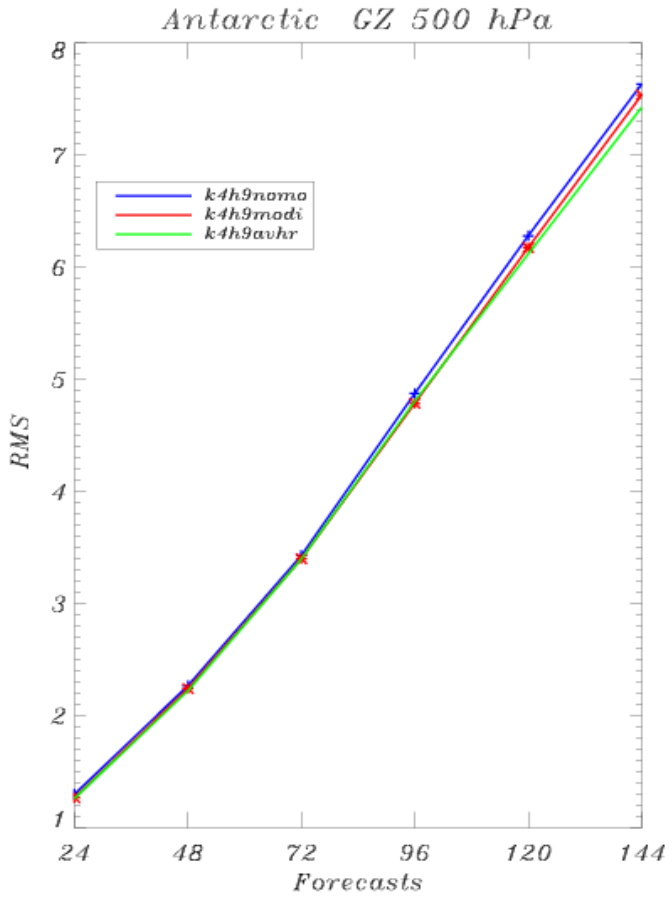
OSE: JAN+FEB 2009 CNTL= all OPE data, no polar AMV, EXP1: + 2 MODIS, EXP2: +2 Modis+ 5 AVHRR. GEM 4D-var.
No polar winds assimilated below 700 hPa

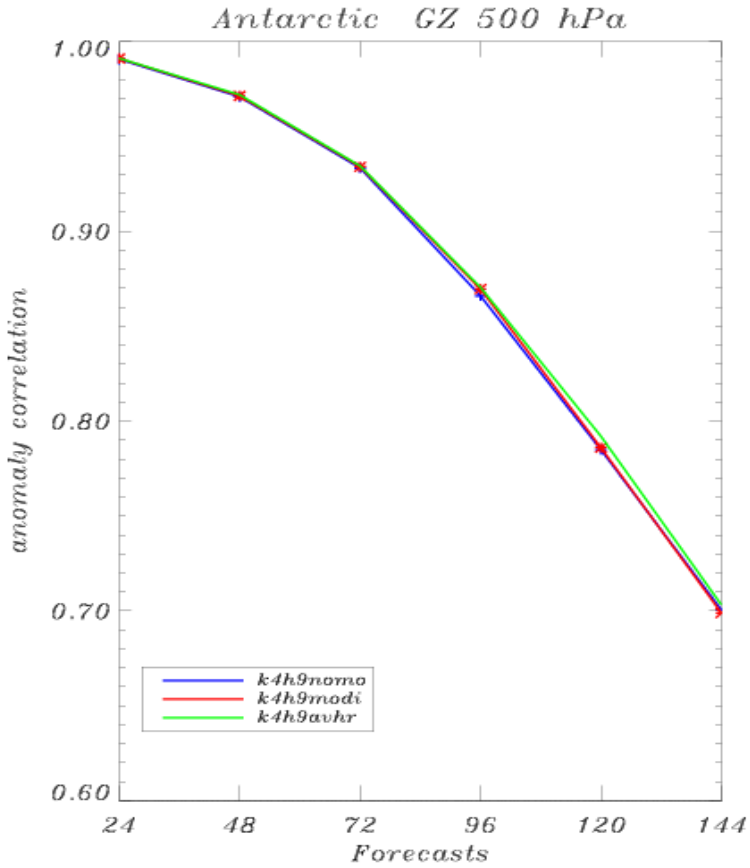
On average 12850 Modis and 5373 AVHRR AMVs per 24-h



