High resolution CO_2 flux inverse modeling using ground-based observations

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Poster MIS01-P08, presented in place of MIS01-12

Motivation – why do we need (global) high resolution CO_2/CH_4 flux inversion tools?

- After IPCC AR5 there is growing perception that climate change is real and anthropogenic GHG emissions are recognized as cause of the climate change, so focus have to be shifted from studying climate change related processes to slowing down and reversing global warming (eg Paris 2015, Future Earth).
- In the field of inverse modeling of the global carbon cycle, the shift is visible towards more research on anthropogenic emissions localized around human settlements.
- Current global flux inversion tools operating at resolution from 3 to 6 degrees globally are good enough for studying flux anomalies and seasonal cycles for regions of 1000-2000 km scale
- However, studies of CH_4 emissions in US with GOSAT (Turner et al) or in China with ground based observations (Thompson et al) suggest higher resolution (0.5 to 1 degrees) is better for studying anthropogenic emissions of CH_4
- Indianapolis study (Lavaux et al 2016) showed need for CO_2 transport/inverse modeling at 1 km scale
- It was shown recently (R. Janardanan et al, GRL 2016), that transport modeling at resolution of GOSAT footprint (0.1 deg) is most efficient for looking at strong localized sources of CO_2

Coupled Eulerian-Lagrangian transport model (NIES TM+Flexpart)

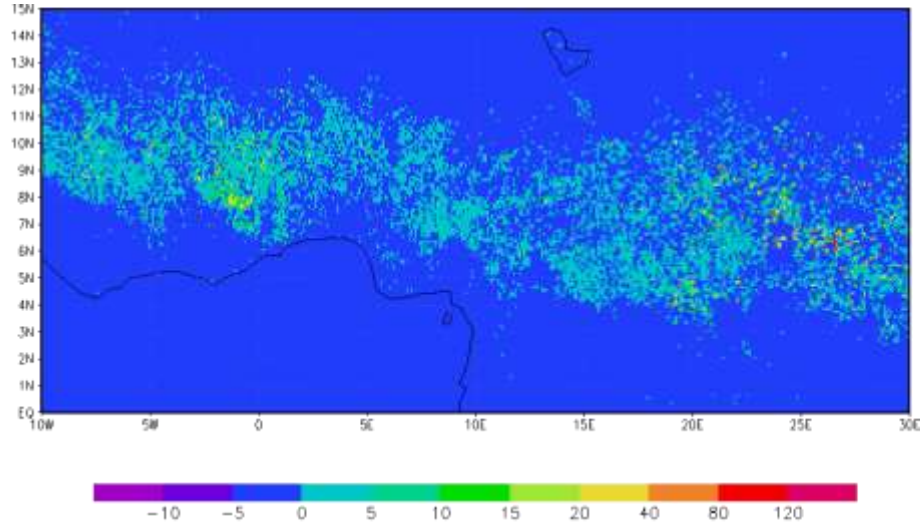
-Configuration of NIES-TM

- resolution 2.5 degree
- mass conserving meteorology, mass fluxes on hybrid isentropic vertical coordinates (Belikov et al 2013)
- hand-coded adjoint with same CPU cost in forward and adjoint modes

-Configuration of Flexpart

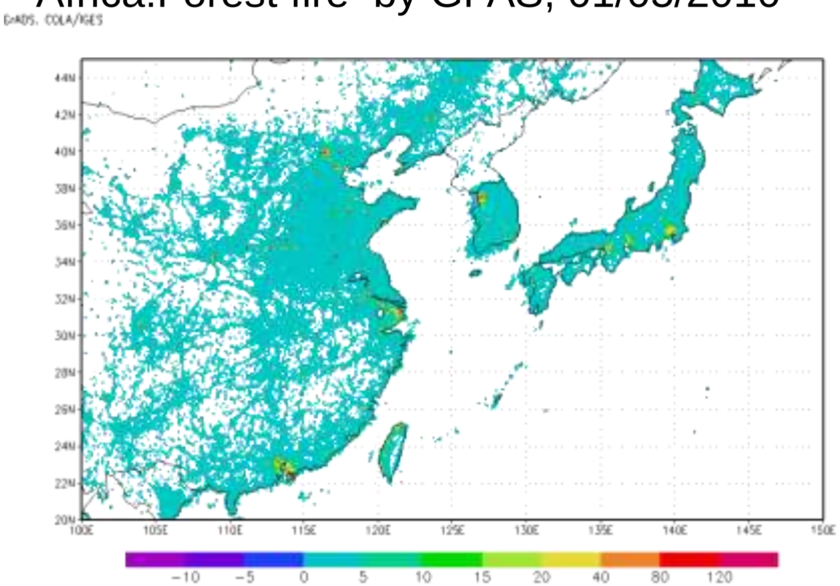
- JCDAS meteorology (1.25 deg, 40 model levels, 6 hourly)
- flux footprints estimated on 0.1x0.1 deg grid
- time window (max) 3 days (for coupling to NIES-TM at 0 GMT)
- for coupling to NIES-TM, concentration footprints estimated on isentropic vertical grid at 2.5 deg horizontal resolution

CO_2 fluxes at 0.1 degree resolution



Africa:Forest fire by GFAS, 01/05/2010

Forest fire/biomass burning:
GFAS daily at 0.1 degree derived from MODIS fire radiative power (FRP) product, Kaiser et al, 2012

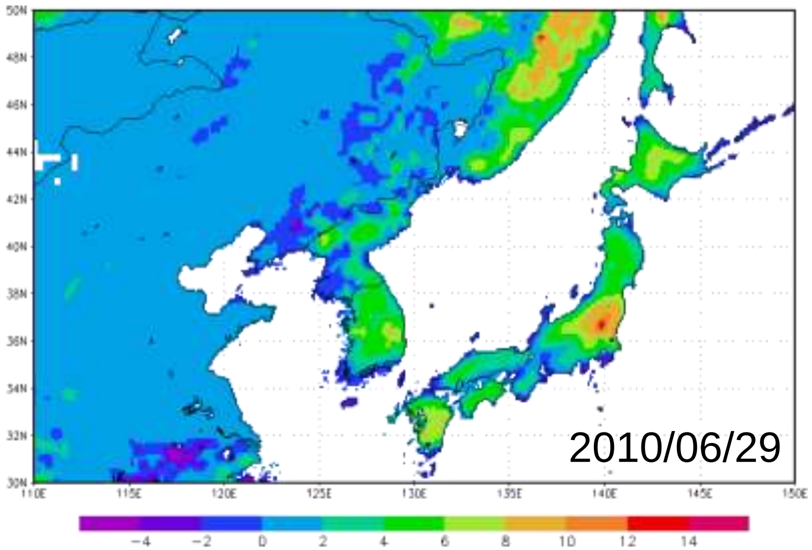


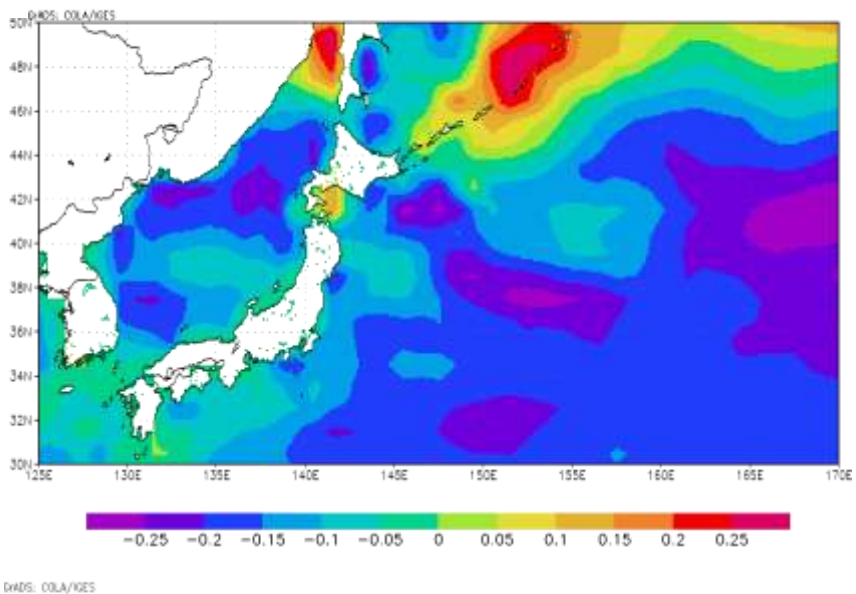
E Asia fossil emissions ODIAC, Jan 2010

Fossil fuel emissions monthly 1 km ODIAC inventory fluxes aggregated to 0.1 degree

