MITgcm sea ice thermodynamics adjoint, an update

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History

- 2006–10: Fenty code (seaice_growth_if.F, etc) merged with main branch
- Feb 2011 : I.Fenty reported sea ice thermodyn adjoint broken when tested for ~ 1yr using the 1-D column & LabSea verification experiment
  I.Fenty provided code mod to seaice_growth.F v1.111 & assessment

  Seaice_Growth_Forward_and_Adjoint_comparisons.pdf
- 2014: I.Fenty re-tested seaice_growth.F and seaice_growth_if.F in Labsea for > 1yr, documented unphysical sensitivity in main branch code
- Jan/2015: I.Fenty attemped to rewrite stripped down version of main-branch seaice_growth.F to follow his seaice_growth_if.F , A.Nguyen tested using Labsea verification exp for multiple 1 year experiments
- Jun/2018: Arash Bigdeli's effort:
  - picked up from where A.Nguyen left off
  - brought code to checkpoint 65q (ASTE stable set up)
  - turned off pkg/CD , turned on all packages and flags required for ASTE
  - switched off pkg/cost for sea ice, used pkg/ecco/gencost for AREA & HEFF
  - switched to full ASTE (llc270) set up, stable adjoint 1yr run for cost=AREA
  - changed code to close salt budget (add saltflux) for nonlinFS≠0 (not virtual salt) cases.
  - added flooding & saltplume

History

- **close heat budget for nonlinFS=2**

main branch: source/sink of heat/fw associated with this negative (unphysical) heff, so remove for adjoint but ,keep to add back later for budget purpose ;

call seaice advection → potentially introduces unphysically small negative heff (NEG)
call reg_ridging → takes care of this unphysical NEG term
call thermodynamics

if SEAICEadjMODE = 0:
remove NEG (heff, snow) from calculation for the adjoint (for thermodynamics)
but keep in forward run to close heat/fw budget.

(options for what we can set in adjoint mode: SEAICEapproxLevInAd [-1,0,1,2,3])

compare main branch seaice_growth.F & seaice_growth_if.F

- regularize area (make derivative well behaved)
- calc all atmospheric and oceanic fluxes available to melt/free ice
- calc various dH and dHsnow and dArea for sea ice growth

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if SEAICEadjMODE = 0:

- keep NEG terms in forward run to close budgets
- **"remove"** NEG terms in adjoint run

- regularize area (make derivative well behaved)
- calc all atmospheric and oceanic fluxes available to melt/free ice
- melt snow
- calc dH/dt
- use reg.area to calc dA/dt

- did not deal with NEG terms b/c dynamics were not considered
- ==========

Arash's contrib

- add treatment of NEG terms
- keep NEG terms in forward run to close budgets
- remove NEG terms in adjoint run

When NEG terms were not removed in adjoint properly → artificial / bogus sensitivity of large magnitude pops up → unphysical sensitivity

When NEG terms were not removed in adjoint properly → artificial / bogus sensitivity of large magnitude pops up → unphysical sensitivity (Arash discovered)

fix:

passed on to the rest of the calculation

```
475 C ======================================================================
476 C  PART 1: Store ice and snow state on onset + regularize actual
477 C                snow and ice thickness
478 C ======================================================================
479 CAB
480         DO J=1,sNy
481          DO I=1,sNx
482          SIheffNeg(I,J,bi,bj)=d_HEFFbyNEG(I,J,bi,bj)*SINegFac
483          SIhsnwNeg(I,J,bi,bj)=d_HSNWbyNEG(I,J,bi,bj)*SINegFac
484          ENDDO
485         ENDDO
486
487         DO J=1,sNy
488          DO I=1,sNx
489
490           HEFF(I,J,bi,bj) = MAX(ZERO, HEFF(I,J,bi,bj))
491           AREA(I,J,bi,bj) = MAX(ZERO, AREA(I,J,bi,bj))
492
493           IF (HEFF(I,J,bi,bj) .LE. ZERO) then
494              AREA(I,J, bi,bj)  = ZERO
495              HSNOW(I,J, bi,bj) = ZERO
496           ELSEIF (AREA(I,J,bi,bj) .LE. ZERO) then
497              HEFF(I,J,bi,bj)  = ZERO
498              HSNOW(I,J,bi,bj) = ZERO
499           ENDIF
500
501           HEFFpreTH(I,J) = HEFF(I,J,bi,bj)
502           HSNWpreTH(I,J) = HSNOW(I,J,bi,bj)
503           AREApreTH(I,J) = AREA(I,J,bi,bj)
504
505 #ifdef ALLOW_DIAGNOSTICS
506           DIAGarrayB(I,J) = AREA(I,J,bi,bj)
507           DIAGarrayC(I,J) = HEFF(I,J,bi,bj)
508           DIAGarrayD(I,J) = HSNOW(I,J,bi,bj)
509 #endif
510          ENDDO
511         ENDDO
512
"/home/abigdeli/nansen/MITgcm_c65q/mysetups/aste_90x150x60/code_SI_box/seaice_growth.F"
```