OSE Impact over Antarctic GZ 500 hpa

no polarAMV MODIS Modis+AVHRR





Validation againts raobs 120-h

No polar AMV vs MODIS+AVHRR

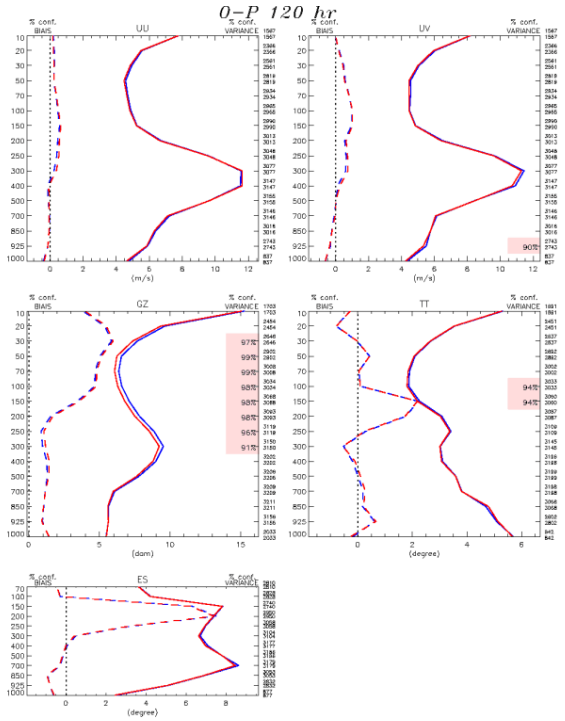
Canadian Arctic

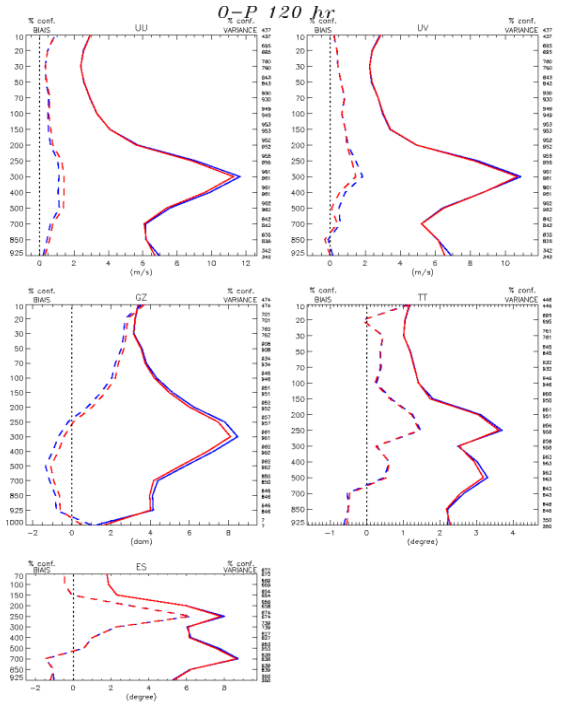
Antarctic

U,V

GZ,T

DPD





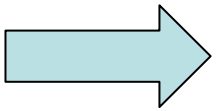
Modest positive impact compared to original Modis AMV impact Obtained in 2005

OSSE for PCW: a challenge

- Current OSSE approach for AMV is to:
  - extract model winds from nature run where AMVs were obtained and perturb “appropriately”.

  Caveat: no such locations for PCW, need to identify targets suitable for getting AMVs, differentiating IR, WV, VIS targets + “perturb appropriately”
- Cleaner approach is to apply AMV software to simulated radiances

  Caveat: heavy processing and need for ~2 km model output over circumpolar area



No fully satisfactory way to conduct an OSSE for AMVs
In general and for PCW area in particular

Simulated radiances: a key for improving AMV product and its QC

- Realism of model output and simulated all sky radiances now allows such studies
- In recent years, IWWG has moved in that direction, indicating strong potential
- PCW science team is preparing proxy radiance datasets over circumpolar area

Model output: defining cloud top height, amount

- Proposed definitions based on cloud transmittance t_c from a window channel, considering cloud emissivity and overlapping assumptions

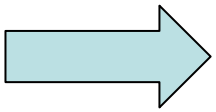
Effective cloud top height CTH: from model top, height where t_c drops to 0.90

Effective cloud amount CFE: $1 - t_c$

Cloud amount CF: same except cloud emissivity set to 1

Cirrus indicator: CI = CFE/CF, 1 means opaque cloud

Many more measures possible: cloud base, local BT variance, surface inversion, multilayering …

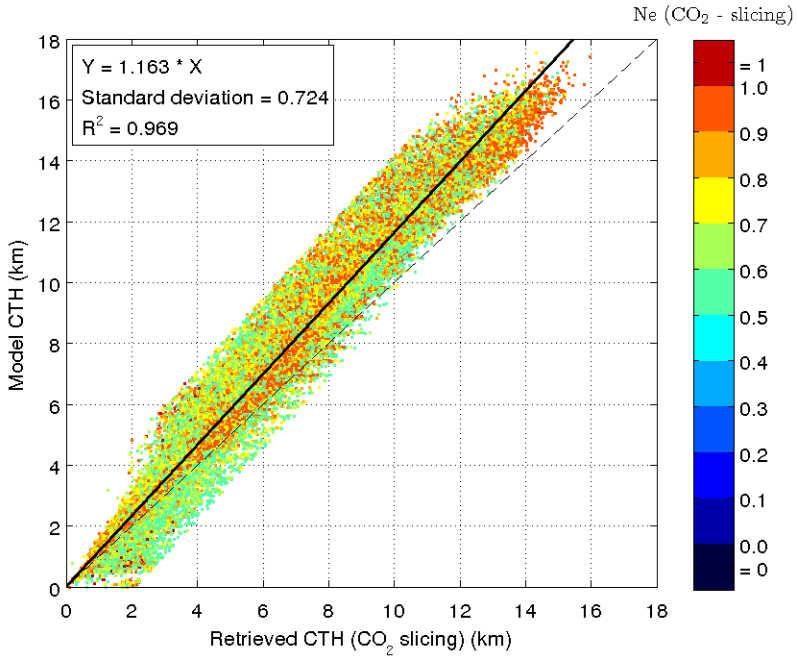


Understanding AMV limitations from target characterization and background info on atmospheric state

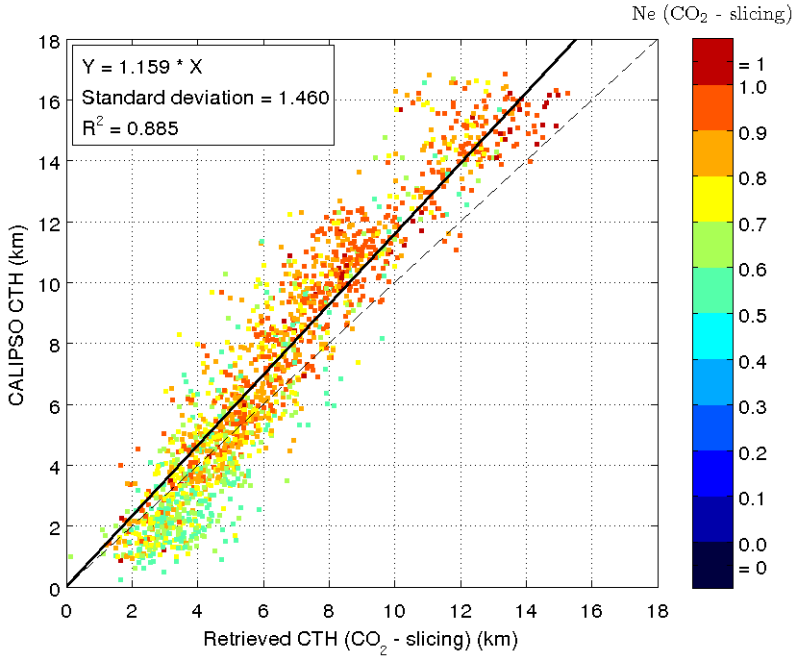
Experience from real and simulated AIRS CTH retrievals using CO2-slicing technique