ODIAC (Oda & Maksyutov, 2011) combines CARMA power plan emissions database, and DMSP nightlights 1 km resolution observation as proxy for population map, country totals same as CDIAC

CO_2 prior fluxes at 0.1 deg resolution





Terrestrial biosphere

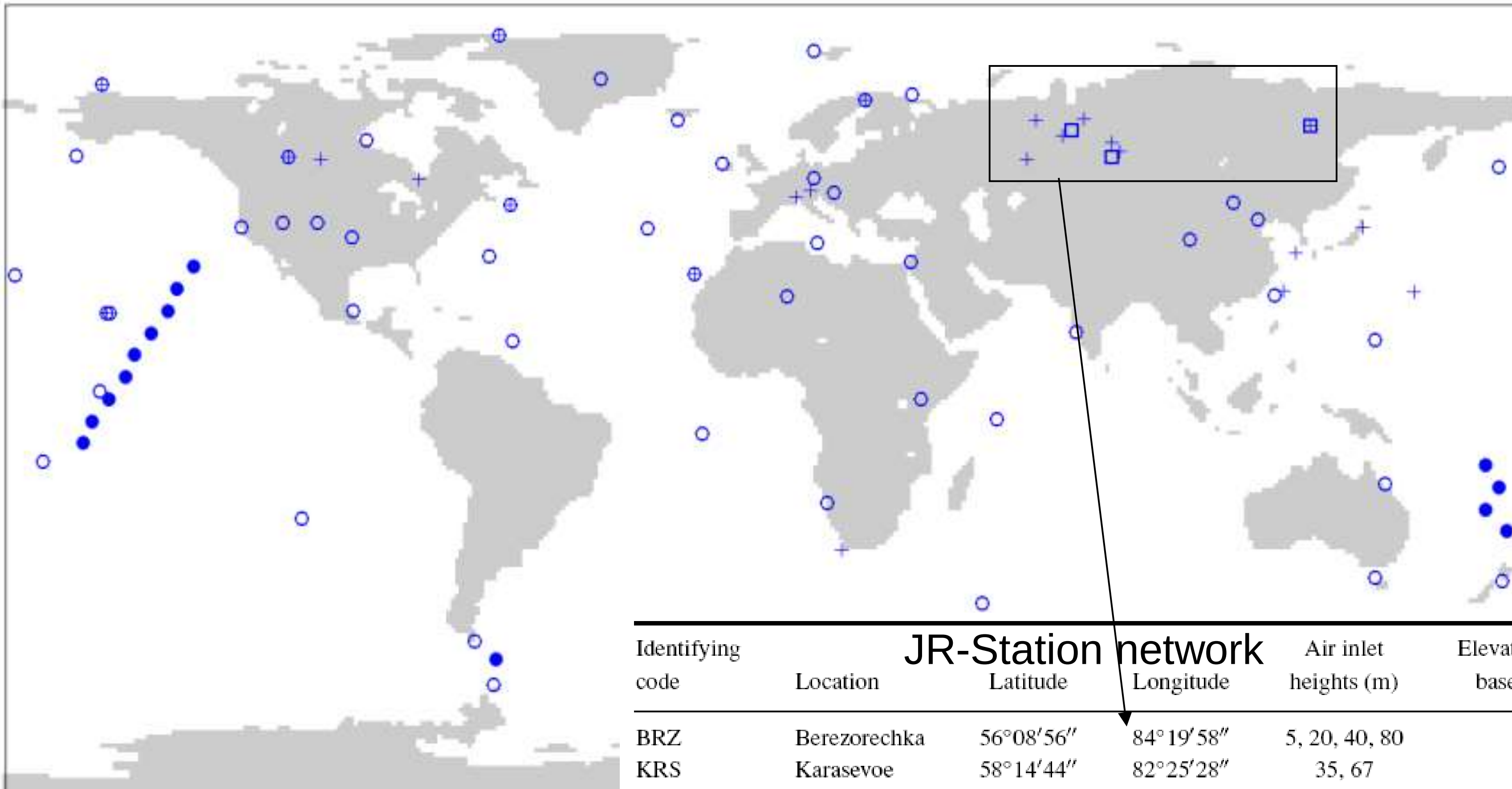
VISIT NEE 0.5 deg daily (JCDAS), Saito et al GMD 2014,

Optimized with atm. CO_2 and other data. Use SYNMAP 1 km vegetation mosaic to remap 0.5 deg fluxes to 0.1 degree

Ocean CO2 surface exchange

Data assimilation of LDEO pCO2 dataset with ocean transport and biogeochemistry model OTTM and its adjoint monthly 1x1 deg fluxes (Valsala, Tellus, 2010) interpolated to 0.1 deg, using MODIS 1 km land/ocean mask

