Assessment of Antarctic ice sheet ECVs from inverse modelling

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ESA Climate Change Initiative
Climate Modelling User Group

Initial project outline

A.Initialisations: infer non observable & poorly know parameters

- Basal friction
- Softening/Stiffening factor
- Applies **inverse methods** to IV and Geometry

C. Prédictions

2100

Initial state
1990s or 2000s

ECV assessment

Initial state
2010s

Are there changes in the initial states ?

B. ECVs validation: from time evolutive simulations SEC, GMB, IV

1990s

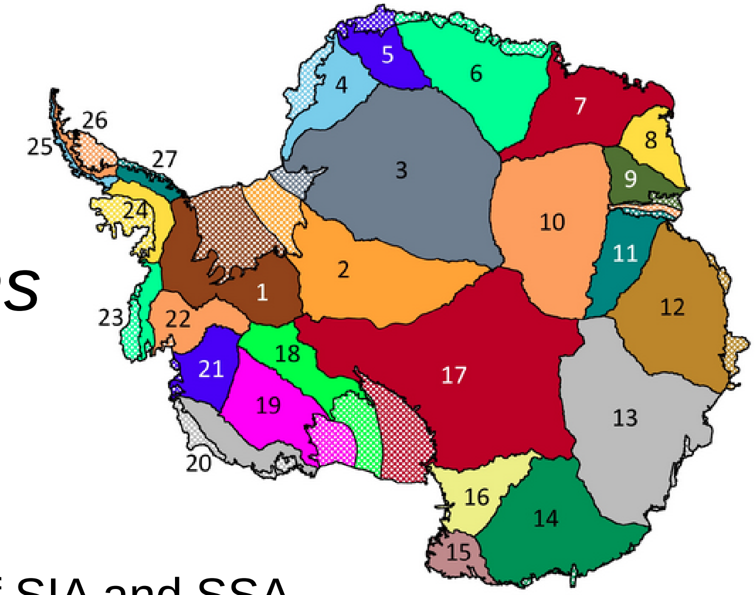
Outputs: SEC (t), M(t), IV(t)

2010s

Areas of interest

Global approach: Antarctic Ice Sheet

- The **f.ETISh** (Fast Elementary Thermomechanical marine Ice Sheet) model [Pattyn 2017]
- 2D plane thermocoupled and vertically integrated model
- Grounding-line flux parametrisation
- Simplified Stokes flow for marine ice sheet
  - Modified hybrid SSA-SIA for grounded ice sheet
  - Modified SSA for floating ice shelves
- For global scale, the grid size is 10 km at most

