

Advanced Training Course on Remote Sensing of the Cryosphere
Leeds (UK), 12-16 September 2016

Challenges of modelling surface mass balance

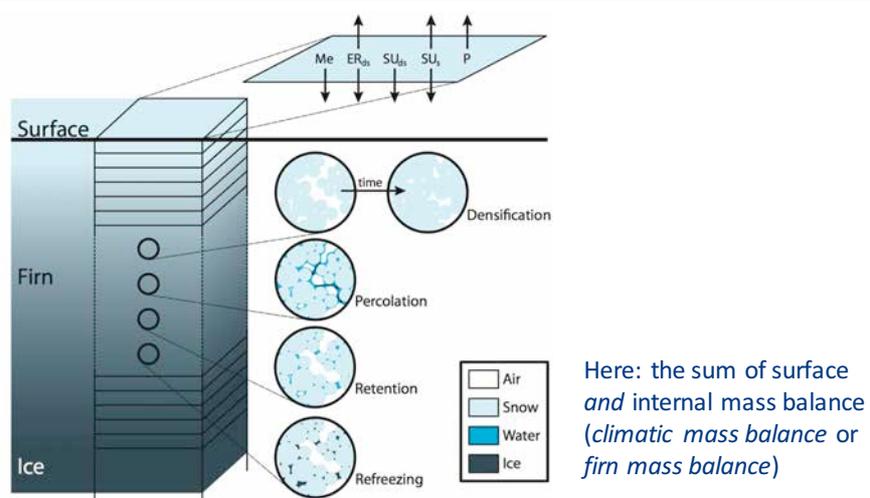
Michiel van den Broeke
Institute for Marine and Atmospheric Research, Utrecht University (IMAU)



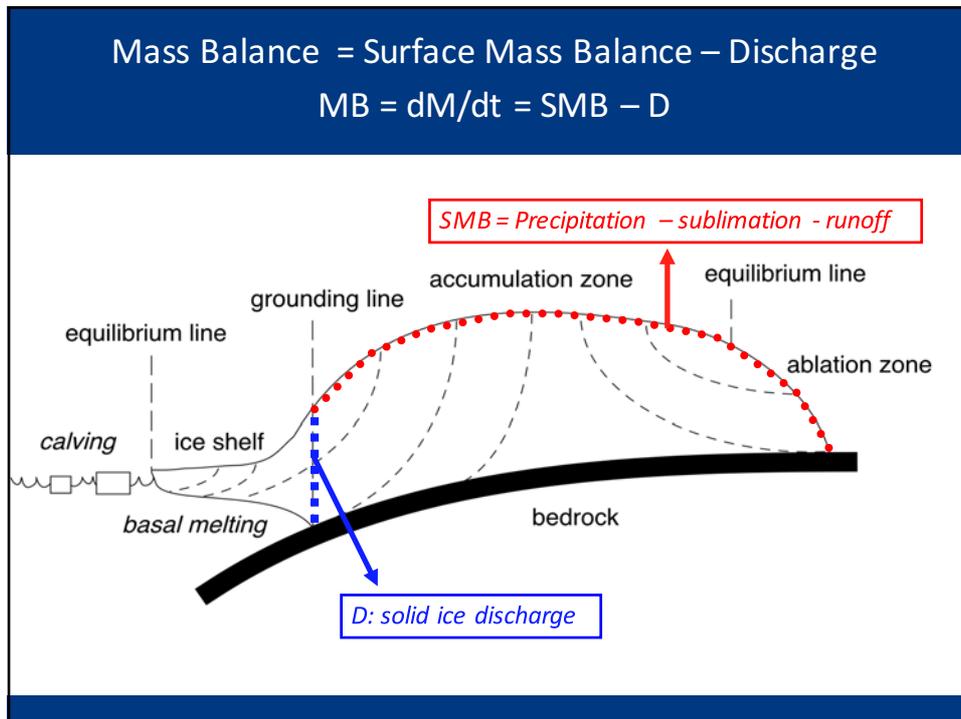
Universiteit Utrecht



How do we define surface mass balance (SMB)?



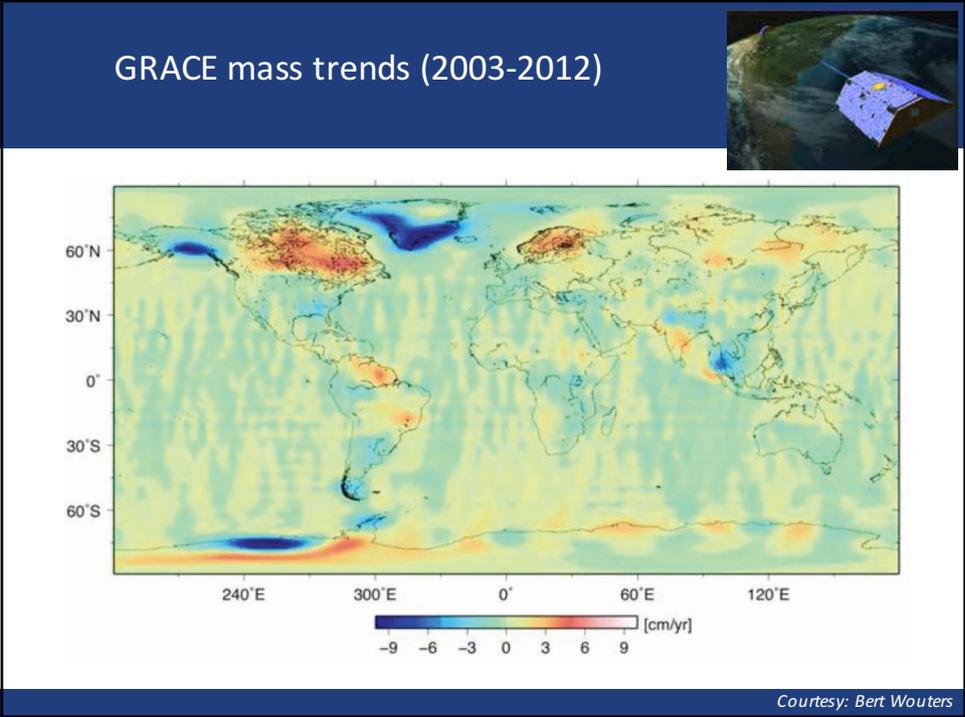
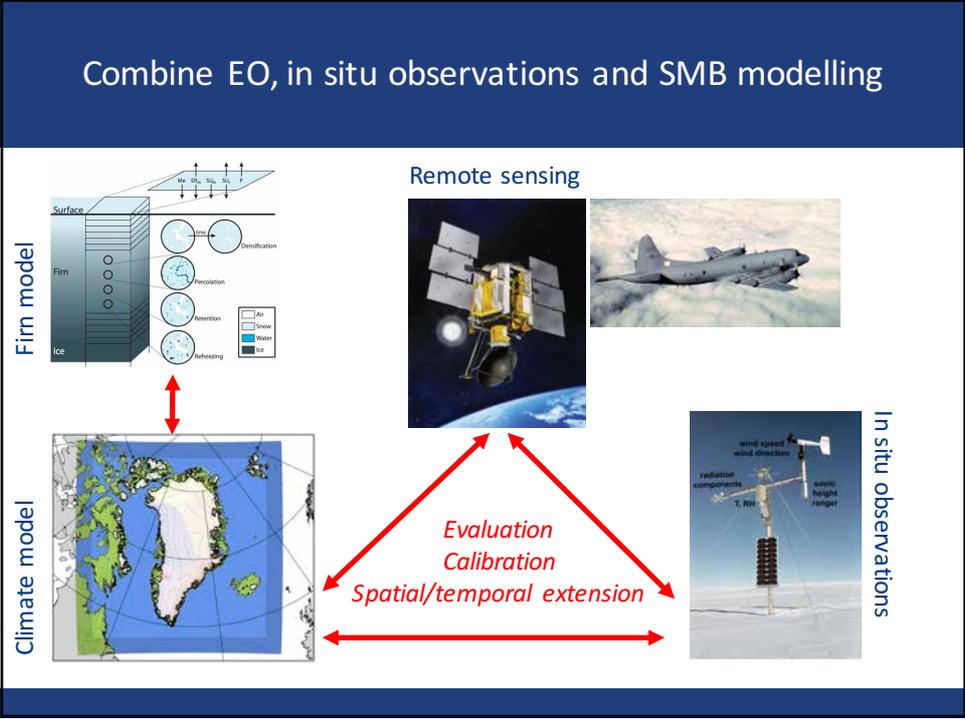
Ligtenberg, PhD thesis, 2014