Observation sites



○ event

+ continuous

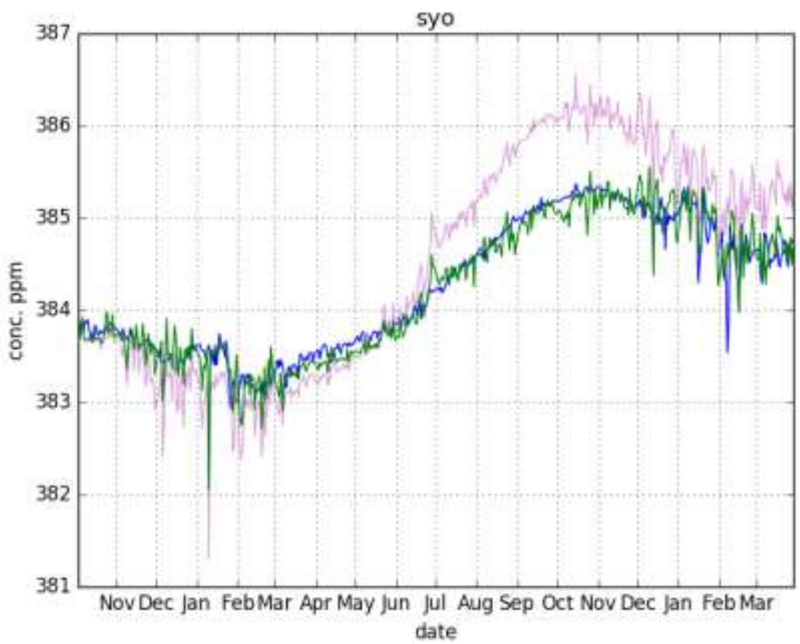
● ship

□ aircraft

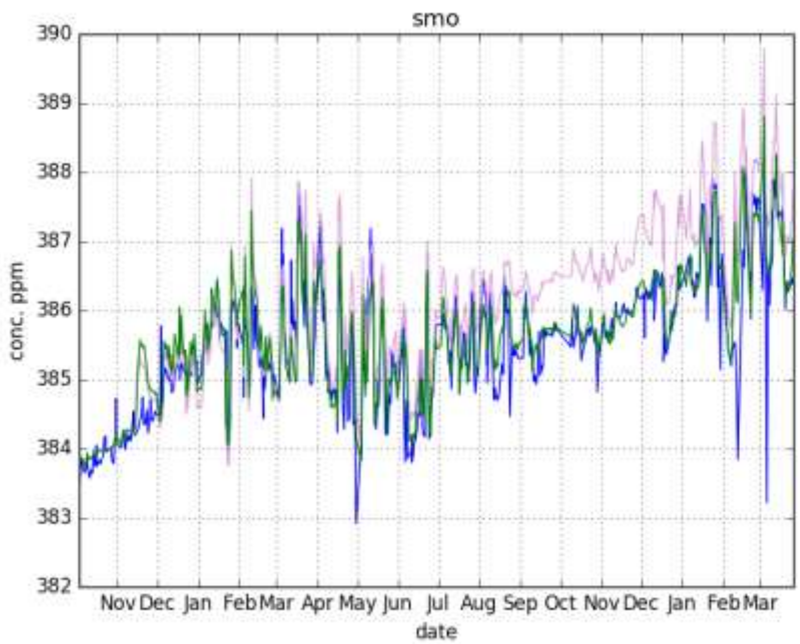
JR-Station network

Identifying code	Location	Latitude	Longitude	Air inlet heights (m)	Elevation at tower base (m a.s.l)[a]
BRZ	Berezorechka	56°08′56″	84°19′58″	5, 20, 40, 80	150
KRS	Karasevoe	58°14′44″	82°25′28″	35, 67	50
IGR	Igrim	63°11′25″	64°24′56″	24, 47	25
NOY	Noyabrsk	63°25′45″	75°46′48″	21, 43	100
DEM	Demyanskoe	59°47′	70°52′	45, 63	75
SVV	Savvushka	51°19′30″	82°07′40″	27, 52	400
AZV	Azovo	54°42′18″	73°01′45″	29, 50	100
VGN	Vaganovo	54°29′50″	62°19′29″	42, 85	200
YAK	Yakutsk	62°50′	129°21′	11, 70	130

Optimized CO_2 concentrations in 2009



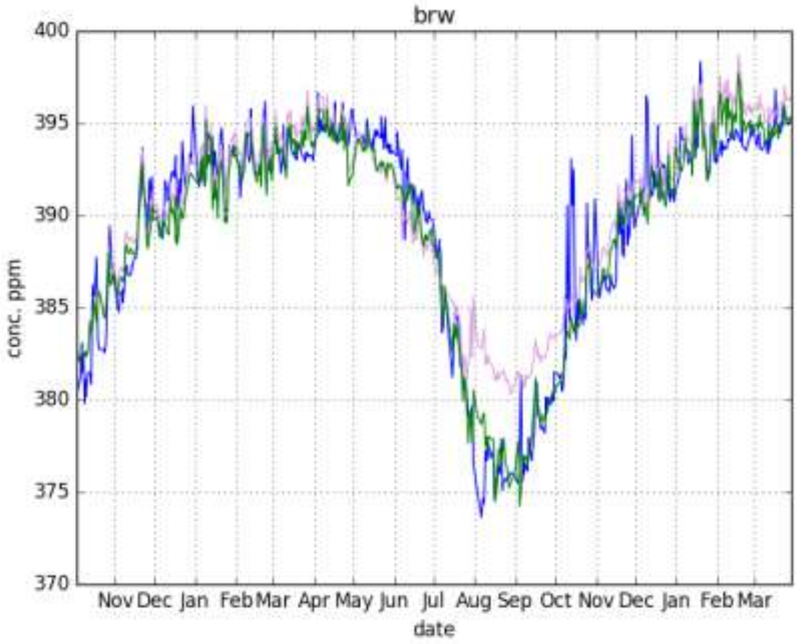
Syowa, Antarctica



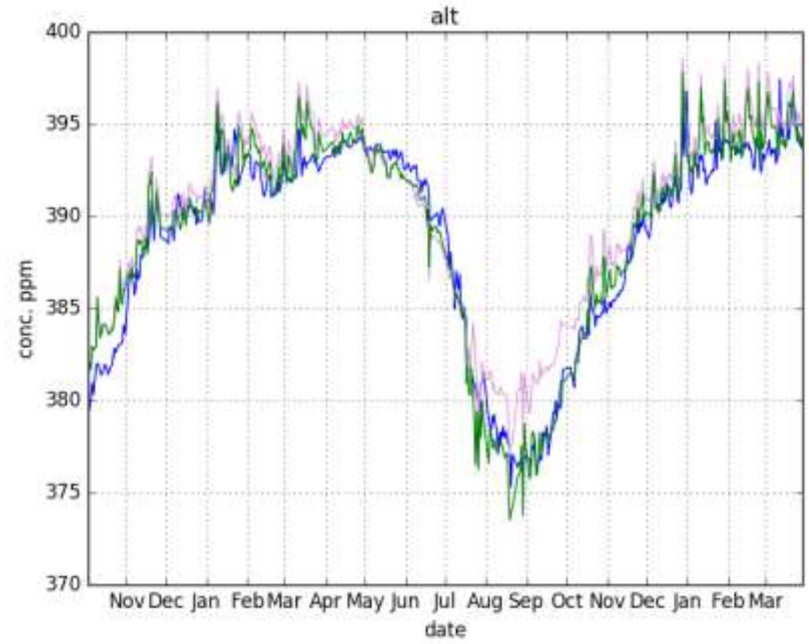
American Samoa (tropics)

observation (blue), forward/prior (plum), inversion (green)

Optimized CO_2 concentrations

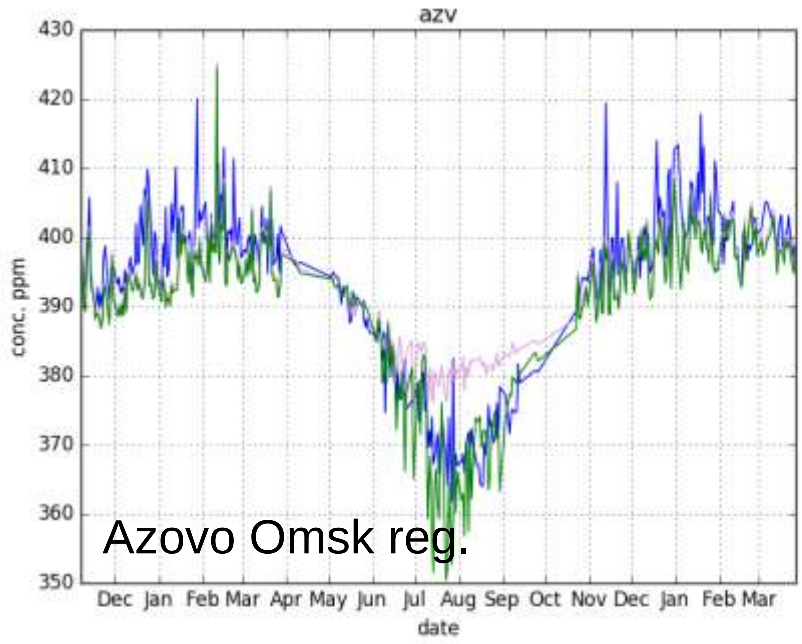


Barrow, Alaska



Alert, Canada

observation (blue), forward/prior (plum), inversion (green)