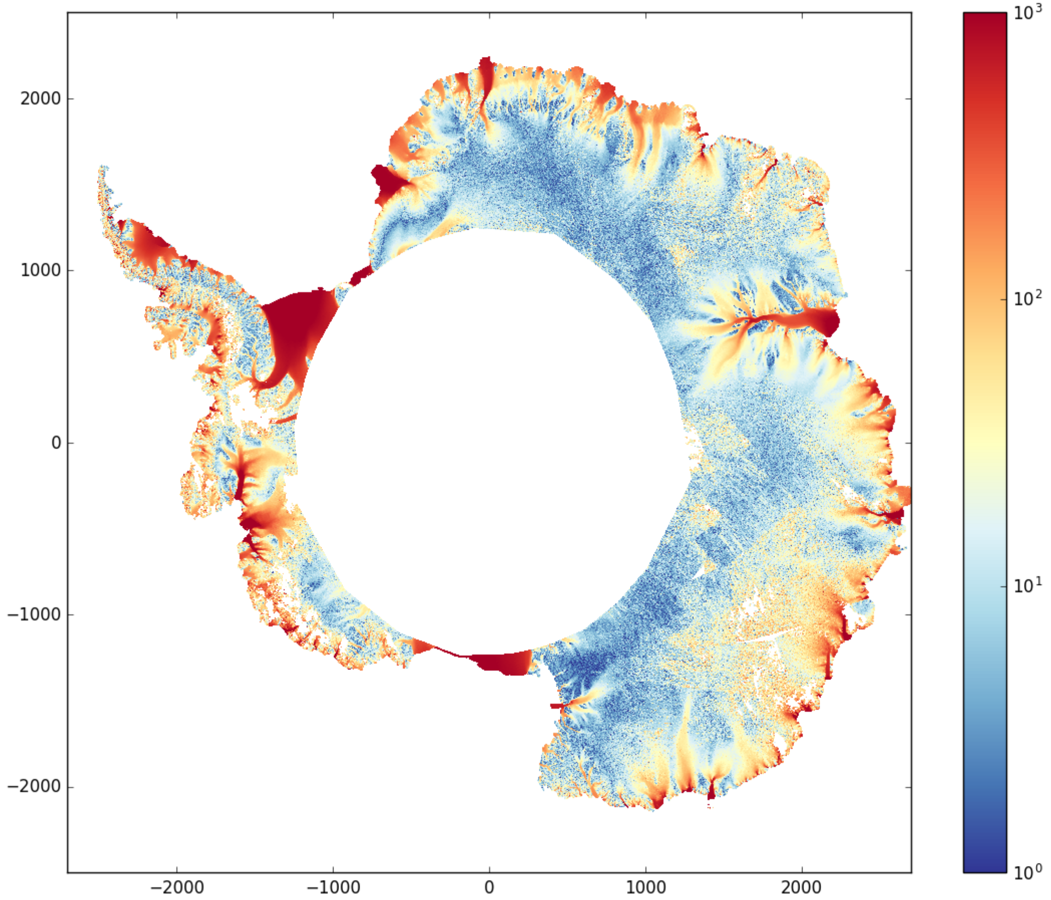


Local approach: 5th & 6th Zwally basins

- The **BISICLES** model [Cornford at al, 2015]
- 3D thermocoupled model
- Grounding line from floatation criterion
- L1L2 approximation of Stokes flow, subtle combination of SIA and SSA
- For local scale
- Needs sub-kilometric resolution at the grounding line
- Adaptive mesh griding

Data from CCI

- To initialise the ice sheet, we need IV (ECV) and Ice Geometry
- To evaluate (or validate) the ECVs SEC & GMB, we need two periods for initialisations



Sentinel Ice Velocities from ENVEO (2015-2017)

+ Bedmap2 dataset for ice geometry

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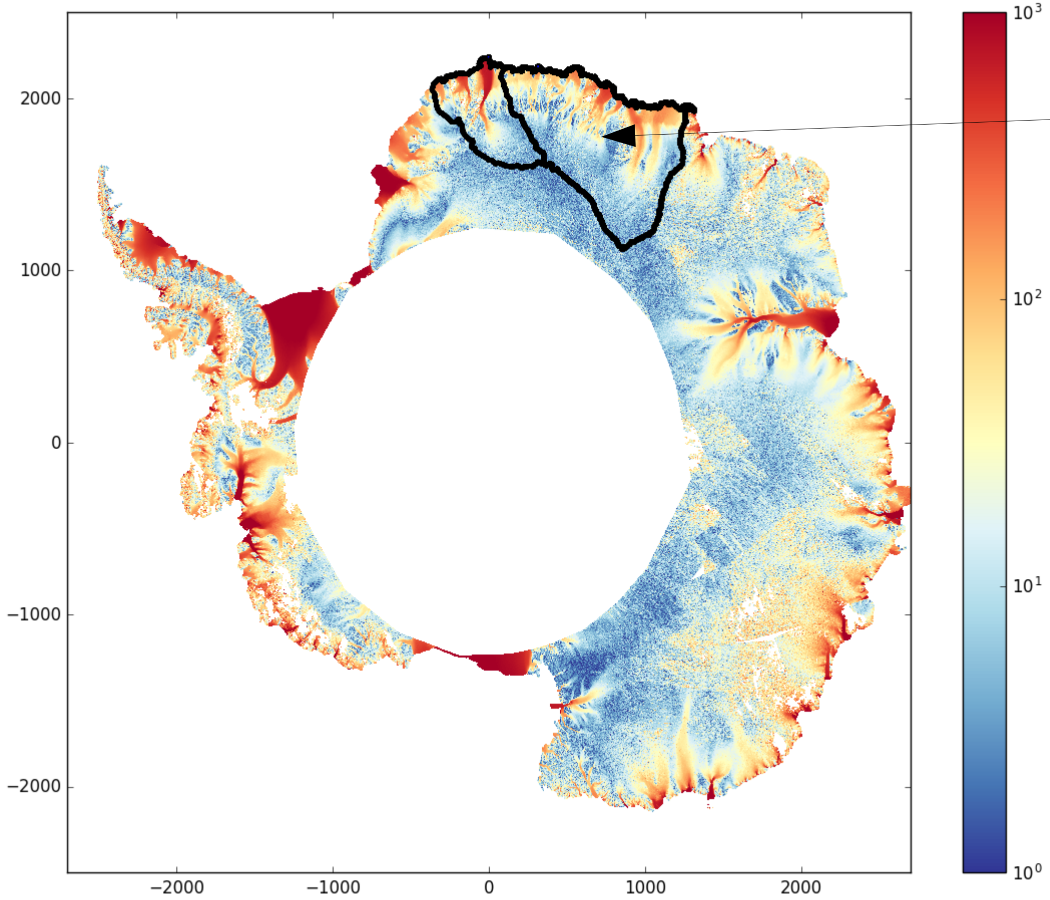