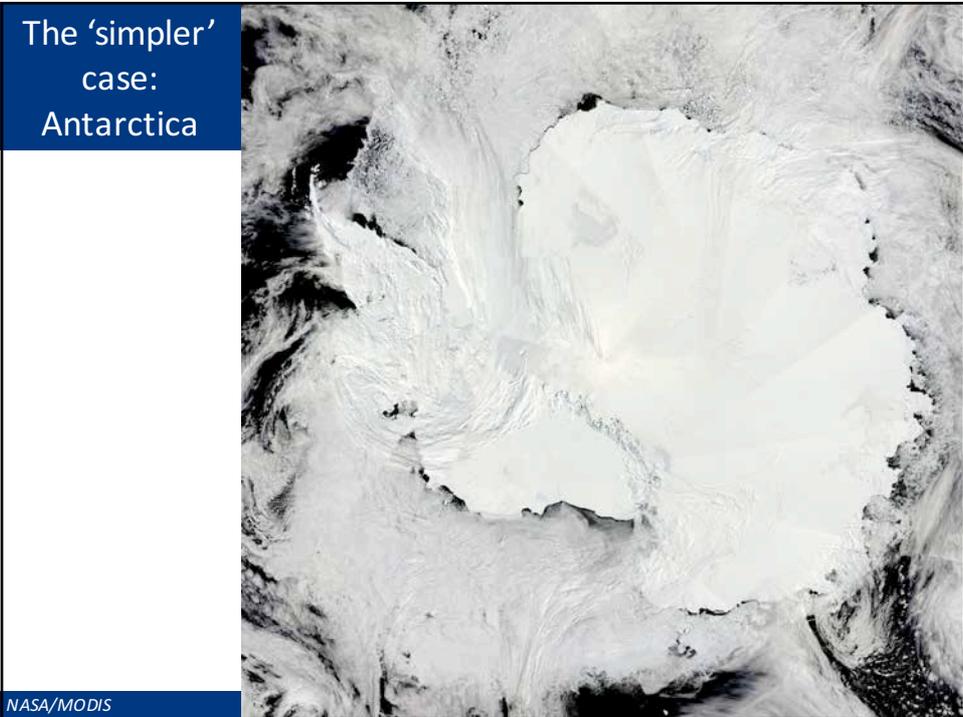
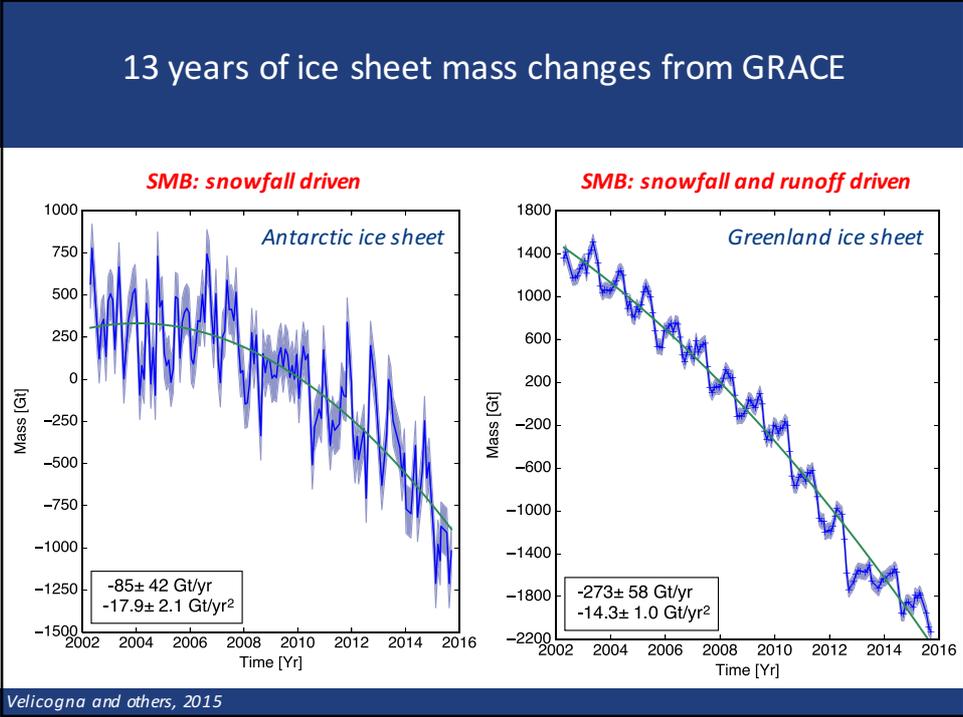


**SMB is challenging:
not one, but three balances!**

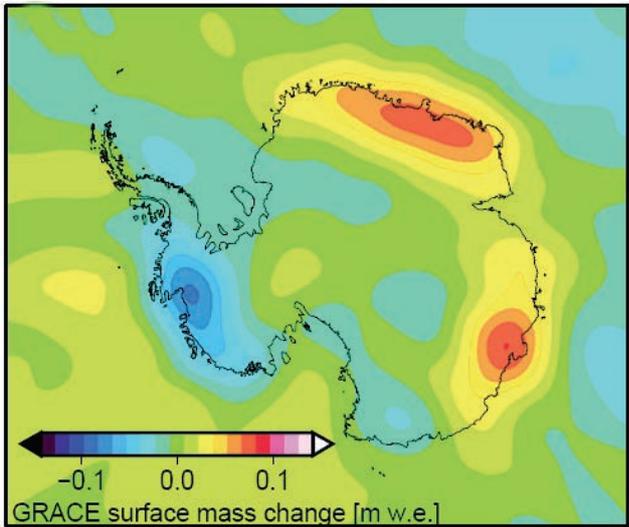
<p>Ice sheet mass balance (MB) $MB = \text{Surface mass balance} - \text{Discharge}$</p>	[Gt yr ⁻¹]
<p>Surface mass balance (SMB) $SMB = \text{Precipitation} - \text{Sublimation} - \text{Runoff} - \text{Erosion}$</p>	[Gt yr ⁻¹]
<p>Liquid water balance (LWB) $\text{Runoff} = \text{Rain} + \text{Condensation} + \text{Melt} - \text{Refreezing} - \text{Retention}$</p>	[Gt yr ⁻¹]
<p>Surface energy balance (SEB) $M = SW_{\text{net}} + LW_{\text{net}} + H + L + G_s$</p>	[W m ⁻²]

J. Paul Getty Museum





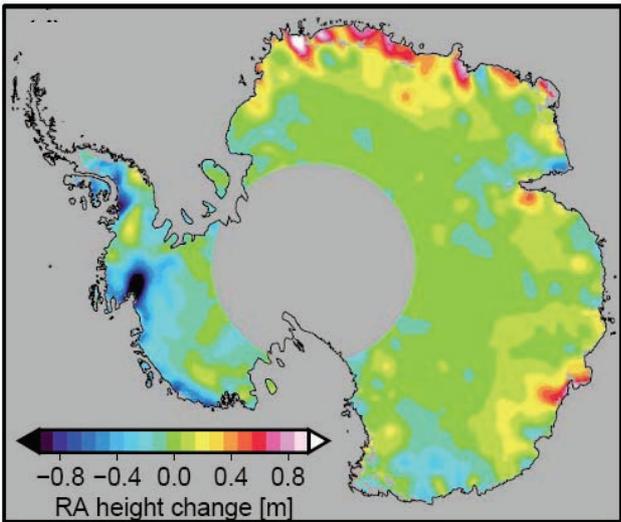
Added value of SMB modelling: a case study for Antarctica



Mass changes in 2009 from GRACE

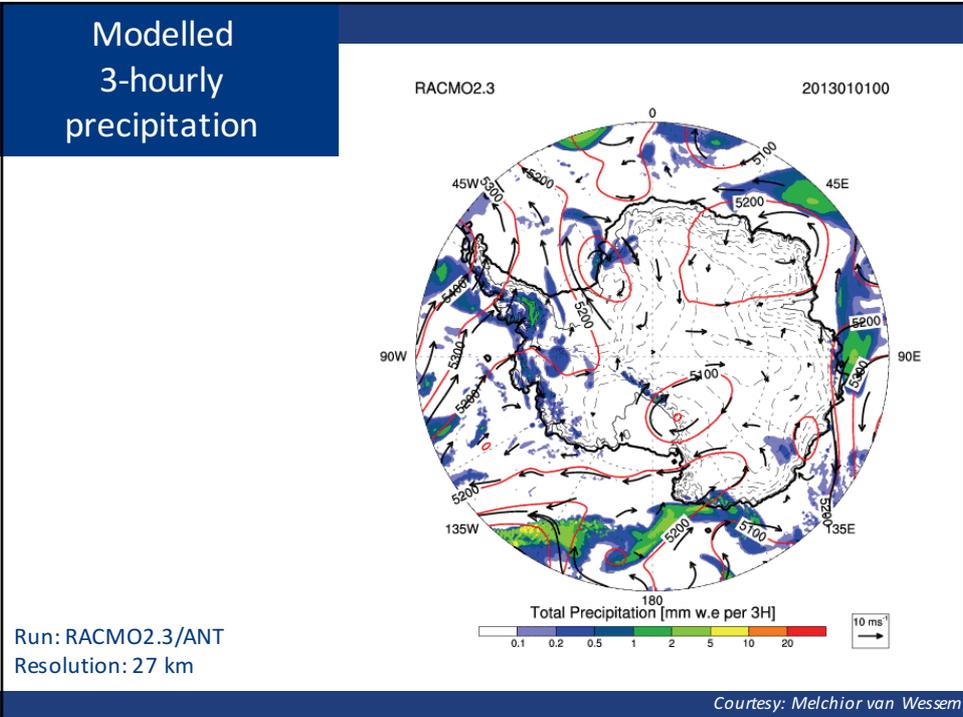
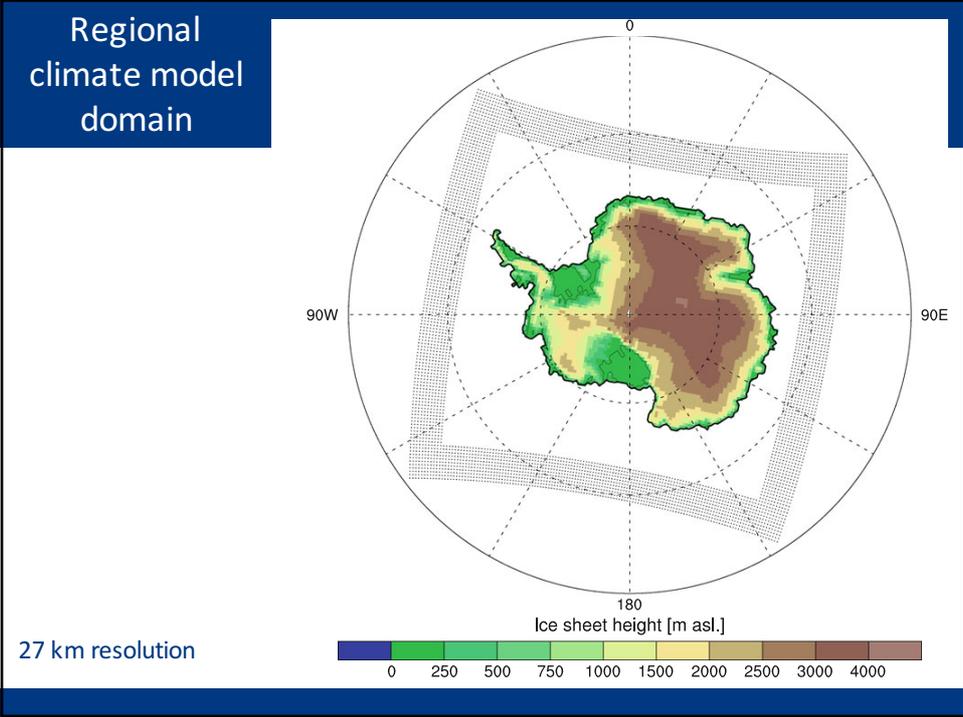
Martin Horwath