Global data

Model CTH vs retrieved CTH from simulated AIRS radiances



CALIPSO CTH vs retrieved CTH from real AIRS radiances



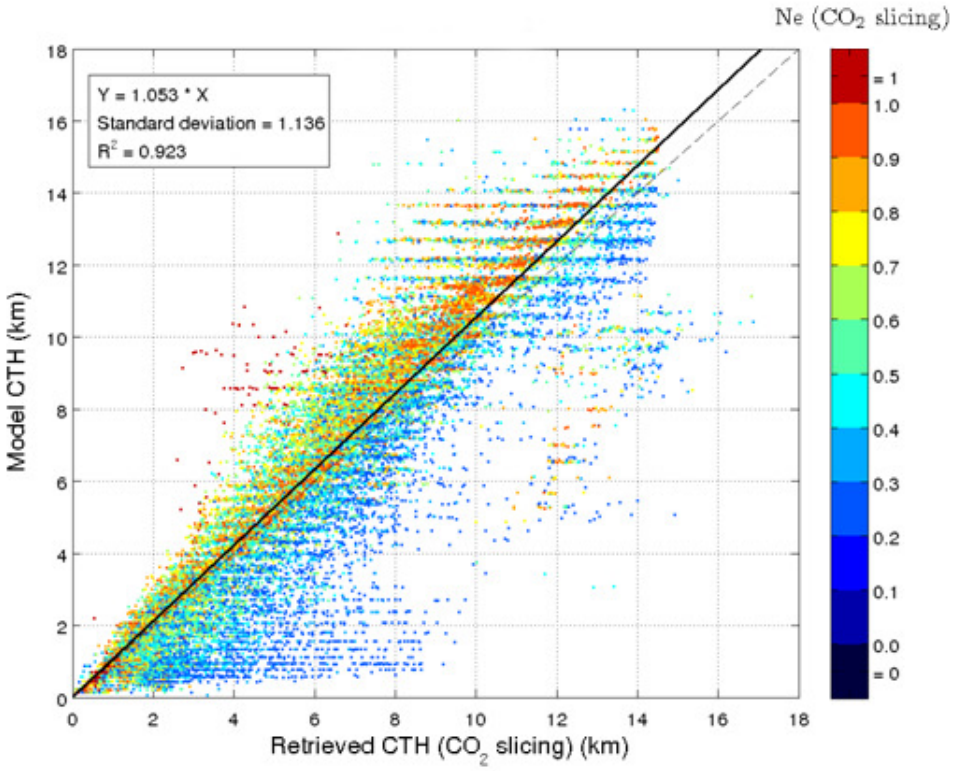
Model definition of CTH corresponds well to that seen by Calipso
Also confirmation of retrieval bias increasing with height

Emissivity ratio considerations: impact of channel selection

Model output (true) height versus retrieved from simulated radiances

Configuration with 12 channels coupled to a reference profile peaking near the surface	
Channel #	Wavenumber
204	707.770
221	712.661
232	715.862
252	721.758
262	724.742
272	727.752
299	735.298
305	737.152
310	738.704
355	752.970
362	755.237
475	801.001
Reference channel	
787	917.209

Assuming emissivity ratio = 1.0
STD excluding outsiders: 1.14 km



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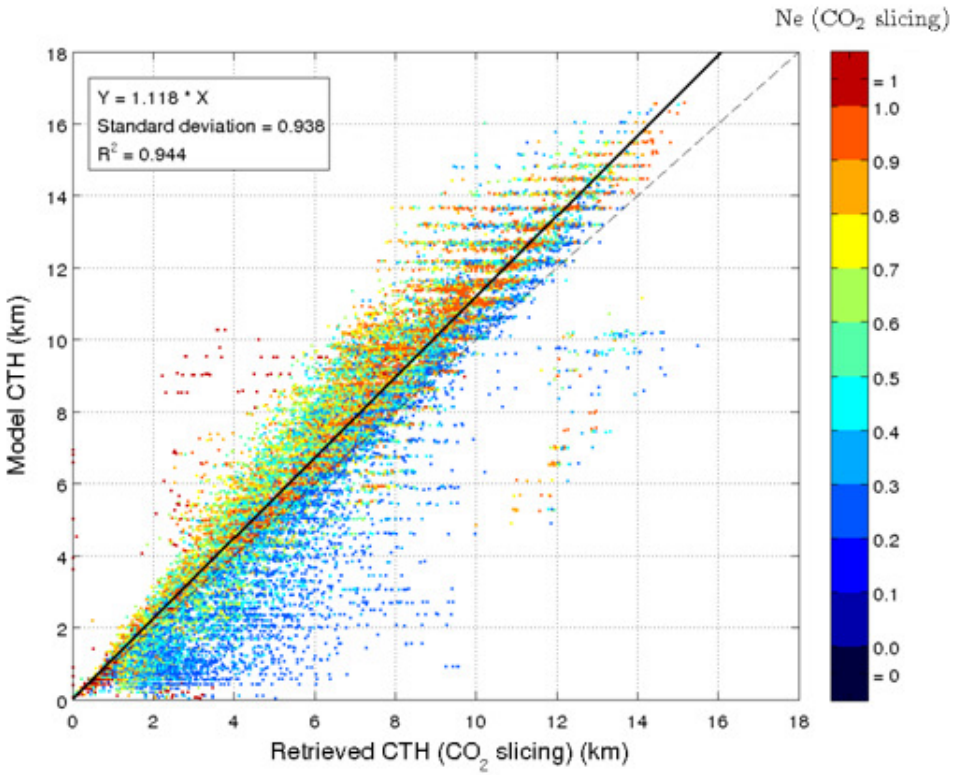
Emissivity ratio considerations: impact of channel selection

Model output (true) height versus retrieved from simulated radiances

Chosen configuration: 13 pairs of coupled channels In narrow limited range				
	Channel		Reference channel	
Pair #	#	cm^{-1}	#	cm^{-1}
1	**204**	707.770	**252**	721.758
2	**221**	712.661	**262**	724.742
3	**232**	715.862	**272**	727.752
4	**252**	721.758	**299**	735.298
5	**262**	724.742	**305**	737.152
6	**272**	727.752	**310**	738.704
7	**299**	735.298	**355**	752.970
8	**305**	737.152	**362**	755.237
9	**310**	738.704	**375**	759.485
10	**355**	752.970	**375**	759.485
11	**362**	755.237	**262**	724.742
12	**375**	759.485	**252**	721.758
13	**375**	759.485	**204**	707.770