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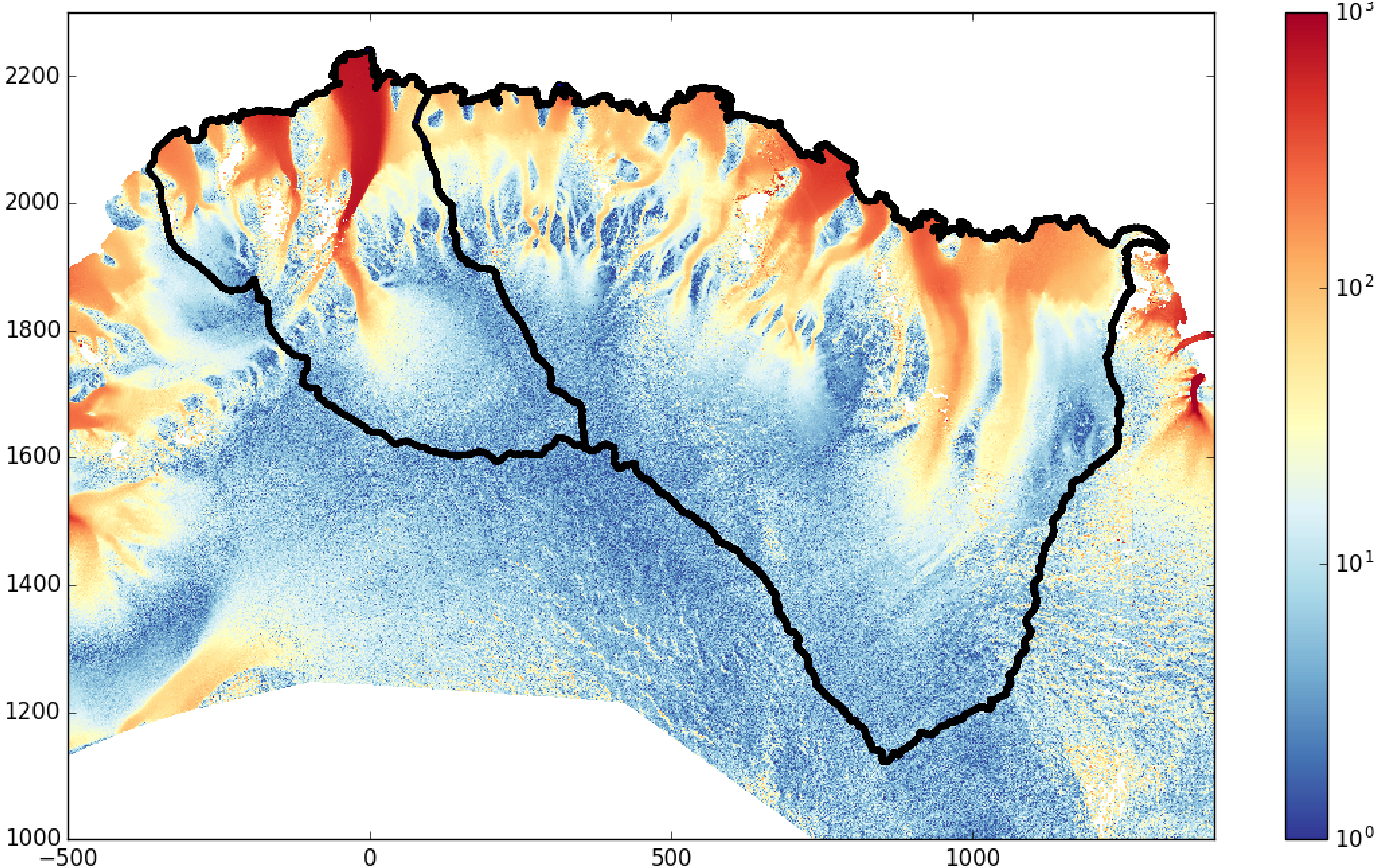
Local modelling, basins 5 & 6