azv
Azovo Omsk reg.
conc. ppm
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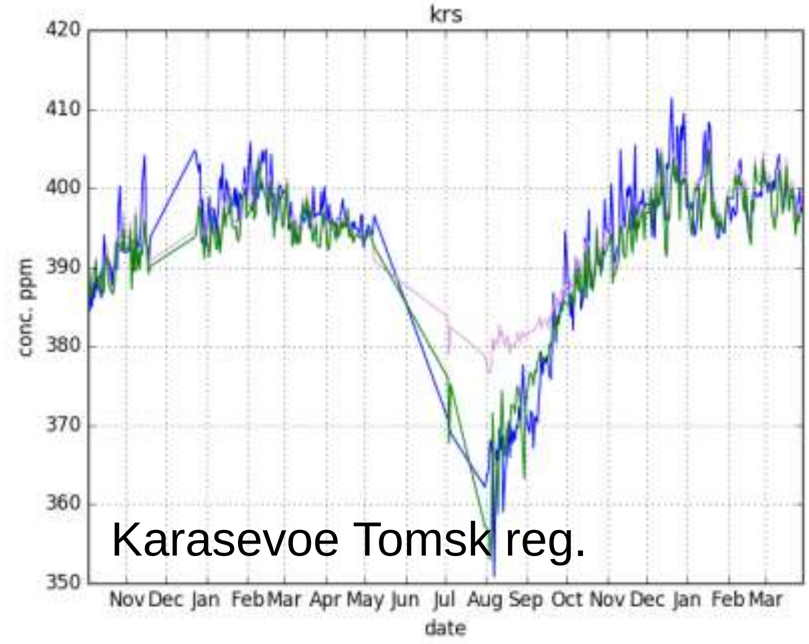
420
410
400
390
380
370
360
350
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
date


krs
Karasevoe Tomsk reg.
conc. ppm
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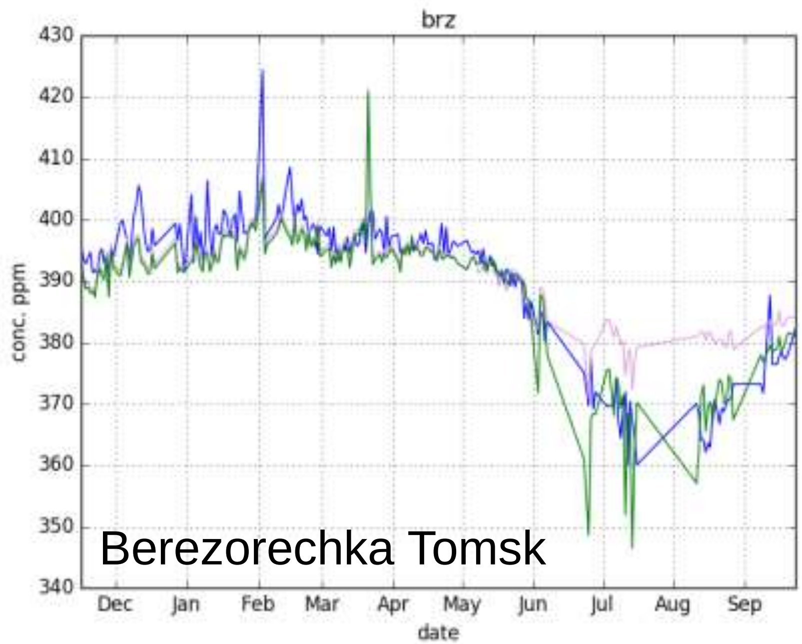
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
date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Berezorechka Tomsk
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Dec Jan Feb Mar Apr May Jun Jul Aug Sep
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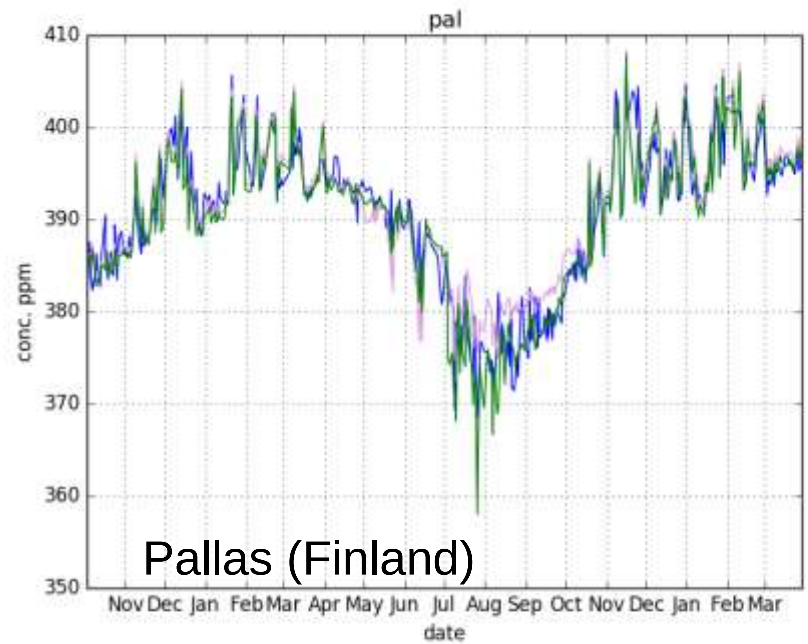
pal
Pallas (Finland)
conc. ppm
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400
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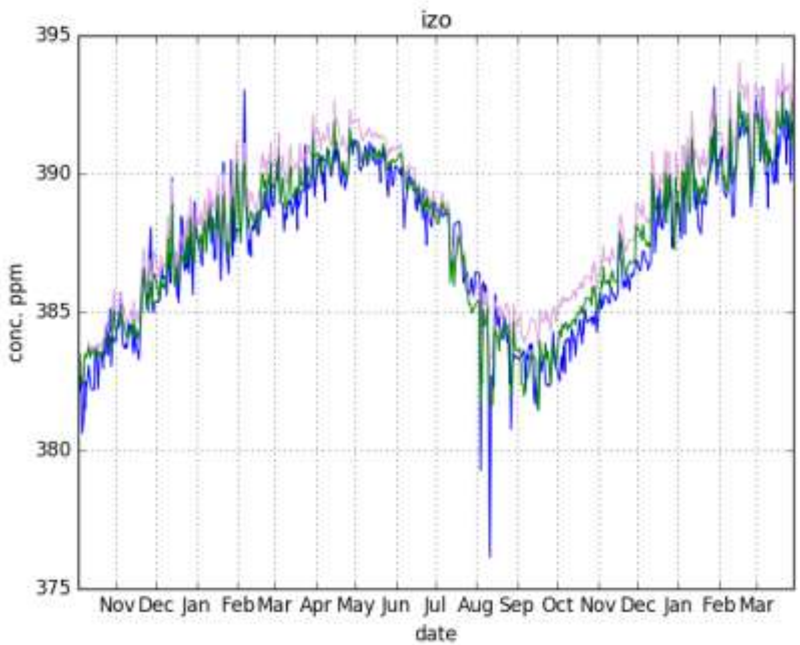
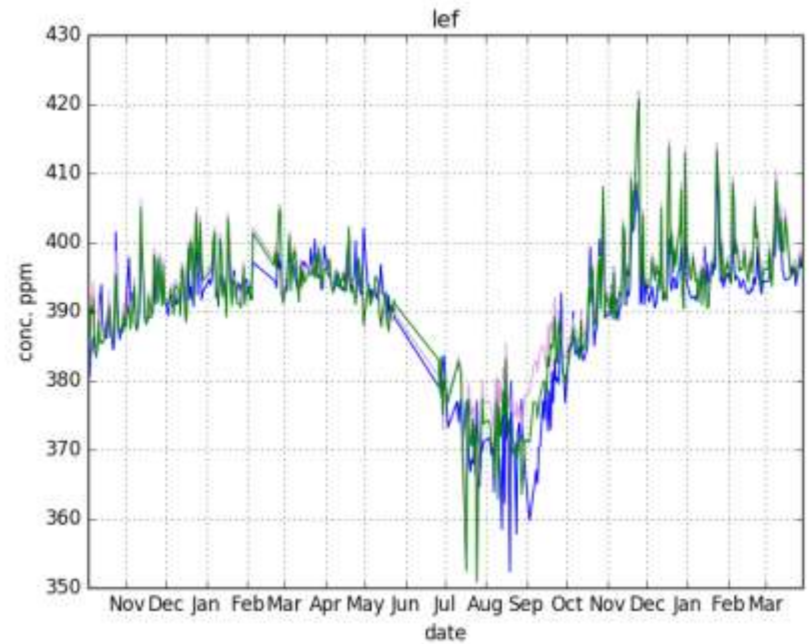
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
date