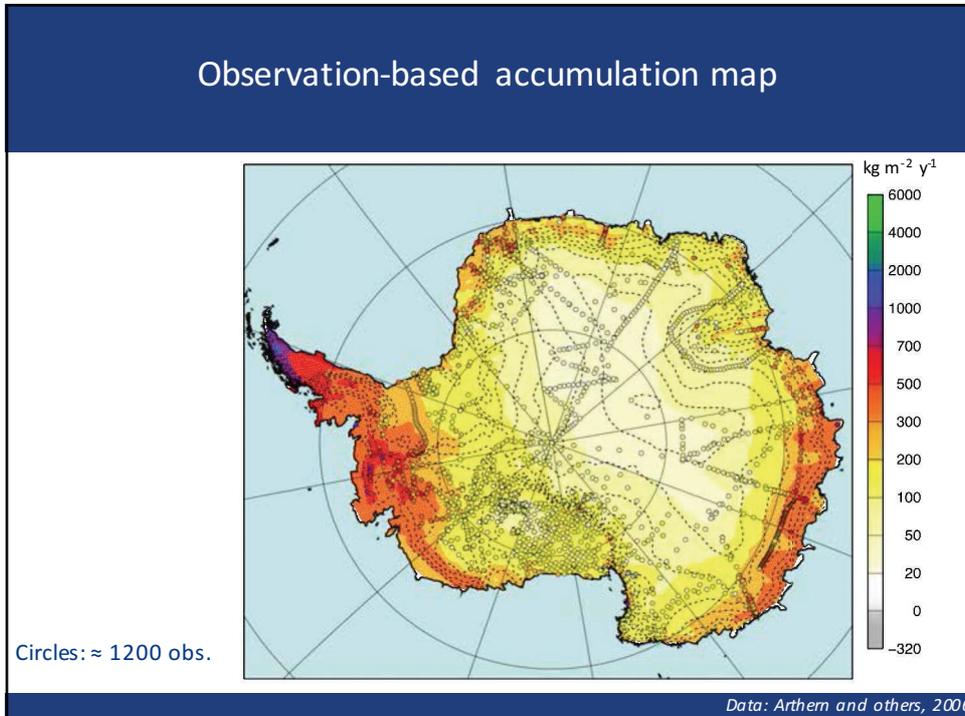
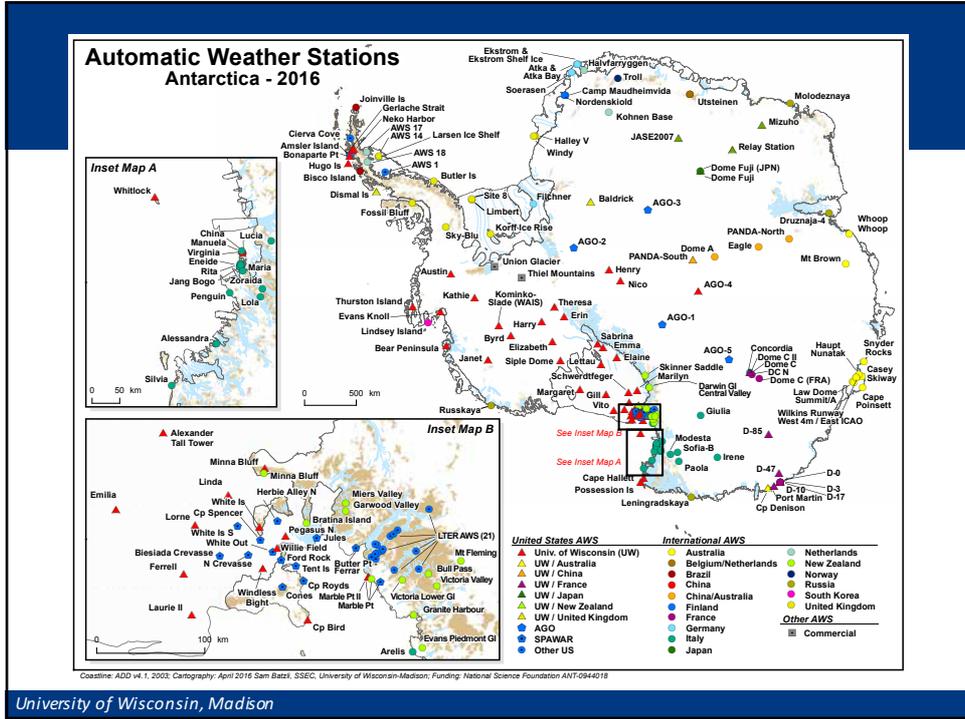
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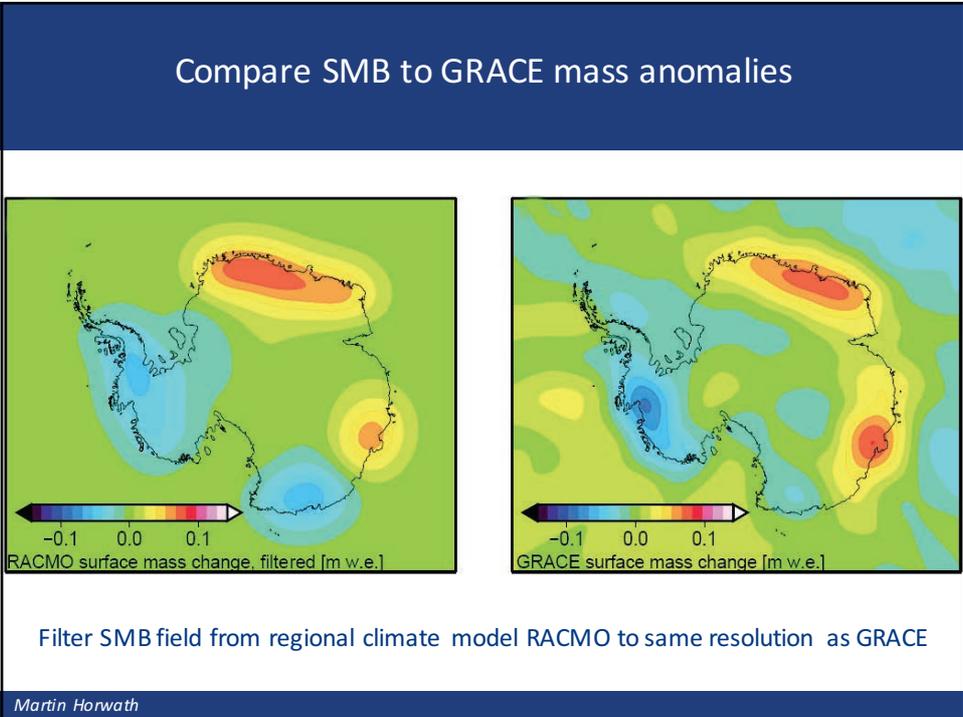
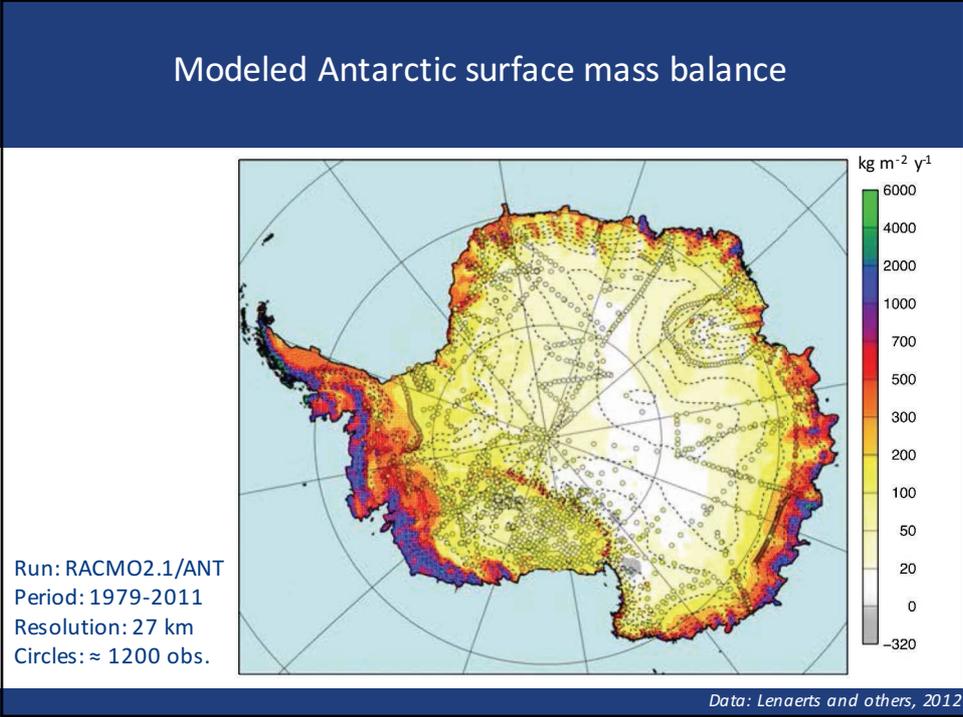