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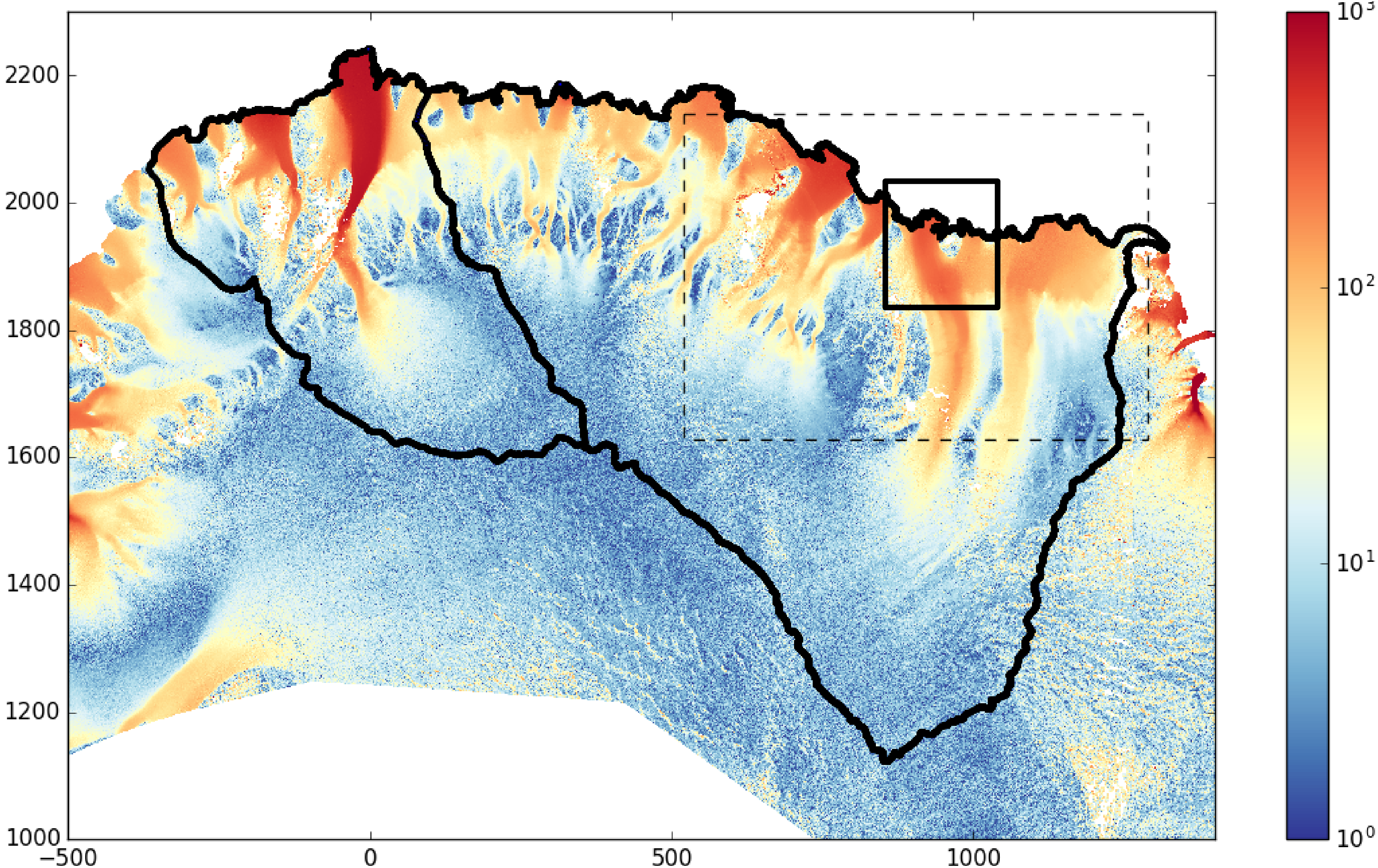
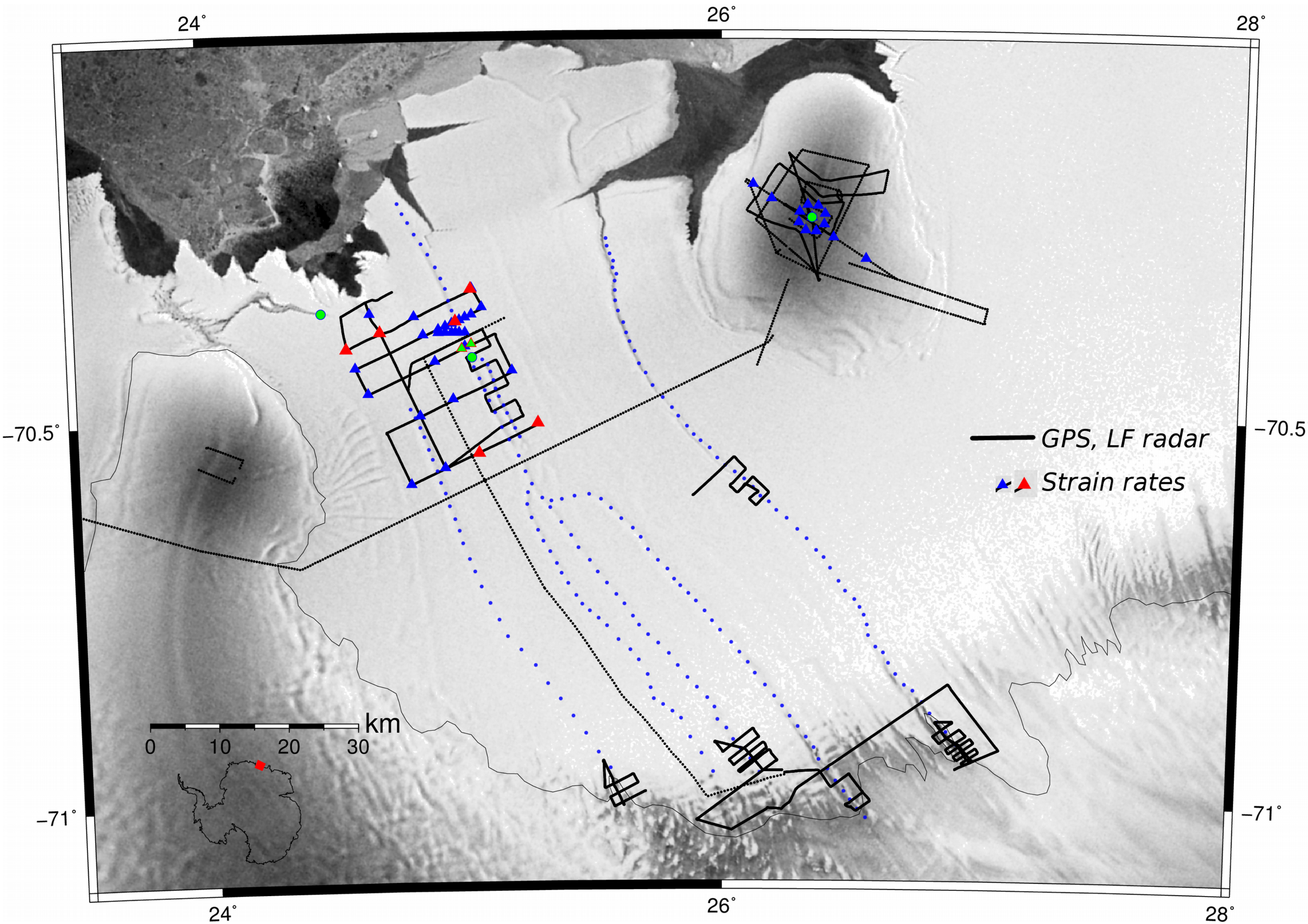