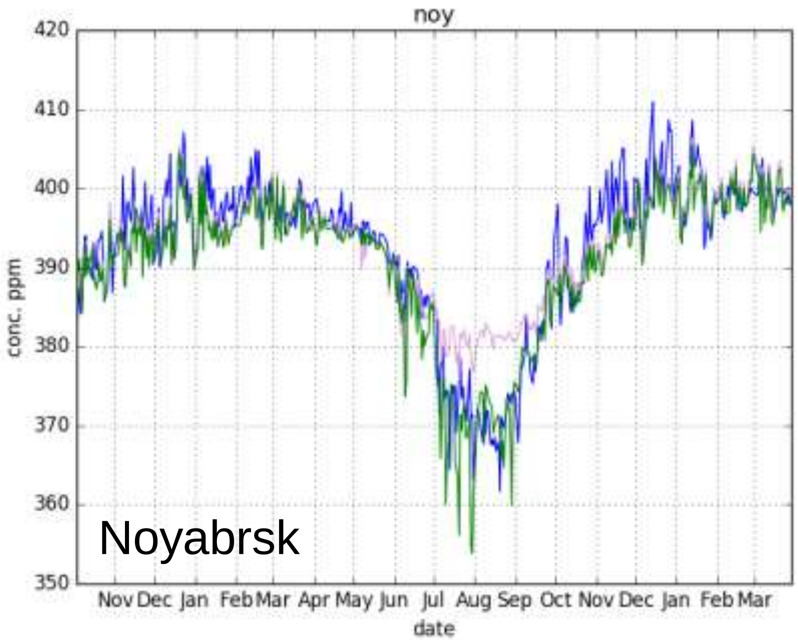
Optimized CO_2 concentrations



Izana, Tenerife (alt 3km)



LEF tall tower, Wisconsin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Noyabrsk
conc. ppm
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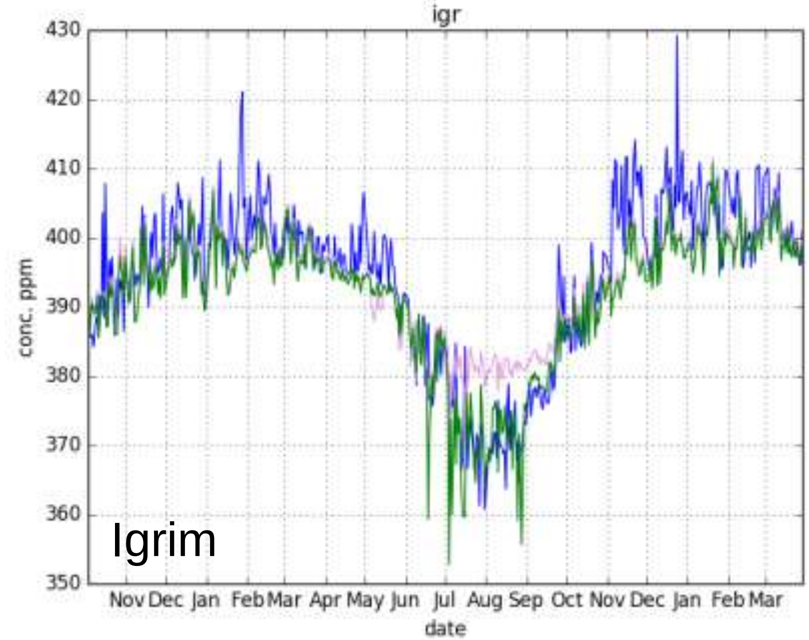
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Igrim
conc. ppm
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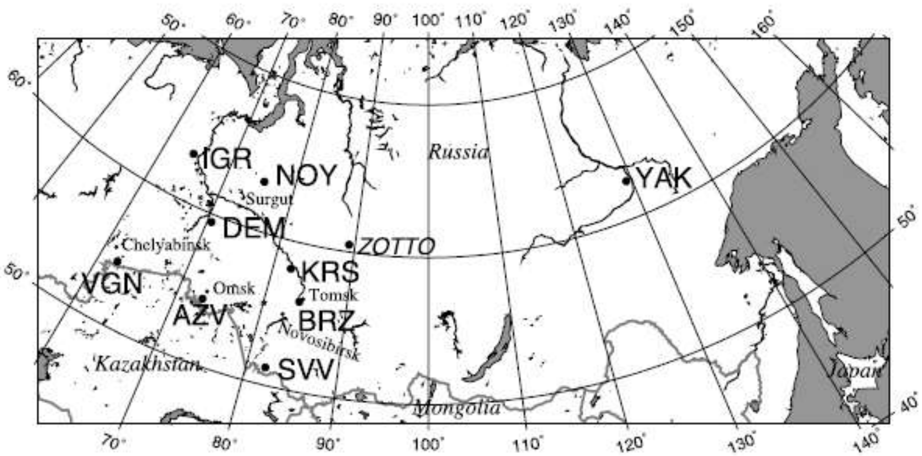
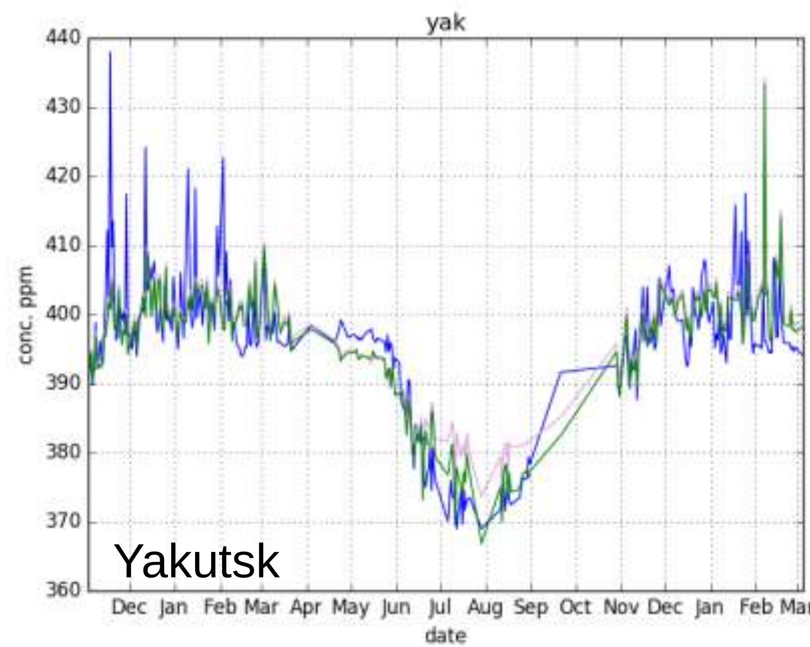
Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
date


IGR
NOY
Surgut
DEM
ZOTTO
YAK
Chelyabinsk
VGN
Omsk
KRS
Tomsk
AZV
BRZ
Novosibirsk
SVV
Russia
Kazakhstan
Mongolia
Japan