NOT passed on to the rest of the calculation

When NEG terms were not removed in adjoint properly → artificial / bogus sensitivity of large magnitude pops up → unphysical sensitivity (Arash discovered)

main branch seaice_growth.F:

```
436           DO J=1,sNy
437            DO I=1,sNx
438
439             tmpscal2 = MAX(-HEFF(I,J,bi,bj),r_QbyATM_cover(I,J)+
440 C           Limit ice growth by potential melt by ocean
441      &           AREApreTH(I,J) * r_QbyOCN(I,J))
442
443             d_HEFFbyATMonOCN_cover(I,J)=tmpscal2
444             d_HEFFbyATMonOCN(I,J)=d_HEFFbyATMonOCN(I,J)+tmpscal2
445             r_QbyATM_cover(I,J)=r_QbyATM_cover(I,J)-tmpscal2
446             HEFF(I,J,bi,bj) = HEFF(I,J,bi,bj) + tmpscal2
447
448 #ifdef ALLOW_SITRACER
449             SItrHEFF(I,J,bi,bj,3)=HEFF(I,J,bi,bj)
450 #endif
451            ENDDO
452           ENDDO
453 #endif /* SEAICE_ITD */
```

- any relationship tmpscal2=max(-HEFF,XXX):
  - if tmpscal2 is only used for budget, then it's ok.
  - if used for adjoint: b=f(tmpscale2), b is now contaminated because db=fxn of dheff if all other argument in max() is zero except dheff.