Elevation changes in 2009 from Envisat

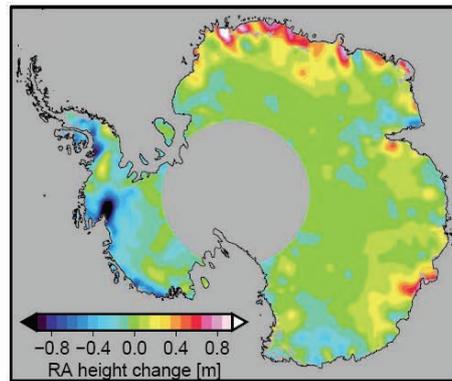
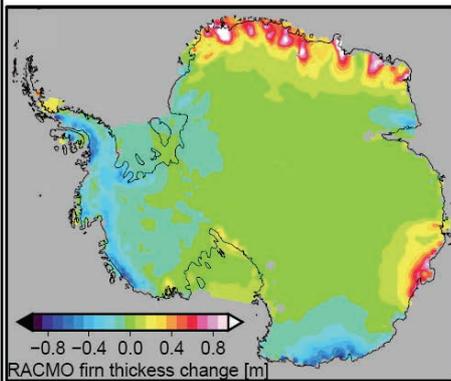
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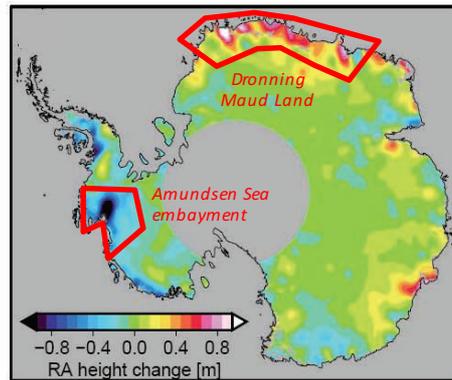
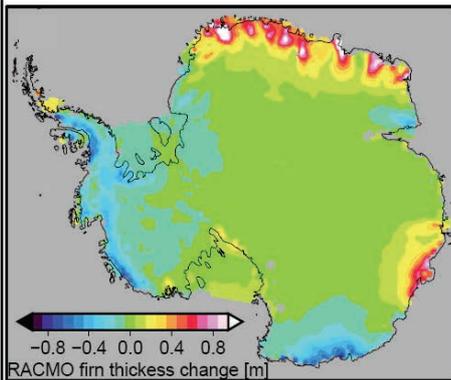
Compare modelled snow depth change to altimetry



Convert snowfall anomalies to firn thickness change, using a firn model

Martin Horwath

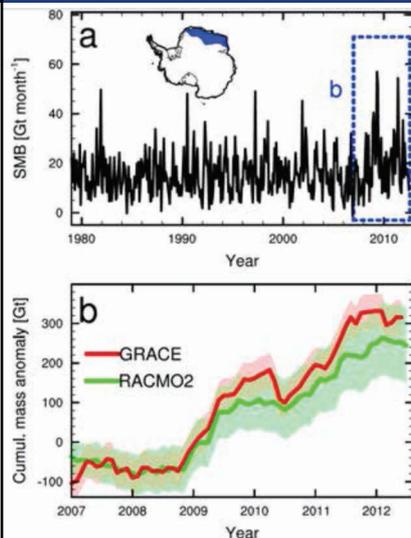
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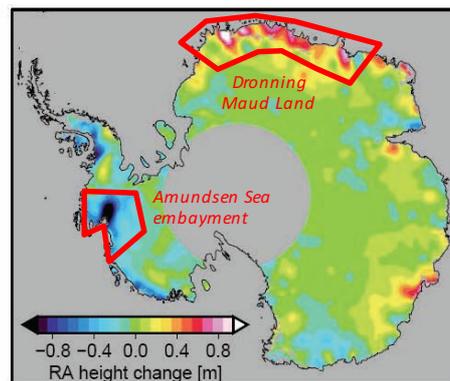
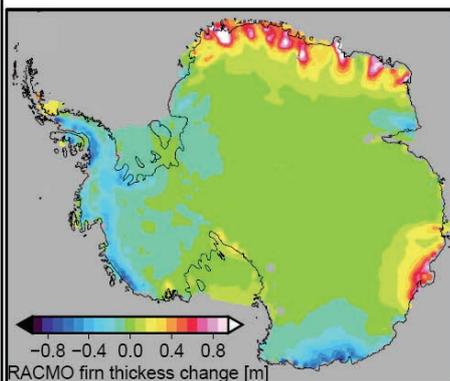
Dronning Maud Land, East Antarctica



- a) SMB from regional climate model
- b) Cumulative SMB anomaly vs. GRACE

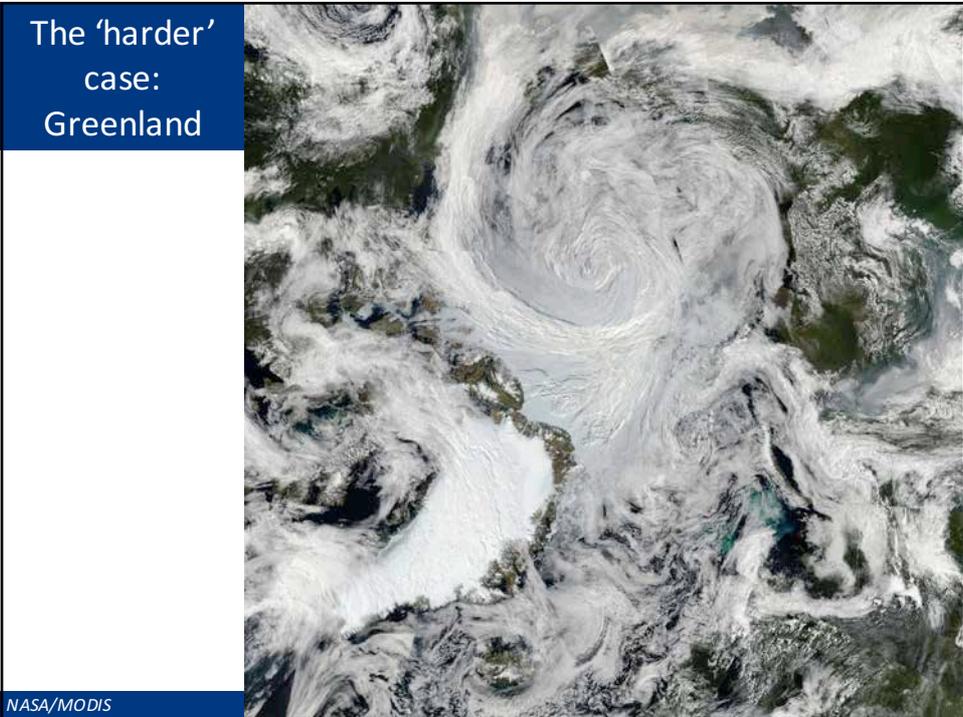
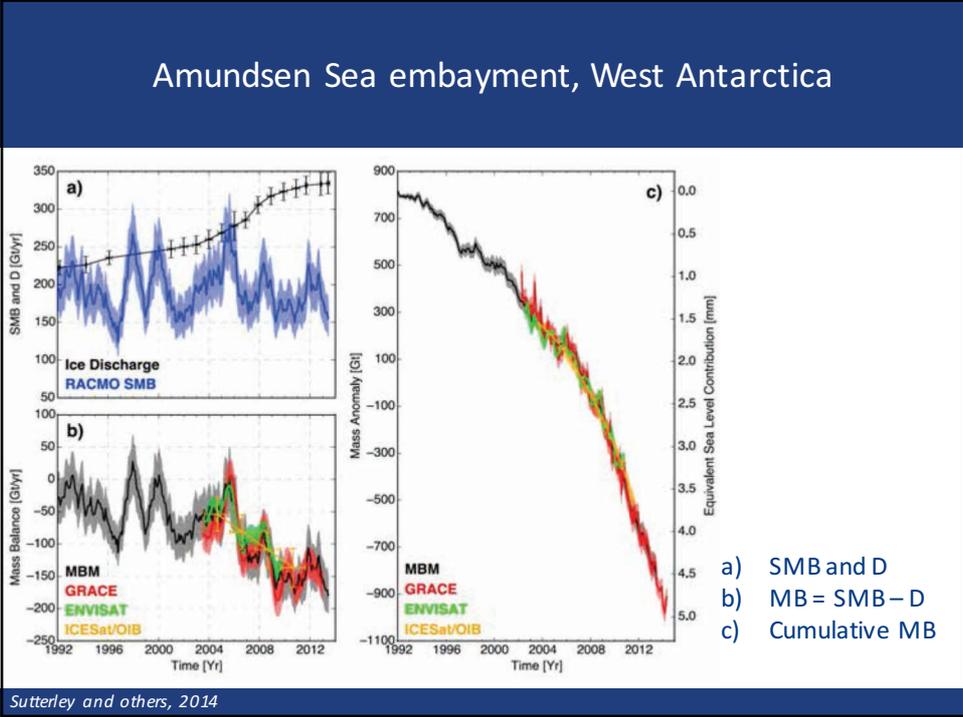
Lenaerts and others, 2013