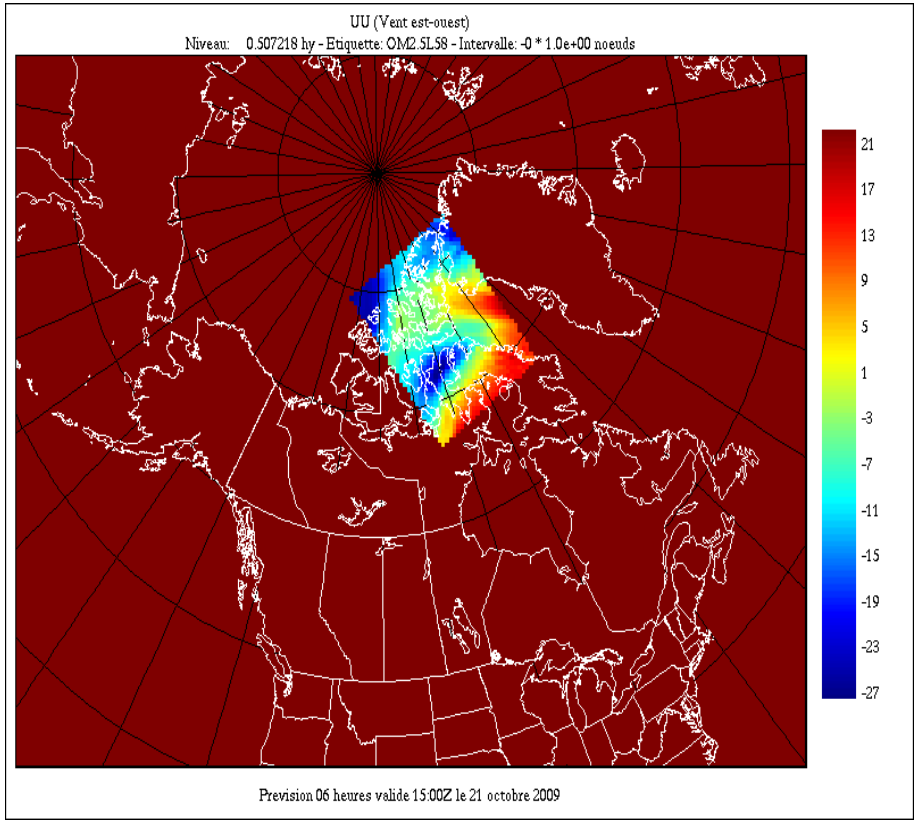
All channels on range 707 – 760 cm^{-1}
STD excluding outsiders: 0.94 km



First experiment with proxy data

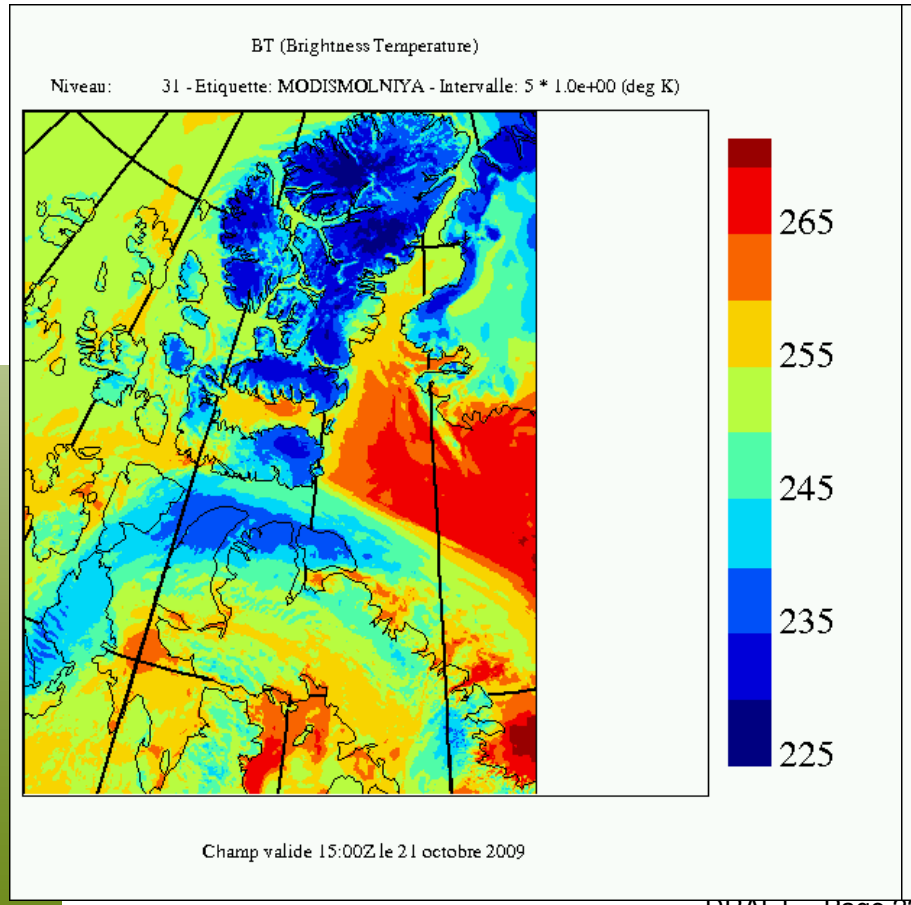
2.5 km model ouput
Over Arctic domain
Remapped to 2 km Polar Stereographic

Sequence of 3 proxy images
30 min apart sent to CIMMS
For AMV extraction
Standard QC