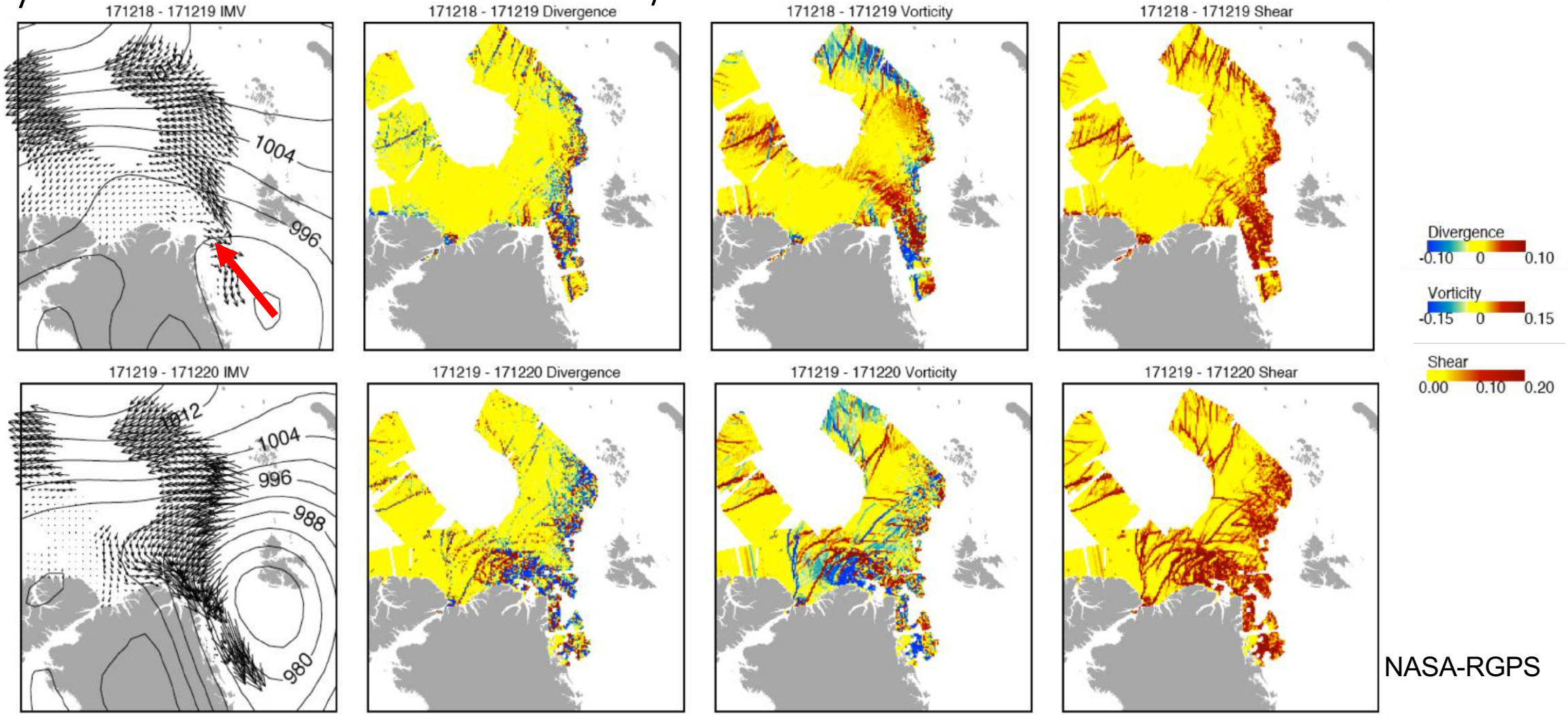
main branch: through sublimation: both heff & hsnow can potentially be NEG, any b = max(blah,-h[snow,eff]), where bllah & hsnow = 0 in adjoint yield adjoint sensitivity calc produces for example db = –dhdnow, now suddenly we have sensitivity of variable b one-to-one to hsnow (with negative sign).

```
1527
1528       IF (.NOT.SEAICE_growMeltByConv) THEN
1529
1530 #ifdef SEAICE_ITD
1531         DO IT=1,SEAICE_multDim
1532          DO J=1,sNy
1533           DO I=1,sNx
1534            tmpscal4 = HSNWITDpreTH(I,J,IT)
1535      &               + d_HSNWbySublim_ITD(I,J,IT)
1536      &               + d_HSNWbyATMonSNW_ITD(I,J,IT)
1537      &               + d_HSNWbyRAIN_ITD(I,J,IT)
1538            tmpscal1=MAX(r_QbyOCN(i,j)*ICE2SNOW*areaFracFactor(I,J,IT),
1539      &                  -tmpscal4)
1540            tmpscal2=MIN(tmpscal1,0. _d 0)
1541 #ifdef SEAICE_MODIFY_GROWTH_ADJ
1542 Cgf no additional dependency through snow
1543            if ( SEAICEadjMODE.GE.2 ) tmpscal2 = 0. _d 0
1544 #endif
1545            d_HSNWbyOCNonSNW_ITD(I,J,IT) = tmpscal2
1546            d_HSNWbyOCNonSNW(I,J) = d_HSNWbyOCNonSNW(I,J) + tmpscal2
1547            r_QbyOCN(I,J)=r_QbyOCN(I,J) - tmpscal2*SNOW2ICE
1548           ENDDO
1549          ENDDO
1550         ENDDO
1551 #else /* ndef SEAICE_ITD */
1552         DO J=1,sNy
1553          DO I=1,sNx
1554           tmpscal1=MAX(r_QbyOCN(i,j)*ICE2SNOW, -HSNOW(I,J,bi,bj))
1555           tmpscal2=MIN(tmpscal1,0.  d 0)
1556 #ifdef SEAICE_MODIFY_GROWTH_ADJ
1557 Cgf no additional dependency through snow
1558            if ( SEAICEadjMODE.GE.2 ) tmpscal2 = 0. _d 0
1559 #endif
1560           d_HSNWbyOCNonSNW(I,J) = tmpscal2
1561           r_QbyOCN(I,J)=r_QbyOCN(I,J)
1562      &                          -d_HSNWbyOCNonSNW(I,J)*SNOW2ICE
1563           HSNOW(I,J,bi,bj) = HSNOW(I,J,bi,bj)+d_HSNWbyOCNonSNW(I,J)
1564          ENDDO
1565         ENDDO
```

High Spatial and Temporal sampling of Arctic Ice Drift (Question: utility for ECCO?)

prepared by R. Kwok (JPL)

What we can do now:
Daily deformation from Sentinel 1A/B



NASA-RGPS

Based on Copernicus Sentinel Imagery 2017, processed by ESA.

MOSAiC Science: Need ice drift at smaller spatial scales and sub-daily time scales

- Momentum transfer/heat flux and ice response Impact of openings and deformation on biogeochemical processes
- Advance understanding of sea ice mechanics/redistribution
- Model Assessment and Improvements
- Satellite Validation

Expected MOSAiC SAR coverage

- Based on MOSAiC science requirements
  - 4X daily (within 100 km of the drifting central observatory)
  - 2X daily (within the Arctic Basin)
  - Duration (three periods – mid 2019 thru mid 2020): before, during, and after the MOSAiC drift/ nine months before (to include the MOSAiC pre-study period) and three months after

Expected SAR coverage by 2021 w/NISAR launch

- Based on a combination of Sentinel-1, RadarSAT Constellation and NISAR
  - Routine 1-2X daily coverage of the entire basin