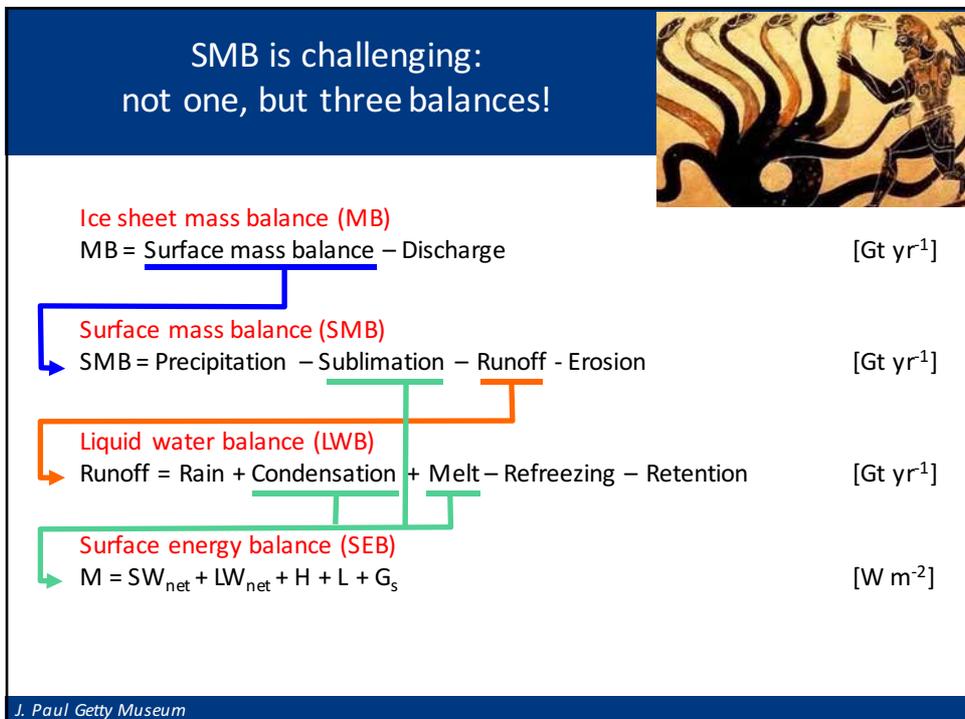
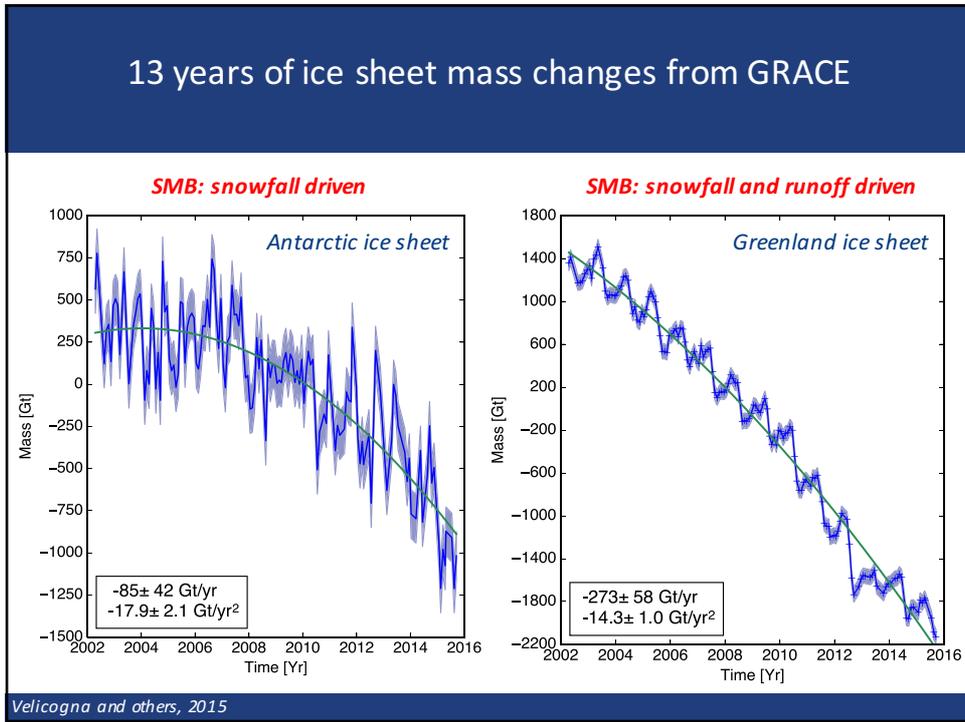
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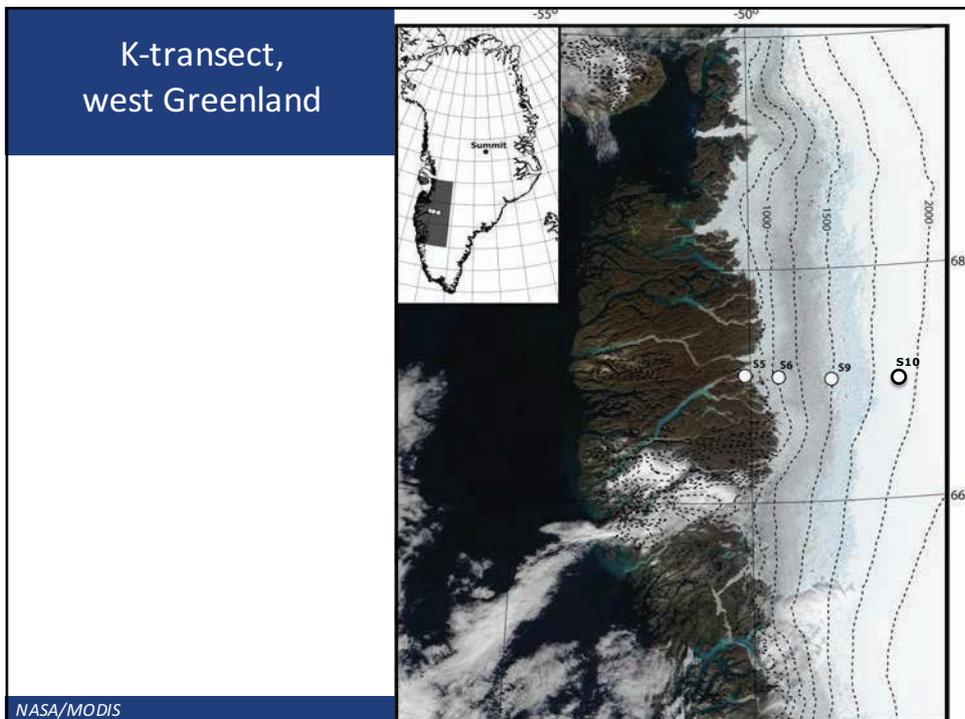
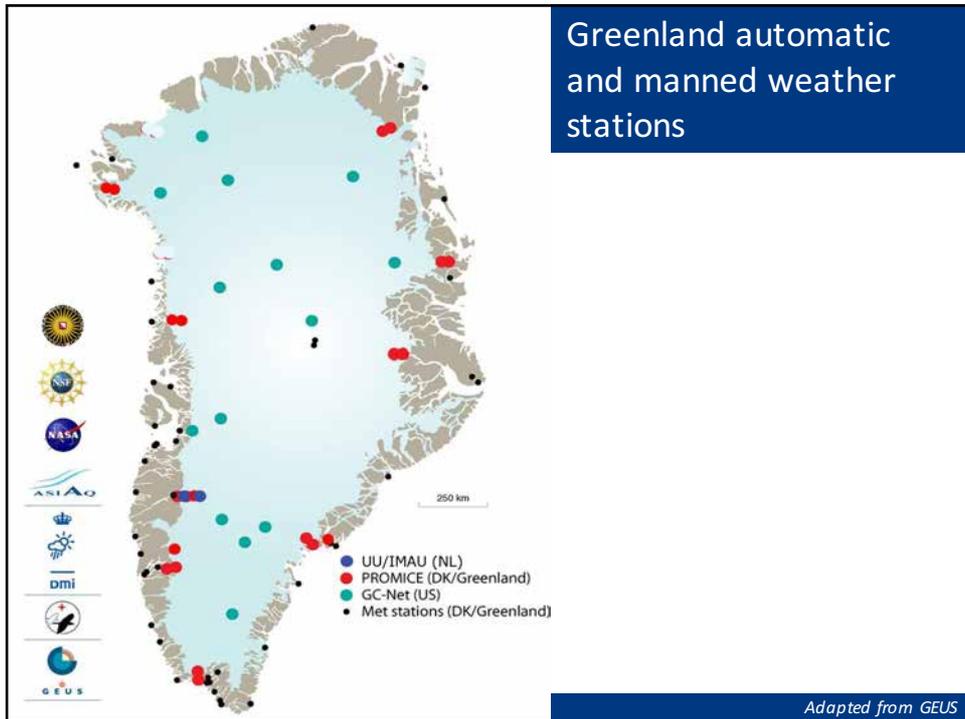


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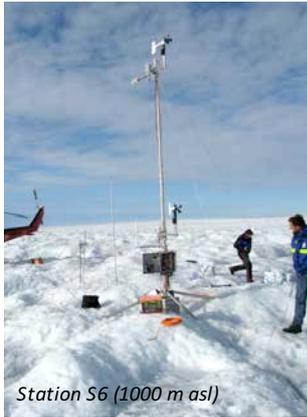
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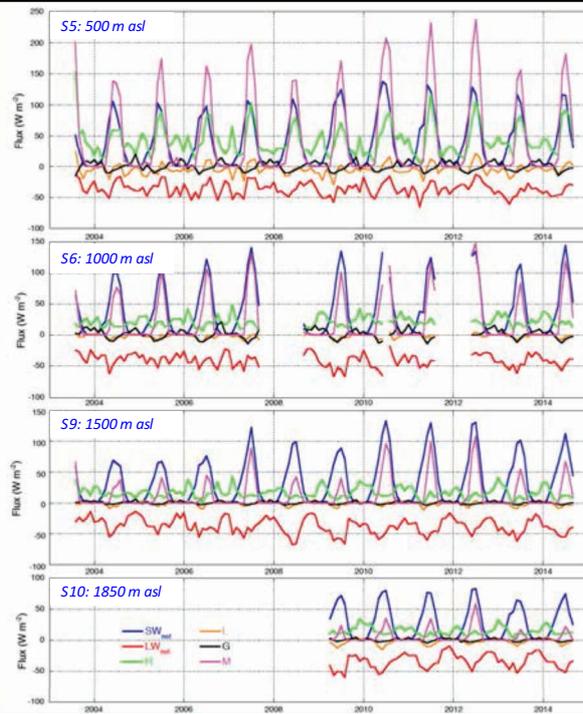