Local modelling, field data



Local modelling, inversion

Principle of an inversion

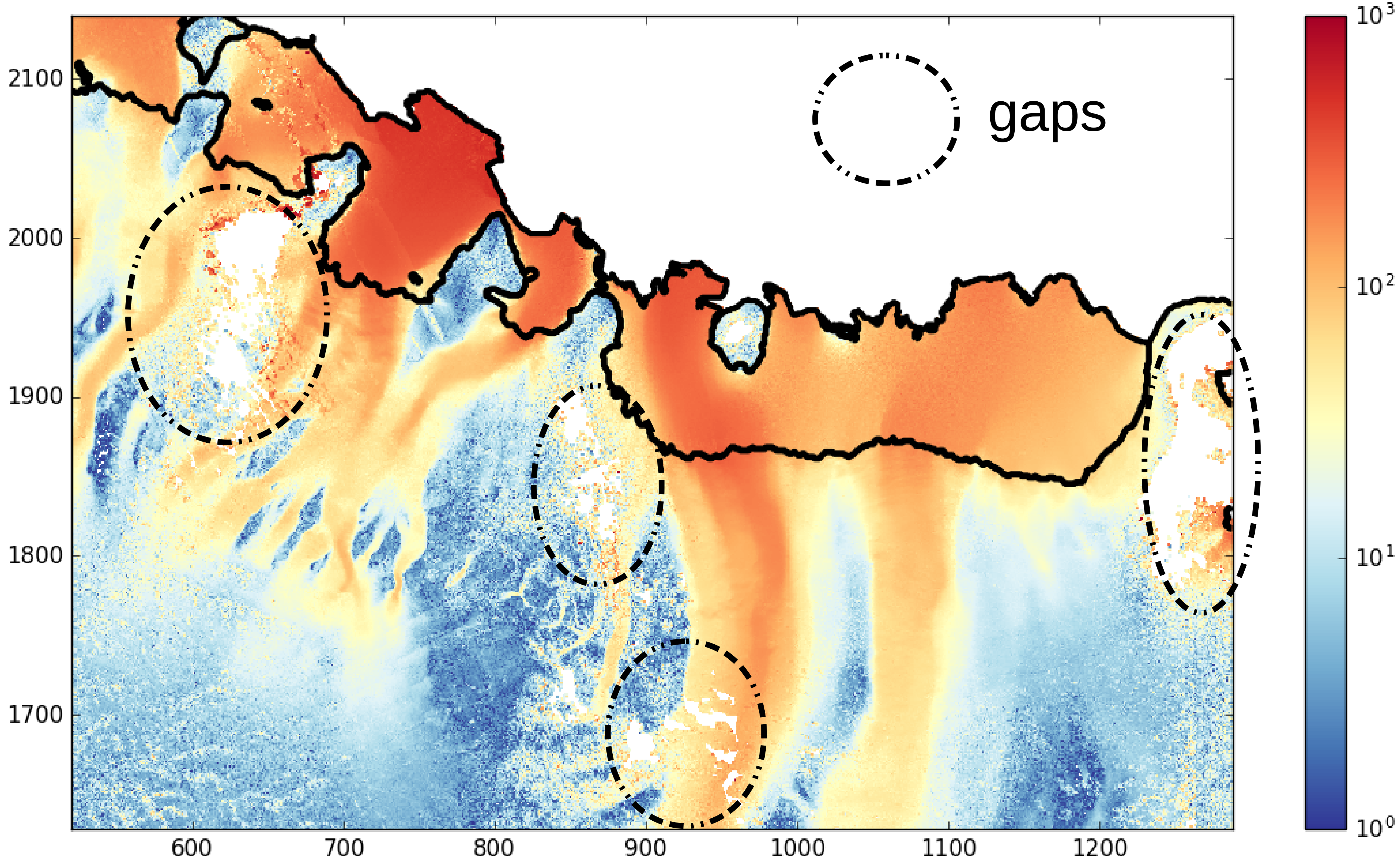
We seek the minimum of the cost function $J = J_m + J_p$

$$J_\mathrm{m} = \frac{1}{2}\int_{\Omega_V} \alpha_u^2(x,y)(|\boldsymbol{u}| - |\boldsymbol{u}_\mathrm{o}|)^2\,\mathrm{d}\Omega$$ Is the misfit between modelling and observations