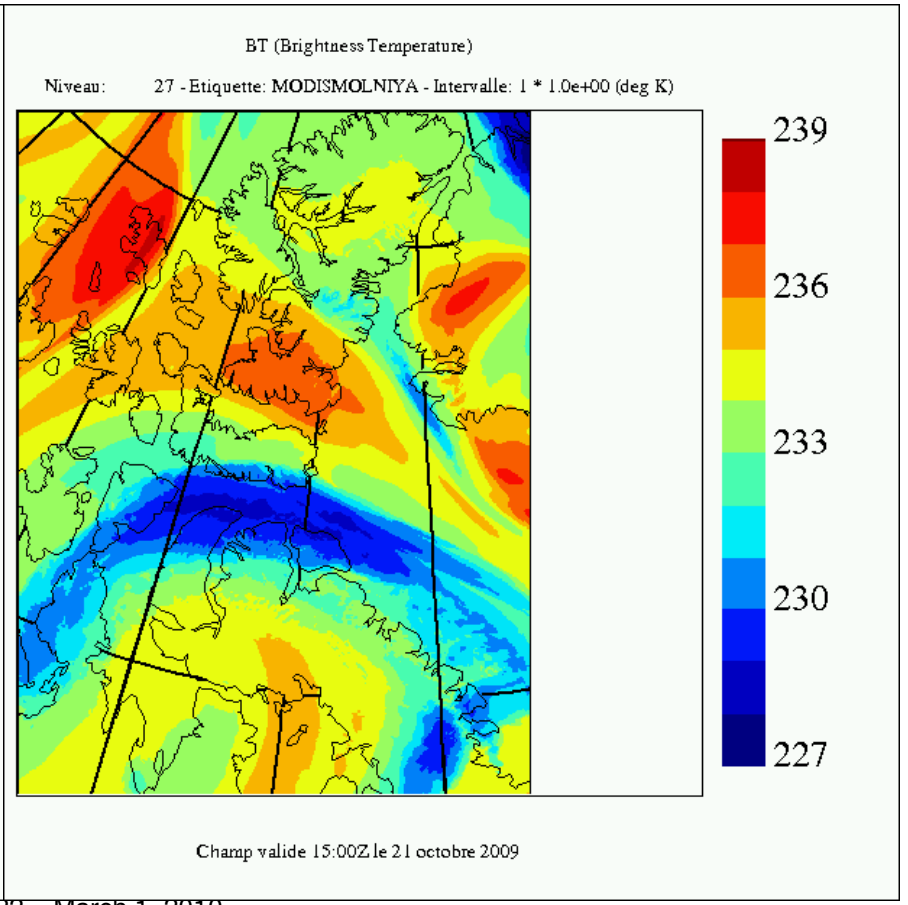


Simulated imagery using RTTOV-cloud

BT(11 micron)

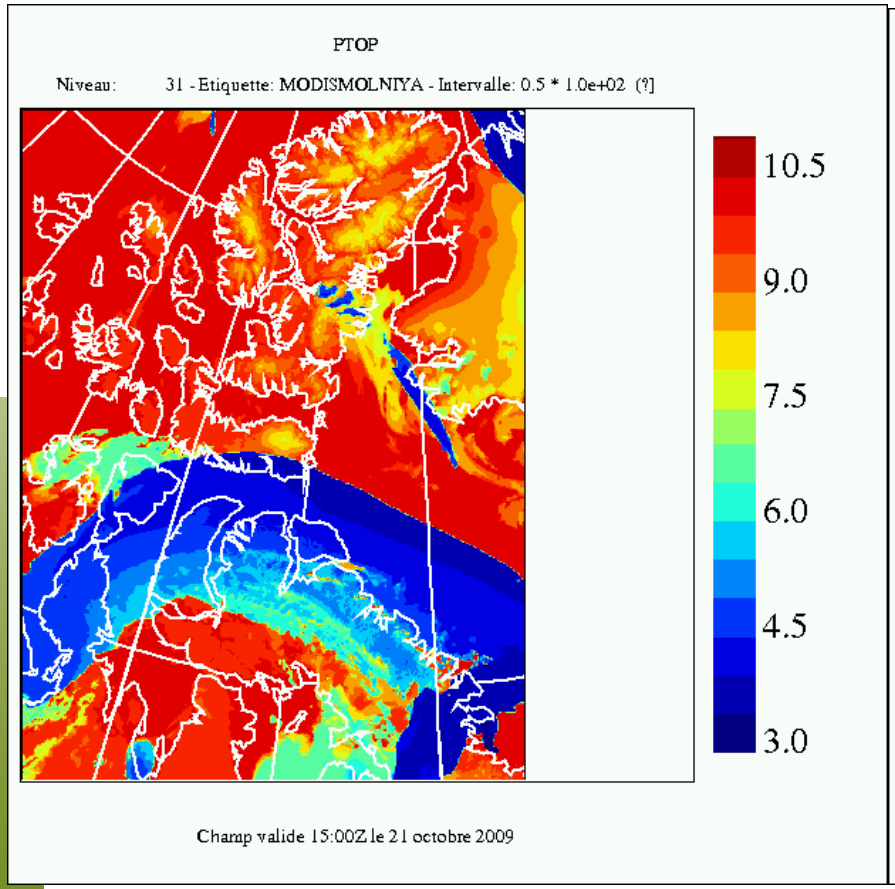


BT(6.7 micron)

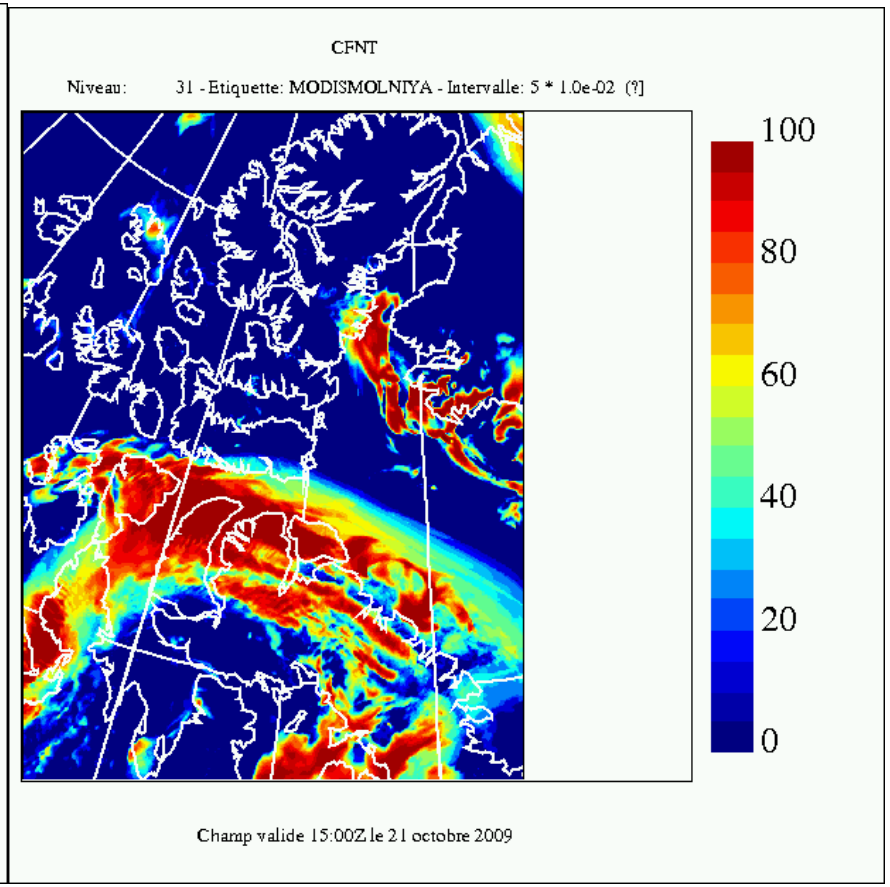


Model cloud parameters

Cloud top height CTH (mb X 100)