Greenland surface energy balance

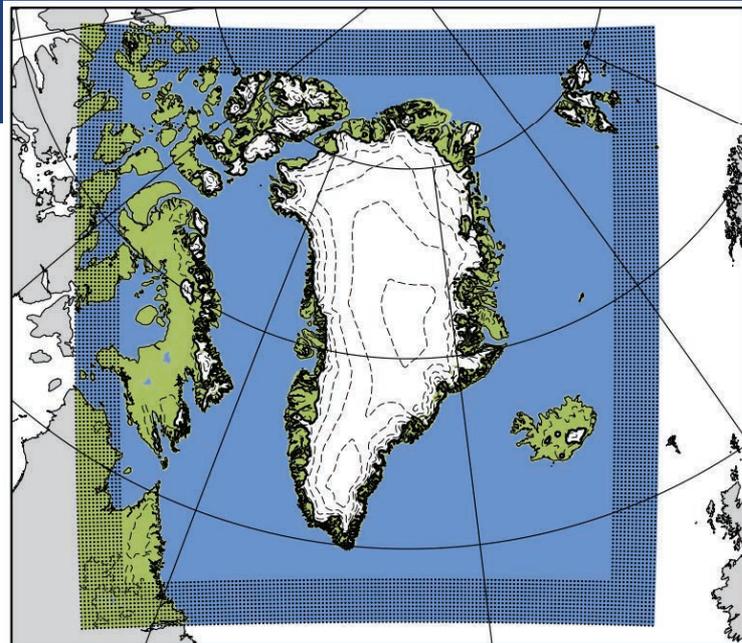


Station S6 (1000 m asl)

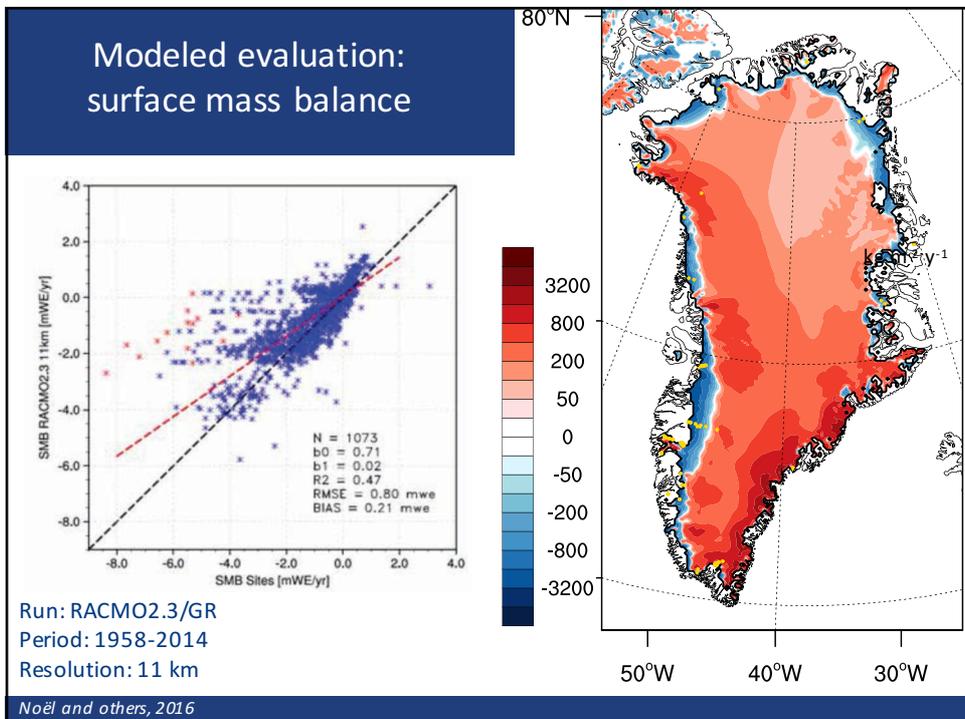
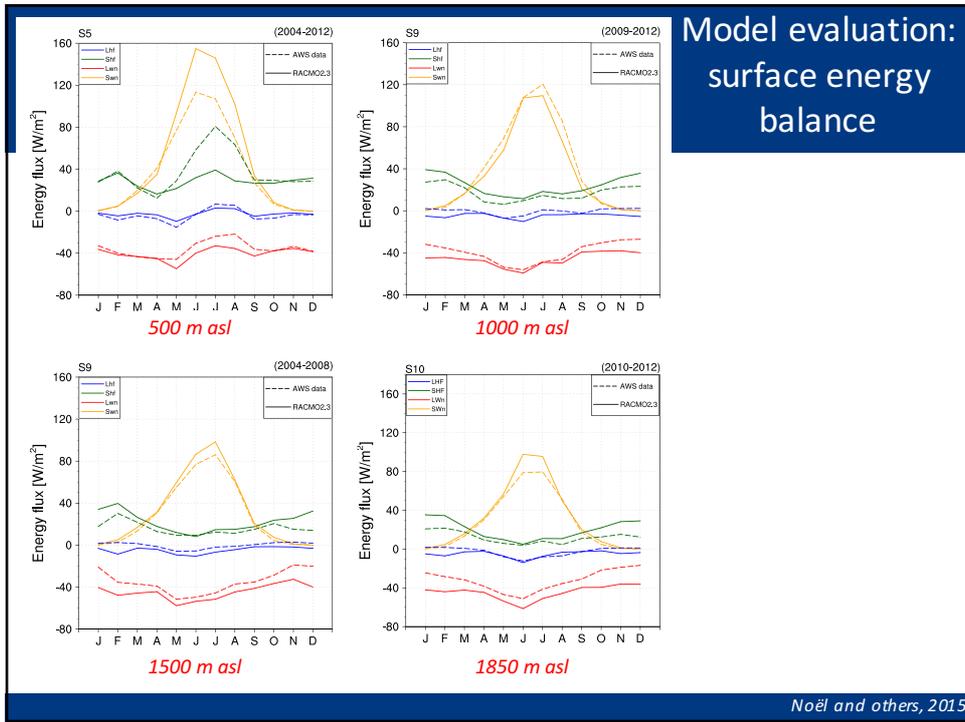


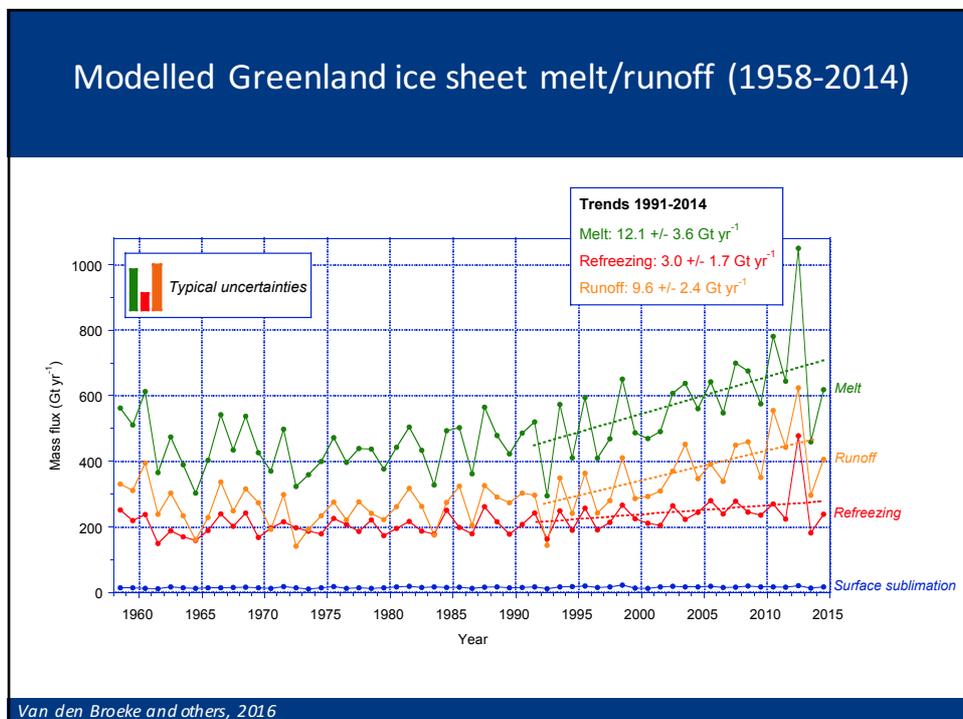
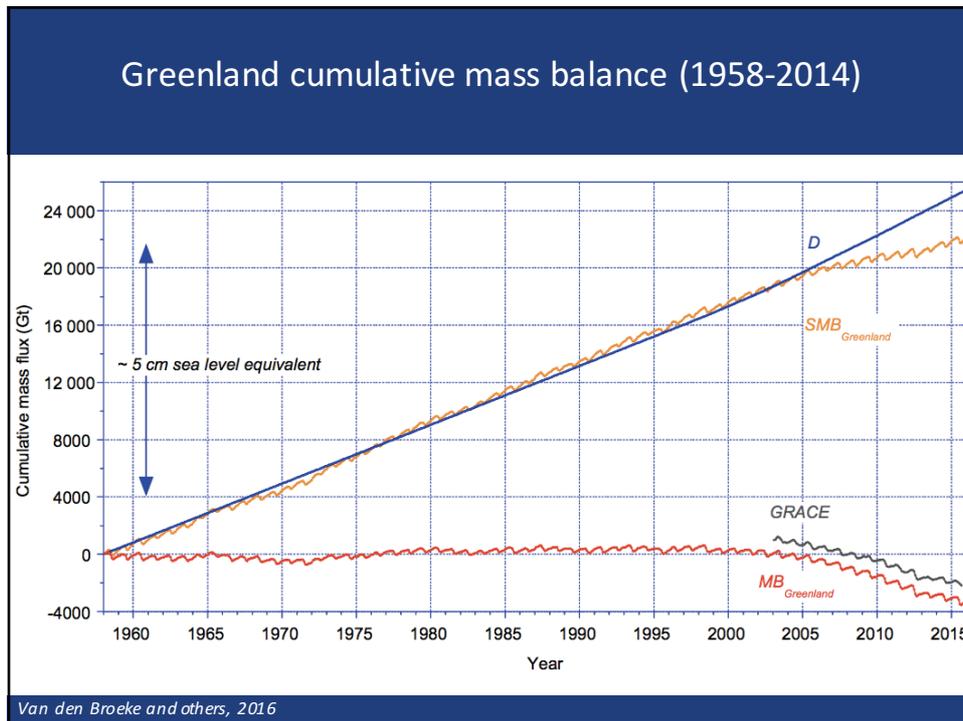
Courtesy: Peter Kuipers Munneke