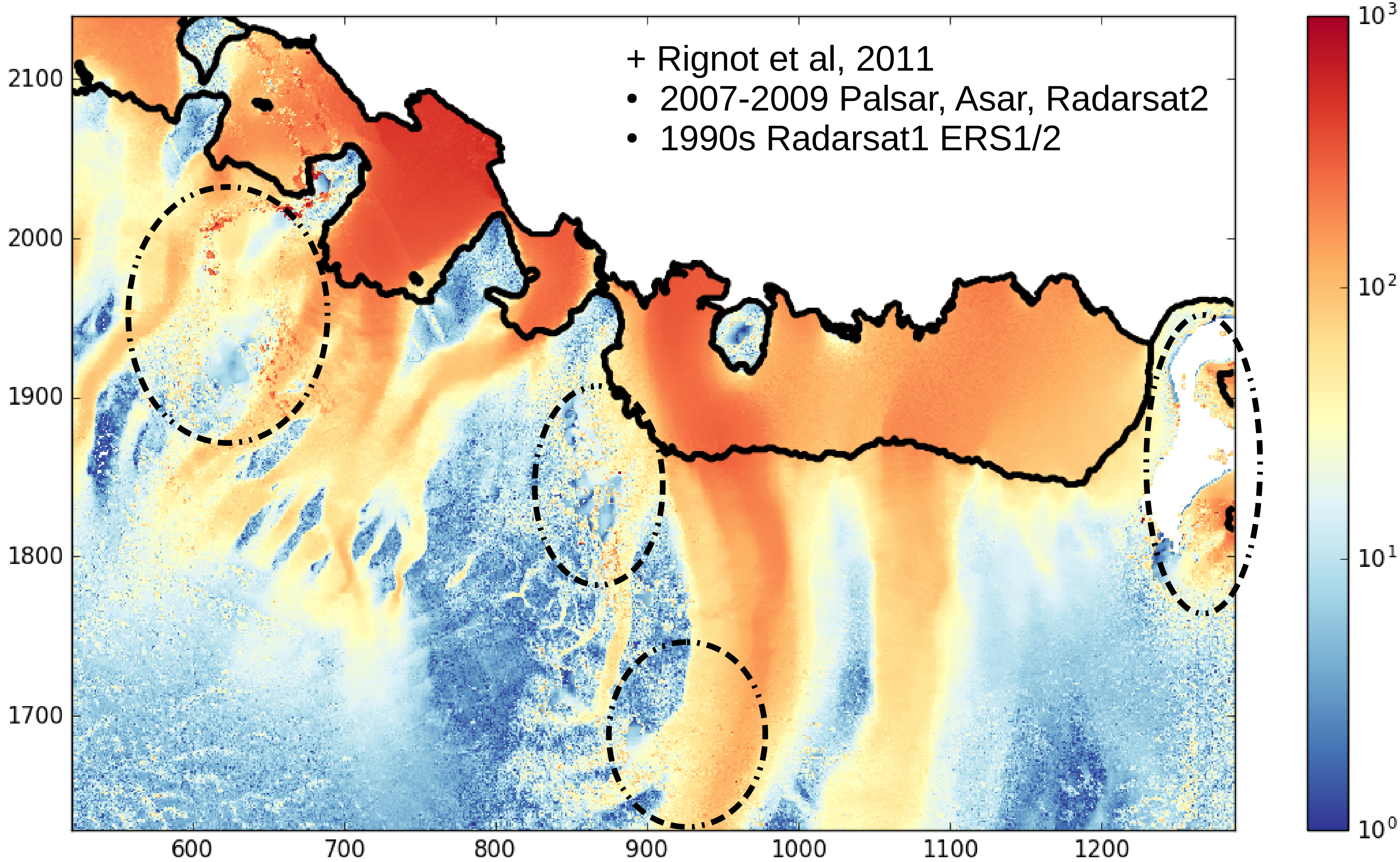
$$J_\mathrm{p} = \frac{\alpha_C^2}{2}\int_{\Omega_V} |\nabla C|^2\,\mathrm{d}\Omega + \frac{\alpha_\phi^2}{2}\int_{\Omega_V} |\nabla \phi|^2\,\mathrm{d}\Omega$$ Is the Tikhonov penalty function