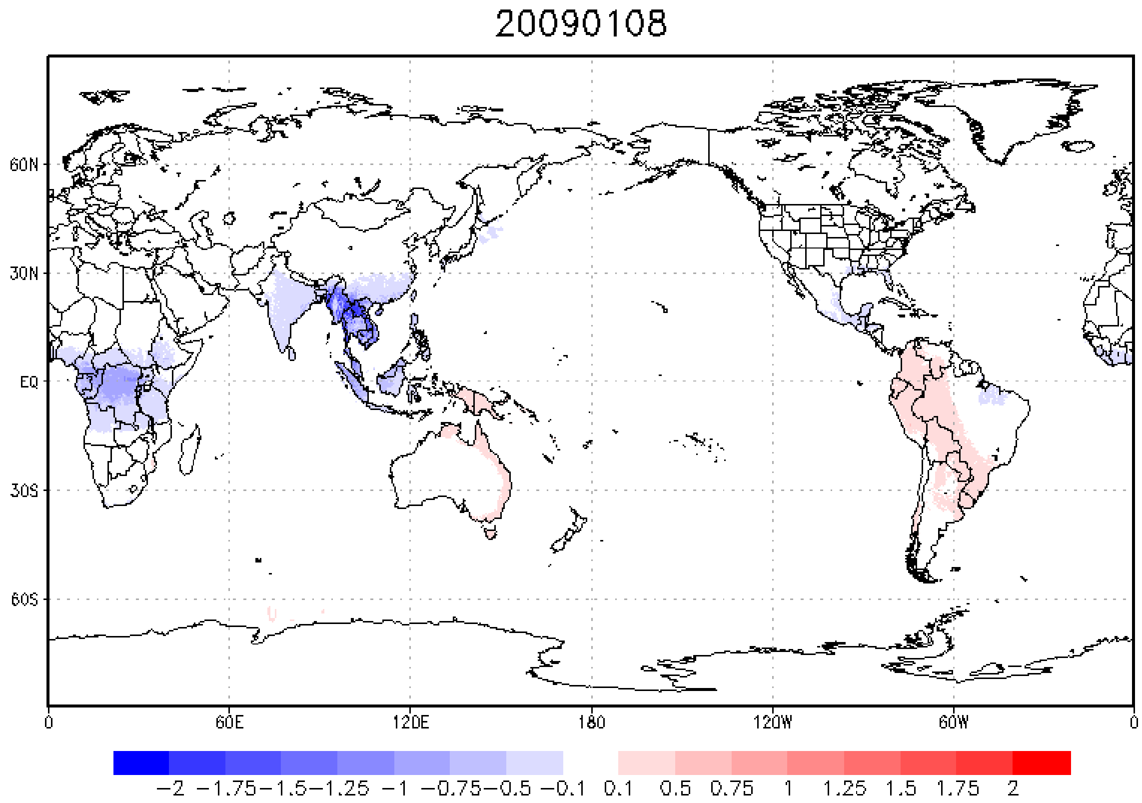

yak
Yakutsk
conc. ppm
440
430
420
410
400
390
380
370
360
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
date

Flux corrections (posterior minus prior) at weekly time step (gC/m²/day) in 2009, estimated with M1QN3 algorithm