Regional climate model

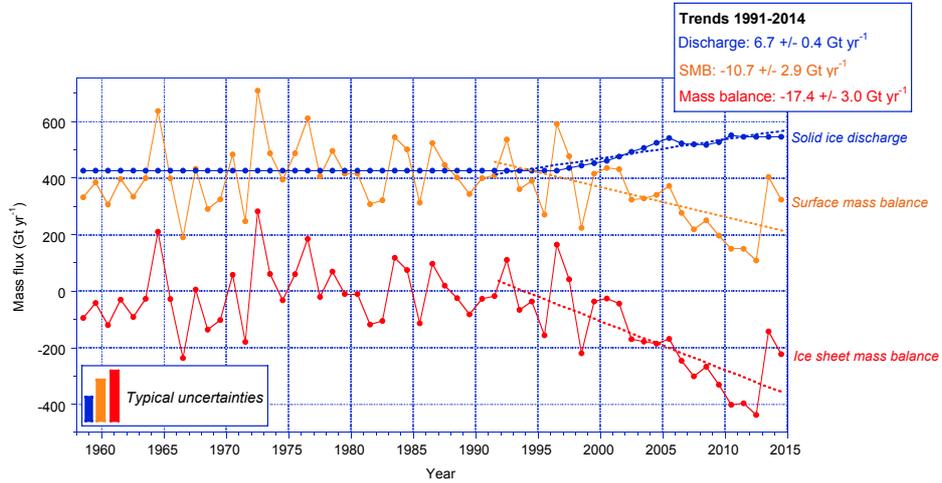


11 km resolution

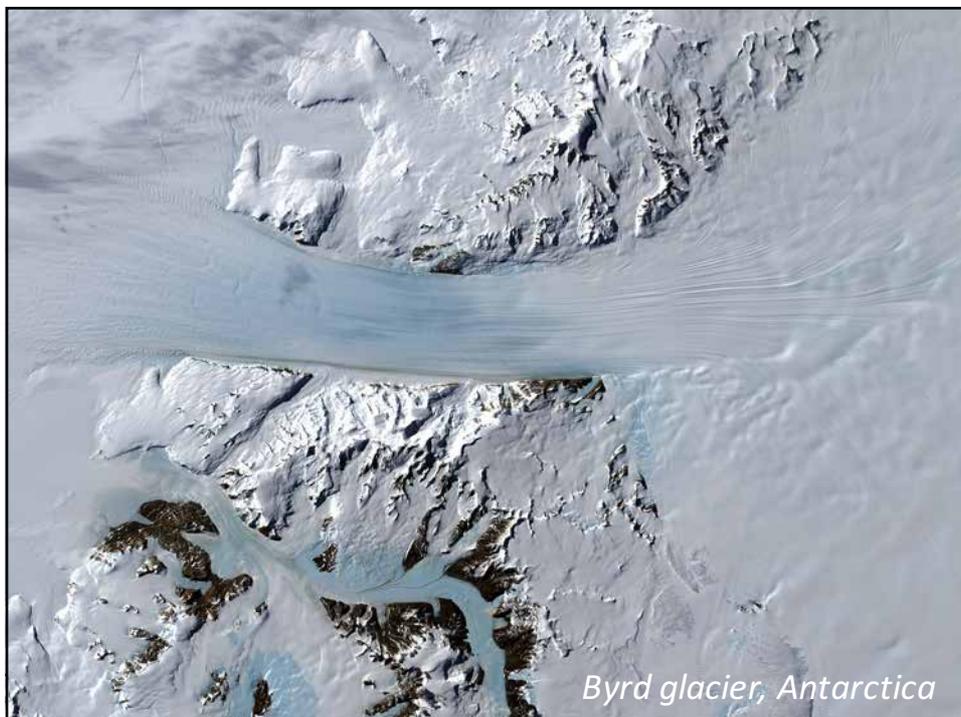




Modelled Greenland ice sheet mass balance (1958-2014)

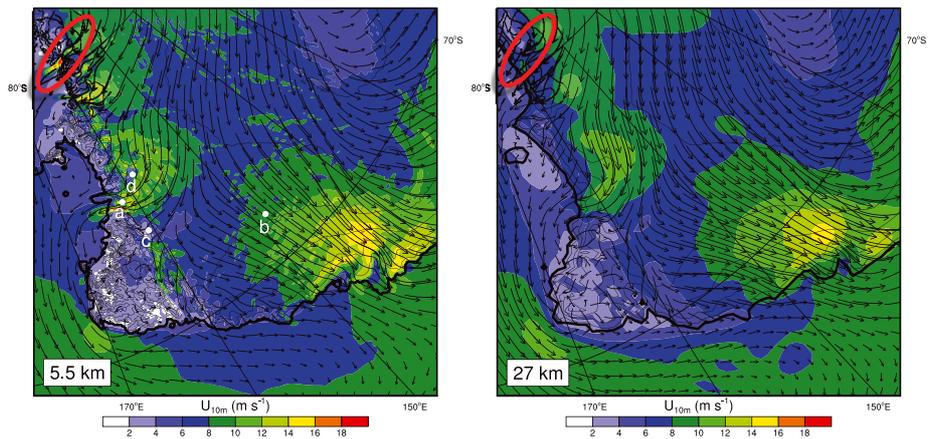


Van den Broeke and others, 2016



Impact of model resolution on net snow accumulation

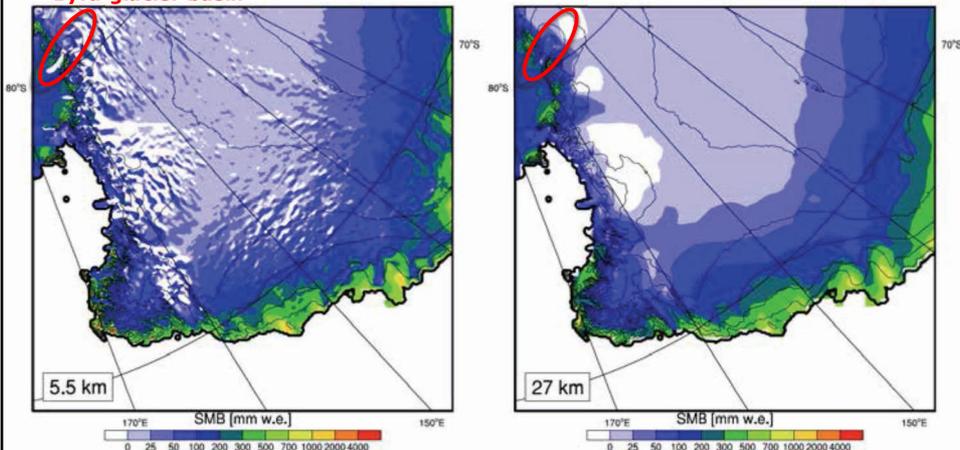
Byrd glacier basin



Lenaerts and others, 2012

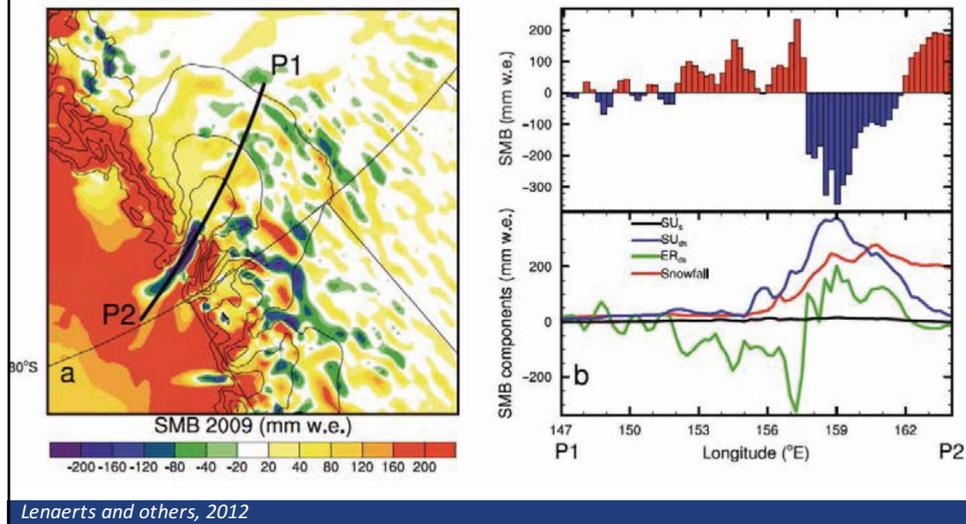
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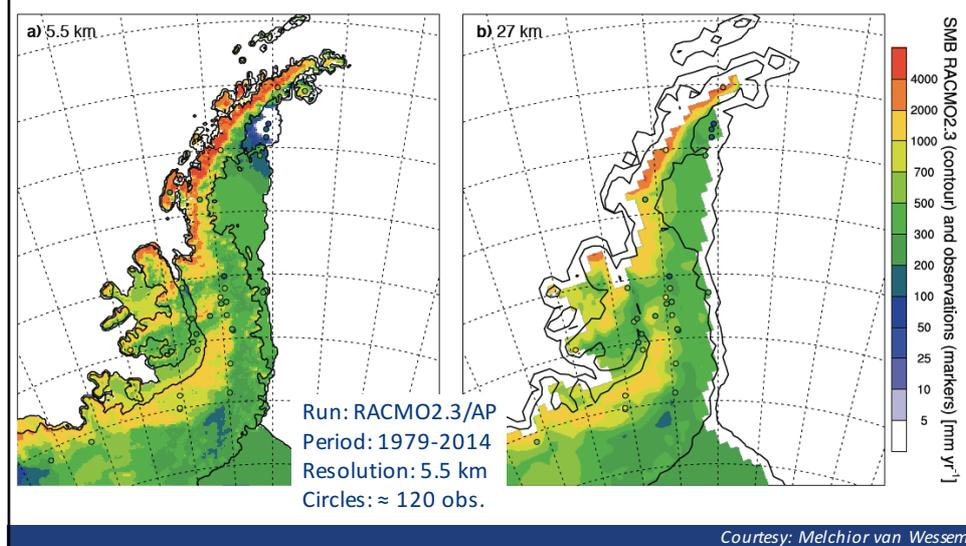