A solution yields **small mismatch** and avoid **over fitting**

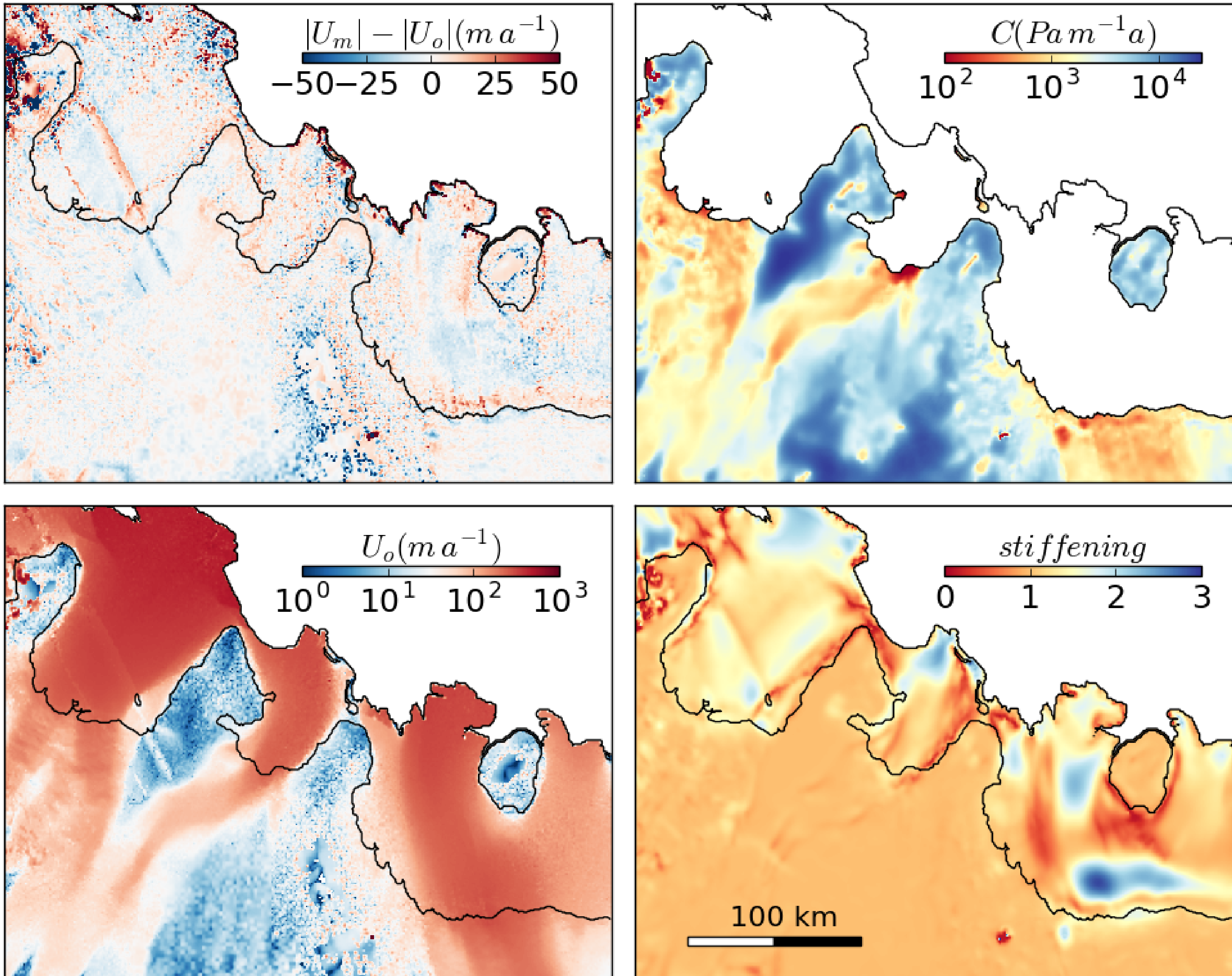
Local modelling, gaps



Local modelling, completing gaps



Local modelling 2010s, results



Conclusions & future work

- We have our local initial state for the 2010s

- We need more ancient data to do the hindcasting
  - Either the 1990s, ERS ½, (it seems) too few data for inverse model
  - Or the 2000s, Palsar, Asar, Radarsat (2007-2009) (Rignot et al., 2011)

- Global modelling to be started

Thank you !

What is next & soon ?

- We need more ancient data to do hindcasting
  - 1990s, ERS ½, too few data for modelling
  - 2000s, Palsar, Asar, Radarsat (2007-2009) ???
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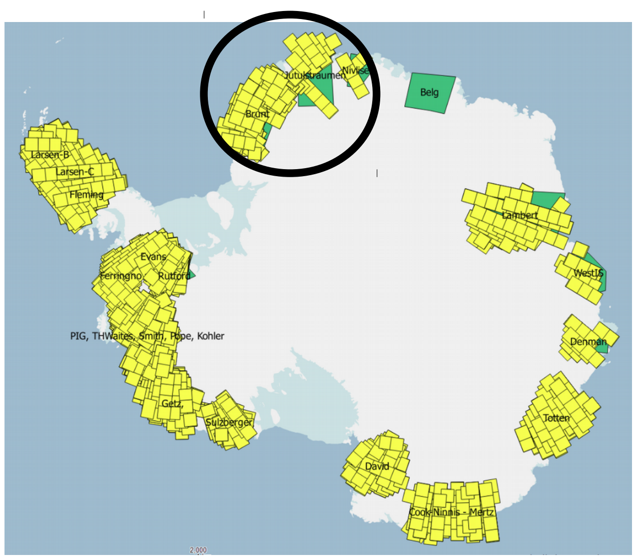
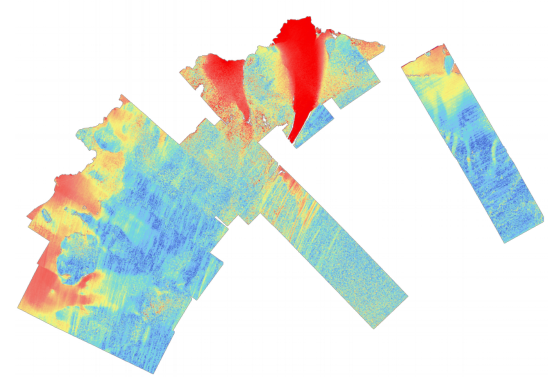