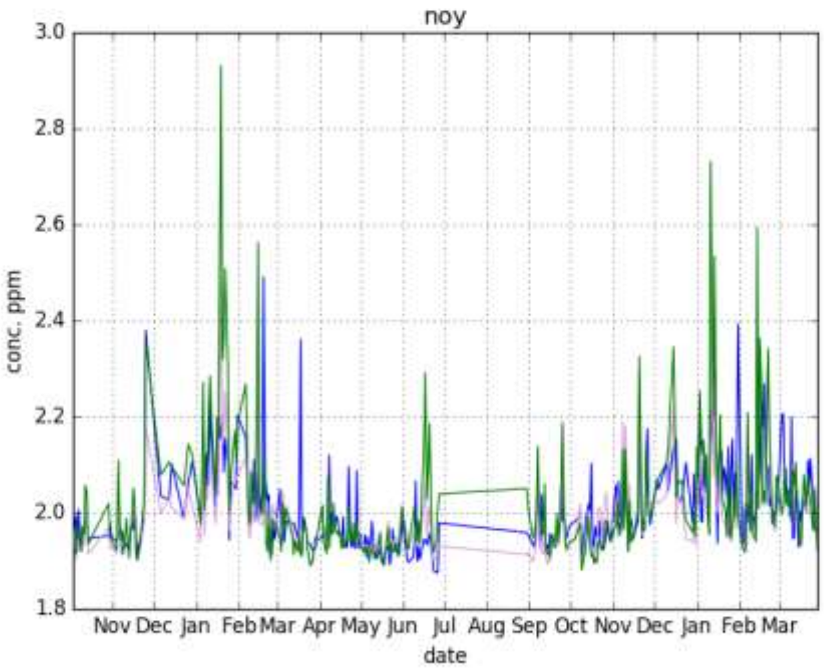
Prior fluxes

Bio VISIT mosaic
Fos ODIAC
Fire GFAS
Ocn OTTM

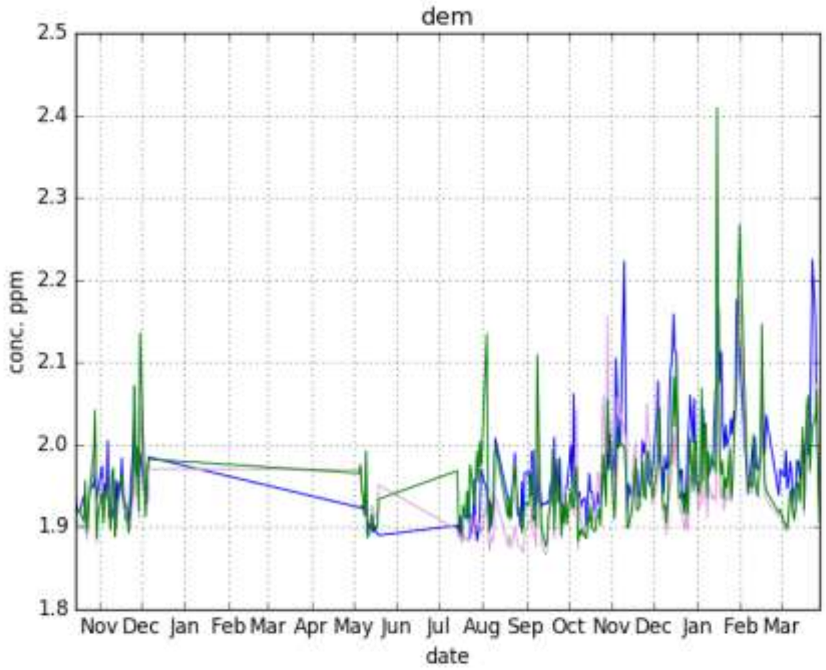
Prior uncertainties
MODIS GPP MOD17



Optimized CH_4 concentrations 2011 West Siberia



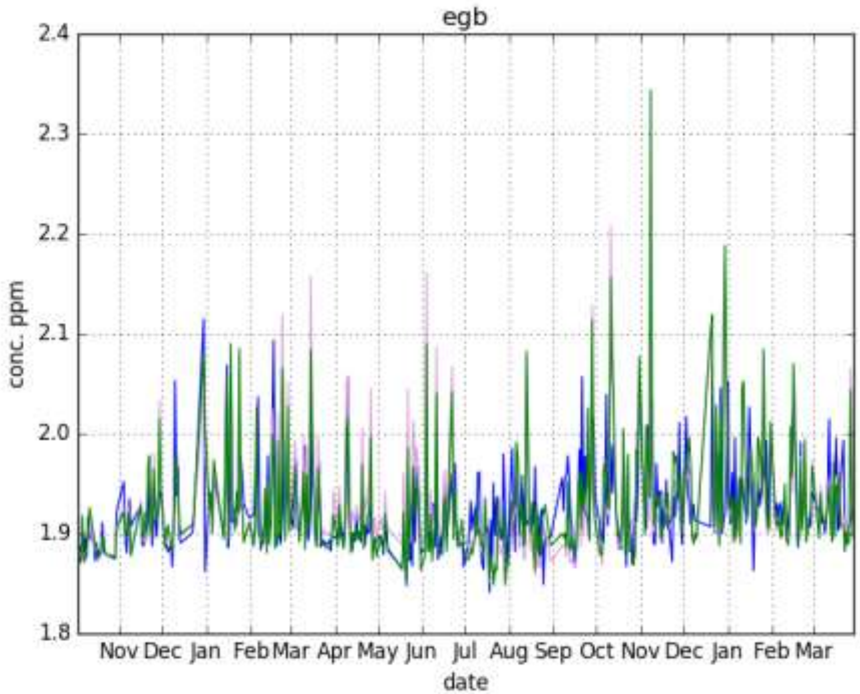
Noyabrsk, West Siberia



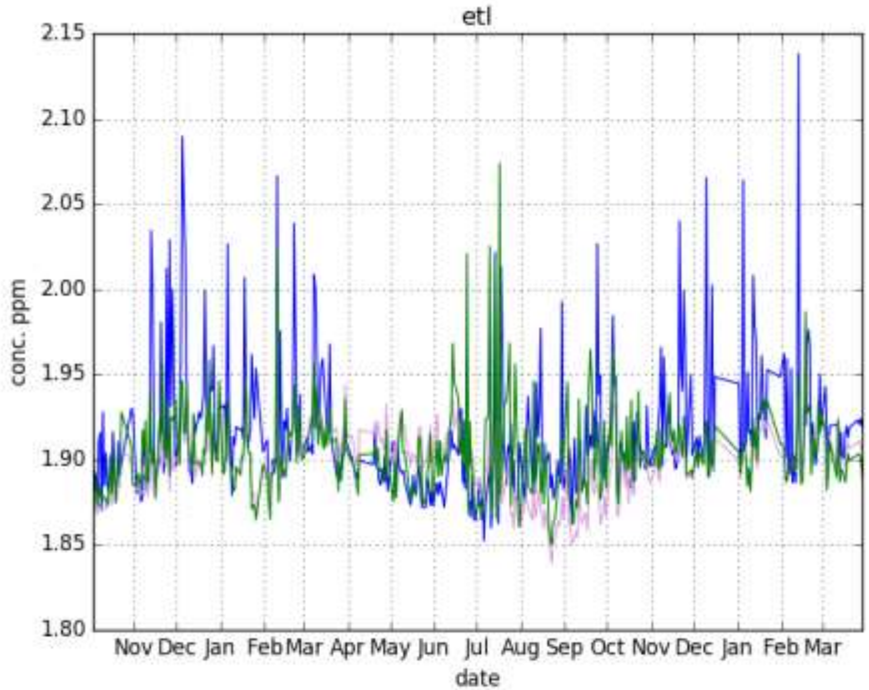
Demyanskoe, West Siberia

observation (blue), forward/prior (plum), inversion (green)