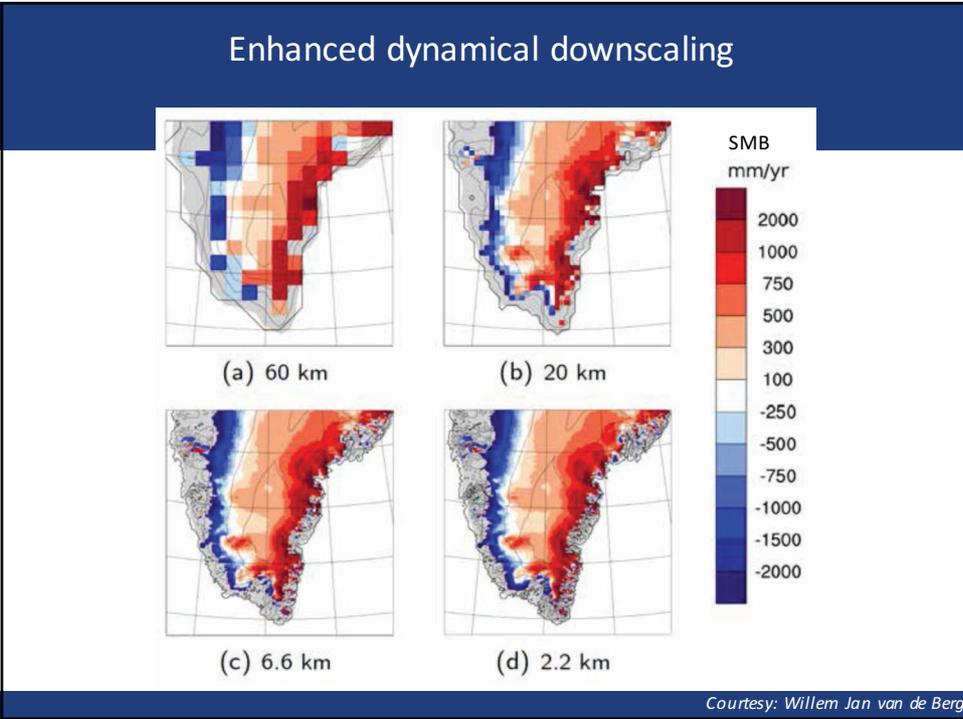
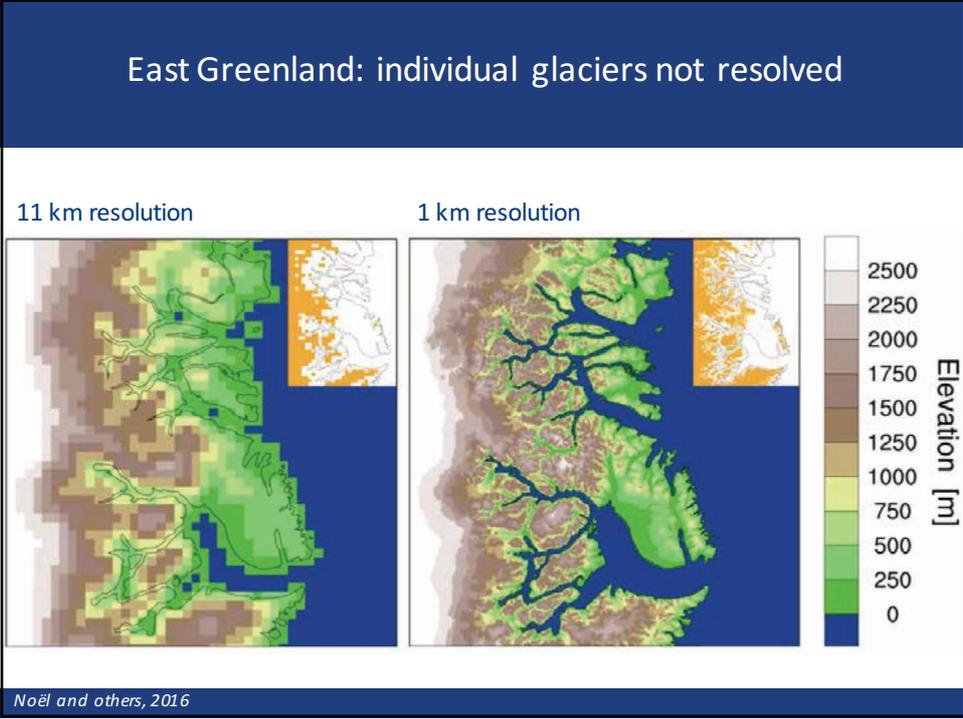
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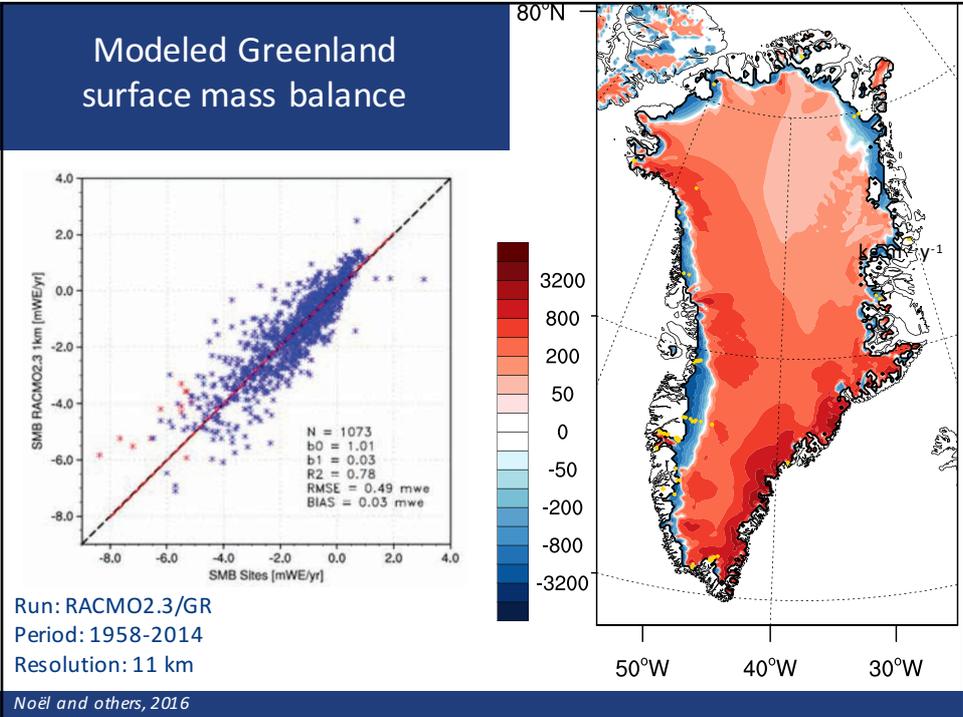
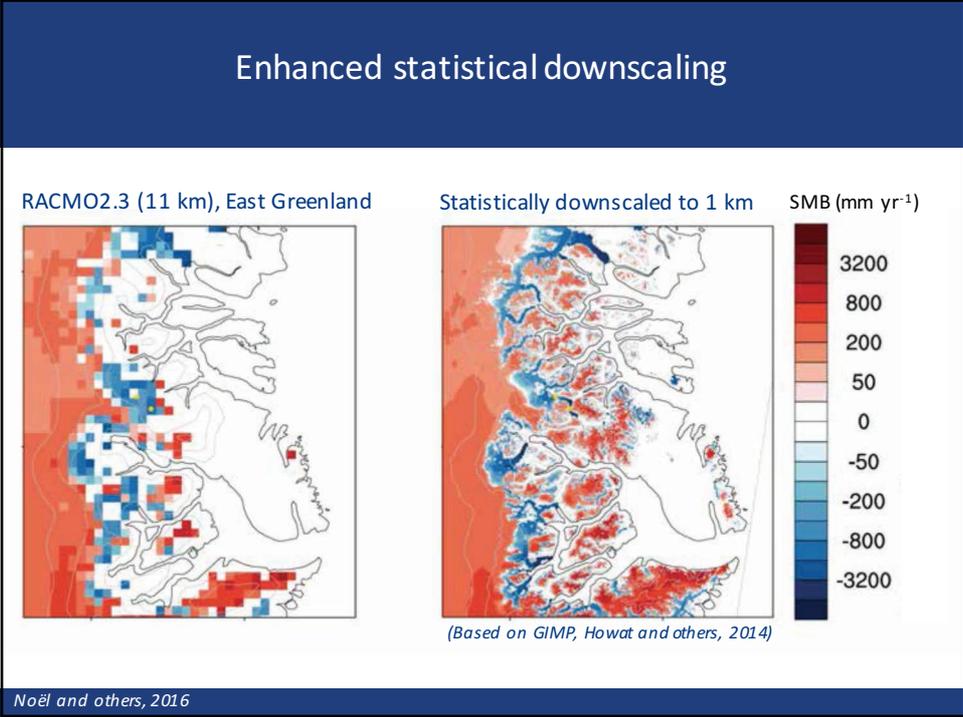
Impact of model resolution on net snow accumulation



Enhanced dynamical downscaling







Outlook

Observations

Focus on accurate radiation and turbulence measurements!

New generation of autonomous weather stations

New generation of satellites: GRACE-2, ICESat-2

Models

Further improve existing atmospheric climate models (clouds)

Further improve existing snow models (heterogeneous percolation)

Move to global model systems (coupled ice sheet models)

Improve prognostic albedo schemes (dust, black carbon, bio-albedo)