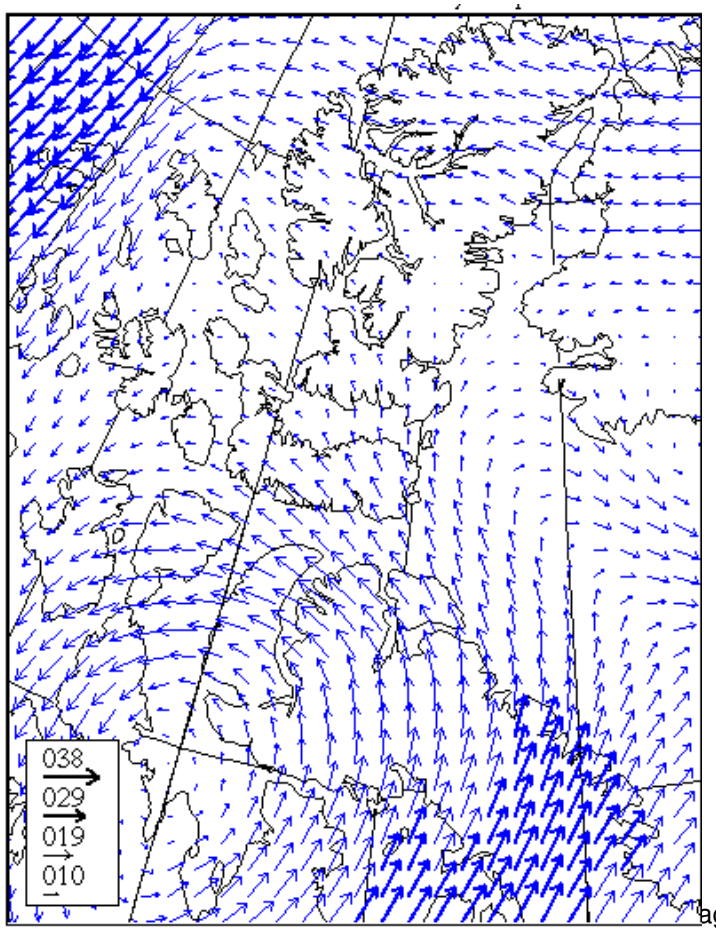


Effective cloud fraction ECF

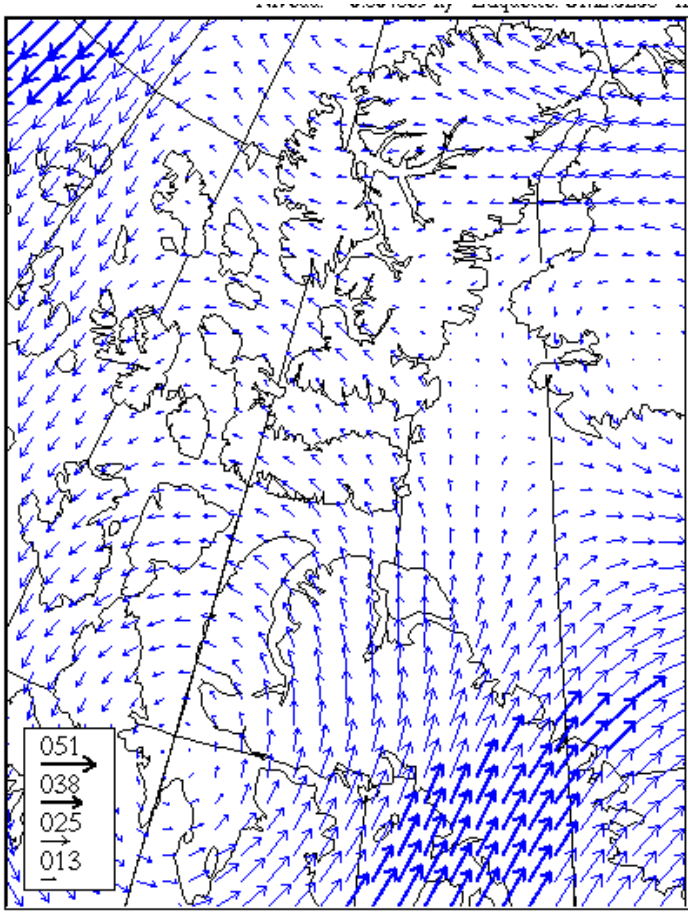


Trial wind 15UTC 21 oct 2009

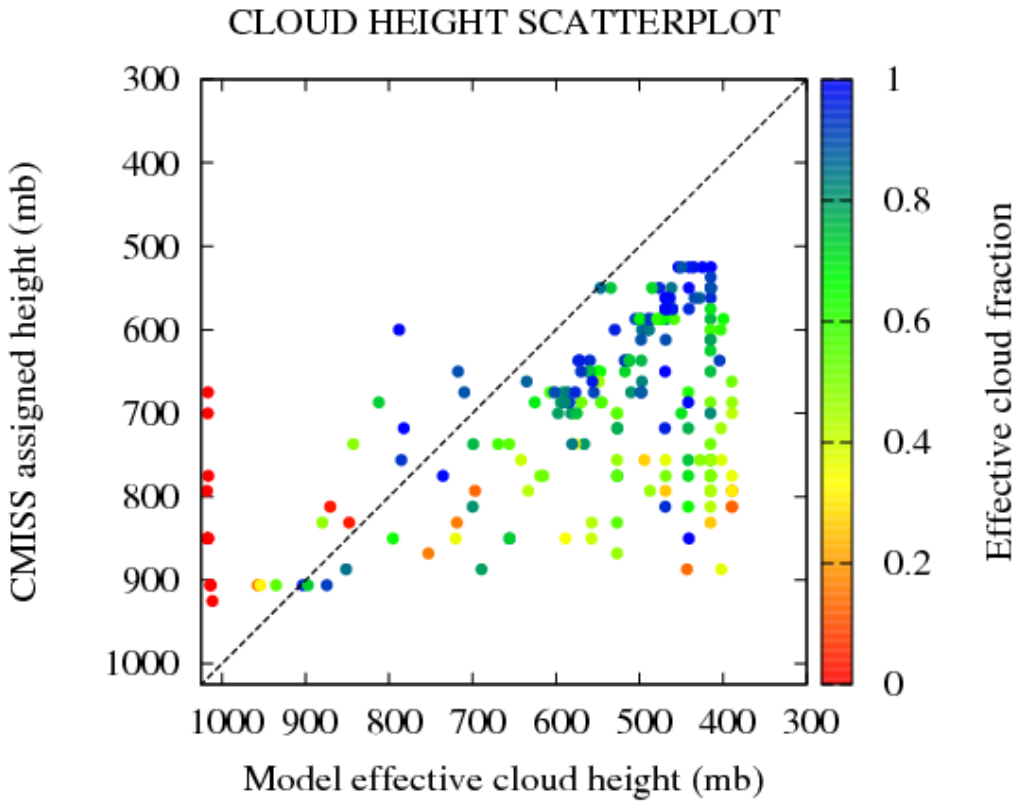
500 hPa (knots)