Optimized CH_4 concentrations Canada 2011



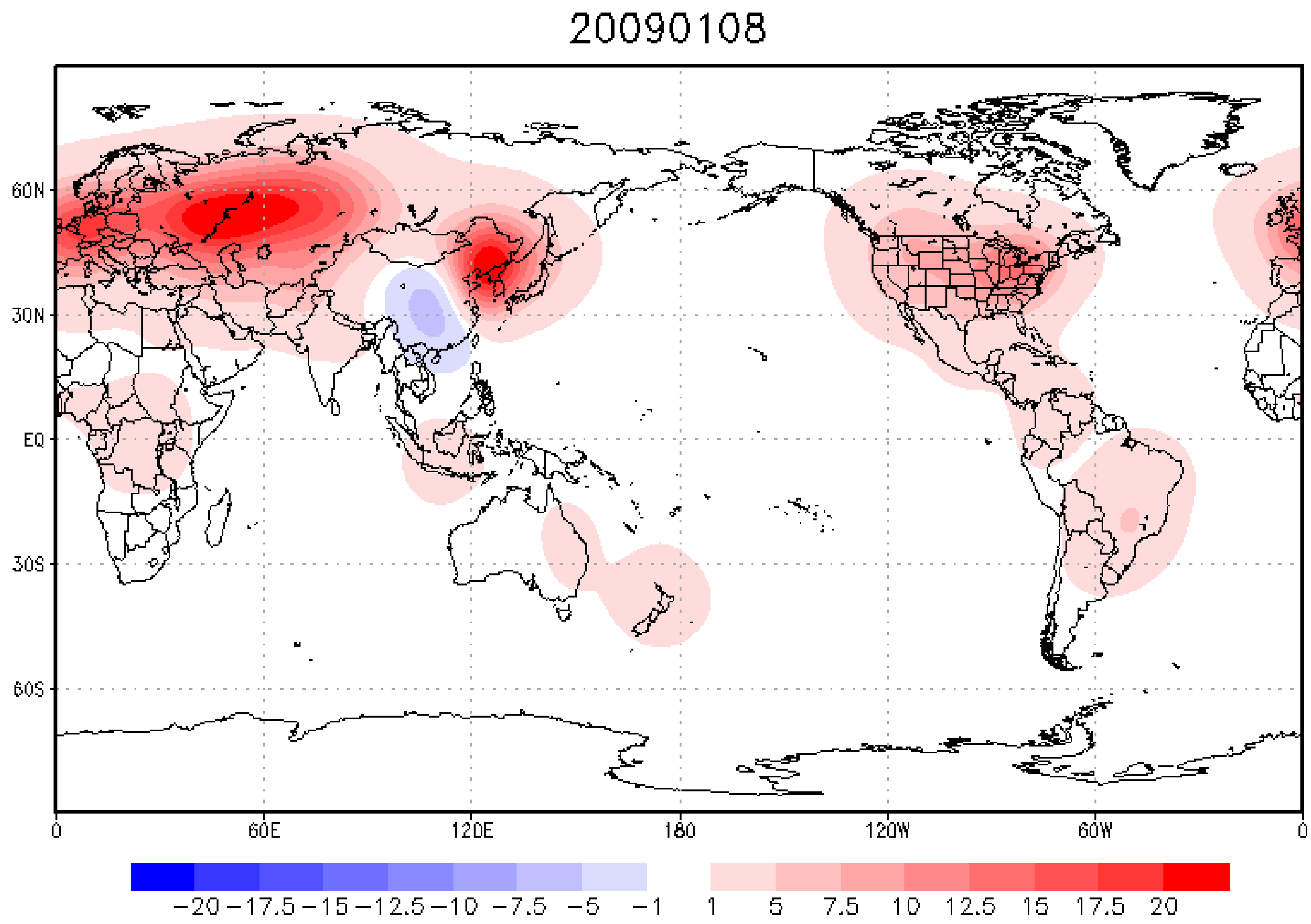
Egbert, Canada



East Trout Lake, Canada

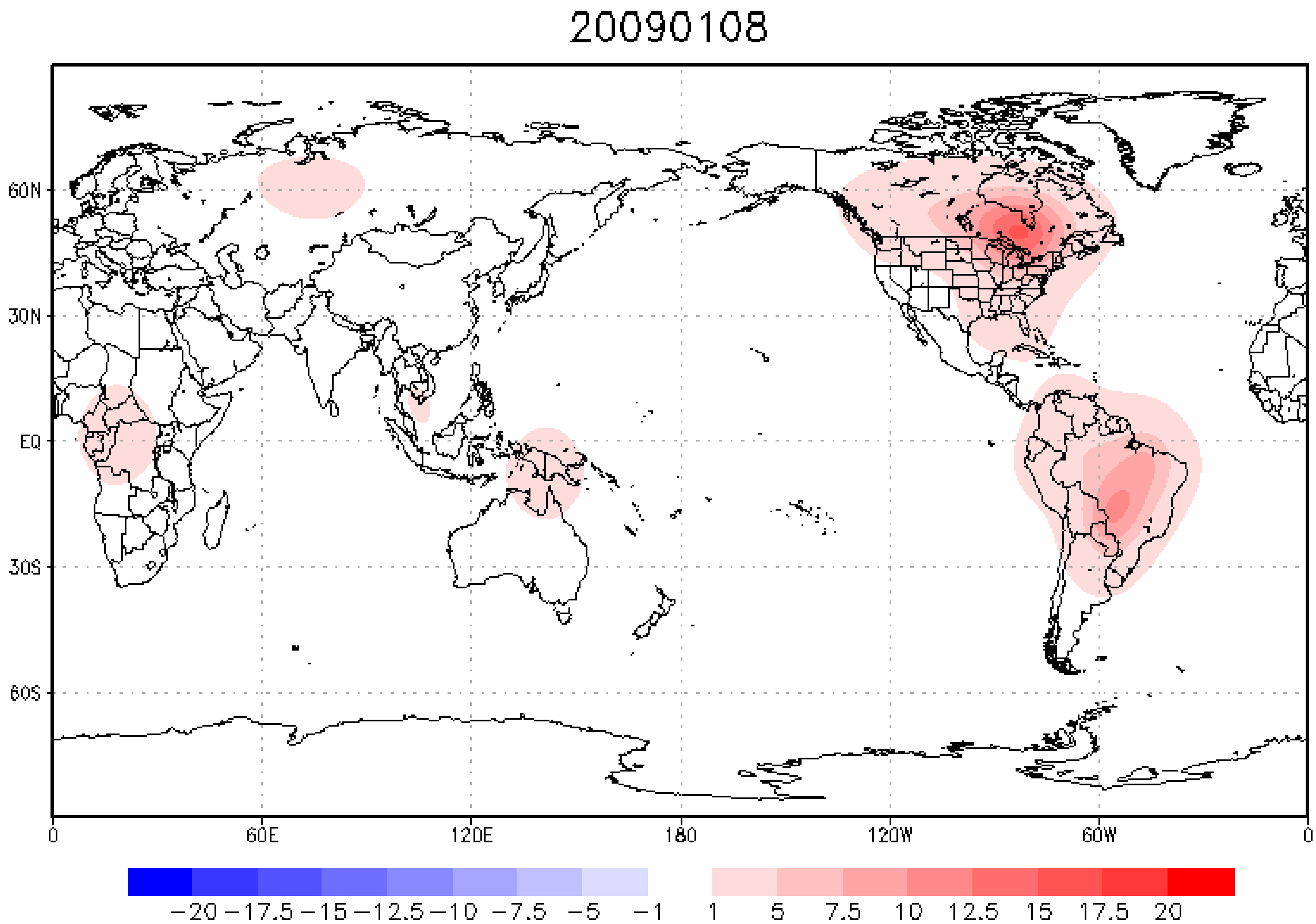
observation (blue), forward/prior (plum), inversion (green)

CH4 emission correction factor (%) by inversion: anthropogenic



Observations – continuous and flask sampling data from WDCGG

CH_4 emission correction factor (%) by inversion: wetlands and rice



Summary and conclusion

We applied computationally efficient approach to high resolution inverse surface flux modeling at fine-grid scale using global ground based observation and JR-Station network.

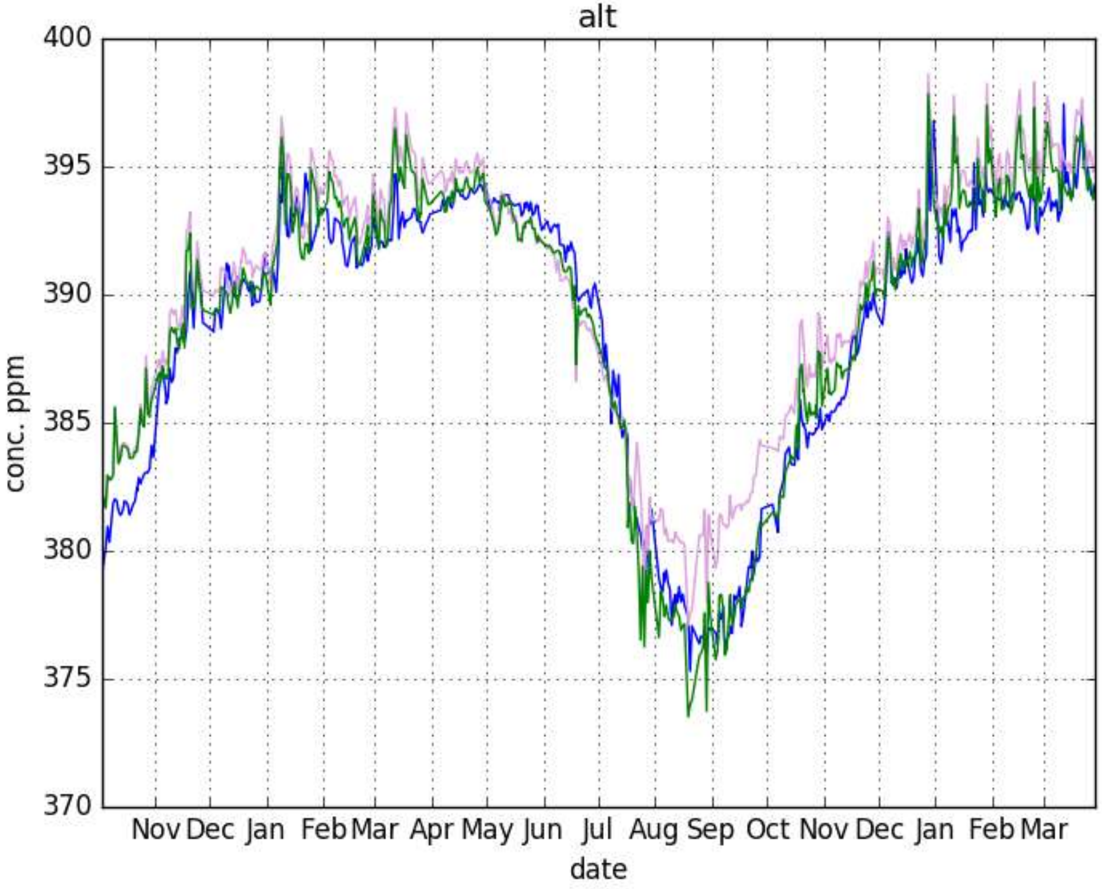
The coupled transport model is used for forward simulation and estimating surface CO_2 fluxes at 0.1 deg with variational data assimilation algorithm

High resolution biospheric flux dataset constructed using a vegetation mosaic approach combining 0.5 deg resolution VISIT NEE simulation for a number of classes and 1 km SYNMAP vegetation map. Anthropogenic CO_2 emissions (ODIAC) and biomass burning are also used at high 0.1 deg resolution.

High resolution modeling improves separation between anthropogenic and natural fluxes.

Strong summertime sink in Siberia is required to match the CO_2 observations in West Siberia

Surface sites



observation (blue), forward/prior (plum), inversion (green)