Committee on Solar and Space Physics:
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The future of MIT research: Ionospheric data assimilation

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Today

What is data assimilation (DA)?

Why is it critical to scientific progress in space science?

What's next?

What is ionospheric DA?

Schunk et al. [2004]

Observations

Yue et al. [2012]

Global 3-D ionosphere for forecast

Matsuo [2016]

Model

DA and scientific progress

DA is critical to scientific progress outlined by CSSP

1. System science
2. Utilize diverse geospace observational system
3. Multi-scale analyses

DA and geospace system science

DA enables true system science consistent with observations

DA and geospace system science

DA enables true system science consistent with observations

Hsu et al. [2014]

DA and geospace system science

DA enables true system science consistent with observations

Electron density [cm^{-3}]

Forecasts after **only estimating** various **ionospheric parameters**

Hsu et al. [2014]

DA and geospace system science

DA enables true system science consistent with observations

Electron density [cm^{-3}]

Forecasts after estimating **both ionospheric and thermospheric** parameters

Hsu et al. [2014]

DA and geospace system science

DA enables true system science consistent with observations

Forecasts after estimating **both ionospheric and thermospheric** parameters

DA is critical to coupled system analyses

Hsu et al. [2014]

DA and bringing together our diverse observational system

AMPERE

SuperDARN radar

DA and bringing together our diverse observational system

DA and bringing together our diverse observational system

DA and bringing together our diverse observational system

Solar Wind-Msphere Coupling

AMPERE-SuperDARN disagreement [m/s]

Without assimilation = large disagreement

November 30, 2011 Storm

With data assimilation for ionospheric conductivity = significantly better agreement

McGranaghan et al., [2016]

DA and bringing together our diverse observational system

Data assimilation better brings ground- and space-based data into agreement

McGranaghan et al., [2016]

Where are we going? Multi-scale analyses

Seamless merging of high-resolution models with multi-scale observations

Where are we going? Multi-scale analyses

Multi-scale data

Ionospheric assimilation

Datta-Barua et al., [2013]

Where are we going? Multi-scale analyses

Multi-scale data

Ionospheric assimilation

Datta-Barua et al., [2013]

High resolution necessary to capture key gradients

Where are we going? Multi-scale analyses

Multi-scale data

Ionospheri

What is the feedback between scales?

Datta-Barua et al., [2013]

Bright future: GNSS

Availability

Exploitation

Union of data with future availability and new advanced techniques embodies the spirit of the National Space Weather Program

Challenges

Uncertainty quantification

Validation (Comprehensive and objective)

Interpretation

Allowing community to use these improvements

Parting thoughts

Bottom line: Data assimilation central to scientific goals of CSSP

Significant progress and exciting possibilities

Critical to allow community to use these improvements

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Backup slides

Ionospheric measurements at a glance

Yue et al. [2012]

DA and bringing together our diverse observational system

How can we quantitatively test the conductance models?

V
ΔB
Σ
V
ΔB
Σ
Local Obs.
Electric Potential
$\Phi = \Phi^{(mod)} + H_\Phi \alpha_\Phi$
Σ
Magnetic Potential
$A = A^{(mean)} + H_A \alpha_A$
Global
Σ
Σ
Σ
Σ
Global
E
J_r
ΔB
E
V
ΔB

#1: SuperDARN to predict AMPERE

V → ΔB

#2: AMPERE to predict SuperDARN

ΔB ⟶ V

V
ΔB
Σ
V
ΔB
Σ
Local Obs.
Electric Potential
$\Phi = \Phi^{(mod)} + H_\Phi \alpha_\Phi$
Σ
Magnetic Potential
$A = A^{(mean)} + H_A \alpha_A$
Global
Σ
Σ
Σ
Σ
Global
E
J_r
ΔB
E
V
ΔB

Σ
Conductances from *Cousins et al.* [2015]
• Original model applied
• Case V ($\Sigma_{H,P,night}$ > 4.0 S)
Conductances from OI output
• strong localization
• weak localization

V
ΔB
Σ
V
ΔB
Σ
Local Obs.
Electric Potential
$\Phi = \Phi^{(mod)} + H_\Phi \alpha_\Phi$
Σ
Magnetic Potential
$A = A^{(mean)} + H_A \alpha_A$
Global
Σ
Σ
Σ
Σ
Global
E
J_r
ΔB
E
V
ΔB

Σ
Conductances from *Cousins et al.* [2015]
• Original model applied C2015 I
• Case V ($\Sigma_{H,P,night}$ > 4.0 S) C2015 V
Conductances from OI output
• strong localization M2015 SL
• weak localization M2015 WL

EarthCube Project:
Magnetosphere-Ionosphere-Atmosphere Coupling