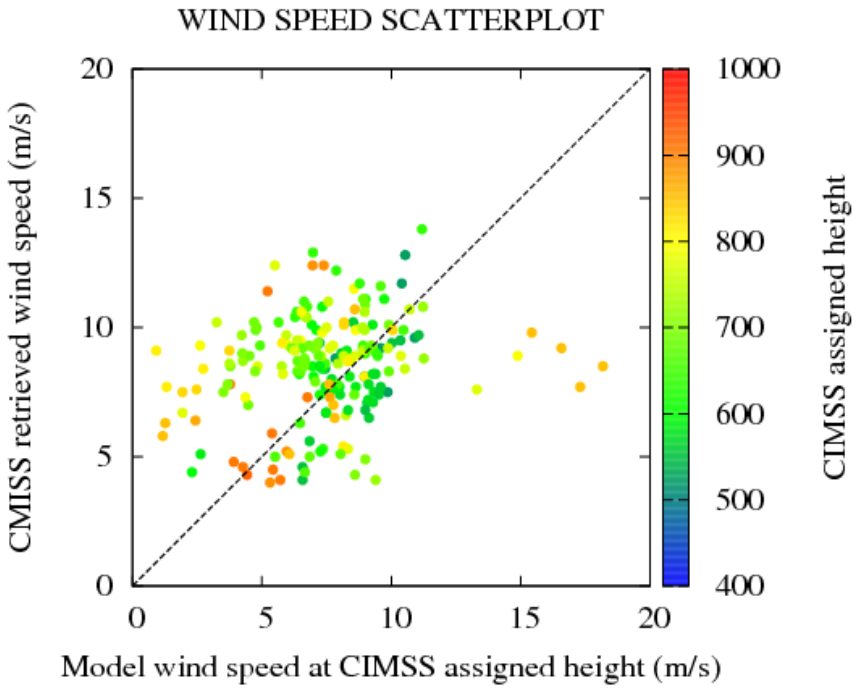
300 hPa (knots)