1995-1996 ERS1/2



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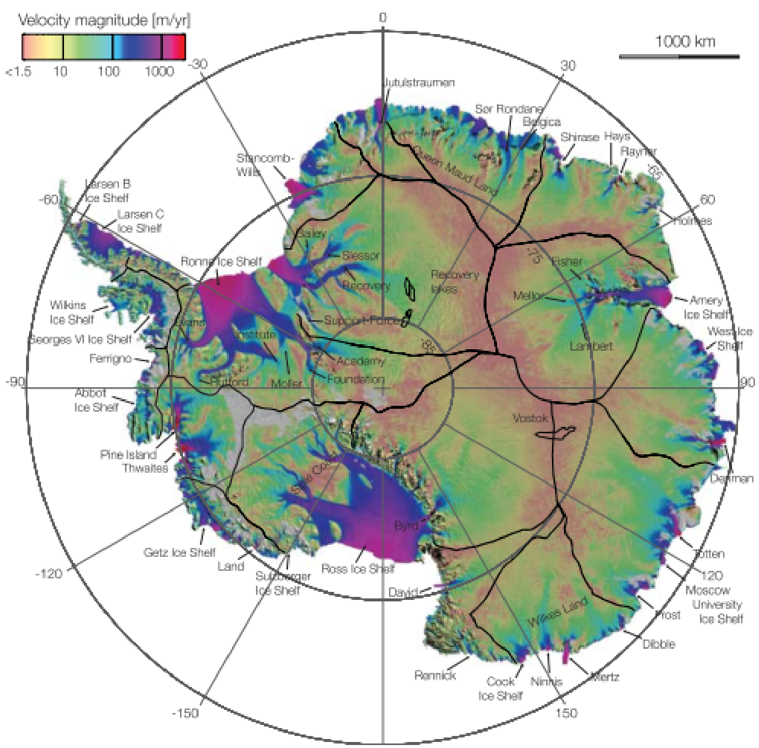

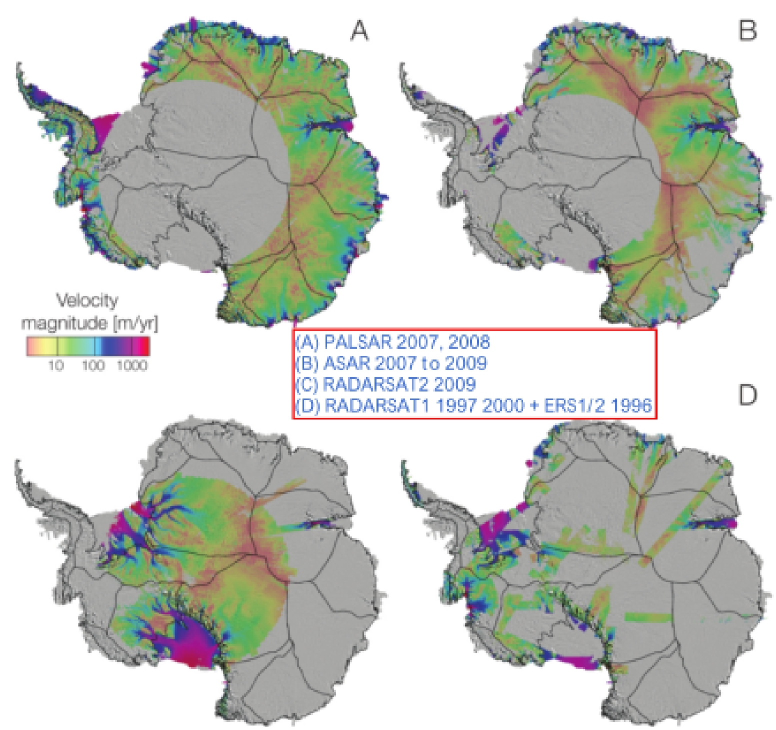

Rignot et al, 2011

Input data

- Bed elevation: Bedmap2 from Fretwell et al, 2013
- Surface elevation:
  - Cryosat2 DEM from Helm et al, 2010 + SEC from CCI
  - Or CCI only
- Firn air content: Ligtenberg et al, 2011
- Surface mass balance
  - Until 2010: RCM (RACMO2, MAR?) forced by ERA-interim
  - Future: RCM + GCM (HadCM3, ECHAM5), SRES (A1B, E1) ?
- Sub ice-shelf melting (3 options)
  - Beckmann and Goosse, 2003 (based on ocean temperature and salinity)
  - Wright et al, 2014 (more melting at the grounding line)
  - Ocean model such as NEMO? (needs good bathymetry)
- Ice temperatures: Pattyn, 2010
- Ice velocities
  - f.ETISh: from ECV IV where available + Rignot et al, 2011
  - BISICLES: coastal areas of DML (between 10°W and 36°E)

Data priorities

Ice sheet initialisation is of highest priority

1. Reference experiments with
   - IV + Surface Elevation from the 1990s
     - BISICLES: DML downstream and upstream of the GL, sub km resolution
     - f.ETISH: West Antarctic + item above, 10km resolution ok

2. SEC over the period 1990–2010 to compare with model outputs

3. Reproducing the reference experiment for further decades means the 2000s and 2010s

Expected outcomes

- Consistency between SEC and GMB and model outputs
- Are basal conditions of ice sheets changing with time when initialising ice sheet at different periods (if enough data)
- Effect of different period of initialisation on contributions to sea level rise over the next century