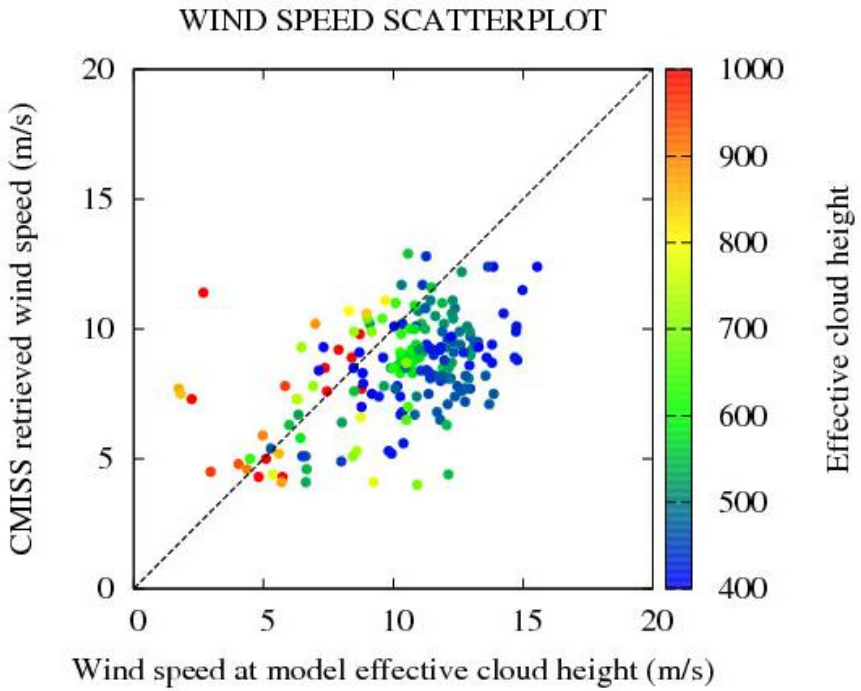


Differences in assigned and model CTH

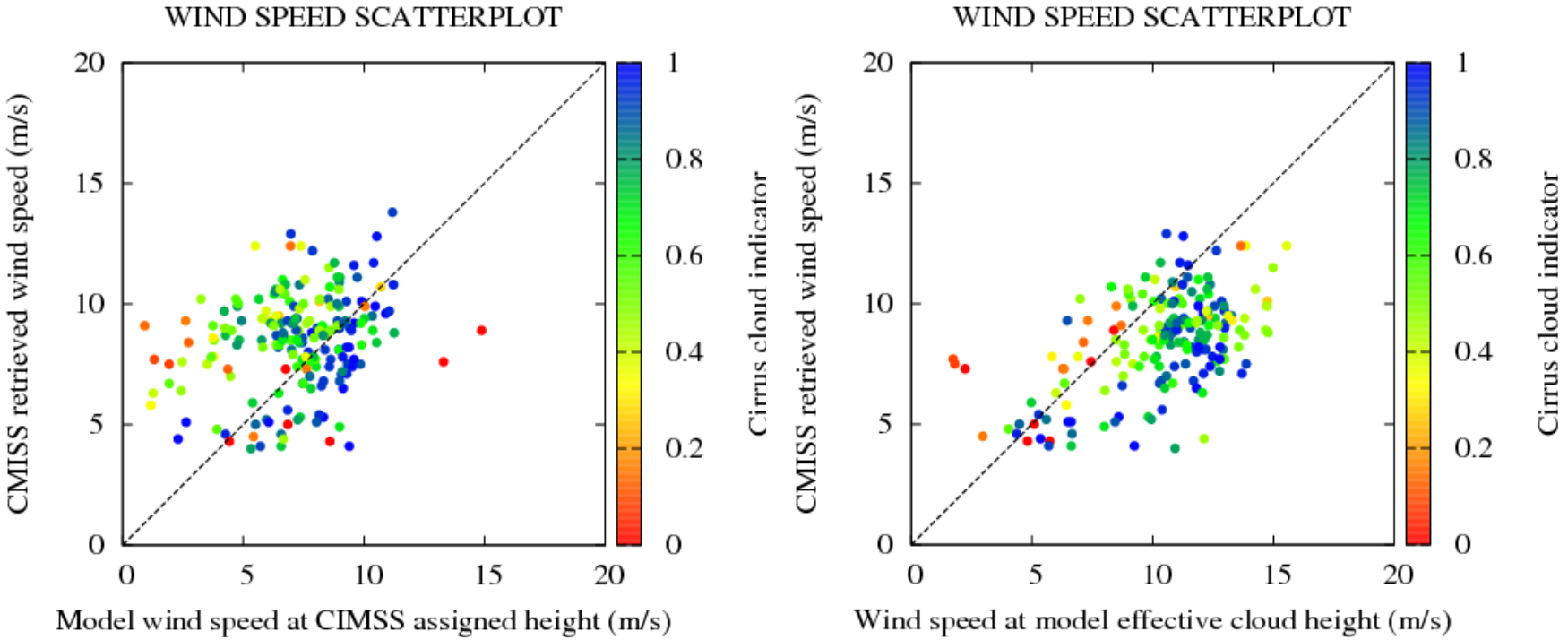


Effect of assigned/model CTH on wind retrieval

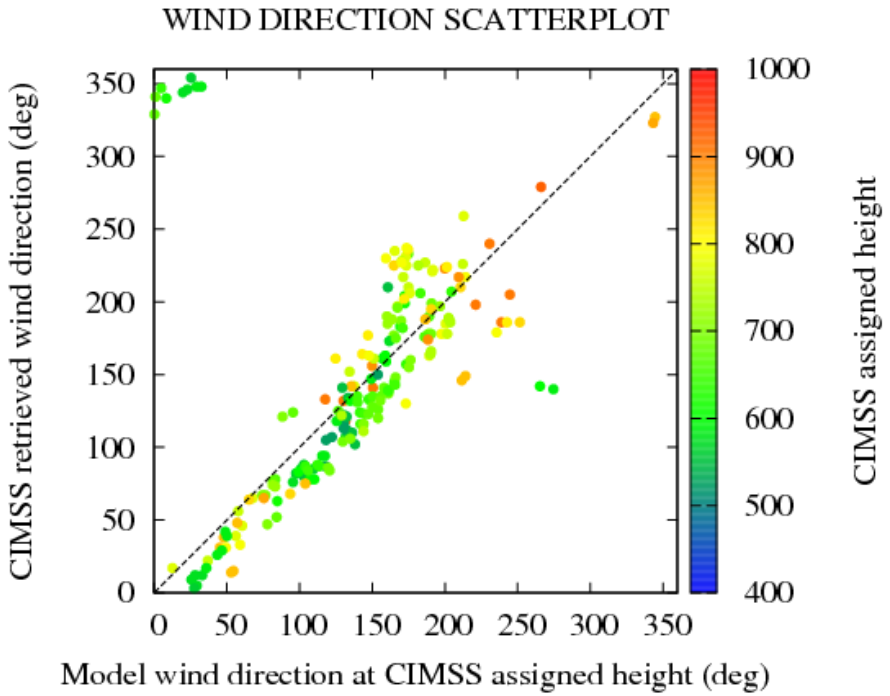


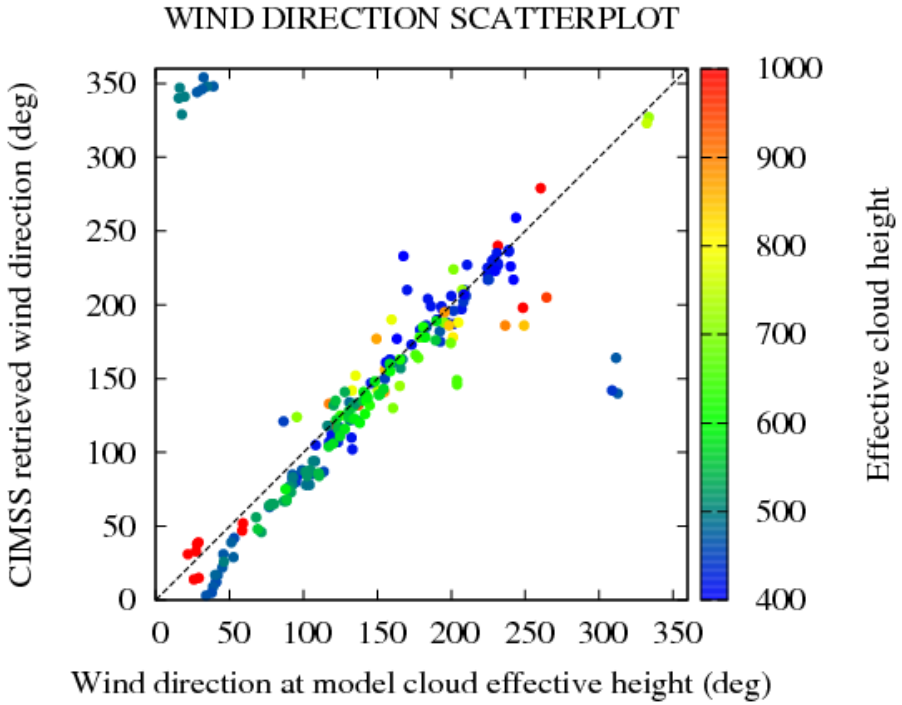


Link to cirrus indicator



Wind direction





Direction improved if model height is used

Conclusion and perspectives

- PCW to provide unique imaging capability the Arctic
  - no gaps 55-90 N, 15 min refresh, 0.5-2 km res
- AMV is a major product of PCW

Looking ahead

- Adapt AMV software to EC environment
- Develop proxy datasets at ~2 km over region 50-90 N H
- Seek improved QC for current polar winds
- Further evaluate possibilities for an OSSE study
- Need to form qualified personnel